

Exploring Active Tectonics in the Dominican Republic

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The devastating 12 January 2010 Haiti earthquake ($M = 7.0$), which killed an estimated 230,000 people and caused extensive damage to homes and buildings, drew attention to the crucial need for improved knowledge of the active tectonics of the Caribbean region. But even before this disastrous event, interest in understanding the active and complex northeastern Caribbean plate boundary had been increasing, because this region has experienced significant seismic activity during the past century and has an extensively documented record of historical seismicity and tsunamis. Moreover, this is an easily accessible region in which to study the continuity of seismic faults offshore and to try to understand the transitions between strike-slip and convergent tectonic regimes. Interest in the region has led to several studies that have improved scientists' knowledge of subduction zone tectonics and earthquake and tsunami hazard assessments [Mann *et al.*, 2002; ten Brink *et al.*, 2006, 2009; Grindlay *et al.*, 2005; Manaker *et al.*, 2008; Granja Bruña *et al.*, 2009; Mondziel *et al.*, 2010].

One recent project, Caribbean–North American Plate Boundary Analysis: From Beata Ridge (Dominican Republic) to Anegada Passage (Lesser Antilles) (CARIBE NORTE), has conducted onshore and offshore surveys in the Dominican Republic region to study subduction, strike-slip, and collision processes in this area (Figure 1). This survey included a cruise aboard the Spanish R/V *Hespérides* in April 2009 and simultaneous fieldwork onshore. The CARIBE NORTE project complements the study of the northeastern Caribbean plate boundary carried out during the Structure and Geodynamics of the Northeastern Boundary of the Caribbean Plate: Puerto Rico (GEOPRICO-DO) project in 2005 [Carbó *et al.*, 2005].

The main goals of these projects are to see if there is subduction in the Muertos Trough, to determine the deep structure across and along Hispaniola and Beata Ridge, to study the existence of a possible tear fault in Beata Ridge that sharply

changes the tectonic regime from frontal thrusting in the Muertos Trough to strike-slip in the Enriquillo–Plantain Garden fault zone, to explore the possible correlations between the onshore structures on Hispaniola and the offshore structures in the Muertos margin, and to evaluate the active deformation and submarine landslides to assess seismic and tsunami hazards. The last goal is especially important because the islands of the northeastern Caribbean are densely

populated, so earthquakes in the region can cause significant destruction and loss of life, as evidenced by Haiti's recent earthquake, which was associated with the Enriquillo–Plantain Garden fault zone.

The cruise collected multibeam bathymetry, gravity, magnetic, high-resolution seismic, and three-channel seismic reflection data (Figure 1). Deep seismic sounding data were acquired using 16 ocean bottom seismometers (OBSs) deployed north and south of the island and 340 portable land seismometers deployed along five profiles in the Dominican Republic. This is the first time OBSs have been used to acquire seismic data in the exclusive economic zone of the Dominican Republic.

