Multidisciplinary Reservoir Characterization of a Giant Permian Carbonate Platform Reservoir: Insights for Recovering Remaining Oil in a Mature U.S. Basin

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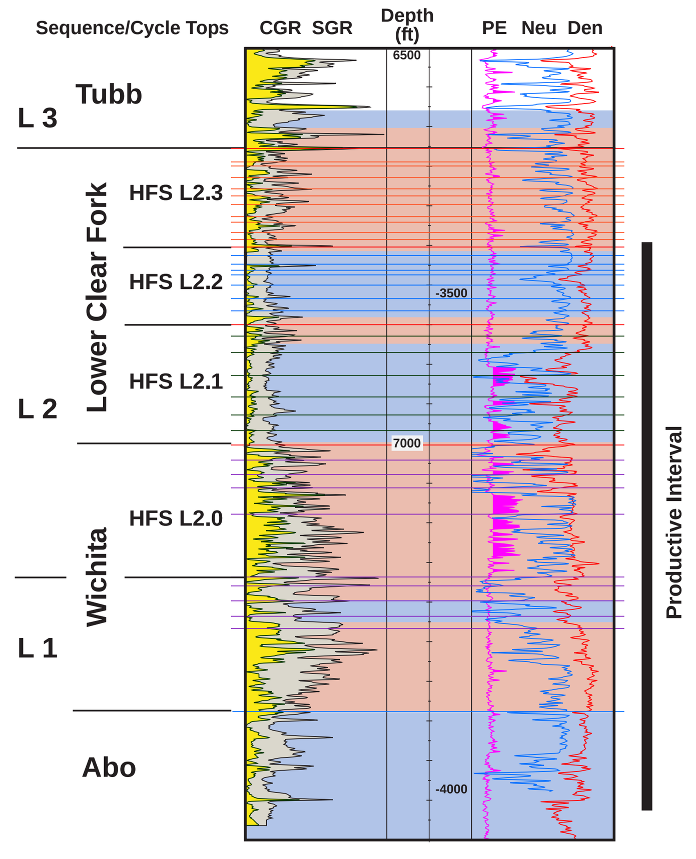
INTRODUCTION

Despite more than 60 years of production history, recovery of the more than 1.5 billion barrels of oil in the Fullerton Clear Fork field, a shallow-water platform carbonate reservoir of Early Permian age in the Permian Basin of West Texas, remains a challenge. To develop a better understanding of the distribution of the original hydrocarbon resource and to devise strategies to recover the huge volume that still remains, we undertook a comprehensive, multidisciplinary study of the reservoir. Crucial elements of the study include (1) geological models of analogous outcrops, (2) description of more than 14,000 ft of core, (3) new core data for rock-fabric analysis, (4) analysis and correlation of more than 850 wireline log suites, (5) a 3-D seismic inversion porosity model, (6) a 35,000-acre (14,000-hectare) reservoir model, and (7) a 2,000-acre (800- hectare) flow simulation.

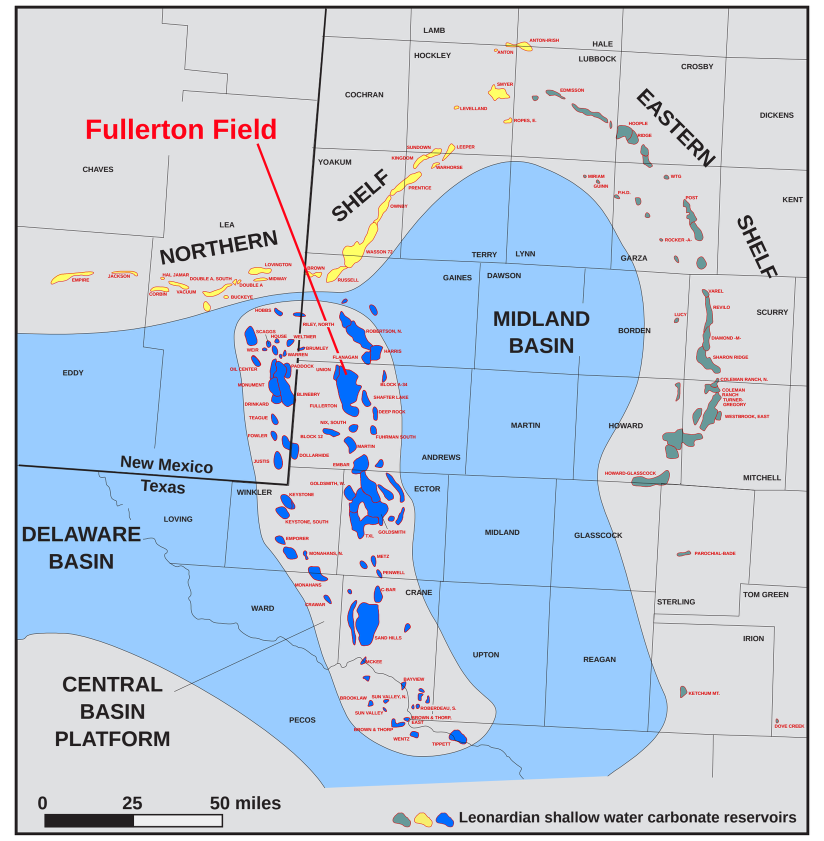
The study utilizes robust outcrop models as a key to proper interpretation of geological, petrophysical, and geophysical subsurface data sets. It demonstrates procedures for producing and utilizing a geologically constrained reservoir framework in reservoir modeling and simulation. It shows the tremendous potential of iterative 3-D seismic porosity inversion models in defining porosity distribution. It illustrates the importance of a rock-fabric-based approach for defining porosity/permeability relationships. Finally, the study defines the distribution of original and remaining oil volumes and provides insights into how these resources may best be recovered.

