MAPS SHOWING THE SURFICIAL GEOLOGY OF THE CULEBRA SHELF, PUERTO RICO

by

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INTRODUCTION

This study presents the surficial and shallow subbottom geology of the insular shelf around Culebra, Puerto Rico. In view of the need for sand and gravel for construction purposes in the area (Rodriquez and Trias, 1989), we inferred the thickness of unlithified, surficial sediment deposits from high-resolution acoustic-reflection profiles and described seafloor sediment samples collected with a Shipek grab. Previous work in the region includes description and classification of the surficial sediment on the Virgin Island platform by Anderson (1981) and Prehmus (1981).

METHODS

Acoustic-reflection profiles

High-resolution subbottom profiles were collected over 343 km of trackline in water depths greater than about 20 m, using an ORE Geopulse boomer-type source that generated a 300-3000 Hz signal at 175 joules and a firing rate of 0.5 seconds. Return signals were received through a Benthos hydrophone with 10 elements spaced approximately 0.3 m apart and routed to a Geopulse 5211A signal processor for amplification and filtering. The processed signal was displayed on an EPC Graphic Recorder at a 125-ms scale with annotation at 5-minute intervals.

An ORE 140 3.5-kHz high-resolution subbottom profiler also was used, and the analog record was displayed simultaneously with the boomer data at a 125-ms scale. The 3.5-kHz system was fired at a 0.25 or 0.5-ms rate.

Navigation control was by P-code global positioning, using a Rockwell International Precision Lightweight GPS receiver (PLGR+) that provided position data every 10 seconds with an accuracy of ±15 meters. The data were logged on a disk through a PC-based navigation program. A Datamarine digital fathometer provided bathymetric data that were logged along with the position information.

We measured the thickness of sand deposits to the nearest meter, nominally at 5-minute intervals on the subbottom profiles, using an assumed acoustic velocity of 1520 m/s. The measurements are shown on the map. Because of the source reverberations in the return signal, we were unable to map reflectors less than about 2 m below the seafloor. Thus any sand accumulation <2 m thick is acoustically unresolvable and has been assigned a thickness value of zero.

Bottom samples

Bottom samples were collected with the Shipek grab sampler at 32 offshore stations. Seventeen sediment samples were collected on beaches around Culebra. Analyses of the samples were carried out according to Poppe and others (1984). Coarse and fine size fractions were separated by wet sieving. The coarse fraction was then dry-sieved and the fine fraction analyzed with a Coulter Counter. Percent carbonate was determined following sample treatment with dilute HCl.

Bathymetry

Aurelio Mercado (written communication, 1993) of the Marine Science Department, University of Puerto Rico (UPR), Mayaguez, compiled bathymetric soundings from National Oceanographic and Atmospheric Administration (NOAA), National Ocean Service (NOS). Additional data were digitized and corrected with the assistance of Kurt Grove and Bruce Taggart (UPR). The work was funded by a grant to the UPR Sea Grant College Program (project number R/OE-25-10). K.M. Scanlon (USGS) digitized a coastline from 1:100,000-scale charts. To provide a positive elevation for the islands, one-meter high areas were assigned to the coastline polygons. We gridded the combined island and bathymetry data set on a 100-m grid cell with an inverse-distance weighted calculation. Contours were extracted from the resulting grid with a 2-m interval from 0 to 50 m depth and with a 50-m interval from 50 m to maximum depth.

RESULTS

Seismic-reflection profiles

Extensive surficial sedimentary deposits appear on all profiles north of Culebra, in water depths from less than 40 m near the island to about 100 m at the shelf break. Two situations can be discriminated (Map 1): 1) flat seafloor, with a continuous sediment blanket that generally is underlain by concordant reflectors (presumed to be stratified bedrock) (Figure1) and 2) uneven seafloor, with sediment accumulations in the valleys between hilly reef exposures and underlain by irregular, buried-reef topography (Figure 2). The two types of deposits are contiguous: sediment has aggraded over reef topography in some places and over horizontally stratified bedrock in others. The boundary of the flat sediment blanket typically is an abrupt termination against an exposed reef (Figure 1), although in a few places it terminates more gradually against low hills in the stratified bedrock surface. The light-brown shaded areas on the map depict the areas that have discontinuous reef exposures, as determined from the profiles. The areas are highly generalized from sparse data, and they probably extend beyond our designation.

The greatest measured sediment thickness north of the island is 11 m, but most measurements fall within the range of 4 to 7 m (Map 1). Thickness variations of the blanket are mainly due to low, rolling relief of the underlying bedrock surface; the blanket is thinner over high areas of this surface. Generalized thickness contours of the surficial sediment deposit are shown on Map 2.

