Lower Permian and Pennsylvanian Stratigraphy and Shale Gas Potential of the Palo Duro Basin

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Abstract

The Palo Duro Basin (Fig. 1) is a northwest-southeast trending cratonic basin in the Texas Panhandle that formed from uplift of the Amarillo/Wichita Mountains during the Pennsylvanian, and subsequent subsidence during the Permian. Sediments were deposited in a number of environments, the most prominent being fan-delta, carbonate shelf, and deep basin settings. Major lithologies in the Pennsylvanian are granite wash, shelf-margin carbonates, and basinal shales, while the Permian hosts the same lithologies, as well as numerous evaporites and red-bed sequences.

This study analyzes log data from 100+ wells in the Palo Duro Basin to correlate and determine the lateral extent of different facies throughout the basin during the Pennsylvanian and Permian. Cross-sections made will help to generate isopach, structure, and other geological maps to identify areas where further geochemical and/or petrophysical analyses can be performed to evaluate Pennsylvanian and lower Permian shale gas potential of the Palo Duro Basin. This project will establish a more detailed stratigraphic framework of Pennsylvanian and lower Permian aged sediments of the basin, as well as determine source rock quality and thermal maturity for potential shale gas plays within the Palo Duro Basin, with a more thorough look along the southern fringes of the basin near the Matador Arch.

Introduction

- Two temporally separate and overlapping sub-basins; 1) NW part of basin formed in the Early Pennsylvanian, and 2) SE portion of basin formed durring the Early Permian (Budnik and Smith 1981)
- Primary depositional environments and lithologies: 1) deltaic sandstones, 2) carbonate shelf , 3) slope system limestone and shales, and 4) deep basin shales (Fig. 3) (Dutton 1980)
- Establish a detailed stratigraphic framework for the Lower Permian and Pennsylvanian sections using electric logs
- Perform petrophysical analysis in select areas to better understand hydrocarbon potential and distribution, with a focus on Swisher, Briscoe, Hall, Hale, Floyd, and Motley counties

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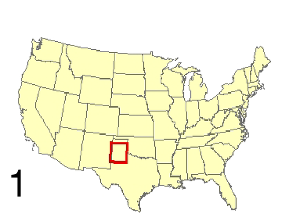
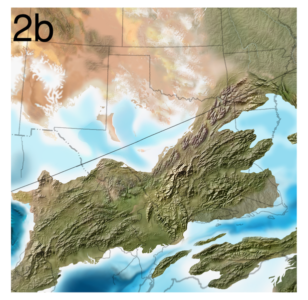


Figure 1.Current day image of the study area.

Figure 2. Blakey maps of the Late Pennsylvanian (2a) and Early Permian (2b).

2a

2b



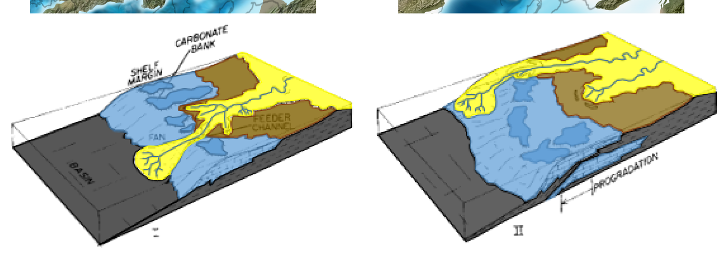


Figure 3. Depositional model of primary lithologies in the Palo Duro Basin (modified from Hanford and Dutton 1980).

System	Series	Group	General Lithology and depositional setting
Quaternary			Fluvial and lacustrine clastics
Tertiary			
Triassic		Dockum	Fluvial-deltaic and lacustrine clastics
Permian	Ochoa		Sabkha salt, anhydrite, red beds, and peritidal dolomite
	Guadalupe	Artesia	
		Pease River	
	Leonard	Clear Fork	
		Wichita	Shelf and shelf-margin carbonate, basin shale, and deltaic sandstone
	Wolfcamp		
Pennsylvanian	Virgil	Cisco	
	Missouri	Canyon	
	Des Moines	Strawn	
	Atoka	Bend	
	Morrow		
Mississippian	Chester		Shelf carbonate and chert
	Meramac		
	Osage		
Ordovician		Ellenburger	Shelf dolomite
Cambrian			Shallow marine (?) sandstone
Precambrian			Igneous and Metamorphic Basement

Figure 4. General strat column of the Palo Duro Basin (modified from Dutton 1980).

