Geologic and Hydrologic Data Collected at Test Holes NC-6 and NC-11, Hatillo and Isabela, Northwestern Puerto Rico

By Jesús Rodríguez-Martínez and John L. Hartley

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Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
gallon per minute (gal/min)	0.06308	liter per second

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows: $°F = 1.8\ (°C) + 32$

Abbreviated water-quality units used in this report:

microsiemens per centimeter at 25 degrees Celsius (μS/cm)

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By Jesús Rodríguez-Martínez[1] *and* John L. Hartley[2]

Abstract

Test holes NC-6 and NC-11 were drilled in the municipalities of Hatillo and Isabela, respectively, in northwestern Puerto Rico as part of a study of the aquifers in the Northern Coastal Province of Puerto Rico. Test holes NC-6 and NC-11 were drilled in 1986 and 1987, to total depths of 2,574 and 2,120 feet below land surface, respectively. Hydrologic and geologic data collected during drilling included continuous lithologic core, water-quality data, water-level head measurements, and estimated of relative yield from the water-bearing zones. Detailed petrological and microfaunal analyses of the core were made to determine the mineralogic content, ages, and paleoenvironments of deposition.

Test holes NC-6 and NC-11 penetrated several geologic formations within the platform carbonates that underlie the Northern Coastal Province in northwestern Puerto Rico. Test hole NC-6 penetrated five formations ranging in age from late Oligocene to early Pliocene: the Lares Limestone, the Cibao Formation, the Los Puertos Formation, the Aymamón Limestone, and the Quebradillas Limestone. Test hole NC-11 penetrated four formations ranging in age from late Oligocene to middle Miocene: the San Sebastián Formation, the Cibao Formation, the Los Puertos Formation, and the Aymamón Limestone.

Test hole NC-6 penetrated seven water-bearing units: a water-table aquifer and six artesian aquifers. The specific conductance of the water in these aquifers varied from 650 to 50,000 microsiemens per centimeter and from 300 to 800 microsiemens per centimeter in the water-table aquifer in the artesian aquifers. Relative yields of the aquifers ranged from 100 to 220 gallons per minute in the water-table aquifer and from 45 to 130 gallons per minute in the artesian aquifers. Water levels in the aquifers ranged from 195 to 205 feet below land surface in the water-table aquifer and from 16 to 165 feet below land surface in the artesian aquifers.

Test hole NC-11 penetrated five water-bearing units: a water-table aquifer and four artesian aquifers. The specific conductance varied from 1,100 to 49,000 microsiemens per centimeter in water from the water-table aquifer and from 450 to 900 microsiemens per centimeter in water from the artesian aquifers. Relative yields ranged from 70 to 240 gallons per minute in the water-table aquifer and from 60 to 75 gallons per minute in the artesian aquifers. Water levels ranged from 270 to 290 feet below land surface in the water-table aquifer and from 70 to 265 feet below land surface in the artesian aquifers.

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INTRODUCTION

Aquifers of the Northern Coastal Province of Puerto Rico are part of a highly karstic coastward-thickening wedge of platform carbonates and minor clastic rocks of Oligocene to Holocene age (Meyerhoff and others, 1983). Karstification of the uplifted carbonate sequence has resulted in the formation of highly distinctive landforms, including tower and cockpit karst (Monroe, 1976). Flanking the central mountains of Puerto Rico, this coastal wedge sequence extends from Aguada in the west to Loíza in the northeast, and encompasses an area of approximately 700 square miles (mi^2; fig.1).

Few geologic and hydrologic data are available for the subsurface coastal areas of northern Puerto Rico. As part of a cooperative study between the U.S. Geological Survey and the Puerto Rico Department of Natural Resources, 15 test holes were drilled (fig. 1) to determine the geologic and hydrologic characteristics of the aquifer system and confining units in the Northern Coastal Province (Torres-González and Wolansky, 1984). The data collected from these test holes are being documented in a series of reports.

Purpose and Scope

This report presents the geologic and hydrologic data collected in 1986 and 1987 at test holes NC-6 and NC-11 in the municipalities of Hatillo and Isabela, respectively. The data collected at these test holes include water levels, aquifer thicknesses, lithology, and water quality of the major aquifers identified at these sites. These data will aid the correlation of major hydrogeologic and geologic units and will help in the determination of the direction and rate of ground-water flow in the Northern Coastal Province.

The drilling and coring program was designed to allow the collection of continuous core samples for geologic, hydrogeologic, and paleontologic analyses. Water-level measurements were made from discrete water-bearing zones.

Location of Study Area

Test hole NC-6 was drilled in Barrio Capaez of the municipality of Hatillo, about 0.8 miles (mi) west of road 130 and 1.4 mi south of Highway 2 (fig. 2). The municipality of Hatillo is located in the northwestern part of Puerto Rico, approximately 48 mi west of San Juan. The land-surface altitude at the drilling site is 292 feet (ft) above mean sea level.

The site of test hole NC-11 is in Barrio Jobos of the municipality of Isabela, about 1.8 mi north of Highway 2 and 0.20 mi north of Road 472 (fig. 3). The municipality of Isabela is located in the northwestern part of Puerto Rico, approximately 63 mi west of San Juan. The land-surface altitude at the drilling site is 289 ft above mean sea level.

DATA-COLLECTION METHODS

A drilling method was used that allowed the continuous retrieval of lithologic core, as well as the collection of water samples, head measurements, and water-flow estimates, with minimum interruption of the drilling operation.

Drilling

Test holes NC-6 and NC-11 were drilled to depths of 2,574 and 2,120 ft, respectively. The holes were drilled using a hydraulically driven, reverse-air system. This system uses threaded, seamless, double-walled drill stem and pressurized air to remove cuttings and cores. As drilling progresses, pressurized air is pumped through the annulus of the two walls of the drill stem, forcing formation water and cores up the center of the drill stem. Cores and water are ejected from the discharge pipe into a cyclone container, which dissipates their energy and also serves as a collector. Both test holes were plugged and abandoned after core collection and down-hole data acquisition were completed.

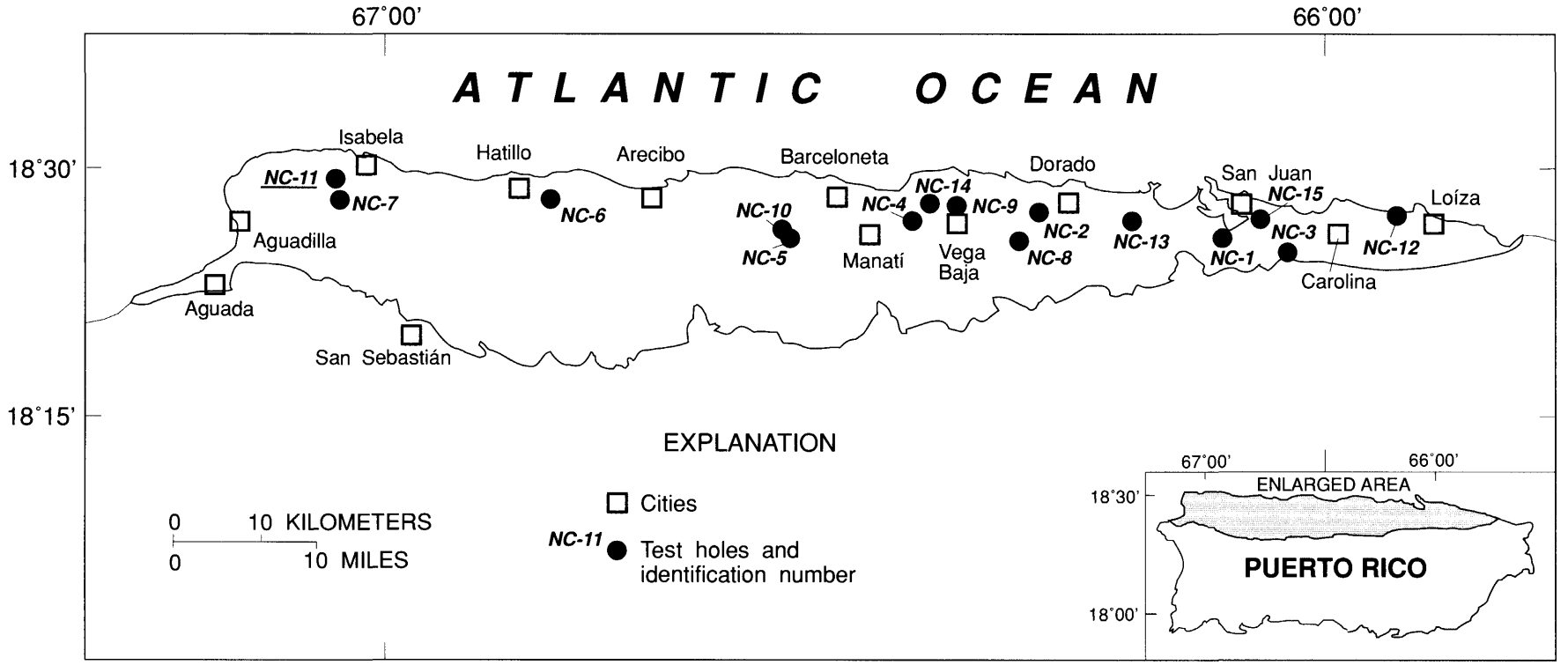

Figure 1. Areal extent of the Northern Coastal Province of Puerto Rico and the location of cities and test holes.

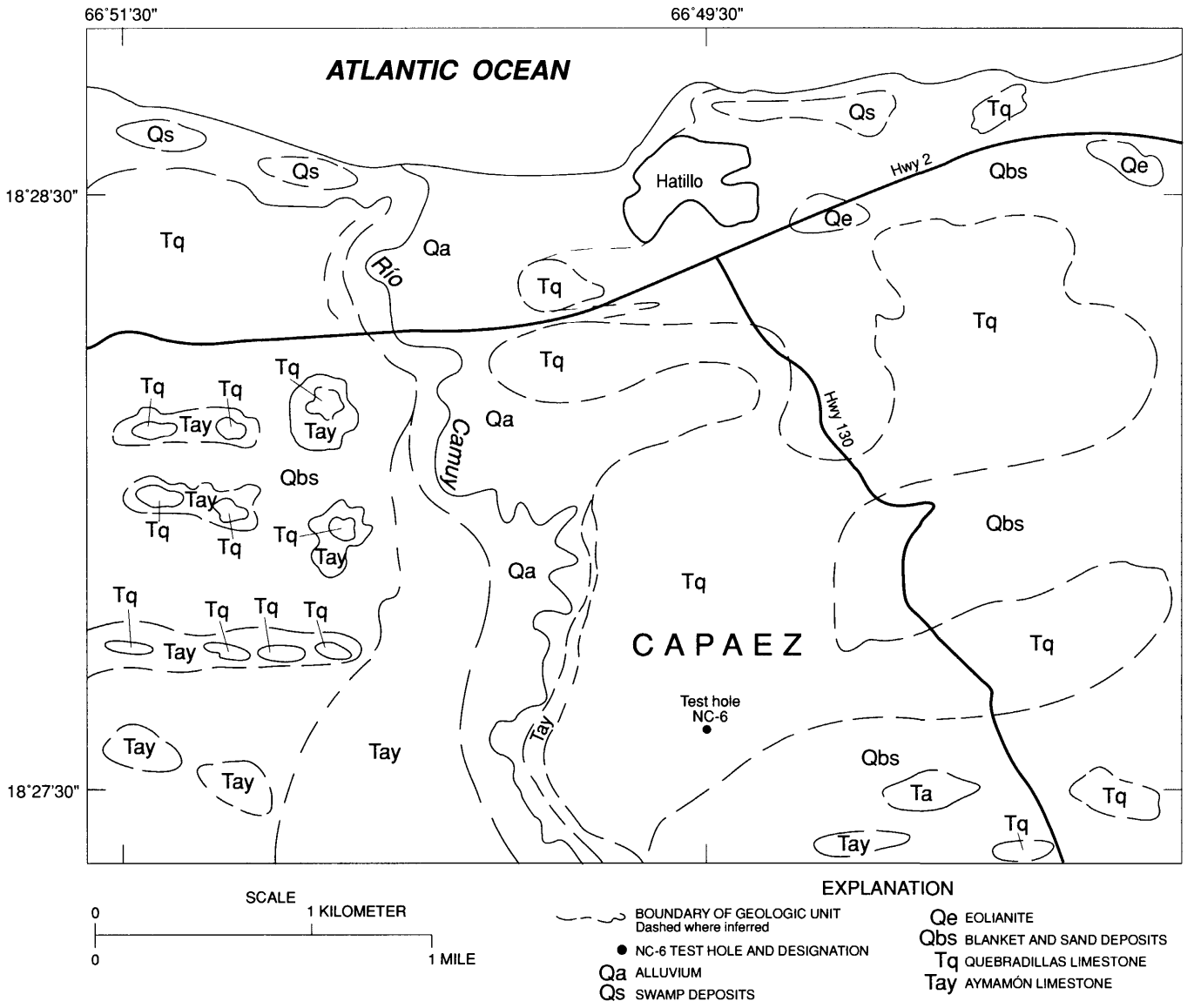

Figure 2. Location and surficial geology at site of test hole NC-6, Hatillo, Puerto Rico.

