Characterization of a Sandstone CO_2 Repository: The Shattuck Sandstone

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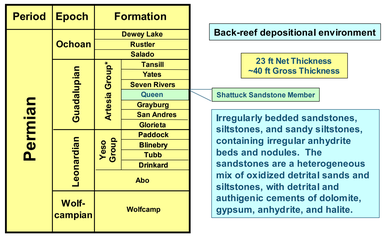
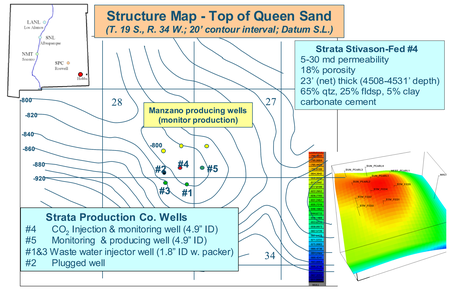
Abstract

Characterization of the Shattuck Sandstone as a CO_2 sequestration reservoir in southeastern New Mexico was undertaken by direct and indirect methods. Important information included 1) the potential for layering in the reservoir and its horizontal compartmentalization, 2) the porosity and 3) permeability of the component sandstones, 3) the potential sealing capacity of the overlying formations, 4) the potential for permeability-enhancing faults and natural fractures, and 5) the in situ stress orientations. Data from geophysical logs, core, tectonic reconstructions, and outcrop studies indicate that the Shattuck Sandstone is a viable CO_2 repository and help to interpret current observed CO_2 injection characteristics.



Stratigraphy

The Shattuck Sandstone Member of the Queen Formation is the host reservoir for the CO_2 sequestration pilot project in the West Pearl Queen field.

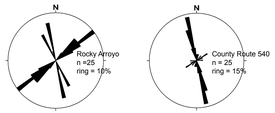


Structure Map of the West Pearl Queen Field

Low-relief structure provides a good CO_2 trap in this depleted oil reservoir.

The Shattuck Sandstone Member of the Queen Formation

This unit was examined where it crops out in Rocky Arroyo and the Guadalupe Mountains west of Carlsbad, NM. These outcrops at 100-130 km (50 to 80 mi) west of the West Pearl Queen field are the closest available. All of the outcrops are fractured. While it may not be possible to extrapolate the fracture sets observed in these outcrops directly into the subsurface, the presence or absence of fractures in outcrop gives an indication of whether the reservoir strata have the potential to be fractured.

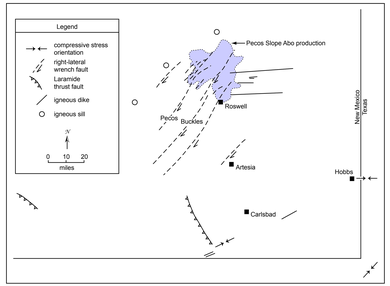


Fracture Strikes within Shattuck Sandstone Outcrops

Outcrops may contain two fracture sets, having strikes of NE-SW and NNW-SSE. The former are typically stained with iron oxide, the latter are typically mineralized with crystalline calcite. Both fracture sets are equally well developed in associated carbonate strata but the NNW-SSE fractures dominate the Shattuck Sandstone. Fractures of this set have average spacings from tens of centimeters to a few tens of meters.

Fractured Carbonate Beds of the Seven Rivers Formation

This unit overlies the Shattuck Sandstone. Two fracture sets are present: parallel and perpendicular to the plane of the page. These fractures reflect the fracture sets within the Shattuck Sandstone. Interbedded evaporites in the Seven Rivers Formation are seals.



Structural Elements of Southeastern New Mexico

Igneous intrusions trend E-W near the northeastern termination of NE-SW striking, right-lateral wrench faults (the Pecos Buckles). The present-day maximum horizontal compressive stress, and reconstructions of the Laramide age maximum horizontal compressive stress, also trend between E-W and NE-SW.
This information suggests the NE-SW fracture set is related to Laramide age tectonics and that fractures are probable in the subsurface.

