Marine geologic map of the Puerto Rico insular shelf

Isla Caja de Muertos Area

by

David K. Beach and James V. A. Trumbull

Introduction

This marine geologic map covers the western half of the Isla Caja de Muertos shelf off the south coast of Puerto Rico. Coverage extends from Playa de Ponce on the west to Punta Petrona, near the town of Santa Isabel, on the east, a distance of 26 km (fig. 1). Within the mapped area the shelf ranges in width from a minimum of 4 km to a maximum of 18 km. Glover (1971, p. 89) named the shelf for the prominent Isla Caja de Muertos, a small upfaulted block of lower and middle Tertiary rocks located near the center of the map area. The Isla Caja de Muertos shelf is not known to be bounded by faults, though Glover suggested faults on the west and south boundaries, and the bathymetry of the insular slope reveals a large east-west fault about 6 to 8 km south of the shelf edge.

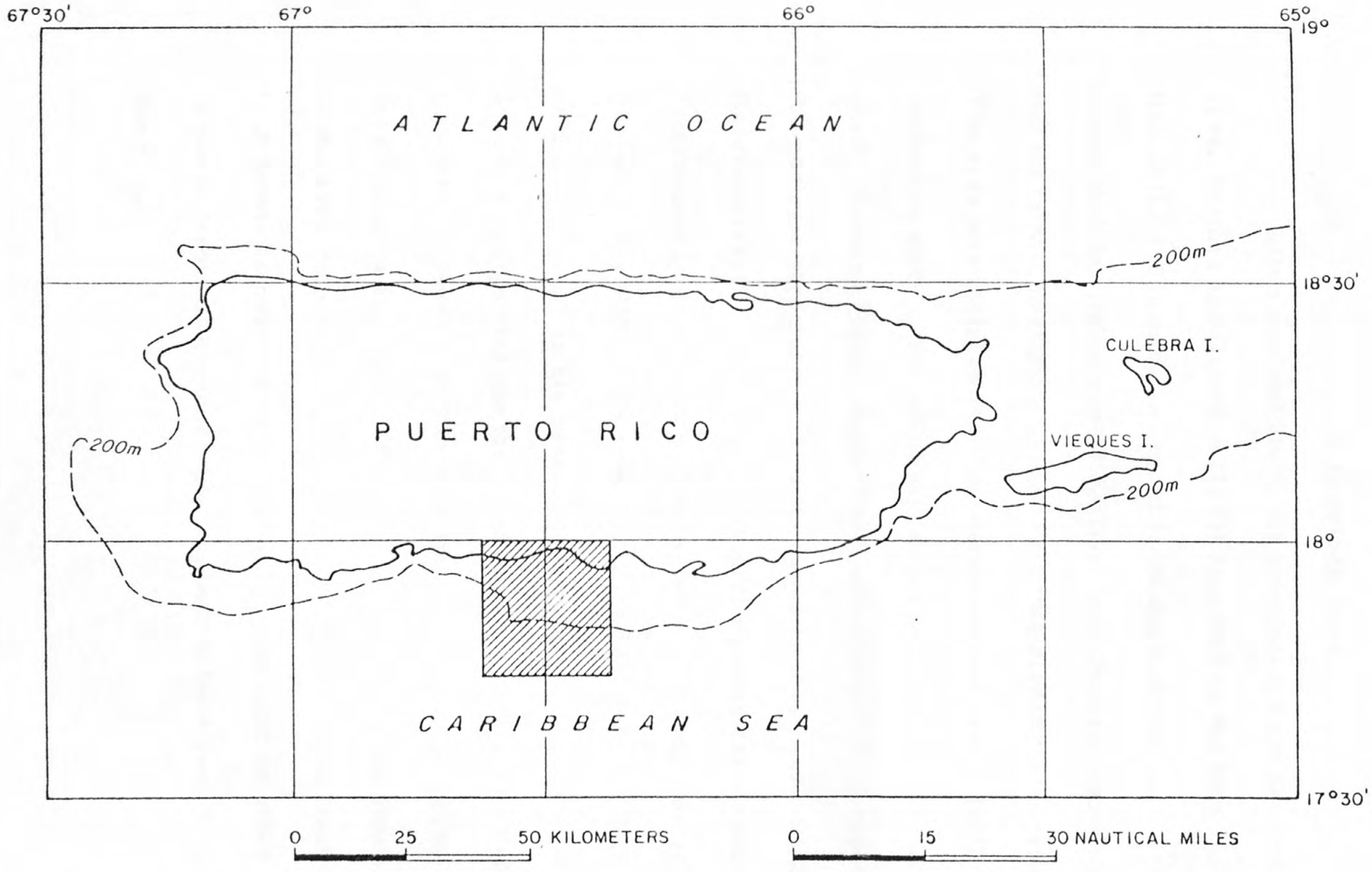


Figure 1. INDEX MAP

SHOWING LOCATION OF MAPPED AREA

Previous work

Little detailed study has previously been devoted to the area. Holmes and Garrison (1973) reported on the type and composition of the sediments, and found from the distribution of trace elements that detrital sediment derived from Puerto Rico is carried along the shore with negligible amounts moving directly across the shelf. The area was included in Schneidermann, and others (1976) reconnaissance study of the sediments of the entire Puerto Rican insular shelf. Denning (1955), Kaye (1957) and Glover (1971) reported on the geologic structure of the area based on their work on land, and Garrison (1969) reported in detail on the geological structure as determined by continuous marine seismic profiling. Seismic refraction work was done in the area by Officer and others (1959). Kaye (1959, p. 115-6), in his overall description of the shorelines of Puerto Rico, pointed out the rapid seaward progradation of Punta Cabullón. Brooks (1973) studied the distribution of Recent foraminifers. Guillou and Glass (1957) briefly described the beach deposits of the area. Colon (1971) reported on current-meter readings from four locations near the Bajo Tasmanian platform; no other work on ocean currents or oceanography appears to have been done within the area.

Bathymetry

(fig. 2)

Numberous smooth sheets from hydrographic surveys by the U. S. Coast and Geodetic Survey (now the National Ocean Survey) have been contoured at a contour interval of 2 m on the shelf and 50 m on the slope in order to portray the submarine physiography of the area.

