Numerical Simulation of Hydraulic Fracturing in Unconventional Reservoirs

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Problem/Challenge

Hydraulic fracturing (HF) is an established process for extracting resources from unconventional reservoirs. However, due to the complex environment of unconventional reservoirs, the detailed propagation of a hydraulic fracture is hard to model. The main issues investigated in this project are:

1. What is the preferred path of a fracture relative to the in-situ stress conditions
2. What is the preferred path of a fracture relative to the rock heterogeneity
3. What is the influence of interlayers that commonly occur in unconventional reservoirs, specifically, geometry (dip angle) and rock properties.

Methods/Calibration

In this research, the finite element method (a numerical simulation approach) has been used to study HF.

A hydraulic fracture will be created once the effective stress reaches the tensile or shear strength of the rock. We couple permeability with the state of stress. The code has been calibrated with results of large-scale experimental laboratory results.

HF in different stress conditions

In order to study the fracture propagation in different stress conditions, 3 cases have been set to simulate HF in different stress settings.

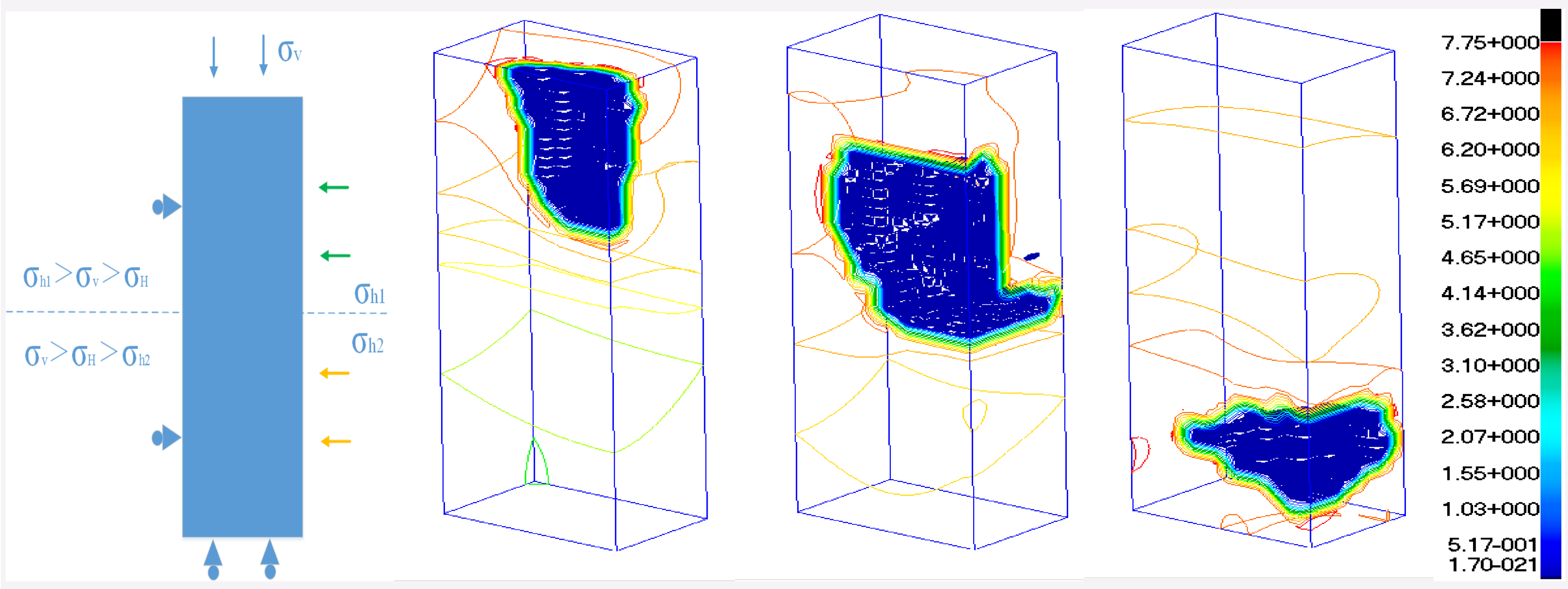

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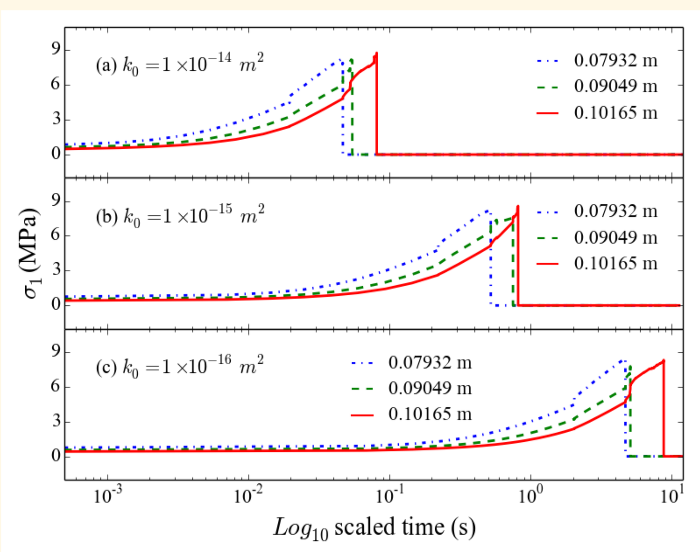
Fig 1. Profile of HF with different stress schemes, shown in von Mises stress

Table 1 Parameters for HF in different stress conditions

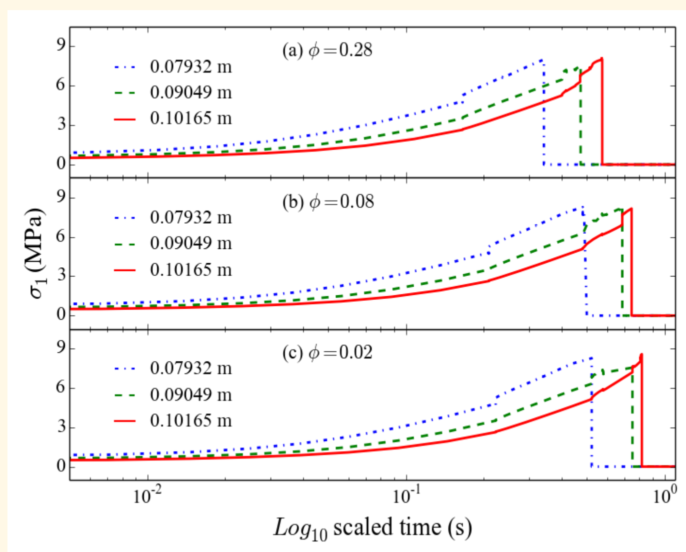
Young's Modulus (MPa)	Poisson's ratio	Porosity (%)	Permeability ($10^{-15}m^2$)	Tensile strength (MPa)	Compressive Strength (MPa)
15500	0.19	14.474	1.036	8	200

HF with different reservoir properties

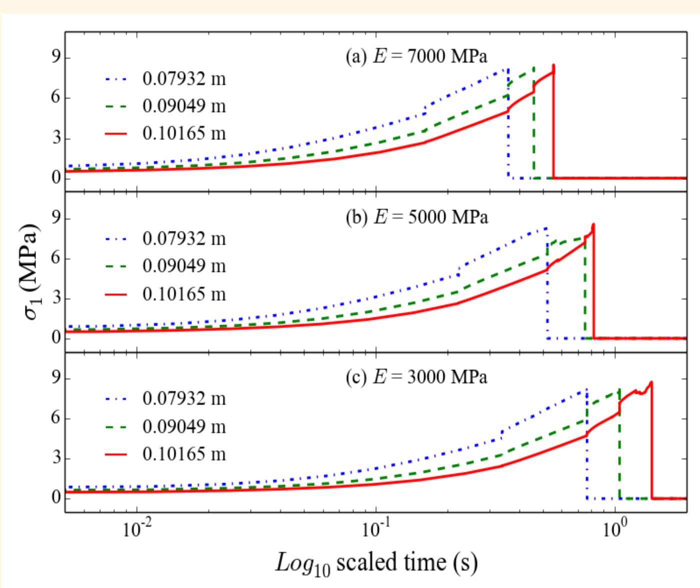
In order to know the influence of reservoir properties on hydraulic fracturing, Permeability, Porosity, Young's modulus and Poisson's ratio have been studied.



