STRATIGRAPHIC VARIATION OF THE LEONARDIAN (PERMIAN) AVALON SHALE AND BONE SPRING FORMATION, SOUTHEASTERN DELAWARE BASIN, REEVES COUNTY, WEST TEXAS, U.S.A.

An Undergraduate Research Scholars Thesis

by

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Submitted to the Undergraduate Research Scholars program at
Texas A&M University
in partial fulfillment of the requirements for the designation as an

UNDERGRADUATE RESEARCH SCHOLAR

Approved by Research Advisor: Dr. Michael Pope

May 2017

Major: Geology

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ABSTRACT

Stratigraphic Variation of the Leonardian (Permian) Avalon Shale and Bone Spring Formation, Southeastern Delaware Basin, Reeves County, West Texas, U.S.A.

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Stratigraphic thickness may vary as a member is deposited basinward of the shelf margin. Leonardian (Lower Permian) Avalon Shale and Bone Spring Formation strata of the southeastern region of the Delaware Basin in Reeves County, West Texas provide an example of these stratigraphic thickness variations. Wireline log data of the Avalon Shale and Bone Spring Formation records a mixed carbonate and siliciclastic slope-basinal system. Units of the Avalon Shale were deposited primarily by sediment gravity flows. Members of the Bone Spring Formation were deposited by reciprocal sedimentation caused by relative sea level change. Transgressions and relative sea level highstands deposited carbonate, whereas regressions and relative sea level lowstands deposited siliciclastic rocks. Carbonate sediment gravity flows and suspension settling of sandstone and shale channelized deposition contribute to the development of Avalon Shale and Bone Spring Formation basin strata. This research investigates the change in stratigraphic thickness of the

Avalon Shale and Bone Spring Formation from the southeastern to the central region of the Delaware Basin throughout Reeves County in a regional context, utilizing well log data. 26 well logs were analyzed and correlated for this study. Correlations show Avalon Shale and Bone Spring Formation units (in stratigraphically descending order); First BS (Bone Spring) Carbonate, Avalon Shale (within the First BS Carbonate; Leonard Shale (also known as "Upper Avalon" in previous studies), Middle Avalon, and Lower Avalon Shales), First BS Sandstone, Second BS Carbonate, Second BS Sandstone, Third BS Carbonate, and Third BS Sandstone have various thinning and thickening stratigraphic thickness trends from west to east, and from northwest to southeast, throughout the southeastern region of the basin. Future work on the Avalon Shale and Bone Spring Formation in the southeastern Delaware Basin can further integrate core, seismic, and petrographic data to better understand the Avalon Shale and Bone Spring Formation's depositional processes and patterns that affected variations of thickness throughout the southeastern to central region of the basin.

ACKNOWLEDGEMENTS

I would like to thank Dr. Michael Pope for his supervision and advisement of this research project, as well as helping to improve the quality of this paper. Special thanks to Tyson Perkes for Third Bone Spring Sand top picking assistance, and Harry Hastings concerning Avalon Shale unit picking criteria and identification. Graduate student Roy Conte is thanked for assistance regarding well log data collection and well log analyses software. Thanks to Dr. Carlos Laya for data collection assistance. Thanks to the rest of the Bone Spring Formation research group students; Kike Komalofe, Kaela Demmerle, Zabeer Hussain, Isabella Gaurone, and Leslie Hutchins for their help involving well log analyses software, and an outlet to share results throughout this project. Special thanks to my friends, colleagues, and the department faculty and staff for making my time at Texas A&M University a truly great experience. Last, I would like to thank my family for their unparalleled support, and encouragement over the years.

NOMENCLATURE

ft	Feet
mi	Miles
m	Meters
N	North
S	South
E	East
W	West
NE	Northeast
NW	Northwest
SE	Southeast
SW	Southwest
BS	Bone Spring
XS	Cross Section

CHAPTER I

INTRODUCTION

This research studies how the units of the Avalon Shale and Bone Spring Formation change in stratigraphic thickness from the southeastern to the central region of the Delaware Basin throughout Reeves County, West Texas in a regional context. This can provide useful information of where Avalon Shale and Bone Spring Carbonate and Sandstone reservoirs may thin or thicken as they near the basin toe-of-slope. Past studies of the Avalon Shale has shown how carbonate-rich sediment gravity flows can negatively or positively effect reservoir performance of the Avalon Shale in Southern New Mexico and West Texas, as well as how Earth modeling has proven to be an effective tool for stratigraphic interpretation of the Avalon Shale, and how through its application, identification of stacking patterns, productive zones (in cross sectional view), and neighborhoods (in map view) can be clarified (Stolz, 2014; Nestor, 2014). Studies on the Bone Spring Formation have primarily been done in New Mexico and West Texas, with one study in New Mexico having shown where new drilling opportunities might lie, examined depositional processes for the First, Second, and Third Bone Spring Sands, and suggested needed revisions to stratigraphic nomenclature used to describe the Bone Spring Formation (Hart, 2000).

Geologic History

Permian Foreland Basin

The Permian Foreland Basin formed from the bending of the lithosphere caused by the collision of the North American and South American plates, parallel and adjacent to the Marathon and Oachita orogenic belts (Hurd et al, 2016; Tai and Dorobek, 2000). The Permian Foreland Basin consists of two sub-basins, with the western one the Delaware Basin, and eastern region, the Midland Basin, which are separated by the Central Basin Platform (Hurd et al., 2016). Stratigraphy of the slopes and basin plain of the Delaware Basin related to this study include, in stratigraphically descending order, the Cutoff Formation, Bone Spring Formation, and Wolfcamp Formation. Leonardian stratigraphy of the Central Basin Platform consists of the Clear Fork and Wichita Formations, and is underlain by the Wolfcamp Formation (Loucks, 1985). Leonardian stratigraphy of the Midland Basin consists of the Leonard, Upper Sprayberry, Lower Sprayberry, and Dean Formations (Yang and Dorobek, 1995), and is also underlain by the Wolfcamp Formation. The study area is located in Reeves County, West Texas, particularly in the south eastern to central region of the Delaware Basin (Figure 2).

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 1. Stratigraphy of the Wolfcamp, Leonard, Guadalupe and Oachita Strata in the Permian Basin (From Loucks et al., 1985). The Wolfcamp, Bone Spring, and Cutoff formations are the subject of this study.

