A Survey of Coastal Beach Sand of Mona Island (Puerto Rico)

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ABSTRACT

Sand samples were collected from 11 coast beaches of Mona Island, Puerto Rico, and were analyzed to determine the composition features and grain size. The composition of the sands was expressed as percentages of the foraminifer *Homotrema rubrum*, limestone fragments, shell fragments, and calcite ($CaCO_3$). Based on previous works and our own results, all the carbonates fraction are biogenic shell material from offshore reefs and shoal carbonate environments.

RESUMEN

Se colectaron muestras de arena de once playas costeras de Isla de Mona, Puerto Rico, y fueron analizadas para deteminar los rasgos de la composición y el tamaño del grano. El composición de las arenas se expresó como los porcentajes del foraminífero *Homotrema rubrum*, los fragmentos de caliza, los fragmentos de caracoles, y calcita ($CaCO_3$). Basándonos en los trabajos previos y nuestros propios resultados, todas las fracciones de los carbonatos son material de caracoles biogénicos arrecifales costeros y los ambientes de los bajíos de carbonato.

Additional Keywords: Beaches, sand analysis, Isla Mona, Isla de Mona, West Indies, Caribbean.
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INTRODUCTION

From historical sources, it is known that Christopher Columbus disembarked on "Amoná" — the Taino name for Mona Island — on the protected shore near Punta Arenas in 1494. This beach was used by the Taino Indians as a resting spot during frequent trips across Mona Passage (Coll y Toste 1907; Arana Soto 1969; Wadsworth 1973). In August 1508, the conquistador Juan Ponce de León, along with 50 men bound from Hispaniola to explore and exploit San Juan Bautista, Puerto Rico, landed on Mona (Coll y Toste 1907; Wadsworth 1973). His landing, like that of Columbus, must have been near Punta Arenas (Wadsworth 1973). Since early times, local fishermen, mostly from Mayagüez and Cabo Rojo, kept vigil on the beaches of Sardinera and Uvero, between April and September, waiting for turtles to come ashore to lay eggs (Abbad y Lasierra 1788). This practice continues to these days, in more secluded beaches such as, Playa Caigo o no caigo, Playa Coco, and Playa Brava, despite the rigorous local and federal laws to protect sea turtles.

The earliest known work documenting beaches and other geologic features of Mona Island was conducted by the Spanish vapor warship "Bazan," sent to Mona in 1856 by the Governor of Puerto Rico. This warship was dispatched in response to illegal extractions of guano by an American ship. In 1858 a map of the island was prepared based upon the trips this ship made to Mona (Wadsworth 1973) (Figure 1). This map, shown in Junta de Calidad Ambiental (1973), documented the names of the beaches known as "El Sardinero" (Las Carmelitas and Sardinera), "Punta

