Webinars

Welcome!

The program will begin soon.

You will not hear audio until we begin.

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Webinars

Building the Bridge to Future Generation of Energy Engineers

Carbon Capture, Utilization & Storage (CCUS)

Jules Reed

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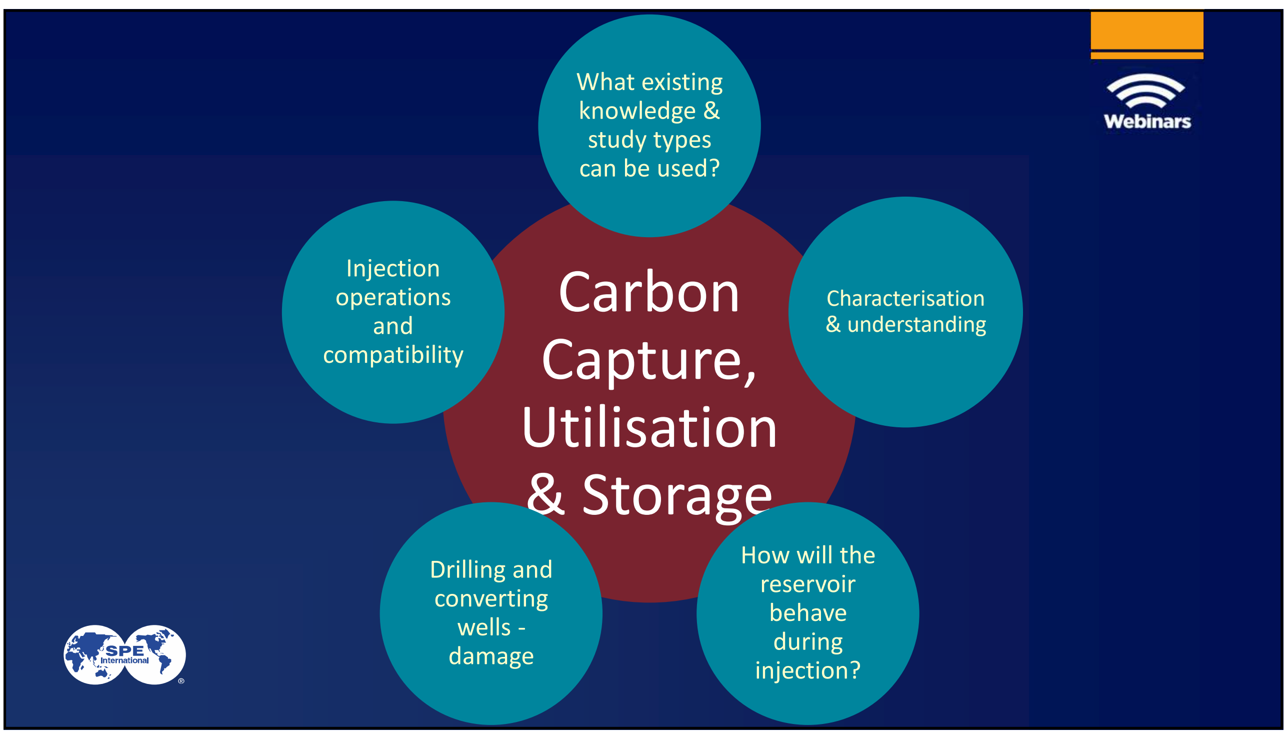

Why is CCUS important?

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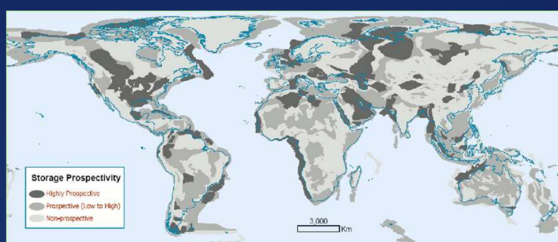
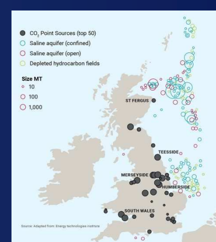
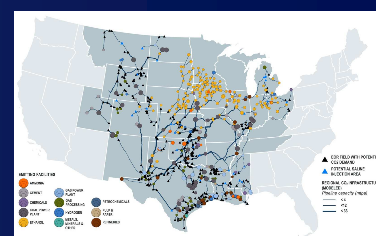
- Carbon needs to be removed from the atmosphere to meet Paris Agreement targets
- In the transition to net zero carbon emissions there is still carbon emission
- Government incentives & funding, e.g. UK £800mn, Canada \$1.8bn, Australia \$300mn
- Pilot projects including Algeria, Canada, China, Germany, Norway, Japan, UAE, UK, USA







Can current reservoir experience be used?

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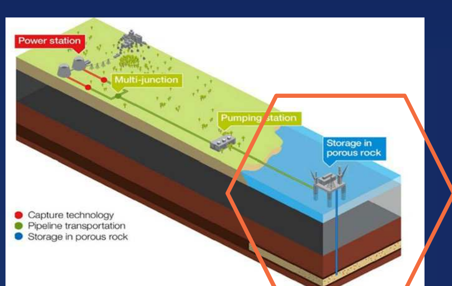
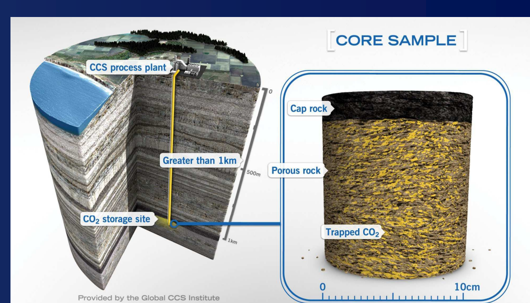
Similar principles are used in subsurface CCUS vs other reservoirs

- Understanding the petrophysical, geomechanical, and geological properties of the injection target formation
- Identifying the capacity of the overlying seal unit
- These are often the same reservoirs that have been previously studied and understood!