Pennsylvanian-Permian Global Climate

The Permian Delaware Basin's global context is traced back to the Pennsylvanian-Permian boundary, which consisted of global climatic events that altered the content of the sedimentary rock record. Permian Basin climate during the Middle Pennsylvanian to early Wolfcampian (Early Permian) was humid to sub-humid due to large scale glaciations of Gondwana spanning from the later Carboniferous (Pennsylvanian) - Sakmarian (Early Permian), with non-glacial climates before and after each glaciation (Saller 2014; Koch and Frank, 2011). These periods of ice amount variation on Gondwana caused large scale eustatic sea level change during the Pennsylvanian - Sakmerian, which are thought to represent transgressive and regressive systems tracts of the sedimentary basins at the time (Koch and Frank, 2011). Eustatic sea level changes can be recorded in various tropical carbonate platforms (Koch and Frank, 2011), of which was recorded by the carbonate-dominated Permian Basin. These ensuing transgressive and regressive cycles caused by the Penn-Perm global climate probably drove the stratification and lithological member variance of the Bone Spring Formation with respect to deposition of carbonates during transgressions and high stands, and siliciclastics during regressions and low stands.

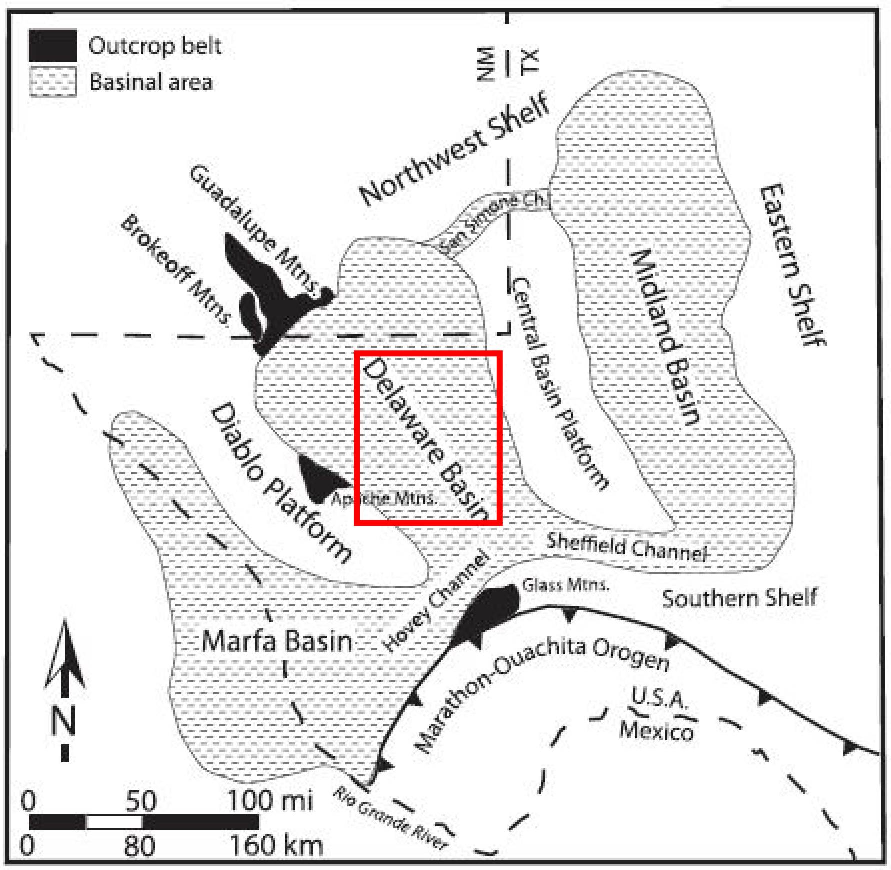

Figure 2. Map of Permian Foreland Basin (modified from Kerans, 2013). The study area is marked in red.

Stratigraphic Framework

Avalon Shale

The Avalon Shale is primarily a fine grained, quartz-rich siltstone, which in recent years, has been targeted for hydrocarbon exploration in New Mexico and West Texas (Nestor et al., 2014; Stolz, 2014). The Avalon Shale is not a chronostratigraphic unit of rock (Stolz, 2014). rather, it is an unconventional resource within the First Bone Spring Carbonate that can be roughly mapped over most of the Delaware Basin, and is productive over 1,500 $\boldsymbol{mi^2}$(Stolz, 2014; Nestor et al., 2014). The Avalon Shale is known to range in thickness from 275-200 m (900-1,700 ft) (Stolz, 2014), and is divided into three informal units, known as, in stratigraphically descending order, the Upper, Middle, and Lower Avalon Shales (Hardie, 2011; EIA, 2011 as reported by Stolz, 2014). The Upper and Lower Avalon Shales, are separated by the Middle Avalon Shale, of which is known to be comprised of thick carbonate sediment gravity flows (Nestor et al., 2014). The Avalon Shale is sometimes referred to as the Leonard Shale, which is also described as a separate rock unit, located slightly above the Avalon Shale (Stolz, 2014). In this study, the terms “Leonard”, “Middle”, and “Lower” Avalon Shales will be used to discuss the given “Upper”, “Middle”, and “Lower” Avalon Shale units respectively. In this study, the Avalon Shale is defined as being within the First Bone Spring Carbonate, comprising an area at the base of the First Bone Spring Carbonate’s first low drops in gamma ray values and mirrored spikes in deep induction resistivity, of which are interpreted as blocky carbonate deposits, down to the top of the First Bone Spring Sandstone.

Bone Spring Formation

The Bone Spring Formation consists of interbedded carbonate and siliciclastic members that can be mapped from the slope to basin plain of the Delaware Basin (Silver and Todd, 1969, Gawloski, 1987, Hart, 1998 as reported by Hart 2000). In stratigraphically descending order, the formation is subdivided into the First Carbonate, First Sandstone, Second Carbonate, Second Sandstone, Third Carbonate, and Third Sandstone. In this study, each member will be described with the “Bone Spring” formation name in front of each member. The First, Second, and Third Bone Spring Sands are correlative with Midland Basin units; Upper Sprayberry, Lower Sprayberry, and Dean Units (Hart, 2000). The members of the Bone Spring Formation are believed to be representative of a model of reciprocal sedimentation, in which the carbonates were deposited during transgressions and high stands, in which the siliciclastic sediment supply was cutoff, and the shelfal carbonate supply was highly productive (Silver and Todd, 1969; Gawloski, 1987; Saller et al., 1989, as reported by Hart, 2000) whereas siliciclastics were deposited during regressions and low stands, and were deposited to the basin plain (Hart, 2000).

