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Carbon Capture Wells – The same, but different

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Elemental Energies

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Presentation Outline

- Introduction to CO2 stores
- What is the same and what is different about CCUS wells?
- Saline aquifer store wells
  - Lower completion selection
  - Salt precipitation and corrosion
- Depleted hydrocarbon wells
  - Re-use of legacy wells
  - CO2 phase behaviour in and beyond the lower completion
  - Well integrity challenges
  - Erosion
  - Hydrates and salt precipitation
- Laboratory testing and modelling
- Conclusions and Acknowledgements

What is CCUS?

- Carbon Capture Utilisation and Storage
  - Removal of CO2 from emitted gas and/or the atmosphere
  - Utilisation eg for enhanced oil recovery
  - Storage in subsurface reservoirs or “stores”

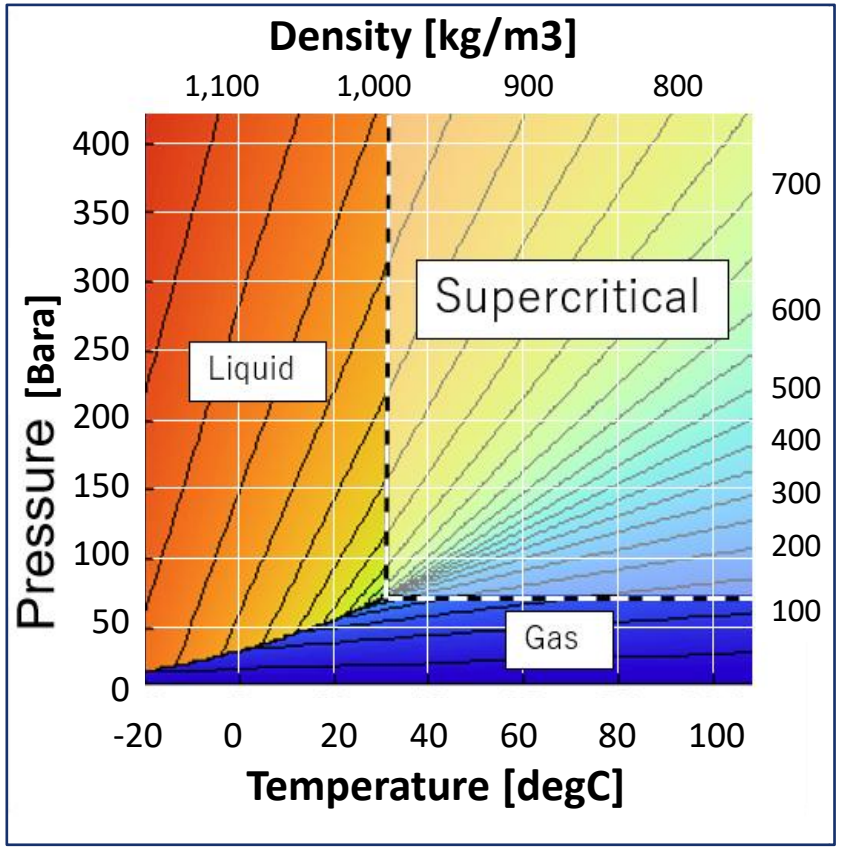
- This presentation will focus on storage
  - In saline aquifers
  - In depleted hydrocarbon reservoirs

What is the same?

- Purpose of Wells
  - Connect surface to reservoir (store)
  - Enable efficient communication between surface and subsurface
  - Must consider safety, well integrity, upper completion, lower completion and sand face design
- Multidisciplinary approach required
- Expensive, but critical to project delivery
- Operating (injection) lifetime

What is different?

- Fluids – CO2 can be challenging
- Temperature
- Phase behaviour
- Rates/velocities
- Corrosion
- Flow control, downhole choking, etc.
- Long term well integrity/security (really long term…..)



