Enhanced CO_2 storage efficiency due to the impact of faults on CO_2 migration in an interbedded saline aquifer

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Abstract

This study explores how geological faults and interbedded layers in saline aquifers can enhance CO_2 storage efficiency. Unlike previous studies that primarily focused on the negative impacts of faults and thin layers, this research highlights their potential advantages. Using the TOUGH2/ECO2N simulation software, a 3D model was developed to simulate CO_2 migration in an interbedded aquifer-aquitard system with leaky faults. The model revealed two key advantages: migration advantage, where faults guide CO_2 into different layers of the aquifer, and dissolution advantage, where the presence of interbeds enhances CO_2 dissolution in brine. When compared to a homogeneous model, the interbedded system showed significantly improved CO_2 storage capacity. Faults act as vertical conduits, directing CO_2 into individual layers, while interbeds serve as horizontal barriers, promoting lateral migration and increasing contact between CO_2 and brine. This combined effect results in more efficient trapping and dissolution of CO_2. The findings suggest that interbedded aquifer-aquitard systems with leaky faults have significant potential for improving CO_2 storage through this dual mechanism of guided migration and enhanced dissolution.

Keywords: Enhanced CO_2 storage efficiency, Interbedded saline aquifer, Migration advantage, Dissolution advantage.

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ABSTRACT

In the interbedded saline aquifer, as have been widely reported, the unexpected leaky fault is most likely to appear in the interbed. Under the combined effect of the leaky fault and the interned, CO_2 storage efficiency was enhanced due to the impact of faults on CO_2 migration in the interbedded saline aquifer. The main reasons include: (i) the fault acted as a conduit to guide CO_2 to move upward and then enter into each individual layer of saline aquifers; (ii) the interbed acted as a nature barrier to force CO_2 that entered into each individual layer of saline aquifers to migrate horizontally under the interbed. For investigating the enhanced storage efficiency, a 3-D numerical model was established in this study based on TOUGH2 / ECO2N code, considering the interbedded aquifer-aquitard system including leaky faults. By comparing the difference of gas CO_2 migrations between the homogenous model and the proposed model, two aspects of migration advantages were obtained for the enhanced CO_2 storage efficiency, namely, the increased horizontal migration area and the decreased gas CO_2 amount under caprock. In addition, the dissolution advantage was obtained for the enhanced CO_2 storage efficiency, by comparing CO_2 dissolution capacities between the homogenous model and the proposed model. It was found that the dissolution advantage was mainly affected by the CO_2 migration advantage, which led to the lager contact area between the CO_2 plume and brine and the larger convection area between the brine containing dissolved CO_2 and the natural brine. Furthermore, different fault distributions (e.g., irregular and regular distributions) were proposed to investigate the effect of fault distributions on CO_2 storage efficiency. The results showed that different fault distributions produced different gas CO_2 migration behaviors while with almost equal dissolution capacities. More importantly, the irregular fault distribution occupied the smallest storage amount in the uppermost saline aquifer, which reveals that the irregular fault distribution is the most ideal for CO_2 storage from the viewpoint of security.