Methods

Stratigraphy

Stratigraphic correlations of the subsurface have been made to identify the lower Permian and Pennsylvanian systems, as well as determine the dominant lithologies that make up these systems, which give insight to depositional environments. Type logs from Dutton (1980) and Handford (1981) were used to identify time stratigraphic boundaries to put constraints on the Pennsylvanian and Lower Permian

Lithologies are separated by gamma ray responses:
- 0-25 Carbonate (Blue/Purple)
- 25-40 Sandstone (Yellow)
- 40-60 Siltstone (Orange)
- 60-200 Shale (Grey/Black)

Shale Gas Potential

More detailed petrophysical analysis and/or geochemical analysis is required to detemine hydrocarbon potential. One method to determine organic content is the Δ log R method (Passey's Method), by crossplotting sonic logs and the natural logarithm of resistivity data (Passey et al. 1990; Bowman 2010).

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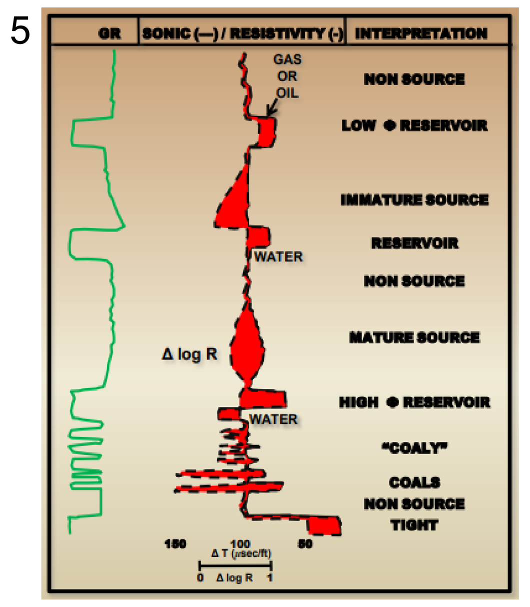


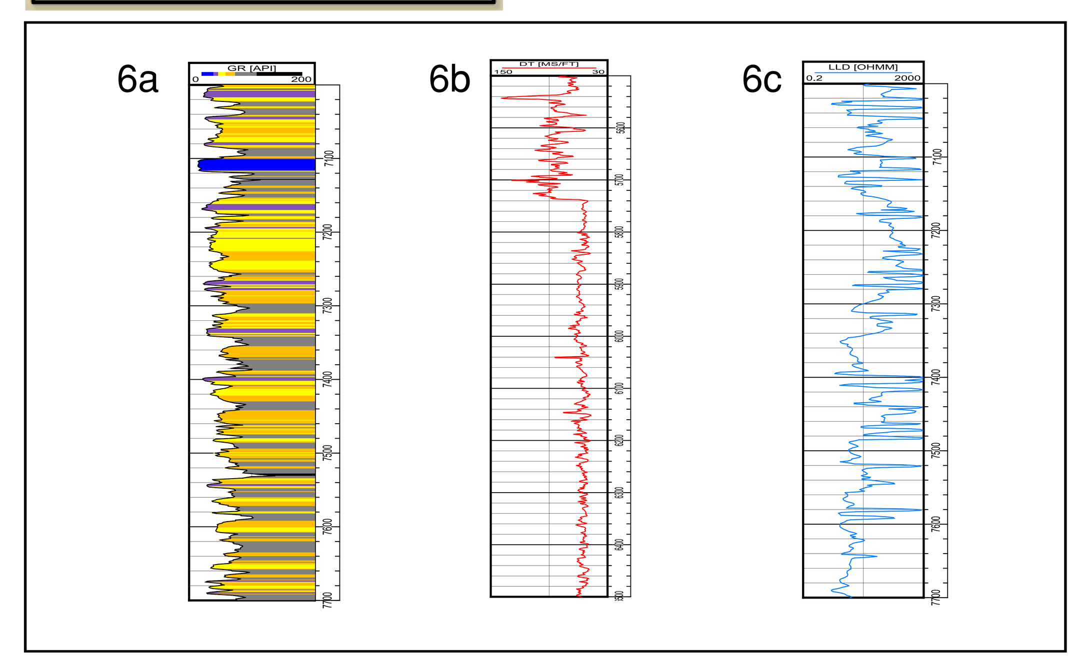
Figure 5. Schematic guide to intepret a variety of trends seen on sonic and resistivity (Δ log R) log overlays (graphed example on Figure 11)