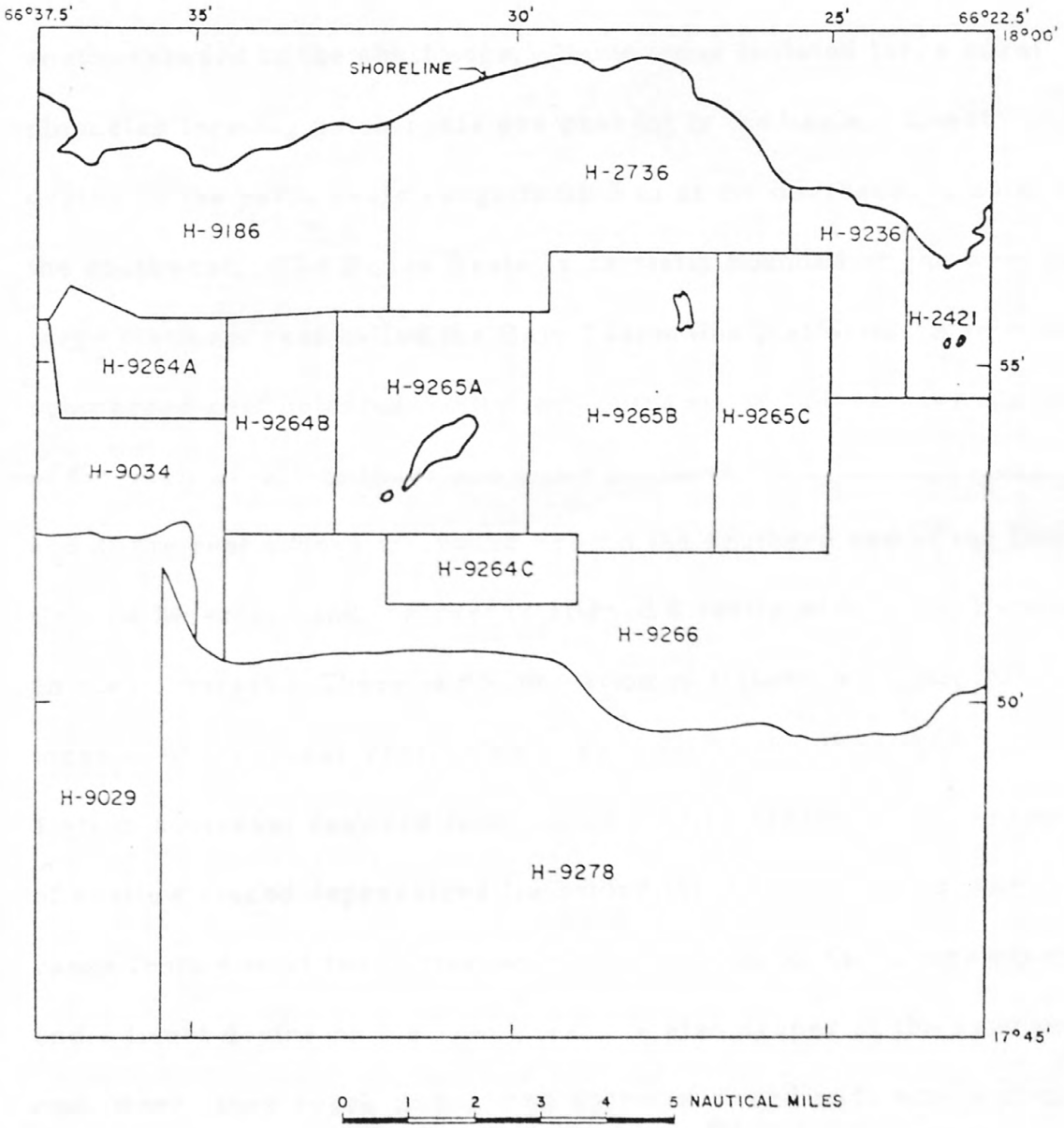


Figure 2.-- INDEX MAP SHOWING NATIONAL OCEAN SURVEY BATHYMETRIC SURVEYS USED IN CONTOURING BATHYMETRY

Caja de Muertos shelf. -- Northwest of the Caja de Muertos fault lies the Ponce Basin, a graben with a smooth inclined floor sloping southwestward to the shelf edge. Numberous isolated large coral pinnacles forming patch reefs are present in the basin. Least depths on the patch reefs range from 5 m at the northeast to 20 m at the southwest. The Ponce Basin is partially bounded on the west by a large platform reef called the Bajo Tasmanian platform. A mid-shelf submerged reef oriented northeast-southwest divides the remainder of the shelf area into inner and outer portions. The southwestern end of the reef swings westward around the southern end of the Isla Caja de Muertos, and the reef is aligned directly with Punta Petrona on the northeast. There is no indication of structural control of the location of the linear reef. The linear mid-shelf submerged reef has a steep southeast seaward face, and a gentle backslope. A number of shallow closed depressions lie behind the reef, in depths that range from 8 m at the northeastern end to 16 m on the southwestern end. Least depths on the reef crest are also deeper at the seaward end, where they reach 12 m, than at the landward end, where crest depths