

DEBORAH SACREY

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President, American Association
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Based at Auburn Energy's Houston office, Deborah King Sacrey brings over 48 years of experience to her role as a geologist/geophysicist. Specializing in oil and gas exploration, she has expertise in 2D and 3D interpretation and multi-attribute neural analysis of seismic data. Deborah holds a degree in Geology from the University of Oklahoma and played a key role in developing and testing Kingdom Software with SMT/IHS. Her notable achievements include discoveries using Paradise software. A prominent figure in the geological community, Deborah has held leadership roles in SIPES, AAPG, and other organizations and became AAPG President on July 1, 2024.

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Machine Learning for Engineers: Calculating Reserves and Visualizing Depletion

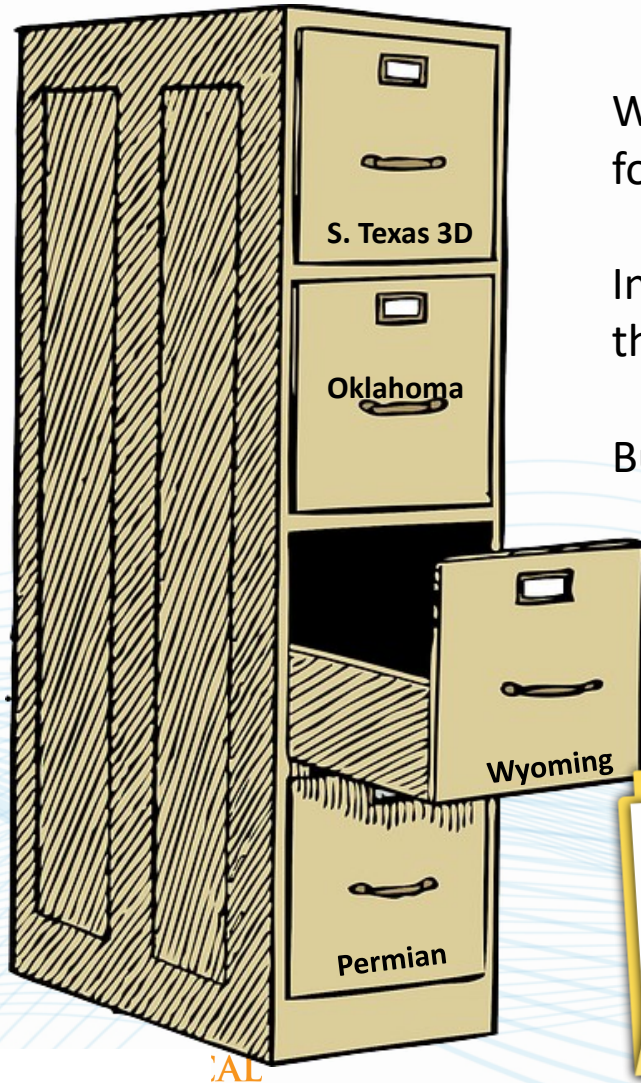
**Ryder Scott 20th Annual Reserves Conference
September 12th, 2024**

This presentation will show:

Cluster analysis using Self-organized maps can be very accurate when determining reserves when the reservoir can be identified, and

Looking for anomalous data points can be key in determining depletion providing the seismic data was acquired after most of the production had taken place.

What is SOM? (Self-organized maps)



We all live in a world where data is organized – which makes it easy to “find” things for which we are looking.

In the case of seismic “organization”, imagine a file drawer with different 3D’s and the folders within are the seismic data files.

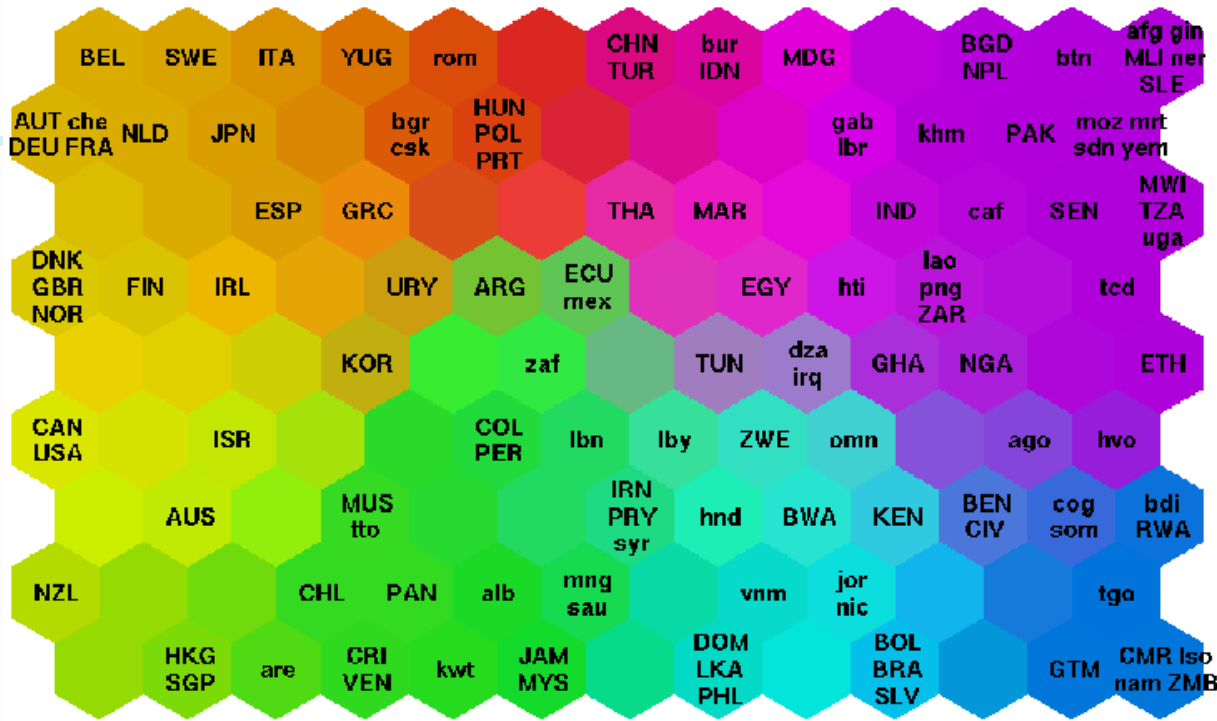
But we want to “organize” those attributes into something meaningful in the subsurface!

Example of Classification of “Attributes” – T. Kohonen

This example shows how the classification process can group clusters of similar information. Using this method with seismic attributes results in a more clear view of the subsurface stratigraphy than can be done in a conventional wavelet interpretation. Using the data in SAMPLE statistics, allows fine resolution of rock properties, regardless of frequency or depth.

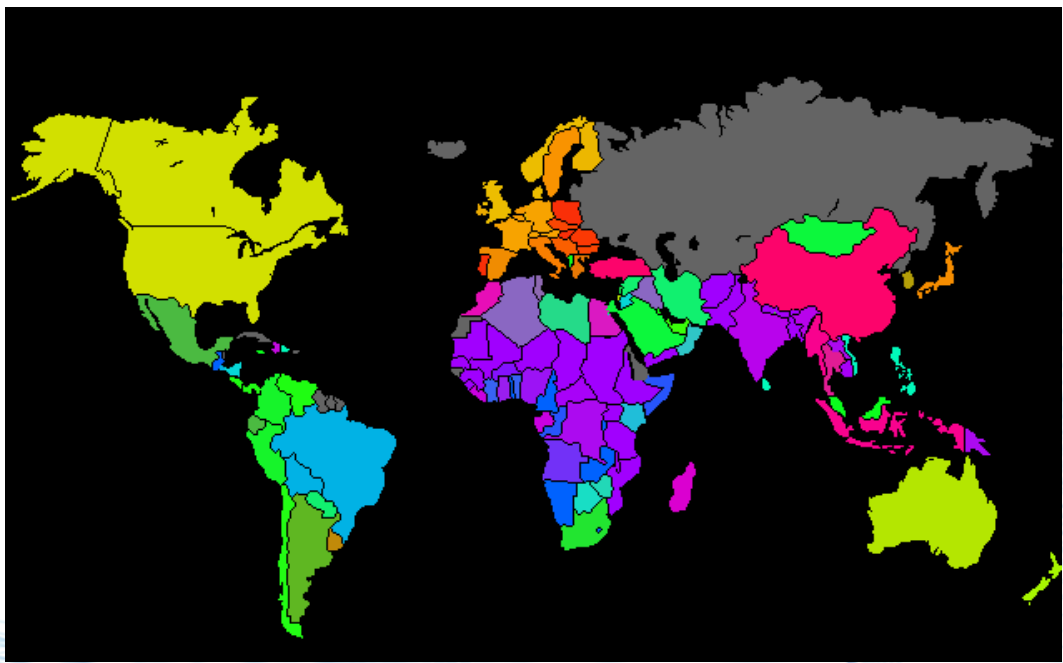
- **Classify statistics which describe quality of life attributes**
such as state of health, longevity, education, income, taxation, population density, etc. (39 in total)
- **Countries with similar quality of life attributes cluster together (126 countries)**
- **Organize data into spreadsheet**
- **Columns = Quality of life attributes**
- **Rows = Country**
- **9 x 13 hexagonal neuron topology (117 neurons)**

AFG	Afghanistan	GRC	Greece	NOR	Norway
AGO	Angola	GTM	Guatemala	NPL	Nepal
ALB	Albania	HKG	Hong Kong	NZL	New Zealand
ARE	United Arab Emirates	HND	Honduras	OAN	Taiwan, China
ARG	Argentina	HTI	Haiti	OMN	Oman
AUS	Australia	HUN	Hungary	PAK	Pakistan
AUT	Austria	HVO	Burkina Faso	PAN	Panama
BDI	Burundi	IDN	Indonesia	PER	Peru
BEL	Belgium	IND	India	PHL	Philippines
BEN	Benin	IRL	Ireland	PNG	Papua New Guinea
BGD	Bangladesh	IRN	Iran, Islamic Rep.	POL	Poland
BGR	Bulgaria	IRQ	Iraq	PRT	Portugal
BOL	Bolivia	ISR	Israel	PRY	Paraguay
BRA	Brazil	ITA	Italy	ROM	Romania
BTN	Bhutan	JAM	Jamaica	RWA	Rwanda
BUR	Myanmar	JOR	Jordan	SAU	Saudi Arabia
BWA	Botswana	JPN	Japan	SDN	Sudan
CAF	Central African Rep.	KEN	Kenya	SEN	Senegal
CAN	Canada	KHM	Cambodia	SGP	Singapore
CHE	Switzerland	KOR	Korea, Rep.	SLE	Sierra Leone
CHL	Chile	KWT	Kuwait	SLV	El Salvador
CHN	China	LAO	Lao PDR	SOM	Somalia
CIV	Cote d'Ivoire	LBN	Lebanon	SWE	Sweden
CMR	Cameroon	LBR	Liberia	SYR	Syrian Arab Rep.
COG	Congo	LBY	Libya	TCD	Chad
COL	Colombia	LKA	Sri Lanka	TGO	Togo
CRI	Costa Rica	LSO	Lesotho	THA	Thailand
CSK	Czechoslovakia	MAR	Morocco	TTO	Trinidad and Tobago
DEU	Germany	MDG	Madagascar	TUN	Tunisia
DNK	Denmark	MEX	Mexico	TUR	Turkey
DOM	Dominican Rep.	MLI	Mali	TZA	Tanzania
DZA	Algeria	MNG	Mongolia	UGA	Uganda
ECU	Ecuador	MOZ	Mozambique	URY	Uruguay
EGY	Egypt, Arab Rep.	MRT	Mauritania	USA	United States
ESP	Spain	MUS	Mauritius	VEN	Venezuela
ETH	Ethiopia	MWI	Malawi	VNM	Viet Nam
FIN	Finland	MYS	Malaysia	YEM	Yemen, Rep.
FRA	France	NAM	Namibia	YUG	Yugoslavia
GAB	Gabon	NER	Niger	ZAF	South Africa
GBR	United Kingdom	NGA	Nigeria	ZAR	Zaire
GHA	Ghana	NIC	Nicaragua	ZMB	Zambia
GIN	Guinea	NLD	Netherlands	ZWE	Zimbabwe



Each “cell/neuron” has unique properties. The closer the cells are together
The closer in properties they are. They can then be organized on a “map” by
their properties. In much the same way, Paradise organizes data in the sub-
surface by the variance in discrete rock properties.

Self-Organizing Maps
(unsupervised classification
of data)



39 quality of life statistics (UN)

126 countries

9X13 hexagonal neuron topology (117
neurons)

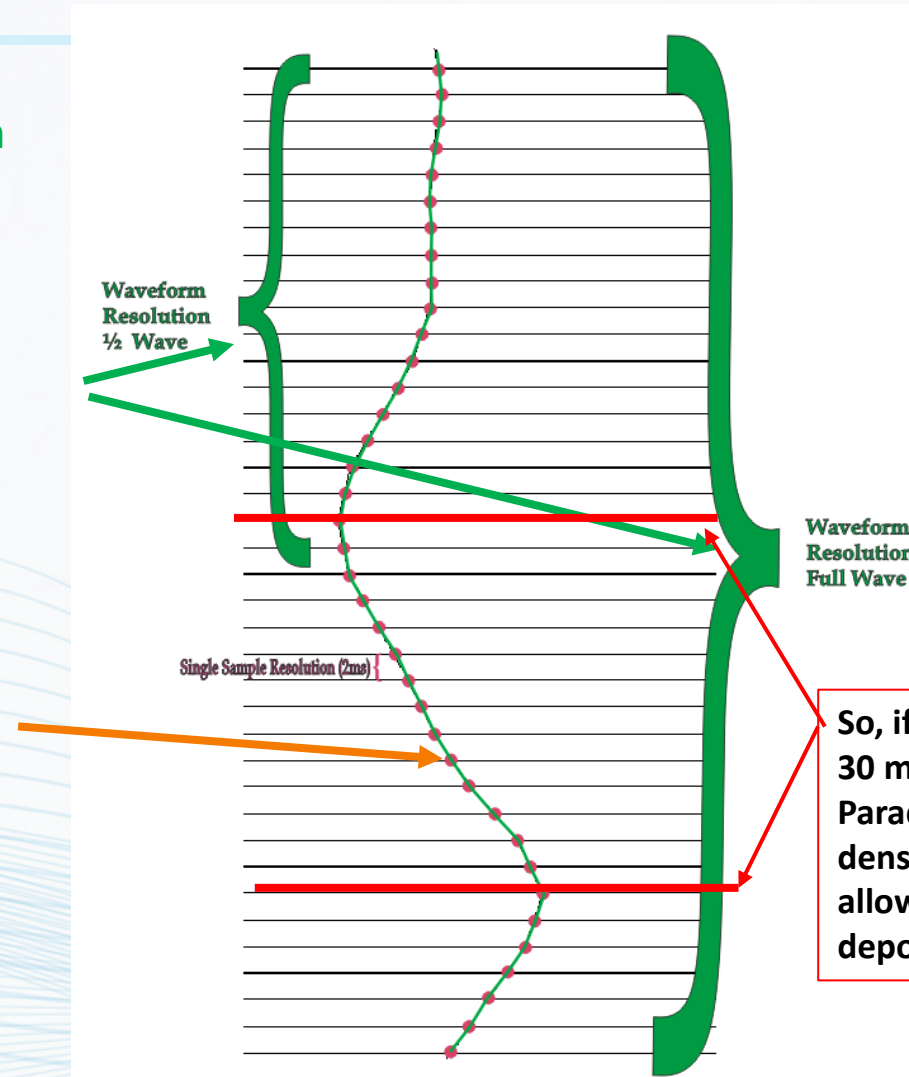
T. Kohonen, 2001

Slide courtesy of Dr. Tom Smith

“Single Sample Resolution” – number crunching!

All other ML software use Waveform Resolution of either $\frac{1}{2}$ or Full Wave Resolution to minimize Data Processing requirements

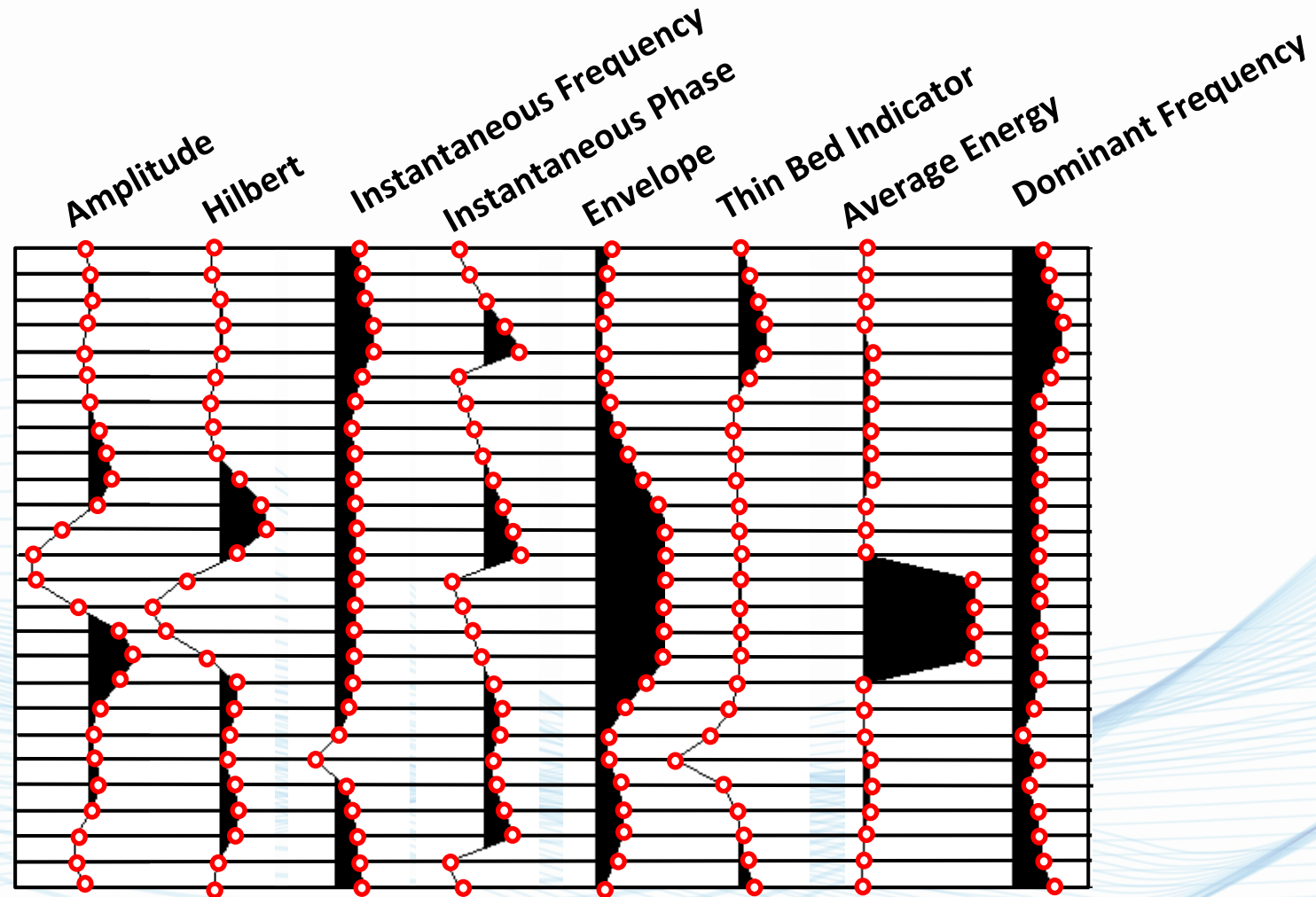
This Software uses Single Sample Resolution In order to enhance the Neural Cluster Process



This Drawing is actual Seismic Amplitude data in 2ms sample rate

So, if the Envelope (trough to peak interval) is 30 ms and you are working with 2ms sample rate, Paradise is statistically analyzing the data 15 times as densely as a mapped wavelet of peak or trough, which allows for much finer resolution in the earth of depositional features!

Every Sample from each Attribute is Input into a PCA or SOM Analysis



Slide courtesy of Rocky Roden

Scale of SOM Results

NOTE: Data points or samples associated with patterns identified by neurons are discrete points. There is no interpolation between data points as in amplitude data. The “tuning thickness” in sample statistics is based upon the interval velocity of the rock from which the sample is taken.

Bin Size

Sample Interval (1 ms)

**Tuning Thickness
for this example**

Slide courtesy of Rocky Roden

TGS Study of the Meramec Production in Blaine and Kingfisher Counties, Oklahoma

Project Objectives:

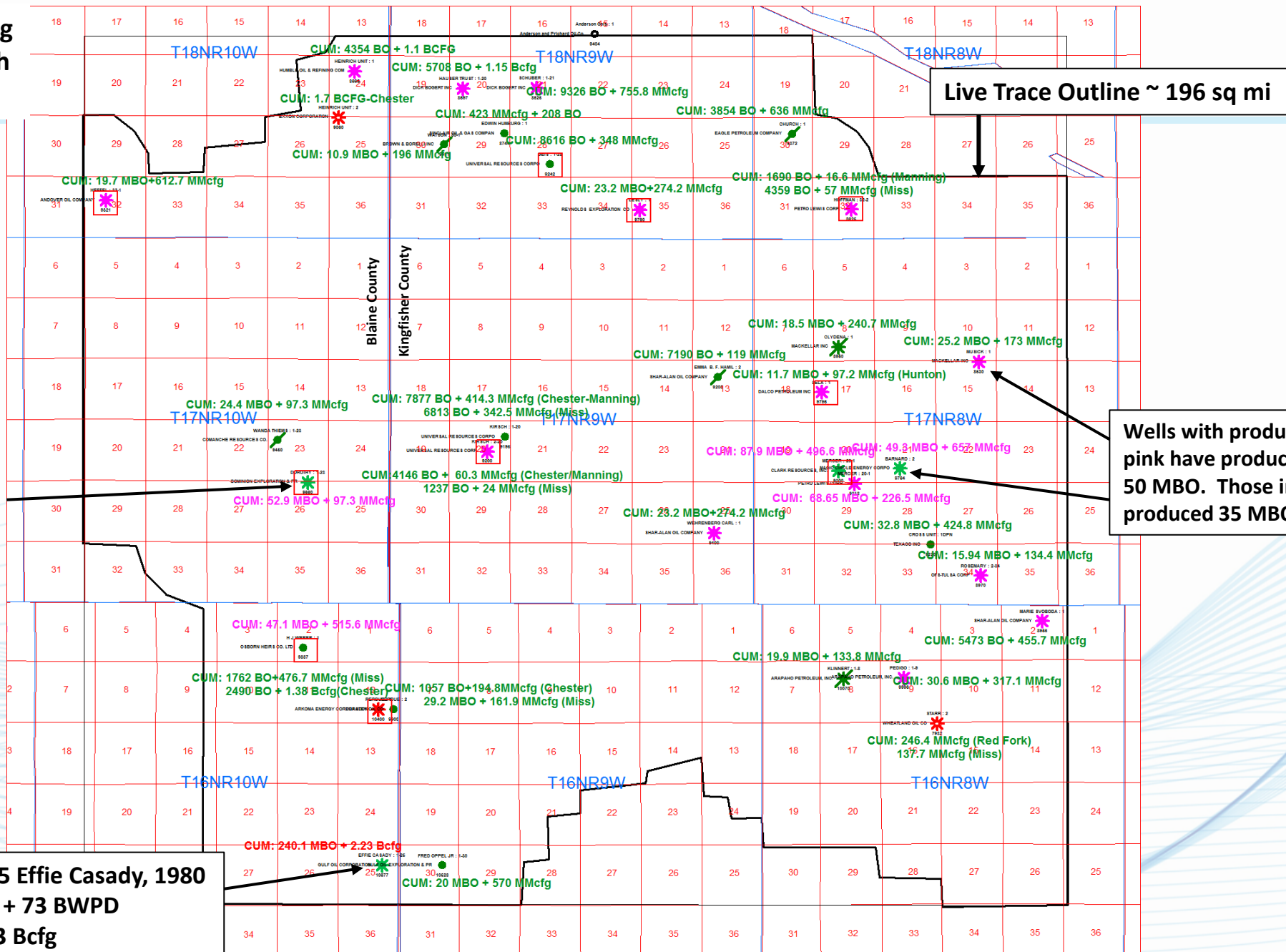
- 1) Discriminate production in the Meramec Formation
- 2) Understand the “accuracy” in the machine learning classification results

Assumptions and Challenges:

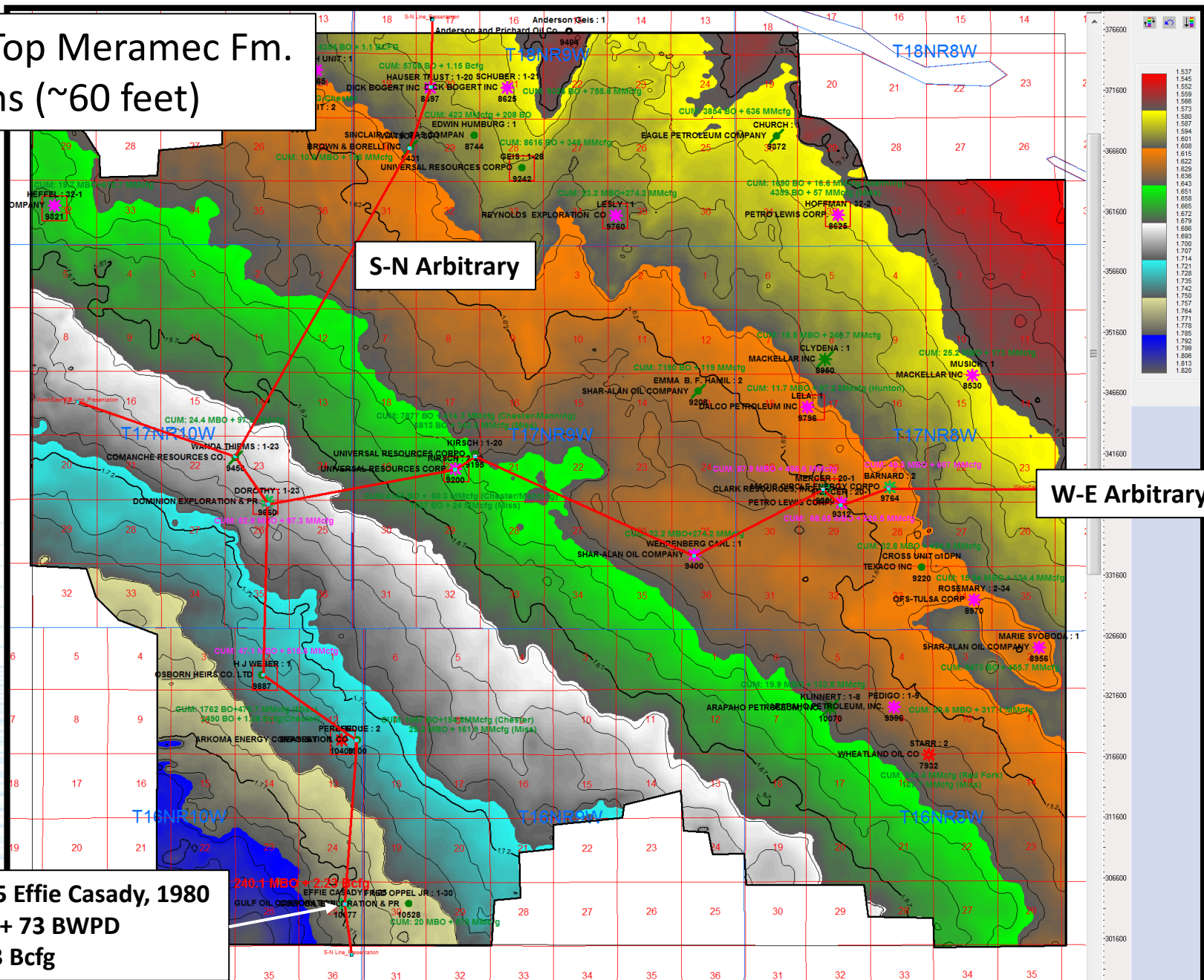
- 1) Production is not necessarily related to only geological changes (reason for only using straight holes for challenge)
- 1) Permeability could not be calculated from the log curves provided in order to calibrate well production
- 3) Difficulty in isolating specific production in all the wells through multiple zone perforations

Culture overlay showing production next to each well.

Square boxes represent those wells in which synthetic seismograms were created to tie the data. In all, 10 synthetic ties were created.



