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GEOLOGY OF ISLA DE MONA, PUERTO RICO

EDWARD F. FRANK
Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN 55455 USA
CAROL WICKS
Department of Geological Sciences, University of Missouri-Columbia, Columbia, MO 65211 USA
JOHN MYLROIE
Department of Geosciences, Mississippi State University, Mississippi State, MS 39762 USA
JOSEPH TROESTER
U.S. Geological Survey, GSA Center, 651 Federal Drive, Suite 400-15, Guaynabo, PR 00965-5703
E. CALVIN ALEXANDER, JR.
Department of Geology and Geophysics, University of Minnesota, Minneapolis, MN 55455 USA
JAMES L. CAREW
Department of Geology, University of Charleston, Charleston, SC 29424 USA

Isla de Mona is a carbonate island located in the Mona Passage 68 km west of Puerto Rico. The tectonically uplifted island is 12 km by 5 km, with an area of 55 km², and forms a raised flat-topped platform or meseta. The meseta tilts gently to the south and is bounded by near vertical cliffs on all sides. These cliffs rise from 80 m above sea level on the north to 20 m above the sea on the southern coast. Along the southwestern and western side of the island a three- to six-meter-high Pleistocene fossil reef abuts the base of the cliff to form a narrow coastal plain. The meseta itself consists of two Mio-Pliocene carbonate units, the lower Isla de Mona Dolomite and the upper Lirio Limestone. Numerous karst features, including a series of flank margin caves primarily developed at the Lirio Limestone/Isla de Mona Dolomite contact, literally ring the periphery of the island.

Isla de Mona is a tectonically uplifted Mio-Pliocene carbonate island in the Mona Passage approximately half way between Puerto Rico and Hispanola. The kidney-shaped island is 12 km long and 5 km wide and covers 55 km² (Peck *et al.* 1981). The bulk of the island forms a flat-topped, raised platform, or meseta, that dips gently to the south (Fig. 1). This meseta is bounded on all sides by vertical to near-vertical cliffs. (The Puerto Ricans refer to the flat-topped, raised platform of Isla de Mona as a meseta. For consistency, the authors of papers in this volume will also use meseta, however, it should not be confused with the geographic definition of the term). Along the north coast the cliff drops vertically from a maximum elevation of 80 m to a depth of at least 30 m below sea level. Along the southern and western margins of the island a Pleistocene fossil reef abuts the base of the 20 to 30 m high cliffs to form a 3 to 6 m high coastal flat. This reef flat is generally narrow with a maximum width of 1 kilometer in the Piedra del Carabinero area of the southern coast. Offshore a modern coral reef parallels the shore from Punta Este, around the southern coast, and northward almost to Punta el Capitan along the western coast of the island. This reef is separated from shore by a shallow lagoon that ranges from a few meters to a few hundred meters wide. A small sister island, Monito, is located 5 km northwest. It is similar in description but occupies only 0.17 km² of area (Peck *et al.* 1981) (Fig. 2).

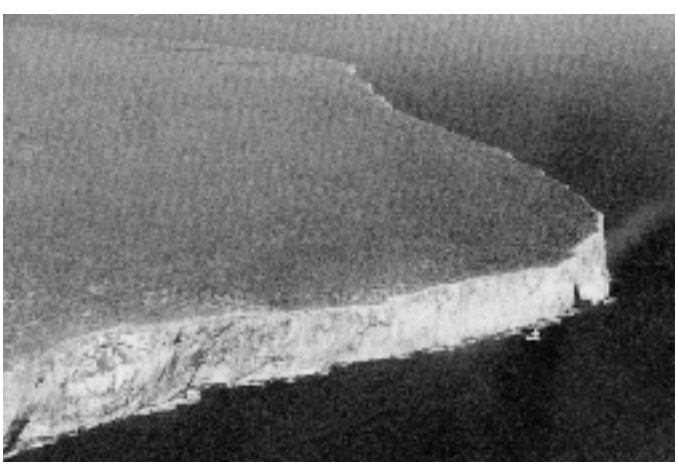

Figure 1. North shore of Isla de Mona showing 70 m high cliffs and flat surface of the meseta or raised platform surface.

TECTONICS

The major tectonic features of the region are the Puerto Rico Trench to the north, the Muertos Trough to the south and southwest, the Anegada Passage to the southeast, and the Mona Canyon trending north-south between Puerto Rico and Hispaniola (Fig. 3). The Puerto Rico Trench marks the boundary between the Caribbean and North American plates. Because it is not completely linear, portions of the boundary of the Caribbean plate are undergoing subduction, while in other areas the relative motion results in strike-slip faults.

