Implications of Sorption on Carbon Dioxide Sequestration in Gas Shales

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1. Background: Adsorption is a primary storage mechanism in nano-porous gas shales. Carbon dioxide, owing to it's smaller size, linear shape, and higher surface potential, has a much higher sorption capacity on gas shales compared to methane. Using the Finite Element Method in COMSOL, adsorbed carbon dioxide storage in shales is highly stable and unlikely to leak (1). However, carbon dioxide injection did not increase methane recovery due to a high sorption uptake reducing diffusivity.

2a. Adsorption Measurement

Adsorption and adsorption uptake were experimentally measured and modelled using the Langmuir isotherm:

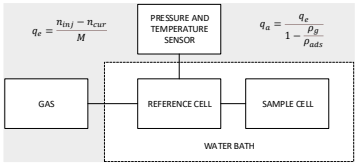


Figure 1: Adsorption measurement rig (2)

Adsorption:

$$q_a = \frac{q_L b_L \rho_g}{1 + b_L \rho_g}$$

Uptake:

$$K_a = \frac{\rho_s q_L b_L}{\left(b_L \rho_g + 1\right)^2}$$

2b. Finite Element Simulation

Methane production and carbon dioxide injection were simulated with an Huff-and-Puff mechanism for 2 scenarios. The generalized diffusion equation was modified to include sorption in COMSOL Transport of Diluted Species module.

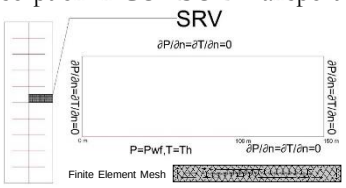
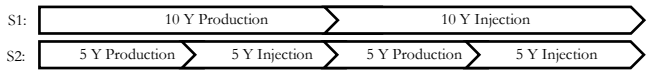


Figure 2: Shale reservoir model and meshing (3)

Diffusion equation:

$$\frac{\partial \rho_g}{\partial t} + \nabla\left(\frac{k}{\mu c_g (\phi + (1-\phi) K_a)} . \nabla P\right) = Q$$



3a. Adsorption Isotherms

24 hours are required to characterize 1 isotherm. Isotherms are Type 1 up to 60 bars. The carbon dioxide sorption capacity is 1.5 times that of methane. Carbon dioxide uptake is 2 times that of methane.

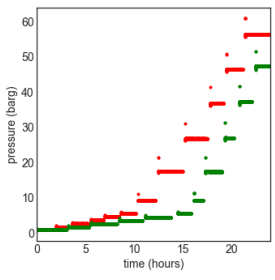


Figure 3: Rig pressure

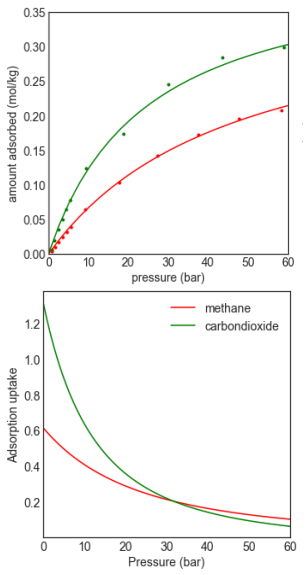


Figure 4: Adsorption results

3b. Carbon Dioxide Storage

During production most of the sorbed methane is left behind in the reservoir; The trend is reversed for carbon dioxide injection because of the shape of the adsorption curve - methane production occurs in the monolayer region; carbon dioxide sequestration occurs in the linear region.

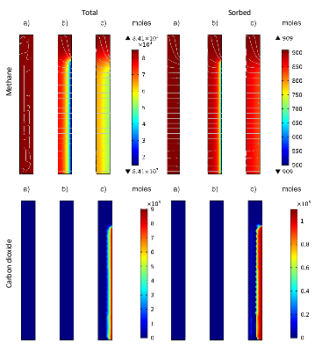


Figure 5: Distribution a) initial b) after production c) after injection

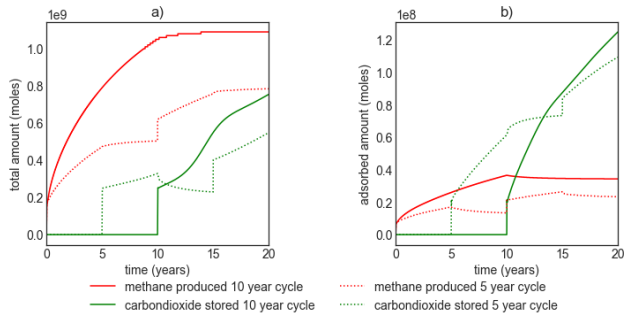


Figure 6: Methane Produced and Carbon Sequestered

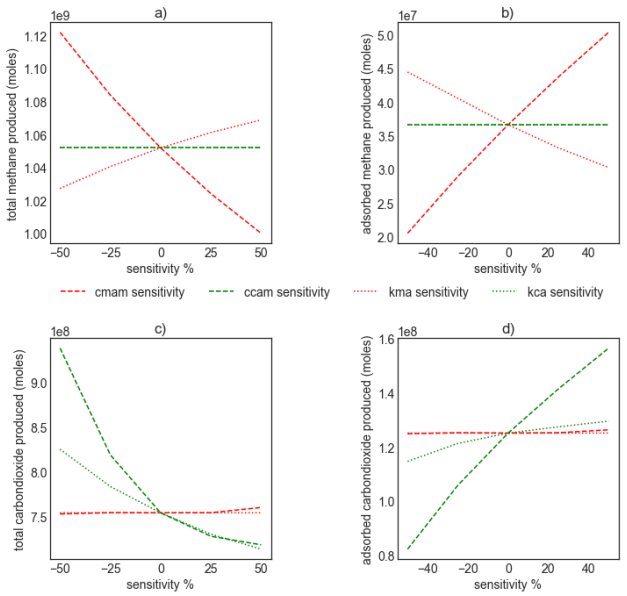


Figure 7: Sensitivity Analysis

Sorption is inversely correlated with total sequestration, positively correlated with sorbed sequestration

4. Conclusion: Carbon dioxide storage potential of gas shales is investigated using adsorption experiments and Finite Element simulation in COMSOL. Sequestration in gas shales is highly stable due to high adsorption uptakes at low partial pressures.

References
[1] Mathieu, P. in ECOS 2006 - (2006); [2] K. Arunachalam, K. Wang, X. Fan, 2020; [3] K. Arunachalam, X. Fan, JNGSE, 2020;

Excerpt from the Proceedings of the 2020 COMSOL Conference