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

Kathryn Michel Riesenberg
Department of Geology
The Colorado College
Colorado Springs, CO 80946

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

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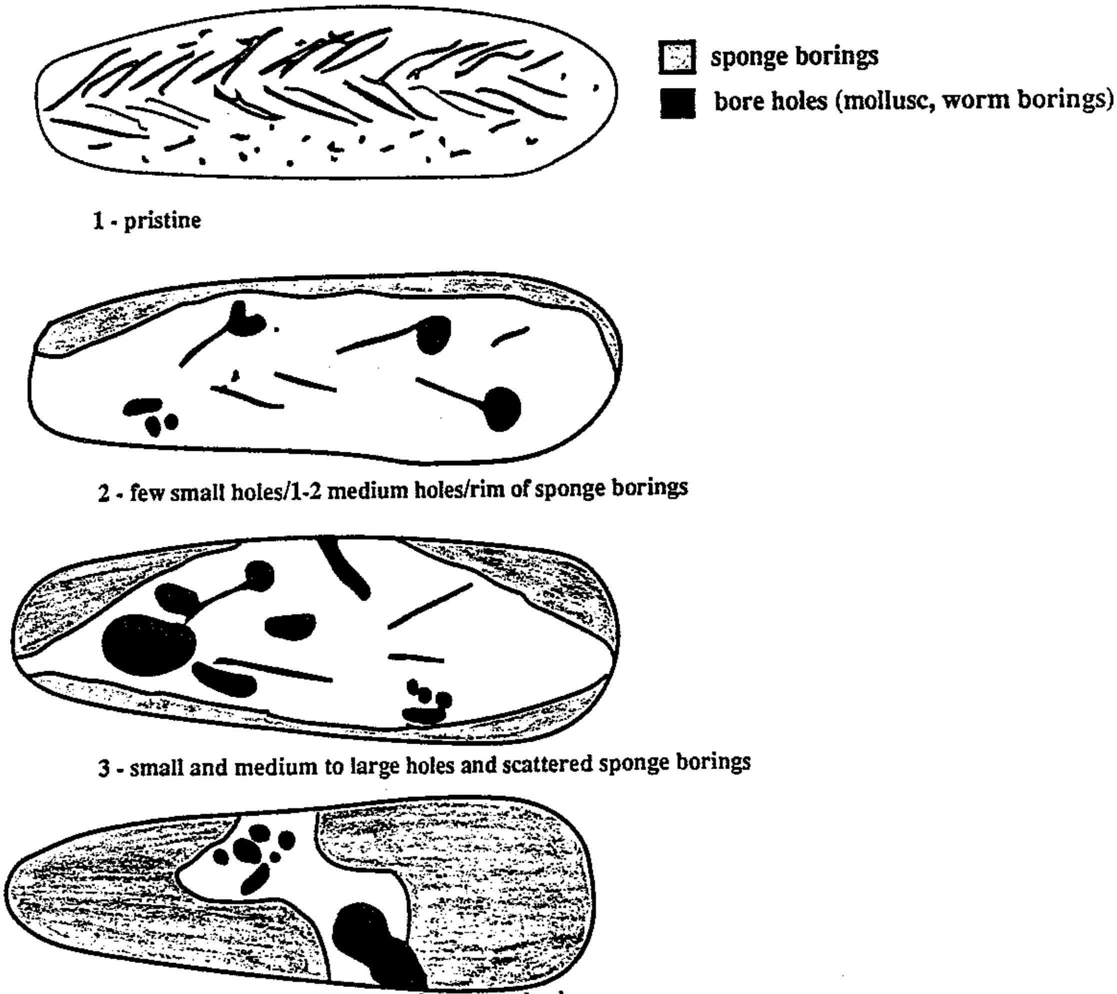
Figure 2b. Scale of Borer Activity



nature of the living roots. When cut open, the bulbs appear as a solid whitish mass resembling the inside of a potato, which is surrounded by a darker shell of the same fibrous substance. The beige skin of the bulb is dotted with irregularities and is paper thin.

