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Virgin Islands Sand Resource Study

1978

by

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This report is preliminary
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Abstract

The depletion of sand resources in the Virgin Islands has necessitated the search for more economical supplies. The dynamic processes which produce sand in the nearshore environments are very slow, and removal of this material would cause a depletion of beaches upon which the island economy is predicated. A search for offshore sources was begun in September 1977. This program was set up for three levels of activity. The first was a broad survey of the intershelf area; the second was a detailed investigation of target areas; the third phase, a study of the sediment dynamics, is presently underway. As a result of the first survey, seven target areas were found. Three of these were examined in detail during the second phase, which showed that two areas contain significant deposits of sand. The "double" deposit on the southwestern coast of St. Thomas contains an estimated 30×10^6 cubic meters of fine sand (0.3-0.5 mm). In the central area, a deposit near Buck Island contains an estimated 12×10^6 cubic meters of material. The sand in the second area is slightly coarser. The textural signature of these deposits is very close to that of the sand found on the beaches, which has been used in the past for construction. Studies are continuing to determine the sediment rates and budget of the shelf region.

Introduction

All islands laboring under the increased population pressure are in a crisis of vanishing natural resources. Nowhere is this so striking as in the U.S. Virgin Islands, where the demand for construction material has increased, and where the availability of basic material is limited (fig. 1).

The only sources of building aggregate are the beaches. However, due to the steep, rocky coastline and general lack of soil, the few beaches that are present are small and occupy pockets in the shoreline. The sand-sized material of which they are composed is predominantly carbonate with little or no land-derived components. Although the rates of buildup are unknown, the processes which move this material shoreward are slow so that littoral sands removed from the system can be replaced by nature only over a period of years. Removal of this and any nearshore sand would undoubtedly reach a critical point at which the destruction would be irreversible. In these islands, where the economy relies on the presence of beaches, such destruction would be an economic disaster. It is, therefore, of vital importance to the islands, that future supplies of aggregate be obtained from a system that does not include the immediate reservoirs that replenish the pocket beaches. The first step in insuring against the loss of beaches, then, is to find an offshore supply of aggregate that is mineable economically without environmental detriment.

Not only is it important to locate such a sand supply, but it is equally important to define the dynamics of the system which produces, transports, and deposits the material. Such questions as:

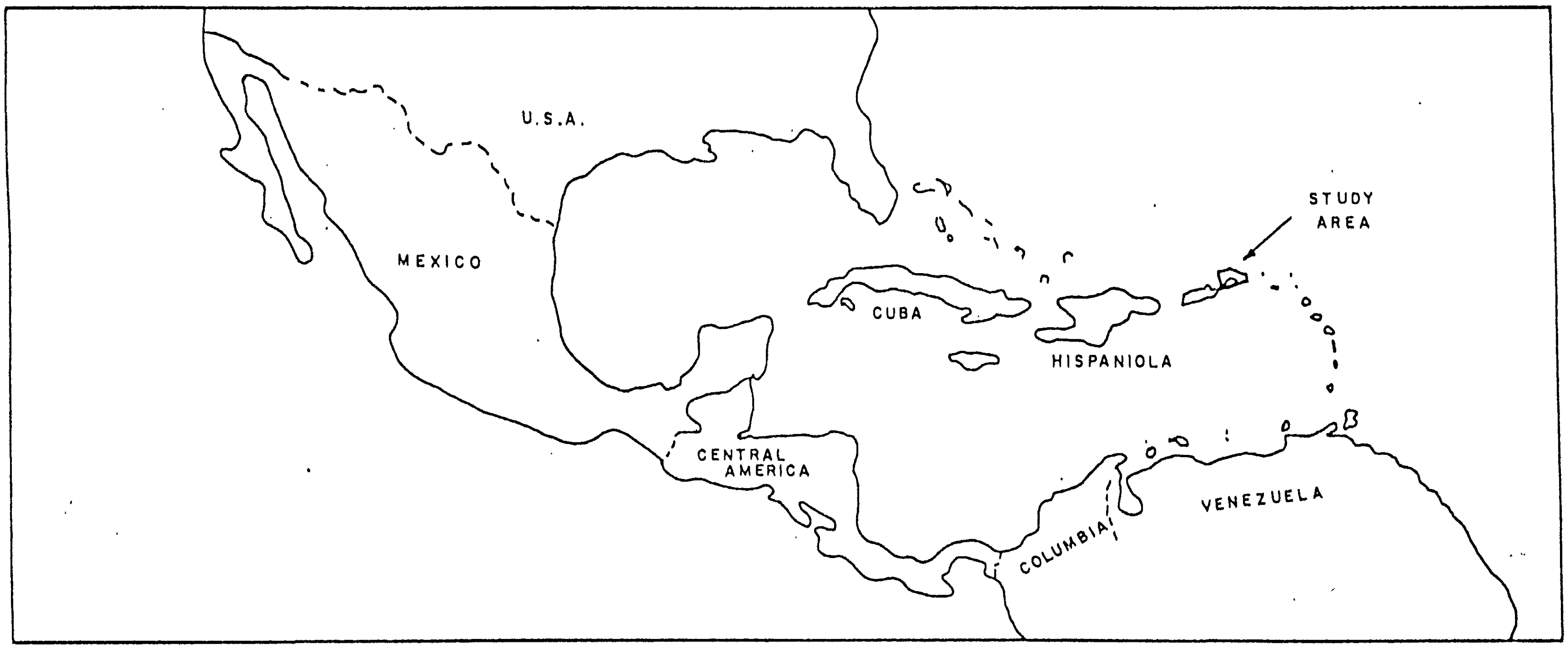


Figure One -- Index map of study area.

Is the system open, non-self replenishing, or is it closed with a source and sink? Are the process which generate the sand presently operating or is the sand relict? What role, if any, does tectonic activity of the area play in creating or maintaining a sand supply? These questions must be answered so that an adequate management program can be developed.

To locate sand deposits and answer the questions of sediment dynamics, a three phase program was begun in September 1977. The first phase was a general survey of the entire insular shelf to locate potential sites of sand deposition, and was completed in December 1977. The second phase focused on three target areas located during the preliminary survey. The third phase, a determination of the sediment budget is presently underway. The results of the first two parts of the program are the subject of this report.

Acknowledgments

The study has involved the tireless efforts of many people. The Department of Conservation and Cultural Affairs, Government of the U.S. Virgin Islands, under Commissioner Verdin Brown, through the Office of Shoreline Management, Werner Wernicke, Director, partially supported this project and their assistance is gratefully acknowledged. In all phases of this program, the Island Resources Foundation, under the direction of Dr. Edward Towle, has played a vital role. In the first phase, IRF provided the vessel, the S. S. ALIANORA, captained by Michael Tate, to the government for use in this program. During the later phases, the laboratory of the Foundation served as field headquarters. To this organization and it's director, sincere thanks are extended. The West Indies laboratory, under direction of Dr. Robert Dill, also provided support and encouragement by supplying the R/V SIRMA which was used in the detailed site surveys.

The coring phase of the study involved a great many people who worked long and hard hours to overcome the elements to provide core material for study. Sincere thanks go to Cyndi Rice, Quenton Dokken, Ronald Circe, Jack Kindinger, Mary Kindinger, Neal Lillard, George Wiley, Tim Martin, and Ronald Miller, who suffered under Captain Bligh Holmes. Thanks is also extended to Captain Dana Fagan of the CARIBE DIVER for his assistance. Also a special thanks is extended to the captain and crew of the R/V OCEANUS, WHOI, for their aid during the February cruise.

Shelf Geology

In order to completely understand the geologic processes at work in the Virgin Islands, some knowledge of the geologic history of the islands' formation and their location tectonically in the Caribbean is necessary. A completely detailed geological and geophysical discussion is beyond the scope of the present work, thus only a brief discussion of the ridge development will be presented.

The major stratigraphy units of the Northern Virgin Islands are presented in table 1. These stratigraphy units may be divided into two groups: The Virgin Island group including the Necker

	Quaternary Alluvium Beach deposits, valley fill, etc.	
	——— Unconformity ———	
	ROGUE'S BAY Calcarenite (40') Poorly cemented shallow water limestones.	Upper Tertiary
	——— Unconformity ———	
	NECKER Formation (6,000'+) Subaerial tuffs and breccias.	Eocene?
	(Intrusion of the Virgin Islands batholith)	
VIRGIN ISLANDS GROUP	TORTOLA Formation (25,000'±) Andesite and augite-andesite tuffs, breccias and volcanic sandstones.	Middle Eocene
	SHARK BAY Member - Andesite tuffs and breccias with abundant glass fragments.	
	SAGE MOUNTAIN Member - Tuffs, breccias and volcanic sandstones. Interfingers with Hans Lollik and Shark Bay members.	
	HANS LOLLIK Member - Pyroxene-bearing andesitic tuffs and breccias.	
	——— Possible Unconformity ———	
	TUTU Formation (9,000'±) Tuffaceous wacke. Includes near the base the COKI POINT Megabreccia lithofacies with neritic fauna. Near the top is the CONGO CAY Limestone Member (300'±), coarsely crystalline limestone.	Albian
	OUTER BRASS Limestone (200' - 300') Thin-bedded, partially silicified radiolarian limestone.	
	LOUISENHOJ Formation (14,000'±) Augite-andesite breccias and tuffs. Near the base is the CABES POINT Cong. lithofacies with pebbles and cobbles of the Water Island Formation.	
	——— Unconformity ———	
	WATER ISLAND Formation (15,000'+) Keratophyre flows, with spilite flows and minor radiolarites. Intruded by dikes and plugs of keratophyre.	Lower Cretaceous?

Table 1. Stratigraphic section of the Virgin Islands formations, from Donnelly (1959) and Helsley (1960).

formation of Eocene age and the Cretaceous Water Island formation. This division is based on age and the origin of the formations. The Water Island formation was deposited during the subaqueous volcanic phase of the Island Ridge formation while the Virgin Island Group contains rock derived from subaerial volcanic eruptions. Intruded into these strata are plutonic rocks, mostly of dioritic and granodioritic composition, which are grouped under the generic name of the Virgin Island batholith; even though geologic continuity cannot be established.

Basement rocks are not exposed in the islands. Their nature, therefore, has to be inferred from geologic, petrologic, and seismic considerations. Based on refraction seismic data, Officer and others (1959) constructed a cross section across the platform (fig. 2). This section indicates a subduction of oceanic material from the north. Analysis of recent seismic data confirms this model (Sykes and Ewing, 1965). The effect of the seismicity is seen in the recent earthquakes (NOAA-EDC unpublished data) and the recent fault features such as the graben in the seafloor directly seaward of Charlotte Amalie (fig. 3).

As a result of the island formation and its tectonic location, two major fault systems have developed within the platform with associated folding and rotation; a right lateral system trending N. 45° W. and a left lateral system trending N. 55° E. Such systems suggest compressional forces in the north-south direction have been active and also suggest that the subduction of the North American

