A COMPARISON OF THE DIAGENESIS OF TWO BAHAMIAN FOSSIL CORAL REEFS

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This paper describes the diagenesis of two Pleistocene coral reefs; the Sue Point Reef, located on San Salvador Island in the eastern Bahamas, and the Devil's Point Reef on Great Inagua Island, the southernmost of the Bahamian islands. At Devil's Point, fieldwork during the summer of 1986 included a general reconnaissance of the reef, the measurement of three geologic cross sections, and the drilling of core samples along those sections. A year later, the Keck geology consortium afforded the opportunity for field studies on the Sue Point Reef. Detailed topographic and geologic maps of the reef were constructed using GTS surveying equiptment. Geologic sections were measured and drill core samples were taken along them.

The formations exposed on San Salvador were deposited during two separate marine regressions. The oldest, the Grotto Beach Formation, ranges from reefal and shallow subtidal facies at the bottom through dunal facies at the top. A well developed caliche horizon, indicating a long period of subaerial exposure, separates the dunal facies from the overlying Rice Bay Formation. All the facies of a regressional shallowing upward sequence are well represented at the Sue Point location. Reefal limestone occurs at the base of the sequence and its resistance to erosion is responsible for the existence of Sue Point. This reefrock consists of *in situ* corals including *Monastrea* sp., *Diploria* sp. *Acropora cervicornis*, and *Porites* sp. and rubblestone areas composed of fragments of branching corals. Above this lies a shallow subtidal calcarenite characterized by steeply dipping, planar tabular cross beds, and scattered fossil molluscs. This lihtology grades into the beach facies, a unit composed of gently seaward-dipping, flat, thin laminae devoid of larger fossils. The final stage of the regression is represented by a dune facies eolianite composed of fine grained and very well sorted grains.

Devil's Point juts out from the west coast of Great Inagua Island and hosts approximately seven km of exposed fossil coral reef along its shoreline. This reef deposit is overlain by a shallowing upwards sequence of facies similar to that of San Salvador with one addition. Parts of the subtidal sand facies were stable enough to preserve abundant burrows. The cross bedded subtidal sand deposits devoid of trace fossils are also present here. Like the Sue Point reef, a caliche horizon caps the sequence including a laminated crust, rhizomorphs, paleosols, and paleosol breccias. Vadose pisolites and caliche dikes have been found at Devil's Point but not at Sue Point. The similarity of the sequences, the identical elevation of reefal deposits with respect to sea level, and the well developed caliche horizon overlying each suggests that they were both deposited during the same marine regression.

Diagenesis in the Marine Phreatic

Many of the skeletons of marine animals and all of the cements deposited in the marine environment consist of aragonite or high magnesium calcite. Due to the excellent preservation of these mineralogies, which are metastable in contact with fresh water, the record of marine diagenesis is still very clear at both fossil reefs.

Aragonite is an abundant and important cement in those facies exposed to marine diagenesis and comprises many of the grains in all facies. Acicular crystals of aragonite cement commonly are associated with a dense, dark gray micrite. In some cases the crystals grow out from the earlier formed micrite, in others the crystals grew before the micrite was precipitated. The acicular crystals of aragonite are oriented parallel to one another only when they grow syntaxially from a skeletal substrate, for example, when lining coral corallites and filling the interiors of gastropod shells. Other acicular crystals that grow inward from the edges of boreholes and cavities are random in orientation. One thin secton containing a cavity in a coral at Devil's Point Reef shows particularly well-developed aragonite botryoids, but these are rare. Much of the micrite is also composed of aragonite generated as lime mud by boring organisms on the reef or as a precipitate.

Many of the skeletal grains that comprise the rocks are aragonite such as the scleractinian corals, fragments of the calcareous green alga *Halimeda*, and mollusc shells. Tangentially arranged layers of aragonite needles coat grains to form ooids. Peloids are also formed of aragonite in the marine environment by precipitation, micritization of grains, and as fecal pellets.

