Longer duration of meta-instability stage of laboratory earthquakes on a 1.5m granite fault

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Laboratory earthquakes are a series of stick slip events occurred on an old or newly formed fracture in laboratory. It is widely used to study the properties and mechanisms of earthquake nucleation, dynamic rupture and post-seismic process since its similarities with nature earthquakes. Meta-instability stage is the later stage of the nucleation process. It holds that when the stress release accelerates and synergizes, the deformation enters an irreversible stage to instability. Thus studying its evolutionary characteristics is more conducive to identifying the arrival of earthquakes in advance.

We perform a series stick slip experiments on a 1.5m granite fault. Using a meter-scale rock as experimental sample can indirectly improve the spatial resolution of observation. More importantly, the scale effect of earthquake preparation process can be studied by comparing the results of centimeter-scale and meter-scale samples, which is helpful to the field application of experimental results.

The experiment was carried out on a large horizontal two-direction servo-control press at the Institute of Geophysics, China Earthquake Administration. The maximum loading capacity of the press in two directions is 100 tons and 200 tons respectively. The local variations of stress and displacement along the fault as well as the variation of the whole sample were recorded during the experiment. The stiffness of the meter-scale sample and press system is 0.003 MPa/um, which is one order of magnitude smaller than that of the centimeter-scale sample and press system in the Institute of Geology, China Earthquake Administration. This enables us to obtain stick-slip events with small stress drop, large displacement and audible energy release at lower confining pressure.

For a single stick-slip event, the beginning of meta-instability stage and quasi-dynamic stage (the later stage of meta-instability stage) can be identified based on the relative displacement and strain observations along the fault. The meta-instability begins in the middle of the fault and extends toward both ends as the instability approaches. During the meta-instability stage, the variation rate of different parts of the fault varies greatly, and tends to synergize with the approach of instability.

The duration of meta-instability is longer under lower loading rate, and the change of normal stress has little effect on the duration of meta-instability under lower normal stress. The duration of meta-instability increases with the increase of fault scale, showing obvious scale effect. The results suggest that meta-instability on natural faults in the field may last for several years, and could be monitored. The non-uniformity of faults with the increase of fault scale may be an important mechanism for the scale effect of the duration of meta-instability.

Keywords: stick slip, earthquake nucleation, meta-instability stage, scale effect, meter-scale rock