Log Property Comparison to Seismic Amplitude Analysis, Ness County, Kansas

Eric Swanson

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Summary

The Mississippian formation in Dickman Field, Kansas, shows a bright amplitude horizon on seismic. Most wells penetrated the top of this formation, however not all wells have a full suite of logs. The goal is to determine if any log properties correlate with this increase or decrease in amplitude along the Mississippian horizon.

The first step was to map the top of the Mississippian Limestone. The map was generated by tying the wells to seismic with an accurate time depth chart by creating a synthetic using the Elmore 3 well. The horizon was then interpolated over the entire 3D by picking every 10th inline and cross line. The next step was to analyze all the wells log properties and pick the top of the Mississippian. Once this was complete the log property values for different logs were cross plotted against amplitude values at the well location. The last step was analyzing these cross plots and look for trends to correlate with petrophysical or geophysical properties.

Statement of problem and Objectives

Dickman Field located in central Kansas produces hydrocarbons from the Mississippian reservoir. The Mississippian in this area ranges from 100 to 300 feet thick. Most of the wells in this study penetrated the top of this formation, with very few penetrating the entire Mississippian formation. The Mississippian formation has been studied extensively in the state of Kansas and surrounding areas because of its shallow nature and hydrocarbon production potential.

The main objective of this study was to try and tie log properties (i.e. gamma ray, resistivity, neutron, calculated porosity) to the bright amplitude at the top of the Mississippian unconformity. The process involved extracting both the amplitude data at the well locations and the petrophysical log data at the Mississippian formation depth and cross plotting the amplitude with the different log data to look for a trend. After careful analysis of the cross plots some trends where identified. Further research was then done to determine geologic/geophysical and petrophysical reasoning behind the trends and define why a trend exits based on knowledge of the field and reasoning found in research.

Background information

Dickman field is located in the northern half of Ness County in central western Kansas (figure 1). The field was discovered in 1962, and has produced 1.8 million barrels of oil to date (Kansas Geologic survey).

Goebel (1968) described extensively the geologic description of Mississippian rocks in western Kansas. Most of the research has been prompted by the large amounts of hydrocarbons present in the Mississippian rocks and it's important to better understand for future potential. Goebel described most of the rocks deposited during this time as carbonate-cherty and noncherty dolomite and limestone and dolomitic limestone. It was noted in Rogers (2007) that the “precambrian, Ordovician, and Mississippian age rocks were exposed and truncated prior to regional Pennsylvanian transgression in most of western Kansas”. This exposure and transgression series caused irregular erosional surface also known as Karst. The regional dip of the Mississippian is approximately 14 ft/mi toward the southern boundary of Kansas Goebel (1968). Goebel also noted that most of the uplift of the western Kansas Mississippian surface occurred before the invasion of the Pennsylvanian seas. This study area sits just west of the central Kansas uplift as can be seen in (figure 2).

Research into seismic attributes correlation began in 2004 (University of Kansas center for Research, et al., 2009). Nissan et al. (2006) published a paper identifying fracture trends and the relationship of these fractures to karst features. In addition a study of the possibilities of carbon dioxide sequestion was done by Sullivan, et al., (2006). Most recent work has been done by Barber and Marfurt (2009) where they modeled the reservoir to determine whether the valley-shaped lineaments in the seismic data where a result of velocity “push down” effect or karstification. Malleswar and Marfurt (2011) additionally showed the relationship between seismic curvature and fractures identified from image logs.

The geology of the Mississippian is mostly interbedded sand, shale, and carbonates Moss (1932). In Dickman Field the Mississippian is mostly fractured porous and solution enhanced shelf carbonates (dolomites) (Liner et al., U. Houston). There is no significant faulting in the area and mostly the stratigraphy is flat except for a channel feature in the south east corner. Most of the production comes from porous Mississippian carbonates with structural closures. The elevation in the area is around 2400 to 2500 feet above sea level. The Mississippian is about 4300 to 4400 depth which is about 1900 feet above sea level. The top of the Mississippian is karst surface where production also comes from sandstone reservoirs in the Lower Cherokee group deposited where the sub aerial karsting created low spots (Liner et al. U. Houston). The Lower Cherokee can be seen in type log in figure 3.

Through further research from (Liner et al., U. of Houston) it is found the seismic vertical resolution is 82.5' and the horizontal resolution is 165'. Also, the top of the Mississippian was determined to be a trough (most negative amplitude). Because amplitudes are an important part of this study a review of the processing parameters are included in Appendix A. The survey was reprocessed in 2007 by University of Houston with the intention of testing various attributes for the larger CO2 sequestion study (Liner et al., U. of Houston). The 3D dataset has 158 inlines and 169 crosslines with 82.5 feet interval spacing and covers 3.3 square miles. (Liner et al. U. Houston).

Methods

The first step was to go through and verify wells with logs and to analyze the petrophysical properties and pick the top of the Mississippian. This involved using a type log from the Califf study (figure 3) and creating several cross-sections in both the north-south direction and the east-west direction to verify the Mississippian top correlated across the field. (Figure 4) is an example of a north-south cross-section. Every well in the project was included in this part of the process. There were 140 wells in the project, (figure 5 shows the outline of seismic and all the wells) of which about 58 had well logs in and around the seismic data area. Of those wells some were outside the 3D or lied close to the border that their tops where used in the cross-section, but were later dropped because it was felt that since the wells were on the edge of the seismic data set they lacked the full fold coverage and the amplitude values could give erroneous values the data. It was next determined that 24 wells were in the seismic area and contained good log data across the Mississippian.

Next step was to extract the log values. This was done by exporting the logs in .las format and importing them into excel. Once this was complete the values from the top of the Mississippian was taken and all data below that depth. In the event that the well was logged below the Mississippian the base depth of the Mississippian was used as the lower cutoff and no data below this point was included. After this a simple average over the logged Mississippian interval was taken for each log value. Figure 6 shows the spreadsheet where all the data was organized.

The Dickman 3D seismic project covers 4121 acres. Amplitude extraction was taken on two horizons. First the horizons were determined by tying the wells to seismic by creating an accurate time-depth chart. This was done by using Elmore 3 and creating a synthetic using SMT synPack module. Next it was determined that the best tie was a trough. The next step was to pick two horizons: 1) the trough that was determined when tying the data and 2)the peak just above. The peak just above was included to incorporate the Lower Cherokee sandstone values in the event of any karst infill. This will be explained in further detail in the results section (figure 7 is an example interpreted crossline). The horizon interpretation was initially done by picking every 10th inline and cross line (figure 8 is an example every 10th inline-cross line picked). After this a picking interpreter in SMT (3D hunt) was used to fill in the remaining in lines and cross lines (figure 9 shows the interpreted horizon for the trough). Once this was complete a grid was made of each horizon extracting the amplitude values (figures 10 and 11). The last step of the amplitude extraction was to record the amplitude value from the grid at each well location. To verify that the gridded amplitude values would represent an accurate amplitude value a test was done on two wells that involved extracting the value of the 3 nearest traces in inline and cross line direction by using the cursor recorded the value of the amplitude at each of these traces. Averaging these 6 traces proved to have a close value of the gridded amplitude within 10%.

The next step was to cross plot each of the amplitudes at the well locations with the different log values for all the wells in the project area and analyze the results.

Results

The results for the resistivity cross plot showed a general increase in amplitude with decreasing resistivity values for both peak and trough (figures 12 and 13). Resistivity measures how resistive a formation and its fluid is, in other words it measures the resistance to passage of an electric current Rider (2000). Most rock materials are insulators, while their enclosed fluids have conductive properties and for water saturation is tied to salinity (resistivity increases with more saline water). Hydrocarbons are infinitely resistive Rider (2000). Some other notes on resistivity: 1) as porosity increases resistivity will decrease 2) hydrocarbon formation resistivity will be higher 3) in tight rock resistivity will be higher. In conclusion in areas where we have higher amplitude we tend to have lower resistivity which could mean we have higher porosity and may be tied to water saturation.

The results on the neutron-amp cross plot showed that values decreased slightly with increasing peak amplitude for the peak (figure 14) and no real trend for the trough (i.e. values for the neutron properties averaged flat over the different trough values) (figure 15). Neutron log values measure porosity and are indicators of hydrocarbon richness. Neutron logs also are more accurate in tighter rocks. The data for the peak-amplitude cross plot showed a decreasing neutron with increasing peak. This could mean where we have higher amplitudes we have greater presence of hydrocarbons or water. Water and oil can be difficult to separate with just this cross plot method, but this could be an indication of water saturation. The lower neutron count could also result from higher porosity which agrees with the resistivity (but these are based on the presence of fluids) and does not agree with the calculated porosity log which should be calibrated to lithology.

The Gamma values on the cross plot had a slight trend of decreasing in gamma value with increasing amplitude values for both the trough and the peak (figures 16 and 17 respectively). Gamma measures the radioactivity of rock. Most often gamma logs are used to quantitatively derive shale volume Rider (2000). Gamma ray also decreases in the presence of carbonates because of the general lack of shales. This decrease in gamma could be a result of the carbonates in the Mississippian along with the harder dense limestone.

There was also a calculated porosity log available on most wells. When this value was cross plotted against amplitude the results showed a decrease in porosity with increasing amplitude for both peak and trough (figures 18 and 19). This could possibly result from less porous more dense limestone causing an increase in reflection impedance.

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Conclusions

There were some trends in the data; although most cross plots resulted in poor correlation and just a general trend. Some of this was probably the result of not having very many wells for most cross plots. However some trends were noticeable. The resistivity showed a decrease in value with increasing amplitude. The gamma values showed a slight increase in amplitude with decrease gamma values. The neutron log showed a very small trend of decreasing neutron values with increasing peak amplitude. No trend was found for the neutron trough cross plot. There was also a calculated porosity which showed a decrease in porosity with increasing peak.

