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Carbon Sequestration and Water Displacement: What are the Important Parameters?

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Some of the attention of the Carbon Capture and Storage (CCS) community has justly moved from concerns directly related to the CO_2 plume to more general and regional concerns linked to pressure change. Zone of elevated pressure extends far beyond the immediate proximity of the CO_2 plume and a regional perspective is warranted to understand far-field impacts of CO_2 injection. This is even more true for multiple injection sites injecting into multiple formations. Such a scenario will create a large elevated pressure zone extending far beyond the limited volume where CO_2 is present. In a closed system, additional mass is accommodated by the compressibility of system components, an increase in fluid pressure, and possibly an uplift of the land surface. In an open system, another coping mechanism involves fluid flux out of the boundaries of the system. This flux could correspond to vertical leakage, for example through low permeability formations. Or fluid migration could occur laterally, in which case the fresh-water-bearing outcrop areas, corresponding to the up-dip sections of the down-dip formations into which CO_2 is injected, could be impacted (saline water pushing less saline water, itself pushing brackish waters which eventually displaces fresh water). An additional potential mechanism, although unwanted and avoidable, is pressure relief through localized conductive pathways such as faults and wells.

A first message, as hinted in previous work, is that multiphase processes do not matter some distance away from the injection zones. A thorough comparison of numerical outputs of a single phase model (standard USGS-developed MODFLOW) and of a multiphase flow compositional model (CMG-GEM in common use in the oil industry) strongly suggests that it is indeed the case. The comparison was applied to a realistic geological configuration (series of aquifers in the upper Texas Gulf Coast). This work is being extended to include other configurations.

A second message emphasizes the importance of including strata both above and below the injection formation. Although CO_2 is unable to move upward through the seal (at least in ideal cases) because of a flow barrier due to capillary forces, water is not impeded in its movement and can flow out of the system freely. Sensitivities studies demonstrate the importance of compressibility/storativity parameters of the system as a whole and of vertical permeability of aquitards/sealing formations in attenuating pressure pulse and fluxes at the boundaries. We are currently investigating the impact of geologic material of variable compressibility/storativity located in the vicinity of the injection layer such clastics with oil/gas residual saturation, salt and gypsum (that may direct and channelize the pressure pulse outwards instead of attenuating it).

A third message underlines the importance of analogs. Because those compressibility/storativity parameters are more often assumed than measured, we also initiated a study of analogs, in particular, large oil/gas plays with large fluid injection/withdrawal, aimed at understanding impact of shales/compressible units on pressure distribution at a regional scale.