"At present, there is no comprehensive treatment available for Burmuda [or Bahamas] polychaetes. Literature on the group is scattered over many years and by several authors." [Barnes, 1974] Sterrer suggests several species that fit my observations, Hydroides parvus (Treadwell) , Vermiliopsis burmudensis, and Spirorbis formosus (Bush) [Sterrer, 1986].

Crustose corraline algae play an important role in accreting shells that are serving as substates for biologic activity. Most probably Mesophyllum sp. and Lithophyllum sp. are found in these enivronments. Lithophyllum is the most likely. "In spite of everything, determination of specimens in this group [corallinaceae] will remain a laborious matter and for the present is fraught with uncertainty" [Taylor, 1960].

Blue-green boring algae are not found in this environment. Blue green algae cannot precipiate skeletal calcium carbonate in waters of normal salinity, such as those where I collected my specimens.

Boring by sponges of the Clionaidae family is well documented. Borings of 0.5mm across were present on a majority of all shells. These could be attributed to either bryozoans or Cliona. On large thick shells well developed bored tracks across the shells were proof of Cliona's presence. In many other shells micro-borings and borings that did no seem to extend throughout the shell might be attributed to Cliona or bryozoans. Very little work has been done on bryozoans in the Carribean but lack of documentation does not rule out their presence.

Forminifera were common on many shells. Homotrema was easily identified and commonly found. Other forams seen suggest the family Planorbulinidae or Planorbulinoides but definitive identification was impossible. A third ulta-small attatched rotaline form was commonly found in micro-borings, whether it settled into previously excavated areas or did its own excavation is not clear.

To better understand the relationship between substrates and bio-eroders, factors such as turbulence, photic energy, nutrient availability, salinity, and sedimentation rate must be evaluated at every sampling site. A standardized sampling technique must be employed to obtain statistically significant results. The bio-eroders studied do not appear to be substrate specific, thus further studies might investigate the relationship between trace-making modern organisms and shell matter.

Exploration of the habitats and traces of modern organisms will play an important role in better understanding paleo environments and ancient trace-making organisms. Both geologists and biologists must collaborate in this exciting new area.

High magnesian calcite is the second major mineral type deposited in the marine environment either in skeletal components or as cement. It forms an inhomogeneous brown micrite which still stains for high magnesian calcite in the Devil's Point Reef samples. High magnesian calcite probably also formed a pelloidal micrite but this no longer stains. The high magnesian calcite forms a lumpy coating on some grains from Devil's Point, but these are indistinguishable from algal micrite rims where they have been converted to low magnesian calcite. Many skeletal fragments such as the coralline red algae, echinoderm fragments and certain foraminifera, originally consisted of high magnesian calcite. Skeletal fragments are the most abundant form of high magnesian calcite that still exists in both study areas today.

Biologic activity plays an important role in the submarine facies. Thin sections made of the edges of corals revealed intense encrustation by coralline red algae and encrusting foraminifera. Extensive macro and micro borings exist throughout the corals and worm tubes are common in the calcarenites above. Algal micrite rims commonly develop on grains as algae bore the outer edges of grains. These borings, especially apparent on more translucent grains such as mollusc fragments, become infilled with micritic aragonite.

Fresh Water Diagenesis

Only low magnesian calcite precipitates in the fresh water environment in these two reefs. The morphologies and degree of cementation vary between Devil's Point Reef and Sue Point Reef. The Devil's Point samples predominantly contain tiny equant grains of calcite spar which are referred to here as microspar. The Sue Point samples contain microspar, but more bladed forms dominate. They also contain a larger grained equant calcite spar which can fill whole areas of intergranular porosity and occur in corallites as well.

Some of the facies must have spent some time in the fresh water phreatic zone, but most textural evidence points to a long stay in the vadose. Cement grain boundaries, meniscus textures, and a high variability in degree of cementation within the rock all indicate a vadose environment. The coarser crystalled equant spar from Sue Point, syntaxial overgrowths on echinoderms and cements evenly distributed around grains are usually evidence of the phreatic zone, but have been reported from the vadose as well.