Environments of Deposition and Depositional Processes

The Avalon Shale and Bone Spring Formation were both deposited into a slope to basin-plain depositional environment, as described by Stolz, 2014, of the Avalon Shale, and Hart, 1998 (Silver and Todd, 1969; Gawloski, 1987), concerning the Bone Spring Formation. Avalon Shale and Bone Spring Formation sediment were deposited by various processes, including carbonate debris flows, and channels, (Figures 3 and 4) (from Louks et al., 1985), (Hart, 2000; Hart, 1998).

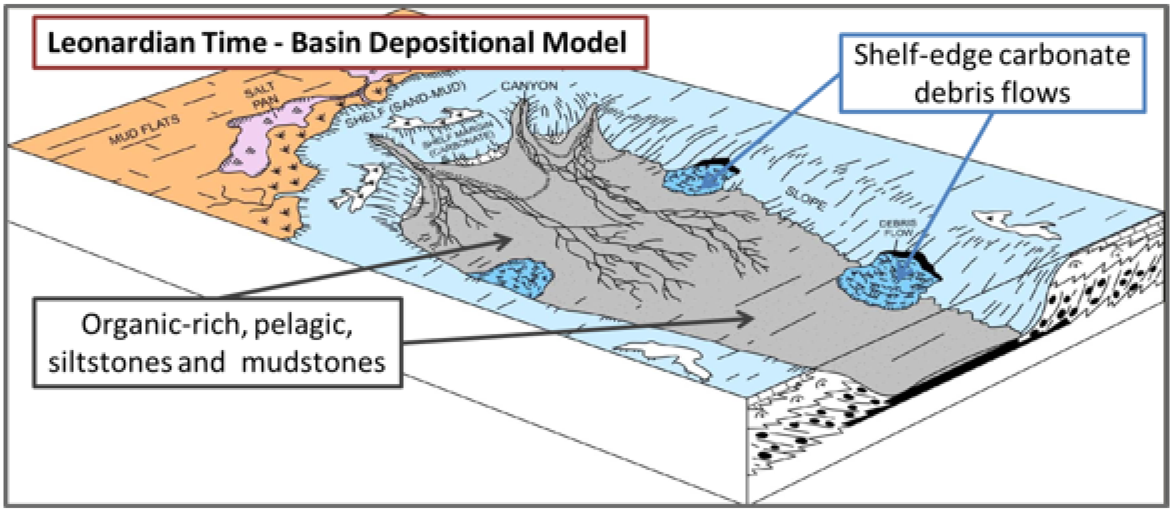

Figure 3. Depositional Model of the Delaware Basin during Leonardian Time (from Loucks et al., 1985). Characteristic depositional processes of the time include carbonate debris origination above the basin floor, and deposition of organic, pelagic siltstones and mudstones out onto the basin floor (Loucks et al., 1985).

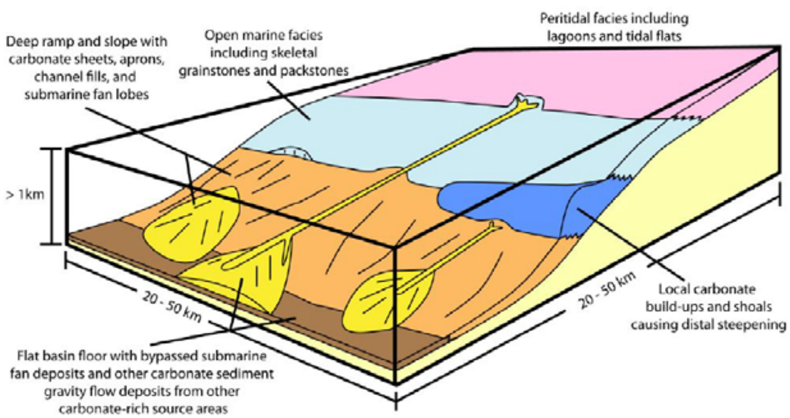

Figure 4. Common Depositional Processes of the Avalon Shale and Bone Spring Formation (from Stolz, 2014). Process types include bypassed submarine fans, submarine lobes, carbonate sediment gravity flows, channels, aprons, and submarine fan lobes (Stolz, 2014).

Causes of Stratigraphic Thickness Variation

Causes of stratigraphic unit thickness variation consist of a range of processes and patterns that affect the overall deposition of sedimentary rocks. These processes and patterns largely include effects of climate and sea level, which themselves are largely driven by tectonism and climatic conditions; tectonic activity produces changes in land elevation of the sediment source, which in turn causes changes in rates of erosion, thus overall causing changes of the overall buildup of sediment and accommodation space (Boggs Jr., 2003; Church and Cue, 2003). Changes in Avalon Shale and Bone Spring member thickness determined from wireline logs can be better supported with outcrop and core studies, and petrographic analyses, of which were not available for this study. Instead, the analyses and interpretation of wireline logs was undertaken in an attempt to point out the locations of stratigraphic thickness changes of the Avalon Shale and Bone Spring formation units throughout the study area in a regional context.

Table 1. Criteria for Well Log Interpretations: Top, Body, and Base Unit Picking Criteria for Avalon Shale and Bone Spring Formation Units used in this study (from Hastings, 2016 and T., Perkes, personal communication, March 21, 2017). Log type abbreviations include GR - Gamma Ray, and Deep. Res. - Deep Induction Resistivity.