Carbonate structures resembling the living bulbous root masses described above were discovered both along bedding planes and oblique to bedding within the Pleistocene eolianite dunes of Rhizomorph City and Man Head Cay (Fig 2C-D). These 125,000 year old bulbs average 2.8cm in width and 8.7cm in length. Cut slabs and partially eroded bulbs (Fig. 3D) have a shell similar to that of the living bulbs which consist of a darker layer surrounding an inner whitish mass. The inner material contains fibers with infrequent and randomly oriented dark vesicular clumps.

STRAIGHT FORMS: Ipomea indica and Ambrosia hispida, known informally as Railroad Vine and Bay Geranium, respectively, are two tropical plants typically located just landward of the backbeach zone in the lower extent of the dune facies. These plants secure themselves in the sand with clusters of root hairs, located at intervals along the trailers of the plant. The securing rootlets cause the stem to protect the narrow strip of sand beneath it from erosion by wind and water. This results in the formation of a ridge which is the same approximate size and shape of the vine. The stems of these two plants also create indentations in the loose sand.

Straight, bifurcating rhizomorphs are common on bedding plane surfaces of Pleistocene eolianite deposits (Fig 3B-C). The rhizomorphs occur as raised casts of the roots or as depressions in the lithified sandstone (root molds). The average diameter of these lithified trailers is 1.1cm, while the average stem diameter of the Railroad Vine is 1.0cm and Bay Geranium is 0.3-0.5cm wide. In some cases the indentations made by the root hair clusters in the sand are still obvious in the lithified sand. The fashion in which Railroad Vine and Bay Geranium grow and interact with the surrounding sand makes it likely that these, or some very similar plants were responsible for the creation of these rhizomorphs classified as "straight trailers."

Y-BRANCHERS: Coccoloba uvifera is commonly known as the Sea Grape, due to its drooping fruit clusters which resemble tiny grapes. Both the roots and the exposed portions of the branches of the plant are smooth, rounded, sinuous, and curving, and both typically contain Y-shaped branches with an average acute angle of 60-70 degrees. The Sea Grape and all shrubby and tree-like bushes on San Salvador tend to dominate the tops of the carbonate dunes, whereas the more viney and trailing plants seem to prefer the interdune and backbeach zones.

Sinuous and curving rhizoliths resembling the roots and branches of the Coccoloba uvifera were discovered both along bedding and perpendicular to bedding in the Pleistocene eolianite dunes of San Salvador Island (Fig 3A). These fossilized root structures occur either singularly, in a large rhizomorph mass of smaller root structures, or as projections from depressions in the Pleistocene dune rock which are thought to be the molds of what once were tree stumps. These structures are typically Y-shaped, with branches which curve and twist as do the modern day Sea Grape roots and stem. The rhizolith forms range from root molds to root casts to rhizocretions to root tubules. The Y-branchers are typically found in the top 2-7 meters of eolian dune deposits (both modern and ancient), where exposures are usually in cliff formations eroded by the sea. They typically stand out in relief due to the preferential preservation of the well cemented rhizolith. They are also found along bedding plane exposures where the paleosol layer between the Pleistocene and Holocene deposits has been worn away by wind and water.

