Project 1.5: Reactive reservoir rocks and their impact on CO_2 storage

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1. Project context and overview

Geological storage of CO_2 requires fundamental knowledge and predictive capabilities on the transport and reactions of injected CO_2 and associated gases (O_2, SO_x, NO_x) to assess the short- and long-term consequences. CO_2 can be stored in the subsurface through various mechanisms including structural trapping, solubility trapping and by precipitation of carbonate minerals.

While mineral trapping is considered to be the safest storage mechanism as it permanently immobilizes the CO_2, the reaction rates and the likely importance for geosequestration is poorly understood. This project has five objectives (see below), which aim to make CO_2 storage more predicable and safer. A range of approaches will be used including desk top studies, laboratory and field experiments and geochemical modelling.

2. Natural analogue studies

By studying rocks associated with natural accumulations of CO_2 we can gain insights into CO_2-water-rock interactions and apply this knowledge to potential storage systems. As such we are able to predict changes that are likely to happen during long-term containment of injected CO_2 (i.e. CO_2 dissolution/mineralization).

Microscopic and high-resolution whole-core analysis are used to identify reaction pathways and the degree of diagenetic mineral and porosity alteration.

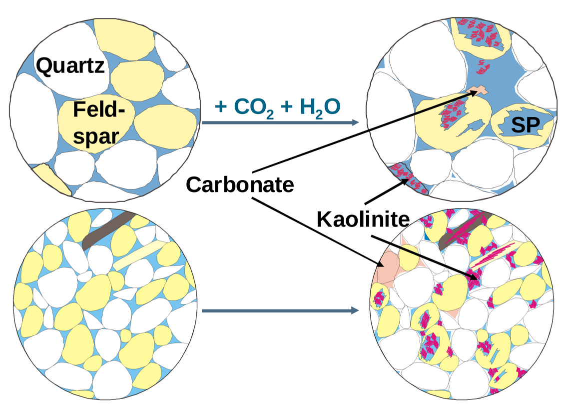

Figure 1 – Differences in diagenetic alterations between coarser and finer sandstone facies. Secondary porosity (SP) is found within the coarser grained facies, whereas finer grained facies are characterised by a greater precipitation of mineral products.

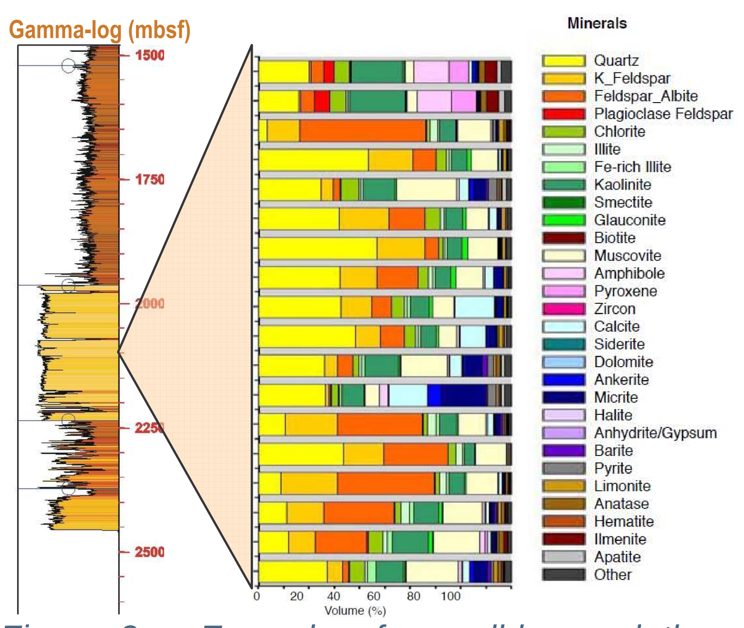

Figure 2 – Example of a well-log and the respective mineral composition at cm-scale using QEMSCAN or Hylogger technology. Note the low proportion of (primary) plagioclase and the high proportion of (secondary) kaolinite and albite.

3. Mineral reactivity and mineral trapping of CO_2

Our ability to generate predictive numerical models of the physical and chemical processes in future storage sites depends on the information used to populate and constrain the models. Pressure-temperature-composition (P-T-X) experiments in batch and flow-through reactors will be carried out to generate thermodynamic and kinetic data for specific minerals and reservoir rocks (Figure 3). Reaction path modeling (Figure 4) and reactive transport modeling (not shown) for potential storage sites and natural analogue sites will be undertaken to improve our predictions of CO_2 storage conditions.

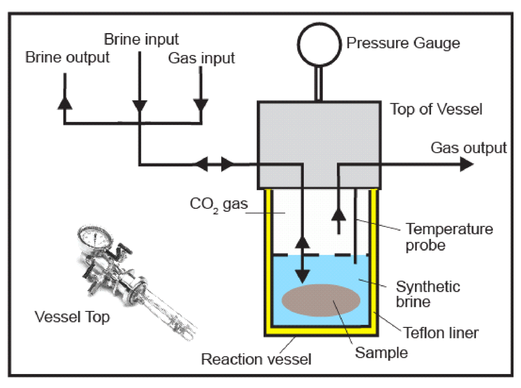

Figure 3 – Batch reactor configuration. Changes in fluid chemistry during the experiment are used to determine dissolution rates and activation energy, as well as catalysing and inhibiting agents in the fluid.

