Henry Galvis Silva[1] and Rita Okoroafor[1]

[1]Texas A&M University

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Abstract

This study aims to explore the potential of underground hydrogen storage, its effects on rock formations, and the subsequent implications for energy and environmental sustainability.

Investigating Rock Alterations in Underground Hydrogen Storage (UHS): A Geochemical and Geomechanical Study.

Henry Galvis, Esuru Rita Okoroafor, Texas A&M University

Keywords: Underground Hydrogen Storage, Saline Aquifers, Rock Mechanics, Sustainable Energy.

Introduction

This study aims to explore the potential of underground hydrogen storage, its effects on rock formations, and the subsequent implications for energy and environmental sustainability.

Harnessing Surplus Energy

In 2022, the energy companies of California (CAISO) and Texas (ERCOT) curtailed:

2.4 million and 4.15 million megawatt-hours (MWh) of utility-scale wind and solar output, respectively. Enough to generate 40,000 ton and 80,000 ton of hydrogen respectively

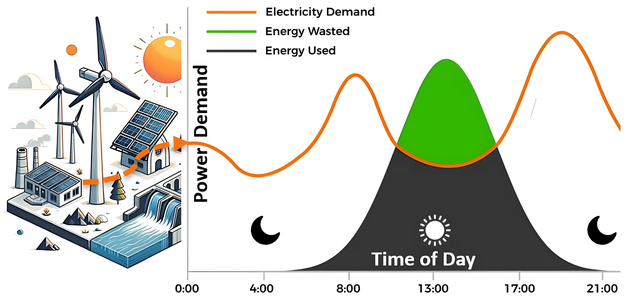


Fig. 1— Power Demand vs Time of Day - Modified from procorre.com

Objective

Evaluating the impact of hydrogen injection on the geomechanical properties of different types of geologies to understand the reactions under various conditions and how this affects the capacity, fluid flow, and structural integrity of these formations.

Novelty

- No previous studies have evaluated the effect of hydrogen on rock mechanics.

- Different geologies will be evaluated under different reservoir conditions.

- An extended rock characterization will be conducted, including also petrophysics, imaging, and XR-D.

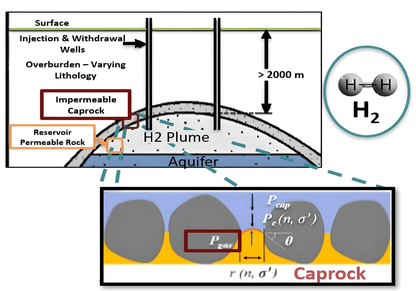


Fig. 2 — Underground Hydrogen Storage Process in Saline Aquifers Modified from Zhu et al. 2020.

Methodology

Rock Samples Characterization (Before and After) hydrogen exposure

Core Samples	**Petrophysics**	Permeability – Porosity – Grain Density
	Geochemical and Images	SEM – X-Ray Diffraction
	Geomechanics	Uniaxial Test

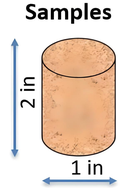


Fig. 3 — Rock Laboratory Characterization Before and After Hydrogen Exposure

Laboratory Experiments

Autoclave Experiments were performed at 3.4 [MPa] and 25 [C] with three different lithologies.

- **30 Days and 90 Days** Experiments for Berea Sandstone, Limestone and Shale(Caprock)

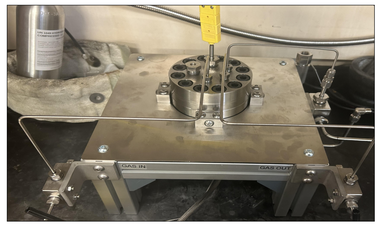


Fig.4 — Autoclave Reactor for Hydrogen-Rock Experiments

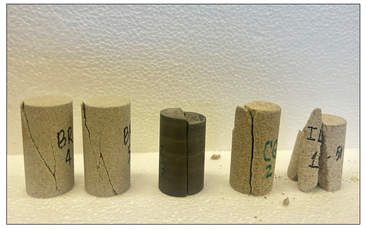


Fig. 5— Rock Samples Evaluated Sandstone, Carbonate and Shale

Results

Petrophysics

Minor petrophysics alterations were observed after the hydrogen experiments on reservoir rocks (sandstone and limestone). Relevant changes were observed on caprocks (Shale)

- **Sandstone:** No representative difference
- **Limestone:** No representative difference
- **Shales:** Porosity increased by 50% and permeability increased by a factor of 3

