USING SEISMIC DATA TO DELINEATE TECTONIC AND DEPOSITIONAL FEATURES WITHIN THE SPRINGER FORMATION, BLAINE, CANADIAN AND CADDO COUNTIES, OKLAHOMA

By

DANIEL JAMES FRITZ

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USING SEISMIC DATA TO DELINEATE TECTONIC AND DEPOSITIONAL FEATURES WITHIN THE SPRINGER FORMATION, BLAINE, CANADIAN AND CADDO COUNTIES, OKLAHOMA

Thesis Approved:

Dr. Jim Puckette

Thesis Adviser

Dr. William Coffey

Dr. Ibrahim Cemen

Dr. Jamie Rich

Dr. A. Gordon Emslie

Dean of the Graduate College

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CHAPTER I

INTRODUCTION

As a result of onlap and erosion, the interpretation of the "Springer" and "Morrow" stratigraphy on the eastern margin of the Anadarko Basin is problematic. This interval has not been interpreted using a genetically related sequence-stratigraphic framework. Currently, there are no detailed sandstone distribution maps for the stratigraphic units within the Springer Formation. Well log data is only able to provide glimpses of sandstone at widely distributed locations and interpretations between these are tenuous. This research is designed to answer several basic questions regarding the way seismic data improves correlation and mapping sandstone distribution. (1) Can 3D seismic data visualize strata between well control points and improve interpretation? (2) Will integrating seismic and well log data provide a means to help identify shale units that represent extensive marine flooding and thereby establish an improved stratigraphic framework for the Springer interval, and (3) is 3D seismic an effective tool for identifying and mapping within the Springer Formation the distribution of thick sandstone bodies such as channel-fill sandstones and tectonic features such as faults? These questions are addressed in a study area located in the eastern Anadarko Basin.

This study area includes parts of several merged 3D seismic data sets, located in southwestern Canadian County, southern Blaine County, and northern Canadian County, Oklahoma in townships 12-14N and from ranges 9-11W (Figure 1). Based on the examination of a south to north trending line through the Anadarko Basin, it is evident that the deepest part of the basin (approximately 40,000 feet deep) is towards the south, whereas the study area is located in an area where the beds are thinning and pinching out against the shelf edge to the north. The shaded box shown in Figure 2 depicts the map view location and tectonic position (cross section) of the study area.

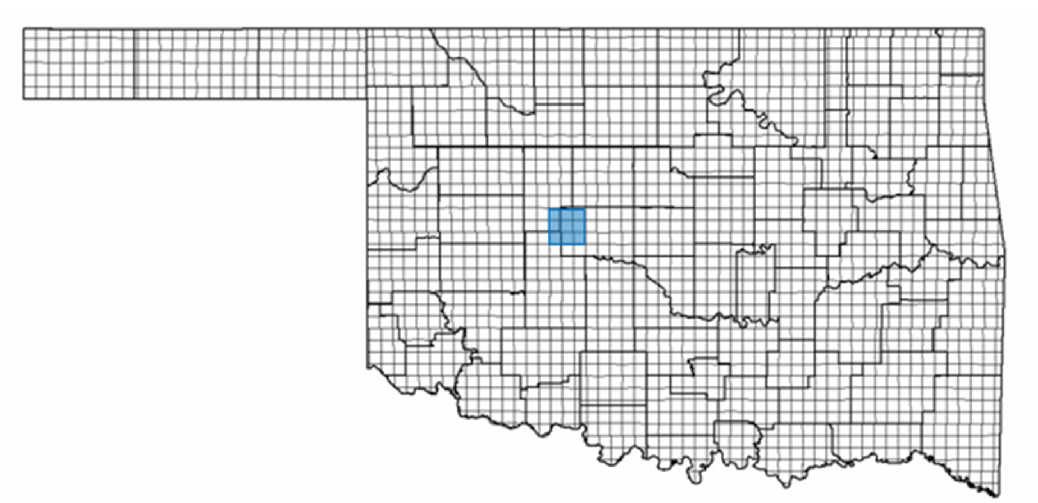

Figure 1. Map of Oklahoma with study area highlighted

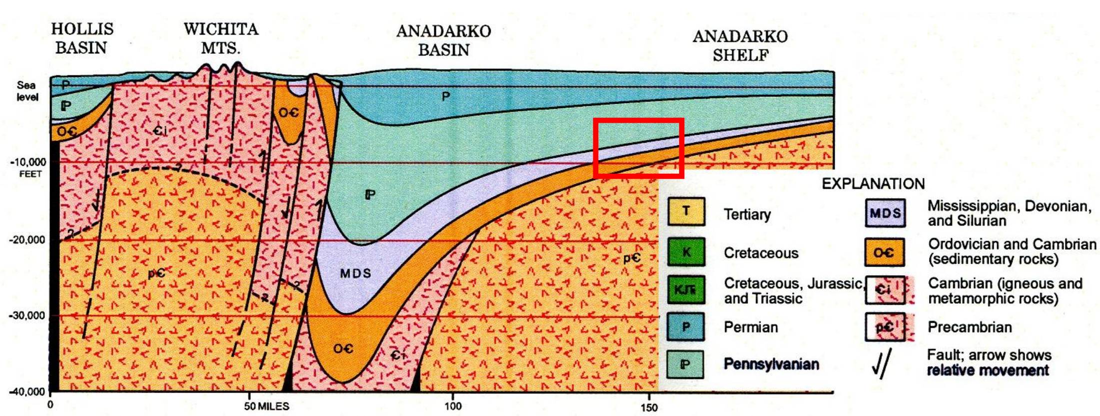

Figure 2. Cross section view of the Anadarko Basin and the position of the study area (Johnson 2008)

Tectonic History:

The Anadarko Basin is considered one of the deepest foreland Paleozoic basins on the North American craton (Al-Shaieb, 1999) and one of the most prolific natural gas producing areas on the North American continent (Cranganu, 2005). A foreland basin is a low-lying region that is adjacent and parallel to a mountain belt formed as the result of the collision of tectonic plates. Foreland basins form when the lithosphere flexes downward in front of a mountain belt in response to the added load of thickened crust that results from the collision of the two plates. Sediments eroded from the mountain belt accumulate in the foreland basin, causing it to further subside and create accommodation for additional sediments (Davis, 1996). The Anadarko Basin lies primarily in the western part of Oklahoma and the Texas Panhandle and is bounded to the east by the Nemaha Ridge, to the west by the Las Animas Arch, to the north by the Central Kansas uplift and to the south by the Wichita-Amarillo Uplift. According to Al-Shaieb (1999), the Anadarko Basin covers an area approximately 90,639 km^2 (35,000 mi^2) (Figure 3). Paleogeographic maps created by Blakey (2006) (Figures 4 and 5) show the two time periods that contain the study interval. Figure 4 (Late Mississippian), shows the mountains to the southwest had not yet formed, but in Figure 5 (Early Pennsylvanian), the Wichita uplift has begun and the Anadarko Basin was subsiding.

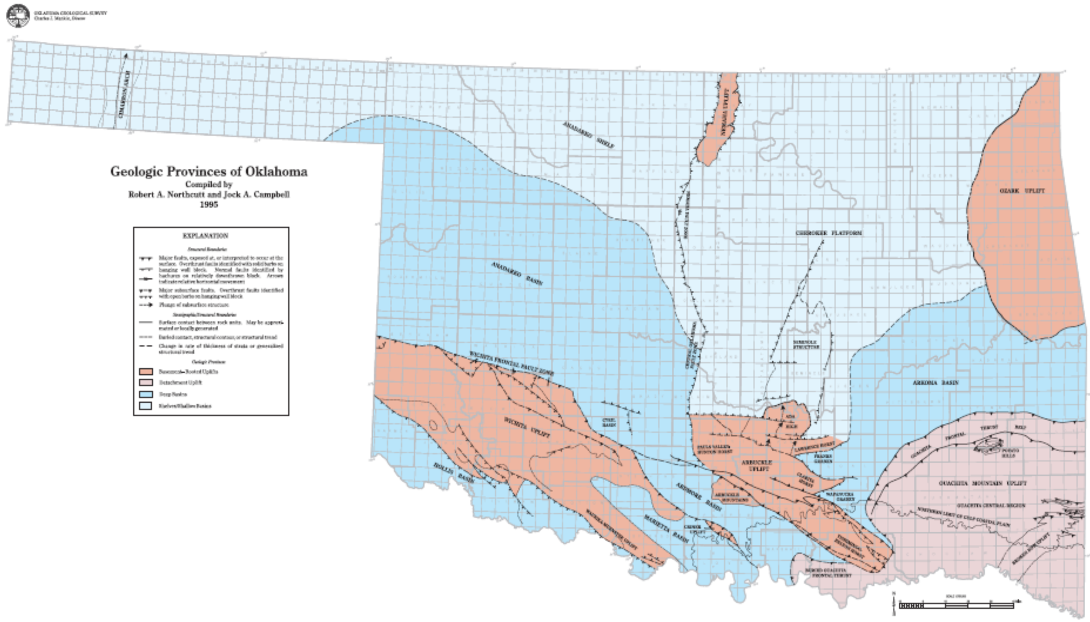

Figure 3. Geologic Provinces of Oklahoma (Northcutt, 1995)

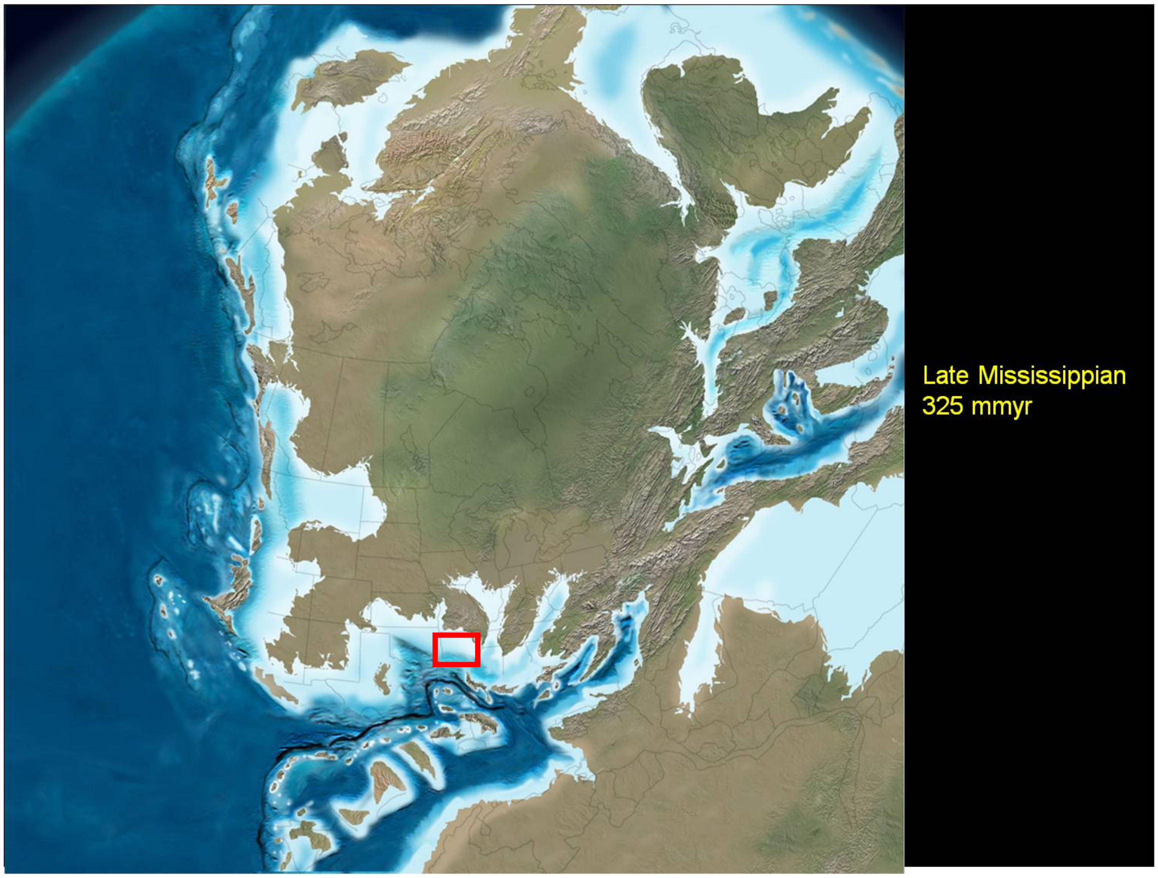

Figure 4. Paleogeographic map of the Late Mississippian time. The Anadarko basin is highlighted by a red box (Blakey, 2006).

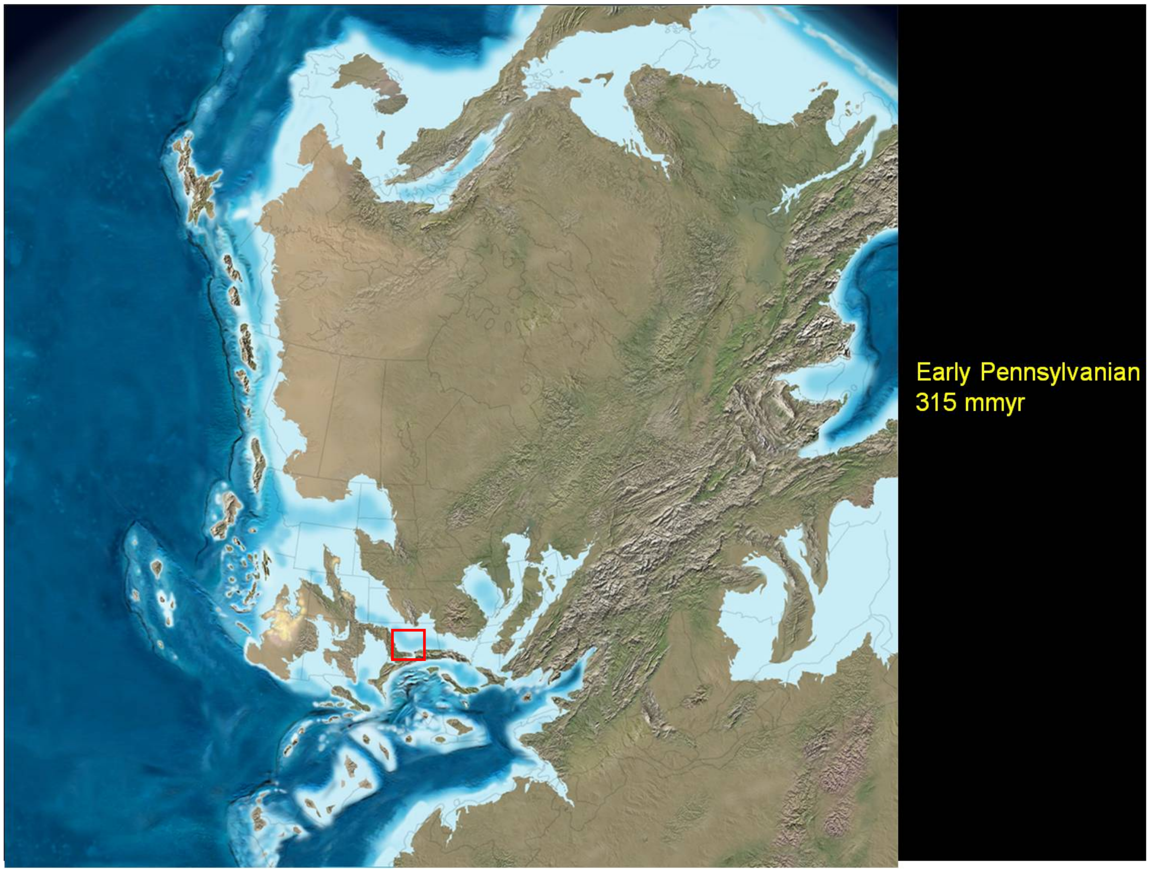

Figure 5. Paleogeographic map of the Early Pennsylvanian time. The Anadarko basin is highlighted by a red box (Blakey, 2006).

