DETECT workflow

The goal of DETECT is to assess geological leakage risks related to fault and fractures in caprocks

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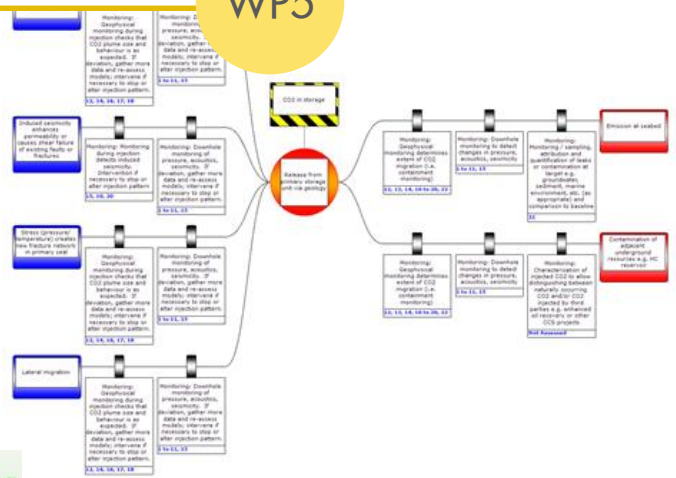
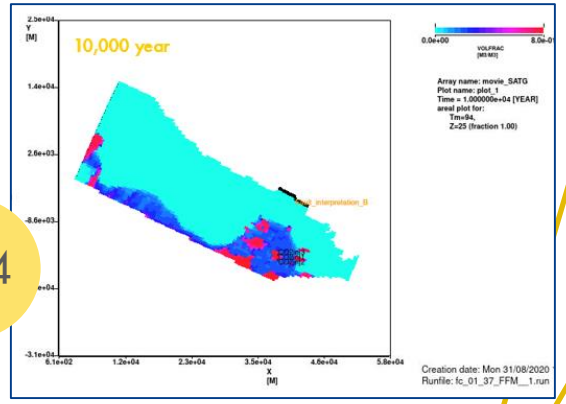
Identify active monitoring barriers relevant for site and expected leakage rates

Modelling results inform effectiveness of passive barriers (in seals and secondary storage units)



WP4



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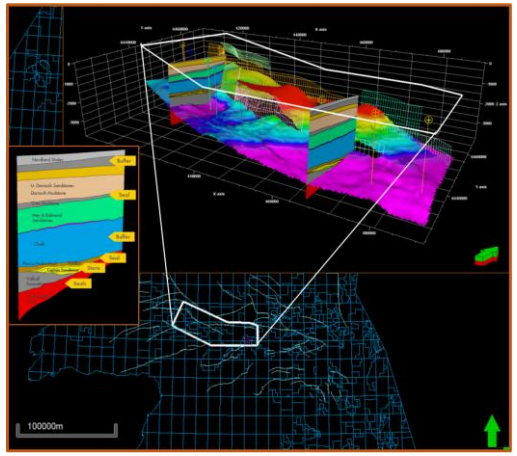


WP3

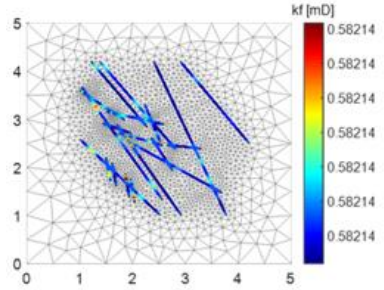
Hydromechanical coupling using lab-derived stress-permeability relations and analytical stress-state model

Effective fracture + matrix vertical permeability, RLP, CPR for each cell in seal derived from numerical up-scaling

Simulate flow in fracture networks in caprocks

Scaling relations based on meso/fine-scale modelling & analogues

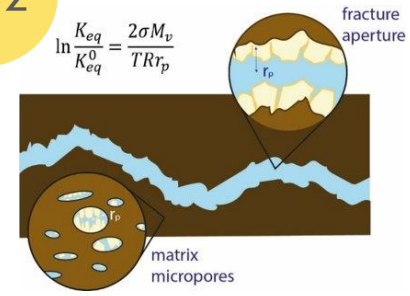
Characterise background stresses and log-derived rock transport and geomechanical properties