Types of study that can help with CCUS

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Core analysis and **petrography/mineralogy**	Understand the nature of reservoirs and caprock
Dynamic properties	Corefloods for relative permeability and residual saturations
Enhanced oil recovery (EOR) *– if injecting to HC reservoir*	Potential to combine storage with enhanced production Corefloods to determine microscopic sweep efficiency
Gas storage cycling	Requires study of possible hysteresis scanning curves
Rock Mechanics/ geomechanics	Understand the reservoir strength and help plan injection operations
Fluid analysis	Characterize native fluids & understand compatibility with CO_2 Understand potential for miscibility, for possible EOR

Types of study that can help with CCUS

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Fluid-fluid & **Rock-fluid-fluid**	Compatibility studies of reactions between native rock & fluids, including scaling, incompatibility, and reaction with minerals
Flowrate dependency	Corefloods to investigate potential for fines mobilization by gaseous or dense phase (supercritical) CO_2
Operational sequence	Corefloods to look at drilling/completion/recompletion/ injection operations and identify opportunities to maximize injectivity
Simulation of thermal cycling	Reservoir temperature conditions to understand impact on rock and wellbore cement when cold fluids are introduced into a warm wellbore

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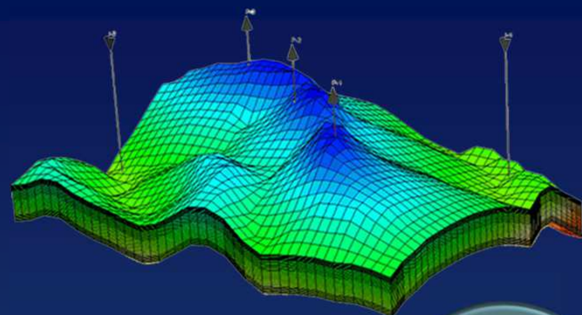
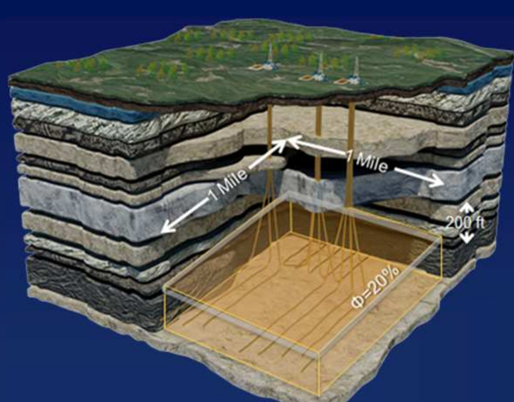
Characterising and understanding the rocks

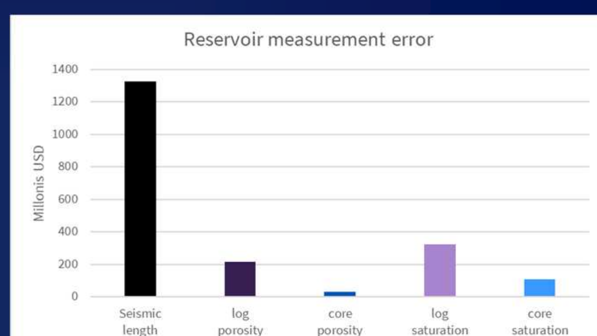


- Density
- Porosity
- Permeability
- Mineralogy
- Grain size distribution
- Pore size distribution
- Relative permeability
- Scaling
- Rock mechanics
- Capillary Pressure
- Wettability
- Fluid analysis
- Rock-Fluid interactions
- Residual saturations
- Enhanced oil recovery
- Formation damage

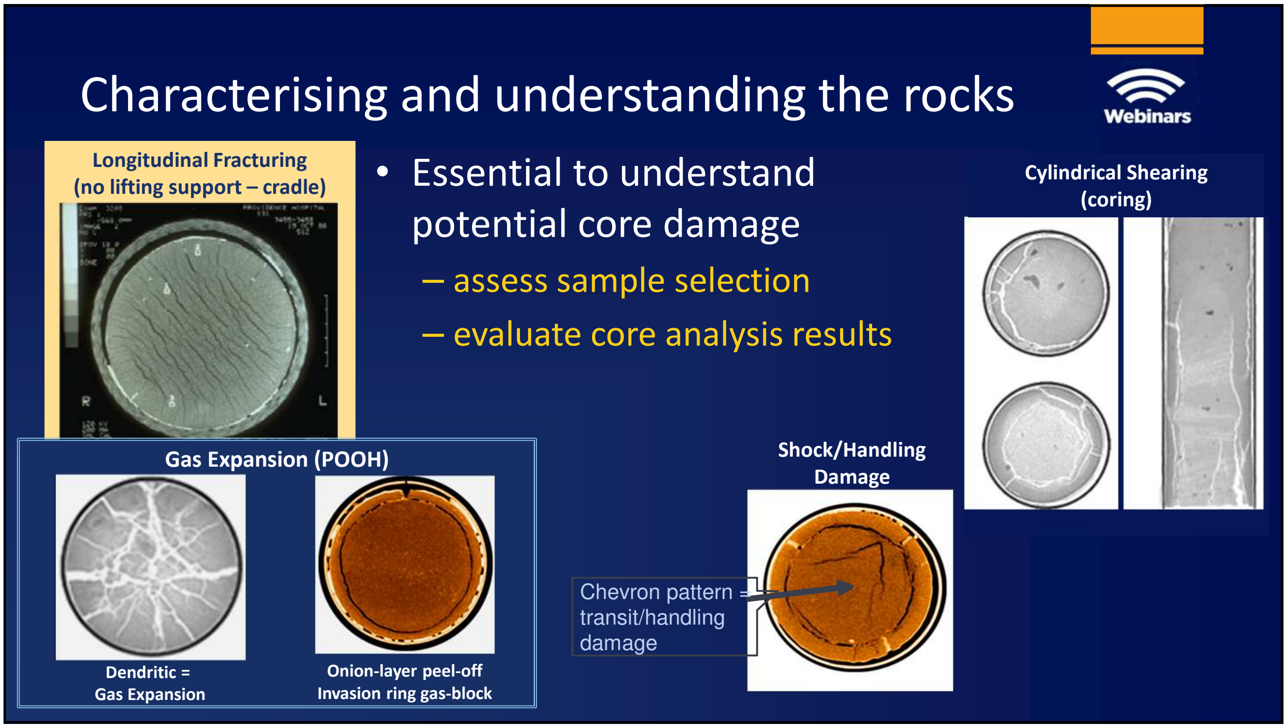
Characterising and understanding the rocks



