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Sedimentologic and Stratigraphic Controls on Reservoir Sweet Spots in Wolfcamp A Howard County, Midland Basin*

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Abstract

Deep-water carbonates can form significant conventional and unconventional reservoir systems, but controls on deposition and reservoir character are still not adequately understood.

This project explores the uppermost “Wolfcamp” (“Wolfcamp A;” early Leonardian), in Howard County, Texas. Core and well log data are used to examine the Wolfcamp A as a case study to understand the sedimentologic and stratigraphic controls on ‘sweet spots’ within deep-water settings of the Midland Basin.

Core data identified eleven distinct lithofacies, grouped into seven facies assemblages. The three dominant facies assemblages are coarse-grained echinoderm and foram rudstone-packstone (CGC), fine-grained calcareous mudstone-packstone (FGMP), and siliceous mudstone-siltstone (SMS). CGC facies have sharp, locally erosive surfaces, rip-up clasts, are massive or have internal grading suggesting deposition from sediment gravity flows (SGFs). SMS and FGMP facies typically show a gradational relationship with CGC facies. The dominance of detrital quartz, lack of radiolarians, presence of shallow-water skeletal fragments, and massive or normal graded laminations suggest SMS and FGMP were deposited as distal portions of SGFs. SMS facies have the best unconventional reservoir potential, with unconventional total porosity ranging from ~6-10%, total organic carbon (TOC) ranging from 2-3.2 wt%, and sufficiently low clay content (<50%) for fracture success.

Three major genetic units identified in core and well logs can be correlated throughout the study area. The lowest unit (U1) is dominantly CGC facies, the middle unit (U2) is characterized by the highest abundance of SMS facies, and the upper unit (U3) is composed of both SMS and FGMP facies. Subunits in U1 are lobe-shaped and sourced from the intersection of the Eastern Shelf and Glasscock “nose”. U2 subunits,

consisting of interbedded SMS and thin CGC intervals, form linear, channel-like bodies sourced primarily from the Eastern Shelf, to the NE of the Glasscock nose. U3 lobe-shaped subunits were sourced from the Eastern Shelf and Glasscock nose.

Ongoing studies are focused on additional details of facies distribution and subunit geometries, controls on deposition, and reservoir sweet spot locations. Initial results suggest unconventional sweet spots in medial to distal locations within U2, and conventional sweet spots in proximal positions within U1.

Significance

Deep-water carbonates can comprise conventional and unconventional hydrocarbon reservoirs and non-reservoir rocks but are not as well understood as siliciclastic deposits and shallow-water carbonates (Montgomery, 1996; Mulder and Alexander, 2001; Playton et al, 2010; Stolz, 2014). The economic potential of such deposits warrants further exploration of the sedimentologic and stratigraphic controls on the distribution of reservoirs to create predictive models that are widely applicable.

Overview

This project investigates deep-water deposits of the "Wolfcamp A," of early Leonardian age, in Howard County, Midland Basin, western Texas. Wolfcamp A is the uppermost subunit of the "Wolfcamp" (Figure 1). By using core and petrophysical well log data, this project explores the Wolfcamp A interval as a case study to understand the sedimentologic and stratigraphic controls on 'sweet spots' within the deep-water settings of the Midland Basin. These controls will be displayed in a conceptual model that will improve understanding of reservoir quality controls in carbonate-rich deep-water deposits in general. The insight gained through this project will provide an understanding of the compositional, sedimentologic, and stratigraphic characteristics of sweet spots in the Wolfcamp A that will lead to prediction of the best reservoirs in other areas.

Results

This study is still ongoing, and this report represents an update on progress. Core and thin section analyses identified eleven distinct lithofacies (Figure 2), seen in well logs as facies assemblages, that fit into the following categories: reservoir-forming mudrocks (unconventional) and carbonates (with macropores), and non-reservoir mudrocks and carbonates. The quartz-rich mudrock facies, characterized by 34.9 – 50.0% quartz, consistently high porosity (average 6.50%), predictably high TOC (average 3.07 wt.%), and brittleness (<33% clay content), form the most promising unconventional reservoirs. Reservoirs with macropores in resedimented carbonates have moderate-to-high porosity (average 4.2%) and low-to-moderate TOC (average 1.88 wt.%). Facies identified from the Wolfcamp A core are interpreted as sediment gravity flow deposits, composed of carbonate platform sediment, detrital quartz deposits, and intrabasinal mixed carbonate and quartz components. Thus, the core is dominated by deposits that were transported into the area, rather than those deposited in situ, such as by pelagic 'rain out.'

