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Electrical Anomalies Observed During Frictional Stick-Slip in Granular Materials

J.R. Leeman[1], M.M. Scuderi[1], C. Marone[1], D.M. Saffer[1]

[1] Department of Geosciences and Energy Institute Center for Geomechanics, Geofluids, and Geohazards, The Pennsylvania State University, University Park, Pennsylvania, USA

Reported electromagnetic anomalies associated with earthquakes include electrical discharges known as earthquake lights, low frequency electromagnetic waves, and electrical resistivity changes in the rock surrounding the earthquake faults. Paleomagnetic data have indicated a natural remnant magnetization many times higher than expected in pseudotachylite samples, suggesting electrical current flow. Additional lines of evidence indicate that faults may be electrically active preceding failure. For example, during the 1995 Kobe earthquake, visible electrical discharges were reported at the surface and investigators located charred vegetation roots at the surface expression of the rupture (Enomoto and Zheng, 1998). Despite the number and variety of observations, the origin of electromagnetic anomalies and their connection to tectonic faulting is poorly understood.

We present data from double direct shear experiments on granular synthetic fault gouge (glass beads) in which the electrical potential difference between the gouge layers and system ground was monitored with a no-contact electrostatic voltmeter. Data were obtained for different humidity conditions, loading velocities, and particle size distributions. A normal stress of 4 MPa was maintained with load point velocities of 1,30, and 100 μm/s.

We find that electrical potential varies systematically during repetitive stick-slip frictional sliding. Voltages rise rapidly after shearing begins, peaking at potentials of up to several hundred volts as the material reaches a steady-state frictional behavior. Subsequently, the potential slowly relaxes as slip continues . Electrical anomalies associated with stick-slip events are superimposed on this long-term trend. Careful measurement shows that observed electrical signals are not influenced by other external factors (i.e. apparatus and environment).

Upon a stick-slip event, electrical potential is observed to increase co-seismically at low shear strain, transitioning to co-seismic potential drops as shear strain increases. At slip velocities of 1-30 μm/s potential changes are on the order of volts, increasing to tens of volts at shear velocity of 100 μm/s. A positive correlation is also observed between co-seismic slip duration and potential change, with longer sliding times leading to higher charging rates. The change of the sign of electrical anomaly coincides approximately with attainment of steady-state mechanical (frictional) behavior.

The observed variations of electrical potential with slip velocity suggests that a triboelectric charging mechanism may be responsible for electronic transfer/expulsion. Dickinson *et al.* (1983) observed the emission of charged particles, excited neutrals, and photons from a solid during tensile fracture, a process referred to as fractoemission. A similar process may be occurring during granular failure, potentially explaining the observed dynamic surface charge.