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GEOLOGY OF THE INSULAR SHELF SOUTH OF ST. THOMAS AND ST. JOHN, U. S. VIRGIN ISLANDS

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This report is preliminary
and has not been edited or
reviewed for conformity with
Geological Survey standards

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Illustrations

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Abstract

A reconnaissance study has been made of the geology of the insular shelf south of St. Thomas and St. John, Virgin Islands. High-resolution seismic-reflection profiling reveals that a buried northeast-southwest striking bedrock ridge controls the shallow structure of the eastern portion of the shelf. This ridge is thought to be related to the Virgin Islands pluton farther north. Bedrock in the western shelf portion is more deeply buried and is thought to be a flatter terrain, probably lithologically similar to rocks exposed on St. Thomas.

The sediment cover appears to consist principally of carbonate grains in the sand-size range. This sand is covered to various degrees by carbonate nodules at depths below about 34 m, but at shallower depths the nodules are not present. Three large areas of sandy bottom were mapped 1) west of Brewers Bay, 2) near Buck Island, and 3) off south-central St. John. Variations in the amounts of land-derived particles, organic matter, and silt/clay sized material were mapped in these bodies.

Introduction

This report is the result of geological investigations made on the insular shelf south of St. Thomas and St. John, Territory of the Virgin Islands. The investigations were conducted jointly by the U. S. Geological Survey and the Caribbean Research Institute, College of the Virgin Islands for the purpose of: 1) providing a reconnaissance map of the distribution of sediment types on the shelf surface, and 2) mapping the gross geological structure of the shelf by the use of high-resolution seismic reflection profiling.

A reconnaissance map of sediment distribution on the shelf surface is desirable for a number of reasons. One of the more immediate uses is that it provides a means of quickly evaluating the potential of the shelf region for supplying sand-sized sediments in sufficient quantities to be used as building materials. Because of the steep, rocky shores and general lack of soil in the Virgin Islands, beaches are small and occupy pockets in the shoreline. The material of which they are composed is largely carbonate and comes from the shell material of offshore organisms. The processes which move this material shoreward to form beaches is extremely slow so that littoral sands removed from the system by man can be replaced by nature only over a period of many years, and there undoubtedly is a point in the removal of sand at which the destruction of beaches becomes irreversible for all practical purposes. It is, therefore, of vital importance that future supplies of building sand be taken from a system that does not include the immediate reservoirs which replenish the beaches. The first step in insuring against the loss of beaches, then, is to find and evaluate offshore supplies of sand.

A second benefit to be derived from the reconnaissance mapping of shelf sediments is the establishment of a framework for more detailed studies to follow. It is highly desirable to develop an understanding of the dynamic system which transports and mixes island-derived clastics with offshore carbonate particles. Is the system closed and non-self-replenishing, or is it open ended with a source and a sink? Are the forces which generated the sand supplies presently operable, or are these sands relict from some ancient environment? To answer such questions, future studies will require a base map from which research problems can be designed. The present study provides such a basis.

The geologic structure of the Virgin Islands platform is also of interest in many ways. Along the crest of the Greater Antillean ridge, the Virgin Islands form the easternmost checkpoints for geologic mapping. The area of exposed rocks is small, however, by comparison with the area covered by younger carbonates and submerged below sea level, so that studying the geology of this region can be compared to looking through a screen in which the holes are smaller than the wires. Any means of extrapolating the bedrock land geology to the concealed regions is, in effect, enlarging the holes and is of immense assistance in deciphering the geology and geologic history of the area.

Mineralization in the metamorphosed zones around plutonic bodies has created metal deposits of commercial value in many parts of the Greater Antilles. Since water depths are not prohibitive over much of the Virgin Islands platform and since plutonic masses are known to be emplaced there, it is not inconceivable that, if present, such mineral deposits could be recoverable. In order to explore such possibilities, a first step would be to map the submerged and buried bedrock surfaces. Such a map would indicate the thickness of overburden and suggest locations for the core holes around which an exploratory program could be designed.

The high resolution seismic profiles made during this study were more experimental than exploratory because of the unique acoustical problems associated with sedimentary materials of such high reflectivity. Although a gross structure map was produced from these profiles, the techniques need further refinement. It is clear, however, that such methods are feasible and, with further experimentation, could unquestionably provide a detailed bedrock map.

Shipboard facilities for the project were provided by the Ocean Survey Program of TEKTITE II through which the R/V ADVANCE II was made available. Seismic profiling was accomplished aboard this vessel during the period April 9-14, 1970. Samples were collected on two later cruises during the periods April 15-20 and October 18-28, 1970.

We would like to express our thanks to Mr. James R. Smith, Coordinator of the Ocean Survey Program, for his assistance in ship scheduling and logistics, and to Capt. Arthur Jordan and the officers and men of the R/V ADVANCE II for their help and hospitality aboard ship. Thanks are also due Nick Hilton, Paul Rainey and Steve Svendson of the Caribbean Research Institute and Paul Doak of Maine Technical Institute for providing the diving support.

Methods

Seismic profiling.--Almost 277 km of high-resolution, continuous seismic-reflection profiles were made in the area of study. The seismic source was a prototype sparker device (Porcupine) consisting of a special electrode constructed by technicians of the Geological Survey and a capacitor bank made by the EG&G Co. of Boston. The electrode consisted of 1 meter of teflon-insulated copper wire pierced by 48 copper pins and surrounded by a steel mesh cage 10 cm in diameter. Electrical arcing from pins to cage created the pressure wave which was a source of acoustical energy. A stored capacity of 600 joules of electrical energy was released through this electrode at intervals of 3/4 second.

Bottom- and subbottom-reflected sound waves were received upon their return by a 4.5 m streamer containing 20 geophones towed about 12 m behind the sound source and approximately 2 m below the water surface. The incoming acoustical energy was amplified, passed through a 250-810 Hz bandpass filter, and printed on a 19-inch (48 cm) Gifft recorder at 1/4 second sweep rate.

Because of the characteristics of the seismic system and the nature of the sediments, the seismic records were affected by strong multiple reflections of the water/sediment interface. All first reflections from deeper horizons which arrived after the first multiple reflection of the bottom were completely overwhelmed by it and subsequent multiples (Fig. 1). This placed the lower limit of acoustic visibility at a distance below the sea floor exactly equal to the water depth, or a maximum of about 60 m. Furthermore, the outgoing seismic signal itself consisted of a band of energy pulses of about 0.01 seconds duration whose first reflection from the sea floor overrode all subbottom reflections to a depth of about 18 m.

Thus, in effect, the subbottom structure must be viewed through a window which permits information only between subbottom depths of 18 and 60 m, or less, depending on water depth. Through this narrow slot, however, a considerable amount of detail can be seen, and the accompanying structure map (Fig. 4) is based upon this.

In the absence of information on the velocities of sound wave travel through the upper sediment layers in this area, absolute depths to subbottom reflectors had to be approximated. All depth calculations were therefore based upon an estimated velocity of 1.80 km/sec in sediment and 1.5 km/sec in water.

