# INTERPRETATION OF THE UPPER RED FORK VALLEY IN THE ANADARKO BASIN: A COMPARISON STUDY BETWEEN PROCESSED, REPROCESSED, AND HIGH FREQUENCY SEISMIC DATA

By

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SEISMIC DATA

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LIST OF GEOPHYSICAL TERMINOLOGY (in alphabetical order)
(Sheriff, 1991)

1. **Band-pass filter:** part of a system that discriminates against some of the information entering it, usually on the basis of frequency; the very low frequencies and the very high frequencies are filtered out

2. **Bandwidth:** the range of frequencies over which a given device is designed to operate within specified limits

3. **Coherency:** frequency-domain concept analogous to correlation in the time domain

4. **Convolution (convolved):** change of waveshape as a result of passing through a linear filter

5. **Deconvolution:** process designed to restore a waveshape to the form it had before it underwent a liner filtering action

6. **Density log:** well log that records formation density

7. **Fold:** the multiplicity of common mid-point data or the number of midpoints per bin; the fold is increased by increasing the number of midpoints in each bin which increases the view of the subsurface

8. **Fourier transformation:** refers to the formulas that convert a time function into its frequency representation

9. **Geological model:** a concept from which one can deduce effects for comparison to observations; used to develop a better understanding of the observations (also referred to as model)

10. **"HFI":** high frequency imaging; the "HFI" seismic data has been processed to extend the bandwidth of seismic data beyond conventional techniques such as spectral whitening and deconvolution; it allows interpreters to see subtle features as well as subtle faulting and very fine depositional sequences (from Geotrace Technologies and Seismic Ventures, Inc.)

11. **Horizon:** the surface separating two different rock layers

12. **Horizontal resolution:** ability to define a bed laterally

13. **Noise:** any unwanted signal or disturbance that does not represent part of a message from a specified source

14. **Ormsby wavelet:** filter of trapezoid shape specified by four corner frequencies, f1, f2, f3, and f4; the filter rejects below f2 and above f3, is linear from f1 to f2, and f3 to f4, and is flat from f2 to f3

15. **Poststack migration:** refers to the migration of stacked data

16. **Prestack migration:** refers to migration performed before stack is done to avoid the reflection-point smearing of dipping reflections and to accommodate strong lateral velocity gradients

17. **Reflection coefficient:** the ratio of the amplitude of the displacement of a reflected wave to that of the incident wave

18. **Refraction statics:** corrections to reflection traveltimes based on first arrivals attributed to refraction travel paths that involve the base of the near-surface low velocity layer

19. **Sonic log:** a well log of the traveltime for seismic waves per unit distance, usually measured in microseconds per foot, which is the reciprocal of the P-wave velocity

20. **Spectral decomposition:** uses smaller windows for Fourier transforming and displaying the frequency-domain spectra

21. **Spectral whitening:** to adjust the amplitudes of all frequency components within a certain band-pass to the same level; method of deconvolving

22. **Synthetic sonic log:** sonic log manufactured from seismic data (also referred to as synthetics)

23. **Vertical resolution:** ability to define the top and base of a bed

24. **Zero-phase:** a filter for which the phase shift is zero for all frequencies; it is the shortest possible wavelet for any given spectrum

# INTRODUCTION

The Pennsylvanian (Desmoinesian) Red Fork interval is a major oil and gas producer in Oklahoma. The Red Fork interval is primarily composed of sandstone and shale with thin interbedded limestones and coals. The Red Fork sandstone is of fluvial origin in northeast Oklahoma. The southerly flowing stream formed a large deltaic complex and shallow marine sand deposits (Al-Shaieb, 2002). In central and northern Oklahoma, a large amount of the Red Fork sand was deposited in channels incised directly into shale. West of the Nemaha uplift and central Oklahoma fault zone, subsidence of the Anadarko basin allowed the accumulation and preservation of thick deltaic sequences. Red Fork deposits in western Oklahoma are extremely diverse, consisting mainly of incised channels trending west and southwest at a high angle to the Nemaha uplift in central Oklahoma (Andrews, 1997). Several of these channel systems are subparallel to present tectonic strike and some geologists have interpreted them as shoreline deposits. Much of the marine Red Fork deposition in the deep Anadarko basin is believed to be the result of gravity flow processes during a sea level lowstand (Puckette, 2002).

## Purpose of Study

The primary purpose of this study is to show through synthetic modeling that the "HFI" seismic data is better suited to interpret the Red Fork interval within the upper Red Fork valley system than the reprocessed and processed data. This study will also show how interpretation is enhanced using this "HFI" data, which facilitates the mapping of the valley systems.

## Location

This study is centered in the central part of the Anadarko basin. Seismic coverage starts in Custer Co. and extends into Blaine and Caddo counties in Oklahoma (Figure 1). The seismic lines were chosen due to their location within the area where a channelized system dominated Red Fork sand deposition.

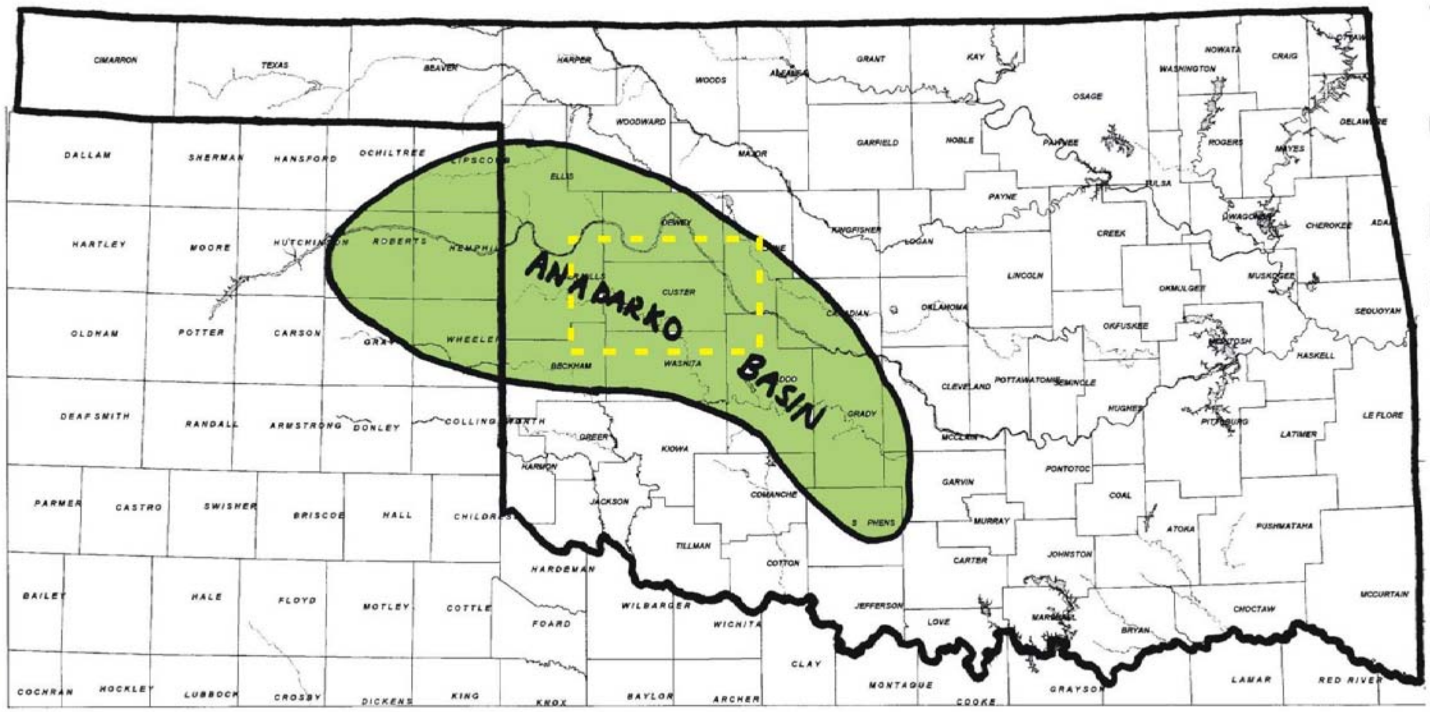



**Figure 1.** Location of study area. Yellow box indicates seismic coverage area. Modified from Johnson, 1971.

## Methodology

Seismic lines provided by Dominion Exploration were used to determine the amount of channel downcutting within the upper Red Fork interval in the Anadarko basin. High frequency seismic data, along with a 2-D arbitrary line that runs through a 3-D seismic shoot, which was provided by Chesapeake Energy, Inc., was compared to the original 2-D data.

A comparison of the quality and resolution of processed, reprocessed, and high frequency seismic was used to determine which seismic data provides the best reflectors to pick horizons and improve stratigraphic and structural mapping.

## Previous Studies

As a result of its importance as an oil and gas producing reservoir, the Red Fork sandstone is highly studied. 2-D and 3-D seismic data have been collected in the vicinity of this study. Amoco acquired 136 $mi^2$ of seismic data in 1993, 1994, and 1996 with the main objective of imaging the upper Red Fork incised valley system to generate drilling prospects in the Red Fork interval of the Anadarko basin. Amoco used spectral decomposition and coherency displays of the 3-D data that enabled the interpretation of the complex valley system. It has been shown by Bottjer and others (2001) that integration of 3-D seismic with the well data was extremely important for an accurate interpretation.

Al-Shaieb and others (2002) studied trapping in the Red Fork reservoirs and compared it to the production, porosity, and detrital composition. The Red Fork interval has been shown to be one of the largest oil and gas producers in Oklahoma. Fluvial-dominated deltaic light oil reservoirs are shown to be prominent in the Red Fork. According to Al-Shaieb and others, the traps in this area form where (1) sandstone trends cross structural noses and anticlinal folds, (2) valley trends are subparallel to strike , and reservoir facies terminate updip against shaley rock, and (3) differential sandstone thickness creates false highs.

Andrews (1997) focused on the distribution of the Red Fork sandstone in Oklahoma. He correlated the petroleum production with the depositional environment using wire-line logs in Alfalfa, Noble and Payne counties.

Puckette and others (2000) focused on the facies and deposition of the upper Red Fork in the deep Anadarko basin. They found that the upper Red Fork basin floor deposits are divided into upper, middle, and lower fan facies. Sequence stratigraphy was used to determine age and depositional history of the Red Fork. Facies analysis on the upper, middle, and lower fans showed that the Red Fork reservoirs that produce the largest volumes of gas are thick channel filled sandstones of the upper and middle fan facies.

Schneider and others (2002) showed the structure of the East Clinton Field using 2-D seismic contouring. He also correlated seismic lines with electric logs that were converted to time domain. The seismic data used in this study was acquired in 1975 and correlated with the logs. New seismic data available for this study can show more resolute features and can fine tune the structural contouring.

Peyton and others (1998) used spectral decomposition and coherency displays of 3-D seismic data to enhance interpretation of a complex incised valley system that would have been difficult to interpret using standard interpretation techniques (Figure 2 and 3).

Initially four main stages of channel fill were identified in the incised valley. Using spectral decomposition and coherency five stages were delineated (Figure 4). Peyton and others (1998) were able to map not only the limits of the Red Fork valley system, but also the distribution of different stages within the valley. They believed that the integration of the well data with 3-D seismic was absolutely essential for an accurate interpretation.

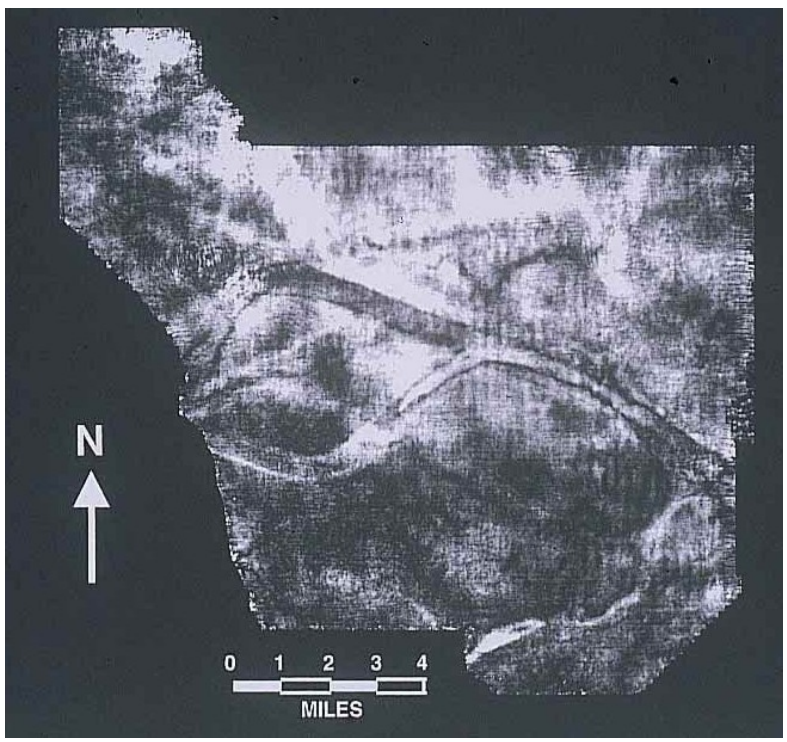



**Figure 2.** 36 Hz amplitude slice from Red Fork spectral decomposition without interpretation (Peyton, 1998) and (Bottjer, 2001).

