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RECOGNITION OF STORM IMPACT ON THE REEF SEDIMENT RECORD

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ABSTRACT

Recognition of the imprint of hurricanes and other storm deposits on the sediment record can provide a useful stratigraphic marker for the study of modern and ancient reef systems. Several recent studies have documented the physical and biological impact of hurricanes on modern reefs immediately following storms. However, it is important to understand how that impact will be preserved in the sediment record of the reef to enable its recognition and proper interpretation when describing reef history and development.

Sediment cores were taken from lagoonal patch reef and forereef settings along the north coast of Jamaica before and after the passage of Hurricane Allen in August 1980. Examination of these cores has revealed that preservation of storm events is variable and may be altered with time. Although storm layers were easily recognized in lagoonal settings within two years following the hurricane, passage of time has made recognition based on grain-size differences more difficult due to bioturbation and grain-size alteration. However, it was possible to identify storm sediments by the presence of allochthonous skeletal grains.

In contrast, while significant damage was noted to reef organisms on the forereef following the hurricane, the sediment record of the storm appears to be patchy and poorly defined. Seven years after the hurricane it was possible to recognize the storm layer only where it had been preserved in protected depressions. Problems in recognition of the storm layer on the forereef may be related to physical and biological reworking of the sediment record. Understanding the problems related to recognition of preservation of storm layers may alter identification and interpretation of ancient storm events.

INTRODUCTION

Although catastrophic hurricanes are relatively uncommon events in the day to day existence of modern reefs, their preservation in the geologic record should be common and easily recognized. Ball et al. (1967) have suggested that the scarcity of ancient storm deposits is probably due to a lack of recognition rather than a lack of existence.

Several investigators have documented the physical and biological effects of hurricanes on modern reefs immediately following storms. Although the actual damage sustained during a particular storm is dependent upon several factors, including wave height and force, bottom topography, and biota present, some general patterns have been noted.

Biologic impact

Biologic changes in dominance and diversity have been noted as delicate, rapidly growing, branching corals like *Acropora cervicornis* are broken and fragmented (Ball et al. 1967, Perkins & Enos 1968, Stoddart 1974, Knowlton et al. 1981, Porter et al. 1981, Rogers et al. 1982, Kjerfve & Dinnel 1983, Tunnicliffe 1983). Occasionally during extremely high energy conditions, improperly oriented massive coral heads of *Montastrea annularis*, *Siderastrea siderea*, or *Porites astreoides* may be broken from the substrate and be reoriented (Mah & Stearn 1986). Mortality of surviving colonies due to abrasion, increased predation, turbidity and sedimentation, and lower salinity resulting from runoff of fresh water from land may be as great as 95 to 98 percent (Knowlton et al. 1981, Rogers et al. 1982, Kaufman 1983, Tunnicliffe 1983). Skeletal remnants of the fragmented corals may be transported shoreward into the lagoon or seaward into deeper water.

Sedimentologic impact

Hurricanes tend to transport sediment from deep water into shallow water environments and from shallow water back into deep water environments. This results in a mixing of sediment textures and skeletal components representing different environments (Hayes 1967). In general there is a net transport of large boulders and mud into nearshore environments during the storm, followed by transport of nearshore sand and clay-sized materials seaward during and after the storm (Ball et al. 1967, Graus et al. 1984).

Major topographic changes may accompany hurricane-related modification of reef biota and sedimentology. Scouring of channels and erosion of sand dunes into wave-cut cliffs and terraces, destruction of rampart islands and mud banks, and accretion of new islands have been noted by Hayes (1967), Perkins & Enos (1968), and Stoddart (1970).

HURRICANE ALLEN

Hurricane Allen has been described as one of the most severe hurricanes in the Caribbean during this century (Porter et al. 1981, Woodley et al. 1981, Graus et al. 1984). As the hurricane traveled along the north coast of Jamaica on the morning of August 6, 1980, it passed within 65 km of the fringing/barrier reef system at Discovery Bay.

The geology and biology of the reefs at Discovery Bay had been documented by numerous investigators, and damage to the reef system caused by Hurricane Allen was dramatic. The greatest destruction occurred in the shallow reef zones with the breakage and mortality of *Acropora* palmata and Acropora cervicornis. Physical damage to corals was reported at depths as great as -50 m at Discovery Bay (Woodley et al. 1981). Woodley et al. (1981) report maximum reef damage on the northeastern coast of Jamaica which was nearest to the storm tract. Physical damage to the reef system was reported to decrease westward to Rio Bueno.

