GEOLOGICAL RECONNAISSANCE SURVEY OF SABA BANK, CARIBBEAN SEA

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ABSTRACT: A preliminary geological survey was made of Saba Bank, a little known, shallow submarine bank located 5 km southwest of the small volcanic island of Saba, in the Leeward. Islands of the eastern Caribbean. Bathymetric, sedimentological and biological data indicate little modern aggradation on Saba Bank, which has minimal reef development and is characterized by sediments rich in residual material derived from late Cenozoic limestone bedrock.

INTRODUCTION

SABA Bank (17°25'N, 63°30'W), one of the few isolated submarine banks in the Caribbean Sea, has never been the subject of firsthand investigations, although mentioned in several discussions of island development such as the well-known Vaughan-Davis "lagoon infilling" controversy (Vaughan, 1919; Davis, 1926). Because marine sediments probably do not accumulate rapidly here, as they do in some shallow subtidal, intertidal and terrestrial environments, Saba Bank offers an interesting area for study. Our observations of the sediments, bathymetry, and bottom communities, however, comprise only a first reconnaissance, which is based on three transects across the bank and several short transects over a ridge along the southeastern edge of the bank platform. (Fig. 1). This work was undertaken during R/V EASTWARD Caribbean Cruise E-33D-70/71.

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BATHYMETRY

Saba Bank is 5 km southwest of the small (12-km square) volcanic island of Saba and 140 km east-southeast of St. Croix, U.S. Virgin Islands. As delineated by the 100-m depth contour on published bathymetric charts, the bank is a completely submerged platform 20-30 m below sea level that covers 1300 sq km. It is raised about 1000 m above the general depths of the sea floor in the vicinity of Saba Island, the only landmass in the immediate area, from which it is separated by a trough 700 m deep (Westermann and Kiel, 1961). Two other shoal areas comparable in size to Saba Island occur north and northwest of Saba Bank (Fig. 1).

Our bathymetric chart (Fig. 1), which was constructed from echo soundings and bathymetric data compiled by J. G. Newton (pers. comm., 1971), indicates that Saba Bank is almost elliptical in shape, the long axis trending ENE-WSW. The platform surface rises from depths of 50 m on its western edge to 7-15 m on its eastern and southeastern edges, where a prominent ridge system (55 km long) borders the platform. Echo-sounding profiles revealed a smooth surface across the bank (Figs. 3. 4, 5) except for one pronounced channel near the northwestern edge.

The southeasternmost margin of Saba Bank is characterized by small shelf-edge ridges (5-10 m relief) seaward of the main ridge development. In general, these shelf-edge ridges rise from an inner trough at 20-m depths to depths of 10-15 m. Most profiles show distinct breaks in the upper slope seaward of the shelf-edge ridges at depths of 70-90 m (Fig. 2).

BOTTOM PHOTOGRAPHY

One 16-exposure camera (Alpine multishot) station was carried out along the eastern and southern edge of Saba Bank. Bottom photographs indicate four characteristic surfaces on the platform edge and upper slope in this area (Fig. 2) :

Platform edge (15-30 m deep; exposures #1-7). —Alternating areas of coral communities and sand are characteristic. Coral areas contain abundant small coral heads and alcyonarians. Some sponges and benthic algae are scattered over a rock substrate. Thin patches of sand occur here and there between the widely separated coral heads. Construction of an interlocking coral framework was not evident in the photographs (Fig. 2, #7). The sandy areas separating and surrounding the coral communities consist of unconsolidated sand- and gravel-sized (2-64 mm) sediment, along with some fragments of reef debris. From the deck of the ship, these large and irregular patches of sand appeared narrow and elongate. The coral-head areas rise slightly above the general surface of the sand patches. Epifauna scattered over the sand indicate that the unconsolidated layer is relatively thin. Large (30-cm wavelength, 5-cm amplitude) but disorganized sand ripples are typical of the sand patches (Fig. 2, #4), along with some pits and mounds that indicate infaunal burrowing.

Slope A (30-110 m; exposures #8 and 9). —Unconsolidated sediment consisting of sand- and gravel-sized material is typical (Fig. 2, #9). Scattered pits and mounds formed by burrowing in fauna are indicated, but no ripples or any other features related to bottom currents. Scattered growths of small sponges (?) also were noted.

Slope B (110-190 m; exposures #10-12). —A relatively smooth, sandy bottom is indicated, with some gravel-sized material. Scattered pits, mounds and trails were noted (Fig. 2, #12).

