Permeability enhancement of granite fracture followed by seismic slip in laboratory experiments

*Takuya ISHIBASHI[1], Hiroshi ASANUMA[1], Derek ELSWORTH[2], Yi FANG[2], Jacques RIVIERE[2], Chris MARONE[2]

1. Fukushima Renewable Energy Institute, National Institute of Advanced Industrial Science and Technology, 2. The Pennsylvania State University

Hydraulic stimulation for the fractured reservoirs such as geothermal and hydrocarbon reservoirs is now a well-known operation for enhancing or maintaining the permeability of reservoir [*Evans et al.*, 2005; *Hä ring et al.*, 2008]. In this operation, as a massive amount of pressurized fluid is injected into the targeted reservoir, preexistent fractures undergo slip/shearing. At the period of fracture slip/shearing, seismicity is triggered in both seismic and aseismic modes [*Ellsworth*, 2013]. Here, considering the fact that the crustal permeability is the essential factor for controlling the fluid flow in the Earth's crust [*Ingebritsen and Manning*, 2010] and the permeability change of rock fracture is closely related to the changes in pore pressure and effective normal stress of rock fracture, it is no wonder that we come to interest in the relationship among frictional strength evolution, fracture permeability evolution, and the manner of seismicity (i.e., seismic or aseismic) during slip/shearing. Although such a relation is fundamental for defining the impact of the hydraulic stimulation or for simulating the nucleation of seismicity adequately [*McClure and Horne*, 2012; *Norbeck and Horne*, 2016], this relation has rarely been investigated and is still poorly understood.

The present study explores this relationship via the laboratory shear-flow concurrent experiments on the Westerly granite fracture. The novelty of our experiment is the fact that the shear velocity is precisely controlled during the fracture permeability measurements. Experimental results demonstrate the possibility that the permeability enhancement of rock fracture is created by frictional shearing of velocity-weakening (potentially unstable slip). To proceed our discussions on this link, we further evaluate the state of contacting asperities and of fracture surface asperities via statistically equivalent digital rock fracture modeling. By combining the experimental study with the numerical study, we can first discuss the aforementioned relationship, and successfully propose the two plausible mechanisms constraining the relationship; change in contacts distribution and shear-induced dilation at the moment of the instantaneous shear velocity jump. Though we haven't completely specified the mechanism that indeed controls the link between mechanical and hydraulic properties of rock fracture herein, these mechanisms should be taken into account in interpreting the field observation such as the abrupt permeability increase of natural fault at the moment of seismic slips [e.g., *Guglielmi et al.*, 2015].

Keywords: fracture permeability, seismic slip, contacts asperities, frictional coefficient