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Geological Sequestration of Carbon Dioxide in the Cambrian Mount Simon Sandstone: Regional Storage Capacity, Site Characterization, and Large Scale Injection Feasibility; Michigan Basin, USA

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The Mount Simon Sandstone and related rock strata in Michigan constitute a significant saline reservoir, geological carbon sequestration (GCS) target. The Mount Simon lies at depths between about 914 m (3,000 ft), on the periphery of the Lower Peninsula of Michigan to almost 4,572 m (15,000 ft) in the central basin. The Eau Claire Formation and other, superjacent strata comprise effective, regional confining layers.

The Mount Simon is predominantly composed of quartzose sandstone with minor interbedded shale and dolomite and occurs in 3 regionally significant gamma ray log facies. Total isopach thickness in Michigan ranges from over 396 m (1,300 ft) in a southwest-northeast trending trough through the center of the state to essentially zero near basement highs in the southeast Lower Peninsula. Available conventional cores indicate that much of the Mount Simon was deposited in shallow subtidal, marine, generally high energy, shelf depositional environments. This depositional system apparently extended over large tracks of the Cambrian, epicratonic surface and produced a laterally extensive (albeit variable thickness) sandstone-dominated, sheet deposit.

Conventional core to log correlation indicate both primary sedimentary facies and depth of burial control reservoir quality, storage capacity and injectivity, in the Mount Simon in the Michigan basin. Depositional facies-related decrease in reservoir quality, due to the admixture of carbonate and argillaceous mineral components to the south and east, are associated with a decrease in formation thickness that results in diminished net porosity and geological carbon storage capacity. A dramatic decrease in porosity at burial depths below about 1,981m (6,500 ft) due to quartz diagenesis results in little or no storage capacity in the deep Michigan basin.

Estimates, using wireline log data from 43 regional wells, indicate in excess of 29 billion metric tons (Gmt) of geological carbon storage capacity in the Mount Simon saline reservoir injection zone, with most storage capacity concentrated in the southwestern Lower Michigan. This area comprises thick, favorable sedimentary facies in the Mount Simon Sandstone and relatively shallow burial depths where only modest diagenetic modification of reservoir quality has occurred.

Numerical simulations of CO_2 injection were conducted using the STOMP-CO_2 simulator to assess the potential for geologic sequestration in the Mount Simon Sandstone reservoir in a prospective area of southwestern Lower Michigan near Holland in Ottawa County. The simulation used an injection period of 20 years at a rate of 600,000 metric tons/year (mt/year),

followed by an equilibration period of 280 years, for a total of 300 years. After 20 years, the total amount of CO_2 injected is 12 million metric tons (Mmt); after 300 years, 9.8 Mmt is simulated to remain as a free phase supercritical CO_2, 0.7 Mmt as entrapped in the capillaries of the reservoir pore system, and 1.5 Mmt dissolved into the brine. The supercritical CO_2 was modeled to have spread into a disk-shaped plume with a radius of 5,905 ft (1.8 km) after 20 years of injection, and to 3.8 km (12,467 ft) after 300 years. The overlying, low-permeability, dense dolomitic and argillaceous Eau Claire Formation retards almost all upward migration of CO_2 with 2 percent of the injected CO_2 invading the lowermost portion of this confining unit. Pressures during injection at the bottom of the caprock (1,540.5m; 5,054 ft depth) are well below the fracture pressure limit of 27.9MPa (4,046.6 psi), assuming a fracture pressure gradient of .018MPa/m (0.8psi/ft) due to the high permeability of the Mount Simon.