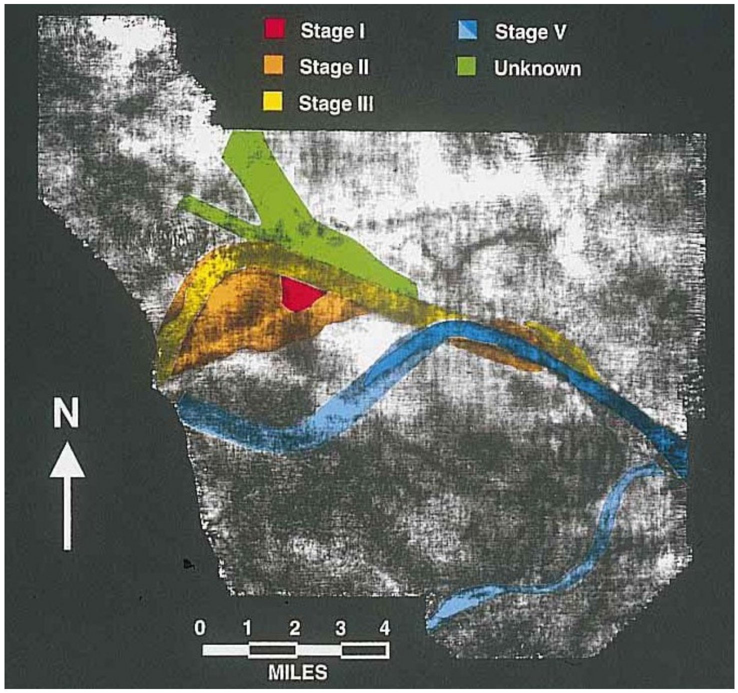



**Figure 3.** 36 Hz amplitude slice from Red Fork spectral decomposition with interpretation (Peyton, 1998) and (Bottjer, 2001).

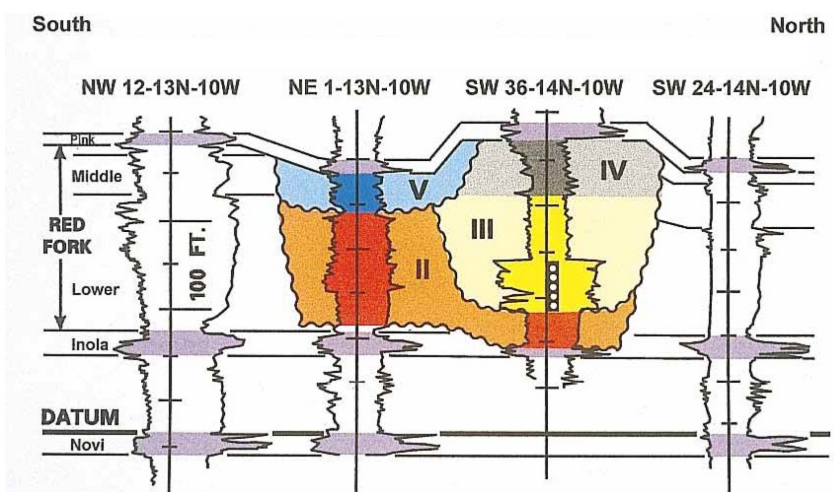



**Figure 4.** Cross section flattened on the Novi limestone horizon (Peyton, 1998) and (Bottjer, 2001).

**ANCIENT DELTAIC DEPOSITS AND FLUVIAL DOMINATED**

**DELTAIC FORMATION**

Ancient deltaic deposits have been identified in stratigraphic successions of many ages, and deltaic sediments are known to be important hosts for petroleum and natural gas, coal, and some minerals such as uranium. Fluvial-dominated deltaic formation in the Anadarko basin occurred due to buoyant dominated river mouths from where the inflow extends as a plume into moderately deep, generally marine waters. The flow detaches from the bed and is thus incapable of moving the bedload beyond the detachment point. Turbulent mixing is strong near the river mouth and a great deal of the coarser suspended load and bed load is deposited, whereas finer-grained sediment is transported farther into the basin before deposition (Boggs, 2001). Figure 5 shows how a delta is formed with sandy mixed load channels.

Sandy
Mixed-Load
Channels

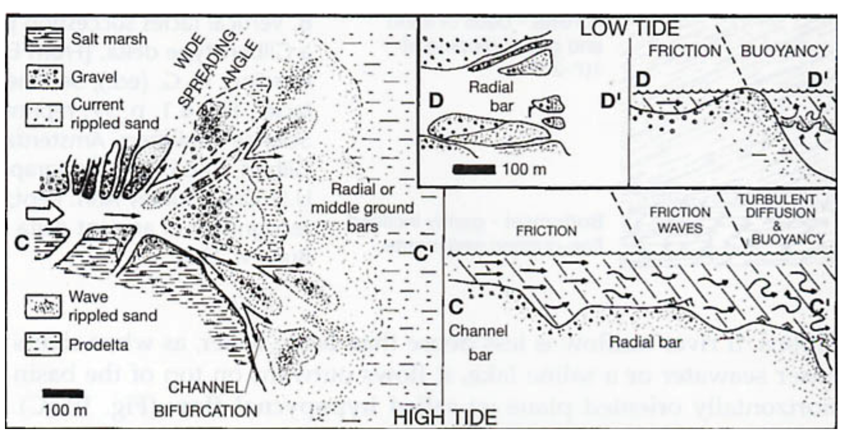



**Figure 5.** Schematic depiction of the complex relationship arising from sediment grain size, river outflow inertia (velocity), outflow friction with the bed, and outflow buoyancy – and its effect on delta formation (Modified from Boggs, 2001).

## History of the Deep Anadarko Basin

During the Pennsylvanian, the sedimentary basins of Oklahoma subsided for longer periods of time and more rapidly than before. Thick sequences of mud, with interbedded sands and carbonates were deposited in these basins. The Pennsylvanian sea reached its maximal level when the Pink Limestone was deposited in the Anadarko basin (Frezon, 1975). The deep Anadarko basin extends from the eastern Panhandle of Texas through the western portion of Oklahoma (Figure 1). The Anadarko basin is a deep, Paleozoic, petroleum rich basin with moderate to high gas saturation in most Red Fork oil reservoirs, which generally produce significantly throughout the life of a field. Producing the gas in the Red Fork reservoirs often depletes the reservoir energy leaving a great deal of the oil behind (Andrews, 1997).

The Red Fork sediments were deposited as a fluvial-deltaic fan complex during the Middle Pennsylvanian (Desmoinesian). The origin for the Red Fork was most likely an extensive drainage system to the north and northeast of Oklahoma, most likely extending as far as the Canadian Shield or even Greenland, and appears to be subparallel to the Midcontinent Rift (Fritz, 2002). A secondary source for the Red Fork was the Amarillo-Wichita Mountains in the south (Fritz, 2002). The Red Fork can be further divided into three coarsening upward parasequences -- upper, middle, and lower. The thickness of the Red Fork is controlled by the arrangement of the Cherokee platform, the Nemaha fault zone and central Oklahoma uplift, and the Anadarko basin (Figure 6) (Andrews, 1997). Deposition of this “Cherokee Group” occurred as a result of several transgressive-regressive cyclothems that developed during the Middle Pennsylvanian (Fritz, 2002).

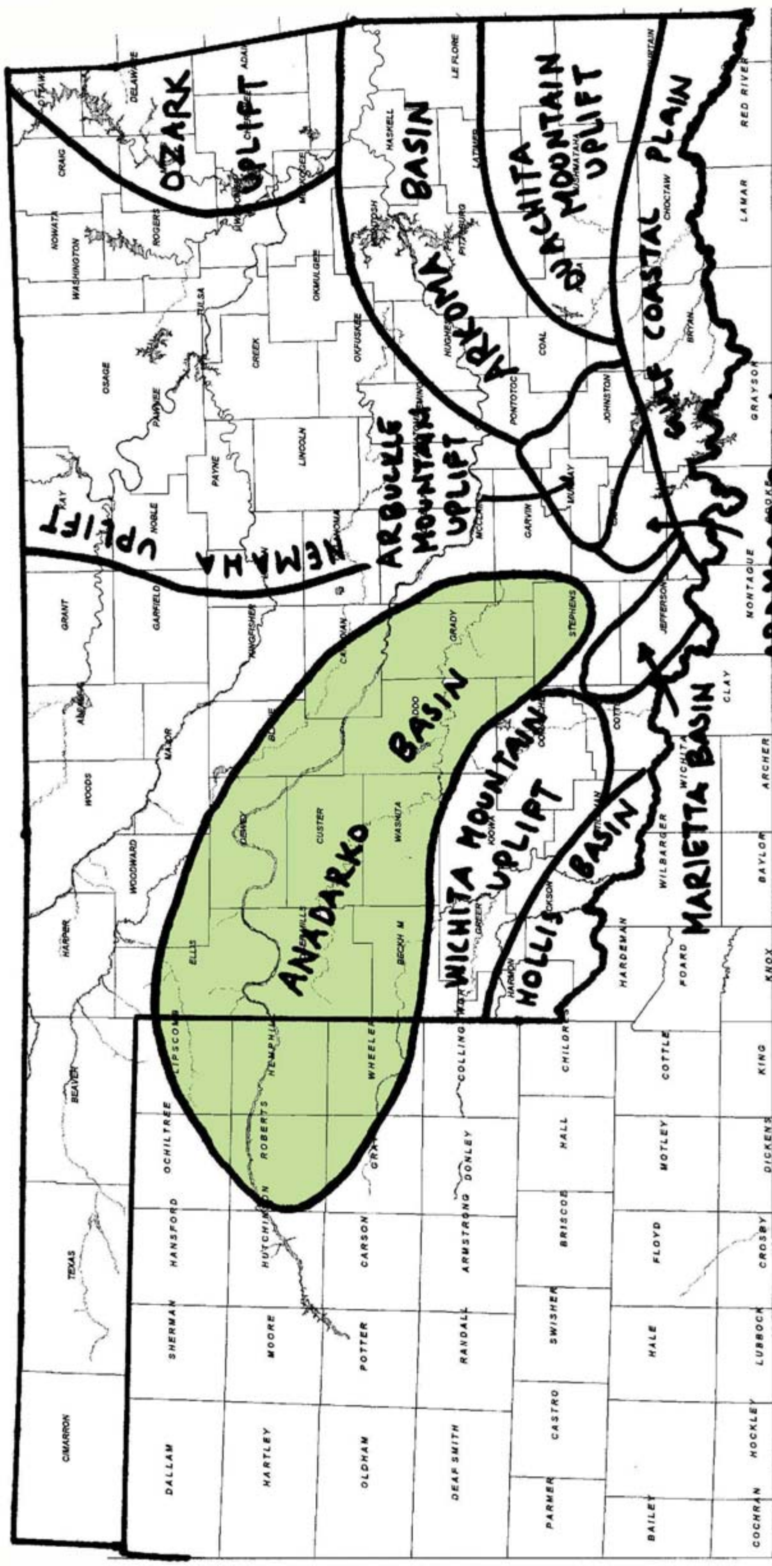



**Figure 6.** Major geologic provinces in Oklahoma (Modified from Johnson, 1971).

The Anadarko Basin was one of the first major tectonic events to occur during the Pennsylvanian time. Numerous tectonic and sedimentary features evolved during the Pennsylvanian along the southern margin of the continent from compressional stresses. In the early Pennsylvanian, the Amarillo-Wichita trend became a region of active uplift bordering the southern margin of the rapidly subsiding Anadarko Basin (Figure 7).