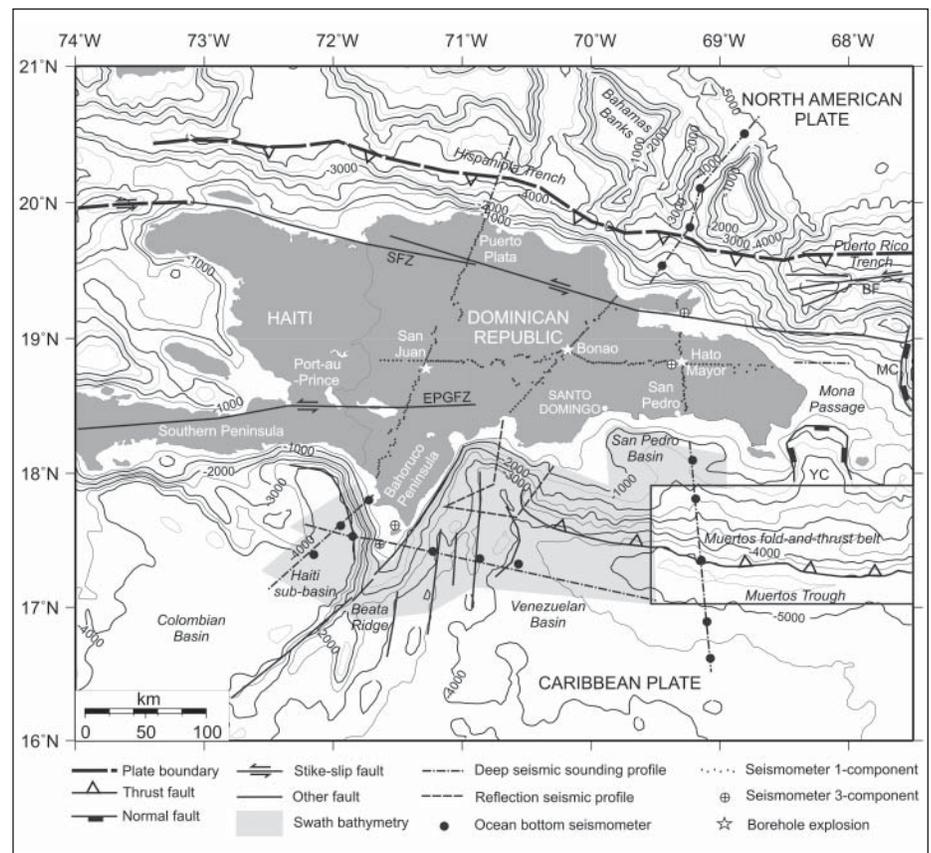


Fig. 1. Map of the area surveyed by the Caribbean–North American Plate Boundary Analysis: From Beata Ridge (Dominican Republic) to Anegada Passage (Lesser Antilles) (CARIBE NORTE) project. The rectangle shows the area surveyed during the previous Structure and Geodynamics of the Northeastern Boundary of the Caribbean Plate: Puerto Rico (GEOPRICO-DO) cruise [Carbó *et al.*, 2005]. Along the onshore deep seismic sounding profiles, 340 land seismometers were deployed. EPGFZ, Enriquillo–Plantain Garden fault zone; SFZ, Septentrional fault zone; MC, Mona Canyon; YC, Yuma Canyon; BF, Bunce Fault. Bathymetry is shown and given in meters below sea level.

The OBSs and the land seismometers were arranged in profiles to provide a continuous seismic record across and along the main tectonic structures of the region. The acoustic sources used for the deep seismic experiment were an air gun array (3850 cubic inches) aboard the R/V *Hespérides* and three 1-ton explosions detonated in 75-meter-deep boreholes at three locations in the Dominican Republic (San Juan, Bonao, and Hato Mayor; see Figure 1).

Researchers are currently processing and interpreting the data recorded by the OBSs and land stations to try to constrain the deep structure of Hispaniola, which has previously been inferred only from seismological data. Because the seismicity is too diffuse in this area to infer the geometry of the plate interface in depth, it was essential to acquire deep seismic data. The deep structure that will be deduced from these data recorded around the Dominican Republic will facilitate tomographic analysis to constrain velocity models in the northeastern Caribbean used, among other things, to relocate earthquakes and study their focal mechanisms. Such information will be key to improving knowledge of the tectonic structure in the region and for earthquake hazard assessments.

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References

- Carbó, A., et al. (2005), Survey explores active tectonics in northeastern Caribbean, *Eos Trans. AGU*, 86(51), 537, 540.
 Granja Bruña, J. L., U. S. ten Brink, A. Carbó-Gorosabel, A. Muñoz-Martín, and M. Gómez-Ballesteros (2009), Morphotectonics of the central

