Regional Assessment of CO_2-Solubility Trapping Potential: Case Study of the Coastal and Offshore Texas Miocene Interval

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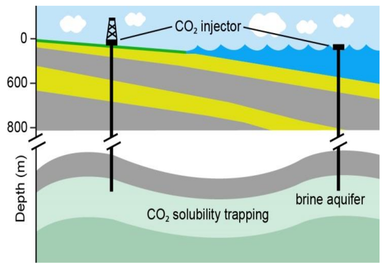
Abstract

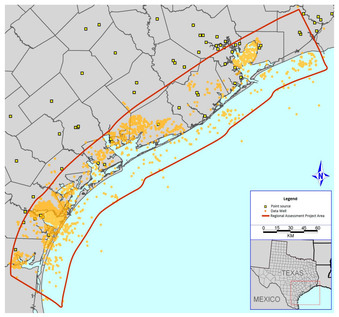


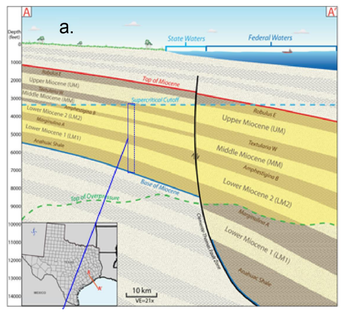
This study presents a regional assessment of CO2-solubility trapping potential (CSTP) in the Texas coastal and offshore Miocene interval, comprising lower, middle, and upper Miocene sandstone. Duan's solubility model, was applied to estimate carbon content in brine saturated with CO2 at reservoir conditions.

Three approaches (simple, coarse, and fine) were used to calculate the CSTP. The estimate of CSTP in the study area varies from 30 Gt to 167 Gt. Sensitivity analysis indicated that the CSTP in the study area is most sensitive to storage efficiency, porosity and thickness and is least sensitive to background carbon content in brine. Comparison of CSTP in our study area with CSTP values for seven other saline aquifers reported in the literature showed that the theoretical estimate of CO2-solubility trapping potential (TECSTP) has a linear relationship with brine volume, regardless of brine salinity, temperature, and pressure. Although more validation is needed, this linear relationship may provide a quick estimate of CSTP in a saline aquifer. Results of laboratory experiments of brine-rock–CO2 interactions and the geochemical model suggest that, in the study area, enhancement of CSTP caused by interactions between brine and rocks is minor and the storage capacity of mineral trapping owing to mineral precipitation is relatively trivial.

Coastal and offshore Texas Miocene interval

- the early Miocene comprises two wedges; The middle Miocene (MM) is a progradational, clastic section formed over a relatively brief period of deposition; the upper Miocene (UM) deposits from the late middle to early late Miocene record extensive margin offlap;
- The primary targets for CO2 storage in the study area include the fluvio-deltaic sandstones contained in the LM1, LM2, MM, and UM clastic wedges. The primary sealing intervals are the regional transgressive mudrock units;
- Brine salinity in the Miocene interval ranges from 4070 mg/L to 274,000 mg/L, with an average value of 119,106 mg/L. Na^+ and Cl^- are the two dominant ions in the brines.





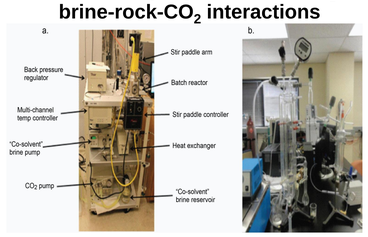
Methods

CO_2-solubility trapping potential estimation

At the basin- or regional-scale, CSTP in brine can be estimated according to the following equation

$$M_{CO2t} = \iiint \emptyset E\left(\rho_s^{CO2} X_s^{CO2} - \rho_b X_0^{CO2}\right) dx dy dz$$

Laboratory experiments of CO_2 dissolution in brine and brine-rock-CO_2 interactions



CO_2 solubility in brine (mass fraction) was calculated

$$S_{CO2} = \frac{M_{co2v} + M_{co2l}}{M_{H2O} + M_{co2v} + M_{co2l}}$$

Sensitivity analysis

Relative sensitivity of the i^{th} parameter

$$RS_i = \frac{M_{CO2t}/M_{CO2t}}{\delta_i/\bar{P}_i}$$

Enhancement of CO_2 solubility in brine caused by CO_2-brine-rock interactions was further quantified with a relative increase in CO_2 mass dissolved

$$RI = \frac{M_{CO2rock} - M_{CO2}}{M_{CO2}} \times 100\%$$

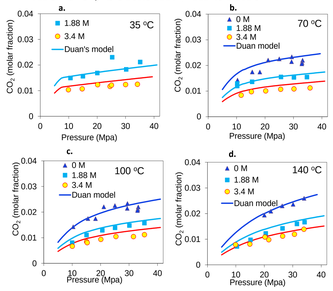
- A set of laboratory experiments for the range of pressure, temperature, and salinity were conducted to provide new dataset for testing Duan's model.
- Three batches of brine-rock-CO2 interactions:
  Temperature and total pressure in reactor were maintained at 100°C and 200 bar in Batch A, 70°C and 200 bar in Batch B, and 100°C and 300 bar in Batch C.

