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SUBSEA (0–40M) TERRACES AND BENCHES, WINDWARD OFF CURAÇAO, NETHERLANDS ANTILLES

BY

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ABSTRACT

At the windward (NE) side of Curaçao at least two well-developed submarine terraces occur. A first, rocky, terrace, 100 to 150 m wide at depths of 5 m inshore to 12–15 m at the drop off, is densely covered with *Sargassum*. A second, sandy, terrace, approximately 50 to 100 m wide at depths of 32 to 40 m, is sparsely covered with corals, sponges, rhodolites and gastropods of the genus *Strombus*. The slope between the first and the second terrace is covered with hermatypic corals and fleshy algae. At several locations a fossil bench occurs at the lower end of this slope. The upper surface of the bench is consistently at 32 m below sealevel. At two localities the bench has an indentation at 34–38 m below sealevel, which possibly is a fossil sealevel notch. The features are regarded as essentially pre-Holocene, markedly different from the situation at the leeward side where the terraces, if present, have been buried underneath Holocene reef accumulations.

INTRODUCTION

Curaçao is one of the islands of the Netherlands Leeward Antilles, which are situated in the southern Caribbean Sea off the Venezuelan mainland. The island consists of a pre-Tertiary core (Beets, 1972), capped by limestones of Eocene, Miocene and Pleistocene age. A series of Pleistocene limestone terraces has been described by de Buisonjé (1974). Curaçao is subjected to strong and persistent easterly tradewinds. As a result the northeast coast, as well as several promontories at the southwest coast, are relatively exposed, while the remainder of the southwest coast is relatively sheltered. Along this leeward coast a flourishing coral fringing reef is found (van den Hoek et al., 1975; Bak, 1977) with at least 16 m Holocene accumulation (Focke, 1976, 1978). The morphology of the coastline and the cliffs has been described by de Buisonjé and Zonneveld (1960), the first windward terrace has been described by van den Hoek (1969), Bak (1975), and Wanders (1976). The windward coast is virtually inaccessible during the greater part of the year. Short periods of calm weather permit diving in March-April and/or September-October. SCUBA transects have been made during these periods in 1976 on 18 stations on the windward coast (Fig. 1) from the shore to depths up to 45 m. The terraces and benches which were discovered during these dives are described as part of a re-evaluation of the Pleistocene sealevel history of the Netherlands Leeward Antilles (Herweijer & Focke, 1978).

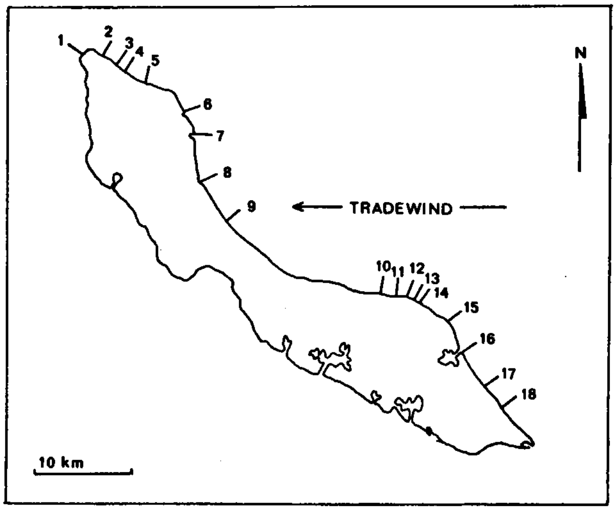

Fig. 1. Map of Curaçao with the location of the SCUBA transects and station numbers.

DESCRIPTION

The submarine morphology along the windward coast is, at least up to a depth of 45 m, remarkably constant. Practically all stations showed two terraces of rather constant depth and width, bordered by steep slopes.

