5th International Offshore CCS Workshop

Liverpool Bay CCS: Technical aspects of CO_2 storing in depleted hydrocarbon fields

19th – 20th May 2022

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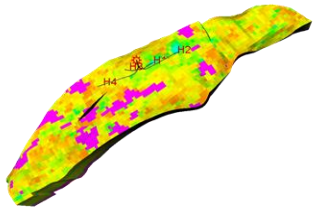
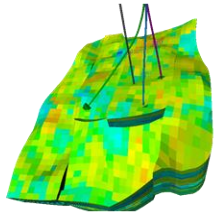
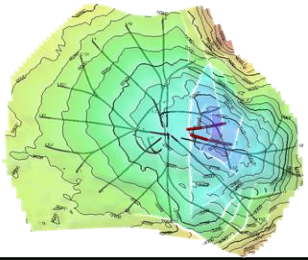
Liverpool Bay CCS – Storage Sites Overview







	Hamilton Main	Hamilton North	Lennox
Fluid Type	Wet Gas	Wet Gas	Light Oil (+ gas cap)
Top Reservoir Depth (ft TVDss)	2270	2590	2450
Porosity (%)	10-23	10-23	10-23
Average Permeability (mD)	600	500	2000
Thickness (ft)*	450	500	900
Initial Condition [P,T]	97 bar, 31.6°C	106 bar, 29.2°C	112 bar, 34.4°C
Start-up	1997	1996	1996
Well type	2 Deviated 2 High Angle (+ 2 Explo)	3 Deviated (+1 Explo)	2 Deviated, 4 Horizontal 8 Multi Drain Horizontal (+ 4 Explo)
RF % (@ YE 2021)	95.2	93.4	89.4

