Fully Coupled Hydro-Mechanical Modeling of Hydraulic Fracturing in Barnett Shale Formation

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29/09/2020

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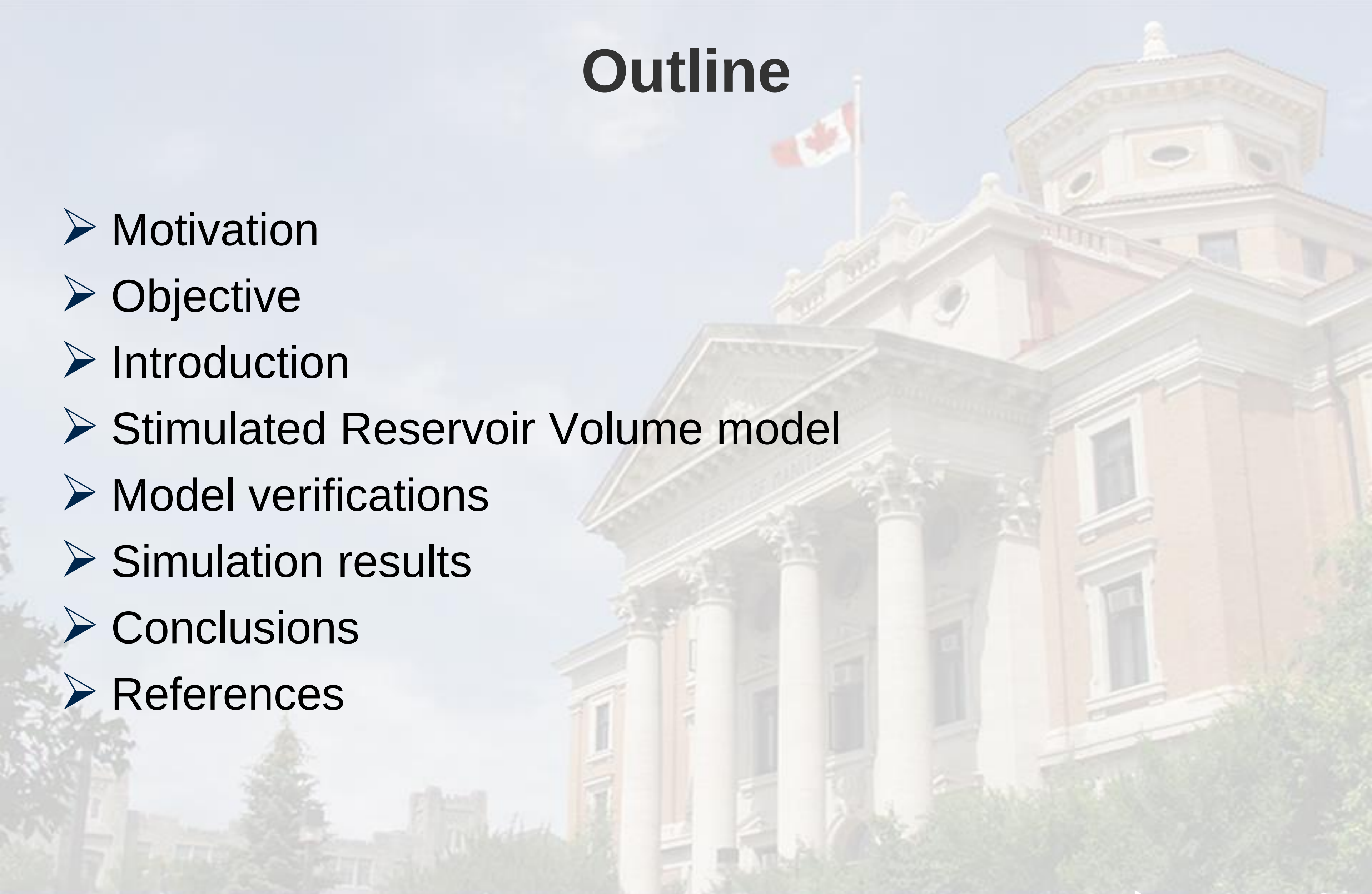
Outline