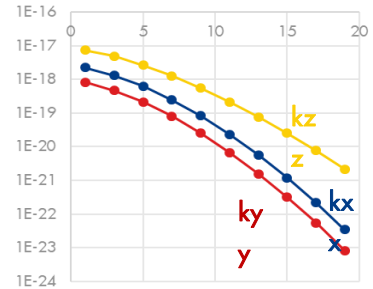
WP2

Experimentation and numerical modeling to characterise single fracture processes

$$\ln\frac{K_{eq}}{K_{eq}^{0}} = \frac{2\sigma M_v}{TRr_p}$$



Quantifying the impact of small-scale physics on CO_2-brine flow at fine-scale



Characterise fault-fracture networks using analogue derived scaling relations: fault throw-length-frequency

The project has been subsidized through the ERANET Cofund ACT (Project no. 271497), the European Commission, the Research Council of Norway, the Rijksdienst voor Ondernemend Nederland, the Bundesministerium für Wirtschaft und Energie, and the Department for Business, Energy & Industrial Strategy, UK.

DETECT

INTEGRATED GEOLOGICAL CO_2 LEAKAGE RISK ASSESSMENT

Meso-scale characterisation and modelling

Context and key insights

Jeroen Snippe, Niko Kampman, Kevin Bisdom, Tim Tambach (Shell International B.V)

Rafael March, Christine Maier, Amanzhol Kubeyev, David Egya, **Florian Doster**,

Tomos Phillips, Nathaniel Forbes Inskip, Roberto Rizzo, Yihuai Zhang, Andreas Busch

(Heriot Watt University)

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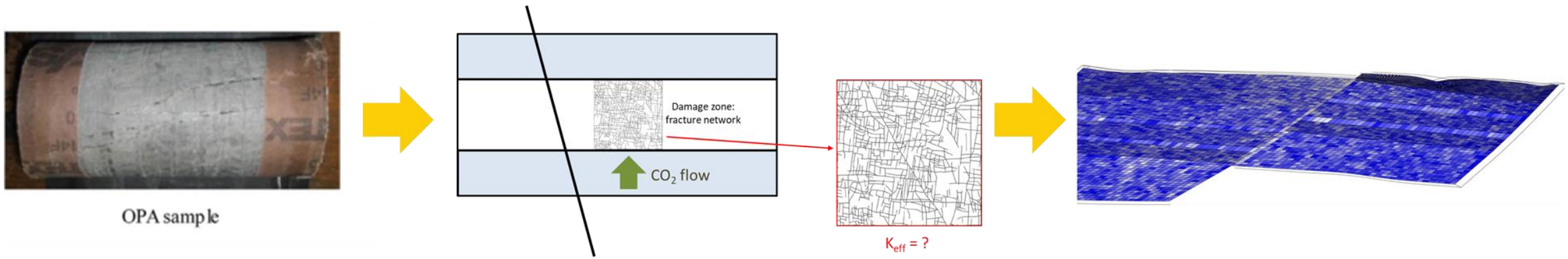
Fracture flow analysis:
A multi-scale approach for stress-flow interaction

Micro scale
Fracture / core scale
μm - cm

Meso scale
Fracture network scale
m – 10s of m

Macro scale
Basin scale
km



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The problem translated to questions

Micro scale

1. What are the permeabilities/transmissivities of individual fractures in typical caprocks and their sensitivity to stress?
2. What are relative permeabilities and capillary presssures of an individual fracture and their sensitivity to stress?

Meso scale

1. What are typical fracture networks in the damage zone of faults?
2. What are the effective permeabilities of those fracture networks and how do these effective permeabilities respond to stress?
3. What are rel perm and cap pres of the fracture network and how do they respond to stress?

