[PS]Characterization of the Jurassic Navajo Sandstone of Central Utah: A Potential Carbon Capture and Sequestration Reservoir*

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Abstract

Increasing societal and regulatory demand for carbon capture and sequestration has initiated feasibility studies to characterize possible storage reservoirs. Two Utah coal-burning power plants located on the western side of the San Rafael Swell in Emery County are currently part of a carbon sequestration study by the Rocky Mountain CarbonSAFE project, funded through the U.S. Department of Energy. This research utilizes outcrop and core data to characterize the stratigraphic architecture and reservoir properties of the Jurassic Navajo Sandstone in Sevier County. These findings will inform reservoir model inputs and identify high porosity/permeability target zones.

In-situ permeabilities, in association with detailed stratigraphic sections and core, were measured with a TinyPerm II device. The Navajo Sandstone shows distinct upper and lower stratigraphic intervals, both of which have reservoir-quality porosity and permeability (~25-200 mD). Depositional features that improve reservoir quality include increased size of dune foresets, lower ratios of wind-ripple to grain-flow laminae, and zones of soft-sediment deformation. Features that decrease reservoir quality include the presence of thin carbonate-rich lenses, first-order bounding surfaces between dune foresets, and high wind-ripple to grain-flow ratios. The lower stratigraphic interval is characterized by small dune foreset thicknesses (0.1 to 5 m sets), very fine to fine grain sizes (3-4 φ), carbonate-rich interdune lenses, and higher ratios of wind-ripple to grain-flow. The upper Navajo interval lacks carbonate lenses and contains thicker foresets (5 to 30 m sets) of fine to medium grain sizes (3-2 φ), with brittle and soft-sediment deformations and lower ratios of wind-ripple to grain-flow laminae.

In the lower Navajo Sandstone interval, lenticular interdune deposits average ~6 beds over a 60 m vertical interval. If this lower interval was to be injected with carbon plumes, which are buoyant and prefer upward flow, interdunes may act as baffles to retard upward vertical migration, delaying movement from the lower interval to the upper stratigraphic interval. High overall permeability throughout the Navajo section and reduced vertical transmissivity in the lower interval demonstrate that the Navajo Sandstone is a suitable reservoir unit for carbon sequestration via supercritical subsurface fluid injection.

Reference Cited

Doelling, H., P. Kuehne, G. Willis, and J. Ehler, 2015, Geologic Map of the San Rafael Desert 30’ x 60’ Quadrangle, Emery and Grand Counties: Utah Geological Survey, Utah Map 267DM.

Characterization of the Jurassic Navajo Sandstone of Central Utah: A Potential Carbon Capture and Sequestration Reservoir

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Increasing societal and regulatory demand for carbon capture and sequestration has initiated feasibility studies to characterize possible storage reservoirs. Two Utah coal-burning power plants located on the western side of the San Rafael Swell in Emery County are currently part of a carbon sequestration study by the Rocky Mountain CarbonSAFE project, funded through the U.S. Department of Energy. This research utilizes outcrop and core data to characterize the stratigraphic architecture and reservoir properties of the Jurassic Navajo Sandstone in Sevier and Emery Counties. These findings will inform reservoir model inputs and identify high porosity/permeability target zones.

In-situ permeabilities, in association with detailed stratigraphic sections and core, were measured with a TinyPerm II device. The Navajo Sandstone shows distinct upper and lower stratigraphic intervals, both of which have reservoir-quality porosity and permeability (~25-200 mD). Depositional features that improve reservoir quality include increased size of dune foresets, lower ratios of wind-ripple to grain-flow laminae, and zones of soft-sediment deformation. Features that decrease reservoir quality include the presence of thin carbonate-rich lenses, first-order bounding surfaces between dune foresets, and high wind-ripple to grain-flow ratios. The lower stratigraphic interval is characterized by small dune foreset thicknesses (0.1 to 5 m sets), very fine to fine grain sizes (3-4 φ), carbonate-rich interdune lenses, and higher ratios of wind-ripple to grain-flow. The upper Navajo interval lacks carbonate lenses and contains thicker foresets (5 to 30 m sets) of fine to medium grain sizes (3-2 φ), with brittle and soft-sediment deformations and lower ratios of wind-ripple to grain-flow laminae.

