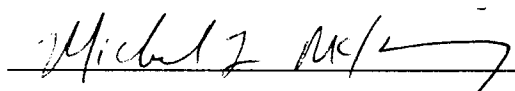


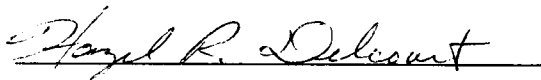
To the Graduate Council:

I am submitting herewith a thesis written by James Andrew Heller entitled "The Bryozoan Paleoecology of The Florala Limestone Member of The Bridgeboro Limestone (Lower Oligocene, Vicksburgian), Southeast Alabama and Northern Florida." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

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Michael L. McKinney, Major Professor

We have read this thesis
and recommend its acceptance:

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Accepted for the Council:

A handwritten signature in cursive script, reading "Lew Minkel", written over a horizontal line.

Associate Vice Chancellor
and Dean of the Graduate School

THE BRYOZOAN PALEOECOLOGY OF THE FLORALA LIMESTONE MEMBER
OF THE BRIDGEBORO LIMESTONE
(LOWER OLIGOCENE, VICKSBURGIAN), SOUTHEAST ALABAMA AND
NORTHERN FLORIDA

A Thesis

Presented for the

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Degree

The University of Tennessee, Knoxville

James Andrew Heller

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ABSTRACT

The Florala Limestone Member of the Bridgeboro Limestone (Lower Oligocene, Vicksburg Stage) comprises a sequence of richly fossiliferous corallgal wackestones and packstones that outcrop in southeastern Alabama and are present in the subsurface of the western Florida Panhandle. Previous research suggests the Florala reflects a quiescent, middle-shelf environment existing at depths between 70 and 80 meters and may represent, in part, a progressive bathymetric shoaling; however, strong empirical data supporting these conclusions are lacking. The current study represents a paleoecological analysis of this unit using its inherently abundant and diverse cheilostome and cyclostome bryozoan assemblages as a principal means of interpretation. This investigation was conducted at two study localities: the type section, located in Covington County, Alabama, and a core from Walton County, Florida. The principal methods of analysis used in this study include the application of zoarial morphology to infer the nature of substrate, turbulence, and relative rates of sedimentation between study sites and among stratigraphic samples, as well as the robust techniques of Detrended Correspondence Analysis (DCA) and rarefaction to quantitatively examine the ecological structure and respective stratigraphic changes in taxonomic associations. The results of this study indicate that considerable paleoenvironmental variation exists than has been previously determined. The inferred paleoecological conditions at the Walton County site denote a higher incidence of particulate substrates, a relatively higher degree of water energy, and possibly greater sedimentation influx than determined for the type locality. Stratigraphic changes in the taxonomic composition of faunal assemblages suggests a pattern of allogenic replacement at both study localities possibly accompanied by a progressive decline in ecological stability and equability. The underlying factor of the allogenic replacement

may have been related to a shallowing in bathymetry, which, on the basis of stratigraphic changes in the abundance of zoarial morphology and taxonomic associations, is a plausible interpretation. The application of known bathymetric ranges of modern congeners to extant taxa found in the Florala suggest an average depth of 60 meters which is close to results from previous studies.

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CHAPTER I

INTRODUCTION

The Florala Limestone Member of the Bridgeboro Limestone (Lower Oligocene, Vicksburg Stage) comprises a vertical sequence of densely fossiliferous corallgal marine strata that crop out in southeast Alabama and are present in the subsurface of the central Florida panhandle (Bryan, 1991, 1993; Huddlestun, 1993). The recent studies of Bryan (1991, 1993) and Huddlestun (1993) regarding eastern Gulf Coastal Plain Oligocene stratigraphy suggest that the Florala Limestone represents a transitional facies between the Bridgeboro Limestone of southwest Georgia/northwest Florida and the Glendon Limestone of south-central /southwest Alabama. This transition is determined primarily from an assemblage of fossils comprised of exclusively Bridgeboro and Glendon faunal and floral elements (Bryan, 1991, 1993; Heller and Bryan, 1992). In addition, the platy coralline algal biofacies of the Florala Limestone appears intermediate in nature between the corallgal-poor sediments of the Glendon Limestone and the massive corallgal rhodolith buildups of the Bridgeboro Limestone (Bryan, 1991, 1993).

Paleoenvironments of the Glendon and Bridgeboro Limestones have been well documented (Coleman, 1983; Manker and Carter, 1987; Baum and Vail, 1988; Loutit and others, 1988; Mancini and Tew, 1992), and Bryan (1991, 1993) has postulated that the change in environments from the Glendon to the Bridgeboro represents a west to east shoaling bathymetric gradient .

The spatial paleoecological variation of the Florala Limestone has never been examined in any great detail, nor have prior interpretations thoroughly documented the environmental history. Bryan (1991), using qualitative petrographic descriptions and field observations, compared sedimentary textures and coralline algae of the Florala

Limestone with a modern analog (the Flower Garden Banks of Minnery, 1990) to derive an estimate of paleobathymetry (70 to 80 meters). Analysis of corallgal growth morphology (the growth - form model of Steneck, 1986) allowed Bryan to characterize the algal substrate as indicative of low physical and biological disturbance. Other types of paleontological data (inherent microfossils, quantitative abundance) were not used to corroborate or refine his conclusions, nor was any attempt made to discern stratigraphic change in the Florala Limestone paleoenvironment. Huddlestun (1993) deduced a more generalized depositional scenario based solely on lithofacies. His interpretation suggested that the Florala Limestone was an off-shore marine environment situated well within the photic zone. Huddlestun also attempted to interpret the sea level history of the Florala Limestone utilizing benthic foraminifera from samples of a core drilled in Walton County, Florida. On the basis of his observations Huddlestun asserted that the stratigraphic sequence represents, at least in part, a progressive shallowing event. Data supporting his contention, however, were never presented in his report thereby making his inference somewhat speculative and anecdotal.

The present study represents an analysis of the Florala Limestone in an attempt to delineate in detail the paleoecological setting and its temporal variation. The richly fossiliferous strata are composed of a variety of calcitic skeletonized organisms that in particular contain a highly diverse assemblage of cheilostome and cyclostome bryozoans. Primary data were derived largely from aut- and synecological interpretations of the constituent bryozoan fauna. Research was conducted with regard to several aspects, including: stratigraphic distribution of bryozoan growth - form abundance, fossil assemblage classification/composition and evaluation of temporal changes in species alpha (within sample) and beta (between sample) diversity. In addition, quantitative thin section petrography was performed in order to supplement the bryozoan analyses with other paleoenvironmental information. The assessment of

petrographic data also served as an independent check on some of the bryozoan-based paleoecological inferences.

The results of the faunal and petrographic studies suggest the following:

(1) The conclusions of previous investigators are generally correct; however, to a large degree their interpretations are incomplete. Initial studies indicate a depositional setting that reflects quiescent, off-shore, marine conditions. More detailed analyses suggest that there is considerable paleoenvironmental variation between exposures in Alabama and subsurface strata in Florida. The overall biotic composition of the Florala Limestone at the type locality in Covington County, Alabama, denotes a comparatively lower energy marine setting than observed approximately seven km to the south in Walton County, Florida. The nature of the fossil assemblages indigenous to both sites suggests distinct differences in substrate and possibly sedimentation rate.

(2) Observed stratigraphic changes in bryozoan taxonomic assemblages of the Florala Limestone demonstrate patterns of allogenic replacement (Dodd and Stanton, 1990). The composition and persistence of faunal associations is different for the Alabama and Florida localities studied indicating discrete ecological circumstances and replacement processes. Despite the paleoecological dissimilarities, corresponding trends in replacement can be discerned for each site. In general, both locales record a transition from relatively equable and stable marine ecosystems with low turnover in species composition to settings of increased environmental stress with contrastingly high turnover in species composition.

(3) Temporal change in the ecology of the Florala Limestone supports Huddleston's contention of a shoaling upward sequence. The marked transition of bryozoan fossil assemblages and other biotic constituents, as well as stratigraphic shifts in zoarial growth-form abundance, indicate a bathymetric trend towards increasingly shallower water depths.

CHAPTER II

GEOLOGIC SETTING

Stratigraphic Framework

Lower Oligocene Vicksburg Provincial Stage stratigraphy in the eastern Gulf Coastal Plain is comprised largely of marine sediments of considerable lithological diversity (MacNeil, 1944; Coleman, 1983; Huddlestun, 1993; Bryan, 1991, 1993). From Mississippi to Georgia these deposits are exposed in a discontinuous, relatively arcuate band approximately 612 km in length. Observed vertical and lateral changes in lithic types can be quite rapid, often occurring at local scales of a few kilometers (Bryan, 1993; Huddlestun, 1993). Lithostratigraphic recognition for the purposes of mapping, however, is generally consistent throughout the eastern Gulf Coast states (with the notable exception of the lithostratigraphic revisions in Georgia by Huddlestun, 1993) (Figure 1).

At the regional level Vicksburg strata can be classified as belonging to one of two prominent lithosomes. One, is a series of primarily terrigenous clastic sediments that are prevalent in exposures in southern Mississippi and southwest Alabama. The other is an sequence of marine limestones which extends through south-central/southeast Alabama, northern Florida and southwest Georgia (Cooke, 1918; MacNeil, 1944; Tew and Mancini, 1992; Bryan, 1993; Huddlestun, 1993). Within the vicinity of south-central Alabama a transitional phase is noted between the two lithosomes, which exhibits lateral gradational and intertonging facies relationships (Tew and Mancini, 1992; Bryan 1991, 1993).

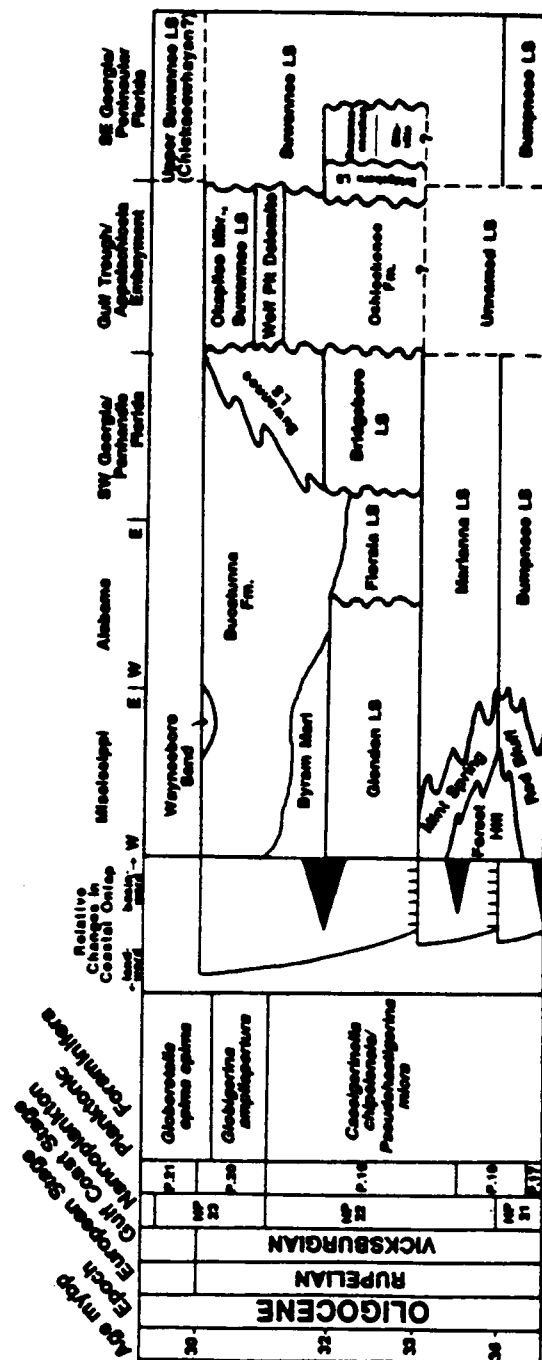


Figure 1. Generalized regional stratigraphy of Vicksburgian units of the eastern Gulf Coastal Plain (modified from Bryan, 1991).

Carbonate and siliciclastic sediments are not mutually excluded from either lithosome. At certain times siliciclastic sedimentation was apparently diminished enough to allow the development of organic buildups and carbonate platform style deposits as far west as the Mississippi - Louisiana border (Coleman, 1983). Similarly, near the end of the Vicksburg Stage terrigenous clastic deposition had extended well beyond the south - central Alabama transition and into the vicinity of the eastern Florida panhandle (Bryan, 1993).

In Mississippi and southwest Alabama Vicksburg lithostratigraphic nomenclature (Figure 1) generally follows that of MacNeil (1944). Stratigraphic units are, in ascending order : the Bumpnose Limestone of western Alabama, and the Red Bluff Clay, Forest Hill Sands, Mint Spring Marl, Marianna Limestone, Glendon Limestone, Byram Formation and Bucatunna Formation in Mississippi and Alabama. Some workers have regarded the youngest unit of the Late Eocene Jackson Group, the Shubuta Member of the Yazoo Clay, as having closer faunal affinities with the Red Bluff Clay than the rest of the Jackson and consequently include it in the Vicksburgian (Cheetham, 1963; Deboo, 1965; Hazel, 1970). Studies by Miller and others (1993) and Flugelman and others (1994) of the Paleogene planktonic foraminifera in this area tend to corroborate a Vicksburgian stage assignment for this unit.

Vicksburg Stage lithostratigraphy in eastern Alabama and the western Florida panhandle is similar to that observed in southwest Alabama with the notable exception of the Red Bluff Clay, Mint Spring Marl, and Byram Formation (MacNeil, 1946; Bryan 1991, 1993). The stratigraphic series typically observed constitutes the following units: the Bumpnose Limestone, Marianna Limestone, Glendon Limestone, and Bucatunna Formation. The Florala Limestone Member of the Bridgeboro Limestone occurs in this area and is postulated to occupy the same stratigraphic level as the Glendon Limestone (Bryan, 1991, 1993; Heller and Bryan, 1992; Huddlestun, 1993).

In the eastern Florida panhandle and southwest Georgia the Vicksburg sequence is comprised of the Bumpnose Limestone, Marianna Limestone, Bridgeboro Limestone, and the Suwannee Limestone (Bryan 1991,1993; Huddlestun, 1993). The Bridgeboro and the Suwannee Limestones are situated on either side of an elongate funnel shaped subsurface structure known as the Gulf Trough (Huddlestun, 1993). This feature (discussed below) is a paleophysiographic element that trends in a northeast direction from the panhandle into northeast Georgia (Figure 2). Units confined to the narrow portion of the Trough are the Ochlockonee Formation and the overlying Wolf Pit Dolostone (Huddlestun (1993). Where the trough widens the Okapilco Member of the Suwannee Limestone is present (Huddlestun, 1993).

The Vicksburg stratigraphic sequence in the northern Florida peninsula and adjacent areas of south - central/southeast Georgia is defined by the following units: The Ellaville Limestone, Suwanacoochee Dolostone and Suwannee Limestone (Huddlestun, 1993). Beds comprising the Ellaville Limestone in the vicinity of Lafayette County and Suwannee County Florida have previously been referred to as the Bumpnose Limestone (Hunter,1972), Byram Limestone (Cooke, 1945) and Suwannee Limestone (MacNeil, 1946; Puri and Vernon, 1964). Paleontological studies by MacNeil (1946) and Hunter (1972) have alluded to the possibility that the youngest strata of the Jacksonian Ocala Limestone, in Lafayette and Suwannee Counties, may have Vicksburgian affinities.

Biostratigraphic correlation of the Vicksburgian in the eastern Gulf Coast is presently being revised (Bryan, 1993). Formations in southwestern Alabama and Mississippi can be tied directly to European stages on the basis of planktonic foraminifera (Mancini and Waters, 1986; Mancini and Tew, 1988, 1991; Miller and others, 1993) and calcareous nannofossils (Bybell, 1982; Siesser, 1983); however, as one travels eastward from this area into the Florida panhandle and southern Georgia, the lithologies undergo a transition from fine grain siliciclastic sediments and argillaceous

limestones into exceedingly pure shallow marine carbonates which are virtually devoid of diagnostic planktonic microfossils (Bryan, 1991, 1993; Bryan and Huddlestun, 1991). Consequently, precise biostratigraphic correlation is difficult. Glawe (1969) established an interregional correlation using a lineage of pectinid molluscs. In Florida and Georgia, however, this lineage is only partially represented (Glawe, 1969), making direct correlation with formations in Alabama and Mississippi impractical. Hazel and others (1980) devised an interregional biozonation based on ostracodes; unfortunately their correlations do not extend far beyond south-central Alabama. Bryan (1991), Bryan and Huddlestun (1991), Heller and Bryan (1992), and Huddlestun (1993) have demonstrated the correlation of the Vicksburg formations in southeast Alabama, southern Georgia, and northern Florida with their respective planktonic microfossil-bearing equivalents utilizing various macrofossils, benthic foraminifera and general lithostratigraphic relationships.

In general, Vicksburg age formations can be assigned directly or correlated to one particular planktonic microfossil zone with the exception of the Mint Spring Marl and Marianna Limestone. These units have been shown to be time transgressive, comprising nannoplankton zone NP 21 in southeastern Mississippi and southwest Alabama and zone NP22 in south-central and southwest Mississippi (Siesser, 1983; Pettaway and Dunn, 1990).

In recent years the Vicksburg has been studied as a part of the eastern Gulf Coast Paleogene sequence stratigraphic research of Vail and others (1987), Baum and Vail (1988), Mancini and Tew (1988, 1991), Tew (1992), Tew and Mancini (1992), and Huddlestun (1993). Recent workers (Mancini and Tew, 1988, 1991; Tew, 1992; Tew and Mancini, 1992) generally recognize three major sequences in the Vicksburg stage in southeast Mississippi and southwest Alabama. Application of biostratigraphic correlation (Mancini and Tew, 1988, 1991), and more recently, magnetic and strontium

isotope stratigraphic techniques (Miller and others, 1993) to these sequences has suggested their correlation to events of the early Oligocene sea level chronology of Haq and others (1987). Sea level highstand-regression cycles in this area correspond to Haq and others (1987) global events TA - 4.3, TA - 4.4, and TA - 4.5 (Figure 1). The presence of these cycles in the Vicksburgian strata of northeast Florida and southeast Georgia has not been extensively investigated. (Bryan, 1991, 1993) has postulated their existence on the basis of stratigraphic correlations between units in Florida and western Alabama. Huddlestun (1993), however, recognized only cycles TA - 4.4 and TA - 4.5 in this area. The confirmation of definitive basal Vicksburg deposits in the northern Florida peninsula and southeast Georgia would indicate the presence of cycle TA 4.3 and may eventually redefine this interpretation.

Regional Geography and Paleoenvironments

The Vicksburg marine sequence in the eastern Gulf Coast Plain is characteristic of a classic passive continental margin setting (Murray, 1961; Miller and others, 1993; Huddlestun, 1993). Throughout much of the early Oligocene this region was relatively isolated from regional tectonic deformation, and, with the exception of localized movement of Jurassic salt deposits (Murray, 1961; Martin, 1978), has been virtually undisturbed since that time. The position of the Vicksburg shelf margin was not significantly different from its present day location (approximately 26° to 32° N) and manifested a diverse array of depositional environments ranging from deltaic systems to tropical coral reefs (Bryan, 1991, 1993; Huddlestun, 1993).

Earliest Vicksburgian deposits in the eastern Gulf Coast, which correspond to the latter half of sea level cycle TA - 4.3, are defined by the upper Shubuta Clay, Forest Hill Sand, Red Bluff Clay and Bumpnose Limestone. The Shubuta, Forest Hill and Red Bluff are interpreted as subenvironments of a prograding constructional delta that

derived its source sediments from regions to the west and northwest of the Gulf Coast (Cooke, 1918; MacNeil, 1944; May, 1974; Tew and Mancini, 1992). The Shubuta and Red Bluff strata are indicative of prodeltaic conditions (Mancini and Tew, 1991; Tew and Mancini, 1992), whereas the Forest Hill lithofacies reflect fluvial, delta plain and delta front characteristics (Dockery, 1982, 1989; Mancini and Tew, 1991; Tew and Mancini, 1992). The Bumpnose Limestone, which developed distal to the Red Bluff, denotes open shelf conditions in Alabama and the Florida panhandle (Bryan, 1991). Strata suggested to be Bumpnose equivalent in the Florida peninsula (Bryan, 1991, 1993; Hunter, 1972) are considered to be contrastingly shallower on the basis of abundant miliolid foraminifera, calcareous green algae and an impoverished macrofauna (Bryan, 1991).

Following deposition of the Shubuta/Forest Hill/Red Bluff deltaic environments, a destructional delta, represented by sediments of the Mint Spring Marl, was initiated by transgression of the Vicksburg sea at the beginning of TA - 4.4 (Mancini and Tew, 1991; Tew and Mancini, 1992; Tew, 1992). Concurrently, fine grain pelagic carbonate sediment of the Marianna Limestone was deposited adjacent to the Mint Spring in southwest Alabama (Pettaway and Dunn, 1990). Sedimentation of the Marianna was quite widespread and extended into Florida panhandle and southwest Georgia (Bryan, 1991, 1993; Huddleston, 1993). As Marianna deposition ceased in southeast Mississippi and southwest Alabama, sediment accumulation of the Mint Spring began in western Mississippi (Pettaway and Dunn, 1990). Continued deepening as a result of transgression eventually introduced Marianna sediments into this area as well (Pettaway and Dunn, 1990).

Sea level rise in the eastern Gulf Coast during TA - 4.4 reached its maximum with the deposition of the Marianna Limestone (Mancini and Tew, 1988, 1991; Tew and Mancini, 1992; Tew, 1992). Following transgression a broad carbonate ramp,

represented by the facies of the Glendon, Florala, and Bridgeboro limestones, became established east of the pelagic environments in Mississippi (Bryan, 1991,1993). The Glendon - Florala - Brigeboro transition is postulated by Bryan (1991) to reflect a west-to-east shallowing bathymetric gradient. Paleoenvironmental conditions are interpreted as changing from slowly aggrading shelf margin deposits of the Glendon to relatively faster accumulating corallgal buildups of the Bridgeboro Limestone (Bryan, 1991, 1993) (Figure 2). Especially convincing evidence of this west-to-east shoaling is the change in the relative abundance and growth-habits of coralline algae. This progresses from the Glendon, a corallgal-poor lithology, into the abundant thin platy coralline algal crust bindstones of the Florala, and farther east prolific rhodolith (algal nodules) and coralline algal maerls of the Bridgeboro Limestone (Bryan, 1991). Using descriptions of a highly similar modern analog, the Flower Garden Banks of the northwestern Gulf of Mexico, Bryan suggested a bathymetric zonation for the Bridgeboro and Florala facies. The reef environment of the Flower Garden Banks exhibits similar sedimentary features to those of the Bridgeboro and Florala limestones. Rhodoliths in the Flower Garden banks occur between depths of 45 and 80 meters, and between 70 to 80 meters grade into thin algal crust "pavements" (Minnery, 1990). Bryan also cited previous research (p. 126) from the Caribbean and the Florida Reef Tract demonstrating the presence of rhodoliths at depths as shallow as 30 meters (Reid and MacIntyre, 1988; Praeger and Ginsburg, 1989). On the basis of these modern examples Bryan proposed a depth zonation of 30 to 70 meters for the Bridgeboro Limestone and 70 to 80 meters for the Florala Limestone. In the proximity of the western edge of the Gulf Trough coral reefs have been identified in the Bridgeboro and possibly represent the shallowest conditions of deposition (Bryan, 1991).

The rhodolith facies of the Bridgeboro is also present on the eastern flank of the Gulf Trough but represents a less developed facies of this unit (Manker and Carter,

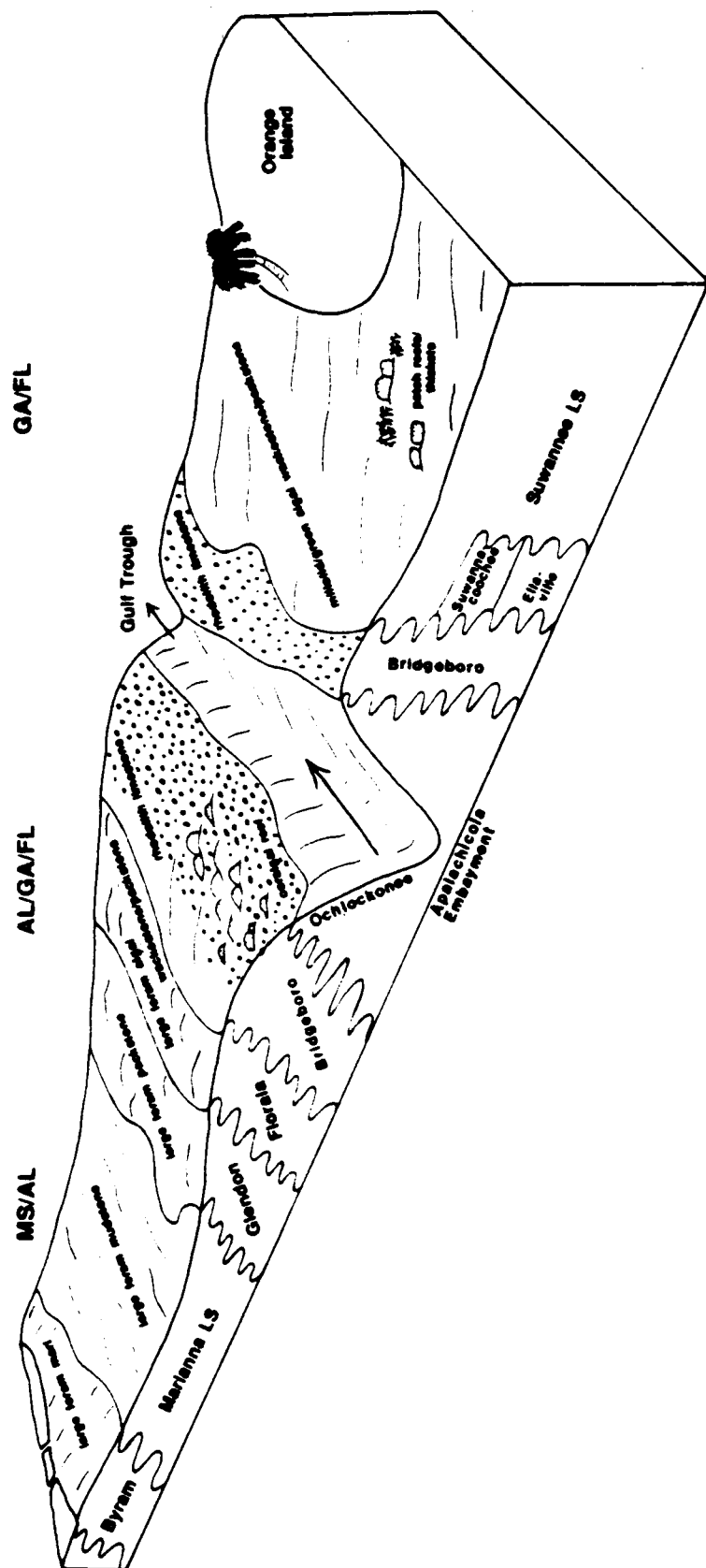


Figure 2. Block diagram reconstruction of Vicksburgian carbonates across the entire eastern Gulf Coastal Plain from Mississippi to Florida (from Bryan, 1991).

1987; Huddlestun, 1993). This coralgall buildup rapidly grades eastward into the rhodolith-poor backreef environment of the Ellaville Limestone and the overlying peritidal deposits of the Suwannacoochee Dolostone (Bryan, 1991; Huddlestun, 1993). Above and adjacent to these units and adjacent to the upper Bridgeboro is the extensive carbonate platform/backreef facies of the Suwannee Limestone (Bryan, 1991). Water depth is interpreted to be exceedingly shallow in the Suwannee, perhaps not exceeding depths of 10 meters (Bryan, 1991). Abundant reef corals also appear throughout much of this formation and in some areas form dense coral thickets (Bryan, 1991, 1993). Massive coral heads of Siderastrea and Montastrea (?) are also common in the Suwannee of the northern Florida peninsula and southern Georgia and may indicate the presence of patch reefs (Bryan, 1991, 1993). During the early Oligocene a large island spanning much of the eastern Florida Peninsula and southeast Georgia existed within the shallow sea of the Suwannee carbonate platform. Evidence for this feature, known as "Orange Island" (Figure 2; Vaughn, 1910) is derived from abundant lower Oligocene land mammal assemblages commonly associated with platform deposits as well as a lack of Vicksburgian strata in this region. This feature is considered by Bryan (1993) to represent an emergent part of the eastern platform. Conditions of platform deposition persisted through TA - 4.5 (Huddlestun, 1993).

Development of the rhodolith and coral reefs of the Bridgeboro Limestone and the shallow marine carbonate environments of the Ellaville, Suwannacooche and Suwannee facies resulted from rapidly flowing tropical waters channeled through the Gulf Trough. This feature, which existed from the middle Eocene to middle Miocene (Huddlestun, 1993), is believed to have funneled warm waters of the Gulf of Mexico Loop Current into this area during periods of high sea level (Bryan, 1991; Huddlestun, 1993). The relatively swift tropical water mass, possibly accentuated by the northeast narrowing of the Trough, provided the necessary conditions (warm, vigorous currents)

to initiate and allow the persistence of the adjacent rhodolith buildups and shallow platform environments (Bryan, 1991, 1993; Huddlestun, 1993).

