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Forward Versus Back Thrusts in Accretionary Wedges: Effects of Rheology and Thickness of the Décollement Layer

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The mechanical processes that control whether major thrusts in accretionary wedges verge forward toward the foreland, versus backward toward the hinterland has long been a topic of debate. Whereas forethrusts are the most common major thrusts, the importance of the globally rare back thrusts has recently been highlighted given their prominence along the Cascadia margin off of the NW coast of North America as well as along the Andaman-Sumatra subduction zone, in the rupture area of the great 2004 earthquake. We address this problem using 2-D numerical models that use a finite-difference, particle-in-cell method with a viscoelastic-plastic rheology for simulating thrusting in accretionary wedges. Simulations of a weak frictional décollement confirm prior numerical and analogue modeling studies in that they predict lower wedge tapers and repeated sequences of doubly verging conjugate thrusts. A forward dipping backstop was shown in prior laboratory experiments to promote backthrusting, and our results confirm that backthrusting occurs near the backstop but as the wedge widens away from the backstop forethrusts become dominant. Other laboratory experimental studies have found that a non-brittle, viscously deforming décollement can promote backthrusting. Our numerical models show that if the viscosity of the décollement layer η is too high, such that the stress scale, $\eta U/H$ (where U is the convergence rate and H is the décollement layer thickness), is comparable to the frictional strength at the base, then forethrusts dominate. For $\eta U/H$ less than the basal frictional strength, doubly verging faults are prominent over a wide range of décollement layer thicknesses. Only for cases with relatively low $\eta U/H$ and décollement layer thicknesses H that are 25-33% of the thickness of the whole, incoming sediment layer do backthrusts dominate. Thus backthrusting appears to require unusual rheological properties of the deepest sediments, which is consistent with the rarity of backthrusting, but is a prediction that requires further testing with seismic and geologic observations.