Managing Multi-Physics and Multi-Scale Challenges in the O&G Sector

Newton Fund – Sustainable Gas Futures Workshop (SGF)

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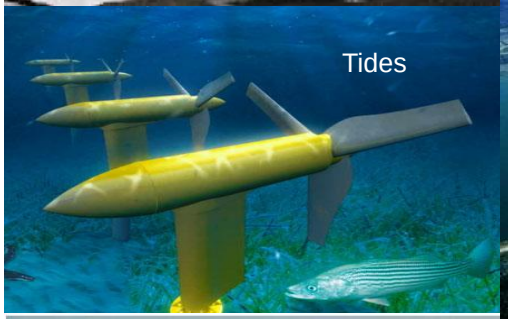
School of Engineering

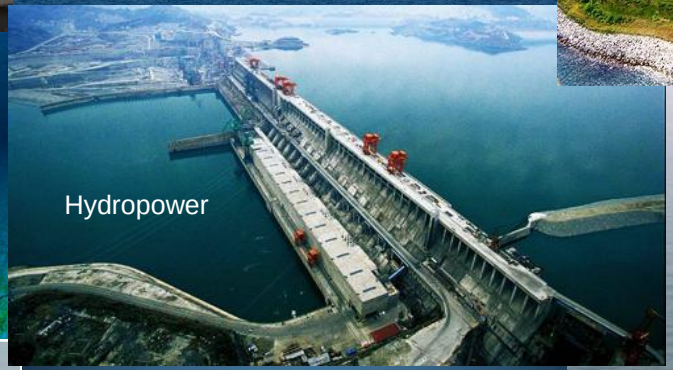
February 25-27th 2015

UNIVERSITY OF ABERDEEN

Overview

Energy Matrix





