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Crustal thickness variations in Venezuela from deep seismic observations

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ABSTRACT

The Caribbean–South America plate boundary zone is a complex zone of plate interactions, forming thrust belts and foreland basins in northern Venezuela. Within the framework of the BOLIVAR and GEODINOS projects, the geodynamics of plate interactions is being investigated using interdisciplinary geological and geophysical methods. Here, we focus on the results of the land based active seismic observations done in 2004 along four deep seismic wide angle profiles, acquired perpendicular to the Caribbean–South America plate boundary in northern Venezuela between longitudes 63° W and 70° W, and ranging from about latitudes 12 °N to about 9 °N. The mostly unreversed profiles provide information on the crustal structure from the oceanic-transitional crust on the southern border of the Caribbean plate to the continental crust of the Caribbean Mountain System and their associated foreland basins, which are bordered to the south by the Guayana Shield, which corresponds to stable South America plate. The derived crustal thickness oscillates around 35 km along the coastline, corresponding to the Caribbean Mountain System, and decreases only slightly towards the Leeward Antilles. To the south, in the area of the Eastern Venezuela Basin, crustal thickness reaches 40 km, increasing towards the Guayana Shield to 45 km. Nevertheless, there are two regions of anomalous crustal thickness, proven by arrivals from the lower crust and the Moho discontinuity. In the eastern part of the Eastern Venezuela Basin, crustal thickness reaches up to 50 km, with high velocity anomalies within the lower crust, which are interpreted as reworked lower crustal and upper mantle material, associated to the plate interactions of the South American and the Caribbean plates. The second anomalous zone is a remarkable crustal thinning from 35 km to 27 km in the Falcón Basin in western Venezuela, which extends eastwards into the Bonaire Basin, as documented by PmP reflections derived from land shots, and observations of the air gun blasts on the stations of the Venezuelan seismological network.

1. Introduction

Interdisciplinary geophysical and geological studies are being carried out within the framework of the BOLIVAR (*B*roadband *O*cean–*L*and *I*nvestigations of *V*enezuela and the *A*ntilles arc *R*egion) and GEODINOS (*Geodi*námica Reciente del Límite *No*rte de la Placa *S*udamericana — Recent Geodynamics of the Northern Limit of the South American Plate) projects in order to investigate the geodynamics of the complex Caribbean–South America (CAR–SA) plate boundary zone. As part of these investigations, active seismic measurements were done in 2004 in northern Venezuela and in the southeast Caribbean (Levander et al., 2006).

Information on the crustal structure of the area is available for the Caribbean plate, where thickened oceanic crust is interpreted as an oceanic plateau (e.g. Edgar et al., 1971; Case et al., 1990). The origin of this thickened oceanic crust has been intensely discussed during the last decades (e.g. Pindell and Dewey, 1982; Sykes et al., 1982; Meschede and Frisch, 1998; Pindell and Kennan, 2001; Kerr and Tarney, 2005; James, 2006). Widely accepted is an origin west of its actual position with an eastward migration of the Caribbean plate of 2 cm/year with respect to the South American continent (e.g. Weber et al., 2001), accommodated along mayor strike slip fault systems on the northern edge of the continent (e.g. Schubert, 1984; Audemard et al., 2000).

In contrast, little has been known about the continental crustal structure and Moho depths in Venezuela, as evidenced in a compilation of crustal thickness at a global scale, presented by Mooney

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et al. (1998). First results of deep wide-angle seismic measurements in Venezuela were obtained for the east coast of Maracaibo Lake in western Venezuela (Gajardo et al., 1986; Guédez, 2003), where a crustal thickness of 40–43 km was derived for this sedimentary basin. Results of seismic studies done on the Guayana Shield in southern Venezuela indicate a crustal thickness of 45 km for the craton (Schmitz et al., 2002), which decreases towards the north, as it enters into the Eastern Venezuela Basin (Schmitz et al., 2005), reaching a thickness of about 35 km near the coast. In the central offshore area, records of airgun shots on the stations of the Venezuelan Seismological Network allow to derive first information on the crustal thickness of the CAR–SA transition zone (Guédez, 2003).

In this contribution, we focus on the land based active seismic observations done in April/May 2004 in northern Venezuela between 63° W and 70° W along four mayor seismic transects (Fig. 1). Along each of the main profiles, two land shots were recorded on portable stations. Records of the air gun lines on the stations of the Venezuelan Seismological Network allow deriving to some extent lateral variations of the crustal structure and thickness. As a result, we are able to derive a map of crustal thickness in Venezuela, which comprises northern and eastern Venezuela from the Caribbean Sea in the north to the Guayana Shield in the south.

2. Geotectonic setting

Northern Venezuelan thrust belts and foreland basins were formed as the result of tectonic interaction between the Caribbean and South American plates. It is therefore important to understand the geology, age and formation hypotheses of the main structures within the southern Caribbean Plate. First, we present here a regional view of the tectonic evolution in the area, including the structure and geology of the Coastal Cordillera and the Eastern Serranía del Interior thrust belts, the Guárico and Maturín basins, the Guayana Shield, the Falcón Basin and the Leeward Antilles (Fig. 1).