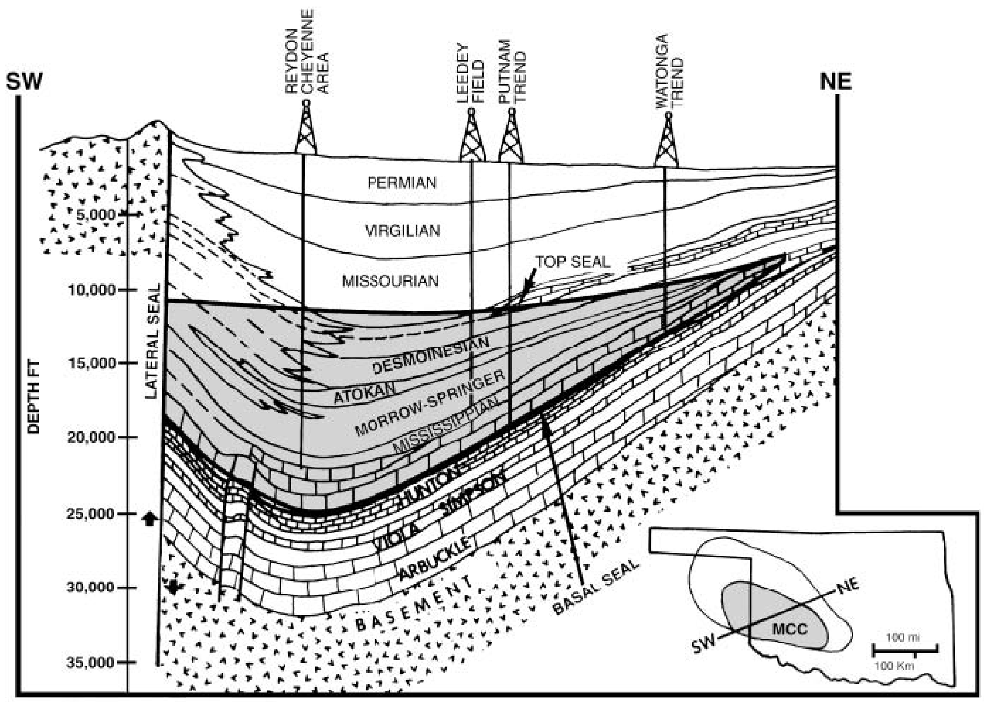



**Figure 7.** Generalized cross section of the Anadarko basin, showing spatial geometry of the megacompartment complex (MCC), the first level of compartmentation in the basin. Arrows in the lower left corner indicate relative fault movement. Inset map shows extent of the MCC with respect to the basin's dimensions (Al-Shaieb, 1992).

Early in the Pennsylvanian, the eastern Anadarko Basin was the site of shallow marine deposition. A sequence of deltaic, carbonate shelf, and prograding-deltaic and shallow marine deposition occurred in this area intermediate between the relatively stable shelf to the north and east and the rapidly subsiding basin to the south and west (Moore, 1979). Because the rate of subsidence exceeded deposition, the coarse sediments eroded from the Amarillo-Wichita uplift were deposited very near to the source, while associated finer grained sediments were distributed only slightly farther into the basin.

The Red Fork formation, a channel deposit, consists of fine-grained sands that were compacted by the subsequent deposition of shales. Production of these sinuous channel fill deposits is found in elongated lenticular stratigraphic traps (Figure 8) (Kennedy, 1982).

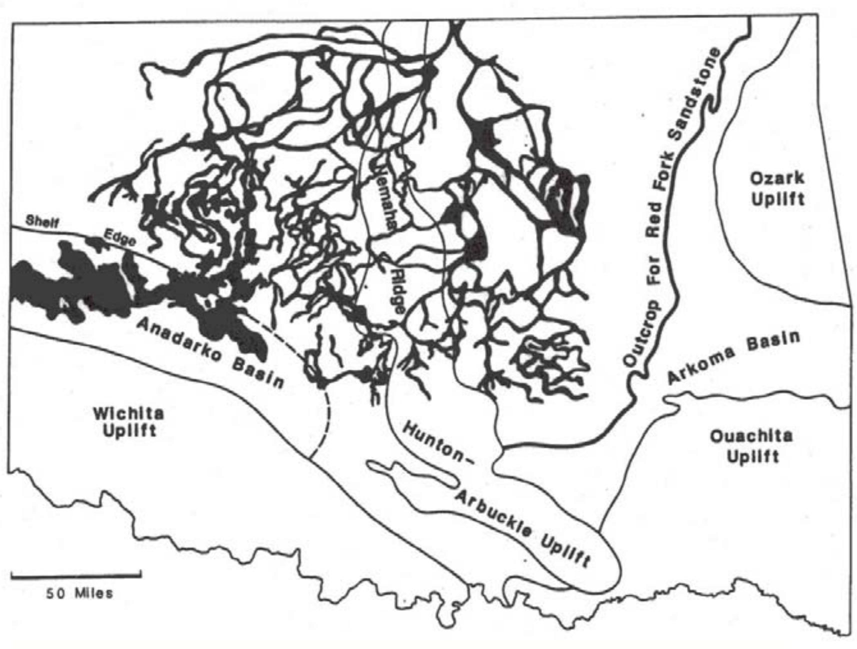



**Figure 8.** General extent of Red Fork Sandstone in Oklahoma, showing distribution of major sandstone bodies (Al-Shaieb, 1989; Cole, 1969; Berg, 1969; Johnson, 1984; Tate, 1985; R.F. Fritz, P.L. Medlock, G.B. Beardall, K. Leggett, M. Kuykendall, and E. Hooker).

## DESCRIPTIVE OVERVIEW OF THE RED FORK INTERVAL

The Red Fork interval lies between the base of the Pink Limestone and the top of the Inola Limestone (Andrews, 1997). The Red Fork represents a regression of the Cherokee Sea after the deposition of the transgressive Inola Limestone (Figure 9). Regional studies indicate a south-southeast thickening into the basin. The Red Fork can be further subdivided into the upper, middle, and lower. According to Puckette and others (2002), the upper fan lithofacies are dominantly channel fill sandstones with thick stratified fining upward sandstone intervals. The upper Red Fork submarine fan complex formed on the basin floor beyond the Anadarko shelf margin. The middle fan facies shows interbedded silty shales indicating a lower flow regime and suspension settling, low density turbidity flow, or clay/silt-rich intervals within the Bouma sequences. The lower fan facies consists of thin bedded turbidites with coarsening upward shale-rich intervals and thin sandstones.


**Figure 9.** Stratigraphic nomenclature for the Anadarko Basin and outcrop nomenclature for the Desmoinesian series. [The names in italics are used in the petroleum industry for identification and classification.]

Red Fork sandstones in the deep Anadarko basin have characteristics of constructional channels. Constructional channels consist of stacked, flat-lying beds flanked by levees which are abruptly replaced laterally by basin plain muds (Figure 10).

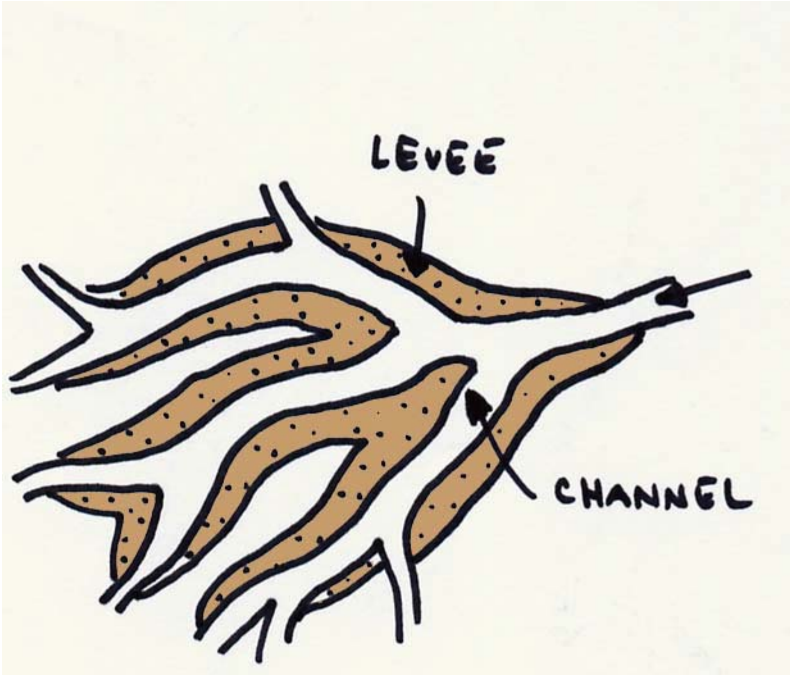



**Figure 10.** Picture of a constructional channel.

The rapid change, in vertical sequence, from channel to overbank facies reflects the abrupt lateral facies change typical of the constructional channel deposition (Whiting, 1984).

Internal features in the Red Fork include interstratification, horizontal laminations, massive bedding, and medium and small scale cross-bedding. Slump structures, bioturbation, rootlets and nodules, fossils, and coal and organic shale have also been noted in core sections (Johnson, 1984).

## STRATIGRAPHY AND DEPOSITIONAL SETTING OF THE UPPER RED FORK

The stratigraphy and depositional setting of the upper Red Fork on the shelf can be divided into three stages. Stage I characterizes the initial downcutting of the valley. It is described as an erosional, suspended-load channel, with steep banks, low sinuosity, and a very low width to depth ratio. Stage I channels typically show a downward-coarsening profile with a sharp base that erodes deeply into underlying middle Red Fork. Channels encountered are very narrow with an average width of 0.3 mi (~ 1600 ft). A channel lag may occur that was derived in part from transported bed load and in part from downwasting along steep valley walls (Figure 11).

Stage II is differentiated by sinuous mixed-load channels with deposition dominant, a moderate width to depth ratio, and a moderate to high relief on basal scour surfaces. Valley fill was originated from terrigenous clastics transported as bedload and suspended load from source areas to the north and east (Figure 12).

An interruption in the "normal cycle" of valley evolution was due to the downward re-adjustment in base level from the south and west. Stage III development represents rejuvenation characterized by a return to earlier valley-forming processes similar to those existing during Stage I. Stage III entailed downcutting and rapid headward erosion upstream through poorly consolidated Stage II meander belt sediments. Rapid erosion in an upstream direction was followed by rapid backfilling of sandstones in a downstream direction as a new grade level was achieved (Figure 13).

The entire sequence of valley evolution would have repeated had it not been for an increase in basin subsidence at the end of the upper Red Fork time, which, together with diminishing sediment supply to the region, resulted in marine advance across the shelf, inundating the excavated Stage III valley. This late upper Red Fork marine transgression concluded in the deposition of the Pink Limestone (Clement, 1991).

Warner (2006) has describes the deposition of the upper Red Fork sands within the valley system as Phase I, II, and III. Phase I deposition is the earliest event in the valley and represents the narrow, initial downcutting of the valley sequence. The rocks are usually poorly correlative shales, silts, and tight sandstones when present. Phase II deposition has a much wider area of distribution with a variety of valley fill facies. Phase II rocks illustrate a classic fining upward sequence pattern. Phase III deposition record the last major incisement within the valley and occur within a narrow steep walled system. These reservoirs are often thick, blocky, porous sands that have been re-worked and are overlain by low resistive marine shales that were deposited by a major transgression which drowned the valley sequence. According to Warner (2006) the lithology of these phase I, II, and III sands greatly influences the seismic signature in the Anadarko basin.

Peyton (1998) and Bottjer (2001) studied what they termed Stage V valley fill using spectral decomposition and coherency on 2D seismic data. Before this data was enhanced using spectral decomposition and coherency, there were thought to be only three stages of valley fill. Without using these processing techniques, one would not know that this new stage is actually a shale-filled valley with no potential for hydrocarbon production. Stage V erosionally removed the productive Stage III within their area of interest. The identification of this new younger stage of valley fill aided in avoiding the drilling of dry holes. The advantage of using spectral decomposition and coherency is that they fine tune the frequency-domain spectra in the time domain.