Top of Stratigraphic Unit	**Well Log Description**
Base of Delaware Mtn. Group	Increase in GR, Low Resistivity Values over thousands of feet.
Cutoff Formation	Sharp drop in GR Values, Low Deep Resistivity, Neutron Porosity and Density Porosity curves overlap.
First Bone Spring Carbonate	Sharp drop in GR Values 30-60’ above this top, then sharp drop in GR where GR < 50 API., Spike in Deep Resistivity, Overlapping Neutron Porosity and Density Porosity curves.
Leonard Shale	Top one-third of the First Bone Spring Carbonate, High GR: GR > 100, Low Deep Resistivity.
Middle Avalon Shale	Most GR > 75 API, abundant GR > 100 API, low number of blocky low GR values < 50 API which are usually at the base, top, or middle of the unit.
Lower Avalon Shale	Mostly GR > 80 API, some blocky GR < 50 nearing base of First Bone Spring Carbonate, Deep Res. middle to high, sharp drops in Deep Res. when mirroring high spikes in GR.
First Bone Spring Sandstone	Top characterized by drop in Deep Res.; Res. < 20 - 40 ohmms, increase in GR.
Second Bone Spring Carbonate	Sharp Drop in GR Values, GR < 50 API., spike in Deep Resistivity, overlapping Neutron-Porosity and-Density Porosity curves.
Second Bone Spring Sandstone	Top characterized by drop in Deep Res.; Deep Res. < 20 - 40 ohmms, increase in GR, high GR and low Deep Res. throughout.
Third Bone Spring Carbonate	Top characterized by sharp drop in GR, with a mirrored sharp spike in Deep Res.
Third Bone Spring Sandstone	Top characterized by drop in Deep Res. of < 20 - 40 ohmms, increase in GR, high GR and low Deep Res. throughout.
Top of Wolfcamp	Sharp, short, drop in GR; GR < 50 API, and sharp spike in Deep Res., cross over in Neutron-Porosity and Density-Porosity curves.

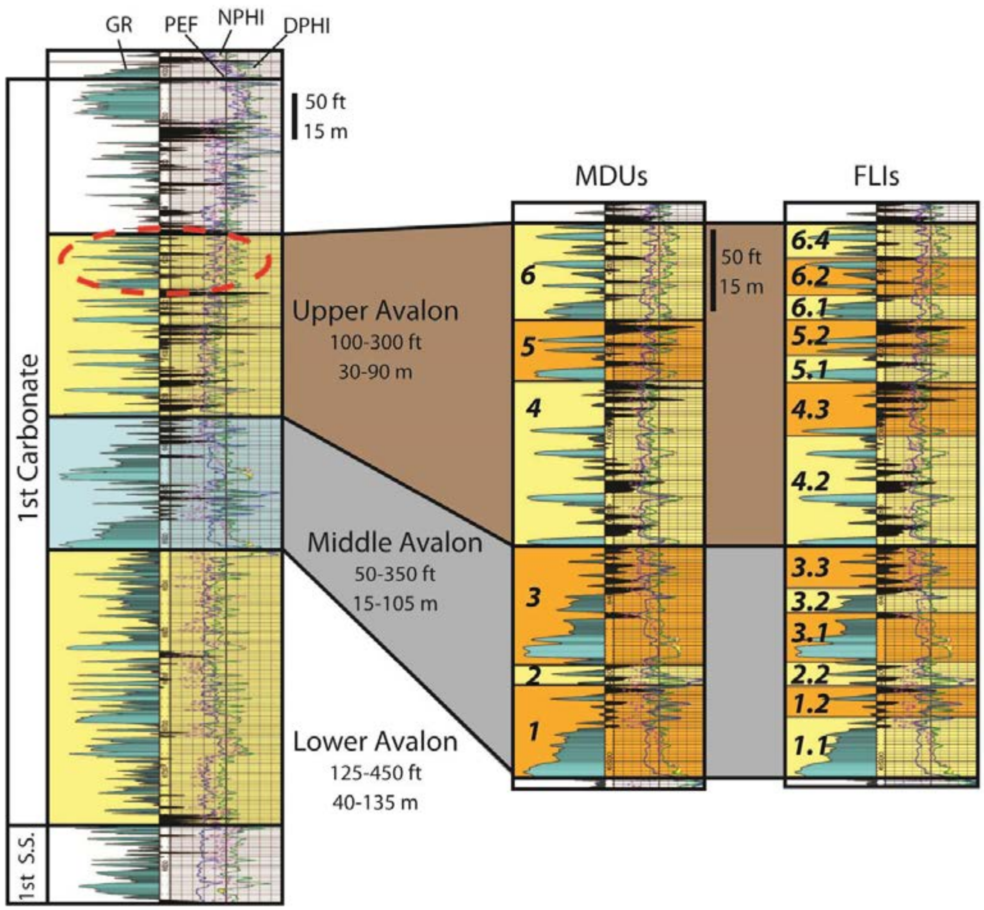

Figure 8. Well Log used as a reference when picking Avalon Shale unit tops during this study (from Stolz, 2014). Log measurements include (abbreviations used above in parenthesis) GR - Gamma Ray from 0-120 API, PEF – Photoelectric Factor from 0 – 10 barns/electron, NPHI – Neutron Porosity from 30 to -10%, and DPHI – Density Porosity from 30 to -10%. Notice the neutron porosity and density porosity curve shapes within each Avalon member; in the Upper Avalon; they are low inclined, and boot shaped. In the Middle, they are more sharply inclined near 90 degrees to the vertical, and in the Lower Avalon, they are more varied, with combinations of sharp horizontal trends, and vertical trend log shapes. These GR, NPHI, and DPHI log trends were seen in each well log concerning the Avalon Shale within this study.

CHAPTER II

METHODS

26 well logs within Reeves County were selected from the Drillinginfo database and correlated (Figure 4). Wells were selected on the basis of their data availability concerning gamma ray, deep induction resistivity, neutron porosity, and density porosity. Average depth and thickness measurements and calculations were made for each Bone Spring member from cross sections provided by Harry Hastings. Third Bone Spring Sand and Avalon Shale tops were picked with guidance from industry. Tops were picked for Bone Spring members above the Third Bone Spring Sand, starting from the First Carbonate to the Third Sand, including depth check backs with the Third Sand. Logs were correlated by picking similar log signatures. Average depth and thickness measurements, log shapes and trends from Stolz, 2014's Avalon Shale well log, and supposed depositional environment change from NW to SE and W to E from the depositional model (Figure 7) from Loucks et al. 1985; slope to basin plain, were taken into account during picking and correlations.

