CARIBBEAN RESEARCH INSTITUTE

RECONNAISSANCE GEOLOGY

OF ANEGADA ISLAND

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INTRODUCTION

General Statement

Anegada Island is a unique, exclusively limestone member of the British Virgin Islands. It has a small settlement of inhabitants who until very recently derived their primary subsistence from fishing. The island is notable in the area for its fishing and for the excellence of its reefs. As the island is somewhat isolated, being accessible only by boat, the natural community structure has been relatively undisturbed by man. Recently, however, the local government leased the island to a British combine who intended to develop the island into a resort center. It is expected by many parties in the area that the heavy construction and tourist influx will affect the natural structure of both the island communities and the surrounding reefs.

As a result, the Caribbean Research Institute, located on St. Thomas, invited scientists of all types to study the various aspects of the island ecosystem. The principal investigator in this report spent part of the summer on Anegada mapping it geologically and doing reconnaissance diving in the surrounding waters.

Location and Description of Study Areas

Anegada Island is a member of the British Virgin Islands located on the northeastern edge of the Virgin Bank, Latitude 18°47'N., Longitude 64°20'W. (see Figure 1). Although associated with the predominantly volcanic Virgin Islands Complex, this island is unique in that it is composed exclusively of carbonate rock, probably of Pleistocene age. It is also unique in the Virgin Islands in that its relief is only 25 feet as compared to the 1100 to 1700 foot relief exhibited by the other islands.

Anegada Island is virtually surrounded by reefs which range in character from fringing on the north shore to a reef platform on the south which is dominated by relatively small patch reefs. An arcuate projection of the fringing reef occurs on the eastern end of the island and extends for a distance of 10 miles along the edge of the bank bordering Anegada passage.

Figure 1 -
Location & regional relationships of Anegada Island. (Modified from USCGS map 1002). Depths in fathoms.

The northern and eastern reefs border on oceanic waters and those of Anegada Passage in close proximity to depths ranging from 1200 to 6000 feet. The southern and western reefs, however, border on a shallow, rather extensive portion of the Virgin Bank, termed Gorda Sound, where water depths range from 30 to 120 feet. Reconnaissance diving indicates that three belts of reefs appear to border this platform, with their bases separated by vertical distances of 12 to 15 feet.

Geologically, the occurrence of this carbonate complex in the Virgin Bank area is of interest because of its completely anomalous character. It is unique in three ways:

1) its relief is maximum of 25 feet vs. the 1700 feet relief of the associate islands;
2) Anegada is exclusively limestone vs. the dominantly volcanic nature of the remaining islands;
3) its age is probably Pleistocene vs. the Cretaceous-Early Tertiary age range of the nearby islands. It serves as a barrier between the shallow, submerged portion of the Virgin Bank (Gorda Sound) and the major wave trains produced by the Trade winds.

Past Work

Geologic interest in the Virgin Islands has progressed through two distinct phases, an earlier phase in which primary activity dealt with general observations on the geographic and geologic nature of the island group. The majority of these early workers (Cleve, 1871, 1881; Hogbom, 1905; Earle, 1924) were interested in the petrographic nature of the metamorphic and sedimentary deposits of the islands on the southern portion of the bank. Vaughn (1916, 1919, 1923), Davis(1926) and Meyerhoff(1926), concentrated on general stratigraphic and geomorphologic setting and Meyerhoff presented the first published topographic profiles across the Virgin Bank. Kemp (1926) presents an excellent summary of the work generated during this early phase. The only author to describe Anegada Island in any detail was Schomburgk (1832) who conducted an excellent general reconnaissance of the island and its natural history.

The recent phase in study of the Virgin Islands was begun by Cedarstrom (1950) with a ground-water survey of St. Croix. Dr. Harry Hess and a series of students (Hess, 1960; Helseley, 1968; Donnelly, 1959, 1964, 1965, 1966; Whetten, 1966) have generated the most detailed studies on the geology, petrology and origin of the islands. All of their studies, however, ignored Anegada Island. A short discussion of Anegada by P.H.A. Martin-Kaye (1959) is the only real mention of the island to this date.

Acknowledgements:

I would like to thank Dr. Edward Towle of the Caribbean Research Institute for suggesting the study. Dr. Arthur Dammann of the Virgin Islands Ecological Research Laboratory provided logistic support. Mr. Ian Koblick and Robert Brody aided greatly in facilitating the work and in supplying background material. Mr. Brody also provided follow-up information on the location and character of the reef arcs leeward of Anegada. Dr. Robert Yeats was very helpful in discussion and criticism of the final manuscript. The study was financed by Ohio University Research Fund Grant 862.

General

Anegada is an island of low relief; maximum elevation is 25 feet, and composed entirely of limestone. Bedrock is exposed over 60% of the island and typically is characterized by a modified karst topography. Solution pits and sinkholes are abundant with maximum diameters of three feet and depths greater than eight feet observed. No permanent streams were found although shallow standing pools were observed after heavy rains.

The western 40% of the island is mantled by loose carbonate sands with a moderate vegetative cover. It is typically much lower relief; maximum elevation is ten feet, and with an irregular surface.

