University of Alberta

Sedimentology of North Sound, Grand Cayman, British West Indies

By

Lisa MacKinnon ©

A Thesis Submitted to the Faculty of Graduate Studies and Research in Partial Fulfillment of the Requirements for the Degree of Master of Science.

Department of Earth and Atmospheric Sciences

Edmonton, Alberta

Spring, 2000

0-612-60151-X

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Name of Author: **Lisa MacKinnon**

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Degree: **Master of Science**

Year This Degree Granted: **2000**

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UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommended to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled SEDIMENTOLOGY OF NORTH SOUND, GRAND CAYMAN, BRITISH WEST INDIES submitted by LISA MACKINNON in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

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November 16, 1999

ABSTRACT

North Sound is the largest (~ 9 km long and ~ 7 km wide) shallow-water lagoon on Grand Cayman. Subsurface sediments can be divided into the Composite Grain, Gastropod, Bivalve, Mangrove Peat, *Halimeda*, *Halimeda*-Benthic Foraminifera-Bivalve, and the Bivalve-*Halimeda* Facies. Isotope analysis on bivalves and sediment samples in North Sound yielded $\delta^{18}O$ and $\delta^{13}C$ signatures which confirm that deposition began in a freshwater pond. Radiocarbon dating of unaltered bivalve shells shows that sedimentation began 4,200 – 4,500 years B.P. Shortly after 3,000 yrs B.P., marine waters overtopped the northern rim of the freshwater basin and started to flood the freshwater pond. Sedimentation rates, 59 – 168 cm/1,000 years, have not kept pace with the high rates of Holocene sea level rise. Deposition of sediments in North Sound is controlled chiefly by short-lived storm events accompanied by high-energy waves and currents, rather than fair-weather processes.

I can't say that I was ever lost, but I was bewildered once for three days.

– Daniel Boone

Dedicated to Bernice and Raymond Knox,
and Esther and Roderick MacKinnon.

Acknowledgments

I am greatly indebted to my supervisor Brian Jones for the endless amount of editing, guidance, dedication, patience, and support that have made this thesis possible. Financial support for this research was provided by a NSERC grant to Dr. Brian Jones (A6090).

I am also indebted to the Department of the Environment, Grand Cayman, and the Water Authority, Cayman Islands who provided accommodation, technical support, and the loan of equipment necessary to carry out field work on Grand Cayman. Thanks to Gina Ebanks-Petrie, and Scott Slaybaugh for their time and advice. Thanks to Hendrick Jan van Genderen for his time and support. Special thanks go to Keith Neale for his excellent navigational skills, and to Kevin Jackson, Jimmy Squire, Paul Lawrence, and Bradley Johnson for their superb SCUBA skills.

I would like to express my gratitude to Doreen Haugan for all her generous assistance. Thanks to Mark Labbe, for his invention of the core cutting device and helping to cut the cores, and Don Resultay for thin section preparation. Thanks to Randy Pakan, for use of his camera equipment and helpful advice. Thanks to Dr. Karlis Muehlenbachs who conducted isotope analyses, and for his invaluable discussion on isotopes. Thanks to members of my defense committee Dr. Brian Chatterton, and Dr. W. G. Evans for their time and constructive criticisms of this thesis.

Thanks to the past and present members of the Carbonate Research Group, Astrid Arts, and Betsy Wilson who showed me the ropes in the beginning, Paul Blanchon, for his helpful advice, C. G. Gu, Rong-yu Li, Jenny Beanish (my dive buddy), Michael Wojcik, for his intriguing conversations, and Alex MacNeil, for his musical entertainment (Natas). Special thanks go to Jenny Beanish and Michael Wojcik for their valuable assistance in the field.

Thanks to all my friends, especially Susan and Burny for helping to divert my attention away from the thesis for a little while. Lastly, I would like to thank to my family, Robert, Sharon, Joanne, Heather, Sean, and Erin for their support.

Table of Contents

List of Tables

List of Figures

Chapter 1
Introduction

1.1 Introduction

Physical and biological processes determine the factors that control sediment deposition in modern shallow-water lagoons. Temporal and/or spatial changes in environmental conditions can have a dramatic effect on these processes and, as a result, alter the geological evolution of the lagoon. Understanding the processes at work in modern lagoons can provide modern analogues that can be used as a basis for the interpretation of ancient carbonate deposits. Such deposits are economically important because of their potential to host hydrocarbons.

This study of North Sound on Grand Cayman provides a detailed analysis of the processes that control carbonate sedimentation in a large lagoonal environment over the last 5,000 years. North Sound was chosen as the study area because: (1) it is situated on Grand Cayman, a geographically isolated tropical island that is almost completely surrounded by fringing coral reefs, (2) it is the largest of numerous shallow-water lagoons on Grand Cayman, being ~ 9 km long and ~ 7 km wide, (3) it contains a thick (>3.0 m) sediment succession, and (4) it contains shells that allow dating of the sediment.

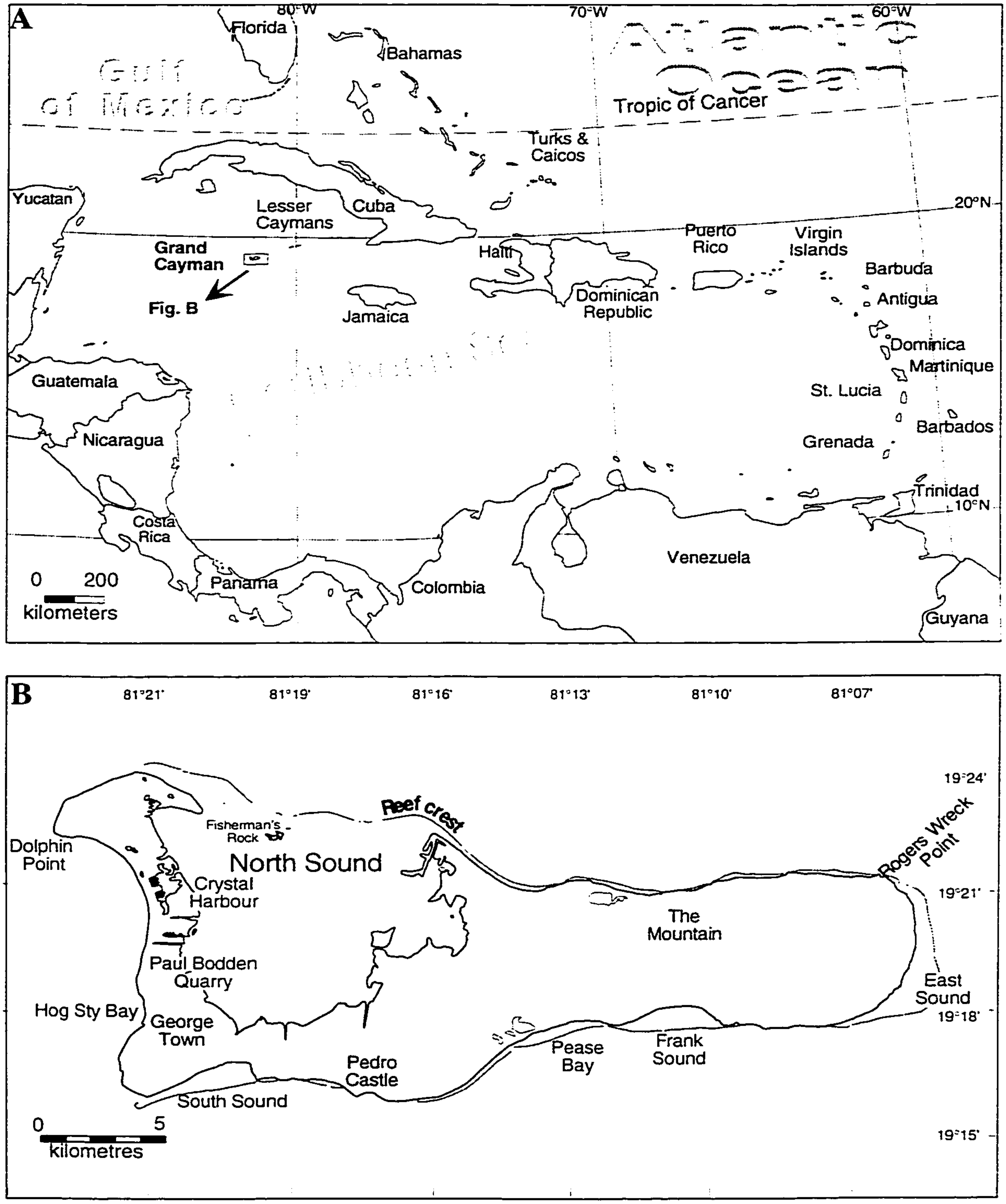


Figure 1.1: (A) Location of Grand Cayman (modified from Hills, 1998).
(B) Location of North Sound on Grand Cayman (modified from Hills, 1998)

1.2 Location and Setting

The Cayman Islands, consisting of Grand Cayman, Little Cayman, and Cayman Brac are located in the Caribbean Sea 240 km south of Cuba and 280 km northwest of Jamaica (Fig. 1.1A). Grand Cayman covers an area of ~196 km^2, and has elevations that are typically < 3 m above sea-level. North Sound is located on the western half of Grand Cayman (Fig. 1.1B). This lagoon, the largest on Grand Cayman, is bounded by land to the east, south, and west. Most of the lagoon is surrounded by mangrove swamps and areas of dense vegetation. A few residential and commercial areas, however, are located on cleared land scattered along the southern and western margins. To the north, a fringing reef separates the lagoon from the Caribbean Sea (Fig. 1.1B). Fisherman's Rock, an outcrop of the Cayman Formation, protrudes from the water surface just to the south of the reef (Fig. 1.1B).

1.3 Tectonic Setting

The Cayman Islands are high points on the Cayman Ridge, an uplifted fault block that extends from the Sierra Maestia Range of Cuba towards the base of the British Honduras Continental Slope (Fig. 1.2) (Falquist and Davies, 1971; Perfit and Heezen, 1978). To the northwest, the ridge is bordered by the Yucatan Basin where the water is up to 4,572 m deep (Perfit and Heezen, 1978). To the south, the Cayman Ridge is

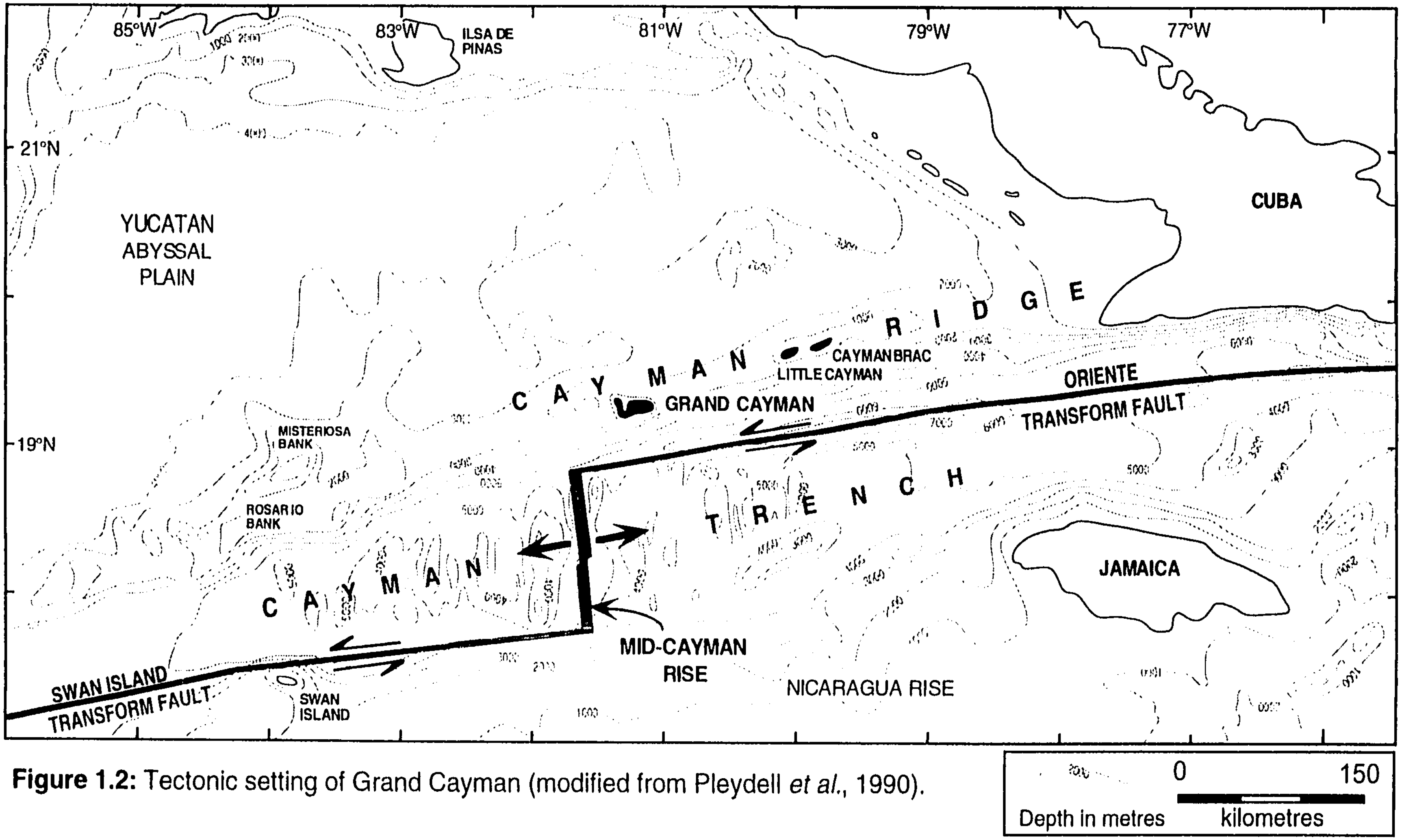


Figure 1.2: Tectonic setting of Grand Cayman (modified from Pleydell *et al.*, 1990).

bordered by the Cayman Trench, a 100 – 150 km wide, > 7,000 m deep depression in the Caribbean crust (MacDonald and Holcombe, 1978).

Development of the Cayman Trench began during the Early Tertiary when left-lateral shear and tensional stresses between the North American and Caribbean Plates resulted in a spreading center that separated the Cayman Ridge and Nicaraguan Plateau (Perfit and Heezen, 1978). Active left-lateral motion of the Oriente and Swan Island Transform Faults, which form the northeastern and southwestern walls of the trench, is estimated to be 2.1 cm/yr (Jordon, 1975). New ocean floor is being formed at the Mid-Cayman Rise, a north-south trending ridge in the center of the trench. The Cayman Ridge is formed of carbonate rocks that overlie volcaniclastics, and metamorphic and plutonic rocks (Perfit and Heezen, 1978; Emery and Milliman, 1980). During the Miocene, subsidence of the Cayman Ridge began at rates of 6 cm/1000 yr (Perfit and Heezen, 1978) to 10 cm/1000 yr (Emery and Milliman, 1980). The Cayman Islands appear to have been tectonically stable over the last 500,000 years (Blanchon and Jones, 1995; Vézina, 1997; Vézina *et al.*, 1999).

1.4 Stratigraphy

Each of the Cayman Islands, which consist of a core of dolostones and limestones of the Oligocene – Pliocene Bluff Group, are unconformably surrounded and partly onlapped by limestones that belong to the Ironshore Formation (Fig. 1.3A) (Matley, 1926; Brunt *et al.*, 1973; Rigby and Roberts, 1976; Jones and Hunter, 1989; Shourie, 1993; Jones *et al.*, 1994; Vézina, 1997; Vézina *et al.*, 1999). The Bluff Group is divided

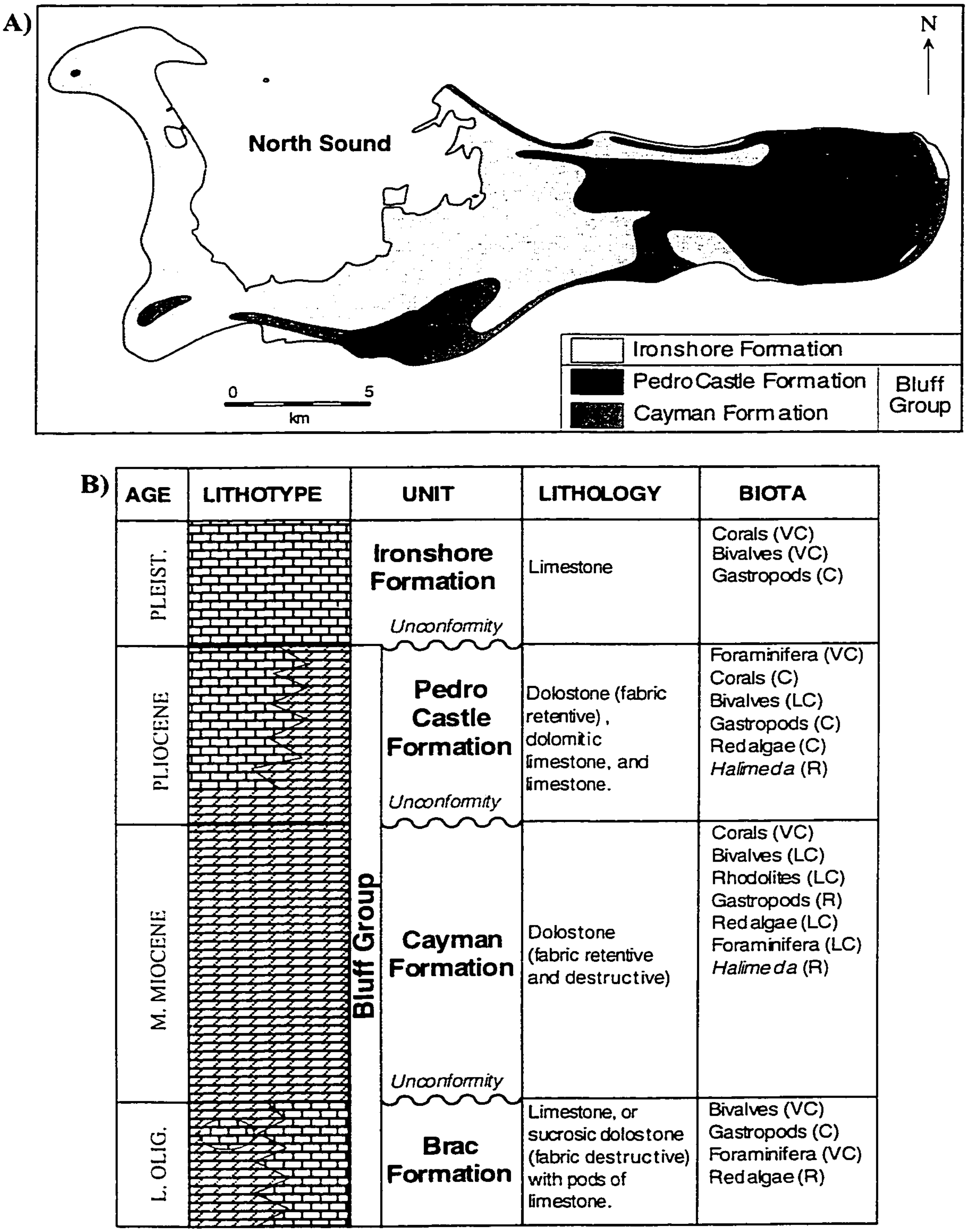


Figure 1.3: **(A)** Geological Map of Grand Cayman (modified from Jones *et al.*, 1994). **(B)** Stratigraphic Column for the Cayman Islands (modified from Jones *et al.*, 1994). VC=Very common; C=common, LC=locally common, R=rare.

into the Brac Formation, the Cayman Formation, and Pedro Castle Formation (Fig. 1.3B). As yet, the Brac Formation has not been found on Grand Cayman.

The Cayman Formation, over 100 m thick, is formed of resistant, microcrystalline, fabric-retentive, white dolostones that contain numerous well-preserved corals, bivalves, rhodolites, gastropods, foraminifera, red algae, and *Halimeda* (Jones and Hunter, 1989; Jones *et al.*, 1994). Extensive leaching of aragonitic fossils, and dissolution associated with karst development are responsible for the formation's characteristic high porosity (locally up to 48% - Jones, pers. comm.) and permeability. Fossil molds and cavities are commonly filled, or partly filled with caymanite, fossiliferous grainstone, terra rosa, and/or flowstone (Lockhart, 1986; Jones, 1994).

A disconformity, marked by numerous sponge and worm borings, separates the Cayman Formation from the overlying Pedro Castle Formation (Jones *et al.*, 1994). The Pedro Castle Formation, 15 – 20 m thick, is composed of soft, rubbly weathered dolostone, dolomitic limestone, and limestone (Jones *et al.*, 1994). Numerous free-living corals, foraminifera, gastropods, red algae, branching corals, rare colonial corals, echinoid fragments, and bivalves are characteristic of this formation (Jones *et al.*, 1994; Wignall, 1995).

The late Pleistocene Ironshore Formation, which unconformably overlies the Bluff Group, is formed of limestone that contains a diverse biota of bivalves, gastropods, corals, green and red algae, and foraminifera (Jones and Hunter, 1990; Hunter, 1994; Vézina, 1997; Vézina *et al.*, 1999). The constituent grainstone, rudstone, packstone-wackestone-mudstone, head coral, and branching coral facies indicate deposition in a shallow-water regime. The formation is divided into four unconformity-bound units, with the age of each unit correlating to the last four successive interglacial highstands (Vézina, 1997; Vézina *et al.*, 1999).

1.5 Modern Lagoons of Grand Cayman

Modern shallow-water lagoons are located parallel to the north, east, and south coasts of Grand Cayman. Each lagoon is separated from the open ocean by a fringing coral reef that stretches from headland to headland. The fringing coral reef marks the uppermost part of a shallow upper terrace that surrounds most of Grand Cayman (Rigby and Roberts, 1976; Roberts, 1976, 1977; Smith, 1988; Ghiold and Smith, 1990; Hunter, 1994; Blanchon, 1995; Blanchon and Jones, 1995; Blanchon *et al.*, 1997). The upper terrace (0-10 m below mean sea level) is separated from a lower terrace (~15-30 m below msl) by a narrow mid-shelf scarp (Blanchon and Jones, 1995; Blanchon *et al.*, 1997). The lower terrace is marked by a shelf-edge reef, which hosts a diverse biota (Blanchon and Jones, 1995; Blanchon *et al.*, 1997). Controls on reef development around Grand Cayman have been outlined by Blanchon and Jones (1993; 1995), Blanchon (1995), and Blanchon *et al.* (1997).

Based on biota and grain-size distribution, Frank Sound and Pease Bay, located on the south coast of Grand Cayman can be divided into the (1) Rubble and Knob, (2) Bare Sand, and, (3) *Thalassia* and Sand zones (Kalbfleisch, 1995; Kalbfleisch and Jones, 1998). These zones, which parallel the reef crest, are controlled by hurricane activity. The hurricanes produce high waves and strong currents that transport shelf and fore-reef sediments into the lagoons. As the current velocity is reduced in the lagoon, the sediment is deposited. The effects of storms and hurricanes described by Kalbfleisch (1995) and Kalbfleisch and Jones (1998) may have similar effects on other shallow-water lagoons of Grand Cayman.

Image analyses of aerial photographs were used by Tongpenyai (1989) and Tongpenyai and Jones (1991) to delineate changes of carbonate facies over the last 15 years in South Sound, Blue Rock Bay, Frank Sound, East Sound (South), and East Sound (North) on Grand Cayman. These analyses suggested that there was a 12 to 45% increase in *Thalassia* growth between 1971 and 1985, and a similar decrease in sand area in these lagoons.

Modern reefs and lagoons around the Cayman Islands contain 47 coral species which have been taxonomically described by Raymont *et al.* (1976) and Hunter (1994). Hunter (1994) recognized a distinct sea-floor zonation based on geomorphologic, sedimentologic, and ecologic components. Sediments from the lagoons around Grand Cayman contain at least 136 species of foraminifera that belong to 50 genera (Li, 1997; Li and Jones, 1998; Li *et al.*, 1998). Twelve foraminiferal assemblages were defined based on recurring associations of species.

1.6 Objectives

To date, studies on the sedimentology of North Sound have provided a two-dimensional examination of surface sediments in the lagoon (Roberts, 1971*a*, 1971*b*, 1976, 1983; Rigby and Roberts, 1976; Li, 1997). This study examines the sedimentary evolution of the lagoon by using unconsolidated sediment cores collected from North Sound. This is accomplished by:

(1) examining the sediment composition and distribution in North Sound.

(2) identifying the biota type and distribution in the lagoon,

(3) outlining the characteristics and distribution of each facies.

(4) assessing the mechanisms that controlled deposition of each facies, and,

(5) radiocarbon dating of sediments.

Given the results of Kalbfleisch (1995), particular emphasis is placed on assessing the effects that storms and hurricanes have had on the sedimentology of North Sound, Grand Cayman.

1.7 Materials and Methods of Study

1.7.1 Field Methods

Water depth, descriptions of the substrate, sediment thickness, sediment cores, and/or surface sediment samples were collected at 60 locations in North Sound (Fig. 1.4). Information at each sampling location was collected by snorkeling and/or SCUBA diving. Water depth was measured using a SCUBA depth gauge, and/or a metal probe. A description of the substrate, including biota and sediment characteristics, was recorded whenever a significant change of the substrate was encountered. Surface sediment samples were obtained by scooping a ~ 0.5 liter of sediment into pre-numbered bags.

Sediment cores were collected by manually hammering a 4 cm diameter PVC pipe, typically 3 m long, into the sediment until it encountered the hard bedrock that underlies the sediment (Fig. 1.5). Sediment thickness was determined from the depth that the PVC pipe was driven into the sediment. At some localities a metal probe was also used to determine depth. Once the PVC pipe was in place, a PVC end cap was then fitted on the top of the pipe before it was manually extracted from the substrate. Another PVC end cap was fitted on the bottom of the pipe as it emerged from the substrate. Forty-nine cores, 0.4 to 2.44 meters long, were collected from North Sound (Fig. 1.4). These core were sealed, and shipped to Edmonton intact.

The main transect completed in North Sound, 9 km long at a bearing of 0° North, was located adjacent to a line of buoys that mark the western edge of the replenishment zone, which is a marine protected zone in North Sound (Fig. 1.4). To maximize the number of facies encountered, the transect was orientated perpendicular to the reef crest. An east-west transect was made directly behind the reef crest (Fig. 1.4) to determine variations in sediment and substrate characteristics parallel to the reef crest. Forty sampling locations were located on these transects. An additional 20 sampling locations were randomly chosen to obtain samples from areas located between the two main transects. Access to the lagoon was obtained using a 45-foot Taurus boat, and from the shoreline. A Global Positioning System (GPS) was used to record accurate latitude and longitude of each sample location.

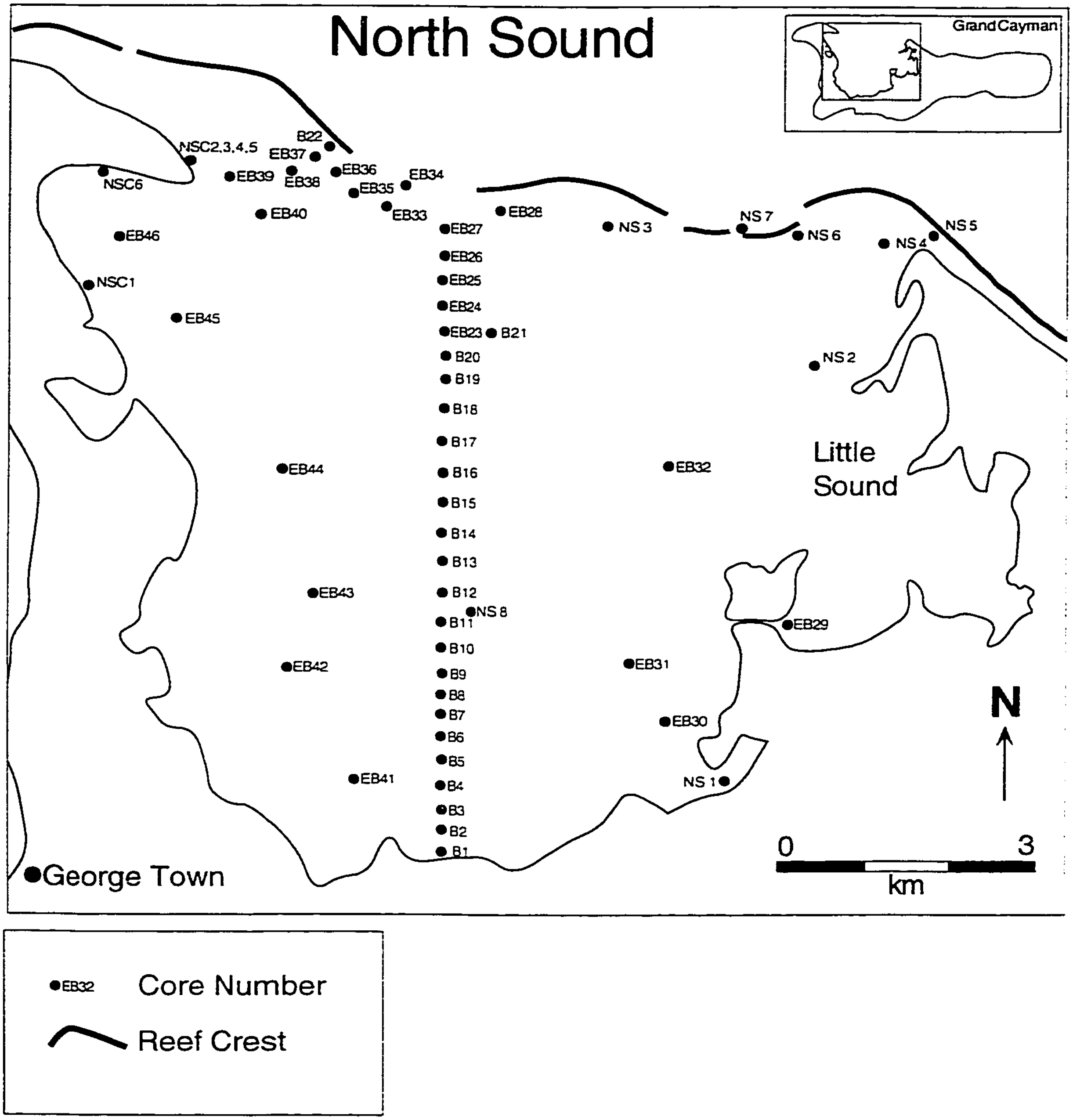


Figure 1.4: Core and surface sediment sample locations in North Sound.

Figure 1.5: A 1.5 inch diameter PVC pipe being hammered into the substrate for sediment core retrieval in North Sound. Note stingrays in background.

1.7.2 Core Recovery

At some localities, core penetration into the sediment was hindered by coarse sediment, boulders, or friction. The PVC pipe was driven into the sediment a number of times at some localities, in order to obtain the maximum thickness possible. Core recovery was 16 to 100%, with most being 60 to 80% (Appendix A). Five of the cores with recovery rates < 60 % contained a layer of coarse shell material at their base (Fig. 1.6). The shell material probably prevented further penetration of the core into the sediment. The remaining cores with recovery rates < 60 % are composed of 56 to 92% mangrove peat located near the top of the core. These cores probably underwent a high degree of compaction because of the high water content of the peat. Other cores, however, with a high recovery rate have a significant thickness of peat near the bottom of the core (Fig. 1.7a). The degree of compaction in these cores was probably low because the peat had already been compacted by the weight of the overlying sediment. Comparison of peat content to core recovery reveals that increasing peat content in the core results in a decrease in core recovery (Fig. 1.7b).

