[PS]Pennsylvanian and Wolfcampian Sequence Stratigraphy Using FMI and Log Analysis on the Western Edge of the Midland Basin: A Tool for Guiding Well Completions*

Shane J. Prochnow[1] and Gregory D. Hinterlong[1]

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Abstract

The Pennsylvanian and Permian (Wolfberry) tight carbonate and shale play in the Midland Basin is most often considered a cost play, resulting in a tendency to be parsimonious with the acquisition of formation evaluation data and other services that facilitate optimal completion, especially with “manufactured” wells. A sequence stratigraphic framework for the play in the western Midland Basin was constructed from Schlumberger high definition image logs (FMI-HD), wire line data, and core to predict lithofacies and reservoir characteristics. The stratigraphic framework has been linked to rock mechanic properties such as Poisson's ratio, Young's Moduli, and estimates horizontal stresses that affect the brittleness and frackability of these reservoirs. The framework describes 32 high-frequency sequences (4th and 5th order) that can be grouped into lower-order composite sequences and correlated for at least 10s of kilometers. Our model predicts both the distribution of brittle lithofacies that are conducive to hydraulic fracturing and the occurrence of favorable reservoir conditions, like porosity development. Porosity, brittleness, natural fracture development, and mud log shows are associated with carbonate-prone high stand (HST) systems tracks, while potential fracture baffles are associated with more siliciclastic-prone and ductile low stand (LST) systems tracts. Brittle and more organic rich mudstones occur in transgressive stand (TST) and lower HST systems tracts, with the best mud log shows often occurring near maximum flooding surfaces. The sequence stratigraphic framework provides excellent perspective for regional opportunity identification and helps to fill interpretive gaps when comprehensive formation evaluation data is not available. This predictive capability assists with all aspects of subsurface assessment from strategic opportunity identification to tactical decisions regarding completion design.

Pennsylvanian and Wolfcampian Sequence Stratigraphy Using FMI and Log Analysis on the Western Edge of the Midland Basin: A Tool for Guiding Well Completions

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Abstract

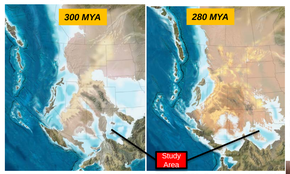
The Pennsylvanian and Permian (Wolfberry) tight carbonate and shale play in the Midland Basin is most often considered a cost play, resulting in a tendency to be parsimonious with the acquisition of formation evaluation data and other services that facilitate optimal completion, especially with "manufactured" wells. A sequence stratigraphic framework for the play in the western Midland Basin was constructed from Schlumberger high definition image logs (FMI-HD), wire line data, and core to predict lithofacies and reservoir characteristics. The stratigraphic framework has been linked to rock mechanic properties such as Poisson's ratio, Young's Moduli, and estimates horizontal stresses that impact the brittleness and fracability of these reservoirs. The framework describes 32 high frequency sequences (4th and 5th order) that can be grouped into lower-order composite sequences and correlated for at least 10s of kilometers. Our model predicts both the distribution of brittle lithofacies that are conducive to hydraulic fracturing and the occurrence of favorable reservoir conditions, like porosity development. Porosity, brittleness, natural fracture development, and mud log shows are associated with carbonate-prone high stand (HST) systems tracks, while potential frac baffles are associated with more siliciclastic-prone and ductile low stand (LST) systems tracts. Brittle and more organic rich mudstones occur in transgressive stand (TST) and lower HST systems tracts, with the best mud log shows often occurring near maximum flooding surfaces. The sequence stratigraphic framework provides excellent perspective for regional opportunity identification and helps to fill interpretive gaps when comprehensive formation evaluation data is not available. This predictive capability assists with all aspects of subsurface assessment from strategic opportunity identification to tactical decisions regarding completion design.

•13-3rd order cycles known globally from Bend to Wolfcamp Time

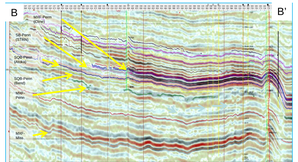
100 m of 3rd order amplitude sea level change.

