Structure of the Lesser Antilles subduction zone from seismic refraction tomography

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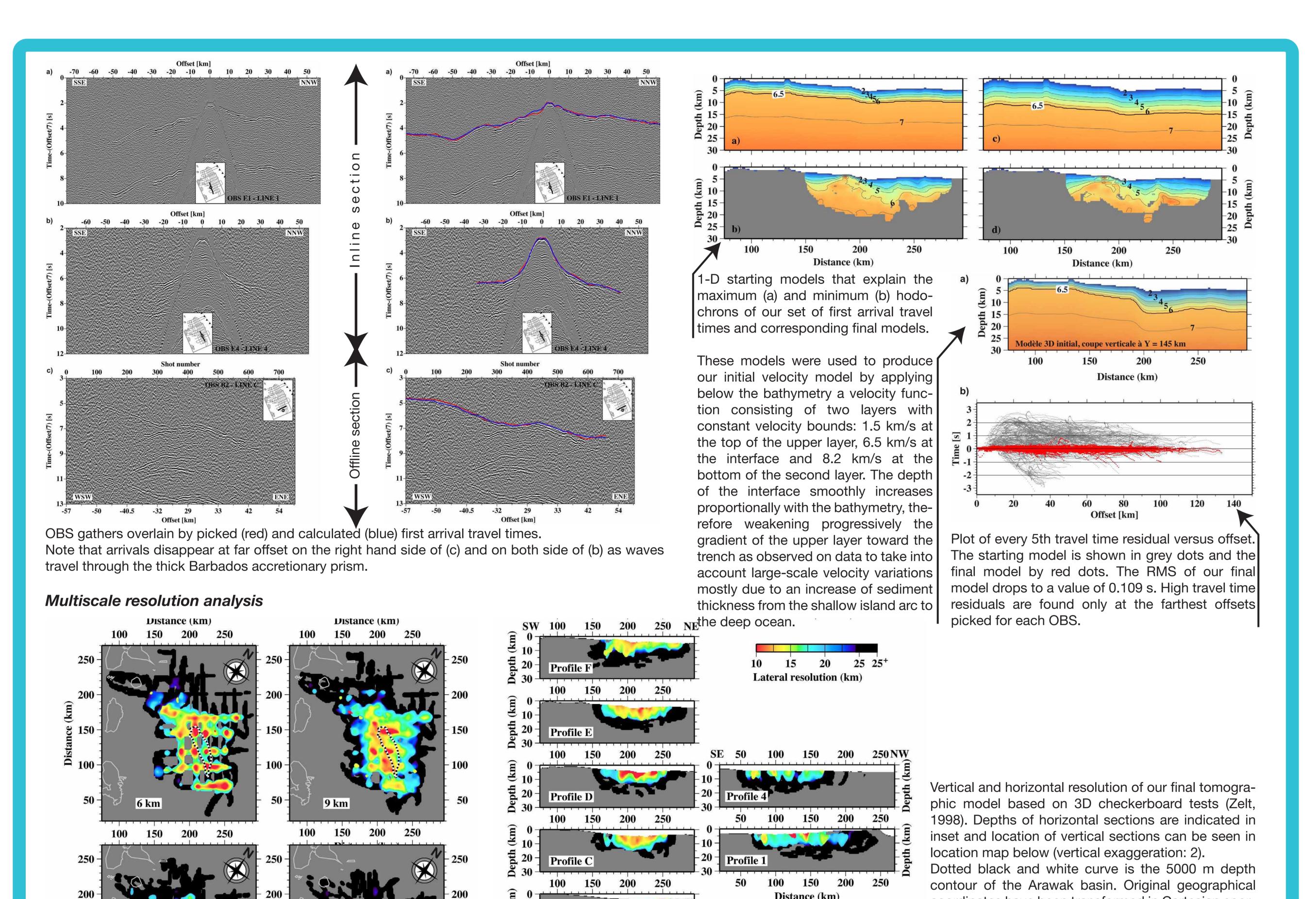