Stratigraphy and Sedimentology:

This study will focus on the stratigraphic units of the Springer interval. The Springer Formation was first named in a stratigraphic study by C. W. Tomlinson in 1929 (Straka, 1972). The Springer interval lies above the Mississippian Caney Formation and below the Pennsylvanian Morrow Formation. The parastratigraphic units of interest, the Britt, Cunningham, and Boatwright are all members that compose the Mississippian "Springer" (Goddard Formation) interval (Figure 6). These stratigraphic units contain important reservoirs that produce large volumes of natural gas.

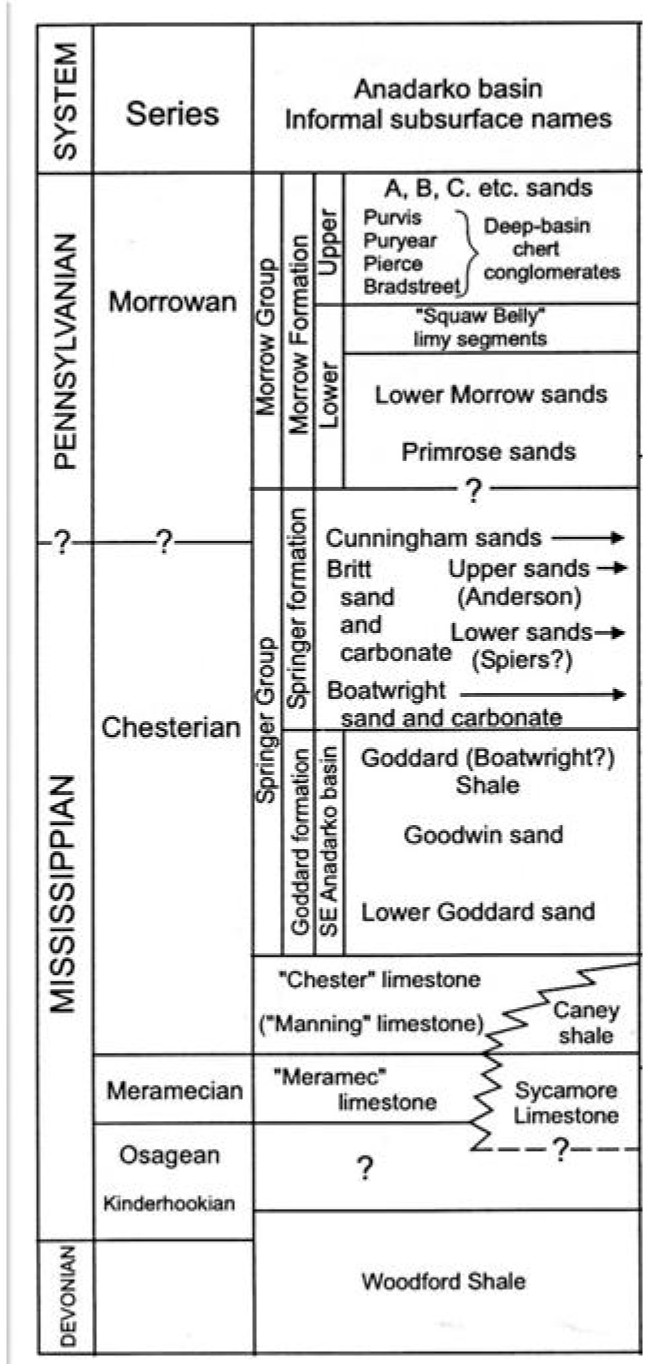

Figure 6. Informal stratigraphic nomenclature for Upper Devonian through Lower Pennsylvanian interval in the Anadarko Basin (Andrews, 2001).

According to Haiduk (1990), “Carbonate deposition prevailed from Ordovician through the late Mississippian in the southern Mid-Continent. The Springer Group represents the change to clastic-dominated sedimentation which prevailed through the remainder of the Paleozoic.” According to Andrews (2001), the depositional setting for the Springer sandstones was a shallow-marine shelf environment in water depths less than 150 feet. These marine deposits are detached from any shoreline and therefore are called offshore bars. Although most Springer sandstones in the Anadarko basin occur as offshore bars, at least two other depositional environments characterize the Springer: sand filled incised channels and turbidites (Andrews, 2001).

A typical well log from the study area (Figure 7) shows the Chester Limestone is a thick carbonate unit. The Chester Limestone is easily recognized on wireline logs by its high resistivity values and is an important seismic reflector. The Boatwright is dominantly shale with occasional sandstone bodies in the form of marine bars. According to Andrews (2001), the Boatwright Sandstone was first described by McBride (1986) as a mature quartz arenite. Haiduk (1990) confirmed the Boatwright as quartz arenite. The Britt interval contains two sandstone zones with interbedded shale. These sandstones occur in two distinct facies: (1) incised channel complexes and (2) marine bars. According to Andrews (2001), “the combined sandstone thickness is generally less than 100 feet. Yet despite this, the Britt is probably the most productive unit in the Springer Group.” Andrews (2001) reported that McBride (1986) classified the Britt Sandstone as a quartz arenite. Rice (1993) also described the Britt sandstones as quartz arenite to subarkose that contain intervals with abundant fossil fragments. The Cunningham Sandstone is primarily a fine to medium grained, well sorted and sub rounded mature sandstone.

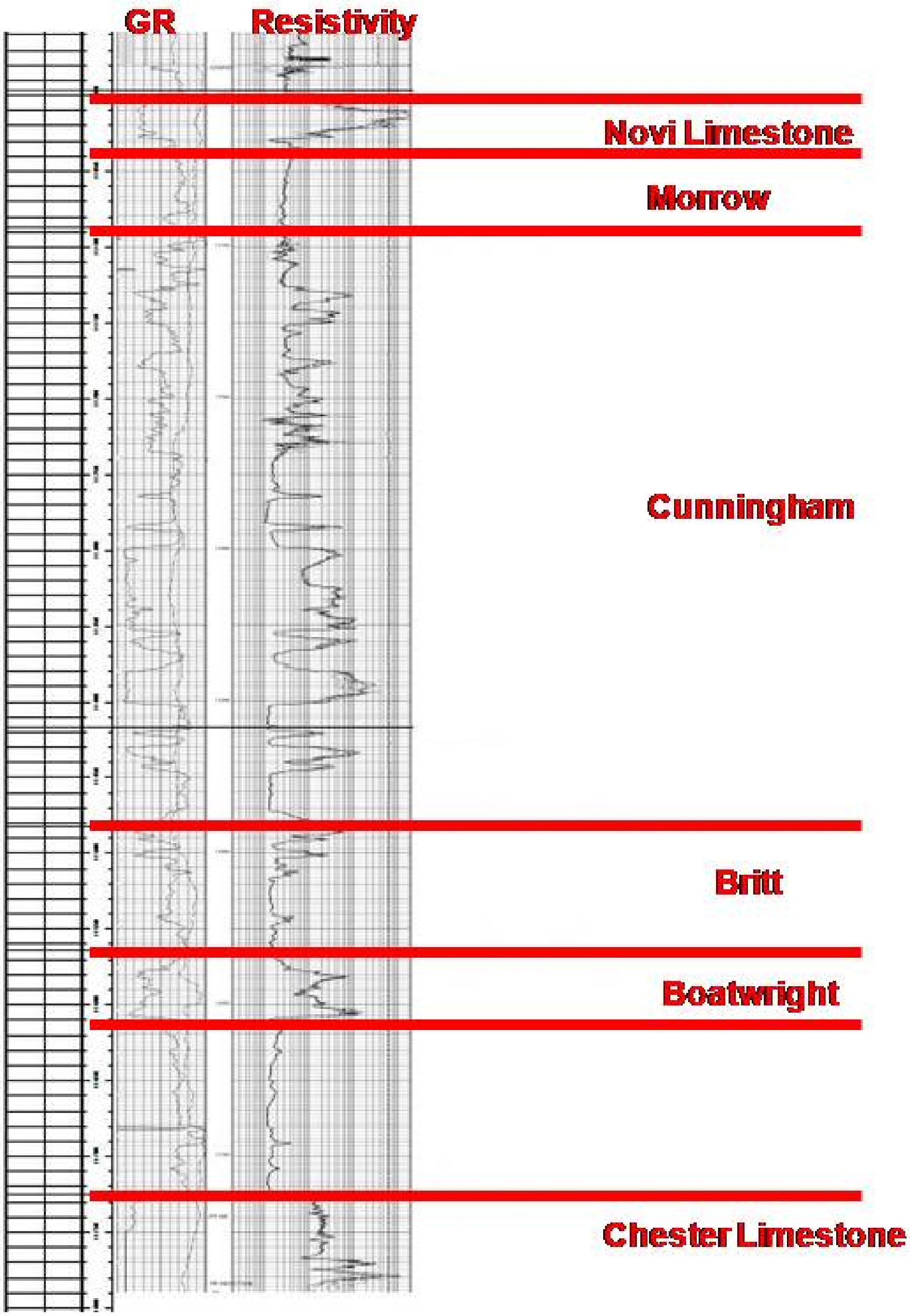

Figure 7. Typical wireline log curves across the interval from the Chester Limestone to the Novi Limestone. Informal stratigraphic nomenclature shown.

Andrews (2001) also states that the Cunningham is classified as a quartz arenite, subarkose and sublitharenite that can be rich in marine invertebrate fauna. Rice (1993) states that the Morrow is composed primarily of shale that contains intercalated thin sand laminae. The Morrow contains a sandy limestone known informally as the Novi Limestone. This limestone is important to this study as it is widely distributed and is easily recognizable on wireline logs and by seismic data.

CHAPTER II

REVIEW OF LITERATURE

Seismic Data Acquisition

Seismic data is acquired in two distinct ways: through land and marine acquisition. For this study area, land acquisition was used to gather the seismic data. In land acquisition, a shot is fired (i.e., energy is transmitted) and reflections from the boundaries of various lithological units within the subsurface are recorded at a number of fixed receiver stations on the surface (Figure 8 and 9) Talagapu (2005). When a seismic survey is first laid out, the geophone stations are typically in-line, but the shot source is not always in-line. Talagapu (2005) reports that when the source is in-line with the receivers – at either end of the receiver line or positioned in the middle of the receiver line – a two-dimensional (2D) profile through the earth is generated; if the source moves around the receiver line causing reflections to be recorded form points out of the plane of the in line profile, then a three-dimensional (3D) image is possible (the third dimension being distance, orthogonal to the in-line receiver-line).

Before 2D/3D seismic data is analyzed, however, the newly acquired data must be processed. According to Talagapu (2005), there are five types of corrections and adjustments that must be made in order to view an accurate seismic survey: time, amplitude, frequency-phase content, data compressing (stacking), and data positioning (migration). These five adjustments “increase the signal-to-noise ratio, correct the data for various physical processes that obscure the desired (geologic) information of the seismic data, and reduce the volume of data that the geophysicist must analyze” (Talagapu 2005).

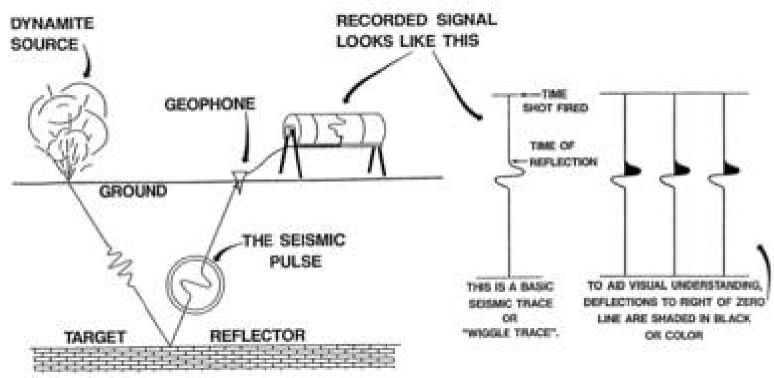

Figure 8. Simplified schematic showing the layout of seismic acquisition (Kessinger 2009)

