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Plate boundary segmentation in the northeastern Caribbean from geodetic measurements and Neogene geological observations

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ABSTRACT

The Caribbean–North America plate boundary in the northeastern Caribbean shows a remarkable example of along-strike transition from plate boundary–normal subduction in the Lesser Antilles, oblique subduction with no strain partitioning in Puerto Rico, and oblique subduction/collision with strain partitioning further west in Hispaniola. We show that this segmentation is well marked in the interseismic strain, as measured using space geodetic data, and in the Neogene deformation regime, as derived from geological observations. Hence, interseismic segmentation, which reproduces the geological segmentation persistent over a long time interval, is inherited from the geological history and long-term properties of the plate boundary. This result is relevant to the assessment of seismic hazard at convergent plate boundaries, where geodetic measurements often show interseismic segmentation between fully–and partially–coupled plate interface regions.

1. Introduction

The Caribbean domain and Central America form a small lithospheric plate between North and South America (Fig. 1). While the North and South American plates show little relative motion in the Present (Patriat et al., 2011), the Caribbean plate moves eastward relative to them at 18–20 mm/yr (DeMets et al., 2000). To the north, this displacement is accommodated along two major east–west-trending strike-slip fault systems on either sides of the Cayman trough, and to the south along the Oca–El Pilar strike-slip fault system. In the NE Caribbean (Fig. 1), the relative plate motion implies oblique convergence and subduction of the Atlantic oceanic lithosphere under the Greater Antilles (Hispaniola and Puerto Rico), transitioning to frontal subduction in the Lesser Antilles, then to pure strike-slip motion along the southern boundary of the Caribbean plate in South America.

This transition from subduction to strike-slip is associated with a geologically persistent segmentation of the plate boundary. Puerto Rico and the Virgin Islands (PRVI) show low-lying topography formed by an Oligocene–Early Pliocene carbonate platform (Moussa et al., 1987) deformed into a broad arch (van Gestel et al., 1998) exempt of significant active faults and apparently behaving as a single rigid block (Byrne et al., 1985; Jansma et al., 2000; Masson and Scanlon, 1991). To the north, the PRVI block is bounded by large, north-dipping normal faults that

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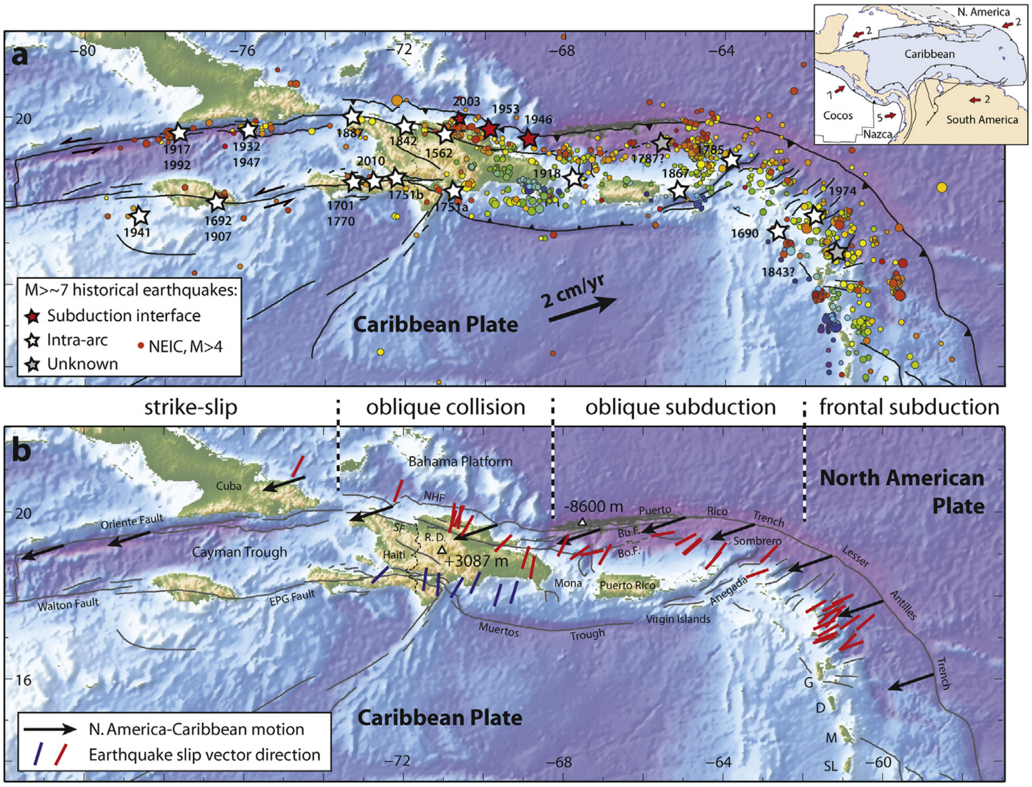