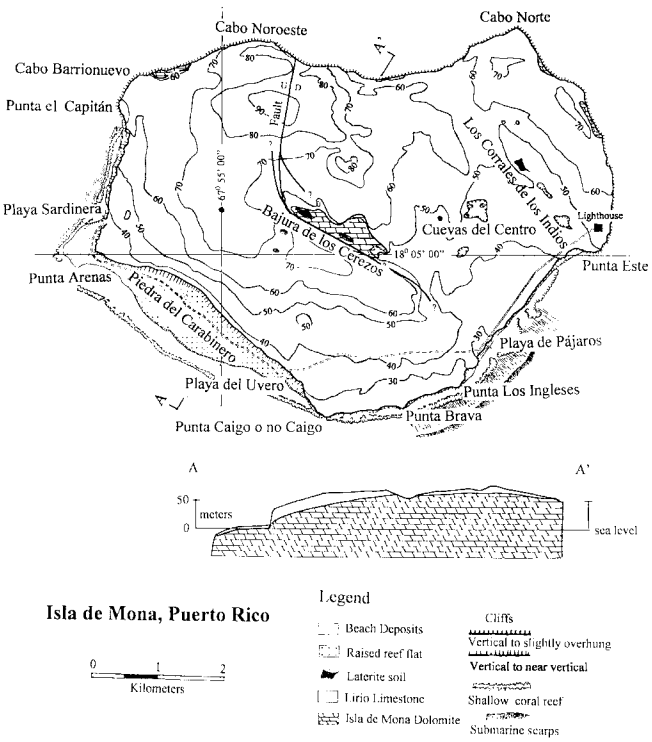

Figure 2. General geologic map and cross section of Isla de Mona, Puerto Rico. Major topographic features are marked. Adapted from Kaye (1959) and Briggs and Seiders (1972).

Compression along the Muertos Trough decreases gradually eastward, ultimately to be replaced by extension in Anegada Passage. Northwest of Puerto Rico, an obvious structural break occurs along Mona Canyon. However, no obvious structural or seismic continuity links Mona Canyon to the Muertos Trough to the south. One possibility is that Puerto Rico and eastern Hispaniola are both undergoing counterclockwise movement as independent or semi-independent blocks. The extensional forces that produced Mona Canyon are a result of the relative movement between them (Masson & Scanlon 1991).

Isla de Mona itself expresses a number of tectonic features. A series of low amplitude, southward plunging anticlines/synclines cross the island. The island has undergone tectonic uplift since deposition and is generally tilted to the south at five to ten meters per kilometer (0.3° to 0.6° dip). A large fault (Fig. 2) extends inward from the north shore through the Bajura de los Cerezos and terminates in the south central portion of the meseta (Briggs & Seiders 1973).

STRATIGRAPHY

Isla de Mona is dominated by a carbonate meseta consisting of two units, the Isla de Mona Dolomite and the Lirio Limestone (Fig. 2). Kaye (1959) placed the age of the Lirio Limestone as Middle Miocene based upon a limited foraminifera assemblage identified in samples. More recent work by Gonzales et al. (1997) suggests a younger date of late Miocene to early Pliocene age for the major carbonate units of the island based upon overall coral assemblages.

The Isla de Mona Dolomite is a pale tan, very finely crystalline, calcitic dolostone. It is thick to massively bedded, and locally cross bedded (Quinlan 1974). The maximum exposure above sea level is 80 m near Cabo Noroeste (Briggs 1974). The dolostone has a limited surface area of outcrop. Volumetrically, however, it makes up the largest portion of the island, extensively cropping along the near vertical cliff faces surrounding the island and in the Bajura los Cerezos area in the central portion of the island.

The Lirio Limestone overlies the Mona Dolomite and forms the cap on the island. It is a pale tan, finely crystalline limestone. The maximum exposed thickness is 40 m near Playa Sardinera, but averages only 10 to 15 m thick along the cliff tops. The limestone bedding ranges from 2 to 5 meters in thickness, with cross beds locally up to 2 to 3 cm thick. The Lirio Limestone is moderately fossiliferous, with accumulations of large coral heads and patch reefs near Cueva del Capitan and Cuevas del Centro (Briggs 1974). This unit is extensively karstified with caves, karren, sinkholes, pits, and enlarged joints across the plateau surface.

Ruiz (1993) did detailed petrographic work on rock samples collected from the island. He provides a description of the origin of the carbonate units as follows: "The carbonate build-up of Isla de Mona is the result of the development of a barrier reef of middle Miocene to earliest Pliocene age. Four reef facies have been identified in the Tertiary deposits of the island. Fore-reef deposits characterized by muds, pelagic foraminifera, and steeply dipping strata are present on the

