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The Key to Commercial-Scale Geological CO_2 Sequestration: Displaced Fluid Management

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At the direction of Governor Freudenthal and with the support of the Wyoming Legislature, the Wyoming State Geological Survey initiated a thorough inventory and prioritization of all Wyoming stratigraphic units and geologic sites capable of sequestering commercial quantities of CO_2 (5–15 MT CO_2/year). This two-year study identified the Paleozoic Tensleep/Weber (and stratigraphic equivalent units) as the leading clastic reservoir candidate for commercial scale geological CO_2 sequestration in Wyoming. This conclusion was based on unit thickness, overlying low permeability lithofacies, reservoir properties, regional distribution patterns, formation fluid chemistry characteristics, and preliminary fluid-flow modeling. This endeavor also identified the Rock Springs Uplift (RSU) in southwestern Wyoming as the most promising geological CO_2 sequestration site in Wyoming and probably in any Rocky Mountain basin. This ranking for the Rock Springs Uplift was based on the following attributes:

- Presence of a thick saline aquifer sequence (~ 750 feet of Weber Sandstone) overlain by a thick sequence of sealing lithologies (**Figure 1**)
- A double-plunging anticline with more than 10,000 feet of closed structural relief
- Huge structural element (50 x 35 miles)
- The targeted reservoir unit (Weber Sandstone) has characteristics required for CO_2 sequestration, including fluid chemistry, porosity, fluid-flow attributes, burial history (i.e., relatively recent basin inversion resulting in sufficient temperature and pressure at depths between 6,000 to 10,000 feet)

The results of the WSGS CO_2 geological sequestration inventory led the agency to collect all available geologic, petrophysical, geochemical, and geophysical data on the Rock Springs Uplift (RSU), and to build a regional 3-D geologic framework model of the uplift. From the results of these tasks and using the FutureGen protocol, the WSGS showed that on the RSU, the Weber Sandstone has sufficient pore space to sequester 18 billion tons (Gt) of CO_2, and the Madison Limestone has sufficient pore space to sequester 8 Gt of CO_2.

In cooperation with the Los Alamos National Laboratory (LANL), the WSGS geologic databases have been combined with numerical models to improve estimates of the CO_2 sequestration potential of the RSU. The WSGS 3-D geologic model constructed with EarthVision software has been gridded using LaGrit software (Voronoi mesh). Shallow and deep sequestration sites on the RSU have been evaluated using the LANL CO_2-PENS software. A variety of RSU CO_2

performance assessment scenarios have been evaluated using the LANL numerical simulator (FEHM).

The results of this research are significant in the global effort to accomplish substantial commercial-scale CO_2 sequestration. For example, one evaluated scenario is the sequestration of 15 million tons (Mt) of CO_2 per year for 50 years in a nine-point injector pattern within a 16 km x 16 km (10 mile x 10 mile) area on the RSU. These parameters were chosen because the Jim Bridger power plant (2,200 MW) is located on the RSU and emits 18 Mt of CO_2 per year. The modeled nine-point injector pattern was located near the power plant on the east flank of the RSU. The nine injection wells, each of which would inject 1.7 Mt of CO_2 per year, were spaced approximately one mile apart. For the commercial-scale sequestration scenario, no fluid flow was allowed down-dip and the initial pressure up-dip was specified as below frac pressure. After 50 years of injection, the CO_2 plumes around the injection wells just barely impinged on one another. *All* of the CO_2 (750 Mt) was contained within the 16 km x 16 km storage area. Moreover, the modeling in this scenario demonstrates that once injection stops, the pressure buildup in the individual injection wells decreases to near initial pressure in 15 years.

The most critical problem in this geological CO_2 sequestration simulation is the relationship between the volume of injected CO_2 and the displaced fluid leaving the storage area (**Figure 2**). In the example cited above, 750 Mt of CO_2 is sequestered in the storage domain and 1 cubic kilometer of fluid must leave the domain over a 75-year period (50 years of CO_2 injection and 25 years post-injection). The key questions are as follows: Can the accommodation space be found within the geologic site to accept this huge volume of fluid that must leave the storage domain? If so, given the heterogeneity of most geological settings (fluid-flow compartmentalization), can fluid migration pathways be maintained so the displaced fluid can migrate from the storage domain to some external accommodation space without disrupting the confining units and destroying the integrity of the rock/fluid system?

It is clear that these preliminary numerical simulations of commercial-scale geological CO_2 sequestration at the RSU strongly suggest that displaced fluids resulting from subsurface CO_2 injection must be managed. To solve this problem, the WSGS proposes a strategy that includes integration of fluid production/water treatment with injection of CO_2. Using this strategy, 750 Mt of CO_2 can be injected and sequestered in the 16 km x 16 km storage domain over a 50-year period, and the 1 cubic kilometer of fluid produced from the structure can be treated at the surface.

