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GROWTH RATE OF A WEST INDIAN (JAMAICAN) REEF

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SUMMARY

The lush coral fringing the north Jamaican coast off Discovery Bay has been studied by surface drilling, underwater drilling, underwater blasting, and seismic reflection profiling.

The reef crest is between 5 and 6 metres thick, and directly overlies Pleistocene biolithites dating from the 120,000 year "Sangamon" interglacial stage. Reef corals directly overlying the Pleistocene biolithites give C^{14} ages of 5500 years, and the reef crest kept pace with rising sea level over most of the width of Discovery Bay.

Dynamiting and underwater drilling at depths of -17, -26, and -36 metres on the fore-reef terrace and fore-reef slope, in both reef frame and in sand channels, yield vertical accretion rates of between 0.55 m and 1 m / 1000 years.

Dynamiting on the top of the vertical wall (deep fore-reef) which extends from -55 m to -120 m yields horizontal accretion rates of approximately 0.22 m / 1000 years.

I. INTRODUCTION

According to one recent definition (Goreau *et al.*, 1972) a coral reef is ". . . a localized shallow-water wave-resistant carbonate structure built up by lime secreting organisms, unconformably deposited on an underlying platform from which it is also morphologically distinct."

Within the range of sea level variations since the last glaciation (clearly within the depth range of active modern reef growth), such a definition provides excellent distinction between modern (= Recent or Holocene) reefs, and the Pleistocene or older substrate. Unfortunately, location of the unconformity surface beneath modern reefs has rarely been accomplished (see Chave *et al.*, 1972, for a recent summary). Some people believe modern reefs are merely thin veneers superficially coating a Pleistocene or older substrate, whereas others believe modern reef growth rates have been appreciable.

In the following note I present the data accumulated to date on the "search for the sub-aqueous Pleistocene", for a single north Jamaican fringing reef off Discovery Bay.

II. METHODS

Several methods have been used to try to penetrate the modern reef frame as deeply as possible. Early efforts concentrated on the use of small explosive charges together with later removal of loosened debris by diver. The near ubiquitous presence of dense submarine cementation (Land and Goreau, 1971) effectively limits the depth of penetration by this method to approximately 1 metre, and then only after many underwater man-hours.

Diamond core drilling was accomplished on the reef crest using a 5 h.p., hand-held, gasoline powered drill operated from a small fibreglass catamaran on calm days. Drilling was also accomplished underwater using a drill constructed for this purpose. The drill consists of a $\frac{1}{3}$ h.p., 110 VAC, 60Hz, 1Ph. submersible pump motor, geared down 3:1, and attached to the diamond core string. Power and drilling water were supplied from an anchored surface vessel.

Acoustic profiling using a 1 in^3 air gun was also attempted.

III. SUMMARY OF RESULTS

A. EXCAVATION OF REEF FRAME BY EXPLOSIVES AND DRILLING, -26m

The fore-reef escarpment (see Goreau and Land, 1974, and Figures 1 and 4 for terminology) has been dynamited twice in the same location, and drilled, in an intensive effort to sample the modern reef frame as deeply as possible. Various stages of the excavation are shown in Land and Goreau, 1971, Fig. 1, and Goreau and Land, 1974, Fig. 10. The location of this site is designated "A" in the location map, Fig. 1. Fig. 2 is a cross-section of the excavation showing the position of the drill hole, and the C^{14} ages of the coral and reef rock. A vertical framework growth rate is approximately 1 m / 1000 years at this depth, -26 m.

