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What controls the topographic asymmetry of two-sided frictional mountain belts?

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Mountain belts formed along convergent plate boundaries often exhibit a significant topographic and structural asymmetry that is correlative with the polarity of subduction and accretion. In general, the side of the orogen on top of the down-going plate, or the pro-side, tends to be wider and less steeply-tapered than the retro-side of the orogen, which is often characterized by a crustal-scale backfold. This asymmetry seems to be relatively invariant of the exact plate kinematics and of orogen-scale climatic influences (e.g., rainshadow).

In this work, we investigate the controls on the topographic asymmetry with a numerical model that employs a non-coaxial flow law to describe frictional deformation. In separate suites of experiments, we examine how topographic asymmetry changes with the degree of isostatic compensation and the internal and basal strengths. We find that the asymmetry of a two-sided frictional wedge is closely related to segmentation of the wedge into three distinct mechanical units: i) a deforming pro-wedge that extends from the pro-deformation front to the main topographic divide, ii) an undeforming, steep block that extends from the divide to the original suture between the pro- and retro-plates, and iii) a deforming retro-wedge that extends from the suture to the retro-deformation front. Increases in the basal strength and in the degree of isostatic compensation both result in a higher block slope and greater topographic asymmetry. We find that these results can be understood through a simple force balance along the boundaries of the steep block. As a whole, our results suggest that the large-scale topographic form and the state of stress are inter-related throughout a two-sided frictional mountain belt.