1. The Challenge

Concentrations of atmospheric CO₂ have increased by more than 35% since industrialisation began, and they are now at their highest for at least 800,000 years [1]. This increased concentration of CO₂ in the atmosphere traps more reflected heat, leading to enhanced climate changes.

Energy Efficiency and Renewable Energy can go some way to reducing CO₂ emissions but the technology gap and time lag is significant. Burning fossil fuels for energy is still the primary method of producing energy.

It is therefore essential that a method of reducing the CO₂ emissions from burning fossil fuels is put into place as soon as possible.

2. A Possible Solution

To reduce the amount of CO₂ entering the Earth’s atmosphere, Carbon Capture and Storage in geological formations is being considered (CCS).

CO₂ is separated from industrial emissions (estimated to be 258 MTCO₂ yr for the UK [2]) and injected into suitable deep geological formations, where CO₂ saturated fluids are sealed by impermeable caprocks overlying the reservoir sandstones (estimated storage capacity of UK geological formations is 20,000 Mt [3]).

The benefits of CCS are: it enables continued use of fossil fuel resources, has the potential for large CO₂ storage/disposal capacity and there is availability of technology (and geologists!).

The drawbacks are that the costs of implementing CCS are significant both as a retrofit to existing power stations and on new power stations. There is also the important consideration of the environmental impact of geological storage, however both can be mitigated with further research, development and knowledge transfer.

3. CO₂ Storage and its Associated Risks

Injected CO₂ is trapped in geological formations under the caprock by a number of different mechanisms: structural trapping (under caprock anticline), stratigraphic trapping (under impermeable layers), solubility trapping (CO₂ dissolving in pore water), mineral trapping (CO₂ trapped by chemical reactions) and capillary trapping, each with its own timescale of effectiveness.

Interaction between CO₂ and reservoir and cap rock may change the geo-chemical and geo-mechanical properties of the caprock, leading to changes in porosity, fracturing and permeability – its integrity. This could lead to the possibility of leakage. (see below right).

It is this caprock integrity that we will investigate experimentally, numerically and by comparison with natural analogues.

4. Geoscientific Investigations

The experimental aim is to subject caprock to CO₂ exposure under reservoir conditions of pressure and temperature and study the geo-chemical and geo-mechanical interactions.

A schematic of the experimental apparatus can be seen below. It consists of a Hassler-type high pressure cell rated to 10,000 psi that accepts cylindrical caprock samples up to 38mm in diameter and 75mm in length. Heating bands on the pressure cell and pipe work keep the temperature constant at 90°C. There are two pressure pumps; one to apply the confining pressure, the other to pressurise the core sample and inject supercritical CO₂ and/or brine through the caprock sample. There are three pressure transducers; one to monitor the confining pressure and two to determine differential pressure across the core sample. There is also a flow meter, back pressure regulator and two tracer input / sampling ports.

The experimental data is used as input and validation for numerical modelling and will be compared with natural analogues.

5. Answers!

Assessment of the risks of the critical combination of process that could lead to caprock failure will be undertaken.

Geo-chemical processes:
- Exactly what mineral trapping will occur within the caprock
- Dissolution and dissolution rates of caprock minerals under CO₂ / brine exposure
- Secondary mineralisation in the caprock under CO₂ / brine exposure

Geo-mechanical processes:
- Fault reactivation pressure of caprocks
- Caprock overpressure values
- Yield pressure and sealing pressure of caprocks
- Measurement of breakthrough pressure of caprocks with CO₂ as non wetting phase

6. Knowledge Transfer

Environmental and geological scientists

Oil and gas industry

Caprock integrity risk analysis

Climate change and CCS models and modelling

International information sharing

Government / environment policy makers: regulations

Media and public education

This project is part of the EU seventh framework programme MUSTANG: A Multiple Space and Time scale Approach for the Qualification of deep saline formations for CO₂ storage.