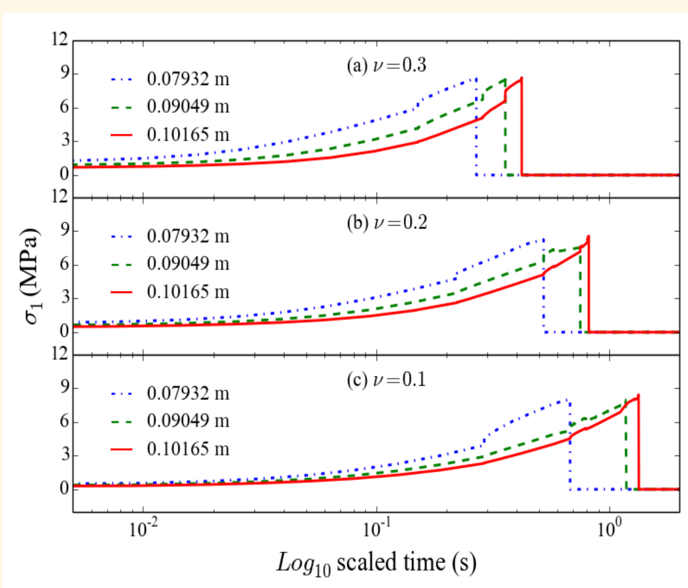
(a) Different permeability



(b) Different porosity

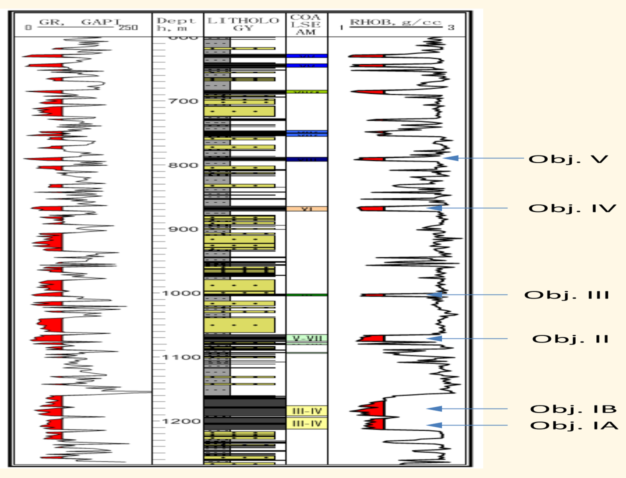


(c) Different Young's Modulus

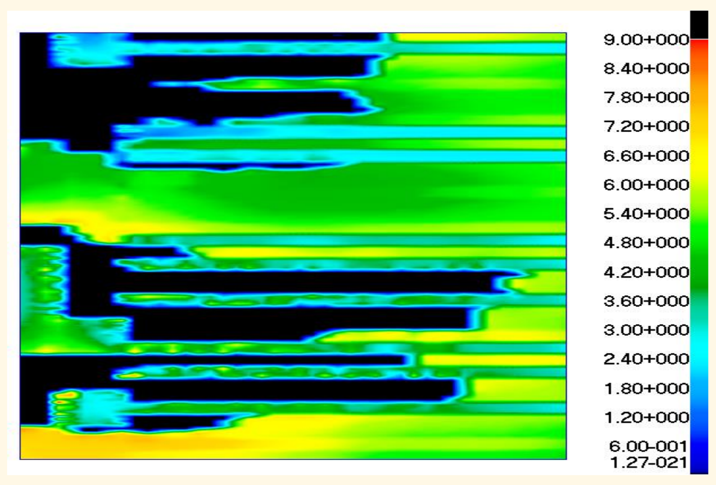


(d) Different Poisson's ratio

Fig 2. Stress at given distances from well centre, for different reservoir properties



