CO_2 Solubility in the Silurian "Clinton/Medina" Sandstone: Multielement Modeling and Implications for Carbon Storage

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Introduction

The long-term storage of industrial carbon dioxide (CO_2) emissions in deep geologic formations, commonly known as Carbon Capture, Utilization, and Storage (CCUS), is an essential part of mitigating the effects of CO_2 on the atmosphere. One of the ways that CO_2 can be stored is as a supercritical fluid within deep saline formations. These formations are well below the level of potable groundwater and contain heavily saturated brines. While the CO_2 and brines are considered immiscible fluids, they are mutually soluble and over time CO_2 can be dissolved into the formation water and mineral precipitation can occur, effectively trapping the CO_2. Historically, solubility work has focused on using either total dissolved solids (TDS) or single-element approximations of CO_2 solubility, but more recent research has shown that CO_2 solubility in aqueous solutions with different salt species can be significantly different, even if the TDS is the same. Therefore, in order to accurately assess the CO_2 storage potential of a brine-saturated formation it may be necessary to use more sophisticated multielement geochemical modeling.

The "Clinton/Medina" Sandstones is a drillers' term for a set of Early Silurian sandstones that correlate to the Medina Group in New York (fig. 1). Lithologically, these sandstones are white, gray, or red fine- to very fine-grained quartzose sandstone, likely deposited in a complex deltaic to shallow marine environment. They have been drilled for oil and gas since the nineteenth century with major production occuring during the 1920s and again in the 1940s and 1970s with advances in drilling technology. The depth of these wells and their natural straigraphic traps potentially make them a good target for CO_2 storage.

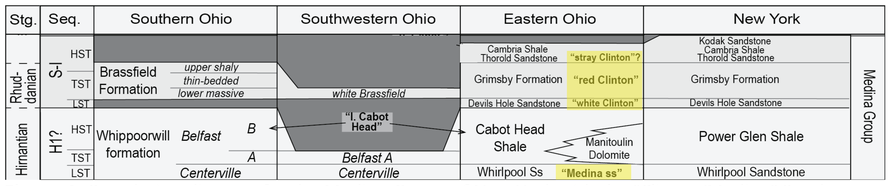

Figure 1: Correlation diagram for the Medina Group of New York with the "Clinton/Medina" Sandstones highlighted. Adapted from Waid and Brett (2019).

Methods

- Historical and modern data (n=225; 28 TDS-only, 79 multielement-only, 118 both) was collected from the Ohio Brine Geochemistry Database. Data was formatted in either parts per million (ppm) or milligrams per liter (mg/L)
- Solubility modeling was performed using the PSUCO2 model developed by Haining Zhao (2014) (fig. 2).
- Because of a lack of pressure and temperature data, lithostatic pressure was estimated at 1 psi/ft depth (22.7 KPa/m) and temperature was estimated using the formula 1°F/100 ft depth +57°F, where 57° is the ambient temperature.

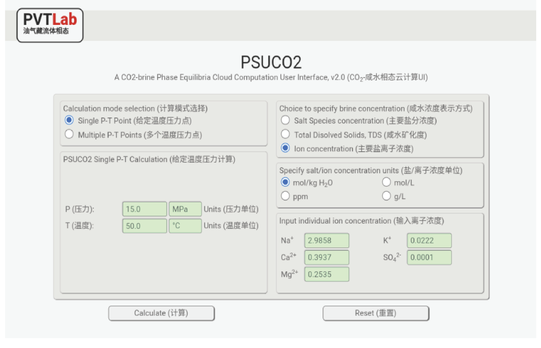

Figure 2: User interface for Haining Zhao's PSUCO2 CO_2 solubility model, found at carbonlab.org.

Discussion

- As expected, the TDS and multielement models produce similar results, with the multielement model solubilities slightly lower on average (Table 1). However, they can diverge by up to 36%, mostly at lower solubilities (fig. 3A). There is a minor pattern of TDS with depth, with the lowest TDS measurements concentrated in the shallowest and deepest parts of the formation with elevated measurements in the middle (fig. 3B).
- Solubility shows a slight correlation with depth using both the TDS and multielement models, but overall solubility appears to be controlled by concentration/composition of the brine (fig. 4)
- There appear to be two zones of elevated solubility in the Clinton brines, one around -2,000 ft and between -3,000 and -5,000 ft (fig. 5). This maybe a result of data bias due to lack of data in the middle depths.

Table 1: Modeled solubility of CO_2 and maximum and minimum percent differences.

