CT characterization of wellbore cement degradation under geologic CO_2 storage conditions

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November 22, 2022

Abstract

This presentation demonstrates a CT scanning and image analysis workflow to characterize wellbore cement degradation under corrosive geologic CO_2 storage (GCS) conditions. The workflow includes 1) acquisition of raw CT images of the cement sample (before and after exposure to CO_2); 2) application of rigid registration to align raw CT images; 3) acquisition of grayscale intensity difference images; 4) application of noise filtering technique to obtain images with good quality; 5) acquisition of 3D pore structure change of the cement sample after CO_2 exposure from grayscale intensity difference images, showing degradation of wellbore cement. To demonstrate an application of the workflow, an experiment of reaction between CO_2 and wellbore cement under corrosive GCS conditions was conducted and the wellbore cement samples used in the experiment went through aforementioned CT scanning and image analysis procedures. CT image analysis results demonstrate a region with increased porosity in the exterior of the cement sample (Zone 1) and a region with decreased porosity next to Zone 1 due to $CaCO_3$ precipitation (Zone 2). Next to Zone 2, a region with increased porosity due to $Ca(OH)_2$ and C-S-H dissolution (Zone 3) was observed. In summary, this study proves feasibility to use 3D CT scanning and CT image analysis techniques to investigate CO_2-induced degradation of wellbore cement.

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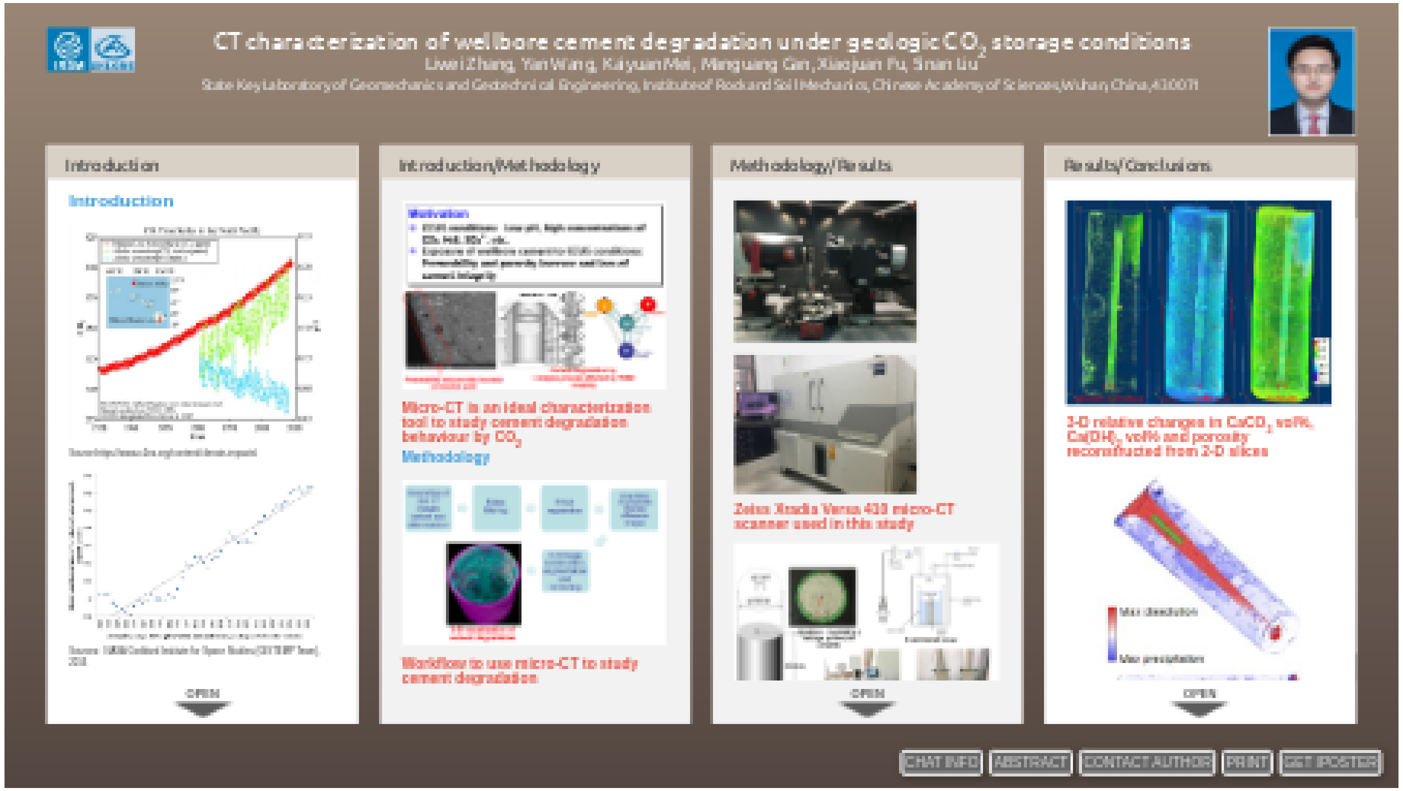