Watney et al. (2001) studied characteristics of chat in south central Kansas nearby field to the Dickman field. Part of the conclusion was “Irreducible water, bound in the chert microporosity, greatly diminishes the resistivity log response and leads to high water saturations in zones that produce large amounts of oil and little water”. Although we don’t have production values for these individual wells high water saturation could be a reason for the change in resistivity.

The accumulation of this data has a few additional results. The Lower Cherokee Sandstone is a thin bed approximately 20’ thick. Rogers (2006) while describing Garfield conglomerate pool, in Pawnee county Kansas (a similar reservoir to adjacent Ness county) described the sand “origin and distribution of valley-fill sand-stone deposits, which produce oil from topographic and or karst depressions carved into Mississippian cherty limestone at the pre-pennsylvanian unconformity”. This karstic infill sandstone could be having an effect on the amplitudes, although it’s below the seismic resolution.

Additionally the results may have a strong tie to water saturation. The decrease in resistivity could mean higher porosity with high water saturation. The decrease in Gamma ray is probably a result from the less shaley carbontes found in the Mississippian. Also, the lower neutron is an indicator of increase pore fluids whether it be from hydrocarbons or water.

After further research it was determined that the geology of the top of the Mississippian was very complex. Many studies were done throughout Kansas and into the play in Oklahoma. In the southern part of Kansas the top of the Missisippian formation contains what’s called chat fields. “Chat” is an informal name for high porosity, low resistivity producing chert reservoirs in the min-continent where porosities can range from 30-50% Watney et al., (2001). Investigating if there was a way to discern chert with the logs available led to the conclusion that since sandstone, quartz, and chert all have the same chemical makeup they will show a similar response on the logs.

Future work could be incorporate production data and or water saturation calculations. At the time of this study there were only 8 wells with production data available. Six of these wells were in an area that was considered good seismic data. Further production data should be available and could be incorporated into this study by further extending the petrophysics analysis of each well log.

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Appendix A: 3D Seismic Processing and Acquisition parameters

Processing Details:

(Note that all amplitude data shown in this report is the reprocessed PSTM seismic data migrated by Kurt Marfurt at University of Houston in 2007)

Original processing by: Sterling Seismic Services LTD.
Date: 12/2001

1. SEGD to internal format conversion Field correlated
2. Geometry and trace edit
3. Gain recovery
4. Surface consistent amplitude analysis and recovery
5. Minimum phase filter application
6. Surface consistent deconvolution Type: spiking operator: 160 ms

Noise: 0.1%

7. Spectral enhancement 20-128Hz
8. Refraction and data correction
9. Green mountain geophysics refraction statics analysis 3D Fathom

Datum: 2600 feet
Velocity: VR 9000ft/sec – Vo 3000 ft/sec

10.	Iteration 1 velocity/mute analysis and application	
11.	Surface-consistent automatic statics	200-1000 ms statics gate
12.	Iteration 2 velocity/mute analysis and application	
13.	Surface-consistent automatic statics	150-1050 ms statics gate
14.	Final velocity/mute/scale analysis and application	
15.	CDP-consistent trim statics	4ms max stat
16.	Bandpass filter	20/18-128/72 Hz/DM
17.	Time variant scaling windows	
18.	Common depth point stack	
19.	Spectral enhancement	20-128 Hz
20.	Post stack noise suppression	FXY Decon
21.	Fourier trace interpolation	110 ft xline interval to 82.5 ft
22.	3D FD migration	95% of RMS velocity field
23.	Spectral enhancement	20-128 Hz
24.	Bandpass Filter	20/24-120-72 Hz/DB
25.	Trace balance time variant scaling windows	

Acquisition details:

1. Date Recorded...........................11/2001
2. Crew..Lockhart Geophysical
3. Source Type..............................Vibroseis

4. Sample Rate..............................2 ms
5. Record End Time.....................2 seconds
6. Receiver Interval......................220 ft
7. Receiver Line Interval…...........660 ft
8. Shot Interval..............................65 ft
9. Shot Line Interval.....................880
10. Sweep.......................................20-128 Hz 12 sec 3DB/OCT
11. Instruments...............................GDAPS
12. Format......................................SEGY
13. Number of Data Channels.........324 MAX

Images

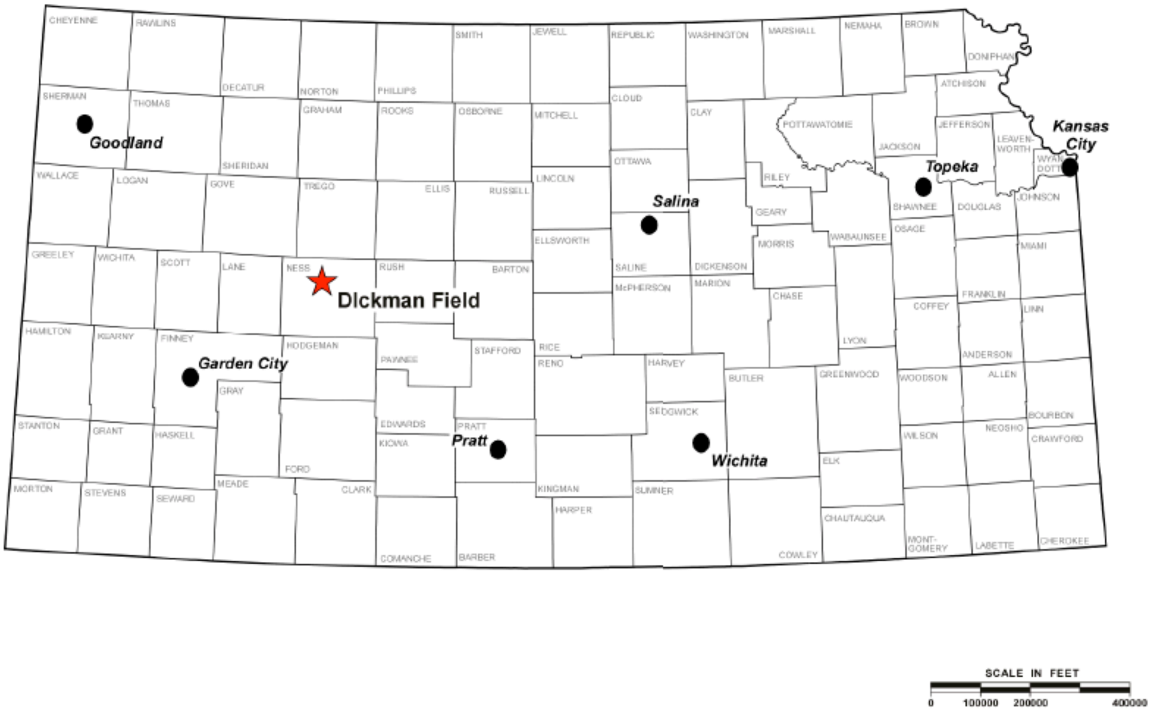


Figure 1: Field location of Dickman Field, Ness County, Kansas

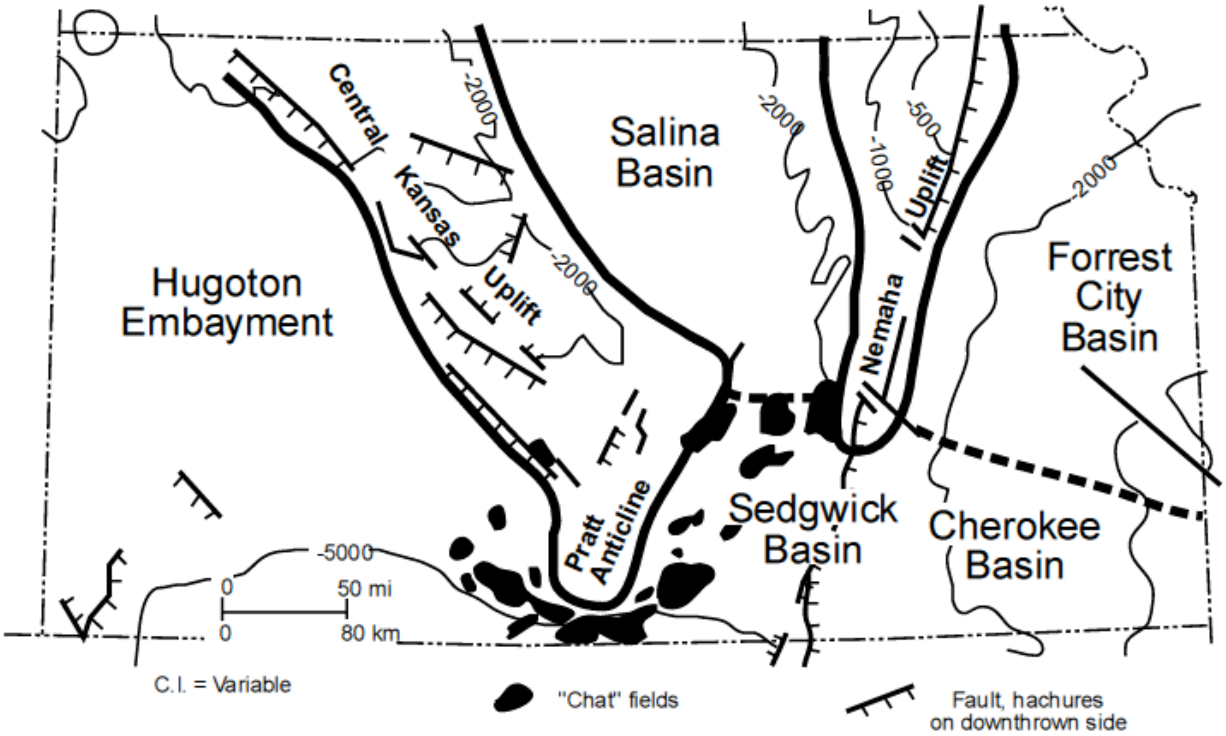


Figure 2: showing regional tectonic elements of south-central Kansas. (Montgomerty et al. 1998)

