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THE PALEOECOLOGY OF THE LIASSIC
BENTHIC FORAMINIFERA
OF GREAT BRITAIN

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ABSTRACT OF THE THESIS

The Paleoecology of the Liassic Benthic Foraminifera of Great Britain

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Thirteen discrete benthic foraminiferal groups are identified by the Q-mode cluster and factor analysis in the strata of Jurassic Great Britain. The thirteen groupings are designated as biofacies, and a model of Liassic benthic foraminiferal paleobathymetry is proposed ranging from very near shore to outer shelf or shelf basins .

Shallow water, lagoonal or shoreline, environments are indicated by Biofacies Alpha and Alpha 1. Biofacies Alpha which is dominated by Eoguttulina and Lenticulina, suggests paleodepth of only a few meters. Biofacies Alpha 1 , an arenaceous-rich biofacies, apparently lived within the influence of wave action. Inner shelf environments are indicated by Biofacies Beta, Gamma and Gamma 1. All three biofacies contain an important Lingulina tenera component. Biofacies Beta is completely dominated by this species; while Biofacies Gamma and Gamma 1 have greater diversity and equitability. The latter biofacies is dominated by Brizalina liassica;

whereas L. tenera is the second most prevalent species.

Biofacies Delta is interpreted as indicating transitional inner shelf to the middle shelf environments. Lingulina tenera and Marginulina prima are the dominant and secondary species, respectively. The assemblage is diverse, and contains calcispheres which points to an open marine environment. In the middle shelf, Biofacies Delta through Iota, , the trend of dominance of the species L. tenera declines and other species become more prominent. In Biofacies Epsilon, Marginulina prima is the dominant species and L. tenera is the second most abundant species. Lenticulina varians and Astacolus pauperatus increase in Biofacies Zeta, and Spirillina infima is the most abundant species in Biofacies Eta and Theta. Biofacies Iota which is characterized by the species L. varians and L. muensteri is interpreted as indicating transitional middle to outer shelf environments. Spirillina infima is less abundant in this biofacies.

Outer shelf environments are suggested by Biofacies Kappa which is dominated by the genus Opthalmidium. Calcispheres are abundant and the declining trend of the species S. infima continues in this biofacies. Outer shelf or shelf basin conditions are indicated by Biofacies Lambda which is dominated by the species

Reinholdella macfadyeni and Lenticulina muensteri.

Lingulina tenera is an important accessory species. This biofacies is prevalent in the lower Toarcian, an interval in which many authors show a significant transgression.

Cycles of sea-level change suggested by the faunal succession of the biofacies of the model are generally similar to the curves for sea level change of Hallam (1978) and Vail et al. (1984).

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in some of the foraminiferiferal genera. Dr. Kenneth Miller contributed many thoughtful suggestions regarding the presentation of the model. After all the major computing companies in the tristate area had failed to devise a way, Dr. Randall Forsythe's crucial discovery enabled the translation of my word processing disks. Dr. Victor Greenhut provided me with invaluable aid with problems involving the scanning electron microscope work on this project. Special mention must be made of the contribution of Steven K. Fox. He taught me a love of geology which coupled with his kindness and sense of humor sustained me in this work.

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INTRODUCTION

During the Liassic period a series of marine transgressions and regressions took place in Northwestern Europe, (Hallam, 1960, 1975, 1978). Shallow shelf seas surrounded emergent massiffs and great thicknesses of limestone, marl and shale formed in stratigraphical rhythms (Barnard, 1950a). In these epicontinental seas provincial marine faunas evolved rapidly (Gordon, 1970; Hallam, 1975).

During the Lias the foraminiferal family Nodosaridae dominated the benthic foraminiferal assemblages in these shelf seas where they underwent evolutionary radiation (Barnard, 1950). The wide morphologic variation that developed in these groups makes discrimination between species, and in some cases, even genera very difficult (Barnard, 1950; Macfayden, 1941).

Over 800 species of benthic foraminifera have been described in the Liassic sections of Western Europe (Brouwer, 1969). Many species descriptions overlap, thus leading to confusion of taxonomy and diminished utility of them as biostratigraphic markers. Because the ammonite biostratigraphy is well understood, there

appeared little need to work out biostratigraphy of another group. Now with the drilling in the North Sea and the discovery of hydrocarbons in the Jurassic, there is a demonstrated need for a foraminiferal biostratigraphy of the Lias, and understanding of their paleoecology.

The biostratigraphy of the Liassic benthic foraminifera is being elucidated. On the European Continent, work was done on the German Lias by Franke (1936) and a zoning of the Lias and Doggers section of Northwestern Germany was made by Bartenstein and Brand (1937). Norvang (1957) described the numerous species of foraminifera and their ranges in Jutland, Denmark. Bizon's (1960) and Bizon and Oertli's (1961) studies delineated the foraminifera of the Lias in the Paris Basin. Ruget and Siegal (1967) examined the ranges of Liassic foraminifera in the Lotharian type section of France in Laneuveville-devant-Nancy. In Spain, del Pozo (1971) analyzed the biostratigraphy and paleoecology of Liassic foraminifera in the Bilbao Basin. An interpretation of the foraminiferal biostratigraphy of a much interrupted sequence in Scania, Sweden was made by Norling (1972). More recently, Exton studied the Liassic microfaunal stratigraphy of Zambujal, Portugal (1981).

Gradstein (1976), working on material recovered from six exploratory wells drilled southeast of Newfoundland, reported on the foraminiferal biostratigraphy and biogeography of the Jurassic. He established two foraminiferal zones for the correlation of Liassic rocks in these wells. He believed there were European and African assemblages which correlated with the assemblages he described (Gradstein, 1976).

In the 19th century work, The Jurassic Rocks of Britain, Woodward (1893) describes some of the benthic foraminifera and their stratigraphic ranges in England and Wales. The utility of this study is limited by its lack of resolution due to problems in recovery and taxonomy.

The first significant foraminiferal biostratigraphy in Dorset-Devon was completed by Macfadyen (1941) on the Green Ammonite Bed fauna of the Prodactylioceras davoei zone. He noted useful markers and also compared Dorset biostratigraphic information with that of the European continent. A problem does exist with Macfadyen's work. His sampling was limited: he utilized six Lang stratigraphic samples (Lang did a detailed stratigraphic study of the Dorset and Devon outcrops, [Lang, 1923, 1924, 1926, 1928, 1936]) and augmented them with other collections. The range was also limited: 12 feet of

bedding out of 111 feet was studied, (Barnard, 1950a).

Barnard's work has contributed a broader understanding of the foraminiferal biostratigraphy at Dorset-Devon where he studied the stratigraphic samples collected by Lang and established ranges of foraminifera species (Barnard, 1950a, 1950c, 1956, 1957, 1960). He noted that there were significant marker species with restricted ranges even though many of the foraminifera were long ranging: Planularia (Cristellaria) inaequistriata Terquem (1863) for example, first appears in the Schlotheimia angulata ammonite zone and ranges through the Arnioceras semicostatum zone of the Lower Lias (Barnard 1950a). He thought that Nodosaria metensis Terquem, (small form) was confined to the H57 bed of Lang, and that Planularia nucleata was a valid marker of the upper Schlotheimia angulatum zone. Dentalina Langi (Barnard, 1950a) appeared only in beds 10, 11, and 12 which are transitional across the S. angulatum - Arietites bucklandi boundary, (Barnard, 1950a). In Barnard's paper on the Lias stratigraphy, he uses faunal composition to mark the zones of the Lias (Barnard, 1950c). This early work was followed by studies on the evolution of certain Super-groups which he termed a plexus. The plexus forms have stratigraphic significance (Barnard, 1956, 1957, 1960). Changes in morphology of Lenticulina, Lingulina and Frondiculina were assigned

form designations; for example, Planularia protracta, Bornemann (Barnard, 1950a) became Lenticulina varians form F (Barnard). It has a stratigraphic range in the Lias from the Echioceras raricostatum to the Prodactylioceras davoei zones of the Lower Lias.

Recently, ERICO Incorporated (1974) summarized the known foraminiferal data in the area of the North Sea. The publication identifies index fossils and names twelve foraminiferal biostratigraphic zones in the Lias. Horton and Coleman (1977) reported the Upper Lias lithostratigraphy and foraminiferal zones at Eppingham, Leicestershire. Here they describe four foraminiferal assemblages within H. exaratum ammonite subzone to the Zugodactylites braunianus subzone of the Toarcian. Copestake (1978) establishes foraminiferal zones for the Lower Lias and Lower Domerian of the Mochras, and Copestake et al. (in prep) "A facies analysis of the Lias of the Mochras Borehole and its paleogeographical implications," describe 5 foraminiferal zones in the Upper Domerian and Toarcian. Copestake and Johnson (1981) added to the data on biostratigraphic ranges of British benthic foraminifera. They prepared range charts of species for the Dorset Coast outcrops and for each of six bore holes. However, they do not name specific foraminiferal zones based on the index species. The present study uses sample preparation techniques which

extend the data on Liassic biostratigraphy of the British Isles.

The assemblages of benthic foraminifera from the Liassic northwestern European shelf seas including Great Britain are considerably different from the assemblages of benthic foraminifera from the Tethys Seaway of the Lias (Gordon, 1970). The Tethyan assemblages are composed primarily of arenaceous foraminifera with complex interiors. However, the assemblages of the northwestern European shelf seas are dominated by Nodosariid foraminifera. These northwestern shelf sea assemblages are also considerably different from the assemblages of benthic foraminifera which inhabit these latitudes today. The foraminifera of today have a more balanced composition which include a great number of superfamilies. They also include planktonic forms which are lacking in the Liassic assemblages. These compositional differences make the Liassic assemblages of the British Isles an interesting subject for paleoecologic study; i.e. what environmental conditions fostered this general condition and how does it vary?

Gordon (1970) noted that the foraminifera of the North Sea area are primarily Nodosariacean in composition. He noted also that some of these assemblages contained significant numbers or proportions

of Miliolacea and Ammodiscacea. His work was conducted on the family level. The environment, he concluded, was that of a shallow shelf sea.

Barnard (1950c) argues this point in his interpretation of the fauna he studied in the Lower Lias of Dorset-Devon. He concludes that the Liassic foraminifera had a much broader range than they do today. Furthermore, Barnard interpreted the blue gray clays in some of the sections as probably mud-flat sediments and not as earlier supposed, deep water sediment, (Barnard, 1950c). He based this conclusion on the presence of other faunal elements (Isocrinus, Ostrea, Gryphaea and fragments of Cidaroides) He concluded that the bathymetric range of many of the species must be wide as they occur in a great variety of sediment types.

Hallam (1960) presented a picture of the Blue Lias at Dorset through an evaluation of the faunal composition and the sediment physio-chemistry. He interpreted Dorset as an offshore facies though not necessarily a deep-water one (in less than 150 m water depth). To the north in Glamorgan is the corresponding near shore facies. Foraminifera did not play a major part in his analysis, and he drew his data on these from Barnard. Hallam's other work (1969, 1975, 1978) contributed greatly to the paleoenvironmental knowledge of the Jurassic, but the

focus is physiochemical and macrofaunal in character.

Del Pozo (1971) completed a paleogeographic reconstruction of the Jurassic and Cretaceous in the Bilbao Basin. He described both the ostracod and the foraminifera fauna in the Bilbao Basin and established foraminiferal and ostracod zonations. He qualitatively determined the paleobathymetry of the Bilbao Basin through analysis of faunal composition and lithology. The Rhaetian and Hettangian of the basin is recrystallized: faunas were not observed. However, for the Sinemurian to the Toarcian, he interpreted faunas as coastal (0-80m), neritic (80-200m) and bathyal (200-2000m). His work was done primarily through thin section analysis. Its importance is that it links foraminiferal species with zones and lithologies; its weakness is its lack of quantitative data and resolution.

Brouwer (1969) studied the foraminiferal assemblages from some seventy Liassic sections in northwestern Europe. He worked with both bituminous and non-bituminous layers and studied more than 1200 samples. He believed that many of the Liassic foraminifera described by previous workers were, in fact, the same and his descriptions include lengthy synonymies. Thus he reduced the great number of benthonic foraminifera species reported in the Lias.

Using matrix analysis, Brouwer identified twenty-one foraminiferal assemblages in the Lias. He proposed a model for faunal succession from shallow to deep or open marine conditions. For example, Polymorphina (Eoguttulina) liassica Strickland assemblage is indicative of a shallow or brackish water environment. In contrast, the Lenticulina muensteri assemblage indicates deep or open marine conditions. Brouwer believed that his data was drawn from too wide an area to attempt any paleogeographic reconstructions.

Exton (1979) identified six microfaunal associations in the Pliensbachian and Toarcian rocks of Zambujal, Portugal. These assemblages were delineated by the relative abundance of constituents. From these associations, he modeled paleoenvironments and related them to global sea level changes. Exton stated that the Zambujal microfaunas were comparable in composition to Jurassic assemblages from Alaska, Newfoundland and the areas once occupied by the Tethys.

The purpose of this study is to add to the emerging picture of the biostratigraphy of Jurassic benthonic foraminifera in the area of Great Britain. Associations of benthic foraminifera will be quantitatively defined and a model of their paleoecology proposed. This

information extends the utility of foraminifera in
hydrocarbon exploration in the area of the North Sea.

SAMPLE COLLECTION AND PREPARATION

The type section of the Liassic crops out along the Dorset-Devon coast of Great Britain, (Figure 1). The Dorset-Devon section is more continuous and less disrupted than many other British outcrops, such as those in the Midlands and Yorkshire (Barnard, 1960). Lang improved upon De la Breche's 1826 survey when he described in great detail the Lower Lias on the Dorset-Devon coast using a scale of 25 inches to the mile and applied Tutchter's ammonite sequence to the stratigraphy of the outcrop sequence (Lang, 1923, 1924, 1926, 1928, 1936). Figure 2 broadly correlates the Dorset-Devon outcrop with other important British Liassic outcrops. Figure 3 correlates the British Lias zones with those used on the European continent (Macfadyen, 1941).

There are some discontinuities in the section at Dorset. The late Sinemurian Oxynoticeras oxynotum ammonite zone is missing. During the late Sinemurian there was erosion, and the Coinstone of Charmouth was formed (Hallam, 1969). There is also a break in sequence noted in the Lower Pliensbachian Hummocky Limestones. This break occurs from the Uptonia jamesoni through the Tragophylloceras ibex ammonite zones. The benthic foraminiferal assemblages spanning the break in sequence are long ranging forms, and the break is not well marked

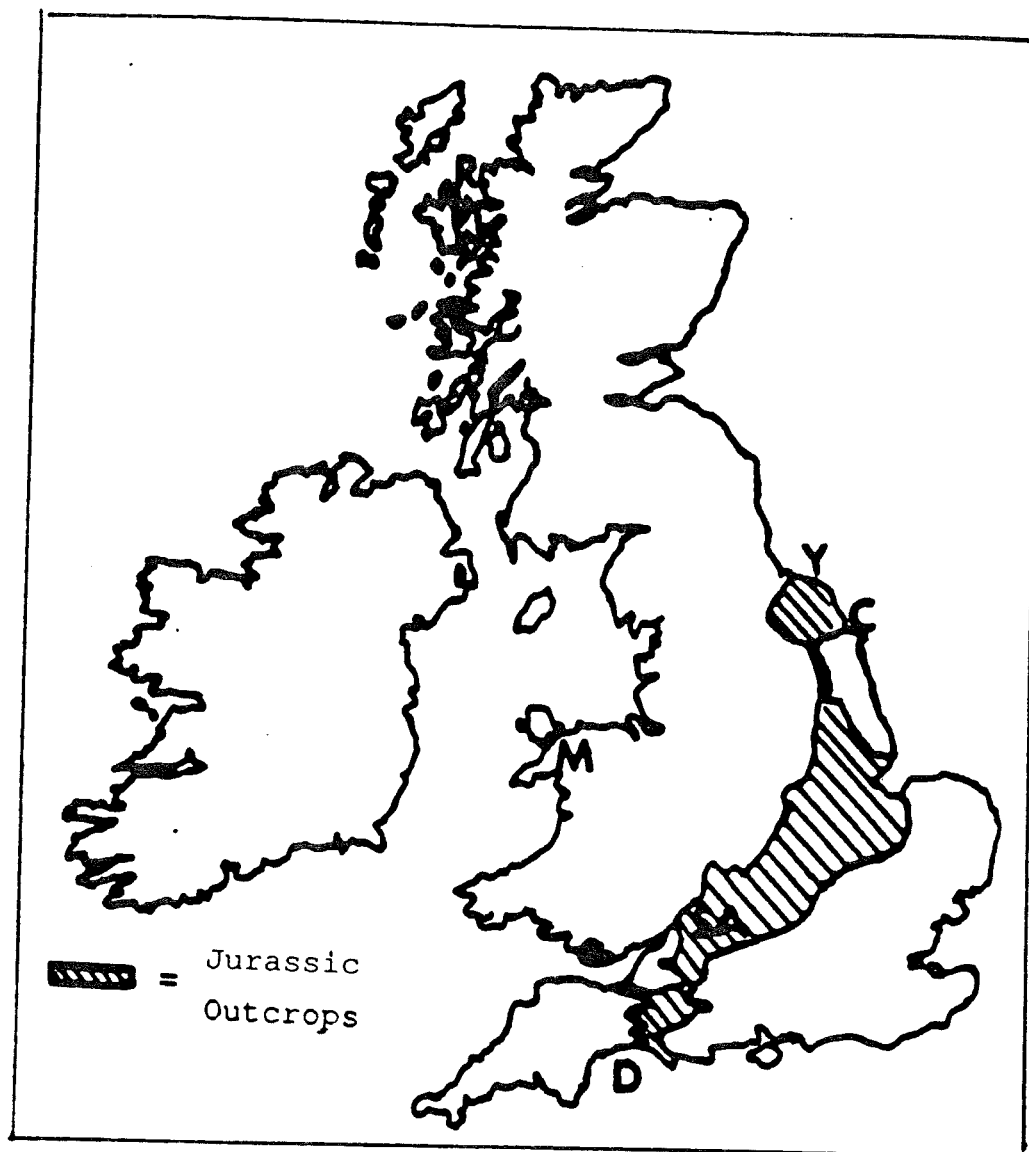
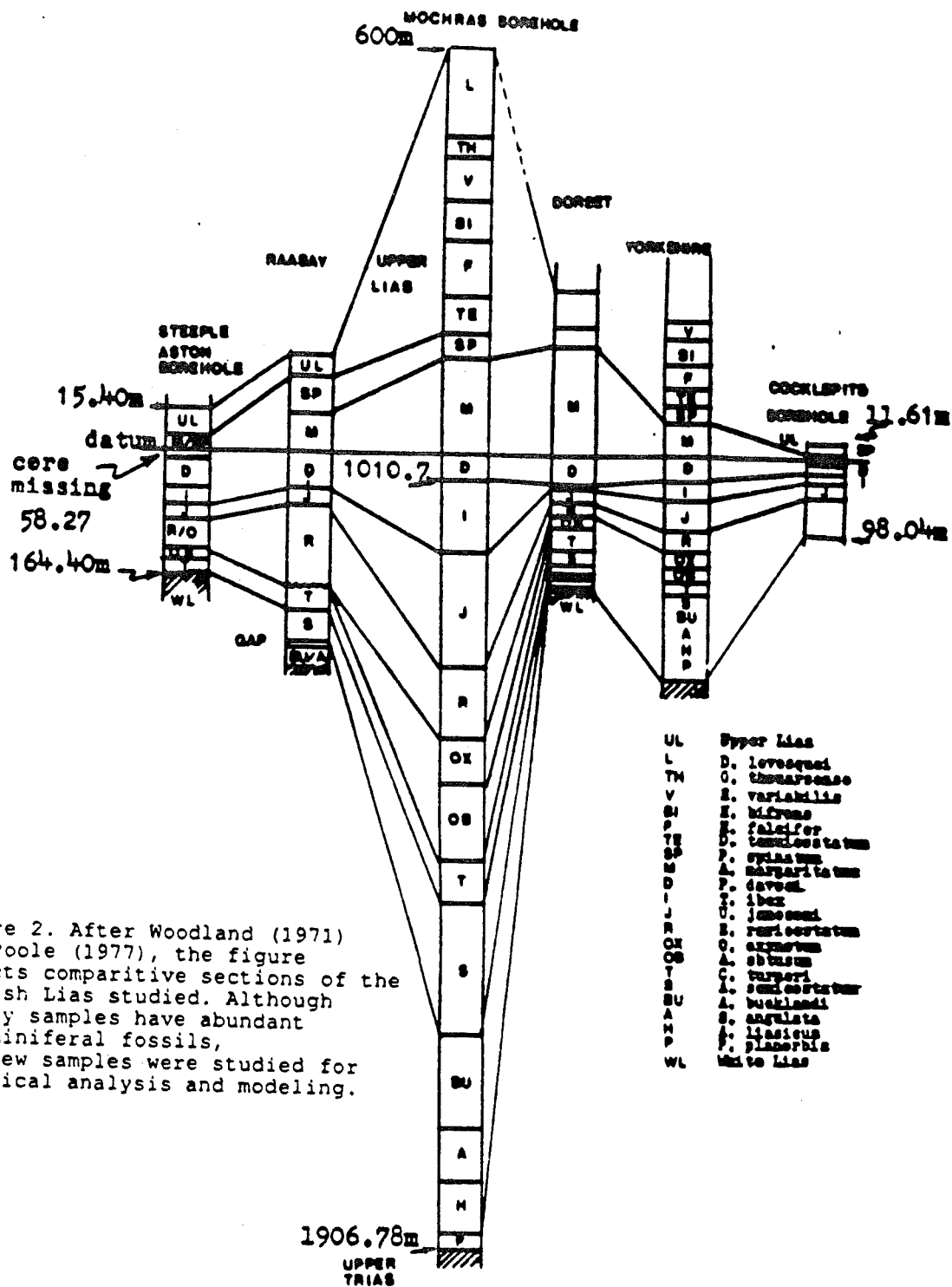


Figure 1. The map depicts the sample location which were used in this study; D = Dorset- Devon Coasts outcrops, Y = Yorkshire Coast Outcrops, R = Raasay Outcrops, M = Mochras Farm Borehole, Llanbedr, Wales, C = Cocklepit's Borehole, Humberside, Nat. Grid Ref. = SE 9322865, SA = Steeple Aston Borehole, Oxfordshire, Nat. Grid Ref. = SU 4672586. (Outcrops samples but not located on the map: Hook Norton Railway Cutting Nat. Grid Ref. = SP 359322, Crickley Hill Nat. Grid Ref. = SO 834148, and Robins Wood Hill, Nat. Grid Ref. SO 930160.



W. A. MACFADYEN ON DORSET LIAS FORAMINIFERA

APPROXIMATE CORRELATION OF LIAS ZONES

	Arkell (1933)	d'Orbigny (1842-50)	Terquem (1858-66)	Quenstedt (1858) and later German authors
Upper Lias	<i>opalinum</i>		<i>Turbo subduplicatus</i>	ξ Jurensis-Schichten
	<i>jurensis</i>		<i>bifrons</i>	
	<i>bifrons, commune</i>	Toarcien	<i>serpentinus</i>	ε Posidonien-Schiefer
	<i>falcifer</i>		marne à posidonies	
Middle Lias	<i>lenuicostatum</i>		<i>Gryphaea cymbium</i> var. <i>dilatata</i>	
	<i>spinatum</i>		marnes feuilletées	δ Amaltheen-Tone
	<i>margaritatus</i>	Liasien	<i>davosi</i> , calcaire à bélemnites	
			<i>T. numismalis</i>	γ Numismalis-Mergel
Lower Lias	<i>davosi*</i>		<i>Gryphaea cymbium</i> var. <i>elongata</i>	
	<i>ibex†</i>		<i>raricostatus</i>	β planicosta zone
	<i>jamesoni</i>			
	<i>raricostatum</i>	Calcaire à gryphées arquées (Terquem)		
	<i>oxynotum</i>		<i>Bel. acutus</i>	α Arieten-Stufe Schlotheimia-Stufe Psilonoten-Stufe
	<i>obtusum</i>		<i>bucklandi, rotiformis</i>	
	<i>semicostatum‡</i>		<i>angulatus</i>	
	<i>bucklandi</i>		<i>planorbis</i>	
	<i>angulatum</i>	Sinemurien		
	<i>planorbis</i>			
	<i>liassica</i>			
	<i>latei</i>			

- * Sometimes termed the *capricornu* zone.
† Sometimes termed the *centaurus* zone.
‡ Sometimes termed the *turneri* or *tuberculatus* zone.

Figure 3. Correlation of the time zones used by Macfadyen (1941) with those used by European authors.

by them (Barnard, 1950A). A large portion of the Middle and Upper Lias are missing at Dorset: the Amaltheus subnodosus through the Dummortieria levesquei subzones are absent. Some of the information on the biostratigraphy and paleoecology of benthic foraminifera lost in these breaks at Dorset can be found in other Liassic sections of Britain.

The samples for this study were supplied through the courtesy of Union Oil Company. They were collected by Ken M. Piel.

The samples were taken from described stratigraphic beds from outcrops along the Dorset Coast (Lang, 1923, 1926, 1928, 1936), outcrops along the Yorkshire Coast (Howarth, 1957), Getty (private correspondence, unpublished, 1977), outcrops on the Isle of Raasay and outcrops in the area of the Vale of Gloucester (Ager, 1955). In addition to the outcrop samples intervals were sampled from the Cocklepits Borehole, Humberside (National Grid. Ref. SE9323-2865), Steeple Aston Borehole, Oxfordshire, (Nat. Grid Ref. SU4687-2586) and the Mochras Borehole Llanbedr, North Wales (Nat. Grid Ref. SH5583-2594).

The samples were prepared at Rutgers University using the following techniques. Fifty to one hundred fifty grams of sample were boiled in a sodium carbonate solution and agitated in an ultrasonic cleaner. The samples were washed on a 63 micron screen to remove the silt and clay fraction. The residue was dried for examination.

Many of the more indurated argillites and marls did not breakdown completely. These samples were processed in a solution of sodium tetraphenylborate, sodium chloride and water after a method described by Martin-Hanken (1979).

Prior to its application, the method was tested on several samples. Test samples were initially boiled in a solution of 300 ML water + 7 G. sodium carbonate and sieved through a 63 micron screen to remove the easily mobile clay particles. If necessary they were then crushed in a mortar to fragments of approximately 0.5-1.0cm. Next the rock chips were boiled several times in the sodium carbonate solution and allowed to soak 24 hours. They were decanted and washed on a 63 micron mesh screen. The residue was then treated in the sodium tetraphenylborate/sodium chloride process (Martin-Hanken,

1979). The time that they soaked in the solution varied as a function of the samples' resistance to breakdown. It was never less than twelve hours in these experiments and at times was as long as one week. The solution was frequently stirred and ultrasonic vibration was used prior to cleaning and during the final wash process.

The following modifications were wrought upon Martin-Hankin's process with these results:

- A) More sample was processed per 100 ML solution than Martin-Hanken recommended. It appears that the amount capable of being broken down is a function of the amount of potassium rich clay minerals in the sample.
- B) The solution-sample mix was heated to a point below the boiling point. This accelerated the breakdown and does not appear to harm the fossils.
- C) When the solution was decanted from the sample residue, it was filtered and saved. It was found that this decanted solution made a good wash for specimens prior to scanning electron microscope examination. It could be used again. It could be strengthened by the addition of 1 gram sodium chloride and 1 gram sodium tetraphenylborate to 200 ml used solution.

A typical sample history is that of sample number 77-190
ROBIN HOODS'S BAY SOUTH (SHALE) .

Sample weight at start 59.60 G.

Residue Na_2CO_3 process: 48.23G.

Quality of breakdown - Poor: Chips of shale.

Residue of Martin-Hankin process: 2.45G.

Quality of breakdown nearly 100%.

MESH SIZE RESIDUE COLLECTED

MICRONS

>420 = 1.00 G. Largely pyritized gastropods
 with chunks of pyrite and
 carbonate.

>250 = 0.10G.

>125 = 0.41G.

>100 = 0.22G.

>75 = 0.55G.

>63 = 0.10G.

The improvement in recovery for the test, using the
 sodium carbonate followed by the sodium tetraphenylborate
 method is demonstrated in Table II Appendix ,

After separation on 420,250,125,and 63 micron

screens, all residue factions including the less than 63 micron fraction were studied. Foraminifera were identified and counted using a light microscope and the SEM. Representative assemblages for each locale and stratum were mounted on slides so that comparison and re-examination were possible.

Samples which were fossiliferous and would not breakdown using the above methods were studied in thin section. These samples were typically ironstones, indurated marls and limestones.

The methods of preparation used in this study increased the recovery and in many places increased the reported stratigraphic range of foraminiferal species. These improvements to the data base justify quantitative analysis.

NUMERICAL METHODS OF ANALYSIS

Quantative counts were made of the foraminiferal component of each sample. In most cases the entire foraminiferal content of the residue was counted. In cases of high dominance by three or four species, counts in excess of 300 were made where it was possible. This was done in an attempt to get all the constituents of the fossil assemblage. The residue in the pan (less than 100 μ mesh screen) was counted as many of the species are diminutive by comparison with modern foraminifera, the majority pass through a 125 μ mesh screen.

The data were entered into the Checklist Program (Phillips, 1982) on an Apple IIe computer. The Shannon-Weiner Information function (Hs) for diversity was determined, as was the equitability (E) for each sample. It was decided to use the Shannon-Weiner (Hs) as the diversity measure as it allows for a diversity calculation in samples of less than 100 total abundance. The diversity-equitability graphs and tables, percentage range charts, sample lists and histograms were produced by the Checklist Program and its Utility Pack.

The data matrix for each grouping of samples was transferred to the Rutgers University AS 9000 mainframe

computer using a program written at Rutgers by Toskos and Dimick (1984) and debugged by C.M. Bashford of Exxon's Computer Technology Division (Appendix I) .

Cluster analysis and factor analysis of the data were completed on the AS 9000. The objective of the cluster analysis is to seek out discrete groupings of either samples (Q mode) or species (R mode), although it can produce groupings which do not actually exist in the matrix. Factor analysis, a multidimensional gradient, will not form groups if these groups do not exist naturally in the data matrix. For this reason both methods were used to discriminate the groupings.

The Numerical Taxonomy System of Multivariant Statistical Programs (NT-SYS, 1974) with the SIMINT subroutine was used for both the cluster and factor analysis of the data. In order to dampen the effect of very large numbers of a few species in a sample, the matrix was standardized using NT-SYS option, which employs standard deviation. In cluster analysis the Unweighted Pair Group Method with arithmetic averaging (UPGMA) was used. The method gives a simple arithmetic statement of equivalence of either the samples or species being clustered and makes sure that each sample or species was treated equally no matter when it was clustered (Olsson and Nyong, 1984).

Rare species (those appearing in only a few of the samples) made the discrimination of both cluster and factor groups very difficult. Following the method utilized by Nyong and Olsson (1984), species appearing in less than twenty percent of the samples of each group were eliminated. The elimination of sporadically occurring species does not affect the identification of biofacies since these are identified by the predominant species.

Once discrete groups were identified, a counter check of the grouping was run using the Sanders Similarity Index. The data are expressed in percent of similarity. A percentage of similarity of eighty or above is regarded as identical. The percentages under 80 reflect the degree of disparity between the samples (Murray, 1973).

Faunal succession was determined at each location using the discrete groups identified in the numerical analysis. Correlation of biofacies could then be determined among the locations using the Sanders Similarity Index Matrix. A paleoecologic model was generated by using percentage of composition, faunal succession, diversity data, and Hallam (1978) and Vail et al. (1984) curves depicting global sea level change.

MOCHRAS BOREHOLE

The Llanbedr (Mochras Farm) Borehole in North Wales penetrates Liassic sediments from the Pleydellia aalensis ammonite subzone of the Toarcian stage through the Alsatites liasicus subzone of the Hettangian stage (Figure 2). Intervals of the Middle and Upper Lias were sampled and their foraminifera counted and identified. The data was clustered using both Q-mode and R-mode. Species which were sporadic in occurrence or appeared in less than 20% of the samples were omitted. The Q-mode clustering gave more discrete groups. The data matrix was then subjected to factor analysis. The Q-mode factor groupings compare well to the Q-mode cluster groupings.

The factor groups and their dominant species were plotted against the stratigraphy of the borehole to determine if there was a faunal succession. If in fact there were a succession, then statements may be made regarding the shifting of environment in space and time, as the vertical succession is an expression of the lateral (Walther's law). The groups would be biofacies, foraminiferal populations adapted to a particular niche.

Four groupings were independently produced by both the cluster and factor analysis. Figure 4 depicts the Q-mode cluster groups, and Figure 5 shows the Q-mode factor groups. A faunal succession is evident and the four

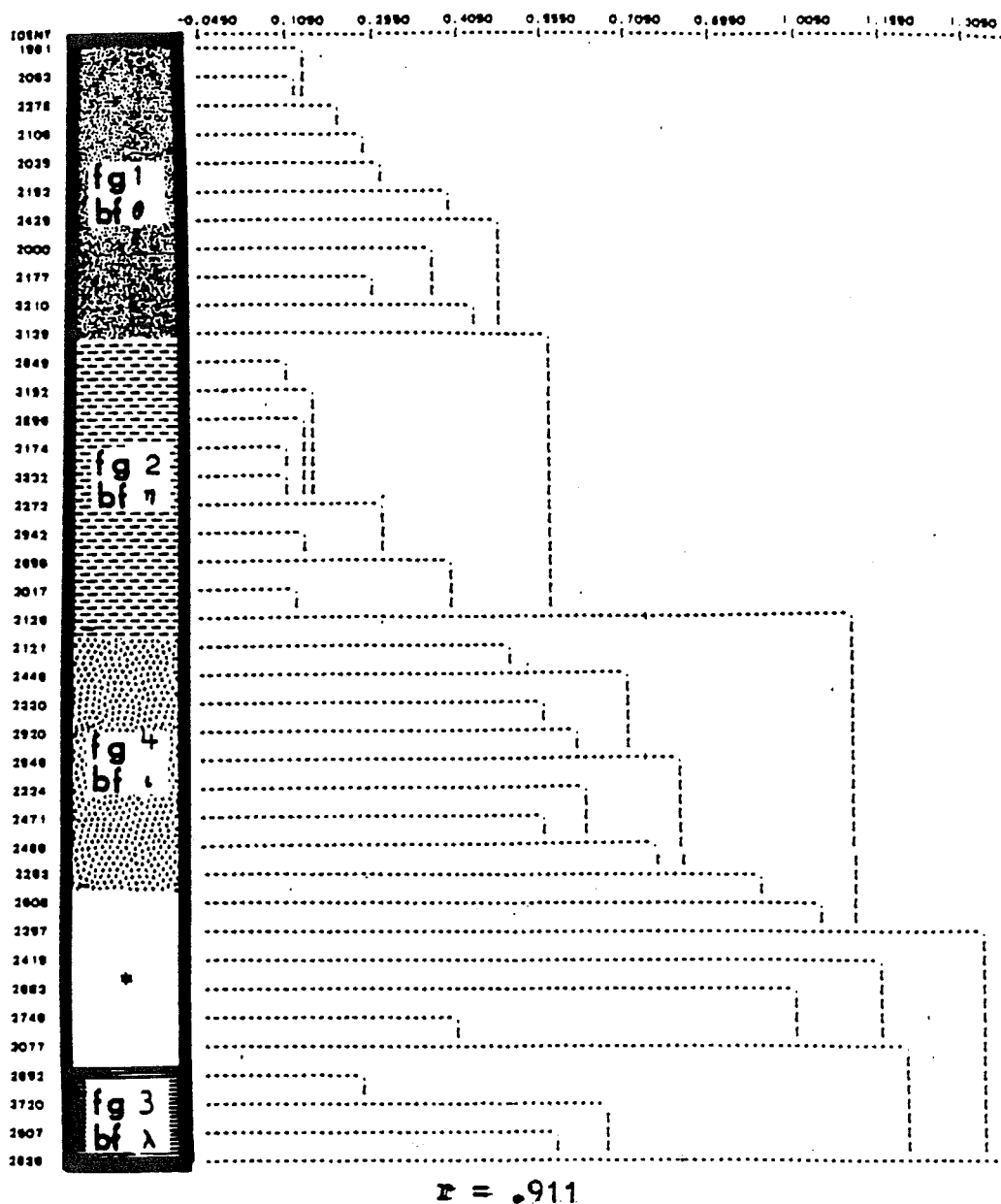
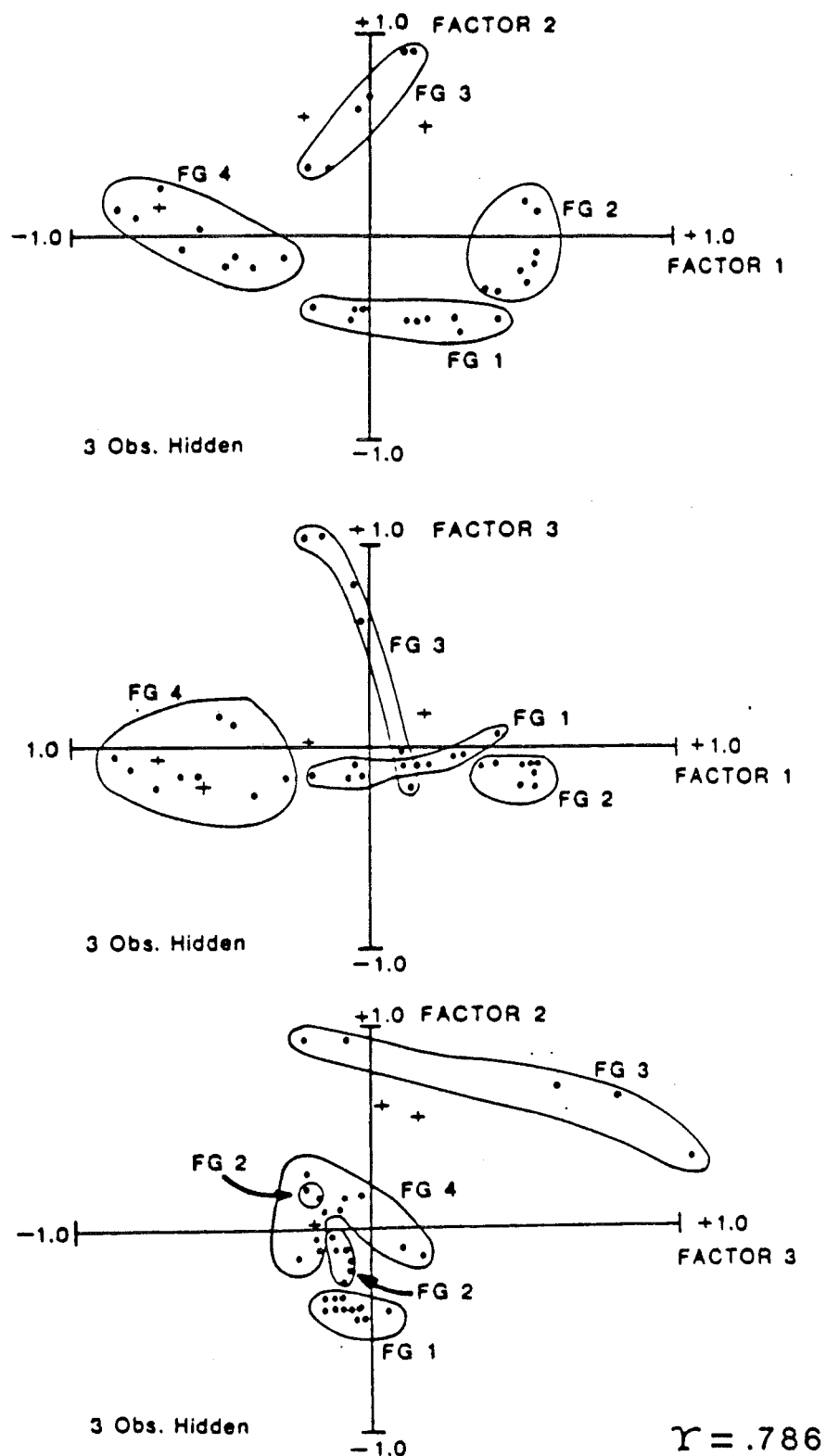


Figure 4. Q-mode cluster analysis of the assemblages from the samples from the Mochras Borehole. (Number = sample number, fg = Q-mode factor group, Bf = biofacies and * = isolates or outliers which do not form in any factor group.



Q-MODE FACTOR ANALYSIS of MOCHRAS
BOREHOLE SAMPLES

Figure 5.

groups appear to be biofacies (Figure 6).

During the Middle Lias one biofacies predominates: Biofacies Eta, cluster-factor group 2, Spirillina infima strongly dominates the assemblage: 40 to 60 percent. The second most abundant species is Lingulina tenera which ranges from 14 to 38 percent. Marginulina prima, Lenticulina varians and Lenticulina muensteri are in most samples in approximately the same proportions: 2 to 12 percent. It is noteworthy that Lenticulina muensteri does not appear until the Amaltheus gibbosus - A. subnodosus subzones. Brouwer (1969) suggest L. muensteri is a deep-water foraminifera.

Neither Rheinholdella macfadyeni nor Opthalmidium northamptonensis are important in number in any of the samples in this group. Fronidularia sulcata is present in most of the samples. Biofacies Eta histograms are shown in Figure 7a & b.

Although there is not always correlations between a factor group and diversity (Hs) or equitability (E), the factor group making up Biofacies Eta has a very narrow range of Hs and E. $Hs = 1.39$ to 1.82 and $E = 0.15$ to 0.49 (Table 1b).

Sanders's Similarity indices were calculated and a

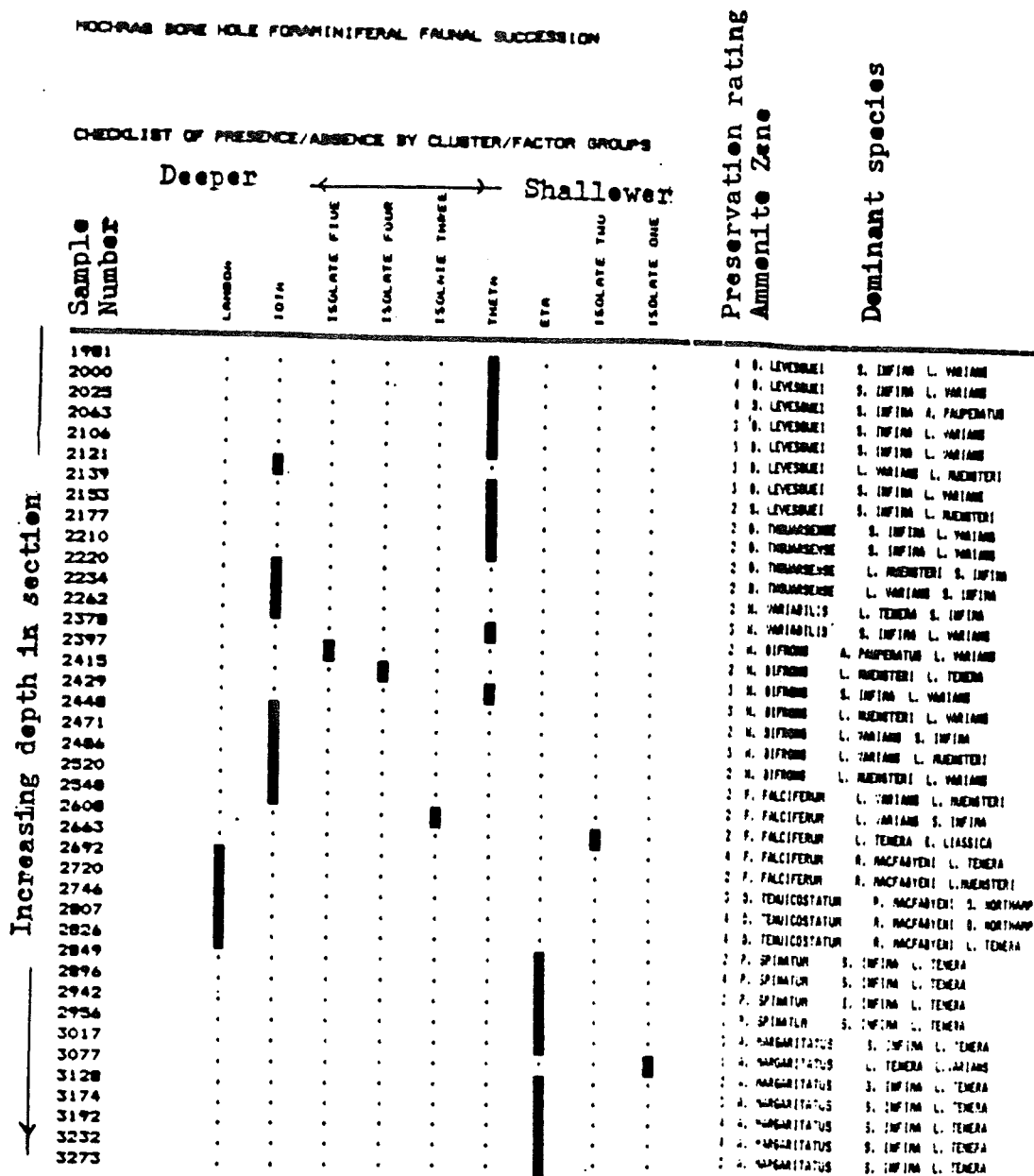
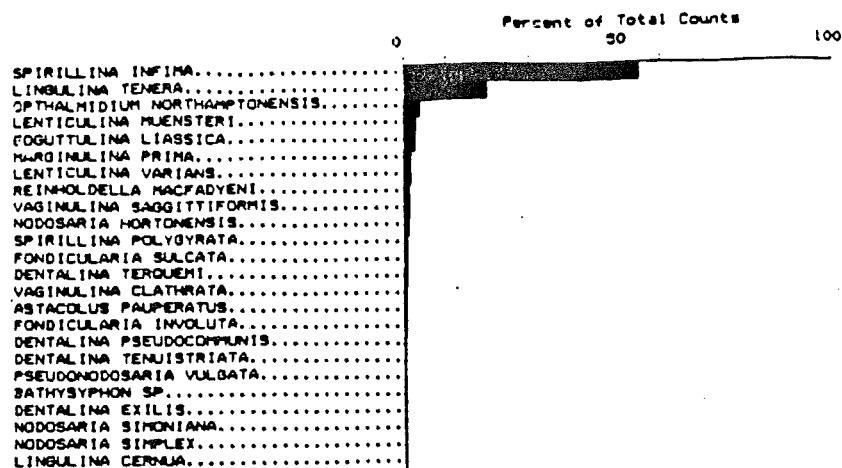
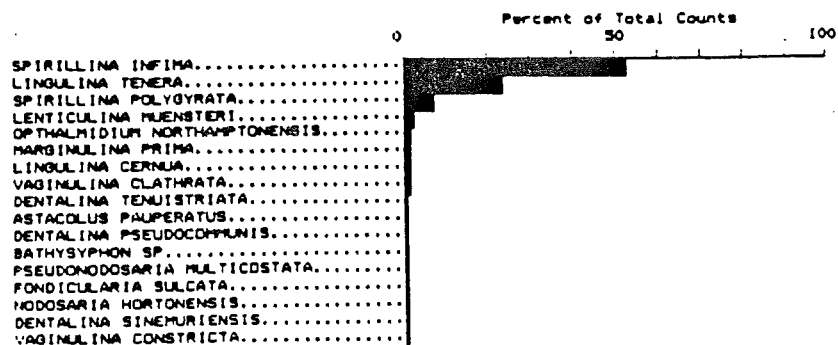


Figure 6. Q-mode cluster factor analysis of the Mochras Farm borehole produced four distinct groups. When the groups are plotted against the sample depth in the core, they reveal the faunal succession. The position of the isolates in the faunal succession is speculative. This model suggests that the groups are biofacies and the depth of the marine environment increases from right to left. Preservation rating: 5 = excellent... 1 = poor. The deeper/ shallower arrangement follows the paleoslope model (pg. 167).

SAMPLE: 2849



SAMPLE: 2896



SAMPLE: 3017

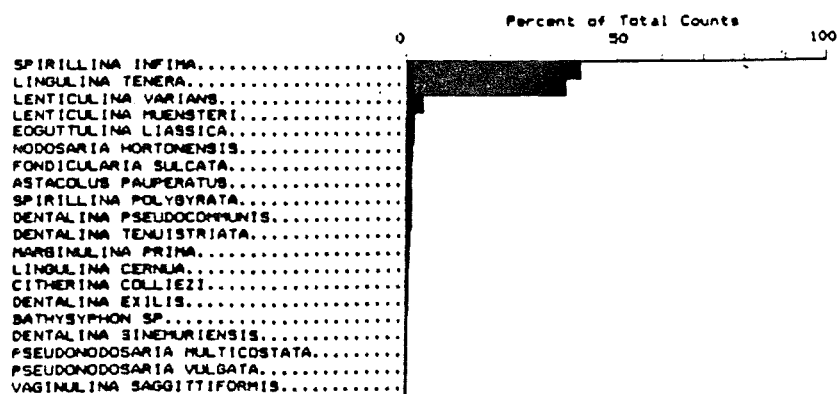
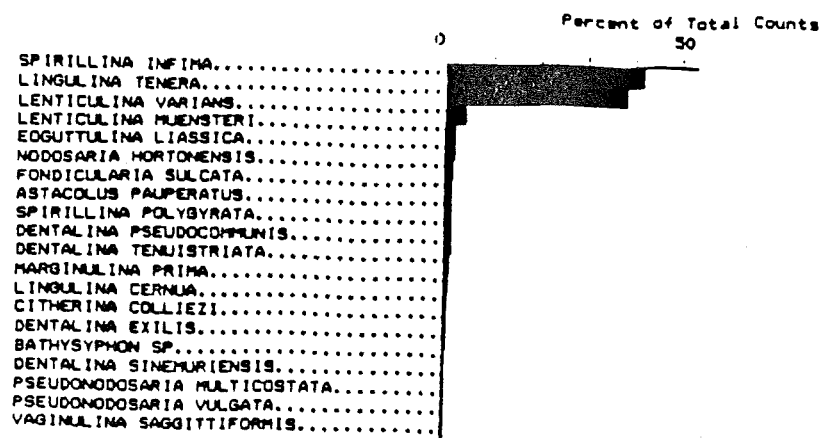


Figure 7a. Histograms of samples typical of Biofacies Eta of the Mochras Borehole.

SAMPLE: 3017



SAMPLE: 3192

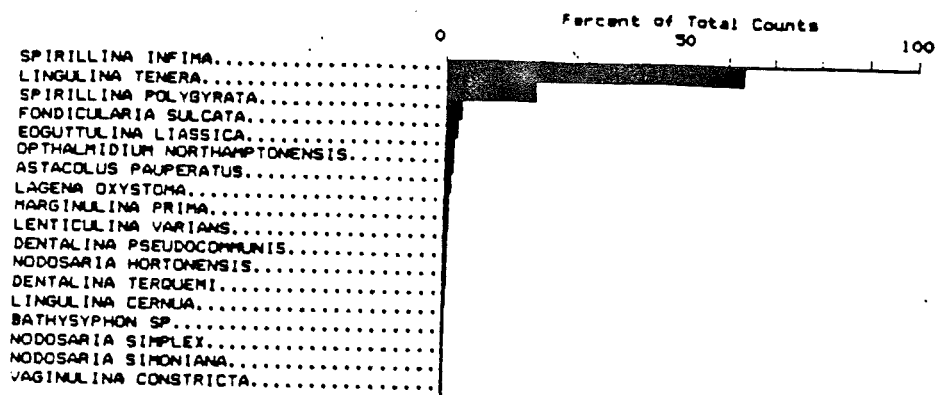


Figure 7b. Histograms of samples typical of Biofacies Eta of the Mochras Borehole.

	Number Of Specimens	Number Of Species	Shannon-Weiner Diversity	Equitability
Sample	N	S	H	E
1981-1986	114	17	1.82	0.36
2000-2000	463	22	1.22	0.15
2025-2029	115	18	1.33	0.21
2063-2068	493	33	1.99	0.22
2106-2111	486	33	2.17	0.26
2121-2125	59	15	2.30	0.67
2139-2144	157	26	2.43	0.44
2153-2158	243	38	2.72	0.40
2177-2182	267	32	2.57	0.41
2210-2215	262	31	2.40	0.36
2220-2225	21	8	1.86	0.80
2234-2239	25	9	1.98	0.81
2262-2266	16	7	1.45	0.61
2378-2383	100	11	1.23	0.31
2397-2402	15	7	1.77	0.84
2415-2420	5	4	1.33	0.95
2429-2434	77	16	2.21	0.57
2448-2453	11	7	1.80	0.86
2471-2476	50	18	2.66	0.79
2486-2491	46	14	2.21	0.65
2520-2525	166	26	2.81	0.64
2548-2552	135	24	2.63	0.58
2608-2613	93	27	3.04	0.78
2663-2668	23	10	2.21	0.91
2692-2697	105	7	0.61	0.26
2720-2725	11	2	0.47	0.80
2746-2751	162	23	1.90	0.29
2807-2812	188	25	2.02	0.30
2826-2830	202	25	2.25	0.38

Table 1a. Upper Liassic samples from the Mochras Borehole.

	Number Of Specimens	Number Of Species	Shannon-Weiner Diversity	Equitability
Sample	N	S	$\bar{H}$	E
2849-2854	608	33	1.71	0.17
2896-2900	129	22	1.77	0.27
2942-2947	260	21	1.82	0.29
2956-2961	57	10	1.59	0.49
3017-3022	361	28	1.74	0.20
3077-3082	8	3	0.74	0.70
3128-3133	292	22	1.46	0.20
3174-3178	209	18	1.65	0.29
3192-3196	467	21	1.42	0.20
3232-3236	540	34	1.62	0.15
3273-3277	60	12	1.38	0.33

Table 1b. Middle Liassic samples from the Mochras Borehole.

matrix was created (Sanders 1960). The assemblage has very high similarity (Table IIIa Appendix). An eighty percent similarity indicates the compared assemblages are virtually identical (Murray, 1973).

The factor group, cluster-factor group 1, which is the second biofacies, Theta, is very closely related in composition to Biofacies Eta (Table IIIc Appendix). There is a very high similarity within the factor group which constitutes this biofacies (Table IIIb Appendix). Biofacies Theta is characteristic of the majority of biofacies present in the top two ammonite zones of the Toarcian (Figure 6).

In Biofacies Theta, like Biofacies Eta, Spirillina infima is the dominant foraminiferal species. Lenticulina varians is usually the second most important component (11 to 25 percent). It is followed by Lenticulina muensteri (2 to 13 percent). Astacolus pauperatus is always present (2 to 8 percent); Eoguttulina liassica is usually present in about the same proportion (3 to 9 percent). Vaginulina clathrata and Lingulina tenera are usually present in about the same proportion (1 to 4 percent). Reinholdella macfadyeni is sporadic in occurrence and is low in percentage (Figure 8a & b).

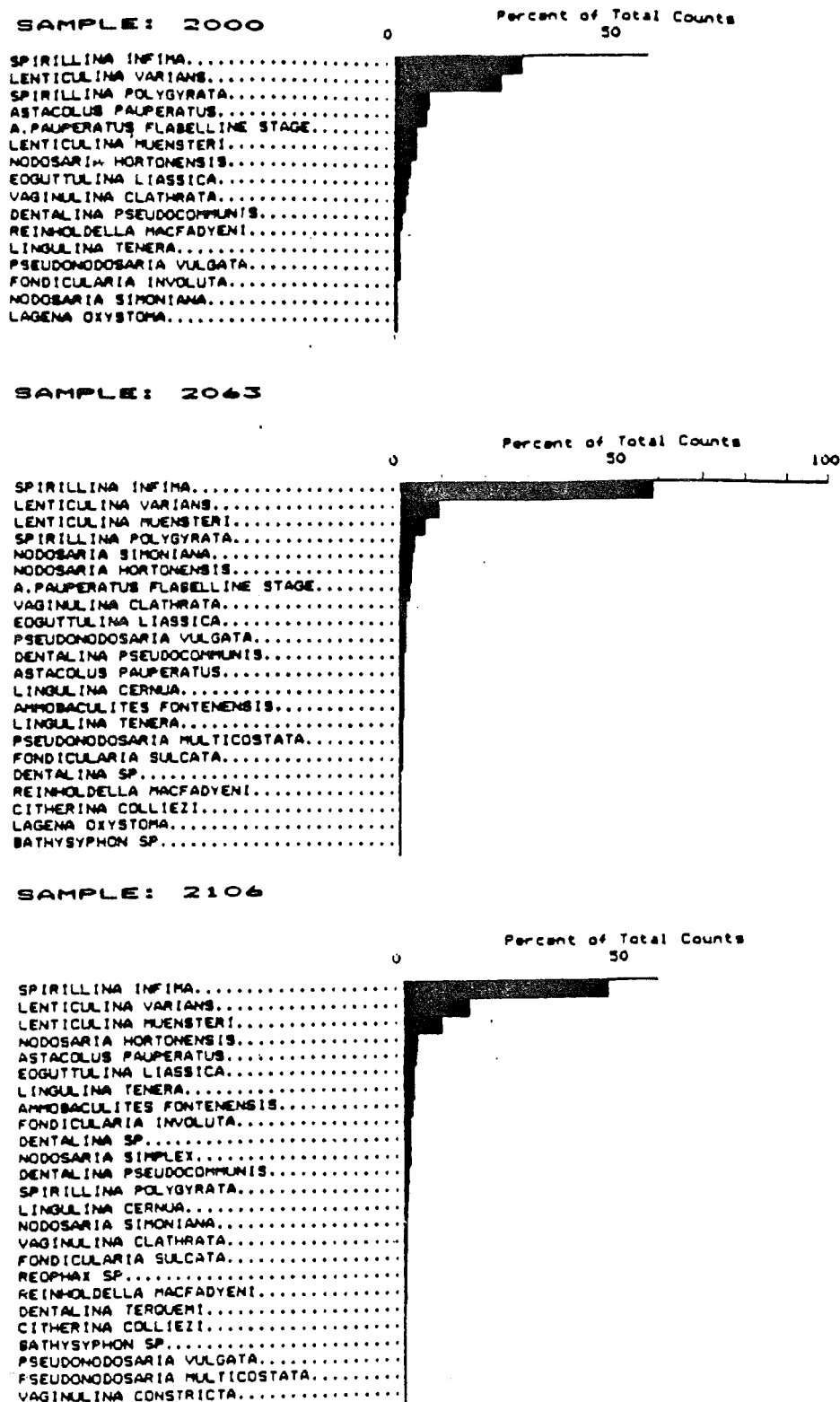
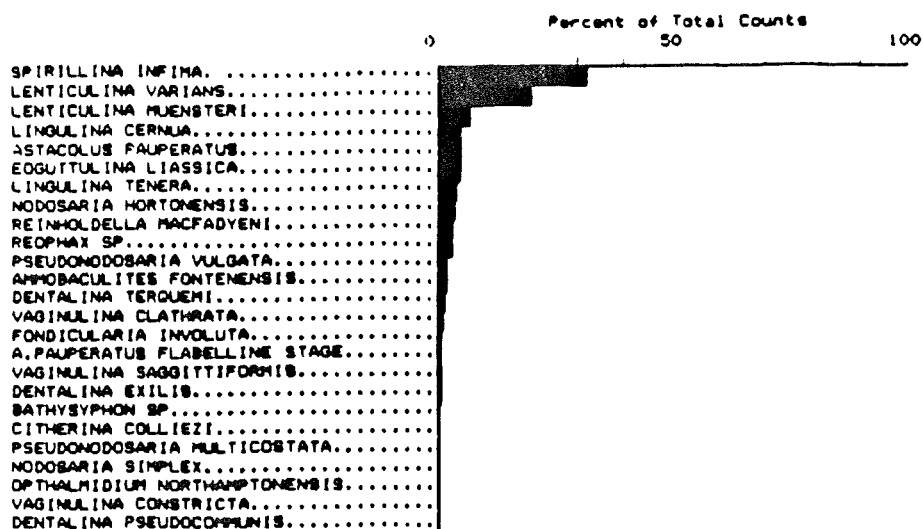


Figure 8a. Histograms of samples typical of Biofacies Theta of the Mochras Borehole.

SAMPLE: 2177



SAMPLE: 2210

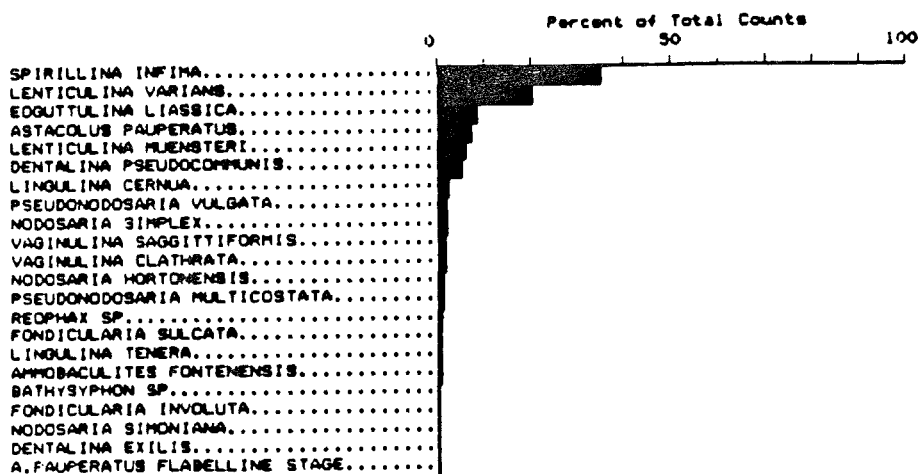


Figure 8b. Histograms of samples typical of Biofacies Theta of the Mochras Borehole.

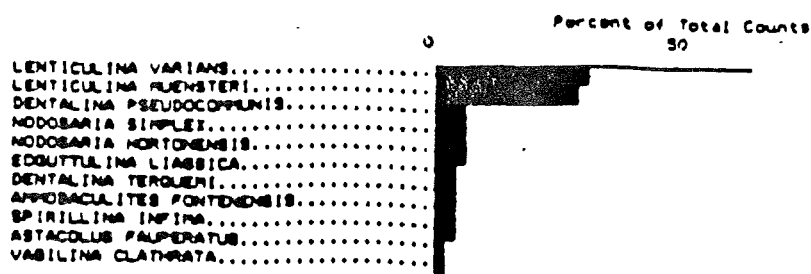
The differences seen in Biofacies Eta and Biofacies Theta are that the latter has less Lingulina tenera and has greater diversity (Table 1). The average Hs for Biofacies Theta is above 2.0 and the Hs for Biofacies Eta is approximately 1.5. Biofacies Eta has Fron dicularia sulcata and Marginulina Prima in almost all samples and Biofacies Theta has none. Biofacies Theta has Eoguttulina liassica, Vaginulina clathrata and Astacolus pauperatus in almost all samples. Another notable difference is that Biofacies Theta has a minor percentage of Dentalina pseudocommunis in the majority of samples. In Biofacies Eta Dentalina pseudocommunis is rare.

Biofacies Iota, cluster-factor group 4, predominates in the Upper Lias from the Harpoceras falcifer subzone through the Grammoceras striatulum subzone. Lenticulina varians and Lenticulina muensteri dominate this biofacies. The combined total percentage of these two species accounts for an average of forty percent of the total species in a sample in this biofacies. The percentage of Spirillina infima in this biofacies has diminished; on the average it accounts for fifteen percent of the population. Lingulina tenera and Eoguttulina liassica are present in almost all samples and equal in proportion (2 to 10 percent). Astacolus pauperatus occurs in every sample (2 to 16 percent). Dentalina pseudocommunis is in almost all of the samples

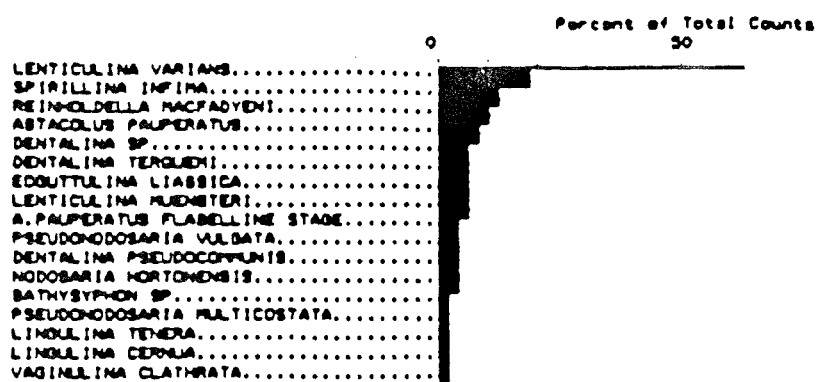
(2 to 14 percent). Whereas, Reinholdella macfadyeni is present only in the samples of this biofacies which have high diversity. Samples 2262 and 2448 are suspect as few foraminifera were recovered. Histograms of typical members of this biofacies are seen in Figure 9. Table IIIId Appendix shows the Sanders's similarity indices matrix for this Biofacies. Biofacies Iota appears to have a closer affinity to Biofacies Theta than it does to Biofacies Lambda, Fig. 5, cluster-factor group 3, (Table IIIId Appendix). In general the diversities (H_s) of this group are in excess of 2.0 and range as high as 2.63 (Table 1a).

Biofacies Lambda, cluster-factor group 3, occurs at the base of the Upper Lias extending through the Dactylioceras tenuicostatum subzone through the Harpoceras exaratum subzone. The dominant species in this assemblage is Reinholdella macfadyeni (30 to 89 percent). Lenticulina muensteri is the second most important species (9 to 18 percent). Most of the samples have a minor amount of Marginulina prima (1 to 5 percent). Ophthalmidium northamptonensis is important in two of the samples. Lingulina tenera is present in most of the samples. Spirillina infima is rare. Typical samples of this biofacies are shown in the histograms of Figure 10.

SAMPLE: 2121



SAMPLE: 2471

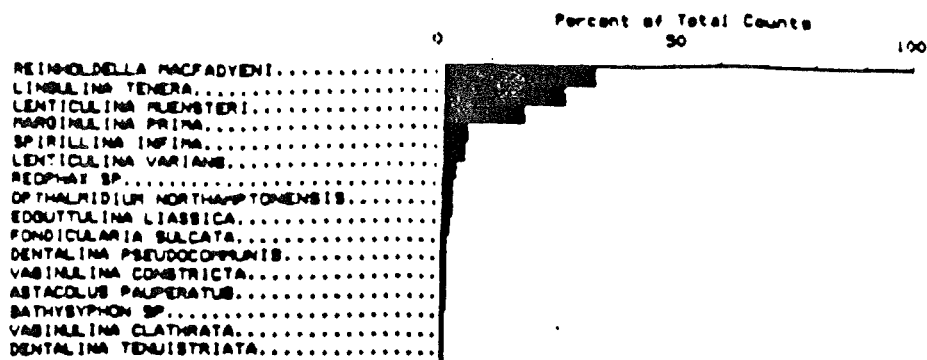


SAMPLE: 2486

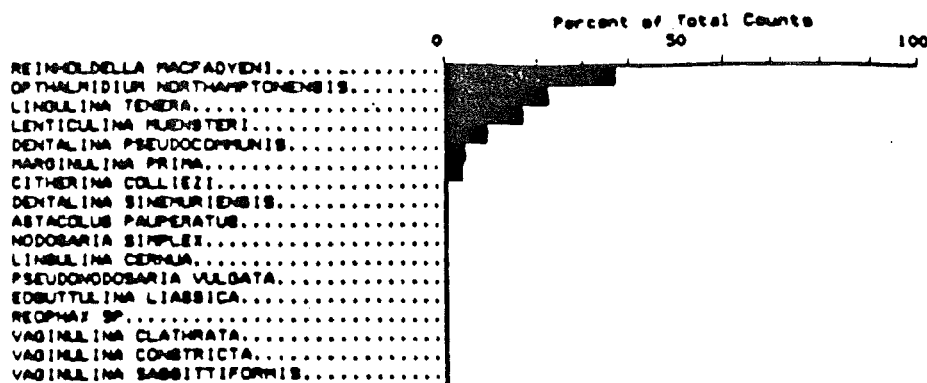


Figure 9. Histograms of samples typical of Biofacies of Iota the Mochras Borehole.

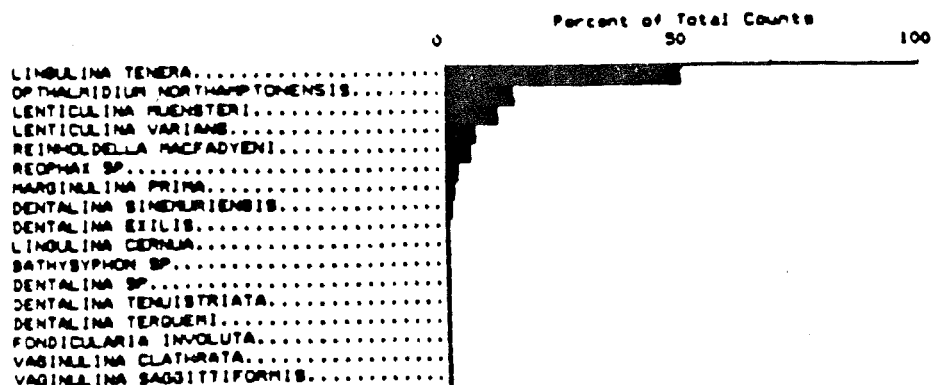
SAMPLE: 2026



SAMPLE: 2007



SAMPLE: 2746



SAMPLE: 2692

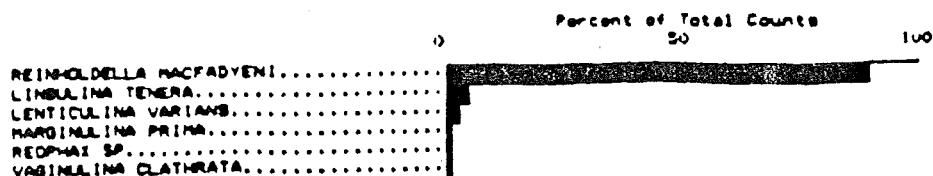


Figure 10. Histograms of samples typical of Biofacies Lambda of the Mochras Borehole.

Sample 2746 of this biofacies has all the important constituents of this group. However, the proportions in which they are present make it similar to the members of Biofacies Eta. This biofacies has a lesser degree of internal similarity than others of this section (Table IIIe Appendix). The samples in this biofacies range in diversity. Sample 2720 may be unreliable because of the low numbers of fossils recovered. Biofacies Lambda is the least clearly defined of the biofacies.

STEEPLE ASTON BOREHOLE

The Steeple Aston Borehole, Oxfordshire, National Grid Reference SP4687 2586, (Figure 1), penetrates a thickness of 500 feet of Liassic strata: Upper Lias, 63' 6"; Middle Lias, 53' 0"; and Lower Lias, 384' 2" (Poole, 1977). The Liassic section is predominantly mudstone interrupted occasionally by limestone, ironstone or cementstone layers (Poole, 1977). Although foraminiferal fossils were recovered from all three divisions of the Lias, preservational and recovery biases make the assemblages obtained from the Upper and Middle divisions unreliable. Only the cluster and factor groups from the Caenisites turneri through the Prodactylioceras davoei ammonite zones of the Lower Lias were used in this study. The Lower Lias ammonite zones beneath the C. turneri zone are absent at Steeple Aston (Figure 1).

Three cluster-factor groups were discerned in this section (Figures 11, 12a&b). These groups reveal a vertical succession, and the vertical is an expression of the lateral faunal succession--Walther's Law, (Figure 13).