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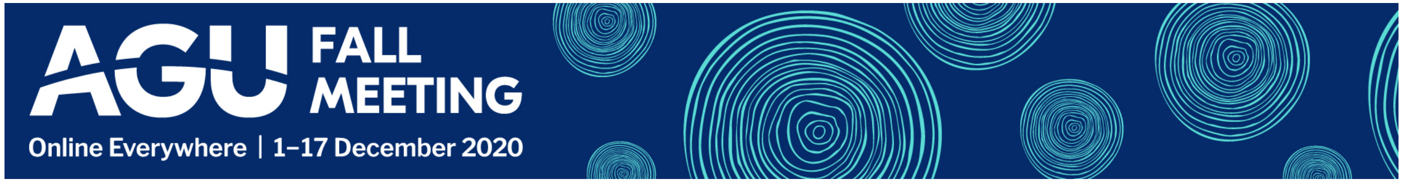
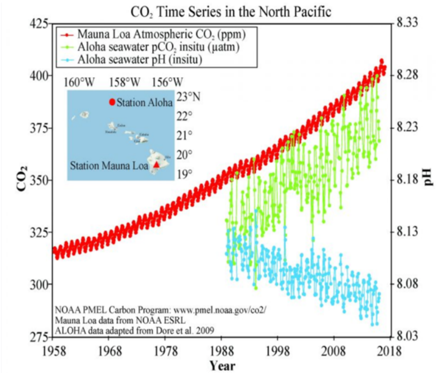
PRESENTED AT:

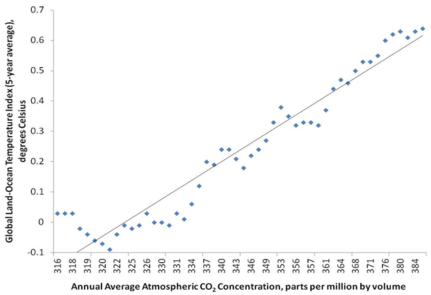


INTRODUCTION

Introduction

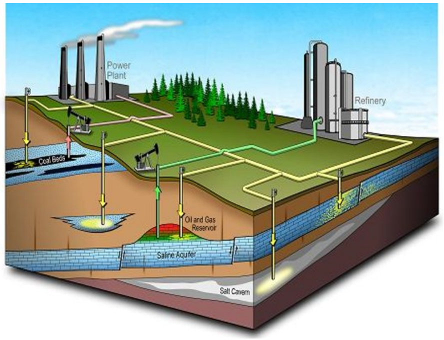


Source:https://www.c2es.org/content/climate-impacts/



Sources: NASA Goddard Institute for Space Studies (GISTEMP Team), 2016

Greenhouse Gas Effect: elevated CO_2 concentration in the atmosphere and global temperature rise



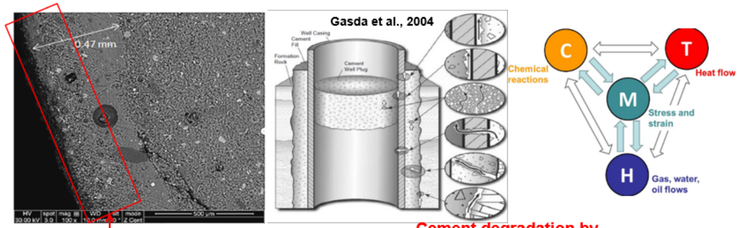
Source: Global CCS Institute, 2017

Carbon Capture, Utilization and Storage (CCUS)—a promising technology to reduce atmospheric CO2 concentration

INTRODUCTION/METHODOLOGY

Motivation

- **CCUS conditions: Low pH, high concentrations of CO_2, H_2S, SO_4^{2-}, etc.**
- **Exposure of wellbore cement to CCUS conditions: Permeability and porosity increase and loss of cement integrity**

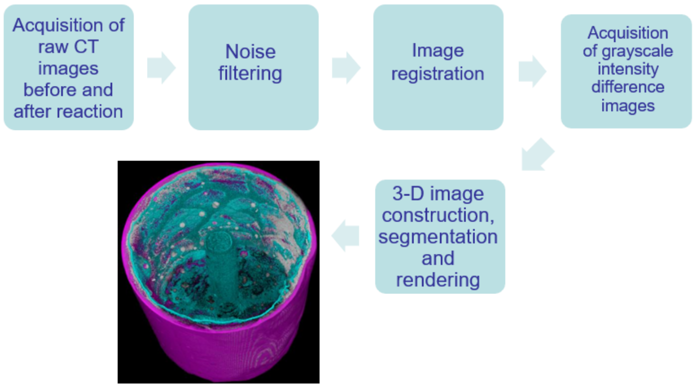


Permeability and porosity increase at reaction zone

Cement degradation by : complex process affected by THMC coupling

Micro-CT is an ideal characterization tool to study cement degradation behaviour by CO_2