Sediment sampling.--All bottom sediment samples were taken with a Shipek sampler, which is a sampling device composed of two concentric half-cylinders. The inner half-cylinder is a sample bucket which, upon contact with the sea floor, is rotated through 180° by two external springs. It is designed to recover a sediment sample with a

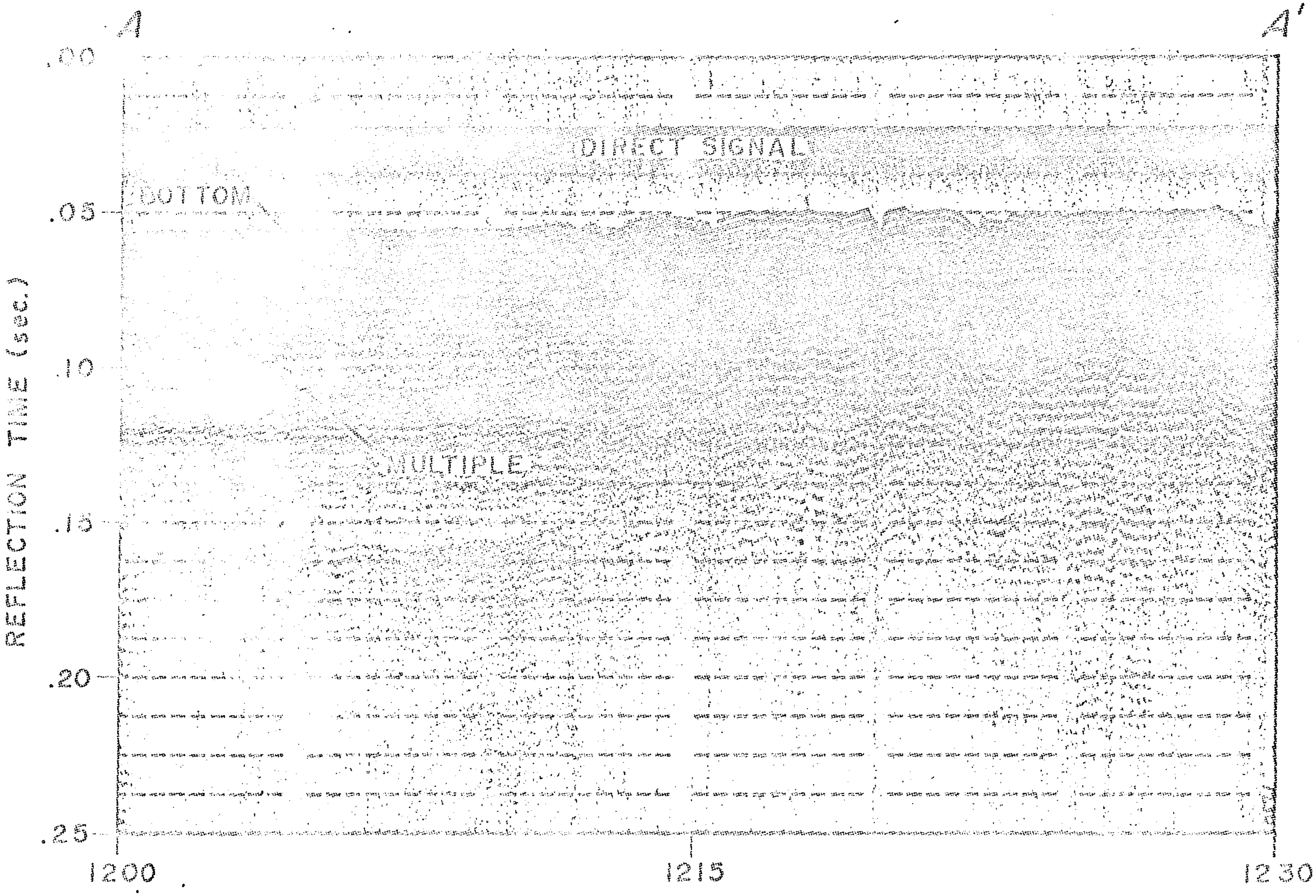

A
A'
DIRECT SIGNAL
BOTTOM
MULTIPLE
REFLECTION TIME (sec.)
.00
.05
.10
.15
.20
.25
1200
1215
1230

FIGURE 1

surface area of 1/25 m^2, about 10 cm deep at the center, and is most useful in the coarse material which was expected in this region.

Samples were taken at the intersections of grid lines spaced one mile north-south by two mile east-west except in areas of high sand-concentration where additional samples were taken at the corners of a one mile grid.

Ordinarily when the sampler was lowered on a sandy bottom, no difficulty was encountered in recovering a sample of the sand. At some stations, however, the sampler returned empty due either to malfunction or because of a hard bottom from which no sample was available. In such cases a second lowering was made immediately to determine the cause of failure and many times large fragments of carbonate material broken from the sea floor were brought up.

Navigation.--Navigation on all cruises was carried out by the ship's officers using visual fixes. With an abundance of landmarks and excellent visibility, the navigational error is estimated to be from a few tens of meters for nearshore fixes to about one kilometer for those fixes farthest offshore.

Sediment analyses.--In the laboratory the samples were washed twice with tap water, given a final washing in distilled water, then dried and split. One-quarter was marked for textural analysis, one-quarter for chemical analysis, and the remaining half was stored for future studies.

The portion marked for textural analysis was passed through a 2 mm sieve to remove the gravel fraction which was weighed and saved.

The < 2 mm portion (sand, silt and clay) was placed in a one-liter settling jar, covered with a carefully determined amount of distilled water and shaken into suspension. It was then allowed to settle for a calculated period of time sufficient to permit the sand-size particles (0.062-2.000 mm) to reach the bottom of the container while the silt and clay particles (< 0.062 mm) were still in suspension. When this time had elapsed, the suspension was siphoned off. The process was repeated until the water removed contained negligible amounts of silt and clay, (usually 2 or 3 settlings) after which the excess water was decanted and/or evaporated and the dried sand and silt/clay fractions were weighed separately. The rough percentage figures used in this report were derived from these weights.

The sample designated for chemical analysis was dried at 100°C and ground to a fine powder. It was then subdivided into samples for organic content determination, insoluble residue content, and trace element analysis.

The samples for organic analysis were weighed, placed in a porcelain crucible and heated slowly in a muffle furnace to about 650°C for a half hour. They were then removed, placed in a desiccator to cool, and reweighed. The reported loss in weight (loss on ignition) is an estimate of the total organic content. In samples containing a high percentage of clay minerals, a correction for absorbed water must be made to obtain "true" estimate of organic content. However, the samples from this study are predominantly carbonate sands, and no correction was necessary.

The samples for insoluble residue analyses were placed in test tubes and weighed. Dilute (8 normal) nitric acid was added in order to destroy the carbonate and organic material present and the samples were heated slowly. When digestion was complete, the samples were washed twice, dried in an oven at 100°C, and reweighed. The fractions remaining were recorded as percent insoluble residue.

Semi-quantitative spectrographic analyses for thirty trace elements are being performed on the remaining sample fractions designated for chemical study. The results of these analyses will be reported at a later date when they have been completed.

Shelf geology

Topography.--An understanding of the geology of continental shelf surfaces and shallow structures is very difficult to reach without the benefit of a reasonably accurate bathymetric map. Since no suitable map was available for this study, it was necessary to construct one by contouring the soundings on old Coast and Geodetic Survey smooth sheets. Although the resulting map (Fig. 2) is extremely useful, it could be vastly improved by the addition of modern, electronic soundings taken along more closely spaced survey lines. The original soundings, taken mostly in the early 1900s, were recorded in fathoms but have been converted to meters for this study.

The insular shelf south of St. Thomas and St. John has an average width of about 14 km. From the rocky shoreline of the islands, the bottom slopes seaward at an initial rate of about 16 m/km to depths of 25 or 30 m, then assumes a more gradual slope to about 45 m at which depth the central and outer platform is essentially level. In the western part of the area, the shelf edge lies at about 45 m below which the slope increases sharply to about 275 m/km. In the eastern part of the area, the slope change occurs at about 55 m, except where a well-developed, drowned reef with crests as shallow as 20-30 m marks the shelf edge.

The shelf can be divided into two parts on the basis of topography and shallow structure. West of a north-south line drawn through the vicinity of Charlotte Amalie, the shelf profile is smooth and no strong topographic trends are apparent (Fig. 3, AA' & BB'). On the other hand, shelf profiles to the east are more rugged and very strong topographic trends are developed along northeast-southwest lines (Fig. 3, CC' & DD').