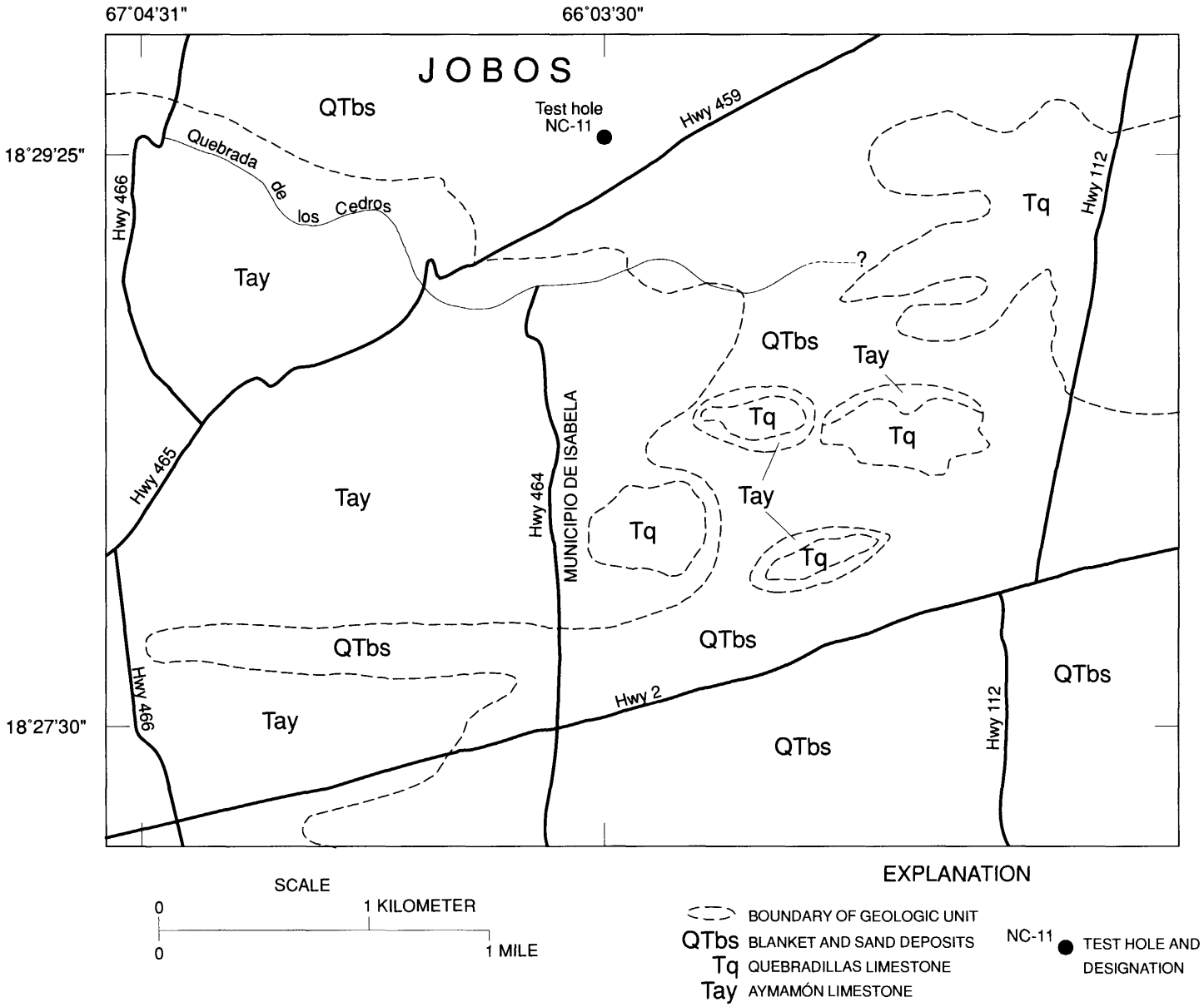

Figure 3. Location and surficial geology at site of test hole NC-11, Isabela, Puerto Rico.

Coring

Test holes NC-6 and NC-11 were cored continuously to their total depth. Cores were retrieved and each section was measured, described, and placed in wooden core boxes for preservation and storage at the University of Puerto Rico at Mayagüez. Each core box contains the equivalent of one drill stem section length of core; approximately 20 ft. A representative split of each core was separated for storage at the U.S. Geological Survey office in San Juan, Puerto Rico. Core recovery ranged from poor to excellent. Poor core recovery was common in cavernous zones.

Hydrologic Measurements

Water-level measurements were made at depth intervals of approximately 20 ft using either an electric sensor or steel tape. Measurements were made on the inside of the drill stem before the next section of drill stem was connected. Time restrictions prohibited a full recovery of water levels. Water-level measurements were also made prior to the start of drilling activity each day and within selected intervals identified on the basis of a noticeable increase in water ejected from the discharge pipe.

Flow measurements were made at the discharge point of the cyclone collector. Although the measurements do not indicate the potential well yield of each of the water-bearing zones, they were made under approximately the same conditions, so that the measured flow reflects the relative yield of each zone. The flow data are, therefore, referred to as "relative yield." Hydraulic continuity and a sustained minimum flow of ten gallons per minute (gal/min), measured at the discharge point of the cyclone collector, were used as criteria for differentiating water-bearing units. Specific-conductance measurements were also made at the discharge point of the cyclone collector to provide information on the quality of formation water. The specific-conductance values were corrected to 25 degrees Celsius.

GEOLOGIC AND HYDROLOGIC DATA

In 1980 the rocks of middle Tertiary age that crop out in the Northern Coastal Province were mapped as seven formational units by Monroe (1980) on the basis of their lithologic character in the outcrop area. A few years later, Seiglie and Moussa (1984) established a new geologic framework for these units using paleontologic data collected from corehole drill cuttings and outcrop samples (fig. 4). They also recognized that the lithologic character of these units change as they extend from their outcrop into the subsurface. This report uses the nomenclature of Seiglie and Moussa (1984).

The Hatillo-Isabela area lies within the western part of the northern karst belt of Puerto Rico. A "juvenile" karst topography characterizes this area, with significant underground drainage that is the result of active dissolution (Monroe 1976). This active dissolution has been attributed to the eastward tilting of the carbonate platform thought to have occurred about one million years ago (Giusti, 1978). This tilting has raised the western part of the platform relative to the eastern part. Evidence of tilting is provided by the presence of sea cliffs in Isabela, the entrenched Río Camuy and Río Guajataca river channels in Hatillo and Isabela, and by springs discharging into these and other rivers along their west banks.

The surficial geology of the Hatillo-Isabela area consists of the Quebradillas and Aymamón Limestones in the highlands and blanket sand deposits, eolianites, swamp deposits, and alluvial deposits of the Río Camuy and Río Guajataca in the lowlands (figs. 2 and 3). As observed in the vicinity of the drilling sites, and in the outcrop belt along the southern border of the carbonate platform, the surficial and underlying rock units form a homocline, which dips toward the north at angles in the range of four to seven degrees (Monroe, 1980). The regularity of dip is interrupted near Isabela by a gentle reversal that seems to be a continuation of the syncline and anticline northeast of the municipality of Isabela (Monroe, 1969).

Because of a lack of well data in the Hatillo-Isabela area, little is known about the aquifer system in this area. Although the existence of the regional water-table aquifer

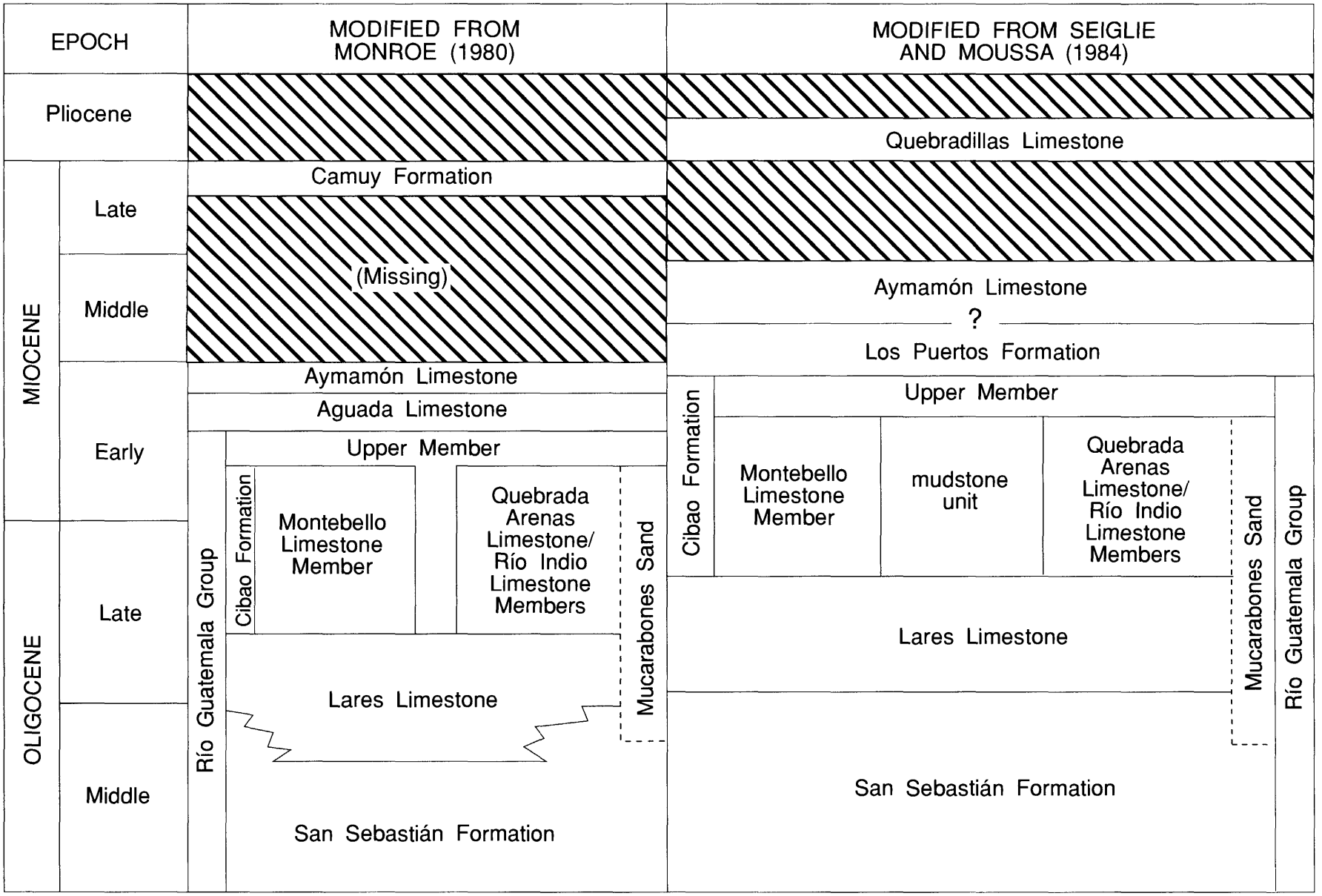

Figure 4. Stratigraphic units comprising the middle Tertiary sequence of the Northern Coastal Province of Puerto Rico.

was known in this area, its hydrogeology was poorly understood before the deep drilling program in the Northern Coastal Province. The presence of artesian water-bearing units in the deep subsurface was considered possible, based on the altitude of outcrop facies along the southern border of the carbonate platform, but it was not until test holes NC-6 and NC-11 were drilled that the existence of artesian conditions in this area was confirmed.

Description of Geologic Units in Test Hole NC-6

Test hole NC-6 penetrated the Quebradillas Limestone, the Aymamón Limestone, the Los Puertos Formation, the Cibao Formation, and the Lares Limestone (table 1; at end of report). The Quebradillas Limestone of Pliocene age is 85-ft thick (0 to 85 ft in depth) and consists of a yellow-orange Globigerinid chalk. It is underlain by a 1,085-ft thick sequence (85 to 1,170 ft in depth) of the Aymamón Limestone, which consists of the following lithologic intervals, in descending order: (a) 66 ft of Amphistegina and a red algae wackestone; (b) 101 ft of Halimeda, red algae, and a benthic foraminifera wackestone-packstone; (c) 14 ft of undifferentiated karstic limestone; (d) 30 ft of Halimeda and a echinoderm-red algae wackestone in the upper half of the interval and a pelecypod-echinoderm-miliolid wackestone in the lower half; (e) 10 ft of undifferentiated karstic limestone; (f) 220 ft of a predominantly red algae wackestone-packstone containing branching coral, Halimeda, gastropods, and large benthic foraminifera grading into a packstone-grainstone in the lower third of this interval; capped by a 7-ft thick mudstone; (g) 30 ft of a pelecypod-soritid-miliolid, dolomitic packstone with minor red algae packstone containing encrusting foraminifera and Amphistegina in the lower part; (h) 26 ft of coral-rich wackestone-packstone in the upper part and red algae packstone-grainstone with minor dolowackestone in the lower part; (i) 189 ft of irregularly interbedded Amphistegina dolowackestone, red algae dolomitic wackestone, red algae wackestone and skeletal grainstone with planktonic foraminifera at approximately 738 ft; (j) 28 ft of branching coral, gastropods and red algae-rich packstone-grainstone; (k) 41 ft of a soritid-Halimeda packstone that becomes a dolopackestone at the base of the interval (l) 83 ft of rhodolitic-pelecypod dolowackestone; (m) 37 ft of red algae and pelecypod rich packstone in the upper half of the interval and Halimeda-head coral rich grainstone in the lower half; (n) 95 ft of red algae-branching coral and echinoderm rich dolomitic packstone, dolopackstone and wackestone; and (o) 110 ft of red algae-Amphistegina wackestone in the upper half of the interval and Halimeda-pelecypod-branching coral rich wackestone in the lower half.

