**Geographic focus of research**
Mabja Dome, southern Tibet

**Amount Requested**
$1,500

**Project Title**
A geologic test of a middle crustal channel flow model; Mabja Dome, southern Tibet

**Project Supervisor**
Jeffrey Lee, jeff@geology.cwu.edu

**Supervisor’s Affiliation**
Professor, Central Washington University

**Problem to be addressed, hypothesis, objectives (1,200 character limit)**
The thermal-mechanical channel flow model proposed by Beaumont et al. (2004) was developed to explain a range of geologic features across the Himalayan orogeny, one of the most impressive orogenic belts on Earth. The model predicts that southward channel flow and exhumation of middle crust results from a gravitational potential energy gradient, ductile middle crust bound above and below by normal and thrust shear zones, respectively, and erosion along the southern front of the Himalaya (Fig. 1). Ductile deformation within the middle crustal channel is predicted to be simple shear along the upper and lower boundaries with an increasing pure shear component towards the center. Geologic data on the kinematics and vorticity (relative contributions of simple vs. pure shear) of middle crustal ductile flow is essential for testing the deformational patterns predicted by the model but is lacking. I request support to test the hypothesis that middle crustal rocks exposed in Mabja Gneiss Dome, southern Tibet, record evidence for middle crustal channel flow. I will use kinematic and vorticity analyses to document deformation patterns in these middle crustal samples.

**Previous works and importance (2,500 character limit)**
The thermal-mechanical model represents a new paradigm that explains the formation of a number of key geologic features in the Himalaya, including a southward extruding low viscosity middle crustal channel and coeval motion along the normal slip southern Tibetan detachment system (STDS) and the thrust slip main central thrust (MCT). An outcome of the model is top-north simple shear towards the top of the channel grading into pure shear at the center which grades into top-south simple shear at the bottom of the channel.

The only geologic studies to test the predicted deformation patterns across the channel were completed by Law et al. (2004) and Jessup et al. (2006) on the Greater Himalayan Sequence (GHS), middle crustal rocks exposed on Mount Everest. They show that vorticity varies with depth from top-north simple shear near the STDS, a large component of pure shear in the center, and approximately equal components of pure and top-south simple shear near the MCT.

One of the most important tests of the channel flow model is to determine whether the pattern of deformation documented in the middle crustal rocks of the GHS can be traced northward into middle crustal rocks exposed in the North Himalayan gneiss domes, southern Tibet. These domes, located ~100 km north of the high Himalaya, expose middle crustal rocks with metamorphic, intrusive, deformational, and timing
histories that have been linked to the GHS (Searle et al., 2003, Lee et al., 2006). One of these domes, Mabja Dome, expose ductilely deformed middle crustal rocks that reached maximum metamorphic conditions of ~700 °C and 8 kbar. These rocks record a deformational history of north-south contraction, north-south extension and doming in response to thrust faulting along a ramp, respectively (Lee et al., 2004). Reconnaissance studies of kinematic indicators associated with extensional deformation suggest a change from top-north ductile shear to top-south shear towards the core, similar to the GHS (Lee et al., 2004). Geochronologic data indicate that extension and peak metamorphism began ~35 Ma and lasted for 12-19 million years (Lee et al., 2006, 2007). The similar deformational, metamorphic, and timing histories in middle crustal rocks of Mabja Dome and the GHS (Searle et al., 2003, Lee et al., 2006) implies that channel flow deformational patterns should also be similar.

Plan to address the problem and test the hypothesis (2,500 character limit)

To test my hypothesis I will use microstructural analyses, electron backscatter diffraction (EBSD), and vorticity analyses on oriented samples of ductilely deformed rocks from Mabja Dome to spatially constrain the location of the transition from top-north shear to top-south shear and to characterize the spatial distribution of pure and simple shear within the dome. Kinematic analysis will be completed on microstructures such as the geometry of strain shadows on porphyroblasts, inclusion trail patterns within porphyroblasts, and grain shape foliations to document shear sense (Passchier et al., 2005). EBSD will be completed on quartz rich samples which do not contain these microstructures. EBSD provides quartz lattice preferred orientations (LPOs) and grain shape preferred orientations (SPOs) from which sense of shear can be determined (Passchier et al., 2005).