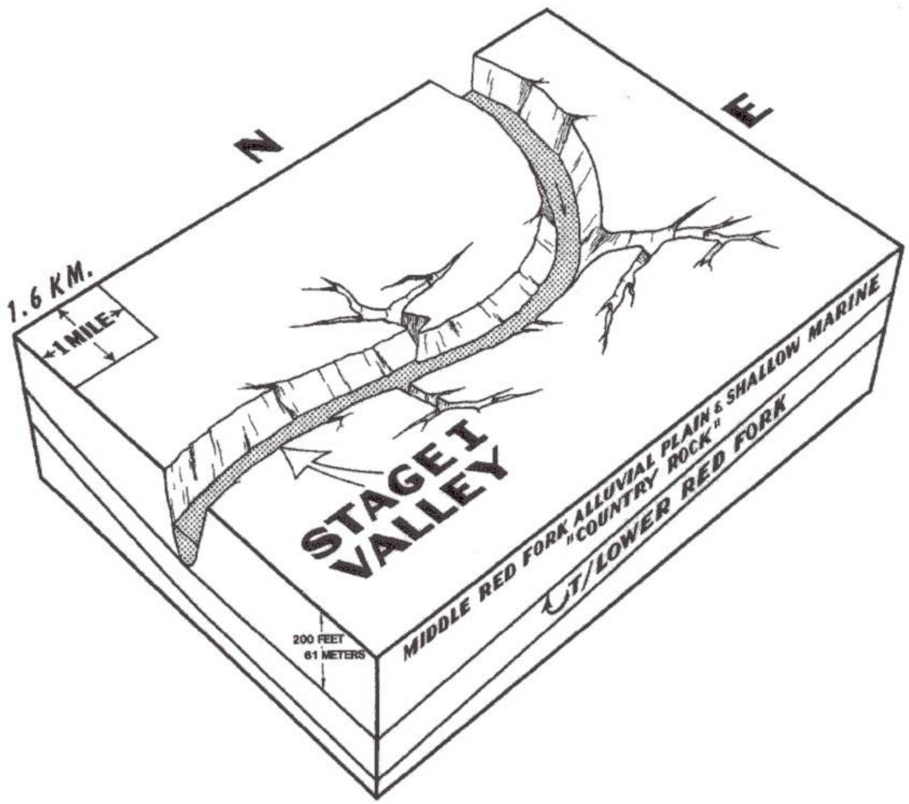


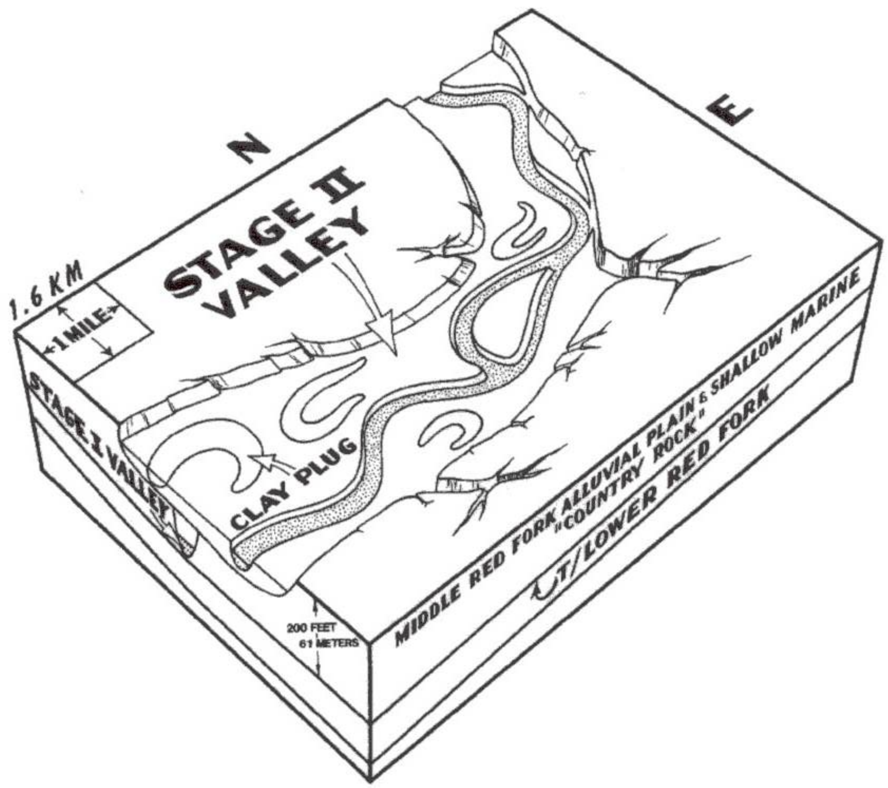

**Figure 11.** Block diagram illustrating initial development of Stage I valley following regression at the end of middle Red Fork time (Modified from Clement, 1991).

**Stage I**
**Very Late Middle or Early Upper Red Fork**

**<u>Description</u>** – Initial downcutting (youthful) response to a lowering of base level

**<u>Characteristics</u>**

1. Suspended load channels – bed erosion dominant
2. Very low width/depth ratio; moderate relief on basal scour surface; steep banks; low sinuosity
3. Lateral channel migration limited
4. Valley fill derived from mass wasting along steep walls and suspended load
5. Poorly sorted; limited channel lag deposits common



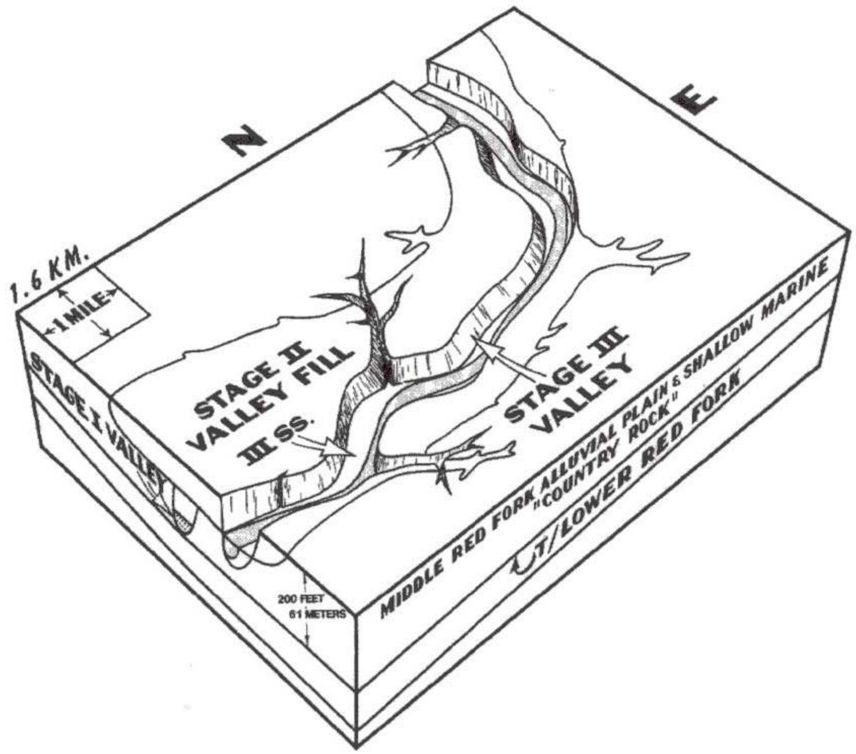

## Stage II

**<u>Description</u>** – Mature valley stage; aggradational sequence; equilibrium adjustment to Stage I base level drop

**<u>Characteristics</u>**

1. Mixed load channels; deposition dominant
2. Moderate width/depth ratio; moderate to high relief on basal scour surface sinuous surfaces
3. Lateral channel migration within incised valley, confined meander belt sequences
4. Valley fill derived from bedload and suspended load, terriginous valley fill
5. Stacked and/or amalgamated point bar, clay plug and overbank deposits

**Figure 12.** Block diagram illustrating development of Stage II incised valley sequence. Lateral channel migration and erosion dominated as the valley broadened and eventually in-filled with terriginous clastics following initial Stage I downcutting (Modified from Clement, 1991).




## Stage III

**<u>Description</u>** – Interruption of normal valley evolution by re-adjustment (lowering of basal level: rejuvenated valley

**<u>Characteristics</u>**

1. Suspended load channels active downcutting through poorly consolidated older valley fill: headward erosion
2. Low width/depth ratio; moderate relief on basal scour surface, steep valley walls; low to moderate sinuosity
3. Lateral channel migration limited
4. Channel sandstones re-worked and redistributed by marine (tidal) processes during transgression
5. Excavated valley infilled by marine muds following transgression

**Figure 13.** Block diagram illustrating development of Stage III rejuvenated valley, which eroded rapidly headward through older, poorly consolidated Stage II valley fill following a lowering of base level in the basin. Sandstone deposited along the floor of the Stage III valley were cannibalized from older Stage II sediments (Modified from Clement, 1991).

## SEISMIC MODELING PARAMETERS

Although many processors of seismic data have the ability to display seismic data with more robust frequencies, Geotrace Technologies, Inc. and Seismic Ventures, Inc. seismic data processing were analyzed in this study. The seismic information used in this study are the processed, reprocessed, and high frequency 2D seismic lines, along with a 2D arbitrary line within a 3D survey. The processed lines have been used by interpreters since the late 1970's to map the Red Fork interval in the Anadarko basin. Post-stack migration processing was used on the processed version of the seismic data to manage the coarse grid of rough velocities obtained.

The reprocessed version of the seismic data has been pre-stack migrated and finer grids of velocities obtained. Also, refraction statics have been applied to better fit the data together along with tighter velocities.

Seismic Ventures, Inc. and Geotrace Technologies, Inc. both have a high resolution process called "high frequency type processing" or "high frequency imaging", HiRes, or HFI. "HFI" will be the common term used to identify the high frequency data. The "HFI" seismic data has been processed to extend the bandwidth of seismic data beyond conventional techniques such as spectral whitening and deconvolution. It allows interpreters to see subtle features as well as subtle faulting and very fine depositional sequences. The data is converted to zero phase before this process is applied to ensure that the end result will yield the most accurate stratigraphic information that is possible.

The technique allows the interpreter to see far greater detail in the data without enhancing destructive noises embedded in the seismic data.

A processing technique used to increase the signal to noise ratio of seismic data is to increase the fold. As the number of midpoints in each bin is increased, the ability to see more of the subsurface is available. The fold of the "HFI" seismic data is greater than the fold of the processed data, which is greater than the processed data thus improving the view of the subsurface.

Synthetic seismic traces were generated from sonic logs using Geographix Seisvision software and digital well log data. Synthetic seismic trace generation used sonic and density log traces to derive a reflection coefficient trace. The reflection coefficient trace is convolved with a wavelet to generate a suite of synthetic traces. The simultaneous creation and display of geological formations based on the synthetic traces is another feature of generating a synthetics model.

The Ormsby wavelets for all of the processed seismic lines have band-pass frequencies of 8-12-48-60 Hz. Frequencies below 8 Hz and above 60 Hz were completely filtered out. The Ormsby wavelets for all of the reprocessed seismic lines have band-pass frequencies of 8-12-70-90 Hz. Frequencies below 8 Hz and above 90 Hz were completely filtered out. The Ormsby wavelets for all of the "HFI" seismic lines have band-pass frequencies of 8-12-110-120. Frequencies below 8 Hz and above 120 Hz were completely filtered out.

The seismic models were also generated in Geographix Seisvision using digital well log data. The Model Builder is used to assemble geological cross sections from well logs from which interpolated synthetic trace models are generated. These trace models are typically used as an empirical modeling tool for evaluating the character of anomalous seismic responses between wells. Geophysicists use these as a visualization tool in modeling the subsurface. Because of the limited digital well log data, the models were generated using only two wells per model. The models were chosen based upon their location on the seismic lines and also whether or not digital data for the wells were available. The seismic models created for lines A-A’, B-B’, C-C’, and D-D’ were all created the same way. Two wells were chosen along each seismic line called Well A and Well B. The wells were input into the modeling program by choosing Well A then Well B. This will give half of the generated model. To get the other half of the model Well B was input first then Well A. Once Well A and Well B were chosen for one end of the model, they were then inverted to give the other end of the model (Figure 14). These models show where the horizons are located based upon the sonic logs generated from seismic data. Each model created used Ormsby wavelets as described above.

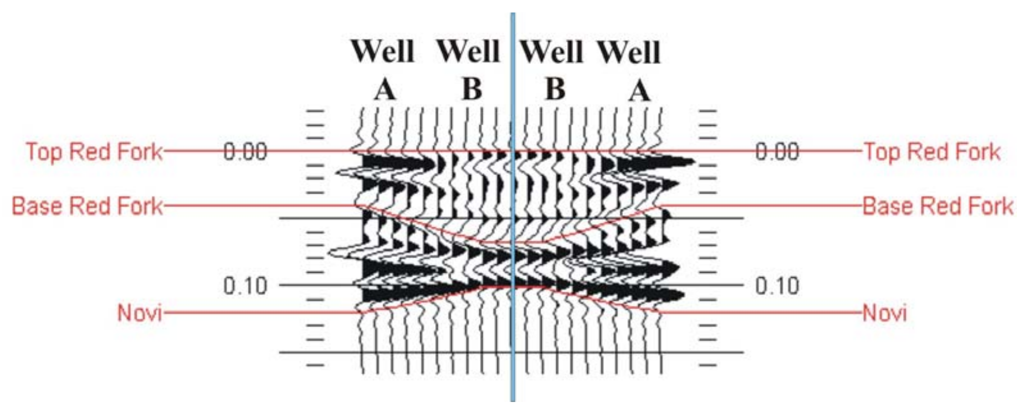



**Figure 14.** Depiction of how the seismic models were generated. The right side is a mirror image of the left side. All of the seismic models were generated using this method.

