Dynamics of subduction under an active Margin: Effects of rheological weakening by fluids and melts
Numerical Modelling

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The dynamics of subduction under an active margin is analyzed by using a 2D coupled geochemical-petrological-thermomechanical numerical model of an oceanic-continental subduction process. This model includes spontaneous slab retreat and bending, dehydration of the subducted crust, aqueous fluid transport, partial melting of both crustal and mantle rocks and melt extraction processes resulting in magmatic arc crust growth. The innovation in this model is the consideration of rheological weakening effects by fluids and melts.

The numerical experiments revealed that rheological weakening by fluids and melts controls the mode of subduction. By varying the weakening effects, five different regimes can be induced showing the following characteristics: (1) formation of a backarc basin, occurance of plumes that (2) ascend and intrude into the continental crust or (3) extend horizontally beneath the continental plate (underplating) or (4) remain above the subducting plate and (5) neither formation of backarc basins nor occurance of plumes. The transition between the different tectonic regimes of subduction at an active margin is caused by the concurrence of rheological weakening by (1) aqueous fluids percolating from the subducting slab into the mantle wedge and (2) melts propagating from the mantle wedge toward the surface.

The aqueous fluids mainly affect the forearc region: strong fluid-related weakening of rocks atop the slab promotes the stacking of sediments and the development of an accretion wedge. Since the material in the subduction channel is weak the coupling of the plates in these regimes of subduction is low and extension in the subduction channel is facilitated. In contrast, a small weakening effect by fluids results in strong coupling of the plates inducing collision-like subduction and subduction erosion. Lithospheric thickening and large sedimentary plumes are the consequence.

Extracted melts rheologically weaken the lithosphere below the arc. Strong rheological weakening by melts in combination with low coupling of the plates allows for necking of the continental lithosphere and leads to the formation of a backarc basin. In the case of sedimentary plumes, weakening of the continental lithosphere by extracted melts generates a weak channel in which the positive-buoyant plumes may ascend. That way silicic intrusions are emplaced in the continental crust. If the continental lithosphere is not sufficiently weakened by melts, the plumes cannot ascend but may extend horizontally leading to underplating.