Application of Cutting-Edge 3-D Seismic Attribute Technology to the Assessment of Geological Reservoirs for CO2 Sequestration

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CONTENTS

Executive Summary

This project involves the application of state-of-the-art seismic attributes toward detailed interpretation, geological model building, and flow simulation at a potential CO2 sequestration site in the Dickman field of Ness County, Kansas. Progress this quarter has centered on technical issues related to porting the project data from GeoFrame to Petrel, since the latter software is better suited for the model building activity and offers direct export to the Eclipse flow simulator. Management issues have also been resolved concerning subcontractor performance and cost sharing.

Activities in Quarter

<u>Progress Importing Dickman Field (KS) Project from GeoFrame to Petrel</u>

<u>Introduction</u>

Petrel is a software package that allows the user to build a reservoir model all the way from Seismic cubes to up-scaled earth model grids with rock, fluid, and flow properties, ready for flow simulation with Petrel or export to a third party simulator. Petrel is PC-based with geosciences data management and the familiar PC interface that requires much less software training and system support than workstation-based systems such as GeoFrame (GF). Much of the geology and geophysics interpretation work for Dickman Field (Kansas) was done in GF between July 2007 and July 2008. Transferring Dickman Field data from GF to Petrel is as a necessary step for better integration of geology, geophysics, and reservoir engineering data to build a unified, gridded earth model. Our colleagues at Texas A&M University are familiar with Petrel and it's ability to build models for export to the Eclipse flow simulator. This workflow is planned for CO2 flow simulation in the Dickman field as part of the current project in 2009 with Texas A&M as collaborator.

The major challenge for the GF -to-Petrel transfer is to preserve important work results on the Dickman Field done by previous workers in GF, including versions of seismic horizons, processed well logs and derived logs, and versions of well tops and lith-ozones, while eliminating unwanted or obsolete interpretation products. The selected GF results were exported as data files of different format. Files not ready for Petrel import were edited to fit the Petrel file format, a manual and time-consuming process. For data types and formats not supported by both GF and Petrel, more editing work was aimed at preserving as much as possible of the work done in GF. Quality control was applied on all data and interpretation products imported to Petrel by cross-checking and comparing key displays in the Petrel and GF systems.

<u>Coordinates and 3D Seismic Data</u>

The Dickman 3D seismic data volume was imported using true coordinates. Imported volumes include full-stack amplitude (Fig. 1.1 and 1.2), acoustic impedance, coherence, and curvature (positive and negative), as well as selected interpretation versions of seismic horizons. The imported data volumes were cross-checked with the GF display using the same amplitude display scheme with selected time slices (Fig. 1.3). Versions of Fort-Scott, Miss-unconformity, and Gilmore City Horizon interpretations were also imported. The data were plotted in 3D and top maps from GF displays with similar z-time ranges were used for QC (Fig. 2-1, 2, 3 and 4). Compared with GF, the Petrel 3D display is very powerful in visualizing the sub-surface geometry and properties of the strata, as shown in Fig. 1.

Wells, Logs, and Tops

Well heads and well path deviation

A total of 134 well x-y locations were loaded in Petrel and the wells with logs were plotted and compared with GF (Fig. 3-1 and 2). Since there are no deviated wells, all well traces were imported with true vertical depth equal to measured depth. Seven important GF well attributes were transferred to Petrel, but some GF well attributes were lost during the transfer. For instance, the user-specified well head display symbols (Borehole Appearance) for production status of the wells were lost, due to differences in well symbol codes between the two applications. In fact, production wells with the same pay-zone formation in GF were assigned different well symbols in Petrel as production wells, dry holes, and other well types. This needs to be fixed well by well after all transfer is done.

Well manager after import

The Petrel 'Well Spreadsheet' is the equivalent of GF's 'Wells and Borehole Data Manager'. It is used to add well properties lost during the transfer, such as borehole sets defined in GF as belonging to a specific geological cross section or missing or wrongly-assigned well symbols.

Import well logs

More than 160 logs from 38 wells were loaded as displayed by the 'Well Spreadsheet' (Fig. 3.3). The logs loaded in Petrel were compared with the GF logs graphically and by cross-checking with the well tops loaded from GF markers (Fig. 4.2). One problem during the transfer of log data is that Petrel has a 'Global Log' folder that was not represented by a specific GF data type. Each GF borehole may contain more than one log with similar 'Code', say 'GR' (original or calibrated), and by querying logs by one of the four criteria. For instance 'Code=GR' ('Property Code', or "Name"), the latest modified GR for each selected borehole will be selected by GeoFrame as a default if no further selection criteria are specified. While in Petrel, loading logs of the same 'Code' from wells creates multiple 'Copy of XX log' in the global log folder, and each one corresponding to only one log in one borehole. There are many 'Copy of GR' logs as shown in Fig. 3-3, and the spread sheet does not give the similar set of querying criteria as in GF. To document these 'Copy of logs' one-by-one in Petrel, as 'Original' and 'Derived' and to link the corresponding types of original or derived logs (for instance, the calibrated GR log with 30-point moving average) is a major task. But it is essential for effectively querying well logs in construction of well correlation cross-sections and seismic-well log overlay sections (in progress).

Import point well data

Four versions of more than 20 geological surfaces from more than 70 wells, totalling 2088 GF markers, were loaded into the Petrel. This came in as 'point well data' with major attributes such as name, associated well traces, stratigraphic surfaces, x, y and z (time/depth) readings, etc., as shown by the Petrel Spread Sheet (Fig. 4.1). Eight stratigraphic surfaces were created in Petrel for geological correlations in the depth domain (Fig. 4.2). Logs and tops were posted for selected wells and compared with cross-sections in GF (Figs. 4.3). Some marker attributes in GF were not transferred directly to the Petrel point data file, such as marker symbols, types, versions, and confidence factors. These attributes will be added in Petrel for tops selected to build the geology model in depth.

Lithozones

GeoFrame 4.2 and lower versions as used for Dickman Field data do not have the tools for exporting litho-zones to files acceptable by Petrel as litho-logs and Petrel does not support the GF litho-zones versioning. Therefore direct transfer of GF litho-zones data to Petrel litho-logs is not possible. The litho-logs in Petrel were created from a selected version of stratigraphic tops using the 'Update Zone Logs' tool. The results are compared with cross sections created in GF (Figs. 4.3 and 4.4), containing six litho-zones across the entire Field for the two reservoirs as sequestration targets and the deeper saline aquifer. For some wells, the lithozone logs are the same as seen in GF cross sections. However, in some wells zones with similar names were repeated. For these wells corrections of the litho-logs are needed.

Grids, Isochrons, and 3D Geometry Modeling

Compared with the work of editing files for loading these data, recreation in the Petrel geology modeling work flow is more time effective. The time-domain tops have already been loaded or computed as shown in Fig. 2 and can generate grids and isochrons using Petrel tools. Those in the depth domain will be created as soon as the editing of stratigraphic tops and lithozones are completed.

An example of 3D a log-seismic overlay is shown in Fig. 5, plotted before and after time-depth conversion. The conversion was already done in GF for four boreholes using synthetic analysis tools, and the resulting time-depth curves were saved as pseudo-check shot curves. These curves were transferred from GF to Petrel for posting the well traces and associated logs to the corresponding seismic reflectors (5.2-5.4). These 3D plots will serve as basis for the reservoir geometry model to be built in Q4.

SPICE Attribute and High-Resolution Stratigraphy

Depth conversion is an essential operation that converts observed seismic reflection times into the depth domain for volumetric model building and other uses. It requires high-fidelity correlation between log tops and seismic events. Here we examine the Mississippian (Miss) formation top since it is basically coincident with the depleted oil reservoir that is one of the CO2 sequestration targets.

Figure 6.1 is the Dickman Field area showing the 3D seismic survey line and cross line numbers, a blue outline of the live (non-zero) seismic area, and all 142 wells. Three of these wells have time-depth curves as shown in Figure 6.2, and only two of these are in the live seismic area. These are the anchor points for identifying the specific seismic event with the Miss. Seismic data extracted along the Elmore 3 to Dickman 6 line is shown in Figure 6.3. The grayscale image is seismic amplitude and the wiggle plot overlay is every 10^{th} amplitude trace with positive values shaded red. Close study of this data shows that both the Elmore 3 and Dickman 6 indicate the same peak event as corresponding to the top of Mississippian. The horizontal red line in Figure 6.3 corresponds to the 840 ms time slice (near the top Miss.) shown in Figure 6.4. It is clear from this image that the Elmore 3 well resides in the channel feature mentioned in previous reports.

To better determine the relationship between channel facies and the top Miss., Figure 6.5 shows an extraction through a SPICE (Smythe et al., 2004) attribute volume. This bedform attribute is useful for delineating stratigraphic relationships and fault patterns. The channel feature is seen in the SPICE data as development of extra bed forms in an area centered on Elmore 3.

In Figure 6.6, a long arbitrary line is shown that snakes though most of the Dickman wells that have Miss tops. The corresponding vertical seismic section is shown in Figure 6.7. This allows a quick view of the relationship between well tops and seismic events.
It should be noted that all well tops in thus section are displayed in time through the application of one of the three time-depth curves discussed earlier. We expect that away from these key wells, the log top and seismic event my drift apart. This is indeed seen in Figure 6.7, but in total the Miss log top consistently indicates connection to the same peak amplitude event. We conclude that this event represents the Miss reflector and well top deviations from it are evidence of small lateral velocity variations not captured by only a few time-depth curves.

Teapot Dome 3D Migration and Attributes

Although our focus is squarely on the goal Dickman field CO2 flow simulation, there was some work done earlier in the project on the Teapot Dome field managed by the Rocky Mountain Oilfield Testing Center (RMOTC). After discussions with Tom Anderson (chief scientist), we agreed to provide migration and attribute volumes to wrap up our involvement at Teapot. The data consists of four migration volumes:

1. PostSTM (post-stack time migration)
2. PostSDM (post-stack depth migration)
3. PreSTM (pre-stack time migration)
4. PreSDM (pre-stack depth migration)

Each migration volume has been used to compute the following attribute volumes:

1. Crossline gradient
2. Principle component filter
3. Energy ratio
4. Fractional derivative amplitude
5. Inline gradient
6. Negative curvature
7. Positive curvature
8. Outer product

Together, these 36 data volumes represent almost 15 GB of data. These have been written to a 5 DVD set and are being sent to Tom Anderson for archiving and distribution to interested parties. The migrations and attributes are based on codes developed by Dr. Kurt Marfurt, and processed by Filipe Lozano (U.H. graduate student).

Work Plan for Next Quarter

The modeling work flow before the flow simulation step includes the following three phases:

1. Stratigraphic depth-time correlation
2. Structural interpretation and geometry grid build
3. Litho/ porosity/permeability property modeling for grid block infilling

In the next quarter our efforts will center on the following work.

Stratigraphic modeling will proceed with the seismic horizons and well tops imported from GeoFrame and previous work in Kingdom software by T. Bjorklund. The main issue is the time-depth correlation of a few horizons, establishing the best-available connection between geologic depth from well logs and reflection time from seismic data.