Macro scale

1. Can we benchmark/test our modelling approach?
2. What are the implications for CCS operations?

Accelerating CCS Technologies

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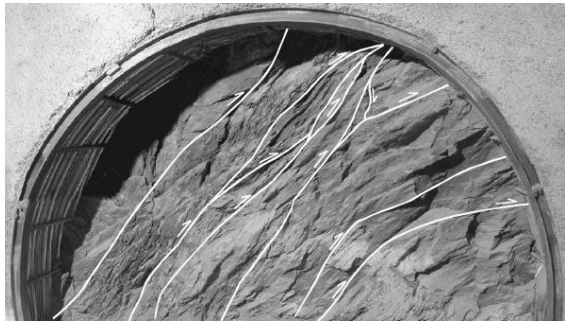
Meso scale - Fracture networks

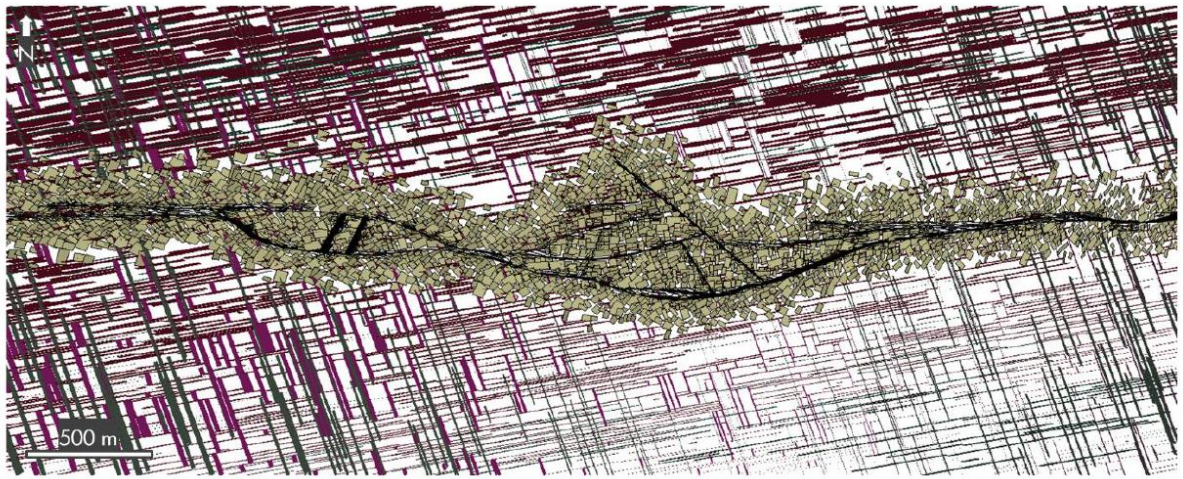
Fracture networks of mudrocks are challenging to obtain: 2D and weather

1. Fracture network directly from galleries and modelled based on geological understanding of the Mt Terri underground laboratory
2. A full 3D model of the fracture networks around the Little Grand Wash fault in Green river Utah



Mont Terri: exposed fracture network.

