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Structural, petrophysical and geomechanical characterization of the Becancour CO_2 storage pilot site (Quebec, Canada)

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The Paleozoic sedimentary succession of the St. Lawrence Platform was characterized to estimate the CO_2 storage capacity, the caprock integrity and the fracture/fault stability at the Becancour pilot site. Results are based on the structural interpretation of 25 seismic lines and analysis of 11 well logs and petrophysical data. The three potential storage units of Potsdam, Beekmantown and Trenton saline aquifers are overlain by a multiple caprock system of Utica shales and Lorraine siltstones. The NE-SW regional normal faults dipping to the SE affect the subhorizontal sedimentary succession. The Covey Hill (Lower Potsdam) was found to be the only unit with significant CO_2 sequestration potential, since these coarse-grained poorly-sorted fluvial-deltaic quartz-feldspar sandstones are characterized by the highest porosity, matrix permeability and net pay thickness and have the lowest static Young modulus, Poisson's ratio and compressive strength relative to other units. The Covey Hill is located at depths of 1145-1259 m, thus injected CO_2 would be in supercritical state according to observed salinity, temperature and fluid pressure. The calcareous Utica shale of the regional seal is more brittle and has higher Young modulus and lower Poisson's ratio than the overlying Lorraine shale. The 3D geological model is kriged using the tops of the geological formations recorded at wells and picked travel times as external drift. The computed CO_2 storage capacity in the Covey Hill sandstones is estimated by the volumetric and compressibility methods as 0.22 tons/km2 with storage efficiency factor E 2.4% and 0.09 tons/km2 with E 1%, respectively. A first set of numerical radial simulations of CO_2 injection into the Covey Hill were carried out with TOUGH2/ECO$_2$N. A geomechanical analysis of the St. Lawrence Platform sedimentary basin provides the maximum sustainable fluid pressures for CO_2 injection that will not induce tensile fracturing and shear reactivation along pre-existing fractures and faults in the caprock. The regional stresses/pressure gradients estimated for the Paleozoic sedimentary basin (depths < 4 km) indicate a strike-slip stress regime. The average maximum horizontal stress orientation (SHmax) is estimated N62.8°E±4.0° in the Becancour-Notre Dame area. The high-angle NE–SW Yamaska normal fault is oriented at 16.7° to the SHmax orientation in the Becancour site. The slip tendency along the fault in this area is estimated to be 0.47 based on the stress magnitude and rock strength evaluations for the borehole breakout intervals in local wells. The regional pore pressure–stress coupling ratio under assumed parameters is about 0.5–0.65 and may contribute to reduce the risk of shear reactivation of faults and fractures. The maximum sustainable fluid pressure that would not cause opening of vertical tensile fractures during CO_2 operations is about 18.5–20 MPa at a depth of 1 km.