Seismic horizons are tracked and mapped in time, and the time-depth model allows this to be converted to depth for input to the gridded geologic model (which is also in depth). The time horizons needing depth conversion include:

Sandstone reservoir. Lower Cherokee sandstone is represented by tops picked in 18/142 wells. It is a thin unit (12-25 ft) that extends to the Mississippi Unconformity (61 wells)

Carbonate Reservoir. Extends from the Mississippi Unconformity to the oil/water contact (tops in 48 wells)

Deep Saline aquifer. Extends from Mississippian oil/water contact to Gilmore City (3 wells)

We do not have check-shots to calibrate the sonic logs for synthetic generation and absolute time-depth matching. But synthetic seismograms can be generated in the two wells with both sonic and density logs (Sidebottom 6, Humphrey 4-18) allowing visual correlation to obtain the time-depth relationship. The main challenge is to improve time picks for Lower Cherokee sandstone, top Miss., and the oil/water contact. This is necessary for the structural model to be able to resolve the two reservoirs from the deep saline aquifer. Figures 7.1 through 7.3 indicate the nature of this task and the encouraging role the SPICE attribute may play.

Structural modeling methods involved in this phase are unique to Petrel, so we will need to gain experience and perform extensive QC before reliable results can be achieved. A structural model includes three processes: fault modeling, pillar gridding, vertical layering. Each will serve as the base for the next and work has to go back and forth between them since problems with the previous process will often not be obvious before starting the next process.

Property modeling: the objective is to distribute known reservoir properties between wells in such a way that it realistically preserves the reservoir heterogeneity within the structural model and matches the well data. The major challenge is the lack of well data input to seed grids (at well locations), say the porosity and water saturation of target zones. Ideally at least 5 wells are needed in a block (bounded by faults) for such modeling input. Here are the data available and possible approaches to get more input points. Five Wells have direct measurements on core porosity/permeability/water saturation within pay zones or non-pay zones in the shallow reservoirs.
Two wells outside the region in different fault blocks have complete log sets for the porosity and water saturation calculation for all three target zones, and one well has proved pay-zone in carbonate and another reservoir. Another four wells have NPHI and RHOB logs needed to compute the porosity. Other wells either lack pay zones, or have NPHI log only so they will not yield accurate porosity results.

It is possible that seismic attribute mapping will help extend these properties from known wells to other wells with pay-zones. If the geometry component can be subtracted from the current seismic reflector geometry, the geometry attributes done in GF (already loaded in Petrel) may help to assign properties to wells, otherwise other seismic attributes must be used.

Cost Status

Baseline Costs Compared to Actual Incurred Costs

2008			
July 1 – Sept. 31	**Plan**	**Costs**	**Difference** (Plan-Costs)
Federal	$33,333.33	$0	$33,333.33
Non-Federal	$12,563.58	$0	$12,563.58
Total	$45,896.91	$0	$45,896.91

Forecasted cash needs vs. actual incurred costs

Notes:

1. Federal plan amount based on original award of $400K averaged over 12 reporting quarters.
   a. Cost this period reflects outstanding invoice to KU/KGS
2. Non-Federal plan amount based on original budget cost share of $150,573 averaged as above.

Analysis of Variance

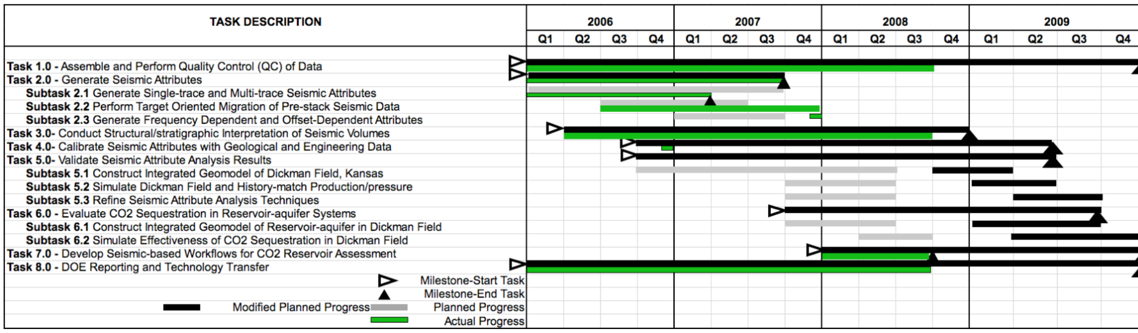
Again, costs were minimal this quarter as we worked to re-align with cost share partners KU and Continental resources (see comments below). This was also aided by UH department support of June Zeng to work on this project, and change of P.I. to Christopher Liner who had other support this summer.

Milestone Plan and Status

Critical Sub-Milestones for Next Quarter

1. Additional tuning of SPICE and, possibly, curvature attributes on Dickman 3D data **Nov 15, 2008** (*Subtasks 2.1, 2.3)*
2. Construct integrated geomodel of Dickman Field, Kansas **Dec 15, 2008** (*Subtask 5.1*)

Actual Progress Compared to Milestones



Note: In anticipation of DOE's acceptance of our request for a 12 month no-cost extension, the timeline has been extended through 2009.

Summary of Significant Accomplishments

Problems and Significant Events

Kansas University and Geological Survey

The original subcontract arrangement with KU/KGS called for work related to petrophysics and flow simulation at the Dickman Field. This involved DOE funding and \$50K cost share. Part of the work (petrophysics) was completed by early 2007 then, for a variety of reasons, progress and payment ceased. To that point, KU had contributed cost share to the amount of \$30,427.33. Negotiations between P.I. C. Liner and KU/KGS personnel in summer 2008 revealed that this subcontractor preferred to withdraw from the project to focus resources and effort. A small outstanding invoice from KU/KGS (\$2302.95) was paid after quarter end to settle the books between UH and this subcontractor.

Continental Resources II

The original subcontract arrangement with Continental Resources II (CRII) called for extensive work on petrophysics and engineering and a cost share of \$100K. For a variety of reasons, this subcontractor was not able to contribute as anticipated despite goodwill on the part of all parties. Negotiations between P.I. C. Liner and Mr. Lew Murray of CRII in summer 2008 resulted in a mutually agreeable solution that relieves CRII of any further obligation to the project or cost sharing (see details of Cost Sharing discussion below).

Texas A&M Petroleum Engineering

This new subcontractor has been added in anticipation of their stepping into the flow simulation role originally planned for KU/KGS. Details will follow in later reports.

Cost Sharing

The original award called for cost sharing of $50K from KU/KGS and $100K from CRII. Due to a variety of reasons (see above), this will change in the no-cost modified budget being prepared for submission to DOE for approval. During summer 2008, we approached Schlumberger about donation of Petrel software for use on this project in building the gridded geologic model required for subsequent flow simulation. The market value of this donation is $417K. In light of this generous cooperation, our cost share breakdown will be as follows:

	Original	**Modified**
KU/KGS	$50,000	$30,427.33
Continental Resources II	$100,763	$0
Schlumberger	$0	$120,335.67
Total	$150,763	$150,763

Personnel

Dr. June Zeng has been working exclusively on this project since Dec 2007 and much of her work is reflected in the last three quarterly reports. Her funding has come from the Department of Earth and Atmospheric Sciences at UH, but will expire on Dec 8, 2008. From that time forward she will be supported by salary funds in the project as long as possible.

Heather King is a graduate MS student in geophysics who will be joining the project in January 2008 as a research assistant. We anticipate that Dickman Field data will form the core of her thesis work, likely on subtle structure and stratigraphy inferred by interpretation of multiple seismic attributes.

Technology Transfer Activities

None in period

Contributors

University of Houston
Christopher Liner (Professor)
Jianjun (June) Zeng (Research Associate)

References

Smythe, J., Gersztenkorn, A., Radovich, B., Liner, C., and Li, C.-F., 2004, SPICE: Layered Gulf of Mexico Shelf Framework from Spectral Imaging, The Leading Edge, 23, 921

Figures

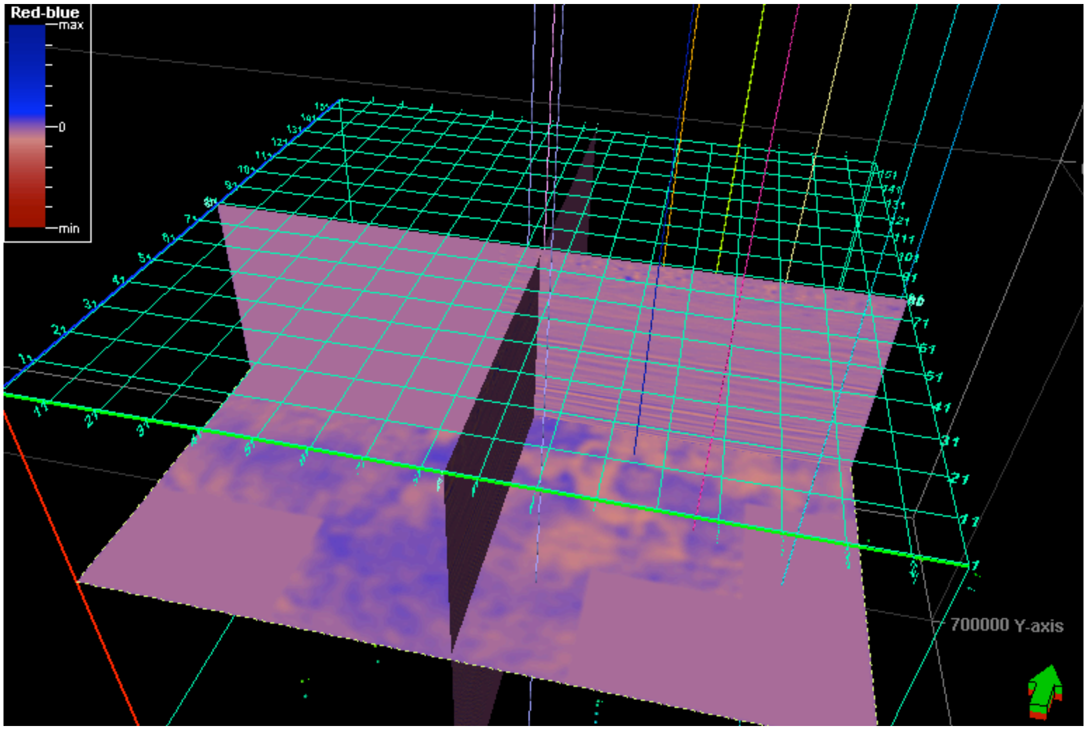


Figure 1.1 View from top, Fort-Scott channel bend around Elmore 3

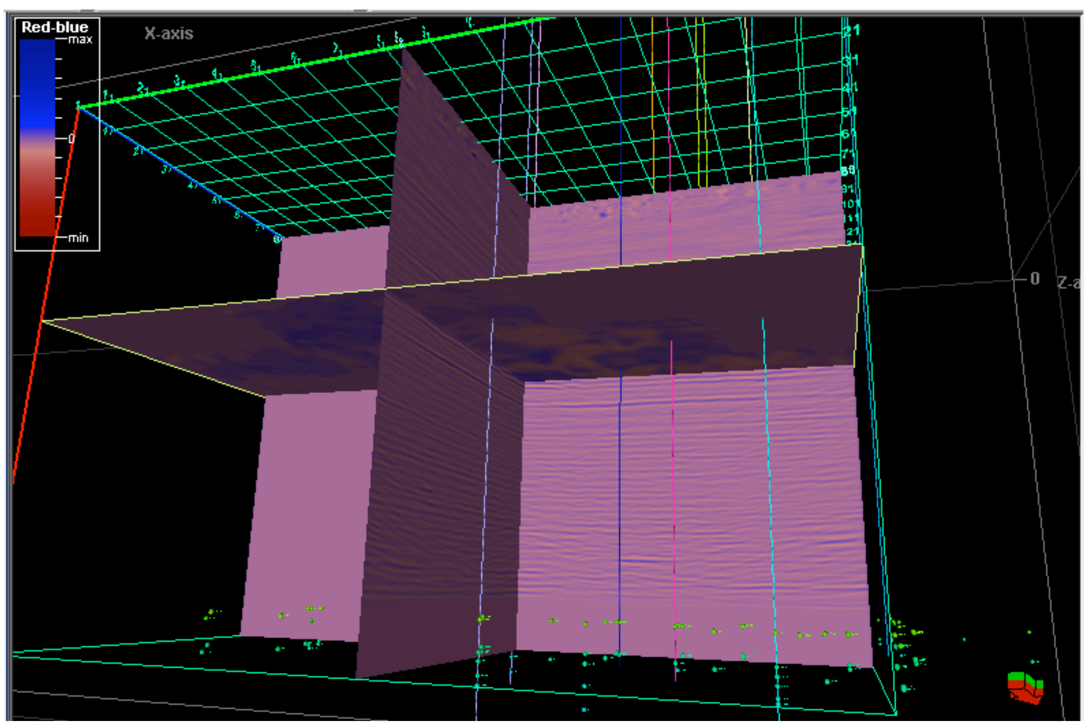


Figure 1.2 View from bottom, markers for Fort-Scott, Miss-Unconformity and Miss-Porosity, and Gilmore-City at TVDSS.