Physiographic Subdivisions

The island can be divided into five distinct areas on the basis of physiographic characters (see figure 2).

Bedrock Ridge- The highest elevations occur on the northeastern and north-central parts of the island along a slightly arcuate ridge which extends from the eastern tip to Soldier Point. The front margin of this ridge is irregular with numerous projections and embayments. The average orientation of these irregularities is N70°E.

The projections tend to coalesce toward the southwest, forming a ridge which generally trends N30°W and which is truncated at its northwesterly extreme, Soldier Point. Maximum relief occurs at Soldier Point and decreases gradually to the southeast.

The general location of the projections and indentations coincides with the location of modern spur and groove structures in the barrier reefs along the northeastern margin of the island. This coincidence could imply analogous origin for the irregular ridge margin.

Bedrock Flat- Directly south and west of the Bedrock Ridge is a large, gently-sloping surface with very little relief. It continues beyond the emergent portion of the island and forms a shallow terrace which extends up to 1/2 mile beyond its southern margin. Solution pits are extremely numerous and range up to 1 meter in diameter. Exposures of this platform are approximately coincident with the extent of the Bedrock Ridge on the east but occur up to 4 1/2 km. further west than Soldier Point.

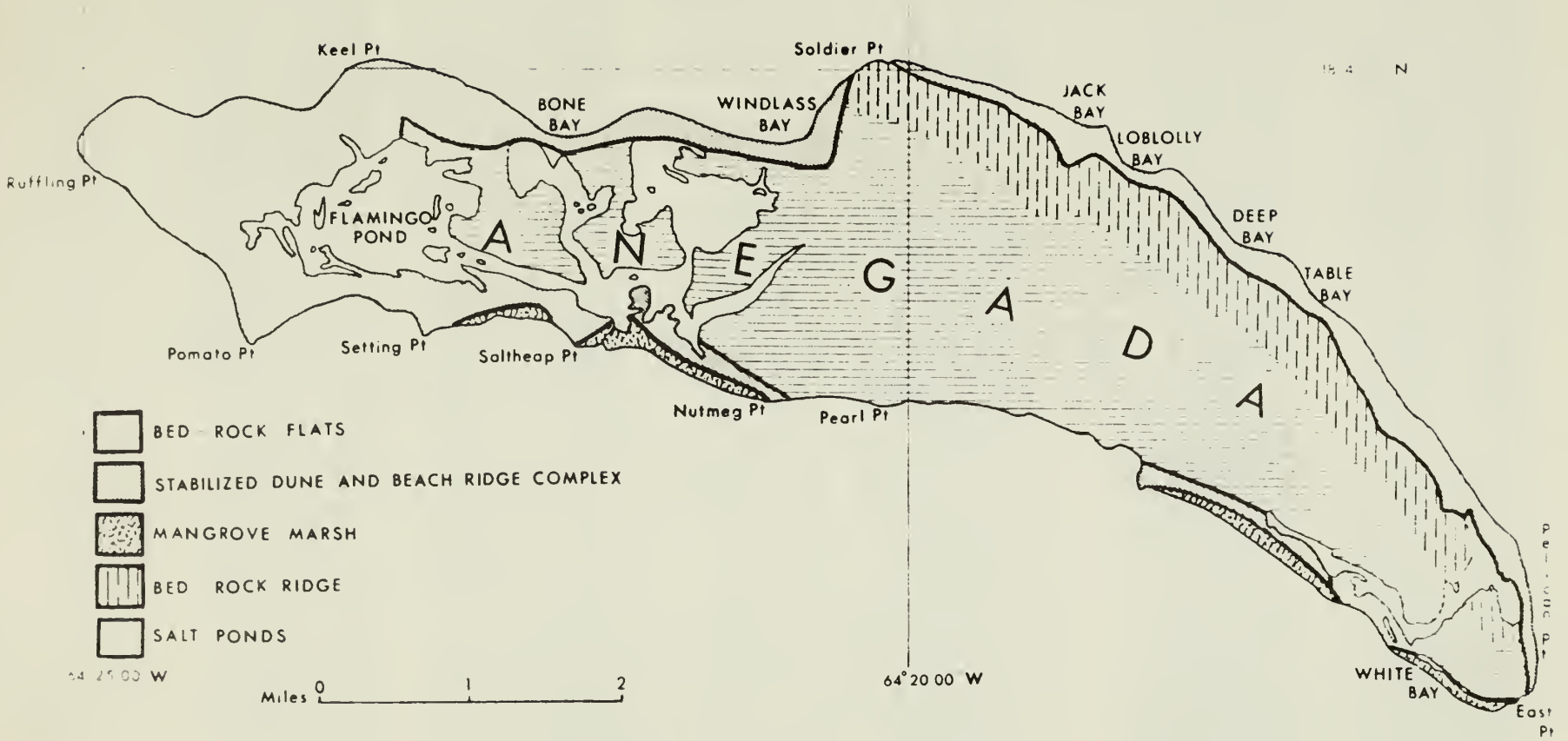

Figure 2 -
Physiographic subdivisions of Anegada Island.