CCS Subsurface Studies Workflow

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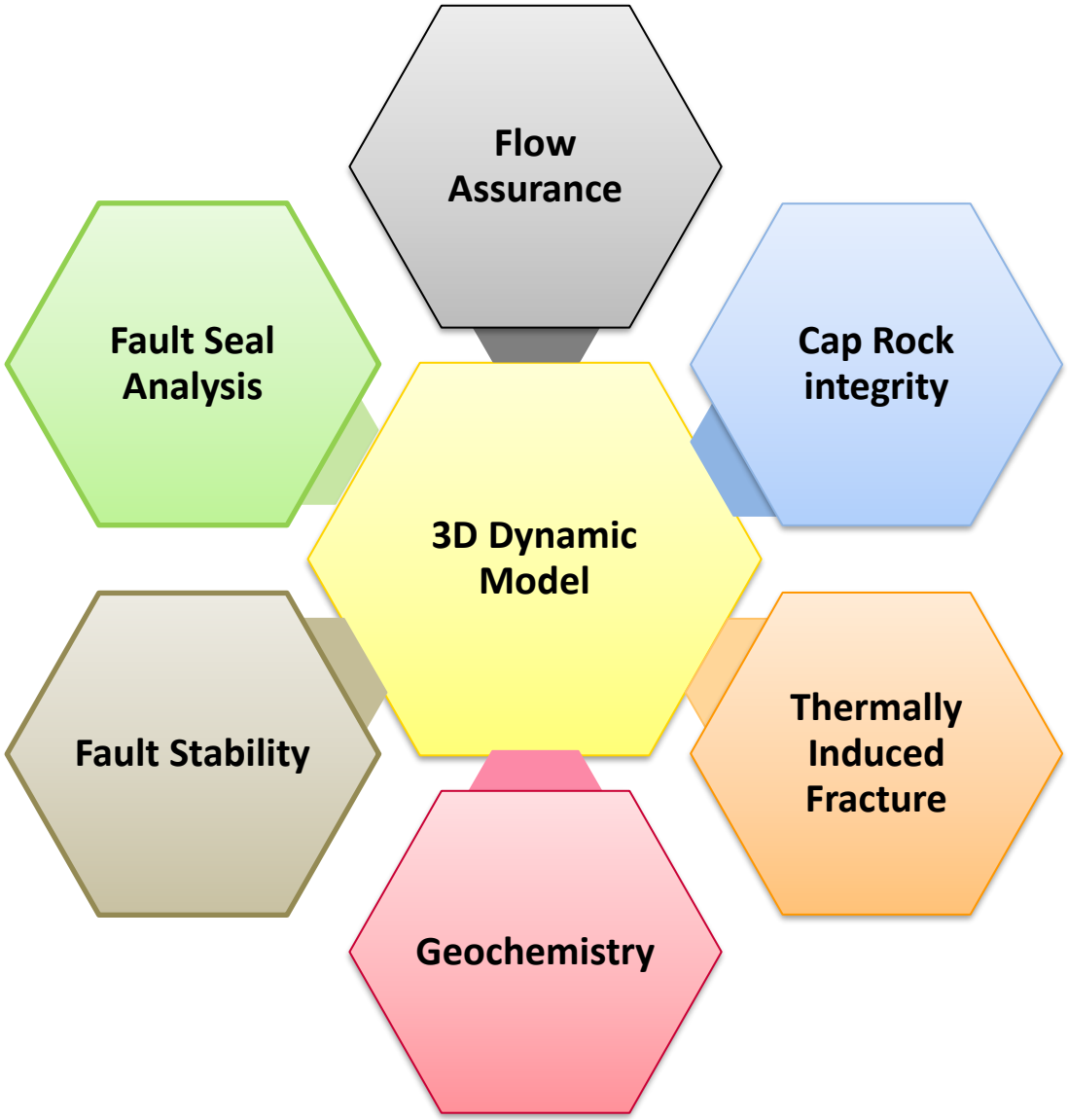
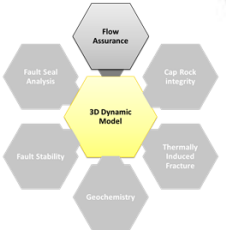
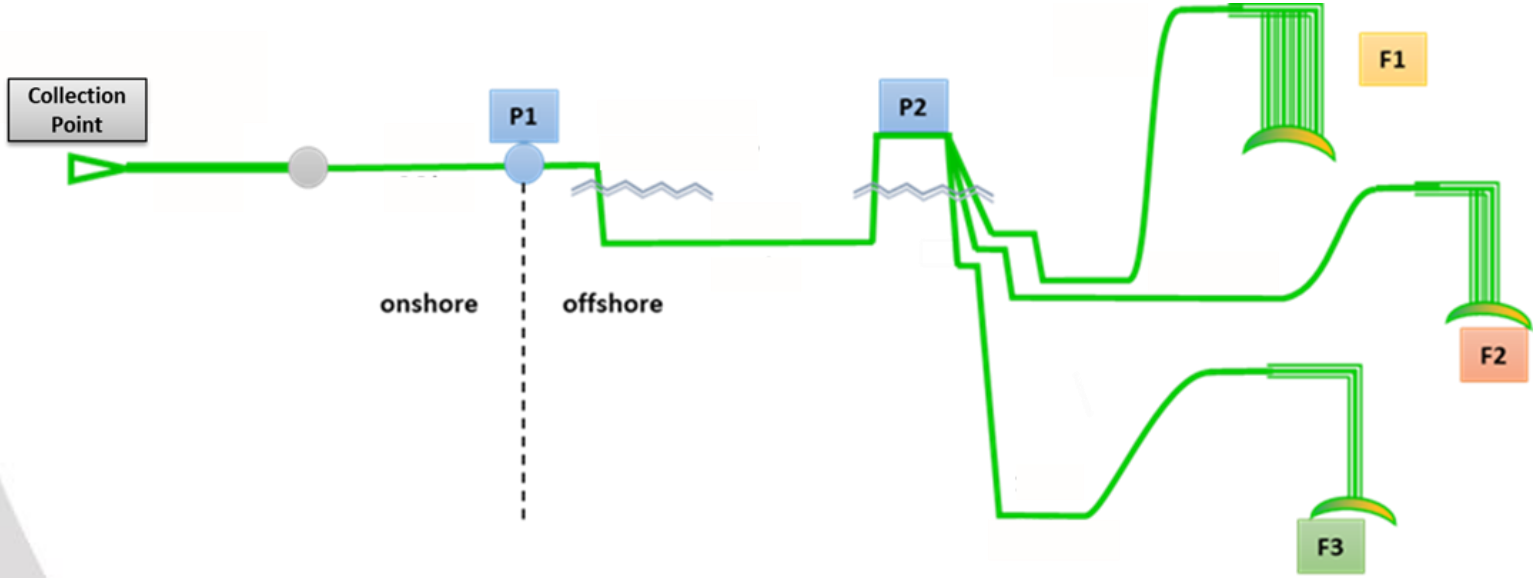