(a) Stratum sequence

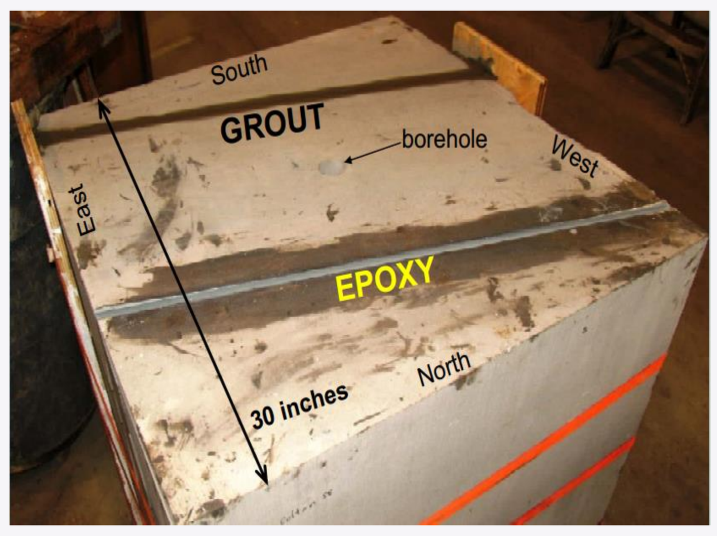


(b) HF profile (MPa)

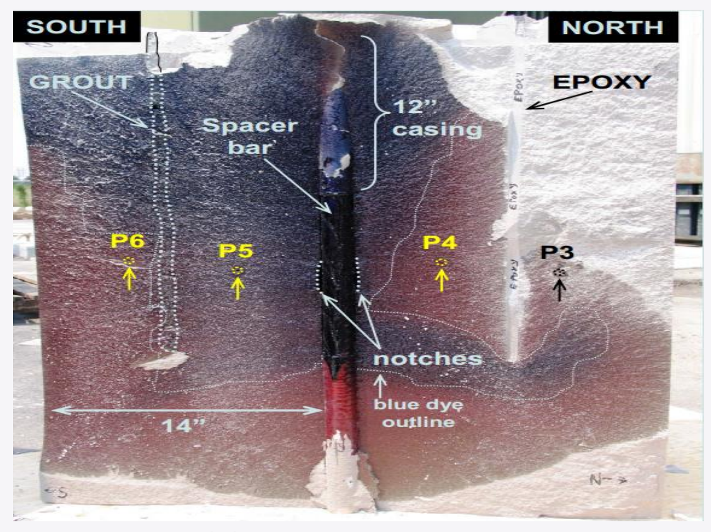
Fig 3. HF with complex reservoir property setting

HF with interlayers

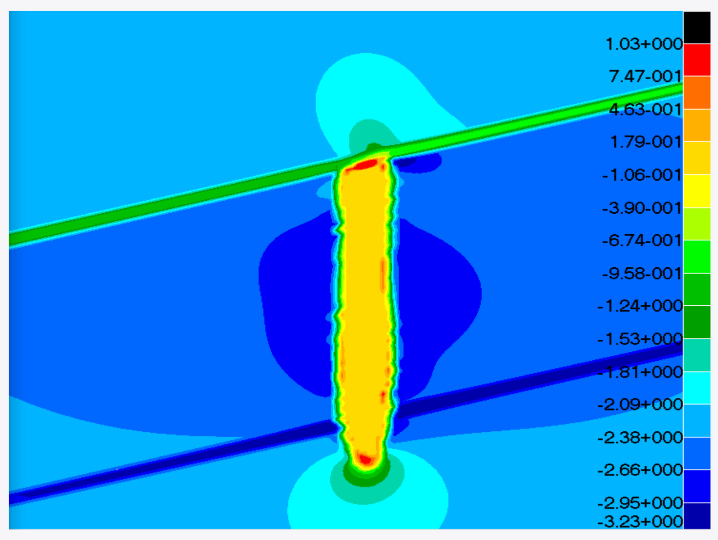
The influences of interlayers on HF have been studied, namely, dip angle and rock properties.