- Muertos thrust belt and Muertos Trough (northeastern Caribbean), *Mar. Geol.*, 263, 7–33.
 Grindlay, N. R., P. Mann, J. F. Dolan, and J.-P. van Gestel (2005), Neotectonics and subsidence of the northern Puerto Rico–Virgin Islands margin in response to the oblique subduction of high-standing ridges, *Spec. Pap. Geol. Soc. Am.*, 385, 31–60.
 Manaker, D. M., E. Calais, A. M. Freed, S. T. Ali, P. Przybylski, G. Mattioli, P. Jansma, C. Prépetit, and J. B. de Chabaliel (2008), Interseismic plate coupling and strain partitioning in the northeastern Caribbean, *Geophys. J. Int.*, 174(3), 889–903.
 Mann, P., E. Calais, J.-C. Ruegg, C. DeMets, P. E. Jansma, and G. S. Mattioli (2002), Oblique collision in the northeastern Caribbean from GPS measurements and geological observations, *Tectonics*, 21(6), 1057, doi:10.1029/2001TC001304.
 Mondziel, S., N. Grindlay, P. Mann, A. Escalona, and L. Abrams (2010), Morphology, structure, and tectonic evolution of the Mona canyon (northern Mona passage) from multibeam bathymetry, side-scan sonar, and seismic reflection profiles, *Tectonics*, 29, TC2003, doi:10.1029/2008TC002441.
 ten Brink, U. S., E. L. Geist, and B. D. Andrews (2006), Size distribution of submarine landslides and its implication to tsunami hazard in Puerto Rico, *Geophys. Res. Lett.*, 33, L11307, doi:10.1029/2006GL026125.
 ten Brink, U. S., S. Marshak, and J.-L. Granja Bruña (2009), Bivergent thrust wedges surrounding oceanic island arcs: Insight from observations and sandbox models of the northeastern Caribbean plate, *Geol. Soc. Am. Bull.*, 121(11-12), 1522–1536.

—A. CARBÓ-GOROSABEL, Departamento de Geodinámica, UCM, Madrid, Spain; E-mail: carbo@geo.ucm.es; D. CÓRDOBA-BARBA, Departamento de Geofísica, UCM; J. MARTÍN-DÁVILA, ROA, San Fernando, Spain; J. L. GRANJA-BRUÑA, P. LLANES ESTRADA, and A. MUÑOZ-MARTÍN, UCM; and U. S. TEN BRINK, USGS, Woods Hole, Mass.

New Surveys of a Branch of the Indonesian Throughflow

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Global ocean circulation is a primary mechanism for transporting energy and nutrients around the planet. At its most basic level, this circulation transports water from the Pacific Ocean through the Indonesian archipelago into the Indian Ocean; these waters join the Agulhas Current, which loops around Africa and in turn joins the Gulf Stream in the Atlantic Ocean. Upon reaching the North Atlantic, waters sink, creep south along the ocean floor as deep water, trace around Antarctica as bottom water, and move to the Pacific Ocean where they upwell, only to seep back into the Indian Ocean through the straits and channels surrounding Indonesia.

The seepage of warm equatorial waters from the western Pacific Ocean into the Indian Ocean is called the Indonesian Throughflow (ITF). Long recognized as a

key component of global ocean circulation, the ITF's magnitude and variability play an important role in determining heat and nutrient exchange to other ocean basins. Scientists' ability to estimate ITF behavior is therefore essential for understanding the global climate system.

Although studies of the ITF have been conducted for more than 2 decades, the ITF branch through the South China Sea (SCS)–Karimata Strait (see Figure 1) has been ignored in past surveys because of its shallow water, which caused many to assume that it had no effect on the main ITF. However, scientists now know that this strait plays an important role in the long-term magnitude and variability of the main ITF—indeed, drifter surveys indicate that it is of comparable importance to the Makassar Strait's role in the ITF during the northwest monsoon (see Figure S1 in the online supplement to this *Eos* issue; [\[.agu.org/eos_elec/\]\(http://www.agu.org/eos_elec/\)\) \[Gordon et al., 2003; Tozuka et al., 2007\]. Further, spatial and temporal patterns of fluxes through the Karimata Strait may influence the effects of monsoons and El Niño–Southern Oscillation \(ENSO\) events, in addition to modifying marine ecosystems, primary productivity, and seasonal fish migration. Therefore, monitoring the transport, heat, and freshwater fluxes associated with the ITF within this strait is important for verification of ocean circulation models and of primary interest to climate research and regional biology.](http://www</p>
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In response to the complete lack of direct observational studies in the Karimata Strait, the South China Sea–Indonesian Seas Transport/Exchange (SITE) program was established by scientists from Indonesia, China, and the United States. This partnership will help to determine heat, freshwater, nutrient, and overall fluxes between the SCS and the Indonesian seas through the Karimata Strait.

Investigating Freshwater Flux

The Asian and Australian monsoons affect ITF magnitude and variability. During the northwest monsoon from October to