Microstructural evaluation of shales using X-ray Computed Tomography

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Introduction

Carbon capture and storage (CCS) is a promising strategy to significantly decrease carbon footprint, with its long-term security relying on caprock integrity. Caprock is the impermeable rock layer that acts as a seal for trapping the stored CO_2 and preventing it from migrating to the surface.

Herein, we present our latest X-ray Micro Computed Tomography (X-ray CT) results of two shale outcrop samples: a cylindrical core of Pierre I and a sample from the Trondheim region. Complementary Wide-Angle X-ray Scattering (WAXS) and Powder X-ray Diffraction (XRD) analyses identify the crystalline mineral phases, while Scanning Electron Microscopy (SEM) provides high-resolution surface morphology and particle geometry.

X-ray Computed Tomography

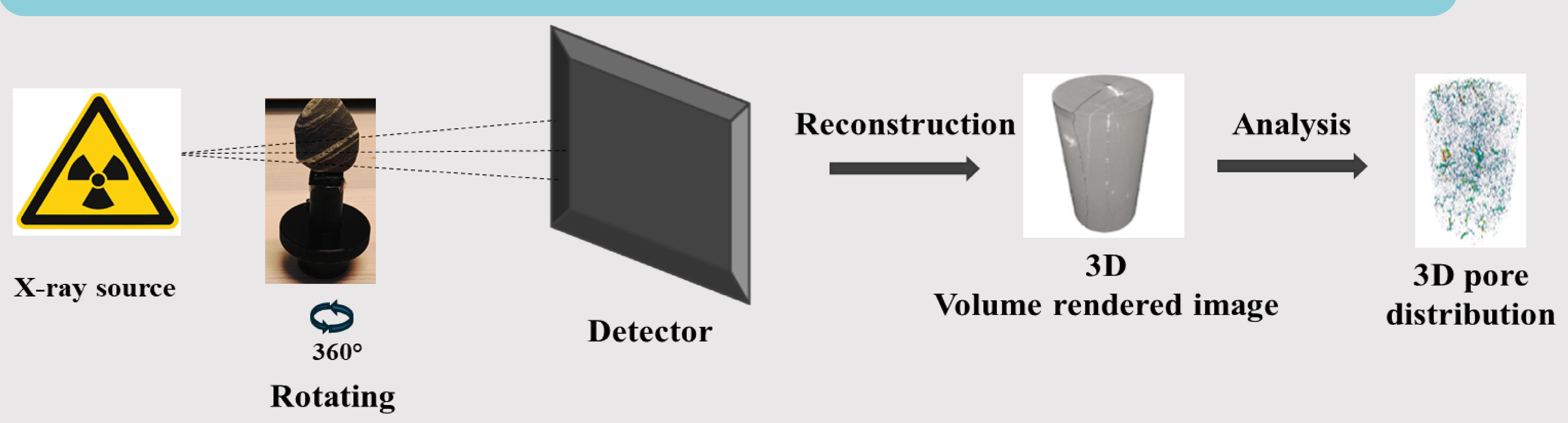


Fig. 1 Schematic representation of X-ray CT

X-ray CT is a non-destructive imaging technique that enables **3D visualization** of a sample's internal structure by acquiring X-ray projections from multiple angles.