Concurrent facies in the Gulf Trough are composed of relatively deep marine sediments of the Ochlockonee Formation which were initially deposited at depths exceeding 200 meters (Huddlestun, 1993). In the northeast area of the Gulf Trough the Ochlockonee grades into comparatively shallower deposits of its Pridgen Limestone Member (Huddlestun, 1993). Throughout the latter half of TA - 4.4 sediment infilling of the Gulf Trough produced regressive conditions which eventually culminated in the restricted shallow marine conditions of the Wolf Pit Dolostone (Huddlestun, 1993).

The depositional setting of TA - 4.5 is characterized by nearshore and marginal marine paleoenvironments of the Byram Formation and Bucatunna Clay in southern Mississippi and southwest Alabama (Hazel and others, 1980; Coleman, 1983; Manning and others, 1985). Sediments of the Byram typically pinch out in southwest Alabama, however, Bryan (1991, 1993) considers isolated beds of gray marl overlying the Marianna Limestone in Jackson County, Florida to be representative of Byram lithology. The Bucatunna facies thickens eastward from Mississippi to Alabama (Hazel and others, 1980) and also extends into the central Florida panhandle where it is considerably more calcareous (Huddlestun, 1993). The Bucatunna is laterally replaced by the Suwanee Limestone in the eastern Florida panhandle and southwest Georgia. In the southern end of the Gulf trough, where relatively deeper marine conditions prevailed, the platform environment of the Suwanee Limestone graded into the coral reef buildup of the Okapi Limestone.

The transition from the late Eocene to the early Oligocene coincided with a major climatic cooling event in the marine and terrestrial realms (Wolfe 1978; Kennet, 1983; Miller and others, 1987; Prothero, 1994). In the eastern Gulf Coast region this climatic shift has been documented on the basis of palynofloral data which indicate a progressive

change to cooler, possibly drier, terrestrial conditions. Earliest Vicksburgian marine fossils, however, demonstrate the presence of a tropical - subtropical sea during this time. Hansen (1992, figure 16.2) notes the predominance of characteristically warm water molluscan taxa in the basal Vicksburg formations of Mississippi and Alabama. In addition, the ostracode genus Jugosocythereis, a tropical - subtropical taxon of the modern oceans, is a common faunal element in Vicksburgian nearshore deposits (Hazel and others, 1980; Hazel, 1990). By middle Vicksburg time marine temperatures became relatively cooler. Studies of the foraminifera of the Marianna Limestone in southwest Alabama by Echols and Schaeffer (1960) denoted a subtropical to temperate latitude biota. Sedimentological studies by Bryan (1991, 1993) implied that with the exception of the carbonate facies in the vicinity of the Gulf Trough, other carbonate units such as the Marianna, Glendon and Florala Limestones exhibit strong affinities with temperate, cool water shelfal carbonates of the present day. The composition of these formations is primarily of calcitic skeletonized debris of which bryozoans are a common component (Bryan, 1991); the Marianna and Glendon contain bryozoans in particularly prolific quantities (Askren, 1968, Bryan, 1991, 1993). Bryomal carbonate sediments are often prevalent in temperate latitude seas (Nelson and others, 1988).

Florala Limestone: Lithology and Stratigraphic Relationships

Huddlestun (1993) described the Florala Limestone as a highly porous, friable, variably indurated bioclastic carbonate containing dense accumulations of coralline red algae and larger benthic foraminifera (*Lepidocyclina* and *Nummulites*). The Florala outcrops at a single locality in southeast Alabama, and occurs primarily as a subsurface unit in the central Florida panhandle. The type section, located in the southeast corner of Covington County, Alabama, (Figures 3) is a massively bedded sequence of wackestones and packstones composed of substantial volumes of thin, platy, coralline

red algae (Figure 4) (Bryan, 1991, 1993; Heller and Bryan, 1992; Huddlestun, 1993). Bryan (1991) observed that some stratigraphic levels within the type section were exclusively micritic algal bindstones. In intervals where the algae are less developed beds exhibit a granular appearance due to the abundance of larger benthic foraminifera and small, club-shaped red algae. In general a gradational change throughout the type section shows a progressive decrease in platey coralline algal textures and a concomitant increase in larger benthic foraminifera. In comparison, subsurface deposits appear more homogeneous, demonstrating diminished quantities of platey coralline algae and a greater abundance of larger benthic foraminifera. Both the type section and subsurface strata become exceedingly well-cemented near the top of the unit.

The Florala Limestone is disconformably overlain by the Bucatunna Clay (Huddlestun, 1993). The basal formational contact, though not exposed at the type section, is observable in core and is considered by Huddlestun (1993) to rest conformably on the Ocala Limestone. During the course of the present investigation it was found that recognition of the Florala below a certain depth was dubious. Examination of Huddlestun's Florala sequence in his reference parastratotype, W-8104, by the author and colleagues revealed an abrupt loss in typical Florala lithologic characteristics approximately 9 meters below the formational contact between the Florala and Bucatunna. This change is characterized by a lack of coralline algae corresponding with an increase in larger benthic foraminifera and porosity. Distinct layers of moderately glauconitic chalk are also noted in the underlying carbonates. This lithology closely resembles the Glendon Limestone of western Alabama, a porous, algal-poor unit containing abundant larger benthic foraminifera, and is regarded as such in the present study. Bryan (1991, 1993) has stated that the Florala overlies the Marianna Limestone. It is possible that tongues or lenses of the Glendon lithology may interfinger with the Marianna and Florala Limestones in the area of western Florida. The Glendon

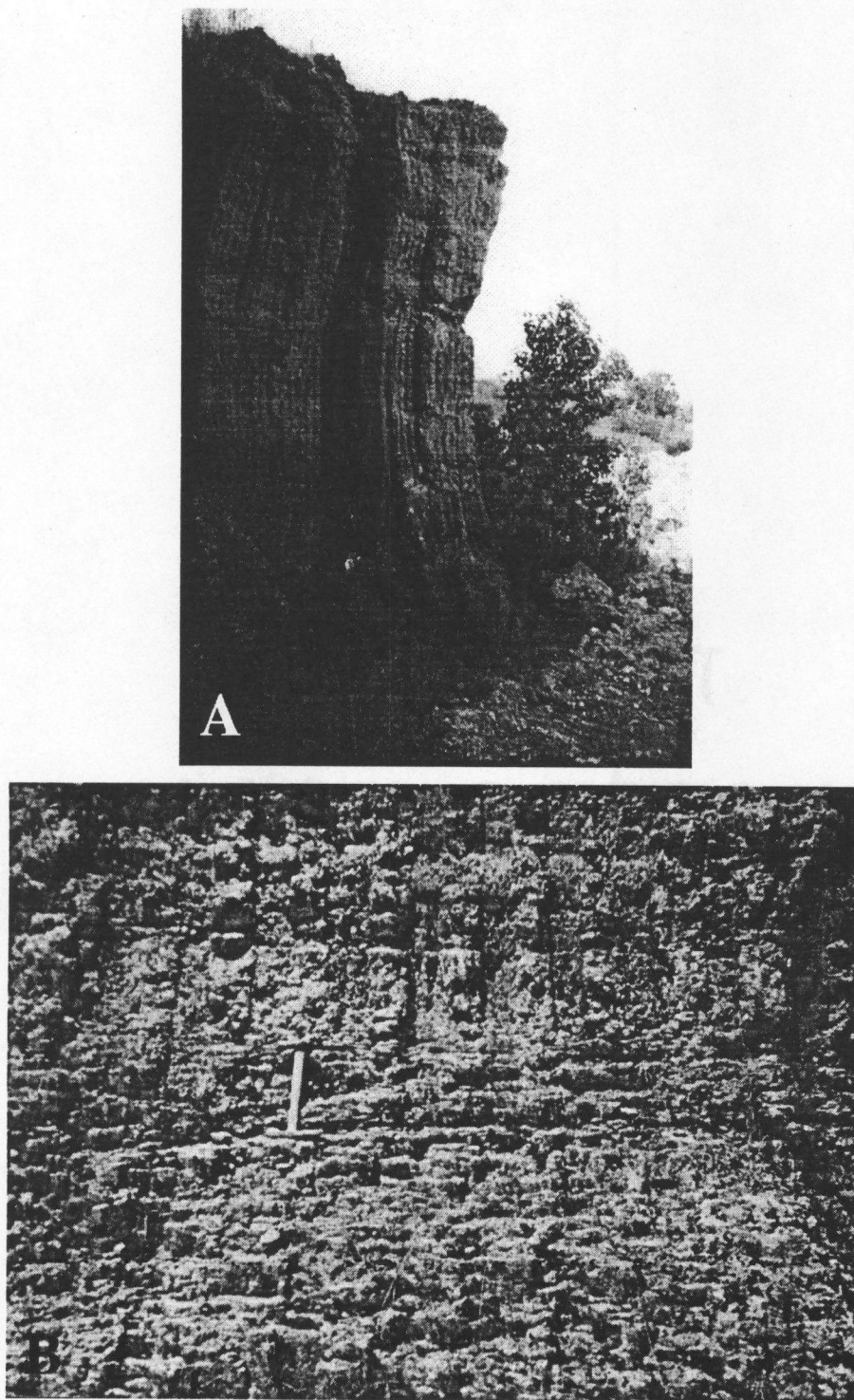


Figure 4. Field photos of the Florala Limestone at the type locality. A, a prominent quarry exposure. B, outcrop showing algal crust development.

Limestone is reported as outlier strata in southwestern Georgia (Huddlestun, 1993) and so could conceivably be represented in the subsurface of the Florida panhandle. Bryan (1991) also noted the similarity of this interval in W-8104 to the Glendon Limestone. Further detailed mapping and subsurface studies are needed to refine the stratigraphic relationships of the Florala.

CHAPTER III

METHODS OF INVESTIGATION

Material for this study was obtained from an exposure of the Florala Limestone Member at the type locality in Covington County, Alabama, and from the subsurface parastratotype W-8104 in Walton County, Florida (Figure 3). Collection emphasis, however, was placed on the type locality owing to the greater availability of samples. The choices of data collection were determined by the nature of fossil preservation at the type locality. A preliminary survey by the author and colleagues, produced very few macrofaunal remains of which the entire collection was exclusively calcitic organisms. Microscopic examination of several disaggregated bulk samples indicated a more substantial and diverse microfauna primarily consisting of larger and smaller benthic foraminifera, and zoarial fragments of cheilostome and cyclostome bryozoa. Preservation was observed to be more suitable with regard to the bryozoan skeletons. Paleoecological interpretations in the present study, therefore, were principally derived from analyses of the bryozoan assemblages. Although better preservation of other microfossils was noted in cuttings from W-8104 the analysis of core samples was limited to bryozoans in order to make comparisons with the type locality. Quantitative thin section petrography also was utilized to supplement the analyses of bryozoan material with other paleoenvironmental data.

Collection And Sample Preparation

A detailed measured section (Figure 5) was compiled from the most accessible exposures at the site. Twenty-seven stratigraphically oriented samples were collected at regular half-meter intervals. An additional 7 lateral samples were also collected at

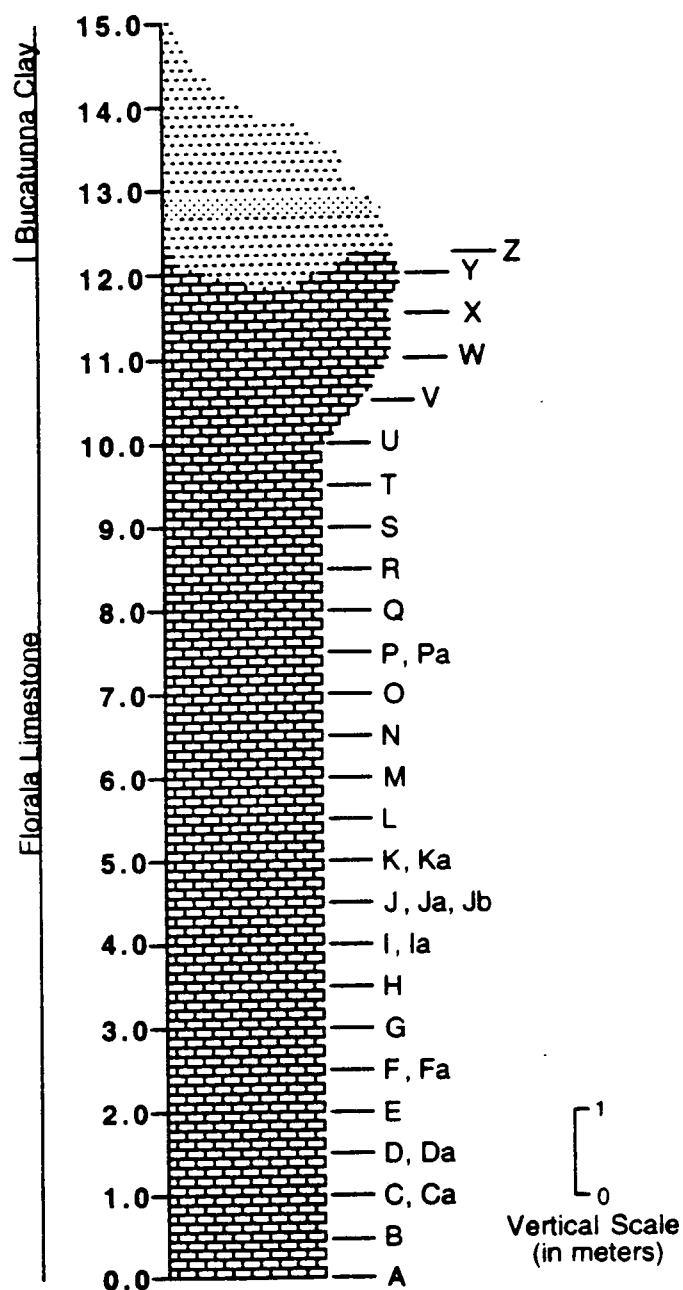


Figure 5. Measured section and sampled intervals of the Florala type section.

intervals where space permitted. Description and sampling of the parastratotype was completed in December, 1992, at the Florida Geologic Survey Core Repository in Tallahassee (Figure 6). Core samples, unlike the type locality, were not extracted at regular intervals owing to missing and poorly recovered segments.

Preparation of samples for the extraction of bryozoans was performed using a technique outlined in Brasier (1980) for the separation of calcareous microfossils from partially indurated limestones. As this procedure is only applicable to loosely and semi-consolidated sediment, collected samples from well cemented intervals were excluded. A total of 24 samples from the type locality and nine samples from the parastratotype were utilized. The separation procedure entailed the breakdown of approximately 100 to 250 grams of limestone acquired from each bulk sample; materials from the core were prepared in their entirety (varying from 4 to 8 grams depending on the sample). Using a mortar and pestle chips and fragments of carbonate were gently crushed into smaller size pieces (1 - 10 mm). For each sample crushed limestone was boiled in a 1000 ml beaker containing a 5N solution of Na_2CO_3 (washing soda) to facilitate disaggregation (approximate duration of 2 hours). Following this step the solution was decanted and the residue oven dried. Thin sections large enough to accommodate greater than 300 point counts were prepared from bulk samples. Core samples were either too small in size or extremely friable to produce adequate thin sections. A total of 37 standard thin sections (5.5 x 7.5 cm) were made.

Analytical Procedures

Paleoenvironmental reconstructions were derived from several different analyses of the data. Bryozoan collections retained from each sample were examined to assess the abundance of zoarial growth-forms and taxonomic content. The quantification of

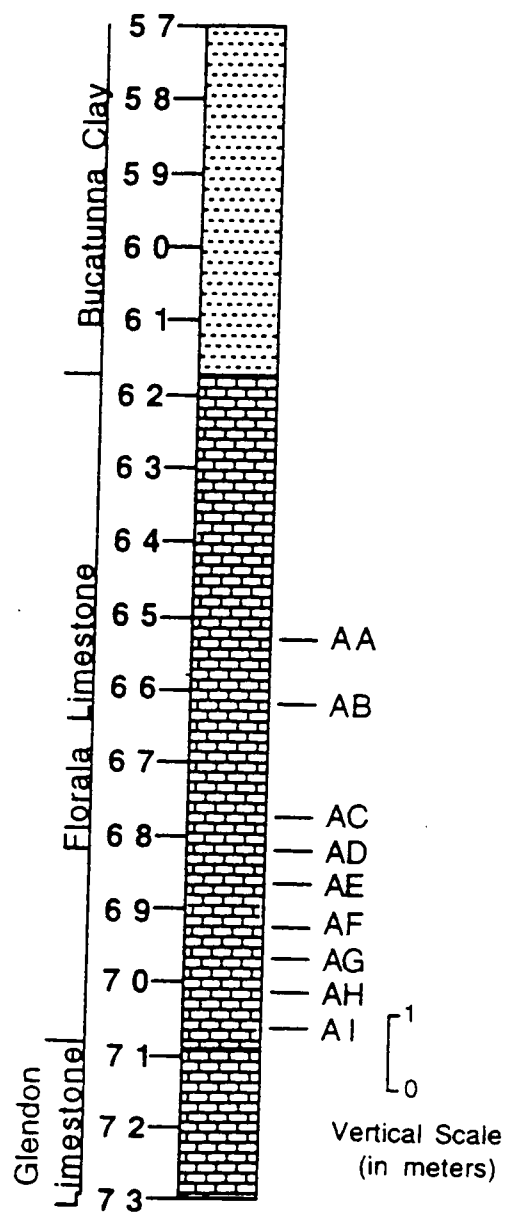


Figure 6. Measured section and sampled intervals of the Florala Limestone in W-8104.

stratigraphic variation on zoarial morphology, as discussed below, is a potentially useful tool in discerning the nature of ancient substrates, turbulence, sedimentation rate, and paleobathymetry. In the present study growth-habit data were tabulated with regard to their absolute abundances among samples and between the two study localities.

Taxonomic data were examined using the robust ordination method of Detrended Correspondence Analysis (DCA) to discern species assemblages and ecological patterns. Stratigraphic variance in taxonomic composition (beta diversity) and richness (alpha diversity) was also calculated to determine the magnitude of biotic change and equability in the type area and core sequences; values of alpha and beta diversity were computed using rarefaction and DCA respectively. In addition, the petrographic data were studied by comparing changes in the percent allochem abundance at the type locality.

Bryozoan identifications and species counts were implemented with the aid of a binocular microscope. Scanning electron microscopy was used for some taxa to resolve finer anatomical details when necessary. Bryozoan taxonomy in this study principally follows the works of Canu and Bassler (1920, 1923, 1928, 1929), McGuirt (1941), Cheetham (1963, 1966), Brood (1972), and Moissette (1988).

Analysis Of Bryozoan Zoarial Growth Form For Paleoenvironmental Interpretation

Growth Form Classification

Colonies of modern and ancient bryozoan species exhibit a diversity of zoarial growth-habits, ranging from flat encrusting forms where the zooids adhere directly to the substrate, to upright-rigid branching and fenestrate structures which fasten to a stable surface by cementation or by rootlets (Cuffey, 1970; Cheetham, 1971; Nelson

and others, 1988; McKinney and Jackson, 1989). Some colonies assume an erect-flexible design where the zooecia are connected by chitinous joints and the entire skeleton is attached to the substrate by chitinous rootlets (Nelson and others, 1988). In addition, several species have colonies which are vagrant or free-living, unattached to the sea floor, that typically display a discoidal or conical architecture (Stach, 1936; Cook, 1968, Nelson and others, 1988). These different zoarial morphologies (as well as their inclusive subdivisions) commonly vary in their adaptive value to any given environment (Cheetham, 1971; Harmelin, 1988; McKinney and Jackson, 1989).

In their comprehensive survey of the evolution of the phylum Bryozoa, McKinney and Jackson contended that growth-form commonly reflects the nature of an ecological niche, more so than phylogenetic heritage. They amply documented numerous examples of growth-forms as adaptive patterns to a multitude of niche factors, including: feeding, competition for space, and differing sediment and hydrodynamic conditions. Their examination of extant and fossil lineages demonstrated the convergence of similar growth types in unrelated groups indicating the exploitation of identical niches by different clades. Ideally it is a combination of environmental parameters, resource availability, degree and frequency of disturbance and competition that ultimately influence the abundance of any particular growth-form (Cheetham, 1963, 1971; Nelson and others, 1988; McKinney and Jackson, 1989; Moissette, 1989). Studies of modern and ancient sedimentary deposits (discussed subsequently) have indicated a consistent relationship between zoarial morphology and specific environmental attributes, namely substrate, sedimentation rate, water agitation, and relative bathymetry (of which all four, to some degree are interrelated). Consequently, determination of the relative proportions of zoarial growth-morphologies present within a sedimentary facies can prove beneficial to paleoenvironmental reconstruction.

The association between zoarial growth-form and environment was originally proposed by Stach (1936) based on his observations of modern cheilostomes and their change in response to depth, turbulence and substrate. Stach constructed nine zoarial categories, each diagnostic of a set of characteristic environmental conditions. In a subsequent study Stach (1937) posited that cheilostome species could be separated into two groups on the basis of a taxon's capacity to manifest more than one zoarial growth-habit. Species displaying one type of growth-form regardless of the ecological setting were recognized as 'stable' forms. These stable forms were considered to reflect highly specialized adaptations and were generally excluded from adverse environmental situations. Species exhibiting different growth-types under varying ecological circumstances were classified as 'unstable' forms. Those taxa with unstable morphologies typically developed a growth form suited for their present habitat. Presumably unstable species could inhabit a wider array of environments than stable types (Cheetham, 1971). Stable colony forms characterized a heritable and evolutionarily constrained species adaptation, whereas multiple growth-habits within a species collectively denoted a heritable adaptation; however, the individual environmental expression represented a nonheritable ecophenotypic response (Cheetham, 1971).

Stach's dichotomous typology relied on the recognition of six stable and three unstable growth-forms. Species that developed the highly specialized colonial design consisted of the following: petraliiform (encrusting flexible - anchored, but pliant - substrates by means of chitinous fibers); reteporiform (erect-fenestrate); cellariform (erect-articulated); catenicelliform (erect-articulated); flustriiform (erect-articulated lacking a calcified skeleton); and lunulitiform (unattached). Unstable species produced colonies that could be membraniporiform (encrusting stable substrates by cementation), vinculariform (erect-cylindrical or -subcylindrical) and eschariform (erect-bilamellar). In

essence Stach's classification implicitly assumed that any taxon manifesting an unstable growth form would inevitably transform into one of the other two unstable morphologies given the appropriate environmental stimuli (Cheetham, 1971; Harmelin, 1988). Later ecological researches of bryozoan growth form, particularly those of Lagaaij and Gautier (1965), Cheetham (1963), and Cook (1968, 1985) have shown that numerous cheilostome species exhibiting an unstable morphology typically retain one form throughout differing environmental settings, and some species with stable forms can display great degrees of ecophenotypic plasticity. McKinney and Jackson (1989) noted that of 340 species examined, 24% had the potential to grow in more than one shape. Commonly, ecologic plasticity is observed in other aspects of the colony structure regardless of morphotype (Harmelin, 1988; McKinney and Jackson, 1989). Such variation can be expressed in branch or stem thickness, zooid size, and the means of substrate adherence.

Growth-form analyses of modern assemblages, conducted by Lagaaij and Gautier (1965) and Schopf (1969), resulted in amended versions of Stach's growth-form classification. Lagaaij and Gautier recognized two subdivisions of the membraniporiform structure: membraniporiform 'A' which encrusted solid substrates and membraniporiform 'B' which encrusted flat flexible substrates. They also introduced three additional growth-form categories: celleporiform, a multilaminar encrusting type; setosellinoform, an encrusting growth-habit with a spiral budding pattern; and adeoniform, a variant of the eschariform class having lobate branches. Lagaaij and Gautier also defined two major growth-form subdivisions on the basis of a colony's substrate attachment: loosely attached (petraliiform, cellariform, and catenicelliform, which fasten to a surface by means of chitinous rootlets) and firmly attached (membraniporiform, setosellinoform, celleporiform, adeoniform, eschariform, vinculariform, and reteporiform, which bind to the substrate by cementation or by

inflexible calcareous rootlets). Schopf incorporated some of Lagaaij and Gautier's terminology into his revised growth-form nomenclature, comprised of four major categories grouped on the basis of substrate preference and observed tolerances of hydrodynamic energy and sedimentation rate. These classes consisted of erect-rigid growth-types (adeoniform, eschariform, reteporiform, and vinculariform), encrusting growth-types (celleporiform, membraniporiform, petraliiform, and setosellinoform), erect-flexible growth-types (catenicelliform, cellariform and flustriform) and unattached growth-types (lunulitiform). Schopf also recognized three additional morphologies from earlier bryozoan workers (hemescharan, lichenoporiform, and orbituliporiform) but excluded their usage due to insufficient ecological data. Both Lagaaij and Gautier's and Schopf's systematizations were also applicable to species of cyclostome bryozoans with analogous growth-habits. Cook (1968) adopted Lagaaij and Gautier's classification and also added the descriptive term *scrupariiform* which denoted a rare encrusting morphology with delicate erect appendages. Brood (1972), in his monograph of the Cretaceous-Danian cyclostome bryozoa of Scandanavia, erected eleven distinct colonial shapes for cyclostome species following the methodology of Schopf. Many of Brood's growth-form descriptions are similar to those of Schopf's as well.

More recently, Nelson and others (1988) have integrated previous zoarial growth-habit classifications to produce a simpler descriptive terminology, one that is more conducive to sedimentological studies. As with Schopf's classification Nelson and others' typology recognizes four broad groupings of encrusting, erect-rigid, erect-flexible and unattached growth-forms. Subdivisions of broader categories using the specialized zoarial morphologic terms for cheilostome and cyclostome faunas (Stach, 1936; Lagaaij and Gautier, 1965; Schopf, 1969; Brood, 1972) have been condensed into ten subcategories on the basis of structural similarity and observed environmental occurrences. Titles for each subcategory are more geometrically descriptive than prior

biological connotations. Nelson and others' growth-form classification (Figures 7 and 8) is used in the present study as it represents the latest and most comprehensive compilation of growth-forms and their related environmental parameters. Nelson and others' growth-form typology can be summarized accordingly:

Encrusting. This category constitutes two groups: unilaminar, which incorporates Stach's (1936) membraniporiform and Brood's (1972) stomatoporiform and unilaminar diastoporiform morphologies; and multilaminar represented by Lagaaij and Gautier's (1965) celleporiform and Buge and Fischer's (1970) Astractosoeciform varieties. Petraliiform in this classification is considered an uncommon variant of the membraniporiform cheilostome species and is grouped as a unilaminar form. Unilaminar species commonly exhibit solidly calcified dorsal surfaces which adhere to flat cohesive (hard), substrates (a prominent feature in all encrusting cyclostomes). Less common are taxa with partly or weakly calcified dorsal walls or species that attach to a surface using chitinous rootlets which Stach (1935) and Lagaaij and Gautier (1965) believed were associated with uncohesive (flexible) substrates (petraliiform and membraniporiform B). Schopf (1969) found little evidence supporting substrate preference in Encrusting (membraniporiform) species and disregarded Stach's and Lagaaij and Gautier's distinction. This is also supported by Nelson and others (1988). The multilaminar growth-habit represents an encrusting adaptation where the zooecia use the existing colony structure as a substrate. The resulting shape is an irregular stacking of multilamellar sheets of zoaria (celleporiform of Lagaaij and Gautier, 1965). Multilaminar growth-habits are further divided into three shape classes denoted as A, B, and C. Multilaminar A faunas construct thick amorphous colonies on a variety of surfaces. Larvae of the multilaminar A class often settle on sedimentary particles which serve as nuclei for attachment and growth. The developing colony eventually

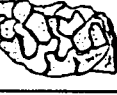
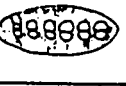
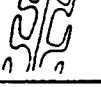
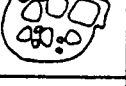
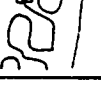
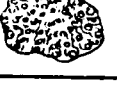
ZOARIAL SHAPE AND APPEARANCE		CLASSIFICATION AND DESCRIPTION	TRANSVERSE SECTION	LONGITUD. SECTION
ENCrustING (EN)	Unilaminar (ul)	 MEMBRANIPORIFORM Unilaminar sheets encrusting solid, sometimes flexible substrate; in latter case dorsal wall poorly calcified		
	(A)	 CELLEPORIFORM A Colonies heaped irregularly in multilaminar masses of variable shape on or around flexible, sometimes rigid substrate; zooecia open on all sides		—
	Multilaminar (ml) (B)	 CELLEPORIFORM B Encrusts pagurid-inhabited gastropod shells forming cylindrical tube from aperture; (sub)spherical nodular zoaria encapsulate substrate		—
	(C)	 CELLEPORIFORM C Hemispherical, multilaminar, heavily calcified basal lamina; zooecia open on outer face		—
ERect RIGID (ER)	Foliaceous (fo)	 ESCHARIFORM Erect, rigid, foliaceous, convoluted, bilamellar colony; zooecia face opposite directions; calcareous base or chitinous rootlets		
	Robust branching (ro)	 ADEONIFORM Erect, robust, lobate to flattened, bifurcating branches; zooecia open on all sides; calcareous base		
	Delicate branching (de)	 VINCULARIIFORM Erect, delicate, (sub)cylindrical, bifurcating branches; zooecia open on all sides; calcareous base		
	Fenestrate (fe)	 RETEPORIFORM Erect, rigid, strongly calcified, fenestrate or reticulate; zooecia open on frontal side; calcareous base		
ERect FLEXIBLE (EF)		 CELLARIIFORM Erect, (sub)cylindrical branches, flexible (jointed) with chitinous nodes; zooecia open on all sides; chitinous rootlets		
FREE-LIVING (FL)		 LUNULITIFORM Disc shaped, unilaminar, heavily calcified basal lamina, zooecia open on outer face; setae allow motility		—

Figure 7. Zoarial growth-form typology (cheilostomes) of Nelson and others (1988).