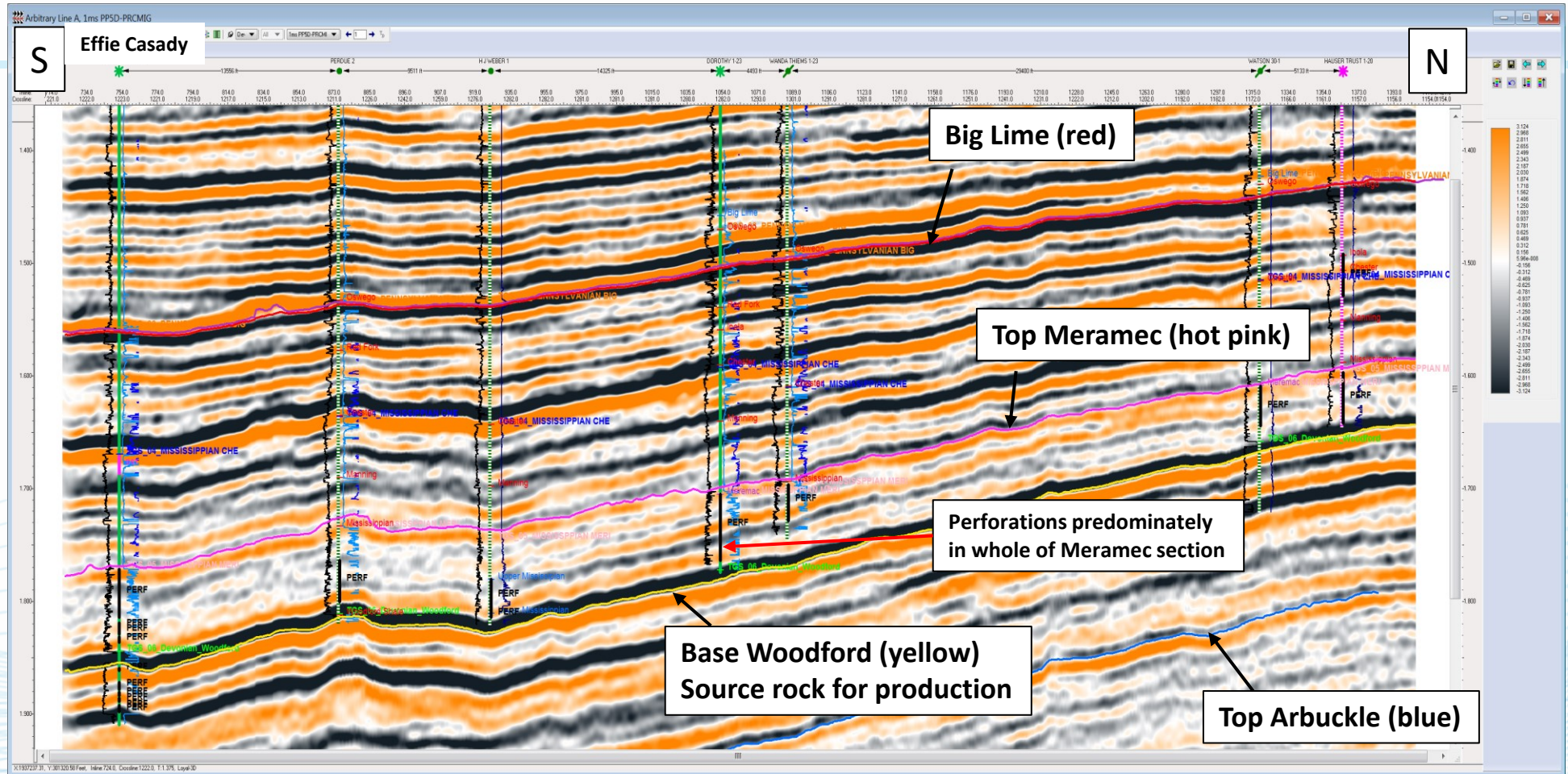
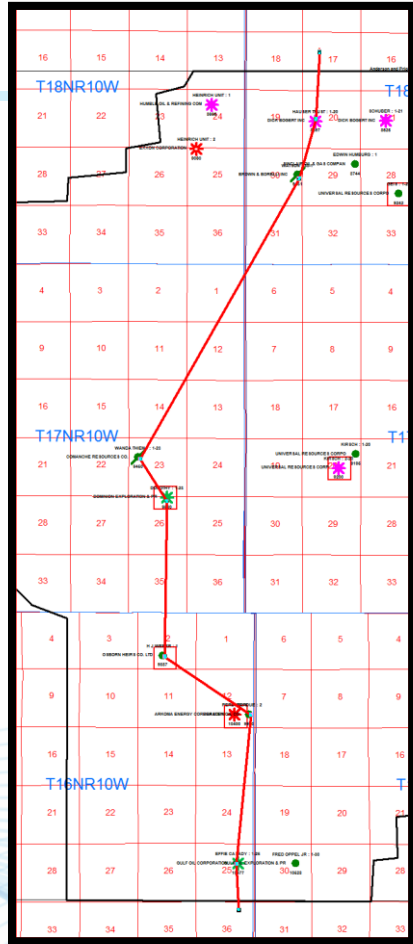
Time Map on Top Meramec Fm.
Cl = 10 ms (~60 feet)



Best Well – Gulf Oil #1-25 Effie Casady, 1980
IPF: 890 BO + 1979 Mcfg + 73 BWPD
Cum: 240.1 MMBO+ 2.23 Bcfg

S-N Arb Line

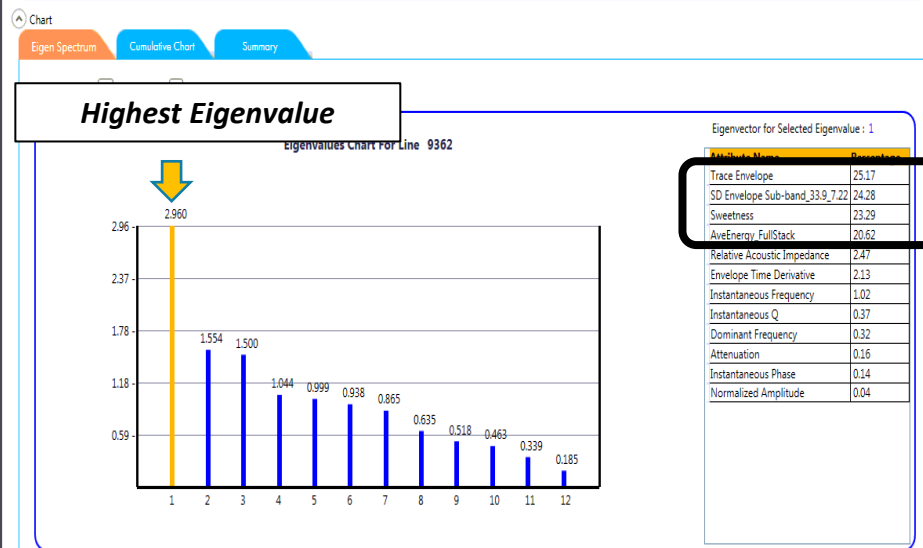
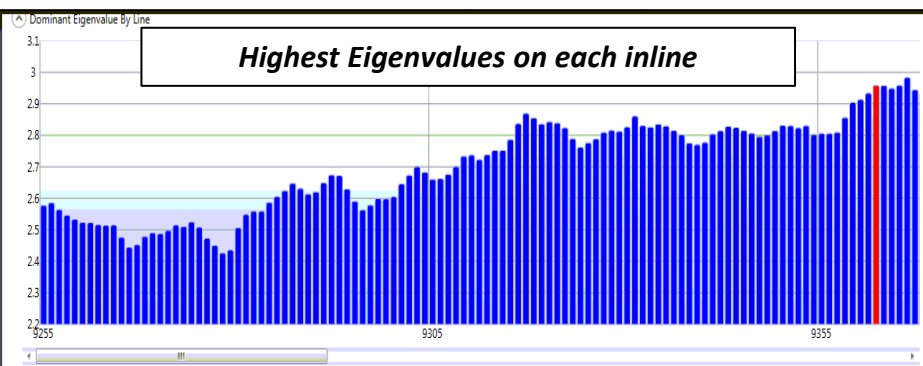
PP5D-PRCMIG (1.3-2.1sec) – Resampled to 1ms and used for Parent attribute



Section thins considerably from south to north – important because source rock is thinning as well

How PCA relates to finding the most significant seismic attributes

(12 seismic attributes were employed)



FIRST PRINCIPAL COMPONENT

Trace Envelope 25.17%

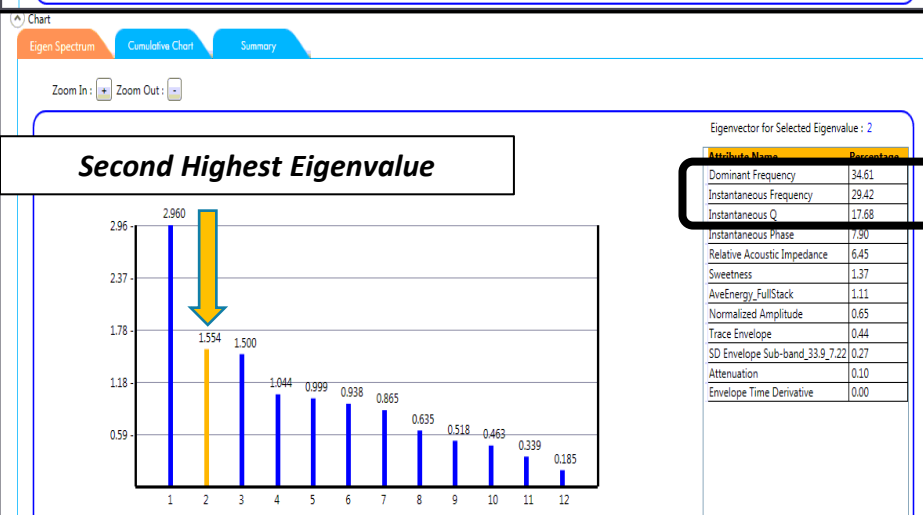
SD Envelope 33.9 Hz 24.28%

Sweetness 23.29%

Average Energy 20.62%

These 4 attributes account for more than 93% of the data found in all 12 attributes used in the analysis

The first principal component accounts for as much of the variability in the data as possible, and each succeeding component (orthogonal to previous) accounts for as much of the remaining variability as possible.



SECOND PRINCIPAL COMPONENT

Dominant Freq 34.61%

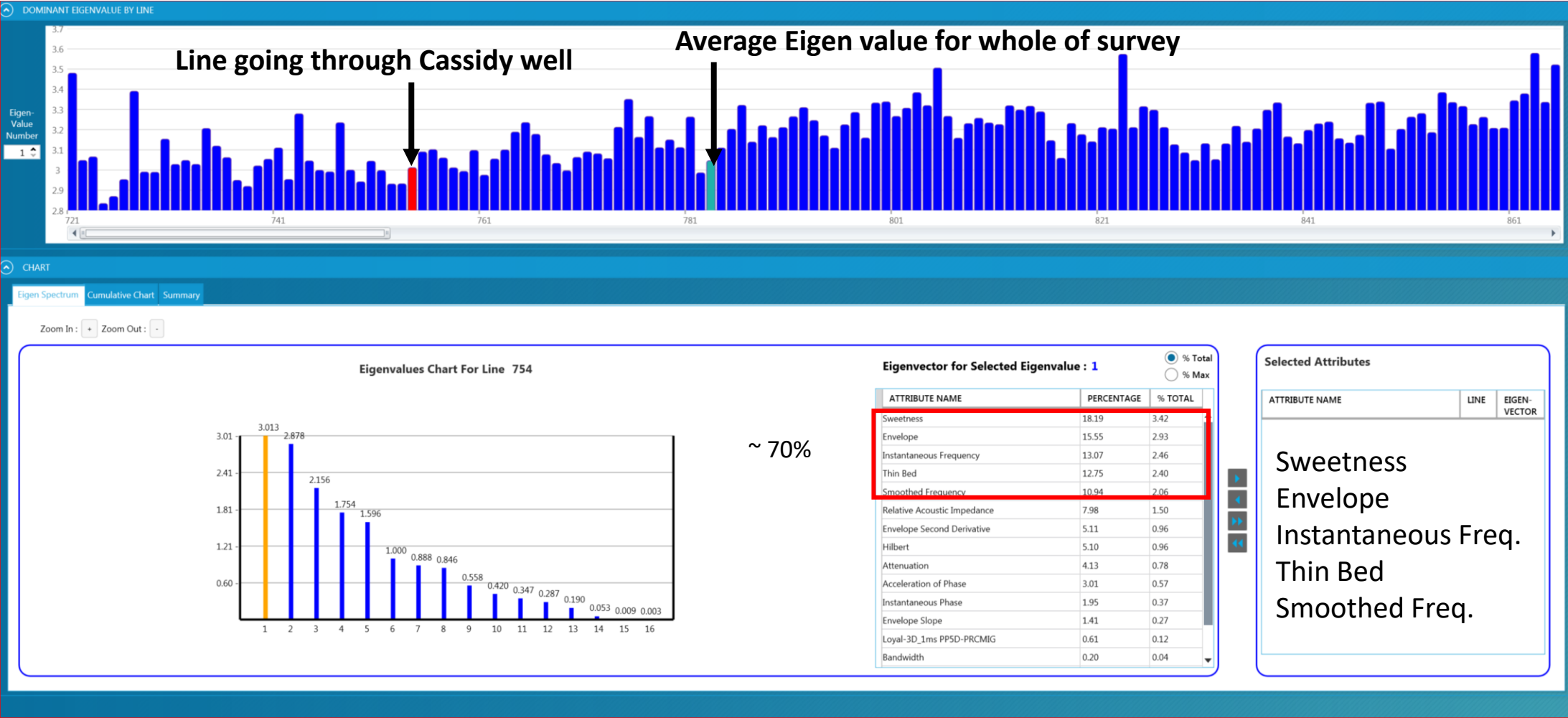
Instantaneous Freq 29.42%

Instantaneous Q 17.68%

These 3 attributes account for more than 81% of the remaining information.

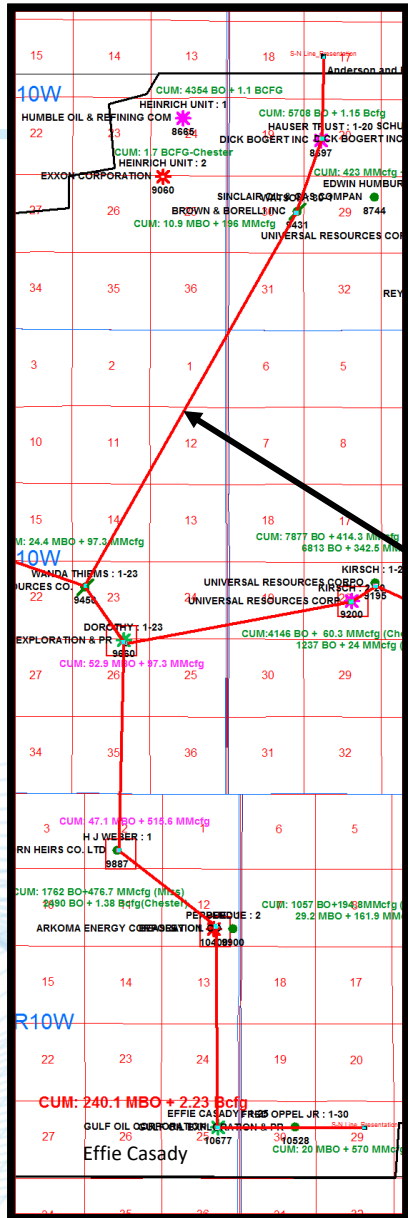
Using Instantaneous attributes in PCA, then SOM

Principal Component Analysis is used in the ThoughtFlow™ to help select those attributes which may contribute more significant information going into the SOM process.



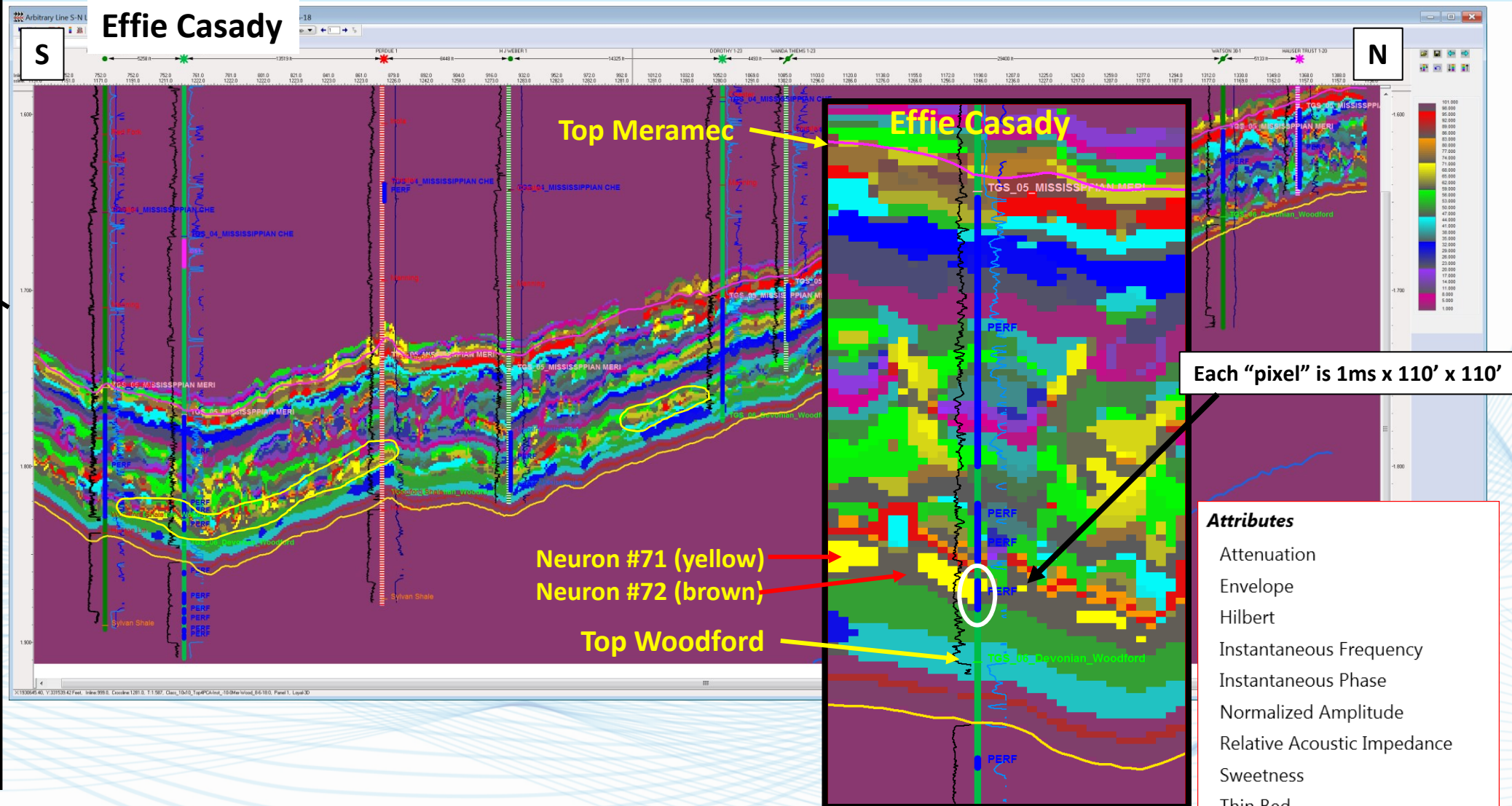
PCA: Eigen Vector 1 – Instantaneous Attributes through Line 754 (going through best well)
Window of focus was 10 ms above Meramec Fm. and 10 ms below Base Woodford Fm.

Arbitrary Line taken from SOM in 3D Survey



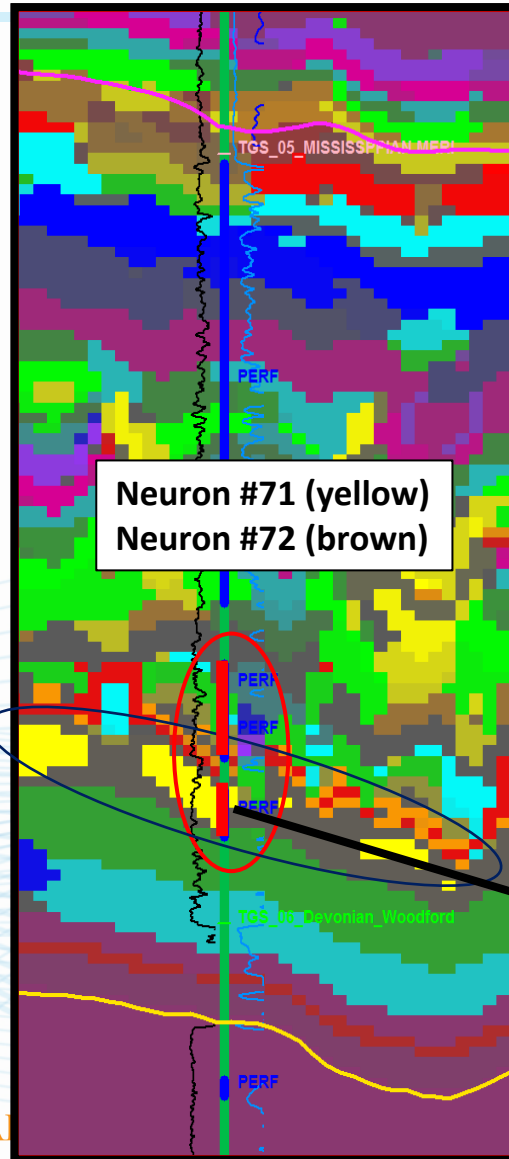
Top4PCA-Inst_10x10_-10 to 0 Mer-Wood

(used top instantaneous attributes from first four Eigen Vectors in a 10x10 topology. Window of analysis is 10 ms above Meramec to Base Woodford)

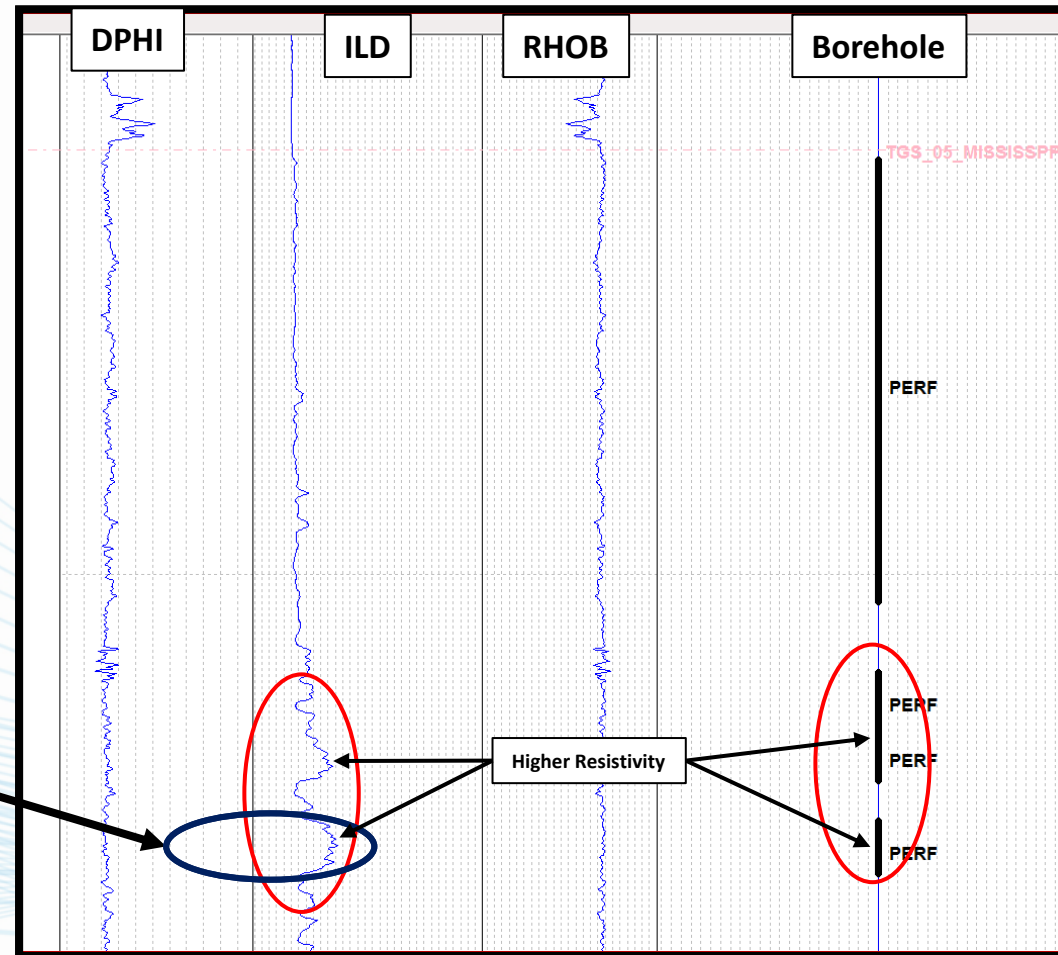


Although porosity is low, there is a distinct neural pattern associated with the higher resistivity section in the log – especially at the lower perforated section of the well.

Effie Casady

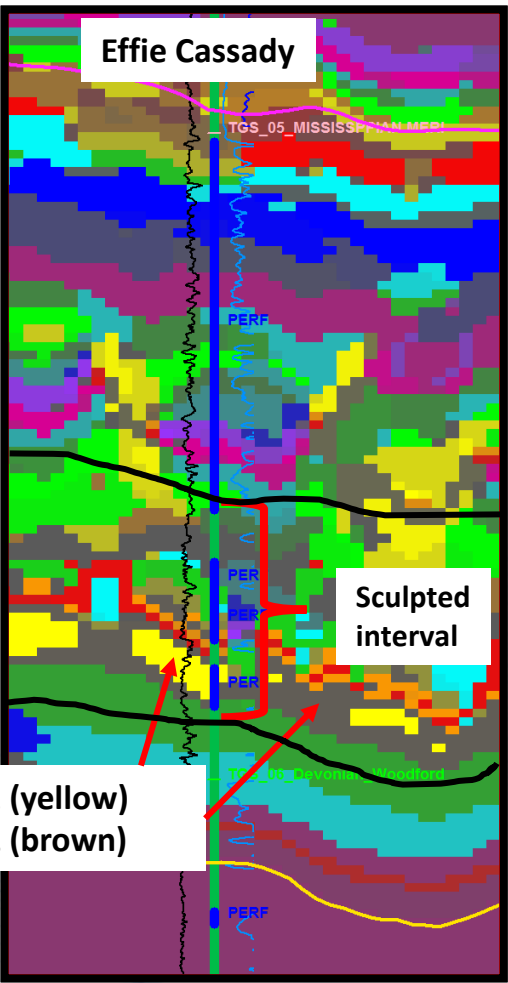
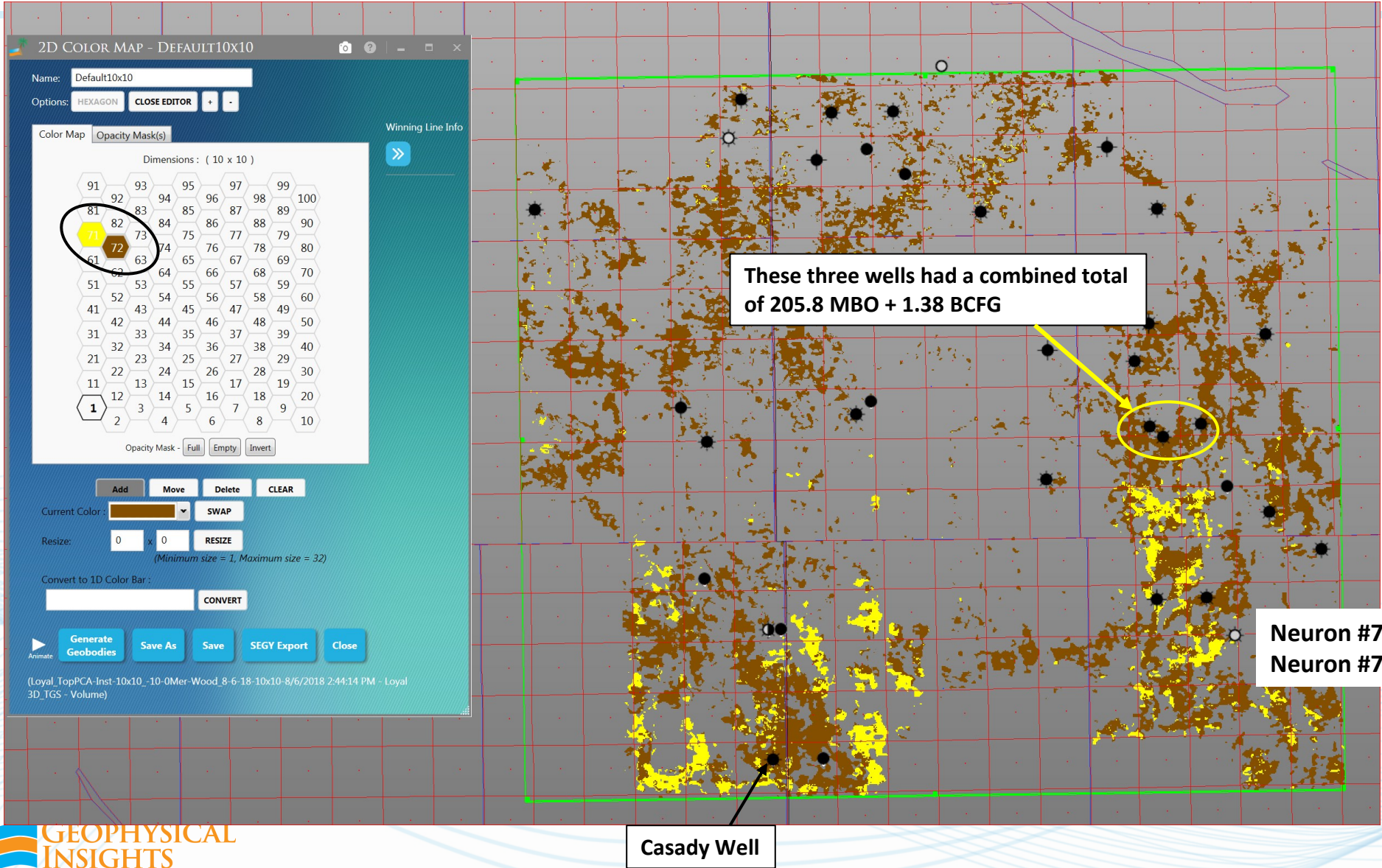


Effie Casady logs



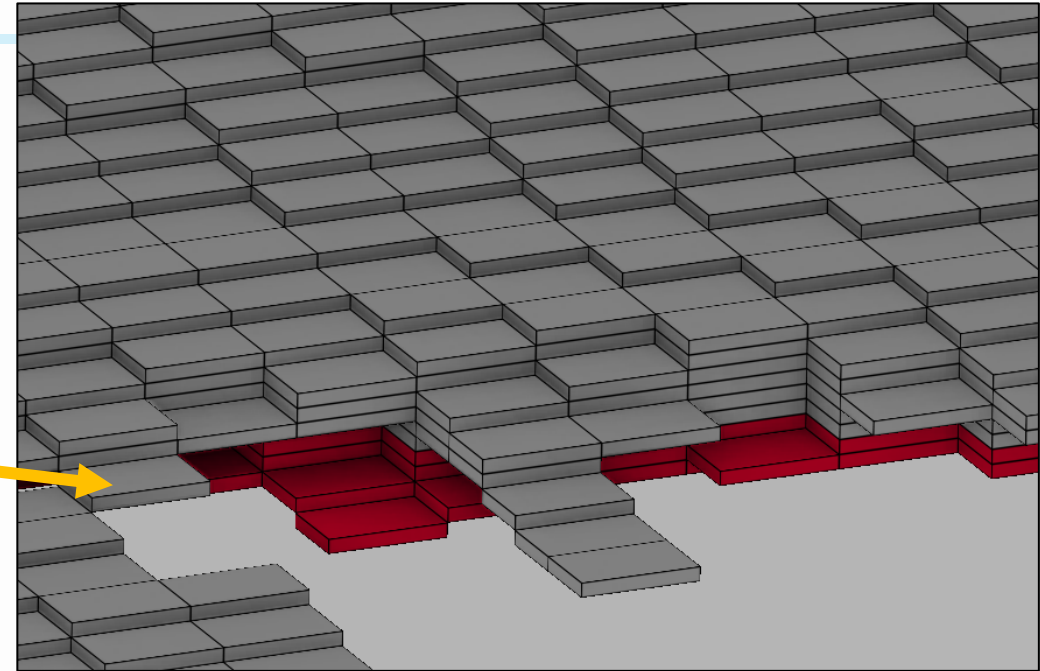
Higher resistivity
was targeted in
the perforations

Here are both neurons, colored in approximately the same color configuration as in the Kingdom display.
This is also a sculpted interval



Geobodies are on a scale of bin X sample increment, therefore, geobodies can be quantified.

Each bin X sample increment can be quantified to compute Gross Rock Volume, Hydrocarbon Pore Volume, etc.