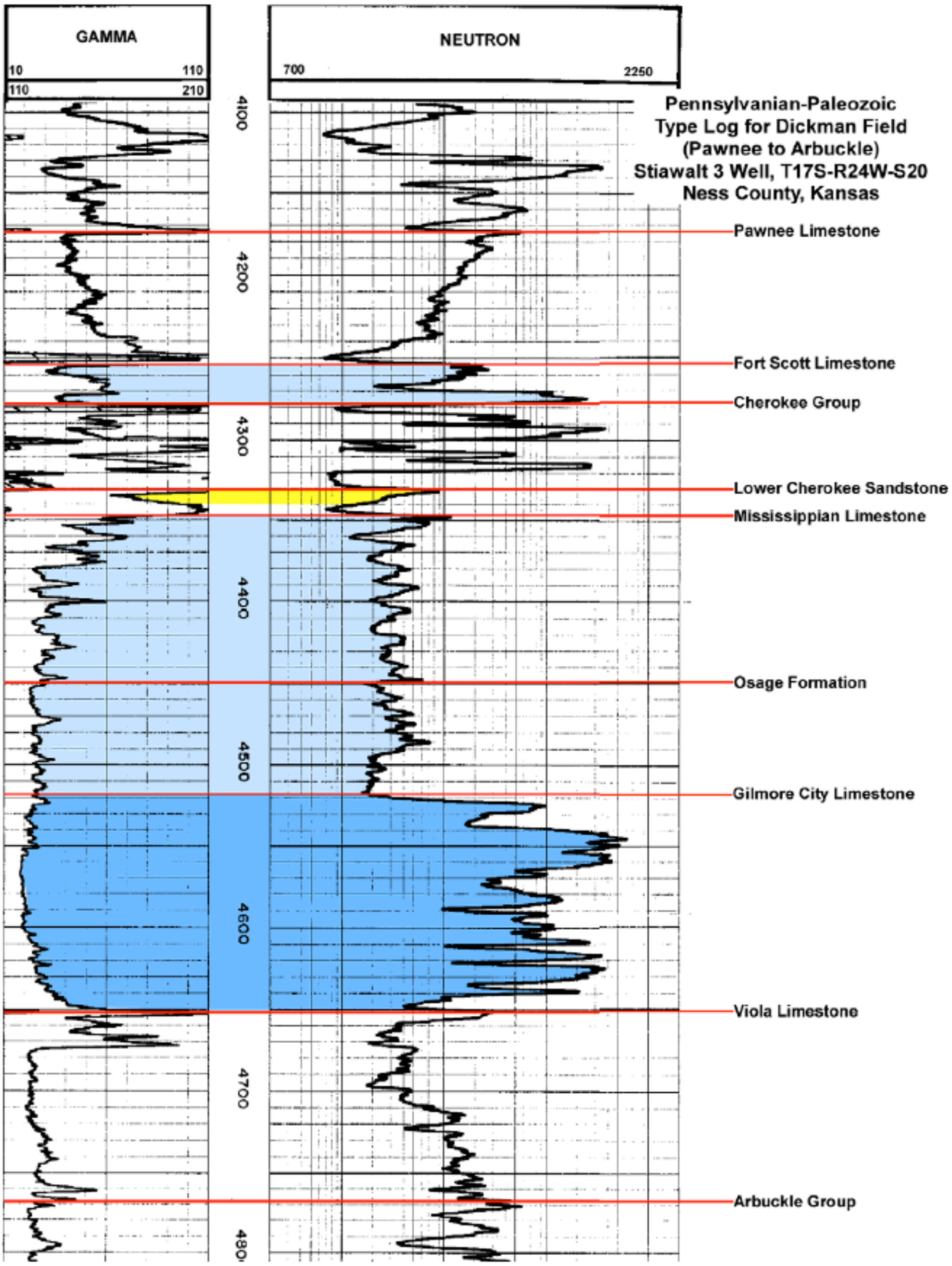


Figure 3: Type log showing the Mississippian Limestone

Arbitrary cross section

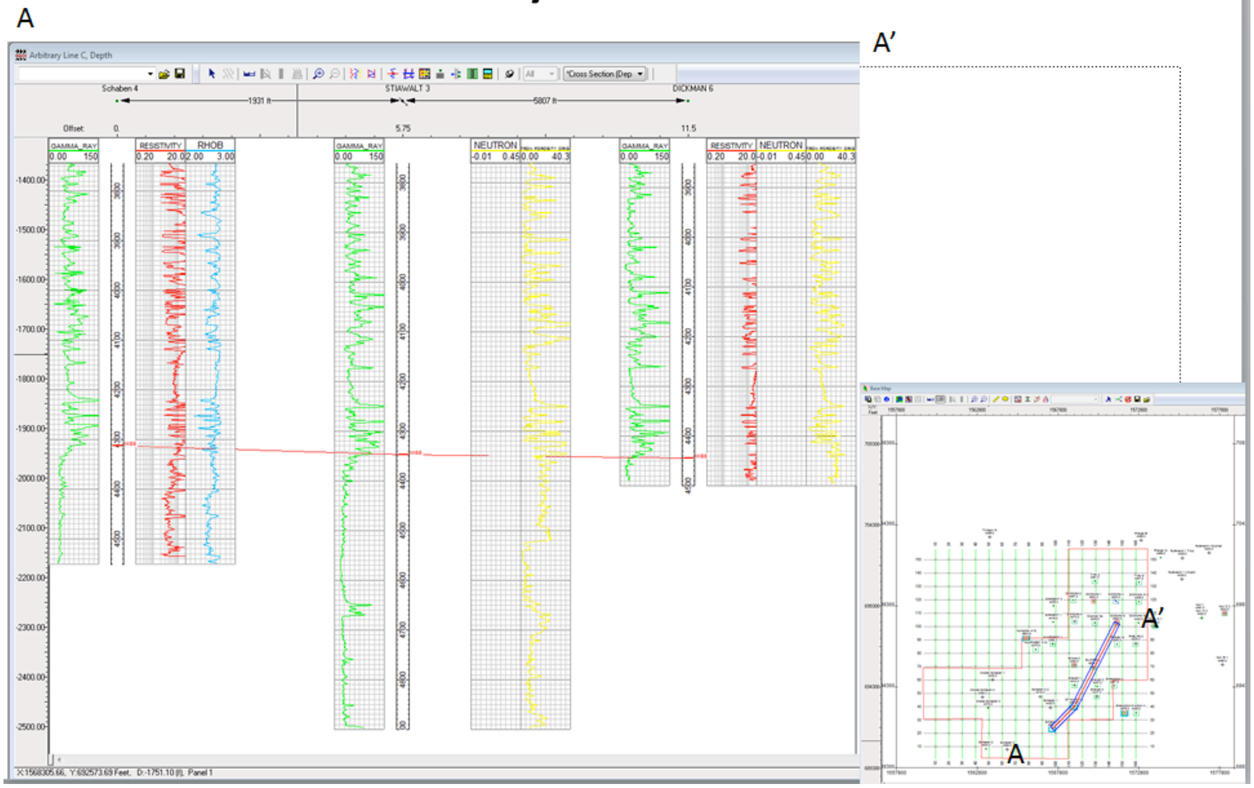


Figure 4 Cross section

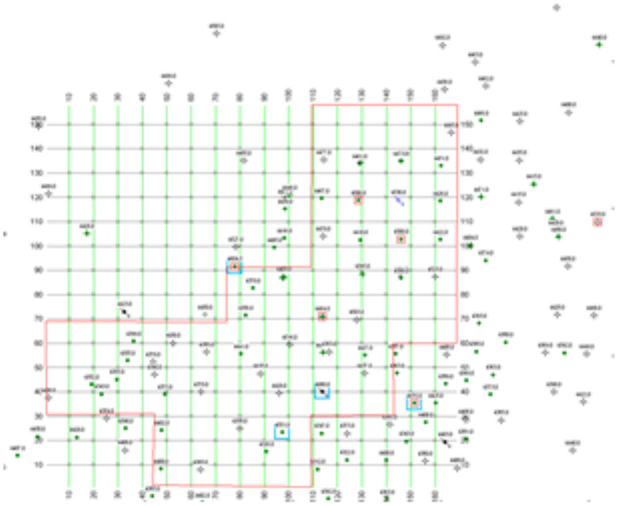
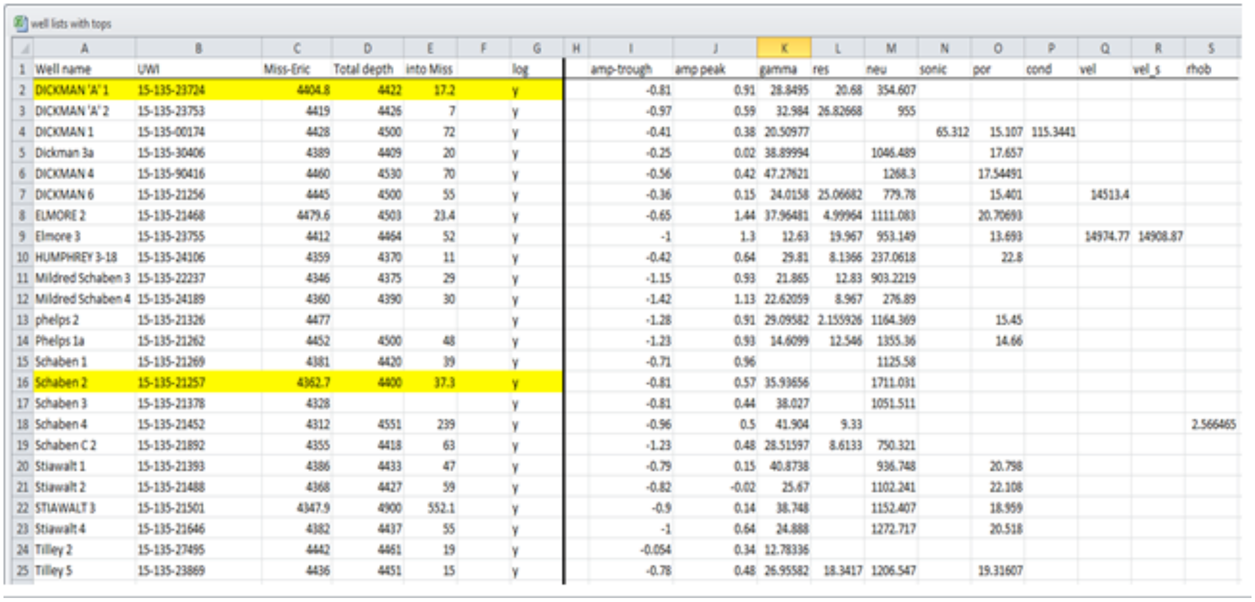