The shelf-edge to the east is serrated, with an almost geometric series of straight-line segments intersecting at angles of 105°-135°, but averaging about 120° (Fig. 2). The edges of northeast-southwest oriented segments are sharpened by the superposition of drowned reefs whose relief is as great as 30 m above the general surface of the outer shelf, although on northwest-southeast oriented segments reefs are absent, or have only local build-ups. All of these shelf-edge reef masses are now dead and are believed to be relicts from Pleistocene low sea-levels. Their positions on northeast-southwest oriented segments of the shelf edge allowed optimum exposure to nutrient-bearing currents which apparently were from the southeast, essentially as they are today.

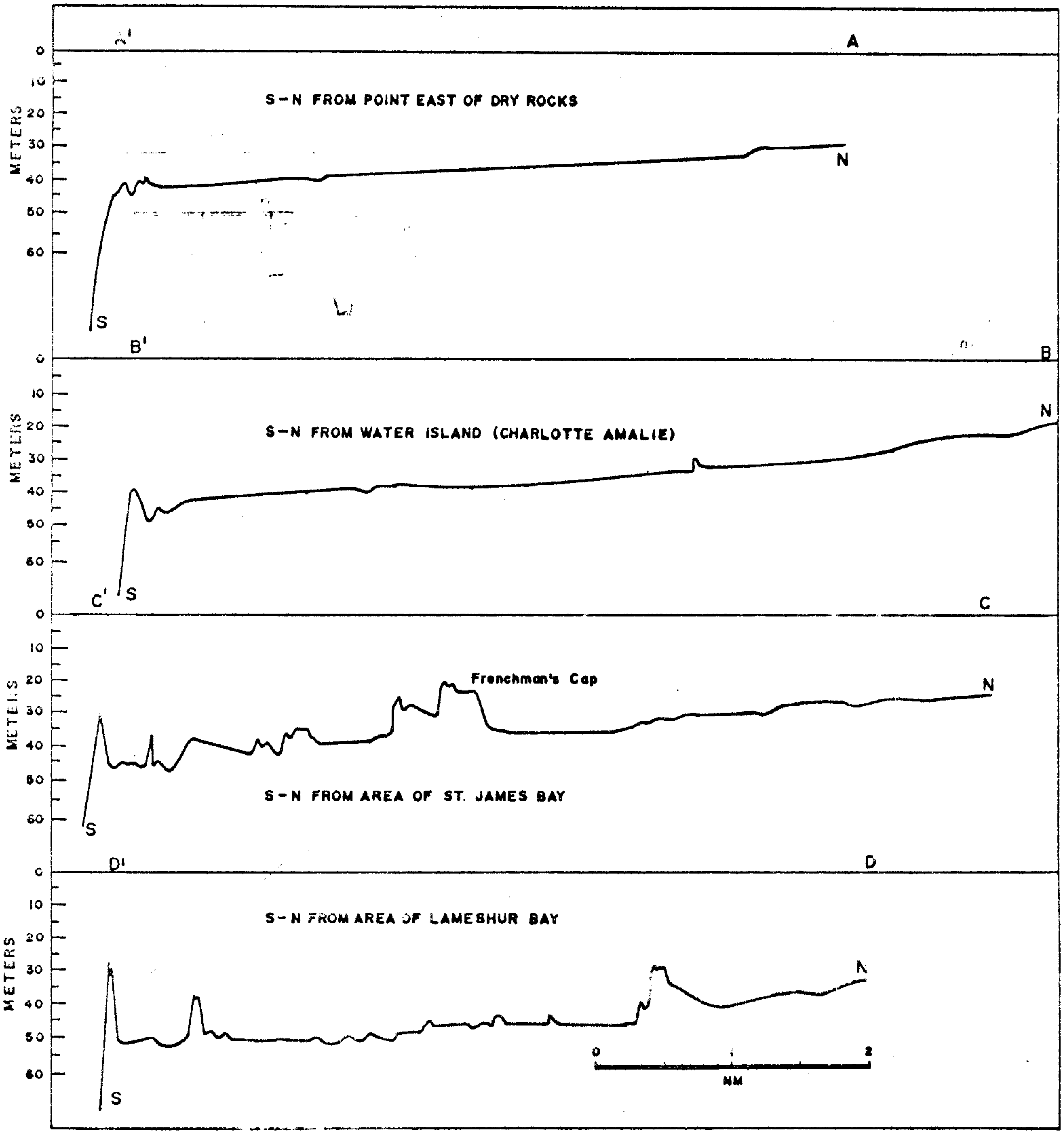

A'
A
S-N FROM POINT EAST OF DRY ROCKS
METERS
0
10
20
30
40
50
60
S
N
B'
B
S-N FROM WATER ISLAND (CHARLOTTE AMALIE)
C'
C
Frenchman's Cap
S-N FROM AREA OF ST. JAMES BAY
D'
D
S-N FROM AREA OF LAMESHUR BAY
0
1
2
NM

FIGURE 3

Shelf-edge serrations diminish in amplitude to the west and beyond Longitude 65°W the shelf-edge is irregular, but bears no reef build-up. Topographic and structural alignments in the western portion are less prominent and appear to be principally east-west and north-south. A few fault scarps are prominent, but do not assume the importance of those to the east.

In addition to the prominent shelf-edge reefs, other reef trends can be traced in the seismic records and by topographic lineations. The most prominent of these is shown in Fig. 2 as a more or less continuous feature south of St. John between Latitudes 18°15'N and 18°17'N. The various profile crossings which delineate the feature are so widely separated that the continuity of the reef as mapped is not certain, and it could be interpreted as more than one reef. Crests near its eastern end are in water depths of 20-25 m, while the western end has crests as deep as 37 m. It appears, at least in part, to be related to a fault scarp as shown in Figure 5 near Kilometer 9, section CC'. The most remarkable characteristic of this reef is its parallelism with the shelf-edge reef. Even the shoreward offset of its southwestern portion is a good approximation of the shelf-edge serration. No explanation of this can be offered.

Structure.--The surface of the shelf consists principally of calcareous sands and gravels and, in places, of consolidated living or dead reefs. Only in a few locations do the underlying basement rocks protrude in the form of small islands or shoals. Blanketing sediments are relatively thin, however, and the structural grain of the basement shows through as low escarpments or reef-capped lines of shoals (Fig.4).

Two buried, northeast-trending basement ridges dominate the eastern shelf area with crests that rise to within a few meters of the bottom as shown by seismic profiles. These ridge crests appear in the seismic profiles as dome-shaped structures without interior reflectors as seen in Figure 5 between Kilometers 5 and 11 in section BB' and centered near Kilometer 2 in section CC'. A line of shoals marks the surface trace of the axis of the northern and larger ridge, and culminates southwestward in the small island of Frenchcap Cay. The island is dioritic, according to Donnelly (1968), who furthermore states:

> "A small series of plutons south of St. Thomas (outcropping on Long Point, St. Thomas, and on Frenchman Cap [sic] and Buck Island) is apparently not connected with the Pillsbury Sound [plutonic] bodies, but lies on the east-west line possibly traceable, through geophysical evidence, westward to Vieques."