Sample Volume (Time)

Depth Conversion Velocity

Gross Rock Volume

Net Rock Volume

Pore Volume

Hydrocarbon Pore Volume (HPV)

Porosity

Water Saturation

Calculated (Bin X * Bin Y * Bin Z(Sample in time/msec. * velocity))

5 Digit Value from User: 12000 Feet/sec (survey units)

$GRV = \text{Sample Volume} * \text{Sample Count}$

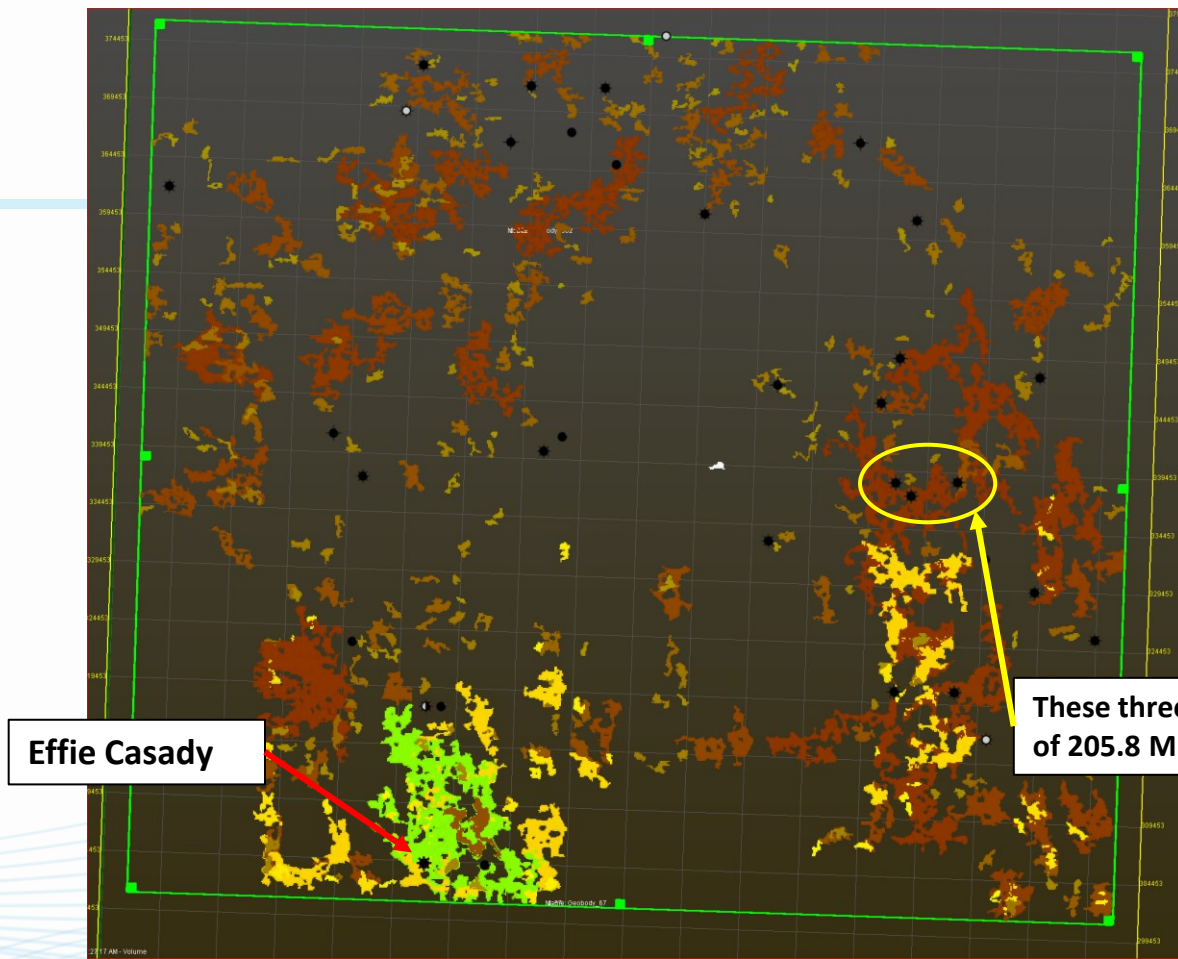
$NRV = GRV * \text{Net Rock Factor (0-1)}$

$PV = NRV * \text{Porosity}$

$HPV = PV * (1-S_w)$

0-1 (from user)

Percentage (by user from log data)



Effie Casady

These three wells had a combined total of 205.8 MBO + 1.38 BCFG

The two key neurons in previous slides have been scanned for Geobodies. The Geobody which may be contributing to the production in the Effie Casady well has been highlighted in green. Highlighting that geobody allows one to know the sample count it contains – which in this case is 32,439 samples (1ms x 110’x110’)

Hydrocarbon Pore Volume, if all values are known, could be calculated to show possible reserve amounts (with recovery factor) and calibrated to known production for reservoir extents. Values used are “estimates” for the Meramec in this area

Velocity (ft/s) :	14000 ft/sec
Net/Gross (0-1) :	0.6
Porosity (0-1) :	0.06
Water Saturation (0-1) :	0.4

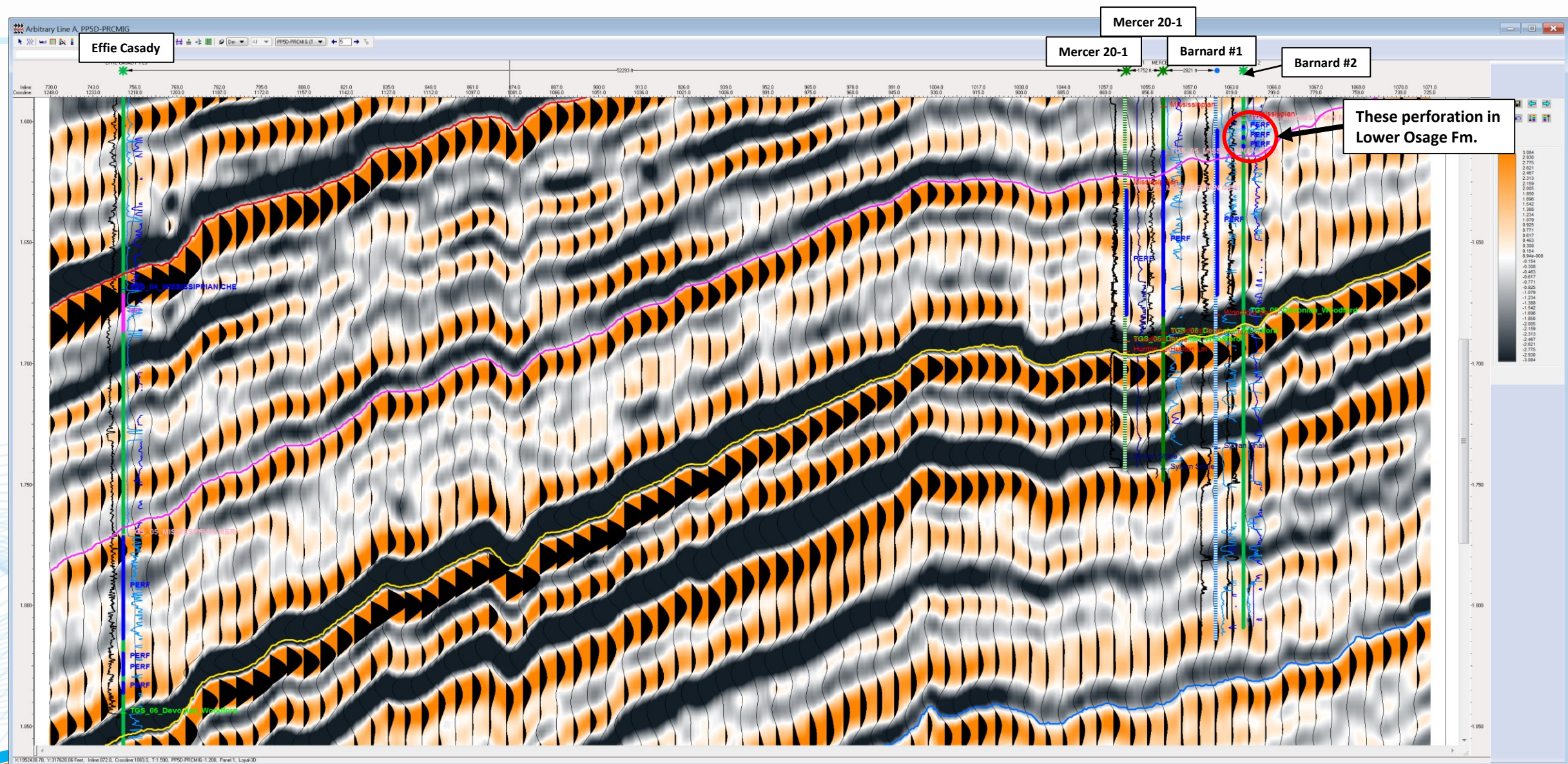
ID	NAME	NEURON	SAMPLE COUNT	EXTERIOR SAMPLE COU	INTERIOR SAMPLE COU	VELOCITY (FT/S) (>=	NET/GROSS (0-1)	POROSITY (0-1)	WATERSATURATION (0	SAMPLE VOLUME (CUBIC FEE	GROSS ROCK VOLUME (CUBIC FE	NET ROCK VOLUME (CUBIC F	PORE VOLUME (CUBIC FEE	HYDROCARBON PORE VOLUME (CUBIC FEET)
67	Geobody_67	72	32,439	24,925	7,514	14000.00	0.60	0.06	0.40	169400.10	5495169000.00	3297102000.00	197826100.00	118695700.00

32,439 samples

HPV = 118,695,700 cubic feet

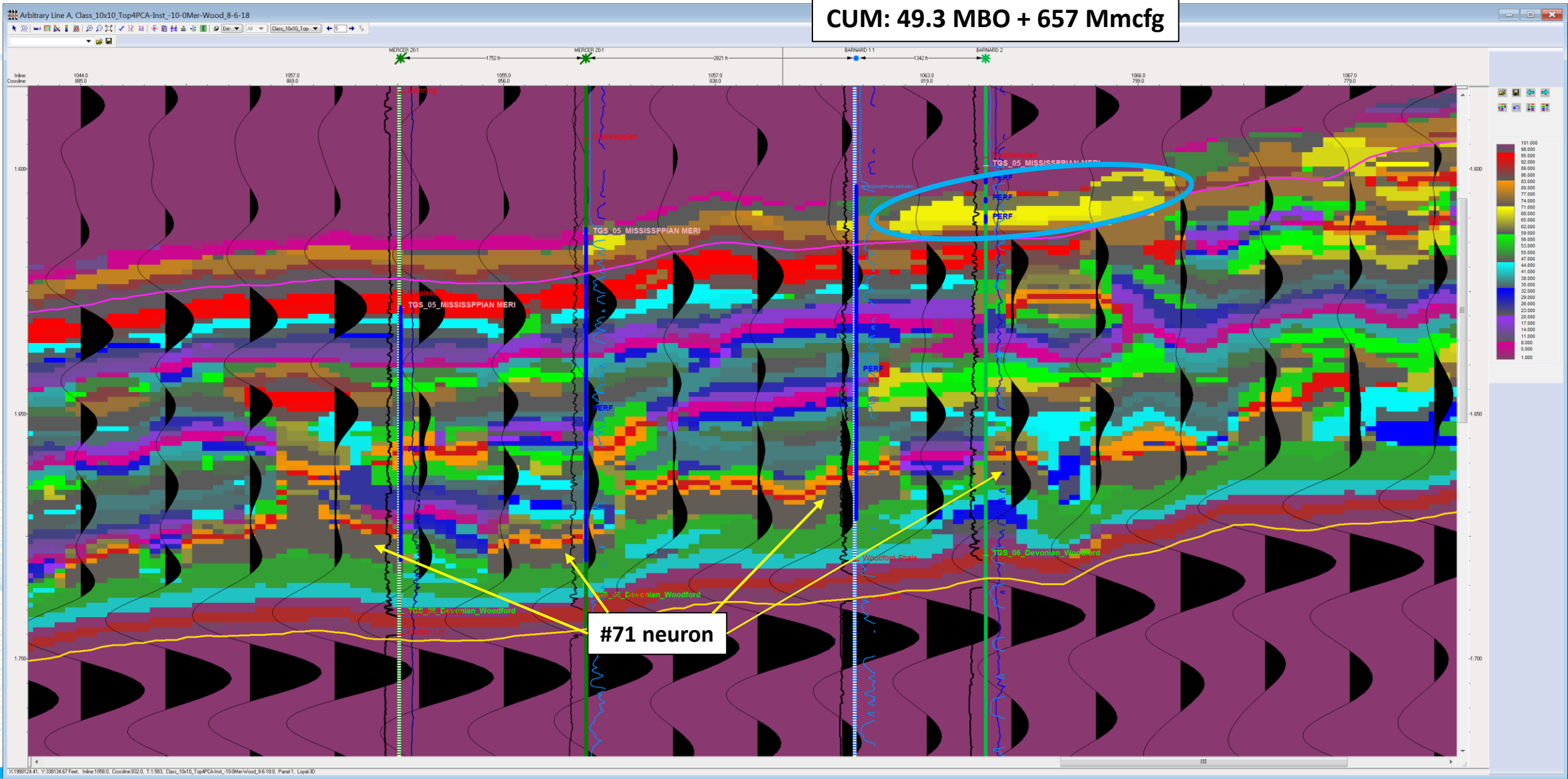
118,695,700 CuFt/43,560 = 2725 ac-ft x 225 BOE/ac-ft = 613,125 BOE Actual is: **611,685 BOE** for the well

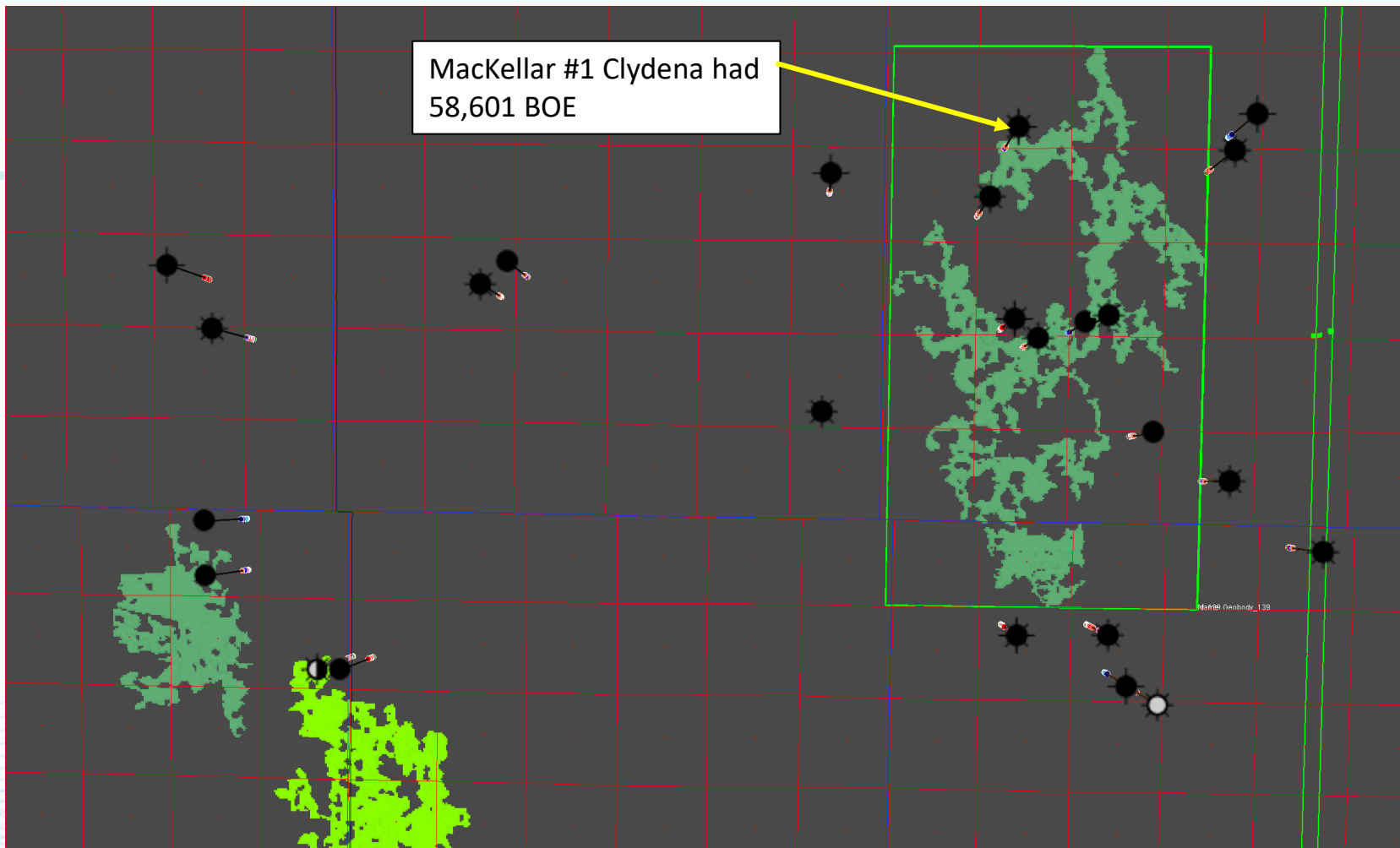
Arbitrary Line in PP5D-PRCMIG from Cassady well to other wells with key neurons



Enlarged section from previous line in Paradise SOM

Barnard
CUM: 49.3 MBO + 657 Mmcfg





I took the total cubic feet of hydrocarbon pore volume and divided by 43,560 (# of square feet in an acre) to get Ac-Ft. Then I multiplied the number of Ac-Ft (2114.4) by the recovery factor given to me by my friend at the large independent to end up with 475,751 BOE. There were only three of the four wells which perforated the key neuron, and the total BOE of those three wells was 423,080.

However, the MacKellar #1 Clydena perforated a small interval of the key neuron, so I added the BOE production from that well to get to 481,681 BOE, which is within **2% error** from the calculated amount

Id: 139

Name:

3586

37758

RESET

Id	Name	Neuron	Sample Count	Exterior Sample Count	Interior Sample Count	Velocity (Feet/sec) (>=0)	Net/Gross (0-1)	Porosity (0-1)	WaterSaturati on (0-1)	Sample Volume (Cubic Feet)	Gross Rock Volume (Cubic Feet)	Net Rock Volume (Cubic Feet)	Pore Volume (Cubic Feet)	Hydrocarbon Pore Volume (Cubic Feet)	
139	Geobody_139	72	37,758	27,786	9,972	14000.00	0.60	0.04	0.40	169400.10	6396208000.00	3837725000.00	153509000.00	92105400.00	

37,758 Samples

HPV = 92,105,400 cu ft

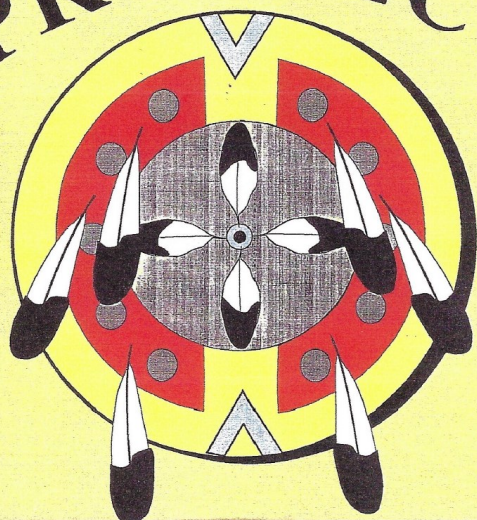
GEOBODY EDITING CONTROLS

Editor Visibility

$$92,105,400 / 43,560 = 2114.4 \text{ Ac-Ft} \times 225 \text{ BOE/Ac-Ft} = 475,751 \text{ BOE}$$

Actual from the three wells perforated in the neuron is 423,080 BOE + 58,601 = 481,681 BOE from Neuron #72

GERONIMO PROSPECT



PALADIN PETROLEUM III, LLC

GERONIMO PROSPECT

Upper Wilcox & Queen City
Targets

Duval County, TX

An “M.L. Driven” Prospect

MAJOR FIELDS IN THE UPPER WILCOX GAS TREND



The **Geronimo Prospect** is on stratigraphic trend with N.E. Thompsonville, Fandango and N.W. Rosita Fields

It has the potential of 300+ BCFGE. The structure is approximately six miles long and two miles wide. Targets are the Upper Wilcox Hinnant Sands from the UW-1 to the UW-17.

The initial test well is designed to test a large faulted, four-way closure with vertical relief in excess of 1000 feet. The prospect exhibits multiple stacked sands with thicknesses ranging from 40 to 100 feet.

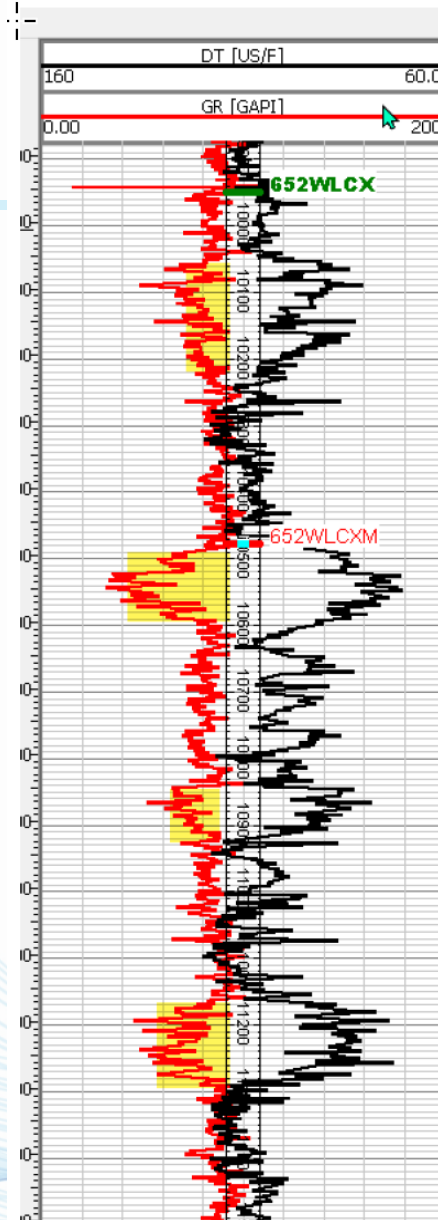
Additional potential can be seen in the Queen City Fm., which would be a non-pipe test at about 9000 feet.

A 27-square mile 3D, acquired in 1998 and reprocessed by Tricon Geophysical recently is the basis for this prospect. All attributes were created using the Far Angle Stack to better support any AVO gas effect in the data.

Gathers at key sands show Type 2P and Type 3 AVO characteristics.

UPPER WILCOX
HINNANT SANDS :
MUY GRANDE FIELD :
10 miles west

260 FT TOTAL SAND



Amoco 1-
Peters

UW-1

UW-2

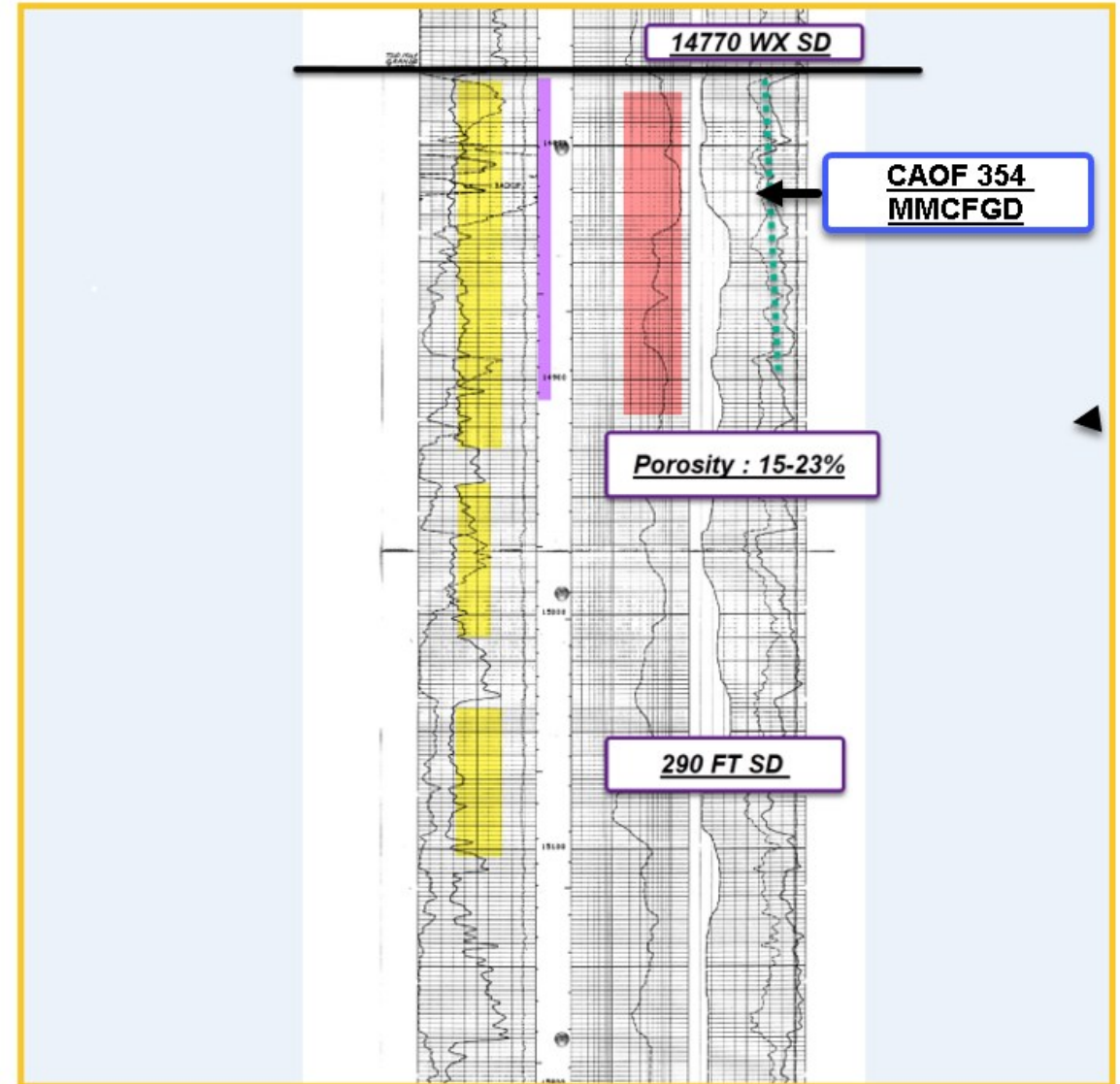
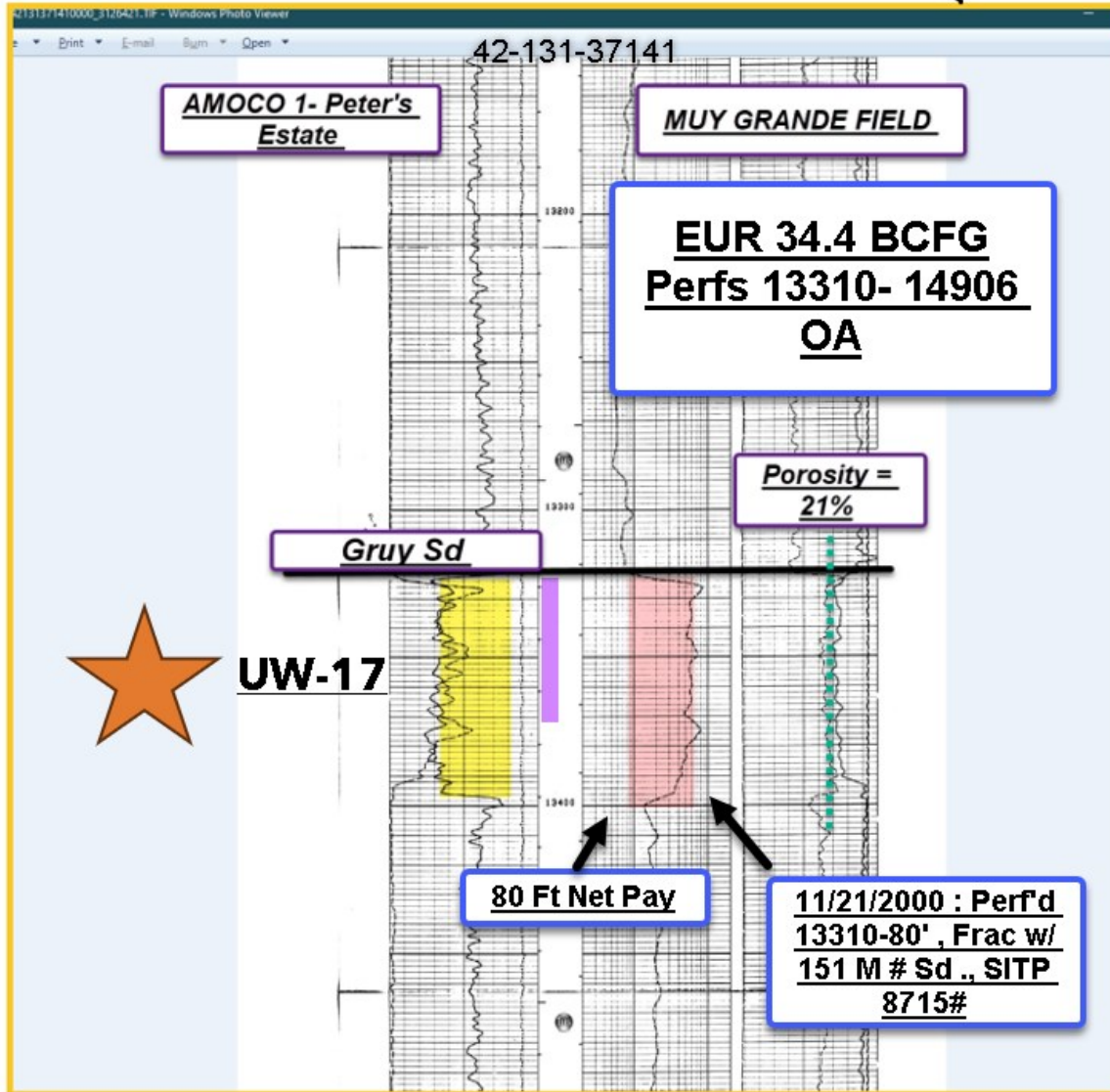
UW-3

