Contribution ID: **276** Type: **Poster Presentation**

FE-SEM observation of gypsum precipitation in wellbore cement exposed to CO2 under geologic carbon storage conditions

Wellbore cement serves as a critical barrier to prevent the migration of CO2 through the wellbore and to the surface in CO2 geological storage sites. However, the cement may exhibit chemical instability under CO2-rich conditions. This research examines the changes in the pore structure of reaction zones within wellbore cement samples that have been subjected to a CO2-rich solution equilibrated with 17 MPa supercritical CO2 for a period of 14 days. Utilizing sophisticated characterization techniques such as Field Emission Scanning Electron Microscopy (FE-SEM), Quantitative Evaluation of Minerals by Scanning Electron Microscopy (QEM-SCAN), and Micro-computed Tomography (micro-CT), a novel mechanism of CO2-cement interaction has been discovered and elucidated. This mechanism involves the filling of nanopores within the cement matrix by gypsum. Gypsum formation is attributed to the release of SO4^2- ions from ettringite (AFt) and monosulfate (AFm) phases, which is induced by a reduction in pH. Based on these experimental findings, an improved CO2-cement reaction model has been developed, incorporating four distinct reaction zones. This model offers a comprehensive framework for understanding the spatial and temporal distribution of minerals in cement resulting from high-pressure and high-concentration CO2-cement interactions. This study indicates that the primary damage caused by high-pressure CO2 corrosion occurs in the outermost region of the cement. The inner region of the cement retains its structural integrity due to the filling of nanopores by gypsum.

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References

Primary author: Prof. WANG, Yan (Institute of Rock and Soil Mechanics, Chinese Academy of Sciences)

Co-authors: Prof. ZHANG, Liwei (Institute of Rock and Soil Mechanics, Chinese Academy of Sciences); Prof. GAN, Manguang (Institute of Rock and Soil Mechanics, Chinese Academy of Sciences); YIN, Yue (Institute of Rock and Soil Mechanics, Chinese Academy of Science); Dr WANG, Hanwen (Institute of Rock and Soil Mechanics, Chinese Academy of Sciences); BLUNT, Martin (Imperial College London)

Presenter: Prof. ZHANG, Liwei (Institute of Rock and Soil Mechanics, Chinese Academy of Sciences)

Session Classification: Poster

Track Classification: (MS10) Advances in imaging porous media: techniques, software and case studies