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Multi-scale Characterization of H2 Storage in Heterogenous Carbonate Reservoirs

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Hydrogen energy is expected to play a significant role in the energy transition with geological storage poised to be one of the few economic options that will enable a large-scale hydrogen economy. Storage in depleted gas fields is an area of active research given the presence of legacy facilities that could be repurposed coupled with the prior knowledge of the reservoir's characteristics. Despite carbonates comprising upwards of 60% of petroleum reservoirs worldwide (Burchette, 2012), there is a critical lack of research pertaining to H2 storage with a significant bias towards relatively homogenous sandstone reference samples and/or other gases.

The role of microporosity in geological storage remains an active research question despite the advances in pore-scale imaging. This is due to limitations arising from the low spatiotemporal resolution and field of view of CT scanners in addition to the complex nature of carbonate pore systems. Analogous research considering CO2 storage, N2, waterflooding and EOR indicates that microporous phases can significantly stratify flow paths into complex geometries due to their high capillary entry pressure, especially in low to intermittent fractional flows. These regions —when water-wet —can lower non-wetting phase residual saturations and boost wetting-phase relative permeabilities to aid recovery during waterflooding (Reynolds et al., 2017; Gao et al., 2019). Furthermore, the complexity of micro-porous carbonates is further exacerbated when wettability is considered. Mixed-wet carbonates can exhibit trapping due to localized wettability alteration resulting in complex flow paths linking between micro- and macro-pores (Bultreys et al., 2016). This is coupled with contact angle hysteresis which is typically accentuated in smaller pore sizes and heterogenous systems (e.g., van Rooijen et al., 2022).

An additional area lacking research is H2 hysteresis across multiple cycles. Despite a majority of studies focusing on one or two cycles only, there are a few indications from microfluidic experiments that the residual trapping remains stable across multiple cycles with a strong correlation with the initial H2 saturation; however, a consensus remains absent (Kimbrel et al., 2022; Gao et al., 2023; Lysyy et al., 2023).

Following the review of opportunities and challenges associated with H2 storage in carbonates, a research plan is proposed that aims to fill the aforementioned gaps through 4D synchrotron imaging of steady-state and cyclic unsteady-state drainage and imbibition experiments at reservoir conditions in carbonate core plugs. The samples are of low permeability and exhibit significant pore system heterogeneity. Finally, integrated field-scale reservoir simulations will be performed to assess the effect of geological structure and anisotropy. The samples display strong variations in petrophysical properties due to leaching and dissolution events, leading to the development of microporous phases with varying degrees of heterogeneity. The intricate geology of these samples renders them a strong candidate for addressing the identified research gaps in addition to supplementing the fundamental principles of imbibition phenomena in heterogeneous porous media.

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References

Bultreys, T., Stappen, J.V., Kock, T.D., Boever, W.D., Boone, M.A., Hoorebeke, L.V. and Cnudde, V. 2016. Investigating the relative permeability behavior of microporosity-rich carbonates and tight sandstones with multiscale pore network models. Journal of Geophysical Research: Solid Earth. 121(11), pp.7929–7945. Burchette, T.P. 2012. Carbonate rocks and petroleum reservoirs: a geological perspective from the industry. Geological Society, London, Special Publications. 370(1), pp.17–37. Gao, J., Kong, D., Peng, Y., Zhou, Y., Liu, Y. and Zhu, W. 2023. Pore-scale mechanisms and hysteresis effect during multi-cycle injection and production process in underground hydrogen storage reservoir. Energy. 283, p.129007. Gao, Y., Qaseminejad Raeini, A., Blunt, M.J. and Bijeljic, B. 2019. Pore occupancy, relative permeability and flow intermittency measurements using X-ray micro-tomography in a complex carbonate. Advances in Water Resources. 129, pp.56–69. Kimbrel, E.J.H., Wildenschild, D., Herring, A.L. and Armstrong, R.T. 2022. The effect of original and initial saturation on residual nonwetting phase capillary trapping efficiency. International Journal of Greenhouse Gas Control. 120, p.103758. Lysyy, M., Liu, N., Solstad, C.M., Fernø, M.A. and Ersland, G. 2023. Microfluidic hydrogen storage capacity and residual trapping during cyclic injections: Implications for underground storage. International Journal of Hydrogen Energy. 48(80), pp.31294–31304. Reynolds, C.A., Menke, H., Andrew, M., Blunt, M.J. and Krevor, S. 2017. Dynamic fluid connectivity during steady-state multiphase flow in a sandstone. Proceedings of the National Academy of Sciences. 114(31), pp.8187–8192. Van Rooijen, W., Hashemi, L., Boon, M., Farajzadeh, R. and Hajibeygi, H. 2022. Microfluidics-based analysis of dynamic contact angles relevant for underground hydrogen storage. Advances in Water Resources. 164, p.104221.

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