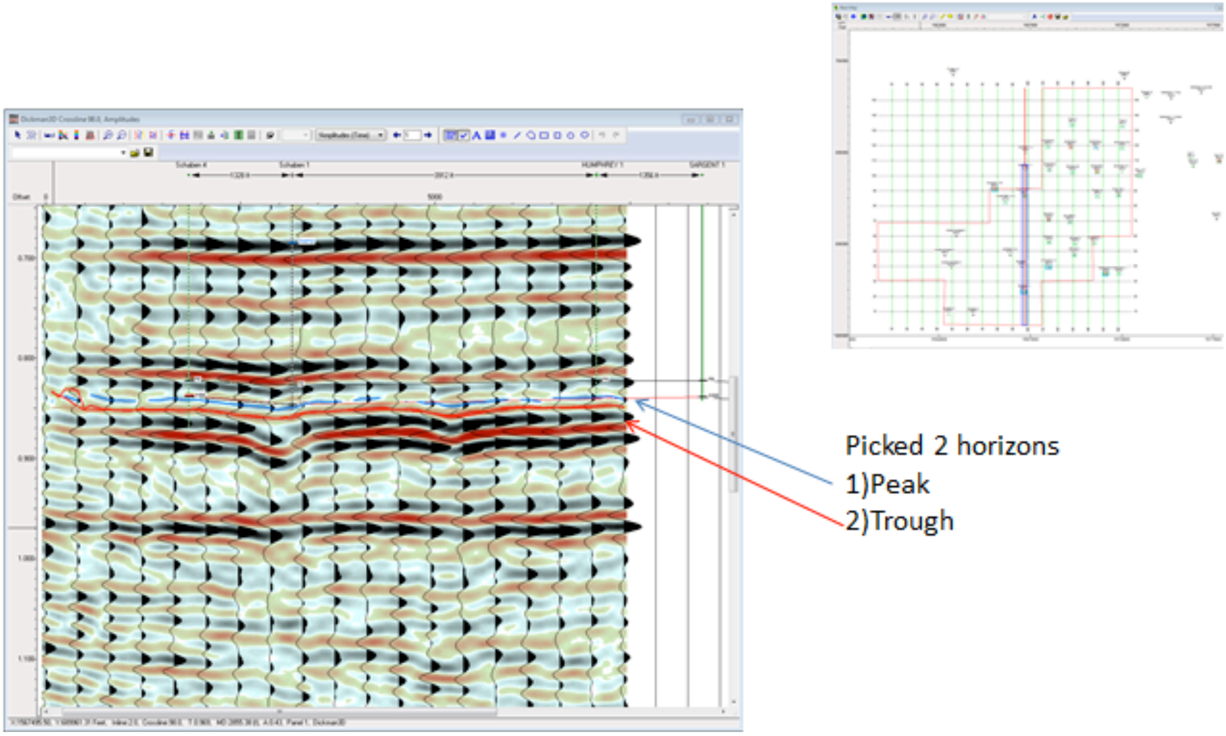
Figure 5: Outline of project area showing red outline of seismic data



well lists with tops

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Well name	UWI	Miss-Eric	Total depth	into Miss		log		amp-trough	amp peak	gamma	res	neu	sonic	por	cond	vel	vel_s	rhob
2	DICKMAN 'A' 1	15-135-23724	4404.8	4422	17.2		y		-0.81	0.91	28.8495	20.68	354.607						
3	DICKMAN 'A' 2	15-135-23753	4419	4426	7		y		-0.97	0.59	32.984	26.82668	955						
4	DICKMAN 1	15-135-00174	4428	4500	72		y		-0.41	0.38	20.50977			65.312	15.107	115.3441			
5	Dickman 3a	15-135-30406	4389	4409	20		y		-0.25	0.02	38.89994		1046.489		17.657				
6	DICKMAN 4	15-135-90416	4460	4530	70		y		-0.56	0.42	47.27621		1268.3		17.54491				
7	DICKMAN 6	15-135-21256	4445	4500	55		y		-0.36	0.15	24.0158	25.06682	779.78		15.401		14513.4		
8	ELMORE 2	15-135-21468	4479.6	4503	23.4		y		-0.65	1.44	37.96481	4.99964	1111.083		20.70693				
9	Elmore 3	15-135-23755	4412	4464	52		y		-1	1.3	12.63	19.967	953.149		13.693		14974.77	14908.87	
10	HUMPHREY 3-18	15-135-24106	4359	4370	11		y		-0.42	0.64	29.81	8.1366	237.0618		22.8				
11	Mildred Schaben 3	15-135-22237	4346	4375	29		y		-1.15	0.93	21.865	12.83	903.2219						
12	Mildred Schaben 4	15-135-24189	4360	4390	30		y		-1.42	1.13	22.62059	8.967	276.89						
13	phelps 2	15-135-21326	4477				y		-1.28	0.91	29.09582	2.155926	1164.369		15.45				
14	Phelps 1a	15-135-21262	4452	4500	48		y		-1.23	0.93	14.6099	12.546	1355.36		14.66				
15	Schaben 1	15-135-21269	4381	4420	39		y		-0.71	0.96			1125.58						
16	Schaben 2	15-135-21257	4362.7	4400	37.3		y		-0.81	0.57	35.93656		1711.031						
17	Schaben 3	15-135-21378	4328				y		-0.81	0.44	38.027		1051.511						
18	Schaben 4	15-135-21452	4312	4551	239		y		-0.96	0.5	41.904	9.33							2.566465
19	Schaben C 2	15-135-21892	4355	4418	63		y		-1.23	0.48	28.51597	8.6133	750.321						
20	Stiawalt 1	15-135-21393	4386	4433	47		y		-0.79	0.15	40.8738		936.748		20.798				
21	Stiawalt 2	15-135-21488	4368	4427	59		y		-0.82	-0.02	25.67		1102.241		22.108				
22	STIAWALT 3	15-135-21501	4347.9	4900	552.1		y		-0.9	0.14	38.748		1152.407		18.959				
23	Stiawalt 4	15-135-21646	4382	4437	55		y		-1	0.64	24.888		1272.717		20.518				
24	Tilley 2	15-135-27495	4442	4461	19		y		-0.054	0.34	12.78336								
25	Tilley 5	15-135-23869	4436	4451	15		y		-0.78	0.48	26.95582	18.3417	1206.547		19.31607				

Figure 6: Spreadsheet showing data collected



Picked 2 horizons
1)Peak
2)Trough

Figure 7: X-line 98 showing the peak and trough horizon pick for the top of the Mississippian

