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A discussion on how, when and where surface processes interplay with extensional tectonic deformation

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Fascinating feedback relationships between surface processes and tectonic deformation have long been highlighted for convergent settings. Mountains influence local climate, with precipitation increasing with mountain height and focusing at windward-facing slopes. The resulting erosion reduces the elevation and width of mountain belts, in turn leading to a focussing of tectonic deformation and exhumation at eroding regions. Thus, in convergent settings, erosion and tectonic deformation show positive feedback by enhancing each other. In comparison, the role of surface processes in extensional settings has received less attention, which does not mean that erosion or sedimentation might not equally affect tectonics deformation during extension. In this presentation, i will review theoretical expectations, discuss numerical experiments, and pose questions on how, when, and where surface processes interplay with tectonic deformation during extension.

How: The removal of material by erosion is expected to decrease vertical crustal stress and reduce brittle strength (which is the main process leading to focussing of deformation in shortening). Sedimentation conversely increases brittle strength. However, sediments of low thermal conductivity in extensional basins can trap heat, increasing crustal temperatures, and reducing viscous crustal strength. Will brittle strengthening or viscous weakening dominate during sedimentation? And during rifting, is erosion the controlling surface process, or sedimentation, or both?

When: Usually, subsidence needs to create accommodation space before sedimentation occurs and rocks should uplift before they can be eroded. This would imply that surface processes need time to start up and cannot play a decisive role in initial stages of deformation. This then begs the question: once an extensional system starts to deform in a certain style, can surface processes still change the style? For rift basins, we find from numerical experiments that sedimentation favours symmetric basins over asymmetric half-graben and single basins over distributed deformation. For rifted margins, i have found that sedimentation promotes hyperextension by forming wide areas of thinned continental crust, thus supressing early break-up. These experiments point out that surface processes seem to be able to exert a control on the style of rifting. But at which stage in rift evolution do surface processes start to play a role? And is there a crucial timing, after which erosion and sedimentation no longer influence the extensional style?

Where: Analogous to convergent tectonic settings, erosion of rift footwalls can enhance tectonic deformation and, on a large-scale, turn a ‘passive’ margin ‘active’ in a tectonic sense. Footwall uplift provides a sediment source region, linking erosion to offshore sedimentation. For rifted margins, where does deposition of sediments (whether they are brittle strengthening or viscous weakening) play the most influential role in the rifting process? Can strong near-footwall sedimentation suppress footwall uplift, thus providing a negative feedback in the system?