Biofacies Delta, cluster-factor group 3, dominates in the C. turneri and Asteroceras obtusum zones and fluctuates with Biofacies Kappa in the Oxynoticeras

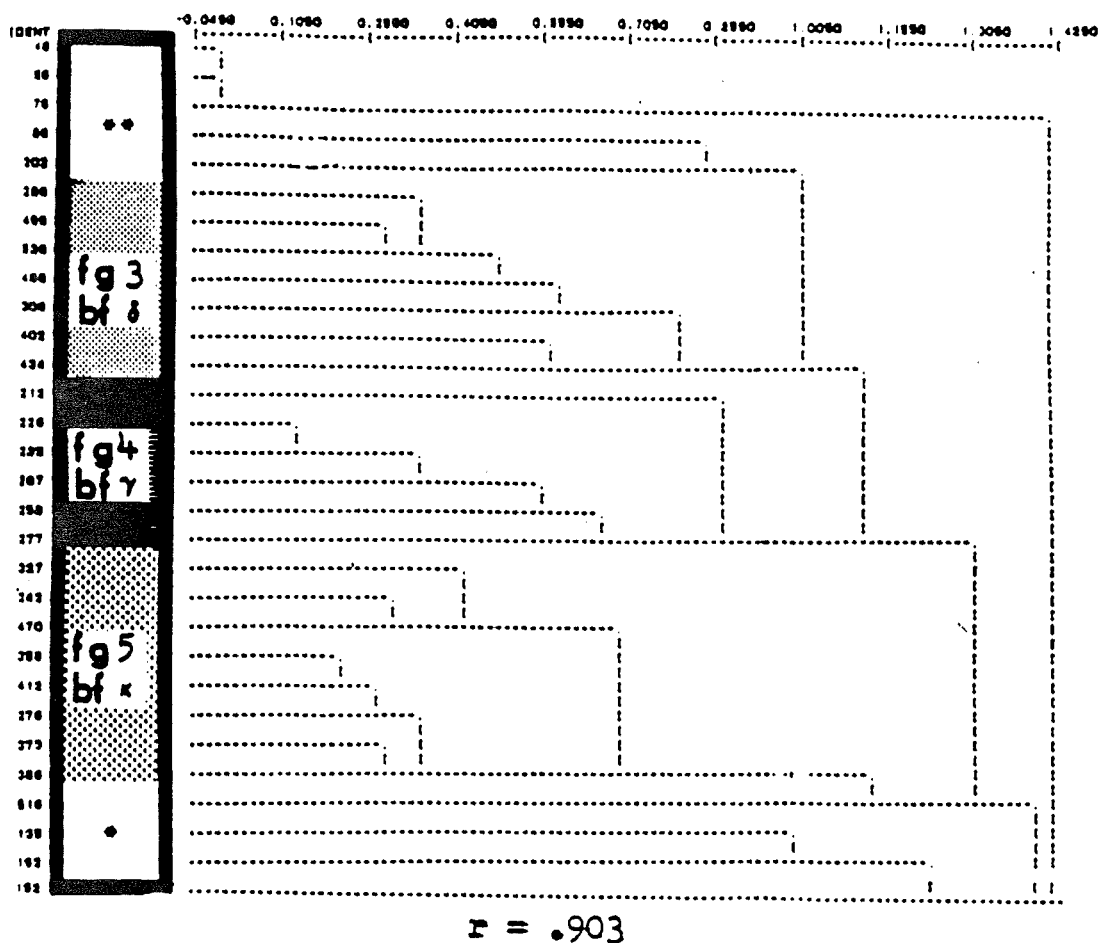
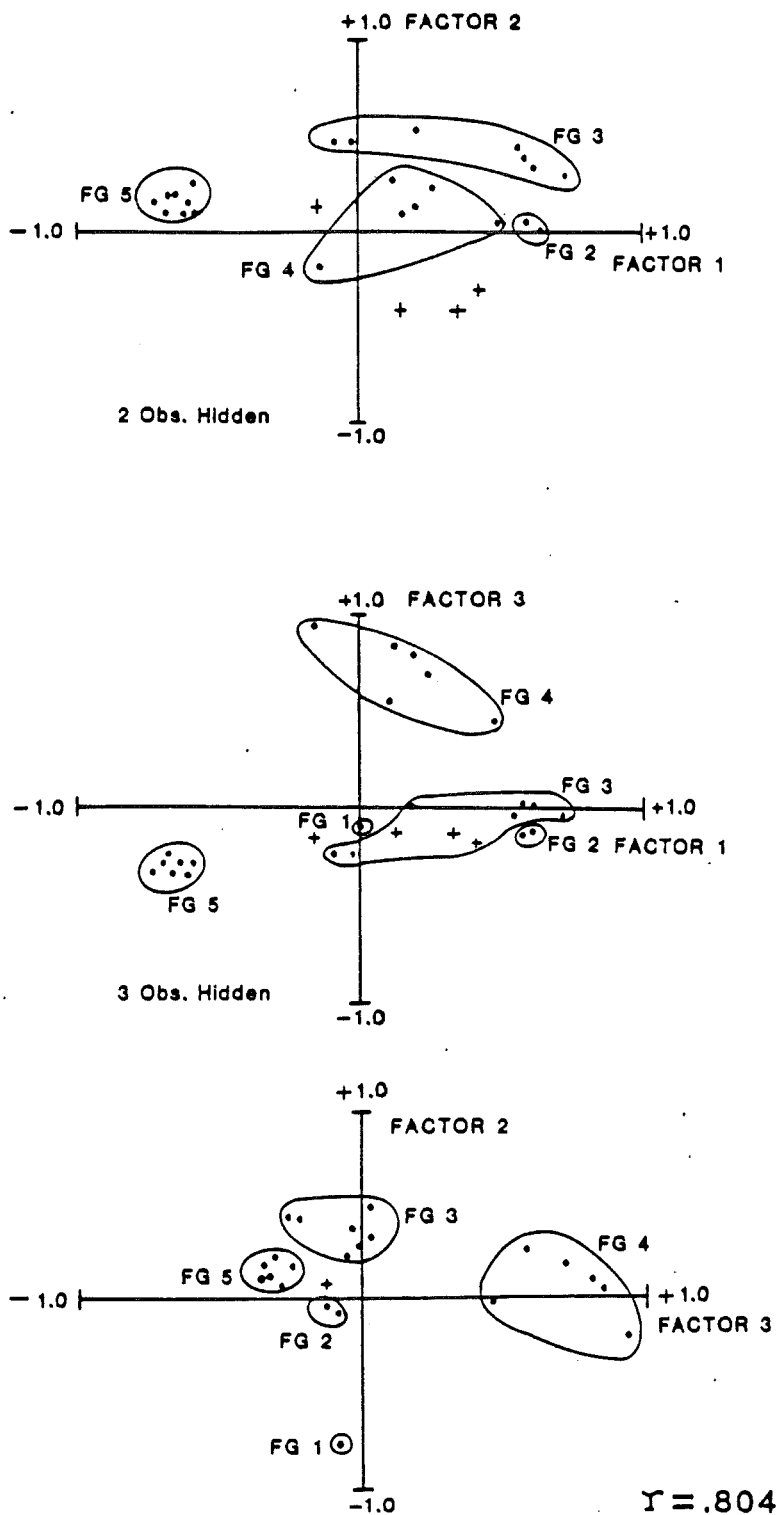


Figure 11. Q-mode cluster analysis of the assemblages from the samples from the Steeple Aston Borehole. (Number = sample number, fg = Q-mode factor group, Bf = biofacies and * = isolates or outliers which do not form in any factor group.



Q-MODE FACTOR ANALYSIS OF
THE STEEPLE ASTON BOREHOLE SAMPLES

Figure 12.

oxynotum through Tragophylloceras ibex zones (Figure 13). Lingulina tenera is the dominant foraminiferal species of Biofacies Delta, ranging from 28 to 91 percent of the total composition. Sample 495-500 has 91 percent L. tenera, and this accounts for its relatively high dissimilarity with the rest of Biofacies Delta (Table IIIIf Appendix). It is far more similar to Biofacies Beta at Dorset (p. 73) and should be designated as such. Marginulina prima, Eoguttulina liassica, and Dentalina pseudocommunis are present in all samples. Lenticulina varians plexus, Frondicularia sulcata and Astacolus pauperatus are present in all but one of the samples. Pseudonodosaria vulgata, Spirillina infima, Opthalmidium macfadyeni, Dentalina sinemuriensis and Vaginulina triquetra are present in more than fifty percent of the samples of this biofacies. The diversity, Hs, of Biofacies Delta, with the exception of sample 495-500, ranges from 2.00 through 2.47 (Table 2). Figure 14 a,b shows histograms of typical assemblages of Biofacies Delta.

Biofacies Kappa, cluster-factor group 5, fluctuates with Biofacies Delta during the O. oxynotum through the Echioceras raricostatum zone and then it is the only biofacies present from the top of the E. raricostatum zone to the lower T. ibex zone. The foraminiferal species Opthalmidium macfadyeni dominates, ranging from

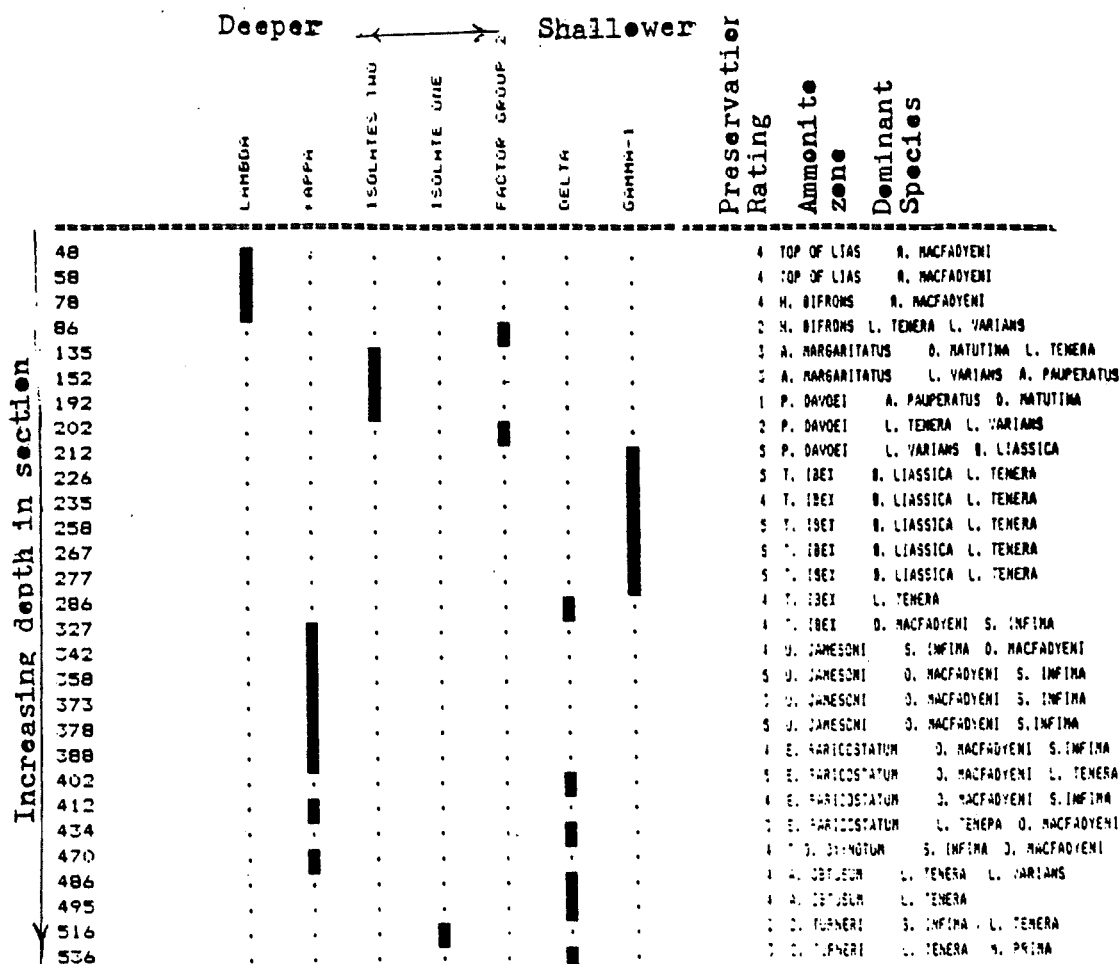
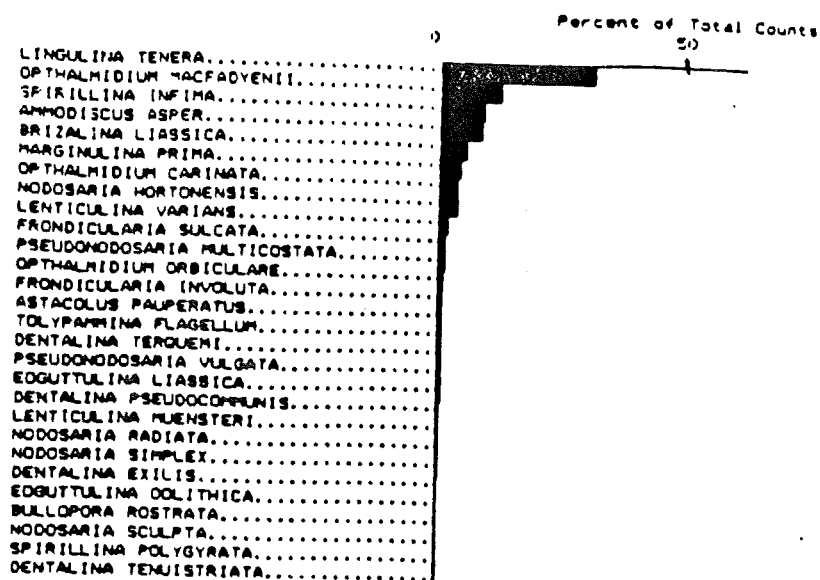


Figure 13. The Q-mode Cluster factor groups of the Steeple Aston Borehole: samples 48-86 have very low abundance (A = 12-29) and low diversity (Ns = 2-7). Samples 202-135 are from a section influenced by caving. Preservation Rating of 5 = Excellent and preservation rating of 1 = poor. The deeper/shallower arrangement follows the paleoslope model (p. 167).

SAMPLE: 304



SAMPLE: 284

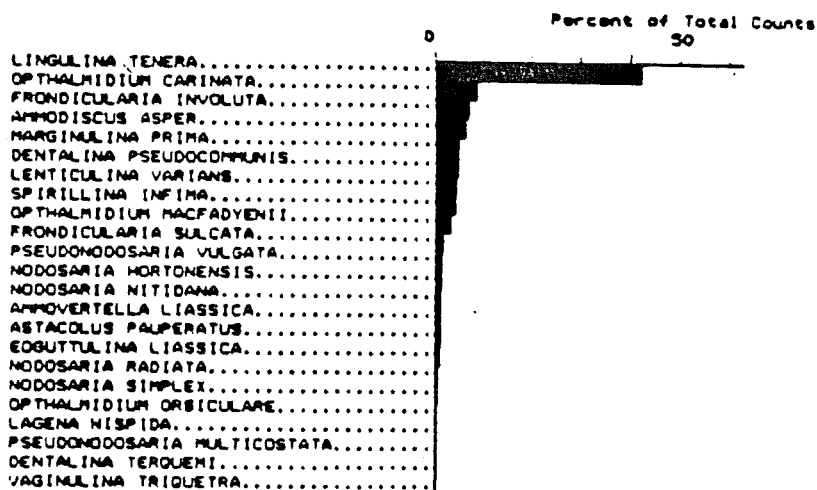
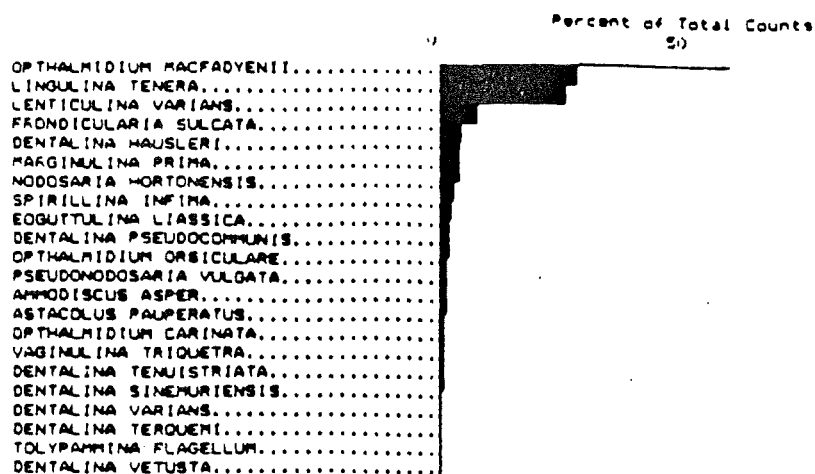


Figure 14a. Histograms of samples typical of Biofacies Delta from the Steeple Aston Borehole.

SAMPLE: 402



SAMPLE: 536

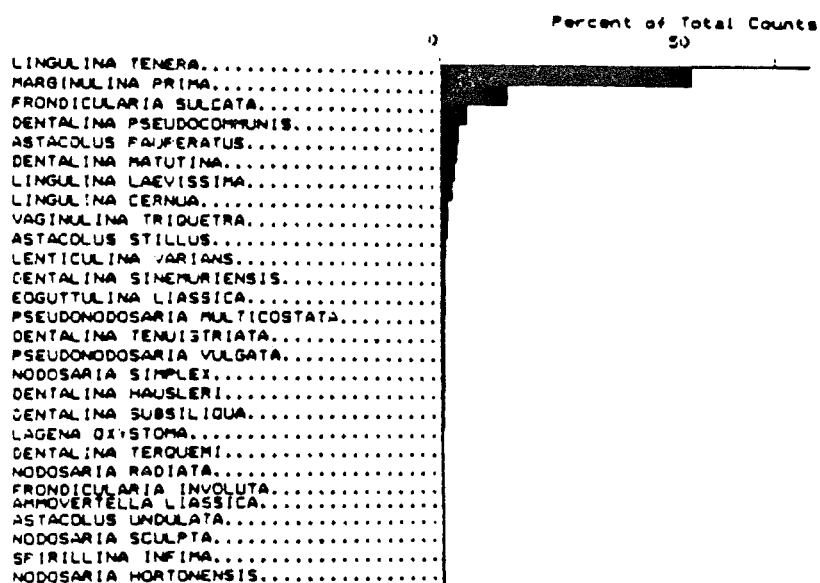


Figure 14b. Histograms of samples typical of Biofacies Delta from the Steeple Aston Borehole.

28 to 85 percent of the total composition of each sample. Spirillina infima is always the secondary species, accounting for 4 to 46 percent of the assemblage. Together these two species account for 55 to 89 percent of the population of each sample of this biofacies. Lingulina tenera is always present, but never in excess of 5 percent of the total.

Ophthalmidium orbiculare and Ophthalmidium carinata are present in all but one of the samples. A variety of other species make up the remainder of the assemblage. Diversity, H_s , in the samples of this Biofacies is quite variable, ranging from 0.97 to 2.47, and equitability, E , ranges from 0.15 to 0.58 (Table 2). Typical assemblages of Biofacies Kappa are shown in Figure 15.

Biofacies Gamma-1, cluster-factor group 4, appears in the T. ibex zone and persists throughout this zone of this core (Figure 13). Brizalina liassica is the dominant foraminiferal species, ranging from 17 to 73 percent of the total population of each sample. In all samples but one, Lingulina tenera is present as the secondary species, accounting for 5 to 33 percent. Lenticulina varians and Dentalina pseudocommunis are present in all samples as the next most common species. Marginulina prima, Astacolus pauperatus, Dentalina terquemi and Frondicularia involuta are common accessory

	Number Of Specimens	Number Of Species	Shannon-Weiner Diversity	Equitability
Sample	N	S	$\bar{H}$	E
48-53	29	2	0.15	0.58
58-60	6	1	0.00	1.00
78-83	4	1	0.00	1.00
86-93	12	7	1.82	0.88
103-108	3	2	0.64	0.94
108-112	1	1	0.00	1.00
117-123	0	0	0.00	0.00
123-125	0	0	0.00	0.00
133-138	40	13	2.29	0.76
152-157	59	13	2.25	0.73
170-175	1	1	0.00	1.00
175-179	1	1	0.00	1.00
192-197	7	4	1.15	0.79
202-207	4	4	1.39	1.00
212-217	63	14	2.41	0.80
226-230	451	14	1.48	0.31
235-239	208	15	1.49	0.29
258-263	325	26	1.43	0.16
267-272	75	20	2.37	0.54
277-282	45	13	2.24	0.72
286-292	474	26	2.27	0.37
306-310	311	30	2.47	0.39
327-333	80	18	2.34	0.58
342-347	486	24	1.74	0.24
358-362	204	7	1.04	0.40
373-378	780	17	0.96	0.15
378-383	797	43	2.47	0.27
388-393	248	24	1.80	0.25
402-407	183	22	2.26	0.43
412-418	131	21	2.09	0.39
434-439	66	15	2.33	0.69
470-474	67	13	1.96	0.55
486-490	137	23	2.56	0.56
495-500	137	11	0.67	0.18
516-521	58	14	2.11	0.59
536-539	658	36	2.00	0.21
539-541	0	0	0.00	0.00

Table 2. Diversity and equitability data for the fossiliferous samples of the Steeple Aston Borehole, Oxfordshire.

SAMPLE: 378

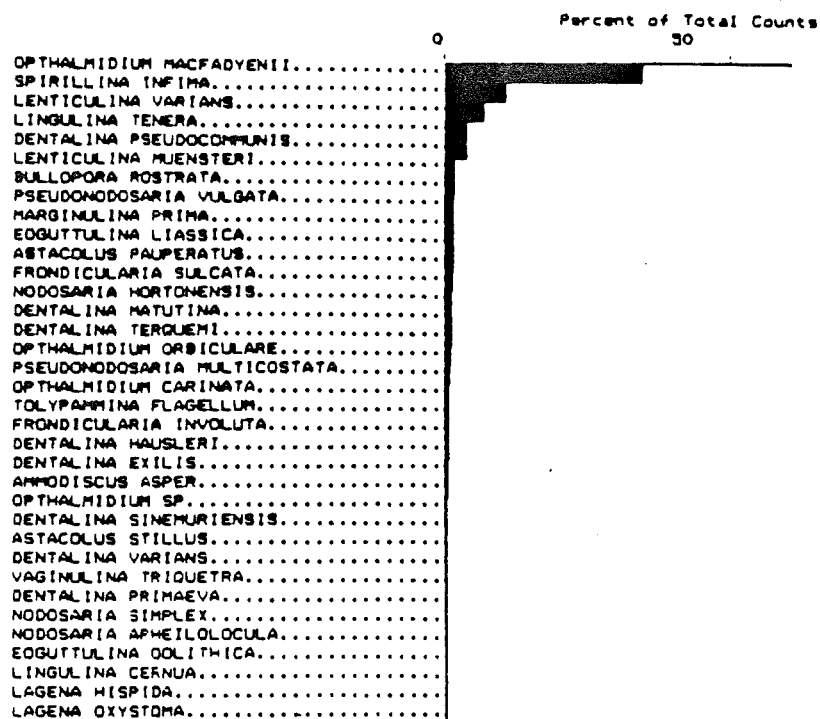
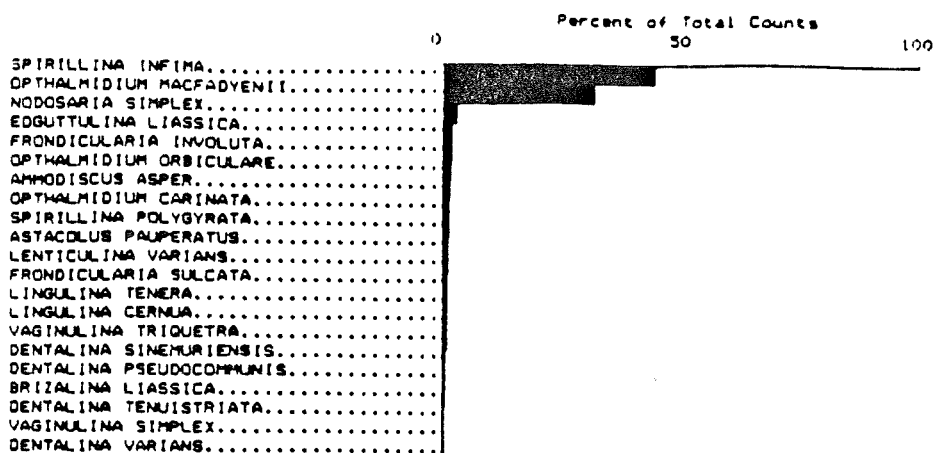


Figure 15a. Histograms of samples typical of Biofacies Kappa from the Steeple Aston Borehole.

SAMPLE: 342



SAMPLE: 388

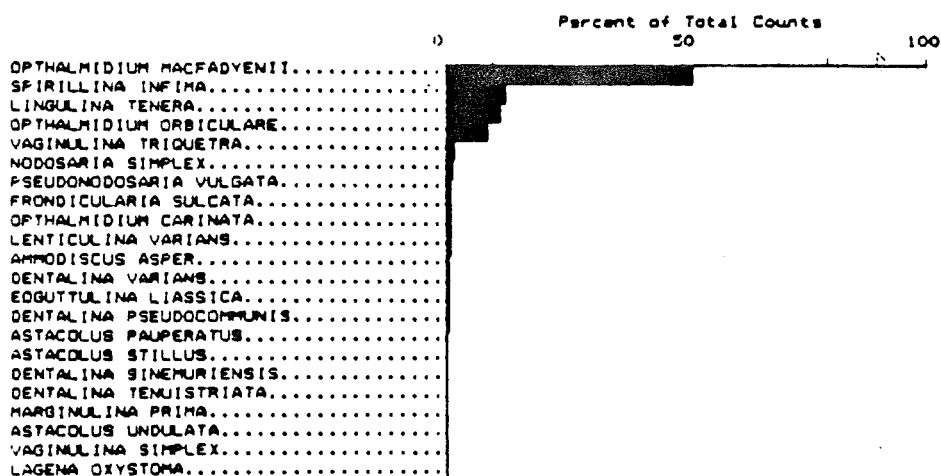
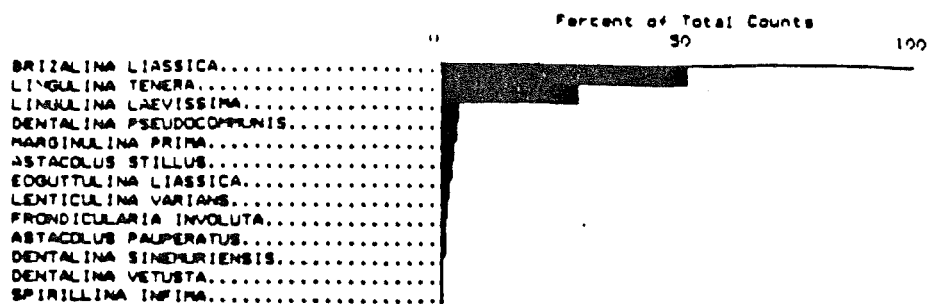


Figure 15b. Histograms of samples typical of Biofacies Kappa from the Steeple Aston Borehole.

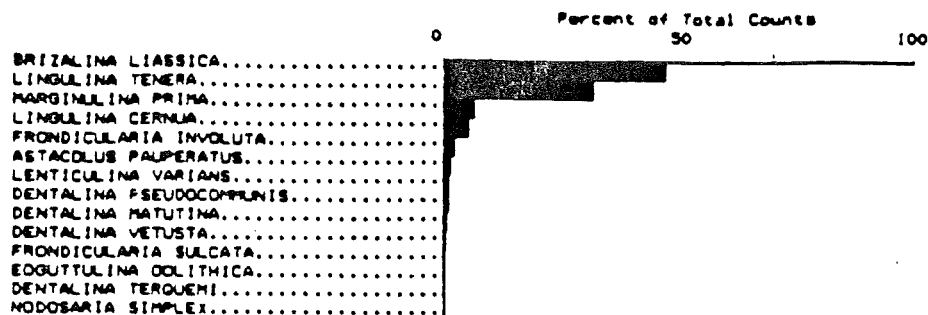
species. The diversity (H_s) of Biofacies Gamma-1 ranges from 1.43 to 2.41. The assemblages in the histograms of Figure 16 are typical of Biofacies Gamma-1.

The similarity of Biofacies Delta, Kappa, and Gamma-1 is reflected in Tables III g,h Appendix. Although there is variation in the composition and proportion of all the constituents of these biofacies, the Sander's Indices corroborate the cluster and factor groupings. Table IIIg Appendix indicates that Biofacies Delta is closer in composition with Biofacies Gamma-1 than it is with Biofacies Kappa. However, the table also shows that Biofacies Kappa has a closer affinity to Biofacies Delta in composition than it does to Gamma-1.

SAMPLE: 235



SAMPLE: 224



SAMPLE: 258

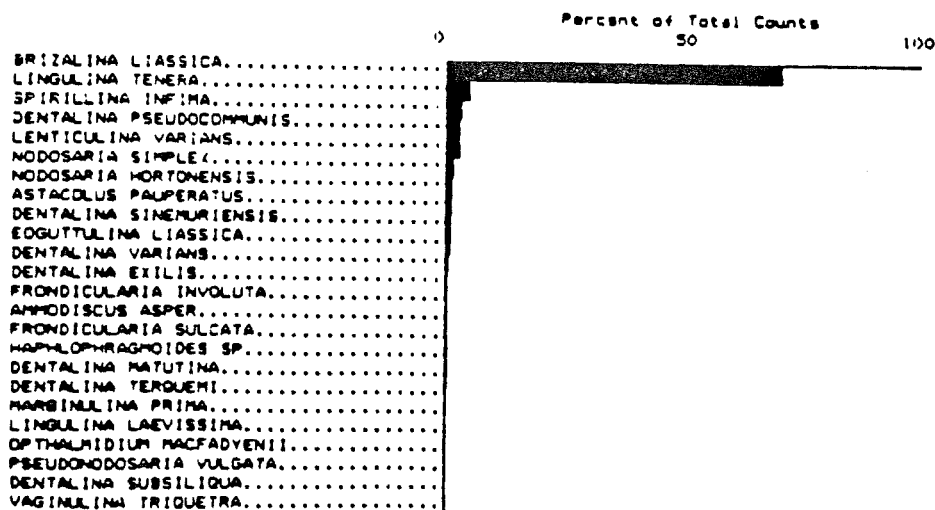


Figure 16. Histograms of samples typical of Biofacies Kappa from the Steeple Aston Borehole.

COCKLEPITS BOREHOLE

Several of the biofacies present in the Steeple Aston Core are also present in the core taken from the Cocklepits Borehole, Humberside, Yorkshire, National Grid Reference : SE 9323 - 2865. The Cocklepits Bore penetrates the Yorkshire Lias from the Harpoceras exaratum Zone of the Toarcian through the Psiloceras planorbis Zone of the Hettangian. Computer analysis of the foraminiferal fossil assemblages recovered produced discrete cluster-factor groups and several isolated samples which did not join in any of the groupings (Figures 17,18). The lithology is predominantly poorly indurated silt-clay, argillite, which is occasionally interrupted by limestone, marl, ironstone, and chamosite rich layers. The rock, for the most part is not as recrystallized as the rocks of the nearby outcrops of the Yorkshire Coast, and therefore the fossil assemblages are not as susceptible to preservational biases. There are , none the less, gaps in the stratigraphic column here. Several ammonite zones are missing while others are poorly established (Figure 19).

The Mochras Borehole Biofacies Lambda is present in the samples taken from intervals 19.18 - 20.11 and 21.06 -21.96 of the Dactylioceras tenuicostatum Zone. These samples did not cluster nor form in any other factor

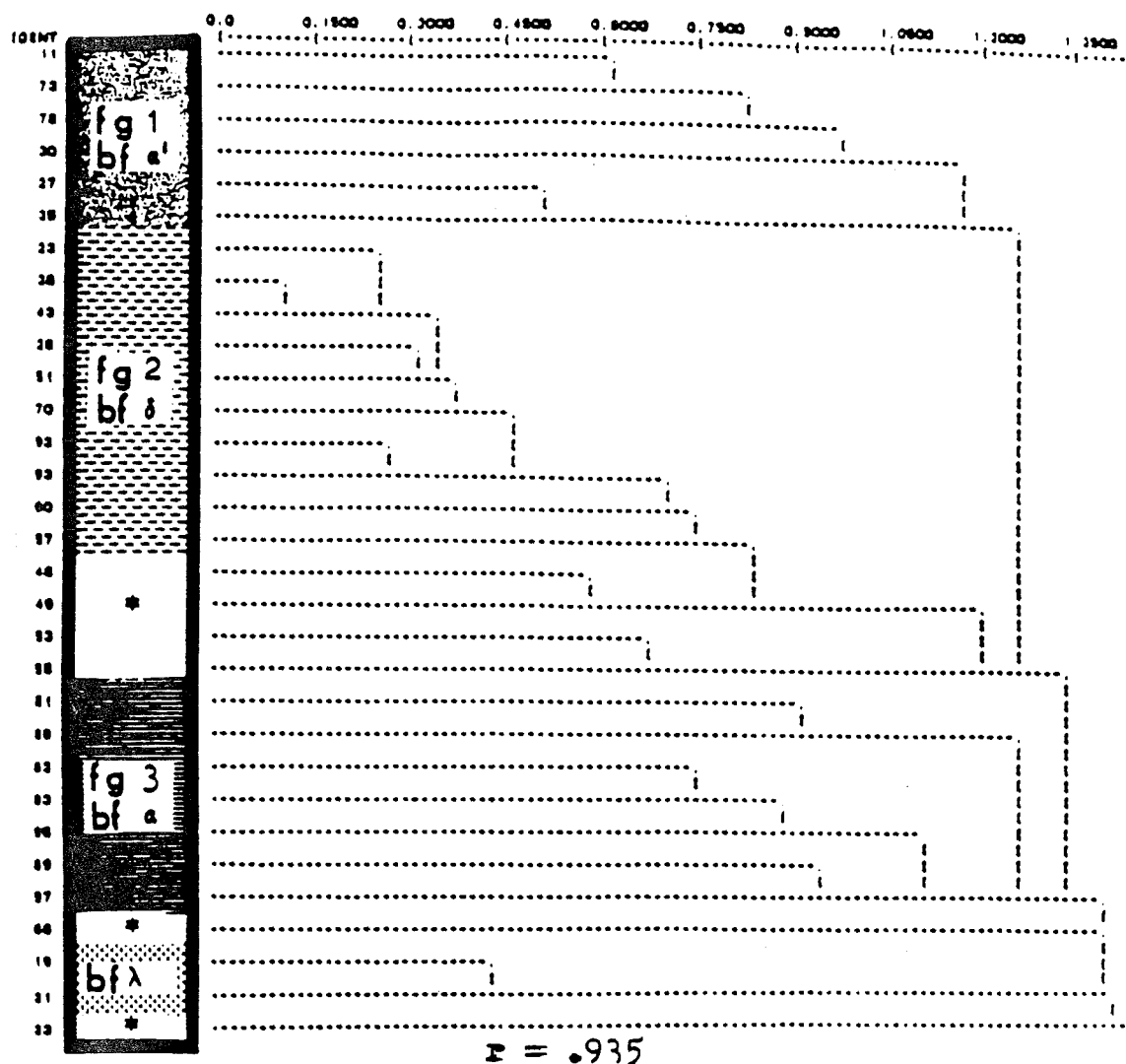
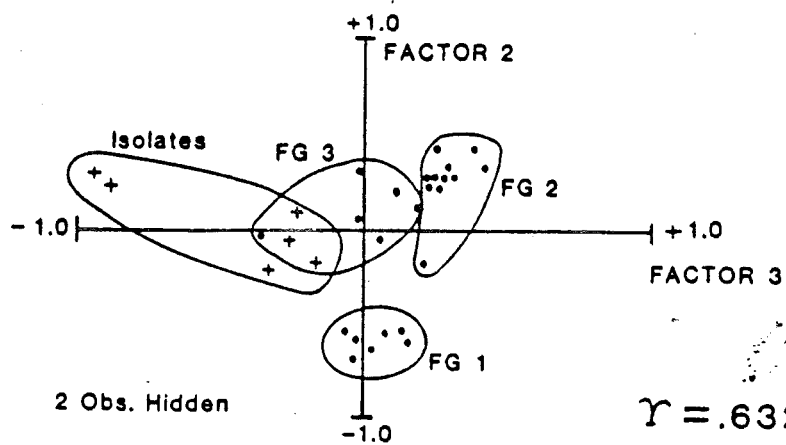
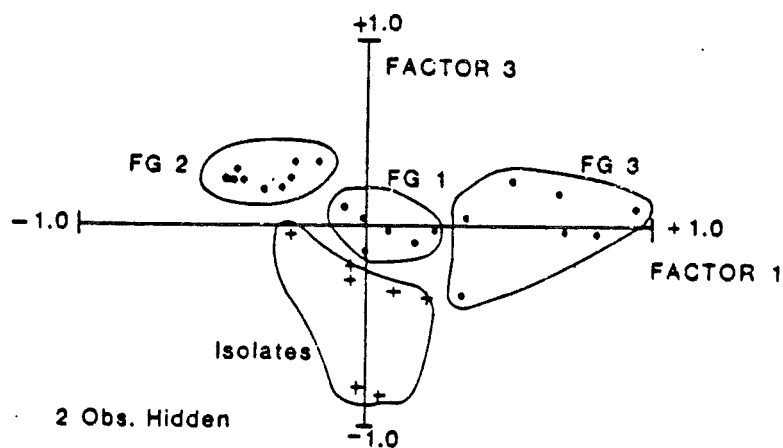
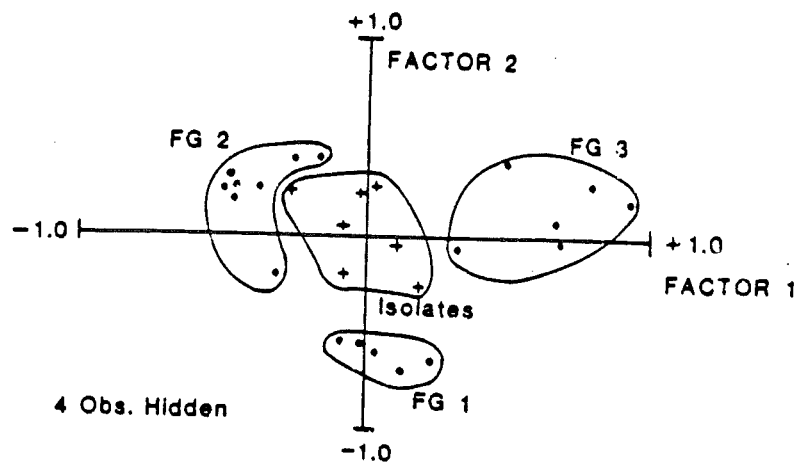


Figure 17. Q-mode cluster analysis of the assemblages from the samples from the Cocklepit's Borehole. (Number = sample number, fg = Q-mode factor group, Bf = biofacies and * = isolates or outliers which do not form in any factor group.



Q-MODE FACTOR ANALYSIS OF
THE COCKLEPITS BOREHOLE SAMPLES
Figure 18.

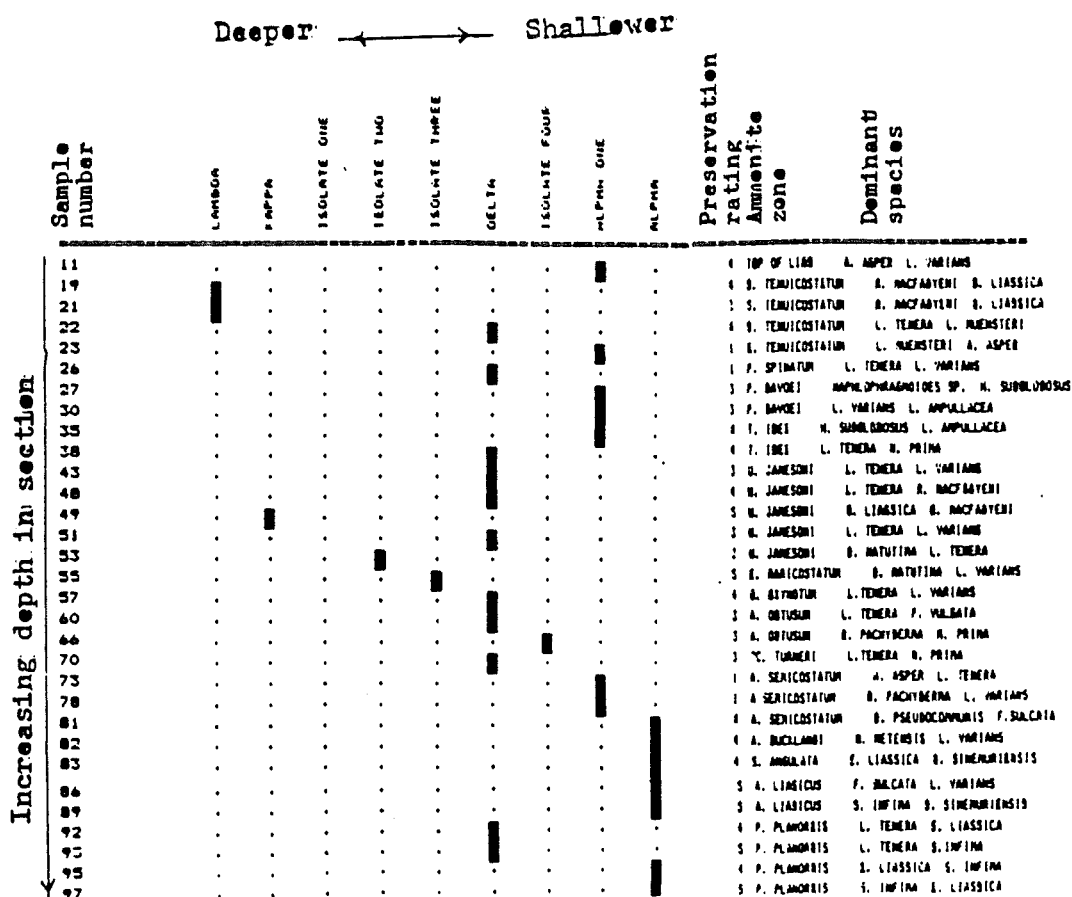


Figure 19. Q-mode cluster-factor analysis of the Cocklepits Borehole produced four distinct groups. When the groups are plotted against the sample depth in the core, they reveal the faunal succession. The position of the isolates in the faunal succession is speculative. This model suggests that the groups are biofacies and the depth of the marine environment increases from right to left. Preservation rating: 5 = excellent... 1 = poor. The deeper/ shallower arrangement follows the paleoslope model (pg. 167).

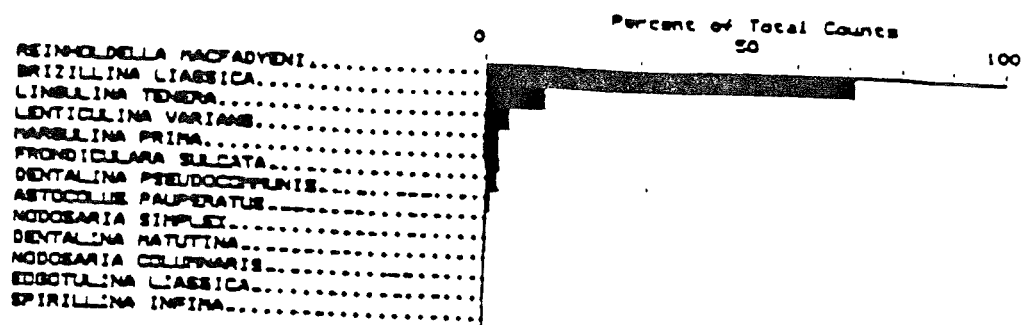
	Number Of Specimens	Number Of Species	Shannon-Weiner Diversity	Equitability
Sample	N	S	$\bar{H}$	E
11.61-12.27	75	19	2.49	0.64
14.36-14.90	1	1	0.00	1.00
16.26-16.30	1	1	0.00	1.00
19.18-20.11	42	12	2.21	0.76
21.06-21.96	505	28	1.56	0.17
22.87-23.32	42	11	1.71	0.50
23.77-24.72	6	3	0.87	0.79
26.60-27.10	167	16	1.88	0.41
27.50-28.43	172	16	2.36	0.66
30.31-31.25	131	23	2.62	0.60
35.89-36.80	229	28	2.71	0.54
38.70-39.60	588	19	1.01	0.14
43.30-44.22	128	13	0.95	0.20
48.91-49.86	545	35	2.42	0.32
49.86-50.80	468	18	1.83	0.35
51.73-52.65	118	17	1.98	0.42
53.63-54.50	20	6	1.27	0.59
55.43-56.37	109	15	2.35	0.70
57.32-58.20	403	25	2.48	0.48
60.99-61.79	10	6	1.70	0.91
66.13-67.03	54	14	2.05	0.56
70.52-71.37	244	16	1.94	0.43
73.12-73.93	23	7	1.76	0.83
78.22-79.08	109	11	1.77	0.53
81.56-82.46	455	29	2.64	0.48
82.46-83.38	17	10	2.20	0.90
83.38-84.27	53	13	2.36	0.82
86.00-86.95	14	6	1.35	0.64
89.55-90.40	288	19	2.57	0.56
92.19-92.92	370	17	1.70	0.32
93.71-94.39	214	13	1.66	0.40
95.48-96.37	149	7	1.14	0.45
97.25-98.13	17	8	1.76	0.72

Table 3. Diversity and equitability data for the fossiliferous samples of the Cocklepit Borehole, Humberside, Yorkshire.

group in the Cocklespits, except to link with each other (Figures 17,18). Using the Sander's Index, a comparison was made between these two samples and those of Mochras Biofacies Lambda. The agreement is as strong as with the other members of the biofacies (Table IIIi Appendix). The major difference here is that the Cocklepits assemblages have 12 -16 percent Brizalina liassica (Figure 20) and the Mochras Biofacies does not; on the other hand, several of the Mochras Biofacies Lambda samples have Ophthalmidium northhamptonensis and Lenticulina munsteri as a constituent and the Cocklespits samples do not. This faunal similarity suggests that environmental conditions of the Lower Toarcian were similar over a broad area.

Stratigraphically, the longest ranging cluster-factor group, group 2, in the Cockelpits Bore extends intermittently from the D. tenuicostatum Zone through the P. planorbis zone of the lower Hettangian, (Figure 19). This group is analogous to Biofacies Delta of the Steeple Aston Borehole, (Table IIIj Appendix), which is also long ranging: Tragophylloceras ibex through Caenisites turneri zones. It is a Lingulina tenera assemblage, with Lenticulina varians usually the second most dominant foraminiferal species. Dentalina pseudocommunis , Marginulina prima, Astacolus pauperatus, and

SAMPLE: 21



SAMPLE: 19

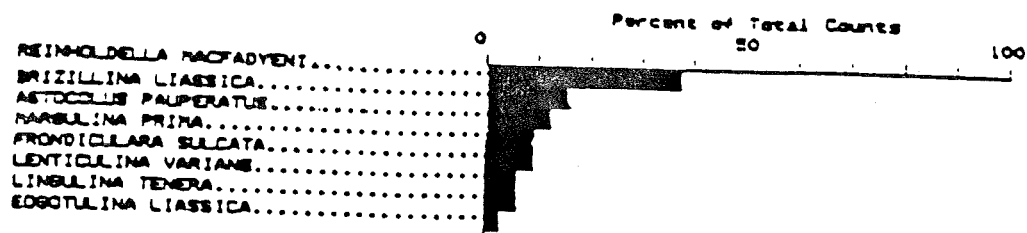


Figure 20. Samples from the 19.18-20.11 interval and the 21.06-21.96 interval of the Cocklepits Borehole are members of Biofacies Lambda which was defined at the Mochras Borehole. The interpretation is that this is a deep water, open marine biofacies.

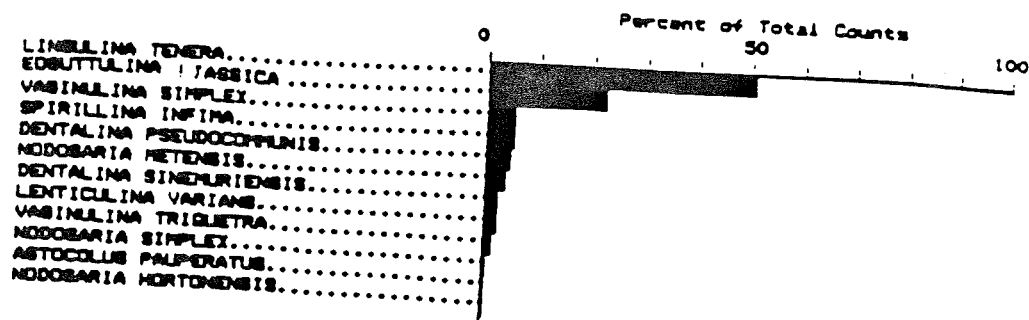
Frondicularia sulcata are in 70 percent or more of the samples and range from 1 -17 percent. Figure 21 shows histograms of samples typical of Biofacies Delta in the Cocklepits Borehole. Although the total range of diversity of this group is from Hs 1.0 -2.5, the most prevalent range is from 1.7 -2.0 (Table 3); at Steeple Aston the prevalent range for Biofacies Delta is Hs 2.0 - 2.5.

Another biofacies first noted at Steeple Aston is present in the sample interval 49.86 - 50.80m of the Cocklepits Borehole. Although sample 49.86-50.80 clusters with group two, its affinity with this group is weak. It appears as an outlier in factor analysis. The high degree of similarity between sample 49.86 -50.80 and Steeple Aston Biofacies Gamma-1 is seen in the Sanders Index numbers in Table 4.

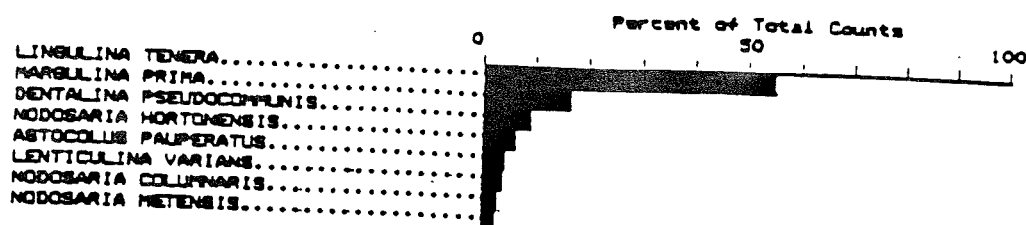
The biofacies is dominated by Brizalina Liassica and Lingulina tenera (Figure 22). Ophthalmidium macfadyeni is a strong constituent. It is possible that this is a transitional assemblage or that some mixing has taken place here.

The fourth biofacies recognized in the Cocklepits Borehole is one that is characterized by a high proportion of arenaceous foraminiferal species. In all

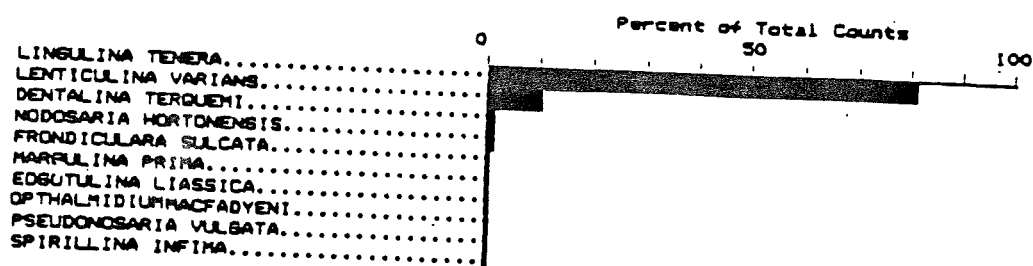
SAMPLE: 92



SAMPLE: 70



SAMPLE: 43



SAMPLE: 26

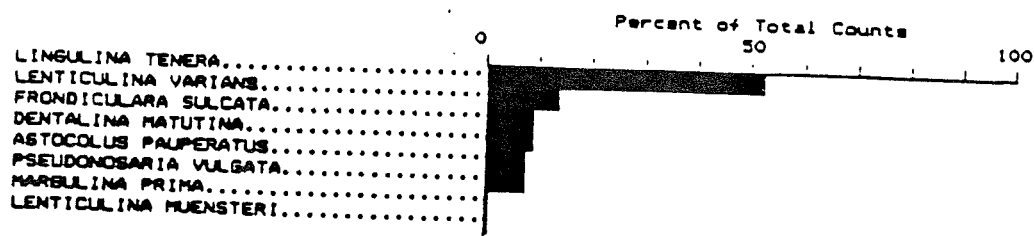


Figure 21. The Cocklepits Borehole samples representative of cluster-factor group2 are analogous to Biofacies Delta defined in the Steeple Aston Borehole. The interpretation of the model is that this is a partially-restricted to open marine biofacies, ranging from middle to inner shelf.

Cocklepits sample	Steeple sample	Aston	Sanders Index
49	212		46
49	226		59
49	235		60
49	258		42
49	267		58
49	277		65

Table 4. Cocklepits sample 49.86 -50.80
compared with the samples constituting Biofacies
Gamma-1 of the Steeple Aston Borehole.

SAMPLE: 49

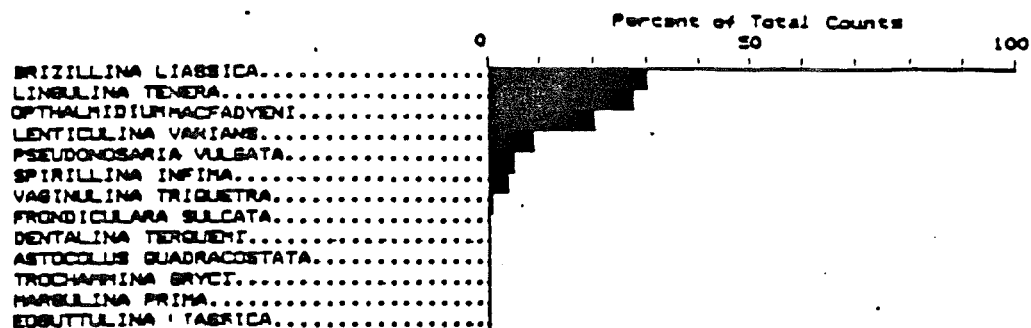


Figure 22. The Histogram is of the sample from interval 49.48-50.80 which is an outlier in the cluster-factor analysis. The sample is a member of Biofacies Gamma-1 which was defined in the Steeple Aston Borehole.

the samples except the sample taken at interval 30.31 - 31.25m the dominant foraminiferal species is arenaceous (in sample 30.31 -31.25, Lenticulina varians dominates one with 23 percent of the total, and the arenaceous species Lagenammina ampullacea is the secondary, accounting for 17 percent). Ammodiscus asper, ranging from 4 -44 percent of the total, and Lenticulina varians, ranging from 10 - 23 percent of the total, are in all the samples of this biofacies. Important arenaceous foraminiferal species are : Haplophragmoides subglobosus, constituting 6 - 15 percent of the total of an assemblage; Haplophragmoides sp., ranging from 4 -25 percent of the total; Trochammina gryci, ranging from 2 - 8 percent of the total; and Lagenammina ampullacea, ranging from 2-17 percent. Other arenaceous species also present but sporadic in occurrence are Ammobaculites fontinensis, Glomospira sp. , Lagenammina sp. , Reophax dentalinaformis, Reophax sp., and Trochammina sp. . The other calcareous species of importance occurring in all of the samples are Lingulina tenera and Astacolus pauperatus . Each species constitutes approximately 5-10 percent of the assemblage (Figure 23).

Table IIIk Appendix shows the similarity among the members of this biofacies. Samples 73.12 - 73.93 and 78.22 - 79.08 have relatively low similarity indices by comparison with the rest of the biofacies. This may be

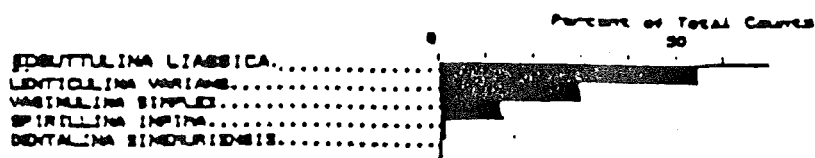
[illegible]

accounted for in that both samples were drawn from the Frodingham Ironstone strata and diagenesis may have biased the assemblage; an alternative to this may be that there may be a stratigraphic control since these samples are much lower in the column ; a third alternative is that this may be a mixed assemblage. Hallam (1967) suggested that these ironstones may be the result of formation of oolites in shallow water and subsequent collection in a nearby basin. These two samples, are less diverse than the rest of the group (Table 3). The mean diversity (H_s) of this group is 2.28 and the median is 2.36.

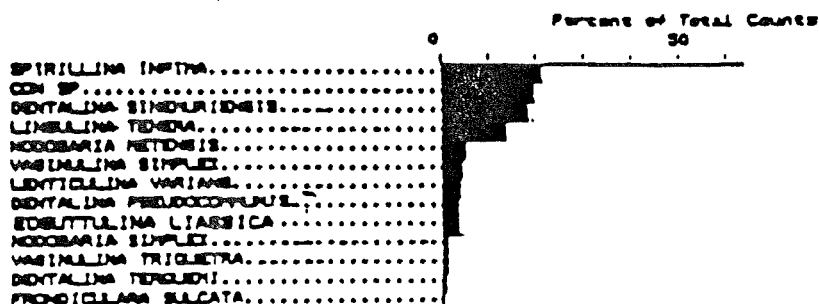
Biofacies Alpha, cluster-factor group 3 of the Cockelpits Borehole, extends from the Psiloceras planorbis zone through the Arietites bucklandi Zone of the lower Sinemurian. It is interrupted only once by Biofacies Delta in the Caloceras johnsoni Subzone. In the cluster groupings, the cluster for Biofacies Alpha was more loosely grouped than the other clusters (Figure 17), and the factor grouping for Alpha had a wide aerial spread (Figure 18). On the Sanders Similarity Index Matrix (Table IIII Appendix) the low numbers show the loose relationship of the groups in terms of percent of species in common. This can be accounted for in two ways. Samples 82.46-83.38, 86.00-86.95, and 97.25-98.13 were influenced by poor recovery and should be discounted

(Table 3). Samples 81.56-82.46, 83.38-84.27 89.55-90.40 and 95.48-96.37 have species in common; however, the proportions are varied. All four samples contain Lenticulina varians, Spirillina infirma, Dentalina sinemuriensis, and Eoguttulina liassica. Dentalina pseudocommunis and Vaginulina triquetra are present in all but sample 95.48-96.37. Samples 81.56-82.46, 83.38-84.27, and 89.55-90.40 have diversities (Hs) over 2.20 but the diversity (Hs) for sample 95.48-96.37 is one 1.14 (Table 3). The variability of the group is seen in the histograms of Figure 24.

SAMPLE: 95



SAMPLE: 89



SAMPLE: 81

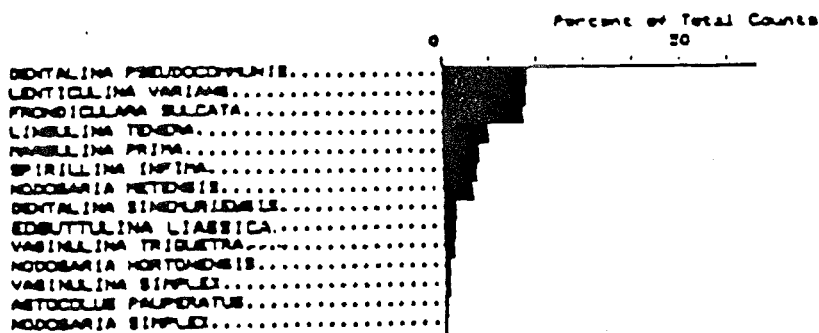


Figure 24. Samples from Cocklebits cluster-factor group 3, Biofacies Alpha, are variable in composition. The histograms compare two high diversity samples, 81 and 85, with a low diversity one, 95. The interpretation of the model is that this biofacies is one which occupies a near shore, shallow marine niche.

DORSET/DEVON OUTCROP SAMPLES

The Dorset and Devon Coast Outcrops are the type section for the Lias. Rhaetian-Lower Sinemurian samples were taken from stratigraphic beds described by Lang (1923, 1924, 1926, 1928 and 1936). The foraminiferal assemblages fall into five cluster-factor groups. One group, cluster-factor group 5 is quite distinct, and the other four appear to grade into one another. The cluster analysis, at first, appeared to demonstrate a chaining effect, and the factor analysis showed two groups: a small discrete grouping and a large number scattered over a much larger area. Cluster groupings were identified, and these were coded (Figure 25) and entered into the SAS Plotting program. The resulting plot showed that there were smaller groupings within the large scatter group and that they corresponded to the cluster groups. The resultant plot also showed that the smaller group was made up entirely of cluster group five (Figure 26).

Cluster-factor group 5 Biofacies Alpha, is prevalent in the lower Hettangian. However, the group ranges through the lower Sinemurian (Figure 27). In this group, sample KMP 75-277 had poor recovery (four fossils) so that it was omitted from the percentage comparisons (Table IIIm Appendix) Eoguttulina liassica, Lenticulina varians, Spirillina infima, and Vaginulina simplex are

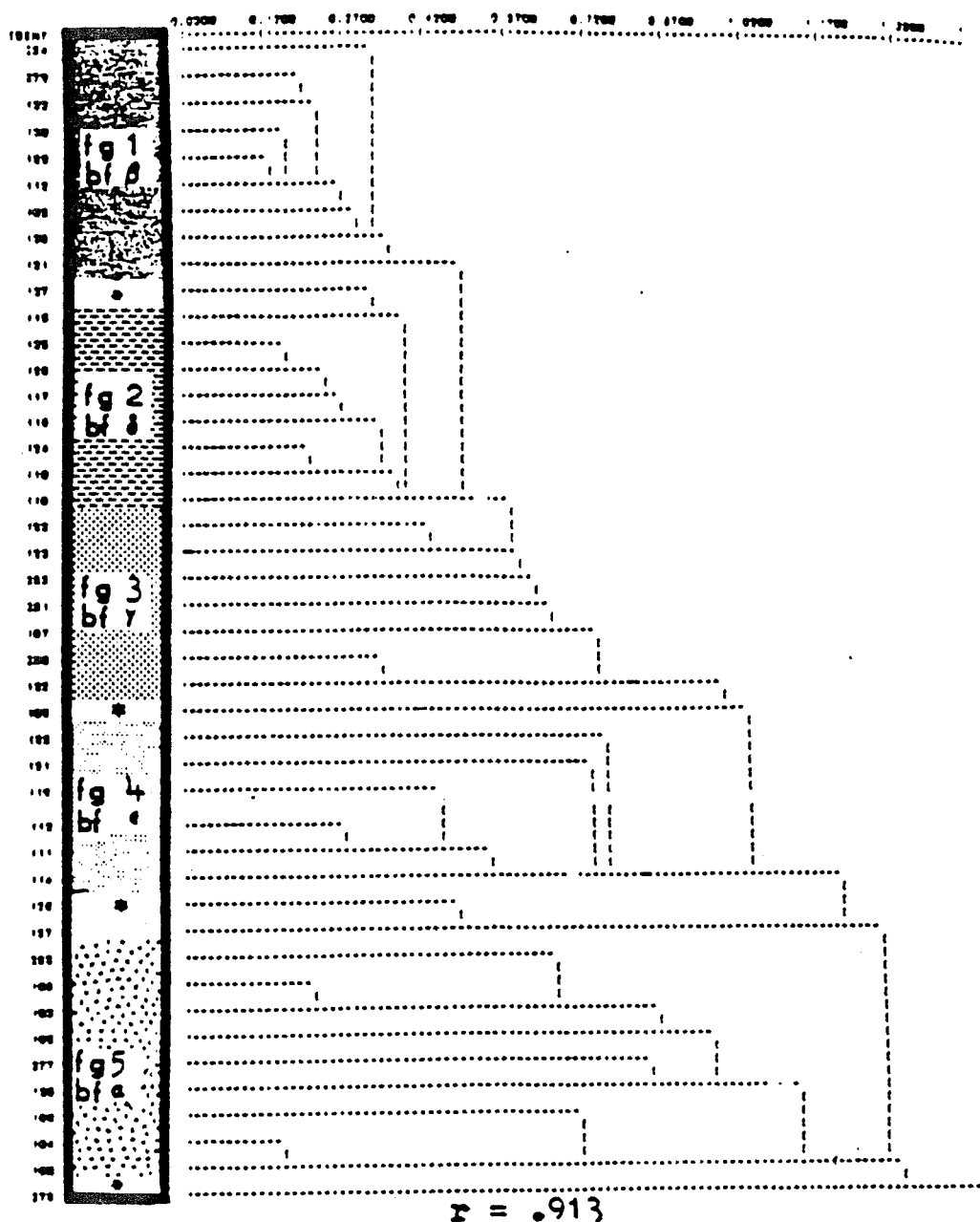
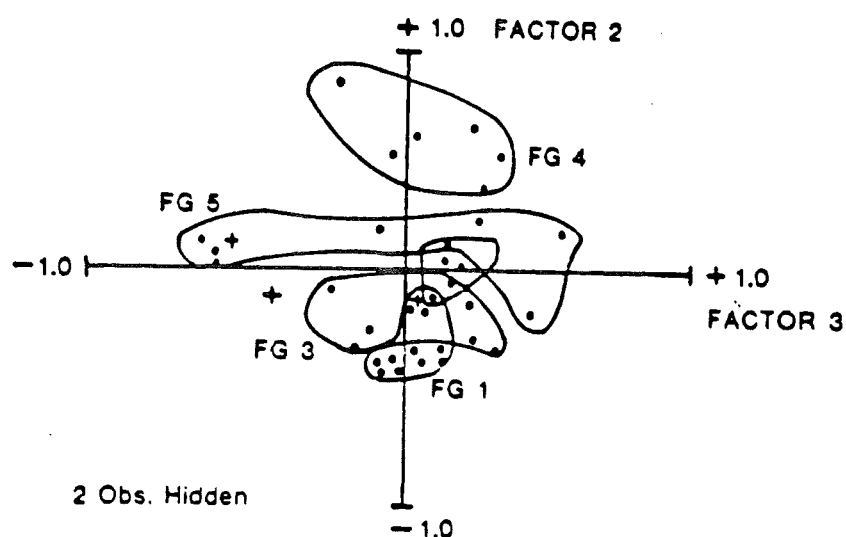
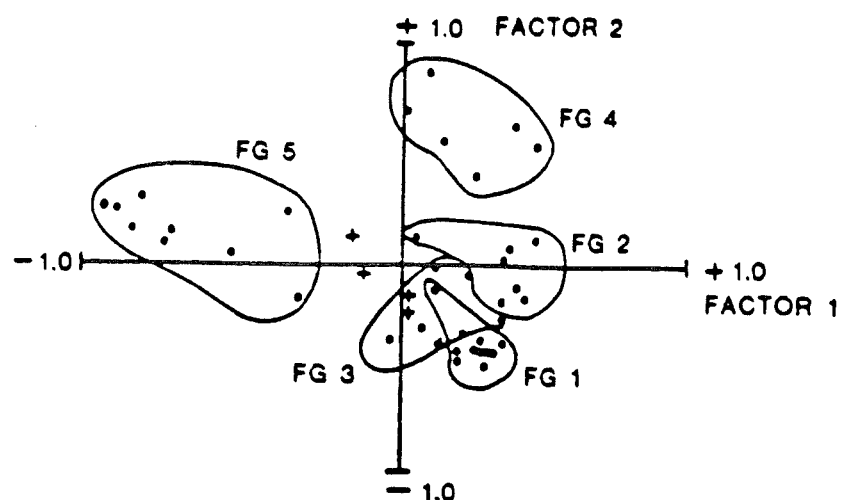
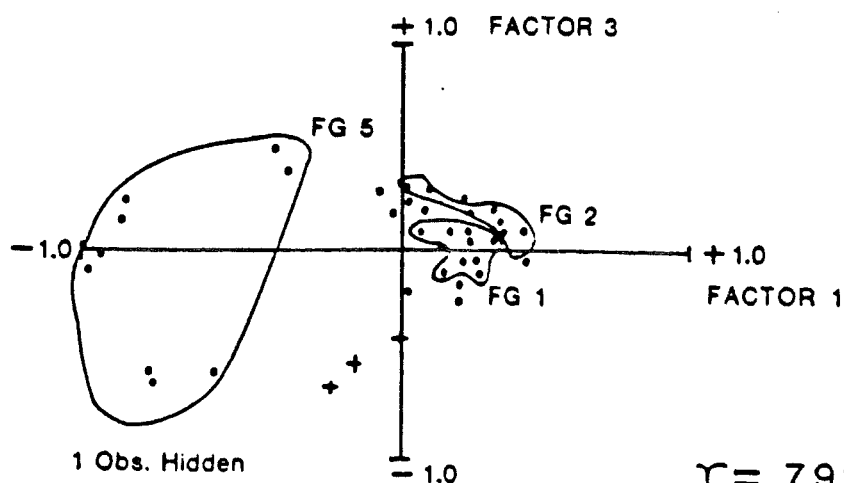


Figure 25. Q-mode cluster analysis of the assemblages from the samples from the Dorset and Devon Coastal Outcrops. (Number = sample number, fg = Q-mode factor group, Bf = biofacies and * = isolates or outliers which do not form in any factor group. The Samples are taken from the Hettangian and lower Sinemurian sections.



