A TAPHONOMIC COMPARISON OF PLEISTOCENE AND MODERN CORALS, SAN SALVADOR ISLAND, BAHAMAS

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INTRODUCTION

The Cockburn Town Fossil Reef, located just northwest of the center of Cockburn Town, on San Salvador Island, displays a shallowing upward sequence reflecting a post-Sangamon lowering of sea level (White et al, 1984). The sequence includes a coral rubblestone, which is largely composed of *Acropora cervicornis* , and a coralstone facies, which is abundant in in situ *Acropora palmata*. These two facies were interpreted by White, et al. (1984) as back reef and reef tract facies respectively. Although the reef has been dated radiometrically to have flourished between 131-119 ky before present (Carew, 1983; Chen et al, 1990), data concerning the rate at which sea level fell has remained elusive.

The Cockburn Town reef provides an exceptional opportunity for a variety of comparative studies because of the exceptional preservation exhibited and its proximity to analogous modern depositional environments. For example, Telephone Pole Reef and Lindsey Reef, located in Fernandez Bay and Long Bay respectively (see Curran, this volume), are generally accepted as modern examples of the coral rubblestone and coralstone described by White et al (1984) from the fossil reef. The purpose of this study is to compare processes of preservation (taphonomy) currently affecting subfossil corals, collected from Telephone Pole Reef and Lindsey Reef, to that preserved in Pleistocene corals collected from the Cockburn Town reef. Parsons and Brett (1991) have pointed out that there is much anecdotal evidence that fossil assemblages are commonly better-preserved than would be predicted from examination of subfossil counterparts (p. 23). This is the first study to quantify this general observation. Moreover, the degree of degradation suffered by carbonate material as a result of biologic processes is related to the time spent in the taphonomically active zone (TAZ, Davies et al, 1989). This zone is roughly equivalent to the sea floor surface. Thus taphonomic comparisons may be used to assess the relative rapidity with which coral material was removed from exposure on the sediment surface by burial: for the Cockburn Town Reef this is related to the rate at which sea level fell during post-Sangamon time. Measurement of a variety of taphonomic attributes (e.g. borer and encruster activity) reveals significant differences in the amount of degradation suffered by modern and ancient material: the Pleistocene is better preserved than the Recent. This suggests that processes of deposition observable in the modern environments studied are not sufficient to explain the preservation in the Cockburn Town Fossil Reef. Associated field experiments have thus far remained inconclusive on determining an actual time between death and burial.

FIELD METHODS

Along the Cockburn Town Fossil Reef, ten *Acropora* samples were collected from within five 9 m^2 sites. A total of 50 specimens was gathered from the fossil reef, resulting in a 4:1 ratio of *Acropora cervicornis* to *Acropora palmata.*

In the modern environment, fifty specimens were obtained from various sites (defined by a 9 m^2 grid). Modern samples were collected in the following quantities: (a) at Telephone Pole Reef, ten pieces of *A. cervicornis* were gathered from four separate sites, totaling forty specimens; and (b) at Lindsey Reef, ten pieces of in situ *A. palmata* were broken off within one site. This ratio comes to that observed in the Cockburn Town reef collection.

Two cages containing pristine specimens of both species of coral were placed at Dump Reef in Graham's Harbor (see Curran, this volume) in January, 1992. They were retrieved and examined for development of potentially preservable encrustation and/or borer activity after intervals of six and twelve months.

LABORATORY METHODS

The 100 samples were categorized using a qualitative scale of abrasion (1=pristine with pristine corallites to 5= heavily abraded with no visible corallites). The amount and types of coverage by preservable encrusters on modern corals were recorded and compared to the degree and types of encrustation

The vadose zone is a region of periodic infiltration of fresh water percolating through rocks whose pore spaces are not fluid saturated. The zone has a different cementation chemistry than those supersaturated with salt water. A characteristic morphology of these crystals is a meniscus shape.

Meniscus shapes appear when the cement precipitates within the waters surrounding air bubbles trapped in the pore spaces. Pendant-shaped cement "dripping" off crystals can also often be observed. The cement collects between grains and forms hourglass-shaped pillars. The calcites of the fresh water environment are low magnesium calcite and, several staining techniques can help distinguish between high and low magnesium calcite.

