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Arc splitting and back-arc spreading evolution: the control of hydration and melts

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While there has been a lot of work focusing on improving our understanding of divergent and convergent plate boundaries, the complex nature of the back-arc region, where convergent margins transition into large-scale extension in the upper plate, is yet to be investigated fully. Indeed, why and how extensional basins open near the boundaries between convergent plates, followed by their tectonic inversion, have long been outstanding questions in plate tectonics.

Here we investigate a wide range of factors that influence the development of back-arc extension using 2D thermo-mechanical code I2VIS employing visco-plastic rheologies, hydration and dehydration processes, melting and surface processes. We systematically vary several parameters to determine their roles and respective importance, including a) fluid and melt induced weakening, b) upper plate geothermal gradient and c) amount of sediment in the accretionary wedge. The fluid and melt induced weakening is implemented by using the Mohr–Coulomb yield criterion that limits the creep viscosity, altogether yielding an effective visco-plastic rheology, and controlled via the melt/fluid pore fluid pressure parameters, λ_{fluid} and λ_{melt}. The upper plate geothermal gradient is controlled by the parameter T_{Moho} . Finally, the amount of sediment in the accretionary wedge is changed through the parameter Sed_{lev}, which controls the minimum y-coordinate sediments can occupy, throughout the model. The higher the Sed_{lev}, the less the height of sediment that can accumulate in the accretionary wedge.

Our extensive series of high-resolution models led to the following conclusions:

- a) a higher upper plate geothermal gradient predictably leads to a more ductile rheology, which then results in an initial wider rift, followed by enhanced melting and earlier arc splitting;
- b) higher erosion and sedimentation rates lead to increasing hydration of the mantle wedge and enhancing mantle melting, and decreasing the stress transfer from the lower to the upper plate;
- c) λfluid controls arc rifting to a greater extent, relative to λ_{melt}, and for λ_{fluid} smaller than 0.2, arc rifting occurs. This means that the fluid induced weakening has to be high, in order to produce arc rifting.

These initial results suggest that the upper plate geotherm has the highest magnitude effects in modulating arc rifting, but fluid and melt induced weakening are also major controls in rift development, in the sense that they regulate whether it happens at all, or not. The height of the accretionary wedge works with the fluid weakening of the upper plate, facilitating arc rifting.