of 6 m are found. Doubtless this mid-shelf submerged reef was formed during a stillstand of sea level. If it was indeed formed parallel with sea level, as seems likely, its seaward tilt may well indicate seaward tilting of the shelf itself since the time of formation of the reef.

On the shelf northwestward of the mid-shelf submerged reef are found the Isla Caja de Muertos and a mangrove island called the Cayo Berberia. Both these islands and the mangrove islands named the Cayos Cabezazos, south of Punta Petrona, have flourishing fringing reefs on their southeastern, or weather, sides.

Prevailing depths on the inner shelf, northwest of the linear mid-shelf submerged reef, are 6 to 14 m. Prevailing depths on the outer shelf are 16 to 20 m. Four isolated submerged patch reefs on the outer shelf rise to depths of 12 to 20 m.

Shelf edge. -- The nature of the shelf edge is varied. South of Playa de Ponce, near the western map edge, a knobby irregular platform reef, a southerly extension of the Bajo Tasmanian platform, occupies the outer shelf. Least depths of 15 m occur near the seaward edge of a shelf generally 30 m deep. A deeper linear shelf-edge reef is present with least depths in the range 31-35 m. The steep insular slope west of this reef forms part of the upper wall of Muertos submarine canyon (Trumbull and Garrison, 1973, fig. 1).