The first terrace is usually 100 to 150 m wide with depths of 4 to 5 m at the coast, to 12 to 15 m at the drop off (Fig. 2). Apart from areas near the eastern tip of the island (Bak, 1975), no flourishing coral communities have been found on the first terrace. It has a rocky bottom, virtually devoid of unconsolidated sediments, and densely covered with the brown alga *Sargassum platycarpum* (van den Hoek, 1969). Together with the algae *Dictyopteris justii* and *Dictyota dentata* it provides for more than 90% of the large standing crop on the terrace, estimated at 440 g dry weight per square meter with a net production of 2550 gC/m²/y (Wanders, 1976). Locally, scattered corals are found on the terrace, predominantly encrusting *Diploria clivosa* and *Porites astreoides* near the coast (Bak, 1975), and *Montastrea*

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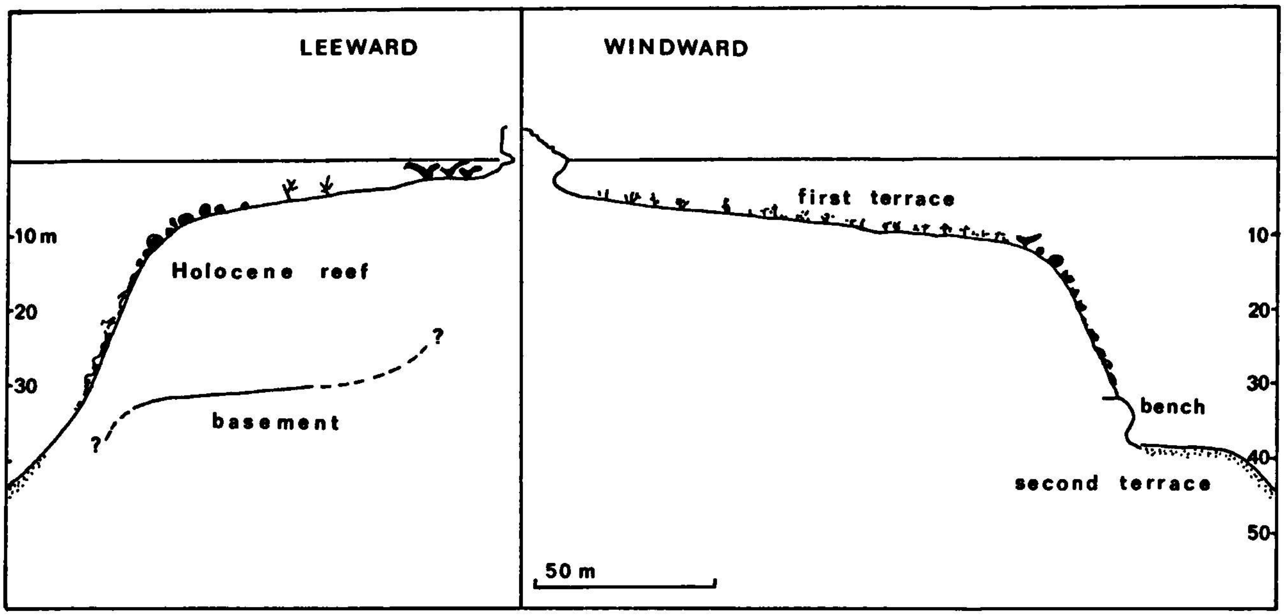

Fig. 2. Bottom profiles of the leeward and windward coast.

annularis, *Acropora palmata* and *Dendrogyra cylindrus* (Fig. 3) somewhat more towards the drop off. Often the fleshy algae cover the drop off as well as the slope beyond, interspersed with corals. Many corals on the drop off are wholly or partially dead with surfaces encrusted by coralline algae or overgrown with fleshy algae (Fig. 4).

The steep slope between the drop off and the second terrace (i.e. between appr. 15 and 30 m) carries more thriving coral communities, although even here dense *Sargassum* vegetation is found on and between the corals. Although the growth forms may be different, the species composition resembles that of the leeward reef (Bak, 1975).