Stabilized Dune and Beach Ridge Complex- Two areas on the island, a narrow strip paralleling the northeastern margin of the island and a broad area comprising about 40% of the western tip, are characterized by extensive, unconsolidated, carbonate sand accumulations. Storm ridges along the northeastern margin attain local elevations of 8 meters and cover associated with them rarely extends more than 100 meters inland.

Maximum relief of sand ridges on the western tip of the island is 4 meters but cover is really much more complete than on the east. Two distinct sets of ridge orientations are present, apparently related to simultaneous accretion on both the northern and southern margins of the island. All ridges are oriented at slight angles to and are normally truncated by modern shorelines. The topographic surface in this section of the island is typically ridge and swale with average relief about 1 1/2 meter.

Salt Ponds - The western half of the island contains an extensive complex of hypersaline lagoons apparently associated with shallow topographic depressions in the bedrock surface. These ponds, which are connected with the sea by a narrow channel located at Salt Heap Point, have a maximum depth of 10 cm. Equipment limitations allowed measurements of only 88% to be made but higher salinities are present as salt crystals are produced and utilized by the native population.

A series of intermittent ponds also exist on the eastern end of the island and are probably fed periodically by storm tides which have access through tidal channels in the mangrove swamps in that area. At the time of this study, most of the ponds in the east were dry, although several mounds of salt recently collected from the basins were present.

Flamingo Pond, the westernmost member of the complex, appears to differ somewhat in that it is apparently not underlain directly by bedrock. Hand probes just beyond the last limestone outcrop suggests that a sharp break in slope of the platform occurs at that point. The coincidence of this break in slope with a similar break observable off the southern shore of the island suggests that Flamingo Pond represents an arm of the sea isolated by sand accretion along the southern perimeter of the island, a process still observed to be active.

Mangrove Marsh - The leeward (southerly) side of the island is charaterized by thick accumulations of mangroves which occur in long, narrow bands paralleling the present shore line. The mangroves are most continuous on the east and distribution becomes more sporadic until they disappear at Setting Point on the west. Clumps of dead and dying mangroves located inland of the present shore suggest that some active extension of Anegada to the south is presently underway.

Bedrock on the island is composed entirely of blue-gray to dark-gray limestones which range in nature from rudaceous biocalcarenite to arenaceous calcilutite (see figure 3). All exposures examined were highly recrystallized. Evidence of pre-modern sub-aerial exposure was found in two localities where pockets of highly-oxidized silt containing terrestrial gastropods are preserved in solution sinks.

On the basis of lithologic and paleontologic variations two distinct facies can be delineated, a high-energy reef front and a quiet-water, relatively protected reef platform.

Reef-Front Facies

This facies is exposed primarily in the topographic highs located along the northeasterly facing portion of the island and is approximately concurrent with the physiographic feature termed the bedrock ridge (see figures 4,5). It is generally oriented N 30°W, parallel to modern prevailing wave trains. Leading face of this ridge is comprised of a series of irregular projections with a general orientation of N 70°E and which appear from aerial photographs to parallel modern spur and groove structures directly seaward of the ridge.

Lithologically this facies ranges from a coarse biocalcirudite, which occurs most commonly around the base and flanks of the ridge and its projections, to a massive, highly recrystallized, poorly fossiliferous calcisiltite and calcarenite at the crest of the ridge. Maximum elevation of the ridge occurs at the northwesterly extreme near Soldier Point where it attains an elevation of about 14 feet above sea level. Topographic expression and continuity decreases to the southeast until a minimum elevation of 6 feet is found at the east end of the island.

Fossil remains present what appears to be a relatively consistent zonation across the ridge from northeast to southwest as follows (see figure 6):

I. a) The basal portion of each mound contains abundant remains of Citarium pica (the whelk) which is now found normally in areas characterized by solid rock substrate and high turbulence. The remains are in fair condition and normally exhibit some abrasion. Exposed thickness of this zone usually ranges from 3 to 6 feet. Corals are not common here although rare Diploria labyrinthiformis do occur.

b) Above the Citarium zone appears an increasing number of small coral heads, normally of Diploria and Montastrea, some of which appear to be in place. As the limestone has been highly recrystallized, smaller fragments are usually not identifiable. Small lenses of shell hash are preserved and portions of Citarium, small gastropods and coral debris are identifiable.