Saline Aquifers

- Need to be huge volume (in order to be viable)
- Well “reach” is permeability dependent
- CO2 plume gravity dependent – impact on well design/completion interval
- Specific challenges with:
  - Lower completion selection
  - Salt precipitation and corrosion

Saline aquifer stores – lower completion

- Sand production on well shut in needs to be considered – cross flow or CO2 hammer
  - Fluid hammer weaker than in water injection wells
  - Cross flow resulting in sand failure and production in reservoirs/stores with weak rock
- Completing injection wells with sand control can present significant formation damage challenges.
  - Residual mud and mud cake need to be addressed….
- Interactions between the injection fluid and the fluid (brine) in the store needs to be considered

Salt precipitation

- Both saline aquifers and depleted hydrocarbon reservoirs contain formation brine, often with salinities at or close to saturation.
- Injected CO_2 can absorb moisture from formation brines in the near wellbore and beyond
  - salt saturation principally in the form of halite (NaCl).
- Depleted gas reservoirs:
  - lower brine pore volume saturations
  - relatively modest volumes of salt deposited (increase of 10-15% volume of original brine volume)
- Saline aquifers
  - Much greater volume of solid salt possible
  - Reduction in porosity / permeability
- Water washing may be required
- For depleted gas reservoirs, introducing uninhibited fresh water to the near wellbore region could significantly increase the hydrate plugging risk.

Corrosion risk in saline aquifer wells

- Pure CO2 is not corrosive so if injection stream is dry then there is no risk until water is encountered….
- CO2 and formation brine are miscible
- Risk of formation of carbonic acid
- Risk to sand face completion integrity
- Shut in, back flow and cross flow risk
- Migration of brine – risk to lower (and upper?) completion integrity - convection

- Mitigation?
  - Material selection
  - Preflush/Overflush of chemical to prevent mixing of CO2 and brine in the wellbore (not so concerned about mixing in the reservoir/store)

Simulation of convection

- When injection well is shut in, convection could lift CO2/water up well resulting in increased corrosion risk higher up completion



Contaminants in CO2 and corrosion

- Sulphur oxides, nitrogen oxides, carbon monoxide, hydrogen sulphide and water can be present in CO2 “supply”
- In the presence of water, acids can then form leading to even greater corrosion risk than with CO2 and water

- Mitigation?
  - Decontamination of supply
  - Material selection
  - Preflush/Overflush of chemical to prevent mixing of CO2 and brine in the wellbore (not so concerned about mixing in the reservoir/store)

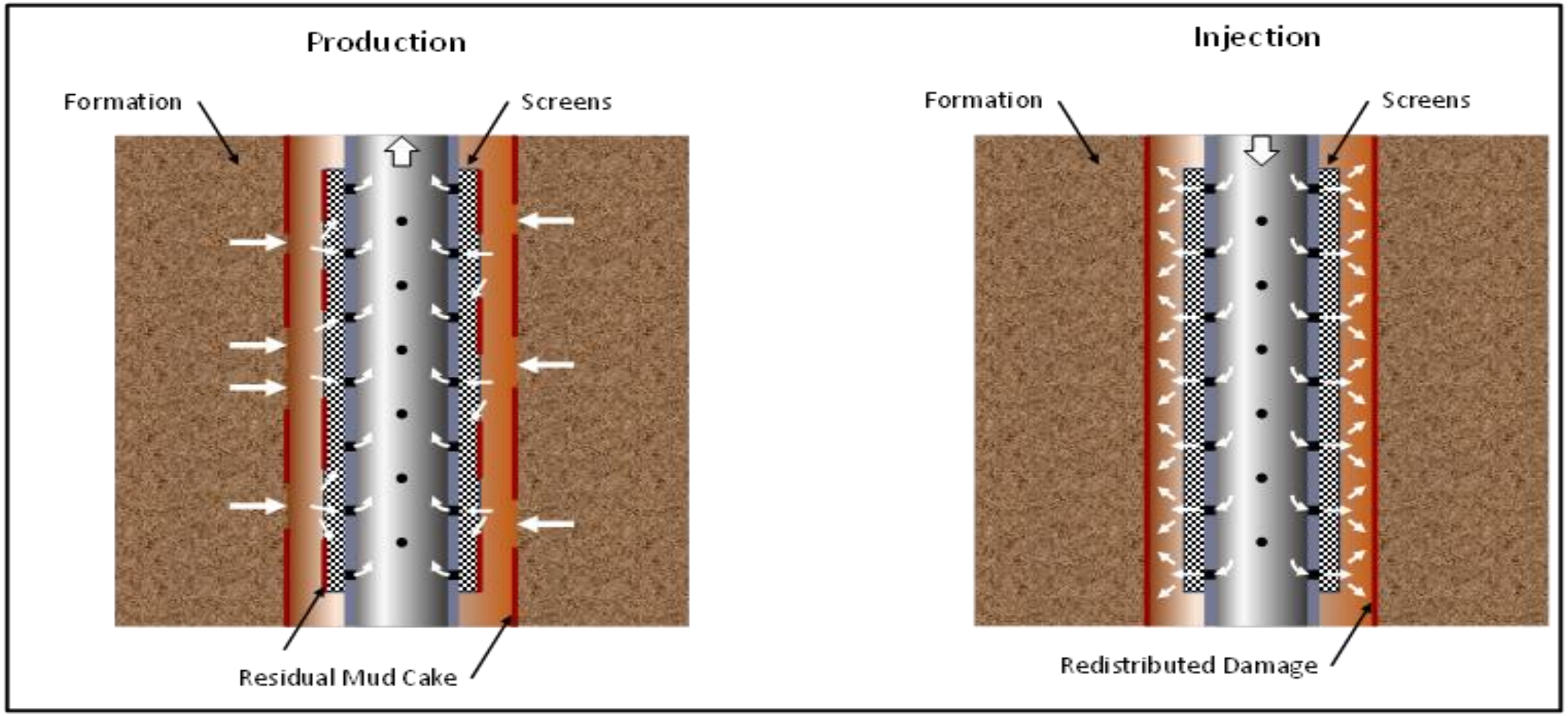
Depleted Hydrocarbon Stores
Well Challenges