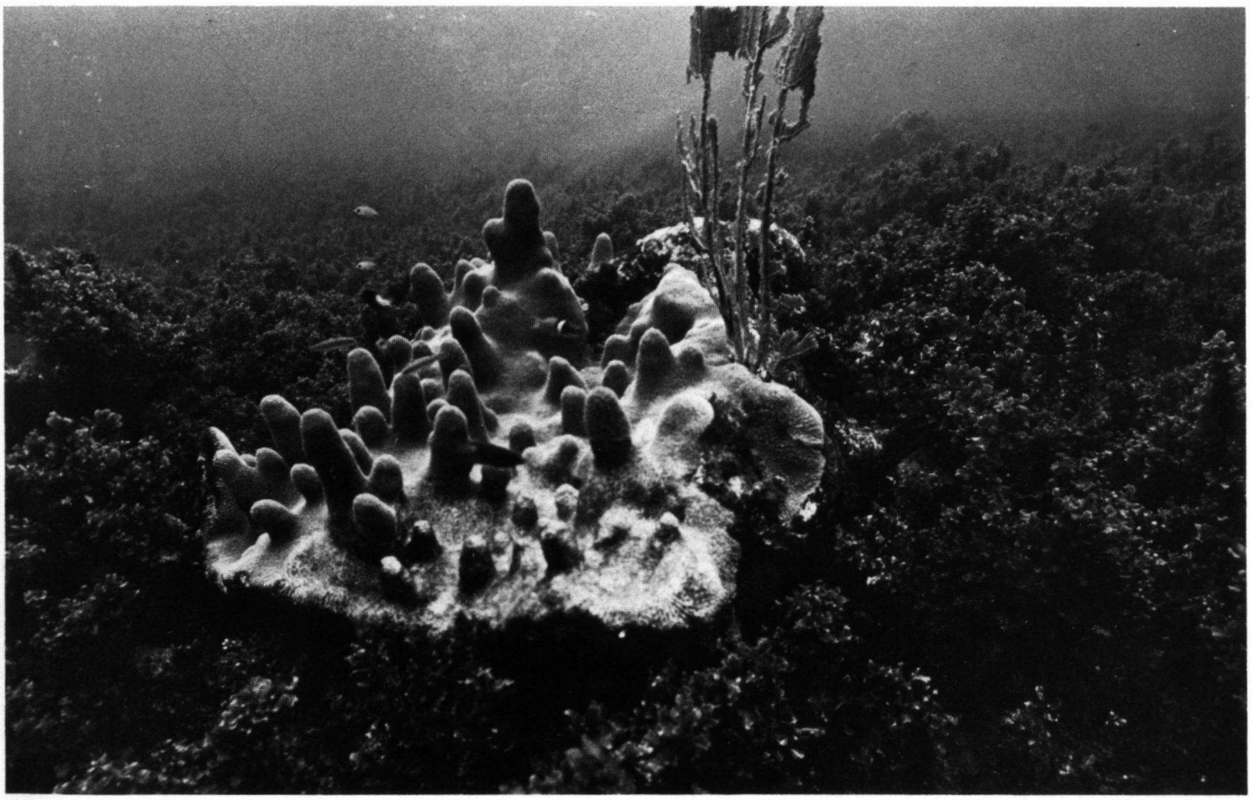

Fig. 3. First terrace with *Dendrogyra* amidst *Sargassum*, station 6, depth 14 m.