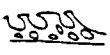
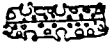
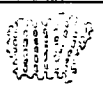
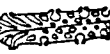
ZOARIAL SHAPE AND APPEARANCE		CLASSIFICATION AND DESCRIPTION	TRANSVERSE SECTION	LONGITUD. SECTION
ENCrustING (EN)	Unilaminar (ul)	 STOMATOPORIFORM Encrusting, rarely partly erect, colony linear or flabelliform, tubuliporidean wall		—
	Multilaminar (ml) (B)	 UNLAMINAR DIASTOPORIFORM Encrusting, unilaminar plates commonly building multilaminar zoaria, tubuliporidean wall		—
		 ATRACTOSOECEFORM Encrusting, pagurid-inhabited gastropod shell; (sub)spherical nodular zoaria encapsulating shell fragment, ceriopord wall	—	
ERect RIGID (ER)	Foliaceous (fo)	 BLAMINAR DIASTOPORIFORM Erect, foliaceous, bilamellar colony; zooecia irregularly developed on opposite sides, tubuliporidean wall		—
	Robust branching (ro)	 HORNERIFORM Erect, robust, triangular or rounded bifurcating branches, zooecia front or lateral, cancellate wall		
	Delicate branching (de)	 OMIDRONIFORM Erect, delicate, triangular, oval or rounded bifurcating branches, zooecia front or lateral, attached to substrate by kenozooids, tubuliporidean wall		
		 PUSTULOPORIFORM Erect, delicate, subcylindrical branching stems, zooecia open on all sides, tubuliporidean wall		
		 CAVARID DIASTOPORIFORM Erect, delicate, hollow, subcylindrical branching stems, zooecia open on all sides, tubuliporidean wall		
	Fenestrate (fe)	 RETICULATE DIASTOPORIFORM Erect, fenestrate, bilaminar fronds, zooecia open in lateral rows, tubuliporidean wall		—
	Radiate (ra)	 LICHENOPORIFORM Erect, branches radiate from crown of stem to form a 'cup', zooecia open on inner surface, tubuliporidean wall		
	Massive (ma)	 CERIOPORIFORM Erect, massive branched, zooecia open on all sides, ceriopord wall		
	ERect FLEXIBLE (EF)	 CRISIFORM Erect, rounded triangular, short segments separated by chitinous joints, zooecia open on one side, tubuliporidean wall		

Figure 8. Zoarial growth-form typology (cyclostomes) of Nelson and others (1988).

encapsulates the host nucleus (Schopf, 1969). Multilaminar B growth-forms are similar to A, however, species of the B group reflect growth on a particular encrusting surface, the occupied gastropod shells of hermit-crabs. Although numerous marine fouling organisms are typically associated with pagurid decapods (Dales, 1971), the symbiosis between bryozoans and hermit crabs is possibly the most ancient with records from the Neogene (Lecointre, 1930, 1934; Douvillé, 1931; Taylor and Cook, 1981; and Walker, 1988) and the Mesozoic (Buge and Fischer, 1970; Aguirre-Urreta and Olivero, 1992). The bryozoan-pagurid symbiosis is of a mutualistic nature, providing the colony with a suitable host substrate and affording the hermit crab an effective means of camouflage (Aguirre-Urreta and Olivero, 1992). Colonies that derive a multilaminar C growth-habit assume a discoidal form and develop by growing outward onto the preexisting host surface rather than encapsulate it.

Erect-Rigid. This class is subdivided into five groups: foliaceous, which consists of Stach's (1936) eschariform and Brood's (1972) bilaminar diastoporiform growth-forms; robust branching, represented by adeoniform and horneriform colonial structures (Lagaaij and Gautier, 1965; Brood, 1972); delicate branching, a compilation of vinculariform and idmidroniform, pustuliporiform, and cavarid diastoporiform architectures (Stach, 1936; Brood, 1972); fenestrate, consisting of reteporiform and reticulate diastoporiform growth-habits (Stach, 1936; Brood, 1972); radiate, derived from a single morphological type, unique to cyclostomes, known as lichenoporiform (Labracherie and Prud'homme, 1967); and massive, a proxy for Brood's (1972) cerioporiform category. Foliaceous taxa develop strongly calcified, broad, bilamellar zoaria which have zooids evenly or irregularly distributed on both sides (Schopf, 1969; Brood, 1972; Nelson and others, 1988). Robust branching forms appear to be an intermediate grade of morphology between foliaceous and erect delicate colony shapes

(Schopf, 1969). Species with robust branching typically develop thickened lobate cylindrical or subcylindrical branches which have zooids evenly distributed on one or both sides of the zoaria (Lagaaij and Gautier, 1965; Nelson and others, 1988). Erect delicate colonies manifest cylindrical or subcylindrical bifurcating zoaria where the zooecia are distributed on all sides; some faunas produce zooids on the frontal or lateral walls only (Schopf, 1969; Brood, 1972, Nelson and others, 1988). In contrast to erect delicate colonies, fenestrate colonies represent an evolutionary transition from solitary bifurcating branches to linked branches (McKinney and Jackson, 1989). Fenestrate taxa often display robust, heavily calcified zoaria with zooecia developed on one or both sides of the colony (Nelson and others, 1988). Specimens classified as radiate demonstrate an erect stalked morphology with thickened calcified branches emanating from a central cone; zooecia are present only on the inward facing portions of the branches (Labracherie and Prud'homme, 1967; Schopf, 1969; Nelson and others, 1988). Massive zoarial growth-forms construct large highly variable amorphous zoaria (Brood, 1972; Nelson and others, 1988). Brood (1972) noted that species with massive colony affinities often propagated short, robust, barrel-shaped branches from a broad calcified base or cylindrical zoaria (sometimes bifurcating) from a narrow base.

Erect-Flexible. Species producing an erect-flexible design have previously been classified as catenicelliform (Stach, 1936; Lagaaij and Gautier, 1965), cellariform (Stach, 1936; Lagaaij and Gautier, 1965; Schopf, 1969), and crisiform (Brood, 1972). Nelson and others (1988) recognize only cellariform and crisiform as representatives of the erect-flexible category, with no justification for excluding the catenicelliform; Bone and James (1993) include the catenicelliform design in a separate subclass of the erect-flexible division known as 'articulated zooidal'. The distinction of catenicelliform from the other erect-flexible forms is determined by the former being a series of articulated

zooids rather than a series of loosely connected zoaria. Regardless, taxa with an erect-flexible adaptation manifest a series of thin, bilamellar or subcylindrical zoaria, or small subcylindrical zooids, connected by slender chitinous nodes (Nelson and others, 1988; Bone and James, 1993). Unlike other erect growth-forms, erect-flexible morphologies are attached to the substrate by a number of flaccid chitinous rootlets (McKinney and Jackson, 1989; Bone and James, 1993).

Free-Living. Taxa that develop a free-living growth form are not anchored or attached to the substrate in any way. Currently this adaptational mode is only observed in cheilostome bryozoans (McKinney and Jackson, 1989) and has been documented in the geologic record as far back as the Cretaceous (Lagaaij, 1963; Håkanson, 1975). Larvae of free-living species commonly settle on sand-size particles which serves as a nucleus for growth (McKinney and Jackson, 1989). The transition from larval stage to adult colony form is rapid, with the larval attachment site becoming integrated into the zoaria (Bone and James, 1993). Species with a free-living existence have evolved specialized zooids that afford the colony a means of crude mobility (McKinney and Jackson, 1989). In certain species these zooids provide a mechanism for sweeping away fine-grain sedimentary detritus, exhuming the colony following a sudden burial event and repositioning the zoarium if suddenly overturned (Greely, 1967; Cook and Chimonides, 1978, 1983; McKinney and Jackson, 1989). Free-living morphologies commonly develop a disc- or conical-shaped zoaria composed of a thick, heavily calcified, aragonitic basal lamina overlain by a thin calcitic lamina (Greely, 1969; Nelson and others, 1988; Bone and James, 1993). In some species the skeletal composition is entirely aragonitic (Bone and James, 1993).

The Environmental Significance of Zoarial Growth-Form

Studies of the relationship between bryozoan morphology and habitat in modern marine environments have indicated a definite correlation between the composition and abundance of zoarial growth-forms and conditions of sedimentation, turbulence, substrate, and depth (Stach, 1936, Lagaiij and Gautier, 1965; Schopf, 1969; Harmelin, 1975; Cook, 1979, 1981; Gordon, 1987; Nelson and others, 1988). Factors of disturbance, notably biological in nature (e.g. predation, grazing, bioturbation), also influence growth-form associations (McKinney and Jackson, 1989). Morphologic assemblages respond as a unit to changing ecological circumstances, however, no particular growth-habit is highly constrained by any environmental influence (Schopf, 1969; Nelson and others, 1988) (Figure 9).

Sedimentation. In their extensive analysis of the bryozoan thanatocoenoses of the Mediterranean Rhône Delta, France, Lagaiij and Gautier (1965) observed that virtually all zoarial morphologies were excluded from areas of exceedingly rapid sediment influx (greater than 40 cm/yr). Schopf (1969), in a similar study of a small portion of the New England continental shelf, noted that substantial sediment deposition was a severe limiting factor to bryozoans; areas with considerable terrigenous clastic sedimentation, for example estuaries, deltas, and environments with frequent turbidity currents, were commonly lacking in bryozoan taxa. The capability of erect taxa to inhabit environments of moderate to high sedimentation rates has been investigated by Cheetham (1971) who concluded that the three dimensional usage of the environment by erect-types (versus the two dimensional limitation of encrusters) reduces the susceptibility of the colony to smothering and adverse affects of turbidity. Interpretations of sediment influx in carbonate environments using the current growth

Environmental Conditions Zoelial Growth - Forms		Substratum			Water Energy			Sedimentation			Shelf Depth		
		Hard	Particulate	Flexible	Low	Moderate	High	Low	Moderate	High	Inner	Middle	Outer
Encrusting	Unilaminar	●		○	○	●	●	●			●	○	
	Multilaminar A	○		●		●	○	●	○		●	●	●
	B	●				●	○	○	●		●	●	
	C		●			●	○	●	○			●	●
Erect - Rigid	Bilaminar	●	○		○	●		●			○	●	○
	Foliaceous												
	Robust Branching	●	○		○	●	○	●	○		○	●	
	Delicate Branching	●	○		●			●	○			●	●
	Fenestrate	●	○		○	●		●	○		○	●	○
	Radiate	●	○		○	●		●			○	●	○
	Massive	●	○		○	●	○	●	○		○	●	
Erect - Flexible		○	●	○		●	○	○	●	●	●	●	○
Free - Living			●			●	○	○	●	●	●	○	

Figure 9. Diagram showing the relative degree of relationship between growth-form and physical environmental factors. Solid circles indicate a strong relationship, open circles denote a weak association (compiled from Nelson and others, 1988 and Moissette, 1993)

form model, as with the present study, are inappropriate. Nelson and others (1988) incorporate previous studies (cited above) that are based entirely in terrigenous clastic settings. The development of carbonate environments is not dependent on the deposition of sediment particles but rather the accumulation of organic remains; therefore the use of zoarial morphology with respect to determination of sedimentation rate in carbonate settings is invalid.

Water agitation. The degree of water turbulence in the marine environment has been found to be of significant influence on the type of growth-form assemblages encountered (Lagaaij and Gautier, 1965; Schopf, 1969; Cuffey, 1970; Harmelin, 1973; Cheetham and Thomsen, 1981; Nelson and others, 1988; McKinney and Jackson, 1989). Encrusting faunas are essentially ubiquitous in their distribution with regard to the degree of agitation, however, they are more commonly associated in settings maintaining moderate to strong water motion (Lagaaij and Gautier, 1965; Schopf, 1969; Cuffey, 1970; Harmelin, 1973; Nelson and others, 1988). In environments dominated by high energy currents encrusting taxa are the predominate growth-form (Schopf, 1969; Harmelin, 1988; Moissette, 1988). This relationship is essentially effected by the two dimensional nature of the encrusting form which imposes two restrictions: The first being that the colony is entirely dependent on the movement of the surrounding water for nutrients; the second being that the planar qualities of the encrusting design increase the colony's susceptibility to the effects of turbidity (Cheetham, 1971; McKinney and Jackson, 1989). Existing in a habitat with moderate to vigorous current action the encrusting colony maximizes its potential for resource procurement while minimizing its vulnerability to sedimentation. McKinney and Jackson (1989) have also posited that the overwhelming presence of encrusting colonies in environments of high turbulence (and consequently shallow depths) may also result from competition with other bryozoan

species which may have greater colonization potential in lower energy (possibly deeper) marine settings. Erect-rigid growth-habits are generally excluded from areas of high agitation due to the possibilities of incurring mechanical breakage (Cheetham, 1971; Harmelin, 1988); encrusting species, which have a reduced exposure to the water column maintain a lower likelihood of being damaged. Erect-flexible taxa, because of their articulated zoarial framework, can sustain stresses imposed by high energy conditions through elastic deformation (McKinney and Jackson, 1989). Despite the capacity to sustain vigorous currents, erect-flexible forms are more commonly observed in environments with moderate water energy (Schopf, 1969; Nelson and others, 1988; Moissette, 1988).

Free-living colonies exhibit a similar environmental preference to that of erect-flexible forms (Schopf, 1969; Nelson and others, 1988). In settings of severe turbulence free-living colonies cannot maintain adequate stability (Cook and Chimonoides, 1978). Two erect-rigid classes are observed to inhabit high energy environments, albeit infrequently; these are the robust branching and massive zoarial growth-habits (Nelson and others, 1988). Studies by Cheetham and Thomsen (1981) and Cheetham and Hayek (1983) of the functional morphology of robust branching cheilostomes have indicated that this design mediates stresses imposed by drag forces across the colony branches. In addition, flattening of the branch tips in conjunction with thickening of the branch (producing the lobate branch shape) enhances resistance to fragmentation (Cheetham and Thomsen, 1981).

Substratum. The texture, cohesiveness, and uniformity of the substrate play an integral role in the morphologic and taxonomic composition of bryozoan associations (Cheetham, 1963; Lagaaij and Gautier, 1965; Rucker, 1967; Schopf, 1969; Egglestone, 1972; Labracherie, 1973; Gordon, 1987; Harmelin, 1988; McKinney and Jackson,

1989). Several zoarial forms demonstrate marked affinities for a particular substratum (Nelson and others, 1988; Moissette, 1988; McKinney and Jackson, 1989). For some taxa the selectivity of a particular sediment surface is related to specific requirements during the larval stage of development (McKinney and Jackson, 1989). Stable, cohesive, 'hard' substrates are commonly dominated by unilaminar encrusting and/or erect-rigid faunas (Nelson and others, 1988; Moissette, 1993). Multilaminar and erect-flexible growth-forms are also common on hard substrata but are not as prevalent as unilaminar and erect-rigid morphologies (Schopf, 1969; Nelson and others, 1988). In contrast loose, uncohesive, 'particulate' substrates are pervaded by erect-flexible, multilaminar C, and free-living growth-forms. Free-living species live almost exclusively on particulate substrates (Lagaaij, 1963; Lagaaij and Gautier, 1965; Schopf, 1969; Cook and Chimonoides, 1978, 1981; McKinney and Jackson, 1988); loose granular detritus that comprises particulate surfaces serve as sites of larval attachment from which a free-living colony will develop (McKinney and Jackson, 1989). Erect-rigid colonies also occupy particulate bottoms, however their presence in large numbers is typically sporadic (Lagaaij and Gautier, 1965; Schopf, 1969; Nelson and others, 1988). A third type of substrate, 'flexible', constitutes anchored pliant surfaces, typically ephemeral in nature, such as aquatic macrophytes and algae. Flexible substrates are usually encrusted by multilaminar A varieties in the absence of other marine fouling competitors (McKinney and Jackson, 1989; Moissette, 1988, 1993). Unilaminar encrusting and erect-flexible growth-habits also utilize flexible surfaces, but to a smaller degree than multilaminar A growth-forms.

It is unclear how differences in substrate source sediments (i.e. terrigenous clastic vs. carbonate) influence growth-habit composition and abundance. Carbonate and siliciclastic sediments differ substantially with regard to the physical character and style of cementation of their respective deposits, this undoubtedly has some degree of

control on the nature of the sessile benthos. Studies as recent as the late 1980's (notably Nelson and others, 1988) derive their environmental characterizations primarily from the results of research by Lagaaij and Gautier (1965) and Schopf (1969) which are based on data collected from terrigenous clastic environments. Clearly further study is warranted as to the effects of sediment type on zoarial morphologic assemblages.

Depth. Bathymetry *per se* is not a primary control in the abundance and diversity of zoarial morphology (Cheetham, 1963; Harmelin, 1988; Nelson and others, 1988). Combinations of physical and biologic parameters which strongly influence zoarial growth-form are indirectly related to depth. In his survey of growth-form and environment Schopf (1969) demonstrated that with increasing depth the percentage of encrusting forms diminished and that the ratio of erect-flexible to erect-rigid forms decreased accordingly. He reasoned that the influence of waves and elevated turbulence, which became more frequent in shallower environments, were the underlying elements effecting this pattern. Schopf postulated that erect morphologies would be more susceptible to mechanical damage than encrusters because of their three dimensional exposure to the water column; erect-flexible growth-habits, however, due to their inherent flexibility would more likely accommodate higher levels of hydrodynamic energy than other erect forms. McKinney and Jackson (1989) noted a similar trend in their analysis of growth-form bathymetric distribution in Atlantic bryozoans. Their conclusions concurred with Schopf's theory and also suggested that other types of disturbance, primarily biological in origin, increase along a decreasing depth gradient and may contribute to the observed trend as well. Nelson and others (1988) and Moissette (1988, 1993) have compiled generalized depth ranges for principal growth-forms (summarized in figure 8). Unilaminar encrusting faunas, depending on the species, can have extreme depth ranges (Prenant and Bobin, 1966), but when present in

superfluous quantities within an assemblage strongly denote inner shelf depths (Nelson and others, 1988; Moissette, 1988, 1993). Multilaminar growth-habits also have eurybathyl distributions. Depending on the multilaminar class the presence of a given variety may vary between inner and outer shelf environments (Nelson and others, 1988). Erect-rigid morphologies attain their optimum abundance and diversity within middle shelf environments (Moissette, 1988; Nelson and others, 1988), however erect-delicate faunas are also prevalent in outer shelf settings as well. Many erect-rigid faunas also inhabit inner shelf depths (Schopf, 1969; Harmelin, 1988; Nelson and others, 1988; McKinney and Jackson, 1989). Taxa that develop robust branching and fenestrate designs, which afford some resistance to moderate degrees of turbulence, are observed in the deepest areas of the inner shelf zone (Schopf, 1969; Winston, 1986; Harmelin, 1988; McKinney and Jackson, 1988). Erect-flexible growth-habits commonly demonstrate affinities for inner and middle shelf habitats, although this growth-form can occur in outer shelf settings as well (Nelson and others, 1988). Free-living colonies are associated with inner and middle shelf bathymetries (Rucker, 1967; McKinney and Jackson, 1989).

The use of zoarial growth-form in paleoenvironmental studies has been implemented by a number of paleontologists during the past three decades. Curiously, very few morphology/paleoenvironment studies were undertaken subsequent to Stach's (1936, 1937) pioneering work. Brown (1952), in his survey of New Zealand Tertiary cheilostomes, recorded the stratigraphic distribution of zoarial growth-classes and briefly commented on their environmental connotation; this is perhaps the earliest study utilizing bryozoans as paleoenvironmental indicators. Brown's work, however, did not attempt to quantify zoarial remains. Cheetham (1963) applied Stach's classification to Late Eocene (Jacksonian) cheilostome associations in the eastern U.S. Gulf Coast Plain and was able to demonstrate on the basis of percentages of zoarial fragments the

relationship between growth-form and distinctive stratigraphic and geographic biofacies. Following Stach's suggested environmental determinants, supplemented with other ecological information, Cheetham was able to reconstruct the oceanographic history of the Gulf Coast Jacksonian, delimiting changes in substrate, depth, and shelf morphology. In a later study Cheetham (1971) incorporated multivariate methods as well as summary statistics to show the corresponding relationship between cheilostome growth-habit and biofacies in a Scandinavian Paleocene bioherm. Pedley (1976) incorporated a zoarial growth-form study of selected strata of the Miocene age Upper Coralline Limestone of Malta. Mapping the percentages of encrusting vs. erect-rigid (predominately erect-delicate) growth-forms throughout key marker beds of Malta, Pedley was able to establish a bathymetric gradient; high percentages of encrusters denoted shallow depths whereas increases in the ratio of encrusting to erect-delicate forms indicated relatively deeper marine conditions. Stratigraphic studies of zoarial growth-form abundance, notably those of Labracherie and Prud'homme (1966), Askren (1968), and more recently Moissette (1993), have documented the effectiveness in using zoarial morphology to discern relative change in paleobathymetry.

Labracherie and Prud'homme (1966) examined changes in growth-habit in response to inferred regressive events within the Eocene strata of the Paris Basin, noting an increase in erect-flexible and encrusting growth-habits during the course of relative sea-level fall. Askren (1968) observed a similar pattern in his investigation of morphologic abundance and distribution throughout the Jacksonian-Vicksburg exposures of St. Stephens, Alabama. Despite sampling at a very coarse scale of resolution (about one sample per formation), Askren's paleoenvironmental interpretation of increasing turbulence and shallowing depths towards the top of the Jackson and Vicksburg stages are consistent with current paleobathymetric inferences for the same locality (Mancini and Tew, 1988, 1991). In his comprehensive study of bryozoan

assemblages in Messinian (Upper Miocene) strata of Algeria, Moissette (1993) demonstrated a progressive stratigraphic transition in the relative abundance of particular growth-habits noting a change from erect-rigid and erect-flexible forms to increasingly greater quantities of encrusting faunas. Moissette attributed this change to decreasing bathymetry. Moissette's growth-form analysis is generally corroborated by previous paleoecologic and lithologic investigations which indicate a regressive event in the Mediterranean during the Late Miocene and Early Pliocene (Moissette, 1993).

Analysis Of Zoarial Remains

Paleoecological interpretations are primarily deduced from numerical assessments of abundance and diversity of the fossil biota. It is imperative, therefore, that the analyst acquire data from "unbiased" sampling methods to assure reliable estimates of fossil population composition (usually unattainable, see Dodd and Stanton, 1990). Bryozoan zoarial skeletons, unlike traditional marine marine microfossils (e.g., foraminifera, radiolaria) require different sampling techniques for the purposes of quantification. While the abundance and richness of solitary invertebrates can be calculated from counts of whole individuals or the predominance of a particular skeletal part, the census of fossil colonial organisms cannot be accurately determined with these methods. This stems primarily from the difficulty of being able to recognize features that might allude to a possible minimum number of colonies (MNC). Similarly, research pertaining to the nature and variation of colony size in bryozoan taxa is virtually nonexistent, thereby limiting the ability to approximate values of MNC.

Postmortem processes often serve to disarticulate and fragment individual colonies, which in turn increases the amount of zoarial debris in the fossil assemblage. Recent preliminary studies by Smith and Nelson (in press), for example, attest to the role of turbulence as one major component of skeletal reduction and fragmentation of

zoarial remains. Other taphonomic factors such as scavenging behavior, burial related breakage, and skeletal degradation undoubtedly contribute to the fractioning of colonies. In addition, methods of sample preparation, particularly those that require the disaggregation of the enveloping sediment by vigorous physical agitation and/or chemical reactions may act to enhance skeletal fragmentation. Another problem to be considered is one introduced by colonial growth. Certain taxa, by nature of their inherent biological characteristics and/or ecological circumstances, may be relatively more predisposed to increased rates of budding than other bryozoan fauna. This, in combination with biostratinomic influences, may produce an overrepresentation in the thanatocoenose with respect to fragments of extensively branched or broadly encrusting colony types. In the analysis of zoarial growth-form the analyst must be wary of the possibility of a numerical bias in the counts of zoarial fragments due to the likely propensity of a potentially greater abundance of branching and encrusting per individual colony.

Although it is virtually impossible to gauge an absolute minimum number of colonies per species or colonies per growth-type from fossil bryozoan remains it is feasible to empirically measure representative numbers of species and proportions of zoarial growth-types from given quantities of sediment. In the present study an attempt was made to determine the amount of processed limestone needed to acquire suitable estimates of species and proportions of zoarial morphologies within stratigraphic samples. Using a method similar to the palynological "species-area" curve (Delcourt, 1979), the number of species and ratios of principal growth-forms can be graphically plotted vs. successively increasing increments of sediment weight. This method, akin to rarefaction, allows for the appropriate amount of sediment for comparisons among stratigraphic samples to be ascertained by simply finding the point on the curve where the frequency of new taxa occurring, or the proportionate value of growth-habits,

begins to diminish with larger sample weights; by applying this method to an array of samples it is possible to choose a maximum value to which all other samples are standardized.

In the course of the present research this type of analysis was limited to bulk samples from the type locality; core samples, because of their smaller size were utilized in their entirety. Six samples were selected from different intervals in the measured section (samples 1, 6a, 11a, 15, 22, 23) of which four were studied to determine the smallest amount of sediment necessary to ensure adequate faunal representation (90%) (samples 1, 6a, 15, 23). Three samples were analyzed to determine the least measure of residue needed to obtain minimum variance ratios of growth-forms (1, 11a, 22). Selected samples were wet sieved over a .149 mm (2.75 phi) sieve, dried, and subsequently subsampled in 5 gram aliquots to a total of eighty grams. Zoarial fragments were extracted from each subsample with a fine camel-hair brush and tabulated as numbers of newly encountered species and zoarial growth-classes (Figures 10, 11, 12, and 13). On the basis of these data amounts of 30 and 40 grams reflect the requisite minimum quantities to determine species and growth-form proportions respectively. All type locality samples were similarly prepared using 50 grams as the standard for ensuing taxonomic and growth-form analyses (species richness comparisons among samples, however, require additional standardization as discussed below). In order to ensure adequate recovery of zoarial material all standardized samples were examined and collected twice for bryozoan remains.

Measurement Of Zoarial Growth-Form Abundance

Standardizing the amount of material to be used on the basis of ratios of growth-forms reduces some error in the data collection, however, the influence of biologic,

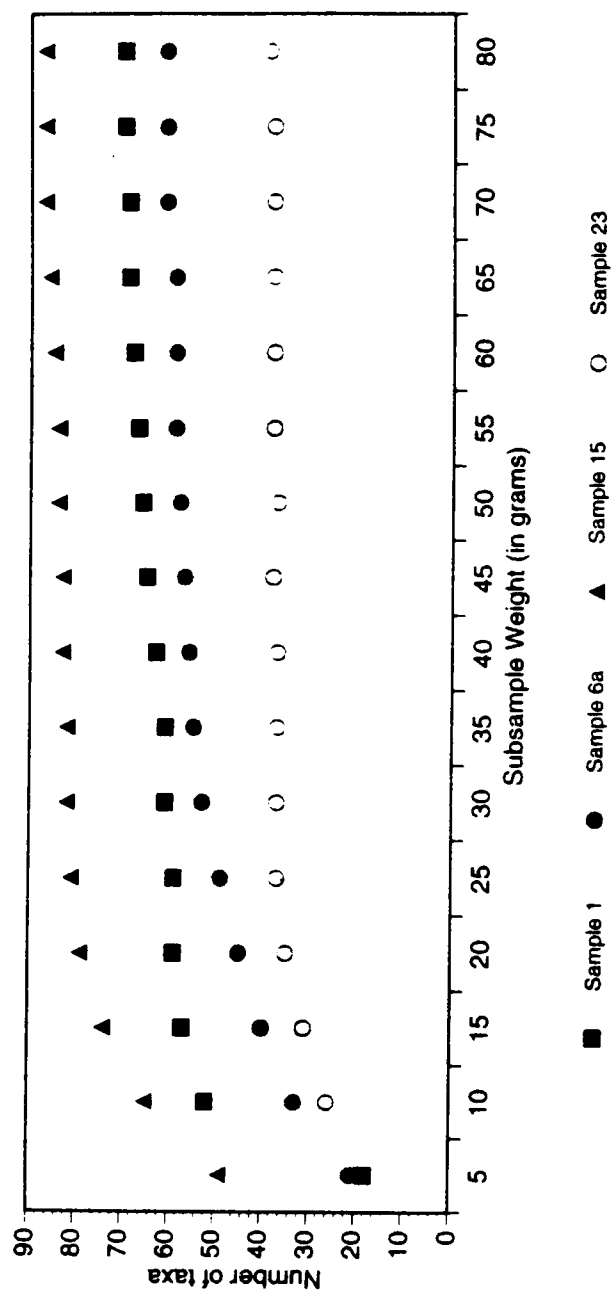


Figure 10. Graph of cumulative species diversity with increasing subsample size.