Local sediment accumulations of measurable thickness appear south, east, and west of Culebra. Detailed surveys are required to confirm and delineate these areas as potential economic sources for sand and gravel. However, most places on the subbottom profiles do not show a subbottom reflector, implying less than the minimum measurable thickness of surficial sediment. A large sediment deposit - the Escollo de Arenas - extends a distance of about 6 kilometers from the northwest corner of the Vieques island, southwest of Culebra (Rodrigues and Trias, 1989). It reaches a maximum thickness of 17 m and has a volume of about 95x10^6 m^3.

Sediment samples

The station locations, plus textural and compositional properties of the sediment samples are listed in Tables 1-4. The shelf sediment samples are predominantly composed of carbonate grains with little or no terrigenous material, and most have a mean grain size in the sand size class. The color typically is white to tan. The sand-size grains are skeletal carbonate, grading to gravel-size fragments of broken mollusk shells and coral. The distribution of samples can be grouped into gravelly sand, sand, and muddy sand categories (Map 2). We recovered sediment samples at some locations where a subbottom reflector does not appear on the profiles, which implies an accumulation less than 2 m thick.

The beach samples typically are sand, with low to moderate amounts of gravel and small amounts of mud. Several of the samples have a significant portion of terrigenous grains, undoubtdely reflecting nearness to a source of detritus eroded from exposed rocks on the island. Many of the shelf and beach samples have a similar median grain size (Figure 4), but the beach samples tend to be better sorted with low silt + clay (mud) component.

Compositionally, the Culebra shelf has a relatively homogenous carbonate sediment cover with small amounts of insoluble residue. In particular, because there are no large rivers on Culebra, the shelf lacks the extensive deposits of terrigenous-rich carbonate mud and more local deposits of terrigenous sand that exist around Puerto Rico island to the west (Schneidermann et al., 1976). The Culebra shelf deposits are more uniformly carbonate rich than the potential offshore sand sources described by Grove and Trumbull (1978), which have mapable units of terrigenous-rich carbonate sand.

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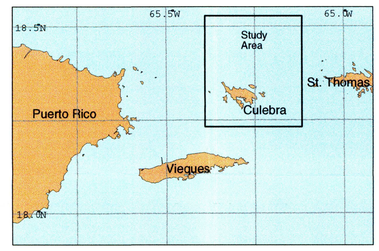

Table 1. Location, texture, and composition of offshore samples

Sta.	Latitude	Longitude	Percent carbonate	Percent gravel	Percent sand	Percent silt	Percent clay	Percent silt +clay	Mean (ϕ)	Visual description
1	18 30.89	-65 20.59	98.9	14.6	73.7	10.8	1.0	11.8	1.5	Carbonate sand w/ shell fragments
2	18 29.40	-65 20.14		82.6	17.4	0.0	0.0	0.0	-3.5	Carbonate gravel w/ coral and shell fragments
3	18 28.02	-65 20.15	99.1	26.7	70.4	2.0	0.5	2.5	0.0	Carbonate sand w/ shell fragments
4	18 26.39	-65 19.99	98.9	35.6	47.6	15.0	1.7	16.7	0.6	Carbonate sand w/ coral and shell fragments
5	18 24.98	-65 20.04	98.7	41.5	50.1	7.5	0.9	9.4	-0.2	Carbonate sand w/ coral and shell fragments
6	18 23.39	-65 20.06	96.1	0.4	24.9	73.3	1.4	74.7	4.3	Sandy carbonate mud
7	18 21.89	-65 20.00	99.6	2.0	97.4	0.4	0.2	0.6	0.5	Carbonate sand
8	18 21.89	-65 15.08	98.2	0.6	49.8	49.2	0.5	50.7	3.8	Muddy carbonate sand
9	18 23.51	-65 15.02	98.3	0.3	39.3	59.3	1.1	60.4	4.0	Sandy carbonate mud
10	18 24.95	-65 15.01	97.2	0.1	28.2	69.8	1.9	71.7	4.4	Sandy carbonate mud
11	18 26.40	-65 15.04	96.9	0.8	23.7	73.0	2.5	75.5	4.5	Sandy carbonate mud
12	18 28.02	-65 15.14	99.5	30.3	63.2	5.7	0.8	6.5	0.1	Carbonate sand w/ coral and shell fragments
13	18 29.55	-65 15.13	98.0	2.6	36.1	60.9	0.4	61.3	3.9	Muddy carbonate sand
14	18 30.95	-65 15.14	99.6	39.9	57.4	2.2	0.6	2.8	-0 5	Carbonate sand w/ shell fragments
15	18 31.11	-65 10.08	99.9	25.4	73.0	1.2	0.5	1.7	-0.1	Carbonate sand w/ shell fragments
16	18 29.44	-65 10.10		66.8	20.3	10.6	2.2	12.8	-1.6	Carbonate sand w/ coral and shell fragments
17	18 27.93	-65 10.13	100.0	3.7	95.4	0.6	0.3	0.9	0.6	Carbonate sand w/ shell fragments
18	18 26.44	-65 10.12	98.3	0.2	62.2	36.3	1.2	37.5	3.7	Muddy carbonate sand
19	18 24 86	-65 10.06	98.3	0.0	74.2	24.2	1.6	25.8	3.4	Muddy carbonate sand
20	18 23 43	-65 10.07	99.4	30.8	66.8	1.8	0.5	2.3	-0.0	Carbonate sand w/ coral and shell fragments
21	18 21.92	-65 10.10		52.2	43.6	3.9	0.3	4.2	-1.2	Carbonate sand w/ coral and shell fragments
22	18 20.04	-65 09.99	99.8	45.8	52.3	1.5	0.4	1.9	-0.7	Carbonate sand w/ shell fragments
23	18 19.98	-65 13.04		56.4	41.3	1.9	0.5	2.4	-1.6	Carbonate sand w/ coral and shell fragments
24	18 17.92	-65 12.00		99.5	0.5	0.0	0.0	0.0	-5.4	Coral fragments
25	18 17.94	-65 09.98	99.9	2.2	96.4	0.9	0.5	1.4	0.8	Carbonate sand w/ shell fragments
26	18 16.88	-65 10.03		96.3	2.4	1.2	0.1	1.3	-4.9	Coral chunk
27	18 17.09	-65 12.98		67.9	13.3	15.7	3.0	18.7	-1.0	Carbonate gravel w/ coral fragments
28	18 14/92	-65 10.01		99.6	0.4	0.0	0.0	0.0	-5.4	Coral fragments
42	18 20.34	-65 22.94	98 8	8.8	89.9	0.9	0.4	1.3	0.9	Carbonate sand
43	18 19.15	-65 21.78		18.5	81.3	0.2	0.1	0.3	0.2	Carbonate sand
44	18 16.94	-65 20.15	99.6	2.9	92.6	3.8	0.6	4.4	2.0	Carbonate sand
49	18 15.80	-65 15.01	99.9	1.5	95.3	3.1	0.2	3.3	1.4	Carbonate sand w/ coral fragments