1.7.3 Core Logging and Thin Section Analysis

The PVC pipe was cut in half parallel to its length, then split using a thin piece of wire and/or a hacksaw blade. Facies were identified and described based on biota and sediment characteristics. Twenty thin sections were made from sediment samples collected from selected core intervals. Sediments were embedded in a blue epoxy and then

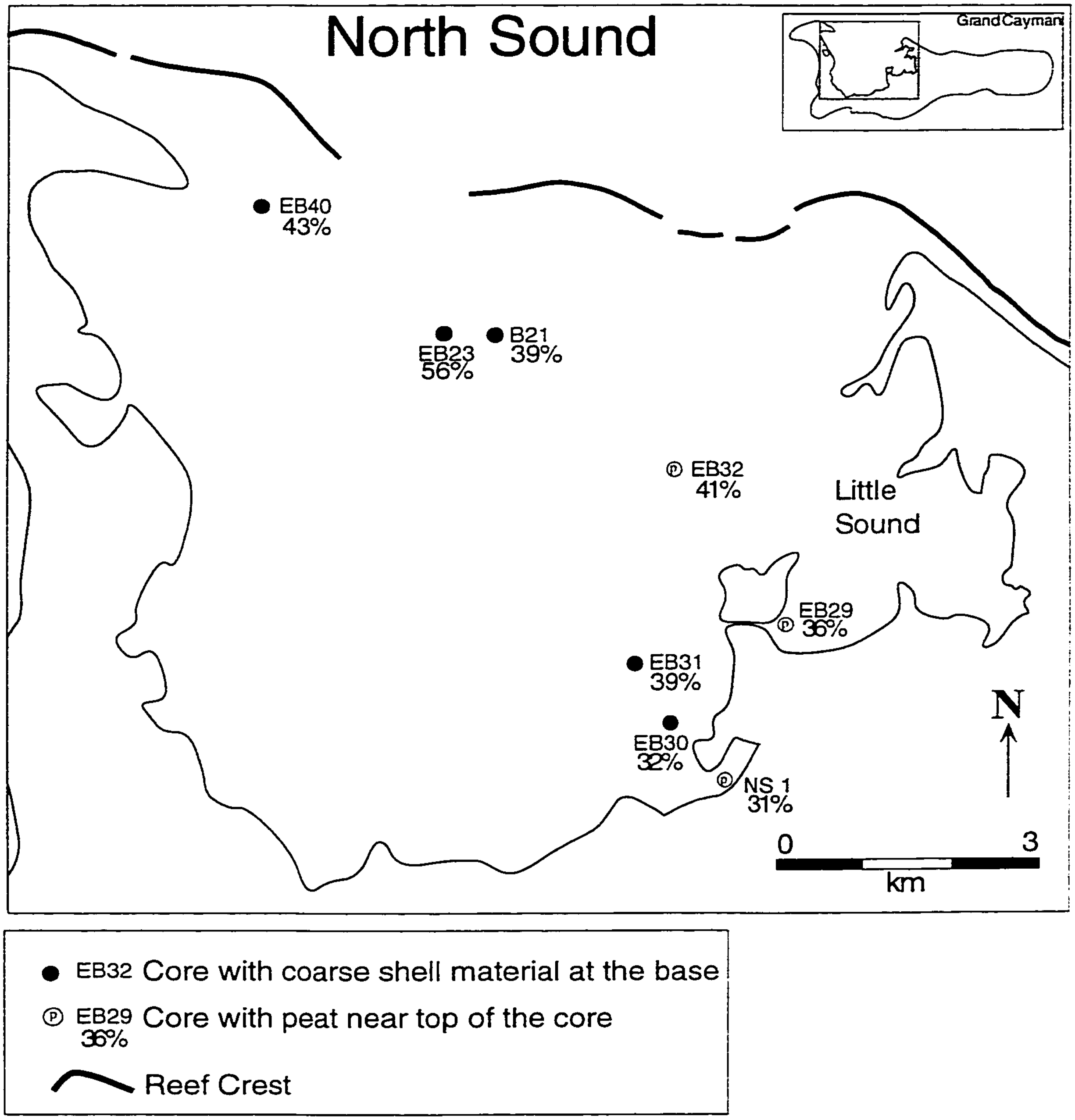
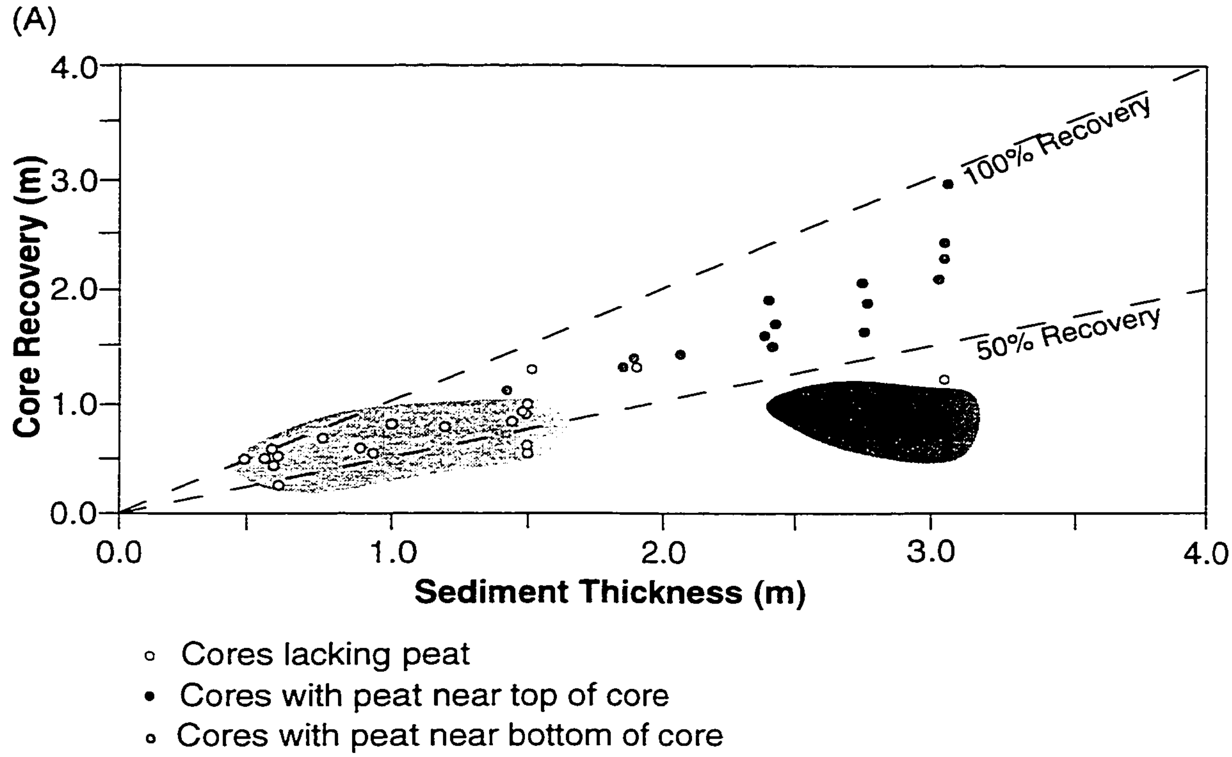


Figure 1.6: Core locations in North Sound with recovery rates of less than 60%.



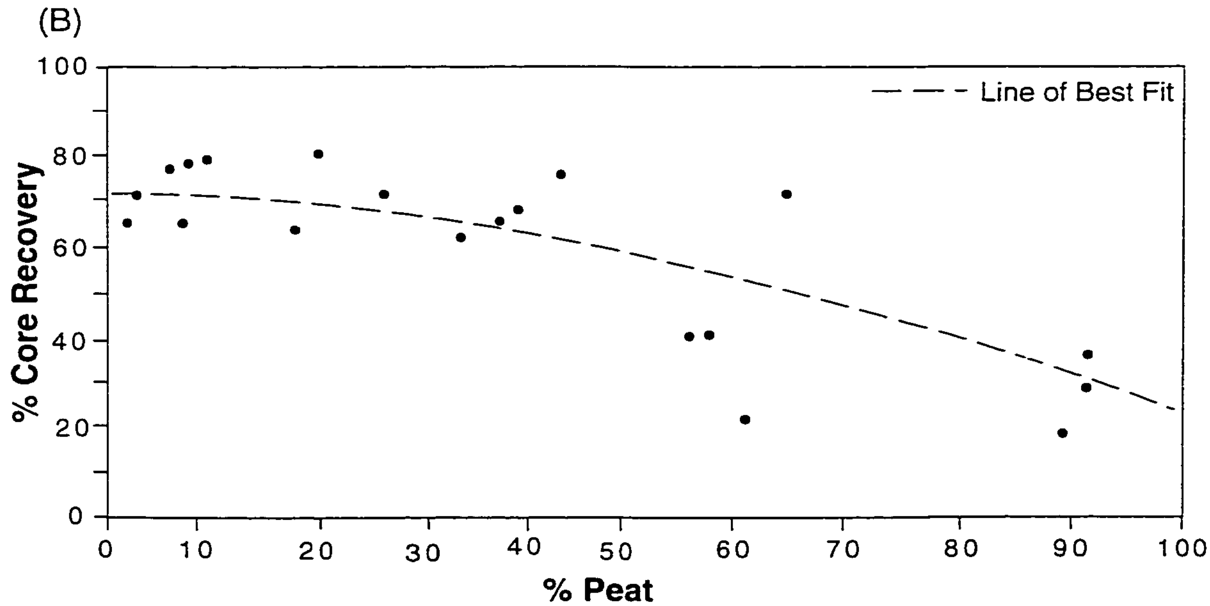


Figure 1.7: (A) Plot of core recovery (m) versus sediment thickness (m) illustrating that cores containing peat near the top of the core have a low recovery rate. (B) Plot of percent core recovery versus percent peat content illustrating the decrease in core recovery with increasing peat content.

thin sectioned. Thin sections were analyzed using a Jenapol petrographic microscope. Grain analysis was done on 100 grains for nine of the thin sections. Grain analysis includes grain identification, measurement of length and width, and estimates of the degree of micritization and boring. Grains were identified using descriptions (e.g., Scholle, 1978) and comparisons with recognized species.

1.7.4 Radiocarbon Analysis

Eight bivalve shells were extracted from basal sediments of selected cores (Appendix C). An 8 mesh W.S. Tyler Canadian Standard sieve was used to wet sieve undesired materials from the shell samples. Shells were then air dried, and sent for conventional radiocarbon dating analyses at the Isotrace Laboratory in Toronto. An average of four high precision analyses were calculated for each sample, except sample B7 (0-1) for which an average of two normal precision analyses were calculated because of the small sample size (115 mg). To eliminate any possible surface contamination, the outer 20 – 40% of shell material was leached with HCl before hydrolysis. Dates are reported as uncalibrated radiocarbon dates in years before present (1950), using the Libby meanlife of 8033 years, and are corrected for natural and sputtering fractionation to the value of $-25^{o}/_{oo}$ PDB (Stuiver and Polach, 1977; Mook and Streurman, 1983; Anderson *et al.*, 1989). Dates have been corrected for the reservoir effect by subtracting 400 yrs from the uncalibrated radiocarbon date (Krog and Tauber, 1974; Neilsen *et al.*, 1995). Errors are within the 68.3% confidence limits.

1.7.5 Isotope Analysis

Ten bivalve shell and sediment samples were collected from six intervals in core B10 for stable isotope analysis. An 8 mesh W.S. Tyler Canadian Standard sieve was used to wet sieve undesired materials from the bivalve shell samples. The bivalve shells were air dried, and analyzed by Dr. K. Muehlenbachs at the University of Alberta isotope analysis laboratory. The samples were powdered and soaked overnight in a NaOCl (5%) solution to eliminate any possible contamination from organic material. Carbon dioxide samples were extracted by reacting the bivalve shell and sediment samples with 100% phosphoric acid (McCrea, 1950). Isotopic composition of the carbon dioxide was measured using a Finnigan-MAT 252 mass spectrometer. Stable isotope values are reported with respect to the VPDB standard.

Chapter 2
Modern Depositional Environments of North Sound

2.1 Introduction

An understanding of the development of modern depositional environments in North Sound carries important implications for deciphering the environmental conditions in which the underlying sediments were deposited. Information from previous studies by Roberts (1971*a*, 1976, 1977; Rigby and Roberts, 1976; Roberts and Sneider, 1982) has been combined with information on bathymetry and sediment thickness collected in this study for the purpose of updating existing information.

Modern depositional environments and organic communities of North Sound were described by Roberts (1971*a*, 1976, 1977; Rigby and Roberts, 1976; Roberts and Sneider, 1982). The major depositional environments in North Sound, based on energy conditions, submarine topography, and substrate characteristics, are the reef-shoal and lagoonal environments (Roberts, 1971*a*; 1976; Roberts and Sneider, 1982). The reef-shoal environments are characterized by water less than 4 m deep, high-energy conditions, and coarse-grained sediments. The lagoonal environments are characterized by waters up to 6 m deep, low-energy conditions, and lime muds. Roberts (1971*a*; Roberts and Sneider, 1982) divided the reef-shoal environments into the reef-crest, rubble flat, moat, rock floor, and the sand flat (Roberts, 1971*a*; Fig. 2.1). For the purposes of this study, however, these are collectively referred to as the reef-shoal environments (Fig. 2.2). The lagoonal environments include the grass plain, restricted lagoon, and shore zone (Fig. 2.1).

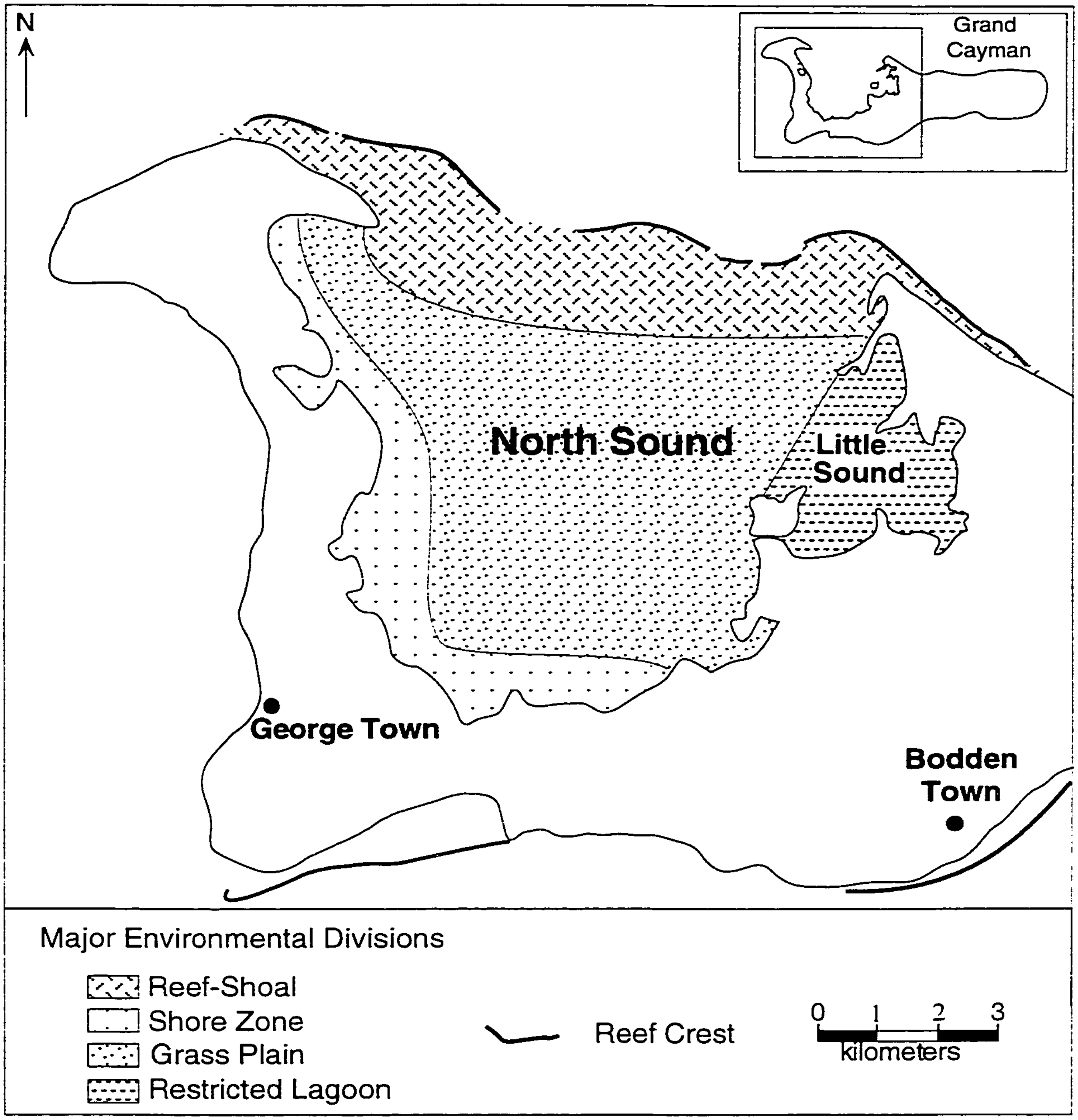


Figure 2.1: Major Environmental Divisions of North Sound based on surface sediment samples collected in North Sound (modified from Roberts, 1971*a*).

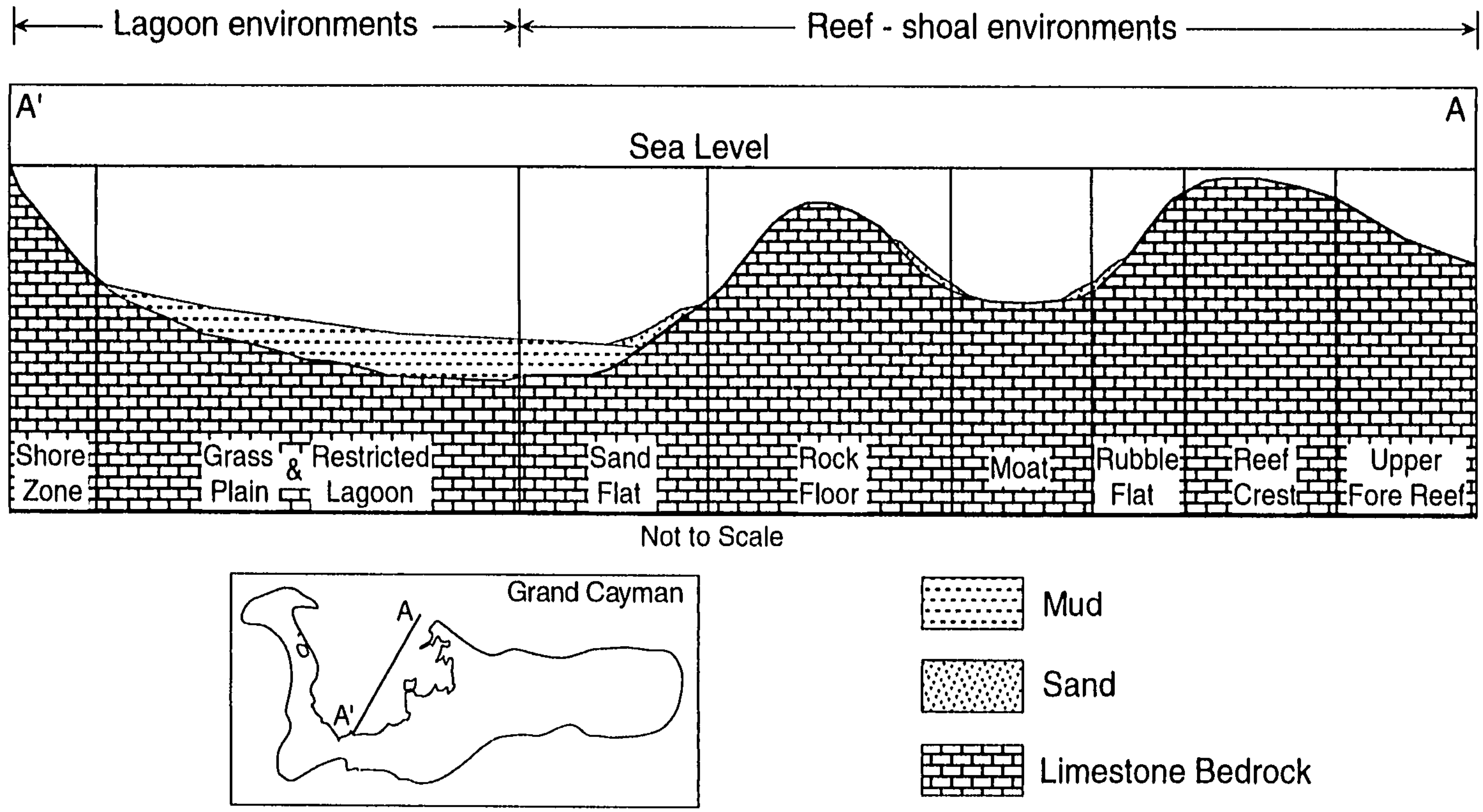


Figure 2.2: Profile of the modern depositional environments in North Sound (modified from Roberts, 1971*a*).

2.1.1 Water Circulation

Roberts and Sneider (1982) developed a water circulation pattern for North Sound (Fig. 2.3) using a two-dimensional hydrodynamic model (Wang and Connor, 1975). Inputs into the model included water depth, water energy lost over the reef crest, and tidal fluctuations. The main controls on circulation in North Sound are tidal fluctuations, wind direction, and wind velocity. Tidal fluctuations average 20 cm between high and low tides. Winds are primarily from the east-northeast, but changes in wind direction and velocity brought about by storms (e.g., Northwest gales during winter storms) can have a significant effect on circulation patterns in the lagoon.

Water velocity is highest (30 – 50 cm/s) near the reef crest. Near-shore currents, flowing in a westerly direction along the north shore of Grand Cayman, enter the lagoon through breaks in the reef crest and over the eastern part of the reef crest. These westerly currents flow along the back-reef, parallel to the reef crest. Water flows out of the lagoon over the western part of the reef crest and through breaks in the reef. Circulation patterns in the interior of the lagoon form two gyres with water velocities of less than 20 cm/s. A counterclockwise rotating gyre dominates flow in the central portion of the lagoon, whereas a clockwise rotating gyre controls circulation in the southern part of the lagoon. Currents in Little Sound flow southeast to southwest with velocities of less than 10 cm/s.

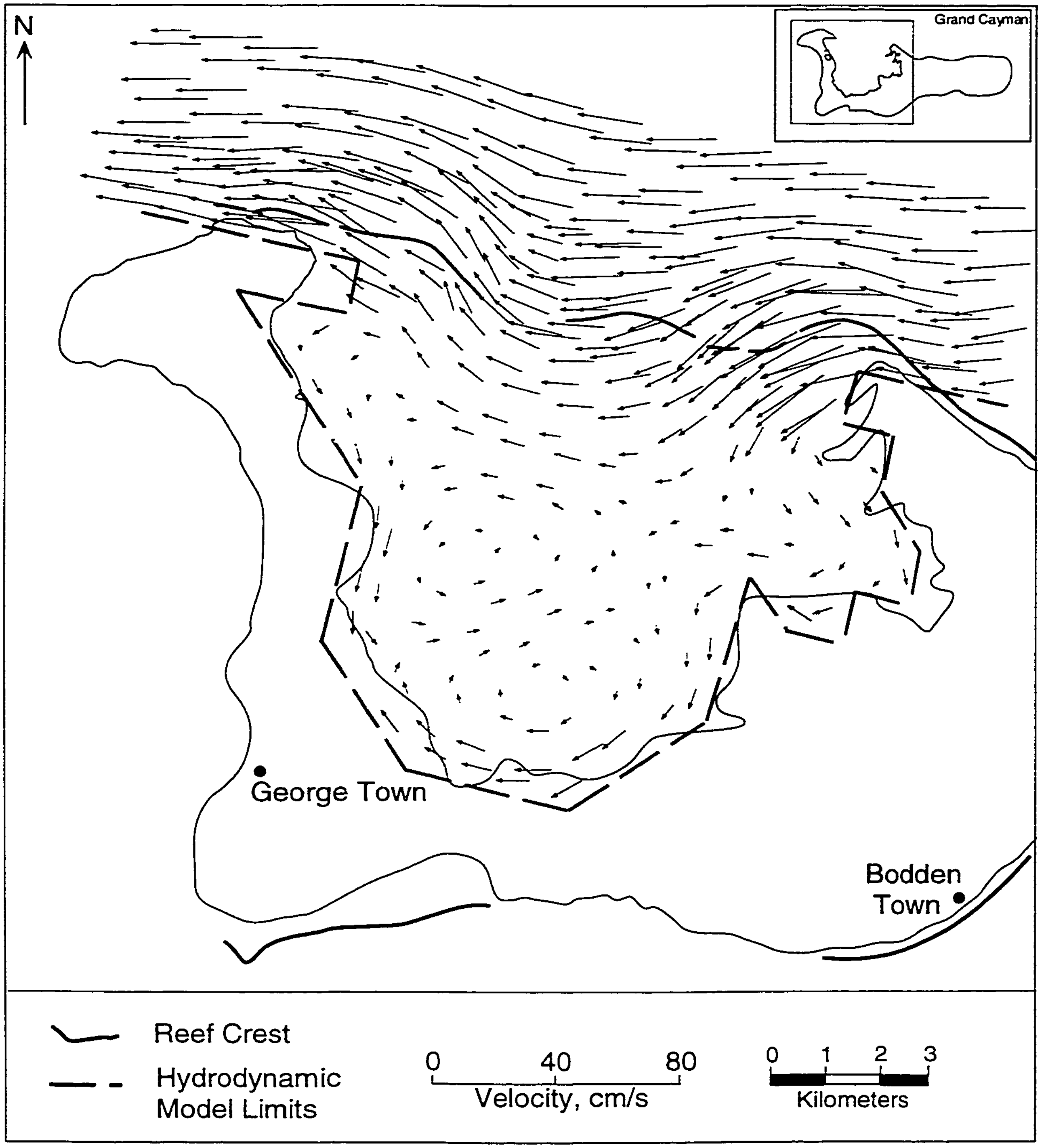


Figure 2.3: Water circulation in North Sound as determined by a two-dimensional, finite-element, hydrodynamic model (modified from Roberts and Sneider, 1982).

2.1.2 Bathymetry

Bathymetry in North Sound is controlled by bedrock topography and sediment thickness. Most of North Sound has water 2.0 - 5.0 m deep (Fig. 2.4). Waters are shallow (< 2.0 m) near the shoreline and gradually increase to a depth of 6 m in the center of the lagoon. Depths at the reef crest are generally < 2.0 m, and gradually increase towards the center of the lagoon. At low tide, the highest points on the reef crest are exposed above the water surface. Channels through the reef crest are up to 4.0 m deep. Maximum depths of ~ 6.0 m are found (1) in the south-central portion of the lagoon, (2) in the center of Little Sound, (3) adjacent to the entrance to Little Sound, and (4) to the east of the main channel. Information on bathymetry collected during this study closely matches that given by Roberts (1971*b*) and Roberts and Sneider (1982).

2.1.3 Water Temperature and Salinity

Temperature differences between waters of North Sound and open shelf waters of Hog Sty Bay (Fig. 1.1) rarely exceed 1°C with North Sound being slightly warmer in summer and slightly cooler in winter (Kalbfleisch, 1995). Water temperatures in Hog Sty Bay, Georgetown, Grand Cayman average 28°C, and vary from 26°C during the winter months (Jan. - March) to 29°C during the summer months (June – Oct.) (Kalbfleisch, 1995; Kalbfleisch and Jones, 1998). Water salinity is highly variable in North Sound. Normal marine salinities prevail near the reef crest where waters of the open ocean enter

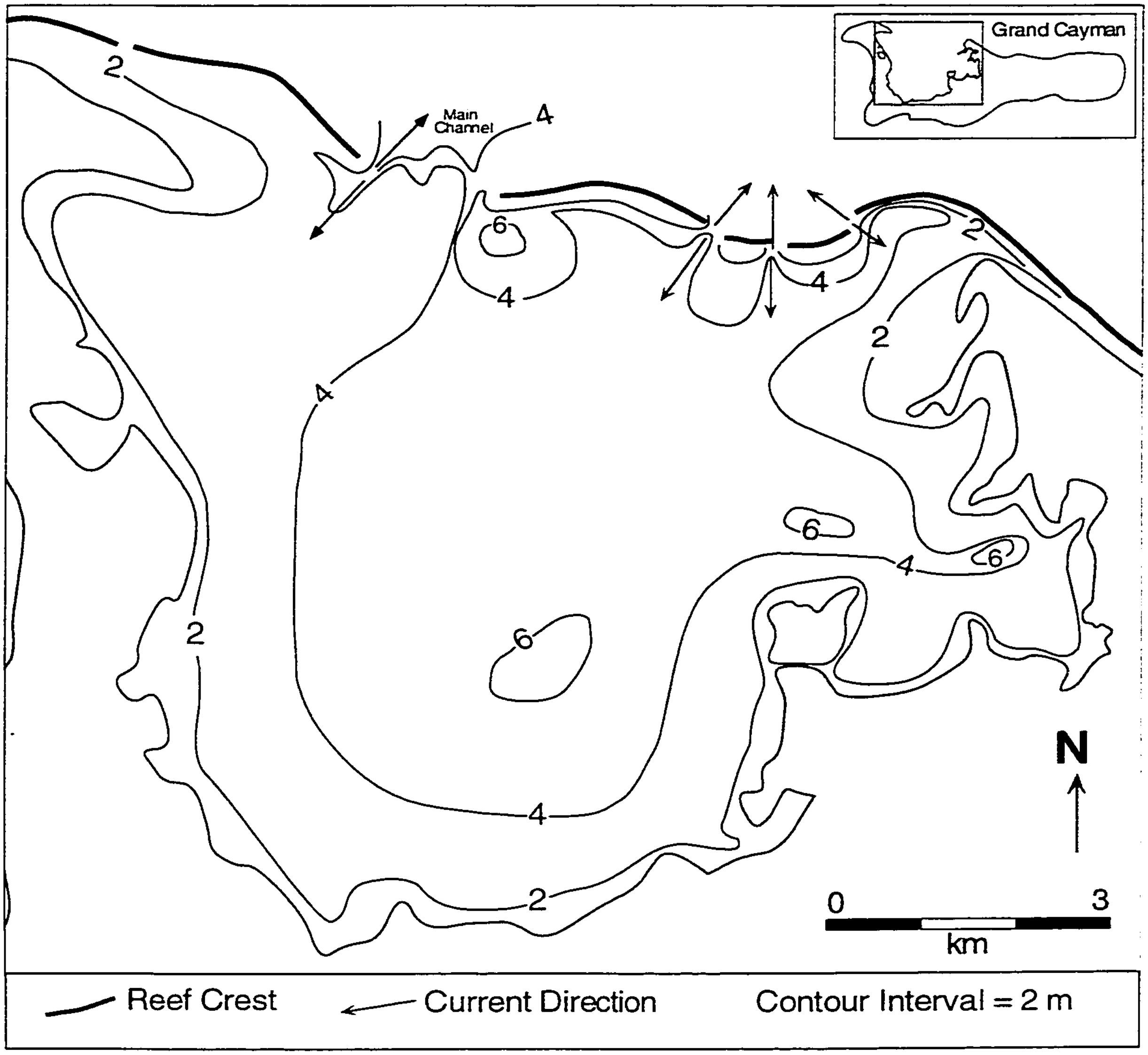


Figure 2.4: Bathymetric map of North Sound based on Roberts (1971*b*) and modified with data collected during this study.

the lagoon; however, salinities are elevated (up to 42 $^{0}/_{00}$) in the main body of the lagoon where circulation is more restricted (Rigby and Roberts, 1976).

2.1.4 Sediment Thickness

Sediment thickness in North Sound is controlled by bedrock topography and the energy level of currents that transport and deposit the sediments. Sediment thickness was measured by Roberts (1971*a*) at 80 locations that were arranged on a grid over North Sound. These data have been supplemented by 56 localities examined in this study. The sediment thickness measurements by Roberts (1971*a*) are generally similar to those obtained in this study. Collectively, they show that the sediment cover is thin (< 1 m) near the shoreline and gradually increases to a thickness of 3 m towards the center of the lagoon (Fig. 2.5). Just behind the reef crest, the sediment is 0.0 – 0.5 m thick. A maximum sediment thickness of 4 m is present in Little Sound, to the southwest of Booby Cay.

2.1.5 Grain Size and Composition

Sediments are cobble to sand-size near the reef crest and decrease in size to lime muds in the inner parts of the lagoon (Roberts and Sneider, 1982). Sediments are composed of skeletal calcium carbonate (Roberts, 1971*a*). Surface sediment samples collected from North Sound by Roberts (1971*b*), revealed significant differences in the

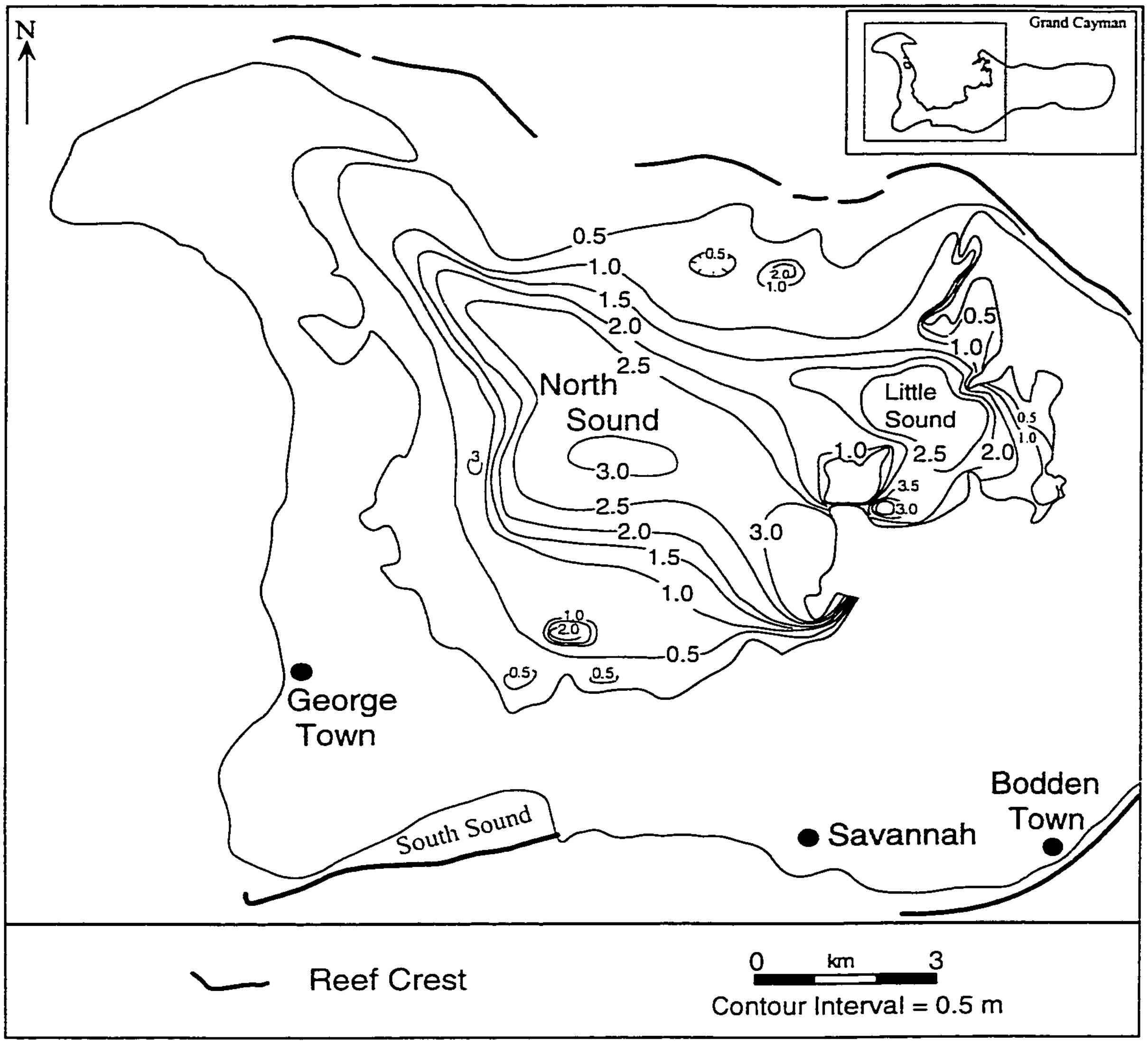


Figure 2.5: Map of unconsolidated sediment thickness in North Sound based on data from Roberts (1971*a*) and data collected during this study.

carbonate mineral composition. These differences indicate that grain composition varies depending on grain size and the depositional environment. Fine-grained sediments contained a higher proportion of high-Mg calcite (HMC) and lower proportions of aragonite when compared with the coarse grain-size fraction. This is due to differential particle size reduction, where the least resistant high-Mg calcite grains bias the fine grain-size fraction in favor of HMC. Since each environment has its characteristic sediment producing organisms, mineralogy depends on the composition of those organisms.

