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Magmatic arc development at an active margin: Numerical modelling

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The formation of a magmatic arc system at 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.

In the numerical experiments, many realistic features characteristic for natural arc settings can be observed. One is the construction of an accretionary wedge, including frontal and basal accretion, as well as subduction erosion. The generation of a magmatic arc results in the growth of a new volcanic (mainly basaltic) layer atop the continental crust leading to subsidence and thinning of the underlaying continental crust. The lateral width of the magmatic arc is constricted to 30-70 km due to the limited extent of the melt extraction area in the hydrated mantle wedge atop the slab. In part of the experiments an intra-arc extension is documented. This process is followed by rapid slab retreat triggering the formation of a backarc basin with the new spreading center resulting in dry decompression melting of the mantle and building of new oceanic floor.

The transition between the different tectonic regimes of subduction at an active margin is strongly controlled by rheological weakening effects of (1) aqueous fluids propagating from the 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 while the absence of such weakening causes subduction erosion. In the latter case, the significant part of magmatic arc crust is produced by melting of subducted sediments forming chemically buoyant plumes in the mantle wedge. The volume of the new basaltic crust is reduced compared to cases without sedimentary plumes. On the other hand, the extracted melts movement mainly affects the rheological properties of the lithosphere below the arc: strong rheological weakening due to propagation of melts promotes necking of the overriding plate resulting in intra-arc extension, slab retreat and formation of new oceanic floor while the absence of such weakening precludes an extension of the overriding plate owing to the high strength of the mantle part of the lithosphere.