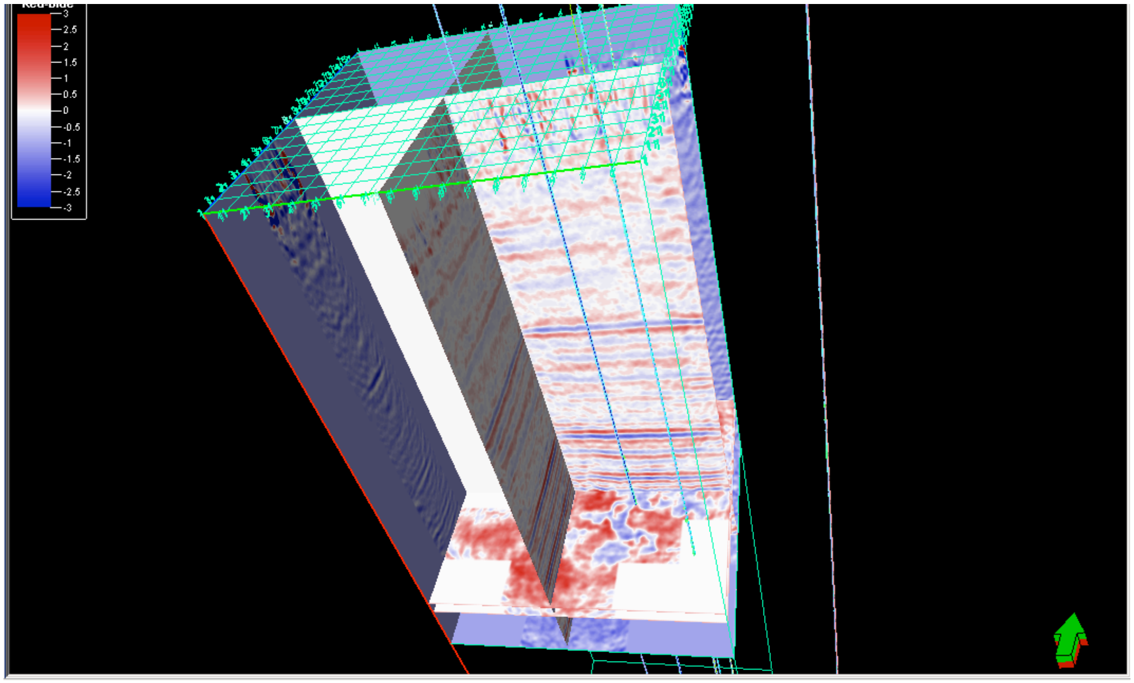


Figure 1.3 3D Cube with depth = 820 ms (Fort Scott top). With borehole traces posted.

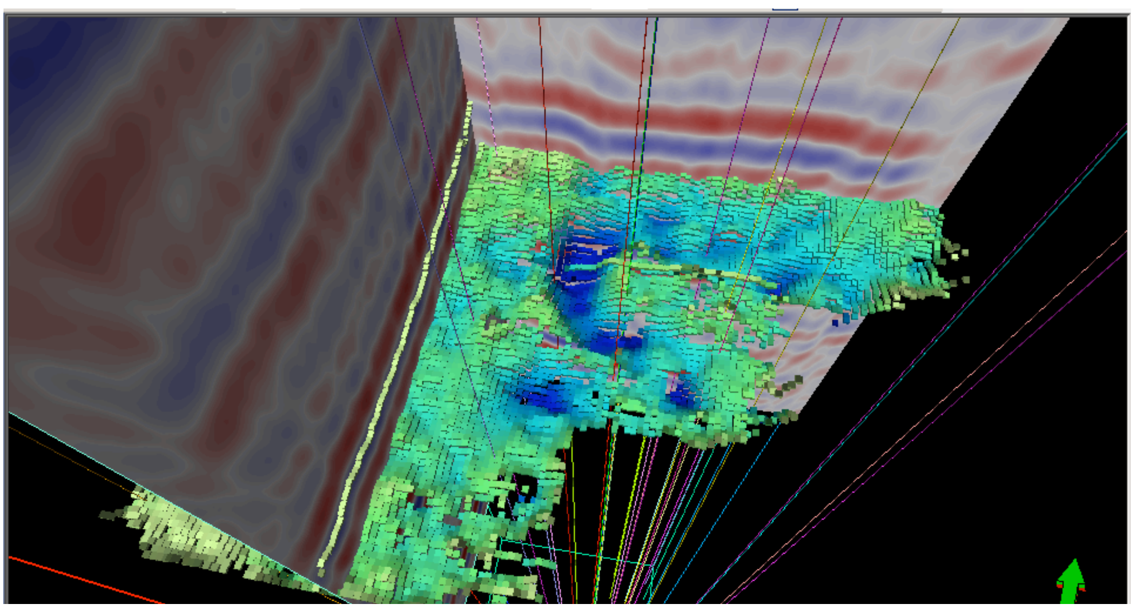


Figure 2.1 Fort-Scott Horizon interpretation, channel bend feature in dark blue

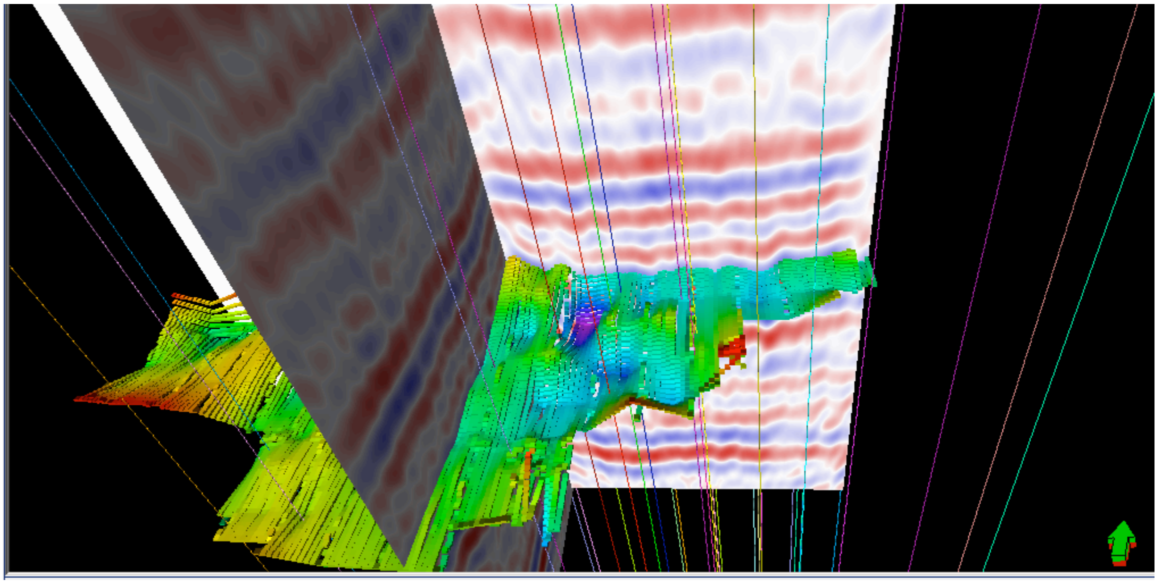


Figure 2.2 Miss Unconformity, karst sinkhole-type features in blue and pink

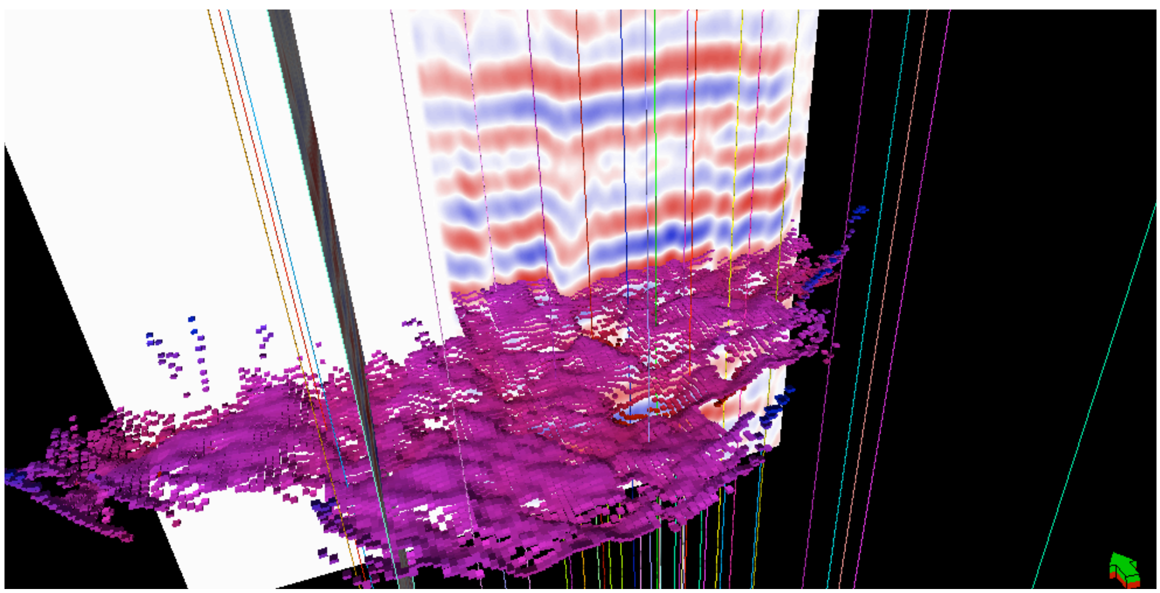


Figure 2.3 Gilmore City Horizon top, more relief.

