Bioturbation effects on permeability in tidally-modified Strawn Group deposits, Texas

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ABSTRACT

Core and wireline logs from the Pennsylvanian (Desmoinesian) Strawn Group deposited along the Eastern Shelf of the Permian Basin in Stonewall and King Counties, TX contain both siliciclastic and carbonate intervals. Interfingering siliciclastics/carbonates suggest that these are deposits of highly complex, prograding and retrograding tidally modified deltaic deposystems that interfinger with carbonate factories along a shallow-dipping tidal shelf and ramp. The complexity of facies and fluctuating bioturbation intensities affect reservoir properties. Previous studies of the effects of bioturbation intensity on permeability provided mixed results. Singh et al. (2023) show bioturbation increasing permeability. In contrast, Tonkin et al. (2010) suggest that permeability may increase or decrease with bioturbation intensity, depending on sediment cleaning, sediment packing, and/or sediment mixing by marine organisms. We use mixed carbonate-siliciclastic deposits of the Upper Strawn to reveal the effects of facies variability and bioturbation intensity on permeability by combining core facies analysis, prior lab core analyses, and new probe permeameter measurements.

Select intervals of slabbed core from the Phillips CB Long C-16 well were evaluated for facies variability, bioturbation intensity, grain size, and permeability. Grain size (GS) was visually assessed on a 1 (clay size) to 8 (gravel) scale. Bioturbation was estimated using the bioturbation index (Bi) of Taylor and Goldring (1993). Bi measurements were binned into classes based on statistically significant averages and plotted against average probe permeability and average grain size (Fig. 1). Historical core plug permeability measurements at one-foot spacing were compared to permeability measured every four inches using an air-based probe permeameter. The four-inch spacing was chosen to give statistically representative average values in highly heterogeneous sediments. Comparison of historical core plug data and probe permeabilities showed that probe measurements were statistically similar to plug values, although probe measurements provided a higher-resolution dataset. Higher-resolution probe measurements allowed us to record data over silty, disaggregated intervals where core plugs otherwise cannot be taken and analyzed.

A comparison of average probe permeability versus Bi shows that permeability is enhanced as Bi increases, up to a Bi = 3 (Fig. 1). As Bi increases above 3, permeability rapidly decreases. A similar trend was observed with average core plug permeabilities, but limited plug samples made the variation statistically insignificant.

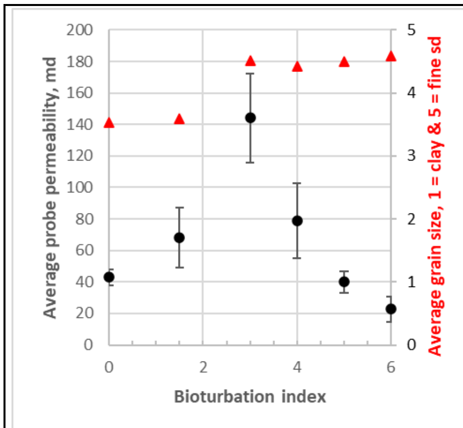

Figure 1: Average probe permeabilities and standard errors versus bioturbation index values (black circles and left axis). Average grain sizes for the same intervals appear in red triangles (right axis).

GS can also affect permeability, so average GS values were also considered (Fig. 1). GS was calculated semi quantitatively through visual grain size analysis. For Bi < 2, the average GS is constant at 3.5; for Bi>2, the average GS increases to 4.5. Thus, we conclude that:

- The increasing permeability trend for data with Bi <2, and the trend of decreasing permeability for Bi>2 is statistically valid and not affected by grain size trends.
- Factors other than average GS (e.g., sorting, stratification) are likely controlling fluctuating permeability trends.

Our analyses show that moderate bioturbation can increase permeability in tidally-modified deposits up to a threshold, in our case a Bi = 3, at which point permeability begins to decrease. Our results may reflect lower-intensity bioturbation increasing connectivity through mud-drapes on sedimentary structures common in tidal systems. Alternatively, higher bioturbation intensities increase sediment mixing and clay distribution in pore spaces, reducing overall permeability.

In comparisons of median probe values for six clastic facies and one carbonate facies, carbonates were the least permeable by a factor of 10 . This may reflect permeability loss from carbonate cement in pore spaces. Ultimately, incorporating higher-resolution probe permeameter measurement into broader drill core and wireline log analyses can provide more statistically significant permeability datasets than core plugs can provide alone.