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Dominant Mechanisms for Activating Non-Optimally Oriented Faults During Hydraulic Fracturing in Duvernay shale reservoirs

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Theory / Method / Workflow

Currently, very few research has focused on underlying mechanisms for activating non-optimally oriented faults during hydraulic fracturing in Duvernay shale reservoirs. We proposed an intetrated geo-engineering approach to investigate such mechanisms. Our methodology first integrates multiple datasets, including seismic catalogs, fault geometries, and in-situ stress measurements. We then employed a Coulomb Failure Stress change (ΔCFS) model to quantify the pore pressure increase and associated poroelastic stress changes resulting from fluid injection. Geomechanical analysis was conducted to compare the initial stability states of faults with varying orientations. Furthermore, a novel conceptual model of "fracture-fault coupling efficiency" was developed to evaluate the effectiveness of fluid pressure transmission between the hydraulic fracture network and pre-existing faults.

Results, Observations, Conclusions

The results demonstrate that the activation of north-south (N-S) faults is primarily driven by efficient pore pressure transfer and containment (Fig.1). While northeast-southwest (NE-SW) faults are favorably oriented within the regional stress field (SHmax ~N43°E), the stimulated fracture network—propagating along this same direction—acts as a conduit that laterally pressurizes the less-favorably oriented, naturally sealed N-S faults. This creates a “pressure compartment” effect, where fluid is effectively trapped, leading to a rapid reduction in effective normal stress on the N-S faults. Thus, the superior “fracture-fault coupling efficiency” to N-S faults, combined with their inherent sealing capacity, overcomes their suboptimal orientation, making them more susceptible to injection-induced activation than the “optimally” oriented NE-SW faults (Fig.2). This finding underscores that fault activation risk depends not merely on initial stress state, but fundamentally on the dynamic interaction between the hydraulic fracture network and the hydraulic properties of the fault zone.

Novel/Additive Information

By introducing an integrated mechanism that combines "fracture-fault coupling" with "pressure compartment" effects, this study moves beyond the limitations of traditional static stress analysis. The resulting framework provides a more predictive tool for assessing induced seismicity risk, directly informing fracturing design strategies to mitigate activation of sealed faults in unconventional plays.

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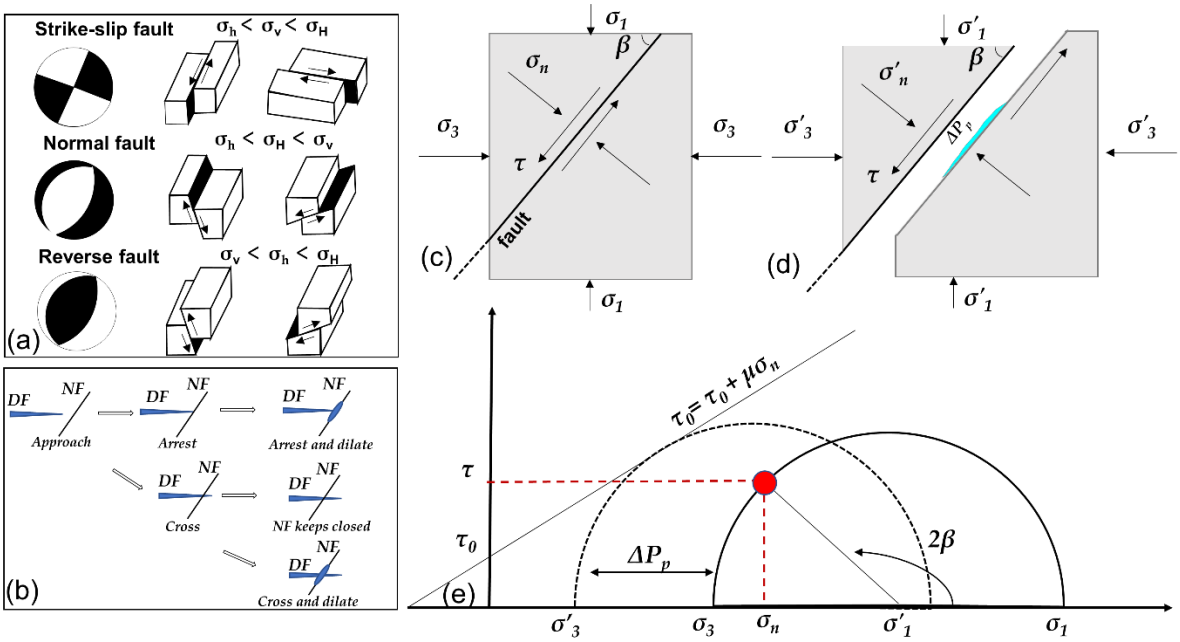


