Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

SSS011-P02 Room: Convention Hall Time: May 27 17:15-18:45

Electromagnetic phenomena prior to stick slip and microstructural evolution in simulated gouges

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In order to clarify how microstructures evolve during seismic nucleation and can be related to electromagnetic phenomena prior to a stick slip, we have undertaken an experimental study on a stick slip with simulated gouges. We used a gas apparatus, and performed stick slip experiments at a confining pressure of 165 MPa and axial strain rate of 10^{-3}/s. Crushed gabbroic powders of 0.3 g were sandwiched between two 50 deg precut shear pistons made of fine-grained gabbro. Displacements and stresses were measured by strain gauges glued on the sample surface. Three pairs of electrode wires were placed to measure changes in electric voltages on frictional surfaces. After an initial compaction of gouges, the sample yielded at an axial stress of about 500 MPa and a displacement of about 0.19 mm. Then the sample monotonically strain weakened towards a main slip with a velocity of 0.5 mm/s. Associated with the strain weakening after the peak stress, one of three electrodes detected progressive increases in a voltage about 0.3 seconds prior to the main slip. With continued displacement, the sliding mode underwent a transition from the stable sliding to the large, audible stick slip with a velocity of 10 m/s. At the main shock, all three electrodes detected large, abrupt increases in voltages. Microstructural observations clarified various modes of shear localization within the gouge including inclined Riedel (R1) shears and boundary-parallel Y shears. R1 shears are evenly distributed open shear bands implying that they were formed presumably during the strain weakening period after the peak stress. On the other hand, the boundary Y shears are continuous, very narrow bands composed of frictional melt indicative of a high speed sliding. Especially, R1 shears were the best developed in the area where the one of electrodes detected the precursor change in the electrode voltage. The predominance of R1 shears where the electrode detected progressive increase in the voltage indicates that the generation and extension of R1 shears cause the stable slip, and accompany the precursor change in electrode voltages observed prior to the main shock after the peak stress. Thus, the transition of the frictional behavior of simulated gouges from seismic nucleation to dynamic ruptures can be correlated to the microstructural evolution within gouges from distributed R1 shears to localized boundary Y shears and accompany clear variations in electromagnetic signals.

Keywords: fault gauge, stick slip, electromagnetic phenomena, microstructure, pre-seismic phenomena, earthquake nucleation process