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Constraints on the seismogenesis of the Nicaragua 1992 slow tsunamigenic earthquake based on seismic travel-time tomography models

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We present a seismic velocity model of the Nicaragua convergent margin obtained by refraction and reflection travel-time tomographic inversion of wide-angle seismic data recorded in 28 ocean bottom hydrophones and 7 land stations along a ∼280 km-long profile. The experiment was conducted by the R/V Maurice Ewing cruise 0005 funded by NSF and German DFG (2000) and by the R/V Sonne cruise SO173-1 within the framework of the SFB574 project of the Kiel University (2003).

For the travel-time inversion we followed a top-to-bottom layer stripping strategy aimed to determine the position of a single reflector and the velocity distribution above it. Once the first layer was inverted, the obtained velocities were overweighted in the model and we extended it to the next reflector. This procedure allows us to keep velocity contrasts across sharp interfaces within the model to account for geological discontinuities. Subsequently, a Monte Carlo-based mean deviation analysis was performed to estimate the uncertainty of the velocity model and the geometry of reflectors. This analysis consisted on randomly varying a reference velocity model, the dipping angle of the reflector and the travel-time data set to create a total of 1000 2D starting models and data sets, that is picked travel times, to later conduct an inversion for each pair. Finally, we calculated the average model and the mean deviation for the velocity distribution and the position of the reflector for the 1000 iterations, which can be interpreted as a measure of the uncertainty of the model parameters.

The velocity model shows three well-differentiated areas in the overriding plate: at the top, the sedimentary cover overlying the basement. Below, the igneous rocks of the basement are divided into western and eastern bodies. In the east, seismic velocities characteristic of upper continental mantle are found at ∼10 km depth below a >5 km thick sedimentary basin, which indicates the presence of extremely thin (4-5 km) crust that thickens to ∼20 km towards the trench. The mantle wedge is thus notably shallow and located only ∼70 km from the trench. It shows relatively low seismic velocity (7.0-7.5 km/s), indicating a 20-25% serpentinization in its shallowest region.

The margin igneous crust shows increasing velocities with a gradient from top to bottom and from the trench towards the coast suggesting a general progressive decrease in the degree of fracturing and alteration. However, under the middle lower slope, there is a relatively low velocity zone which could be explained by a locally higher degree of fracturing and could be an indication of fluids migrating from the subducted sediments. The interplate reflector of the tomographic model of the overriding plate fits well with the plate boundary reflection imaged on coincident multichannel seismic reflection data, with the exception of the segment right under the low velocity zone. The mismatch could be caused by seismic anisotropy related to fracturing and fluids.

The dipping angle of the interplate boundary is very well constrained with the wide-angle data. Thus the tomographic velocity model can be used to study the geological structures involved in the rupture of the 1992 tsunamigenic earthquake. The hypocenter is located at the base of the crust of the overriding plate, with aftershocks distributed all along the interplate boundary, from almost the trench axis down to the shallowest part of the serpentinized mantle wedge.