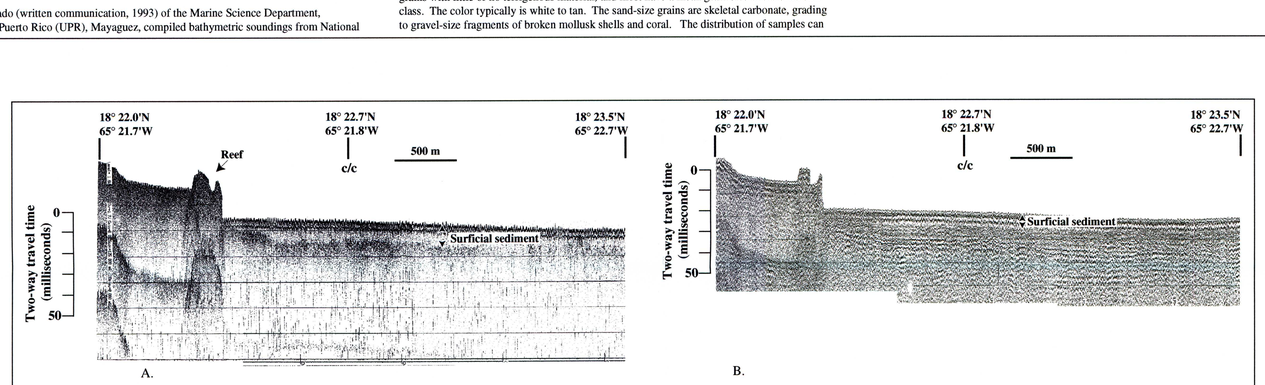

Figure 1. 3.5-kHz (A) and boomer (B) profiles of the edge of the sand blanket where it terminates against a reef. The boomer profile indicates stratified bedrock beneath the surficial sediment blanket. Location indicated on Map 1.

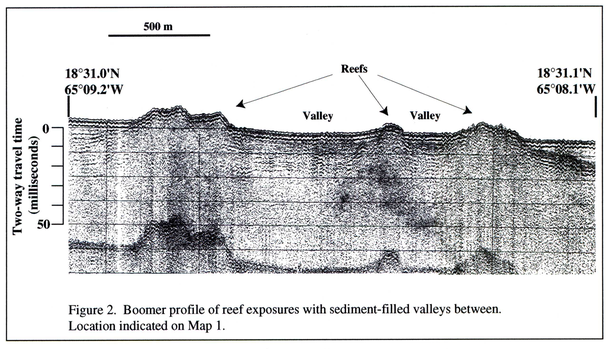

Figure 2. Boomer profile of reef exposures with sediment-filled valleys between. Location indicated on Map 1.