Figure 6a. Example of a gamma ray curve, which meeasures the natural radioactivity of the formation,aiding in identifying lithology. In this study, lithologies are distinguished by color; blue/purple = carbonate, yellow = sandstone, orange = siltstone, and grey/black = shale.

Figure 6b. Sonic log, which measures the time it takes for sound to travel through the rock

Figure 6c. Resistivity curve, which measures how resistive the fluid in the pore space of a formation is to an electrical current.

6a 6b 6c



Results

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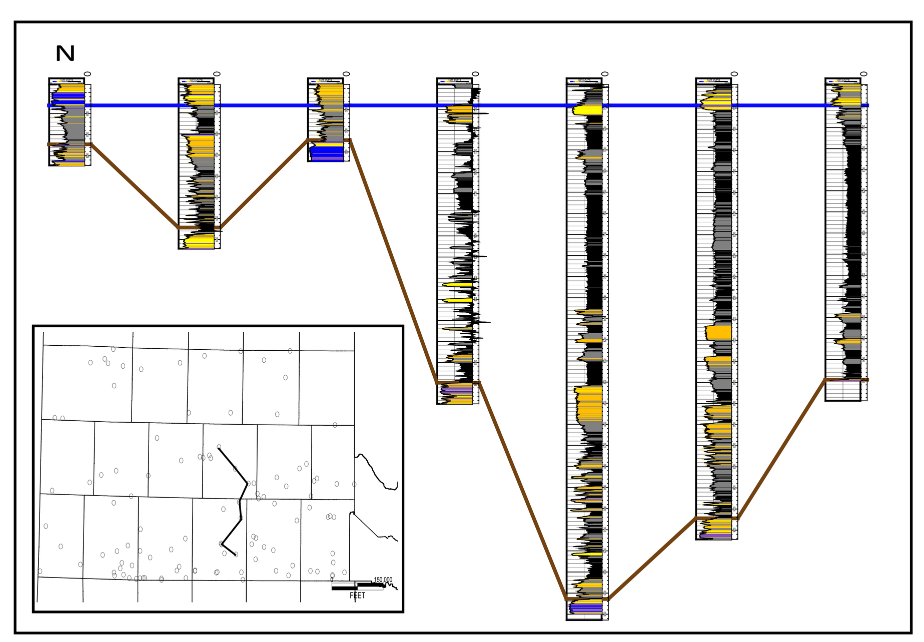

Figure 7. North-south cross section of the Palo Duro Basin, through Briscoe and Floyd Counties. Index map next to cross section shows tie line for the stratigraphic correlation.