2 Obs. Hidden



1 Obs. Hidden

$r = .792$

Figure 26. Q-MODE FACTOR ANALYSIS OF DORSET HETTANGIAN AND LOWER SINEMURIAN OUTCROP SAMPLES

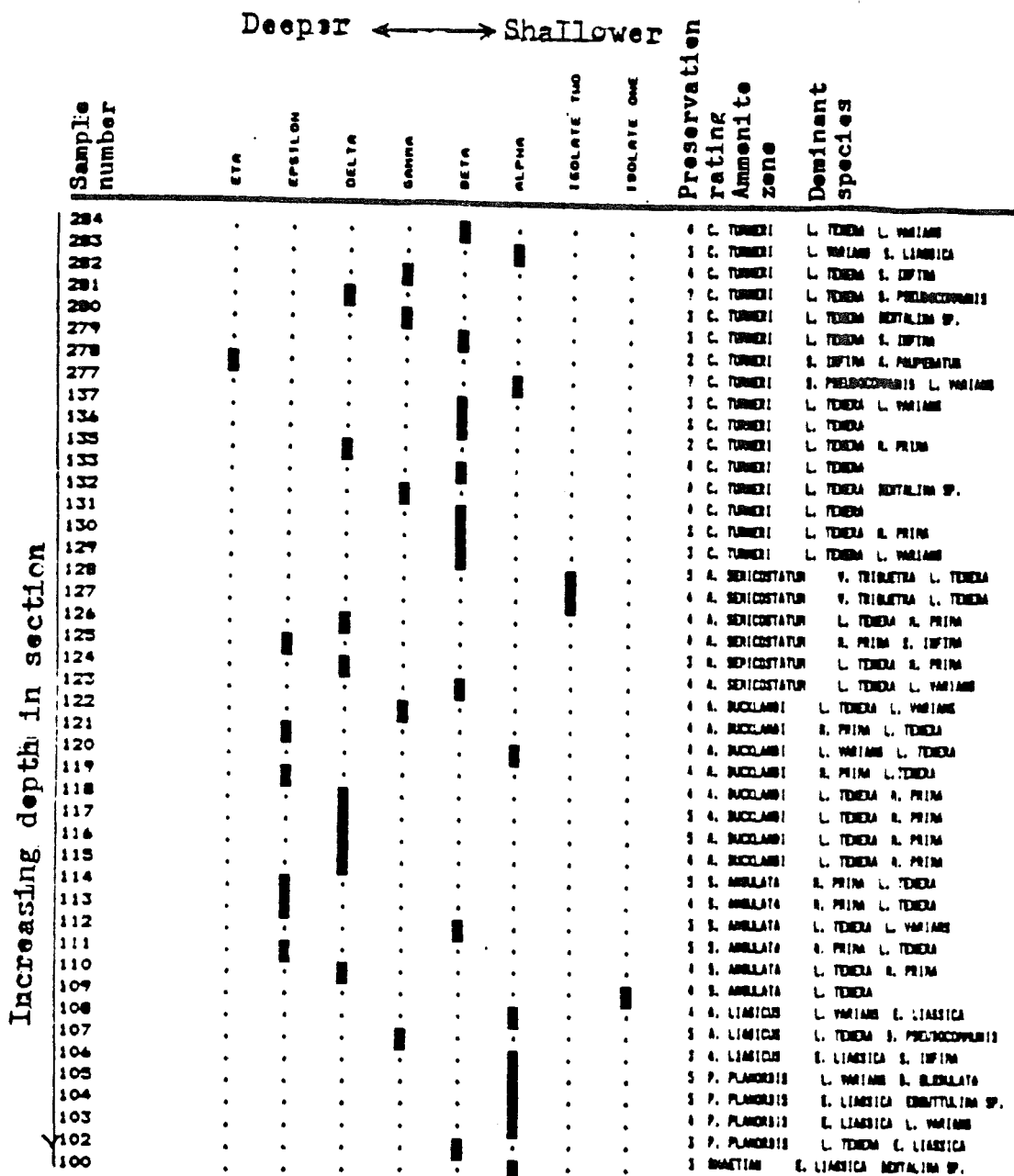
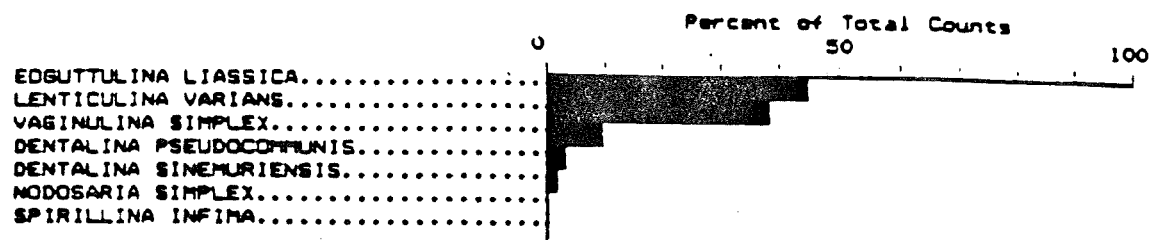


Figure 27. Faunal succession of benthic foraminifera of the Dorset Devon outcrops is depicted using cluster-factor groupings. The depth of the marine environment increases from right to left. Preservation rating: 5 = excellent... 1 = poor. The deeper/shallower arrangement follows the paleoslope model (pg. 167). The position of the outliers is not significant.

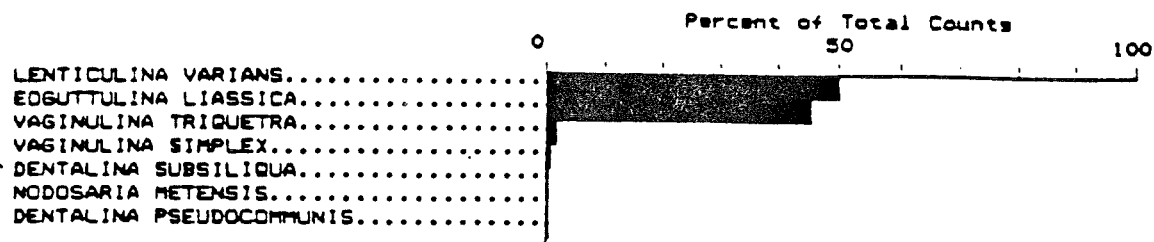
the most important species in this group. With the exception of sample KMP 75- 106, Eoguttulina liassica and Lenticulina varians are the first and second most abundant species. Eoguttulina liassica is the dominant foraminiferal species in the assemblages from the top of the Rhaetian through the Psiloceras planorbis ammonite zone, with the exception of sample KMP 75-105 in which Lenticulina varians dominates. From the Alsatites liasicus zone through the lower Sinemurian, Lenticulina varians dominates in total percentage in the group. The species Spirillina infirma and Bullopore globulata (Barnard) are important as secondary species in samples KMP75-105 and KMP75-106. The group is quite variable. Important accessory species are Eoguttulina oolithica, Dentalina pseudocommunis, Dentalina sinemuriensis, Nodosaria metensis, Lingulina tenera and Vaginulina simplex. Typical examples of this cluster-factor group are samples KMP75-103 and KMP75-108, and KMP75-283 (Figure 28).

Some similarities exist between Biofacies Alpha at Dorset and Cocklepit Biofacies Alpha which is also quite variable (Table IIIm Appendix). Samples CP95.48-96.37 and KMP75-103 and KMP75-108 are identical and sample KMP75-103 shows a very close compositional similarity with 95.48. Sample KMP75-283 has a composition quite similar to CP82.43-83.38 and CP83.38-84.27. Both groups

SAMPLE: 103



SAMPLE: 108



SAMPLE: 283

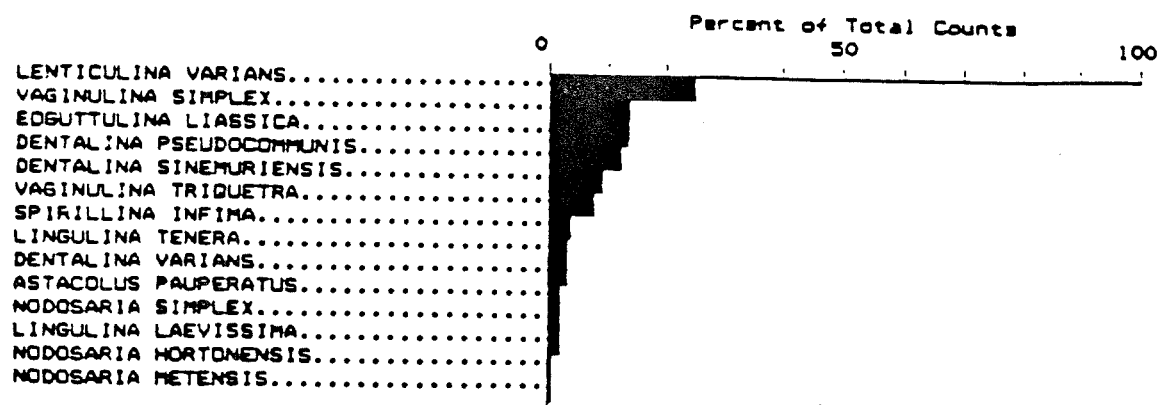


Figure 28. The histograms are of typical samples from cluster-factor group five, Biofacies Alpha, of the Dorset/Devon Hettangian and lower Sinemurian section.

demonstrate a wide range in diversity (H_s): Dorset 0.33-2.54 with a mean of 1.68 and a median of 1.49 and Cocklepit 1.14-2.64 with a mean of 1.97 and a median of 2.20 (Table 5). Both show a similar trend of increasing diversity in higher stratigraphic beds. However, the variability of the two groups is too great for more precise comparisons. (Table IIIIm Appendix).

There are four cluster-factor groups which grade into one another (Figures 25,26). Group 1, Biofacies Beta, is least like the other three. Cluster-factor group 1 is compared to group 3, to which it is closest in composition, in a Sanders Similarity Index Matrix in (Table IIIIn Appendix). Factor group one has a high degree of similarity among its constituent samples: many samples are identical. Low recovery in several of the samples was a problem in this group (Table 5). Lingulina tenera is the dominant species in every sample of this group, and it has a very high range of percent of the total composition (50-83%).

The second most prevalent species varies in these samples. Lenticulina varians, Eoguttulina liassica, Spirillima infima, Marginulina prima, Lingulina cernua, and Vaginulina triquetra are all second in total percentage in different samples. In no case does the secondary species exceed seventeen percent of the total

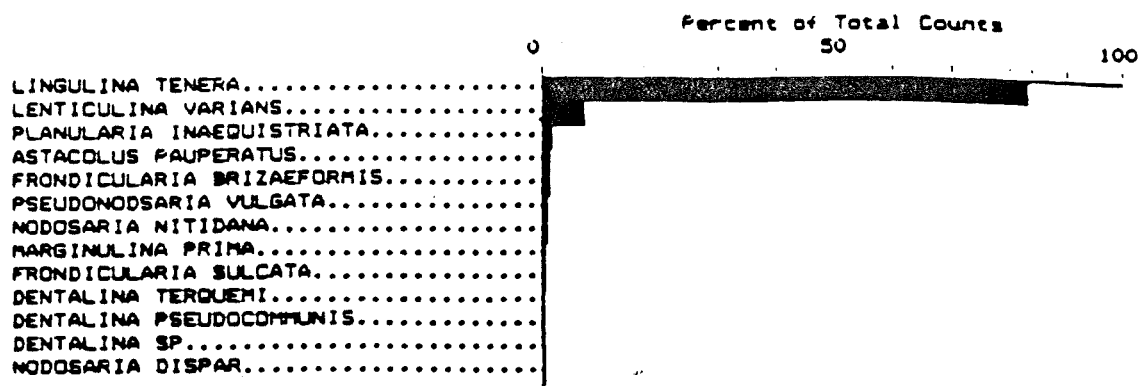
Sample	Number Of Specimens N	Number Of Species S	Shannon-Weiner Diversity H	Equitability E
284	321	18	1.84	0.33
283	157	14	2.31	0.45
282	304	21	1.81	0.29
281	138	19	2.24	0.50
280	34	9	1.74	0.45
279	151	10	1.05	0.29
278	423	21	2.06	0.38
277	5	5	1.61	1.00
137	6	4	1.24	0.87
136	20	5	0.98	0.55
135	25	7	1.26	0.50
134	120	10	0.92	0.25
132	36	7	1.55	0.66
131	27	7	1.55	0.54
130	102	12	1.10	0.25
129	18	6	1.16	0.55
128	21	5	1.34	0.77
127	46	13	2.13	0.65
126	120	17	1.83	0.57
125	251	21	2.00	0.33
124	84	13	1.67	0.41
123	277	32	2.81	0.52
122	343	27	2.32	0.38
121	504	41	2.96	0.47
120	145	23	1.95	0.31
119	262	25	2.51	0.49
118	215	30	2.59	0.44
117	201	14	1.53	0.55
116	306	19	2.11	0.44
115	623	38	2.59	0.33
114	529	32	2.62	0.45
113	680	36	2.56	0.39
112	286	14	0.80	0.16
111	507	24	1.87	0.27
110	121	18	1.81	0.34
109	306	32	2.92	0.58
108	321	11	1.49	0.40
107	106	15	2.11	0.55
106	204	20	2.26	0.48
105	303	24	2.34	0.55
104	121	7	1.15	0.45
103	256	8	1.46	0.54
102	20	4	0.80	0.56
100	164	4	0.33	0.33

Table 5. Diversity and equitability data for the fossiliferous samples of the Dorset and Devon Hettangian and lower Sinemurian outcrop samples.

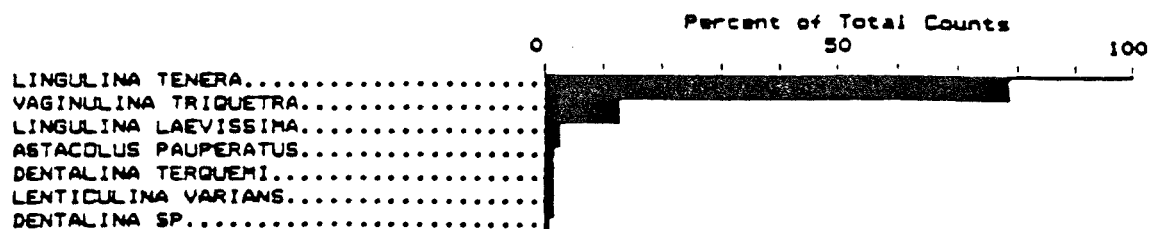
assemblage in any sample. There is a relatively high ratio of the dominant species Lingulina tenera to secondary species in group one. The species which are common in the other groups are rare/absent in this group. There are few species of the genera Dentalina and Nodosaria and those that are present are few in number. Planularia inaequistriata and Pseudonodosaria vulgata are absent entirely. These two species are conspicuous in this stratigraphic range. Samples KMP 75-112, KMP75-133, and KMP 75-284 are typical of this assemblage (Figure 29).

Cluster-factor group 1 is closest in composition to group 3 (Table III In Appendix). Factor group 3 has a high degree of variation in the proportion of the characteristic species present with the exception of the dominant species Lingulina tenera. which ranges from 27-48 percent of the total composition. The secondary species, as in group one, varies from sample to sample. Dentalina pseudocommunis, Dentalina sp, Lenticulina varians, Marginulina prima and Spirillina infima are major constituents of this group and alternate with one another as the secondary species in the different samples. The proportion of the secondary species ranges from 11-43 percent of the total in the various samples of this group. Eoguttulina liassica and Vaginulina triquetra are common constituents of both groups,

SAMPLE: 112



SAMPLE: 133



SAMPLE: 284

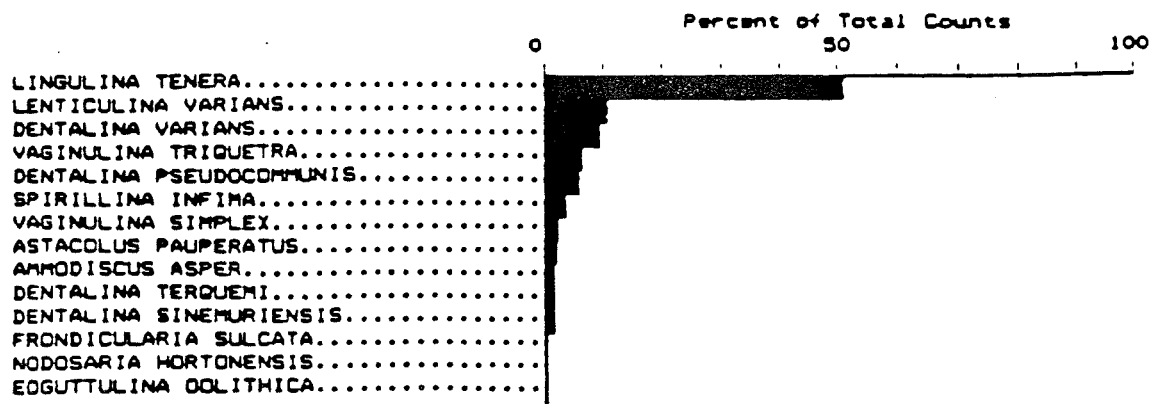


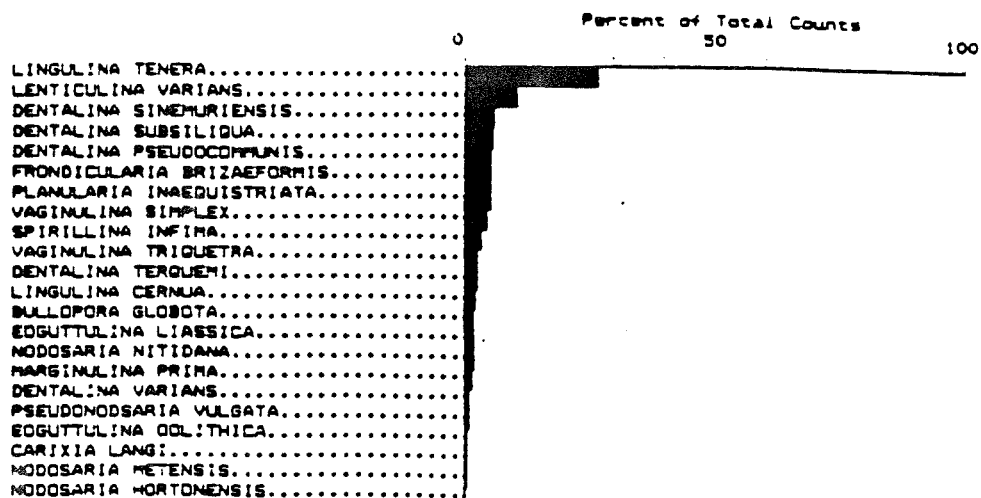
Figure 29. The histograms are of typical samples from cluster-factor group one, Biofacies Beta, of the Dorset/Devon Hettangian and lower Sinemurian section.

ranging from 1-15 percent of the total.

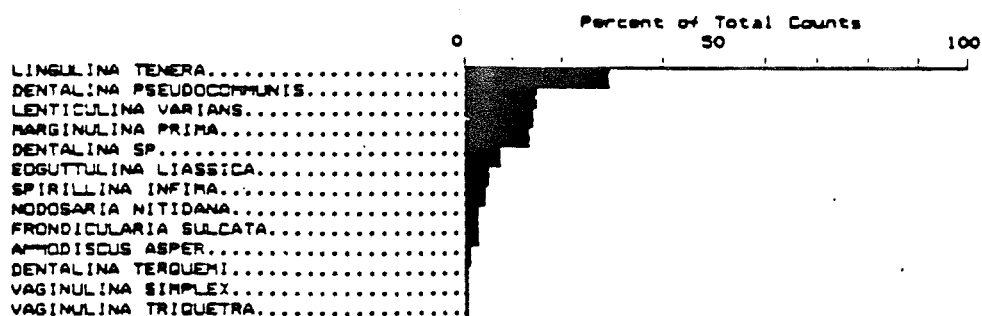
This group is distinguished from Biofacies Beta, cluster-factor group 1 in the greater number of species and the abundance of the genera Dentalina and Nodosaria. Spirillina infima is more common, 1-24% of the total, and present in more than eighty percent of the samples of this group. Samples KMP 75-282, KMP 75-281, and KMP 75-123 are typical of this group (Figure 30). The diversity trend of group three is generally higher than group one. The mean for group one is $H_s=1.11$ and the median is $H_s=1.05$. The mean for group three is $H_s=2.05$ and the median is 1.81 (Table 5). Cluster-factor group 3, Biofacies Gamma, is closer in composition to group 2, Biofacies Delta, than it is to group one, Biofacies Beta (Table IIIIn, o Appendix).

Lingulina tenera always dominates the assemblage in cluster-factor group 2, Biofacies Delta, accounting for 38-58 percent of the total. Marginulina prima is always present in second largest numbers, ranging from 14-30% of the assemblage. Together these two species account for from 50-70% of each sample. Lenticulina varians is usually present but accounts for only 2-7 percent. In group two, Eoguttulina liassica and Eoguttulina oolithica are more common than they are in group 4. They occur in 85% of the samples in 2 and 50% in group 4.

SAMPLE: 123



SAMPLE: 281



SAMPLE: 282

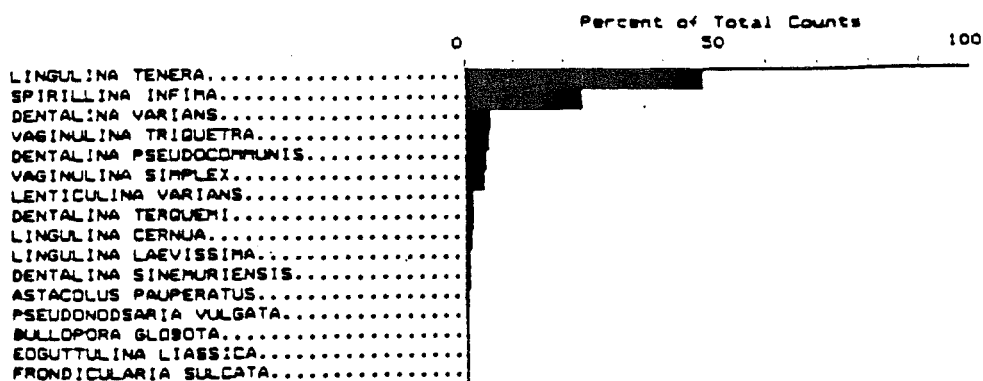


Figure 30. The histograms are of typical samples from cluster-factor group, Biofacies Gamma, of the Dorset/Devon Hettangian and lower Sinemurian section.

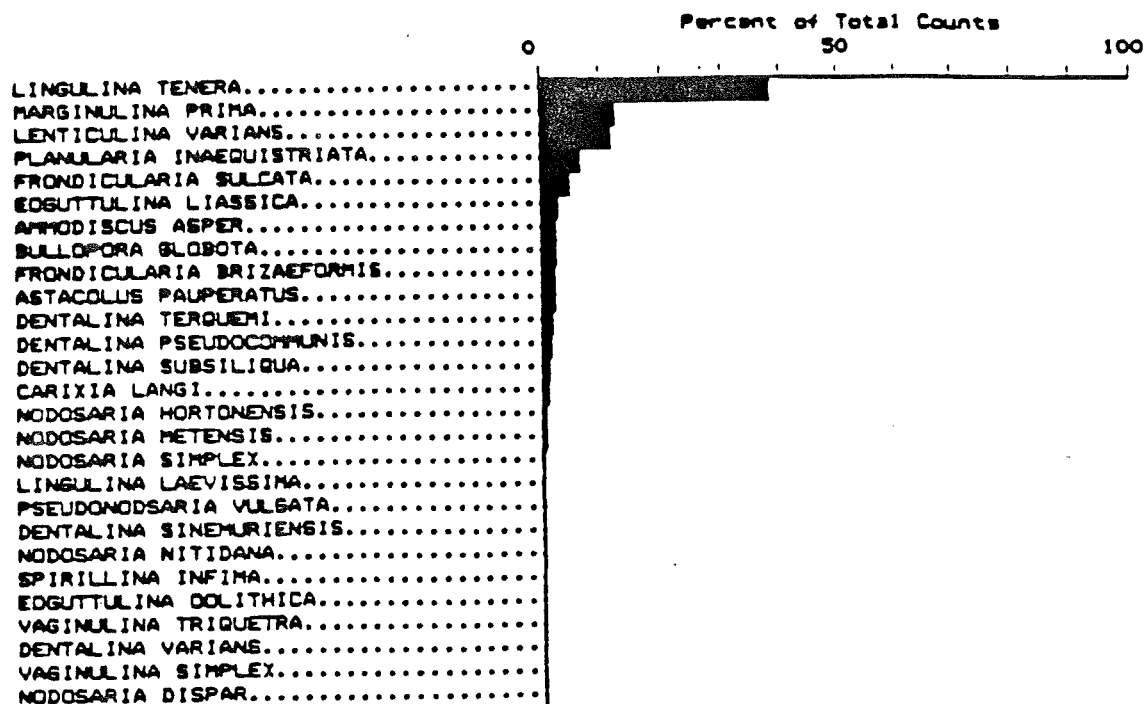
In cluster-factor group 4, Biofacies Epsilon, the dominant species, Marginulina prima, increases in proportion ranging from 20 to 44 percent, and the proportion of Lingulina tenera drops to 0 to 26 percent of the population. Lingulina tenera is absent in sample KMP75-125, and is second in importance in only fifty percent of the samples of this group. Increasing in proportion in group 4 and ranging up to nineteen percent, Lenticulina varians is an important constituent of the assemblage. It is second in abundance in sample KMP75-114 and third in samples KMP75-119, KMP75-125 and KMP75-121. Spirillina infima and Ammodiscus asper become common, occurring in more than eighty percent of the samples. Spirillina infima, twenty-one percent of the total composition, is the second most abundant species in sample KMP75-125. The adherant species Bullopore globulata and Carixia langi, although present in both group 2 and 4, are more prevalent in group 4. Bullopore globulata, twelve percent of the total composition, is the second most abundant species in sample KMP75-121. Because Carixia langi is a trace fossil known by a cross-hatch pattern of channels in shelly material and plates, it is nearly impossible to get an accurate count of this species in a sample.

Both groups have many accessory species in common. The genera Dentalina and Nodosaria are abundant: Dentalina pseudocommunis 1 to 11 percent, Dentalina sinemuriensis 1 to 7 percent, Dentalina subsiliqua 1 to 7 percent, Dentalina varians 1 to 3 percent, Nodosaria hortonensis 2 to 6 percent, Nodosaria metensis 1 to 3 percent, Nodosaria nitidana 1 to 3 percent, and Nodosaria simplex 1 to 3 percent. Planularia inaequistriata, a good index species for this stratigraphic range, is in most of the assemblages of both group and ranges from 2 to 13 percent of the total. Frondicularia sulcata averages five percent of the sample in each group and Frondicularia brizaeformis is usually present ranging from 1 to 7 percent. Vaginulina triquetra is a minor component of both groups. Samples KMP75-115 and KMP75-117 are typical of Biofacies Delta, factor group 2 (Figure 31). Samples KMP75-111 and KMP75-119 are typical of Biofacies Epsilon, factor group 4 (Figure 32).

In general factor group 4 has a higher diversity than factor group 2. The diversity range for group 4 is Hs 1.25 to 2.59 with a mean of 1.92 and a median of 1.81; where as, factor group 4 has a range of Hs 1.87 to 2.96 with a mean of 2.35.

Factor groups 1,2,3 and 4 were compared with groups from the core samples. Steeple Aston Biofacies Delta is

SAMPLE: 115



SAMPLE: 117

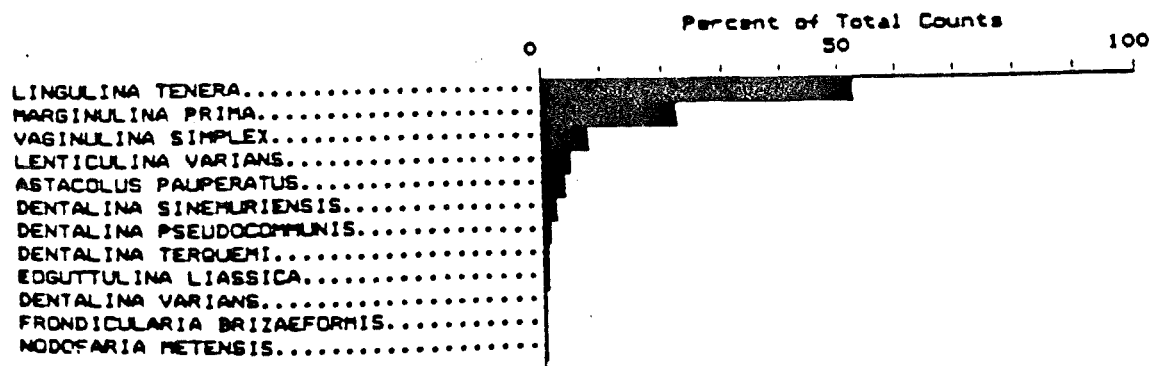
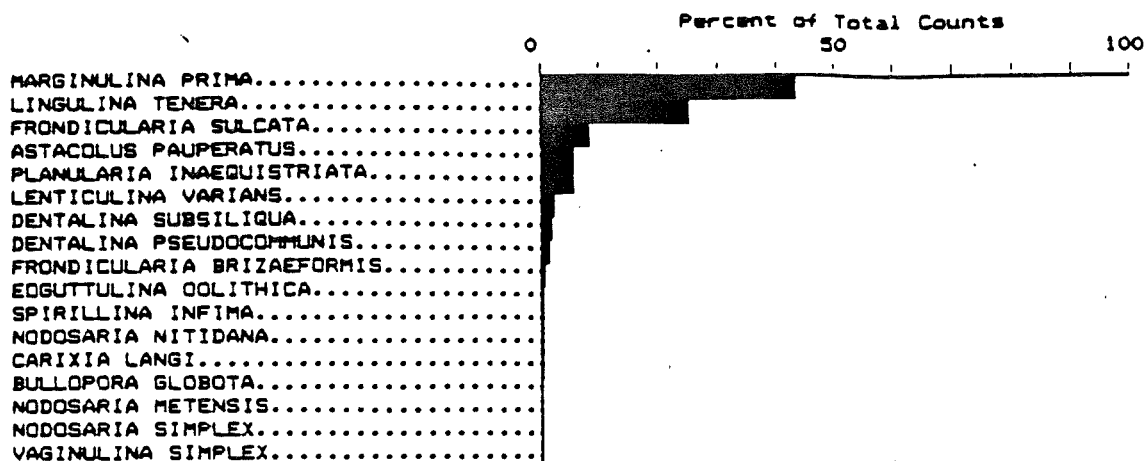


Figure 31. The histograms are of typical samples from cluster-factor group two, Biofacies Delta, of the Dorset/Devon Hettangian and lower Sinemurian section.

SAMPLE: 111



SAMPLE: 119

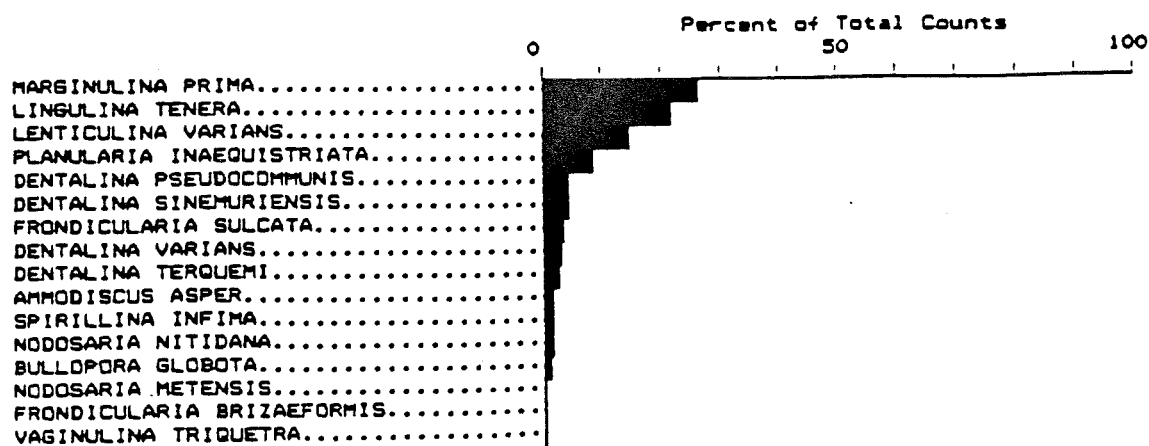


Figure 32. The histograms are of typical samples from cluster-factor group four, Biofacies Epsilon, of the Dorset /Devon Hettangian and lower Sinemurian section.

very close in composition to factor group 2 (Table IIp Appendix). Factor group 2 has a higher percentage of Marginulina prima and in general slightly more Lenticulina varians; whereas, Opthalmalidium macfadyeni is important in Steeple Aston Biofacies Delta and not present in Hetlos factor group 2.

COMPOSITE OF UPPER SINEMURIAN, PLIENSBACHIAN,
AND TOARCICAN SAMPLES OF DORSET

The upper Sinemurian, Pliensbachian and Toarcian outcrop samples of Dorset were not included with the clustering and factoring of the Hettangian and Lower Sinemurian because the matrix would have been too large. A composite, Compos, of these Upper Sinemurian, Pliensbachian and two Toarcian samples was made, and this matrix was analyzed through cluster and factor analysis. Seven cluster-factor groups were produced and several isolated samples which would not cluster were discriminated, (Figures 33,34).

Group 2, which has the greatest stratigraphic range, is comparable to Steeple Aston Biofacies Delta (Figure 35). The comparison is made on a Sanders' Similarity Index Matrix (Table IIIq Appendix). Although there is a variation in cluster-factor group 2, the high percentage of species in common indicate that it is one and the same biofacies. There are a few differences noted between the groups here, such as a greater diversity in the genus Dentalina at Dorset, while the Steeple Aston assemblage has more abundant Opthalmidium macfadyeni. The Dorset assemblage also has a slightly higher percent of Lenticulina varians. The minor differences between Hetlos cluster-factor group 2 and Compos cluster-factor

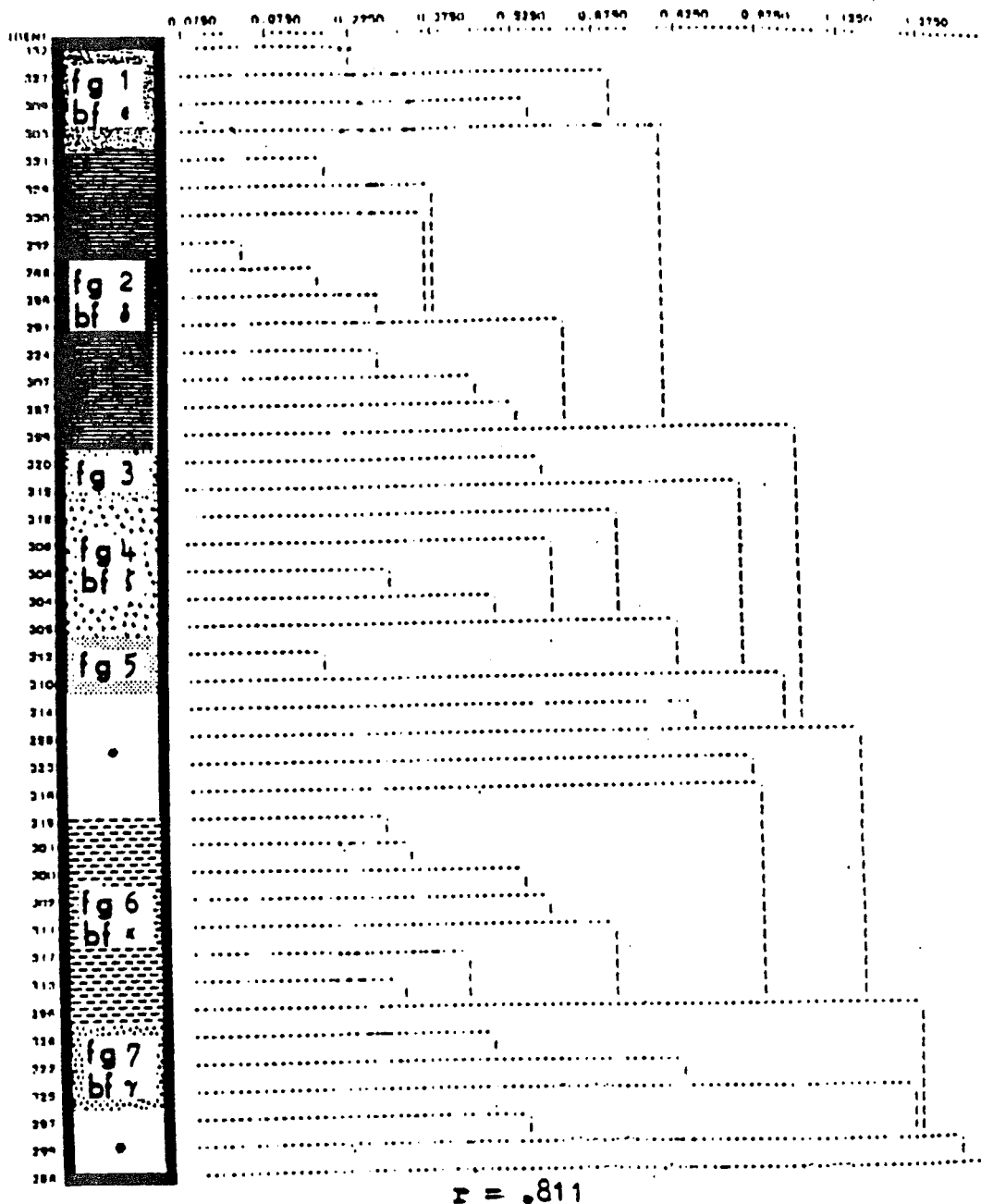


Figure 33. Q-mode cluster analysis of the assemblages from the samples from the Dorset Coastal Outcrops. (Number = sample number, fg = Q-mode factor group, Bf = biofacies and * = isolates or outliers which do not form in any factor group. The Samples are taken from the upper Sinemurian through lower Toarcian sections.

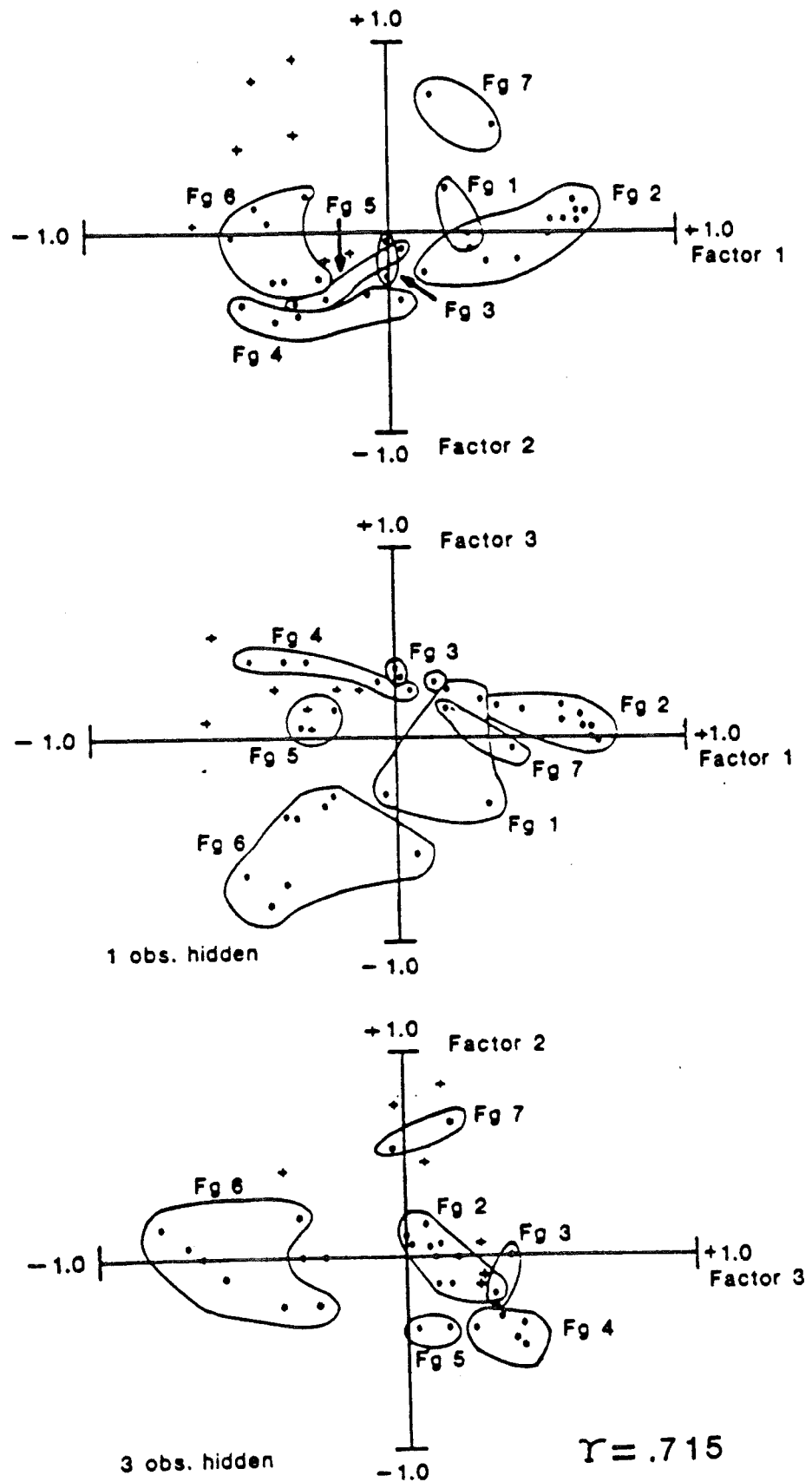


Figure 34.Q mode FACTOR ANALYSIS OF THE DORSET COMPOSITE

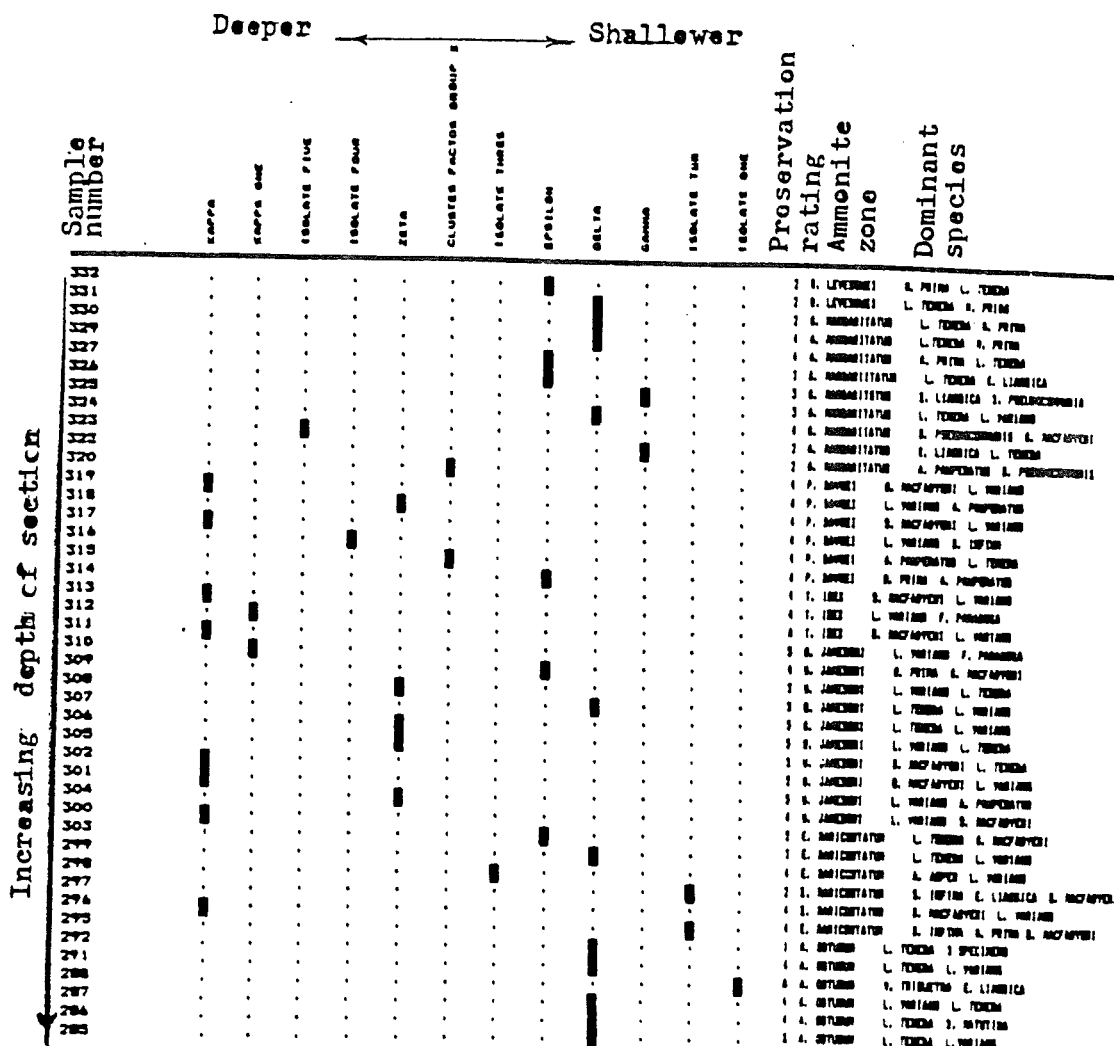


Figure 35. Faunal succession of benthic foraminifera of the Dorset outcrops is depicted using cluster-factor groupings. The depth of the marine environment increases from right to left. (Preservation rating: 5 = excellent... 1 = poor). The deeper/shallower arrangement follows the paleoslope model (pg. 167). The position of the outliers is not significant.

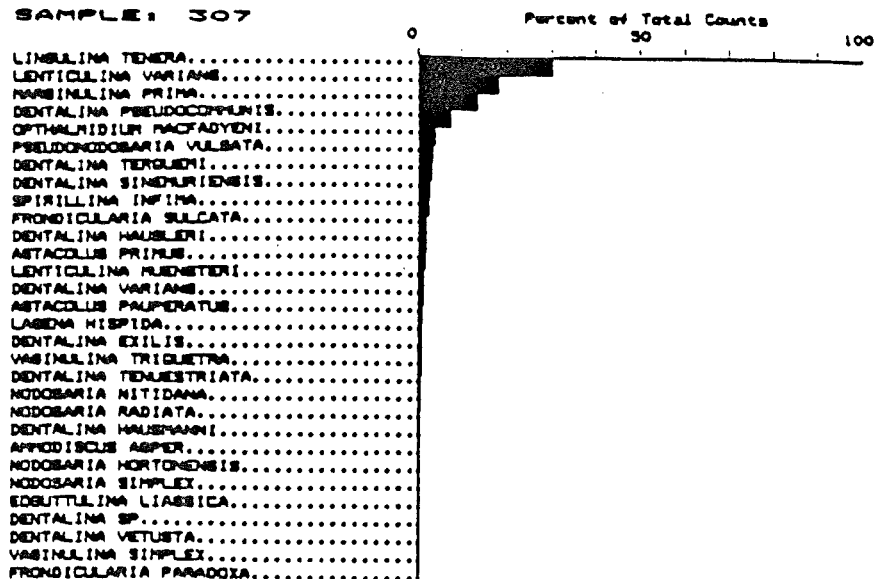
	Number Of Specimens	Number Of Species	Shannon-Weiner Diversity	Equitability
Sample	N	S	H	E
302	32	7	1.61	0.71
301	74	12	1.55	0.39
300	24	15	2.30	0.66
329	36	11	1.83	0.57
327	76	15	2.06	0.53
326	60	16	2.32	0.64
325	21	11	2.14	0.77
324	16	5	1.30	0.73
323	15	9	1.97	0.80
322	60	22	2.56	0.59
320	17	9	2.04	0.85
319	289	30	2.59	0.44
318	81	11	1.71	0.50
317	99	16	2.00	0.46
316	195	26	2.56	0.53
315	34	6	1.50	0.75
314	348	31	2.53	0.41
313	510	17	0.79	0.13
312	493	24	1.79	0.25
311	719	33	2.58	0.40
310	830	31	2.15	0.28
309	970	39	2.66	0.37
308	413	30	2.54	0.42
307	628	39	2.51	0.33
306	180	14	1.77	0.42
305	821	24	1.31	0.15
302	972	26	1.65	0.20
301	450	16	1.84	0.40
304	78	6	1.15	0.53
300	152	16	1.91	0.42
303	768	24	1.86	0.27
299	368	33	2.83	0.48
298	352	21	2.10	0.39
297	100	12	1.70	0.46
296	674	20	1.73	0.28
295	297	20	2.20	0.45
292	3	2	0.64	0.94
291	686	32	1.93	0.22
288	3	2	0.64	0.94
287	398	23	2.31	0.40
286	229	10	1.05	0.28
285	705	11	0.38	0.13

Table 6. Diversity and equitability data for the fossiliferous samples of the Dorset composite.

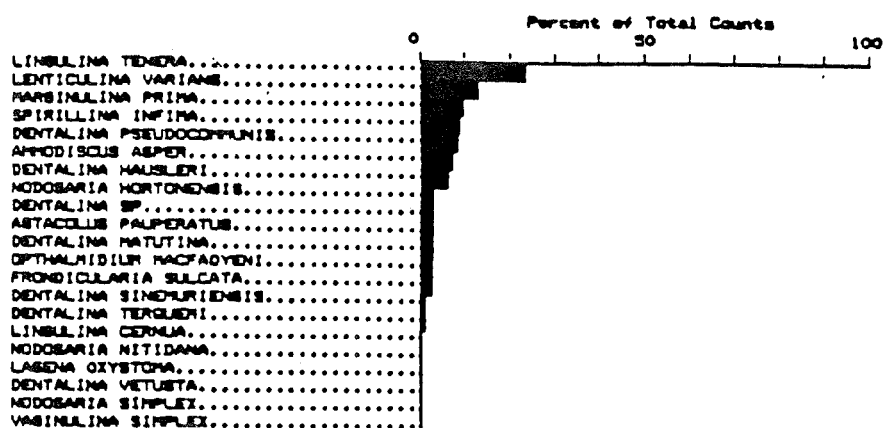
group 2 can be attributed to differences in stratigraphy. The Hettangian and lower Sinemurian samples have Nodosaria metensis and Planularia inaequistriata as minor components in almost all samples. These are absent or rare in the upper Sinemurian, Pliensbachian and Toarcian samples. The genus Lagena is a minor component in the latter samples. Histograms for samples KMP75-291, KMP75-299, and KMP75-307 are most typical of Biofacies Delta at Dorset (Figure 36). There is a greater range in sample diversity in the Dorset samples: $H_s=0.38$ - $H_s=2.83$. Steeple Aston Biofacies Delta's diversity ranges from $H_s=0.67$ - $H_s=2.56$. Six out of seven of the Steeple Aston Biofacies Delta samples are $H_s=2.0$ or above. The median diversity at Steeple Aston is 2.27; whereas at Dorset it is 1.83 (Table 6). In conclusion, Biofacies Delta persists at Dorset from the Alstatites angulata zone through the Dumortieria levesquei ammonite zones.

A second assemblage which also has a long stratigraphic range is cluster-factor group 6; it fluctuates with the other biofacies at Dorset through the upper Sinemurian and Pliensbachian (Figure 35). This assemblage is dominated by Opthalmidium macfadyeni. It is the most prevalent foraminiferal species in every sample in this group, ranging from 21-85 percent of the total. The second most important species in each sample alternates between Lenticulina varians and Lingulina

SAMPLE: 307



SAMPLE: 299



SAMPLE: 291

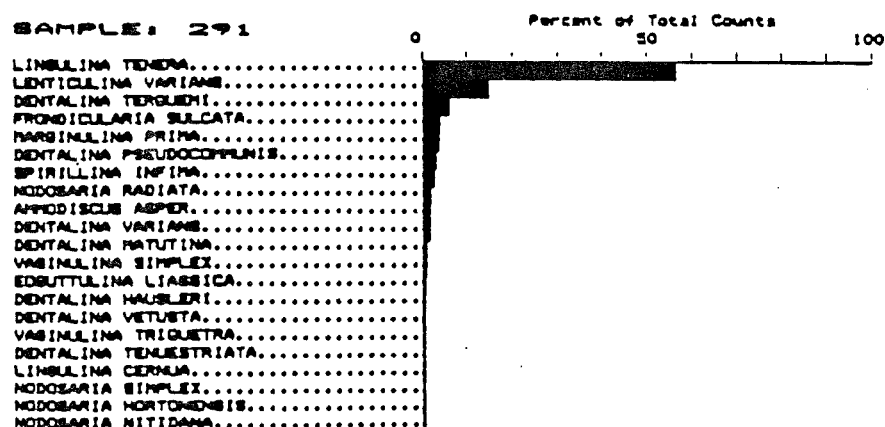


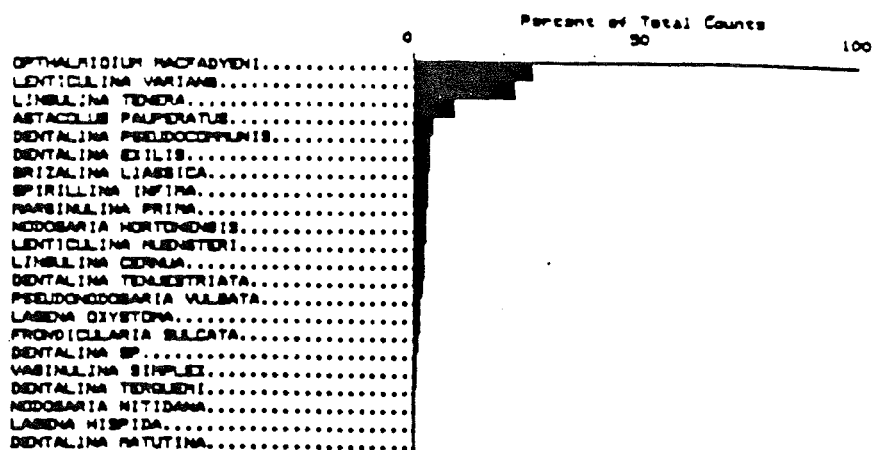
Figure 36. The histograms are of typical samples from cluster-factor group two, Biofacies Delta, of the Dorset composite.

tenera. These secondary species range from 10-30 percent of the total abundance of each sample. This assemblage approximates Steeple Aston Biofacies Kappa. A comparison is made on a Sanders' Similarity Index (Table IIIr Appendix). There are some notable variations, however; the Steeple Aston Biofacies has Spirillina infima as its second most important species (4-46 percent of the total), and the percentages of abundance of Lenticulina varians and Lingulina tenera are approximately half of their abundance in the Dorset samples. Although Spirillina infima is present in 70 percent of the samples of the Dorset group, its abundance is significantly lower (1-7 percent). The Dorset group has a higher abundance of Marginulina prima (1-9 percent). The Dorset samples have sparse, sporadic occurrences of Lagena hispida, Lagena oxystoma and Nodosaria nitidana. They also have a greater variety in the genus Dentalina. Although both groups of assemblages contain Dentalina exilis (rare), Dentalina matutina (rare), Dentalina pseudocommunis (common), Dentalina sinemuriensis (rare) and Dentalina terquemii (rare), the Dorset assemblages also include sparse occurrences of Dentalina hausleri, Dentalina hausmanni, Dentalina tenuistriata and Dentalina vetusta. Astacolus pauperatus is a minor constituent of the assemblages at Dorset, ranging for 1-8 percent of the total and in six out of seven of the samples. In the Steeple Aston assemblages it is in 75 percent of the

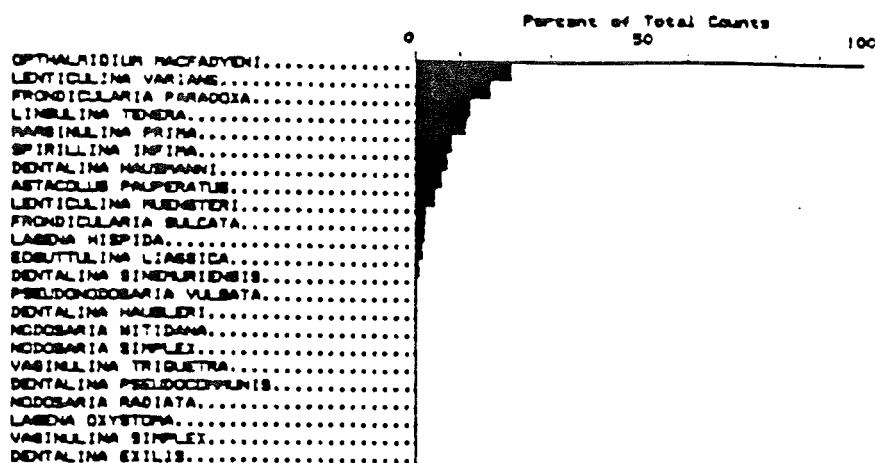
samples and ranges from 1-6 percent of the total. Samples KMP75-302, KMP75-311 and KMP75-319 are typical of cluster-factor group 6 (Figure 37). The assemblages are members of the same biofacies. It may be that the Dorset assemblages are situated more toward the edge of the environmental parameters which produced the group known as Biofacies Kappa.

Composite cluster-factor group 1 is analogous to Hetlos cluster-factor group 4, Biofacies Epsilon. A comparison of the two groups is seen in Table III (Appendix). This is a Marginulina prima (20-39 percent of the total), Lingulina tenera (14-34 percent of the total) assemblage. Lenticulina varians is the third important component, ranging from 6-22 percent of the total composition. Differences between these two groups may be attributed to stratigraphic and substrate control. The group from the Hettangian-lower Sinemurian contains: Bullopore globulata and Carixia langi, while the group from the upper Sinemurian-Pliensbachian does not. This may be caused by a lack of material in the substrate of the variety to which these species adhere. Also the Upper Sinemurian-Pliensbachian group lacks the species Fronicularia brizaeformis, Nodosaria metensis, and Planularia inaequistriata which are common in the Hettangian-lower Sinemurian sections. This may be caused by the stratigraphic differences in the groups. Samples

SAMPLE: 319



SAMPLE: 311



SAMPLE: 302

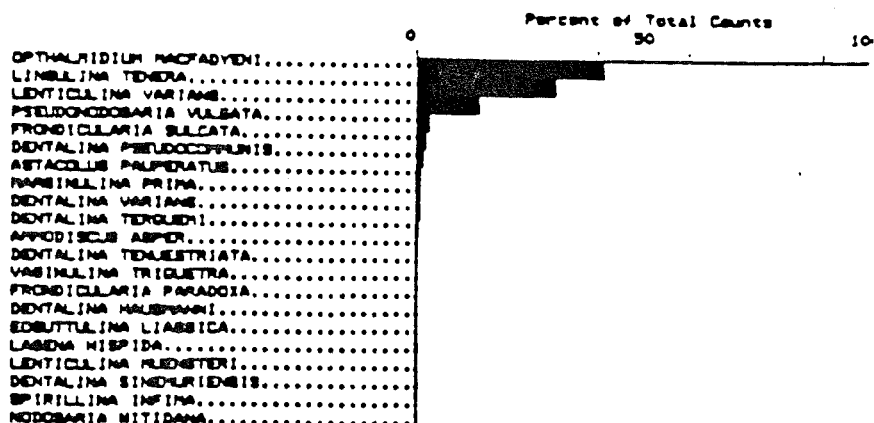
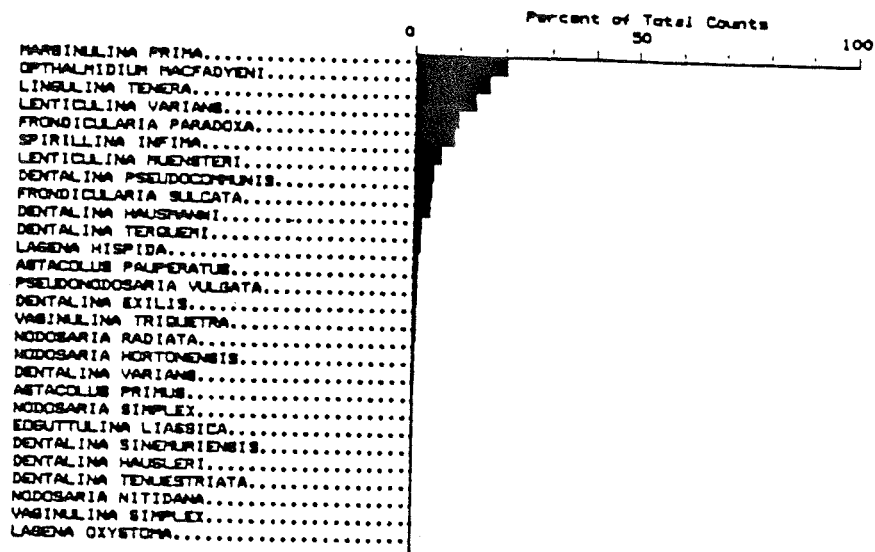


Figure 37. The histograms are of typical samples from cluster-factor group six, Biofacies Kappa, of the Dorset composite.

KMP75-309 and KMP75-303 are typical of this biofacies (Figure 38).

Cluster-factor group 7 is comprised of two samples from the Amaltheus stokesi subzone of the Amaltheus margaritatus ammonite zone of the upper Pliensbachian (Figure 35). This cluster-factor group is analogous to cluster-factor group 3 of the Hettangian-lower Sinemurian samples, Biofacies Gamma. The group is a Lingulina tenera-Eoguttulina liassica assemblage. The percentage of composition of Lingulina tenera is a little lower in this grouping than in the Hettangian-lower Sinemurian counterpart, and the percentage of Eoguttulina liassica is higher. The percentages of composition of Dentalina pseudocommunis, Dentalina sinemuriensis, Frondicularia sulcata, Marginulina prima, Spirillina infima, and Vaginulina triquetra, the minor components of importance, are approximately the same. An added minor constituent which is not present in the Hettangian-lower Sinemurian samples of this biofacies is Opthalmidium macfadyeni. Another difference between the two groups is that the upper Pliensbachian factor group has a lower percentage of Lenticulina varians present. These two samples in this group have high diversity: $H_s=2.32$, $H_s=2.56$. They are within the total diversity range of the Hettangian-lower Sinemurian, but in the upper fifty percentile.

SAMPLE: 309



SAMPLE: 303

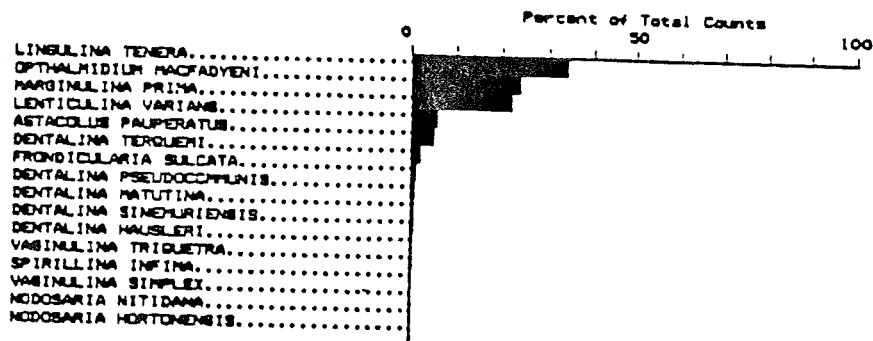


Figure 38. The histograms are of typical samples from cluster-factor group one, Biofacies Epsilon, of the Dorset composite.

Cluster-factor group 5 of the composite is also composed of only two samples: KMP 75-312 and KMP 75-310. This group is dominated by the species Lenticulina varians (30-40 percent of the total), and Fron dicularia paradoxa is the second most important species (30-33 percent of the total). The important accessory species are Ophthalmidium macfadyeni, Lingulina tenera, Marginulina prima and Astacolus pauperatus. These species have a range from 2 to 13 percent of the total composition in these samples. The genus Dentalina is abundant and a number of species are present. Fron dicularia sulcata and Lagena hispida are present in both samples in minor amounts. Cluster-factor group 5 is closest to composite cluster-factor group 6 in composition. It appears that the high proportion of Fron dicularia paradoxa differentiates this cluster-factor group from cluster factor group 6. The divergence may simply be the result of opportunism of the species F. paradoxa. Both samples have low equitability, $E=.25$ and $E=.28$ and a mid range diversity, $Hs=1.79$ and $Hs=2.15$.

Cluster-factor groups 3 and 4 do not show a close compositional link with the other cluster-factor groupings of the Dorset outcrops. Group 3 is weak in significance because of the low number of specimens. However, the recovery in group 4 was significant. A comparison of the two groups on a Sanders Similarity

Index Matrix is seen on Table IIIIt Appendix. Both groups are characterized by a high percentage of the species Lenticulina varians, Lingulina tenera, and Astacolus pauperatus. Astacolus pauperatus is the dominant species in group 3 ranging from 29-36 percent of the assemblage, and Lenticulina varians is the dominant species in group 4 ranging from 23-62 percent of the total. The genera Dentalina and Lagena are more prevalent in group 4, also. Group 4 has a diversity range of $H_s=1.15$ - $H_s=2.54$ with a median of 1.71. Samples KMP 75-305, KMP 75-306, and KMP 75-308 are typical of this cluster-factor grouping, (Figure 39). Sample KMP 75-316 shows a compositional affinity with these two groups. This sample was an isolate in the cluster-factor analysis.

Compos cluster-factor groups 3 and 4 differ from cluster -factor group 2 (Biofacies Delta) in the proportion of many primary constituents. Marginulina prima is absent in group 3 and does not exceed 5 percent in group 4, whereas it ranges from 4-19 percent in group 2. The species Lingulina tenera is also less abundant in groups 3 and 4. It ranges from a low of 3 percent to a maximum of 36 percent in groups 3 and 4; however, in cluster-factor group 2 the range is 24-95 percent. Astacolus pauperatus and Lenticulina varians are more prevalent in groups 3 and 4 than in group 2, ranging from 3-35 percent and 15-62 respectively. The significantly

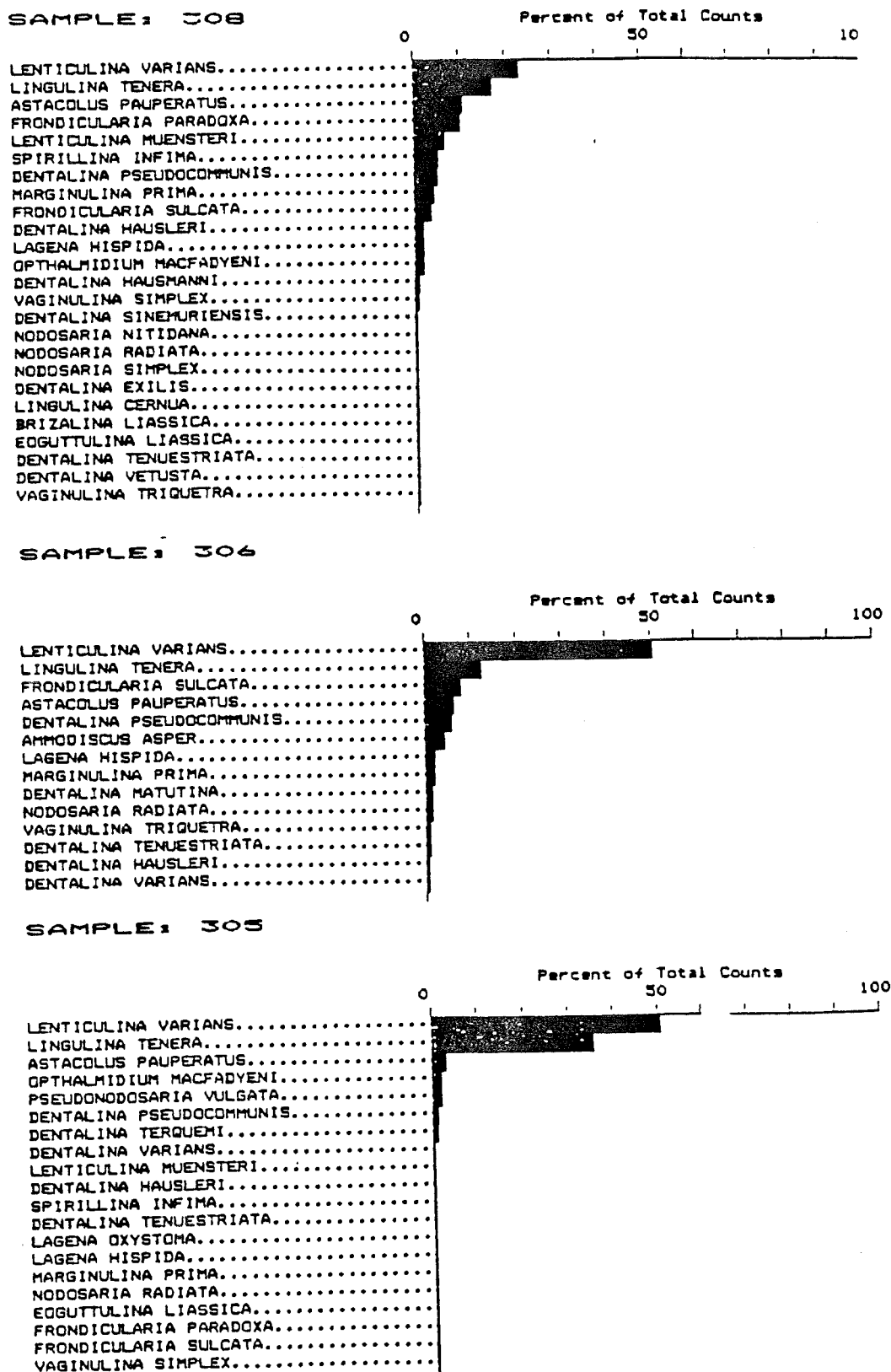


Figure 39. The histograms are of typical samples from cluster-factor group four, Biofacies Zeta, of the Dorset composite.

lower proportion of Marginulina prima and higher proportion of Lenticulina varians distinguishes cluster-factor groups 3 and 4 of Compos from the Hettangian-lower Sinemurian cluster-factor group 4. However, it appears that Compos cluster-factor groups 3 and 4 are an intermediate biofacies between Steeple Aston Biofacies Delta and Biofacies Kappa, as is the Hettangian-Lower Sinemurian cluster-factor group 4. It may be that differences in stratigraphy and substrate caused the differences in composition.

Of the remaining samples, two of the isolates which do not join in a major group, KMP 75-295 and KMP 75-297 of the E. raricostatum zone show an affinity for each other and for sample KMP 75-278 from the lower Sinemurian C. turneri zone. This sample did not join in a group either. All three samples are dominated by Spirillina infima, 36-50 percent of the total; although the majority of species present are constituents of all three samples, their proportions are highly variable and make further comparison quite difficult. This group of samples may be a precursor to Mochras Biofacies Eta. In the composite, the group appears intermediate between groups 4, Biofacies Epsilon and 6, Biofacies Kappa.

Mochras Samples	Dorset Samples		
	KMP 75-278	KMP 75-295	KMP 75-297
2846	63	46	52
2896	62	45	53
2942	47	53	53
2956	48	52	53
3017	64	50	46
3128	67	49	57
3174	59	44	53
3192	52	48	56
3232	60	45	52
3273	59	48	53

Table 8. Sander's Similarity Index Matrix shows the similarity of the Dorset isolates and Mochras Biofacies Eta.

MIDDLE AND UPPER LIASSIC SAMPLES FROM
YORKSHIRE AND THE MIDLANDS

Samples were also taken of Middle and Upper Liassic stratigraphic beds in Yorkshire outcrops described by Howarth (1955), and from Liassic stratigraphic beds described by Agar (1955) in the Midlands. These samples were clustered and factored together as there was generally poor recovery. This analysis produced four groups and one isolate (Figures 40,41).

The isolate, sample 77-324, was taken at Crickley Hill from the Pea Grit 1.5 m above the base. It is from a level above the Hildoceras biforns zone of the Toarcian. Sample 77-324 is a Wackestone, Dunham classification, of rounded skeletal grains which were coated with algae and ironstone, (limonite). This sample was studied in thin section and also the residue of a very poor disaggregation was examined. The recovery was poor: an assemblage of 19 foraminiferal fossils comprised of seven species. This assemblage was dominated by Lenticulina muensteri. Lenticulina varians, Pseudonodosaria sp. and Spirillina infima were conspicuous. This assemblage was very likely influenced by preservational bias; there were calcite rhombs present, drusy mosaic cement and cavity filling, as well as, syntaxial replacement rims. The assemblage resembles

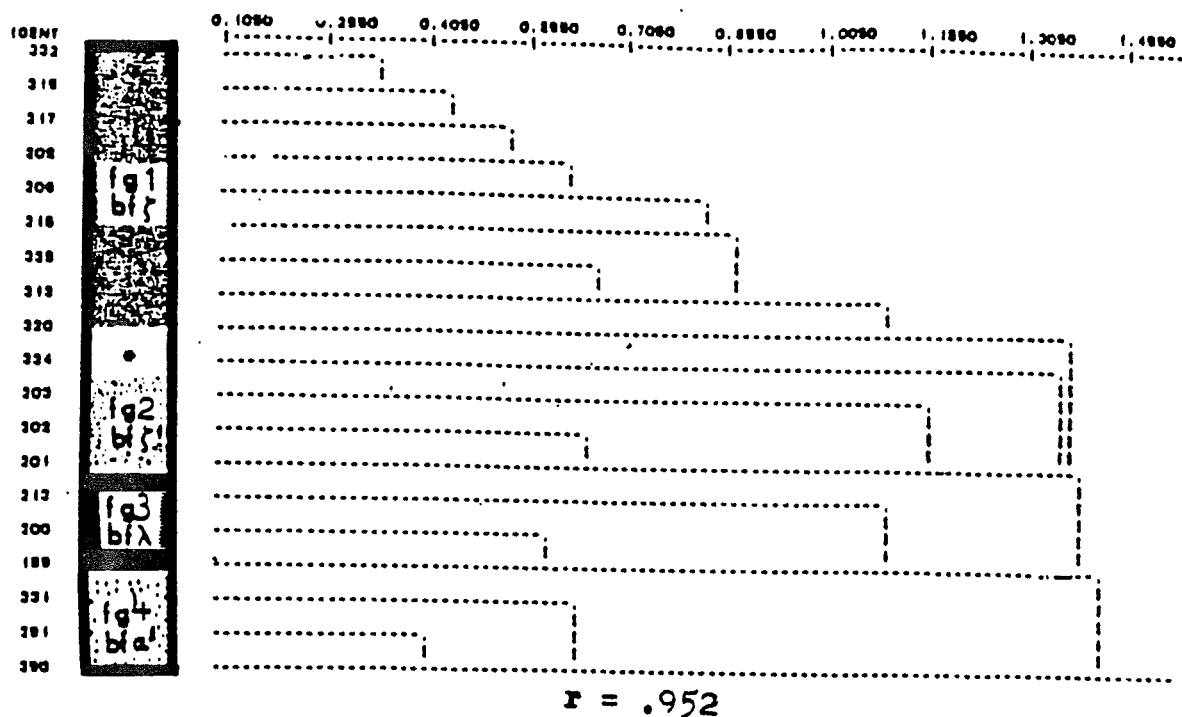


Figure 40. Q-mode cluster analysis of the assemblages from the samples from outcrops in the Midlands and Yorkshire. (Number = sample number, fg = Q-mode factor group, Bf = biofacies and * = isolates or outliers which do not form in any factor group.