- Motivation
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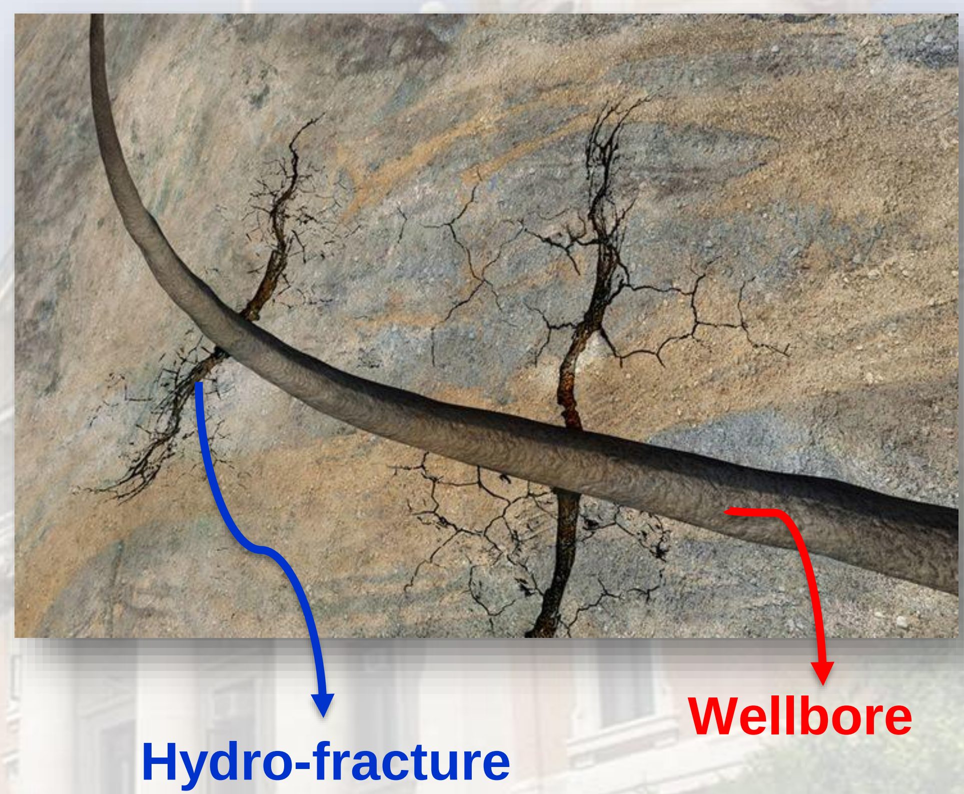
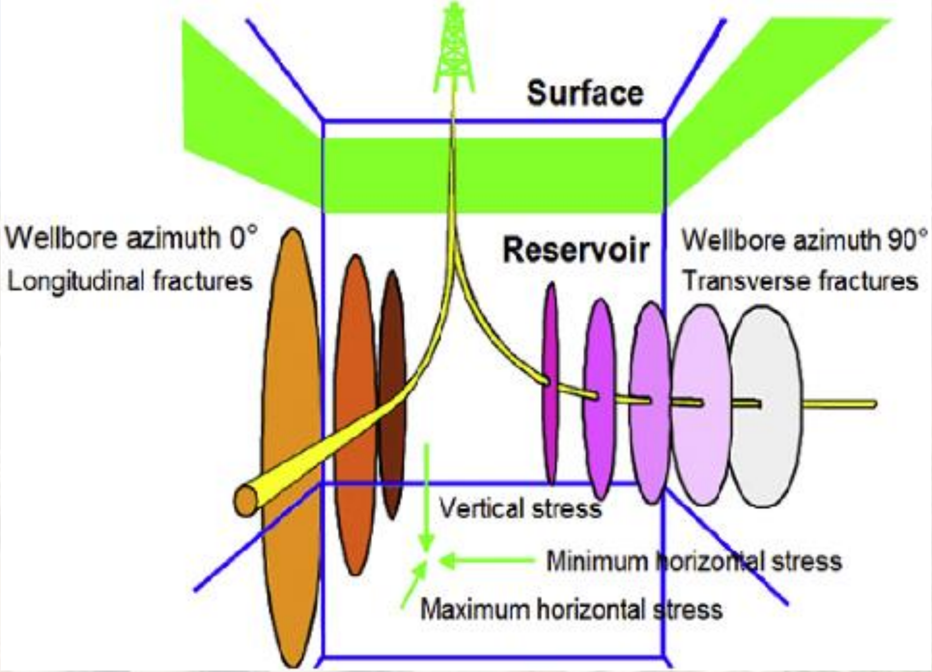
Motivation

- Unconventional shale gas reservoirs have major contribution in hydrocarbon production.
- Natural fractures in the host rocks have substantial impacts on the developed artificial fractures.
- Poroelastic behavior prediction of the reservoir helps to improve the hydraulic fracturing to be more effective and efficient.



Objective

- What is the best wellbore orientation azimuth for hydraulic fracturing?
- What is the effect of hydro-fracture growth orientation on the poroelastic response of SRV?
- How is the fluid flow within the SRV during hydraulic fracturing?



