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Small-scale convection beneath continental rifts: evidence from the Rio Grande rift

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Recent seismic imaging across the Rio Grande rift in the southwestern US revealed unexpected structures in the underlying mantle. A low seismic wave velocity is found below the Rio Grande rift, while high velocity structures are present at the eastern side of the rift below the Great Plains. The low seismic wave velocity anomaly below the Rio Grande rift has been interpreted as being partially of melt origin, and high velocity structures below the western Great Plains have been proposed to be the result of small-scale convection; cold downwelling lithospheric material with probably a compositional contribution.

We perform a dynamic test of these interpretations using a passive rift model for isochemical convection. The models self-consistently produce a rift localized at approximately the right distance from the border to the nearby thicker Great Plains lithosphere, and emphasize that rifting can only initiate due to far-field extension, i.e., after the compressional Farallon subduction regime of the western US ceased. With realistic upper-mantle rheologies, small-scale convection indeed forms, aided by the lithospheric step. The resulting thermal anomalies produce seismic low velocity anomalies below the rift of a similar amplitude as those imaged seismically, allowing the presence of small amounts of melt only. The lateral extent of the observed low velocities below the Rio Grande rift is as in the models, where it is controlled by the spacing between downwelling limbs of the small-scale convection. The fast velocity structure below the western Great Plains is produced by cold downwelling lithosphere. The thermal rifting models can predict the seismic amplitudes and do not require a compositional contribution.