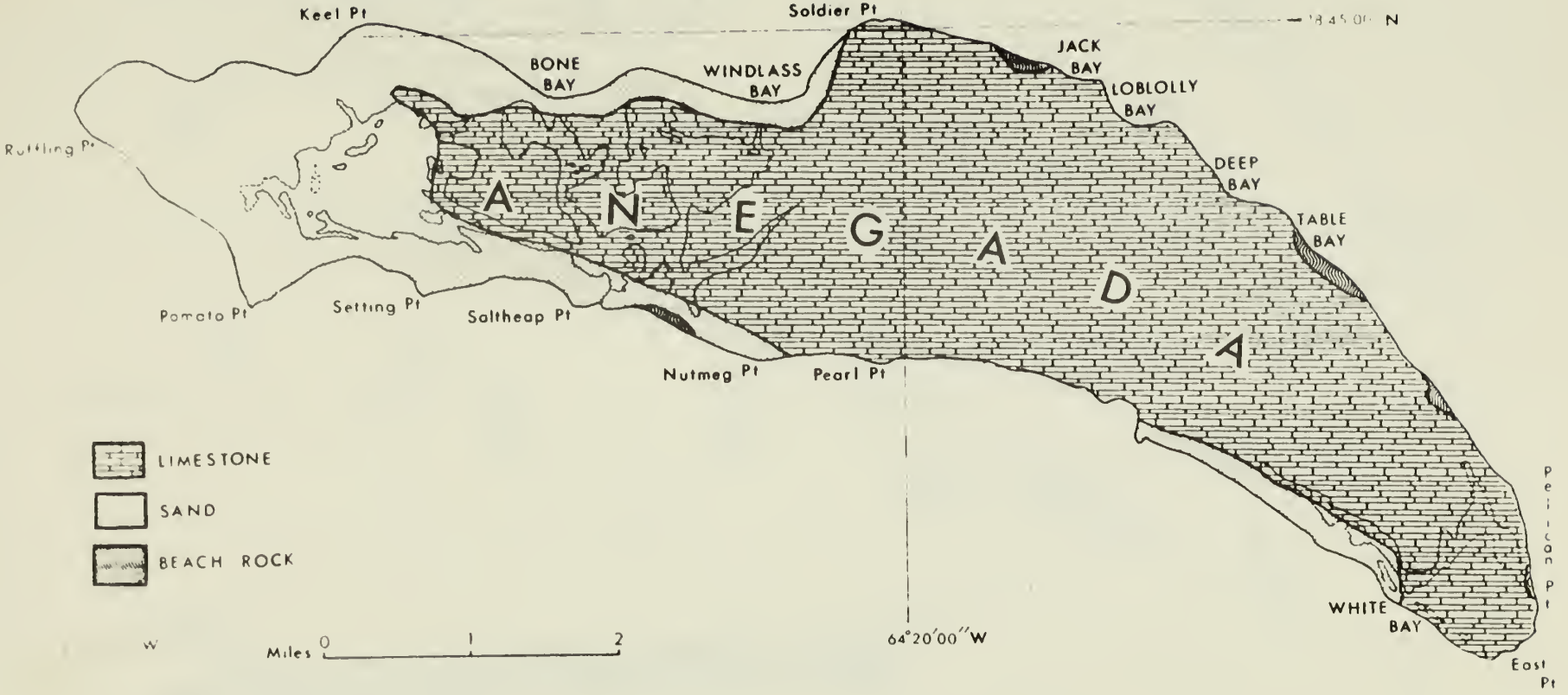

Figure 3 -
Bedrock geology of Anegada Island.