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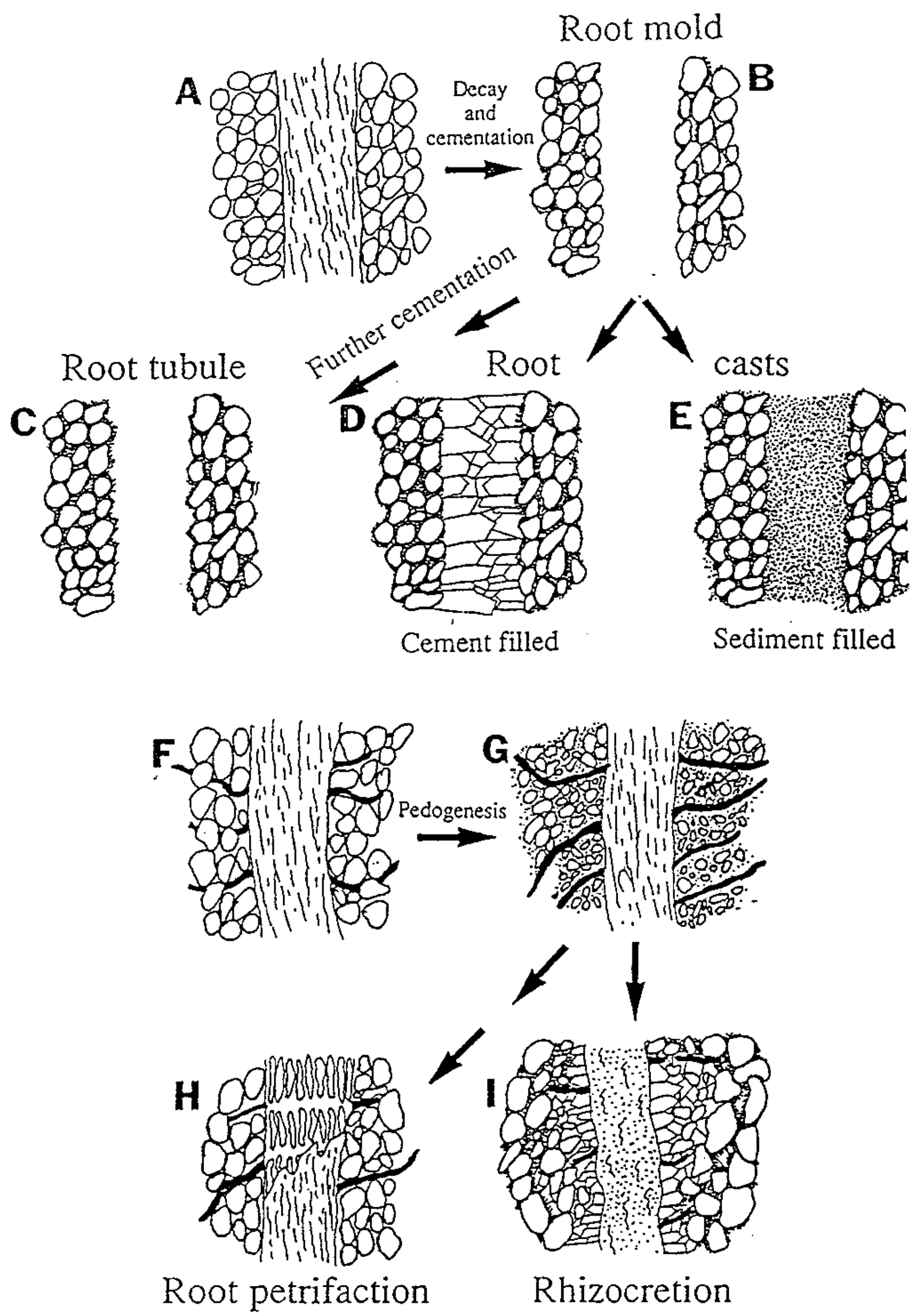

Figure 1. A) Living root system in uncemented sediment. B) Root mold; a void is left when the living root has decayed and cementation of the sediment has begun. C) Root tubule; the sediment around the mold has now become completely cemented with calcium carbonate. D) Root cast; the root mold, through diagenesis, has become filled with calcite cement. E) Root cast; the root mold has filled with sediment, which also cements the surrounding larger particles. F) Root with root hairs within carbonate sand. G) As pedogenesis occurs the sediment surrounding the root is broken up into sand sized particles. H) Root petrifaction; partly decayed root and root hairs impregnated with calcite. I) Rhizocretion; mineral accumulations concentrically build as the root decays. Modified from Klappa (1980).