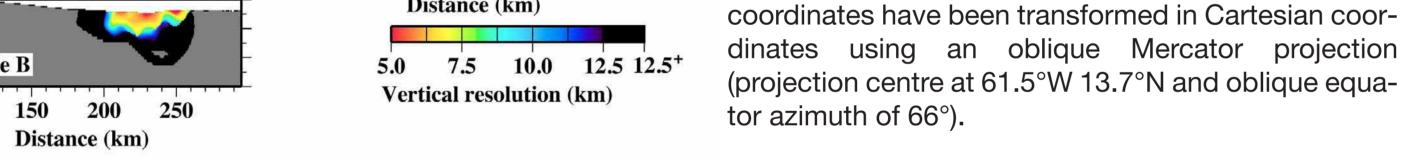






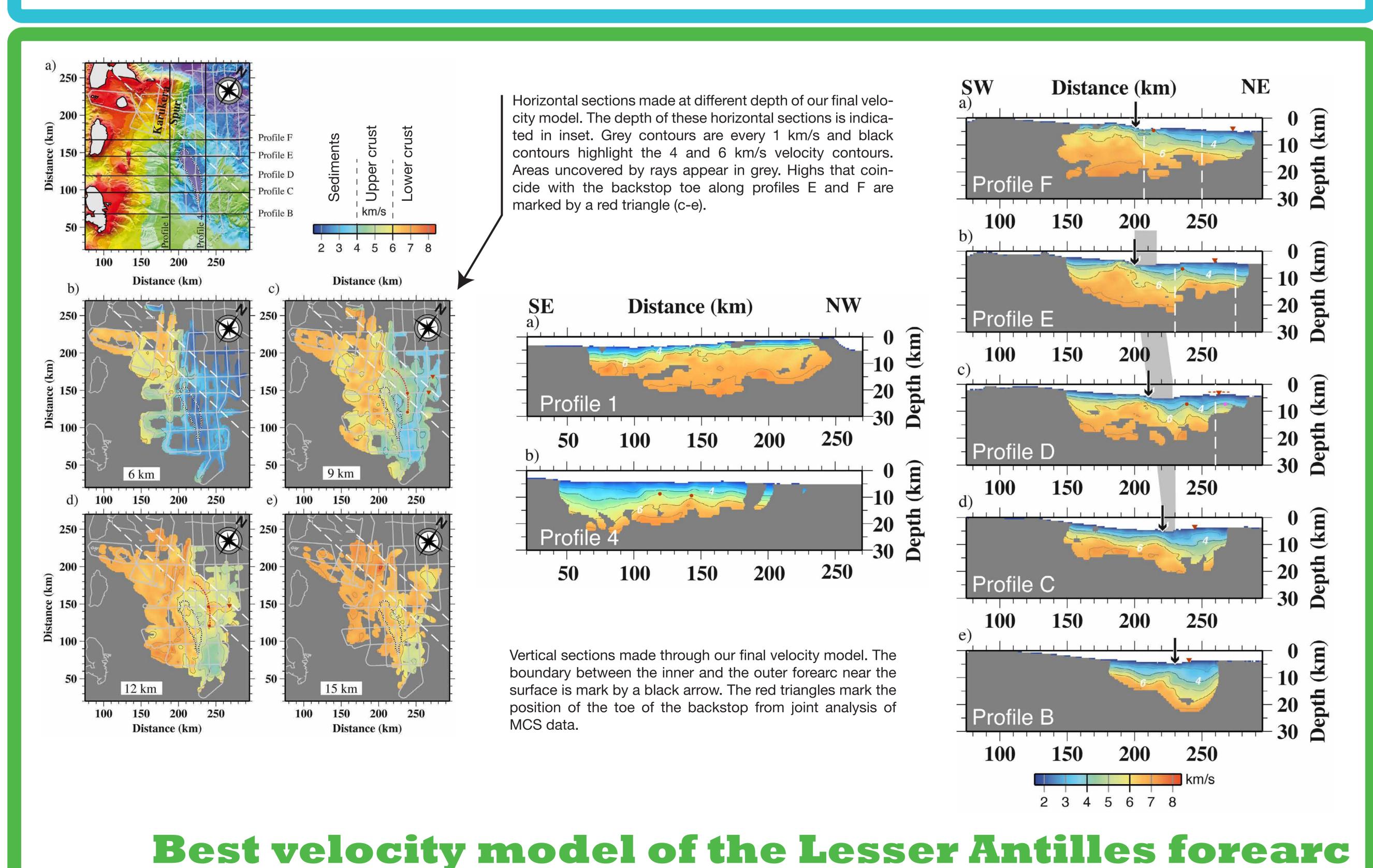






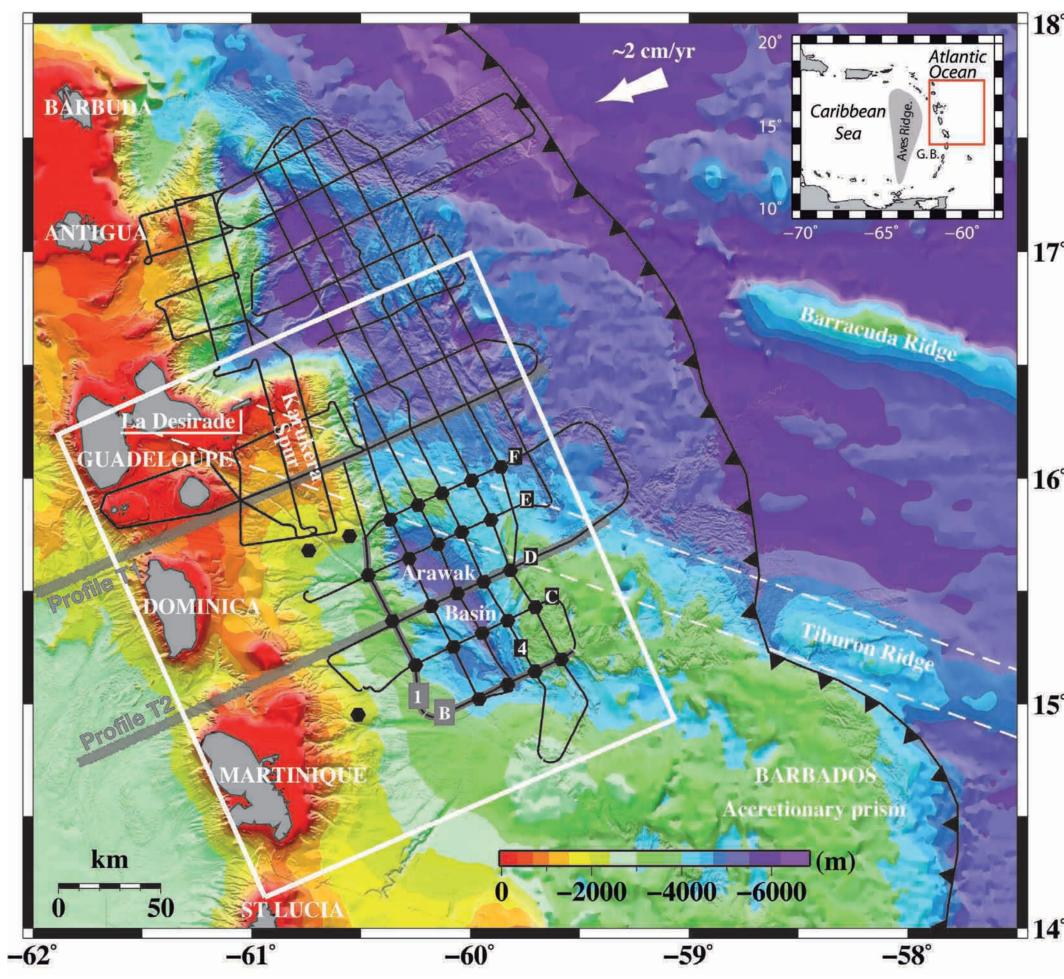
3D tomography of first arrivals

The data constrain the structure of the forearc upper crust down to 15 km

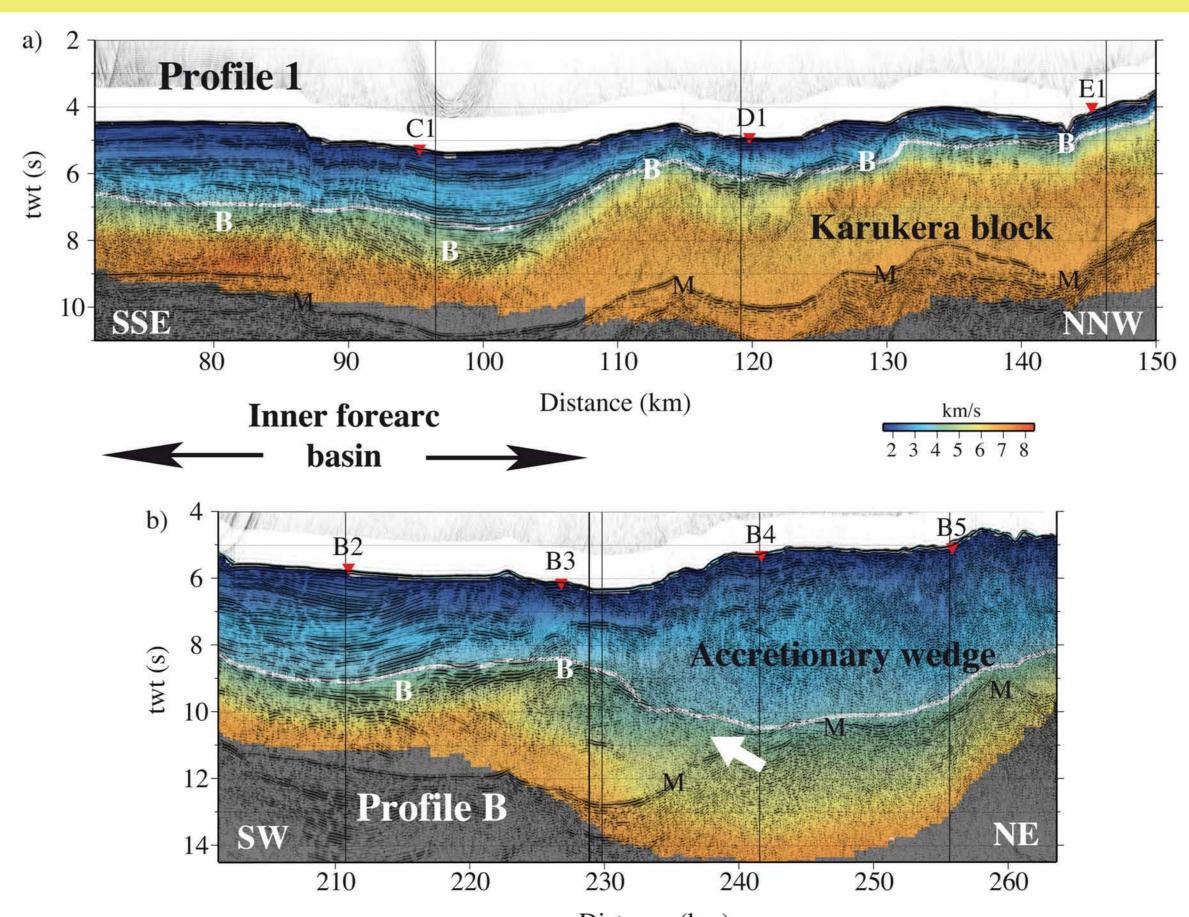


In 2007, two wide-angle seismic experiments were conducted to constrain the structure of the central Lesser Antilles subduction zone.

- During the Sismantilles II experiment, seismic refraction data recorded by a network of 27 OBSs over an area of more than 6000 km2 provide new insights on the crustal structure of the forearc offshore Martinique and Dominica islands.
- The tomographic inversion of first arrival travel times provides a 3D P-wave velocity model down to 15 km (Evain et al., in press). Basement velocity gradient shows the forearc made of two distinct units: A high velocity gradient domain named the inner forearc in comparison to a lower velocity gradient domain located further trenchward named the outer forearc.