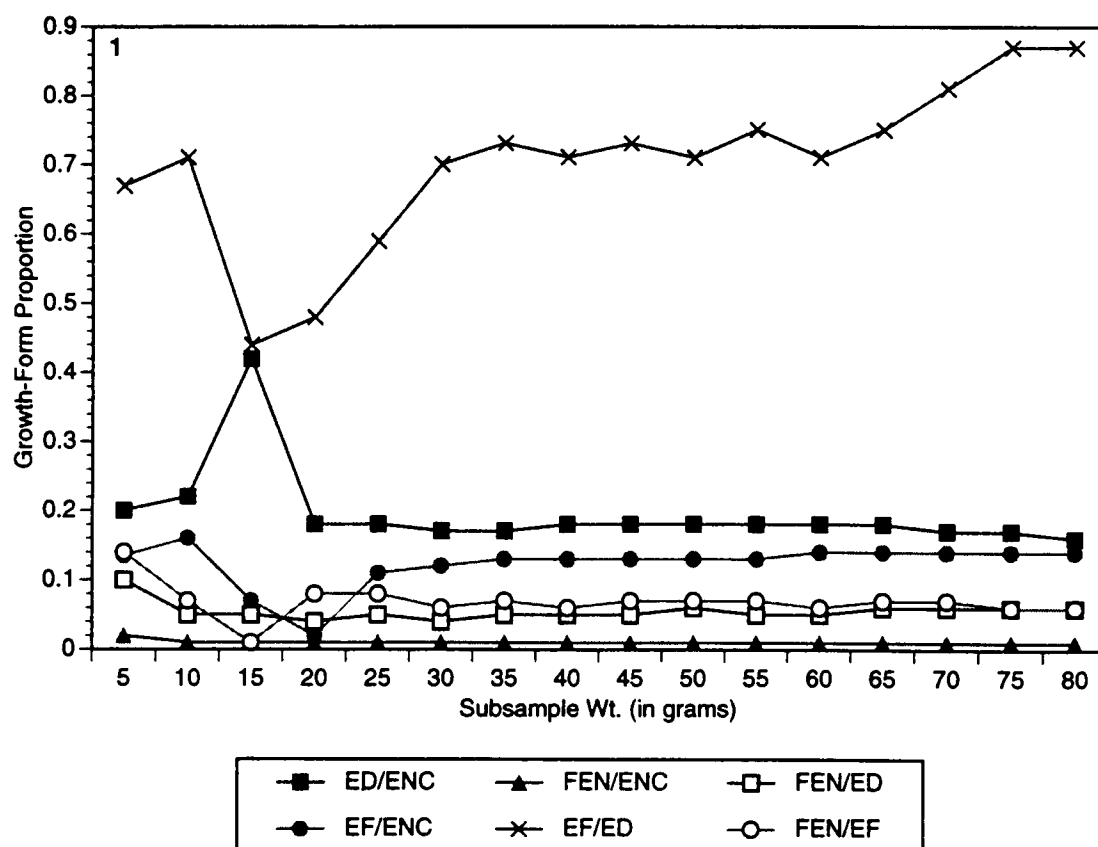


Figure 11. Graph of cumulative growth-form proportions with increasing sample size (sample 1). Encrusting category (ENC) is inclusive of all encrusting varieties. Abbreviations: ED - Erect-Delicate, EF - erect-Flexible, FEN - Fenestrate.

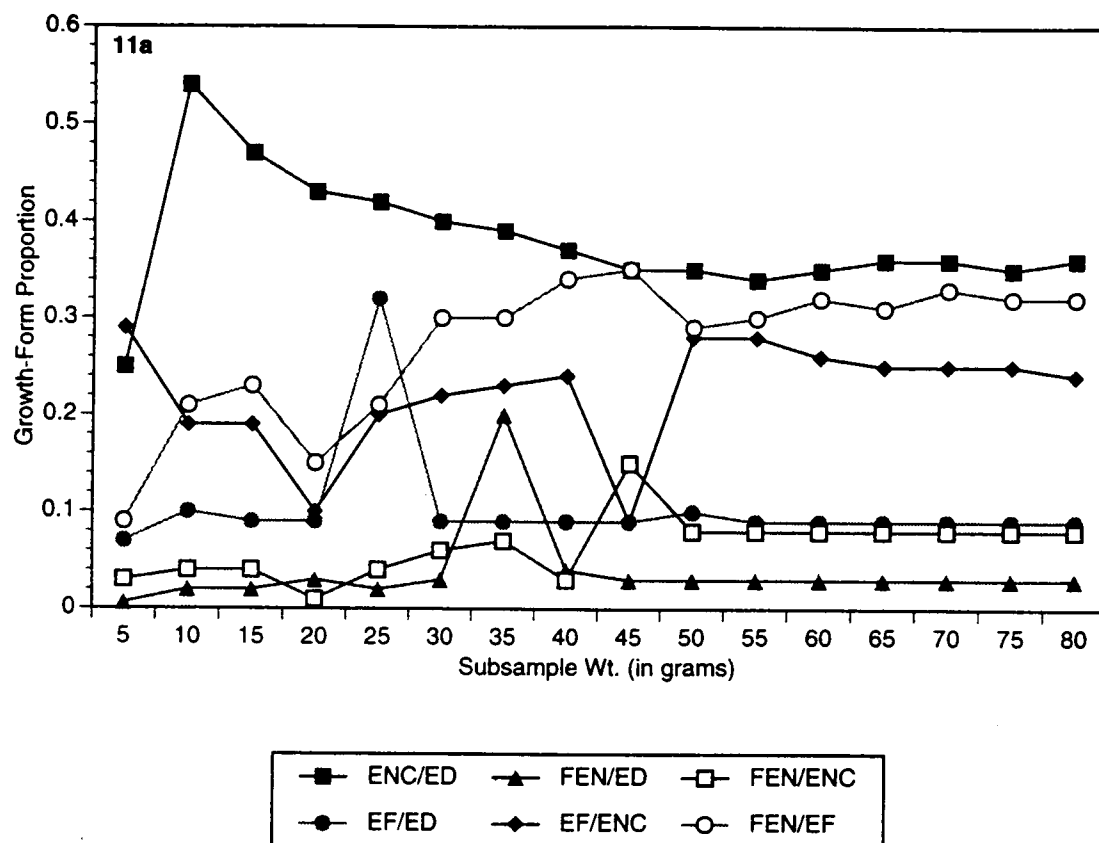


Figure 12. Graph of cumulative growth-form proportions with increasing sample size (sample 11a).

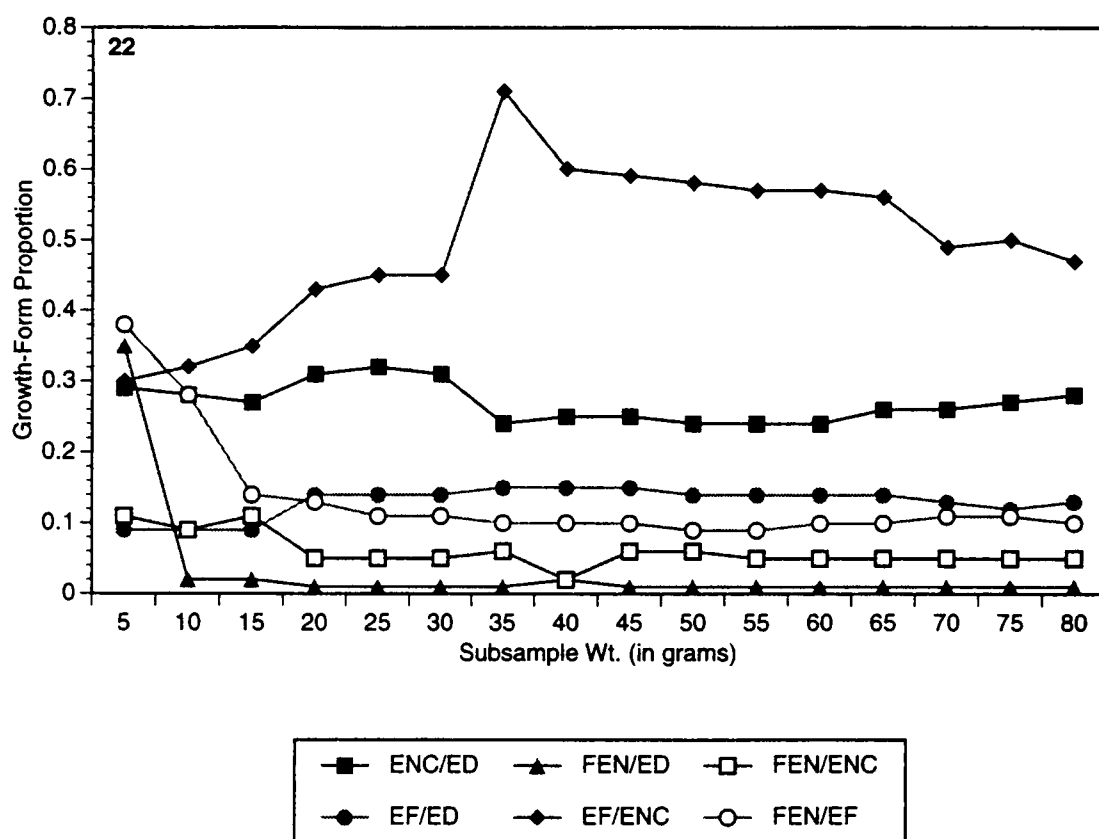


Figure 11. Graph of cumulative growth-form proportions with increasing sample size (sample 22).

ecologic, and taphonomic affects cannot be directly assessed to provide an adequate correction factor. Quantification of zoarial growth-form abundance requires a combination of measurement methods to provide objective interpretations. There are three techniques available for the purposes of analyzing growth-form abundance: numerical counts, weight, and volumetric percentages. The former two techniques were utilized in the present study. Fragment counting, which is strongly dependent on zoarial representation, is the most commonly used indicator of growth form abundance (Nelson and others, 1988; Hageman and others, in press), but for obvious reasons (stated above) is not without considerable bias. Weight compilations of different zoarial classes, used in conjunction with count data, may potentially offer a means of gauging morphologic abundance. Nebelsick (1992) employed both weight and counts in a study of echinoid fragments and biofacies relationships, observing that weight may counter collection related breakage in all cases. Computation of growth-form weight/sample does not account for differential effects of diagenesis or dissolution and generally underrepresents the biomass for the total number of fragments as some sediment encased, encrusted, or particle-encrusting zoaria must be excluded.

Collection of weight data during the course of this research entailed weighing the total number of zoaria per growth-class (omitting specimens encapsulated by sediment, encrusted, and particle encrusting zoaria) for each sample to the nearest .001 gram using an analytical balance. The stratigraphic distribution of numerical counts and weights were analyzed graphically. Omissions of zoarial material undoubtedly reduce the reliability of the biomass interpretation; to what degree is difficult to ascertain.

Ordination

A variety of multivariate techniques exists for analyzing ecological information (Gauch, 1982; Digby and Kempton, 1987; Ludwig and Reynolds, 1988; Reyment,

1991; Shi, 1993). Perhaps one of the best methods for summarizing community level data with minimal bias is the technique of Detrended Correspondence Analysis (DCA). A powerful ordination method, DCA provides a sophisticated means of discerning the structure and organization of large complex ecological data sets and for quantifying the associations between taxa and samples (Hill and Gauch, 1980; Gauch, 1982; Shi, 1993). Like many multivariate analyses DCA attempts to reduce an array of data to a few principal axes of variation and to represent the data geometrically with respect to their underlying factors (i.e. environmental or biotic influences). A variant of Correspondence Analysis, DCA is similar in that it constructs dual ordinations of samples and taxa and projects their positions on the principal axes simultaneously. This in turn allows the investigator to interpret the structure of sample data in terms of the structure of taxonomic data and *vice versa* (Gauch, 1982; Birks and others, 1988). In addition, DCA incorporates detrending and rescaling algorithms to eliminate the affects of non-linear distortions which are commonly encountered with other ordination models (Hill and Gauch, 1980; Gauch, 1982; Ludwig and Reynolds, 1988; Shi, 1993). A beneficial consequence of the detrending and rescaling process is that the principal axes lengths acquire standard scaling. The resulting ordination lengths are expressed in units of standard deviations (Hill and Gauch, 1980; Gauch 1982). Changes in the expression of taxonomic composition (beta diversity), reflected by sample position along any given axis, are commonly referred to as changes in 'beta standard deviations' (Gauch, 1982). Sample scores with values of approximately 1.0 beta standard deviation reflect a 50% change in taxonomic composition; total community (or fossil assemblage) replacement occurs in about 4.0 beta standard deviations (Gauch, 1982). For a complete bibliography of DCA analysis in marine paleoecology the reader is referred to Shi (1993).

DCA provides other additional advantages that make it especially conducive for paleoecological analyses. These include the following:

(1) While traditional ordination techniques (e.g. Principal Components Analysis, Polar Ordination, Correspondence Analysis) require data to meet the criteria of statistical linearity, DCA makes no assumptions in this regard. As the process of detrending adjusts for the effects of non-linear structure in the data, considerations pertaining to normality and linearity need not be addressed.

(2) Eigenvalues are derived from a Chi-square distance matrix. The mathematical properties of this particular dissimilarity metric tend to abate the statistical noise within the data set thereby enhancing the signal (Prentice, 1980; Birks and others, 1988).

(3) As with most ordination procedures the principal or 'first non-trivial' axis in DCA explains the largest percentage of variation in the model. The interpretation of this axis denotes the primary ecological influence of the observed taxonomic compositions. DCA produces an optimal ordering of species and samples on the first principal axis, much like CA, that maximizes the correlation between samples and species scores (Palmer, 1993). The situation of sample scores along the first non-trivial axis indicates the response of fossil assemblages (in beta standard deviations) to change in the assigned ecological factor. This is particularly useful when sample scores represent stratigraphic data. By plotting the values of sample scores from the first non-trivial axis in the order of stratigraphic succession a direct quantitative measure of the magnitude of change, in terms of beta diversity, is obtained (Birks, 1988; Delcourt and Delcourt, 1990, 1991). Moreover, by taking the difference between successive sample scores an estimate of the rate of beta diversity change (Δ beta diversity) is calculated (Jacobson and Grimm, 1986; Delcourt and Delcourt, 1991). Beta diversity measures derived from the ordination of presence-absence data are referred to as beta F and Δ beta F (where F stands for floristic or faunistic) whereas beta diversity metrics based on ordination of

quantitative data are referred to as beta D and Δ beta D (where D stands for dominance) (Delcourt and Delcourt, 1991). The rate of change in beta diversity is synonymous with the rate of faunal turnover in species composition (Delcourt and Delcourt, 1991).

In the present study DCA ordinations were constructed from presence-absence data of bryozoan species in order to avoid the problems encountered with species representation determined from counts of zoarial fragments. DCA was implemented using a modified version of the FORTRAN program DECORANA (Hill, 1979). A total of three ordinations were produced: one, a composite utilizing the data from both study localities, and two separate ordinations comprising the data sets of the individual stratigraphic sequences from which values of Δ beta F were computed. Taxonomic data used in the composite ordination were inspected for outliers following the procedure of Shi (1993) which required the omission of species occurring in 5% or less of the total data array. This minimum figure was increased to 18% which resulted in 67 species being removed from the data set (those species occurring in 6 out of 34 samples). One sample was also excluded from the composite analysis due to its paucity of taxa (sample d, which contained 13.3% of the total species represented). Ordinations of site specific data included the entire data set for the locality under consideration.

Determination of Alpha Diversity

An important component of reconstructing the paleosynecology of fossil assemblages is taxonomic richness (alpha diversity). Comparisons of alpha diversity in a succession of samples taken from spatial or temporal environmental gradients can give information about the nature of relative ecological stability and equability (Dodd and Stanton, 1990). Changes from high levels of alpha diversity to low levels of alpha diversity, for example, may be effected by a decline in resource availability and/or physical environmental parameters (Magurran, 1988; Dodd and Stanton,

1990). Variation along a 'richness gradient' can also result from coinciding changes in the intensity and inherent type of physical and biological disturbances encountered (Connell, 1978; Walker, 1989; Petratis and others, 1989). In some situations high measures of alpha diversity can be initiated and maintained through intermediate grades of disturbance (Connell, 1978). MacArthur (1972) recognized that in addition to resource and environmental factors the degree of niche overlap was an important determinant in the total species richness of a community at any given time or place.

Analyzing stratigraphic changes in bryozoan alpha diversity presents a major problem because the numerical representation of various taxa will be strongly influenced by intrinsic differences in zoarial production and biostratigraphic effects. Different taxa will inevitably demonstrate enumerative biases making comparisons among samples difficult to interpret. One obvious solution is to simply record the number of taxa present within a sample (Kempton, 1979). This method, however, is highly dependent on the number of zoarial fragments recovered. As the quantity of zoarial fragments will typically differ from one stratigraphic sample to another, counts of species do not provide an effective means of comparing richness values among samples. Standardizing sample sizes and microfossil extraction procedures will reduce bias somewhat, nevertheless this will not obviate the effects of varying frequencies of zoarial remains. Use of diversity indices such as the Shannon - Wiener Information Statistic and Simpson's Index (Dodd and Stanton, 1990), which compute a single value representing both richness and dominance diversity of an assemblage, are inappropriate for bryozoan data. Functions of dominance diversity, or the relative abundance of individuals comprising the taxa, are extremely susceptible to error from large differences in taxonomic representation (Birks and others, 1988; Birks and Line, 1992). Simpson's index is relatively less (though still greatly) affected by large scale differences in taxonomic abundances than the Shannon - Wiener Information Statistic, however it is

very insensitive to the presence of rare species (Hill, 1973; Birks and Line, 1992). A richness measure is required for bryozoan species data that will counteract the influences of representational biases, adjust for sample variation, and maintain sensitivity to rare taxa.

Birks and others (1988) and Birks and Line (1992) recognized similar problems from their studies of species richness in Holocene pollen-stratigraphical data from western Europe and Great Britain. They realized that because of disparities in pollen production and dispersal capabilities of different taxa, and the variation in the number of grains among stratigraphic samples, that the application of typical richness measures would be inappropriate. They proposed the use of rarefaction analysis as a means of determining bias-free estimates of alpha diversity. Developed by Sanders (1968), and later modified by Hurlbert (1971), the technique of rarefaction permits direct comparisons of richness for samples of varying size. The rarefaction index, $E(S_n)$, calculates the expected number of taxa that would be recorded if the total number of individuals counted in any given number of samples were the same. $E(S_n)$ provides minimum variance unbiased measures of the predicted number of species from a random sample of n individuals drawn from a population of N individuals comprised of S taxa (Hurlbert, 1971; Raup, 1975; Heck and others, 1975; Tipper 1979; Birks and Line, 1992). The value of $E(S_n)$, for any sample of size n , is a function of both richness and equitability of the proportions of species in the sample (Smith and Grassle, 1977; Tipper, 1979; Birks and Line, 1992). Large samples of n individuals $E(S_n)$ permit richness estimates that are both without bias and sensitive to the presence of rare taxa (Smith and Grassle, 1977; Birks and Line, 1992). Standardizing samples of varying faunal abundance to a common sample size will result in an information deficit as each sample will be adjusted from a value of S to a value of $E(S_n)$ (Tipper, 1979; Magurran, 1988; Birks and Line, 1992). This loss of information, however, is not critical if the

objective is to compare richness among samples in a stratigraphic sequence (Birks and Line, 1992). It should also be noted that in employing rarefaction in the study of fossil bryozoan alpha diversity the analyst is not subsampling from a population of individuals, but rather fragments of individuals; this important caveat should be considered when interpreting the results. The ultimate goal, however, is to achieve a scaled richness measure of taxa, for which rarefaction is highly suited.

Employing rarefaction analysis in paleoecological research requires that several assumptions be made concerning the data, none of which are ever completely valid (Sanders, 1968; Hurlbert, 1971; Tipper, 1979; Birks and Line, 1992). These consist of the following:

(1) The entire collection of taxa recovered from a sample must be an adequate statistical representation of the fossil of the fossil assemblage or community from which it was derived. This is, of course, extremely unlikely given the affects of preservational bias and the nature of paleontological collection.

(2) Samples within or among stratigraphic sequences being compared should be similar in taxonomic identity. Collections being analyzed should generally be limited to specified faunal elements.

(3) Samples should be processed consistently using standardized methods. Taxonomic collections for each sample should reflect comparable faunal identification.

(4) Sample collections to be compared should reflect similar paleoenvironments in order to reduce the influence of habitat heterogeneity.

(5) Rarefaction analysis must be limited to interpolation of sample counts n not exceeding the largest count N . As the rarefaction algorithm cannot exceed N repetitions it cannot be used as a means of extrapolations or estimating the total richness of the original fossil assemblage.

(6) The variance of $E(S_n)$ is applicable only for samples being scaled to values of $n < N$. It is necessary to compute variances of $E(S_n)$ values (and their respective confidence limits) to evaluate the richness differences among samples.

(7) The sample collection reflects a random sampling (without replacement) of the original fossil assemblage. This is usually unattainable in paleontological studies due to the vagaries of preservation and collection. In the present study, however, an attempt was made to ensure adequate representation of taxa for all samples (see above).

Rarefaction values and their associated 95% confidence limits were compiled for all stratigraphic samples, save one, using the FORTRAN program RAREPOLL (Birks and others, 1988; Birks and Line, 1992). To the knowledge of the author this is the first application of RAREPOLL to a marine paleoecologic study. Following procedures outlined in Birks and Line (1992) samples were scaled to the smallest sample count (sample n , where $N = 309$). One sample, d , was omitted from the analysis because of its scarcity of identifiable faunal material ($N = 44$); this sample was considered to be an outlier and not representative of the typical richness observed. The unrarefied sample was included in the graphic plot of stratigraphic $E(S_n)$ values, of its respective locality, for comparative purposes.

Petrographic Analysis

Thin section data were compiled using an automated point counter. With the exception of two samples (samples 7 and 11a), all thin sections were point counted with a minimum of 500 counts. At this level a given allochem comprising 10% of the total number of counts has a standard deviation of 4% (Van der Plas and Tobi, 1965; Patterson and Fishbein, 1989). Petrographic data were examined graphically with respect to percentage abundance per stratigraphic level. Recognition of petrographic

constituents follows the work of Bathurst (1975) and Johnson (1971). Classification and interpretation follows that of Dunham (1962).

CHAPTER IV

RESULTS

Zoarial Growth Form

Comparison of the type area and W-8104 reveal significant differences in the composition and abundance of zoarial growth-form (Figures 14,15, and 16).

Comparatively greater amounts of erect-flexible, free-living, and robust branching growth-habits are exhibited in samples from W-8104. In contrast, the standardized type locality samples display considerably larger quantities of erect-delicate, unilaminar, and multilaminar C growth-types. Although core samples are substantially smaller than the portions of sediment used from the type area collections the number of zoarial fragments per sample are comparable for both sites, thereby suggesting the observed differences in zoarial morphology are real and not unduly biased. Recorded weight data are probably misleading due to the two influences: an overrepresentation of robust colony growth-habits (i.e. erect-delicate and multilaminar C) and the omission of sediment enveloped zoaria and particle adhering encrusters.

Stratigraphic changes in growth-form abundance are characterized by several distinctive patterns. Type locality data (Figure 14) show a progressive transition from predominately encrusting assemblages in the basal portion of the sequence to associations dominated by erect-delicate morphologies in higher levels. Erect-flexible zoaria also manifest a significant percentage of counted fragments in samples Q - T, taken from the upper part of the measured section; a related increase in erect-flexible biomass is discernible as well. The amount of erect-flexible material diminishes towards the top of the section. Data collected from W-8104 (Figure 15) show less change than observed at the type locality. Percentage abundances of erect-flexible zoarial counts show a slight increase towards the top of the core in conjunction

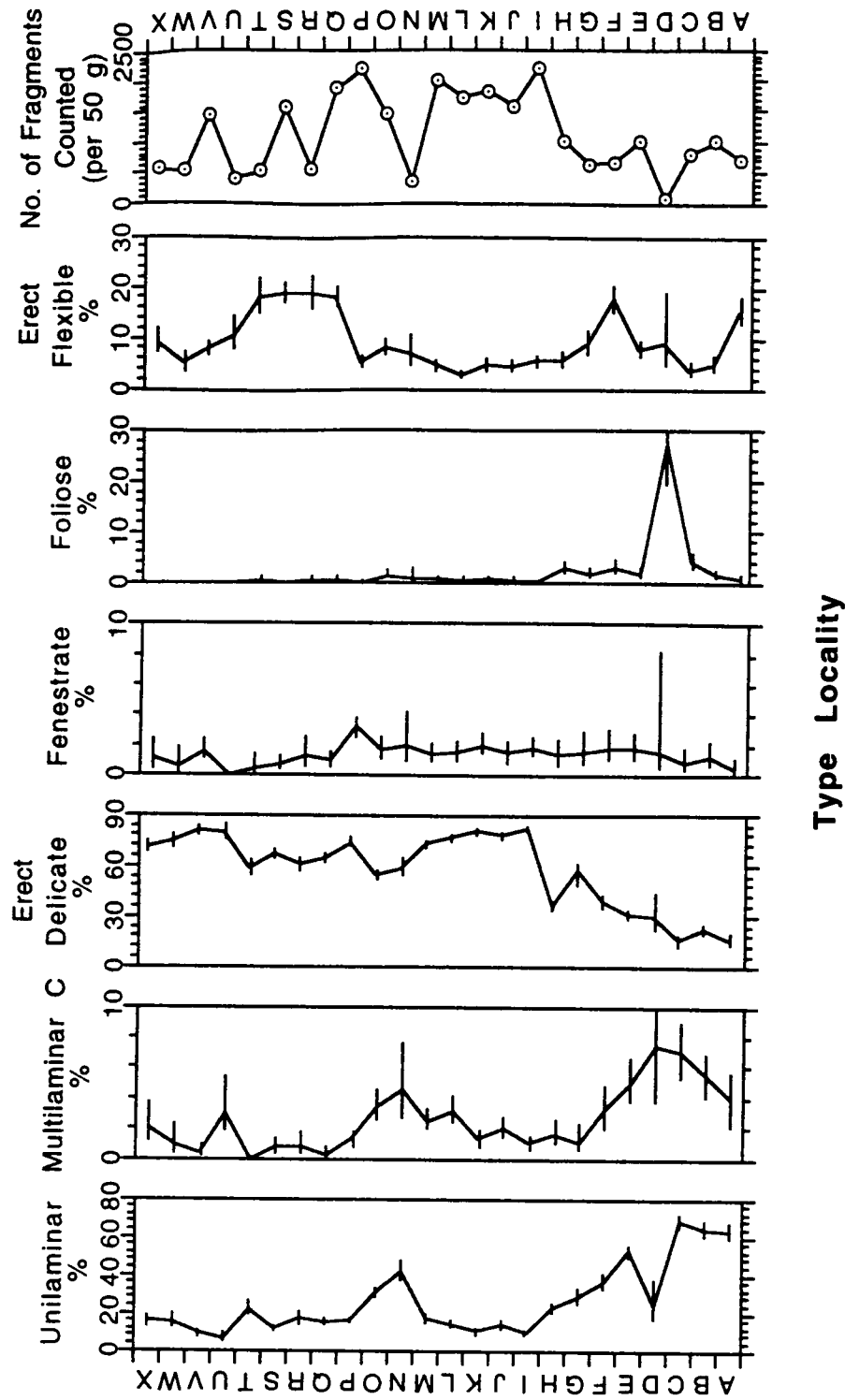
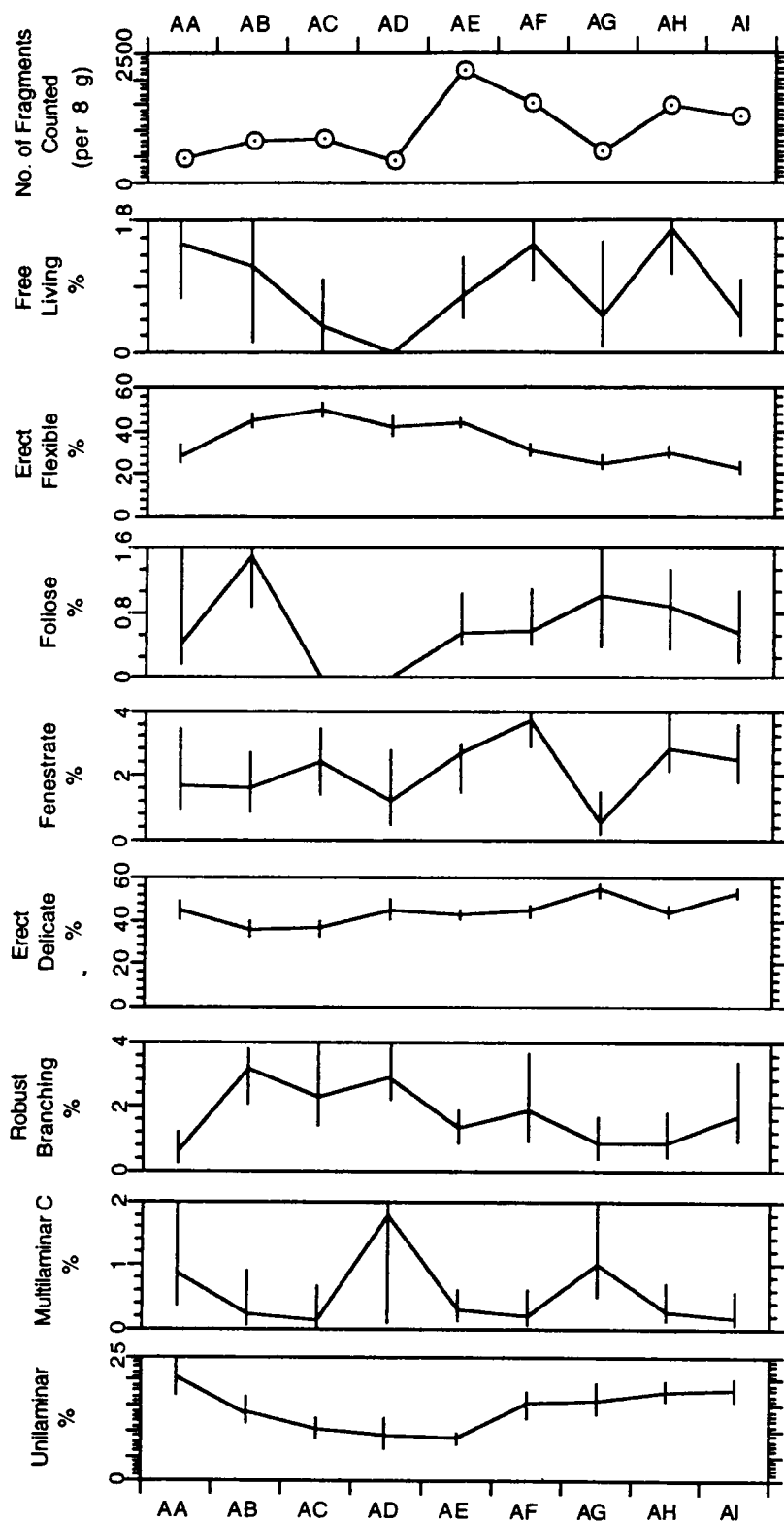


Figure 14. Graph of zoarial growth-form counts per stratigraphic level at the type locality. Horizontal bars represent 95% confidence limits for counts inside the sum (calculations based on the equation of Mosimann, 1965).



