STRATIGRAPHIC CORRELATION OF THE LATE PENNSYLVANIAN-EARLY PERMIAN STRATA IN THE DELAWARE BASIN

An Undergraduate Research Scholars Thesis

by

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TABLE OF CONTENTS

Page

ABSTRACT 1

DEDICATION 2

ACKNOWLEDGMENTS 3

CHAPTER

I. INTRODUCTION 4

II. METHODS 6

III. ANTICIPATED RESULTS 7

IV. DISCUSSION 8

V. CONCLUSION 10

REFERENCES 11

FIGURES 13

ABSTRACT

Stratigraphic Correlation of the Late Pennsylvanian- Early Permian Strata in the Delaware Basin in Northwest Texas

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The stratigraphic interval from the Late Pennsylvanian Wolfcamp Formation to the Early Permian Bone Spring and Avalon formations are composed of interbedded shale, carbonate, and sandstone (Harris, 2000). This project determined the shale distribution within Loving County, New Mexico and Winkler County, Texas. Each group member was given a specific county to determine the shale distribution. The shale distribution in these units were identified by analyzing subsurface well logs. Thus, lithology, gamma-ray, and resistivity well logs from the Delaware Basin were analyzed with Techlog©. Once these units were correlated in each county, the shale layers were correlated from one county into the other. The data collected can be used to determine the optimal place to drill for oil and gas from these units.

DEDICATION

To our family, friends, and academic advisors that have encouraged us to pursue our dreams and strive for academic greatness.

ACKNOWLEDGEMENTS

We would like to thank Dr. Michael Pope for providing us with the opportunity to be involved in such an up and coming project for our research.

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Finally, thanks to our parents for their support and pushing us to persevere.

CHAPTER I

INTRODUCTION

During the Permian, the South American plate collided with the North American plate within the Ouachita-Marathon Orogeny (Hurd et al., 2016). The orogenic event was followed by a dry period of continental warming. Furthermore, the mountains created by the orogeny induced a rain shadow effect, causing the leeward side of the mountains to be even drier and caused widespread evaporite deposition. Terrestrial plants and animals evolved greatly during the Permian but were nearly wiped out by a mass extinction at the end of the Permian. During the Pennsylvanian to the Middle Permian, glaciation affected the globe and produced high-frequency, high-amplitude sea level fluctuations.

In west Texas, the Permian Basin is the foreland of the Marathon-Ouachita orogenic belt, and this basin is comprised of several parts including: the Central Platform Basin, the Midland Basin, and the Delaware Basin (Mack, 1997). The Delaware Basin formed as a sub-basin of the Permian Basin (Hurd et al. 2016). Around this same time, organic-rich shale and siltstone layers were deposited in the basin due to the sea level fluctuations (Mack, 1997). Thus, the Cutoff Formation and the Lower San Andres Formation were deposited after the post-tectonic phase of the Permian Foreland Basin (Hurd et al., 2016).

The Delaware Basin has a distinctive slope break between the shallowly dipping shelf margin and the steeper dipping upper slope. Due to high levels of erosion, channel systems cut through this break. During the Permian when water filled the basin, the channels acted like a funnel and filtering system for the eroded sediments; coarser grained siltstone and sandstone remained in the levees and channels and the finer grained mudstone settled to the center of the basin. Techlog©, a well correlation program, was used to distinguish the different shale layers within the channels with an emphasis on the Wolfcamp, Bone Spring, and Avalon formations (Figure 2 & 3).

CHAPTER II

METHODS

Several articles relating to the formation of the Delaware Basin (Yang and Dorobek, 1995) and the Late Pennsylvanian- Permian stratigraphy in this area were synthesized to begin this project. The Wolfcampian, Bone Springs, and Avalon units were analyzed because of their great interest for drilling in today's environment. Wireline logs, including gamma-ray, resistivity, and sonic, were analyzed and correlated across Lea County New Mexico and Loving County Texas (Figure 1). We describe the correlations in our senior thesis and presented these results at the Department of Geology and Geophysics undergraduate research conference in March, 2017.