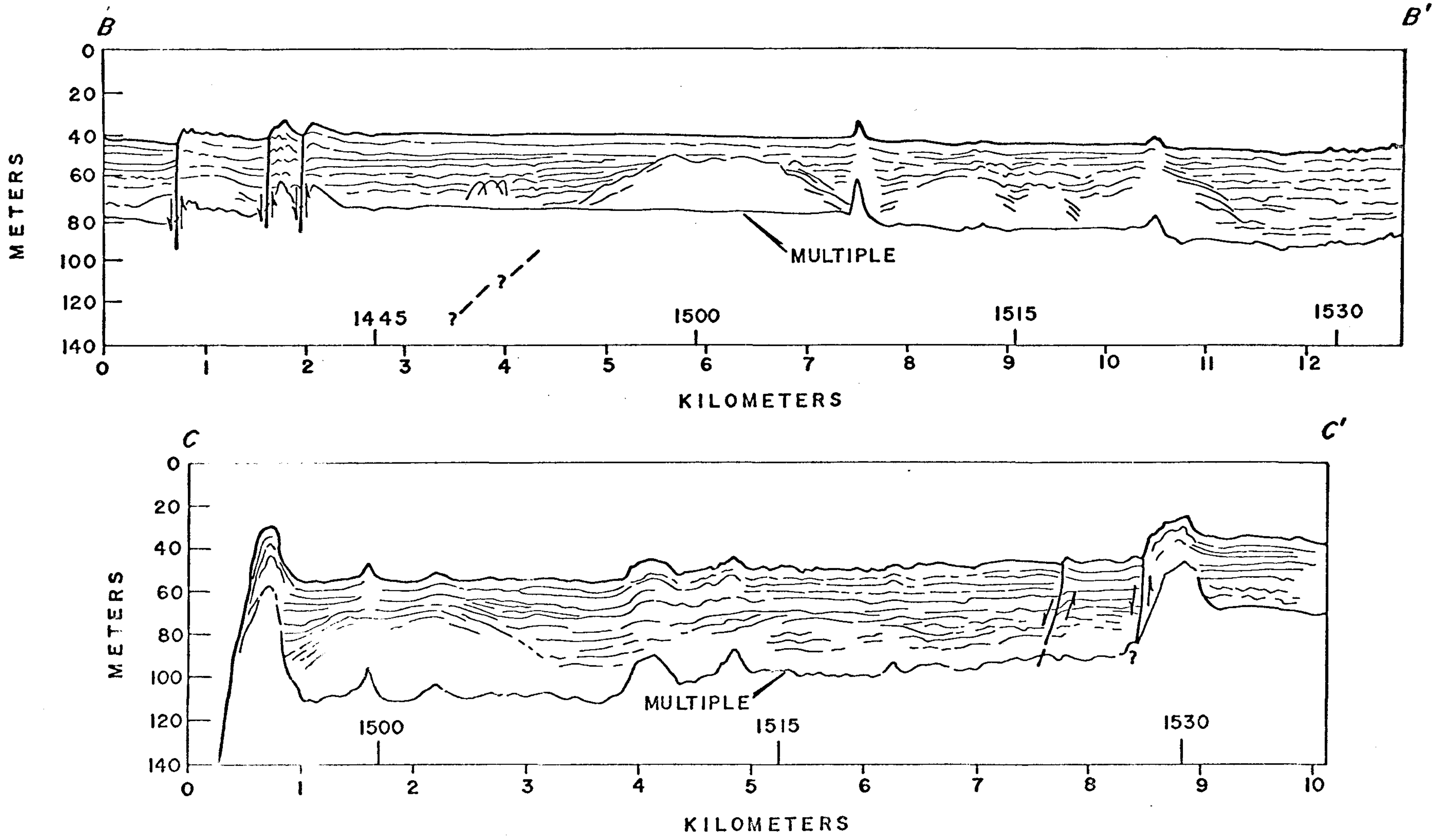
A series of normal faults, down-dropped to the north, parallel the northern flank of the larger ridge. This zone of faulting is shown near Kilometer 1 in section BB' (Fig. 5), and is clearly marked on the shelf surface by scarps which indicate the recency of fault movement. It is difficult to measure the displacement across these faults with accuracy, but from the profiles it can be estimated at about 5-10 m. North of this zone of faulting, the seismic profiles show only horizontally layered reflectors except in a small area south of St. James Bay where a zone of disorganized reflectors may indicate thinly covered basement.

The smaller of the two buried ridges lies along the outermost edge of the shelf south of St. John. It can be seen in the high-resolution profiles only in an area about 5 miles long and one mile wide (Fig. 4 and Fig. 5, CC'), and is not exposed on the shelf surface as far as is known.

Some faulting can be seen in the horizontally bedded sediments between ridge crests as seen near Kilometers 8-9, section CC' (Fig. 5). Vertical displacement is relatively small and none of the faults is of great length. They may be confined to the sediment overburden and have resulted from compaction of the sediment cover where it thickens between ridges.

The western portion of the shelf lacks the strong structural character that exists to the east. No basement reflector can be identified to the depth limits of the high-resolution profiles. Faulting is not as important here as in the eastern portion, and the faults seen cannot be traced any great distances. The "Sail Rock Fault" (Donnelly, 1965) appears in the records and in the shelf topography as a prominent scarp striking southeasterly. Three additional faults with apparent strikes from east-northeast to northeast were mapped, all with down-to-the-south vertical displacement.

The structural character of the shelf as shown by high-resolution seismic profiles is in good accord with the known geology of the region. A dioritic batholith, which intrudes various rock units and lies principally in the British Virgin Islands, has been described by Helsley (1960) and Donnelly (1966). Termed the Virgin Islands pluton by the latter



B
B'
METERS
0
20
40
60
80
100
120
140
KILOMETERS
0
1
2
3
4
5
6
7
8
9
10
11
12
1445
1500
1515
1530
MULTIPLE
?
?
?
C
C'
METERS
0
20
40
60
80
100
120
140
KILOMETERS
0
1
2
3
4
5
6
7
8
9
10
1500
1515
1530
MULTIPLE
?

FIGURE 5

author, this intrusive body is thought to underlie the Sir Frances Drake Channel and at least the northern portion of Pillsbury Sound. Although that area is submerged, the presence of the batholith is indicated by the occurrence of small dioritic outcrops and metamorphosed rocks along the shorelines. On the shelf to the south, Buck Island, Capella Island and Frenchcap Cay are reportedly dioritic also (Donnelly, 1966). Since Frenchcap Cay is on the buried ridge seen in the high resolution seismic profiles, the lithology of the ridge may be largely igneous.

Regional aeromagnetic data offer further evidence on the size and location of plutonic bodies in the area. Figure 6 is a compilation of such data from published sources (Griscom and Geddes, 1966; Bracey, 1968) which shows that the area enclosed by the +500 isogam contour very closely approximates, at least in its northern portion, Helsley's (1960) map of the Virgin Gorda pluton (the Virgin Islands pluton of Donnelly, 1966). The prong of high magnetic anomaly which trends southwesterly across the shelf south of St. Thomas coincides with the location and trend of the buried ridges shown in Fig. 4, and suggests a plutonic origin for the rocks of that area as well. Since their magnetic character is completely different from that of the rocks on St. Thomas, the northern limit of the shelf pluton must lie near the fault zone which trends southwesterly from the vicinity of Bovocoap Point. Furthermore, since no dioritic rock is exposed along the projected trend of the larger ridge crest on the southern shore of St. John, the intrusive rocks either underlie the island at great depth, or the pluton has a northeastern limit offshore of St. John. From the