Figure 8. West-east cross section of the Palo Duro Basin, from Bailey to Castro Counties. Index map next to cross section shows tie line for stratigraphic correlation

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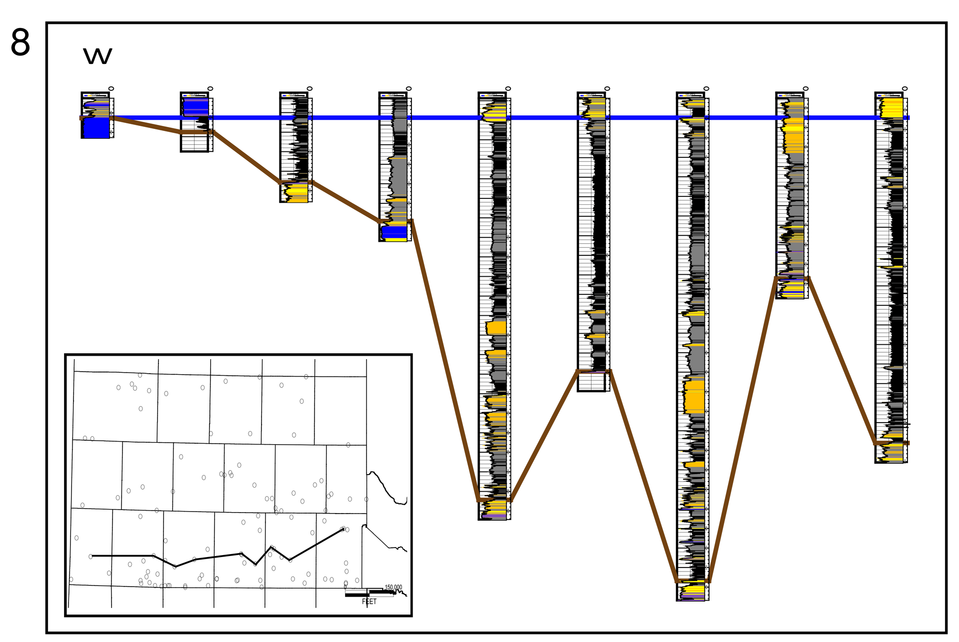

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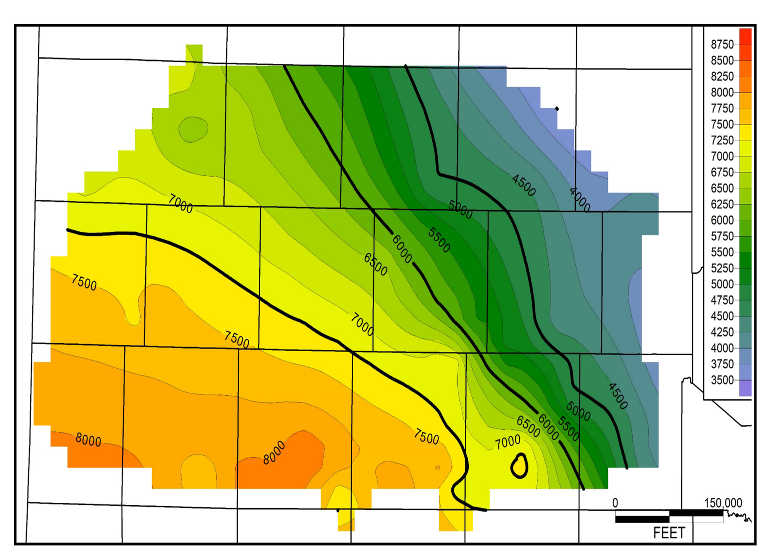

Figure 9. Structure contour map of the top of the Pennsylvanian.

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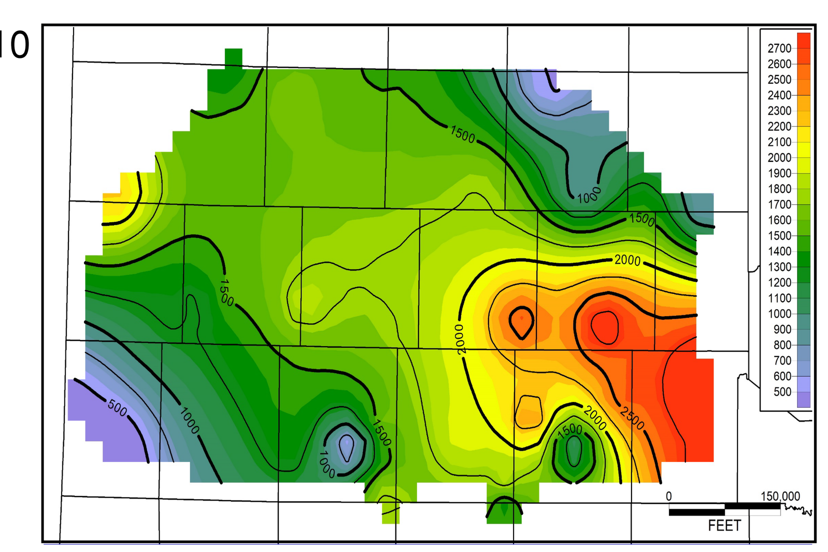

