Geophysical Research Abstracts
Vol. 13, EGU2011-7070, 2011
EGU General Assembly 2011

Flat-slab dehydration, non-volcanic tremors and roll-back in Central Mexico

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Recent seismic and magnetotelluric experiments, aimed at better characterizing the shape and state of the subducting slab and continental crust beneath Central Mexico, exposed significant differences with conclusions of previous studies. A new slab geometry is revealed in which the subducting Cocos slab is perfectly flat between 120 to 290 km from the trench, after which it plunges into the asthenosphere at a dip angle of $\sim$65°, in sharp contrast with the previously proposed $\sim$20° dip angle. Seismic tomography studies show negative P-wave velocity anomalies (-2 to -4%) in the mantle wedge beneath the Mexican Volcanic Belt, and positive anomalies (+2 to +3%) for the subducted Cocos slab. Magnetotelluric experiments exposed a very low-resistivity area (1–10 Ωm) located within the continental crust just below the Mexican Volcanic Arc. Finally, several spots of non-volcanic tremors (NVTs) have been recorded inside the continental crust above the flat-slab segment. While all these experiments provide a better picture of the subduction system beneath Central Mexico, several key processes need further investigation. In this study, we take advantage of these new observations to better constrain the thermal structure beneath Central Mexico. Two different thermal models are computed for a mantle potential temperature (T p) of 1,350 and 1,450°C, respectively. The new thermal structures are then converted into P-wave velocity anomalies and compared with the observed V p anomalies. We found that a T p of 1,450°C produced larger V p anomalies that do not fit the observations. However, using a T p of only 1,350°C, our predicted V p anomalies are positive (+2 to +3%) for the cold slab and negative (-2 to -4%) in the mantle wedge. These V p estimates are consistent with the observed seismic tomography from P-wave arrivals, and therefore we conclude that a T p of 1,350°C is a better estimate for the mantle potential temperature beneath Central Mexico. The new thermal model, in conjunction with phase diagrams for sediments, hydrated basalt and lithospheric mantle, have been used to estimate the amount and location of fluids released from the subducting Cocos slab. Several dehydration pulses have been identified along the slab interface where most of the fluids stored in sediments and oceanic crust are released into the overlying continental crust above the flat-slab. We found a good correlation between the pattern of these dehydration pulses and the location of NVTs, suggesting that slab dehydration is responsible for triggering the tremors. We suggest that NVT bursts localized above the flat slab segment represent the manifestation of ongoing continental crust hydration and weakening, a process that has been going on since 15 Ma ago when the Cocos slab entered into a flat-slab regime. Such continuous weakening would have reduced the suction forces that kept the slab in a flat regime in the last 15 Ma, allowing the slab to easily roll back. The continuous low-resistivity region recorded beneath the volcanic front in Central Mexico might represent the evidence of slab dehydration and crust weakening over time.