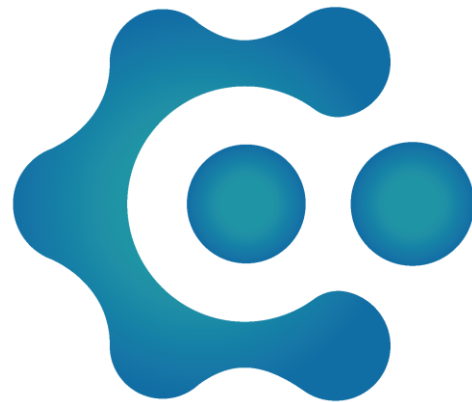




CO₂
STORAGE
CONFERENCE
2026



Exploring The Importance of Production Chemistry for Efficient and Economical Carbon Capture, Utilisation and Storage (CCUS) – Identifying Risks and Mitigation Strategies

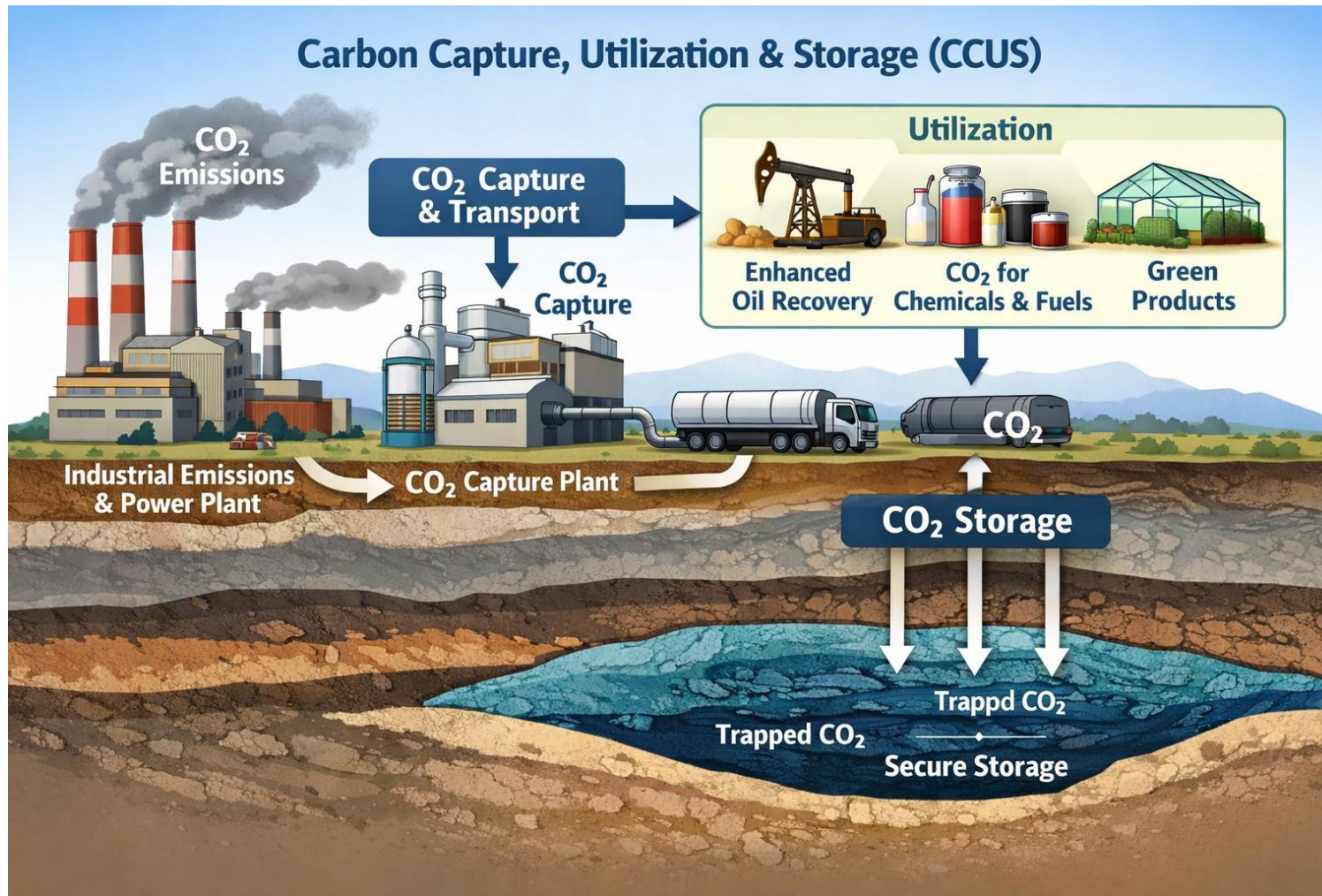
Stephen Heath – Creative Chemical Solutions Ltd

Khosro Jarrahan, Eric MacKay – Heriot Watt University

Overview

- **What is CCUS?**
- **Relevance of production chemistry?**
- **Production Chemistry Risks and Mitigation Strategies**
 - **Corrosion**
 - **Bacteria**
 - **Scale**
 - **Hydrates**
 - **Asphaltenes**
- **Conclusions**

Carbon Capture Utilisation and Storage (CCUS)