Possible scenarios of wellbore and hydro-fractures orientation

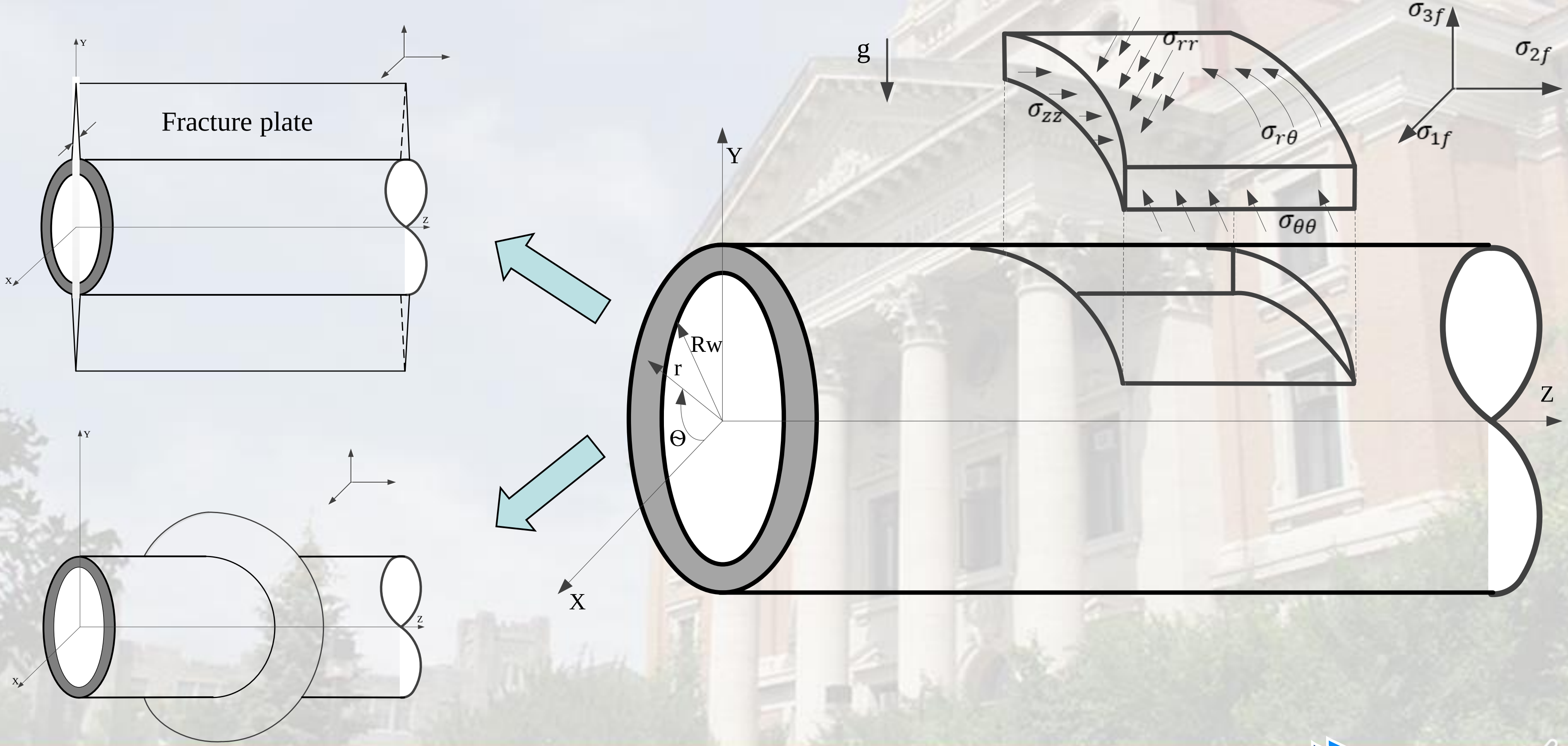
SWPU, Petroleum. (2015). Technical status and challenges of shale gas development in Sichuan Basin, China. Petroleum. 1. 1-7, Fig. 5

Introduction

- Hydraulic fracturing (or fracking) is the process of injecting pressured water into a borehole to induce tensile fracture within the rock formation.
- The Stimulated Reservoir Volume (SRV) modeling technique was integrated with the finite element approach to simulate a 3-D poroelastic porous matrix.
- The SRV of the hot basal formation of Barnett shale rock at the depth of 2600 m and the thickness of 60 m embedding horizontal borehole, plate-like natural fractures and hydro-fractures were modeled to simulate the poroelastic behaviour.
- The transient simulations was run for 8 hours of stimulation.
- Two orientation of wellbore azimuth resulted in transverse and longitudinal hydro-fractures.

