

Evaluation of CO₂, He, C1-C5 gaseous hydrocarbons at an engineered CO₂ injection, Cranfield, Mississippi

GCCC Digital Publication Series #10-04

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Keywords:

Field study-Cranfield-MS, Modeling-Geochemical, Rock-water-CO₂ reaction, Rock-CO₂-water interaction

Cited as:

Romanak, K.D., Zhang, T., Gilbert, K., Yang, C., Bennett, P., and Hovorka, S., Evaluation of CO₂, He, C1-C5 gaseous hydrocarbons at an engineered CO₂ injection, Cranfield, Mississippi: presented at the 9th Annual Conference on Carbon Capture & Sequestration, Pittsburgh, PA, May 10-13, 2010. GCCC Digital Publication Series #10-04.

1. Introduction.

Sampling gases and fluids during deep CO₂ injection is challenging, but yields important information on deep subsurface processes. During an engineered CO₂ injection at Cranfield, MS, samples from 2 observation wells (~3000m depth) were continuously collected over 30 days using a pressure-loop U-Tube sampler and analyzed by gas chromatography. The target oil and gas reservoir has hydrocarbon-rich brines (93.6% CH₄, 3.9% CO₂, 2.2% C₂H₆, 0.24% C₃H₈, 0.061% He), while the injected gas is similarly complex, (2.36% CH₄, 97.4% CO₂, 0.21% C₂H₆, 0.007% C₃H₈, 0.005% He). A gas mixing model with these two end members and He to calculate mixing fractions during the course of CO₂ injection was used to characterize the origin of the sampled gas during the observation period. Mixing of gases from heterogeneous CO₂ invasion, assumed to occur, 1) during transport of the CO₂ plume to the observation wells due to aquifer heterogeneities, and 2) in the wellbore during sampling, is one of the main physical processes. Deviations from the model may identify chemical processes between injected and reservoir gases and brine.

2. Background

SECARB Phase III Cranfield unit operated by Denbury

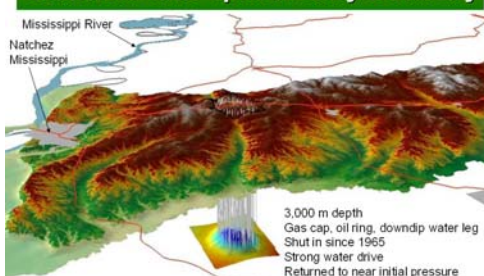


Fig. 1. Pilot injection set at the Cranfield Site. Figure by Tip Meckel and Susan Hovorka

■ SECARB Phase 3 in the Cranfield Unit is operated by Denbury Resources East of Natchez, Mississippi

Cranfield Geometric Overview

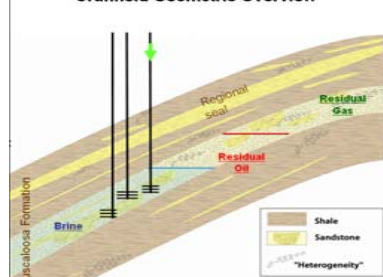
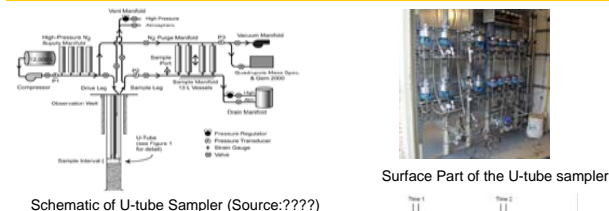


Fig. 2. Figure courtesy of Tip Meckel and Susan Hovorka

■ Cranfield is part of the Upper Cretaceous Tuscaloosa-Woodbine Trend of the Mississippi Salt Basin

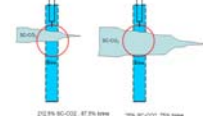
3. Sampling



Schematic of U-tube Sampler (Source:?????)