Exposing the calcite grains of the saturated zone to fresh water and partial saturation may cause a dissolution of the grains as well as the cements. Dissolution is often seen in the thin sections as progressively destroying the intergranular cement as well as the original calcite grains and leaving behind a muddy micritic residue. Dissolution can be further intensified with the adjunct of micro-bacteria and plant root activities. Rhizomorphs were found in field evidence, and suggest that this form of dissolution seems likely.

Marine and non-marine cements can be seen to overlap one another within the thin-sections of thin-sections taken from northern Sue Point. In most cases, specific types of diagnostic features overlapped each other and were thus non sequential. However, the overlapping sequences of cementation were pervasive throughout the samples studied. Additional examination is in progress in an attempt to identify correlations of cementation history that may be held in common by sections which are parallel laterally in the rock outcrop.

Conclusions

The petrologic evidence supports the idea that the rocks at northern Sue Point have been effected by more than one fluctuation in sea level. Besides the obvious fact that the outcrop itself is made up of marine sediments which are now sitting above water, sequences of alternating marine to non marine cements are seen in thin-section analysis. Other post depositonal evidence, for example aragonite cementation on dissolution surfaces, also suggest alternating environments. This petrologic data complies with San Salvador field evidence that sea level has risen and fallen several times in the last hundred thousand years (see various articles in Mylroie, 1989). This conclusion is also concordant with worldwide data which validates several sea level fluctuations in the Quaternary. Research for further petrologic evidence is still in progress at this time.

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observed on the Pleistocene specimens (see Figure 1). Encrusters present on both ancient and modern specimens included: coralline algae, worm tubes < 1 mm, worm tubes ≥ 1 mm, bryozoa, and corals. After encrustation analysis, the corals were cut longitudinally and examined for borer activity, including sponge, mollusc and worm borings. The degree and types of borer activity were recorded using a quantitative scale developed for this study (see Figures 2a and 2b).

The previously pristine specimens from the Dump Reef cages were examined after six-month and twelve-month intervals to better understand the rates of bioerosion. Changes in the degree and types of encrustation and borer activity were recorded.

OBSERVATIONS AND DISCUSSION

Results of Surface Analysis

The encrustation and abrasion data indicate that the surface areas of the Pleistocene corals are much more pristine than that of the modern sub-fossil specimens. Six of the eight categories analyzed (including coverage, abrasion, coralline algae, both divisions of worm tubes, and coral encrusters) show significant differences between ancient and modern taphonomic conditions (see Figure 1). This suggests that the modern coral has been exposed on the sea floor for a longer period of time than the Cockburn Town Fossil Reef corals were or that encrusting organisms are more active today.

Results of Borer Analysis

The comparative data of the degree of borer activity provide a clear illustration of the relatively low degree of degradation (caused by boring organisms) observed in the Pleistocene corals and the relatively high degree observed in the recent corals. Two-thirds of the modern specimens display heavy borer activity whereas only two percent of the ancient corals exhibit such extreme activity. A large majority of the ancient corals displays only slight bioerosion (see Figures 2a and 2b). Again, this suggests that the modern subfossils had more exposure on the sea floor, allowing a greater accumulation of bioeroders or that borer organism activity is more intense today.

Results of Exposure Experiments

After a six-month time period, six pieces of previously pristine *Acropora cervicornis* and *Acropora palmata* , which had been placed with eight other pieces of *Acropora* in cages at Dump Reef, were examined for development of coral degradation. Results showed that corallites had remained pristine and no surface borings were present. Small worm tubes(less than 1 mm in diameter) covered approximately 30% of one specimen but were not visible on the rest of the corals. No other preservable encrusters were observed.

After another six-month interval, the remaining eight pieces of *Acropora* were examined for further development of degradation. On average, corallites were 65% pristine and small worms tubes covered approximately 60-80% of the corals. Coralline algae represented less than 5% of the total surface area of each coral observed. No surface borings were present.

