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Improving MMV of geological CO_2 storages with consideration of geochemical reactions: a review of the state of the art and challenges

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Summary

Geological storage of anthropogenic CO_2 is one of the most viable ways to reduce carbon emissions into the atmosphere and to aid in meeting the goal of net-zero carbon emissions. Geological CO_2 storage occurs through various mechanisms: stratigraphic structural trapping of mobile supercritical CO_2, capillary trapping of residual immobile CO_2, solubility storage of CO_2 in water and/or residual oil in saline aquifers and depleted hydrocarbon reservoirs, and carbonation through CO_2-water-rock interactions with mineral dissolution and secondary precipitation. Measurement, monitoring and verification (MMV) of CO_2 storage in saline formations and depleted oil and gas reservoirs is essential to ensure the near- and long-term safety of carbon storage. Successful execution of MMV plans and remediation depend on reliable forecasting of CO_2 storage capacity, injectivity, migration, containment and leakage, which in turn requires an accurate static and dynamic geological simulation models obtained through comprehensive characterization of a storage site through geological studies, routine and special core analyses, and fluid PVT property measurements.

CO_2 injection and dissolution into formation water can reduce water pH, consequently inducing mineral dissolution, release and transport of ions, and secondary mineral precipitation. The chemical changes can also result in alteration of rock wettability and thus capillary pressure, porosity and permeability, and even mechanical strength of reservoir and cap rocks. CO_2 solubility and mineralization trapping is a significant component and the safest mechanism of long-term carbon storage. Yet, most field studies and dynamic simulations often ignore or significantly simplify the involved geochemical reactions due to a lack of relevant data, complexity of incorporation of water-rock interactions into reservoir simulations with reactive transport, constraints of computational resources, and time.

In this study, a review of the state of the art of understanding of CO_2-water-rock interactions in geological carbon storage process and its effect on CO_2 transport and storage is provided within the context of fluid properties, laboratory core studies, dynamic simulations and field examples. The challenges of incorporating CO_2 reactive transport into dynamic reservoir simulations to improve the forecasting reliability of such models and thus better MMV plans of geological CO_2 storage projects in saline formations and depleted oil and gas reservoirs are also discussed. Overall, this study provides some guidelines on consideration of geochemical reactions to improve MMV of geological CO_2 storage projects for practicing geologists and engineers and future studies.