- *Rates/pressures from 3D dynamic model fed to CCS Subsurface Special Studies*
- *Evaluation of 'storage complex' behaviour to evaluate additional constraints on rates/pressures*
- *Thermal effects evaluated within each specialistic study*
- *Continuous iteration until no more constraints emerge from special studies outcomes*

Flow Assurance



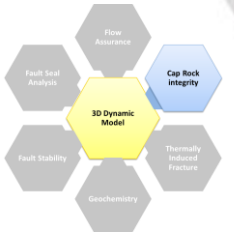
- *Flow Assurance studies objectives:*
  - *Define process units and equipment to guarantee the transport within the system design constraints ($\min_t BHT = 4\,°C;\ \max_t P_{flowline}$)*
  - *CO_2 behaviour across the system (from gathering point up to the storage units)*
- ***Technical aspects***
  - *Parallel storage unit filling*
  - *Linking 3D dynamic model with flow assurance simulations*
  - *Low-P/Low-T reservoirs*



Main outcomes

- *Paired Flow Assurance – 3D Reservoir model*
- *Surface equipment design to honour project injection rates*
- *BHT safely above the limit for all the wells involved*

Cap Rock Integrity

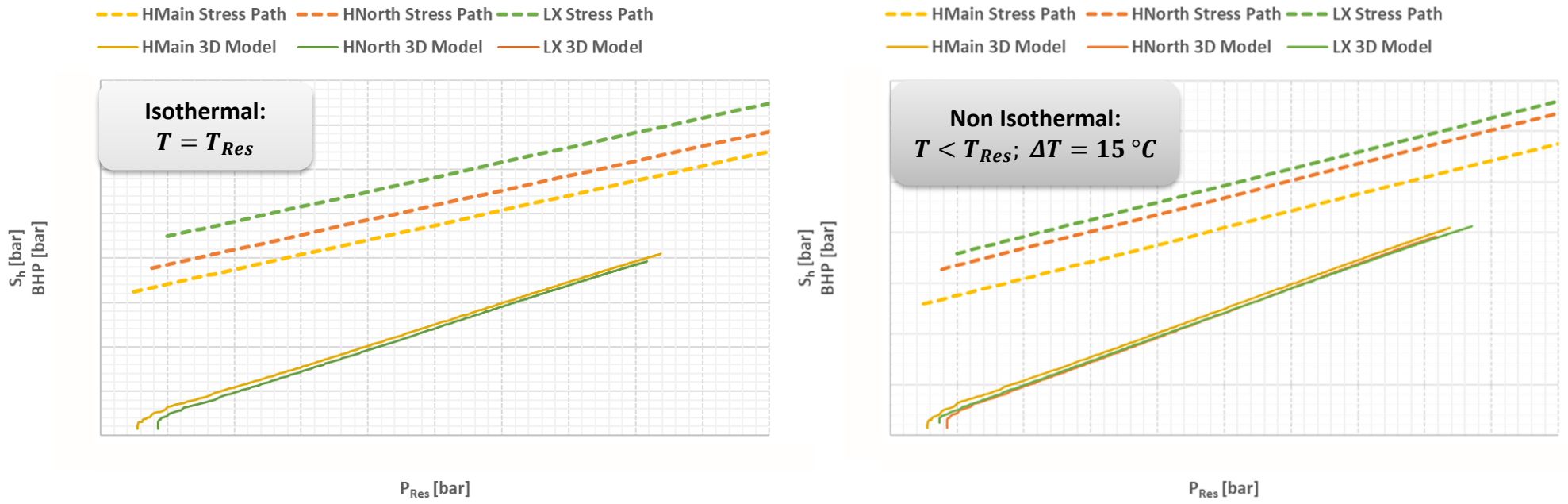


- *Evaluation of cap-rock stress field under CO_2 injection via 1D analytical models*
- *Dataset comprising of core (2020 experiments) and log data (DTC), integrated with literature (thermal rock properties).*

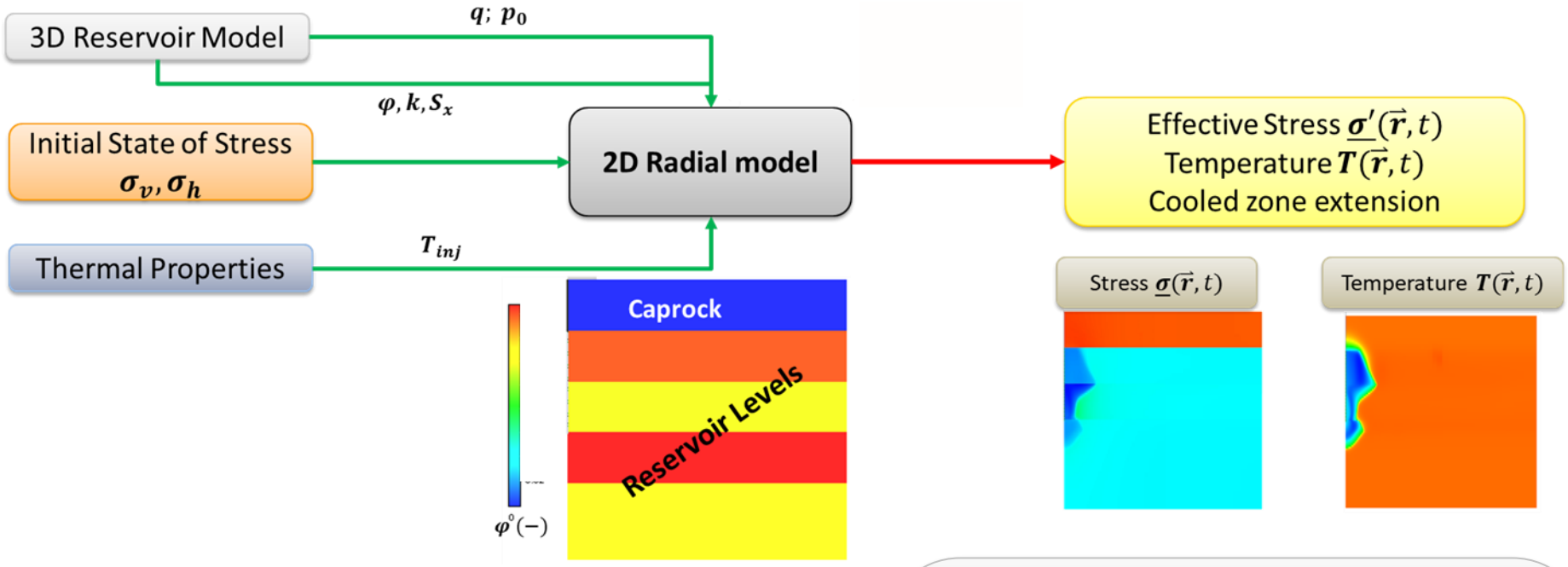
Main outcomes

- *Reservoir repressurization path below the minimum horizontal stress envelope*
- *Injection partitioning sustainable*

