Subduction in the Southern Caribbean

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BOLIVAR and Venezuelan Networks

The southern Caribbean is bounded at either end by subduction zones: In the east at the Lesser Antilles subduction zone the Atlantic part of the South American plate subducts beneath the Caribbean. In the north and west under the Southern Caribbean Deformed Belt accretionary prism, the Caribbean subducts under South America. In a manner of speaking, the two plates subduct beneath each other. Finite-frequency teleseismic P-wave tomography confirms this, imaging the Atlantic and the Caribbean subducting steeply in opposite directions to transition zone depths under northern South America (Bezada et al, 2010).

The two subduction zones are connected by the El Pilar-San Sebastian strike-slip fault system, a San Andreas scale system. A variety of seismic probes identify where the two plates tear as they begin to subduct (Niu et al, 2007; Clark et al., 2008; Miller et al. 2009; Masy et al, 2011). The El Pilar system forms at the southeastern corner of the Antilles subduction zone by the Atlantic tearing from South America. The deforming plate edges control mountain building and basin formation at the eastern end of the strike-slip system.

In northwestern South America the Caribbean plate tears, its southernmost element subducting at shallow angles under northernmost Colombia and then rapidly descending to transition zone depths under Lake Maracaibo (Bezada et al., 2010). We believe that the flat slab produces the Merida Andes, the Perija, and the Santa Marta ranges. The southern edge of the nonsubducting Caribbean plate underthrusts northern Venezuela to about the width of the coastal mountains (Miller et al., 2009). We infer that the underthrust Caribbean plate supports the coastal mountains, and controls continuing deformation.

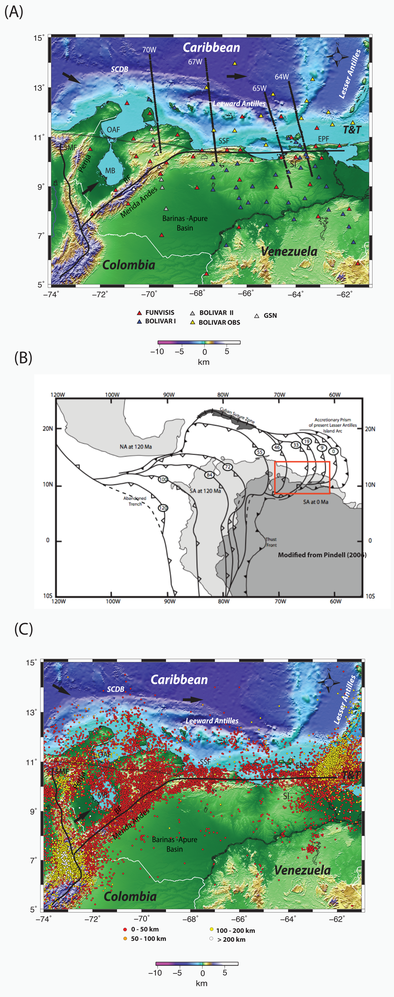


Figure 1: A.- Broadband seismic stations in Venezuela and Wide angle seismic profiles. B.- Tectonic setting of the region. C.- Seismicity of the Caribbean -South America plate boundary and Venezuela.
MB=Maracaibo Block, BF= Bocono Fault, OAF=Oca-Ancon Fault, SMF=Santa Marta Fault, SSF=San Sebastian Fault, EPF = El Pilar Fault, SI = Sierra del Interior, CC = Cordillera de la Costa. T&T = Trinidad and Tobago. SCDB = Southern Caribbean deformed belt.