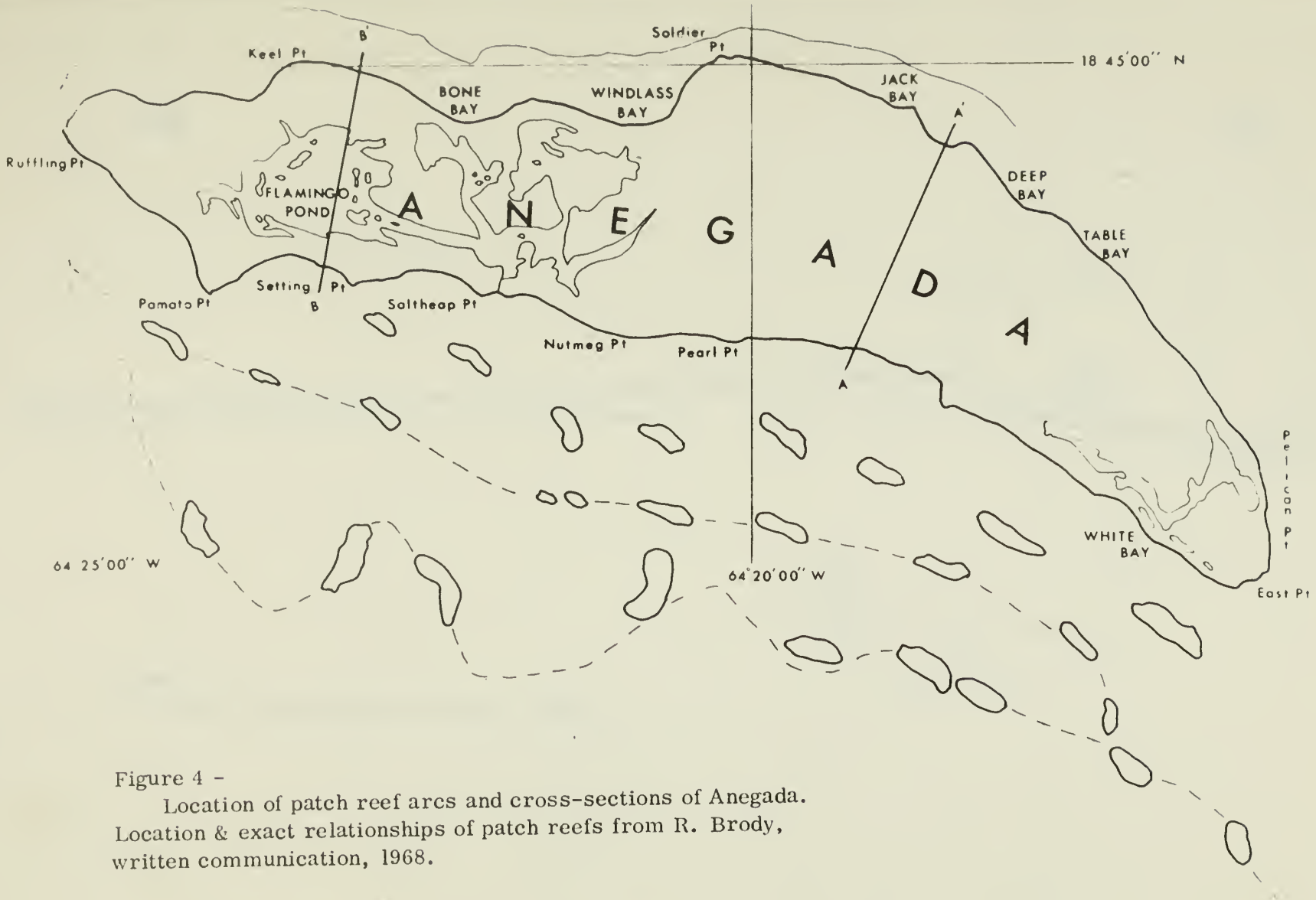

Figure 4 -

Location of patch reef arcs and cross-sections of Anegada. Location & exact relationships of patch reefs from R. Brody, written communication, 1968.

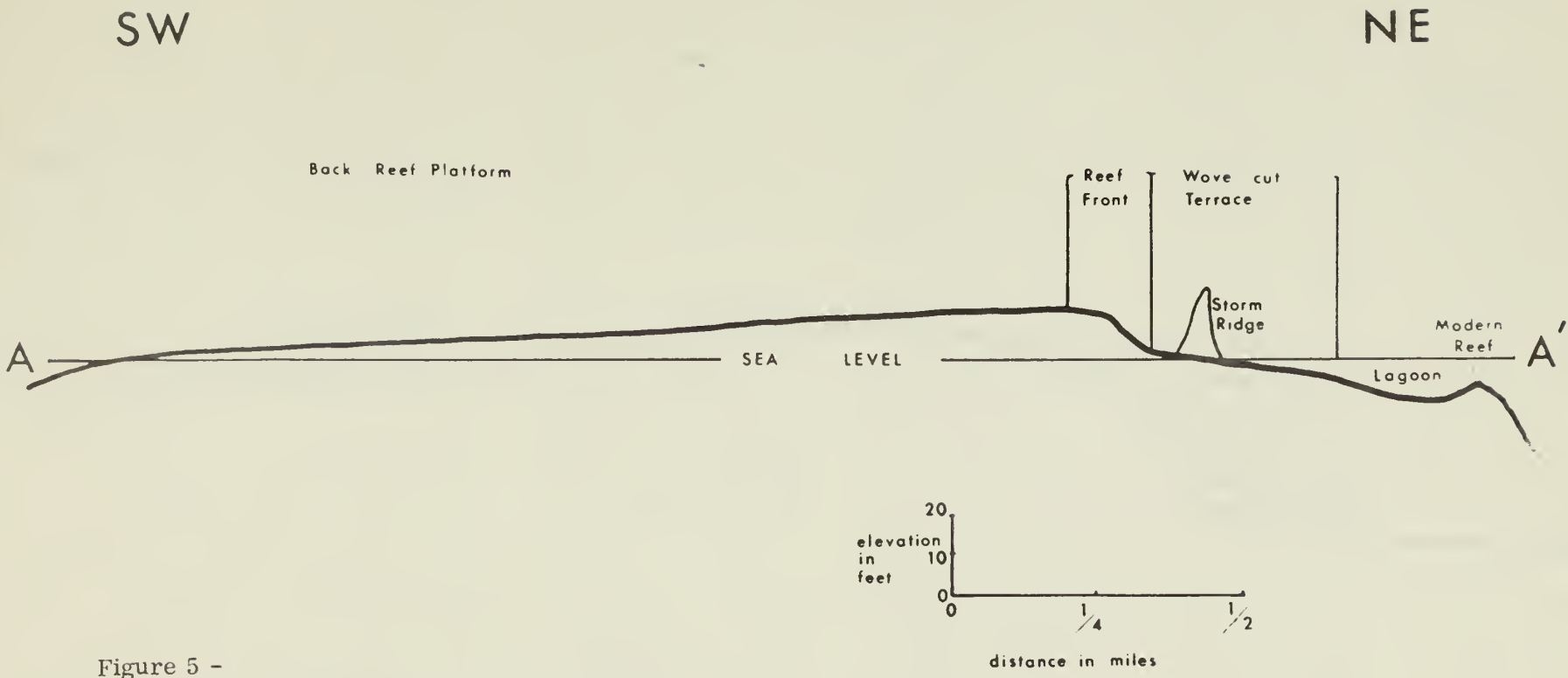

Figure 5 -
Cross-section through East end of Island.