Stress Paths



Thermally Induced Fracture



- *Cold fluid injection into a warmer formation induces an alteration of the stress state*
- *Methodology standardisation w/ full integration of multiple data sources*
- ***Technical challenges***
  - *Low-P, Low-T formations*
  - *Compositional 2D radial thermo-hydro-mechanical model: identification of a suitable numerical code*

Main Outcomes

- *Near-wellbore stress and temperature distributions*
  - *Effective stresses positive for the whole duration in each storage complex*
  - *Limited cooled front extension during injection operation*
- ***No risk of tensile failure occurrence***

Geochemistry (1)

- *Geochemical studies objectives:*
  - *Trapping mechanism identification*
  - *CO_2 – triggered minerals dissolution/precipitation*
  - *CO_2 – induced near wellbore dry-out effects (salts precipitation) due to H_2O vaporization (stripping)*
- ***Technical aspects***
  - *Mineralogy and chemistry: formation data retrieval and experimental analysis*
  - *Main physical phenomena determination*
  - *Numerical code identification to couple fluid-dynamics and geochemistry*

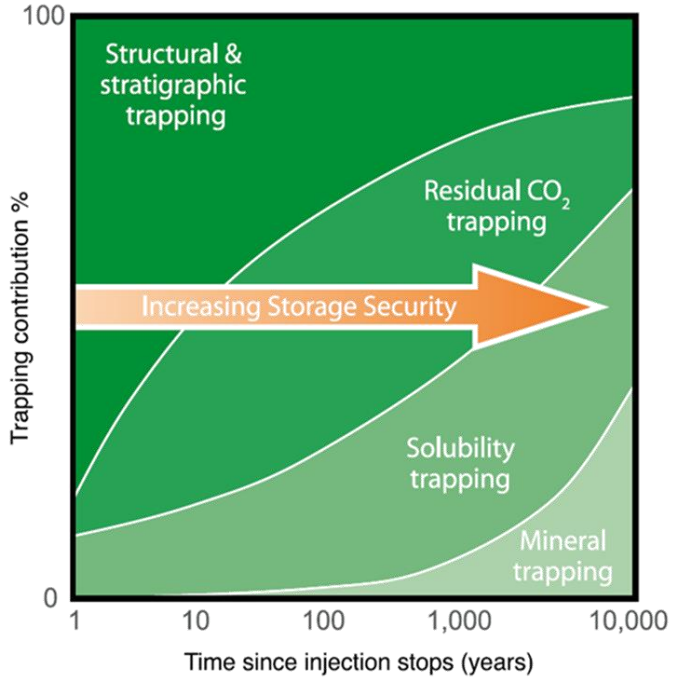
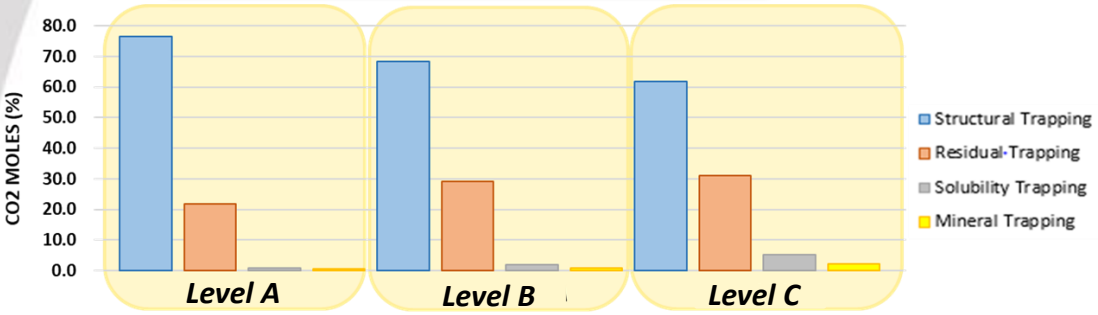