Geophysical Studies

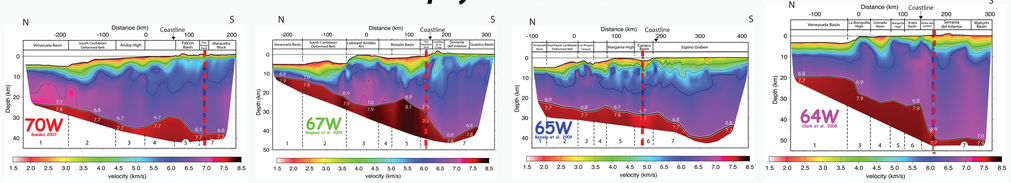


Figure 2: Results from four wide-angle seismic profiles collected onshore and offshore Venezuela in 2004 as part of the BOLIVAR project (See figure 1A for location). The wide-angle profiles sample different stages of margin development from west to east, each crossing the margin roughly perpendicularly. The models show lateral heterogeneity, as they cross features such as normal oceanic crust, oceanic plateau crust, the SCDB accretionary wedge, remnant island arcs, a major strike-slip system (Oca - San Sebastian- El Pilar fault system), forearc and foreland basins, a fold and thrust belt, and the edge of cratonic South America

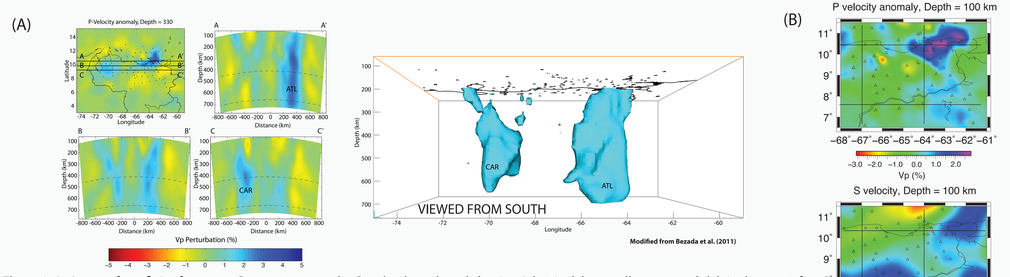


Figure 3: A. -Images from finite-frequency P-wave tomography. Results show the subducting Atlantic slab, as well as a second slab in the west of the study area that we interpret as a subducting fragment of the Caribbean plate. Both slabs have steep dips where imaged and can be traced to depths greater than 600 km. The Atlantic slab extends continent-ward south of the plate bounding strike-slip margin. The steep subduction of the Caribbean occurs ~500 km landward from the trench, implying an initial stage of shallow subduction as far to the east as the Mérida Andes region. B.- Top: P- wave velocity anomaly at 100 km. Bottom Shear velocity structure from rayleigh wave tomograpgy at 100 km

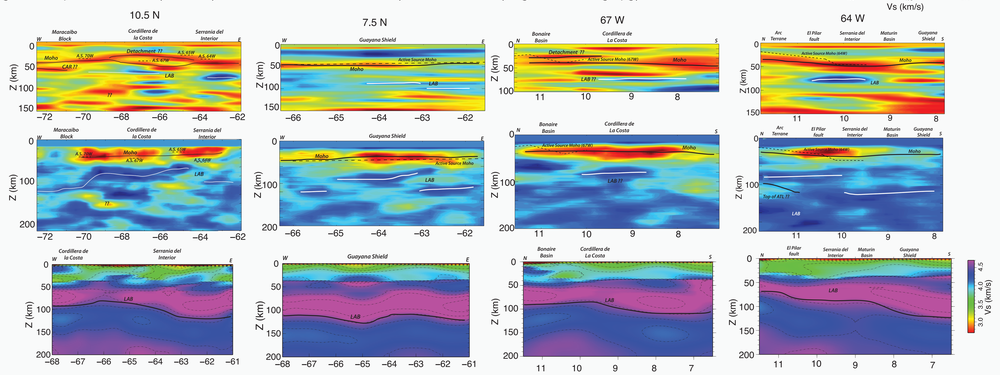
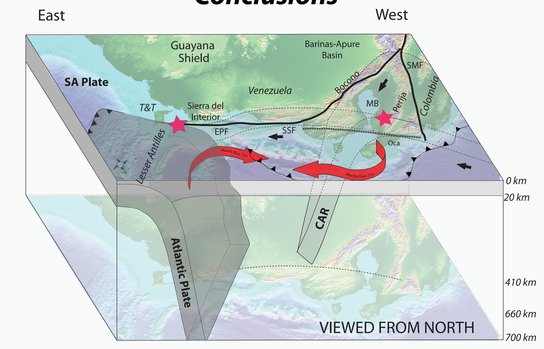