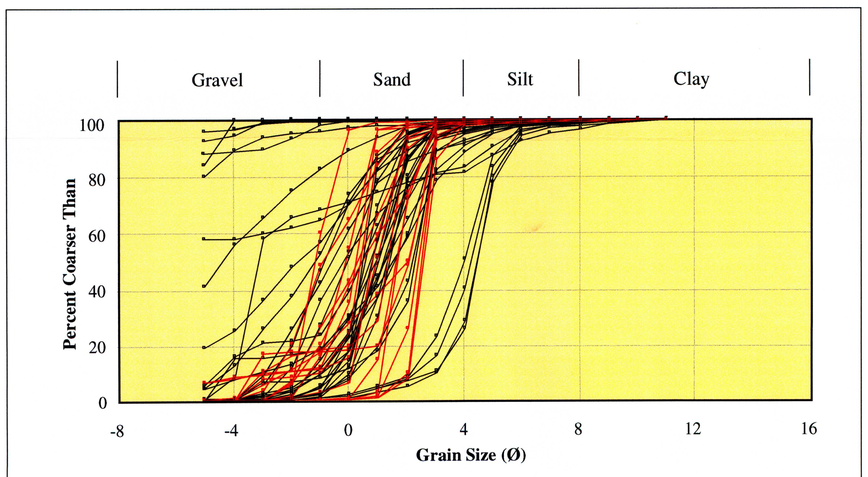

Figure 3. Cumulative grain sizes of shelf sediment samples (black) and beach samples (red).

Table 2. Summary statistics of offshore samples

	Percent carbonate	Percent gravel	Percent sand	Percent silt	Percent clay	Percent silt +clay
Maximum	100.0	99 6	97.4	73 3	3.0	75.0
Minimum	96.1	0.0	0.4	0.0	0.0	0.0
Mean	98.8	29.9	52.5	16.7	0.8	17.9
Std. Dev.	1.0	32.6	30.1	24.7	0.8	25.1

Table 3. Location, texture, and composition of beach samples

Sta.	Latitude	Longitude	Percent carbonate	Percent gravel	Percent sand	Percent silt	Percent clay	Percent silt +clay	Mean (ϕ)
200	18 16.97	-65 17.15	92.7	2.3	96.2	1.2	0.3	1.5	1.0
201	18 18.18	-65 18.57	95.5	17.4	81.5	0.8	0.3	1.1	1.2
202	18 18.18	-65 18.63	86.2	11.2	87.5	0.8	0.5	1.3	0.5
203	18 16.87	-65 17.18	20.9	59.5	40.2	0.2	0.1	0.3	-1.1
204	18 19.38	-65 15.38	92.9	0.0	98.6	1.1	0.3	1.4	2.5
205	18 17.82	-65 15.93	41.5	19.7	79.5	0.7	0.1	0.8	0.6
206	18 17.82	-65 15.43	62.0	16.0	82.5	1.1	0.4	1.5	-0.1
207	18 17.82	-65 16.62	14.6	25.6	72.8	1.2	0.4	1.5	0.3
208	18 19.70	-65 19.00	98.3	0.0	98.6	1.1	0.3	1.4	2.6
209	18 19.10	-65 19.05	42.3	48.1	51.4	0.3	0.2	0.5	-0.6
210	18 17.82	-65 18.03	79.8	17.1	81.7	0.8	0.4	1.2	1.1
211	18 18.40	-65 14.72	98.1	11.9	86.7	0.9	0.5	1.4	-0.2
212	18 18.32	-65 15.05	95.8	9.6	89.1	0.8	0.5	1.3	0.2
213	18 19.92	-65 16.98	96.4	0.0	99.7	0.2	0.1	0.3	1.8
214	18 20.27	-65 19.50	95.7	17.6	81.7	0.6	0.1	0.7	0.8
215	18 19.87	-65 18.00	98.7	0.0	98.1	1.4	0.5	1.9	2.4
216	18 19.40	-65 19.82	94.1	0.0	98.9	0.9	0.2	1.1	1.7

Table 4. Summary statistics of beach samples

	Percent carbonate	Percent gravel	Percent sand	Percent silt	Percent clay	Percent silt +clay
Maximum	98.7	59.5	99.7	1.4	0.5	1.9
Minimum	14.6	0.0	40.2	0.2	0.1	0.3
Mean	76.8	15.1	83.8	0.8	0.3	1.1
Std. Dev.	28.9	16.9	16.6	0.4	0.2	0.5