



Contribution ID: 351

Type: Oral Presentation

Advanced 4D Imaging of Shales at Micro- to Nano-scale: Investigating the time-lapse evolution Under Subsurface Thermal, Hydrological, Mechanical, and Chemical Conditions

Tuesday, 14 May 2024 12:00 (15 minutes)

Mudstones and shales are the source of unconventional oil and gas reservoirs, as well as the primary control on the sealing efficiency for subsurface storage applications (e.g. energy, CO₂, H₂, waste). However, their fine-grained and heterogeneous nature makes their full characterisation highly challenging. Here we demonstrate the multi-scale and dynamic imaging approaches that can help meet these challenges and discuss limitations and future opportunities.

Microstructures can be characterised at scales from sub- nm (<1 nm) to over 1 m, using multi-scale and multi-model imaging approaches [1-3], including X-ray tomography, Focused Ion Beam Scanning Electron Microscope and Transmission electron microscopy tomography. The majority of pores in mudstones/shales range from 0.2 nm to 3µm, and we have documented 4 major types with 3 distinct size distributions [4]. Based on the REV analysis, pore sizes, types and distribution can be upscaled via three stages from sub-nm to cm-scale[5]. The permeability is pressure dependant, ranging from 1.0×10^{-17} to $1.0 \times 10^{-22} \text{m}^2$ [3, 5]. CO₂ adsorption is 3-7 times higher than CH₄ and over 10 times higher than H₂ [6]. Image based modelling has demonstrated that the non-Darcy effects (e.g., slip flow and Knudsen diffusion). Adsorption/desorption and surface diffusion takes major controls over time after injection [7].

Dynamic imaging of mudstones/shale has provided the opportunity to characterise the thermo-hydro-mechanical-chemical (THMC) properties and the coupling mechanism in mudstones/shales to investigate the sealing ability under realistic reservoir conditions. These include high temperature (from less than 10 °C up to 1000 °C) [8], high pressure (e.g. confining pressure, indentation, torsion, deformation and fractures; up to 65 MPa) [9], fluids (e.g. diffusion, adsorption, flowing through, multi-phase flow) [10] and complex chemistry environment (brine and drilling fluids) [11]. Based on the dynamic behaviours observation and quantification, It can be concluded that mudstone/shales with horizontally thin-layered laminations, few fractures and less reactive minerals may act as the best caprocks.

Whilst the above has led to an improved understanding of shale/mudstone microstructure under static and dynamic conditions, significant challenges still remain regarding representivity and up-scaling, experimental analysis at subsurface-realistic temperatures, pressure and chemistry, accurate estimations of the long-term behaviours and the proper monitoring techniques.

1. Taylor, K. G., & Ma, L. 2021. GeoExpro, Vol. 18, No. 1 - 2021. 2. Ma, L., et al., 2017. International Journal of Coal Geology, 180, 100-112. 3. Ma, L. et al., 2016. . Marine and Petroleum Geology, 72, 193-205. 4. Ma, L., et., al 2019 . Scientific reports, 8(1), 1-14. 5. Ma, L., et al., 2019. Energy, 181, 1285-1297. 6. Ma, L. et al. 2021. Energy & Environmental Science, 14(8), 4481-4498. 7. Guo, B., et al., 2018. Advances in Water Resources, 122, 70-84. 8. Wang, K., et al., 2021. International Journal of Coal Geology, 244, 103-116. 9. Figueroa Pilz, F., et al., 2017. Journal of Geophysical Research: Solid Earth, 122(4), 2553-25. 11. Godinho, J. R., et al., 2019). Minerals, 9(8), 480.

Acceptance of the Terms & Conditions

[Click here to agree](#)

Student Awards

Country

UK

Porous Media & Biology Focused Abstracts

References

Conference Proceedings

I am interested in having my paper published in the proceedings.

Primary authors: MA, Lin (University of Manchester); Prof. TAYLOR, Kevin (University of Manchester)

Presenter: MA, Lin (University of Manchester)

Session Classification: MS17

Track Classification: (MS17) Complex fluid and Fluid-Solid-Thermal coupled process in porous media: Modeling and Experiment