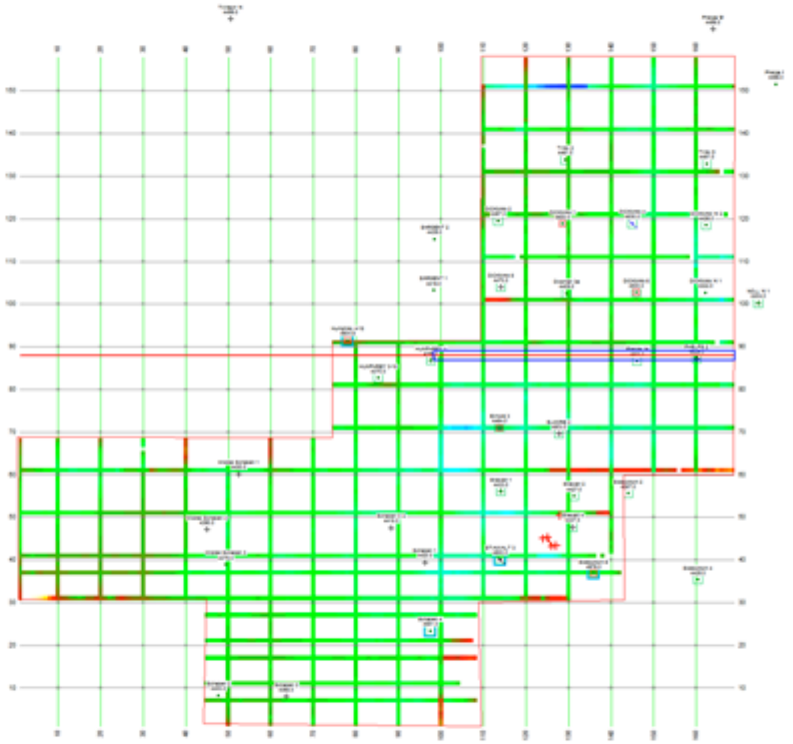
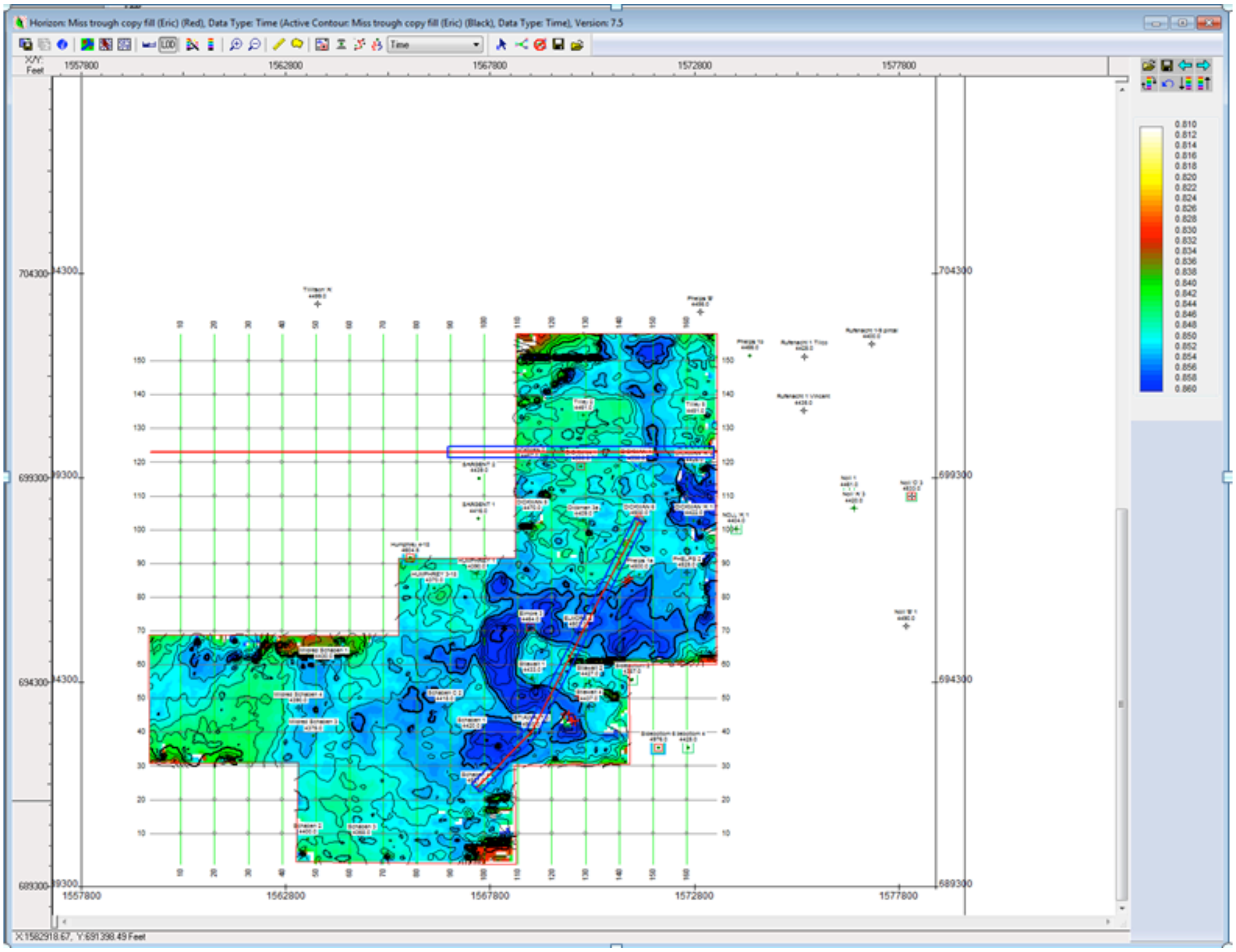


Figure 8: Every 10th inline and cross line picked on survey



Horizon: Miss trough copy fill (Eric) (Red), Data Type: Time (Active Contour: Miss trough copy fill (Eric) (Black), Data Type: Time), Version: 7.5