2.2 Modern Depositional Environments

2.2.1 Reef-Shoal Environments

Roberts (1971*a*; 1976; Rigby and Roberts, 1976; Roberts and Sneider, 1982) divided the reef-shoal environment into the reef-crest, rubble flat, moat, rock floor, and sand flat environments (Fig. 2.2). These environments, located in the northern part of North Sound, include the reef and a ~ 2 km wide band on the landward side of the reef (Fig. 2.1). *Acropora palmata* is the most dominant coral of the reef environment (Table 2.1). The reef crest consists of the fore reef slope, which is a gently dipping rock surface in front of the reef crest, and a back reef debris plane that gently dips towards shore. The reef is constructed of cobble size rubble derived from the branching coral *Acropora palmata*.

The rubble flat is characterized by shallow waters and a debris plane that slopes gently in a shoreward direction (Fig. 2.2). Debris consists of boulder to cobble sized

Environment		Grain Size	Corals	Other Biota	Comments
Lagoonal Environments	Shore Zone	Fine Sand	*Porites divaricata* *Porites furcata* *Siderastrea radians*	*Alcyonarians* Encrusting sponges Red algae Brown algae Green algae Bivalves Gastropods Foraminifera	low - energy Shallow water thin sediment cover
	Grass Plain	Fine Sand	*Porites divaricata* *Porites furcata*	*Thalassia testudinum* *Callianassa* Green algae Holothurians Echinoids Gastropods Encrusting sponges Bryozoa Foraminifera Bivalves	low - moderate energy moderate -deep water thick sediment cover
	Restricted Lagoon	Fine Sand		*Thalassia testudinum* *Callianassa* Green algae Holothurians Echinoids Gastropods Encrusting sponges Bryozoa Foraminifera Bivalves	low - energy moderate - deep water thick sediment cover
Reef Shoal Environments	Reef Crest Rubble flat Moat Rock floor Sand flat	Boulder to Sand	*Acropora* *Diploria* *Montastrea* *Agarcia* *Porites* *Siderastrea* *Dendrogyra* *Eusmilia*	*Millepora* Green algae *Diadema* Foraminifera Coralline algae Red algae Serpulids Bryozoa Brown algae Alcyonarians Sponges Vascular marine plants Gastropods Starfish	high - energy shallow water thin sediment cover aggregate grains

Table 2.1: Summary of corals and other biota characteristic to modern depositional environments of North Sound based on data extracted from Roberts (1971*a*).

branches of *Acropora palmata* that have been broken during storms. The debris is extensively bored and encrusted by marine organisms.

Shoreward from the rubble flat, the boulders and cobbles progressively decrease to sand sized materials of the moat zone (Fig. 2.2). The moat is characterized by an abrupt drop of the substrate, forming a depression parallel to the reef crest, which becomes gradually shallower in a shoreward direction (Fig. 2.2). The moat is 0 - 100 m wide, with water 1.8 - 4.5 m deep. The floor of the moat is an exposed rock surface that is covered with a thin veneer of sand.

The rock floor is a band of rocky substrate lacking any sediment cover, and forms a topographic high parallel to the reef crest. Situated between the moat and lime muds of the inner lagoon, it forms a small barrier between the reef and inner lagoon (Fig. 2.2).

The coralgal sand apron, located shoreward of the rock floor covers the northern and northeastern areas of the lagoon (Fig. 2.2). Sand consists of skeletal debris derived from biological and physical breakdown of the reef community. Aggregate grains and skeletal grains cemented by aragonite are located adjacent to main passages through the fringing reef. These grains result from recent submarine cementation (Roberts, 1971*c*).

2.2.2 Grass Plain

The grass plain environment (Fig. 2.1), which covers ~ 60% of North Sound, is named after the seagrass *Thalassia testudinum*. Water velocities in these areas are less than 20 cm/s. The dense *Thalassia* growth is responsible for the thick sediment accumulations of up to 3 m. In the northern part of this environment, the *Thalassia* is sparse and sediments are sand-sized rather than lime muds. Similarly, along its southern boundary, the sediment thickness decreases as *Thalassia* growth becomes sparse. Much of the biota in this environment, including holothurians, short-spined echinoids, gastropods, and *Porites divaricata*, inhabit the areas between the blades where they are protected from currents and predators (Table 2.1). Encrusting sponges, bryozoa, and foraminifera live on the flat surfaces of the *Thalassia* blades.

2.2.3 Restricted Lagoon

The restricted lagoon environment consists of Little Sound, which is a naturally restricted basin that is separated from the main portion of North Sound (Fig. 2.1). Water circulation, which is isolated from the main circulation patterns, has velocities < 10 cm/s. Water depths increase from < 2 m near the shore to 6 m the near the center of the basin. Fine-grained, highly organic sediments which characterize this environment are derived from the dense mangrove swampland that surrounds Little Sound. The biota is similar to that of the grass plain environment (Table 2.1), with *Thalassia testudinum* being the most abundant member of the organic community. The northern indentation of Little Sound is populated by the unusual tetradial jellyfish *Cassiope*, which is associated with *Thalassia* on a muddy organic-rich, fine-textured substrate. In this study, *Cassiope* were also found on the floor of the lagoon to the south of Booby Cay.

2.2.4 Shore Zone

The shore zone, which is 0.5 – 1.5 km wide, extends along the western and southern margins of North Sound (Fig 2.1). Low-energy waters with depths of < 3 m characterize this zone. A thin veneer of fine-grained sediments, < 2 m deep, cover the bedrock lows. The exposed bedrock highs are colonized by biota which prefer the solid substrate (Table 2.1).

2.3 Synopsis

Modern depositional environments in North Sound include the Reef–shoal, Grass Plain, Restricted Lagoon, and Shore Zone environments. The Reef–shoal environment is a high-energy, shallow water environment which included the reef crest, and a 2 km wide band on the landward side of the reef. In the Grass Plain environment, waters are low to moderate energy, and 2 – 6 m deep. Dense *Thalassia* growth is responsible for thick sediment accumulations of up to 3 m. The restricted lagoon environment is a naturally restricted basin with characteristics similar to those of the Grass Plain environment. The Shore Zone is characterized by low energy, shallow (<2 m) waters, with bedrock lows covered by a thin veneer of fine-grained sediments.

Chapter 3
Depositional Architecture of North Sound

3.1 Introduction

Subsurface sediments in North Sound are divided into seven facies based on the relative abundance of allochems, allochem preservation, and grain size (Table 3.1). Each facies is named according to the abundance of skeletal components, as determined by thin section and core analyses. Facies names begin with the most abundant component, with the less abundant components (≥ 10%) listed in order of decreasing abundance (Table 3.1). Facies in North Sound include the Composite Grain, Gastropod, Bivalve, Mangrove Peat, *Halimeda*, *Halimeda*–Benthic Foraminifera-Bivalve, and Bivalve-*Halimeda* Facies (Table 3.1).

The reef can be considered an additional facies. Studies by Blanchon (1995) and Blanchon and Jones (1995), however, have shown that the reef crest is mainly formed of coral rubble, and lacks loose sediments. Thus, the amount of sediment is insufficient for collection of sediment samples and/or sediment cores, and no attempt was made to document the structure of the reef.

Preservation of allochems is determined by the degree of fragmentation and micritization. The term "micritization" is used in this study to describe the alteration of a preexisting fabric to micrite (microcrystalline carbonate < 4 μm in size) by decrease in crystal size or by destruction of an ordered crystal arrangement (*cf.* Alexandersson, 1972; MacIntyre and Reid, 1995).

Facies	Colour	Grain Size	Main Components	Minor Components	Allochem Preservation	Sorting
Bivalve - *Halimeda*	Buff to light beige	Medium to coarse sand	Bivalves (34%) *Halimeda* (10%)	Benthic Foraminifera (6%) Red Algae (3%) Coral Fragments (2%) Unknown / Other (45%)	High fragmentation Partial micritization of allochems	Moderate to well sorted
Halimeda	Light to dark grey	Medium to coarse sand	*Halimeda* (47%)	Benthic Foraminfera (9%) Bivalves (6%) Composite Grains (5%) Coral Fragments (2%) Gastropods(1%) Unknown / Other (30%)	High fragmentation, Extensive micritization	Moderate to well sorted
***Halimeda* - Benthic Foraminifera-Bivalve**	Light to dark grey	Medium sand to pebble	*Halimeda* (49%) Benthic Foraminfera (16%)	Bivalves (9%) Composite Grains (2%) Red Algae (2%) Coral Fragments (1%) Echinoderms (1%) Unknown / Other (20%)	Moderate to high fragmentation (with exception of numerous articulated, bivalves), Extensive micritization	Moderate to poorly sorted
Mangrove Peat	Dark brown to black	Fine-grained organics	Peat (95%)	Bivalves (~5%)	Well preserved articulated and disarticulated bivalves	Moderate to well sorted
Bivalve	Light to dark grey	Medium sand to pebble	Bivalves (90%)	Organics (~10%)	Well preserved bivalve shell fragments	Moderate to poorly sorted
Gastropod	White and black	Fine-grained organics to granule	Gastropods (90%)	Organics (~10%)	Well preserved gastropod shells	Moderate to poorly sorted
Composite Grain	White to light beige	Silt to clay	Composite Grains (95%)	Unknown / Other (5%)	Well preserved mollusc and benthic foraminifera fragments in a micrite groundmass	Well sorted

Table 3.1: Facies of North Sound, Grand Cayman. Percentages are averages of 3 thin section samples of each facies, except the Gastropod, Bivalve and Mangrove Peat facies in which percentages are estimates based on core observations.

3.2 Bedrock

Unconsolidated sediments in North Sound lie on an irregular bedrock surface. It is not known if the bedrock consists of limestone belonging to the Ironshore Formation or dolostones of the Cayman Formation because no wells have been drilled into the bedrock beneath North Sound. Fisherman's Rock, located south of the reef crest, is composed of dolostone belonging to the Cayman Formation (Fig. 1.1). The Ironshore Formation, however, is distributed over most of the western half of Grand Cayman (Fig. 1.3A). Thus, it seems more probable that the bedrock underlying the sediments in North Sound is limestone of the Ironshore Formation.

3.3 Facies

3.3.1 Composite Grain Facies

Description: The Composite Grain Facies (Fig. 3.1A and B), which is fine-grained and white to light beige in color, is composed almost entirely (95%) of composite grains. Generally, the sediments are silt to clay-sized (< 0.06 mm) and very well-sorted. The composite grains are formed of aragonitic bivalves, gastropods, and/or benthic foraminifera fragments embedded in a micrite groundmass. Individual species cannot be recognized because of the small size of the fragments. Minor components, which form ~ 5% of grains in this facies, include very fine-grained and heavily micritized grains that are unidentifiable. These grains are probably fragments of the micrite groundmass derived from breakdown of the composite grains

Figure 3.1: **(A)** Core photo of the Composite Grain Facies illustrating the clay to silt-sized composite grains.
(B) Thin section photo of the Composite Grain Facies illustrating skeletal components embedded in a micrite groundmass.

Distribution: The Composite Grain Facies always lies on the bedrock surface (Fig 3.2; 3.4, 3.5). It is overlain by the Mangrove Peat Facies in the central part of the lagoon in cores B13, EB42, EB43, EB44 and by the *Halimeda* Facies along the southern margin of the lagoon in cores B6, B14, and EB41 (Fig. 3.2; 3.3; 3.4; 3.5). This facies has a lateral extent of ~ 2 km north-south, and ~ 3 km east-west. It attains a maximum thicknesses of ~ 1 m in core EB42 and 0.5 m in core B6, and decreases in thickness to the north.

Interpretation: Sediments of the Composite Grain Facies are probably derived from the limestone bedrock on which they are deposited. The presence of a micrite groundmass between the skeletal components, suggests that the grains were derived from a hard ground or limestone bedrock. Subsequent erosion of the bedrock, through wave action (cores B6, and B14) and organisms boring into the hard substrate (cores B6, B13, and B14), probably produced the composite grains. The bedrock from which the composite grains originated is probably the Ironshore Formation. Both the Composite Grain Facies and the Ironshore Formation are composed of white to light beige limestones that contain similar fossils. Skeletal components common to both include bivalves, gastropods, and benthic foraminifera.

Fine-grained sediments of this facies were probably deposited in shallow (< 2 m), low-energy lagoonal waters that allowed fine-grained sediments to settle out of suspension. Exposure of the sediments to high-energy water would have resulted in erosion.

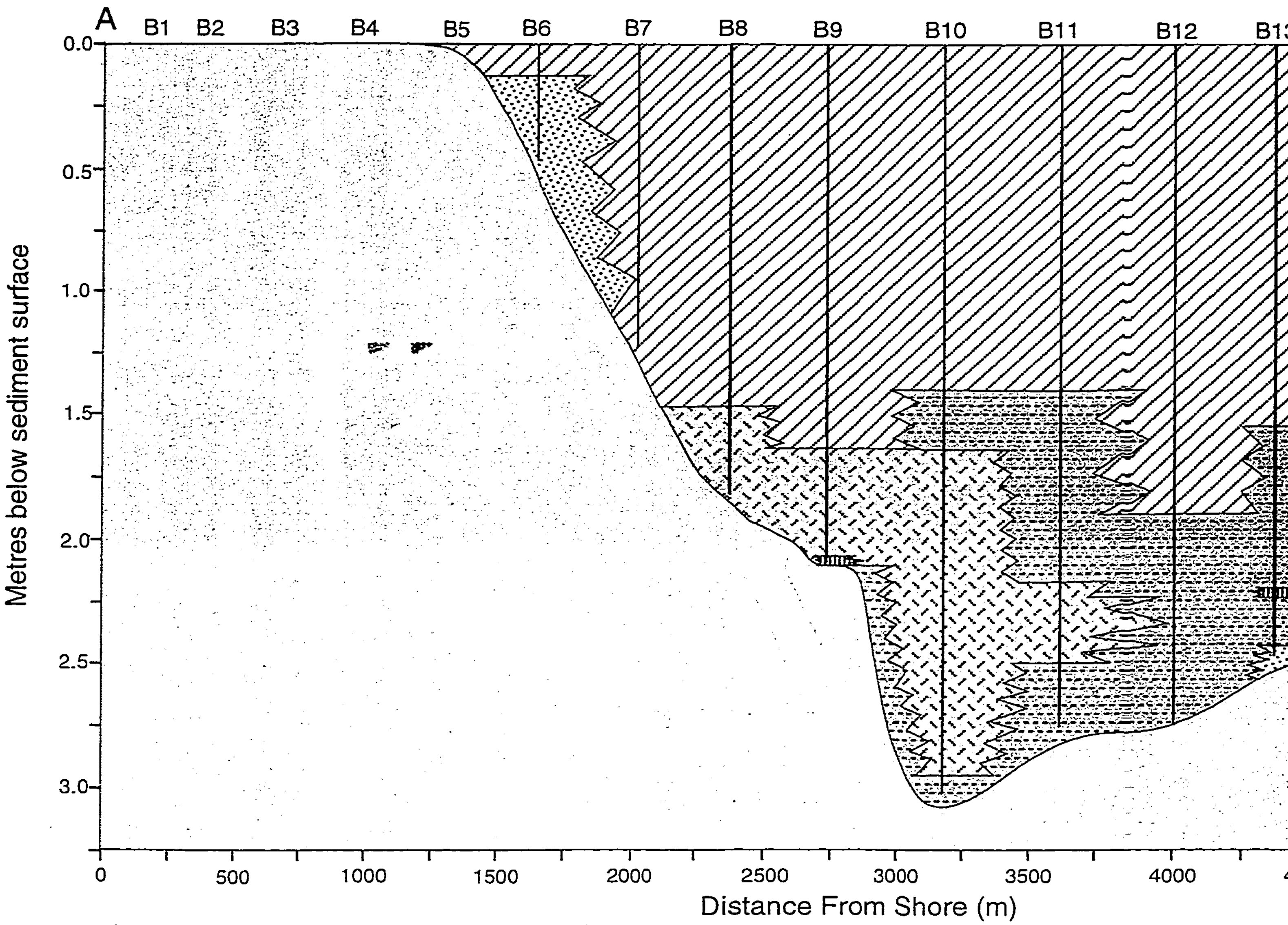
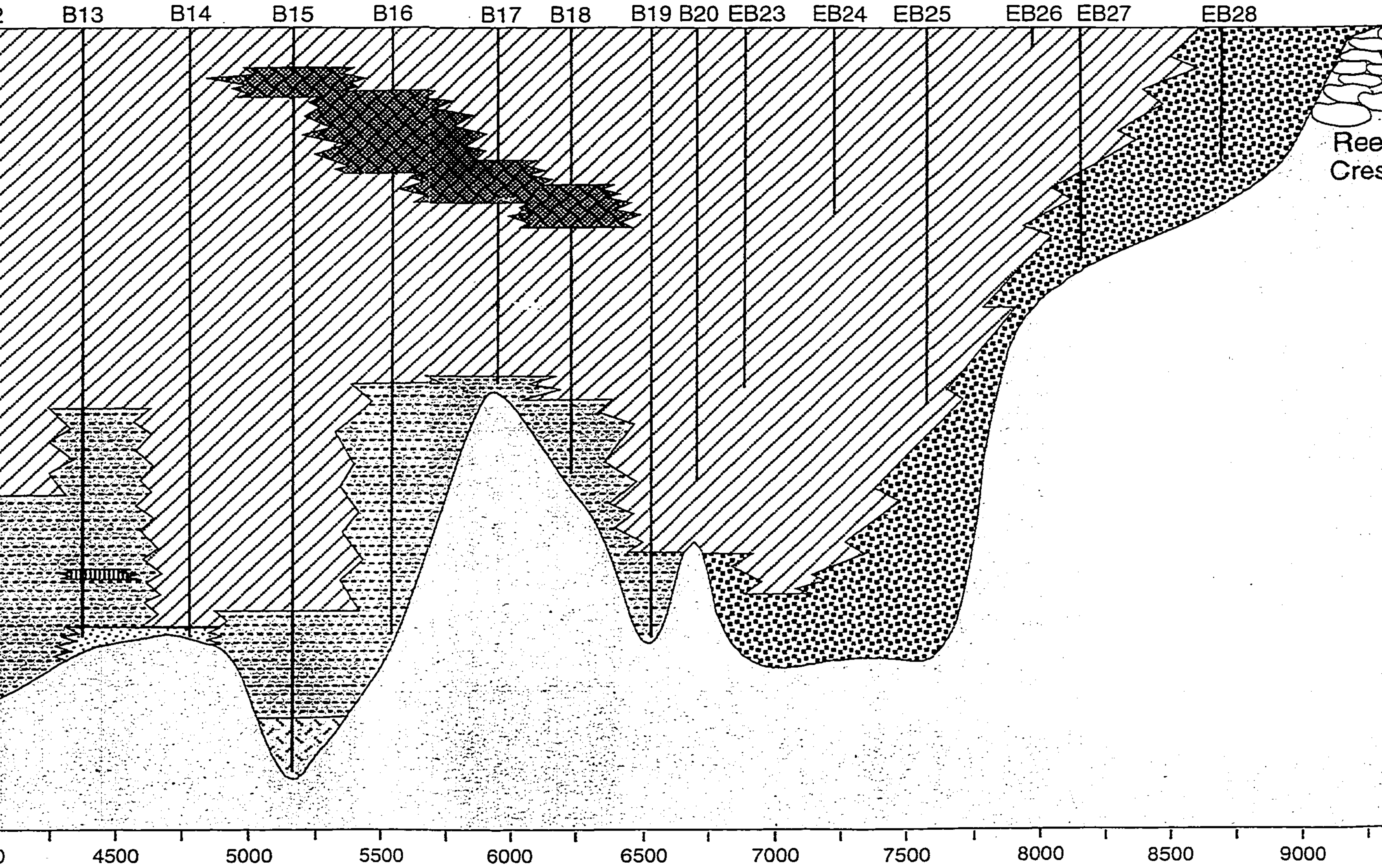
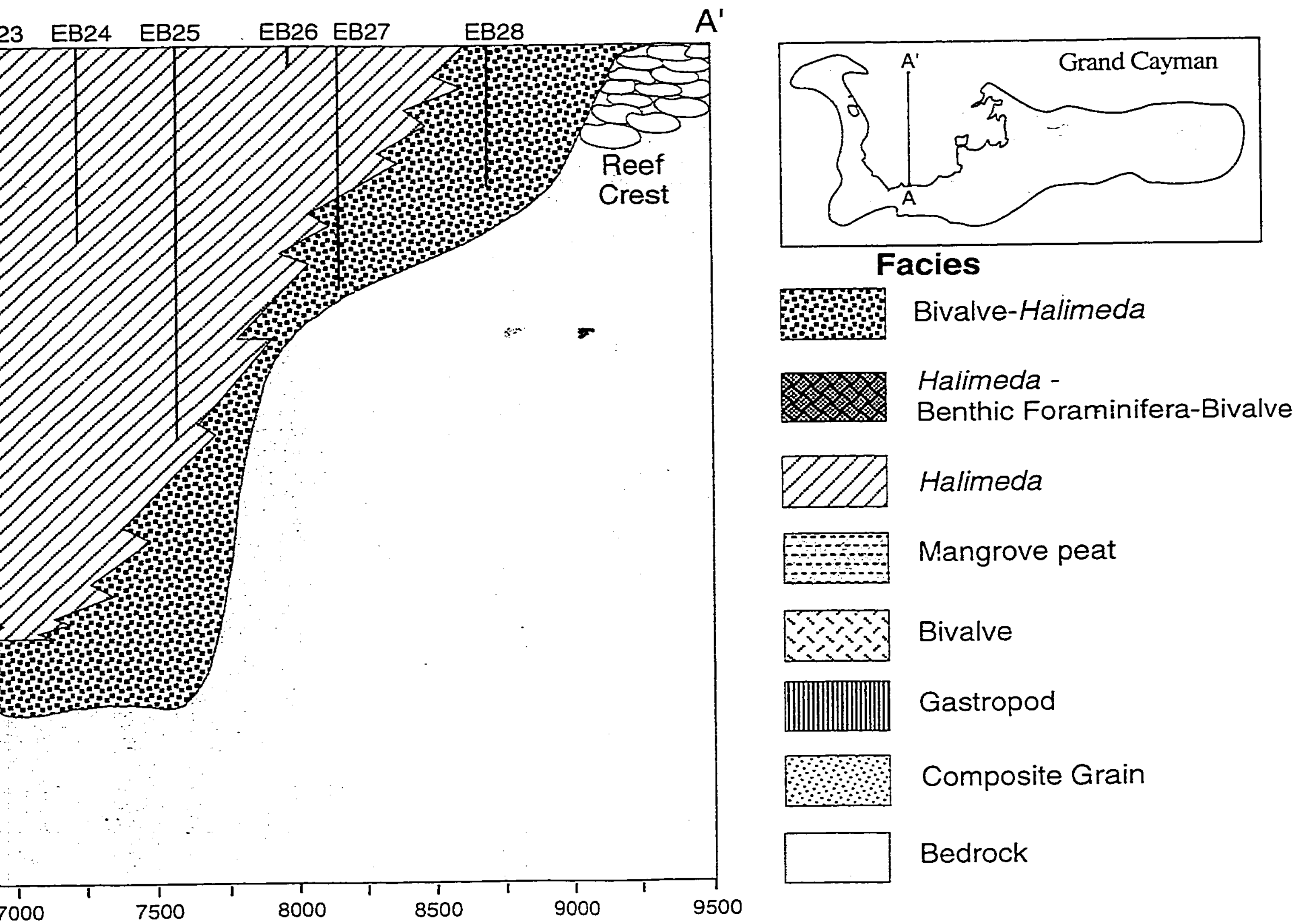


Figure 3.2: Cross-section of the North-South transect across North Sound illustratiı ng core locat



ore locations and facies distribution.


23
EB24
EB25
EB26
EB27
EB28
A'
Reef
Crest
7000
7500
8000
8500
9000
9500
A'
Grand Cayman
A
Facies
Bivalve-*Halimeda*
Halimeda -
Benthic Foraminifera-Bivalve
Halimeda
Mangrove peat
Bivalve
Gastropod
Composite Grain
Bedrock

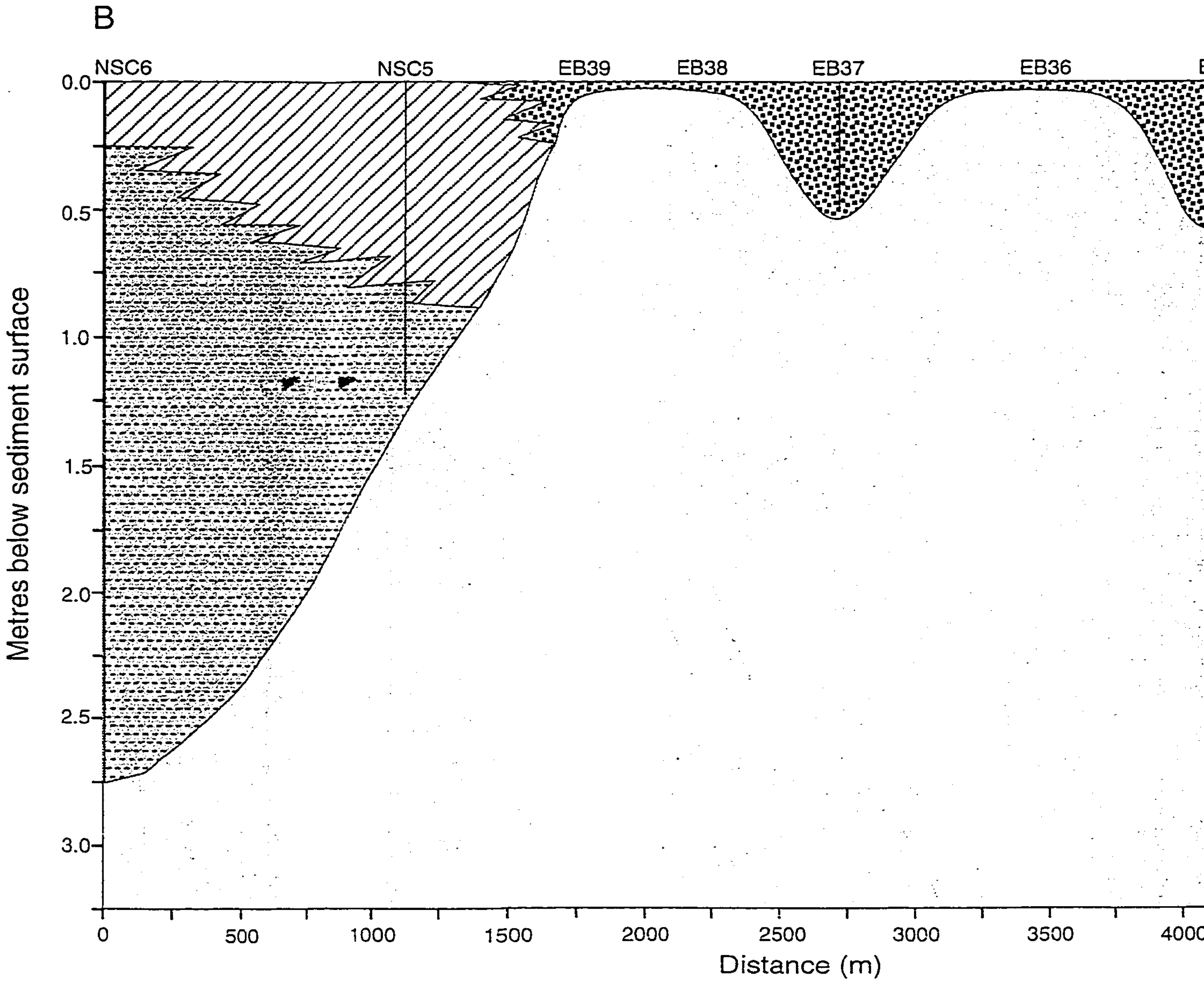
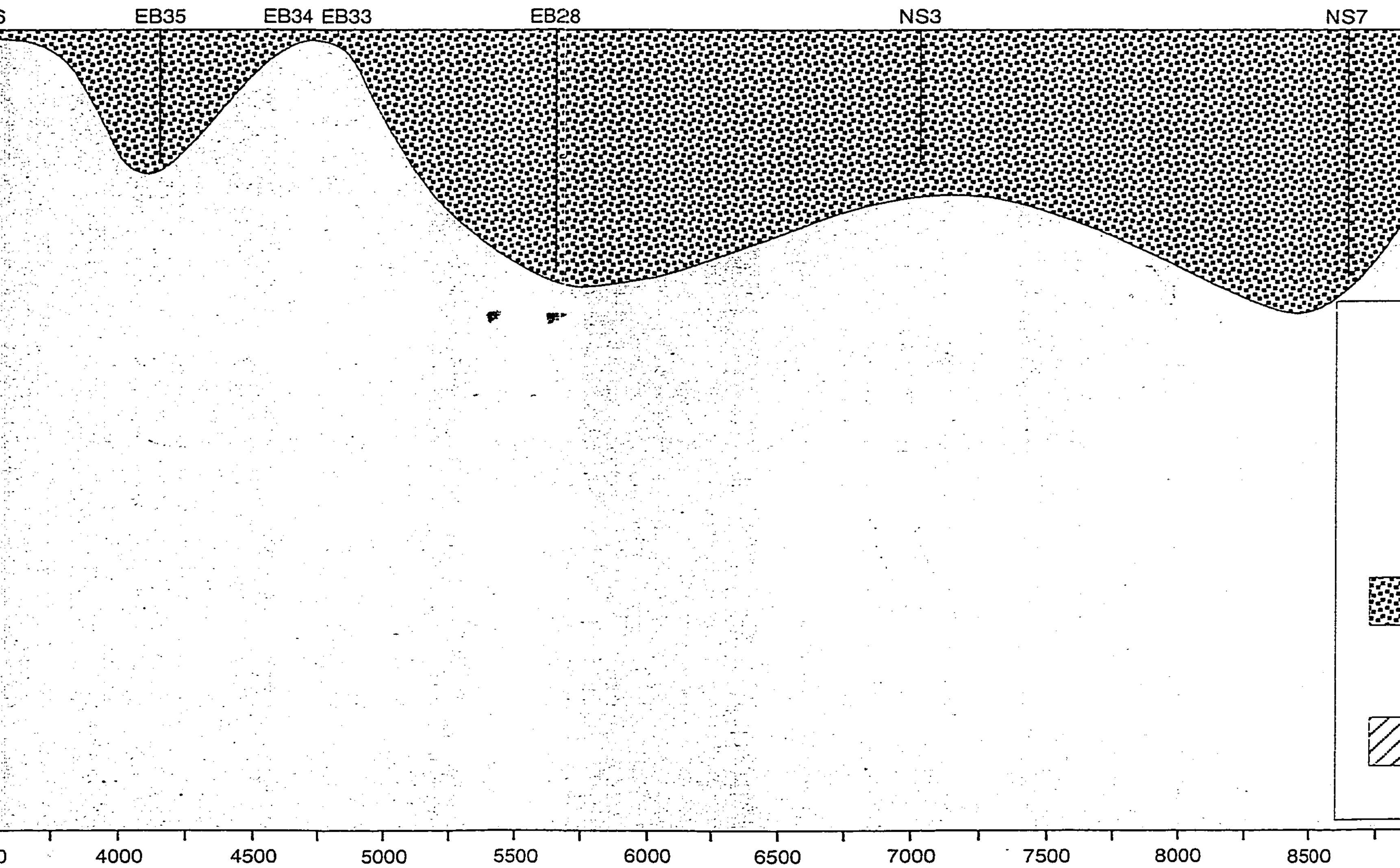
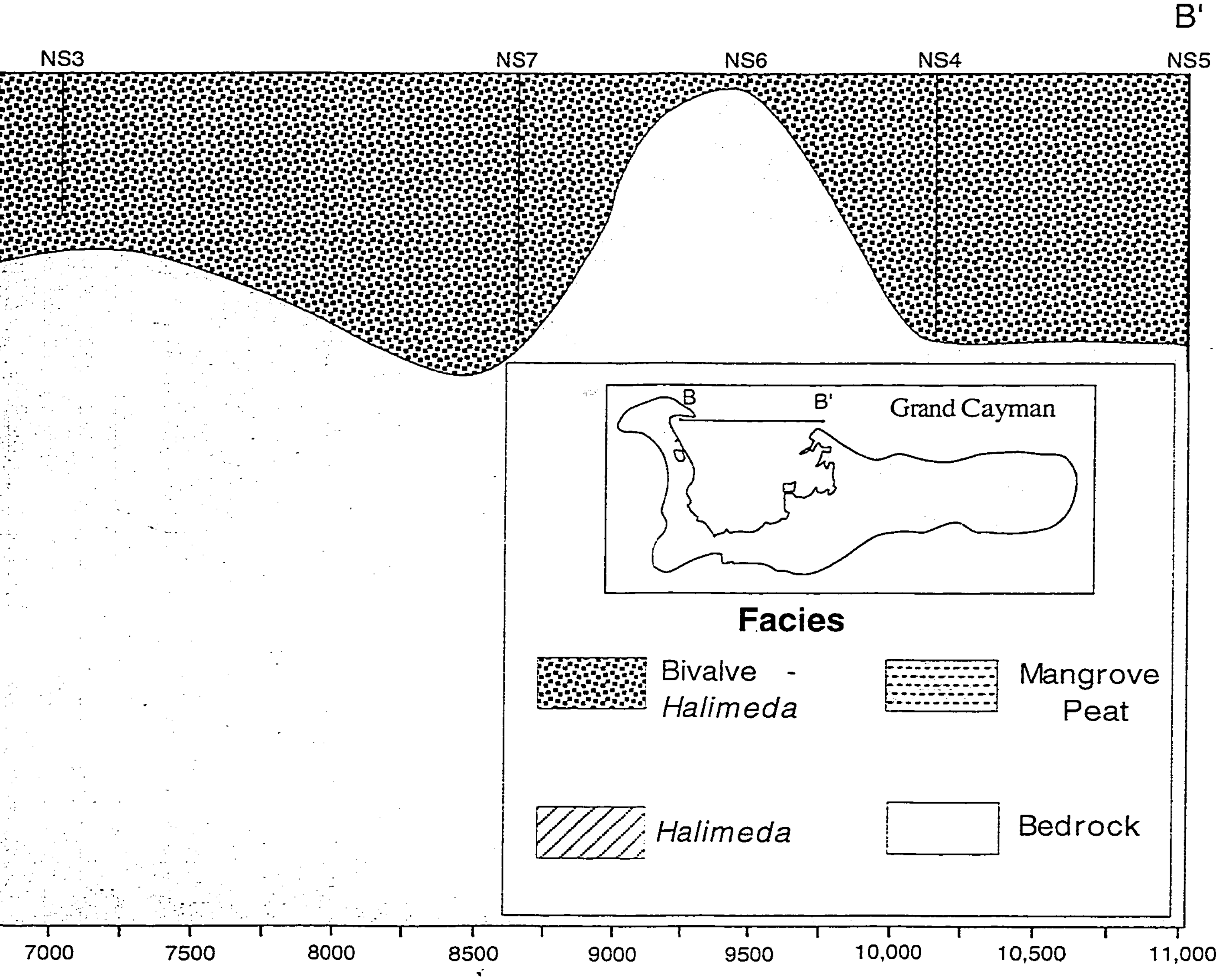


Figure 3.3: Cross-section of the west-east transect across North Sound illustrating core



trating core locations and facies distribution.