Continuing southeastward, the next 6 km of shelf edge lacks any prominent feature other than a break in slope at a depth of about 50 m. The insular slope here is simply a seaward continuation of the slope of the floor of the Ponce Basin. The Ponce Basin is floored with mud delivered by longshore transport, and this mud may have prevented coral growth at the shelf edge in this area.

The shelf edge from southwest of Isla Caja de Muertos eastward to the east edge of the map displays a linear ridge, discontinuous in the western half of the distance, but continuous in the eastern half. The eastern half for a distance of 8 km displays a double outer ridge. Least depths on both the inner and the outer ridges are consistently 20 to 22 m. The valley between them has closed depressions with greatest depths of 42 to 45 m. The shelf behind the double ridge system is at depths generally from 34 to 44 m. This shelf-edge ridge, both where single and where double, is clearly a submerged coral reef of the type described by MacIntyre (1972). The type is characterized as having been originally established in relation to a pre-existing sea level lower than the present one. The source mechanism and age relationships of the double ridge system are not known. The same double-ridge phenomenon at the shelf edge is present southwest of Parguera, near the western end of the southern insular shelf of Puerto Rico.

Insular slope. -- The surface of the insular slope contains one remarkable large-scale feature. At depths in the range 1200-1600 m, the smoothly southward-inclined surface of the insular slope is interrupted by a linear east-west series of outlier hills alternating with northward-oriented valleys each of which has eastward and westward extensions. Such a surficial configuration can only be the result of a large-scale fault oriented east-west and upthrown on the south side.

In the extreme southeast corner of the map the surface of the insular slope rises to the southeast. This is the base of the western flank of the Escollo Investigator (Investigator Bank).

Sediment types

A nearshore zone generally 1 to 2 km wide is floored with highly terrigenous dark fine sand. The principal components are rounded mafic rock fragments, quartz and plagioclase feldspar. The minor biogenic component decreases in concentration from east to west. Mud is present in the protected areas around Caleta de Cabullón. Mangrove lines the coast at Punta Petrona and Punta Cabullón. The intertidal zone and beaches are primarily coarse sand and lag cobbles. The water over this nearshore terrigenous zone is commonly highly turbid because of its load of clay and silt. The high average turbidity of coastal waters is evident on the accompanying map (fig. 3) which gives an average of Secchi disc readings over a period of two years.

Silt and clay floor the Ponce Basin. In the northern part of the basin, near land, the sediment is dark and of terrigenous origin. It is apparently brought to the basin in suspension by the prevailing west-bound turbid coastal water current. Silt and clay are deposited on the patch reefs that dot the basin. In the southern part of the basin the sediment is buff-colored biogenic carbonate. Organism burrows and tracks are common in both parts of the basin.