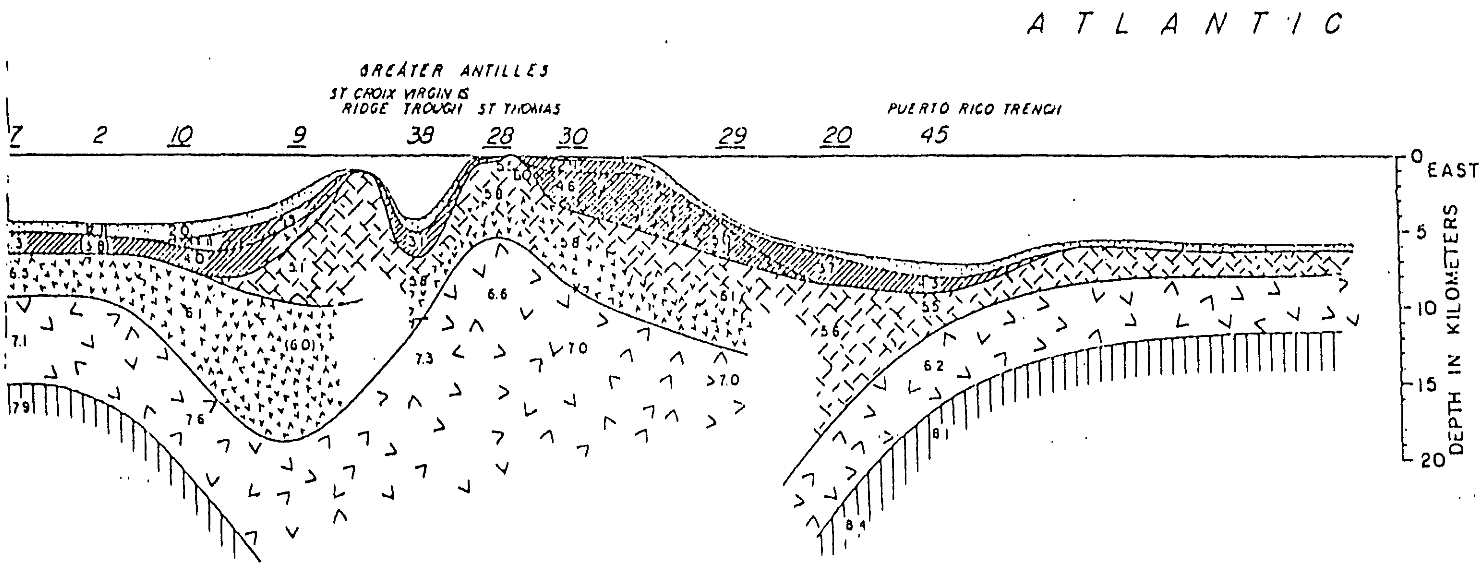


Figure Two -- Structural section of the Virgin Island Ridge

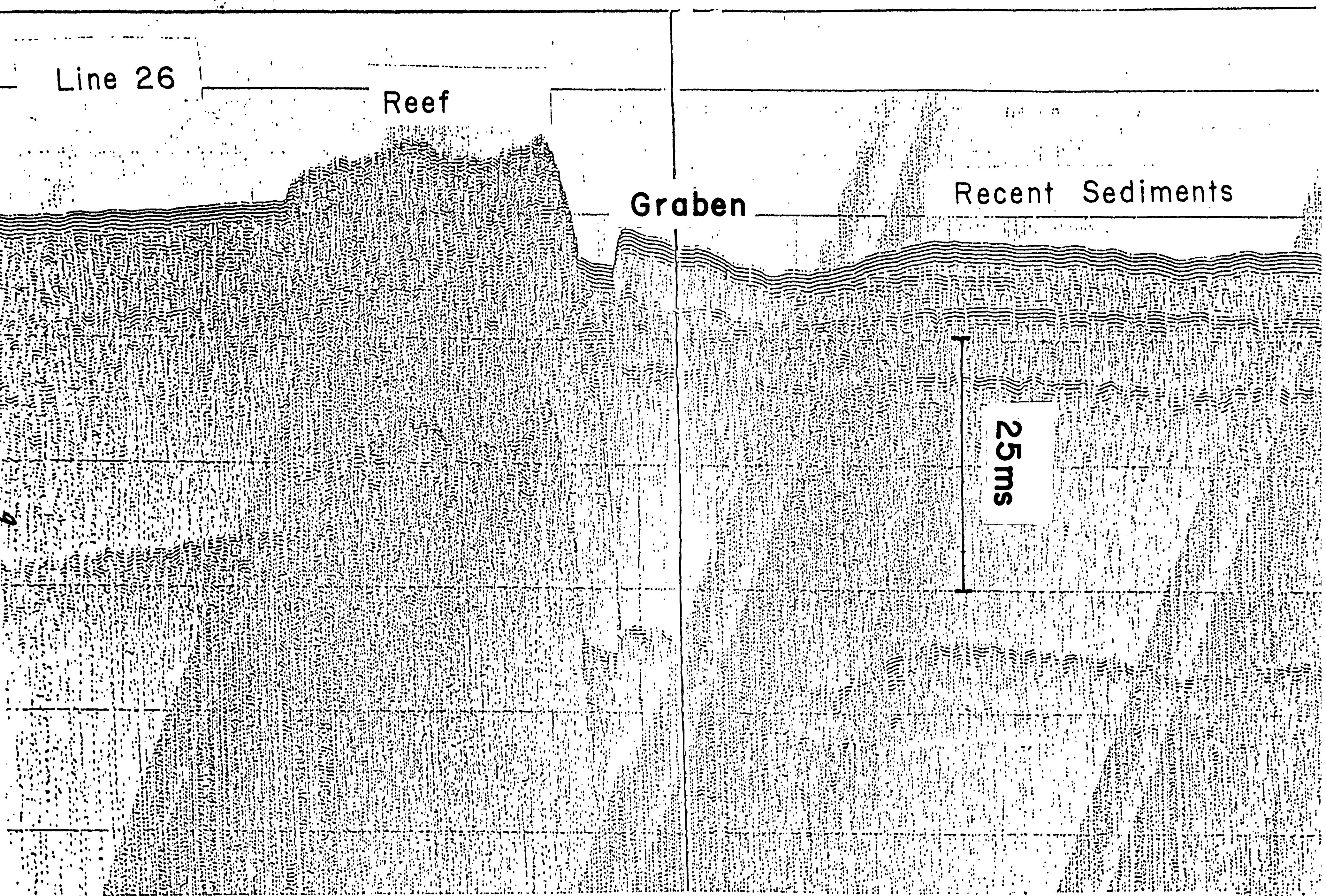


Figure Three -- 2.5 Khz profile south of Amalie with evidence of recent tectonic movement

Plate from the north is more active than the subduction from the east.

Topography

The insular shelf south of St. Thomas-St. John has an average width of about 14 km. From the islands to a depth of 25-30 m, the bottom slopes seaward at an initial rate of about 16m/km, then assumes a more gradual slope to a depth of 45 m, then becomes essentially horizontal. In the west the shelf edge lies at a level of about 45 m below sea level; while in the eastern regions, the edge occurs at a depth of 55 m, except where well developed reef crests peak as shallow as 20-30 m.

The southern shelf, on the basis of topography, can be divided into three parts. In the Virgin Passage the sea floor is very irregular and bounded on the east by a scarp some 5-10 m in height. This region has been interpreted to be exposed bedrock (Donnelly, 1965). From a north-south line through the western tip of St. Thomas to Sail Rock, to a north-south line through Charlotte Amalie, the shelf is smooth; broken only occasionally by small reef features. To the east, the sea floor surface becomes more rugged and very strong topographic ridges are developed with northeast-southwest trend.

The shelf edge in the east is serrated, with an almost geometric series of straight-line segments intersecting at angles of 105-135° averaging 120°. The edges of northeast-southwest oriented segments are sharpened by the superposition of reefs whose relief is as great as 30 m above the surface of the outer shelf. On the northwest-southeast oriented segments reefs are absent, or have only minor


SEAFLOOR TOPOGRAPHY
U.S. VIRGIN ISLAND PLATFORM
Mary Kindinger 1978
contour interval 1m
ST. THOMAS
ST. JOHN
18° 30'
18° 20'
18° 10'
65°10'
65°00'
64°50'
64°40'

Figure Four

topographic expression. The position of the reefs on northeast-southwest oriented segments of the shelf edge allow for optimum exposure to nutrient-bearing currents from the southeast.

Shelf-edge serrations diminish in amplitude to the west, so that beyond longitude 65°W. the shelf edge is irregular, but bears no large reef build-up. Topographic and structural alignments in the western postion are less prominent and appear to be principally east-west and north-south. A few fault scarps are recognizable but do not assume the prominence 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 a more or less continuous feature south of St. John between latitudes 18°15'N. and 18°17'N. Crests near its eastern end are in water depths of 20-25 m, while at the western end, the reef has crests as deep as 37 m. The most remarkable characteristic of this reef is its parallelism with the shelf-edge reef. Even the shoreward offset in the southwestern portion is a good approximation of the shelf-edge serration.

North of St. Thomas, the shelf topographically is characterized by four distinct zones. Near the island, a perched, relatively shallow, platform exists, and is bounded seaward by scarps except in the Virgin Passage where there is a gradual deepening of the sea floor to a depth of 54 m. The central zone is extremely flat. The flatness is broken near the outer shelf edge by a series of banks which actually appear to be reeflike masses paralleling the shelf edge. These masses rise to about 25 m below sea level. Bordering these reefs, seaward, is a smooth ramp which grades into the shelf edge. Unlike the south side, the shelf edge, which occurs at a depth of 55 m, is smoothly concave to the southeast with no breaks in the curvature.

Surficial Geology

Approximately 1750 km of high resolution seismic reflection profiles were made during two cruises, the SS ALIANORA in September-October 1977 and the R/V OCEANUS in February 1978 (fig. 5). The record quality was excellent for profiles south of the islands of St. Thomas and St. John. North of St. Thomas, however, the records obtained were of very poor quality as a result of heavy swells (4-6 m). As a result, more detailed information was obtained on the southern platform.

In addition to the high resolution seismic profiles, variations in the total magnetic field were measured during the OCEANUS cruise. The accompanying total magnetic map was constructed from the data and has not been corrected for the regional trend (fig. 6). It has been determined, however, that no magnetic storms occurred during the duration of the data collection, so that the map represents the relative magnetic variation present in the underlying rocks plus the regional gradient.

Positions were established during both cruises by precision radio navigation instrumentation. The only exception to this was in the Virgin Passage in which due to instrument malfunction, fixes

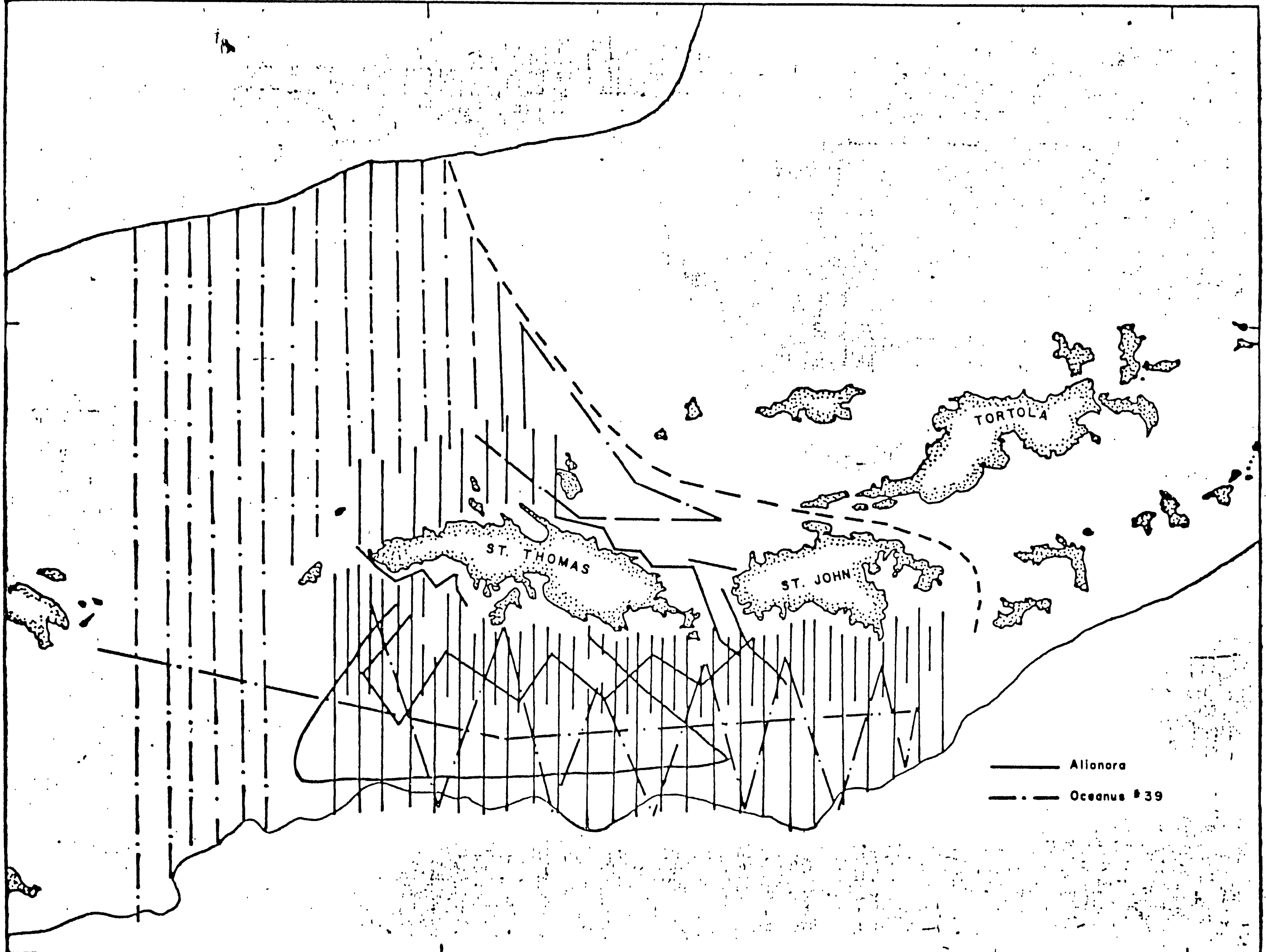


Figure Five--- Track lines of vessels used in Platform study.

were made by radar. The geophysical equipment used is listed in table II.

Eleven distinct "seismic stratigraphic" units were defined from the profiles and mapped. Distinct features such as faults, channels, and structural trends, were also mapped. Figures 7, 8, 9, and 10 are illustrative of the seismic units which are mapped in figure 11 and defined in table III.

Eastern zone--East of a north-south line through Buck Island the sea floor is dominated by northeast-southwest trending reefs which appeared to have formed along fault scarps. This area is also dominated by a basement ridge with a crest that rises to a few meters of the sea floor. This ridge appears in profiles as a dome-shaped structure in cross section without internal reflectors and marked by a high positive magnetic and gravity anomaly (fig. 12). The position of this feature indicates that French Cap Cay is an exposed outcrop of this mass. The island is composed of a dioritic rock which according to Donnelly (1966) is:

> "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."

No geophysical evidence for such continuation to the west is apparent from the data, but it is definitely traceable to the east

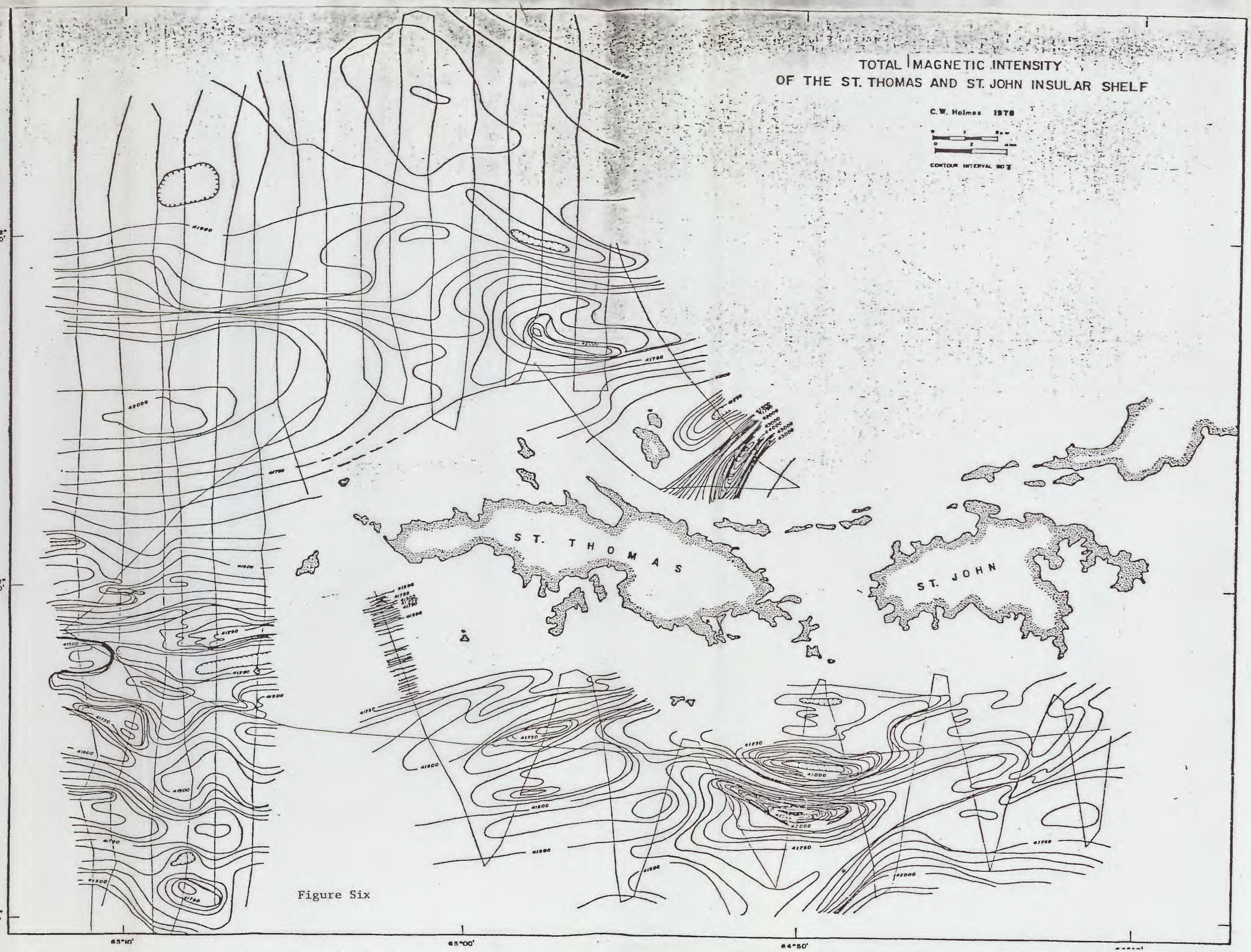

TOTAL MAGNETIC INTENSITY
OF THE ST. THOMAS AND ST. JOHN INSULAR SHELF
C.W. Holmes 1978
ST. THOMAS
ST. JOHN
18° 30'
18° 20'
18° 10'
65°10'
65°00'
64°50'