X:1582918.67, Y:691398.49 Feet

Figure 9 Structure map of Mississippian

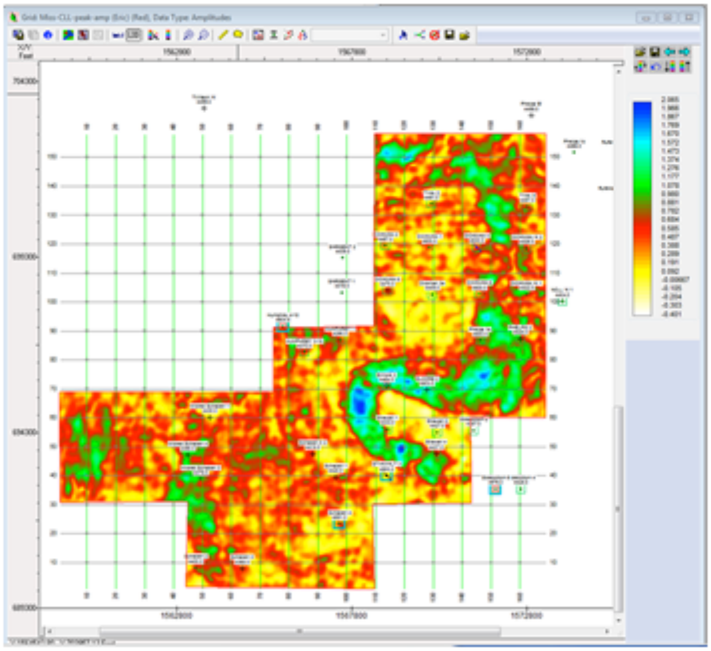


Figure 10: Amplitude of the peak horizon

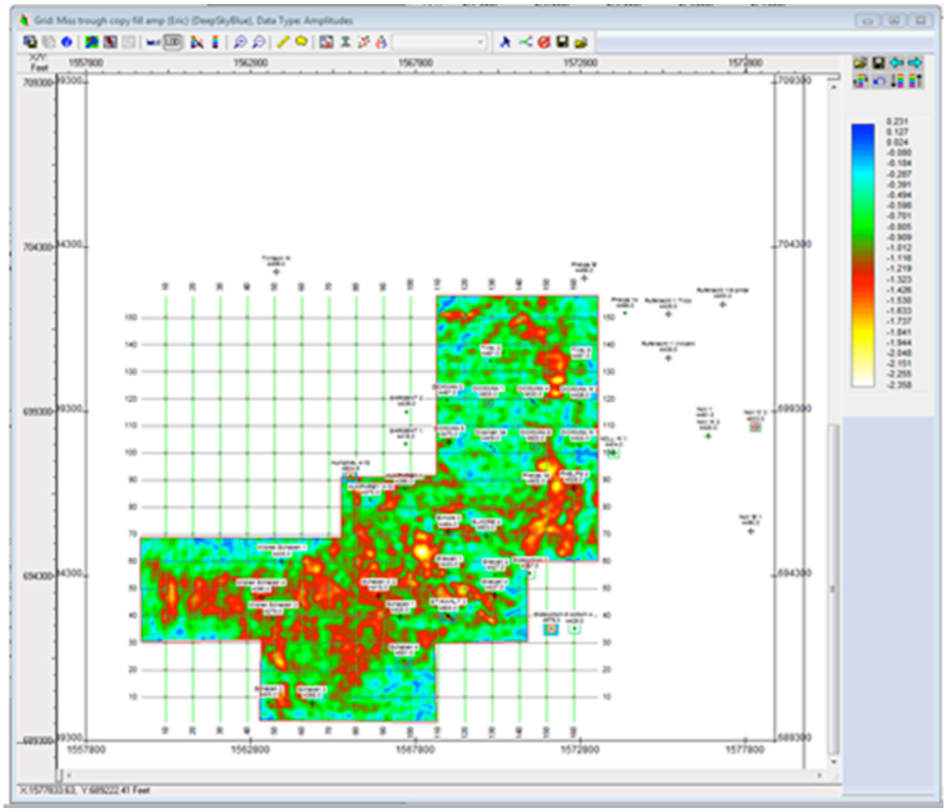
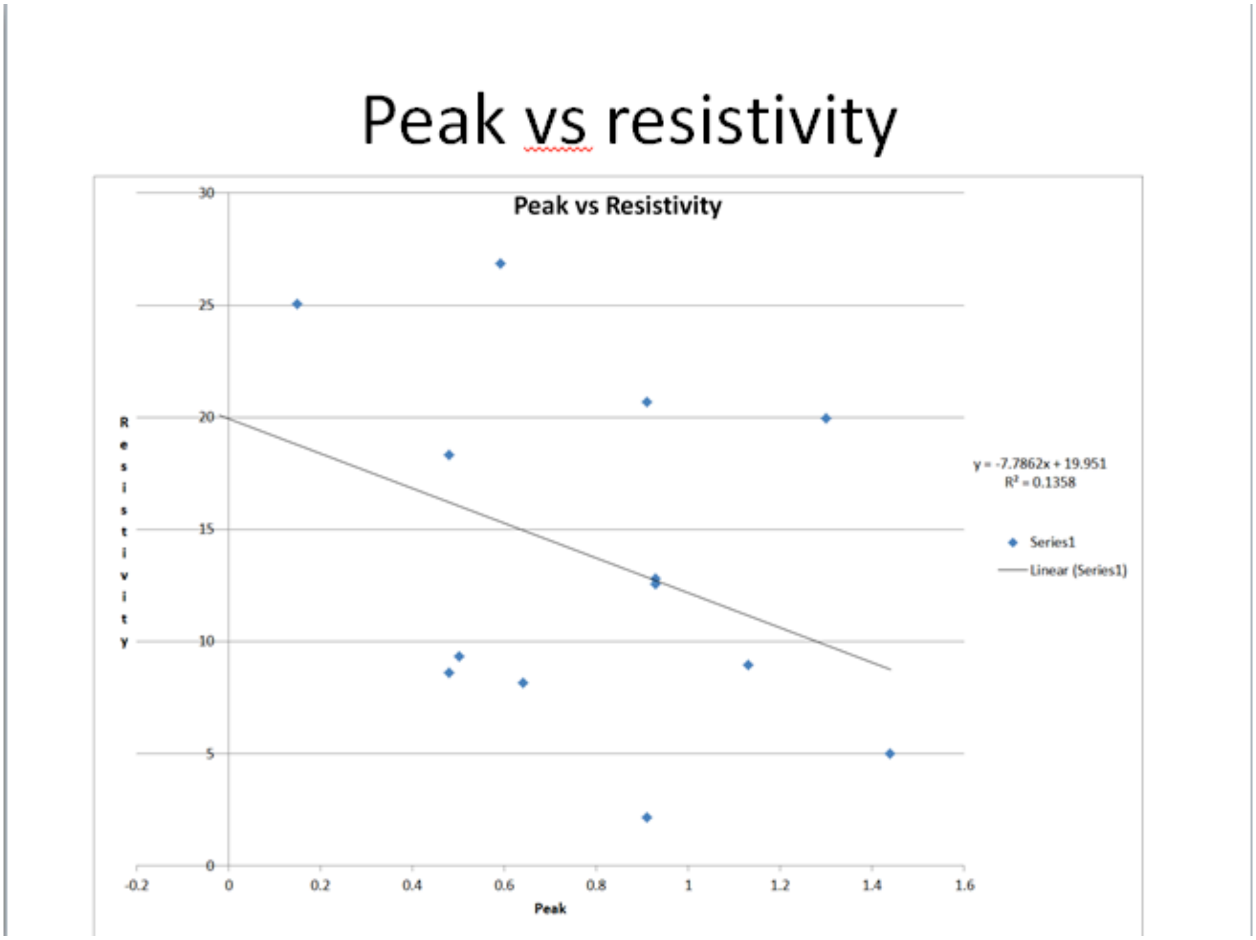
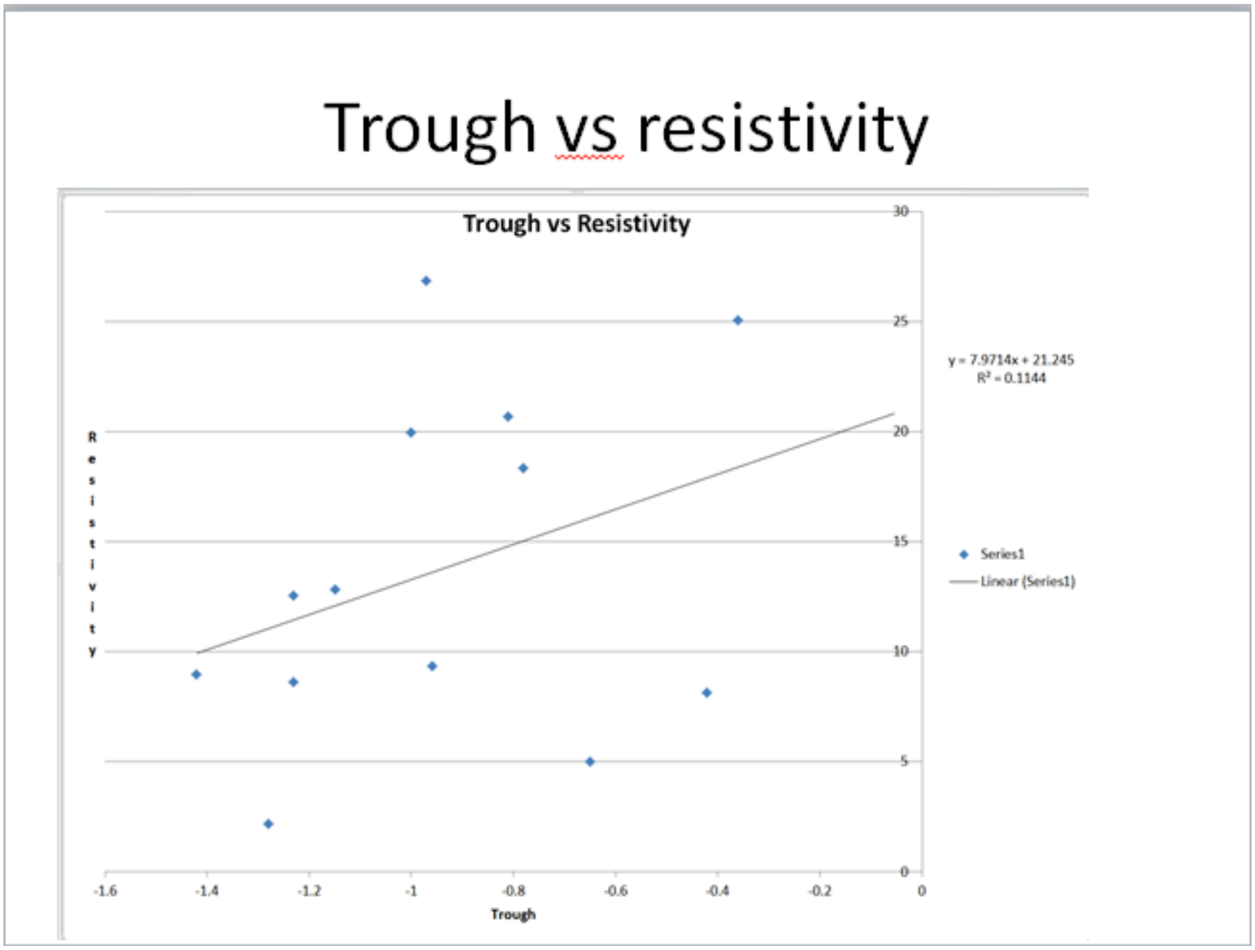