X-ray CT results

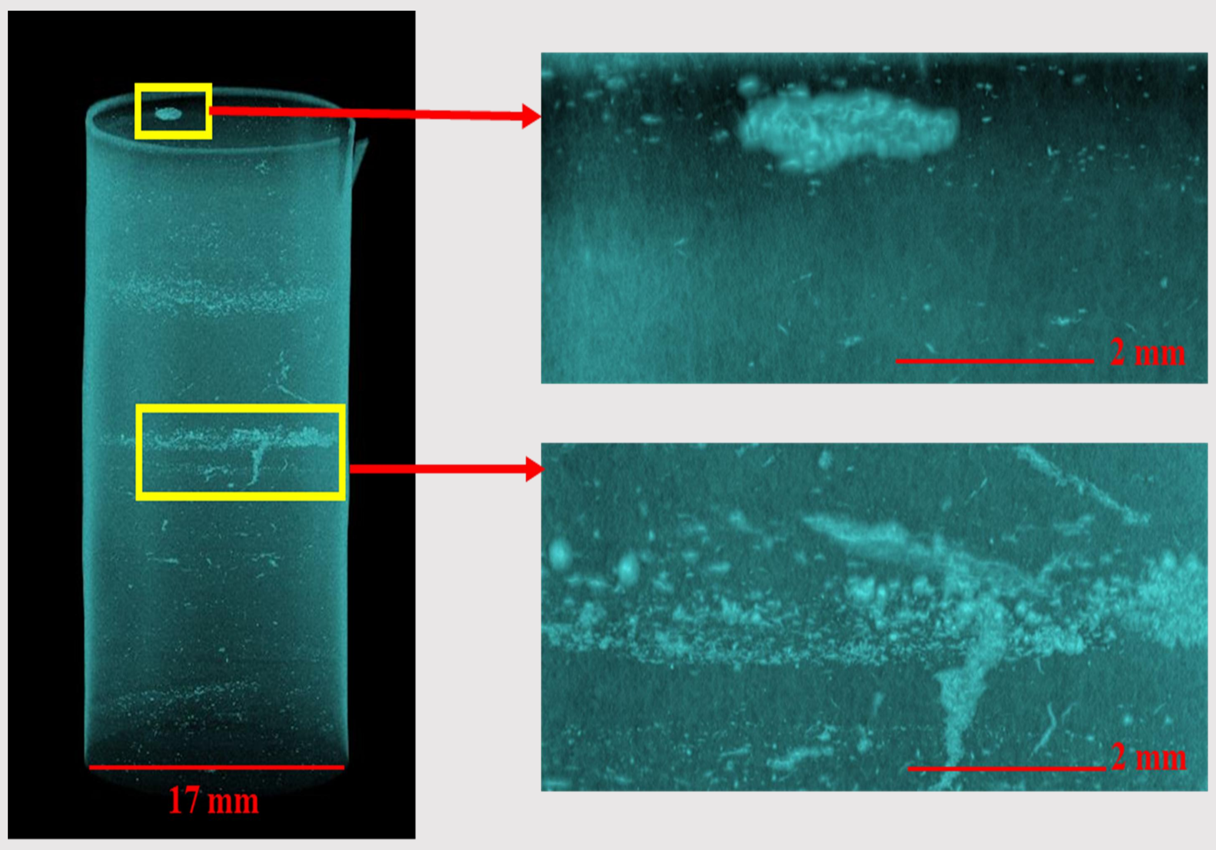
