Quantifying chemical and petrophysical alterations in porous materials by CO_2 using HRXCT

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Introduction

Geological sequestration of CO_2 is a transitional solution to reduce the concentration of greenhouse gases in the atmosphere pending sufficient renewable energy alternatives. CO_2 can also be used as raw product for industrial processes whereby CO_2 is sequestered and new materials are formed. Carbonation can be used to stabilize mineral waste or even be transformed into innovative materials. Understanding the mineral-CO_2 interactions is essential in the advances of the carbonation process and the upscaling of geological storage. Accurately translating chemical data from reactor experiments and petrophysical data of reservoir rocks to a model for reactive transport is often a challenging step. This is mainly due to the complexity of the used reservoir rocks in the experiments, resulting in a model that cannot be univocally calibrated or even validated.

1. Research outline

Understanding the interactions between CO_2 and mineral phases in porous media and the influence of these reactions on the porosity/permeability is essential in the enhancement of CO_2 sequestration and other carbonation processes.

Current research:

Lab/reactor experiments

Objectives:

Analysing reaction kinetics & petrophysical changes (porosity/permeability)

Translating the results to a model for reactive transport

Difficulties:

- **Complexity of the host rock**
- **Model validation/calibration**
- **Upscaling**

Solutions:

Starting from a well characterized artificial homogeneous material

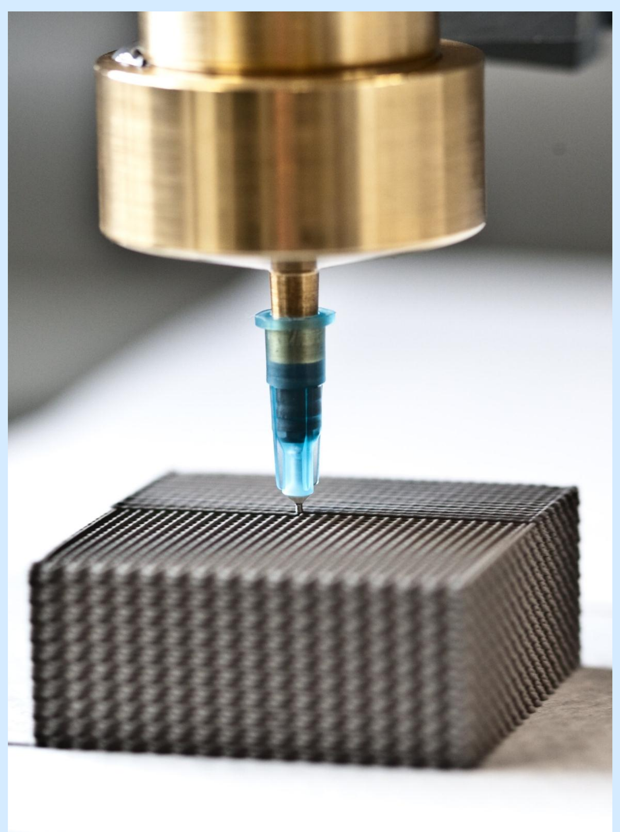
This research starts from a clear verifiable design:

1. Batch reactor tests on mineral powders (pure calcite and wollastonite)
   → *analyse reaction kinetics*
2. Create artificial porous materials from mineral powders
   → *controllable petrophysical parameters (porosity, reactive surface,…)*
3. Flow through reactor tests on artificial porous materials
   → *influence of the petrophysical parameters*
   → *quantifying the physico-chemical changes in 3D through time using HRXCT.*

2. Artificial porous materials

3D fibre deposition is a technique frequently used to make scaffolds and ceramic membranes from powders.