The value of a log curve at a particular time sample is calculated as an average. This average is determined using a triangular weighting function applied to all depth values which fall within a time window on either side of the depth sample. The numbers on either side of the models is the time window. The top of the Red Fork is at 0.00 sec because this is the first formation horizon entered in the model. The scale is in increments of 0.01 sec (Figure 14). The larger the sample interval the greater the smoothing of log character due to the averaging of the time sample.

The vertical resolution of the beds is found by the formula $\lambda/4$, where $\lambda$ is the wavelength of the seismic data. A bed can be resolved if it is less than $\lambda/4$ in thickness. . Horizontal resolution refers to the ability to resolve a bed laterally. Vertical resolution refers to the ability to resolve the top and bottom of the bed. The velocity can be found from the equation $V = 1/\Delta t$ where V equals the velocity and $\Delta t$ equals the transit time from the sonic log. The velocity of the Red Fork in this area is approximately 12,000 feet per second.

## COMPARISON OF SEISMIC DATA

The analysis of this data will start in the western part of the study area and proceed east. Processed, reprocessed, and "HFI" seismic data, along with seismic models, will be compared to each other to show the resolution and mapability of the Red Fork interval. An arbitrary 2D line, within a 3D survey, will be compared with the "HFI" seismic of the line closest to it, to show a much clearer picture of the subsurface one can get using 3D seismic data. Also, all of the lines are perpendicular to the channel cut in the basin. All of the 2D lines have had synthetic sonic logs generated from well log data to provide formation tops. Along with these synthetics, geological models were generated to give an ideal image of the downcutting of the Red Fork interval in this study area. Figure 15 shows where the seismic lines are located in the study area.

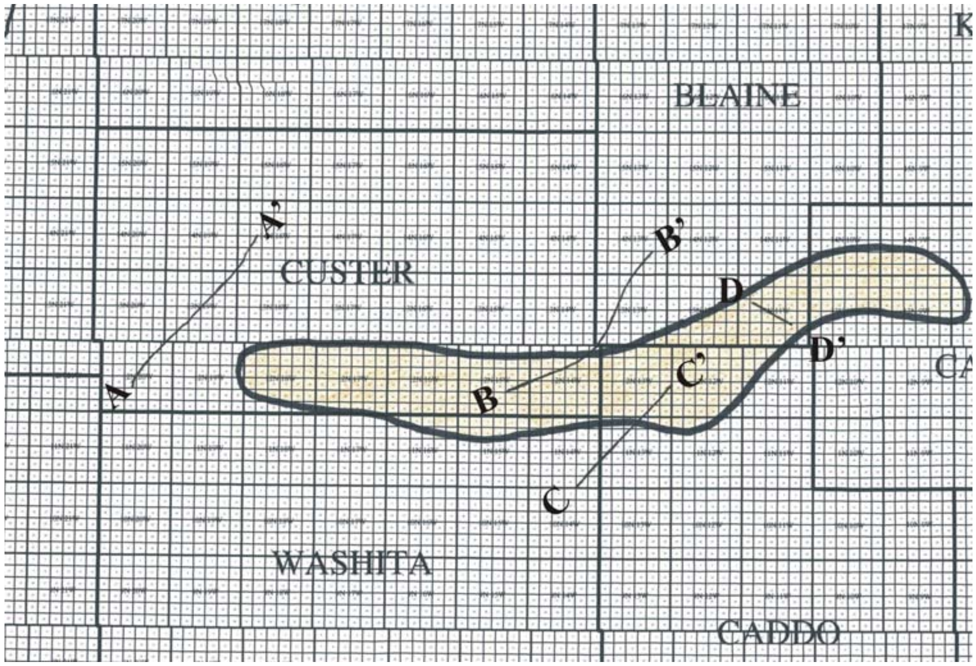



**Figure 15.** Upper Red Fork valley system with location of seismic lines. Generalized outline of the Red Fork channel system provided by Warner (2006).

Line A-A' is located in T. 12N R. 20W and goes through T. 14N R. 18W in Custer, Co (Figure 15). The seismic models for this processed line show little to no downcutting of the channel in this area. The models were generated using two wells along A-A' to show the amount of downcutting that occurs in this part of the basin as discussed previously. Figure 16 shows the model generated with a reprocessed frequency of 8-12-70-90 Hz. The left half of the model shows flat horizons for the Red Fork. The right half of the model is the mirror image of the left used for visualization purposes. Figure 17 shows the model generated with a "HFI" frequency of 8-12-110-120 Hz. From the λ/4 rule discussed earlier, the vertical resolution of the reprocessed model is approximately 37.5 feet while the resolution of the "HFI" model is approximately 25 feet.

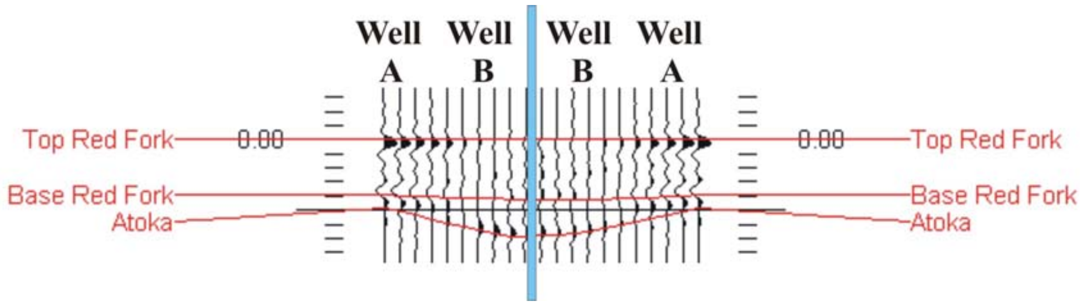



**Figure 16.** Line A-A' reprocessed model showing little to no downcutting of the channel. Ormsby frequency of 8-12-70-90 Hz was used in the band-pass filter. Well A and Well B were used to construct the model and then inverted to show a mirror image.

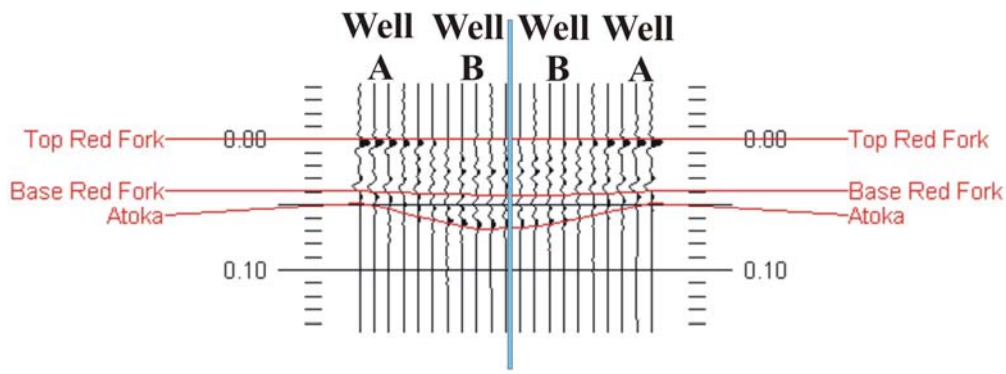



**Figure 17.** Line A-A' "HFI" model showing little to no downcutting of the channel. Ormsby frequency of 8-12-110-120 Hz was used in the band-pass filter. Well A and Well B were used to construct the model and then inverted to show a mirror image.

The reprocessed seismic data for A-A' shows some detail of the Red Fork. The horizons cannot be mapped continually due to the abundance of noise in the data (Figure 18). The reprocessed data show the top of the Red Fork is at approximately 2.03 seconds and the base is at approximately 2.05 seconds. The "HFI" version of the seismic data of A-A' shows more detail than the reprocessed seismic data. Here the Red Fork interval is shown as a continuous horizon and the mapping of the interval is more obvious (Figure 19). The "HFI" data shows the top of the Red Fork is at approximately 2.09 seconds and the base is at approximately 2.14 seconds. According to the "HFI" data, the Red Fork interval is actually deeper than originally thought. In this area of the basin high frequency seismic data is not necessary to view the subsurface due to the lithology of the Red Fork sands in this area. According to Warner, phase II sands are present in this area of the basin. Because of the presence of these phase II sands, the reprocessed data is sufficient to use in mapping the Red Fork. The "HFI" data does not enhance the quality of the data in this area of the basin. The depth of the Red Fork along A-A' is approximately 12,038 feet which correlates with both the reprocessed and "HFI" data sets.

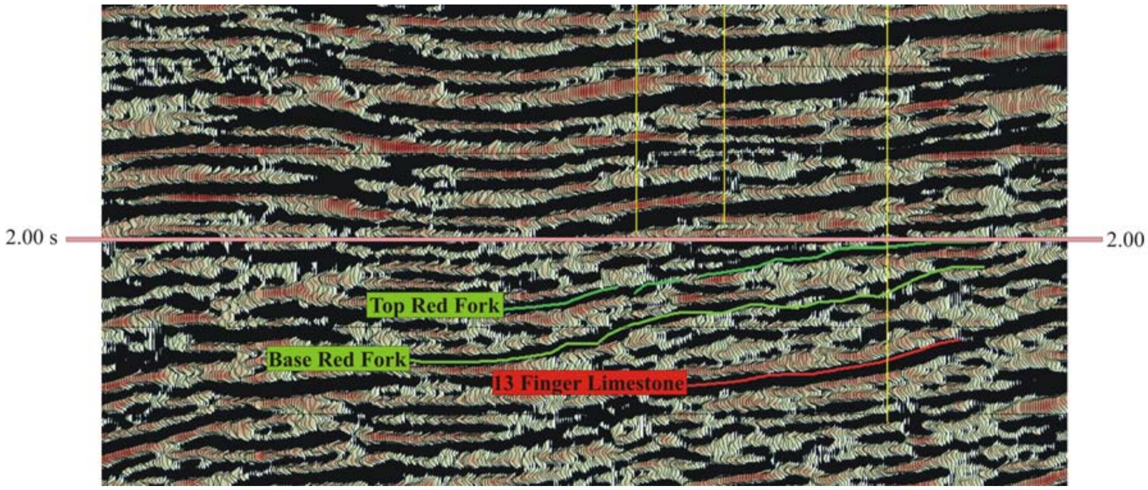



**Figure 18.** Line A-A' reprocessed seismic line with horizons. Horizons are not continuous throughout. The pink line indicates the time. (Yellow lines indicate well locations.)

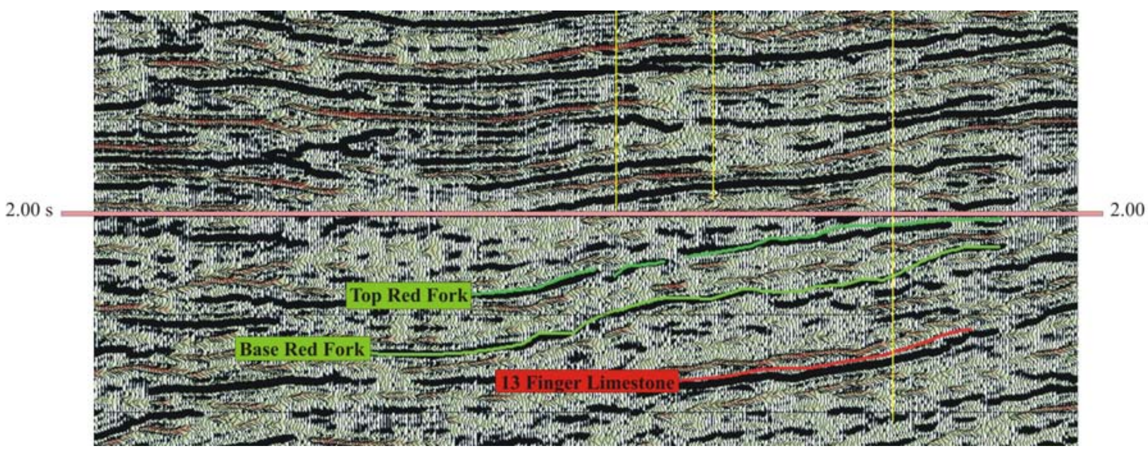



**Figure 19.** Line A-A' "HFI" seismic line with horizons. Horizons are more continuous with less noise. The pink line indicates the time. (Yellow lines indicate well locations.)