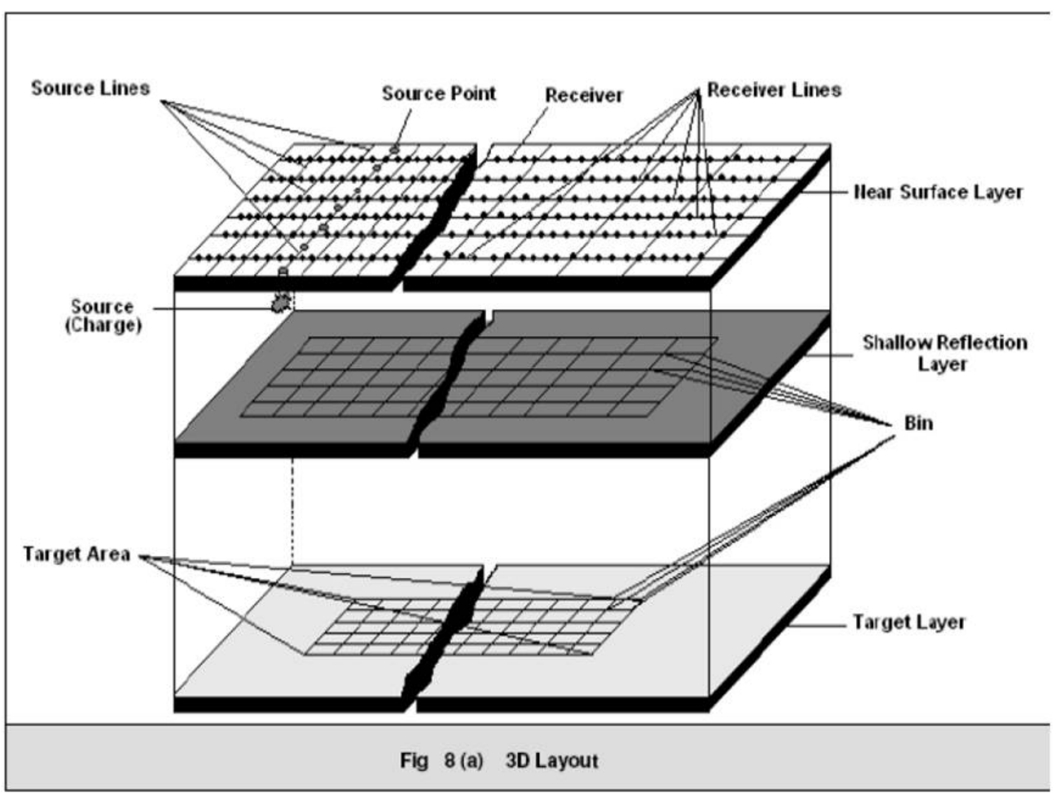

Figure 9. 3D layout of seismic acquisition (Talagapu 2005)

Well Log Data vs. Seismic Data

In this study, seismic data will be used to interpret stratigraphy and augment correlations based on well log data. Wittick (2009) reports that the two primary earth acoustic properties that affect the earth's seismic response are velocity and density, and the product of velocity and density is acoustic impedance. These changes in acoustic impedance cause seismic reflections. Therefore, the two most important logs to the seismic process are the sonic and density logs. Wittick (2009) also states that these logs are able to vertically resolve intervals two feet thick, but they are only able to investigate six to eight inches away from the well bore whereas seismic data is not capable of two-foot vertical resolution, but the horizontal resolving power of seismic data is as large as the seismic survey. This shows the difference in resolution between well logs and seismic data. Sonic and density logs have excellent vertical resolution and poor horizontal resolution, whereas seismic data has excellent horizontal resolution and poor vertical resolution (Wittick, 2009). In the study area, the goal is to use seismic data to fill in the gaps between wells to improve the accuracy of the overall geological interpretation.

CHAPTER III

METHODOLOGY

Introduction:

This research is dovetailed to a study within the same area that uses wireline logs to establish the stratigraphic framework and map the distribution of Springer sandstones. The methods are outlined as follows:

(1) Establish a working stratigraphic framework using well logs and established industry names,

(2) Select wireline logs to build a set of synthetic seismograms,

(3) Use mapping software to tie wireline log stratigraphy to the seismic data,

(4) Create synthetic model and analyze validity by comparing wireline well log picks to an equally scaled synthetic model and seismic profile,

(5) Analyze data for tuning effects that might obscure data and inhibit interpretation,

(6) Generate isochron and time structure maps, and

(7) Establish velocity and convert time structure maps to depth maps

Stratigraphic Framework:

To start the project, well logs were examined and formation tops picked for the Novi Limestone, Lower Cunningham, Morrow Base, the Britt Hot Shale, the Boatwright

Hot Shale, and the Chester Limestone. Using the Petra software and the resistivity, gamma ray, and porosity logs to pick the tops, the positions of these units were located. More than 1300 well logs were reviewed throughout the entire project area so that an accurate interpretation of stratigraphy could be applied to the seismic data.

Synthetic Seismograms:

Twenty nine wells were chosen to be used to create synthetics, also known as synthetic seismograms (Figure 10), and tie log picks to the seismic data. According to Schlumberger (2009), a synthetic is “a seismic trace at a wellbore generated from wireline log data. Synthetic seismograms are generated by calculating reflection coefficients from the sonic and density logs and then applying an ideal or real wavelet to the reflections to obtain the seismic "wiggle" traces. Synthetic seismograms are usually generated to compare with the actual seismic data and identify reflectors with layers and formations already known in the wellbore” (Schlumberger, 2009). In order to determine which wells in the project area had sonic logs, the Petra database was searched and filtered to identify wells that had sonic data. From this new list of wells, the wells were located that had available sonic logs down through the deepest formation that was part of our study (in this case the Chester Limestone). In order to create the synthetic ties, the program GeoGraphix was employed to tie the log picks to the seismic data.

Ormsby and Ricker calculations were used to produce synthetics. The Ormsby filter (Figure 10) was used to tie the synthetic to the subsurface seismic data. The Ormsby filter, as defined by Sheriff (2002) is a filter of trapezoidal shape specified by four corner frequencies, f1, f2, f3, f4. The filter rejects below f2 and above f3, is linear from f1 to f2 and from f3 to f4, and flat from f2 to f3. The Ricker wavelet was used to construct the

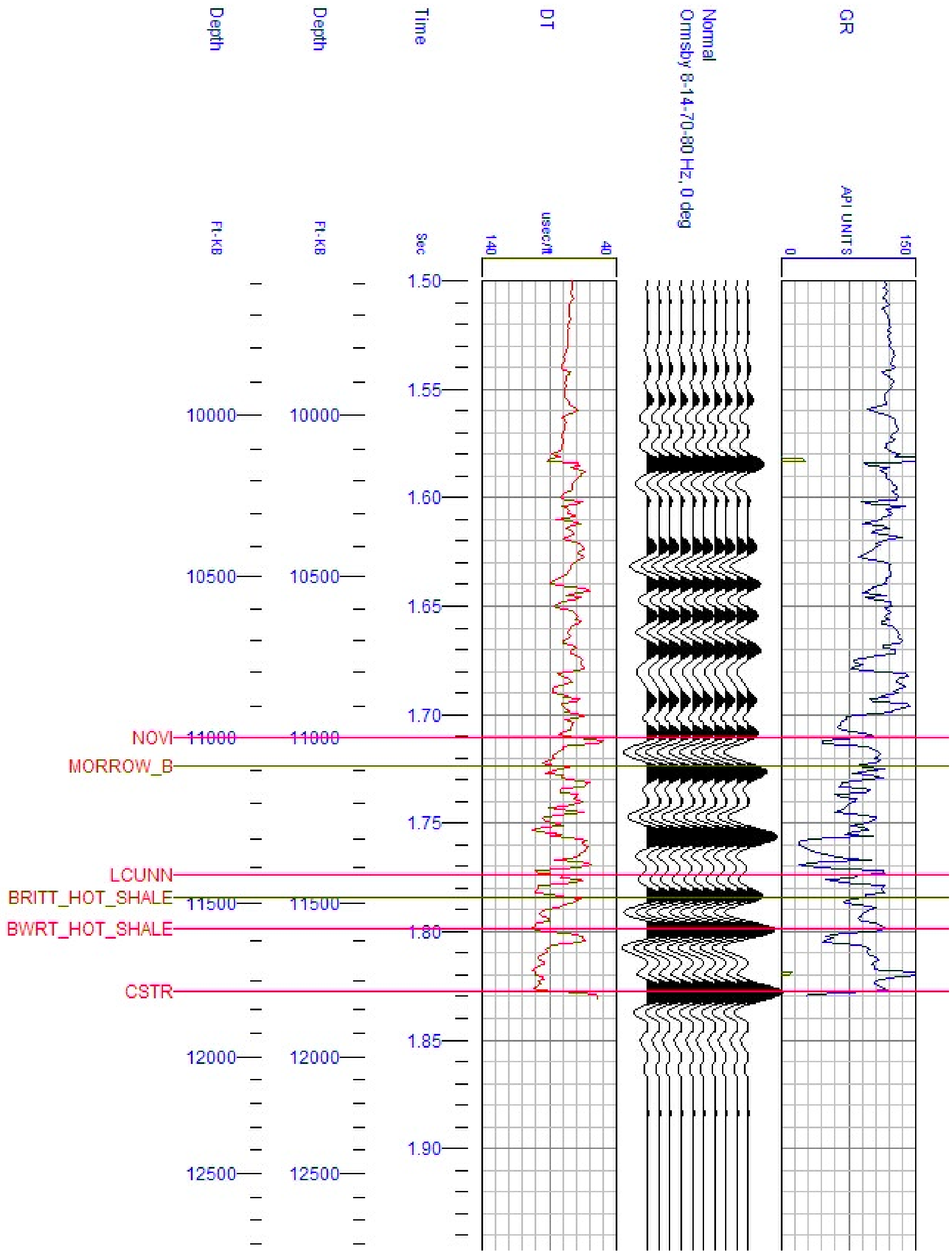

Figure 10. Typical synthetic seismogram in the study area. The position of reflectors compared to the sonic log and gamma ray curves is shown.

synthetic models. Sheriff (2002) defines the Ricker wavelet as a zero-phase wavelet, the second derivative of the Gaussian function or the third derivative of the normal probability density function and is often used in synthetic modeling.

Tying Synthetics to Wireline Log Stratigraphy:

After importing the sonic log into the synthetic creator, formation tops were added. For each formation top picked in Petra, Petra saved a depth value and listed the name of the formation top picked at that depth. It was necessary to manually input the depth values and assign the matching formation name to that value. After importing depths of the formations, a synthetic trace was generated and set to the same scale as the seismic data. This tied the well log data to the seismic data.

Synthetic Model:

After the synthetics were created, GeoGraphix was used to create a synthetic model that ran across the entire dataset to see how the synthetic ties behaved across the study area. Ricker wavelets were employed to generate the profile shown in Figure 11. In creating this model, it is important to compare the well log picks alongside an equally scaled synthetic model and an equally scaled seismic line to determine if the pattern (such as peak amplitude) are similar, and the seismic, seismic synthetic and wireline-log based cross section show similar features such as thinning, onlap, and truncation. Figure 11 is a montage that shows all three interpretations.

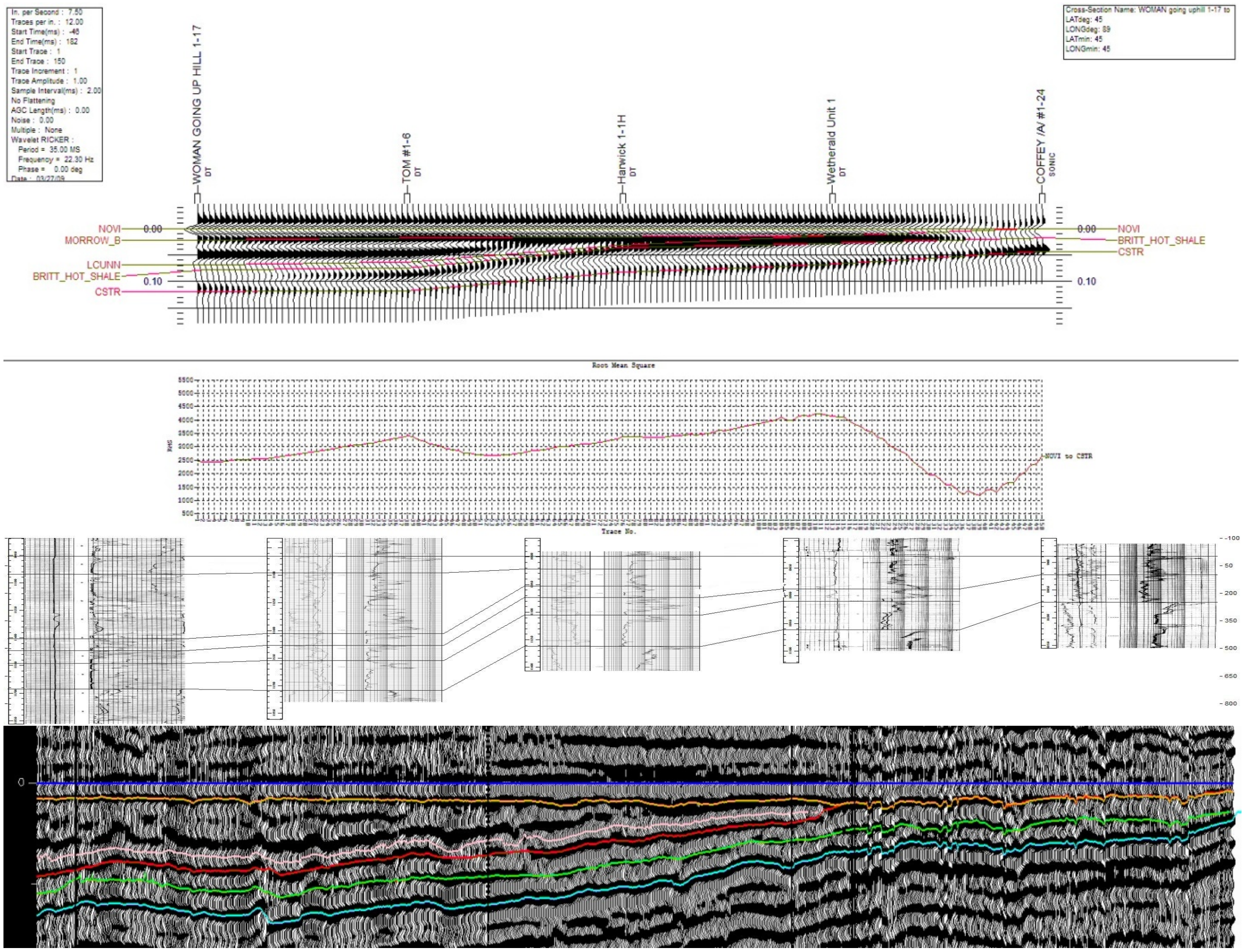

Figure 11. Synthetic model, well log correlation and seismic line comparison showing the similarities between the patterns of stratification and truncation.

Tuning Effects:

When analyzing these three models: wireline log, synthetic seismic and seismic, the apparent thinning to the east is obvious as is the thickening of the interval in the western part of the study area. All three models show similar thinning of the overall package and when the black peaks of the synthetic converge, a spike develops in the total amplitude, and a decrease in vertical resolution results. The amplitude decreases after the peaks become one solid peak. This is evident in the amplitude curve shown in Figure 11. This "spike" in the amplitude is called a tuning effect.