SETTING

Type Log



Geography



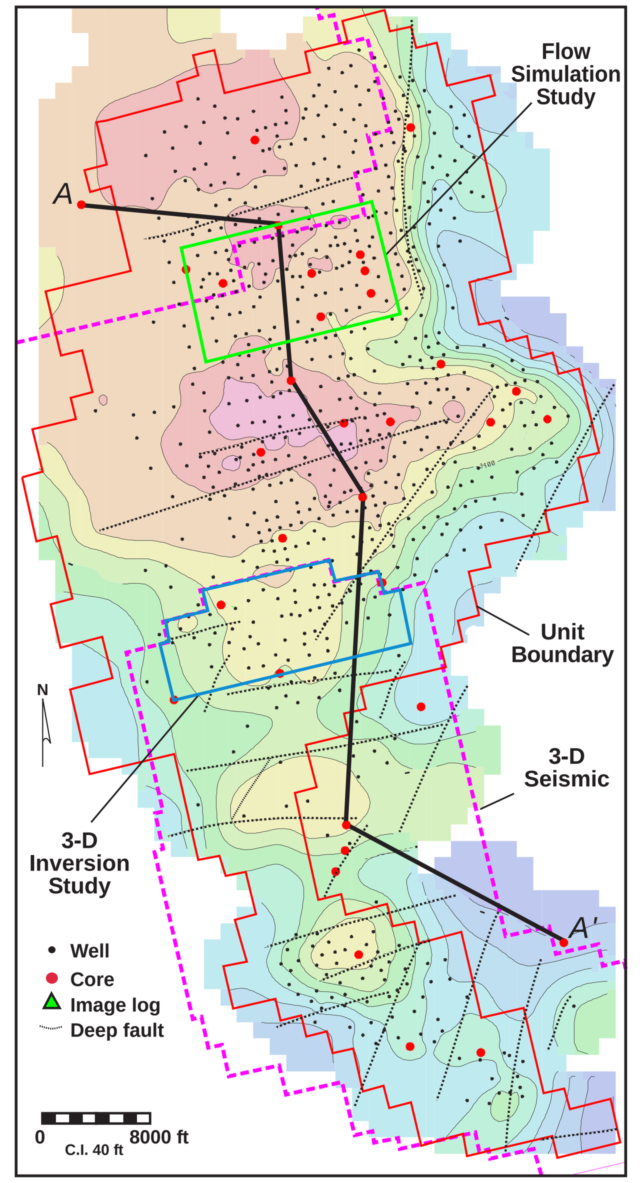
Fullerton Clear Fork field is one of the largest fields in the Permian Basin, covering an area of about 35,000 acres (14,000 hectares). The field, which includes more than 1,200 wells, contained between 1.5 and 2.0 billion barrels of oil at discovery.