The Los Puertos Formation of Miocene age is 340-ft thick and spans the interval from 1,170 to 1,510 ft in test hole NC-6. This unit is divided into the following intervals, in descending order: (a) 60 ft of benthic foraminifera coarse-grained grainstone, bearing bryozoans and miliolids with minor Halimeda and dasyclad algae-rich wackestone-packstone; (b) 10 ft of fenestral mudstone; (c) 45 ft of gastropod and miliolid rich packstone with claystone, marl, and minor wackestone; (d) 136 ft of a predominantly red algae packstone-grainstone, containing pelecypods and Kuphus, with minor dark-gray marl and bryozoan packstone-grainstone; two calichified breccia zones were in this interval; (e) 31 ft of a Halimeda-red algae-miliolid packstone, wackestone-packstone and wackestone with a basal calichified breccia; (f) 18 ft of red algae-pelecypod-Halimeda packstone-grainstone; (g) 20 ft of soritid-miliolid argillaceous wackestone; and (h) 20 ft of red algae packstone, packstone-grainstone and wackestone-packstone in the upper one third and soritid-rich burrowed wackestone bearing red algae, with minor Halimeda-articulate red algae packstone and grainstone in the lower two thirds of the interval.

The Cibao Formation, also of Miocene age, is 950-ft thick (1,510 to 2,460 ft in depth) and is divided into the upper member, the Montebello Limestone Member, and a lower interval similar in lithologic character to that of the upper member. The upper member is 602-ft thick (1,510 to 2,112 ft in depth) and consists of the following intervals, in descending order: (a) 140 ft of a benthic foraminifera-red algae-mollusc, locally argillaceous wackestone, with minor dolowackestone and claystone and a 6-ft red algae-burrowed packstone forming the base of the interval; (b) 111 ft of a benthic foraminifera-

mollusc claystone-marl with minor wackestone, a siltstone and silty-sandy claystone capping the interval; (c) 139 ft of a red algae-oyster wackestone and grainstone, locally argillaceous and burrowed, with minor siltstone and claystone; (d) 110 ft of an oyster and benthic foraminifera rich claystone with minor marl; and (e) 102 ft of a benthic foraminifera-burrowed wackestone, minor wackestone-packstone and packstone-grainstone.

The Montebello Limestone Member is 106-ft thick (2,112 to 2,218 ft in depth) and consists of a red algae-benthic foraminifera wackestone-packstone, with minor wackestone and red algae-argillaceous packstone in the middle part and a benthic foraminifera-red algae argillaceous packstone and wackestone-packstone in the lower part.

The lower 242 ft of the Cibao Formation is lithologically similar to the upper member of the Cibao Formation and is divided, in descending order, into: (a) 82 ft of benthic foraminifera-mollusc wackestone-packstone; (b) 100 ft of mollusc and red algae bearing claystone, with localized marly and minor sandstone at the top; and (c) 60 ft of benthic foraminifera-echinoderm wackestone.

The lowermost 114 ft penetrated in test hole NC-6 corresponds to the Lares Limestone. This formation is of Oligocene age and consists of the following principal lithologies in descending order: (a) 60 ft of echinoderm-benthic foraminifera-dolomitic wackestone; and (b) 54 ft of Kuphus-benthic foraminifera-argillaceous wackestone containing minor wackestone-packstone.

Description of Water-Bearing Units in Test Hole NC-6

Test hole NC-6 penetrated seven water-bearing units: a water-table aquifer and six artesian aquifers (fig. 5). The uppermost water-bearing unit is contained within the Aymamón Limestone and the uppermost strata of the Los Puertos Limestone and extends from the water table (201 ft below land surface) to a depth of 1,270 ft. The base of this unit is at the top of the first confining unit, which is located within the Los Puertos Formation, and extends to a depth of 1,290 ft. Underlying this confining unit is a 180-ft thick artesian aquifer (1,290 to 1,470 ft in depth), which is also in the Los Puertos Formation. Beneath this aquifer is a second confining unit, which is 30-ft thick (1,470 to 1,500 ft in depth). It is located in the lowermost part of the Los Puertos Formation. A 45-ft thick artesian aquifer lies at depth of 1,500 to 1,545 ft in the lowermost strata of the Los Puertos Limestone and in the upper member of the Cibao Formation. The third confining unit penetrated by test hole NC-6 is 320-ft thick and extends from 1,545 to 1,865 ft, corresponding to the upper member of the Cibao Formation. It is underlain by an artesian aquifer that is 40-ft thick and extends to a depth of 1,905 ft. A fourth confining unit (1,905 to 2,020 ft in depth) and the underlying artesian aquifer (2,020 to 2,045 ft in depth) are also located within the upper member of the Cibao Formation. A fifth confining unit that is 45-ft thick extends to 2,090 ft and lies within the basal strata of the upper member of the Cibao Formation. The underlying artesian aquifer extends from 2,090 to 2,180 ft, and is contained within the and lowermost strata of the upper member of the Cibao Formation and the Montebello Limestone Member. A sixth confining unit, extending from 2,180 to 2,200 ft (20-ft thick), is located in the lower part of the Montebello Limestone Member. The underlying 75-ft thick artesian aquifer, extends to 2,275 ft and is contained within the lowermost part of the Montebello Limestone Member and the upper part of the lower Cibao Formation, which has lithology that resembles that of the upper member of the Cibao Formation.

Specific conductance, relative yields, and water levels varied substantially among the aquifers penetrated by test hole NC-6. The specific conductance of water in the water-table aquifer gradually increased from 650 microsiemens per centimeter (µS/cm) at a depth of 235 ft to 800 µS/cm at a depth of 296 ft (table 2, fig. 5). From 296 ft the specific conductance of the water rapidly increased downward to a maximum of 50,000 µS/cm at a depth of 900 ft and then decreased to 45,000 µS/cm at a depth of 1,270 ft. In the artesian aquifers the specific conductance of water decreased from a maximum of 800 µS/cm in the first artesian aquifer penetrated to a minimum of 300 µS/cm in the sixth artesian aquifer. The relative yield ranged from 100 to 220 gal/min in the water-table aquifer and from 45 to 130 gal/min in the artesian aquifer. The water level in the water-table aquifer varied from 195 to 205 ft below land surface, and from 16 to 165 ft below land surface in the artesian aquifers (table 2).

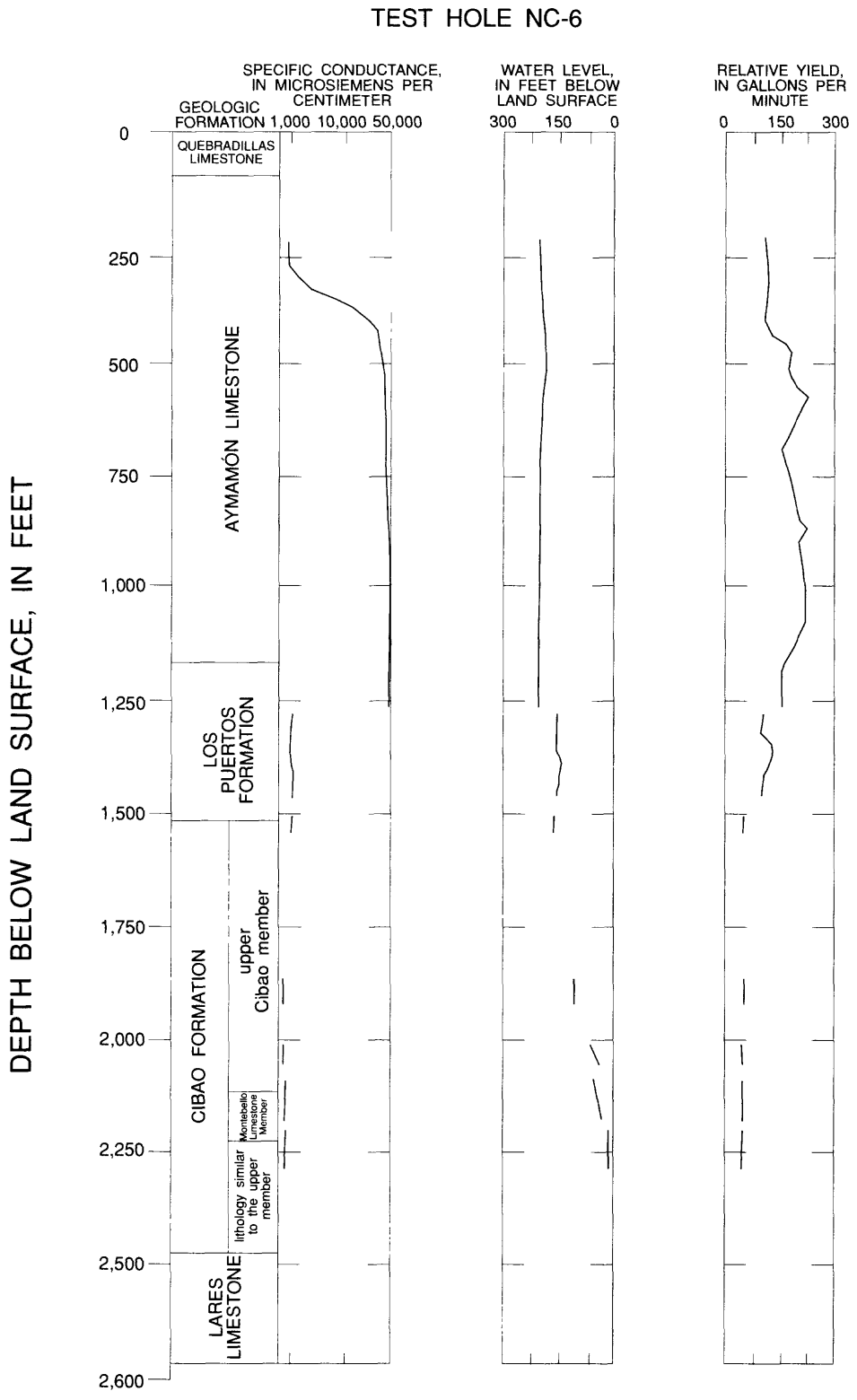

Figure 5. Geologic units, specific conductance of water, water level, and relative yield at test hole NC-6, Hatillo, Puerto Rico.

Table 2. Selected hydrologic data from test hole NC-6, Hatillo, Puerto Rico

Depth below land surface, in feet	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Water level, in feet below land surface	Relative Yield in gallons per minute
	Water-Table Aquifer		
235	650	201	100
250	700	201	100
296	800	201	105
350	4,750	200	110
377	20,000	200	110
400	28,000	195	110
435	40,000	195	105
500	42,000	203	180
534	43,800	203	180
574	43,000	204	180
600	43,500	203	220
675	46,000	197	180
725	43,500	203	165
800	42,500	203	180
900	50,000	203	220
934	47,000	202	205
1,000	46,000	202	210
1,100	45,000	203	210
1,200	44,000	205	150
1,270	45,000	205	150
	First Artesian Aquifer		
1,290	800	158	100
1,340	700	162	105
1,385	700	153	130
1,430	800	153	102
1,470	750	160	102
	Second Artesian Aquifer		
1,500	700	165	53
1,510	550	165	50
1,545	450	165	50
	Third Artesian Aquifer		
1,865	450	100	55
1,905	400	100	55
	Fourth Artesian Aquifer		
2,020	400	55	50
2,045	400	45	55
	Fifth Artesian Aquifer		
2,090	500	50	50
2,180	300	43	45
	Six Artesian Aquifer		
2,200	300	16	45
2,275	300	16	50

Description of Geologic Units in Test Hole NC-11

Test hole NC-11 penetrated the Aymamón Limestone, the Los Puertos Formation, the Cibao Formation, and the San Sebastián Formation (table 3; at end of report). The Aymamón Limestone of Miocene age extends from land surface to a depth of 845 ft and consists of the following lithologic intervals, in descending order: (a) 80 ft of modern soil with minor chalk; (b) 240 ft of Amphistegina and skeletal wackestone-packstone and wackestone, with minor encrusting and planktonic foraminifera wackestone; (c) 46 ft of head coral-mollusc-Halimeda dolopackstone-dolowackestone; (d) 94 ft of red algae packstone and Lepidocyclina-Amphistegina wackestone-packstone; (e) 40 ft of head coral-Amphistegina-Halimeda, wackestone, wackestone-packstone, and packstone; (f) 100 ft of molluscan wackestone-packstone, with minor echinoderm-red algae wackestone-packstone; (g) 35 ft of mollusc-Halimeda-Amphistegina wackestone and minor crustose red algae wackestone-packstone; (h) 45 ft of red algae dolowackestone; (i) 60 ft of skeletal and red algae dolomitic wackestone with a minor gastropod-bearing dolowackestone at the base; and (j) 105 ft of predominantly red algae wackestone-packstone alternating with a minor red algae dolowackestone and branched coral-red algae packstone with minor amounts of skeletal grainstone at the top of the interval.