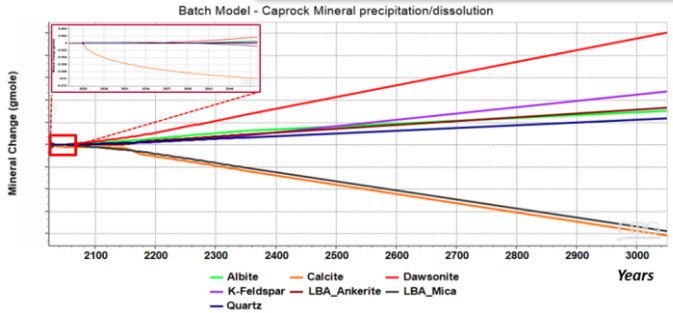
Image Source: IPCC. (2005). Carbon Dioxide Capture and Storage.

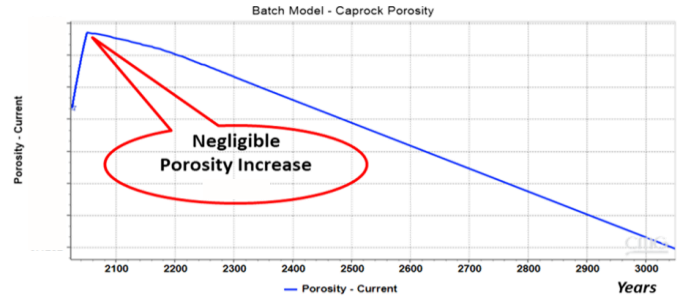
Geochemistry (2)

Trapping Mechanisms

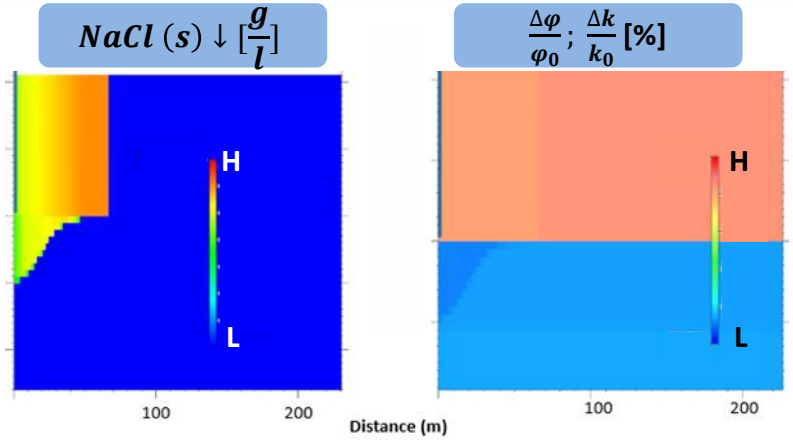


CO_2- triggered caprock-brine interactions: Kinetic Models





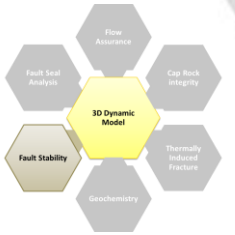
CO_2-triggered phenomena in reservoir rock



Main Outcomes

- *Negligible CO_2 mineral trapping*
- *Limited reactivity of caprock lithology*
- *No threats to well injectivity recognized*

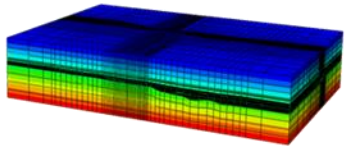
Fault Stability Analysis (1)