CCUS reduces impact of CO₂ emission

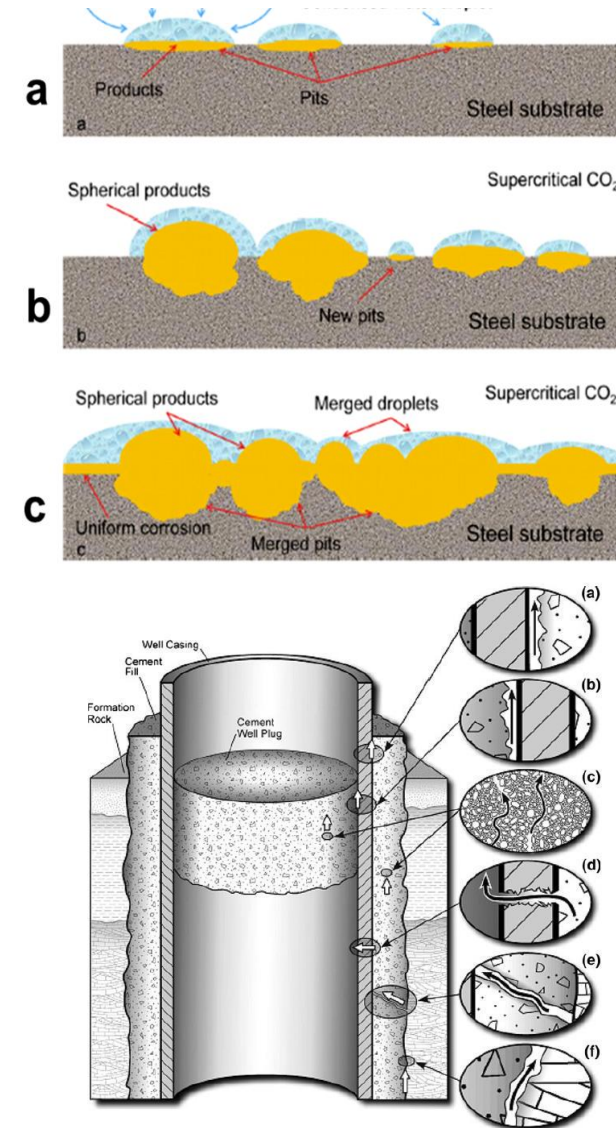
- Vital to achieve Net Zero targets
- CCUS will support heavy industry through transition to low carbon economy

The Importance of Production Chemistry

- **A range of production chemistry issues can impact the efficiency of CCUS**
 - Corrosion – CO_2 , H_2S , NO_x and SO_x
 - Bacteria – bacterial growth and biofilms, biomineralisation
 - Scale – Halite, calcite matrix dissolution reducing geomechanical integrity, controlled calcium carbonate, calcium sulphate or barium sulphate deposition for reducing leaks and maintaining rock integrity, topside calcium carbonate if carbonated brine injected and produced
 - Hydrates – Controlled CO_2 hydrate formation for improved carbon capture, CO_2 hydrates reduce CO_2 injection in pipelines and the near well bore region
 - Asphaltenes – Precipitation during CO_2 injection into depleted oil reservoirs
- **Effective production chemistry management and monitoring strategies are essential for safe, sustainable and efficient CCUS**
 - Minimise CO_2 footprint for any adopted chemical control process

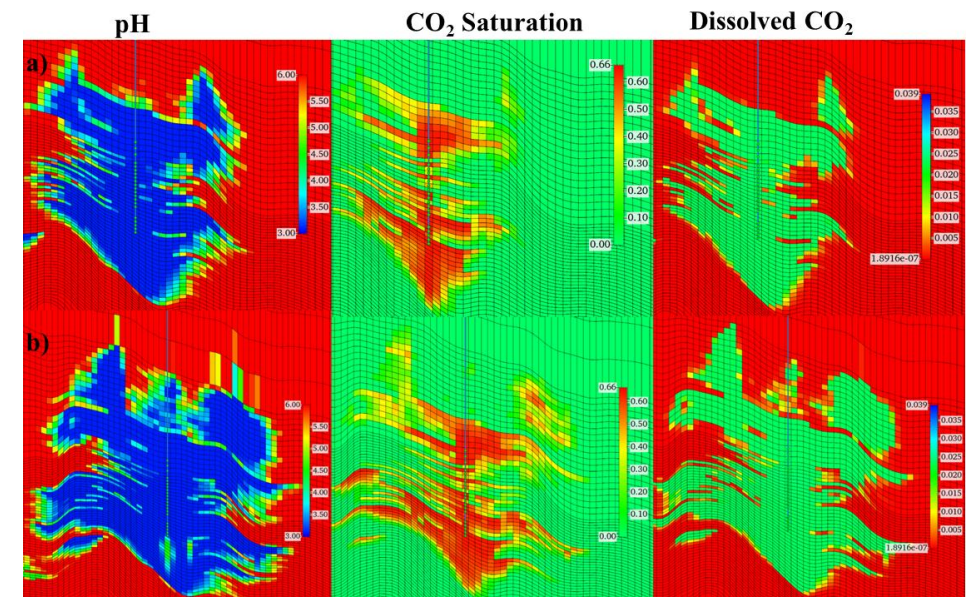
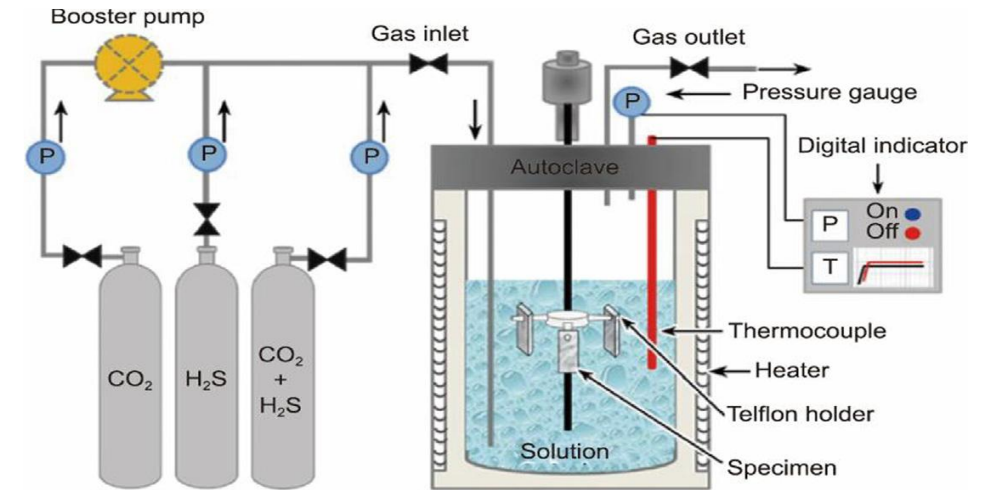
Corrosion