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Geology of San Rafael Swell, Utah

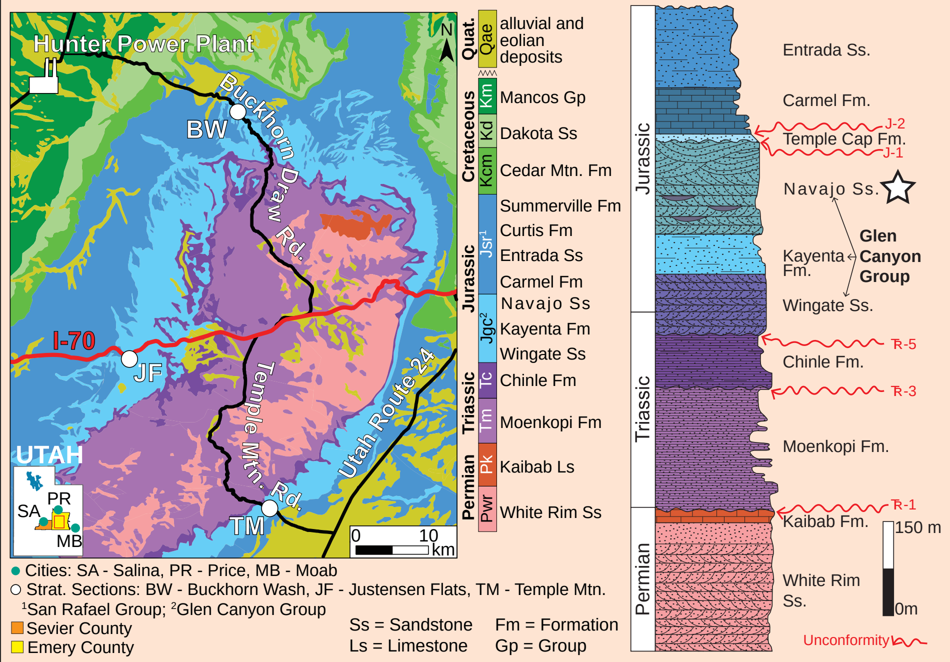

Figure 1. Locations of measured stratigraphic sections and geologic units with major unconformities labeled (modified from Doelling et al., 2015). The San Rafael Swell is a doubly plunging anticline with hinges to the northeast and southwest. The Navajo Sandstone is the uppermost unit of the Jurassic Glen Canyon Group and arguably represents the most vast eolian deposit on Earth. The Kayenta Formation intertongues with the base of the Navajo. The Navajo is unconformably overlain by the Temple Cap Formation along the eastern side of the San Rafael Swell, whereas the Carmel Formation typically overlies the Navajo on the western side of the San Rafael Swell. The Hunter Power Plant, which is one of two prospective carbon-capture sites, is located less than 40 km away from the Buckhorn Wash (BW) study site.