•Undoubtedly, many more glacially Controlled 4th and 5th order cycles constructed on 0.1 to 0.5 my times.

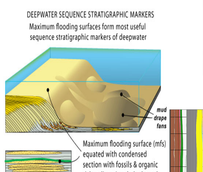
With permission from Science Haq and Schutter, 2008

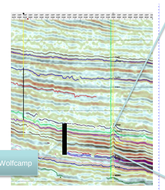


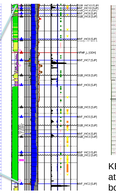
With permission from Blakey, 2006; *Geosystems, Inc., 2010.*



Seismic Cross Section of the Lupin Area, Western Edge of Midland Basin



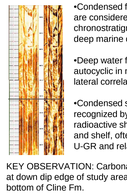




•Condensed flooding surfaces are considered the most reliable chronostratigraphic marker for deep marine correlation.

•Deep water fan systems are autocyclic in nature, making lateral correlation difficult.

•Condensed surfaces can be recognized by organic rich radioactive shale draped on fans and shelf, often with much higher U-GR and relative resistivity.

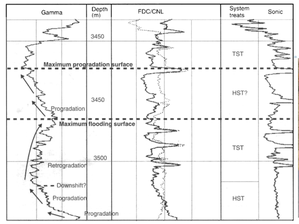


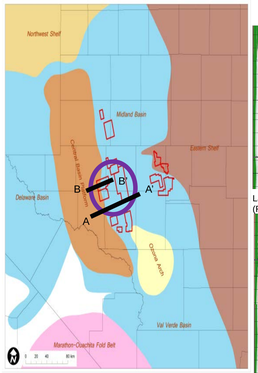
KEY OBSERVATION: Carbonate mound structure at down dip edge of study area. Suggest TST at bottom of Cline Fm.

•Well log through the Jurassic Ula Field, offshore Norway.

•*Maximum Flooding Surfaces* and *Maximum Progradation Surfaces* are picked from the GR curve and used to package stratigraphy.

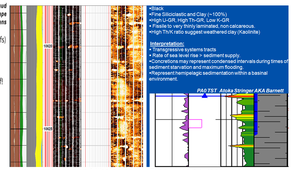
•Lowstand wedges and sequence boundaries are difficult to positively ID from log data along – they require understanding of facies displacement (Emery and Myers, 2007).



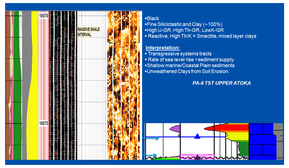


Six Wolfberry wells in this study are located on the western edge of the Midland Basin (purple circle) and were logged with the Schlumberger FMI image tool. Shown seismic transects are black lines. Red polygons are Chevron active development areas.

A condensed, deep water hard ground, probably a maximum flooding surface.



Late Pennsylvanian Lithofacies A – Black Shale (Reservoir)



Late Pennsylvanian Lithofacies B – Organic Mudstone (Non-Reservoir)

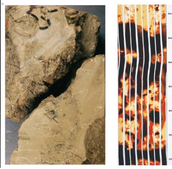
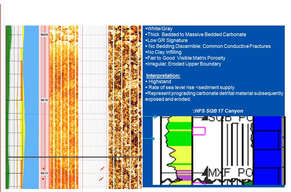
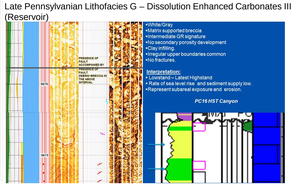


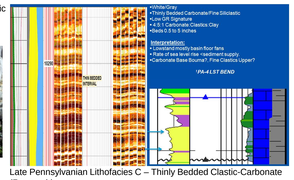
Image log and core pair of karsted, cycle -top carbonates. Cross Timbers 22 BA No 7 well from University Block 9 Field, Andrews County – Wolfcamp on the Central Basin Platform about 30 miles NW of Lupin.