Fig.1. (a) Relationships between hydraulic fracture (HF) and natural fractures/faults (NF) during stimulations. (b) Schematic of fault reactivation under different faulting stress regimes. (c) Normal and shear stress acted on the fault plane. (d) New normal and shear stress with a pore-fluid pressure increase along the fault plane. (e) Mohr circles with (solid) and without (dashed) pressure increase. τs and τ0 are fault shear strength and cohesion strength.

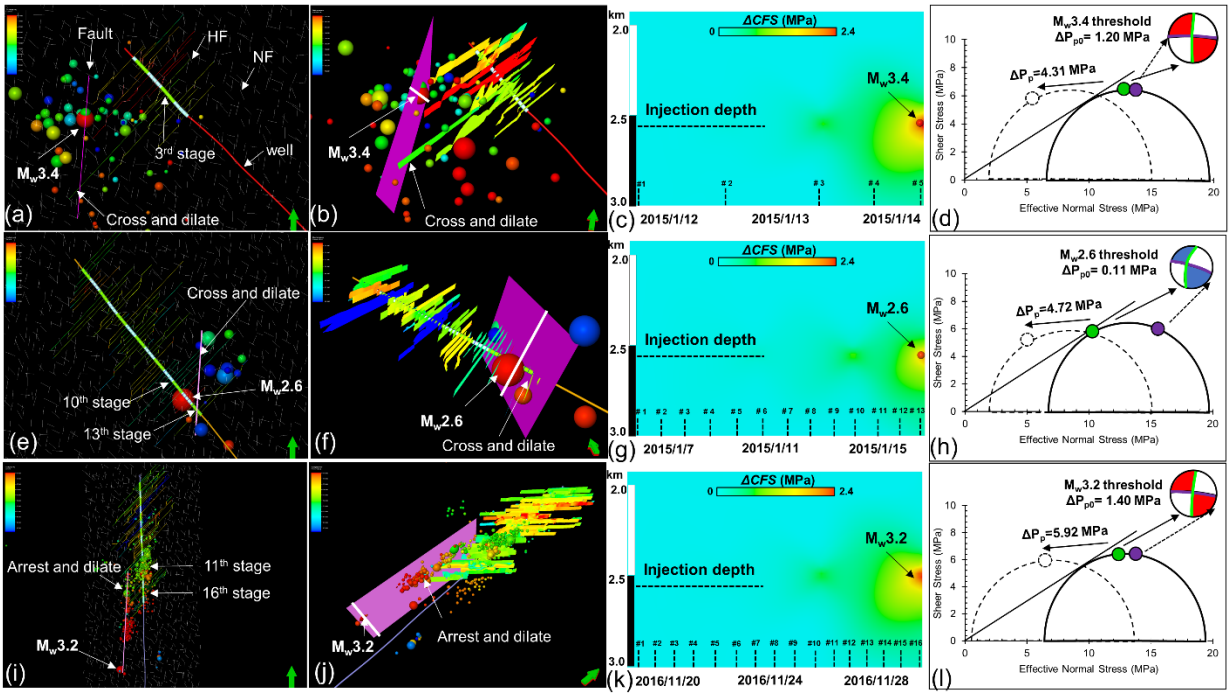


Fig.2. Fault stability evaluation in three cases. (a-b,e-f,i-j) 2D and 3D unconventional fracture networks at the nucleation moment. White lines in the fault plane mark the following profile. (c,g,k) Spatiotemporal ΔCFS along the fault plane during HF. The x-axis denotes the fracturing date, while the y-axis shows the absolute depth below sea level. (d,h,i) Mohr circles before HF and at the nucleation moment. The green and white circles denote the original and updated stress state of related faults. The purple circles show the stress state for the auxiliary fault plane.

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