Stratigraphy

SERIES	STAGE	STAGE	SUBSURFACE: PLATFORM AND MARGIN – NEW MEXICO		SUBSURFACE: PLATFORM AND MARGIN – TEXAS		OUTCROP: GUADALUPE MOUNTAINS/SIERRA DIABLO, Texas - New Mexico – PLATFORM	MARGIN	SEQUENCE
LOWER PERMIAN	Kungurian	Leonardian	San Andres		San Andres		San Andres	Cutoff	Guad 1
								Victorio Peak	Leo 7-8
			Glorieta		Glorieta		Glorieta		Leo 6
			Yeso	Paddock	Upper Clear Fork	Clear Fork Group	Victorio Peak		Leo 5
				Blinebry					Leo 4
				Tubb	Tubb				Leo 3
				Drinkard	Lower Clear Fork				Leo 2
			Abo		Wichita Group / Abo			Bone Spring	Leo 1
			Wolfcamp		Wolfcamp		Hueco	Hueco	Wolf 3

Field Structure and Data

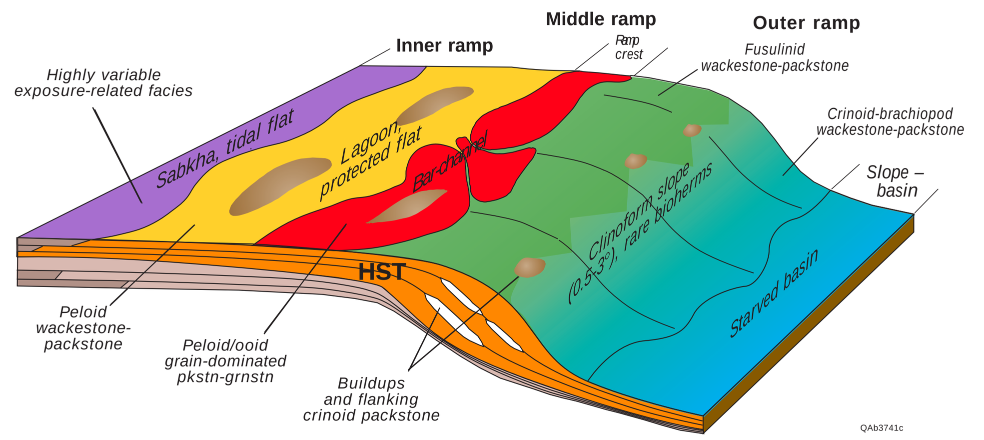
Datum: Base of Sequence L3



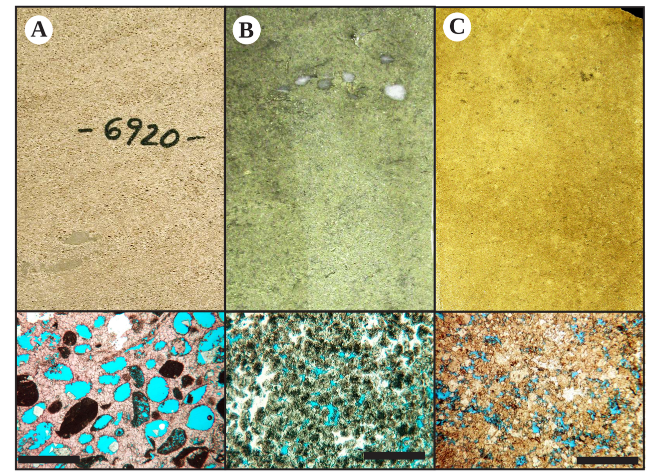
Field structure is a function of Pennsylvanian block faulting. There is good evidence of continuing reactivation of some of faults during and after Leonardian deposition.

GEOLOGICAL CHARACTERIZATION

Depositional Model

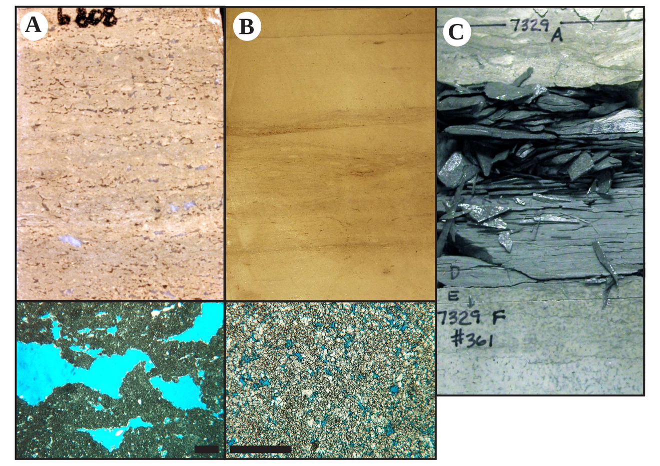


Middle ramp and ramp crest subtidal, grain-rich facies L2.1 & L2.2 (Lower Clear Fork)



