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Feedbacks between magmatic intrusions, faulting, and surface processes at continental rifts

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During continental rifting, faulting, magmatic injection, and surface processes collectively shape the landscape. Although feedbacks between surface processes and faulting at rifts have been explored, the relationship between shallow magmatic intrusions, topography, and surface processes is poorly understood. Magmatic injection is controlled in part by lithospheric stress, and should therefore respond to rift-associated perturbations to the stress field. Along with normal fault formation and evolution, surficial mass redistribution via erosion, sediment transport, and deposition alters lithospheric stresses and has the potential to influence dike emplacement and long-term rift structure. Here we present a series of two-dimensional (2-D) numerical model runs utilizing the particle-in-cell, finite difference code SiStER to quantify the feedbacks between tectonic, magmatic, and surface processes that shape continental rifts. In our models, extension is accommodated through a combination of magmatic intrusion and tectonic stretching. Magmatic intrusion occurs within a narrow region when and where the sum of horizontal deviatoric stress and magmatic overpressure exceeds the tensile strength of the lithosphere. Magmatic overpressure is thus a key parameter that strongly modulates the sensitivity of dike emplacement to faulting, bending, and topographically-induced variations in lithosphere stress. Our results first probe the relationships between fault-related stresses and the timing and depth-distribution of magmatic intrusions at a rift with no active surface processes. In these cases, the locus of magmatic spreading migrates vertically in response to the evolving stress field. The 2-D tectonic model is then coupled to a 1-D landscape evolution model, which modifies topography concurrent with extension. In the simplest case, topographic diffusion effectively redistributes the topographic load, contributing to variations in injection-controlling lithospheric stresses. We compare our tectonic-responsive results with models that incorporate active surface processes to constrain the conditions under which surface processes modulate magmatic injection. Our simulations suggest that the development and redistribution of topography exerts an important control on the partitioning of tectonic and magmatic strain at extensional plate boundaries.