W-8104

Figure 15. Graph of zoarial growth-form counts per stratigraphic level at site W-8104. See figure 14 for explanation regarding horizontal bars.

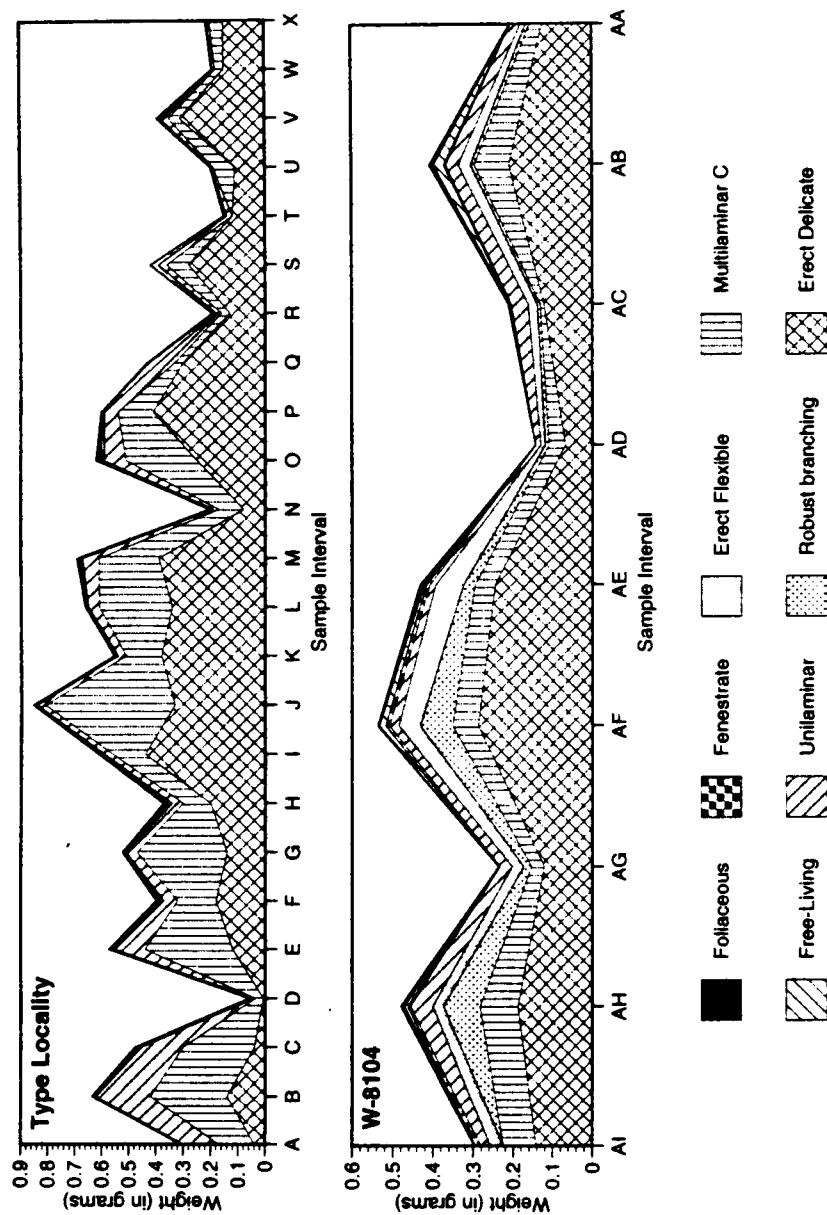


Figure 16. Graph of zoarial growth-form weight per stratigraphic level.

with an associated minor decrease in unilaminar and erect-delicate growth-forms.

Changes in the biomass for these growth-forms does not correspond with count based abundance; this is due in part to the exclusion of sediment encapsulated and particle encrusting specimens.

Ordination Results

The results of the composite Detrended Correspondence Analysis are shown in Figures 17, 18 and 19, and comprise separate plots of species and sample ordination scores for the first and second non-trivial axes. Eigenvalues for the first and second axes define gradients of 2.28 and .92 beta standard deviations in length respectively. The first non-trivial axis accounts for the greatest portion of variance explained in the model and represents 61% of the total inertia; axis 2 explains 25%. The large relative size of the first ordination axis indicates one principal direction of variation in the data structure (Birks, 1988). Sample scores form two distinct clusters, specific to locality, at near opposite ends of the gradient. The ecological component of the sample ordination, interpreted on the basis of species scores, is defined by three groupings of taxa. Species located between 1.9 and 3.4 on axis 1 are fauna that are highly endemic to the W-8104 samples. Taxa situated between -0.75 and 1.6 reflect a generalist association with genera and species that occur in both study localities. A third assemblage, located between -1 and -1.6 delimit taxa that show affinities with the type locality. The first ordination axis can be interpreted as a species response to differences in substrate where the taxonomic composition of samples demonstrates preferences for hard substrates (type locality - low sample scores) or particulate substrates (W-8104 - high sample scores). *Lunulites*, a common free-living genus in the W-8104 samples demonstrates a predisposition for loose particulate sediments (Cheetham, 1963) and contributes to the polarity observed in

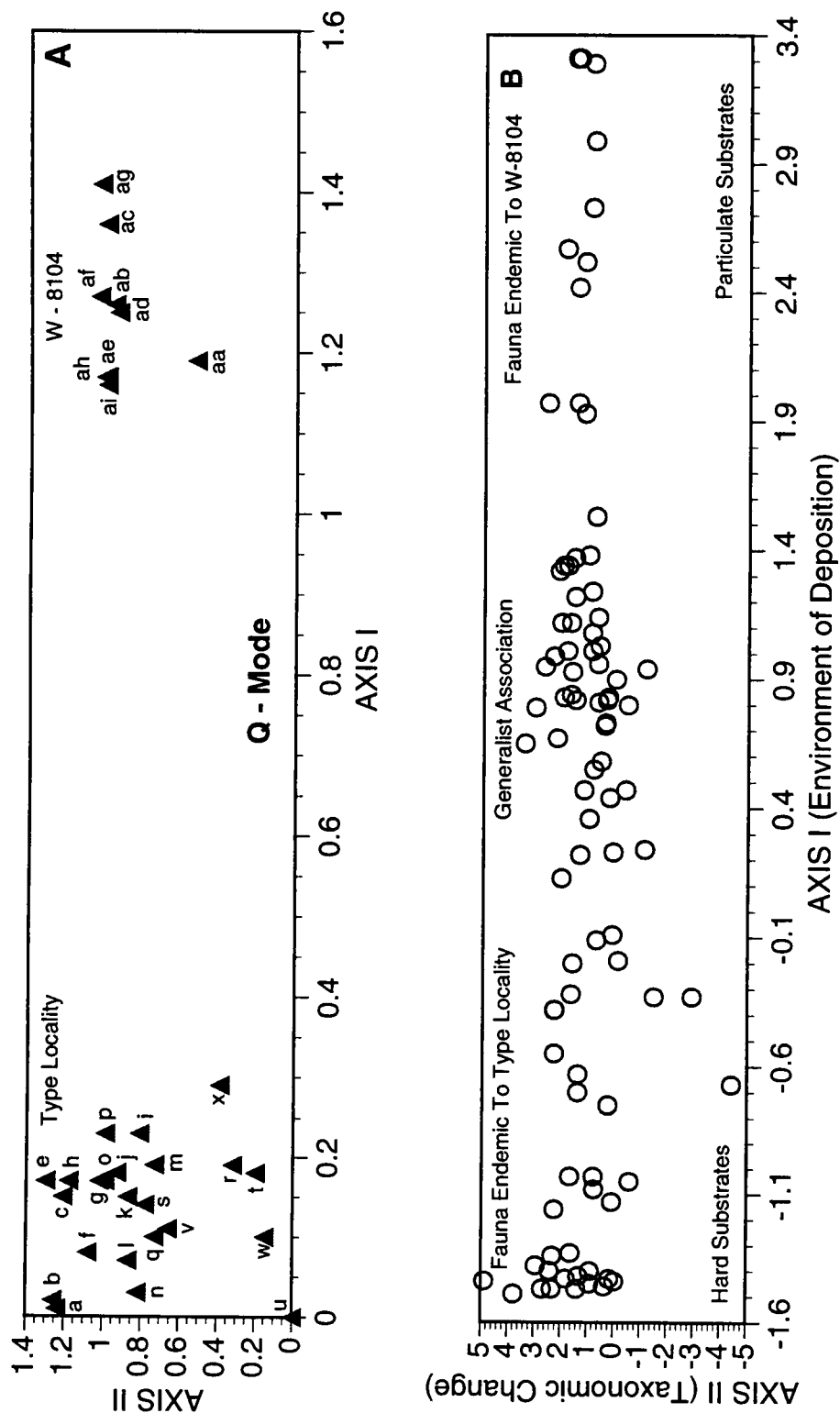


Figure 17. Plot of DCA axis 1 vs. axis 2. A, sample ordination scores. B, species ordination scores.

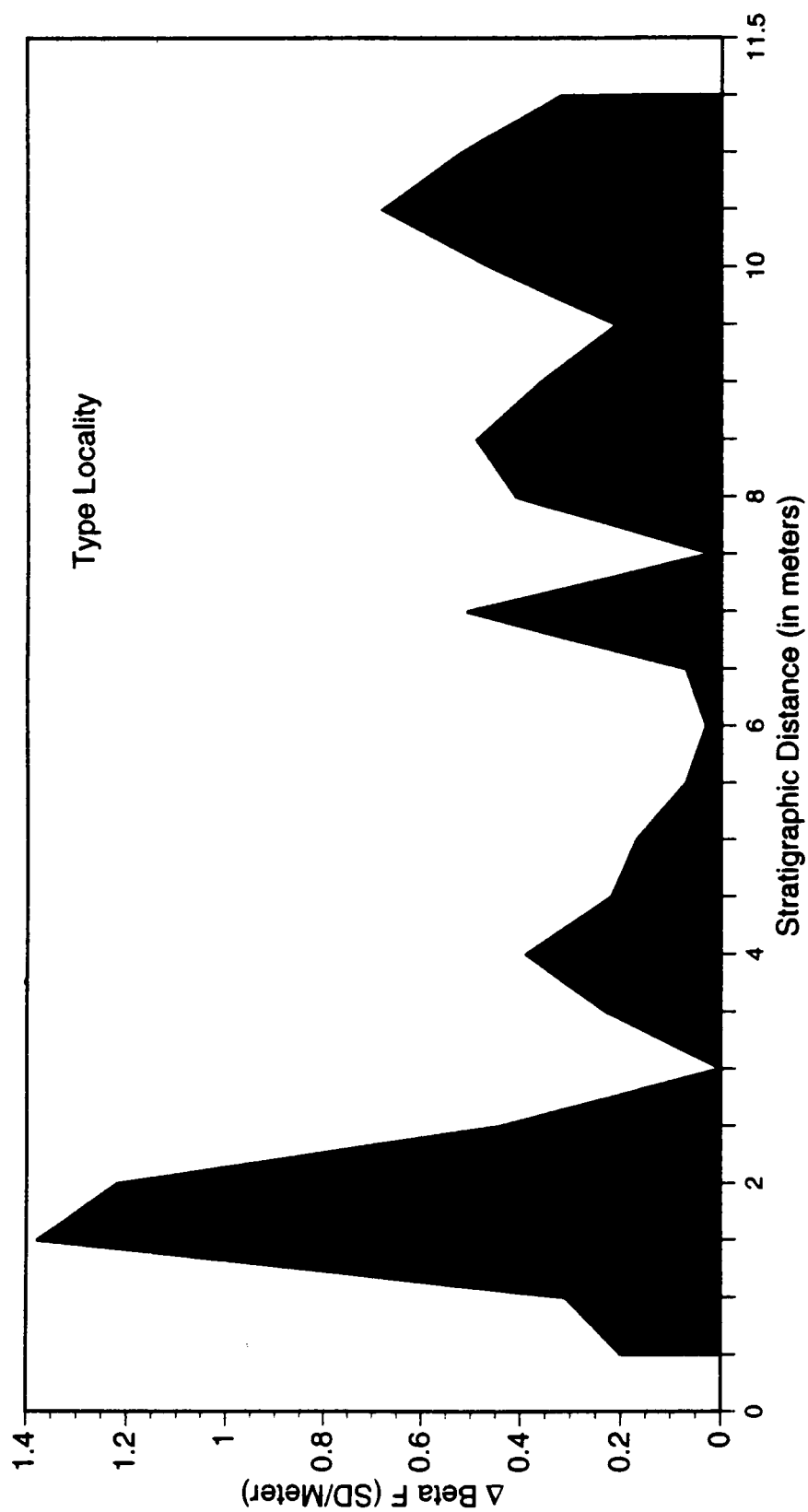


Figure 18. Values of Δ Beta F plotted as a function of distance (type locality).

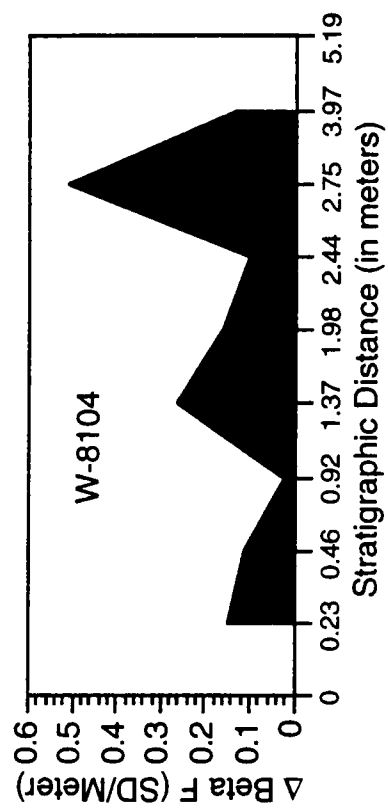


Figure 19. Values of Δ Beta F plotted as a function of distance (W-8104).

the sample ordination. Unilaminar encrusting taxa, notably *Gephyrotes* sp.

Hippopleurifera spp., *Probosidea* spp., *Aimolousia* sp. and *Didymosella* cf. *crassa* and erect-rigid and erect-flexible taxa such as *Sertella*, *Exidmonea*, and *Crisia*, are fauna that are commonly associated with hard substrates (Moissette, 1988; Nelson and others, 1988). The second ordination axis can be interpreted as a change in taxonomic composition through time. Examination of sample scores along the second axis display a crude ordering of samples in stratigraphic succession. Associations delimiting the underlying gradient are composed of stratigraphically ephemeral taxa, primarily with unilaminar growth-habits (e.g. *Gephyrotes* sp., *Hippopleurifera crassicolis*, *H.* sp. A, *H.* sp. B., *Aimolousia* sp., *Didymosella* cf. *crassa*), toward the upper part of the species graph and relatively more stratigraphically long ranging, eurytopic (generalist) taxa (e.g. *Exidmonea triforata*, *Exidmonea grillator*, *Entalophora probosidea*, *Tubucellaria vicksburgica*, *Floridinella vicksburgica*, *Scrupocellaria milneri*, *S. williardi*, *Holoporella* sp. A, *H.* sp. B, *Nellia tenella*) toward the lower end of the species graph.

The Beta diversity results for bryozoan taxonomic data from the type area and W-8104 (Figure 13) demonstrate a general increase in the rate of change in species composition through time. At the type locality a large (>50%) turnover in faunal assemblages is noted at 1.5 meters. This sudden apparent displacement of taxa results from an impoverished sample (D) which comprises 35% of the species in the previous sample. The pattern of increasing Δ Beta F is interpreted as being effected by a gradual attrition of ephemeral taxa and the persistence of generalist species. The cause of this loss of taxa is speculative at best. As discussed below this change may be related to a shallowing in bathymetry. The ultimate cause of this shallowing may be related to change in global or local climate or possibly tectonics.

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Rarefaction Results

The results of the rarefaction analysis for the type locality (Figure 20) demonstrate a pattern of general decline in species richness over time. Values of $E(Sn)$ at the type area sequence show a statistically significant drop in levels of alpha diversity, punctuated by minor increases in richness, from the base of the measured section to the top. In contrast, richness estimates of samples taken from W-8104 (Figure 20) show very little significant change throughout the length of the sampled core section.

Petrography Results

Previous petrographic studies by Bryan (1991) indicated that the Florala Limestone, at the type locality, consists of wackestone and packstone lithologies. In the present study lime-mud rich lithologies were commonly observed. In general, wackestone textures are prevalent throughout much of the section. Examination of the allochem data (Figure 21) reveals few stratigraphic trends among bioclastic constituents. The dominant allochem within the Florala type section is the coralline red alga *Lithothamnion* which occurs in rock forming abundance in most samples. Less common are two varieties of coralline algae tentatively identified as *Lithophyllum*. *Lithophyllum* A is present in the lower part of the section, *Lithophyllum* B in the upper part of the section. Both algal types occur in minor amounts, however, *Lithophyllum* B. appears to increase slightly towards the top of the section. *Lithophyllum* B also constitutes the

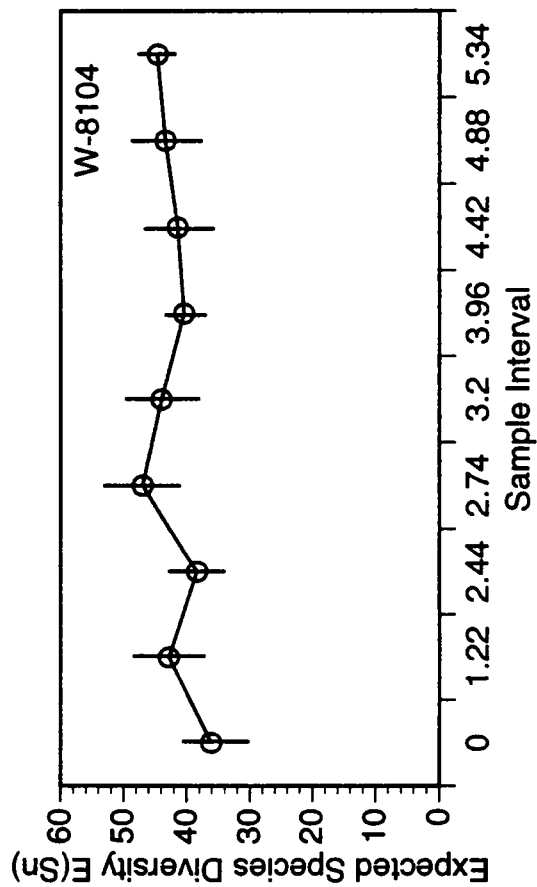
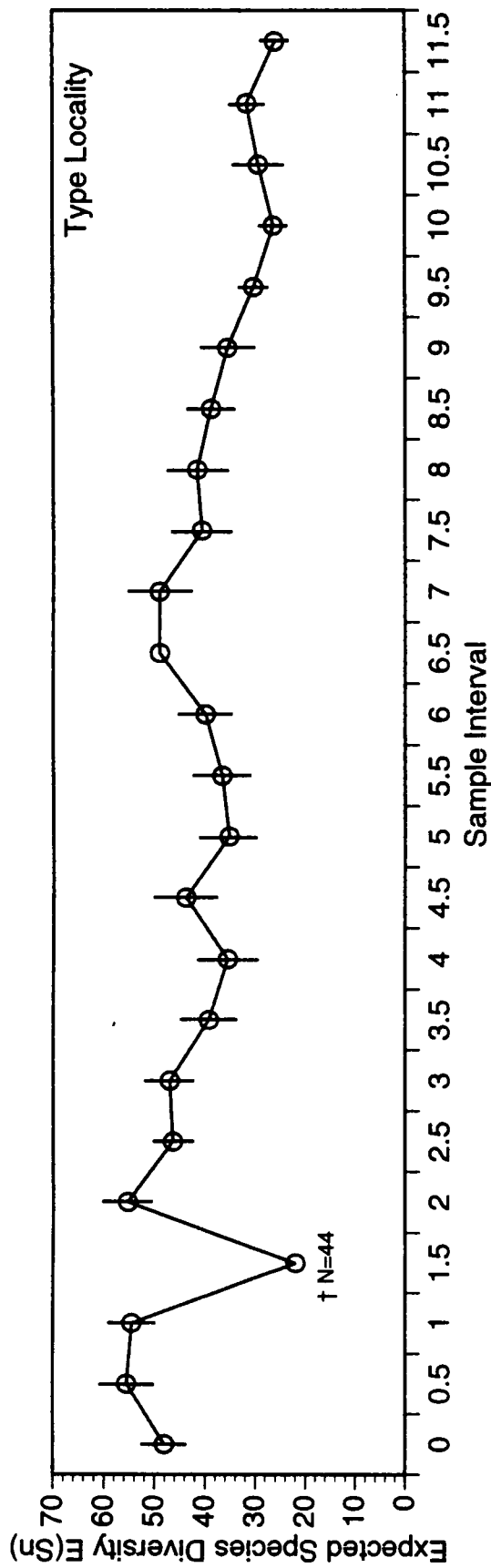


Figure 20. Graph of values of $E(S_n)$ per stratigraphic level at type locality and site W-8104.

Sample Interval	% Cement	% Lime Mud	% <i>Lithothamnion</i>	% <i>Lithophyllum</i> sp. A	% <i>Lithophyllum</i> sp. B
A	9.0	78.4	9.2	0.6	0.0
B	7.4	75.9	12.7	0.6	0.0
C	21.6	57.2	17.0	1.2	0.0
D	6.0	81.0	7.6	0.4	0.0
E	12.6	77.8	6.0	0.0	0.0
F	37.4	46.0	12.6	0.0	0.0
G	8.6	70.0	16.6	0.4	0.0
H	9.4	84.4	3.8	0.0	0.0
I	25.4	58.6	5.8	0.0	0.0
J	8.9	70.7	5.2	0.0	0.0
K	18.7	53.4	0.2	0.0	0.0
L	9.4	68.6	10.2	0.0	0.4
M	11.7	66.9	13.3	0.0	0.0
N	3.6	72.7	16.1	0.4	0.0
O	5.9	66.9	19.8	0.2	0.4

Figure 21. Percentages of petrographic constituents per stratigraphic level.

Sample Interval	% Cement	% Lime Mud	% <i>Lithothamnion</i>	% <i>Lithophyllum</i> sp. A	% <i>Lithophyllum</i> sp. B
P	8.6	66.9	5.1	0.4	1.0
Q	10.0	66.8	5.4	4.0	8.2
R	27.6	51.6	6.0	0.0	1.2
S	13.0	64.2	12.4	0.0	0.0
T	7.5	74.5	8.5	0.0	0.3
U	8.6	67.9	14.0	0.0	0.2
V	11.2	66.7	9.0	0.0	1.0
W	10.4	67.6	14.9	0.0	1.0
X	11.6	74.7	3.2	0.0	1.4
Y	6.8	67.8	15.0	0.0	2.2
Z	13.0	64.2	5.9	0.0	1.0

Figure 21. Continued.

Sample Interval	% <i>Archaeolithothamnion</i>	% <i>Lepidocyclus</i>	% <i>Nummulites</i>	% Cyclostome	% Cheilostome
A	0.0	0.2	0.0	0.4	0.2
B	0.0	0.2	0.0	0.2	0.4
C	0.0	1.0	0.2	0.2	0.8
D	0.0	1.6	0.0	0.6	0.2
E	0.0	0.2	0.2	0.0	0.0
F	0.0	1.8	0.2	0.0	0.0
G	0.0	1.8	0.2	0.2	0.0
H	0.0	0.8	0.0	0.0	0.0
I	0.0	7.0	1.2	0.6	0.0
J	0.0	8.4	0.7	0.5	3.0
K	0.0	10.4	1.8	1.0	0.2
L	0.0	7.6	1.8	0.2	0.4
M	0.0	2.7	1.7	1.5	0.2
N	0.0	3.0	1.0	0.2	0.4

Figure 21. Continued.

Sample Interval	% <i>Archaeolithothamnion</i>	% <i>Lepidocyclus</i>	% <i>Nummulites</i>	% Cyclostomes	% Cheilostomes
O	0.2	1.6	0.4	0.4	0.2
P	0.0	5.1	3.7	0.8	0.2
Q	0.0	5.4	4.0	0.4	0.0
R	0.0	7.4	3.6	1.2	0.2
S	0.0	3.8	3.6	0.6	0.4
T	0.0	1.5	1.5	2.8	0.0
U	0.0	1.4	2.6	1.2	0.0
V	0.4	3.0	3.6	1.2	0.4
W	0.0	3.5	1.5	0.0	0.5
X	0.0	3.0	3.8	0.8	0.0
Y	0.0	3.4	2.2	0.8	0.0
Z	0.0	7.7	3.4	0.2	0.8

Figure 21. Continued.

Sample Interval	% Brachiopods	% Echinoderms	% Ostracodes	% Molluscs
A	0.0	1.4	0.6	0.0
B	0.0	0.4	2.2	0.0
C	0.0	0.4	0.4	0.0
D	0.2	0.8	1.8	0.0
E	0.0	1.4	0.6	0.0
F	0.0	1.4	0.0	0.0
G	0.0	1.4	0.6	0.0
H	0.2	0.8	0.6	0.0
I	0.0	1.0	0.2	0.2
J	0.0	1.5	0.0	0.5
K	0.2	1.0	0.6	1.0
L	0.2	1.0	0.0	0.2
M	0.2	0.6	0.8	0.4
N	0.2	0.6	0.8	0.4

Figure 21. Continued.

Sample Interval	% Brachiopods	% Echinoderms	% Ostracodes	% Molluscs
O	0.6	2.4	0.8	0.2
P	0.6	1.8	0.0	1.0
Q	0.0	1.8	0.4	0.8
R	0.0	1.2	0.0	0.0
S	0.0	1.8	0.2	0.0
T	1.0	1.3	0.8	0.3
U	0.2	2.8	0.0	1.0
V	0.0	1.0	0.4	2.2
W	0.0	0.7	0.0	0.0
X	0.0	0.8	0.0	0.6
Y	0.2	1.2	0.0	0.4
Z	0.0	1.0	0.4	0.2

Figure 21. Continued.

Sample Interval	% Brachiopods	% Echinoderms	% Ostracodes	% Molluscs
O	0.6	2.4	0.8	0.2
P	0.6	1.8	0.0	1.0
Q	0.0	1.8	0.4	0.8
R	0.0	1.2	0.0	0.0
S	0.0	1.8	0.2	0.0
T	1.0	1.3	0.8	0.3
U	0.2	2.8	0.0	1.0
V	0.0	1.0	0.4	2.2
W	0.0	0.7	0.0	0.0
X	0.0	0.8	0.0	0.6
Y	0.2	1.2	0.0	0.4
Z	0.0	1.0	0.4	0.2

Figure 21. Continued.

the two petrographic constituents. Cheilostome and cyclostome bryozoans, and brachiopods, which constitute a very meager volumetric amount of the Florala, do not exhibit any apparent stratigraphic trends.

In general, the petrographic character of the Florala Limestone type locality suggests a depositional setting of low energy situated within the lower realm of the photic zone. The high percentage of lime-mud for each sample strongly indicates very little current or wave activity. The presence of coralline red algae and discernable lack of any type of calcareous green algae imply depths greater than 30 meters (Scoffin, 1987). Stratigraphic changes in the abundance of the larger benthic foraminifera, notably *Nummulites*, also indicate a potential decrease in the general bathymetry. *Nummulites* are commonly associated with shallow marine deposits (Frost and Langenheim, 1974) and their overall increase in abundance towards the top of the type section probably denotes a shallowing in water depth.

CHAPTER V

DISCUSSION

Analysis of the bryozoan faunal elements of the Florala Limestone suggest that there is considerable paleoenvironmental variation between the type section in Covington, County, Alabama, and subsurface strata in Walton County, Florida. On the basis of zoarial growth-form composition and abundance discrete differences can be inferred with respect to substrate and possibly turbulence and sedimentation rate. The higher abundance of free-living colonies and erect-flexible growth-forms in W-8104 indicate that in general the substrate was particulate in nature or relatively more particulate in nature than observed at the type section. Growth-classes with preferences for cohesive 'hard' substrata, such as unilaminar and multilaminar C encrusting varieties and erect-delicate growth forms, occur in comparatively smaller percentages in several core samples suggesting a minimum availability of inhabitable hard surfaces. Erect-delicate morphologies, however, are tolerant of particulate substrates and have been observed to utilize available uncohesive surfaces in large numbers, albeit infrequently (Nelson and others, 1988). In contrast the dominant growth-habits at the Florala type section consist of encrusting (unilaminar and multilaminar C) and erect-delicate zoaria suggesting the predominance of hard substrates. This interpretation is supported by the abundant *Lithothamnion* algal crusts comprising the majority of strata at the type section which may have provided stable cohesive surfaces for colony growth. W-8104's greater quantities of erect-flexible and robust branching zoaria also imply comparatively greater levels of water agitation than the type area; erect-flexible and robust branching growth-habits are especially predisposed to living under conditions of moderate turbulence (Nelson and others, 1988). The smaller amount of erect-delicate zoaria, which have strong preferences for low energy environments may also reflect increased water motion

as well. Contrastingly greater numbers of erect-delicate zoaria comprise the majority of samples at the type locality and indicate minimal current activity. Petrographic data, notably the large volumetric percentages of lime mud in several samples, support this inference as well. Sedimentation influx at the W-8104 site was perhaps occurring at higher rates than at the type locality given the nature of zoarial morphologies.

