2-D Seismic Modeling of CO_2 Fluid Replacement of the Redwater Leduc Reef for CO2 Storage Project, Alberta

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The Devonian Redwater reef, northeast of Edmonton, Alberta, is being evaluated for geological storage of CO_2 for the Heartland Area Redwater CO_2 Storage Project. It is located close to large sources of CO_2 in the Redwater-Fort Saskatchewan-Edmonton region. The reef complex has a triangular shape with an area of about 600 km^2 and lies at depth of approximately 1000 m (-400 m elevation), and has a thickness of up to 300 m. The reef is underlain by the Cooking Lake carbonate platform and overlain by the Ireton Shale which forms the caprock to the proposed CO_2 storage. A shale embayment occurs around some parts of the reef margin at the Mid-Leduc level. The main objective of the study was to build a 2D geological model of the Redwater reef, from the reef center to off-reef, with 40% CO_2 saturation in the entire Leduc formation. Fluid substitution seismic modeling was then undertaken to generate a 2D synthetic seismic data to trace the consequences of CO_2 saturation on the facies within the reef and formations below the reef based on seismic attributes and characters.

Common shot ray tracing and finite difference modeling were undertaken to evaluate the variations in the seismic response of the Redwater reef along a 2D line across the reef with 40% CO_2 saturation in the full Leduc formation. The input geological model was based on well data and depth-converted seismic data from the interpretation of existing 2D seismic lines in the area. Ray tracing and finite difference synthetic seismic sections demonstrate similar seismic attributes for the Mannville, Nisku, Ireton, Cooking Lake, and Beaverhill Lake Formations. The Cooking Lake and Beaverhill Lake formations display positive structure below the reef in time sections due to the lateral velocity change from on-reef to off-reef, but corrected in the depth seismic sections. Terminations and the lateral position of the Upper and Middle Leduc events are obvious on the pre-stack time and depth-migrated sections. Higher amplitudes at the base of Upper-Leduc member are evident near the reef margin due to the higher porosity of the foreslope facies in the reef rim compared to the tidal flat lagoonal facies within the central region of the reef. Time-lapse seismology proved an enormous amplitude difference for the seismic data before and after 40% CO_2 saturation. A high amplitude occurrence at the top of upper-Leduc, top of the rim, and base of Leduc was strong evident to monitor the CO_2 saturation seismically.