CHAPTER III

RESULTS

Late Pennsylvanian- Middle Permian stratigraphy of the Delaware Basin is composed of interbedded shale, carbonate, sandstone, and is capped by Late Permian bedded evaporites. We correlated Late Pennsylvanian-Early Permian strata of the Delaware Basin from New Mexico toward west Texas. Multiple cross sections were constructed to track the lithologic patterns and thickness variations of these units from the north (New Mexico) to the south in west Texas. The regional variation of thickness was apparent in the cross section from Lea County, New Mexico to Loving County, Texas (Figure 2 & 3). The parasequences that occurred in Lea and Loving county depict some of the flooding events in this area and indicate that most parasequences shallow upward (Figure 6). Blocky sands located in the gamma-ray wireline logs may indicate channels. The correlation of parasequences indicates that the sandstone and shale pinch out southward into Texas. The depositional environment by Loucks et al., illustrates how sediment was transported and deposited from the Northwest Shelf of the Permian Basin into the Delaware Basin (Figure 5). Furthermore, our cross section shows the transition of a more sandstone-rich shelf to a more organic-rich basin, similar to the Loucks et al., model.

CHAPTER IV

DISCUSSION

The deep-water portion of the Delaware basin was fed by multiple channel systems (Hurd et al. 2016). We hypothesized that the channels were either from a point source, meaning the channel source fed numerous levees from the same place, or there was a line source of sediment with interconnected channel systems and its sediment deposits, along the shelf break.

There were two main types of sediment dispersal in the Permian Basin: gravity flows and mass transport deposits (Figure 5). During the lowstand, transgression, and a majority of the highstand phases of sedimentation, sediment dispersal was dominated by gravity flows and accumulation of organic-rich shale. During the final stages of the highstand, sediment dispersal was dominated by unconfined flow and mass transport of sediments (Hurd et al., 2016). The overlap of sediment lobes is interpreted to be the results of multiple turbidite fans that overlapped one another, produced by a line source.

The sandstone (1st, 2nd, and 3rd Bone Spring Sandstone Member) and carbonate (1st, 2nd, and 3rd Carbonate Member) members of the Bone Spring Formation are a result of sedimentation from the change in sea level (Hart, 2000). Carbonates were deposited during transgressive highstand phases whereas sandstone was deposited during lowstand depositional phases (Harris, 1993).

The thickness of First Bone Spring Carbonate and Second Bone Spring Sandstone from Lea County in New Mexico decreases southward into west Texas. As a result, the First Bone Spring Carbonate was reduced by 15.24 m and the Second Bone Spring Sandstone was reduced by 7.62 m. The wireline logs are categorized into multiple units (Figure 4). In descending order these formations make up the Delaware Basin slope: Brushy Canyon, Cutoff Formation, and the Bone Springs Formation (Hurd et al., 2016). An unconformity occurs at the boundary between the Bone Spring Formation and the Shumard Member (Hurd et al., 2016). The drowned outer shelf on which the lower/middle San Andres unconformity-bounded sequence occurs is where the Cutoff Formation formed (Harris, 1988a). In other words, the Cutoff Formation is bounded by unconformities (Hart, 1998). The Cutoff Formation is composed of the El Centro and the Shumard members (Hurd et al., 2016). The El Centro Member consists of interbedded lime mudstone-shale and medium-bedded lime mudstone (Harris, 2000). The Shumard Member primarily consists of medium-bedded, cherty lime mudstone; however, additional lithologies occur below the lime mudstone (Harris, 2000). These lithologies include 1 to 2 m of fine-grained sandstone, intraclastic rudstone lenses, and 1 m of shale (Harris, 2000). The Bone Spring Formation can be sub-divided into six different members: First Bone Spring Carbonate, First Bone Spring Sandstone, Second Bone Spring Carbonate, Second Bone Spring Sandstone, Third Bone Spring Carbonate, and Third Bone Spring Sandstone (Hart, 1998). The First Bone Springs Carbonate is difficult to separate from the First Bone Springs Sand and is based on the density and resistivity logs (Figure 2 & 3). Carbonate units have a higher density than sandstone units being approximately 2.71 g/cm^3- 2.83 g/cm^3 for carbonate and 2.65 g/cm^3 for sandstone. The resistivity of carbonate (1000-100000 ohms) also is higher than sandstone (75-10000 ohms).