Slope C (190-270 m; exposures #13-16). —Unconsolidated muddy sands, with little obvious gravel-sized material, are characteristic. Pits, mounds, and trails are common, but no bottom current activity was indicated. Large numbers of deep-water echinoids, *Clypeaster ravenelii* (A. Agassiz) were noted (Fig. 2, #16).

ROCK-DREDGE SAMPLES

Three rock-dredge samples were collected from the southern outer edge and upper slope of Saba Bank (16054), and from the platform edge (16080) and slope A (16081) depth zones along the camera station profile. Their description is given in Table 1.

SEDIMENT DREDGE SAMPLES

Thirty-six Pierce Box Dredge sediment samples were collected along one north-south (A-A') and two east-west (B-B' and C-C') transects (see Fig. 1). Their size, composition, and mineralogical characteristics were plotted on bathymetric cross-sections established for each transect (Figs. 3, 4, 5). Two sediment facies were evident from these profiles, a platform facies, and a slope facies.

Platform facies. — On most of the platform this facies occurs at depths less than 100 m, except along the southeast edge of the bank, where it reaches the upper slope. Skeletal grains (coral, coralline algae, *Halimeda*, mollusks, benthonic foraminifers) and abundant lithic or rock fragment grains are the chief components. The lithic grains, which are dominant in all but *Halimeda*-rich samples, consist of biomicrites and fossiliferous micrites. Largely superficial ooliths are minor components of one sample (16095) in the central area of the bank, and in three samples (16067, 16068, 16069) from the northwestern edge. Discoloration and extensive boring of numerous carbonate grains made their identification difficult, but x-ray diffraction analyses indicate largely aragonite (average 49 percent) and magnesium calcite (average 41 percent), with a significant amount of calcite (average 10 percent). For the most part, these sediments are coarsely skewed, exhibiting a wide range of sorting (well sorted to poorly sorted), and highly variable mean sizes (—0.55 ∅ to 2.30 ∅). Acid insoluble residues generally contain less than 5 percent non-carbonate (mainly quartz, feldspar, volcanic glass, and heavy minerals).

Gravel-sized rock fragments were dredged up from the bank platform in several widely spaced sediment samples (16057, 16075, 16096, see Fig. 1). Sample 16057 consists of light brown, fossiliferous micrite having a relict pelletoid texture and containing scattered. and well-preserved small gastropod, *Cerithium eburneum* Brugière; this shallow-water species (<10 m) is common in the Caribbean and ranges in age from Pleistocene to Holocene (R. S. Houbrick, 1974, pers. comm.). The limestone in 16057 is up to 20 percent argillaceous and slightly silty. Rock sample 16075 is a light, grey-brown biomicrite containing fine to coarse skeletal grains (foraminifers and mollusks) in a chalky fossiliferous micrite matrix. A variety of peneroplid and miliolid species were identified in this material, together with some rare elphidiids (R. Todd, written comm., no. 0-73-111). These foraminifers are said to be a shallow (bank) assemblage, typical of the bank west of Andros Island, which is unlikely to occur deeper than 10 m. All the identified species range widely in age, the shortest span being Oligocene to Holocene for *Elphidium poeyanum* (d'Orbigny). Some skeletal grains in sample 16075 are discolored grey to dark grey. This rock is both argillaceous and sandy, the sand grains consisting of fine quartz, feldspar and heavy minerals. Rock fragments in sample 16096 are cream-colored, fine to medium-grained, pelleted limestone. The pellets consist of micrite and fossiliferous micrite and some have a superficial oolitic coating. Medium-sized, well-rounded skeletal grains are scattered throughout. This rock contains a trace of very fine quartz sand and has a fine to very finely crystalline, blocky sparry calcite cement.

X-ray diffraction analyses of these three rock samples indicate largely magnesium calcite (average 70 percent) and aragonite (average 30 percent), and a probable trace of dolomite in sample 16057.

Slope Facies. — This facies occurs on the slope below 100-m depths, and also at the outer edge of the platform in the northern and western areas of Saba Bank. Moderately to poorly sorted fine sediments (mean 2-3 ∅ of this facies tend to be finely skewed, and contain significant amounts of silt- and clay-sized material. The carbonate components are mainly planktonic foraminifers, and varying concentrations of benthonic foraminifers, *Halimeda*, coral, coralline algal and molluskan debris. Aragonite, calcite and magnesium calcite occur in approximately equal proportions in all samples analyzed. Samples contain generally more than 5 percent non-carbonate grains (average 10 percent), consisting primarily of volcanic glass, siliceous skeletal debris, feldspar, heavy minerals, and clay minerals.