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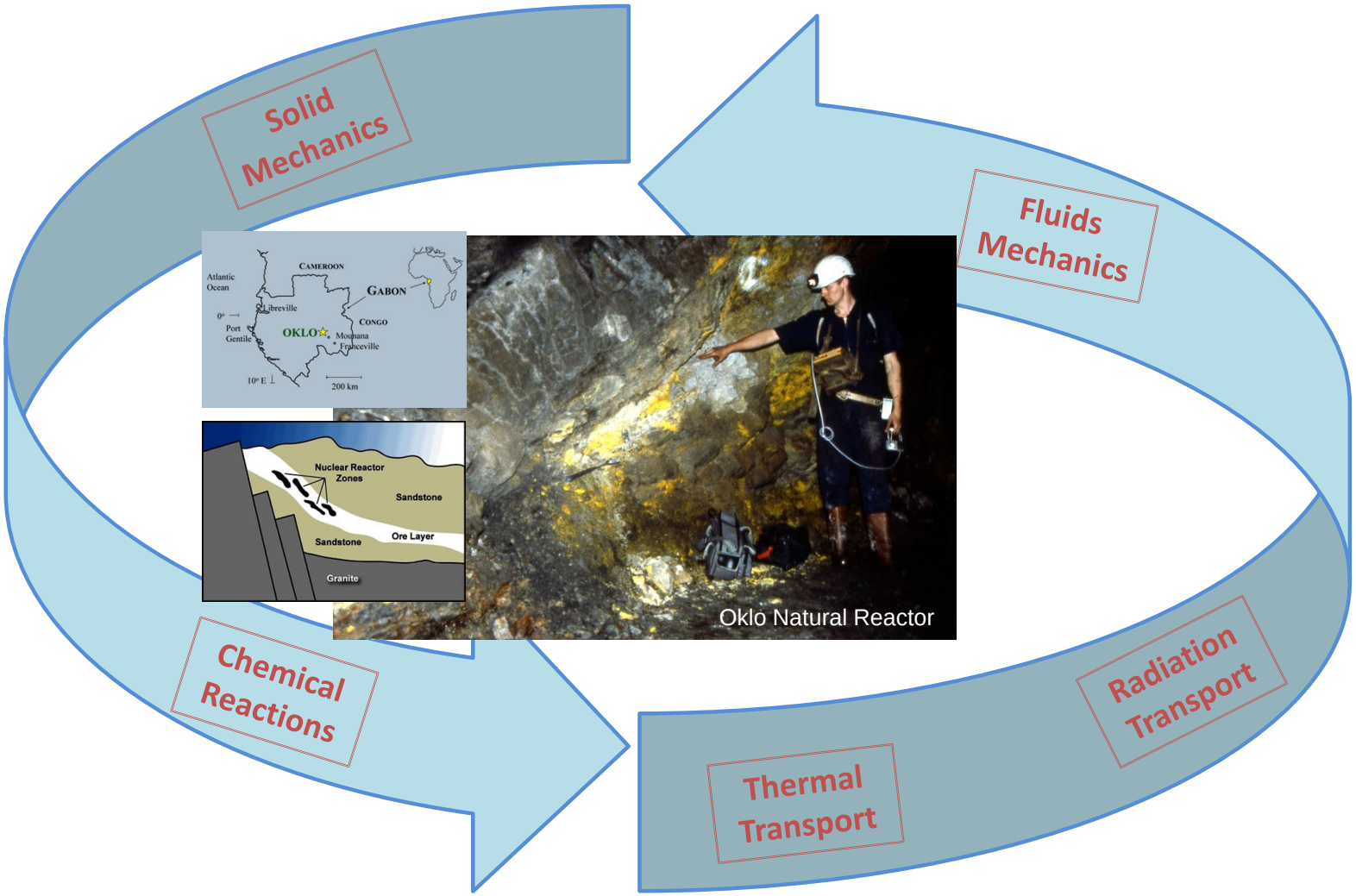
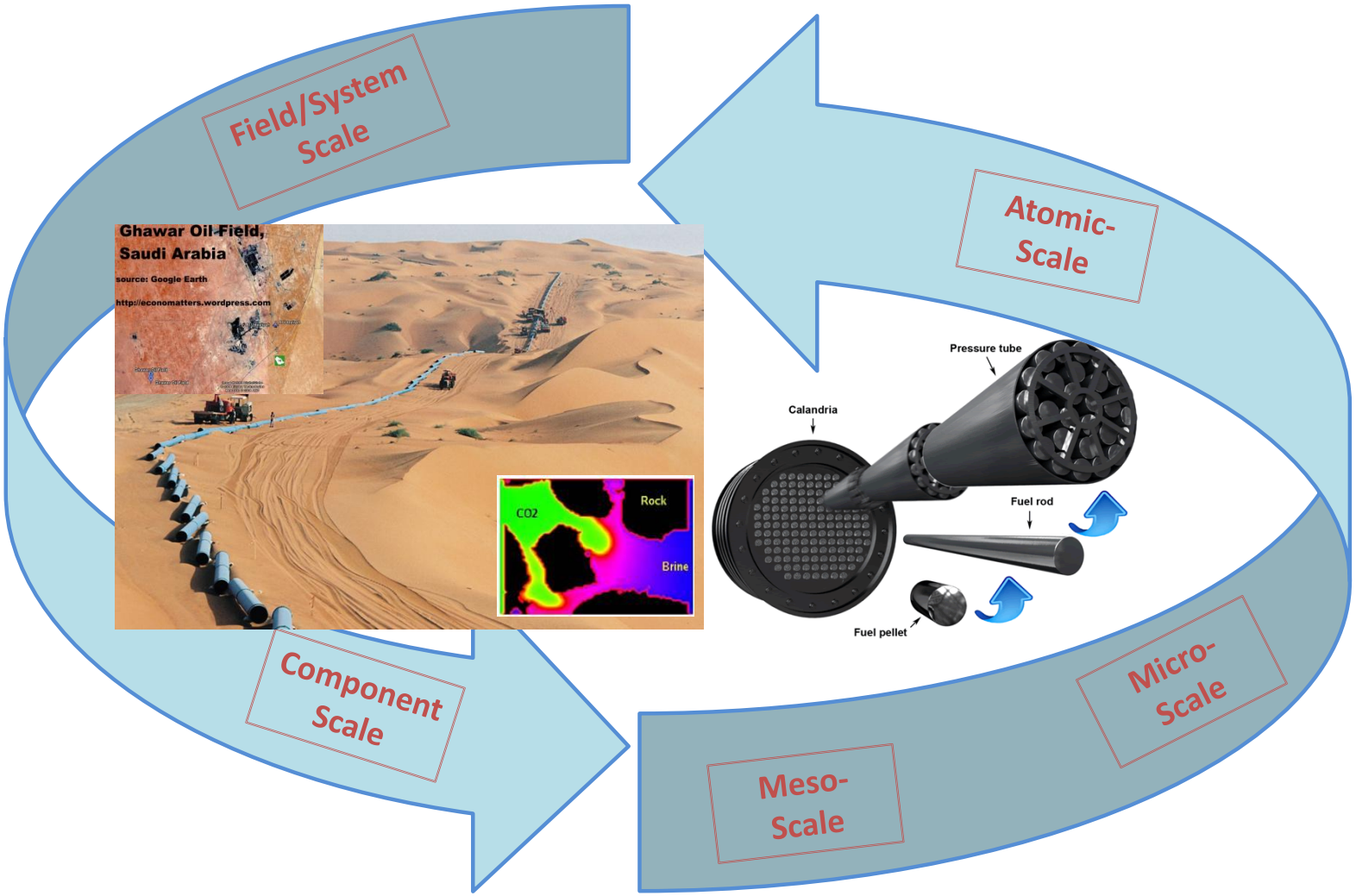
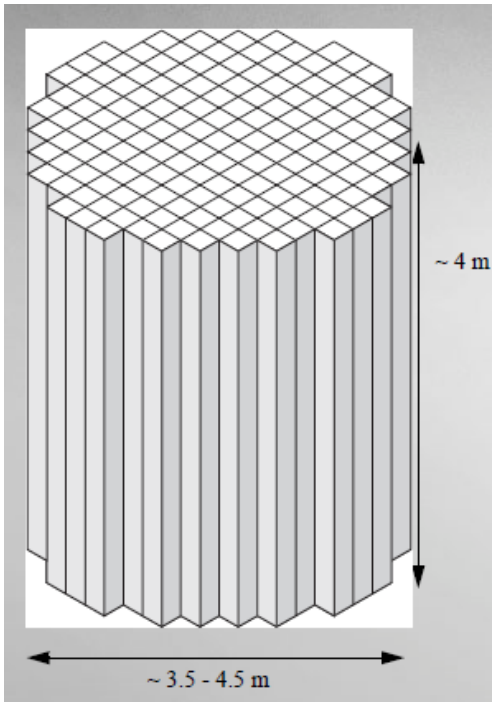
Multi-Physics Problems: Synergy Solutions