Unilaminar encrusting zoaria which are strongly limited to settings of low sedimentation, are typically diminished in comparison with the type area assemblages.

The abundant erect-flexible remains, and the presence of free-living and robust branching zoaria, all of which demonstrate tolerances to moderate and high levels of turbidity, suggest that rates of sedimentation were higher to the south of the type locality. Ordination results also corroborate the differences between localities.

Taxonomic compositional differences segregate type and core locations in eigenspace indicating their intrinsic ecological preferences, which is interpreted as primarily influenced by substrate. Bathymetric ranges for modern bryozoan congeners found in the Florala Limestone suggest a mean depth of 60 meters for both localities (Figure 22). This is in close agreement with the bathymetric inference of Bryan (1991, 1993) who determined a depth range of 70 to 80 meters.

Stratigraphic changes in bryozoan assemblages of the Florala Limestone type and core localities exhibit corresponding patterns interpretable as allogenic replacement (where biotic change results from species response to abiotic environmental influences; Dodd and Stanton, 1990). The transition of faunal associations is evident in the composite ordination (Figure 17) which shows a general, though imperfect, ordering of samples in stratigraphic succession. Faunal assemblages comprising samples from W-8104 show considerably less temporal change than observed at the type locality, implying that environmental conditions were relatively constant over the time of sediment accumulation. The minimal change in alpha diversity in the core also

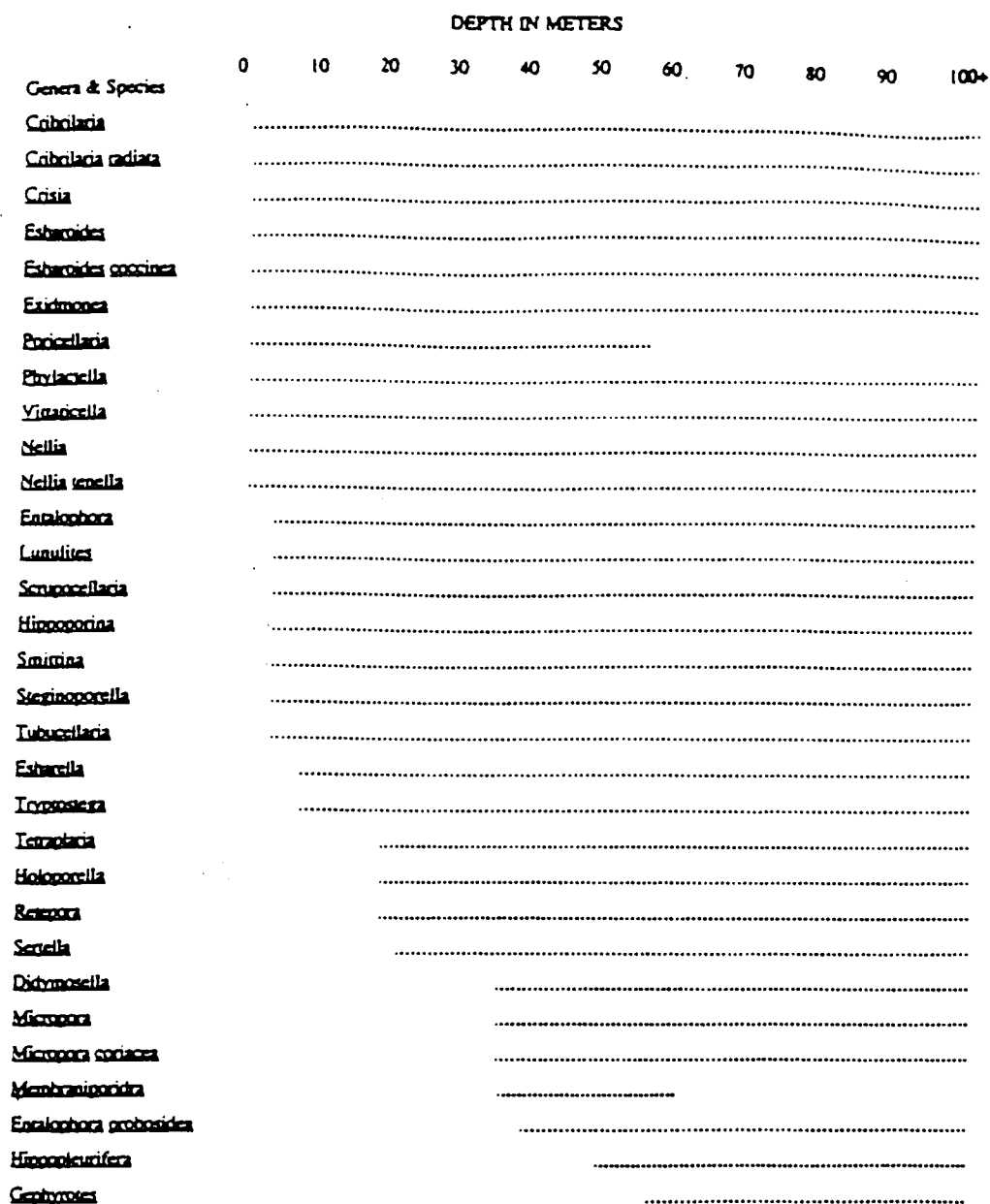


Figure 22. Compiled bathymetric ranges of extant bryozoan taxa occurring within the Florala Limestone.

in the core also implies this as well. The observed shift from oldest to youngest intervals at both sites, which manifest very different taxonomic compositions, suggest a similar response to a single, or series of, extraneous environmental factors.

Examination of the change in values of Beta F and rarefied species richness of the Florala bryozoan assemblages suggest a general decline in the equilibrium and stability over time, particularly at the type locality. Rates of turnover in taxonomic composition show an increase in values at successively higher stratigraphic levels for both sites. Community replacement at the type locality shows a period of low faunal changeover between 2.5 and 6 meters followed by relatively higher levels of displacement with significant compositional shifts approaching 0.8 beta standard deviations at 6.5, 9.5, and 11.0 meters (Figure 18). A large peak exceeding 1.0 Beta standard deviations at 1.5 meters represents a very sudden and dramatic loss of taxa, either as a localized extinction, or simply a sample error, were the taxa may have simply existed in a location adjacent to the sampled interval in the section. Turnover in faunal associations at W-8104 show fewer and typically lower magnitude displacements than the type locality with two turnovers of .26 and .51 occurring at 68.45 meters and 67 meters respectively (Figure 18). Peaks in Δ Beta F values correspond to losses of rare sporadic taxa over the duration of both measured sequences. This pattern suggests that ecological circumstances were changing from generally stable and equable situations to relatively unstable and perhaps less hospitable environmental circumstances. This interpretation is less applicable to Δ Beta F values from the core due to fewer numbers of samples and a coarser scale of sampling. Declining values of $E(Sn)$ at the type section support the notion of progressive ecological degradation at the site. Species richness estimates of samples from W-8104 show a potentially slight increase in diversity towards the top of the core, but differences in alpha diversity among samples are not discernible. This minimal change in richness, however, is consistent with the inference

of environmental constancy over time at the site. Patterns of species composition and richness may also be distorted due to differences in sediment accumulation between the study localities, however a lack of chrono- and biostratigraphic data severely limit a thorough evaluation of this problem. In addition it should be noted that differences in Δ Beta F and $E(Sn)$ between the two localities may also be real. Perhaps less change in W-8104 is observed simply because the biota existed in a setting that was more buffered from the allogenic affects.

Huddlestun (1993) has posited that the paleoenvironmental history of the Florala Limestone reflects a progressive bathymetric shallowing. Data supporting this inference were never presented in Huddlestun's research making this conclusion anecdotal. In the present study the analyses of bryozoan assemblages and petrographic data imply that Huddlestun's interpretation is plausible. Vertical changes in the Florala bryozoan species associations, and consequently the resulting zoarial morphologic assemblages, are the result of external environmental influence(s). By examining the nature of allogenic replacement it is possible to ascertain if change in bathymetry, particularly shallowing, is the potential underlying factor. The effects of replacement are especially recognizable at the type locality as demonstrated by the ordination results. If depth change can be perceived at the type locality then it may be concluded that concomitant changes at W-8104 are the result of this influence as well. The mechanisms of replacement are probably different for these two sites given their disparate taxonomic assemblages, however, the corresponding changes suggest a similar biotic response to the same ecological stimulus.

Allogenic replacement at the type locality displays a shift from a diverse association dominated by unilaminar taxa in the basal strata of the measured section to a less heterogeneous association of erect-rigid and erect-flexible taxa. Zoarial morphologic assemblages show a corresponding transition from an abundant encrusting fauna in the

lower 2.5 meters (samples A - F; Figure 13) to an assemblage comprised of erect-delicate, and less commonly, erect-flexible forms (samples G - X; Figure 13). In conjunction with these changes a corresponding trend is noted from the volumetric abundance of the larger benthic foraminiferal genera *Lepidocyclina* and *Nummulites* (Table 1) which show an associated increase following the decline of the encrusting assemblage. The volumetric proportions of larger benthic foraminifera and the coralline alga *Lithothamnion* also show a moderate inverse relationship in several samples (compare abundance in Table 1). It is interesting to note that encrusting morphologies appear to negatively covary in abundance with larger benthic foraminifera, and for some samples show an associated increase with the volumetric gain of *Lithothamnion*. The relationship between larger benthic foraminifera, *Lithothamnion* and zoarial morphologic assemblages is not clear. It is postulated that the thin *Lithothamnion* crusts served as stable substrates for the proliferation of encrusting taxa. The relatively cohesive and firm surfaces would have provided adequate sites for colony attachment and growth. The development of larger benthic foraminiferal populations possibly reduced the availability of habitable hard substrates, effecting comparatively more particulate conditions, and in turn, allowed the colonization of erect-delicate forms which display a greater tolerance to uncohesive sediments than encrusting colonies. Simultaneous changes in substrate conditions and foraminiferal abundance are possibly related to decreasing bathymetry. The larger benthic foraminifera *Nummulites*, which is typically found in ancient shallow water facies (Frost and Langenheim, 1974), shows a discernible increase throughout the measured section suggesting a progressive change to shallower conditions. A notable increase in erect-flexible zoaria in samples Q - T may also suggest a decrease in depth; erect-flexible faunas, which are adapted to living in conditions of moderate water agitation, may indicate a closer position to wave base.

In general, the observed transition in zoarial remains and petrographic constituents suggest that regression is a conceivable explanation for changes at the Florala type area. Manker and Carter (1987) have postulated that the stratigraphic sequence of the Bridgeboro Limestone at its type section in southwest Georgia represents a gradual shoaling or regressive sequence on the basis of changes in the inherent algal flora. A decrease in the abundance of coralgall rhodoliths and the presence of dasycladacean algae over time at the Bridgeboro site were interpreted as evidence of shoaling or relative drop in sea level. Associated changes in W-8104, though less evident, offer some indication that a decrease in bathymetry may have occurred. Increases in the abundances of erect-flexible zoaria towards the top of the core would suggest relatively higher levels of turbulence and possibly a greater degree of proximity to wave base.

It is unclear how the influence of biostratigraphic factors and diagenesis affect the bryozoan thanatocoenoses; very little research exists regarding the taphonomy of bryozoan remains. Smith and others (1992) have explained the potential of carbonate dissolution of bryozoan assemblages concluding that the degree of zoarial robustness and surface area greatly determine the preservational success. Smith and Nelson (in press) studied the role of hydrodynamic abrasion in the formation of zoarial assemblages and determined that zoarial size and thickness were of integral importance in diminishing the destructive effects of abrasion. Similarly, it is also uncertain how important the influence of skeletal mineralogy is to the fossilization potential of bryozoan taxa. The loss of species in an assemblage comprised of organic skeletons, for example, is unknown as there is a lack of studies in this regard; nor is there a documented fossil record of bryozoan with organic framework compositions. In general the mineralogical composition of most species are highly conducive to preservation. The skeletal mineralogies for most bryozoans are primarily low-magnesium calcite;

however, some species develop aragonitic and combinations of aragonite-calcite frameworks (Tucker and Wright, 1992). The fossilization of aragonitic and aragonite-calcite secreting bryozoa have not been researched in any great detail, however, Greely (1969) in a survey of Paleogene species of *Lunulites* from the U.S. Gulf Coastal Plain - a genus secreting an aragonite-calcite composite - noted that aragonite was more susceptible to dissolution in non-detrital carbonate facies. This suggests that in carbonate environments bryozoa with aragonitic skeletons or skeletal components are less likely to be preserved.

The results of this study are in close agreement with the interpretation of Bryan (1991, 1993) and do not seem to radically influence his Vicksburgian carbonate model. Clearly further research on a larger scale, utilizing bryozoans or a comparable microfauna, will clarify paleobathymetric relationships within the Oligocene of the Gulf Coastal Plain. Sampling along an east-west transect through the Vicksburg carbonate sequence and employing the techniques utilized in this study may undoubtedly shed light on the paleoecologic nature and depositional history of the Vicksburg.

CHAPTER VI

SUMMARY

The Florala Limestone Member of the Bridgeboro Limestone demonstrates a greater range of paleoenvironmental variation than previously interpreted. Analyses of bryozoan zoarial remains and petrographic data indicate discernible differences in paleoecological conditions between the Florala type section in southeast Alabama and subsurface deposits in Walton County, Florida. The paleoenvironmental setting at the type area generally demonstrates quiescent marine conditions, dominated by bryozoan faunas showing affinities for stable cohesive sediment surfaces and minimal sedimentation influx. In comparison, the bryozoan assemblages from the W-8104 core hole in Walton County, Florida, denote relatively higher levels of turbulence, a predominance of particulate substrates and possibly higher rates of sedimentation. Stratigraphic changes in the taxonomic associations of the type locality and W-8104 indicate a pattern of allogenic replacement where the external environmental influence effecting biotic response was a progressive decrease in bathymetry, either by sea level fall or shoaling. Associated changes in alpha and beta diversity at the type area show a progressive degradation in the paleoenvironment over time; species richness and faunal turnover in the W-8104 sequence are less clearly defined, although turnover in taxonomic associations did occur, albeit less frequently than determined at the type locality. Differences in sampling and possibly rates of sediment accumulation between the two sites likely contribute to the patterns of richness and faunal changeover observed.

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APPENDICES

Appendix A. Species list and zoarial growth-form totals of type locality.

100

Taxon/Sample Interval	1	2	3	4
ERECT-FLEXIBLE FAUNAS				
<i>Bicellaridae</i> sp.indet.	0	4	2	0
<i>Cantecellidae</i> sp. indet.	0	0	0	0
<i>Crisia</i> sp.	13	25	6	0
Erect-Flexible cheilostome sp. A	0	0	0	0
<i>Nellia tenella</i>	0	0	0	0
<i>Poricellaria</i> sp.	8	1	2	1
<i>Scrupocellaria</i> cf. <i>elliptica</i>	0	0	0	0
<i>Scrupocellaria</i> <i>milneri</i>	3	2	3	0
<i>Scrupocellaria</i> <i>rathburni</i>	0	0	0	0
<i>Scrupocellaria</i> <i>resseri</i>	0	0	0	0
<i>Scrupocellaria</i> <i>williardi</i>	7	8	0	0
<i>Semihawsellina</i> <i>exilis</i>	0	0	0	0
<i>Tubucellaria</i> <i>vicksburgica</i>	6	7	17	5
<i>Vincularia</i> sp.	0	0	0	0
<i>Vittaticella</i> sp.	0	0	0	0
Erect-Flexible Growth-Form Totals:	37	47	30	6
ERECT-DELICATE FAUNAS				
<i>Crisulipora</i> <i>prominens</i>	4	3	2	3
<i>Crisulipora</i> <i>rugosadoralis</i>	0	1	1	1
<i>Enoplostomella</i> <i>vallata</i>	0	1	0	0
<i>Enoplostomella</i> <i>defixa</i>	0	0	0	0
<i>Entalophora</i> <i>cornuta</i>	0	0	2	2
<i>Entalophora</i> <i>compressa</i>	0	0	0	0
<i>Entalophora</i> <i>elongotuba</i>	0	0	0	0
<i>Entalophora</i> <i>lunata</i>	0	0	0	1
<i>Entalophora</i> <i>probosidea</i>	28	73	42	4
<i>Entalophora</i> <i>quissenberryae</i>	7	0	4	0
<i>Entalophora</i> <i>semota</i>	0	10	4	0
<i>Exidmonea</i> sp. A	0	0	0	0
<i>Exidmonea</i> sp. B	0	0	0	0
<i>Exidmonea</i> <i>grandiosa</i>	0	0	0	0
<i>Exidmonea</i> <i>grallator</i>	15	17	3	1
<i>Exidmonea</i> <i>petri</i>	0	0	0	0
<i>Exidmonea</i> <i>triforata</i>	55	110	53	5
<i>Filisparsa</i> <i>atomicula</i>	0	0	0	0
<i>Filisparsa</i> <i>biseriata</i>	0	0	0	0
<i>Filisparsa</i> <i>ingens</i>	0	2	0	0
<i>Filisparsa</i> cf. <i>simulator</i>	0	0	0	0
<i>Filisparsa</i> <i>typica</i>	0	0	8	0
<i>Oncousesia</i> sp.	2	5	0	0
<i>Plueronea</i> <i>fenestrata</i>	0	0	0	0

Appendix A. (continued)

101

Taxon/Sample Interval	1	2	3	4
<i>Membraniporida spissimilaris</i>	40	39	25	3
<i>Membraniporida sp. A</i>	0	3	0	0
<i>Membraniporida sp. B</i>	0	0	0	0
<i>Microecia sp.</i>	3	4	3	0
<i>Micropora coriacea</i>	0	0	0	0
<i>Onychella ? sp.</i>	0	0	0	0
<i>Plagioecia sp. A</i>	11	0	3	0
<i>Plagioecia cf. hirta</i>	3	22	6	0
<i>Perigastrella sp. A</i>	7	4	6	0
<i>Perigastrella sp. B</i>	0	0	0	0
<i>Perigastrella plana</i>	0	1	0	0
<i>Proboscina sp. A</i>	19	0	12	1
<i>Proboscina alternata</i>	0	0	0	0
<i>Proboscina sp. B</i>	6	20	15	0
<i>Proboscina sp. C</i>	1	1	7	1
<i>Proboscina calubra</i>	1	0	0	0
<i>Platonea sp. A</i>	0	4	0	0
<i>Platonea clavata</i>	1	9	3	0
<i>Proboscina clavitaramosa</i>	17	22	27	0
<i>Proboscina sp. D</i>	17	3	0	0
<i>Proboscina geminata</i>	0	40	20	0
<i>Proboscina rectalineata</i>	3	12	2	0
<i>Phylactella sp.</i>	4	1	3	0
<i>Retonchylla sp.</i>	1	1	0	0
<i>Rhyncozoon ? sp.</i>	0	5	0	0
<i>Setosella ? sp.</i>	4	2	3	0
<i>Schizopodrella sp. A</i>	0	4	1	0
<i>Schizopodrella sp. B</i>	0	2	4	0
<i>Smittina sp. A</i>	0	6	6	0
<i>Smittina sp. B</i>	0	5	0	0
<i>Smittina ? sp.</i>	3	5	6	0
<i>Stomochatesella ? sp.</i>	0	0	0	0
<i>Tryptostega sp.</i>	1	3	1	0
<i>Tubulipora sp. A</i>	0	1	1	0
<i>Tubulipora sp. B</i>	0	0	0	0
<i>Stomatopora sp.</i>	60	115	54	0
Unilaminar Encrusting Growth-Form Totals:	371	564	468	18
MULTILAMINAR FAUNAS				
<i>Holoporella sp. A</i>	9	26	43	5
<i>Holoporella sp. B</i>	12	25	13	0
Multilaminar Growth-Form Totals:	21	51	56	5

Appendix A. (continued)

102

Taxon/Sample Interval	1	2	3	4
<i>Pustulopora</i> ?	0	0	0	0
Erect-Delicate Growth-Form Totals:	112	224	122	21

UNILAMINAR ENCRUSTING FAUNAS

<i>Aimolousia</i> ? sp.	1	3	0	0
<i>Aplousina</i> ? sp.	1	3	8	0
<i>Aechmella</i> ?	15	17	12	0
<i>Buffonella</i> sp.	23	11	5	0
<i>Callopora</i> ? sp.	0	0	0	0
<i>Costazzia</i> ?	1	0	0	0
<i>Crassimarginatella</i> sp.	1	1	1	1
<i>Cribrilaria radiata</i>	18	12	8	0
<i>Cyclocolposa</i> ? sp.	0	0	0	0
<i>Desmoplagioecia</i> sp.	0	0	2	0
<i>Diaperoecia</i> sp. A	9	19	2	0
<i>Diaperoecia clava</i>	12	20	14	0
<i>Diastopora</i> sp.	1	1	1	1
<i>Didymosella</i> cf. <i>crassa</i>	0	0	0	0
<i>Encrusting</i> sp. A	2	7	5	1
<i>Encrusting</i> sp. B	1	7	1	1
<i>Encrusting</i> sp. C	0	0	0	0
<i>Encrusting</i> sp. D	0	1	0	0
<i>Encrusting</i> sp. E	0	1	0	0
<i>Enoplostomella crassimularis</i>	7	0	0	0
<i>Esharella</i> sp.	2	1	6	0
<i>Esharoides</i> sp. A	1	0	4	0
<i>Esharoides coccinea</i>	18	45	16	1
<i>Floridina</i> ? sp.	0	1	0	0
<i>Floridinella vicksburgica</i>	22	46	133	2
<i>Gephyrotes</i> sp.	1	4	0	0
<i>Herpetopora</i> ? sp.	0	1	1	0
<i>Hippoporina</i> cf. <i>lucens</i>	0	2	0	0
<i>Hippoporina</i> sp.	1	1	1	1
<i>Hippodiplosia</i> cf. <i>magniporosa</i>	2	0	5	0
<i>Hippomanella</i> sp. A	0	2	4	1
<i>Hippomanella</i> sp. B	0	0	7	0
<i>Lagenipora</i> ? sp.	0	0	0	0
<i>Lichenopera</i> sp. A	3	1	1	0
<i>Lichenopera boletiformis</i>	1	1	4	0
<i>Lichenopera goldfussi</i>	0	0	6	0
<i>Lichenopera prolifera</i>	3	2	7	0
<i>Lichenopera</i> cf. <i>verrucosa</i>	1	1	1	0
<i>Membrandaecium</i> sp.	21	17	2	0

Appendix A. (continued)

103

Taxon/Sample Interval	1	2	3	4
ROBUST BRANCHING FAUNAS				
<i>Hippomanella costulata</i>	0	0	0	0
<i>Membranipora</i> ?	0	0	0	0
<i>Porella</i> sp. A	1	1	1	1
<i>Porella</i> cf. <i>abditata</i> ?	0	0	0	0
<i>Stamenocella</i> sp. A	0	0	0	0
<i>Stamenocella</i> sp. B	0	0	0	0
<i>Steginoporella</i> ?	0	0	0	0
Robust Branching Growth-Form Totals:	1	1	1	1
FENESTRATE FAUNAS				
<i>Retepora</i> cf. <i>lacinosa</i>	3	10	7	1
<i>Reteporellina</i> ? sp.	0	3	0	0
<i>Sertella</i> sp.	0	0	0	0
Fenestrate Growth-Form Totals:	3	13	7	1
FOLIOSE FAUNAS				
<i>Exochoecia rugosa</i>	4	15	31	0
<i>Heteropora</i> ? sp.	0	0	0	0
Foliose Growth-Form Totals:	4	15	31	0
FREE-LIVING FAUNAS				
<i>Lunulites</i> sp.	0	0	0	0

Appendix A. (continued)

Taxon/Sample Interval	104			
	5	6	7	8
ERECT-FLEXIBLE FAUNAS				
<i>Bicellaridae</i> sp.indet.	10	13	4	11
<i>Cantecellidae</i> sp. indet.	0	0	1	0
<i>Crisia</i> sp.	15	46	11	19
Erect-Flexible cheilostome sp. A	0	0	0	0
<i>Nellia tenella</i>	0	0	1	2
<i>Poricellaria</i> sp.	22	17	1	7
<i>Scrupocellaria</i> cf. <i>elliptica</i>	0	0	0	0
<i>Scrupocellaria milneri</i>	1	0	2	4
<i>Scrupocellaria rathburni</i>	3	0	1	0
<i>Scrupocellaria resseri</i>	0	0	0	0
<i>Scrupocellaria williardi</i>	17	27	23	23
<i>Semihawsellina exilis</i>	0	0	0	0
<i>Tubucellaria vicksburgica</i>	9	15	12	33
<i>Vincularia</i> sp.	0	0	0	0
<i>Vittaticella</i> sp.	0	0	1	0
Erect-Flexible Growth-Form Totals:	77	118	57	99
ERECT-DELICATE FAUNAS				
<i>Crisulipora prominens</i>	0	1	1	0
<i>Crisulipora rugosadoralis</i>	0	1	6	1
<i>Enoplostomella vallata</i>	0	0	0	2
<i>Enoplostomella defixa</i>	0	0	0	0
<i>Entalophora cornuta</i>	1	4	0	0
<i>Entalophora compressa</i>	1	0	0	2
<i>Entalophora elongotuba</i>	0	0	0	1
<i>Entalophora lunata</i>	0	0	0	0
<i>Entalophora probosidea</i>	85	91	85	140
<i>Entalophora quissenberryae</i>	8	9	7	18
<i>Entalophora semota</i>	11	5	8	3
<i>Exidmonea</i> sp. A	0	0	0	0
<i>Exidmonea</i> sp. B	0	0	0	0
<i>Exidmonea grandiosa</i>	0	0	0	0
<i>Exidmonea grallator</i>	19	17	22	32
<i>Exidmonea petri</i>	0	0	0	2
<i>Exidmonea triforata</i>	156	116	206	375
<i>Filisarsa atomicula</i>	0	0	0	0
<i>Filisarsa biseriata</i>	0	1	0	0
<i>Filisarsa ingens</i>	3	1	9	0
<i>Filisarsa</i> cf. <i>simulator</i>	0	0	0	0
<i>Filisarsa typica</i>	22	4	2	0
<i>Oncousesia</i> sp.	0	3	4	5
<i>Pueronea fenestrata</i>	5	0	2	1

Taxon/Sample Interval	5	6	7	8
<i>Pustulopora</i> ?	0	0	0	0
Erect-Delicate Growth-Form Totals:	316	259	359	590

UNILAMINAR ENCRUSTING FAUNAS

<i>Aimolousia</i> ? sp.	0	0	1	4
<i>Aplousina</i> ? sp.	0	0	0	0
<i>Aechmella</i> ?	12	6	2	1
<i>Buffonella</i> sp.	5	0	1	2
<i>Callopora</i> ? sp.	1	0	1	0
<i>Costazzia</i> ?	0	0	0	0
<i>Crassimarginatella</i> sp.	1	1	1	1
<i>Cribrilaria radiata</i>	8	2	0	2
<i>Cyclocolposia</i> ? sp.	0	0	0	0
<i>Desmoplagioecia</i> sp.	4	0	0	0
<i>Diaperoecia</i> sp. A	0	2	5	5
<i>Diaperoecia clava</i>	5	6	0	3
<i>Diastopora</i> sp.	1	3	1	1
<i>Didymosella</i> cf. <i>crassa</i>	1	0	0	0
<i>Encrusting</i> sp. A	0	0	6	3
<i>Encrusting</i> sp. B	2	1	2	0
<i>Encrusting</i> sp. C	0	0	0	0
<i>Encrusting</i> sp. D	0	0	0	0
<i>Encrusting</i> sp. E	0	0	0	0
<i>Enoplostomella crassimularis</i>	5	0	1	4
<i>Esharella</i> sp.	6	0	0	1
<i>Eshareoides</i> sp. A	5	0	0	0
<i>Eshareoides coccinea</i>	35	13	4	3
<i>Floridina</i> ? sp.	0	0	0	0
<i>Floridinella vicksburgica</i>	41	20	2	9
<i>Gephyrotes</i> sp.	5	4	2	1
<i>Herpetopora</i> ? sp.	0	0	0	0
<i>Hippoporina</i> cf. <i>lucens</i>	0	0	0	0
<i>Hippoporina</i> sp.	1	1	1	1
<i>Hippodiplosia</i> cf. <i>magniporosa</i>	1	0	2	5
<i>Hippomanella</i> sp. A	6	2	2	1
<i>Hippomanella</i> sp. B	4	0	0	2
<i>Lagenipora</i> ? sp.	0	1	1	1
<i>Lichenopera</i> sp. A	2	0	0	0
<i>Lichenopera boletiformis</i>	5	1	5	7
<i>Lichenopera goldfussi</i>	3	1	1	0
<i>Lichenopera prolifera</i>	0	2	1	3
<i>Lichenopera</i> cf. <i>verrucosa</i>	1	0	0	0
<i>Membrandaecium</i> sp.	10	8	1	2

