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

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Emerging Challenges in Subsurface Utilization

DOMAINS	TECHNOLOGIES
CO_2 sequestration	Flow path enhancement
Shale gas development	Control of fluid flow
Nuclear waste disposal	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 ⇨ 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 N_2/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 ⇨ 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

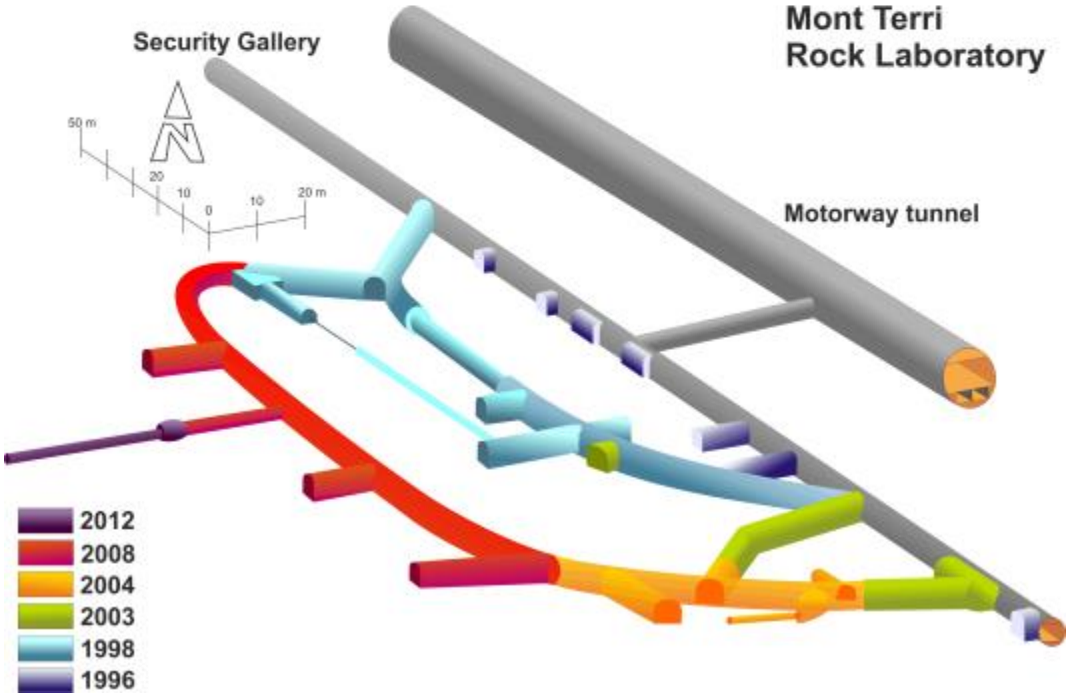
- Understanding of local and regional geomechanical characateristics
- Characterization of natural fractures and their representation via DFNs
- Reduced-physics models of frac propagation for real-time control ☑
- Fracture conductivity distribution using hydraulic tomography ☑

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



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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