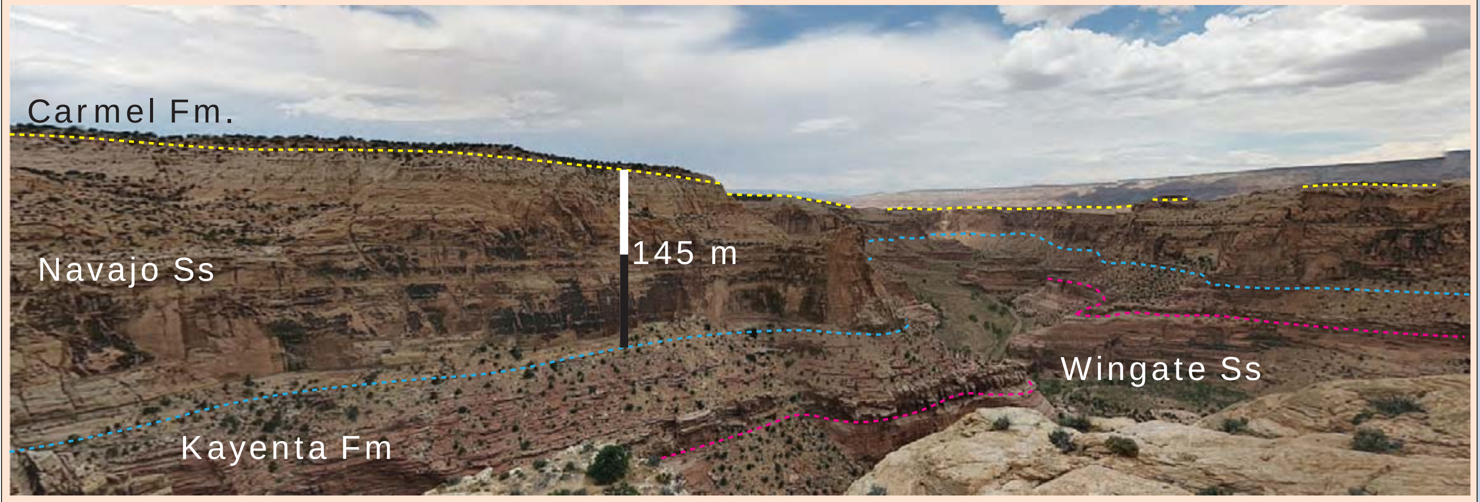

Figure 2. View to the northeast from Buckhorn Cliff overlooking Carmel, Navajo, Kayenta and Wingate, looking into Buckhorn Wash. Note that the Navajo's lower contact with the Kayenta is variable as the two intertongue, but the upper contact with the Carmel is an unconformity delineated by the J-2. Also note that the Temple Cap Formation is not present in outcrop at this location.

Data and Methods

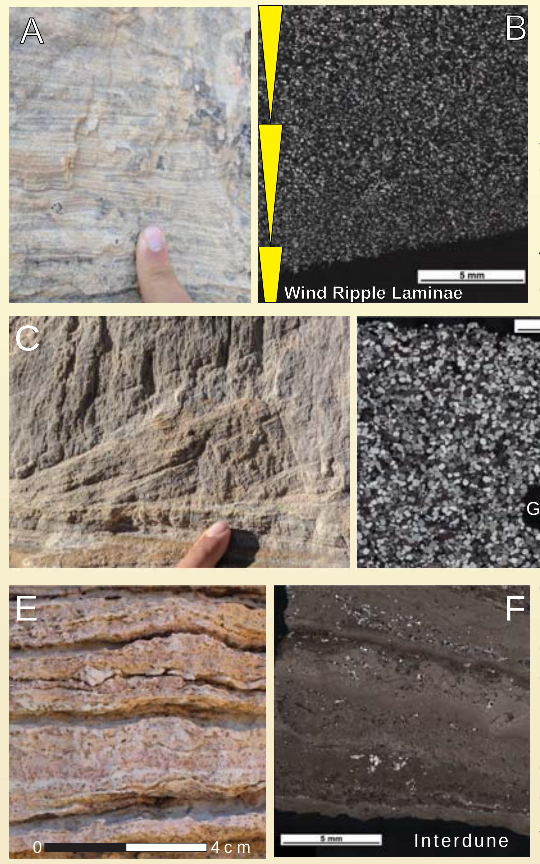

Figure 3. A) Wind ripple laminae (WRL) in outcrop. **B)** WRL in thin section displaying characteristic inverse grading. **C)** Grainflow (GF) tongues pinching out against dune toe. **D)** GF in thin section exhibiting massive texture. **E)** Carbonate cemented interdune deposit (ID). **F)** ID in thin section exhibiting carbonate-rich matrix and re-precipitated carbonate reducing original and/or secondary porosity.

