Key Challenges and Opportunities on Adaptive Control of Fractures and Fluid Flow in Subsurface Energy Extraction and Storage

USDOE Subsurface Issues Briefing
22 July 2014, Washington DC
Emerging Challenges in Subsurface Utilization

**DOMAINS**

- CO₂ sequestration
- Shale gas development
- Nuclear waste disposal

**TECHNOLOGIES**

- Flow path enhancement
- Control of fluid flow
- Improved process models
Area 1 – Flow Path Enhancement

Better stimulation with energized fracturing

- Average frac job uses 2-4 million gallons of water
- Slickwater alternative $\Rightarrow$ N$_2$ or CO$_2$ (with foam)
  - Reduces water and proppant requirements
  - Produces more uniformly distributed fractures
  - Improves gas/oil recovery
  - Alleviates water scarcity considerations
- More common in Canada than in the U.S.
Area 1 – Flow Path Enhancement

Energized fracturing - challenges

• Cost considerations/perceptions
• Limited data on productivity improvement
• Large-scale supply of $\text{N}_2/\text{CO}_2$
• Tubular performance
• Relative permeability effects
• Performance modeling tools
Area 2 – Control of Fluid Flow

**Nanoparticles for mobility control**

- Surfactant stabilized CO$_2$ foams for EOR applications are costly + high degradation risk

- Alternative $\Rightarrow$ nanoparticles as stabilizing agents
  - Optimal foam generation in high velocity regions
  - Less adsorption and thermal degradation
  - Limited capillary trapping in pores
  - Can be obtained from low-cost natural sources

- Demonstrated in laboratory experiments
Area 2 – Control of Fluid Flow

Nanoparticles - challenges

- Cheaper sourcing of natural nanoparticles with good performance
- Performance in field scale
- Better understanding of nanoparticle transport in variety of rock types and fractured media
- Mechanistic models of sweep improvement from nanoparticle introduction
Area 3 – Improved Process Models

Prediction of fracture propagation

• Coupled fluid flow and geomechanics modeling
  ▪ Knowledge of natural fracture network, reservoir geology, geophysics and petrophysics
  ▪ Can predict: (a) microseismic response, (b) proppant distribution and fracture conductivity, (c) overall fracture network dimensions
  ▪ Data and computation intensive

• Conventional hydraulic fracturing models assume planar frac geometry and simplified hydraulics
Area 3 – Improved Process Models

*Fracture propagation modeling - challenges*

- Understanding of local and regional geomechanical characteristics
- Characterization of natural fractures and their representation via DFNs
- Reduced-physics models of frac propagation for real-time control
- Fracture conductivity distribution using hydraulic tomography
Cross-cutting Challenges

• Testing at field scale
  ▪ Technology available but logistical issues
  ▪ Technology tested only in laboratory

• Computational modeling
  ▪ Full-physics models data intensive
  ▪ Reduced physics models not developed

• Research often proprietary in nature
An Outside the Box Proposal

- **Mont Terri** – Swiss underground facility for hydrogeological, geochemical and geotechnical characterisation of Opalinus Clay
- Multiple international partners for 15+ yrs
- Broad range of in-situ experiments
Shale Underground Rock Laboratory

• Patterned along Mont Terri (and other URLs such as Aspo, Grimsel, Mizunami, YMP ESF)

• Public-private partnership (with possibility of international cooperation)

• Potential areas of focus
  ▪ Field-scale transport processes
  ▪ Efficacy of different treatments
  ▪ Testing of tomographic concepts
Concluding Remarks

• Adaptive control of fracturing and fluid flow important for multiple subsurface applications

• Fundamental research needed on materials development and testing, and rock-fluid interaction

• Improved computational models needed for integrated systems and real-time control

• A shale underground rock laboratory (as a public-private partnership) would be a valuable resource