The Aymamón Limestone is underlain by the Los Puertos Formation (Miocene age) that extends 324 ft from 845 to 1,169 ft below land surface. The Los Puertos Limestone consists of the following lithologic intervals, in descending order: (a) 155 ft of red algae-skeletal-planktonic foraminifera-dolomitic packstone, with a thin red algae wackestone and wackestone-packstone at the top; (b) 40 ft of Amphistegina-crustose red algae-rhodolitic wackestone; (c) 65 ft of a locally dolotimized red algae packstone and oyster-Halimeda packstone-grainstone; and (d) 64 ft of head and branched coral boundstone, red algae packstone-grainstone, Halimeda-dolomitic wackestone, and a red algae grainstone at the base of the interval.

In test hole NC-11, a 641-ft thick section of undifferentiated Cibao Formation was penetrated at depths of 1,169 to 1,810 ft below land surface. This formation is also of Miocene age and underlies the Los Puertos Limestone. It consists of the following lithologic intervals, in descending order: (a) 46 ft of Dasyclad-branched coral-mollusc dolomitic wackestone, quartzose sandy limestone, gastropod dolopackstone and skeletal-dolomitic packstone; (b) 45 ft of oyster-bearing claystone-marl and skeletal wackestone-packstone; (c) 10 ft of echinoderm wackestone; (d) 130 ft of Halimeda-benthic foraminifera-mollusc argillaceous wackestone-packstone with red algae dolowackestone, oyster claystone and red algae wackestone-packstone at the base; (e) 75 ft of red algae-soritid packstone with minor Kuphus packstone; (f) 124 ft of soritid-miliolid-branched coral-mollusc wackestone with minor oyster claystone-marl; (g) 80 ft of gastropod and miliolid bearing wackestone-packstone with minor amounts of skeletal and pecten bearing dolowackestone, black shale and algae boundstone; and (h) 111 ft of head coral-red algae wackestone with minor red algae dolowackestone and gastropod-bearing marl.

The lowermost 310-ft section penetrated in test hole NC-11 was in the San Sebastián Formation of Oligocene age. This formation consists of the following lithologic intervals, in descending order: (a) 25 ft of benthic foraminifera-mollusc marl with minor red algae grainstone; (b) 65 ft of benthic foraminifera wackestone interbedded with clay-rich volcaniclastic gravel and claystone-marl; and (c) 220 ft of carbonaceous claystone with minor siltstone and gravel and an interbedded argillaceous wackestone containing benthic foraminifera and echinoderm at the base of the interval.

Description of Water-Bearing Units in Test Hole NC-11

Test hole NC-11 penetrated five water-bearing zones: a water-table aquifer and four artesian aquifers (fig. 6). The uppermost water-bearing unit is contained within the Aymamón Limestone, the Los Puertos Formation, and the uppermost strata of the Cibao Formation. It extends from the water table (278 ft below land surface) to a depth of 1,190 ft. The base of this unit is at the top of the first confining unit, which extends to a depth of 1,225 ft and is located in the Cibao Formation. Underlying this confining unit is a 55-ft thick artesian aquifer, extending

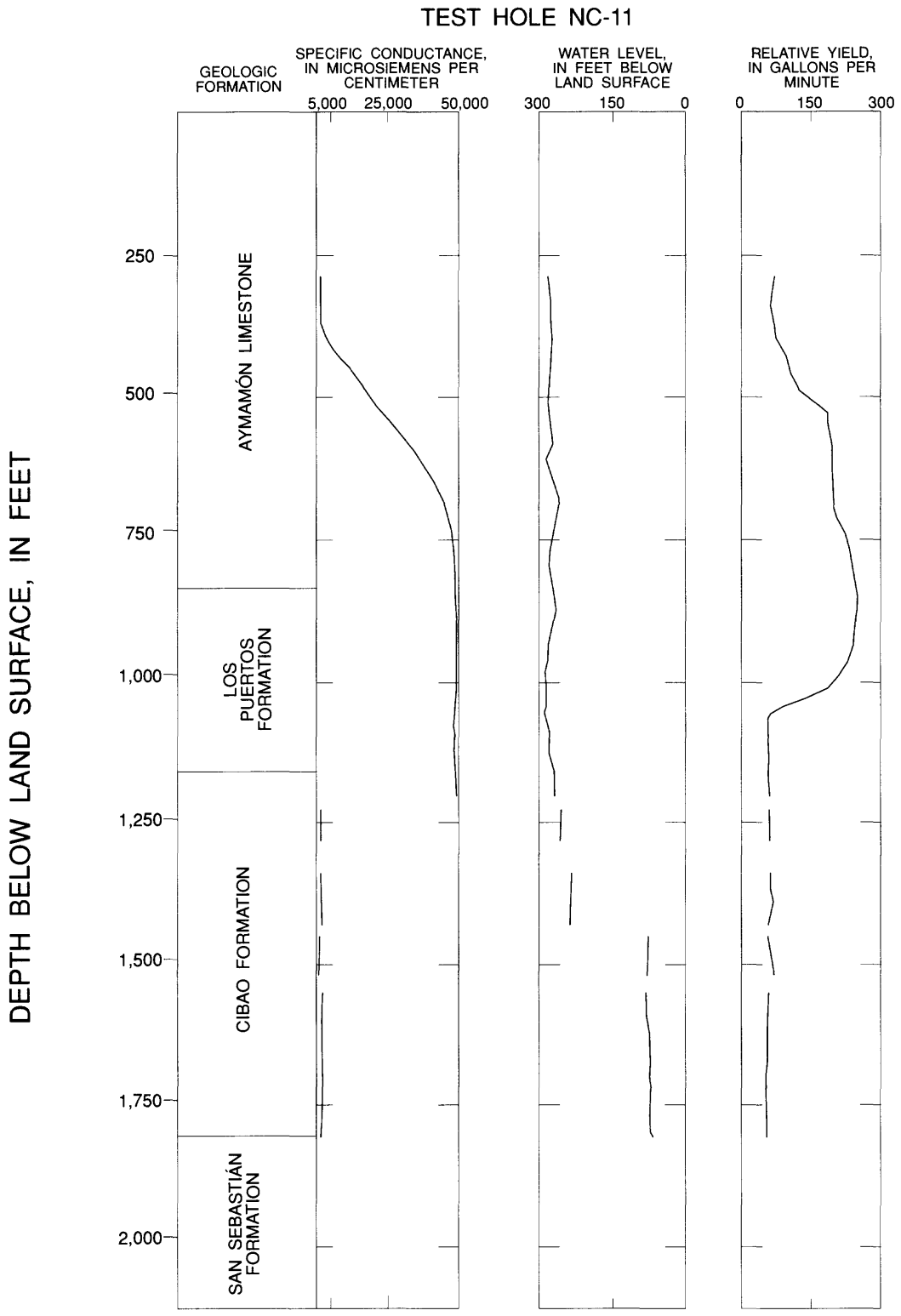

Figure 6. Geologic units, specific conductance of water, water level, and relative yield at test hole NC-11, Isabela, Puerto Rico.

to a depth of 1,280 ft; also contained within the Cibao Formation. The second, third, and fourth artesian aquifers with the intervening confining units also are located within the Cibao Formation at intervals of 1,347 to 1,428 ft, 1,450 to 1,525 ft, and 1,553 to 1,810 ft, respectively.

The specific conductance of water in the aquifers penetrated by test hole NC-11 ranged from less than 500 to 49,000 µS/cm. The specific conductance of water in the water-table aquifer varied from 1,100 µS/cm at a depth of 278 ft to 3,000 µS/cm at a depth of 400 ft (table 4, fig. 6). From 400 ft downward, the specific conductance of water in this aquifer increased to a maximum of 49,000 µS/cm at a depth of 860 ft. Specific conductance remained constant from 860 ft to a depth of 950 ft and then decreased lightly to 48,000 µS/cm at a depth of 1,000 ft. Below this depth the specific conductance remained constant at 48,000 µS/cm to a depth of 1,190 ft. The specific conductance of water in the artesian aquifers ranged from 450 to 900 µS/cm.

Relative yields and water levels varied among the five aquifers penetrated by test hole NC-11. The relative yield ranged from 70 to 240 gal/min in the water-table aquifer and from 60 to 80 gal/min in the artesian aquifers (table 4). Water level in the water-table aquifer varied from 270 to 290 ft below land surface and from 70 to 265 ft below land surface in the artesian aquifers (table 4).

SUMMARY

Test holes NC-6 and NC-11 were drilled in the municipalities of Hatillo and Isabela, respectively, in northwestern Puerto Rico. Test holes NC-6 and NC-11 were drilled to depths of 2,574 and 2,120 ft, respectively. Data collected from these test holes include core lithology, water levels, specific conductance of water, and relative yields.

Test hole NC-6 penetrated rocks ranging from Late Oligocene to Late Pliocene in age, corresponding to the following formations: the Lares Limestone, the Cibao Formation, the Los Puertos Formation, the Aymamón Limestone, and the Quebradillas Limestone. Test hole NC-6 penetrated seven water-bearing units: a water-table aquifer and six artesian aquifers. The specific conductance of water from these aquifers varied from 650 to 50,000 µS/cm in the water-table aquifer and ranged from 300 to 800 µS/cm. The relative yield ranged from 100 to 220 gal/min in the water-table aquifer and from 45 to 130 gal/min in the artesian aquifers. The water level in the water-table aquifer varied from 195 to 205 ft below land surface and ranged from 16 to 165 ft below land surface in the artesian aquifers.

Test hole NC-11 penetrated rocks ranging from late Oligocene to middle Miocene in age, corresponding to the following formations: the San Sebastián Formation, the Cibao Formation, the Los Puertos Formation, and the Aymamón Limestone. Test hole NC-11 penetrated five water-bearing units: a water-table aquifer and four artesian aquifers. The specific conductance of water in these aquifers varied from a minimum of 1,100 µS/cm to a maximum of 49,000 µS/cm in the water-table aquifer and ranged from 450 to 900 µS/cm in the artesian aquifers. The relative yield ranged from 70 to 240 gal/min in the water-table aquifer and from 60 to 80 gal/min in the artesian aquifers. The water level ranged from 270 to 290 ft below land surface in the water-table aquifer and from 75 to 265 ft below land surface in the artesian aquifers.

Table 4. Selected hydrologic data from test hole NC-11, Isabela, Puerto Rico

Depth below land surface, in feet	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius	Water level, in feet below land surface	Relative Yield in gallons per minute
	Water-Table Aquifer		
278	1,100	278	75
355	1,300	278	80
400	3,000	277	95
470	15,000	280	130
500	20,000	280	180
600	36,000	285	200
675	44,000	268	205
735	47,000	275	240
800	48,000	275	240
860	49,000	270	240
950	49,000	290	230
1,000	48,000	290	180
1,045	48,000	290	70
1,100	48,000	285	70
1,190	48,000	270	70
	First Artesian Aquifer		
1,225	500	265	65
1,280	600	265	70
	Second Artesian Aquifer		
1,347	800	240	72
1,425	850	240	75
1,428	900	240	72
	Third Artesian Aquifer		
1,450	450	75	70
1,525	450	77	80
	Fourth Artesian Aquifer		
1,553	850	77	70
1,555	800	80	70
1,810	450	70	60

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Table 1. Lithologic description of core of test hole NC-6, Hatillo, Puerto Rico

Latitude: 18°27'57"
Longitude: 66°49'26"
Land surface elevation: 294 feet above mean sea level
Total depth: 2,574 feet

Lithologic Description	Depth, in feet below land surface
Miocene-Pliocene Series	
Quebradillas Limestone	
Chalk, yellow-orange; globigerinid.	0 - 85
Miocene Series	
Aymamón Limestone	
Packstone, pale yellow-orange, dense; crustose red algae and Amphistegina common; rhodolitic in the lower part. Porosity: 3-5 percent; moldic; intraparticle; minor vuggy; fracture in the lower part of the unit.	85 - 100
Boundstone-wackestone, very pale orange; Amphistegina common; Halimeda, red algae, and encrusting foraminifera are present; coral is rare. Porosity: 3-5 percent; moldic; intraparticle; minor vuggy.	100 - 140
Wackestone, very pale orange to creamy-white, dense; Amphistegina present to common; crustose red algae present; encrusting foraminifera at the top of the unit. Porosity: 12-15 percent; moldic; interparticle.	140 - 170
Wackestone-packstone, grayish-orange to pale orange; partially calichified (recovery is locally powdery); red algae rare to present; Halimeda and molluscs very rare.	170 - 202
Cavernous porosity; no, to very poor, recovery.	202 - 240
Wackestone-packstone, grayish-orange to pink (from 262-270), creamy-white (241-269), medium- to coarse-grained; grains are micritized; unidentified skeletal fragments abundant; miliolids, molluscs, echinoderms, red algae, and branched coral present; Heterostegina rare. Porosity: 12 percent; moldic; interparticle.	240 - 270
Limestone, grayish-orange; karstified; intraclasts and geopetal fabrics.	270 - 285
Wackestone, white, yellow staining; Halimeda present to common; ostracodes, echinoderms present; red algae, molluscs and soritids rare. Porosity: 10 percent; moldic; fractures filled with yellow colored cement or soil.	285 - 300