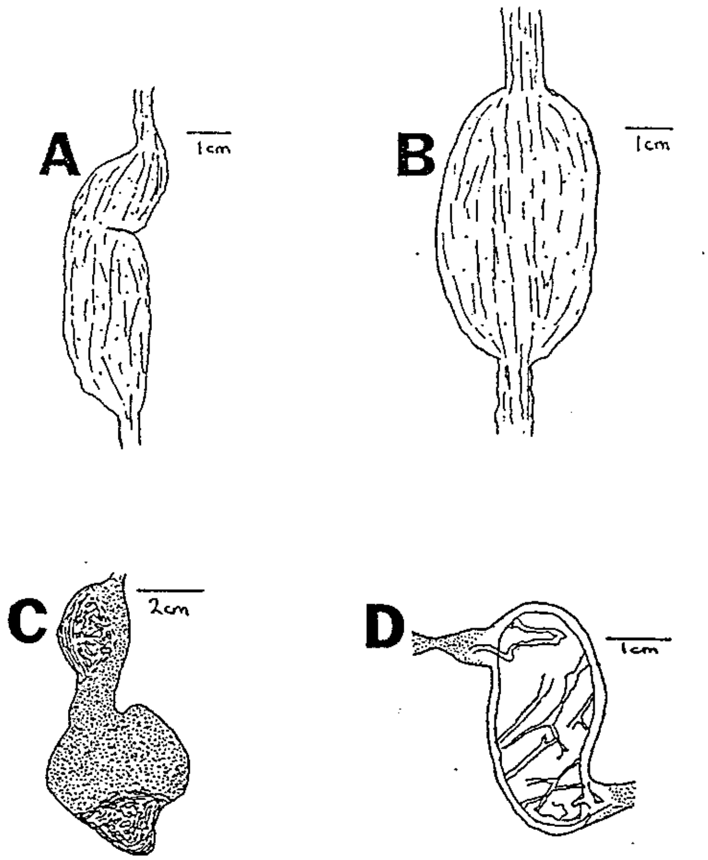

Figure 2. A-B) Living bulbous roots. C) Pleistocene bulbous root structure with areas eroded away. D) Cross-section of Pleistocene bulbous root structure.

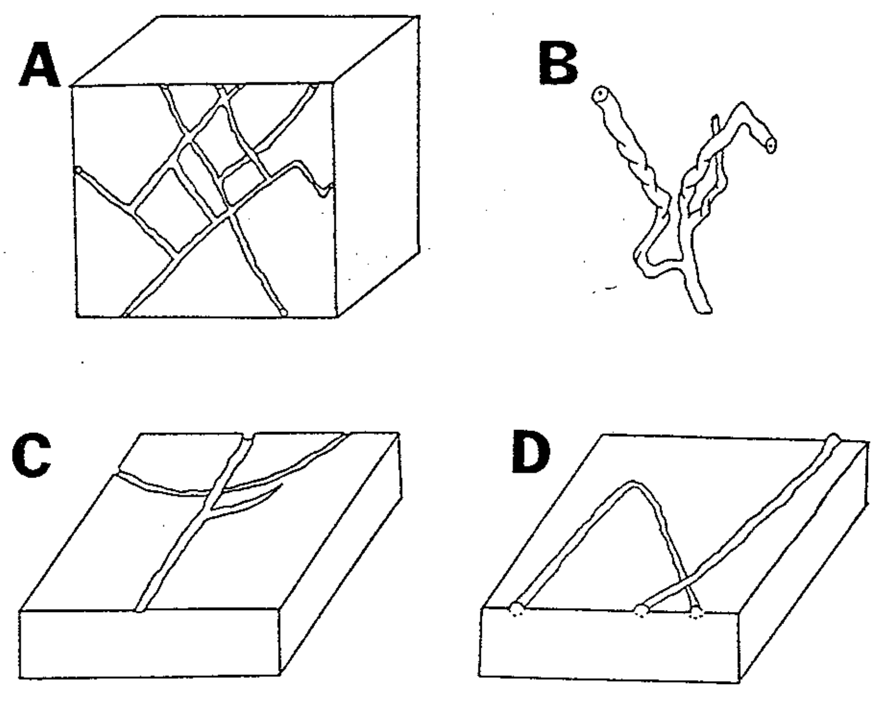

Figure 3. A) Vertical, freestanding rhizoliths. B) Y-branching rhizoliths. C) Bedding parallel root mold. D) Raised straight trailer.