Implications

The comparative analysis of the amount of bioerosion and encrustation on the 100 specimens collected from the coral rubblestone facies, coralstone facies and sub-fossil material from the modern environments provides important information about the rate at which post-Sangamon sea level changed. Sub-fossil material has been carefully examined to determine the degree of bioerosion of *Acropora* resulting from exposure on the sea floor. My data on coral degradation indicate that the fossil corals are significantly more pristine when compared to their sub-fossil counterparts: assuming that the abundance of bioeroders has remained constant since the Pleistocene, the Cockburn Town corals must have experienced rapid removal from exposure on the sea floor perhaps by rapid burial. Both bioerosion and encrustation are less abundant in the fossil corals, indicating that the Pleistocene reef had been exposed on the sea floor for less time than the current sub-fossil material. Rapid burial is one process which could result in relatively pristine fossils. Results, however, of the Dump Reef experiments suggest exposure for more than one year had occurred.

On a larger scale, the results of this study imply that the fossil record of the Cockburn Town Reef does not necessarily result from processes of slow steady accumulation of skeletal material. Instead, they suggest that well-preserved fossil assemblages within the record represent relatively short spans of exposure to bioerosional activity. Thus, the fossil record of the Cockburn Town Fossil Reef could perhaps be seen more as an unusual process rather than the result of processes observable today.

Figure 1. DATA FROM ENCRUSTATION ANALYSIS

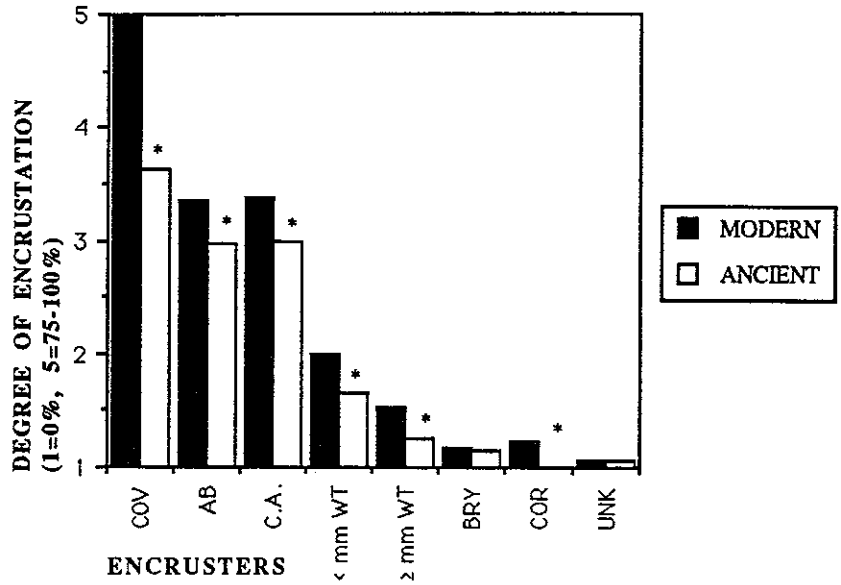

Figure 2a. DATA FROM BORER ANALYSIS

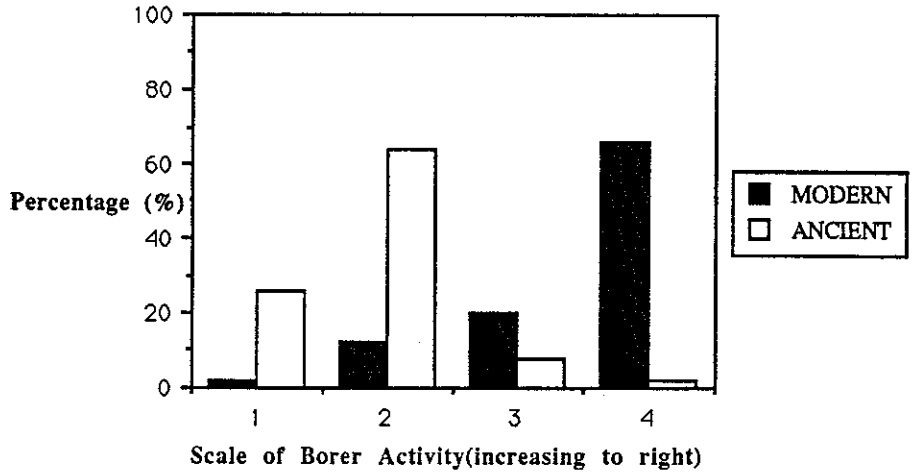

Figure 1. Graph of comparative analysis of encrustation. Categories observed: coverage (COV), abrasion (AB), coralline algae (C.A.), worm tubes less than 1 millimeter in diameter (< mm WT), worm tubes greater or equal to 1 millimeter in diameter (≥ mm WT), bryozoa (BRY), encrusting corals (COR). Asterisks (*) indicate categories which exhibit significant differences between modern and ancient encrustation ($\alpha = 0.05$, $n = 100$).