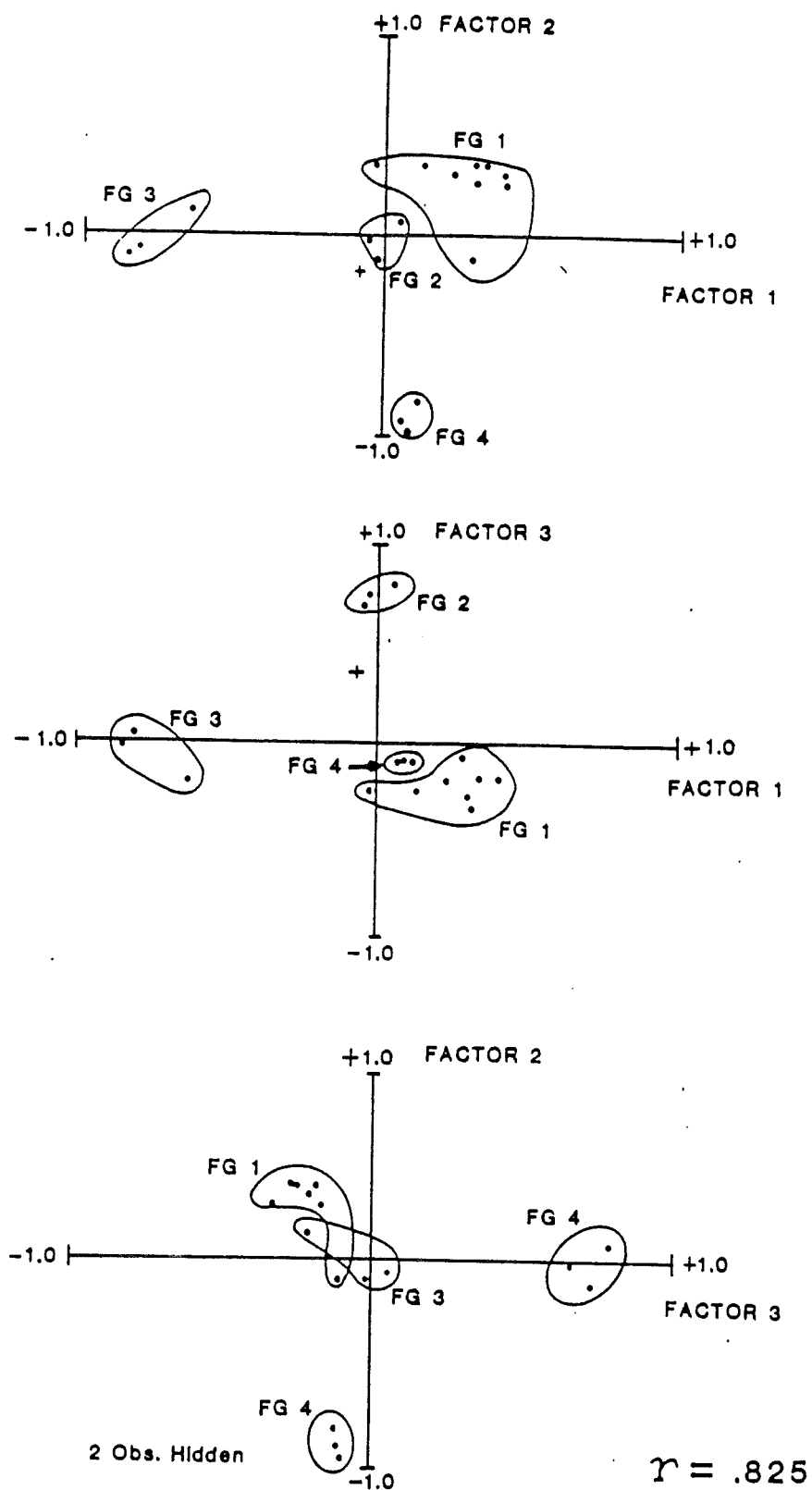


Figure 41. YORKSHIRE AND MIDLANDS COMPOSITE
Q-MODE FACTOR ANALYSIS

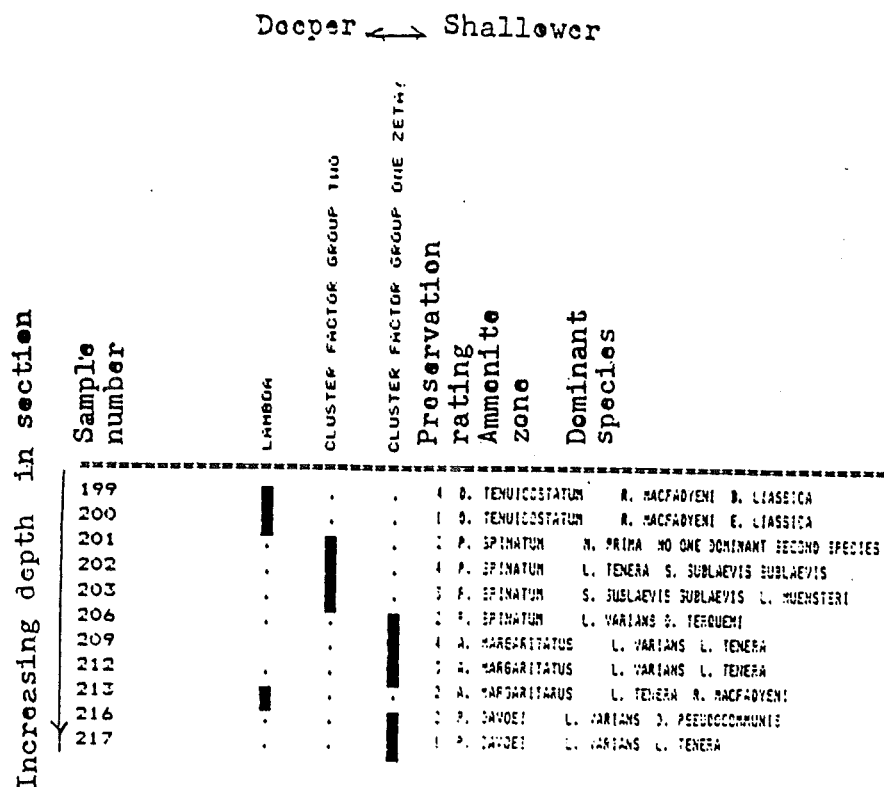


Figure 42. Faunal succession of benthic foraminifera of the Yorkshire outcrops is depicted using cluster-factor groupings. The depth of the marine environment increases from right to left. (Preservation rating: 5 = excellent... 1 = poor). The deeper/shallower arrangement follows the paleoslope model (pg. 167). The position of the outliers is not significant.

Mocharas Biofacies Iota, but it would be presuming too much to be more definite because of the preservation.

The largest cluster-factor group of Yormid was group 1, present both at Yorkshire and the Midlands. Yormid group 1 ranges from the Prodactylioceras davoei Zone of the lower Pliensbachian through the Pleuroceras spinatum Zone of the upper Pliensbachian (Figure 42). The assemblage is dominated by Lenticulina varians ranging from 18-70 percent of the total assemblage. It is the dominant species in all samples of this group except KMP 77-325 where it is the second in importance. The important accessory species are Lingulina tenera (4-33 percent), Dentalina terquemi (8-28 percent), Dentalina pseudocommunis (1-29 percent), and Astacolus pauperatus (1-14 percent). The assemblage has a strong compositional relationship with the Pliensbachian samples from the Dorset outcrops, Compos factor-cluster groups 3 and 4. A Sanders Similarity matrix indicates the compositional affinity of Yormid 1 with Compos 3 and 4, (Table IIIu Appendix). Because of low recovery in samples KMP 77-320, KMP 77-319, KMP 77-317, and KMP 77-316, they were excluded from the comparison matrix and the diversity comparison. The diversity range of Yormid group 1 is $H_s=1.15-2.19$ with a median of 1.96, and the range of Compos 3 and 4 is 1.15-2.54 with a median of $H_s=1.71$ (Tables 6,7). Although preservation may have

YORKSHIRE OUTCROP SAMPLES

	Number Of Specimens	Number Of Species	Shannon-Weiner Diversity	Equitability
Sample	N	S	H	E
218	0	0	0.00	0.00
217	11	3	0.86	0.79
216	17	5	1.53	0.92
214	0	0	0.00	0.00
213	3	2	0.64	0.94
212	37	10	2.09	0.81
211	1	1	0.00	1.00
210	2	1	0.00	1.00
209	103	16	1.96	0.45
208	2	2	0.69	1.00
207	2	1	0.00	1.00
206	79	10	1.57	0.48
205	0	0	0.00	0.00
204	0	0	0.00	0.00
203	425	19	1.96	0.37
202	244	17	1.94	0.41
201	21	11	1.79	0.54
200	100	10	1.60	0.49
199	1330	9	0.77	0.24

MIDLANDS OUTCROPS

341	1	1	0.00	1.00
332	79	8	1.15	0.39
331	31	4	1.20	0.83
330	3	1	0.00	1.00
329	3	2	0.64	0.94
328	1	1	0.00	1.00
327	1	1	0.00	1.00
326	0	0	0.00	0.00
325	239	19	2.19	0.47
324	26	6	1.00	0.45
321	0	0	0.00	0.00
320	3	3	1.10	1.00
319	7	3	0.80	0.74
291	148	16	1.62	0.32
290	50	5	1.16	0.64

Table 7. Diversity and equitability data for the fossiliferous samples of the Midlands-Yorkshire composite.

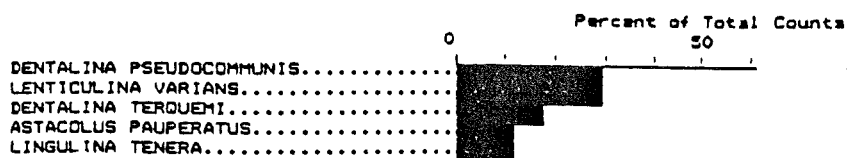
biased these results, other evidence indicates that these groups are members of the same biofacies.

Histograms of typical Yorkshire samples KMP 77-216, 212, 209, 206 from group 1 are shown in Figure 43.

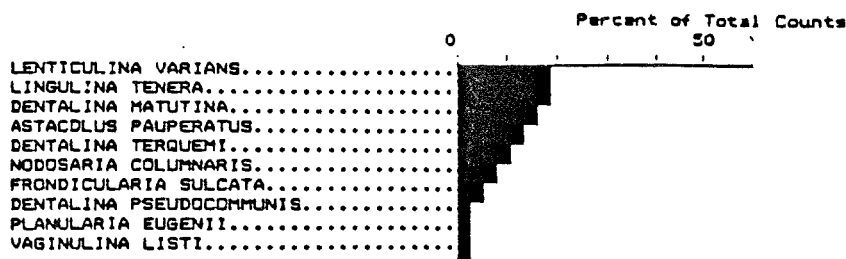
Cluster-factor analysis discriminated a group, Yormid Group 4, from the Midlands which was dominated by arenaceous foraminifera. Two of the samples come from the Upper Liassic strata of the Scisum beds from the outcrops at the Hook Norton Railway cutting (KMP 77-291, KMP 77-290). The third, sample KMP 77-331, was taken from the middle of bed 16 (Agar 1955) at Robin's Wood Hill (Almaltheus margaritatus Zone. All three assemblages are dominated by Ammodiscus asper which ranges from 36-59 percent of the total composition. Trochammina gryci is the second major species in two of the samples. The other important accessory species are Haphlophragmoides sp., Haphlophragmoides subglobosus, Ammobaculites fontinensis, Lentinulina varians and Dentalina pseudocommunis. The diversity range is low and narrow, $H_s = 1.16-1.62$ with a median of $H_s = 1.20$ (Table 7). This group is analogous to Cocklepit Biofacies Alpha-1. Histograms of samples attest to the importance of the arenaceous component and that there are sufficient calcareous species to suggest that solution bias is at a minimum (Figure 44).

Cluster-factor group 2 is all from the P. spinatum

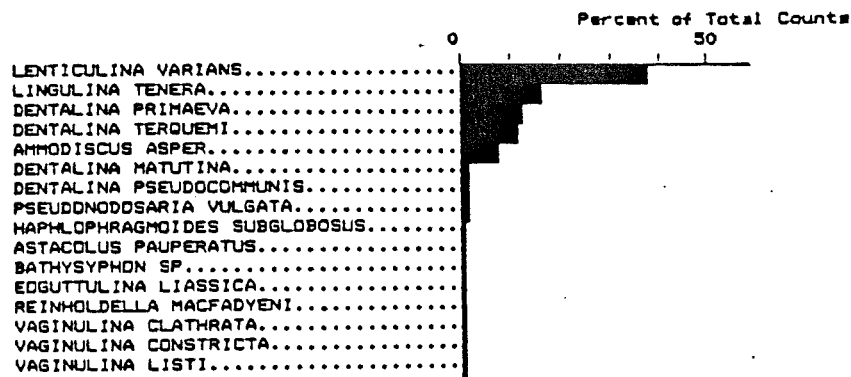
SAMPLE: 216



SAMPLE: 212



SAMPLE: 209



SAMPLE: 206

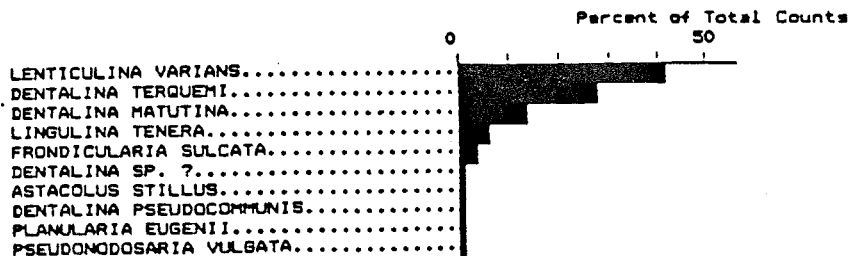
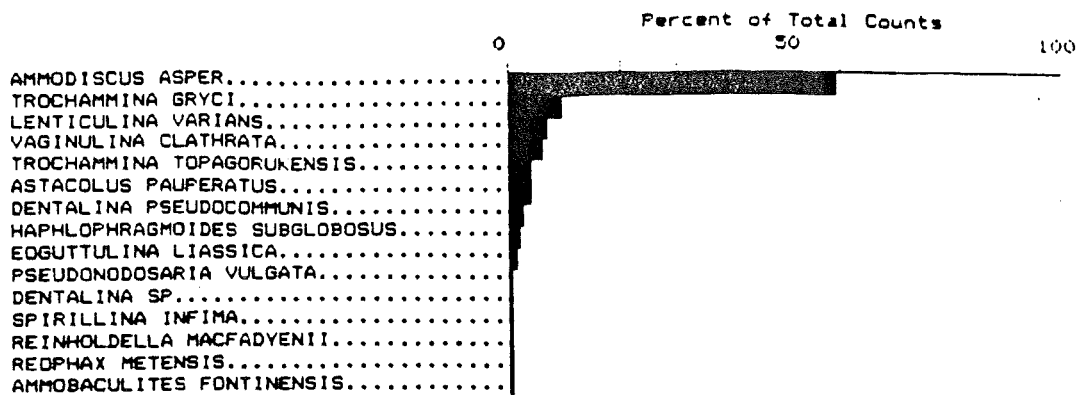
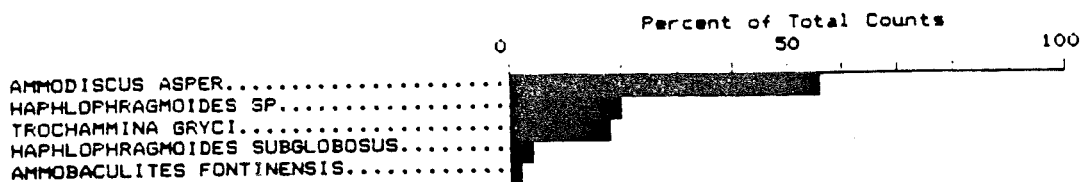


Figure 43. The histograms are of typical samples from cluster-factor group one, Biofacies Zeta, of the Midlands -Yorkshire composite.

SAMPLE: 291



SAMPLE: 290



SAMPLE: 331

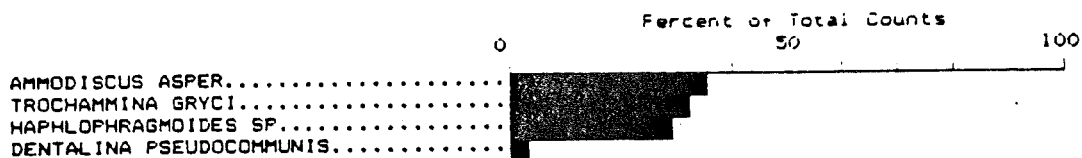


Figure 44. The histograms are of typical samples from cluster-factor group four, Biofacies Alpha-1, of the Midlands -Yorkshire composite. They are dominated by arenaceous foraminifera.

Zone of the outcrop at Brackenberry Wyke (Figure 42).

The samples were taken from stratigraphic beds described by Howarth (1955). Sample KMP 77-203 came from Bed 55, a shale containing P. hawskerense. Sample KMP 77-202 was taken from Bed 57 which although micaceous was similar to Bed 55. Sample KMP 77-201 is a marly shale from Bed 59. There is an ironstone layer between Beds 55 and 57 and a closely laminated shale with jet, a shiny black lignitic material (Hallam, 1975, 1955) intervenes between Beds 57 and 59, (Figure 42). The foraminiferal assemblages from these three samples have a rather loose compositional affinity where one assemblage apparently grades into the next. Saracenaria sublaevis sublaevis (46 percent) dominates sample KMP 77-203, and Lenticulina muensteri (15 percent of the total) is the second most important species. Dentalina terquemi (10 percent), Marginulina prima (6 percent), and Pseudonodosaria vulgata are the important accessory species. Minor species Fronicularia sulcata, Lenticulina varians and Astacolus pauperatus are present in all three samples. In sample KMP 77-202 Marginulina prima (38 percent) dominates the assemblage and Saracenaria sublaevis sublaevis (24 percent of the total) is the second most important. Lenticulina varians is more abundant (12 %) while Lenticulina muensteri is less abundant (2 %). Marginulina prima (52 percent of the total) dominates the assemblage in sample KMP 77-201.

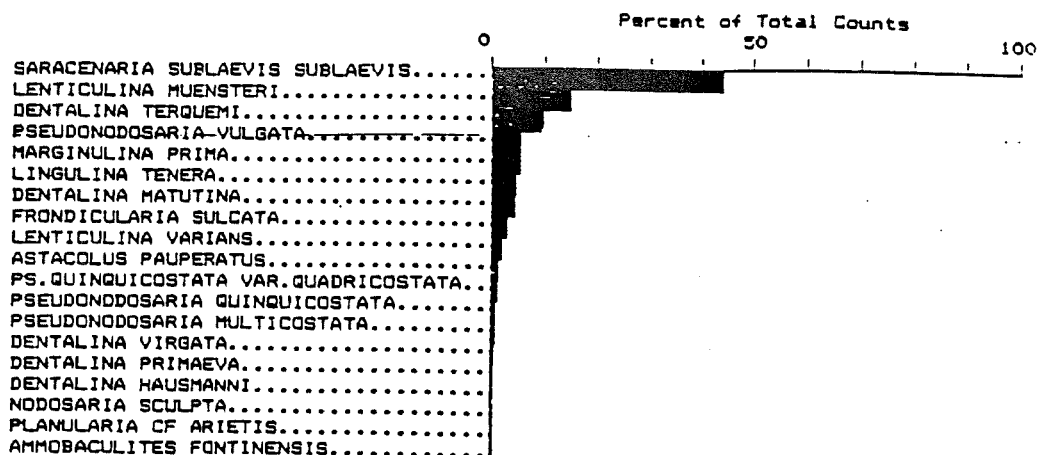
There is no Saracenaria sublaevis sublaevis present.

It is noteworthy that this is a thick walled species and likely would survive any diagenetic changes that Marginulina prima would. Histograms of the samples of this group are seen in Figure 45. The diversity which is narrow in range: $H_s=1.96-1.79$, declines upward from Bed 55 to 59 as does the total abundance (Table 7). There appears to be an upward shoaling at Brackenberry Wyke from the Pleuroceras apyrenum to the Pleuroceras hawskerense. Subzones of the Pleuroceras spinatum zone.

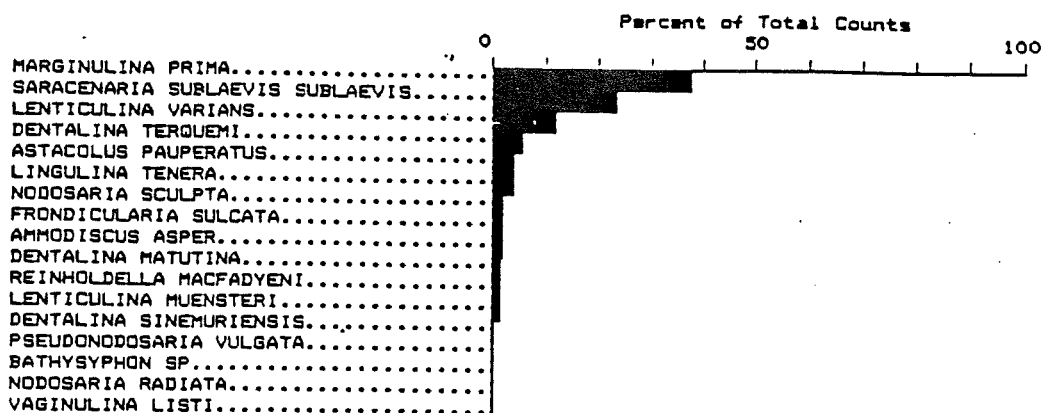
The final cluster-factor group discriminated was an assemblage dominated by Rheinholdella macfadyenii: Yormid factor group 3 , Biofacies Lambda. Sample KMP 77-313 was disregarded as only three foraminiferal fossils were recovered. Samples KMP 77-200 and KMP 77-199, Howarth Beds 61 and 62 of the Dactylioceras tenuicostatum Zone, had significant recovery. The secondary species present is Brizalina liassica in KMP 77-199 and Eoguttulina liassica in KMP 77-200. Marginulina prima and Lenticulina varians form H are present in both assemblages. Also both assemblages contain arenaceous foraminifera. A very small, gracile Brizalina sp. is present in both assemblages in small numbers.

Howarth (1955) described Bed 61, KMP 77-200, as a shale with a row of limestone doggers. This sample had

SAMPLE: 203



SAMPLE: 204



SAMPLE: 201

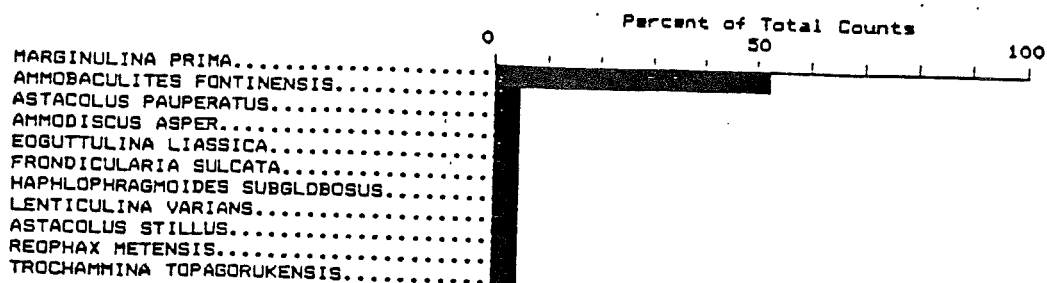
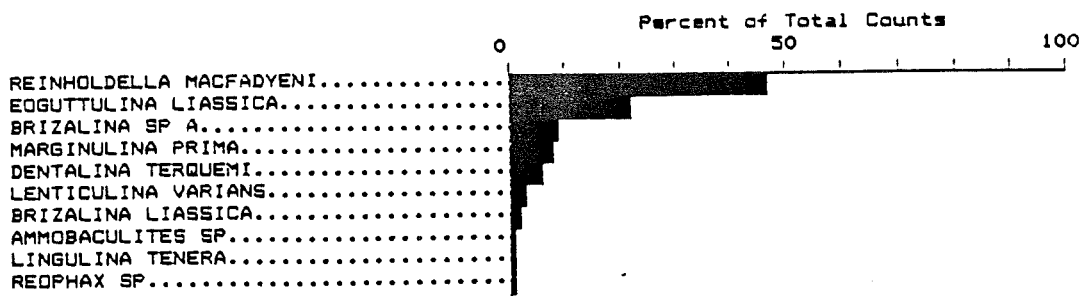


Figure 45. The histograms are of typical samples from cluster-factor group two, Biofacies Zeta-1, of the Midlands -Yorkshire composite.

few foraminifera by comparison with Bed 62, KMP 77-199, which is a shale with six rows of red doggers (Howarth, 1955). In processing, the breakdown of these samples was poor - aggregates of silt-clay particles remained as there was a calcareous cement. Dolomite rhombs and pyrite framboids were present further illustrating diagenetic effects. The preservation of KMP 77-200 was poor, but the preservation of sample KMP 77-199 was quite good. Pollen-like transparent ellipsoids were found in both samples. Biotite, muscovite, chlorite and hematite were also present in both samples. Only one ostracod species was recovered from KMP 77-199, Ogmoconchella sp., and this species and Kinkelinella sermioisensis were the only ostracods seen in KMP 77-200. Echinoid debris and shell fragments were present in both. A thin section of a nodule found in sample KMP 77-199 was made. Micrite made up more than 90 percent of the thin section. Pyrite framboids were conspicuous. Seven Rheinholdella sp., two nodosariid foraminifera, and a pyritized Brizalina sp. were identified. In addition to the foraminifera, there were recrystallized spines, ghosts of spicules, and gastropods. In general the material seen in the nodule thin section resembled the material of the bed. Histograms of these samples are in Figure 46.

The diversities and equitabilities of these two samples are low: KMP 77-199 $H_s=0.77$ and $E=.24$ and KMP

SAMPLE: 200



SAMPLE: 199

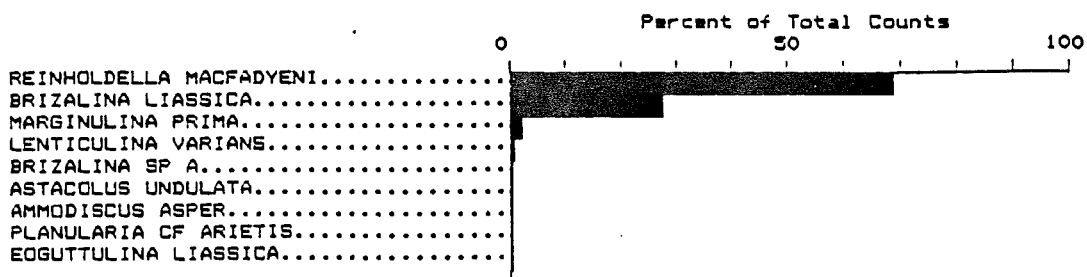


Figure 46. The histograms are of typical samples from cluster-factor group three, Biofacies Lambda, of the Midlands -Yorkshire composite.

77-200, $H_s=1.60$ and $E=.49$, (Table 7). This factor group is analogous to Mochras Biofacies Lambda and Cocklepits samples 19 and 21 which are also from the D. tenuicostatum zone. It is possible that this assemblage is a biofacies produced solely by a preservational bias, one produced in a partially restricted marine environment, or is a deep-water assemblage and that the low diversity is a product of the nearly stagnant conditions of the seas during the Lower Toarcian (Hallam 1967c, 1975, 1978, Johnson, 1977, and Lord 1978). I favor the latter interpretation. Estimates of global sealevel change (Hallam, 1978, Vail et al. 1984) during the D. tenuicostatum Zone support the suggestion that this is a deeper water assemblage.

A comparison of the Yorkshire sample cluster factor groups is made on a Sanders Similarity Index Matrix, Table IIIv Appendix. The matrix indicates that there is considerable variability among the members of each group, and that there is low compositional similarity among the groups.

MODEL

From the cluster and factor groupings of the assemblages of benthic foraminifera, it is possible to erect a paleobathymetric model of Liassic benthic foraminiferal biofacies. The foraminiferal succession at a given location is also observed in the vertical succession. Using this direct application of Walther's Rule (1894, cited in Blatt et al. 1972) a paleobathymetric model can be constructed.

Modeling commenced at Steeple Aston Bore, since the most distinct assemblages are observed in the succession (Figure 13). The zones of the lower Lias beneath Uptonia jamesoni ammonite zone are missing at this location; however, from the U. jamesoni Zone through the middle of the Prodactylioceras davoei Zone, the record is nearly complete. A non-sequence, indicated by pyritized and phosphatic nodules and shelly debris resting in bedding planes, however, is reported at the top of the Asteroceras obtusum Zone-147 meters, (Poole 1977).

Three biofacies and one isolate were produced by the cluster and factor analysis. Applying Walther's Rule the vertical succession suggests a lateral benthic succession from a nearshore Eoguttulina liassica-Lingulina tenera

(Biofacies Gamma 1) to a Lingulina tenera dominated assemblage (Biofacies Delta), to an Opthalmidium macfadyanii-Spirillina infima assemblage (Biofacies Kappa).

Biofacies Gamma 1 ranges from the Tragophylioceras ibex Zone to the lower Prodactylioceras davoei Zone. It is the only biofacies present between the '85' marker band and the '100' marker band in the core. There is more ironstone in this section of the core. Few ammonites and belemnites are reported from this section. Chlorite and muscovite are common. Yellow translucent pollen-like spheres are present. Hallam (1975) concludes that the ironstones were formed in shallow water or near shore. In fact, the Froddingham Ironstones studied at the Cocklepits core show oolites forming on benthic foraminiferal nuclei (this study); Plate 2. The oolites point to a shallow-water origin. The median diversity of the samples in this biofacies is $H_s=1.49$ and the median equitability is $E=.31$. The samples with lower abundance have the higher diversity and equitability. Thus the samples with greater recovery probably represent the original community. Hallam (1978) shows a regression in the middle Pliensbachian, and Vail et al. (1984) report a drop in global sea level in the mid-Pliensbachian. In the area of the Inner Moray Firth, they depict near shore conditions in their model. The

foregoing data support the interpretation that Biofacies Gamma 1 is the nearest shore biofacies of those present at Steeple Aston.

The second group, Biofacies Delta, ranging from the Caenitisites turneri Zone through the T. ibex Zone is a shallow water biofacies. It alternates with Biofacies Kappa through most of its range, (Figure 13). There is less ironstone noted in this section. Ammonites are more abundant, and the yellow spheres are still present. Brachiopod spats occur in the residue, and there is also a general increase in the number of ostracod species. Diversity shows a wide range, but compared with Biofacies Gamma 1 there is a general increase. The diversity median is $H_s=2.27$ and the median equitability is $E=.39$. There is also a general increase in the number of species present in Biofacies A, median $N_s=23$, as opposed to Biofacies C where the median $N_s=14$. Hallam (1978) shows vacillation in global sea level from the latest early Sinemurian through lower Pliensbachian. Hallam's record shows a general increase in global sea level at the top of the early Sinemurian followed by a regression in the late Sinemurian which was then replaced by a transgressive phase (Figure 47). The late Sinemurian transgression was followed by a shoaling in the earliest Pliensbachian. In the early Pliensbachian there was a transgressive phase once again which was terminated by

AGE		TIME SCALE MA after Kent & Gradstein 1985	TIME ROCK Hollam 1978	AMMONITE ZONES ARKELL 1956	DORSET BIOFACIES	DORSET SEQUENCES After Hollam, 1978 Deep Shoal	STEEPLEASTON BIOFACIES	MIDLANDS SEQUENCES - Hollam				
								SOUTH		EAST		
								D	S	D	S	
EARLY JURASSIC (LIASSIC)	LATE	190	TOARCIAN	UPPER	<i>Lyteroceras jurensis</i>		G		B			
					<i>Hilderoceras bifrons</i>					C		C
				LOWER	<i>Herpoceras falcifer</i>							
					<i>Dactyloceras tenuicostatum</i>	$\epsilon \sigma$	F		B		B	
	MIDDLE	195	PLIENSCHACHIAN	UPPER	<i>Pleuroceras spinatum</i>	MISSING		B		B		B
					<i>Amalthus margaritatus</i>	$\epsilon - \sigma$ $\epsilon - \sigma - \gamma$ $\sigma - \gamma$	B				F	
				LOWER	<i>Proctylloceras davoel</i>	K		B	CAVING			
					<i>Tragophylloceras lites</i>	K						
	EARLY LIASSIC	200	SINEMURIAN		<i>Uptonia jamesoni</i>	K	F					
					<i>Echloceras raricostatum</i>	MISSING $K - \eta - \epsilon - \sigma$	F					
					<i>Oxynoticeras oxynotum</i>	MISSING					B	
				MIDDLE	<i>Asteroceras obtusum</i>	η	E					B
	HETTANGIAN	205	HETTANGIAN	LOWER	<i>Caenolites turneri</i>	$\delta - \beta - \alpha$ $\gamma - \beta - \alpha$	C					
					<i>Arnioceras semicostatum</i>	$\epsilon - \sigma$ $\sigma - \gamma - \beta$	G		G			
					<i>Arietites bucklandi</i>	$\epsilon - \sigma$ $\epsilon - \sigma - \beta$						
				UPPER	<i>Schlotheimia angulata</i> (<i>Haslicus</i>)	$\epsilon - \sigma$ $\epsilon - \sigma - \beta$ $\gamma - \alpha$	D			D		
TRIASSIC	RHAETIAN			LOWER	<i>Psiloceras planorbis</i>	$\gamma - \alpha$ $\beta - \alpha$ α	E	D	F	D	F	D

Figure 47. A Comparison of the model with the Hallam (1978) sedimentary sequences and the records of global sea level change.

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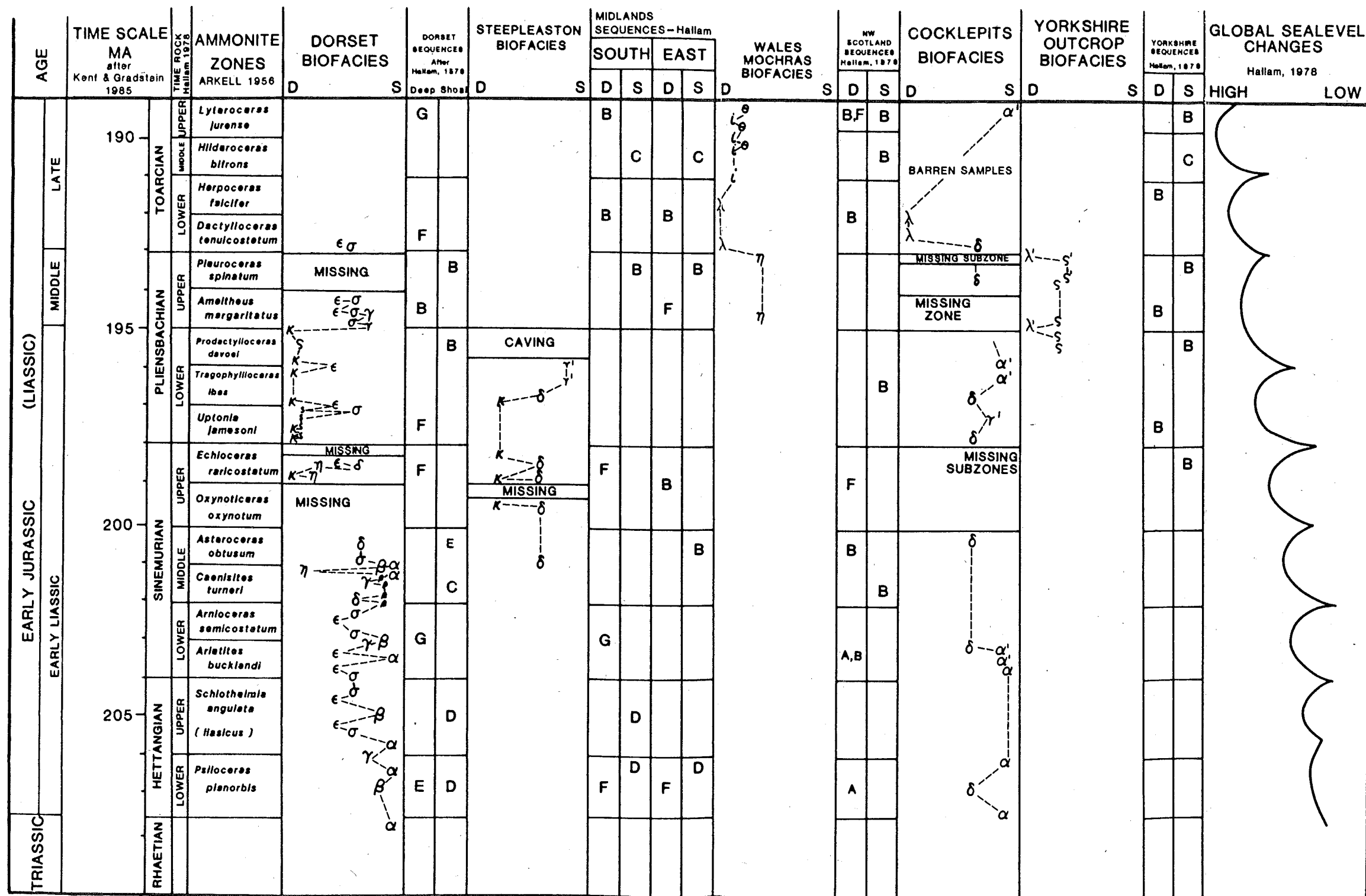


Figure 47. A Comparison of the model with the Hallam (1978) sedimentary sequences and the records of global sea level change.

regression in the middle Pliensbachian. Vail et al. (1984) concur with this model. At Inner Moray Firth they describe near shore conditions changing to marine and then regressing back to deltaic during this period (Figure 48).

Biofacies Kappa predominates from the Echioceras raricostatum Zone through the Uptonia jamesoni Zone, where it is the only biofacies present, and terminates in the base of the Tragophylloceras ibex Zone. The assemblages of this biofacies are overwhelmingly dominated by Opthalmidium macfadyenii and Spirillina infima which make up from 56-89 percent of the total in each sample. The section contains no ironstone layers and little limonite was noted in the residue. A greater abundance of ammonites and number of ammonite species are reported from this section. More belemnites are recorded in this interval, as well. Calcispheres which Banner (1972) and Bolli (1974) have shown to be indicative of open marine conditions are present in three of the samples. In general, there is a greater number of ostracod species present in these samples. Brachiopod spats also occur. Diversity declines in general, from that of Biofacies A. The median $H_s=1.80$ and the median equitability is $E=.27$. The preponderance of the two dominant species makes the equitability low. These two species completely dominate this niche through two

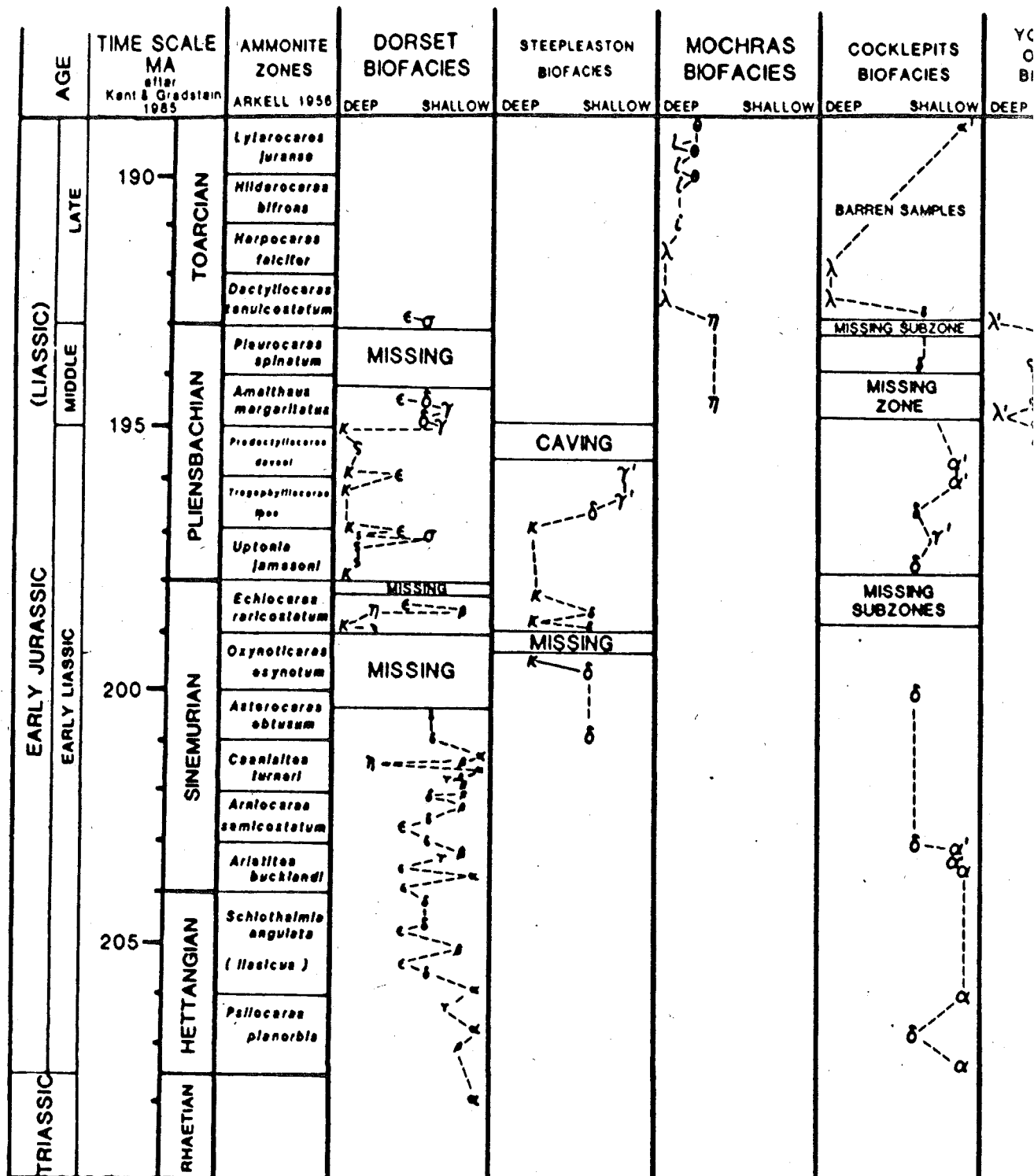
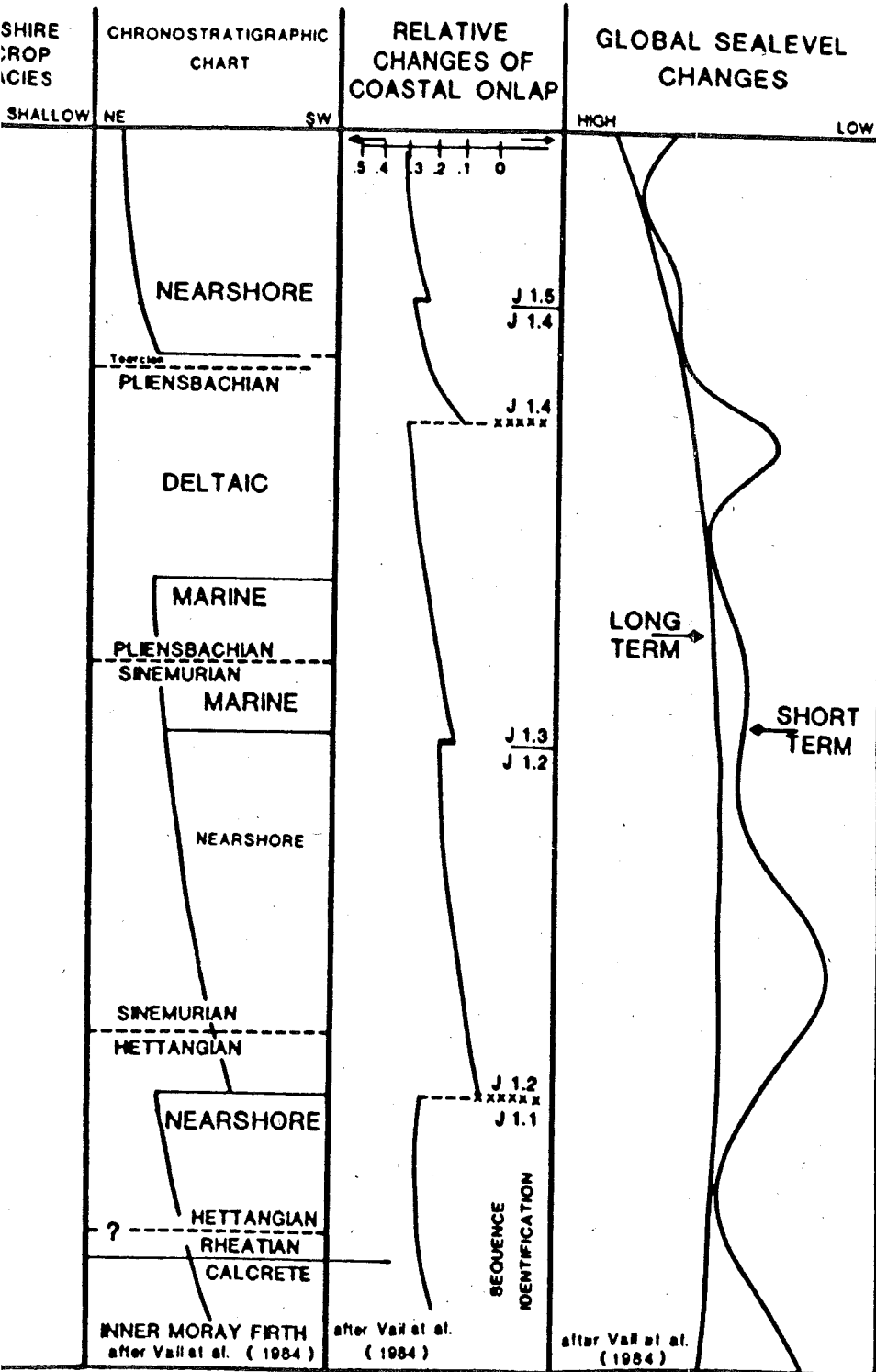


Figure 48. A comparison of the model with the Vail et al. (1984) curves of the global sea level. There is no information on how Vail et al. interprets their 1984 data with the new version of the sea level curve (Haq et al., 1987).



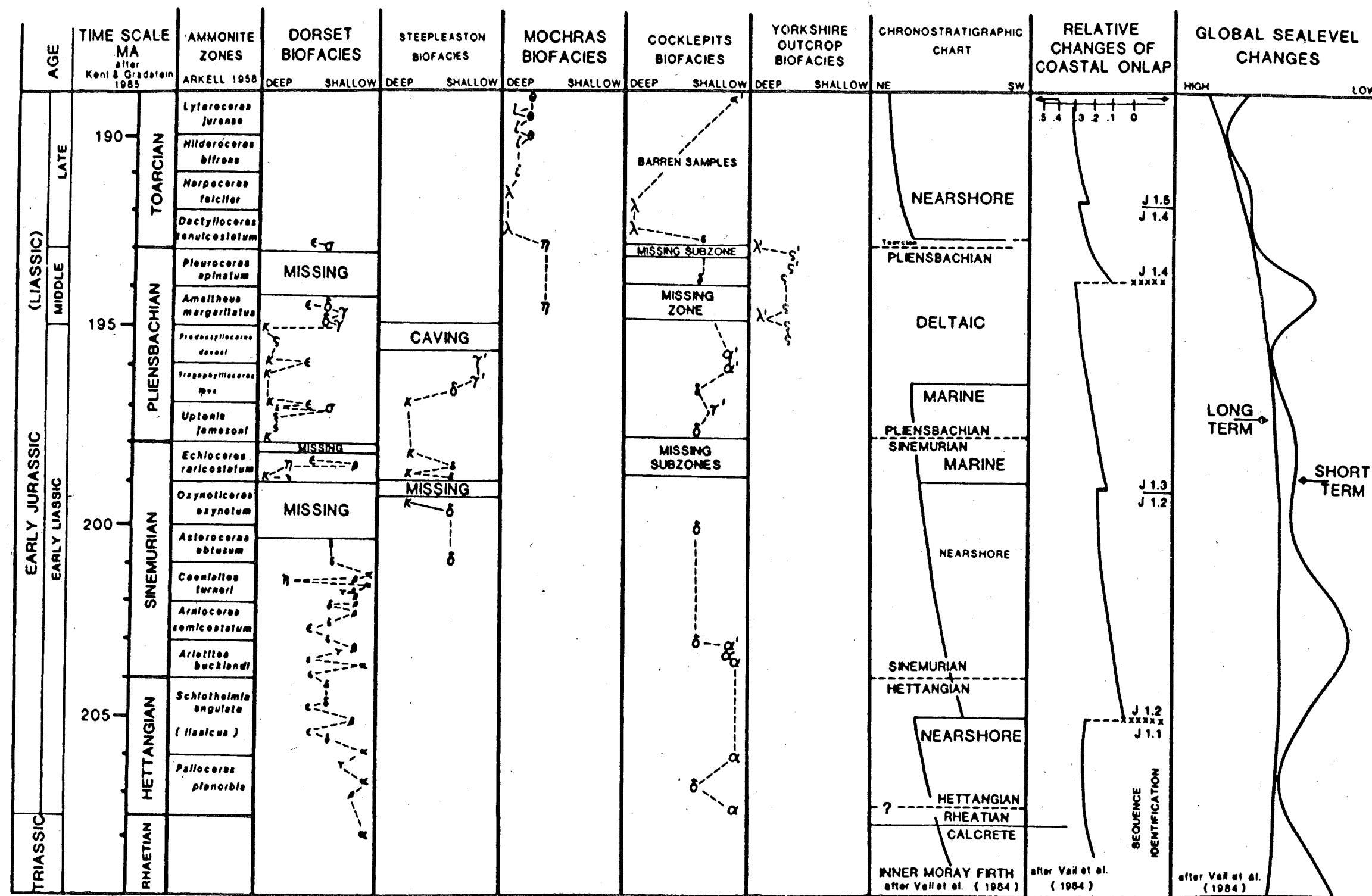


Figure 48. A comparison of the model with the Vail et al. (1984) curves of the global sea level. There is no information on how Vail et al. interprets their 1984 data with the new version of the sea level curve (Haq et al., 1987).

ammonite zones and into the base of a third. The median number of species is 21. Hallam (1978) shows a rise in sea level in the latest Sinemurian which was followed by a brief lowering at the Sinemurian/Pliensbachian boundary (Figure 47). This, in turn, was succeeded by another eustatic rise in the early Pliensbachian. Vail et al. (1981) show a similar pattern in their coastal on-lap diagram (Figure 48). Also at Inner Moray Firth the environment is near shore at the top of the Sinemurian and marine in the lower Pliensbachian (Vail et al. 1984). This suggests that the Opthalmidium macfadyenii-Spirillina infima assemblage (Biofacies Kappa) was adapted to a marine environment which was the farthest off shore of the three biofacies.

The breadth of the model can be extended by next including the biofacies discriminated by computer analyses of the Hettangian and lower Sinemurian outcrop samples of Dorset and the composite made from upper Sinemurian, Pliensbachian and Toarcian samples of Dorset. Biofacies Delta persists throughout the Dorset stratigraphic section. It is possible to correlate the Steeple Aston section with the Dorset section using Biofacies Delta. The absence of Gamma 1 in this section may be due to an evolutionary control rather than an environmental one. Three biofacies modeled, which are taken to be closer to shore than Biofacies Delta, are identified by the cluster-factor analysis.

Biofacies Alpha, Hetlos cluster-factor group 5, is a highly variable group in terms of the percent of composition of the component species. The majority of the samples of this group are from the lowermost zones of the Lower Lias: Psiloceras planorbis and Alsatites liasicus ammonite Zones. Thereafter, the presence of Biofacies Alpha in the stratigraphic column is spotty: once in the Arietites bucklandi and twice in the Microderoceras birchi Zones. The lithology from which the samples were drawn is primarily shale; there are, however, occasional marly beds.

With the exception of the samples drawn from Beds H29b and 82 (the Pavior) which contained ammonites of the genera Psiloceras and Promicroceras, as well as, species of ostrea, pectins and Spiriferina, Lang reports no accessory fauna (Lang 1924,1926). In the residue collected on screens with mesh size greater than 63 microns in the P. planorbis Zone, only echinoids and scolecondonts occur with the foraminifera; and in the A. liasicus Zone a few brachiopods and pelecypod spates with echinoids and scolecodonts are present. The number of ostracod species present increase from two in sample KMP75-105 (Bed h53 Top) to 5 in sample KMP75-120 (Bed 42), a marly shale. Most samples contain no ostracods. Sample KMP75-106 yielded an ammonite and three species

of gastropods. The lithic component of the residue is largely black-brown, organic rich mud flakes.

The diversity of assemblages in Biofacies Alpha is highly variable. Rapid evolution took place among the foraminiferal species during the early Hettangian (Barnard 1950). The variable diversity of the assemblages suggests that that they had not reached equilibrium. The instability of the assemblages may also be a reflection of the instability of conditions such as salinity, substrate and temperature in a shallow water, near shore environment. The dominant foraminiferal species are Eoguttulina liassica and Lenticulina varians. The important accessory species are Spirillina infima, Bullopore globulata, Eoguttulina oolithica, Dentalina pseudocommunis, Dentalina sinemuriensis, Nodosaria metensis, Lingulina tenera, and Vaginulina simplex.

This is the first persistent foraminiferal biofacies to occur after the discontinuity at the top of the Rhaetian, White Lias, at Dorset. The fact that it comes with a transgressive phase, that it has few ammonites and no belemnites reported with it, that there are very few ostracod species, and that the residues are organic rich muds indicates that this is a near shore environment. This interpretation is supported by Hallam's record for global sea level which shows gradual increase in sea level through the early Hettangian (Hallam 1973) with a

shoaling in the middle Hettangian, followed by another increase (Figure Model 47). This hypothesis is also compatible with Vail et al. 1984 (Figure 48).

Biofacies Beta, Hetlos cluster factor group 1, interfingers with Biofacies Alpha in the succession in the P. planorbis Zone and again in the M. birchi Subzone (Figure 25). Lingulina tenera dominates the assemblage and Eoguttulina liassica is the second most important species in the P. planorbis zone. The biofacies does not appear again until the Caenisites brooki Subzone and fluctuates with other biofacies through the Microderoceras birchi Subzone.

The lithology is primarily paper shale with the exception of two beds: 76 c-f and 73b described as conchoidal marl and a slabby marl respectively (Lang 1926). All but three of the beds contain ammonites of the genera Psiloceras, Arnioceras, Arietites, Promicroceras, Pholidophorus, Cymbites and Microderoceras (Lang 1926). The beds are rich in iron sulfide. Preparation of samples KMP75-129 through KMP75-137 produced an opaque black fluid which, when dehydrated, yielded a yellow wax-like substance. Thus the samples were taken to be kerogen rich. The residue collected on a 63 micron mesh screen is organic rich black-brown mud flakes. The residue yields relatively few fossils. Two

samples contain ostracods: Ogmoconchella ellipsoidea and Klingerella moorei. Several samples had echinoids and scolecodonts and one sample had ostrea. There is a general dirth of shelly material.

Foraminifera recovered were small or stunted in size. Biofacies Beta is completely dominated by the species Lingulina tenera which ranges from 50-83 percent of the total foraminifera recovered. Important accessory species are Lenticulina varians, Eoguttulina liassica and Vaginulina triquetra. Species of the genus Dentalina are conspicuous and Marginulina prima and Frondicularia sulcata are present in about 50 percent of the samples. The diversity of this biofacies is low - ranging from $H_s=0.16-1.84$ (Table 5).

The generally low diversity, the diminutive size of the foraminifera recovered, the lithology, and the occurrence of the biofacies early in a transgressive phase indicate that Biofacies Beta is a near-shore biofacies. Since Biofacies Beta has more ammonites associated with it than Biofacies Alpha, Biofacies Beta is more seaward than Alpha. The stunted or diminutive size of the foraminifera, the iron sulfide, and the kerogen in the sediments indicate that the environment was oxygen deficient.

Foraminiferal size increases from KMP75-283 (Biofacies Alpha) to KMP75-284 (Biofacies Beta) to KMP75-285 (Biofacies Gamma). This is particularly noticeable in the species, Lingulina tenera. In the Present, foraminiferal size often increases with water depth (Bandy, 1964).

There is agreement between the modeling of Biofacies Beta and Hallam's sea level curve. A general transgression was briefly interrupted in the early Sinemurian by a regressive phase (Hallam, 1978). Vail et al. (1984) show a variable phase in the early Sinemurian followed by a transgression. This is in general accord with the model (Figures 47,48).

Biofacies Gamma, Hetlos cluster-factor group 3 and Compos cluster-factor group 7, is present in the Hettangian and lower Sinemurian of the Dorset section and again in the A. margaritatus Zone of the Pliensbachian. This biofacies is intermediate between Biofacies Beta and Delta. The lithology from which the assemblage is drawn is shale in the Psiloceras planorbis through lower Caenisites turneri Zones. In the upper beds of the Caenisites turneri Zone, Microderoceras birchi Subzone, the assemblages occur in conchoidal marl and cement stone (Lang 1923,1926). In the Eype nodule strata of the A. margaritatus Zone the sediment is a grey clay (Howarth, 1957). The residue collected on a 63 micron mesh screen

is an organic-rich brown-black mud with calcite, chlorite, gypsum, and abundant muscovite and pyrite.

Six ammonite genera were reported by Lang from the Hettagian and lower Sinemurian strata in which this biofacies is found: Promicroceras (4 species), Cymbites, Microderoceras, Paracoronicer, Charmasseicer and Arnioceras (Lang 1923, 1924, 1926). In the Pliensbachian strata the genera Amaltheus and Tragophylloceras are present (Howard 1957). Lang also reported the presence of belemnites, brachiopods, and pelecypods (Lang 1923, 1924, 1926). In the residue three species of ostracod were present. Echinoid spines and plate fragments, crinoid stalks, scolecodont material and unidentifiable shelly debris were conspicuous.

The foraminiferal assemblage is dominated by Lingulina tenera as it is in Biofacies Beta, but the dominance drops to 27-48 percent of the total composition. The second most dominant species varies from sample to sample ranging in proportion from 11-43 percent. Dentalina pseudocommunis, Dentalina sp., Lenticulina varians, Marginulina prima, and Spirillina infima are all important constituents of the biofacies and alternate as the second most dominant species. Eoguttulina liassica and Vaginulina triquetra are common constituents, ranging from 1-15 percent of the total.

There is a greater abundance and number of species of the genera Dentalina and Nodosaria than there is in Biofacies Beta.

The diversity (Hs), equitability (E) and number of species (Ns) are greater on the whole for Biofacies Gamma than Biofacies Beta (Table 5). This indicates that Biofacies Gamma is from a deeper (more seaward) environment than Biofacies Beta.

When the model is compared with Hallam's curves for sea level rise, there is general accord. In the early Sinemurian there was a rise in sea level followed by a lowering in the middle Sinemurian. At Dorset the entire Oxynoticeras oxynotam Zone is missing. In the Echioceras raricostatum Zone of the upper Sinemurian, there is a return to deeper waters. The three samples from the upper Caenisites turneri Zone, suggest a brief transgressive pulse in the general shoaling during the middle Sinemurian (Figures 47,48).

Vail et al. (1984) show variable rising sea level during the lower Sinemurian, a brief rise during the early middle Sinemurian, and a lowering during the upper Sinemurian. This is consistent with the model, (Figure 48).

Biofacies Delta (Hetlos cluster-factor group 2 and the composite cluster-factor group 2) is present and ranges through the entire Dorset Liassic section. First appearing in the Schlothemia angulata Zone of the upper Hettangian, it alternates with the other biofacies through the Sinemurian and lower Pliensbachian and then reappears in the Toarcian above the disconformity in the uppermost Pliensbachian. Table IIIp, Appendix, is a Sander's Similarity Index Matrix showing the high degree of similarity between the Hettangian and lower Sinemurian assemblages with the Biofacies originally described in the Steeple Aston Bore. Table IIIq, Appendix, shows the consistent character of this biofacies through the Liassic section at Dorset. Many of these assemblages are nearly identical.

The strata from which the samples are drawn are shales and marl in the Hettangian and lower Sinemurian sections (Lang 1924,1926). However, in the upper Sinemurian and Pliensbachian section the strata varies: marls, cementstones, limestones, blue grey clay, shaley sandstones and calcareous sandstone (Lang,1926 and Howarth, 1957). Thus, this biofacies does not appear to be substrate dependent. An alternative hypothesis is that there is some mixing or transportation of material in some of the samples from the higher stratigraphic sections.

The strata from the Hettangian and Lower Sinemurian section contain a rich and varied ammonite fauna (Lang 1923,1924). Ammonites of the genera Microdoceras, Arnioceras, Agassiceras, Philidophorus, and Arniaceratoides are present. In the stratigraphic beds immediately adjacent to 74W from which sample KMP75-125 was drawn. Cymbites and Arietites are also reported (Lang 1923,1924). The diversity of the ammonite genera increases upward through the Lower Sinemurian stratigraphic section. Belemnites, brachiopods, pelecypods and crinoids are also present (Lang 1924,1926).

The upper Sinemurian, Pliensbachian, and Toarcian beds containing this biofacies contain the following ammonite genera: Amalthaus, Amauroceras, Lytoceras, Epophioceras, Promicroceras, Xipheroceras, Cymbites, Asteroceras, and Platypleuroceras. Also present are belemnites, brachiopods and pelecypods (Lang 1926,1928). The trend toward increase of ammonite diversity persists through this section of the stratigraphic column.

In the residue collected on a 63 micron mesh screen, five ostracod species are present with Biofacies Delta in the Hettangian and Lower Sinemurian samples. Eight species of ostracods are associated with Biofacies Delta

in the Upper Sinemurian, Pliensbachian and Toarcian samples.

Other fauna associated with Biofacies Delta at Dorset is as follows: brachiopods, calcispheres which are indicative of more open marine environments (Banner 1972 and Belli 1974), crinoids, gastropods, holothurians, pelecypods, and scolecodonts.

Biofacies Delta at Dorset shows a general trend toward increase in number of foraminiferal species and diversity (Tables 5,6). The dominant foraminiferal species in Biofacies Delta at Dorset is always Lingulina tenera which accounts for approximately forty to sixty percent of the assemblage. Two samples in this group from the composite analysis, KMP75-285 and KMP75-286 have a higher percentage of Lingulina tenera and, therefore, show a great similarity with Biofacies Gamma. They represent a transitional assemblage, Marginulina prima and Lenticulina varians are the second most prevalent species in the biofacies. The genera Dentalina and Nodosaria are abundant and many species of each are present in most samples of Biofacies Delta at Dorset.

A comparison of the model with the Hallam sea level record reveals that the two are generally compatible (Figure 47). Biofacies Delta is generally present during

episodes of inferred sea level rise. The model is in agreement with the Vail et al. (1984) record of sea level change. During the early Sinemurian Biofacies Delta was present in a period in which sea level was deepening. In the early middle Sinemurian, Biofacies Delta is again present during a period which is suggested as deepening, and it is again present at the beginning and end of a cycle which is interpreted as a lowering of sea level, which is consistent with an interpretation of Biofacies Delta as a transitional biofacies. In the upper Sinemurian the biofacies is present in an interval which is inferred as variable, and once again, in the A. margaritatus Zone of the Pliensbachian, Biofacies Delta is present in intervals of variable change in sea level (Figure 48). Biofacies Delta's presence during phases of change in sea level cycles is compatible with its shallow, open-marine designation in the model.

Biofacies Epsilon is present in the Dorset section from the P. angulata Zone of the Hettangian through the A. margaritatus Zone of the Pliensbachian, cluster-factor groups Hetlos 4 and Compos 1 and isolate 314. The Toarcian assemblage was rejected from the modeling because the recovery and the preservation of the fossils are poor. Biofacies Epsilon fluctuates with Biofacies Delta throughout most of the succession through this stratigraphic section.

The lithology from which the samples were drawn is predominately shale and clay with the exception of two marl beds (Lang, 1923, 1924, 1928, 1936 and Howarth, 1957). In the residue recovered on the 63 μ screen, black-brown to grey mud flakes predominate and pyrite is ubiquitous, which points to oxygen deficient conditions. Other minerals noted are biotite, glauconite, chlorite, gypsum, limonite, and muscovite.

The ammonite genera associated with Biofacies Epsilon in the Hettigian and lower Sinemurian section is diverse: Aggassiceras, Arnioceratoides, Charmasseiceras, Coroniceras, Scholothemia (Lang, 1923, 1924). The upper Sinemurian through Pliensbachian strata in which Biofacies Epsilon occurs contains eight ammonite genera: Aegoceras, Amaltheus, Echioceras, Echioceratoides, Liparoceras, Platypheuroceras, Tragophylloceras, and Uptonia (Lang, 1928, and Howarth, 1947).

A diverse ostracod assemblage associated with this biofacies was collected on a 63 micron mesh screen. Twenty species and/or variant forms are present.

Other faunal constituents were also identified in the residue. Calcspheres are present and, in some cases, they are the major constituent in the lithology, i.e. Sample KMP75-114. Belemnites, brachiopods, pelecypods,

scolecodonts and sponge spicules are present. In addition to the fauna, yellow translucent sphere and resinous material are conspicuous.

The foraminiferal assemblage is dominated by the species Marginulina prima which ranges in proportion from 20 to 44 percent. The proportion of Lingulina tenera drops from Biofacies Delta to a maximum of thirty-five percent. A third species, Lenticulina varians, increases in importance. Spirillina infima and Ammodiscus asper become more prevalent while species of the genera Dentalina, Fronidicularia, Nodosaria and Planularia continue to be conspicuous accessory constituents as they were in Biofacies Delta.

The range of diversity for the assemblages in Biofacies Epsilon is from $H_s = 1.86$ to 2.96 with a median of 2.36 . The equitability (E) ranges from 0.27 to 0.53 with a median of 0.37 . The number of species ranges from fifteen to forty-one with a median of twenty-five (Tables 5,6). There is a general trend of increase in diversity from Biofacies Delta to Biofacies Epsilon. Biofacies Epsilon is from a more open marine environment than Biofacies Delta, although there is a very strong relationship between the two biofacies. In comparing the model with Hallam's and Vail's records for global sea level change, there is general agreement, (Figures 47,48).

Biofacies Zeta is identified in the lower Pliensbachian of the Dorset section. Biofacies Zeta is the cluster-factor groups four and three of the composite of the upper Sinemurian through Toarcian assemblages. As previously described cluster-factor groups four and three have high similarity, but interpretation of group three is hampered by low recovery. In group four the recovery was excellent.

Biofacies Zeta is the dominant biofacies in the Uptonia jamesoni Zone of this stratigraphic section. Zeta interfingers with Biofacies Kappa and Biofacies Delta in this Zone. Zeta is not present in the Tragophylloceras ibex Zone, but it again interfingers with these same two biofacies in the Prodactylioceras davoei Zone. Cluster-factor group three which is attributed to Biofacies Zeta is present in the top of the P. davoei Zone and the bottom of the Amaltheus stokesi subzone of the A. margaritatus Zone of the upper Pliensbachian, Figure 35.

The U. jamesoni samples are taken from marl; while the P. davoei samples are from blue-grey clay, Lang (1928, 1936). In the residue collected on a 63 micron mesh screen the following lithic components are present: calcite, chlorite, dolomite, glauconite, limonite,

muscovite, and siderite. Pyrite aggregates, framboids and tubes are ubiquitous, indicating a low oxygen environment. Some diagenetic changes have taken place: this is especially notable in the samples of cluster-factor group three.

The strata in which the biofacies is present contains a diverse ammonite fauna. Lang lists nineteen species in these beds. Lang also identifies eight belemnite species, four gastropod species, three brachiopod species, eight pelecypod species, Isocrinus basaltiformis, a crinoid, and the echinoderm Eodiaderma c.f. minutum, (Lang, 1928, 1936).

In the residue collected on the 63 micron screen are bryozoans, calcispheres, echinoid material, gastropods, and eight ostracod species.

Biofacies Zeta is dominated by Lenticulina varians, Lingulina tenera, and Astacolus pauperatus. Marginulina prima is an important accessory species; however, its abundance is low when compared with Biofacies Epsilon. The genera Dentalina and Fronicularia are important constituents. The species Opthalmidium macfadyeni and Opthalmidium orbiculare are usually present, but few in number.

The diversity and the equitability in Biofacies Zeta are highly variable (Table 6), and of little use in reconstruction of the paleoenvironment of the biofacies. However, the associated fauna, especially the ammonite, belemnite, and calcisphere components, point to an open marine environment. Comparison with Hallam's and Vail's records for global sea level change (Hallam, 1978 and Vail et al., 1984) is consistent with this interpretation (Figures 47, 48).

The clustering and factoring of the composite of the Yorkshire and Midlands samples produced a group--Yormid cluster-factor group 1-- which has a strong similarity with Biofacies Zeta. The major difference is the decrease in the percentage of the species Astacolus pauperatus and the absence of the genus Ophthalmidium. In the Yormid cluster factor group 1, the species Pseudonodosaria vulgata is present, and it is not present in the Dorset groups. There is a similarity between the two groups (Table 7), and they actually may be the same biofacies.

The Yorkshire samples are from the A. margaritatus Zone through the P. spinatum Zone. The Midlands samples are from the T. ibex-P. davoei Zones (sample KMP77-325) and from the P. spinatum Zone (sample KMP77-332). Hallam (1978) Figure 47, shows an increase in sea level

during the A. margaritatus Zone. Vail et al. (1984) show an open marine condition in the early Pliensbachian followed by deltaic conditions in the middle and upper Pliensbachian at the Moray Firth, Figure 48. This is consistent with the model.

Three samples did not form in any cluster-factor group in the Dorset computer analysis: KMP75-278 (Hetlos), and KMP75-295 and KMP75-297 from the composite. These three samples are dominated by the foraminiferal species Spirillina infima Strickland. They are very similar to Biofacies Theta which was modeled on the cluster-factor groups produced from the analysis of the Mochras Bore Hole. A Sanders Similarity Matrix, Table 8, depicts the relationship. This is likely one biofacies.

