Sequestration NOT on Shaky Ground

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A recent journal article by MIT Professor Dan Rothman and his post-doc Yossi Cohen was published on January 21, 2015. This work was funded by the Center for Nanoscale Control of Geologic CO_2, an Energy Frontier Research Center funded by the US Department of Energy, Office of Science, Office of Basic Energy Sciences under Award no. DE-AC02-05CH11231, subcontract 6896518. A citation for the paper is given below:

Cohen Y, Rothman DH. 2015. Mechanisms for mechanical trapping of geologically sequestered carbon dioxide. Proc. R. Soc. A 471: 20140853. <link to paper>

The abstract from the paper follows:

Carbon dioxide (CO_2) sequestration in subsurface reservoirs is important for limiting atmospheric CO_2 concentrations. However, a complete physical picture able to predict the structure developing within the porous medium is lacking. We investigate theoretically reactive transport in the long-time evolution of carbon in the brine–rock environment. As CO_2 is injected into a brine–rock environment, a carbonate-rich region is created amid brine. Within the carbonate-rich region minerals dissolve and migrate from regions of high-to-low concentration, along with other dissolved carbonate species. This causes mineral precipitation at the interface between the two regions. We argue that precipitation in a small layer reduces diffusivity, and eventually causes mechanical trapping of the CO_2. Consequently, only a small fraction of the CO_2 is converted to solid mineral; the remainder either dissolves in water or is trapped in its original form. We also study the case of a pure CO_2 bubble surrounded by brine and suggest a mechanism that may lead to a carbonate-encrusted bubble owing to structural diffusion.

Upon reading the paper, my opinion is that it is a good piece of basic science research. They do NOT bring up the topic of whether our view of the integrity of geologic storage of CO_2 is impacted by their results. Therefore, any statements they make on this topic have NOT been peer reviewed. This is important because the MIT News Office did an article on the research entitled "Sequestration on shaky ground – study finds a natural impediment to the long-term sequestration of carbon dioxide".

As I stated above, the study makes no claims about sequestration being on shaky ground. This claim is derived from quotes by Cohen in the news article:

"If it turns into rock, it's stable and will remain there permanently," says postdoc Yossi Cohen. "However, if it stays in its gaseous or liquid phase, it remains mobile and it can possibly return back to the atmosphere."

"The expectation was that most of the carbon dioxide would become solid mineral. Our work suggests that significantly less will precipitate."

To compound the problem, other news outlets have picked up on the press release (see links below).

Bloomberg

Forbes

There are two points in Cohen's quotes that need closer examination.

1. *The expectation was that most of the carbon dioxide would become solid mineral*

This may have been Cohen's expectation, but it is definitely not the expectation of those scientists actively looking at geologic storage of CO_2. Here is the text from the IPCC Special Report on Carbon Dioxide Capture and Storage (SRCCS):

The mechanism known as geochemical trapping occurs as the CO_2 reacts with the in situ fluids and host rock. First, CO_2 dissolves in the in situ water. Once this occurs (over time scales of hundreds of years to thousands of years), the CO_2-laden water becomes more dense and therefore sinks down into the formation (rather than rising toward the surface). Next, chemical reactions between the dissolved CO_2 and rock materials form ionic species, so that a fraction of the injected CO_2 will be converted to solid carbonate materials over millions of years. [Technical Summary, pg. 32]

First, we are talking timescales (e.g., millions of years) far greater than those required to analyze the effectiveness of geologic storage of CO_2. Secondly, there is nothing in the journal paper that remotely contradicts the above finding of the IPCC. What it does is shed some light on what "fraction of the injected CO_2 will be converted to solid carbonate materials".

2. *if it stays in its gaseous or liquid phase, it remains mobile and it can possibly return back to the atmosphere.*

This quote is analogous to me saying, "if you cross the street, you may get hit by a car." Yes it may leak, but the question is will it and under what circumstances. The Cohen and Rothman paper does not address the storage mechanisms associated with the time scales of interest to understand the leakage potential. The paper has nothing to offer on this topic. The following statement from the IPCC SRCCS represents the consensus of experts on this topic:

Observations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1000 years.

Once again, nothing in the Cohen and Rothman paper contradicts this statement.

The Clean Air Task Force has blogged two pieces related to the paper and MIT News article:

Geologic Carbon Storage: A Safe Bet

When Good Science Gets Badly Communicated

I asked a few experts in geologic storage of CO_2 to add their opinions. These are shown below:

Prof. Sally Benson, Stanford University, coordinating lead author of IPCC SRCCS chapter on geologic storage of CO_2: When asked in what way does it change the current view on the practicality of geologic storage of CO_2, her response was: *Not at all.*

Dr. Susan Hovorka, Senior Research Scientist, Bureau of Economic Geology, The University of Texas at Austin: *The press release is built on an error in fact: Cohen says. "The expectation was that most of the carbon dioxide would become solid mineral. Our work suggests that significantly less will precipitate." This statement shows a serious misunderstanding about what is hypothesized and demonstrated about storage mechanisms. For sedimentary rocks, mineral trapping has always been considered a minor and long term contributor.*

Prof. Ruben Juanes, MIT, expert on physics of multiphase flow in porous media: *There seems to be a major disconnect between what Cohen and Rothman's paper says and what the news release says. The concluding paragraph of the paper states "Our results suggest that only a small fraction of the injected CO2 is converted to a solid mineral. The remainder stays in its dissolved ionic form or is trapped in its original form." The fact that only a small fraction of the injected CO2 will precipitate into carbonate minerals is well known, and says little about the storage security provided by the other, and much more effective, storage mechanisms (stratigraphic, capillary and solubility trapping). In fact, it is these other mechanisms (and not mineral trapping) that have been incorporated in studies of storage capacity and efficiency in deep saline aquifers under a variety of hydrogeologic scenarios. The risk of leakage in* CO_2 *sequestration is an issue that deserves careful attention, but the critical processes are pore pressure increase and fault activation, and not the small fraction (if any) of mineral precipitation that may occur in the very long term.*