B'
NS3
NS7
NS6
NS4
NS5
B
B'
Grand Cayman
Facies
Bivalve - Halimeda
Mangrove Peat
Halimeda
Bedrock
7000
7500
8000
8500
9000
9500
10,000
10,500
11,000

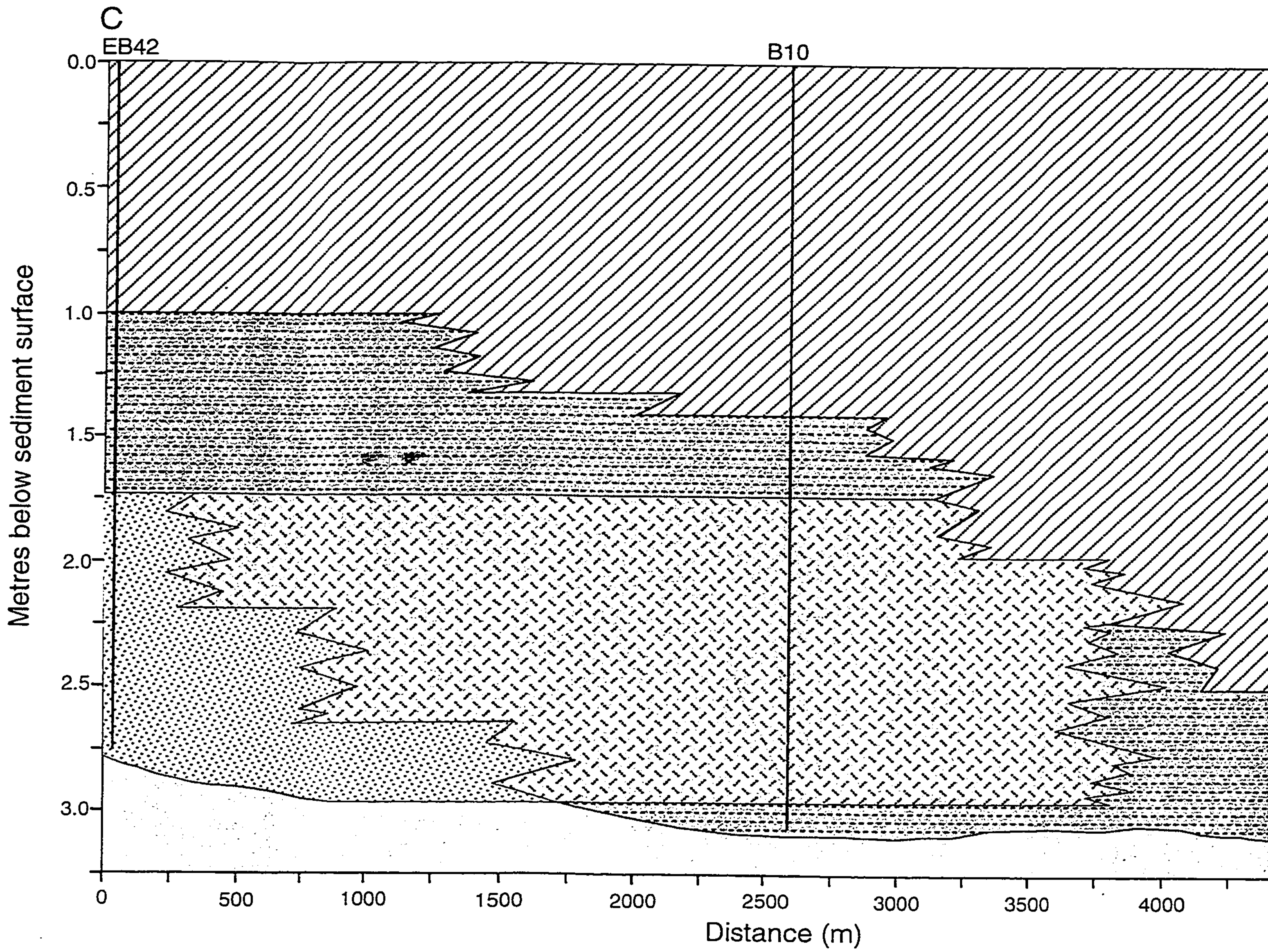
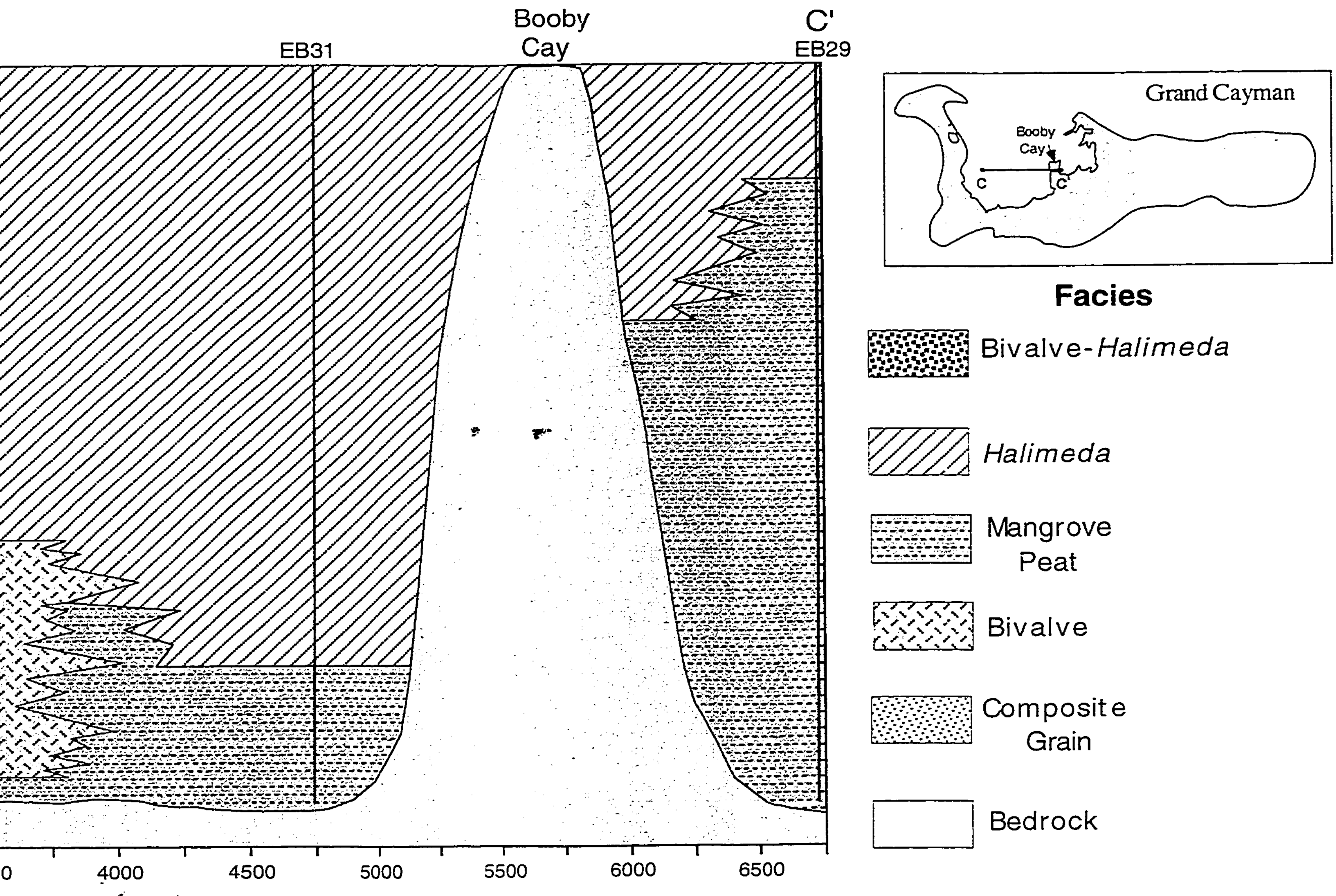
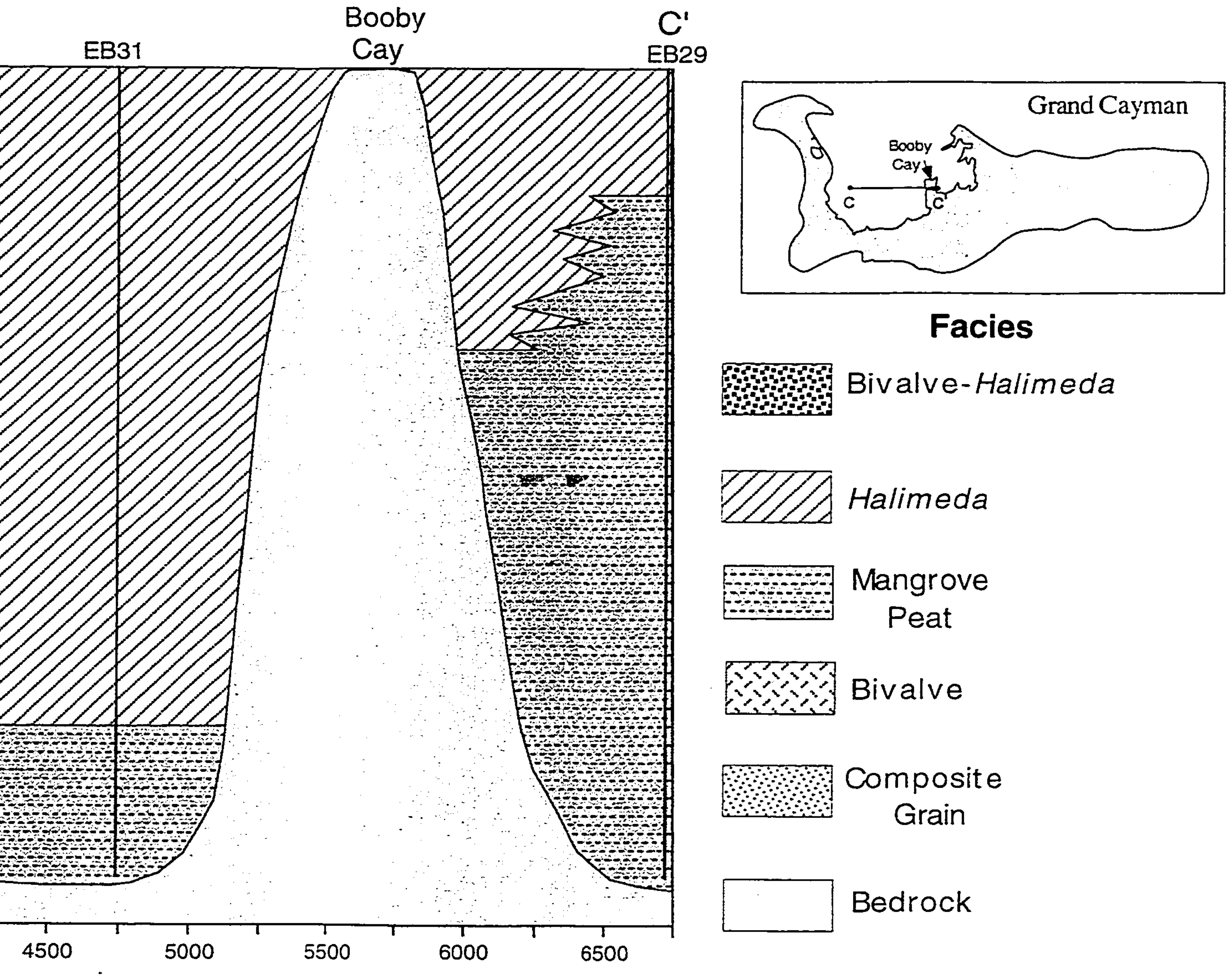


Figure 3.4: Cross-section between cores EB42, B10, EB31, and EB29 across North Sound illu



ss North Sound illustrating core locations and facies distribution.



lustrating core locations and facies distribution.

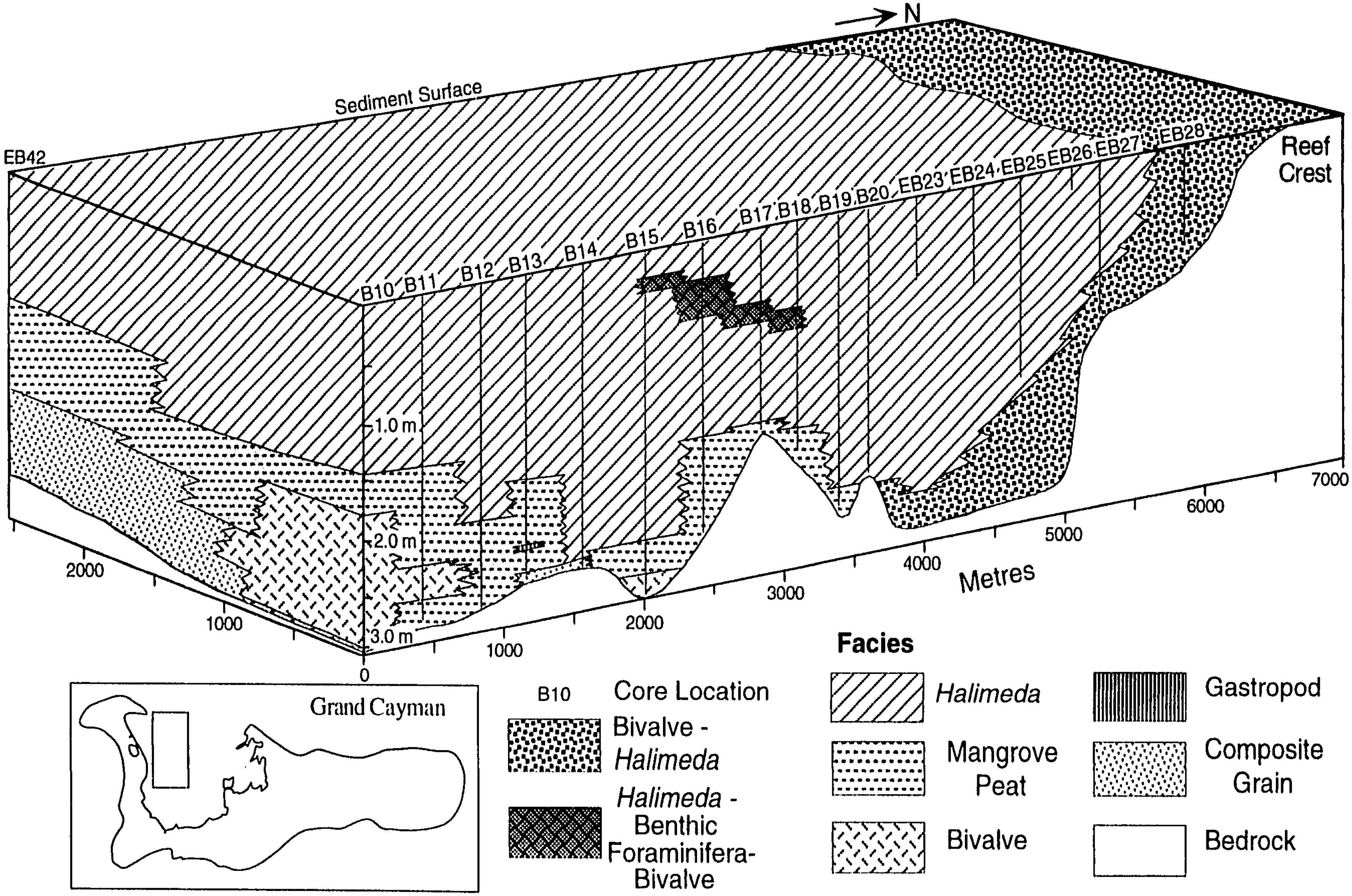


Figure 3.5: Block diagram of the Northwestern part of North Sound illustrating facies distribution. Top of block is representative of a flat sediment surface.

3.3.2 Gastropod Facies

Description: The Gastropod Facies consists of numerous (~ 90%) small gastropods that average 2.0 mm in length, have a diameter of 1.5 mm, and an aperture length of ~ 1.0 mm (Fig. 3.6A). They are intermixed with a small amount (~ 10%) of organics (Fig. 3.6A). The gastropods belong to the species *Amnicola forsythi*, which was described by Pilsbry (1930) in his study of the land and freshwater molluscs of Andros, Bahamas.

Distribution: The Gastropods Facies, located at the base of core B9, is deposited on the bedrock surface and is overlain by the Bivalve Facies (Fig. 3.3; 3.5). In core B13, however, the Gastropod Facies consists of a ~ 7 cm thick lens within the Mangrove Peat Facies (Fig. 3.2; 3.5). The lateral extent of the facies is unknown because it is less than the distance between the core locations (~ 1.5 km).

Interpretation: *Amnicola forsythi* is a freshwater or slightly brackish water species (Pilsbry, 1930), indicating that the facies is of a freshwater origin. The gastropods probably inhabited the mangrove environment to seek shelter, food, etc. among the dense mangrove roots. Water energy was probably low, because high-energy waters would have removed the fine-grained organics. Water depth was probably < 1 m, since mangroves rarely grow in waters deeper than this.

3.3.3 Bivalve Facies

Description: The Bivalve Facies (Fig. 3.6B) consists almost entirely (90%) of the bivalve *Mytilopsis domingensis* which is more commonly known as the "false mussel" (Conrad,

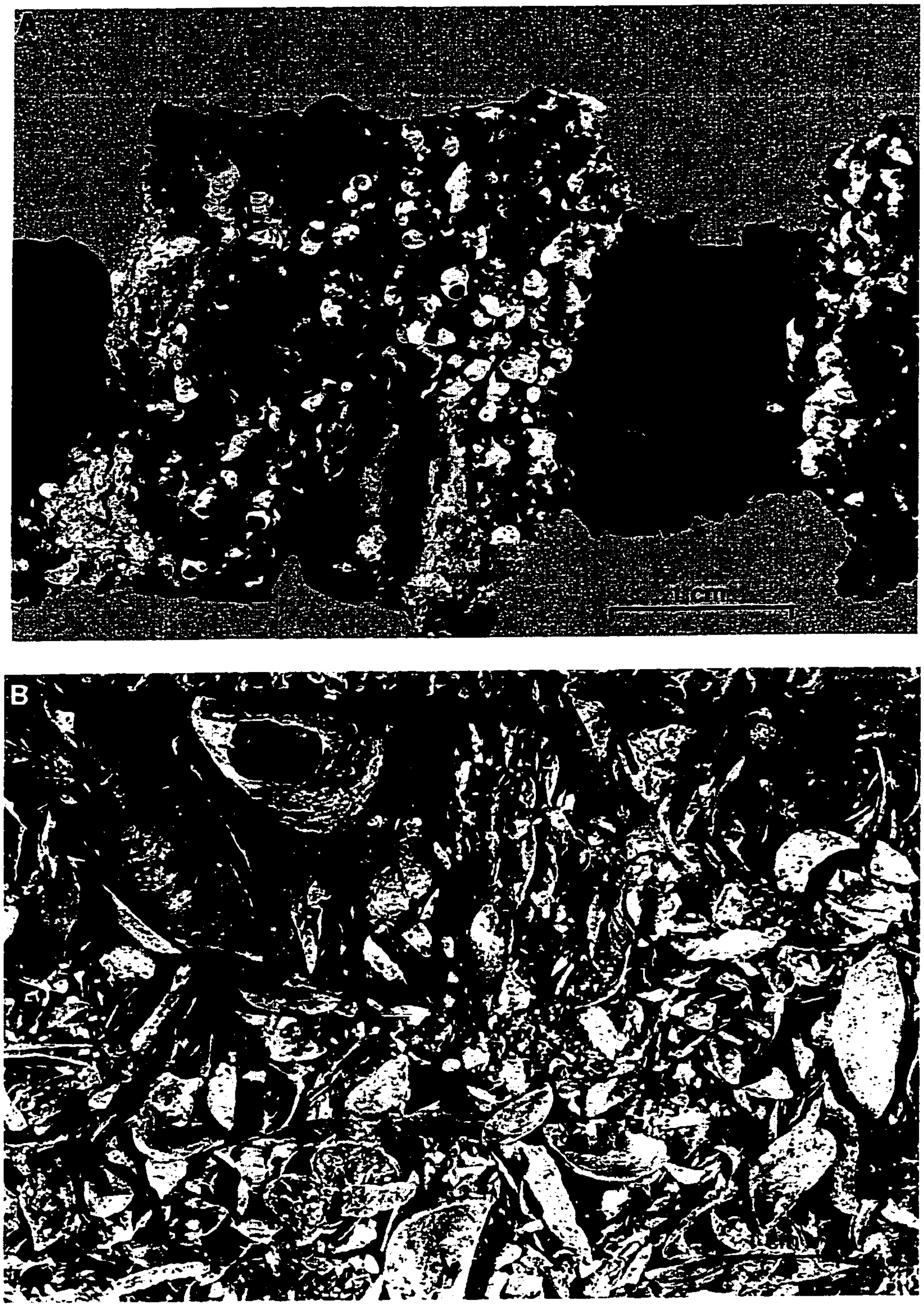


Figure 3.6: **(A)** Core photo of the Gastropod Facies showing abundant *Amnicola forsythi* shells ~ 2.0 mm long. **(B)** Core photo of the Bivalve Facies showing whole and fragmented *Mytilopsis domingensis* shells.

1857). This species, belonging to the family Dreissenidae, is identified by its mussel-like shape, greyish white color, and an interior splotched with dark-grey (Warmke and Abbott, 1962). Most shells in this facies lack the dark-brown periostracum that characterize living shells. The bivalves are thin and fragile, disarticulated with rare articulated shells, and mostly whole but commonly fragmented (Fig. 3.6B). The shells, which are 1.5 to 2.5 cm long, are intermixed with a small amount (~ 5%) of fine-grained organics (Fig. 3.6B). Sediments are generally silt-sized to pebble-sized bivalves (0.04–64 mm), and moderately to poorly-sorted.

Distribution: The Bivalve Facies lies above bedrock in cores B8, B15, above the Mangrove Peat Facies in cores B10 and B11, and above the Gastropod Facies in core B9 (Fig. 3.2; 3.5). It is overlain by the Mangrove Peat Facies in core B10, B11, B15 and by the *Halimeda* Facies in cores B8, and B9. This facies, restricted to the center of the lagoon, has a lateral extent of ~ 2.0 km north-south. Facies thickness increases shoreward from ~ 0.10 m in core B15 to 0.60 m in core B9.

Interpretation: The bivalve *Mytilopsis domingensis* grows attached to rocks or branches, typically in brackish to fresh water (Warmke and Abbott, 1962). The delicate and thin-shelled nature of these bivalves is consistent with forms that attach themselves to mangrove roots (cf. Stenzel, 1971). In addition, the Bivalve Facies is overlain by a succession of peat in cores B10 and B11. The Bivalve Facies probably represents the bivalves that attached themselves to the prop roots of mangrove trees. As such, it was probably deposited in swamp waters.

Low-energy waters in mangrove swamps prevented damage to the delicate, thin shells of *Mytilopsis domingensis* (*cf.* Stenzel, 1971). Water depths were probably < 1 m, because mangroves rarely grow in waters deeper than this.

3.3.4 Mangrove Peat Facies

Description: The Mangrove Peat Facies (Fig. 3.7) is characterized by dark brown to black organic–rich sediments, that probably originated in mangrove swamps. Sediments are generally well-sorted. The organics are fine-grained (< 0.06 mm), with the exception of scattered wood fragments, ~ 1.5 cm long, found in core NSC#3. The wood fragments probably came from mangrove trees. Rare bivalves (*Chione cancellata*, family Veneridae) are scattered throughout the peat. This species was found by Abott (1958) wherever there is clear sand and water 1.5-9 m deep, during his study of the marine molluscs of Grand Cayman. The bivalves are articulated, disarticulated, mostly whole and exhibit a low degree of micritization. This facies is commonly intermixed with sediments derived from the overlying *Halimeda* Facies. Intermixing probably resulted from bioturbation.

Distribution: The Mangrove Peat Facies overlies bedrock over most of the lagoon. In core B15, however, it overlies the Bivalve Facies, and in cores B13 and B14 it overlies the Composite Grain Facies (Fig. 3.2; 3.3; 3.4; 3.5). It is overlain by the *Halimeda* Facies over most of the lagoon; however, in cores B10 and B11 it is overlain by the Bivalve Facies, and by the Gastropod Facies in core B9. A small lens of the Gastropod Facies is encased by the Mangrove Peat Facies in core B13.

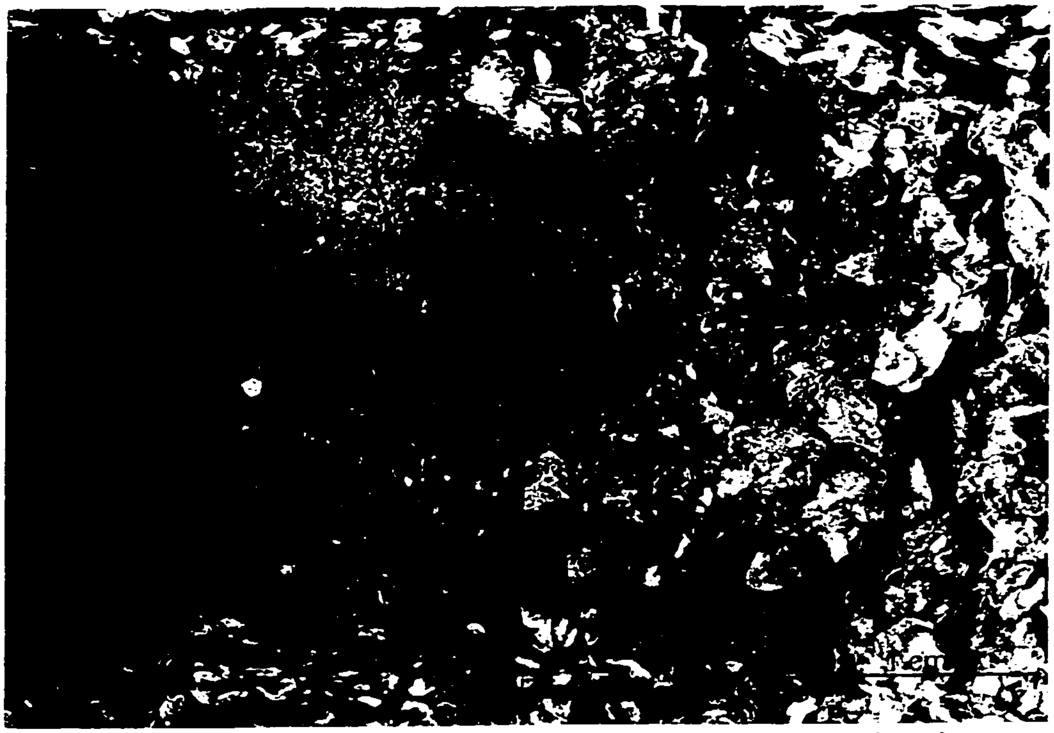


Figure 3.7: Core photo of the Mangrove Peat Facies showing intermixing with the overlying *Halimeda* Facies.

The sharp contact between light colored sediments of the Composite Grain Facies and dark, rich peat of the Mangrove Peat Facies is obvious in core (Fig. 3.7). A sharp contact also separates the Bivalve and Mangrove Peat Facies. In contrast, the contact between the Mangrove Peat and the overlying *Halimeda* Facies is typically irregular. Peats are commonly intermixed with the overlying *Halimeda* Facies. The facies extends laterally for 5 km north-south, and probably extends the entire width of the lagoon (~ 10 km) east-west. A maximum thickness of ~ 1.0 m is found in the central parts of the lagoon.

Interpretation: Similarities between organics found in this facies and the peats being deposited at present in North Sound (e.g. Little Sound-top of core EB29), suggest that the organics were probably derived from mangrove swamps. In addition, the presence of bivalves in the peat indicates that the peat was deposited in an intertidal to subtidal area. Mangroves are one of the few plants that can survive beneath the water surface.

The Bivalve Facies, which is overlain by the Mangrove Peat Facies in core B10, B11, and B15, contains the bivalve *Mytilopsis domingensis*. This species is found in brackish to fresh water, which indicates that the peat was probably deposited in brackish to fresh waters before saline waters entered North Sound. In contrast, the marine bivalve *Chione cancellata* was found in the upper parts of the Mangrove Peat Facies above the Bivalve Facies. This suggests that during deposition of the Mangrove Peat Facies, marine water invaded the freshwaters that were originally present in North Sound.

At the time of deposition, the mangrove swamps probably occupied a more extensive area than today (Fig. 3.2; 3.3; 3.4; 3.5). As sea level rose, the mangrove swamps gradually retreated in a shoreward direction, where shallow waters (< 2 m) prevailed. Peats were produced as roots and leaves from the mangrove trees were deposited in the swamp waters, and continuously buried beneath layers of organic debris. Mangroves have many prop roots that attach the tree to the substrate and transport nutrients (Scoffin, 1970). Bivalves found on the soft peat of the mangroves, were buried along with the peat.

Mangroves are rarely found growing in waters deeper than 1 m, thus the Mangrove Peat Facies was deposited in shallow (< 1 m), low-energy water. The dense mesh of prop roots acts as a baffle for currents, and water velocities decrease to almost 0 cm/s upon entering the mangrove swamps (Scoffin, 1970).

Fragmentation of shells in the Mangrove Peat Facies is low. This indicates that sediment accumulation was relatively rapid, and/or the sediments were well protected from high-energy waters. Moderate to strong currents would have eroded the fine-grained peat. Intermixing of sediments with the overlying facies, however, suggests that the upper portion of this facies was subjected to minor bioturbation or reworking by moderate to high-energy waters created by passing storms.

3.3.5 *Halimeda* Facies

Description: The *Halimeda* Facies (Fig. 3.8) is characterized by a high content (40-50%) of disarticulated, whole, and fragmented *Halimeda* plates. Skeletal components are predominantly medium sand-sized to granule sized (0.25-4 mm) with large bivalves (< 40 mm long), and are moderately-sorted. This facies typically includes numerous *Halimeda* plates (40-50%), benthic foraminifera (peneroplid, *Archaias*, miliolid, *Homotrema rubrum*) (5-10%), along with fewer bivalves (*Chione cancellata; Glycymeris? sp.; Codakia? sp.*), gastropods, coral fragments, and composite grains (Table 3.1; Fig. 3.9). The numerous *Halimeda* plates are responsible for the light to dark grey color of the sediments. In cores B13, B14, and B15, *Halimeda* grade from disarticulated, whole plates with scattered large bivalve shells at the base of the facies to disarticulated, fragmented *Halimeda* plates near the top of the facies. Benthic foraminifera, which are whole and fragmented, have generally undergone little micritization. *Halimeda* grains are commonly entensively micritized, and have a high degree of fragmentation. Approximately 30% of the skeletal components are unidentifiable because of the extensive micritization, and/or the small grain size (< 0.25 mm).

Distribution: In the central part of the lagoon, the *Halimeda* Facies overlies the Mangrove Peat Facies, except in cores B8 and B9 where it overlies the Bivalve Facies (Fig. 3.2; 3.3; 3.4; 3.5). To the north it interfingers the Bivalve-*Halimeda* Facies, whereas to the south it interfingers with the Composite Grain Facies (Fig. 3.2; 3.3; 3.4; 3.5). The upper boundary of this facies is exposed at the sediment–water interface over most of the lagoon. This facies is the most extensive in North Sound, having a lateral extent of 7 km north-south, and 7 km east-west. In the south-central part of the lagoon (core B15) it is up to 2 m thick. Thickness decreases towards the periphery of the lagoon (Fig. 3.2; 3.3; 3.4; 3.5).

