Carbon Capture and Storage Masterclass (G502)

Tutor(s)

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Overview

This course will provide participants with awareness of the geoscience needs for CCS projects; namely subsurface CO2 storage volumetrics, CO2 flow in the subsurface away from injector wells, the goal of safe and permanent storage of CO2 and cost-benefit issues linked to aquifer depth, well design, etc. The course will establish basics, such as how much CCS is needed to make a difference to global warming, and explore what types of CO2 injection are already happening, including information from CO2-enhanced oil recovery projects. The course will deal with CO2 as a fluid phase and how much CO2 can be stored per cubic meter in terms of porosity and over entire aquifers. It will deal with how quickly CO2 can be injected and the role of aquifer permeability. The course then moves on to the all-important geomechanical effects of CO2 injection and feedbacks between induced mineral dissolution and rock strength and other rock properties. The full range of possible interaction between CO2 and both aquifer and top-seal will be covered, as will the range of possible leakage mechanisms that need to be assessed. The course will conclude with consideration of monitoring strategies.

Duration and Logistics

Classroom version: A 3-day course comprising a mix of lectures, case studies and exercises. The manual will be provided in digital format and participants will be required to bring a laptop or tablet computer to follow the lectures and exercises.

Virtual version: Five 3.5-hour interactive online sessions presented over five days. Digital course notes and exercise materials will be distributed to participants before the course. Some exercises may be completed by participants off-line.

Level and Audience

Intermediate. The course is largely aimed at geoscientists, but engineers will also find the course instructive. Intended for sub-surface scientists, with an emphasis on geoscience topics. Participants will probably have a working knowledge of petroleum geoscience. However, the subject matter of this course, the geoscience of carbon capture and storage, is covered from basic principles.

Objectives

You will learn to:

1. Develop awareness of the role of geoscience in CCS and of CCS in CO2 emissions reductions.
2. Appreciate what CO2 injection projects have occurred so far and how they differ from industrial CCS.
3. Understand CO2 as a fluid in the subsurface and the fluid injection pressure and effective stress regimes that CO2 injection will involve.

4. Build awareness of the volumetrics of CO_2 storage from the micro (pore-scale) to the macro (aquifer volumes).
5. Gain an appreciation of the question of CO_2 flow away from injector wells controlled by permeability and aquifer architecture.
6. Understand the range of effects that CO_2 can have on the host aquifer, from geomechanical to geochemical.
7. Assess the role of top-seal and fault-seal properties and how they will influence CO_2 storage, from risk of fracking, or induced seismicity, to mineral dissolution.
8. Understand the range of ways that CO_2 could escape from the planned storage sites.
9. Develop an awareness of the range of monitoring strategies that could be employed to ensure safe and long-term storage of CO_2.

Course Content

Session 1: Background, context, EOR-CCS and produced CO2-CCS

Lectures

- Why is CCS needed?
- How does CCS fit into the bigger picture of CO_2 emissions-reductions?
- The energy transition
- Examples of EOR-CCS
- Examples of in-field CCS
- Industrial scale CCS
- How is CO_2 separated from flue and other gases: the regenerative amine process?
- The range of possible fates of CO_2 in the subsurface as a function of time
- CO_2 injection rates, constant or variable (seasonal, supply and economy effects)
- Injected CO_2 purity and the effect of other fluids (due to cost and practicality of CO_2 separation)

Exercises

- Estimation of mass of CO_2 locked away by CCS thus far.
- Assessment of how many CCS projects are needed at the current rate of emission.
- Appraisal of mass of localized vs dispersed CO_2 generation.

Session 2: Overview of geoscience context, CO_2 in the subsurface and volumetrics

Lectures

- Overview of geoscience context: volume/mass, flow, avoidance of leakage and lowest cost and energy
- CO_2 P-T phase diagram
  Physical properties of CO_2: density, wettability, viscosity and miscibility (water, oil)
- CO_2-H_2O mixing and water acidity
- CO_2 storage per cubic meter, reservoir core porosity
- Controls on reservoir porosity
- What are typical aquifer porosities in different basinal settings?
- Extent and gross volume of reservoir (ultimate CO_2 storage capacity) and sand body size
- Aquifer CO_2 storage compartments

Exercises

- CO_2 phase behavior in different aquifer pressure regimes.
- Estimation of water acidity due to injected CO_2.
- Comparing aquifer porosity of CCS sites.
- Calculation of CO_2 storage in sandstones with different porosities (per cubic meter).
- Estimation of total storage capacity of CO_2 in different aquifers.

