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Late Quaternary uplift along the North America-Caribbean plate boundary: Evidence from the sea level record of Guantanamo Bay, Cuba

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ABSTRACT

The tectonic setting of the North America-Caribbean plate boundary has been studied intensively, but some aspects are still poorly understood, particularly along the Oriente fault zone. Guantanamo Bay, southern Cuba, is considered to be on a coastline that is under a transpressive tectonic regime along this zone, and is hypothesized to have a low uplift rate. We tested this by studying emergent reef terrace deposits around the bay. Reef elevations in the protected, inner part of the bay are ~11–12 m and outer-coast, wave-cut benches are as high as ~14 m. Uranium-series analyses of corals yield ages ranging from ~133 ka to ~119 ka, correlating this reef to the peak of the last interglacial period, marine isotope stage (MIS) 5.5. Assuming a span of possible paleo-sea levels at the time of the last interglacial period yields long-term tectonic uplift rates of 0.02–0.11 m/ka, supporting the hypothesis that the tectonic uplift rate is low. Nevertheless, on the eastern and southern coasts of Cuba, east and west of Guantanamo Bay, there are flights of multiple marine terraces, at higher elevations, that could record a higher rate of uplift, implying that Guantanamo Bay may be anomalous. Southern Cuba is considered to have experienced a measurable but modest effect from glacial isostatic adjustment (GIA) processes. Thus, with a low uplift rate, Guantanamo Bay should show no evidence of emergent marine terraces dating to the ~100 ka (MIS 5.3) or ~80 ka (MIS 5.1) sea stands and results of the present study support this.

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1. Introduction

The complex boundary between the North America plate and the Caribbean plate at its northern margin (Fig. 1) is considered to be primarily a left-lateral, strike-slip zone, ~100–~250 km wide, that extends over a distance of ~2000 km (Fig. 1). East of the spreading zone near the Cayman Islands, the plate boundary is dominated by two main subparallel faults, the Enriquillo-Plantain Garden fault zone (often called the "EPGFZ") in the south and the Oriente-Septentrional fault zone in the north (Fig. 2; note that just the Oriente portion of the Oriente-Septentrional fault zone is shown here). The North America-Caribbean plate boundary is seismically active and has been studied intensively (Calais et al., 1998; Mann, 2007; Mann et al., 1995, 2002; Pindell and Kennan, 2009; Prentice et al., 2010). Mann et al. (2002), using Global Positioning System (GPS) measurements, infer that the rigid interior of the Caribbean plate is moving northeastward, but rates of horizontal movement vary among individual crustal blocks within the plate, ranging from 19 to 20 mm/yr (e.g., Puerto Rico) to 4–17 mm/yr (e.g., Dominican Republic). Although much of the movement along the northern plate boundary is known to be horizontal, detailed studies have shown that vertical movement is also a component of Quaternary tectonics, and late Quaternary uplift rates vary significantly along its length. For example, Mann et al. (1995), studying the emergent, ~120 ka coral reef terraces in Haiti, report that uplift rates vary from ~0.37 m/ka in the northwestern peninsula, to ~0.19 m/ka in the western part of Haiti, to zero in the south-central part of western Haiti, on Gonave Island. Higher uplift rates in some areas may be due to restraining bends in the major strike-slip faults that accommodate movement along the North America-Caribbean plate boundary (Mann, 2007).

To the west of Haiti, movement along the North America-Caribbean plate boundary is accommodated primarily by the Oriente fault zone, which parallels the southern coast of Cuba (Fig. 2). Rojas-Agramonte et al. (2005) proposed that the Oriente fault zone has undergone considerable evolution over time, from a region