Figure Six

TABLE II. Geophysical System

	S.S. ALIANORA	R/V OCEANUS	R/V SIRMA
Acoustical source	Del Norte minisparker	Del Norte minisparker	
Output (power)	300 j	700 j	
Source depth	3 m	0 m	
Hydrophone	24 element	24 element	
Hydrophone depth	3 m	0 m	
Recorder (analog)	EPC #4100	EPC #4100	
Recorder (tape)		H. P. tape	
Amplifier	Del Norte 570A ASP	Del Norte 570A ASP	
Filter band	600-1000 hr	300-1000 hr	
High resolution system		EDO 2.5 kHz	EDO 2.5 kHz
Low depth		10 m	2 m
Rep. rate		0.5 sec.	0.25 sec.
Recorder		EPC 4600	EPC 4600
Magnetics		Gradiometer	
Navigation	Miniranger	Trisponder/radar	Trisponder

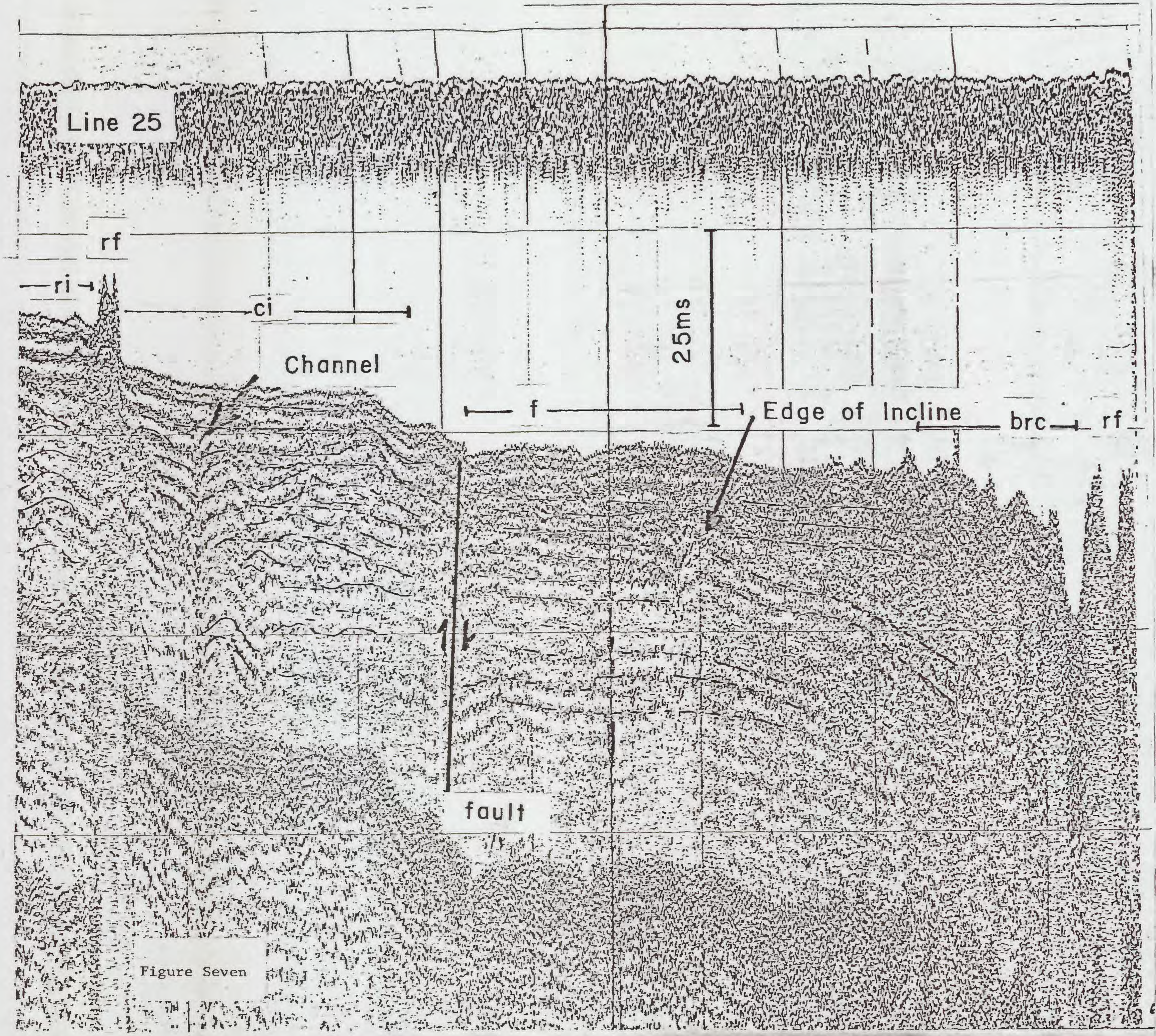


Figure Seven

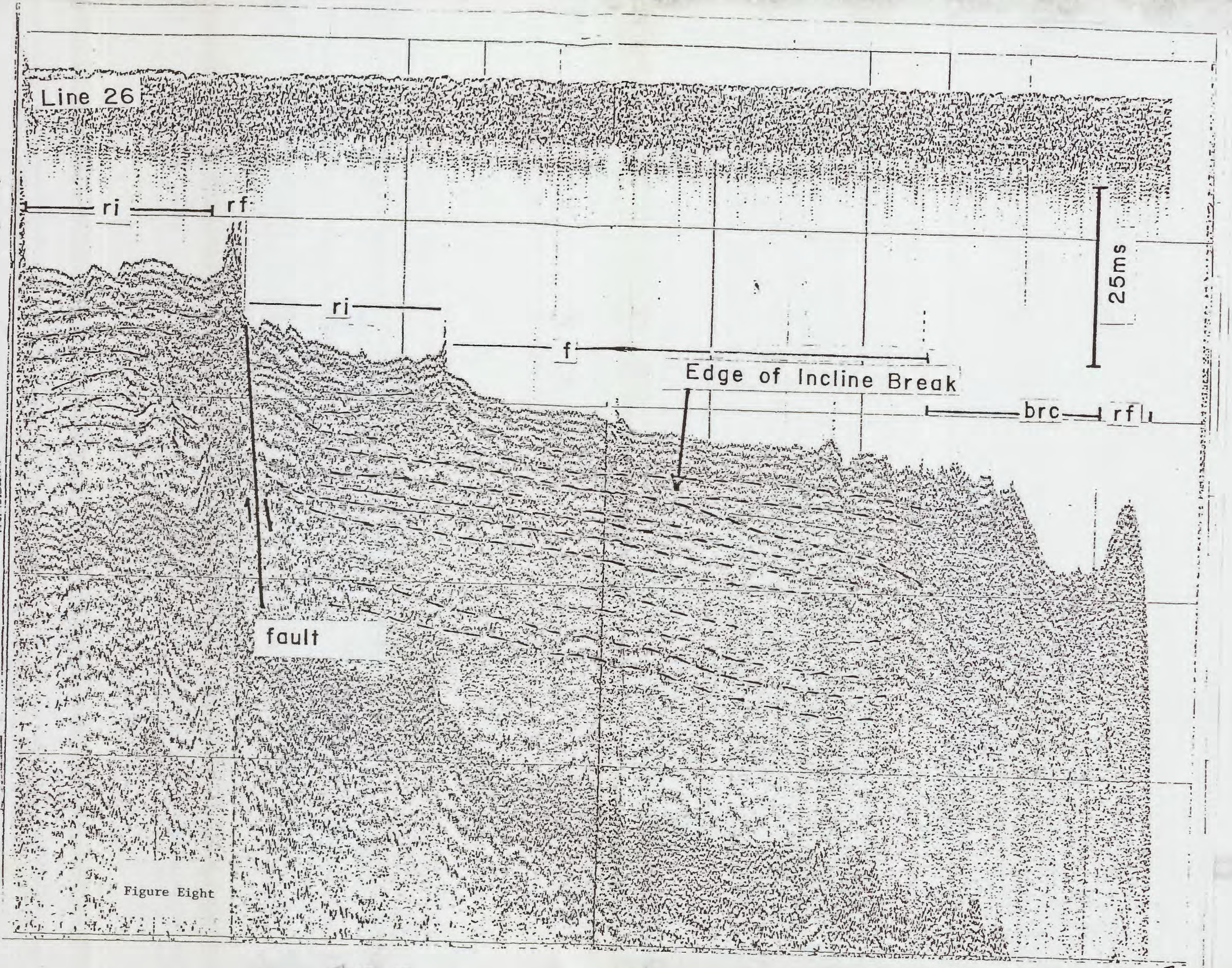


Figure Eight

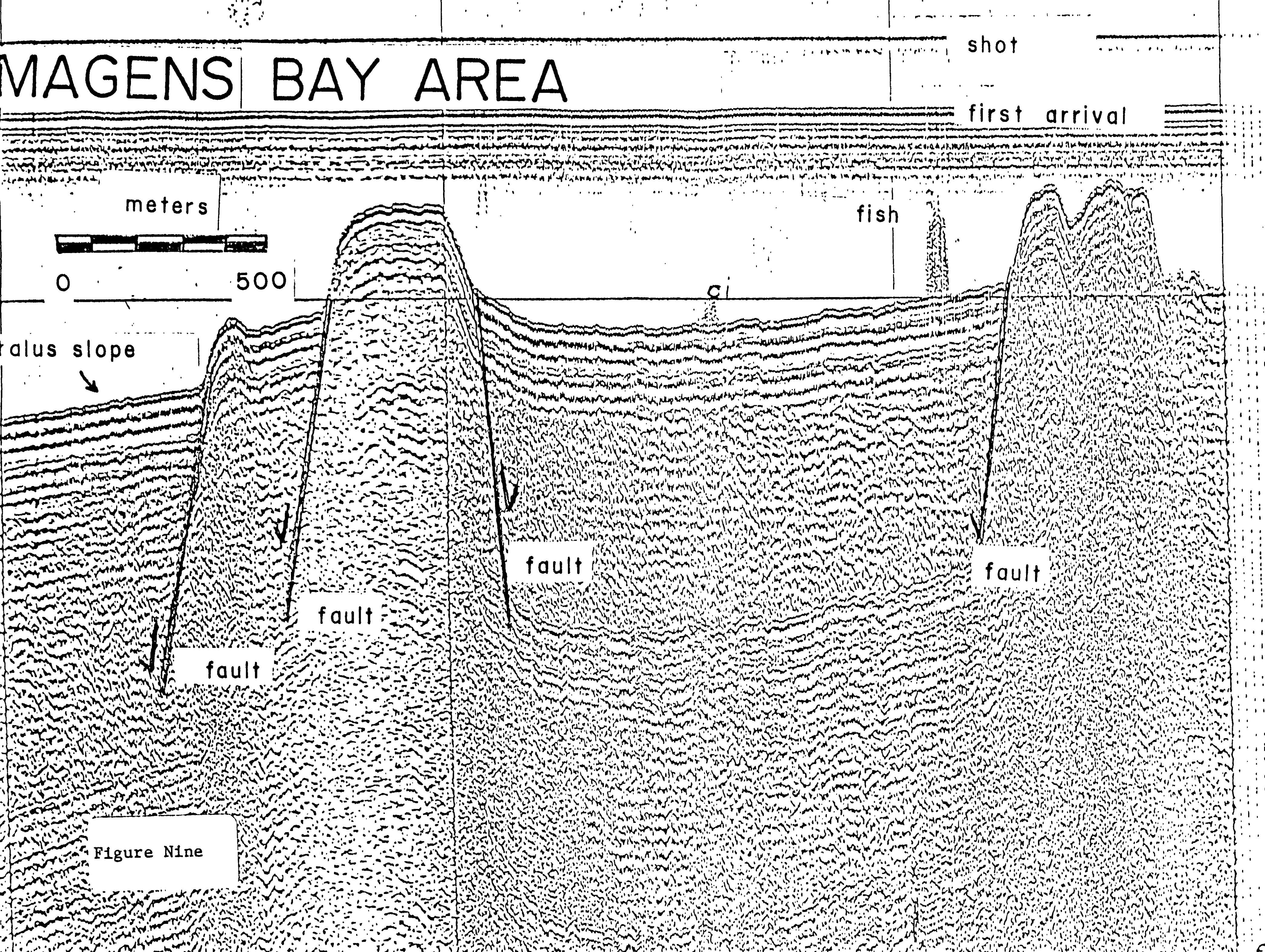

MAGENS BAY AREA
shot
first arrival
meters
0
500
fish
CL
alus slope
fault
fault
fault
fault

