Geophysical Research Abstracts, Vol. 9, 02960, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-02960

The 3-D Nature of Stress Fields in Physical Experiments and its Impact on Models Overall Evolution

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Numerical simulations can be – and most often are - designed to be strictly two-dimensional in terms of both stresses and strains. By contrast, experimental models are inherently 3-D physical objects, therefore their stress and strain distributions usually vary in 3 dimensions. Even when deformation appears to be plane strain, most models are subjected to non-plane stress conditions.

A classic example is that of the "edge effects": the style, spacing or orientation of structures in models change along strike because of shear stresses along lateral boundaries. Typically, normal or reverse faults have traces curving near the sidewalls, whereas in the model's centre, fault traces are perpendicular to the direction of shortening or extension. When interpreting the experiment's results, it is tempting to assume that structures in cross sections located near the centre, far from the sidewalls are exempt from the influence of lateral shear stresses, especially if the model's width greatly exceeds its thickness.

However, this assumption is risky, particularly in settings involving a low-strength detachment level. For example, simple tests can help us illustrate the large impact of lateral friction, even on relatively wide models. We conducted a series of shortening experiments in which the 2-D conditions were identical (the base remained fixed and the backstop mobile; the detachment level was moderately weak), but having different lateral boundary conditions (fixed, mobile, or lubricated sidewalls).

- If the sidewalls are fixed, lateral shear stresses cause some additional resistance to the advance of the fold-and-thrust belt, the belt is shorter, its taper steeper, and its advance slower.

- If the sidewalls are mobile and move at the same rate as the backstop, lateral friction promotes forward advance of the belt. The belts is wider, its taper lower, and its advance faster.

These differences in structural evolution are even greater if the basal decollement is very weak.

- In models having fixed walls, folds and thrusts in the belt propagate from the backstop towards the foreland, and the surface slope dips toward the foreland.
- The complete opposite result occurs when the sidewalls are mobile: Folds and thrusts in the belt propagate from the foreland toward the backstop and the wedge's slope dips toward the backstop.
- In experiments where the sidewalls are effectively lubricated (i.e., with negligible lateral shear stresses), deformation no longer obeys the classic critical-taper evolution. The overall surface slope is near zero. Folds and thrusts propagate out of sequence, forming alternatively near the backstop, near the foreland, or near the model's centre.

These drastic differences in the resulting geometry and kinematics of experimental fold-and-thrust belts demonstrate that edge effects can strongly influence, or even totally control, the evolution of the entire model, far from the lateral boundaries. The mechanics of a physical model, like that of natural geologic systems, is always three-dimensional.