- The inner forearc is likely the extension at depth of the Mesozoic magmatic crust outcropping to the north in La Désirade Island and along the scarp of the Karukera spur and then represent the eastern limit of the Caribbean Plateau.
- The outer forearc probably consists of magmatic rocks of a similar origin. It could be either part of the margin of the Caribbean Plateau, like the inner forearc, but the crust was thinned and fractured during the past tectonic history of the area or by recent subduction processes, or an oceanic terrane more recently accreted to the
- Whereas the inner forearc appears as a rigid block uplifted and tilted as a whole to the south, short wavelength deformations of the outer forearc basement are observed, beneath a 3 to 6 km thick sedimentary pile, in relation with the subduction of the Tiburon ridge and associated seamounts.
- North, offshore Dominica Island, the outer forearc is 70 km wide. It extends as far as 180 km to the east of the volcanic front where it acts as a backstop on which the accretionary wedge developed. Its width decreases strongly to the south to terminate offshore Martinique where the inner forearc acts as the backstop.
- Two dense wide-angle seismic refraction lines, shot during the Trail experiment (2007) provides a 2D velocity model across the whole arc north and south of Dominica Island. Wide-angle reflection travel times were inverted to constrain the deepest interfaces. It appears that the overriding plate is characterized by a thick crust, the Moho interface being at 30 km depth along both profiles. To the south, an intracrustal interface 20 km deep that strikes only beneath the inner forearc region is also imaged separating the upper crust from the lower crust.

