

Comments on Economides and Ehlig-Economides, "Sequestering carbon dioxide in a closed underground volume," SPE 124430, October 2009

Geologic Carbon Sequestration Program
Earth Sciences Division
LBNL

Group summary comments write-up by
Curt Oldenburg, Karsten Pruess,
Jens Birkholzer, and Christine Doughty

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General Summary

The paper examines the pressure increase resulting from injection of CO₂ into a 1D radial system with closed boundaries. The finding is that unacceptably high pressures are obtained when only 1% or less of the pore volume is occupied by injected CO₂. These results are used to make the general conclusion that large-scale CCS is not feasible.

Comments

The authors present an analysis for closed systems that includes only compressibility to accommodate injected CO₂. The calculations they present are correct for the highly artificial case of a closed system. However, the closed volume conceptual model does not represent real aquifer systems whose caprock has low but non-zero permeability. Tight caprocks have permeabilities of order of microdarcies on regional scales, and there is an extensive body of work that demonstrates that such permeabilities will substantially reduce large-scale pressurization from fluid injection.

Furthermore, the main finding that CO₂ storage in closed reservoirs can utilize only a small fraction of total pore volume is not new. LBNL scientists (Zhou et al., 2008) concluded that, "...less than half a percent of the total pore volume of a closed system would be available for the volumetric storage of CO₂ in a closed system during the injection period." Zhou et al. went on in their paper to examine capacity of realistic systems that are not completely closed (i.e., allow for pressure dissipation and brine migration into and through non-zero permeability seals) and found much higher storage capacity factors.

The need for a closed reservoir, not to mention the difficulty in actually finding any large-scale closed reservoirs, makes the closed-system assumption of the authors highly dubious. On the latter point, no hydrologic system is truly closed over the long time periods (10²-10³ year) and large length scales associated with large-scale CCS (1-100 km²). For example, even if the caprock seal permeability is on the order of a microdarcy (10⁻¹⁸ m²), over the large distances that elevated pressure will propagate during CO₂ injection, brine will be able to flow into the caprock seal in sufficient volume to mitigate pressure rise. On the former point, CO₂ migration, e.g., up dip along a gently sloping monocline, promotes trapping by the mechanisms of dissolution, residual gas trapping, and carbonate mineral formation. As up-dip flow occurs, eventually all of the CO₂ may become trapped even if there is no closure to the structure and the system is open. A second example is that of structural trapping. Specifically, consider the case of free-phase CO₂ buoyantly

trapped in an anticline while the aquifer providing the gas-water contact may be entirely open with the reservoir formation actually outcropping at the surface. The point here is that open systems do not necessarily produce CO₂ leakage to the atmosphere, even over very long (>10³ year) time scales, and can in fact enhance trapping.

For the sake of argument, if we do restrict consideration to hypothetical closed systems, or to a compartmentalized reservoir that can be considered closed on a given time scale, there are methods that can be used to carry out CCS. For example, brine could be produced from the storage reservoir in equal volume to the injected CO₂ to maintain reservoir pressure. Second, the process of brine production with surface dissolution of CO₂ and subsequent brine reinjection could be undertaken, resulting in reduced pressure rise relative to direct CO₂ injection due to increased density of the reinjected CO₂-charged brine. Third, down-hole (in situ) mixing and dissolution of CO₂ with brine could be carried out. The authors do not discuss any kind of process other than direct injection.

To summarize, the authors consider a narrow, and naturally rare, class of reservoirs that are totally closed. They then assume a simple direct injection of CO₂ and find capacity is limited to less than 1% or less of pore volume. The result is not new, and the assumption of a closed reservoir is an end-member case. From this narrow analysis, the authors make sweeping conclusions that are not relevant to the general feasibility of CCS.

Final Comment

The general issue of large-scale pressure changes arising from CO₂ storage in deep saline formations (open or closed) is well recognized in the scientific and technical community, and various studies have been conducted showing magnitude and extent of such changes for simplified systems as well as real sedimentary basins (e.g., Birkholzer et al., 2009; Birkholzer and Zhou, 2009; Nicot et al., 2008; Yamamoto et al., 2009). None of these studies has concluded that CO₂ storage is not feasible. A certain amount of pressure change will cause no harm and can be tolerated. There are various examples of deep formations over-pressured from natural processes.

References

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