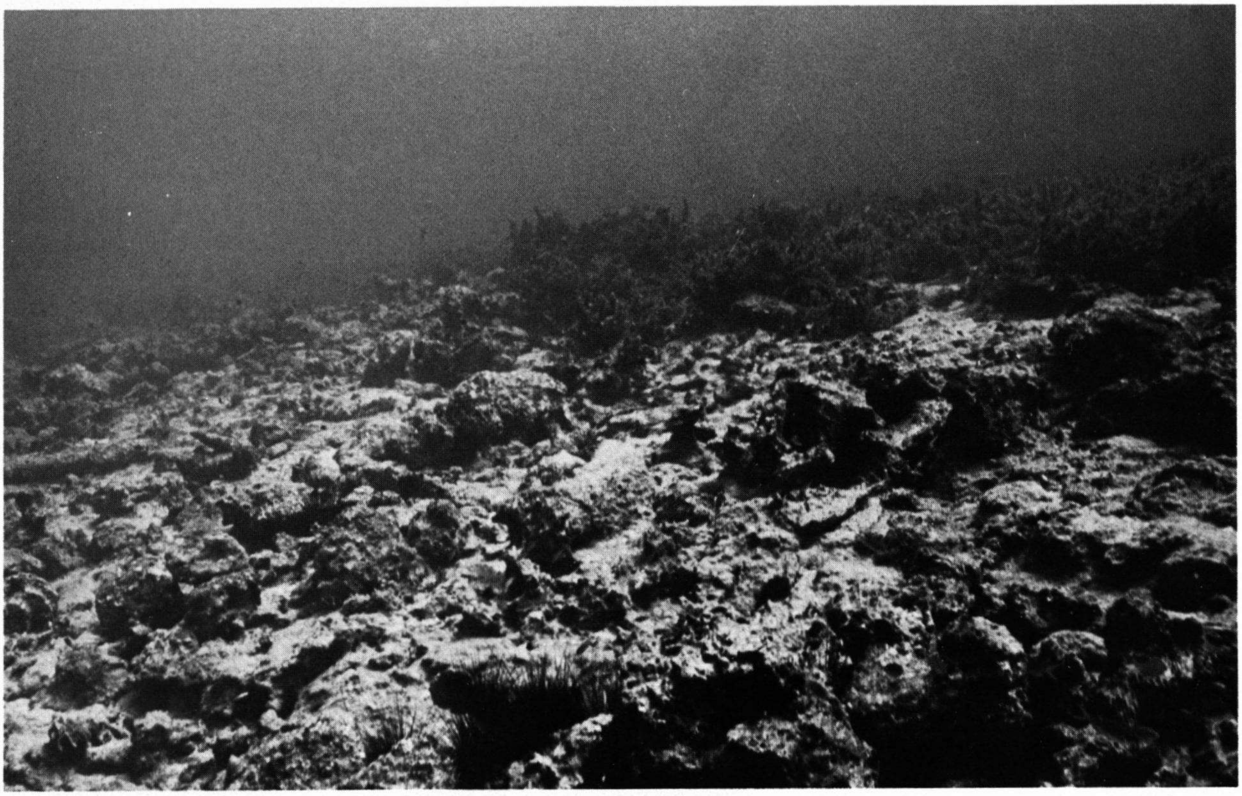

Fig. 4. Drop off of the first terrace, showing *Sargassum* fields (upper right) and coralline algal encrusted surfaces, station 11, depth 15 m.

Fig. 5. The transition between the coral and algal covered slope and the second terrace, station 14, depth of break —32 m; apparent downsloping of second terrace due to optical distortion of wide-angle lens.