- Seismic height error – ca. ± 15% length
- Log porosity – ca. ± 3.5 porosity units (p.u.)
- Log saturation – ca. ± 10 saturation units (s.u.)



- Controlled core data
  - Core porosity - ± 0.5 p.u.
  - Core saturation - ± 3 s.u.
- Possible uncertainty reduction: 200 MM$ - based on $50 /ton CO_2


Characterising and understanding the rocks
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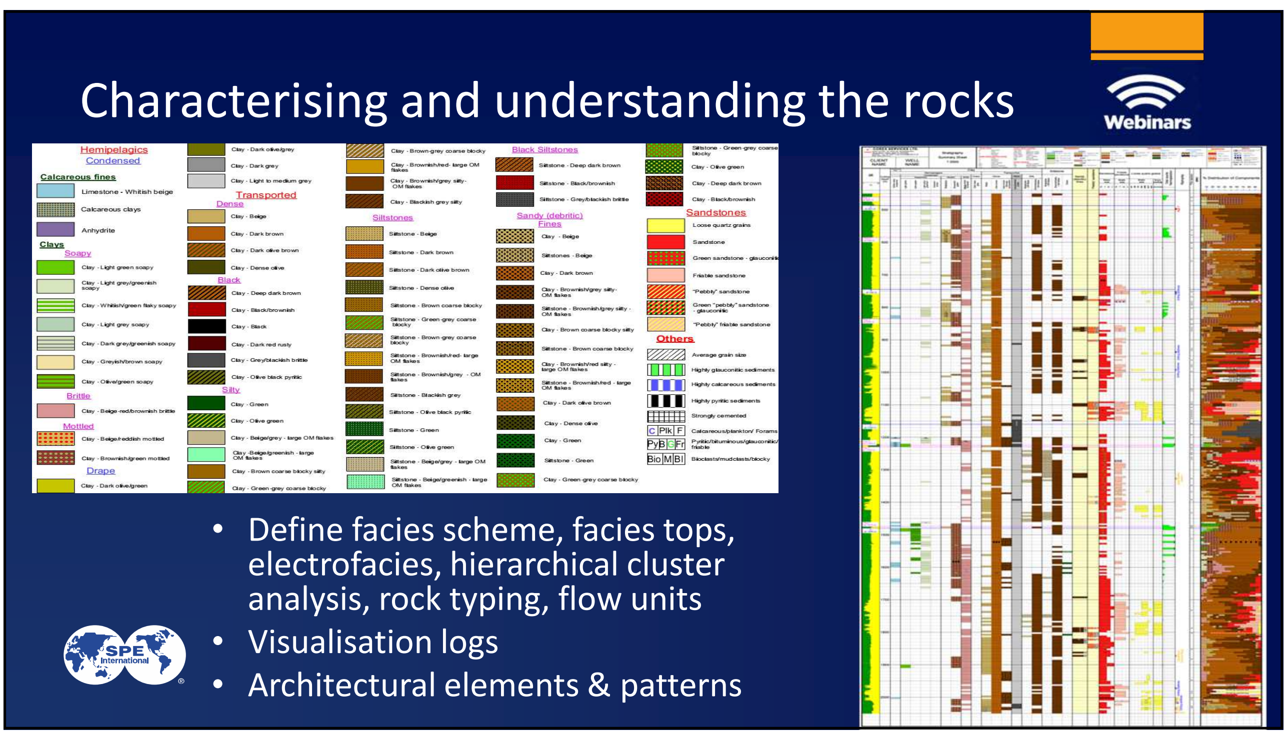
Longitudinal Fracturing
(no lifting support – cradle)
• Essential to understand potential core damage
– assess sample selection
– evaluate core analysis results
Cylindrical Shearing
(coring)
Gas Expansion (POOH)
Dendritic =
Gas Expansion
Onion-layer peel-off
Invasion ring gas-block
Shock/Handling
Damage
Chevron pattern =
transit/handling
damage