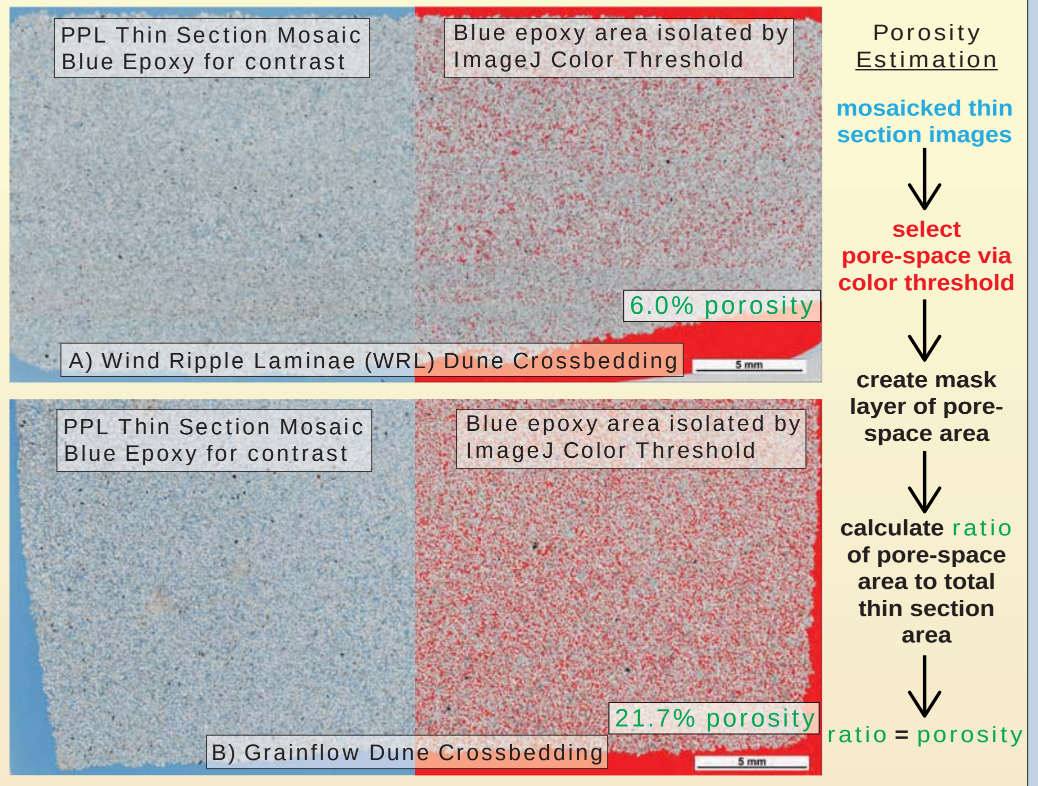

Figure 5. Blue-epoxy thin section mosaics were used to estimate porosity with ImageJ color threshold tool. Thin sections were cut perpendicular to bedding and capture crossbedding grain-size boundaries. Although 3-D porosity is more accurate, this is a cheap and effective method of estimating 2-D porosity with standard thin sections.