Variability in lithofacies, distribution patterns and geometries, and variation in source directions, may reflect relative sea-level fluctuations. Vertical changes in the composition and sourcing of the deposits in the Wolfcamp A core suggest the system was transitioning from being dominantly fed by a carbonate source(s), to a quartz-rich source(s) (Figure 1). This transition creates three distinct units within the core, which can be correlated throughout the study area. The lower unit in the core is dominantly composed of coarse carbonate packages, which are lobe-shaped and march basinward in their 3-D distribution (Figure 3a). The middle unit in the core is characterized by the highest abundance of quartz-rich mudrock facies, and in 3-D the deposits transition from channel-shaped to lobe-shaped through time (Figure 3b). The first deposit of the middle unit marks a significant backstep towards the platform margin (Figure 3). The upper unit in the core is composed of both quartz- and carbonate-rich facies; the 3-D distribution of these deposits is complex and still being investigated.

A preferred transport pathway from the shelf and slope into the basin is identified as extending basinward from approximately the intersection of the Glasscock "nose" and the Eastern Shelf. Correlation and mapping of lithofacies packages indicates that along this preferred transport path, deposits become finer-grained and enriched in quartz and clay moving basinward. Additionally, at proximal toe-of-slope locations that are outside of this preferred transport path, deposits are finer-grained and carbonate-poor relative to proximal deposits within the preferred transport path.

Ongoing study includes analysis of finer-scale subunits, identified as facies association packages in well logs, which will provide further insight to relative sea-level fluctuations and source transitions for the area. A map of the locations of the most promising reservoir facies will be developed, to gain predictability of sweet spot locations. This will be displayed in a conceptual model, with applications to analogue settings.

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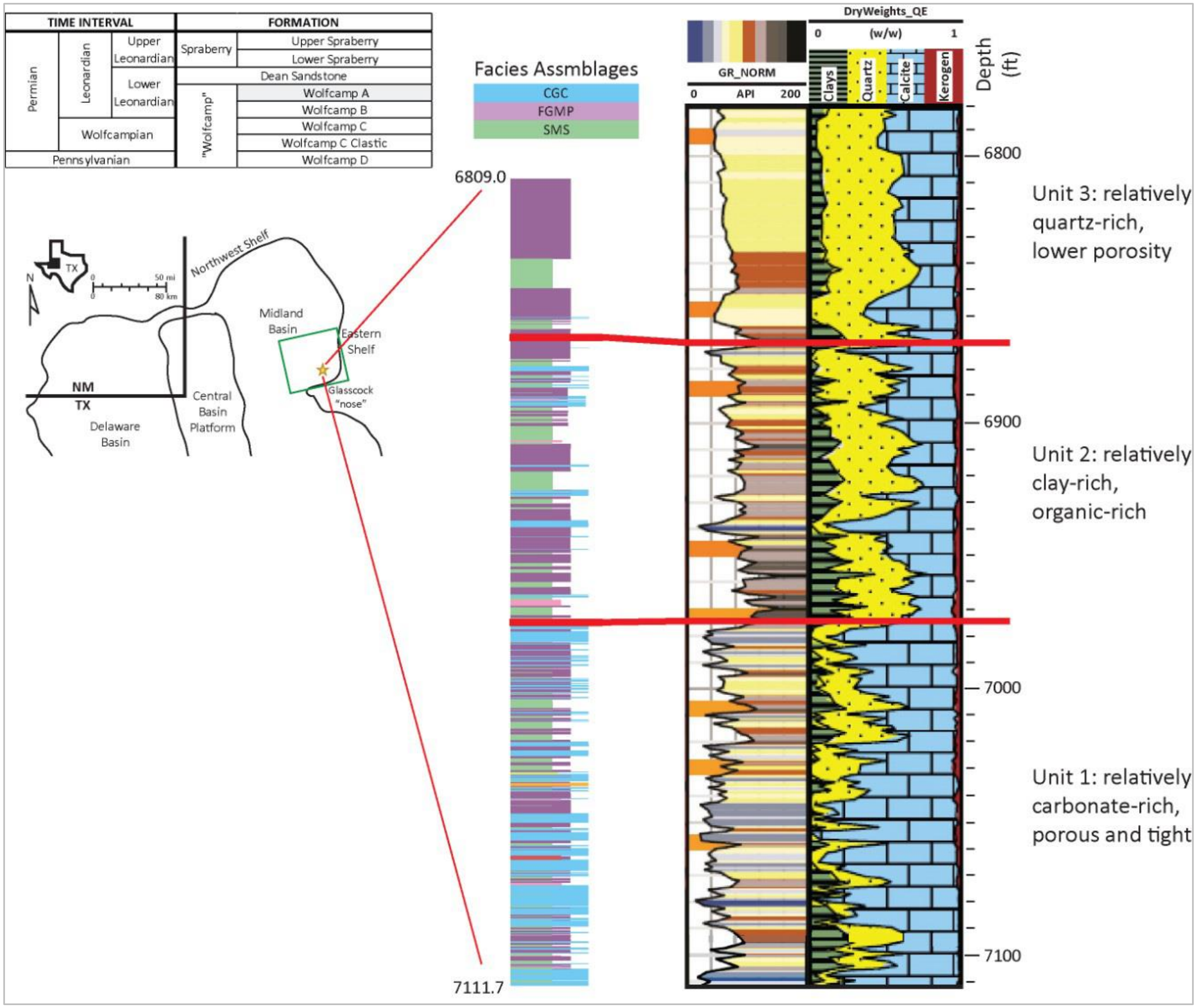