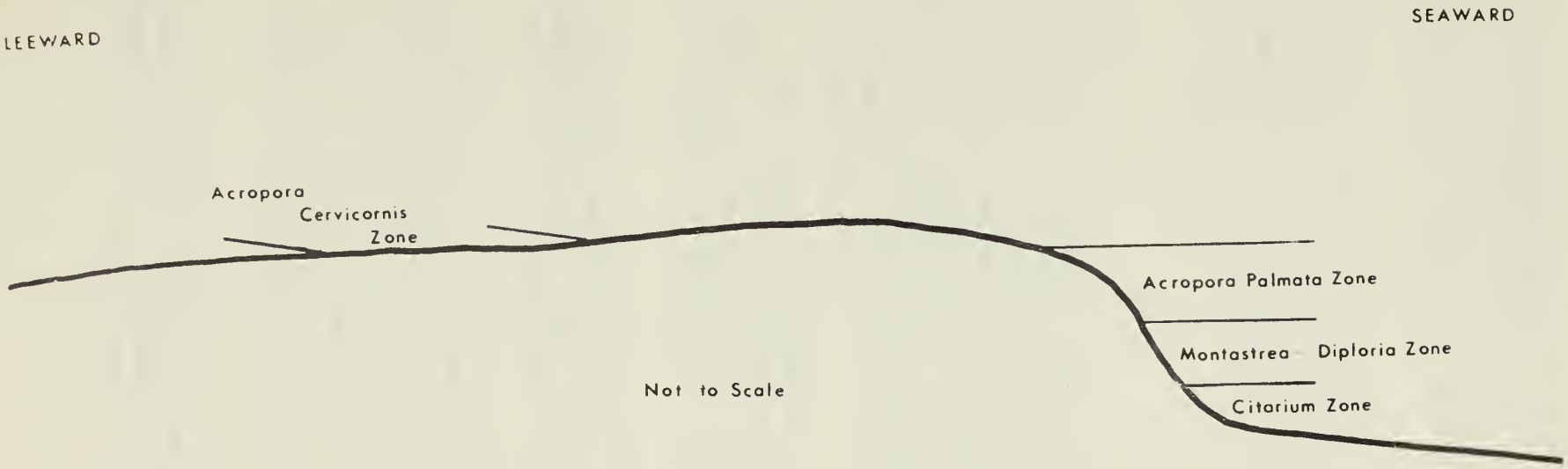

Figure 6 -
Enlargement of zonation along front of fossil barrier.

c) Overlying the Diploria-Montastrea zone is one which the dominant organism is Acropora palmata. These remains are normally not in place but are extremely abundant on the upper flanks of the ridge. This facies usually occupies the crest of the knolls and most other fossils have been virtually obliterated by recrystallization.

d) The south and southwestern sides of the knolls are usually characterized by an abundance of fragments of Acropora cervicornis. This zone may extend up to 200 meters in back of the knolls in some cases, particularly on the eastern end of the island, and appears to grade somewhat into the quiet-water sediments to the southwest.

Reef Platform Facies

This facies is much more extensive than the reef front facies to the northeast and occurs over approximately 60% of the island (see figure 7). It is lower topographically and slopes gently to the southwest extending below low tide mark out to a maximum distance of approximately 0.6 miles from the leeward shore in some areas. It is asymmetrical with regard to the reef-front facies, extending up to 4 1/2 kms. further west than Soldier Point although eastern extent is approximately concurrent with the ridge. The southerly limit of this facies is bounded by a scarp with a relief of approximately 12 feet.

Lithologically this facies is a rudaceous biomic rite with abundant lenses of biocalcarenite. Fossils are abundant and usually intact although recrystallized. The most conspicuous forms are Codakia, commonly in situ, Millepora, Olivella sp. Montastrea, Diploria, and Acropora sp.cf. A cervicornis.

The corals do not occur randomly but are normally concentrated in relatively small areas which may or may not have a relative relief up to 3 feet with surrounding exposures. These concentrations are interpreted as representing small patch reefs developed locally on the platform.

Preliminary study of the area leeward of Anegada Island suggests that the present living patch reefs are not randomly distributed. Instead, they appear to be forming on the edges of several terraces, each separated vertically by approximately 12 to 15 feet of relief (see figure 8). The innermost arc, forming on the edge of the submerged segment of the bedrock flat, intersects the island at a position just east of Setting Point. This would coincide fairly well with the scarp tentatively identified by probes on the northeastern side of Flamingo Pond and where at least one fossil patch reef was discovered (see Figure 7).