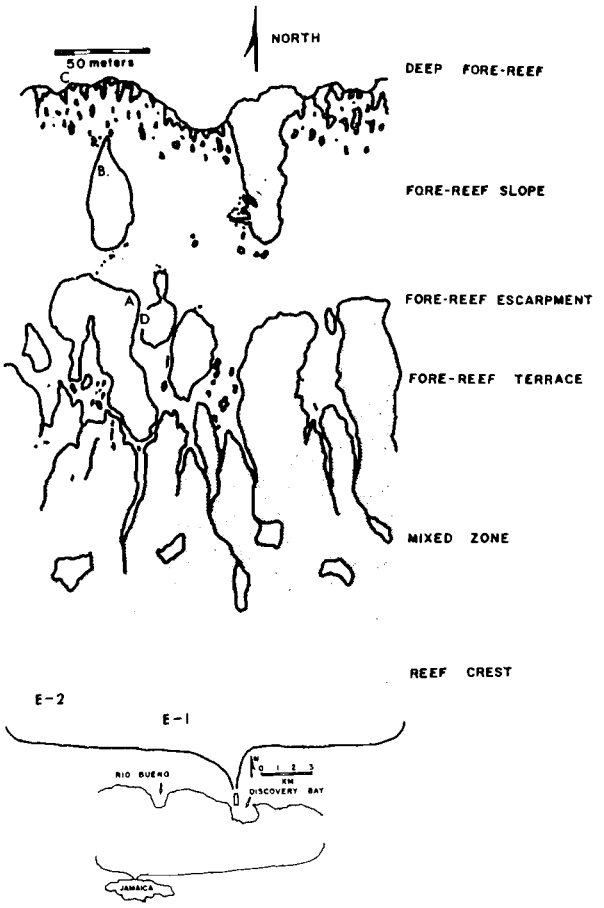

Figure 1. Map of the reef off Discovery Bay, Jamaica, showing the location of sampling sites discussed in text. Stippled areas are coral covered, white areas are sand covered. For depths, see Fig. 4. Map after Goreau and Land, 1974. Fig. 2, and aerial photographs.

B. EXCAVATION OF REEF FRAME BY EXPLOSIVES, -36 m

A "Pinnacle Reef" extending above the fore-reef slope ("B" in Fig. 1) was dynamited once, and cleared sufficiently for an *in situ* sample of coral to be obtained from 80 cm below the reef-water interface. The C^{14} age of the sample was 1160 ± 70 years, yielding a vertical framework growth rate of 0.55 m / 1000 years.

C. EXCAVATION OF DEEP REEF FRAME BY EXPLOSIVES, -60m

The top of the vertical reef "wall" which extends from -55m to -120 m has been dynamited ("C" in Fig. 1), and two samples obtained approximately

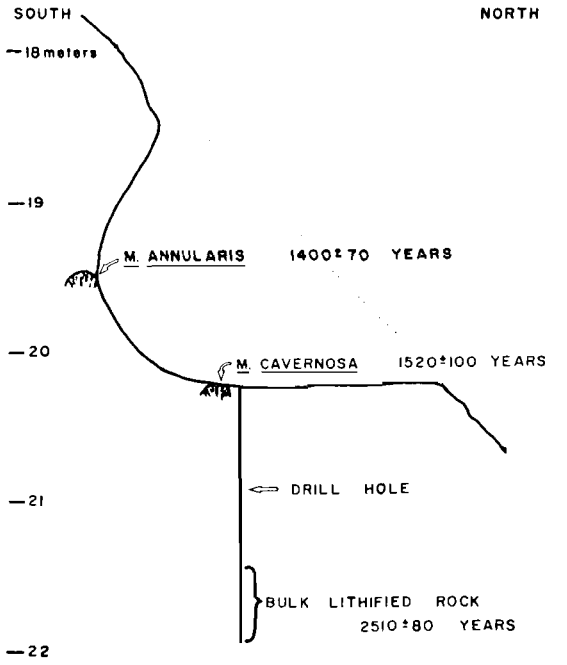

Figure 2. North-south cross-section through the excavation in the fore-reef escarpment at point "A" in Fig. 1. Dotted line shows the original reef-water interface before excavation. Lithified sediment immediately overlying the coral *M. cavernosa* yielded a C^{14} age of 1070 ± 70 years.

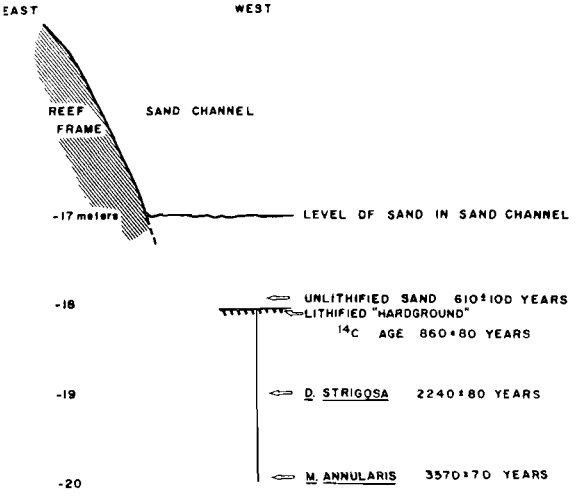

Figure 3. East-west cross-section through a sand channel at point "D" in Fig. 1 depicting the stratigraphy which was found. One metre of unlithified sand was removed, and the lithified "hardground" drilled an additional two metres.

30 cm behind the living reef frame yielded ages of: 6870 ± 80 and 1370 ± 70 years. The large discrepancy in age is undoubtedly due to the fact that the material dated was sediment, not *in situ* coral, and could thus have had a long history of transport from shallower water. The younger age gives the more reasonable rate of reef accretion, and suggests the "wall" is accreting seaward at a horizontal rate of 0.22 m / 1000 years.