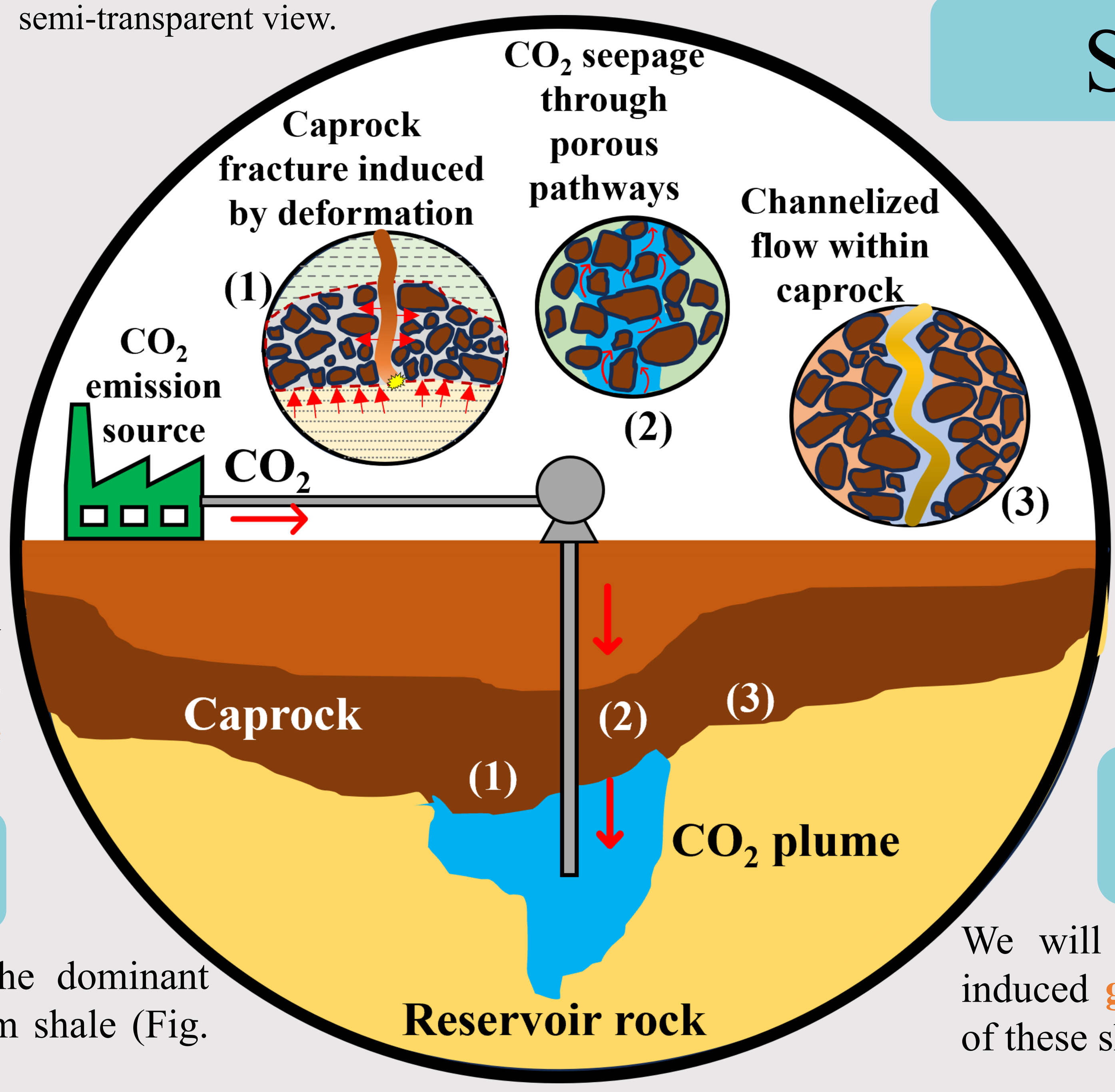