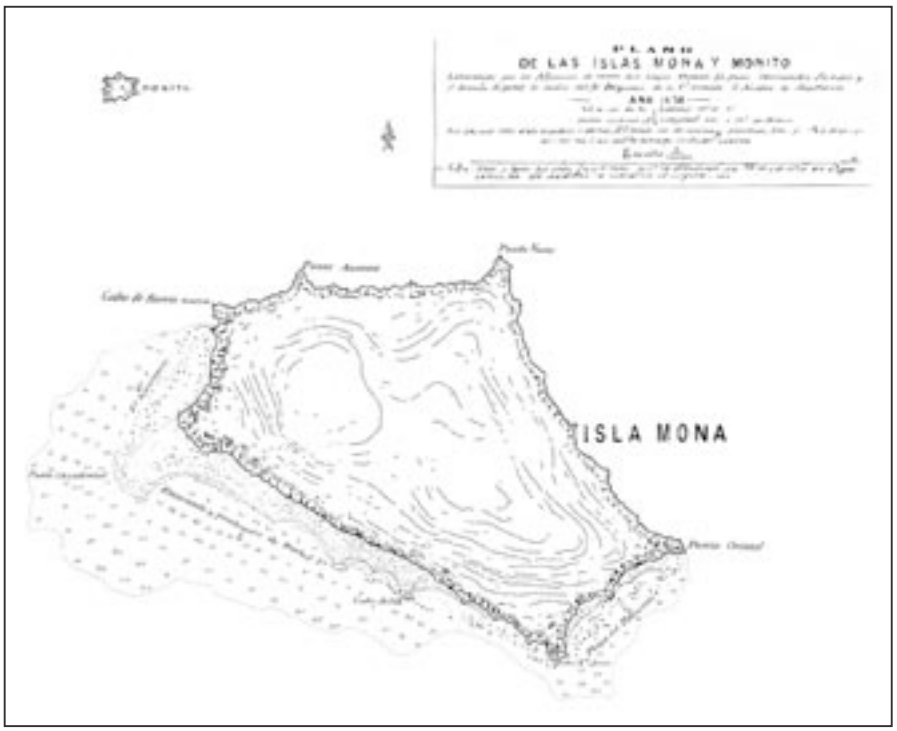

Figure 1. Map of Mona Island by the 1858 expedition in the Spanish vapor warship "Bazán" to Mona Island (Puerto Rico). (Redrawn by Peter Rocafort.)

Occidental" (Punta Areas), "Ensenada y fondeado de Isabel 2da" (Mujeres and Carabinero), "Cabo Julia" (Uvero), "Cabo S. [San] Juan" (Punta Caigo o no caigo), and "Playa del Patrocinio" (including the beaches Caigo o no caigo, Coco, Brava, Playa de Pájaros to Punta Este).

In his master's thesis, Hernández-Ávila (1970) treated the orientation, configuration, and sediment attributes of the beaches of Mona Island. He studied the shoreline from the west to southeast, showing that it possessed its own distinctive characteristics in relation to beach orientation and degree of exposure to the wave regime. He gathered traverse sediment samples from various beach zones and analyzed the samples for size and sorting statistical parameters, and description of general constituents. Hernández-Ávila constructed four wave refraction diagrams for four different wave conditions (Hernández-Ávila 1970). Sand analysis showed uniformity in size and composition, and that the beach material was moderately well sorted. Hernández-Ávila hypothesized that the source of beach sediment was the fringing and barrier reefs. Beach profile variations and sediment size distribution patterns seem to coincide with refracted wave energy convergence and divergence patterns. Beach alignment and foreland formation agree closely and support the dominant refracted swell being the main factor affecting the orientations of shorelines. He also proposed that Monito Island's wave focusing effect is the principal cause in the formation and control of Punta Arenas (Hernández-Ávila 1970).

Rivera (1973) described the soils of the coastal plain from "Anclaje Sardinero" (Sardinera) to "Desembarcadero Uvero" (Uvero), western and southwestern Mona Island, respectively. He reported the "Coastal beach" (Ch) as 0.2 km^2 of the 57.5 km^2 of the island. The coastal beaches of Mona Island consisted of narrow strips of light-colored, pinkish white beach sands along the coast. The sands are calcareous, containing numerous seashells, corals, and shell fragments throughout; no volcanic fragments were found (Rivera 1973). He also recorded the soils "Limestone outcrop" (Lo) as 55.7 km^2, "Jaucas sand" (Jd) as 0.6 km^2, and the "San Germán cobby sandy loam" (ScB) as 1.1 km^2 of the coastal plain studied (Rivera 1973).

Other historical accounts and scientific reports of the coastal geomorphology of Mona Island do exist. Brusi y Font (1884), Hübener (1898), Wadsworth (1973, 1977), Cardona Bonet (1985, 1989, 1991), and Dávila Dávila (2003) reviewed the prehistory and history of the island and mentioned early beach uses and modern management. The general geology and coastal geomorphology of Mona Island was studied by Kaye (1959), Aaron (1973), Taggart (1992), González et al. (1997), and Frank et al. (1998), and geologic maps were drawn by Briggs and Seiders (1972) and Rodríguez et al. (1977). Biological studies of the coasts of Mona Island included the works on flora (Woodbury et al. 1977; Alvarado de Gracia 1990; Cintrón and Rogers 1991; Nieves-Rivera et al. 1999) and fauna (Pagán-Font 1973; Seiglie et al. 1977; Canals et al. 1983; Diez and van Dam 2002; Schärer 2003; Nieves-Rivera and Williams 2003).