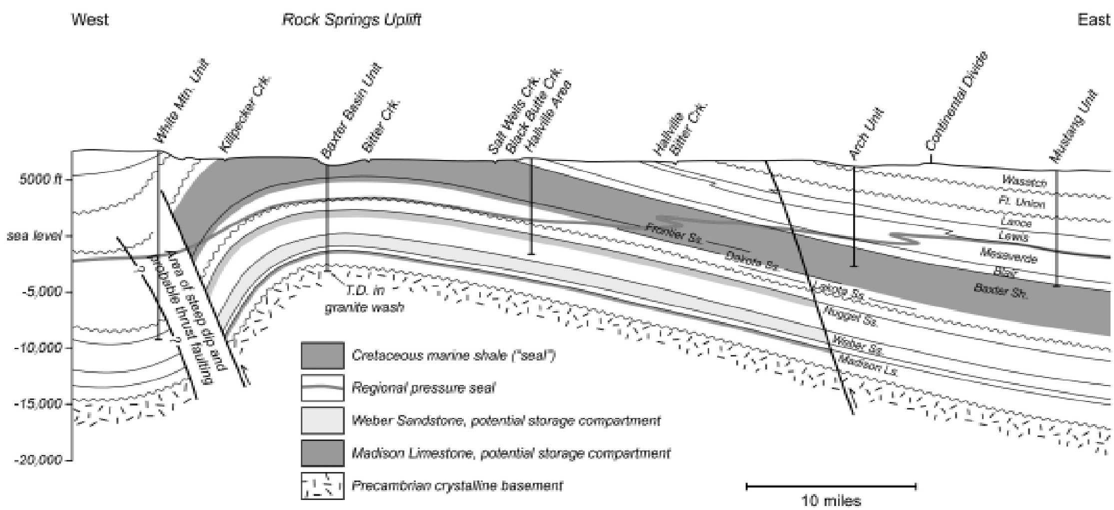

Figure 1. East-west cross section of the Rock Springs Uplift. The primary CO_2 sequestration target formation is the Weber Sandstone, and the secondary target is the Madison Limestone. These targeted stratigraphic units are overlain by approximately 5,000 feet of low-permeability shales and bounded by faults.

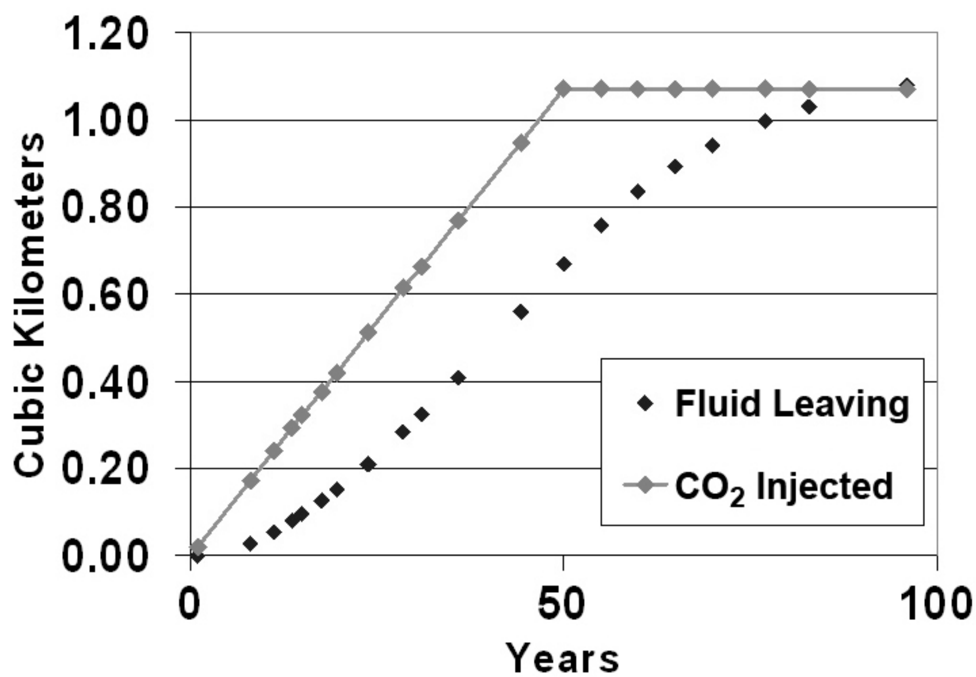

Figure 2. Injected CO_2 and displaced fluids vs. time for the numerical simulation at the Rock Springs Uplift (750 Mt CO_2 sequestered over the course of 50 years via nine injector wells). The displaced fluids exit the storage domain (16 km x 16 km) in order to keep the domain below frac pressures.