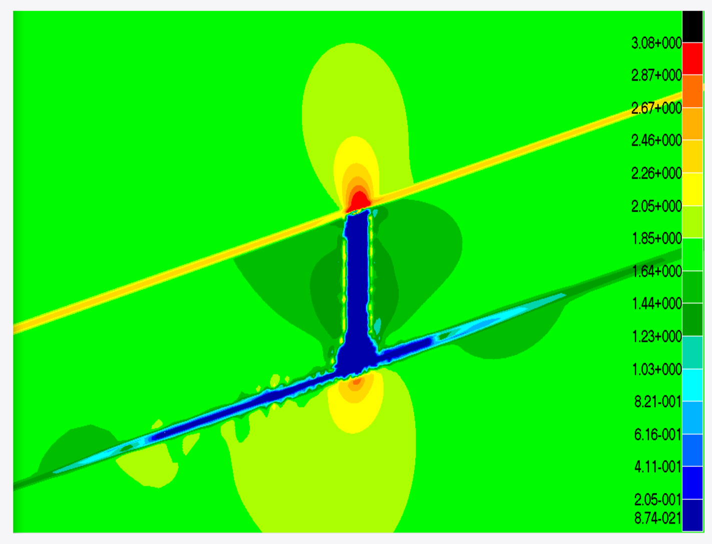
(a) Model



(b) Test result

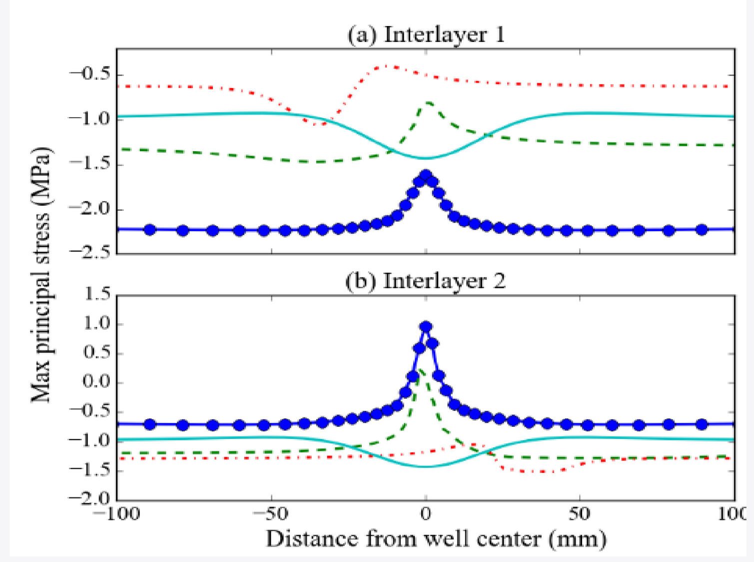


(c) Verification (Max principal stress, MPa)

