Geophysical Research Abstracts
Vol. 12, EGU2010-8201, 2010
EGU General Assembly 2010

Thermo-mechanical laboratory modeling of lithospheric-scale processes: the example of deep continental subduction and exhumation of UHP/LT rocks

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Purely mechanical (isothermal) laboratory experiments of continental subduction suggested existence of two principal regimes of this process, defined by the interplate pressure and inversely proportional to the pull-force. The pull-force itself depends on the difference between the average density of the subducting lithosphere and the surrounding mantle. In both high and low compression regimes, the continental crust reaches a critical depth proportional to its strength. Although these modeling results correspond quite well to geological data, it was purely mechanical and did not consider change in the mechanical properties during subduction. In nature, however, both pressure and temperature increase causing the strength of the subducting crust and mantle to be reduced by about one order of magnitude when reaching $\sim$100 km-depth. Thermo-mechanical laboratory experiments revealed that such strong change deeply affect the subduction and exhumation processes. In the low compression regime, the crust can only subducts to $\sim$120 km-depth in the asthenosphere. By then, it has become too hot and weak and undergoes large deformation, including upward ductile flow of the deeply subducted portions and a localized failure of the upper crust at depth of a few tens of kilometers. This deformation is accompanied by the delamination of the crustal and mantle layers. In the high compression regime, the deeply subducted continental crust reaches greater depth ($\sim$150 to 200 km) and maintains lower temperature when continental subduction triggers the subduction of the fore-arc block or the arc plate. 2-D thermo-mechanical laboratory modeling of continental subduction thus show that exhumation of deeply subducted continental crust is possible in the low compression regime (i.e. when the effective interplate pressure Pn is lower than the lithostatic pressure), while for the deeply subducted continental crust to be preserved at low temperature at great depth, the continental subduction should be in the high compression regime (i.e. Pn is higher than the lithostatic pressure). 3D thermo-mechanical laboratory experiments have then be produced showing that this apparent contradiction can be solved when, within the background of a generally high compression regime, the interplate pressure is locally reduced in some specific 3D situations, which then allows the local buoyancy-driven exhumation of UHP/LT material.