The second arc is located seaward of the first with a base at approximately 22 feet below sea level and the third even further seaward with a base at approximately 35 feet. It is possible that other series exist at deeper positions as depth contours appear to follow similar patterns

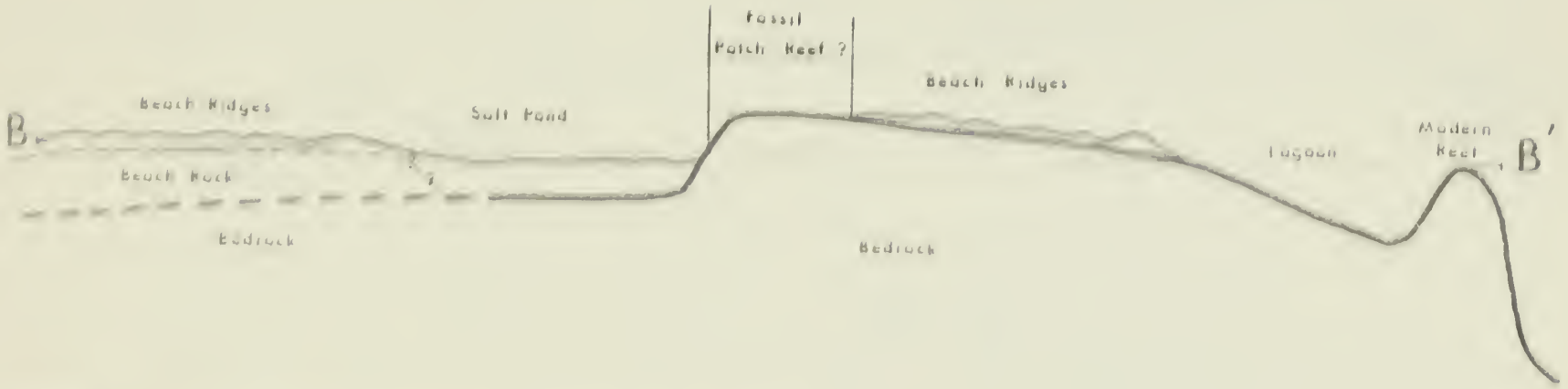

Figure 7 -
Cross-section B-B' through Western end of island.

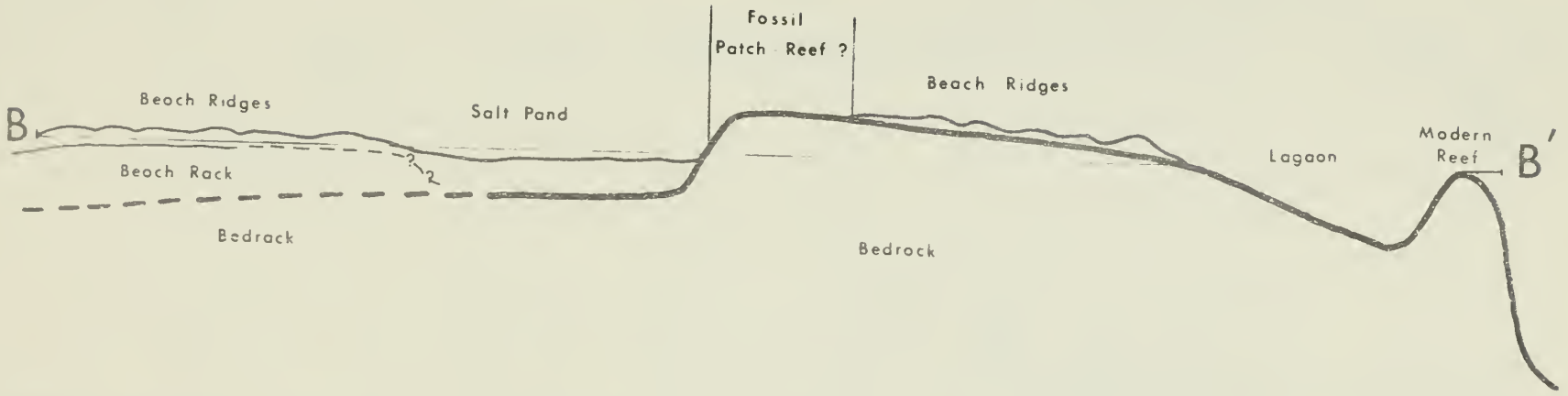

Figure 7 -
Cross-section B-B[1] through Western end of island.