Heavy minerals. — The heavy mineral suites in the sediments of both facies consist mainly of orthopyroxenes and clinopyroxenes, with lesser amounts of hornblende and magnetite. This pyroclastic heavy mineral assemblage is similar to that reported in sediments off the west coast of Barbados (Macintyre, 1970), where the pyroclastic components derive mainly from La Soufrière on the island of St. Vincent.

Discussion

Although not directly observed, Saba Bank previously has been discussed and interpreted in several ways: e.g., "remnant of the coastal plains on the Caribbean side of the mountainous backbone of the Antillean ridge" (Spencer, 1904, p. 357); a submarine plateau "leveled by planation agencies, which almost certainly were both subaerial and submarine" (Vaughan, 1919, p. 304); and "an atoll-lagoon floor, deprived of its original reef and probably somewhat planed down by low-level abrasion in the post glacial epoch" (Davis, 1926, p. 138). It is particularly interesting to note that Saba Bank figured in the "lagoon infilling" controversy in which Vaughan suggested that "no one would try to explain Saba, Rosalind, or Pedro Bank as the result of infilling behind barrier reefs" (1919, p. 304), whereas Davis (1926) suggested that lagoon infilling behind mid-Tertiary reefs was an "essential process" in the formation of "platform masses" such as Saba Bank.

Initially, it was thought that our air-gun subbottom profiles across the bank might throw some light on this question, but the surveys lacked sufficient subbottom penetration to disclose information about internal structure. Consequently, the internal structure of Saba Bank remains unknown.

Our limited data from the ridge along the southeastern edge of Saba Bank indicate a sparse coral cover consisting of small heads of deep-reef hermatypes and alcyonarians. This epibenthic assemblage, which includes abundant crustose coralline algae and sponges, is comparable to that noted on many relict shelf-platform and shelf-edge submerged reefs in the eastern Caribbean (Macintyre, 1972). As in the case of deeper communities associated with most of these submerged reefs, the Saba community shows no sign of forming an interlocking reef framework. The Saba Bank ridge, however, cannot be considered a submerged reef because the ridge system, including the small shelf-edge features, occurs well within the depth range required for vigorous growth of reef-building corals (Macintyre, 1972).

Cores from this ridge obviously are needed before we can speculate on its age of formation and relationship to pre-existing sea levels. Marked breaks in the upper slope (Fig. 2), however, occur at a depth at which similar inflection points have been reported off most eastern Caribbean islands (Macintyre, 1972). These features were believed to have formed during a stillstand in the Holocene transgression at approximately 80 m below present sea level.

The distribution of the two characteristic sediment facies of Saba Bank appears to be controlled largely by the degree of agitation on the sea floor, which in turn is related to wind and current direction, and water depth. This relationship is clearly demonstrated by the occurrence of fine pelagic sediments from the slope facies in depths of less than 50 m only in the northwestern and western areas of the bank platform, i.e., leeward of the westerly currents (U.S. Navy Oceanographic Office, 1973) and trade winds of this area. The coarser sediments of the platform facies, on the other hand, extend below 100 m on transects across the windward eastern and southeastern edges of the bank.

A predominantly residual origin for the coarser platform facies sediments is indicated by the lithological similarity between the dominant lithic components in this facies and the late Cenozoic shallow-water limestones dredged from the same area. Relatively large quantities of calcite in most samples from this area also suggest erosion of bedrock on Saba Bank. Although the time of erosion of this material is difficult to determine, the grey and black discoloration of many carbonate grains in the mud-free sediments of the platform facies suggests exposure to pre-existing anaerobic conditions, such as tidal marsh environments during Pleistocene or post-Pleistocene sea-level fluctuations (Doyle, 1967; Macintyre, 1970).

Taken together, the residual sediments of the Saba platform facies, the rock fragments of late Cenozoic shallow-water deposits on the platform, and the absence of reef development, all suggest a rather thin veneer of modern material on Saba

Bank (i.e., deposited in relation to present sea level). This suggestion, however, contradicts Spencer's contention that the bank surface "has been leveled by coral growth and sands derived from them" (1904, p. 357). Nor does it agree with Davis's (1926) suggestion of "postglacial aggravation with respect to present sea level" (p. 138) to explain the depths of this and other banks.