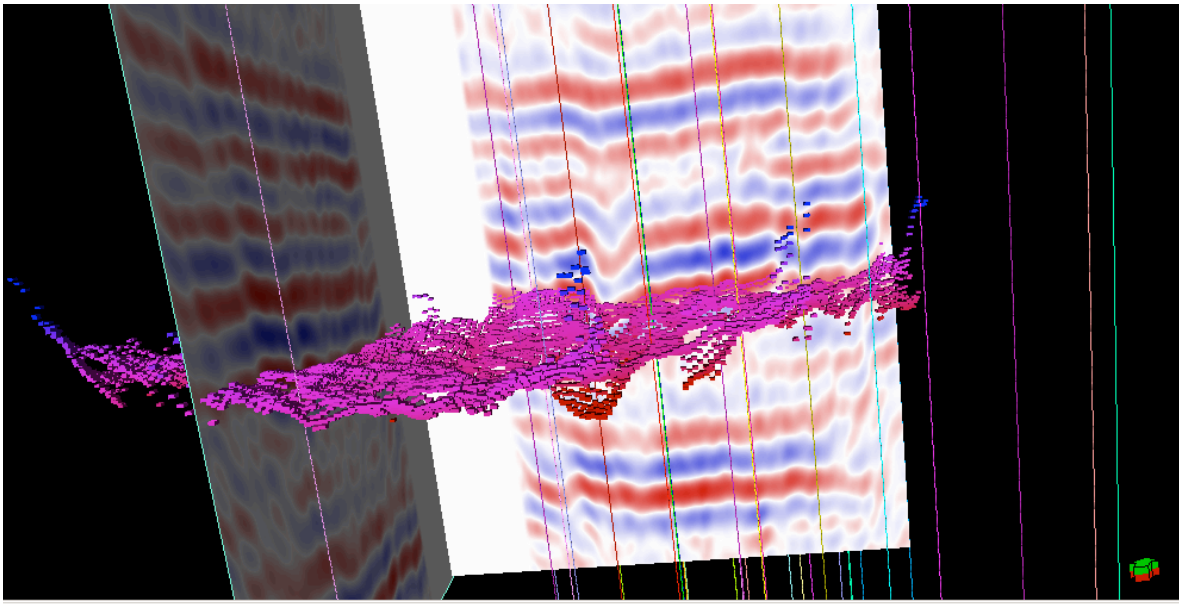


Figure 2.4 The sinkholes on Gilmore City horizon

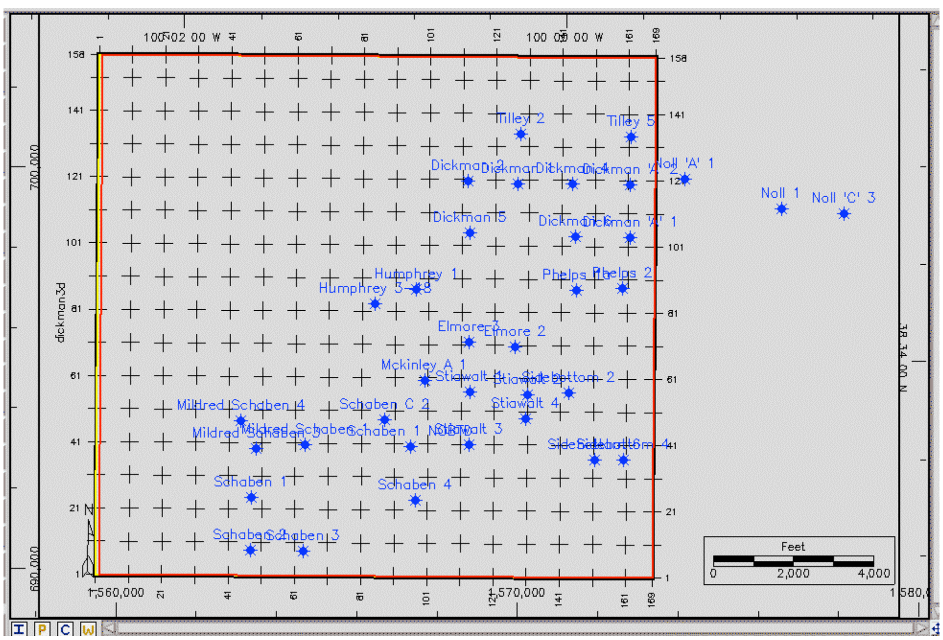
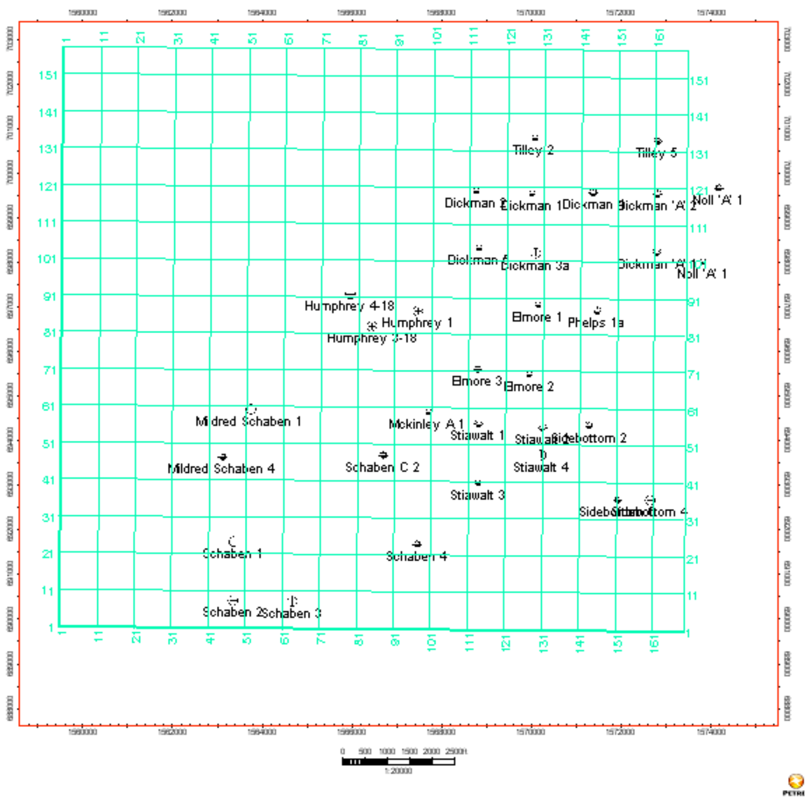


Figure 3.1 GeoFrame well location map



3.2 Petrel Well location map.

		Name	UWI	GR	ILD	ILM	ITT	LLS	NPHI	NPOR	PEF	PHIT	PIGN	RO	
3		Dickman 1	15-135-00174	Yes	Yes	No	No	No	No	No	No	No	No	No	N
126		Tilley 5	15-135-23869	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
123		Tilley 2	15-135-27495	Yes	No	No	No	No	No	No	No	No	No	No	N
119		Stiawalt 4	15-135-21646	Yes	No	No	No	No	Yes	No	No	No	No	No	N
118		Stiawalt 3	15-135-21501	Yes	No	No	No	No	Yes	No	No	No	No	No	N
117		Stiawalt 2	15-135-21488	Yes	No	No	No	No	Yes	No	No	No	No	No	N
116		Stiawalt 1	15-135-21393	Yes	No	No	No	No	Yes	No	No	No	No	No	N
115	✓	Sidebottom 6	15-135-24144	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	N
113		Sidebottom 4	15-135-22028	Yes	No	No	No	No	Yes	No	No	No	No	No	N
111		Sidebottom 2	15-135-21462	Yes	No	No	No	No	Yes	No	No	No	No	No	N
107		Schaben C 2	15-135-21892	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
102		Schaben 4	15-135-21452	Yes	No	No	No	No	No	No	No	No	No	No	N
101		Schaben 3	15-135-21378	Yes	No	No	No	No	Yes	No	No	No	No	No	N
100		Schaben 2	15-135-21257	Yes	No	No	No	No	Yes	No	No	No	No	No	N
97		Schaben 1	15-135-21163	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
67		Phelps 2	15-135-21326	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
65		Phelps 1a	15-135-21262	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
59		Noll 1	15-135-23069	Yes	No	No	No	No	Yes	Yes	No	No	No	No	N
58		Noll 'C' 3	15-135-22757	Yes	No	No	No	No	Yes	No	No	No	No	No	N
49		Noll 'A' 1	15-135-23030	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
46		Mildred Schabe	15-135-24189	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
45		Mildred Schabe	15-135-22237	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
42		Mildred Schabe	15-135-00502	Yes	No	No	No	No	Yes	No	No	No	No	No	N
30		Humphrey 4-18	15-135-24762	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Y
29		Humphrey 3-18	15-135-24106	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
27		Humphrey 1	15-135-20711	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
12		Elmore 3	15-135-23755	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
11		Elmore 2	15-135-21468	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
9		Dickman 6	15-135-21256	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
7		Dickman 4	15-135-90416	Yes	No	No	No	No	Yes	No	No	No	No	No	N
5		Dickman 3a	15-135-30406	Yes	No	No	No	No	Yes	No	No	No	No	No	N
2		Dickman 'A' 2	15-135-23753	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
1		Dickman 'A' 1	15-135-23724	Yes	Yes	No	No	No	Yes	No	No	No	No	No	N
133		Whitetail Ranch	15-135-23941	No	No	No	No	No	No	No	No	No	No	No	N