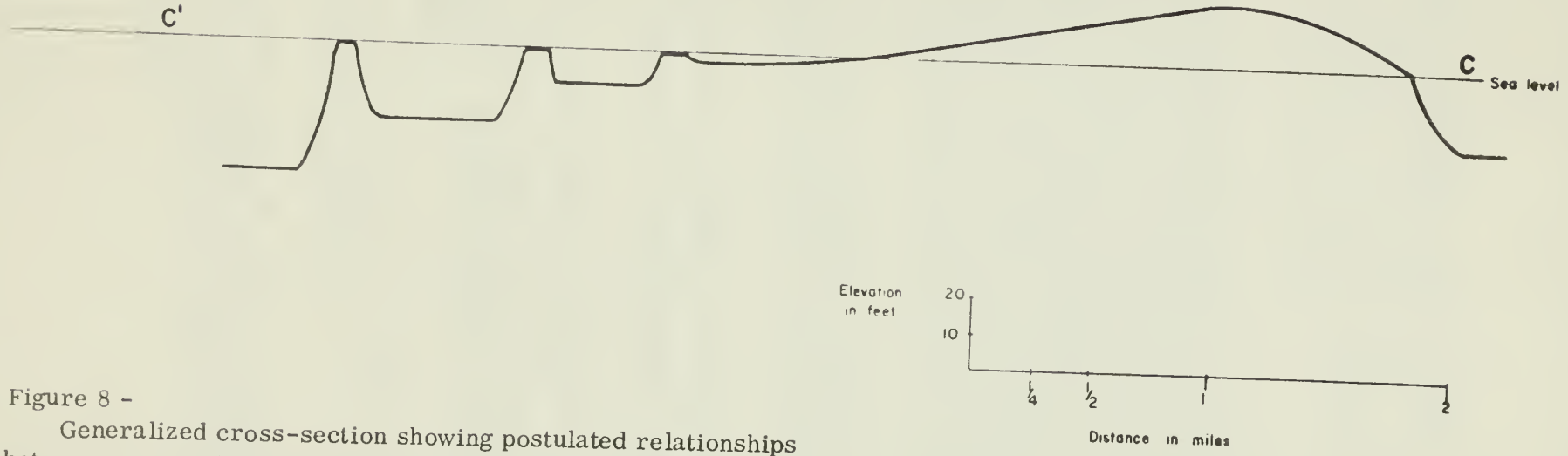

Figure 8 -

Generalized cross-section showing postulated relationships between emergent portion of island and terraces bounded by patch reefs.

out to a depth of 60 feet and are associated with the barrier reef extension of Anegada Island southwestward along the Anegada Passage.

The presence of these subtending arcs and platforms suggests that Anegada has been developed over at least three cycles of activity. Each terrace would represent the lagoon-back reef facies of reef development during one cycle. The northeastern face of the island would be growing seaward as a barrier in response to nutrient optimums normally present where shelf edge is perpendicular to major wave trains.

Development of the leeward scarps is more difficult to explain. The most probable hypothesis based on present information would be that location of the scarps is controlled by coral growth along the leeward side of the developing barrier reef-reef platform complex. As currents strike the northeastern edge of the platform, some major water masses are shunted south into Anegada Passage, allowing development of the present barrier reef extension. Location of the southernmost tip of this extension will control the point at which spillover onto the Virgin Bank will occur. From that point, diffraction will allow waves to strike Anegada from the southeast although intensity of activity will be much decreased as the wave system moves northwestward.

Development of each scarp, therefore, could be controlled by exact position of the fringe in conjunction with sea-level changes which were widespread during the ice advances and retreats of the Pleistocene.

Points of data which tend to support this hypothesis are:

1. Water movements similar to the proposed system are present today.

2. Major sand cover on the island is located to the west.

3. Active sediment transfer from east to west was observed while on the island. In some cases, this sediment transfer was sufficient to adversely affect reef establishment near Ruffling Point.

4. Fossil evidence shows asymmetry of dominant facies with the reef platform facies shifted to the southwest with respect to the barrier reef facies.

5. Current orientations taken on fossil materials in the reef platform show a general current direction to the northwest. This indicates the conditions similar to those in evidence today were prevalent during the earlier stages of development.

6. Previous emergence of the island is indicated by the presence of relict pockets of an indurated reddish clay and soil containing terrestrial gastropod fossils.

SUMMARY

Part of the transition zone between the Puerto Rico Trench and the Caribbean Island Arc lies on the northern edge of the Virgin Islands Platform. This northern edge is above water on Anegada Island, on the northeastern-most projection of the Virgin Bank. Its low relief (maximum 8 m) and exclusively Late Cenozoic limestone lithology contrasts strongly with the relatively high relief (320-440 m) and dominately Cretaceous to Early Tertiary clastic-volcanic lithologies of the associated islands.

Field mapping of Anegada and reconnaissance diving on the surrounding reefs suggest that the emergent portion represents the maximum elevation attained by a series of periodically re-established barrier reef-carbonate platform complexes. A windward fossil barrier reef is exposed along the northeastern edge of the island, oriented approximately perpendicular to modern wind and wave train directions. Fossil distributions suggest a high energy zone (Citarium Biofacies) at the base of the Atlantic-facing scarp of the reef, overlain by a coral-dominant (Montastrea-Diploria Biofacies) with some Acropora palmata. Quiet-water platform deposits containing Codakia (in situ), Strombus, and numerous other molluscan genera occur leeward (southward) of the fossil barrier. Local accumulations of Montastrea, Diploria, and Acropora cervicornis in these platform deposits may represent the presence of fossil patch reefs.

Two small submerged terraces extending leeward of the island and bounded on the south by vertical scarps with 4 or 5 m relief may represent older platforms analogous to that exposed on Anegada.

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