How fluids impact seismic/aseismic slip in the Ecuadorian subduction zone? The HIPER marine project

Audrey Galve¹, Andreas Rietbrock², Philippe Charvis¹, Giorgio De la Torre³, Sandro Vaca⁴, Monica Segovia⁴, Anne Meltzer⁵, Susan Beck⁶, and the HIPER Team*

¹Université Côte d'Azur, IRD, CNRS, Observatoire de la Côte d'Azur, Géoazur, France
²Karlsruhe Institute of Technology, Geophysical Institute, Germany
³Instituto Oceanográfico y Antártico de la Armada, Guayaquil, Ecuador
⁴Instituto Geofísico, Escuela Politécnica Nacional, Quito, Ecuador
⁵Department of Earth and Environmental Sciences, Lehigh University, USA
⁶Department of Geosciences, University of Arizona, USA
* A full list of authors appears at the end of the abstract

Identifying the circulation of fluids in subduction zone system and understanding their role on the megathrust fault slip modes remains one of the outstanding challenges in Earth Sciences. As these faults have the capacity to generate mega-earthquakes, the associated hazard to the society is significant.

The Ecuadorian subduction zone is one of the places in the world where very large earthquakes can occur, as shown by the Mw 8.8 earthquake in 1906. In April 2016, a Mw 7.8 earthquake broke the southern part of the 1906 earthquake rupture zone, causing hundreds of deaths and millions of dollars in damages along an increasingly populated coastline. The seismological and geodetic network in place since several years and a dense post-seismic deployment, contributed to observe and define the rupture zone and areas affected by aseismic slip on the shallowest portion of the megathrust fault. Those hints of transient slip behaviors, for which fluids have been invoked to explain their occurrence, bring Ecuador to the forefront of natural laboratories to study the link between fluids and slip mode.

The HIPER marine campaign in March/April 2020 on board R/V Atalante was designed to acquire a dense active/passive, 2D/3D, onshore/offshore dataset, and in particular to derive the role of fluids in slip modes on the Ecuadorian margin. Thanks to an international consortium (Ecuador, Germany, France, United States) we had access to a large number of OBS (47) and land stations (~700) to record both R/V Atalante’s shots and the seismic activity.

The large-N experiment allowed a high density onshore/offshore deployment to perform shots and earthquakes FWI (Full Waveform Inversion) and obtain sufficient resolution to tackle the role of fluids with respect to interplate roughness, the nature of sediments, upper plate and lower plate's structural heterogeneity in seismic/aseismic slip behavior.
A few days after starting the marine campaign, countries closed their frontiers due to the Covid-19 health crisis. The HIPER marine campaign was stopped and scientists on board were repatriated home. During the 10 days out of the 42 days planned, we managed to acquire the planned multichannel seismic reflection lines (abstract by L. Schenini - TS12.1). However, we collected only one of the three planned OBS wide-angle seismic lines (abstract by A. Skrubej - GD4.3), and no OBSs have been deployed for seismic activity monitoring.

The unique joint reflection/refraction line is perpendicular to the trench, sampling the megathrust fault where aseismic slip occurs, north of Pedernales. On our tomographic inversion, iso-velocity contours characterizing the oceanic crust entering the subduction, are downwards deflected 15 km before the trench. Such observation could be related to fluids affecting the crust and the upper mantle. On MCS image, we observe within the trench a rough oceanic basement, with a horst-like topographic high which outcrops at sea-bottom. Such structure could facilitate fluids infiltrating the crust before the trench in addition to bending faults, and possibly explain low Vp anomaly obtained on our coincident tomographic image.

A new marine campaign HIPER 2.0 is rescheduled in March/April 2022 to acquire the missing data.