Evolution of Caribbean subduction from P-wave tomography and plate reconstruction

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Background

- Caribbean subduction governed tectonic evolution, associated hazards and distribution natural resources.
- One of only two zones that subducts Atlantic seafloor, formed by slow-spreading, a global end member of old oceanic lithosphere subducting at slow speeds.
- Poorly understood subduction history involving changes in length and shape of the trench and several generations of arcs.

Aims

- In our Volatile Recycling in the Lesser Antilles (VoiLA) project, we installed the first ocean-bottom seismometer (OBS) network in the region (red triangles, Fig. 1). Using these data, we improve imaging of the eastern Caribbean upper mantle using teleseismic P waves,
- We compare imaged fragments of subducted plate with subduction locations predicted from a recently published plate reconstruction.

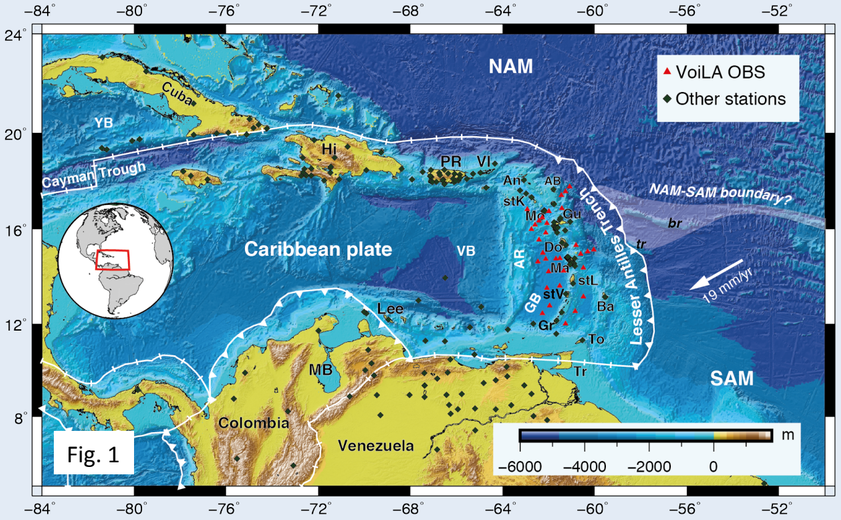
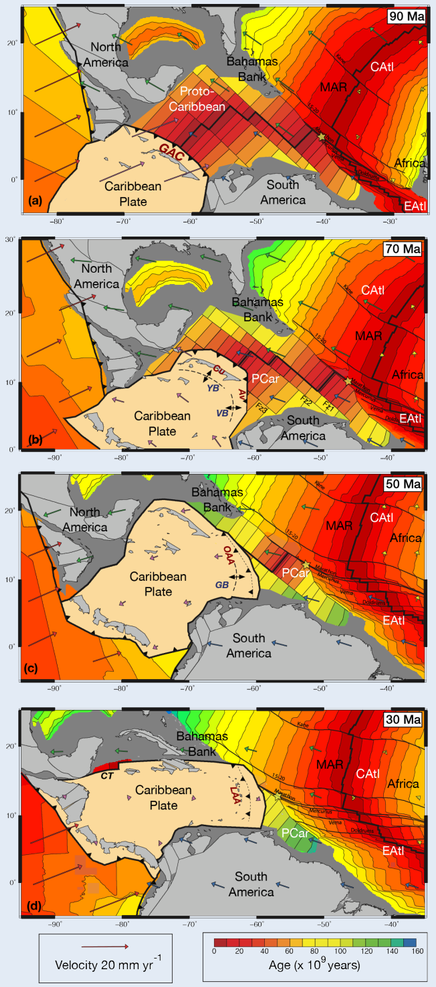


Plate reconstruction

Reconstruction: Müller et al. (*Tectonics*, 2019) updated as follows: (1) improved geometry of Atlantic opening boundaries (2) Proto-Caribbean opening was reconstructed using an improved geometry of the ridge between North and South America and assuming symmetric spreading



90 Ma – early stage of subduction along Great Arc of the Caribbean (GAC), while Proto-Caribbean ridge was actively spreading => forming two slabs

70 Ma – northern and southern parts of the GAC migrate outwards to subduct the oldest Proto-Caribbean lithosphere, accompanied by back-arc spreading in the Yucatán (YB) and Venezuelan (VB) Basins. Proto-Caribbean ridge stops spreading. Fz1, Fz2, Fz3 are hypothetical fracture zones

50 Ma – northern (Cuban) segment of GAC inactive after docking against the Bahamas Bank, and back-arc spreading initiated in the Grenada Basin (GB), allowing the active arc to move eastwards to the Outer Antillean Arc (OAA).

30 Ma – subduction of the large-offset fracture zone at the eastern end of the Proto-Caribbean (marked as Fz1 on 70 Ma map has led to a rapid younging of the subducting slab, inducing a forward jump of the active arc to the current Lesser Antillean Arc (LAA)

Fig. 2

P-wave tomography

model VoiLA-P19: Joint inversion of data from regional seismic networks (VoiLA experiment and additional land stations on Fig .1) together with the highest quality data from the global EHB catalogue [Engdahl et al., BSSA 1998], using the method of Widiyantori and van der Hilst (GJI 1997) where a fine regional grid is embedded in a coarser global grid.