Characterising and understanding the rocks
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• Define facies scheme, facies tops, electrofacies, hierarchical cluster analysis, rock typing, flow units
• Visualisation logs
• Architectural elements & patterns
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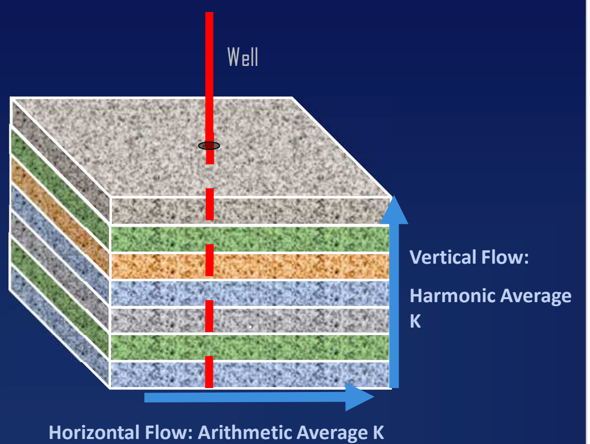
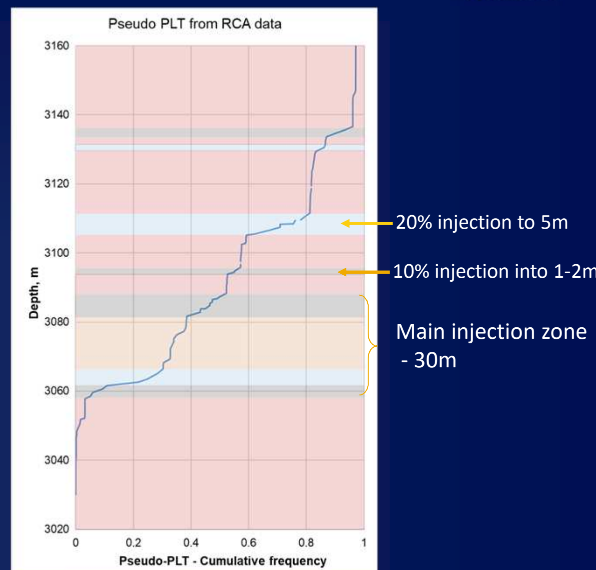
Characterising and understanding the rocks





Core Analysis and Petrography

Seal Unit

- Seal capacity
  - Strength / Threshold
- Seal integrity
  - Failure stress
- Exposure properties - CO_2 impact (time-based)

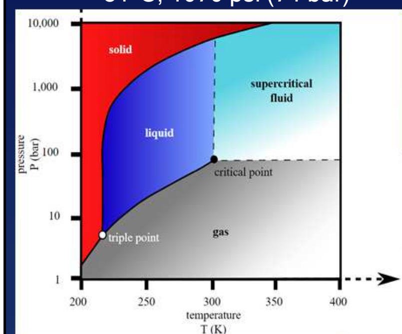
Reservoir

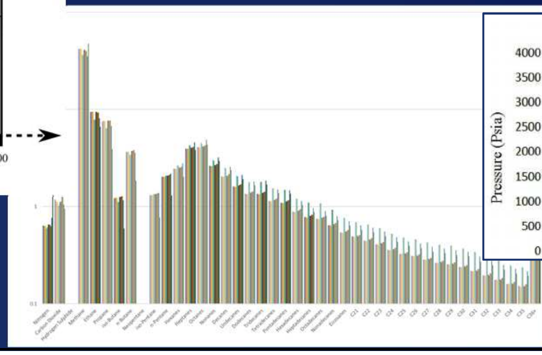
- Current properties
  - Storage capacity
  - Injection capacity
  - Petrophysical characterisation
  - Petrographic characterisation
- Exposure properties
  - CO_2 impact

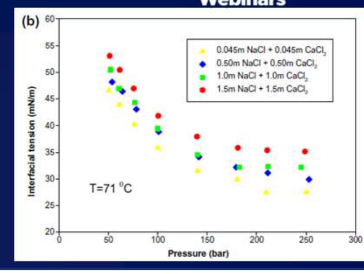
Fluid analysis

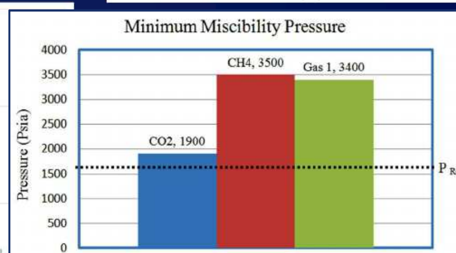
- Gas / Liquid / Supercritical fluid
- Water chemistry
- Water-CO_2
- CO_2-hydrocarbon if considering EOR-CCS

Critical Point
31°C, 1070 psi (74 bar)



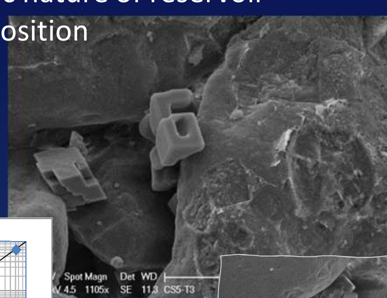


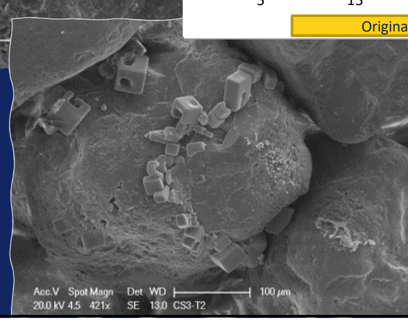


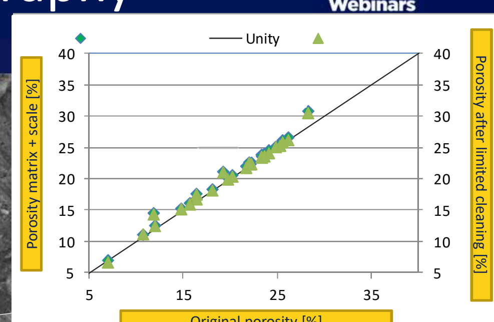


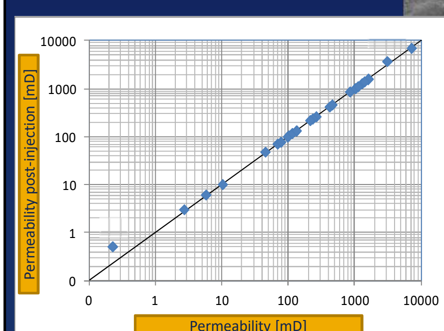
Core Analysis and Petrography

- Process designed to specific nature of reservoir mineralogy and fluid composition