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TABLE 1

DESCRIPTION OF ROCK DREDGE SAMPLES

Station No.	*Depth Interval In Meters*	*Sample*	*Significant Live Material*
16054	40-100	Coral debris lightly encrusted by sponges and crustose coralline algae.	Sponges and Alcyonarians are abundant. Corals included—: *Agaricia* sp., *Montastrea annularis, Porites porites, Stephanocoenia michelinii.*
16080	15-45	Rounded and crustose coralline algal and foraminiferal encrusted coral debris	Corals, alcyonarians and sponges. Corals included—: *Stephanocoenia michelinii, Agaricia* sp., *Siderastrea siderea, Porites porites, Diploria strigosa, Colpophyllia natans, Montastrea annularis, Montastrea cavernosa, Meandrina meandrites,, Mycetophyllia lamarckiana.*
16081	30-80	Large fragments of bored and crustose coralline algal and foraminiferal encrusted coral debris	Sponges and a few alcyonarians. One small colony of *Madracis decactis.*

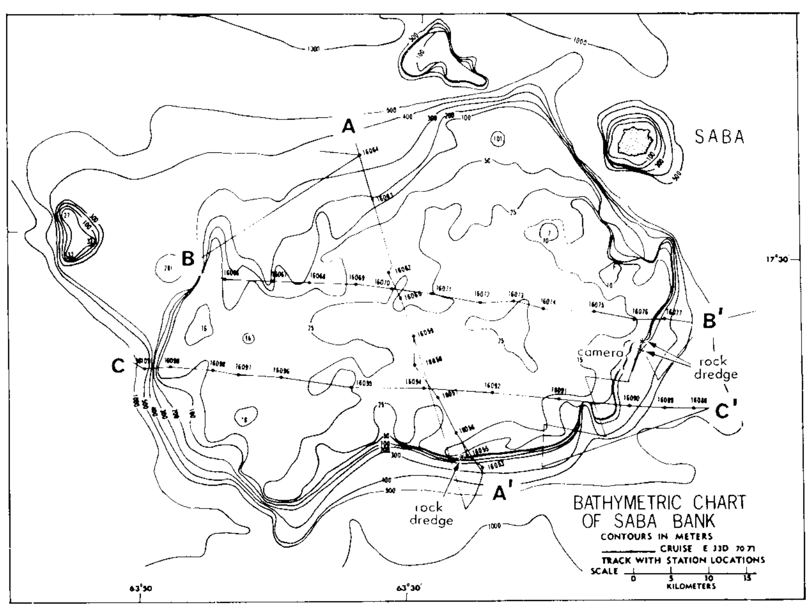


FIG. 1.—Bathymetric map of the study area showing locations of sediment and rock-dredge samples, the bottom camera station, and cross-sections given in Figs. 3, 4, 5.

