Investigating the episodic growth of accretionary systems through work minimization, analog experiments and numerical models

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Awarded through: The Joseph Hartshorn Memorial Award

Progress Report

The Joseph Hartshorn Memorial Award helped relieve the economic burden of traveling to Paris in order to perform physical accretionary wedge experiments in one of the most innovative tectonic modeling labs in the world. This visit has achieved several significant goals. Assisting the physical accretion experiments allowed me to more completely understand the rigor and careful scaling exacted for each experiment. Consequently, this first-hand experience has greatly improved my understanding of physical accretion experiments that I am now simulating numerically. In part due to the award, I was able to present a work optimization analysis of the numerical simulation of physical accretion experiments at AGU 2015 (1). We are also finalizing a manuscript intended for submission to JGR (2) to present this work. Additionally, the visit has continued and deepened the Geomechanics research group's collaboration with the Tectonophysics group at the Université de Cergy-Pontoise (UCP).

As a summary of the work optimization analysis greatly facilitated by the visit to the UCP tectonic modeling lab, the abstract of the manuscript (2) describes: We employ work optimization to predict the geometry of accretion faults at the front of an evolving accretionary wedge. We calculate the gain in efficiency due to the propagation of faults of systematically varying dips and positions in numerical simulations of two stages of a physical accretion experiment. Faults that produce the largest gains in efficiency, or change in external work per fault area propagated, $\Delta W_{ext}/\Delta A$, are considered most likely to develop. The analysis very exactly predicts the thrust dips, to within a few degrees of the observed. Near the location where the observed thrusts develop, the work optimization predicted dips more closely match the observed dips than Coulomb failure planes. The analysis predicts the position of the first forethrust almost exactly, differing by <1 mm from the observed, and predicts the geometry of the first backthrust with similar success when the observed forethrust is included in the system. The analysis also closely predicts the positions of the second backthrust and forethrust, but less exactly than the first forethrust. The position of the most efficient second backthrust and forethrust differ from the observed by 16 mm and 10 mm, respectively. However, range of backthrust and forethrust positions that produce >80% of the maximum $\Delta W_{ext}/\Delta A$ differs by <1 mm from the observed. Estimates of $\Delta W_{ext}/\Delta A$ due to fault propagation in these numerical simulations are within the range of $W_{prop}/\Delta A$ calculated for the simulated physical experiments.

(1) McBeck, J., Cooke, M., Herbert, J., Maillot, B., Souloumiac, P. (2015) Predicting the Evolution of Faulting in Accretionary Prisms with Work Optimization: Insights from Numerical Simulations of Analog Experiments, presented at 2015 Fall Meeting, American Geophysical Union, San Francisco, Calif., 14-18 Dec.

(2) McBeck, J., Cooke, M.L., Herbert, J.W., Maillot, B., Souloumiac, P., Work optimization predicts accretion faulting: An integration of physical and numerical experiments, in prep. for the Journal of Geophysical Research: Solid Earth.