Interpretation: Sediments in the *Halimeda* Facies are derived largely from the breakdown of *Halimeda*. Present day sediments that are being deposited beneath dense

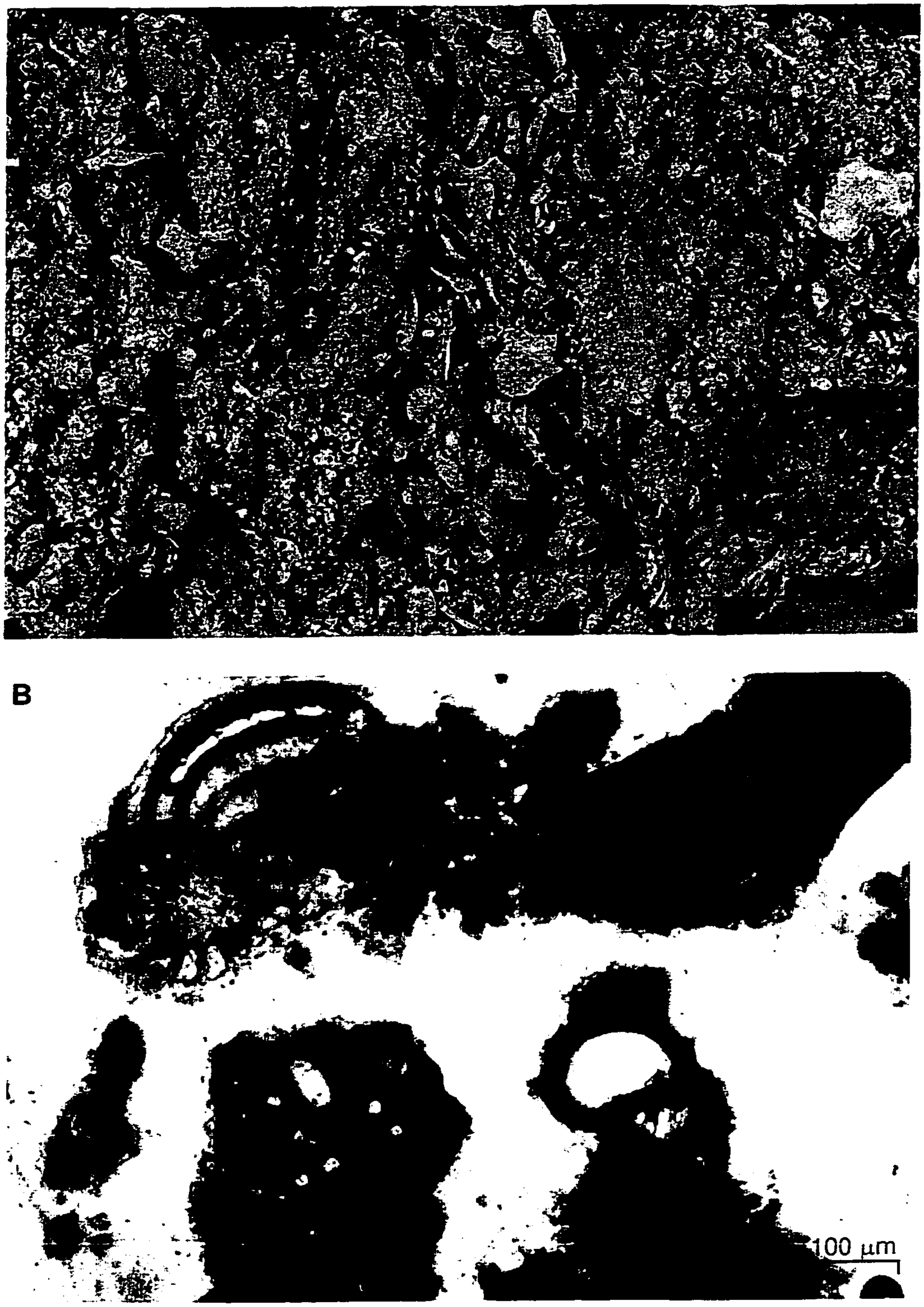


Figure 3.8: **(A)** Core photo of the *Halimeda* Facies showing *Halimeda* fragments. **(B)** Thin section photo of the *Halimeda* Facies showing the micritized *Halimeda* fragments.

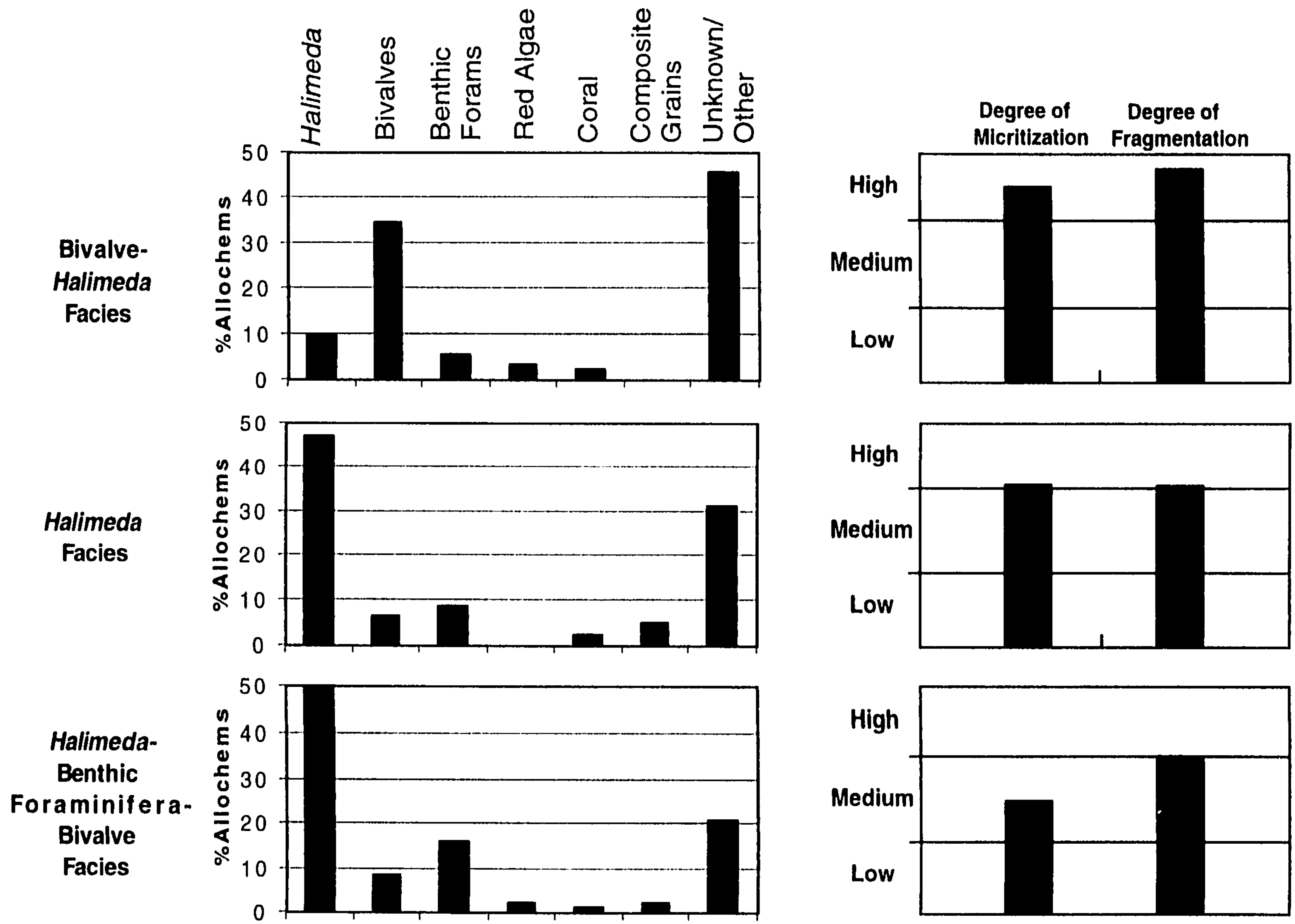


Figure 3.9: Comparison of allochem abundance, degree of micritization, and degree of fragmentation in the three sand-sized facies including the Bivalve-*Halimeda*, *Halimeda*, and *Halimeda*-Benthic Foraminifera-Bivalve Facies.

Thalassia meadows have characteristics similar to those of the *Halimeda* facies. Studies have shown that micritization of *Halimeda* grains is a major source of carbonate muds (Shinn *et. al.*, 1989; Lowenstam, 1955; Stockman *et. al.*, 1967; Neumann and Land, 1975; Land, 1970; Patriquin, 1972; Nelsen and Ginsburg, 1986; Reid *et. al.*, 1992). Micritization of *Halimeda* begins when the alga is still alive, and continues on the shallow seafloor after death (Macintyre and Reid, 1995; Reid and Macintyre, 1998).

The seagrass *Thalassia testudinum* was probably very abundant in this facies. Recognizing the presence of *Thalassia* in sedimentary deposits is almost impossible because it decays rapidly and preservation is rare (Jones and Desrochers, 1992). The presence of *Thalassia* may be identified by poor sorting of sediments, the presence of mound-like structures, and/or by the nature of encrusting biota (Jones and Desrochers, 1992). Sediments in the *Halimeda* facies were subjected to bioturbation and reworking that destroyed any sedimentary structures, such as bedding, that were initially present. The homogenization of sediments by bioturbation or reworking would have removed any areas of poorly sorted sediments, and/or mound-like structures.

The *Halimeda* Facies was deposited in moderate to deep waters (< 6 m) of low to moderate energy. *Halimeda* inhabits modern depositional environments with similar conditions (Roberts, 1976; Roberts and Sneider, 1982; MacIntyre and Reid, 1995; Kalbfleisch, 1995; Kalbfleisch and Jones, 1997). Kalbfleisch (1995) and Kalbfleisch and Jones (1998) found *Halimeda* inhabiting the shallow waters (0.5-2.0 m) of Frank Sound and Pease Bay, Grand Cayman.

Skeletal grains in the *Halimeda* Facies are generally fragmented. The northern portion of this facies must have been frequently subjected to the forces of passing storms and hurricanes because of its close proximity to the reef crest. The high degree of micritization of skeletal components suggests that the sediments were exposed at the surface for a relatively long period before eventually being buried.

3.3.6 *Halimeda*–Benthic Foraminifera-Bivalve Facies

Description: The most obvious characteristic of the *Halimeda*-Benthic Foraminifera-Bivalve Facies (Fig. 3.10A and B) is the numerous (7-11%) articulated, and disarticulated bivalve (*Anadara?* sp.; *Codakia?* sp.) and gastropod (*Astraea?* sp.) shells. The bivalves are predominantly epifaunal (*Codakia?* sp.), but infaunal species (*Anadara?* sp.) are also common. Grain size is medium sand to large bivalves (0.25-64 mm), and moderately to poorly sorted. The high percentage of fine-grained materials gives the facies a light to dark grey color. This facies consists of *Halimeda* (30-65%), benthic foraminifera (*Homotrema rubrum*, Miliolid) (6-34%), bivalves (7-11%) and minor amounts (< 6%) of composite grains, gastropods, red algae, coral fragments, and echinoderms (Table 3.1; Fig. 3.9). The percentage of bivalves (7-11%) may be slightly underestimated, because the larger shell fragments that are common throughout the facies were not included in the analysis. The large size difference between the articulated bivalves and the highly fragmented bivalves in thin section makes it almost impossible to calculate a percentage that accurately accounts for both size distributions. *Halimeda* plates are disarticulated, whole and fragmented and partially to extensively micritized. Benthic foraminifera are

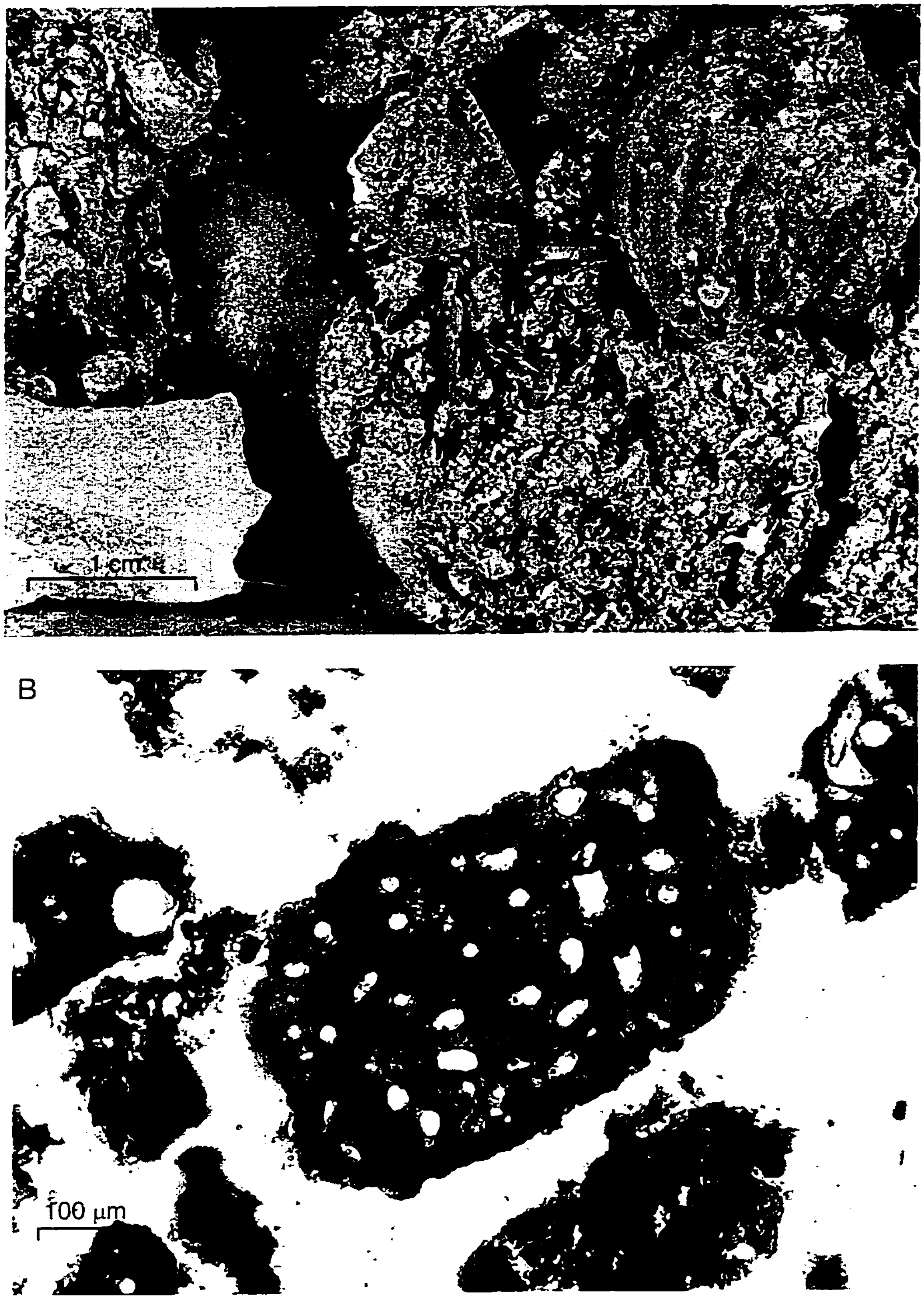


Figure 3.10: **(A)** Core photo of the *Halimeda*-Benthic Foraminifera-Bivalve Facies showing large shells. **(B)** Thin section photo of the *Halimeda*-Benthic Foraminifera-Bivalve Facies showing micritized *Halimeda* fragments.

commonly fragmented, and with low degrees of micritization. Bivalves are articulated and disarticulated, whole and fragmented, with the larger bivalves being mostly whole.

Distribution: The *Halimeda*-Benthic foraminifera-Bivalve Facies forms a lens in the center of the lagoon that is encased by the *Halimeda* Facies (Fig. 3.2; 3.5). The lens is 1.5 km long north-south, and < 1 km east-west. This facies is 0.2 - 0.3 m thick.

Interpretation: Deposition of the *Halimeda*-Benthic Foraminifera-Bivalve Facies probably took place in dense *Thalassia* meadows. Sediments found in the modern *Thalassia* meadows are similar to those in the *Halimeda* Facies, with the exception of a higher content of bivalves and a slightly higher percentage of benthic foraminifera. Bivalves and benthic foraminifera may have been buried more rapidly and better preserved in denser *Thalassia*.

Waters of the *Halimeda*-Benthic Foraminifera-Bivalve Facies were moderate to deep (< 6 m). Water energies were relatively low. The high degree of articulation of many of the bivalves, both epifaunal and infaunal, suggests that sediments were subjected to little abrasion.

The degree of fragmentation of sediments in the *Halimeda*-Benthic Foraminifera-Bivalve Facies is variable. Fragmentation and micritization of fine-grained sediments in this facies is similar to the *Halimeda* Facies. In contrast, articulated and disarticulated bivalve shells are mostly whole, suggesting that bivalves were rapidly buried before fragmentation.

3.3.7 Bivalve–*Halimeda* Facies

Description: The Bivalve-*Halimeda* Facies (Fig. 3.11) is recognized by its coarse-grain size, the presence of *Homotrema rubrum* (recognized by its characteristic reddish color), and its high content of bivalve shell fragments. Skeletal components are coarse-sand sized (0.50-2 mm) and well to moderately-sorted. This facies is formed of bivalves (30-40%), *Halimeda* plates (10%), and minor amounts (< 6%) of red algae and benthic foraminifera (Table 3.1; Fig. 3.9). Echinoderms are represented by spines (< 2 mm long). The high percentage (30–40%) of grains derived from bivalves is responsible for the overall light beige color of this facies. Bivalves and *Halimeda* plates are disarticulated with moderate to high degrees of fragmentation. The red algae and benthic foraminifera display lower degrees of fragmentation. Most of the allochems are partially micritized, with ~ 45% of the grains being unidentifiable due to extensive micritization. Most allochems have rounded edges, indicating a fair amount of abrasion.

Distribution: The Bivalve-*Halimeda* Facies is located in the most northern part of the lagoon where it forms a band, up to ~ 1 km wide, on the landward side of the reef crest (Fig. 3.2; 3.3; 3.5). It directly overlies bedrock and interfingers with the *Halimeda* Facies to the south. This facies is up to 0.7 m thick in core EB28, and decreases in thickness towards the reef crest. It has a lateral extent of ~ 1.0 km in a north-south direction, and ~ 10 km in an east-west direction.

Interpretation: Deposition of the Bivalve-*Halimeda* Facies took place immediately behind the reef crest. The abundance of red algae in this facies suggests that many grains were derived from the reef, because red algae are commonly found encrusting the

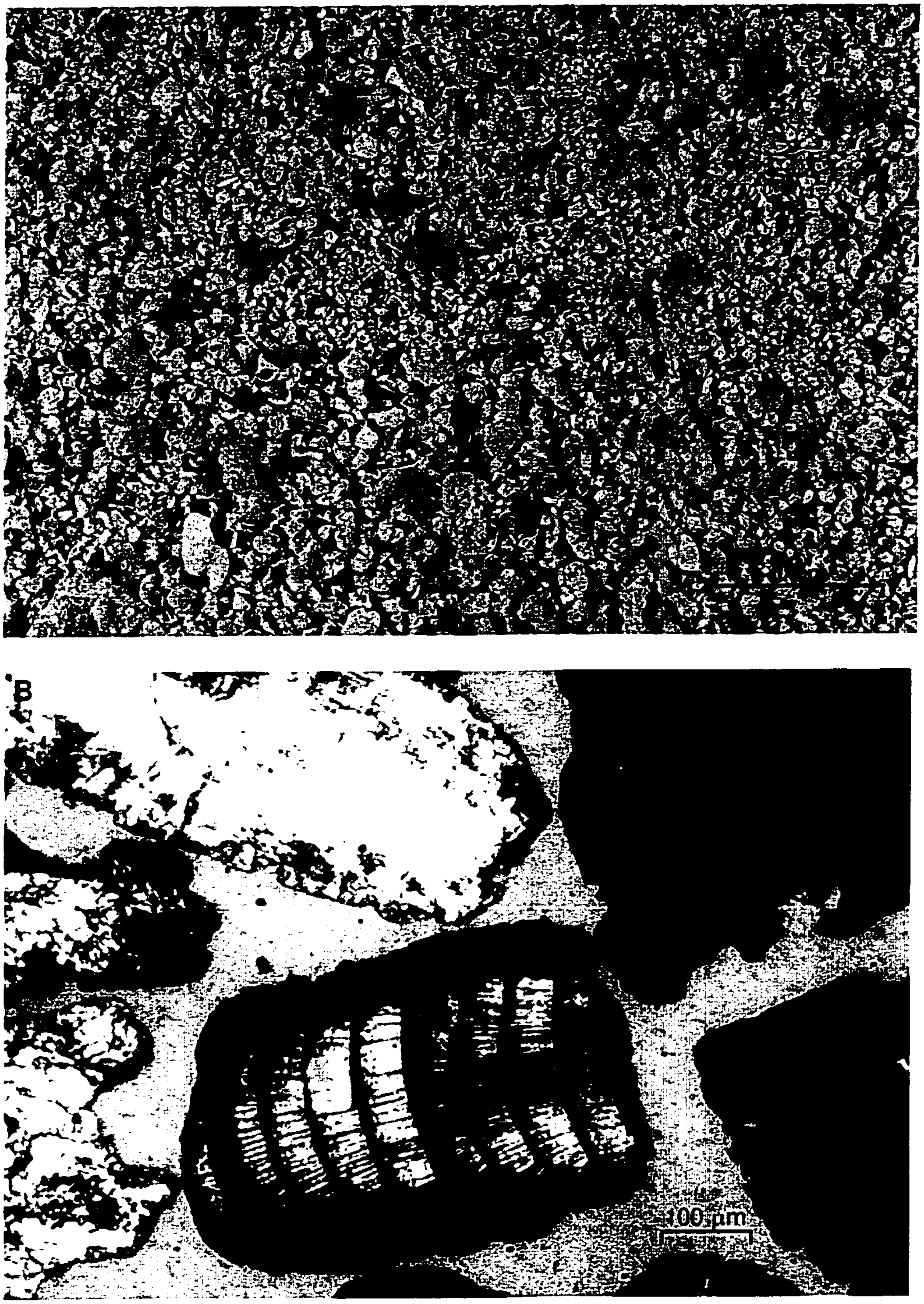


Figure 3.11: **(A)** Core photo of the Bivalve-*Halimeda* Facies showing the coarse grain size. **(B)** Thin section photo of the Bivalve-*Halimeda* Facies showing red algae, bivalve shell fragments,and *Halimeda* fragments.

underside of coral rubble behind the reef crest. The well rounded sediments indicate that this facies was subjected to a relatively high amount of abrasion from wave action.

Waters of the Bivalve-*Halimeda* Facies are shallow (< 4 m). Water energy was high, indicated by the high amount of abrasion and the location of the facies directly behind the reef crest. High energy wave action and currents stripped the sediments of the fine-grained materials, leaving behind coarse-grained sands.

Sediments in the Bivalve-*Halimeda* Facies have been subjected to little or no micritization, although some grains have undergone partial micritization. This suggests that sediments were not exposed to surface conditions for an extended period of time.

3.4 Trends in Sediment Characteristics

Composition: *Halimeda* plates are most abundant in the *Halimeda* Facies, located in the central parts of the lagoon, and decrease in abundance towards the *Halimeda*-Benthic Foraminifera-Bivalve Facies near the reef crest (Fig. 3.12). Bivalves are common throughout the lagoon. They are most abundant near the reef crest in the Bivalve-*Halimeda* Facies, and decrease in abundance moving shoreward into the *Halimeda* Facies. Benthic foraminifera are relatively common throughout the lagoon. There is, however, a slightly decreasing trend moving from the center of North Sound towards shore and towards the reef crest into the Bivalve-*Halimeda* Facies. Encrusting and coralline red algae are abundant in the northern part of the lagoon near the reef crest, and rapidly decrease in abundance away from the reef crest into the *Halimeda* Facies. Coral fragments are relatively rare in the subsurface sediments, and are found mostly in the

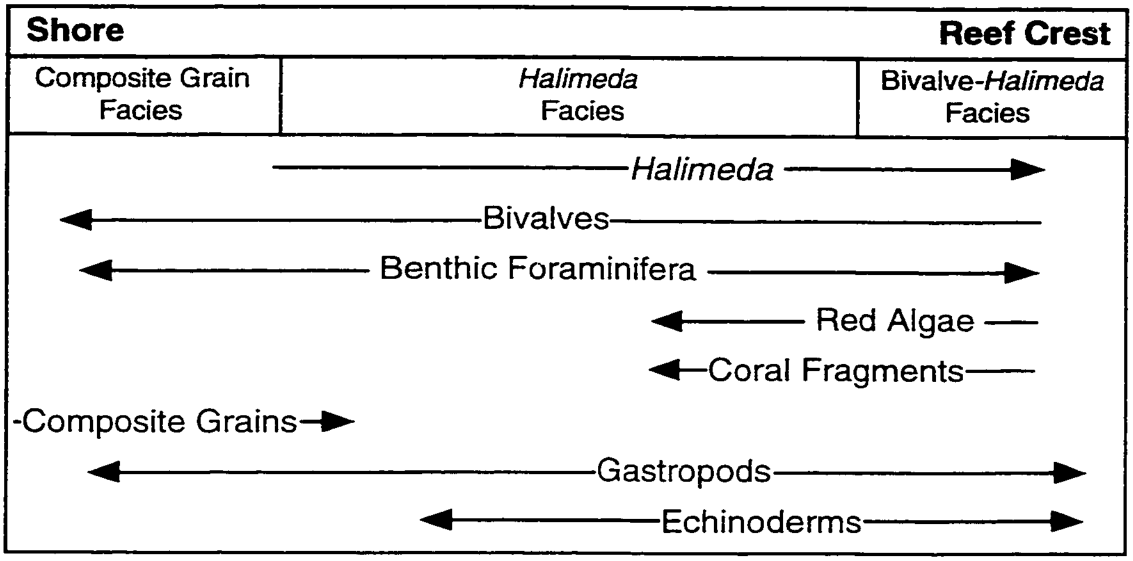


Figure 3.12: Trends in grain composition across North Sound. Arrows point to decreasing abundance for each grain type.

northern part of North Sound. Composite grains are restricted to the Composite Grain Facies in the southern part of the lagoon. They are most abundant along the southern margin and decrease in abundance to the north. Gastropods and echinoderms are relatively rare throughout the lagoon; however, they are slightly more abundant near the reef crest.

Fragmentation: The degree of fragmentation of subsurface skeletal grains in North Sound increases from the reef crest to the shoreline (Fig. 3.13). Sediments of the Bivalve-*Halimeda* Facies are coarse sand-sized. Moving towards shore, the *Halimeda* Facies contains medium sand to pebble-sized bivalves. Along the southern margin of the lagoon, sediments of the Composite Grain Facies are silt to clay-sized. No trends were observed when comparing the degree of fragmentation with increasing depth below the sediment surface.

Micritization: Micritization of subsurface sediments also tends to increase in a shoreward direction (Fig. 3.13). Sediments of the Bivalve-*Halimeda* Facies have been subjected to little micritization. Moving shorewards, skeletal allochems of the *Halimeda* Facies have been partially to extensively micritized. No trends were observed when comparing the degree of micritization with increasing depth below the sediment surface.

Sorting: Sediments in North Sound are poorly sorted near the reef crest, but become progressively more well-sorted in a shoreward direction (Fig. 3.13). Sediments grade from poorly sorted coral rubble immediately behind the reef crest, to moderately sorted sediments of the Bivalve-*Halimeda* Facies. Moving shorewards, sediments of the Composite Grain Facies are very well-sorted. The exception to this is the poorly sorted

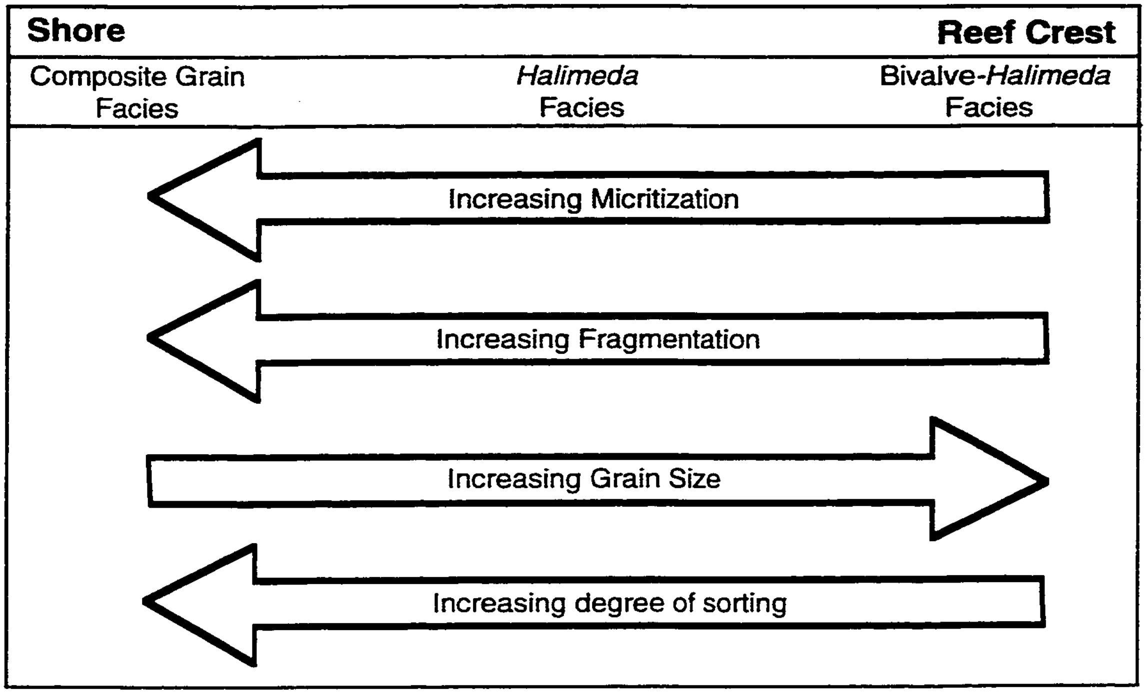


Figure 3.13: Trends in sediments in North Sound. Illustrates increasing trends in micritization, fragmentation, grain size and sorting across North Sound.

lens of *Halimeda*-Benthic Foraminifera-Bivalve Facies, located in the *Halimeda* Facies near the center of the lagoon.

Grain Size: Grain size generally decreases in a shoreward direction (Fig. 3.13). Medium to coarse sand-sized grains of the Bivalve-*Halimeda* Facies are located immediately behind the reef-crest. Moving shoreward into the *Halimeda* Facies, the grains are medium sand-sized. Grains decrease to silt to clay-sized sediments of the Composite Grain Facies along the southern margin of North Sound. Mangrove peats are fine-grained and commonly contain bivalve shells up to 4 cm long.

Measurements of length and width of skeletal components were obtained by thin section analysis in the three sand-sized facies, which include the *Halimeda*, *Halimeda*-Benthic Foraminifera-Bivalve, and Bivalve-*Halimeda* Facies. The lack of correlation between the type of allochem and its size (Fig. 3.14), indicates that breakdown of the allochems was dominated by physical processes (Kalbfleisch, 1995), not by the type of organism.

Sedimentary and Biogenic Structures: Sedimentary and biogenic structures seem to be absent in all facies, except the Mangrove Peat Facies. The absence of structure is probably due to bioturbation, and mixing of sediments from wave action and strong currents. Heavy bioturbation of sediments would have destroyed any evidence of sedimentary and/or biogenic structures that may have once been present. In addition, strong waves and currents during severe storms and hurricanes have the ability to destroy these structures by intermixing sediments, and forcing the fine-grained sediments into

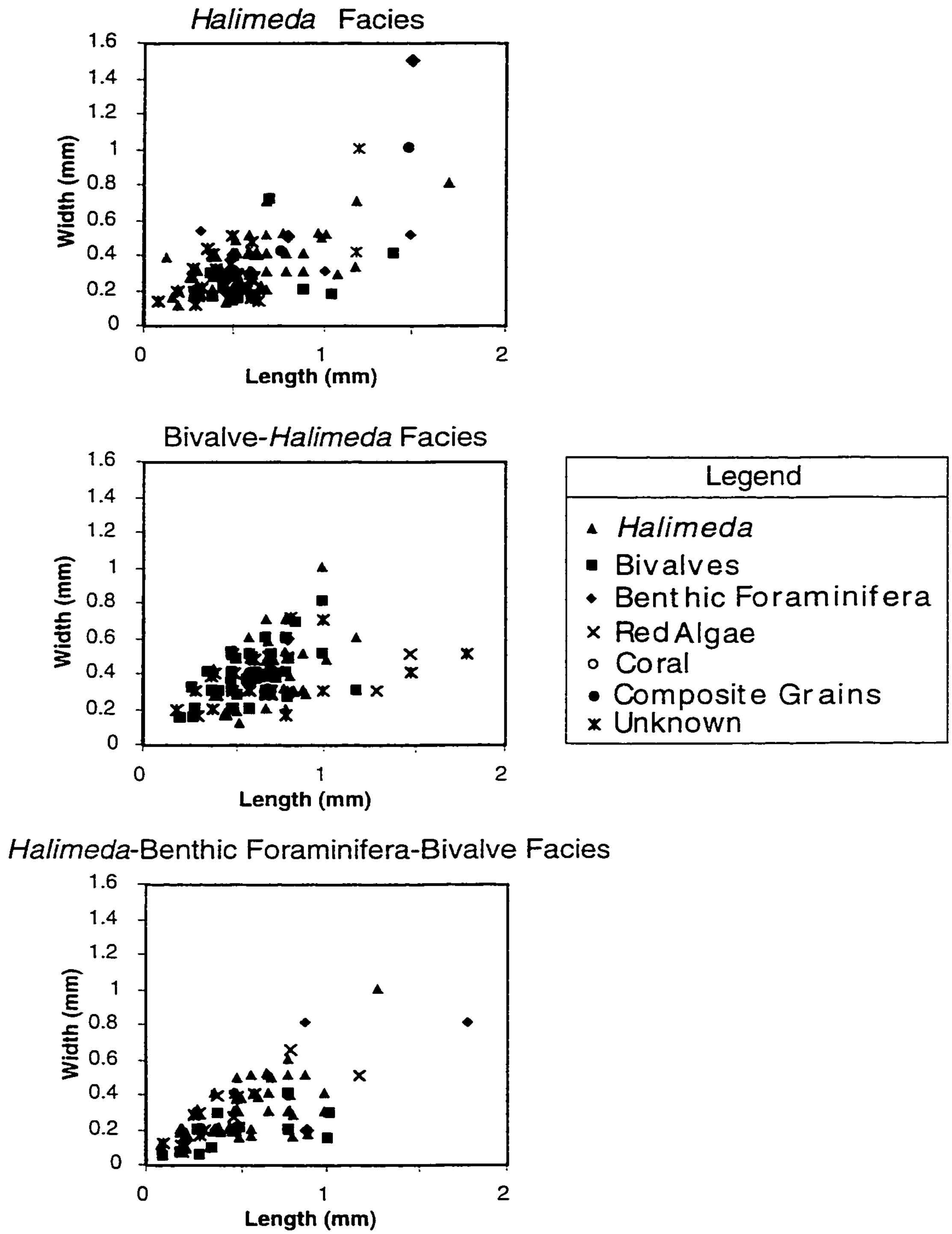


Figure 3.14: Comparison of skeletal component versus length and width of the component.

suspension. Intermixing of sediments by bioturbation or wave action is obvious in the mangrove peat, because of the distinct contrast between light colored sediments of the surrounding facies, and the dark color of the mangrove peat.