CHAPTER IV

RESULTS

Cross Section Basemaps

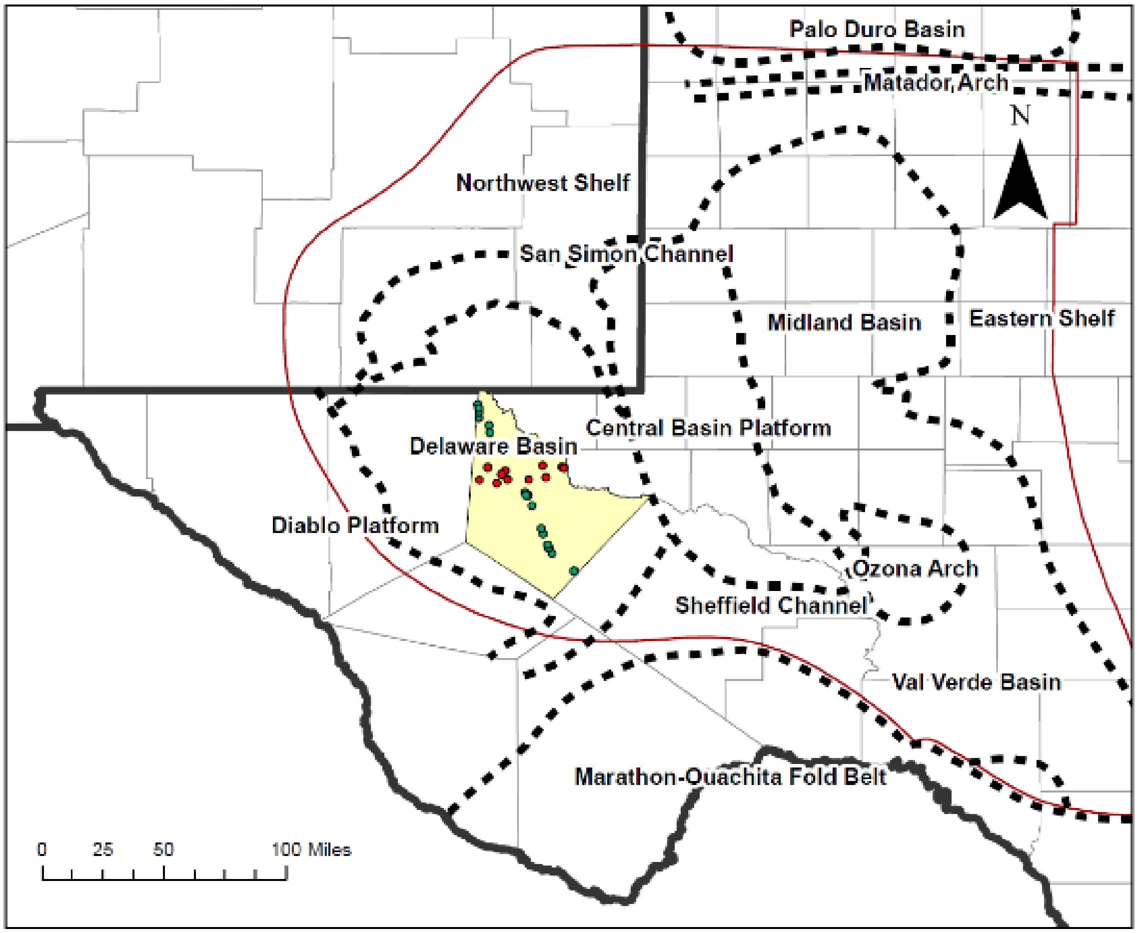

Figure 4. Map of eastern Mexico, southern New Mexico, and west Texas (Trend Data from Permian Basin Geologic Synthesis Project: Project GIS Data). The study area in Reeves County (Yellow) includes 26 well logs (circles). Created using ArcGIS. Datum: NAD1927.