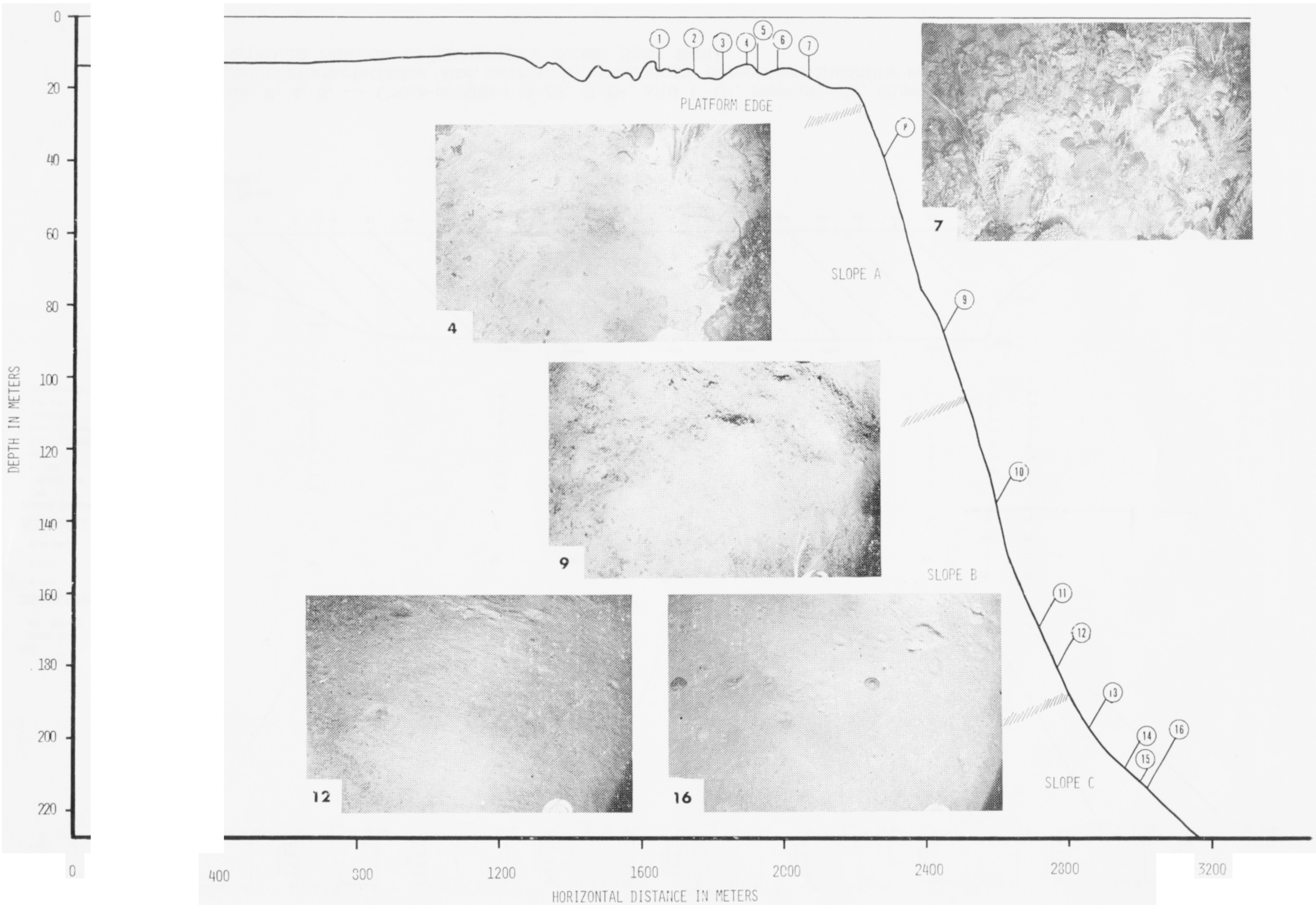
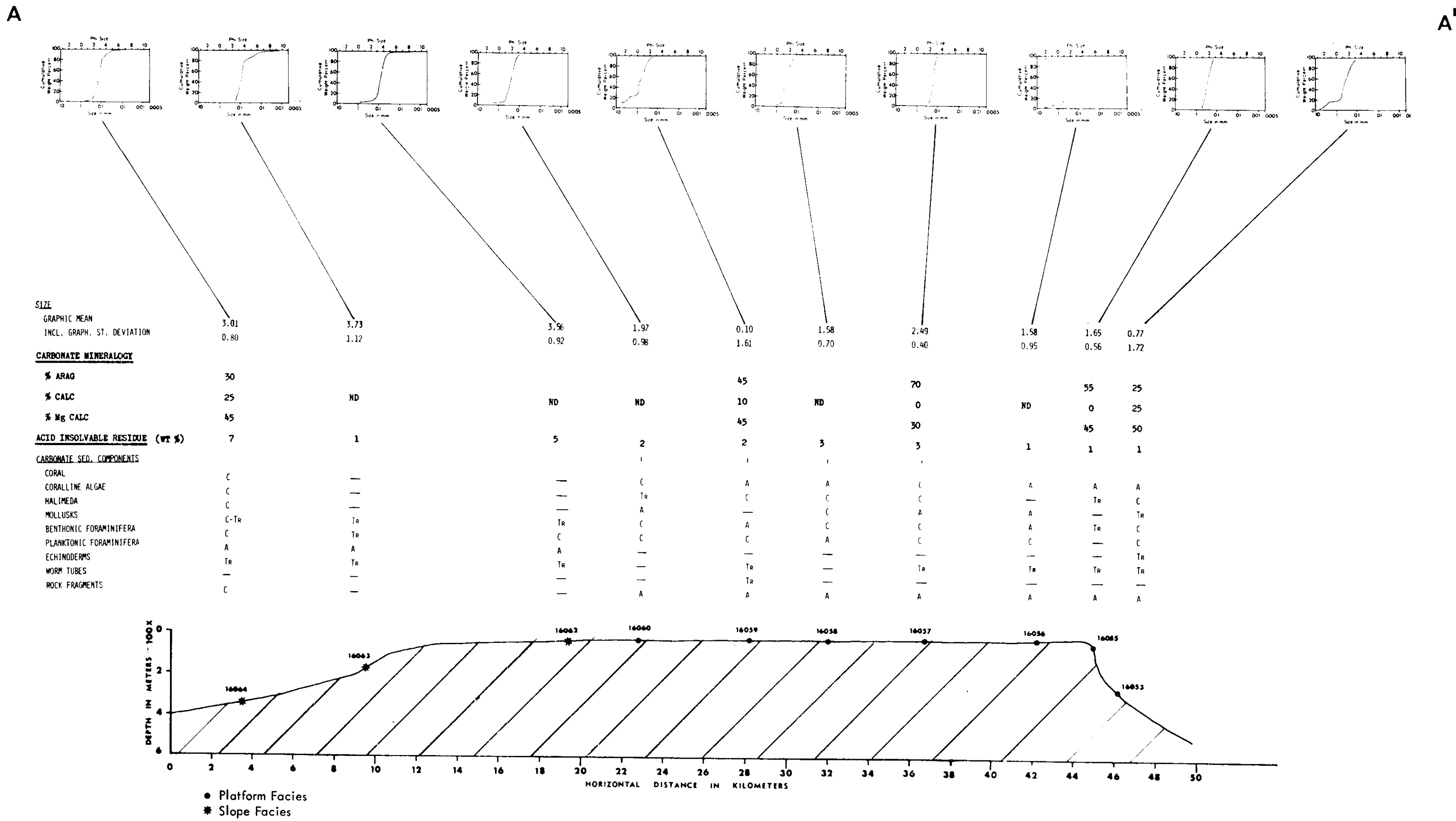