Figure 11: Amplitude map of trough



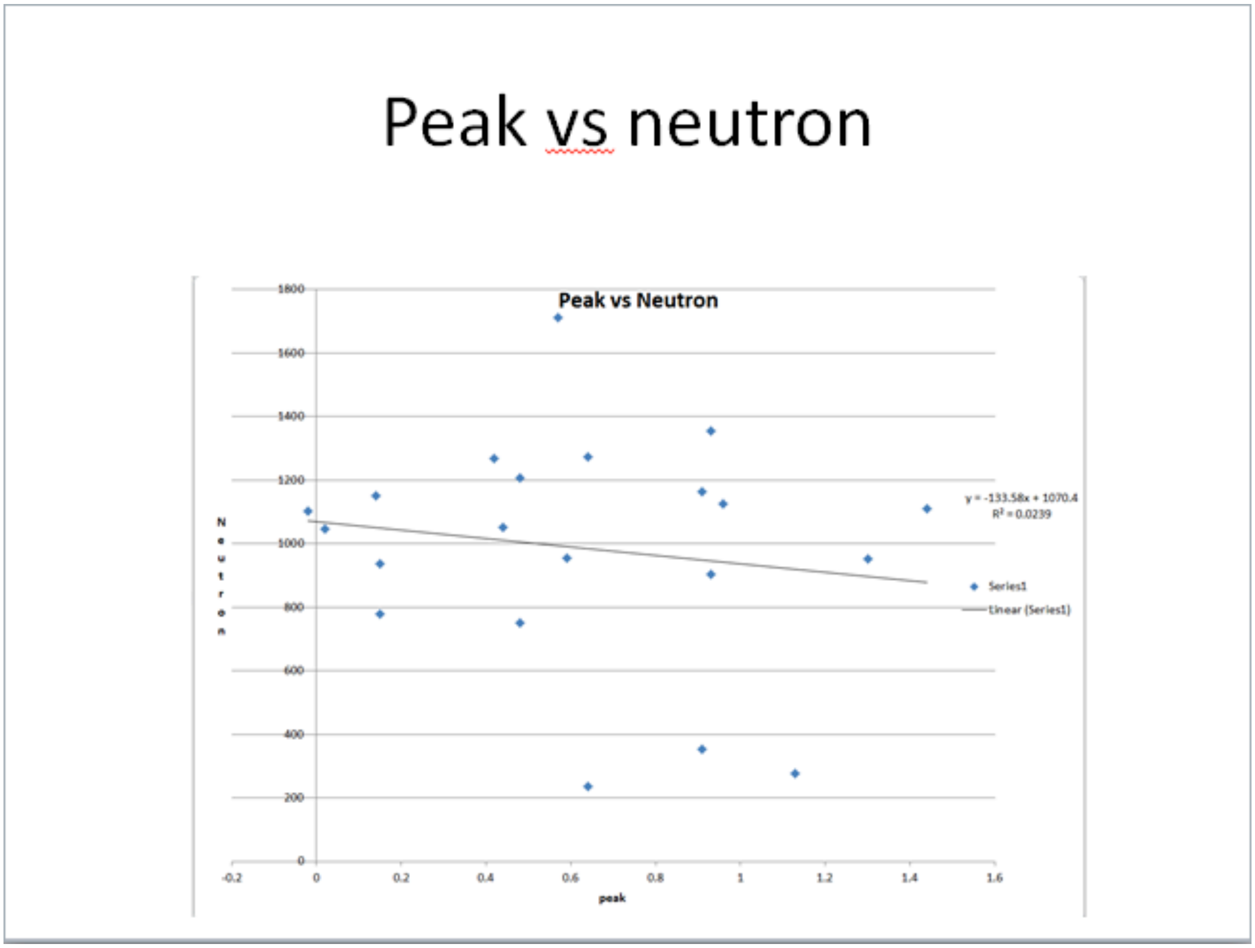
Peak vs resistivity

Figure 12: Peak vs Resistivity



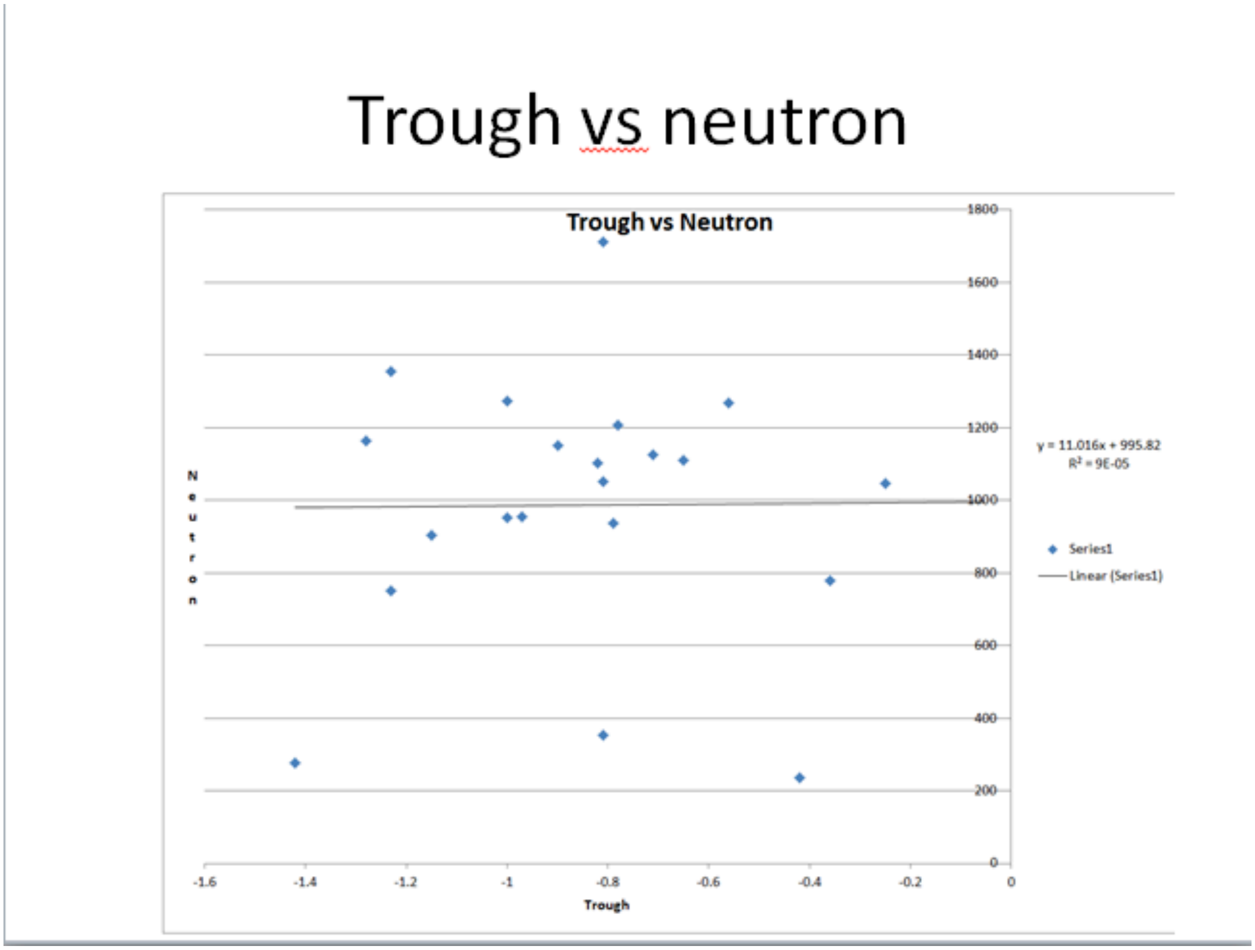
Trough vs resistivity

Figure 13: Trough vs Resistivity



Peak vs neutron

Figure 14: Peak vs Neutron



Trough vs neutron

Figure 15: Trough vs Neutron