Multi-Scale Problems: Synergy Solutions

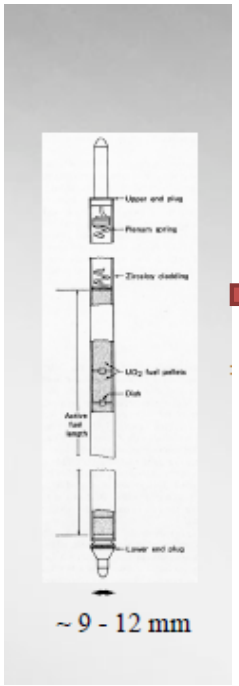


Synergy Solutions for Multi-Scale Problems: From Nuclear Systems ...



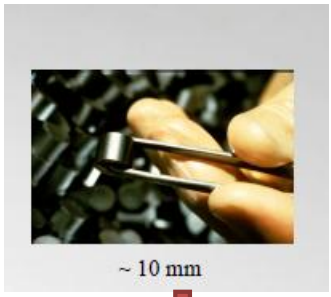
Nuclear core

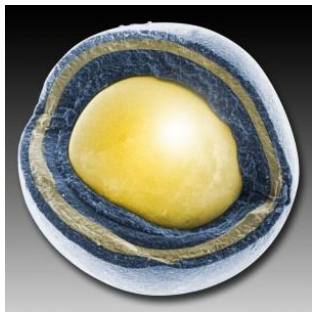
Fuel assembly



Fuel rods

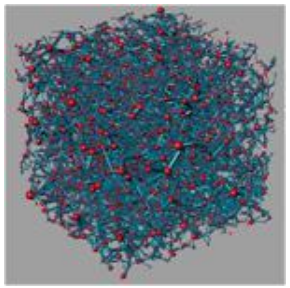
Fuel pellets

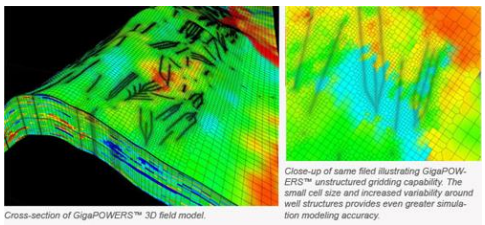




TRISO particles Uranium coated with graphite): ~ 1mm

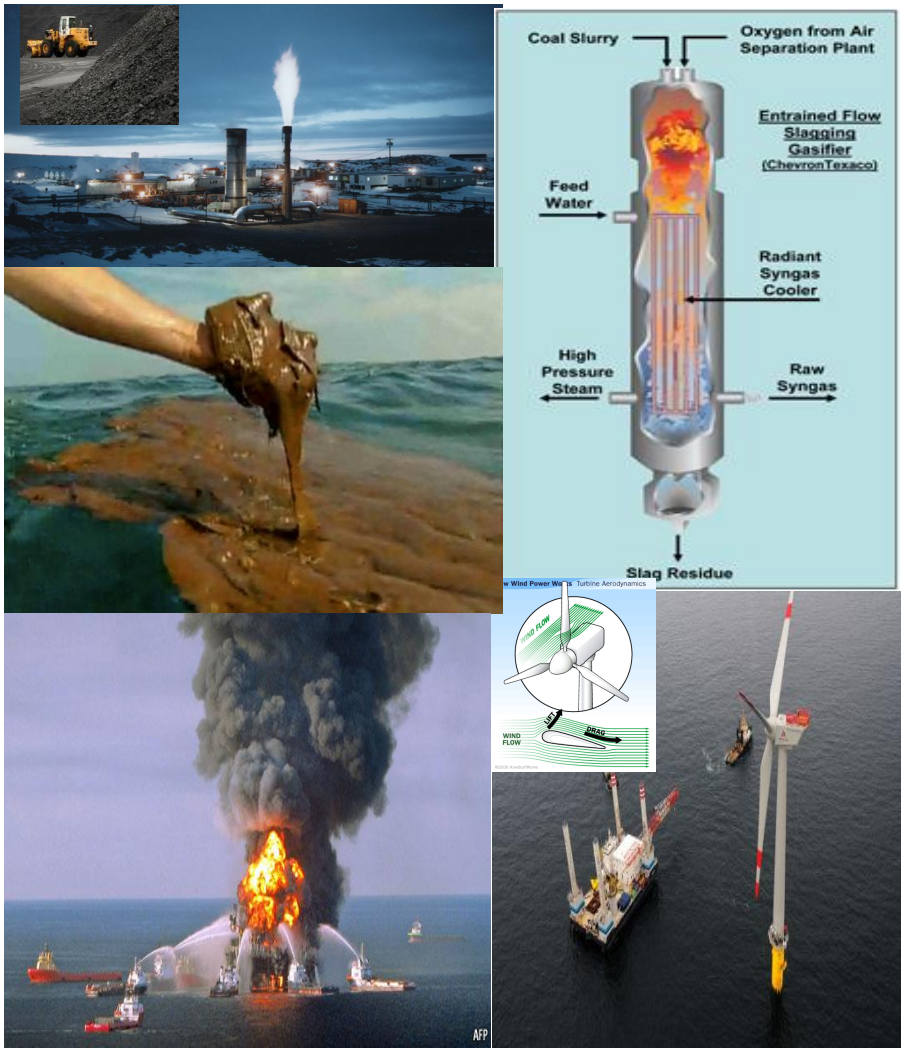
Synergy Solutions for Multi-Scale Problems: Applied to O&G Exploration and Processing





Source: Kansas Geological Survey, Saudi Aramco, Imperial College London.