Table 1. Lithologic description of core of test hole NC-6, Hatillo, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Wackestone, white, gray-orange mottling, chalky, rubbly, calichified; thin-shelled bivalves, echinoderms, red algae, ostracodes and miliolids noted. Porosity: very high, but undetermined; vuggy; interparticle.	300 - 310
Karst rock, grayish-orange, dense; spar lined vugs. Porosity: greater than 25 percent; vuggy.	310 - 320
Lime mudstone, pale orange-brown, dense, laminate.	320 - 325
Packstone-wackestone, very pale orange to yellow-gray, dense; red algae common to abundant; molluscs and branched coral abundant at 348-352 feet; Halimeda present to common; Amphistegina present. Porosity: 10-15 percent; moldic; vuggy; interparticle.	325 - 370
Packstone-wackestone, very pale orange to yellow-gray, dense; red algae common to abundant; Halimeda present to common; branching coral, molluscs, Amphistegina present; top of the unit is rhodolitic rudstone containing encrusting foraminifera. Porosity: 5-7 percent; moldic.	370 - 435
Packstone, creamy-white; red algae abundant; echinoderms, soritids rare; ostracodes and small gastropods present; Halimeda rare; possible fenestral structures noted. Porosity: 5-7 percent; moldic and fracture.	435 - 440
Packstone; packstone-wackestone; creamy-white, very coarse, poorly sorted, dense; locally a rudite; red algae abundant; small coral fragments, encrusting foraminifera, molluscs and intraclasts present; massive coral in the lower 10 feet. Porosity: a few percent; moldic.	440 - 468
Packstone; packstone-wackestone; creamy-white, dense; grains micritized; red algae abundant; echinoderms common to abundant; Halimeda and molluscs present (increase in abundance towards the top of the unit); small gastropods and ostracodes abundant at the top of the unit; miliolids, soritids and Amphistegina rare to common; interbedded with red algae foraminifera grainstone. Porosity: greater than 15 percent; moldic and intraparticle.	468 - 480
Same as above, but not interbedded with red algae foraminifera grainstone.	480 - 525
Packstone-grainstone, very pale orange to yellow-gray, medium-to very coarse-grained, pelloidal; grains are micritized; soritids, miliolids Amphistegina present; molluscs present to common; branched coral common; Halimeda(?) present. Porosity: 5-7 percent; moldic.	525 - 536
Packstone, pale yellowish-orange, chalky; skeletal; recovery is rubbly; molluscs and scattered branched coral present. Porosity: 1-5 percent; interparticle.	536 - 540

Table 1. Lithologic description of core of test hole NC-6, Hatillo, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Packstone, very pale orange, densely crystalline, very fine to silty; 3-5 percent interparticle dolomitic at the base of the unit; mostly unidentified skeletal fragments; a few miliolids and echinoderms noted. Porosity: 3-5 percent; interparticle.	540 - 555
Packstone, creamy-white to grayish-orange, very coarse grained; red algae 25 moldic and vuggy algae and encrusting foraminifera common; echinoderms, coral and Amphistegina present. Porosity: 25 percent; moldic; vuggy.	555 - 565
Wackestone-packstone, creamy-white to grayish-orange, crystalline; porites molds abundant; small gastropods at 560-570 feet; Amphistegina rare to present; echinoderms and rhodolites rare. Porosity: 7-10 percent; vuggy; moldic.	565 - 586
Dolomite, grayish-orange, chalky.	586 - 589
Packstone-grainstone, pale orange, very coarse grained; red algae common; Amphistegina present to common; branched coral present; patchy zones of dense cementation with other areas more porous due to dissolution. Porosity: 10-15 percent; vuggy.	589 - 596
Dolopackstone, grayish-orange, fine- to coarse-grained, poorly sorted; Amphistegina molds present to common; red algae present. Porosity: 20 percent; vuggy; intercrystalline; moldic.	596 - 612
Same as in 589-596.	612 - 615
Chalk, pale orange; locally dolomitic.	615 - 625
Packstone-grainstone, very pale orange, pelloidal, very coarse grained; dolomitic (table 2); red algae, coral, echinoderms, and Amphistegina present. Porosity: 15-20 percent; vuggy; moldic; intercrystalline.	625 - 630
Chalk, yellow-gray, pelloidal, dolomitic (10 percent). Traces of red algae, echinoderms and molluscs. Porosity: 25-30 percent; intercrystalline; minor moldic.	630 - 640
Packstone-grainstone; yellow-gray. Red algae, echinoderms and pelloids present; unidentified molds (probably Amphistegina and moldic, molds common). Porosity: 25-30 percent; intercrystalline; moldic.	640 - 646
Dolowackestone, yellow-gray. Same as 640-646 feet.	646 - 664
Wackestone-packstone, creamy-white to pale yellow-gray, dolomitic; Amphistegina common to abundant; grains strongly micritized with a strong textural inversion. Porosity: 5-10 percent; vuggy; intercrystalline.	664 - 671

Table 1. Lithologic description of core of test hole NC-6, Hatillo, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Wackestone, very pale orange, chalky, dolomitic(?); a few small foraminifera, echinoderms and molluscs present. Porosity: 10-12 percent; interparticle.	671 - 680
Dolowackestone, very pale orange to grayish-orange. Red algae 10-12, vuggy and present; echinoderms present; a few small rounded pelloidal intraclasts noted. Porosity: 10-12 percent; vuggy; intercrystalline.	680 - 700
Dolowackestone, pale yellowish-brown, densely crystalline; molluscs common; soritids present. Porosity: 7 percent; moldic; minor intercrystalline.	700 - 708
Packstone, grayish-orange; patchy dolomitic; comprises very fine grained red algae fragments and a few soritids. Porosity; 5-7 percent; intercrystalline; moldic.	708 - 724
Grainstone, very pale orange, fine grained, well sorted; tiny molds of unidentified skeletal fragments common to abundant; echinoderms common; soritids and miliolids rare. Porosity: 25 percent; moldic.	724 - 737
Wackestone, creamy-white, dense, fining upwards into a chalk, pelloidal, dolomitic; micritized grains present; echinoderms present to common; red algae and molluscs present; foraminifera rare. Chalk, pelloidal burrowed; traces of red algae, molluscs and soritids; echinoderms present; ostracodes and planktonic foraminifera common. Porosity (in wackestone) few percent; moldic; fracture. Porosity (chalk): undetermined interparticle.	737 - 785
Packstone-grainstone, very pale orange to pale yellow-orange, medium- to very-coarse grained, faintly laminated near the base, dolomitic in parts; grains heavily micritized; articulate red algae and Amphistegina common; molluscs present to rare; gastropods locally common from 790 to 792 feet; corals are noted at the top of the unit. Porosity: 5-10 percent; vuggy; intracrystalline; moldic; highest in the dolomitic zones.	785 - 813
Wackestone-packstone, creamy-white to very pale orange, dense. Dolomitic in the lower 20 feet; grains highly micritized; Amphistegina present to common to locally abundant; Halimeda common in the center of the unit and rare elsewhere; molluscs, red algae and echinoderms present soritids, high-spired gastropods occur at the top of the unit. Porosity: 15-17 percent; moldic; vuggy; locally as high as 25 percent in the dolomitic zones.	813 - 860
Dolowackestone, pale yellow-brown to very pale orange; red algae, molluscs and Amphistegina present; scattered heads of massive coral and rhodolites banks. Porosity: 25-30 percent; vuggy; intercrystalline.	860 - 920

Table 1. Lithologic description of core of test hole NC-6, Hatillo, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Dolowackestone-dolopackstone, pale yellow-brown to very pale orange; red algae, molluscs and Amphistegina present; molds suggesting Halimeda present; large masses of crustose red algae occurs at the top of the unit; massive coral occurs at 930 to 933 feet. Porosity: 20-25 percent; moldic; intercrystalline.	920 - 942
Grainstone, very pale orange; Halimeda abundant; echinoderms present to common; benthic and encrusting foraminifera rare; large bored oyster fragments noted; locally reef rock. Porosity: 20-25 percent; moldic; interparticle.	942 - 960
Chalk, dense, skeletal.	960 - 964
Dolopackstone, light olive-gray; red algae the dominant fossil; locally rhodolitic; Amphistegina, molluscs, and coral present; molds suggest Halimeda may be present. Porosity: > 25 percent; vuggy; interparticle.	964 - 970
Wackestone-packstone, yellowish-gray; red algae and coral present throughout the unit; large molluscs present at the bottom.	970 - 980
Dolomite, light olive-gray; fossils obscured by alteration. Porosity: > 25 percent; vuggy; moldic.	980 - 985
Wackestone-packstone, very pale orange, pelloidal; Halimeda common in the lower part; red algae common and highly micritized; molluscs and echinoderms present; soritids and Amphistegina rare. Porosity: 5-7 percent; moldic; vuggy.	985 - 1,000
Wackestone-packstone, very pale orange, very coarse grained, dolomitic; vuggy and echinoderms rare to present; reef rock occurs in the upper 2 feet moldic. Porosity: 10 percent; vuggy; moldic.	1,000 - 1,017
Dolowackestone, very pale orange, very fine grained; red algae is the only noted fossil. Porosity: 15-20 percent; intercrystalline.	1,017 - 1,023
Packdolostone, very pale orange to pale grayish-orange, very coarse grained; grades to dolomitic packstone; red algae present to common; Amphistegina common but present only as molds; molluscs and coral present with coral locally concentrated in small buildups. Porosity: > 20 percent; moldic; vuggy.	1,023 - 1,060
Dolowackestone-dolopackstone, very pale orange to grayish-orange; similar to 1,023-1,060. Porosity: > 20 percent; moldic; vuggy.	1,060 - 1,096
Wackestone-dolowackestone, very pale orange; Halimeda common to abundant; molluscs common; red algae and minor coral present; brecciated intraclasts noted. Porosity: > 20-25 percent; intercrystalline moldic; fracture.	1,096 - 1,108

Table 1. Lithologic description of core of test hole NC-6, Hatillo, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Dolomite (recognized as dolowackestone in parts), yellow-brown, sucrosic; fossils and textures obscured; molluscs, red algae, foraminifera, Kuphus and porites noted in the lower 10 feet of the unit. Porosity: > 30 percent; intercrystalline; moldic.	1,108 - 1,120
Dolomite, mottled grayish-orange and moderate yellow-brown; locally brecciated by solution vugs; scattered red algae fragments and echinoderms. Porosity: 10-25 percent; intercrystalline; vuggy.	1,120 - 1,148
Dolomite, yellow-brown, sucrosic; same as in 1,108-1,120 feet.	1,148 - 1,170
Los Puertos Formation	
Grainstone, yellow-gray, fine- to coarse-grained; foraminifera abundant; articulate red algae and bryozoans common. Porosity: 15-25 percent; moldic; vuggy.	1,170 - 1,175
Packstone-wackestone, medium gray, mottled, pelloidal, faintly laminated, burrowed; quartzose; Halimeda and dasyclad algae common; red algae, miliolids, and soritids present; encrusting foraminifera and Amphistegina common. Porosity: 5-7 percent; moldic.	1,175 - 1,183
Packstone-grainstone, yellow-gray, fine to medium-grained; skeletal grains micritic; miliolids and articulate red algae abundant; Halimeda rare to present; quartz present throughout and partially dissolved in the upper part of the unit; lower part of unit densely cemented containing abundant calcite spar lined vugs; upper part of unit mostly chalky rubble suggesting calichification. Porosity: 15 percent; vuggy in lower part; undetermined amount of interparticle or microscale porosity in the chalky zone.	1,183 - 1,197
Grainstone, yellow-gray, very coarse grained; foraminifera and bryozoans abundant; red algae rare. Porosity: 20-25 percent; vuggy.	1,197 - 1,205
Packstone-grainstone, yellow-gray, very fine grained, densely cemented; skeletal grains micritic; miliolids and articulate red algae abundant; Halimeda rare to present. Porosity: a few percent; moldic; vuggy.	1,205 - 1,215
Wackestone, light- to medium-gray, very fine; argillaceous in the lower 10 feet; root molds present; unidentified skeletal fragments, molluscs, foraminifera present; echinoderms rare. Porosity: 5-7 percent; moldic.	1,215 - 1,232
Mudstone, tan, microcrystalline; abundant ostracodes; fenestral structures and pellet filled burrows(?). Equivalent to the rock type that makes up the intraclasts in the top of interval between 1,250 and 1,270 feet.	1,232 - 1,242