MATERIALS AND METHODS

A preliminary profile of the size and composition of the beach sand of Mona Island is herein discussed.

Study sites — Mona Island is a 55.7 km^2 elevated carbonate platform, located at 18•• 3-8' N and 67••51-57' W, south-central of the Mona Passage in the northeastern Caribbean Sea. The island has a total area of 57.5 km^2 (Rivera 1973). It is about 68 km west of Punta Higuero, Puerto Rico, and 60 km east of Punta Espada, Dominican Republic. Mean annual precipitation is 600 to 1,200 mm and mean annual temperature is 24 to 28•€. The climate has been described as subtropical dry, typical of an offshore Puerto Rican island (Calvesbert 1973; Nieves-Rivera et al. 1999).

Mona Island is characterized by a very flat, gently sloping upland surface that terminates in high, sheer sea cliffs along its northern and southern perimeter and in somewhat lower, less steep cliffs that descend to coastal lowlands along its western, southwestern, and southeastern margin. Geologically, the island is composed almost entirely of Lirios limestone and Isla de Mona dolomite that vary widely in texture, age, and origin (Frank et al. 1998). Steep cliffs dominate both, the north and east coasts, of Mona. The sea cliffs and escarpments around the periphery of the island contain numerous caves whose distribution is chiefly limited to certain well-defined zones within the carbonate rocks (Kaye 1959; González et al. 1997). Typically, the caves contain deposits of phosphorite, a granular material derived from bat guano and composed largely of the mineral apatite, a calcium phosphate (Wadsworth 1977). The phosphorite, used principally for fertilizer, is the only rock or mineral resource of Isla de Mona that has been commercially exploited. Other mineral resources include limestone and dolomite. It is highly doubtful, however, that these deposits could be developed economically under present market conditions.

Beach sands and beach rock (calcium carbonate-cemented beach sand) are common features of the western and southwestern Mona Island. The largest sandy areas extend from Playa Sardinera southeastward to Playa Uvero, and from Punta los Ingleses northeastward to Playa de Pájaros, and slightly beyond (Hernández-Ávila 1970). The beach deposits are composed of fine to medium-grained, grayish-pink calcite and aragonite sand, chiefly

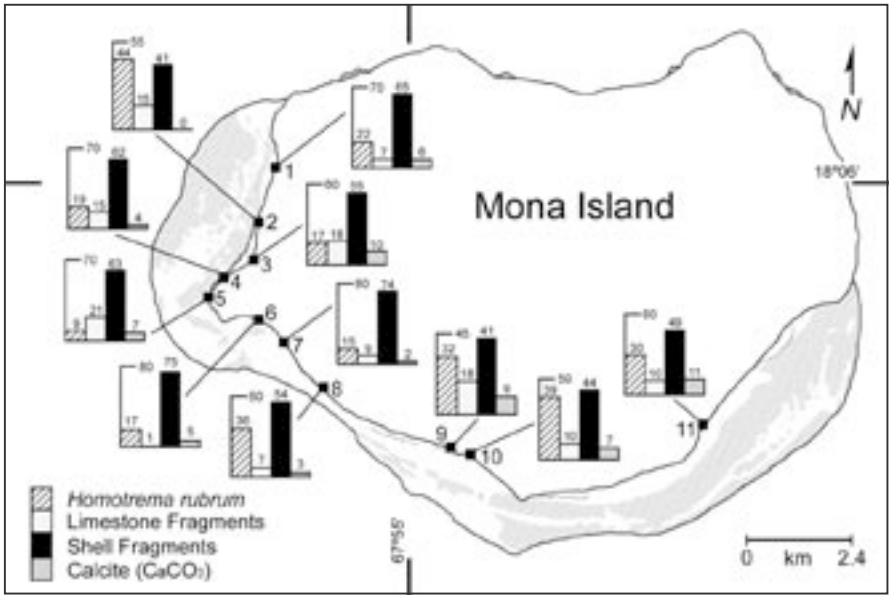

Figure 2. Collecting localities and sand composition (graphs: percentage in y-axis versus sample number in x-axis), Mona Island. Outer line represents the shelf and grayish areas represent coral reefs (mostly groove and spur system). Beach stations are discussed in the materials and method section. Modified from Cintrón et al. (1975).