Scope

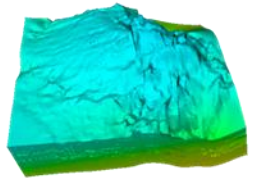
To calculate the effective stress alteration on faults and to assess the rate partition avoiding any potential slippage occurrence

Geomechanical ***Finite Element model***



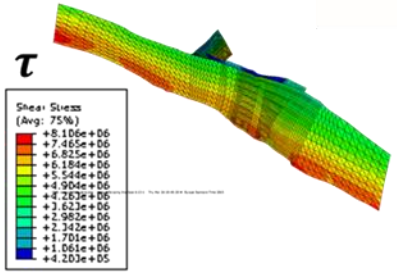
Faults geometry *from the structural model*

Dynamic Model outcomes

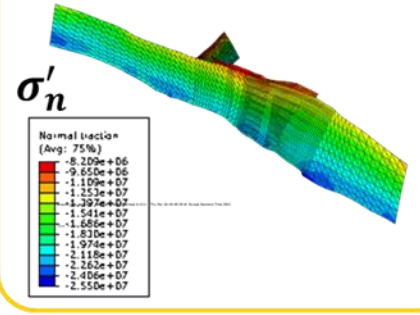


Stress projection *on the fault surface to evaluate normal* (σ'_n) *and shear* (τ) *components*

τ

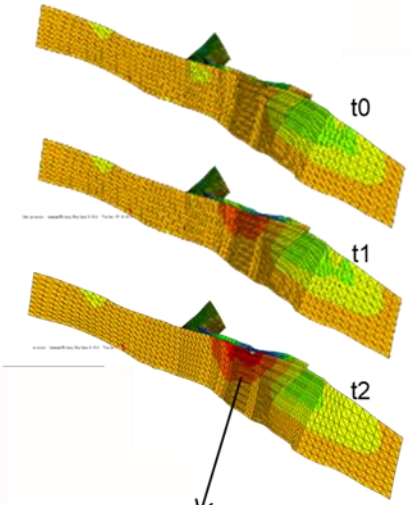


σ'_n



$$ST = \frac{\tau}{\sigma_n{}'}$$

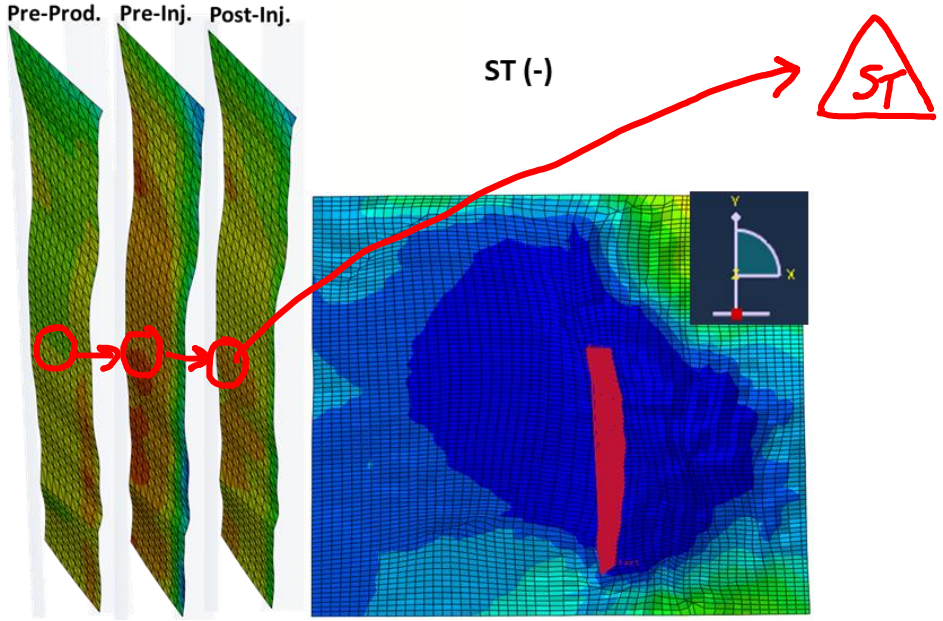
Slip Tendency (ST) computed *on fault surface at different times* (***t***)