A tuning effect is defined as “a phenomenon of constructive or destructive interference of waves from closely spaced events or reflections. At a spacing of less than one-quarter of the wavelength, reflections undergo constructive interference and produce a single event of high amplitude. Tuning effects are evident in Figures 12, 13, and 14. At spacing greater than one quarter of the wavelength, the event begins to be resolvable as two separate events. The tuning thickness is the bed thickness at which two events become indistinguishable in time, and knowing this thickness is important to seismic interpreters who wish to study thin reservoirs” (Schlumberger, 2009). It is also important to determine the frequency of the data and what the overall tuning thickness (that is, the thickness that two amplitudes can be interpreted before the two amplitudes can’t be distinguished from each other). Tuning thickness is found by using this equation:

$$\text{Tuning Thickness} = \lambda/4$$

Where λ is the wavelength. In order to find the wavelength, this equation had to be used:

$$\lambda = V/f$$

Where V is the velocity and f is the frequency of the interval.

In windowing the data between the Chester Limestone and the Novi Limestone, the frequency of the data could be obtained (Figure 15). The average frequency of this windowed area was determined to be approximately 40-50 Hz. After discovering what the average frequency of the data was, an average velocity was calculated for the interval between the Boatwright Hot Shale and Britt Hot Shale using the sonic log. It was determined that the average velocity was around 11,100 ft/sec, therefore the wavelength was found to be approximately 220 ft. The tuning thickness is thus found to be around 55-60 feet, so it can be determined that the Boatwright Hot Shale and Britt Hot Shale can be interpreted accurately provided the beds never get closer than 55-60 feet apart. After confirming that the data appeared to produce similar patterns, the individual synthetics were printed so that they could be manually tied in to the seismic dataset.

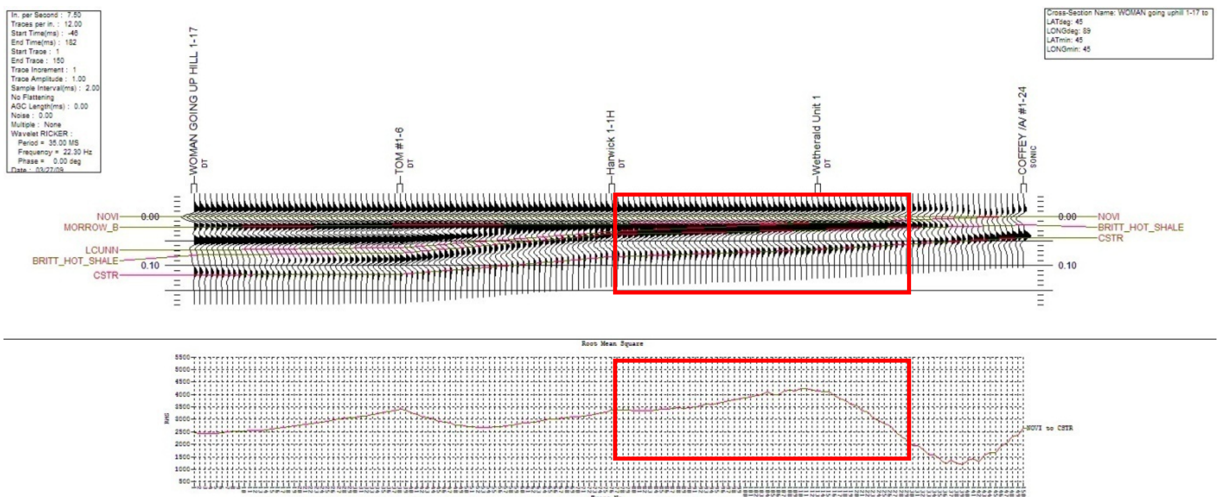

Figure 12. Synthetic model that shows tuning effects

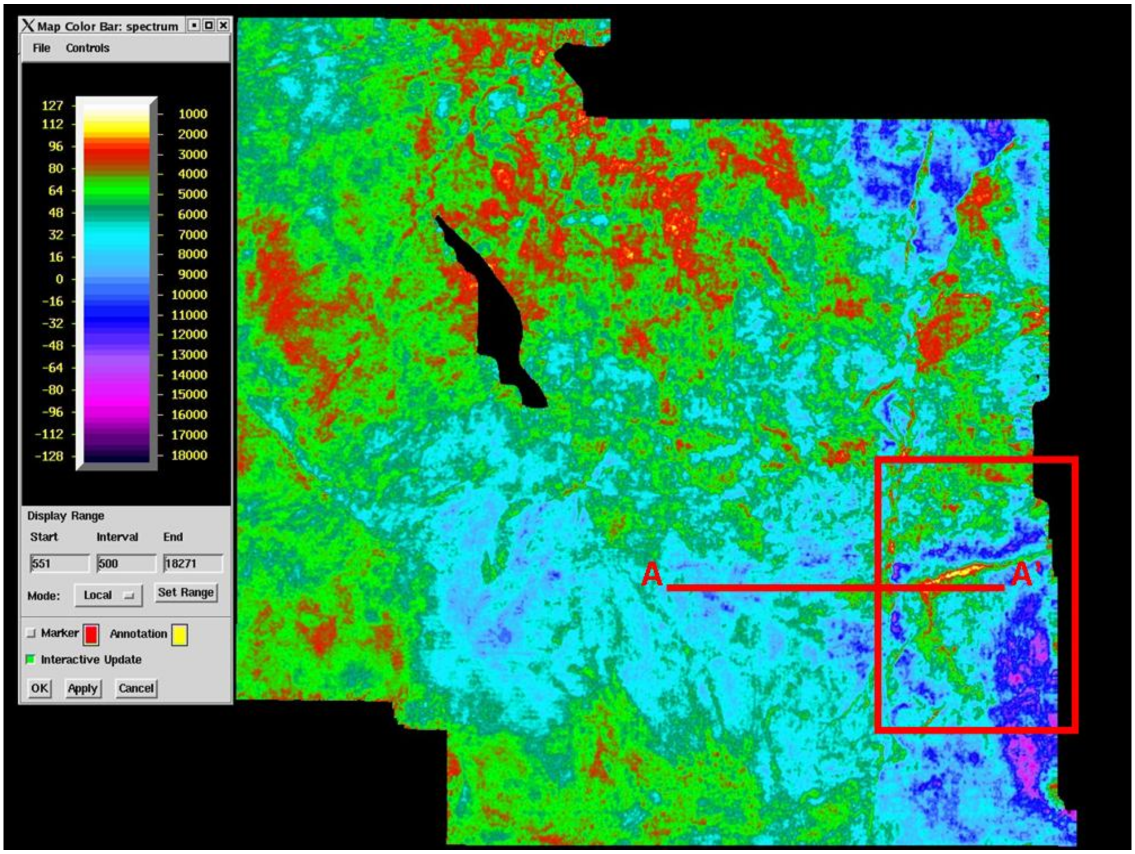

Figure 13. Tuning effects as indicated by the < shape seen in the red box in the map of the Chester Limestone to Novi Limestone isochron

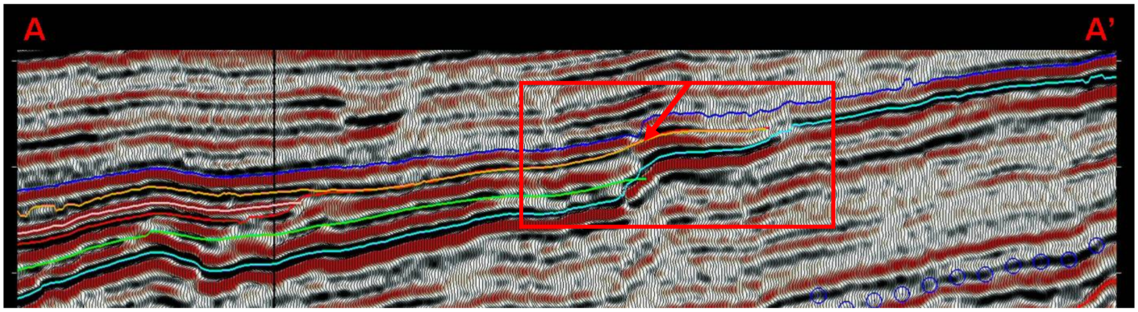

Figure 14. Tuning effects in seismic profile as evidenced by seismic reflectors that converge into a single event (arrow within box).

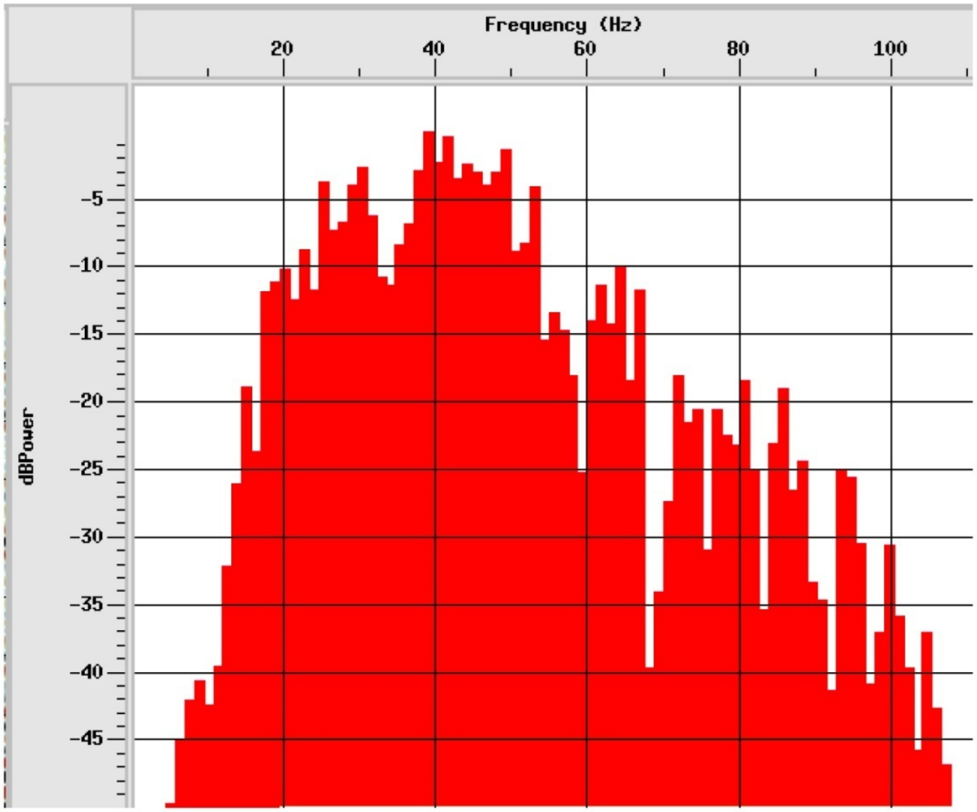

Figure 15. Chart comparing frequency distribution and power in decibels (dB).

The synthetics were printed and SeisWorks, a program to view seismic data, was used to retrieve a seismic line that contained several wells used to create synthetics. A scaled plot of the seismic line was printed at the same scale as the synthetics created in GeoGraphix. After printing the seismic line, the synthetics were matched to well paths displayed on the seismic line and marked where each stratigraphic unit of interest tied into the seismic data. After initially marking the paper copy of the seismic line, SeisWorks was used to mark the formation tops in the 3D dataset. Synthetics were distributed across the entire 3D dataset to ensure the most accurate interpretation. This is important because seismic data can be very deceptive and it is sometimes difficult to determine where the boundaries between beds, especially the lateral continuation based on vertical resolution occur. Generating synthetics throughout the entire dataset increases the validity of the interpretation and the accuracy of any subsequent work.

Isochron and Time Structure Maps:

Interpretation began by locating wells with synthetic ties and selecting a small geographical area around each well to be interpreted so that the geophysical interpretation in between wells could be more accurate. The first unit interpreted was the Chester Limestone, which is a strong seismic reflector throughout the entire survey. After interpreting the Chester Limestone, the interpretation was extended to the Boatwright Hot shale, Britt Hot shale, Lower Cunningham, Morrow, and the Novi Limestone. Also, while using SeisWorks, isochron maps were created that displayed the total thickness between the horizon intervals in time (Figure 16). These isochron maps were generated for the intervals of the Chester Limestone to the Novi Limestone (Figure 17), the Chester to Boatwright Hot Shale (Figure 18), the Boatwright Hot Shale to the Britt Hot Shale (Figure 19), the Britt Hot Shale to the Lower Cunningham, the Lower Cunningham to the Morrow (Figure 20), the Britt Hot Shale to the Morrow, and the Novi to the Morrow (Figure 21).

After completing the interpretations of these horizons and these isochrons in SeisWorks, the horizon values were imported into a mapping program called Petrosys. In Petrosys, it was possible to import the horizons interpreted in SeisWorks and make clearly defined, smooth time maps that were able to define the structural attitude for the Chester Limestone (Figure 22), the Boatwright Hot Shale, Britt Hot Shale, Lower Cunningham, Morrow, and the Novi formations.

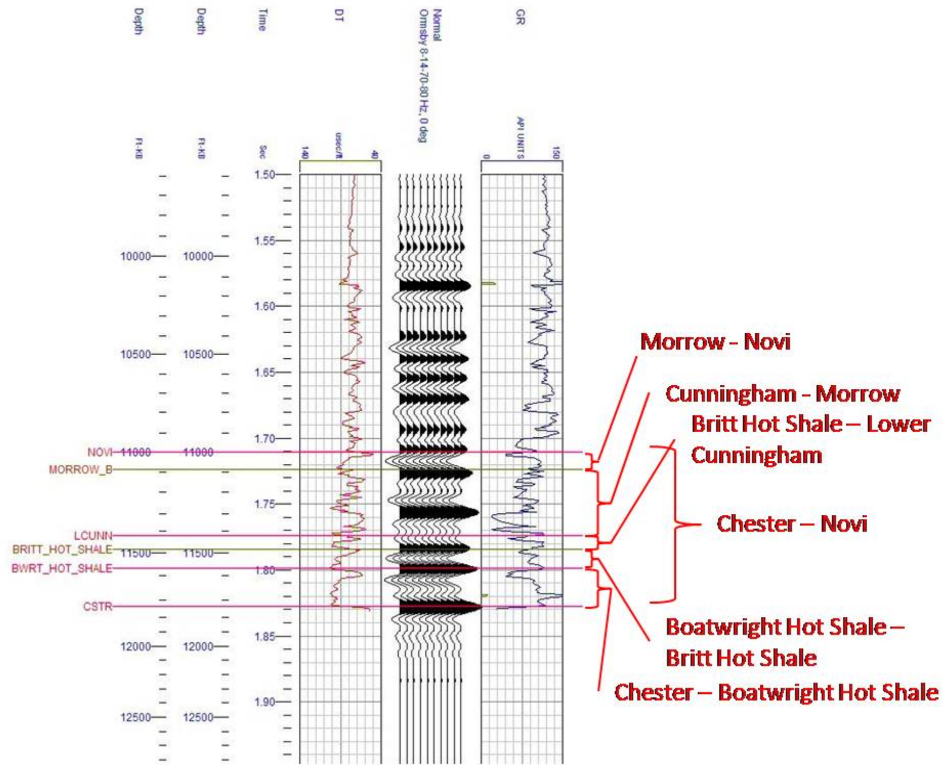

Figure 16. Synthetic with isochron intervals displayed. The Britt Hot Shale marks the base of the Cunningham shale. The Boatwright Hot Shale marks the base of the Britt shale interval. The "hot shale" nomenclature was used due to the ability to recognize these boundaries on wireline logs.

