PERMEABILITY VARIATIONS IN SIMPLE PORE GEOMETRIES: INTEGRATING ACOUSTIC VELOCITY, ELECTRICAL RESISTIVITY, AND DIGITAL IMAGE ANALYSIS

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PROJECT OBJECTIVES

- Investigate why carbonate samples with similar pore geometries (large, simple pores: high DomSize, low PoA) and high acoustic velocities exhibit variable permeability.
- Correlate electrical resistivity and permeability in these samples to identify microstructural controls (e.g., microporosity, cementation, pore connectivity).
- Develop a predictive model to distinguish high- vs. low-permeability zones in carbonates with high velocity and simple pore structures using integrated acoustic, resistivity, and DIA data.

PROJECT RATIONALE

Carbonate reservoirs units with simple pore geometries (e.g., oomoldic rocks and grainstones) often display high acoustic velocities due to stiff frameworks but sometimes show drastic permeability variability. In most cases, regions that exhibit high acoustic velocity and simple pore geometry also show high permeability. There are, however, exceptions to this rule. Oomoldic rocks, completely inverted ooid grain stones, are an example of high acoustic velocity rocks with simple pore geometry that sometimes lack any connectivity at all (e.g. Anselmetti and Eberli, 1999). High electrical resistivity correlates in many cases with low permeability (e.g., cemented zones), but Verwer et al. (2011) revealed that high-permeability samples can also exhibit high resistivity if pore structures limit electrical connectivity (e.g., isolated vugs). This paradox complicates reservoir characterization and water saturation calculations but might be exploitable in combination with acoustic velocity.

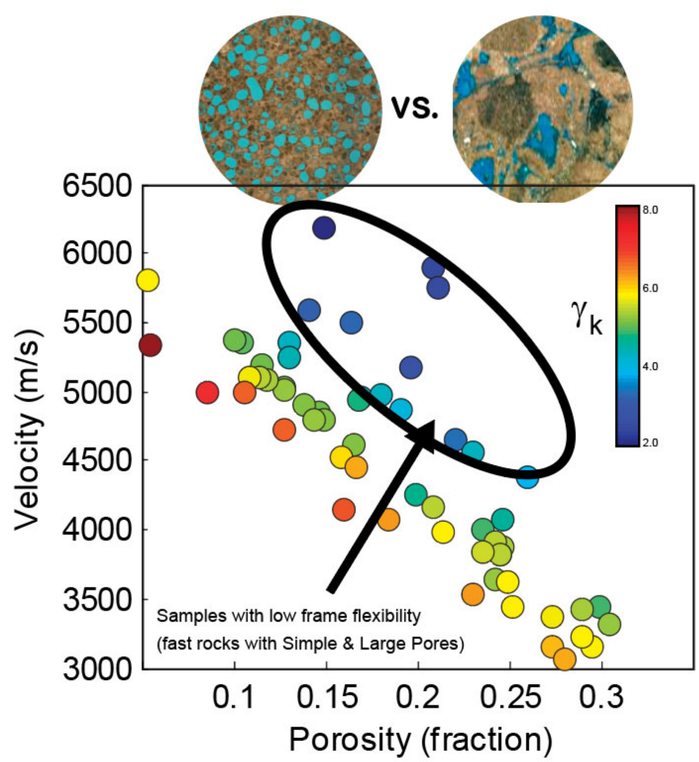

Figure 1: velocity-porosity cross plot with samples colored by γ_k. Low γ_k samples (large DomSize and low PoA) frequently have high permeability but are sometimes completely disconnected (oomoldic).

DATA/METHODOLOGY

This study will re-analyze representative samples to resolve conflicting relationships between velocity, resistivity, and permeability in simple-pore carbonates, leveraging Digital Image Analysis (DIA) to quantify microstructural controls. We plan to measure ~30 carbonate core plugs with high DomSize (>300 µm) and low PoA (<50 mm^{-1}) (simple pores) that are expected to show high acoustic velocity (>4,500 m/s) but variable permeability (0.1–1,000 mD). We will incorporate a variety of different rock types to provide a diverse range of applicability (e.g., microbialites, grainstones, travertines, ...).

APPROACH AND METHODOLOGY

We will address the lack of understanding of how microporosity, pore geometry, and overall connectivity influence permeability in rocks with macroscopically similar pore structures and re-evaluate the existing ambiguities. The Challenge is to separate rocks with simple pore space geometries (stiff rocks) that have connected pore networks and most often high permeability (Weger et al., 2024) from those with less connected (or unconnected) pore networks. Both have low PoA and high DOMSize and they show high velocities for their given porosity resulting in low $\gamma_{k.}$ But, samples with a high number of pores connections and lower tortuosity show more effective transport of ionic charge (Norbisrath et al., 2015).

SIGNIFICANCE

This study will resolve ambiguities in log-based permeability prediction, enabling better identification of high-permeability zones in carbonates with simple pore structures. By integrating resistivity measurements with acoustic velocity and pore geometry data, this project will enable more accurate discrimination of samples with fewer pore connections (e.g., isolated vugs or large, poorly connected pores) that will exhibit high resistivity but may have low permeability from samples with well-connected pores will show lower resistivity and higher permeability. This advancement will improve reservoir models, enhance log-based permeability predictions, and refine water saturation calculations, ultimately supporting better decision-making in exploration and production, particularly in complex carbonate reservoirs like microbialites or pre-salt plays.

REFERENCES

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