Multi-Scale and Multi-Physics Models and Simulations



(a) Design and optimisation of facilities (on/off-shore);

(b) Risk and environmental safety;

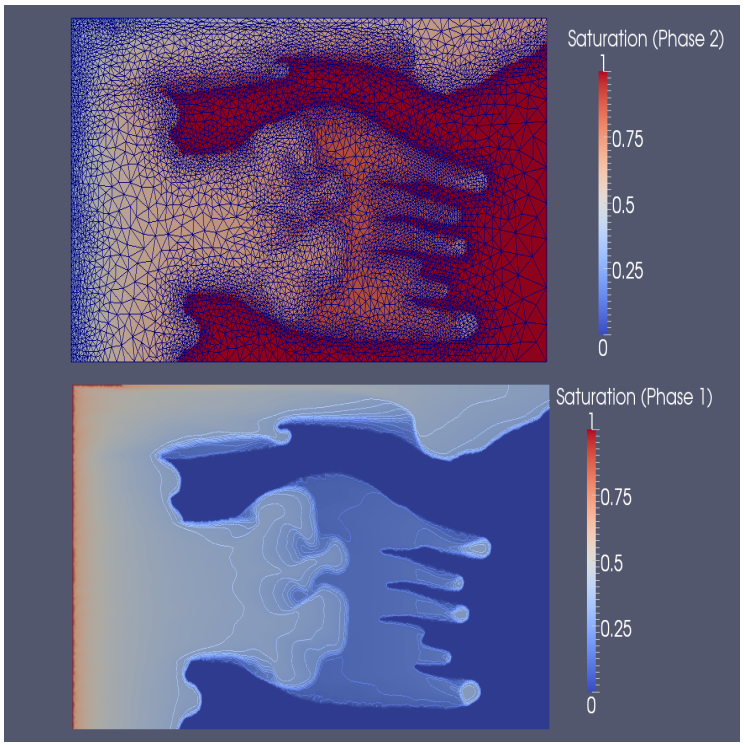
(c) Turbulence and structural integrity in subsea facilities and wind farm power plants;

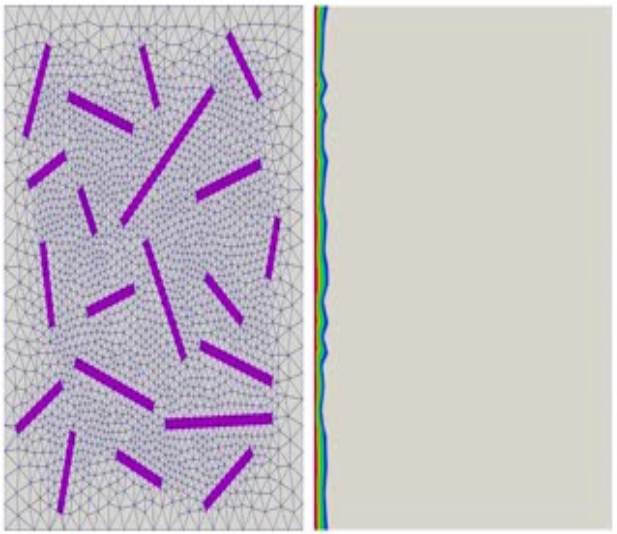
(d) Oil and gas reservoirs, underground contamination flows, CCS, subsurface gas storage.

Life Cycle Assessment

A. Oil and Gas Exploration: Multiphase Flows in Porous Media
   1. Enhanced Oil Recovery (EOR):
      (a) Injection of miscible and immiscible fluids (NG, H_2O, CO_2, steam etc);
      (b) Suppression of fingering: adjusting viscosity (injection of chemicals, e.g., polymers);
      (c) Thermal EOR (e.g., SAGD) and HPHT reservoirs;
      (d) Microbial EOR;
   2. EOR-CCS;
   3. Flows in fractures.

✓ Research Challenge: Multiphase and multi-component flows in heterogeneous and fractured porous media; Advanced (more accurate) predictive models.