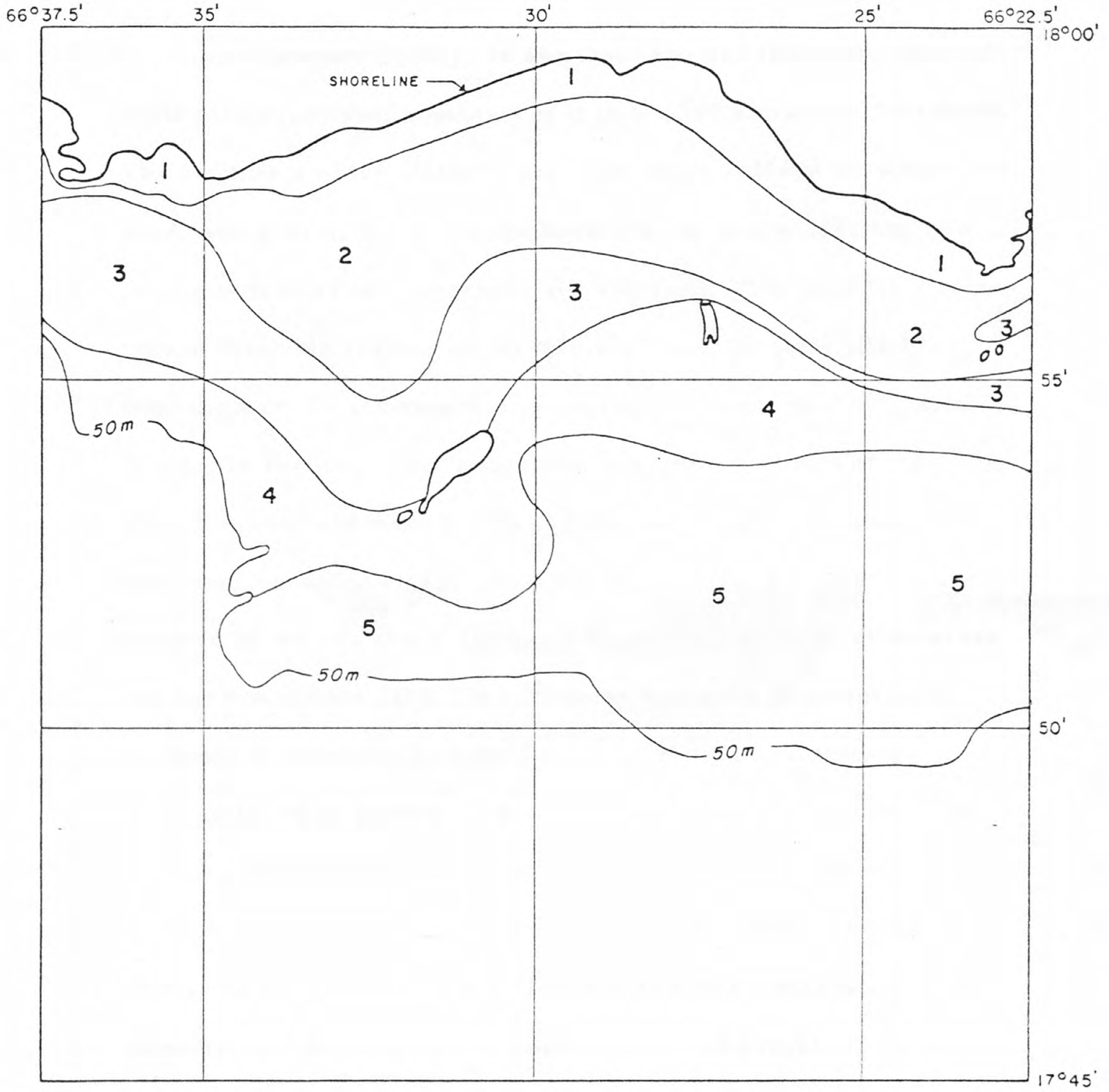


Figure 3. MAP SHOWING
TURBIDITY OF SHELF WATERS AS MEASURED BY SECCHI DISK

Between the Caja de Muertos fault and the prominent mid-shelf submerged reef southeast of it is located a mid-shelf platform. The sediments of the platform are dominantly skeletal carbonate silt, sand, and gravel, but at the northeastern, or nearshore, end is a strong admixture of terrigenous silt and sand. The very low percentage of insoluble residue on the mid-shelf and the outer shelf is prominent on the accompanying map (Fig. 4) showing percentage of insoluble residue in surficial shelf sediments. Major components of the mid-shelf platform sediment are Halimeda, molluscan fragments, foraminifers, coralline algae, and coral fragments. Large areas are covered by the sea grass Thalassia testudinum whereas other areas are bare carbonate sand. In both these areas the unconsolidated sediment is underlain by a hard rock floor; sediment thickness is as little as 10 cm in some places. Northeast, east, and southeast of Isla Caja de Muertos the mid-shelf platform has a cemented hard surface of low relief, encrusted with coralline algae. On this surface grow soft coral gorgonia, sponges and small encrusting coral colonies, and thin patches of biogenic sand and gravel are found.