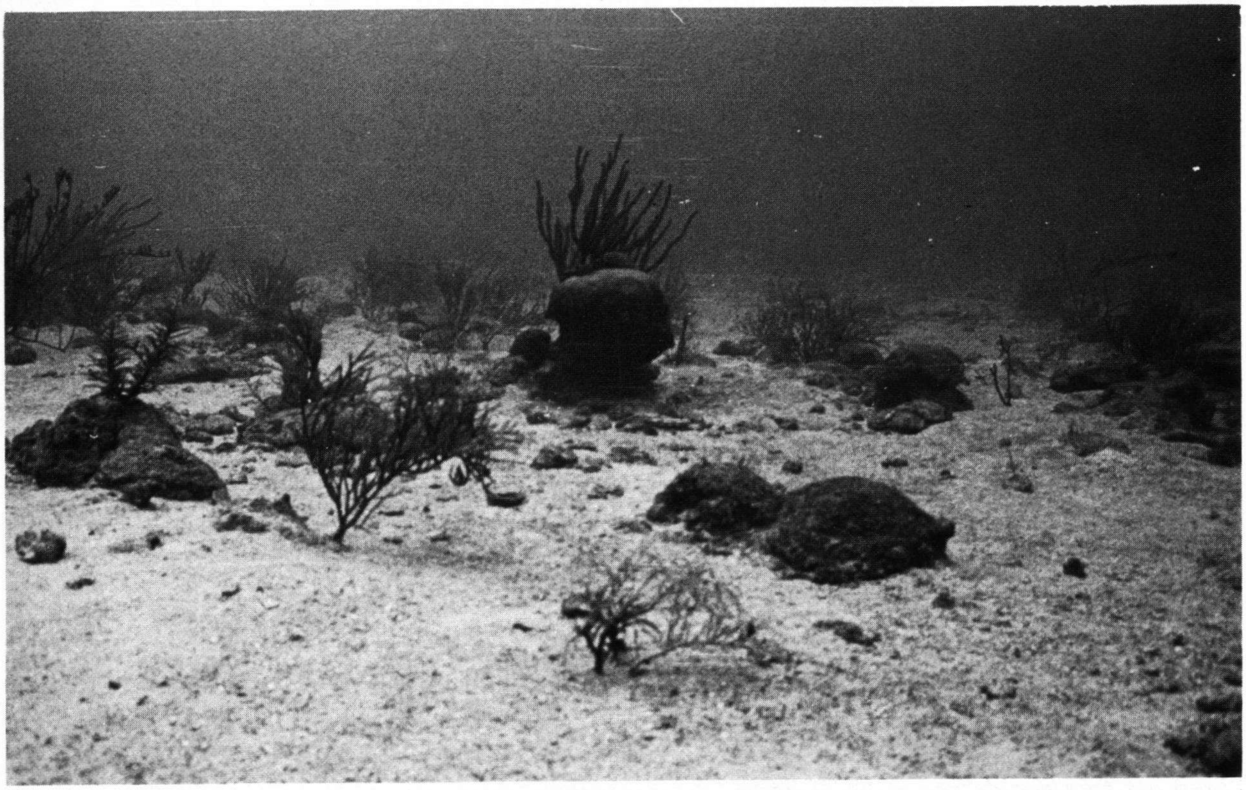

Fig. 6. Second terrace, station 10, depth —34 m, showing corals, gorgonians and rhodolites on a sandy bottom.