CHAPTER V

CONCLUSION

During the Late Pennsylvanian to Early Permian in the Delaware Basin, carbonate was deposited in the time of late transgression and highstand, whereas sandstone and shale were deposited in a time of lowstand-early transgression. The cross section A-A' shows the regional variation that occurs throughout the units. The parasequences record some of the flooding events present within the First Bone Spring Carbonate. The flooding events caused the sandstone and shale to erode and eventually pinch out as the units move southward into Texas. Blocky sands located in the gamma-ray wireline logs may indicate channels; channels can be good reservoirs. Thus, there is a possibility that oil and gas reservoirs lie within the blocky sands.

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FIGURES

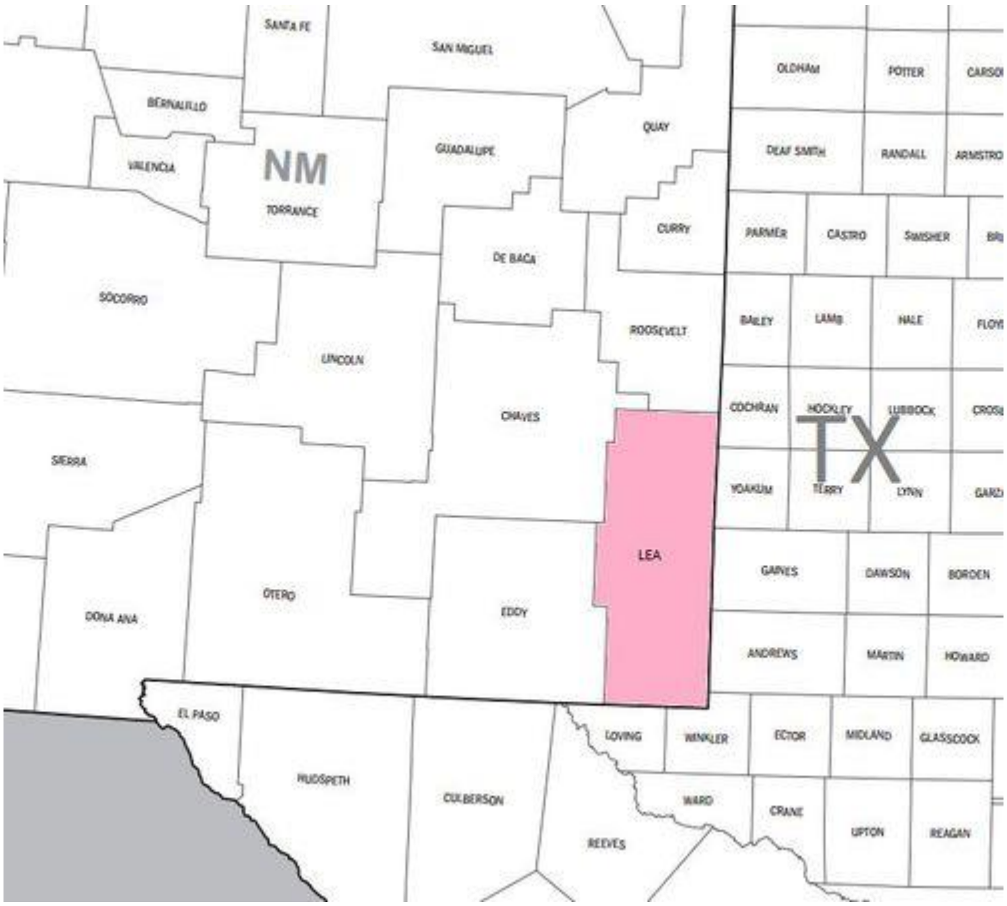

Figure 1. County Map of New Mexico and Texas.

