Magmatic arc development at an active margin - Numerical Modelling

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We use a 2D coupled geochemical-petrological-thermomechanical numerical model of an oceanic-continental subduction process to analyse the development of a magmatic arc. The 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 particular, the model takes into account weakening effects by fluids and melts.

Rheological weakening by fluids and melts controls the mode of subduction. Five different tectonic regimes of subduction can be distinguished: (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 (stationary plumes) and (5) neither formation of backarc basins nor occurance of plumes.

These regimes of subduction influence the crust production rate, the degree of melt extraction in the mantle wedge, the region where melts are produced and determine which melts are produced. In case of formation of a backarc basin, the crust production rate is much higher than in the other regimes, partly due to decompression melting of dry mantle peridotite that occurs as trench retreat and necking of the continental lithosphere take place. Like this, a new spreading center emerges in the backarc basin and oceanc floor is produced.

Another control on the crust production rate is the angle of the subducting plate which in turn depends on the coupling of the plates. Strong coupling leads to a collision-like subduction where a steep angle of the descending plate decreases the crust production as the amount of molten hydrated mantle is reduced. The coupling of the two plates is strongly controlled by the degree of weakening by hydrous fluids that mainly affect the forearc region and the subduction channel.

In case sedimentary plumes develop, crustal material reaches the hot regions of the mantle wedge. Hence new crust is produced from melting of subducted sediments and subducted, mainly oceanic crust. As the plumes develop in various ways, the regions in which melts are produced and where depleted material is situated are different in the different regimes of subduction. Horizontally extending plumes (underplating) or ascending plumes lead to a wide area beneath and partly in the continental lithosphere where melts are produced and depleted material is remains. In contrast, this region is much smaller in regimes with stationary plumes.