UW-4

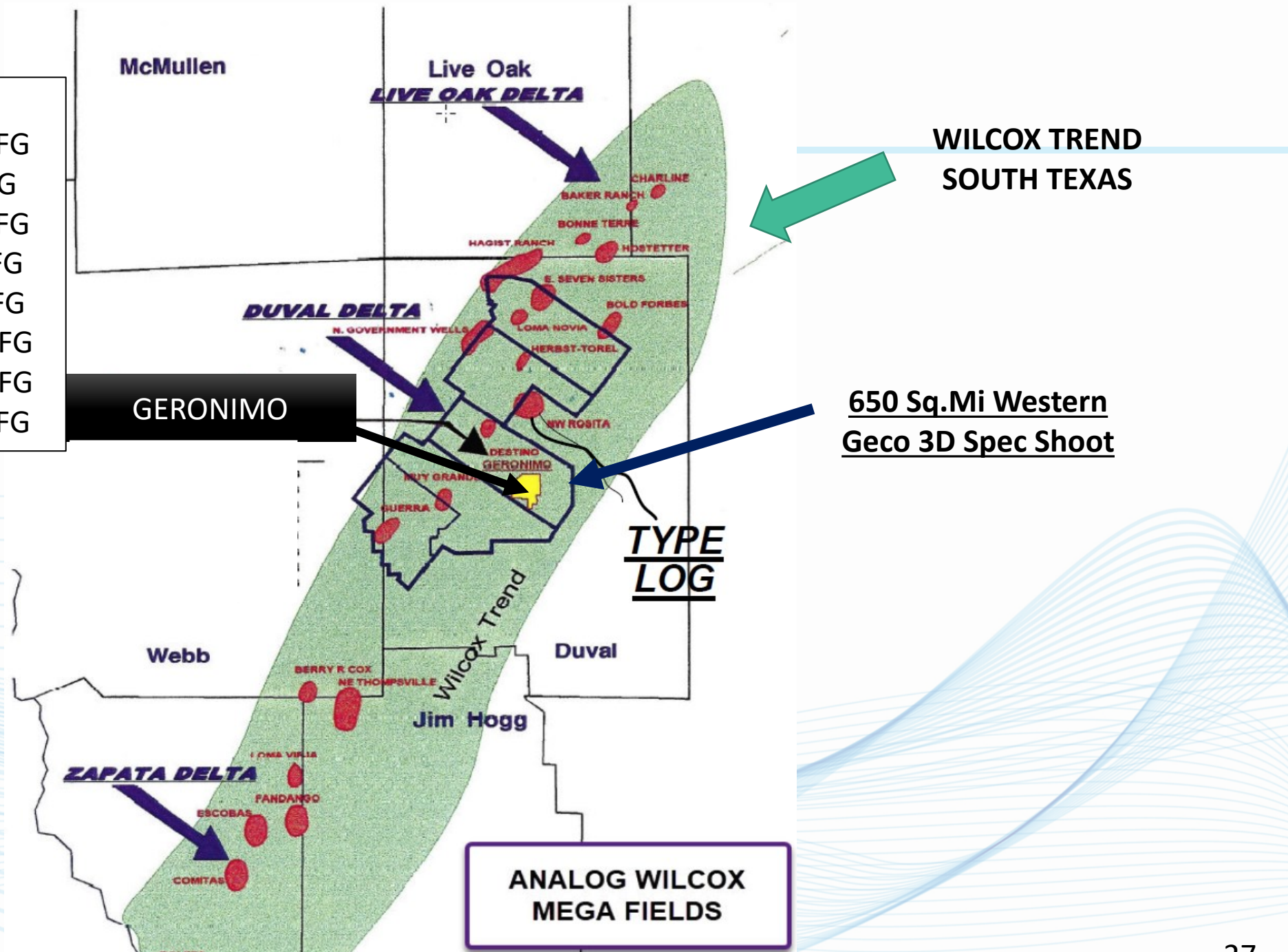
HINNANT SAND SERIES

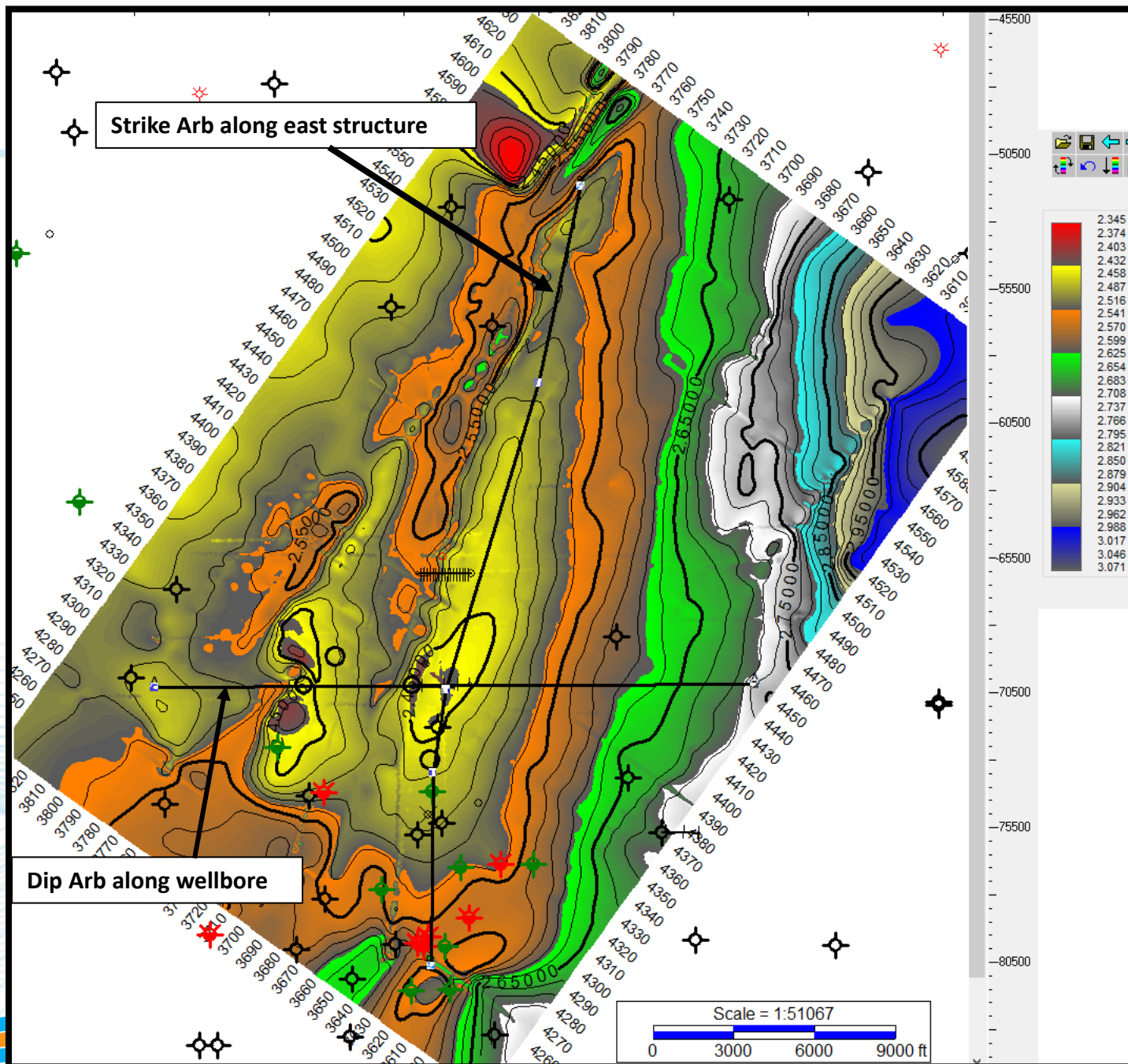
Sonic Porosities : 22-
28%

ANALOG UW – 17 PAY FOR WEST LOCATION



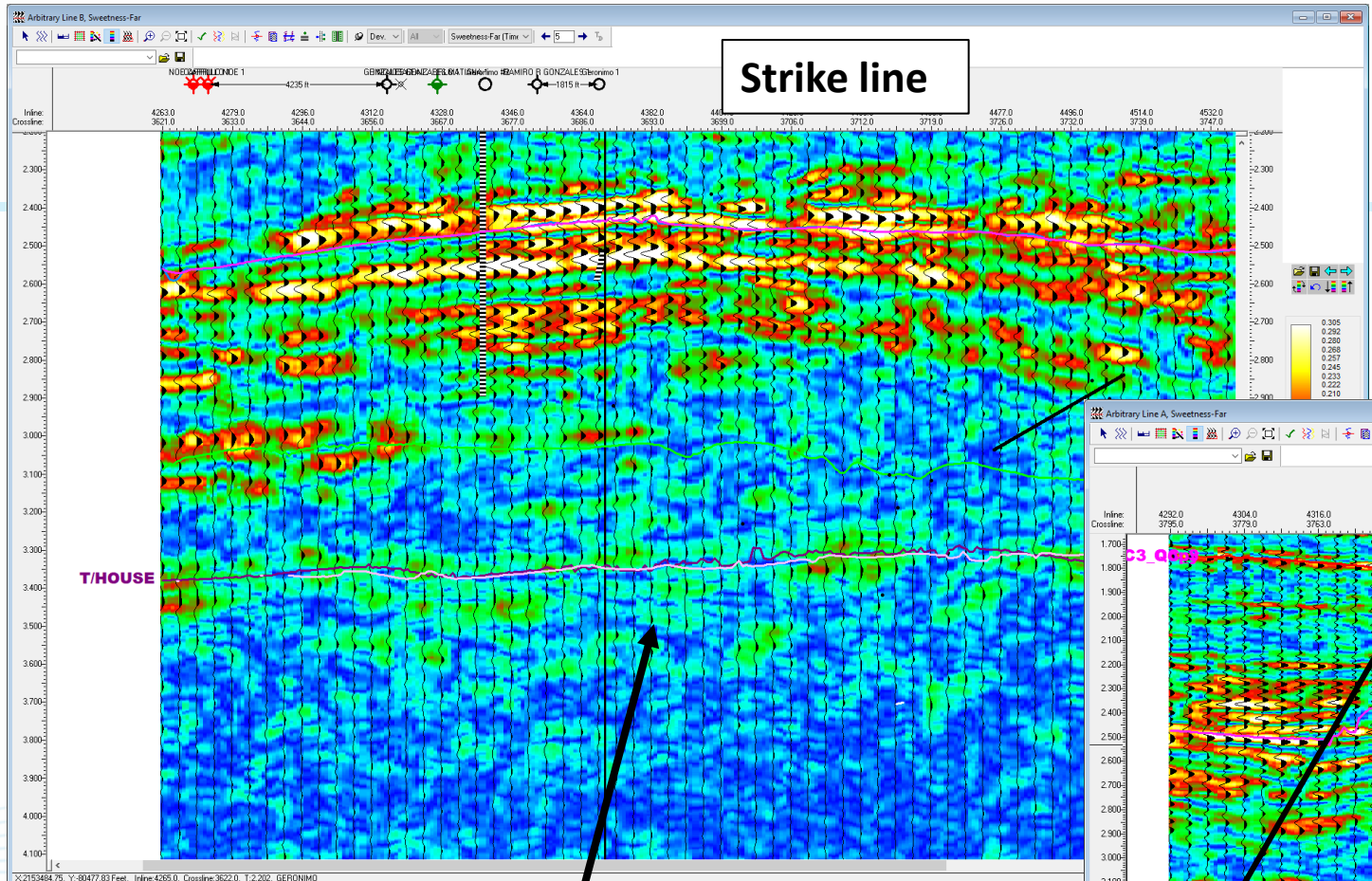
Field	EUR
Hagist Ranch	507 BCFG
E. Seven Sisters	427 BCFG
N.W. Rosita	375 BCFG
N.E. Thompsonville	705 BCFG
Fandango	372 BCFG
Roleta	404 BCFG
Lopeno	306 BCFG
Bob West	633 BCFG



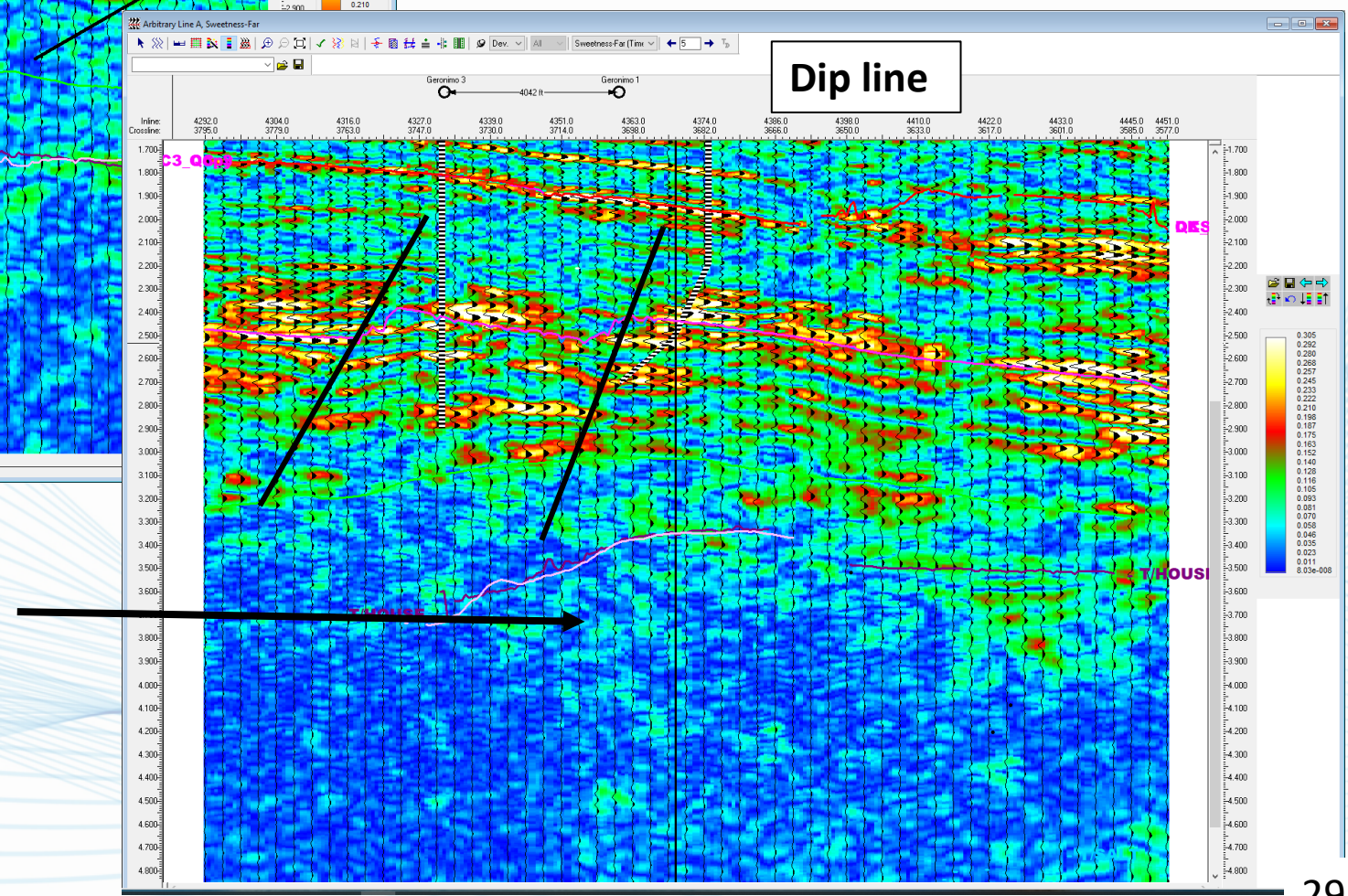


Time Structure Grid of Near Top Wilcox
CI = 20 ms (~100')

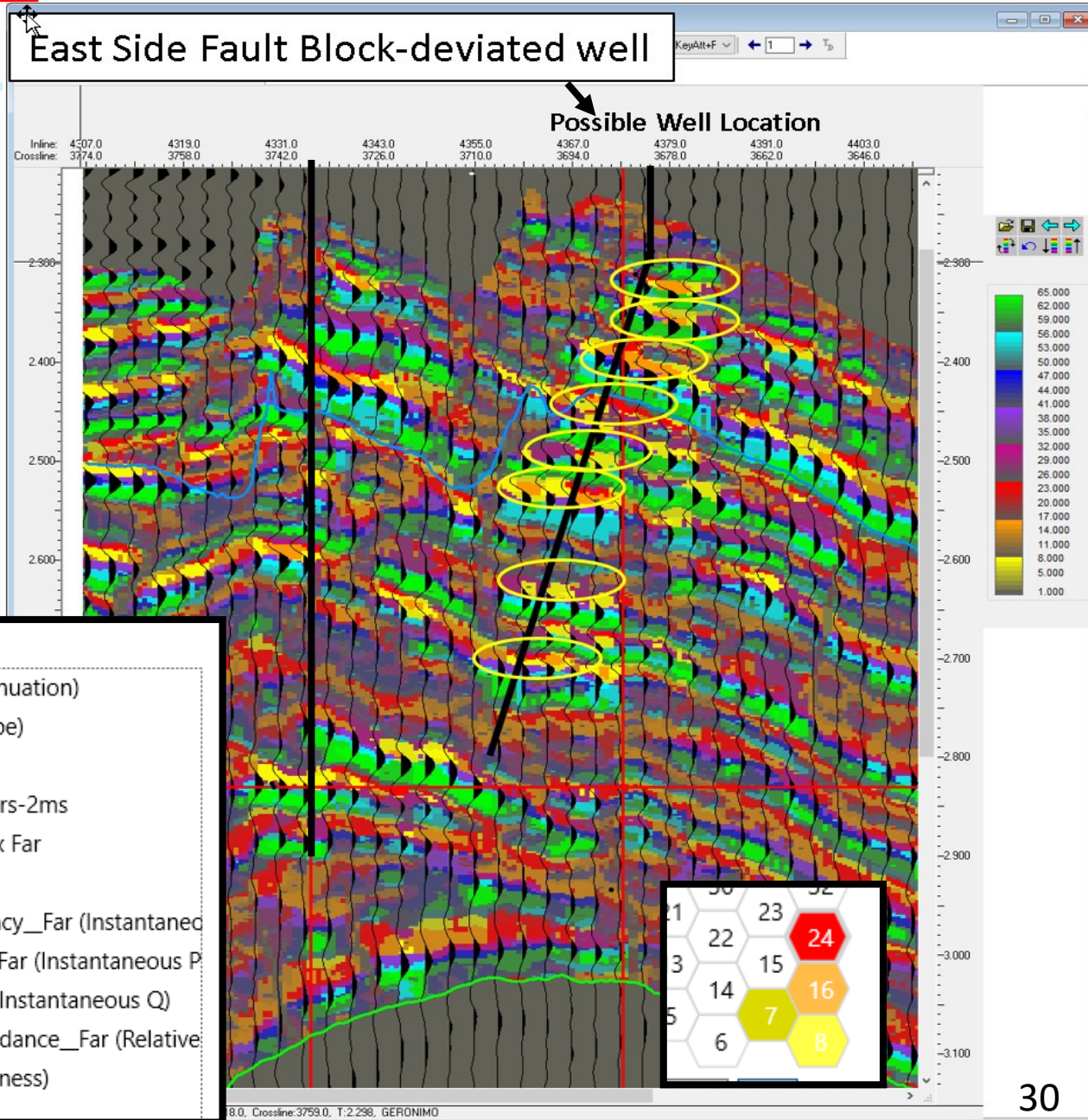
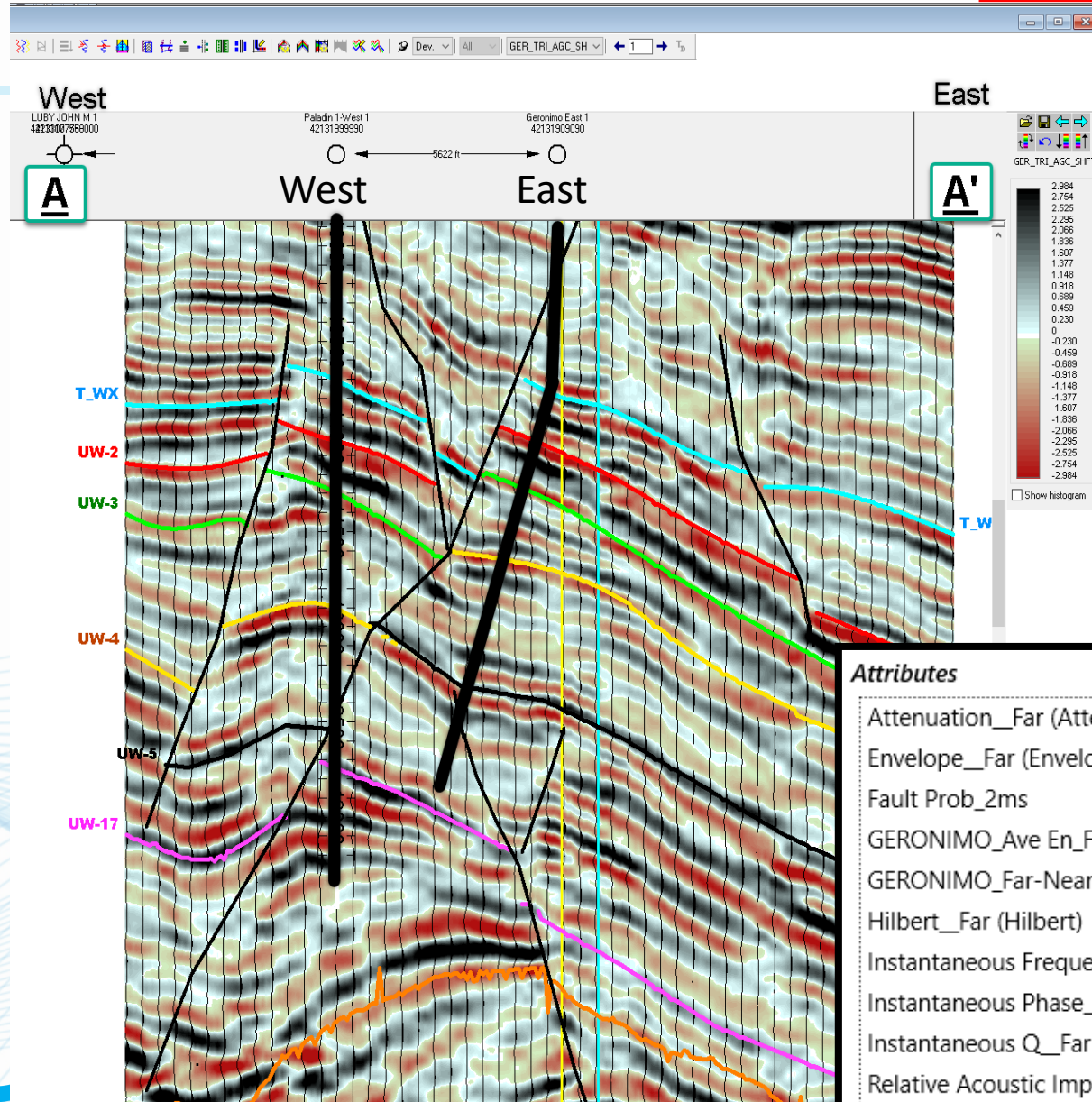
At the Top Wilcox (UW-1) the Geronimo Structure maps out as an elongate faulted anticlinal structure 6 miles in length and 2 miles in width' very similar to the N.E. Thompsonville structure.

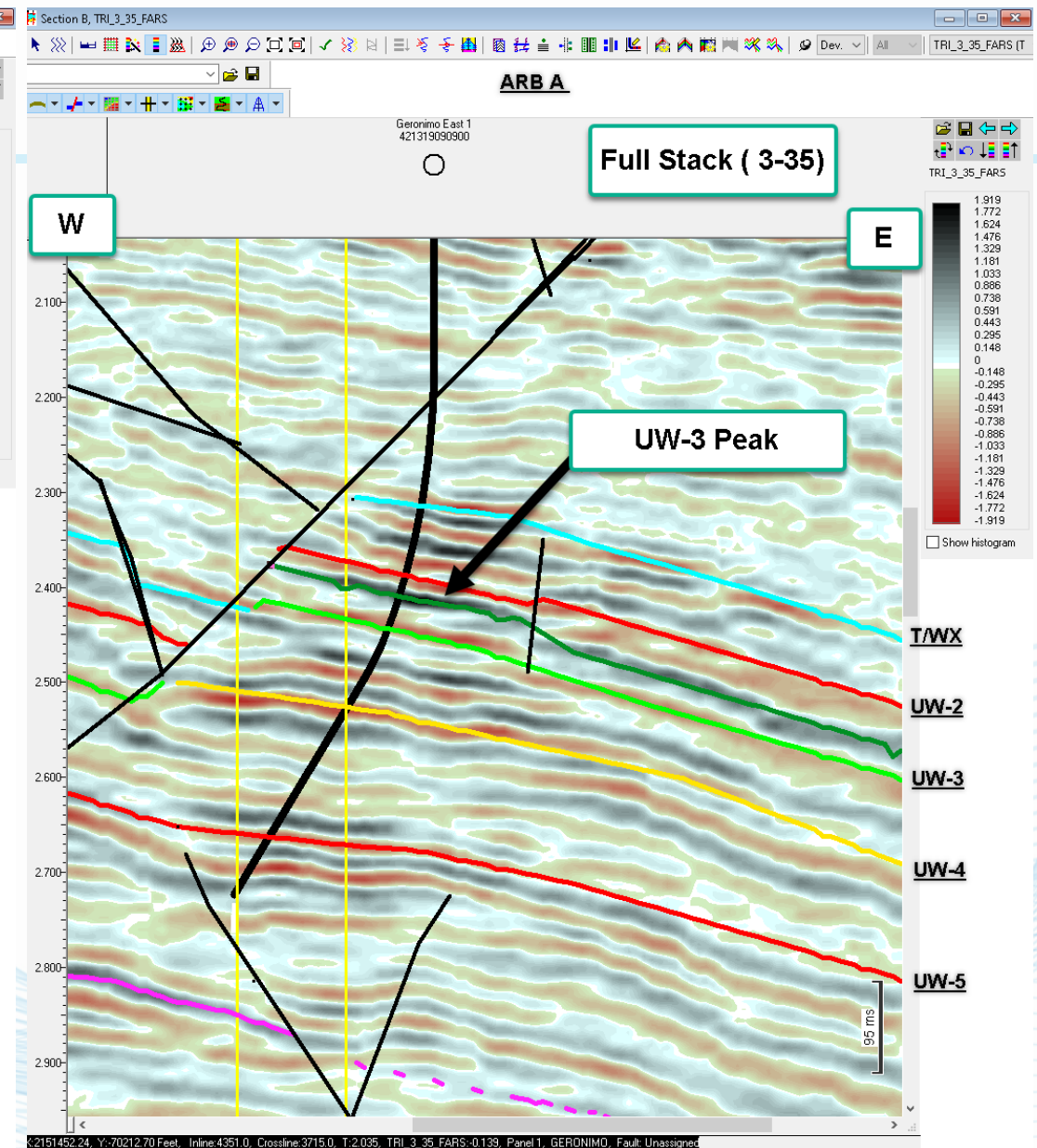
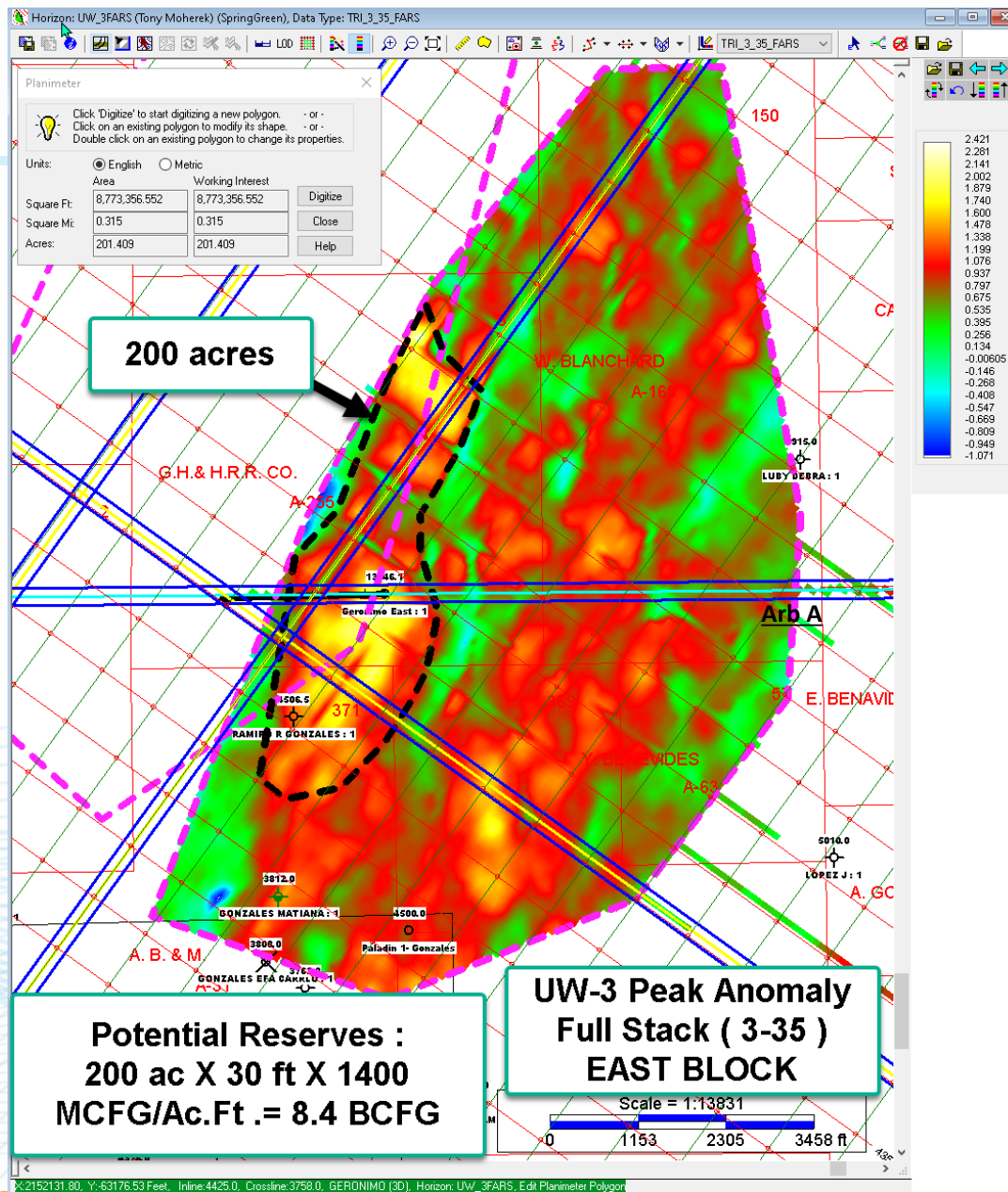


Presence of Upper Wilcox Sands by use of **Sweetness Attribute**. Sweetness is derived by taking the Envelope and dividing by square root of the frequency.