Little Grand Wash Fault in Green River, Utah outcrop, core and fracture model



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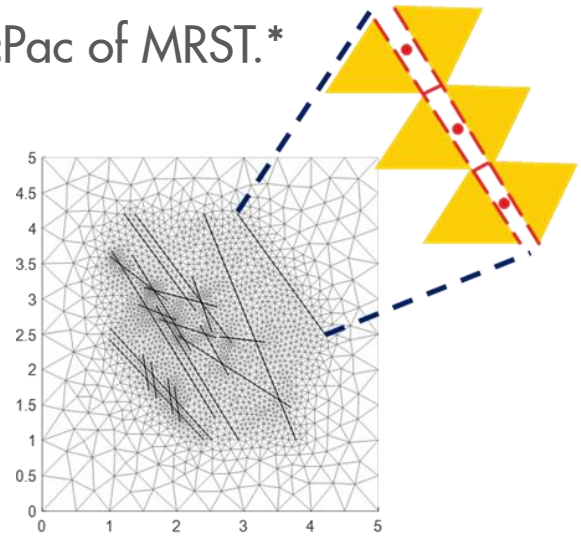
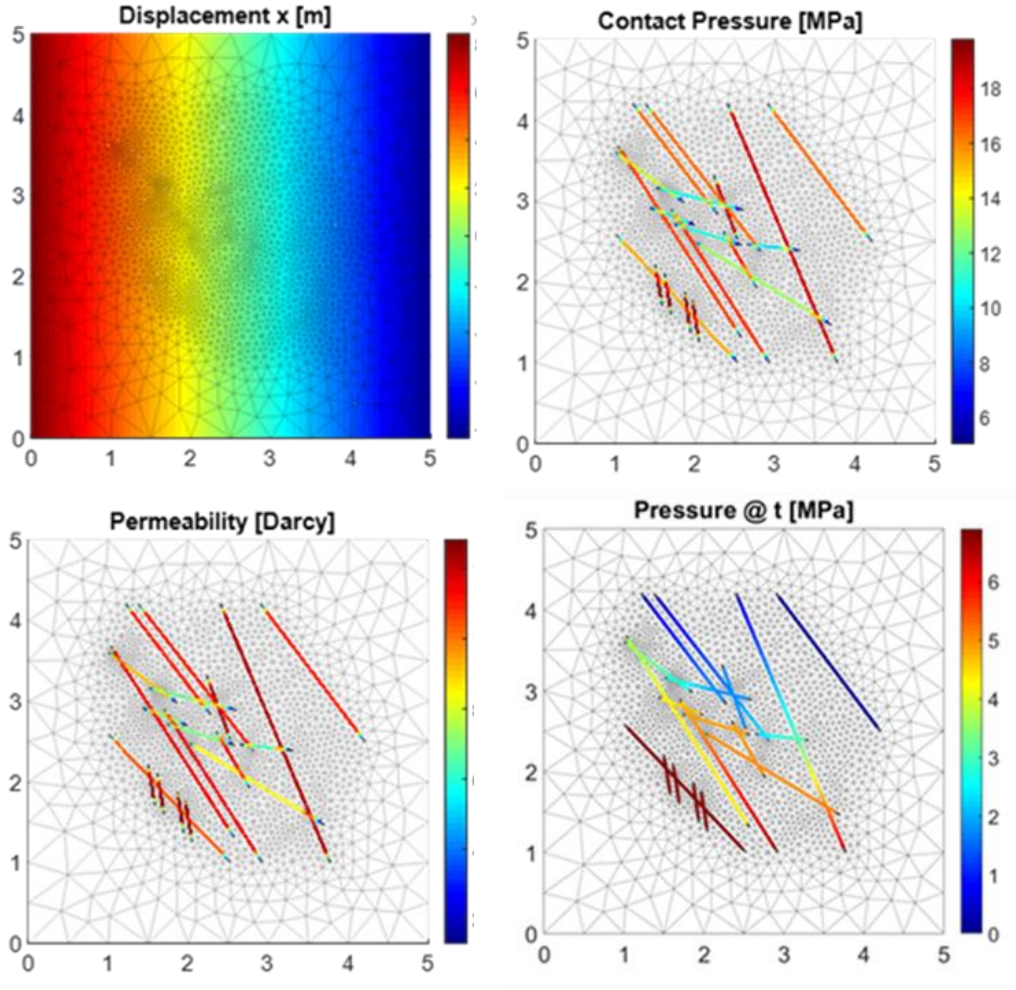
Meso scale - Single phase flow

1. Numerical upscaling in 2D for explicitly represented fracture networks:
    1. MRST Virtual element elastic representation with simplified contact mechanics
    2. Normal stress on fractures used to obtain local permeabilities with results from micro scale
    3. Effective permeabilities using FracPac of MRST.*





- Preprint March et al (2020)
- book-chapter available on request

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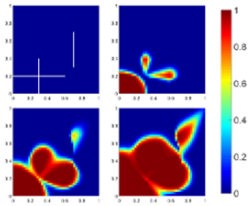
MRST modules for treating fractures

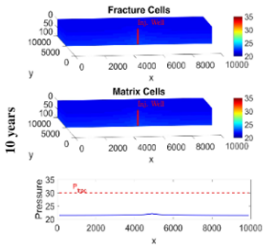
Numerical formulations based on geometrical and virtual domains and connections