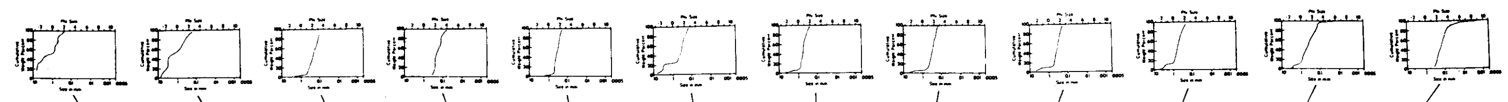
FIG. 2.—Bathymetric profile of camera station with representative photographs of different bottom types: #4 — Sand patches that occur between coral-head areas; #7 — Scattered coral heads and alcyonarians on a rock substrate; #9 — Sand and gravel-sized sediment bottom; #12 — Sandy bottom with marked decrease in gravel-sized material; #16 — Muddy sands and echinoids.



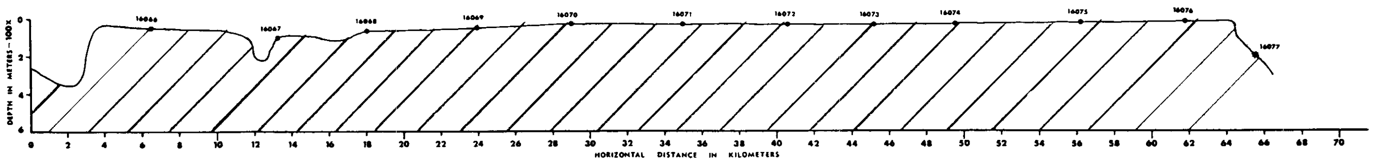
FIGS. 3, 4, 5. — Cross-sections A-A[1], B-B[1], and C-C[1], respectively, showing the distribution of sediment characteristics (size, carbonate mineralogy, percentage insoluble residue and carbonate grain type) in relation to bathymetry across Saba Bank.