Figure Nine

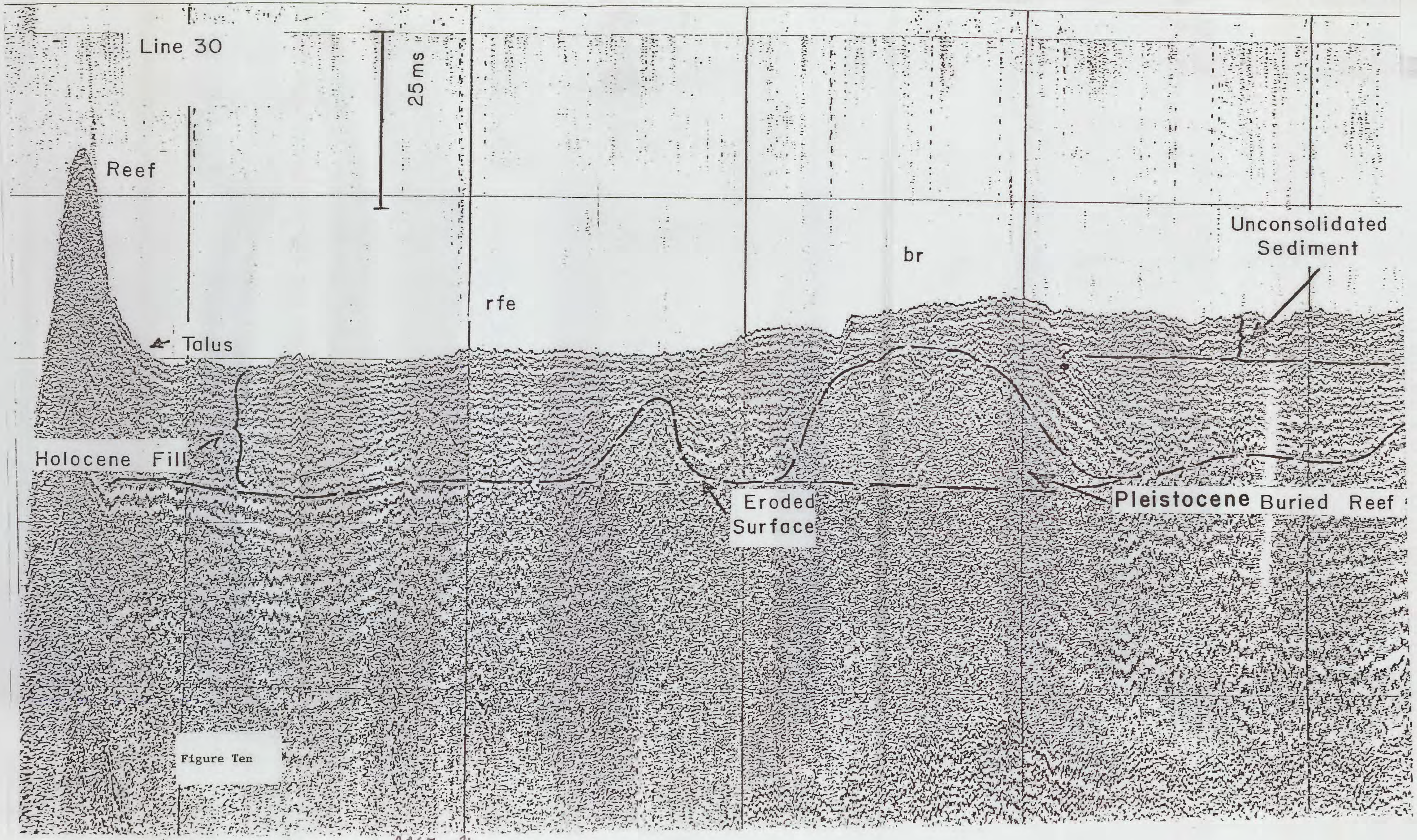
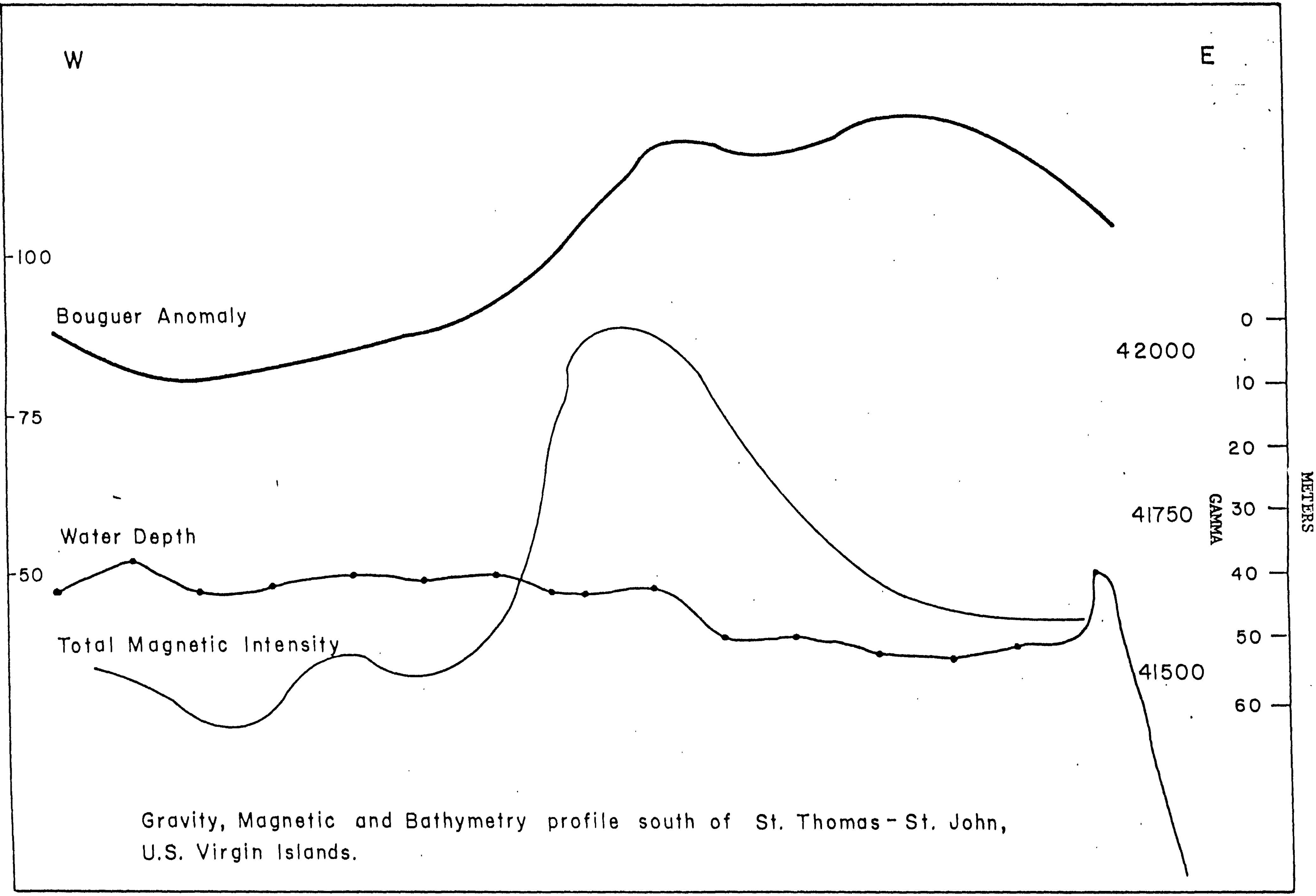

Line 30
25 ms
Reef
Talus
rfe
br
Unconsolidated Sediment
Holocene Fill
Eroded Surface
Pleistocene Buried Reef

Figure Ten

Figure Eleven

Table III. Definition of "seismic stratigraphic" unit

Symbol	Description	Interpretation
f	horizontal or near-horizontal reflectors	Virgin Island group
ri	surface diffuse reflection zone over subparallel irregular reflectors	recent sediment overlying rocks of the Water Island formation
Ci	bottom conformable reflectors over sub-parallel irregular reflectors	carbonate cap over rocks of the Water Island formation
	subparallel irregular reflector	outcrops of the Water Island formation
rfe	surface diffuse units, over horizontal reflectors, over irregular subparallel reflectors	recent sediment over-lying a thin carbonate cap or interlagoonal sediment over rocks of the Water Island group
brc	subsurface reflectors diffuse with no apparent reflectors below surface section	back reef sediment fill
btr	no internal reflectors due to hard surface (many multiples), defined on broken topographic expression	region of extensive block faulting
ht	no internal reflectors due to hard surface (many multiples)	possible exposed bedrock
rf	defined on topographic expression, a lack of internal reflective with no magnetic signature	reef
br	subsurface reflector outline a subsurface homogeneous mass with no magnetic character	buried reef
s	no subsurface data with no topographic expression	erosional ramp



Gravity, Magnetic and Bathymetry profile south of St. Thomas - St. John, U.S. Virgin Islands.

Figure Twelve

and may be exposed on the small islands at the eastern end of St. John. The ridge trend is offset to the south in a similar manner as the inner reef. The magnetic isopleth also suggests such a left lateral offset of the ridge. This configuration in the ridge trend, the reef trend, and magnetic isopleths suggest a deep sinistral fault trending northwest-southwest to which the surface faults are antithetical.

Western zone--The western shelf (south of St. Thomas) in contrast to the eastern shelf, is relatively featureless. Rocks under the inner shelf in the Brewers Bay region are horizontal as suggested by the horizontal reflectors and are interpreted to belong to the Virgin Island group. Further offshore, the strata underlying the recent sediment and carbonate caps are represented by irregular reflectors and are interpreted to be rocks of the Water Island formation.

A midshelf fault separates the irregular reflectors with a seaward sequence of horizontal reflectors. The stratigraphic nature of this unit is unknown. A distinctive feature of this outer unit is a seaward inclined disconformity which truncates the horizontal units and separates them from an overlying mass which has no internal reflectors. The dip of the incline varies from 3 to 4°. This disconformity is believed to be an erosional surface rotated into its present position in the early Holocene.

The boundary between the eastern and western shelf areas is indistinct, but the differences between them are great and suggest that a large fault may separate the regions. The only evidence for such an offset, however, is the configuration of the magnetic isopleths which suggest right lateral motion on some deep fault.

On the inner shelf, an east-west channellike feature was mapped. This feature is cut into the pre-Holocene surface and is presently filled with what appears to be recent unconsolidated material. An arm or extension of this channel appears to head in all major valleys on the south side of St. Thomas. The peculiar aspect of the channel is that it indicates drainage to the west through the Savanna passage and not the more direct route across the shelf to the south. Such a route may be expected if the southern shelf was higher during the time that the channel was constructed.

Virgin Passage--The acoustically hard and irregular surface prevented the obtaining of any subbottom information in the Virgin Passage. The eastern boundary of this zone is marked by a scarp which is interpreted by Donnelly (1965) to be a fault (Sail Rock). The trend of this feature is the same as the proposed faults which separate the eastern and western regions and cut the center of the eastern shelf.

Northern Shelf--To the north, the hard surface of the Virgin Passage deepens with concurrent subbottom seismic information revealed. The central shelf is underlain by flat-lying reflectors, broken by occasional buried reefs. These reefs have been truncated by erosion so that the sea floor in the central shelf region is featureless. Seaward of this plain are massive reefs and banks.

In the immediate vicinity of the island of St. Thomas, faulting has produced uplifted, reef surmounted structures which have acted like dams, trapping sediment and creating terraces. Internally, the reflectors of these features are quasi-irregular and mapped as irregular. There is however a significant difference in the degree of irregularity with those on the south side of the island being broad whereas the reflectors on the north being closed. The reflectors on the north are interpreted to be talus and sediment rapidly deposited and not part of the core rocks of the island.

Late Pleistocene-Holecene history--The Pleistocene epoch is characterized by the advance and retreat of glacial ice in the northern hemisphere with the concurrent rise and fall of sealevel. Coupled with this and the fact that the islands seem to be undergoing subsidence, the shelf edge would be the area where the greatest difference in features would be expected. South of St. John, one of the most prominent subbottom reflectors is interpreted to be an eroded surface (fig. 11). In the western region, the inclined surface which truncates some of the underlying reflectors is interpreted to be an erosion surface. Similarly, on the northern shelf the truncated buried reefs also are evidence of a low stand of sea. These surfaces and the subsequent features suggest that the eustatic changes in sea level played an important role in the sediment budget of the area.