Figure 10. Isopach contour map of the Pennsylvanian.

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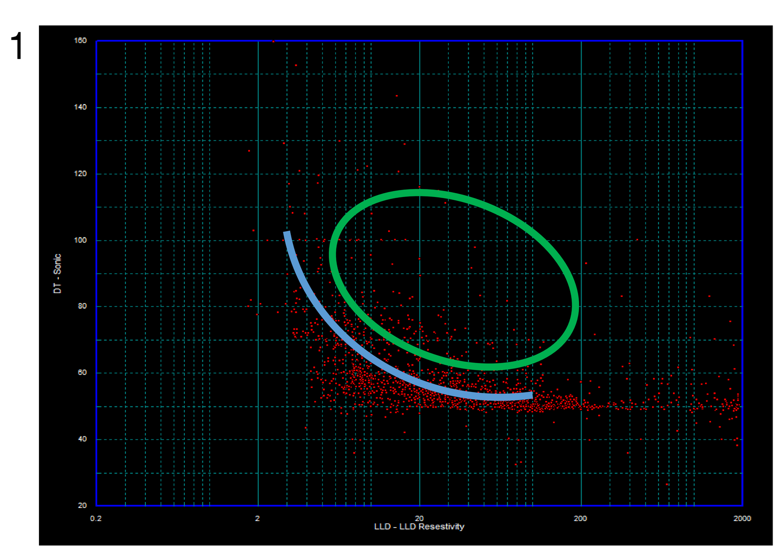

Figure 11. Δ log R crossplot highlighting excess resistivity.

Discussion

Results from stratigraphic correlations show a general thickening of net shale in the Pennsylvanian system moving from the north to south and west to east (Fig. 7 and 8). Net shale thickness generally increases from Bailey to Motley county where it starts to thin onto a stuctural high before thickening again in Castro county. These trends are apparent in structure and isopach maps of the Pennsylvanian system (Fig. 9 and Fig. 10). Figure 9 depicts the trend of the top of the Pennsylvanian, showing a shallowing in the southeast, while the isopach map (Figure 10) shows the same thinning and thickening sequences, following a NW-SE axis.

Plotting both sonic logs and the natural logarithm of resistivity logs using Passey's method (Fig. 5) show some areas of "excess resisivity," where a certain rock has fast transit times and highly resistive pore fluids. Using Passey's method on a well in Briscoe county shows highly resistive fluids in the pore space of rocks with fast travel time values (Fig. 11).

Conclusion

Correlating Lower Permian and Pennsylvanian sections of the subsurface show laterally extensive shale units throghout much of the southeastern and northwestern portions of the Palo Duro Basin. Defining accurate depositional environments of these shale units will require more a more detailed look into the geologic trends of each stratigraphic unit as well as their rock properties, though the lateral extensiveness of these shales are apparent and do come in thick sequences throughout the basin.

Initial petrophysical analysis studies of the Lower Permian and Pennsylvanian components of the Palo Duro Basin show source rock potential through Δ log R crossplots, indicated by areas of high resistivity and a speed up in sonic transit time. Further examination of source rock potential will be done to place constraints on potential hydrocarbon sourcing areas. Though source potential appears to be present, there is still a question regardinig thermal maturity of the basin. Once there is further study into the source potential of the basin as a whole, maturation of the basin will be adressed.

References

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