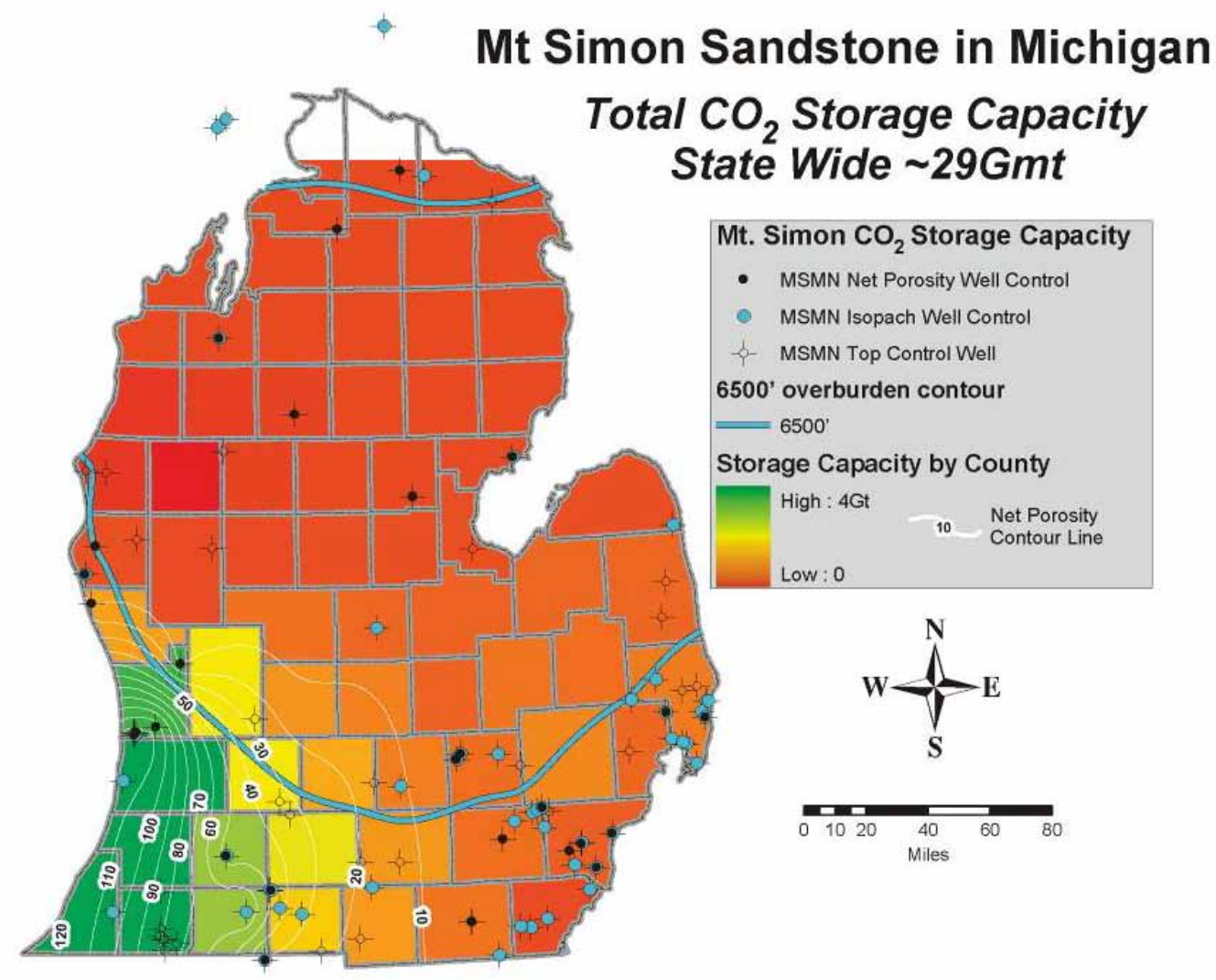
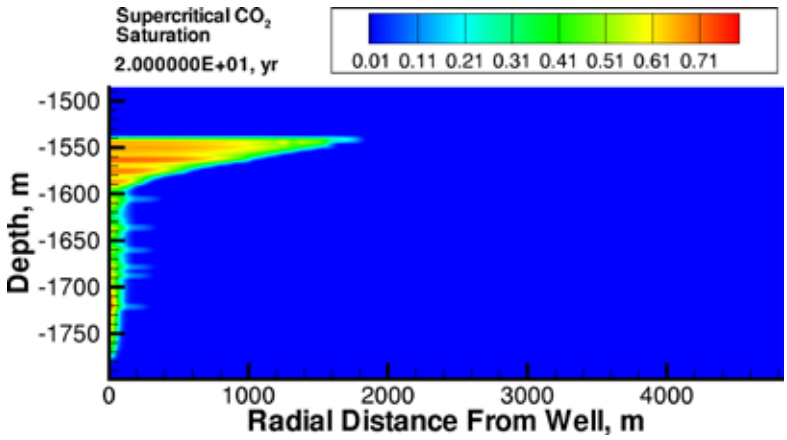
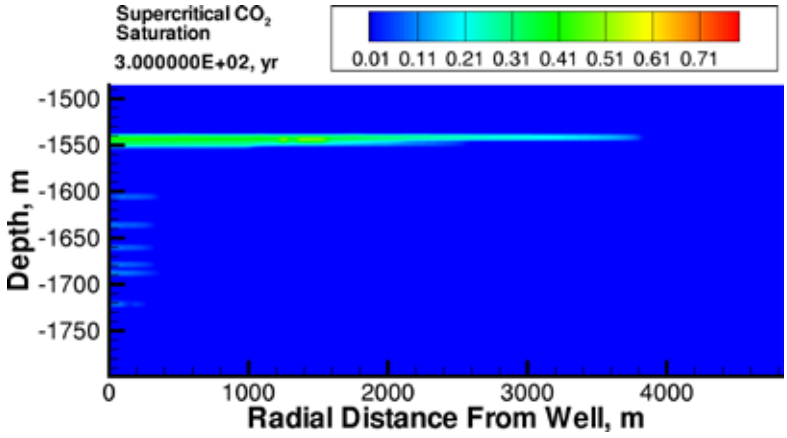


Figure 1. Map of calculated geological sequestration storage capacity in Michigan, by county, with net porosity contour lines. Total storage capacity is estimated at over 29Gmt, mostly in the southwest portion of the state.



a.



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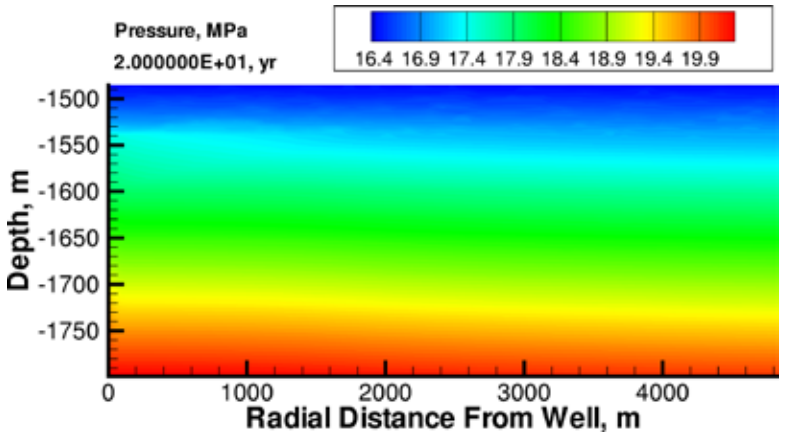

c.

Figure 2. Saturation of supercritical CO_2 after 20 years of injection into the Mount Simon formation (a); saturation of supercritical CO_2, 280 years after end of 20-year injection into the Mount Simon formation (b.); and formation Pressure in the Mount Simon formation after supercritical CO_2 injection (c.).