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Strain localization for subduction initiation: Inference from lithospheric scale modelling

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Subduction is key for driving for plate tectonics. Yet it is still unclear what controls the location and nucleation of subduction zones, in particular, if subduction can initiate in oceanic domain or at passive margins. It is widely accepted that it critically depends on the rheology of the oceanic lithosphere and can occur upon failure of the load-bearing crustal and mantle layers. However, when the oceanic lithosphere is too strong, shear strength of the oceanic lithosphere is too high to permit failure, and subduction may occur by deforming a passive margin at ocean-continent transition. Therefore, this physical analogue modelling study aims at exploring favourable rheological and kinematic conditions that lead to the development of subduction zones, either in oceanic domain, or at the transition to the continent. A selection of experiments, involving both oceanic an continental lithospheres in compression, is used to investigates the role of lithospheric mantle strength, age of oceanic lithosphere and convergence rate for scenarios where convergence is orthogonal to the passive margin.

Model results show that subduction demands different stages of deformation: (1) Failure of the crust (2) Under-thrusting of the oceanic lithosphere (3) Subduction requiring failure of the lithospheric mantle and sinking of oceanic plate into the asthenosphere. When crustal deformation occurs at passive margin, strain localization during under-thrusting depends mainly on the strength difference between the lower crust of the oceanic and continental lithosphere. Finally subduction is mainly controlled by the viscous strength of the lithospheric mantle and the density of the oceanic lithosphere. It provides us parameters to define rheological conditions enabling subduction in oceanic or continental domain. However this boundary of rheologic conditions may change in response to weakening processes such as plumes or weak zones. This shows the importance of thermo-mechanical feed-backs for location of subduction initiation.