2.1. Caribbean and South American plates

The present day lateral displacement of the Caribbean Plate is 1.5–2.0 cm/yr with respect to the South American Plate, with a sinistral sense of shear in the north and a dextral sense of shear in the south (Mann et al., 1990; Weber et al., 2001). Wide areas of compressional, extensional and strike–slip tectonic regimes characterize the margins of the Caribbean Plate. The location of the Caribbean Plate boundary is more clearly defined along the western and eastern margins, other boundaries are more complex and still subject to debate. The Lesser Antilles and Middle America Arc systems are predominately convergent margins with well-developed seismic Benioff zones and volcanic arcs, with convergence rates of 4 cm/yr and 7.4 cm/yr respectively (Westbrook and McCann, 1986; DeMets et al., 1994). The northern and southern boundaries of the Caribbean Plate have experienced Neogene strike–slip, compression and extension, across a broad plate boundary zone. The evolution of the southeastern margin of the Caribbean Plate has been debated controversly. For many years, the South American–Caribbean boundary has been interpreted as a narrow zone of pure strike–slip movement (Molnar and Sykes, 1969; Pérez and Aggarwal,

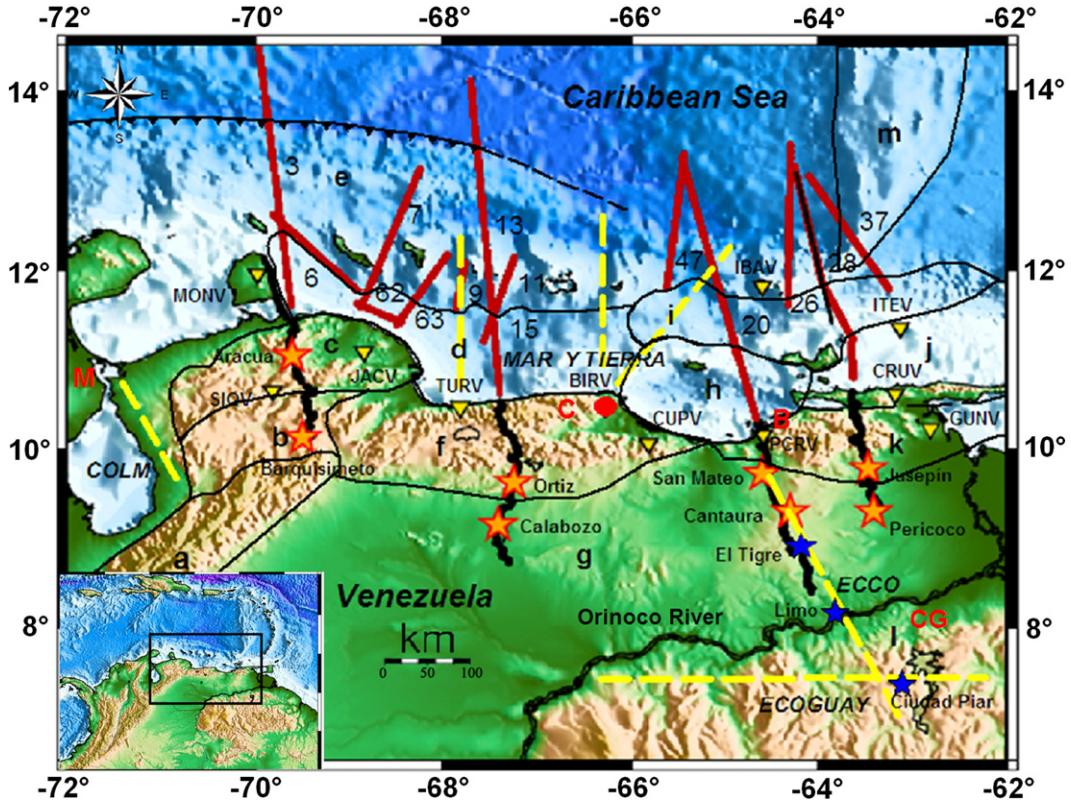

Fig. 1. Location map with airgun lines (red lines with line numbers), seismological stations from the Venezuelan Seismological Network (inverted triangles with station codes; sections displayed in this paper from stations MONV = Monte Cano, TURV = Turiamo, PCRV = Puerto La Cruz, CRUV = Carúpano) and land shots (stars with shot point name) with the respective recording lines (black), used in this study. Simplified tectonic units after Stephan (1985) and Ysaccis et al. (2000): a) Mérida Andes, b) deformed Mesozoic passive margin and Lara nappes, c) Falcón Basin, d) Bonaire and other minor marine basins, e) Southern Caribbean Deformed Belt with subduction in the north and Leeward Antilles in the south (including the Aruba–Curaçao Basin), f) Caribbean nappes and Coastal Cordillera Thrust Belt, g) Eastern Venezuela Basin, sub-divided into the Guárico Basin in the west and the Maturín Basin in the east, h) Tuy–Cariaco Basin, i) Blanquilla Basin, j) Carúpano Basin, k) Serranía del Interior Thrust Belt, l) Guayana Shield, m) Aves high. Location of seismic profiles obtained during previous experiments indicated with yellow lines (recording lines), red circles (seismological stations) and blue stars (shot points): COLM (Gajardo et al., 1986), MAR and TIERRA (Guédez, 2003), ECOGUAY (Schmitz et al., 2002), ECCO (Schmitz et al., 2005); M = Maracaíbo, C = Cacacas, B = Barcelona, CG = Ciudad Guayana.