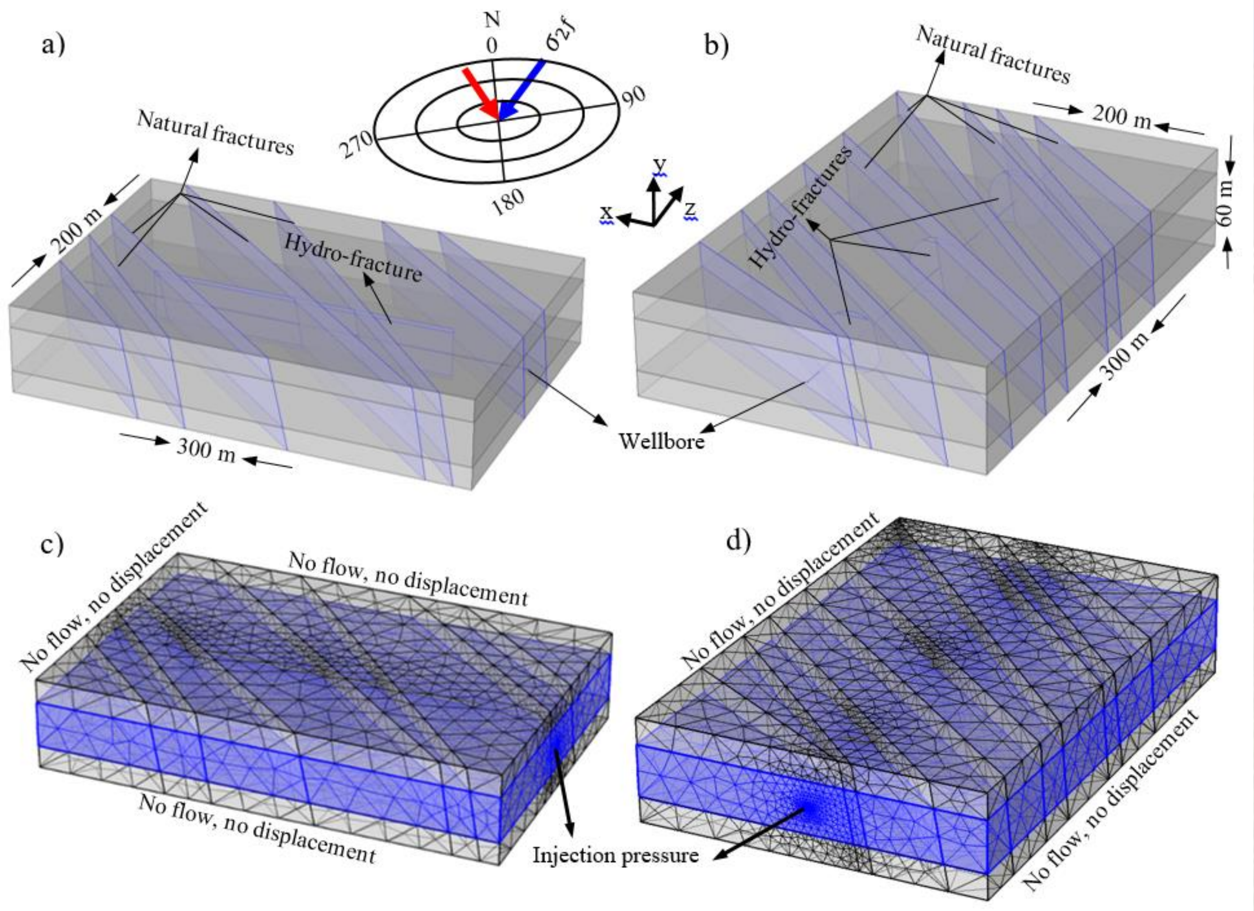
Introduction

- where θ (°) and the non-zero stress components (σ_{rr}, $\sigma_{\theta\theta}$, $\sigma_{r\theta}$,σ_{zz}) are shown around the wellbore.



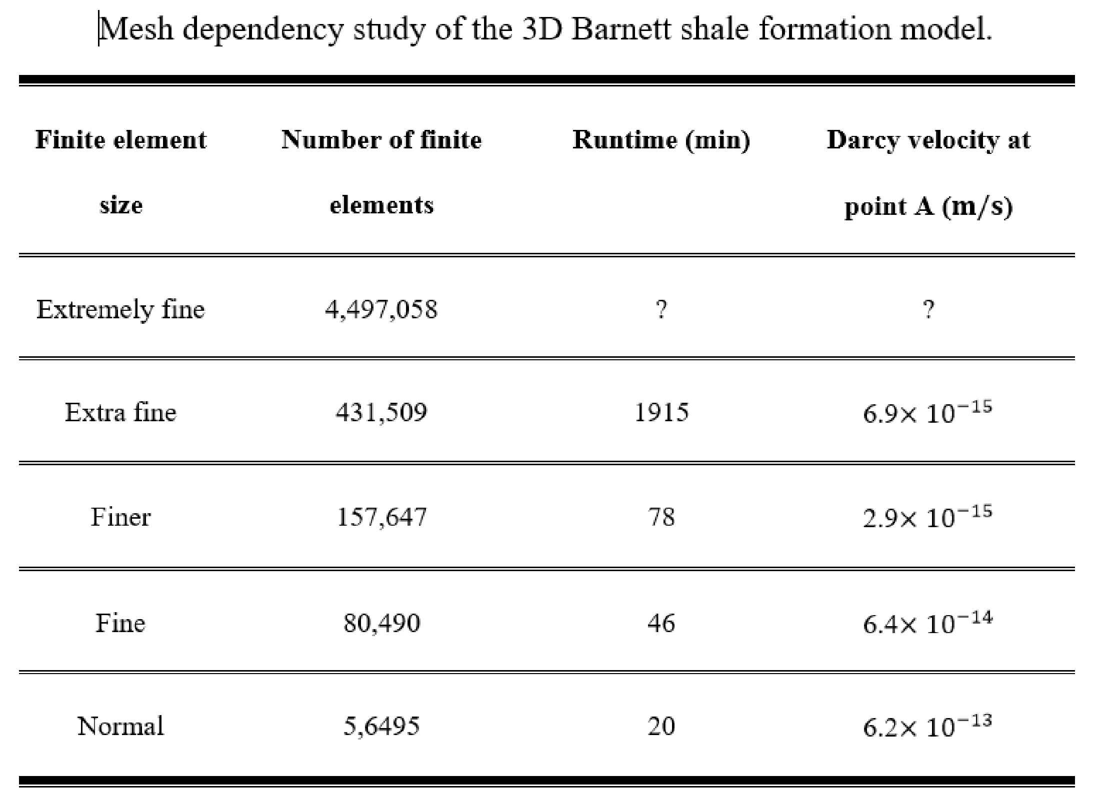
Stimulated Reservoir Volume model

- Computational domains for each wellbore/hydro-fracture orientation
- The compass rose with the azimuth of the maximum in-situ stress in blue and the natural fractures in red
- c) 114,093 finite element mesh
- d) 157,647 finite element mesh



Stimulated Reservoir Volume model

- Using: COMSOL Multiphysics 5.3a
- System: Intel® Core™ i7-7700k CPU at 4.20 GHz.
- Distinct walls of fractures were defined as 2-D interior boundaries



Mesh dependency study of the 3D Barnett shale formation model.