A model for the shelf development is presented in cartoon nature in figure 13. This model suggests a similar history for each region differing only in the tectonic elements. In the eastern region, reef

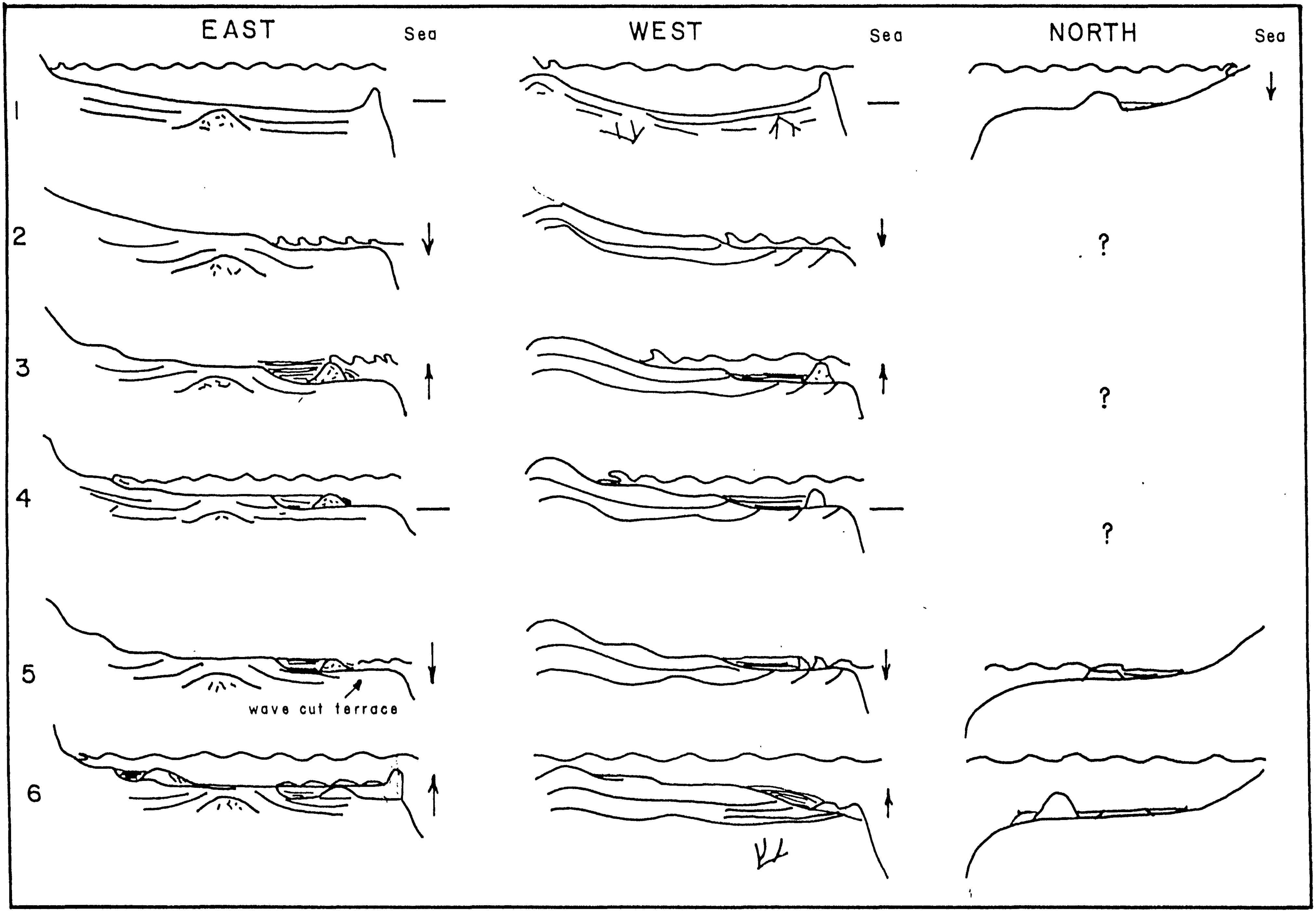


Figure Thirteen -- Model of shelf developement. (Solid arrows indicate sealevel motion) development at the edge of the platform was interrupted by a lowering of sea level exposing the entire platform. During this low stand, wave erosion cut a surface about one-third the way across the shelf. During the subsequent rise in sea level, a reef developed midway on the shelf. This rise must have occurred relatively rapidly to cause the reef to develop well back from the shelf edge with no reef development on the shelf edge. During this time, back reef or lagoonal deposits were deposited landward of the reef. Sea level again fell, but this fall was not as great as the previous drop and reef development in the form of patch reef formed seaward of the main reef mass. The last rise in the sea was relatively slow and a reef of significant proportions was formed at the shelf edge. This rise also formed a reef at the shelf edge with associated lagoonal deposits.

A slightly different scenario occurred on the western shelf. Like the east, a reef was forming on the edge subsequent to the lowering of sea level but with the shelf rotated to bring the outer edge up. Such a rotation would account for the drainage near the core of the platform to be shifted to the west instead of across the shelf. The subsequent lowering of sea level eroded this section, exposing the older material on the shelf edge. The rise in sea level to the midshelf area produced a reef-lagoonal sequence at the edge and not on the shelf. The subsequent lowering of the sea eroded most of this complex and formed a wave cut terrace. The last rise in sea level provided the edge reef development; however, because the water lacks the nutrients that abounded in the east, the west development is not as great as in the east. The reef configuration in this area also suggests subsequent shelf-edge subsidence which may be fault controlled.

The northern shelf has much the same history with the drop in sea level eroding the midshelf reef complex. The subsequent rise in sea level caused the reef development to be shifted toward the north. This may be due to the tectonic activity and a possible change in water flow. The poor records on the north hinder a comprehensive study of the area.

Shelf Sediments

The tectonic activity and the resulting structural setting has had a profound effect on the sediment distribution of the shelf. The fault and faultline scarps, particularly those trending northeast-southwest formed excellent locals for the establishment of reefs. This is particularly true of those scarps in the eastern region where the uplifts combined with nutrient-rich upwelling enhancing the formation of reefs. On the inner shelf, the larger reef also formed close to secondary nutrient sources; for example, near the southern entrance to Pillsbury Sound where water flowing through the sound mixes with the normal western flow across the shelf. These reefs appear to be the productive zones from which the sand on the shelf is derived.

Agents of distribution--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. Currents in the Southwestern Roads region have been measured to have a maximum of 2.0 knots in the Savanna Passage. Measurements on the open shelf indicate a maximum current velocity of 0.2 knots. The net effect is transportation of water to the west (NOAA, 1972, unpub. data).

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 one meter and periods of 5 seconds. A two-meter, seven-second wave would have a wave base of 30 meters.

Types of shelf deposit--Sand is present on the shelf in three types of deposits; blanket, "sand waves", and sand "shadows". The most common deposit is the blanket type which averages about one meter in thickness and seems to be omnipresent except on topographic highs. "Sand waves" were found in two areas, one midshelf south of St. Thomas and another directly seaward of the harbor of Charlotte Amalie. These features are asymmetrical with the steep lee side facing west (fig. 14). This is suggestive of a significant west moving current. The horizontal extent of these features of the mid-shelf region is unknown as only one traverse was made of high energy resolution to detect them. The pattern of those on the inner shelf also is unknown because the track lines were not close enough to accurately map them. Also, it is not known whether these are presently active or a response to some past current pattern.

The most significant deposits, those with the greatest volume per unit surface area, are the "sand shadows". These deposits formed immediately in the lee of large topographic highs and have all the features of sand shadows complete with the scour. Three regions were selected for extensive investigation; the Southwestern Roads region, the Buck Island-Charlotte Amalie area, and the Capella-St. James Bay area. Four other potential sites were located; two south of St. John, one in Pillsbury Sound and one north of Magens Bay. The sites south of St. John will be examined this year, but the remaining sites, although of scientific interest, are of dubious economic value because of the severe conditions which at times prevail.

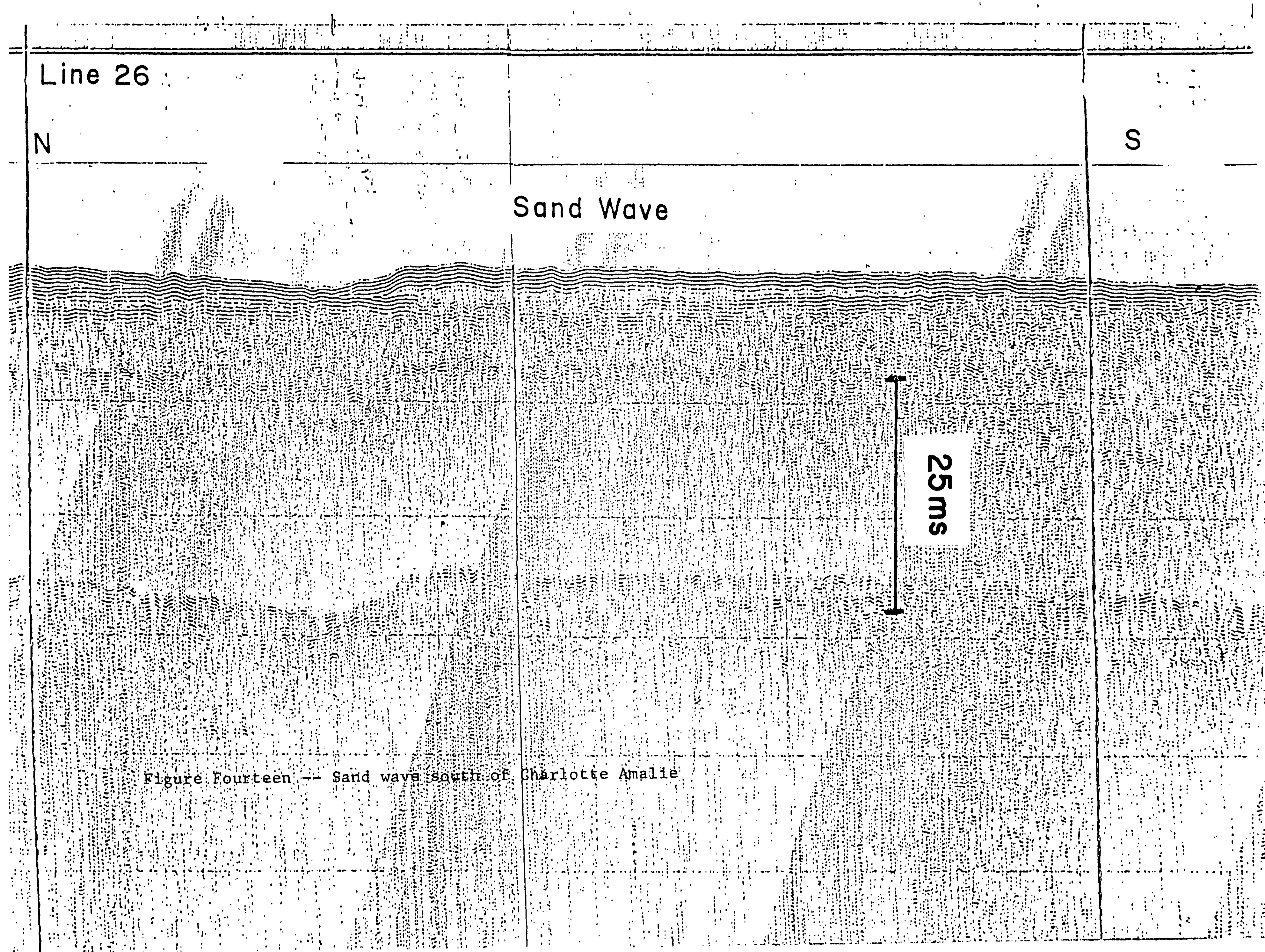
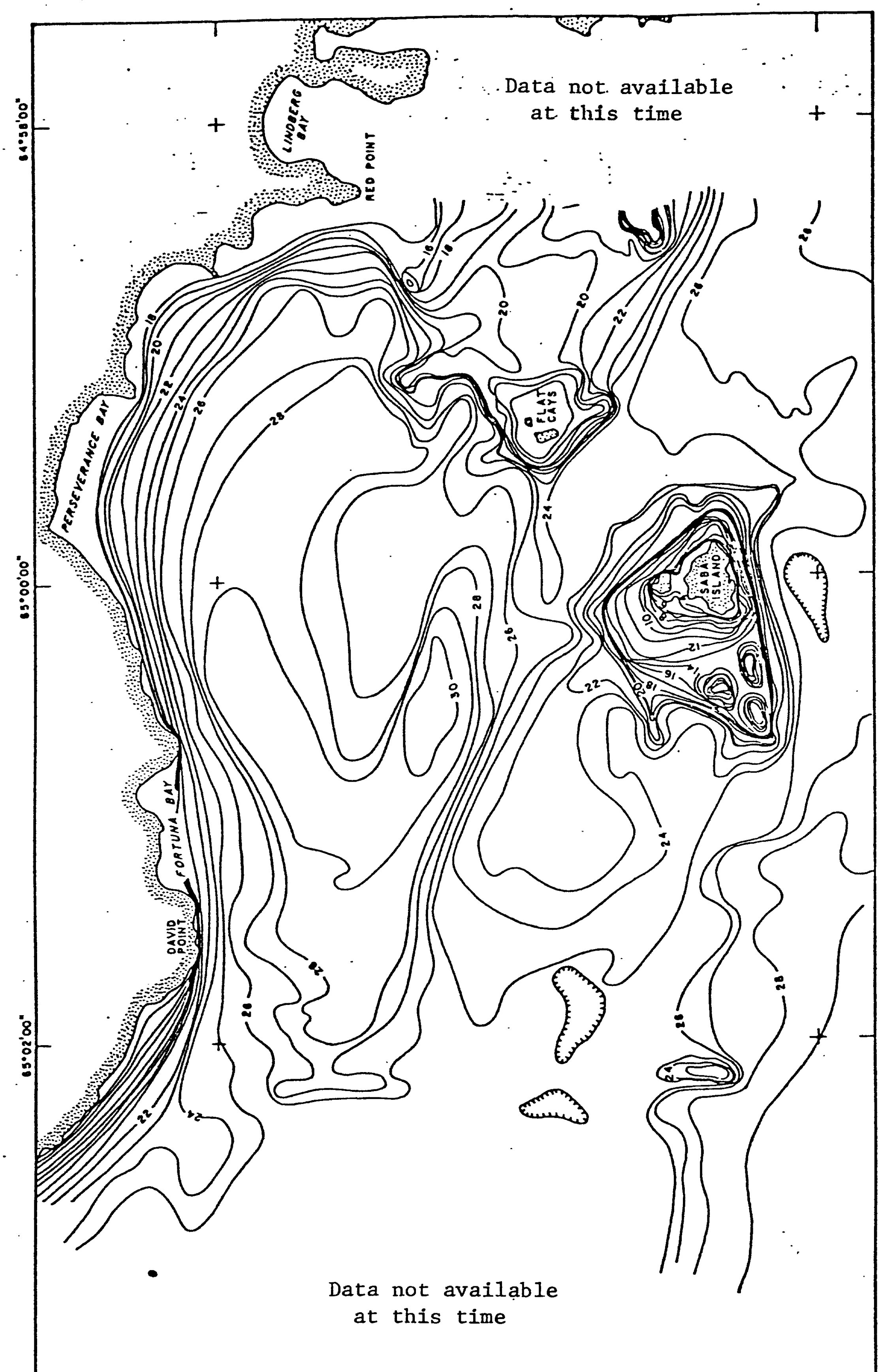


Figure Fourteen -- Sand wave south of Charlotte Amalie

Southwestern Roads--The Southwestern Roads is the region bounded by the southwestern coast of St. Thomas, the offshore islands of Saba and Savana. Within this area, the bathymetry details two topographic highs which trend to the northwest from the Flat Cay and Saba Island rises. These ridges are separated by a distinct channel, with quasi-channellike depression between the Flat Cay high from the shoreface of the island.

The high resolution survey of this area clearly defines these ridges as recent sedimentary deposits (fig. 15). The cross section normal to the shore shows the deposits are formed on a convex irregular basin of bedrock material (fig. 16). Also of note is internal reflectors mapped within the deposits closest to land. The apparent offset of this reflector noted near the toe of the shoreface sand body apparently is a fault and also points to relative recent tectonic activity. The extent of these deposits are shown by the isopach map (fig. 17).