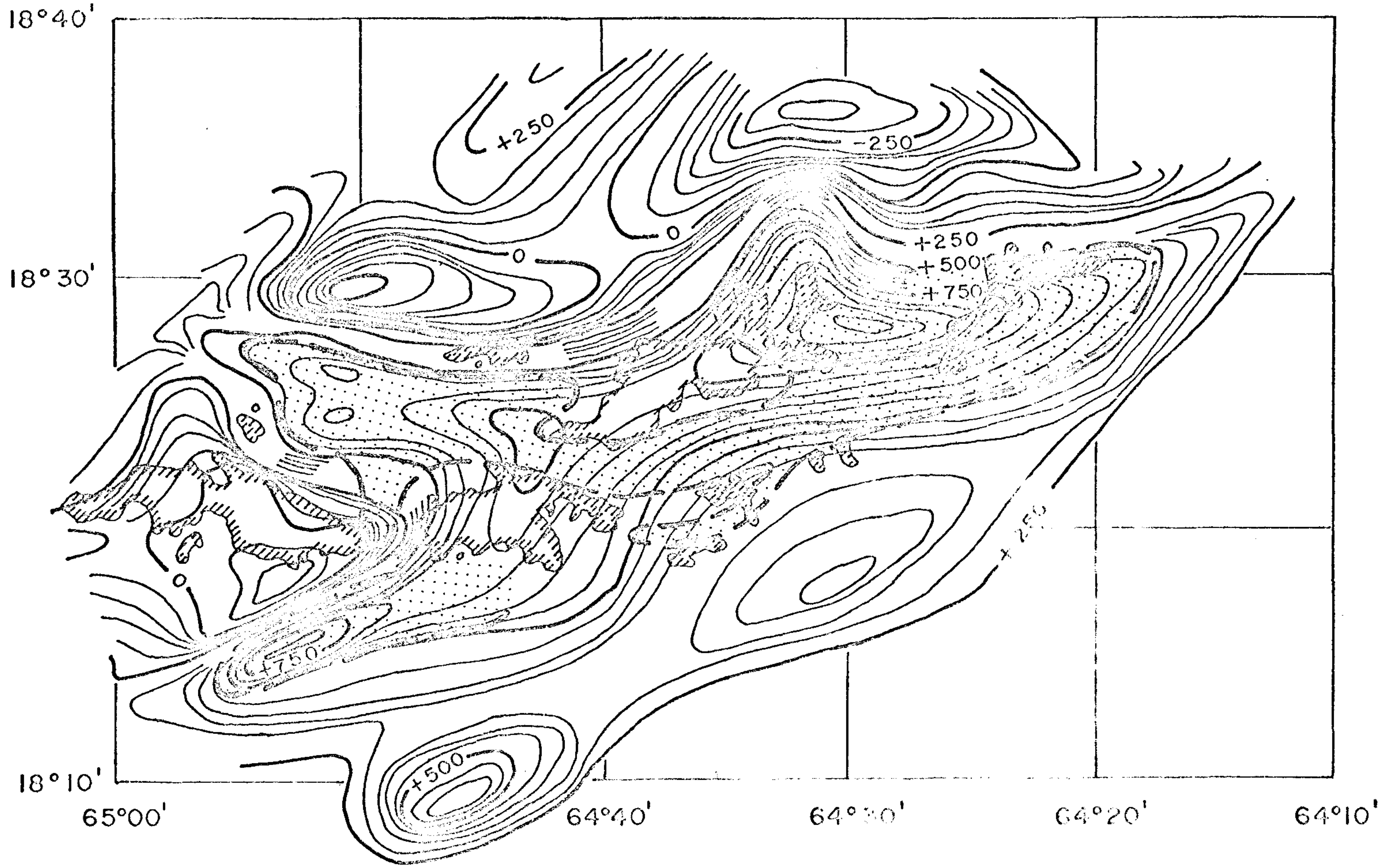


FIGURE 6

preliminary data at hand, it appears that the shelf pluton may be connected to the larger Virgin Islands pluton at great depth, but more geophysical data must be collected before a definitive map can be drawn.

The striking contrasts in topographic and structural character seen in Fig. 2 between the eastern and western parts of the shelf are due principally to the differences in bedrock topography underlying the two areas. In the east, the configuration of the upper surface of the shelf pluton controls the structural grain. Faults follow the axis of thickest fill in bedrock valleys or parallel the steep ridge flanks. Reef trends are related to scarps and other topographic highs and consequently lend emphasis to the basement trends.

In contrast, the region of smoother topography to the west is probably underlain by rocks similar to those on St. Thomas whose relief is either more subdued or more deeply buried beneath capping sediments of uncertain thickness. Based on bottom roughness shown in seismic and bathymetric profiles, Donnelly (1965) believed bedrock to be outcropping in a shelf area lying mainly to the west of the limits of this study. Profiles of the present study which overlap this area do not bear out his interpretation, however. Although the surface reflector shows roughness, shallow subbottom reflectors are present which are flat and unbroken (Fig. 1). Since it is very unlikely that formations such as those exposed on St. Thomas would possess internal acoustic-reflecting surfaces, it is presumed that these reflectors indicate relatively soft, horizontally bedded sediments. This portion of the shelf is therefore believed to be covered by Quaternary sediments to depths of at least 45 m, or the limit of acoustic "visibility" in the area, and the observed surface roughness probably marks the presence of erosional features.

It might be noted that the quality of the record shown in Fig. 1 deteriorates badly to the right of 1212 hours, and that reflectors are more difficult to distinguish thereafter. In records of poorer quality, this section could be interpreted as bedrock outcropping at the surface on the basis of an apparent lack of internal reflectors. The real explanation, however, lies in the extreme irregularity of the bottom, which tends to "fog" the record with extraneous acoustic reflections from the sides of the many depressions.

Sediments.--Knowledge of physical agents affecting the distribution of sediment on the insular shelf is very limited although the available data on tides, currents, and waves in the northeast Caribbean are of some value in estimating their effect on the shelf. Tidal ranges on the southern Virgin Islands platform range from an average of 12 cm to a maximum of 24 cm at the time of spring tide (ESSA, 1970). The low range is due to the proximity of a tidal node off the south-central coast of Puerto Rico. Surface currents in the region flow predominantly from east to west with an average velocity of 0.7 knots (U. S. Naval Oceanographic Office, 1965), but at times the flow is in the opposite direction with an average velocity of 0.5 knots. These currents are the result of a combination of general oceanic circulation modified by tidal forces and, on the shelf, may become locally stronger during certain periods of the tidal cycle. Chart 905, for example, warns of strong rip tides in the Southwestern Roads at the west end of St. Thomas. Divers have also reported strong currents on the reef at the shelf edge south of St. John (Nick Hilton, personnel communication).

The predominant wind in the region is east-northeast with a velocity of greater than eleven knots (force 4) fifty percent of the time. The direction of resultant wave motion is to the west with waves greater than one meter in height approximately forty percent of the time. Two meter waves occur fifteen percent of the time on the average. The calculated effective wave base, or that depth at which the horizontal velocity of a wave is capable of moving particles 0.125 mm in diameter by traction, is 6 meters for waves with heights of 1 meter and periods of 5 seconds. A two meter, seven second wave would have a wave base of 30 meters.

The gross lithology of the samples was described aboard ship when they were freshly taken, and from these descriptions (Appendix I), a generalized map of the distribution of surface sediment types was made (Fig. 7). This map shows that two sediment types dominate the shelf. Sand, composed of fragments of the carbonate tests of molluscs and foraminifera and other carbonate grains of undetermined origin predominates near shore. The sedimentary cover of the shelf farther seaward is dominated by carbonate nodules.

The three areas where sand constitutes the principal sediment size are: 1) the region west of Brewers Bay; 2) the vicinity of Buck Island; and 3) south of St. John. Scattered pockets of sand occur on the outer shelf south of Buck Island. Textural and chemical analyses were made only on the sand-silt-clay fraction of the samples from these areas. The analytical results are listed in Appendix II.

The sand in the Brewers Bay region is deposited in a trough bounded by the main island of St. Thomas and by a topographic ridge extending from Saba to Savanna Island. Silt- and clay-size particles range from 35.8 percent of the total sample in the immediate Brewers Bay area to less than 1.0 percent near the outer boundaries of the sand mass (Fig. 8). Although some of this fine material may have been carried out by the strong runoff during a week of torrential rains prior to the sampling period, the general pattern of fine concentrations in protected areas to coarser material in the more open sections is believed to be characteristic of the region. The distribution of insoluble residue generally mirrors the distribution of the silt-clay portion of the samples (Fig. 9). Microscopic examination of this residue showed it to consist mainly of land derived detritus. The total organic content ranges from 7.75 percent to less than 2.5 percent. The highest value was found in the central portion of the basin.

Direct observations of the sea floor in the Brewers Bay area were made on four dives. In the central part of the area (Sites 4 and 5, Fig. 10), the sediment on the shelf floor was composed principally of fine sand. At Site 4, carbonate nodules were estimated to have an areal density of three per square meter. No carbonate nodules were seen at Site 5. At Sites 6 and 7, carbonate nodules were more numerous, but did not obscure the underlying sand. At each site a core tube was driven into the sand to a depth of 1.25 - 1.5 m, indicating unconsolidated material of at least that thickness.

