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Crustal flow at the margin of high plateaux: A lithospheric-scale experimental approach

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A serie of analogue models was performed in order to explore the mechanisms of exhumation of high grade rocks at the margin of high plateaux. Experiments are scaled for gravity and simulate convergence between a hot, weak and thin lithosphere lacking a resistant mantle layer (high plateau, HP) and a cold and thick cratonic lithosphere (CL). The HP consists in a three-layer crust made of a low-viscosity silicone simulating partially molten lower crust (PMLC), overlaid by a medium-viscosity silicone simulating the middle crust, and a thin sand layer modelling the brittle upper crust. The CL is made of three layers, from bottom to top: a high-viscosity silicone (resistant mantle layer), a medium-viscosity silicone (lower crust) and a sand layer (upper crust). The model lithospheres float on a low-viscosity and dense solution of sodium polytungstate, simulating the asthenosphere. A set of laterally constrained experiments was run by changing the velocity of convergence, and the strength / thickness of the layers, to explore various degrees of coupling amongst lithospheric layers and between the two lithospheres. Several sets of experiments with comparable parameters were performed and stopped at different amounts of shortening, then frozen and cut for observation on serial cross-sections. For all experiments, the same kinematic scenario occurs. First, shortening affects preferentially the HP. Shortening proceeds by homogeneous thickening of the entire ductile crust and the formation of pop-downs of upper brittle crust after preferential development of HP-verging thrust faults. The crust rapidly acquired a double thickness under the HP, whereas the inner parts of the CL became moderately thickened as a continental subduction of CL mantle initiates under the HP. The part of the PMLC in contact with the CL starts to form a CL-verging antiform evolving into a wedge-shaped channel being injected into the lower crust of the CL. The channel is exhumed by slip along the reverse shear zone acting as the ramp accommodating subduction of the CL mantle below the HP. Injection of PMLC induces far field horizontal displacements of lower crust of the CL towards the foreland. The main foreland-verging thrusts affecting the CL form at that time. After a certain amount of injection and amplification, the roof of the antiform is horizontally sheared backward (i.e., toward the HP) along a flat shear zone whose upper wall coincides with the brittle-ductile transition. This shear zone emerges as the latest back thrust developed in the model, which bounds the outermost pop-down formed in the HP.

These results suggest the amplification of a domal antiform resulting in injection of a non-cylindrical channel of PMLC from under HP into the crust of the CL, producing large finite exhumation of the PMLC even in the absence of erosion at the margin of HP. Erosion would favour greater exhumation ending with the formation of a dome of PMLC at the surface, accompanied by back tilting (and consecutive reorganization) of the flat shear zone accommodating return flow of mid/upper crust toward the HP above the channel. Analogy with the Himalayan-Tibet orogen suggests the South Tibetan detachment system may result from such a late reorganization in the exhumation of the Higher Himalaya Crystalline. The experiments provide constraints on the initiation stages of crustal flow at the margin of HP and may allow refining the channel flow model.