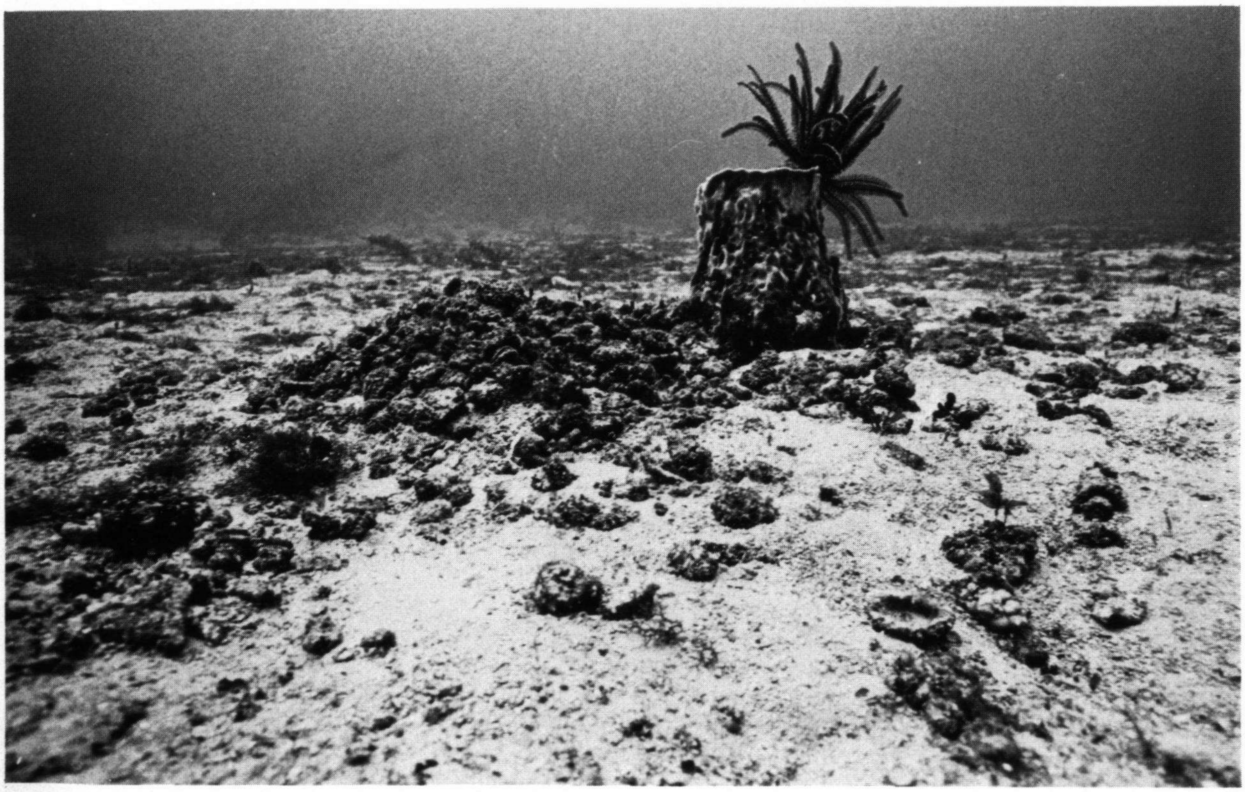

Fig. 7. Second terrace, station 5, depth —35 m, showing sponge with attached crinoid and heap of rhodolites.

Fig. 8. *Strombus gallus* (left) and *Manicina areolata*, two characteristic inhabitants of the second terrace.

The second terrace, 30 to 50 m wide and 30 to 40 m deep, is as well developed and laterally continuous as the first terrace. The coral and algal covered slope changes abruptly into the unconsolidated calcareous sands of the second terrace (Fig. 5). In some areas scattered corals occur on the sand (Fig. 6), but the greater part of the terrace is barren sand with scattered sponges and gorgonians (Fig. 7). Striking is the abundance of the conch *Strombus* on all studied locations, particularly *S. gigas* and *S. gallus* (Fig. 8), small colonies of the coral *Manicina areolata* (Fig. 8), lying loose on the sand, and red algal nodules (rhodolites). *S. gigas* has long been known from the island as a common inhabitant of shallow, protected lagoons (Wagenaar Hummelinck & Roos, 1969). The conch is also abundant in the very shallow water deposits of the Pleistocene reefs (de Buisonjé, 1974). The conches of the second terrace are significantly more bored, especially by sponges, and physically damaged, as compared with their shallow water counterparts. The rhodolites often occur in strange heaps (Fig. 7), which contain up to a few hundred nodules each, and which are as yet unexplained. Evidence of animal inhabitation, such as emptied shells, has not been found.

The second drop off, at depths of 35 to 42 m, is sandy as the second terrace itself. Also the slope beyond the drop off is covered with sand as far down (ca. 50 m) as could be seen.