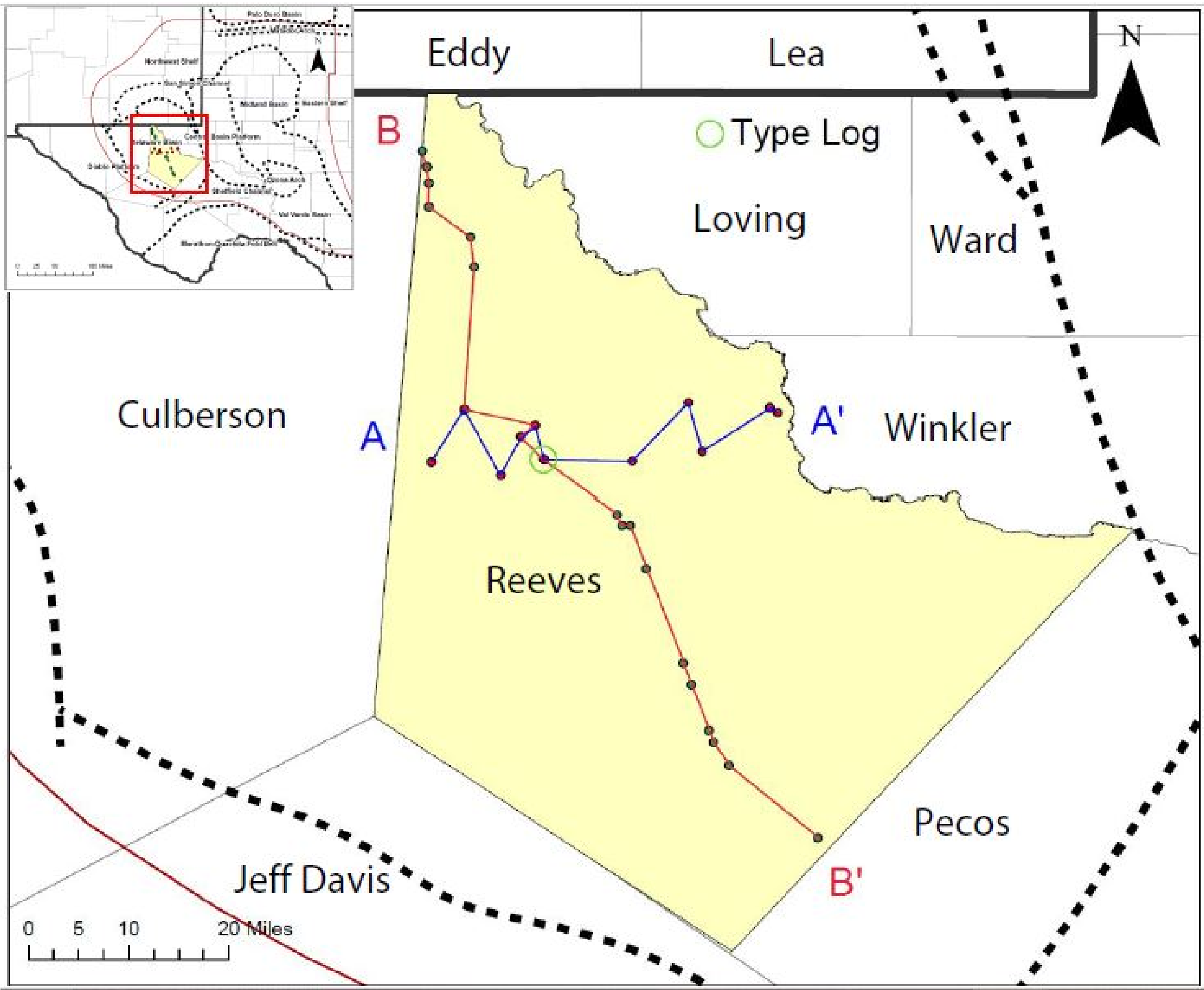

Figure 5. Cross Section Map with inset study map (trend data from UT Permian Basin Synthesis Project). The map of wells in relation to Delaware Basin Trend Map. Lines between wells were traced in Adobe Illustrator. The strike cross section line (A-A’) runs through 11 wells, from West to East, whereas the dip cross section line (B-B’) is through 21 wells, from NW to SE within Reeves County. Created using ArcGIS. Datum: NAD1927.

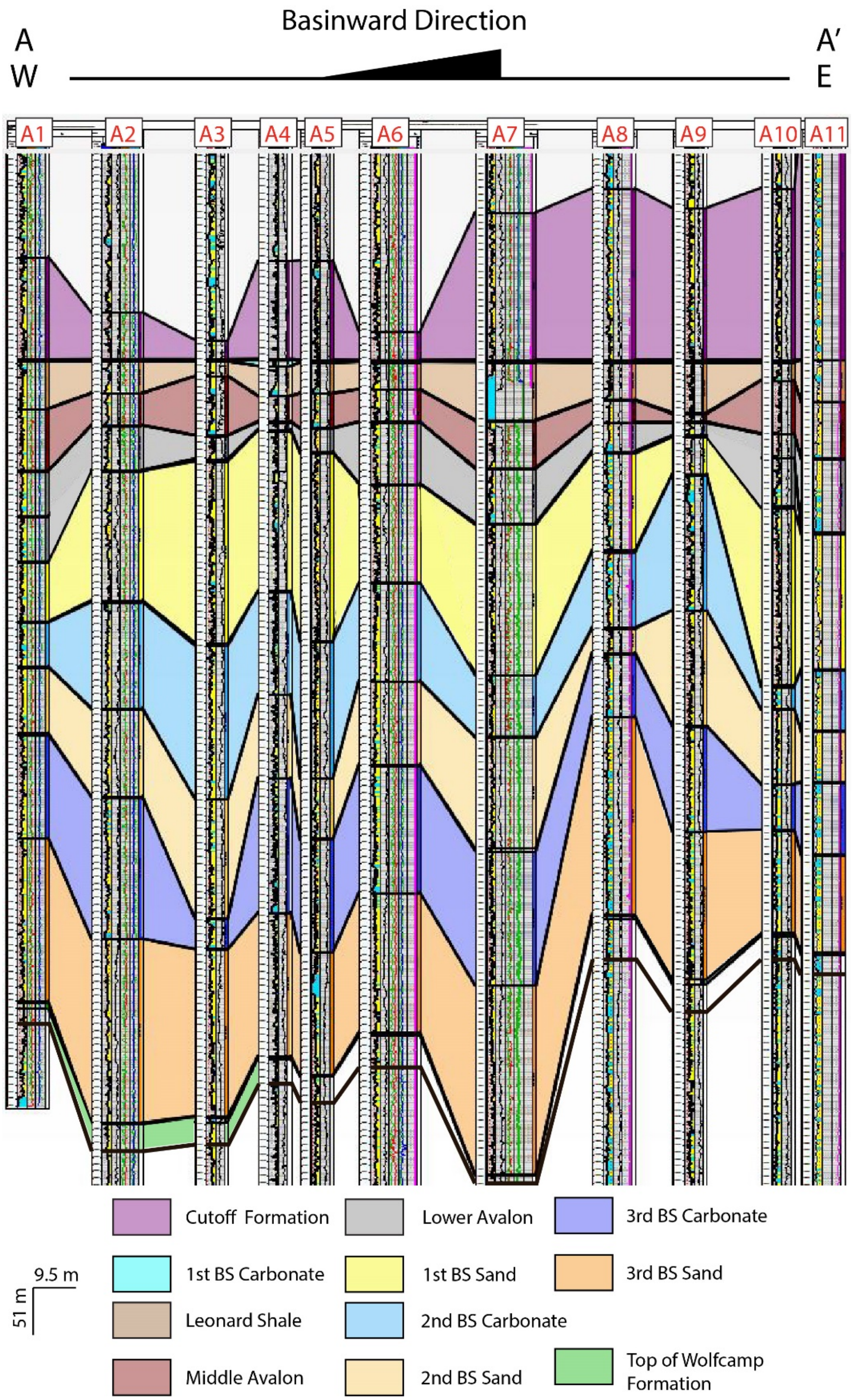

Figure 8. Scaled Stratigraphic XS: A-A' (W-E). Notice the thinning and thickening trends. Created using Techlog, edited with A. Illustrator.