Figure 2a. Graph of comparative analysis of borer activity. Borer activity includes sponge (e.g. *Cliona*), mollusc (e.g. *Lithophaga*) and worm borings. See Fig. 2b for illustration of the scale used. Results indicate significant differences between modern and ancient borer activity ($\alpha = 0.05$, $n = 100$)

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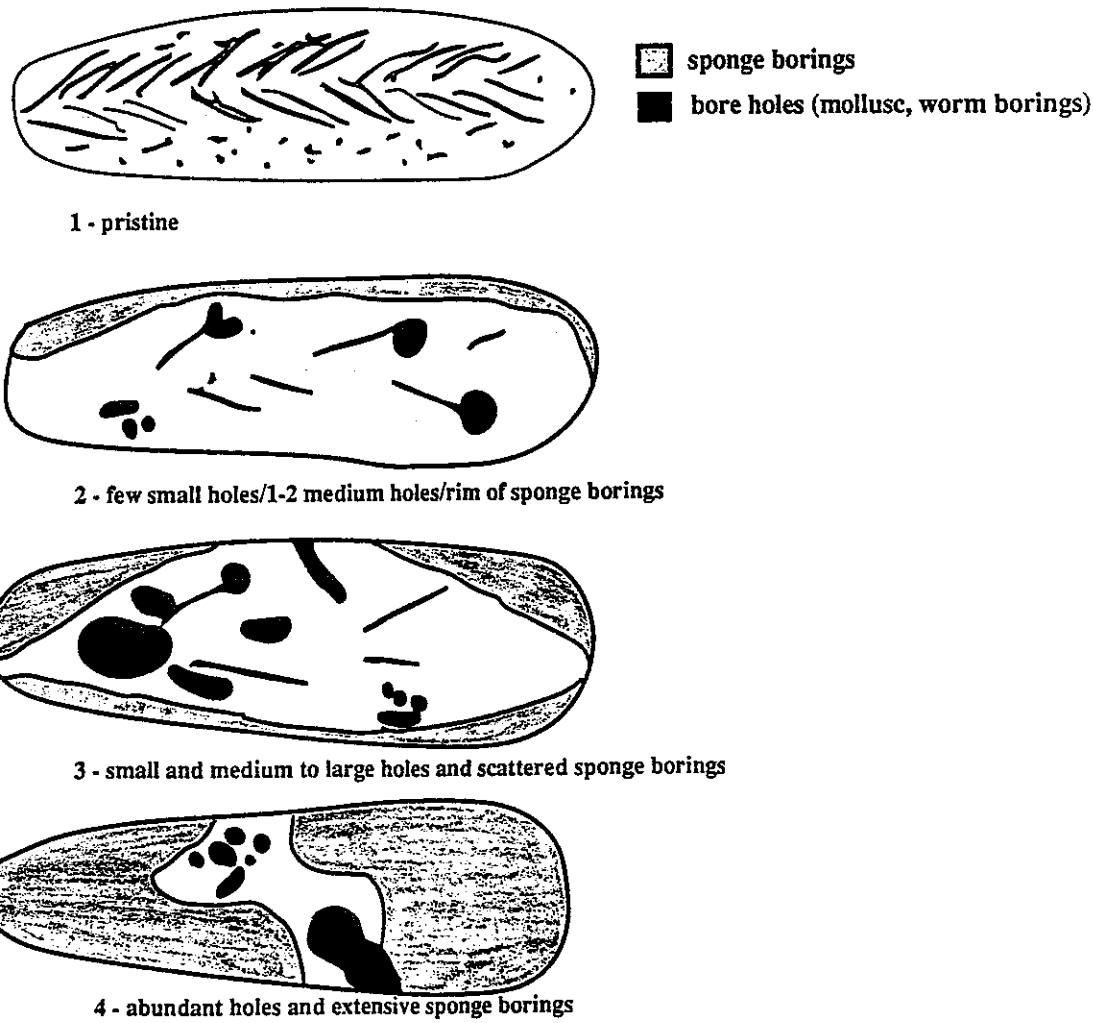
Figure 2b. Scale of Borer Activity



Classification and Interpretation of Pleistocene and Holocene Rhizomorphs, San Salvador Island, Bahamas.