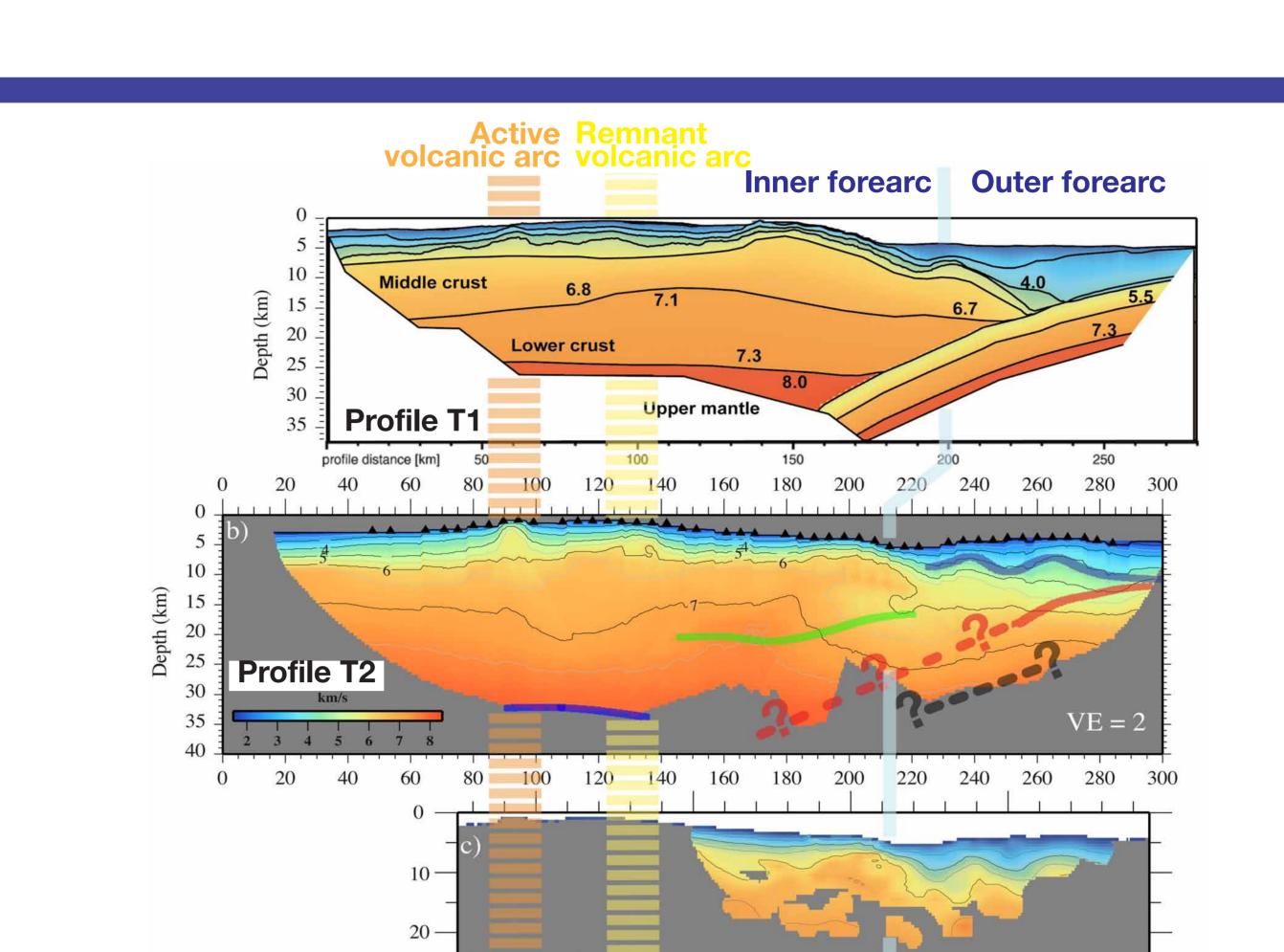


Map of the 2007 seismic experiment presented dataset in central Lesser Antilles. The bathymetry is a compilation of data acquired during the experiment and existing data from Smith and Sandwell (1997), Deplus et al. (2001) and Feuillet et al. (2001). Black lines and hexagons represent respectively shot lines and OBS locations during the Sismantilles 2 experiment. Thick grey lines are MCS profiles 1 and B and deep profiles shot during the Trail experiment.