Table 1. Lithologic description of core of test hole NC-6, Hatillo, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Packstone, light to medium gray, dense, quartzose; pelloidal matrix; foraminifera are dominant fossil and include miliolids, Heterostegina, and soritids; high spired and other gastropods common; Halimeda present; red algae rare; ostracodes mudstone intraclasts at top of the unit. Porosity: 2-5 percent; moldic.	1,242 - 1,250
Same as 1,242-1,250 feet, but with common small gastropods and bivalves.	1,250 - 1,270
Claystone, light gray.	1,270 - 1,275
Wackestone(?), light gray; calichified matrix with dark gray muddy clasts. Porosity: 15 percent; interparticle; vuggy.	1,275 - 1,280
Marl-claystone, light gray.	1,280 - 1,285
Packstone-grainstone, light to medium gray; chalky and calichified between 1,275-1,280 and 1,307 feet; articulate red algae abundant; molluscs, including Kuphus present through the unit and in samples from 1,307 feet; serpulid worm tubes are common between 1,310 and 1,320 feet; a grainstone occurs at 1,300-1,310 feet; recovery is often rubbly. Porosity: 1-2 percent; moldic in dense rock; > 20 percent in calichified zones.	1,285 - 1,330
Calichified breccia overlain by a dark gray marl.	1,330 - 1,335
Packstone-grainstone, light- to medium-gray; articulated red algae abundant; molluscs, including Kuphus, present throughout the unit and abundant at 1,335-1,340 feet; bryozoans common around 1,377 feet. Recovery is often rubbly.	1,335 - 1,420
Wackestone to wackestone-packstone, light gray to white, chalky; Halimeda abundant; red algae, miliolids and soritids present; molluscs noted in the upper 10 feet of the unit. Porosity: 25 percent; vuggy; interparticle.	1,420 - 1,440
Packstone, light gray to yellow-gray, densely cemented; Halimeda abundant; red algae, miliolids and soritids present; molluscs rare. Porosity: 3-5 percent; moldic.	1,440 - 1,452
Packstone-grainstone, light gray; large dark gray intraclasts; red algae about 75 percent of the total fossils; molluscs, Halimeda and foraminifera rare. Porosity: 15 percent in the sample but higher in the unit as a whole; interparticle; vuggy.	1,452 - 1,470
Wackestone, light gray, chalky to argillaceous; fossils include soritids, miliolids, and a few gastropods.	
Wackestone-packstone; packstone-grainstone; medium gray; red algae greater than 75 percent of total fossil content; molluscs, Halimeda and foraminifera rare; large molluscs abundant between 1,495 and 1,500 feet. Porosity: few percent; moldic.	1,490 - 1,510

Table 1. Lithologic description of core of test hole NC-6, Hatillo, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Cibao Formation	
upper member	
Grainstone, medium gray, fine- to very-coarse grained, laminated; grains imbricated; gastropods, and Kuphus present; echinoderms and miliolids rare; intraclasts of red algae packstone-wackestone are present. Porosity: 20 percent; interparticle; intraparticle.	1,510 - 1,515
Wackestone-mudstone, light gray, clayey, burrowed; traces of organic material; patchy dolomite in light gray marly claystone between 1,520 and 1,525 feet; large molluscs present in lower grainier rocks while high-spired gastropods occur in upper part of unit. Porosity: 5 percent in the molluscs; moldic.	1,515 - 1,545
Wackestone, medium-gray, mottled with yellow-gray, fine- to very coarse grained, fairly well sorted, dense; shoaling to a grainstone; articulate red algae fragments common; Halimeda common; small bivalves, gastropods and Kuphus present; echinoderms and miliolids rare; intraclasts of red algae packstone-wackestone present. Porosity: few percent in lower part of unit where molluscs occur.	1,545 - 1,555
Wackestone, light gray, clayey, burrowed; traces of organic material; soritids, miliolids, and ostracodes present throughout; molluscs common in the lower 10 feet of the unit; dasyclad algae rare. Porosity: few percent in lower part of unit; moldic.	1,555 - 1,570
Dolomudstone-dolowackestone, greenish-gray, burrowed mottled; tiny gastropods and bivalves rare.	1,570 - 1,572
Wackestone-claystone, light greenish-gray, argillaceous, burrowed; vaguely pelloidal matrix; all fossils micritized; articulate red algae common to abundant; molluscs, ostracodes and small rhodolites present; soritids, miliolids, dasyclad algae, Halimeda rare to present; echinoderms, encrusting foraminifera, and intraclasts rare; few beds of dense packstone-wackestone in the lower part of unit. Porosity: 1-2 percent; fracture; vuggy.	1,572 - 1,585
Same as in 1,570-1,572.	1,585 - 1,593
Claystone, pale greenish-gray.	1,593 - 1,604
Wackestone, pale greenish-gray, argillaceous; interbedded with marl; somewhat chalky at top of unit; few foraminifera and molluscs noted.	1,604 - 1,620
Same as in 1,593-1,604.	1,620 - 1,630

Table 1. Lithologic description of core of test hole NC-6, Hatillo, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Packstone, grades upward to a clayey wackestone by 1,645; light gray and light greenish-gray, mottled; red algae, miliolids, and soritids common; ostracodes and thin-shelled bivalves rare to present; echinoderms and worm tubes rare; red algae absent in clayey section; ostracodes with rest of fossils common in clayey section. Porosity: 5-7 percent; moldic; vuggy; intraparticle.	1,630 - 1,652
Claystone, olive-green, sandy and silty; pecten rare.	1,652 - 1,657
Siltstone, olive-green.	1,657 - 1,660
Wackestone-claystone, greenish-gray; tiny thin-shelled gastropods and bivalves; pecten and miliolids noted; oysters occur at top of unit.	1,660 - 1,700
Mudstone, light gray, microcrystalline.	1,700 - 1,708
Claystone, pale greenish-gray, yellow-brown mottled; soritids and miliolids present; molluscs occurring above 1,722 feet.	1,708 - 1,735
Wackestone, light gray, argillaceous, poorly fossiliferous; soritids and miliolids present; large gastropods at top of unit.	1,735 - 1,740
Claystone, very light greenish-gray; oxidized iron-rich particles (pyrite?) present; soritids, miliolids, and a few bivalves occur at top of unit.	1,740 - 1,755
Wackestone, light greenish-gray, argillaceous, irregularly laminated; soritids, miliolids, bryozoans, and ostracodes noted.	1,755 - 1,770
Claystone, light gray, dense, grades up to a thin wackestone-packstone; overlain by 2 feet of quartz sand and 2 feet of dark gray shale.	1,770 - 1,780
Wackestone, light greenish-gray, clayey, poorly fossiliferous, burrowed and vaguely pelloidal in places; soritids and ostracodes present to common; calcispheres, miliolids, and bryozoans present; echinoderms and molluscs rare.	1,780 - 1,840
Claystone, dark olive-green.	1,840 - 1,850
Wackestone, very pale yellow-gray, clayey, pelloidal; root molds; miliolids, soritids, echinoderms, and thin-shelled molluscs present; bryozoans rare. Porosity: 2-3 percent; fracture; moldic.	1,850 - 1,865
Grainstone, very light gray, poorly sorted, medium- to coarse-grained, Heterostegina abundant; echinoderms and miliolids present; red algae rare. Porosity: 12 percent; interparticle; particle	1,865 - 1,875
Wackestone, light greenish-gray, argillaceous; wispy laminations; traces of organics present; echinoderms common; red algae, soritids, ostracodes, and miliolids present; molluscs and encrusting foraminifera rare; burrows with a wackestone-packstone texture. Porosity: 3-5 percent; intraparticle in most of unit; 7-10 percent in burrows.	1,875 - 1,902

Table 1. Lithologic description of core of test hole NC-6, Hatillo, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Claystone, light greenish-gray to olive-green; locally silty; oysters, miliolids, other mollusc and coral fragments near top of unit.	1,902 - 1,944
Claystone, pale greenish-gray; conchoidal fracture; miliolids and worm tubes present.	1,944 - 1,960
Claystone, pale olive-green, purple mottled; miliolids rare.	1,960 - 1,980
Same as in 1,944-1,960.	1,980 - 1,985
Same as in 1,960-1,980.	1,985 - 2,012
Wackestone, very light gray, dense, clayey, burrowed; irregular argillaceous laminations; red algae abundant; miliolids common; soritids and echinoderms present; molluscs rare (mostly thin-shelled bivalves).	2,012 - 2,023
Wackestone; wackestone-packstone, very light gray, burrowed and pelloidal; unit shoals up to a 2-feet thick medium- to coarse-grained foraminifera grainstone; miliolids and pelloids common in wackestone; echinoderms and molluscs present; red algae, soritids, and rotalid foraminifera rare. Porosity: 10-12 percent in wackestone; 20 percent in grainstone; moldic; vuggy; intraparticle.	2,023 - 2,045
Limestone, fragmental; mixed with mud; disaggregated caliche layer.	2,045 - 2,050
Wackestone; packstone-grainstone, mottled, very light to medium gray; miliolids present; soritids, echinoderms, porites and ostracodes rare to present. Porosity: 3-5 percent; vuggy; interparticle.	2,050 - 2,112
Montebello Limestone Member	
Packstone, very light gray, pelloidal; unit appears to be partially calichified; articulate red algae fragments abundant; crustose algae present; Halimeda and dasyclad algae present to common; encrusting foraminifera, echinoderms, and molluscs present; miliolids, soritids, Miogypsina, and branched coral rare; many fossils have micritic rims. Porosity: patchy distribution with some areas of the unit densely cemented; up to 25-30 percent; moldic; vuggy.	2,112 - 2,120
Wackestone-packstone, very light gray, dense, slightly clayey, pelloidal; chalky in upper few feet; miliolids present; soritids, echinoderms, porites, and ostracodes rare to present. Porosity: 3-5 percent; vuggy; interparticle.	2,120 - 2,148
Claystone, green.	2,148 - 2,150

Table 1. Lithologic description of core of test hole NC-6, Hatillo, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Packstone, medium- to coarse-grained, well cemented, pelloidal; articulate red algae dominant fossil; leafy crustose red algae present; echinoderms, benthic foraminifera, and molluscs present; massive coral and abundant crustose red algae occur from 2,153-2,156 feet; root molds present; yellow brown mottling caused by partial calichification in coral rich zone. Porosity: > 20 percent; especially high in calichified portion of interval.	2,150 - 2,180
Mudstone-wackestone, grades up to a chalky and slightly marly wackestone by 2,185 feet; benthic foraminifera and red algae present.	2,180 - 2,195
Claystone, light gray; thin-shelled bivalves present.	2,195 - 2,200
Packstone, yellow-gray; grades upwards to a wackestone-packstone; articulate red abundant; Miogypsina present to common; Amphistegina; small rotalids and Lepidocyclina rarely noted; echinoderms and intraclasts present; miliolids rare; pecten occur in upper part of interval. Porosity: 10-12 percent; interparticle; intraparticle.	2,200 - 2,218
Undifferentiated Cibao Formation	
(similar to the upper member)	
Claystone; marl, light gray.	2,218 - 2,224
Wackestone-packstone, light greenish-gray, with medium gray mottling in places, very fine- to coarse-grained, poorly sorted; burrowed, pelloidal; ostracodes and echinoderms common; miliolids present to common; molluscs present; red algae present between 2,255 and 2,275 feet and common in a packstone shoal at 2,252-2,254 feet, but rare elsewhere in unit; molluscs absent from the upper 10 feet of the unit. Porosity: traces to 7 percent; interparticle; intraparticle.	2,224 - 2,275
Claystone; marl.	2,275 - 2,280
Marl; argillaceous wackestone, very light gray to light greenish-gray, dense; foraminifera and molluscs rare.	2,280 - 2,285
Shale, greenish-gray; minor chalky marl.	2,285 - 2,290
Same as in 2,280-2,285.	2,290 - 2,295
Sand, terrigenous, calcareous; sandy mudstone; marl.	2,295 - 2,305
Claystone-marl, light greenish-gray, poorly fossiliferous; a few thin beds of wackestone; miliolids and molluscs rare.	2,305 - 2,350
Wackestone; marl, light greenish-gray; lignite occurs at 2,357-2,358 feet; articulate red algae present.	2,350 - 2,362
Claystone, greenish-gray; few miliolids present.	2,362 - 2,370

Table 1. Lithologic description of core of test hole NC-6, Hatillo, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Shale, black, silty.	2,370 - 2,374
Claystone, greenish-gray; molluscs common with some occurring as whole fossils; a thin bed of miliolid rich wackestone occurs at top of unit.	2,374 - 2,390
Claystone, light greenish-gray, calcareous; topped with a few feet of wackestone containing oysters and blackened clasts.	2,390 - 2,420
Marl; wackestone, greenish-gray, clayey and silty; a few layers of claystone; a thin bed of lignite occurs from 2,433-2,435 feet; fossils are few and include soritids, miliolids, echinoderms, and thin-shelled molluscs.	2,420 - 2,450
Wackestone; wackestone-packstone, light gray to light greenish-gray, pelloidal, burrowed; articulate and crustose red algae present to common; echinoderms present; foraminifera and thin-shelled bivalves rare.	2,450 - 2,460
Oligocene Series	
Lares Limestone	
Wackestone, light greenish-gray, slightly argillaceous, dolomitic; fine irregular laminations and horsetail stylolites with argillaceous material often concentrated along the stylolites; fossils micritic; echinoderms present; red algae and ostracodes rare. Porosity: 5-7 percent; intercrystalline; fracture.	2,460 - 2,516
Claystone, light gray; localized chalky marl.	2,516 - 2,530
Wackestone-packstone, light olive-gray, chalky, argillaceous; interbedded with marl; with irregular laminations and thin lenses of clay; molluscs, including Kuphus present; foraminifera rare, include Miogypsina and miliolids; red algae may be common but grains are altered and identification is questionable. Porosity: few percent; interparticle.	2,530 - 2,538
Claystone-marl, olive-green; grades into a gray claystone with blebs of coal in the upper 6 feet of the unit.	2,538 - 2,552
Wackestone-marl, light gray to olive-gray; soritids and red algae present in the bottom 10 feet, decreasing upward; a few scattered gastropods noted. Porosity: few percent; interparticle.	2,552 - 2,574

