Geophysical Research Abstracts
Vol. 21, EGU2019-6752, 2019
EGU General Assembly 2019

Understanding Injection-Induced Seismicity and Aseismic Fault Slip Coupling Laboratory and In-Situ Experiments with Hydromechanical Models

Marco Maria Scuderi (1), Frederic Cappa (2,3), Cristiano Collettini (1,4), Yves Guglielmi (5), and Jean-Philippe Avouac (6)

(1) La Sapienza, La Sapienza, Geosciences, Roma, Italy (marco.scuderi@uniroma1.it), (2) Université Côte d'Azur, CNRS, Observatoire de la Côte d'Azur, IRD, Géoazur, (3) Institut Universitaire de France, Paris, (4) Istituto Nazionale di Geofisica e Vulcanologia, INGV, (5) Lawrence Berkeley National Laboratory, Earth and Environmental Sciences, Berkeley, (6) California Institute of Technology, Seismological Laboratory

Injection of fluids into the deep subsurface can at times generate measurable or even damaging earthquakes, but often they only produce aseismic deformations along faults and fractures. Understanding the relationship between variations in the state of stress associated with injected pressure and aseismic vs. seismic deformation is a fundamental problem in the estimation of how the crust responds to fluid injection and the associated induced seismic hazard.

In this study, we couple laboratory and in-situ measurements of fault-parallel ('slip') and fault-perpendicular ('opening') displacement during controlled fluid injection experiments. We compare the in-situ fluid injection experiment with laboratory unconventional creep tests and find that in both cases increasing fluid pressure causes accelerated aseismic creep that is accompanied by fault dilation.

To unravel the origin of the observed fault behavior, we characterized fault frictional stability at different levels of fluid pressure by performing velocity step experiments and retrieve the rate- and state- frictional properties. We show that as fluid pressure is increased the fault evolves from velocity strengthening to weakening at slow slip rate. However, as the slip rate is increased we document a transition to velocity strengthening independently of the fluid pressure level.

We use the results from laboratory experiments to inform a three-dimensional hydromechanical model to test if these properties are consistent with the in-situ observations and shed light on the origin of aseismic deformation and seismicity. We find that aseismic slip initiates within the pressurized region, however, earthquakes nucleation is inhibited because the size of the critical nucleation length remains bigger than the pressurized radius. Nonetheless, sustained aseismic creep can accumulate shear stress beyond the pressure front favoring seismicity in nearby prone areas.

Through our multiscale investigation, we demonstrate that fault slip induced by fluid injection in a natural fault at the decametric scale is quantitatively consistent with fault slip and frictional properties measured in the laboratory. The increase in fluid pressure first induces accelerating aseismic creep and fault opening. As the fluid pressure increases further, friction becomes significantly rate-strengthening favoring aseismic slip. Our study reveals how coupling between fault slip and fluid flow promotes stable fault creep during fluid injection. Seismicity is most probably triggered indirectly by the fluid injection due to loading of non-pressurized fault patches by aseismic creep.