Diagenetic Controls on Distribution and Reservoir Character of Deep-Water Deposits in the Permian Wolfcamp, Bone Spring, or Wolfbone Plays of the Delaware and Midland Basins

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Subsurface Application: Permian Basin slope and basin center plays such as Avalon, Wolfcamp, Bone Spring, Leonard, Wolfbone

Status: Ongoing research (one project completed for one KICC sponsor)

Timing: Upon funding

Funding: Seeking funding

Purpose

This project proposes to study diagenetic controls on porosity reduction and preservation in Bone Spring, Wolfcamp or Wolfbone carbonates of the Delaware or Midland basins (Figure 1). It addresses the fundamental question of porosity preservation in deepwater carbonates to provide models for distribution of deepwater conventional reservoirs, unconventional reservoirs and nonreservoir rocks. The result will be a conceptual model by which the distribution of reservoir porosity in deepwater carbonate plays can be predicted.

Project Description

It is well known that many deepwater carbonates are deposited with great amounts of inter- and intraparticle porosity. Many of these carbonates preserve this porosity at depth or are subject to diagenetic processes of porosity enhancement, leading to good deepwater conventional carbonate reservoir properties. On the other hand, the porosity in many other deepwater carbonates have largely been occluded by cementation and pressure solution. These diagenetic processes are primary controls on the lateral interface between grainy deepwater conventional reservoirs, low-permeability unconventional reservoirs, and non-reservoir rock. Predictability requires an improved understanding of diagenetic processes affecting deepwater carbonates.

In the Permian of West Texas and New Mexico, deepwater conventional reservoir systems are well known (Saller et al., 1989a,b; Hobson et al., 1985; Mazzullo and Reid, 1987; Mazzullo, 1989, 1994; Griffin and Breyer, 1989; Leary and Feeley, 1991; Montgomery, 1996; Pacht et al., 1996; Mazzullo and Montgomery, 1997). Harris and Wiggins (1985) reported diagenetic differences between shelf and basinal strata, and Mazzullo and Harris (1991) documented multiple diagenetic phases affecting Bone Spring deposits. In low-permeability unconventional areas of the basin there is still evidence for a history of cementation and fluid flow (Poros et al. 2014). Yet, in the grainy carbonates of the Avalon Shale in the center of the Delaware basin (KICC study by Stolz, 2014), porosity and permeability have been eliminated by diagenetic processes, even in grainy sediment gravity flow deposits.

Our group has pioneered approaches to petrographic, geochemical and fluid inclusion analysis for understanding diagenetic and fluid flow history of unconventional carbonate reservoirs (e.g. Goldstein and Mitchell, 2013). We propose to study the diagenetic history of lateral and vertical transects in the Permian basin to develop an understanding of the
controls on porosity preservation. Methodology will include core description, thin section petrography, CI and UV petrography, SFM study, fluid inclusion microthermometry, and stable isotope analysis. These data will be used to understand the controls on porosity preservation and occlusion in Permian Basin deepwater carbonates (e.g. Mazzulo and Harris, 1991). The project will test multiple hypotheses of diagenetic alteration including:

- It is possible that cements are locally derived. For example, there is a negative correlation between clay and carbonate in the Avalon Shale. In thin sections, the carbonate in the muds have been attacked by pressure solution. If a grainy carbonate bed is surrounded by muds, much of the original depositional carbonate in the muds may have been dissolved. This may be because of the local chemical environment during burial induced by the clays and organic matter in the mudstone facies. The dissolved carbonate precipitates locally in the interbedded grainy carbonates where the local chemical environment is different. Where grainy carbonates are interbedded with muds or at least closely associated with them spatially, the carbonates are not porous. Where those muds are largely absent locally (such as in more proximal parts of the slope) there is no local source of dissolved CaCO$_3$ to cause cementation. Porosity in deepwater grainy carbonates are therefore preserved where the muds are absent or not abundant locally, immediately above or below, or interbedded with the grainy carbonate.

- Variation in cementation may be a secular change related to external forcing. It is well known that orbital forcing has an impact on early cementation of other deepwater carbonates (e.g. Molenaar and Zijlstrab, 1997). If carbonate cements are marine in origin and early, then rate of cementation may correlate to climate, sea level, or water circulation parameters.
• Porosity may simply be controlled by water depth. Given increased water depth, undersaturation with respect to carbonate phases is likely. Early grain-to-grain dissolution could be an early phenomenon related to pore seawater chemistry associated with depth and microbial metabolism. Similar grain-to-grain dissolution has been known for years in vadose settings as a mimic of grain-to-grain pressure solution. A similar process may take place in deepwater settings to reduce porosity early.

• Diagenetic history in the Permian basin deepwater carbonates is most likely complex and related to multiple events of fluid flow that had an impact on porosity evolution. This could include early marine diagenesis, later brine reflux, multiple events of fracturing and tectonically driven hydrothermal fluid flow, and then uplift and influx of meteoric waters (e.g. Hiemstra and Goldstein, 2014; Figure 3). Understanding the controls on fluid flow will provide improved models for cementation and thermal history.

**Deliverables**
This project will provide vertical and lateral transects of diagenetic history in deepwater deposits in the Permian Basin. These transects will be correlated to reservoir quality. Data will include paragenetic history, thermal signature from fluid inclusions, salinity history, hydrocarbon migration, and integration of paragenesis with fluid inclusions and stable isotopes. The result will formulate improved conceptual models for porosity preservation and cementation in deepwater carbonates in the system, allowing for improved predictability. It will predict the lateral interface between grainy deepwater conventional reservoirs, low-permeability unconventional reservoirs, and non-reservoir rock.

![Carbonate Content vs. Permeability](image)

**Figure 2.** Plot showing permeability in relation to carbonate content in the Avalon Shale. Permeability is shown to increase with decreased carbonate, illustrating the poorer reservoir properties of carbonate-rich strata.

*Kansas Interdisciplinary Carbonates Consortium Prospectus – June 2015*
Figure 3. Summary of paragenesis in relation to tectonic history of the Permian basin for the Indian Basin field of New Mexico (after Hiemstra and Goldstein, 2014).

References