Figure 1. Comparison of the facies assemblage log developed from core analysis and the associated Sparky-1 well logs (normalized gamma ray and modeled mineralogy) shows vertical changes in the composition and sourcing of sediment gravity flows into the area. Bold red horizontal lines separate the three major units (U1, U2, U3), distinguished by dominant composition and facies assemblage prevalence. Well logs are from Rock Oil. The stratigraphic chart of basinal late Paleozoic strata in the Midland Basin, and a map of the study area location (green polygon) are also shown. The location of the Sparky-1 well is marked by a gold star.

Facies Assemblage Name	Facies Name	Facies % of Wolfcamp A in Sparky-1		Dominant Grains	Grain Size & Sorting	Contacts	Bedding & Sedimentary Structures	Interpreted Depositional Mechanisms
Coarse-Grained Packstone - Rudstone (CGC)	**Echinoderm & Foram Rudstone – Packstone (RP)**	**22%**	**4%**	Echinoderm fragments, foraminifera	0.05 mm – 4 cm; Poorly to very poorly sorted	Sharp or gradational upper & lower contacts	Massive, normally graded, inversely graded	Hyperconcentrated to concentrated density flows, turbidity flows
	Massive Echinoderm & Foram Floatstone (MF)		**6%**	Echinoderm fragments, foraminifera	0.05 mm – 4 cm; Poorly sorted	Sharp upper & lower contacts	Massive	Hyperconcentrated density flows
	Echinoderm & Foram Packstone (CP)		**12%**	Echinoderm fragments, foraminifera	0.05 mm – 2 cm; Very poorly to poorly sorted	Sharp or gradational upper & lower contacts	Massive, normally graded, rarely inversely graded	Hyperconcentrated to concentrated density flows, turbidity flows
Dominantly Calcareous Mudstone – Wackestone (FGMP)	**Calcareous Md-Wk, w/ <10% Quartz-rich Mud-Slt (FGC10)**	**49%**	**36%**	Echinoderm fragments, foraminifera	0.005 mm – 4 mm; Poorly to well sorted	Sharp or gradational upper & lower contacts	Laminated (massive, normally graded, prominent to vague), rarely structureless	Turbidity flows, concentrated density flows
	Calcareous Md-Wk, w/ <40% Quartz-rich Mud-Slt (FGC40)		**14%**	Echinoderm fragments, foraminifera	0.005 mm – 4 mm; Poorly to well sorted	Sharp or gradational upper & lower contacts	Laminated (massive, normally graded, prominent to vague)	Turbidity flows, concentrated density flows
Dominantly Quartz-rich Mudstone – Siltstone (SMS)	**Quartz-rich Mud-Slt, w/ <10% Calcareous Md-Wk (S10)**	**27%**	**14%**	Detrital quartz, siliceous spicules	0.005 mm – 4 mm; Poorly to well sorted	Sharp or gradational upper & lower contacts	Laminated (massive, normally graded, prominent to vague), rarely structureless	Turbidity flows, concentrated density flows
	Quartz-rich Md-Slt, w/ <40% Calcareous Md-Wk (S40)		**12%**	Detrital quartz, siliceous spicules	0.005 mm – 4 mm; Poorly to well sorted	Sharp or gradational upper & lower contacts	Laminated (massive, normally graded, prominent to vague)	Turbidity flows, concentrated density flows

