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Mantle flow and orography: the effect of basal lithospheric shearing and lateral erosion gradients on continental rifting

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Mantle plume-lithosphere interactions modulated by surface processes across extensional tectonic settings give rise to outstanding topographies and sedimentary basins. However, the nature of these interactions and the mechanisms through which they control the evolution of continental rifts are still elusive. Basal lithospheric shearing due to plume-related mantle flow leads to extensional lithospheric rupturing and associated magmatism, rock exhumation, and topographic uplift away from the plume axis by a distance inversely proportional to the lithospheric elastic thickness. When moisturized air encounters a topographic barrier, it rises, decompresses, and saturates, leading to enhanced erosion on the windward side of the uplifted terrain. Orographic precipitation and asymmetric erosional unloading facilitate strain localization and lithospheric rupturing on the wetter and more eroded side of an extensional system. This simple model is validated against petro-thermo-mechanical numerical experiments where a rheologically stratified lithosphere above a mantle plume is subject to fluvial erosion proportional to stream power during extension. These findings are consistent with Eocene mantle upwelling and flood basalts in Ethiopia synchronous with distal initiation of lithospheric stretching in the Red Sea and Gulf of Aden as well as asymmetric topography and slip along extensional structures where orography sets an erosional gradient in the Main Ethiopian Rift (MER). I conclude that, although inherently related to the lithosphere rheology, the evolution of continental rifts is even more seriously conditioned by the mantle and surface dynamics than previously thoughts.