- New wells may be challenging to drill and complete due to the depletion
  - significant overbalance likely
  - increased overbalance can lead to increased formation damage
- Flow back (clean-up) of depleted store wells is highly unlikely
  - challenges with direct injection for saline aquifers above also exist for depleted reservoirs.
- Significant cooling associated with CO2 injection can present further challenges
  - Joule Thomson cooling
  - Where and when?
- High rates of injection planned could also bring associated formation damage.
  - For many of the planned stores the injection rates are in excess of production rates during hydrocarbon production
  - High injection rates can increase the risk of fines migration and for injection wells fines are pushed deeper in to the formation
  - Away from the wellbore, as velocities decrease fines can accumulate and block pores

Re-use of legacy production wells

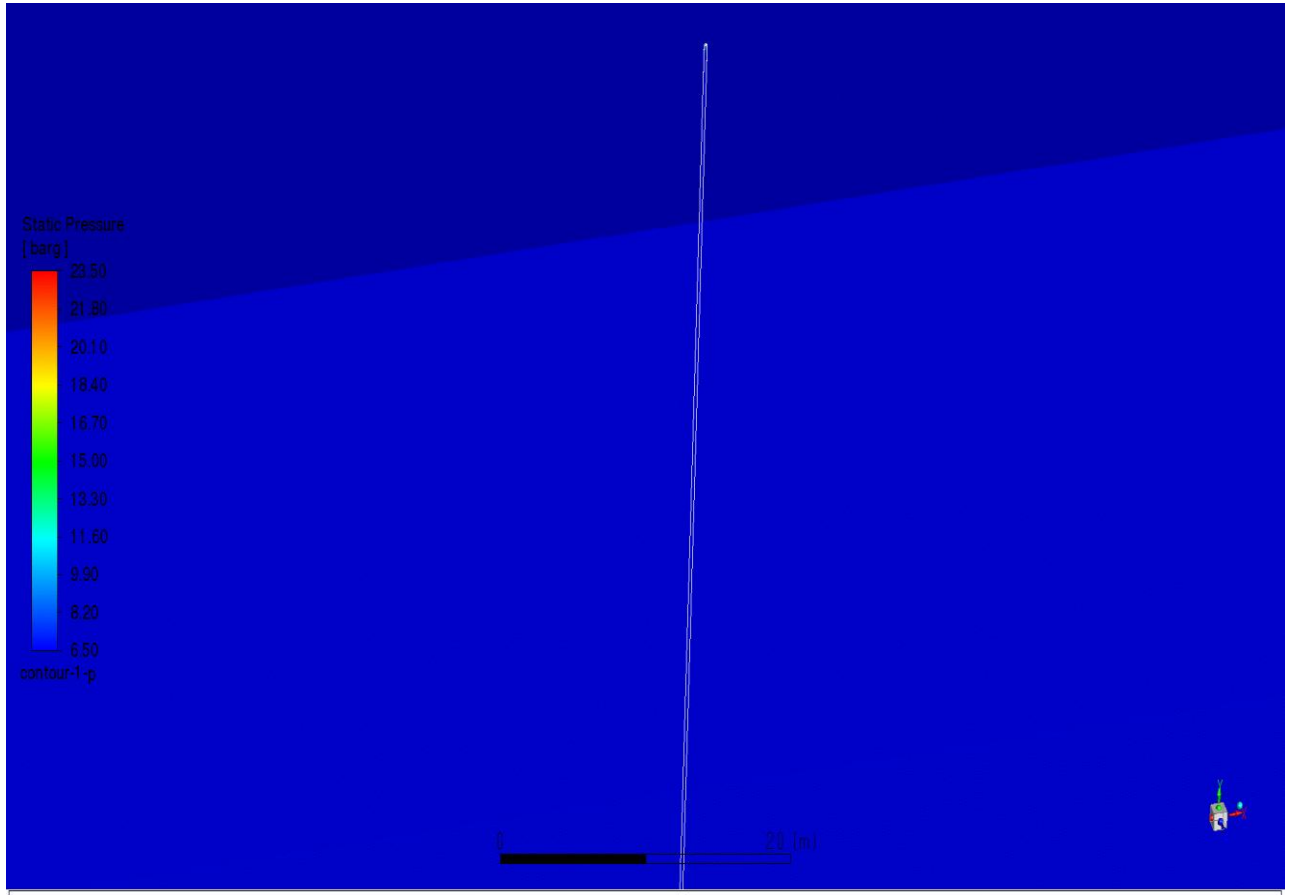
- Low cost injection wells
- Challenges with new wells drilling and completion – legacy wells may be best initial option
- Advantage – they have effectively been cleaned up with production flow for years if not decades
- However, legacy formation damage must also be considered –
  - Can not assume that wells that have flowed easily in the production direction will accept similar flow in the injection direction
  - In open hole completions
    - significant residual mud cake on the sand face
    - when flow direction is reversed the residual mud cake can be redistributed and impede injection
    - source of redistributed mud cake could be from the formation face or could be completion damage