Fig. 1. (Color online.) Seismicity and kinematics of the NE Caribbean. The inset shows Caribbean and surrounding plates, red arrows show relative motions in cm/yr: a: NEIC seismicity 1974–2015 is shown with circles colored as a function of depth, stars show large ($M > 7$) instrumental and historical earthquakes; b: red and blue bars show earthquake slip vector directions derived from the gCMT database [www.globalcmt.org], black arrows show the present-day relative motion of the NA plate with respect to the Caribbean.

collapse Late Tertiary carbonates toward the Puerto Rico Trench (Le Pichon et al., 1985). Earthquake slip vectors on the Puerto Rico subduction interface are parallel to the Caribbean-North America (NA) relative plate motion (Fig. 1b), therefore suggesting oblique subduction without strain partitioning (McCaffrey, 2002).

In contrast, most of the island of Hispaniola to the west shows evidence of significant recent deformation with major active left-lateral strike faults and the highest elevation of the Caribbean Islands at Pico Duarte (3087 m, Fig. 1b). To the north, Hispaniola is currently colliding with the edge of the Bahamas Platform as evidenced by offshore compressional structures (Dolan et al., 1998; Mann et al., 2002) and by the occurrence of the *M*8.1 1946 reverse faulting and tsunamigenic earthquake (Dolan and Wald, 1998). Earthquake slip vectors along the North Hispaniola plate interface are highly oblique to the Caribbean–NA relative plate motion (Fig. 1b), suggesting the partitioning of strain across that segment of the plate margin (Calais et al., 2002).

These seismotectonic observations have recently been complemented by geodetic measurements of plate boundary deformation using the Global Positioning System (GPS). GPS measurements in the Caribbean go back to the late 1980s (DeMets et al., 2000; Dixon et al., 1998; Jansma et al., 2000), but only recently have we access to sufficiently dense measurements to determine both the kinematics of rigid-body motions within the plate boundary zone and of strain accumulation on major faults (Benford et al., 2012; Calais et al., 2002; Mann et al., 2002). Here we update the most recent solution of Symithe et al. (2015) with new measurements at episodic sites in Haiti and an additional 1.5 year of observations at continuous GPS sites throughout the region. We focus on the NE Caribbean plate boundary, where ~200 continuous and episodic GPS sites can currently be used for deformation measurements. We identify plate-boundary perpendicular shortening in south-central Haiti, a feature that had not been reported before. It appears continuous to the west with the Muertos Trough. Using the GPS-derived kinematic model as an ending point, we propose a reconstruction of plate boundary kinematics in the NE Caribbean during the past 20 Ma.

2. Geodetic data and velocities

We process the GPS data using the methodology described in Symithe et al. (2015) using the GAMIT–GLOBK software package (Herring et al., 2010) to obtain a position–velocity solution expressed in the International Terrestrial Reference Frame (ITRF, version 2008) (Altamimi et al., 2011). To optimally tie the solution to the ITRF, we combine our regional solutions with global daily solutions of the global International GNSS Service (IGS) network. Our