Fig. 2 X-ray CT images of Pierre I shale cylindrical plug with dimensions 17 mm dia. × 31 mm height in semi-transparent view.

Understanding the quantity and morphology of highly dense mineral inclusions is essential, as they can act as stress concentrators, significantly influencing **fracture initiation** and propagation.



Mineral phases

X-ray diffraction pattern in Fig. 3a reveals quartz as the dominant mineral phase of Pierre I shale. In contrast, the Trondheim shale (Fig. 3b) is dominated by clinochlore.

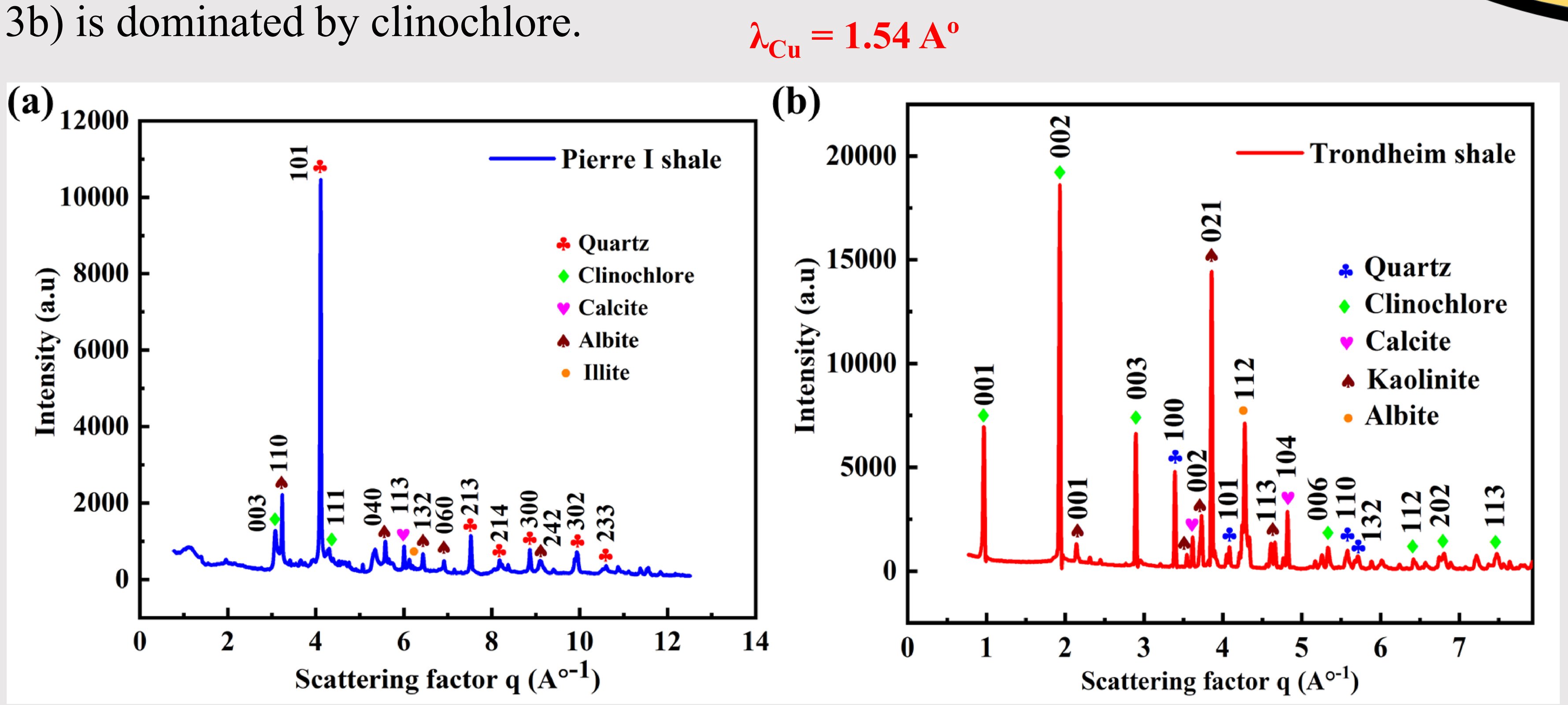


Fig. 3 Powder X-ray diffractograms of a) Pierre I and b) Trondheim shale

WAXS results