Re-use of legacy production wells



Simulation of CO2 injection well

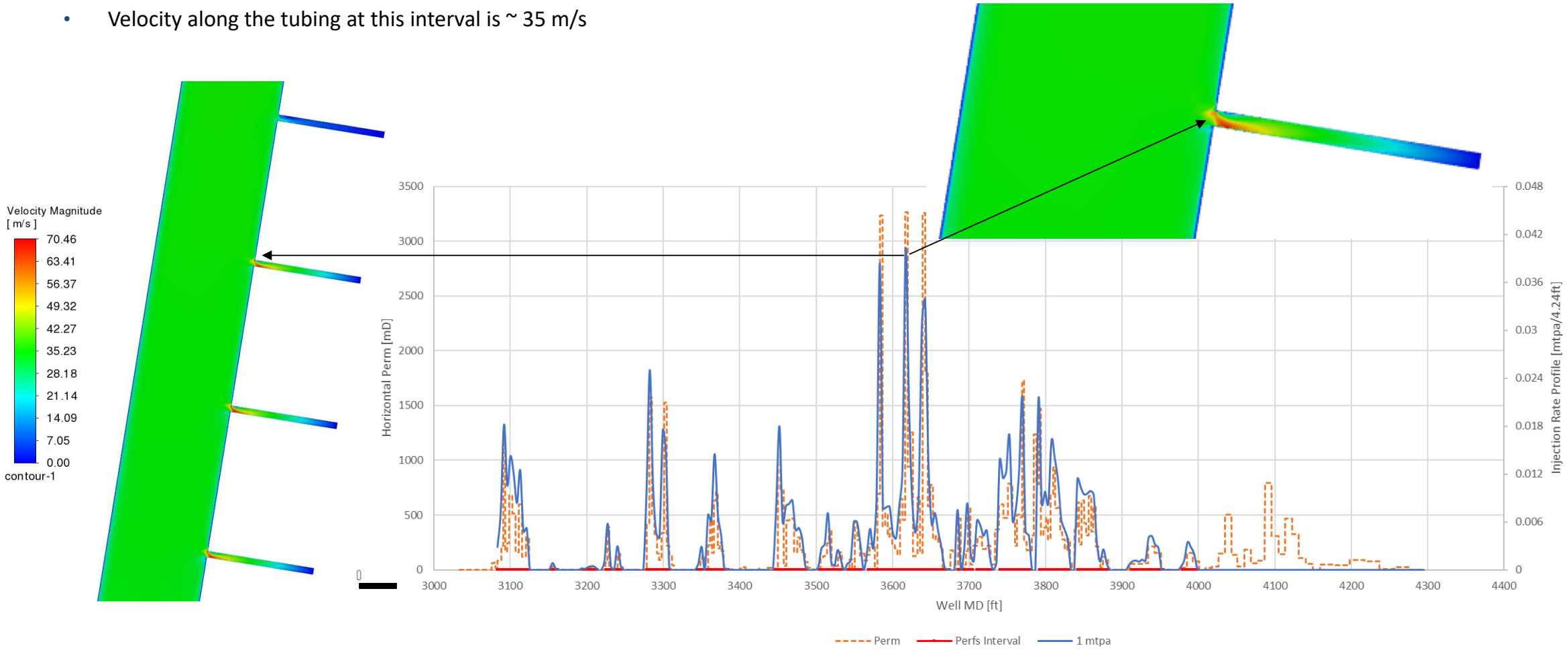
- Pressure increases in near wellbore
- Strong heel to toe effect – stronger at higher injection rates and early in injection



CO2 Injectioin - Reservoir Pressure Profile (Time=1.0000e-03 s)
Injection Time: 0.00 hrs / 0.00 days