Figure 2. Descriptive table of the most prevalent lithofacies, and their facies assemblages, identified in the Wolfcamp A core along with interpreted depositional mechanisms. These lithofacies cover 98% of the Wolfcamp A in the Sparky-1 core. Details of facies dominated by carbonate minerals are shaded blue, and those of facies dominated by quartz are shaded yellow. Facies assemblages are colored to coordinate with Figure 1.

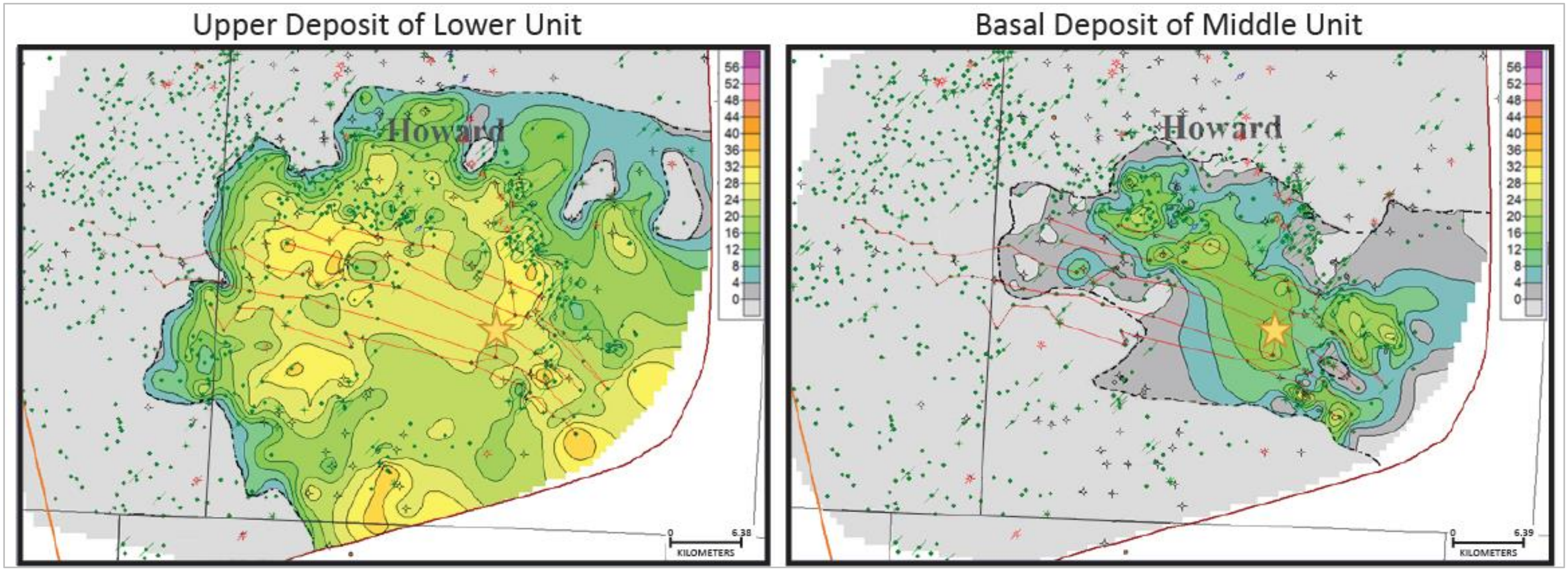

Figure 3. Isopach maps of two intervals identified in the Wolfcamp A. Map of one of the upper carbonate-rich deposits in U1 (left) shows a lobe-shaped distribution, with indications of bifurcation and post-depositional erosion. In contrast, the quartz- and organic-rich basal deposit of U2 (right) has a channel-shaped distribution. Initial deposits of U2 are backstepped towards the platform margin (curved dark red line at the right on each map). Subsequent U2 deposits prograde towards the basin. Thicknesses in feet. Gold star in each map shows location of the Sparky-1 well.

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