The beds from which these samples were taken are grey to black conchoidal marl and black conchoidal marl (Lang, 1926). The lithic constituents collected in the residue are pyrite aggregates and framboids, calcite aggregates, sparse sphalerite crystals and sparse black-brown mud flakes. It is very likely that the environment of deposition was a reducing one and that diagenesis has taken place.

Ten ammonite species were identified in these three Dorset Beds. In addition to the ammonite fauna,

Plagiostoma gigantum and Oxytoma inaequivalve, lamellibranch molluscs, are present (Lang, 1926).

The associated microfossils present in the residue are echinoid spines and plates, gastropod, scolecodont debris, the ostracod, Macrocypris sp. , and yellow pollenlike spheres. With the exception of sample KMP75-295 the preservation is poor and recrystallization is evident.

The Dorset assemblages are compatible with the hypothesis that Biofacies Theta is from an open marine environment. Theta is present at Dorset in a brief transgressive pulse in the predominantly shallow environment of the C. turneri Zone (Hallam, 1978), and once again in a transgressive pulse during the lower E. raricostatum Zone.

Biofacies Kappa which was modeled on an assemblage from the Steeple Aston Bore Hole is dominated by Opthalmidium macfadyeni. The Dorset assemblage dominated by Opthalmidium macfadyeni is close enough in similarity to be considered the same biofacies, (Table 6). Biofacies Kappa, Dorset composite cluster-factor group 6, first appears at Dorset during the E. raricostatum Zone where it interfingers with Biofacies Theta and Biofacies Zeta. In the U. jamesoni zone it interfingers with Zeta again. Biofacies Kappa persists through the T. ibex zone

interfingering with a very closely related assemblage, Kappa 1. (The Kappa 1 assemblage, cluster factor group 5, was included within group 6 in one factor analysis and it was positioned next to 6 in the other two factor analyses, Figure 34. Biofacies Kappa appears twice during the P.davoei zone, KMP75-317 and KMP75-319, next to Biofacies Zeta in the succession, Figure 35. The presence of Biofacies Kappa in the Dorset stratigraphic column is nearly synchronous with the model assemblage in the Steeple Aston column.

The lithology associated with Biofacies Kappa at Dorset is blue-gray clay in the samples from the P.davoei Zone and black-grey to gray-black marl in the samples from the T.ibex and U. jamesoni Zones (Lang, 1928, 1936). The lithic components collected on a 63 μ screen are brown-black mud flakes, blocky calcite and aggregates of marl, abundant pyrite aggregates and framboides (many of the ammonite, gastropod and foraminifera fossils were either replaced or infilled by/with pyrite.), biotite, muscovite, and chlorite.

A diverse macrofossil fauna is reported from the beds in which Biofacies Kappa is present. Thirty-seven ammonites were identified (Lang 1928,1936). Seventeen belemnite species are present. Ten pelecypod species, ten gastropod species, and two echinoderm species are also

present (Lang 1928, 1936).

The microfossils identified in the residue are also diverse. Ammonite, brachiopod, gastropod, and pelecypod spats are common. Shelly debris, scolecodont material, holothurian material and sponge spicules are also present. Although their abundance is low, the ostracod species are diverse. Nine species are present in these beds.

The Dorset Biofacies Kappa, like the model type at Steeple Aston, exhibits a wide range of diversity and equitability. The dominance of Opthalmidium macfadyeni is as high as 83 percent of the total assemblage in one sample at Dorset. This pattern is seen also in the Steeple Aston Kappa. The important accessory species are similar in type but differ in their percentage of the total abundance. These two assemblages are the same biofacies but the Dorset assemblage may be from a slightly more open marine environment.

The Dorset foraminiferal data coupled with the macrofossil evidence support the idea that Biofacies Kappa is from an open marine environment. There are common and diverse ammonites which Hallam (1975) modeled as deeper water indicators. The belemnite fauna is rich.

Deposit feeding pelecypods, i.e. Nuculana (?Rolliera) galatea, which are prevalent in the deeper water facies, are present. Also present are small pelecypods such as Luciniola which Hallam (1975) lists as an indicator of deeper water environment .

Two sample assemblages of the composite, KMP75-310 and KMP75-312, are virtually identical (Sanders Similarity Index of 84). They are stratigraphically continuous with Biofacies Kappa (Figure 35). Also as previously stated, they (group 5) were either included with Biofacies Kappa (group 6) or between it and Biofacies Zeta (group 4) in the factor analysis (Figure 34). The presence of Fronicularia paradoxa as an important constituent, 29 and 33 percent of the total assemblage, and the lower percentage of abundance of Opthalmidium macfadyeni, 5 and 11 percent of the total assemblage, differentiates this group from Biofacies Kappa.

The lithology varies in these two samples. Sample KMP75-310 is taken from a blue-grey marl bed of the Upper Darker Marl (Bed 118a), and sample KMP75-312 is from a brown marly shale (Bed 119) (Lang, 1928). Resinous material, brown mudflakes, pyrite, calcite, and carbonaceous material are the lithic constituents of

the residue.

The ammonites are varied suggesting an open marine condition (Hallam, 1975). Twenty species and forms are present in these two beds (Lang 1928). The beds also contain eight belemnite species, four pelecypod species, three brachiopod species, and two gastropod species, (Lang, 1928).

The fossil fauna identified in the residue contains shelly debris, holothurian material, scolecodont material abundant gastropod spates, echinoid spines, and six ostracod species.

The evidence indicates that the Kappa 1 assemblage is from a deep-water environment. Although it is similar to Biofacies Kappa, there are some important distinctions. It is possible that the Kappa 1 assemblage is a separate biofacies marked by the Lenticulina varians and Fronicularia paradoxa dominance. However, it would be imprudent to model a biofacies on two samples.

Further modeling of Liassic foraminiferal biofacies can be done by examining the groups produced by the cluster and factor analysis of the assemblages drawn from the Middle and Upper Liassic section of the Mochras Bore Hole. Since there is a large gap in this stratigraphic section of the Dorset outcrops, it is advantageous to

study these sections here.

Biofacies Eta Mochras cluster-factor group 2 is the most important biofacies present during the Middle Lias (Figure 6). This is a Spirillina infima- Lingulina tenera assemblage. There is a very high degree of similarity among the assemblages of the biofacies (Table IIIA Appendix); many of the assemblages are identical. Biofacies Eta is the shallowest of the Middle and Upper Lias biofacies.

The lithology of this section is marly silt and mudstones ranging from grey to dark grey in color. There are a few impure limestones present, and in general, this lithology is harder than the Upper Liasic section (Wood and Woodland, 1968). In the residues collected on the 63 micron screen, there is abundant dolomite, calcite and aggregates of marly silt and clay size particles which did not break down. Lignite, bituminous material and light brown organic material are present throughout. Muscovite is conspicuous and minor amounts of chlorite are present. Although pyrite is present, it is not a major constituent. A few pyrite framboids are noted in two of the samples, but pyritized tubes occur in three of the samples. The scarcity of pyrite may be indicative of better water circulation in this environment.

The flora and fauna for this section of the Mochras Bore Hole was identified by Johnson (1977): plant remains, ammonites, bryozoans, vertebrates and echinoids. Hallam (1969) describing the P. spinatum Zone of the Midlands cited a dense belemnite population, a very dense brachiopod population consisting of few species, pelecypods, crinoids and ammonites of the genera Pleuroceras and Dactylioceras. Woodland (1971) recorded four ammonite genera from the Mochras : Amaltheus, Protogammoceras, Pleuroceras, and Tragophylloceras. The fauna present in the sample residues collected on the 63 micron screen is sparse with the exception of foraminifera, ostracoda, and echinoid material. While most of the samples have undefined shelly debris, only two have pelecypod spats (rare) and no brachioopod spats are present. Sponge spicules were absent with the exception of a very rare occurrence in sample 3232. Sample 2849 had rare holothurian and scolecodont material and rare belemnite fragments. Twenty ostracod species and /or forms are present.

The foraminifera are dominated by Spirillina infima and Lingulina tenera, commonly accounting for 65-85 percent of the total. Opthalmidium northamptonensis, Opthalmidium orbiculare, Astacolus pauperatus, Marginulina prima, Lenticulina varians, Nodosaria hortonensis and species of the genera Dentalina,

Fron dicularia, and Vaginulina are the common accessory constituents. The range of diversity of the biofacies is very narrow, $H_s=1.38$ and $H_s=1.82$, with a median of 1.65 and the equitability ranges from 0.15-0.49 with a median of 0.20 (Table 1b). When these statistics are plotted against one another, the points cluster in Johnson's (1977) partially restricted to restricted marine sector. The diversity values are within the range which Nyong and Olsson (1984) found for inner to middle shelf assemblages. In their modeling of the Campanian and Maestrichtian of the New Jersey Coastal Plain, they found that diversity ranged from 1.5 to 2.2 for inner and middle shelf. Johnson (1977) shows the Spirillina assemblage dominant in the middle to top of the Spinatum Zone only. This study shows that this biofacies ranges throughout the Middle Liassic section of the Mochras Borehole, and that a stable foraminiferal assemblages persists from 3278'-2849', Figure 6. This biofacies is modeled as a middle shelf biofacies. The paleobathymetry is consistent with the hypothesis that shoaling occurred in the Middle Lias (Hallam 1978, Vail et al. 1984) in the Spinatum Zone. It may also be that the assemblage endured here in the Cardigan basin through the Pliensbachian regression and was replaced by Biofaces Lambda when the lower Toarcian transgression commenced. Alternately, it can be interpreted that there is an unreported hiatus in the Mochras Borehole and some of the

correlations of the core are incorrect.

Biofacies Theta is very closely related to Biofacies Eta, which is dominated by Spirillina infima, but the secondary species is Lenticulina varians. Lingulina tenera is present only in small numbers, averaging 1-5 percent of the total. Table IIIC, Appendix, a Sander's Similarity Matrix, shows the very high degree of similarity between these two biofacies. Biofacies Theta alternates with Biofacies Iota through the middle and upper Toarcian, Figure 6.

The lithology of this section of the Mochras Borehole is light grey calcareous mudstones and siltstones, with a sandy shelly limestone thirty-one inches thick occurring at 2058' (Wood and Woodland, 1968). The residue collected on the 63 micron mesh screen contains abundant lignite and bituminous material. Light brown organic material is present, but not abundant. Pyrite is an important constituent and framboids occur in one-third of the samples. Although muscovite and chlorite are present, they are not dominant constituents, and glauconite and limonite are very rare and only in two samples.

Woodland (1971) identified twelve ammonite genera in

the stratigraphic section of the Mochras Bore Hole from the Striatulum through Aalensis Zones. Johnson (1977) showed frequent occurrences of ammonites, pelecypods, gastropods, echinoids, plant remains, spicules, and radiolarians. He also indicates less frequent to rare occurrences of belemnites, bryozoans, brachiopods, and holothurians during these intervals in the Mochras Bore. The residues contain the following microfossils: common gastropods, sponge spicules, echinoids and undefined shelly debris and twenty species and/or forms of ostracoda; less common to rare are ammonite, brachiopod, and pelecypod spats .

The foraminiferal assemblage is dominated by Spirillina infima and Lenticulina varians. The important accessory species are Lenticulina muensteri and Astacolus pauperatus. Dentalina pseudocommunis, Eoguttulina liassica, Nodosaria hortonensis, and Lingulina tenera are common constituents and are present in the majority of the samples, although their abundance is low (usually less than eight percent of the total assemblage).

The diversity (H_s) of Biofacies Theta is more wide ranging than Biofacies Eta. However, the majority of the Biofacies Theta samples have a higher diversity than the Biofacies Eta samples. When one plots diversity (H_s) against equitability (E), they cluster in the normal

marine sector described by Johnson (1977).

Even though Biofacies Theta is strongly related to Eta, the evidence suggests that Theta is from a deeper or more open marine environment. Comparison with the Hallam (1978) curves and Vail et al. (1984) records show reasonable agreement. Both depict a gradual shallowing at the end of the Lias, Figures 47,48.

Biofacies Iota, Mochras cluster-factor group 1 is an assemblage dominated by the species Lenticulina varians and Lenticulina munsteri which, when combined, average about 45 percent of the total assemblage. Spirillina infima is the most important accessory species; it averages 15 percent of the total assemblage. Although low in abundance, Astacolus pauperatus and E. liassica are present in all samples making up this group. Dentalina pseudocommunis and Lingulina tenera are common; however, they are absent from a few of the samples.

Biofacies Iota dominates from the F. falciferum Subzone through the middle of the H. bifrons Zone. In the T. striatulum Subzone, it interfingers with Biofacies Theta (Figure 6).

The assemblages were recovered from samples in which the lithology was primarily light grey marl which was rich in pyrite. The presence of pyrite framboids, sparry

calcite and dolomite indicate diagenetic changes which accounts for the relatively poor preservation and recovery of the foraminifera. The residue collected on the 63 μ mesh screen also contains common muscovite, minor amounts of chlorite, and rare glauconite and limonite. Bituminous material and lignite are present in the majority of the residues.

Woodland (1971) identified three ammonite genera in the section from the top of the Falciferum through middle of the Fibulatum Zone: Hildoceras, Dactylioceras, and Phylloceras; in the stratigraphic section from the Variabilis to Striatulum Subzones he listed seven ammonite genera: Grammoceras, (?) Hammatoceras, Haugia, Lytoceras, Mercaticeras, Phynatoceras, and Polypsectus.

Numerous microfaunal fossils are also in the residue. Undefined shell debris is ubiquitous. Sponge spicules are abundant and present in the majority of the samples. Brachiopod, gastropod, and pelecypod spats are present in a minority of the samples, but they are not common. Eleven ostracod species are present in the residues.

Preservation is poor in the samples in which Biofacies Iota is found and recovery in many of the samples is low (Table 1 and Figure 60. However, the

samples in which more than forty specimens were recovered were very diverse: Hs ranged from 2.21 to 2.80. The equitability of these samples was also high, 0.58-0.79 (Table 1).

The diversity of the assemblages is within the range which Nyong and Olsson (1984) found for middle to outer shelf environment of the Campanian and Maestrichtian of the New Jersey Coastal Plain. When diversity (Hs) is plotted with the equitability (E), these assemblages plot in the area of normal marine conditions according to Johnson's figure (1977). Brouwer (1969) thought that the assemblages dominated by Lenticulina gottengensis (= Lenticulina muensteri) might inhabit a deep water paleoenvironment since the lithology in which the assemblage occurs is rich in ammonites and belemnites. As the assemblages occurs in the H. bifrons Zone in the Mochras stratigraphic section and Vail shows a global rise in sea level at the top of the middle Toarcian, there is strong reason to believe this is an outer shelf or deep basin assemblage.

Biofacies Lambda, Mochras cluster-factor group 3, is the deepest water biofacies of the model. In the Mochras Borehole stratigraphic section, Biofacies Lambda occurs in the Dactylioceras tenuicostatum and Harpoceras falcifer Zones of the Upper Lias.

The lithology in which the biofacies is present is organic-rich, dark grey silty mudstone (Wood and Woodland, 1968). In the residue light brown organic material, bituminous material and lignite are abundant. Although few framboids were noted, pyrite and muscovite are very abundant. Chlorite, calcite and dolomite are conspicuous and glauconite is present but rare. The lithology is indicative of stagnant conditions (Hallam, 1975).

Hallam (1967) identified five ribbed species of Dactylioceras in the paper shales at Lincoln in the Midlands in the D. tenuicostatum Zone. Abundant belemnites and the ammonites Dactylioceras tenuicostatum and semicelatum occur in the Grey Shales fauna of Yorkshire. Woodland (1971) identified three genera of ammonites in the D. tenuicostatum zone of the Mochras Bore; Dactylioceras, (?) Phylloceras, Tiltoniceras. In the Exaratum Zone he identified six genera: Dactylioceras, Hildaite, Hildoceras, Lytoceras, Nodicoeloceras and Phylloceras. Johnson (1981) noted plant remains, megaspores, gastropods, pelecypods, bryozoans, spicules, ammonites, and echinoids for this interval in his paleoecologic examination of this section of the Mochras Bore. The microfauna recovered on the 63 μ mesh screen is sparse. Echinoid spines occur in

sixty percent of the samples. Brachiopod spates, gastropods and sponge spicules are very rare, occurring in twenty percent of the samples. Eleven ostracod species are present. The ostracoda in general are sparse and no more than six species are present in one sample. It is also interesting to note that it appears that in this biofacies the number of species of ostracoda is lower when the percentage of the foraminiferal species Reinholdella macfadyeni is higher.

The foraminiferal assemblage is dominated by Reinholdella macfadyeni, which ranges from 4 to 86 percent of the total. Lingulina tenera is the second most important species (4 to 48 percent of the total). Lenticulina muensteri, Opthalmidium northamptonensis, and Lenticulina varians are the most important accessory species. Brouwer (1969) placed the genus Reinholdella at the deep end of his faunal succession with Lenticulina gottengensis (muensteri). Johnson (1977) showed assemblages dominated by Reinholdella occurring in deep restricted marine - outer shelf (?) conditions.

The foraminiferal assemblages are characterized by relatively low abundance and average to good preservation. The diversity and equitability of the assemblages is variable (Table 1): the Hs ranges from 0.47 to 2.25 and the E from 0.26 to 0.80. When these two

statistics are plotted, the assemblage falls into the partially restricted to very restricted marine groupings of Johnson (1977).

In the D. tenuicostatum Zone, a major transgression commenced which was followed with poor circulation and stagnation during the Harpoceras falcifer Zone (Hallam 1967, 1975, 1978, Johnson 1977, and Lord 1978). Hallam (1967) states that it was likely that the Dactylioceras genera filled an ecological niche which was vacated by the Pleuroceras, whose extinction may have been caused by the regression at the end of the Middle Lias. Dactylioceras colonization and subsequent radiation would have been made possible by the Toarcian transgression (Hallam 1967). Johnson (1977) believes that it was stagnation which produced the low diversity values of his Reinholdella dreheri assemblages of the H. falciferum Zone of the Mochras. He believes they are a deep-water assemblages. The samples with the lowest diversities in Biofacies Lambda, 2692 and 2720, are from the H. falciferum Zone. The consensus and evidence point to a deep restricted or outer shelf environment for the biofacies.

The assemblage is present in the Cocklepits Borehole, D. tenuicostatum section, samples 21.06-21.96 and 19.18-20.11. Reinholdella macfadyeni constitutes 12

to 16 percent of the total assemblage. Brizalina liassica is the second most important species. Opthalmidium northamptonensis, Marginulina prima var. spinata, Lingulina tenera, Lenticulina varians, and Frondicularia sulcata are conspicuous. Diversity of the assemblages is $H_s=2.21$ and $H_s=1.56$. Equitability is $E=0.76$ and $E=0.17$. The flood of Reinholdella macfadyeni occurs in the stratigraphically lower sample. This likely indicates the onset of the major lower Toarcian transgression in the Yorkshire area. It may also show that Brizalina liassica survived the shoaling at the end of the Middle Lias by migrating with the regression developing a broader niche. Alternately, Brizalina liassica became acclimated to deeper water conditions in the later stages of its evolutionary history and became a constituent of Biofacies Lambda.

This same combination of the species Reinholdella macfadyeni and Brizalina liassica is seen in the D. tenuicostatum zone samples from the Yorkshire outcrops at Brackenberry Wyke (Samples KMP77-200 and KMP77-199 cluster-factor group 3). In addition to these two species, Lenticulina varians, Eoguttulina liassica and Marginulina prima, are the important constituents (Figure 46).

Howarth (1955) described the lithology of the beds as shale with limestone doggers. The residue for the

outcrop samples contains abundant calcite, muscovite, chlorite, pyrite, and aggregates of silt and clay size particles. There is a minor amount of biotite, pyrite framboids, magnetite, siderite, and hematite. The Cocklepits Bore samples are 92 to 95 percent clay and silt and the residue contains chlorite, lignite, muscovite, hematite and limonite.

The faunal elements in the residue are similar: echinoid spines, crinoid material, gastropods, yellow pollen-like spheres, a minor amount of shelly debris and six species of ostracoda. Most of the samples have only two species present. The Yorkshire site is occupied by Biofacies Lambda. The differences in composition between Yorkshire and the type locality could possibly indicate a somewhat shallower environmental condition, a more restricted condition with less circulation, or difference in substrate control.

The Cocklepits Borehole, Humberside, Yorkshire penetrates the Lias from its top through the P. planorbis ammonite Zone. Cluster and factor analysis produced groups which correlate with biofacies modeled from other Liassic sections. The most persistent, Biofacies Delta, extends intermittently from the Caloceras johnstoni Subzone of the P. planorbis through the D. tenuicostatum Zone of the upper Lias, Figure 19. Biofacies Alpha dominates the Hettangian Stage, and extends through the

A. bucklandi zone of the Lower Sinemurian, Figure 19.

Biofacies Alpha at the Cocklepits is a highly variable biofacies as it is in the type locality at Dorset. The lack of stability in this biofacies is consistent with the unstable conditions in a nearshore environment.

Brouwer (1969) placed the Eoguttulina liassica assemblage nearest shore in his foraminiferal faunal succession. He suggested that if E. liassica were similar to its recent counterparts, then its abundance might indicate water depths of 2 to 12 meters or a lagoonal or nearshore environment (Brouwer, 1969).

One cluster-factor group that did not appear in abundance at the other locations was cluster-factor group 1, Biofacies Alpha-1. Alpha-1 is a biofacies with a large arenaceous foraminiferal component. The only other locality where this biofacies occurs with some frequency is in the Midlands outcrop samples (cluster-factor group 4). Two samples are from the Upper Lias Scissum Beds at Hook Norton Railway Cutting, and one is from the Amaltheus margaritatus Zone of Robin's Wood Hill, Agar bed 16.

The lithology in which Biofacies Alpha 1 is found is variable. Of the Cocklepits samples, samples from intervals 73.12 to 73.95m and 78.22 to 79.08m are indurated Frodingham Ironstone. The sample from interval

clay/silt combination: ninety-four percent. Material washed through a 63 micron mesh screen. The residue contained some limestone, ironstone and grey-brown mud. Pyrite, pyrite tubes, hematite, limonite or goethite, and very rare glauconite are present. The sample from interval 30.39 to 31.25m is very fine grained also: ninety-one percent of the material washes through the 63 micron screen. In the residue are aggregates of ironstone, pyrite tubes, brown organic material, calcareous ooliths, lignite, hematite, muscovite, quartz and chlorite. There is rare glauconite also. The sample from interval 27.50 to 28.43m is immediately beneath indurated ironstones. Ninety-seven percent of the material from this interval passed through the 63 μ mesh screen. The residue contains very abundant pyrite and pyrite tubes, minor amounts of calcite, quartz, muscovite, lignite, hematite, goethite or limonite and glauconite are present. The residue also contains a red-brown resinous material. Outcrop samples are similar to the upper levels of the borehole material. Ninety-five to ninety-nine percent of the sample washes through the 63 micron mesh. The residues are similar and show diagenetic effects: i.e. pyrite framboids are altered to limonite or goethite as are some of the fossil casts. There are some pellets present, as well as, fiber strands, sphalerite and siderite.

The residue contains a varied microfossil fauna: holothurian debris and sponge spicules are present in the upper stratigraphic levels and pelecypods, echinoids and brachiopods are more common in the lower samples. The ostracoda are diverse. The lower Sinemurian samples have thirteen species and the lower Pliensbachian samples contain twelve species. The discovery of Acanthocythere faveolata, Cytheropteryina comica, Prognocythere levigata, and Camptocythere toarciana at this level is interesting, as they are reported from the Toarcian of the Lias and Bajocian and Bathonian of the Middle Jurassic. These species may have a broader stratigraphic range than previously reported by Bate (1978) or there may be some bridging in this core. If Prognocythere levigata is correctly identified and in place, it is important in that this species is found in the Upper Estuarine Series in the shallow or brackish water facies (Bate, 1978). Nine species of ostracoda are present in the Top of the Lias sample.

The microfauna in the residue of the Midlands samples is sparse. As previously noted diagenesis may have significantly altered these samples. Only sample KMP77-291 has microfossils other than arenaceous foraminifera. Undefined shelly fragments and pelecypod fragments are common. Yellow and amber pollen like ellipsoids and pyrite tubes and chitinous material are

conspicuous. Four species of ostracoda, two species of gastropods and scolecodent material complete the assemblage.

The foraminiferal biofacies at the Cocklepits has an arenaceous component which ranges from thirty to fifty percent of the total. The outcrop samples, in which a diagenetic factor is assumed, range from eighty to one hundred percent arenaceous foraminifera. Ammodiscus asper is an important constituent in all of the assemblages. Ammobaculites fontinensis is present in small numbers in thirty-three percent of the samples, and Ammobaculites sp. is rare and present in only one sample. Glomospira sp. is present in one sample, and it is rare. Haphlophragmoides sp. is conspicuous in all but the Frodingham ironstone samples and Haphlophragmoides subglobosus is present in more than fifty percent of the samples. Lagenammmina ampullacea, and Lagenammmina cf. L. difflugiformis, are present in thirty-three percent of the samples. Reophax dentalinaformis, Reophax metensis, and Reophax sp. are very rare, but present, occurring in only one or two samples. Trochammina gryci is an important constituent which occurs in all of the samples except the Frodingham Ironstone, and Trochammina sp. is present in one of the samples of this biofacies.

A calcareous component is very important in all but

two of the aforementioned outcrop samples. Lenticulina varians, Lingulina tenera, and Astacolus pauperatus are in all the samples which have a calcareous component and Dentalina pseudocommunis is in all but one. The remainder of the calcareous assemblage is variable and stratigraphic factors may account for some of the disparity.

Diversity and equitability of Biofacies Alpha-1 are variable, and because of recovery differences and possible diagenetic effects these statistics were not used in the environmental study of this biofacies.

Brouwer (1969) pointed out that ammonites and belemnites were conspicuously absent from the lithology in which these two species, Ammodiscus asper and Ammobaculites fontinensis, occur abundantly. Hallam (1978) stated that ammonites are prevalent in open marine conditions and scarce nearshore. He also states that the arenaceous foraminifera of simple structure, Ammobaculites, Ammodiscus, Hyperammina, and Reophax are characteristic of the marginal marine sediments which pass into coal measures. Hallam (1966,1978) suggested a shallow water, close to river deltas, origin for the ironstone facies. In the SEM and thin section study of the Frodingham Ironstones, oolites were found with foraminiferal, gastropod and ostracod nuclei, which

points to a shallow water environment within wave activity.

In the Recent, Walton (1964) in his study of the Gulf of Mexico found that a fauna of Ammoastuta, Trochammina, and Haplophragmoides is associated with the edges of marine marshes. In the Mississippi Delta, the Miliammina dominant zone had Ammoastuta, Trochammina and Ammobaculites with it, and the Ammobaculites dominant fauna was just seaward of it. Murray (1973) in his study of the Recent shows Ammobaculites ranges from hyposaline marshes and lagoons to inner shelf, and Reophax ranges from 0 to 150 meters. The Recent genus Saccammina, is morphologically similar to Lagenammina. Murray (1973) showed that Saccammina inhabits waters which range in depth from 0 to 100 meters. The genus Trochammina is separated into two groups: group one has a narrow environmental range of intertidal and marsh; while group two is much broader ranging to bathyal and abyssal depths (Murray, 1973). In a shelf traverse made off of Long Island, U.S.A., Ammodiscus siliceus, Reophax scotti, Saccammina atlantica, Trochammina lobata and Trochammina ochracea were noted most abundant in water depths of 40 to 60 meters (Murray 1973). The difficulty in applying the environmental preferences of recent foraminifera with any degree of certainty to the Liassic is that none of

the Liassic species have survived into the present. However, if the Liassic species behaved in a manner similar to their modern counterparts, then it is reasonable that Biofacies Alpha-1 is a biofacies with a very shallow, nearshore niche.

A comparison of the model with Hallam's (1978) and Vail's (1984) records of global sea level change and the sedimentary cycles supports the concept that Biofacies Alpha-1 is a shallow water biofacies. Both Hallam and Vail show shallowing cycles at the top of the Lias, (Figures 47, 48). Again in the P. Spinatum Zone both authors show shallowing episodes. The sample from Robin's Wood Hill from the upper A. margaritatus Zone may reflect the early stages of this shallowing or a local condition; it is suspect because there may be a preservation bias. The evidence is strong that Biofacies Alpha-1 is a very nearshore biofacies, even extending into the wave zone at times.

LIASSIC

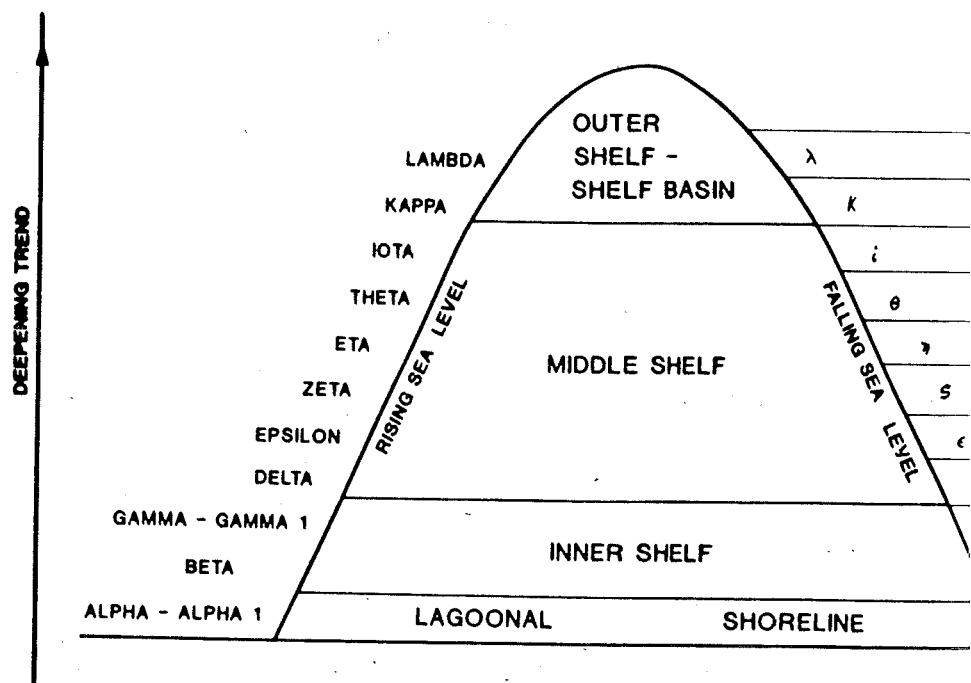
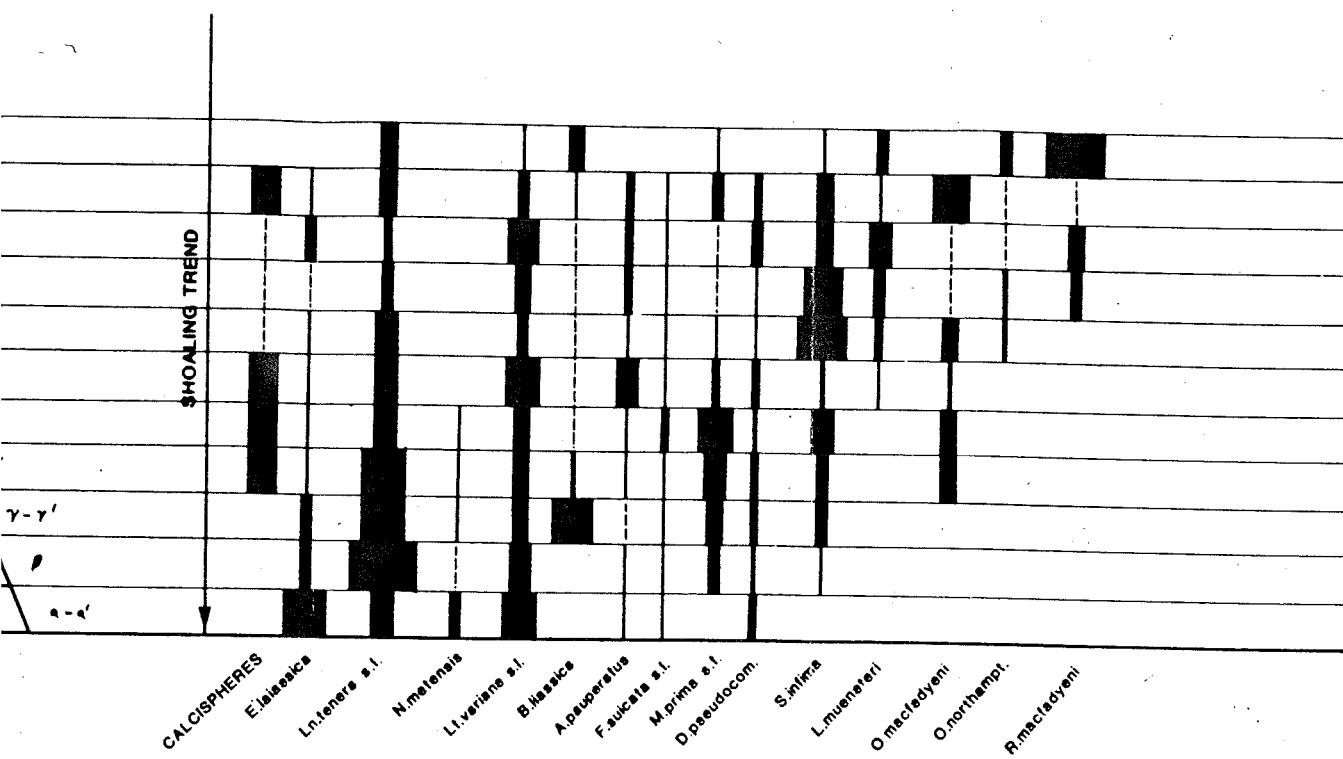


Figure 49.

PALEOSLOPE MODEL



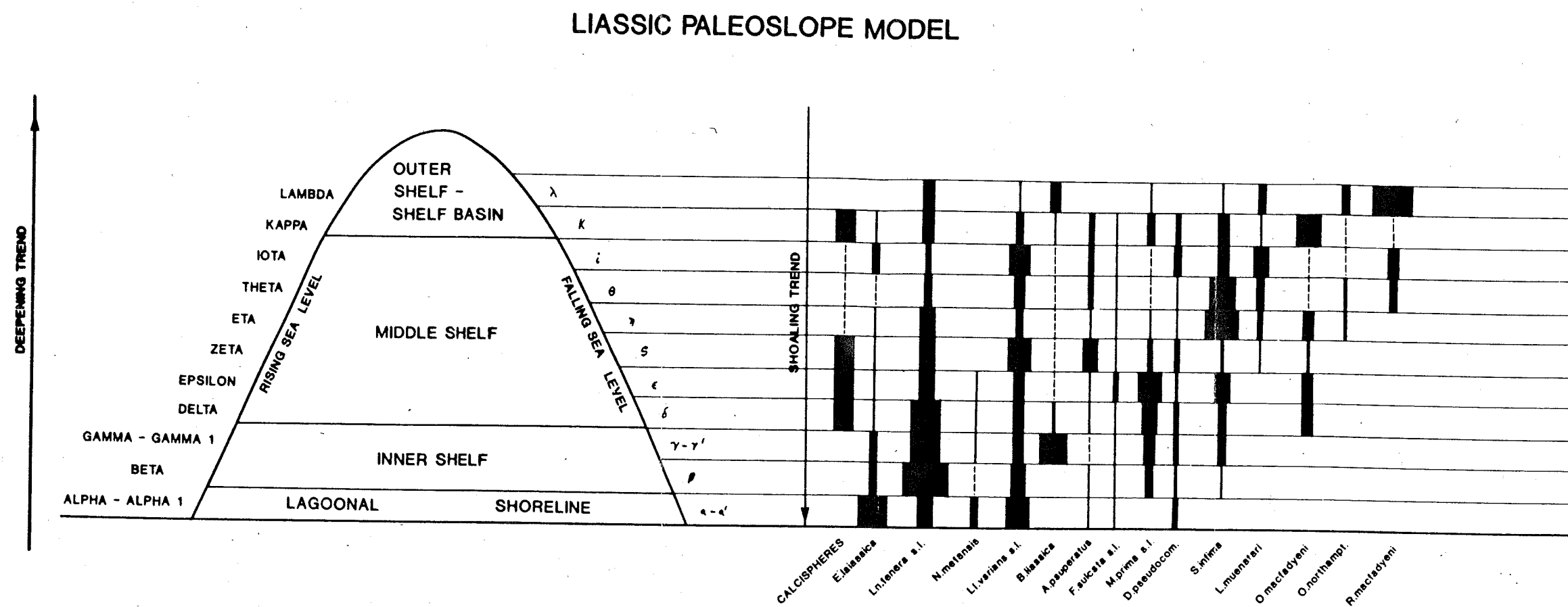


Figure 49.

ENVIRONMENT	FORAMINIFERAL BIOFACIES	DOMINANT SPECIES	AVERAGE PERCENT OF TOTAL	TYPE LOCALITY	CLUSTER FACTOR GROUP	OTHER LOCALITY WHERE BIOFACIES ARE PRESENT	CLUSTER FACTOR GROUP
RESTRICTED MARINE NEAR SHORE ADJACENT TO WAVE BASE INNER SHELF SHALLOW	ALPHA	<i>Eguttulina</i> <i>Nassella</i> <i>Lenticulina</i> <i>variosa</i> <i>Lingulina</i> <i>tenera</i> All other species = AOS		DORSET (HETLOS)	5	COCKLEPITS BOREHOLE	3
	ALPHA 1	<i>Arcaeoecus</i> <i>Foraminifera</i> Component <i>Lenticulina</i> <i>variosa</i> <i>Lingulina</i> <i>tenera</i>		COCKLEPITS BOREHOLE	1	YORKSHIRE	4
	BETA	<i>Lingulina</i> <i>tenera</i>		DORSET (HETLOS)	1		
	GAMMA	<i>Lingulina</i> <i>tenera</i> <i>Lenticulina</i> <i>variosa</i>		DORSET (HETLOS) (COMPOSITE)	3 7		
	GAMMA 1	<i>Brizalina</i> <i>Nassella</i> <i>Lingulina</i> <i>tenera</i>		STEEPLE ASTON BOREHOLE	4	COCKLEPITS BOREHOLE SAMPLE 40	~4
	DELTA	<i>Lingulina</i> <i>tenera</i>		STEEPLE ASTON BOREHOLE	2	COCKLEPITS BOREHOLE DORSET	

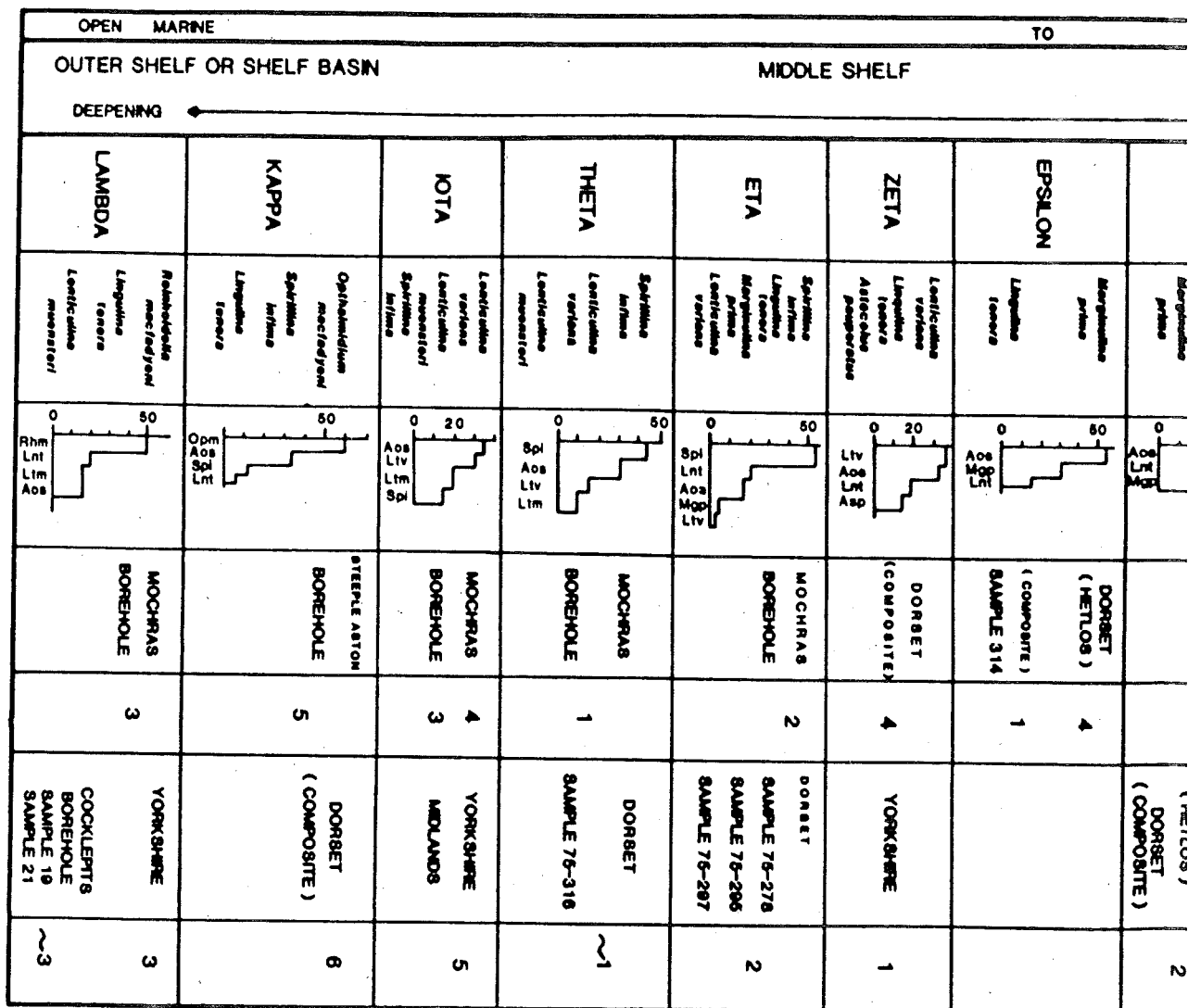


Figure 50. Liassic Paleoslope Model with the type localities and the Q-mode cluster-factor groups.

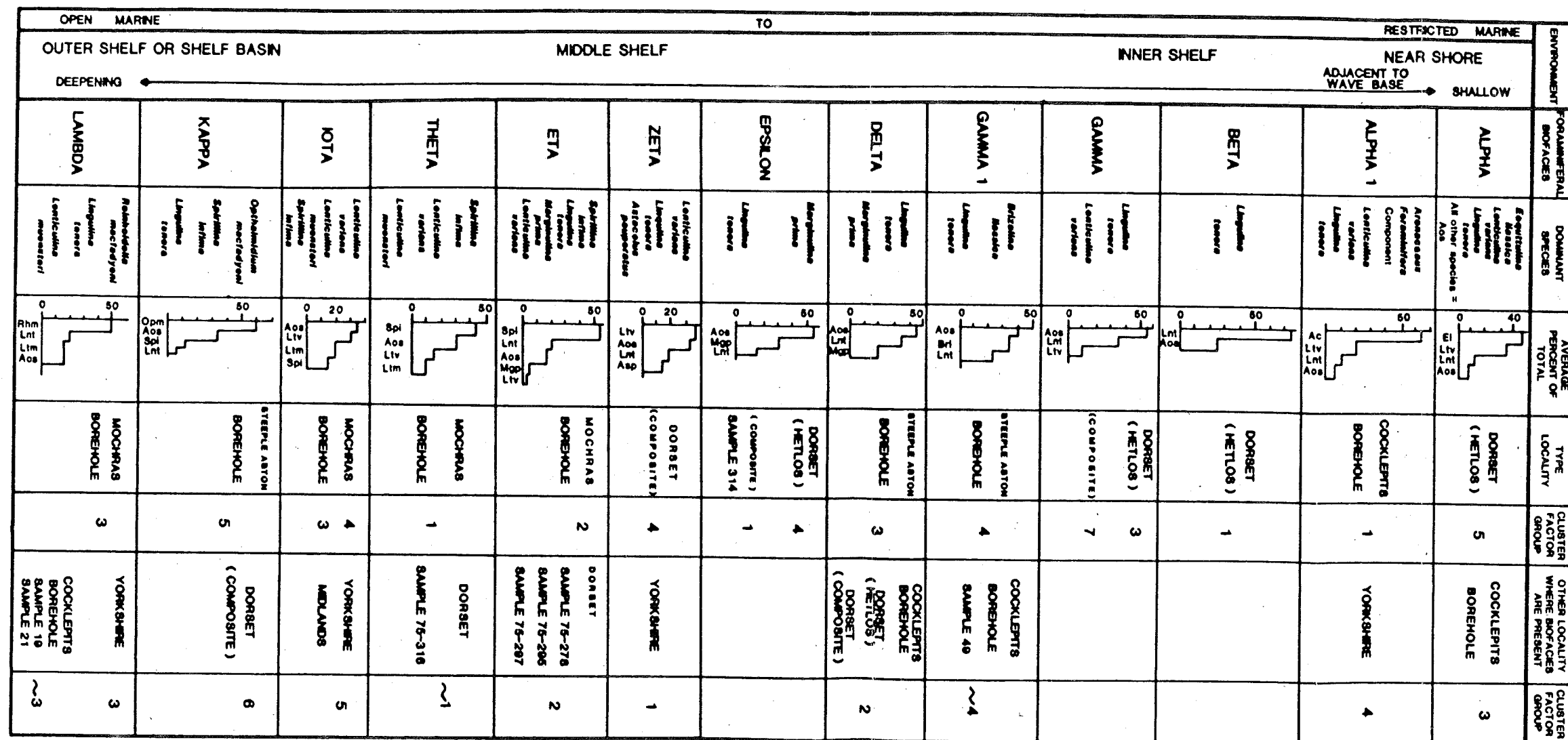


Figure 50. Liassic Paleoslope Model with the type localities and the Q-mode cluster-factor groups.

Summary

In the Liassic, 174-205Ma, a series of marine transgressions took place in northwestern Europe, creating epicontinental seas and emergent massifs. In these seas evolutionary radiation and subsequent provincialism of foraminifera took place. Q-mode cluster and factor analysis of the foraminiferal assemblages in the Liassic have identified 13 groupings which are taken to represent biofacies.

Biofacies Alpha and Biofacies Alpha 1 are very nearshore biofacies ranging from perhaps lagoonal assemblages to near beach front assemblages within the influence of wave action. They are present in the lower Lias at both Dorset and Yorkshire, and they are most common in the Hettangian Stage. Biofacies Alpha is a calcareous assemblage dominated by Eoguttulina liassica, Lenticulina varians and Lingulina tenera. Brouwer (1969) believed that assemblages with abundant Eoguttulina liassica occupied lagoonal environments or very shallow seas, a few meters in depth. Biofacies Alpha is also diverse in other species of Eoguttulina. Although Eoguttulina is an accessory in almost all other biofacies in the Liassic, it is not a dominant form. Very few ammonites and ostracoda are associated with this biofacies which supports an interpretation which favors a

very near shore environment (Hallam, 1967). Also, the benthic foraminiferal assemblages are variable; substantial differences in percentage of composition exist, and this too can be regarded as characteristic of environments where physical and biological parameters can be quite variable, (e.g. salinity, temperature, sediment influx and trophic resources). Alternately, the variability of assemblages in Biofacies Alpha may be due to the great evolutionary radiation which took place in the Hettangian. The occurrence and distribution of Biofacies Alpha is consistent with the published global sea level curves (Hallam 1978, Haq et al. 1987 and Vail et al. 1984) for the Jurassic which show that sea level was at its lowest stand in the Hettangian (Fig. 47 and 48).

Biofacies Alpha 1, a nearshore assemblage dominated by arenaceous foraminifera, is associated with iron rich sediments and indurated ironstones. This biofacies occurs sporadically in the Cocklepits Borehole, Humberside, Yorkshire and in the upper Lias Scissum Beds of the Hook Norton Railway Cutting. Biofacies Alpha 1 is characterized by oolites which are conspicuously nucleated on the foraminifera and associated microfauna (plate 2 figs. 12, 16). This suggests that this biofacies occupied a wave-dominated, nearshore environment. The genera Ammobaculites, Ammodiscus, Haplophragmoides, Lagenammina, and Trochammina together

account for an average of 55-60 percent of the total assemblage. Lingulina tenera and Lenticulina varians, accounting for an average of 33 percent of the total, are the important calcareous species. Biofacies Alpha 1 and the associated ironstone facies most probably occupied nearshore environments adjacent to Biofacies Alpha. Hallam (1967) also suggested a shallow water origin for the ironstone facies. Biofacies Alpha 1 is associated with the lowering and early rise in the Toarcian on the sea level records of Hallam (1978) and Vail et al. (1984). Alpha 1 is present at Yorkshire in the P. davoei zone. Hallam (1978) shows shoaling sedimentary sequences at Yorkshire in this interval.

Biofacies Beta is dominated by the species Lingulina tenera which averages 75 percent of the total assemblage. The abundance trend of Lingulina tenera reaches its apex in Biofacies Beta (Fig. 49). In biofacies occupying deeper water environments the abundance of L. tenera generally declines even though the species continues to be an important constituent. The abundance trend suggests the environment of Biofacies Beta is optimum for this species. The other important species in Biofacies Beta are Lenticulina varians, Eoguttulina liassica, and Vaginulina triquetra. Ammonites and ostracoda, which are more abundant in this biofacies than in Biofacies Alpha, indicate a farther off shore environment than either Alpha or Alpha 1.

Biofacies Beta is most common in the Hettangian and lower Sinemurian and is most often present in the sedimentary sequences which Hallam (1978) regarded as indicative of shoaling and which Vail et al. (1984) and Haq et al. (1987) show as low stands of sealevel on their cycle chart (Figs. 47 and 48).

Biofacies Gamma is a transitional biofacies between Biofacies Beta and the more open marine Biofacies Delta. Lingulina tenera is not as abundant as in Biofacies Beta, averaging 35 percent of the total assemblage. Lenticulina varians averages 10 percent of the total assemblage. Diversity is greater in Biofacies Gamma than in the nearer shore biofacies (Alpha to Beta). More ammonite and ostracod species are also present. Biofacies Gamma is found in transgressive beds in the lower Hettangian. In a faunal succession interpreted here as a shoaling succession in the Dorset lower Sinemurian (Fig. 27), it occurs between Biofacies Epsilon (open marine) and Biofacies Beta (near shore) (Figs. 27 , 49). Biofacies Gamma is also present in a transgressive sequence at the top of the C. turneri Zone at Dorset above Beta (near shore, shallow) and below Delta (open marine). It subsequently reappears above Biofacies Delta and, in turn , is replaced by Biofacies Beta (Figs. 27,49). This is interpreted here as brief cycle occurring in an intermediate phase of Hallam's

shoaling sequence at Dorset. Biofacies Gamma, in addition, occurs at the base of the A. margaritatus zone at Dorset, where it is associated with Biofacies Delta, an open marine biofacies. Hallam's sedimentary sequences show a general deepening trend associated with this zone. The sea level records of Hallam (1978), Haq et al. (1987), and Vail et al. (1984) show a rise in the lower middle Lias followed by an abrupt fall in the upper middle Lias. The distribution of Biofacies Gamma is consistent with these interpretations.

Biofacies Gamma 1 is observed only in the T. ibex Zone in the Steeple Aston Borehole. It is dominated by Brizalina liassica, which averages 45 percent of the assemblage. Lingulina tenera is the secondary species, averaging 28 percent of the total, and Astacolus, Dentalina, Lenticulina and Marginulina are common constituents. As the percentage composition, other than the species Brizalina liassica, is similar to Biofacies Gamma at Dorset the environment occupied by the biofacies is regarded as similar to that of Gamma. Fewer ammonites and belemnites occur in this section than in the other Liassic sections of this borehole (Poole, 1977). Calcispheres which are regarded here as indicative of open marine conditions are absent. Also there is conspicuous ferric hydroxide in the residue which is not present in the residues of the other biofacies of this

core, Hallam (1966, 1975) suggested a shallow environment for the ironstone facies. For these reasons Biofacies Gamma 1 is regarded as a nearshore biofacies. At the Moray Firth northeast of this area in the lower-middle Pliensbachian, Vail et al. (1984) showed a shift in environment from open marine to deltaic conditions. At Dorset and at Yorkshire the Hallam sedimentary sequences in the top of the lower Pliensbachian are shoaling sequences. The Hallam curve for sea level rise showed a lowering in the middle Pliensbachian. The occurrence and distribution of Biofacies Gamma 1 is consistent with this sea level record, with the interpretation of the sedimentary sequences and with the shift of environmental conditions in the northeast.

Biofacies Delta is the most common and widespread of the Liassic biofacies. It is dominated by Lingulina tenera and Marginulina prima which average 60 percent of the total assemblage. The percentage of L. tenera remains approximately the same as in Biofacies Gamma, as does the percentage of Lenticulina varians. However, the increase in the percentage of M. prima from an average of 7 to 10 percent in Biofacies Gamma to an average of 20 percent is the significant difference (Fig. 49). Calcispheres are present as well as a large number of ammonite genera. In addition numerous belemnites and ostracoda occur. Together this is indicative of a deeper and/or more open marine environment than is indicated by

Biofacies Gamma. At Dorset in the Sinemurian, Biofacies Delta occurs in all three of the sea level cycles shown on the Hallam (1978) curve where it, in general, corresponds to intermediate stands of sea level. There is similar correspondence to Hallam's curve for the Steeple Aston Sinemurian section (Fig. 47). In the lower Pliensbachian at Dorset, Steeple Aston and Yorkshire Biofacies Delta is also associated with intermediate stands of sea level on the Hallam curve. Thus, Biofacies Delta probably occupied a marginal open marine environment between the inner and middle shelf.

Biofacies Epsilon is an assemblage which is very closely linked to Biofacies Delta. Biofacies Epsilon is dominated by Lingulina tenera and Marginulina prima, except that M. prima averages about 30 percent of the total whereas L. tenera averages 15-20 percent (Fig. 49). Foraminiferal diversity is high. The accessory fauna consists of abundant ammonites, belemnites, and ostracoda. Calcispheres are common. Biofacies Epsilon is interpreted as an open marine biofacies. At Dorset biofacies Epsilon is most frequently associated with Hallam's deepening sedimentary sequences and with the deepening trends on the sea level curve of Vail et al. (1984). The bulk of the evidence supports the conclusion that Biofacies Epsilon is an open water transitional biofacies which occupied inner to middle shelf environments. The environment of deposition of

Biofacies Epsilon is similar to that of Biofacies Delta except that it was probably deeper.

Lenticulina varians (averaging 35 percent of the total), Lingulina tenera (averaging 15-19 percent), and Astacolus pauperatus (averaging 15 percent) are the dominant species of Biofacies Zeta (Fig. 49).

Marginulina prima is less common than in Biofacies Epsilon. This biofacies is notable in outcrops at Dorset and Yorkshire. In the Dorset faunal succession this biofacies frequently occurs between Biofacies Kappa (deep water) and Biofacies Epsilon (inner to middle shelf, Fig. 35) and at Yorkshire Biofacies Zeta is associated with Biofacies Lambda (outer shelf or shelf basin, Fig. 42). At Dorset the biofacies occurs in beds which have rich assemblages of ammonites, belemnites, brachiopods, ostracods, and pelecypods. Calcispheres are also present. In the lower Pliensbachian at Dorset, Biofacies Zeta is associated with sedimentary sequences regarded by Hallam (1978) as deepening and at Yorkshire Biofacies Zeta is present at the top of the Pliensbachian which Hallam (1978) and Vail et al. (1984) show as recessive. At Yorkshire Biofacies Zeta is part of a faunal succession which appears in a recessive cycle (Figs. 42, 49); in the stratigraphic succession Biofacies Zeta (middle shelf) occurs above Biofacies Lambda (a deep water biofacies). A similar assemblage, Zeta 1, which is very likely a transitional assemblage,

rests on top of these, and subsequently, Biofacies Lambda replaces Zeta 1 at the Pliensbachian/Toarcian Boundary. The presence of a slightly different assemblage than Zeta (Zeta 1) may be indicative that sea level was rising during deposition of the upper part of the P. spinatum Zone. Haq et al. (1987) show that the transgression generally considered to have begun at the base of D. levesquei zone of the upper Lias began earlier in the top of the P. spinatum zone.

Spirillina infima and Lingulina tenera characterize biofacies Eta, ranging from 65 to 85 percent of the total assemblage. This biofacies pervades the Middle Lias of the Mochras Borehole. Similar assemblages occur at Dorset where they appear as isolates. An abundant brachiopod and belemnite fauna occur in coeval beds at the Midlands (Hallam, 1967). Four ammonite genera occur in this section in the Mochras Borehole (Imvey-Cook, 1971). Good conditions of circulation are suggested by the general lack of pyrite. There is little change in the proportion of foraminiferal species in this assemblage in the Mochras Borehole which suggests that middle Liassic conditions did not fluctuate as they did at Dorset, Yorkshire, and Steeple Aston where various biofacies are present. The Vail and Hallam curves show a rising trend in the A. margaritatus Zone which is followed by a shallowing in the P. spinatum Zone. The foraminiferal fauna in this locale does not appear to

have altered in response to this rise and fall of sea level.

Biofacies Eta also appears in a faunal succession in the Dorset section in the upper Sinemurian. In this section a transgressive trend is indicated by the upward replacement of Biofacies Eta (middle shelf environment) by Biofacies Kappa (outer-middle shelf environment). Above this a recessive trend is indicated by the successive replacement of Biofacies Eta by Biofacies Epsilon and subsequently Biofacies Delta (Figs. 27, 49). This interpretation is consistent with sea level curves of Hallam (1978) and Vail et al. (1984) which show a deepening at this time followed by a subsequent shoaling.

The dominance of Spirillina infima continues in Biofacies Theta, but the abundance declines to an average of 45 percent of the total. The abundance of Lingulina tenera drops significantly to an average of 5 percent, while the abundance of Lenticulina varians increases to an average of 17 percent. Lenticulina muensteri becomes the third most abundant species with an average of 7 percent of the total. Astacolus pauperatus is common. This biofacies has a higher diversity and equitability than Biofacies Eta and is thus placed in a middle shelf environment seaward of Biofacies Eta. The presence of 12 ammonite genera in this section of the core (Imvey-Cook, 1971) adds support to this interpretation. Both sea

level curves (Hallam, 1978 and Vail et al. 1984) indicate recessive cycles at the top of the Toarcian. Biofacies Theta alternates with Biofacies Iota, a deeper water biofacies, in the middle Toarcian of the Mochras Borehole and subsequently becomes the only biofacies present in the top of the Toarcian there (Figs. 47,48). This succession is indicative of a shallowing upward sequence (Fig.49).

The percentage of L. muensteri and L. varians increases while that of S. infima decreases when Biofacies Iota is compared with biofacies Theta (Fig. 49). Diversity and equitability are higher in Biofacies Iota than in Biofacies Theta. Ten ammonite genera are present in the middle to upper Toarcian sections of the Mochras core where this biofacies occurs (Woodland, 1971). Brouwer (1969) believed that the L. muensteri assemblage was from a deep water environment. Biofacies Iota marks the apex of the middle to upper Toarcian sea level rise (Figs. 47,48,49). Iota's subsequent replacement by Theta in the Upper Toarcian section of the Mochras core marks the return to shallower middle shelf conditions and shoaling which took place at the top of the Toarcian and the bottom of the Aalenian (Hallam, 1978, Vail et al. 1984).

Opthalmidium macfadyeni dominates Biofacies Kappa which is prominent in the Dorset and Steeple Aston sections. Calcispheres are present in this biofacies.

At Dorset a rich ammonite assemblage of thirty seven species and forms are associated with Biofacies Kappa. Together with the ammonites are diverse belemnites (seventeen species), and diverse brachiopods, pelecypods, and gastropods (Lang, 1928,1936). The deposit feeding pelecypods and the pelecypod Lucinola, which are found in the Dorset beds, are regarded by Hallam (1975) as indicators of deep water. Thus the associated invertebrate faunal evidence suggests a deep water environment for this biofacies. Comparison with the sea level curves show that this biofacies is generally present during sea level rises except at Dorset. The lack of agreement at Dorset in the P. davoei zone may mean that the shoaling came later, because Lang (1936) identified a rich ammonite and belemnite fauna in beds 125 and 126 (Samples KMP 75-317 and KMP 75-319). Biofacies Kappa is regarded as indicative of outer shelf or deep shelf basin environments.

Biofacies Lambda is the deepest water or most outer shelf foraminiferal biofacies of the Liassic of Britain. This biofacies is completely dominated by Reinholdella macfadyeni which is at its apex of abundance in this biofacies (Fig. 49). It declines in abundance in the shallower depth and more shoreward biofacies (Fig. 49). This species is thick walled, heavily ornamented, and has a massive umbilical plug, (Pl. 9). Coarse ornamentation is one of the features in Recent

foraminifera which is associated with depth (Bandy, 1964). The biofacies is present at the base of the Toarcian in both the Cocklepits and the Mochras Boreholes. Biofacies Lambda occurs in mudstones rich in pyrite and organics which is suggestive of poor circulation. Hallam (1975) states that the regression in the P. spinatum Zone was followed by a transgression which was accompanied by stagnation. Johnson (1976) found that assemblages dominated by the genus Reinholdella had low diversity and he attributed this low diversity to poor circulation in a shelf basin or on the outer shelf. He believed that these assemblages were deep water assemblages. The low diversity in some of the Biofacies Lambda samples is interpreted here as the result of the Toarcian stagnation or oxygen minimum conditions. Seven ammonite genera and abundant belemnites are associated with this biofacies in the Mochras section (Imvey-Cook, 1971) further supporting a deep water environment for this biofacies. Both the Vail et al. (1984) and the Hallam (1978) curves show transgressive trends in the lower Toarcian which correlates well with the interpretation of Biofacies Lambda as an outer shelf and/or shelf basin assemblage.

The paleoslope model of Liassic foraminiferal biofacies should be tested on the yet undescribed Liassic foraminiferal assemblages of Raasay, Skye. Too few samples from Raasay were available for this study to

allow accurate numerical analysis; however, the few which were studied reveal a rich foraminiferal assemblage. Another suitable area to test this model would be the Liassic marine sections of the North American continent.

Further study should be done which compares the foraminiferal paleoecology with that of the ostracoda since and the ostracoda are also abundant in the British Lias and they are well preserved and distinctive. Published work on Liassic ostracod paleoecology is scarce.

CHECK LIST OF LIASSIC SPECIES

The following check list of species contains the most typical drawings and current scanning electron micrographs of the species of Liassic foraminifera encountered in this study. It is not intended to be a complete synonymy but rather to cover the morphologic variations seen in the species .

Suborder: Textularina Delage and Herouard, 1896.

Family: Ammodiscidae Reuss, 1862.

Ammodiscus asper Terquem, 1863. (Pl. 2, fig. 1)

Ammodiscus asper (Terquem) Barnard, 1950, fig.1a,i,ii.

Ammodiscus asper (Terquem) ERICO Inc., 1974, pl.8.3 sp.15.

Ammodiscus asper (Terquem) Horton & Coleman, 1977, pl.2,fig.8.

Ammodiscus asper (Terquem) Exton, 1979, pl.4,fig.2.

This species is one of the most important species of Biofacies Alpha-1. It ranges throughout the Lias, but it occurs both in large size and numbers in Biofacies Alpha-1.

Ammodiscus siliceus Terquem, 1862. (Pl. 7, fig. 20)

Ammodiscus siliceus (Terquem)

Brouwer, 1969, pl.1, fig.10, 11.

Ammodiscus siliceus (Terquem) Exton, 1979, pl.4,fig.3.

The spiral suture is distinct in this species so that a white spiral line is readily detected.

Ammovertella liassica Barnard, 1950. (Pl. 7, fig. 25)

Ammovertella liassica Barnard, 1950, fig.1c.

This adherent species readily distinguished from *Tolypammina flagellum* by the copious white, lustrous cement of the chamber wall (Barnard, 1950). All of the specimens observed in this study do not demonstrates *Tolypammina flagellum*'s tendency to branch. Often the test becomes separated from the surface to which it has been adhered and the tube, after the coil portion of the test, breaks off.

Glomospira perplexa Franke, 1936. (Pl.2 fig. 13; Pl.5. fig.8)

Glomospira perplexa Franke, 1936, pl.1, fig.12.
Glomospira perplexa (Franke) Brouwer, 1969, pl.1, figs.16,17.

Glomospira perplexa demonstrates complex streptospiral coiling. The species is not one of the Ammodiscus referred to by Barnard, which is simply reversing its coiling direction. The coiling pattern of G. perplexa is more intricate than Glomospira described by Brady (1884) from the Recent and by Exton (1979) from the Pliensbachian of Zambujal, Portugal. This species is rare in the areas of this study, occurring in the Hildoceras bifrons Zone of the Mochras Borehole and Prodactylioceras davoei Zone of the Cockle pits Borehole.

Tolypammina flagellum Terquem, 1870. (Pl. 7, fig. 21)

Webbina flagellum Terquem, 1870, pl.20, fig.30.
Tolypammina flagellum (Terquem) Macfadyen, 1941, pl.1, fig.8.
Tolypammina flagellum (Terquem) Barnard, 1950, fig.1b.

Family: Astrorhizidae Brady, 1881.

Bathysyphon M.Sars in G.O. Sars, 1872. (Pl. 9, fig. 11)

Bathysyphon sp. (?)

The elongated tubes are common in the residue of the samples of the Mochras Borehole; however, they are generally fragmented. It is possible on many to note a constriction. The test wall is made of fine grain silty material.

Jaculella liassica Bartenstein & Brand, 1937.

Jaculella liassica Bartenstein & Brand, 1937, pl.2b, fig.1, pl.3, fig.4a,b.

Thin tapering arenaceous fine grained tubes present in one sample from Steeple Aston Bore in the Prodactylioceras davoei Zone and one sample of the Mochras Borehole in the Dumortieria levesquei Zone. Bartenstein and Brand show a range throughout the Lias. These tapering tubes are conspicuous in both samples but impossible to count because of the fragmentation.

Rhizammina Brady, 1879.

Rhizammina sp. (?)

This species is a fine grained, arenaceous tube with bifurcations. As many of the specimens are but fragments, it is difficult to describe this species further from the material at hand.

Family: Ataxophragmiidae Schwager, 1877.

Verneuillinoides mauritii Terquem, 1866. (Pl. 8, fig. 16,17)

Verneuillinoides mauritii (Terquem) Brouwer, 1969,
pl.2, fig.2-4.

Verneuillinoides mauritii (Terquem) Exton, 1979,
pl.1, fig.4.

Verneuillinoides mauritii (Terquem) Copestake &
Johnson, 1981, pl.6.1.1, fig.5,6,10.

This species ranges from the Upper Sinemurian through the Lower Pliensbachian, (Copestake and Johnson). This species is rare.

Family: Hormosidae Haeckel 1894.

Reophax complanata Franke, 1936.

Reophax complanata Franke, 1936, pl.1, fig.23.

The impressed central portion of the chambers are characteristic of this large species of Reophax. This is a very fragile species and its rarity is likely due to diagenesis or sample processing.

Reophax dentalinaformis Brady, 1884. (Pl. 2, figs. 12,18)

Reophax dentalinaformis Brady, 1884, pl.30, fig.21,22.

Reophax dentalinaformis (Brady) n.f. liassica Franke,
1936, pl.1, fig.20,21.

Reophax dentalinaformis (Brady) Bartenstein & Brand,
1937, pl.1a, fig.4, pl.1b, fig.4-13.

The apertural necks on the specimens recovered were very short or nonexistent. This could be the result of abrasion. It is doubtful that the Liassic species persists to the Recent.

Reophax metensis Franke 1936. (Pl. 7, fig. 19)

Reophax metensis Franke 1936, pl.1, fig.17.
Reophax metensis (Franke) Bartenstein & Brand, 1937,
 pl.10, fig.8.

Reophax sp. (Pl. 7, figs. 17,18)

Family: Lituolidae Lamarck, 1809.

Ammobaculites fontinensis Terquem, 1870. (Pl. 5, figs. 1,2)

Ammobaculites fontinensis (Terquem) Barnard, 1950a,
 pl.1, figs.1,2.
Ammobaculites fontinensis (Terquem) Brouwer, 1969,
 pl.1, figs.1,2,3.
Ammobaculites fontinensis (Terquem) Horton & Coleman,
 1977, pl.2, fig.5.
Ammobaculites fontinensis (Terquem) Exton, 1979,
 pl.8, fig.2.

Ammobaculites vetustus Terquem & Berthelin, 1875.

Ammobaculites vetustus (Terquem & Berthelin) Brouwer,
 1969, pl.1, figs.4,5.
Ammobaculites vetustus (Terquem & Berthelin) Horton &
 Coleman, 1977, pl.2, fig.6.

Haphlophragmoides subglobosus G.O.Sars, 1812. (Pl.2, fig.10)

Haphlophragmoides subglobosus (G.O.Sars) Bartenstein &
 Brand, 1937, pl.4, fig.12.

The grey color, impressed sutures, and nearly globular chambers are characteristic of the species at Dorset. The first appearance at Dorset is in the C. turneri Zone. In the Cocklepits Borehole, it first appears in the U. jamsoni Zone. It is an important accessory species in Biofacies Alpha-1.

Haphlophragmoides sp. Bartenstein & Brand, 1937. (Pl. 2, fig. 9)

Haphlophragmoides sp. Bartenstein & Brand, 1937,
 pl.1, fig.20a, 20b.

Family: Saccamminidae Brady, 1884.

Lagenammina sp. cf. *Lagenammina ampullacea* Brady, 1884.
(Pl. fig.15)

Reophax ampullacea Brady, 1884, pl.30.fig.6.

Proteonina ampullacea (Brady) Franke, 1936,
pl.1,fig.7.

Proteonina sp. ERICO Inc., 1974, pl.8, sp.1 non 2.

Lagenammina jurassica (Barnard) Exton, 1979,
pl.4,fig.1.

Moore (1964) places Proteonina in the genus Lagenammina. It is very doubtful that this is the identical species that Brady describes. His species was described from a station in the South Pacific, 1491, at 120 fathoms. The species in this study is flask shaped, flattened, unilocular and has a circular aperture on a neck. The walls are very fine grained. The species is a minor constituent of Biofacies Alpha-1 of the Cocklepit Borehole.

Lagenammina sp.cf. *Lagenammina difflugiformis* Brady, 1884. (Pl. 2, fig. 14)

Reophax difflugiformis Brady, 1884, pl.30,fig.3 only.

Brady's species originates in the South Atlantic from station 323 at 1900 fathoms. The Liassic species is unilocular, ellipsoidal with a circular aperture on the neck. The species is found in association with Lagenammina sp. cf. Lagenammina ampullacea. The possibility exists that the later species is produced by a post-mortem compression of the test due to sediment compaction. The species is a minor constituent of the Biofacies Alpha-1 of the Cocklepit Borehole.

Thurammina jurensis Franke, 1936. (Pl. 5, fig. 22)

Thurammina jurensis Franke, 1936, pl.1,fig.8.

Thurammina jurensis (Franke) Exton, 1979, pl.8.,fig.1.

Thurammina jurensis (Franke) Cokestake & Johnson,
1981, pl.6.1.1,fig.1.

Family: Trochamminidae Schwager 1877.

Trochammina gryci Tappan, 1955. (Pl. 7, fig. 22)

Trochammina nana form A, Bartenstein & Brand, 1937,
pl.2b, fig.40a,b.

Trochammina gryci (Tappan) Brouwer, 1969,
pl.1, figs.24,25.