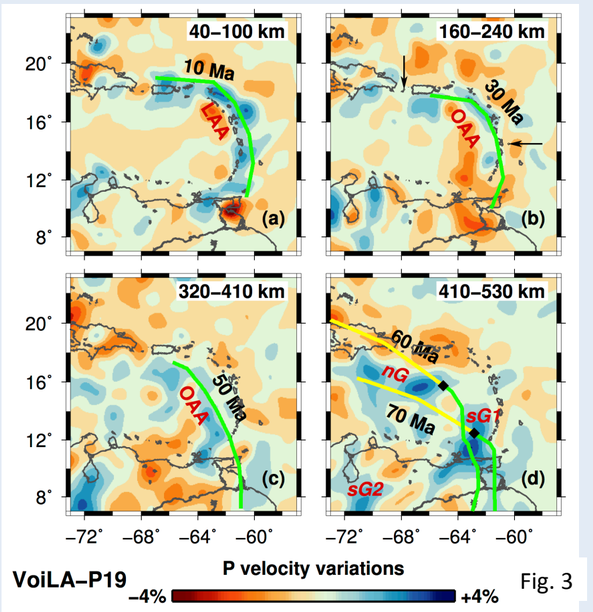


Fig. 3

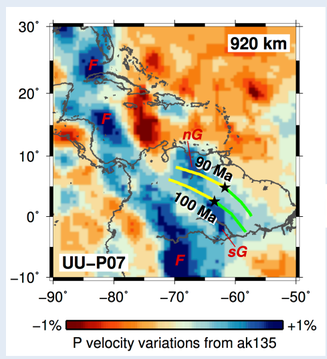


Fig. 4

In the **lower mantle**, our predicted slab positions agree well with two anomalies below north-eastern South America, as imaged by Van Benthem et al. (JGR, 2013). Slabs subducted at the northern and southern GAC were separated by the at this time active proto-Caribbean ridge (★)

Upper mantle: Good match between observed high velocity anomalies and reconstructed trenches with slab sinking rate of ~1 cm/yr, consistent with convergence rates along the Caribbean subduction zones.

- Above ~ 200 km depth, high velocities correspond to position of subduction along Lesser Antilles Arc (**LAA**),
- between ~250-450 km correspond to subduction along the Outer Antilles Arc (**OAA**),
- in the transition zone to the southern (**sG**) and northern (**nG**) part of the Great Arc of the Caribbean. ◆ – position of extinct Proto-Caribbean spreading centre, a weakness zone, where we propose the GAC slab tore into two slab segments
- **sG2** may be a segment of the sG slab sheared off against South American continental keel

Conclusions

- In eastern Caribbean **upper mantle**, material subducted at different trenches **from 70 Ma** has accumulated in similar location due to westward movement of the Americas.
- 100-120 Ma slab in the shallow **lower mantle** below northeastern South America consistent with **start of GAC subduction prior** to the most significant phase of **CLIP** plume volcanism
- **Slab gaps** found at the location of the Proto-Caribbean **spreading ridge**, **detachment** of the northern GAC slab after Cuba docked with North America, and a **lateral tear** below Grenada, likely along a Proto-Caribbean fracture zone.
- NAM-SAM plate boundary is yet to start subducting, but subdued anomalies (arrows Fig 3b) may correspond to **hydrated plate-domain boundary** between lithosphere formed in Proto-Caribbean and that formed in Equatorial Atlantic .

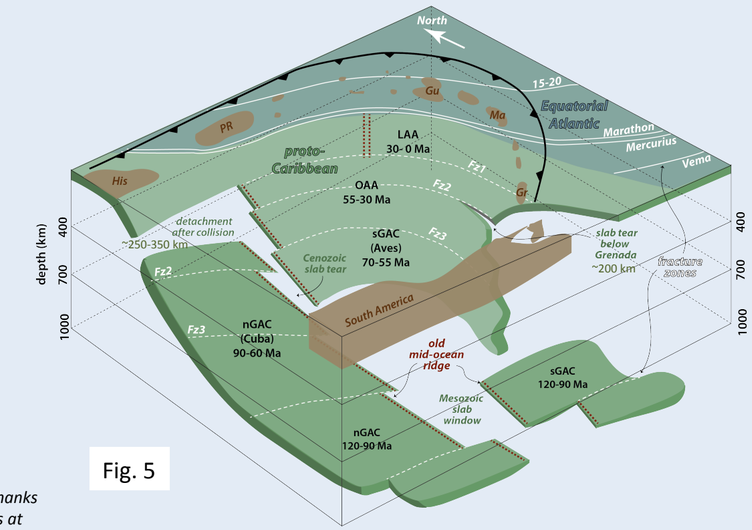


Fig. 5

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