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CO2 column height influenced by geothermal gradient in sedimentary basins of the USA

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One of the greatest risk factors in assessment of CO2 storage potential is seal integrity in a spectrum of subsurface conditions. Secure storage of CO2 can be attained when the capillary entry pressure of the sealing formation is greater than the buoyant pressure of CO2 rising through water-filled pores. Maximum CO2 column height is an important factor in buoyancy, but its prediction is difficult in frontier-basin settings that lack context from oil and gas production. In such data-poor settings, coarse-scale structural contour maps can indicate large structural traps containing porous reservoirs several thousands of feet thick for potential CO2 storage. It is tantalizing to include the entire volume of the trap in resource assessments, but would the potential CO2 column height be too great for an overlying shale formation to effectively seal?

Utilizing oil and gas industry techniques, we calculate a balance of capillary entry and buoyant pressures for prospective CO2 reservoir seals and brine-supercritical CO2 mixtures to evaluate depths at which seals can contain a given CO2 column height across the United States. We vary the density of supercritical CO2 with depth according to hydrostatic pressure and the regional geothermal gradient, vary pore-throat radius according to an empirical relationship of exponentially diminishing radius with depth, and hold constant other variables, including interfacial tension, contact angle, and brine density. The results indicate that individual basins generally exhibit a nonlinear relationship of increasing maximum CO2 column height with depth. Moreover, "cold" basins with relatively low geothermal gradients, such as the Great Valley of California, which was a Mesozoic-Cenozoic forearc basin prior to the evolution of California to a transform continental margin, can sustain the same CO2 column heights at much shallower depths than "hot" basins with higher geothermal gradients. This is because supercritical CO2 is denser at given depths of "cold" basins and, as a result, less buoyant. Results from a selection of sedimentary basins in the United States show that the depths at which seals can support a given CO2 column height vary by as much as a factor of 1.5 based on differences among geothermal gradients. For example, our calculations predict that a maximum CO2 column height of 500 m is contained at 2 km subsurface depth in the "cold" Great Valley, California (conservative geotherm of 12.5 °C/km), and at 3.5 km depth in the "hot" Green River Basin, Wyoming (maximum geotherm of 40 °C/km). These insights have important implications for supercritical CO2 sequestration assessments. A general understanding of regional tectonics that impact the lithospheric geotherm can provide informed predictions of temperature gradients and column height variability with depth in frontier sedimentary basins.