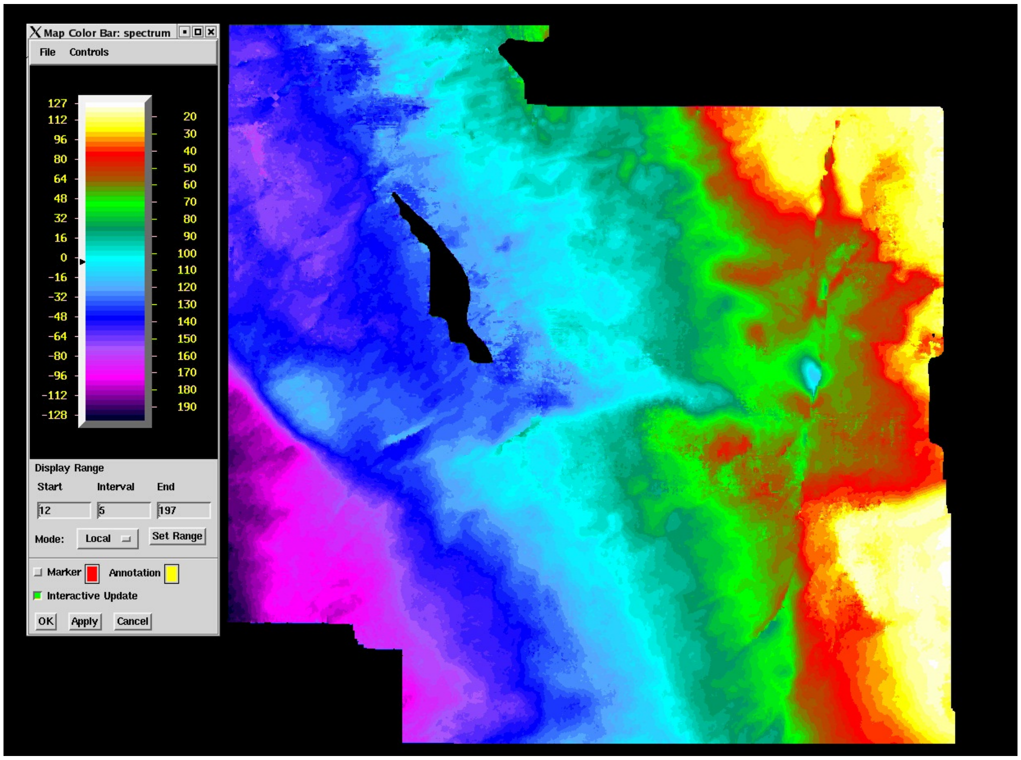

Figure 17. Chester Limestone to Novi Limestone isochron. Cooler colors indicate thicker interval; hotter colors indicate thinner interval.

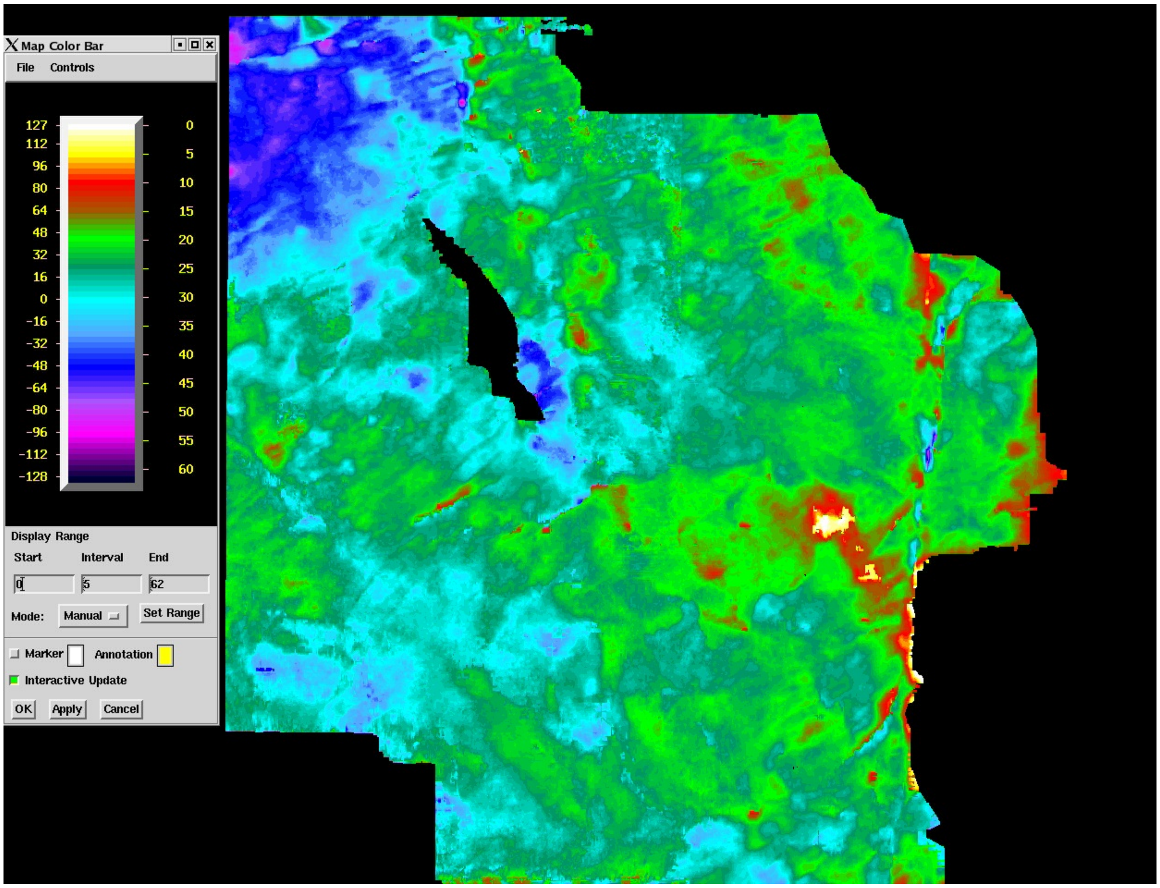

Figure 18. Chester Limestone to Britt shale base (Boatwright Hot Shale) isochron. Cooler colors indicate thicker interval; hotter colors indicate thinner interval.

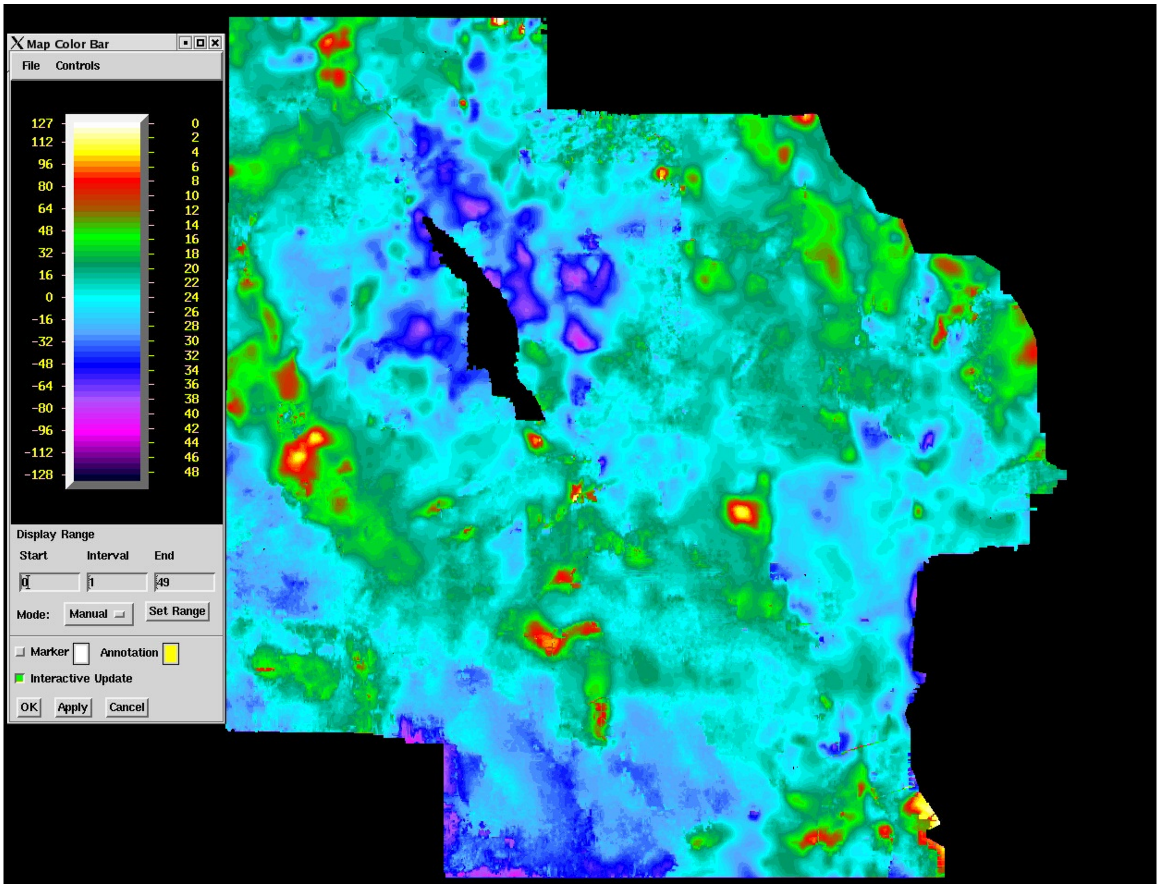

Figure 19. Britt shale base (Boatwright Hot Shale) to the Cunningham shale base (Britt Hot Shale) isochron. Cooler colors indicate thicker interval; hotter colors indicate thinner interval.

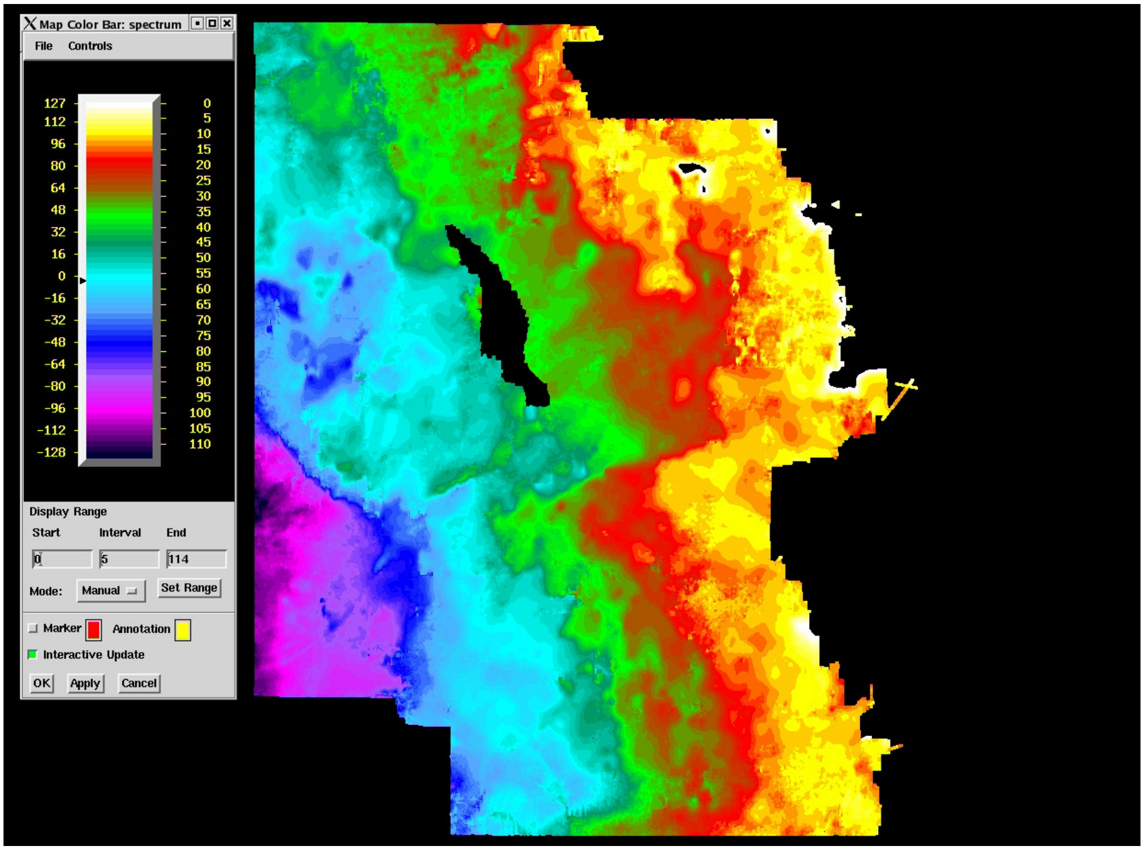

Figure 20. Lower Cunningham sandstone to the Morrow base isochron. Cooler colors indicate thicker interval; hotter colors indicate thinner interval.