3.5 Synopsis

Seven facies have been identified in North Sound. These facies include the Composite Grain, Gastropod, Bivalve, Mangrove Peat, *Halimeda*, *Halimeda*-Benthic Foraminifera-Bivalve, and the Bivalve-*Halimeda* Facies. The three sand-sized facies, which include the *Halimeda* Facies, Bivalve Facies, and the *Halimeda*-Benthic foraminifera-Bivalve Facies, are relatively similar in composition and grain size, but vary slightly in their degree of micritization and fragmentation.

Deposition of the Composite Grain Facies took place in shallow (< 2 m), low-energy lagoon waters. Grains were derived from the limestone bedrock that underlies this facies. The Gastropod Facies, which consists of the gastropod *Amnicola forsythi* and organics, was deposited in a freshwater swamp. The Bivalve Facies, consisting largely of the thin-shelled bivalve *Mytilopsis domingensis*, was deposited in low-energy, < 2 m deep, brackish to fresh water. The Mangrove Peat Facies was deposited in the mangrove swamps that lined the periphery of the lagoon. Deposition of the *Halimeda* Facies took place in deeper (< 6 m), moderate to high energy waters of the central part of the lagoon. Deposition of the poorly sorted sediments of the *Halimeda*–Benthic Foraminifera-Bivalve Facies took place among the dense mesh of *Thalassia* blades. The

Bivalve–*Halimeda* Facies was deposited in high-energy waters immediately behind the reef crest. Facies were deposited under conditions similar to those that exist today in North Sound.

Chapter 4
Sedimentological Evolution

4.1 Introduction

Determining the sedimentological evolution of North Sound, which involves the derivation of a sea level curve, sedimentation rates, and paleogeographic changes, relies to a large extent on accurate dating of the sediments. The rate of sea level rise ultimately controls the evolution of sedimentary sequences in modern lagoons (e.g., Bosence et al., 1985; Rasmussen and Neumann, 1988; Andersen and Boardman, 1987; Colby and Boardman, 1988; Boardman et al., 1989). To ensure that the history of North Sound is accurately described, radiocarbon dates must not only be proven reliable, but applicable to the sedimentary sucession found in North Sound.

4.2 Radiocarbon Dating

Radiocarbon dating is the most widely used method for dating materials that are used to track Holocene sea level changes (Pirazzoli, 1991). Although the accuracy of radiocarbon dating methods has increased dramatically since the 1970's, there are still limitations associated with this method. One of these limitations is the vertical mixing of sediment by bioturbation. In areas with high biological activity, shells can be moved up into younger sediments or down into older sediments. Furthermore, sediments can be reworked by wave action and strong currents. The effects of bioturbation and reworking may be reduced if areas with high sedimentation rates are selected (Nielsen et al., 1995).

In addition, under specific chemical conditions, the original $CaCO_3$ composition of marine shells can be replaced by a different polymorph, possibly with a younger ^{14}C content (Arnold, 1991). This process commonly takes place when an aragonite shell undergoes inversion to calcite.

Radiocarbon variations in the reservoir (e.g., atmosphere, ocean, lake) from which carbon is derived during growth of shell material, results in a sample having a $^{14}C/^{12}C$ displacement from a reference value (Arnold, 1991). As a result of this "reservoir effect", marine shells commonly yield ^{14}C ages that are 300 - 700 yrs older than their true age (Arnold, 1991). Marine shells are usually corrected for the reservoir effect by subtracting 400 yrs from their measured radiocarbon age. It is rare, however, for freshwater shells to yield ^{14}C dates significantly older than their true age (Arnold, 1991).

Radiocarbon ages were obtained from eight bivalve shell and bivalve shell fragment samples from cores collected in North Sound (Table 4.1). Freshwater/brackish water bivalve shells, and marine shells were dated. A plot of the ^{14}C ages in comparison to depth below sea level reveals an increase in the age of bivalve shells with increasing depth (Fig. 4.1). The bivalve shells were probably subjected to little or no vertical mixing from bioturbation and reworking. The bivalve shells are still aragonitic and there is no petrographic evidence of recrystallization that may have affected their ^{14}C age determinations. The marine bivalve shell ages were corrected for the reservoir effect by subtracting 400 yrs from their measured ^{14}C age.

The oldest ^{14}C dated shells in North Sound, 4160 $\pm$ 40 yrs B.P., came from the Bivalve Facies 0.60 m above the base of core B10 in the centre of the lagoon (Fig. 4.2).

Code	Sample #	Depth from base of core (cm)	Description	Sample Weight (mg)	Depth BSL (m)	Age (yrs BP)	Corrected Age * (yrs BP)	Facies
1	B7 (0-2.5)	0 - 2.5	*Chione cancellata*	115	4.88	1940 ± 50	1540 ± 50	*Halimeda*
2	B10 (58-59)	58 - 59	*Mytilopsis domingensis*	315	6.12	4160 ± 40	4160 ± 40	Bivalve
3	B15 (0-2.5)	0 - 2.5	*Mytilopsis domingensis*	332	7.02	3770 ± 40	3770 ± 40	Bivalve
4	B15 (43-46)	43 - 46	*Anodontina alba*	297	6.56	2520 ± 30	2120 ± 30	Mangrove Peat
5	B16 (113-118)	113 - 118	*Anadara sp.?*	629	4.92	2600 ± 40	2200 ± 40	Mangrove Peat
6	B17 (40-46)	40 - 46	*Codakia sp.?*	370	3.96	1540 ± 30	1140 ± 30	*Halimeda*
7	EB23 (0-2.5)	0 - 2.5	*Glycymeris sp.?*	593	4.58	1310 ± 30	910 ± 30	*Halimeda*
8	EB40 (0-2.5)	0 - 2.5	*Codakia sp.?*	457	3.05	2870 ± 30	2470 ± 30	*Halimeda*-Benthic Foraminifera-Bivalve

Table 4.1: Radiocarbon dates obtained on bivalve shells and bivalve shell fragments collected from North Sound, Grand Cayman. * Ages of marine shells have been corrected for reservoir effect by subtracting 400 yrs.

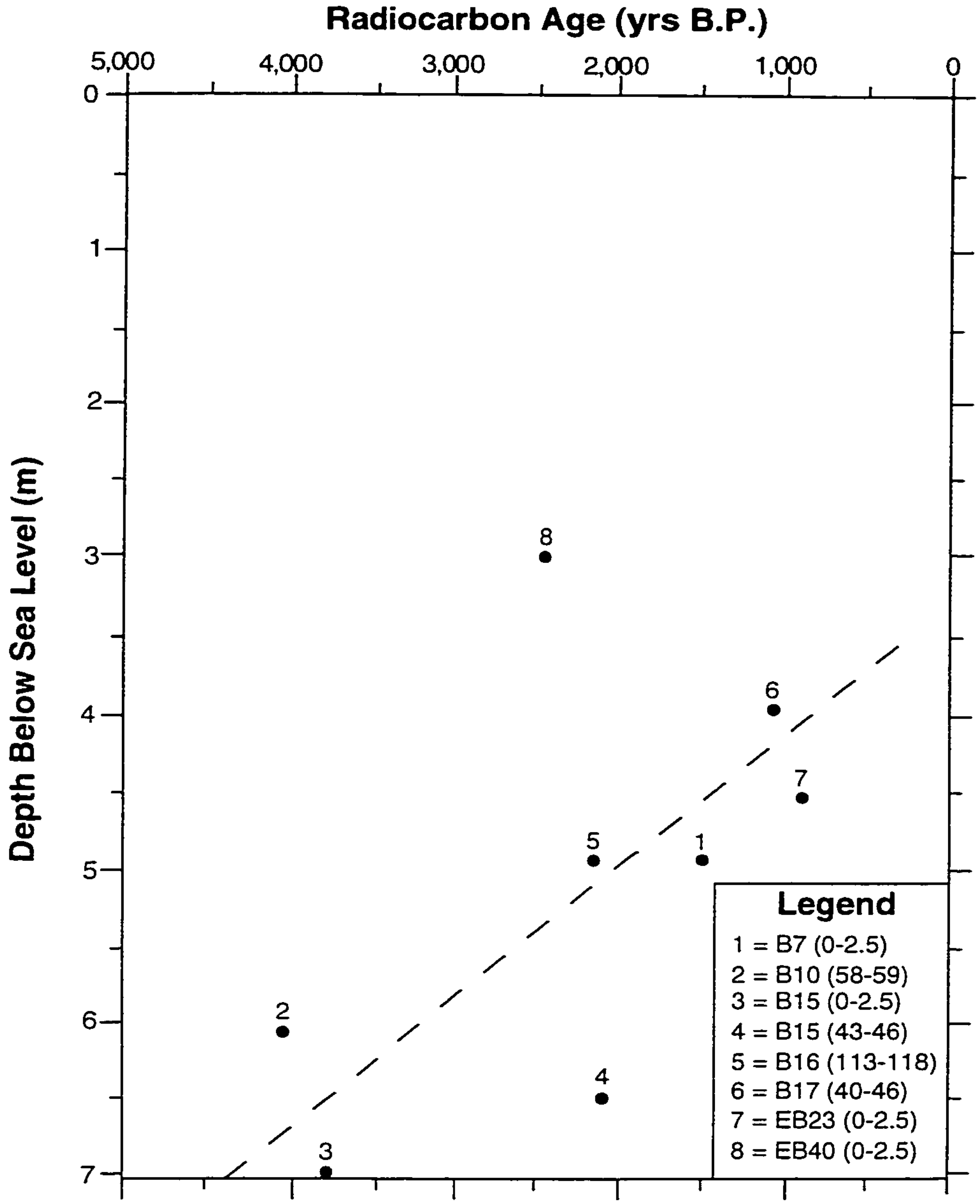


Figure 4.1: Plot illustrating increasing radiocarbon ages (years Before Present) with increasing depth (mbsl) for bivalves collected in North Sound, Grand Cayman. Radiocarbon ages have been corrected for the reservoir effect by subtracting 400 yrs.

This suggests that just before 4,160 ± 40 yrs B.P., deposition of organics and freshwater bivalve shells began in a shallow bedrock depression in the central part of North Sound. Another bivalve shell from the Bivalve Facies at the base of core B15 yielded an age of 3770 ± 40 yrs B.P. (Fig. 4.2).

Marine bivalves from the Mangrove Peat Facies in core B16 yielded an age of 2,200 ± 40 yrs B.P. (Fig. 4.2). A second age of 2,120 ± 30 yrs B.P. was obtained on the Mangrove Peat Facies 0.43 – 0.46 m from the base of core B15. The presence of marine shells in this upper part of the Mangrove Peat Facies indicates that marine waters entered North Sound after deposition of the Bivalve Facies.

Deposition of the *Halimeda* Facies began ~ 2,000 yrs B.P., as indicated by ^{14}C ages of 1540 ± 50 yrs B.P. (core B7) and 910 ± 30 yrs B.P. (core EB23) obtained from shells in the *Halimeda* Facies (Fig. 4.2).

^{14}C dates were not obtained on the Bivalve-*Halimeda* Facies because the bivalve fragments are too small for analysis. The Bivalve-*Halimeda* Facies, however, is the lateral equivalent of the *Halimeda* Facies, suggesting that deposition of that facies took place contemporaneously (Fig. 4.2).

An age of 2470 ± 30 yrs BP was obtained from a shell in the *Halimeda*-Benthic Foraminifera-Bivalve Facies at the base of core EB 40 (Fig. 1.4). This core is located ~1 km behind the reef crest adjacent to the main channel (Fig. 4.2). The age of this bivalve seems a little old for the depth (0.6 m) at which it was retrieved. The bivalve shell was probably reworked from an older succession of sediments, perhaps in the fore reef

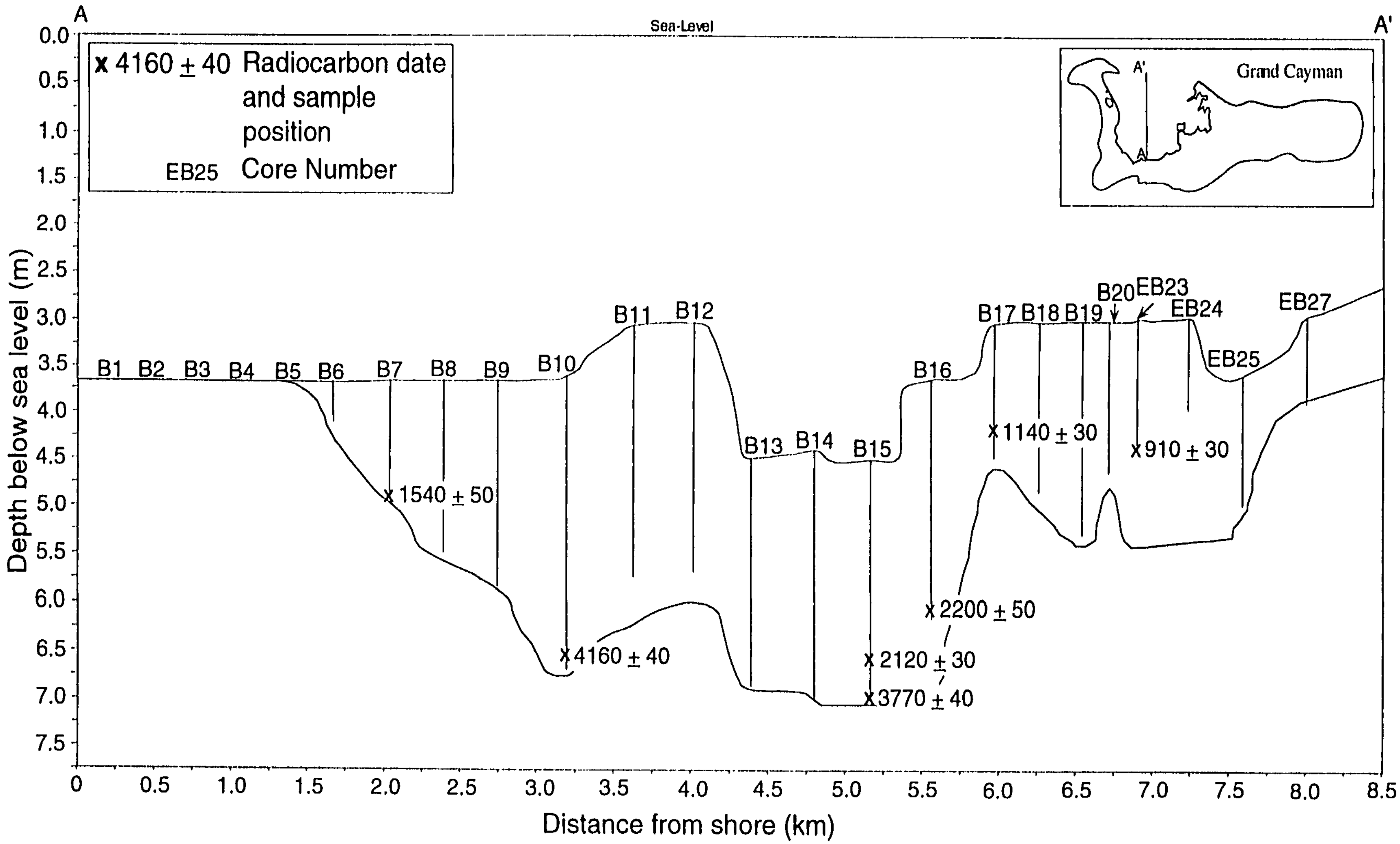


Figure 4.2: Diagram illustrating the location of bivalve shell samples taken for radiocarbon dating, and dates obtained on each sample in relation to depth below the sediment surface. Radiocarbon ages have been corrected for the reservoir effect by subtracting 400 yrs.

environment, and deposited in the back reef environment from a subsequent storm event that had sufficient energy to erode and transport the sediments shoreward.

4.3 Sea Level Estimates from Subsurface Sediments in North Sound

Assessing changes in the rate of Holocene sea level rise is an important step in evaluating the effects of future sea level rise. Many studies have calculated the rates of Holocene sea level rise in the Caribbean (Redfield, 1967; Scholl and Stuiver, 1967; Scholl et al., 1969; Neumann, 1972; Wanless, 1982; Digerfeldt and Hendry, 1987; Boardman et al., 1989; Fairbanks, 1989; Lidz and Shinn, 1991; Pirazzoli, 1991; Ellison, 1993). Although there is a considerable amount of debate over the rate of sea level rise, Holocene sea level curves show that the rate of sea level rise has decreased over the last ~ 5,000 yrs.

One of the difficulties in measuring rates of sea level change is accounting for the effects of local and/or regional subsidence or uplift. In order to produce an accurate record of sea level change, rates of uplift or subsidence must be accurately delineated. Grand Cayman appears to have been tectonically stable for the last 125,000 years because a wave-cut notch that formed during the Sangamon highstand is still at 6 m above present-day sea level (Jones and Hunter, 1994). This is also the same elevation as found elsewhere in the world. Therefore, deposition of sediments in North Sound has been primarily controlled by changes in sea level rise. As yet, a Holocene sea level curve has not been constructed for Grand Cayman. Holocene sea level curves for the Bahamas and Bermuda are used as a basis of comparison because they were based on data derived from tectonically stable platforms. Fairbanks' (1989) sea level curve for Barbados was also used because it is based on ^{14}C dating of *Acropora palmata* which is considered to be a reliable indicator of sea level. Barbados, however, is a tectonically unstable island.

The ages of Cayman samples relative to Holocene sea level curves for the Bahamas (Boardman *et al.*, 1989), Bermuda (Neumann, 1971), and Barbados (Fairbanks, 1989) correlate most closely with the Barbados curve (Fig. 4.3). Six of the eight ^{14}C ages fall on, or close to, the Fairbanks (1989) sea level curve (Fig. 4.3). The bivalve shell obtained from core EB40 was probably reworked, and therefore, does not plot as close to the Barbados curve. Similarly, the ^{14}C age 2120 ± 30 yrs B.P. obtained from a bivalve in core B15 (43-46) does not plot close to the Barbados sea level curve (Fig. 4.3). That bivalve shell, however, was obtained from the top of the Mangrove Peat facies in core B15 where there has been some intermixing with sediments of the overlying *Halimeda* Facies. This is probably the reason for the younger than expected age that was obtained from this bivalve shell.

Holocene sea level curves for the Bahamas (Boardman *et al.*, 1989), Bermuda (Neumann, 1971), and Barbados (Fairbanks, 1989), show differing rates of Holocene sea level rise in the Caribbean. The Holocene sea level curve for the Bahamas, as proposed by Boardman *et al.* (1989), is based on radiocarbon dating of basal peat samples from sediment cores collected in lagoons and tidal flats, and on rates of coastal erosion from San Salvador, Andros Island, and Bight of Abaco (Fig. 4.3). The curve shows that sea level rapidly rose from -11.3 m at 8,000 yrs B.P. to -3 m at 5,000 yrs B.P. After ~ 5,000 yrs B.P., changes in the rate of sea level rise became progressively slower rising from –1.4 m

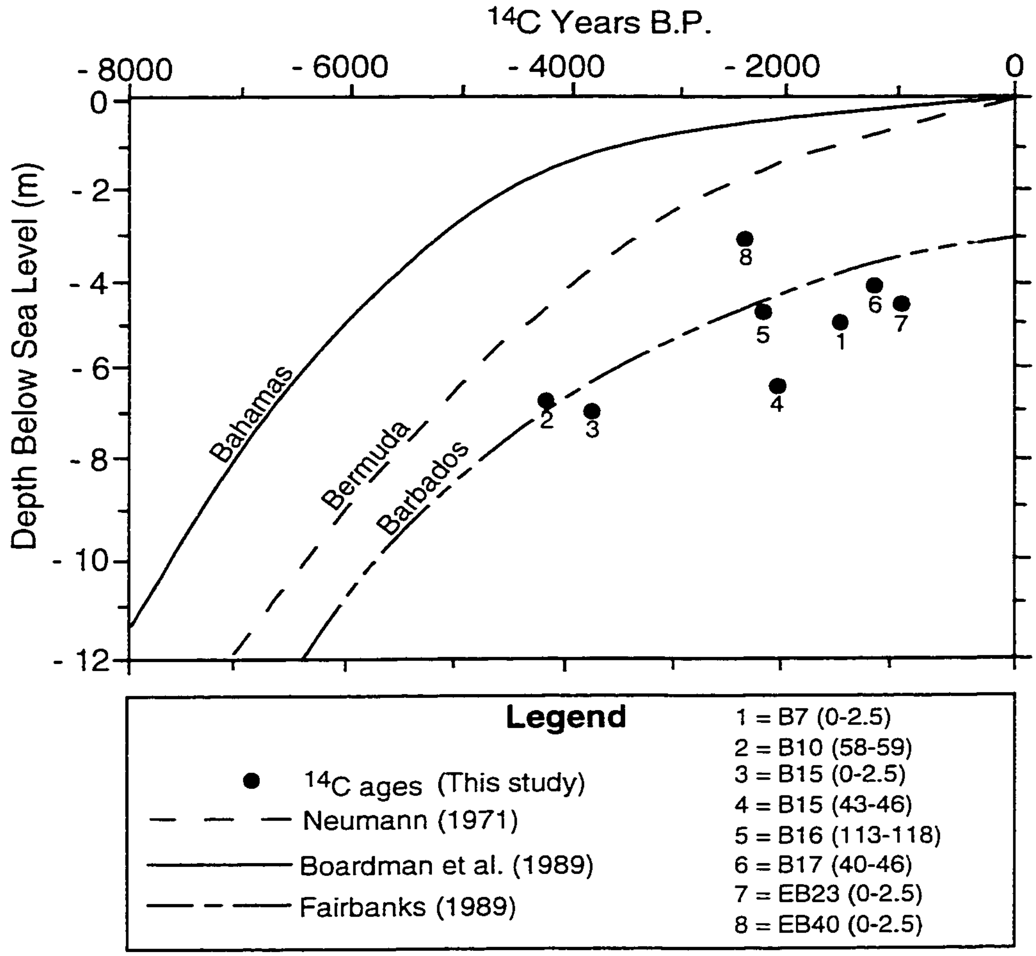


Figure 4.3: Ages and locations of Cayman samples relative to the Holocene sea level curves for the Bahamas (Boardman *et. al.*, 1989), Bermuda (Neumann, 1971), and Barbados (Fairbanks, 1989). Code numbers correspond to core number, and depth (cm) from the core bottom. Radiocarbon ages have been corrected for the reservoir effect by subtracting 400 yrs.

at 4,000 yrs B.P. to present sea level. The slow rate of sea level rise during the last 2,000 yrs decreases the accuracy of the sea level curve because of the increased potential for erosion of peat by waves and currents (Boardman et al., 1989).

Neumann's (1971) Holocene sea level curve for Bermuda is based on samples of peat and aragonitic shell material obtained from two peat filled marsh and submarine peat localities. The sea level curve shows a rapid rise from –7 m at 5,000 yrs B.P. to present sea level, a rate of 140 cm/1,000 yrs (Fig. 4.3). This sea level curve is considered to be an accurate record of sea level rise because it contains only ^{14}C dates from peat samples that rested directly on Pleistocene bedrock. This avoids errors that can be produced by sediment compaction. Data based on peat analysis is considered to be more accurate than data based on other materials, such as wood and shells, because peat is less likely to be affected by displacement (Redfield, 1967).

The Holocene sea level curve constructed by Fairbanks (1989), based on ^{14}C dating of *Acropora palmata,* is considered to be an important and accurate record of sea level change over the last 17,000 years. Although *Acropora palmata* can live to depths of 17 m (Hunter, 1994), it forms monospecific stands in water < 5 m deep (Blanchon, 1995). The latter are deemed to be an excellent indicator of sea level. In addition, it is the dominant coral of many reef-crest communities, and its massive size minimizes postdepositional transport and compaction (Fairbanks, 1989). Evidence indicates, however, that the south coast of Barbados is being uplifted at a rate of ~ 34 cm/1,000 yrs (Fairbanks, 1989). The accuracy of sea level curves constructed from data obtained from tectonically unstable islands is commonly problematic because of the variability of rates of uplift and/or subsidence over time.

Although the Bahamas and Bermuda are tectonically stable, there is a significant difference (~ 4 m) between the two sea level curves produced by Neumann (1971) and Boardman *et al.* (1989) (Fig. 4.3). Neumann (1971) dated 31 basal peat samples located near bedrock in order to eliminate compaction errors, as well as, aragonite shell material. Boardman *et al.* (1989), however, dated 10 basal peat samples directly in contact with the bedrock surface. The sea level curve by Boardman *et al.* (1989) is probably a less reliable record of sea level rise because of the small amount of samples dated, and the peat samples were possibly slightly contaminated with materials derived from the bedrock surface in which they were directly in contact. Neumann (1971) used data obtained from both ^{14}C dating of aragonitic shell material, and ^{14}C dating of basal peat samples. These aragonite shells may have differing isotope fractionation values, which would alter the ^{14}C dates obtained. Another possibility is the use of different half-life values; however, neither study reports the values used.

The sea level curve by Fairbanks (1989) is considered to be an accurate record of sea level because *Acropora palmata* is not affected by compaction errors, and monospecific stands are restricted to water ≤ 5 m. Meischner and Vollbrecht (1999), however, suggested that a number of problems are associated with the Barbados sea level curve (Fairbanks, 1989), including variable uplift rates on Barbados, subsurface erosion of reefs by groundwater runoff, and the possibility that the *A. palmata* reef is in fact an accumulation of rubble deposited over time. These problems may be the reason for lower rates of Holocene sea level change calculated for Barbados compared to sea level rates for the Bahamas and Bermuda.

4.4 Isotope Analysis

Marine waters and freshwaters possess different isotopic signatures (Mook, 1970). Freshwater is depleted in ^{18}O relative to marine water, because ^{16}O is more susceptible to evaporation (Epstein and Mayeda, 1953). Similarly, freshwater is depleted in ^{13}C compared to marine water because of the presence of CO_2 gas derived from land plants (Faure, 1977). Since an isotopic equilibrium exists between calcium carbonate and the water from which it was precipitated (McCrea, 1950; Epstein *et al.*, 1953; Clayton and Degens, 1959), isotope analysis may indicate if carbonate materials were precipitated from marine or freshwaters.

$\delta^{13}C$ values obtained for bivalve shell and sediment samples collected from the Bivalve Facies (1.58 – 2.90 m) and the lower portion of the Mangrove Peat Facies (2.90 – 3.05 m) from core B10 in North Sound range from –7.3 to –4.44 indicating deposition in freshwater (Table 4.2). Isotope values obtained on bivalve shells and sediment samples collected 0.0 - 1.58 m from the top of core B10 range from 5.03 to –1.08 indicating deposition in marine waters (Fig. 4.4). A major inflection point in the $\delta^{13}C$ curve is located at a depth of ~ 1.58 m from the top of core B10. That inflection point marks the base of the transgression as marine water replaced the freshwater. This is also the contact between the Bivalve Facies and the overlying Mangrove Peat Facies.

Interval from top of core B10 (cm)	Facies	Description	Sediment		Bivalve Shells	
			$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$
57 - 59	*Halimeda*	*Anodontina alba*	1.93	5.03	-0.61	2.3
77 - 79	*Halimeda*	*Anodontina alba*	3.44	4.76	-	-
105 - 107	Mangrove Peat	*Anodontina alba*	1.99	4.03	-0.66	-0.4
142 - 144	Mangrove Peat	*Chione cancellata*	-	-	-1.08	-0.14
172 - 174	Bivalve	*Mytilopsis domingensis*	3.06	-4.44	0.11	-6.26
285 - 287	Bivalve	*Mytilopsis domingensis*	3.63	-4.27	-1.24	-7.3

Table 4.2: Isotopic composition values obtained on bivalve shells and sediment samples collected from North Sound, Grand Cayman.

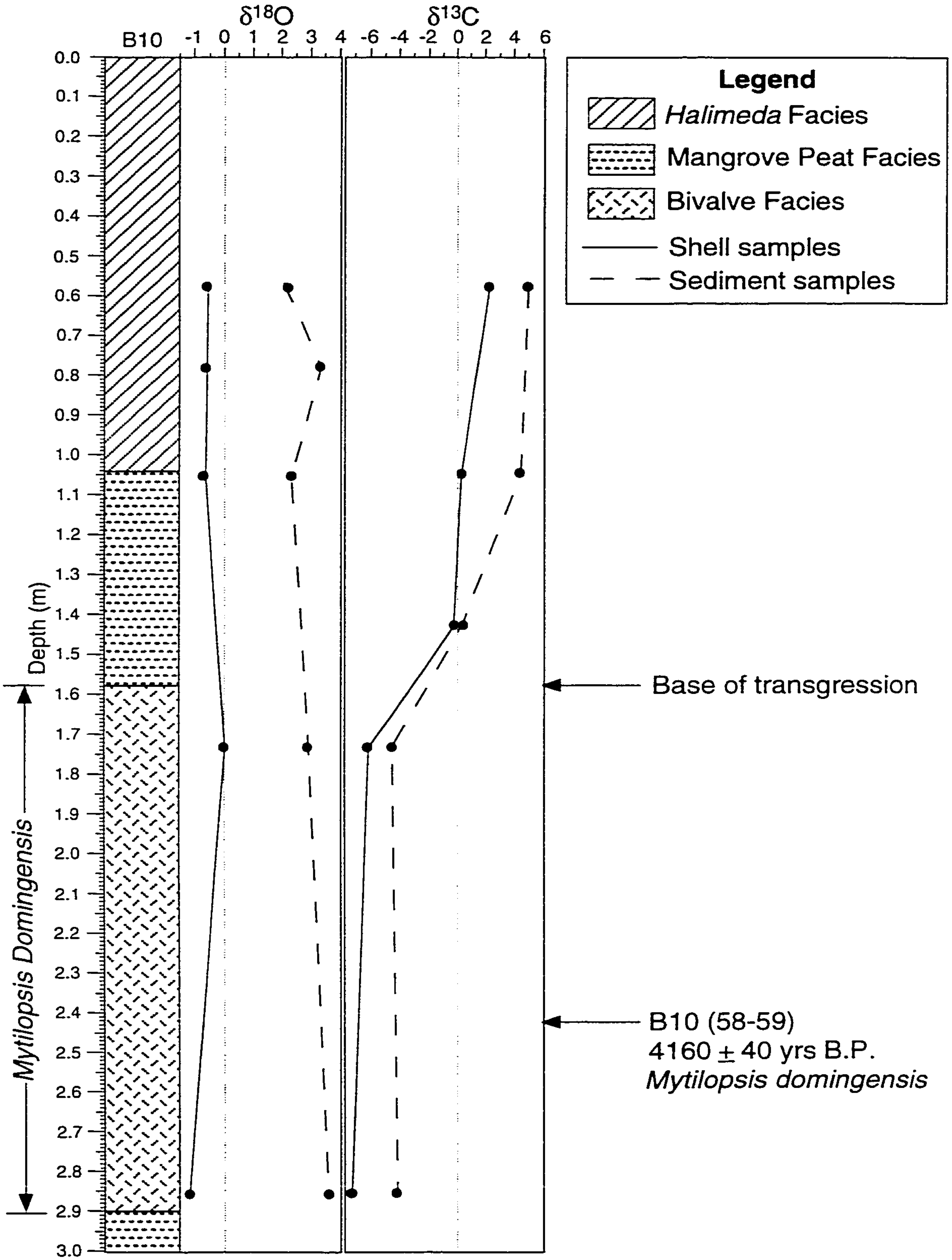


Figure 4.4: Comparison of $\delta^{18}O$ and $\delta^{13}C$ data obtained from bivalve shell and sediment samples in core B10 in North Sound, Grand Cayman. Note age of bivalve shell (*Mytilopsis domingensis*).

$\delta^{18}O$ values derived from bivalve shells and sediment samples, -1.24 to 3.63, show no correlation to depth below the sediment surface (Fig. 4.4). The lack of correlation and low variability indicate that the $^{18}O/^{16}O$ ratio of the water has been relatively homogeneous, which is probably because both the fresh and marine waters were located close to each other. Freshwaters in the lagoon were not substantially depleted in ^{18}O by evaporation compared to nearby marine water. In contrast, an important difference exists between $\delta^{18}O$ values obtained on bivalve shells compared to $\delta^{18}O$ values obtained from the sediment samples. Essentially the sediment samples are derived from fragmentation of skeletal components. The most probable explanation for the $\delta^{18}O$ variation between the shells and sediments is due to isotope fractionation. Calcium carbonate fragments contained in the organic rich sediments were probably subjected to a higher degree of postdepositional recrystallization and oxygen isotope exchange with waters enriched in ^{18}O, because of their smaller size compared to the bivalve shells. Also, sediment is formed of grains derived from many different sources, therefore isotope values are averages of more than one grain type.