The largest most extensive deposit has a maximum thickness of over 8 meters. The total volume for this body is approximately $20.5x10^6$ cubic meters. The smaller deposit, northwest of Flat Cay, has a maximum thickness of 7 meters and contains an approximate volume of $12.9x10^6$ cubic meters. No calculations were made for the deposits on the shoreface because this deposit is attached to the beach dynamically and removal would have an adverse effect on the beach developed in Brewers Bay.



WESTERN ST. THOMAS-SOUTHWESTERN ROADS
TOPOGRAPHY OF SEA FLOOR

CONTOUR INTERVAL: 1 METER

Figure Fifteen

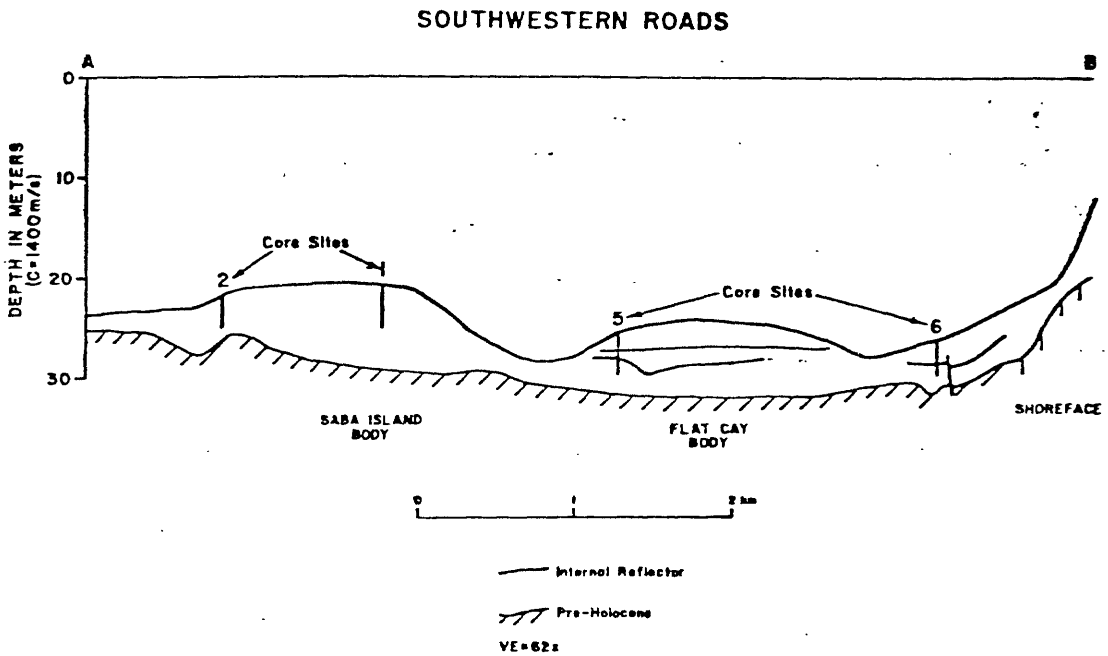
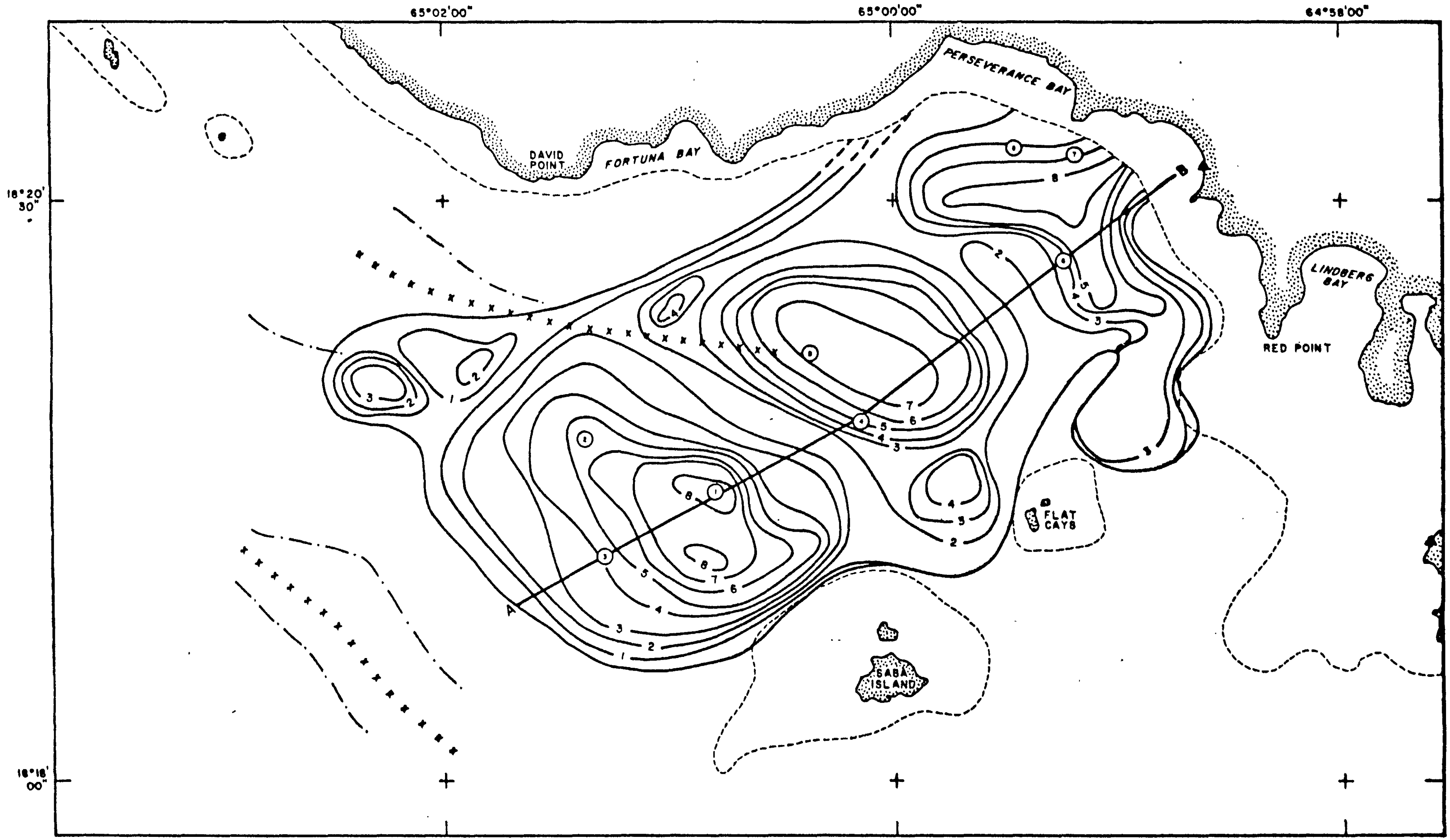


Figure Sixteen -- Cross section through the deposits, Southwestern Roads region.

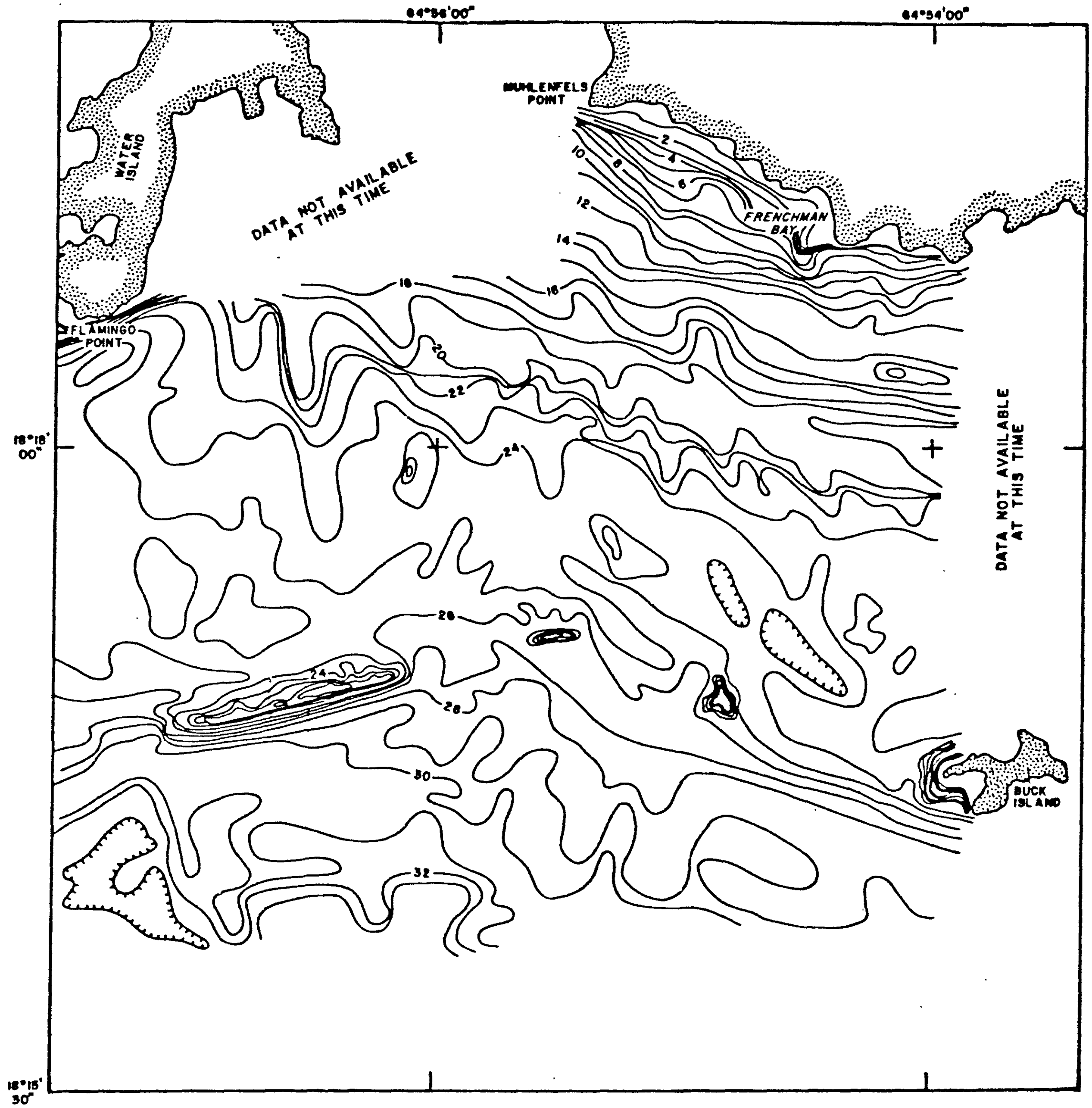


WESTERN ST. THOMAS-SOUTHWESTERN ROADS
ISOPACH OF RECENT SEDIMENT

CONTOUR INTERVAL: I METER
CORE LOCTION
xxxxxx AXIS OF CHANNEL
TRANSPONDER LOCATION
EDGE OF CHANNEL
CROSS SECTION

Figure Seventeen

Central St. Thomas Inner Shelf--The sea floor in this region is dominated by the northeast trending reef and its partially buried eastward extension and the topographic high associated with Buck Island (fig. 18). Together these features project a step between them, and create the two tier topographic configuration of the area. The upper tier is dominated by the ridge sediment trending northwest from Buck Island, and the shoreface slope. The lower tier is comparatively smooth. The cross section shows that the recent sediment lies on a gentle incline of basement material (fig. 19). In Section A-B, the channel which drained central St. Thomas through what is now the harbor, the sand waves of the upper tier, and the nature of the deposit near Buck Island are illustrated. Section C-D, normal to the coast illustrates the sand waves on the lower tier, and the geometry of the deposit near Buck Island. In this latter section, the internal reflector is seen to outcrop suggesting recent readjustment to the present hydraulic regime and that erosion is presently active on the lower tier. The thickness of the sediment cover is aptly demonstrated in figure 20. The thickest deposit is that associated with the harbor fill, with a secondary site of deposition northwest of Buck Island. It is difficult to determine the thickness and volume in all "sand wave dunes" due to a lack of good topographic control. The deposit near Buck Island, however, contains approximately 10.8×10^6 cubic meters of material. No estimate was made of the volume of harbor-associated material. A surprising and interesting discovery was the almost complete lack of sedimentary material on the lee side of the large reef.