Appendix A. (continued)

106

Taxon/Sample Interval	5	6	7	8
<i>Membraniporida spissimilaris</i>	26	25	5	0
<i>Membraniporida sp. A</i>	0	4	1	1
<i>Membraniporida sp. B</i>	0	0	0	0
<i>Microecia sp.</i>	0	0	0	0
<i>Micropora coriacea</i>	1	0	0	0
<i>Onychella ? sp.</i>	0	0	0	0
<i>Plagioecia sp. A</i>	6	1	2	6
<i>Plagioecia cf. hirta</i>	9	8	3	0
<i>Perigastrella sp. A</i>	2	2	0	0
<i>Perigastrella sp. B</i>	0	0	0	0
<i>Perigastrella plana</i>	1	0	0	0
<i>Proboscina sp. A</i>	0	8	8	1
<i>Proboscina alternata</i>	0	0	0	0
<i>Proboscina sp. B</i>	6	10	0	6
<i>Proboscina sp. C</i>	1	1	1	1
<i>Proboscina calubra</i>	0	0	0	0
<i>Platonea sp. A</i>	0	0	0	0
<i>Platonea clavata</i>	3	0	0	0
<i>Proboscina clavitaramosa</i>	8	9	9	10
<i>Proboscina sp. D</i>	9	0	0	3
<i>Proboscina geminata</i>	14	12	8	10
<i>Proboscina rectalineata</i>	0	10	0	0
<i>Phylactella sp.</i>	1	0	0	1
<i>Retonchylla sp.</i>	0	0	0	1
<i>Rhyncozoon ? sp.</i>	0	0	0	0
<i>Setosella ? sp.</i>	3	4	0	1
<i>Schizopodrella sp. A</i>	1	0	0	0
<i>Schizopodrella sp. B</i>	0	0	0	0
<i>Smittina sp. A</i>	9	5	3	0
<i>Smittina sp. B</i>	10	0	0	1
<i>Smittina ? sp.</i>	6	9	1	1
<i>Stomochatesella ? sp.</i>	0	0	0	0
<i>Tryptostega sp.</i>	0	0	0	0
<i>Tubulipora sp. A</i>	0	0	1	0
<i>Tubulipora sp. B</i>	0	0	0	0
<i>Stomatopora sp.</i>	69	50	28	43
Unilaminar Encrusting Growth-Form Totals:	360	238	120	156
MULTILAMINAR FAUNAS				
<i>Holoporella sp. A</i>	43	12	3	5
<i>Holoporella sp. B</i>	7	9	3	5
Multilaminar Growth-Form Totals:	50	21	6	10

Appendix A. (continued)

Taxon/Sample Interval	107			
	5	6	7	8
ROBUST BRANCHING FAUNAS				
<i>Hippomanella costulata</i>	1	0	1	1
<i>Membranipora</i> ?	0	2	0	0
<i>Porella</i> sp. A	1	1	1	1
<i>Porella</i> cf. <i>abdit</i> a ?	0	0	0	0
<i>Stamenocella</i> sp. A	0	0	0	0
<i>Stamenocella</i> sp. B	0	0	0	0
<i>Steginoporella</i> ?	0	0	0	0
Robust Branching Growth-Form Totals:	2	3	2	2
FENESTRATE FAUNAS				
<i>Retepora</i> cf. <i>lacinosa</i>	14	9	9	8
<i>Reteporellina</i> ? sp.	1	0	0	1
<i>Sertella</i> sp.	3	3	1	5
Fenestrate Growth-Form Totals:	18	12	10	14
FOLIOSE FAUNAS				
<i>Exochoecia rugosa</i>	8	17	10	28
<i>Heteropora</i> ? sp.	0	0	0	0
Foliose Growth-Form Totals:	8	17	10	28
FREE-LIVING FAUNAS				
<i>Lunulites</i> sp.	0	0	0	0

Taxon/Sample Interval	9	10	11	12
<i>Pustulopora</i> ?	0	0	0	0
Erect-Delicate Growth-Form Totals:	1714	1240	1453	1230

UNILAMINAR ENCRUSTING FAUNAS

<i>Aimolousia</i> ? sp.	0	0	0	1
<i>Aplousina</i> ? sp.	0	3	0	0
<i>Aechmella</i> ?	3	0	1	2
<i>Buffonella</i> sp.	8	4	6	2
<i>Callopora</i> ? sp.	0	1	0	0
<i>Costazzia</i> ?	0	0	0	0
<i>Crassimarginatella</i> sp.	1	1	1	1
<i>Cribrilaria radiata</i>	1	0	4	5
<i>Cyclocolposa</i> ? sp.	0	5	0	1
<i>Desmoplagioecia</i> sp.	0	1	0	0
<i>Diaperoecia</i> sp. A	5	0	0	5
<i>Diaperoecia clava</i>	5	7	2	12
<i>Diastopora</i> sp.	2	1	1	1
<i>Didymosella</i> cf. <i>crassa</i>	5	5	5	1
<i>Encrusting</i> sp. A	4	1	5	3
<i>Encrusting</i> sp. B	2	0	2	2
<i>Encrusting</i> sp. C	2	0	0	0
<i>Encrusting</i> sp. D	0	0	0	0
<i>Encrusting</i> sp. E	0	0	0	0
<i>Enoplostomella crassimularis</i>	0	1	0	3
<i>Esharella</i> sp.	3	7	2	13
<i>Esharoides</i> sp. A	0	3	1	3
<i>Esharoides coccinea</i>	1	16	12	7
<i>Floridina</i> ? sp.	0	1	0	0
<i>Floridinella vicksburgica</i>	10	2	12	0
<i>Gephyrotes</i> sp.	0	3	0	0
<i>Herpetopora</i> ? sp.	0	0	0	0
<i>Hippoporina</i> cf. <i>lucens</i>	0	0	0	0
<i>Hippoporina</i> sp.	1	1	1	1
<i>Hippodiplosia</i> cf. <i>magniporosa</i>	2	7	2	0
<i>Hippomanella</i> sp. A	0	1	0	0
<i>Hippomanella</i> sp. B	0	1	0	0
<i>Lagenipora</i> ? sp.	0	2	2	1
<i>Lichenopera</i> sp. A	0	0	0	1
<i>Lichenopera boletiformis</i>	0	2	1	9
<i>Lichenopera goldfussi</i>	1	2	0	0
<i>Lichenopera prolifera</i>	0	0	2	1
<i>Lichenopera</i> cf. <i>verrucosa</i>	8	0	0	0
<i>Membrandaecium</i> sp.	1	6	2	4

Taxon/Sample Interval	9	10	11	12
ERECT-FLEXIBLE FAUNAS				
<i>Bicellaridae</i> sp.indet.	1	1	2	2
<i>Cantecellidae</i> sp. indet.	0	0	0	0
<i>Crisia</i> sp.	5	1	1	0
Erect-Flexible cheilostome sp. A	0	1	0	1
<i>Nellia tenella</i>	2	7	0	2
<i>Poricellaria</i> sp.	12	5	1	0
<i>Scrupocellaria cf.elliptica</i>	0	0	0	0
<i>Scrupocellaria milneri</i>	4	12	12	3
<i>Scrupocellaria rathburni</i>	0	0	1	0
<i>Scrupocellaria resseri</i>	0	0	0	0
<i>Scrupocellaria willardi</i>	5	8	5	0
<i>Semihawsellina exilis</i>	1	1	0	0
<i>Tubucellaria vicksburgica</i>	89	36	66	40
<i>Vincularia</i> sp.	0	0	0	0
<i>Vittaticella</i> sp.	0	0	0	0
Erect-Flexible Growth-Form Totals:	119	72	88	48

ERECT-DELICATE FAUNAS

<i>Crisulipora prominens</i>	7	1	2	3
<i>Crisulipora rugosadoralis</i>	0	9	5	7
<i>Enoplostomella vallata</i>	0	3	0	0
<i>Enoplostomella defixa</i>	0	0	0	0
<i>Entalophora cornuta</i>	10	16	10	0
<i>Entalophora compressa</i>	6	8	1	4
<i>Entalophora elongotuba</i>	1	3	0	0
<i>Entalophora lunata</i>	0	0	0	0
<i>Entalophora probosidea</i>	431	334	575	430
<i>Entalophora quissenberryae</i>	50	30	55	28
<i>Entalophora semota</i>	11	15	5	13
<i>Exidmonea</i> sp. A	0	0	0	0
<i>Exidmonea</i> sp. B	0	5	0	0
<i>Exidmonea grandiosa</i>	0	0	0	0
<i>Exidmonea grallator</i>	75	29	44	56
<i>Exidmonea petri</i>	11	0	10	1
<i>Exidmonea triforata</i>	915	659	643	607
<i>Filisarsa atomicula</i>	2	0	0	0
<i>Filisarsa biseriata</i>	0	1	0	0
<i>Filisarsa ingens</i>	15	16	5	9
<i>Filisarsa cf. simulator</i>	0	0	0	1
<i>Filisarsa typica</i>	135	56	80	31
<i>Oncousesia</i> sp.	15	33	5	21
<i>Plueronea fenestrata</i>	21	12	2	7

Appendix A. (continued)

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Taxon/Sample Interval	9	10	11	12
<i>Membraniporida spissimilaris</i>	18	7	10	9
<i>Membraniporida sp. A</i>	4	1	2	0
<i>Membraniporida sp. B</i>	0	0	0	0
<i>Microecia sp.</i>	0	1	0	0
<i>Micropora coriacea</i>	0	0	0	0
<i>Onychella ? sp.</i>	1	0	0	1
<i>Plagioecia sp. A</i>	2	0	1	0
<i>Plagioecia cf. hirta</i>	1	5	0	5
<i>Perigastrella sp. A</i>	0	0	0	1
<i>Perigastrella sp. B</i>	0	0	0	0
<i>Perigastrella plana</i>	0	0	0	0
<i>Proboscina sp. A</i>	5	2	7	8
<i>Proboscina alternata</i>	0	0	0	0
<i>Proboscina sp. B</i>	3	3	6	5
<i>Proboscina sp. C</i>	1	2	2	1
<i>Proboscina calubra</i>	0	0	0	0
<i>Platonea sp. A</i>	7	2	1	1
<i>Platonea clavata</i>	1	11	12	4
<i>Proboscina clavitaramosa</i>	3	6	12	0
<i>Proboscina sp. D</i>	0	0	3	0
<i>Proboscina geminata</i>	6	15	13	10
<i>Proboscina rectalineata</i>	2	1	2	2
<i>Phylactella sp.</i>	1	0	0	0
<i>Retonchylla sp.</i>	0	0	0	0
<i>Rhyncozoon ? sp.</i>	0	0	0	0
<i>Setosella ? sp.</i>	0	0	0	1
<i>Schizopodrella sp. A</i>	1	0	0	0
<i>Schizopodrella sp. B</i>	0	0	0	0
<i>Smittina sp. A</i>	0	2	1	0
<i>Smittina sp. B</i>	0	0	0	0
<i>Smittina ? sp.</i>	4	3	1	4
<i>Stomochatesella ? sp.</i>	0	0	0	0
<i>Tryptostega sp.</i>	0	0	0	0
<i>Tubulipora sp. A</i>	6	5	1	0
<i>Tubulipora sp. B</i>	0	1	1	1
<i>Stomatopora sp.</i>	25	54	27	49
Unilaminar Encrusting Growth-Form Totals:	165	215	177	193
MULTILAMINAR FAUNAS				
<i>Holoporella sp. A</i>	10	14	9	30
<i>Holoporella sp. B</i>	13	15	11	20
Multilaminar Growth-Form Totals:	23	29	20	50

Appendix A. (continued)

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Taxon/Sample Interval	9	10	11	12
ROBUST BRANCHING FAUNAS				
<i>Hippomanella costulata</i>	0	2	1	0
<i>Membranipora</i> ?	0	3	0	3
<i>Porella</i> sp. A	1	1	1	1
<i>Porella</i> cf. <i>abdit</i> a ?	1	0	1	0
<i>Stamenocella</i> sp. A	1	0	0	0
<i>Stamenocella</i> sp. B	0	0	0	0
<i>Steginoporella</i> ?	1	0	0	0
Robust Branching Growth-Form Totals:	4	6	3	4
FENESTRATE FAUNAS				
<i>Retepora</i> cf. <i>lacinosa</i>	35	23	33	20
<i>Reteporellina</i> ? sp.	2	0	2	1
<i>Sertella</i> sp.	2	0	2	4
Fenestrate Growth-Form Totals:	39	23	37	25
FOLIOSE FAUNAS				
<i>Exochoecia rugosa</i>	0	2	9	1
<i>Heteropora</i> ? sp.	2	1	1	0
Foliose Growth-Form Totals:	2	3	10	1
FREE-LIVING FAUNAS				
<i>Lunulites</i> sp.	0	0	1	0

Appendix A. (continued)

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Taxon/Sample Interval	13	14	15	16
ERECT-FLEXIBLE FAUNAS				
<i>Bicellaridae</i> sp.indet.	8	4	14	0
<i>Cantecellidae</i> sp. indet.	0	0	0	0
<i>Crisia</i> sp.	3	2	5	18
Erect-Flexible cheilostome sp. A	1	0	0	0
<i>Nellia tenella</i>	3	0	2	19
<i>Poricellaria</i> sp.	0	0	0	12
<i>Scrupocellaria</i> cf. <i>elliptica</i>	1	0	1	3
<i>Scrupocellaria</i> <i>milneri</i>	5	0	6	7
<i>Scrupocellaria</i> <i>rathburni</i>	1	0	1	1
<i>Scrupocellaria</i> <i>resseri</i>	0	0	6	0
<i>Scrupocellaria</i> <i>williardi</i>	9	3	56	10
<i>Semihawsellina</i> <i>exilis</i>	0	0	0	0
<i>Tubucellaria</i> <i>vicksburgica</i>	63	7	28	32
<i>Vincularia</i> sp.	0	0	0	15
<i>Vittaticella</i> sp.	0	0	0	0
Erect-Flexible Growth-Form Totals:	94	16	119	117
ERECT-DELICATE FAUNAS				
<i>Crisulipora</i> <i>prominens</i>	7	0	13	3
<i>Crisulipora</i> <i>rugosadoralis</i>	10	5	5	6
<i>Enoplostomella</i> <i>vallata</i>	1	0	4	2
<i>Enoplostomella</i> <i>defixa</i>	0	1	0	1
<i>Entalophora</i> <i>cornuta</i>	16	2	8	0
<i>Entalophora</i> <i>compressa</i>	3	0	1	4
<i>Entalophora</i> <i>elongotuba</i>	0	0	0	0
<i>Entalophora</i> <i>lunata</i>	0	0	0	0
<i>Entalophora</i> <i>probosidea</i>	557	41	173	466
<i>Entalophora</i> <i>quissenberryae</i>	20	3	10	39
<i>Entalophora</i> <i>semota</i>	9	3	5	0
<i>Exidmonea</i> sp. A	2	0	0	0
<i>Exidmonea</i> sp. B	0	0	0	0
<i>Exidmonea</i> <i>grandiosa</i>	0	0	2	0
<i>Exidmonea</i> <i>grallator</i>	27	8	62	38
<i>Exidmonea</i> <i>petri</i>	5	0	6	0
<i>Exidmonea</i> <i>triforata</i>	638	88	452	1003
<i>Filisparsa</i> <i>atomicula</i>	0	0	0	0
<i>Filisparsa</i> <i>biseriata</i>	0	0	1	0
<i>Filisparsa</i> <i>ingens</i>	10	5	5	1
<i>Filisparsa</i> cf. <i>simulator</i>	0	0	0	0
<i>Filisparsa</i> <i>typica</i>	71	0	43	49
<i>Oncousesia</i> sp.	41	3	3	0
<i>Plueronea</i> <i>fenestrata</i>	13	1	5	9

Taxon/Sample Interval	13	14	15	16
<i>Pustulopora</i> ?	0	0	1	2
Erect-Delicate Growth-Form Totals:	1443	174	814	1639

UNILAMINAR ENCRUSTING FAUNAS

<i>Aimolousia</i> ? sp.	0	0	2	1
<i>Aplousina</i> ? sp.	0	0	2	0
<i>Aechmella</i> ?	4	0	2	1
<i>Buffonella</i> sp.	6	6	5	2
<i>Callopora</i> ? sp.	0	0	0	0
<i>Costazzia</i> ?	1	0	0	0
<i>Crassimarginatella</i> sp.	1	1	1	1
<i>Cribrilaria radiata</i>	12	7	8	0
<i>Cyclocolpota</i> ? sp.	0	0	0	2
<i>Desmoplagioecia</i> sp.	0	0	0	1
<i>Diaperoecia</i> sp. A	12	2	13	13
<i>Diaperoecia clava</i>	4	5	10	15
<i>Diastopora</i> sp.	1	2	1	2
<i>Didymosella</i> cf. <i>crassa</i>	5	2	0	0
<i>Encrusting</i> sp. A	0	0	3	0
<i>Encrusting</i> sp. B	3	0	2	1
<i>Encrusting</i> sp. C	0	0	1	0
<i>Encrusting</i> sp. D	0	0	0	1
<i>Encrusting</i> sp. E	0	0	0	0
<i>Enoplostomella crassimularis</i>	0	0	7	17
<i>Esharella</i> sp.	7	1	2	2
<i>Esharoides</i> sp. A	0	0	4	2
<i>Esharoides coccinea</i>	25	6	42	0
<i>Floridina</i> ? sp.	0	0	1	1
<i>Floridinella vicksburgica</i>	4	0	4	23
<i>Gephyrotes</i> sp.	0	0	0	0
<i>Herpetopora</i> ? sp.	0	0	1	0
<i>Hippoporina</i> cf. <i>lucens</i>	0	0	1	0
<i>Hippoporina</i> sp.	1	1	1	1
<i>Hippodiplosia</i> cf. <i>magniporosa</i>	6	1	3	8
<i>Hippomanella</i> sp. A	0	0	0	4
<i>Hippomanella</i> sp. B	0	0	0	4
<i>Lagenipora</i> ? sp.	0	0	0	0
<i>Lichenopera</i> sp. A	0	0	0	3
<i>Lichenopera boletiformis</i>	6	1	4	5
<i>Lichenopera goldfussi</i>	0	0	0	5
<i>Lichenopera prolifera</i>	1	5	3	0
<i>Lichenopera</i> cf. <i>verrucosa</i>	0	0	0	1
<i>Membrandaecium</i> sp.	4	2	1	1

Appendix A. (continued)

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Taxon/Sample Interval	13	14	15	16
<i>Membraniporida spissimilaris</i>	7	2	26	13
<i>Membraniporida sp. A</i>	2	0	20	8
<i>Membraniporida sp. B</i>	0	0	0	1
<i>Microecia sp.</i>	0	0	2	0
<i>Micropora coriacea</i>	0	0	0	1
<i>Onychella ? sp.</i>	0	0	0	1
<i>Plagioecia sp. A</i>	3	0	8	1
<i>Plagioecia cf. hirta</i>	12	5	12	1
<i>Perigastrella sp. A</i>	1	0	2	0
<i>Perigastrella sp. B</i>	0	0	1	0
<i>Perigastrella plana</i>	0	0	0	0
<i>Proboscina sp. A</i>	15	3	0	32
<i>Proboscina alternata</i>	0	0	0	0
<i>Proboscina sp. B</i>	0	3	32	9
<i>Proboscina sp. C</i>	3	1	1	3
<i>Proboscina calubra</i>	7	0	1	1
<i>Platonea sp. A</i>	11	0	0	0
<i>Platonea clavata</i>	5	1	3	15
<i>Proboscina clavitaramosa</i>	17	0	24	12
<i>Proboscina sp. D</i>	0	0	13	13
<i>Proboscina geminata</i>	26	2	0	14
<i>Proboscina rectalineata</i>	1	0	2	0
<i>Phylactella sp.</i>	0	0	0	0
<i>Retonchylla sp.</i>	0	0	0	1
<i>Rhyncozoon ? sp.</i>	0	0	1	1
<i>Setosella ? sp.</i>	2	3	1	2
<i>Schizopodrella sp. A</i>	0	0	1	0
<i>Schizopodrella sp. B</i>	0	0	0	12
<i>Smittina sp. A</i>	1	0	3	0
<i>Smittina sp. B</i>	0	0	0	0
<i>Smittina ? sp.</i>	0	0	6	0
<i>Stomochatesella ? sp.</i>	0	1	0	0
<i>Tryptostega sp.</i>	0	0	2	0
<i>Tubulipora sp. A</i>	2	0	1	2
<i>Tubulipora sp. B</i>	0	0	1	1
<i>Stomatopora sp.</i>	82	11	154	75
Unilaminar Encrusting Growth-Form Totals:	313	88	456	352

MULTILAMINAR FAUNAS

<i>Holoporella sp. A</i>	21	10	18	11
<i>Holoporella sp. B</i>	23	2	32	8
Multilaminar Growth-Form Totals:	44	12	50	19

Appendix A. (continued)

Taxon/Sample Interval	115			
	13	14	15	16
ROBUST BRANCHING FAUNAS				
<i>Hippomanella costulata</i>	0	0	0	0
<i>Membranipora</i> ?	0	2	0	0
<i>Porella</i> sp. A	1	1	1	1
<i>Porella</i> cf. <i>abditata</i> ?	0	0	0	0
<i>Stamenocella</i> sp. A	0	0	1	0
<i>Stamenocella</i> sp. B	0	0	0	1
<i>Steginoporella</i> ?	0	0	0	1
Robust Branching Growth-Form Totals:	1	3	2	3
FENESTRATE FAUNAS				
<i>Retepora</i> cf. <i>lacinosa</i>	27	5	21	27
<i>Reteporellina</i> ? sp.	0	1	1	4
<i>Sertella</i> sp.	0	0	3	35
Fenestrate Growth-Form Totals:	27	6	25	66
FOLIOSE FAUNAS				
<i>Exochoecia rugosa</i>	12	0	19	6
<i>Heteropora</i> ? sp.	0	0	0	0
Foliose Growth-Form Totals:	12	0	19	6
FREE-LIVING FAUNAS				
<i>Lunulites</i> sp.	0	0	1	1

Appendix A. (continued)

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Taxon/Sample Interval	17	18	19	20
ERECT-FLEXIBLE FAUNAS				
<i>Bicellaridae</i> sp.indet.	2	0	9	0
<i>Cantecellidae</i> sp. indet.	0	0	0	0
<i>Crisia</i> sp.	41	10	19	0
Erect-Flexible cheilostome sp. A	9	1	0	1
<i>Nellia tenella</i>	22	1	2	0
<i>Poricellaria</i> sp.	81	27	110	6
<i>Scrupocellaria</i> cf. <i>elliptica</i>	16	1	0	0
<i>Scrupocellaria</i> <i>milneri</i>	17	4	10	0
<i>Scrupocellaria</i> <i>rathburni</i>	0	0	0	0
<i>Scrupocellaria</i> <i>resseri</i>	2	1	6	0
<i>Scrupocellaria</i> <i>williardi</i>	8	2	6	1
<i>Semihawsellina</i> <i>exilis</i>	0	0	0	0
<i>Tubucellaria</i> <i>vicksburgica</i>	130	56	132	37
<i>Vincularia</i> sp.	12	2	0	0
<i>Vittaticella</i> sp.	0	0	0	0
Erect-Flexible Growth-Form Totals:	340	105	294	45

ERECT-DELICATE FAUNAS

<i>Crisulipora prominens</i>	6	1	12	0
<i>Crisulipora rugosadoralis</i>	3	1	14	2
<i>Enoplostomella</i> <i>vallata</i>	1	0	0	0
<i>Enoplostomella</i> <i>defixa</i>	1	0	0	0
<i>Entalophora</i> <i>cornuta</i>	10	0	14	0
<i>Entalophora</i> <i>compressa</i>	2	0	0	0
<i>Entalophora</i> <i>elongotuba</i>	0	0	0	0
<i>Entalophora</i> <i>lunata</i>	0	0	0	0
<i>Entalophora</i> <i>probosidea</i>	407	124	297	106
<i>Entalophora</i> <i>quissenberryae</i>	22	5	21	6
<i>Entalophora</i> <i>semota</i>	3	2	0	0
<i>Exidmonea</i> sp. A	0	0	0	0
<i>Exidmonea</i> sp. B	0	0	0	0
<i>Exidmonea</i> <i>grandiosa</i>	0	0	0	0
<i>Exidmonea</i> <i>grallator</i>	30	12	39	71
<i>Exidmonea</i> <i>petri</i>	2	2	0	0
<i>Exidmonea</i> <i>triforata</i>	635	158	594	90
<i>Filisarsa</i> <i>atomicula</i>	0	0	0	0
<i>Filisarsa</i> <i>biseriata</i>	0	0	0	0
<i>Filisarsa</i> <i>ingens</i>	2	0	0	4
<i>Filisarsa</i> cf. <i>simulator</i>	0	0	0	0
<i>Filisarsa</i> <i>typica</i>	37	6	27	0
<i>Oncousesia</i> sp.	5	2	11	7
<i>Plueronea</i> <i>fenestrata</i>	34	4	3	3

Taxon/Sample Interval	17	18	19	20
<i>Pustulopora</i> ?	2	0	9	0
Erect-Delicate Growth-Form Totals:	1219	335	1060	309

UNILAMINAR ENCRUSTING FAUNAS

<i>Aimolousia</i> ? sp.	2	0	0	0
<i>Aplousina</i> ? sp.	0	0	0	0
<i>Aechmella</i> ?	5	1	0	0
<i>Buffonella</i> sp.	3	0	0	0
<i>Callopora</i> ? sp.	0	0	0	0
<i>Costazzia</i> ?	0	0	0	0
<i>Crassimarginatella</i> sp.	1	1	1	1
<i>Cribrilaria radiata</i>	0	1	1	0
<i>Cyclocolposia</i> ? sp.	0	0	0	0
<i>Desmoplagioecia</i> sp.	0	0	0	0
<i>Diaperoecia</i> sp. A	3	12	15	1
<i>Diaperoecia clava</i>	6	0	10	1
<i>Diastopora</i> sp.	0	1	3	1
<i>Didymosella</i> cf. <i>crassa</i>	0	0	0	0
<i>Encrusting</i> sp. A	7	1	2	2
<i>Encrusting</i> sp. B	0	0	0	0
<i>Encrusting</i> sp. C	0	0	1	0
<i>Encrusting</i> sp. D	0	0	0	0
<i>Encrusting</i> sp. E	0	0	0	0
<i>Enoplostomella crassimularis</i>	16	0	1	0
<i>Esharella</i> sp.	1	0	0	0
<i>Esharoides</i> sp. A	0	0	0	0
<i>Esharoides coccinea</i>	2	1	2	2
<i>Floridina</i> ? sp.	1	0	1	0
<i>Floridinella vicksburgica</i>	21	1	14	2
<i>Gephyrotes</i> sp.	0	0	0	0
<i>Herpetopora</i> ? sp.	0	0	0	0
<i>Hippoporina</i> cf. <i>lucens</i>	0	0	0	0
<i>Hippoporina</i> sp.	1	1	1	1
<i>Hippodiplosia</i> cf. <i>magniporosa</i>	15	5	1	0
<i>Hippomanella</i> sp. A	0	0	0	0
<i>Hippomanella</i> sp. B	0	0	0	0
<i>Lagenipora</i> ? sp.	2	0	0	0
<i>Lichenopera</i> sp. A	1	0	3	0
<i>Lichenopera boletiformis</i>	5	0	0	0
<i>Lichenopera goldfussi</i>	1	0	0	0
<i>Lichenopera prolifera</i>	2	3	2	0
<i>Lichenopera</i> cf. <i>verrucosa</i>	2	1	1	0
<i>Membrandaecium</i> sp.	3	0	1	0

Appendix A. (continued)

118

Taxon/Sample Interval	17	18	19	20
<i>Membraniporida spissimilaris</i>	18	4	4	0
<i>Membraniporida sp. A</i>	0	1	5	0
<i>Membraniporida sp. B</i>	1	0	0	0
<i>Microecia sp.</i>	0	0	0	0
<i>Micropora coriacea</i>	1	0	0	0
<i>Onychella ? sp.</i>	0	0	0	0
<i>Plagioecia sp. A</i>	6	0	3	0
<i>Plagioecia cf. hirta</i>	0	0	2	0
<i>Perigastrella sp. A</i>	0	0	1	0
<i>Perigastrella sp. B</i>	0	0	0	0
<i>Perigastrella plana</i>	0	0	0	0
<i>Proboscina sp. A</i>	36	0	4	3
<i>Proboscina alternata</i>	0	0	0	0
<i>Proboscina sp. B</i>	8	0	0	0
<i>Proboscina sp. C</i>	2	1	2	2
<i>Proboscina calubra</i>	0	0	0	0
<i>Platonea sp. A</i>	6	0	2	0
<i>Platonea clavata</i>	3	3	3	0
<i>Proboscina clavitaramosa</i>	12	2	11	0
<i>Proboscina sp. D</i>	2	0	0	0
<i>Proboscina geminata</i>	7	7	11	1
<i>Proboscina rectalineata</i>	0	1	0	0
<i>Phylactella sp.</i>	0	0	0	0
<i>Retonchylla sp.</i>	0	0	0	0
<i>Rhyncozoon ? sp.</i>	0	0	0	0
<i>Setosella ? sp.</i>	0	0	1	0
<i>Schizopodrella sp. A</i>	0	0	1	0
<i>Schizopodrella sp. B</i>	1	0	0	0
<i>Smittina sp. A</i>	3	0	1	0
<i>Smittina sp. B</i>	0	0	0	0
<i>Smittina ? sp.</i>	0	0	0	0
<i>Stomochatesella ? sp.</i>	2	0	0	0
<i>Tryptostega sp.</i>	0	0	0	0
<i>Tubulipora sp. A</i>	2	1	5	0
<i>Tubulipora sp. B</i>	1	0	5	0
<i>Stomatopora sp.</i>	82	31	56	1
Unilaminar Encrusting Growth-Form Totals:	310	98	196	38
MULTILAMINAR FAUNAS				
<i>Holoporella sp. A</i>	2	1	5	0
<i>Holoporella sp. B</i>	1	1	7	0
Multilaminar Growth-Form Totals:	3	2	12	0