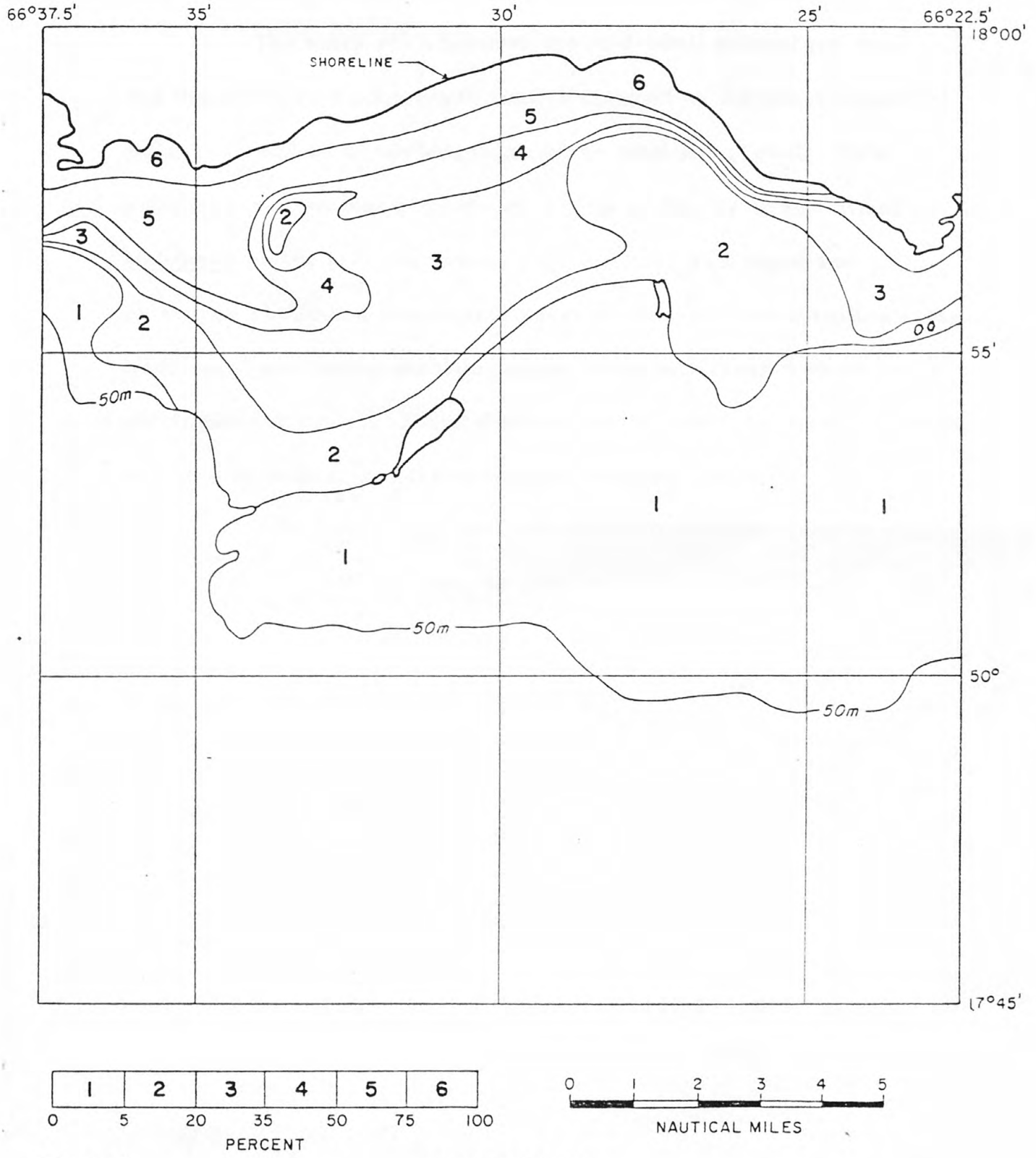


Figure 4. MAP SHOWING
PERCENTAGE INSOLUBLE RESIDUE IN SURFICIAL SHELF SEDIMENTS

An average of readings taken over a period of two years. Highly turbid water covers much of the Ponce basin, which is floored with silt and clay.

The outer shelf between the mid-shelf submerged-reef and the shelf-edge submerged reef is covered by a blanket deposit of light-colored buff to tan biogenic coarse sand and gravel. This sediment is composed almost exclusively of five basic constituents: Halimeda plates and fragments, foraminifers, gastropod and pelecypod shells and fragments, coral fragments, and coralline algae. Nodules of encrusting coralline algae commonly reach 5 to 10 cm in maximum dimension. Skeletal particles are generally worn, rounded, and stained brown, and the sediment is clearly relict.

The prominent mid-shelf submerged reef that extends from south of Isla Caja de Muertos northeastward toward Punta Petrona is similar to the shelf-edge submerged reef in that little or no active reef framework coral growth is now taking place. Both submerged reefs are constructed of intergrown and cemented calcareous skeletal material, primarily coral and coralline algae. Gorgonians and sponges are the dominant modern organisms. Both the mid-shelf and the shelf-edge reefs seem clearly to be remnant from times of lower sea level, when their active growth took place. The characteristics of both the mid-shelf and the shelf-edge reefs correspond almost exactly to the submerged reefs described by MacIntyre (1972), except that the mid-shelf submerged reef ranges in depth from only 6 to 16 m. Several drowned patch reefs are present on the outer shelf. Morphologically they are similar to flourishing reefs off southwestern Puerto Rico described by Almy and Garrison-Torres (1963).

