Carbon Dioxide Sealing Capacity of the Tuscaloosa Marine Shale: Insights from Mercury Injection Capillary Pressure Analyses

Celeste D. Lohr and Paul C. Hackley

U.S. Geological Survey, 12201 Sunrise Valley Dr., MS 956, Reston, Virginia 20192

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EXTENDED ABSTRACT

All EPA Class VI CO_2 injection permits require top seal evaluation as a required step in determination of caprock seal integrity for carbon dioxide (CO_2) sequestration (U.S. Environmental Protection Agency, 2013). However, only a few seal evaluation studies have been published for active or planned CO_2 sequestration sites. This study aims to assess regional sealing capacity of the Upper Cretaceous Tuscaloosa marine shale (TMS). In this paper, we use mercury injection capillary pressure (MICP) analyses to obtain TMS porosity, permeability, and capillary entry pressure data, and to assess seal capacity for CO_2 sequestration by calculating potential CO_2 column height. This work is part of a broader study (Lohr and Hackley, in press) which also examines the sealing capacity of shales in the Lower Tuscaloosa, in addition to that of the TMS, for CO_2 sequestration and enhanced oil recovery, and discusses the implications of decades of drilling activities and its potential effects on seal integrity.

Twenty-three core and cuttings samples of the TMS, mostly from southern Mississippi, with a depth range of 7274–12,539 ft (2217–3822 m), were collected and submitted to a commercial laboratory for MICP analyses (Fig. 1). Each sample was crushed to 20–35 mesh size, subjected to Soxhlet extraction, and dried under vacuum. Mercury was injected and equilibrated into each crushed sample at stepwise pressure increments to calculate Swanson (1981) permeability and to report porosity and median pore-throat data. In order to calculate the seal capacity, or CO_2 column height, laboratory pressures were converted from an air-mercury (air–Hg) phase system to a brine–CO_2 system. The converted pressure data, along with proxy interfacial tension, contact angle, and density parameters from the literature, were used to calculate the potential CO_2 column height in a brine–CO_2 system at each pressure point.

Results show that porosity in the TMS samples ranges from ~4–10%; all permeability values are <0.003 mD (Fig. 2). Median pore throat sizes and pore radii range from ~0.003–0.01 µm and 0.01–0.2 µm, respectively. The data illustrate an increase in permeability with increasing porosity. Comparatively, similar Devonian to Pliocene shales described in the literature (Nelson, 2009) exhibit larger pore throat ranges, but similar porosity and permeability. TMS mercury entry pressures range from 709–8288 psia

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(~5–57 MPa). At close to initial 100% brine saturation, CO_2 column heights of all samples range from ~66–853 ft (~20–260 m) and 52% of the samples can retain a CO_2 column of 328 ft (100 m) before any mercury intrusion. These same samples also have the highest mercury entry pressures within the overall sample set.

Overall, the calculated CO_2 column heights suggest that the TMS has a high sealing capacity, capable of retaining a CO_2 column of ~66–853 ft at close to 100% water saturation (no capillary breakthrough). This result is similar to a previous TMS CO_2 column height study (Lu et al., 2011) that described TMS samples from the Cranfield CO_2–enhanced oil recovery (EOR) site in Mississippi. Our work provides further evidence that the TMS could serve as a regional seal for future CO_2 sequestration in Tuscaloosa sandstones below the TMS, and also could prove advantageous in future Lower Tuscaloosa sandstone EOR efforts in southern Mississippi given the lateral continuity, high capillary entry pressures, and low permeability of the TMS.