CENTRAL ST. THOMAS INNER SHELF
TOPOGRAPHY OF SEA FLOOR

CONTOUR INTERVAL: 1 METER

Figure Eighteen

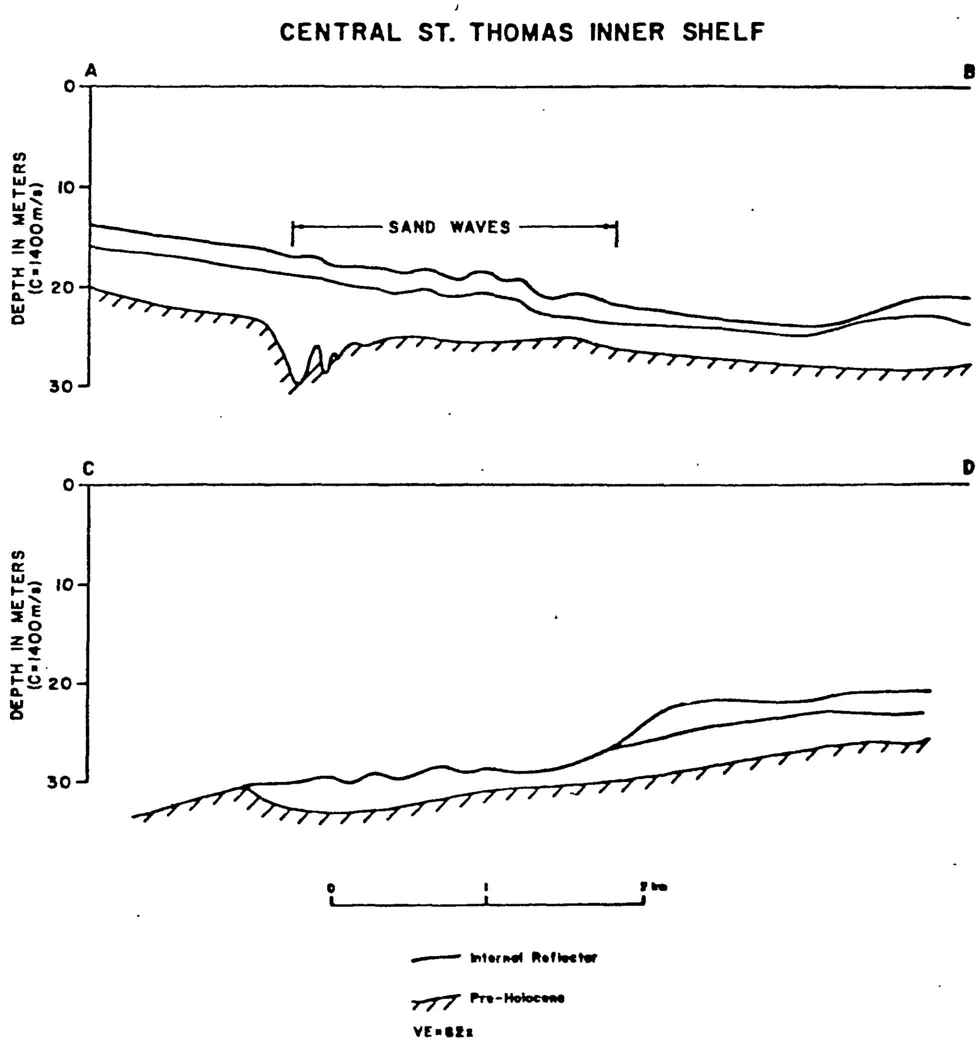
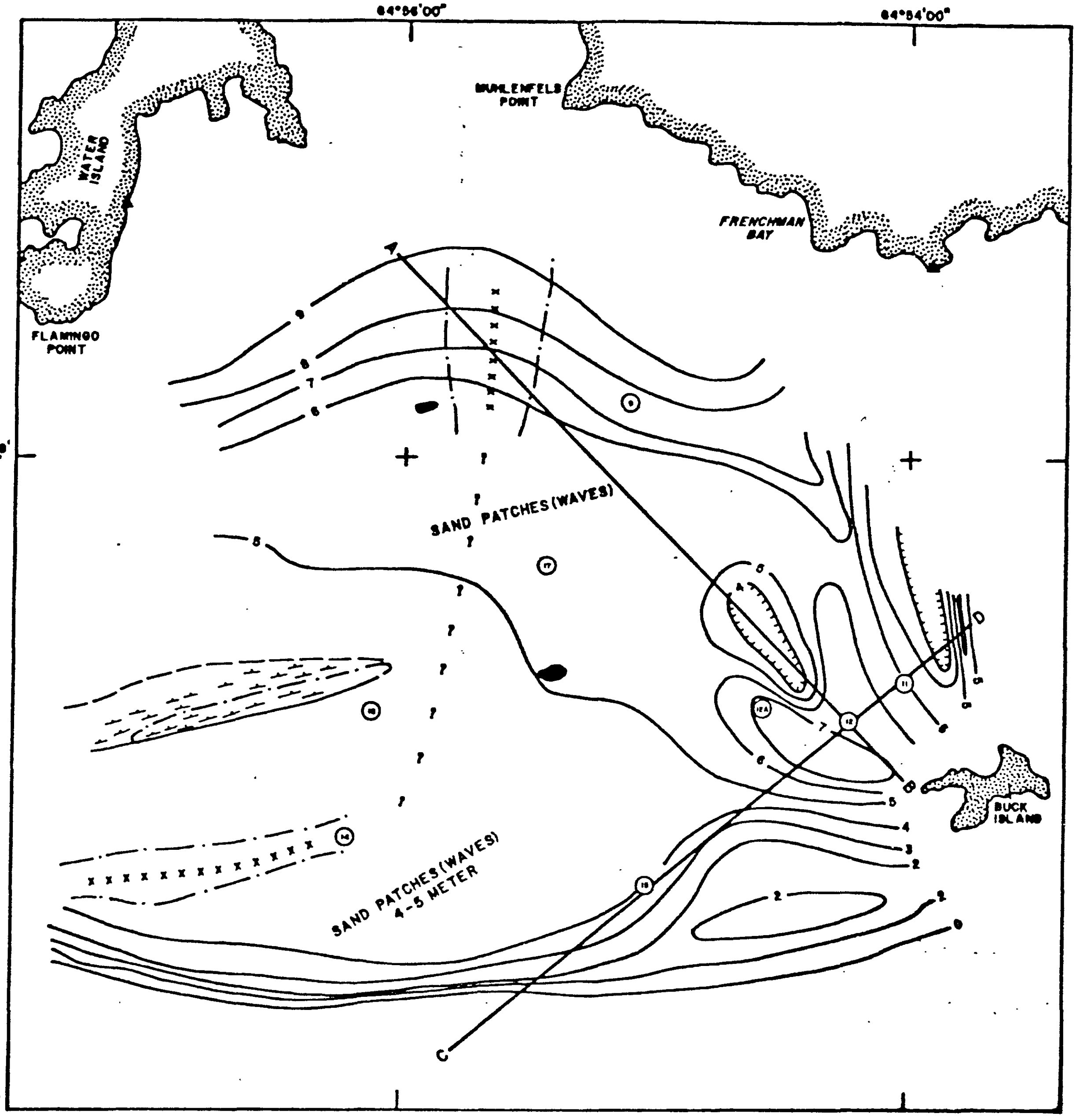


Figure Nineteen -- Cross sections through the sand deposits of the central region.



CENTRAL ST. THOMAS INNER SHELF
ISOPAC' OF RECENT SEDIMENT

0 1 2 km

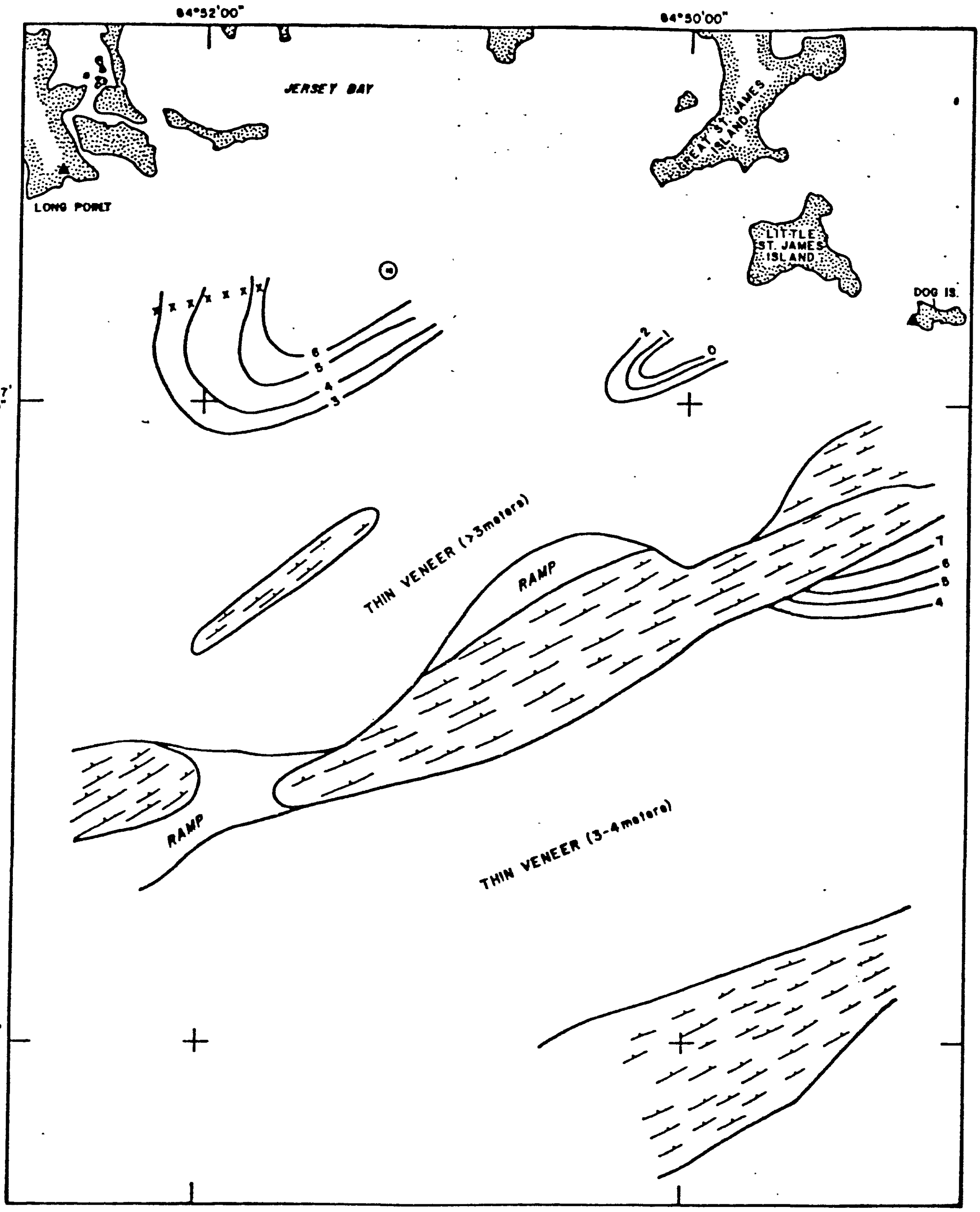
CONTOUR INTERVAL: 1 METER

- CORE LOCTION
- AXIS OF CHANNEL
- TRANSPONDER LOCATION
- REEF
- EDGE OF CHANNEL
- CROSS SECTION
- PROBABLE AXIS OF CHANNEL
- OUTCROP OF SUBBOTTOM MATERIAL IN FORM OF REEF-LIKE FEATURE

Figure Twenty

Eastern St. Thomas Inner Shelf--The preliminary survey of this area indicated that this region would be a prime locale for sand deposition. The detailed survey of this region, however, failed to identify any significant deposits. This area is dominated by a large reef complex which bisects the area. Some material has accumulated in the fore reef area at the eastern edge of the reef, but this is not significant and no volume calculations were made (fig. 21). Again, no significant deposition was found behind the reef. The reason for this is unclear but may be the result of strong current flowing on the inner shelf sweeping the area clean. Material formed behind this area may be incorporated into the "sand waves" in the central area south of Charlotte Amalie.

Nature and composition of the sediment--The surficial appearance of the sea floor did not appear to vary significantly from area to area. A typical photograph illustrates the bottom which is covered with various carbonate-producing organisms (fig. 22). One of the most common sediments was nodular material composed of algae and the incrusting foraminifera Gypsina plana. The diverse nature of the surficial material produced a bimodal size sediment distribution with the larger fraction dominated by nodules in various forms of disintegration. The fine fraction is composed of mollusca fragments (40-50%), coraline algae (25-35%), halameda (10-15%), and others (0-25%). The domination of material other than coral fragments suggests that reef framework detritus presently plays a minimal role in the sand budget and that the budget is the result of organisms which use the reef environs.



EASTERN ST. THOMAS INNER SHELF
ISOPACH OF RECENT SEDIMENT

0 1 2 km

CONTOUR INTERVAL: 1 METER

⊙ CORE LOCTION
xxxxxx AXIS OF CHANNEL
▲ TRANSPONDER LOCATION
REEF

Figure Twenty-one

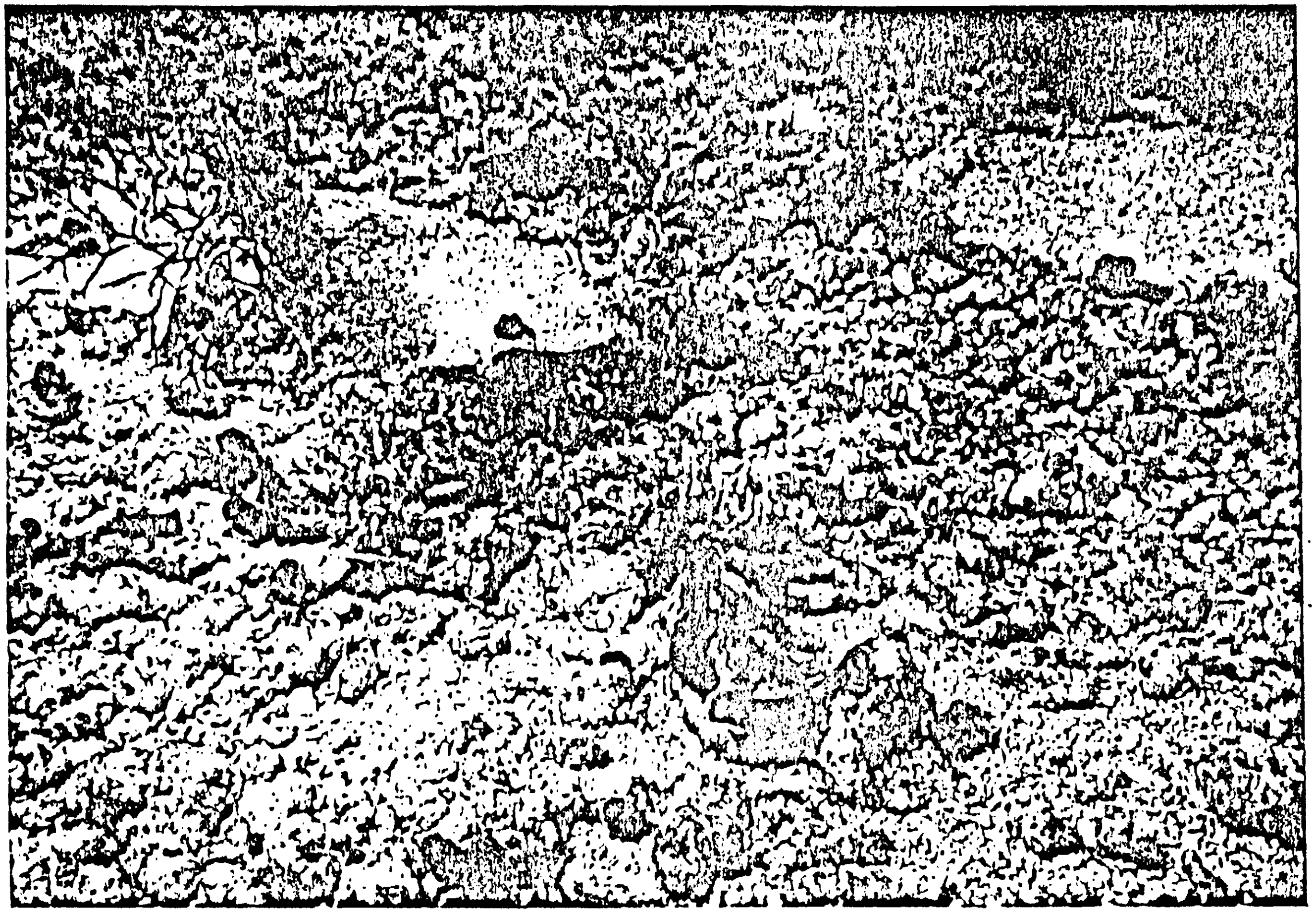


Figure Twenty-two -- Seafloor photograph, representative of the seafloor nature on the surface of the sand deposits.