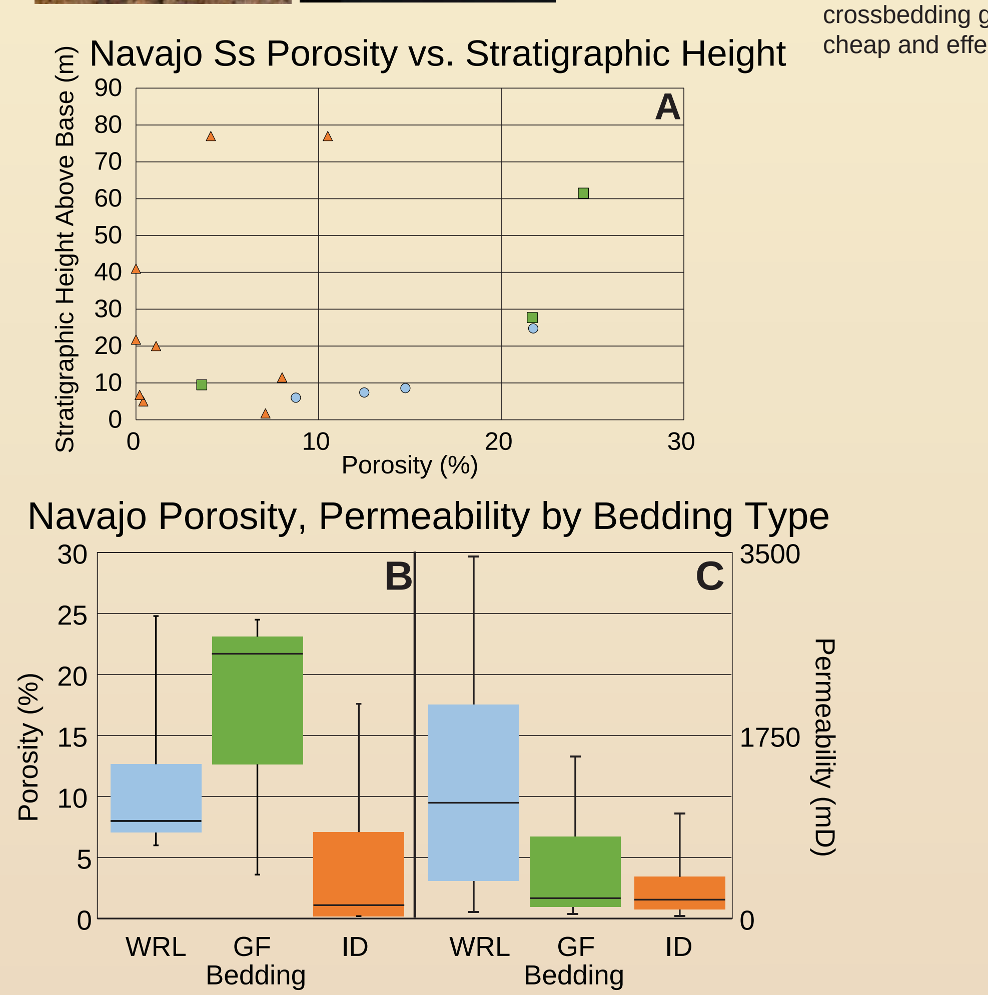

Figure 4. A) 2D porosity was derived using thin-sections mounted in blue epoxy and analysis in ImageJ software via color thresholds. Porosity is greater higher in stratigraphic secions for wind ripple lamina (WRL - ○) and grainflows (GF - ■). Carbonate cemented interdunes (ID - △) generally have <10% porosity and show no clear trends with stratigraphic height. **B)** Porosity is lowest for ID, indicating they will act as baffles and barriers. GF crossbeds have the largest porosity and would provide adequate pore-space for a reservoir, whereas WRL will provide a lower quality storage and potentially act as minor baffles. ID beds will likely act as baffles and possibly as barriers to flow. Porosity sample size: n = 19. **C)** Permeability measured on outcrop with TinyPerm II and follow same relative values as porosity except for low GF values. Error in permeability measurements may be due to caliche buildup in pore-space; sample size: n = 31.