Live reefs can be divided into three groups: fringing reefs, patch reefs and a few nearshore fringing reefs in the Ponce basin, and the Bajo Tasmanian platform and its southern extension.

Live fringing reefs are found east and south of the Cayos Cabezazos, Cayo Berberia, and the northeastern end of the Isla Caja de Muertos. Their dominant feature is a flourishing reef creat of Acropora palmata. This crest reaches to just below sea level and is nearly continuous. Seaward of the crest is a zone dominated by the hydrozoan Millepora complanata, the blades of which are oriented perpendicular to the reef crest. Seaward of this zone in water depths greater than 3 m is a zone of large massive coral heads where Montastrea annularis is dominant. Typical reef zonation as described by Goreau (1959) for reefs in Jamaica and by Saunders and Schneidermann (1973) for southwestern Puerto Rico is restricted by limited water depths; depths at the base of the frining reefs range from 6 to 16 m. Backreef from the creasts is an extensive zone of Porites porites with occasional Millepora complanata and other forms. Carbonate banks formed of skeletal silt, sand and gravel occur behind the fringing reefs. The mangrove islands Cayos Cabezazos and Cayo Berberia are located in the center of these banks. Plates of the green algae Halimeda are the dominant component of the bank sediment, and coral and coralline algae fragments are abundant on the windward side of the islands. Mollusk fragments and foraminifers are also present. Rippled sands are common on the back-reef and at the base of the reef-front slope.

Geologic Structure

The dominant structural element of the western Muertos Shelf is the Caja de Muertos fault. A reflection seismograph survey by Denning (1955) determined that 1100 m of vertical displacement near the north end of the Isla Caja de Muertos decreases to zero near the shoreline. The fault was also detected in the continuous seismic profiles of Garrison (1969), who confirmed the scissors movement detected by Denning. Garrison also found several subsidary faults near the landward end of the major fault.

The Caja de Muertos fault bounds the Ponce structural and bathymetric basin on the southeast. At the northwestern side of the Ponce basin Garrison (1969) detected and named the Bajo Tasmanian fault zone, shown as a single fault on the present map. It thus appears that the Ponce basin is structurally a graben. Neither the Caja de Muertos fault nor the Bajo Tasmanian fault zone has been detected on land (Glover, 1971).

Garrison also detected an unnamed east-west fault, upthrown to the south, in the central part of the shelf. Its effect is evident in the bathymetry shown on the present map: depression contours are found north of it, and bathymetrically high areas are found south of it.

As previously noted, the bathymetry of the insular slope in the depth range 1200-1600 m is strongly indicative of the presence of an east-west fault, upthrown on the south, and here named the Investigator fault. Lacking seismic data, the amount of vertical offset can only be roughly estimated on the basis of bathymetry alone to be several hundred meters. A projection of the fault trend to the east coincides with the north flank of Investigator Bank is bounded on the north by Investigator fault.

References Cited

Almy, C. C. Jr., and Carrion-Torres, Carlos, 1963, Shallow-water stony corals of Puerto Rico: Caribbean Journal of Science, v. 3, nos. 2-3, p. 133-162.

Brooks, W. W., 1973, Distribution of Recent foraminifera from the southern coast of Puerto Rico: Micropaleontology, v. 19, no. 4, p. 385-416.

Colon, E. F., 1971, Estuaries, bays, and coastal currents around Puerto Rico: Mayaguez, Puerto Rico, Water Resources Research Institute, Partial technical completion report no. 8, 40 p.

Denning, W. H., 1955, Preliminary results of geophysical exploration for gas and oil on the south coast of Puerto Rico: San Juan, Commonwealth of Puerto Rico Economic Development Administration, Division of Mineralogy and Geology, Bull. 2, 17 p.

Garrison, Louis E., 1969, Structural geology of the Muertos Insular shelf, Puerto Rico: U.S. Geological Survey Open-file report 69-298, 9 p.