Finite element size	**Number of finite elements**	**Runtime (min)**	**Darcy velocity at point A (m/s)**
Extremely fine	4,497,058	?	?
Extra fine	431,509	1915	6.9×10^{-15}
Finer	157,647	78	2.9×10^{-15}
Fine	80,490	46	6.4×10^{-14}
Normal	5,6495	20	6.2×10^{-13}

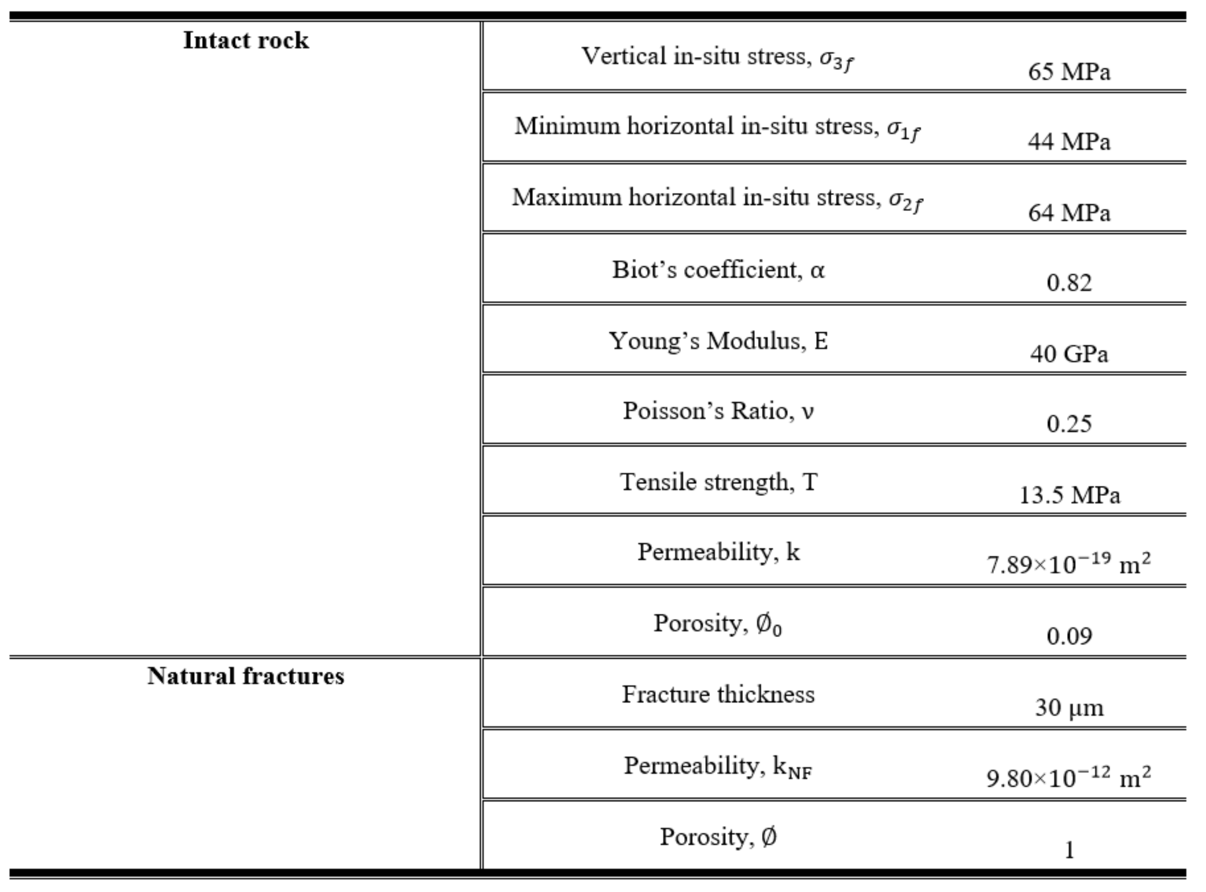
Model Builder

Physics interfaces in study:

- Darcy's law (dl):
  - Poroelastic Storage
  - Fracture Flow
- Solid Mechanics (solid):
  - Linear Elastic Material:
    - External Stress

Multiphysics coupling in study:

- Poroelasticity (poro)

