Eric G. Daub

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Education

University of California, Santa Barbara, CA
Ph.D. Physics, 2009
Thesis: *Deformation and Localization in Earthquake Ruptures and Stick-Slip Instabilities*
Advisor: Jean M. Carlson

Williams College, Williamstown, MA
B.A. Physics *cum laude*, with Honors in Physics, 2004
Thesis: *The Primary Sequence Limit of pre-mRNA Splice Site Detection*
Advisor: Daniel P. Aalberts

Professional Experience

Los Alamos National Laboratory, Geophysics Group and Center for Nonlinear Studies

September 2009-present: Postdoctoral Research Associate
Developed a constitutive model to describe observed tremor and slow slip at Parkfield, analyzed particle-scale deformation in discrete element simulations of dynamic earthquake triggering, assessed the physics and scaling properties of laboratory stick-slip in granular materials, studied stick-slip and plastic deformation in bulk metallic glasses, examined the global earthquake record to look for clustering of large earthquakes. Advisor: Paul A. Johnson

University of California, Santa Barbara, Physics Department

June 2005-September 2009: Graduate Student Researcher
Developed constitutive laws for amorphous solids, applied friction laws to numerical simulations of dynamic earthquake rupture and laboratory data on stick-slip. Advisor: Jean M. Carlson

Sept 2004-June 2005: Teaching Assistant, Introductory Physics
Led weekly laboratory sessions and graded lab reports and led discussion sections on non-laboratory weeks. Administered online homework assignments, held weekly office hours, prepared homework solutions, and assisted the instructor with grading exams.

Williams College, Physics Department

June 2003-June 2004: Undergraduate Student Researcher
Assessed the limitations of using only primary sequence data in bioinformatics, developed a new method for computational pre-mRNA splice site detection. Advisor: Daniel P. Aalberts

Sept 2002-May 2004: Math and Science Resource Center Tutor, Introductory Physics
Provided weekly help with homework assignments and led review sessions prior to exams.

Feb 2002-May 2002: Teaching Assistant, Introductory Physics
Helped the instructor with lab experiments and graded weekly homework assignments.

Keck Graduate Institute

June 2002-Aug 2002: Undergraduate Student Researcher
Conducted protein immobilization experiments with Cytochrome C. Advisor: Angelika Niemz

Honors and Awards

Outstanding Student Presentation Award, American Geophysical Union Fall Meeting, December 2008, "Accounting for Gouge-Scale Strain Localization in Dynamic Earthquake Ruptures"

Outstanding Student Presentation Award, Seismological Society of America Annual Meeting, April 2008, "Shear Strain Localization in Elastodynamic Rupture Simulations"

Southern California Earthquake Center Grant, 2009 (PI: Jean M. Carlson), "Shear Strain Localization in Dynamic Earthquake Rupture: Shear Heating, Dynamic Weakening, and Slip Below the Seismogenic Zone"

Southern California Earthquake Center Grant, 2008 (PI: Jean M. Carlson), "Dynamic Fault Weakening due to Shear Strain Localization: Constitutive Laws, Rupture Dynamics, and Ground Motion"

Southern California Earthquake Center Grant, 2007 (PI: Jean M. Carlson), "Rapid Weakening due to Fault Gouge Localization: Constitutive Laws, Rupture Dynamics, and Ground Motion"

Southern California Earthquake Center Grant, 2006 (PI: Jean M. Carlson), "Rapid Weakening on Earthquake Faults: Implications for Constitutive Laws and Earthquake Rupture Modeling"

Elected to Sigma Xi, Williams College, 2004

Publications and Research

M. Griffa, E. G. Daub, R. A. Guyer, P. A. Johnson, C. Marone, and J. Carmeliet, "Meso-mechanical analysis of deformation characteristics for dynamically triggered slip in a granular medium," *Phil. Mag.*, submitted. We analyze the particle scale motions in discrete element simulations both with and without applied mechanical vibration. We examine both the affine and non-affine components of particle motions, and study the details of volumetric, deviatoric, and rotational strains within the affine particle motions. Our results show that vibration results in both affine and non-affine motion in the granular layer, and mobilizes grain contacts, allowing for triggered failure at a lower shear stress.