In the vicinity of Buck Island sand occurs between St. Thomas and a series of disconnected topographic highs which parallels the shore and rises above the 34 m isobath. A prominent ridge extending southeast from Bovocoap Point on St. John forms the southwestern boundary of the sand concentration (Fig. 7). The silt-clay fraction in the sediments of this area ranges from 6.07 to 0.0 percent and averages 2.90 percent. The finest material is in the western and more protected sector (Fig. 8). The insoluble residue consists mainly of rock fragments and ranges from 4.85 to 0.05 percent with the largest amounts northwest of Buck Island on the down current side (Fig. 9). The organic content of this sand ranges from 4.74 to 2.24 percent and averages 3.55 percent. As presently mapped, the distribution of this organic material appears to be random.

Four dives were made in the western portion of the Buck Island sand deposit (Fig. 10). At Sites 1 and 2, carbonate nodules were observed lying on top of the sand and were reported to cover 50 percent of the surface. At Site 3 carbonate nodules and "rubble" covered the bottom, although sand was the principal underlying material. No sand was observed at Site 8 where the bottom was covered with coral debris. At each of the sites, except Site 8, a coring tube was driven into the underlying sand at least 1.25 m and in no instance were carbonate nodules found below the surface.

The sand which occurs in scattered pockets on the outer shelf south of Buck Island is generally coarse and clean as shown by the low silt-clay content of less than one percent (Fig. 8). The organic content of this sand averages about 3.8 percent with an insoluble residue of less than 0.3 percent (Fig. 9). These deposits may occur in the depressions which characterize the topography of the outer shelf.

The sand south of St. John is deposited between the island and a reef which trends ESE from a point 3.7 km south of Red Point (Fig. 7). The silt-clay fraction of the sand ranges from 20.0 to 0.0 percent and averages 4.7 percent with the highest percentages occurring in the material from a depression south of Bovocoap Point (Fig. 8). Insoluble residues ranges from 8.84 to 0.26, with the highest value in Reef Bay (Fig. 9). The organic content ranges from 6.68 to 2.62 percent averaging 4.27 percent.

As mentioned previously, the sand is composed of fragments of molluscan shells, foraminifera, and carbonate grains of unknown origin. The latter are believed to result from the disintegration of carbonate nodules. In a laboratory experiment, nodules were heated at 700°C for half an hour to remove any organic material in their composition. After cooling, these nodules broke down into carbonate sand grains similar to those found in the samples. The fact that these grains can be artificially produced from carbonate nodules and that such nodules were never observed to occur below the surface, strongly suggests that nodules play an important role in the sand budget of the region.

Summary

A reconnaissance geological/geophysical study was conducted on the insular shelf in the Virgin Islands south of St. Thomas and St. John. A bathymetric map was made from existing published and unpublished data of the National Ocean Survey. High-resolution continuous seismic profiling was used to examine the shallow subbottom structure. Grab samples of the surface sediment were collected and analyzed to determine the patterns of sediment distribution.

From these investigations the following conclusions are drawn:

1) The insular shelf in the region investigated consists of two distinct physiographic and structural provinces controlled principally by the underlying bedrock.

2) The area east of a line along the longitude of Charlotte Amalie is dominated by a northeast-southwest trending plutonic mass. The area to the west of that line is underlain by rocks related to those exposed on St. Thomas.

3) Regional magnetic and geologic studies indicate that the shelf pluton is related to, but possibly not connected with the larger Virgin Islands pluton to the north.

4) The thickness of sediment covering the bedrock surface appears greater in the western area, and also in a bedrock valley in the plutonic body in the east.

5) The sediments on the surface of the shelf consist principally of sand near shore and carbonate nodules offshore. Under the

influence of currents and local shelf topography, sand is exposed in three areas. These areas are centered a) west of Brewers Bay, b) near Buck Island, and c) south of St. John. Each area has a topographic barrier on its southeastern edge acting as a dam against the westward flowing currents.

6) Within these areas of sand, silt and clay percentages are as great as 35.8 near shore, but diminish to less than 1.5 near the outer edges. Organic content is nearly a constant 3.8 percent.

7) Carbonate nodules appear to be important in the sand budget of the shelf. They predominate below 34 m but are less common at shallower depths where wave forces are strong enough to break them down into sand-size material.

8) In all areas, insoluble residues were highest near the land, indicating that land derived detritus is not being moved to great distances offshore.

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Appendix I

Sta. No.	Lat.	Long.	Meters	% Rec.		Sample Kept	Field Description
1	18°20.2	65°05.9	82	0	0	None	
2	18°19.1	65°06.2	53	5	-	None	Algal cobbles
3	18°18.15	65°06.2	51	TR	-	None	Algal cobbles
4	18°18.35	65°06.1	28	TR	-	None	Algal cobbles
5	18°16.15	65°05.95	23	0	0	None	
6	18°15.0	65°06.1	25	0	0	None	
7	18°14.25	65°06.1	25	0	0	None	
8	18°13.25	65°05.8	29	0	0	None	
9	18°12.20	65°05.92	40	TR	TR	None	Trace of coral
10	18°11.1	65°06.1	34	0	0	None	
11	18°12.0	65°04.1	36	0	0	None	
12	18°13.18	65°03.89	40	TR	TR	Yes (CRI)	Trace of sand, med.-coarse grained
13	18°14.10	65°03.89	29	0	0	None	
14	18°15.20	65°03.89	31	10	-	Yes	25% algal nodules, 5% gravel, 70% med. grained sand
15	18°16.12	65°03.8	32	5	0	Yes (CRI)	30% algal covered coral, 20% gravel, 50% med. sand
16	18°17.24	65°03.9	31	30	-	Yes	70% algal nodules, 10% fine gravel, 20% poorly sorted med. sand
17	18°18.2	65°03.91	29	30	-	Yes	50% algal nodules, 15% gravel, 5% coarse sand, 30% silty fine sand
18	18°19.1	65°03.7	27	40	-	Yes	5% gravel, 95% med. coarse sand

Sta. No.	Lat.	Long.	Meters	% Rec.		Sample Kept	Field Description
19	18°20.2	65°03.7	22	0	0	None	
20	18°20.1	65°0.17	27	20	-	Yes	5% algal cobbles, 94% M-C, sand, 1% silt, coraline & RF.
21	18°19.1	65°01.7	23	25	-	Yes	5% gravel, 95% med. sand
22	18°18.30	65°01.7	29	30	1	Yes	90% algal nodules, 3% gravel, 7% sand
23	18°17.20	65°01.6	31	5	20		50% gravel, 50% poorly sorted sand, gravel-algal sand, algal fragments
24	18°16.18	65°01.7	31	0	1		Large algal nodules
25	18°15.0	65°01.8	37	20			2 algal nodules w/5% sand, 5% gravel, 95% med. sand
26	18°14.08	65°01.8	37	TR	TR		Algal nodules, trace of coral sand
27	18°13.08	65°01.65	46	TR	TR		Traces of coral sand
28	18°11.85	64°01.7	86	0	0	None	
29	18°12.05	64°59.58	48	TR	-	None	Coral sand
30	18°13.20	64°59.5	40	TR	-	None	Trace of sand w/algal nodules
31	18°14.09	64°59.4	40	TR	0	Yes	Trace of coraline sand
32	18°15.1	64°59.5	42	TR	0	None	Trace of coraline sand
33	18°16.1	64°59.5	31	0	>1	None	Trace of coraline sand
34	18°17.19	64°59.5	27	0	TR	None	Scant coraline sand
35	18°18.23	64°59.5	25	TR	TR	None	Med.-coarse sand
36	18°19.2	64°59.6	25	20	-	Yes	Coarse angular algal frag. 10%; med.-fine sand 79%; silt, 1%