D. EXCAVATION OF A SAND CHANNEL, -17m

During the summer of 1971, as part of an Organization for Tropical Studies course in tropical reefs, Mr. John Gifford, University of Miami, constructed an air-lift and began to excavate the sand channel just east of excavation "A" ("D" in Fig. 1). The stratigraphy and C^{14} ages of the samples obtained from the excavation and from subsequent drilling, are presented in Fig. 3. A vertical accretion rate of 0.84 m / 1000 years is observed.

E. SURFACE DRILLING OF THE REEF CREST

Two holes were drilled in the reef crest, at positions indicated in Fig. 1, "E-1" and "E-2". Hole "E-1" did not reach the Pleistocene unconformity, and a sample of *A. palmata* recovered from between -5 and -5.5 m yielded a C^{14} age of 5300 ± 80 years. Hole "E-2" recovered Pleistocene biolithites of the *Falmouth* formation (Land and Epstein, 1971) at a depth of -4.3 m. Samples of *M. annularis* and *A. palmata* directly overlying the Pleistocene from hole "E-2" yielded a C^{14} age of 5050 ± 100 years. If one plots these ages and depths versus one of the accepted curves for the rise of modern sea level for North America (eg. Morner, 1971), it is clear that corals established themselves on the Pleistocene substrate as soon as the substrate was flooded, and kept pace with the rise of sea level over most of the width of Discovery Bay. The Pleistocene rock as recovered during drilling, and as is exposed below approximately -8 m in the ship channel dredged through the Discovery Bay reef, appears to have undergone no diagenesis as the result of its being re-submerged following the "Wisconsin" glaciation.

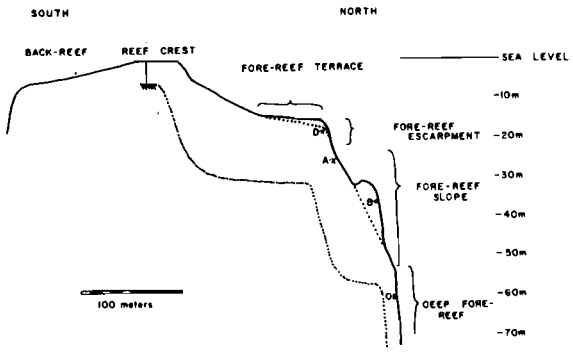

Figure 4. North-south cross-section through the Discovery Bay reef. The drill hole on the reef crest and the depth to the Pleistocene unconformity is shown. The Pleistocene unconformity is elsewhere inferred on the basis of growth rates at the various excavation sites (shown on the cross-section by lettered x's) discussed in the text, and the terraced nature of uplifted Pleistocene carbonate terrains. It is not clear what underlies the "pinnacles" on the fore-reef slope, although blocks derived from the underlying Pleistocene cliffs seem a distinct possibility.

F. ACOUSTIC PROFILING

Very little useful data resulted from extensive, slow speed acoustic profiling using a 1 in ^{3} air gun and standard hydrophone array. It is probable that the density differences between the Pleistocene limestones and the lithified modern reefs are too small to reflect seismic energy from the boundary.

IV. DISCUSSION

Fig. 4 presents a cross-section of the reef off Discovery Bay using all available data. I have taken the liberty to extrapolate the Pleistocene-Recent contact based on:

(1). The framework growth rates as discussed in this paper, and

(2). The geomorphology of uplifted carbonate reef terrains of Barbados and New Guinea (Mesolella *et al.*, 1969).

It should be emphasized that although Modern reef growth is impressive, and nearly all the lateral (ie. parallel to shore) variations in reef geomorphology such as buttresses, sand channels, etc. are Modern growth features, most of the down-dip features such as the terraces and escarpments are deeply mantled Pleistocene features. Nowhere is the Pleistocene exposed.* Given approximately

*The reference by Goreau and Goreau (1973) to an exposed Pleistocene "notch" along the north coast of Jamaica is no longer tenable. The feature in question is almost certainly a "growth overhang" formed as the fore-reef escarpment grows out over the sands of the fore-reef slope, only to have the sands slump away as the result of earthquake or storm, leaving the overhanging "notch". Examination of the rock in the deepest part of the "notch" indicates that it has the mineralogy and texture of modern reef frame, not Pleistocene limestone. Also, a dynamite excavation very close to the "notch" site at Eaton Hall specified by Goreau and Goreau yielded only modern reef frame with an age of 1940 ± 90 years. T. F. Goreau selected the dynamite site, participated in the excavation, and was aware of the analytical results.

60,000 years, the modern reef could reach sea level over its entire present width, and present a near-vertical escarpment extending from sea level to approximately -120 m. to the sea, resulting in a vastly different geomorphology and ecology (Goreau and Land, 1974).

ACKNOWLEDGEMENTS

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