Appendix A. (continued)

119

Taxon/Sample Interval	17	18	19	20
ROBUST BRANCHING FAUNAS				
<i>Hippomanella costulata</i>	0	0	0	0
<i>Membranipora</i> ?	0	0	0	0
<i>Porella</i> sp. A	1	1	1	1
<i>Porella</i> cf. <i>abdit</i> a ?	0	0	0	0
<i>Stamenocella</i> sp. A	0	0	0	0
<i>Stamenocella</i> sp. B	8	1	1	0
<i>Steginoporella</i> ?	0	0	0	0
Robust Branching Growth-Form Totals:	9	2	2	1
FENESTRATE FAUNAS				
<i>Retepora</i> cf. <i>lacinosa</i>	4	2	11	2
<i>Reteporellina</i> ? sp.	0	1	0	0
<i>Sertella</i> sp.	14	4	0	0
Fenestrate Growth-Form Totals:	18	7	11	2
FOLIOSE FAUNAS				
<i>Exochoecia rugosa</i>	0	0	0	0
<i>Heteropora</i> ? sp.	6	0	0	0
Foliose Growth-Form Totals:	6	0	0	0
FREE-LIVING FAUNAS				
<i>Lunulites</i> sp.	0	0	0	0

Appendix A. (continued)

120

Taxon/Sample Interval	21	22	23	24
ERECT-FLEXIBLE FAUNAS				
<i>Bicellaridae</i> sp.indet.	0	3	0	0
<i>Cantecellidae</i> sp. indet.	0	0	0	0
<i>Crisia</i> sp.	0	5	0	0
Erect-Flexible cheilostome sp. A	0	0	0	0
<i>Nellia tenella</i>	0	0	0	0
<i>Poricellaria</i> sp.	1	13	1	0
<i>Scrupocellaria</i> cf. <i>elliptica</i>	0	0	0	0
<i>Scrupocellaria</i> <i>milneri</i>	0	5	1	0
<i>Scrupocellaria</i> <i>rathburni</i>	0	0	0	0
<i>Scrupocellaria</i> <i>resseri</i>	0	0	0	0
<i>Scrupocellaria</i> <i>williardi</i>	0	12	0	1
<i>Semihawsellina</i> <i>exilis</i>	0	0	0	0
<i>Tubucellaria</i> <i>vicksburgica</i>	35	79	24	21
<i>Vincularia</i> sp.	0	0	0	0
<i>Vittaticella</i> sp.	0	0	0	0
Erect-Flexible Growth-Form Totals:	36	117	26	22
ERECT-DELICATE FAUNAS				
<i>Crisulipora</i> <i>prominens</i>	3	3	2	0
<i>Crisulipora</i> <i>rugosadoralis</i>	0	22	0	0
<i>Enoplostomella</i> <i>vallata</i>	0	0	0	0
<i>Enoplostomella</i> <i>defixa</i>	0	0	0	0
<i>Entalophora</i> <i>cornuta</i>	0	1	0	6
<i>Entalophora</i> <i>compressa</i>	0	0	1	0
<i>Entalophora</i> <i>elongotuba</i>	0	1	0	1
<i>Entalophora</i> <i>lunata</i>	0	0	0	0
<i>Entalophora</i> <i>probosidea</i>	80	365	182	60
<i>Entalophora</i> <i>quissenberryae</i>	11	17	8	21
<i>Entalophora</i> <i>semota</i>	1	8	7	0
<i>Exidmonea</i> sp. A	0	0	0	0
<i>Exidmonea</i> sp. B	0	0	0	0
<i>Exidmonea</i> <i>grandiosa</i>	0	0	0	0
<i>Exidmonea</i> <i>grallator</i>	104	143	30	20
<i>Exidmonea</i> <i>petri</i>	1	0	1	0
<i>Exidmonea</i> <i>triforata</i>	91	573	118	216
<i>Filisarsa</i> <i>atomicula</i>	0	0	0	0
<i>Filisarsa</i> <i>biseriata</i>	0	0	0	0
<i>Filisarsa</i> <i>ingens</i>	1	4	1	0
<i>Filisarsa</i> cf. <i>simulator</i>	0	0	0	0
<i>Filisarsa</i> <i>typica</i>	0	9	28	16
<i>Oncousesia</i> sp.	12	14	0	0
<i>Plueronea</i> <i>fenestrata</i>	3	4	2	2

Appendix A. (continued)

121

Taxon/Sample Interval	21	22	23	24
<i>Pustulopora</i> ?	0	1	0	0
Erect-Delicate Growth-Form Totals:	328	1187	403	366

UNILAMINAR ENCRUSTING FAUNAS

<i>Aimolousia</i> ? sp.	0	0	0	0
<i>Aplousina</i> ? sp.	0	0	0	0
<i>Aechmella</i> ?	0	4	0	0
<i>Buffonella</i> sp.	0	1	1	0
<i>Callopora</i> ? sp.	0	0	0	0
<i>Costazzia</i> ?	0	0	0	0
<i>Crassimarginatella</i> sp.	1	1	0	0
<i>Cribrilaria radiata</i>	0	0	0	0
<i>Cyclocolposa</i> ? sp.	0	0	0	0
<i>Desmoplagioecia</i> sp.	0	0	0	0
<i>Diaperoecia</i> sp. A	3	12	2	4
<i>Diaperoecia clava</i>	0	8	4	0
<i>Diastopora</i> sp.	1	1	2	1
<i>Didymosella</i> cf. <i>crassa</i>	0	0	0	0
<i>Encrusting</i> sp. A	0	0	3	0
<i>Encrusting</i> sp. B	0	0	0	0
<i>Encrusting</i> sp. C	0	0	0	0
<i>Encrusting</i> sp. D	0	0	0	0
<i>Encrusting</i> sp. E	0	0	0	0
<i>Enoplostomella crassimularis</i>	0	2	0	2
<i>Esharella</i> sp.	0	0	0	0
<i>Esharoides</i> sp. A	0	1	0	0
<i>Esharoides coccinea</i>	0	5	1	1
<i>Floridina</i> ? sp.	0	0	0	0
<i>Floridinella vicksburgica</i>	2	3	2	2
<i>Gephyrotes</i> sp.	0	0	0	0
<i>Herpetopora</i> ? sp.	0	0	1	0
<i>Hippoporina</i> cf. <i>lucens</i>	0	0	0	0
<i>Hippoporina</i> sp.	1	1	0	0
<i>Hippodiplosia</i> cf. <i>magniporosa</i>	0	0	0	0
<i>Hippomanella</i> sp. A	0	0	0	0
<i>Hippomanella</i> sp. B	0	0	0	0
<i>Lagenipora</i> ? sp.	0	0	0	0
<i>Lichenopera</i> sp. A	0	0	0	0
<i>Lichenopera boletiformis</i>	0	0	0	3
<i>Lichenopera goldfussi</i>	0	1	0	0
<i>Lichenopera prolifera</i>	0	0	0	0
<i>Lichenopera</i> cf. <i>verrucosa</i>	0	2	0	0
<i>Membrandaecium</i> sp.	0	1	0	0

Appendix A. (continued)

122

Taxon/Sample Interval	21	22	23	24
<i>Membraniporida spissimilaris</i>	0	10	3	2
<i>Membraniporida sp. A</i>	0	1	2	0
<i>Membraniporida sp. B</i>	0	0	3	0
<i>Microecia sp.</i>	0	0	0	0
<i>Micropora coriacea</i>	0	0	0	0
<i>Onychella ? sp.</i>	1	0	0	0
<i>Plagioecia sp. A</i>	0	0	0	0
<i>Plagioecia cf. hirta</i>	2	2	0	0
<i>Perigastrella sp. A</i>	0	1	0	0
<i>Perigastrella sp. B</i>	0	0	0	0
<i>Perigastrella plana</i>	0	0	0	0
<i>Proboscina sp. A</i>	3	1	7	5
<i>Proboscina alternata</i>	0	0	1	0
<i>Proboscina sp. B</i>	1	0	0	0
<i>Proboscina sp. C</i>	1	1	3	2
<i>Proboscina calubra</i>	0	0	0	0
<i>Platonea sp. A</i>	0	0	0	0
<i>Platonea clavata</i>	1	0	2	1
<i>Proboscina clavitaramosa</i>	0	0	0	0
<i>Proboscina sp. D</i>	1	0	0	1
<i>Proboscina geminata</i>	7	7	2	0
<i>Proboscina rectalineata</i>	0	2	0	0
<i>Phylactella sp.</i>	0	0	0	0
<i>Retonchylla sp.</i>	0	0	0	0
<i>Rhyncozoon ? sp.</i>	0	0	0	0
<i>Setosella ? sp.</i>	0	0	0	0
<i>Schizopodrella sp. A</i>	0	1	0	0
<i>Schizopodrella sp. B</i>	0	0	0	0
<i>Smittina sp. A</i>	0	1	2	0
<i>Smittina sp. B</i>	0	0	0	0
<i>Smittina ? sp.</i>	0	0	0	0
<i>Stomochatesella ? sp.</i>	0	0	0	0
<i>Tryptostega sp.</i>	0	0	0	0
<i>Tubulipora sp. A</i>	0	0	0	0
<i>Tubulipora sp. B</i>	0	0	0	0
<i>Stomatopora sp.</i>	2	59	13	0
Unilaminar Encrusting Growth-Form Totals:	48	151	77	48
MULTILAMINAR FAUNAS				
<i>Holoporella sp. A</i>	3	3	3	4
<i>Holoporella sp. B</i>	0	3	1	1
Multilaminar Growth-Form Totals:	3	6	4	5

Taxon/Sample Interval	21	22	23	24
ROBUST BRANCHING FAUNAS				
<i>Hippomanella costulata</i>	0	0	0	0
<i>Membranipora</i> ?	0	0	0	0
<i>Porella</i> sp. A	1	1	1	1
<i>Porella</i> cf. <i>abditata</i> ?	0	0	0	0
<i>Stamenocella</i> sp. A	0	0	0	0
<i>Stamenocella</i> sp. B	0	1	0	0
<i>Steginoporella</i> ?	0	0	0	0
Robust Branching Growth-Form Totals:	1	2	1	1
FENESTRATE FAUNAS				
<i>Retepora</i> cf. <i>lacinosa</i>	0	17	3	3
<i>Reteporellina</i> ? sp.	0	0	0	0
<i>Sertella</i> sp.	0	5	0	0
Fenestrate Growth-Form Totals:	0	22	3	3
FOLIOSE FAUNAS				
<i>Exochoecia rugosa</i>	0	0	0	0
<i>Heteropora</i> ? sp.	0	0	0	0
Foliose Growth-Form Totals:	0	0	0	0
FREE-LIVING FAUNAS				
<i>Lunulites</i> sp.	0	0	0	0

Appendix B. Species and growth-form totals for W-8104.

	124					
Taxon/Sample Interval	AA	AB	AC	AD	AE	AF
ERECT-FLEXIBLE FAUNAS						
<i>Bicellaridae</i> sp. indet.	0	4	6	1	13	0
<i>Catenicellidae</i> sp. indet.	1	0	0	0	0	0
<i>Crisia</i> sp.	88	202	210	88	254	179
Erect-flexible cheilostome sp. A	0	2	0	0	1	0
Erect-flexible cheilostome sp. B	0	0	1	0	1	0
Erect-flexible cheilostome sp. C	0	0	0	0	1	0
<i>Filicrisia</i> sp.	0	2	2	0	2	0
<i>Nellia tenella</i>	9	26	23	4	28	6
<i>Poricellaria</i> sp.	0	1	2	4	20	10
<i>Scrupocellaria clausa</i>	12	16	18	8	70	19
<i>Scrupocellaria milneri</i>	6	32	43	26	147	57
<i>Scrupocellaria rathburni</i>	2	14	67	4	35	13
<i>Scrupocellaria resseri</i>	0	1	5	0	0	0
<i>Scrupocellaria williardi</i>	2	24	25	8	76	22
<i>Semihawswellia exilis</i>	5	28	67	23	164	103
<i>Tetraplaria</i> sp.	1	1	2	0	0	0
<i>Tubucellaria vicksburgica</i>	7	8	9	9	48	50
<i>Vincularia</i>	0	0	1	0	0	0
<i>Vittaticella</i> sp.	0	0	0	0	1	0
Erect-Flexible Growth-Form Totals:	133	361	481	175	861	459
ERECT-DELICATE FAUNAS						
<i>Crisulipora</i> sp. A	15	11	55	43	171	0
<i>Crisulipora rugosadoralis</i>	2	2	1	0	3	5
<i>Enoplostomella defixa</i>	0	1	1	0	0	0
<i>Enoplostomella magniporosa</i>	0	0	1	1	1	1
<i>Enoplostomella n. sp.</i>	0	0	0	0	1	1
<i>Enoplostomella vallata</i>	2	2	0	0	4	3
<i>Entalophora cornuta</i>	5	10	7	2	10	18
<i>Entalophora compressa</i>	2	2	0	0	0	0
<i>Entalophora lunata</i>	0	1	4	0	4	7
<i>Entalophora probosidea</i>	30	179	94	43	284	175
<i>Entalophora quissenberryae</i>	6	10	5	1	17	5
<i>Entalophora semota</i>	1	2	0	1	10	2
Erect-delicate cheilostome sp. A	0	0	0	1	0	1
Erect-delicate cheilostome sp. B	0	0	0	0	0	3
<i>Exidmonea grallator</i>	4	0	0	2	13	16
<i>Exidmonea petri</i>	3	0	0	0	0	0
<i>Exidmonea triforata</i>	114	145	97	83	254	308
<i>Filisarsa</i> sp. A	0	1	0	0	0	0
<i>Filisarsa</i> sp. biseriata	1	0	1	2	3	0
<i>Filisarsa</i> cf. simulator	7	15	6	3	30	31

Appendix B. (continued)

Taxon/Sample Interval						125
	AA	AB	AC	AD	AE	AF
<i>Filisparsa</i> cf. <i>typica</i>	9	1	25	7	51	52
<i>Oncousecia</i> sp.	0	3	9	1	37	31
<i>Plueronea</i> sp. A	0	0	0	0	0	0
<i>Plueronea</i> cf. <i>fenestrata</i>	1	0	0	0	0	2
<i>Porella</i> cf. <i>cylindrica</i>	2	1	0	2	16	3
<i>Pustulopora</i> sp.	0	0	1	0	0	
<i>Smittina</i> cf. <i>cophia</i>	0	0	0	0	1	0
Erect-Delicate Growth-Form Totals:	204	386	307	192	910	664

UNILAMINAR ENCRUSTING FAUNAS

<i>Aechmella</i> sp. A	0	1	0	0	0	0
<i>Aechmella</i> sp. B	3	8	2	0	1	0
<i>Buffonella</i> sp.	0	2	0	0	0	2
<i>Crassimarginetella</i> sp.	0	1	0	0	0	0
<i>Cribrilaria radiata</i>	1	0	1	0	0	0
<i>Cyclicopora</i> sp.	0	1	0	0	5	0
<i>Cyclocolpota</i> sp.	12	0	0	0	0	2
<i>Didymosella crassa</i>	0	0	2	0	5	3
<i>Diaporecia</i> sp.	0	0	0	0	2	7
<i>Esharoides coccinea</i>	0	0	0	0	1	0
<i>Esharoides</i> n. sp.	0	1	0	2	0	1
<i>Floridina</i> ? sp.	0	1	1	0	0	1
<i>Floridinella vicksburgica</i>	3	12	27	8	76	31
<i>Hippodiplosia magniporosa</i>	0	1	0	0	0	3
<i>Hippomanella</i> sp. A	0	0	0	1	1	0
<i>Hippomanella pungens</i>	0	0	0	0	0	3
<i>Hippoporina</i> sp.	0	0	1	0	0	0
<i>Lagenipora</i> sp.	0	0	0	0	0	1
<i>Lichenopora</i> sp. A	0	1	1	0	0	5
<i>Lichenopora</i> cf. <i>boletiformis</i>	0	0	1	1	9	0
<i>Lichenopora goldfussi</i>	0	0	0	0	1	0
<i>Lichenopora prolifera</i>	0	0	0	0	0	4
<i>Lichenopora verrucosa</i>	0	0	0	0	1	0
<i>Membrandaecium</i> sp.	0	3	3	2	3	7
<i>Membraniporidra</i> sp. A	3	13	3	0	25	33
<i>Membraniporidra</i> cf. <i>arcana</i>	0	6	0	3	9	3
<i>Membraniporidra</i> sp. B	0	0	0	0	0	0
<i>Membraniporidra</i> sp. C	3	0	5	0	9	2
<i>Membraniporidra spissimilaris</i>	5	5	21	3	20	33
<i>Micropora coriaca</i>	2	22	11	0	1	6
<i>Parasmittina</i> sp.	0	2	0	0	0	0
<i>Perigastrella</i> sp. A	0	0	0	0	1	8
<i>Perigastrella</i> cf. <i>plana</i>	0	3	0	0	0	0

Appendix B. (continued)

Taxon/Sample Interval						126
	AA	AB	AC	AD	AE	AF
<i>Phylactella</i> sp.	0	0	0	0	0	0
<i>Plagioecia</i> sp.	0	0	2	1	0	2
<i>Plagioecia</i> cf. <i>hirta</i>	0	0	0	0	4	0
<i>Proboscina</i> sp. A	1	0	1	2	6	2
<i>Proboscina</i> <i>clavitaramosa</i>	2	3	0	0	0	2
<i>Proboscina</i> <i>geminata</i>	0	0	0	0	2	2
<i>Proboscina</i> sp. D	0	0	0	0	1	0
<i>Rhagosostoma</i> ? sp.	0	0	0	0	0	0
<i>Rosseliana</i> sp.	0	0	0	5	7	32
<i>Schizopodrella</i> sp.	0	1	0	0	7	0
<i>Smittina</i> ? sp. A	0	0	0	0	0	1
<i>Smittina</i> cf. <i>ampla</i>	0	0	0	0	0	1
<i>Smittina</i> <i>granulosa</i>	0	0	1	0	1	0
<i>Smittina</i> cf. <i>telum</i>	0	0	0	0	0	6
<i>Stomatopora</i> sp. A	9	6	2	18	2	0
<i>Stomatopora</i> sp. B	0	0	0	0	18	0
<i>Tryptostega</i> sp.	0	0	1	0	4	0
<i>Tubulipora</i> sp.	0	1	0	1	0	2
Unilaminar encrusting sp. A	0	0	1	0	0	4
Unilaminar encrusting sp. B	1	1	1	0	3	3
Unilaminar encrusting sp. C	0	6	0	0	0	1
Unilaminar Encrusting Growth-Form Totals:	45	101	88	47	225	213
Multilaminar A Faunas						
Cerioporidae sp. indet.	0	0	1	0	3	0
Multilaminar A Growth-Form Totals:	0	0	1	0	3	0
Multilaminar C Faunas						
<i>Holoporella</i> sp. A	4	2	1	6	3	3
<i>Holoporella</i> sp. B	0	0	0	2	0	2
Multilaminar C Growth-Form Totals:	2	2	1	8	3	5
Robust Branching Faunas						
<i>Adeonellopsis</i> sp.	6	5	3	4	14	33
<i>Hippomanella</i> <i>costulata</i>	0	0	0	1	0	2
<i>Hornera</i> sp.	0	0	0	0	3	1
<i>Membranipora</i> sp.	0	0	0	0	0	0
<i>Meniscopora</i> sp.	0	0	0	0	1	0
<i>Metracolposia</i> sp.	1	0	0	0	0	0
Robust-branching sp. A	1	0	0	0	0	0
<i>Stamenocella</i> sp. A	0	5	3	1	9	6
<i>Stamenocella</i> sp. B	0	0	1	0	1	5
<i>Stamenocella</i> sp. C	0	1	0	0	0	0

Appendix B. (continued)

	127					
Taxon/Sample Interval	AA	AB	AC	AD	AE	AF
<i>Trigonopora sp.</i>	0	1	0	3	2	5
Robust Branching Growth-Form Totals:	8	12	7	9	30	52
Fenestrate Faunas						
<i>Retepora sp. A</i>	8	11	19	5	28	52
<i>Retepora sp. B</i>	0	2	1	0	7	3
<i>Sertella sp.</i>	0	0	0	0	2	0
Fenestrate Growth-Form Totals:	8	13	20	5	37	55
Foliose Faunas						
<i>Exochoecia rugosa</i>	2	0	7	0	12	9
Free-Living Faunas						
<i>Lunulites sp.</i>	7	10	3	0	17	23

Taxon/Sample Interval	AG	AH	AI
ERECT-FLEXIBLE FAUNAS			
<i>Bicellaridae</i> sp. indet.	1	2	3
<i>Catenicellidae</i> sp. indet.	0	0	0
<i>Crisia</i> sp.	53	187	443
Erect-flexible cheilostome sp. A	0	0	0
Erect-flexible cheilostome sp. B	0	0	0
Erect-flexible cheilostome sp. C	0	0	0
<i>Filicrisia</i> sp.	0	0	0
<i>Nellia tenella</i>	1	8	8
<i>Poricellaria</i> sp.	0	7	3
<i>Scrupocellaria clausa</i>	10	16	15
<i>Scrupocellaria milneri</i>	12	67	56
<i>Scrupocellaria rathburni</i>	3	7	0
<i>Scrupocellaria resseri</i>	0	0	0
<i>Scrupocellaria williardi</i>	11	26	25
<i>Semihawswellia exilis</i>	28	102	142
<i>Tetraplaria</i> sp.	0	0	0
<i>Tubucellaria vicksburgica</i>	19	21	26
<i>Vincularia</i>	0	0	0
<i>Vittaticella</i> sp.	0	0	0
Erect-Flexible Growth-Form Totals:	138	443	721
ERECT-DELICATE FAUNAS			
<i>Crisulipora</i> sp. A	62	95	115
<i>Crisulipora rugosadoralis</i>	0	0	1
<i>Enoplostomella defixa</i>	0	0	0
<i>Enoplostomella magniporosa</i>	0	1	0
<i>Enoplostomella n. sp.</i>	0	0	0
<i>Enoplostomella vallata</i>	0	0	0
<i>Entalophora cornuta</i>	8	11	2
<i>Entalophora compressa</i>	0	0	2
<i>Entalophora lunata</i>	1	1	1
<i>Entalophora probosidea</i>	62	144	157
<i>Entalophora quissenberryae</i>	3	7	9
<i>Entalophora semota</i>	0	0	1
Erect-delicate cheilostome sp. A	0	0	0
Erect-delicate cheilostome sp. B	0	0	0
<i>Exidmonea grillator</i>	7	8	7
<i>Exidmonea petri</i>	0	0	0
<i>Exidmonea triforata</i>	168	286	284
<i>Filisparsa</i> sp. A	0	0	0
<i>Filisparsa</i> sp. biseriata	0	0	0
<i>Filisparsa</i> cf. simulator	6	39	27

Taxon/Sample Interval	AG	AH	AI
<i>Filisparsa cf. typica</i>	36	45	41
<i>Oncousecia sp.</i>	2	4	0
<i>Plueronea sp. A</i>	1	0	0
<i>Plueronea cf. fenestrata</i>	0	2	0
<i>Porella cf. cylindrica</i>	0	1	0
<i>Pustulopora sp.</i>			
<i>Smittina cf. cophia</i>	0	1	0
Erect-Delicate Growth-Form Totals:	356	645	647

UNILAMINAR ENCRUSTING FAUNAS

<i>Aechmella sp. A</i>	1	1	0
<i>Aechmella sp. B</i>	0	4	0
<i>Buffonella sp.</i>	0	0	0
<i>Crassimarginetella sp.</i>	0	0	0
<i>Cribrilaria radiata</i>	2	1	1
<i>Cyclicopora sp.</i>	0	0	0
<i>Cyclocolposia sp.</i>	0	0	0
<i>Didymosella crassa</i>	0	4	3
<i>Diaporecia sp.</i>	1	0	1
<i>Esharoides coccinea</i>	1	2	0
<i>Esharoides n. sp.</i>	0	0	0
<i>Floridina ? sp.</i>	0	0	0
<i>Floridinella vicksburgica</i>	9	24	48
<i>Hippodiplosia magniporosa</i>	1	1	1
<i>Hippomanella sp. A</i>	0	0	0
<i>Hippomanella pungens</i>	0	1	8
<i>Hippoporina sp.</i>	0	0	0
<i>Lagenipora sp.</i>	0	0	0
<i>Lichenopora sp. A</i>	0	5	4
<i>Lichenopora cf. boletiformis</i>	0	0	0
<i>Lichenopora goldfussi</i>	0	0	0
<i>Lichenopora prolifera</i>	0	0	0
<i>Lichenopora verrucosa</i>	0	0	1
<i>Membrandaecium sp.</i>	0	3	5
<i>Membraniporidra sp. A</i>	0	8	4
<i>Membraniporidra cf. arcana</i>	0	0	0
<i>Membraniporidra sp. B</i>	0	3	1
<i>Membraniporidra sp. C</i>	0	5	10
<i>Membraniporidra spissimilaris</i>	19	23	35
<i>Micropora coriaca</i>	2	2	1
<i>Parasmittina sp.</i>	0	0	0
<i>Perigastrella sp. A</i>	0	4	0
<i>Perigastrella cf. plana</i>	0	0	0

Taxon/Sample Interval	AG	AH	AI
<i>Phylactella</i> sp.	0	1	0
<i>Plagioecia</i> sp.	2	4	2
<i>Plagioecia</i> cf. <i>hirta</i>	0	0	13
<i>Proboscina</i> sp. A	0	5	0
<i>Proboscina</i> <i>clavitaramosa</i>	2	1	1
<i>Proboscina</i> <i>geminata</i>	2	1	2
<i>Proboscina</i> sp. D	0	1	0
<i>Rhagosostoma</i> ? sp.	0	1	0
<i>Rosseliana</i> sp.	0	35	0
<i>Schizopodrella</i> sp.	0	0	0
<i>Smittina</i> ? sp. A	0	1	0
<i>Smittina</i> cf. <i>ampla</i>	0	0	0
<i>Smittina</i> <i>granulosa</i>	0	0	0
<i>Smittina</i> cf. <i>telum</i>	0	1	2
<i>Stomatopora</i> sp. A	4	25	16
<i>Stomatopora</i> sp. B	0	0	0
<i>Tryptostega</i> sp.	1	4	1
<i>Tubulipora</i> sp.	0	0	0
Unilaminar encrusting sp. A	0	2	0
Unilaminar encrusting sp. B	3	1	0
Unilaminar encrusting sp. C	2	0	0
Unilaminar Encrusting Growth-Form Totals:	52	174	160
Multilaminar A Faunas			
Ceriporidae sp. indet.	0	3	0
Multilaminar A Growth-Form Totals:	0	0	0
Multilaminar C Faunas			
<i>Holoporella</i> sp. A	1	2	1
<i>Holoporella</i> sp. B	5	1	1
Multilaminar C Growth-Form Totals:	6	3	2
Robust Branching Faunas			
<i>Adeonellopsis</i> sp.	13	46	0
<i>Hippomanella</i> <i>costulata</i>	1	0	0
<i>Hornera</i> sp.	0	0	4
<i>Membranipora</i> sp.	1	0	0
<i>Meniscopora</i> sp.	0	0	0
<i>Metracolposa</i> sp.	0	0	0
Robust-branching sp. A	0	0	0
<i>Stamenocella</i> sp. A	1	3	0
<i>Stamenocella</i> sp. B	0	0	0
<i>Stamenocella</i> sp. C	0	0	0

Taxon/Sample Interval	AG	AH	AI
<i>Trigonopora sp.</i>	0	1	0
Robust Branching Growth-Form Totals:	15	50	4
Fenestrate Faunas			
<i>Retepora sp. A</i>	13	41	28
<i>Retepora sp. B</i>	0	1	0
<i>Sertella sp.</i>	0	0	0
Fenestrate Growth-Form Totals:	13	42	28
Foliose Faunas			
<i>Exochoecia rugosa</i>	2	9	6
Free-Living Faunas			
<i>Lunulites sp.</i>	3	25	6

VITA

James Andrew Heller, the son of Paul and Mildred Heller, was born September 8, 1965, in Montpelier, Vermont. He spent his childhood and teenage years growing up on his parents farm in the neighboring town of East Montpelier. He earned his high school diploma in 1983 from Union-32 High School, and the following fall enrolled as a high school postgraduate in the Northfield Mt. Hermon School, located in Northfield, Massachusetts. He earned another diploma in the spring of 1984 and subsequently entered Rutgers College of Rutgers University, in New Brunswick, New Jersey, the fall of that year. He graduated from Rutgers with a Bachelor of Arts in Geological Sciences in the spring of 1988. After working for a year Jim entered the graduate program in geology at the University of Tennessee, Knoxville, where he decided to specialize in the discipline of paleontology. During an interim from 1991 - 1992 he also took employment with the State of Tennessee's Division of Groundwater Protection as an environmental specialist. He graduated from the University in the summer semester of 1995 with a Master of Science Degree and is currently seeking gainful employment.