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Laboratory study to better understand hydraulic fracturing-induced seismicity and fracture propagation

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Unconventional geo-energy resources, such as shale gas and geothermal energy, are supposed to play an essential role in energy transition and carbon neutrality. Currently, hydraulic fracturing is still the dominant stimulation strategy to obtain economic production. Hydraulic fracture (HF) propagation behavior is significant to characterize the reservoir and evaluate the stimulation efficiency. Interpretation of the reservoir fracture growth is challenging due to the coupled effects of geological and engineering conditions. Under controlled conditions, laboratory study can better reveal the physical mechanisms of induced seismicity and HF propagation. We conducted two separate laboratory studies using shale and granite samples, respectively. For the uniaxial loading experiments of shale samples, multifractal method, time-frequency analysis, event location, and micro-CT scanning techniques were utilized to quantitatively characterize acoustic emission events and HFs. The fracturing process could be divided into three stages as the initial stage, the quite stage, and the fracturing stage. For the true triaxial loading experiments of granite samples, the influence of multiple structural planes (SPs) on the HF propagations was studied. The HF geometry displayed four basic patterns when encountering SPs, namely, propagation along the SPs, branching, capture, penetration/non-dilation. The cementing strength and mechanical properties of the SPs influence the HF behaviors significantly. Laboratory fracturing experiments can help provide theoretical and technical guidance for field hydraulic fracturing operations in shale reservoirs and enhanced geothermal systems. Future work will involve a more systematic analysis and comparison between HF propagation behaviors for different rocks under different geological and engineering conditions.