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Combined seismic and gravity modeling reveal trench-parallel variations in the degree of mantle serpentinization of the incoming Cocos plate, offshore Nicaragua

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We present a detailed seismic velocity model of the overriding plate at the convergent Nicaraguan margin, obtained by travel-time inversion of wide-angle seismic data acquired during the cruise EW-0005 (2000). The data correspond to the profile NIC125 (NW-SE), which is located on the continental slope and runs parallel to the trench. It is 190 km-long and was recorded by 12 Ocean Bottom Hydrophones (OBH).
For the travel-time inversion a top-to-bottom layer-stripping strategy was followed aimed to determine the position of reflectors at the top of the basement and at the inter-plate boundary, as well as the velocity distribution above them. This process allows us to account for sharp velocity contrasts across geological interfaces. Subsequently, a Monte Carlo-based mean deviation analysis was performed to estimate the model parameter uncertainty, such as depth of the reflector and velocity values.
The 2-D velocity model of the upper plate shows a ∼4 km sedimentary cover with velocities between 2 km/s and 3.0 km/s. Below, the basement is ∼12 km thick with velocities between 4 km/s and 6.5 km/s. The velocity fields at the basement show also a significant lateral variation, with the lowest velocity coinciding with the chaotic facies observed in the Multichannel Seismic (MCS) data along a coincident profile, indicating the presence of fractures and fluids. The depth of the inter-plate reflector displays a systematic misfit of ∼1s that is best explained by a ∼15% velocity anisotropy, probably related to rock fracturing and to the presence of fluids.

The seismic velocity model of the upper plate was then converted to density using several existing empirical laws for the sediments and basement, and different models were tested to determine the density structure of the crust and mantle of the underlying (subducting) plate that best fits the observed gravity anomaly. The results of the forward gravity modeling clearly show that it is necessary to introduce significant lateral and vertical velocity (density) variations in the crust and upper mantle of the incoming plate to account for the observed gravity anomaly. The incorporation of lateral density variations reduces the root mean square (RMS) residual anomaly from ∼12 mGal (best fit obtained with a laterally uniform model) to ∼3 mGal (lateral variation).

Our best fitting model shows that the upper mantle density at the northwestern part of the profile, which coincides with the area where the incoming plate is more pervasively faulted, should be up to 10% lower than in the southwestern part. Then, assuming that the mantle density anomalies are entirely caused by variations in the degree of mantle serpentinization, we show that the difference in the degree of serpentinization between the most altered and the less altered mantle segments (at a given depth below the Moho) can be as large as ∼16 %. This fact means that there can be significant along-strike variations in the amount of water that is stored in the mantle and transported by the incoming plate and, therefore, in the amount of water that is likely involved in the dehydration process.