Core Analysis and Petrography

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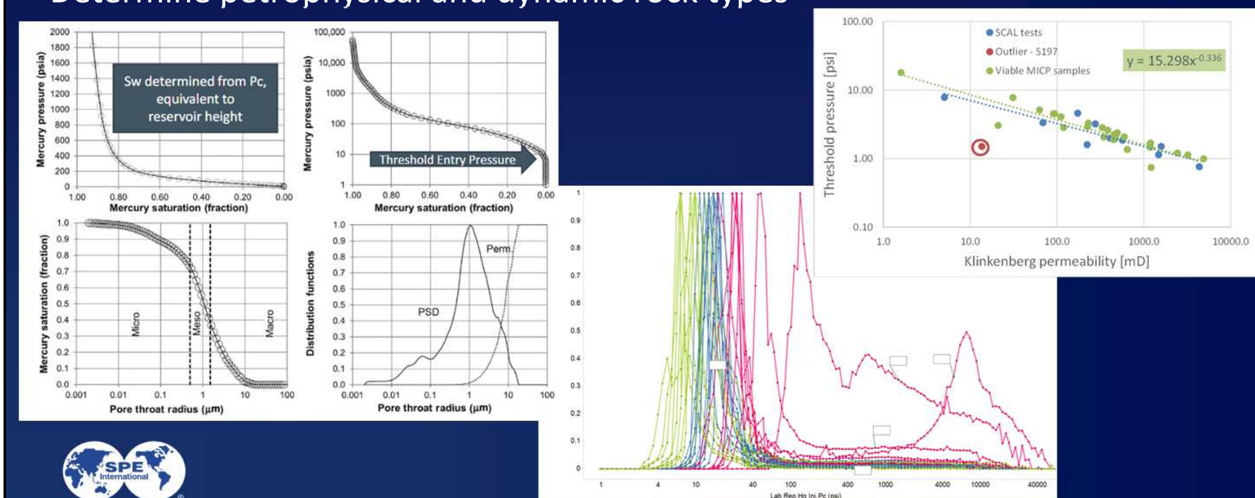
- Determine petrophysical and dynamic rock types



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Core Analysis and Petrography

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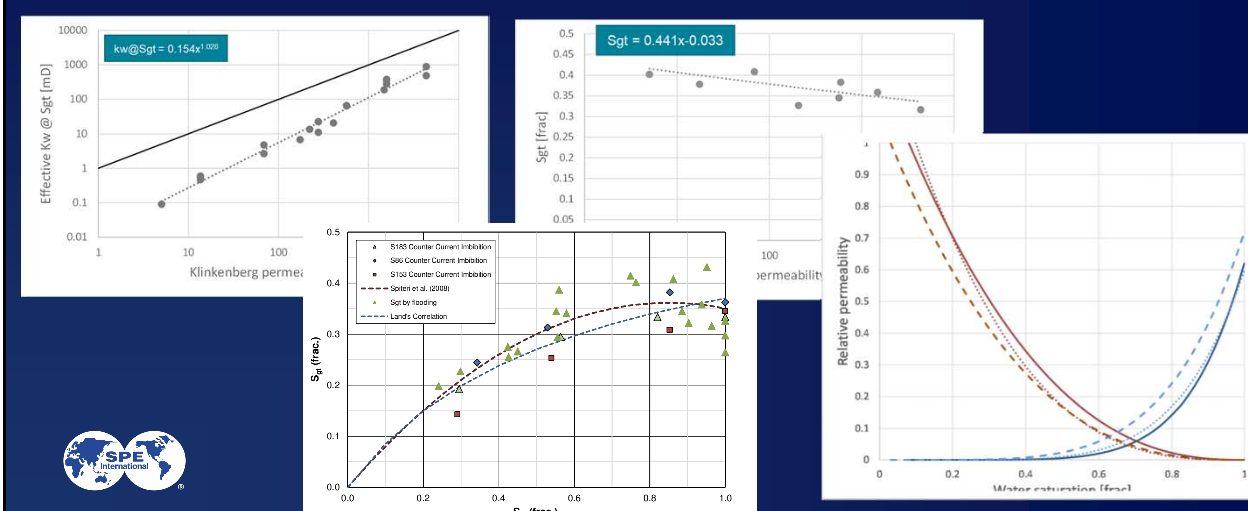
- Determine petrophysical and dynamic rock types



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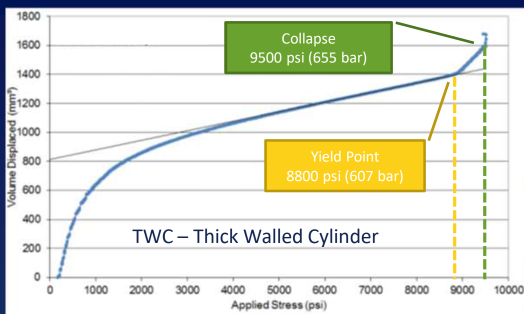
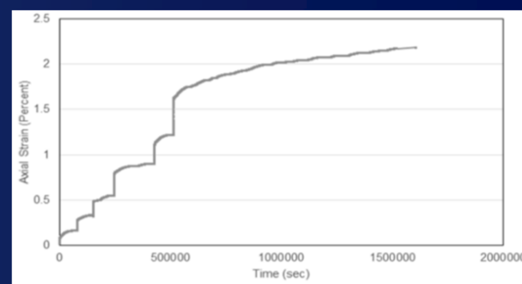
Rock Mechanics

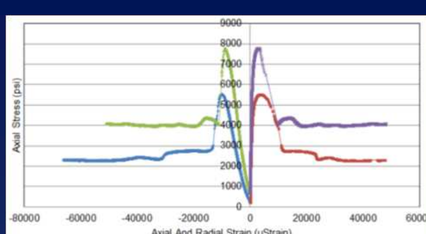


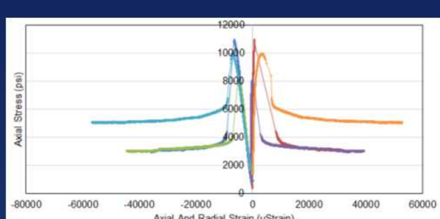
- Thick Walled Cylinder (TWC)
- Uniaxial Stress (Creep)
- Acoustic Travel Time
- Tensile strength