- Dry CO₂ is not corrosive
- CO₂ readily soluble in water
 - Corrosive to metals, cements and reservoir minerals
- Contains impurities (H₂O, O₂, H₂S, NO_x and SO_x) which have an important impact on corrosion rates
- Corrosion mechanism different to oil and gas transport
- Tubing and casing material, cement and reservoir integrity are essential to prevent leaks of CO₂ and other greenhouse gases



Corrosion Mitigation Strategies

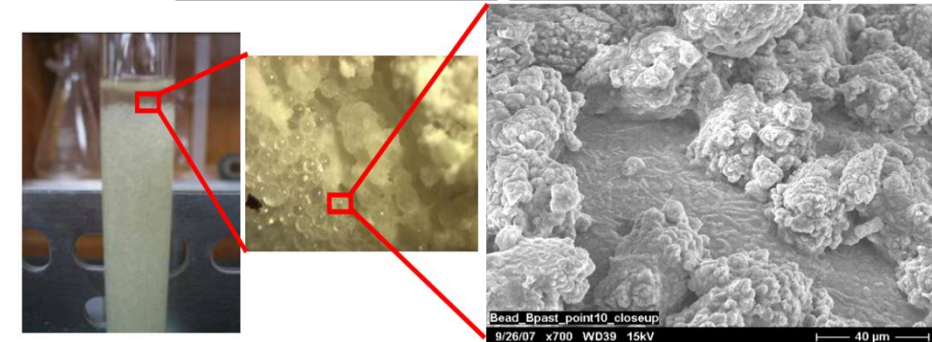
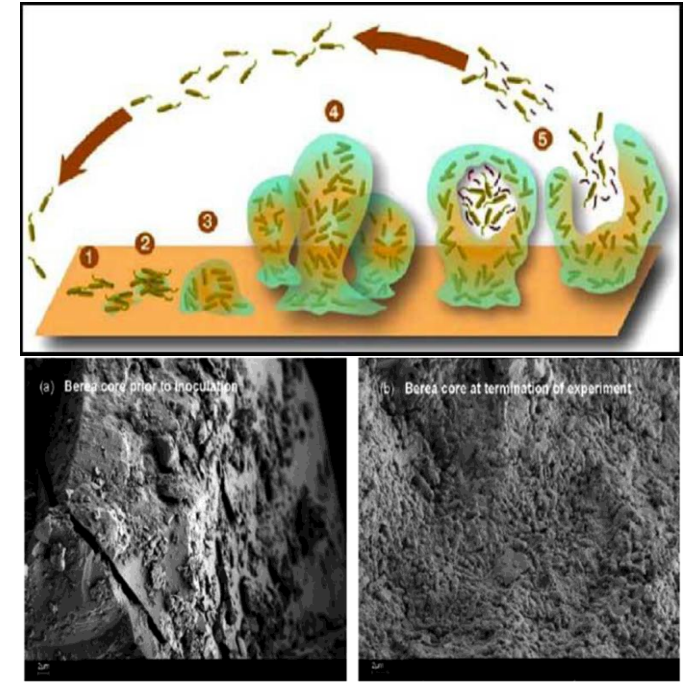
- Dry CO₂ and analyse and quality control CO₂ impurity content (O₂, H₂O, H₂S, NO_x, SO_x)
- Selection of appropriate corrosion resistant materials (CRA and CO₂ resistant cements) – costly!!
- Use corrosion inhibitors (batch or continuous treatments) to protect pipelines – develop test methods
- Use corrosion prediction and reservoir models to estimate corrosion rates and pH, CO₂ saturation and dissolved CO₂ in the near well bore region
- Sodium formate completion brines
- Controlled in-situ calcium carbonate biomineralisation



(Sevendik et al, 2025)