3.3 Petrel well data manager showing the wells and logs loaded

	Well Identifier	Surface	X	Y	Z	MD	TWT picked	TWT auto	TVT	TST	Interpreter	Dip angle	Dip azimuth	Missing	Confidence factor	Used by dep.conv.	Us ge
997	Sidebotto	FORT_SCOTT_ST	1571927.66	692701.02	-1859.00	4256.00	838.50	834.16			STEVE S					☑ Yes	☑ Y
244	Sidebotto	BASE_PENN_LIME	1571927.66	692701.02	-1927.00	4324.00		841.20			STEVE S					☑ Yes	☑ Y
660	Sidebotto	MISSISSIPPIAN_S	1571927.66	692701.02	-1986.10	4383.10	851.00	845.63			STEVE S					☑ Yes	☑ Y
061	Sidebotto	CHEROKEE_GRO	1571927.66	692701.02	-1884.50	4281.50		837.20			WellPix					☑ Yes	☑ Y
483	Sidebotto	MISSISSIPPIAN_P	1571927.66	692701.02	-1958.04	4355.04		843.53			WellPix					☑ Yes	☑ Y
2030	Sidebotto	OSAGE_STEVE_S	1571927.66	692701.02	-2063.00	4460.00		867.36			STEVE S					☑ Yes	☑ Y
2083	Sidebotto	GILMORE_CITY_S	1571927.66	692701.02	-2119.00	4516.00		887.26			WellPix					☑ Yes	☑ Y
2084	Sidebotto	GILMORE_CITY_S	1571927.66	692701.02	-2119.00	4516.00	880.00	887.26			GFDM					☑ Yes	☑ Y
983	Sidebotto	DEEPERMISSI2_S	1571927.66	692701.02	-2049.00	4446.00		862.59			WellPix					☑ Yes	☑ Y
671	Sidebotto	WARSAW_LIMEST	1571927.66	692701.02	-1988.00	4385.00		845.77			STEVE S					☑ Yes	☑ Y
801	Sidebotto	DeeperMISS1_SB6	1571927.66	692701.02	-2013.00	4410.00		850.31			WellPix					☑ Yes	☑ Y
619	Sidebotto	HUSPUCKNEY_TR	1571927.66	692701.02	-1631.11	4028.11		793.64			TRC					☑ Yes	☑ Y
243	Sidebotto	BASE_PENN_LIME	1571927.66	692701.02	-1927.00	4324.00		841.20			TRC					☑ Yes	☑ Y
071	Sidebotto	CHEROKEE_GRO	1571927.66	692701.02	-1887.00	4284.00		837.50			TRC					☑ Yes	☑ Y
641	Sidebotto	KANSAS_CITY_GR	1571927.66	692701.02	-1649.94	4046.94		797.35			TRC					☑ Yes	☑ Y
869	Sidebotto	PAWNEE_LIMEST	1571927.66	692701.02	-1776.40	4173.40		822.26			TRC					☑ Yes	☑ Y
494	Sidebotto	MISSISSIPPIAN_W	1571927.66	692701.02	-1960.00	4357.00		843.67			WMB 3/04					☑ Yes	☑ Y
777	Sidebotto	MARMATON_TRC	1571927.66	692701.02	-1731.86	4128.86		813.49			TRC					☑ Yes	☑ Y
996	Sidebotto	FORT_SCOTT_W	1571927.66	692701.02	-1859.00	4256.00		834.16			WMB 3/04					☑ Yes	☑ Y
070	Sidebotto	CHEROKEE_WMB	1571927.66	692701.02	-1887.00	4284.00		837.50			WMB 3/04					☑ Yes	☑ Y
672	Sidebotto	WARSAW_LIMEST	1571927.66	692701.02	-1988.00	4385.00		845.77			ACO-1					☑ Yes	☑ Y
113	Sidebotto	STONE_CORRAL_	1571927.66	692701.02	692.58	1704.42		335.77			TRC					☑ Yes	☑ Y
289	Sidebotto	HEEBNER_SHALE	1571927.66	692701.02	-1320.00	3717.00		732.35			STEVE S					☑ Yes	☑ Y
397	Sidebotto	LANSING_GROUP	1571927.66	692701.02	-1363.00	3760.00		740.82			STEVE S					☑ Yes	☑ Y
713	Sidebotto	MARMATON_STE	1571927.66	692701.02	-1696.00	4093.00		806.42			STEVE S					☑ Yes	☑ Y
702	Sidebotto	BASE_KANSAS_CI	1571927.66	692701.02	-1690.00	4087.00		805.24			STEVE S					☑ Yes	☑ Y
54	Sidebotto	STONE_CORRAL_	1571927.66	692701.02	721.00	1676.00		330.17			STEVE S					☑ Yes	☑ Y
457	Sidebotto	CHEROKEE_SAND	1571927.66	692701.02	-1955.00	4352.00		843.30			STEVE S					☑ Yes	☑ Y
624	Sidebotto	MISS_OIL/WATER	1571927.66	692701.02	-1982.48	4379.48		845.36			STEVE S					☑ Yes	☑ Y
465	Sidebotto	Top_Karst_Susan	1571927.66	692701.02	-1955.55	4352.55		843.34			WellPix					☑ Yes	☑ Y

Figure 4.1 Well top data manager showing marker data (2008 in total for 28 stratigraphic tops from 4 interpretation versions)