Table 3. Lithologic description of core of test hole NC-11, Isabela, Puerto Rico

Latitude: 18°29'19"
Longitude: 67°03'13"
Land surface elevation: 289 feet above mean sea level
Total depth: 2,120 feet

Lithologic Description	Depth, in feet below land surface
Miocene Series	
Aymamón Limestone	
Modern soil.	0 - 53
Chalk, creamy-white.	53 - 65
Modern soil.	65 - 80
Wackestone-packstone, creamy-white to very pale orange; very fine grained, Amphistegina abundant. Porosity: 15 percent; interparticle.	80 - 120
Wackestone-packstone, creamy-white to very pale orange, very fine grained; Amphistegina abundant; oysters and solitary corals occur in upper 20 feet of the unit. Porosity: 15 percent; interparticle.	120 - 170
Wackestone, very pale orange; Amphistegina common; molluscs, echinoderms, encrusting, and planktonic foraminifera present. Porosity: 10 percent; vuggy; interparticle.	170 - 180
Packstone, very pale orange to grayish-orange, skeletal, recrystallized; layers of calcareous sand present; Amphistegina common; molluscs, echinoderms, encrusting, and planktonic foraminifera present. Porosity: 10 percent; vuggy; interparticle.	180 - 190
Packstone, very pale orange to grayish-orange, skeletal, recrystallized; red algae and rhodolites common; benthic foraminifera, including soritids, present; molluscs rare.	190 - 213
Wackestone-packstone, creamy-white; thin-shelled pelecypods abundant; high-spired gastropods, pecten, corals, red algae, and ostracodes present. No recovery between 216 and 220 feet. Porosity: 12-17 percent; moldic.	213 - 222
Wackestone, white, recrystallized, fragmental; fossils include encrusting foraminifera, ostrocodes, red algae, molluscs, and pelloids. Porosity: 7-10 percent; moldic; vuggy; fracture.	222 - 230
No recovery.	230 - 320
Wackestone-packstone, very pale orange; massive coral common, branched coral, encrusting red algae, and molluscs present; limpets noted. Porosity: 15-20 percent; vuggy.	320 - 342
Wackestone-packstone, very pale orange, dolomitic, very fossiliferous; thin-shelled pelecypods abundant; high-spired gastropods, pecten, corals, red algae, and ostrocodes present. Porosity: 12-17 percent; moldic.	342 - 345

Table 3. Lithologic description of core of test hole NC-11, Isabela, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Packstone, creamy-white, calcisilt; appears to be a recemented breccia in places.	345 - 348
Wackestone, creamy-white, dolomitic, poorly fossiliferous; ostrocodes present; soritids and molluscs rare; gradational with unit above. Porosity: 10-12 percent; moldic.	348 - 360
Same as in 342-345.	360 - 368
Wackestone locally boundstone, grayish-orange-pink, dolomitic; crustose red algae common; Halimeda, encrusting foraminifera, molluscs, echinoderms, and corals present. Porosity: 5-7 percent; vuggy; moldic.	368 - 378
Packstone, very pale orange, very fine grained sand to silt calcisilt, slightly dolomitic, faintly laminated; articulate red algae fragments common; echinoderms, miliolids, and molluscs present; soritids and encrusting foraminifera rare; massive coral present at top of unit. Porosity: 17-20 percent; interparticle; moldic; vuggy.	378 - 408
Wackestone-packstone, very pale orange to creamy-brown; Amphistegina present to common; rhodolitic in the lower 15 feet of the unit; molluscs present in the lower part of unit; soritids occur in the upper part of unit; echinoderms, red algae, and benthic foraminifera present; oysters occur at top of unit. Porosity: 20-25 percent; vuggy; moldic; intraparticle.	408 - 463
Wackestone, creamy-white; massive coral and rhodolites present (form 2-3 foot thick buildups); crustose red algae and benthic foraminifera present. Porosity: 10 percent; moldic; vuggy.	463 - 473
Wackestone-packstone, grayish-orange-pink, burrowed; Amphistegina abundant; echinoderms common; algae and benthic foraminifera rare. Porosity: 7-10 percent; moldic; intraparticle; fracture.	473 - 493
Packstone, very pale orange, fine- to coarse-grained sand, poorly sorted; rhodolites abundant at 490-495 and 500-504 feet; Amphistegina common; molluscs common; soritid foraminifera and coral rare. Porosity: 12-15 percent; interparticle; minor moldic.	493 - 504
Packstone-wackestone, very pale orange, grayish-orange-pink; unit contains zones of very fine grained to silty mollusc-rich packstone-wackestone near 560, 540, 525, and 510 feet; benthic and planktonic foraminifera present. Porosity: 12-15 percent; interparticle; vuggy; intraparticle.	504 - 580

Table 3. Lithologic description of core of test hole NC-11, Isabela, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Packstone-wackestone, very pale orange, skeletal, fine sand to silt-sized fragments in the upper few feet of unit; echinoderms common; molluscs, benthic foraminifera and planktonic foraminifera present; molluscs most common in silty portion of unit; red algae, bryozoans and encrusting foraminifera rare. Porosity: 20-25 percent; interparticle, intraparticle; moldic.	580 - 597
Wackestone, creamy-white, dense; Amphistegina common at base of unit with decreasing abundance upward; red algae, coral and molluscs present; Halimeda locally abundant in upper part of unit; echinoderms and nests of fecal pellets also noted. Porosity: 5-7 percent; moldic.	597 - 633
Packstone, moderate orange-pink to very pale orange, fine- to medium-sand sized, fairly well sorted; many grains have been micritized; lower portion of unit is densely cemented and shows faint laminations; Amphistegina abundant; pelloids common; echinoderms, molluscs, and rhodolites noted. Porosity: 6-7 percent; 5-7 percent; interparticle.	633 - 640
Wackestone-packstone, tan with orange mottling, dolomitic; red algae, Halimeda and molluscs dominant fossils; crustose red algae common at top of unit, locally forming coralgal reef rock; soritids noted; Amphistegina present as molds; branched coral noted. Porosity: 7-10 percent; moldic, intercrystalline; vuggy. Much of original porosity filled by later cementation.	640 - 650
Dolowackestone, tan; red algae present to locally abundant; rhodolites noted. Porosity: 12 percent; intercrystalline; moldic.	650 - 680
Dolowackestone, very pale orange, grades to dolomitic wackestone, mostly fine-sand sized skeletal fragments; upper 10 feet recovered as centimeter sized fragments of densely crystalline brecciated limestone; crustose red algae, massive and branched coral and molluscs present; foraminifera rare and include soritids and rotalids. Porosity: 15 percent; moldic, vuggy; intercrystalline; fragmental recovery in upper part of unit indicates vuggy porosity may be higher.	680 - 703
Packstone, white to very pale orange, poorly sorted; fossils include Amphistegina, soritid and miliolid foraminifera, red algae, echinoderms, and small branched coral. Porosity: 15 percent; interparticle; moldic.	703 - 707
Wackestone, very pale orange to yellowish-gray, dense, dolomitic; patchy dolowackestone; pelloidal muddy intraclasts noted; fossils include red algae, soritids, and Amphistegina. Porosity: 17-20 percent; vuggy; intercrystalline; moldic.	707 - 725
Dolowackestone, very pale orange, chalky.	725 - 736

Table 3. Lithologic description of core of test hole NC-11, Isabela, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Grainstone-packstone, very pale orange; recrystallization has obscured many of the fossils; foraminifera common, including soritids, Amphistegina, miliolids, and rotalids; small molluscs, branching coral, and rhodolites occur near bottom of unit; red algae present. Porosity: 15 percent; interparticle; moldic.	736 - 749
Dolowackestone, tan; red algae and echinoderms noted; probable small fractures infilled with dolomitic cement. Porosity: 30-40 percent; micro-scale vuggy; moldic(?).	749 - 760
Packstone, very pale orange, dense; red algae common; echinoderms, coral, and molluscs present; soritids, miliolids, and other benthic foraminifera noted. Porosity: 5 percent; moldic.	760 - 790
Dolowackestone, grayish-orange; articulate red algae fragments abundant; very-coarse sand sized molds of unidentified origin common; molluscs, Amphistegina, rhodolites, and massive coral present. Porosity: 10 percent; moldic; intercrystalline.	790 - 795
Packstone-boundstone, very pale orange, tightly cemented; coral common occurs in both branched and massive forms; molluscs, worm tubes, soritids, and echinoderms present. Porosity: 1-3 percent; moldic.	795 - 807
Packstone, very pale orange, dense, slightly dolomitic, tightly cemented locally; articulate red algae fragments and pelloids abundant; soritids, echinoderms, Amphistegina, molluscs, Halimeda, and encrusting foraminifera present; miliolids rare. Porosity: 10-20 percent; moldic; vuggy. Porosity is highest in areas with abundant originally aragonitic fossils.	807 - 823
Wackestone, white with orange tint, chalky, dolomitic; massive coral, red algae, rhodolites, and highly altered Amphistegina present. Porosity: 5 percent; interparticle; intercrystalline; moldic.	823 - 827
Packstone-wackestone, very pale orange, dense at the base and becomes slightly chalky upward; large molluscs common to abundant in lower half; coral occurs throughout unit and locally forms reef-rock; crustose red algae abundant and locally rhodolitic; Amphistegina and echinoderms present. Porosity: 7-10 percent; moldic; some interparticle porosity in chalky portion of unit.	827 - 845
Los Puertos Formation	
Grainstone-Packstone	
Very light gray, calcisiltite, slightly dolomitic; articulate red algae fragments and echinoderms most common fossils; benthic foraminifera present; planktonic and encrusting foraminifera and ostracodes rare.	845 - 857

Table 3. Lithologic description of core of test hole NC-11, Isabela, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Packstone, yellowish-gray, dolomitic; grades upwards to a packstone-wackestone; very fine- to coarse-sand grain size; poorly sorted; contains organic material and blackened fossils; Amphistegina, Halimeda, echinoderms, and red algae common; planktonic and miliolid foraminifera present; soritid and encrusting foraminifera; molluscs rare to present; rhodolites occur in middle of unit. Porosity: 20-25 percent; intercrystalline; interparticle; moldic.	857 - 865
Packstone-wackestone, light gray, calcisiltite dolomitic; identifiable fossils include planktonic foraminifera, Amphistegina, ostrocodes, echinoderms, red algae, and bryozoans. Porosity: 25 percent; interparticle; intraparticle.	865 - 875
Same as in 857-865.	875 - 890
Same as in 865-875.	890 - 915
Packstone, yellowish-gray, very fine- to medium-sand grain size, fair- to poorly-sorted, dolomitic; red algae, Halimeda, and bryozoans present; soritids, miliolids, and echinoderms rare; large gastropods abundant in lower 5 feet of interval and scattered throughout the rest of interval; oysters noted; fossil fragments subjected to extensive dissolution. Porosity: 25 percent; vuggy; moldic; interparticle.	915 - 930
Same as in 890-915.	930 - 946
Same as in 915-930.	946 - 985
Wackestone-floatstone, yellow-gray, dolomitic; spherical and dense rhodolites abundant; Amphistegina rare at bottom, become increasingly common toward the top of interval; echinoderms, Halimeda, molluscs fragments, encrusting and planktonic foraminifera, and ostrocodes present.	985 - 1,023
Calcisiltite, yellow-gray, slightly dolomitic; vaguely laminated; molluscs, bryozoans, and benthic foraminifera present. Porosity: >10 percent; interparticle.	1,023 - 1,040
Wackestone-packstone, yellow-gray; crustose and articulate red algae abundant; benthic foraminifera present; unit grades locally into a boundstone.	1,040 - 1,052
Boundstone, consisting of massive coral and rhodolites in a wackestone-packstone matrix; contains blackened intraclasts.	1,052 - 1,055
Packstone-wackestone, light yellowish-gray; locally grades into a boundstone; Halimeda abundant; Amphistegina and red algae present to common; echinoderms and molluscs present; oysters occur at top of unit. Porosity: 15-20 percent; moldic; interparticle.	1,055 - 1,075