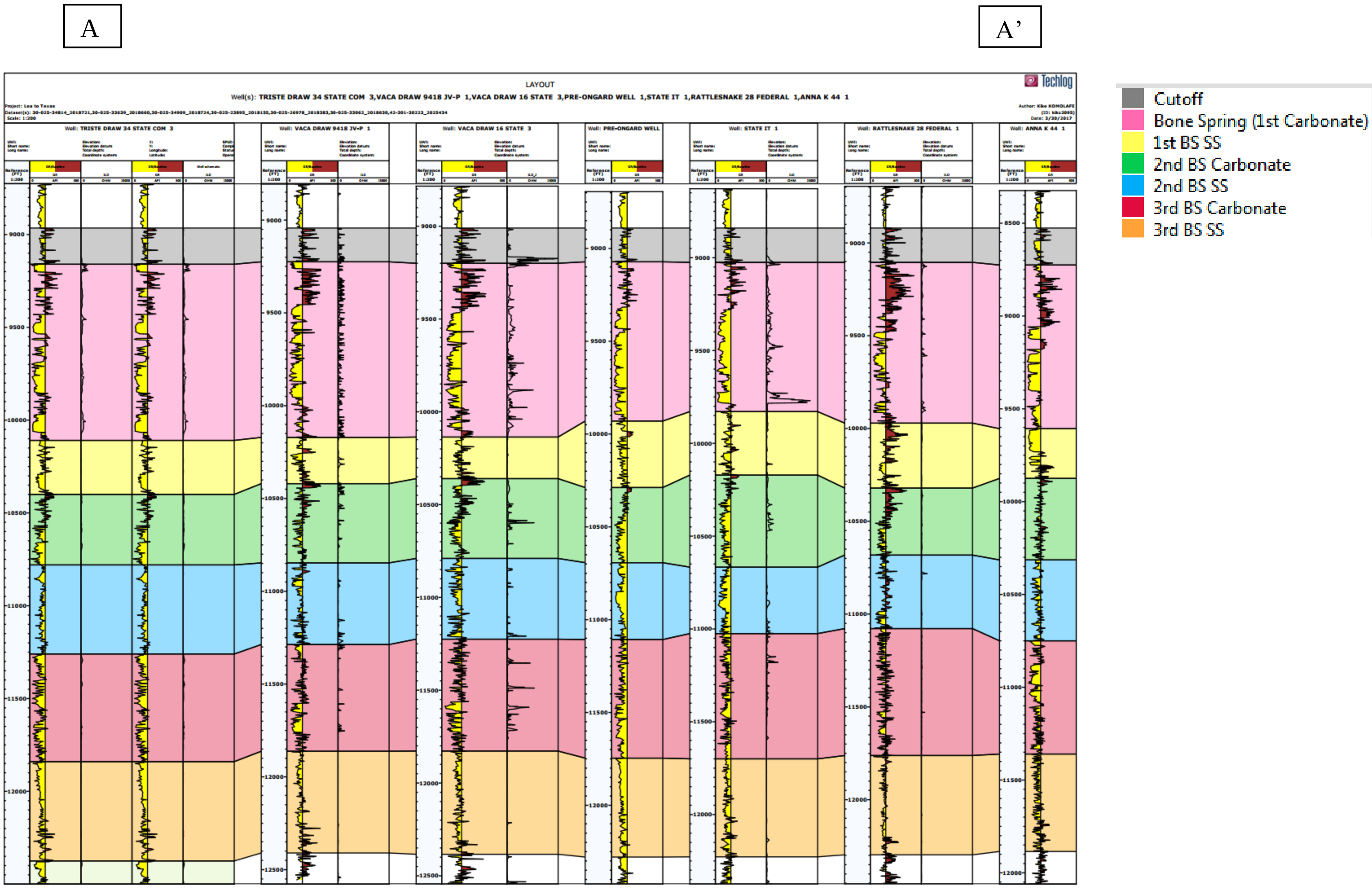

Figure 2. Wireline logs running from Lea County, NM to Loving County, TX