Line B-B' is located in the middle of the study area running from T. 12N R. 15W in Custer Co., through T. 14N R. 13W in Blaine, Co. (Figure 15). The seismic models for this line show moderate downcutting of the channel in this area. The Novi limestone marker shows an artificial structural high, which is due to how the model was generated. Figure 20 shows the model generated with a processed frequency of 8-12-48-60 Hz. The left half of the model shows dipping horizons of the base of the Red Fork. The right half of the model is a mirror image of the left side and is used for visualization purposes. The resolution of the processed model is 50 feet. Figure 21 shows the model generated with a reprocessed frequency of 8-12-70-90 Hz and has a resolution of approximately 36 feet. Figure 22 shows the model generated with a "HFI" frequency of 8-12-110-120 Hz and has a resolution of approximately 25 feet. Figure 23 shows how the horizons were picked using the synthetic data generated for a well located on this line.

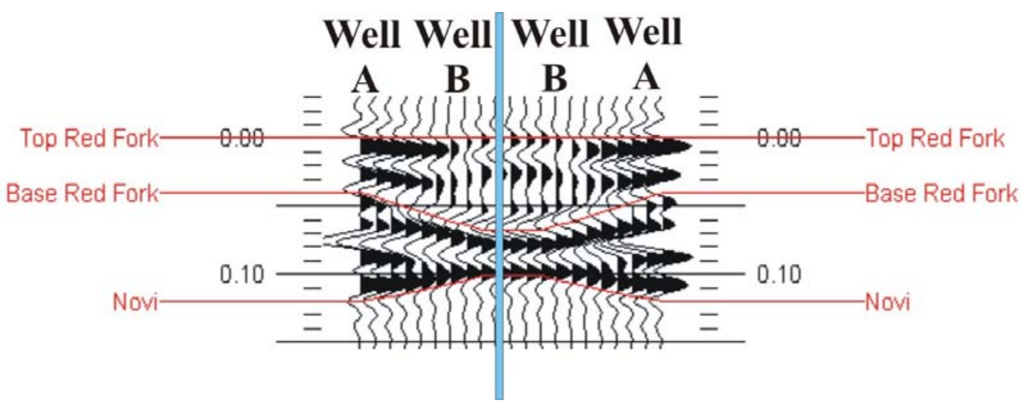



**Figure 20.** Line B-B' processed model showing moderate downcutting of the channel. Ormsby frequency of 8-12-48-60 Hz was used in the band-pass filter. Well A and Well B were used to construct the model and then inverted to show a mirror image.

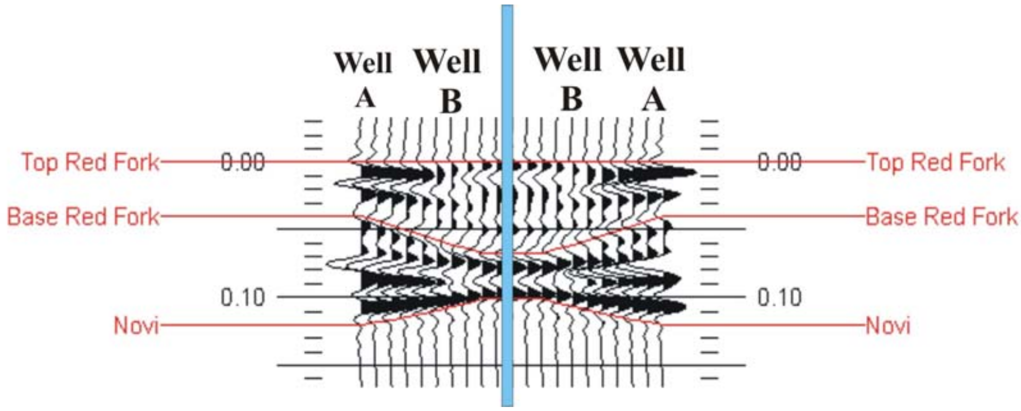



**Figure 21.** Line B-B' reprocessed model showing moderate downcutting of the channel. Ormsby frequency of 8-12-70-90 Hz was used in the band-pass filter. Well A and Well B were used to construct the model and then inverted to show a mirror image.

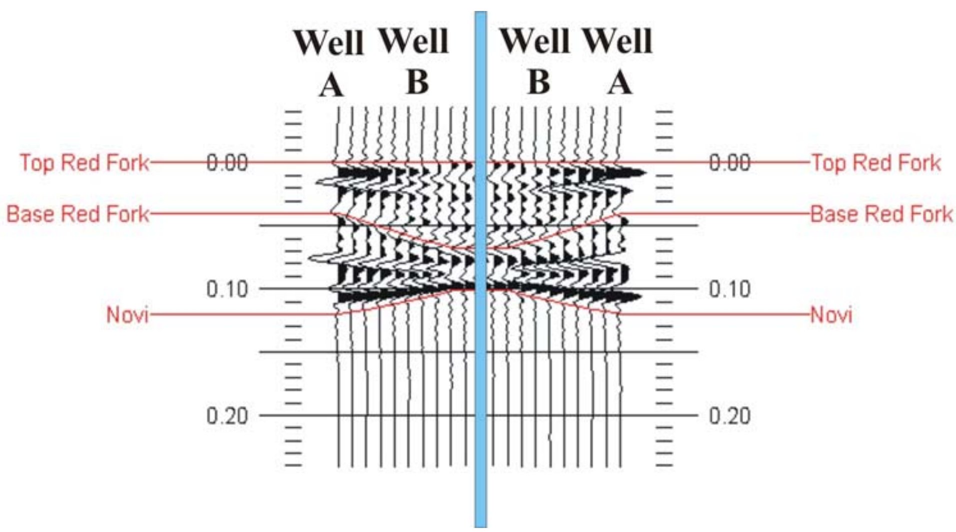



**Figure 22.** Line B-B' "HFI" model showing moderate downcutting of the channel. Ormsby frequency of 8-12-110-120 Hz was used in the band-pass filter. Well A and Well B were used to construct the model and then inverted to show a mirror image.

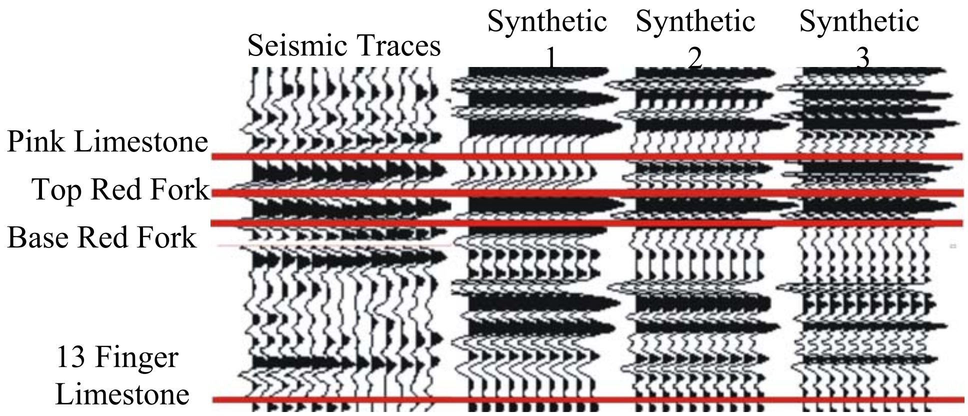



**Figure 23.** Synthetic seismic data showing Red Fork marker beds on a well located on Line B-B'. The reflectors from the seismic lines match well with the reflectors from the synthetic. Synthetic 1 was generated using a band pass filter of 8-12-48-60. Synthetic 2 was generated using a band pass filter of 8-12-70-90. Synthetic 3 was generated using a band pass filter of 8-12-110-120.

The original processed seismic data for B-B' shows very little detail of the Red Fork interval (Figure 24). The base of the Red Fork horizon is not continuous on this data set; therefore it is hard to get an accurate location of the bottom of the bed. The processed data shows the top of the Red Fork at 1.55 seconds and the base is at approximately 1.59 seconds. The reprocessed seismic data shows slightly more detail, but at a slightly deeper depth than the original processed data (Figure 25). The horizons are more continuous in the reprocessed data set than in the processed data set. The reprocessed data shows the top of the Red Fork at 1.52 seconds and the base is at approximately 1.59 seconds. The "HFI" version of the seismic data show more detail than the reprocessed and confirms a more accurate location of the Red Fork interval (Figure 26). The "HFI" data shows the top of the Red Fork at approximately 1.50 seconds and the base is at approximately 1.55 seconds. The correct position of the Red

Fork interval is seen in the “HFI” data set. By comparing the “HFI” data with the processed and reprocessed data, one can see that the location of the Red Fork interval is in fact shallower than originally picked. In this area of the basin, the “HFI” seismic data makes interpretation easier and somewhat more accurate in picking the Red Fork interval. The synthetics that were generated match much more closely with the “HFI” data than with the processed and reprocessed data sets. Because phase III sands are present in this area of the basin, the “HFI” data enhances the view of the subsurface and aids in picking the correct horizons. The depth of the Red Fork at B-B’ is 11,968 feet and correlates with the “HFI” data set.

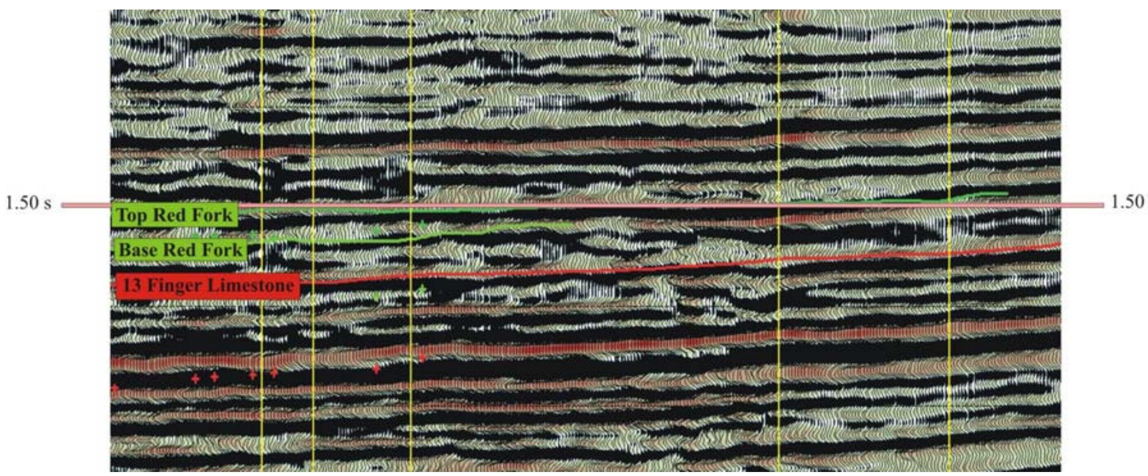



**Figure 24.** Line B-B’ processed seismic line with horizons. The base of the Red Fork is not continuous throughout. The pink line indicates the time. (Yellow lines indicate well locations.)

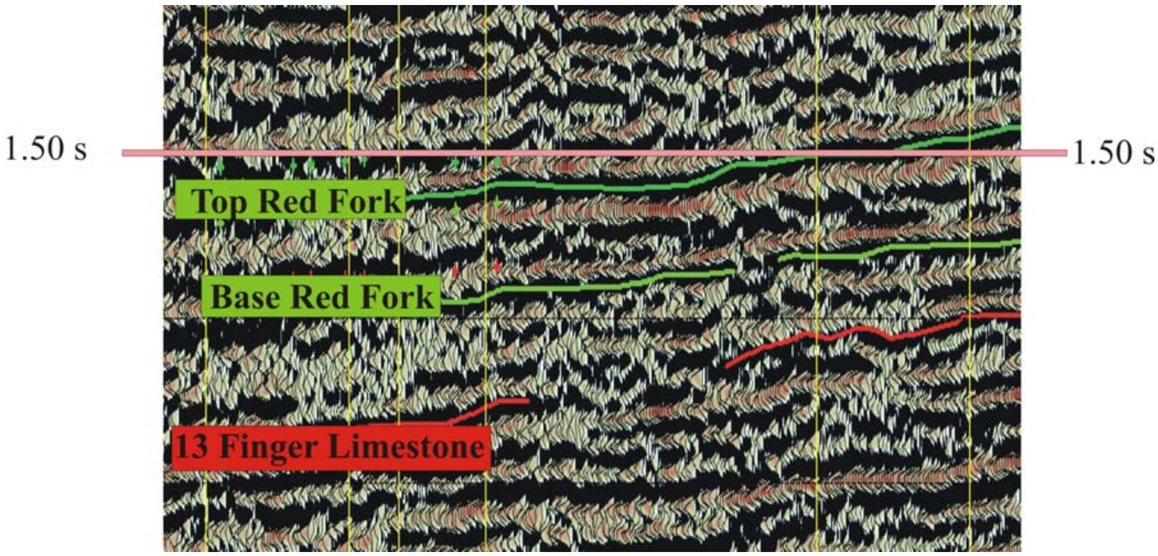



**Figure 25.** Line B-B' reprocessed seismic line with horizons. The horizons are more continuous and show the Red Fork at a slightly deeper depth than the processed data. The pink line indicates the time. (Yellow lines indicate well locations.)