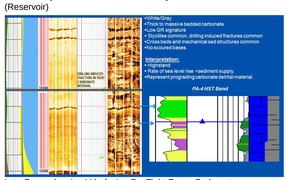
Late Pennsylvanian Lithofacies G – Dissolution Enhanced Carbonates III (Reservoir)



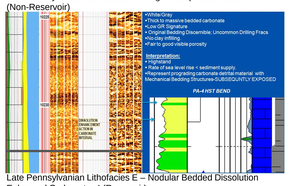
Late Pennsylvanian Lithofacies H – Collapse Breccia (Non-Reservoir)



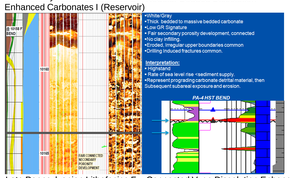
Late Pennsylvanian Lithofacies C – Thinly Bedded Clastic-Carbonate (Reservoir)



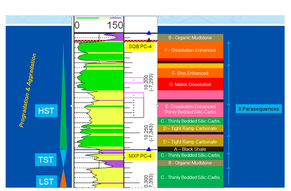
Late Pennsylvanian Lithofacies C – Tight Ramp Carbonate (Non-Reservoir)



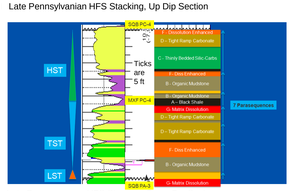
Late Pennsylvanian Lithofacies E – Nodular Bedded Dissolution Enhanced Carbonates I (Reservoir)



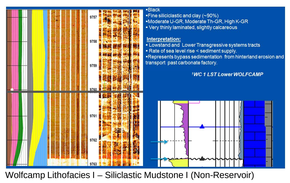
Late Pennsylvanian Lithofacies F – Connected Vugs Dissolution Enhanced (Reservoir)



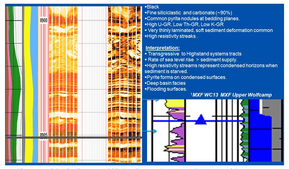
Late Pennsylvanian HFS Stacking, Up Dip Section



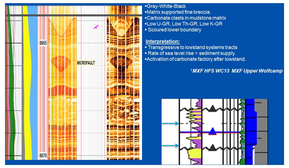
Late Pennsylvanian HFS Stacking, Down Dip Section



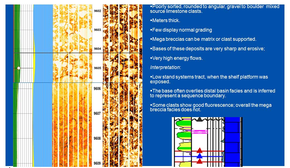
Wolfcamp Lithofacies I – Siliclastic Mudstone I (Non-Reservoir)



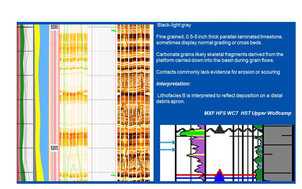
Wolfcamp Lithofacies J – Siliclastic Mudstone II (Reservoir)



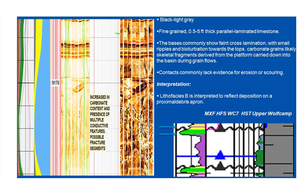
Wolfcamp Lithofacies L – Distal Debris Flow (Non-Reservoir)



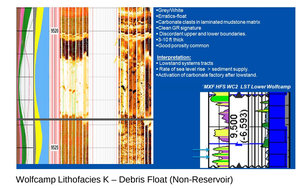
Wolfcamp Lithofacies M – Mega Breccia (Non-Reservoir)



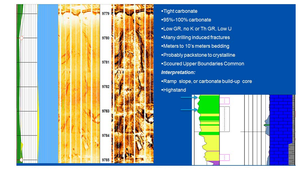
Wolfcamp Lithofacies N – Distal Carbonate Turbidities (Reservoir)



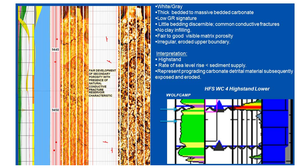
Wolfcamp Lithofacies O – Proximal Carbonate Turbidities (Non-Reservoir)



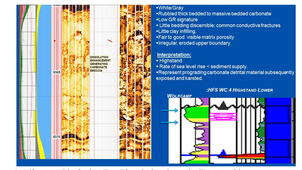
Wolfcamp Lithofacies K – Debris Float (Non-Reservoir)