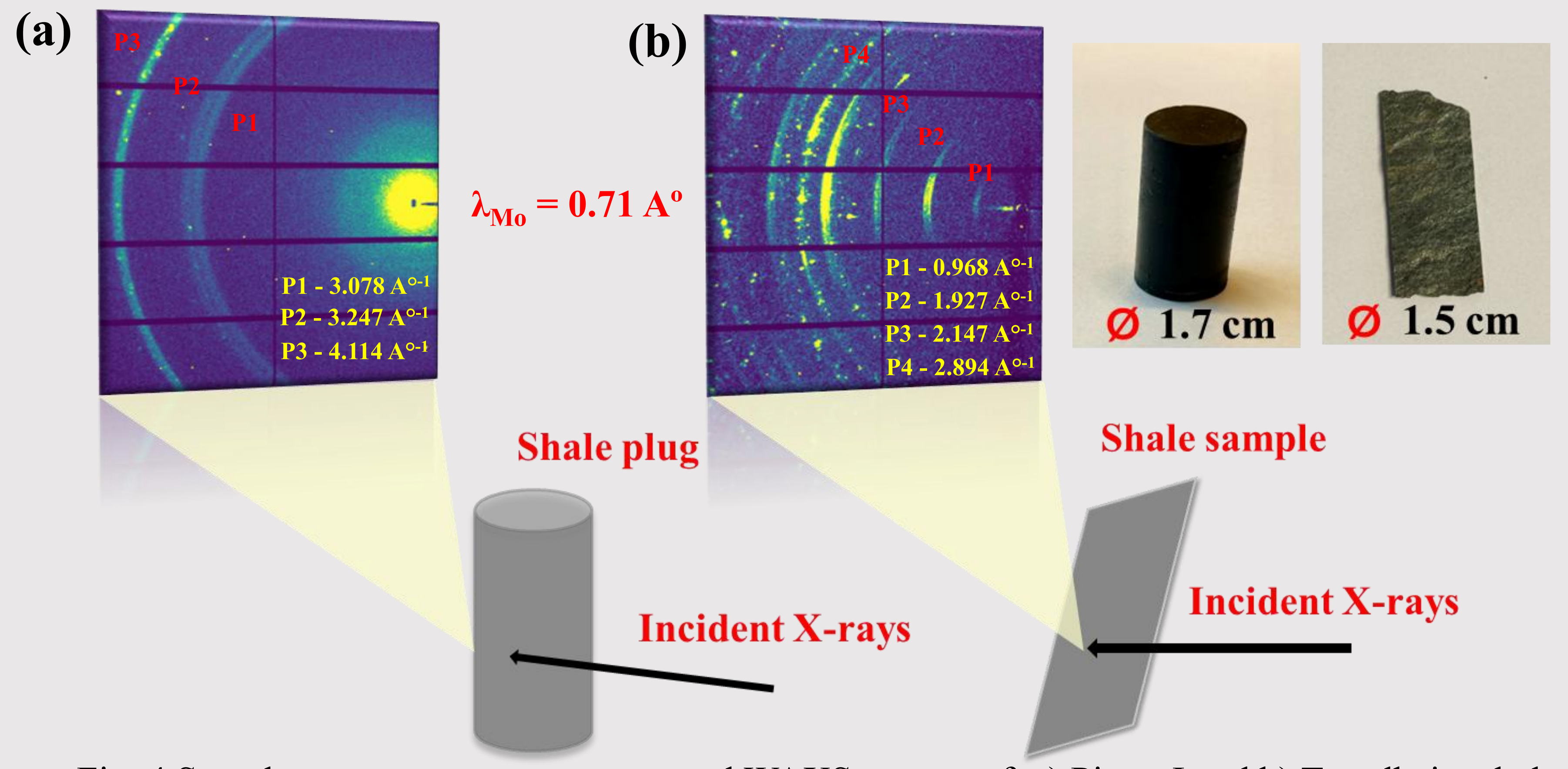


Fig. 4 Sample measurement geometry and WAXS spectra of a) Pierre I and b) Trondheim shale

The **anisotropic** Debye-Scherrer diffraction rings in Fig. 4b suggest preferred orientation, as opposed to the uniform (isotropic) rings in Fig. 4a.

Surface morphology

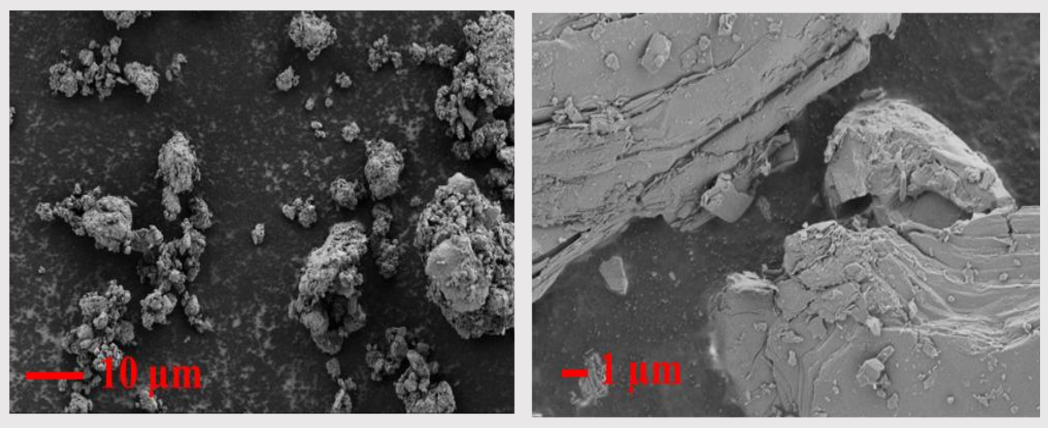
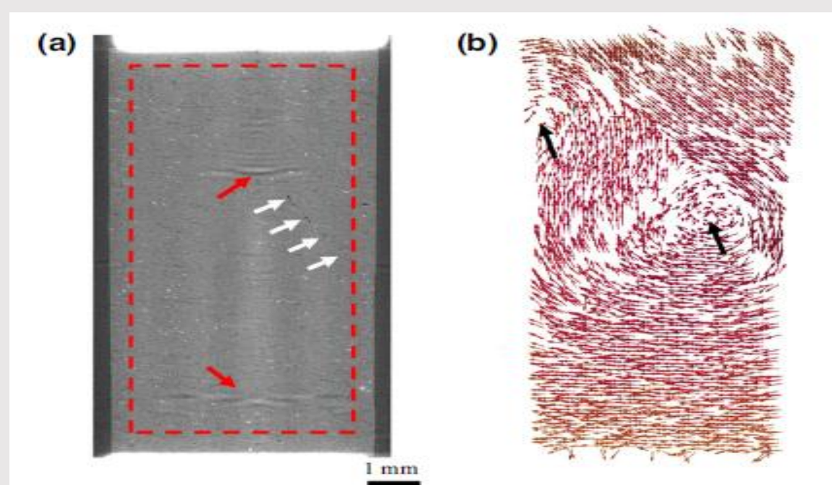


Fig. 5 SEM images of a) Pierre I and b) Trondheim shales

Pierre I shale in Fig 5a exhibits densely aggregated, fine-grained particles, while the Trondheim shale is characterized by larger, platy mineral grains, indicative of a more **laminar** structure.