Trochammina topagorukensis Tappan, 1955. (Pl. 7, figs. 23,24)

Trochammina topagorukensis (Tappan) Brouwer, 1969,
Trochammina topagorukensis (Tappan) Horton & Coleman,
1977, pl.2, figs.9,10.

Suborder: Miliolina Delage and Herouard, 1896.

Family: Fischerinidae Millet, 1898.

Carixia langi Macfadyen, 1941. (Pl. 4, figs. 3,4)

Carixia langi Macfadyen, 1941, pl.1, figs. 18,19,20.

Carixia langi (Macfadyen) Moore, 1964, fig. 337,1.

Carixia langi (Macfadyen) Copestake & Johnson, 1981,
pl.6.1.1, fig.2.

This is a conspicuous foraminiferal species which is known by the cross-hatch pattern etched in the surface to which it adhered (Macfadyen, 1941). Copestake and Johnson (1981) have recovered specimens with the calcareous tubes. In this study the tubes were largely absent. The tubes were, in some instances, replaced by glauconite and pyrite.

Family: Nubeculariidae Jones, 1875.

Nubeculinella tibia Jones & Parker. (Pl. 9, fig. 15)

Nubeculinella tibia (Jones & Parker) Copestake &
Johnson, 1981, pl.6.1.1, fig.14.

Opthalmidium carinata Kubler & Zwingli, 1866. (Pl.9, fig.1)

Opthalmidium carinata (Kubler & Zwingli) Macfadyen, 1941, pl. 1, fig. 12.

Opthalmidium carinata (Kubler & Zwingli) Brouwer, 1969, pl. 2, fig. 8.

Wood and Barnard (1945) included some of Macfadyen's specimens of this species in their O. macfadyeni. In this study the specimens of this species have a pronounced carinate margin.

Opthalmidium macfadyeni Wood & Barnard, 1945. (Pl. 9, figs.2,3)

Opthalmidium macfadyeni Wood & Barnard, 1945, pl. 9, figs. a-g.

This species dominates Biofacies Kappa.

Opthalmidium orbiculare Burbach (Pl. 8, figs. 28,29)

Opthalmidium orbiculare Brouwer, 1969, pl. II, figs. 9,10.

Opthalmidium northamptonensis Wood & Barnard, 1945. (Pl. 8, fig. 27; Pl. 9, fig. 9)

Opthalmidium northamptonensis Wood & Barnard, 1945, pl. 8, figs. a-g.

Opthalmidium sp. (sp. nov.?) (Pl. 9, figs. 4-7)

In the Uptonia jamesoni Zone of the Steeple Aston Bore, a species of Opthalmidium is present which may be a variation of O. macfadyeni as it is similar to it in all ways except there are very fine raised costae on the test surface.

'Spiroloculina' sp. A. Copestake & Johnson, 1981. (Pl.7, fig.11)

'Spiroloculina' sp. A. Copestake & Johnson, 1981, pl. 6.1.1, figs. 9,12,13.

'Spiroloculina' sp. B. Copestake & Johnson, 1981. (Pl. 7, figs. 12,13)

'Spiroloculina' sp. B. Copestake & Johnson, 1981, pl. 6.1.1, figs. 8,11.

Suborder: Rotaliina Delage & Herouard, 1896.

Family: Bolivinitidae Cushman, 1927.

Brizalina liassica Terquem, 1958. (Pl. 3, figs. 23,24,25)

Brizalina liassica (Terquem) Brouwer, 1969, pl. 7,
figs. 20-27.

Brizalina liassica (Terquem) Exton, 1979, pl. 3, fig.
14.

Brizalina liassica (Terquem) Copestake & Johnson,
1981, pl. 6.1.5, fig. 17.

This species is the primary constituent of Biofacies Gamma 1 from the T. ibex Zone of the Steeple Aston Bore Hole. At Dorset its range is from the T. ibex Zone to the A. margaritatus Zone; however, it is not nearly as abundant. It is abundant in Yorkshire in the Cocklepits Bore Hole in the U. jamesoni zone and again in the D. tenuicostatum Zone.

Brizalina sp. (sp. nov.?) (Pl. 7, fig. 6)

A small thin walled test of five to six chambers arranged in a brizalina manner after an oblong proloculus, this species is much smaller than B. liassica. The test outline remains narrow, and subparallel; whereas the test outline of B. liassica expands rapidly after the first few chambers.

Family: Ceratobuliminidae Cushman, 1927.

Conorboides sp. (Pl. 6, figs. 27,28)

?Conorboides sp. Brouwer, 1969, pl. 7, figs. 31,32.

Conorboides sp. 1 Horton & Coleman, 1977, pl. 2,
figs. 13,14.

Reinholdella (?) planiconvexa (Fuchs) Copestake
& Johnson, 1981, pl. 6.1.5, figs., 12,16.

This species has a conspicuous, open umbilicus. It is an important species in the Lower Lias of the Cocklepits Borehole.

Reinholdella macfadyeni (Ten Dam 1947) emend. Hofker, 1952. (Pl. 9, figs. 20-23)

Reinholdella macfadyeni (Ten Dam), Brouwer, 1969, pl. 8, figs. 3-7.

Reinholdella macfadyeni (Ten Dam), Horton & Coleman, 1977, pl. 3, figs., 1,2,3.

Reinholdella macfadyeni (Ten Dam), Copestake & Johnson, 1981, pl. 6.1.5, fig. 7.

This species dominates Biofacies Lambda. The species is prominent in the *D. tenuicostatum* Zone of the Upper Lias of the Mochras Bore Hole and the Cocklepits Bore Hole. It is the only species of abundance recovered in the biased assemblages of the Upper Lias of the Steeple Aston Bore Hole.

Reinholdella margarita Terquem.

Reinholdella margarita Terquem, Copestake & Johnson, 1981, .1.5, fig. 13.

Reinholdella pachyderma subsp. A. (Pl. 6, figs. 29-31)

Reinholdella pachyderma subsp. A Copestake & Johnson, 1981, pl. 6.1.5, fig. 10.

Family: Glandulinidae Reuss, 1860.

Tristix liasina Berthelin, 1879. (Pl. 9, fig.14)

Tristix liasina (Berthelin) Macfadyen, 1941, pl. 4,
figs. 56a,b.

Tristix liasina (Berthelin) Moore, 1964, fig. 421, 6.

Tristix liasina (Berthelin) Horton & Coleman, 1977,
pl. 4, fig. 9.

Tristix liasina (Macfadyen 1941) Exton, 1979, pl. 15,
fig. 9.

Tristix liasina (Berthelin) Copestake & Johnson, 1981,
pl.6.1.4.pl.8.

Family: Involutinidae Butschli, 1880.

Involutina liassica Jones, 1853. (Pl. 2, fig.11;
Pl.5,fig.20)

Nummulites ? liassicus Jones, 1853.

Problematina c.f. liassica (Jones) Barnard, 1950, fig.
10 a.b.c.

Involutina liassica (Jones) Moore, 1962, fig. 605, 1,
2.

Involutina liassica (Jones) Brouwer, 1969, pl. 8,
figs. 8-10.

Involutina liassica (Jones) Gradstein, 1977, pl. 6,
fig.3.

Involutina liassica (Jones) Copestake & Johnson, 1981,
pl. 6.1.5, fig. 9.

This species is common in the Frodingham Ironstone of the Cocklepits Bore Hole samples, occurring in Biofacies Alpha-1. At Dorset this species is present from the *E. raricostatum* Zone through the *P. davoei* Zone in this study, where it is associated with Biofacies Delta in low abundance and in Biofacies Theta and Kappa in greater abundance. Barnard (1950) suggests that this may show *I. liassica*'s migration or that the two groups may be different species. If the groups are one species and migrated, then they have also adapted to a new niche in deeper water.

Family: Nodosariidae Ehrenberg, 1838.

Astacolus denticulata-carinata Franke, 1936. (Pl.7, figs. 1,2)

Cristellaria (Astacolus) denticulata-carinata Franke, 1936, pl. 9, fig. 38.

A robust species with a rectilinear portion following an initial coil, the teeth on the peripheral margin number from two to five on the average. They occur at the lower point of the ventral edge where the coiling ceases and the arcuate rectilinear portion commences. The species is present at Raasay in samples KMP75-401 from the Upper Broadford Beds of the semicostatum Zone, KMP75-399 from the Pabba Shales of the raricostatum Zone and KMP75-404 of the ibex zone. At Robinswood Hill the species is present in the ibex, davoei, and spinatum Zones. In Yorkshire in the Cocklepits Bore Hole, the species is conspicuous in the Upper Sinemurian. The species has a wide geographic and stratigraphic range in Britain from the Upper Sinemurian through the Toarcian.

Astacolus pauperatus Jones & Parker, 1860 (Pl.8, figs.1,4)

Cristellaria (planularia) crepidula (Fichtel & Moll) Franke, 1936, pl. 9, figs. 22,23a,b.

Planularia pauperata (Jones & Parker) Barnard, 1950a, figs. 3,4.

Planularia pseudocrepidula, Adams, 1957, text figs. 1-5.

Astacolus pauperatus (Jones & Parker) Brouwer, 1969, pl. 6, figs. 22-25.

Astacolus pseudocrepidulatus (Adams), Exton, 1979, pl. 6, fig. 5.

Astacolus pauperatus is a species with considerable morphologic variation. The test is compressed and the sutures shallow and oblique, curving at both ends (Barnard 1950a). The coiling portion of the test is rapidly replaced by the rectilinear growth. The coil is seldom more than 180 degrees of whorl and the proloculus is generally oval in shape. Barnard (1950a) and Adams (1957) give thorough descriptions of the varied morphology of the species. Brouwer (1969) placed all these forms in the species *Astacolus pauperatus* Jones & Parker.

Astacolus pauperatus ranges throughout the Lias. This species is a major constituent of Biofacies Zeta, an open marine biofacies.

Astacolus primus d'Orbigny, 1850. (Pl. 7, fig. 3)

Planularia protracta (Bornemann) Barnard, 1950, fig. 8h.

Lenticulina varians form F Barnard, 1960, pl. 2, figs. 13-15, pl. 5, figs. 1-6.

Astacolus cf. prima (d'Orbigny) Ruget & Sigal, 1967, pl. 2, fig. 7a-b.

Marginulinopsis gr. vetusta (d'Orbigny) Ruget & Sigal, 1967, pl. 1, figs 1-4.

Astacolus primus (d'Orbigny) Brouwer, 1969, pl. 4, figs. 6-8.

This is a robust species. The initial coiling portion may have a slight keel. There is considerable variety in the species morphology (Barnard, 1960, Brouwer, 1969).

Astacolus quadricostata Terquem, 1863. (Pl. 4, figs. 5,6)

Cristellaria (Astacolus) quadricostata (Terquem) Franke, 1936, pl. 11, fig. 4.

Cristellaria (Astacolus) quadricostata (Terquem) Bartenstein & Brand, 1937, pl. 4, fig. 71; pl. 5, fig. 57.

Cristellaria quadricostata (Terquem) Macfadyen, 1941, pl. 2, fig. 25a-b.

Marginulinopsis quadricostata (Terquem) Norvang, 1957, pg. 372, figs. 108-113.

Marginulinopsis quadricostata (Terquem) Ruget & Sigal, 1967, pl. 1, figs. 18a-b.

Astacolus quadricostata (Terquem) Brouwer, 1969, pl. 6, figs. 9-10.

Astacolus speciosus (Terquem) Exton, 1979, pl. 2, fig. 3.

It is possible to distinguish between this species and Astacolus undulata (Terquem) by the extension of the dorsal keel along the ventral concave curve of the chambers; it also has fewer ribs (Norvang, 1957).

Astacolus semireticulata Fuchs, 1970. (Pl. 7, figs. 4,5)

Astacolus semireticulata (Fuchs), Copestake & Johnson, 1981, pl. 6.1.2, fig. 1.

Excellent examples of this species are found in the Lower Lias of Raasay in samples KMP75-398, KMP75-400, KMP75-401. The reticulate ornamentation ceases as the test extends its rectilinear growth.

Astacolus stillus Terquem, 1866. (Pl. 2, figs. 2,3)

Astacolus stillus (Terquem) Franke, 1936, pl. 9. fig. 26.

Astacolus gr. stilla (Terquem), Ruget & Sigal, 1967, pl. 2, figs. 6a-b, fig. 18.

Astacolus stillus (Terquem) Exton, 1979, pl. 4, figs. 14,15,16, pl. 2, fig. 7.

Franke (1936) distinguished A. stillus from A. crepidula in that A. stillus had a keel. Norvang (1957) states that this is not a sufficient reason for separating the two species as many of the A. stillus collected in Denmark have a keel and many do not. There is controversy regarding the dividing of this species from Astacolus pauperatus = Astacolus crepidula. Barnard (1960) included Astacolus crepidula from the Angulata zone in his Lenticulina varians plexus form B. In this study Franke's standard of differentiation has been used.

Astacolus undulata Terquem, 1858. (Pl. 4, fig. 7)

Marginulina undulata (Terquem), Barnard, 1950. fig. 5f.

Marginulina radiata (Terquem), Norvang, 1957, figs. 94, 95.

Marginulinopsis radiata (Terquem), Ruget & Sigal, 1967, pl. 1, figs. 17a-b.

Astacolus undulata (Terquem), Brouwer, 1969, pl. 6, fig. 11.

Marginulina undulata (Terquem), ERICO, 1974, pl. 8.3, fig. 13.

Vaginulina curva (Franke), Copestake & Johnson, 1981, pl. 6.1.4, fig. 9.

This species has more irregular ribs and a less compressed test than Vaginulinopsis exarata (Norvang, 1957). It does not possess the keel along the inside of the ventral curve (Norvang, 1957). Copestake and Johnson (1981) assert Vaginulina curva (Franke, 1936) is synonymous with Marginulina radiata (Terquem 1866) and equal to Marginulina radiata (Norvang, 1957).

Citharina colliezi Terquem, 1866. (Pl. 9, fig. 10)

Citharina colliezi (Terquem), Brouwer, 1969, pl. 2, fig. 16.

Citharina colliezi (Terquem), ERICO, 1974, pl. 8.4, fig. 12.

Citharina colliezi (Terquem), Horton & Coleman, 1977, pl. 3, fig. 8.

Citharina colliezi (Terquem), Copestake & Johnson, 1981, pl. 6.1.2, fig. 2.

This species is common in the Upper Lias.

Dentalina deslongchampsii Terquem, 1863. (Pl. 6, fig. 1)

Dentalina deslongchampsii (Terquem), Macfadyen, 1941,
pl. 2, fig. 35.

This is a very rare species.

Dentalina exilis Franke, 1936. (Pl. 8, fig. 5)

Dentalina exilis Franke, 1936, pl. 2, fig. 25.

Dentalina exilis (Franke), Ruget & Sigal, 1967, pl. 7,
figs. 16a-b.

Dentalina exilis (Franke), Exton, 1979, pl. 5, fig. 7.

Test is arched and very slender. The proloculus is apiculate. The chambers are barrel-shaped cylinders separated by deep, straight sutures. The chambers, particularly the ultimate and penultimate, are elongate and the apertural end is drawn to a point with a central aperture (Franke, 1936).

Dentalina gladiiformis Franke, 1936. (Pl. 8, figs. 6, 7)

Dentalina gladiiformis Franke, 1936, pl. 2, fig. 22.

Dentalina gladiiformis (Franke), Bartenstein & Brand,
1937, pl. 3, fig. 10, pl. 5, fig. 21.

Dentalina gladiiformis (Franke), Barnard, 1963, fig.
4.

Dentalina gladiiformis (Franke), Ruget & Sigal, 1967,
pl. 7, fig. 6.

Dentalina gladiiformis (Franke), Brouwer, 1969, pl. 2,
fig. 17.

Macfadyen (1941) places *Dentalina gladiiformis* Franke, 1936 and *Dentalina gladiiformis* (Franke) Bartenstein and Brand 1937, pl. 2, fig. 10 and pl. 5, fig. 21 into his *Dentalina deslongchampsii* synonymy. Barnard (1963) indicates *Dentalina gladiiformis* a species and notes fine striations on the chambers at the sutures. The striations are very faint and are present on many, but not all, specimens in this study.

Dentalina hausleri Schick, 1903. (Pl. 8, fig. 8)

Dentalina hausleri (Schick), Franke, 1936, pl. 3, fig.
6.

Dentalina hausleri (Schick), Barnard, 1950, fig. 5.

Dentalina hausleri (Schick), Ruget & Sigal, 1967, pl.
6, figs. 21a-b.

Dentalina hausleri (Schick), Brouwer, 1969, pl. 2,
fig. 17.

Dentalina hausleri (Schick), Horton & Coleman, 1974,
pl. 4, fig. 3.

This study uses Barnard's (1950) taxonomy and separates the smooth species, Dentalina varians, from this ribbed species, Dentalina hausleri.

Dentalina hausmanni Bornemann, 1854. (Pl. 8, figs. 9, 10)

Vaginulina hausmanni Bornemann, 1854, pl. 3, fig. 25.
Dentalina hausmanni (Bornemann), Franke, 1936, pl. 2, fig. 15.

Species has a distended oval-shaped chamber in section. There is a slight coil before the rectilinear portion of the test. Barnard includes this in his D. terquemi synonymy. It is possible that it is a variant of this species but this study separates the two species based on the initial tendency to coil.

Dentalina langi Barnard, 1950. (Pl. 8, figs. 11-13)

Dentalina langi Barnard, 1950, fig. 5e.
Dentalina langi (Barnard), Brouwer, 1969, pl. 2, fig. 19.
? Marginulina obliquecostulata (Hagenmayer, 1959),
Copestake & Johnson, 1981, pl. 6.1.3, fig. 15.

Barnard (1950) suggests that this species is confined to the top of the Angulatum and base of the Bucklandi zones. Copestake and Johnson (1981) suggest that Marginulina obliquecostulata may be synonymous with D. langi (Barnard). As their figure is of an incomplete test, this can not be confirmed.

Dentalina matutina d'Orbigny, 1849. (Pl. 6, figs. 2, 3)

Dentalina matutina (d'Orbigny) Barnard, 1950, fig. 5d.
Dentalina matutina (d'Orbigny) Ruget & Segal, 1967, figs. 3a-b, 5, 6, 12..
Dentalina matutina (d'Orbigny) Brouwer, 1969, pl. 2, figs. 20-24.
Dentalina matutina (d'Orbigny) Copestake & Johnson, 1981, pl. 6.1.2, fig. 9.

All of the above authors with the exception of Ruget and Segal (1967) combine the species Dentalina matutina d'Orbigny and Dentalina primaeva d'Orbigny. Ruget and Segal (1967) show that Dentalina primaeva d'Orbigny has finer and more numerous costae; Dentalina matutina sensu stricto has approximately twelve robust costae, (Barnard 1950). This study separates the two species on the basis of the number and thickness of the costae. Those with 16 to 20 fine costae were religated to the species Dentalina primaeva d'Orbigny. It is quite possible that they are one species and part of a larger group, (Brouwer, 1969).

Dentalina numismalis Franke, 1936. (Pl. 6, fig. 6)

Dentalina numismalis, Franke, 1936, pl. 2, fig. 4.

Dentalina primaeva d'Orbigny, 1849. (Pl. 6, figs. 4, 5)

Dentalina primaeva (d'Orbigny) Franke, 1936, pl. 3, fig. 17.

Dentalina primaeva (d'Orbigny) Ruget & Segal, 1967, pl. 6, figs. 13 a-b, 17, 24.

Although this species is often included in the *Dentalina matutina* synonymies (Macfadyen 1941, Barnard 1950, Brouwer 1969, and Copestake and Johnson 1981), this study identifies this as a discrete species on the basis of finer more numerous costae (approximately 16 to 20).

Dentalina pseudocommunis Franke, 1936. (Pl. 1, figs. 8, 9; Pl. 8, fig. 14)

Dentalina pseudocommunis Franke, 1936, pl. 2, figs. 20a-b.

Dentalina pseudocommunis (Franke) Barnard 1950, fig. 5k.

Dentalina pseudocommunis (Franke) Ruget & Segal, 1967, pl. 7, figs. 11a-b.

Dentalina pseudocommunis (Franke) Exton, 1979, pl. 2, fig. 15.

This species is ubiquitous in the Lias.

Dentalina quadrilatera fm. *quinquelatera* Franke, 1936. (Pl. 6 fig. 7)

Dentalina quadrilatera fm. *quinquelatera* Franke, 1936, pl. 3, fig. 8.

Test has a rectilinear series of chambers with a distinct arch. There are five costae which tend to indent at the sutures. The sutures are shallow, but distinct. The aperture is radiate and centrally located on the ultimate chamber. This species is very rare.

Dentalina sinemuriensis Terquem. (Pl. 8, figs. 15-17)

Dentalina sinemuriensis (Terquem) Franke, 1936, pl. 2, figs. 23a-b.

Dentalina sinemuriensis (Franke) Bartenstein & Brand, 1937, pl. 4, fig. 31, pl 5, fig. 19, pl 6, fig. 12, pl. 8, figs. 11a-c.

Dentalina sinemuriensis (Terquem) Exton, 1979, pl. 6, fig. 9.

Dentalina sp. A Brouwer, 1969. (Pl. 6, fig. 9)

Dentalina sp. A Brouwer, 1969, pl. 2, fig. 29.

A smooth form of *Dentalina* with deep, straight sutures. There is an elongate neck which terminates in a radiate aperture on the dorsal margin. The proloculus is apiculate and elipsoidal. The test is only slightly arcuate. The chambers are barrel shaped. The species may be a variant of *Dentalina gladiiformis*. The species is very rare; therefore, designation as a new species is unwise in this study.

Dentalina subsiliqua Franke, 1936.

Dentalina subsiliqua Franke, 1935, pl. 2, figs. 21 a-c.

Dentalina subsiliqua (Franke) Narnard, 1963, figs. 4 a-b.

Dentalina subsiliqua (Franke) Ruget & Segal, 1967, pl. 7, figs. 15 a-b.

Dentalina tenuistriata Terquem, 1866. (Pl. 2, fig. 4)

Dentalina tenuistriata (Terquem) Franke, 1936, pl. 3, fig. 7.

Dentalina tenuistriata (Terquem) Brouwer, 1969, pl. 2, fig. 27.

Dentalina tenuistriata (d'Orbigny) ERICO, 1974, pl. 8.4, fig. 6.

The striae on the test of this species are fine and numerous. They tend to parallel the test walls. The costae on *Dentalina matutina* are robust, are somewhat oblique and tend to number around twelve. This study suggests that the specimen figured in ERICO 1974 pl. 8.4, fig. 6 is *Dentalina tenuistriata* and is misidentified.

Dentalina terquemi d'Orbigny, 1849. (Pl. 2, figs. 5-7; Pl. 6, fig. 10)

Dentalina terquemi (d'Orbigny) Barnard, 1950, fig. 1f.

Dentalina terquemi (d'Orbigny) Ruget & Segal, 1967, figs. 20 a-b, 22 a-b.

Dentalina terquemi (d'Orbigny) Brouwer, 1969, pl. 3, figs. 1-3,

Dentalina terquemi (d'Orbigny) Hortan & Coleman, 1977, pl. 3, fig. 5.

Dentalina terquemi (d'Orbigny) Exton, 1979, pl. 5, fig. 9.

Dentalina tortilis Franke, 1936. (Pl. 6, fig. 11)

Dentalina tortilis Franke, 1936, pl. 2. fig. 19.

Dentalina tortilis (Franke) Ruget & Segal, 1967, pl. 7, figs. 8 a-b, 13 a-b.

Dentalina tortilis (Franke) Exton, 1979, pl. 5. fig. 4.

Dentalina varians Terquem, 1866.

Dentalina varians (Terquem) Franke, 1936, pl. 2. fig. 6.

Dentalina varians (Terquem) Horton & Coleman, 1977, pl. 3, fig. 7.

This species is distinguished from *Dentalina hausleri* by the thin test wall and complete lack of costae. The borate process improves the recovery of this fragile species.

Dentalina vetusta d'Orbigny, 1850. (Pl. 6, fig. 12)

Dentalina vetusta (d'Orbigny) Macfadyen, 1941, pl. 2, fig. 37.

Dentalina virgata, Terquem, 1866. (Pl. 6, figs. 13-15)

Dentalina virgate (Terquem) Macfadyen, 1941, pl. 2, fig. 38.

This species is rare. It is larger in size and thicker is chamber wall than *Dentalina tenuistriata*.

Frondicularia brizaeformis Bornemann, 1854. (Pl. 6, figs. 16,17)

Frondicularia brizaeformis (Bornemann) Barnard, 1957, text figs. 1 a-f, 2 a-f.

Frondicularia brizaeformis (Bornemann) Ruget & Segal, 1967, pl. 4, figs. 15 a-b.

Frondicularia cf. intumescens (Bornemann) Ruget and Segal, 1967, pl. 4, figs. 13 a-b.

Frondicularia nitidia (Terquem) Ruget & Segal, 1967, pl. 4, figs. 12,16.

Frondicularia brizaeformis (Bornemann) Brouwer, 1969, pl. 5, fig. 1.

Frondicularia brizaeformis (Bornemann) Exton, 1979, pl. 2, figs. 8-9.

This study concurs with Barnard (1957); there is a variety in the morphology of this species which may be attributed in part to ontogeny. Ruget and Segal (1967) ascribe various morphologies to separate species.

Barnard (1957) could find no stratigraphic significance to the variety of forms and this study finds no ecologic significance.

Fron dicularia involuta Terquem, 1866. (Pl. 2, fig. 8)

Fron dicularia involuta (Terquem) Barnard, 1950a, pl. 2, figs. 8-9.

Berthelina involuta (Terquem) Ruget & Segal, 1967, pl. 4, figs. 9-10.

Fron dicularia involuta (Terquem) ERICO, 1974, pl. 8.5, figs. 13-14.

Barnard (1950a) includes *Fron dicularia lignaria* (Terquem 1966) in his synonymy. This study follows Barnard's taxonomy in the case of *Fron dicularia involuta*. This species often occurs with *Fron dicularia paradoxa*.

Fron dicularia paradoxa Berthelin, 1879. (Pl. 9, fig. 18)

Fron dicularia paradoxa (Bertheli) Barnard, 1957, text figs. 2 g-j.

Plectofron dicularia paradoxa (Berthelin) Horton & Coleman, 1877, pl. 4, figs. 12,13.

Fron dicularia sulcata Bornemann, 1854. (Pl. 1, figs. 19-21; Pl. 5, figs. 16-19; Pl. 6, figs. 18-20)

Fron dicularia sulcata (Bornemann) plexus, Barnard, 1957, pl. 1, pl. 2, figs 1-23.

Fron dicularia bicostata (d'Orbigny) Brouwer, 1969, pl. 5, figs. 2-23.

Fron dicularia sulcata (Bornemann) ERICO 1974, pl. 8.1, figs. 1-20.

Fron dicularia bicostata (d'Orbigny) subsp. *terquemi*, Exton, 1979, pl. 2, fig. 10.

Fron dicularia bicostata (d'Orbigny) *bicosta* d'Orbigny Exton, 1979, pl. 2, fig. 11.

Fron dicularia bicostata (d'Orbigny) subsp. *sulcata* (Bornemann) Exton, 1979, pl. 2, fig. 12.

Fron dicularia bicostata (d'Orbigny) subsp. *dubia* (Bornemann) Exton, 1979, pl. 2, fig. 13.

Fron dicularia muelensis (Ruget & Segal) Exton, 1979, pl. 2, fig. 14.

Fron dicularia terquemi (subsp. A Barnard) Copestake & Johnson, 1981, pl. 6.1.2, figs. 10-11.

Fron dicularia terquemi subsp. B Copestake & Johnson, 1981, pl. 6.1.2, figs. 6,8.

Fron dicularia terquemi muelensis (Ruget & Segal) Copestake & Johnson, 1981, pl. 6.1.2, fig. 12.

The ornamented *Fron dicularia* of the Lias have created a taxonomic problem as the above references demonstrate. Barnard (1957) proposed the *Fron dicularia*

sulcata plexus and described its evolution. This study utilizes Barnard's plexus designations. The plexus forms have stratigraphic significance (Barnard 1957, ERICO 1974); however, this study finds no environmental significance attached to the distinctions in morphology.

Lagena davoei Macfadyen, 1941. (Pl. 5, fig. 6)

Lagena davoei Macfadyen, 1941, pl. 4, figs. 63 a-b.

Lagena hispida Reuss

Lagena hispida (Reuss) Macfadyen, 1941, pl. 4, figs. 64 a-b.

Lagena laevis Montague.

Lagena laevis (Montague) Bartenstein & Brand, 1937, pl. 6, fig. 22, pl. 8, fig. 32, pl. 10, fig. 28.

Lagena laevis (Montague) Macfadyen, 1941, pl. 4, figs. 65 a-b.

Lagena oxystoma Reuss. (Pl. 5, fig. 7)

Lagena oxystoma (Reuss) Franke, 1936, pl. 9, fig. 8.

Lagena oxystoma (Reuss) Bartenstein & Brand, 1937, pl. 4, fig. 67, pl. 5, fig. 49.

Lagena sp. cf. L. clavata d'Orbigny. (Pl. 5, fig. 5)

Lagena clavata Franke, 1936, Pl. 9, fig. 4.

Lagena tenuicostata Franke, 1936.

Lagena tenuicostata Franke, 1936, pl. 9, fig. 9.

Lenticulina d'Orbigny Roemer 1839.

Lenticulina d'Orbigny (Roemer) Bartenstein & Brand, 1937, pl. 9, figs. 56 a-d.

Lenticulina d'Orbigny (Roemer) Brouwer, 1969, pl. 7, figs. 5, 6

Lenticulina d'Orbigny (Roemer) Gradstein, 1976, pl. 5, fig. 7, pl. 6, fig. 1.

Lenticulina d'Orbigny (Roemer) Exton, 1979, pl. 6, fig. 10.

Lenticulina d'Orbigny (Roemer) Copestake & Johnson, 1981, pl. 6.1.2, fig. 14.

This species is a valuable index species for the Toarcian-Aalenian (Brouwer, 1969, Gradstein, 1976). Its rectangular ornamentation which is parallel to the direction of coiling aids in quick, accurate identification.

Lenticulina muensteri Roemer, 1839. (Pl. 5, fig. 21; Pl. 8, figs.. 21,22)

Lenticulina gottingensis (Bornemann 1854) Franke, 1936 pl. 11, fig. 22.

Cristellaria (Lenticulina) munsteri (Roemer)

Bartenstein & Brand, 1937, pl. 9, figs. 49-50, pl. 10, figs. 38 a-b, pl. 11a, figs. 13 a-d, pl. 11b, figs. 19 a-d, pl. 12a, figs. 16 a-b, pl. 12b, figs. 15 a-e, pl. 13, fig. 36, pl. 14b, figs. 14 a-c, pl. 15a, figs. 34 a-c, pl. 15c, figs. 19 a-e.

Lenticulina gottingensis (Bornemann 1854) Exton, 1979, pl. 3, fig. 7.

The species L. muensteri (Roemer 1839) of this study does not include the species L. gottingensis (Bornemann) figured by Brouwer (1969, pl. 7, figs. 7-8). The species figured has a sutural rib. L. muensteri (Roemer) has a smooth test surface.

Barnard (1960) in his study of the Lenticulina varians plexus suggests that the young form of plexus member F was equal to Cristellaria L. muensteri (Roemer). This study separates L. muensteri from Barnard's plexus form F as large numbers of this form were found. This species has considerable variation in its morphology.

Johnson (1976) includes L. muensteri acutiangulata (Terquem 1864), L. muensteri muensteri (Roemer 1839) and L. muensteri subalata (Reuss 1854) in a plexus. Johnson shows its environmental range to extend from inner to outer shelf (Johnson, 1976) but suggests that each member might inhabit a different environmental range. L. muensteri muensteri (Roemer) is the only plexus member which extends in the deepest environmental niche in his model (Johnson, 1976).

L. muensteri (Roemer) is a conspicuous member of the deeper, more open marine biofacies: Biofacies Theta-Biofacies Lambda.

Lenticulina varians Bornemann 1854. (Pl. 1, figs. 23,24; Pl. 3, figs. 10-16; Pl. 4, fig. 2)

Lenticulina varians (Bornemann) Barnard, 1960, plexus pls.1-5, flabelline pl.6.

This study uses Barnard's plexus with the following exceptions: Cristellaria (L.) muensteri (Roemer), Cristellaria (L.) crepidula and Cristellaria A. prima d'Orbigny have been separated from the plexus and studied as discrete species.

Stratigraphy rather than environment appears to control the plexus forms present. Lenticulina muensteri

and Astacolus pauperatus=Cristellaria (L.) crepidula appear to be controlled by the environmental factors as they are important constituents of Biofacies Theta-Biofacies Lambda and Biofacies Zeta respectively. Astacolus primus is present in an environmental range of Biofacies Delta through Kappa of the Dorset assemblages.

Lingulina cernua Berthelin, 1879.

Lingulina cernua (Berthelin) Franke, 1936, pl. 6, figs. 8 a-d.

Lingulina cernua (Berthelin) Bartenstein & Brand, 1937, pl. 5, fig. 334, pl. 6, fig. 18.

Lingulina cernua (Berthelin) Barnard, 1956, pl. 1, figs. 6 a-b.

Lingulina esseyana Deecke, 1886. (Pl. 4, fig. 9)

Lingulina esseyana (Deecke) Barnard, 1956, pl. 1, figs. 3 a-b, 4.

Lingulina laevisissima Terquem 1866. (Pl. 6, figs. 18,19)

Lingulina lanceolata (Haeusler) Franke, 1936, pl. 6, fig. 10.

Lingulina lanceolata (Haeusler) Bartenstein & Brand, 1937, pl. 2b, fig. 17.

Lingulina laevisissima (Terquem) Macfadyen, 1941, pl. 3, figs. 51 a-b.

Lingulina laevisissima (Terquem) Barnard, 1956, pl. 1, figs. 5 a-b.

Macfadyen (1941) notes that the species designated L. laevisissima (Terquem) Franke, 1936, pl. 6, fig. 11, and L. laevisissima (Terquem) Bartenstein and Brand, 1937 pl. 8, fig. 22 are not L. laevisissima. These show a rapidly expanding test rather than the sub-parallel sides of L. laevisissima (Terquem). Barnard (1956) includes Franke (1936)'s L. laevisissima (pl. 6, fig. 11) in his synonymy. Barnard (1956) also suggested the possibility that L. cernua, L. lanceolata and L. laevisissima were all one long ranging species.

Lingulina nodosaria Terquem, 1870. (Pl. 7, figs. 7,8)

Frondicularia nodosaria (Terquem) Bartenstein & Brand, 1937, pl. 12a, fig. 6, pl. 13, fig. 14, pl. 15a, fig. 21.

Lingulina nodosaria (Terquem) Barnard, 1950a, text fig. 16.

Lingulina nodosaria (Terquem) Barnard, 1957, pl. 1, figs. 7 a-b, 8 a-b.

Lingulina tenera occidentalis Berthelin, 1879. (Pl. 9, fig. 12)

Lingulina tenera occidentalis (Berthelin) Copestake & Johnson, 1981, pl. 6.1.3, fig. 4.

Barnard (1957) did not include this form in his *Lingulina tenera* plexus. This study treats it separately.

Lingulina tenera Bornemann 1854. (Pl. 1, fig. 22; Pl. 2 fig. 12; Pl. 3, figs. 1-9)

Lingulina tenera (Bornemann) Barnard plexus, Barnard 1957, pl. 2, pl. 3, figs. 1-13.

This study uses the Barnard plexus. Barnard (1957) suggests that the variety of morphology was stratigraphically controlled. This study can identify no consistent link between the morphologic variation and the Biofacies. It is likely that the plexus is simply an example of iterative evolution similar to that which occurs in the ammonites. Biofacies Beta is completely dominated by this plexus, fifty to eighty-three percent of total composition.

Lingulina testudinaria Franke, 1936. (Pl. 9, fig. 13)

Lingulina testudinaria, Franke, 1936, pl. 6, fig. 19.
Lingulina testudinaria, (Franke) Copestake & Johnson, 1981, pl. 6.1.3, figs. 1, 2, 3.

Marginulina (saracenaria) hamus Terquem, 1866B. (Pl. 4, figs. 17, 18)

Marginulina (saracenaria) hamus (Terquem), Barnard, 1950, pl. 5, fig. g.
Marginulina (saracenaria) hamus (Terquem), Brouwer, 1969, pl. 4, fig. 6.
Marginulina (saracenaria) hamus (Terquem), Copestake & Johnson, 1981, pl. 6.1.3, fig. 14.

The species was identified only in the Dorset section of this study in the *Angulata* and *Bucklandi* Zones. Barnard (1950) shows its presence at Dorset restricted to the *Bucklandi* Zone. Brouwer (1969) states that this species is only found in the Hettagian and Lower Sinemurian. Barnard also expressed some doubt as to whether the Dorset species was in fact *M. (saracenaria) hamus* (Terquem) because of the less well marked, curved portion in the Dorset species (Barnard, 1950).

Marginulina porrecta Terquem.

Marginulina porrecta (Terquem), Franke, 1936, pl. 8, figs. 13-15.

This species is rare in the British Liassaic section.

Marginulina prima d'Orbigny, 1950. (Pl. 1, figs. 11,12; Pl. 3, figs. 18-22)

Dentalina insignis, Franke, 1936, pl. 3, figs. 11a-b.

Marginulina incisa, Franke, 1936, pl. 8, figs. 11,12.

Marginulina prima d'Orbigny f. *rugosa*, (Bornemann), Franke, 1936, pl. 8, fig. 1.

Marginulina prima d'Orbigny f. *gibbosa*, (Terquem), Franke, 1936, pl. 8, fig. 2.

Marginulina prima d'Orbigny f. *pramelonga*, (Terquem & Berthlin) Franke, 1936, pl. 8, fig. 3.

Marginulina prima d'Orbigny f. *recta*, (Terquem) Franke, 1936, pl. 8, fig. 4.

Marginulina prima d'Orbigny f. *acuta*, (Terquem) Franke, 1936, pl. 8, fig. 5.

Marginulina prima d'Orbigny f. *gibberula*, (Terquem & Berthlin, Franke, 1936, pl. 8, fig. 6.

Marginulina prima d'Orbigny f. *ornata*, (Terquem), Franke, 1936, pl. 8, fig. 7.

Marginulina burgundiae, (Terquem), Franke, 1936, pl. 8, fig. 8.

Marginulina interrupta, (Terquem), Franke, 1936, pl. 8, fig. 9.

Marginulina interrupta f. *spinata*, (Terquem), Franke, 1936, pl. 8, fig. 10.

Marginulina spinata (Terquem), Macfadyen, 1941, pl. 2, figs. 33a,b.

Marginulina prima d'Orbigny f. *burgundiae*, (Terquem), Norvang, 1957, figs. 100-102.

Marginulina prima d'Orbigny subsp. *prima*, (d'Orbigny) Norvang, 1957, figs. 98,99,103,104,

Marginulina prima d'Orbigny subsp. *rugosa*, (Bornemann) Norvang, 1957, fig. 97.

Marginulina prima (d'Orbigny), Brouwer, 1969, pl. 4, figs. 8-15.

Marginulina prima (d'Orbigny), ERICO, 1974, pl. 8.3, fig. 9.

Marginulina prima (d'Orbigny), Exton, 1979, pl. 3, figs. 1-2.

Marginulina prima interrupta (Terquem), Copestake & Johnson, 1981, pl. 6.1.3, fig. 11.

Marginulina prima spinata (Terquem), Copestake & Johnson, 1981, pl. 6.1.3, figs. 9-10.

The Marginulina prima plexus is common throughout the Lias. Norvang (1957) asserts that it is a part of the Marginulina radiata (astaculus quadricostata) super group. The plexus is the dominant component of Biofacies Epsilon. In the numerical analysis no attempt was made to isolate various members of the plexus.

Marginulina sp. A. (Pl. 4, figs. 22,23)

Rectilinear test of eight to ten chambers, which are barrel shaped, this species appears to have a coiling portion. The species is ornamented with five fine costae. Although there is some resemblance to Nodosaria quinquelatera (Franke) there is a distinct coiling portion. This form may be simply an aberrant growth product. It is very rare.

Marginulina sp. B.

This form is a finely striated species of Marginulina which is less robust than Marginulina costulata Hagenmeyer. The coiling portion of the test is distinct. This form may be an aberrant growth form of Marginulina obliquecostulata or Nodosaria metensis. The form is very rare.

Marginulina sp. psi. (Pl.1, figs. 13,14)

The proloculus is globular followed by a very brief coiling portion which in turn is followed by a rectilinear series of chambers. It is ornamented with eleven to eighteen costae. The costae which give the appearance of spiraling are, at times, discontinuous at the sutures. At other times the costae bifurcate. The costae terminate either on the apertural face or at the short apertural neck. The radiate aperture is located toward the dorsal margin on the apertural face of the ultimate chamber. The sutures are distinct. The test is robust and composed of five to ten chambers. This form is common in the Lower Lias of Dorset and Raasay.

Marginulina/Nodosaria sp. Alpha. (Pl. 4, fig. 21)

The test has a globular proloculus followed by six to ten elongate chambers which appear to have a slight coil. The chambers are ornamented with ten to fifteen ribs or costae which are longitudinal, parallel and generally continuous. The costae are slightly impressed at the sutures. The sutures are distinct and nearly horizontal. The sutures at times halt or slightly offset the costae. This is a common robust form in the Lower Lias. This form mostly closely resembles Nodosaria sculpta (Terquem) from which it differs in its somewhat irregular costae and slight coiling.

Nodosaria apheilolocula Tappan, 1955.

Nodosaria apheilolocula (Tappan), Horton & Coleman, 1977, pl. 3, figs. 12-13.

Nodosaria apheilolocula (Tappan), Exton, 1979, pl. 2, fig. 2.

This is a very fragile species and it is rare that two chambers are found articulated. The species' long, thin neck between chambers and the chambers' spiny ornamentation make it easily identifiable. Exton's (1979) clearly shows spines and spine bases.

Nodosaria columnaris Franke, 1936. (Pl.4, fig.13).

Nodosaria columnaris, Franke, 1936. pl. 4, fig. 19.

Nodosaria columnaris, (Franke), Barstenstein & Brand, 1937, pl. 3. fig. 17.

Nodosaria columnaris, (Franke), Barnard, 1950, pl. 4, fig. e

Nodosaria columnaris, (Franke), Ruget & Segal, 1967, pl. 8, figs. 3a-b, 5a-b.

Nodosaria columnaris, (Franke), Brouwer, 1969, pl. 3, figs. 6-7.

Nodosaria columnaris, (Franke), ERICO, 1974, pl. 2, fig. 6.

Nodosaria columnaris, (Franke), Exton, 1979, pl. 1, fig. 7.

Barnard (1950) shows this species only in the Semicostatum Zone of the Dorset outcrops. This study extends it's range. It is conspicuous at Dorset from the Bucklandi through the Semicostatum Zone. A rare individual was recovered in the Lower Pliensbachian of Dorset (Sample KMP75-300). In Raasay the species is present in the Semicostatum Zone. While in Yorkshsire, at the outcrops and in the Cocklepits Borehole it ranges from the Semicostatum Zone through the Tenuicostatum zone of the Upper Lias. In the Steeple Aston Borehole and the Mochras Borehole the species is also present in the Middle and Upper Lias. The species is distinctive; it's range is so broad as to offer little resolution beyond a range of Bucklandi--Levesquei Zones.

Nodosaria crispata Terquem, 1866. (Pl. 4, fig. 13)

Nodosaria crispata (Terquem), Bartenstein & Brand,
1937, pl. 3, fig. 13.

Nodosaria crispata (Terquem), Brouwer, 1969, pl. 2,
fig. 31.

Nodosaria crispata (Terquem), Exton, 1979, pl. 4, fig.
8.

Exton's (1979) figure appears to lack the neck
between chambers.

Nodosaria dispar Franke, 1936. (Pl. 4, fig. 19)

Nodosaria dispar, Franke, 1936, pl. 4, fig. 18.

Nodosaria dispar, (Franke), Norvang, 1957, fig. 80
only.

Nodosaria dispar, (Franke), Ruget & Segal, 1967, pl.
8, figs. 9a-b.

Nodosaria dispar, (Franke), Brouwer, 1969, pl. 3,
figs. 8-9.

Nodosaria dispar, (Franke), Exton, 1979, pl. 2, fig.
1.

The spindle shaped test outline is the key to this
species recognition. The test is seldom made up of more
than three chambers.

Nodosaria hirsuta d'Orbigny. (Pl. 5, fig. 9)

Nodosaria hirsuta (d'Orbigny), Bartenstein & Brand,
1937. pl. 4, figs 39a-b, pl. 5, fig. 26.

This species is recognized by the subglobular smooth
chambers separated by a thin neck. The test is
rectilinear. No complete specimens were found. Exton
(1979) includes *N. hirsuta* in his synonymy of *N.*
aphelocula (Tappan).

Nodosaria hortonensis Terquem, 1866. (Pl. 4, fig. 19)

Nodosaria hortonensis (Terquem), Macfadyen, 1941, pl.
3, figs. 41a-b.

Nodosaria hortonensis (Terquem), Barnard, 1950, pl. 4,

Nodosaria hortonensis (Terquem), Exton, 1979, pl. 1,
fig. 8.

This species is common throughout the Lias.
Macfadyen (1941) combines *Nodosaria dispar* (Franke) with
this species; Brouwer (1969) on the other hand suggests
that this species is a more regular form of *Nodosaria*
dispar (Franke). This study treats these as discrete
species.

Nodosaria issleri Franke, 1936. (Pl. 5, fig. 11)

Nodosaria issleri Franke, 1936, pl. 5, fig. 6.

Nodosaria issleri (Franke), Norvang, 1957, fig. 82.

Nodosaria issleri (Franke), Ruget & Segal, 1967, pl. 8, figs. 26a-b.

Nodosaria issleri (Franke), Copestake & Johnson, 1981, pl. 6.1.4, figs. 1-2.

Copestake and Johnson (1981) note the relationship between this species and N. radiata (Terquem), N. mitis (Terquem & Berthlin), and Pseudonodosaria multicostata (Bornemann). The semismooth ultimate chamber, pronounced aperture and flush sutures differentiate it from the other species (Copestake & Johnson, 1981).

Nodosaria metensis Terquem, 1863. (Pl.1, fig. 18; Pl.6, fig. 20)

Nodosaria metensis (Terquem), Barnard, 1950, pl. 4, fig.f.

Nodosaria metensis (Terquem), Norvang, 1957, fig. 72.

Nodosaria metensis (Terquem), Ruget & Segal, 1967, pl. 7, fig. 24.

Nodosaria metensis (Terquem), ERICO, 1973, pl.8.2, fig.4.

Nodosaria metensis (Terquem), Exton, 1979, pl. 1, fig. 9.

Barnard's 1950 variation, N. metensis var. robustus was included in the abundance count for this species. This study does mention, however, that Barnard's variation is indeed distinct from N. metensis sensu stricto.

Nodosaria nitidana Brand, 1937. (Pl.5, fig. 10; Pl.6, fig.22)

Nodosaria nitidana (Brand), Barnard, 1950, pl. 4, fig. 9.

Nodosaria nitidana (Brand), Ruget & Segal, 1967, pl. 9, fig. 6.

Nodosaria nitidana (Brand), ERICO, 1974, pl. 8.2, fig. 5.

This smooth nodosariid species is common throughout the Lias. A distinction can be made from Pseudonodosaria vulgata (Bornemann) which it resembles in very small tests. N. nitidana can be discriminated by its impressed sutures which do not overlap the preceeding chambers in a glanduline fashion.

Nodosaria oculina Terquem & Berthlin, 1875.

Nodosaria oculina (Terquem & Berthlin), Franke, 1936, pl. 4, figs. 21-22.

Nodosaria oculina (Terquem & Berthlin), Bartenstein & Brand, 1937, pl. 8, fig. 14.

Nodosaria oculina (Terquem & Berthlin), Norvang, 1957, fig. 77.

Nodosaria oculina (Terquem & Berthlin), Brouwer, 1969, pl. 3, fig. 13.

Norvang (1957) differentiates *N. oculina* from *N. mitis* by *N. oculina*'s lack of constrictions at sutures.

Nodosaria prima d'Orbigny, 1849. (Pl. 4, fig. 20)

Nodosaria prima (d'Orbigny) Macfadyen, 1936, pl. 4, figs. 253 a, b.

Nodosaria prima (d'Orbigny) Barnard, 1949, fig. 1h.

Nodosaria prima (d'Orbigny) Ruget & Segal, 1967, pl. 8, figs. 14, 15, 24.

Nodosaria prima (d'Orbigny) ERICO, 1974, pl. 2, fig. 8.

? *Nodosaria pyriformis* Terquem, 1858.

Nodosaria pyriformis (Terquem), Macfadyen, 1941, pl. 3, fig. 44.

Very rare; the identification of this species is questionable as the specimens in this study, like Macfadyen's (1941) figure, were fragmented. The chamber shape is quite similar.

Nodosaria quadrilatera Terquem, 1858.

Nodosaria quadrilatera (Terquem), Bartenstein & Brand, 1937, pl. 4, fig. 35.

Nodosaria radiata Terquem, 1886. (Pl. 5, fig. 13)

Nodosaria radiata (Terquem), Franke, 1936, pl. 4, fig. 20.

Nodosaria radiata (Terquem), Norvang, 1957, fig. 71.

Nodosaria radiata (Terquem), Brouwer, 1969, pl. 3, fig. 17.

Macfadyen (1941) did not differentiate between *N. radiata* and *N. sculpta*. Norvang (1957) included forms with up to ten ribs in the species *N. radiata*. The comparison of figures of *N. mitis* (Terquem & Berthlin), Norvang, (1957) figure 74, Ruget & Segal (1967) plate 8, figures 27, 29, 30 and Exton (1979) plate 1, figure 10 show a strong resemblance to *N. radiata*. This study places

those forms with six to eight ribs in the species, N. radiata and those with nine to fourteen in the species, N. sculpta.

Nodosaria regularis Terquem, 1862. (Pl.. 6, fig. 21)

Nodosaria regularis (Terquem), Franke, 1936, pl. 3, fig. 19.

Nodosaria regularis (Terquem), Exton, 1979, pl. 8. fig. 7.

Copestake and Johnson (1981) describe a N. regularis subsp. A which is three to four times larger than the N. regularis regularis described by Terquem. It is also stratigraphically distinct. Nodosaria regularis is a fragile, sparse species; however, this observation may be the result of a preservational bias.

Nodosaria sculpta Terquem, 1866. (Pl. 5, figs. 14,15)

Nodosaria sculpta (Terquem), Macfadyen, 1941, pl. 3, fig. 45.

Macfadyen (1941) included D. mitis (Terquem & Berthlin) Franke (1936) in his synonymy. This study agrees with Macfadyen's conclusion. Exton (1979) included D. oculina (Terquem & Berthlin) in his synonymy of the species Nodosaria mitis. There is a strong relationship in morphology in the species N. sculpta, N. radiata, N. oculina and N. mitis.

Nodosaria simoniana d'Orbigny, 1849. (Pl. 9, fig. 19)

Nodosaria simoniana (d'Orbigny), Franke, 1936, pl. 4, fig. 9.

Nodosaria simoniana (d'Orbigny), Macfadyen, 1936, figs. 353-354.

Nodosaria simoniana (d'Orbigny), Norvang, 1957, fig. 70.

Nodosaria simplex Terquem, 1858. (Pl.1, fig 10; Pl.6, fig.28)

Nodosaria simplex (Terquem), Franke, 1936, pl. 4, fig. 6.

Nodosaria simplex (Terquem), Macfadyen, 1941, pl. 3, fig. 46.

Nodosaria simplex (Terquem), Barnard, 1950, pl. 4. fig. h.

Nodosaria simplex (Terquem), Exton, 1979, pl. 4, fig. 9.

This smooth nodosariid species is found throughout

the Lias. The test is smaller than N. regularis, and the chambers are more elongate while the sutures are not as constricted. Test walls are thin.

Nodosaria sp. 2393 (?) sp. nov. (Pl. 6, figs. 24-26)

This species of Nodosaria is thick walled and ornamented with from sixteen to twenty-two ribs which run the length of the test. With the exception of the suture between the proloculus and second chamber, the ribs are not impressed at the suture. The sutures, after the first, are flush with the test surface and indistinct. The ribs do not continue onto the apertural face which is smooth. The aperture is centrally located, circular, and has a shallow lip. The proloculus is globular. The species resembles Pseudonodosaria multicostata except that there is no overlap of the proloculus by the second chamber. It is possible that this is an aberrant form of Pseudonodosaria multicostata. It is common in many of the samples of the Lower Lias of Dorset.

Nodosaria subprismatica Franke, 1936. (Pl. 5, fig. 12)

Nodosaria subprismatica, Franke, 1936, pl. 4, fig. 17.
Nodosaria subprismatica, (Franke), Ruget & Segal,
 1967, pl. 8, figs. 25a-b.
Nodosaria subprismatica, (Franke), Exton, 1979, pl.
 15, fig. 4.

(?) Planularia cf. arietis Issler, 1908.

Planularia cf. arietis (Issler), Franke, 1936, pl. 9,
 fig. 28.
Planularia cf. arietis (Issler), Ruget & Segal, 1967,
 pl. 3, figs. 12, 15.

Norvang (1957) includes this species in his Planularia inaquistriata (Terquem) synonymy noting that breadth of the test was not sufficient reason for specific separation. It is very likely that Norvang is correct. However, this study utilizes this designation for the broader forms which are stratigraphically distinct from the Lower Lias Planularia inaquistriata.

Planularia eugenii Terquem, 1863. (Pl. 4, fig. 8)

Planularia eugenii (Terquem), Norvang, 1957, fig. 150.
Astacolus eugenii (Terquem), Brouwer, 1969, pl. 7,
 fig. 3.
Citherina eugenii (Terquem), Exton, 1979, pl. 2, fig.
 5.

Norvang (1957) sites the close relationship between this species and Planularia inaequistriata from which it is separated on the basis of fewer and more regular ribs.

Planularia inaequistriata Terquem, 1863.

- Cristellaria (Planularia) inaequistriata (Terquem),
 Franke, 1936, pl. 10, figs. 24-25.
Planularia inaequistriata (Terquem), Barnard, 1950,
 pl. 8, figs. c,d,g.
Planularia inaequistriata (Terquem), Norvang, 1957,
 figs. 148-149.
Planularia inaequistriata (Terquem), Ruget & Segal,
 1967, pl. 3, figs. 11a-b.
Planularia inaequistriata (Terquem), ERICO, 1974, pl.
 8.2, figs. 10-12.

Norvang (1957) cites the close relationship between P. eugenii and this species. Planularia inaequistriata is apparently restricted to the Hettangian and Sinemurian in Europe (Exton, 1979). The related species P. eugenii and P. cf. arietis, range higher in the stratigraphic column: Norvang (1957) P. eugenii = Lias delta; Exton (1979) P. eugenii = Ibex Zone; Ruget and Segal (1967) P. cf. arietis = Lias alpha through delta.

Pseudonodosaria quinquicostata Bornemann, 1854. and
Pseudonodosaria quinquicostata var. quadrucostata
 Bornemann, 1854. (Pl. 5, fig. 25)

Glandulina quinquicostata (Bornemann), Franke, 1936,
 pl. 5, figs. 25-26.

The variation resembles all aspects of Pseudonodosaria quinquicostata sensu stricto except that it has four costae instead of five. This variation is not common.

Pseudonodosaria multicostata Bornemann, 1854. (Pl. 5, figs. 23,24)

- Pseudoglandulina multicostata (Bornemann), Franke,
 1936, pl. 5, fig. 20.
Pseudoglandulina multicostata (Bornemann), and
Pseudoglandulina multicostata (Bornemann) var.
semicostata, Barnard, 1958, pl. r, figs a-b.
Pseudoglandulina multicostata (Bornemann), Norsvang,
 1957. fig. 87.
Nodosaria multicostata (Bornemann), Brouwer, 1969, pl.
 4, fig. 2.
Pseudonodosaria multicostata (Bornemann), ERICOm 1974,
 pl. 8.3, figs. 7,10,11.
Pseudonodosaria multicostata (Bornemann), Exton, 1979,
 pl. 3, fig. 5.

This study does not separate Pseudonodosaria multicostata var. semicostata (Barnard) from the species sensu stricto. This variation was regarded as a senile stage of growth.

Pseudonodosaria oviformis Terquem, 1863. (Pl. 5, fig. 26)

Glandulina oviformis (Terquem), Franke, 1936, pl. 5, fig. 11.

Pseudoglandulina oviformis (Terquem), Bartenstein & Brand, 1937, pl. 4, fig. 40.

Pseudoglandulina oviformis (Terquem), Macfadyen, 1941, pl. 3, fig. 47.

Pseudoglandulina oviformis (Terquem), Barnard, 1950, pl. 6 fig. h.

Pseudonodosaria vulgata Bornemann, 1854. (Pl. 5, figs. 27, 28)

Glandulina vulgata (Bornemann), Franke, 1936, pl. 5, figs. 9 a-b.

Pseudoglandulina vulgata (Bornemann), Macfadyen, 1941, pl. 3, fig. 50.

Pseudoglandulina vulgata (Bornemann), Barnard, 1950, pl. 4 fig. c.

Pseudoglandulina vulgata (Bornemann), Norvang, 1957, fig. 85.

Nodosaria vulgata (Bornemann), Brouwer, 1969, pl. 4, figs. 44-5.

Pseudonodosaria vulgata (Bornemann), ERICO, 1974, pl. 8.4 figs. 13-14.

This study includes the many variations of this species as one species in the numerical analysis.

Saracenaria sublaevis sublaevis Franke, 1936. (Pl. 7, figs. 9, 10)

Cristellaria (Saracenaria) sublaevis Franke, 1936, pl. 9, figs. 30-32.

Saracenaria sublaevis (Franke), Norvang, 1957, fig. 151.

Saracenaria sublaevis (Franke), Brouwer, 1969, pl. 6, fig. 16.

Saracenaria sublaevis sublaevis (Franke), Copestake & Johnson, 1981, pl. 6.1.4, fig. 6.

Vaginulina clathrata Terquem, 1863. (Pl. 8, figs. 25,26)

Vaginulina clathrata (Terquem), Barnard, 1950a, fig.
17.

Vaginulina clathrata (Terquem), Horton & Coleman,
1977, pl. 3. fig. 11.

Vaginulina compressa Terquem.

Vaginulina compressa (Terquem), Franke, 1936, pl. 8,
figs. 27a-b.

Vaginulina constricta Terquem & Berthlin, 1826. (Pl. 2,
fig. 22)

Vaginulina constricta (Terquem & Berthlin), Franke,
1936, pl. 8, fig. 24.

Vaginulina constricta (Terquem & Berthlin), Macfadyen,
1941, pl. 4, figs. 57a-b.

Vaginulina listi Bornemann, 1854. (Pl. 7, figs. 14,15)

Vaginulina listi (Bornemann), Norvang, 1957, fig. 119.

Vaginulina listi (Bornemann), Norling, 1968, pl. 9.

Vaginulina listi (Bornemann), Brouwer, 1969, pl. 3.
figs. 19-24.

Vaginulina listi (Bornemann), Exton, 1979, pl. 4, fig.
13.

Vaginulina sagittiformis Terquem, 1868. (Pl. 9, fig. 24)

Vaginulina sagittiformis (Terquem), Franke, 1936, pl.
8, figs. 37-38.

Vaginulina sagittiformis (Terquem), Brouwer, 1969, pl.
4, fig. 1.

Vaginulina simplex Terquem, 1863. (Pl. 1, fig. 15)

Vaginulina simplex (Terquem), Barnard, 1950, pl. 8,
fig. e.

This species is very common in the Hettangian of
Dorset. It is an important constituent of Biofacies
Alpha.

Vaginulina triquetra Terquem. (Pl. 1, figs. 16,27; Pl. 7,
fig. 14)

Vaginulina triquetra (Terquem), Franke, 1936, pl. 8,
figs. 28-29.

Family: Polymorphinidae d'Orbigny, 1839.

Bullopore globulata Barnard, 1950. (Pl. 4, figs. 1,2)

Bullopore globulata Barnard 1950, fig. 1e.

Bullopore globulata (Barnard) Exton, 1979, pl. 5, fig. 16.

This is a robust, adherent species which has nearly hemispheric chambers which appear to abut one another. The tapering neck of *Bullopore rostrata* is not discernable.

Bullopore rostrata Quenstedt, 1858. (Pl. 4, fig. 3)

Bullopore rostrata (Quenstedt) Franke, 1936, pl. 12, fig. 11.

Bullopore rostrata (Quenstedt) Bartenstein & Brand, 1937, pl. 12A. figs. 20 a-b.

Bullopore rostrata (Quenstedt) Macfadyeni, 1941, pl. 1, figs. 13-17.

This species is discriminated from *B. globulata* by its more elongate chambers with a tapered neck between chambers (Barnard, 1950). *B. rostrata* is not as common as *B. globulata* in the Lower Lias at Dorset. It is a much more gracile species than *B. globulata*. The chambers are often filled with pyrite.

Eoguttulina inovroclaviensis Bielecka & Pozaryski, 1954. (Pl. 1, fig. 7)

Eoguttulina inovroclaviensis (Bielecka & Pozaryski) Lloyd, 1962, pl. 1, fig. 7 a-c.

Eoguttulina liassica Strickland 1846. (Pl. 1, figs. 1-3)

Eoguttulina liassica (Strickland) Bartenstein & Brand, 1937, pl. 2A fig. 23, pl. 4, fig. 74 a-b.

Eoguttulina liassica (Strickland) Barnard, 1950, fig. 6b, f.

Eoguttulina liassica (Strickland) Lloyd 1962, pl. 1, figs. 1a-d, 2a-c, 3a-c, text fig. 2a-e.

Eoguttulina liassica (Strickland) Brouwer, 1969, pl. 7, figs. 18.19.

Eoguttulina liassica (Strickland) Exton, 1979, pl. 5, fig. 15.

This species occurs in small numbers throughout the Lias. It is a major constituent in Biofacies Alpha where it occurs with other primary species: *Lingulina tenera* and *Lenticulina varians*.

Eoguttulina oolithica Terquem, 1874. (Pl. 1, fig. 4)

Eoguttulina oolithica (Terquem) Bartenstein & Brand, 1937, pl. 10, figs. 43 a-b.

Eoguttulina oolithica (Terquem) Lloyd, 1962, pl. 1, figs. 5a-c, 8a-c, text fig. 5a,b.

This species grows much larger than *Eoguttulina liassica*; its sutures, however, are barely discernable. *E. oolithica* is common in Biofacies Alpha.

Eoguttulina polygona Terquem, 1864. (Pl. 1, figs. 5,6)

Eoguttulina polygona (Terquem) Lloyd, 1962, pl. 1, figs. 4a-c, text fig. 3a-c.

Eoguttulina sp. (adherent form) Lloyd, 1982.

Lloyd (1962) questioned the eoguttuline arrangement of chambers; however, this study shows positive eoguttuline chamber arrangement. This form is common in the Hettangian of Dorset in Biofacies Alpha. The flattened side of the test often appears separated from the chambers and this willow-leaf shaped half of the test is the only portion preserved. Many, however, were studied in their articulated form.

Family: Spirillinidae Reuss, 1862.

Spirillina infima Strickland, 1896. (Pl. 8, fig. 23)

Spirillina infima (Strickland) Barnard, 1952, figs. 1,2,3.

Spirillina infima (Strickland) Lloyd, 1962, pl. 2, figs. 2,3.

Spirillina infima (Strickland) Exton, 1979, pl. 1, fig. 5.

Barnard included in his *Spirillina infima* synonymy *Spirillina polygyrata*, Gumbel. This study religates those specimens with a pronounced convex surface and a discernable umbilicus to the species *Spirillina polygyrata*. *Spirillina infima* is the dominant constituent in Biofacies Eta and Biofacies Theta. It is the dominant foraminiferal species throughout the Middle Lias and the top of the Upper Lias in the Mochras Bore Hole.

Spirillina polygyrata Gumbel, 1862. (Pl. 8, fig. 24)

Spirillina polygyrata (Gumbel) Bartenstein & Brand,
1937, pl. 4, fig. 10, pl. 6, fig. 7, pl. 14c, fig.
3, pl. 15a, figs 2a-c, pl. 15c, figs. 1a-d.

Spirillina polygyrata (Gumbel) Lloyd, 1962, pl. 2,
figs. 1 a-b.

Spirillina polygyrata is a common accessory species in Biofacies Eta and Theta. *Spirillina polygyrata* has a noticeable umbilicus in which the tube is visible; often, however, the umbilicus is filled with calcareous material.

Conicospirillina trochoides Berthelin, 1879.1

Conicospirillina trochoides (Berthelin) Moore, 1964,
figs. 475,5.

Conicospirillina trochoides (Berthelin) Copestake &
Johnson, 1981, pl. 6.1.5, figs. 4.5.

```

1000 HOME : VTAB (12): PRINT SPC( 8)"FILE REFORMATING ROUTINE": VTAB (2
2): INPUT "PRESS (RETURN) TO CONTINUE";W$
1010 HOME : VTAB (8): PRINT "THIS PROGRAM WILL READ FILES GENERATED"
1020 PRINT "BY THE 'CHECKLIST' PACKAGE AND CHANGES": PRINT "THEM TO A SA
S/FORTAN COMPATABLE FORMAT"
1030 PRINT : PRINT "THE NEW FORMAT IS HF3.0, WHERE H IS": PRINT "THE NUM
BER OF SPECIES (MAX 26/LINE)"
1040 VTAB (22): INPUT "PRESS (RETURN) TO CONTINUE";W$
1050 HOME : VTAB (12): PRINT "      MAKE SURE YOU KNOW HOW MANY /CKH": PRINT
"      FILES YOU HAVE"
1060 VTAB (22): INPUT "PRESS (RETURN) TO CONTINUE";W$
1070 D$ = CHR$ (4)
1080 DIM F$(200),A$(10,140)
1090 HOME : VTAB (8): PRINT "PRESS (RETURN) TO SEE THE CATALOG": PRINT "
PRESS ANY OTHER KEY TO CONTINUE": GET W$: PRINT CHR$ (13)
1100 WS = ASC (W$): IF WS ( ) 13 THEN GOTO 1180
1110 HOME : VTAB (8): INPUT "WHICH SLOT? (3 FOR BOTH) ";D$: DO = D
1120 IF D ( ) 3 THEN GOTO 1140
1130 FOR DO = 1 TO 2
1140 HOME : PRINT D$;"CATALOG";",D";DO
1150 PRINT "PRESS A KEY TO CONTINUE ": GET W$: PRINT CHR$ (13)
1160 IF D ( ) 3 THEN GOTO 1180
1170 NEXT DO
1180 HOME : VTAB (8): INPUT "FILE NAME (WITHOUT /CK) ";A$: INPUT "NUMBER
OF FILES";N
1190 HOME : VTAB (8): INPUT "DESTINATION FILE NAME: ";B$
1200 HOME : VTAB (8): INPUT "ORIGINATING DRIVE: ";D1: INPUT "DESTINATION
DRIVE: ";D2
1210 PRINT D$;"OPEN";B$;",D";D2
1220 PRINT D$;"WRITE";B$
1230 PRINT D$;"CLOSE";B$
1232 PRINT D$;"OPEN";A$;"/CK,D";D1
1233 PRINT D$;"READ";A$;"/CK"
1234 INPUT NOS: INPUT NOS
1235 PRINT D$;"CLOSE";A$;"/CK"
1236 FOR I = 0 TO N - 1
1237 NA = 1
1238 NX = 9
1242 IF I > 0 THEN NA = 1
1243 IF I > 0 THEN NX = 10
1250 C$ = A$ + "/CK" + STR$ (I)
1260 PRINT D$;"OPEN";C$;",D";D1
1270 PRINT D$;"READ";C$
1280 INPUT NS
1290 BL = 10: IF I = 0 THEN BL = 11
1300 FOR JA = 1 TO BL: INPUT W$: NEXT JA
1310 FOR KK = 1 TO NS
1320 FOR JJ = NA TO NX
1330 INPUT A$(JJ, KK)
1340 NEXT JJ
1350 IF KK = NS GOTO 1370
1355 IF I > 0 GOTO 1370
1360 INPUT W$
1370 NEXT KK

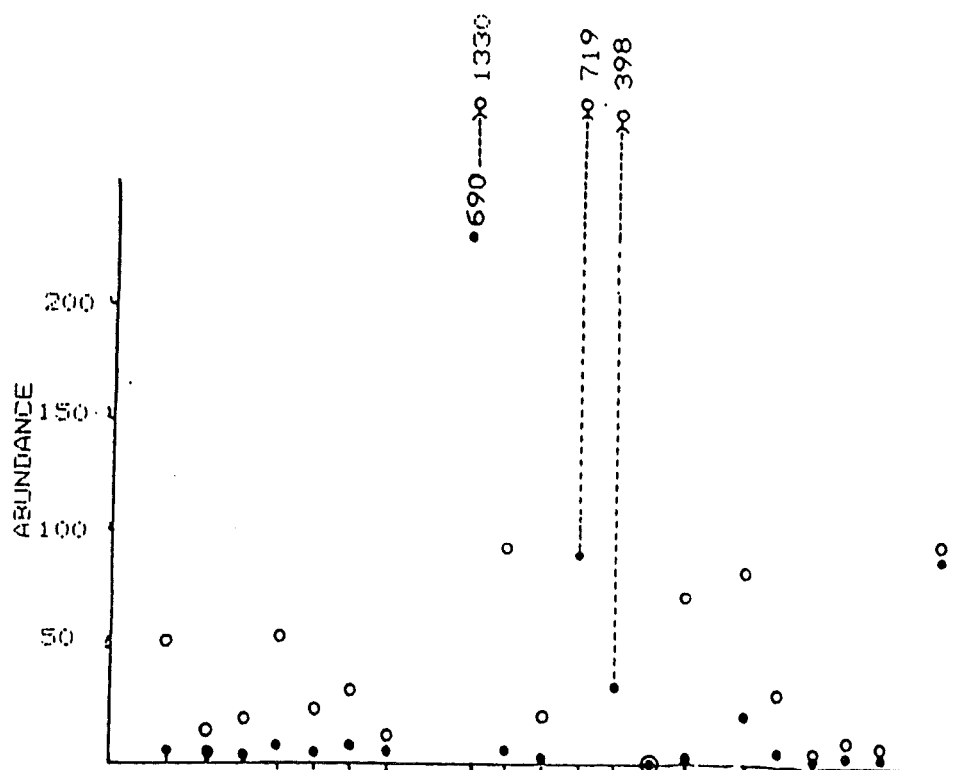
```

Table I (Appendix) . Program for transferring the Phillips matrix
 on the Apple IIe to the As 9000.

```

1380 PRINT D$;"CLOSE";A$
1390 L = 0
1395 IF I = N - 1 THEN NX = NOS - (9 + 10 * (N - 2))
1400 FOR J = NA TO NX
1410 FOR K = 1 TO NS
1420 IF LEN (A$(J,K)) = 0 THEN A$(J,K) = "000"
1430 IF LEN (A$(J,K)) = 1 THEN A$(J,K) = "00" + A$(J,K)
1440 IF LEN (A$(J,K)) = 2 THEN A$(J,K) = "0" + A$(J,K)
1450 F$(L) = F$(L) + A$(J,K)
1460 IF NS > 26 AND LEN (F$(L)) >= 78 THEN F$(L) = " " + F$(L);L =
    L + 1
1470 NEXT K
1480 IF NS > 26 AND LEN (F$(L)) >= 78 THEN GOTO 1510
1490 F$(L) = " " + F$(L)
1500 L = L + 1
1510 NEXT J
1520 L = L - 1
1521 NB = NOS
1522 IF I = N - 1 THEN NB = NOS - (9 + 10 * (N - 2))
1523 IF I = 0 AND NOS < 9 THEN NB = NOS
1525 IF I + 1 = N AND NS / 26 = INT (NS / 26) THEN L = ( INT (NS * 3 /
    78)) * NB
1530 IF I + 1 = N THEN L = ( INT (NS * 3 / 78) + 1) * NB
1540 PRINT D$;"APPEND";B$;" ,D";D2
1550 PRINT D$;"WRITE";B$
1560 FOR II = 0 TO L
1570 PRINT F$(II)
1580 NEXT II
1590 PRINT D$;"CLOSE";B$
1600 X = FRE (0)
1610 FOR JJ = 0 TO L
1620 F$(JJ) = ""
1630 NEXT JJ
1640 FOR JA = NA TO NX
1650 FOR KA = 1 TO NS
1660 A$(JA,KA) = ""
1670 NEXT KA
1680 NEXT JA
1690 NEXT I
1700 END

```



•• Na_2CO_3 preparation only

○: Na_2CO_3 preparation followed by $\text{NaB}(\text{C}_6\text{H}_5)_4 + \text{NaCl}$ prep.