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INTRODUCTION: San Salvador island rests upon an isolated carbonate platform approximately 620km (385mi) east-southeast of the Florida peninsula. The island itself is simply the subaerially exposed portion of the San Salvador Bank, a small part of the arcuate system of carbonate platforms which make up the Bahama Archipelago. The island is capped by a well exposed sequence of Pleistocene and Holocene eolianites which are most easily accessed along the coastal regions of the island.

The upper 3 to 5 meters of the coastal eolianite deposits contain abundant rhizoliths. Klappa (1980) defines a rhizolith [rhizomorph] as an organosedimentary structure resulting in the preservation of roots of higher plants, or remains thereof, in mineral matter. Klappa (1980) goes on to define five basic morphotypes of rhizoliths: "1) root molds, which are tubular voids that outline positions of former, now decayed roots; 2) root casts, which are sediment-and/or cement-filled root molds, 3) root tubules, which are cemented cylinders around root molds; 4) rhizocretions, which are pedodiagenetic mineral accumulations around living or dead plant roots, and 5) root petrifactions, which are mineral impregnations or mineral replacements of organic matter whereby anatomical features of roots have been preserved partially or totally " (Fig. 1 B—E,H, I)

During a four-week study on the island of San Salvador in June of 1992, three of Klappa's (1980) five basic morphotypes were discovered in both the Holocene and Pleistocene dune deposits. Detailed description and measurement of these features provide the basis for further classification of these structures. Variations in form are ascribed to differences in both diagenetic history and original plant type. Concretionary and bulbous root appendage structures (Fig. 2 A-D) were observed in both modern and ancient (Pleistocene) deposits. In addition, straight bedding-parallel rhizoliths, and branching rhizoliths that commonly take the form of a smooth and rounded Y (both perpendicular and parallel to bedding plane), were commonly found within the top 2-3 meters of eolianite (Fig. 3). Comparison of these ancient root structures (rhizoliths) and modern plants from the Island of San Salvador provide documentation of a fossil record for many plant types in this locality, is used to assess the taphonomic factors that may have led to preferential preservation of particular plant types, and leads to a better understanding of the floral history and paleoclimate of the island.

FIELD AREA AND METHODS: An extensive study of Pleistocene eolianites was conducted in two main areas, Man Head Cay, off the island's northeast Coast and "Rhizomorph City" (at the Gulf), located at the southeast corner of the island. Both of these areas are composed of highly karsted eolianites capped by a thin layer of calichified paleosol crust. At both sites, rhizoliths extend throughout the top 3-5m of eolianite and deeper, but stop abruptly at the paleosol in the upward direction. Detailed descriptions were made of characteristic geometries of rhizoliths, and their stratigraphic locations were recorded. Field methods included the measurement of the diameter, length, and angle of branching of the rhizoliths, and detailed sketching of the full range of morphotypes. Photographs of rhizomorphs and surrounding terrain were made and samples of the separate and distinct forms were taken for petrographic study. Similar data were taken at the Pleistocene rocks of Sue Point and the Holocene eolianites of North Point, where bedding plane exposures of rhizoliths are abundant.

A survey of modern plants was carried out at two sites, Coast Guard Beach and Sandy Point. This involved photography of flora and respective root systems exposed by trenching, sketching the distribution of plant types and growth patterns, and the measurement of diameter, length and angle of branching of plants.

RESULTS: BULBOUS FORMS: Bulbous roots were discovered along an erosional scarp created by a fall storm near the backshore-dune transition area of Coast Guard Beach (Fig 2A-B). The bulbs occur at intervals along exposed root systems, and average approximately 2.8cm in width and 4.9cm in length. The roots themselves are slightly irregular in thickness and approximately 0.5cm in width. As many as three bulbous masses occur along one continuous root strand with a typical spacing between bulbs of 5-7cm. The roots are found entangled in root systems belonging to the tropical plant Coccoloba uvifera, one of the most common shrubby plants on the island. The slender roots along which the bulbs occur, could not, however, be traced back to the original source due to lack of equipment, inhospitable terrain, and the fragile