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Potential Changes in Clearwater Shale Following CO_2 Exposure

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Summary

The Clearwater Shale, a regional caprock for natural gas accumulations and oil sands deposits in northeastern Alberta, Canada, serves as the primary seal for potential CO_2 storage in the underlying Wabiskaw and McMurray sandstone reservoirs (Peng et al., 2023; Huang et al., 2024). Despite its significance, limited studies have explored the effects of CO_2 injection on Clearwater Shale in the context of geological storage. To address this gap, six shale samples from five wells (Townships 68–74, Ranges 5–7, west of the fourth meridian in Alberta) at depths of 400.80–522.70 m were investigated through CO_2–brine–rock interaction experiments.

The experiments were conducted under simulated CO_2 storage conditions (22 ± 1°C, 5 MPa) over 84 days, with periodic sampling of brine and shale every 14 days to monitor changes in water chemistry and mineral composition. X-ray diffraction (XRD) analysis revealed that the original shales primarily consist of quartz (43.2–68.3 wt.%), clay minerals (26.2–45.1 wt.%), K-feldspar (1.1–3.8 wt.%), and albite (1.9–13.6 wt.%), with minor dolomite in some samples.

Post-CO_2 exposure, albite and K-feldspar in shale appear to have reacted with CO_2 and brine, forming dawsonite and quartz. This reaction likely increased the solid volume, potentially enhancing the long-term sealing integrity for CO_2 storage. In brine chemistry, total dissolved solids (TDS) initially spiked and then stabilized, while [Ca^{2+}], [Mg^{2+}], and [K^{+}] remained largely unchanged. In contrast, [Na^{+}], [Fe^{2+}], and [Mn^{2+}] exhibited variability over time without discernible trends.

These results provide insights into the mineralogical and geochemical responses of Clearwater Shale to CO_2 injection, with implications for its long-term effectiveness as a caprock and for understanding potential stress changes in geological storage settings.

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