Evaluating gneiss dome thermal evolution using coupled thermomechanical finite-element modeling

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The Himalaya-Tibetan (HT) orogenic system is a result of continental collision between India and Asia since the Eocene (ca. 55-50 Ma) and is comprised of four tectonostratigraphic sequences separated by faults and shear zones.
This study focuses on two prevailing models for the evolution of the Himalayan orogen: critical taper wedge extrusion and gravity-driven lateral mid-crustal flow (channel flow).

Cottle et al. 2015
Resolving uncertainties regarding gneiss dome evolution leads to richer understanding of how the middle crust accommodates shortening in large collisional systems.

Figure 2. Diagrammatic cross section through Himalaya and southern Tibet showing (1) thrust faulting along MCT (or MBT), (2) normal faulting within Higher Himalayas, and (3) backthrusting near Tsangbo suture zone. Kinematic relationships imply that shallow wedge of crustal material must have moved southward relative to both India and Tibet. Wedge is bounded above by north-dipping normal fault(s) (2) and below by north-dipping thrust faults, possibly but not necessarily MCT or MBT (1). Geometry shown at depth is speculative.

Burchfield and Royden, 1985
Uncertainties on the origin of North Himalayan gneiss domes are due to poor
constraints on the deep crustal relationships among the MCT, STD, and Great
Counter Thrust (GCT)

Larson et al. 2010
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In one model for the evolution of Kangmar Dome, cooling histories are interpreted to be a result of thrusting upward and southward over a north dipping ramp above cold Tethyan sediments.
Models of thrust emplacement for a Mohr-Coulomb material show temperature distributions consistent with extension above the thrust.
Models of thrust emplacement for a Mohr-Coulomb material indicate normal fault development

Thigpen et al. (in prep) Tectonics
Brittle-to-ductile transition is modeled using combined Drucker-Prager/von Mises stress criterion

- **Elastic behavior**
  \[ \varepsilon_{ij} = \left(\frac{1 + \nu}{E}\right) \sigma_{ij} - \frac{\nu}{E} \text{trace} (\sigma) \delta_{ij} \]

- **Brittle behavior**
  \[ \tau_{DP} = c \cos \varphi + p' \sin \varphi \]

- **Viscous time-dependent deformation**
  \[ \tau_c = A \frac{1}{n \dot{\varepsilon}^n} \exp \left(\frac{Q}{nRT}\right) \]
Thermal steady state is approached starting at 60 million years.
A fully coupled 2-D model of a large, hot collisional orogen with upper-to-middle crust mechanical and thermal properties is used to monitor thermal effects of heat transport.
Rheologically weak middle crust presents difficulties in performing numerical experiments but preliminary results indicate potential for gneiss dome evolution and channel development.

Thigpen et al. (in prep) Tectonics
Understanding gneiss dome evolution leads to richer understanding of how the middle crust accommodates shortening in large collisional systems

Thigpen and Hatcher, 2009
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Questions?

Wagner et al. 2010