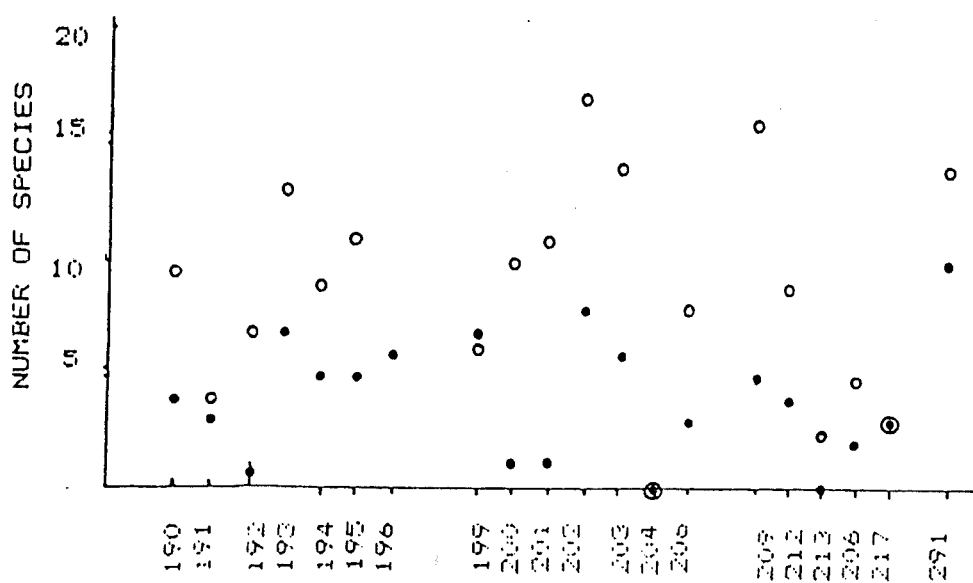


Table II. The improvement in recovery for the test, using sodium carbonate followed by the sodium tetraphenylborate sodium chloride process.

MOCHRAS BOREHOLE

B I O F A C I E S ETA

		3273	3232	3192	3174	3125	3017	2956	2942	2896	2849
B I O F A C I E S E T A	3273	100	82	81	88	45	69	68	70	77	77
	3232	82	100	76	83	76	70	68	70	78	79
	3192	81	76	100	82	69	63	68	70	71	70
	3174	88	83	82	100	76	70	67	69	77	77
	3125	75	76	69	76	100	83	65	65	74	70
	3017	69	70	63	70	83	100	60	65	67	67
	2956	68	68	68	67	65	63	100	86	71	73
	2942	70	70	70	69	65	65	86	100	70	75
	2896	77	78	71	77	74	67	71	70	100	77
	2849	77	70	73	77	70	67	73	75	77	100

Table III a . Matrix made of Sanders Similarity Indices for samples constituting Biofacies Eta of the Mochras Borehole.

B I O F A C I E S T H E T A

MOCHRAS BOREHOLE

	2429	2378	2210	2177	2153	2139	2106	2063	2025	2000	1981
2429	100	62	68	68	63	66	66	59	50	63	65
2378	62	100	60	60	61	60	72	77	82	53	81
2210	68	60	100	72	62	68	66	57	50	70	59
2177	68	60	72	100	59	74	67	59	53	67	59
2153	63	61	62	59	100	64	68	60	52	54	65
2139	66	60	68	74	64	100	72	60	48	63	64
2106	66	72	66	67	68	72	100	69	61	61	75
2063	59	77	57	58	60	60	69	100	68	56	83
2025	50	82	50	53	52	48	61	68	100	44	68
2000	63	53	70	67	54	63	61	56	44	100	59
1981	65	81	59	59	65	64	75	83	68	59	100

Table III b. Matrix made of Sanders Similarity Indices for samples constituting Biofacies Theta of the Mochras Borehole.

		B I O F A C I E S						ETA			
		MOCHRAS BOREHOLE									
		3273	3232	3192	3174	3125	3017	2956	2942	2896	2849
B	2429	43	42	42	41	45	49	53	52	42	45
I	2378	65	61	67	66	55	53	63	64	62	62
O	2210	38	38	39	38	42	46	47	46	38	41
F	2177	42	39	43	40	43	48	51	50	42	50
A	2153	46	43	44	43	47	52	57	53	43	45
C	2139	40	42	43	40	43	48	56	51	43	48
I	2106	55	54	53	53	56	55	65	63	53	55
E	2063	64	61	64	62	55	52	64	66	57	64
S	2025	67	59	68	66	55	50	56	58	58	62
T H E T A	2000	34	33	33	32	37	40	42	41	33	37
	1981	63	62	66	63	56	52	70	69	58	63

Table III c. Matrix made of Sanders Similarity Indices for samples in Biofacies Eta plotted against Biofacies Theta of the Mochras Borehole.

MOCHRAS BORE HOLE

BIOFACIES-----IOTA

BIOFACIES LAMBDA

B	2548	2520	2486	2471	2448	2262	2234	2220	2121	2826	2807	2746	2720	2692
I 2548	100	60	63	58	49	39	55	63	58	35	19	24	18	10
O 2520	60	100	58	62	43	30	48	60	50	38	21	25	25	15
F 2486	63	58	100	56	63	50	67	64	55	31	16	25	16	10
A 2471	58	62	56	100	38	36	54	52	42	29	22	20	16	17
C 2448	49	43	63	38	100	43	52	58	65	23	9	18	18	3
I 2262	39	30	50	36	43	100	48	41	43	21	18	19	0	8
E 2234	55	48	67	54	52	48	100	73	44	19	13	14	4	7
S 2220	63	60	64	52	58	41	73	100	59	33	19	23	18	8
i 2121	58	50	55	42	65	43	44	59	100	30	14	19	29	4
B 2429	47	46	52	47	32	26	54	62	33					
I 2878	35	40	39	38	22	18	45	49	24					
O 2210	53	51	56	56	42	38	67	67	44					
F 2177	57	52	58	52	37	34	59	65	38					
A 2153	47	46	42	43	25	23	45	56	40					
C 2139	52	53	56	46	37	29	52	66	42					
I 2106	48	50	48	46	31	26	55	59	38					
E 2043	33	36	35	34	18	16	40	46	25					
S 2025	27	34	32	33	11	13	35	39	16					
T 2000	56	59	60	53	42	39	64	62	44					
H														
E 1981	41	44	42	38	23	20	44	54	31					
T														
A														

Table III d. Matrix made of Sanders's similarity indices for samples in Biofacies Iota, in Biofacies Iota plotted against Biofacies Lambda, and in Biofacies Theta plotted against Biofacies Iota in the Mochras Borehole.

MOCHRAS BOREHOLE						
B I O F A C I E S						LAMBDA
	2826	2807	2746	2720	2692	
L	2826	100	66	50	17	42
A						
M	2807	66	100	48	46	43
D						
A	2746	50	48	100	17	14
	2720	50	46	17	100	82
	2692	42	43	14	82	100
B	3273	33	19	27	0	7
I						
O	3232	33	18	30	0	7
F						
A	3192	28	20	21	0	6
C						
I	3174	31	17	26	0	5
E						
S	3128	36	20	40	0	7
E	3017	39	19	44	2	8
T						
A	2956	38	27	33	2	9
	2942	33	26	28	8	9
	2896	32	21	28	2	6
	2849	35	28	33	5	10

Table III e. Matrix made of Sanders Similarity Indices for samples in Biofacies Lambda and in Biofacies Eta plotted against Biofacies Lambda in the Mochras Borehole.

STEEPLE ASTON BOREHOLE

B I O F A C I E S DELTA

	286	306	402	434	486	495	536
286	100	77	56	57	66	55	67
306	77	100	68	68	44	39	47
402	56	68	100	68	54	35	44
434	57	68	68	100	53	33	55
486	66	44	54	53	100	44	63
495	55	39	35	33	44	100	64
536	67	47	44	55	63	64	100

Table III f. Matrix made of Sanders Similarity Indices for samples in Biofacies Delta of the Steeple Aston Borehole.

S T E E P L E A S T O N B O R E H O L E																
BIOFACIES								DELTA		B I O F A C I E S				KAPPA		
		285	306	402	434	486	495	536			327	342	358	343	378	388
G A M M A	212	48	41	30	42	59	22	33			28	11	3	3	29	7
	226	43	49	57	38	49	38	46			18	8	3	4	15	5
	235	50	51	40	41	38	45	49			13	9	4	4	19	6
	258	23	25	18	17	22	10	16			25	16	7	9	28	13
1	267	57	57	49	47	53	31	44			34	16	9	11	36	12
	277	43	39	39	46	36	27	30			33	18	14	13	29	16
	327	38	54	55	56	30	9	24			100	68	60	37	60	49
K A P P A	342	29	39	46	44	12	10	9			58	100	64	42	58	58
	358	15	32	41	40	3	3	3			60	64	100	72	64	75
	373	13	25	41	29	5	3	4			37	42	72	100	67	65
	378	37	46	58	53	33	12	22			60	58	64	67	100	69
	388	20	37	45	39	9	6	10			49	58	75	65	69	100

Table III g. Matrix made of Sanders Similarity Indices for samples in Biofacies Kappa, in Biofacies Kappa plotted against Biofacies Delta, and in Biofacies Kappa plotted against Biofacies Gamma 1 in the Steeple Aston Borehole.

STEEPLE ASTON BORE HOLE						
B I O F A C I E S GAMMA 1						
	212	226	235	258	267	277
212	100	46	45	33	61	52
226	46	100	90	61	69	51
235	45	90	100	73	70	56
258	33	61	73	100	52	40
267	61	69	70	52	100	77
277	52	51	56	40	77	100

Table III h. Matrix made of Sanders Similarity Indices for samples in Biofacies Gamma 1 of the Steeple Aston Borehole.

B I O F A C I E S

	COCKLEPITS		MOCHRAS SAMPLES				
	19	20	2692	2720	2746	2807	2826
19	100	64	47	38	19	46	48
21	64	100	80	71	15	54	46
2692	47	80	100	82	14	43	42
2720	38	71	82	100	17	46	50
2746	19	15	14	17	100	48	50
2807	46	54	43	46	48	100	66
2836	48	46	42	50	50	66	100

Table III i. The comparison of the Cocklepits assemblages from intervals 19.18-20.11 and 21.06-21.96 with Mochras Bore Hole Biofacies 4 shows that the Cocklepits assemblages are as similar to the Mochras Biofacies as the members of that Biofacies are to themselves. Sample 2746 is weakly linked to the biofacies as the proportions of Lingulina tenera and Rheinholdella macfadyenii are reversed. Sample 2746 has 51 percent Lingulina tenera and Rheinholdella macfadyenii has only 5 percent.

B I O F A C I E S D E L T A

S T E E P L E A S T O N B O R E H O L E

		286	306	402	434	486	495	536
C								
O	22	61	44	37	40	49	65	71
C								
K	26	60	41	39	35	63	54	69
L								
E	38	64	46	42	37	51	85	70
P								
I	43	61	44	38	32	53	84	63
T								
S	48	56	73	64	64	54	37	45
B	51	66	45	44	44	59	54	79
I								
O	57	52	51	43	43	70	32	57
F								
A	60	50	36	32	36	42	46	49
C								
I	70	66	48	42	49	63	58	79
E								
S	92	61	44	38	37	45	56	56
	93	62	49	38	57	49	63	68

Table III j. Matrix made of Sanders Similarity Indices comparing Biofacies Delta of the Steeple Aston Borehole with Cocklepits Factor Group 2. It shows that these samples belong to one biofacies: Biofacies Delta.

B I O F A C I E S ALPHA 1							
COCKLEPITS FACTOR GROUP 1							
C							
O							
C		11	27	30	35	73	78
K							
L							
E	11	100	45	50	44	49	51
P							
I	27	45	100	53	76	33	33
T							
S	30	50	53	100	58	33	42
F							
35		44	76	58	100	28	28
/							
G	73	49	33	33	28	100	61
1	78	51	33	42	28	61	100

Table III k. Matrix made of Sanders Similarity Indices comparing factor group 1 members which shows the loose tie that samples 73 and 78 have with the rest of the group. These two samples were drawn from the Frodingham Ironstone interval.

STEEPLE ASTON BOREHOLE

B I O F A C I E S A L P H A

B I O F A C I E S		81	82	83	86	90	95	97
	81	100	60	49	41	41	26	25
	82	60	100	61	31	51	34	33
	83	49	61	100	24	55	38	38
	86	41	31	24	100	13	18	14
A L P H A	90	41	51	55	13	100	15	39
	95	26	34	38	18	15	100	28
	97	25	33	38	14	39	28	100

Appendix III 1. Matrix made of Sanders Similarity Indices for samples in Biofacies Alpha of the Cocklepit Borehole.

B I O F A C I E S A L P H A

H E T L O S F A C T O R G R O U P 5	HETLOS FACTOR GROUP 5								
		283	120	108	106	105	104	103	100
	283	100	39	43	39	51	31	53	15
	120	39	100	55	29	37	9	47	2
	108	43	55	100	42	41	49	85	48
	106	39	29	42	100	29	38	47	34
	105	51	37	41	39	100	17	44	15
	104	31	9	49	88	17	100	59	82
	103	53	47	85	47	44	59	100	45
	100	15	2	48	34	15	82	45	100

C O C K L E P I T S A L P H A	HETLOS FACTOR GROUP 5								
		283	120	108	106	105	104	103	100
	81	51	47	25	41	32	13	30	4
	82	60	42	36	46	49	21	30	14
	83	63	19	39	50	35	34	43	25
	85	33	49	19	11	21	1	19	0
	89	37	29	13	54	26	15	30	5
	91	55	33	86	44	41	66	87	55
	97	33	6	21	54	23	28	30	20

Table III m. Matrix made of Sanders Similarity Indices for samples in Biofacies Alpha of the Cocklepits Borehole compared with Dorset Factor Group 5. This is Biofacies Alpha from a near shore environment.

B I O F A C I E S B E T A											
HETLOS FACTOR GROUP 1											
		284	279	137	136	133	131	130	129	112	102
H											
E											
T	284	100	62	62	55	65	64	59	63	62	59
L	279	62	100	51	70	81	65	77	75	76	76
O	137	62	51	100	50	52	58	63	69	58	65
S	136	55	70	50	100	70	63	72	70	71	70
F	133	65	81	52	70	100	64	81	77	85	75
A	131	64	65	58	63	64	100	64	63	68	63
C	130	59	77	63	72	81	64	100	83	85	76
T	129	63	75	69	70	77	63	83	100	85	75
O	112	62	76	58	71	85	68	85	85	100	75
R	102	54	76	65	70	75	63	76	75	75	100
G											
R											
O											
U											
P											
1											

HETLOS FACTOR GROUP 1											
		284	279	137	136	133	131	130	129	112	102
H											
E											
T											
L											
O	282	74	65	53	53	59	56	50	50	55	50
S	281	63	37	61	37	34	49	46	48	43	34
F	280	44	39	58	32	38	56	46	41	39	40
A	132	52	49	57	51	49	66	57	54	51	48
C	123	60	35	38	31	34	37	36	40	41	33
T	122	70	42	44	41	45	45	43	48	48	41
O	107	52	41	41	49	41	45	48	39	45	44
R											
G											
R											
O											
U											
P											
3											

Table III n. Matrix made of Sanders Similarity Indices comparing samples in Dorset Factor Group 1 with Dorset Factor Group 3, Biofacies Gamma.

BIOFACIES DELTA vs. EPSILON

H E T L O S	HETLOS FACTOR GROUP 2								HETLOS FACTOR GROUP 4					
	135	126	124	118	117	116	115	110	125	121	119	114	113	111
S 135	100	83	77	61	78	60	59	69	30	37	54	45	47	56
F 126	83	100	71	69	81	67	69	76	37	40	57	47	50	57
A 124	77	71	100	62	86	67	74	83	64	43	57	66	59	63
C 118	61	69	62	100	68	78	85	68	28	54	63	50	56	64
T 117	78	81	86	68	100	67	68	77	35	41	59	53	54	6
R 116	60	67	67	78	67	100	75	70	34	60	69	55	60	59
G 115	59	69	74	85	68	75	100	80	40	61	72	66	77	66
O 110	59	76	83	68	77	70	80	100	69	43	65	76	70	75
P 282	53	61	55	57	61	52	55	50	29	28	40	24	30	36
2 281	50	55	58	50	52	66	63	54	30	51	66	48	46	49
H 280	50	53	53	55	57	53	56	51	23	32	43	36	38	44
E 132	60	60	57	50	59	48	50	53	9	19	34	26	27	35
L 123	38	46	45	59	49	66	66	49	28	61	63	39	50	46
S 122	44	53	53	62	56	61	68	47	23	47	60	45	39	38
F 107	49	63	45	52	45	60	56	50	14	21	37	27	31	38
A 107	49	63	45	52	45	60	56	50	14	21	37	27	31	38

3

Table III o. Matrix made of Sanders Similarity Indices for samples from the Dorset Outcrops of the Hettangian and Lower Sinemurian comparing Factor Group 2 with Factor Group 4, Factor Group 2 with Factor Group 3 and Factor Group 3 with Factor Group 4.

		B I O F A C I E S				DELTA			
		HETLOS		FACTOR		GROUP 2			
S T A S T O N D E L T A		135	126	124	118	117	116	115	110
	286	62	68	58	59	64	56	61	57
	306	47	47	45	50	45	45	53	45
	402	44	46	40	45	41	41	50	43
	434	46	48	44	49	46	46	47	42
	486	60	61	68	61	59	61	68	59
	495	65	59	47	47	59	41	46	47
	536	84	84	66	66	79	70	66	69

Table III p. Matrix made of Sanders Similarity Indices comparing samples in Biofacies Delta of the Steeple Aston Borehole with Factor Group 2 of the Dorset Outcrop samples from the Hettangian and Lower Sinemurian.

B I O F A C I E S D E L T A											
		C O M P O S			F A C T O R			G R O U P 2			
		331	330	329	324	307	299	291	287	286	285
C O M P O S	331	100	55	89	73	61	54	79	55	59	61
	330	55	100	59	61	54	53	59	46	46	49
	329	89	59	100	78	65	62	71	58	51	55
	324	73	61	78	100	67	56	72	68	51	55
	307	61	54	65	67	100	73	69	76	34	40
F A C T O R	299	54	53	62	56	73	100	62	67	32	33
	291	79	59	71	72	69	62	100	64	64	65
	287	55	46	58	68	76	67	64	100	30	32
	286	59	46	51	50	34	32	64	30	100	79
	285	61	49	55	55	40	33	65	32	79	100
G R O U P	2										
H E T L O S	135	81	54	76	67	52	44	69	48	62	63
	126	80	59	82	72	59	50	72	54	54	60
	124	74	51	74	70	61	54	71	53	45	48
	118	60	59	62	59	73	53	57	55	42	45
	117	78	57	80	70	56	49	69	47	68	60
F A C T O R	116	64	54	72	62	68	54	55	60	37	43
	115	68	58	71	65	67	65	69	61	43	47
	110	72	54	75	63	56	47	63	51	46	49
G R O U P	2										

Table III q. Matrix made of Sanders Similarity Indices comparing Compos Cluster-factor group 2 with Steeple Aston Biofacies Delta at Dorset (Hetlos factor group 2).

B I O F A C I E S KAPPA

COMPOS FACTOR GROUP 6

C O M P O S		319	317	313	311	302	301	300
S	319	100	37	37	52	51	51	50
F	317	37	100	53	40	65	53	47
A	313	37	53	100	32	51	41	36
C	311	52	40	32	100	64	71	64
T	302	51	65	51	64	100	62	70
R	301	51	53	41	71	62	100	80
G	300	50	47	36	64	70	80	100
R								
O								
U								
P								
6								
S								
T		319	317	313	311	302	301	300
A								
S	470	38	33	28	41	34	36	43
T	412	48	47	52	51	61	53	50
O								
N								
K	388	39	52	58	40	55	45	43
A	373	53	60	54	54	70	60	56
P	358	33	47	64	31	46	38	37
P								
A	342	35	39	37	44	42	41	39
	327	49	41	39	49	44	47	44

Table III r. Matrix made of Sanders Similarity Indices comparing Compos Cluster-factor group 6 with Steeple Aston Biofacies Kappa.

B I O F A C I E S EPSILON

COMPOS FACTOR GROUP 1						HETLOS FACTOR GROUP 4					
C		332	327	309	303	125	121	119	114	113	111
O											
M	332	100	80	49	55	53	38	68	66	64	70
P											
O	327	80	100	51	60	43	44	70	65	57	63
S											
F	309	49	51	100	67	42	50	59	54	52	45
/											
G	303	55	60	67	100	35	40	57	54	54	60
1											

Table III s. Matrix made up of Sanders Similarity Indices comparing Compos Cluster-factor group 1 with Hetlos Factor group 4. This is Biofacies Epsilon.

B I O F A C I E S Zeta

C O M P	COMPOS FACTOR GROUP 3				COMPOS FACTOR GROUP 4				
		320	315		318	308	306	305	304
F	320	100	68		50	53	48	43	49
/									
G	315	68	100		71	55	49	58	54
3									
C	318	50	71		100	47	53	49	66
O									
M	308	53	55		47	100	61	58	51
P	306	48	49		53	61	100	76	73
F									
/	305	43	58		49	58	76	100	68
G									
	304	49	54		66	51	73	68	100
4									

Table III t. Matrix made up of Sanders Similarity Indices comparing Compos Cluster-factor group 3 with Compos Factor group 4.

		COMPOS FACTOR GROUPS 3/4						YORMID FACTOR GROUP 1				
C		318	315	308	306	305	304	332	325	212	209	206
O												
M												
P	318	100	71	47	52	48	66					
O												
S	315	71	100	55	44	55	54					
F	308	47	55	100	60	58	51					
/												
G	306	52	44	60	100	76	73					
3	305	48	55	58	76	100	68					
/												
4	304	66	54	51	73	68	100					
Y												
O												
R	332	43	26	29	57	60	68	100	45	41	47	64
M												
I	325	28	51	52	46	62	37	45	100	63	43	48
D												
	212	39	55	55	49	45	46	41	63	100	42	55
F												
/	209	42	41	55	54	62	51	47	43	42	100	48
G												
	206	44	28	32	55	53	52	64	48	55	48	100
1												

Table III u. Matrix made of Sanders Similarity Indices comparing Yormid Cluster-factor group 1 with Compos Cluster-factor group 3 and 4. There is reasonable agreement and this is likely a single biofacies.

Y O R K S H I R E O U T C R O P S											
F A C T O R G R O U P	FACTOR GROUP 1					FACTOR GROUP 2			FACTOR GROUP 3		
	216	217	212	209	206	201	202	203	213	200	199
216	100	40	55	56	54						
217	40	100	47	58	48						
212	55	47	100	52	55						
209	56	58	52	100	59						
206	54	48	55	59	100						
201	5	5	10	1	4	100	46	12			
202	20	20	30	27	24	46	100	45			
203	14	4	22	15	20	12	45	100			
213	12	27	19	17	6	0	13	2	100	39	33
200	10	10	10	10	10	6	20	5	39	100	53
199	1	1	1	1	1	0	11	3	33	53	100

Table III v. Matrix made of Sanders Similarity Indices comparing Yorshire Outcrop Cluster-factor groups. The comparison on the matrix shows there is much compositional variation in each group and that there is low similarity among groups.

Mochras Borehole Samples

sample interval (depth in feet from surface)	Zone
2849' 4"-2854' 1"	<u>P. spinatum</u>
2896' 6"-2900' 9"	<u>P. spinatum</u>
2942' 11"-2947' 1"	<u>P. spinatum</u>
2956' 8"-2961' 5"	<u>P. spinatum</u>
3017' 6"-3022' 2"	<u>A. margatitatus</u>
3077' 10"-3082' 4"	<u>A. margatitatus</u>
3128' 8"-3133' 6"	<u>A. margatitatus</u>
3174' 0"-3178' 6"	<u>A. margatitatus</u>
3192' 0"-3196' 2"	<u>A. margatitatus</u>
3232' 0"-3236' 6"	<u>A. margatitatus</u>
3273' 2"-3277' 8"	<u>A. margatitatus</u>

Table IV. Mochras B, samples are taken from designated intervals below the tenuicostatum Ammonite Zone of the Toarcian Stage.

Mochras Borehole Samples

sample interval (depth in feet from surface)	Zone
1981'-1986'4"	<u>D. levesquei</u>
2000'10"-2000'15"	<u>D. levesquei</u>
2025'2029'9"	<u>D. levesquei</u>
2063'8"-2068'10"	<u>D. levesquei</u>
2106'11"-2111'9"	<u>D. levesquei</u>
2121'-2125'3"	<u>D. levesquei</u>
2139'6"-2144'3"	<u>D. levesquei</u>
2153'8"-2158'6"	<u>D. levesquei</u>
2177'6"-2182'4"	<u>G. thouarsense</u>
2210'2"-2215'6"	<u>G. thouarsense</u>
2220'4"-2225'1"	<u>G. thouarsense</u>
2234'8"-2239'2"	<u>G. thouarsense</u>
2262'6"-2266'9"	<u>H. variabilis</u>
2378'6"-2383'1"	<u>H. variabilis</u>
2397'4"-2402'0"	<u>H. bifrons</u>
2415'11"-2420'8"	<u>H. bifrons</u>
2429'9"-2434'5"	<u>H. bifrons</u>
2448'10"-2453'6"	<u>H. bifrons</u>
2471'6"-2476'5"	<u>H. bifrons</u>
2486'2"-2491'2"	<u>H. bifrons</u>
2520'3"-2525'	<u>H. bifrons</u>
2548'2"-2552'11"	<u>F. falciferum</u>
2608'3"-2613'1"	<u>F. falciferum</u>
2663'10"-2668'5"	<u>F. falciferum</u>
2692'4"-2697'	<u>F. falciferum</u>
2720'6"-2725'6"	<u>F. falciferum</u>
2746'9"-2751'7"	<u>D. tenuicostatum</u>
2807'6"-2812'3"	<u>D. tenuicostatum</u>
2826'6"-2830'6"	<u>D. tenuicostatum</u>

Table V. Mochras A, samples are taken from designated intervals above the base of the tenuicostatum Ammonite Zone of the Toarcian Stage.

Steeple Aston Borehole Samples

sample interval (depth in feet from surface)	Zone
48'6"-53'6"	Top of Lias
58'6"-60'6"	Top of Lias
78'8"-83'7"	<u>H. bifrons</u>
88'6"-93'4"	<u>H. bifrons</u>
135'2"-138'4"	<u>A. margaritatus</u>
152'2"-157'4"	<u>A. margaritatus</u>
192'4"-197'4"	<u>P. davoei</u>
202'8"-207'6"	<u>P. davoei</u>
212'4"-217'0"	<u>P. davoei</u>
226'0"-230'8"	<u>T. ibex</u>
235'0"-239'10"	<u>T. ibex</u>
258'0"-263'0"	<u>T. ibex</u>
267'10"-272'11"	<u>T. ibex</u>
277'8"-282'5"	<u>T. ibex</u>
286'10"-292'0"	<u>T. ibex</u>
327'6"-333'3"	<u>T. ibex</u>
342'6"-347'11"	<u>U. jamesoni</u>
358'4"-362'6"	<u>U. jamesoni</u>
373'9"-378'8"	<u>U. jamesoni</u>
378'8"-383'8"	<u>U. jamesoni</u>
388'8"-393'8"	<u>E. raricostatum</u>
402'10"-407'10"	<u>E. raricostatum</u>
412'10"-418'0"	<u>E. raricostatum</u>
434'2"-439'7"	<u>E. raricostatum</u>
470'0"-474'11"	(?) <u>O. oxynotum</u>
486'5"-490'8"	<u>A. obtusum</u>
495'10"-500'8"	<u>A. obtusum</u>
516'1"-521'0"	<u>C. turneri</u>
536'4"-539'4"	<u>C. turneri</u>

* Zonation of the samples based on Poole (1977).

Table VI. Steeple Aston, samples are taken from designated intervals from the C. turneri Ammonite Zone through the Upper Lias.

Cocklepits Borehole Samples

sample interval (depth in meters from surface)	Zone
11.61-12.27	Top of Lias
14.36-14.90	Top of Lias
16.26-16.30	<u>D. tenuicostatum</u>
19.18-20.11	<u>D. tenuicostatum</u>
21.06-21.96	<u>D. tenuicostatum</u>
22.78-23.32	<u>D. tenuicostatum</u>
23.77-24.72	<u>D. tenuicostatum</u>
26.60-27.10	<u>P. spinatum</u>
27.50-28.43	<u>P. davoei</u>
30.31-31.25	<u>P. davoei</u>
35.89-36.80	<u>T. ibex</u>
38.70-39.60	<u>T. ibex</u>
43.30-44.32	<u>U. jamesoni</u>
48.91-49.86	<u>U. jamesoni</u>
49.86-50.80	<u>U. jamesoni</u>
51.73-52.65	<u>U. jamesoni</u>
53.65-56.37	<u>U. jamesoni</u>
55.43-56.37	<u>E. raricostatum</u>
57.32-58.20	<u>O. oxynotum</u>
60.99-61.79	<u>A. obtusum</u>
66.18-67.80	<u>A. obtusum</u>
70.52-71.37	<u>C. turneri</u>
73.12-73.93	<u>A. semicostatum</u>
78.22-79.08	<u>A. semicostatum</u>
81.96-82.46	<u>A. semicostatum</u>
82.46-83.38	<u>A. bucklandi</u>
83.38-84.27	<u>S. angulata</u>
86.00-86.95	<u>A. liasicus</u>
89.55-90.40	<u>A. liasicus</u>
92.19-92.92	<u>P. planorbis</u>
93.71-94.79	<u>P. planorbis</u>
95.48-96.37	<u>P. planorbis</u>
96.25-98.13	<u>P. planorbis</u>

Table VII. Cocklepits, samples are taken from designated intervals from the P. planorbis Ammonite Zone through the Upper Lias.

SAMPLE INFORMATION FROM UNION OIL COMPANY DATA

<u>Sample Number</u>	<u>Description</u>
KMP75-100	Pinhay Bay , Devon, Rhaetic, just below the top of the White Lias
KMP75-101	Pinhay Bay , Devon, Blue Lias, Bed H1 of Lang, <u>P. planorbis</u> Zone, Barren.
KMP75-102	Pinhay Bay , Devon, Bed H29 of Lang paper shale, <u>P. planorbis</u> Zone
KMP75-103	Pinhay Bay , Devon, Bed H29 of Lang siltstone at bed top <u>P. planorbis</u> Zone
KMP75-104	Pinhay Bay , Devon, Bed H53 of Lang, top shale of the <u>C. johnstoni</u> Sub-zone
KMP75-105	Pinhay Bay , Devon, Bed H29 of Lang upper part, <u>C. johnstoni</u> Sub-zone
KMP75-106	Pinhay Bay , Devon, Bed H59 of Lang paper shale, <u>A. liassicus</u> Zone
KMP75-107	Pinhay Bay , Devon, Bed H61 of Lang paper shale, <u>A. liassicus</u> Zone
KMP75-108	Pinhay Bay , Devon, Bed H71 of Lang paper shale, <u>A. liassicus</u> Zone
KMP75-109	Pinhay Bay , Devon, Bed H75 of Lang, <u>S. angulata</u> Zone
KMP75-110	Pinhay Bay , Devon, Bed H85 of Lang, <u>S. angulata</u> Zone
KMP75-111	Pinhay Bay , Devon, Bed H91 of Lang, <u>S. angulata</u> Zone
KMP75-112	Seven Rock Point, Devon, Bed 6 of Lang, Lower Skulls Shales, <u>S. angulata</u> Zone
KMP75-113	Seven Rock Point, Devon, Bed 16 of Lang, Upper White Shales, <u>S. angulata</u> Zone
KMP75-114	Seven Rock Point, Devon, Bed 18 of Lang, Specketty Shales, top bed of <u>S. angulata</u> Zone
KMP75-115	Seven Rock Point, Devon, Bed 22 of Lang, Mongrel Shales, <u>A. bucklandi</u> Zone

Table VIII. Dorset-Devon, samples are taken from
Hettangian, Sinemurian, Pliensbachian and Toarcian outcrops.

- KMP75-116 Seven Rock Point, Devon, Bed 28 of Lang, Top Tape Shales, A. bucklandi Zone
- KMP75-117 Seven Rock Point, Devon, Bed 32 of Lang, Gumption Shales, A. bucklandi Zone
- KMP75-118 Seven Rock Point, Devon, Bed 36 of Lang, bottom part of Rattle Shales, A. bucklandi Zone
- KMP75-119 Seven Rock Point, Devon, Bed 36 of Lang, top part of Rattle Shales, A. bucklandi Zone
- KMP75-120 Seven Rock Point, Devon, Bed 42 of Lang, Venty Shales, A. bucklandi Zone
- KMP75-121 Seven Rock Point, Devon, Bed 44 of Lang, Top Quick Shales, A. bucklandi Zone
- KMP75-122 Seven Rock Point, Devon, Bed 46 of Lang, Glass Bottle Shales, top bed of A. bucklandi Zone
- KMP75-123 The Spittles, E. of Lyme Regis, Dorset SY 348 927, Bed 48 of Lang, A. semicostatum Zone (reynesi)
- KMP75-124 The Spittles, E. of Lyme Regis, Dorset, Fish Bed Shales, Bed 50 of Lang, A. semicostatum Zone (scipionianum)
- KMP75-125 The Spittles, E. of Lyme Regis, Dorset SY 349 929-350 928, Lower Lias, Shales with Beef (calcite), Bed 56a, of Lang A. semicostatum Zone (sauzeanum)
- KMP75-126 The Spittles, E. of Lyme Regis, Dorset SY 349 929-350 928, Lower Lias, Shales with Beef (calcite), Bed 59, of Lang A. semicostatum Zone (sauzeanum)
- KMP75-127 The Spittles, E. of Lyme Regis, Dorset SY 349 929-350 928, Lower Lias, Shales with Beef (calcite), Bed 63d, of Lang A. semicostatum Zone (sauzeanum)
- KMP75-128 The Spittles, E. of Lyme Regis, Dorset SY 349 929-350 928, Lower Lias, Shales with Beef (calcite), Bed 70c, of Lang A. semicostatum Zone (sauzeanum)

- KMP75-129 The Spittles, E. of Lyme Regis, Dorset
SY 349 929-350 928, Lower Lias, Shales
with Beef (calcite), Bed 73b of Lang,
C. turneri Zone (brooki), basal marl of
zone
- KMP75-130 The Spittles, E. of Lyme Regis, Dorset
SY 349 929-350 928, Lower Lias, Shales
with Beef (calcite), Bed 74b, of Lang,
C. turneri Zone (brooki)
- KMP75-131 The Spittles, E. of Lyme Regis, Dorset
SY 349 929-350 928, Lower Lias, Shales
with Beef (calcite), Bed 74c, of Lang,
C. turneri Zone (brooki)
- KMP75-132 The Spittles, E. of Lyme Regis, Dorset
SY 349 929-350 928, Lower Lias, Shales
with Beef (calcite), Bed 74g, of Lang,
C. turneri Zone (birchi) basal shale of
subzone
- KMP75-133 The Spittles, E. of Lyme Regis, Dorset
SY 349 929-350 928, Lower Lias, Shales
with Beef (calcite), Bed 74n, of Lang,
C. turneri Zone (birchi)
- KMP75-134 The Spittles, E. of Lyme Regis, Dorset
SY 349 929-350 928, Lower Lias, Shales
with Beef (calcite), Bed 74u, of Lang,
C. turneri Zone (birchi)
- KMP75-135 The Spittles, E. of Lyme Regis, Dorset
SY 349 929-350 928, Lower Lias, Shales
with Beef (calcite), Bed 74w, of Lang,
C. turneri Zone below birchi nodular
limestone
- KMP75-136 The Spittles, E. of Lyme Regis, Dorset et
SY 349 929-350 928, Lower Lias, Shales
with Beef (calcite), Bed 75b, of Lang,
C. turneri Zone , between birchi nodular
and birchi tabular limestone
- KMP75-137 The Spittles, E. of Lyme Regis, , Dorset
SY 349 929-350 928, Lower Lias, Black Ven
Marls, Bed 76b of Lang, C. turneri Zone,
shales next above birchi tabular limestone

- KMP75-277 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls, shales
next above birchi tabular limestone, Bed
76b of Lang, C. turneri Zone (birchi)
- KMP75-278 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls, 3.0m
above birchi tabular limestone, Bed
76c of Lang, C. turneri Zone (birchi)
- KMP75-279 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls, 4.5m
above birchi tabular limestone, Beds
76e-f of Lang, C. turneri Zone (birchi)
- KMP75-280 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls,
77b of Lang, C. turneri Zone (birchi)
- KMP75-281 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls, Bed
79 at 0.5m above Bed 78 of Lang, C.
turneri Zone
- KMP75-282 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls, Bed
79 of Lang, at 0.5m below the Lower Cement
Bed(Bed 80), C. turneri Zone
- KMP75-283 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls, Bed
81 of Lang, at 2.5m below the Pavior= Upper
Cement Bed (Bed 82), C. turneri Zone
- KMP75-284 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls, Bed
81 of Lang, immediately below the Pavior=
Upper Cement Bed (Bed 82), C. turneri Zone,
top shale of zone
- KMP75-285 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls, Bed
83 of Lang, immediately above the Pavior=
Upper Cement Bed (Bed 82), A. obtusum Zone,
basal shale of zone
- KMP75-286 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls, Bed
83 of Lang, 1.5m above Pavior= Upper
Cement Bed (Bed 82), A. obtusum Zone

- KMP75-287 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls, top of
83 of Lang, at 4.0m above the Pavior= Upper
Cement Bed (Bed 82), A. obtusum Zone
- KMP75-288 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls,
at 7.0m above the Pavior= Upper
Cement Bed (Bed 82), A. obtusum Zone
- KMP75-289 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls,
at 10.0m above the Pavior= Upper
Cement Bed (Bed 82), A. obtusum Zone
- KMP75-290 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls,
at 13m above the Pavior= Upper
Cement Bed (Bed 82), A. obtusum Zone
- KMP75-291 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls,
at 15.6m above the Pavior= Upper
Cement Bed (Bed 82) just below Limestone
with Brachiopods, A. obtusum Zone
- KMP75-292 Black Ven, W. of Charmouth, Dorset SY 356
932, Lower Lias , Black Ven Marls,
at 18.3m above the Pavior= Upper
Cement Bed (Bed 82) just below Limestone
with Brachiopods, A. obtusum Zone

Note: Samples KMP75- to 293 show an apparent over-measurement of the thickness of the interval sampled. Lang (1926) gives 41 feet 9 inches (= 12.67m) for the interval top of the Upper Cement Bed to the top of the Coinstone. Our measurements give 19.2m. Lang's measurements were made mostly on Stonebarrow and ours entirely on Black Ven. Even allowing for some thickening westwards and for the angle of slope of the section, there seems to be some excess here. For this reason, neither Lang Beds 84-86 nor the boundary between the obtusum and stellare subzones have been identified.

R.V.M. Union Oil

- KMP75-294 Stonebarrow Cliff, E. of Charmouth, Dorset,
SY 374 929-374 931, Lower Lias, Black Ven
Marls, 0.8m above Coinstone, Bed 90c of
Lang, E. raricostatum Zone (densinodulum)

- KMP75-295 Stonebarrow Cliff, E. of Charmouth, Dorset, SY 374 929-374 931, Lower Lias, Black Ven Marls, 4.0m above Coinstone, Bed 94 of Lang, E. raricostatum Zone (densinodulum)
- KMP75-296 Stonebarrow Cliff, E. of Charmouth, Dorset, SY 374 929-374 931, Lower Lias, Black Ven Marls, 7.0m above Coinstone, Bed 96 of Lang, E. raricostatum Zone (densinodulum)
- KMP75-297 Stonebarrow Cliff, E. of Charmouth, Dorset, SY 374 929-374 931, Lower Lias, Black Ven Marls, 9.6m above Coinstone, Bed 98 of Lang, E. raricostatum Zone (raricostatum) basal clay of subzone
- KMP75-298 Stonebarrow Cliff, E. of Charmouth, Dorset, SY 374 929-374 931, Lower Lias, Black Ven Marls, 2.7m above Watch Ammonite Stone, Bed 100 of Lang, E. raricostatum Zone (densinodulum)
- KMP75-299 Stonebarrow Cliff, E. of Charmouth, Dorset, SY 374 929-374 931, Lower Lias, Black Ven Marls, 4.2m above Watch Ammonite Stone, and immediately below Hummocky Limestone, Bed 102 of Lang, E. raricostatum Zone (raricostatum)

Note: Slight discrepancies between Lang's measurements of Coinstone--Watch Ammonite Stone and Watch Ammonite Stone -- Hummocky Limestone can be accounted for by the angle of slope of the section.

R.V.M. Union Oil

- KMP75-300 Stonebarrow Cliff, E. of Charmouth, Dorset, SY 374 929-374 931, Lower Lias, Belemnite Marls, Lower Paler Marls 0.8m above Hummocky Limestone, Bed 107 of Lang, U. jamesoni Zone (taylori)
- KMP75-301 Stonebarrow Cliff, E. of Charmouth, Dorset, SY 374 929-374 931, Lower Lias, Belemnite Marls, base of Lower Darker Marl, 2.15m above Hummocky Limestone Bed 110 of Lang, U. jamesoni Zone (polymorphus)
- KMP75-302 Stonebarrow Cliff, E. of Charmouth, Dorset, SY 374 929-374 931, Lower Lias, Belemnite Marls, base of Lower Darker Marl, 7m above Hummocky Limestone Bed 110 of Lang, U. jamesoni Zone (polymorphus)

- KMP75-303 Stonebarrow Cliff, E. of Charmouth, Dorset,
SY 374 929-374 931, Lower Lias, just below
Hummocky Limestone, similar to sample 299
- KMP75-304 Stonebarrow Cliff, E. of Charmouth, Dorset,
SY 374 929-374 931, Lower Lias, Belemnite
Marls, Lower Paler Marls,
Bed 108 of Lang, U. jamesoni Zone (taylori)
- KMP75-305 Immediately W. of waterfall at the mouth of
Ridge Water, E. of Charmouth, Dorset,
SY 388 924, Belemnite Marls, Lower Darker Marl,
Bed 110b of Lang, U. jamesoni Zone
(polymorphus)
- KMP75-306 Immediately W. of waterfall at the mouth of
Ridge Water, E. of Charmouth, Dorset,
SY 388 924, Belemnite Marls, Lower Darker Band,
Bed 112 of Lang, U. jamesoni Zone
(polymorphus) top of subzone
- KMP75-307 Immediately W. of waterfall at the mouth of
Ridge Water, E. of Charmouth, Dorset,
SY 388 924, Belemnite Marls, Middle Pale Band,
Bed 113b of Lang, U. jamesoni Zone
(brevispina)
- KMP75-308 Immediately W. of waterfall at the mouth of
Ridge Water, E. of Charmouth, Dorset,
SY 388 924, Belemnite Marls, Middle Dark Band,
Bed 114 of Lang, U. jamesoni Zone
(brevispina) top of subzone
- KMP75-309 Immediately W. of waterfall at the mouth of
Ridge Water, E. of Charmouth, Dorset,
SY 388 924, Belemnite Marls, Upper Pale Band,
Bed 115 of Lang, U. jamesoni Zone
(jamesoni)
- KMP75-310 Immediately W. of waterfall at the mouth of
Ridge Water, E. of Charmouth, Dorset,
SY 388 924, Belemnite Marls, Upper Darker
Marls, lower part of Bed 118a of Lang, U.
jamesoni Zone (jamesoni)
- KMP75-311 Immediately W. of waterfall at the mouth of
Ridge Water, E. of Charmouth, Dorset,
SY 388 924, Belemnite Marls, Upper Darker
Marls, lower part of Bed 118c of Lang, T.
ibex Zone (masseanum)

- KMP75-312 . Immediately W. of waterfall at the mouth of Ridge Water, E. of Charmouth, Dorset, SY 388 924, Belemnite Marls, Belemnite Shale, Bed 119 of Lang, T. ibex (valdani)
- KMP75-313 Between Seatown and Golden Cap, Dorset SY 413 918, Belemnite Marls, Crumbly Bed, Bed 120 of Lang, T. ibex Zone (valdani)
- KMP75-314 Between Seatown and Golden Cap, Dorset SY 413 918, Green Ammonite Beds, Bed 122a of Lang, P. davoei Zone (maculatum)
- KMP75-315 W. side of Golden Cap, Dorset SY 402 919, Green Ammonite Beds, Bed 122 of Lang 4.7m below presumed Lower Limestone, P. davoei Zone (maculatum)
- KMP75-316 W. side of Golden Cap, Dorset SY 402 919, Green Ammonite Beds, Bed 122 of Lang immediately below presumed Lower Limestone, P. davoei Zone (maculatum)
- KMP75-317 Amphitheater to W. side of Golden Cap, Dorset, SY 400 920, Green Ammonite Beds, top of Bed 125 of Lang immediately below Red Band, P. davoei Zone (capricornus) top of subzone
- KMP75-318 Amphitheater to W. side of Golden Cap, Dorset, SY 400 920, Green Ammonite Beds, base of Bed 127 of Lang immediately above Red Band, P. davoei Zone (figulinum) base of subzone
- KMP75-319 Main gully on S. face of Golden Cap, Dorset, SY 408 918-407 921, Green Ammonite Beds, just below Upper Limestone, top of Bed 128 of Lang, P. davoei Zone (figulinum)
- KMP75-320 Main gully on S. face of Golden Cap, Dorset, SY 408 918-407 921, 1.5m below Lowest Tier, Bed 132 of Lang, A. margaritatus Zone, (stokesi)
- KMP75-321 Main gully on S. face of Golden Cap, Dorset, SY 408 918-407 921, Middle Lias, Eype Clay, just above Top Tier, Bed 11 of Howarth, A. margaritatus Zone, (stokesi)
- KMP75-322 Main gully on S. face of Golden Cap, Dorset, SY 408 918-407 921, Middle Lias, Eype Clay, 9.5m above Top Tier, Bed 11 of Howarth, A. margaritatus Zone, (stokesi)

- KMP75-323 Main gully on S. face of Golden Cap, Dorset,
SY 408 918-407 921, Middle Lias,
16.6m above Top Tier, top of Bed 11 of Howarth,
A. margaritatus Zone, (stokesi)
- KMP75-324 Main gully on S. face of Golden Cap, Dorset,
Eype Clay, 21.3m above Top Tier, Bed 13 of
Howarth, A. margaritatus Zone, (stokesi)
- KMP75-325 Main gully on S. face of Golden Cap, Dorset,
SY 408 918-407 921, Middle Lias, Eype Clay,
28m above Top Tier, Bed 15 of Howarth, A.
margaritatus Zone, (stokesi)
- KMP75-326
- KMP75-327 Ridge (= Down) Cliff, E. of Seatown, Dorset,
SY 423 915, Middle Lias, Eype Clay,
1m above Eype Nodule Bed, Bed 19 of Howarth, A.
margaritatus Zone, (stokesi)
- KMP75-328 Rejected
- KMP75-329 Dog House Cliff, E. of Seatown, Dorset,
SY 433 913, Middle Lias, near top of
Down Cliff Sands Bed, Bed 23 of Howarth, A.
margaritatus Zone, (stokesi)
- KMP75-330 Ridge (= Down) Cliff, E. of Seatown, Dorset,
SY 423 915, Middle Lias, Eype Clay,
10.5m above Eype Nodule Bed, Bed 19 of Howarth,
A. margaritatus Zone, (stokesi)
- KMP75-331 Thorncombe Beacon, W. of Eypes Mouth, Dorset,
SY 443 912, Upper Lias, Down Cliff Clay,
1.5m below base of Bridport Sands, D. levesquei
Zone (moorei)
- KMP75-332 Thorncombe Beacon, W. of Eypes Mouth, Dorset,
SY 443 912, Upper Lias,
9.15m below base of Bridport Sands, D.
levesquei Zone (moorei)

Yorkshire Outcrop Samples

Sample numbers	Location	Zone
KMP77-199	Bed 62, top Brackenberry Wyke	<u>D. tenuicostatum</u>
KMP77-200	Bed 61, base Brackenberry Wyke	<u>D. tenuicostatum</u>
KMP77-201	Bed 59 Brackenberry Wyke	<u>P. spinatum</u>
KMP77-202	Bed 57 Brackenberry Wyke	<u>P. spinatum</u>
KMP77-203	Bed 55 Brackenberry Wyke	<u>P. spinatum</u>
KMP77-206	Bed 40 Brackenberry Wyke	<u>P. spinatum</u>
KMP77-209	Bed 32 Jet Wyke	<u>A. margaritatus</u>
KMP77-212	Bed 27, base Jet Wyke	<u>A. margaritatus</u>
KMP77-213	Bed 25 Jet Wyke	<u>A. margaritatus</u>
KMP77-216	Bed 2 Cowbar Nab	<u>P. davoei</u>
KMP77-217	Bed 10 Cowbar Nab	<u>P. davoei</u>

Samples used from Midlands outcrops.

KMP77-290	Scissum Beds Hook Norton Railway Cutting	Upper Lias
KMP77-291	Scissum Beds Hook Norton Railway Cutting	Upper Lias
KMP77-325	Gray shale with nodules, Robin's Wood Hill	<u>ibex/davoei</u>
KMP77-332	Robin's Wood Hill	<u>A. spinatum</u>

*Samples were taken from beds described by Howarth (1955), "The Domerian of the Yorkshire Coast", Proc. York. GEO. SOC. V. 30, pp. 147-75.

Table IX. Yorkshire, samples taken from outcrop beds described by Howarth (1955).

CHECKLIST OF GRAPHIC ABUNDANCE BY HIGHEST APPEARANCE

- Abundant (>25 %)
- ▒ Common (>15 %)
- ░ Few (>5 %)
- ░ Rare (>1 %)
- ░ Very Rare (<1 %)
- ? Questionably Present
- Not Present

2849-2854	1	AMMOBACULITES UETUSTA
2896-2900	2	ASTACOLUS PAUPERATUS
2942-2947	3	BATHYSYPHON SP
2956-2961	4	DENTALINA EXILIS
3017-3022	5	DENTALINA MATUTINA
3077-3082	6	DENTALINA PSEUDOCOMMUNIS
3128-3133	7	DENTALINA TENUISTRATA
3174-3178	8	DENTALINA TERQUEMI
3192-3196	9	EOGUTTULINA INOUROCLAVIENSIS
3232-3236	10	EOGUTTULINA LIASSICA
3273-3277	11	FRONICULARIA INVOLUTA
	12	FRONICULARIA SULCATA
	13	L. VARIANS PABELLINE STAGE
	14	LAGENAHMIA AMPULLACEA
	15	LENTICULINA MUENSTERI
	16	LENTICULINA VARIANS
	17	LINGULINA CERNUA
	18	LINGULINA TENERA
	19	LINGULINA TENERA OCCIDENTALIS
	20	MARGINULINA PRIA
	21	NODOSARIA HORTONENSIS
	22	NODOSARIA NITIOANA
	23	NODOSARIA SIMONIANA
	24	NODOSARIA SIMPLEX
	25	OPHTHALMIDIUM ORBICULARE
	26	OPHTHALMIDIUM NORTHAMPTONENSIS
	27	PSEUDONODOSARIA VULGATA
	28	REINHOEELLA MACFAOYENI
	29	SPIRILLINA INFIMA
	30	SPIRILLINA POLYGYRATA
	31	VAGINULINA CLATHRATA
	32	VAGINULINA SAGGITIFORMIS
	33	VAGINULINA TRIQUETRA
	34	DENTALINA SINEHURIENSIS
	35	FRONICULARIA BRIZAEFORMIS
	36	FRONICULARIA PARADOXA
	37	PSEUDONODOSARIA MULTICOSTATA
	38	VAGINULINA CONSTRICTA
	39	ASTACOLUS STILLUS
	40	CONICOSPILLINA TROCHOIDES
	41	DENTALINA HAUSHANNI
	42	DENTALINA SP. ?
	43	LAGENA OHYSTOMA
	44	LINGULINA NODOSARIA
	45	LINGULINA TESTUDINAREA
	46	NODOSARIA SCULPTA
	47	BRIZALINA LIASSICA
	48	CITHARINA COLLIEZI
	49	NODOSARIA COLUMNARIS
	50	NODOSARIA RAOIATA
	51	LINGULINA SP
	52	PLANULARIA EUENII
	53	SPIROLOCULINA SP A
	54	VAGINULINA SIMPLEX
	55	CITHERINA SP.
	56	EOGUTTULINA OOLITHICA
	57	LAGENA LAEVIS
	58	TRISTIA LIASSICA
	59	VAGINULINA COMPRESSA
	60	AMMOBACULITES FONTINENSIS
	61	DENTALINA QUADRILATERA FN QINQUELATERA
	62	DENTALINA SUBSILIQUA
	63	DENTALINA VARIANS
	64	NODOSARIA DISPAR
	65	PSEUDONODOSARIA OVIFORMIS
	66	REOPHAN METENSIS
	67	REOPHAN SP
	68	TRISTIA LIASSIANA
	69	TROCHAMMIA GRYCI

Appendix IV. Mochras borehole Middle Liassic species.

CHECKLIST OF GRAPHIC ABUNDANCE BY HIGHEST APPEARANCE

- = Abundant (>25 X)
 = Common (>15 X)
 = Few (>5 X)
 = Rare (>1 X)
 = Very Rare (<1 X)

? = Questionably Present
 - = Not Present

1	AMMOACULITES SP	1981-1984
2	AMMOACULITES SP	2000-2000
3	AMMOACULITES SP	2025-2029
4	AMMOACULITES SP	2063-2068
5	AMMOACULITES SP	2092-2097
6	AMMOACULITES SP	2106-2111
7	AMMOACULITES SP	2121-2125
8	AMMOACULITES SP	2139-2144
9	AMMOACULITES SP	2153-2159
10	AMMOACULITES SP	2177-2182
11	AMMOACULITES SP	2210-2215
12	AMMOACULITES SP	2220-2225
13	AMMOACULITES SP	2234-2239
14	AMMOACULITES SP	2262-2266
15	AMMOACULITES SP	2318-2323
16	AMMOACULITES SP	2378-2383
17	AMMOACULITES SP	2397-2402
18	AMMOACULITES SP	2415-2420
19	AMMOACULITES SP	2429-2434
20	AMMOACULITES SP	2448-2453
21	AMMOACULITES SP	2471-2476
22	AMMOACULITES SP	2486-2491
23	AMMOACULITES SP	2500-2505
24	AMMOACULITES SP	2508-2513
25	AMMOACULITES SP	2543-2548
26	AMMOACULITES SP	2592-2597
27	AMMOACULITES SP	2720-2725
28	AMMOACULITES SP	2744-2749
29	AMMOACULITES SP	2807-2812
30	AMMOACULITES SP	2824-2830
31	AMMOACULITES SP	
32	AMMOACULITES SP	
33	AMMOACULITES SP	
34	AMMOACULITES SP	
35	AMMOACULITES SP	
36	AMMOACULITES SP	
37	AMMOACULITES SP	
38	AMMOACULITES SP	
39	AMMOACULITES SP	
40	AMMOACULITES SP	
41	AMMOACULITES SP	
42	AMMOACULITES SP	
43	AMMOACULITES SP	
44	AMMOACULITES SP	
45	AMMOACULITES SP	
46	AMMOACULITES SP	
47	AMMOACULITES SP	
48	AMMOACULITES SP	
49	AMMOACULITES SP	
50	AMMOACULITES SP	
51	AMMOACULITES SP	
52	AMMOACULITES SP	
53	AMMOACULITES SP	
54	AMMOACULITES SP	
55	AMMOACULITES SP	
56	AMMOACULITES SP	
57	AMMOACULITES SP	
58	AMMOACULITES SP	
59	AMMOACULITES SP	
60	AMMOACULITES SP	
61	AMMOACULITES SP	
62	AMMOACULITES SP	
63	AMMOACULITES SP	
64	AMMOACULITES SP	
65	AMMOACULITES SP	
66	AMMOACULITES SP	
67	AMMOACULITES SP	
68	AMMOACULITES SP	
69	AMMOACULITES SP	
70	AMMOACULITES SP	
71	AMMOACULITES SP	
72	AMMOACULITES SP	
73	AMMOACULITES SP	
74	AMMOACULITES SP	
75	AMMOACULITES SP	
76	AMMOACULITES SP	
77	AMMOACULITES SP	
78	AMMOACULITES SP	
79	AMMOACULITES SP	
80	AMMOACULITES SP	
81	AMMOACULITES SP	
82	AMMOACULITES SP	
83	AMMOACULITES SP	
84	AMMOACULITES SP	
85	AMMOACULITES SP	
86	AMMOACULITES SP	
87	AMMOACULITES SP	
88	AMMOACULITES SP	
89	AMMOACULITES SP	
90	AMMOACULITES SP	
91	AMMOACULITES SP	
92	AMMOACULITES SP	
93	AMMOACULITES SP	
94	AMMOACULITES SP	
95	AMMOACULITES SP	
96	AMMOACULITES SP	
97	AMMOACULITES SP	
98	AMMOACULITES SP	
99	AMMOACULITES SP	
100	AMMOACULITES SP	

Appendix V. Mochras borehole Upper Liassic species.

CHECKLIST OF INDIAN ABORIGINAL BY HIGHEST APPEARANCE

- Abundant 1275 31
 - Common 1214 31
 - Fair 120 27
 - Rare 121 31
 - Very Rare 121 31
 - ? = Questionably Present
 - = Not Present

1	AMPHIBIUM	1275	31
2	AMPHIBIUM	1275	31
3	AMPHIBIUM	1275	31
4	AMPHIBIUM	1275	31
5	AMPHIBIUM	1275	31
6	AMPHIBIUM	1275	31
7	AMPHIBIUM	1275	31
8	AMPHIBIUM	1275	31
9	AMPHIBIUM	1275	31
10	AMPHIBIUM	1275	31
11	AMPHIBIUM	1275	31
12	AMPHIBIUM	1275	31
13	AMPHIBIUM	1275	31
14	AMPHIBIUM	1275	31
15	AMPHIBIUM	1275	31
16	AMPHIBIUM	1275	31
17	AMPHIBIUM	1275	31
18	AMPHIBIUM	1275	31
19	AMPHIBIUM	1275	31
20	AMPHIBIUM	1275	31
21	AMPHIBIUM	1275	31
22	AMPHIBIUM	1275	31
23	AMPHIBIUM	1275	31
24	AMPHIBIUM	1275	31
25	AMPHIBIUM	1275	31
26	AMPHIBIUM	1275	31
27	AMPHIBIUM	1275	31
28	AMPHIBIUM	1275	31
29	AMPHIBIUM	1275	31
30	AMPHIBIUM	1275	31
31	AMPHIBIUM	1275	31
32	AMPHIBIUM	1275	31
33	AMPHIBIUM	1275	31
34	AMPHIBIUM	1275	31
35	AMPHIBIUM	1275	31
36	AMPHIBIUM	1275	31
37	AMPHIBIUM	1275	31
38	AMPHIBIUM	1275	31
39	AMPHIBIUM	1275	31
40	AMPHIBIUM	1275	31
41	AMPHIBIUM	1275	31
42	AMPHIBIUM	1275	31
43	AMPHIBIUM	1275	31
44	AMPHIBIUM	1275	31
45	AMPHIBIUM	1275	31
46	AMPHIBIUM	1275	31
47	AMPHIBIUM	1275	31
48	AMPHIBIUM	1275	31
49	AMPHIBIUM	1275	31
50	AMPHIBIUM	1275	31
51	AMPHIBIUM	1275	31
52	AMPHIBIUM	1275	31
53	AMPHIBIUM	1275	31
54	AMPHIBIUM	1275	31
55	AMPHIBIUM	1275	31
56	AMPHIBIUM	1275	31
57	AMPHIBIUM	1275	31
58	AMPHIBIUM	1275	31
59	AMPHIBIUM	1275	31
60	AMPHIBIUM	1275	31
61	AMPHIBIUM	1275	31
62	AMPHIBIUM	1275	31
63	AMPHIBIUM	1275	31
64	AMPHIBIUM	1275	31
65	AMPHIBIUM	1275	31
66	AMPHIBIUM	1275	31
67	AMPHIBIUM	1275	31
68	AMPHIBIUM	1275	31
69	AMPHIBIUM	1275	31
70	AMPHIBIUM	1275	31
71	AMPHIBIUM	1275	31
72	AMPHIBIUM	1275	31
73	AMPHIBIUM	1275	31
74	AMPHIBIUM	1275	31
75	AMPHIBIUM	1275	31
76	AMPHIBIUM	1275	31
77	AMPHIBIUM	1275	31
78	AMPHIBIUM	1275	31
79	AMPHIBIUM	1275	31
80	AMPHIBIUM	1275	31
81	AMPHIBIUM	1275	31
82	AMPHIBIUM	1275	31
83	AMPHIBIUM	1275	31
84	AMPHIBIUM	1275	31
85	AMPHIBIUM	1275	31
86	AMPHIBIUM	1275	31
87	AMPHIBIUM	1275	31
88	AMPHIBIUM	1275	31
89	AMPHIBIUM	1275	31
90	AMPHIBIUM	1275	31
91	AMPHIBIUM	1275	31
92	AMPHIBIUM	1275	31
93	AMPHIBIUM	1275	31
94	AMPHIBIUM	1275	31
95	AMPHIBIUM	1275	31
96	AMPHIBIUM	1275	31
97	AMPHIBIUM	1275	31
98	AMPHIBIUM	1275	31
99	AMPHIBIUM	1275	31
100	AMPHIBIUM	1275	31

Appendix VII. Cocklebits borehole Liassic species.

CHECKLIST OF GRAPHIC ABUNDANCE BY HIGHEST APPEARANCE

= Abundant (>25 %)
 = Common (>15 %)
 = Few (>5 %)
 = Rare (>1 %)
 = Very Rare (<1 %)
 ? = Questionably Present
 . = Not Present

114		1	AMMODISCUS ASPER
113		2	ASTACOLUS PAUPERATUS
112		3	ASTACOLUS QUADRICOSTATA
111		4	ASTACOLUS UNOULATA
110		5	BULLOPORA GLOBULATA
109		6	CARIXIA LANGI
108		7	DENTALINA LANGI
107		8	DENTALINA PSEUDOCOMMUNIS
106		9	DENTALINA SINEMURIENSIS
105		10	DENTALINA SUBSILIQUA
104		11	DENTALINA TORTA
103		12	DENTALINA VARIANS
102		13	EOGUTTULINA LIASSICA
101		14	EOGUTTULINA DOLITHICA
100		15	EOGUTTULINA SP. ADHERANT
		16	FRONDIICULARIA BRIZAEFORMIS
		17	FRONDIICULARIA SULCATA
		18	LENTICULARIA VARIANS
		19	LINOULINA ESSEYANA
		20	LINOULINA TENERA
		21	MARGINULINA HAMUS
		22	MARGINULINA PORRECTA
		23	MARGINULINA PRIHA
		24	NODOSARIA HORTONENSIS
		25	NODOSARIA METENSIS
		26	NODOSARIA REGULARIS
		27	NODOSARIA SIMPLEX
		28	NODOSARIA SP. 2593
		29	PLANULARIA EUGENII
		30	PLANULARIA INAEQUISTRIATA
		31	PSEUDONODOSARIA MULTICOSTATA
		32	PSEUDONODOSARIA VULGATA
		33	ASTACOLUS STILLUS
		34	DENTALINA SP. A BROUWER
		35	DENTALINA TERQUEMI
		36	LAGENA TENUCOSTATA
		37	LINGULINA CERNUA
		38	NODOSARIA NITIOANA
		39	SPIRILLINA INFIMA
		40	TOLYPHAMMINA FLAGELLUM
		41	TROCHAMMINA SP.
		42	VAGINULINA SIMPLEX
		43	VAGINULINA TRIQUETRA
		44	DENTALINA SP. I
		45	NODOSARIA DISPAR
		46	BULLOPORA ROSTRATA
		47	DENTALINA EXILIS
		48	MARGINULINA/NODOSARIA SP. ALPHA
		49	DENTALINA TENUISTRIATA
		50	LINOULINA NODOSARIA
		51	NODOSARIA RAOIATA
		52	SPIRILLINA POLYGYRATA
		53	VAGINULINA LISTI
		54	MARGINULINA SP. PSI
		55	EOGUTTULINA POLYGONA
		56	DENTALINA GLADIIFORMIS
		57	EOGUTTULINA INDOUROCLAVIENSIS

Appendix VIII. Dorset Hettangian outcrop species.

CHECKLIST OF SPECIFIC ABUNDANCE BY HIGHEST ABUNDANCE

- Abundant (120-21)
 - Common (10-21)
 - Fair (1-21)
 - Rare (1-1)
 - Very Rare (1-1)
 - ? = Questionably Present
 - = Not Present

264	1	AMMODISCUS REPER
263	2	ASTACOLUS PAUPERATUS
262	3	DENTALINA MATUTINA
261	4	DENTALINA PSEUDOCOMMIS
260	5	DENTALINA SINEMURIENSIS
259	6	DENTALINA TERQUEMI
258	7	DENTALINA VARIANS
257	8	ECOUTTULINA DOLITHICA
256	9	PRONODICULARIA BULGATA
255	10	HAPHLOPHRAOCHIDES SUBLOBOSUS
254	11	LASEMA SP. L. OF CLAVATA
253	12	LENTICULINA VARIANS
252	13	LINGULINA TENERA
251	14	MODOBARIA HORTONENSIS
250	15	MODOBARIA SCULPTA
249	16	SPHILLINA IMPIHA
248	17	VAGINULINA SIMPLEX
247	18	VAGINULINA TRIQUETRA
246	19	ECOUTTULINA LABRICA
245	20	LINGULINA LAEVISSIMA
244	21	MODOBARIA METENSIS
243	22	MODOBARIA RADIATA
242	23	MODOBARIA SIMPLEX
241	24	BULLDPODA SLOBLATA
240	25	LINGULINA CERNUA
239	26	PSEUDOMODOBARIA UULATA
238	27	REOPHAN SP.
237	28	SPHILLOLOCULINA SP. S
236	29	DENTALINA MURISALIS
235	30	DENTALINA SP. I
234	31	PRONODICULARIA SP. OF P. LISHAIA
233	32	MARGINULINA PRIMA
232	33	MODOBARIA CRISPATA
231	34	MODOBARIA MITIDANA
230	35	PLANULARIA EUGENII
229	36	MODOBARIA DISPAR
228	37	DENTALINA TORTA
227	38	ASTACOLUS STILLUS
226	39	DENTALINA SAGITTIFORMIS
225	40	DENTALINA SUBSILIQUA
224	41	HAPHLOPHRAOCHIDES SP.
223	42	REOPHAN METENSIS
222	43	SPHILLOLOCULINA SP. A
221	44	ASTACOLUS QUADRICOCTATA
220	45	PRONODICULARIA PARADOXA
219	46	LINGULINA ESSEYANA
218	47	DENTALINA SP. A BROUWER
217	48	MODOBARIA SINOHIANA
216	49	MODOBARIA REGULARIS
215	50	DENTALINA EXILIS
214	51	MODOBARIA COLUMNARIS
213	52	VAGINULINA SAGITTIFORMIS
212	53	PRONODICULARIA INVOLUTA
211	54	PLANULARIA INAEQUISTRATA
210	55	PSEUDOMODOBARIA OVIFORMIS
209	56	AMMOVERTELLA LIRASSIOA
208	57	CARINIA LANDI
207	58	CONOBOLIDES SP.
206	59	DENTALINA PRINAEVA
205	60	PRONODICULARIA BIREPERFORIS
204	61	TOLYPANNA FLAGELLUM
203	62	VAGINULINA LISTI
202	63	LASEMA MINIMA AMPULLAEOA
201	64	LINGULINA MODOBARIA
200	65	MODOBARIA SP. 355
199	66	AMMOBOLULITES FONTINENSIS
198	67	AMMOBOLULITES VETUSTA
197	68	BULLDPODA ROSTRATA
196	69	LASEMA OXYSTOMA
195	70	MARGINULINA/MODOBARIA SP. ALPHA
194	71	PSEUDOMODOBARIA MULTICOCTATA
193	72	DENTALINA NAUSLERI
192	73	DENTALINA VETUSTA
191	74	MODOBARIA SUBPILATIONA
190	75	VAGINULINA COMPRESSA
189	76	VAGINULINA CONSTRICTA
188	77	AMMOBOLULITES SP.
187	78	AMMODISCUS SILICEUS
186	79	MODOBARIA OCULINA
185	80	MARGINULINA MANUS
184	81	ASTACOLUS UNDULATA
183	82	ECOUTTULINA SP. ADHERANT
182	83	LASEMA TENUCOCTATA
181	84	MARGINULINA SP. STRIATED

Appendix IX. Dorset Lower Sinemurian outcrop species.

- Abundant (>25 %)
- Common (>15 %)
- Few (>5 %)
- Rare (>1 %)
- Very Rare (<1 %)

7 - Questionably Present
 - Not Present

Appendix X. Dorset Upper Sinemurian outcrop species.

- = Abundant (>25 %)
- = Common (>15 %)
- = Few (>5 %)
- = Rare (>1 %)
- = Very Rare (<1 %)

7 = Questionably Present
 - = Not Present

Appendix XII. Dorset Upper Pliensbachian outcrop species:

- Abundant (>25 %)
- Common (>15 %)
- Few (1-5 %)
- Rare (<1 %)
- Very Rare (<1 %)

7 - Questionably Present
 - Not Present

Appendix XIII. Yorkshire/ Midlands outcrop species.

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PLATE 1

All foraminifera figured in plate 1 are conspicuous members of Biofacies Alpha.