- Triaxial Compressive Strength
  - Single stage
  - Multi-stage
- Pore volume compressibility



Rock Mechanics

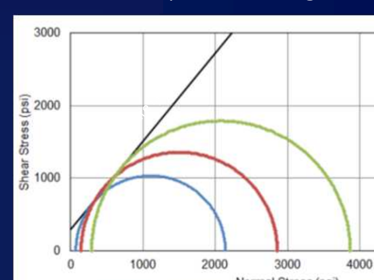


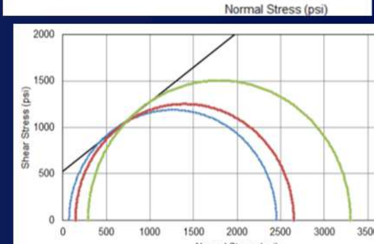


Stress (bar)	ΔYM	ΔPR	ΔPeak Stress
20	0.97	0.81	0.92
50	0.82	0.41	1.15
100	1.27	0.74	1.20
		Residual Strength	**1.04**

- Rock Strength
  - Current
  - After CO_2 exposure

Triaxial Compressive Strength



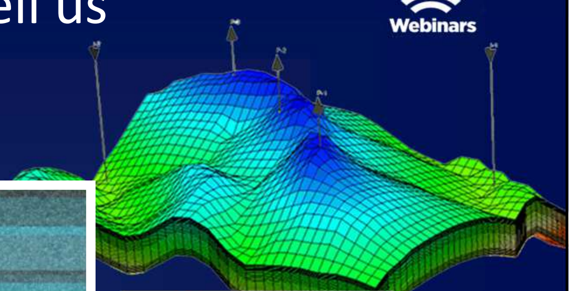


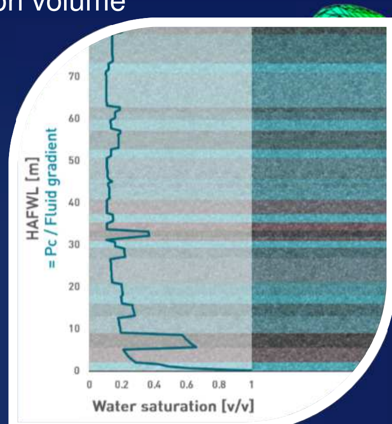
Core Analysis and Petrography

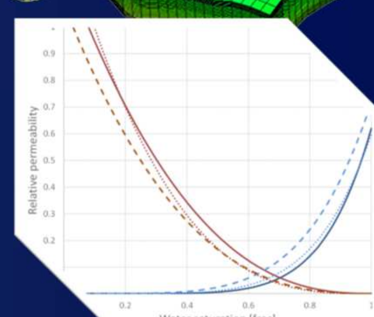
- How does exposure to CO_2 impact on reservoir & seal properties?

What all this can tell us

- Modelling CO_2 injection needs data input
  - Storage capacity
  - Saturation vs injection volume
  - Saturation vs height
  - Reservoir integrity
  - Wellbore stability
  - Exposure impact
  - Fluid properties







What about well operations?

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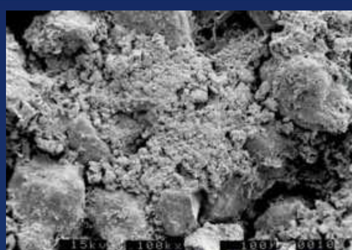
Formation Damage

- Reservoirs material (rock & fluids) can react with operational fluids, injection fluid, changes in conditions (P & T)
- Reactions can reduce permeability and production/injection
- Reducing risk & Add value by identifying the change mechanisms



Why is this relevant to CCUS?

- Well operations will be carried out
- CO_2 can react with reservoir material
- CO_2 can amplify scaling risk

Wellbore operations

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- What is the CO_2 going to be injected into?
  - New well, convert existing well?
- What are we going to do prior to injection?
- Could these operations impact upon injectivity?
- Can damage be avoided?

How to examine this

- Reservoir-conditions laboratory simulations
- Examine planned well operations or well history + planned conversion
- Measure impact, identify & visualise alterations
- Use data to confirm operations or identify potential for improvement

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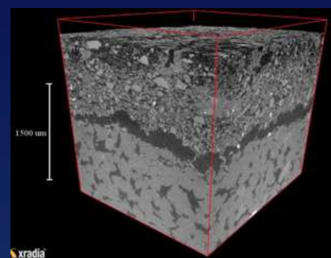
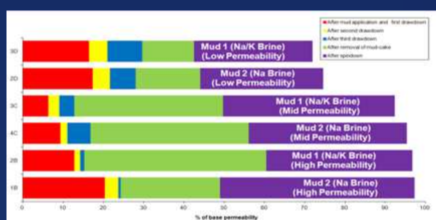
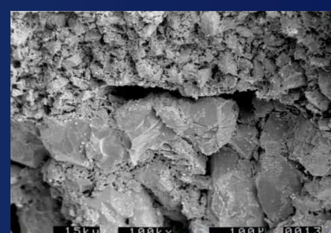
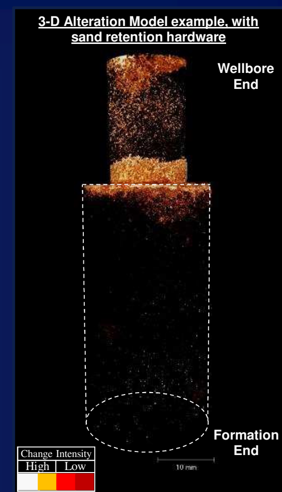
Reservoir-conditions coreflood simulations