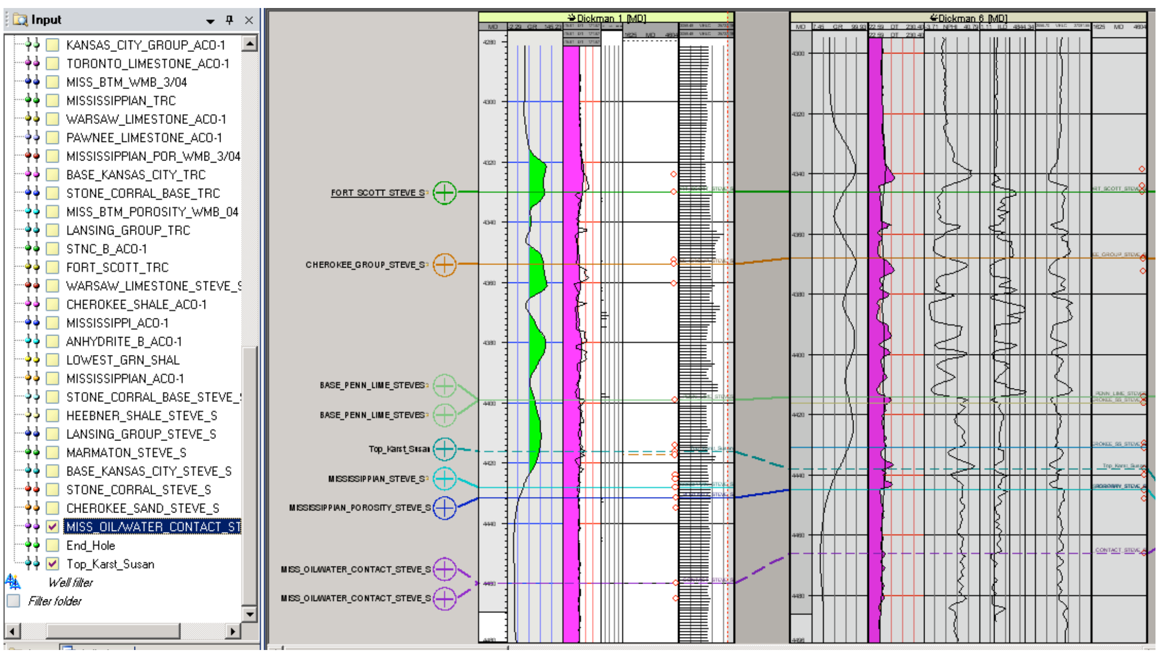


Figure 4.1 Stratigraphic tops with logs in the focus of study

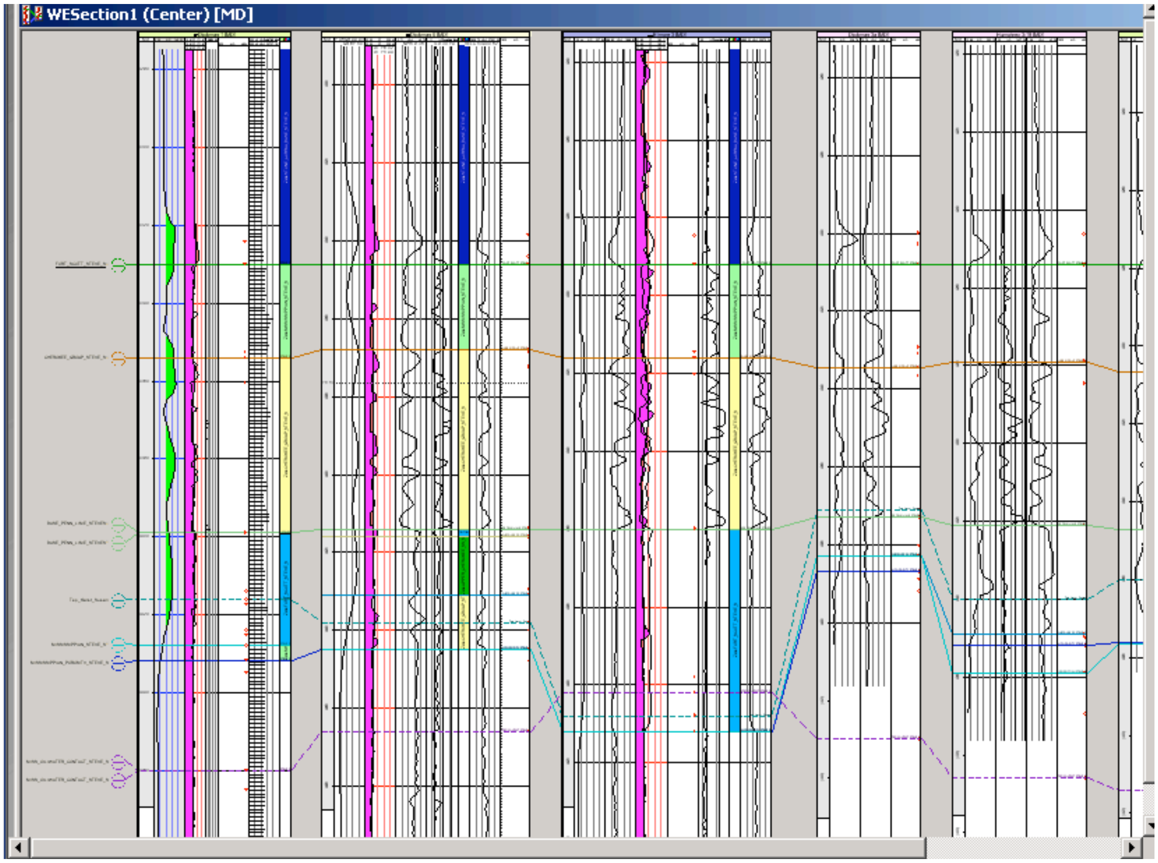


Figure 4.3 Litho-zones of the research focus created in Petrel

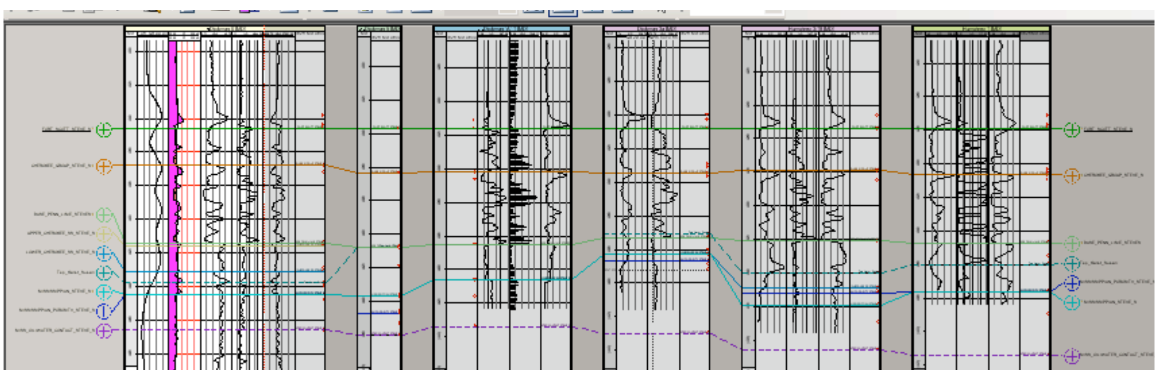
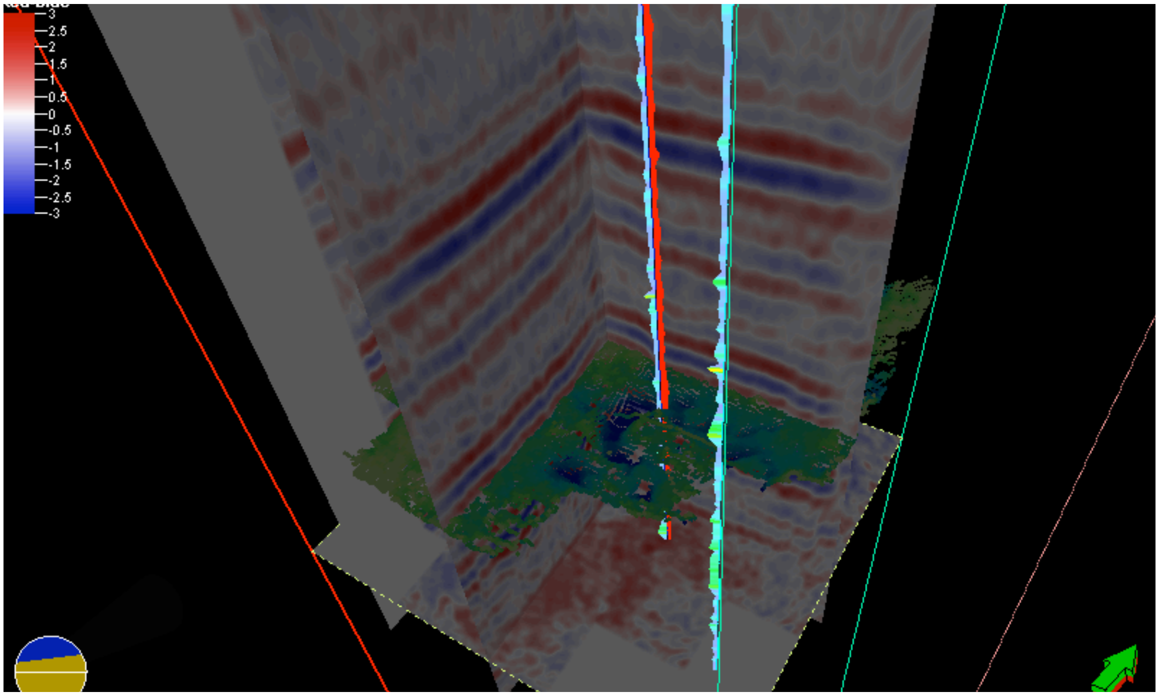
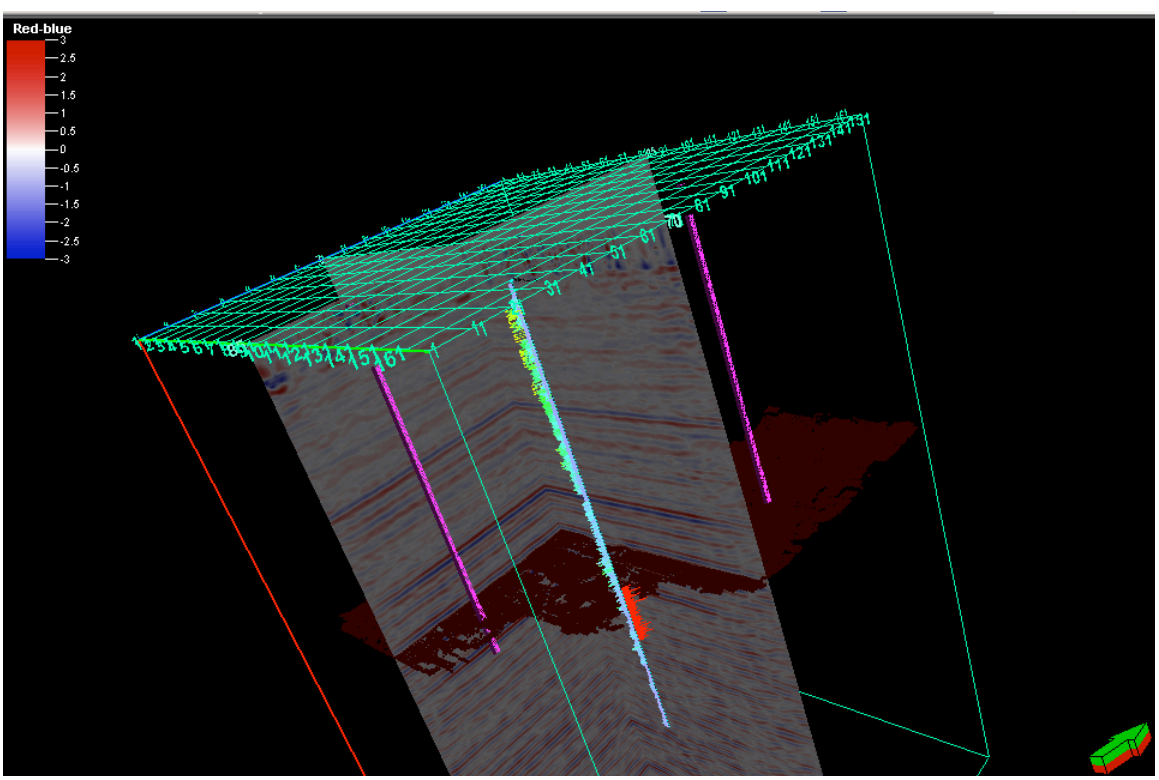


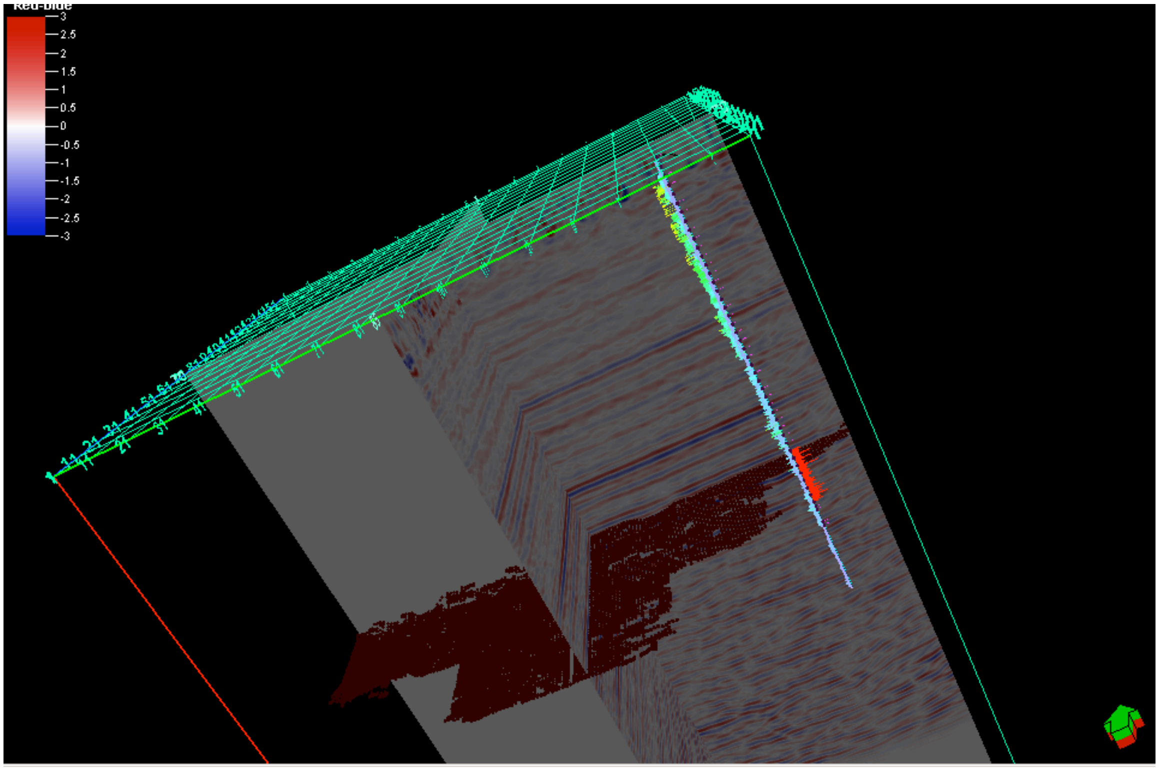
Figure 4.4 West to East cross section 1



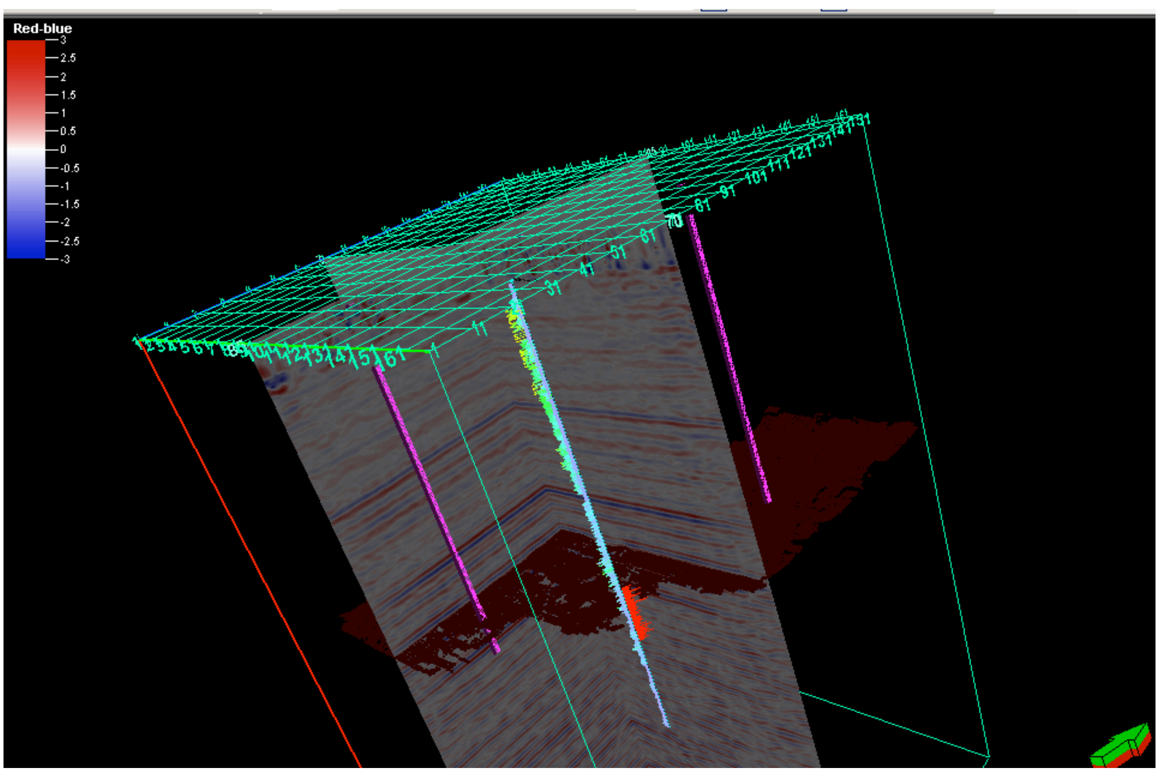
5.1 Well log display (before T-Z conversion). The green horizon is the Fort Scot Horizon



5.2 Well log display (after T-Z conversion). The red horizon is the Fort Scot Horizon. Conversion is currently possible on wells with sonic logs.



5.3 SideBottom 6 with pseudo-checkshot and logs.



5.4 More wells with pseudo-checkshot calibrated from Synthetics from Dickman 6, Sidebottom6 and Elmore3. Other pseudo-checkshots did not work.