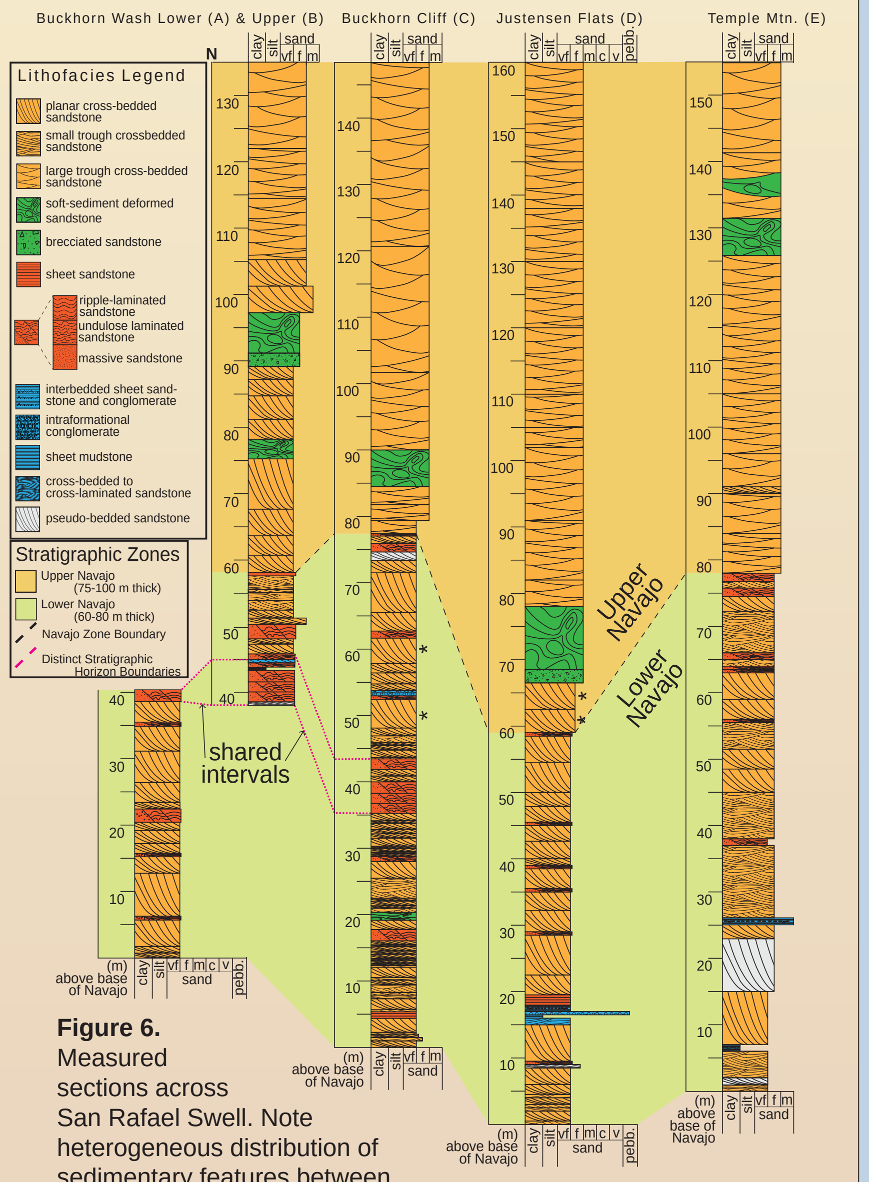

Figure 6. Measured sections across San Rafael Swell. Note heterogeneous distribution of sedimentary features between upper and lower Navajo.

Analysis and Conclusions

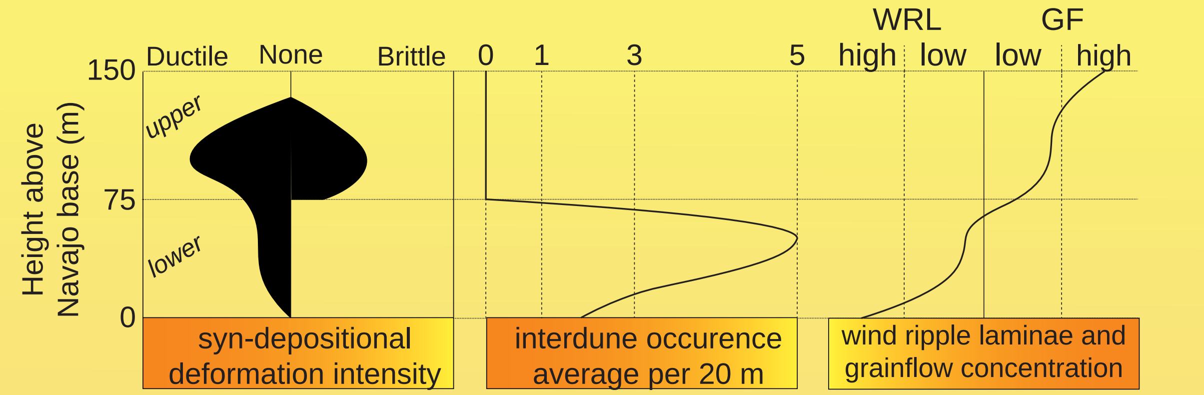

Figure 7. Common trends found in all Navajo Ss measured sections. Sedimentary features in the lower Navajo act to restrict fluid flow while features in the upper Navajo act to enhance fluid flow.

flow	scale	flow path	bed or horizon feature
unrestricted	µm - hm		massive sand
	cm-dm		ductile deformation
ideal reservoir	cm-dm		brittle deformation
	cm-m		**dune grainflow tongue crossbedding**
	mm-cm		**dune wind ripple lamina crossbedding**
moderately restricted	cm-dm		dune reactivation surface
baffles	cm-dm		dune migration surface
	hm-km		deflation (erosional) surface
barriers	dm-hm		**interdune lens (no carbonate)**
very restricted	dm-hm		**interdune lens (carbonate cemented)**

Figure 8. Preferential flow pathways by feature from unrestricted flow (green) to very flow-restricted (red). Flow directions are blue and features are dashed in red. The lower Navajo Ss contains a higher concentration of flow barriers and baffles than the upper Navajo. dm = decameter (10 m); hm = hectometer (100 m)

Conclusions

- The Navajo Ss exhibits ideal porosity and permeability for a potential carbon capture and sequestration (CCS) storage reservoir via subsurface injection.
- Higher ratios of grainflow crossbedding to wind ripple laminae crossbedding and the absence of interdune laminae in the upper Navajo Ss (~80-150 m) suggest that this upper region has better reservoir potential.
- Although the Lower Navajo Ss (~0-80 m) has a lower average porosity and permeability than upper, it is still reservoir quality.
- Bed boundaries defined by changes in grain size, porosity and permeability at both the millimeter-scale and meter-scale act as primary controls on hydraulic transmissivity and guide fluid pathways.

Reference

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Acknowledgements

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