The 4 km/s velocity contour (white line) coincides almost perfectly with the strong basement (B) reflector, except the short wavelength variations (<10 km, e.g. profile 1 at km-100 and profile B at km-215). We consider thereafter in our study the 4 km/s velocity contour as representing the basement. The thick white arrow represents the trenchward termination of

The background represents the tomographic velocities from our final model converted to two-way travel time (TWT).



Comparison between models obtained along the profiles shot across the Island Arc respectively North (profile T1, Kopp et al., 2011) and south of Martinique Island (profile T2).

Profile D is the coincident section in the 3D Model.

Along profile T2, major reflection observed on the data are modelled as floating reflectors in the tomographic model (Korenaga et al., 2000):

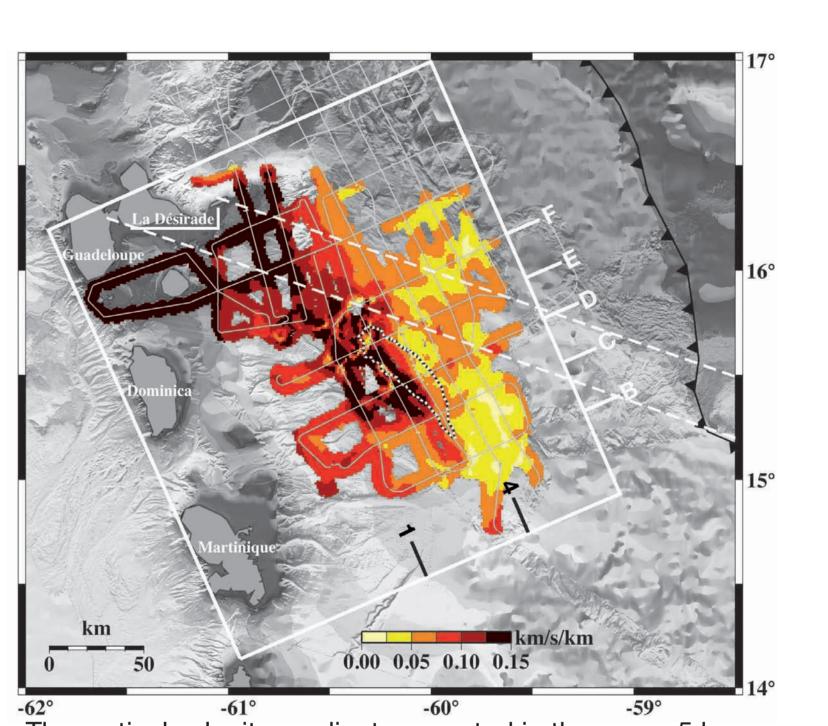
- a clear intracrustal reflector marks the inner part of the forearc; - the active and remnant volcanic arcs are highlighted by high velocity
- Comparing T1 and T2 models shows:

bodies (plutons) in the uppermost crust.

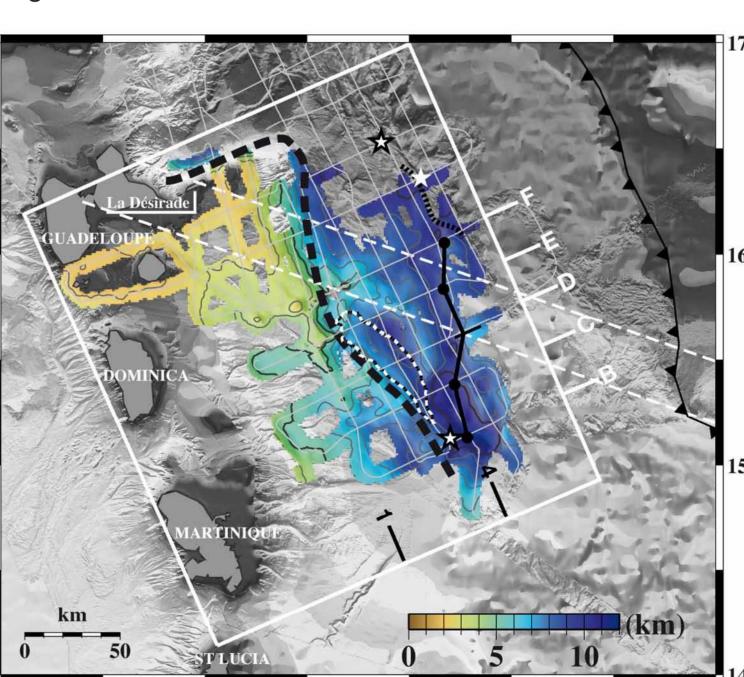
- the Moho is 32 to 33 km deep;

- the transition between the high velocity inner forearc and the low velo-
- city outer fore arc is shifted by 15 km to the east along profile T1;
- the ~30 km thick crust beneath the arc and the forearc would be consistent with the LIP's nature of the crust.