Parameters used to assess CO_2-solubility trapping potential

Parameters	Average	Standard deviation	Coefficient of variation
Total area (km²)	37441	-	-
Midpoint depth (m)	1606	179.2	0.11
Sand Thickness	389.8	174.9	0.45
Sand Porosity	0.32	0.014	0.043
Salinity (mass fraction)	0.119	0.042	0.35
Temperature (°C)	60.7	4.1	0.068
Pressure (MPa)	15.8	1.8	0.11
Brine density (g/cm3)	1.07	0.031	0.029
Density of brine saturated with CO_2	1.10	0.030	0.027
Mass fraction of CO_2 in brine after saturation with CO_2	0.032	0.0052	0.16

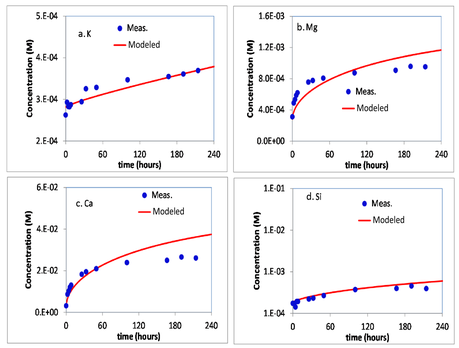
Results and discussion

Laboratory measurements of the CO_2-solubility in brine

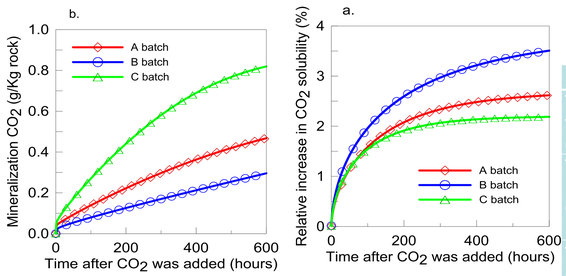


Experimental validation of Duan's solubility model26, 27 at various temperature, pressure, and salinity values

Enhancement of CSTP caused by mineral reactions

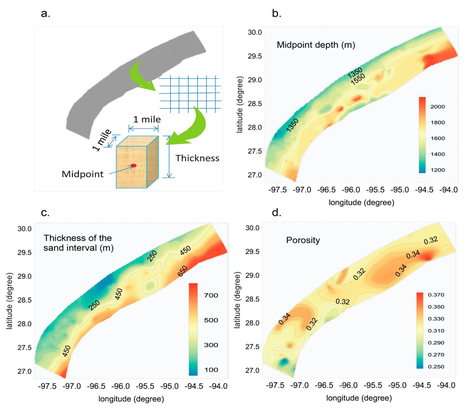


Comparison of concentrations modeled and measured after CO_2 was added to Batch B. (Temperature and total pressure in the reactor were maintained at 70° C and 200 bar.)



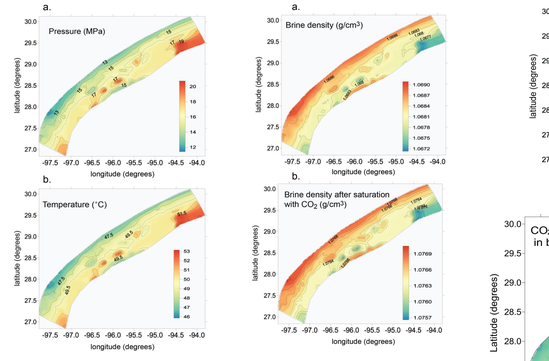
(a) relative increase in CO_2 solubility caused by mineral reactions and (b) mineralization CO_2 in three batch experiments simulated using geochemical model. Note that the dawsonite precipitation is assumed in the model simulations.

Estimate of CO_2-solubility trapping potential



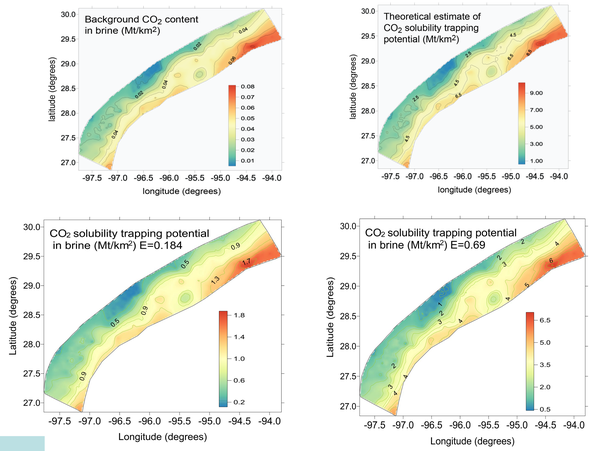
CO_2-solubility trapping potential estimated with the three approaches

		Simple	Coarse	Fine
Total brine volume (km³)		(4.7±1.5)×10³	(4.7±1.5)×10³	(4.7±1.5)×10³
Total background CO_2 content in brine	Gt	1.06 ±0.76	1.36±0.83	1.35±0.83
	Mt/km²	0.028±0.020	0.036±0.022	0.036±0.022
TECSTP (E=1.0)	Gt	167±55.4	168±55.6	166±55.3
	Mt/km²	4.47±1.48	4.48±1.49	4.45±1.48

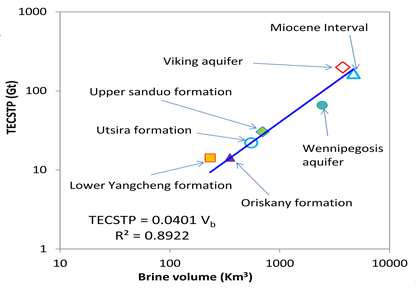


Sensitivity analysis of parameters to estimation of CO_2-solubility trapping potential in the Miocene interval

Parameter	Relative change in parameter (-)	Relative change in CO_2-solubility trapping potential in brine (-)	Relative sensitivity (-)
Midpoint depth	0.11	0.0062	0.056
Porosity	0.044	0.044	1.0
Thickness	0.898	0.898	1.0
Storage coefficient	0.5	0.5	1.0
Brine salinity	0.35	0.13	0.37
Background carbon content	0.907	0.0	0.0



Theoretical estimate of CO_2-solubility trapping potential (TECSTP) versus brine volume in seven storage formations reported in literature



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