Sampling Procedure

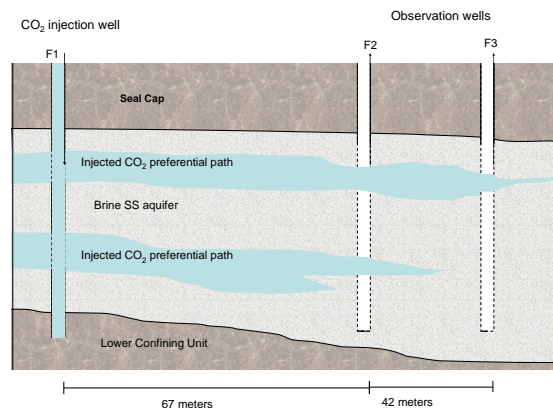
- Prior CO₂ plume arrives at the observation well, N₂ gas is used to lift water samples;
- After CO₂ plume reaches the observation well, CO₂ will be self lifted.



Schematic of CO₂ plumes arriving at the observation well at different times

4. Mixing Model

Assumption: Gas sampled from the U-tube Sampler is a mixture of gas injected and gases extracted from brine. This mixing process occurs when CO₂ plume moves from the injection well to the monitoring well, as well in the borehole of observation well. Such mixing process is caused by heterogeneity of the reservoir.



Two end members are considered in the mixing model: injected gas and gas extracted from the brine. Based on a conservative component, He, mixing ratio is given by

$$f = \frac{C_n^O - C_n^b}{C_n^I - C_n^b} \quad C_n^O, C_n^b, C_n^I \text{ are concentrations of He measured at the observation well, injectate, and brine}$$

f ranges from 0 to 1

Then with this mixing ratio, concentrations of other gas components

$$C_n^C = fC_n^I + (1-f)C_n^b \quad n = \text{CO}_2, \text{CH}_4, \text{C}_2, \text{C}_3$$

5. Results

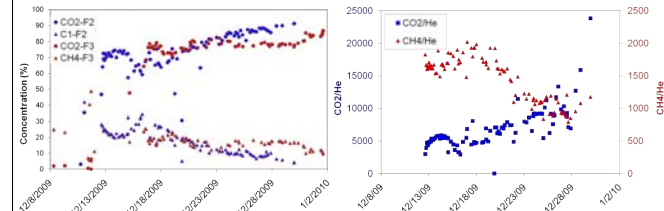


Fig. 5. Observed gas compositional change in observation wells in the course of CO₂ injection. CO₂ and CH₄ versus He ratios suggest an initial source, then depletion of CH₄.

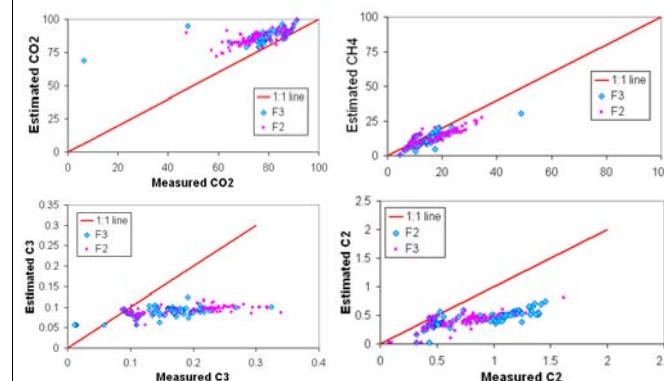


Fig. 6. Enrichment of hydrocarbons shows that CO₂/brine interaction occurs in subsurface aquifer reservoir. The unit of measured and calculated gas concentration is in % mole volume.

Estimated values from the model were plotted against measured values. Deviations from the 1:1 line indicate a loss or gain of the gas in question. The gas mixing model accounts for variability in the two end member components such that chemical processes in the reservoir can be distinguished.

6. Concluding remarks

CO₂ and CH₄ versus He ratios indicate that there is initially a source of CH₄, which is depleted. Preliminary mixing models suggest that measured concentrations of CO₂ and CH₄ deviate slightly from modeled values compared to deviations for C₂ and C₃. Measured CO₂ is slightly lower than modeled values indicating dissolution, while CH₄ concentrations are slightly higher indicating enrichment. Both C₂ and C₃ are enriched in the gas phase during CO₂ transport over 60m. The magnitude of enrichment for hydrocarbons increases with from C₁ to C₄.