MSc thesis in Geohydrology or Environmental Engineering:

Residual trapping of CO2 during geological storage in sandstone reservoir rocks

General Introduction

Carbon dioxide capture and storage (CCS) is a technology for reduction of greenhouse gas (GHG) emissions to the atmosphere. It is the only technique available to reduce emissions related to the burning of fossil fuels, which currently account for more than 80% of the primary energy supply worldwide. It is therefore an important part in a portfolio of measures to reduce GHG emissions and anthropogenic influence on the climate.

Secure trapping of carbon dioxide (CO_2) in deep geological formations is critical for the long-term safety of geological CO_2 storage (GCS). In deep saline aquifers, the injected CO2 displaces saline water present in the formation and trapping of CO2 occurs through different trapping mechanisms and over multiple scales, from the pore to the reservoir scale. Well-controlled laboratory experiments are essential to obtain fundamental understanding of these processes and predict the CO2 trapping capability of potential storage formations. A challenge for the laboratory experiments is that GCS is done in deep formations (> 800 m below ground) where the pressure is high enough that the CO2 exists in a highly compressed and liquid-like, supercritical state. Laboratory experiments have been done at high pressure in small core samples (e.g. Krevor et al. 2011) or at ambient pressure using analogue fluids (e.g. Neufeld et al., 2010; Trevisian et al., 2014), which have similar properties to those of CO2 and saline water at formation pressure and temperature. Experiments at intermediate scale (larger than the core scale) are needed to capture the effects of geological heterogeneity and dimensionality of the flow field on the CO2 trapping mechanisms and related safety of the GCS operations.

Residual trapping of CO2

When supercritical (sc) CO2 flows through water-saturated porous rocks, small droplets and ganglia of the scCO2 will be trapped and left behind in the trace of the free-phase scCO2 migration due to variations in the capillary properties of the rock pores. This is called residual trapping and constitutes a very secure form of CO2 storage because residually trapped CO2 is immobile. Well-controlled experiments on the relevant spatial scales are essential to understand and quantify residual trapping of CO2 in natural porous rocks. In particular, to understand the effects of geological heterogeneity of the storage rocks on the trapping, intermediate scale experiments where heterogeneity is present are essential. Trevisian et al. (2014) looked at residual trapping using fluids analogue to a supercritical CO2 – saline water system in sand box experiment, but to date, no studies at intermediate laboratory scale have been performed on real reservoir rocks. In this study, experimental techniques will be developed and these techniques will be applied to perform experiments on real rock samples assessing the effects of heterogeneity on residual trapping of CO2. Rock samples from an outcrop of reservoir sandstone in Sweden will be collected. Thin slices (in the order of 1 cm thick and 20 – 50 cm in width and height) of sandstone rock will be cut and sealed in a solid but transparent frame with ports allowing controlled fluid flow through the rock slice. The hydraulic properties of the rock slices will be characterized using hydraulic and tracer tests. Flow-through experiments using two immiscible fluids having similar properties (analogue) to supercritical CO2 and saline water will then be performed. The dynamics of the two-phase flow and trapping process will be documented and particularly the residual trapping of the CO2-analogue fluid will be quantified using light transmission techniques developed in a parallel MSc thesis project. The effects of heterogeneity on the residual trapping will be assessed.

The objectives include to:

1. Develop techniques to cut and seal intact slices of sandstone rock in a solid but transparent frame (1 cm thick and in the order of 20 – 50 cm in width and height)
2. Investigate the effects of geological heterogeneity in the natural sandstone on residual trapping of CO2
    - characterize the hydraulic properties and the heterogeneity of the natural rock slices
    - develop and perform flow-through experiments using analogue fluids to an scCO2 – saline water system
    - quantify migration and residual trapping using light-transmission techniques
    - assess the effects of heterogeneity on the migration and residual trapping

Light-transmission measurement techniques

Light-transmission (LT) techniques will be developed in a parallel MSc thesis project. These LT techniques will be used to quantify and visualize flow and transport processes in porous media. LT has effectively been used to quantify multiphase flow of nonaqueous phase liquids (NAPLs) in porous media, in intermediate scale experiments (e.g. Wang et al., 2008). A very strong and uniform light panel is used to send visible light trough a relatively thin two-dimensional (2D) sample of porous media, such as a 1 cm thick transparent sand tank or sealed rock slice (Figure 1). The light that goes through the porous medium depends on the nature of the fluids present in the pore space. An industrial CCD camera is used to quantify the amount of light that goes through the sample at every pixel. This information is then used to quantify the fluids or change in fluid composition in the system.

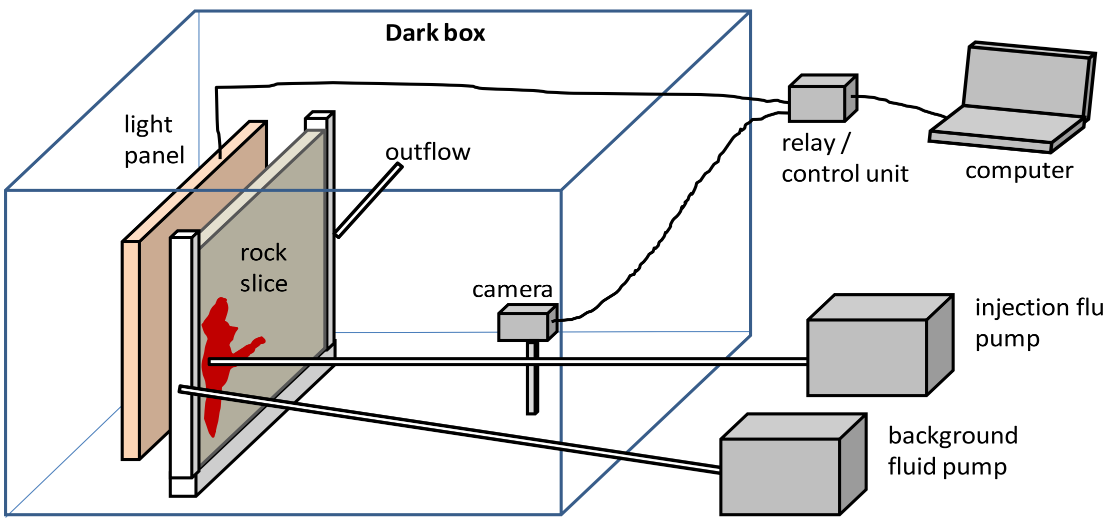

Figure 1. Setup for intermediate-scale experiments using light-transmission measurements of fluid saturations and concentrations.

References

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