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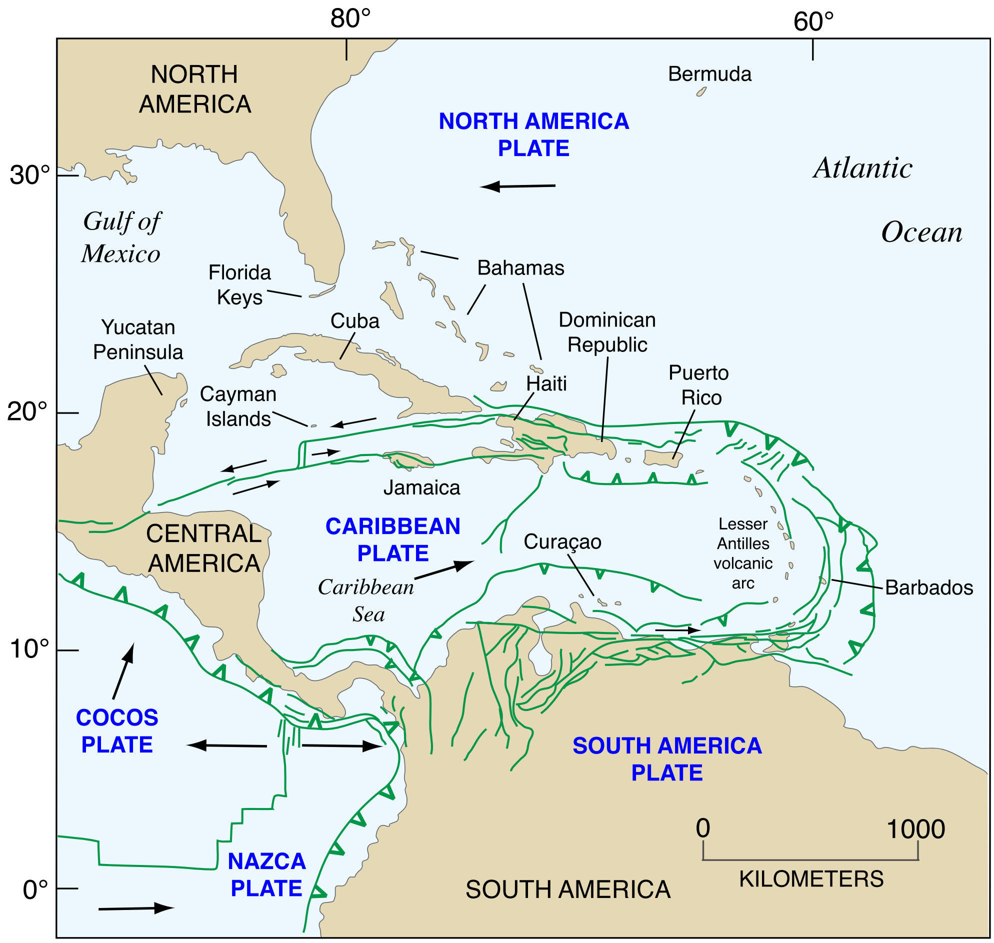

Fig. 1. Tectonic map of the Caribbean Basin and surrounding areas, showing faults (redrawn from Mann (2007) and Pindell and Kennan (2009)), lithospheric plates, directions of present plate movements (arrows), and localities referred to in text.

dominated by compression (late Eocene-Oligocene), to transtension (late Oligocene to Miocene [?]), to transpression (Pliocene to present), when the region had fully evolved into a transform fault zone. If the Oriente fault zone is now characterized by transpression, there should be a measurable component of vertical movement, although possibly small. Such a vertical component of movement could be expressed as uplifted, wave-cut marine terraces or uplifted, constructional coral reef terraces, similar to what Mann et al. (1995) report for Haiti.

Going back more than a century, early investigators noted the presence of emergent coral reef terraces on the coasts of Cuba, but struggled with interpretations of whether these landforms represented uplift, subsidence, or both (Agassiz, 1894; Crosby, 1882; Hill, 1895; Vaughn, 1919). Part of the frustration for these pioneering scientists in interpreting the Cuban terraces was likely due to Darwin's (1889, with earlier editions in 1842 and 1874) theory of coral reef formation, which posits that coral reefs form as a result of long-term regional subsidence. Thus, the presence of *emergent* coral reef terraces on the coast of Cuba, sometimes at considerable elevation, was difficult for early investigators to reconcile with long-term subsidence.

Later investigators provided new hypotheses about the terraces of southern Cuba. Taber (1934) studied a flight of 12 terraces situated ~22 km to the east of Cabo Cruz (Fig. 2). He considered that the terraces in southern Cuba were erosional, wave-cut features, rather than constructional reef terraces, but he recognized that the highest of these terraces (at least ~300 m above present sea level) were too high to be explained by eustatic sea-level rise from any Pleistocene interglacial period. Thus, he concluded that there must have been Quaternary uplift and in fact offered the possibility that the lowest terrace in southern Cuba could even be of Holocene age, implying a relatively high rate of uplift. Taber (1934) inferred that each terrace represented a discrete, presumably coseismic, uplift event. A few decades later, Horsfield (1975), in a pan-Caribbean review of marine terrace records, also noted that a detailed marine terrace record is present along the southern coast of Cuba. Consistent with modern concepts of marine terraces and sea level history, however, he recognized that each terrace likely represented an interglacial high-sea stand, rather than a discrete coseismic event. Horsfield (1975) hypothesized that the numbers of terraces and the altitudes of the highest terrace were positively correlated with uplift rate. Thus, by these criteria, Horsfield (1975) inferred that along the eastern Cuban coast, uplift rates would be highest near Punta de Maisí (Fig. 2), where his estimates of the number of terraces was greatest and terrace elevations are highest. He speculated that uplift rates should decrease to the west, toward Cabo Cruz. More recently, Rojas-Agramonte et al. (2005) reported marine terraces at elevations up to ~200 m in the Santiago area of southern Cuba (Fig. 2), and inferred that these landforms must have been elevated by tectonic uplift. Because of the relatively high elevations of some of the terraces in this part of Cuba, Rojas-Agramonte et al. (2005, p. 177) interpreted the southeastern part of the island to be experiencing a high rate of tectonic uplift.

It is important to point out, however, that in the absence of