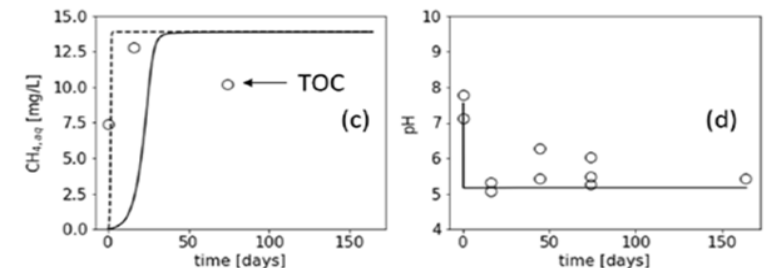
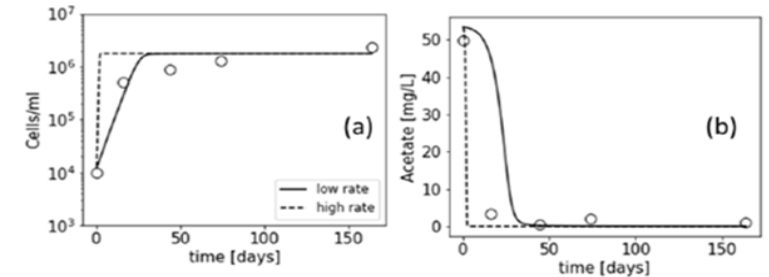
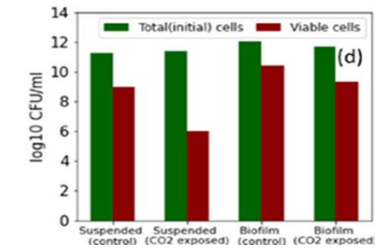
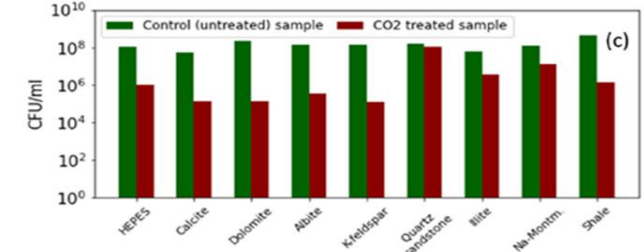
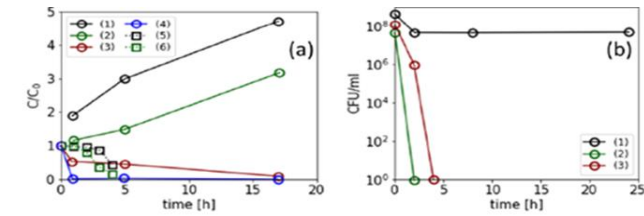
Bacteria - Biogeochemical Impact of CO₂ Injection

- Bacteria can impact the CO₂ storage process
- Microorganisms may affect the reservoir's capacity to store CO₂
 - Biofilm formation which alters flow and storage
 - Microbially enhanced biomineralisation
 - Dissolution of carbonate minerals through acid production
 - Acid producing bacteria can induce corrosion
- Microbial activity can affect bio-mineralisation in two ways:
 - Providing the chemical components (carbonate ions) needed to induce precipitation of calcium carbonate
 - Changing the solution properties (pH increase) to drive the reaction towards precipitation of calcium carbonate
- Microbial activity impacts on the geochemistry in deep subsurface geological formations



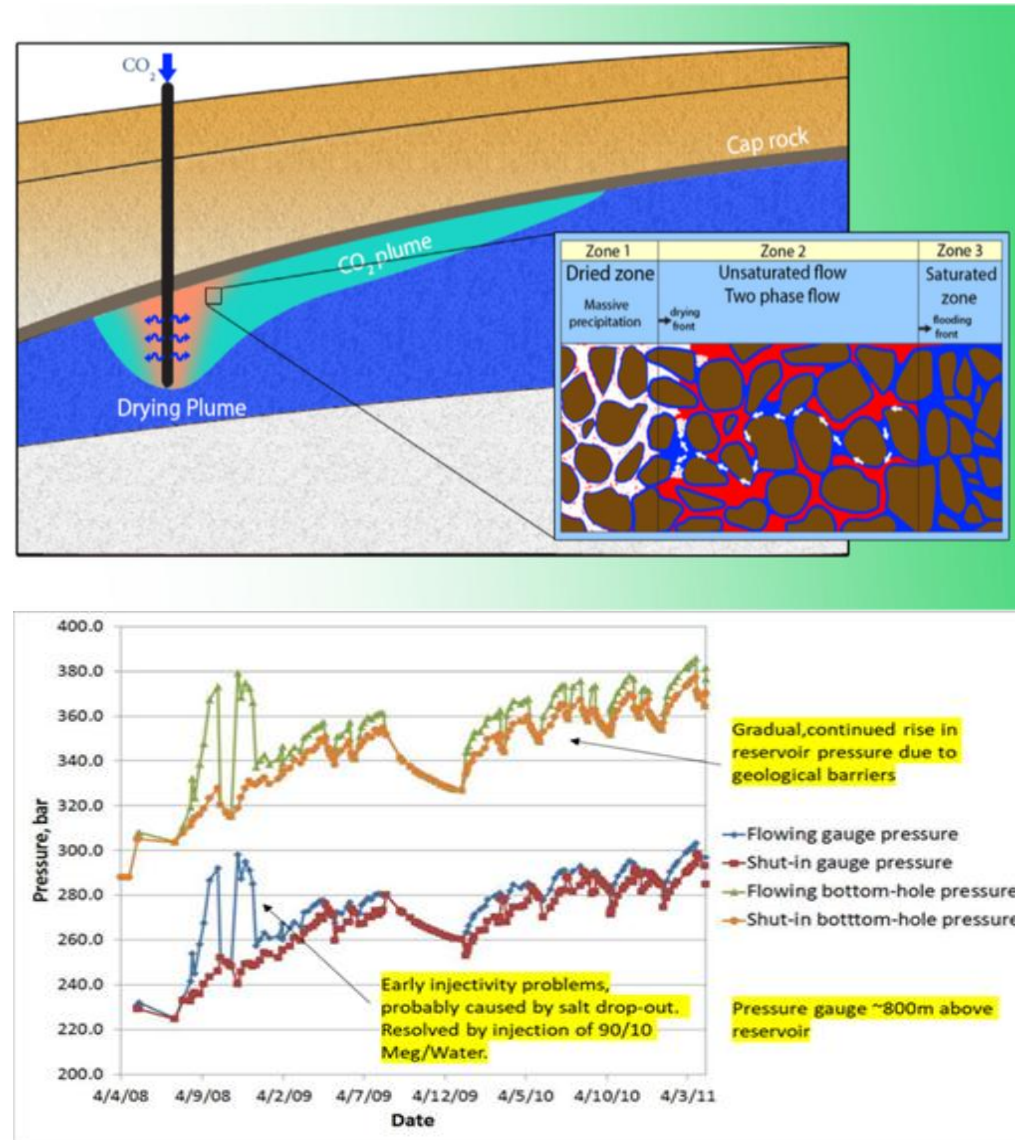
Bacteria

- CO₂ restricts bacterial growth although bacteria can adapt
 - Bacteria unlikely to grow in near well bore area
- Laboratory tests to understand bacterial growth and speciation and impact of reservoir rock
- Predictive models with PhreeqC
- Control biofilm formation to induce biomass and/or calcium carbonate scale in-situ through biomineralisation – work needed to understand kinetics and yield
- Impact of any chemicals/nutrients to induce biofilm and/or biomineralisation will need to be established on CO₂ injection, storage, material and rock integrity