Figure 3. Beach rock and sand in Las Carmelitas, Mona Island. Also notice the pedestal boulder formed by bioerosion in the shallow lagoon. (Photo: Luis A. Padilla)

Figure 4. View of Sardinera III, next to the museum, Mona Island. Monito Island is located at the horizon left side. (Photo: Á. M. Nieves-Rivera)

corn-minute shell debris (Rivera 1973). The beach deposits are of Holocene age (Kaye 1959; Taggart 1992).

Method — Sand samples were collected from 11 beaches of the western and southwestern coasts of Mona Island (Figure 2). The beaches studied were located at the following station numbers:

(1) Las Carmelitas (18°06'01.9" N, 67°56'16.9") (Figure 3),

(2) Sardinera I (no coordinates, a third of the way to Esqueleto/Diamante Cave),

(3) Sardinera II (18°05'32.7" N, 67°56'30.2" W, next to dock),

(4) Sardinera III (18°05'18.5" N, 67°56'20.5" W, close to weather station Mona Island-2, no. 66-6258-7) (Figure 4),

(5) Punta Arenas (18•04'49.5" N, 67•56'36.5" W),

(6) Mujeres I (18•04'85.4" N, 67•56'37.9" W, close to mangrove forest) (Figure 5),

(7) Mujeres II (18°04'37.0" N, 67°55'58.4" W, next to airstrip),

(8) Carabinero (18°04'06.2" N, 67°55'34.6" W, where beach is nearest the shelf),

(9) Uvero I (18•03'61.9" N, 67•54'35.1" W, close to gazebos),

(10) Uvero II (no coordinates, next to the tomb of Tomás Andújar), and

(11) Playa de Pájaros (18°03'87.4" N, 67°52'02.5"W, next to dock).

The samples were taken from the beach immediately above the swash zone and were analyzed for the grain size and composition features (Martínez 1988). Sampled sands were observed with stereo and compound microscopes. The composition of the sands was expressed by percentages of the foraminifer *Homotrema rubrum* limestone fragments, shell fragments, and calcite ($CaCO_3$). *Homotrema rubrum* depository is indicated by its locality numbers of the Geology Museum, Department of Geology, University of Puerto Rico, Mayagüez, Puerto Rico (UPRMP).

RESULTS AND DISCUSSION

Oceanographic Observations — Sea surface and aeolian currents obviously affect the beach budget directly. This phenomenon could be seen in Mona Island beaches (e.g., Playa Sardinera, Punta Arenas, Playa Carite, Punta Toro, and Playa Mujeres). Surface seawater salinity ranges from 34 to 41 g/L, with temperatures of 26 to 30•€, a pH of 7.8 to 8.4, a total alkalinity of 75 to 128 mg/L, and a dissolved oxygen (DO) value of 5.0 to 7.8 mg/L (Nieves-Rivera et al. 2003). Wicks and Troester (1998) reported seawater salinity of 33.7 g/L and a pH of 8.2. Temperature and salinity profiles obtained by Corredor and Weinberg (1980) denote strong stratification in nearby waters. This stable, stratified density field inhibits enrichment of surface waters (Caribbean Surface Water of Wüst (1964)) by vertical transport. Offshore water turbidity ranges from 0 to 45 Jackson Turbidity Unit, or JTU (Nieves-Rivera et al. 2003).

Figure 5. View of Mujeres I, Mona Island. (Photo: María Ortiz)

Sea surface currents of Mona Island were studied by Kaye (1959), Perl and Cintrón (1975), and Metcalf et al. (1977). Cintrón et al. (1975) determined that wave direction is from the east 46% of the time, from the southeast 16% of the time, and from the northeast 13% of the time. According to Corredor and Weinberg (1980), chlorophyll-a distribution clearly indicates the presence of a halo of high phytoplankton concentration close to Mona, which is evidence of an island mass effect. Corredor and Weinberg (1980) also found that dissolved nitrate and nitrite concentrations show a marked impoverishment of nutrient salts in the upper layers.

