Laboratory Study of Till Rheology

Andrew Rathbun, Chris Marone, Sridhar Anandakrishnan, Richard Alley

Department of Geosciences,
Pennsylvania State University, University Park, PA 16802

(arathbun@geosc.psu.edu)

Recent studies show that small-amplitude stress changes can trigger ice sheet motion and subglacial seismicity. Deformation in the subglacial region plays a key role in determining slip behavior, including creep, transient slip, stick-slip motion, and seismicity. However, progress in understanding these phenomena is limited by uncertainty in the rheology and frictional properties of glacial till. We report on detailed laboratory experiments to measure the creep of till sampled from the Matanuska Glacier, Alaska and Caesar Till from the Scioto Lobe of the Laurentide Ice Sheet, sampled in central Ohio.

Experiments were conducted in a servo-controlled, double direct shear apparatus with air dried samples at a normal stress of 1 MPa. Till was sheared in a three-block arrangement in which two layers are sandwiched between a central forcing block and two stationary blocks. We studied the effect of saturation, initial deformation fabric, stress history, and the boundary conditions of loading. The nominal frictional contact area is 100 cm^2 and remains constant during shear. The layer thickness is 1 cm prior to shear. All blocks are grooved perpendicular to the shear direction to ensure that deformation occurs within the layer. The Matanuska till has grains ranging from 6.3 mm to finer than .063 mm with a mean of 2.67 mm whereas the Caesar till has a smaller mean grain size of 0.60 mm, but lacks silt and clay sized particles.

We conducted both constant strain rate and constant stress tests. Constant strain rate tests were used to study rate/state frictional rheology using perturbations in slip rate, which were imposed during steady sliding. Constant shear stress experiments were employed to study frictional creep. In these tests, stress steps were conducted at 2 % and 5 % steps of the shear strength with strain rate calculated at 20 and 40 minute intervals after the stress steps. Strain rate was calculated by taking a linear fit of strain versus time over two minutes. The stress exponent, n was then calculated from the equation $d\varepsilon/dt = b\tau^n$. Where ε is strain, τ shear stress, and b is a constant. Under these conditions till was found to deform plasticly with a stress exponent that ranged from n=5 to n=13. Experiments taken directly to constant load conditions without an initial displacement exhibited a lower strain rate and smaller stress exponent than experiments, which first deformed the sample to failure with an initial 10 micron displacement.