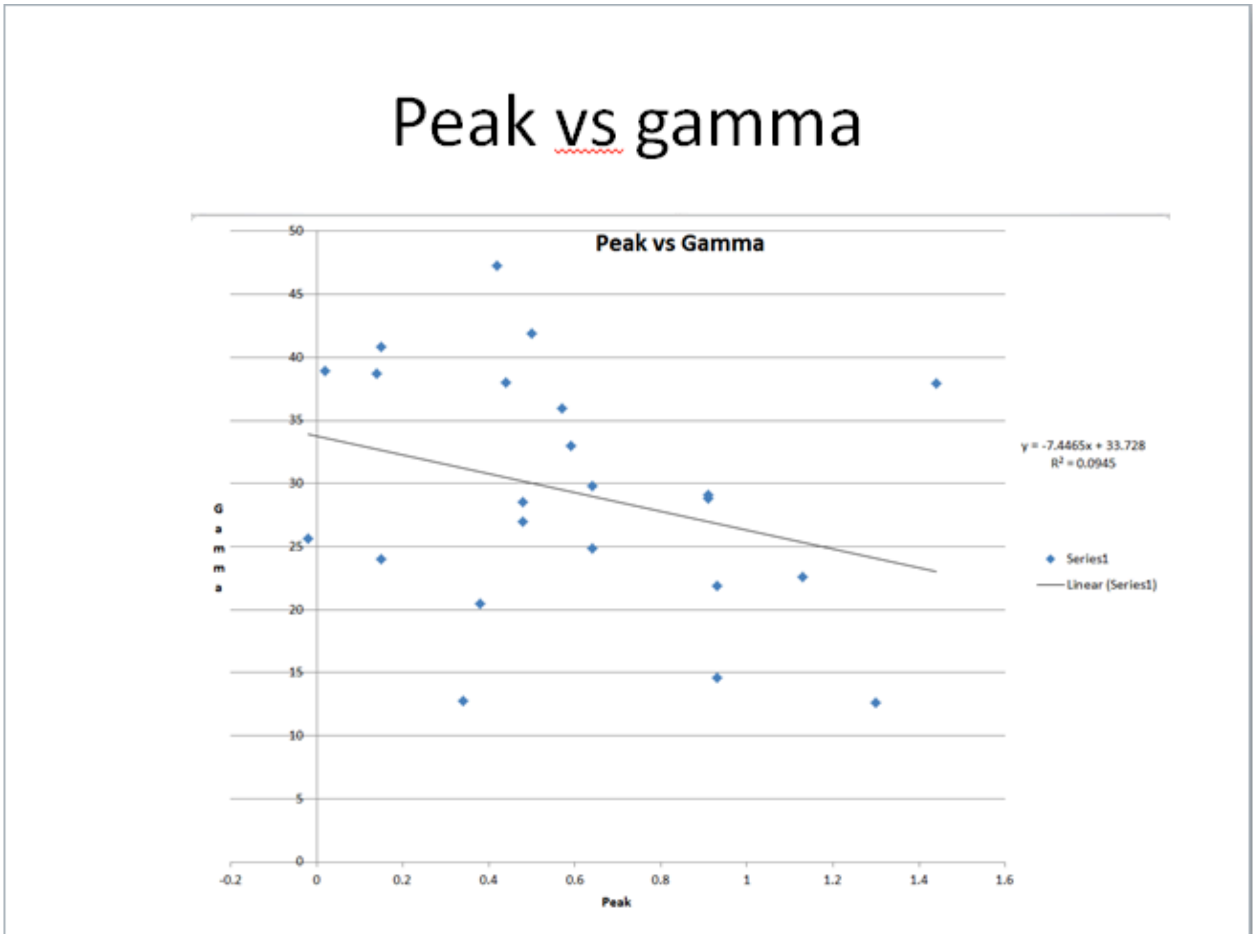
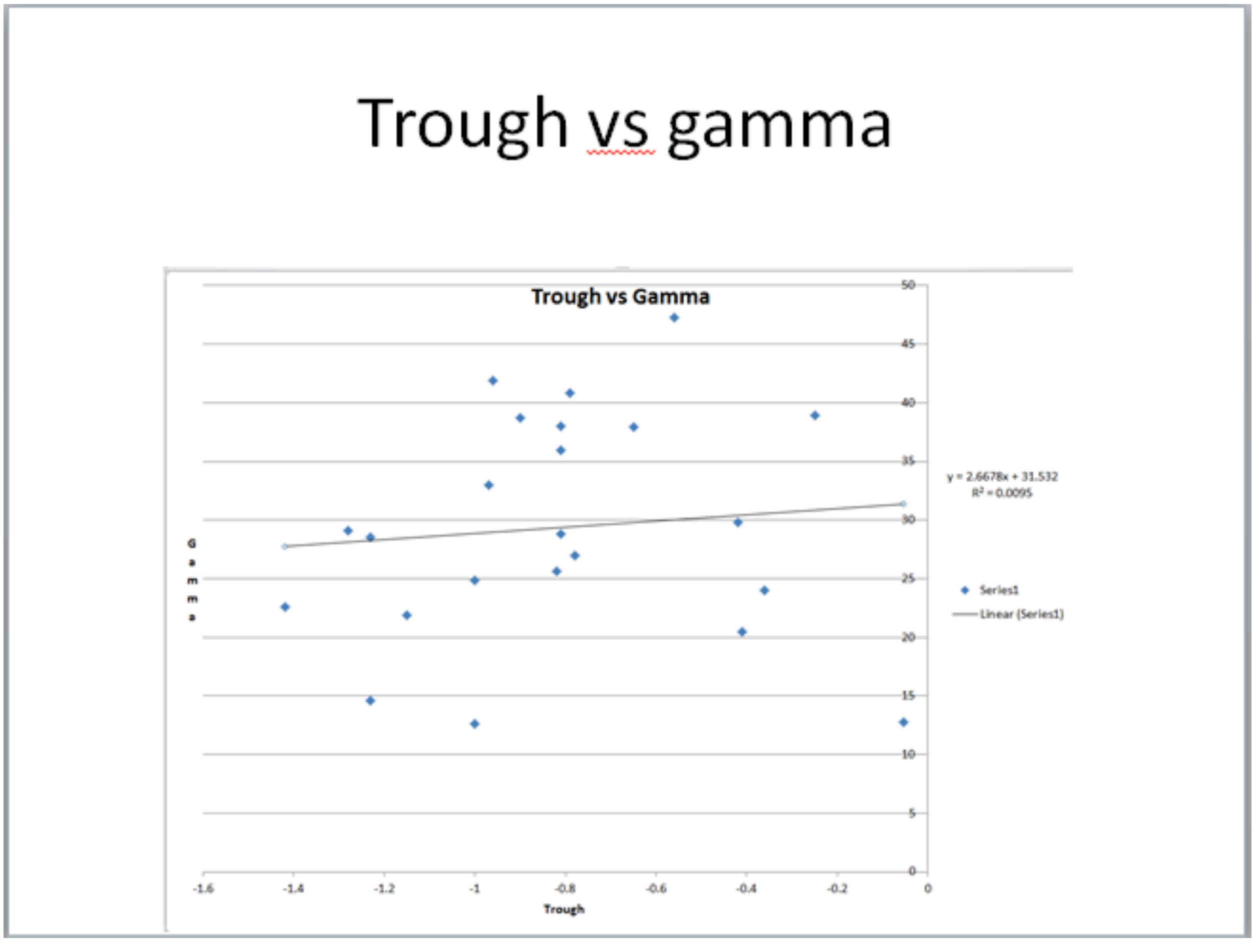
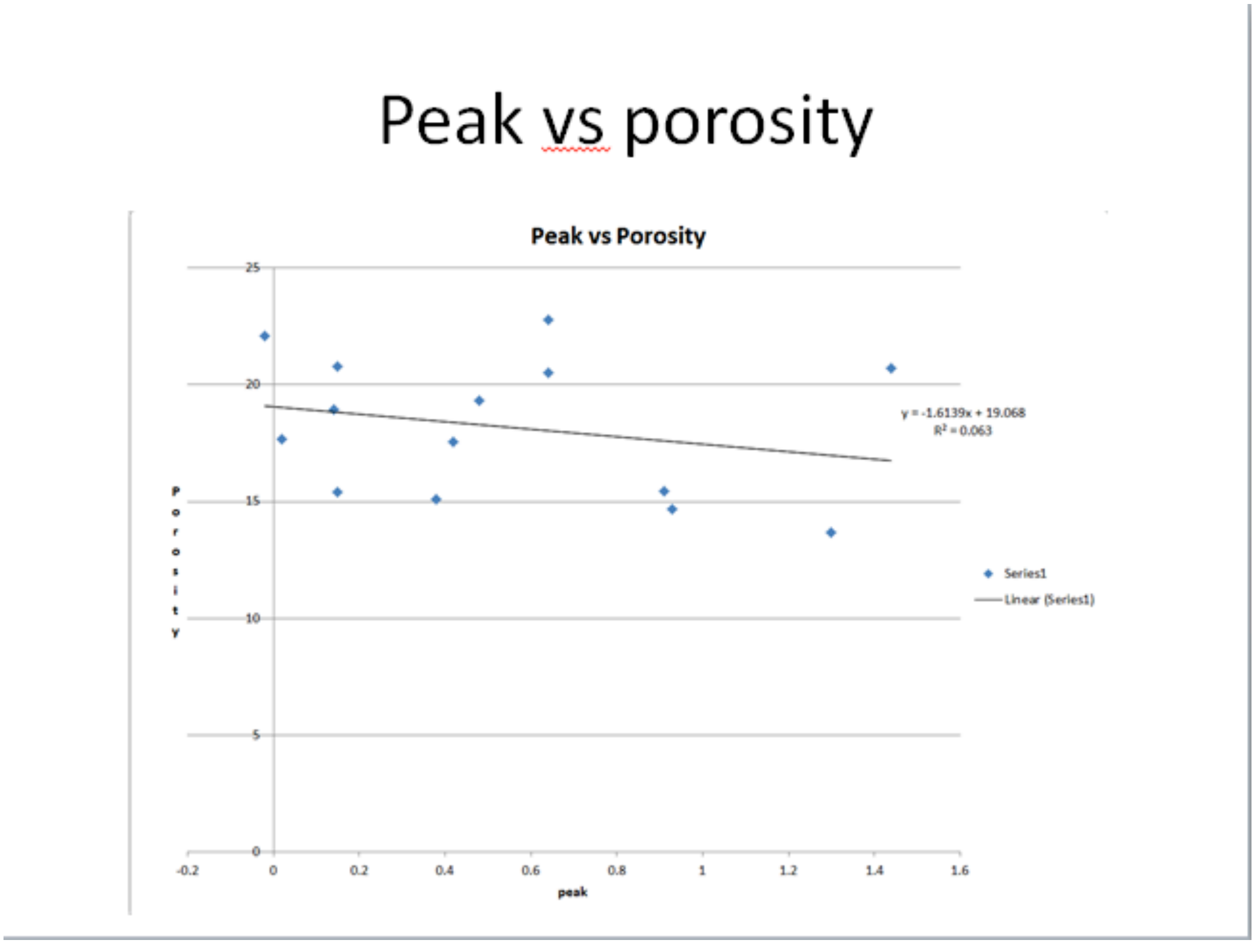


Figure 16: Peak vs Gamma



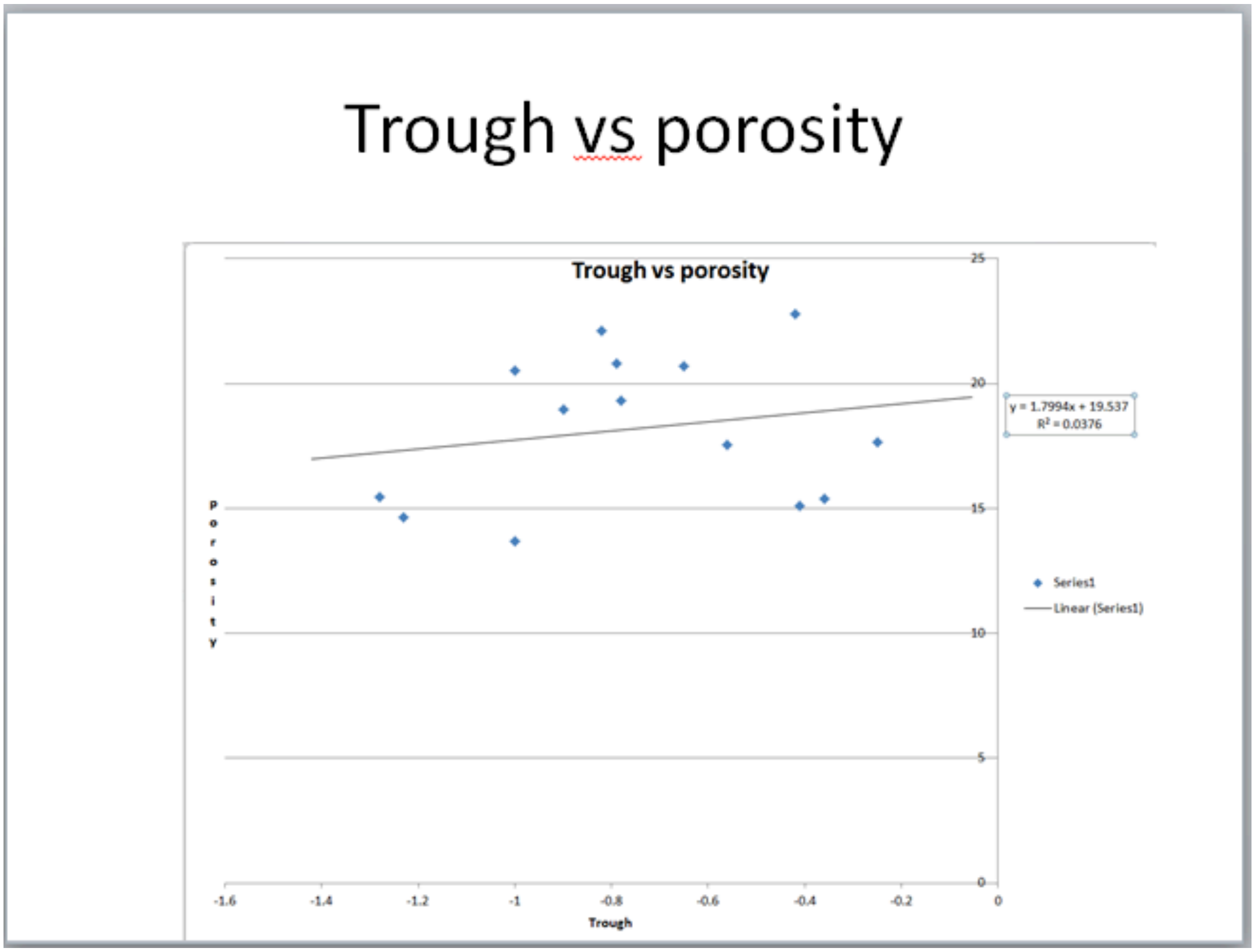
Trough vs gamma

Figure 17: Trough vs Gamma



Peak vs porosity

Figure 18: peak vs porosity cross-plot



Trough vs porosity

Figure 19: Trough vs Porosity