Marine aragonite and high magnesian calcite undergo mineralogic change to low magnesian calcite and dissolution in the fresh water zone. The conversion of high magnesian calcite, one of the first stages, occurs without textural change. Devil's Point samples still retain much of their high magnesian calcite whereas it is almost completely missing from the Sue Point rocks. The micrites are being replaced by low magnesian calcite spar in some areas in both reefs. One coral from San Salvador is extensively replaced by blocky calcite spar, but most of the corals retain their original aragonite mineralogy. Dissolution is evident in the micrites found capping corals and in selected grains of the grainstones. The former place of a dissolved grain is commonly marked by an intact algal micrite envelope.

The greater abundance of blocky calcite spar in the Sue Point samples and their lack of high magnesian calcite when compared to the Devil's Point samples indicates more intense diagenesis in the fresh water zone. The current climate of San Salvador is wetter than that of Great Inagua and petrographic evidence indicates this may have been true in the past as well.

Structures and Microscopic Textures Associated with Caliche Formation

Caliche is a low magnesian calcite deposit that forms wherever conditions are arid enough to prevent removal of dissolved carbonates from the immediate subaerial environment. These dissolved carbonates are rapidly redeposited in a variety of cement forms. Both the Sue Point and Devil's Point reefs are overlain by a thin, laminated calcrete crust. These are reddish-brown in color due to organic, iron, aluminum, and clay mineral content. The crusts may have formed beneath a soil by the continued accumulation of carbonate dissolved from the soil on top of the rock surface, thus, resulting in little alteration of the rock. Conversely, they may have formed by alteration of the uppermost millimeters of the exposed rock sequence through constant dissolution and reprecipitation in areas where precipitation does not endure long enough to permit much downward percolation of water with its dissolved constituents. Patches of red paleosol occur across the Sue Point reef above the laminated crusts. These form by the accumulation of silica and clay rich loess blown in from the arid regions of West Africa. Similar red paleosols are locally abundant at the Devil's Point location. Rhizomorphs are abundant at the Sue Point reef and are found at

Devil's Point as well. These result from intense cryptocrystalline calcite cement precipitation around a root and commonly stand out from their more friable host rocks.

Several distinctive cement textures result from calichification. Random needle fiber calcite is a void filling network of extremely long thin calcite crystals thought to precipitate from rapidly supersaturated solutions associated with root hairs and fungal hyphae. Alveolar micrite is comprised of sinuous lines of dark brown cryptocrystalline calcite that can form cellular structures within voids. This has been attributed to precipitation of calcite on bunches of millimeter sized roots. Both of these cement textures are limited to larger pore spaces and solution holes. Cryptocrystalline calcite is the most abundant cement associated with calichification. It represents rapid deposition from a supersturated solution which gives rise to many nucleii rather than adding material to a few well-developed crystals. The laminated crusts are composed of cryptocrystalline calcite and it occurs as coating on the grains below the crusts as well. Crypto crystalline calcite is more abundant at Devil's Point reef whereas random needle fiber calcite and alveolar micrite are more common at the Sue Point reef due probably to a greater influence of vegetation at Sue Point.

Comparison

The sequence of lithologies deposited at Sue Point and Devil's Point are similar in many respects. Both are regressive shallowing upward sequences progressing from reefal deposits at the bottom to eolianites on top. These reefal deposits both have an identical elevation with respect to sea level. A well developed caliche crust with associated paleaosol caps both sequences. This provides strong evidence that both the Sue Point fossil reef and the Devil's Point fossil reef along with their overlying calcarenites were deposited during the same marine regression. After deposition, however, the fossil reefs and the associated overlying sequences underwent slightly different diagenesis. The current climate of San Salvador is wetter that that of Great Inagua and petrographic evidence indicates this may have been true in the past as well. The greater abundance of blocky calcite spar in the Sue Point samples and their lack of high magnesian calcite as compared to the Devil's Point samples indicate more intense diagenesis in the fresh water zone. The evidence for phreatic zone cementation is inconclusive on both islands. The greater abundance of coarse calcite spar and lack of high magnesian calcite at Sue Point may indicate a brief period of phreatic zone cementation or simply more frequent precipitation and, hence, greater abundance of water in the vadose zone.