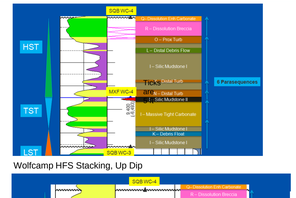
Wolfcamp Lithofacies P – Massive Tight Carbonate (Non-Reservoir)



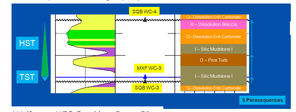
Wolfcamp Lithofacies Q – Dissolution Enhanced Carbonates (Reservoir)



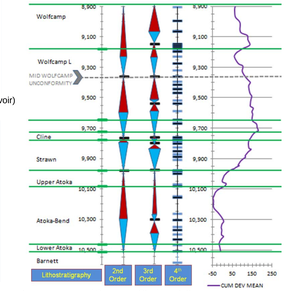
Wolfcamp Lithofacies R – Dissolution Breccia (Reservoir)



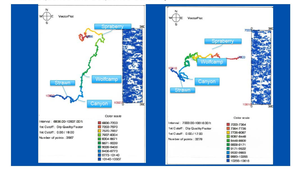
Wolfcamp HFS Stacking, Up Dip



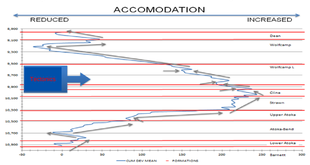
Wolfcamp HFS Stacking, Down Dip



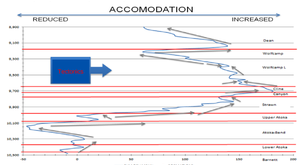
Parasequence and Sequence Stacking Pattern



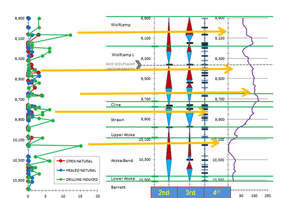
Bedding Dips Provide Insight on Transgression and Regression Episodes



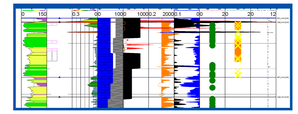
Up Dip Parasequence Cycle Trends

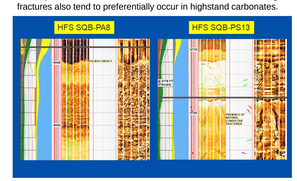


Down Dip Parasequence Cycle Trends



Parasequence and sequence stacking patterns compared to fracture identified in image log.





HFS Boundary Associated Secondary Dissolution in the Strawn FM

Parasequence and sequence stacking patterns compared to porosity development. Ideal locations for horizontal landings are identified.

HFS Boundary Associated Secondary Dissolution WC-3 Lower Wolfcamp

Summary

High Frequency Sequences (HFS) and composite sequences can be correlated across the Midland Basin. Cyclic zones of enhanced secondary porosity are identified in the Late Pennsylvanian and lower Wolfcamp section of the western edge of the Wolfberry play in the Midland basin. These zones of enhanced secondary porosity cap high frequency sequences and are correlative for km to tens of kilometers. The exposure features described on the margin of the Midland Basin are similar to platform Wolfcamp exposure features described by Saller and others (1994, 1999) on the Central Basin Platform about 48 km to the NW. The sequence stratigraphic framework can be continued using cased hole wireline tools in new wells, and enhanced porosity targets can be picked now that curve data is calibrated to image and log data from this study. There is an opportunity to save some money not hydraulic fracturing these zones, but perforate and acid only. Resource development should still consider geologic change and changing opportunities, especially at the edges of basins.

Lessons Learned

High resolution sequence stratigraphy can be scaled down to the individual field scale and are especially helpful in identifying completion targets for perforation and hydraulic fracturing.

Best Practices

FMI logs should be run frequently. Sequence Stratigraphy can be a cost saving measure because of its predictive capabilities, ultimately saving the money that would have been spent on extra frac stages.

Challenges

Cost of FMI logs and time to interpret them.