- Controllable mineralogical composition
- Controllable 3D pore network
  Deduct the influence of different parameters like mineralogy, reactive surface, porosity, permeability
- Homogeneous rectangular 3D grid
  Ideal for modelling and upscaling

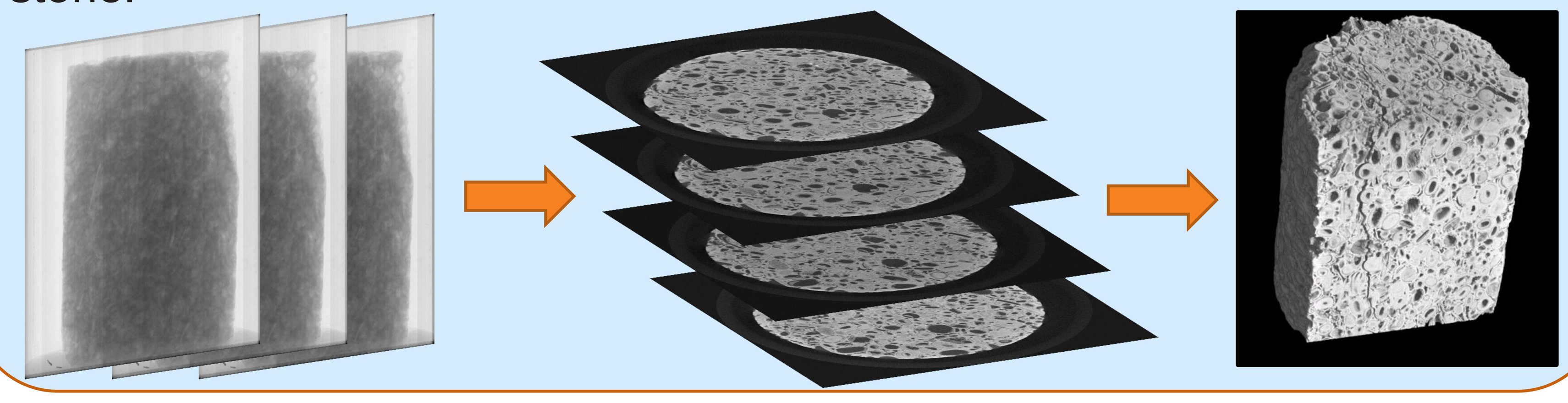


3. HRXCT

High resolution X-ray computed tomography (HRXCT)

- 3D visualization of the internal structure of the sample
- little to no sample preparation
- up to a submicron resolution on small samples
- non-destructive: internal changes (porosity, fractures,…) can be visualized and quantified in time

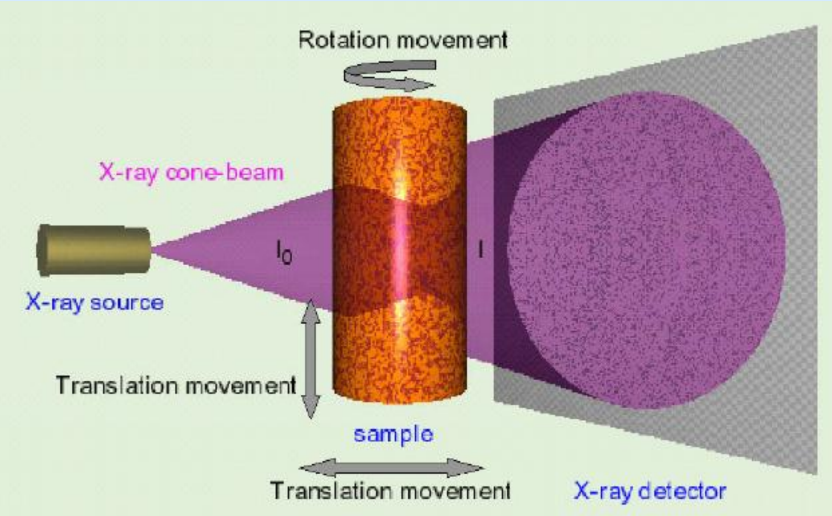
A 3D model is obtained by reconstructing digital radiographs, taken from different orientations by rotating the sample 360 degrees, to create cross sections. The cross sections are then rendered to obtain a 3D model of the stone.

