Development and characterization of a geostatic model for monitoring shallow CO_2 injection

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Summary

A 25 sq. km static geomodel was updated for shallow injection into the 7 m thick Belly River Fm. at 295 m depth in Newell County, AB. Effective porosity and permeability were calibrated to six core lab analyses. A P10-50-90 framework was run to give conservative, typical, and optimistic scenarios of the reservoir's storage capacity. The regressional shoreline sandstone interval remains consistent across the study area giving a mean effective porosity of 11% and permeability of 0.57 mD. Dynamic simulation was completed on the P10-50-90 static cases for multiple injection scenarios, totaling 5000 t/CO_2 after a 5-year period. No significant variations existed in the results between the three static cases. The evolution of the CO_2 plume was observed at 1-year during injection and 5-years during injection, as well as the 1-year and 10-year mark for the post-injection period. The final 10-year post-injection result simulated a laterally extensive plume, expanding to 350 m in length and 20 m of vertical migration above the BRS Formation. The target interval proves as an ideal reservoir, and the seal interval demonstrates containment over a 10-year post-injection period.

Introduction

- This study is based on the 5 km by 5 km geostatic model constructed in Dongas and Lawton (2014), and is a continuation to further update and characterize the BBRS Formation for shallow CO_2 injection.
- The injection zone is located in Newell County, AB at 295 m depth, and remains a consistent 8 m thickness throughout the geomodel.

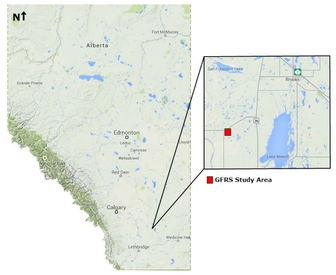
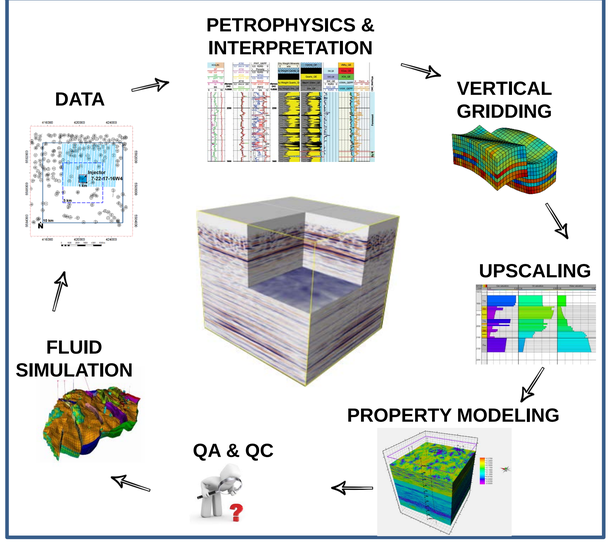


FIG. 1: Location of the GFRS study area (© Google, INEGI 2014).

Model Workflow Overview



Petrophysical Update

Porosity & Permeability

- The mean PHIE value for the BBRS Fm. was calculated to be 11%.
- Intrinsic permeability (K_INT) was calculated for the 88 wells using the Timur-Coates free-fluid model (Luthi, 2013). The mean K_INT value for the BBRS Fm. was calculated to be 0.57 mD.

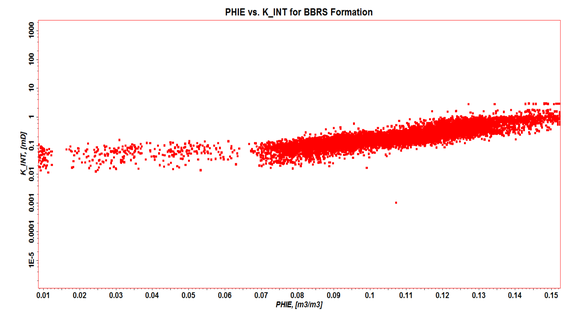


FIG. 2: PHIE-K_INT relationship for the BBRS Formation.

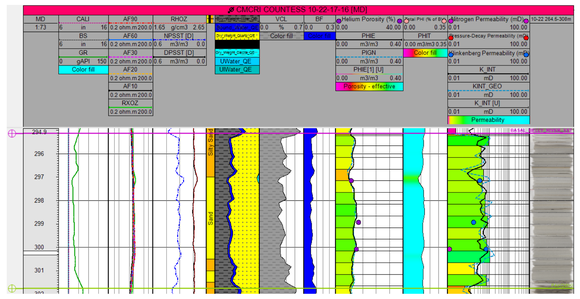


FIG. 3: Well section window of 10-22 well displaying permeability estimated using the Timur-Coates equation with the plotted core lab measurements.

Log-to-Core Calibration

- Six core samples were analyzed for effective porosity and permeability (κ) using the Tight Rock Analyses (TRA) and Routine Core Analyses (RCA) methods provided by Schlumberger Reservoir Laboratories Canada (2015).
- The K_INT curve required a calibration step, and was increased using a 10:1 scalar factor to honour the core-measured permeability (FIG. 4).