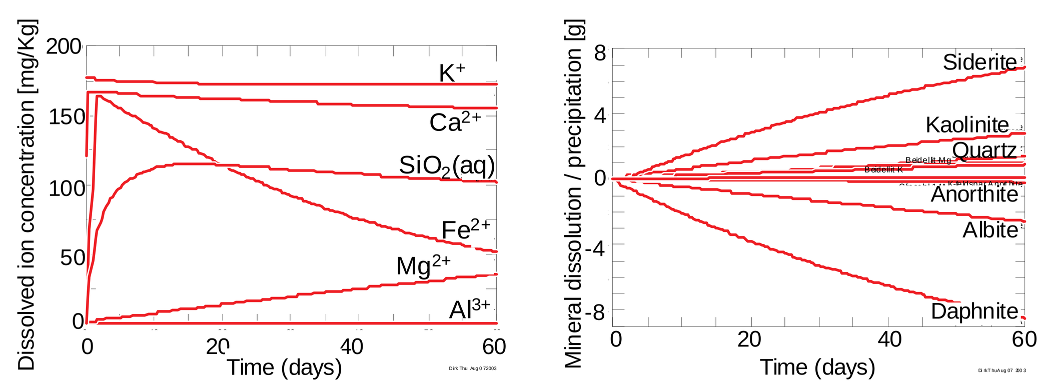

Figure 4 – Example of reaction path modelling of batch reactor experiments showing predicted fluid and mineral changes.

4. The impact of co-contaminants: SO_x, NO_x, O_2

The injection of SO_x (SO_2 / SO_3) and NO_x (NO / NO_2) gases from coal-fired powerplants and O_2 from oxyfuel powerplants imposes risks to the operation as corrosion of the well casing and acidification associated with particular fluid-rock reactions may occur. For example, iron can be mobillised and oxidised clogging pores near the injection.

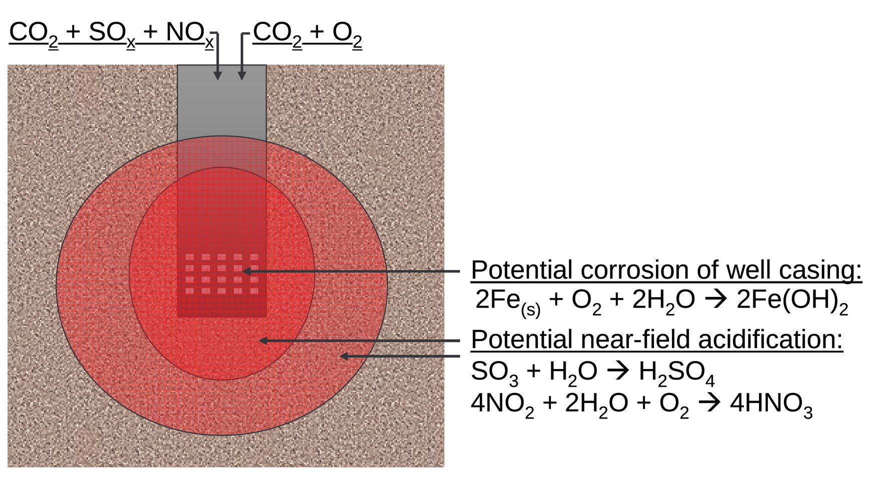

Figure 5 – Conceptual representation of potential impacts imposed by co-contaminant gases near the injection well.

5. Tracer studies to determine the *in situ* residual gas saturation

At the Otway site, noble gases (krypton, xenon) and organic tracers (triacetin, tripropionin, propylene glycol i-acetate) will be injected and their concentrations will be followed at the nearby monitoring well. The results will be used to determine gas-water partitioning and to model the residual gas saturation. Changes in water chemistry during the experiment will also be used to determine short-term fluid-rock interactions.

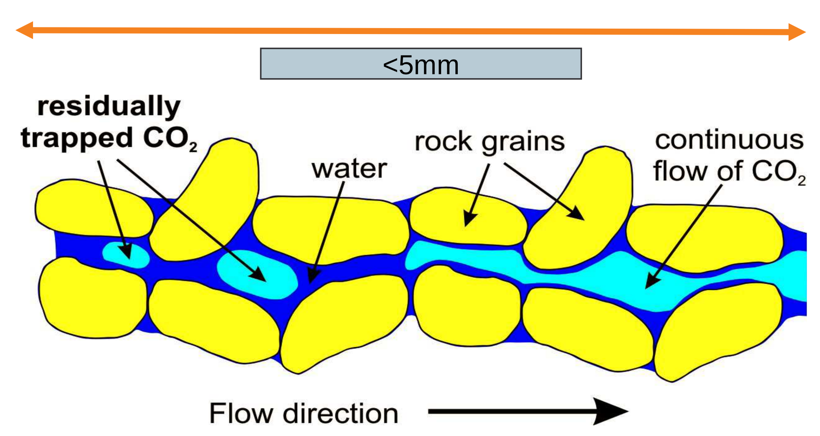

Figure 6 – Conceptual representation of residually trapped (supercritical) CO_2 .