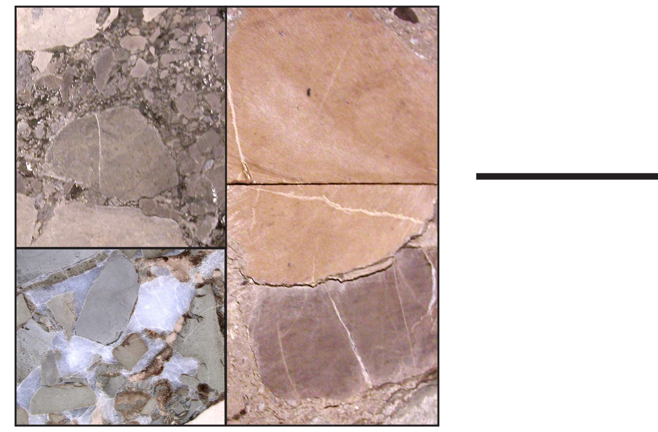
A. Moldic ramp crest limestone grainstone
B. Peloid grain-dominated dolomite grainstone (interparticle pores)
C. Peloid packstone (moldic and interparticle pores)

Inner ramp tidal flat, mud-rich facies L1 & L2 (Wichita & Lower Clear Fork)



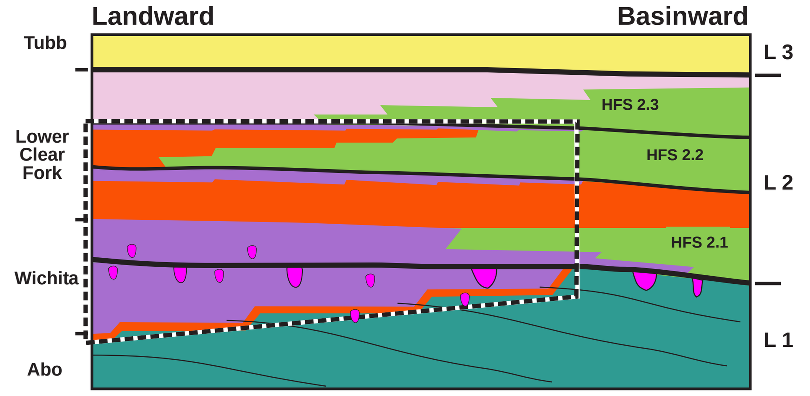
A. Fenestral mudstone-packstone (fenestral pores)
B. Laminated mudstone (fine- to micro-crystalline pores)
C. Clay-rich organic-pond mudstone

Karst facies: L1 & L2 (Wichita)



Polymict and monomict conglomerate and breccia locally present above and below L1/L2 sequence boundary.