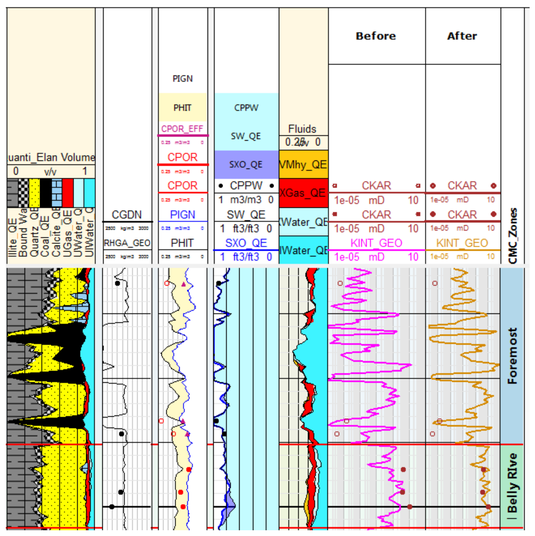


FIG. 4: Before and after log-to-core calibration of K_INT data for the 10-22 well (Swager,2015).

Dynamic Simulation

Simulation Input Parameters

- The PHIE and K_INT P10-50-90 cases of the 25 sq. km model were used as the main input.
- The geodynamic model is defined by the number (n) of cells in (nX, nY, nZ) giving (125, 127, 69).
- The simulation parameters used are outlined in Table 4.
- Table 4. denotes the 5-year injection plan for the dynamic model and simulation scenarios.

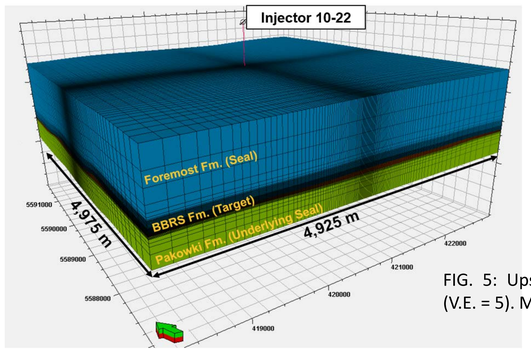


FIG. 5: Upscaled 3-D grid of the geodynamic model (V.E. = 5). Modified from Lee (2015).

Table 3. Simulation parameters used on the dynamic model for CO_2 injection. Modified from Lee (2015).

Parameter	Value
Pressure (reference datum) at 300 m depth	2.94 MPa
Reservoir temperature (isothermal)	20°C
Salinity	1,000 ppm
Rock compressibility (3 samples near 300 m)	4.18 E-04 (1/bar)
Maximum allowable BHP at 300 m depth	6.615 MPa
K_v/K_h	0.1
CO_2-water relative permeability	S_{wmin}=0.5, K_{rCO2}=0.5 (end-point gas K_r)

Table 4. Five-year injection plan used for the dynamic model simulation scenarios.

Date	Injection Period	Shut-in Period
January 1, 2016 – October 14, 2017	3 months	1 month
October 15 – December 31, 2017	-	2.5 months
January 1 – December 31, 2018	2 months	1 month
January 1, 2019 – November 30, 2020	3 months	1 month

Simulation Results

- Injection rates increase over time for both layer cake and heterogeneous cases (FIG. 6).
- Greater CO_2 saturations increase the $K_{rCO2\text{-}H2O}$, allowing greater volumes of CO_2 to be stored in the reservoir.
- No significant variations between the P10-50-90 PHIE and K_INT cases for simulation results (FIG. 7).
- Plume expands to a total length of 250 m in the E-W direction, and reaches 15 m above the BBRS Fm. after 1-year post injection. Simulation results conclude containment of the total injection of 5000 t/CO_2 over a 5-year period.

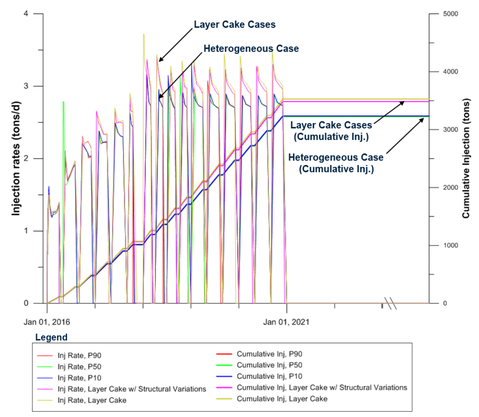


FIG. 6: Simulated CO_2 injection into the BBRS Fm. over a five-year period constrained by maximum allowable BHP, taken by Lee (2015).

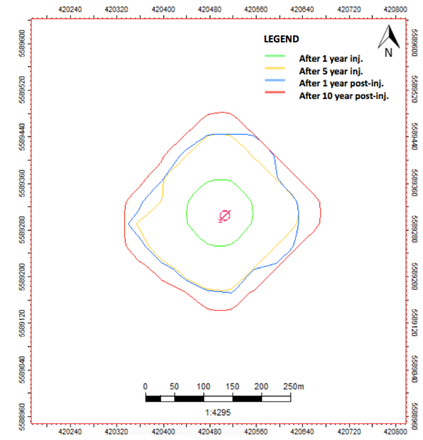


FIG. 7: Plan view of the P50 case of the depicting the CO_2 plume edges, modified from Lee (2015).

Acknowledgements

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