B

B'

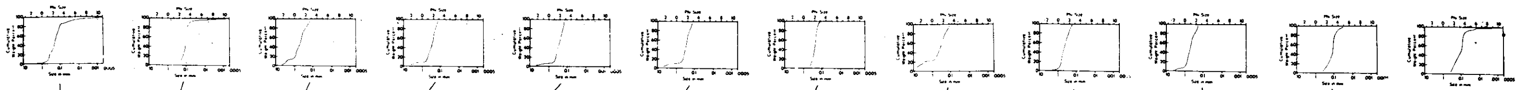


	16066	16067	16068	16069	16070	16071	16072	16073	16074	16075	16076	16077
SIZE												
GRAPHIC MEAN	-0.45	-0.55	2.30	2.51	1.49	0.78	0.93	1.79	1.50	0.92	1.44	2.87
INCL. GRAPH. ST. DEVIATION	1.7	1.77	0.87	0.67	0.53	1.79	0.79	0.96	0.94	1.02	1.35	1.17
CARBONATE MINERALOGY												
% ARAG		20	45	45	40	55	55	75	75	55	35	40
% CALC	ND	20	20	0	10	0	0	0	5	5	20	25
% Mg CALC		55	35	50	50	45	45	25	20	40	45	35
ACID INSOLVABLE RESIDUE (% 1a)	1	[illegible]	8	11	3	3	2	3	2	1	2	35
CARBONATE SED. COMPONENTS												
CORAL	—	A	C	C	C	C	Tr	Tr	C	A	C	C
CORALLINE ALGAE	C	C	C	Tr	—	C	—	Tr	—	Tr	C	C
HALIMEDA	—	A	C	A	C	A	A	A	A	Tr	C	C
MOLLUSKS	A	A	C	C	A	C	A	C	A	A	C	C
BENTHONIC FORAMINIFERA	A	A	C	Tr	A	C	—	Tr	—	C	C	A
PLANKTONIC FORAMINIFERA	—	—	—	—	—	—	—	—	—	—	C	C
ECHINODERMS	Tr	—	Tr	Tr	—	—	—	—	—	Tr	Tr	Tr
WORM TUBES	Tr	C	—	—	—	—	—	—	—	—	—	Tr
ROCK FRAGMENTS	A	A	C	C	A	C	A	—	A	A	C	A

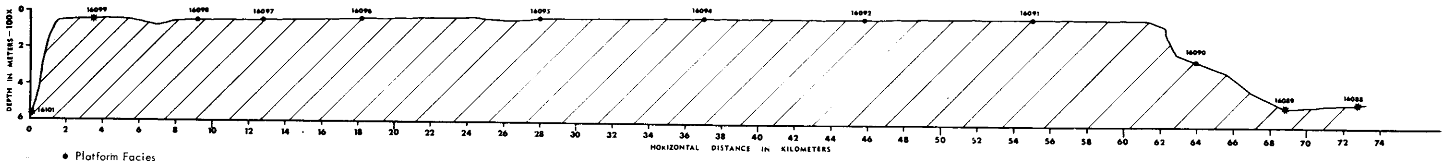


• Platform Facies
● Slope Facies

C C'



	16101	16099	16098	16097	16096	16095	16094	16092	16091	16090	16089	16088
<u>SIZE</u>												
GRAPHIC MEAN	2.33	3.03	0.92	1.73	1.86	1.82	2.12	0.65	1.15	1.03	2.92	3.05
INCL. GRAPH. ST. DEVIATION	1.47	0.56	1.36	1.10	1.02	1.23	0.47	2.05	.77	1.00	0.91	1.16
CARBONATE MINERALOGY												
% ARAG	35		25	40	35	45	55		75	60		25
% CALC	35	ND	10	15	10	10	10	ND	5	10	ND	45
% Mg CALC	25		65	40	55	40	35		20	30		25
ACID INSOLVABLE RESIDUE	3	6	2	1	4	1	2	2	1	1	11	15
<u>CARBONATE SED. COMPONENTS</u>												
CORAL	—	C	C	C	A		C	A	A	—	C-Tr	Tr
CORALLINE ALGAE	—	Tr	A	C	C	C	—	C	Tr	—	C	—
HALIMEDA	Tr	C	A	A	A	A	A	C	A	A	C	—
MOLLUSKS	Tr	C	C	A	A	A	A	A	A	A	C Tr	C
BENTHONIC FORAMINIFERA	—	C	C	C	A	C	C	C	Tr	—	C	—
PLANKTONIC FORAMINIFERA	A	A	—	—	—	—	—	—	—	—	A	A
ECHINODERMS	Tr	—	—	Tr	—	—	—	Tr	—	—	Tr	Tr
WORM TUBES	Tr	—	Tr	—	—	—	—	Tr	Tr	—	Tr	—
ROCK FRAGMENTS	C	C	C	A	—	A	—	A	A	—	C	C



● Platform Facies
● Slope Facies