A COMPARATIVE STUDY OF MODERN AND PLEISTOCENE ENVIRONMENTS OF CORALLINE ALGAE ON SAN SALVADOR ISLAND, BAHAMAS

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Because coralline algae are significant constituents of modern nearshore environments, one would expect such algae to be preserved in fossil reefs. The red alga *Neogoniolithon* has both crustose and branching habits. Study of modern algal environments reveals that the latter habit is sensitive to both wave energies and water depth. It would therefore be an ideal paleo-indicator of such conditions.

This study was designed to compare the modern populations of *Neogoniolithon* with any observable *Neogoniolithon* preserved in fossil reefs on the island of San Salvador, Bahamas. Three modern environments were used as models for three well exposed fossil reef environments around the island. The purpose was to determine if *Neogoniolithon* is an identifiable member of fossil reefs, preserved in enough detail to determine wave energetics of the fossil environment. Of the three fossil reefs examined, two contained *Neogoniolithon*. In these two, enough of the coralline algae was preserved to make a first approximation of energy level and depth of the water by comparing the fossil forms with modern analogues.

Modern environments

Three modern locations were chosen for study: Pigeon Creek, Bonefish Bay, and East Beach. Each site had an abundance of the red calcareous alga *Neogoniolithon* but represented a different energy regime.

The outlet to Pigeon Creek is located in a tranquil bay on the southeastern end of the island. The Pigeon Creek tidal delta and a large bed of *Thalassia* grass along with a string of islands protect the bay from extreme wave action. *Neogoniolithon* extends approximately 50 m from the high tide shoreline in water never more than 1 m deep at high tide. The alga is concentrated in a zone approximately 15 m to 27 m from the high tide shoreline. Individual branches bifurcate an average of 4 times and have a diameter of 1 mm to 3 mm.

Bonefish Bay is located about 4.5 km south of the north shore along the western coast. The study site is a small ridge about 60 m from the high tide shoreline. Although the bay is on the lee side of the island, it has few buffers from westerly winds so wave energy ranges from calm to moderately energetic. *Neogoniolithon* is most dense in a zone approximately 60 m long and 25 m wide parallel to and 60 m from the high tide shoreline. It grows mostly on the top of the beach rock ridge at depths of approximately 45 cm to 60 cm at high tide. The clusters are not as dense as those of the Pigeon Creek zone. Individual branches bifurcate approximately 3 to 4 times, and are 2 mm to 3 mm in diameter.

East Beach faces the open ocean on the northeastern coast of the island and is therefore exposed to rough weather from the east. *Neogoniolithon* grows atop small patch reefs. One such reef has a large, dying colony of *Porites porites* almost completely covered by growing *Neogoniolithon* . Other clusters of *Neogoniolithon* grow randomly over the top surface of the patch reef, at depths of up to 130 cm at high tide. Individual branches tend to bifurcate only 1 to 2 times, and are 3 mm to 8 mm in diameter.

Pleistocene fossil environments

The three fossil sites, Grotto Beach, Cockburn Town, and Sue Point, were chosen because they were particularly well exposed and accessible. Each of the three reefs abuts the ocean, forming small cliff heads. Thin sections from samples taken from these reefs were prepared and examined. A general XRD analysis showed peaks for calcite and aragonite, as expected.

The Grotto Beach Fossil Reef is adjacent to a modern beach on the southwest end of the island, and a good vertical section of the reef is visible because the sea has eroded the side of the reef facing the bay. Previous work on this reef (Hattin and Warren 1989) has revealed that it is likely that it grew during a Sangamonian rise in sea level approximately 125,000 years ago. The probable depositional cycle is a shallowing-upward sequence beginning with the salts and raise the salinity. In this scenario, the sensitive foraminifera were unable to live in this salinity and just died.

FURTHER WORK:

Seasonal sampling of North Point would be necessary to document annual variation in the living foraminifera. Coring of the Holocene and Pleistocene beach rock would document ancient distribution patterns of these and perhaps other foraminifera.

