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What controls graben spacing and morphology?

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Fault patterns in extension often contain several superposed length scales. We review what theoretically controls these length scales and discuss applications to continental rifts, the Basin and Range province, and grooved terrain on Ganymede. The longest deformation wavelengths are associated with the separation of individual grabens and the distance between faults inside each graben, which influences graben morphology. Moho undulations are sometimes observed at similar length scale as graben separation. In the Basin and Range province of the United States, the longest wavelength is expressed as dip domains of Range-bounding faults. Theoretical analyses based on the necking and localization instabilities in multi-layer assemblages, confirmed by analogue and numerical studies, indicate that the length scale of tectonic features should be proportional to thickness of strong and/or brittle layers in the lithosphere. These theories can guide interpretation of the two longest wavelengths of deformation observed during rifting. Classically, the longest wavelength has been associated to necking of a crust-upper mantle stack and the other of the brittle crust. However, analyses in which the depth-dependence of brittle strength is included predict a very slow grow rate of necking in extension. Therefore, localization is the best candidate for controlling fault spacing in the upper crust. The second wavelength must reflect deeper processes, one of which is lithosphere scale necking. Alternatively, localization in the upper mantle or the presence of décollement levels can provide a second deformation length scale. The interaction between these two tectonic wavelengths can be studied numerically and experimentally. Models generate a variety of graben morphology from a basic trough to complex structures with secondary faulting.