- fig. 1, Eoguttulina liassica Strickland, Sample KMP 75-106, Lang Bed H59, Pinhay Bay, Devon, 82x.
- fig. 2, Eoguttulina liassica Strickland, Sample KMP 75-106, Lang Bed H59, Pinhay Bay, Devon, 180x.
- fig. 3, Eoguttulina liassica sp. adherant form, Sample KMP 75-108, Lang Bed H71, Pinhay Bay, Devon, 165x, note the flange.
- fig. 4, Eoguttulina oolithica Terquem, Sample KMP 75-106, Lang Bed H59, Pinhay Bay, Devon, 90x.
- fig. 5, Eoguttulina polygona Terquem, Sample KMP 75-106, Lang Bed H59, Pinhay Bay, Devon, 105x.
- fig. 6, Eoguttulina polygona Terquem, Sample KMP 75-106, Lang Bed H59, Pinhay Bay, Devon, 128x.
- fig. 7, Eoguttulina Inovroclaviensis Bielecka & Pozarsky, Cocklepit Borehole Interval 89.55-90.40m, P. angulata Zone, Yorkshire, 135x.
- fig. 8, Dentalina pseudocommunis Franke, Sample KMP 75-109, Lang Bed H75, Pinhay Bay, Devon, 75x.
- fig. 9, Dentalina pseudocommunis Franke, Sample KMP 75-109, Lang Bed H75, Pinhay Bay, Devon, 82x.
- fig. 10, Nodosaria simplex Terquem, Sample KMP 75-106, Lang Bed H59, Pinhay Bay, Devon, 150x.
- fig. 11, Marginulina prima d'Orbigny, Sample KMP 75-108, Lang Bed H71, Pinhay Bay, Devon, 38x.
- fig. 12, Marginulina prima d'Orbigny, juvenile, Sample KMP 75-108, Lang Bed H71, Pinhay Bay, Devon, 38x.
- fig. 13, Marginulina sp. psi, juvenile, KMP 75-108, Lang Bed H71, Pinhay Bay, Devon, 90x. Note the discontinuous ribs which have a tendency to spiral around the test.
- fig. 14, Marginulina sp. psi, KMP 75-108, Lang Bed H71, Pinhay Bay, Devon, 60x. Note the irregular ribs.
- fig. 15, Vaginulina simplex Terquem, Sample KMP 75-

106, Lang Bed H59, Pinhay Bay, Devon , 173x.

- fig. 16, Vaginulina triquetra Terquem, Sample KMP 75-106, Lang Bed H59, Pinhay Bay, Devon, 173x.
- fig. 17, Vaginulina triquetra Terquem, Sample KMP 75-122, Lang Bed 46, Glass Bottle Shales, Seven Rock Point, Devon , 150x.
- fig. 18, Nodosaria metensis Terquem, Sample KMP 75-109, Lang Bed H75, Pinhay Bay, Devon, 113x.
- fig. 19, Frondicularia sulcata Bornemann, Sample KMP 75-109, Lang Bed H75, Pinhay Bay, Devon, 113x. Note this is Barnard's plexus form A'; the fifth rib is eroded the left side of the test.
- fig. 20, Frondicularia sulcata Bornemann, Sample KMP 75-109, Lang Bed H75, 225x. Note this is the apertural view of the test in fig. 19.
- fig. 21, Frondicularia sulcata Bornemann, Sample KMP 75-111, Lang Bed H91, Pinhay Bay, Devon, 75x. Note This is Barnard's plexus form B.
- fig. 22, Lingulina tenera Bornemann, Sample KMP 75-107, Land Bed H61, Pinhay Bay, Devon , 98x. This is Barnard's plexus form C.
- fig. 23, Lenticulina varians Bornemann, Sample KMP 75-108, Lang Bed H71, Pinhay Bay, Devon, 135x. This is Barnard's plexus form B.
- fig. 24, Lenticulina varians Bornemann, Sample KMP 75-108, Lang Bed H71, Pinhay Bay, Devon, 75x. This is Barnard's plexus form B.

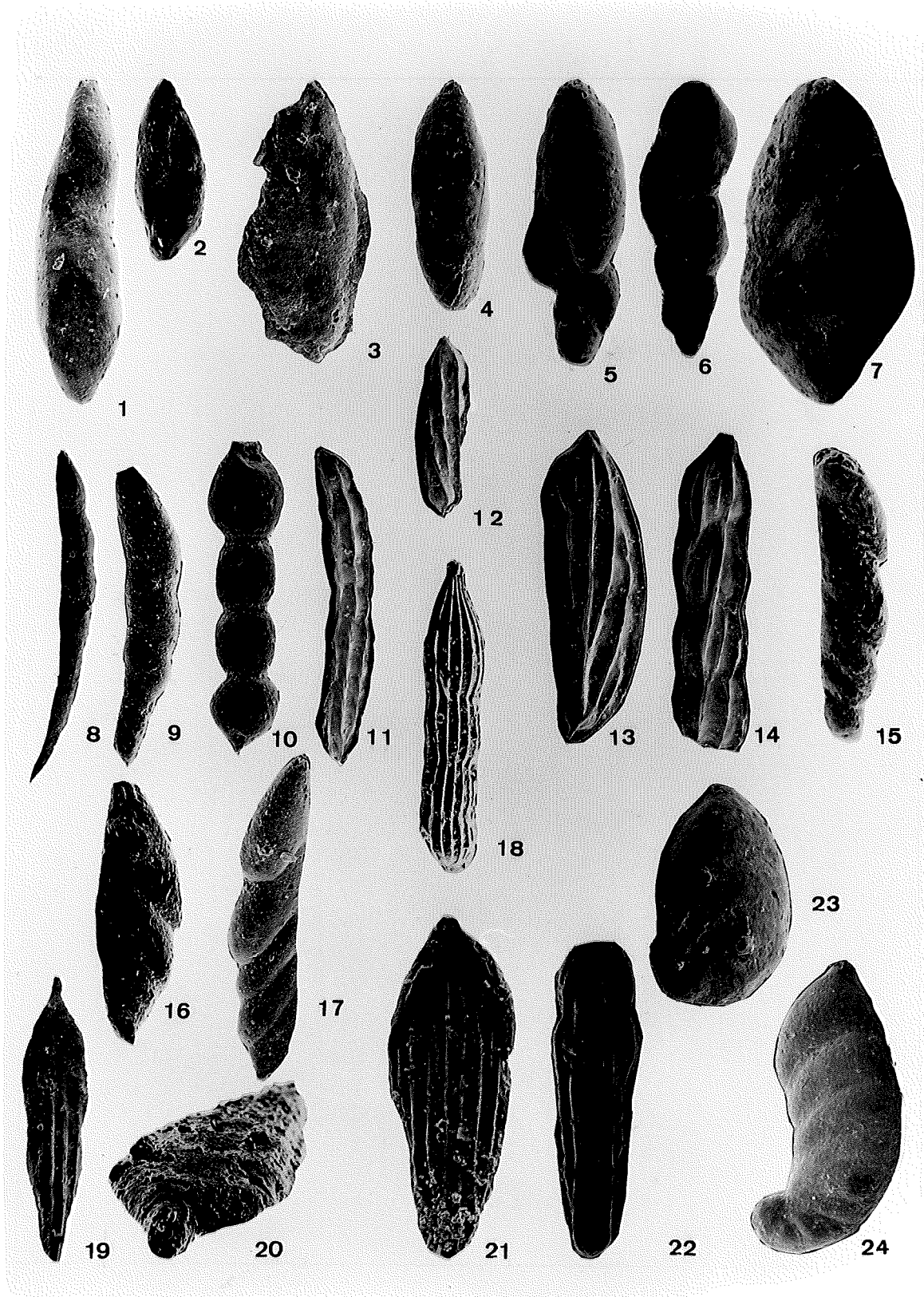


Plate 2

Common constituents of Biofacies Alpha 1.

- fig. 1, Ammodiscus asper Terquem, Sample KMP 75- 115, Lang Bed 22, Mongrel Shales, Seven Rock Point, approx. SY 326 908-330 913 Devon, 75x.
- fig. 2, Astacolus stillus Terquem, Sample KMP 75-404, Upper Pabba Shales Beds, T. ibex zone, Raasay , Skye 150x.
- fig. 3, Astacolus stillus Terquem, apertural view of fig.2, 195x. Note the parallel sides of the test.
- fig. 4. Dentalina tenuistriata Terquem, Cocklepits Borehole interval 35.89-36.80m, T. ibex Zone, 38x.
- fig. 5, Dentalina terquemi d'Orbigny, Sample KMP 75-398, Upper Pabba Shales Beds, U. Jamesoni Zone, Raasay, Skye, 38x.
- fig. 6, Dentalina terquemi d'Orbigny, Sample KMP 75-398, Upper Pabba Shales Beds, U. Jamesoni Zone, Raasay, Skye, 98x.
- fig. 7, Dentalina terquemi d'Orbigny, Sample KMP 75-398, Upper Pabba Shales Beds, U. Jamesoni Zone, Raasay, Skye, 60x.
- fig. 8, Frondicularia involuta Terquem, Cocklepits Borehole interval 35.89- 36.80m, T. ibex Zone Yorkshire, 150x.
- fig. 9, Haphlophragmoides sp. Bartenstein & Brand, Cocklepits Borehole interval 27.50 28.73m, P. davoei Zone, Yorkshire, 128x.
- fig. 10, Haphlophragmoides subglobosus. G. O. Sars, Cocklepits Borehole interval 35.89-36.80m, T. ibex Zone, Yorkshire, 75x.
- fig. 11, Involutina liassica Jones, Cocklepits Borehole, interval 73.12-73.93m, Frodingham Ironstone, A. semicostatum Zone, Yorkshire, 53x.
- fig. 12, Lingulina tenera Bornemann, juvenile, Cocklepits Borehole interval 73.12-73.93m, Frodingham Ironstone, Yorkshire, 120x. Note that an oolith has nucleated on the L. tenera.
- fig. 13, Glomospira perplexa Franke, Cocklepits Borehole

interval 27.50-28.73m, P. davoei Zone,
Yorkshire, 113x

- fig. 14, Lagenammina sp. cf. L. difflugiformis Brady,
Cocklepits Borehole interval 35.89-36.80m,
T. ibex Zone, Yorkshire, 143x. Note that the
unilocular chamber is eggshaped, not flattened.
- fig. 15, Lagenammina sp. cf. L. ampullacea Brady,
Cocklepits Borehole interval 35.89-36.80m, T.
ibex Zone Yorkshire, 143x. Note that the
unilocular chamber is flattened, flask-shaped
with parallel sides.
- fig. 16, Gastropod, Cocklepits Borehole interval 73.12-
73.93m, A. semicostatum Zone, Yorkshire, 75x.
Note that an oolith has nucleated on the
gastropod.
- fig. 17, Reophax dentalinaformis Brady, Cocklepits
Borehole interval 35.89-36.80m, T. ibex Zone
Yorkshire, 128x.
- fig. 18, Reophax dentalinaformis Brady, Cocklepits
Borehole interval 35.89-36.80m, T. ibex Zone
Yorkshire, 113x.
- fig. 19, Reophax sp. cf. R. dentalinaformis Brady,
Cocklepits Borehole interval 35.89-36.80m,
Yorkshire 128x. Note that there is a slight
off-set to the chambers.
- fig. 20, Reophax sp., Cocklepits Borehole interval 35.89-
36.80m, T. ibex Zone Yorkshire, 90x.
- fig. 21, Frondicularia sp., Cocklepits Borehole interval
35.89-36.80m, T. ibex Zone, Yorkshire, 98x.
- fig. 22, Vaginulina constricta Terquem & Berthelin,
Cocklepits Borehole interval 35.89-36.80m,
T. ibex Zone, Yorkshire, 83x.
- fig. 23, Trochammina sp., Cocklepits Borehole
interval 35.89-36.80m, T. ibex Zone, Yorkshire,
150x.
- fig. 24, Trochammina sp., Cocklepits Borehole
interval 35.89-36.80m, T. ibex Zone, Yorkshire,
173x.

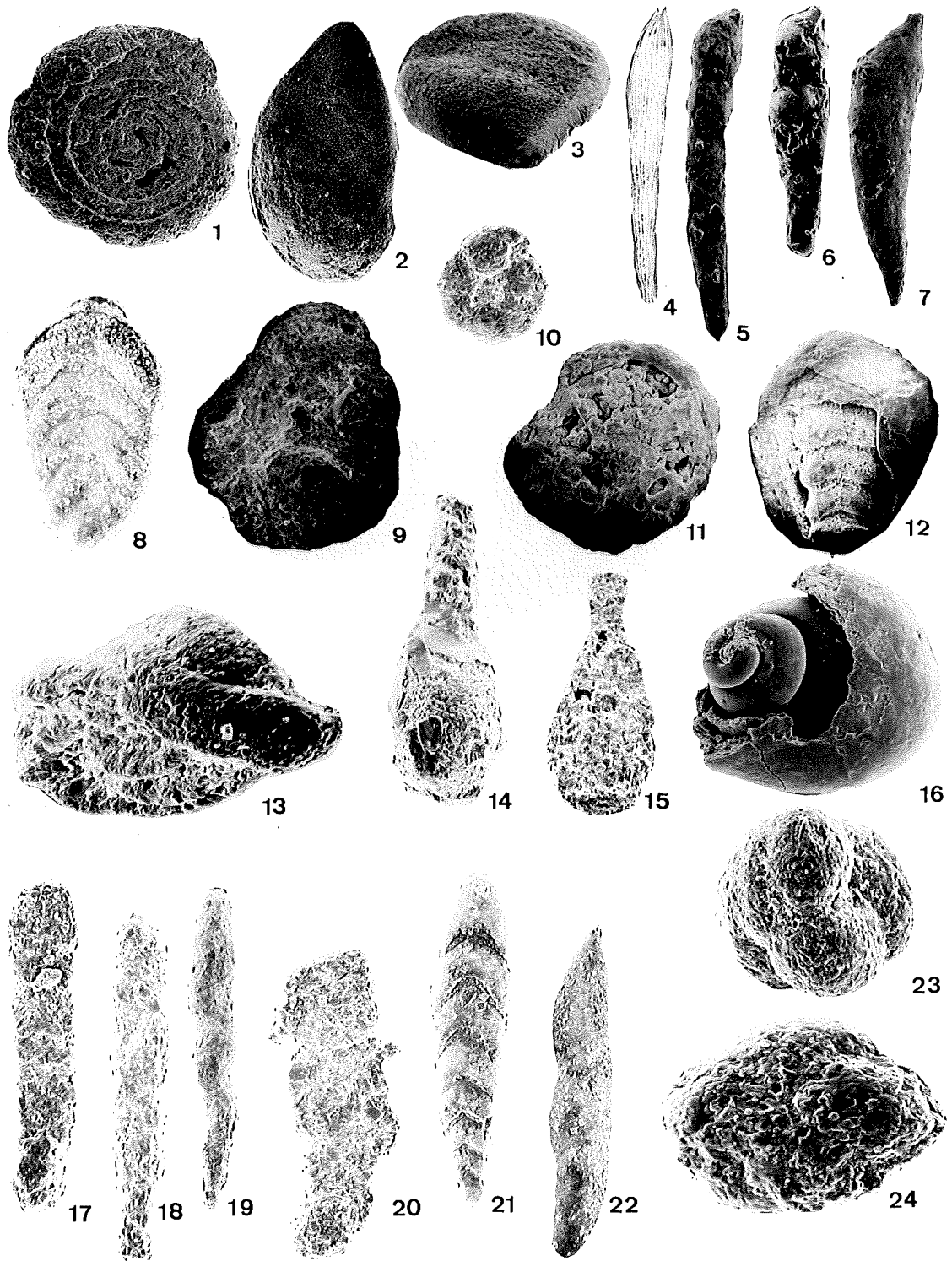


PLATE 3

Dominant species of the Biofacies Beta, Gamma, Gamma 1, Delta and Epsilon.

- fig. 1, Lingulina tenera Bornemann, Barnard plexus form A "striata", Cocklepits Borehole interval 95.48-96.37m, P. planorbis Zone, Yorkshire, 75x.
- fig. 2, Lingulina tenera Bornemann, Barnard plexus form B "tenera", Cocklepits Borehole interval 43.30-44.22m, T. ibex Zone, Yorkshire, 83x.
- fig. 3, Lingulina tenera Bornemann, Barnard plexus form C Sample KMP 75-111, Lang Bed H91, Pinhay Bay, Devon, 98x.
- fig. 4, Lingulina tenera Bornemann, Barnard plexus form C Sample KMP 75-109, Lang Bed H75, Pinhay Bay, Devon, 75x.
- fig. 5, Lingulina tenera Bornemann, Barnard plexus form D-E Sample KMP 75-122, Lang Bed 46, Glass Bottle Shales, Seven Rock Point, Devon, 75x.
Note there is both a central rib and bifurcated secondary ribs.
- fig. 6, Lingulina tenera Bornemann, Barnard plexus form G, "octocostata", Cocklepits Borehole interval 38.70-39.60m, T. ibex Zone, Yorkshire, 150x.
Note the internal chevron shape of the chambers and the radiate crystal arrangement of the chamber wall. There is a resemblance to the genus Fronicularia.
- fig. 7, Lingulina tenera Bornemann, Barnard plexus form I "pupa", Cocklepits Borehole interval 38.70-39.60m, T. ibex Zone, Yorkshire, 68x.
- fig. 8, Lingulina tenera Bornemann, Barnard plexus form I "pupa", Cocklepits Borehole interval 38.70-39.60m, apertural view of fig. 7, 255x.
- fig. 9, Lingulina tenera Bornemann, Barnard plexus form I "pupa", Cocklepits Borehole interval 38.70-39.60m, T. ibex Zone, Yorkshire, 68x. Note there is less of a central rib and fewer ribs on the ultimate chamber than the form in fig. 7.
- fig. 10, Lenticulina varians Bornemann, Barnard plexus form B, Sample KMP 75-115, Lang Bed 22, Mongrel Shales, Seven Rock Point Devon, 98x.
- fig. 11, Lenticulina varians Bornemann, Barnard plexus form C, Sample KMP 75-115, Lang Bed 22, Dorset

60x. Note the boss and the raised ribs.

- fig. 12, Lenticulina varians Bornemann, apertural view, Sample KMP 75-404, T. ibex Zone of the Upper Pabba Shales, Raasay, Skye, 143x. Note that the test is bi-convex, viewed from this angle.
- fig. 13, Lenticulina varians Bornemann, Barnard plexus form F, Sample KMP 75-291, Black Ven Marls, 15.6m above the Pavior=The Upper Cement Bed, 38x.
- fig. 14, Lenticulina varians Bornemann, Barnard plexus form F, Sample KMP 75-291, Black Ven Marls, 15.6 above the Pavior=The Upper Cement Bed, 75x.
- fig. 15, Lenticulina varians Bornemann, Barnard plexus form F, Cocklepits Borehole interval 57.32-58.20m, O. oxynotum zone, Yorkshire, 45x.
- fig. 16, Lenticulina varians Bornemann, internal view, Cocklepits Borehole interval 43.30-44.22m, T. ibex Zone, Yorkshire, 135x.
- fig. 17, Marginulina prima d'Orbigny var. spinata Terquem, Sample KMP 75-314, Green Ammonite Beds, Lang Bed 122a, Dorset, 68x.
- fig. 18, Marginulina prima d'Orbigny var. spinata Terquem, apertural view of fig. 17, 113x. Note the thick, flat apertural face, the radiate aperture and the placement of the aperture toward the dorsal edge of the test.
- fig. 19, Marginulina prima d'Orbigny var. spinata Terquem, Cocklepits Borehole interval 21.06-21.96m, D. tenuicostatum zone, Yorkshire, 75x.
- fig. 20, Marginulina prima d'Orbigny, Sample KMP 75-400, A. semicostatum zone of the Upper Broadford Beds, Raasay, Skye, 75x.
- fig. 21, Marginulina prima d'Orbigny, Sample KMP 75-111, Lang Bed H91, Pinhay Bay, Devon, 90x.
- fig. 22, Marginulina prima d'Orbigny, Sample KMP 75-111, Lang Bed H91, Pinhay Bay, Devon, 56x.
- fig. 23, Brizalina liassica Terquem, Steeple Aston Borehole interval 235'-239' P. davoei zone, Oxfordshire, 75x.
- fig. 24, Brizalina liassica Terquem, Sample KMP 75-314 Green Ammonite Beds, Lang Bed 122a, Dorset,

150x.

fig. 25, Brizalina liassica Terquem, internal view,
Steeple Aston Borehole interval 235'-239', P.
davoei Zone, Oxfordshire, 90x.

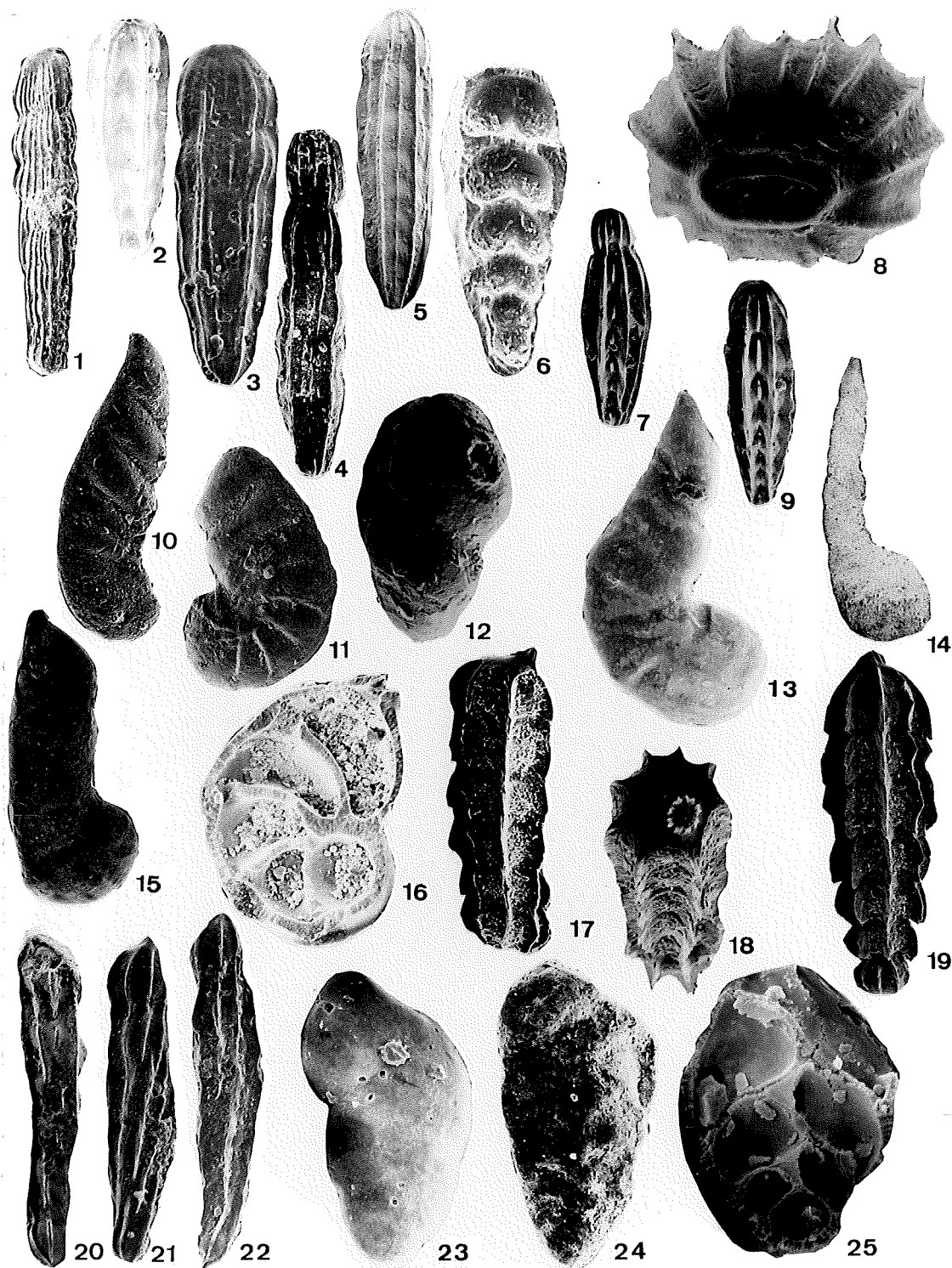


PLATE 4

Common accessory species for Biofacies Delta- Epsilon

- fig. 1, Bullopore globulata Barnard, sensu stricto, Sample KMP 75-121, Lang Bed 45, (Bottom of the gmuendense Subzone of Hallam), Top Quick Shales, Seven Rock Point, Devon, 113x.
- fig. 2, Bullopore sp cf. B. globulata, Sample KMP 75-111, Lang Bed H91, Pinhay Bay, Devon, 75x. Note the specimen retains the neck of B. rostrata but the chambers are globular.
- fig. 3, Bullopore rostrata Quenstedt and Carixia langi Macfadyen, Sample KMP 75-123, Lang Bed 48, Grey Ledge Shales, the Spittles East of Lyme Regis, Dorset, 53x. Note B. rostrata has a neck and the chambers, are elongate rather than globular.
- fig. 4, Carixia langi Macfadyen, Sample KMP 75-109, Lang Bed H75, Pinhay Bay, Devon, 60x. Note the tubes in the micrograph are filled and/or are replaced by glauconite.
- fig. 5, Astacolus quadricostata Terquem, Sample KMP 75-398, Upper part of the Pabba Shales, U. jamesoni Zone, Hallaig shore, Raasay, Skye, 68x.
- fig. 6, Astacolus quadricostata Terquem, Sample KMP 75-115, Lang Bed 22, Mongrel Shales, Seven Rock Point, Devon, 90x.
- fig. 7, Astacolus undulata Terquem, Sample KMP 75-398, Upper part of the Pabba Shales, U. jamesoni Zone, Hallaig shore, Raasay, Skye, 60x.
- fig. 8, Planularia eugenii Terquem, Sample KMP 75-111, Lang Bed H91, Pinhay Bay, Devon, 56x.
- fig. 9, Lingulina essayana Deecke, Sample KMP 75-114, Lang Bed 18, Upper White Shales, Seven Rock Point, Devon, 113x.
- fig. 10, Planularia inaequistriata Terquem, Sample KMP 75-111, Lang Bed H91, Pinhay Bay, Devon, 53x. Note this species is a good index fossil for the Lower Lias.
- fig. 11, Planularia inaequistriata Terquem, Sample KMP 75-111, Lang Bed H91, Pinhay Bay, Devon, 83x.

- fig. 12, Lenticulina varians Bornemann, flabelline stage, Sample KMP 75-314, Green Ammonite Beds, Lang Bed 122a, Dorset, 75x. Note the test sides are convex rather than parallel as is the case for A. pauperatus flabelline stage.
- fig. 13, Nodosaria columnaris Franke, Sample KMP 77-212, Jet Wyke, Howarth Bed 27, A. margaritatus Zone, Yorkshire coast, 83x.
- fig. 14, Nodosaria crispata Terquem, Sample KMP 75-109, Lang Bed H75, Pinhay Bay, Devon, 113x.
- fig. 15, Nodosaria dispar Franke, Sample KMP 75-121, Lang Bed 44, Top Quick Shales, Seven Rock Point, Devon, 45x. Note the spindle shape of the test.
- fig. 16, Nodosaria dispar Franke, Sample KMP 75-109, Lang Bed H75, Pinhay Bay, Devon, 105x.
- fig. 17, Marginulina (Saracenaria) hamus Terquem, Sample KMP 75-115, Mongrel Shales, Lang Bed 22, Seven Rock Point, Devon, 60x. Note this is a useful index species for the Hettangian-Sinemurian Boundary.
- fig. 18, Marginulina (Saracenaria) hamus Terquem, Sample KMP 75-115, Mongrel Shales, Lang Bed 22, Devon, 53x.
- fig. 19, Nodosaria hortonensis Terquem, Cocklepits interval 48.91-48.96 m, U. Jamesoni Zone, Yorkshire, 83x.
- fig. 20, Nodosaria prima d'Orbigny, Sample KMP 75-109, Lang Bed H75, Pinhay Bay, Devon, 68x.
- fig. 21, ? Marginulina/Nodosaria sp. Alpha, Sample KMP 75-106, Lang Bed H59, Pinhay Bay, Devon, 68x.
- fig. 22, Marginulina sp.A. Sample KMP 75-109, Lang Bed H75, Pinhay Bay, Devon, 53x.
- fig. 23, Marginulina sp.A. Sample KMP 75-109, Lang Bed H75, Pinhay Bay, Devon, 53x.
- fig. 24, Calcispheres Sample KMP 75-114, Lang Bed 18, Specketty Shales, Seven Rock Point, Devon, 450x. Note the calcispheres make up the major portion of the shale of this sample.
- fig. 25, Calcispheres. Enlargement of the center of the

figure 24, 2250x. Note the sphere has two halves and an aperture.

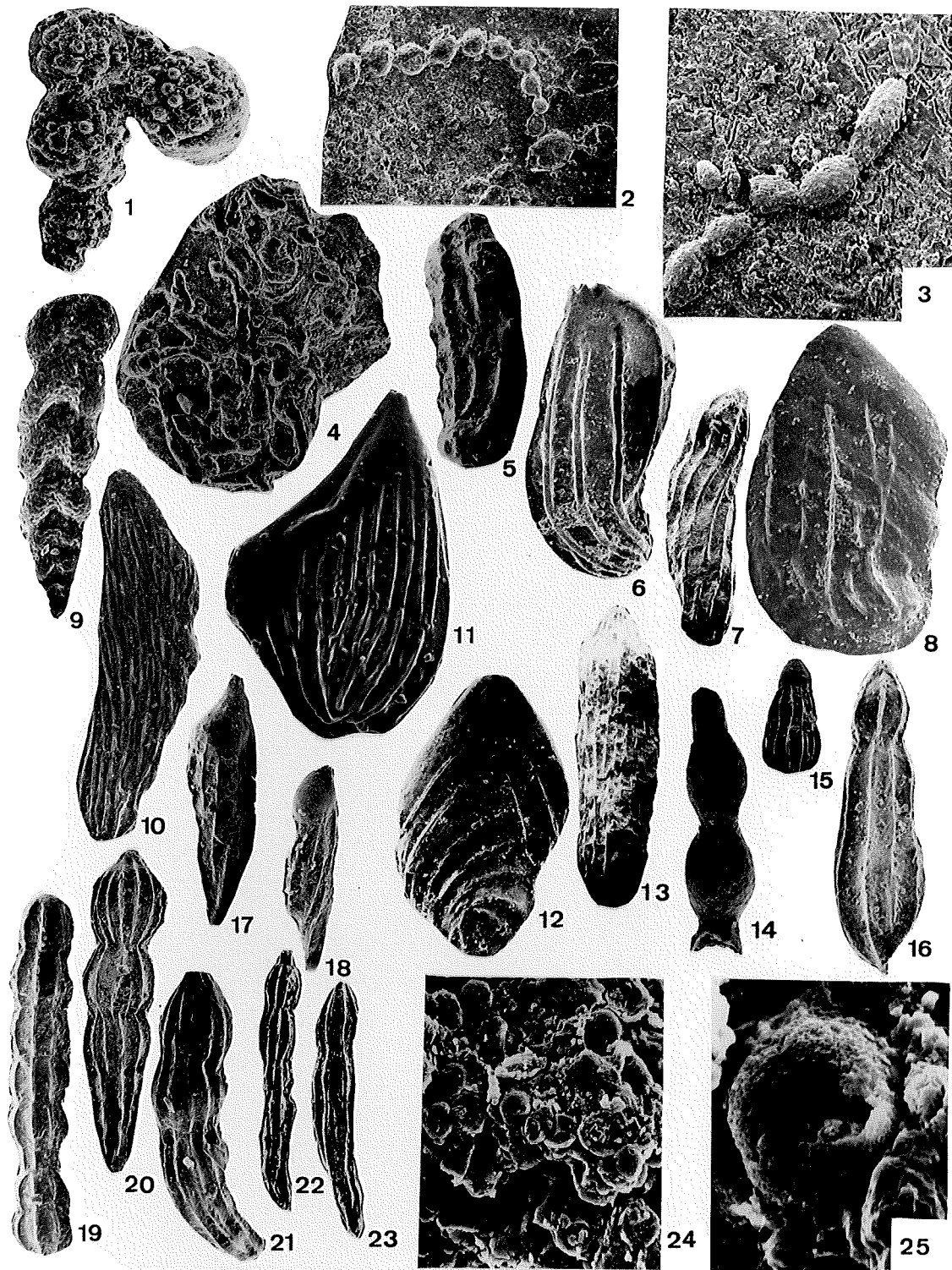


PLATE 5

Common accessory species of the various biofacies.

- fig. 1, Ammobaculites fontinensis Terquem, Sample KMP 75-291, Hook Norton Railway cutting, Scissum Beds, Upper Lias, 113x.
- fig. 2, Ammobaculites fontinensis Terquem and Berthelin, Mochras Borehole interval 2826-2830' D. tenuicostatum Zone, 150x.
- fig. 3, Ammobaculites sp. Sample KMP 75-398, Upper part of the Pabba Shales, U. jamesoni Zone, Hallaig shore, Raasay, Skye, 68x. Note U. jamesoni is abundant and U. augusta and P. brevispina are present in this shale layer.
- fig. 4, Citherina sp. Mochras Borehole interval 21.53-21.58', D. levesquei Zone, Wales, 188x.
- fig. 5, Lagena sp. cf. L. clavata d'Orbigny, Steeple Aston Borehole interval 373-378', U. jamesoni Zone, Oxfordshire, 158x.
- fig. 6, Lagena davoei Macfadyen, Sample KMP 75-316, Green Ammonite Beds, Lang Bed 122, West side of Golden Cap, Dorset, 75x.
- fig. 7, Lagena oxystoma Reuss, Sample KMP 75-309, Belemnite Marls, Lang Bed 115, East of Charmouth, Dorset, 75x.
- fig. 8, Glomospira perplexi Franke, Mochras Borehole interval 2429-2434', H. bifrons Zone, Wales, 150x.
- fig. 9, Nodosaria hirsuta d'Orbigny, Sample KMP 75-300, Belemnite Marls, Lang Bed 107, Stone Barrow Cliff, East of Dorset, 155x.
- fig. 10, Nodosaria nitidana Brand, Sample KMP 75-123, Lang Bed 48, The Spittles, East of Lyme Regis, Dorset, 158x.
- fig. 11, Nodosaria issleri Franke, Sample 75-399, 3.0 m above the base of the Pabba Shales, E. raricostatum Zone, Hallaig shore, Raasay, Skye, 90x.
- fig. 12, Nodosaria subprismatica Franke, Sample KMP 75-398 U. jamesoni Zone, upper part of the Pabba Shales, Hallaig shore, Raasay, Skye, 75x.

- fig. 13, Nodosaria radiata Terquem, Sample KMP 75-399, Pabba Shales, E. rariscostatum Zone, Hallaig shore, Raasay, Skye, 105x.
- fig. 14, Nodosaria sculpta Terquem, Sample KMP 75-404, apertual view of specimen in fig. 15.
- fig. 15, Nodosaria sculpta Terquem, Sample KMP 75-404, Pabba Shales, P. davoei Zone, Hallaig shore, Raasay, Skye, 105x.
- fig. 16, Frondicularia sulcata Bornemann, Barnard plexus form E, Sample KMP 77-325, Robins Wood Hill, T. ibex-P. davoei Zone, 45x. Note the central rib.
- fig. 17, Frondicularia sulcata Bornemann, Barnard plexus form F, Cocklepits Borehole interval 38.70-39.60 m, T. ibex Zone, Yorkshire, 60x. Note the central rib is missing.
- fig. 18, Frondicularia sulcata Bornemann, Barnard plexus form K, Sample KMP 75-299, Black Ven Marls, Lang Bed 102, Stonebarrow Cliff East of Charmouth, Dorset, 60x.
- fig. 19, Frondicularia sulcata Bornemann, Barnard plexus form J, Sample KMP 77-325, Robins Wood Hill, T. ibex-P. davoei Zone, 45x. Note there are only faint traces of any ribs.
- fig. 20, Involutina liassica Jones, Sample KMP 75-316, Lang Bed 122, Belemnite Marls, West side of Golden Cap, Dorset, 150x
- fig. 21, Lenticulina muensteri Roemer, Sample KMP 75-308 Lang Bed 114, Belemnite Marls, East of Charmouth, Dorset, 105x.
- fig. 22, Thurammia jurensis Franke, Mochras Borehole interval 2177-2182', G. thouarsense Zone, Wales, 150x
- fig. 23, Pseudonodosaria multicostata Bornemann Cocklepits Borehole interval 55.48-56.37m, U. jamesoni Zone, Yorkshire, 75x.
- fig. 24, Pseudonodosaria multicostata Bornemann Sample KMP 75-291, Black Ven Marls, 15.6 m above Pavior = Upper Cement Bed, West of Charmouth, Dorset, 30x.
- fig. 25, Pseudonodoaria quinquecostata Boremann, Sample

KMP 75-404, T. ibex Zone upper part of the
Pabba Shales, Hallaig shore, Raasay, Skye, 98x.

- fig. 26, Pseudonodoaria oviformis Terquem, Cocklepits
Borehole interval 26.60-27.10m, P. spinatum
Zone, Yorkshire, 150x.
- fig. 27, Pseudonodoaria vulgata Bornemann, Sample KMP
& 29, 75-113, Lang Bed 16, Upper White Shales, Seven
Rock Point, Devon, 45x. Note this form is
referred to as the "Pupa" form.
- fig. 28, Pseudonodoaria vulgata Bornemann, Sample KMP 75-
113, Lang Bed 16, Upper White Shales, Seven
Rock Point, Devon, 90x. Note the sutures are
flush and the test edges become parallel.

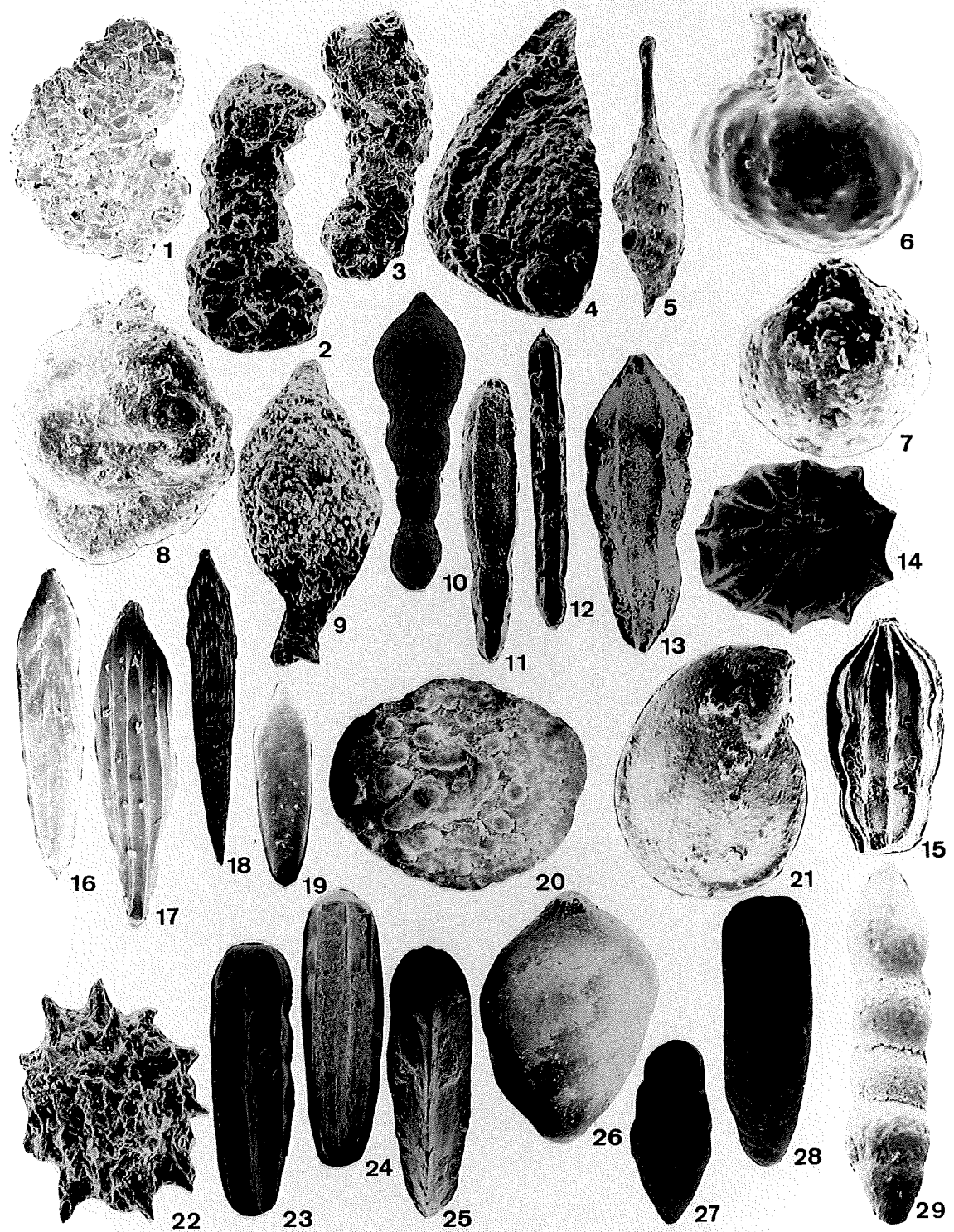


Plate 6

Common accessory species of various biofacies.

- fig. 1, Dentalina delongchampsii Terquem, Sample KMP 75-314, Lang Bed 122a, Green Ammonite Beds, between Seatown and Golden Cap, Dorset SY 413 918, 75x.
- fig. 2, Dentalina matutina d'Orbigny, Cocklepit Borehole interval 57.30-58.20m, E. raricostatum Zone, Yorkshire, 38x.
- fig. 3, Dentalina matutina d'Orbigny, Cocklepit Borehole interval 57.30-58.20m, O. oxynotum Zone, Yorkshire, 68x.
- fig. 4, Dentalina primaeva d'Orbigny, Cocklepit Borehole interval 55.43-55.37m, E. raricostatum Zone, Yorkshire, 75x.
- fig. 5, Dentalina primaeva d'Orbigny, Cocklepit Borehole interval 57.30-58.20m, E. raricostatum Zone, Yorkshire, 38x.
- fig. 6, Dentalina numismalis Franke, Sample KMP 75-291, Black Ven Marls 15.6m above Pavior = Upper Cement Beds and just below the Limestone with Brachiopods, West of Charmouth, Dorset, 75x.
- fig. 7, Dentalina quadrilatera fm. quinquelatera Franke, Sample KMP 75-398, U. jamesoni zone, Upper part of the Pabba Shales, Hallaig Shore, Raasay, Skye, 83x.
- fig. 8, Dentalina quadrilatera fm. quinquelatera Franke, apertural view of figure 7, 143x.
- fig. 9, Dentalina sp. A Brouwer 1969, Sample KMP 75-122, Lang Bed 46, Glass Bottle Shales, Seven Rock Point, Devon, 60x.
- fig. 10, Dentalina terquemi d'Orbigny, Sample KMP 75-113, Lang Bed 16, Upper White Shales, Seven Rock Point, Devon, 98x.
- fig. 11, Dentalina torta Franke, Sample KMP 75-113, Lang Bed 16, Upper White Shales, Seven Rock Point Devon, 38x.
- fig. 12, Dentalina vetusta d'Orbigny, Sample KMP 75-314 Lang Bed 122a, Green Ammonite Beds, P. davoei Zone between Seatown and Golden Cap, Dorset, 137x.

- fig. 13, Dentalina virgata Terquem, Sample KMP 75-314, Lang Bed 122a, Green Ammonite Beds, P. davoei Zone between Seatown and Golden Cap, Dorset, 53x.
- fig. 14, Dentalina virgata Terquem, Sample KMP 75-314, apertural view of figure 13, 90x.
- fig. 15, Dentalina virgata Terquem, Cocklepits Borehole interval 38.70-39.60m, T. ibex Zone, Yorkshire, 90x.
- fig. 16, Frondicularia brizaeformis Bornemann, Sample KMP 75-404, Upper Pabba Shales, P. davoei Zone, Hallaig Shore, Raasay, Skye, 75x.
- fig. 17, Frondicularia brizaeformis Bornemann, Sample KMP 75-111, Lang Bed H - 91, Pinhay Bay, Devon, 60x.
- fig. 18, Lingulina laevisissima Terquem, Sample KMP 75-120 Lang Bed 42, Venty Shales, Seven Rock Point, Devon, 128x.
- fig. 19, Lingulina laevisissima Terquem, Sample KMP 75-124, Lang Bed 50, Fish Bed Shales, The Spittles, East of Lyme Regis, Dorset, 113x.
- fig. 20, Nodosaria metensis Terquem, Sample KMP 75-109, Lang Bed H - 75, Pinhay Bay, Devon, 113x.
- fig. 21, Nodosaria regularis Terquem, Sample KMP 75-109, Lang Bed H - 75, Pinhay Bay, Devon, 90x.
- fig. 22, Nodosaria nitidana Brand, Sample KMP 75-123, Lang Bed 48, Grey Ledge Shales, The Spittles, East of Lyme Regis, Dorset, 45x.
- fig. 23, Nodosaria simplex Terquem, Sample KMP 75-121, Lang Bed 44, Top Quick Shales, Seven Rock Point, Devon, 90x.
- fig. 24, Nodosaria sp. 2394, Sample KMP 75-111, Lang H - 91, Pinhay Bay, Devon, 45x.
- fig. 25, Nodosaria sp. 2394, Sample KMP 75-404, Upper Pabba Shales, P. davoei Zone, Hallaig Shore, Raasay, Skye, 75x.
- fig. 26, Nodosaria sp. 2394, Sample KMP 75-404, apertural view of figure 25, 150x.

- fig. 27, Conorboides sp. cf. Conorboides sp. Brouwer 1969, Cocklepits Borehole interval 89.55-90.40m, S. angulata Zone, Yorkshire, 218x. Note Copestake and Johnson (1981) show this form synonymous (?) to Reinholdella ? planiconvexa Fuchs.
- fig. 28, Conorboides sp. cf. Conorboides sp. Brouwer 1969, Cocklepits Borehole interval 89.55-90.40m umbilical view, Yorkshire, 165x. Note the umbilicus is wide open.
- fig. 29, Reinholdella pachyderma subsp. A Copestake & Johnson 1981, peripheral view along the aperture Cocklepits Borehole interval 48.91-49.96m, U. jamesoni Zone, Yorkshire, 150x.
- fig. 30, Reinholdella pachyderma subsp. A Copestake & Johnson 1981, umbilical view, Cocklepits Borehole interval 48.91-49.96m, U. jamesoni Zone, Yorkshire, 150x. Note the partially open umbilicus.
- fig. 31, Reinholdella pachyderma subsp. A Copestake & Johnson 1981, spiral view, Cocklepits Borehole interval 48.91-49.96m, U. jamesoni Zone, Yorkshire, 150x.

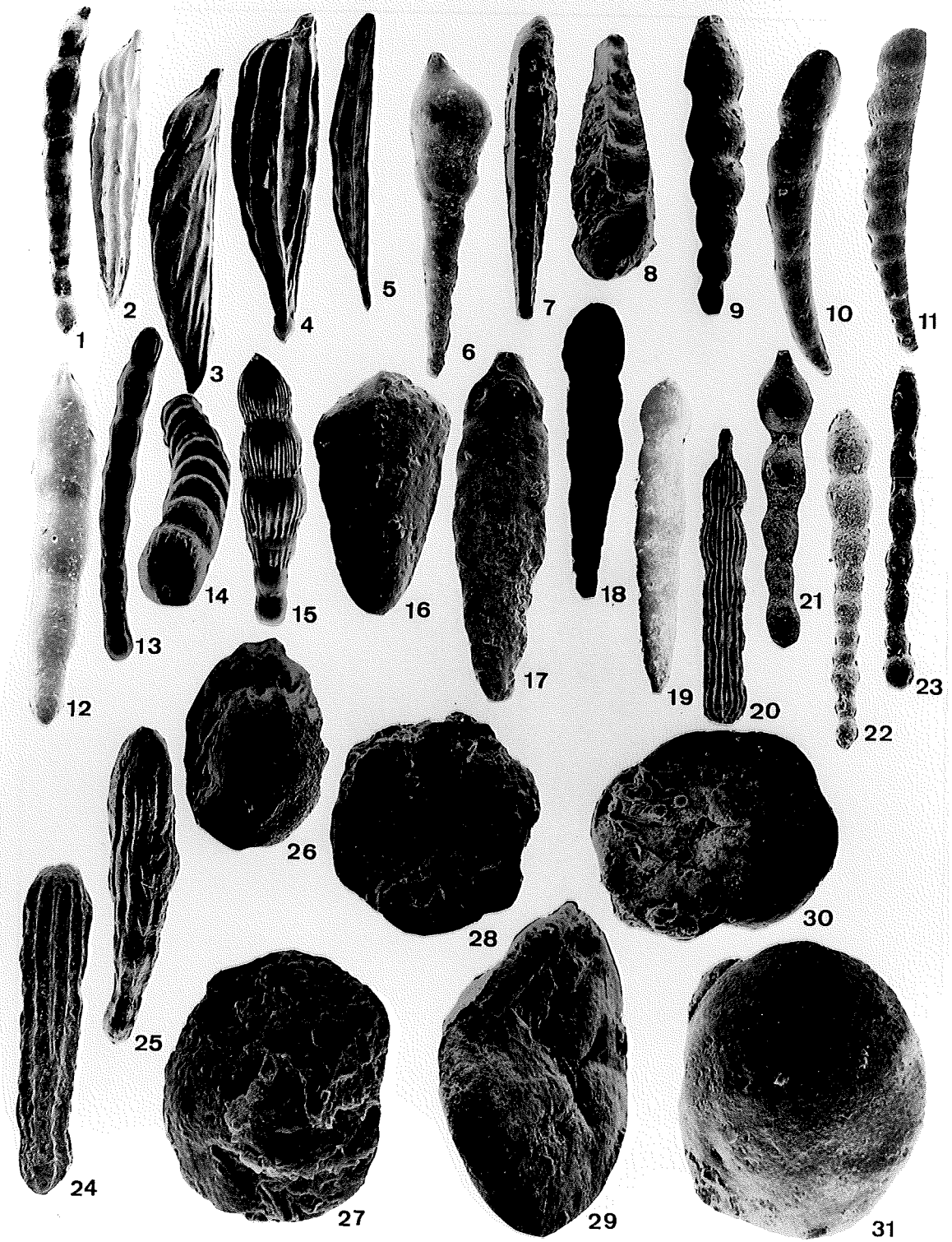


Plate 7

Common accessory species from various biofacies.

- fig. 1, Astacolus denticulata-carinata Franke, Cocklepits Borehole interval 57.32-58.20m, O. oxynotum Zone, Yorkshire, 150x.
- fig. 2, Astacolus denticulata-carinata Franke, Cocklepits Borehole interval 57.32-58.20m, O. oxynotum Zone, Yorkshire, 75x.
- fig. 3, Astacolus primus d' Orbigny, Cocklepits Borehole interval 57.32-58.20m, O. oxynotum Zone, Yorkshire, 30x. Note the oblique sutures.
- fig. 4, Astacolus semireticulata Fuchs, Sample KMP 75-401, Upper Broadford Beds, A. semicostatum Zone, Hallaig Shore, Raasay, Skye, 90x. Note this bed had common ammonites, brachiopods and bivalves.
- fig. 5, Astacolus semireticulata Fuchs, Sample KMP 75-400, Upper Broadford Beds, A. semicostatum Zone, Hallaig Shore, Raasay, Skye, 45x. Note the reticulate ornamentation covers the coiling portion and ceases shortly after the rectilinear portion of the test begins.
- fig. 6, Brizalina sp. (sp. nov.?) , Sample KMP 77-200, Howarth Bed 61, D. tenuicostatum Zone, Brackenberry Wyke, Yorkshire, 170x. Note careful observation shows the Braziline arrangement of the chambers and a calcareous test. The aperture is terminal and open. Small grains of silt and clay adhere to the test. This species is much smaller, gracile than Brazilina liassica.
- fig. 7, Lingulina nodosaria Terquem, Sample KMP 75-109, Lang Bed H - 75, S. angulata Zone, 113x. Note KMP 75-109 is an isolate in both cluster and factor analysis. The high diversity of the sample, its equitability, and its stratigraphic position suggest that this is a deep water assemblage.
- fig. 8, Lingulina nodosaria Terquem, Sample KMP 75-122, Lang Bed 46, A. bucklandi Zone, 90x.
- fig. 9, Saracenaria sublaevis sublaevis Franke, Sample 75-314, Lang Bed 122a, Green Ammonite Beds P. davoei Zone, between Seatown and Golden

Cap, Dorset, 135x. Note the test has been bored through by an organism.

- fig. 10, Saracenaria sublaevis sublaevis Franke, Sample 75-314, Lang Bed 122a, Green Ammonite Beds, P. davoei Zone, between Seatown and Golden Cap, Dorset, apertural view of figure 9, 203x .
- fig. 11, Spiroloculina sp. A Copestake & Johnson 1981, Sample KMP 75-119, Lang Bed 36, Rattle Shales, Biofacies Epsilon, Seven Rock Point, Devon, 135x.
- fig. 12, Spiroloculina sp. B Copestake & Johnson 1981, Sample KMP 75-119, Lang Bed 36, Rattle Shales, Biofacies Epsilon, Seven Rock Point, Devon, 113x.
- fig. 13, Spiroloculina sp. B Copestake & Johnson 1981, Sample KMP 75-119, Lang Bed 36, Rattle Shales, Biofacies Epsilon, Seven Rock Point, Devon, 135x.
- fig. 14, Vaginulina listi Bornemann, Sample KMP 75-109, Lang Bed H - 75, Pinhay Bay, Devon, 120x.
- fig. 15, Vaginulina listi Bornemann, Sample KMP 75-400, Upper Broadford Beds, Hallaig Shore, Raasay, Skye, 75x.
- fig. 16, Vaginulina triquetra Franke, Sample KMP 75-122, Lang Bed 46, Glass Bottle Shales, Seven Rock Point, Devon, 98x.
- fig. 17, Reophax sp. (adherent) Mochras Borehole interval, 2153-2158', D. levesquei Zone, Wales, 68x.
- fig. 18, Reophax sp. (adherent) Mochras Borehole interval 3232-3236', A. margaritatus Zone, Wales, 90x.
- fig. 19, Reophax metensis Franke, Sample KMP 75-291, Scissum Beds, Upper Lias, Hook Norton Railway Cutting, 113x. Note this is an Alpha - 1 Biofacies.
- fig. 20, Ammodiscus siliceus Terquem, Sample KMP 75-291, Scissum Beds, Upper Lias, Hook Norton Railway Cutting, 135x. Note this is an Alpha - 1 Biofacies.
- fig. 21, Tolypammina flagellum Terquem, Sample KMP 75-123, Lang Bed 48, Grey Ledge Shales, The

Spittles, East of Lyme Regis, Dorset, 45x.

- fig. 22, Trochammina gryci Tappan, Cocklepits Borehole interval 35.89-36.80m, T. ibex Zone, Yorkshire, 75x.
- fig. 23, Trochammina topagorukensis Tappan, Sample KMP 75-291, Scissum Beds, Upper Lias, Hook Norton Railway Cutting, peripheral view, 195x.
- fig. 24, Trochammina topagorukensis Tappan, Sample KMP 75-291, Scissum Beds, Upper Lias, Hook Norton Railway Cutting, spiral view, 203x.
- fig. 25, Ammovertella liassica Barnard, Sample KMP 75-307, Lang Bed 113b, U. jamesoni Zone, East of the waterfall at the mouth of Ridge Water, East of Charmouth, Dorset, 90x.

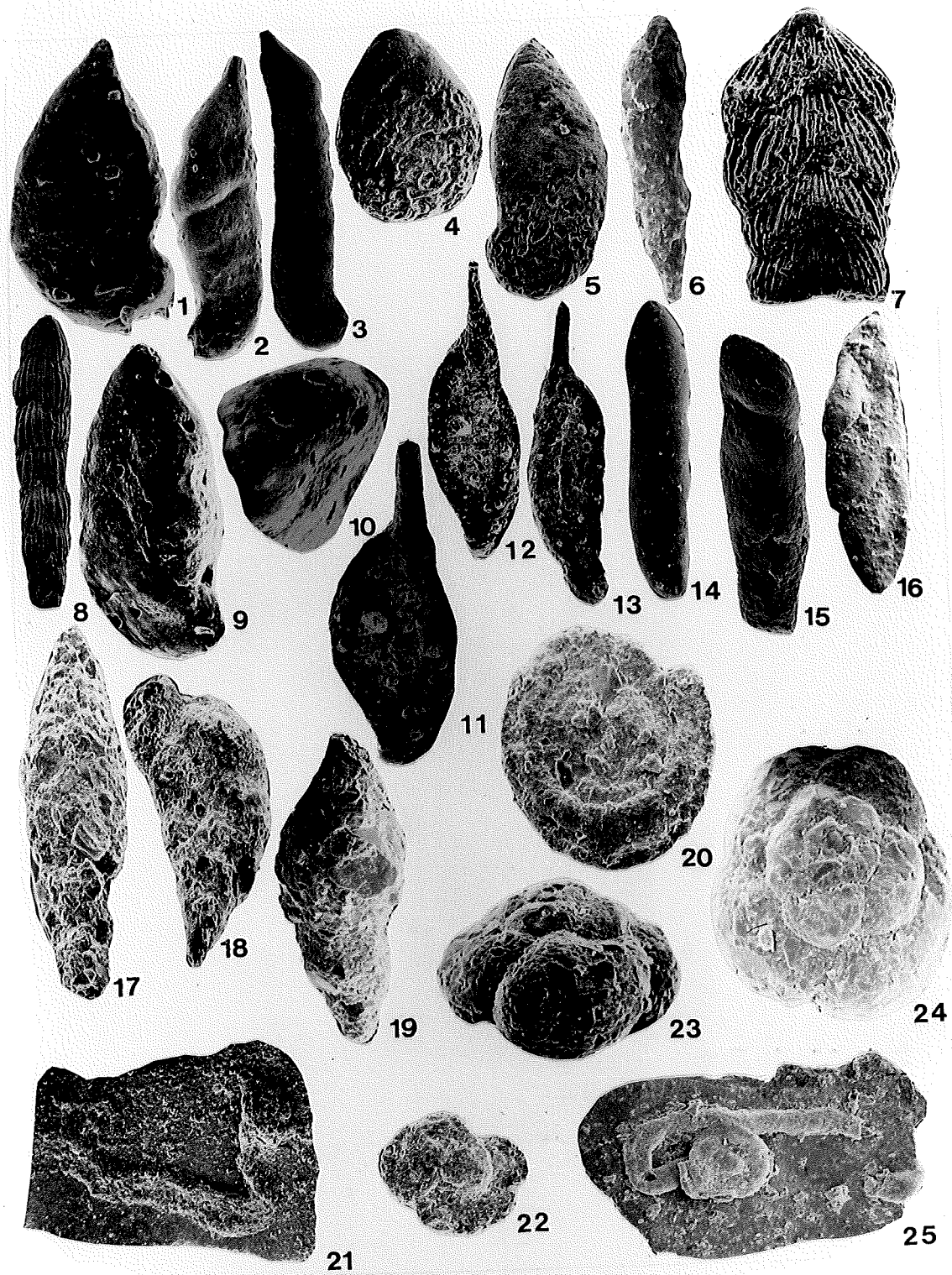


Plate 8

Primary species in Biofacies Zeta--Iota.

- fig. 1, Astacolus pauperatus Jones & Parker, Sample KMP 75-117, Lang Bed 32, Gumption Shales, A. bucklandi Zone Seven Rock Point, Devon, 60x.
- fig. 2, Astacolus pauperatus Jones & Parker, Sample KMP 75-117, Lang Bed 32, Devon, 113x.
- fig. 3, Astacolus pauperatus Jones & Parker, Sample KMP 75-117, Lang Bed H75, Devon, 113x.
- fig. 4, Astacolus pauperatus Jones & Parker, flabelline stage, Mochras Borehole interval 2153-2158', D. levesquei Zone, Wales, 113x. Note the ultimate chevron-shaped chamber nearly overlaps the entire test periphery.
- fig. 5, Dentalina exilis Franke, Sample KMP 75-109, Lang Bed H75, Pinhay Bay, Devon, 45x.
- fig. 6, Dentalina gladiiformis Franke, Sample KMP 75-109, Lang Bed H75, Pinhay Bay Devon, 120x.
- fig. 7, Dentalina gladiiformis Franke, Sample KMP 75-121, Lang Bed 44, Top Quick Shales, Seven Rock Point, Devon, 75x.
- fig. 8, Dentalina hausleri Schick, Sample KMP 75-299, taken immediately below Lang Bed 102, the Hummocky Limestone, Stone Barrow Cliff East of Charmouth, 45x.
- fig. 9, Dentalina hausmanni Bornemann, Sample KMP 75-314, Green Ammonite Beds, Lang Bed 122a, Dorset, 53x.
- fig. 10, Dentalina hausmanni Bornemann, Sample KMP 75-291. Black Ven Marls, west of Charmouth, 15.6m above the Pavior=Upper Cement Bed, just below Limestone with Brachiopods, 68x.
- fig. 11, Dentalina langi Barnard, Sample KMP 75-113, Lang Bed 16, Upper White Shales, Seven Rock Point, Devon, 90x.
- fig. 12, Dentalina langi Barnard, Sample KMP 75-113, Lang Bed 16, Upper White Shales, Seven Rock Point, Devon, 30x.

- fig. 13, Dentalina langi Barnard, Sample KMP 75-113, Lang Bed 16, Upper White Shales, Seven Rock Point, Devon, 60x. Note this species is a marker for the Hettangian-Lower Sinemurian Boundry at Dorset.
- fig. 14, Dentalina pseudocommunis Franke, Sample KMP 75-111, Lang Bed H91, Pinhay Bay, Devon, 60x.
- fig. 15, Dentalina sinemuriensis Terquem, Sample KMP75-118, Lang Bed 36, Rattle Shales, Seven Rock Point, Devon, 188x.
- fig. 16, Dentalina sinemuriensis Terquem, Sample KMP75-121, Lang Bed 44, Top Quick Shales, Seven Rock Point, Devon, 83x.
- fig. 17, Dentalina sinemuriensis Terquem, Sample KMP75-122, Lang Bed 46, Glass Bottle Shales, Seven Rock Point, Devon, 68x.
- fig. 18, Frondicularia sulcata Bornemann, Barnard plexus form C, Sample KMP 75- 119, Lang Bed 36, top of Rattle Seven Rock Point, Devon, 45x.
- fig. 19, Frondicularia sulcata Bornemann, Barnard plexus form D, Sample KMP 75- 115, Lang Bed 22, Mongrel Shales, Seven Rock Point, Devon, 68x.
- fig. 20, Frondicularia sulcata Bornemann, Barnard plexus form D, Sample KMP 75- 115, Lang Bed 22, Devon, 75x.
- fig. 21, Lenticulina muensteri Roemer, Sample KMP 75-314, Green Ammonite Beds, Lang Bed 122a, Dorset 75x.
- fig. 22, Lenticulina muensteri Roemer, peripheral view of fig. 21, 90x. Note view shows broad apertural face, aperture, and convex, smooth sides.
- fig. 23, Spirillina infima Strickland, Sample KMP 75-401, Upper Broadford Beds, E. Semicostatum Zone, Raasay, Skye, 210x. Note this bed was rich in brachiopods and bivalves; Spiriferina walcotti is abundant.
- fig. 24, Spirillina polygyrata Gumbel, Sample KMP 75-109, Lang Bed H - 91, Devon, 218x.
- fig. 25, Vaginulina clathrata Terquem, Cocklepits Borehole interval 21.06-21.96m, D. tenuicostatum Zone, Yorkshire, 38x.

- fig. 26, Vaginulina clathrata Terquem, Sample KMP 77-291, Hook Norton Railway Cutting, Scissum Beds, Upper Lias, 60x.
- fig. 27, Opthalmidium northamptonensis Wood & Barnard, Mochras Borehole interval 2153-2158', D. levesquei Zone, Wales, 188x.
- fig. 28, Opthalmidium orbiculare Burbach, Steeple Aston Borehole interval 342'-347', U. jamesoni Zone, Oxfordshire, 240x.
- fig. 29, Opthalmidium orbiculare Burbach, Cocklepits Borehole interval 49.86-50.80m, U. jamesoni Zone, Yorkshire, 225x.



PLATE 9

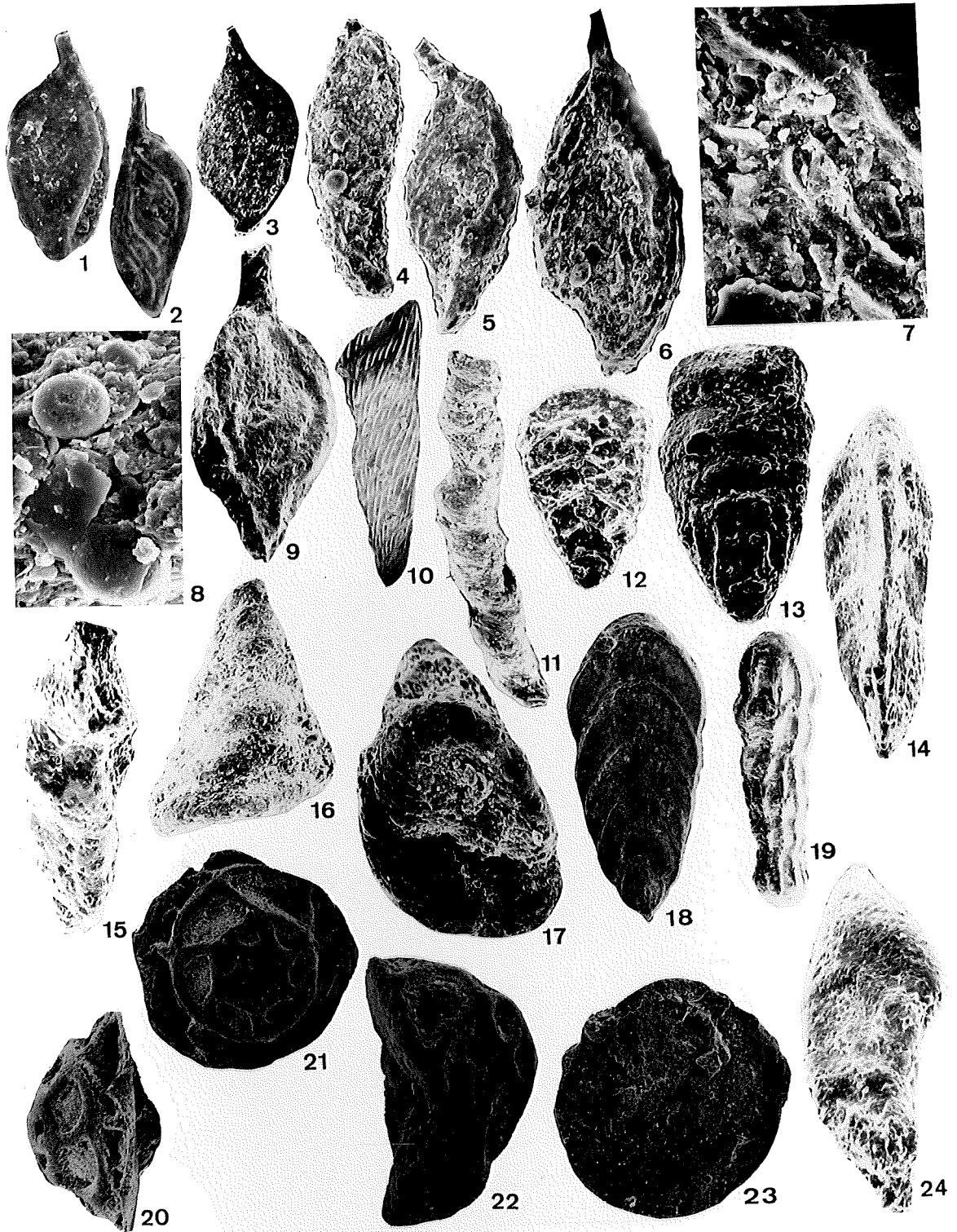
Primary species and accessory species for Biofacies Kappa and Lambda.

- fig. 1, Opthalmidium carinata Kubler & Zwingli, Steeple Aston Borehole interval 342-347 m, T. ibex Zone, Oxfordshire, 188x. Note the carinate margin of the test.
- fig. 2, Opthalmidium macfadyeni Wood and Barnard, Sample KMP 75-296, Black Ven Bed 96, Dorset, 150x.
- fig. 3, Opthalmidium macfadyeni Wood and Barnard, Sample KMP 75-314, Green Ammonite Beds, Lang Bed 122a, Dorset, 113x.
- fig. 4, Opthalmidium sp. var. striata, Steeple Aston Borehole interval 373-378', U. jamesoni Zone, Oxfordshire, 195x. Note the calcisphere attached to the test surface.
- fig. 5, Opthalmidium sp. var. striata, Steeple Aston Borehole interval 373-378', U. jamesoni Zone, Oxfordshire, 225x.
- fig. 6, Opthalmidium sp. var. striata, Steeple Aston Borehole interval 373-378', U. jamesoni Zone, Oxfordshire, 188x. Note the ornament consists of fine irregular ridges which are subparallel to the long axis of the test. They are sinuous and discontinuous. This may be a new species or simply a variation of O. macfadyeni. This form is common in Kappa.
- fig. 7, Enlargement of the ornamentation of the specimen in Figure 6, 750x.
- fig. 8, Calcisphere, in Shale, Steeple Aston Borehole interval 373-378', U. jamesoni Zone, Oxfordshire, 975x.
- fig. 9, Opthalmidium northamptonensis Wood & Barnard, Mocharas Borehole interval 2807-2812', H. falciferum Zone, Wales, 150x.
- fig. 10, Citharina colliezi Terquem, Cocklepits Borehole interval 38.70-39.60 m, T. ibex Zone, Yorkshire, 23x.
- fig. 11, Bathysyphon sp., Mochras Borehole interval 2177-2182', G. thouarsense Zone, Wales, 120x.

- fig. 12, Lingulina tenera occidentalis, Berthelin, Mochras Borehole interval 2949-2954', P. spinatum Zone, Wales, 188x. Note each chamber has a thickened border outlining its periphery.
- fig. 13, Lingulina testudinaria Franke, Mochras Borehole interval 2942-2947', P. spinatum Zone, Wales, 128x.
- fig. 14, Tristrix liasina Berthelin, Mochras Borehole interval 3232-3236', A. margaritatus Zone, Wales, 75x.
- fig. 15, Nubeculinella tibia Jones & Parker, Mochras Borehole interval 2548-2552', H. falciferum Zone, Wales, 128x.
- fig. 16, Verneuilioides mauritii Terquem, Sample KMP 75-300, Belemnite Marls, Lang Bed 107, Dorset, 113x.
- fig. 17, Verneuilioides mauritii Terquem, Umbilical view of specimen in figure 16, 150x.
- fig. 18, Frondicularia paradoxa Berthelin, Steeple Aston Borehole interval 378-393', U. jamesoni Zone, Oxfordshire, 135x.
- fig. 19, Nodosria simoniana d'Orbigny, Samples KMP 75-285, Black Ven Marls, Lang Bed 83, West of Charmouth, Dorset, 150x.
- fig. 20, Reinholdella macfadyeni Ten Dam emend. Hofker, peripheral view, Cocklepit Borehole interval 21.06-21.96 m, D. tenuicostatum Zone, Yorkshire, 105x. Note the umbilical plug extends outward considerably from the umbilicus.
- fig. 21, Reinholdella macfadyeni Ten Dam emend. Hofker, spiral view, Cocklepit Borehole interval 21.06-21.96m, D. tenuicostatum Zone, Yorkshire, 96x.
- fig. 22, Reinholdella macfadyeni Ten Dam emend. Hofker, edge view along aperture Cocklepit Borehole interval 21.06-21.96', D. tenuicostatum Zone, Yorkshire, 105x.
- fig. 23, Reinholdella macfadyeni Ten Dam emend. Hofker, umbilical view, 21.06-21.96 m, D. tenuicostatum Zone, Yorkshire, 105x. The plug has filled the

umbilicus.

fig. 24, Vaginulina sagittiformis Terquem, Mochras
Borehole interval 2807-2812', D. tenuicostatum
Zone, Wales, 188x.



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