Session 3: Flow of CO_2 and geomechanical and chemical interactions with aquifer rocks

Lectures

- Aquifer permeability and its effect on CO_2 injection and flow
- What are typical aquifer permeabilities in different basinal settings?
- Controls on aquifer permeability
- Will permeability limit injection volumes?
- Aquifer architecture and connectivity and larger scale CO_2 flow
- Comparison of advanced sedimentology in CCS work vs resource extraction
- Static and conceptual reservoir models for oil and gas vs aquifer models for CCS
- Stratigraphic and fault-seal barriers and baffles
- Injection pressures and CO_2 flow rates
- Stress states in aquifers ahead of CCS (maximum and minimum principal stress)
- Fluid pressure and rock pressure related to failure
- Dilational and compactional failure of bulk rock
- Formation damage – does rock failure matter and will fractures help injectivity?
- Possible role of pre-existing faults and risk of leakage
- New fractures (fracking) near the well-bore region and risk of leakage

Exercises

- Injection rates and flow rate calculations for varying aquifer permeability.
- Comparing aquifer permeability of CCS sites.
- Deriving stress states from well data.
- Assessing failure risk during injection based on rock strength and stress data.

Session 4: Geochemical interactions and geomechanical and rock property feedbacks with aquifer rocks

Lectures

- Chemistries of CO_2-water-rock interaction
- Dissolution of minerals in aquifers
- Range of minerals that might dissolve, roles of mineralogy and lithofacies
- Possible effects of dissolution on rock properties: geomechanical, porosity and permeability effects
- Where will dissolution occur: near the injection well or throughout aquifer?
- Driving force and rate of precipitation of new minerals in aquifers
- The abiding problem of predicted dawsonite precipitation
- Rate of mineral growth vs rate of injection to mitigate climate change
- Halite precipitation due to dehydration of highly saline aquifers: transient or permanent
- Types of top-seal lithologies and overview on effectiveness to trap CO_2
- Characterization methods for top-seals: a greater drive than for oil and gas exploitation
- Top-seals at hydrocarbon sites vs aquifers, proven vs potential
- Mudstone top-seal sedimentology, lateral continuity, thickness, brittle vs ductile behaviours (lessons from shale gas)
- Top-seal mineral dissolution risk
- Top-seal geomechanical failure risk
- CO_2 column heights and top-seal capillary entry pressures

Exercises

- Classification of aquifers in terms of risk of mineral dissolution.
- Prediction of possible effects of dissolution on porosity and permeability in near well-bore region.
- Prediction of possible effects of dissolution on rock strength in near well-bore region.
- Qualitative assessment of top-seal susceptibility to alteration based on mineralogy.

Session 5: Leakage scenarios and monitoring the CCS site

Lectures

- CO_2 column heights and top-seal capillary entry pressures
- Injection well completions and risk of cement dissolution
- Reiteration of risk of fracking due to high pressure injection
- Pre-existing open faults (seldom a problem in oil and gas fields)
- Escape of CO_2 via thief zones; need to understand sedimentary architecture
- Escape via old, abandoned wells: how good are plugs?
- Flow to updip edge of aquifer and escape of CO_2
- Monitoring strategies available: cost vs benefit
- 4-D seismic and gravity and CO_2 monitoring
- Sea floor monitoring
- Microseismic monitoring
- Monitoring wells

Exercises

- Calculation of CO_2 column height based on top-seal SCAL data.
- CO_2 pressure variations linked to injection rates.
- Detecting CO_2 escape using geochemical data.
- Prediction of effects of CO_2 escape via unplugged wells on storage efficacy.