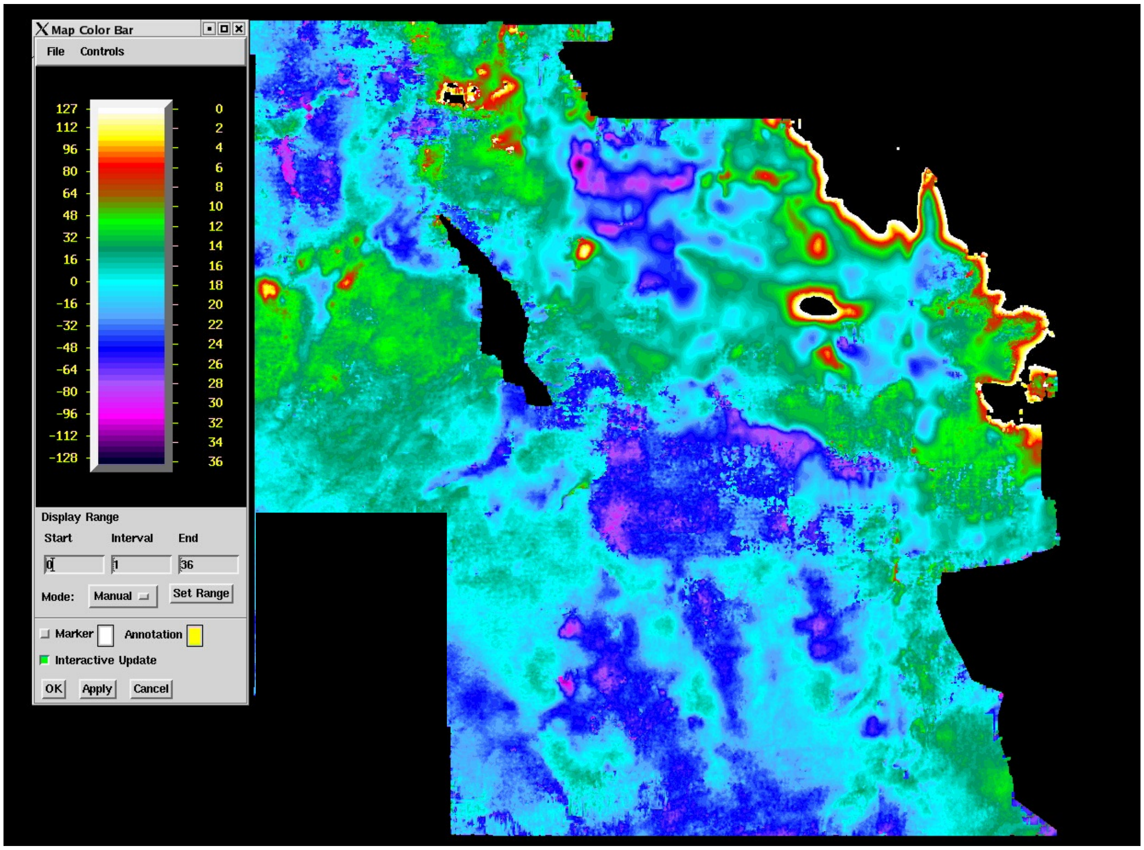

Figure 21. Morrow base to Novi limestone isochron. Cooler colors indicate thicker interval; hotter colors indicate thinner interval.

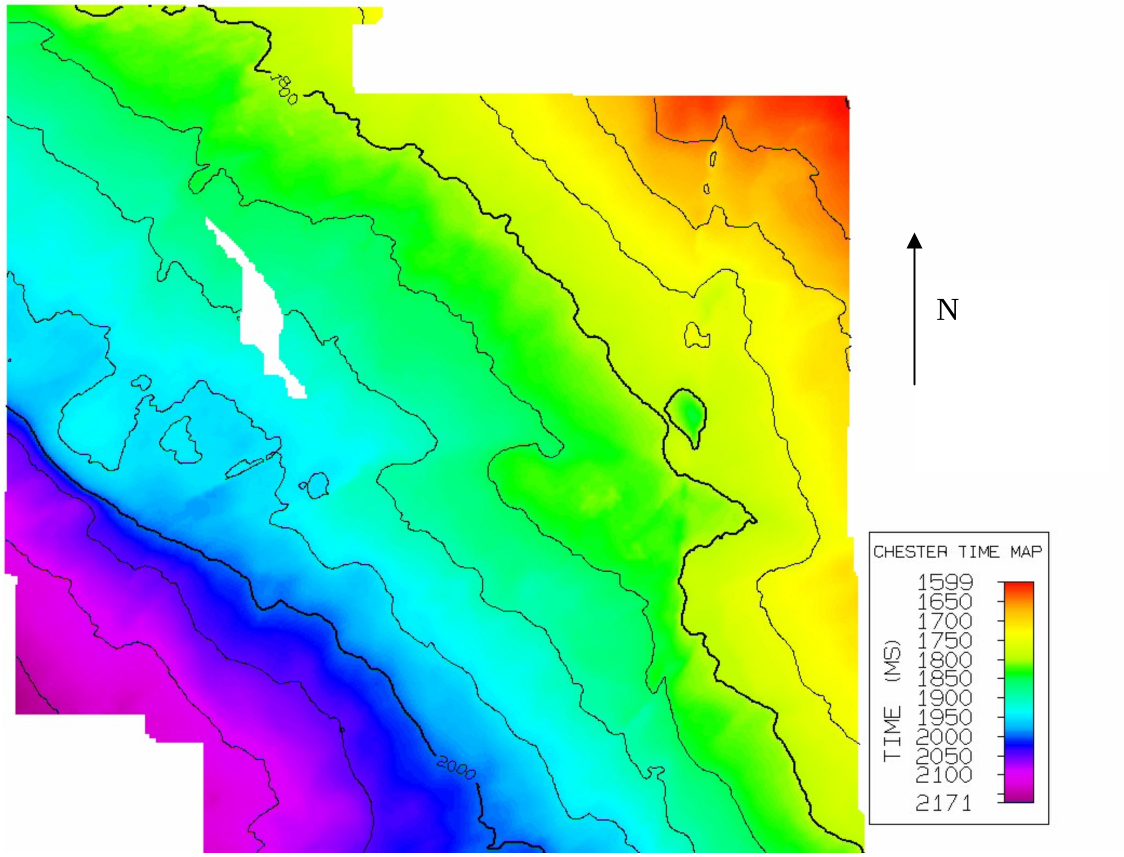

Figure 22. Chester Limestone time map showing increasing two-way travel time to the southwest (deepening) and decreasing two-way travel time to the northeast (shallowing).

Velocity Calculation and Time to Depth Conversion:

The next step was to convert time maps into depth maps. The 1300 wells interpreted by Phillips (2009) to identify the position of the units, were imported into Petrosys and added to a database. To construct the depth map, the average velocity had to be calculated for each well imported into Petrosys. Once the average velocity at each well was calculated, a velocity map for each horizon could be generated that could then in turn be used to create a depth map. These computations were also done using the Petra software. To calculate the velocities for the entire survey, the following equation was used:

$$V = D/T$$

Where V is the velocity in feet/second, D is the depth in feet and T is the time in seconds for the formation top at the selected well. However, the seismic data used in SeisWorks was in two-way time and in milliseconds, so the equation used became:

$$V = 2000D/TWT$$

Where V is the velocity in feet/second, D is the depth in feet and TWT is the two-way time in seconds. The well log database that was imported into Petrosys was opened and the time values from the time horizon in SeisWorks were added and velocity maps for the Chester Limestone (Figure 23), the Boatwright Hot Shale, Britt Hot Shale, the Lower Cunningham, Morrow, and the Novi formations were created. After creating these velocity maps, the depth map of the area was generated using the equation:

$$D = VT/2000$$

Velocity was multiplied by the time value map and divided by 2000 (since the time map was from SeisWorks, it was in two way time and in milliseconds and not seconds) to get the depth maps for the Chester Limestone (Figure 24), the Boatwright Hot Shale, Britt Hot Shale, the Lower Cunningham, Morrow Base, and the Novi Limestone.

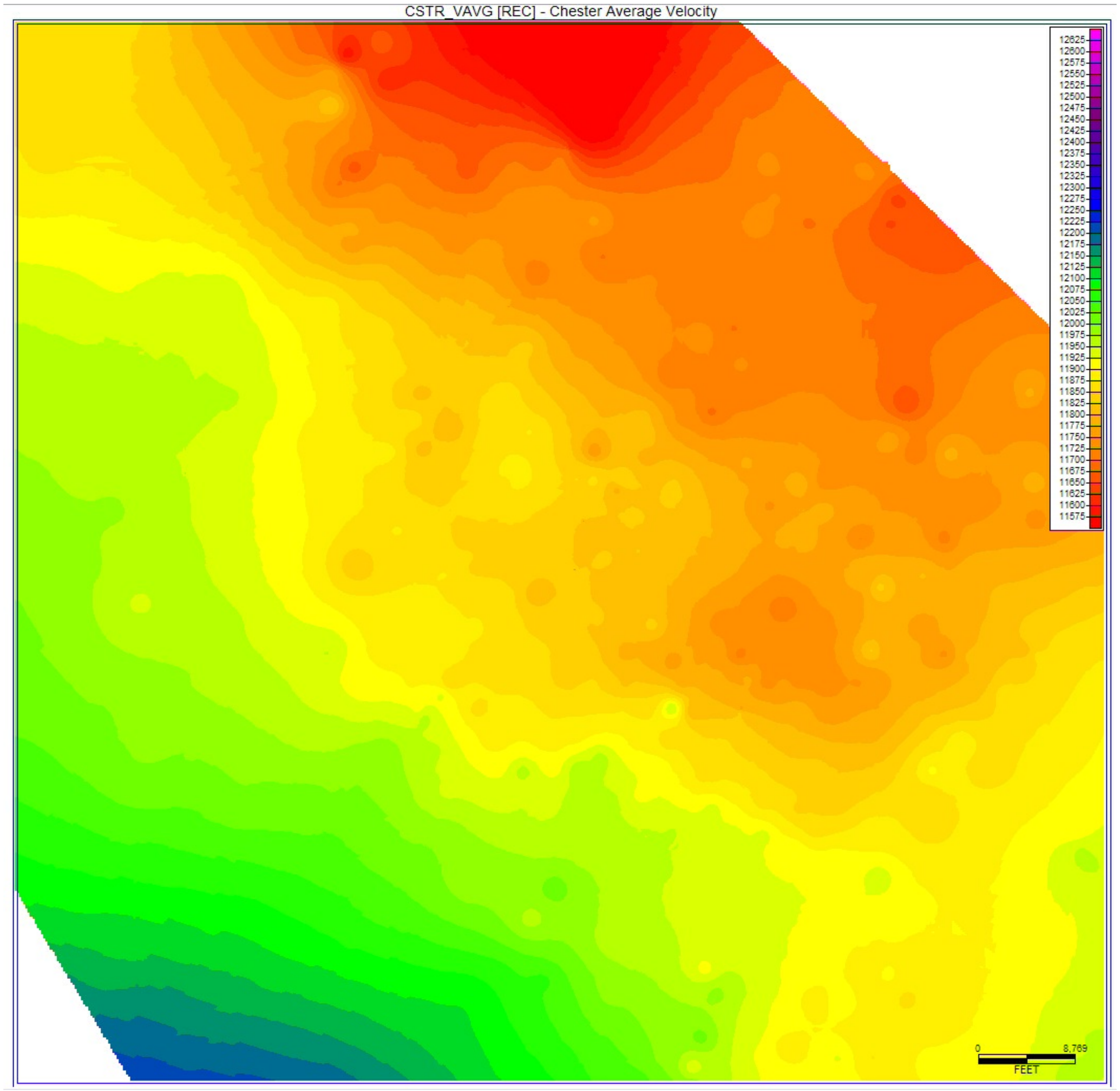

Figure 23. Map showing the average velocity from the surface to the top of the Chester Limestone. Average Velocity Ranges from 11,575 ft/sec to 12,625 ft/sec. The velocities follow the same general trend as seen in the two-way time map in Figure 20

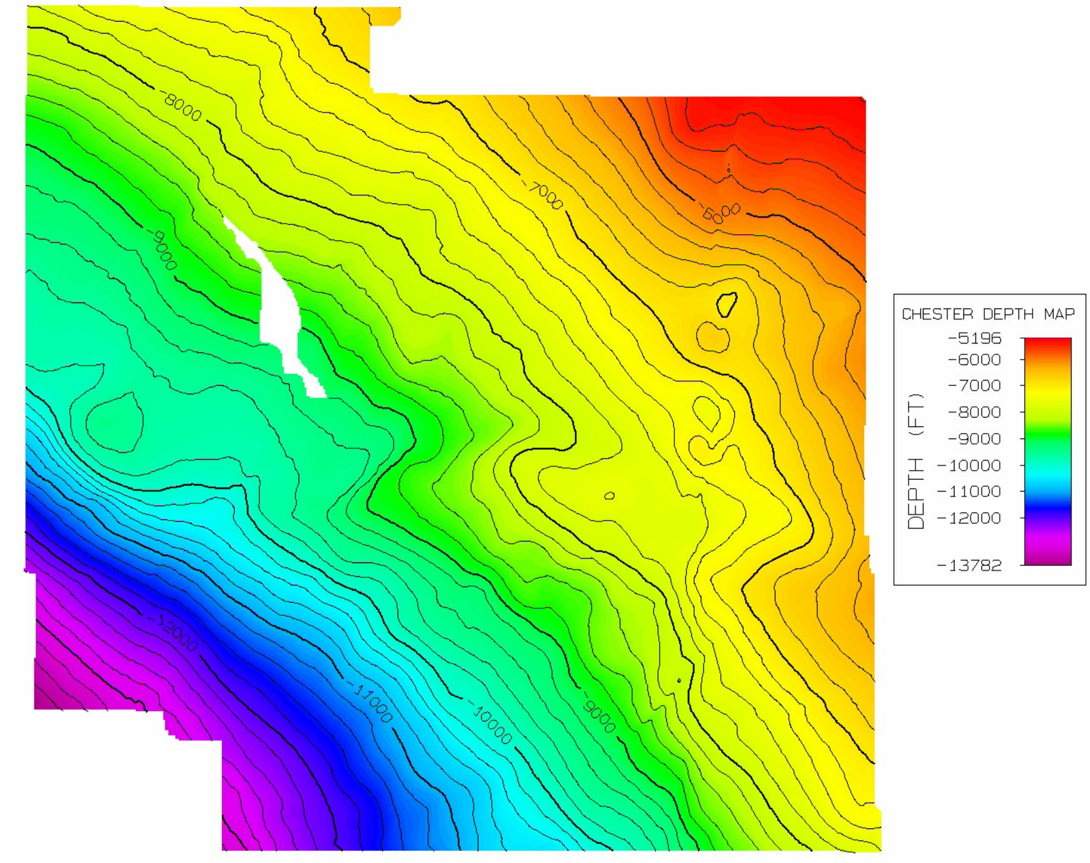

Figure 24. Chester Limestone depth map showing southwestern deepening of the top of the Chester Limestone toward the basin axis.

RMS Amplitudes:

In addition, each of the interpreted horizons from SeisWorks was examined using RMS amplitude extractions via the StratAmp software to potentially identify geologic features such as a channel system or an amplitude anomaly. RMS (also known as root mean square) amplitude is defined as the square root of the average of the squares (in this case, the average of the amplitudes in between the selected intervals) of a series of measurements. The auto-correlation value (without normalizing) for zero lag is the mean square value (Sheriff, 2002). An amplitude anomaly is defined as “an abrupt increase in seismic amplitude that can indicate the presence of hydrocarbons, although such anomalies can also result from processing problems, geometric or velocity focusing or changes in lithology. Amplitude anomalies that indicate the presence of hydrocarbons can result from sudden changes in acoustic impedance, such as when gas sandstones underlie a shale, and in that case, the term is used synonymously with hydrocarbon indicator" (Schlumberger, 2009). RMS amplitude extractions were taken for the following intervals: (1) the Chester Limestone to the Novi Limestone (Figure 25), (2) the Chester Limestone to Boatwright Hot Shale, (3) the Boatwright Hot Shale to the Britt Hot Shale, (4) the Britt Hot Shale to the Lower Cunningham sandstone, (5) the Lower Cunningham sandstone to the Morrow Base, (6) the Britt Hot Shale to the Morrow Base, and (7) the Morrow Base to the Novi Limestone.

