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Seismological evidence for a multi-fault network at the Ecuadorian subduction interface

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The simplified view of the subduction interface is that of a single plane along which seismic and aseismic deformation occurs. In reality, however, exhumed subduction zones and geophysical imaging have shown that the seismogenic plate interface is a deformed, 100m-1km thick tabular region. Within this region, we currently do not know if seismic slip is localized on a single fault or distributed over several active faults, and how this impacts seismogenesis and the timing of deformation. Here, we use high-resolution earthquake locations to shed light on these questions.

We focus on the aftershock sequence of the March 27th 2022, Mw 5.8 Esmeraldas earthquake which occurred at 19 km depth at the plate interface in Ecuador, and which was recorded by the dense temporary seismic network deployed during the HIPER2 marine campaign. We use machine learning to detect and pick over 1700 earthquakes (Mw 0-3), which we then locate using a double difference algorithm with cross-correlation times and a 3D velocity model. This allows us to obtain an exceptionally detailed image of the seismicity at the plate interface, which falls into a 200-400 m thick zone, comparable to plate interface thicknesses observed in exhumed subduction zones. Using a cross-correlation threshold of 0.75, we extract families of similar earthquakes, whose geometry we investigate using the 3-point method. These families generally occur on subparallel, sometimes superposed planes with a thickness of 0-40 m that is comparable to the thickness of individual fault zones observed within fossil subduction shear zones. These individual fault zones appear to form a network whose geometry impacts the aftershock expansion, itself controlled by afterslip rather than diffusive processes, thus demonstrating the importance of considering the 3D structure of the plate interface when modeling slip.