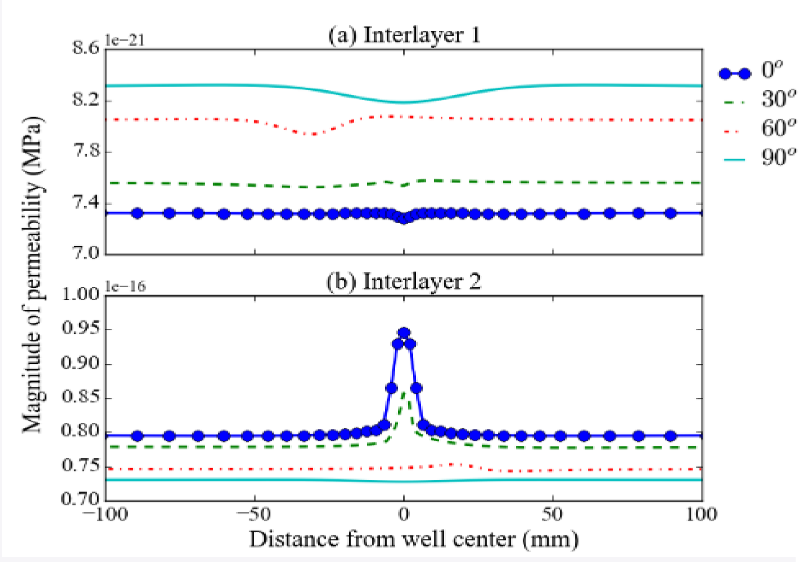


(d) Change Strength of Sandstone(grout)

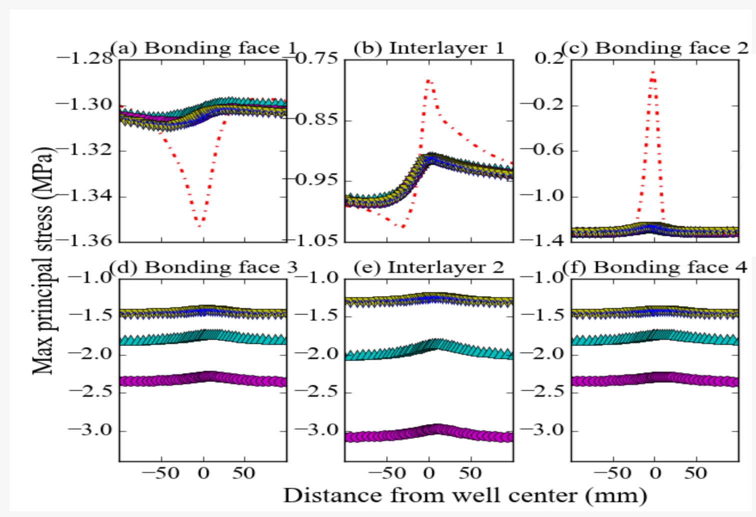
Fig 4. HF with interlayers



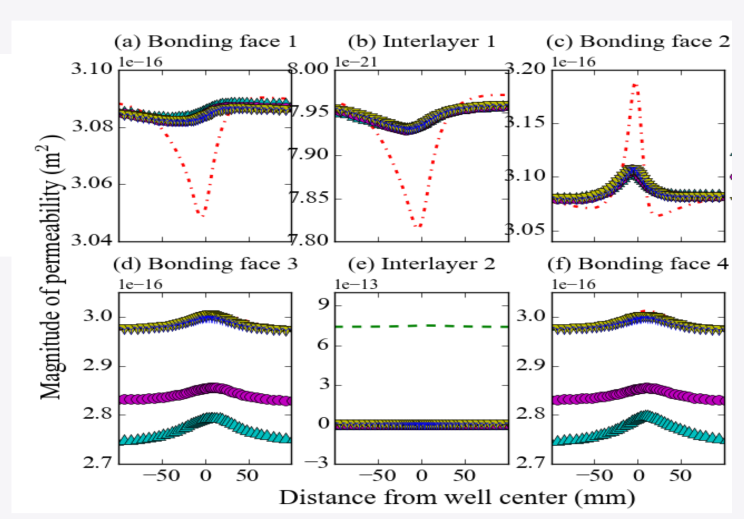
(a) Max principal stress



(b) Permeability



(c) Max principal stress



(d) Permeability

Fig 5. HF with interlayers at a certain time: (a-b) different dip angles; (c-d) different rock properties

Conclusions

1. In simple stress conditions, the difference in the minimum and maximum stress will influence the width of the hydraulic fracture.
2. The reservoir properties will influence HF. In a heterogeneous situation, the initiation and propagation is complex in its location and development.
3. Different dip angles will lead to different stress conditions in interlayers, which further influence the permeability in the interlayer.
4. Interlayer properties influence HF both on arrival at and departure from the reservoir-interlayer interface.