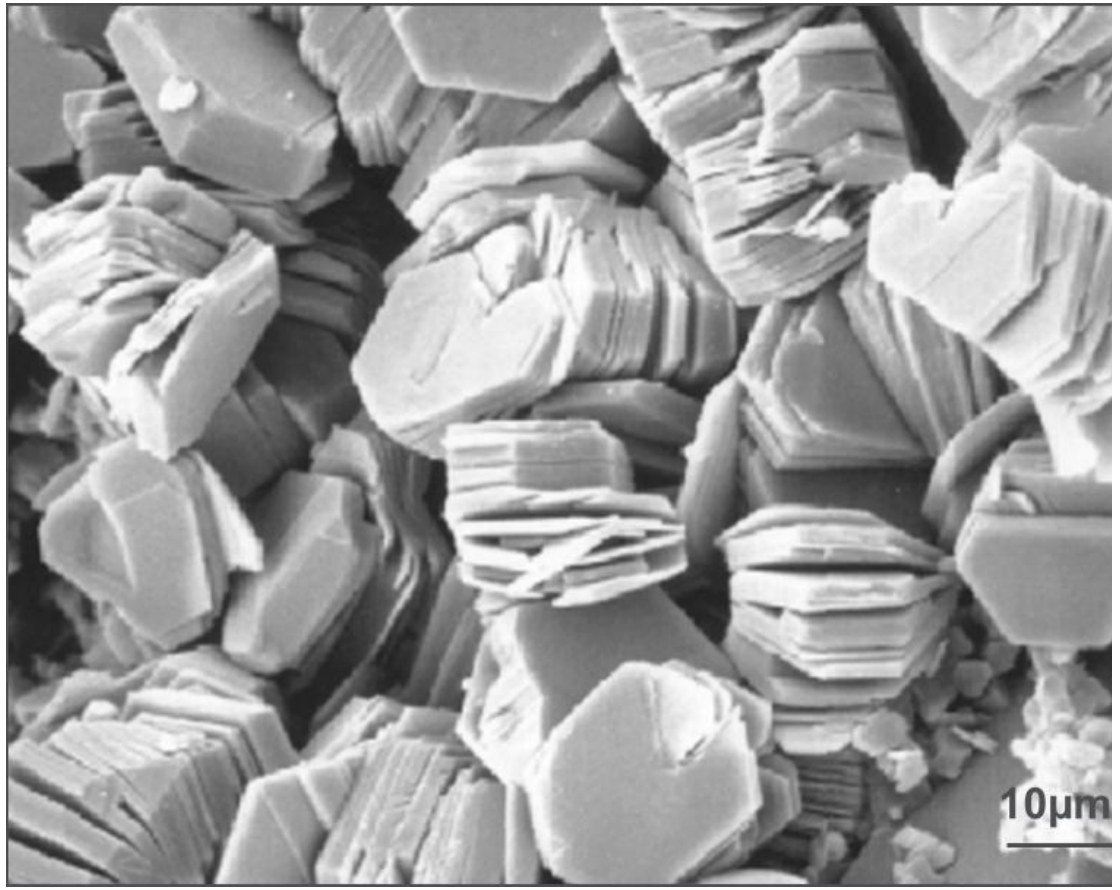
Example - high velocity at sand face

- The CO2-gas velocity entering the perforation reaches ~ 70 m/s, which then reduces as CO2-gas enters the formation
- Velocity along the tubing at this interval is ~ 35 m/s



Let's talk about fines migration….

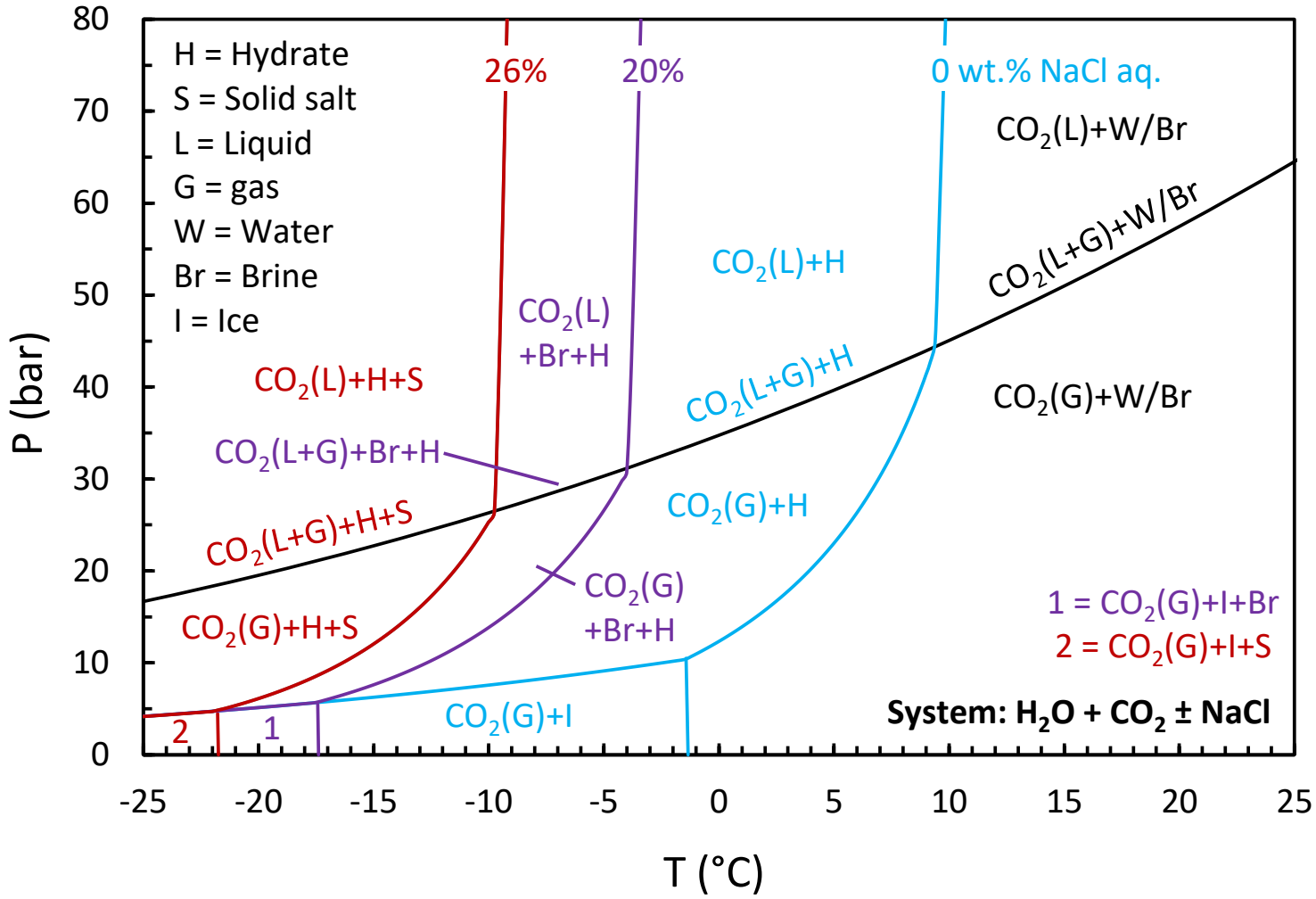
- In 2009 – 2010 I served as an SPE distinguished lecturer, throwing paper in the air to demonstrate fines migration….
- I was often subsequently recognised as "the paper throwing guy"
- So, lets talk about fines migration….
  - Imagine a fines rich CO2 store
  - Imagine the turmoil amongst the fines when suddenly CO2 at high velocity arrives……