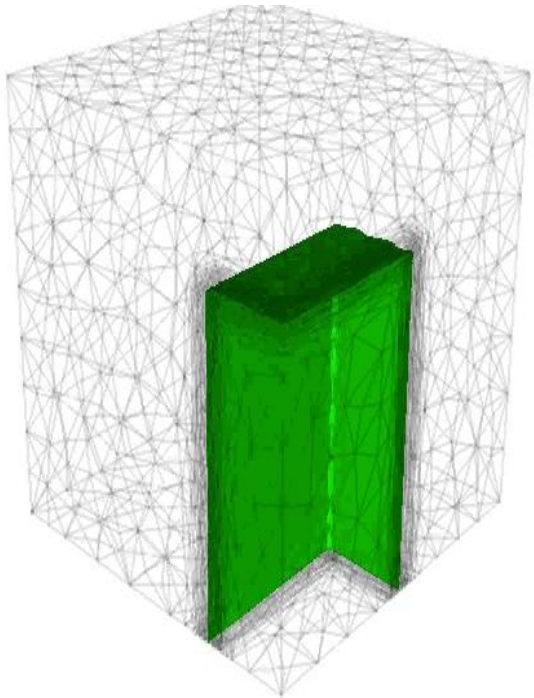


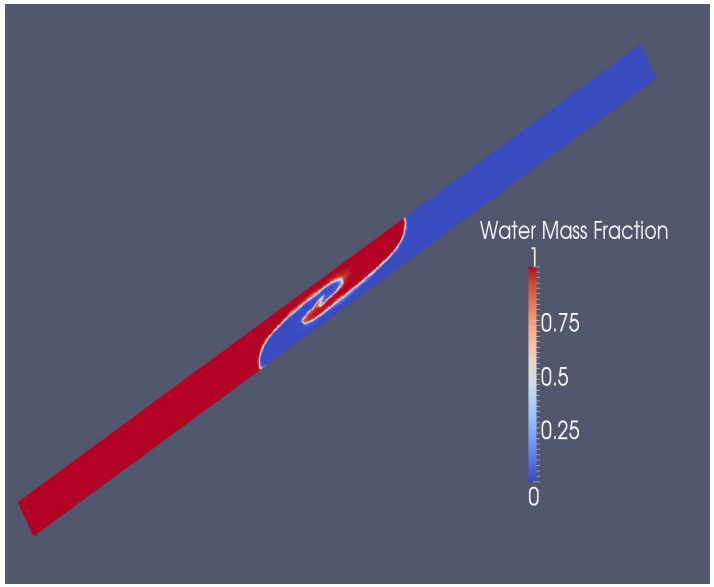


Life Cycle Assessment

B. Oil and Gas Exploration: Multiphase Flows in Constrained Regions
   1. Stratified shear flows (e.g., cement and mud interaction in well completion);
   2. Flows in umbilical cables (e.g., injection of chemicals in wells and pipelines);
   3. Sloshing in LNG tanks;
   4. Non-Newtonian flows: fundamental constitutive rheology relations (e.g., polymer solutions transport and injection);
   5. Multiphase flow meters.

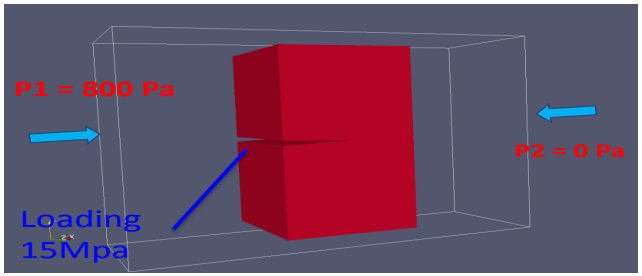
✓ Research Challenge: Fundamental understanding of laminar and turbulent single and multiphase flow dynamics. Extend to field-scale applications.