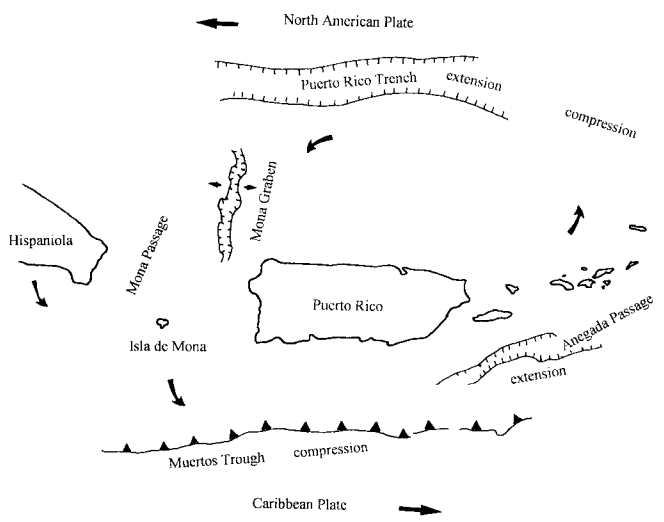

Figure 3. Regional tectonics of the Isla de Mona area showing major structural features and relative plate motions. Adapted from Mason and Scanlon (1991).

southwestern cliffs. A reef is exposed along the southeastern coast as well as in the western tip of the island. A transition between reef-flat and back-reef deposits is present to the north of the reef. Lagoon deposits composed of pelleted muds, benthic foraminifera, and coralline algae, makes up the bulk of the island's carbonates. Scattered patch-reefs are locally developed in the lagoon facies" (p. 70-71). Ruiz treats both units as part of a single reef complex.

The nature of the contact between the Lirio Limestone and the Isla de Mona Dolomite has been the subject of much speculation. In the cliffs along the eastern and northern shores of the island, there is a marked difference in the coloration of the rock units above and below the major band of cave development. Kaye (1959) found that the unit above the band was darker and a relatively pure limestone while the unit below the cave band was a lighter color and dolomitic limestone or dolomite. An apparent angular unconformity was also noted at the contact between the upper darker-colored rocks and the lower lighter-colored rocks in the cliffs around Punta Este. Kaye (1959) defined the upper unit, which forms a thin cap over much of the island, as the Lirio Limestone and the lower unit, which makes up the bulk of the island, as the Isla Mona Limestone.

Briggs and Seiders (1972) redefined these units so that the entire exposed cliff near Punta Arenas was reassigned to the Lirio Limestone and the Isla Mona Limestone was renamed the Isla de Mona Dolomite. Briggs (1974) suggested, as an alternative interpretation, that the contacts between the two unit might be essentially conformable with the apparent angular unconformity simply being large scale crossbeds. He also notes that where the contact is exposed in the cliffs along the western and southeastern shores of the island, examination from a distance gives the impression that the lower few meters of the Lirio Limestone grade laterally into the upper Isla de Mona Dolomite. Ruiz (1993) does not directly address the question of the nature of the contact between the Lirio Limestone and the Isla de Mona Dolomite. Gonzales *et al.* (1997) found the Lirio Limestone/Isla de Mona Dolomite contact to be conformable. The lithology at the base of the Lirio Limestone is dolomitic limestone and gradually changes upward into almost pure limestone at the top of the unit. The dolomitized section extends several meters above the unit contacts.

The Pleistocene-aged reef tracts, composed primarily of a mixed head-coral facies overlain by an extensive *Acropora palmata* reef-crest facies, extend along 14 km of the southern and western coasts of the island (Fig. 2). These deposits are found at elevations of up to 5 m msl, and at distances of several hundred meters from the present day shoreline (Taggart 1993).

Radiometric dating using the $^{230}Th/^{234}U$ method have shown these reefs to have been active from 128-107 Ka (Taggart 1993). The presence of these last interglacial deposits at positions between sea level and 6 m msl indicate there has been no tectonic movement of the Mona platform for over 100,000 years.

Locally, these reef tracts are capped by beach sands. Boulders of Isla de Mona Dolomite and Lirio Limestone fell from the cliffs and are sporadically located at the base of the cliffs surrounding the island. Large coral boulders up to 5 m across have been torn from the Holocene reefs and deposited on top of the late Pleistocene coastal flats in the southwestern portion of the island within the last 3,000 years (Taggart *et al.* 1993).

KARST DEVELOPMENT

A variety of karst features are found on the island. The most prominent of these are a series of caves that ring the periphery of the island. The majority of these caves are developed at the Lirio Limestone/Isla de Mona Dolomite contact, whereas others are independent of this formational boundary. The caves are flank margin caves and range in size from a meter or less across to caves containing series of large interconnected rooms that extend more than one kilometer. Floor areas of some individual caves and cave systems are in excess of 150,000 m^2. The caves are all restricted to the edge of the island with a maximum inward penetration of 240 m from the cliff face (Frank 1993; Mylroie *et al.* 1995, Frank *et al.* 1998).

Another significant karst feature is Bajura de los Cerezos, a closed, internally drained, depression in the center of the island, developed along a fault line. Other important karst features include: (1) Cuevas del Centro, a series of large nested sinkholes; (2) Los Corrales de los Indios, a dissolutional valley formed along a fracture; (3) Camino de los Cerezos pit area, an area containing a large number of vertical shafts; and (4) the surface of the meseta has been etched by dissolution into small-scale pits.

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