6. Microbial mineralisation and biofilm formation

The formation of biofilms and microbially mediated mineral precipitation to plug local high-permeability zones is considered an intervention technique in case of a leakages. Reaction chemistry, microbial community structure and microbial activity will studied in laboratory experiments to maximise the formation of microbial barriers.

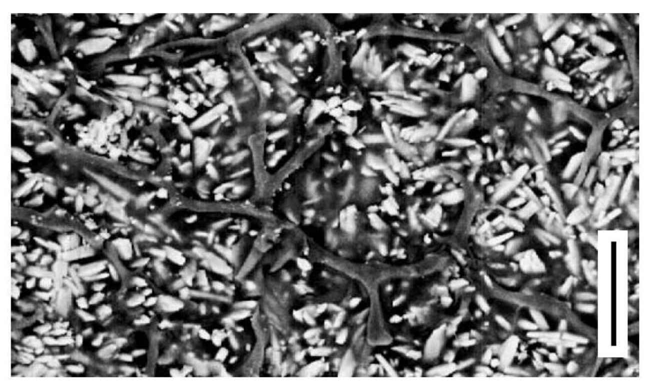

Figure 7 – Scanning electron microscope photograph of organic matter (dark grey) associated with authigenic aragonite crystals observed in a carbonate crust from a submarine methane / CO_2 seep. Scale bar is 25 µm. From: Aloisi et al., 2002, Earth and Planetary Science Letters 203: 195 – 203.

7. Integration and outcomes

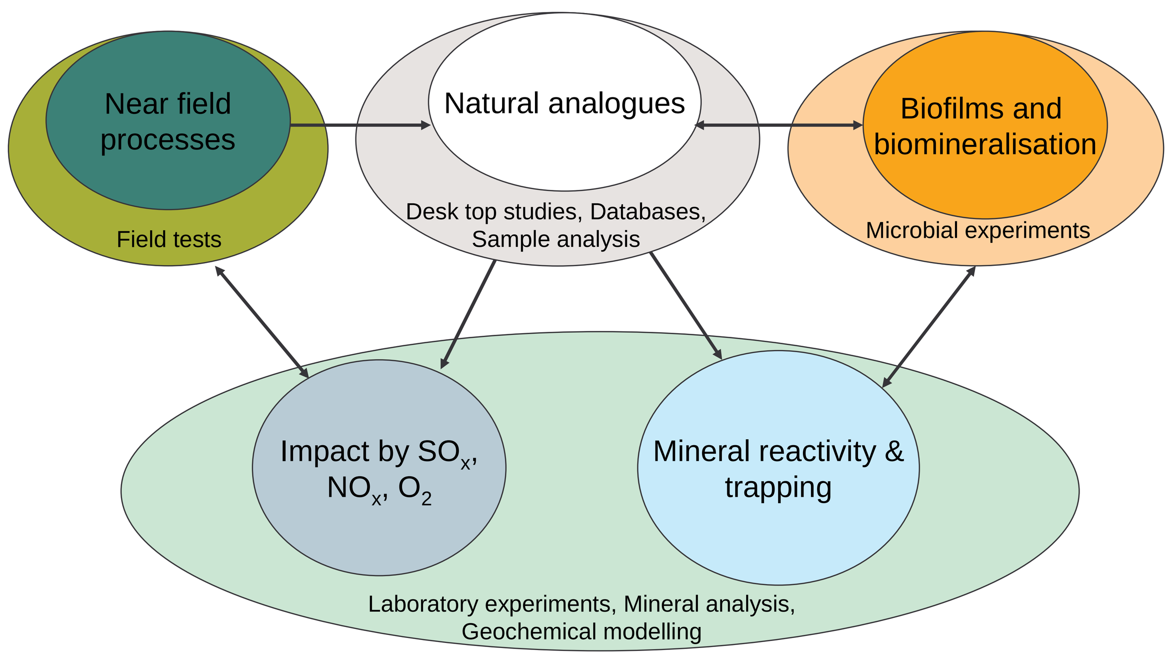

Figure 8 (left) – Representation of project components and how they relate to each other. This comprehensive projects consists of five components, which are interconnected in various ways. The study of natural analogues takes a central role as it provides fundamental information on the nature of reservoirs. For example, it provides information on formation water chemistry and mineral assemblages used to design laboratory experiments. Experimental and modelling studies are undertaken within the same components to develop synergies across disciplines. Geochemical modelling and petrographic studies are undertaken at a range of spatial scales to address issues of heterogeneity and up-scaling.

This project will improve our understanding of the geochemical impacts of CO_2 storage, for example, through the study of fluid-rock reaction pathways and rates. Such information will be integrated in models to improve our predictive capabilities.

This project aims to make CO_2 storage safer by addressing risks associated with the injection of co-contaminants and by developing intervention techniques in case of leakages.

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