Kinematic vorticity studies provide a quantitative estimate of the relative percentage of simple (vorticity = W = 1) and pure shear (W = 0) (pure and simple shear components are equal when W = 0.71) within the sample, thus providing a method for interpreting channel flow deformation within the dome (Lee et al., 2004). I will use two techniques to measure vorticity, the rigid grain and the grain shape foliation techniques, to document the spatial distribution of simple vs. pure shear. The rigid grain technique (Wallis et al., 1993) entails measuring the aspect ratios (R) of rigid porphyroclasts such as garnet, chloritoid and hornblende, and its angle to the foliation. Grains above a critical aspect ratio (Rc) will rotate into a stable orientation versus grains below which will rotate freely. From Rc, we can calculate vorticity using the equation W = (Rc^2-1)/(Rc^2+1) (Passchier, 1987). Grain shape foliation is developed by stretching and rotation of grains in the direction of the instantaneous stretching axis (ISA) during deformation (Wallis, 1995). The angle between the grain long axis and the foliation defines the ISA which relates to a vorticity number by the equation W = sin 2θ (Wallis, 1995).

Duration
January 2007-June 2008

Budget (what for, amount budgeted, amount requested from GSA)

Thin sections

22 Standard Thin Sections, $18 each, total $396
6 Polished Thin Sections, $34 each, total $204
EBSD analyses
$150/sample, 6 samples, total $900

**Budget justification (1,200 character limit)**
EBSD analyses to characterize the kinematics of deformation in quartz rich rocks will be completed on six samples from Mabja Dome at $150 per sample at the facility at University of California, Santa Barbara under supervision of Dr. Brad Hacker; total $900. Polished thin sections, $34 per sample, from existing samples will be needed in order to complete the EBSD analyses; total $204.

Vorticity analyses will be completed from existing thin sections along with twenty-two new thin sections. The new thin sections cost $18 per sample; total $396. Experience shows that at least 200 rigid grains per sample must be measured to accurately define a vorticity number (Jessup et al., 2006). Twenty-two additional thin sections will be required in order to obtain 200 rigid grains per sample. Total requested is $1500.

**Amount and nature of other funds, facilities, materials, etc. (1,200 character limit)**
Results from the National Science Foundation project “Geometry and timing of gneiss dome formation, southern Tibet, China” forms the foundation for this project and supporting funding expired in 2000. Central Washington University owns the microscope and software which will be used to perform the vorticity analysis.

**Other grants (year applied, amount requested and received)**

**Resume (2,500 character limit)**

**Education**
Idaho State University
Pocatello, Idaho
Bachelors of Science in Geology                              Graduation Date: July 2006
Minor in Geotechnologies
Central Washington University
Ellensburg, WA                                               Expected
Masters of Science in Geology                               Graduation Date: June 2008

**Work/Internship Experience**
National Oceanic and Atmospheric Administration (NOAA)
Earth Systems Research Laboratory
May 2006 – August 2006
Description:
• Analysis of precipitation, soil moisture and soil temperature data to understand soil infiltration impacts on flooding.
• Utilized Unix and Fortran programming.

ISU GIS Training and Research Center
Bureau of Land Management (BLM)
August 2004 – May 2006
Description:
• Created wildfire susceptibility models for Bingham, Bear Lake, and Fremont Counties, Idaho.
• Utilized GIS (Geographic Information Systems) and Remote Sensing using ArcGIS, Idrisi, and ENVI.

Publications

Presentations

References Cited (2,500 character limit)


Figure

Figure 1. Cross section across the Himalaya and southern Tibet showing Mabja Dome (MD) and middle crustal channel flow. Channel flow is bounded below by the Main Central Thrust (MCT) and above by the Southern Tibetan Detachment System (STDS). GKT, Gyirong-Kangmar thrust fault system; MHT, Main Himalayan Thrust; MBT, Main Boundary Thrust. From Lee et al. (2006).