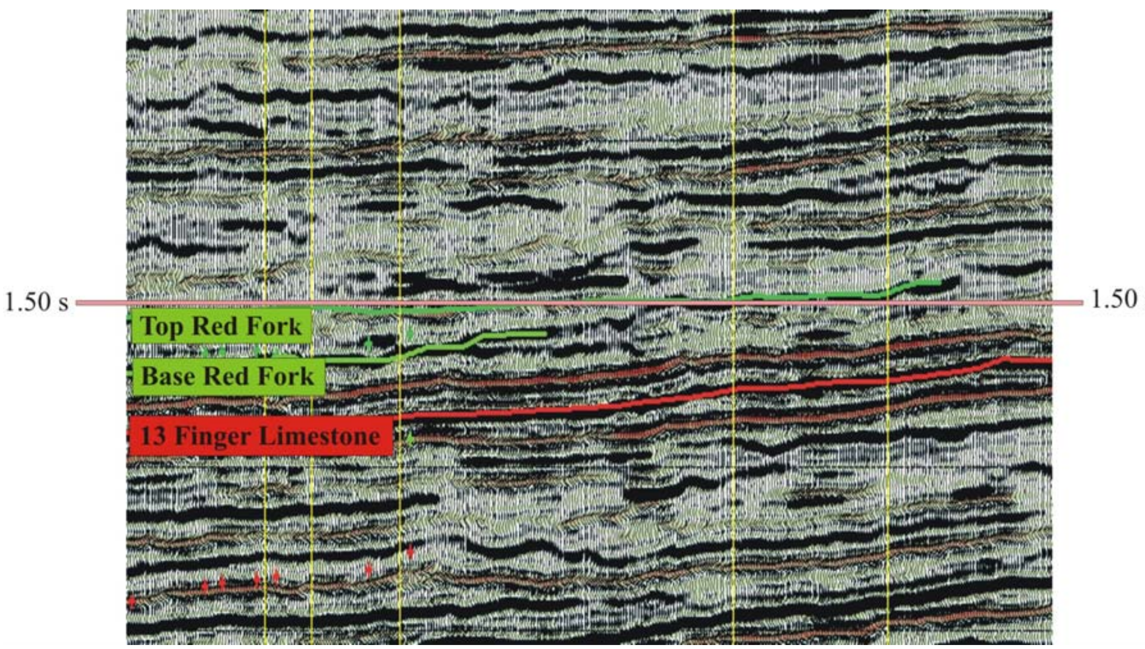



**Figure 26.** Line B-B' "HFI" seismic line with horizons. The horizons are more continuous and the Red Fork is in fact shallower than in the reprocessed and processed data sets. The pink line indicates the time. (Yellow lines indicate well locations.)

Line C-C' is located in the eastern most part of the study area and is located in 11N 14W in Washita county and runs through 12N 13W in Caddo county (Figure 15). The seismic models for this line show a great deal of downcutting of the channel. Figure 27 shows the model generated with a reprocessed frequency of 8-12-70-90 Hz and has a resolution of approximately 36 feet. The 13 Finger Limestone shows an artificial structural high which is again due to how the model was generated. The left half of the model shows dipping horizons of the base of the Red Fork. The right half of the model is a mirror image used for visualization purposes. Figure 28 shows the model generated with a "HFI" frequency of 8-12-110-120 Hz and has a resolution of approximately 25 feet. The "HFI" data can better resolve the beds than the reprocessed data.

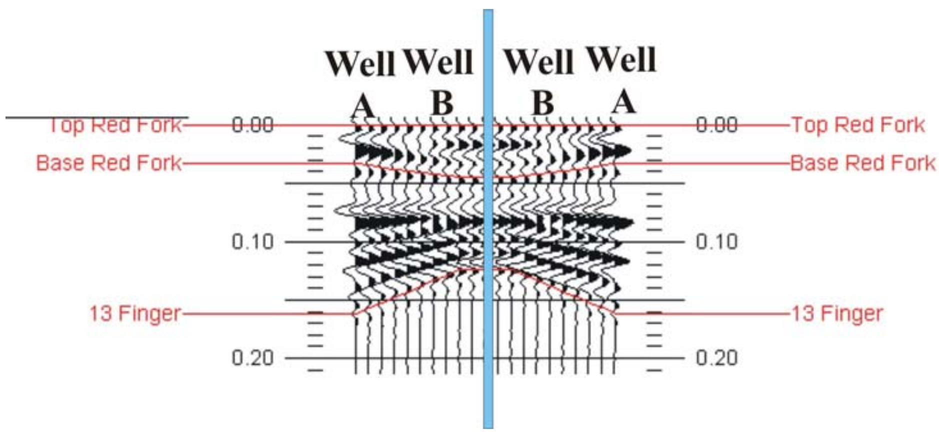



**Figure 27.** Line C-C' reprocessed model showing moderate downcutting of the channel. Ormsby frequency of 8-12-70-90 Hz was used in the band-pass filter. The 13 Finger Limestone is an artificial high due to how the model was generated. Well A and Well B were used to construct the model and then inverted to show a mirror image.

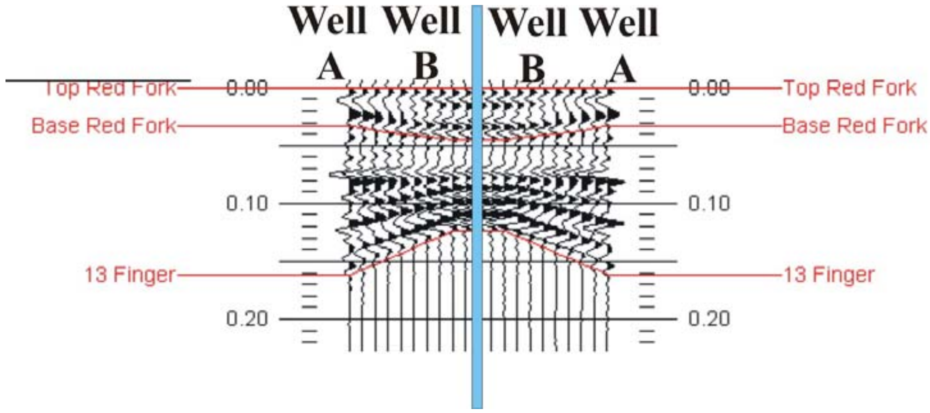



**Figure 28.** Line C-C' "HFI" model showing moderate downcutting of the channel. Ormsby frequency of 8-12-110-120 was used in the band-pass filter. The 13 Finger Limestone is an artificial high due to how the model was generated. Well A and Well B were used to construct the model and then inverted to show a mirror image.

The reprocessed seismic data in this area of the study seems sufficient to map the Red Fork interval (Figure 29). The horizons are continuous and the synthetics generated match quite well. The reprocessed data shows the top of the Red Fork at approximately 1.51 seconds and the base at approximately 1.53 seconds. However, the "HFI" seismic data is much more accurate in mapping the Red Fork interval in this area of the study due to the matching of the synthetics (Figure 30). The synthetics generated match even more closely with the "HFI" data than with the reprocessed seismic data. This gives even more credibility to using "HFI" data in picking the location of the Red Fork. The "HFI" data shows the top of the Red Fork at approximately 1.49 seconds and the base at approximately 1.53 seconds. The "HFI" data is better to use due to the presence of the phase III sands. The depth of the Red Fork at C-C' is 11,815 feet correlates with the "HFI" data set.

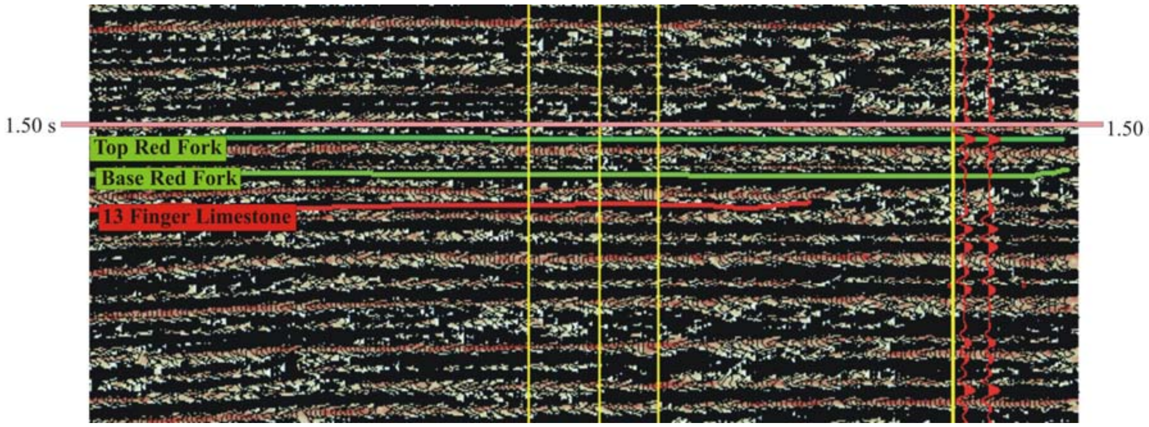



**Figure 29.** Line C-C' reprocessed seismic line with horizons. Synthetics match well indicating a good pick for the Red Fork interval. The pink line indicates the time. (Yellow lines indicate well locations.)

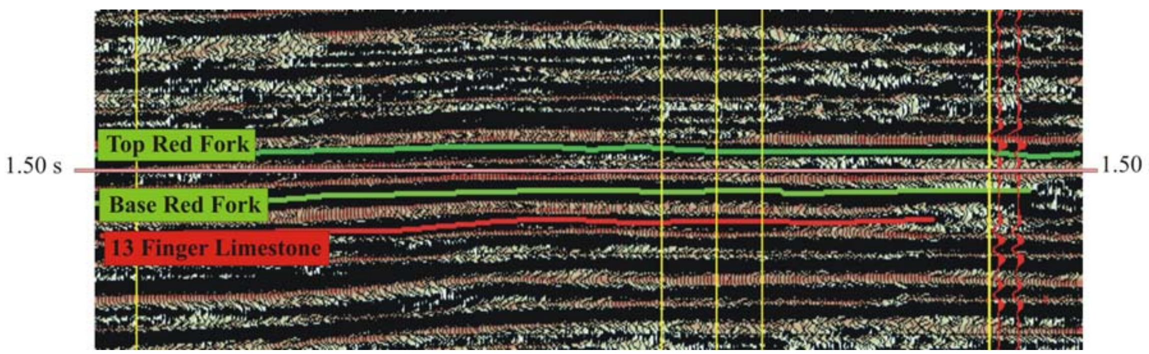



**Figure 30.** Line C-C' "HFI" seismic lines with horizons. Synthetics match much better than the reprocessed data indicating the "HFI" seismic data is more accurate. The pink line indicates the time. (Yellow lines indicate well locations.)

Line D-D' is located in the eastern most part of the study also and is located in 13N 11W, Blaine, Co. (Figure 15). Line D-D' is an arbitrary line located within a 3D study. The seismic model for this line shows a great deal of downcutting of the channel. Figure 31 shows the model generated with a "HFI" frequency of 8-12-110-120 Hz and has a resolution of approximately 25 feet. Figure 32 shows how the horizons were picked using the synthetic data generated for this well.