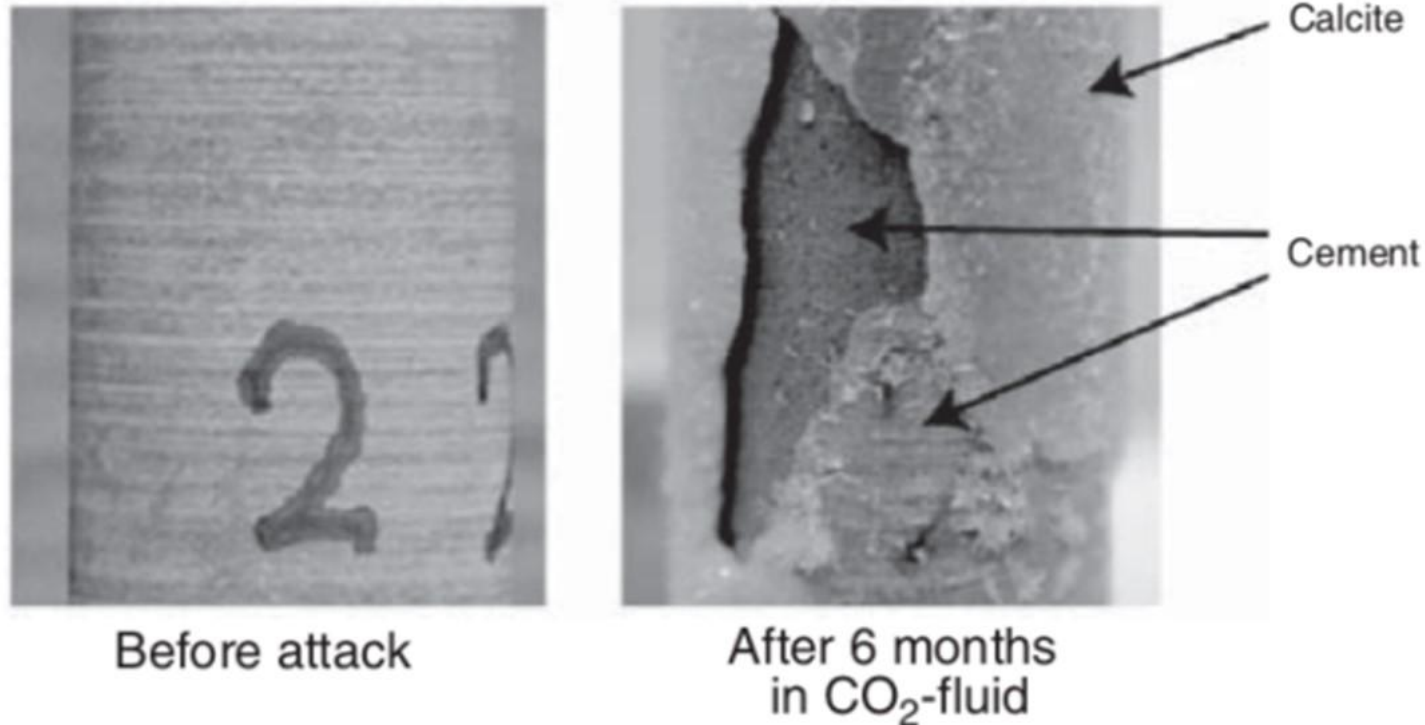
CO₂ Injection – Halite Scale

- Injection of dry CO₂ can induce halite scale deposition
- Halite scale can be predicted with scale prediction software and 1 and 2D reservoir models
- Dependent upon temperature, salinity and CO₂ injection rates
- Mitigation:
 - High CO₂ Injection Rates
 - Soft water pre-flush
 - MEG/water mixture,
- No critical salinity risk established. Problems can occur at low salinity