250 2D tomography of first arrival

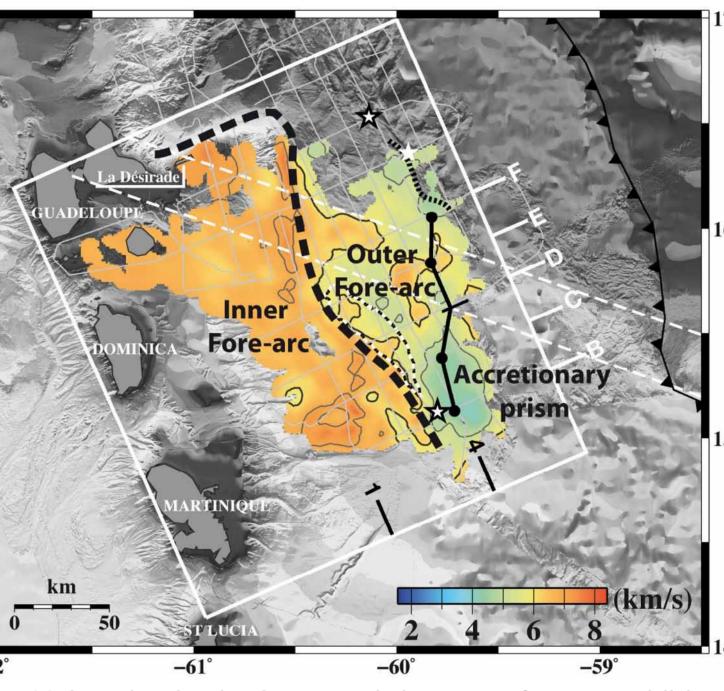


The vertical velocity gradient computed in the upper 5 km of the basement, based on the 4 km/s velocity contour, highlights the different nature of the inner and outer forearc

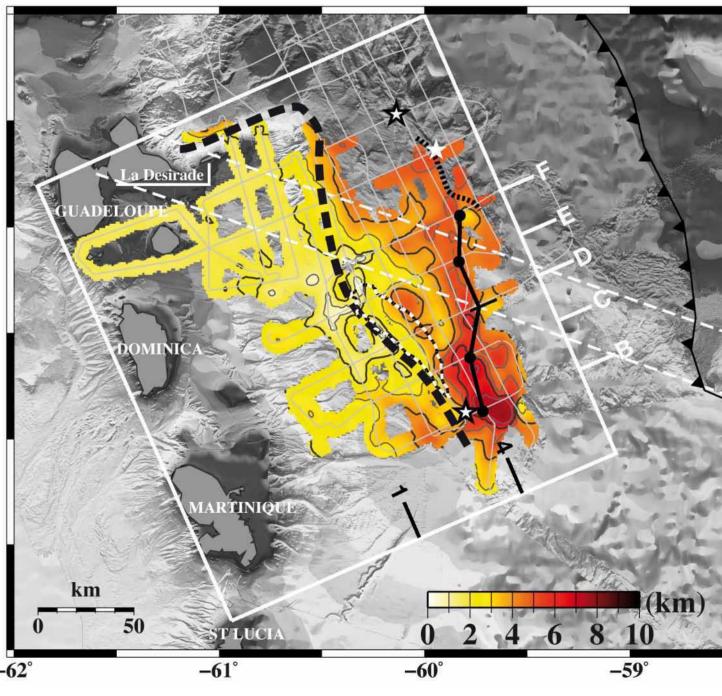


Depth of the forearc basement based on the 4 km/s velocity contour. The inner forearc basement is dipping

La Désirade Island.