In order to obtain three-dimensional data, cores were obtained from the sites of major deposition, the crests of sand waves and channels (fig. 23). Samples from these cores are presently being analyzed to determine the textural variation, the mineralogical and biological composition, the composition and content of the noncarbonate fraction, and the rate of sedimentation.

The textural analysis has been completed and analyzed by sieving methods with the classes chosen to compare with those required by the engineering specifications for the sand to be used in the foundation structures for the airport extension (fig. 24). All of these analyses have been completed. Analysis of the data indicates that the deposition sites have a uniform size grade distribution with a modal diameter of between 0.3 and 0.15 mm (fine sand). Samples taken from the beach surrounding the island are very similar.

Thus far the rates of sedimentation have been established for only two cores; core 3 from the Saba sand body (fig. 25), and core 5 from the Flat Cay sand body. Surprisingly, the rates of sedimentation for each is similar, about 1 cm/yr. The preliminary data on which these rates are based, suggest more rapid deposition in the older sections of the core. This section is immediately above the internal reflector, which appears to be the result of a higher non carbonate mud concentrations.

Plans and Work in Progress

At the present time, there is insufficient data to make any conclusions about the means of sedimentation on the shelf. The present

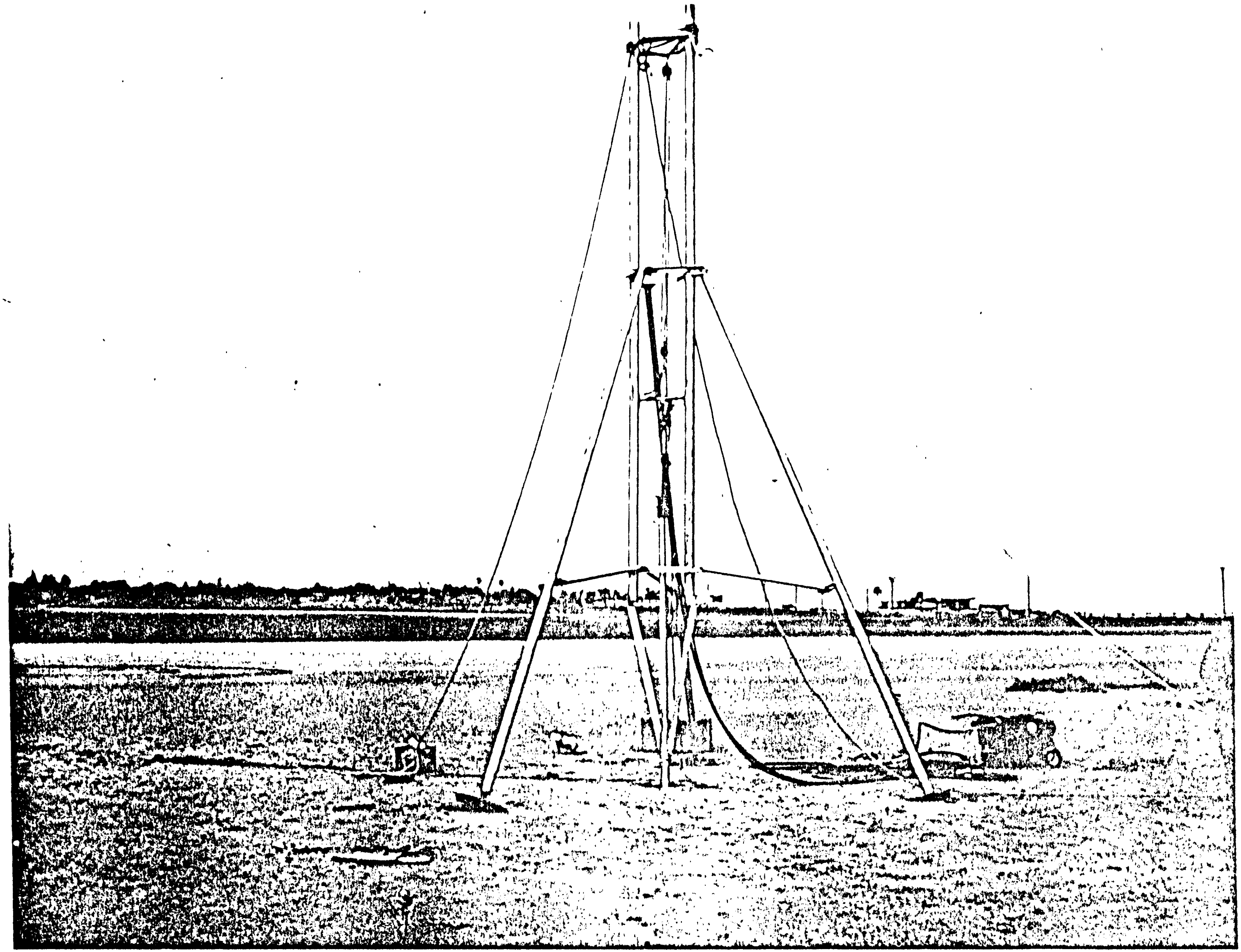


Figure Twenty-Three -- The coring rig used in the project.

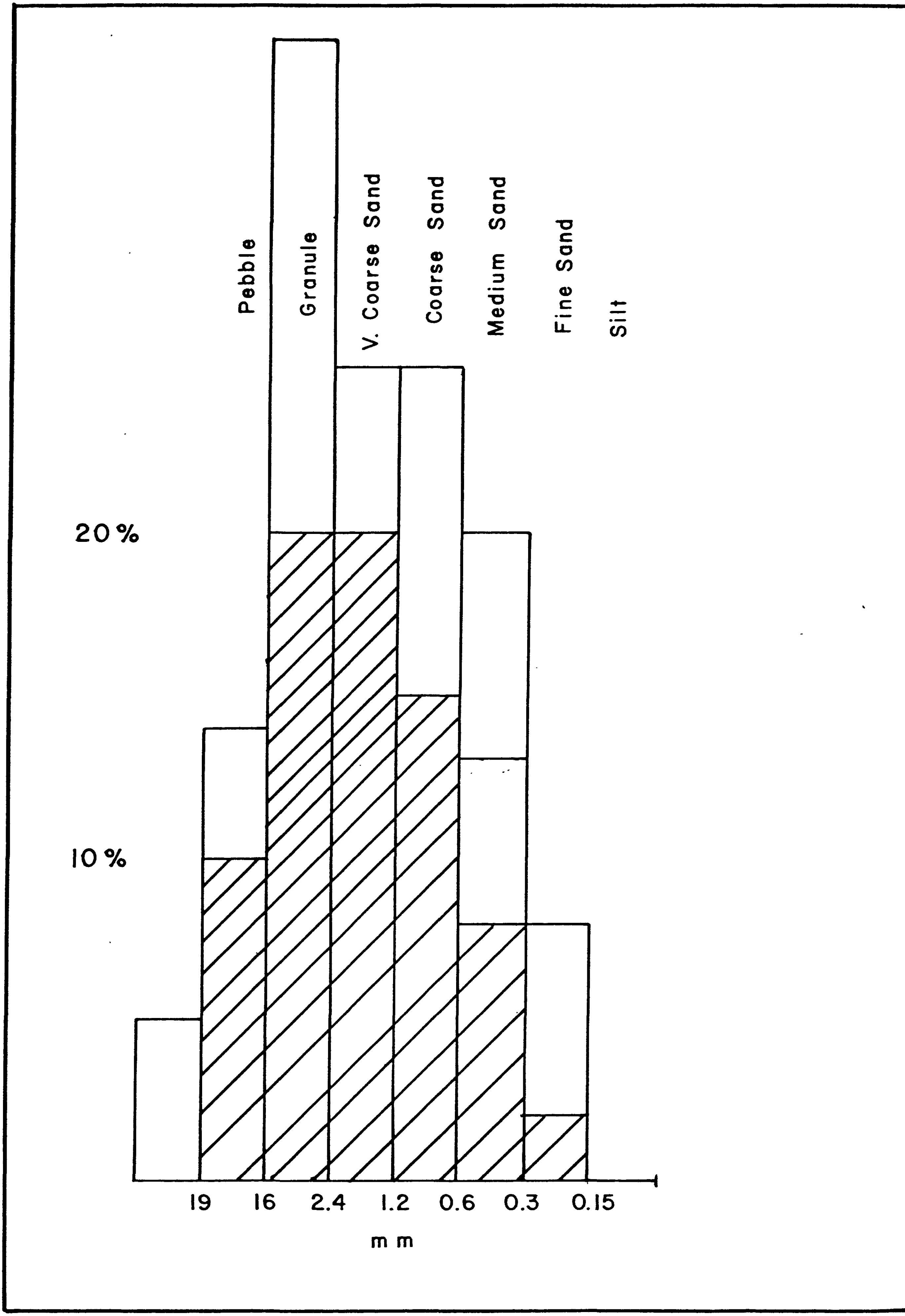


Figure Twenty-four -- Size distribution of the sand specified for airport foundation construction.

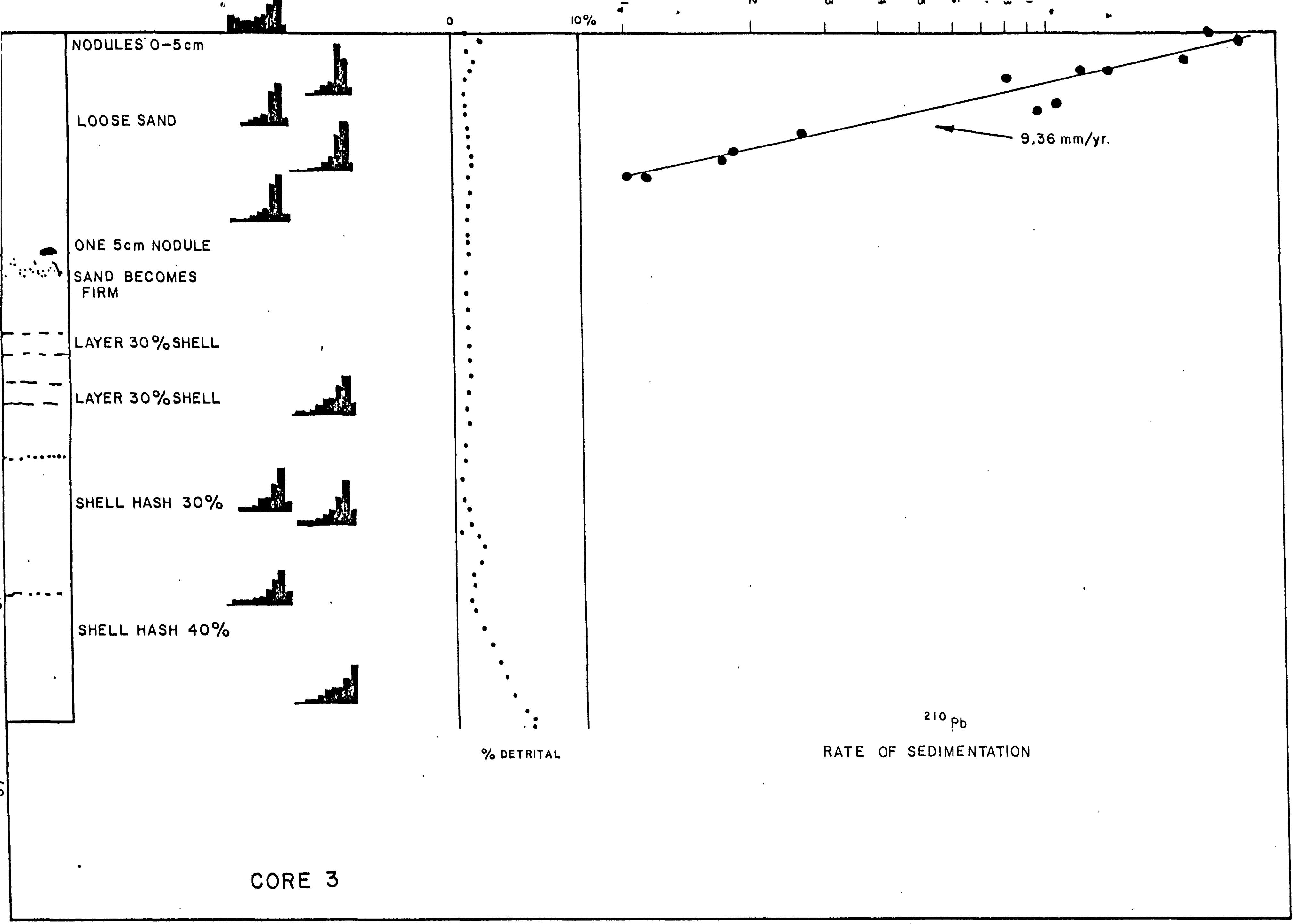


Figure Twenty-five -- Data for Core Three, including description, size distribution, non-carbonate contribution and rate of sedimentation.

year's study is being undertaken to fill the gaps in our knowledge so that the sediment budget can be detailed. These studies include continued laboratory analyses into the chemical, biological, and mineralogical nature of the sediments. In addition, more field data is to be collected on the rate of carbonate production by determining the ratio of live to dead carbonate producers in the environments of the shelf. More samples will be collected from the reef masses for radiometric dates in order to establish a time frame of reef and sediment development.

In addition, during the coming year, the two regions south of St. John will be investigated in detail. Along with this survey, a side scan sonar survey will be made in the sand wave area. Current measurements will also be made near the sea floor at selected sites. This information will fill in the data gaps and provide information for a comprehensive sediment budget.

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