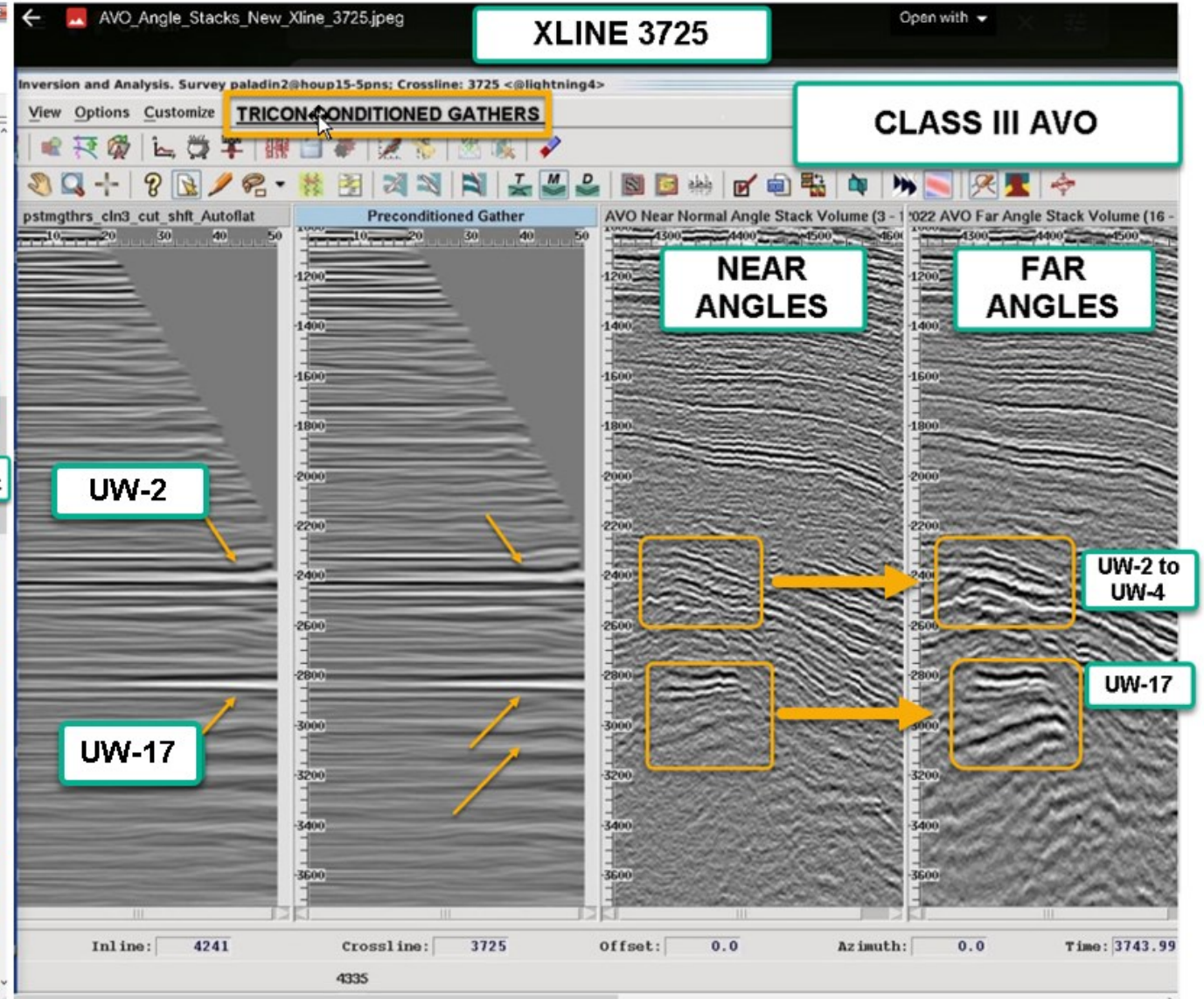
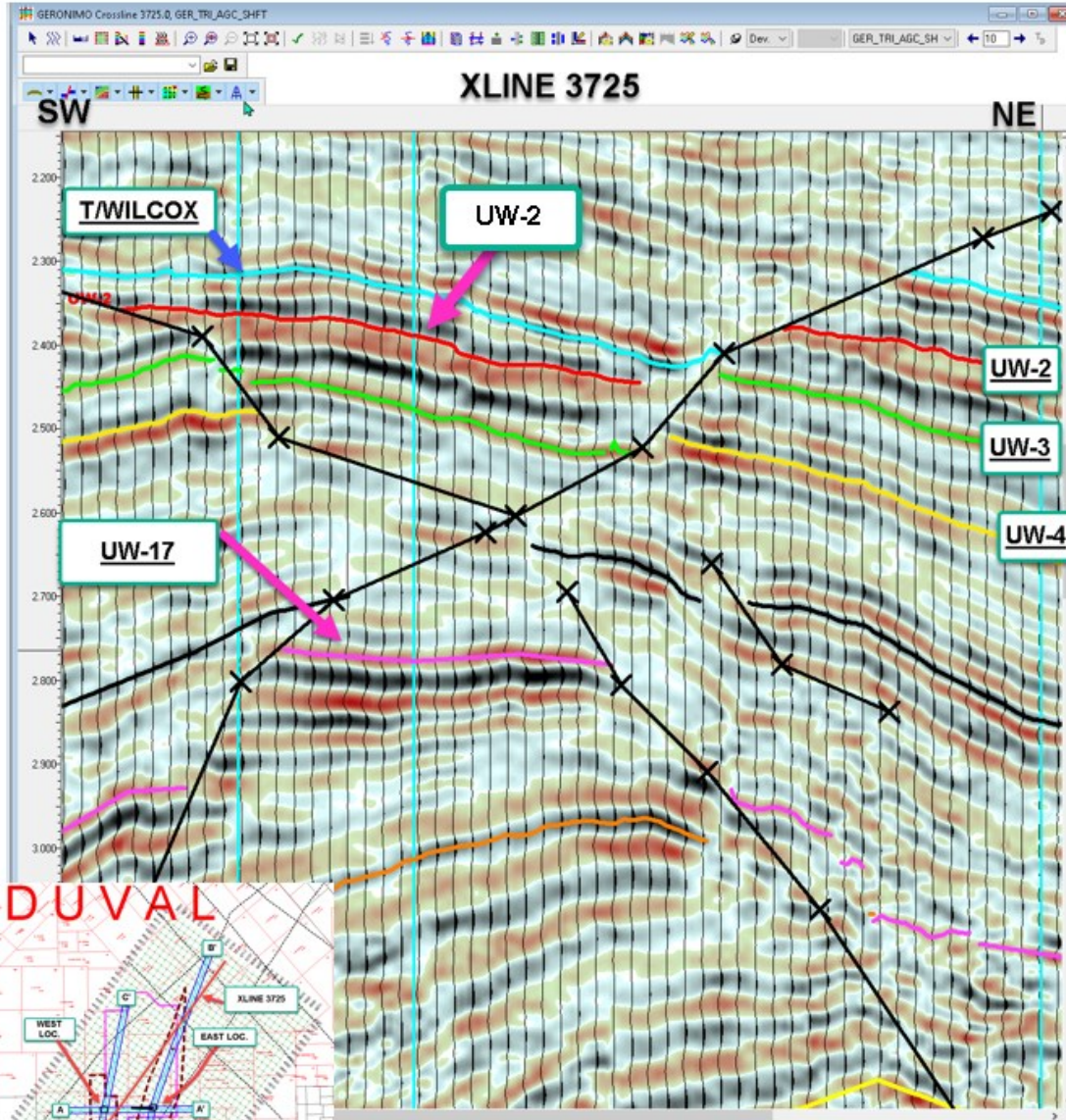


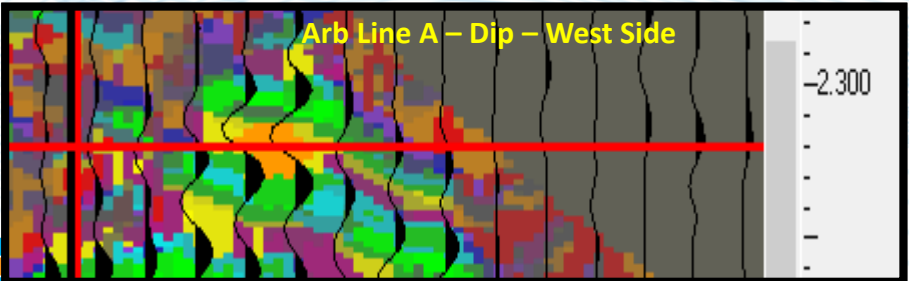
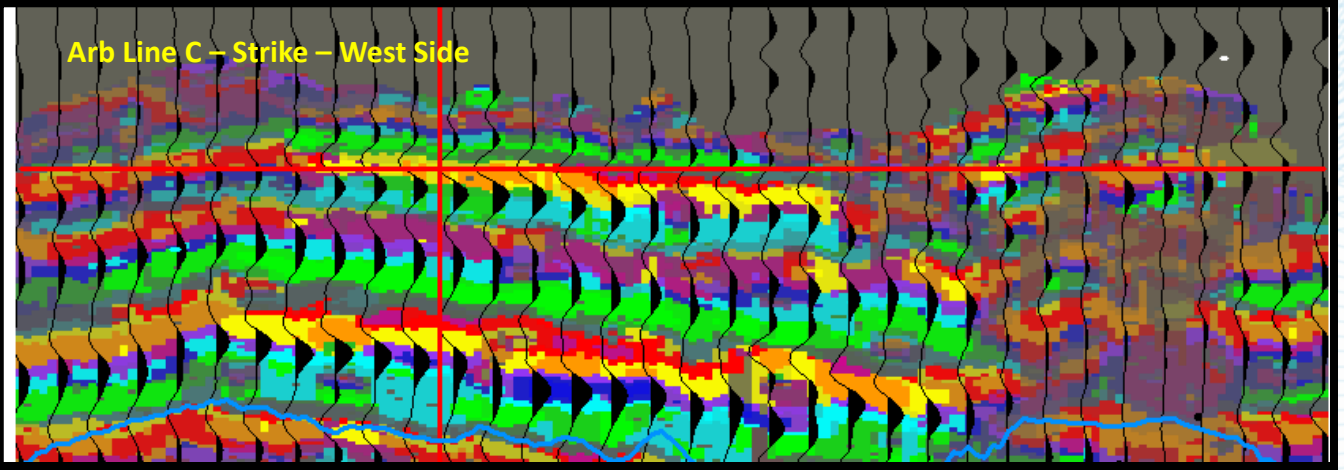
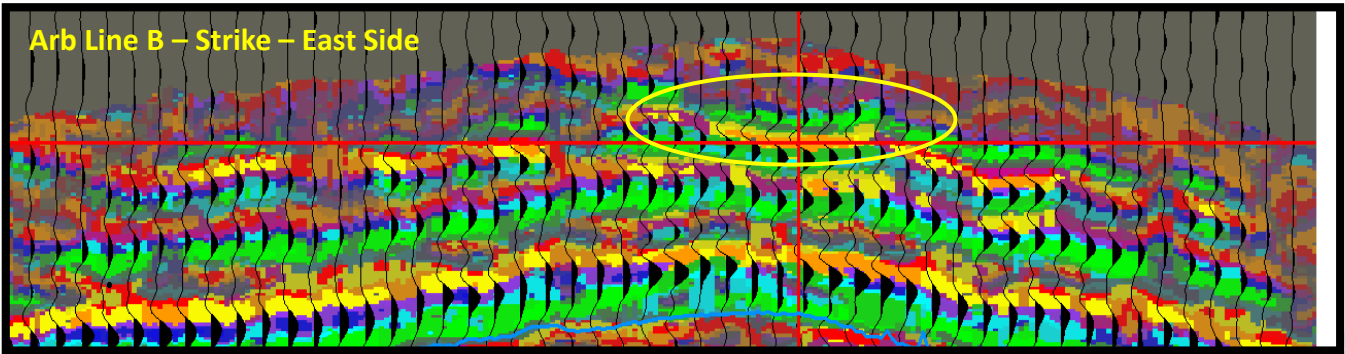
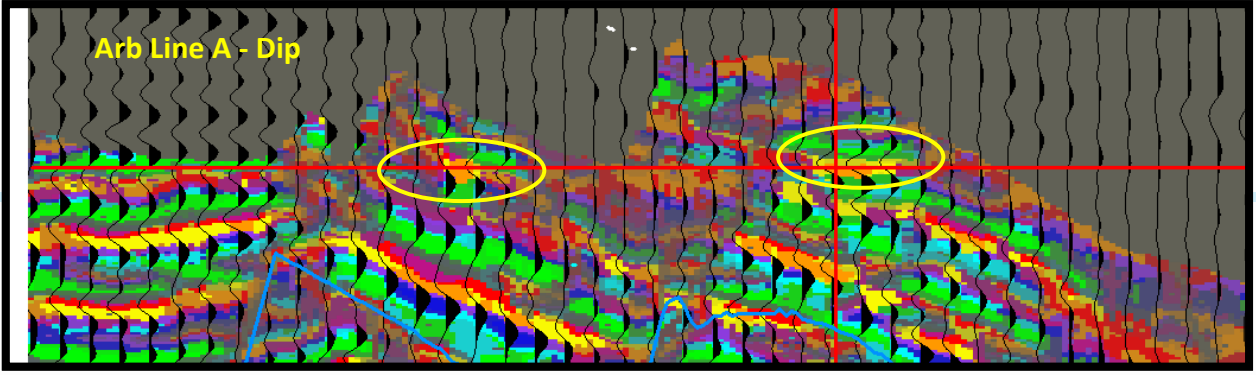
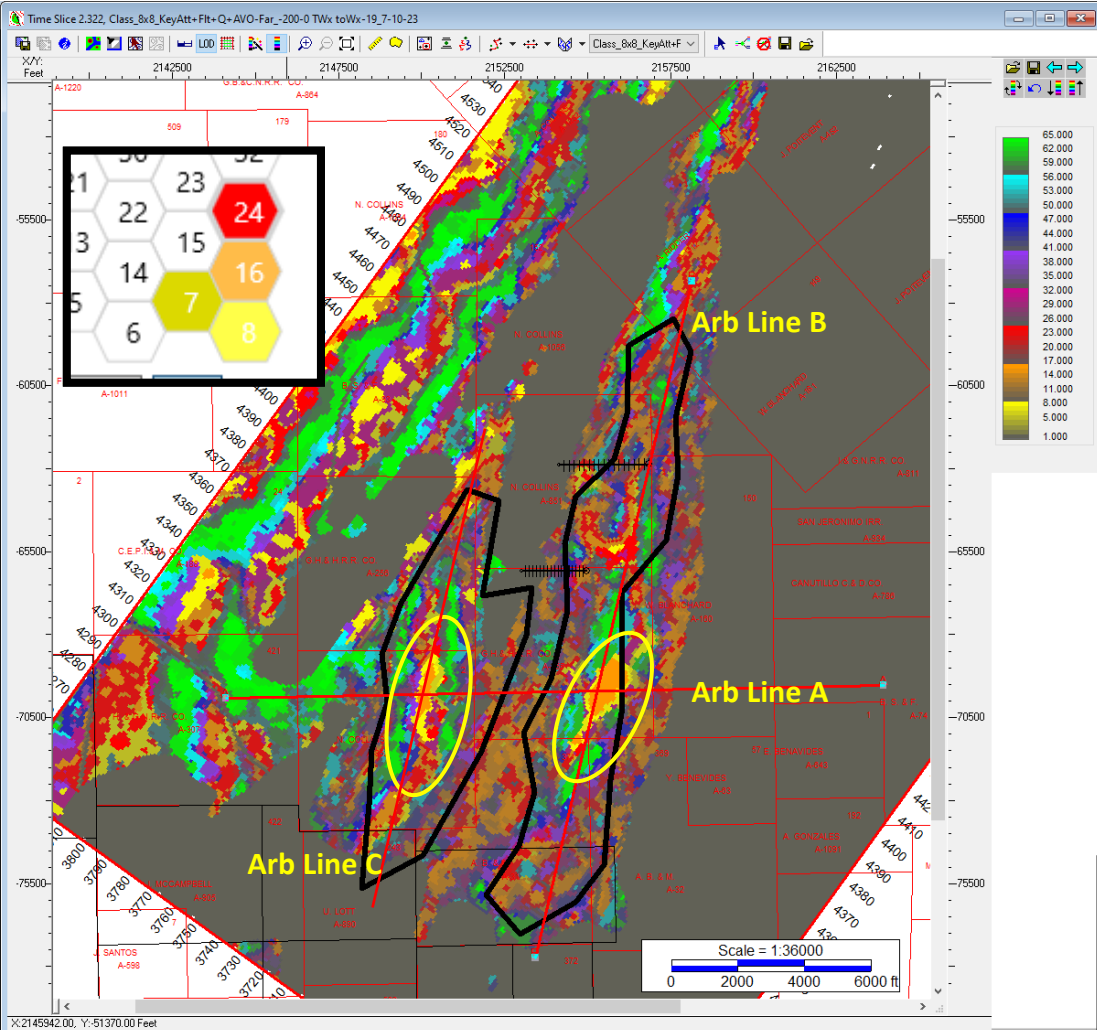
No evidence of sands in the Middle to Lower Wilcox – House Sands





CLASS III AVO Signature Along XLINE 3725





Upper Sand – West Side

Geobody Details

Velocity Units: Feet/sec Volume Units: Acre-Feet

Id: 829,2715,82,387,3126,387,3266,3255 Name:

Id	Name	Neuron	Sample Count	Exterior Sample Count	Interior Sample Count	Interval Velocity (Feet/sec) (>=0)	Net/Gross (0-1)	Porosity (0-1)	Water Saturation (0-1)	Sample Volume (Acre-Feet)	Net Rock Volume (Acre-Feet)	Hydrocarbon Pore Volume (Acre-Feet)
82	Geobody_82	16	73	57	16	11000.00	0.85	0.23	0.35	1.72	106.72	15.95
95	Geobody_95	16	976	523	453	11000.00	0.85	0.23	0.35	1.72	1426.78	213.30
387	Geobody_387	24	258	245	13	11000.00	0.85	0.23	0.35	1.72	377.16	56.39
2715	Geobody_2715	7	233	223	10	11000.00	0.85	0.23	0.35	1.72	340.61	50.92
2735	Geobody_2735	7	258	242	16	11000.00	0.85	0.23	0.35	1.72	377.16	56.39
2766	Geobody_2766	7	181	179	2	11000.00	0.85	0.23	0.35	1.72	264.60	39.56
2786	Geobody_2786	7	377	334	43	11000.00	0.85	0.23	0.35	1.72	551.12	82.39
2829	Geobody_2829	7	611	443	168	11000.00	0.85	0.23	0.35	1.72	893.20	133.53
3126	Geobody_3126	8	722	618	104	11000.00	0.85	0.23	0.35	1.72	1055.47	157.79
3181	Geobody_3181	8	179	171	8	11000.00	0.85	0.23	0.35	1.72	261.67	39.12
3255	Geobody_3255	8	68	60	8	11000.00	0.85	0.23	0.35	1.72	99.41	14.86
3266	Geobody_3266	8	1,224	804	420	11000.00	0.85	0.23	0.35	1.72	1789.32	267.50

Total Acre*Feet = 1127.7 x 2000Mcfg/Ac*Ft = 2.255 Bcfg + Liquids

Upper Sand – East Side

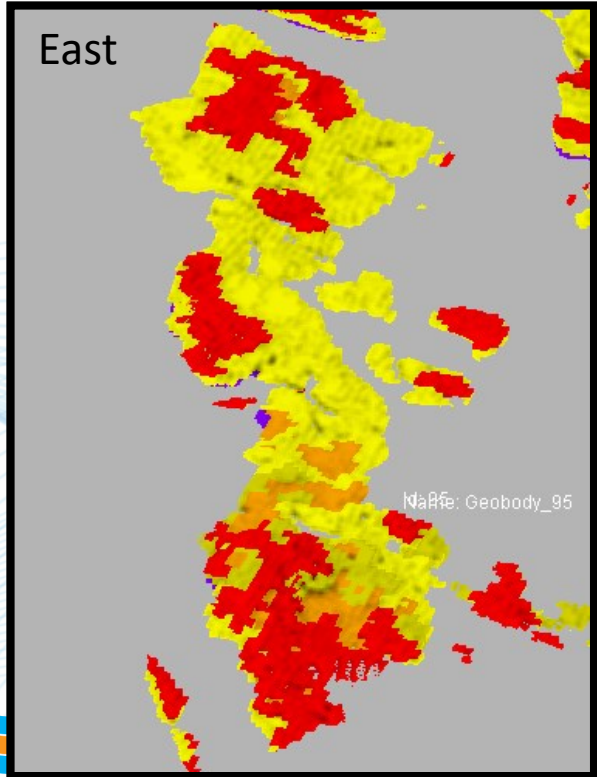
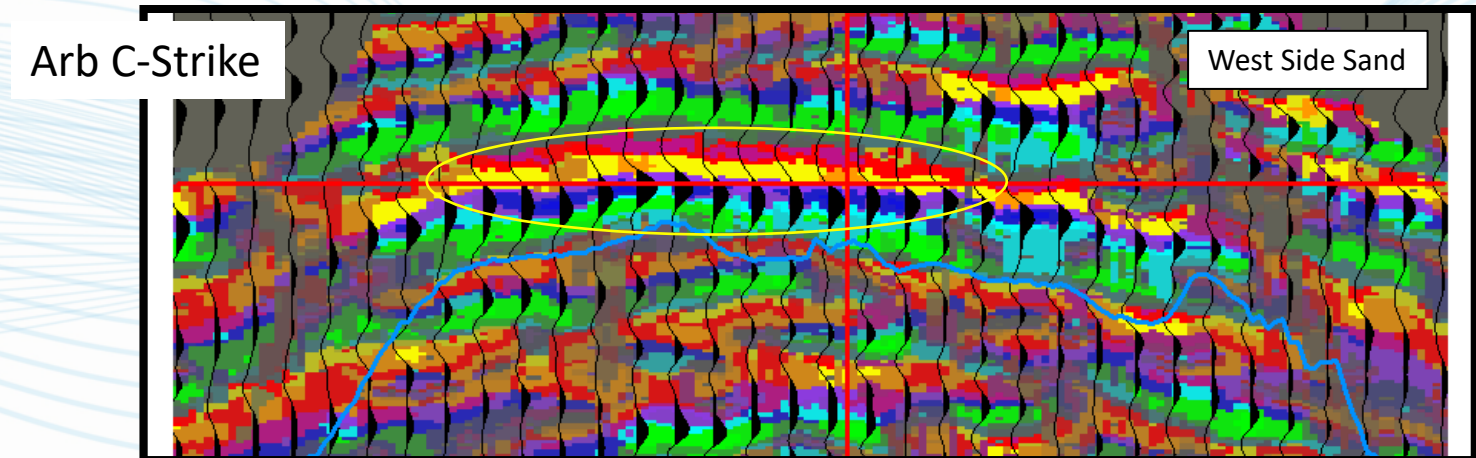
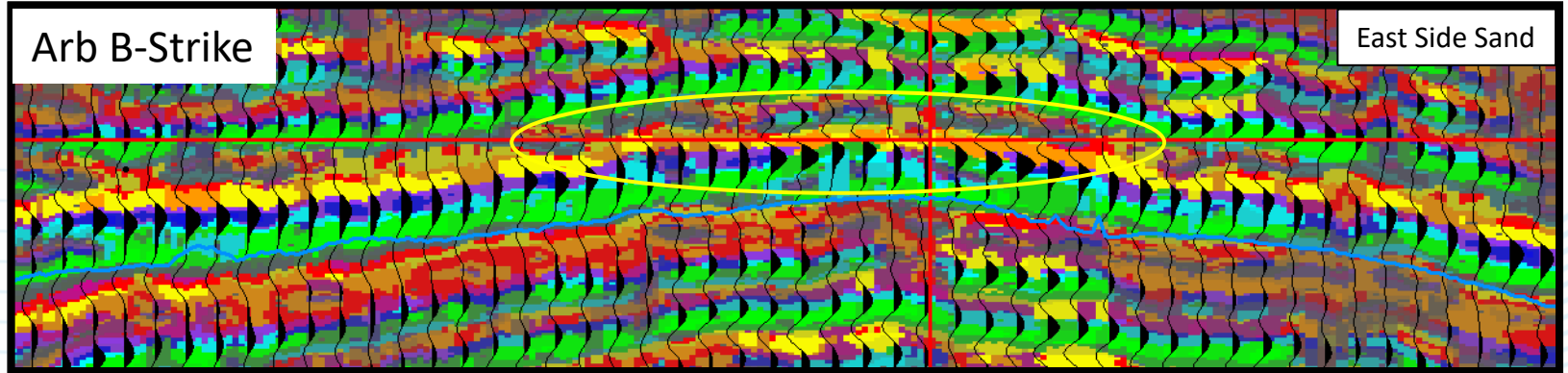
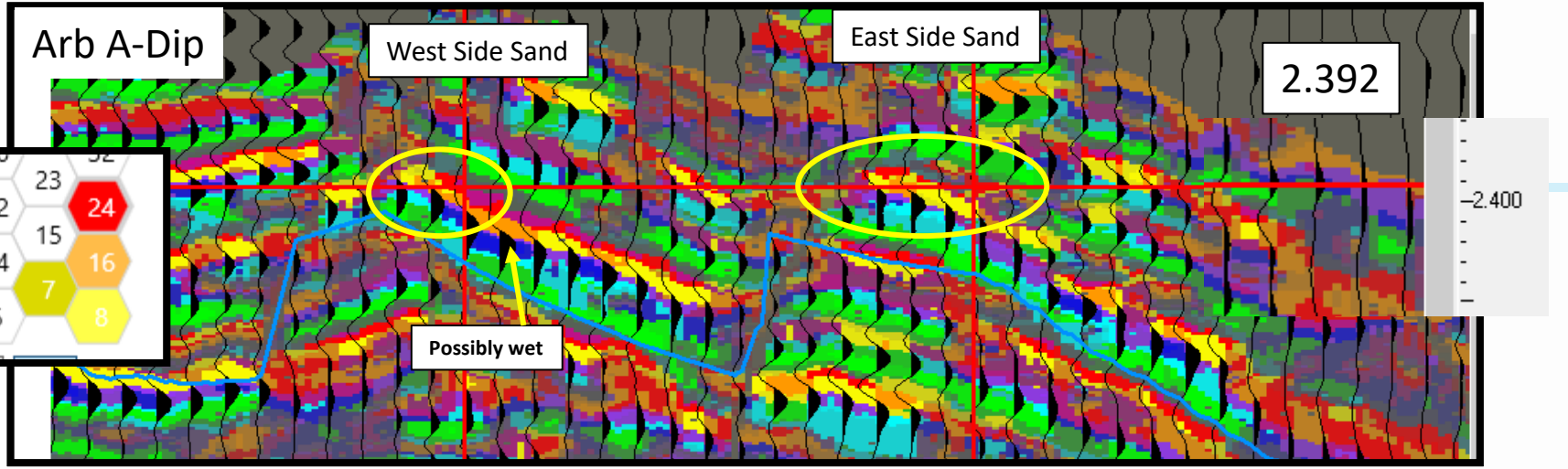
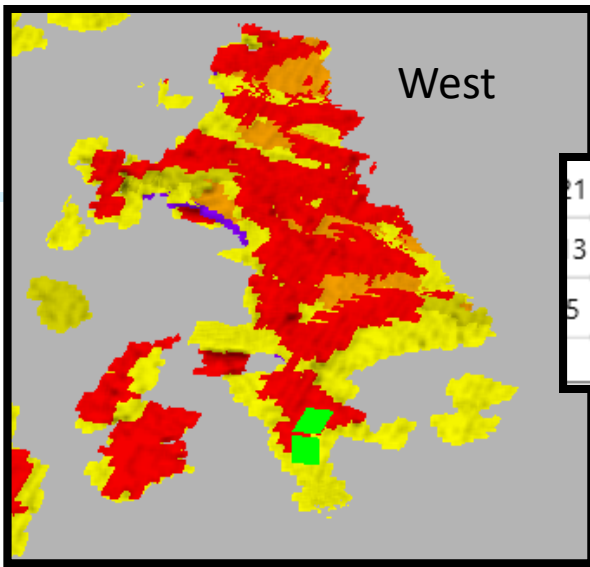
Geobody Details

Velocity Units: Feet/sec Volume Units: Acre-Feet

Id: 2,494,3313,2898,3307,3312,3365,501 Name:

Id	Name	Neuron	Sample Count	Exterior Sample Count	Interior Sample Count	Interval Velocity (Feet/sec) (>=0)	Net/Gross (0-1)	Porosity (0-1)	Water Saturation (0-1)	Sample Volume (Acre-Feet)	Net Rock Volume (Acre-Feet)	Hydrocarbon Pore Volume (Acre-Feet)
492	Geobody_492	24	80	70	10	11000.00	0.85	0.23	0.35	1.72	116.95	17.48
494	Geobody_494	24	119	108	11	11000.00	0.85	0.23	0.35	1.72	173.96	26.01
501	Geobody_501	24	116	113	3	11000.00	0.85	0.23	0.35	1.72	169.58	25.35
2898	Geobody_2898	7	110	104	6	11000.00	0.85	0.23	0.35	1.72	160.81	24.04
3307	Geobody_3307	8	72	62	10	11000.00	0.85	0.23	0.35	1.72	105.25	15.74
3312	Geobody_3312	8	1,116	860	256	11000.00	0.85	0.23	0.35	1.72	1631.44	243.90
3313	Geobody_3313	8	796	537	259	11000.00	0.85	0.23	0.35	1.72	1163.64	173.96
3365	Geobody_3365	8	62	53	9	11000.00	0.85	0.23	0.35	1.72	90.64	13.55

Total Acre*Feet = 540.03 x 2000Mcfg/Ac*Ft = 1.08 Bcfg + Liquids



Geobody Details

West Side Sand

Velocity Units: Feet/sec

Volume Units: Acre-Feet

Id: 58,104,710,746,762,2659,317,34,3050

Name:

Id	Name	Neuron	Sample Count	Exterior Sample Count	Interior Sample Count	Interval Velocity (Feet/sec) (>=0)	Net/Gross (0-1)	Porosity (0-1)	WaterSaturation (0-1)	Sample Volume (Acre-Feet)	Net Rock Volume (Acre-Feet)	Hydrocarbon Pore Volume (Acre-Feet)
28	Geobody_28	16	2,113	1,327	786	11000.00	0.85	0.23	0.35	1.72	3088.92	461.79
34	Geobody_34	16	262	197	65	11000.00	0.85	0.23	0.35	1.72	383.01	57.26
68	Geobody_68	16	1,388	785	603	11000.00	0.85	0.23	0.35	1.72	2029.07	303.35
104	Geobody_104	16	500	301	199	11000.00	0.85	0.23	0.35	1.72	730.93	109.27
300	Geobody_300	24	140	139	1	11000.00	0.85	0.23	0.35	1.72	204.66	30.60
317	Geobody_317	24	165	165	0	11000.00	0.85	0.23	0.35	1.72	241.21	36.06
318	Geobody_318	24	211	210	1	11000.00	0.85	0.23	0.35	1.72	308.45	46.11
346	Geobody_346	24	3,578	3,285	293	11000.00	0.85	0.23	0.35	1.72	5230.55	781.97
353	Geobody_353	24	76	74	2	11000.00	0.85	0.23	0.35	1.72	111.10	16.61
710	Geobody_710	40	1,680	1,573	107	11000.00	0.85	0.23	0.35	1.72	2455.93	367.16
746	Geobody_746	40	168	168	0	11000.00	0.85	0.23	0.35	1.72	245.59	36.72
762	Geobody_762	40	149	147	2	11000.00	0.85	0.23	0.35	1.72	217.82	32.56
2659	Geobody_2659	7	56	56	0	11000.00	0.85	0.23	0.35	1.72	81.86	12.24
3020	Geobody_3020	8	9,166	6,307	2,859	11000.00	0.85	0.23	0.35	1.72	13399.46	2003.22
3050	Geobody_3050	8	656	532	124	11000.00	0.85	0.23	0.35	1.72	958.98	143.37

Total Acre*Feet = 4369.67 x 2000Mcfg/Ac*Ft = ~8.74 Bcfg + Liquids

Geobody Details

Velocity Units: Feet/sec

East Side Sand

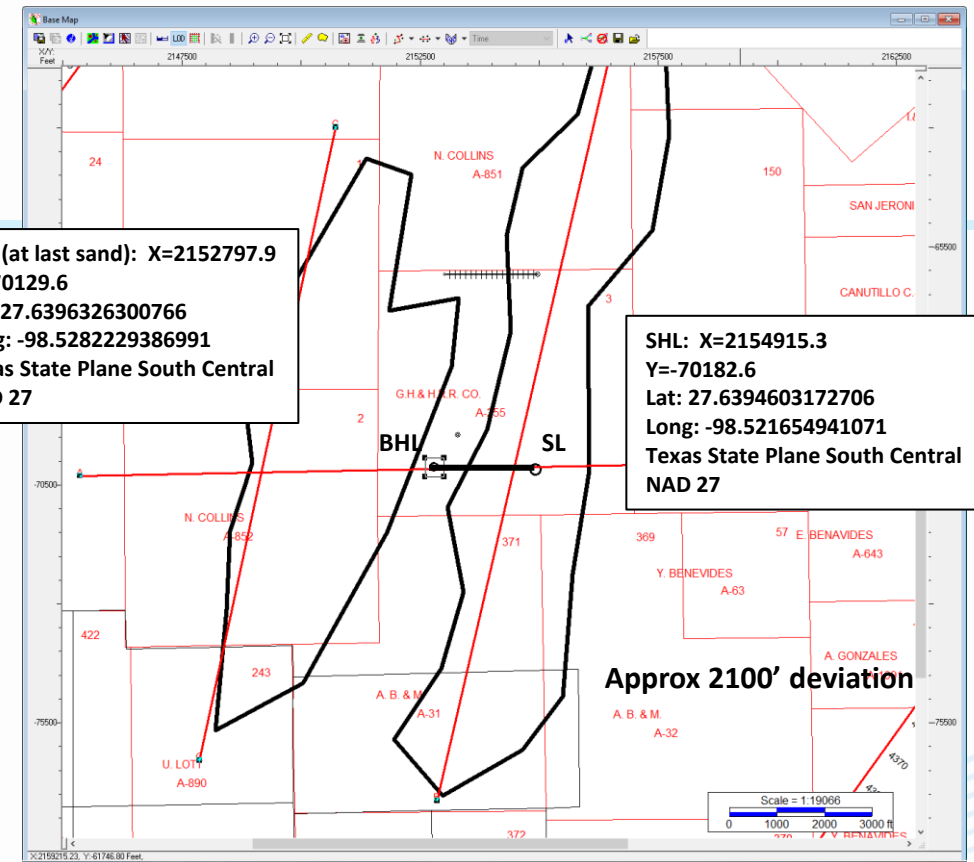
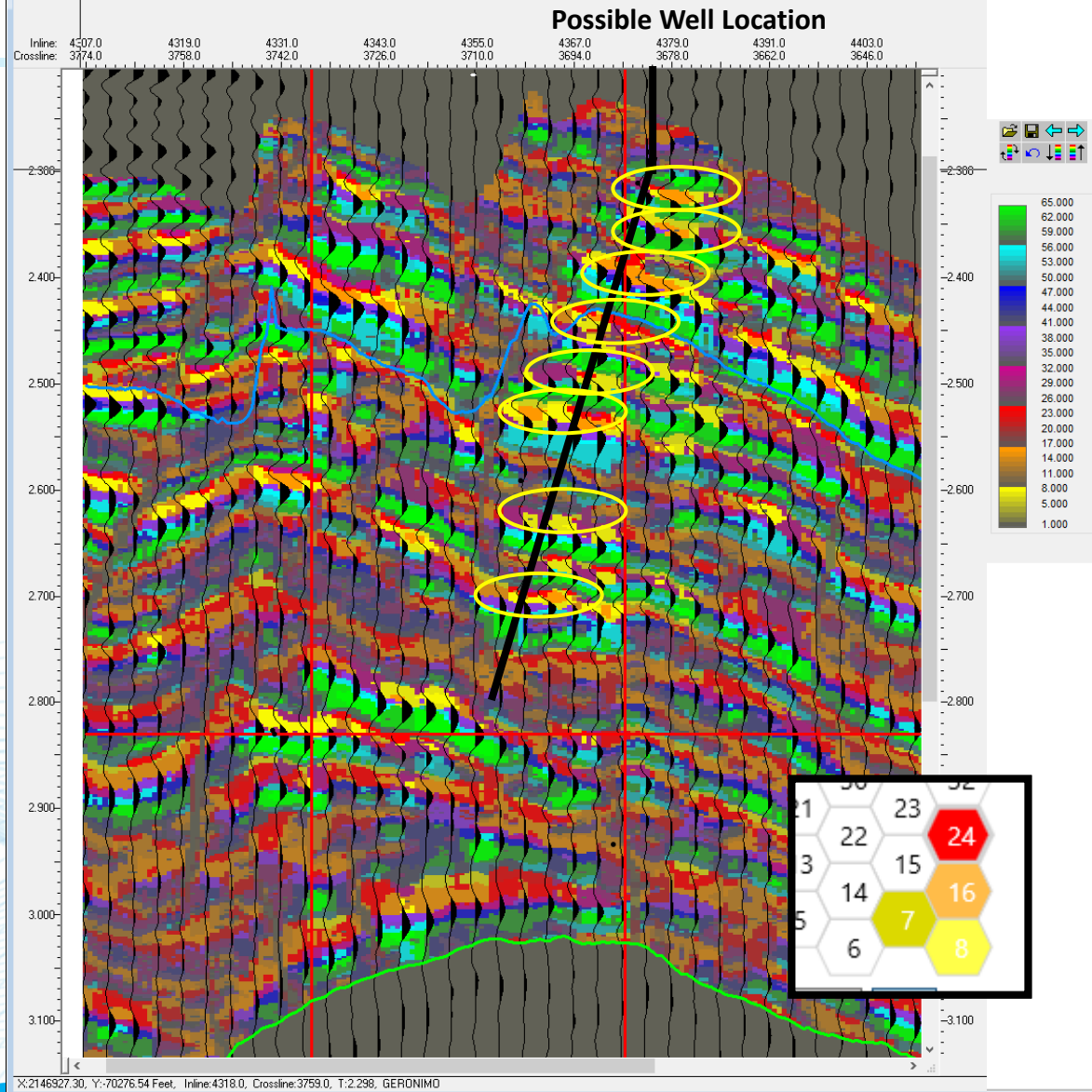
Volume Units: Acre-Feet