High ST Area
(**NO slip** for $ST < \mu$)

Fault Stability Analysis (2)

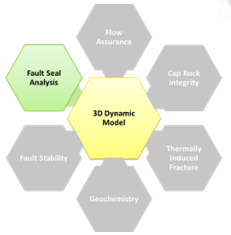
Results: slip tendency (ST)



Main Outcomes

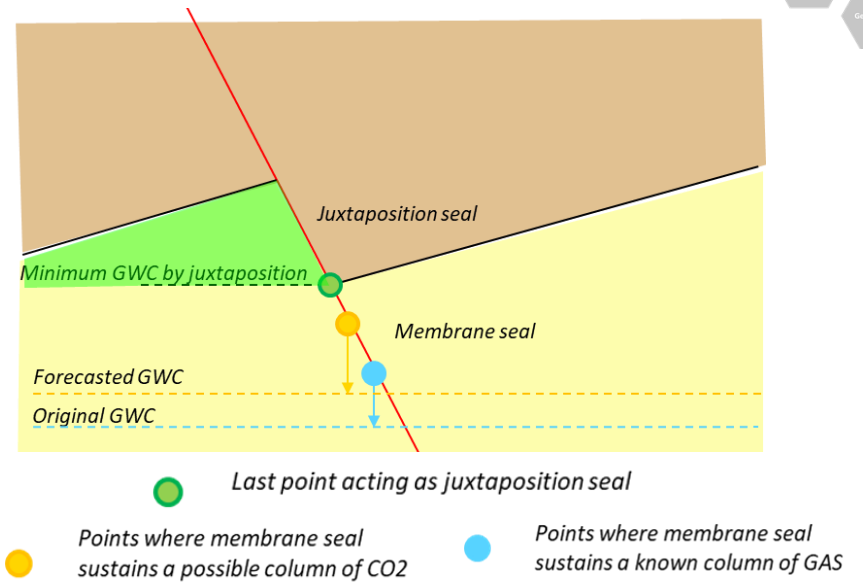
- *40+ faults analyzed across three storage units*
- *ST at the injection end (ST_2) always lower than initial fault ST (ST_0)*
- ***No critical faults** emerge from the fault stability analysis, so the risk of **induced seismicity** is **negligible***

Fault Seal Analysis



- *Fault Seal Analysis study purpose*
  - *Validate initial contact depths*
  - *Determine maximum CO_2 column height via deterministic and probabilistic approach*
  - *Quantify maximum sustainable pressure at fault level*

- ***Technical aspects***
  - *Methodology derived from exploration trap evaluation*
  - *Low-P and Low-T formation: CO_2 IFT properties*



Main Outcomes

- *Deterministic and probabilistic determination of CO_2 column height evaluation*

Conclusions and Way Forward

- *For Liverpool Bay CCS project, the **storage complex** and **FFD plan** are **de-risked** by an **extensive and robust subsurface database** and by a developed suite of **3D modelling** and **CCUS special studies** (geology, reservoir engineering, geomechanics, geochemical etc.)*

- ***To date studies confirm** the **suitability** of **Hamilton Main**, **Hamilton North** and **Lennox** to **securely store at least 109 MT** of carbon dioxide (base case); **no criticalities** are **recognized**.*

- *Some **activities** are **ongoing/planned** aiming **to fully de-risk** both **CO_2 conformance** and **containment risks**; study results will be included in the developed models*
  - ***Bathymetric** and **3D** high resolution **seismic** (for overburden characterization)*
  - ***Sedimentological study** on **Mercia Mudstone Group***
  - ***Laboratory experimental studies***

Thank you for your attention