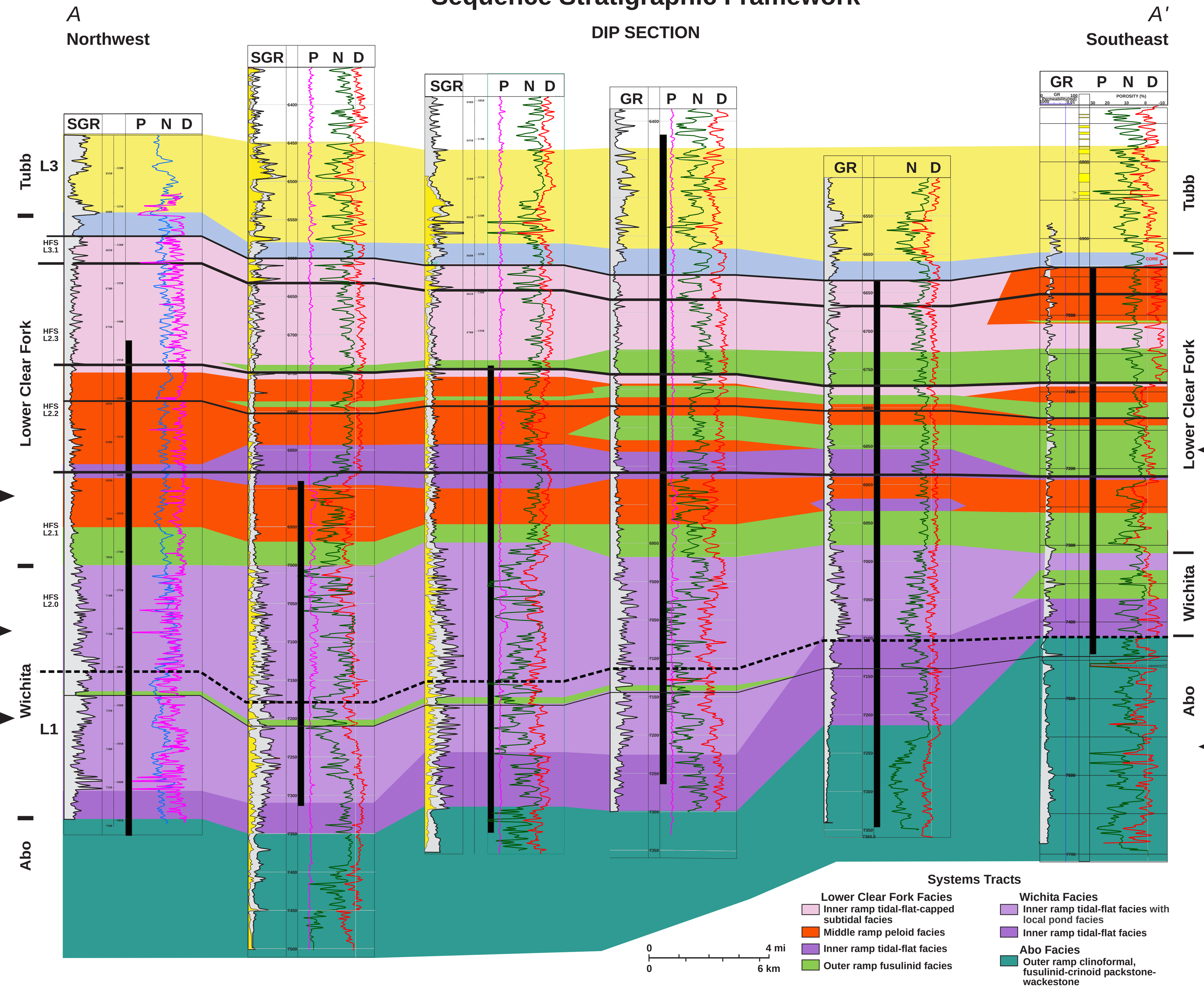
Sequence Stratigraphic Model



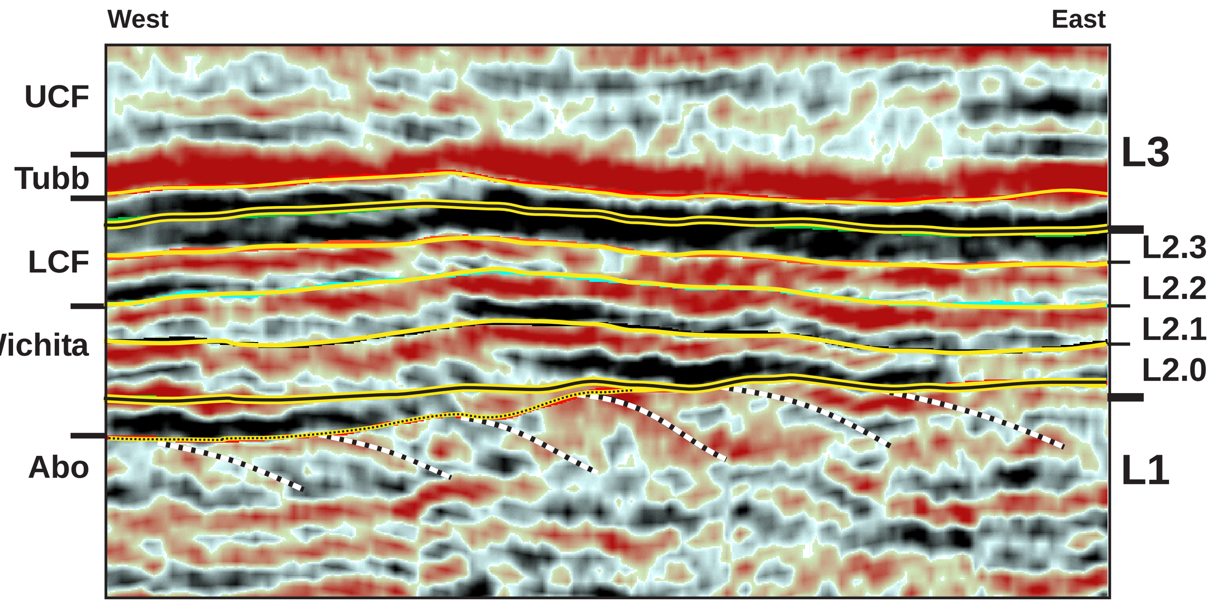
FACIES TRACTS
- Tidal-flat wackestone-siltstone
- Inner ramp tidal-flat-capped wackestone
- Inner ramp amalgamated tidal flat
- Middle ramp grain-rich packstone
- Outer ramp fusulinid wackestone-packstone
- Clinoformal, outer ramp fusulinid-crinoid wackestone-packstone