Future work

We will further this study by understanding the CO_2 -induced **geochemical reactions**, and **mechanical behavior** of these shales under supercritical conditions.



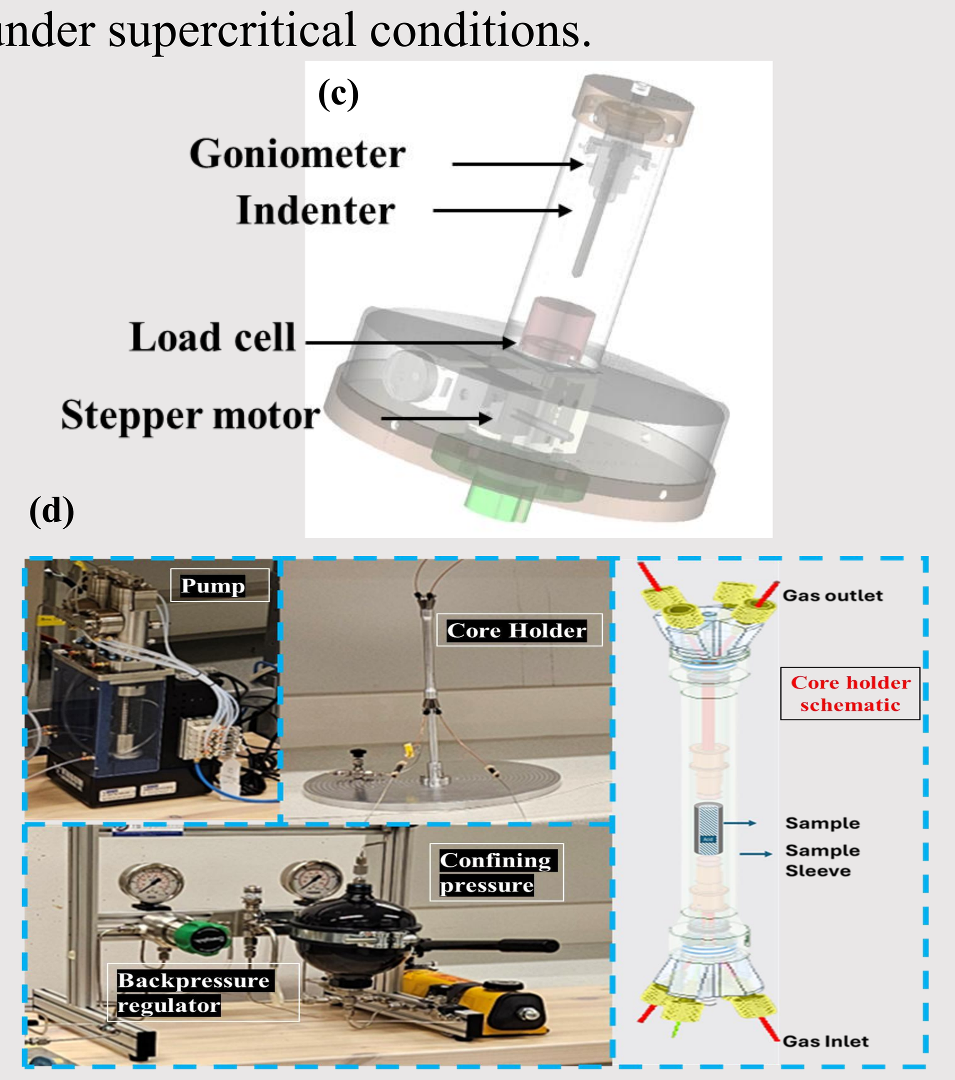


Fig. 6 a) Strain localization in Draupne shale b) Displacement vector field using the **digital volume correlation (DVC)** c) Indentation stage for real time measurements and d) core flooding setup at home laboratory

Acknowledgements

The authors would like to acknowledge funding provided via the European Commission's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie Grant Agreement ID: 101118369, Material Science Innovation for Accelerated, Sustainable and Safe Implementation of Carbon Capture and Storage (MISSION-CCS). Jessica Zeman is thanked for the core flooding setup. The authors would like to thank the Norwegian Research Council for financial funding for the SaltyPORE project (FRINATEK, project no. 335519).

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