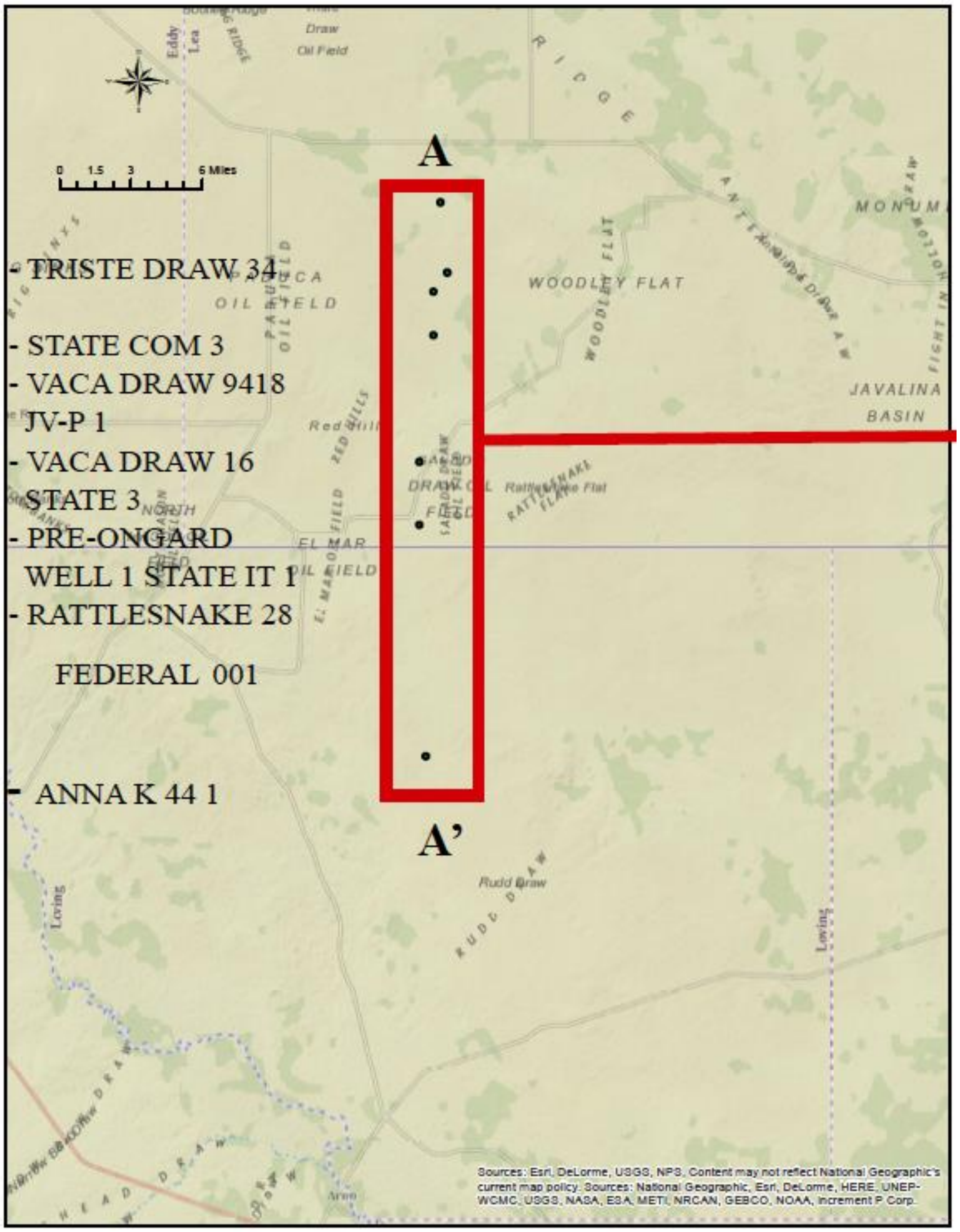

Figure 3. Location map of the wireline logs:

- TRISTE DRAW 34
- STATE COM 3
- VACA DRAW 9418 JV-P 1
- VACA DRAW 16 STATE 3
- PRE-ONGARD WELL 1 STATE IT 1
- RATTLESNAKE 28 FEDERAL 001
- ANNA K 44 1

SYSTEM	SERIES OR EPOCH	DELAWARE BASIN		NORTHWEST SHELF	CENTRAL BASIN PLATFORM
PERMIAN	OCHOA	Dewey Lake		Dewey Lake	Dewey Lake
		Rustler		Rustler	Rustler
		Salado		Salado	Salado
		Castile			Castile
	GUADALUPE	Delaware Mtn. Group	Lamar Bell Canyon	Tansill	Tansill
				Yates	Yates
			Cherry Canyon	Seven Rivers	Seven Rivers
				Queen	Queen
				Grayburg	Grayburg
			Brushy Canyon	San Andres	San Andres
				Glorieta	Glorieta
	LEONARD		Cutoff Formation	Clear Fork Yeso	Clear Fork
		Bone Spring Fm.	1st Bone Spring Carbonate		
			1st Bone Spring Sand		
			2nd Bone Spring Carbonate	Wichita Abo	Wichita
			2nd Bone Spring Sand		
			3rd Bone Spring Carbonate		
			3rd Bone Spring Sand		
	WOLFCAMP	Wolfcamp		Wolfcamp	Wolfcamp

Figure 4. The Cutoff Formation and the Bone Spring Formation make up the Delaware Basin slope. The Bone Spring Formation can be subdivided into 6 different members. Thus, in descending order these units are correlated within the wireline logs: Cutoff Formation, First Bone Spring Carbonate, First Bone Spring Sand, Second Bone Spring Carbonate, Second Bone Spring Sand, Third Bone Spring Carbonate, and Third Bone Spring Sand.