Figure 4: PdS (top) and SdP (middle) receiver function profiles showing the major crustal and lithospheric structures observed in the region. The Moho discontinuity is imaged clearly in the whole region. The Lithosphere Asthenosphere Boundary (LAB) is observed on the SdP profiles. Profiles show evidence of the shallow Caribbean and Atlantic slabs beneath South America. Bottom: Shear velocity profiles from Rayleigh wave tomography using two plane wave method (Forsyth and Li, 2005) and sensitivity kernels (Yang and Forsyth, 2006) in order to improve lateral resolution. In these sections the LAB is clearly observed.

Conclusions



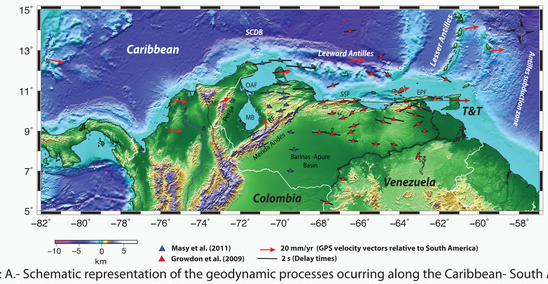


Figure 5: A.- Schematic representation of the geodynamic processes ocurring along the Caribbean- South America Plate boundary. The atlantic tears off of South America in a highly localized zone 150 km east of 64W. On the other side of the SSF, Caribbean tears beneath the Maracaibo block. Both of the subducting slabs penetrate the transition zone. Seismic anisotropy along the nothern edge of the Maracaibo Block indicates the presence of a trench parallel mantle flow that passes around the north west corner of the subducting Caribbean plate, similary the same interpretation could be made for the subducting Atlantic plate. B.-Shear wave splitting (Masy et al., 2011, Growdon et al.,2009) and GPS measurements.

References and Acknowledgments

-Yuan,X,R.Kind, X. Li, and R. Wang (2006) The S receiver function: synthetics and data example, Geophys. J. Int.
-Bezada,M.J.,A.Levander, and B.Schmandt (2010), Subduction in the Southern Caribbean: Images from finite-frequency P-wave tomography, J.Geophys. Res.
-Miller, M.S., A. Levander, F. Niu and A. Li (2009) Upper mantle structure beneath the Caribbean-South American plate boundary from surface wave tomography, J. Geophys. Res.
-Magnani,M.B., C.A. Zelt, A. Levander and M. Schmitz (2009) Crustal structure of the South America-Caribbean plate boundary at 67W from controlled-source seismic data, J. Geophys. Res.
- Bezada, M.J., M/B. Magnani, C.A. Zelt, M. Schmitz and A. Levander (2010) The Caribbean- South American plate boundary at 65W: Results from wide angle seismic data, J. Geophys. Res.
- Guedez, M., 2007, Crustal Structure across the Caribbean-South American plate boundary at 70W - Results from seismic refraction and reflection data, unpublished thesis (M.S) Rice University.
-Clark,S.A., A. Levander, M. B. Magnani and C. A. Zeltt (2008), Interating aregional wide angle velocity model with seismic reflectin data and structural interpretations of the Caribbean-South American plate boundary at 64W, Tectonics.
-Masy, J., Niu, F., Levander, A., & Schmitz, M. ,2011, Mantle flow beneath northwestern Venezuela: Seismic evidence for a deep origin of the MA©rida Andes. Earth and Planetary Science Letters, 305(3-4), 396-404.
-Growdon, M. A., Pavlis, G. L., Niu, F., Vernon, F. L., & Rendon, H. ,2009. Constraints on mantle flow at the Caribbean-South American plate boundary inferred from shear wave splitting. Journal of Geophysical Research, 114(B2), 1-7.
-Pindell, P.,Kennan,L.,Stanek,K., Marsh,W., Draper, G., 2006, Foundations of Goulf of Mexico and Caribbean evolution: eight controversies resolved. Geologica Acta,4(1-2),303-341.
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