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Numerical modeling of crustal growth at active continental margins

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The dynamics and melt sources of crustal growth at active continental margins are investigated on the basis of a 2D coupled petrological-thermomechanical numerical model of an oceanic-continental subduction zone. The model includes spontaneous slab retreat and bending, dehydration of subducted crust, aqueous fluid transport, partial melting, melt extraction and melt emplacement in form of both extrusive volcanics and intrusive plutons. Depending on variable model parameters such as plate velocities and degree of rheological weakening induced by fluids and melts, the following three geodynamic regimes of crustal growth were identified: (i) stable arcs (ii) compressional arcs with plume development and (iii) extensional arcs.

Crustal growth in a stable arc setting results in the emplacement of flattened intrusions within the lower crust. At first trondhjemitic melts, extracted from partially molten rocks located atop the slab (gabbros and basalts), intrude into the lower crust followed by mantle-derived (wet peridotite) basaltic melts from the mantle wedge. Thus extending plutons form in the lower crust, characterized by a successively increasing mantle component and low crustal growth rates (20 km3/km/Myrs).

Compressional arcs are accomplished by the formation and emplacement of hybrid plumes. In the course of subduction localization and partial melting of basalts and sediments along the slab induces Rayleigh Taylor instabilities. Hence, buoyant plumes are formed, composed of partially molten sediments and basalts of the oceanic crust. Subsequently, these plumes ascend, crosscutting the lithosphere before they finally crystallize within the upper crust in form of silicic batholiths. Additionally, intrusions are formed in the lower crust derived by partial melting of rocks located atop the slab (basalts, gabbros, wet peridotite) and inside the plume (basalts, sediments). Crustal growth rates increase with time before reaching a steady state (60km3/km/Myrs).

Subduction in an extensional arc setting results in decompression melting of dry peridotite. The backward motion of the subduction zone relative to the motion of the plate leads to thinning of the overriding plate. Thus, hot and dry asthenosphere rises into the neck as the slab retreats, triggering decompression melting of dry peridotite. As a result crustal growth rates increase to values of about 100km3/km/Myrs.