Id: 35,141,2833,787,786,714,723,808,802

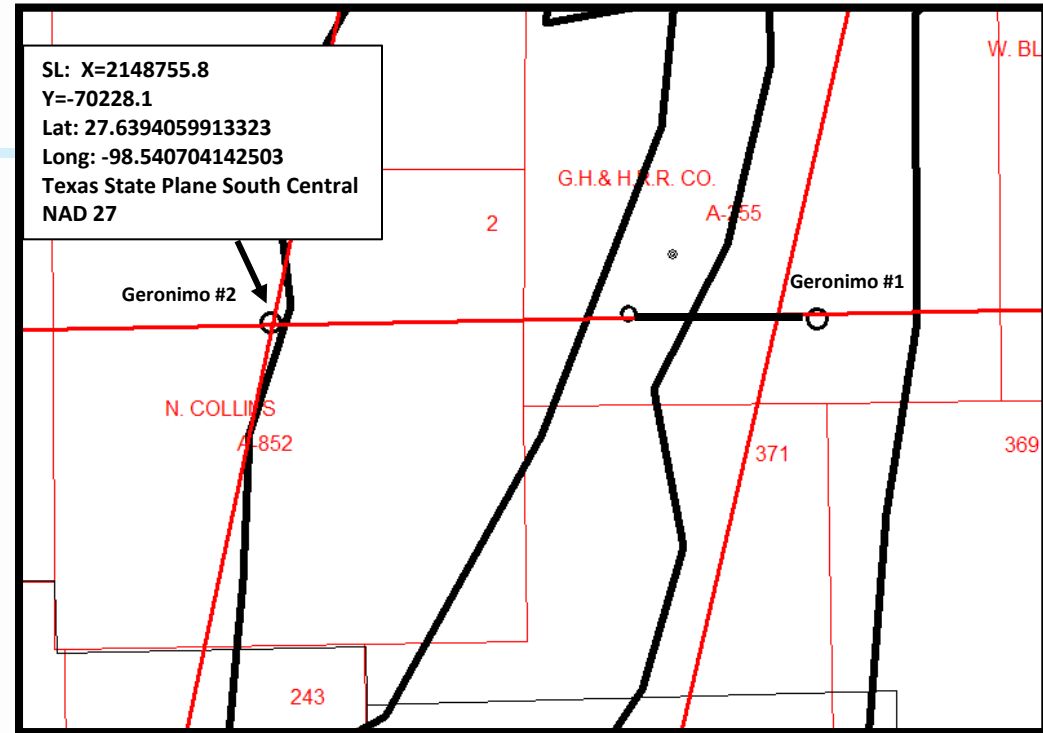
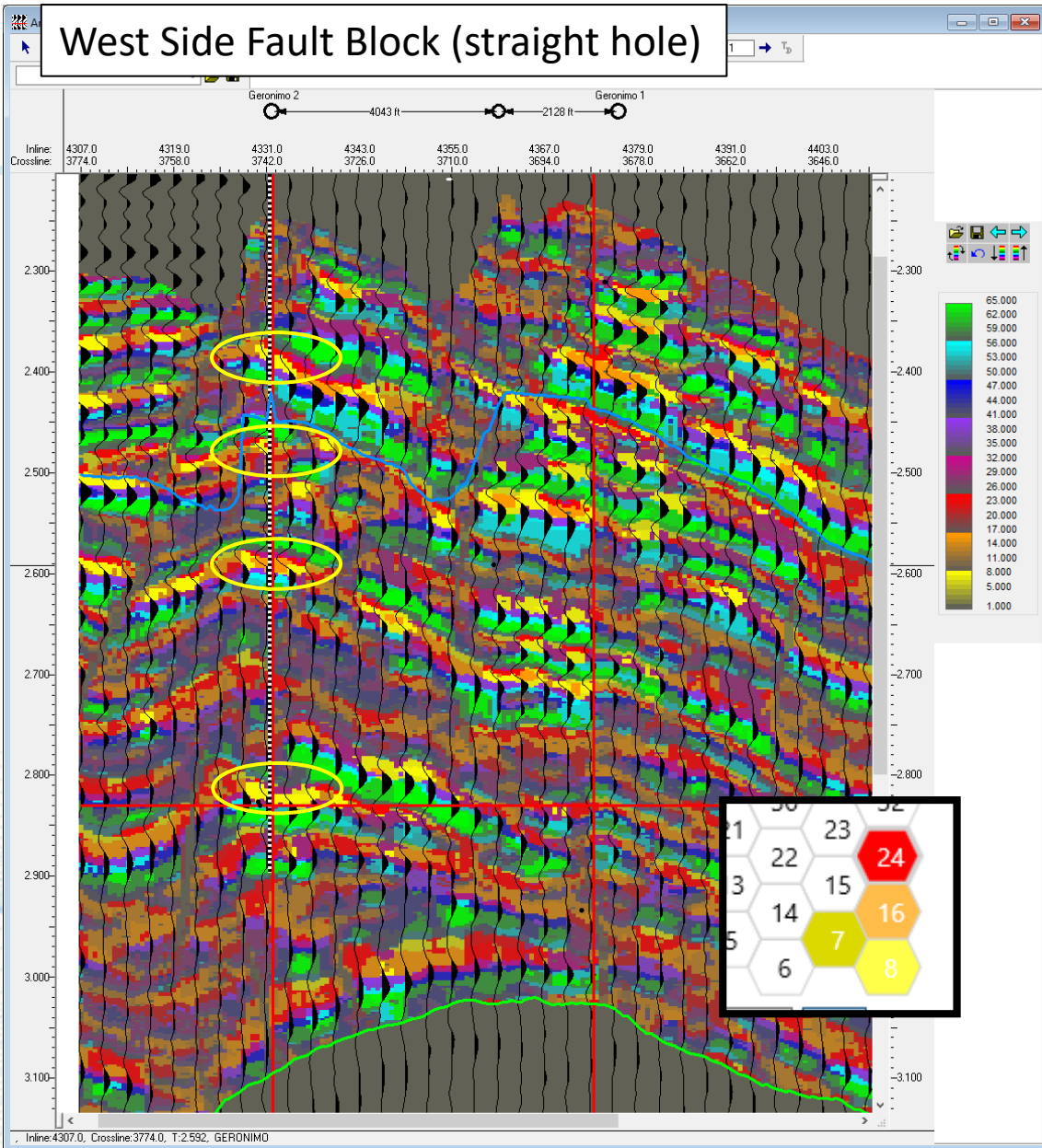
Name:

Id	Name	Neuron	Sample Count	Exterior Sample Count	Interior Sample Count	Interval Velocity (Feet/sec) (>=0)	Net/Gross (0-1)	Porosity (0-1)	WaterSaturation (0-1)	Sample Volume (Acre-Feet)	Net Rock Volume (Acre-Feet)	Hydrocarbon Pore Volume (Acre-Feet)
53	Geobody_53	16	3,608	2,150	1,458	11000.00	0.85	0.23	0.35	1.72	5274.41	788.52
141	Geobody_141	16	548	383	165	11000.00	0.85	0.23	0.35	1.72	801.10	119.76
321	Geobody_321	24	165	162	3	11000.00	0.85	0.23	0.35	1.72	241.21	36.06
326	Geobody_326	24	173	167	6	11000.00	0.85	0.23	0.35	1.72	252.90	37.81
340	Geobody_340	24	161	160	1	11000.00	0.85	0.23	0.35	1.72	235.36	35.19
344	Geobody_344	24	2,092	1,931	161	11000.00	0.85	0.23	0.35	1.72	3058.22	457.20
350	Geobody_350	24	507	461	46	11000.00	0.85	0.23	0.35	1.72	741.17	110.80
395	Geobody_395	24	2,529	2,214	315	11000.00	0.85	0.23	0.35	1.72	3697.06	552.71
495	Geobody_495	24	224	223	1	11000.00	0.85	0.23	0.35	1.72	327.46	48.95
714	Geobody_714	40	1,169	1,153	16	11000.00	0.85	0.23	0.35	1.72	1708.92	255.48
723	Geobody_723	40	2,020	1,940	80	11000.00	0.85	0.23	0.35	1.72	2952.97	441.47
786	Geobody_786	40	155	145	10	11000.00	0.85	0.23	0.35	1.72	226.59	33.88
787	Geobody_787	40	57	57	0	11000.00	0.85	0.23	0.35	1.72	83.33	12.46
802	Geobody_802	40	413	408	5	11000.00	0.85	0.23	0.35	1.72	603.75	90.26
808	Geobody_808	40	199	194	5	11000.00	0.85	0.23	0.35	1.72	290.91	43.49
2753	Geobody_2753	7	117	115	2	11000.00	0.85	0.23	0.35	1.72	171.04	25.57
2765	Geobody_2765	7	95	92	3	11000.00	0.85	0.23	0.35	1.72	138.88	20.76
2833	Geobody_2833	7	230	217	13	11000.00	0.85	0.23	0.35	1.72	336.23	50.27
2839	Geobody_2839	7	383	345	38	11000.00	0.85	0.23	0.35	1.72	559.89	83.70
3028	Geobody_3028	8	17,320	11,163	6,157	11000.00	0.85	0.23	0.35	1.72	25319.50	3785.27
3176	Geobody_3176	8	863	728	135	11000.00	0.85	0.23	0.35	1.72	1261.59	188.61
Total Acre*Feet = 7198.22 x 2000Mcfg/Ac*Ft = ~14.4 Bcfg + Liquids												

East Side Fault Block-deviated well

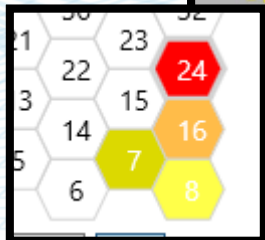
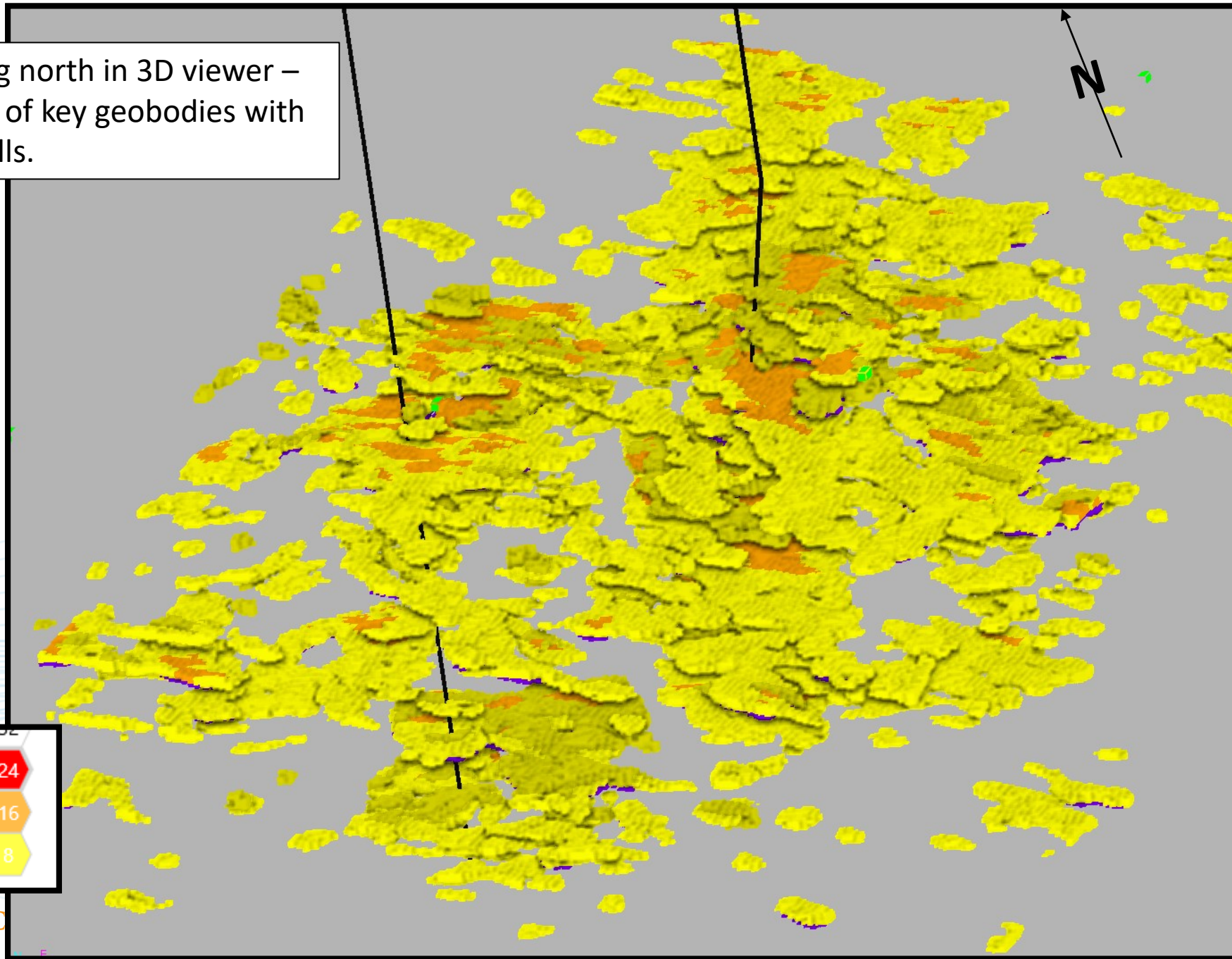


Upside potential for well for all sands intercepted
 could be as much as **39.66 Bcfg + Liquids**



Upside potential for well for all sands intercepted could be as much as **19.87Bcfg + Liquids**

View looking north in 3D viewer –
penetration of key geobodies with
first two wells.



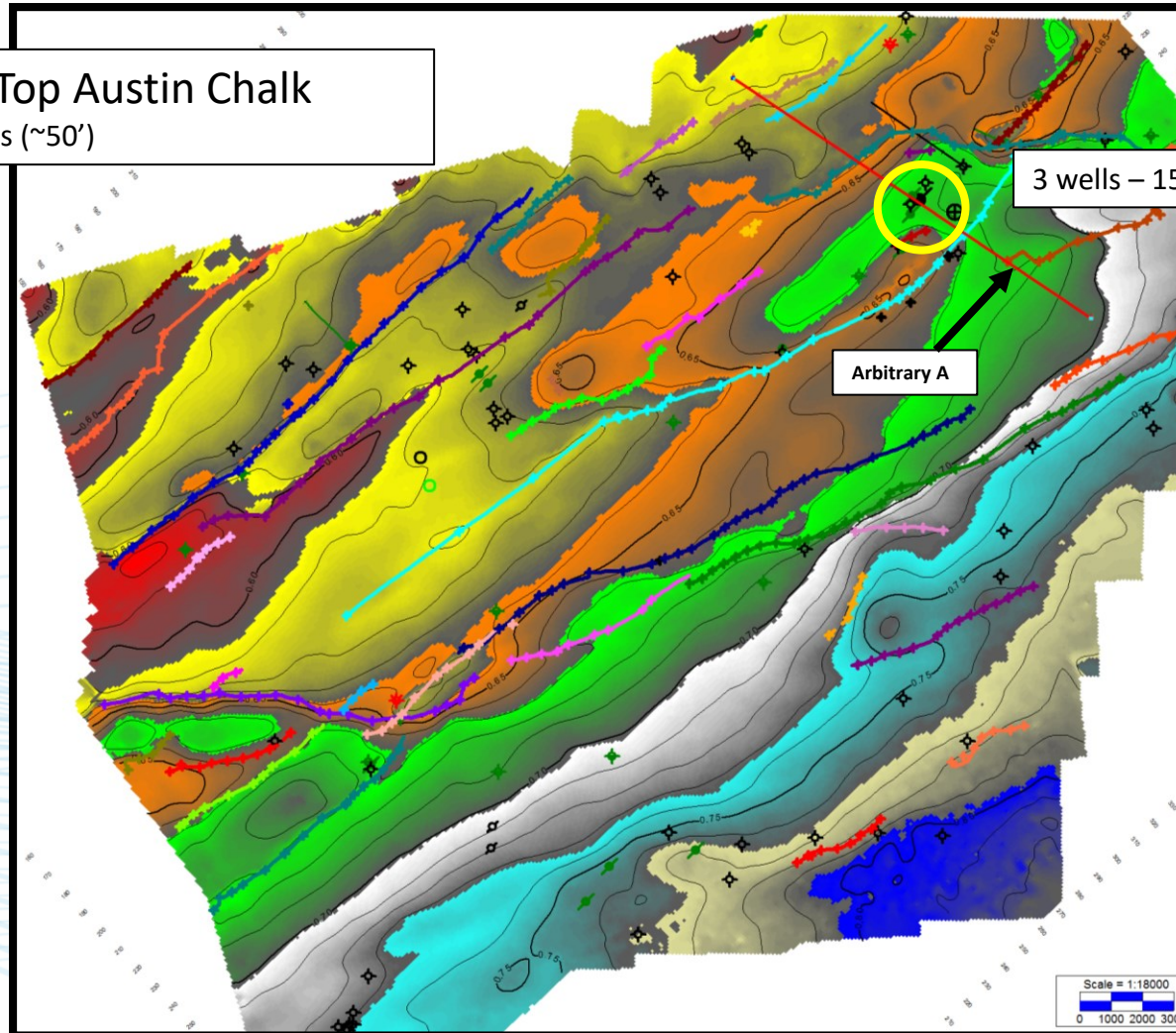
Visualizing Depletion using Low Probability Volumes

The importance of understanding “Stack” and “Halo Neurons” in ANY reservoir – but especially in Carbonates. Also – a good example of how “pre-conceived” ideas about the reservoir are not always correct! And – throw in the importance of the “Low Probability” volume assessment too!

Case History #1 – Austin Chalk - Texas

Time Structure Map – Top Austin Chalk

CI = 10 ms (~50')

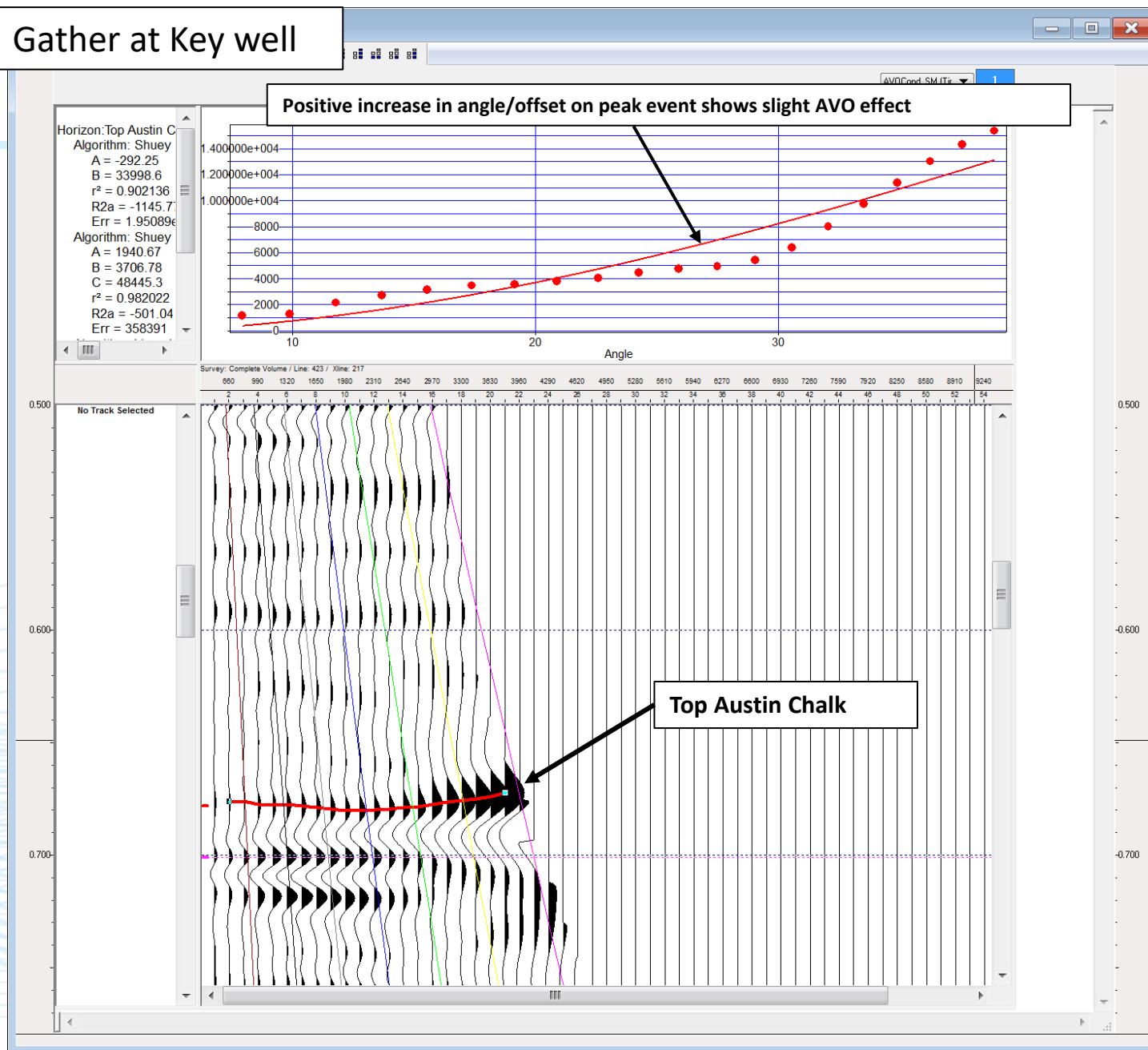


3 wells – 158 MBO at 2100 feet!

Arbitrary A

Scale = 1:18000
0 1000 2000 3000

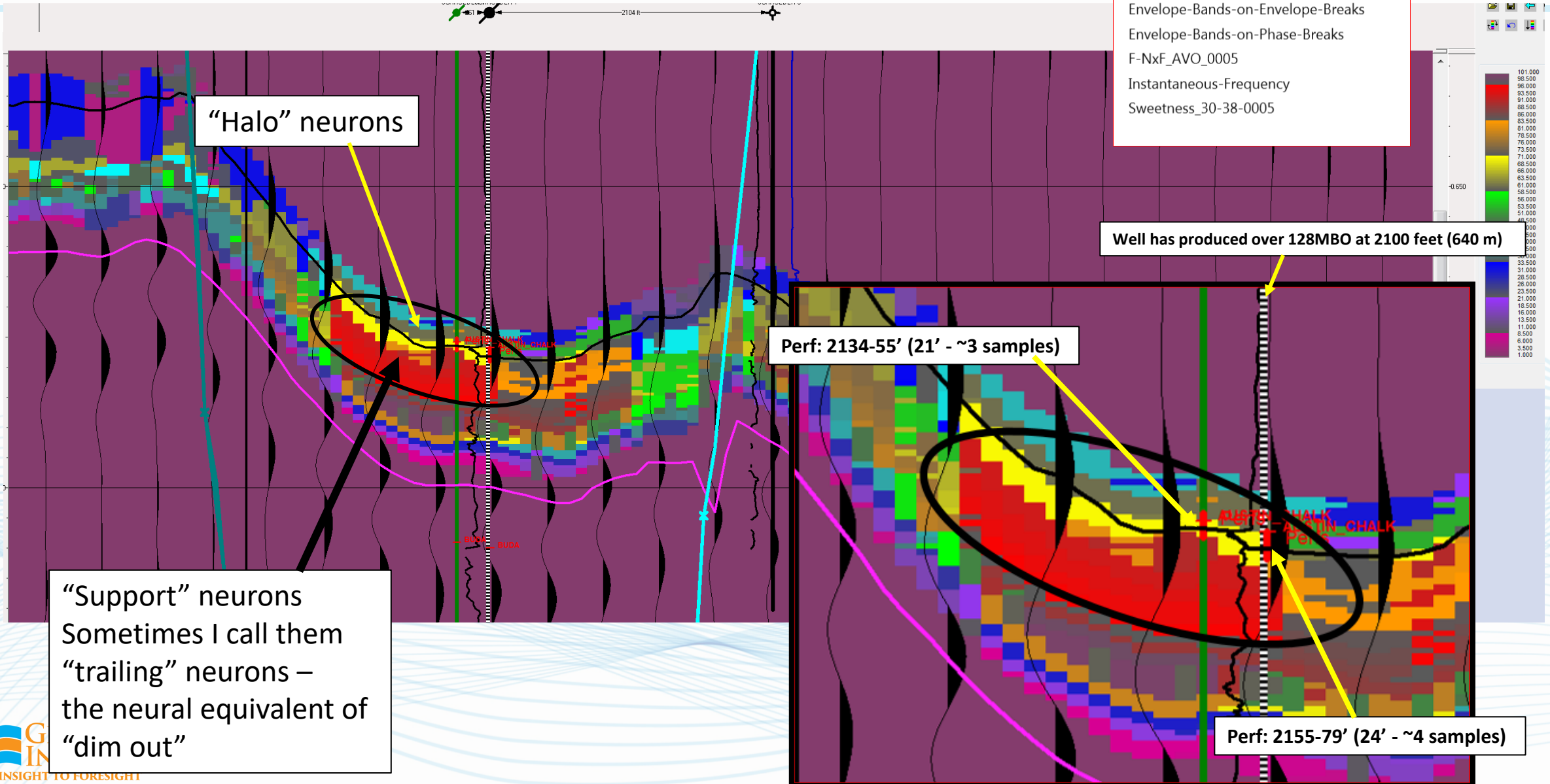
Gather at Key well

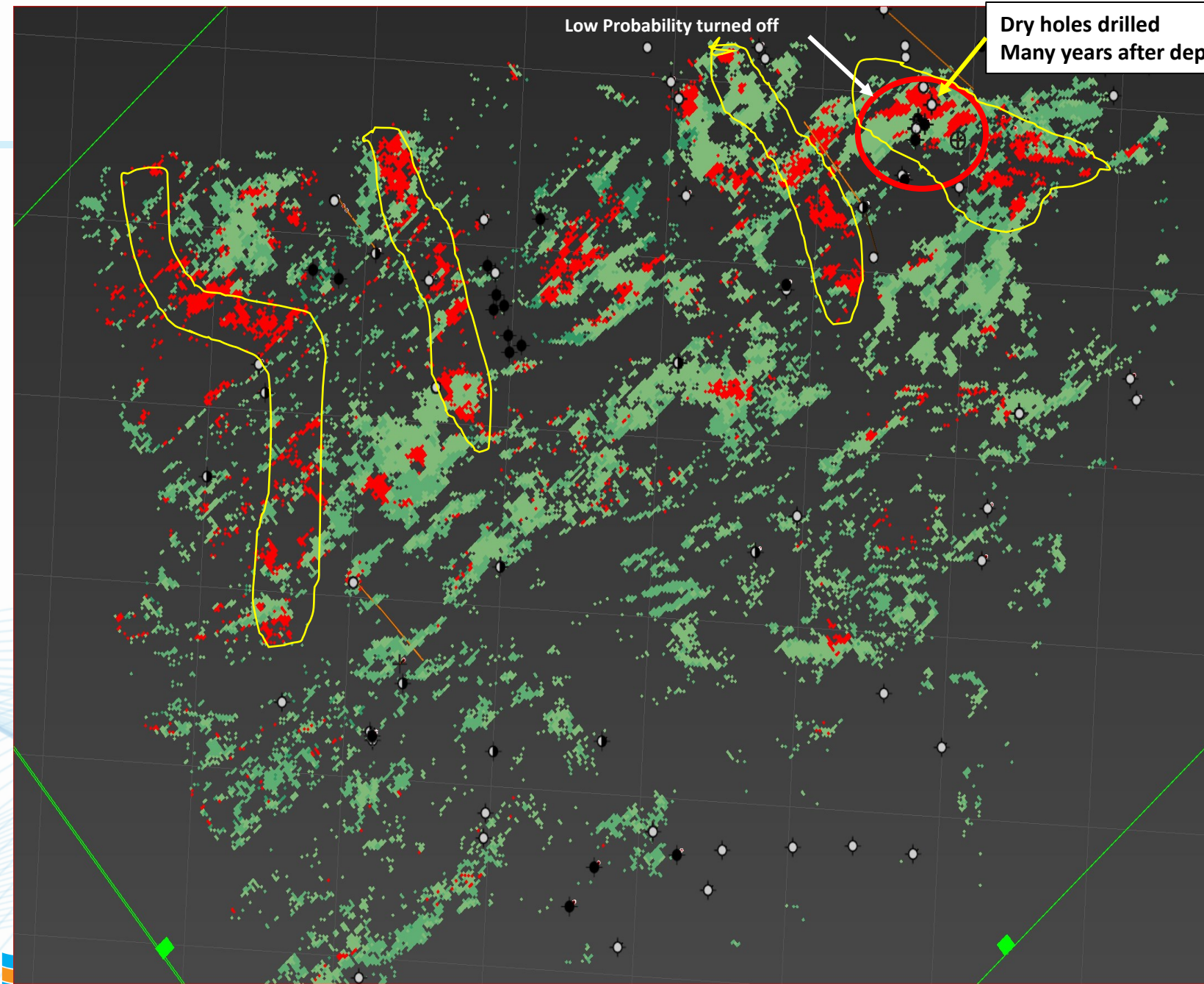


Neurons 71 (main), 53, 62, 72, and 82 (supporting) better define porosity

Attributes

- Complete Volume_AVOSk_30-38_0005(2)
- Complete Volume_Relative Acoustic Imped
- Envelope-Bands-on-Envelope-Breaks
- Envelope-Bands-on-Phase-Breaks
- F-NxF_AVO_0005
- Instantaneous-Frequency
- Sweetness_30-38-0005





