Contribution ID: **136** Type: **Poster Presentation**

Numerical simulation CO2 sequestration in deep saline aquifers coupled with enhanced reservoir water and geothermal energy system recovery

Wednesday, 15 May 2024 16:10 (1h 30m)

Deep saline aquifers are ideal geological storage sites for CO2, containing abundant water and geothermal resources. Injecting CO2 into deep saline aquifers while simultaneously extracting reservoir water can slow down the rise in reservoir pressure, increasing the safety of storage. This approach also extracts water resources to offset the cost gap incurred during the storage process. Simultaneously, the heat in the reservoir water (geothermal energy) can be directly used for power generation and heating, further enhancing the resource utilization efficiency of deep saline aquifers. Therefore, a coordinated development approach for deep saline aquifers involving CO2 injection, water extraction, geothermal energy extraction, and carbon storage is proposed. This approach is divided into two phases: the first phase involves extracting formation water and geothermal energy during CO2 injection, and the second phase involves using CO2 as a heat medium to extract geothermal energy after depleting formation water. A numerical simulation model coupling gas-water two-phase heat flow is established to verify the advantages of this new development approach. Additionally, optimal injection methods, well pattern, and injection-production parameters for the new approach are provided.

The research results indicate that simultaneous water and geothermal extraction during CO2 injection can delay the rise in formation pressure, providing more storage space for CO2 and increasing the amount of sequestration. Continuing geothermal extraction after depleting formation water not only retrieves more heat but also further increases geological storage capacity. CO2 injection induces geochemical reactions, increasing porosity and connectivity, creating favorable conditions for sustained CO2 injection, and the extraction of formation water and geothermal energy. Intermittent injection is the optimal injection method to maximize the delay in formation pressure rise. Production wells and injection wells should be located in the same layer, with more injection wells placed in structurally lower positions. Taking the Qing 3rd member of the deep saline aquifer in the Daqing Oilfield, Jilin Province, as an example. The optimal injection parameters are an injection rate of 10,000 m3/d, an injection-production ratio of 0.8, a cyclic injection time of 3 months, and a cyclic injection-production time ratio of 1.

The new development approach provides a novel method and perspective for geological storage of CO2 in deep saline aquifers. Its aim is to establish a theoretical foundation and scientific basis for the efficient utilization of resources in deep saline aquifers. This research is of reference significance for supporting the “Dual Carbon” goals and promoting efficient resource coordination.

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Primary authors: XIE, Zehao (Southwest Petroleum University); Prof. ZHAO, Yulong (Southwest Petroleum University); Prof. CAO, Cheng (Southwest Petroleum University); Mr LUO, Ruike (Southwest Petroleum University); Prof. WEN, Shaomu (Petrochina Southwest Oil and Gas Field Company); Prof. HU, Yong (Petrochina Southwest Oil and Gas Field Company); Prof. PENG, Xian (Exploration and Development Research Institute, Southwest Oil and Gas Field Company, petrochina); Prof. ZHAO, Zihan (Exploration and Development Research Institute, Southwest Oil and Gas Field Company, petrochina); Prof. ZHANG, Liehui (Southwest Petroleum University)

Presenter: XIE, Zehao (Southwest Petroleum University)

Session Classification: Poster

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