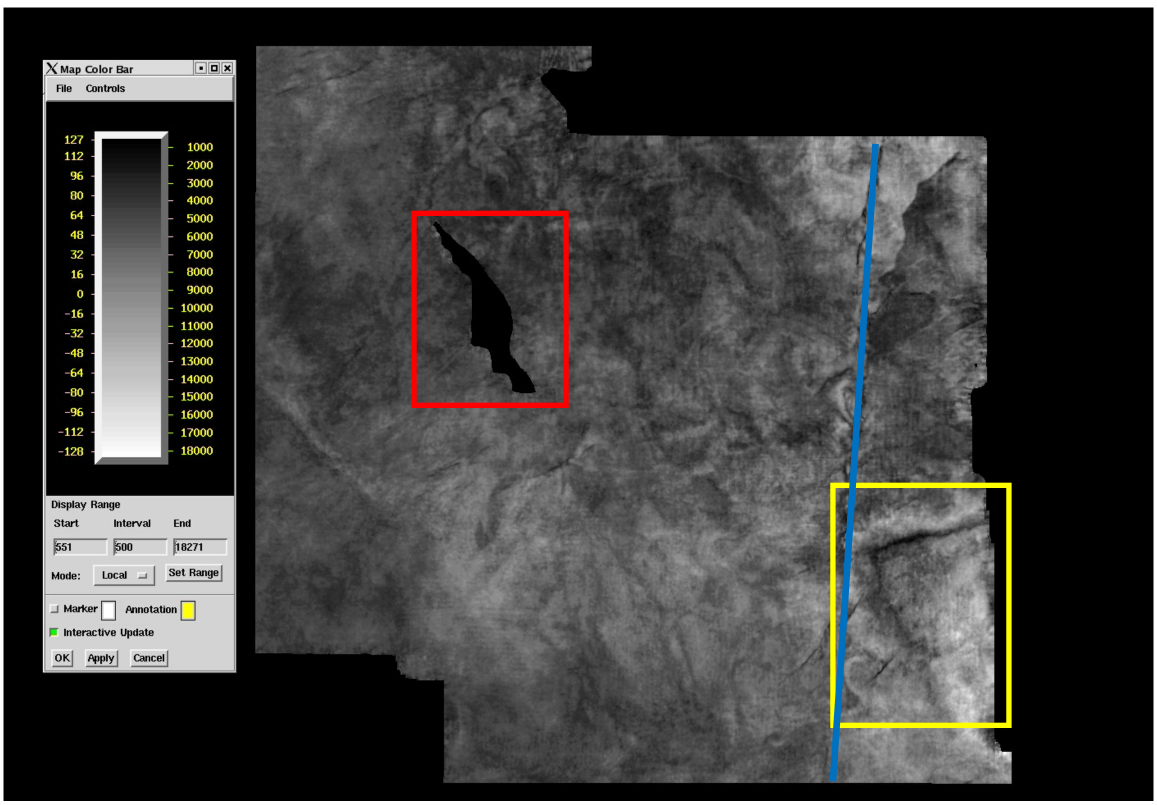

Figure 25. Map showing the amplitude extractions for the interval between the Chester Limestone and the Novi Limestone. Notable features Include: (1) interpreted apparent fault (blue line) (2) Hole in seismic data due to the town of Geary, OK (red box) and (3) tuning effect on the east side of the study area (yellow box)

CHAPTER IV

FINDINGS

Examination of the Chester Limestone to the Novi Limestone isochron map (Figure 26) reveals several features that are noteworthy. The red arrow in Figure 26 marks an area where there is significant thinning in the total thickness between these two limestones; the white arrow marks an area of thickening of the interval along the north-south trending lineament that is interpreted using seismic lines to be a fault (blue line). The yellow arrow in Figure 26 denotes an area that appears to be a structural high in the western part of the study area. Seismic lines taken through this feature confirm that it is a structural high. One of these lines (A-A' in Figure 26) is shown in Figure 27. Critical east dip is evident on the section immediately to the right of the vertical lines that represent wells.

The Chester Limestone to Boatwright Hot Shale isochron (Figure 28) shows that there is an apparent substantial thickening of this interval in the northwest part of the study area (shown as box on Figure 28). A northwest to southeast trending seismic line through the area (Figure 29) shows the thickening of the Chester Limestone to Boatwright Hot Shale interval. This thicker area map represents a depocenter and therefore has potential for higher accommodation and sand accumulation. Figure 30, the Cunningham shale (Britt Hot Shale) to Britt shale base (Boatwright Hot Shale) isochron,

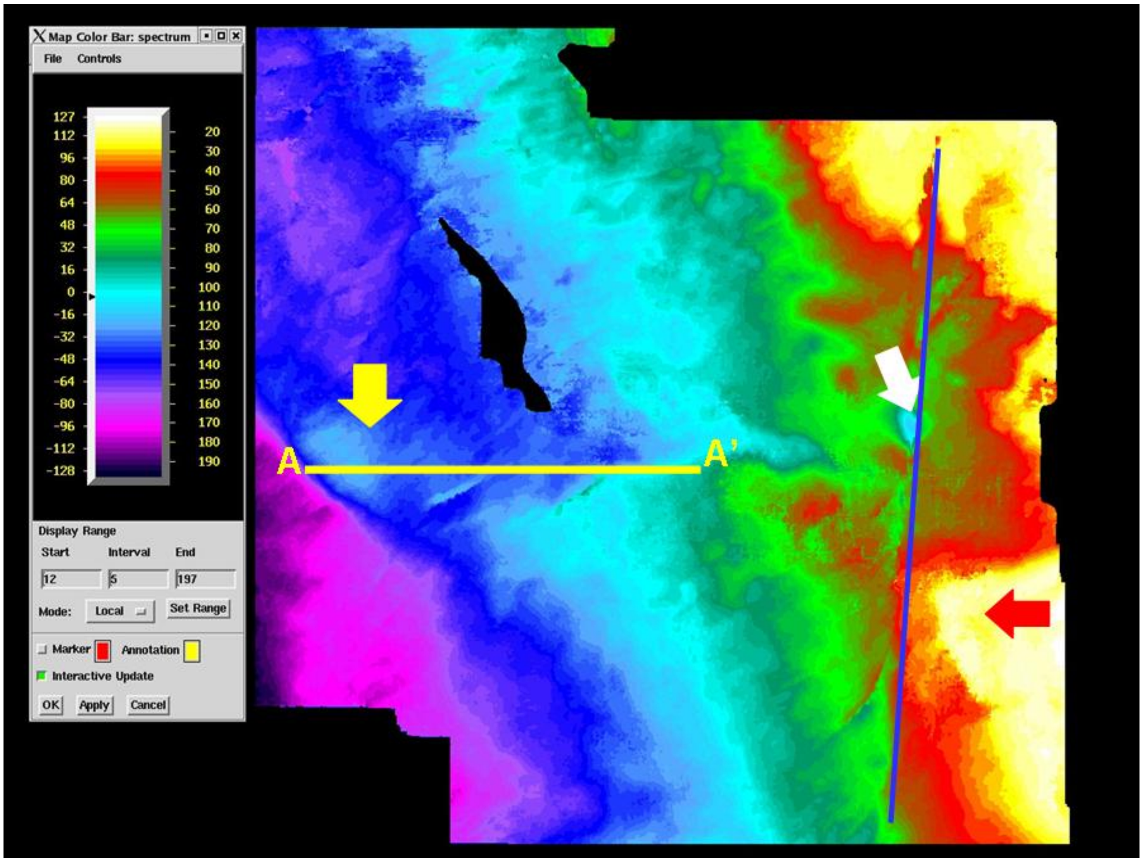

Figure 26. Chester Limestone to Novi Limestone isochron. Notable features include: (1) area where there is significant thinning in the total thickness between these two limestones (red arrow), (2) North-south trending lineament that appears to be a fault (blue line), (3) area of thickening along the fault (white arrow), and (4) an area that appears to be a structural high in the western part of the study area (yellow arrow)

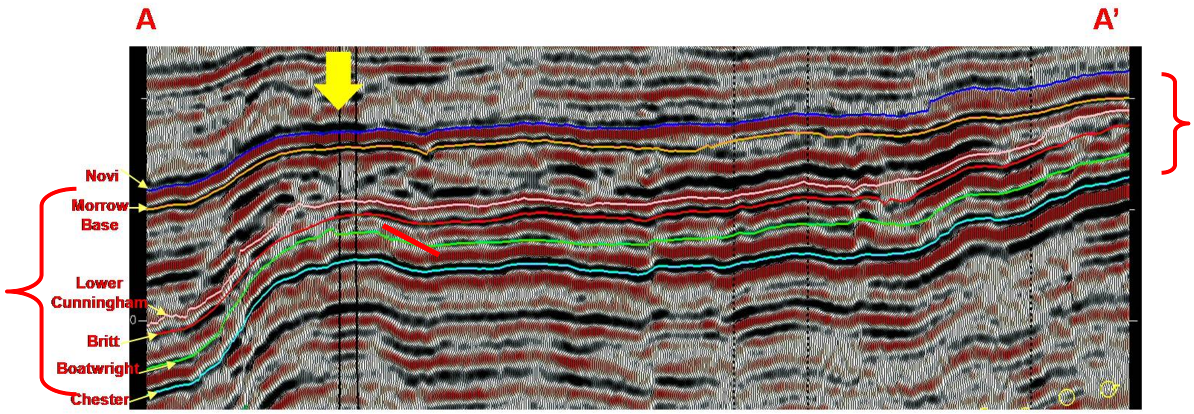

Figure 27. A-A' Seismic line through structural high (yellow arrow) identified in Figure 26. This seismic section shows critical easterly dip to the right (east) of vertical lines representing wells. This dip is identified by the red reference line. Critical north dip is evident in seismic lines not shown in this thesis.

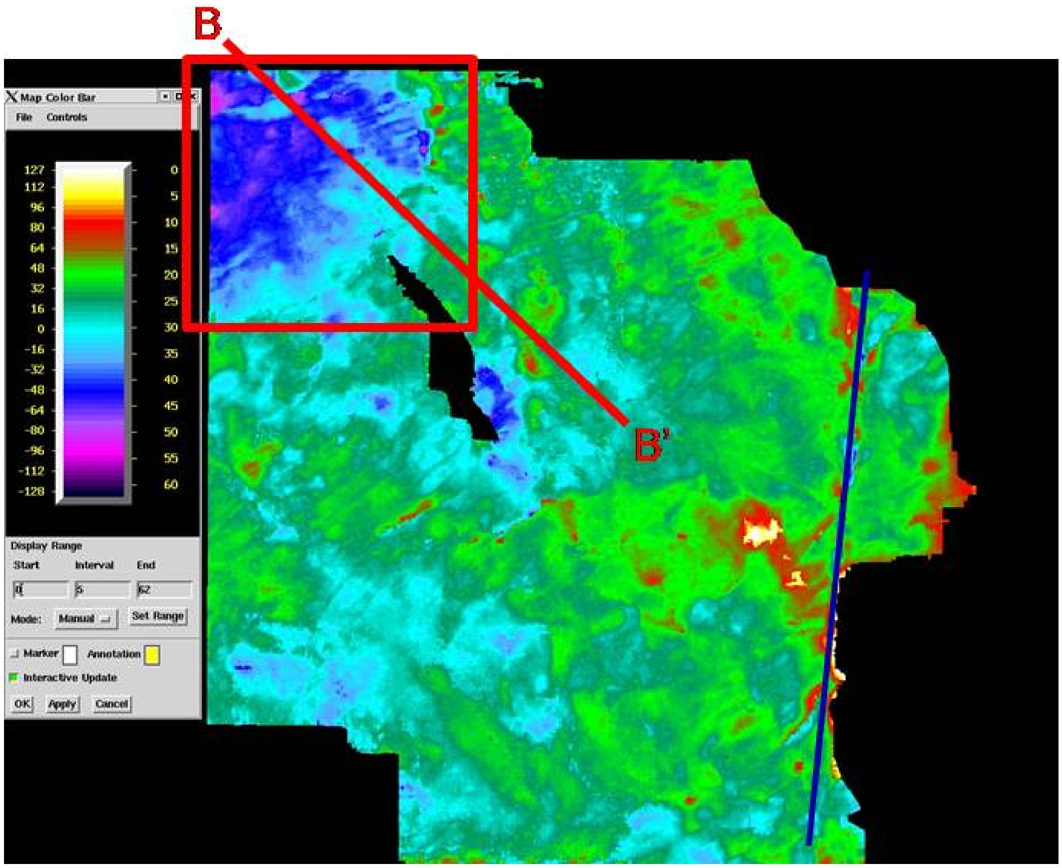

Figure 28. Chester Limestone to Britt shale base (Boatwright Hot Shale) isochron map showing an apparent thickening in the northwest part of the study area. Seismic B-B' is shown in Figure 29. Thickening implies greater accommodation during Boatwright time and potential thick sandstone bodies. Color scale ranges from 0ms to 60ms.