4.5 Sedimentation Rates

Sedimentation rates for North Sound can be calculated by comparing sediment thickness data and ^{14}C ages of the bivalves (Table 4.3). Rates of sediment accumulation vary between 59.1 cm/1,000 yrs and 168 cm/1,000 yrs (Table 4.3). A sedimentation rate

Core	Age (years BP)	Facies	Thickness (m)	Avrg. Sedimentation Rate (cm/1000 yrs)	Avrg. Sedimentation Rate (mm/year)
B7 (0-2.5)	1540 ± 50	- *Halimeda*	1.22	79.2 cm/1,000 yrs	0.792 mm/yr
B10 (58-59)	4160 ± 40	- *Halimeda* - Bivalve	2.46	59.1 cm/1,000 yrs	0.591 mm/yr
B15 (0-2.5)	3770 ± 40	- *Halimeda* - *Halimeda*-Benthic Foraminifera-Bivalve - Mangrove Peat - Bivalve	2.44	64.7 cm/1,000 yrs	0.647 mm/yr
B15 (43-46)	2120 ± 30	- *Halimeda* - *Halimeda*-Benthic Foraminifera-Bivalve - Mangrove Peat	1.98	93.4 cm/1,000 yrs	0.934 mm/yr
B16 (113-118)	2200 ± 40	- *Halimeda* - *Halimeda*-Benthic Foraminifera-Bivalve - Mangrove Peat	1.31	59.5 cm/1,000 yrs	0.595 mm/yr
B17 (40-46)	1140 ± 30	- *Halimeda* - *Halimeda*-Benthic Foraminifera-Bivalve	0.91	79.8 cm/1,000 yrs	0.798 mm/yr
EB23 (0-2.5)	910 ± 30	- *Halimeda*	1.53	168 cm/1,000 yrs	1.680 mm/yr
EB40 (0-2.5)	2470 ± 30	- Bivalve-*Halimeda* - *Halimeda*-Benthic Foraminifera-Bivalve	0.61	0.25 cm/1,000 yrs	0.025 mm/yr

Table 4.3: Sedimentation rates based on ^{14}C ages obtained on bivalve shells in North Sound, Grand Cayman.

for the Bivalve-*Halimeda* and *Halimeda*-Benthic Foraminifera-Bivalve Facies in core EB40 (Fig. 1.4) was calculated at 0.25 cm/1,000 yrs. This is probably unreliable because the ^{14}C age came from a bivalve shell probably derived from reworked sediments. Rates of sedimentation for North Sound are comparable to the accumulation rates of 30 – 100 cm/1,000 yrs that James and Bone (1991) estimated for warm water carbonates. During the last 4200 years, sea level rise in North Sound averaged ~ 95 cm/1,000 yrs; however, sedimentation rates averaged only ~ 76 cm/1,000 yrs. Thus, there has been a progressive increase in accommodation space during this period.

4.5 Mechanisms that Controlled Deposition

A decrease in grain-size across a lagoon coupled with an unimodal grain-size distribution for skeletal components are evidence of a system dominated by physical processes (Kalbfleisch, 1995; Kalbfleisch and Jones, 1995). Sediments in North Sound display a decrease in grain-size from the reef crest to the shore. Measurements of length and width of grains in the three sand-sized facies show no correlation between allochem type and size (Fig. 3.14). In a system dominated by biological processes, a plot of length versus width of the allochem should illustrate a correlation between allochem types and their size. The lack of correlation (Fig. 3.14), however, suggests that deposition of sediments in North Sound is dominated by physical processes.

Hurricanes have a high historical frequency on Grand Cayman, with a recurrence interval of ~ 7 years (Blanchon, 1995). Kalbfleisch (1995) and Kalbfleisch and Jones

(1995) argued that severe storms and hurricanes have a tremendous effect on the sedimentology of Frank Sound and Pease Bay, Grand Cayman. In Frank Sound and Pease Bay, under fair-weather conditions, operative processes include limited sediment production from *Thalassia* epibionts, limited coral growth, foraminifera, and molluscs, bioerosion, bioturbation, and *Thalassia* colonization (Kalbfleisch, 1995; Kalbfleisch and Jones, 1995). These processes, however, exert little control over sediment or biota distribution. Conversely, severe storms and hurricanes exert a tremendous influence over the depositional processes in Frank Sound and Pease Bay (Kalbfleisch, 1995; Kalbfleisch and Jones, 1995). Kalbfleisch and Jones (1995) showed that during the height of a storm, waves and currents carry sediments from the fore-reef environment into the lagoon. As the sediment laden current passes over the lagoon floor, it loses energy due to frictional attenuation and sediment is deposited. A sediment wedge is formed as coarser materials are deposited near the reef crest and finer sediments are transported shoreward. Similarly, these processes control the sediment distribution pattern found in North Sound.

4.7 Depositional History of North Sound

By integrating all of the available sedimentological information and ages it is possible to outline a four-stage evolution of North Sound.

Stage A : Deposition of sediments in North Sound began 4,200 – 4,500 years B.P. in a freshwater swamp located in a shallow bedrock depression overlying Pleistocene bedrock. Deposition of the Composite Grain Facies began ~ 4,200 yrs B.P. from erosion of the limestone bedrock that forms the floor of the pond (Fig. 4.5A). Freshwater gastropods

(*Amnicola forsythi*) attached themselves to the roots of mangroves trees, and were deposited along with the fine-grained organics derived from the mangroves. The freshwater pond became home for numerous bivalves (*Mytilopsis domingensis*). Oxygen and carbon isotope analyses on bivalves (*Mytilopsis domingensis*), derived from the Bivalve Facies in core B10, confirm that deposition of the facies took place in freshwater. As the water level rose, organics and freshwater bivalves of the Bivalve Facies were deposited in the shallow waters, at rates of 59 - 65 cm/1,000 yrs.

Stage B: Approximately 3,000 yrs B.P., fine-grained organics that were derived from mangroves lining the periphery of North Sound, were deposited in the bedrock depressions of the lagoon (Fig. 4.5B) at rates of 60 to 93 cm/1,000 yrs. As sea level continued to rise, the mangroves retreated shoreward tracking shallower waters.

Stage C: Shortly after 3,000 yrs B.P., marine waters overtopped the north rim of the freshwater basin and marine waters started to flow into the pond (Fig. 4.5C). Reef development was probably initiated as waters became deeper. In the early stages of a transgression a minimum water depth (lag depth) must be reached before sedimentation can begin (Jones and Desrochers, 1992). The lag depth must be reached before circulation becomes effective enough to allow sediment production, accumulation and dispersal (Ginsburg, 1971; Hardie and Shinn, 1986; Boardman et al., 1989). The lag depth is estimated to be 1 to 2 m (Enos, 1977; Harris, 1979). If we assume that sea level rose at a maximum rate of 95 cm/1000 yrs, this suggests that it must have taken ~ 1000 yrs for sea level to rise 1.0 m above the northern rim of North Sound. Since deposition of the

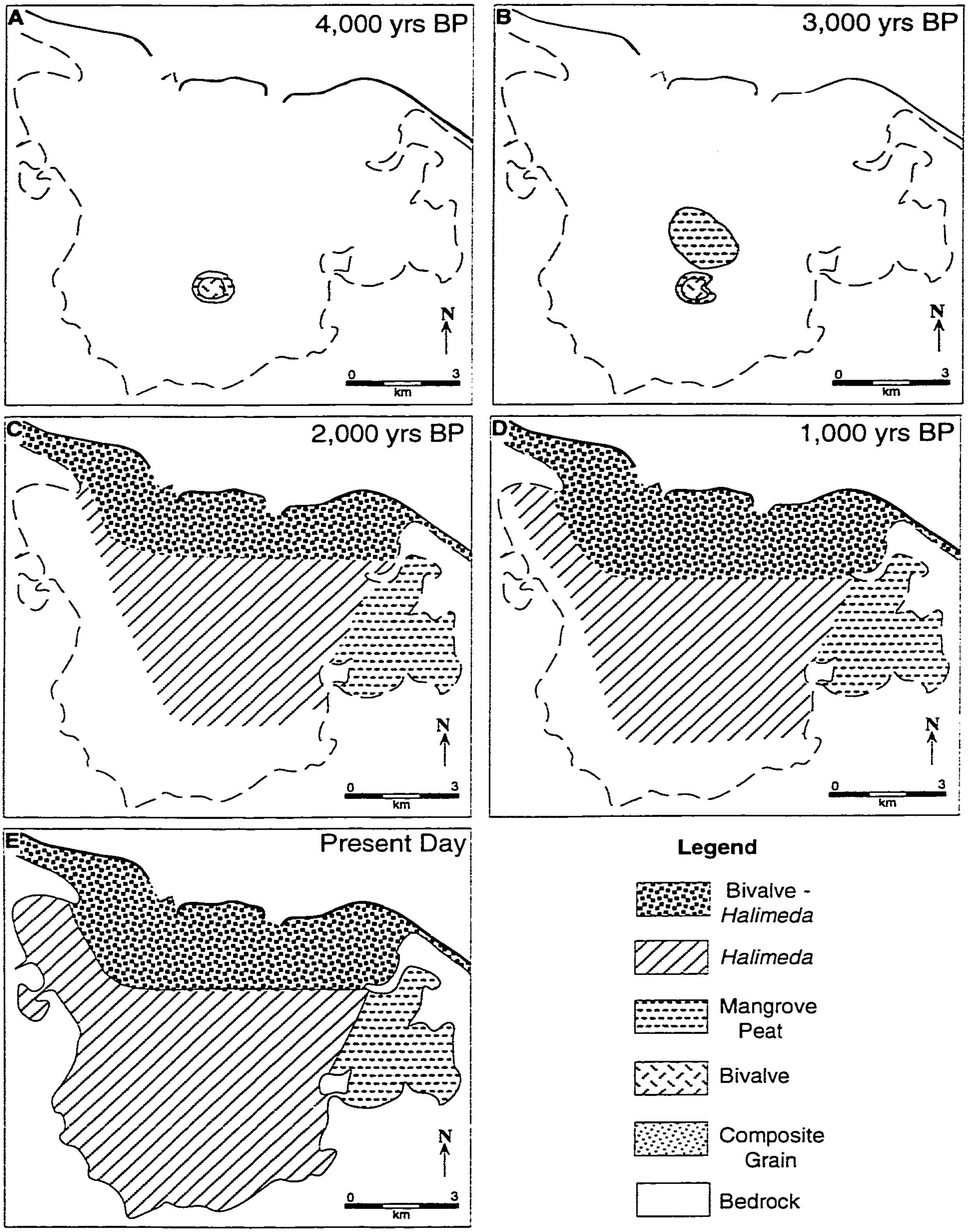


Figure 4.5: Diagram depicting the evolution of North Sound over the last ~4,000 yrs BP.

Halimeda Facies and reef growth began ~ 2,000 yrs B.P. then the invasion of marine waters into North Sound began ~ 3,000 yrs B.P.

After growth of the fringing-reef along the northern margin of North Sound was established, deposition of the coarse-grained Bivalve-*Halimeda* Facies began behind the reef crest. As sediments were transported from the fore-reef environment during severe storms and hurricanes (Fig. 4.5C), high-energy wave activity removed any fine-grained sediments in this area and transported them shoreward. This led to the deposition of the *Halimeda* Facies at rates of 79.8 to 168 cm/1,000 yrs.

Later in this stage, the *Halimeda*-Benthic Foraminifera Facies was deposited where dense patches of *Thalassia* allowed for protection of articulated and whole bivalve shells in the dense mesh of blades.

Stage D: Approximately 1,000 yrs B.P., the facies in North Sound began to develop characteristics that are similar to those of present day North Sound (Fig. 4.5D). Deposition of the *Halimeda* Facies dominated the central portion of the lagoon, whereas coarse-grained sediments of the Bivalve-*Halimeda* Facies were deposited behind the reef crest.

Stage E: This stage represents present day sedimentation in North Sound (Fig. 4.5E).

Chapter 5
Conclusions

Data collected from 60 sediment sampling and core sampling locations in North Sound has led to the following conclusions:

(1) Subsurface sediments in North Sound can be divided into the Composite Grain, Gastropod, Bivalve, Mangrove Peat, *Halimeda*, *Halimeda*-Benthic Foraminifera-Bivalve, and the Bivalve-*Halimeda* Facies.

(2) Isotope analysis on bivalve shells and sediment samples in North Sound yielded $\delta^{18}O$ and $\delta^{13}C$ signatures which confirm that the Composite Grain, Gastropod, and Bivalve Facies took place in a freshwater pond.

(3) Radiocarbon dates obtained on eight bivalve shell samples reveals that sedimentation began 4,200 – 4,500 years B.P. Shortly after 3,000 yrs B.P., marine waters overtopped the northern rim of the freshwater basin and started to flood the freshwater pond.

(4) Sedimentation rates in North Sound, 59.1 cm/1,000 yrs to 168 cm/1,000 yrs, have not kept pace with the high rates of Holocene sea level rise.

(5) A decreasing grain size trend across North Sound and the lack of correlation between grain size and type reveal that deposition of sediments in North Sound is controlled

chiefly by short-lived storm events accompanied by high-energy waves and currents, rather than fair-weather processes.

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Appendix A

Core sampling localities in North Sound including depth core penetrated the substrate, length of core recovered, and water depth.

Core #	Latitude	Longitude	Sediment Depth Penetrated (m)	Core Recovered (m)	Water Depth (m)
NS 1	N 19° 18.370'	W 81° 17.751'	3.05	1.02	1.22
NS 2	N 19° 21.461'	W 81° 17.264'	1.5	1.42	1.53
NS 3	N 19° 22.500'	W 81° 18.481'	1.0	0.78	1.7
NS 4	N 19° 22.364'	W 81° 16.719'	0.6	0.52	3.05
NS 5	N 19° 22.541'	W 81° 16.261'	1.2	0.82	3.05
NS 7	N 19° 22.554'	W 81° 17.550'	1.0	0.74	3.05
NS 8	N 19° 19.688'	W 81° 19.556'	3.05	2.08	6.1
B6	N 19° 18.636'	W 81° 19.615'	0.46	0.7	3.66
B7	N 19° 18.827'	W 81° 19.619'	1.22	0.81	3.66
B8	N 19° 19.014'	W 81° 19.628'	1.80^{+}	1.43	3.66
B9	N 19° 19.217'	W 81° 19.616'	2.14	1.4	3.66
B10	N 19° 19.460'	W 81° 19.612'	3.05	2.23	3.66
B11	N 19° 19.687'	W 81° 19.617'	2.75	2.21	3.05
B12	N 19° 19.910'	W 81° 19.628'	2.75	1.74	3.05
B13	N 19° 20.100'	W 81° 19.617'	2.44	1.81	3.05
B14	N 19° 20.325'	W 81° 19.617'	2.44	1.51	4.58
B15	N 19° 20.539'	W 81° 19.618'	2.44	2.44	4.58
B16	N 19° 20.746'	W 81° 19.614'	2.44	1.67	3.66
B17	N 19° 20.964'	W 81° 19.611'	1.37	1.11	3.05
B18	N 19° 21.118'	W 81° 19.610'	1.83^{+}	1.50	3.05
B19	N 19° 21.284'	W 81° 19.615'	2.44	1.91	3.05
B20	N 19° 21.376'	W 81° 19.497'	1.83	1.36	3.05
B21	N 19° 21.487'	W 81° 19.350'	1.53	0.66	3.05
B22	N 19° 23.139'	W 81° 20.759'	0.92	0.36	3.05
NSC 1	N 19° 22.079'	W 81° 22.564'	0.5 - 0.25	0.56	1.98
NSC 2	N 19° 22.962'	W 81° 21.762'	-	0.4	0.61
NSC 3	N 19° 22.962'	W 81° 21.748'	-	0.7	0.61
NSC 4	N 19° 22.962'	W 81° 21.734'	-	0.6	0.61
NSC 5	N 19° 22.962'	W 81° 21.719'	1.22	0.65	0.61
NSC 6	N 19° 22.935'	W 81° 22.378'	2.75	0.5	0.92

Appendix A (continued)

Core #	Latitude	Longitude	Sediment Depth Penetrated (m)	Core Recovered (m)	Water Depth (m)
EB 23	N 19° 21.489'	W 81° 19.614'	1.53	0.89	3.05
EB 24	N 19° 21.665'	W 81° 19.608'	-	0.74	3.05
EB 25	N 19° 21.863'	W 81° 19.625'	1.53	0.99	3.66
EB 27	N 19° 22.168'	W 81° 19.605'	0.92	0.57	2.75
EB 28	N 19° 22.531'	W 81° 19.381'	0.92	0.66	2.75
EB 29	N 19° 19.556'	W 81° 17.250'	3.05	1.13	2.14
EB 30A	N 19° 18.875'	W 81° 18.405'	1.53	0.97	3.05
EB 30B	N 19° 18.875'	W 81° 18.405'	1.53	0.5	3.05
EB 31	N 19° 19.366'	W 81° 18.624'	3.05	1.23	2.44
EB 32	N 19° 20.788'	W 81° 18.337'	2.44	1.00	4.58
EB 35	N 19° 22.638'	W 81° 20.095'	0.61	0.63	3.05
EB 37	N 19° 22.973'	W 81° 20.876'	0.46	0.38	3.36
EB 40	N 19° 22.551'	W 81° 21.286'	0.61	0.28	2.44
EB 41	N 19° 18.342'	W 81° 20.417'	1.53	0.99	2.44
EB 42	N 19° 18.801'	W 81° 20.999'	2.75	1.91	3.05
EB 43	N 19° 19.878'	W 81° 20.816'	3.05	2.13	3.36
EB 44	N 19° 20.578'	W 81° 21.031'	3.05	1.36	3.97
EB 45	N 19° 21.893'	W 81° 21.793'	3.05	0.90	2.75
EB 46	N 19° 22.391'	W 81° 22.197'	2.75	0.58	2.75

Appendix B

Surface sampling localities in North Sound including water depth.

Sample #	Water Depth (m)	Latitude	Longitude
NSSS1	1.53	N 19° 21.461'	W 81° 17.264'
NSSS2	1.7	N 19° 21.500'	W 81° 18.481'
NSSS3	3.05	N 19° 22.364'	W 81° 16.719'
NSSS5	3.66	N 19° 22.500'	W 81° 17.106'
NSSS6	1.22	N 19° 17.850'	W 81° 19.652'
NSSS7	3.66	N 19° 18.636'	W 81° 19.615'
EB 33	-	N 19° 22.527'	W 81° 17.753'
NSSS10	4.58	N 19° 22.789'	W 81° 20.464'
NSSS11	2.75	N 19° 22.908'	W 81° 21.146'

Appendix C
Core Logs

Legend

Facies

Bivalve - *Halimeda*

Halimeda -
Benthic Foraminifera-Bivalve

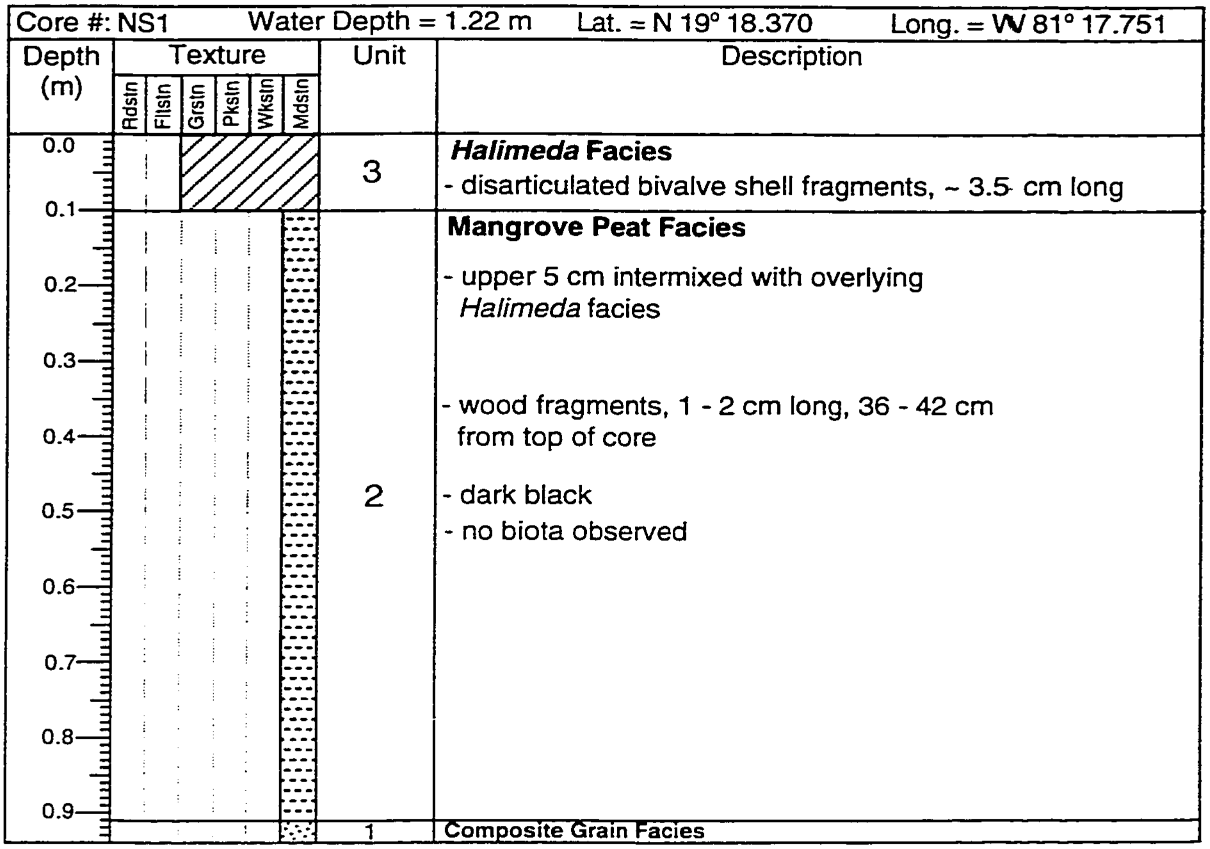
Halimeda

Mangrove Peat

Bivalve

Gastropod

Composite Grain


Core #: NS1
Water Depth = 1.22 m
Lat. = N 19° 18.370
Long. = W 81° 17.751
Depth (m)
Texture
Rdstn
Fltstn
Grstn
Pkstn
Wkstn
Mdstn
Unit
Description
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
3
Halimeda Facies
- disarticulated bivalve shell fragments, ~ 3.5 cm long
2
Mangrove Peat Facies
- upper 5 cm intermixed with overlying *Halimeda* facies
- wood fragments, 1 - 2 cm long, 36 - 42 cm from top of core
- dark black
- no biota observed
1
Composite Grain Facies

Core #: NS2 | Water Depth = 1.53 m | Lat. = N 19° 21.461 | Long. = W 81° 17.264

Depth (m)	Texture (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0 – 0.45		2	***Halimeda* Facies** - *Thalassia* roots in top 10 cm - light grey - fragments of *Codakia sp.?*, ~ 2.5 cm long, 30 cm from top of core - articulated, whole *Anodontina alba*, ~ 3.5 cm long, 40 - 45 cm from top of core
0.45 – 1.3		1	**Bivalve-*Halimeda* Facies** - beige - Benthic foraminifera throughout - grains are medium sand to granule-sized (0.50 - 3 mm), moderately sorted - disarticulated whole *Anodontina alba*, ~ 1 cm long,104 cm from top of core

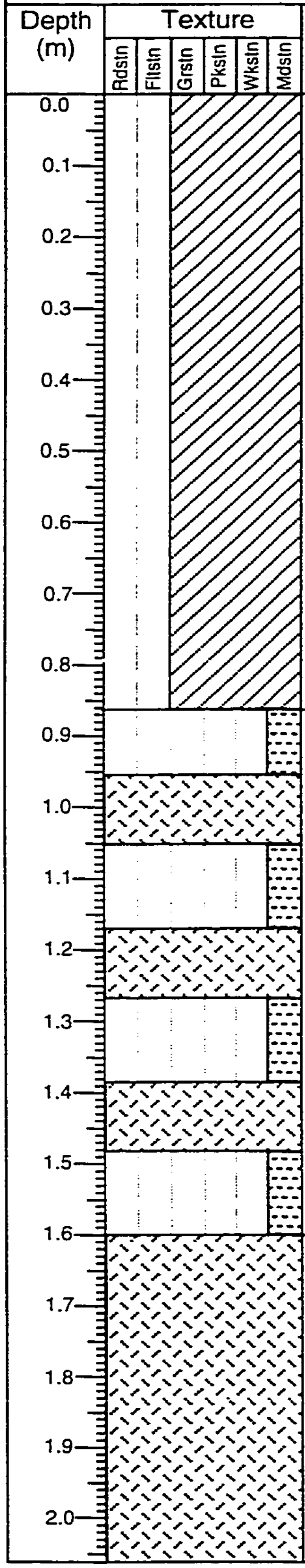
Core #: NS3	Water Depth = 1.70 m	Lat. = N 19° 22.500	Long. = W 81° 18.481
Depth (m)	Texture (Rdstn, Flltstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0 – 0.7		1	**Bivalve-*Halimeda* Facies** - light beige - grains are medium to coarse sand-sized (0.50 - 2 mm), well to moderately sorted - echinoid spines, ~ 2 - 4 mm long - numerous *Homotrema rubrum*

Core #: NS4	Water Depth = 3.05 m	Lat. = N 19° 22.364	Long. = W 81° 16.719
Depth (m)	Texture (Rdstn, Flltstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0 – 0.4		1	**Bivalve-*Halimeda* Facies** - grains are medium sand to granule-sized (0.50 - 3 mm), well to moderately sorted - numerous *Homotrema rubrum* - light beige

Core #: NS5	Water Depth = 3.05 m	Lat. = N 19° 22.541	Long. = W 81° 16.261
Depth (m)	Texture (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0–0.6		1	**Bivalve-*Halimeda* Facies** - grains are medium sand to granule-sized (0.50 - 3 mm), well to moderately sorted - numerous *Homotrema rubrum*

Core #: NS7	Water Depth = 3.05 m	Lat. = N 19° 22.554	Long. = W 81° 17.550
Depth (m)	Texture (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0–0.7		1	**Bivalve-*Halimeda* Facies** - grains are medium to coarse sand-sized (0.50 - 2 mm), well to moderately sorted - numerous *Homotrema rubrum* throughout - disarticulted, fragmented and whole *Divaricella quadrisulcata* ~ 1.8 cm long, and *Imbricaria? sp.* shells at 45.0-73.5 cm depth

Core #: NS8 | Water Depth = 6.10 m | Lat. = N 19° 19.688 | Long. = W 81° 19.556



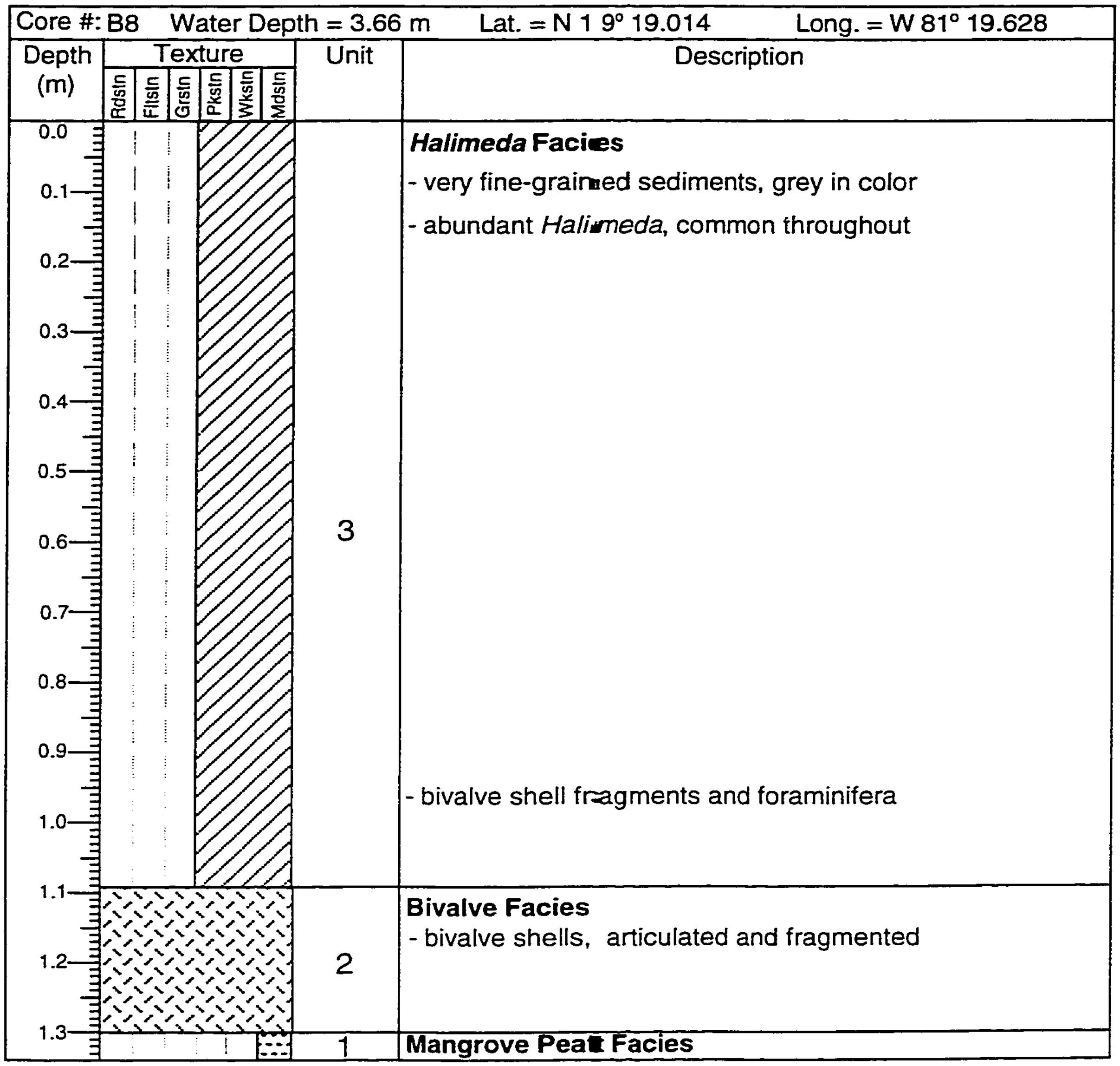
Unit	Description
3	***Halimeda* Facies** - articulated *Anodontina alba*, ~ 1.5 cm long, 21 cm from top of core - sediments grade upwards from dark grey to light grey - disarticulated whole *Halimeda* plates are common - disarticulated whole *Anodontina alba*, ~ 2 cm long, 74 cm from top of core
2	**Intermixed Mangrove Peat and Bivalve Facies** - disarticulated whole *Chione cancellata*, ~ 1.5 cm long, 0.96 m from top of core
1	**Bivalve Facies** - *Mytilopsis domingensis, 1.5 to 2.5 cm long,* intermixed with ~ 5 - 10% peat

Core #: B6 Water Depth = 3.66 m Lat. = N 19° 18.636 Long. = W 81° 19.615

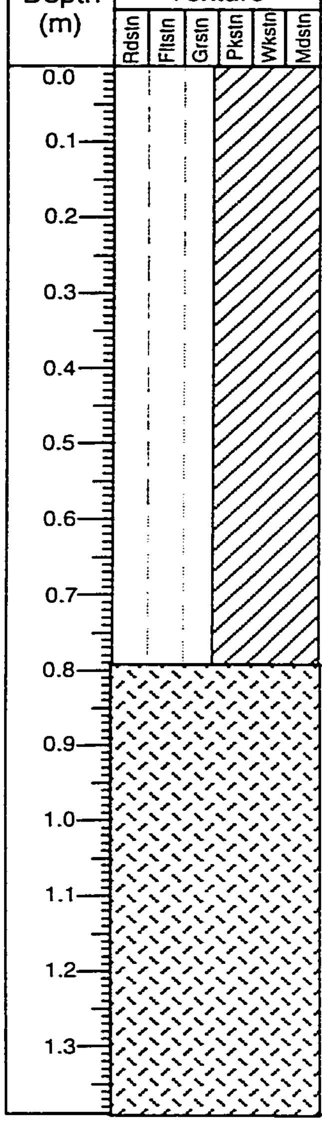
Depth (m)	Texture (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0–0.22		2	***Halimeda* Facies** - *Thalassia* roots in upper 5 cm of facies
0.22–0.65		1	**Composite Grain Facies** - very difficult to split core into halves - white to light beige in color - partially lithified, fine-grained sediments

Core #: B7 Water Depth = 3.66 m Lat. = N 19° 18.827 Long. = W 81° 19.619

Depth (m)	Texture (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0–0.73		1	***Halimeda* Facies** - small articulated bivalves throughout core - abundant *Halimeda*, articulated and fragmented


Core #: B8 Water Depth = 3.66 m Lat. = N 1 9° 19.014 Long. = W 81° 19.628
Depth (m)
Texture
Rdstn
Flstn
Grstn
Pkstn
Wkstn
Mdstn
Unit
Description
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
3
Halimeda Facies
- very fine-grained sediments, grey in color
- abundant *Halimeda*, common throughout
- bivalve shell fragments and foraminifera
2
Bivalve Facies
- bivalve shells, articulated and fragmented
1
Mangrove Peat Facies

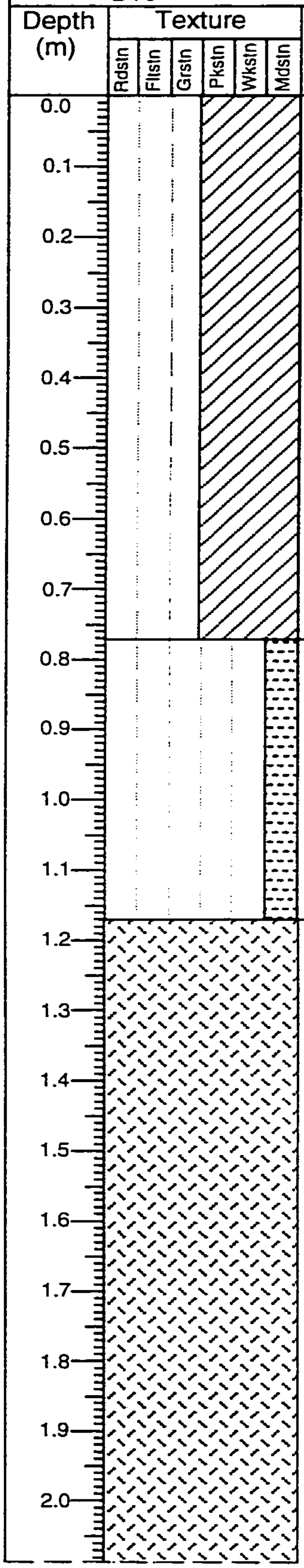
Core #: B9 Water Depth = 3.66 m Lat. = N 19° 19.217 Long. = W 81° 19.616



Depth (m)	Unit	Description
0.0–0.8	2	***Halimeda* Facies** - fine-grained sediments containing bivalve shells (1.5-4.0 cm in length, *Anodontia alba*), mostly whole but commonly fragmented - *Halimeda* are commonly whole plates near the base of the facies, and rapidly become fragmented towards the top of the core - color grades upwards from brown-grey to light-grey - an articulated bivalve shell, *Antigona listeri* ~ 4.5 cm long, found at base of facies (marine)
0.8–1.37	1	**Bivalve Facies** - numerous, very small (1-2 mm in length), gastropod shells *Amnicola oscitans* (freshwater to brackish) in lower 7.5 cm of core

Core #: B10 Water Depth = 3.66 m Lat. = N 19° 19.460 Long. = W 81° 19.612

Depth (m) | Texture | Unit | Description



Unit 4

***Halimeda* Facies**

- top 10 cm of facies with rare roots
- shell fragments (< 1.5 cm long) in lower 20-30 cm.
- lower 10 cm, dark grey, grading upwards to light-grey

Unit 3

Mangrove Peat Facies

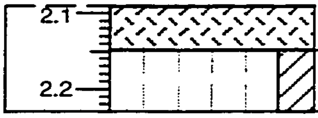
- articulated bivalve shell (4.0 cm long) at 0.80-0.82 m, *Anodontia alba*
- articulated bivalve shell (3.5 cm long) at 1.06-1.09 m, *Antigona listeri*

Unit 2

Bivalve Facies

- bivalves, *Mytilopsis domingensis*, mostly fragmented, with scattered disarticulated, whole valves. Articulated bivalves rare.