Interactions Between Cement/Rock and Injected CO₂

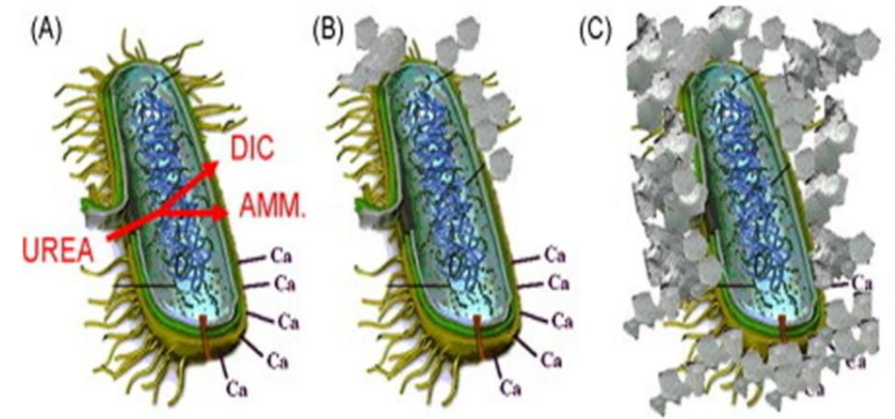
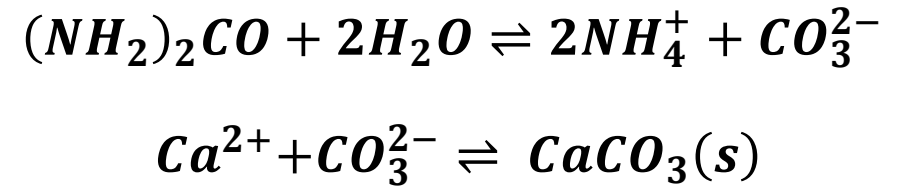
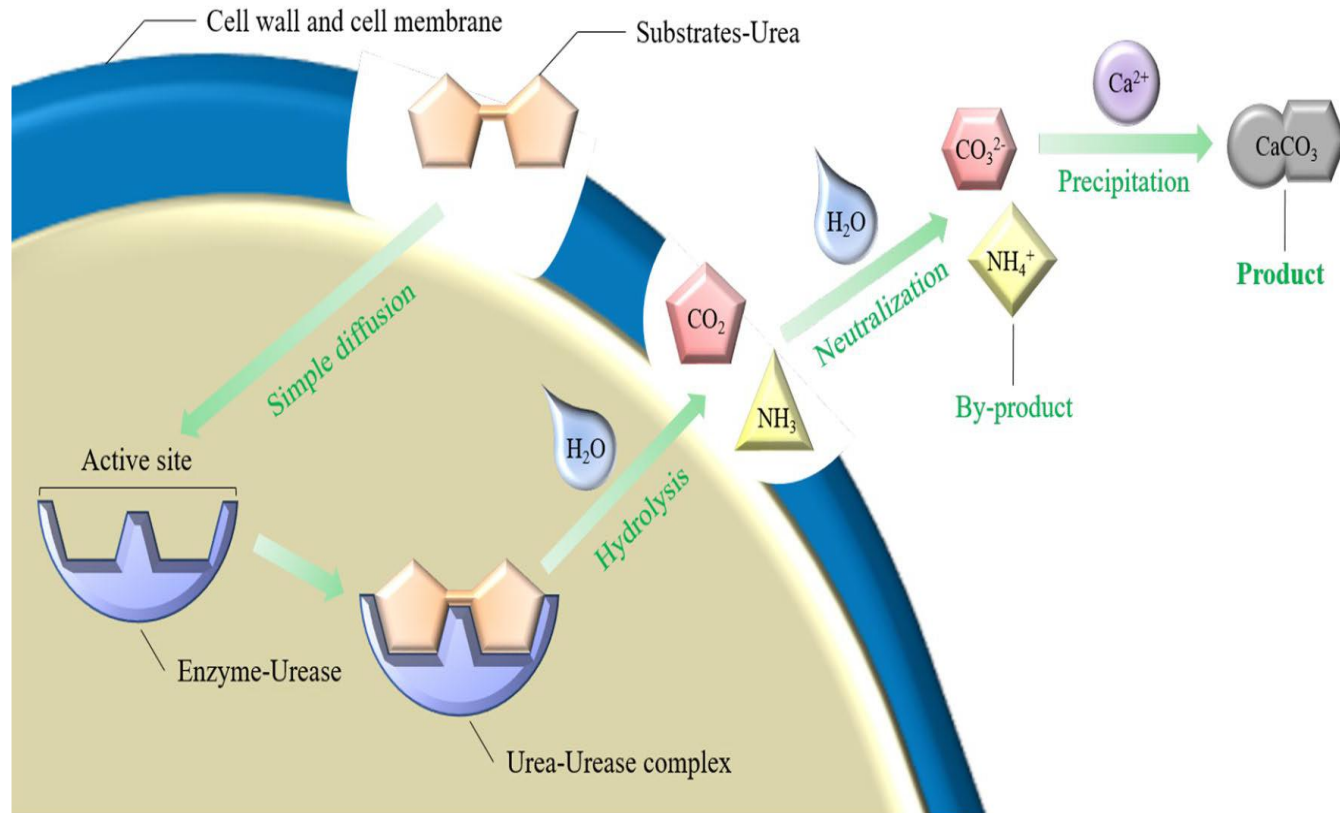
- The injection of CO₂ induces geochemical reactions with minerals in cement, reservoir rock and its caprock – reduce geo-mechanical integrity and induce leaks through calcite and other mineral dissolution



Mitigation

- More CO₂ resistant cement – polymers etc
- Add in chemical component like silica gel to increase strength
- Controlled scale deposition in cement or formation – calcium/barium sulphate or biomineralisation of calcium carbonate
- Reservoir buffering

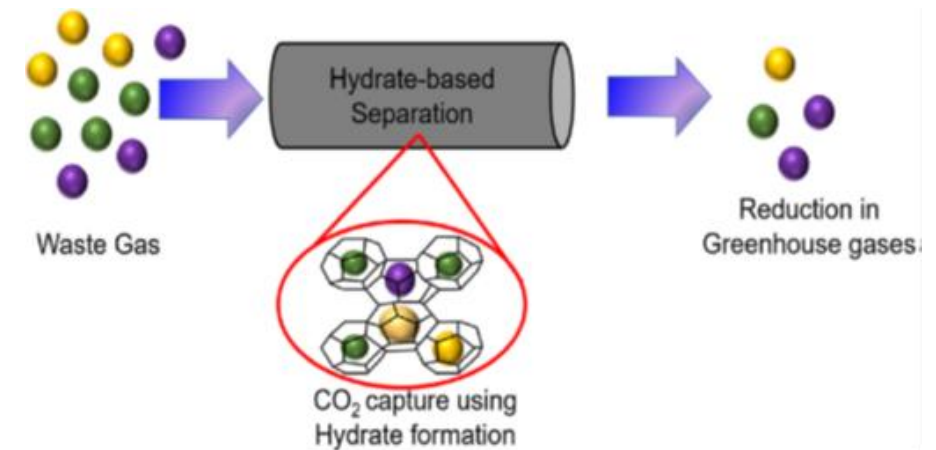
Biom mineralisation (Ureolysis) – Controlled Mineral Precipitation