	% difference (Whole data set)	mCO₂ TDS (mol/Kg H2O)	mCO₂ multielement (mol/Kg H2O)
Max.	36.78	1.16	1.11
Min.	0.0012	0.34	0.36
Avg.	6.56	0.63	0.57

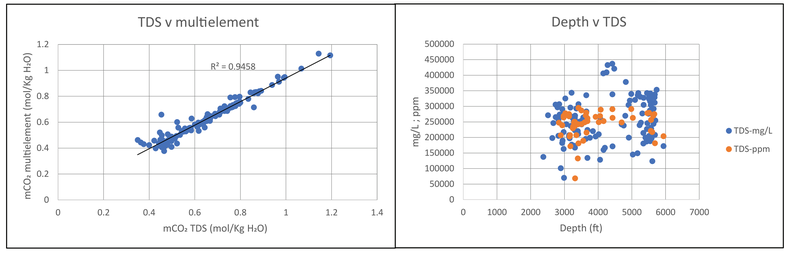

Figure 3: A: Plot comparing modeled CO_2 solubility between the TDS and multielement methods. B: Plot showing the relationship between depth and TDS. Of the three components to CO_2 solubility, lower TDS will increase solubility, higher pressure will increase solubility and lower temperature will increase solubility.

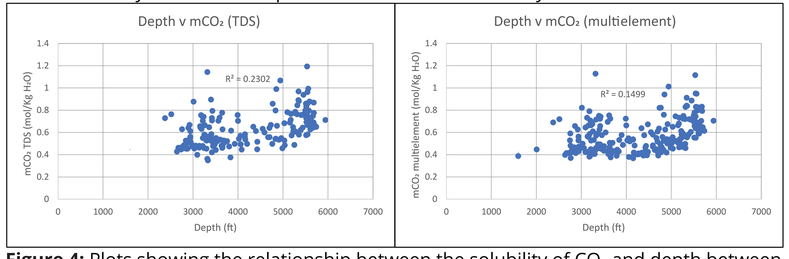

Figure 4: Plots showing the relationship between the solubility of CO_2 and depth between the TDS and multielement methods. The *R* values shown are only to illustrate individual trends, because of the difference in size of the two datasets.

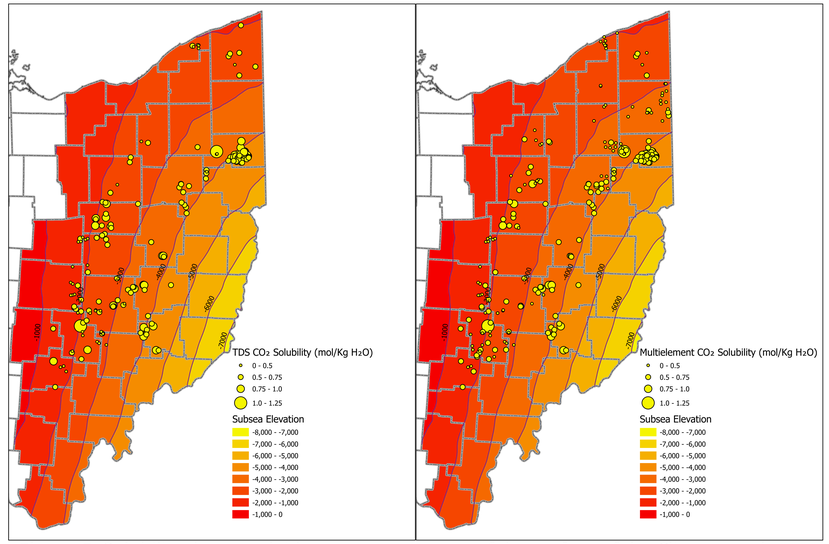

Figure 5: Solubility data overlaid on a structure map of the surface of the Clinton sands. In the TDS data there appears to be a concentration of higher solubilities in the north (especially in the 0.75-1.0 range); however, when the multielement model is applied, the overall solubility looks much more like what we see in the rest of the formation.

Conclusions and Future Work

- If the data is available, multielement modeling can give a more accurate measure of CO2 solubility than total dissolved solids, especially at lower solubilities.
- The solubility of CO2 in brines from the "Clinton/Medina" interval is highly variable and controlled mostly by the composition of the brine in question.
- Given the limitations of the data coverage, there appear to be two zones of elevated solubility corresponding to lower TDS concentrations, which may be better for CO2 injection.
- In the future there are plans to do similar solubility work for other formations, as well as mapping individual components in order to see the geochemical gradients present in the Clinton brines.

References Cited:

Waid, C. B. T. and Brett, C. E., 2019, Sequence Stratigraphy in Mixed Carbonate and Clastic Sections: Examples from the lower Silurian of Ohio in Core and Outcrop: Columbus, AAPG Eastern Section Field Trip Guidebook 3, 58 p.

Zhao, H., 2014, Phase Equilibria in CO2-Brine System for CO2 Storage: The Pennsylvania State University (Pennsylvania), PhD Thesis, 169 p.