P. Johnson, B. Carpenter, M. Knuth, B. Kaproth, P.-Y. Le Bas, R. Guyer, E. G. Daub, and C. Marone, "Nonlinear dynamical triggering of slow-slip on simulated earthquake faults with implications to Earth," *J. Geophys. Res.*, submitted. We investigate the dynamics of triggered slow, silent slip in laboratory experiments on sheared granular material. We study a steadily-sliding granular layer at low normal stress, and trigger slip events by applying vibration of varying amplitudes. We show that larger amplitude vibrations result in slip events with larger stress drops, thickness changes, and acoustic emission counts, suggesting that nonlinear elastic behavior of the gouge plays an important role in triggering of slow slip in the earth.

M. Griffa, E. G. Daub, R. A. Guyer, P. A. Johnson, C. Marone, and J. Carmeliet, "Vibration-induced unjamming of sheared granular layers and the micromechanics of dynamic earthquake triggering," *EPL* **96**, 14001 (2011). We study the mechanics of dynamic earthquake triggering by using the Discrete Element Method to investigate the effect of external vibration applied to a granular material under shear. We find that vibration nucleates slip by inducing plastic rearrange-

ments in the gouge, allowing slip to initiate at a reduced shear stress relative to simulations without applied vibration.

E. G. Daub, D. R. Shelly, R. A. Guyer, and P. A. Johnson, "Brittle and ductile friction and the physics of tectonic tremor," *Geophys. Res. Lett.* **38**, L10301 (2011). We develop a physical constitutive model combining brittle and ductile processes to capture the dynamics of tectonic tremor. Our model produces all types of observed transient faulting behaviors, including earthquakes, tremor, transient silent slip, and steady sliding, which we summarize in a fault slip phase diagram.

E. G. Daub, and J. M. Carlson, "Friction, Fracture, and Earthquakes," *Ann. Rev. Cond. Matt. Phys.* **1**, 397-418 (2010). We review the multiscale earthquake problem and describe a physical model for plastic deformation and strain localization in fault gouge. We examine fault scale implications of microscopic strain localization in dynamics rupture simulations with strain localization.

A. M. Hermunstad, E. G. Daub, and J. M. Carlson, "Energetics of strain localization in a model of seismic slip," *J. Geophys. Res.* **115**, B06320 (2010). We examine how dissipated energy is partitioned between thermal heating and configurational disorder in a continuum model for sheared fault gouge. We find that less energy is dissipated as thermal heat than the traditional method of partitioning in seismology. Strain localization decreases the total dissipation but increases the amount of thermal heating.

E. G. Daub, M. L. Manning, and J. M. Carlson, "Pulse-like, crack-like, and supershear earthquake ruptures with shear strain localization," *J. Geophys. Res.* **115**, B05311 (2010). We examine the effect of shear strain localization on the spatial propagation of slip in dynamic earthquake rupture simulations. The dynamic weakening provided by strain localization allows for pulse-like rupture, and decreases the minimum stress required for both sub-Rayleigh and supershear earthquakes to rupture the entire fault.

E. G. Daub and J. M. Carlson, "Stick-slip instabilities and shear strain localization in amorphous materials," *Phys. Rev. E* **80**, 066113 (2009). We study the impact of strain localization on the stabilitiy of frictional slipping in amorphous materials. We model localization of deformation with a continuum model for amorphous materials, and investigate the parameter regimes where stick-slip occurs through a linear stability analysis and numerical integration. Strain localization produces stick-slip over a wider range of parameters, and can produce irregular stick-slip cycles.

M. L. Manning, E. G. Daub, J. S. Langer, and J. M. Carlson, "Rate dependent shear bands in a shear transformation zone model of amorphous solids," *Phys. Rev. E* **79**, 016110 (2009). We study the formation and dynamics of shear bands in a continuum model for amorphous materials. We show that while steady sliding is linearly stable, shear bands form due to transient effects, and we construct a deformation map that predicts when shear bands form based on numerical simulations.