X-Ray Diffraction

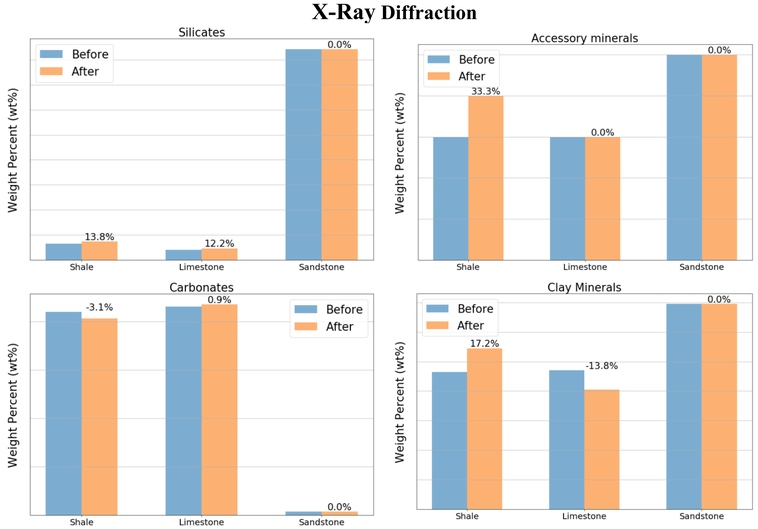
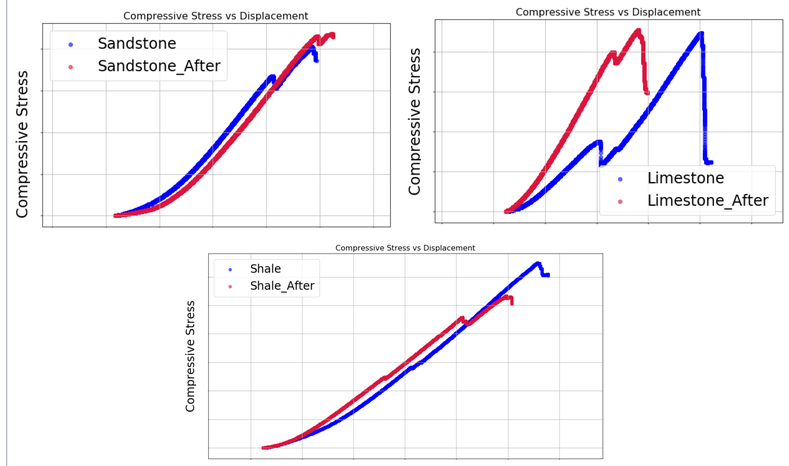


Fig. 6— XR-D Analysis Before and After for Sandstone, Carbonate and Shale

- **Sandstone:** No representative difference
- **Limestone:** 15% reduction on clay minerals and 10% increase on silicates
- **Shale:** 50% increase in clay fraction (Chlorite, Smectite) – 75% increase in Plagioclase

Geomechanics UCS



- **Sandstone:** Representative changes in the elastic modulus, Poisson's ratio, and ductility. **Limestone:** Lower Residual Strength. More Brittle behavior after treatment, Rock present more energy absorbed (becomes stiffer)
- **Shales:** Peak Strength reduction by 15%. No significant differences on the mechanical behavior were observed

Conclusion

- Reservoir rocks did not present significant petrophysical changes, only shales showed increased on porosity and permeability.
- Important chemical changes were observed in the clay fraction of shales, changes in reservoir rocks are more attributed heterogeneities.
- Reservoir rocks (sandstones and limestone) both presented a brittle behavior after hydrogen exposure and becoming stiffer; however, no significant changes were observed in the mechanical properties of the seal rocks (shale).
- UHS is unlikely to significantly affect reservoir mechanics, but additional caprock experiments are needed to ensure seal integrity as porosity and permeability may change.

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References

Bai, T., Tahmasebi, P. Coupled hydro-mechanical analysis of seasonal underground hydrogen storage in a saline aquifer, J. Energy Storage 50 (2022) 104308.

Okoroafor, E. R., Saltzer, S. D., & Kovscek, A. R. (2022). Toward underground hydrogen storage in porous media: Reservoir engineering insights. International Journal of Hydrogen Energy, 47(79), 33781-33802.

Okoroafor, E. R., & Galvis, H. (2023, June). Underground Hydrogen Storage in Porous Media: The Role of Petrophysics. In SPWLA Annual Logging Symposium (p. D031S001R002). SPWLA.