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The evolving energy budget of accretionary wedges

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The energy budget of evolving accretionary systems reveals how deformational processes partition energy as faults slip, topography uplifts, and layer-parallel shortening produces distributed off-fault deformation. The energy budget provides a quantitative framework for evaluating the energetic contribution or consumption of diverse deformation mechanisms. We investigate energy partitioning in evolving accretionary prisms by synthesizing data from physical sand accretion experiments and numerical accretion simulations. We incorporate incremental strain fields and cumulative force measurements from two suites of experiments to design numerical simulations that represent accretionary wedges with stronger and weaker detachment faults. One suite of the physical experiments includes a basal glass bead layer and the other does not. Two physical experiments within each suite implement different boundary conditions (stable base versus moving base configuration). Synthesizing observations from the differing base configurations reduces the influence of sidewall friction because the force vector produced by sidewall friction points in opposite directions depending on whether the base is fixed or moving. With the numerical simulations, we calculate the energy budget at two stages of accretion: at the maximum force preceding the development of the first thrust pair, and at the minimum force following the development of the pair. To identify the appropriate combination of material and fault properties to apply in the simulations, we systematically vary the Young's modulus and the fault static and dynamic friction coefficients in numerical accretion simulations, and identify the set of parameters that minimizes the misfit between the normal force measured on the physical backwall and the numerically simulated force. Following this derivation of the appropriate material and fault properties, we calculate the components of the work budget in the numerical simulations and in the simulated increments of the physical experiments. The work budget components of the physical experiments are determined from backwall force measurements and incremental velocity fields calculated via digital image correlation. Comparison of the energy budget preceding and following the development of the first thrust pair quantifies the tradeoff of work done in distributed deformation and work expended in frictional slip due to the development of the first backthrust and forethrust. In both the numerical and physical experiments, after the pair develops internal work decreases at the expense of frictional work, which increases. Despite the increase in frictional work, the total external work of the system decreases, revealing that accretion faulting leads to gains in efficiency. Comparison of the energy budget of the accretion experiments and simulations with the strong and weak detachments indicate that when the detachment is strong, the total energy consumed in frictional sliding and internal deformation is larger than when the detachment is relatively weak.