SEQUENCE STRATIGRAPHY
- HFS High-frequency sequence
- L 1 Composite sequence
- Reservoir interval
- Karst breccia and conglomerate
- 200 ft

Sequence Stratigraphic Framework

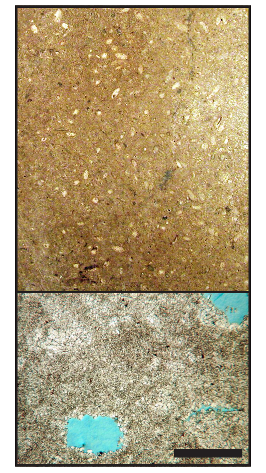


Seismic Architecture



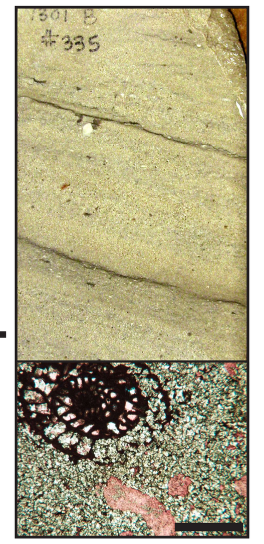
Reservoir architecture defined by 3-D seismic and outcrop data
L1: progradational, partly clinoformal; L2: largely aggradational and horizontal

Proximal outer ramp L1 (Abo); L2 (Lower Clear Fork)



Fusulinid wackestone-packstone with moldic and interparticle pores

Distal outer ramp clinoforms L1 (Abo)

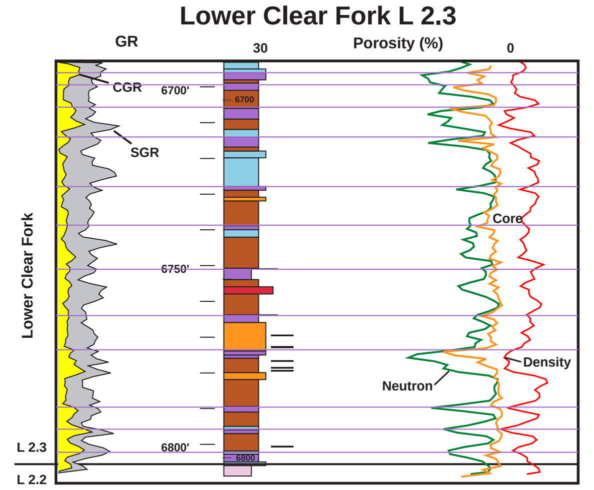


Fusulinid-crinoid wackestone-packstone with interparticle pores

Cyclicity and Reservoir Framework

Cores and outcrops demonstrate a direct relationship between facies, cycle stacking, and porosity: high porosity is usually associated with grain-rich facies at cycle tops. This relationship forms a basis for the use of porosity logs in cycle correlation and flow-unit definition.

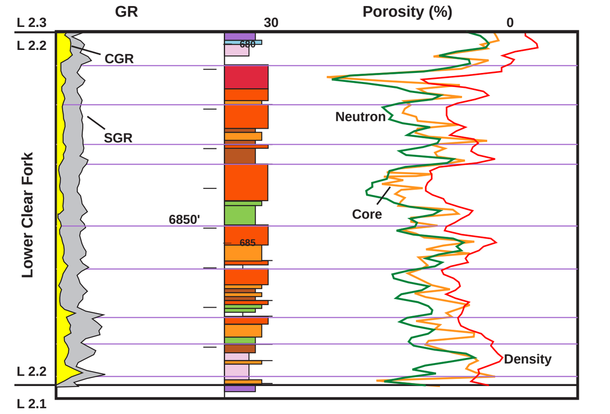
Lower Clear Fork L 2.3



- Tidal flat
- Peritidal mudstone
- Peloid wackestone-packstone
- Skeletal wackestone
- Peloid packstone
- Ooid/peloid grain-dominated packstone
- Siltstone/sandstone
- Tidal-flat-capped cycle

L 2.3 is a low-accommodation sequence in which cycles are characterized by porous tidal-flat caps that are readily defineable and correlatable on porosity logs.