https://bitbucket.org/HWUCarbonates/mrst-hwu-fractures

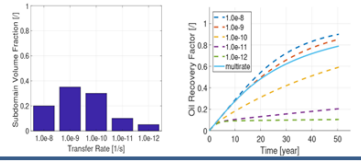
Discrete Fracture and Matrix



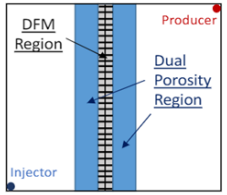
Dual Porosity



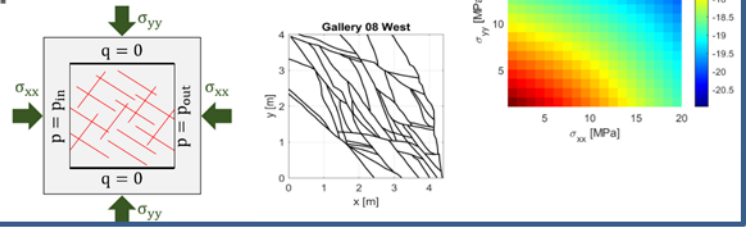
Multi-Rate Dual-Porosity



Combination of them



Upscaling of stress-sensitive fracture permeabilities



Integrating single core stress-aperture experiments with effective permeability upscaling of fracture networks

https://bitbucket.org/HWUCarbonates/mrst-hwu-fracpack

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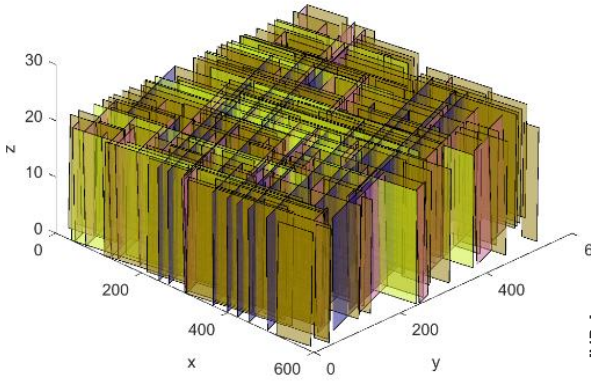
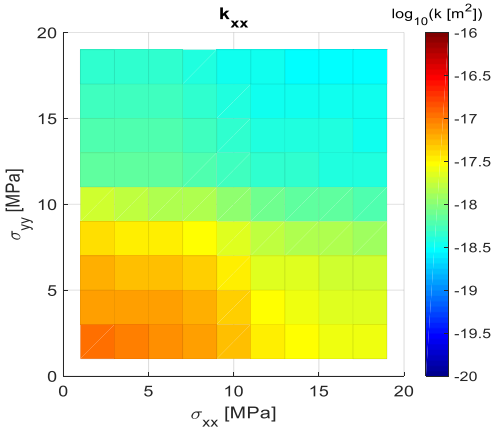
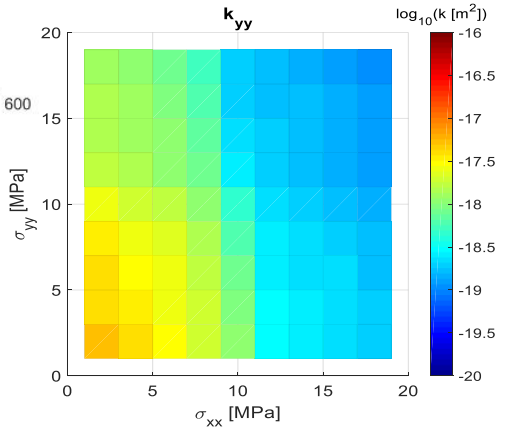
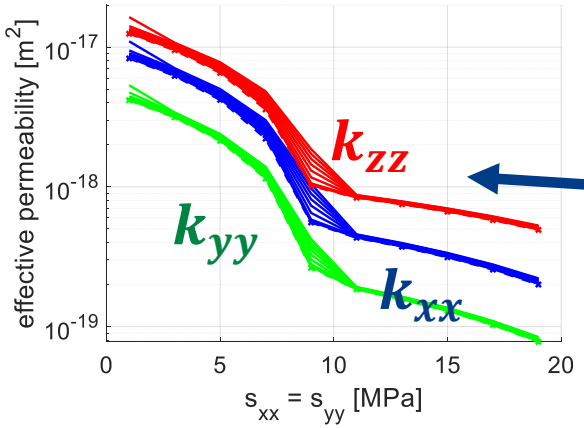
Meso scale - Single phase flow