Sand Analysis — Sand samples collected at Mona Island coast beaches and analyzed for composition features (Figure 2) and size (Figure 6) were found to be almost identical in composition. The sand size analysis showed the uniformity, composition, and sorting, similar to the results by Hernández-Ávila (1970). Sand samples from the beaches Mujeres II and Carabinero showed the largest and smallest differences in size in regards to the rest of the samples studied. All the carbonates fraction are biogenic shell material from offshore reefs and shoal carbonate environments. Calcium carbonate is supplied to the beach by the shoreward transport to the shells of marine organisms. The composition changes in calcium carbonate material as a function of the available supply of each and the transport system. The beaches of the southwestern coast are continuous in most cases, having discontinuous patches with similar sand composition. Sand composition and net shore drift indicators have been used to determine the separate systems. Current movement and

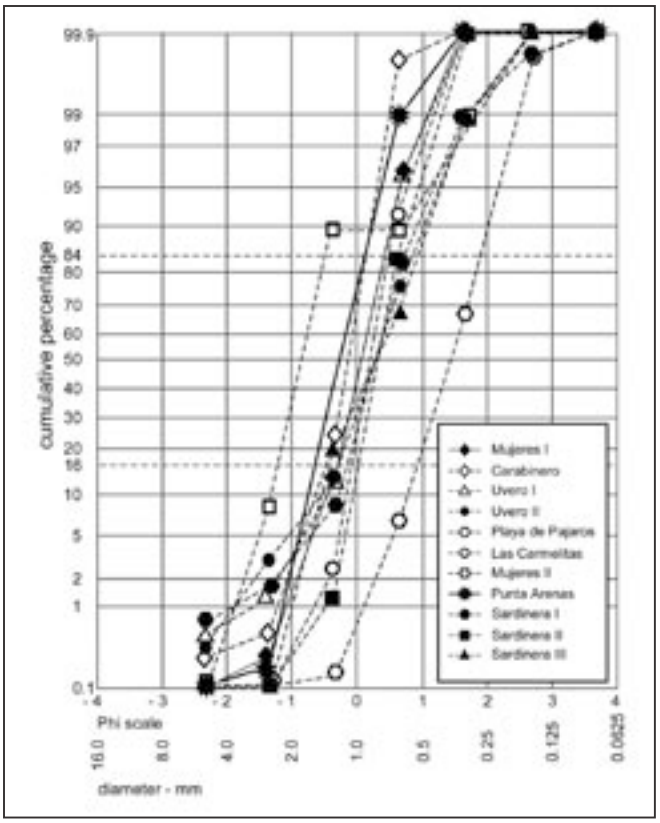

Figure 6. Size analysis (cumulative percent versus phi).

longshore drift on the southwestern coast from Sardinera to Uvero is from north to south (Perl and Cintrón 1975).

Figure 2 shows that *Homotrema rubrum* (compared with specimens UPRMP-2818, SB-10 and IC-1 of G. A. Seglie Foraminifer Collection at UPRMP) varied from a maximum of 44% from Playa Sardinera (Stn. 2) to a minimum of 9% from Punta Arenas (Stn. 5). The limestone fragments varied from a maximum of 21% from Punta Arenas (Stn. 5) to a minimum of 1% (minimum) from Playa Mujeres (Stn. 6). All shell fragments amounted to 75% (maximum) from Playa Mujeres (Stn. 6) to 41% (minimum) from Sardinera and Uvero (Stn. 2 and 9). Finally, calcium carbonate ($CaCO_3$) amounted to 11% (maximum) from Playa de Pájaros (Stn. 11) to 0% (minimum) from Playa Sardinera (Stn. 2).

This study agrees with the findings of Hernández-Ávila (1970). He found that sediment size analyses and bulk constituent percentages disclosed that the beach sediments of Mona Island are uniform in size and composition (Figure 3). They are moderately well sorted, coarse skeletal sand. The most probable source of beach sediment seems to be the fringing and barrier reefs, following the conclusions of Hernández-Ávila (1970).

CONCLUSIONS

We found that the composition of the sand samples from coast beaches of Mona Island were composed of percentages of the foraminifer *Homotrema rubrum*, limestone fragments, shell fragments, and calcite ($CaCO_3$). Based on previous works and our own results, all the carbonates fraction are biogenic shell material from offshore reefs and shoal carbonate environments.

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