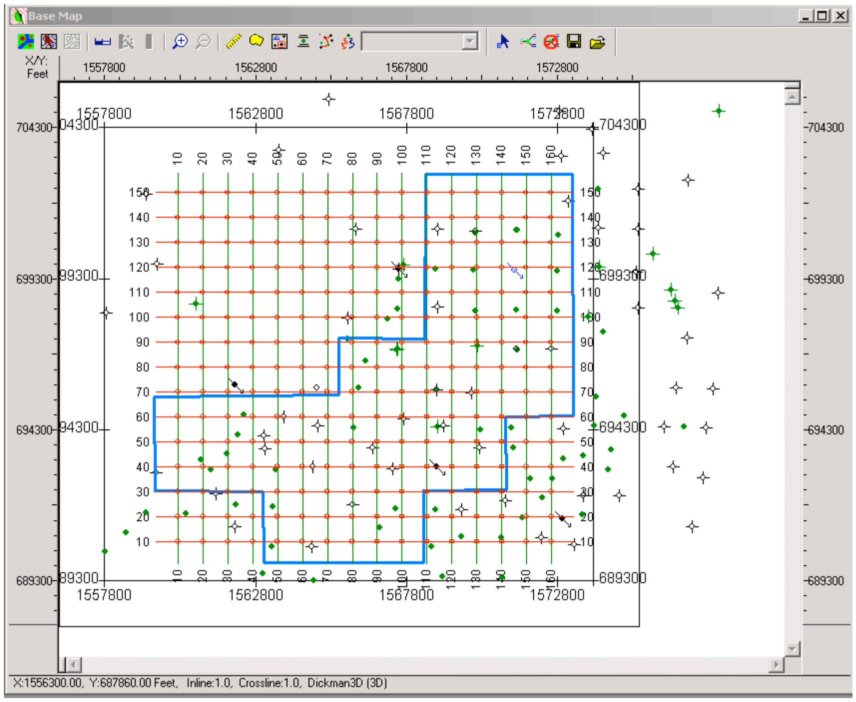


Figure 6.1. Dickman field showing 3D seismic grid, blue outline of live data area, and all well control.

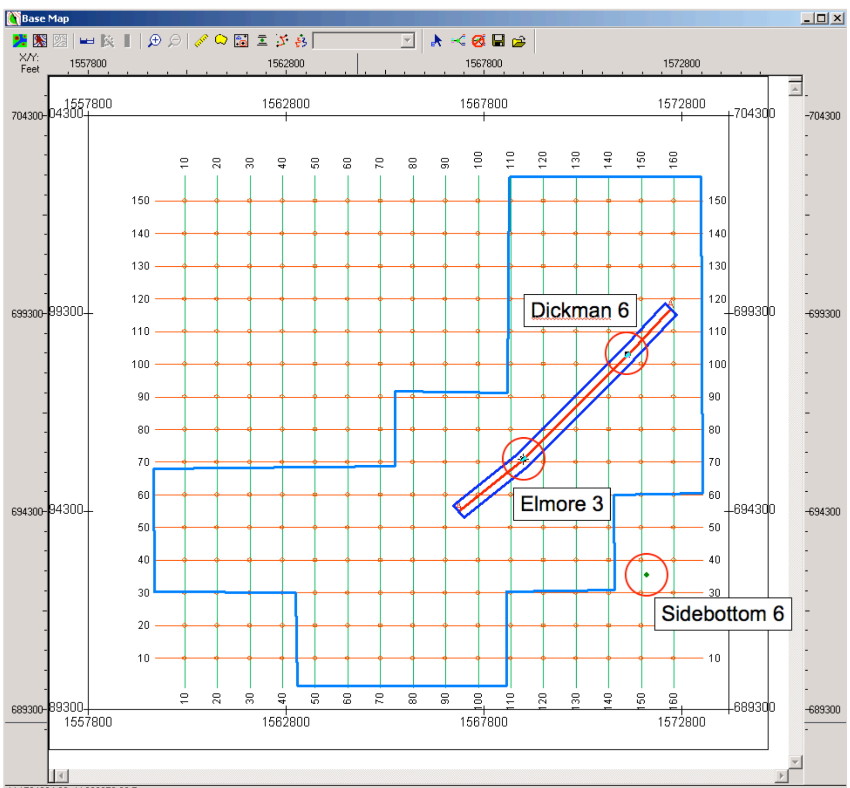


Figure 6.2. Three wells have time-depth curves. The arbitrary line (red) is drawn between the two T-D wells in the live survey area and shown in Figure 6.3.

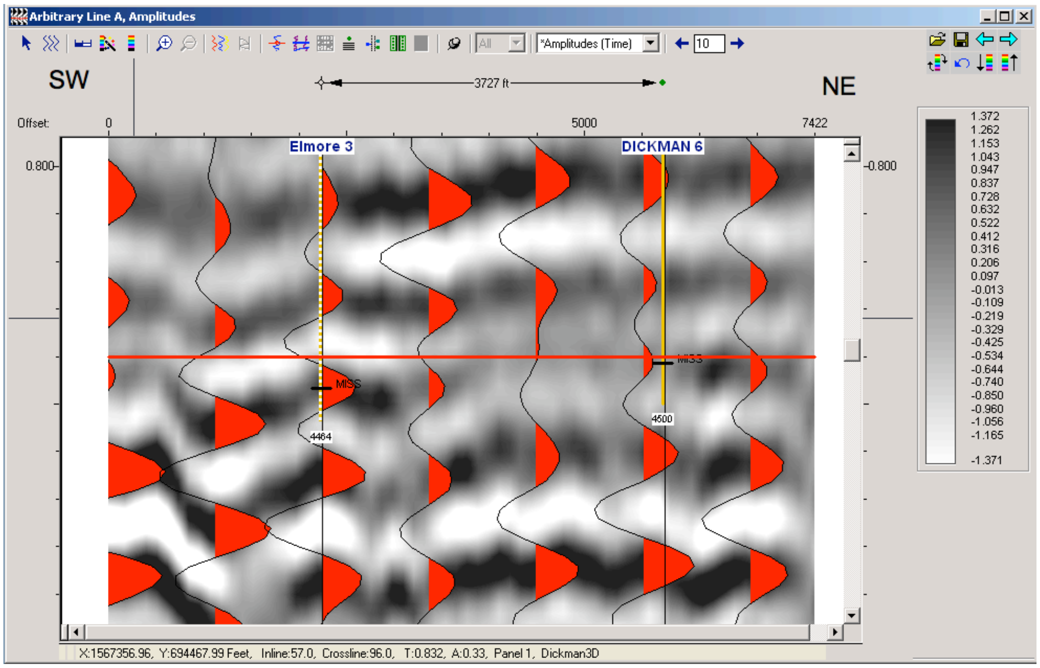


Figure 6.3. Seismic amplitude section through the Elmore 3 and Dickman 6 (wells with time-depth curves). The trace overlay is also amplitude displayed every 10th trace with peak shaded red. Note that both wells indicate the same peak event associated with top of the Miss. formation.

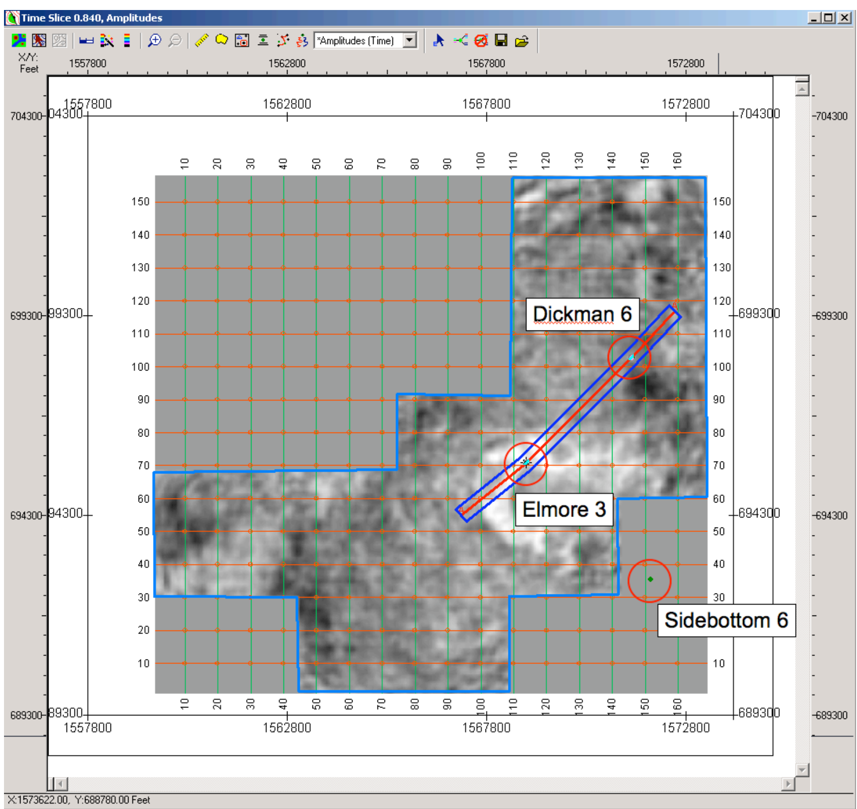


Figure 6.4. Seismic amplitude along the 840 ms timeslice indicated in the previous figure. Elmore 3 is seen located in an incised channel feature discussed in earlier reports.

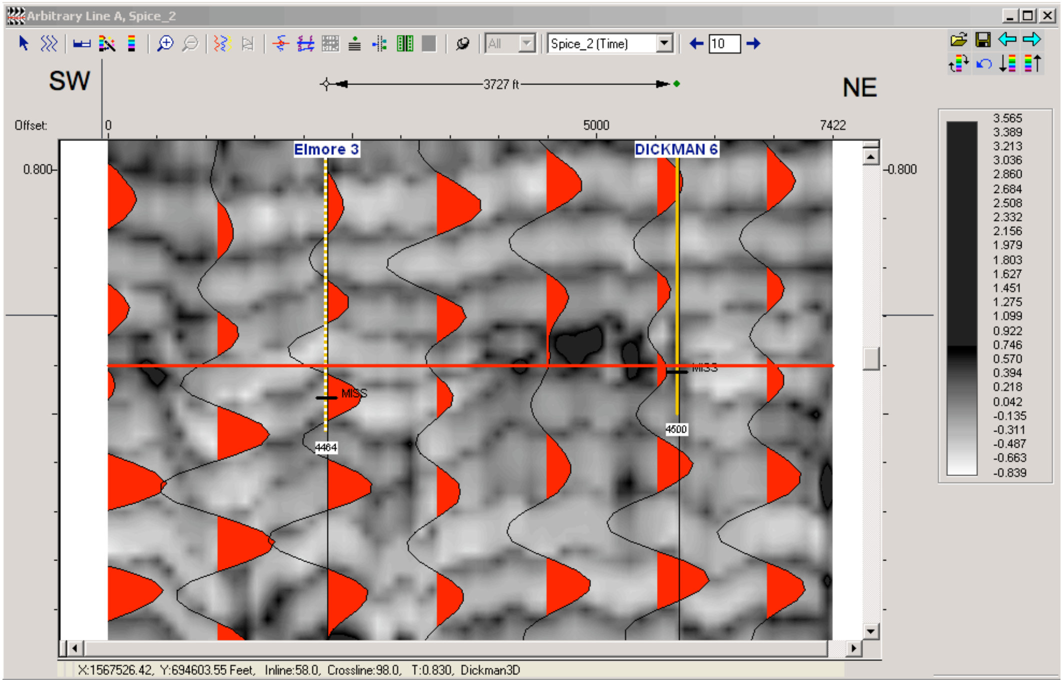


Figure 6.5. SPICE attribute display coincident with the amplitude data in Figure 6.3. The channel feature centered on Elmore 3 is clearly seen as development of new bedforms.