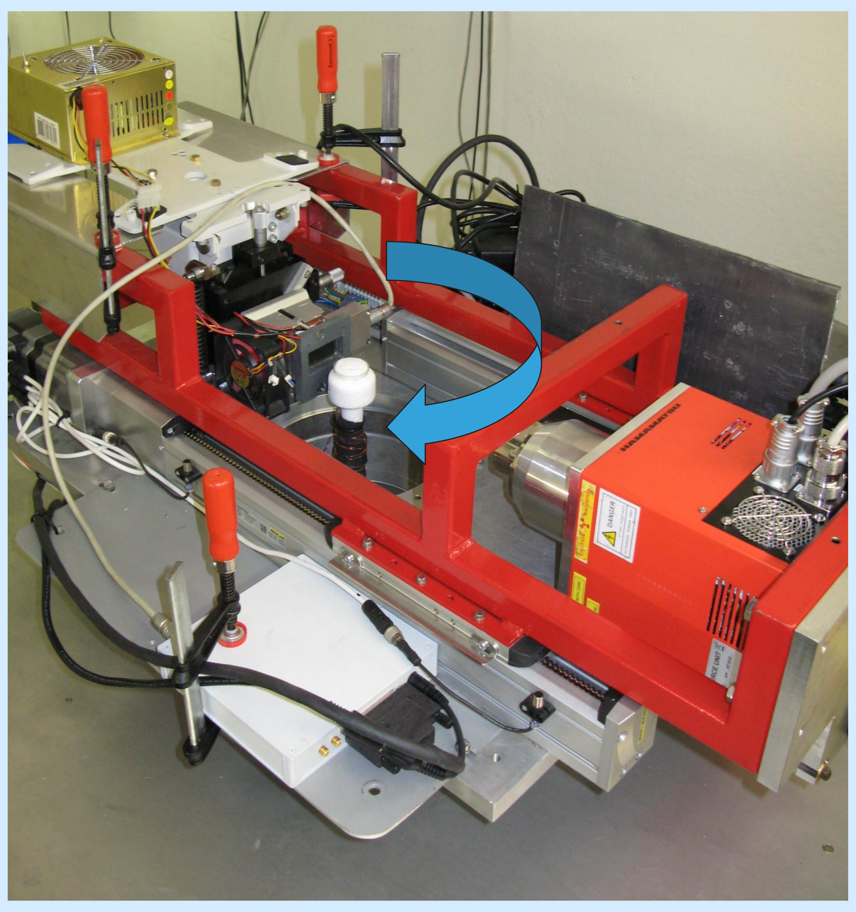


4. EMCT

Conventional lab-based X-ray micro-tomography or synchrotron X-ray micro-tomography:

- Fixed source - detector setup with in between a rotating sample
- Hard to scan a sample under external influences like temperature and pressure (e.g. inside a reactor).





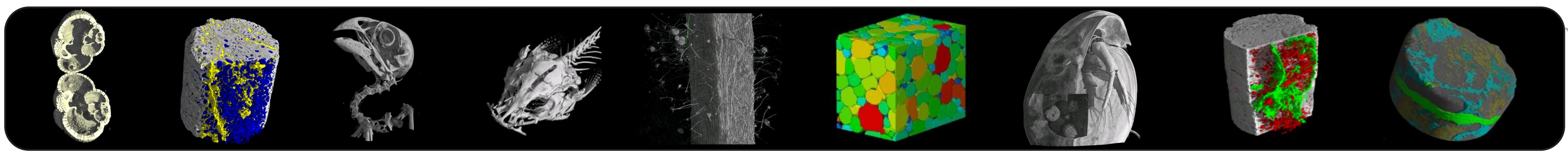
The EMCT (Environmental micro-CT) is developed at the centre for X-ray tomography of Ghent University (UGCT) to overcome this problem:

- Fixed sample stage
- Rotating source and detector
- Possibility for environmental stages or small specialised reactors
- Visualization of the sample under external conditions and analysis of changes over time

In this research, a specialized flow through cell is developed to visualize and quantify physico-chemical changes up to a resolution of 5 µm.

Outlook

This research with reactor experiments on artificial porous materials in combination with traditional analysis and with non destructive 3D analysis (HRXCT) allows to quantify the physico-chemical changes through time and the influence on porosity and permeability. By combining these experimental results with the models for reactive transport through porous media, the models can be validated and eventually calibrated. This will later on help to understand more complex experiments on complex reservoir materials and the optimisation of the carbonation processes for the stabilisation of mineral waste and the production of innovative building materials.



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