- Chemicals can be added to promote controlled Calcium Carbonate biomineralisation – Increase CO₂ sweep, solubility trapping, geo-mechanical strength and prevent leaks
- Reduce risks associated with CO₂ injection and storage

Hydrates

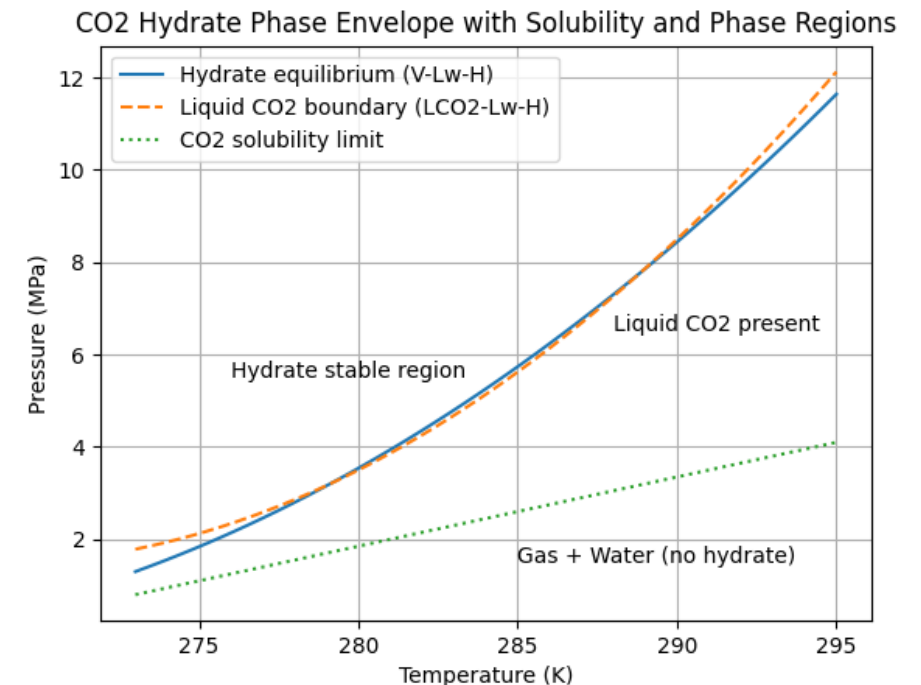
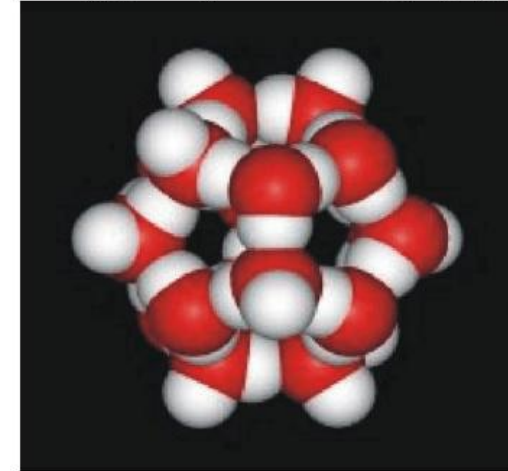
- Gas hydrates are crystalline deposits of gas and water which physically resemble ice
- Form at low temperatures and elevated pressures
- Controlled CO₂ hydrate formation could offer improved gas separation capability and storage
- Need to understand gas hydrate phase equilibrium conditions – simulation and laboratory testing
- Still faces problems for industry application
 - High operating pressure
 - Low hydrate formation rates
 - Control deposition rates



Hydrates

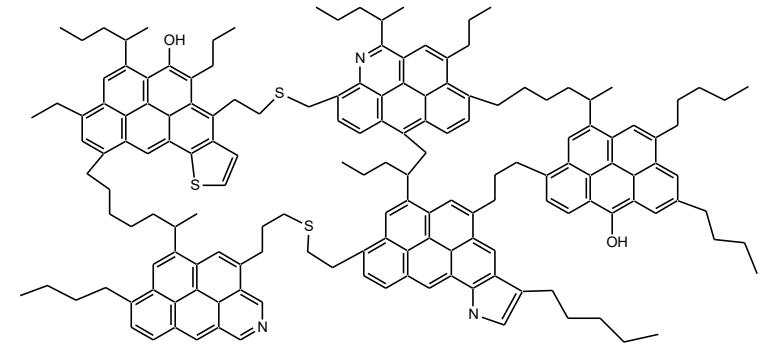
- Hydrates can form downhole due to pressure increase and Joule Thompson cooling – reduce CO₂ injectivity and impacts storage efficiency
- Specialist PVT software can be used to understand hydrate solubility envelopes
- Laboratory testing (rocking cell tests and core floods) to confirm hydrate formation
- Hydrates stabilised using MEG pre-flush or batch kinetic hydrate inhibitors (KHI) or anti-agglomerates (AA)
- Impact of any chemicals on CO₂ injection and storage needs to be investigated

