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4D seismic tracking of the CO_2 plume at the Aquistore CO_2 storage site

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Summary

Since 2015, more than 600,000 tonnes of CO_2 have been injected into a deep saline formation at the Aquistore CO_2 storage site in southeast Saskatchewan. The storage reservoir extends over a a depth interval of 3130-3350 m comprising Cambro-Ordovician clastic formations (Winnipeg and Deadwood) lying unconformably on the Precambrian basement. Geological site characterization and assessment was largely based on interpretation of 3D seismic data acquired prior to drilling of the injection and observation wells in 2012 (e.g., White et al., 2016; White, 2018). The 3D data depict gently SSE-dipping strata with a prominent SSE-NNW-striking structural fabric including a ridge on the Precambrian surface interpreted to be a basement fault. The presence of this fault has an expression in the overlying reservoir strata where it appears seismically as a flexure but could also be a fault/fracture zone that is not fully resolved by the seismic data.

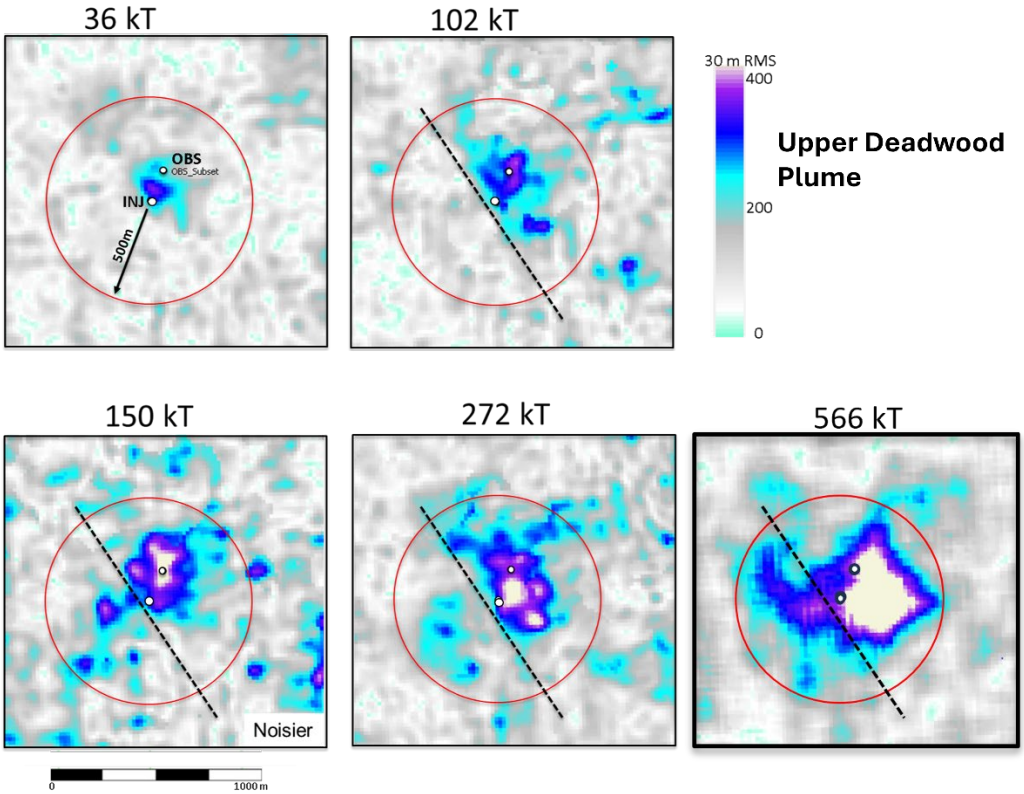

Figure 1 Time-lapse amplitude differences for the upper Deadwood interval. Observed amplitude differences in the 4D seismic volumes are interpreted as zones of CO2 saturation. Injection and observation well locations are indicated by the circles.

4D seismic data has been used to track the evolution of the CO_2 plume since the start of injection in 2015. Surface seismic and VSPs have been acquired using a permanent 2D array of shallow buried geophones and well-based distributed acoustic sensing (DAS), respectively. 4D seismic surveys have been acquired at times when cumulative injected CO_2 was 0, 36, 102, 141, and 272 ktonnes, respectively (Roach and White, 2018; Movahedzadeh et al., 2021). The most recent 3D survey was acquired in November, 2023 with 566 ktonnes of CO_2 injected which is more than double the quantity of CO_2 in place during the previous survey in 2020.

The 4D seismic data image a primary CO_2 plume within a ~10 m thick high-permeability interval within the upper Deadwood Formation of the reservoir as well as a secondary plume within the overlying Black Island member of the Winnipeg Formation. The primary plume has continued to expand in sequential 4D images (see Figure 1) with migration generally appearing to be in the regional up-dip direction (NNW). The interpreted structural flexure/basement fault that is sub-parallel to the dominant structural trends (White et al., 2016) appears to be a barrier that limits the westward flow of CO_2 from the injection well. Even in the 2023 image (Figure 2), this appears to be the case although the trajectory of the fault in the vicinity of the wells is not as obvious. Revisions to the geological flow model for the reservoir have incorporated this feature which strongly controls resultant CO_2 plume shapes in the flow simulations. (Rangriz Shokri et al. 2019).

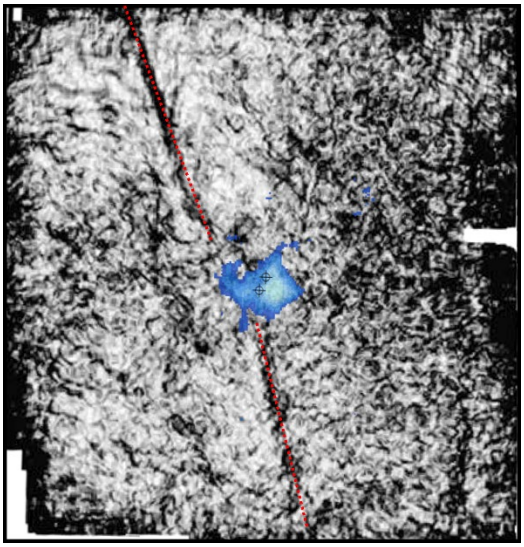

Figure 2 2023 seismic plume image superposed on seismic attribute slice from within the reservoir from the baseline 3D survey. The trace of the interpreted basement fault is dash in red. Area cover by image is approximately 5x6 km. The frame shown is oriented 2^o east of north.

References

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