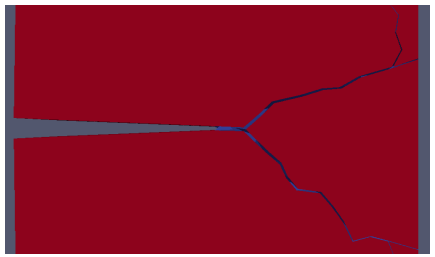


Life Cycle Assessment

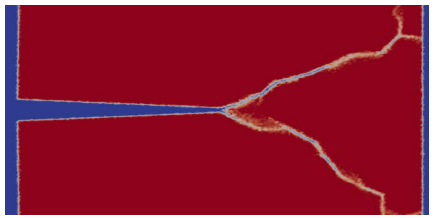
C. Oil and Gas Exploration: Geophysics
   1 Solid Mechanics;
   2 Fracking and Formation of Fractures: Environmental Impact (microseismicity and rock physics);
   3 Subsurface characterisation:
      (a) Resolving heterogeneities;
      (b) Upscaling.



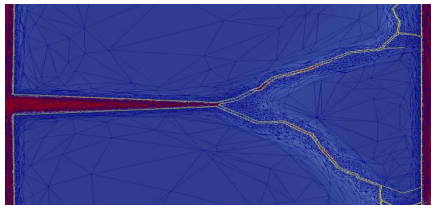
fracture propagation simulated by FEMDEM



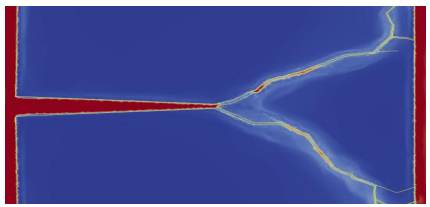
solid concentration



adaptive mesh captures the fracture walls



fluid velocity



✓ Research Challenge: Geomechanical models (coupling with multi-fluid models); Fracking technologies and environmental impact; Impact of heterogeneity and upscaling techniques on exploration; Salt caves stability (gas storage).

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Risk Mitigation and Planning (Flow Assurance)

D. Identification of Risks

1. Hydrates (Clathrate of NG and CO_2):
   (a) Formation (onset of precipitation): thermodynamic stability;
   (b) Transport and deposition of particles;
   (c) Resuspension and resolubilisation.
2. Asphaltenes and Wax:
   (a) Formation (onset of precipitation): thermodynamic stability;
   (b) Transport and deposition of particles;
   (c) Resuspension and resolubilisation.
3. Uncontrolled Water Production:
   (a) Formation water;
   (b) Breakthrough of injected water;
   (c) Perforation in the aquifer;
   (d) Water migration from high-permeability layer and/or through fractures connecting the well to aquifers;
   (e) Barrier breakdown during stimulation.

E. Strategies for Mitigation and Remediation

1. Sensor technologies (accuracy, mobility);
2. Minimisation of heat and pressure losses;
3. Chemical inhibitors, emulsion breakers, viscosity controllers etc;
4. Chemicals (e.g., polymers) to shut off of water-bearing channels or fractures to prevent migration of water to the well.

✓ Research Challenge: New and more accurate thermodynamic models; Novel chemcical compounds and impact on thermo-physical and rheological properties; *Optimal sensor location technology*.

Multi-Physics, Multiphase and Multi-Scale (MMM): Research Directions

1. From pore- to core- to field-scales:
   (a) Fluid-rock interactions;
   (b) Accurate fluid and rock thermophysical and rheological properties at reservoir conditions;
   (c) Assessing and representing heterogeneities, porosities, wettabilities, etc;
   (d) Flow regime transitions: from Darcy to Navier-Stokes flows;

2. Impact on productivity:
   (a) Uncontrolled water production;
   (b) Flow instabilities in recovery processes;
   (c) Multiphase and compositional flows (equilibrium and non-equilibrium thermo-fluid dynamics);
   (d) Fracture formations (induced or natural occurrence);
   (e) Flow Assurance (hydrates, asphaltenes, air-lifting, etc);

3. Predictive science and technology for Risk Management (safety and environmental):
   (a) Sensor technologies: accuracy, mobility, response-time, etc (e.g, assessing flow of CO_2 plumes under CCS conditions; pressure and temperature changes; caprock perforation and fracture propagation etc);
   (b) Emergency response systems: rapid models to support accident scenarios;
   (c) More accurate predictive models for production: novel techniques for history matching and data assimilation.