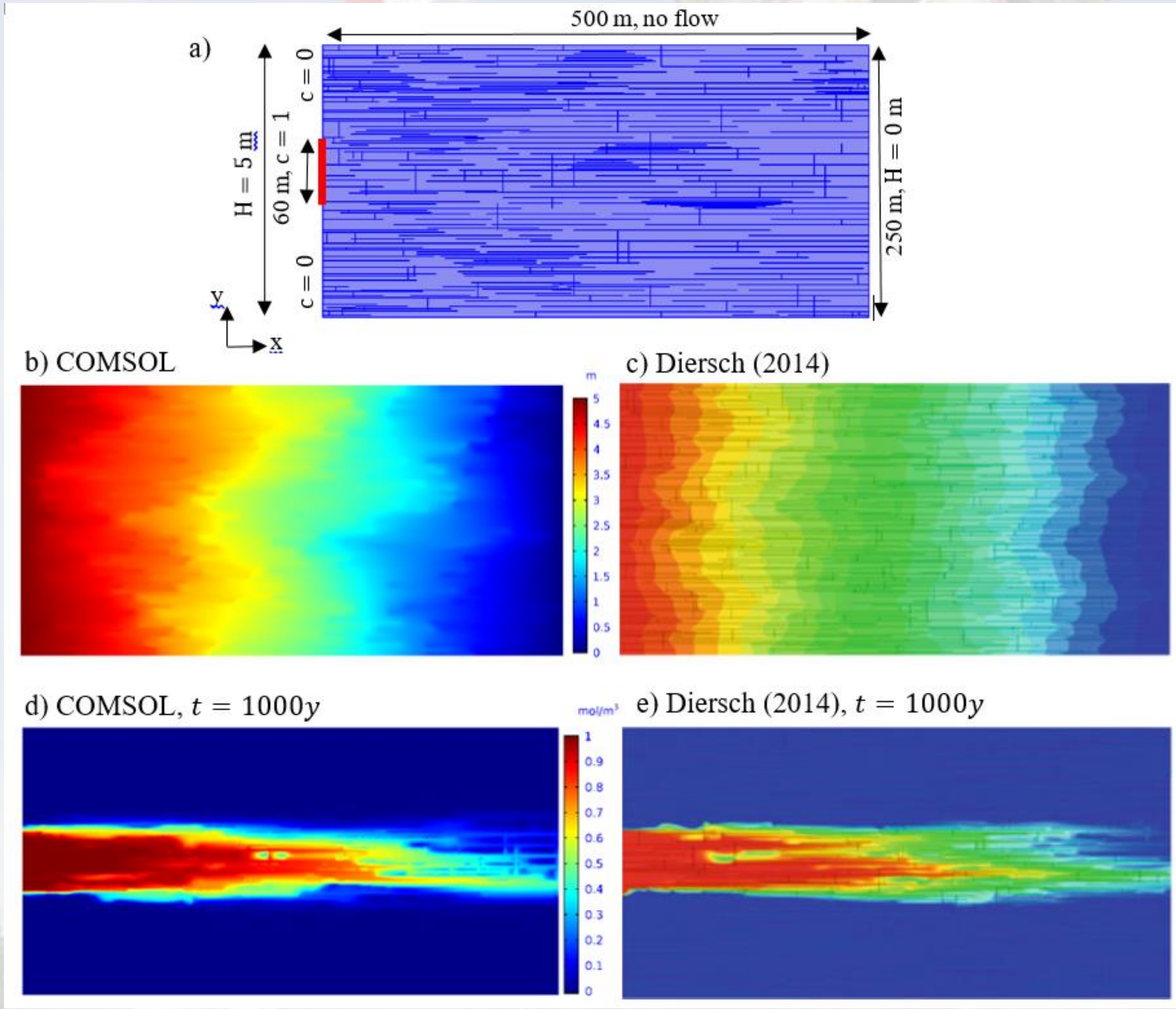


Intact rock	Vertical in-situ stress, σ_{3f}	65 MPa
	Minimum horizontal in-situ stress, σ_{1f}	44 MPa
	Maximum horizontal in-situ stress, σ_{2f}	64 MPa
	Biot's coefficient, α	0.82
	Young's Modulus, E	40 GPa
	Poisson's Ratio, ν	0.25
	Tensile strength, T	13.5 MPa
	Permeability, k	7.89×10^{-19} m^2
	Porosity, $\emptyset_0$	0.09
Natural fractures	Fracture thickness	30 μm
	Permeability, k_{NF}	9.80×10^{-12} m^2
	Porosity, $\emptyset$	1

In-situ stress and mechanical properties of the Barnett shale at a depth of 2600 m