E. G. Daub and J. M. Carlson, "A constitutive model for fault gouge deformation in dynamic rupture simulations," *J. Geophys. Res.* **113**, B12309 (2008). We compare a physics-based friction model for fault gouge deformation to phenomenological friction laws in dynamic earthquake simulations. Our simulations show that a frictional length scale that increases with slip rate decreases peak slip rates and decreases nucleation lengths in earthquake rupture.

E. G. Daub, M. L. Manning, and J. M. Carlson, "Shear strain localization in elastodynamic rupture simulations," *Geophys. Res. Lett.* **35**, L12310 (2008). We model strain localization in dynamic earthquake rupture simulations. We find that localization is a mechanism for dynamic weakening on an earthquake fault, which increases the stress drop and slip rate in numerical models of ruptures.

D. P. Aalberts, E. G. Daub, and J. W. Dill, "Quantifying optimal accuracy of local primary sequence bioinformatics methods," *Bioinformatics* **21**, 3347 (2005). A scaling study determines the intrinsic limitations of using primary sequence bioinformatics datasets. Our PSR method for pre-mRNA splice site detection is more accurate than other methods.

Research in Progress

Plastic flow and stick-slip dynamics in bulk metallic glasses
We examine stick-slip behavior in bulk metallic glasses under uniaxial compression. Deformation in these experiments occurs through plastic deformation in localized shear bands, which we model using Shear Transformation Zone (STZ) Theory. We examine the temperature dependence of stick-slip, and find that the model captures the scaling of stress drop and plastic strain rate with temperature in laboratory experiments exhibiting stick-slip.

Are megaquakes clustered?
We examine the global earthquake record since 1900 to look for clustering in the largest events above magnitude 7. We find that with aftershocks removed, the earthquake catalog is mostly consistent with a random catalog. We also analyze synthetic clustered catalogs and show that with 110 years of data, discerning clustering in the magnitude 8 and above data is difficult with general statistical tests for clustering. However, more focused tests geared towards the specific nature of clustering in the dataset can perform much better.

Scaling of stick-slip instabilities in granular materials
We study the effect of varying experimental conditions in laboratory stick-slip to determine the important physics in sheared granular materials. We find that dilation plays an important role in the failure process, and show that the dilation rate scales with the slip rate, normal stress, and layer thickness.

Implications of shear strain localization for coseismic slip below the seismogenic zone.
We are studying strain localization in ductile rocks at depth due to a dynamic rupture propagating downdip from the seismogenic zone. Strain during the interseismic period is broad as the materials at depth are rate strengthening, but a transient instability during rapid slip due to the propagation of a dynamic rupture causes localized strain.

Conference Presentations

"Friction in the lower crust at Parkfield, CA, constrained by tectonic tremor observations," International Conference on Nonlinear Elastic Materials, Prague, Czech Republic, June 2011.

"Modeling plastic flow serrations in bulk metallic glasses," International Conference on Nonlinear Elastic Materials, Prague, Czech Republic, June 2011.

"The dynamics of tectonic tremor throughout the seismic cycle," poster, AGU Fall Meeting, San Francisco, CA, December 2010.

"Brittle and ductile friction and the physics of tectonic tremor," Earthscope Spectrum of Fault Slip Behaviors Workshop, Portland, OR, October 2010.

"Brittle and ductile friction and the physics of tectonic tremor," poster, SCEC Annual Meeting, Palm Springs, CA, September 2010.

"Inferring *in situ* tremor conditions at the Parkfield Seismic Laboratory," International Conference on Nonlinear Elastic Materials, Otranto, Italy, July 2010.

"Scaling of stick-slip instabilities in granular materials," APS March Meeting, Portland, OR, December 2009.

"Stick-slip instabilities and shear strain localization in granular materials," poster, AGU Fall Meeting, San Fransisco, CA, December 2009.

"Strain Localization in a Model of Coseismic Slip Below the Seismogenic Zone," poster, SCEC Annual Meeting, Palm Springs, CA, September 2009.

"Shear Strain Localization in a Model of Coseismic Slip Below the Seismogenic Zone," SSA Annual Meeting, Monterey, CA, April 2009.