CO₂ gas hydrate - CO₂(H₂O)₈



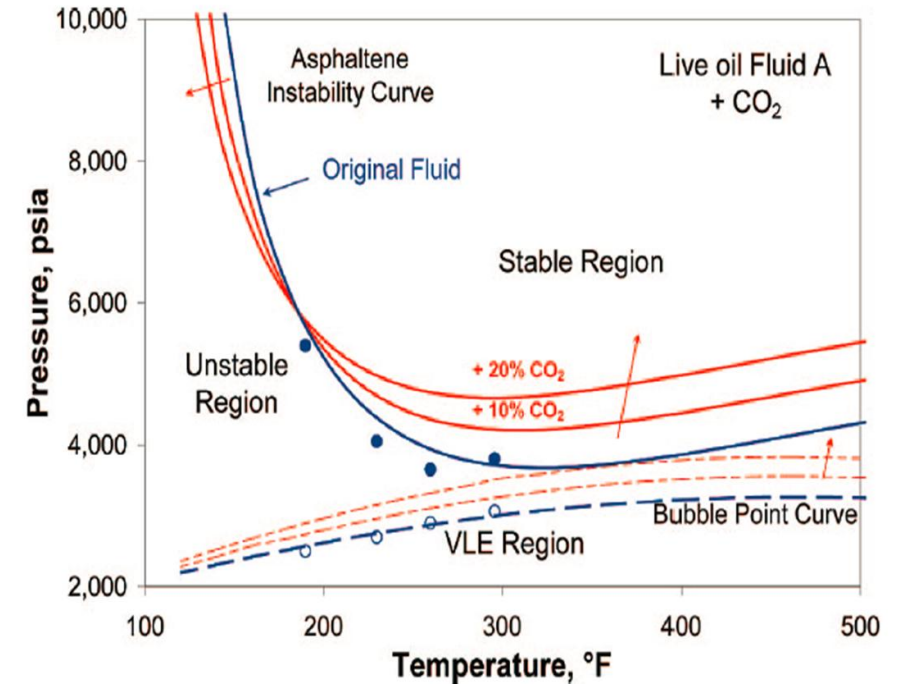
Asphaltenes

- Asphaltenes are heavy, polar complex molecules stabilised in crude oil by resins
- CO₂ displaces resins causing asphaltenes to precipitate which can cause formation damage and changes in rock surface wettability which alters CO₂ flow dynamics
- Problem will only occur with CO₂ injection in depleted oil reservoirs
- Precipitation influenced by oil composition, clay minerals, injection gas purity and temperature and pressure



Asphaltenes

- Asphaltene issues can be predicted via PVT software and standard laboratory testing
- Asphaltenes can be mitigated by periodic batch solvent injection and CO₂ compatible asphaltene inhibitors
- Other treatments based upon silica aerogel nanoparticles, carbon quantum dots and iron and aluminium oxide nanoparticles have also been proposed
- CO₂ WAG helps to stabilise flow and reduce extent of precipitation
- Reservoir simulators can optimise treatment design
- Any chemicals considered for use will need to be evaluated in terms of CO₂ compatibility, formation damage and impact on CO₂ injection and storage



Conclusions

- **The capture and storage of CO₂ in geological reservoirs is accompanied with a range of production chemistry related issues**
 - **Impact the efficiency of the CO₂ injection and utilisation/storage processes**
- **Bacteria can impact the CO₂ storage process**
 - **Biofilm formation**
 - **Biom mineralisation**
 - **Dissolution of carbonate minerals through acid production**
- **Corrosion can occur during CO₂ transport in carbon steel pipeline**
 - **CO₂ dissolved in water condensed on the pipeline surface water lowers pH and increases corrosion risk**
 - **Presence of contaminants such as oxygen and acid gases like H₂S, NO_x and SO_x will exacerbate the problem**
 - **Mechanism of corrosion is different to oil and gas and requires method development for laboratory testing for both supercritical and gas phase CO₂**
 - **Results in integrity losses and potential CO₂ leaks**
 - **Mitigated with CO₂ compatible corrosion inhibitors, coatings and controlled mineral deposition to protect cement. CRA also works but considered uneconomic.**
- **Injecting dry, supercritical carbon dioxide into geological reservoirs can evaporate saline water leading to halite precipitation**
 - **Stop or reduce the efficiency of the CO₂ injection process**
 - **Understood with scale prediction and 1D/2D reservoir models**
 - **Mitigated with freshwater or MEG/water pre-flush or batch treatments**

Conclusions

- **The injection of CO₂ in a geological reservoir induces various geochemical reactions with the minerals in the cement, reservoir rock and its caprock**
 - **Geochemical reactions must be understood including any formation damage**
 - **Reservoir models can predict pH, CO₂ saturation and dissolved CO₂ in the near well bore region**
 - **Impact the geo-mechanical properties such as caprock deformation and strength**
 - ❖ **Leads to pathways for leakage of injected CO₂**
 - ❖ **Mitigated by controlled biofilm/biomineralisation or other chemical treatments**
- **Controlled biomineralisation can increase CO₂ sweep and solubility trapping, reduce leaks and maintain geo-mechanical integrity**
- **Hydrates can form during CO₂ injection due to pressure increase and Joule Thompson cooling**
 - **Impacts CO₂ injection efficiency**
 - **Mechanism and kinetics need to be understood**
 - **Mitigated by MEG pre-flush/batch injection or CO₂ compatible hydrate inhibitors**
- **Controlled CO₂ hydrate formation can be used to improve purity of captured CO₂**
- **Asphaltenes can deposit in the near wellbore region during CO₂ injection into depleted oil reservoirs**
 - **Confirmed with laboratory tests**
 - **Mitigated with pre-flush or batch solvent injection or chemical inhibitors**
- **Impact of any chemicals added must be understood on efficiency of CO₂ injection and storage process**

Thank you and Acknowledgements