Sta. No.	Lat.	Long.	Meters	% Rec.		Sample Kept	Field Description
37	18°20.35	64°59.5	27	20	-	Yes	Fine sand w/ RF.
38	18°18.1	64°57.42	23	60	-	None	Cobbles of algal nodules
39	18°17.1	64°57.42	24	5	0	None	One algal nodules w/ trace of coraline sand
40	18°16.15	64°57.57	31	0	20	Yes	3 algal nodules and coraline sand
41	18°15.1	64°57.5	47	1	0	Yes (CRI)	Med. coraline sand
42	18°14.2	64°57.25	49	TR	TR	None	Fine sand
43	18°13.05	64°57.32	51	25	-	Yes	Med. sand
44	18°12.10	64°57.21	53	0	1	None	Broken algal nodules
45	18°12.15	64°55.35	59	10	-	None	Cobbles of algal nodules
46	18°13.10	64°55.35	49	0	0	None	
47	18°14.05	64°55.35	48	TR	0	None	Trace coarse sand
48	18°15.1	64°55.35	44	45		Yes	95% med.-fine sand, 5% algal fragments
49	18°16.1	64°55.35	38	TR	50	None	Algal nodules /tr. sand
50	18°17.2	64°55.30	26	25		Yes	Med. to fine sand, all carbonate.
51	18°18.2	64°55.30	20	25	0	Yes	5% algal nodules, 95% med. sand, all carbonate frags.
52	18°19.2	64°55.30	11	50	0	Yes	Med.-coarse sand, some tr of silt
53	18°18.20	64°53.32	22	50	-	Yes	Coarse sand 70%, globular mass organic encrusted organism 25%, silt 5%; carbonate 50%, RF 50%

Sta. No.	Lat.	Long.	Meters	% Rec.		Sample Kept	Field Description
54	18°17.15	64°53.30	29	50	-	None	Cobble, algal nodules
55	18°15.99	64°53.12	33	95	0	Yes	Well sorted sand
56	18°14.9	64°53.20	40	0	5	None	2 algal nodules w/tr of sand
57	18°14.1	64°53.28	34	80	-	Yes	5% gravel, 95% med. sand
58	18°13.0	64°53.30	53	0	2	Yes	Gravelly sand 30%, Hal plates (gravel) 70%, poorly sorted sand
59	18°12.05	64°53.20	53	2	2	Yes	Algal nodules 40%, Hal. plates 40%, poorly sorted gravel 20%
60	18°10.98	64°53.21	47	0	0	None	
61	18°12.0	64°51.2	38	1	1		10% Hal. gravel, 50% med. grain sand, 40% fine sand
62	18°13.0	64°51.15	50	20	0		50% algal nodules, 30% Hal. gravel, 20% poorly sorted med. sand
63	18°14.1	64°51.15	22	0	1	None	1 elk horn coral
64	18°15.2	64°51.2	38	30	30	Yes	75% algal nodules, of remaining 40%, 15% is Hal gravel; 25% poorly sorted med. grained sand
65	18°16.1	64°51.2	31	5	0	Yes	10% Hal gravel, 90% med. coarse sand
66	18°17.0	64°51.35	24	TR	40	Yes	Algal nodules 10%, med. coarse sand 90%
67	18°18.15	64°51.1	22	25	-	Yes	5% gravel, 95% med. coarse sand, some silt, sand coraline frag., algal frag., etc.
68	18°20.28	64°49.0	29	TR	40	Yes	3 algal nodules 30%, 20% branching algal gravel, 2% coarse sand, 50% fine sand

Sta. No.	Lat.	Long.	Meters	% Rec.		Sample Kept	Field Description
69	18°19.1	64°49.1	23	15	-	Yes	2 algal nodules very little sand > 10% of total sample poorly sorted
70	18°18.18	64°49.1	-	-	-	-	No samples taken due to danger of ship
71	18°17.12	64°49.1	26	0	10	None	Algal nodules
72	18°16.15	64°49.2	35	10	-	None	Algal nodules
73	18°15.0	64°49.2	26	0	5	Yes	Coral (solid)
74	18°14.20	64°48.9	46	TR	0	Yes	Med. sand
75	18°13.09	64°49.1	51	TR	0	Yes	Med. sand
76	18°12.09	64°49.1	55	0	0	None	
77	18°10.91	64°47.10	100	0	0	None	
78	18°12.0	64°47.10	51	1	0	Yes	Med. sand
79	18°13.0	64°47.10	49	0	TR	Yes	Med. sand
80	18°14.01	64°47.10	28	0	2	None	Coarse sand, algal nodules
81	18°15.05	64°46.95	55	TR	1	None	Med. sand w/algal nodules
82	18°16.05	64°47.1	50	0	TR	None	Med. sand
83	18°17.25	64°46.95	37	45	0	Yes	Algal nodules w/5% coarse sand, 95% med. sand, 98% carbonate material, 2% rock frags.
84	18°18.0	64°47.05	27	10	10	Yes	Algal nodules > 50%, 10% algal sand, 5% coarse sand, ~30% v. fine sand and silt ~5% silt

Sta. No.	Lat.	Long.	Meters	% Rec.		Sample Kept	Field Description
85	18°19.2	64°44.85	11	5	5	Yes	5% gravel, 95% poorly sorted sand <1% silt, carbonate frag. w/R.F.
86	18°18.2	64°44.85	28	TR	TR	Yes	Hal. sand w/sponges, RF present
87	18°17.25	64°44.80	34	TR	50	Yes	5% algal nodules, 20% coarse sand, 75% med. sand, sand composed of algal frags. and coraline frags.
88	18°16.2	64°44.9	47	0	1	None	Fine sand
89	18°15.2	64°44.7	50	0	0	None	
90	18°14.1	64°44.8	68	0	0	None	
91	18°13.05	64°44.8	54	1	0	None	Algal nodules
92	18°12.09	64°44.7	60	1	1	Yes (CRI)	Algal nodules w/poorly sorted sand
93	18°10.9	64°44.8	60	0	5	None	Algal nodules and biological material
94	18°12.5	64°42.4	344	0	0	None	
95	18°13.2	64°42.8	42	0	1	None	An algal nodule (cobble)
96	18°14.0	64°42.8	42	0	0	None	
97	18°15.1	64°42.7	49	30	-	Yes	Jaws partly open, one 10 cm dia. algalnodule, 80% coarse gravel of Hal. frag., 10% sand, Hal. frag.
98	18°16.1	64°42.8	48	30	-	Yes	Jaws partly open, 30% algal nodule (7 cm), 30% gravel, 20% coarse sand, 20% med. sand, predominately carb.

Sta. No.	Lat.	Long.	Meters	% Rec.		Sample Kept	Field Description
99	18°17.1	64°42.75	42	2	1		20% coarse Hal. sand, 80% M-f well sorted sand < 1% silt
100	18°18.1	64°42.75	22	30		Yes	10% algal nodules, 5% gravel of mollusc frag., 50% coarse sand, 35% mud, carbonate w/RF.
101	18°19.1	64°40.8	27	TR	10	Yes	1 algal nodule, w/coarse sand
102	18°18.0	64°40.7	33	40	-	Yes	20% algal nodules, 80% gravelly sand, poorly sorted sand composed of Hal. sand, forams, etc.
103	18°17.2	64°40.8	37	0	TR	None	Med. sand
104	18°16.1	64°40.7	46	10	0	Yes	Algal nodules varying from 1.5 to 1 in. dia. 75% of recovered sample. Rest 10% gravel, 15% poorly sorted sand
105	18°16.1	64°40.7	46	10	-	Yes	Jaws open, 3-two inch algal nodules, 10% gravel, 5% Hal. sand
106	18°14.1	64°40.7	55	30	-	Yes	Algal nodules
107	18°13.15	64°40.8	206	90		Yes	5% coarse sand, 10% med. sand, 3% fine sand, 55% med. coarse material, shell and shell hash
108	18°14.99	64°38.5	510	0	0	None	
109	18°16.2	64°38.5	59	0	0	None	
110	18°17.1	64°38.5	35	0	TR	Yes (CR1)	Well sorted med. sand, 30% coarse, 60% med., 10% fine
111	18°18.1	64°38.55	34	90	-	Yes	80% med. sand, 1% silt, 19% algal nodules

Sta. No.	Lat.	Long.	Meters	% Rec.		Sample Kept	Field Description
143							No samples
144							" "
145							" "
146							" "
147	18°18.56	64°56.4	18	50	-	Yes	2% Hal. gravel, 98% med. sand
148	18°17.68	64°56.5	25	0	40	Yes	70% algal nodules, 5% Hal. plates, 25% sand (med.-fine)
149	18°17.7	64°55.48	23	TR	TR		Coarse sand
150	18°16.7	64°55.35	27	50	-		Med. sand (good sand)
151	18°16.7	65°54.30	20	60	-		10% coarse gravel, 90% med. to silty sand
152	18°17.65	65°54.35	23	1	25		5% fine grained, 95% poorly sorted med. grained sand, silty.