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patch reef building, which eventually was covered by prograding subtidal and beach sediments. Hattin and Warren (1989) define a reef-cap facies of densely intergrown arborescent *Neogoniolithon*, which covers approximately 20 m^2. In situ coralline algae can be found throughout this facies, which Hattin and Warren (1989) classify as an algal framestone. Bifurcations are apparent. Petrographic study shows *Neogoniolithon* to be the dominant fossil within the algal layer. Individual branches are well preserved and approximately 1 mm to 2 mm in diameter. Perithallial layering tends to consist of two to four layers on average, although branches were found with none or as many as nine. Some solution of branches had occurred, but the effects were localized within particular hypothallial and perithallial layers. Other large particles included shell and *Halimeda* fragments, but are neither as widespread nor as ubiquitous as the *Neogoniolithon*.

The fossil reef at Cockburn Town is on the north side of town, adjacent to the town dock and extending northward along the coast. Corals of the Cockburn Town reef have been dated and are about the same age as that of the Grotto Beach reef. The diagenetic history has also been determined to be a shallowing-upward sequence (White and others 1984). It is therefore probable the two fossil reefs underwent growth and burial during the Sangamonian high stand 125,000 b.p. *Neogoniolithon* can be found in a thin layer above coral rubblestone and below calcarenite eolianite. Complete heads of coralline algae are preserved within this layer, and are exposed in near-growth position. Petrographic study revealed that individual branches of *Neogoniolithon* have a diameter of 4 mm to 5 mm on average. Perithallial layers number about seven to nine. Like the Grotto Beach *Neogoniolithon*, these branches appear well preserved. Solution is preferential along hypothallial layers. A few *Halimeda* fragments or other clasts such as *Homotrema* (?) were found. Corals were found in two thin sections, one of which was identified as *Porites*. In this particular section, the *Neogoniolithon* branches directly off the coral. This arrangement is a direct fossil analog of the *Neogoniolithon-Porites* relationship found on East Beach.

The Sue Point fossil reef is located along the western coast just north of Bonefish Bay and south of Victoria Hill Settlement. The observable reef consists of two exposures separated by piles of rubble and a stretch of modern carbonate beach sand. A search for coralline algae was made along the north half of the Sue Point reef but none were found.

Discussion

It would appear that the modern alga secretes a skeleton selectively according to its environment. The modern specimens of *Neogoniolithon* observed at these sites have similar branching structure but varying size and shape. The Pigeon Creek *Neogoniolithon* has an elaborate easily fractured structure that would not survive in a rough water/high energy environment such as that of East Beach. Conversely, the stubbier East Beach *Neogoniolithon* would be overshadowed and overtaken in the tranquil environment of Pigeon Creek. Working under the hypothesis that wave energy controls size and form of *Neogoniolithon*, one would expect that the algae at Bonefish Bay to be intermediary to the forms the other two modern sites, and such is indeed the case.

The growth of *Neogoniolithon* also seems to be depth controlled. Although the genus can survive throughout the photic zone, the San Salvador specimens do not grow deeper than 1.5 m. The quiet water forms actually became exposed at low tide.

If one generalizes from the data observed in the modern environments in San Salvador, the following would likely be true for high energy environments:

1) *Neogoniolithon* branches are short and thick;
2) very little bifurcation of branches occurs; and
3) *Neogoniolithon* grows close enough to sea level so as to consider it at sea level

A similar scheme can be arranged for low and moderate energy environments. If accurate, such schemes can be applied to fossil environments to determine ancient conditions of wave and surf energy.

Well preserved *Neogoniolithon* at the two fossil sites containing the alga created a situation ideal for comparison between the two. The Cockburn Town and Grotto Beach algal facies are similar in that both are underlain by near-growth position corals and overlain by eolianites. The algal layer represents a good approximation of sea level at the time of algal growth. However, the algae differed enough so that the distinctive growth forms from each reef were recognizable in hand specimen. The Grotto Beach *Neogoniolithon* displayed unrestricted growth, across the facies. Distinct heads of *Neogoniolithon* were often difficult to distinguish from each other. Average branch diameter was very similar to that of Pigeon Creek, as were growth patterns. On the other hand, Cockburn Town *Neogoniolithon* resembled the *Neogoniolithon* forms found on East Beach, and even the *Neogoniolithon-Porites* relationship was found in both places. This difference in form is evident under the microscope. Horizontal cross sections through branches reveal that the Cockburn Town *Neogoniolithon* is greater in diameter than that of Grotto

