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Imaging the megathrust in subduction zones: lessons from Greece, Ecuador and the Lesser Antilles

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Understanding the physical parameters and processes that control the seismogenic behavior of subduction zones megathrust faults remains one of the outstanding challenges in Earth Sciences.

Here we present important results from several large seismic experiments aimed at addressing this question. These experiments focused on the three subduction zones off Greece, the Lesser Antilles islands, and Ecuador, with different convergence rates and seismic activities. Surveys included multibeam bathymetry, multichannel reflection seismic (MCS) and wide-angle seismic (WAS) acquisitions over the forearc domain, as well as teleseismic receiver-functions and local earthquakes monitoring with temporary deployments of seismological networks.

Our results demonstrate the needs of both dense and extensive geophysical investigations.

In the central Lesser Antilles subduction zone, the interplate has been imaged down to the backstop at 12-15 km depth over the 350-km-long Antigua to Martinique islands segment. The outer forearc crust is strongly faulted in response to the two subducting Tiburon and Barracuda ridges (SISMANTILLES1-and-2 surveys). Two WAS profiles constrained the deeper geometry of the interplate down to the forearc Moho located at 28 km depth (TRAIL survey). The OBS networks deployed over several months (OBSANTILLES and OBSISMER surveys) revealed mantle wedge supraslab earthquakes and M4-5 possible repeaters with flat-trust mechanisms. The joint active-

source/local earthquake seismic tomography let us to unveil the V_p and V_p/V_s heterogeneity along the slab surface and derive unprecedented constraints on multi-stage fluid release from subducting slow-spread oceanic lithosphere. Farther northwest, where the convergence obliquity strongly increases, we constrained the geometry of the interplate down to the forearc Moho at 25 km depth. Strain partitioning localizes on inherited major structures within the forearc domain, like the left-lateral partitioning system of the Anegada Passage and the 850-km-long Bunce fault, located along the backstop (ANTITHESIS survey).

On the southwestern Hellenic subduction zone, MCS and WAS acquisitions highlight the existence of an outer forearc crust beneath the forearc Matapan Trough, but its highly complex structure prevented us to image the interplate (ULYSSE survey). Acquisition by the R/V Marcus Langseth with its 8-km-long streamer finally made it possible (SISMED survey). Dense receiver-function acquisition on a 300-km-long mobile seismic network constrained the 3D geometry of the slab top underneath central Greece. This imaging revealed that the subducting oceanic crust and backstop updip limit are segmented by 9 trench-normal subvertical faults, seismically active at intermediate depths and possibly of inherited origin (THALES WAS RIGHT survey).

South of the 1906 M8.8 Ecuador-Columbia rupture area, the April 2016 Mw7.8 Pedernales subduction earthquake and its ensuing postseismic phase revealed a combination of seismic/aseismic slip behavior. Fluid-enriched parts of the megathrust fault and structural margin segmentation are hypothesized to play a major role in controlling slip behavior but direct observations are still lacking. Previous MCS acquisitions revealed very locally a fluid-rich subduction channel along with severe damage effect of the forearc margin due to seamounts subduction (SISTEUR survey). Forthcoming 3D seismic acquisition along this segment will examine the impact of the along-strike and along-dip variations of the physical properties and fluid content on the slip mode (HIPER survey).