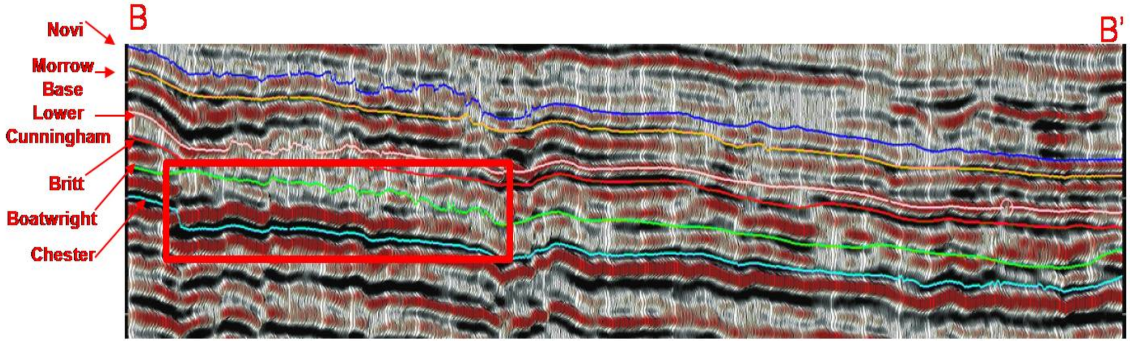

Figure 29. Northwest to southeast trending seismic line B-B' through thickening of Chester Limestone-Britt shale base (Boatwright Hot Shale) interval. Location of B-B' is shown in Figure 28

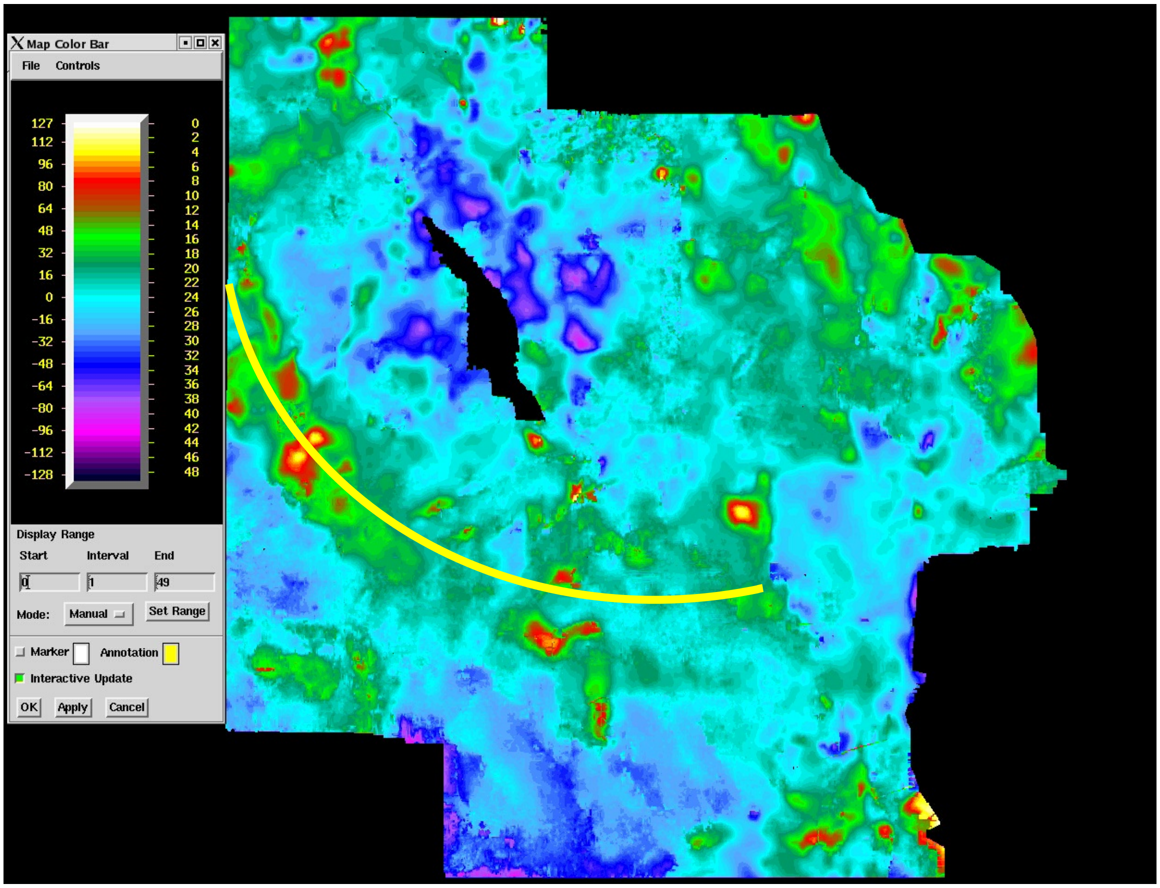

Figure 30. Britt shale base (Boatwright Hot Shale) to the Cunningham shale (Britt Hot Shale) isochron showing apparent thinning along the yellow line

indicates that there is an apparent thinning of the beds along the area which include the structural high identified in Figures 26 and 27. This arcurate trend of thinning is shown by the yellow line. The Novi Limestone to Morrow Base isochron also identifies several interesting features. In the one area of the study, a fork-like feature is evident where the thickness between the Novi to Morrow is greater. A seismic line (C-C') is taken through this feature indicates there are two distinct channel-like features in the Morrow interval. These are not shown due to the proprietary nature of this data.

The RMS amplitude extractions for the Chester Limestone to the Novi Limestone (Figure 31) interval indicate several features identified in previous images. These include the interpreted fault (blue line trending north to south), which is clearly visible. The red arrow points towards the tuning effect caused by the pinching out and convergence of multiple beds. This thinning occurs off the southeast flank of the anticline and thinning trends identified in Figures 17, 18, 19, 20 and 21. The thickening is abrupt and may be evidence for syndepositional tectonics, possibly deep-seated faulting. The anticlinal feature was reactivated during the Pennsylvanian Orogen to give the structure shown in Figure 27.

Other RMS amplitude extractions were generated including Boatwright Hot Shale to Britt Hot Shale, which shows several distinct channel-like features in the southeastern part of the study area. Seismic sections and well log data in this area confirms these channel-like features. The seismic line indicates changes in amplitude that correspond to thick sandstone bodies identified on well logs. These amplitude changes are absent in the area where well logs indicate only shale in the interval. The Morrow Base to Novi Limestone RMS amplitude extraction map also indicates channel-like features including

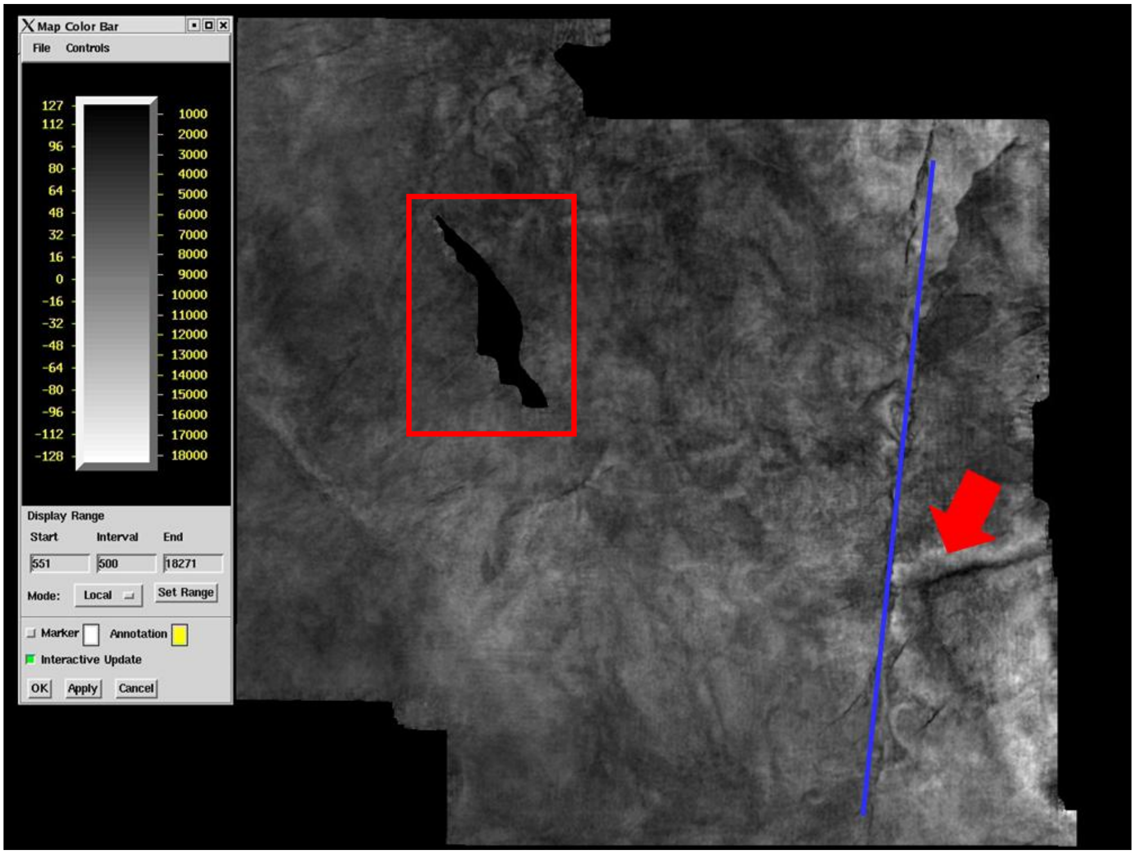

Figure 31. Chester Limestone to the Novi Limestone RMS amplitude map with three distinct features: (1) the North-South trending lineament that appears to be a fault (blue line), (2) V shaped anomaly that represents tuning thickness (red arrow), and (3) No seismic data due to the town of Geary, OK (red box)

one that trends northeast to southwest across the study area. This channel was confirmed with seismic sections and using the Boatwright Hot Shale to Britt Hot Shale RMS extraction analog. This channel appears to bifurcate and was evident on the Novi Limestone to Morrow Base isochron. An east west seismic line confirmed this channel-like feature. All amplitude maps generated appeared to identify channel-like features.

In the Chester Limestone to the Morrow Base interval, channel-like features have a northwest to southeast trend. In contrast, channel-like features identified on the Novi Limestone to Morrow Base amplitude map have a northeast to southwest trend. Present tectonic dip is to the southwest and most stratigraphic units thicken in this direction, which is evidence of a southwestern depocenter during the Springer time. Based on this paleobasinal configuration, one would expect most channels to trend northeast to southwest. In order for the channels to be trending northwest to southeast, or parallel to paleobathymetry, paleo structural features and/or localized depocenters may have existed during this time in deposition. These features could have affected the direction of flow and influenced channel-like trends evident within the study area.

CHAPTER V

CONCLUSION

The process of converting raw seismic data into a form that can be interpreted and utilized for a variety of geological applications (specifically, the identification of sandstone) involves the collection and integration of data from several sources. This study is a part of a larger study comparing interpretation of an area using subsurface well logs and 3D seismic data. The goals of this study were to (1) test the hypothesis that 3D seismic can effectively image strata between well control points in the Springer interval; (2) test the hypothesis that seismic can effectively identify units (such as shales that represent prolonged marine conditions) necessary to construct a sequence stratigraphic framework; and (3) is 3D seismic an effective tool for identifying and mapping the distribution of thick sandstone bodies such as sandstone-filled channels within the Springer Formation. Based on the analysis of 3D seismic data with input of subsurface data from well logs, the following conclusions were formulated:

(1) Synthetic seismograms created from sonic and density well logs were correlated to seismic lines and found effective in identifying amplitudes that corresponded to the Chester Limestone, Britt shale base (Boatwright Hot Shale), Cunningham shale base (Britt Hot Shale), Lower Cunningham Sandstone, Morrow Base and Novi Limestone units.

(2) Seismic generated time maps effectively define structural attitudes of beds, identified lineaments interpreted as faults, internal stratigraphic thickness, and channel-like features.

(3) RMS amplitude extraction maps confirmed the features identified on isochron maps and enhanced the signature of channel-like features.

(4) Channel-like features in the Chester Limestone to Morrow Base (Boatwright to Britt to Cunningham to Morrow Base) appear to have a dominant northwest to southeast trend.

(5) Morrow Base to Novi Limestone interval channel-like features trend northeast to southwest.

(6) Channel-like features in the Boatwright to Britt interval were confirmed using seismic sections and well log control to contain thick sandstone bodies.

(7) Channel-like features in the Morrow Base to Novi Limestone interval were confirmed on seismic sections, but are not penetrated by wells.

(8) Seismic sections extended from the Novi Limestone datum show the apparent angular unconformity at the Morrow Base. The timing of the unconformity and subsequent subsidence of the basin may have affected Morrow channel trends.

Other seismic attributes in this area could be observed, potentially giving a more accurate interpretation and identification of channels and sandstone distribution. As it stands now, the information contained herein about the Anadarko Basin is a valuable starting point for any future projects in the area.

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VITA

Daniel James Fritz

Candidate for the Degree of

Master of Science

Thesis: USING SEISMIC DATA TO DELINEATE TECTONIC AND DEPOSITIONAL FEATURES WITHIN THE SPRINGER FORMATION, BLAINE, CANADIAN AND CADDO COUNTIES, OKLAHOMA

Major Field: Geology

Biographical:

Education: Graduated from Edmond North High School, Edmond, Oklahoma in May 2003. Graduated from Oklahoma State University, Stillwater, Oklahoma with a Bachelors of Science degree in May 2007. Completed requirements for the Master of Science degree with a Major in Geology at Oklahoma State University, Stillwater, Oklahoma in July, 2009.

Experience at Oklahoma State University:
Geology Research Assistant 2007-2009
Oklahoma State Ultimate Frisbee Club President 2007-2008
Oklahoma State Ultimate Frisbee Club Secretary 2005-2007

Work Experience:
Marathon Oil Corp., Intern
Offshore Gulf May 2007 - August 2007

Devon Energy Corp., Intern
Deepwater Gulf May 2008 – August 2008

Professional Memberships:
Association of American Petroleum Geologists (AAPG)

Name: Daniel J. Fritz Date of Degree: July, 2009

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: USING SEISMIC DATA TO DELINEATE TECTONIC AND DEPOSITIONAL FEATURES WITHIN THE SPRINGER FORMATION, BLAINE, CANADIAN AND CADDO COUNTIES, OKLAHOMA

Pages in Study: 46 Candidate for the Degree of Master of Science

Major Field: Geology

Scope and Method of Study: The Springer interval in an area of the eastern Anadarko Basin was analyzed using a 3D seismic dataset. The purpose was to determine if 3D could effectively image the rock volume between well control points. Specifically the study was designed to test the ability of 3D seismic to delineate tectonic features such as faults and depositional features such as thick sandstone bodies that are potential gas reservoirs. Seismic was also utilized to improve the stratigraphic framework by utilizing extensive marine shale deposits and the truncation of the Springer section against the Pennsylvanian unconformity.

Findings and Conclusions: Synthetic seismograms were created and found to be effective in correlating to several different stratigraphic units. Seismic data was able to effectively define structural attitude of beds, and was able to identify faults, internal stratigraphic thickness and channel-like features. RMS amplitudes were able to identify features seen on isochron maps and enhanced the view of the channel-like features. Channel-like features in the Chester Limestone to Morrow Base interval have a northwest to southeast trend, whereas in the Morrow Base to Novi Limestone interval, the channel-like features trend northeast to southwest. Channels were confirmed using seismic sections and well logs. Seismic sections show the apparent angular unconformity at the Morrow Base. Subsequent basinal subsidence may have affected the trends of Morrow channels.

ADVISER’S APPROVAL: Jim Puckette