Evidence for transient fluid pathways in the mantle of the subducting Nazca slab from seismological observations and modeling of the Poisson's ratio

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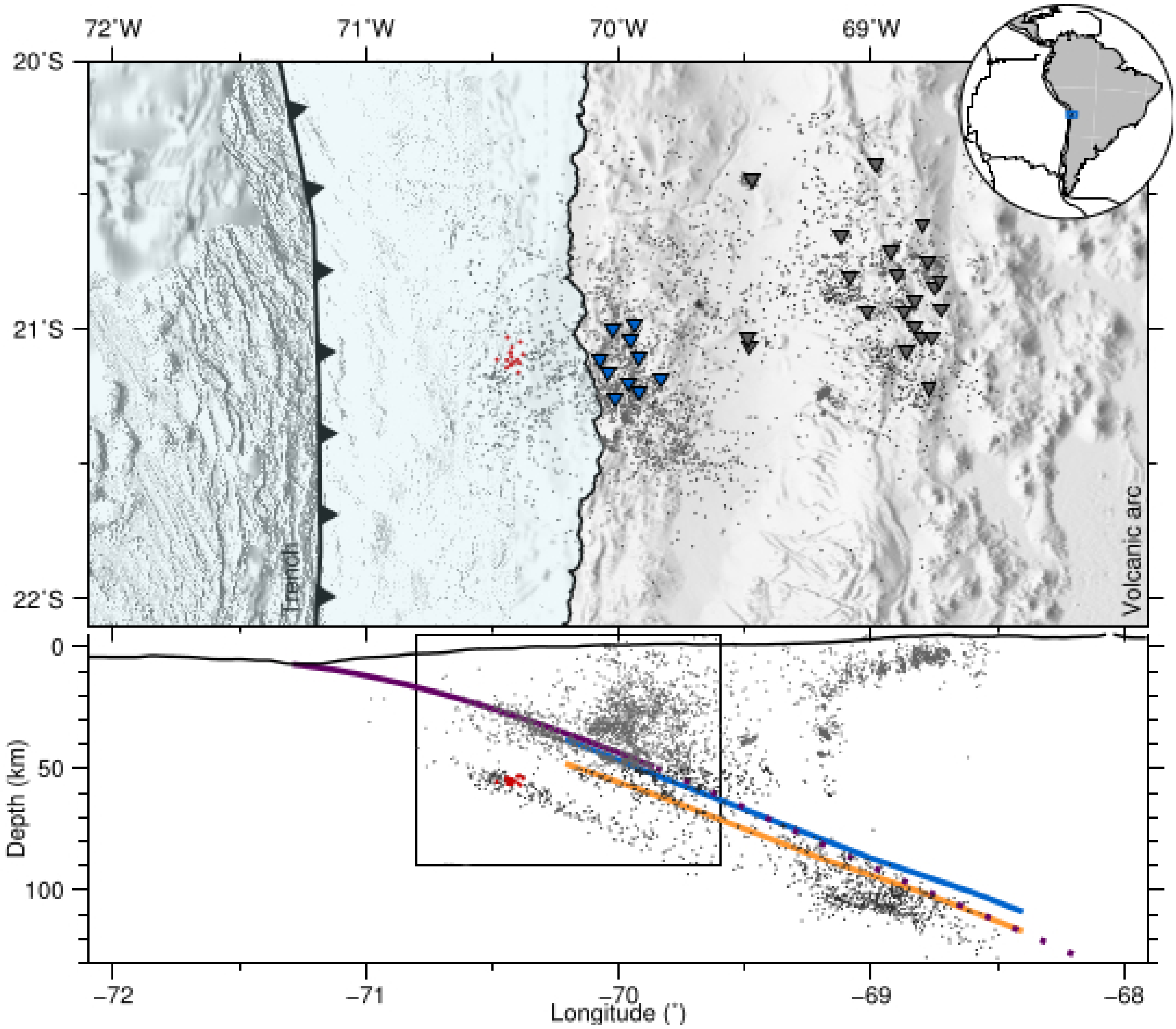
Subduction zones worldwide show the common pattern of a lower seismicity plane, where earthquakes occur at intermediate depth within the mantle of the subducting slab. In order to explain the occurrence of these earthquakes different earthquake nucleation mechanisms have been proposed. Some of them attribute seismicity to different transient phenomena that accompany the metamorphic breakdown of water bearing mineral phases. Event though such mechanisms can well explain the distinct shape of the lower seismicity plane and can well be reproduced in laboratory experiments, they are based on the assumption that the subducting plate is hydrated tens of kilometers below the oceanic Moho. Direct evidence for this assumption is scarce.

To detect the possible presence of fluids in the slab mantle, as predicted by the dehydration hypotheses, we estimated the Poisson's ratio of a small rock volume that hosts intra-slab earthquakes by employing a non-tomographic seismic method that has its greatest sensitivity in the direct vicinity of the earthquakes and delivers unique results. We interpret our results by means of a state-of-the-art coupled thermodynamic-poroelastic model. We additionally determine focal mechanisms in the lower seismicity plane to gain information about the prevailing stresses.

The joint interpretation yields a picture in which seismicity occurs at a low rate at 50km depth in a dehydrating but not over-pressured environment at low, overall tensile differential stresses. The modeling results indicate that the fluid occupies a minor volume fraction in the order of only 0.1% and constitutes an interconnected, vein-shaped and therefore transient pore network. These findings are in agreement with results from laboratory experiments, numerical simulations and outcrop studies. They imply that the oceanic mantle of the subducting Nazca slab must be at least weakly hydrated to a depth of 20-30km below the seafloor. Our interpretation can also be applied to tomographic images of other lower seismicity planes, e.g. in Japan.

Keywords: Mantle dehydration, Fluid processes, Seismology


72˚W
71˚W
70˚W
69˚W
20˚S
21˚S
22˚S
Trench
Volcanic arc
0
50
100
Depth (km)
−72
−71
−70
−69
−68
Longitude (˚)