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Deformation of simulated fault gouge layers just before stick-slips

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INTRODUCTION
Since frictional sliding is a dissipative process, it is inevitably associated with pattern formation. We will achieve the better understandings only when the dynamic and geometrical data are synthesized. The evolution of structures inside simulated gouge layers has been studied up to now (e.g. Logan et al., 1992; Gu and Wong, 1994). Logan et al. (1992) summarized the processes; R-shears after the yielding point, P-shears thereafter, and eventually high velocity slips along Y-shears. The author will revisit this problem focusing especially on seismic precursors.

EXPERIMENTAL METHOD
Experimental apparatus: Tri-axial apparatus with gas pressure media.
Samples: Cylindrically shaped gabbro (20mm x 40mm).
Pre-cut: Pre-cut at 45 degrees, and the surfaces were finished by #4000 abrasives or 3 micron meter diamond past.
Confining pressure: 100 to 150 MPa at room temperature
Sensors: Strain gauges or strain gauges pasted on leaf springs. Two pairs of them were set across gouge layers. They were replaced when they were broken during experiments.
Data sampling: Data were sampled via LabView at 2 MHz from 6ch.
Data analysis: After subtracting deformation of rock samples, strain components (shear strain parallel to the gouge layer and normal strain) were calculated.

EXPERIMENTAL RESULTS
The changes in slip behavior can be distinguished as follows.
Stage-1: After yielding gouge layers creeps at about0.05 mm/sec, associated with strain hardening. R1-shears are found in the samples taken out at this stage.
Stage-2: Creep motions turned to a strain softening mode. The slip velocity was at a little faster (0.06 to 0.4 mm/sec) than in the stage-1. It is notable that the slip velocity was nearly constant.
Stage-3: At 7 to 20 msec before the main large stick-slip event, slip rare is accelerated up to 6.7 mm/sec (mean slip rate of 1.5 to 3 mm/sec), but it decreases just before the main event. It is notable that the gouge layer is slightly dilated (about 1%) at the beginning of this stage, and that very weak elastic waves were sometimes radiated.
Stage-4: Eventually the main slip with high velocities (exceeds 10 m/sec) occurs. The simulated gouge attached to the precut surfaces are comminuted and melted, but even the footprints of melting cannot be observed along R-shears.

DISCUSSION and CONCLUSIONS
#1 During the stage-1 shear compaction proceed associated with the incipient development of R-shears.
#2 During the stage-2 R-shears will have been vigorously developed associated with the formation of stress chains. Slow slips along R-shears and the axial loading will have come to equilibrium, resulting a constant slip rate.

#3 At the beginning of the stage-3 the stress chains rotate to dilate gouge layers. Stresses concentrate at the intersecting points of R-shears and the pre-cut surfaces, and incipient slips occur there.
#4 Eventually seismic fast slip started by the slip instability of flash melting, resulting the continuous thin melt layer along Y-shears during the stage-4.
#5 A melt layer, which is a proxy of high velocity slips, is traced along one of the pre-cut surfaces, and it disappears at a point where a R-shear is developed. At the intersection point of the R-shear to the counter pre-cut surface a melt layer appears again. The R-shears are never associated with melting. Therefore, it is reasonably concluded that seismic slips tend to nucleate on a R-shear, and that the characteristic sequence of pre-slips is preceded just before earthquakes.

Keywords: stick-slip, gouge layer, pre-slip, dilation, Riedel shear