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Continental delamination: Insights from laboratory models

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Delamination is a vividly discussed process, which has often been used to explain regional uplift associated with alkaline magmatism (e.g. Tibet, Anatolia, Colorado plateau, Sierra Nevada California), either by peeling and coherent detachment or convective removal of lithospheric mantle. But mechanisms of delamination, relationships between mantle flow and lithosphere, and surface consequences still remain poorly understood.

We performed a parametric study at different structural levels of factors influencing the dynamics of delamination by peeling of the lithospheric mantle by using laboratory models. The adopted set-up consists of a three-layers visco-elastic body (analogue for upper crust, lower crust, lithospheric mantle) locally thickened/thinned to simulate a lithospheric root and an adjacent weak zone, lying on a low viscosity material simulating the upper mantle. Each experiment is monitored using high-resolution cameras positioned in the lateral and top views. We focus our attention on the quantification of the mantle circulation pattern and the evolution of surface topography realized using Feature Tracking and a 3D laser scanner, respectively.

All of the experiments show the same typical sequence of three phases. First, a slow initiation with progressive tilting and decoupling of the extremity of the lithospheric root, while moderate mantle flow rises in the adjacent weak zone. A higher zone is present above the weak zone from the beginning of the experiment and a dynamic depression deepens above the lithospheric root. During a second stage, the ascending mantle intrudes the lower crust and triggers delamination of the lithospheric mantle, which propagates parallel to the length of the model. A typical three-fold signal of dynamic topography follows the hinge of the delamination: an uplifted bulge caused by upward mantle flow, a trough due to the detaching lithospheric mantle and a small bulge due to bending. In the final stage, the delaminating lithospheric mantle sinks near-vertically and the upper part of the model moves rapidly in the direction opposite to the delamination (retroward). This motion is related to the growth of a counterflow rising in the delaminated area and pushing the whole upper part of the model retroward. Amplitude of topography increases until the delaminating lithospheric mantle reaches the bottom of the box. These results - consistent with previous analytical and numerical models - highlight a strong interdependence between induced mantle circulation, delamination dynamics, plate kinematics and surface topography. Finally, the highlighted features have been compared to natural systems where a delamination process has been proposed.