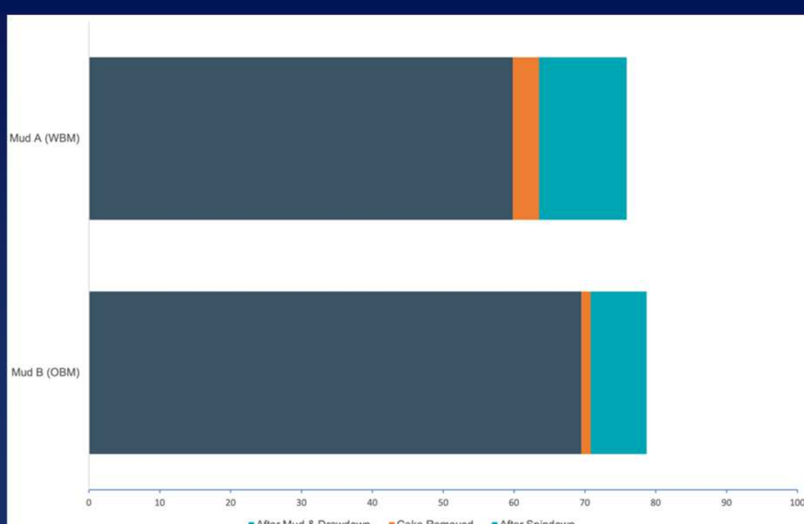








Case study: drilling CCUS well



Injection Issues

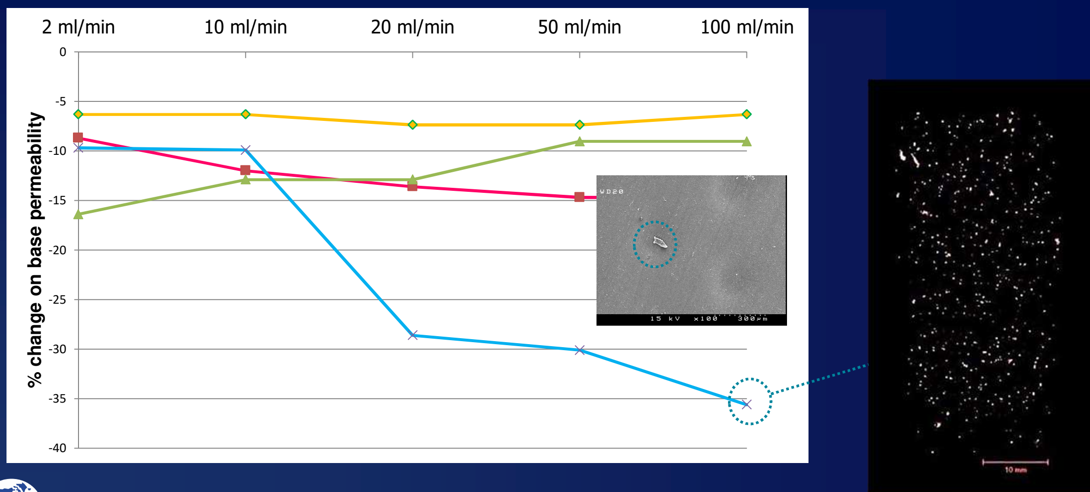
- Does CO_2 injection cause fines migration or other change mechanisms?
- Is this due to rate/viscosity, chemistry, or a combination?
- Is there a difference when injecting gaseous, liquid or supercritical CO_2?

How to examine this

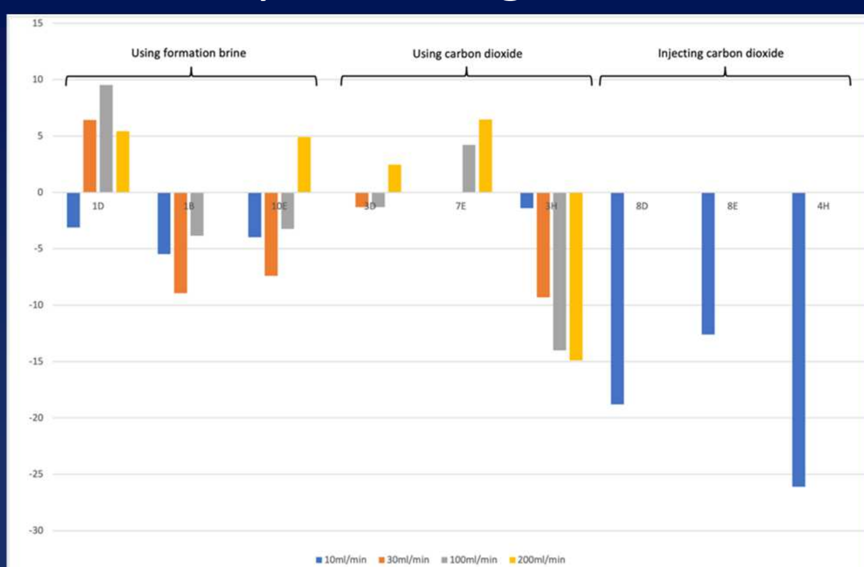
- Reservoir-conditions laboratory simulations
- Interaction with representative reservoir material
- "Flowrate dependency", fines migration, injection
- Are there changes, what changes, caused by what?
- Is any impact upon injection inevitable, is it acceptable, or can it be avoided/removed?

Examining carbon dioxide safely

Permeability vs injection rate



Case Study: fines migration



Compatibility & scaling

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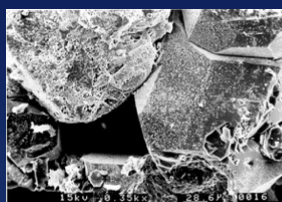
- Is there a risk of precipitation due to injection?
- Is it caused by chemistry, change in conditions, or both?
- What precipitates and is it avoidable or treatable?



