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The role of crustal strength in promoting magmatism during break-up

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The strength of the crust has a strong impact on the evolution of continental extension and break-up. Strong crust may promote focused narrow rifting, while wide rift modes might be due to a weaker crustal architecture. The strength of the crust also influences deeper processes within the asthenosphere. To quantitatively test the implications of crustal strength on the evolution of continental rift zones, we developed a 2-D numerical model of lithosphere extension that can predict the rare Earth element (REE) chemistry of erupted lava. We find that the difference in crustal strength leads to a different rate of depletion in light elements relative to heavy elements. By comparing the model predictions to rock samples from the Basin and Range, USA, we can demonstrate that slow extension of a weak continental crust can explain the observed depletion in melt chemistry during slow extension. Extension within the Main Ethiopian Rift is very slow. Our model would suggest that magmatism within this narrow rift zone can only be explained by the rapid localisation of strain caused by a strong lower crust configuration. We demonstrate that the slow extension of a strong lower crust above a mantle of potential temperature of $1350\,^{\circ}\mathrm{C}$ can fit the observed REE trends and the upper mantle seismic velocity. The thermo-mechanical model implies that melt composition could provide quantitative information on the style of break-up and the initial strength of the continental crust.