Glover, Lynn, 1971, Geology of the Coamo area, Puerto Rico, and its relation to the volcanic arc-trench association; U.S. Geological Survey Professional Paper 636, 102 p.

Goreau, T. F., 1959, The ecology of Jamaican coral reefs, I, Species composition and zonation: Ecology, v. 40, no. 1, p. 67-89.

Guillou, R. B., and Glass, J.J., 1957, A reconnaissance study of the beach sands of Puerto Rico: U.S. Geological Survey Bulletin 1042-I, p. 273-303.

Kaye, C. A., 1957, Notes on the structural geology of Puerto Rico: Geological Soceity of America Bulletin, v. 68, no. 1, p. 103-118.

Holmes, C. W., and Garrison, L. E., 1973, Composition of the sediment on the insular shelf and upper slope of south-western and south central Puerto Rico: U.S. Geological Survey Open-file report, 2 sheets.

Kaye, C. A., 1959, Shoreline features and Quaternary shoreline changes, Puerto Rico U.S. Geological Survey Professional Paper 317-B, p. 49-140.

MacIntyre, I. G., 1972, Submerged reefs of eastern Caribbean: American Association of Petroleum Geologists Bulletin, v. 56, no. 4, p. 720-738.

Officer, C. B., Ewing, J. I. Hennion, J. F., Harkrider, D. G., and Miller, D. E., 1959, Geophysical investigations in the eastern Caribbean--summary of 1955 and 1956 cruises, in Ahrens, L. H., and others, eds., Physics and chemistry of the earth: New York, McGraw-Hill, v. 3, p. 17-110.

Saunders, C. E. and Schneidermann, Nahum, 1973, Carbonate and sedimentation on the inner shelf, Isla Magueyes, Puerto Rico: Mayaguez, University of Puerto Rico Water Resources Research Institute, 77 p.

Schneidermann, Nahum, Pilkey, O. H., and Saunders, Craig, 1976, Sedimentation on the Puerto Rico Insular Shelf: Journal of Sedimentary Petrology, v. 46, no. 1, p. 167-173.

Trumbull, J. V. A., 1975, Preliminary bathymetric base map of the Isla Caja de Muertos area, Puerto Rico: U.S. Geological Survey Open-File map 75-329, scale 1:40,000.

Trumbull, J. V. A., and Garrison, L. E., 1973, Geology of a system of submarine canyons south of Puerto Rico: U.S. Geological Survey Journal of Research, v. 1, no. 2, p. 293-299.

DESCRIPTION OF MAP UNITS

NZ — NEARSHORE ZONE - Dark gray silt and fine sand, predominantly terrigenous but includes biogenic grains. Biogenic components decrease toward west, silt increases toward west

SB — SHELF BASIN - Silt and clay, dark gray and predominantly of terrigenous origin in the north, light-colored biogenic carbonate in the south

MP — MID-SHELF PLATFORM - Biogenic sand and gravel, mixed with terrigenous grains near land. Large areas thickly populated with Thalassia, and large areas of rippled bare sand. Near Isla Caja de Muertos is cemented in a hard surface of low relief. Grains generally unworn and unstained

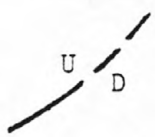
OS — OUTER SHELF - Biogenic coarse sand and gravel, with calcareous algal nodules common. Grains generally worn, rounded, and stained brown

SR — SUBMERGED REEFS - Drowned reefs, biologically constructed of intergrown and cemented calcareous (predominantly coral and coralline algae) skeletal material. No active reef framework coral growth but abundant growth of gorgonians, sponges and small encrusting corals

LR — LIVE REEFS - Biologically constructed reefs with active reef framework coral growth. Includes fringing reefs east and south of the Cayos Cabezazos, Cayo Berberia, and the northern end of Isla Caja de Muertos; numerous patch and fringing reefs in the Ponce basin; and the Bajo Tasmanian platform reef and its southern extension

CB — CARBONATE BANKS - Skeletal silt, sand and gravel, formed of detritus derived from fringing reefs. Includes some hard bottom formed of calcareous algal crusts

LS — INSULAR SLOPE - Blanket deposit of hemipelagic sand, silt and clay, dominantly calcareous



Fault, dashed where conjectural. U, upthrown side, D, Downthrown side