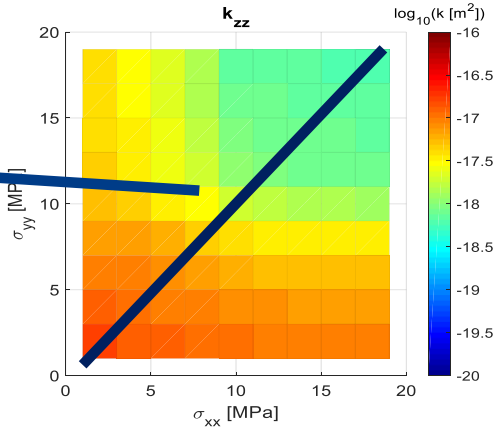
2. Numerical upscaling in 3D for explicitly represented fracture networks
    1. Stress field projected onto 3D fracture networks to obtain local normal stresses
    2. Local permeabilities are calculated using results from micro scale
    3. Effective permeabilities using a embedded discrete fracture modelling approach in MRST*











$s_{zz} = 1\text{MPa}$

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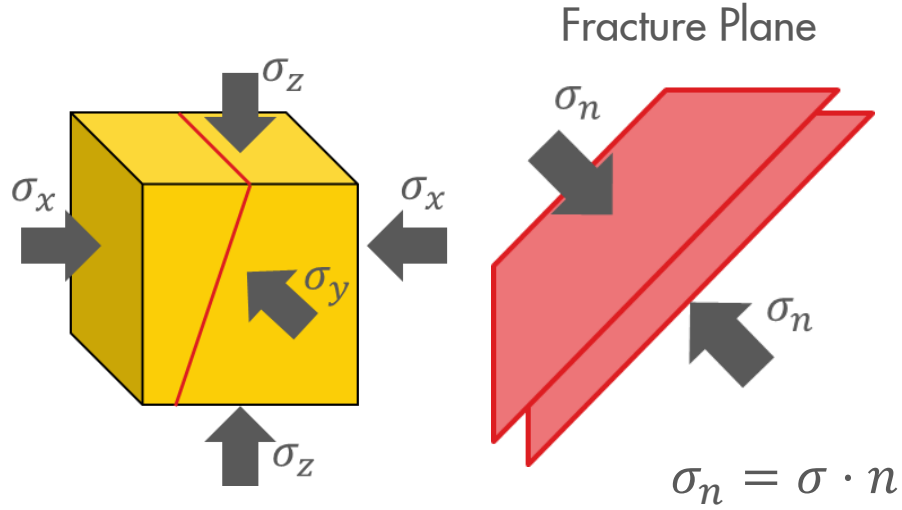
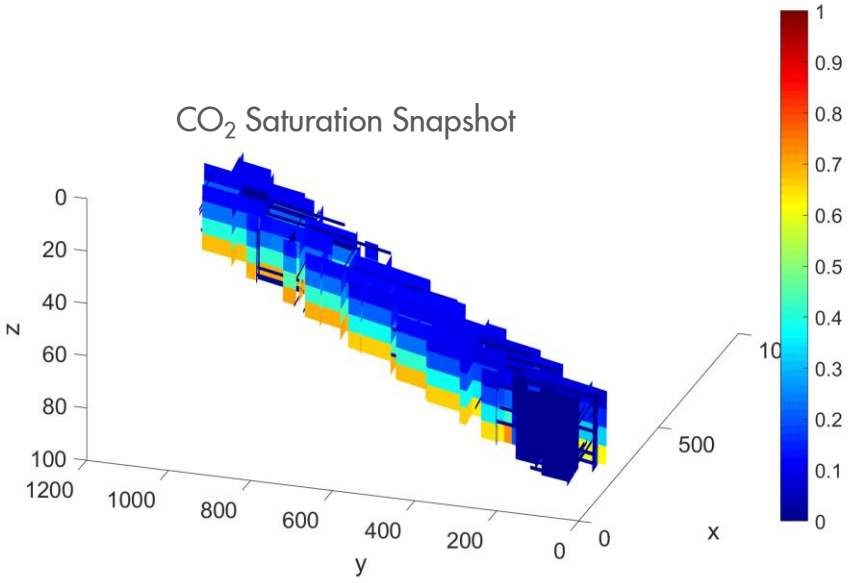
Meso scale - Multi-phase flow