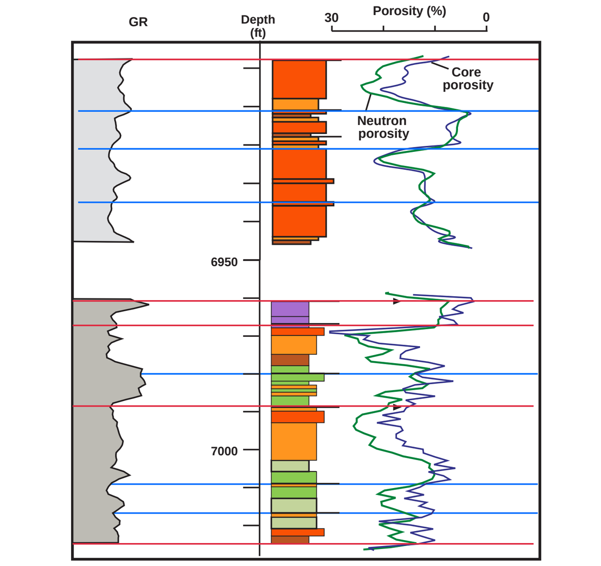
Lower Clear Fork L 2.2



- Tidal flat
- Peritidal mudstone
- Peloid wackestone-packstone
- Skeletal wackestone
- Peloid packstone
- Ooid/peloid grain-dominated packstone
- Fusulinid wackestone-packstone
- Tidal-flat-capped cycle

L2.2 and L2.1 comprise dominantly subtidal cycles whose tops are generally grain-rich packstones. Note good correlation between high porosity and cycle tops and poor correlation to gamma-ray logs.