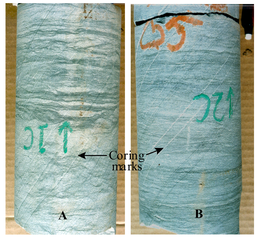
Core Study

The core study consisted of approximately 30 ft of predominately unslabbed, discontinuous, four-inch diameter core from the Queen Formation in the Stivason Federal #1 well.

Three generalized lithologies are present in core from the Stivason Federal #1 well. The main reservoir lithology (lithology C at right) is a poorly cemented, oil stained sandstone exhibiting between 15-20% porosity and irregular permeabilities (up to 200 millidarcies). The percentage of the reservoir represented by this lithology is unknown due to missing core, although about a third of the core available consists of this facies. The upper parts of the core (predominantly consisting of lithology A) represent the confining strata rather than the reservoir rock: lithology C represents about 80% of the core available from the designated main reservoir intervals.

High-Porosity Sandy Reservoir for CO_2 Sequestration

Entire core available for study from the Stivason Federal #1 well. Core boxes are 3ft long and core is 4 inches in diameter for scale.



Lithologies A and B

A) Note the change in bedding at the center of section 1C near the tip of the green arrow – this illustrates the sometimes abrupt transition between lithology A (upper half) and lithology B (lower half).

B) Illustrates a change in gray siltstone laminae from the "wispy" bedding in A to a more planar style of bedding. Spiral coring induced marks or grooves are observed on both sections of core.

Low-porosity/low permeability units interbedded with high-porosity reservoir quality rock units will prevent vertical migration of CO_2.

Lithology C - Primary Reservoir Rock

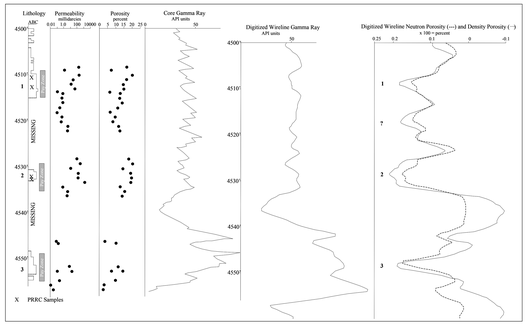
Portions of lithology C are poorly cemented and friable – the rock disintegrates under minimum pressure indicating good reservoir potential.

Lithology C - Primary Reservoir Rock

Coring induced petal fracture within lithology C at a depth of 4512 ft. Blue/Green arrow points uphole.

Lithology C - Primary Reservoir Rock

A heavily oil stained zone within lithology C near the 4513 ft mark. Enlarged photograph illustrates the bedding-parallel nature of the heaviest oil stain. This area is on the "backside" of core section 5F.



Core to Wireline Log Correlation Chart

The logs show that the reservoir is divided into three main high porosity zones. The three generalized lithologies are correlated here to permeability and porosity data provided by Core Labs, a core gamma ray log and the wireline gamma ray and neutron porosity logs.

Conclusions

This work represents the initial geologic approach and evaluation of a potential repository using limited available data. Early work involved finding well logs and core, then incorporating this information with outcrop data and lithologic and tectonic evaluations to ultimately determine the potential of this reservoir for a small scale test.

Natural fractures have the potential to control the direction and facility of fluid flow within a reservoir. While it may not be possible to extrapolate the fracture sets observed in outcrop directly into the subsurface, the presence or absence of fractures in outcrop gives an indication of whether the reservoir strata have the potential to be fractured. No natural fractures are present in the core but two coring-induced petal fractures were observed. This absence in the small sample represented by the core does not preclude fracturing in the reservoir.

The three permeability and porosity zones will make a good CO_2 sequestration reservoir with or without natural fractures.

Acknowledgements

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