Methodology

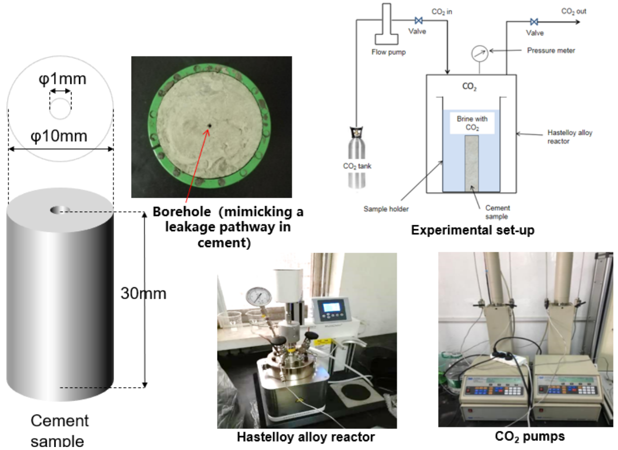


3-D visualization of cement degradation

Workflow to use micro-CT to study cement degradation

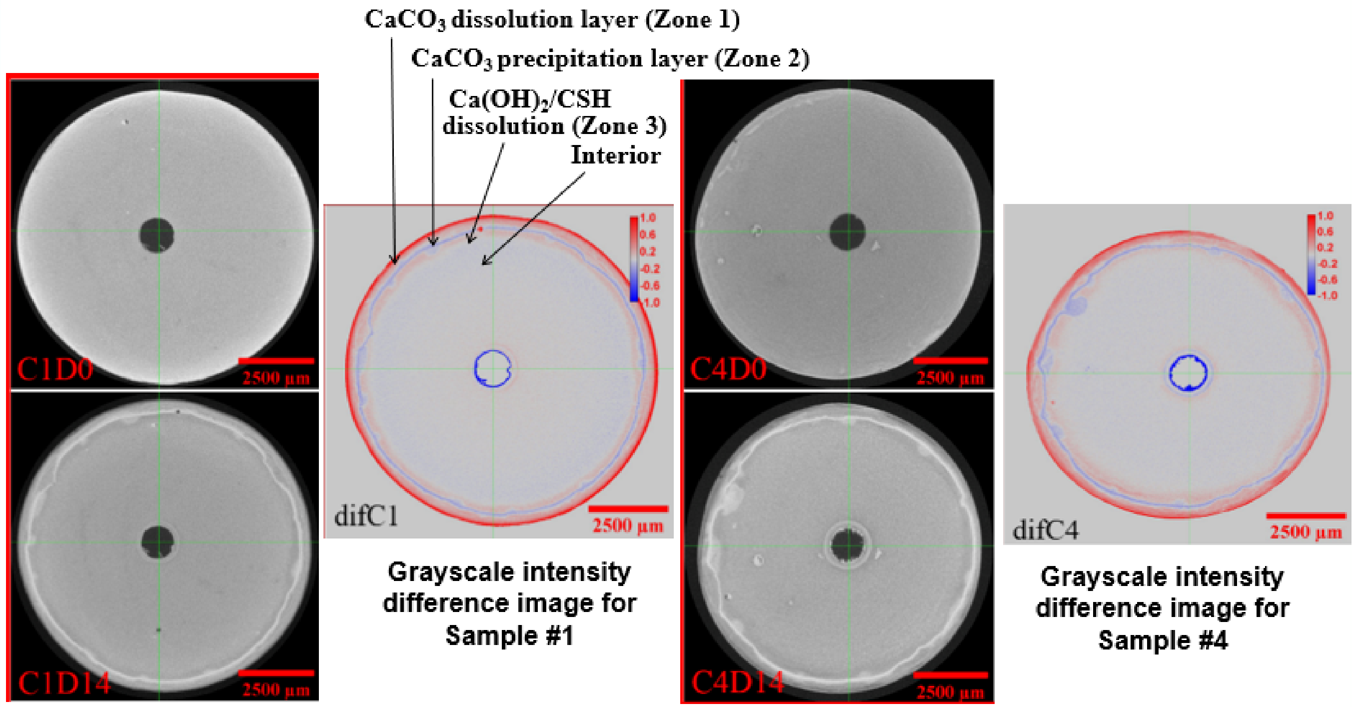
METHODOLOGY/RESULTS

Zeiss Xradia Versa 410 micro-CT scanner used in this study



CO_2 exposure experiment

Results



Grayscale intensity images before and after reaction for Sample #1

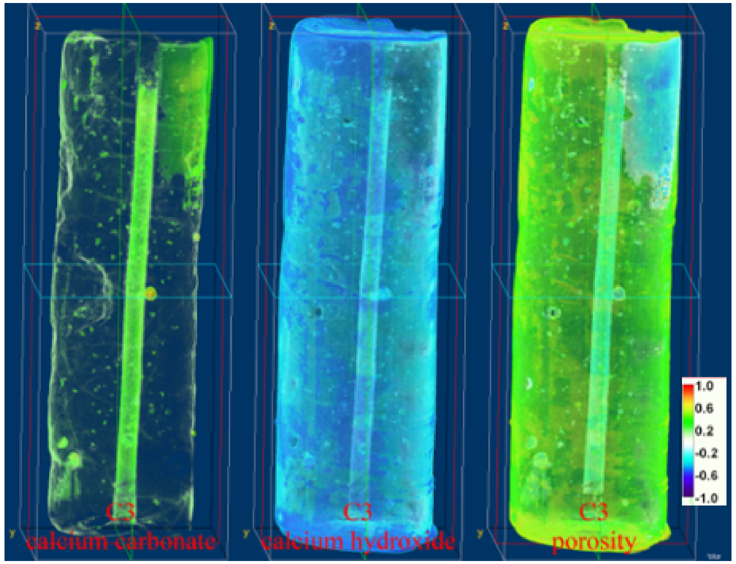
Grayscale intensity difference image for Sample #1

Grayscale intensity images before and after reaction for Sample #4

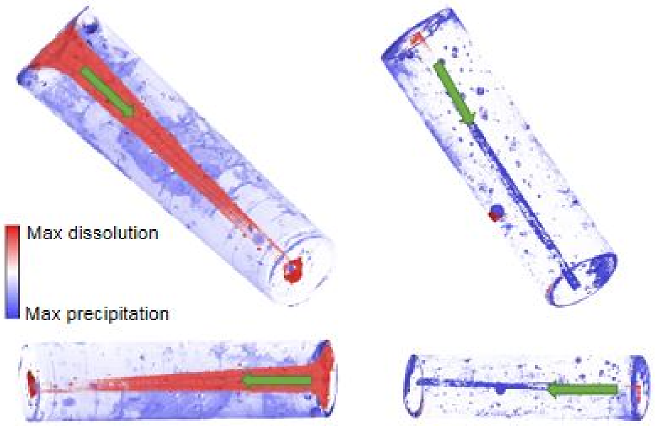
Grayscale intensity difference image for Sample #4

2-D micro-CT slices of the cement sample after exposure to CO_2

RESULTS/CONCLUSIONS



3-D relative changes in $CaCO_3$ vol%, $Ca(OH)_2$ vol% and porosity reconstructed from 2-D slices



With flow No flow

Flow within cement fracture accelerates cement dissolution

Conclusions

• CT imaging of the cement after reacting with CO_2 reveals 3 reaction zones and the dissolution-precipitation-dissolution "sandwich" pattern

• Dissolution mainly occurs in the exterior, and no dissolution is observed in the fracture (no flow case)

• When there is flow within the fracture, dissolution of cement occurs surrounding the fracture.

ABSTRACT

This presentation demonstrates a CT scanning and image analysis workflow to characterize wellbore cement degradation under corrosive geologic CO_2 storage (GCS) conditions. The workflow includes 1) acquisition of raw CT images of the cement sample (before and after exposure to CO_2); 2) application of rigid registration to align raw CT images; 3) acquisition of grayscale intensity difference images; 4) application of noise filtering technique to obtain images with good quality; 5) acquisition of 3D pore structure change of the cement sample after CO_2 exposure from grayscale intensity difference images, showing degradation of wellbore cement. To demonstrate an application of the workflow, an experiment of reaction between CO_2 and wellbore cement under corrosive GCS conditions was conducted and the wellbore cement samples used in the experiment went through aforementioned CT scanning and image analysis procedures. CT image analysis results demonstrate a region with increased porosity in the exterior of the cement sample (Zone 1) and a region with decreased porosity next to Zone 1 due to $CaCO_3$ precipitation (Zone 2). Next to Zone 2, a region with increased porosity due to $Ca(OH)_2$ and C-S-H dissolution (Zone 3) was observed. In summary, this study proves feasibility to use 3D CT scanning and CT image analysis techniques to investigate CO_2-induced degradation of wellbore cement.