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Assessing the Geothermal Potential and Carbon Capture and Storage Potential on the Al-Wajh Formation of the Yanbu Basin Through Coupled Reservoir Modeling and Simulations

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Abstract

Global energy demand continues to rise alongside CO_2 emissions, driving countries to expand low-carbon energy sources while deploying mitigation technologies such as carbon capture and storage (CCS). Saudi Arabia is an example of this dual approach, committing to net-zero emissions by 2060 and targeting 1 GW of installed geothermal capacity. While traditional geothermal projects target's are crystalline rocks near volcanic regions, that often require hydraulic stimulation to enhance permeability, this study focuses on assessing the geothermal potential of hot sedimentary aquifers together with their potential for CO_2 storage.

This study investigates both the geothermal and CO_2 storage potential of the Al-Wajh Formation in the Yanbu Basin, in western Saudi Arabia. A static geological model was generated using available and analogue data to capture reservoir heterogeneity caused from variations in depositional environments. Facies trends were reproduced through stochastic and conditioned facies merging. Porosity decrease with depth due to compaction was represented using well-log data and published data to assess its impact on flow capacity and CO_2 injection efficiency. Reservoir simulations were performed to evaluate CO_2 trapping mechanisms and heat transport processes in surbsurface to represent these processes on the basin.

Initial results show that geothermal production of around 80 L/s per well at 120 °C could be achieved, with reinjection at 60 °C for sustaining pressure and delaying thermal breakthrough when producers are spaced 1.4–1.75 km apart. Reservoir heterogeneity in the fluvial deposits strongly influences thermal breakthrough showing the need for additional well and core data to improve reservoir understanding. The results also highlight how productivity can be drastically reduced when targeting deeper areas when aiming for higher temperatures showing the importance of considering compaction curves for target evaluation. For CO_2 storage, an injection rate of 0.7 Mt CO_2/yr per well through four wells over 50 years was achieved on the simulations, with residual trapping being the dominant trapping mechanism once injection stops. Residual trapping would account for around 68% of the CO_2 trapped years after injections stops. Ultimate storage capacity is strongly controlled by reservoir extent, fault transmissibility, and the sealing capacity of the overlying Yanbu Formation (salt) which could influence how pressure is dissipated during the injection.

The findings provide valuable guidance for potential hot sedimentary aquifer geothermal and Carbon Capture and Storage Projects in Saudi Arabia, supporting the country's climate change mitigation goals.