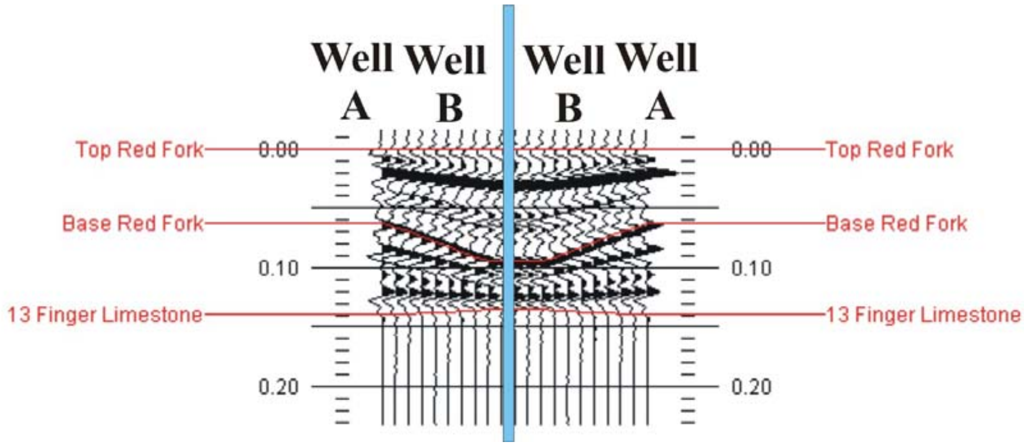



**Figure 31**. Line D-D' "HFI" model showing abundant downcutting of the channel. Ormsby frequency of 8-12-110-120 Hz was used in the band-pass filter. Well A and Well B were used to construct the model and then inverted to show a mirror image.

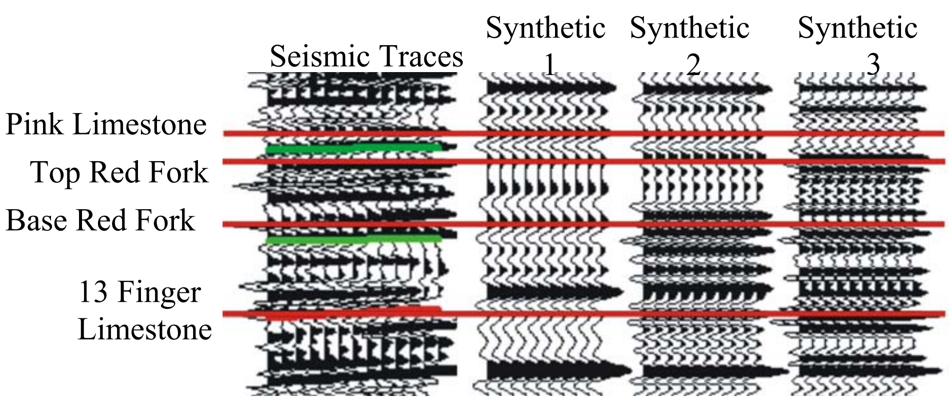



**Figure 32.** Synthetic seismic data showing Red Fork marker beds on a well located on Line D-D'. Synthetic 1 was generated using a band pass filter of 8-12-48-60. Synthetic 2 was generated using a band pass filter of 8-12-70-90. Synthetic 3 was generated using a band pass filter of 8-12-110-120.

The "HFI" seismic data shows great detail and how one is able to map the Red Fork horizon continuously (Figure 33). The "HFI" data shows the top of the Red Fork at approximately 2.02 seconds and the base at approximately 2.08 seconds. The synthetics generated match very well with the seismic traces giving confidence to the correctly picked horizons. "HFI" seismic data is the only processing technique available for D-D' because this line is located within a 3D survey. However, 3D data was not available for this study. The depth of the Red Fork at D-D' is 11,950 feet and correlates with the "HFI".

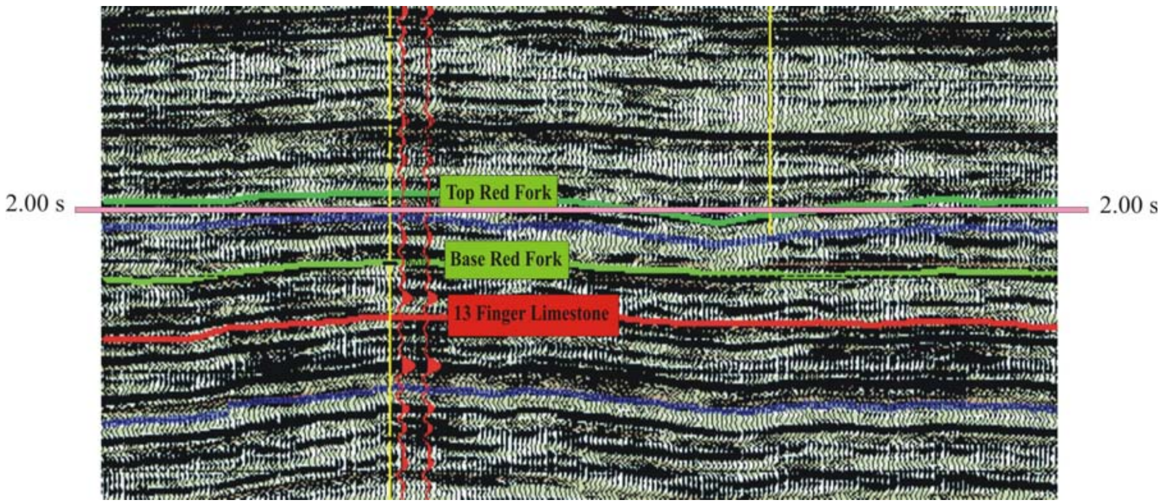



**Figure 33.** Line D-D' "HFI" arbitrary 2D line running through a 3D survey. Horizons are continuous and the synthetics match well indicating a more accurate interpretation of the Red Fork,. The pink line indicates the time. (Yellow lines indicate well locations.)

## CONCLUSIONS

1. The lithofacies of the Red Fork in this valley system greatly influence the quality of seismic data needed for accurate interpretation, whether it is processed, reprocessed, or "HFI". The seismic data obtained in A-A' show that the mapping of phase II sands do not require the reprocessed or "HFI" seismic data. Phase III sands show up better in the "HFI" data as seen in lines B-B', C-C', and D-D'.
2. Because of the low resolution, the processed seismic data does not provide the accuracy needed to map the top and base of the Red Fork. Previous studies indicate that interpreters had a difficult time interpreting and mapping the Red Fork interval with this processed data alone.
3. The reprocessed seismic data gives the interpreter an improved identification of the Red Fork interval. Since Line A-A' does not traverse through the upper Red Fork valley system, the reprocessed seismic data is sufficient to use in mapping and identifying the Red Fork interval. In this area of the basin, the "HFI" does not enhance the quality of the data.

4. The “HFI” seismic data gives the interpreter an ideal image of the subsurface, especially in the deepest portion of this upper Red Fork valley system. Because the Red Fork sands in the deepest part of the channel are phase III sands, the “HFI” seismic data is useful in identifying the top and base of the Red Fork interval. Since Lines B-B’, C-C’, and D-D’ all traverse through the upper Red Fork valley system, the use of “HFI” seismic data is recommended for mapping this area of the Anadarko basin.

## REFERENCES


Al-Shaieb, Z., Puckette, J.O., Abdalla, A.A., and Ely, P.B., 1992, Three levels of compartmentation within the overpressured interval of the Anadarko basin: AAPG Bulletin, vol. 76, no. 13, p. 69-83.

Al-Shaieb, Z., Shelton, J.W., and Puckette, J.O., 1989, Sandstone reservoirs of the Mid-Continent: Syllabus for a short course sponsored by the Oklahoma City Geological Society, p. 3-33.

Al-Shaieb, Z., and Puckette, J.O., 2002, The Red Fork Sandstone: An overview of fluvio-deltaic platform and shelf reservoirs: Oklahoma Geological Survey Circular 108, p. 237.

Andrews, R.D., 1997, Fluvial-dominated deltaic (FDD) oil reservoirs in Oklahoma: The Red Fork play: Oklahoma Geological Survey Special Publication 97-1, p. 1-90.

Boggs, Jr., S. Principles of sedimentology and stratigraphy. Upper Saddle River: Prentice-Hall, Inc., 2001.

Bottjer, R., Peyton, L., Partyka, G., and Warner, A., 2001, Interpretation of Red Fork incised valleys using 3-D seismic, Watonga-Chickasha trend, Anadarko Basin, Oklahoma: Oklahoma Geological Survey Circular 104, p. 99-103.

Clement, W.A., 1991, East Clinton field—U.S.A., Anadarko basin, Oklahoma: AAPG Special Volumes, vol. A024, p. 207-267.

Frezon, S.E., and Dixon, G.H., 1975, Texas panhandle and Oklahoma: in paleotectonic investigations of the Pennsylvanian system in the United States, Part I: Introduction and regional analyses of the Pennsylvanian system: Oklahoma Geological Survey Professional Paper, No. 853, p. 177-195.

Fritz, R.D., and Beaumont, E.A., 2002, Red Fork sandstone of Oklahoma: Depositional history, sequence stratigraphy, and reservoir distribution: Oklahoma Geological Survey Circular 108, p. 240.

Johnson, C.L., 1984, Depositional environments, reservoir trends and diagenesis of Red Fork sandstones, in portions of Blaine, Caddo, and Custer counties, Oklahoma: Oklahoma City Geological Society Shale Shaker, vol. 35, no. 2, p. 30-46.

Johnson, K.S., 1971, Guidebook for geologic field trips in Oklahoma: Oklahoma Geological Survey Educational Publication no. 2, p. 1-15.

Kennedy, C.L. The Deep Anadarko basin. Denver: Eastwood Printing and Publishing Co. 1982.

Peyton, L., Bottjer, R., and Partyka, G., 1998, Interpretation of incised valleys using new 3-D seismic techniques: A case history using spectral decomposition and coherency: The Leading Edge, vol.17, no. 9, p. 1294-1298.

Puckette, J.O., Anderson, C., and Al-Shaieb, Z., 2000, The Deep-marine Red Fork sandstone: A submarine-fan complex: Oklahoma Geological Survey Circular 103, p. 177-184.

Puckette, J.O., and Al-Shaieb, Z., 2002, The Red Fork sandstone: Overview of marine and deep-marine reservoirs: Oklahoma Geological Survey Circular 108, p. 119-133.

Schneider, R.E. and Clement, W.A., 2002, History of the east Clinton gas field, Custer County, Oklahoma: A seismic-stratigraphic case study: Oklahoma Geological Survey Circular 108, p. 73-110.

Sheriff, R.E. Encyclopedic Dictionary of Applied Geophysics. Tulsa: Society of Exploration Geophysicists, 1991.

Warner, Al. Personal interview. 26 April 2006.

Whiting, P.H., 1984, Depositional environment of Red Fork sandstones, deep Anadarko Basin, western Oklahoma: Oklahoma City Geological Society Shale Shaker, vol. 34, no. 9, p. 104-119.

**VITA**

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Candidate for the Degree

of Master of Science

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Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: INTERPRETATION OF THE UPPER RED FORK VALLEY IN THE ANADARKO BASIN: A COMPARISON STUDY BETWEEN PROCESSED, REPROCESSED, AND HIGH FREQUENCY SEISMIC DATA

Pages in Study: 44 Candidate for the Degree of Master of Science

Major Field: Geology

Scope and Methodology: Seismic lines will be used to determine the amount of downcutting of the Red Fork interval within the Anadarko basin. High frequency seismic data, along with a 2D arbitrary line that runs through a 3D seismic shoot, will be compared to the original 2D data. The comparison of the quality and resolution of processed, reprocessed, and high frequency seismic data will show which seismic data set is easier to pick horizons and in stratigraphic and structural mapping.

Findings and Conclusions: The lithofacies of the Red Fork sands in this valley system greatly influence the quality of seismic data, whether it is processed, reprocessed, or "HFI". The processed seismic data is not very useful in picking locations of intended horizons. The reflectors are not continuous so there is a lot of guess work as to the intended interval. The reprocessed seismic data gives the interpreter a better idea as to which reflector the Red Fork interval is. Since Line A-A' does not traverse through the upper Red Fork valley system, the reprocessed seismic data is sufficient to use in mapping and identifying the Red Fork interval. In this area of the basin, the "HFI" does not enhance the quality of the data. The "HFI" seismic data gives the interpreter an ideal image of the subsurface, especially in the deepest portion of this upper Red Fork valley system. Because the Red Fork sands, in the deepest part of the channel, are phase III sands, the "HFI" seismic data is useful in identifying the top and base of the Red Fork interval. Since Lines B-B', C-C', and D-D' all traverse through the upper Red Fork valley system, it is wise to use the "HFI" seismic data to interpret and map this area of the Anadarko basin. The amount of migration and increase of fold aids in the ability to interpret this interval.

ADVISOR'S APPROVAL: Dr. Surinder Sahai