Core #: B10

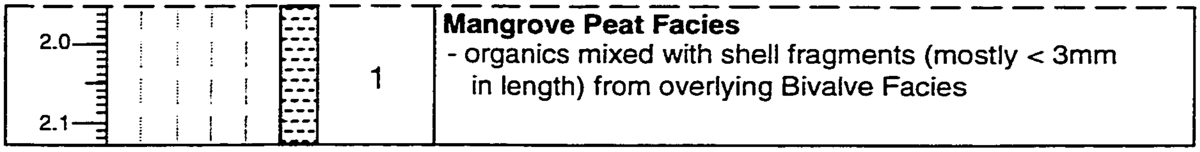


1	**Mangrove Peat Facies** - lacks any biota

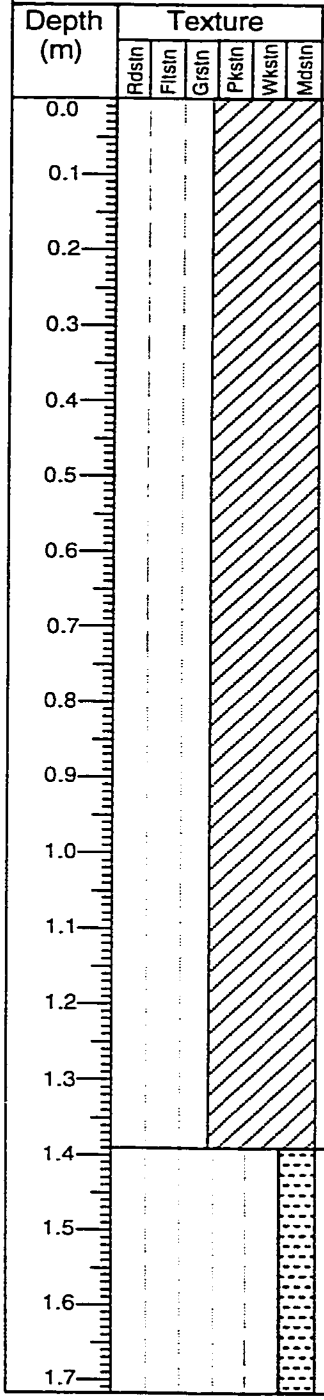
Core #: B11 Water Depth = 3.05 m Lat. = N 19° 19.687 Long. = W 81° 19.617

Depth (m)	Texture (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0–1.0		4	***Halimeda* Facies** - *Halimeda* fragments average ~ 4 mm long throughout - fragmented valve of *Anodontia alba* (~ 3 cm in length) at base of facies
1.0–1.7		3	**Mangrove Peat Facies** - *Antigona listeri* common in upper 0.20 m, articulated and disarticulated valves, ~ 2.5 cm long - articulated *Anodontia alba* (~ 2.5 cm long) at base
1.7–1.9		2	**Bivalve Facies** - numerous *Mytilopsis domingensis*, valves are mostly whole and disarticulated - facies is fairly unconsolidated and mixed with organics (~ 5%)
1.9–		1	**Mangrove Peat Facies**

Core #: B11

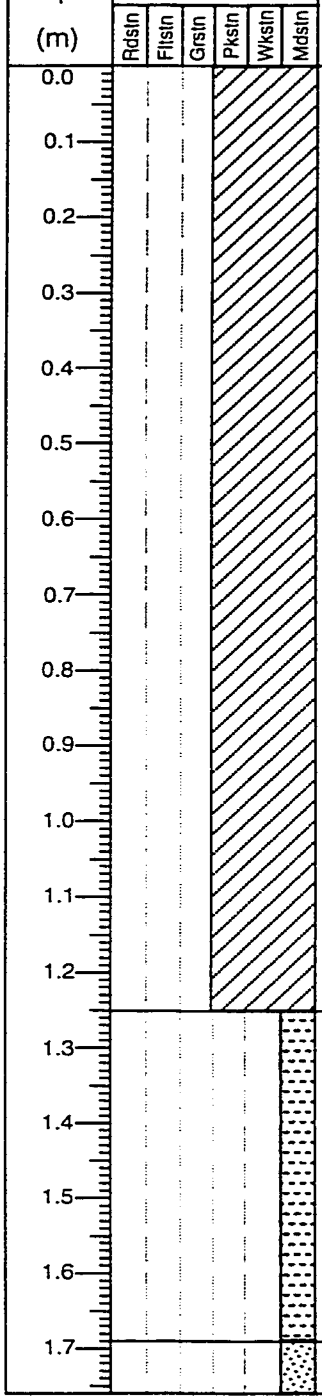

2.0
2.1
1
Mangrove Peat Facies
- organics mixed with shell fragments (mostly < 3mm in length) from overlying Bivalve Facies

Core #: B12 Water Depth = 3.05 m Lat. = N 19° 19.910 Long. = W 81° 19.628



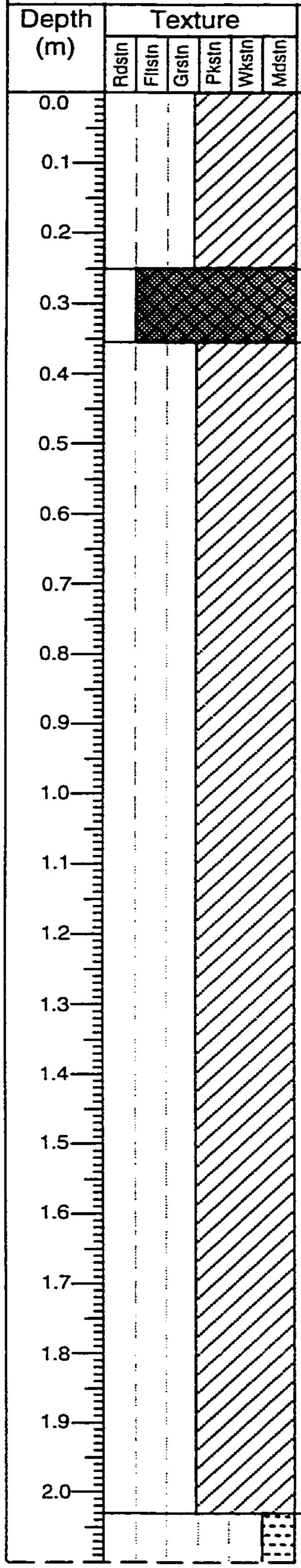
Unit	Description
2	***Halimeda* Facies** - well-lithified by silt and clay-sized sediments - light-grey to beige - numerous *Halimeda* plates, whole and fragmented; whole and fragmented Benthic Foraminifera scattered throughout - bivalve shell fragments (< 2 cm long) common throughout - gastropods (< 1 cm long) common throughout
1	**Mangrove Peat Facies** - fine-grained organics intermixed with overlying *Halimeda* facies - upper10 cm composed predominantly of the *Halimeda* facies with minor amounts of fine-grained organics

Core #: B13	Water Depth = 3.05 m	Lat. = N 19° 20.100	Long. = W 81° 19.617
Depth (m) / Texture (Rdstn, Flfstn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**	
0.0–1.25	3	***Halimeda* Facies** - *Halimeda* grade from larger fragments (~ 4 mm long) near base, to smaller fragments (~ 2 mm long) near top. - light-grey - *Anodontia alba* (~ 3.5 cm long) located 0.17-0.18 m from top	
1.25–1.69	2	**Mangrove Peat Facies** - abundant, very small (1-2 mm long), *Amnicola oscitans* (freshwater to brackish) scattered throughout organics - upper 10 cm is intermixed with overlying *Halimeda* facies	
1.69–1.75	1	**Composite Grain Facies**	



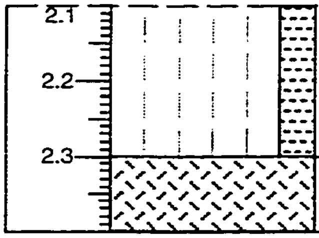
Core #: B14	Water Depth = 4.58 m	Lat. = N 19° 20.325	Long. = W 81° 19.617
Depth (m)	Texture (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0–1.4		2	***Halimeda* Facies** - color grades upward from a brown-grey to a light-grey - echinoid spine, 1 cm long, at a depth of 0.94 m - mangrove fragments ~1.0-1.5 long are scattered throughout lower 0.5 m of core - lower 0.5 m of facies contains mostly whole *Halimeda; Halimeda* become progressively more fragmented upwards - lower 10 cm contains organics mixed with mostly whole, but commonly fragmented *Halimeda* plates
		1	**Composite Grain Facies**

Core #: B15 Water Depth = 4.58 m Lat. = N 20° 19.539 Long. = W 81° 19.618



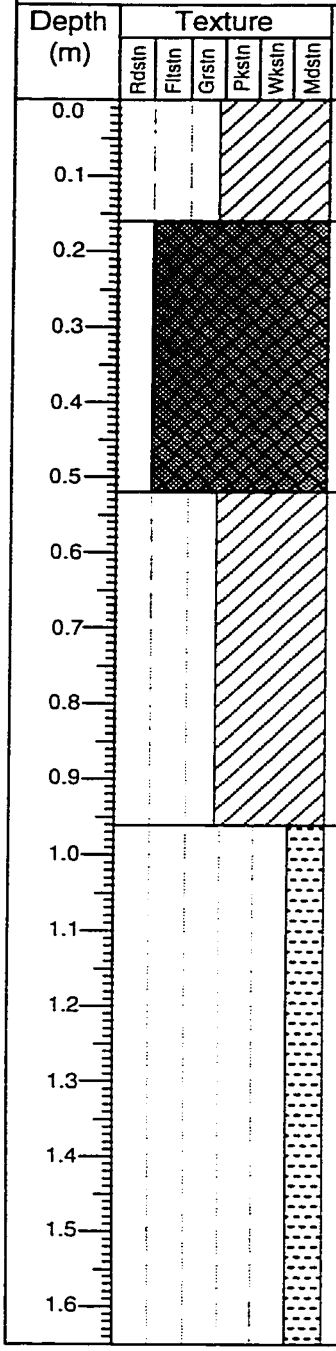
Unit	Description
5	***Halimeda* Facies** - cluster of *Thalassia* roots and blades (~ 9 cm long) located at the top - a branching coral fragment *Acropora* ? (2 cm long) located 20 cm from the top
4	***Halimeda*- Benthic Foraminifera-Bivalve Facies** - bivalve frags (< 1.5 cm long) are mainly *Anodontia alba*
3	***Halimeda* Facies** - sediments grade from dark grey at base to light grey at top of core - sediments extremely well-lithified
2	**Mangrove Peat Facies**

Core #: B15



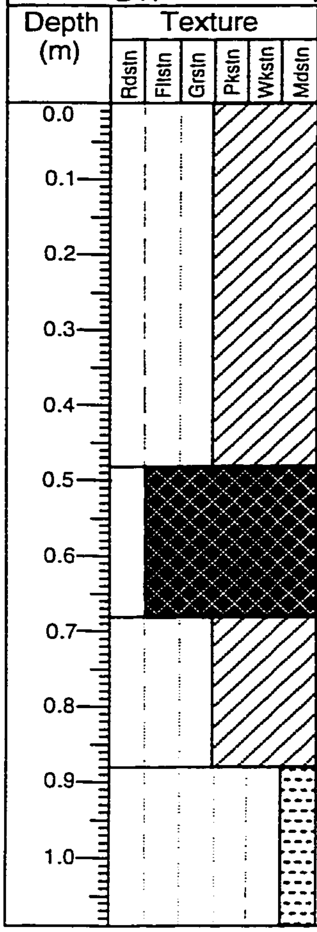
2	**Mangrove Peat Facies** - peat intermixed with overlying *Halimeda* Facies - contact with overlying facies gradational, basal contact with underlying facies is also gradational
	Bivalve Facies - disarticulated *Mytilopsis domingensis*, 1.5 to 2.0 cm long

Core #: B16 Water Depth = 3.66 m Lat. = N 19° 20.746 Long. = W 81° 19.614



Unit	Description
4	***Halimeda* Facies** - *Thalassia* roots (< 1.5 cm long) prevasive throughout - pieces of *Thalassia* blades (< 2 cm long) scattered throughout
3	***Halimeda*- Benthic Foraminifera -Bivalve Facies** - numerous disarticulated whole and fragmented bivalves (predominantly *Anadara sp.?*), < 4 cm long, throughout
2	***Halimeda* Facies** - sediments grade from dark grey at base to light grey at top - small patch of peat (< 1 cm thick) extends entire width of core, located 0.79-0.80 m from top of core
1	**Mangrove Peat Facies** - mangrove peat intermixed with sediments of overlying *Halimeda* facies - peat is dark brown, no bivalves or gastropods - bottom 5 cm of core contains some sediment from Composite Grain Facies

Core #: B17 Water Depth = 3.05 m Lat. = N 19° 20.964 Long. = W 81° 19.611



Unit	Description
4	***Halimeda* Facies** - whole, articulated *Codakia sp. ?*, 4 cm long - minor *thalassia* roots ~ 1 cm long - grades upwards from light grey to beige at top
3	***Halimeda*- Benthic Foraminifera Facies** - bivalve shell and gastropod fragments scattered throughtout < 2 cm long - disarticulated, whole bivalve shell fragment (unknown species)
2	***Halimeda* Facies** - slightly finer grained and darker than overlying *Halimeda* facies
1	**Mottled peat with *Halimeda*** - patches of peat (2 - 3 cm long) intermixed with *Halimeda* facies

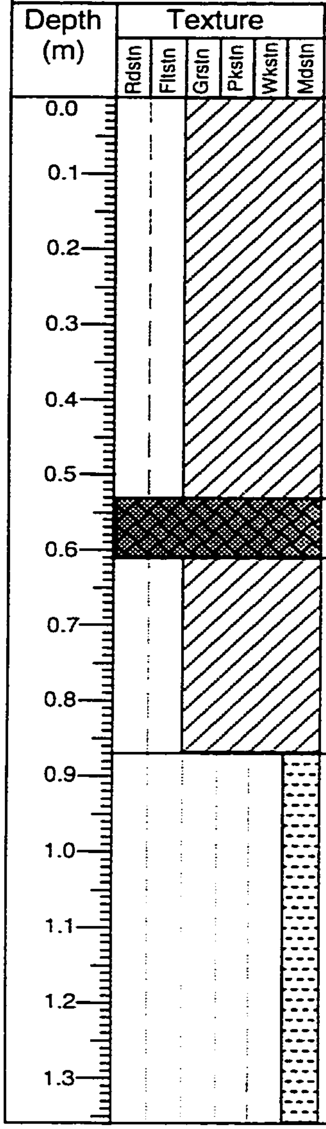
Core #: B18 Water Depth = 3.05 m Lat. = N 19° 21.118 Long. = W 81° 19.610

Depth (m)	Texture (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0 0.1		4	***Halimeda*** **Facies** - *Thalassia* roots ~ 3 cm long
0.2		3	***Halimeda-*** **Benthic Foraminifera Facies** - articulated *Codakia sp. ?* ~ 4.5 cm long - disarticulated bivalve shell (unknown sp.) ~ 4.5 cm long
0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3		2	***Halimeda*** **Facies** - light beige - bivalve shell fragments ~ 1.5 cm long 0.75 to 0.80 m from core top - bivalve shell fragments ~ 1.5 cm long1.15 to1.17 m from core top
1.4		1	**Mangrove Peat Facies** - peat intermixed with overlying *Halimeda* facies

Core #: B19 Water Depth = 3.05 m Lat. = N 19° 21.284 Long. = W 81° 19.615

Depth (m)	Texture (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0–1.6 (0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6)		3	***Halimeda* Facies** - *Thalassia* fragments located top 3 cm - upper 20 cm slightly more consolidated than the lower portion - *Thalassia* roots pervasive throughout top 20 cm - light grey throughout - disarticulated, whole *Anadara sp.?* ~ 1.5 cm long
1.7–1.8		2	**Mangrove Peat Facies intermixed with *Halimeda* Facies**
		1	**Mangrove Peat Facies**

Core #: B20 Water Depth = 3.05 m Lat. = N 19° 21.376 Long. = W 81° 19.497



Unit	Description
4	***Halimeda* Facies** - *Thalassia* roots pervasive throughout upper 20 cm - fairly consolidated - bivalve and gastropod shell fragments 0.55 to 0.60 cm from top
3	***Halimeda*-Benthic Foraminifera-Bivalve Facies**
2	***Halimeda* Facies** - grades upwards from light grey to light beige
1	**Intermixed Mangrove Peat and *Halimeda* Facies**

Core #: B21	Water Depth = 3.05 m	Lat. = N 19° 21.487	Long. = W 81° 19.350
Depth (m)	**Texture** (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0–0.5			***Halimeda* Facies** -*Thalassia* roots scattered throughout top 32 cm - grey-beige - disarticulated, whole bivalve (*Chione cancellata*), 1.5 cm long, at 24.0-25.5 cm - Benthic Foraminifera are common, and *Halimeda* are predominantly fragmented -whole *Cerithium ? sp.*, < 2 cm long, fragmented, disarticulated *Chione cancellata* (< 3 cm long) near base

Core #: B22	Water Depth = 3.05 m	Lat. = N 19° 23.139	Long. = W 81° 20.759
Depth (m)	**Texture** (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0–0.3		1	**Bivalve-*Halimeda* Facies** - abundant *Homotrema rubrum* - sediments are loosely packed

Core #: NSC1	Water Depth = 1.98 m	Lat. = N 19° 22.079	Long. = W 81° 22.564
Depth (m)	**Texture** (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0 – 0.4		1	***Halimeda* Facies** - light grey - rare *Thalassia* roots, ~ 1 cm long, in upper 20 cm - grains are medium sand to pebble-sized (0.25 - 64 mm) - disarticulated, whole *Codakia sp.?*, 42 cm from top of core

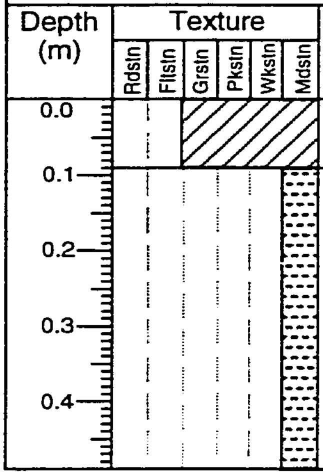
Core #: NSC2	Water Depth = 0.61 m	Lat. = N 19° 22.962	Long. = W 81° 21.762
Depth (m)	**Texture** (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0 – 0.4		1	***Halimeda* Facies** - whole *Halimeda* fragments - sediments grade upwards from coarse grained to fine-grained sands

Core #: NSC3	Water Depth = 0.61 m	Lat. = N 19° 22.962	Long. = W 81° 21.748
Depth (m)	**Texture** (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0 – 0.6		2	***Halimeda* Facies** - fragments of *Thalassia* blades, < 2 cm long, in top 3 cm - *Thalassia* roots, < 1 cm long, 8 - 26 cm from top - sediments grade upwards from dark grey-yellowish to very light grey-beige - *Cerithium* sp.? and *Polinices lacteus* shells < 1 cm long - patch of wood fragments, < 2 cm long and 2 cm wide, 50 - 55 cm from top of core
0.6 –		1	**Mangrove Peat Facies** - peat intermixed with overlying *Halimeda* facies

Core #: NSC4	Water Depth = 0.61 m	Lat. = N 19° 22.962	Long. = W 81° 21.734
Depth (m)	**Texture** (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0 – 0.36		2	***Halimeda* Facies** - *Thalassia* fragments, up to 5 cm long, present in upper 5 cm - *Thalassia* roots abundant in upper 18 cm - medium brown to grey
0.36 – 0.58		1	**Mangrove Peat Facies** - upper 0.12 m intermixed with overlying *Halimeda* facies

Core #: NSC5	Water Depth = 0.61 m	Lat. = N 19° 22.962	Long. = W 81° 21.719
Depth (m)	**Texture** (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0 – 0.33		2	***Halimeda* Facies** - medium brown to grey - *Thalassia* fragments, < 2 cm long, in upper 25 cm - grains are medium sand to pebble-sized (0.25 - 64 mm)
0.33 – 0.68		1	**Mangrove Peat Facies** - intermixed with overlying *Halimeda* facies - no biota observed

Core #: NSC6 Water Depth = 0.92 m Lat. = N 19° 22.935 Long. = W 81° 22.378



Unit	Description
2	***Halimeda* Facies** - *Halimeda* are predominantly whole
1	**Mangrove Peat Facies** - peat is dark brown to black in color - no biota are observed - numerous rootlets throughout

Core #: EB23	Water Depth = 3.05 m	Lat. = N 19° 21.489	Long. = W 81° 19.614
Depth (m)	Texture (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0 – 0.8		1	***Halimeda* Facies** - *Thalassia* roots throughout upper 20 cm - light grey - articulated *Codakia sp.?* ~ 0.7 cm long at 0.45 cm from core top

Core #: EB24	Water Depth = 3.05 m	Lat. = N 19° 21.665	Long. = W 81° 19.608
Depth (m)	Texture (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0 – 0.6		1	***Halimeda* Facies** - abundant *Thalassia* roots ~ 2 cm long in top 20 cm - *Thalassia* roots scattered 0.20 to 0.47 m from core top - light grey to beige - whole *Cerithium?* sp., ~ 1.5 long, 42 cm from top of core - *Halimeda* plates mostly fragmented throughout

Core #: EB25	Water Depth = 3.05 m	Lat. = N 19° 21.863	Long. = W 81° 19.625
Depth (m)	**Texture** (Rdstn, Flistn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0–0.9		1	***Halimeda* Facies** - *Thalassia* roots throughout top 10 cm - whole gastropods, ~ 1 cm long, throughout core - light to dark grey - disarticulated *Halimeda* fragments, mostly fragmented with sparse disarticulated whole *Halimeda* plates - disarticulated *Anadara sp.?*, ~ 2.5 long, located 0.80 to 0.83 cm from top of core

Core #: EB27	Water Depth = 2.75 m	Lat. = N 19° 22.168	Long. = W 81° 19.605
Depth (m)	**Texture** (Rdstn, Flistn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0–0.46		2	***Halimeda* Facies** - *Thalassia* roots, ~ 1 - 2 cm long, throughout - *Halimeda* plates disarticulated, mostly fragmented
0.46–0.55		1	***Halimeda*-Benthic Foraminifera- Bivalve Facies** - abundant disarticulated bivalve shells (~ 1.5 cm long)

Core #: EB28	Water Depth = 2.75 m	Lat. = N 19° 22.531	Long. = W 81° 19.381
Depth (m)	**Texture** (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0–0.6		1	**Bivalve-*Halimeda* Facies** - light beige - numerous *Homotrema* throughout - sediments grade upwards from mostly disarticulated, whole *Codakia?* sp. and *Imbricaria?* sp. shells, ~ 0.6 cm long, to coarse sand-sized sediments - bivalve shell fragments are commonly burrowed

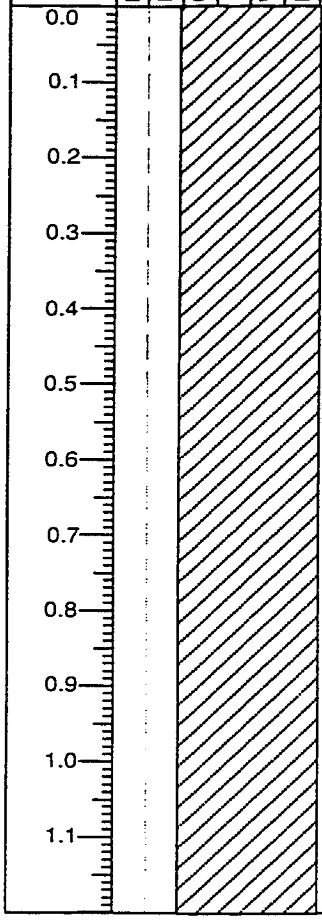
Core #: EB29	Water Depth = 2.14 m	Lat. = N 19° 19.556	Long. = W 81° 17.250
Depth (m)	**Texture** (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0–0.08		2	***Halimeda* Facies** - numerous benthic foraminifera
0.08–1.1		1	**Mangrove Peat Facies** - upper 5 cm is intermixed with overlying *Halimeda* facies - disarticulated, whole *Codakia sp.?* ~ 10 cm from top of core - dark brown to black organics with rootlets scattered throughout, no biota observed

Core #: EB30A	Water Depth = 3.05 m	Lat. = N 19° 18.875	Long. = W 81° 18.405
Depth (m)	Texture (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0 – 0.9		1	***Halimeda* Facies** - grades upwards from dark grey to light beige - disarticulated, whole *Chione cancellata*, ~ 2.5 cm long, 26 cm from top of core - disarticulated, whole and fragmented *Halimeda* plates scattered throughout - grains are medium sand to pebble-sized bivalves (0.25 - 64 mm) - disarticulated, whole *Anadara sp. ?* (burrowing bivalve), ~ 2.5 cm long, 60 cm from top of core

Core #: EB30B	Water Depth = 3.05 m	Lat. = N 19° 18.875	Long. = W 81° 18.405
Depth (m)	Texture (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0 – 0.4		1	***Halimeda* Facies** - grades upward from light grey to beige - disarticulated, fragmented *Anodontina alba*, ~ 3 cm long, 20 cm from top - disarticulated, whole and fragmented *Halimeda* plates scattered throughout - grains are medium sand to pebble-sized bivalves (0.25 - 64 mm)

Core #: EB31 Water Depth = 2.44 m Lat. = N 19° 19.366 Long. = W 81° 18.624

Depth (m) | Texture (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn) | Facies | Description



Facies: 1

***Halimeda* Facies**

- *Thalassia* roots, ~ 3 cm long, in upper 5 cm

- *Halimeda* are mostly whole 0.53 - 1.2 cm from top of core

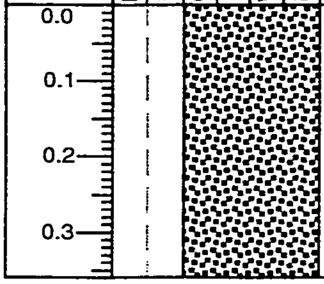
- disarticulated, whole *Anodontina alba*, ~ 4 cm long, 20 cm from top of core

- grains are medium sand to pebble-sized bivalves (0.25 - 64 mm)

Core #: EB32	Water Depth = 4.58 m	Lat. = N 19° 20.788	Long. = W 81° 18.337
Depth (m)	**Texture** (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0 – 0.4		2	***Halimeda* Facies** - grades upward from dark grey to light beige - disarticulated, whole bivalve *Chione cancellata,* ~ 2.5 cm long, and whole *Astrea sp.?* 28-29 cm from top of core,
0.4 – 0.9		1	**Mangrove Peat Facies** - peat intermixed with overlying *Halimeda* facies - dark brown to black, with small (< 1 cm long) rootlets scattered throughout

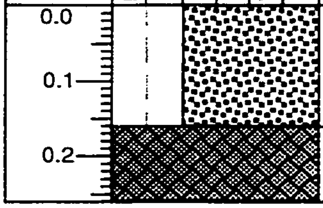
Core #: EB35	Water Depth = 3.05 m	Lat. = N 19° 22.638	Long. = W 81° 20.095
Depth (m)	**Texture** (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0 – 0.5		1	**Bivalve-*Halimeda* Facies** - grains are medium to coarse sand-sized (0.50 - 2 mm), and moderately sorted - numerous *Homotrema rubrum* throughout - light beige

Core #: EB37 Water Depth = 3.36 m Lat. = N 19° 22.973 Long. = W 81° 20.876



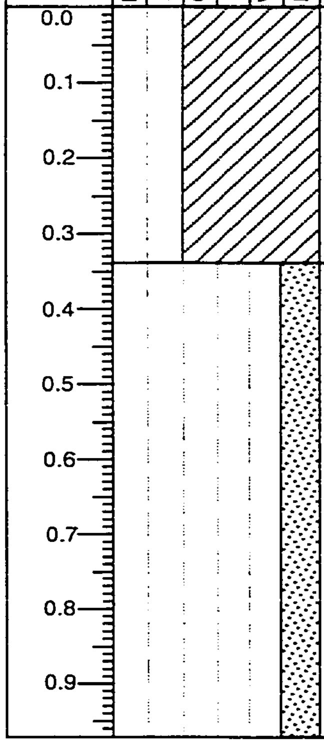
Depth (m)	Texture (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0–0.3		1	**Bivalve-*Halimeda* facies** - coral fragments ~ 1.5 - 2 cm long - rare fragmented *Imbricaria?* sp. and *Polinices lacteus* ~1 cm diam. in lower 10 cm

Core #: EB40 Water Depth = 2.44 m Lat. = N 19° 22.551 Long. = W 81° 21.286



Depth (m)	Texture (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0–0.1		2	**Bivalve-*Halimeda* facies** - few roots scattered in lower 3 cm
0.2		1	***Halimeda*-Benthic Foraminifera facies** - abundant,fragmented and disarticulated *Chione cancellata* 3 cm - some fragments of coral rubble (*Porites* sp.?)

Core #: EB41 Water Depth = 2.44 m Lat. = N 19° 18.342 Long. = W 81° 20.417



Depth (m)	Texture (Rdstn, Flstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0–0.3		2	***Halimeda* Facies** - grey-brown - *Thalassia* fragments and roots 0 - 7 cm from top of core - articulated *Codakia sp.?*, ~ 2.5 cm long, 10 cm from top of core - bivalve and gastropod fragments, < 1.5 cm long, throughout
0.4–0.9		1	**Composite Grain Facies** - white - grains are silt to clay sized (< 0.06 mm)

Core #: EB42 Water Depth = 3.05 m Lat. = N 19° 18.801 Long. = W 81° 20.999

Depth (m)	Texture (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0 – 0.57	Grstn	3	***Halimeda* Facies** - medium grey - *Halimeda* plates predominantly fragmented throughout - articulated, whole *Anodontina alba*, ~ 3 cm long, 52 - 55 cm from top of core
0.57 – 0.99	Mdstn	2	**Mangrove Peat Facies** - sediments intermixed with overlying *Halimeda* facies
0.99 – 1.8	Mdstn	1	**Composite Grain Facies** - white - grains are silt to clay sized (< 0.06 mm)

Core #: EB43 Water Depth = 3.36 m Lat. = N 19° 19.878 Long. = W 81° 20.816

Depth (m)	Texture (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0–1.2	Grstn	3	***Halimeda* Facies** - sediments grade upwards from dark grey to light grey - disarticulated, whole *Codakia sp.?*, ~ 2.5 cm long, with obvious boring, located ~ 30 cm from top of the core - articulated, whole *Codakia sp.?*, ~ 1 cm long, 56 cm from top of core - *Halimeda* plates are mostly whole at 73 to 1.2 cm from top of core - Benthic Foraminifera common throughout
1.2–1.25	Mdstn	2	**Mangrove Peat Facies**
1.25–2.05	Mdstn	1	**Composite Grain Facies** - white - grains are silt to clay sized (< 0.06 mm)

Core #: EB44	Water Depth = 3.97 m	Lat. = N 19° 20.578	Long. = W 81° 21.031
Depth (m)	**Texture** (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	**Unit**	**Description**
0.0–0.5		3	***Halimeda* Facies** - *Thalassia* roots < 3 cm long in upper 13 cm - light grey
0.5–1.3		2	**Mangrove Peat Facies** - upper 30 cm intermixed with overlying *Halimeda* facies - rootlets are common - sediments grade upward from black to black - dark brown from intermixing with overlying *Halimeda* facies - no shells observed
1.3–		1	**Composite Grain Facies**

Core #: EB45	Water Depth = 2.75 m	Lat. = N 19° 21.893	Long. = W 81° 21.793
Depth (m)	Texture (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0 – 0.8		1	***Halimeda* Facies** - grades upward from dark grey to light beige - disarticulated *Anodontina alba*, ~1.5 cm long, 22 cm from top of core - disarticulated bivalve shell fragments, < 2 cm long, 43 - 44 cm from top of core - disarticulated *Anodontina alba*, ~ 1.5 cm long, 55 cm from the core top - sparse patches of peat, ~ 2 cm long, 64 - 90 cm from the top of core

Core #: EB46	Water Depth = 2.75 m	Lat. = N 19° 22.391	Long. = W 81° 22.197
Depth (m)	Texture (Rdstn, Fltstn, Grstn, Pkstn, Wkstn, Mdstn)	Unit	Description
0.0 – 0.1		2	***Halimeda*-Benthic Foraminifera-Bivalve Facies** - disarticulated and articulated *Anodontina alba*, ~ 3.5 cm long - fragment of *Thalassia* rhizome ~ 2.5 cm long
0.2 – 0.5		1	***Halimeda* Facies** - fragment of *Thalassia* blade ~ 3.0 cm long - unfragmented gastropods (*Cerithium?* sp.) 0.5-1.0 cm long, fragments of *Codakia?* sp. and *Linga pennsylvanica* < 1.5 cm long - bottom 7 cm contains wood fragments, 1.0 - 2.0 cm long