EXAMINATION OF SEDIMENT RECORD

In order to determine the character of the sediment record of Hurricane Allen, cores of reef sediments were obtained at several localities along the north-central Jamaican coast during 1981 to 1987, using an underwater pneumatic drill and core barrel (figure 1). Forereef cores were taken from the middle of sand channels at Maria Buena Bay (in depths of -40 and -60 feet), at Dancing Lady Reef (in depths of -50, -55, and -60 feet) and Mooring I (in depths of -40, -60, and -65 feet) at Discovery Bay, and at Pear Tree Bottom (in depths of -55 and -60 feet). In 1980, 1981, 1982, 1984, and 1986, lagoonal reef cores were taken along north-south and east-west transects of the Red Buoy Patch Reef and Columbus Park Reef within Discovery Bay.

Sediment cores were split into 2.5 cm intervals which were wet and dry sieved into phi (0) grades and weighed. Sand-sized and coarser sediments were examined under a binocular microscope to determine biotic origin of skeletal grains. Hurricane intervals were then identified based on abnormal abundances of Acropora cervicornis. Graphs of grain size versus weight percent were plotted for each core, indicating the hurricane layer where possible.

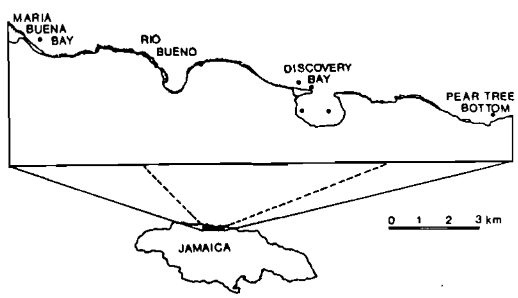

Figure 1. Map showing the distribution of sediment cores along the north-central coast of Jamaica. Dots indicate the position of cores.

RESULTS

Preliminary results of this investigation have been reported by Bonem (1984, 1985).

Lagoonal reef cores

Cores taken during 1981 and 1982, along transects of the Red Buoy Patch Reef in eastern Discovery Bay were examined in detail to identify differences in skeletal composition and grain size related to the biotic zonation described by Bonem & Stanley (1977). During that investigation it was noted that two anomalous intervals occurred near the top of each core. One interval appeared to be related to dredging of the ship channel into Discovery Bay in 1977, and the second interval,

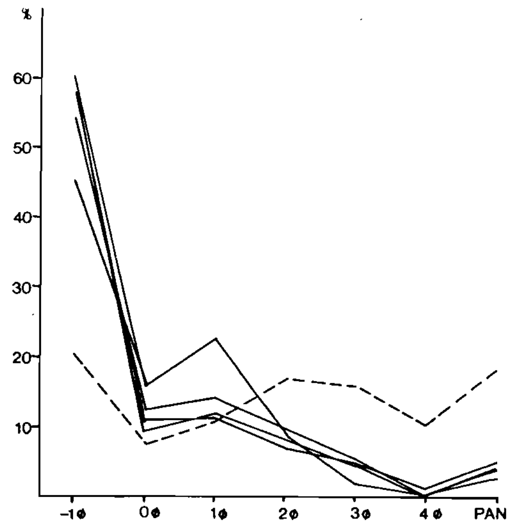

Figure 2. Graph showing the relationship between phi (0) grain size and weight percent for the Sponge Zone at the Red Buoy Patch Reef. Hurricane interval is shown in dashed lines and indicates increased amounts of fine sediments.

containing relatively large amounts of Acropora cervicornis fragments, could be related to Hurricane Allen based on comparison with cores taken in 1980 prior to the passage of the hurricane.

In graphs showing phi grain size versus weight percent "normal" sediment intervals are shown by solid lines and the hurricane interval is represented by dashed lines. Some normal lines were omitted from graphs included here for clarity.

In shallow zones of the patch reef, as represented by the Sponge Zone in figure 2, the hurricane interval contains an anomalously large weight percentage of finer sediment (>2 phi). In contrast, the deeper reef zones, such as the Massive Coral Zone and Agaricia Zone of Bonem & Stanley (1977), an increase in intermediate sand-sized sediment (+1 phi) and accumulation of debris coarser than -1 phi is noted. This is shown in the graph of the sediment record from the Agaricia Zone (figure 3). Graphs from other areas of the reef either show the same trends (but in a less impressive manner) or appear to lack evidence of the deposition of a hurricane-related layer.

Cores taken at Columbus Park Reef in western Discovery Bay during 1984, showed similar trends. However, when additional cores were taken at the Red Buoy Reef in 1986, the patterns of anomalous grain-size distribution were still present, but were much less distinct. The storm layer appeared to have been mixed, perhaps by bioturbation or physical reworking, into a broad, less diagnostic interval.