How to examine this

- Range of options, typically computer modelling + coreflood laboratory simulations
- Model various conditions & mixes – likelihood & scale types
- Inject using representative core and fluids – what happens and where
- Use data to put scaling risk into context & help decide whether avoiding or remedial actions may be necessary

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Scale prediction modelling

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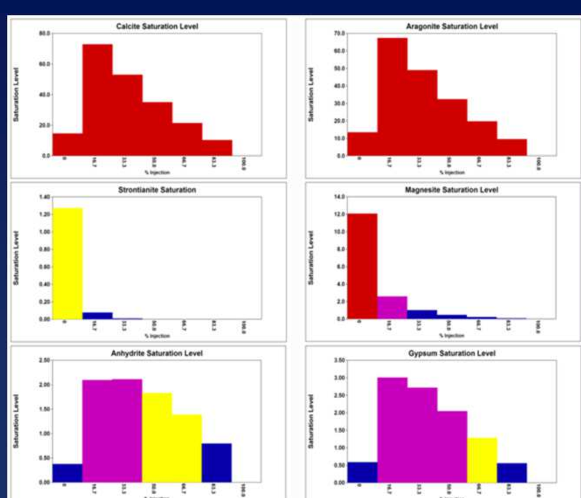

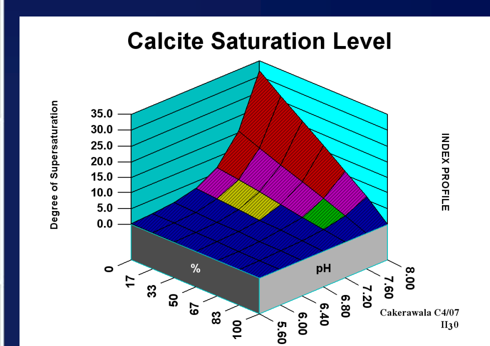

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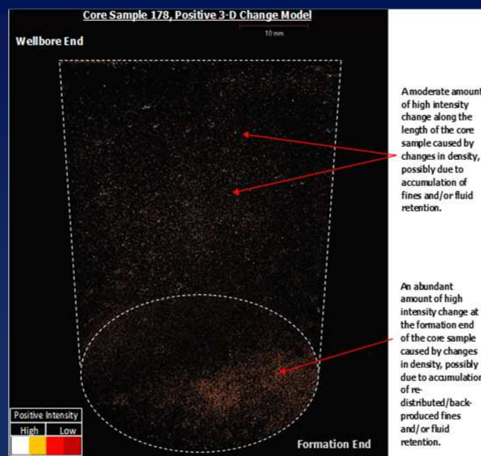
Visualising changes



Treating damage

- Was the mechanism identified?
- Is treatment required to avoid or remediate?
- Do the treatments work as intended or have unexpected side-effects?

How to examine this

- How and when will the treatment options be deployed?
- Repeat studies with treatment - does it have an impact?
- Important to understand & visualise the impact as well as any unexpected results
- If necessary, review candidates and repeat

Understanding treatment fluid impact

- Severe reduction in permeability
  - Approx. 60%
- What caused that alteration?

New visualisation techniques show us more

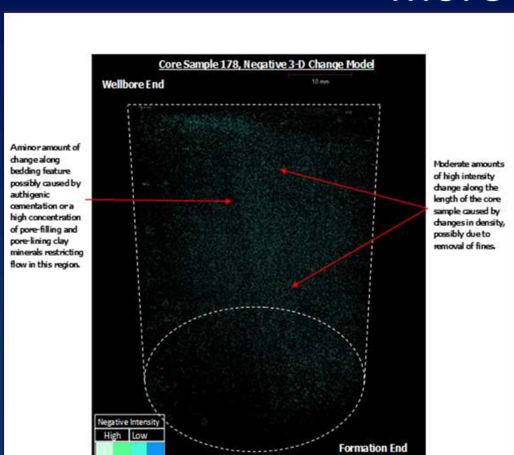


Fig 2: Negative 3-D 'change model' of the high intensity features scattered throughout core sample 178. A white border has been included around the edges of the core sample for depiction purposes only.

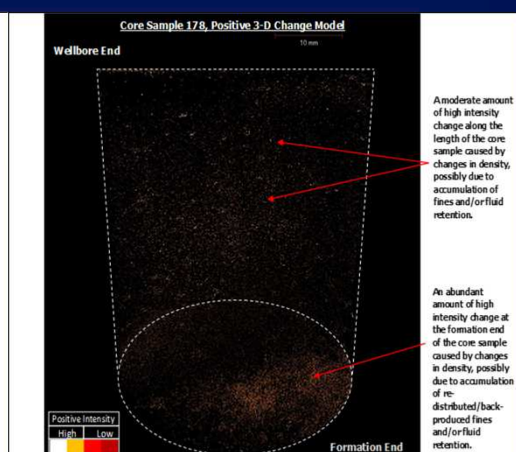


Fig 3: Positive 3-D 'change model' of the high intensity features scattered throughout core sample 178. A white

Was the treatment suitable?

- Combination of changes = severe reduction in permeability (ca. 60%)
- Clay:
  - some removal,
  - some accumulation
- Inhibitor:
  - fluid retention, particularly associated with clay minerals
- Overall:
  - reduction in pore volume
- Result:
  - suitable chemical?

Final thoughts

- Vast subsurface experience, and how to examine them, exists. Use it!
- Reservoir chemistry & properties and human interventions define CO_2 injectivity
- Understanding behaviour at every process stage reduces uncertainty to reduce risk and add value
- As CCUS evolves, so will techniques. Chemical and microbial sequestration may move to reservoirs. There is vast experience in advanced testing available
- As always: there is no substitute for quality laboratory data using representative materials!

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Any Questions?

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