At station 13 (Fig. 1) a bench was found (Figs. 9B, 10) with a remarkably smooth surface and a horizontal upper level at 32 m below sealevel. At some places the bench disappears underneath coral growth prominences of the slope, to be picked up again further on, again with the upper level at —32 m. Clearly the bench is an older structure, in the process of being buried underneath recent coral growth. The bench is encrusted with coralline algae and other organisms. Attempts to obtain a rock sample failed, although it clearly demonstrated the presence of hard rock underneath the encrustations. Stations 17 and 18 (Fig. 1) showed smoothly surfaced structures similar to the bench of station 13. In both cases the upper level is again situated at —32 m. The structures are however exposed to greater depths, and show a well-developed indentation at 35 tot 38 m below sealevel (Figs. 11 & 12). The indentation is continuous along the entire length of the structures, and did not vary in depth interval. It is noteworthy that on those stations without such structures, the break between the slope and the second terrace is always found very close to —32 m. One of these stations (no. 5, Fig. 9) showed a break close to this depth on the second terrace itself.

DISCUSSION

The first windward terrace has approximately the same dimensions and the same depth range as its leeward counterpart (Fig. 2). The leeward shallow terrace is the result of considerable Holocene reef accumulation (Focke, 1978). Similar subsurface data are however not available for the windward coast, and the age of the windward terrace is thus

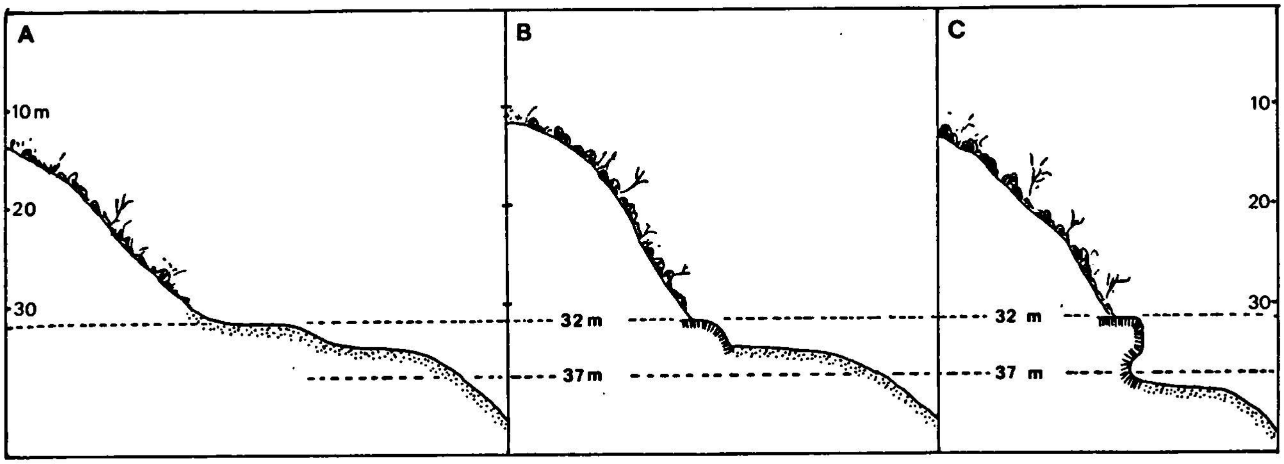

Fig. 9. Bottom profiles of the second terrace at stations 5 (A), 13 (B) and 17 (C).

Fig. 10. Fossil bench at station 13; note smooth surface and horizontal nature; second terrace at left is in fact horizontal.

unknown. It seems unlikely however that the windward terrace is the result of similar Holocene accumulation; at present, reef accumulation does not take place on the windward terrace, although of course it may have occurred in the past (examples of algal pavements underlain by Holocene reefs are known (W. H. Adey, pers. comm. 1977), for example on Martinique). Large scale Holocene accumulation however would have buried fossil structures such as the benches of stations 13, 17 and 18. Such features are indeed unknown from leeward reef areas. If, instead of accumulative, the terrace is of erosional origin, a Holocene origin is likewise improbable. Considering the nature of the Holocene (Flandrian) transgression, the terrace has been submerged for less than 7000 years. With a width of 150 m, erosion rates would be necessary of 20 mm/y, much higher than normal marine erosion rates of limestones (cf. Hodgkin, 1964; Trudgill, 1976). The windward terrace is therefore most likely of pre-Holocene age.