Low Probability turned off

Dry holes drilled
Many years after depletion

Default10x10

Options: **HEXAGON** **CLOSE EDITOR** + -

Color Map Opacity Mask(s)

Dimensions: (10 x 10)

91	92	93	94	95	96	97	98	99	100
81	82	83	84	85	86	87	88	89	90
71	72	73	74	75	76	77	78	79	80
61	62	63	64	65	66	67	68	69	70
51	52	53	54	55	56	57	58	59	60
41	42	43	44	45	46	47	48	49	50
31	32	33	34	35	36	37	38	39	40
21	22	23	24	25	26	27	28	29	30
11	12	13	14	15	16	17	18	19	20
1	2	3	4	5	6	7	8	9	10

Opacity Mask - **Full** Empty Invert

Add **Move** **Delete** **CLEAR**

Current Color: **SWAP**

Resize: x **RESIZE**

(Minimum size = 1, Maximum size = 32)

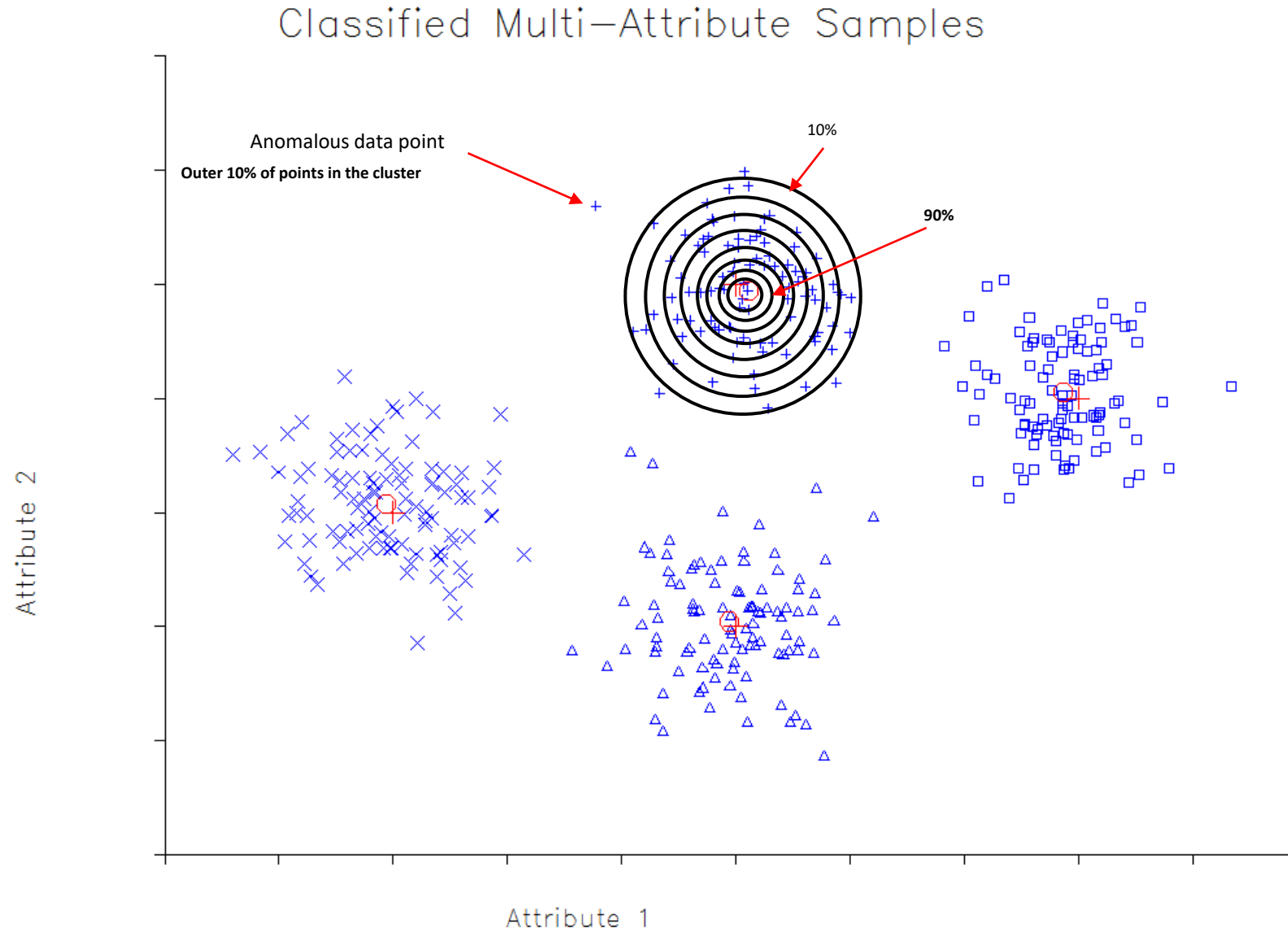
Attributes

- .AVOSTk_30-38_0005(2)
- .Relative Acoustic Imped
- Envelope-Bands-on-Envelope-Breaks
- Envelope-Bands-on-Phase-Breaks
- F-NxF_AVO_0005
- Instantaneous-Frequency
- Sweetness_30-38-0005

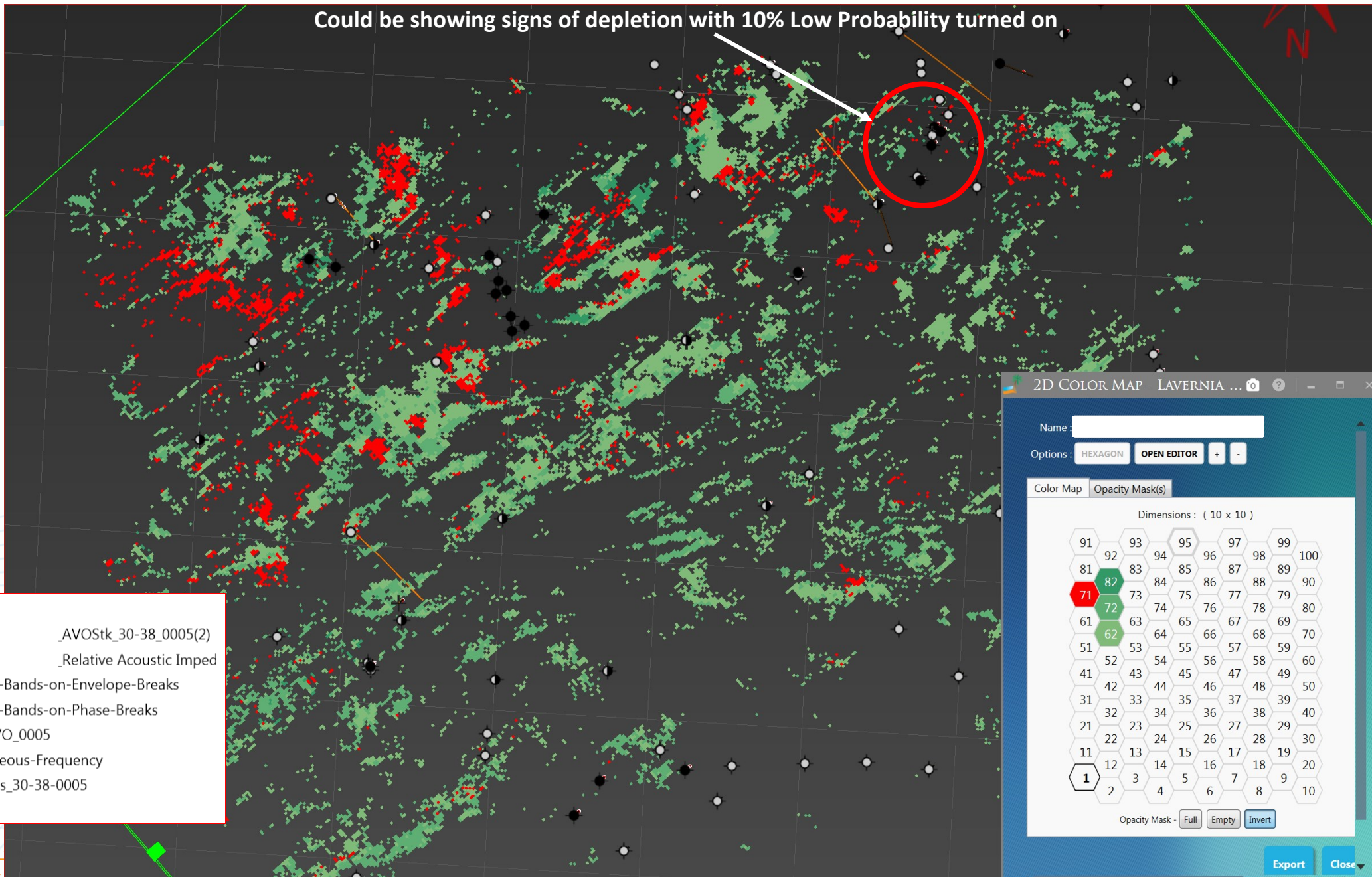
Export **Close**

2-17-10x10_Hex-9/22/2017 1:00:20

Low Probability Volume – outside “edge” of data points are furthest away from center of cluster – and are considered “most anomalous”. So, if attributes are used which are “hydrocarbon indicators” then the “low probability” anomalies could possibly be hydrocarbon indicators. At the very least, they would tend to show the best of the properties of the attributes used in the analysis

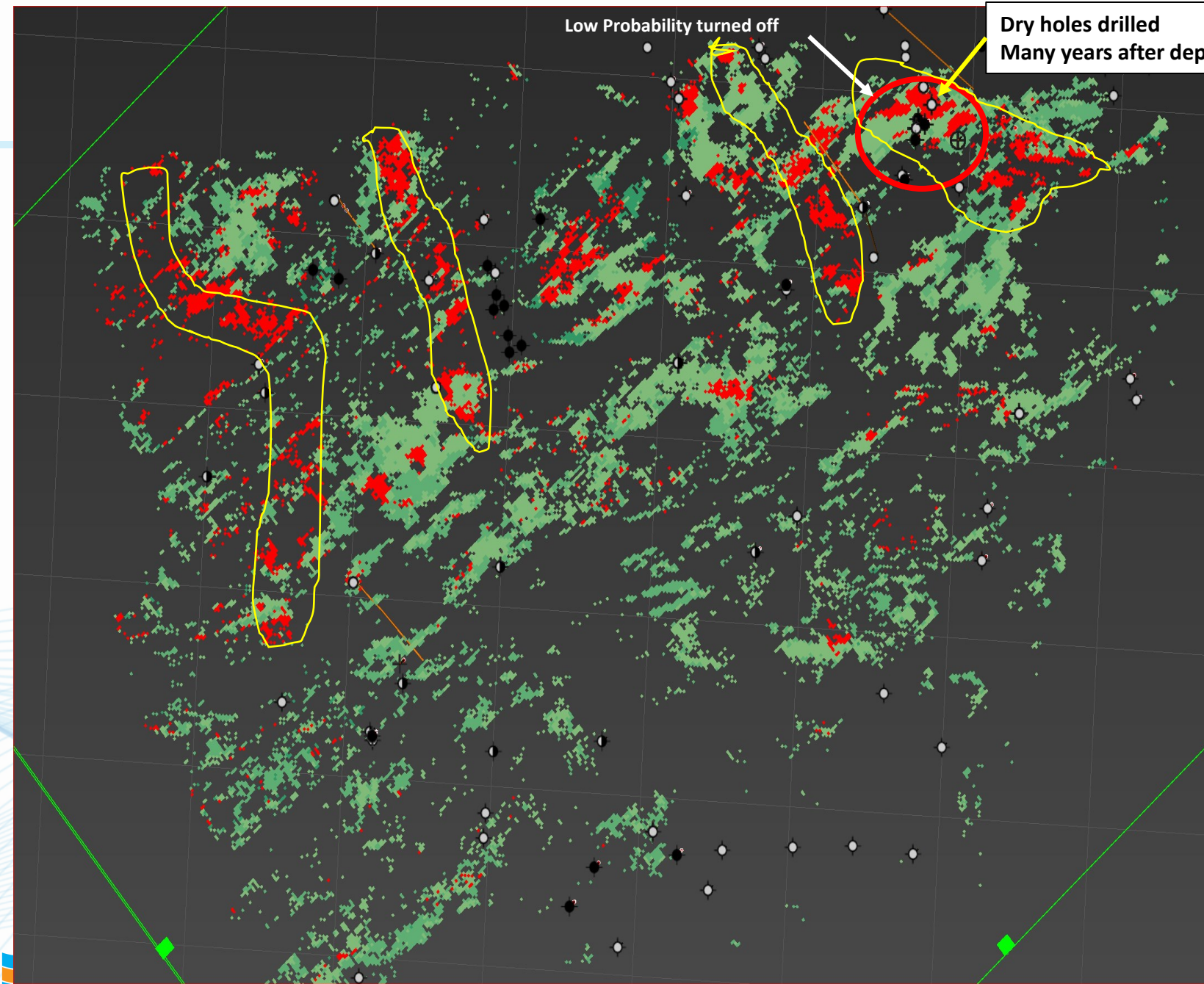


Could be showing signs of depletion with 10% Low Probability turned on



Attributes

_AVOSTk_30-38_0005(2)
_Relative Acoustic Imped
Envelope-Bands-on-Envelope-Breaks
Envelope-Bands-on-Phase-Breaks
F-NxF_AVO_0005
Instantaneous-Frequency
Sweetness_30-38-0005



Low Probability turned off

Dry holes drilled
Many years after depletion

Default10x10

Options: + -

Color Map Opacity Mask(s)

Dimensions: (10 x 10)

91	92	93	94	95	96	97	98	99	100
81	82	83	84	85	86	87	88	89	90
71	72	73	74	75	76	77	78	79	80
61	62	63	64	65	66	67	68	69	70
51	52	53	54	55	56	57	58	59	60
41	42	43	44	45	46	47	48	49	50
31	32	33	34	35	36	37	38	39	40
21	22	23	24	25	26	27	28	29	30
11	12	13	14	15	16	17	18	19	20
1	2	3	4	5	6	7	8	9	10

Opacity Mask -

Current Color:

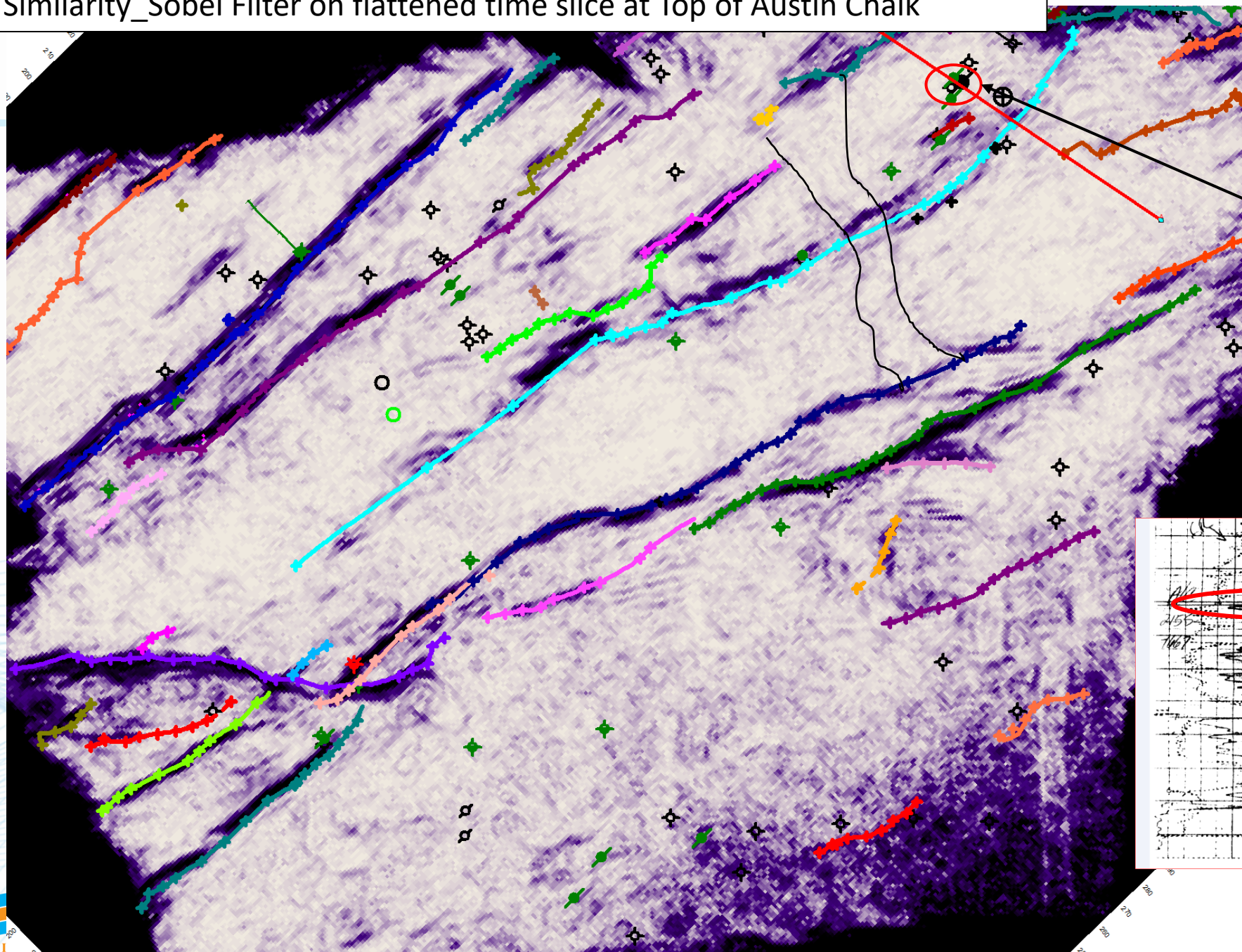
Resize: x
(Minimum size = 1, Maximum size = 32)

Attributes

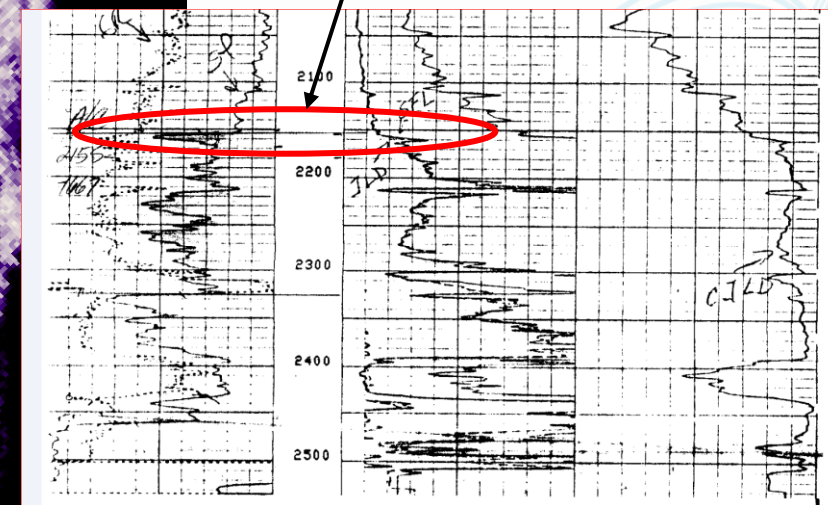
- .AVOSTk_30-38_0005(2)
- .Relative Acoustic Imped
- Envelope-Bands-on-Envelope-Breaks
- Envelope-Bands-on-Phase-Breaks
- F-NxF_AVO_0005
- Instantaneous-Frequency
- Sweetness_30-38-0005

2-17-10x10_Hex-9/22/2017 1:00:20

Similarity_Sobel Filter on flattened time slice at Top of Austin Chalk

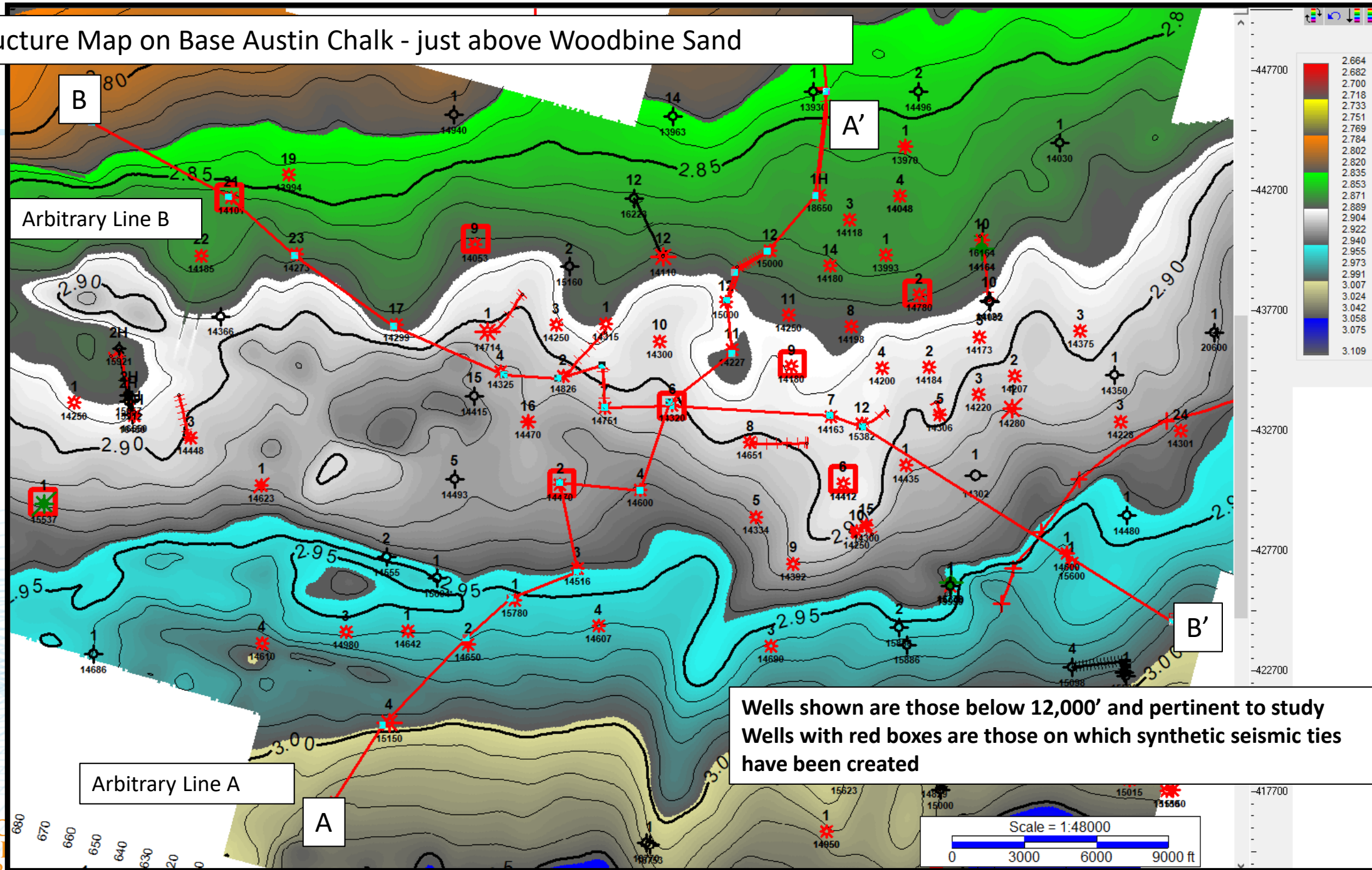


Key thin, calcareously cemented sand which was productive at the top of The Chalk

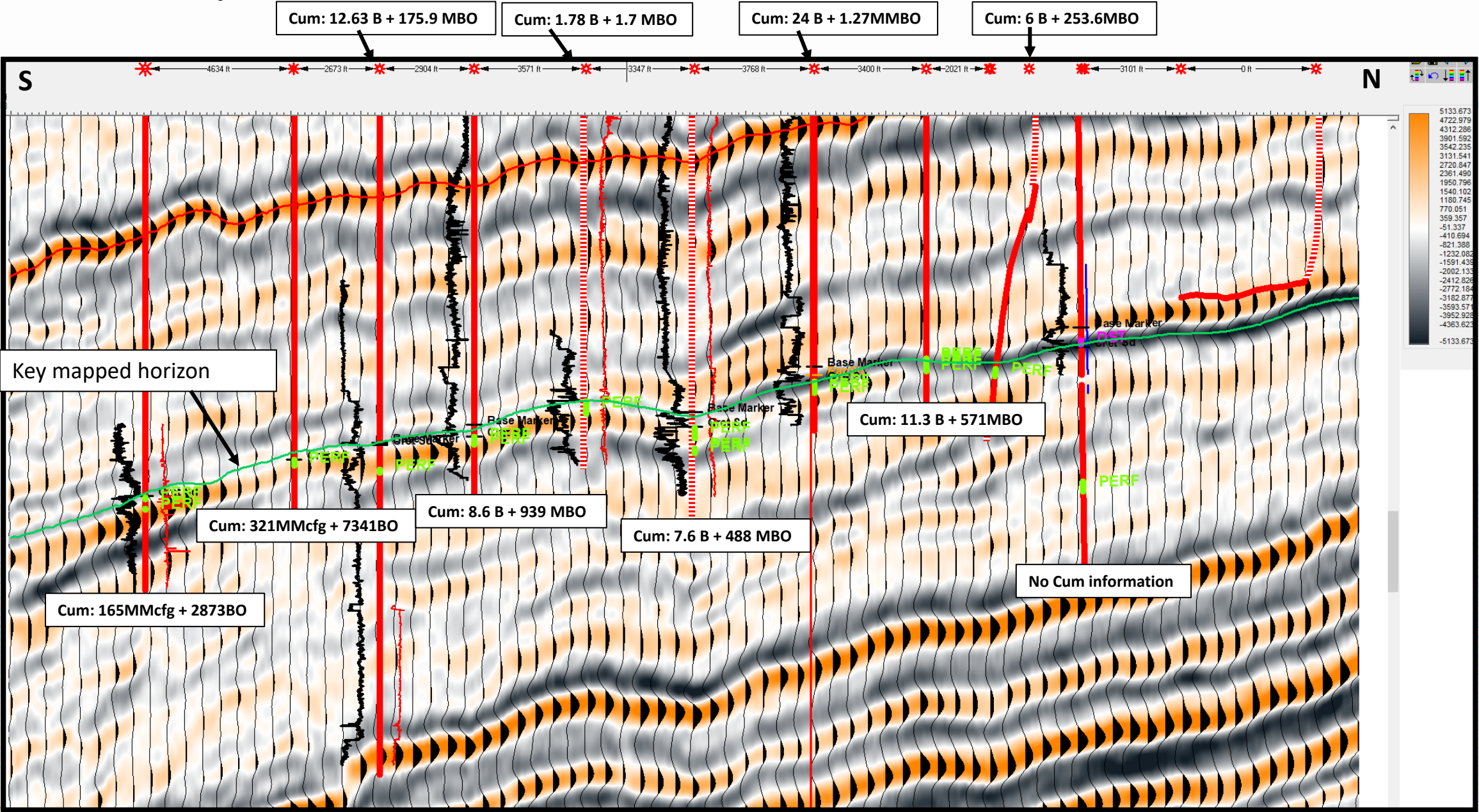


Double A Wells – Woodbine Paradise evaluation

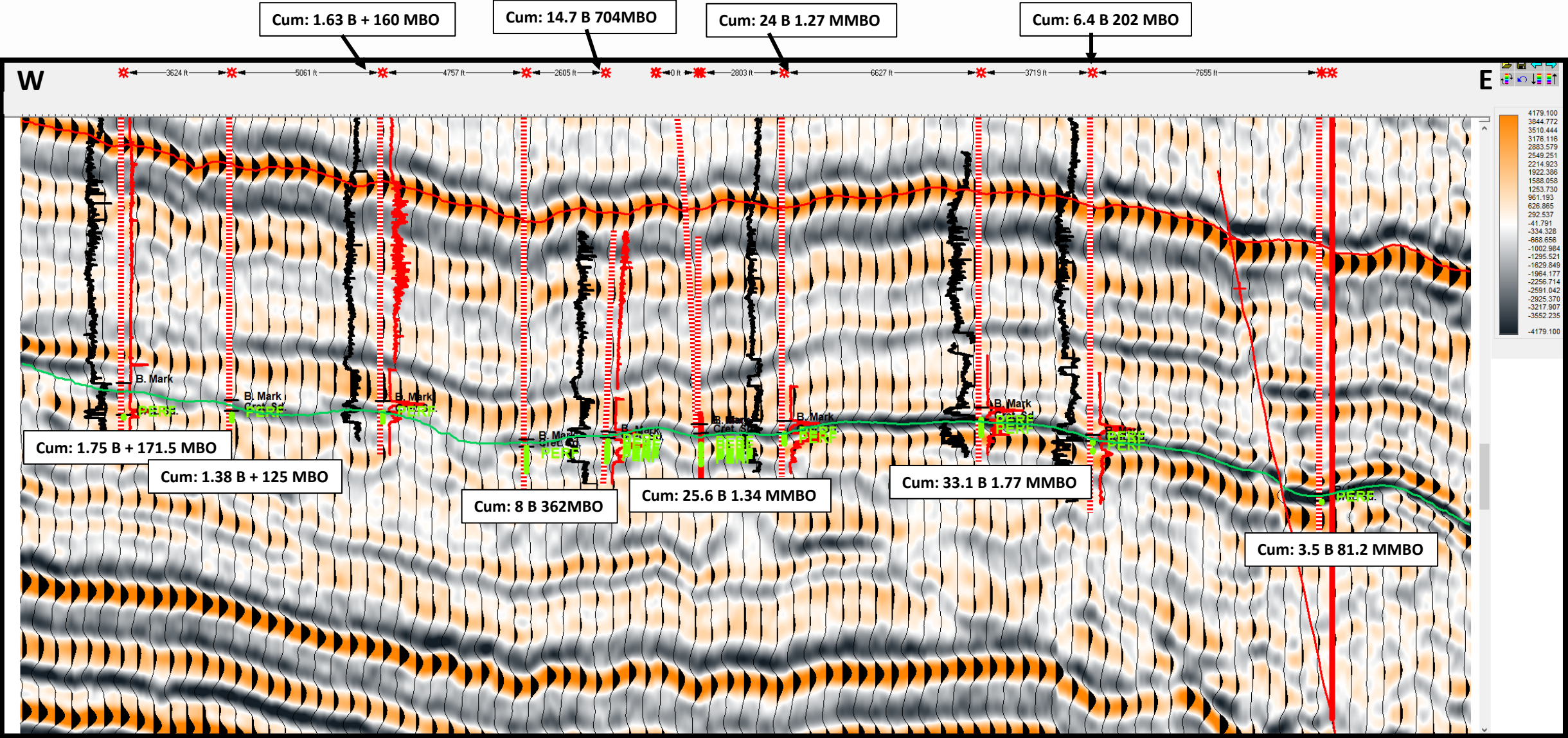
Structure Map on Base Austin Chalk - just above Woodbine Sand