ANALYSIS OF A MODERN PATCH REEF, SNAPSHOT REEF, SAN SALVADOR ISLAND, BAHAMAS

Durelle Smith
Department of Geology
Smith College
Northampton, MA 01063

INTRODUCTION

Existing studies of coral reefs have focused primarily on barrier and fringing reefs. There have been few studies devoted to patch reefs, and there is surprisingly little known about the ecologic "health" of modern patch reefs in terms of community structure, diversity, and short-term change. Coral-dominated patch reefs are well documented from the fossil record of tropical, shallow marine environments (Scoffin, 1978), and patch reefs are prominent in modern reefal settings (Brown and Dunne, 1980). The few studies that have focused on organism distribution and diversity on patch reefs have used line transects to sample the reefs (Chiappone and Sullivan, 1991), even though patch reefs generally exhibit only minor zonation.

This study focuses on Snapshot Reef, a small *Montastrea annularis*-dominated patch reef located off the west coast of San Salvador Island, Bahamas. A different mapping approach was used in this analysis of the reef. A plan map of the reef was made in a previous study of Snapshot Reef in 1984 (Fig. 1), and this map was used instead of line transects to document the distribution and abundance of organisms on the reef. Descriptive and statistical analyses were then performed on the data to provide a view of the present state of Snapshot Reef.

Similar data from the 1984 study of Snapshot Reef provided an opportunity for comparison of the state of the reef then and now. Through analyses of data gathered from the two studies, short-term changes on the reef can be determined, and these may serve to indicate the present "health" of this patch reef. Such studies provide baseline data concerning the "health" of modern patch reefs and are much needed in light of present-day concerns about the global well-being of reefs and possible detrimental effects of human activity.

FIELD METHODS

The original plan map (Chambers, 1984) was used to define the reef area for this study. Buoys were placed in the four corners of the 50 m by 50 m reef area and coral heads were numbered using the map as a reference. Sixty-four heads were identified, numbered, and studied in detail.

Data concerning the abundance and distribution of organisms was collected for each coral head. The following protocol was created to provide systematic observation at each coral head: 1. The approximate percentage of live coral coverage (1= 0-20%, 2= 20-40%, 3= 40-60%, 4= 60-80%, 5= 80-100%); 2. The dominant coral found on the head; 3. The total number of coral species present; 4. *Montastrea annularis* morphotypes present, as described by Knowlton et al. (1992); 5. The relative abundance of non-coral components, i.e. algae, sponges, octocorals, and bare rock (1 = rare, 2 = minor, 3 = common, 4 = dominant); 6. Depth of water; and 7. Height of the coral head.

DATA ANALYSIS METHODS

Frequency histograms were created using the 1992 data to illustrate general trends found throughout the reef and to create a descriptive definition of the present state of the reef. The program SYSTAT was used to perform statistical analyses of the data. General descriptive statistics including the mean, median, standard deviation, and variance of the data were calculated. Pearson and Spearman correlation matrices were used to determine correlations between pairs of variables. Multiple regressions were used to determine relationships between groups of variables to see if any of the measured variables were predictors of height or percent living coral on a head.

T-tests were used to compare the 1984 data with the 1992 data to see if there were any significant short-term changes on the reef. Multiple regressions were plotted to determine if any variables from the 1984 study were predictors of the height or percent living coral for a given head in 1992.

Height and percent living coral were chosen as the dependant variables for the multiple regressions because these variables appear to be the best indicators of the "health" of the reef. To be able to predict either of these variables may prove to be a powerful step in predicting the "health" of a reef.

RESULTS

Present State of Snapshot Reef

Frequency histograms of height (Fig. 2), percent living coral (Fig. 3), number of coral species (Fig. 4), presence of *Montastrea annularis* morphotypes, presence of *Agaricia agaricities*, and abundance of non-coral components were created. The average coral head height is 1.36 m, the average percent living coral is 37%, the