Terraces such as described in this paper, whether subsea or emerged, accumulative or abrasional, have traditionally

Fig. 11. Fossil cliff at station 17 with possible sealevel notch at ca. —37 m.

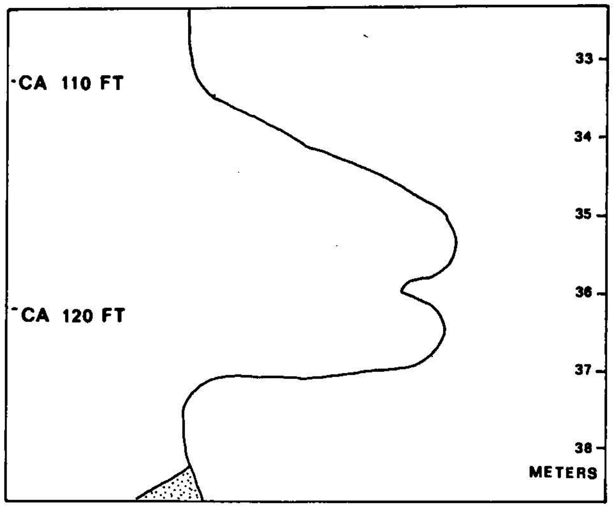

Fig. 12. Submarine notch at Jamaica, after a sketch by T. F. Goreau; depths in meters added for the purpose of this paper.

been associated with Pleistocene sealevel fluctuations. A recent re-evaluation of the emerged Pleistocene terraces of Curaçao (Herweijer & Focke, 1978) has demonstrated that a single terrace may be associated with more than one sealevel event, and that consequently, data on the elevation of the terraces are insufficient to allow local or regional correlations. This is especially true for areas of low uplift rates such as Curaçao, where several sealevel events, even from different interglacial periods, may leave evidence within the same vertical interval. Yet, according as more data on the emerged terraces and their relation to sealevel events become available, the submarine features may become meaningful even without subsurface data, if only because the number of possible correlations will decrease. At least three subsea levels have now been documented on the windward coast: the first terrace at 5–15 m, the fossil benches at 32 m, and the second terrace at 35 m. The indentation in the benches could be a fossil sealevel notch; such an interpretation is suggested by the morphology of the indentation (the profile), its horizontal nature, and its lateral continuity. Goreau and Goreau (1973) described a submarine notch from Jamaica at a similar depth. Land (1974, footnote p. 411) did not support this interpretation, regarding the feature as a growth overhang. T. F. Goreau however seems to have held on to his original interpretation, even after the re-examination reported by Land (1974) (N. I. Goreau, pers. comm. 1977). The Jamaican notch is said to be at — 40 m (Goreau & Goreau, 1973); the depth notations in feet however (Fig. 12) show that the depth range is in fact 34 to 37 m, remarkably similar to the notch of Curaçao. If the latter is indeed a sealevel notch, it is probably associated with the second terrace. A terrace at similar depth has been independently inferred at the leeward side, now buried underneath the Holocene reef (Fig. 2).

Several sealevel maxima from stages 5 and 7 in deep sea stratigraphy (e.g. Emiliani, 1971) are probably represented in the emerged coral reefs of Curaçao (Herweijer & Focke, 1978). It is evident, taking the tectonic behaviour of the island into consideration, that several of the lower eustatic maxima from stages 3 and 5 may have been responsible for the formation of the subsea terraces. More accurate stratigraphic work on the emerged terraces or offshore subsurface data is needed to determine the place of the subsea features within the framework of Pleistocene sealevel history.

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