Geophysical Research Abstracts
Vol. 16, EGU2014-10735, 2014
EGU General Assembly 2014

Dynamic topography in subduction zones: insights from laboratory models

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The topography in subduction zones can exhibit very complex patterns due to the variety of forces operating this setting. If we can deduce the theoretical isostatic value from density structure of the lithosphere, the effect of flexural bending and the dynamic component of topography are difficult to quantify. In this work, we attempt to measure and analyze the topography of the overriding plate during subduction compared to a pure shortening setting.

We use analog models where the lithospheres are modeled by thin-sheet layers of silicone putty lying on low-viscosity syrup (asthenosphere). The model is shorten by a piston pushing an oceanic plate while a continental plate including a weak zone to localize the deformation is fixed. In one type of experiments, the oceanic plate bends and subducts underneath the continental one; in a second type the two plates are in contact without any trench, and thus simply shorten. The topography evolution is monitored with a laser-scanner.

In the shortening model, the elevation increases progressively, especially in the weak zone, and is consistent with expected isostatic values. In the subduction model, the topography is characterized, from the piston to the back-wall, by a low elevation of the dense oceanic plate, a flexural bulge, the trench forming a deep depression, the highly elevated weak zone, and the continental upper plate of intermediate elevation. The topography of the upper plate is consistent with isostatic values for very early stages, but exhibits lower elevations than expected for later stages.

For a same amount of shortening of the continental plate, the thickening is the same and the plate should have the same elevation in both types of models. However, comparing the topography at 20, 29 and 39% of shortening, we found that the weak zone is 0.4 to 0.6 mm lower when there is an active subduction. Theses values correspond to 2.6 to 4 km in nature. Although theses values are high, there are of the same order as dynamic topography and could represent the dynamic effect of the slab sinking into the asthenosphere and lowering the elevation of the upper plate.