FAULT-SIZE DEPENDENT FRACTURE ENERGY AND RUPTURE DYNAMICS OF CASCADING EARTHQUAKES IN MULTISCALE FRACTURE NETWORKS

Alice-Agnes GABRIEL [1,2], ***Dmitry I. GARAGASH*** [3],
Kadek H. PALGUNADI [4,5], ***P. Martin MAI*** [4]

[1] Scripps Institution of Oceanography, UCSD, La Jolla, USA
[2] Department of Earth and Environmental Sciences, LMU Munich, Munich, Germany
[3] Department of Civil and Resource Engineering, Dalhousie University, Halifax, Canada
[4] Physical Science and Engineering,
King Abdullah University of Science and Technology, Thuwal, Saudi Arabia
[5] Swiss Seismological Service, ETH Zurich, Zurich, Switzerland

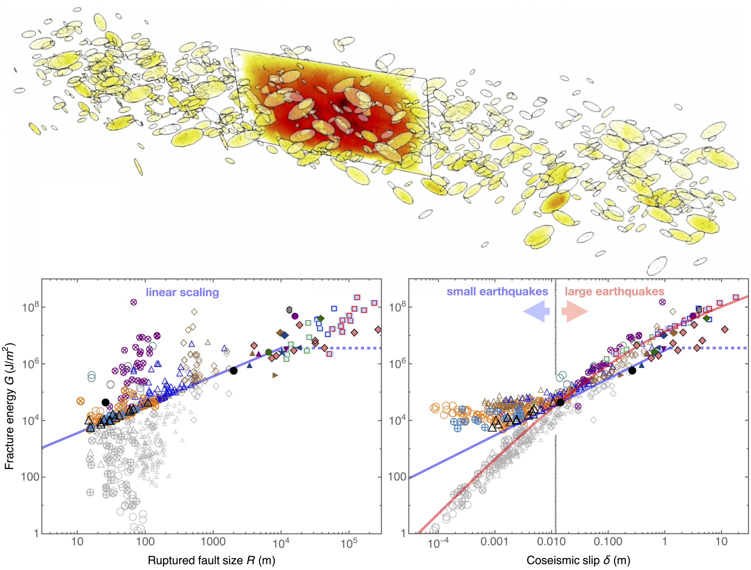
contact: algabriel@ucsd.edu

Earthquakes vary in size over many orders of magnitude, often rupturing in complex multi-fault and multi-event sequences. However, the scaling of the earthquake energy budget remains enigmatic. Here, we propose that fundamentally different fracture processes govern small and large earthquakes. We combine seismological observations with physics-based models, finding that both dynamic weakening and restrengthening effects are non-negligible in the energy budget of small earthquakes.

New analytical descriptions of crack-like circular dynamic ruptures with flash-heating friction and co-seismic restrengthening, as well as bilaterally expanding kinematic pulse-like ruptures with co-seismic stress recovery allow us to derive physics-based corrections and estimate the total earthquake fracture energy across scales of global seismological observations of small and large earthquakes. We add newly measured total fracture energy from thirteen realistic 3D rupture simulations of past small repeating and large well-recorded earthquakes spanning magnitudes 1.9 – 9.2.

Our analysis reveals a linear scaling relationship between fracture energy and fault size and a break in scaling with slip. Our proposed minimum fracture energy may reflect a local fault property, which can be explained by a well-localized near-front process zone that depends on fault size. We apply this scaling using supercomputing and unveil large dynamic rupture earthquake cascades involving over 700 multi-scale fractures within a fault damage zone. Our results provide a simple explanation for seismicity across all scales with implications for comprehending earthquake genesis and multi-fault rupture cascades.

Note: Figure is on the next page.


linear scaling
Fracture energy G (J/m²)
Ruptured fault size R (m)
small earthquakes
large earthquakes
Coseismic slip δ (m)