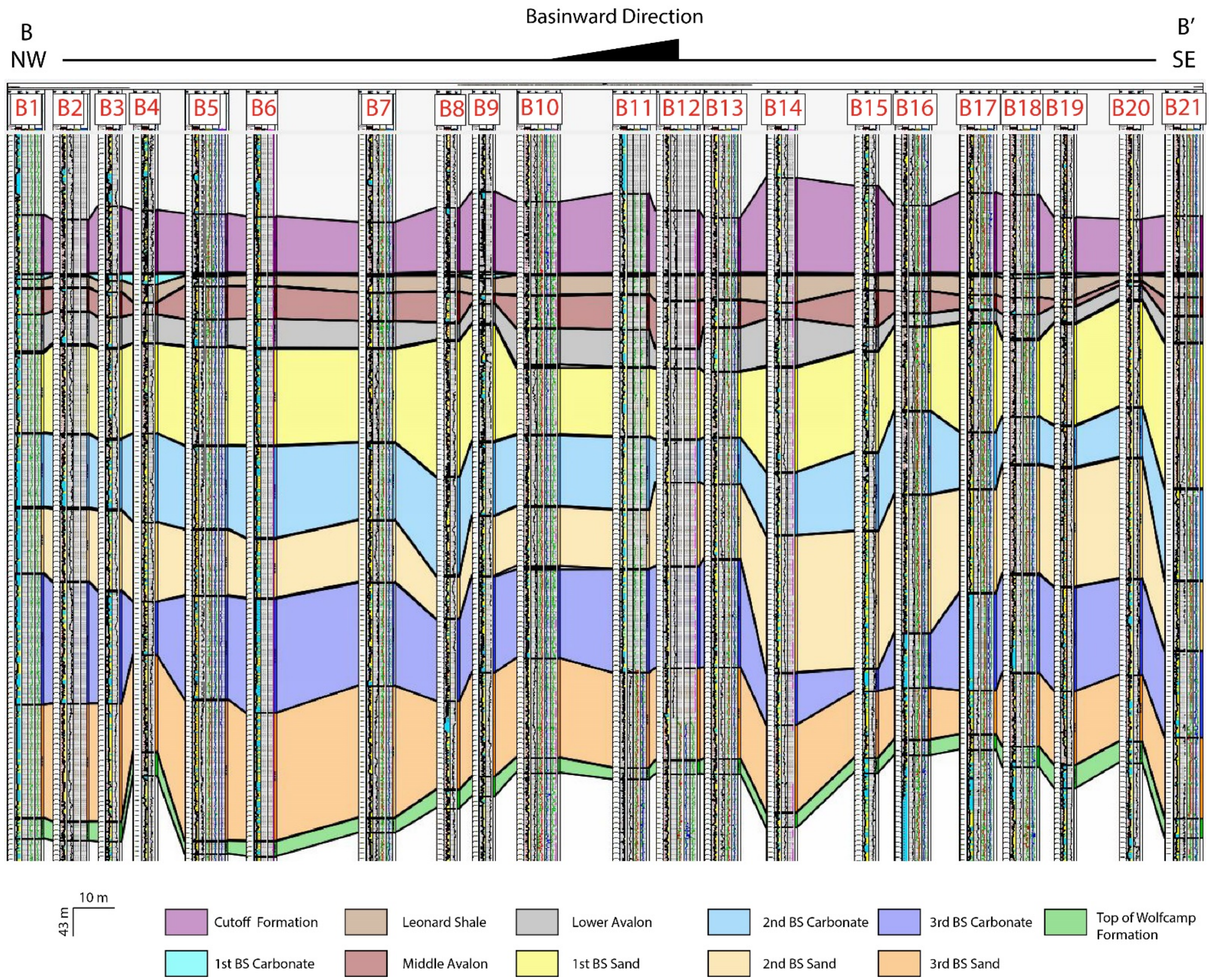

Figure 9. Scaled Stratigraphic Cross Section: B-B' running from NW to SE, and flattened on top of the First Bone Spring Carbonate. Created using Techlog.

CHAPTER V

DISCUSSION

Variations in Unit Thickness

Cross section A-A'

Avalon Shale

In cross section A-A' (Figure 8), the Leonard Shale varies in thickness. The Leonard Shale thins from well A1 to well A3, thickens from well A3 to well A7, thins from well A7 to well A8, thickens again from well A8 to well A9, thins from well A9 through well A10, and thickens from well A10 through well A11 (Figure 8). The Middle Avalon thins from well A1 to A2, thickens from well A2 to A3, thins from well A3 to A4, thickens from well A4 to A7, thins from well A7 to A9, thickens from well A9 to A10, and thickens from well A10 to A11 (Figure 8). The Lower Avalon thins well A1 to A4, thickens from well A4 to A6, thins from well A6 to A9, thickens from well A9 to A10, and thickens from well A10 to A11 (Figure 8).

Bone Spring Formation

The First Bone Spring Carbonate will be referred to in this description as ranging from just above the Leonard Shale, including the first clean carbonate within the light blue zones at the top of the cross section in Figure 8, through the Leonard and Middle Avalon Shales, and downwards to the base of the Lower Avalon Shale. The First Bone Spring Carbonate thins from well A1 to A4, thickens from well A4 to A7, thins from well A7 to A9, thickens from well A9 to A11 (Figure 8). The First Bone Spring Sand thickens from well A1 to A5, thins from well A5 to A6, thickens from well A6 to A7, thins from well A7 to A8, thickens from well A9 to A10, and thins from well A10 to A11 (Figure 8). The Second Bone Spring Carbonate thickens from well A1 to A3, thins from well A3 to A4, thickens from well A4 to A5, thins from well A5 to A8, thickens from well A8 to A9, thins from well A9 to A10, and thickens from well A10 to A11 (Figure 8). The Second Bone Spring Sand thickens from well A1 to A3, thins from well A3 to A5, thickens from well A5 to A7, thins from well to A8, thickens from well A8 to A9, and thins from well A9 to A11 (Figure 8). Third Bone Spring Carbonate thickness variations include thickening from well A1 to A2, thinning from well A2 to A3, thickening from well A3 to A4, thinning from well A4 to A5, thickening from well A5 to A7, thinning from well A7 to A8, thickening from well A8 to A9, thinning from A9 to A10, and thickening from well A10 to A11 (Figure 8). The Third Bone Spring Sand thickens from well A1 to A2, thins from well A2 to A5, thickens from well A5 to A7, and thins from well A7 to A11 (Figure 8).

Cross section B-B’

Avalon Shale

In cross section B-B’ (Figure 9), the Leonard Shale thickens from well B1 to B2, stays relatively constant in thickness from well B2 to B3, thickens from well B3 to B4, thins from well B4 to B5, thickens from well B5 to B8, thins from well B8 to B9, thickens from well B9 to B10, thins from well B10 to B11, thickens from well B11 to B12, thins from well B12 to B13, thickens from well B13 to B14, thins from well B14 to B15, thickens from well B15 to B17, stays relatively constant from well B17 to B18, thickens from well B18 to B19, thins from well B19 to B20, and thickens from well B20 to B21 (Figure 9). The Middle Avalon Shale thins from well B1 to B2, stays relatively constant in thickness in thickness from well B2 to B4, thickens from well B4 to B5, slightly thins from well B5 to B7, thickens from well B7 to B8, thins from well B8 to B9, thickens from well B9 to B12, thins from well B12 to B14, thickens from well B14 to B15, thins from well B15 to B17, thickens from well B17 to B18, thins from well B18 to B20, and thickens from well B20 to B21 (Figure 9). The Lower Avalon Shale thickens from well B1 to B2, thins from well B2 to B5, thickens from well B5 to B6, thins from well B6 to B9, thickens from well B9 to B10, thins from well B10 to B12, thickens from well B12 to B14, thins from well B14 to B17, thickens from well B17 to B18, thins from well B18 to B20, and thickens from well B20 to B21 (Figure 9).