Table 3. Lithologic description of core of test hole NC-11, Isabela, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Packstone, yellowish-gray, medium grained, slightly dolomitic; articulate red algae fragments abundant; fine grained molds of unidentified skeletal material common; Halimeda, miliolids, ostrocodes, and Amphistegina present to rare; small rhodolites with an open leafy structure, with evidence of having been bored, occur at top of interval.	1,075 - 1,092
Boundstone, yellow-gray; matrix of dolomitic pelletal wackestone; massive and branched coral and rhodolites common; Halimeda abundant; echinoderms and foraminifera present; thin shelled pelecypods, high-spired gastropods, bryozoans, and ostrocodes rare; foraminifera include Amphistegina, planktonics and lesser amounts of encrusting types, miliolids, rotalids, and soritids. Porosity: 10-12 percent; moldic; minor intercrystalline.	1,092 - 1,110
Same as in 1,075-1,092.	1,110 - 1,124
Boundstone, consists of massive coral and molluscs (including oysters), in addition to the fossils.	1,124 - 1,140
Wackestone, light greenish-gray, dolomitic; few percent quartz present; Halimeda, abundant; bryozoans, red algae, molluscs, and echinoderms present; foraminifera include soritids, encrusting types and Amphistegina; platy coral and Kuphus noted. Many of the fossils have been blackened.	1,140 - 1,156
Grainstone, very light gray, fine- to very fine-grained, laminated, slightly glauconitic; red algae dominant constituent; miliolids, molluscs, and ostrocodes present. Porosity: 20 percent; moldic; interparticle.	1,156 - 1,169
Cibao Formation (undifferentiated)	
Wackestone, light olive-gray to yellowish-gray; upper part of unit dolomitic; few percent quartz present; blackened intraclasts noted; where not dolomitic the matrix is silty; Halimeda most common fossil; molluscs common in bottom few feet of in interval with decreasing upward abundance; articulate red algae fragments, Kuphus and foraminifera present; foraminifera include miliolids, soritids, rotalids, planktonics, and Amphistegina; ostrocodes, echinoderms, and bryozoans rare; branched coral occurs at top of unit. Porosity: 10-15 percent; moldic; vuggy.	1,169 - 1,190
Interbedded fine grained sandstone and quartz rich packstone-wackestone; benthic foraminifera and traces of bryozoans noted.	1,190 - 1,200
Sand, fine grained, quartzose.	1,200 - 1,201
Siltstone, greenish-gray, quartz rich, dolomitic; small gastropods present. Porosity: 20-25 percent; intercrystalline.	1,201 - 1,211

Table 3. Lithologic description of core of test hole NC-11, Isabela, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Wackestone, medium light gray, mottled with very light gray; matrix recrystallized to microspar; dominant constituent are very fine grained skeletal fragments; miliolids the most common identifiable fossil; soritids, molluscs, ostracodes, and branched coral noted. Porosity: 7 percent; moldic.	1,211 - 1,220
Claystone, light greenish-gray.	1,220 - 1,228
Same as in 1,211-1,220. Porosity: 12-15 percent; moldic; vuggy in a given sample. The vuggyness of the interval as a whole may result in greater overall porosity.	1,228 - 1,236
Wackestone-packstone, yellowish-gray.	1,236 - 1,242
Claystone, light greenish-gray; molluscs noted.	1,242 - 1,249
Wackestone-packstone, very light gray to yellowish-gray; densely crystalline and locally brecciated; ostracodes, echinoderms, and massive coral noted. Porosity: 10-12 percent; moldic; fracture.	1,249 - 1,260
Wackestone-packstone, yellow-gray, argillaceous, silty; Halimeda common and well preserved; red algae, molluscs, ostracodes, and foraminifera present (miliolids and soritids most common, Amphistegina and planktonic foraminifera present); bryozoans and echinoderms rare; blackened intraclasts present. Porosity: 7-10 percent; moldic.	1,260 - 1,282
Packstone, light gray; molluscs abundant.	1,282 - 1,285
Wackestone-packstone, sand and gravel sized fragments mixed with varying amounts of clay; molluscs common in lower 5 feet of interval; foraminifera occur throughout interval.	1,285 - 1,292
Claystone, greenish-gray.	1,292 - 1,295
Same as 1,285-1,292 feet; gastropods abundant between 1,313 and 1,323 feet.	1,295 - 1,329
Claystone, greenish-gray.	1,329 - 1,333
Same as in 1,285-1,292.	1,333 - 1,345
Dolomudstone-dolowackestone, greenish-gray to light greenish-gray mottled; red algae is dominant fossil; soritids, echinoderms, and bryozoans noted. Porosity: 7-10 percent; intercrystalline; moldic.	1,345 - 1,352
Packstone, light gray, very fine- to coarse-sand sized grains, dominantly gravel sized recovery; argillaceous in upper 10 feet; red algae and Halimeda common to abundant; other fossils include soritids, miliolids, molluscs, echinoderms, ostracodes, a few faverina fecal pellets, Dasyclad algae, Kuphus, and coral.	1,352 - 1,365
Claystone; siltstone; dark gray; thin-shelled pelecypods abundant.	1,365 - 1,371

Table 3. Lithologic description of core of test hole NC-11, Isabela, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Wackestone-packstone, yellowish-gray, similar to 1,352-1,365; recovery is generally fragmental; branched coral common in lower part of unit.	1,371 - 1,396
Limestone, gravel sized clasts; minor quartz.	1,396 - 1,400
Same as in 1,352-1,365; recovery fairly continuous.	1,400 - 1,417
Packstone-wackestone, light gray with light greenish-gray mottling; interbedded with claystone and gravel to coarse sand sized limestone clasts; very fine- to coarse-sand sized grains; red algae common to abundant; Halimeda common; other fossils include soritids, miliolids, molluscs, echinoderms, ostracodes, a few faverina fecal pellets, and porites.	1,417 - 1,428
Packstone-wackestone, light gray and light greenish-gray mottled; similar to above but without claystone and less Halimeda; Porites noted. Porosity: 5-7 percent; moldic; fracture.	1,428 - 1,440
Limestone, sand and gravel sized clasts mixed with clay.	1,440 - 1,445
Packstone, yellowish-gray, very fine- to coarse-sand sized grains; red algae and Halimeda common to abundant; other fossils include soritids, miliolids, molluscs, echinoderms, ostracodes, and a few faverina fecal pellets. Porosity: 12-15 percent; moldic; vuggy; intraparticle.	1,445 - 1,466
Dolowackestone, greenish gray, burrow mottled; fossils not common and occur as molds; the assemblage includes foraminifera (soritids?), red algae, ostracodes, and molluscs; pyrite common; traces of organic material noted. Porosity: < 5 percent; moldic; intercrystalline.	1,466 - 1,471
Wackestone, light gray, burrowed, recovery fragmental in upper 12 feet of interval; matrix is clotty; fossils include miliolids, soritids, echinoderms, red algae, ostracodes, bryozoans, tiny gastropods, and calcipheres; opaline silica noted both as a cement and replacement mineral.	1,471 - 1,490
Claystone-marl, light greenish-gray; soritids abundant.	1,490 - 1,495
Same as 1,471-1,490.	1,495 - 1,526
Wackestone, light greenish-gray, marly; a thin bed of nonfossiliferous claystone occurs between 1,540 and 1,543 feet; small pelecypods and a few soritids noted.	1,526 - 1,550
Wackestone, mottled medium gray to medium light gray, burrowed; matrix is clotty to vaguely pelloidal; burrowing has produced zones of dense and more porous limestone; foraminifera are the dominant fossils and include miliolids (most common) soritids, rotalids and other unidentified benthic varieties, and planktonic foraminifera; molluscs present as fine sand-sized fragments; ostracodes, echinoderms, and intraclasts of pelloidal mudstone noted. Porosity: 10-12 percent; moldic; vuggy. The vuggy porosity occurs preferentially in some of the burrows.	1,550 - 1,563

Table 3. Lithologic description of core of test hole NC-11, Isabela, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Wackestone, mottled very light gray and dark gray; fossils include miliolids, molluscs (abundant), ostracodes, and bryozoans; soritids and traces of coral were noted. Porosity: 5-7 percent; moldic; vuggy.	1,563 - 1,571
Wackestone, mottled medium gray to very light gray; lighter colored portions of rock subjected to dissolution and may be outer margins of vugs; fossils are sparse and include miliolids, molluscs, and ostracodes. Porosity: 5-7 percent; vuggy; moldic. Porosity may be higher in the unit as a whole due to large vugs.	1,571 - 1,585
Wackestone, mottled light gray and yellow-gray; dolomitic yellow-gray patches may represent burrows; recovery is rubbly in lower 5 feet of unit; bryozoans most common fossil; ostracodes, molluscs, soritids, rotalids, planktonic and encrusting foraminifera, and clacispheres rare; a few muddy intraclasts noted. Porosity: averages 7 percent; moldic; interparticle; intercrystalline in the dolomitic portion of interval.	1,585 - 1,600
Packstone, very light gray to yellowish-gray; equivalent to 1,660-1,673; locally rubbly recovery; dolomudstone, occurs between 1,615 and 1,618 feet at top of interval; high-spired gastropods and small pecten noted in upper part of interval.	1,600 - 1,625
Dolowackestone-dolomudstone, mottled greenish-gray; fossils rare and include very fine- to fine-sand sized fragments of red algae and echinoderms; dolomitization may have obscured other fossils. Porosity: 20 percent; intercrystalline; minor moldic.	1,625 - 1,629
Shale, black; thin shelled pelecypods noted.	1,629 - 1,631
Packstone-wackestone, mottled light gray and yellowish-gray; fragmental recovery between 1,635 and 1,640 feet; dominantly silt and fine sand sized fragments in upper few feet of unit; soritids and miliolids common; molluscs abundant in upper few feet of unit. Porosity: 15-20 percent; moldic; interparticle; vuggy.	1,631 - 1,654
Coralgal boundstone, very light gray, light gray and yellow-gray; fossils include massive coral, encrusting and minor articulate red algae, high-spired gastropods and pelecypods. Porosity: 12-15 percent; moldic; interparticle; vuggy(?).	1,654 - 1,660
Packstone-wackestone, mottled light gray and yellowish-gray; dominantly silt and fine sand sized fragments in upper few feet of unit; soritids and miliolids common; molluscs common; echinoderms and ostracodes present. Porosity: 12-15 percent; interparticle; moldic.	1,660 - 1,675
Sand, coarse; gravelly; calcareous; scattered fragments of molluscs and foraminifera.	1,675 - 1,680
Wackestone, very light gray, burrow mottled; argillaceous in lower 15 feet; recovery rubbly between 1,682 and 1,700 feet.	1,680 - 1,740

Table 3. Lithologic description of core of test hole NC-11, Isabela, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Wackestone, mottled very light gray to light gray; grades upwards to packstone-grainstone; articulate red algae fragments dominant fossil; molluscs common and include a varied gastropod assemblage; miliolids, soritids, and ostracodes present; possible root molds noted. Porosity: 5-7 percent; moldic.	1,740 - 1,750
Dolowackestone, yellowish-gray, sparsely fossiliferous, pelloidal matrix; size and texture of pelloids indicate they are red algal fragments; fossils occur as very fine- to fine-grained fragments and include red algae, molluscs, rare soritids, and echinoderms; pyrite is present. Porosity: 15 percent; intercrystalline; interparticle; moldic; vuggy.	1,750 - 1,755
Marl, greenish-gray.	1,755 - 1,760
Wackestone-dolowackestone, light gray; recovery is mostly as gravel sized fragments; small gastropods, bivalves and foraminifera present. Porosity: indeterminable due to fragmental recovery but probably at least 25-30 percent; vuggy: interparticle.	1,760 - 1,776
Marl, light gray to greenish-gray.	1,776 - 1,785
Dolowackestone, light greenish-gray, burrow mottled; a layer of marl occurs at 1,797-1,807 feet; red algae is the most common fossil; Halimeda and dasyclad algae, molluscs, and soritids present; miliolids and echinoderms rare; most of fossils except echinoderms and red algae from upper half of interval preserved as micrite rimmed molds. Porosity: 20 percent; moldic; intercrystalline.	1,785 - 1,810
Oligocene Series	
San Sebastián Formation	
Marl, light greenish-gray; trace amounts of foraminifera and thin-shelled molluscs present; pyrite noted.	1,810 - 1,825
Marl, light greenish-gray; grainstone, fine- to medium-grained, faintly laminated; articulated red algae fragments is dominant fossil; miliolids, soritids, and molluscs noted.	1,825 - 1,830
Claystone; wackestone, marly; fossils include a few foraminifera, pelecypods and pecten; very fine sand-sized quartz and volcanic rock fragments noted.	1,830 - 1,890
Gravel, rock fragments and quartz, clay rich, poorly sorted.	1,890 - 1,900
Marl; claystone; olive-green; lenses of terrigenous sand.	1,900 - 1,940
Claystone, red-brown, locally sandy.	1,940 - 1,960
Claystone, olive-green.	1,960 - 2,020

Table 3. Lithologic description of core of test hole NC-11, Isabela, Puerto Rico--Continued

Lithologic Description	Depth, in feet below land surface
Claystone, yellow-brown with olive-green, red and purple mottling between 1,970 and 2,022 feet; a layer of lignite occurs at 1,992 to 1,994 feet; quartz, feldspar, and volcanic rock fragments common near top of interval.	2,020 - 2,060
Claystone; marl; very pale olive-green to light gray.	2,060 - 2,080
Packstone, very light gray, fine- to medium-grained; burrowing has created patches of wackestone and grainstone within the interval; miliolids and echinoderms common; other fossils include Miogypsina, crustose red algae, encrusting foraminifera, ostracodes and molluscs. Porosity: 3-5 percent; vuggy; minor fracture.	2,080 - 2,090
Claystone, olive-green; wackestone, argillaceous; miliolids common; soritids, bryozoans, ostracodes, and echinoderms present; minor quartz noted.	2,090 - 2,120

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