Lower Clear Fork L 2.1

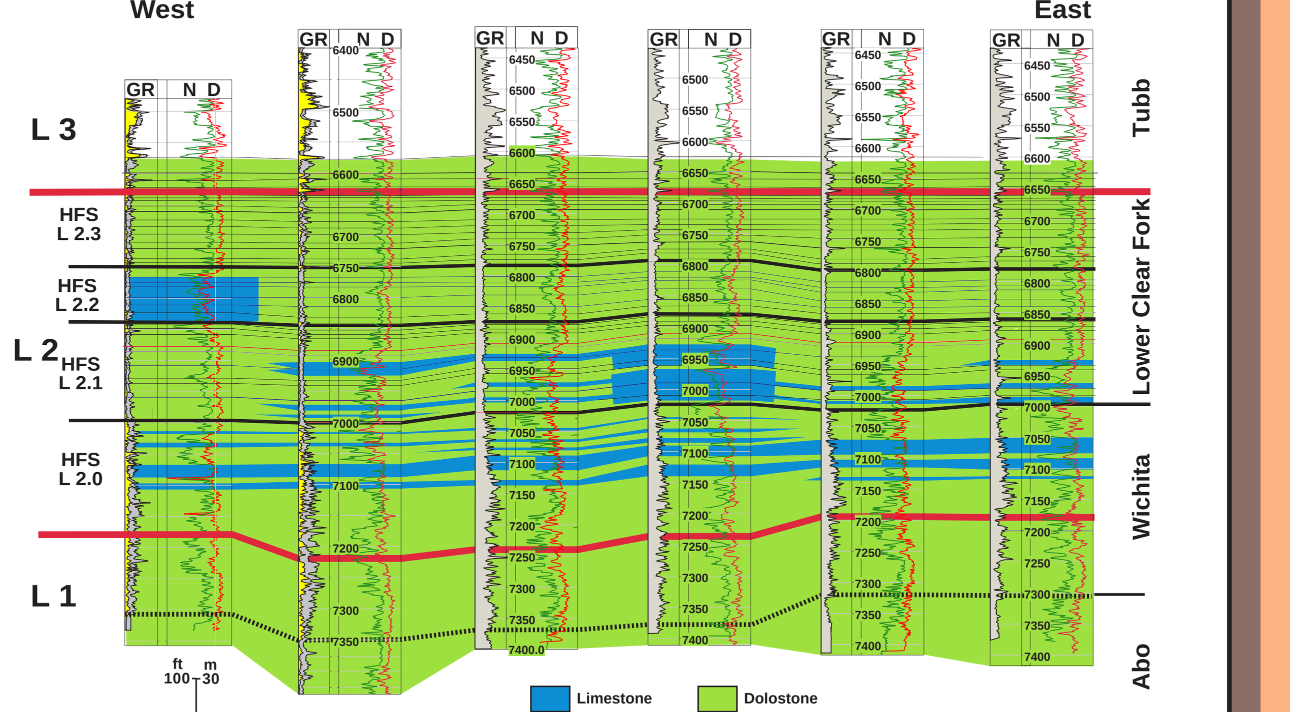


- Tidal-flat wackestone-packstone
- Peloid grain-dominated packstone
- Fusulinid wackestone-packstone
- Oncoid-fusulinid wackestone-packstone
- Peloid packstone
- Peloidal wackestone
- Tidal-flat cycle top
- Subtidal cycle top

Mineralogy and Controls of Porosity Distribution

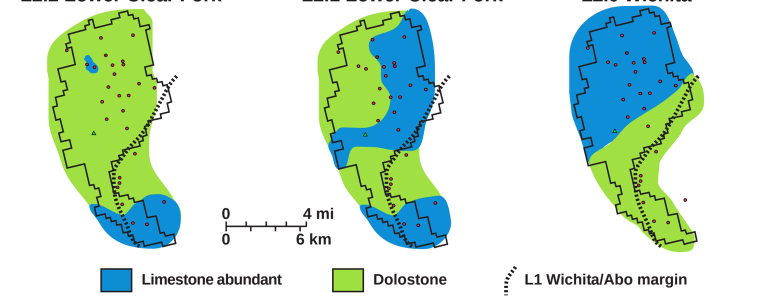
Although mostly dolostone, the reservoir contains significant volumes of limestone whose distribution is important for (1) defining reservoir architecture, (2) controlling fluid flow, and (3) understanding porosity development.

Stratigraphic Distribution of Limestone

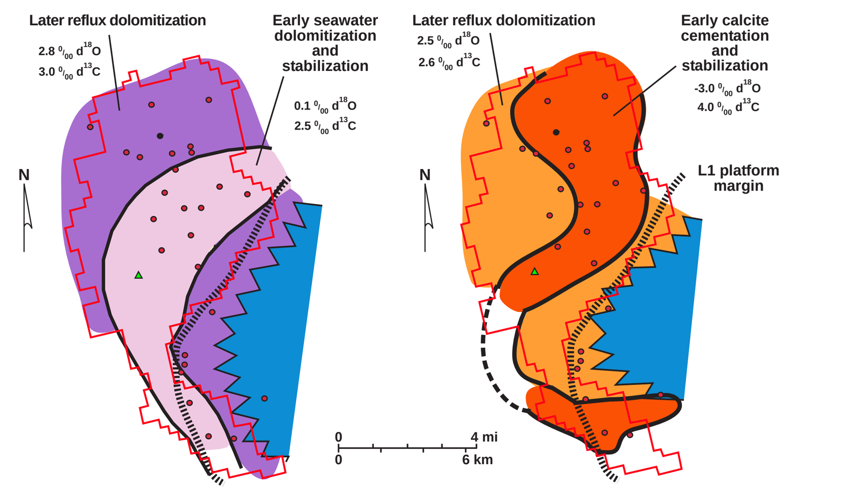


1. Tidal-flat (mud-rich) limestones (L1/L2 Wichita) are low-flow baffles, whereas subtidal (grain-rich) limestones (L2 Lower Clear Fork) are high-flow zones.
2. Reservoir architecture in the poorly cyclic peritidal L1/L2 Wichita succession is best defined by limestone distribution (cycle bases).
3. Limestone is most common in the transgressive leg of the L2 sequence. This is consistent with incomplete reflux dolomitization from an updip/upsection fluid source.

Geographic Distribution of Limestone



Early Diagenesis and Structure Control Porosity Distribution



- High-porosity Wichita tidal-flat margin
- Low-porosity Wichita inner ramp tidal flat
- Low-porosity Lower Clear Fork outer ramp subtidal
- High-porosity Lower Clear Fork ramp crest
- Low-porosity Lower Clear Fork mid-ramp subtidal
- Wichita/Abo inner/outer ramp margin
- Core
- Image log
- Unit boundary

Mineralogy and geochemical data suggest that high-porosity trend in Wichita is the result of early dolomitization along the outer tidal-flat margin. High-porosity trend in the Lower Clear Fork is the result of early calcite stabilization along the platform-margin ramp crest. (Isotope data from this study and Kaufman [1991]).

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