1. Darcy based upscaling approach for relative permeabilities and capillary pressure.
   1. Local capillary pressure and relative permeabilities in fractures from micro scale
   2. Stresses are projected onto fractures plains
   3. Numerical steady state pseudoisation approach using EDFM
   4. Rel perms and capillary pressure dependent on saturation, pressure gradient, stress
2. Invasion percolation based algorithm to obtain breakthrough capillary pressure for fracture networks based on individual fractures invasion percolation stress related break through values





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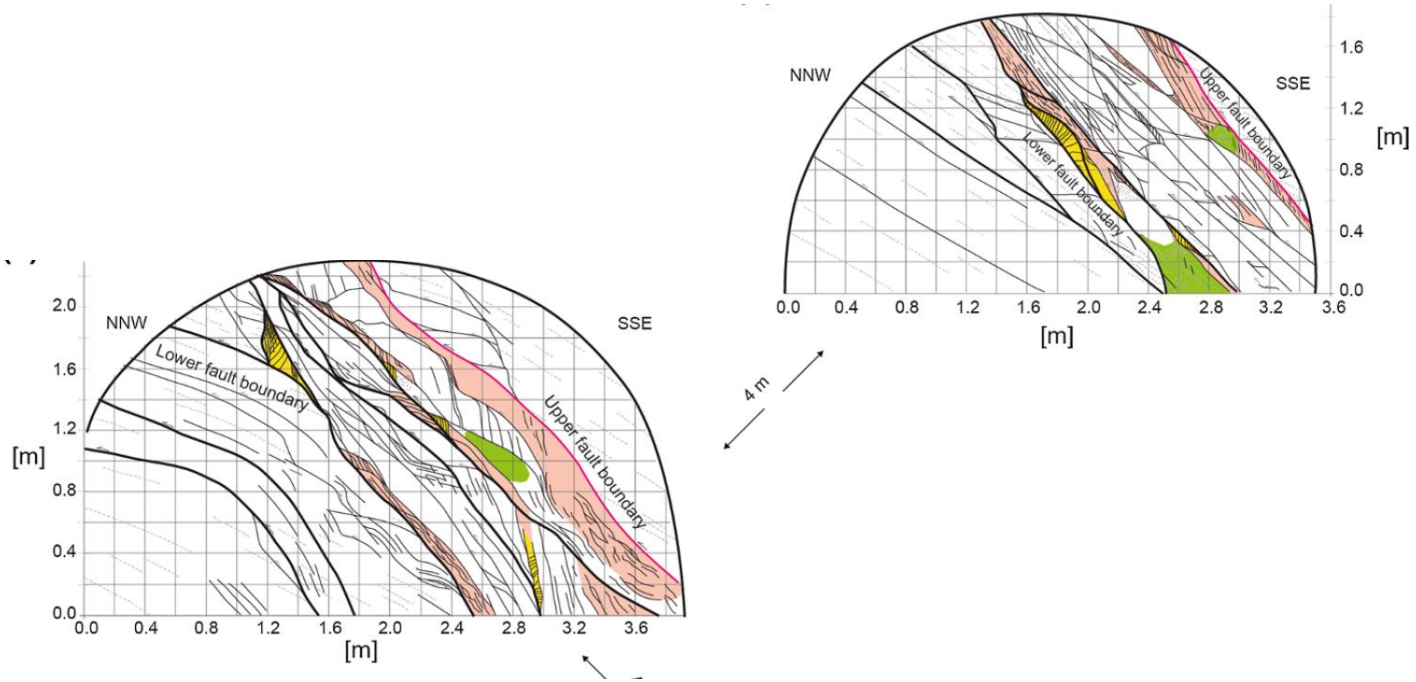
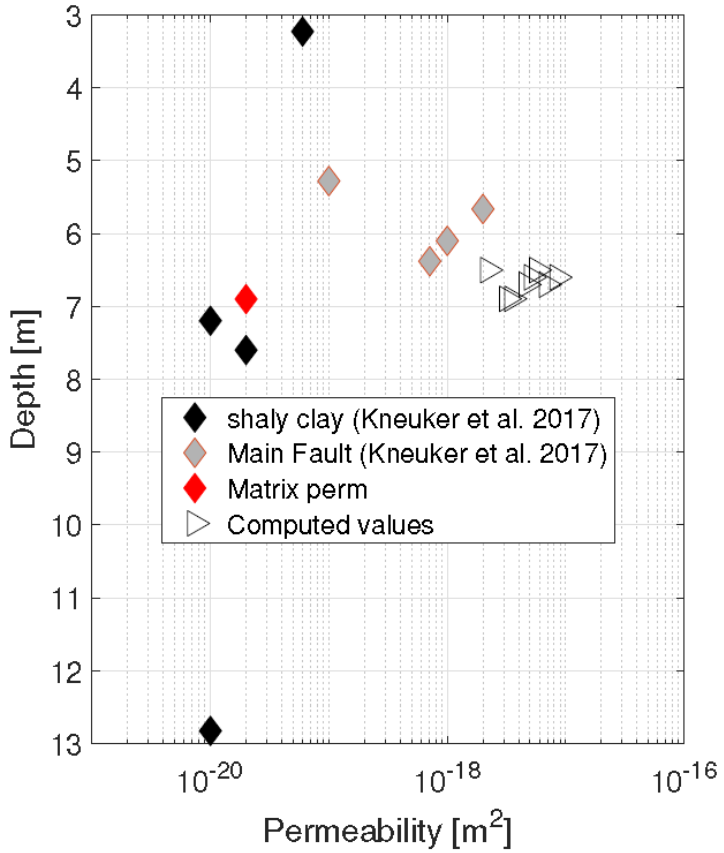
Macro scale – Benchmarks 1 – Mt Terri