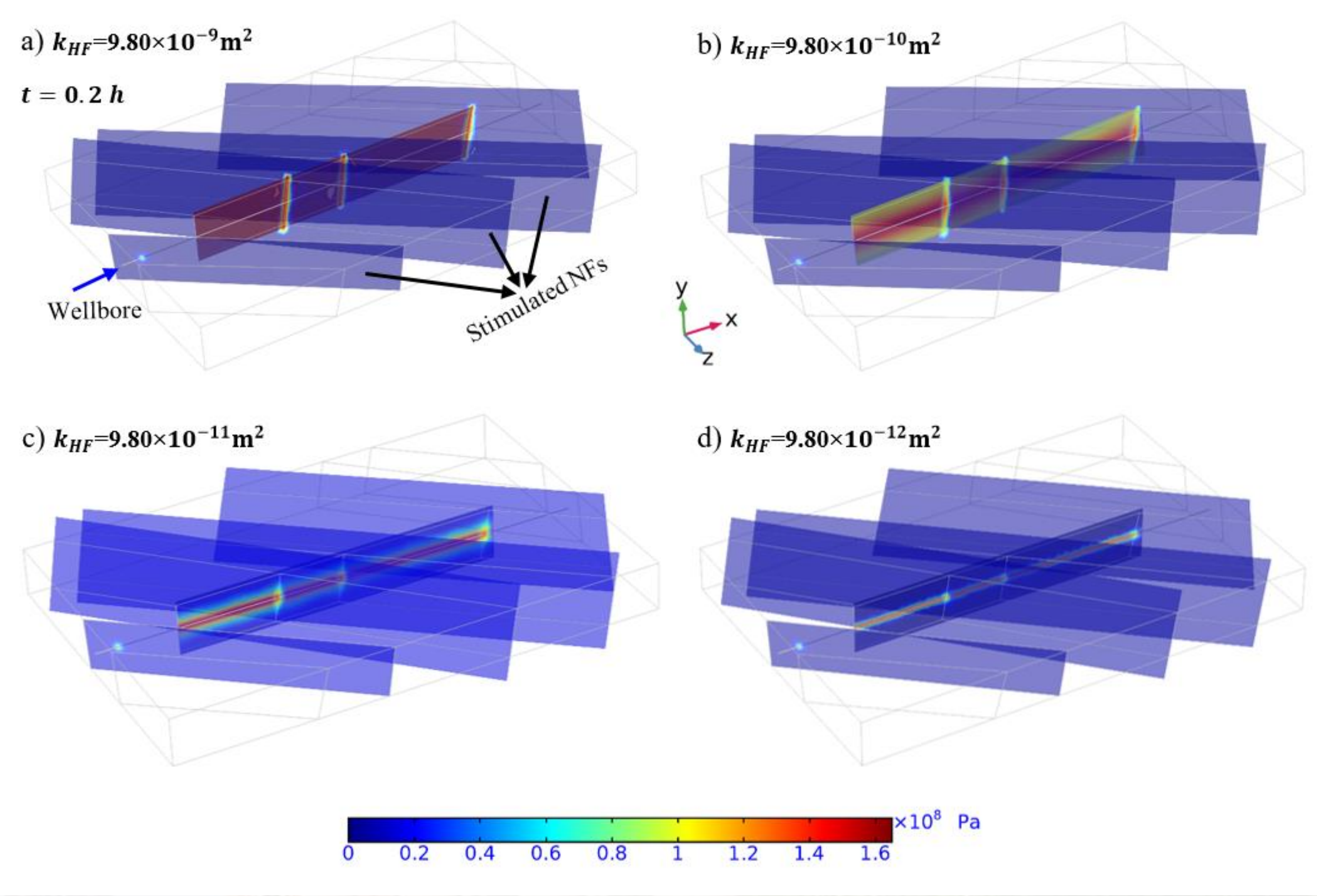
Model verification

- A 2-D fracture network model
- Steady state hydraulic head simulation contour in the fracture network
- Solute concentration contour in the fracture network

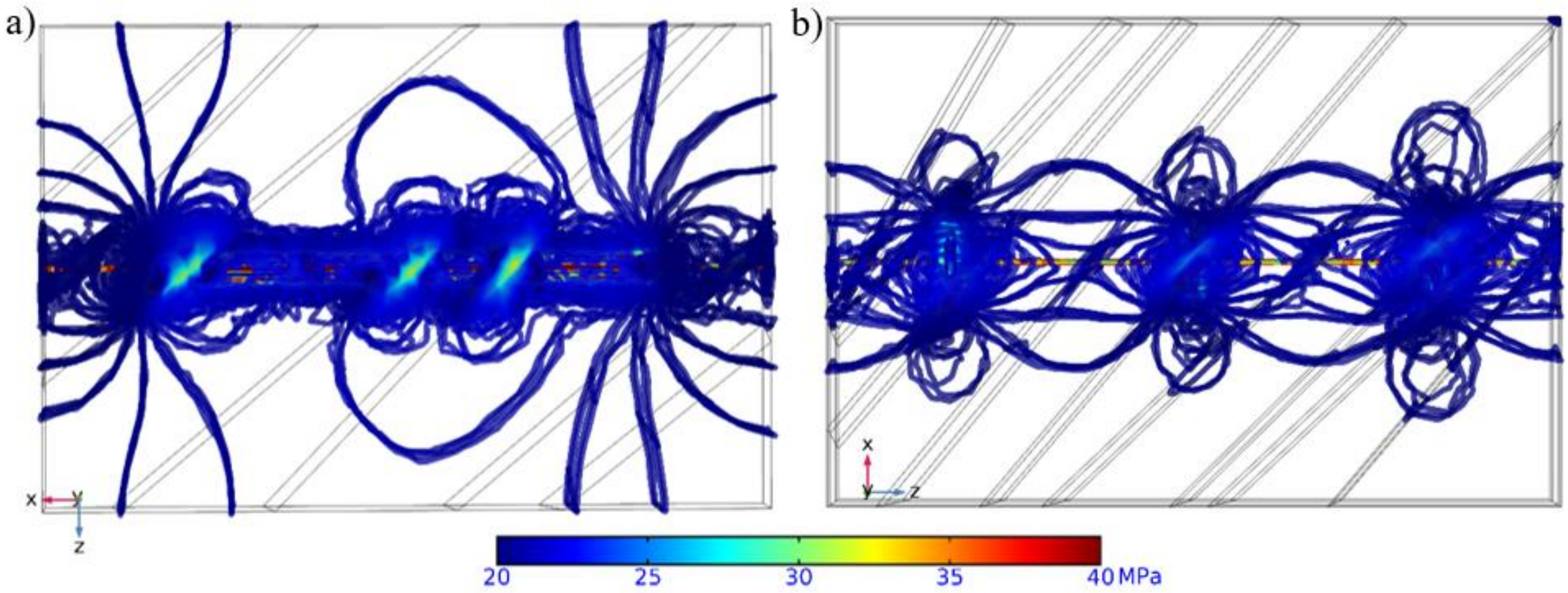


Simulation results

- Longitudinal hydro-fracture
- Contours of pore pressure within the stimulated fracture network
- Results of after 0.2 hours of injection



