

SEIZE

Laboratory Frictional Studies Of Fault Gouge: A Test Of Hypotheses For Controls on the Updip Limit of the Seismogenic Zone Along Subduction Thrusts

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- The goal of this work is to understand the role of clays in determining whether slip will be seismic or aseismic within subduction zone megathrusts.
- Gouge materials studied include pure Ca-smectite, samples of natural gouge material collected from the San Gabriel, CA fault zone and ODP leg 190, a suite of smectite-quartz mixtures, and a natural illite shale (grain size ranging from 2-500 μm).
- We studied frictional strength and its second-order variations as a function of slip velocity and normal stress in the double-direct shear geometry to shear strains of ~ 7 -30 at room humidity and temperature. Slip velocities were varied from 0.1-200 $\mu\text{m/s}$ and normal stress ranged from 5-150 MPa.
- The coefficient of friction (μ) ranges from 0.42-0.68 for the illite shale over a range of normal stresses from 5-150 MPa and sliding velocities from 0.1–200 $\mu\text{m/s}$, illite shale exhibits only velocity-strengthening behavior, opposite to the widely expected, potentially unstable velocity-weakening behavior of illite.
- Smectite sheared under identical conditions exhibits low friction ($\mu = 0.15$ -0.32) and a transition from velocity weakening at low normal stress to velocity strengthening at higher normal stress (>40 MPa).
- Our data, specifically the velocity-strengthening behavior of illite shale under a wide range of conditions, do not support the hypothesis that the smectite-illite transition is responsible for the seismic-aseismic transition in subduction zones.
- We suggest that other depth- and temperature- dependent processes, such as cementation, consolidation, and slip localization with increased shearing, may play an important role in changing the frictional properties of subduction zone faults, and that these processes, in addition to clay mineralogy, should be the focus of future investigation.
- Our work needs to be extended to a broader range of conditions applicable to the hypocentral region of subduction zone earthquakes.

Figures and Captions

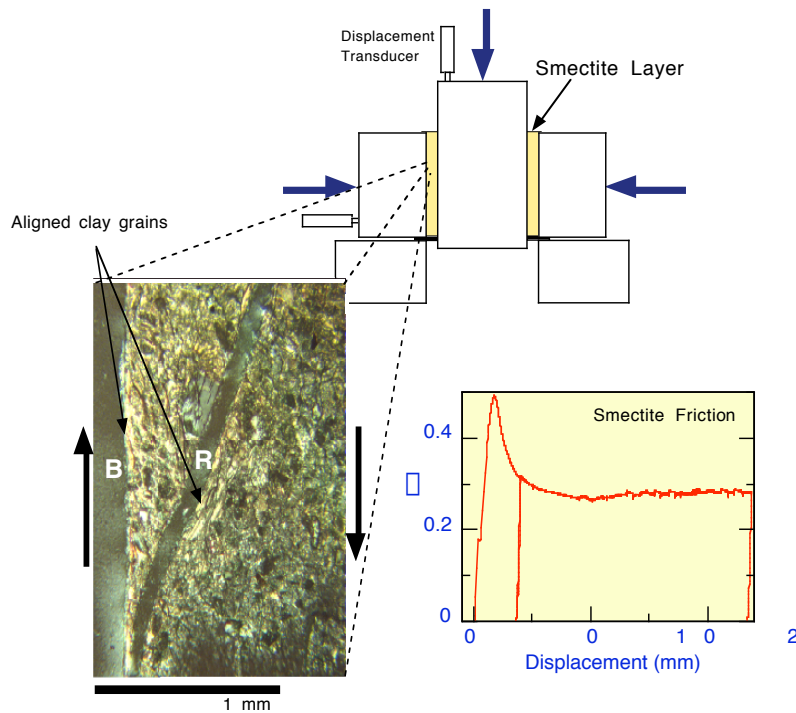


Figure 1: Double-direct shear geometry used for investigation of the frictional properties of subduction zone materials. Photomicrograph of sample deformed to a shear strain of 6 at a normal stress of 15 MPa, taken in cross-polarized light. Sense of shear is shown by the arrows. B and R denote interpreted boundary and Riedel shears, respectively. Note the strong alignment of clay grains (shown as bright areas) and the crack (opened during epoxy impregnation) that has formed along the structure interpreted as an R_1 Riedel shear band. Panel at lower right shows coefficient of friction versus shear displacement for a 3-mm thick layer of smectite gouge. This experiment included an unloading-reloading cycle at 4 mm displacement. Note the pronounced peak strength and weakening in the first few mm of displacement associated with progressive alignment of clay grains.

Publications and Presentations

Papers:

Marone, C., Saffer, D., and K. M. Frye, Weak and Potentially Unstable Frictional Behavior of Smectite Clay, *Eos, Trans., Am. Geophys. Un.*, 80 (46), F689, 1999.

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Saffer, D. M., Frye, K. M., Marone, C, and Mair, K. Laboratory Results Indicating Complex and Potentially Unstable Frictional Behavior of Smectite Clay, *Geophysical Research Letters*, 28, 2297-2300, 2001.

Green, H.W. II, and C. Marone, Instability of Deformation, Plastic Deformation Of Rocks, Eds. Karato, S. and H. R. Wenk, *Reviews in Mineralogy and Geochemistry*, ISBN 0-939950-63-4, 2002.

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Saffer, D. M., and C. Marone, Comparison of smectite and illite frictional properties: application to the updip limit of the seismogenic zone along subduction megathrusts, *Earth and Planetary Science Letters*, 215, 219-235, 2003.

Dugan, B., Marone, C., Hong, T. Compaction behavior & permeability of sediments from Sites 1194 and 1198, SR-DR, 17437A, ODP, 2003.

Abstracts:

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Shibazaki, B., and C. Marone, Transition process from quasi-static nucleation to high-speed dynamic rupture of a strike-slip fault with a rate- and state-dependent friction law, *Eos, Trans., Am. Geophys. Un.*, 80 (46), F935, 1999.

Montési, L. G. J., Marone, C., Hirth, G., and S. L. Karner, Frictional properties and microstructure of simulated diabase gouge at temperatures up to 400°C., *Eos, Trans., Am. Geophys. Un.*, 80 (46), F689, 1999.

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Shibazaki, B., Marone, C., and S. Yoshida, Nucleation process, and the associated convection current in a fault model with dilatancy and fluid movement, *Eos, Trans., Am. Geophys. Un.*, F 2001.

Marone, C., Saffer, D., Friction Mechanics at the updip limit of seismogenic faulting along subduction megathrusts. *Eos, Trans., Am. Geophys. Un.*, F 2003.

Mair, K., Marone, C., and Young, P., Rate dependence of acoustic emissions generated during granular shear *Eos, Trans., Am. Geophys. Un.*, F 2003.

Numelin, T., Marone, C., and Kirby, E., Variations in frictional behavior of fault gouge along a low angle normal fault system, *Eos, Trans., Am. Geophys. Un.*, F 2003.

Selected Invited Talks:

Fall AGU, Special Session: At the Seismogenic Front: Dynamic Processes at Convergent Margins, Dec. 2003.

Costa Rica Seismogenesis Project (CRISP) Workshop, Kiel, Germany, Oct. 2003

Margins Theoretical Workshop: Seismogenic Zone Experiment, Snowbird, Utah, Mar. 2003.

Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE) Workshop, July, 2003.

Margins Theoretical Workshop: Rheology and Deformation of the Lithosphere, Jan. 2000.