Report of Transnational Access Projects

(Note: the information here will be publicly disclosed in the Geo-INQUIRE website, do not include sensitive information)

Project ID: ***C1-TA2-531-1***

Principal investigator: ***Francesco Mosconi, Università La Sapienza di Roma, Italy, https://scholar.google.com/citations?user=e6u2_FoAAAAJ&hl=it***

Project team (if applicable): ***Dr. Francesco Mosconi, Prof. Elisa Tinti (Uni Rome), Prof. Massimo Cocco (INGV), Dr. Emanuele Casarotti (INGV), Italy***

Project title: Rupture dynAmics unveileD with fAulT roughnEss

Project acronym: RADIATE

Hosting installation: LMU, CINECA for Leonardo booster access

Hosting team: ***Thomas Ulrich, Alice-Agnes Gabriel, Iris Christadler (LMU), Piero Lanucara, Giorgio Amati (CINECA)***

Period of access: ***6.-18.20.2024***

Report of activities:

Geometric complexity is a key source of heterogeneity in crustal faults, as it perturbs the local stress field and can strongly affect rupture dynamics, particularly in fluid-induced earthquakes. We perform 3D dynamic rupture simulations of fluid-induced microearthquakes using SeisSol. The simulations include spatially variable pore pressure fields derived from a two-phase flow model and are conducted under in-situ stress conditions representative of the Bedretto Underground Laboratory. The fault plane is characterized by a band-limited fractal roughness. We explore how variations in roughness-controlling parameters influence the dynamics of a fluid-induced rupture. This work is part of the ERC-Synergy project FEAR, which aims to induce a M~1 earthquake on a natural fault via hydraulic stimulation.

Our results show that, under identical remote stress conditions, smoother faults exhibit two distinct rupture behaviors: either the rupture arrests near the nucleation patch or evolves into a well-developed dynamic event. Depending on the fault's constitutive parameters (e.g.,

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dynamic friction) and local stress conditions, a rupture that nucleates efficiently may either self-arrest or propagate across the entire fault. In contrast, rougher faults (characterized by higher-amplitude geometric irregularities) display a broader spectrum of rupture behaviors, generally associated with lower-magnitude events than planar fault under the same initial conditions. Notably, increasing the maximum wavelength defining fault roughness enhances the likelihood of larger-magnitude ruptures. When roughness is confined to shorter wavelengths, rupture behavior is more consistent. However, the presence of longer-wavelength roughness promotes more complex and potentially irregular rupture modes, with events predominantly self-arresting but occasionally transitioning to runaway propagation.

Our results highlight that the rupture process of microearthquakes appears to be strongly influenced by spatial variations in stress, especially at the crack-tip where a localized cohesive zone intensifies interaction with small-scale heterogeneities.

Project outcomes:

https://agu.confex.com/agu/agu25/meetingapp.cgi/Paper/1941833

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