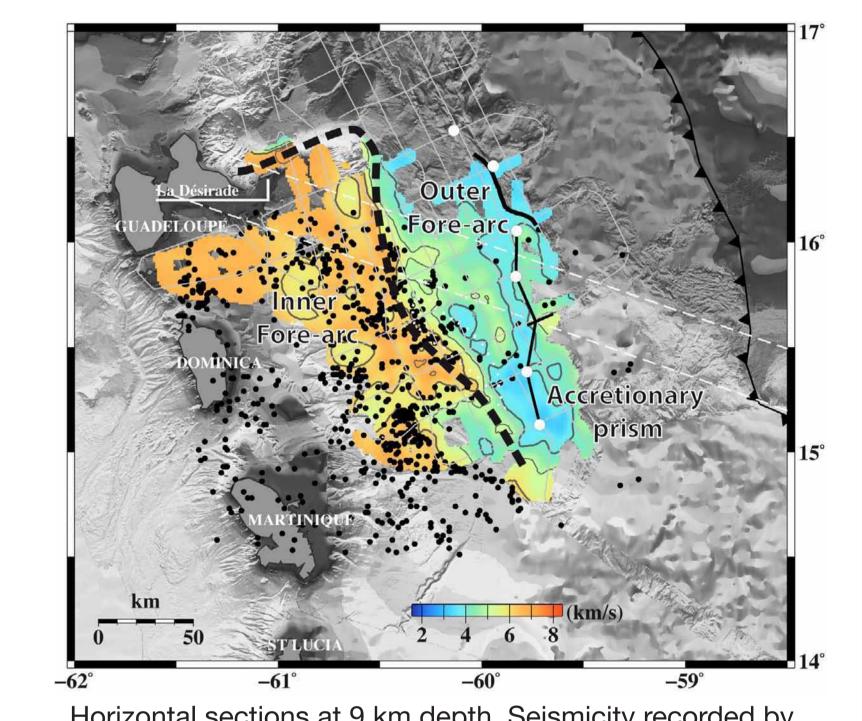
contrasted seismic velocities.



Map of the sedimentary thickness. Both depth of the basement and sedimentary thickness are underestimated within the inner forearc sedimentary basin (south of the

This study illuminates the 3D seismic structure of the forearc in the central Lesser Antilles subduction

- Seismic velocities in the basement highlight an outer forearc and an inner forearc located further arcward. - The inner forearc likely corresponds to the eastern margin of the Mesozoic Volcanic system that outcrops on
- The inner forearc appears as a rigid crustal block that may be uplifted to the northwest by 4 km relative to the basement of the outer forearc. It may be due partly to the subduction of the Tiburon ridge.
- The basement of the outer forearc exhibits slightly lower velocity and lower velocity gradient. It undergoes short wavelength deformations related to the subduction of the seafloor reliefs that controls depocenter of 2 to 4-km thick sedimentary basins (i.e. the Arawak Basin).
- The backstop is the trenchward limit of the outer forearc that forms a rigid buttress to the accretionary wedge. It is located about 180 km trenchward of the volcanic front, offshore Dominica Island, and retreats arcward to 145 km offshore Martinique.
- Offshore Martinique, the accretionary wedge reaches a thickness of 7-km.
- The outer forearc could be either the prolongation of the inner forearc, having been eroded and altered by the subduction process, or it could be the result of accretion of a major volcanic terrane to the inner forearc in the past history of the Lesser Antilles subduction zone.
- The main seismic activity is concentrated, beneath the dense, thick and rigid inner forearc because it likely increases the vertical stress applied to the subducting plate.



an onshore offshore network of seismometers from January to the end of August 2007. More than 700 micro-earthquakes were located precisely by using HypoEllipse (Ruiz et al., in press). At this depth the inner forearc appears with velocities higher than 6 km/s. Most of the seismicity during this period of time is located beneath the inner forearc (Karukera block) except beneath the deep sedimentary basin located on top of the inner forearc (north east of Martinique Island) where it is coincident with the seismic gap observed in the southern part of the inner forearc.

White star is the position of the backstop termination determined by Kopp et al. (2011). White stars with black contour outline also this termination but modelled by Roux (2007). Black dotted line is the position of the backstop's toe according to Bangs et al. (2003) and Christeson et al. (2003). Black dots and the full black line are the backstop's toe determined in this study using both MCS data and our tomographic model. Dashed black line separates the inner forearc and Karukera block from the outer forearc and accretionary prism. It is close to the 6 km/s velocity contours of the horizontal sections at 12 km depth and follows the arcward border of the Arawak basin.

The Lesser Antilles Thales scientific party is composed of Bayrakci, G., Bécel, A., Charvis, H., Krabbenhoeft, A., Laigle, M., Lebrun, J. F., Monfret, T., Papenberg, C., Planert, L., Ruiz, M., Sapin, M., Weinzierl, W.

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Major results