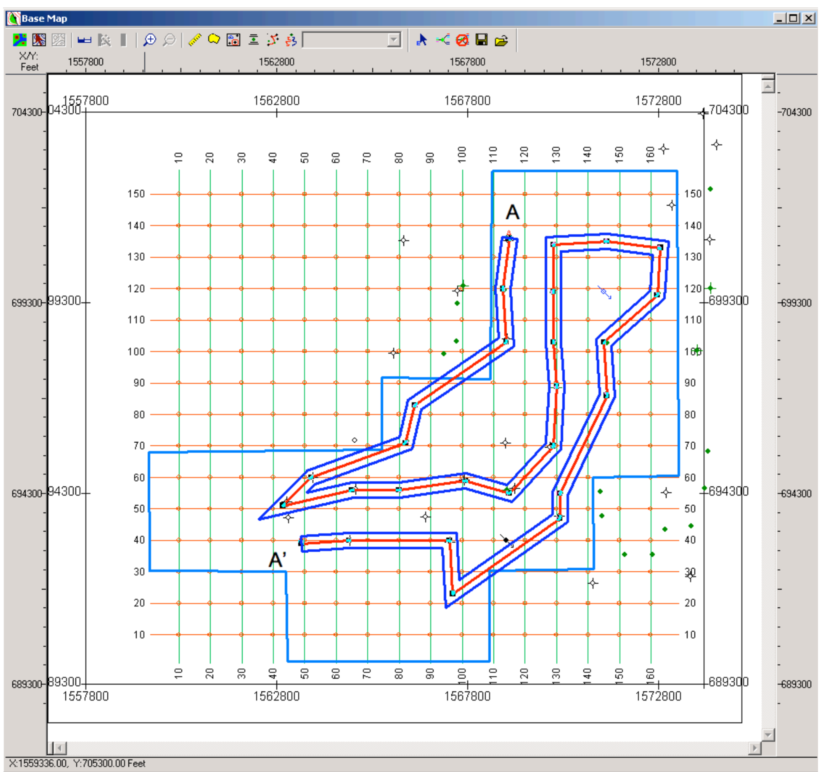


Figure 6.6. Irregular arbitrary line though many wells having a Miss top.

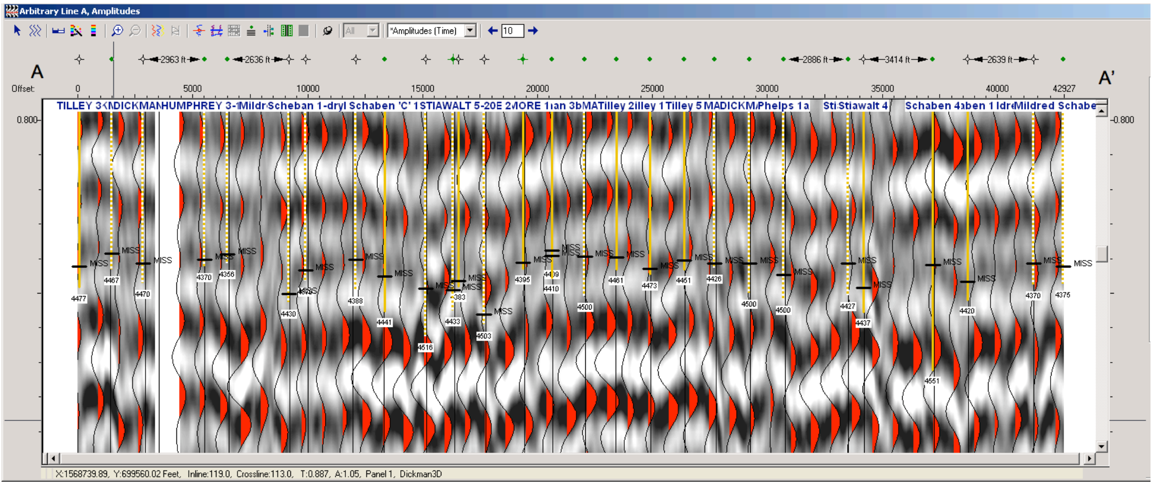


Figure 6.7. Line A-A' of previous figure showing seismic amplitude (gray background and red wiggle overlay) as well as Miss top from all wells in the traverse. Despite time-conversion being based only 3 time-depth curves, the Miss log tops consistently indicate a peak event with the top Miss.

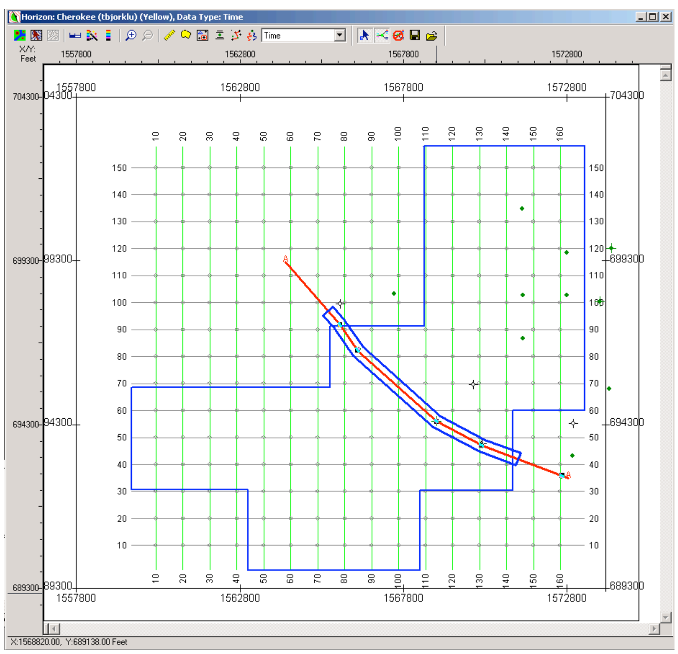


Figure 7.1. Dickman map showing all wells with Lower Cherokee Sand tops, along with an extracted seismic profile line along 4 of the wells.

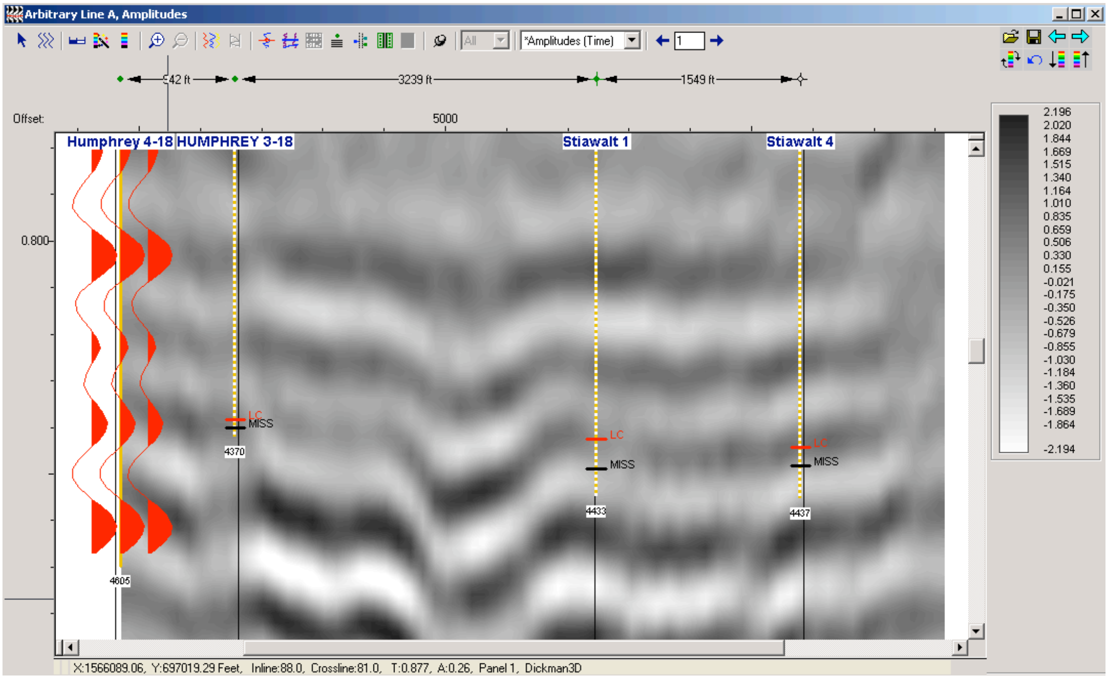


Figure 7.2. Extracted seismic along line shown in Figure 7.1. The Humphry 4-18 synthetic is shown on the left as well as Lower Cherokee (LC) and top Mississippian (Miss) formation tops in other wells. The seismic amplitude data shown here gives an ambiguous relationship between wave features and formation tops due since the interval between them is well below seismic resolution.

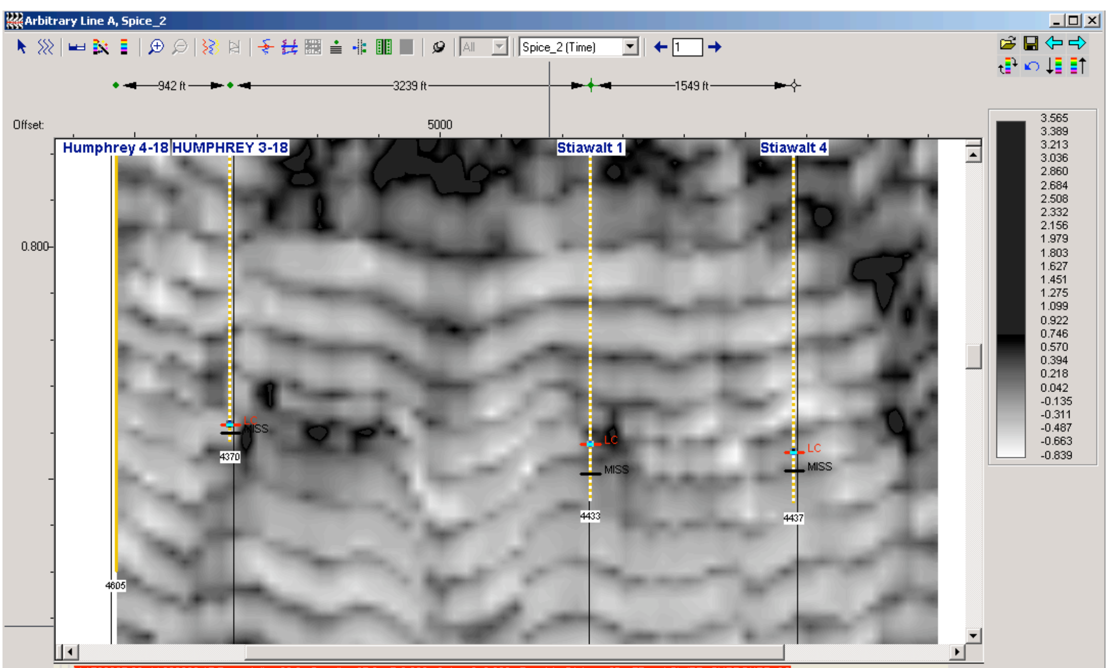


Figure 7.3. SPICE attribute section for line shown in Figure 7.2. This holds some promise as a calibration and QC tool for tracking LC and Miss through the seismic amplitude volume.