Mt Terri effective permeabilities are compared with permeabilities obtained from field test.





From Bossart & Milnes – Mont Terri Rock Laboratory 20 years (2018)

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Summary, conclusions and outlook

- DETECT takes an integrated approach to assess leakage risks around faults in CCS operations
- We have presented an integrated multi-scale approach to understand the interplay of stress and permeabilities including experiments and numerical modelling in caprocks for CCS
- For every stage several different approaches are taken. A rigorous comparison and conclusion is pending.
- The workflow is supported by
  - Being able to reproduce the order of magnitude of field test in the Mt Terri underground laboratory
  - Matching location and order of magnitude of leakage rate around the Little Grand Wash fault in Green River, Utah
- Implications for CCS in North Sea formations are currently ongoing.

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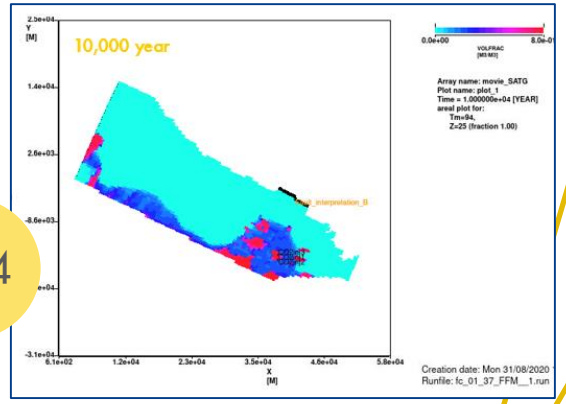

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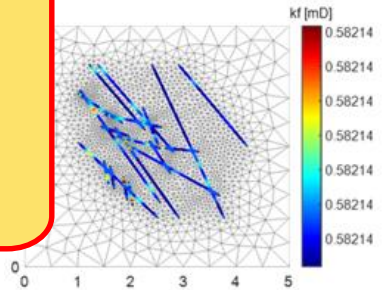

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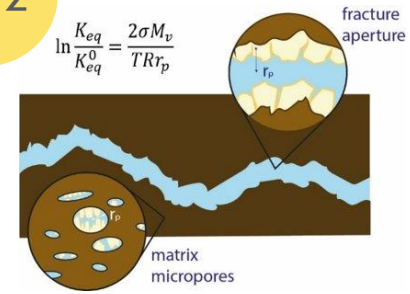

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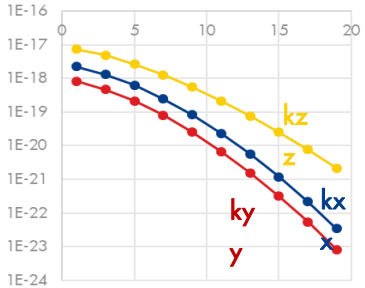

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Contact:

f.doster@hw.ac.uk

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