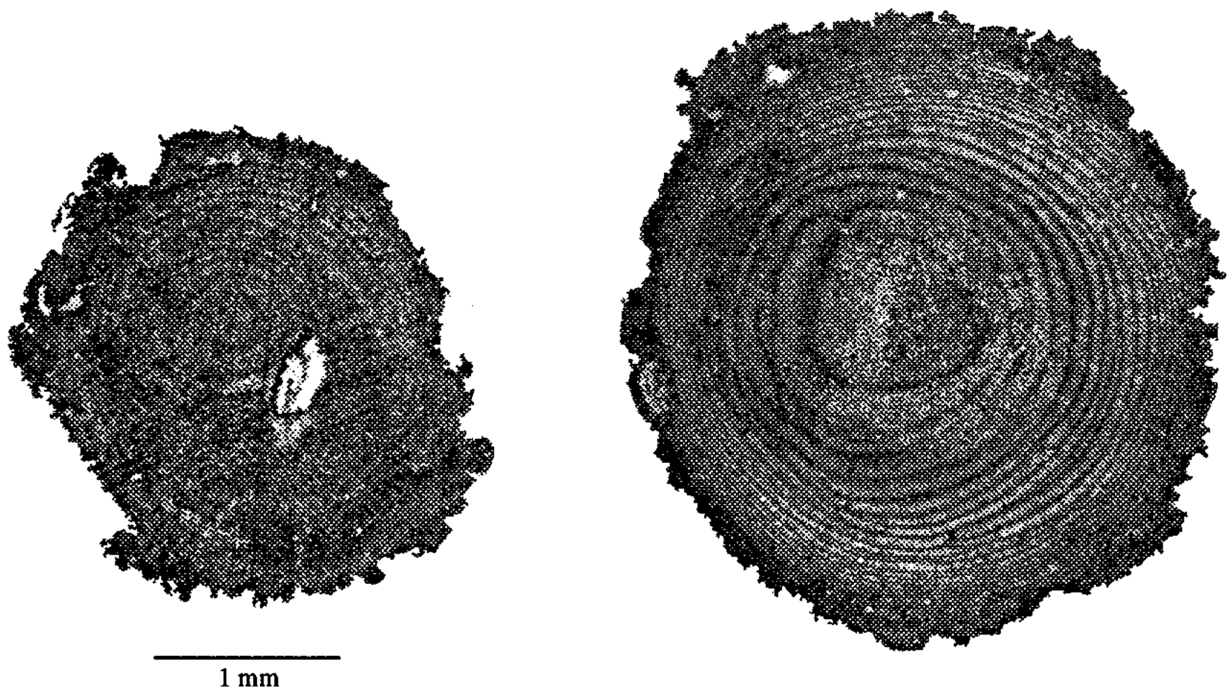

Figure 1. Grotto Beach (left) and Cockburn Town (right) *Neogoniolithon* cross-sections

Beach (Figure 1). From this evidence, it would appear that the Cockburn Town reef grew under higher energy conditions than those at Grotto Beach.

Hattin and Warren (1989) suggest East Beach as a modern analog for the Grotto Beach fossil reef. This is an oversimplification of the paleo-energetic conditions of growth. Although the East Beach patch reefs are similar to the Grotto Beach fossil reef, the extensive nature of the *Neogoniolithon* there suggests its having formed in a more tranquil environment. A more accurate analog of the growth conditions would be those of Pigeon Creek, but no patch reefs were observed there. However, a tranquil environment does not preclude the formation of a patch reef. To find a direct analog of the Grotto Beach reef, a more thorough investigation of the region is necessary. No direct analog for the Cockburn Town fossil reef was observed on San Salvador. The algal forms imply that the growth conditions of the reef were similar to those currently at East Beach, but there is no bank/barrier reef at East Beach comparable to the fossil reef at Cockburn Town.

References

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