SAMPLES FROM APRIL RADIAL LINES

Sta. No.	Lat.	Long.	Meters	% Rec.		Sample Kept	Field Description
3	18°11.5	64°55.5	45	5	-	Yes	Algal nodules
4	18°12.0	64°55.4	44	TR		Yes	Sea fans
5	18°13.7	64°55.5	43	80		Yes	Hal. sand, med.-coarse
6	18°16.5	64°55.4	31	80		Yes	Med. to coarse sand, w/some rock frags.
7	18°18.4	64°55.5	21	80		Yes	Fine coral sand
8	18°19.2	64°55.9	15	80		Yes	Sand w/mud, high H_2S order
9	18°20.2	64°55.3	3	40		Yes	Mud
12	18°11.5	64°48.3	42	0	0	None	

Sta. No.	Lat.	Long.	Meters	% Rec.	Sample Kept	Field Description
13	18°14.6	64°49.0	52	TR -	None	
14	18°16.2	64°50.8	32	50	None	Algal cobbles
15	18°17.2	64°51.3	25	80	Yes	Medium to coarse sand
16	18°17.5	64°51.6	27	80	Yes	Coral-algal sand
17	18°17.8	64°51.7	26	80	Yes	Medium to fine sand
36	18°14.4	65°04.3	31	0	None	
37	18°17.5	65°01.7	31	0	None	
38	18°19.3	65°00.6	27	75	Yes	Sand w/algal nodules
39	18°20.1	64°59.4	27	20	Yes	Fine sand
40	18°20.6	64°59.6	23	25	Yes	Sand, coarse
			CORES			
1	18°17.35	64°55.8		-	CRI	Bottom covered w/algal nodules w/patches of sand; 3.5 feet
2	18°18.2	64°55.35		-	CRI	Few algal nodules; good sand
3	18°18.1	64°56.2		-	CRI	Bottom algal plain w/ sand below
4	18°19.7	65°00.2		-	CRI	Fine sand & silt, algal nodule 3/59 meter, 5' core
5	18°20	64°58.9		-	CRI	Fine sand w/no algal nodules seen, 5' core
6	18°19.2	65°00.9		-	CRI	Algal nodules cover surface, layer of silt & sand below, 2' core
7	18°19.8	65°01.2		-	CRI	Algal rubble with sand below, core 4.5'
8	18°17.65	64°57.4		-	CRI	Algal plain, sand below core 4.5'

Appendix II

Project: Virgin Islands (Cruise II)

Sample No.	% Sand	% Silt/Clay	Ignition Lost	Insoluble %
06-014	99.7	0.23	3.74	0.09
06-016	99.4	0.6	2.89	0.07
06-017	99.0	1.0	2.87	0.21
06-018	99.4	0.51	3.70	0.07
06-020	93.1	6.8	3.08	1.16
06-036	99.7	0.25	4.32	0.47
06-037	64.1	35.8	3.68	3.07
06-040	98.1	1.8	4.34	0.82
06-043	99.3	0.61	3.49	0.37
06-048	97.4	2.5	3.59	0.12
06-050	97.0	2.9	2.24	0.71
06-051	96.7	3.2	3.54	1.25
06-052	93.9	6.07	3.74	3.81
06-055	99.7	0.24	3.93	0.05
06-057	99.3	0.65	4.63	0.59
06-065	100.0	0.0	4.07	0.33
06-067	98.4	1.8	4.74	1.70
06-068	97.4	2.52	6.82	0.62
06-083	97.9	2.0	4.67	0.47
06-084	79.9	20.0	3.33	2.66
06-085	100.0	0.0	4.44	8.84
06-086	97.2	2.7	6.68	1.26
06-087	98.3	1.6	2.59	0.26
06-100	98.5	1.4	2.62	1.61
06-107	62.0	37.9	2.62	2.92
06-111	99.2	0.76	4.18	1.09
06-112	97.1	2.8	6.34	1.77
06-113	90.0	9.9	2.21	0.42
06-116	76.3	23.6	3.66	1.04
06-118	95.8	4.1	2.51	1.42
06-122	92.6	7.3	7.75	1.51
06-123	97.2	2.7	4.33	1.84
06-127	79.5	20.4	2.50	.610
06-128	99.2	0.78	4.33	1.44
06-136	98.2	1.7	2.25	0.76
06-138	97.8	2.1	2.98	1.25
06-147	96.0	3.9	3.04	3.80
06-150	97.2	2.79	3.38	2.56
06-151	97.4	2.56	3.16	2.21
06-152	96.4	3.5	3.73	4.85

FIGURE 2


CHARLOTTE AMALIE
ST. THOMAS
ST. JOHN
SOUTHWEST ROAD
WATER ISLAND
SABA IS.
DRY ROCKS
SAIL ROCK
LONG PT.
ST. JAMES BAY
PILLSBURY SOUND
BOVOCOAP PT.
REEF BAY
LAMESHUR BAY
RED PT.
BUCK IS.
CAPELLA IS.
FRENCHCAP CAY
A
A'
B
B'
C
C'
D
D'
18°20'
15'
10'
10'
05'
65°00'
55'
50'
45'
40'
64°36'
0 1 2
SCALE IN NAUTICAL MILES
CONTURE INTERVAL 2 METERS
U.S. Geological Survey – 1971

FIGURE 4


CHARLOTTE AMALIE
ST. THOMAS
ST. JOHN
WATER ISLAND
SOUTHWEST ROAD
SABA IS.
DRY ROCKS
LONG PT.
ST. JAMES BAY
PILLSBURY SOUND
BOVOCOAP PT.
REEF BAY
LAMESHUR BAY
RED PT.
SAIL ROCK
BUCK IS.
CAPELLA IS.
FRENCHCAP CAY
A
A'
B
B'
C
C'
18°20'
18°15'
18°10'
65°10'
05'
65°00'
55'
50'
45'
40'
64°36'
OUTLINE OF RIDGE
as seen in seismic profiles
FAULTS
Hachured on Down-Thrown side,
dashed where uncertain
Island faults after Donnelly (1966)
ZONE OF FAULTING
down to north


CHARLOTTE AMALIE
ST. THOMAS
ST. JOHN
PILLSBURY SOUND
SABA IS.
DRY ROCKS
SAIL ROCK
BUCK I.
CAPELLA I.
FRENCHCAP CAY
PREDOMINATE SURFACE SEDIMENT TYPE
SAND
CARBONATE NODULES
MUD
NO SAMPLE RECOVERED

FIGURE 7


CHARLOTTE AMALIE
ST. THOMAS
ST. JOHN
PILLSBURY SOUND
ST. JAMES BAY
LONG PT.
BOVOCAP PT.
REEF BAY
LAMESHUR BAY
RED PT.
WATER ISLAND
SOUTHWEST ROAD
SABA IS.
DRY ROCKS
SAIL ROCK
BUCK IS.
CAPELLA IS.
FRENCHCAP CAY
Extent of Sand
Extent of Sand
Extent of Sand
20.4
18°20'
15'
10'
05'
65°00'
55'
50'
45'
40'
64°36'
Silt — Clay
%

FIGURE 9

Insoluble Residue
%

APPENDIX III