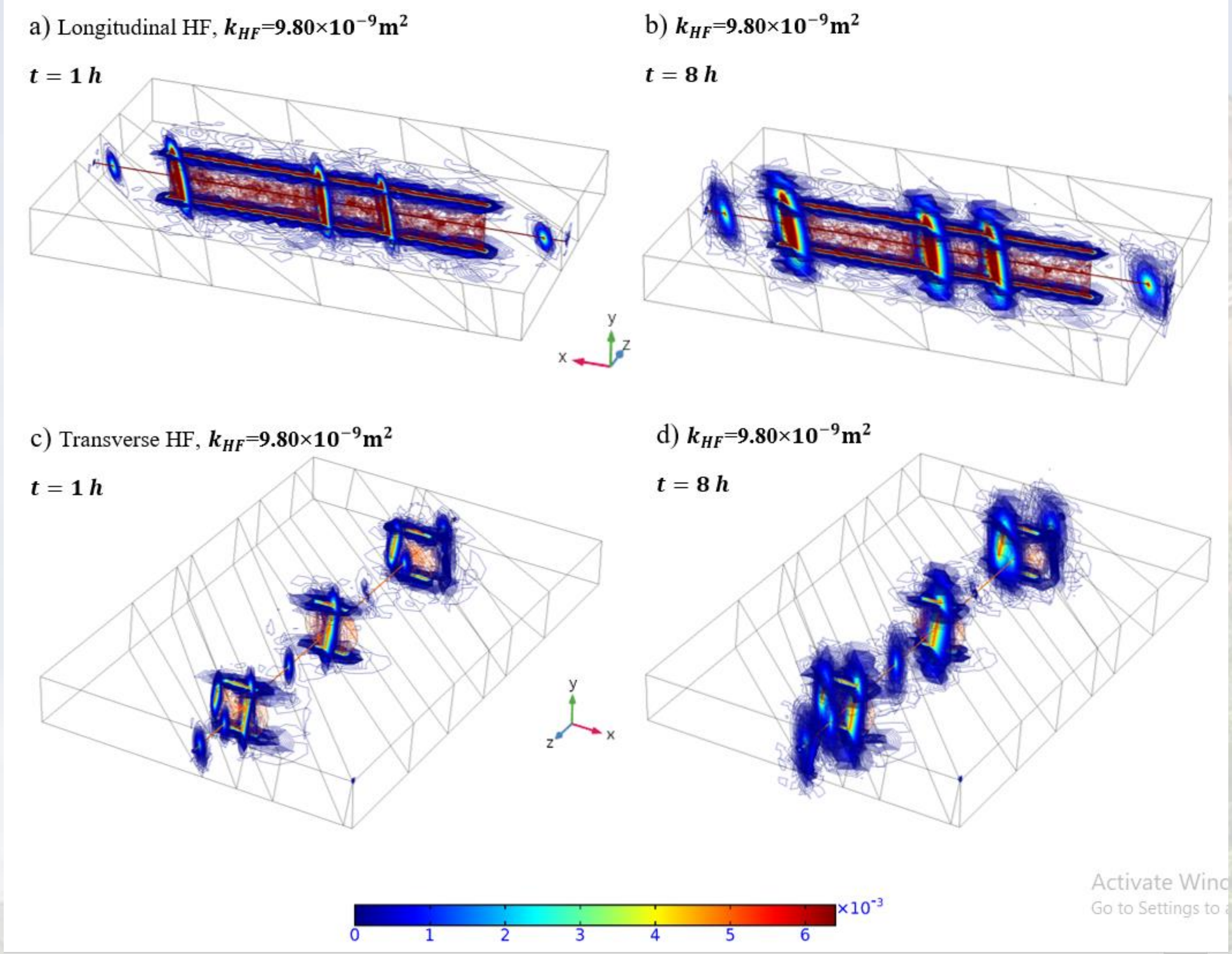
Simulation results



- The von Mises stress distribution after 8 hours of operation a) longitudinal hydro-fracture orientation and b) transverse hydro-fracture orientation at $k_{HF} = 9.80 \times 10^{-9} m^2$

Simulation results

- Longitudinal vs transversal
- The change in the increment of water content in hot basal shale section at depth of 2600 m of the Barnett formation
- $k_{\mathrm{HF}} = 9.80 \times 10^{-9}\mathrm{m}^2$



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Summary and Conclusion

What is the effect of hydro-fracture growth orientation on the poroelastic response of SRV?

- Transverse hydro-fractures showed the higher increase in the porosity per unit break down pressure
- Transverse hydro-fractures triggered a lower von Mises stress intensity (i.e. 27 MPa) around the wellbore, comparing to the von Mises stress intensity triggered by the longitudinal hydro-fracture (i.e. 33 MPa)
- The low stress intensity around the wellbore with transverse hydro-fractures assured a higher safety

What is the best wellbore orientation azimuth for hydraulic fracturing?

- The wellbore that is drilled in the direction of maximum horizontal in-situ stress of the formation inducing transvers hydro-fractures

How is the fluid flow within the SRV during hydraulic fracturing?

- The higher breakdown pressure (*i.e.* 165 MPa) was required to create a longitudinal hydro-fracture comparing to the required break down pressure of transvers hydro-fractures (*i.e.* 78 MPa).

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