Gas Hydrate & Ice Formation

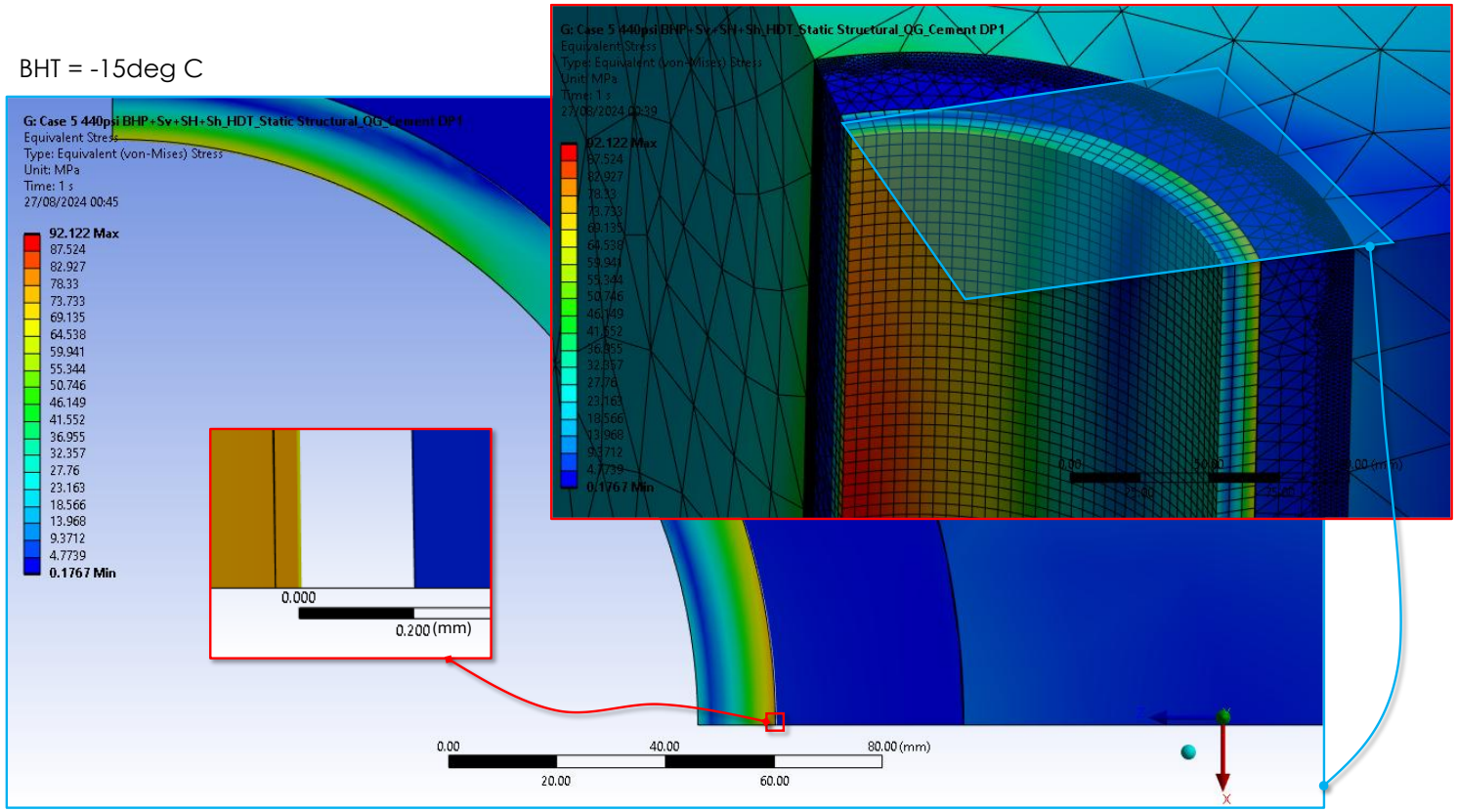
- Gas hydrates
  - group of ice-like solids formed through the combination of water and suitably sized ‘guest’ molecules
  - typically formed under low temperature and elevated pressure conditions (Sloan & Koh, 2008).
- Low temperatures required for hydrate / ice formation
  - Cold injection fluid
  - CO_2 liquid vaporisation and / or Joule Thomson (JT) cooling on injection into depleted gas reservoirs
- Saline formation water can help inhibit hydrate / ice formation, however, if the temperature drops below -10 °C, brine will completely solidify to solid hydrate and salt.
- The formation of CO_2 hydrates in sediment pores can impede CO_2 injection and prevent its migration through reservoir rocks (Almenningen et al., 2019; Yang et al., 2010; Peat et al., 2023).
- We need to consider “hydrate migration” and water accumulation as potential challenges

A complex relationship!



Well integrity challenges - debonding

- Low temperatures and temperature cycling can cause casing-cement-formation debonding and significant leak path development



Well geometry and flexibility

- Downhole chokes to enable consistent sand face delivery with variable CO2 supply at surface
- Challenges with qualification for high velocity and thermal impact
- Erosion, qualification and innovation

Laboratory Testing and Modelling

- Injection Fluid Quality
  - Solids – erosion and formation/completion damage
  - Chemistry – phase behaviour, precipitates, etc.
- Drilling and completion fluids
  - Interaction with CO2
  - Performance evaluation very similar to conventional wells but…..
    - Using CO2
- Critical Velocity Testing
  - Very high rates (for depleted stores)
- Upscaling Results
  - CFD etc.
  - The same, but different

Conclusions

- There are many well design and construction challenges associated with the injection of CO2 for CCS.
  - Vary depending on the initial conditions of the store.
  - Some of these challenges are similar to those we experience in oil and gas production and water injection wells but there are additional factors
- Many of the challenges can be addressed through careful planning, modelling, yard and laboratory testing.
- Tests are similar to those undertaken for conventional oil and gas developments but with adjustments and changes required in procedures to render testing more appropriate for CO2 injection optimization.
- CO2 storage wells and reservoirs are the same, but different.

Acknowledgements

“If I have seen further it is by standing on the shoulders of Giants” – Isaac Newton, 1675

Some of my Giants:

- Russ Gilbert
- Dr Ross Anderson – Production Chemist and Hydrate Specialist
- Dr Rick Lemanczyk and Raymond Tibbles – SPE DL Points of Contact

Questions?

- Any questions or comments?

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