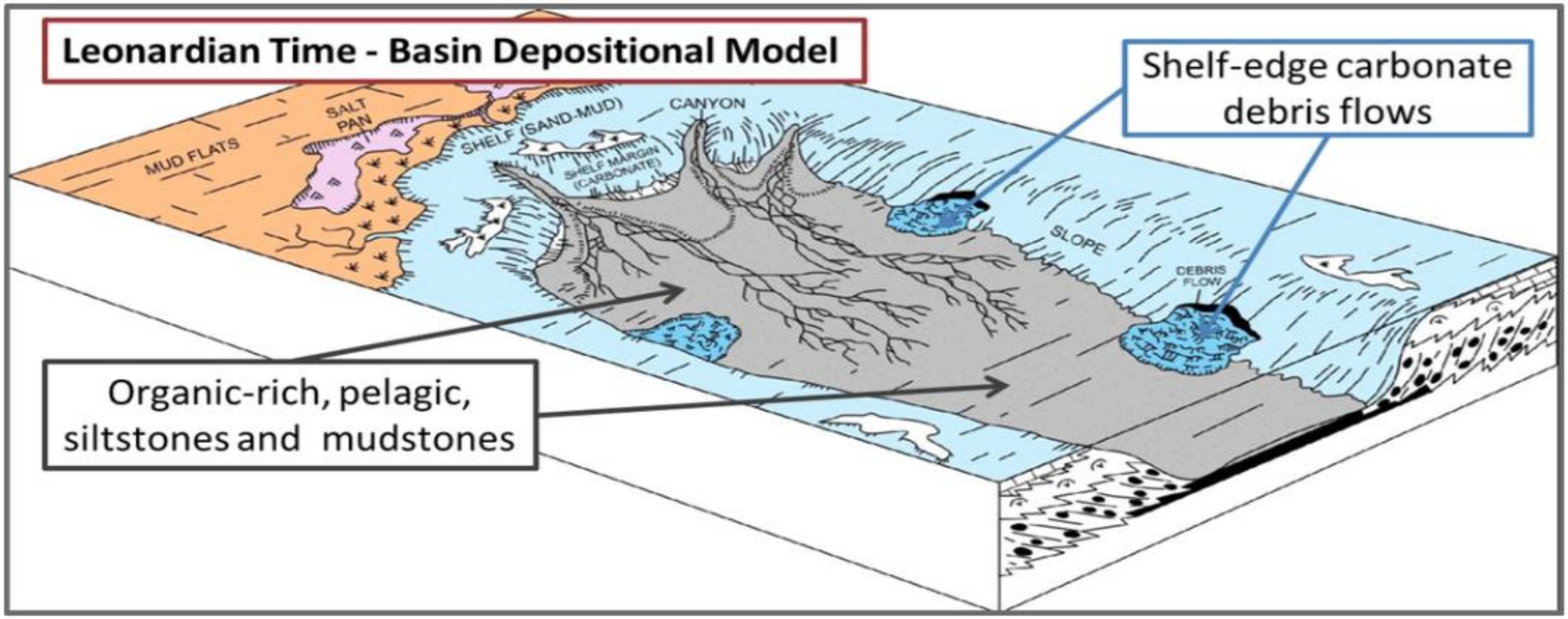

Figure 5. Depositional environment model of the Delaware Basin.

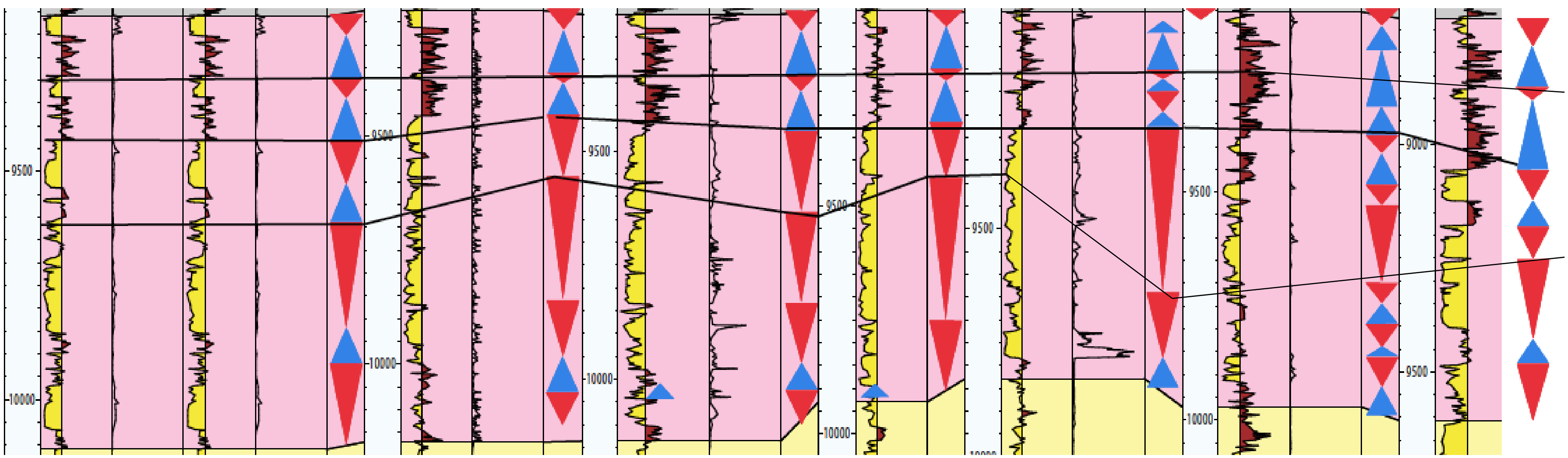

Figure 6. Parasequences of the First Carbonate Member of the Bone Spring Formation