Bone Spring Formation

The First Bone Spring Carbonate will be described in this section as in the previous section; ranging from just above the Leonard Shale, to the base of the Lower Avalon Shale. The First Bone Spring Carbonate thins from well B1 to B4, thickens from well B4 to B6, stays relatively constant in thickness from well B6 to B7, thins from well B7 to B9, thickens from well B9 to B10, stays relatively constant in thickness from well B10 to B12, thickens from well B12 to B13, thins from well B13 to B17, thickens from well B17 to B18, thins from well B18 to B20, and thickens from well B20 to B21 (Figure 9). The First Bone Spring Sand thickens from well B1 to B2, stays constant from well B2 to B4, thickens from well B4 to B5, thins from well B5 to B7, thickens from well B7 to B8, thins from well B8 to B11, stays relatively constant from well B11 to B13, thickens from well B13 to B14, thins from well B14 to B16, thickens from well B16 to B17, thins from well B17 to B18, and thickens from well B18 to B21 (Figure 9). The Second Bone Spring Carbonate thickens from well B1 to B2, thins from well B2 to B3, thickens from well B3 to B4, thins from well B4 to B5, thickens from well B5 to B6, thins from well B6 to B7, thickens from well B7 to B8, thins from well B8 to B9, stays relatively constant in thickness from well B9 to B10, thickens from well B10 to B11, thins from well B11 to B12, thickens from well B12 to B15, stays relatively constant in thickness from well B15 to B16, thins from well B16 to B19, and thickens from well B19 to B21 (Figure 9). The Second Bone Spring Sand thickens from well B1 to B4, thins from well B3 to B8, thickens from well B8 to B10, thins from well B10 to B11, thickens from well B11 to B12, thins from well to B13, thickens from well B13 to B15, thins from well B15 to B17, stays relatively constant in thickness from well B18 to B19, thickens from well B19 to B20, and thins from well B20 to B21 (Figure 9). The Third Bone Spring Carbonate thins from well B1 to B4, thickens from well B4 to B6, thins from well B6 to B13, thins from well B13 to B15, thickens from well B15 to B18, stays relatively constant in thickness from well B18 to B19, thins from well B19 to B20, and stays relatively constant in thickness from well B20 to B21 (Figure 9). The Third Bone Spring Sandstone thickens from well B1 to B2, stays relatively constant in thickness from well B2 to B3, thins from well B3 to B4, thickens from well B4 to B5, thins from well B5 to B6, stays relatively constant in thickness from well B6 to B7, thins from well B7 to B8, thickens from well B8 to B9, thins from well B9 to B11, thickens from well B11 to B12, thins from well B12 to B13, stays relatively constant in thickness from well B13 to B14, thins from well B14 to B17, thickens from well B17 to B18, stays relatively constant in thickness from well B19 to B20, and thickens from well B20 to B21 (Figure 9).

CHAPTER VI

CONCLUSION

Conclusion

In a regional context, the Leonard, Middle, and Lower Avalon Shale units have repeated thinning and thickening trends from west to east (Figure 8), while the Leonard Shale gradually thickens from northwest to southeast, Middle Avalon gradually thickens, then thins from northwest to southeast, and Lower Avalon Shale thickens and thins twice, and thins at the end from northwest to southeast (Figure 9). First and Second Bone Spring Sandstones generally thicken from west to east (Figure 8) and northwest to southeast (Figure 9), while Second and Third Bone Spring Carbonates thicken and thin from west to east (Figure 8), stay relatively constant in thickness, then thin from northwest to southeast (Figure 9). Third Bone Spring Sandstone unit thickness generally thin from West to East and northwest to southeast (Figure 8; Figure 9).

Future Work

Future work on the Avalon Shale and Bone Spring Formation in the southeastern Delaware Basin can further integrate core, seismic, and petrographic data to 1) confirm well log interpretations in this study, 2) to better understand the Avalon Shale and Bone Spring Formation’s depositional processes and patterns that affected variations of stratigraphic thickness throughout the southeastern to central region of the basin. Studies could include creation of sub-surface maps, and isopach maps to represent depth variation of units, and varying stratigraphic thickness of units throughout the study area. Correlation and mapping of certain depositional processes and patterns that affected deposition and reservoir quality of the Avalon Shale and Bone Spring Formation could also be of significant research interest.

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APPENDIX

Well List

Datum: NAD1927

Well API	Latitude	Longitude
42-389-32862	31.469419	-104.018112
42-389-30269	31.54465	-103.971
42-389-31297	31.450268	-103.917999
42-389-31230	31.505405	-103.889114
42-389-32520	31.522169	-103.868492
42-389-32353	31.47256	-103.856
42-389-32517	31.470364	-103.728058
42-389-32139	31.554779	-103.647079
42-389-32637	31.484529	-103.627495
42-389-32178	31.54784	-103.529686
42-389-30269	31.544649	-103.97052
42-389-32200	31.91713	-104.031166
42-389-32215	31.149942	-103.642876
42-389-32219	31.870981	-104.022057
42-389-31297	31.450268	-103.917999
42-389-30281	31.793194	-103.961472
42-389-30276	31.749479	-103.956444
42-389-30269	31.544649	-103.97052

42-389-32520	31.522169	-103.868492
42-389-31230	31.505405	-103.889114
42-389-32353	31.472563	-103.855698
42-389-32501	31.394987	-103.750237
42-389-32438	31.37948	-103.743164
42-389-10542	31.379484	-103.730453
42-389-31202	31.317242	-103.708748
42-389-31222	31.181448	-103.6548
42-389-31225	31.149942	-103.642876
42-389-32584	31.083956	-103.617157
42-389-32608	31.067358	-103.610626
42-389-31669	31.034491	-103.588715
42-389-31244	30.949669	-103.52203
42-389-32567	30.930349	-103.460304