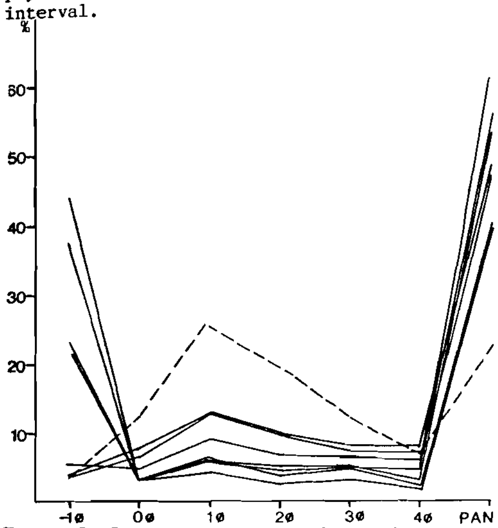

Figure 3. Graph showing the relationship between phi (0) grain size and weight percent for the Agaricia Zone at the Red Buoy Patch Reef. Hurricane interval is shown in dashed lines and indicates increased amounts of sediment in the +1 phi range.

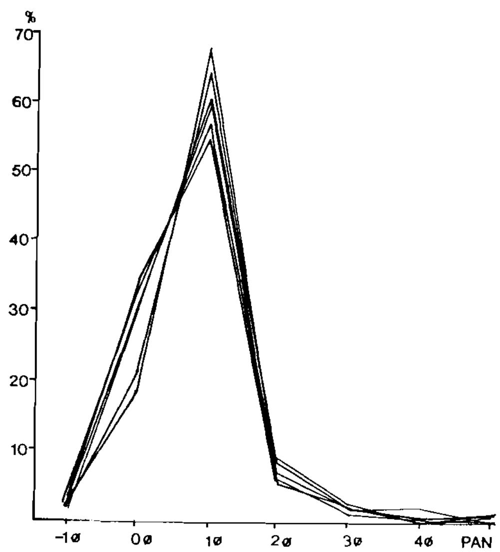

Figure 4. Graph showing the relationship between phi (0) grain size and weight percent for intervals within a core obtained at -55 feet in a sand channel at Dancing Lady Reef. No hurricane interval could be identified in this core.

Fringing/barrier reef cores

In an attempt to determine whether the patterns observed for the hurricane interval preserved in patch reefs within Discovery Bay could be recognized on the forereef, sediment cores were obtained from 4 reef areas along the north-central coast of Jamaica.

Figure 4 shows the graph obtained from a core taken at a depth of -55 feet at Dancing Lady Reef on the west forereef of Discovery Bay. The pattern shown in this graph is typical of cores taken from the middle of open sand channels at Maria Buena Bay and Dancing Lady and Mooring I at Discovery Bay. Only at Pear Tree Bottom, where the sand channel at -60 feet was protected on three sides by steep buttresses, was evidence of the storm layer found. Figure 5 illustrates a shift to coarser sediment sizes within the interval that contained anomalously great amounts of identifiable Acropora cervicornis fragments.

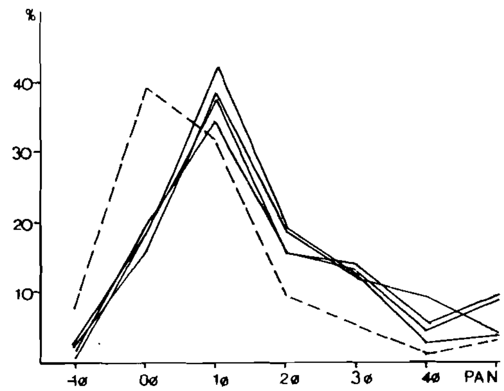

Figure 5. Graph showing the relationship between phi (0) grain size and weight percent for intervals within a core obtained at -60 feet in a restricted sand channel at Pear Tree Bottom. Hurricane interval is shown in dashed lines and shows an increase in coarse sediment weight percent.

IMPLICATIONS

Despite observations of major damage to the Jamaican reef system caused by Hurricane Allen, recognition of the passage of the hurricane based on examination of the reef sediment record is difficult. The results of this study support predictions made by the computer model published by Graus et al. (1984). This model suggests that disturbance of the sediment record will be minimized in protected catchment areas or sediment traps within the lagoon or on the forereef. Thus, preservation of the storm layer will be patchy and limited to areas where sediments have not been reworked by physical or biological processes.

Where the layer is recognized, either on the forereef or in the lagoon, it shows a general pattern of coarse sediments being mixed with fine sediments in low energy or deep water environments, and finer sediments being washed into shallow water or high energy environments.

Understanding of the the problems and preservational patterns of storm layers in the reef sediment record through time, may greatly modify recognition and interpretation of ancient storm events.

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