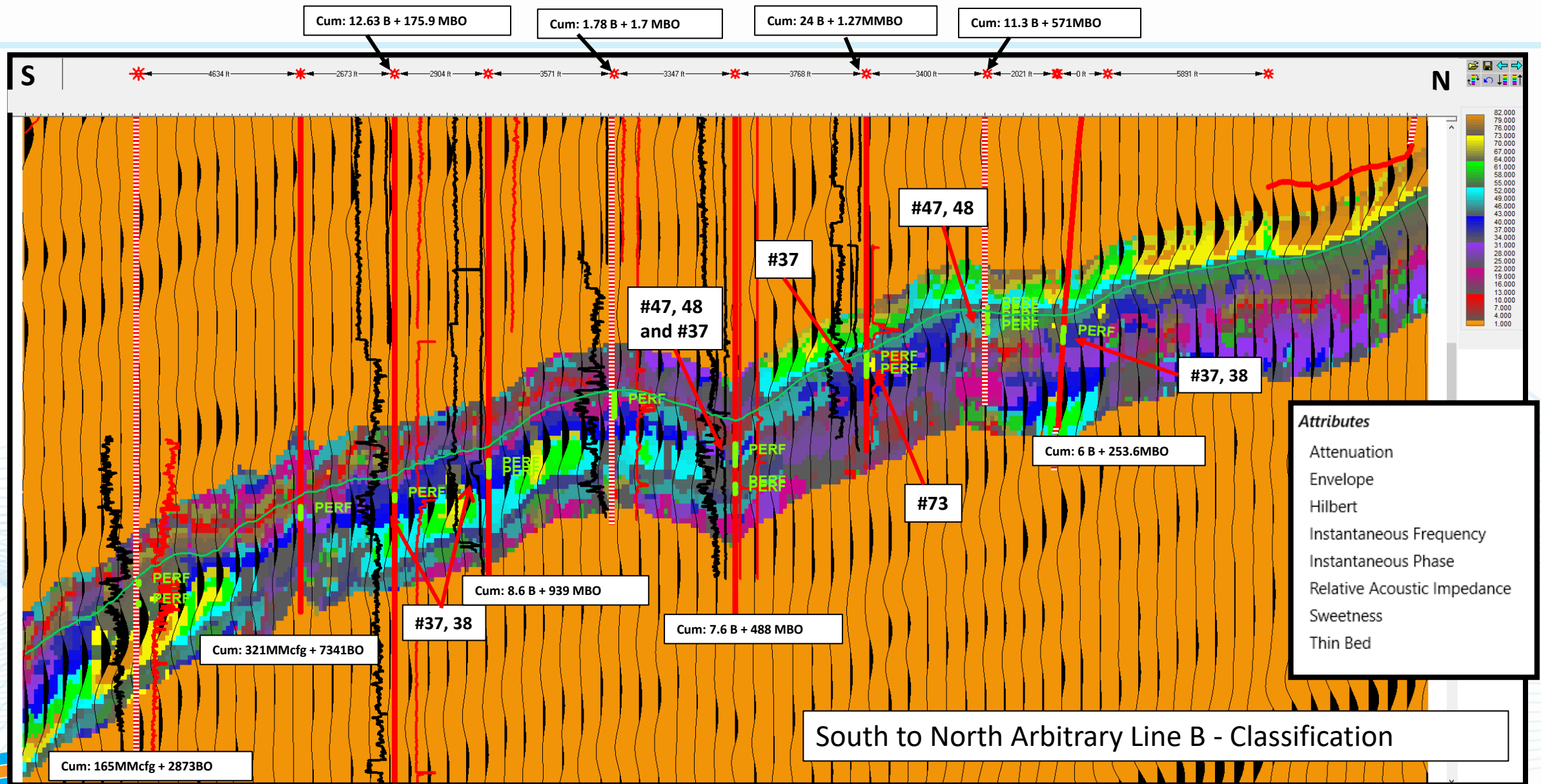
South to North Arbitrary Line B - PSTM



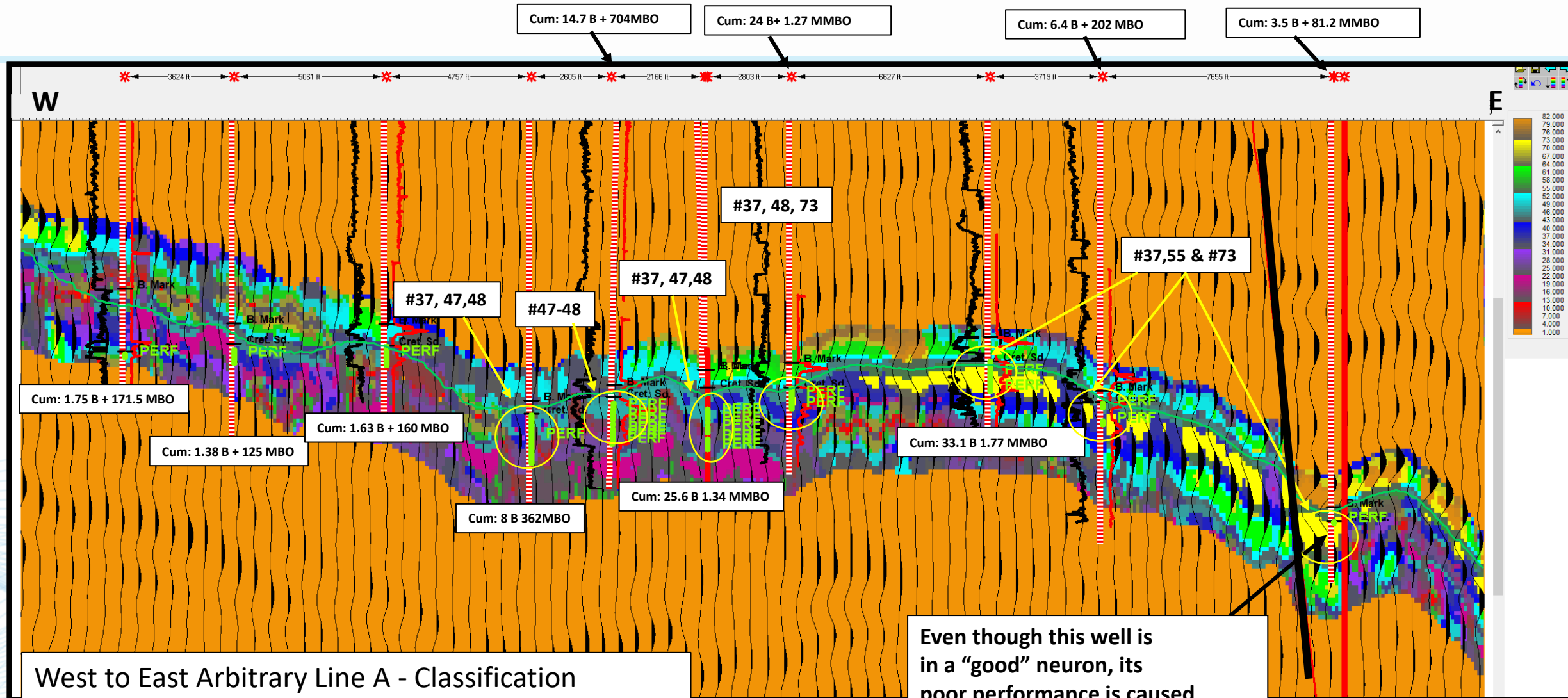
West to East Arbitrary Line A - PSTM



After several “recipes” of attributes and looking at different topologies (numbers of neural classes), it was determined that a 9x9 matrix tied the wells the best. The best production appears to come from perforations which fall in Neurons #73 (yellow), #55 (dark green) and #37 and #38 (dark blue), with secondary neurons of #47 and #48 (aqua). Over all the wells, additional neurons #39,40,41 and 13 contribute to the better production

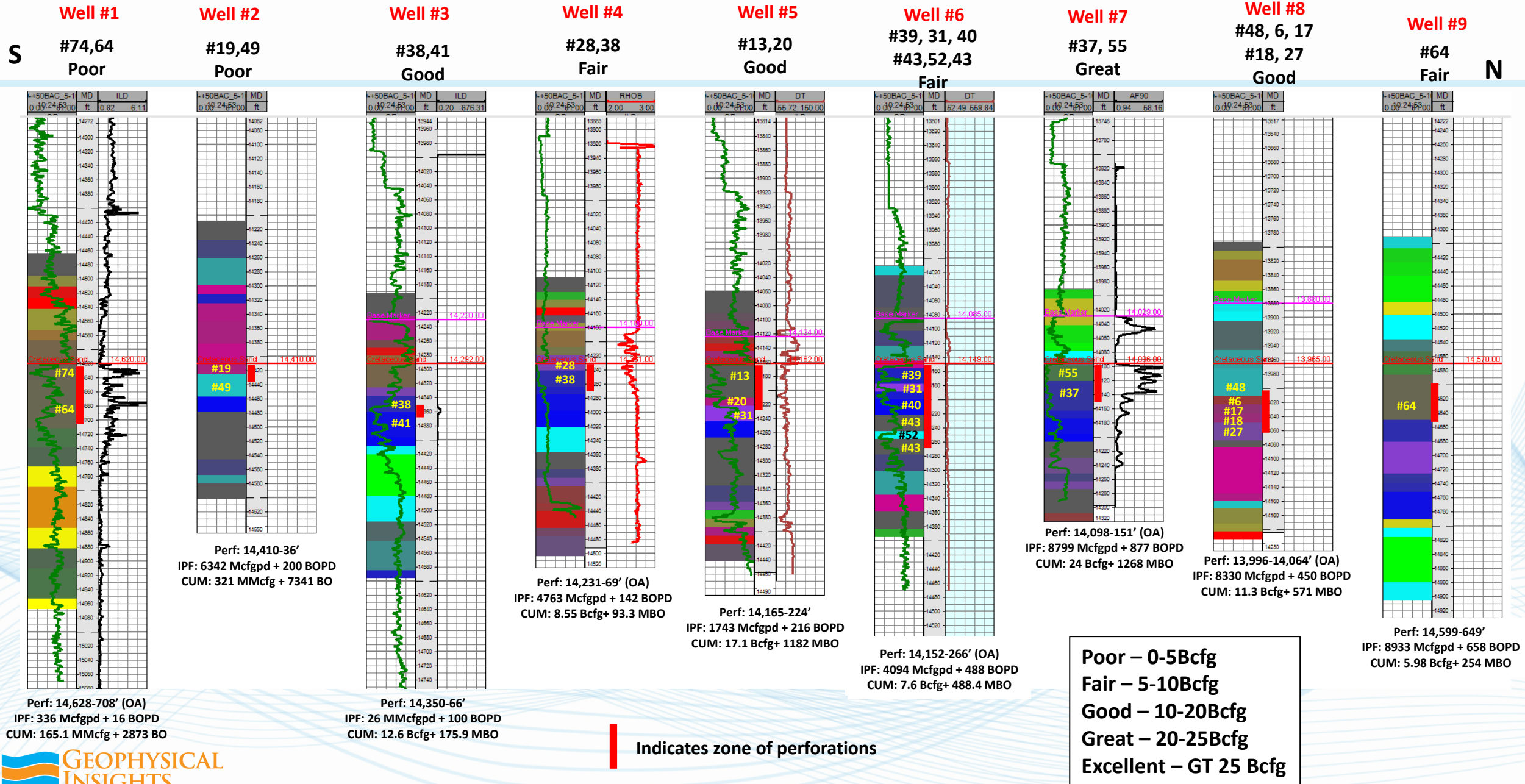


This is more obvious when looking at the West to East



West to East Arbitrary Line A - Classification

Cross-Section A – with SOM extracted along well bore – and flattened on Woodbine Sand



Cross-Section B – with SOM extracted along well bore – and flattened on Cretaceous Sand

W

E

Well #10

Well #11

Well #12

Well #13

Well #14

Well #15

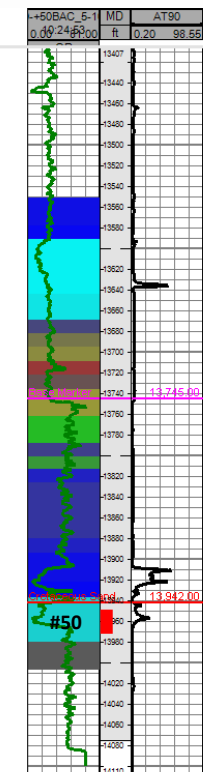
Well #7

Well #16

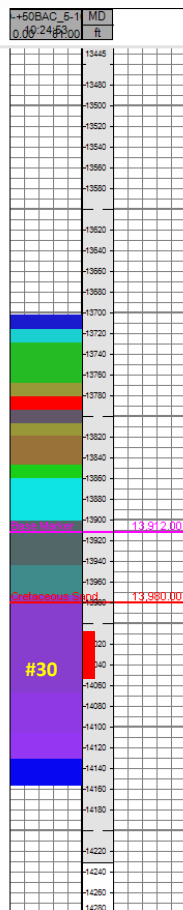
Well #17

Across a fault and down dip but was told it had excellent porosity and perm

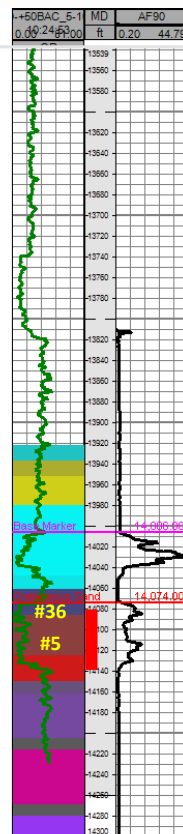
Well #18



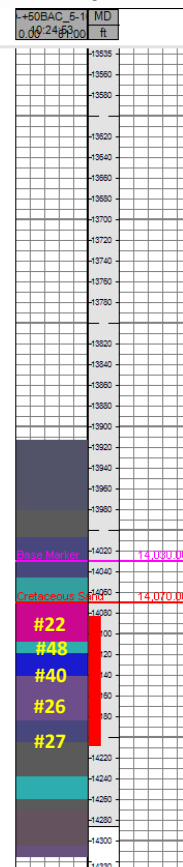
Perf: 13,950-62'
IPF: 4815 Mcfgpd
CUM: 1.75 B + 171.5 MBO



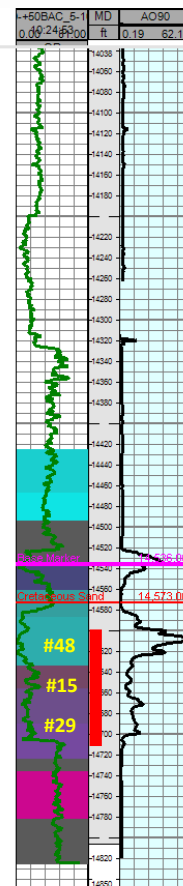
Perf: 14,000-44'
IPF: 3414 Mcfgpd
+353 BOPD
CUM: 1.38 B + 125.4 MBO



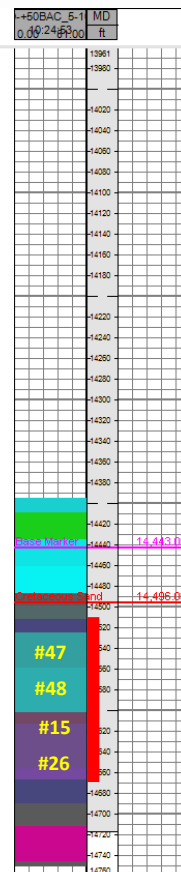
Perf: 14,075-132'
IPF: 3032 Mcfgpd
+339 BOPD
CUM: 1.63 B + 160 MBO



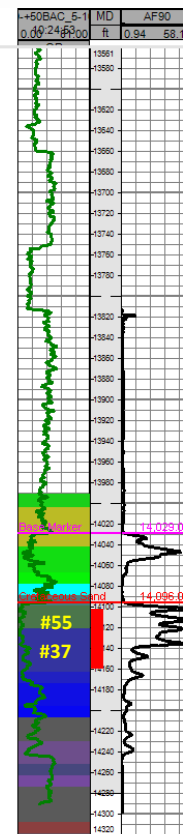
Perf: 14,074-200'(OA)
IPF: 6330 Mcfgpd
+736 BOPD
CUM: 8.03 B + 362 MBO



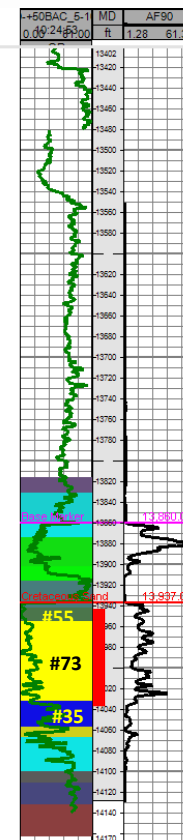
Perf: 14,592-702'(OA)
IPF: 3711 Mcfgpd
+312 BOPD
CUM: 14.7 B + 704.3 MBO



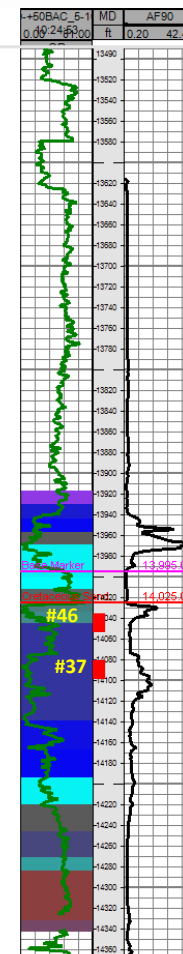
Perf: 14,554-660'(OA)
IPF: 8520 Mcfgpd
+932 BOPD
CUM: 25.6 B + 1342 MBO



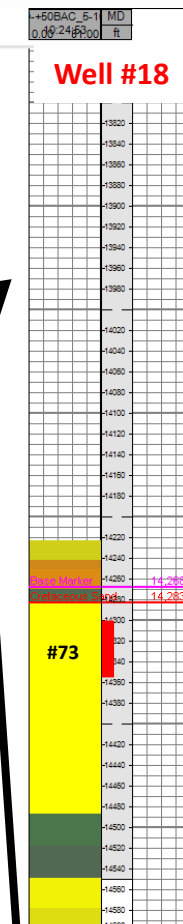
Perf: 14,098-151'(OA)
IPF: 8799 Mcfgpd
+877 BOPD
CUM: 24 B + 1270 MBO



Perf: 13,937-14,028'(OA)
IPF: 6276 Mcfgpd
+522 BOPD
CUM: 33.1 B + 1774 MBO



Perf: 14,028-40' & '075-090'
IPF: 1349 Mcfgpd
+69 BOPD
CUM: 778.8 MMcfg + 40 MBO

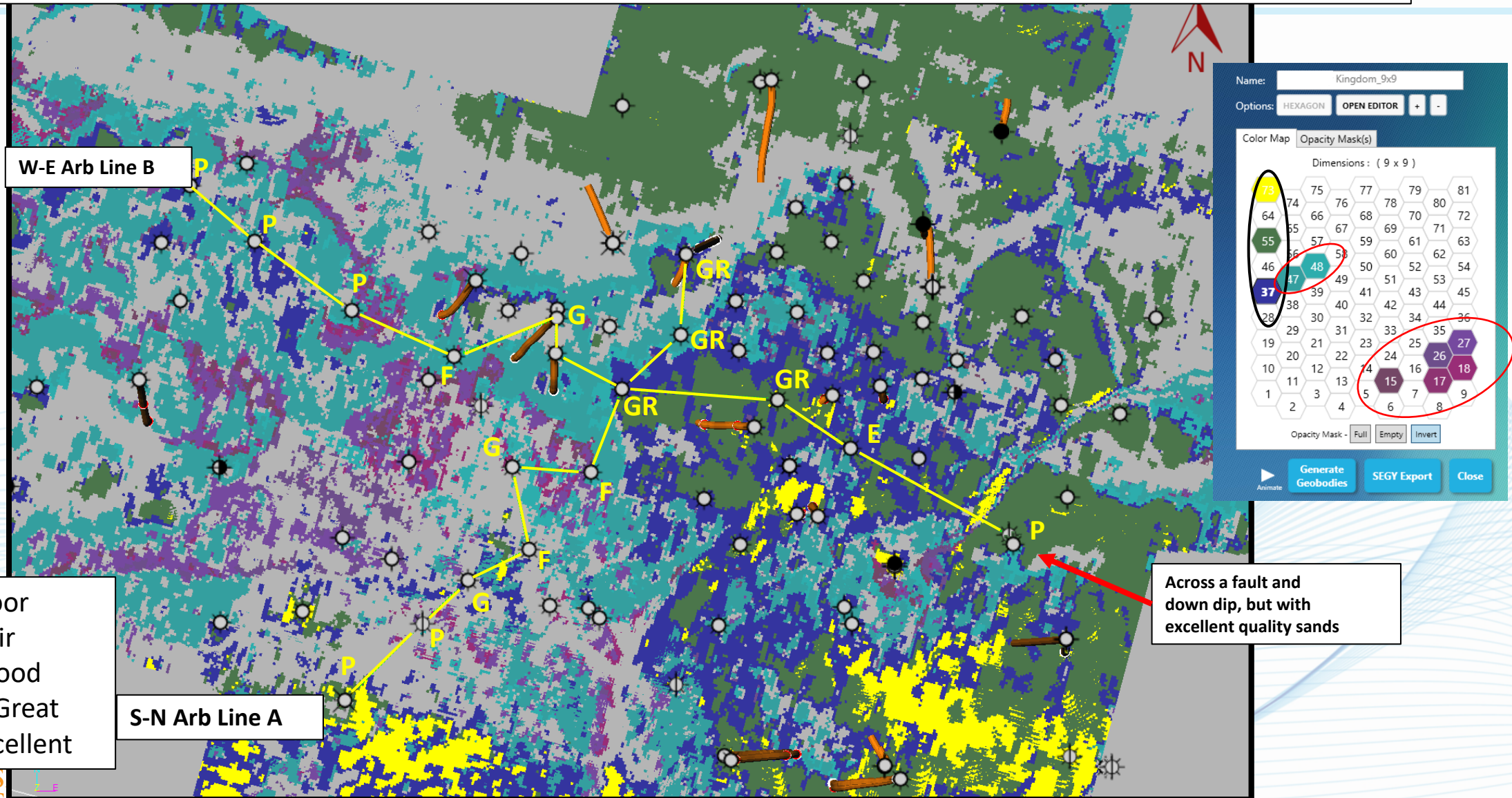


Perf: 14,293-342'
IPF: 1543 Mcfgpd +55 BOPD
CUM: 3.5 B _81.2 MBO

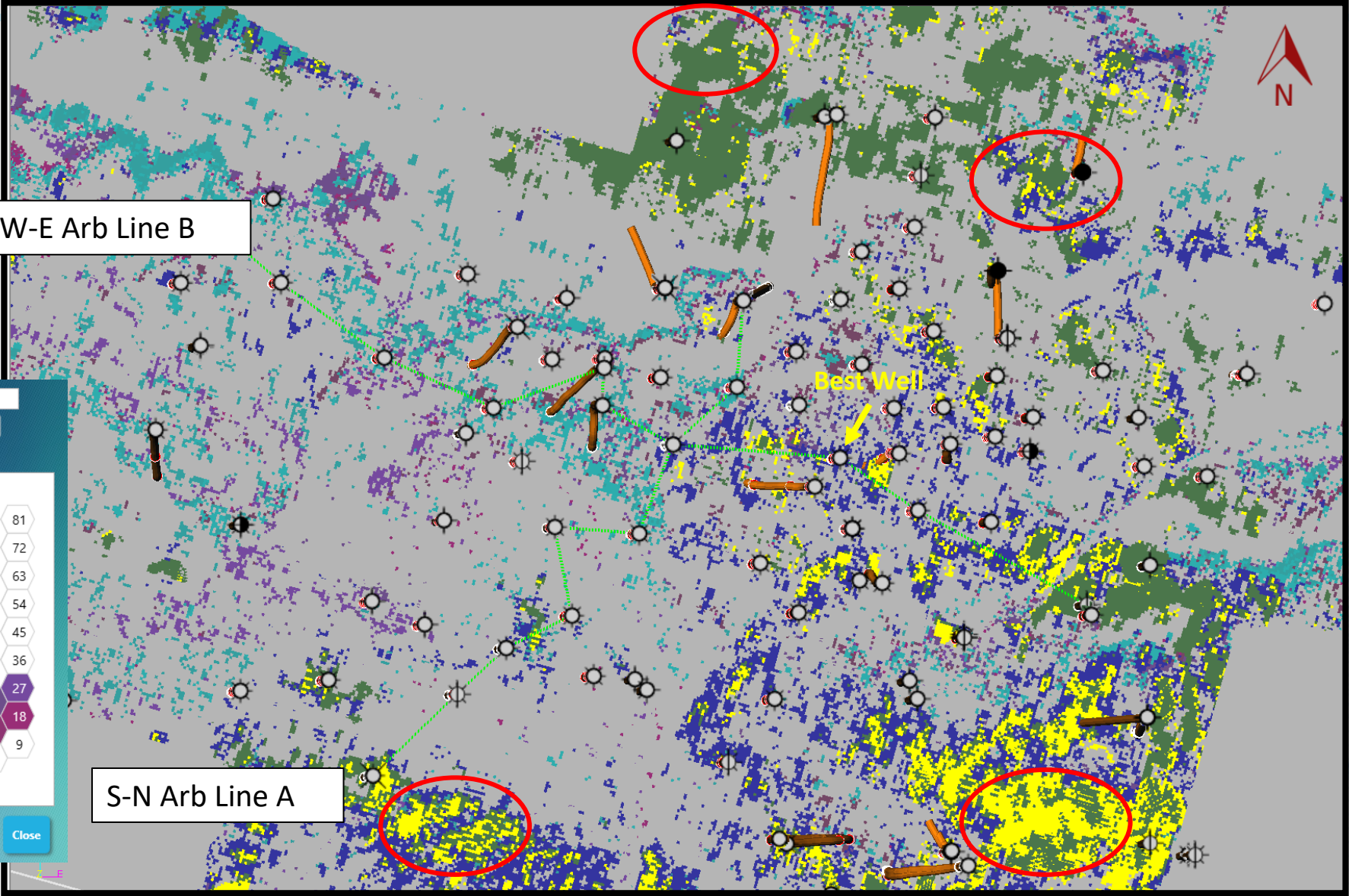
Indicates zone of perforations

Poor – 0-5Bcfg
Fair – 5-10Bcfg
Good – 10-20Bcfg
Great – 20-25Bcfg
Excellent – GT 25 Bcfg

This is the areal extent of all Key neurons related to production turned on within a zone from the Key horizon down to 20 ms below the horizon. The neurons found at the perforations in the “Great” and “Excellent” wells are #37, 55 and 73, with other “Good” wells using Neurons #47 and 48. Neurons #15, 17, 18, 26, and 27 are generally associated with wells with “Poor” or “Fair” Production.



Same view, but with only the most 10% anomalous data points turned on – showing the depletion of reserves in the field. There do seem to be a few spots left (circled in red), which may hold enough reserves to be economic for drilling.



Name: Kingdom_9x9

Options: HEXAGON OPEN EDITOR + -

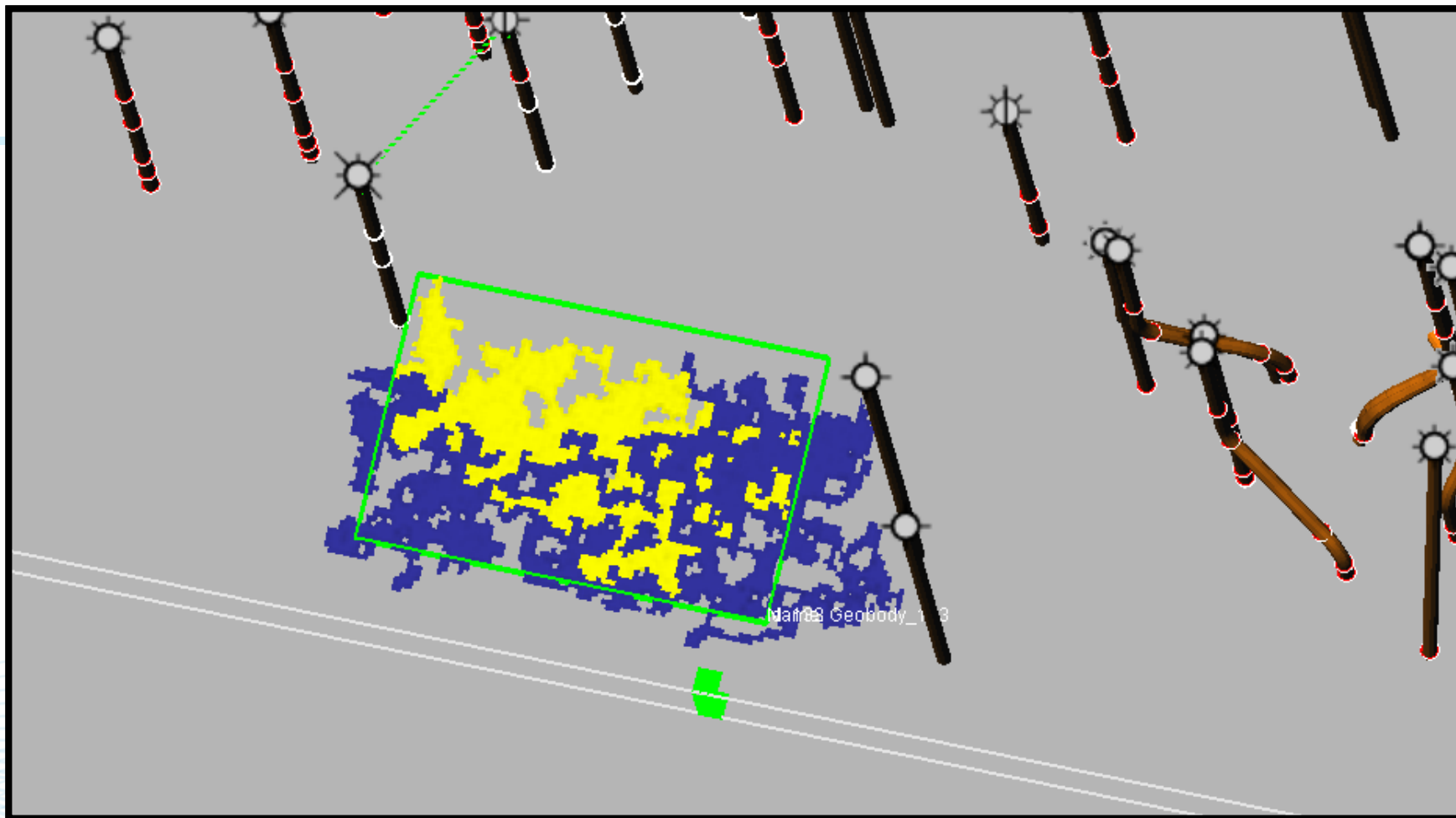
Color Map Opacity Mask(s)

Dimensions: (9 x 9)

73	74	75	76	77	78	79	80	81
64	65	66	67	68	69	70	71	72
55	56	57	58	59	60	61	62	63
46	47	48	49	50	51	52	53	54
37	38	39	40	41	42	43	44	45
28	29	30	31	32	33	34	35	36
19	20	21	22	23	24	25	26	27
10	11	12	13	14	15	16	17	18
1	2	3	4	5	6	7	8	9

Opacity Mask - Full Empty Invert

Generate Geobodies SEGY Export Close



In the most southern area, the total net acre feet is about 10,252. This is the combination of both Geobodies which are neurons #73 and #37. An estimated interval velocity of 14,000 ft/sec was used. A net/gross ratio of 80%, porosity of 25% and water saturation of 30% were also estimated based on log curve analysis and verbal communication with the operator.

If one assumes a recovery factor of 2000 Mcfg/AcFt and 54 BO/MMcfg (average for field), then this area has the potential of producing 20.5 Bcfg and over 1.1MMBO. These estimates would put a well here in the “Great” category

Velocity Units: Feet/sec

Volume Units: Acre-Feet

Id: 133,22

Name:

Id	Name	Neuron	Sample Count	Exterior Sample Count	Interior Sample Count	Interval Velocity (Feet/sec) (>=0)	Net/Gross (0-1)	Porosity (0-1)	WaterSaturation (0-1)	Sample Volume (Acre-Feet)	Net Rock Volume (Acre-Feet)	Hydrocarbon Pore Volume (Acre-Feet)
22	Geobody_22	37	12,080	9,889	2,191	14000.00	0.80	0.25	0.30	3.89	37622.88	6584.00
133	Geobody_133	73	6,731	4,520	2,211	14000.00	0.80	0.25	0.30	3.89	20963.54	3668.62

Conclusions:

It is possible to be very accurate in estimating/predicting potential reserves using geobodies derived from Self-organized Maps.

It is possible to use Low Probability volume calculated during SOM process to see depletion- if seismic data was shot AFTER most of the production had occurred, thus being able to look at possible stranded reserves.

Thank You!

For more information

Please go to:

www.geoinsights.com