"Modeling Strain Locailzation and Stick-Slip Instabilities in Amorphous Materials," poster, Dynamics Days, San Diego, CA, January 2009.

"Accounting for Gouge-Scale Strain Localization in Dynamic Earthquake Ruptures," AGU Fall Meeting, San Francisco, CA, December 2008.

"Shear Strain Localization in Dynamic Rupture and Stick-Slip Models," poster, SCEC Annual Meeting, Palm Springs, CA, September 2008.

"Shear Strain Localization in Elastodynamic Rupture Simulations," SSA Annual Meeting, Santa Fe, NM, April 2008.

"Shear Strain Localization in Elastodynamic Rupture Simulations," AGU Fall Meeting, San Francisco, CA, December 2007.

"A Constitutive Model for Fault Gouge Deformation in Dynamic Rupture Simulations," poster, SCEC Annual Meeting, Palm Springs, CA, September 2007.

"Constitutive Modeling of Weakening in Fault Gouge: Implications for Earthquake Rupture Dynamics," SSA Annual Meeting, Waikoloa, HI, April 2007.

"Constitutive Modeling of Dilation, Compaction, and Rapid Weakening in Granular Fault Gouge," poster, AGU Fall Meeting, San Francisco, CA, December 2006.

"Dilation and Compaction of Earthquake Faults: A Constitutive Model and Its Application to Rupture Dynamics," poster, Feedback and Dynamics in Nature Workshop, Grace Hopper Conference, San Diego, CA, October 2006.

"Dilation and Compaction of Earthquake Faults: A Constitutive Model and Its Application to Rupture Dynamics," poster, SCEC Annual Meeting, Palm Springs, CA, September 2006.

"Bioinformatics in the Thermodynamic Limit: Applications to pre-mRNA Splice Site Detection," APS March Meeting, Montreal, Canada, March 2004.

<u>Seminars</u>

"Earthquake physics from small to global scales," Geology Seminar, University of Oregon, Eugene, October 2011.

"Modeling plastic flow, strain localization, and stick-slip in bulk metallic glasses," CNLS Postdoc Seminar, Los Alamos National Laboratory, July 2011.

"Brittle and ductile friction and the physics of tectonic tremor," Seminar, Institut de Physique du Globe, Paris, November 2010.

"The physics of strain localization in dynamic earthquake rupture simulations," Earthquake Science Center Seminar, United States Geological Survey, Menlo Park, August 2010.

"Scaling of stick-slip instabilities in granular materials," KITP program on the Physics of Glasses, University of California, Santa Barbara, July 2010.

"Plastic Deformation and Strain Localization in Amorphous Materials and Earthquake Dynamics," CNLS Postdoc Seminar, Los Alamos National Laboratory, February 2010.

"Shear Strain Localization in Amorphous Materials and Dynamic Earthquake Rupture," Earth and Environmental Sciences Seminar, Los Alamos National Laboratory, March 2009.

"Deformation and Localization in Earthquake Ruptures and Stick-Slip Instabilities," Condensed Matter Physics Seminar, University of Pennsylvania, February 2009.

"The Physics of Shear Bands and Strain Localization in Dynamic Earthquake Rupture," Geophysics Seminar, University of Southern California, September 2008.

"Solving $F = ma$ for an Earthquake," Graduate Student Colloquium, UCSB, May 2008.

Professional Activities

Postdoctoral Representative, Worker Safety and Security Team, Earth and Environmental Sciences Division, Los Alamos National Laboratory

American Geophysical Union Member, 2006-present
American Physical Society Member, 2002-present

Outreach

Teaching Assistant, UCSB Physics Circus, 2005-2006
Scheduled science demonstrations at local elementary schools, recruited students and faculty to participate in the Physics Circus, trained undergraduate and graduate physics students to perform demonstrations at events, and maintained the Physics Circus demonstration equipment and website.

Physics Circus Award, UCSB Physics Department, 2006, 2007

Volunteer, UCSB Physics Circus, 2004-2009

References

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Prof. James Langer
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