RYDER SCOTT 20th ANNUAL RESERVES CONFERENCE

DEBORAH SACREY

Owner, Auburn Energy
President, American Association of Petroleum Geologists

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

GEOPHYSICAL INSIGHTS
FROM INSIGHT TO FORESIGHT

This presentation will show:

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

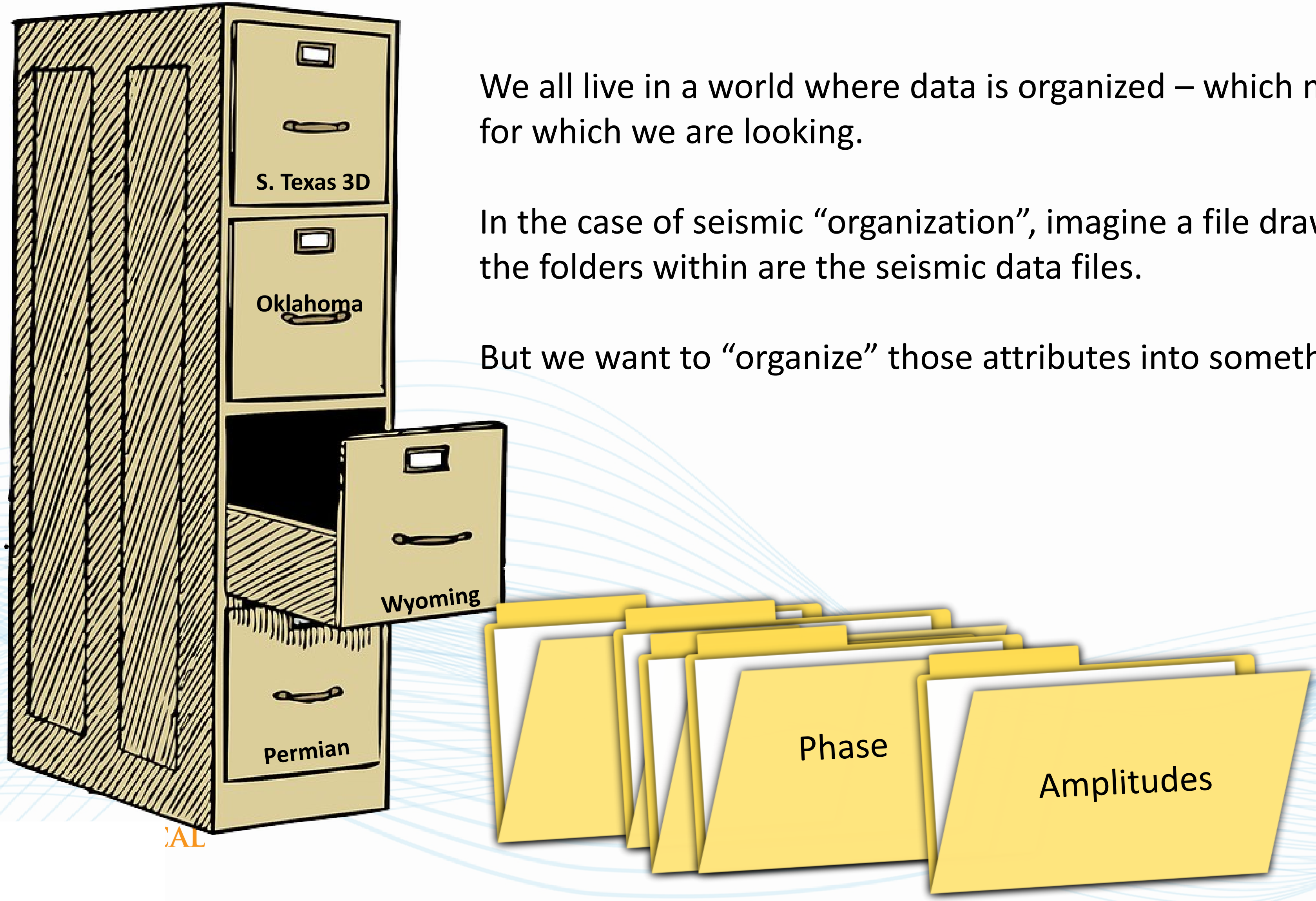
Looking for anomalous data points can be key in determining depletion providing the seismic data was acquired after most of the production had taken place.

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.

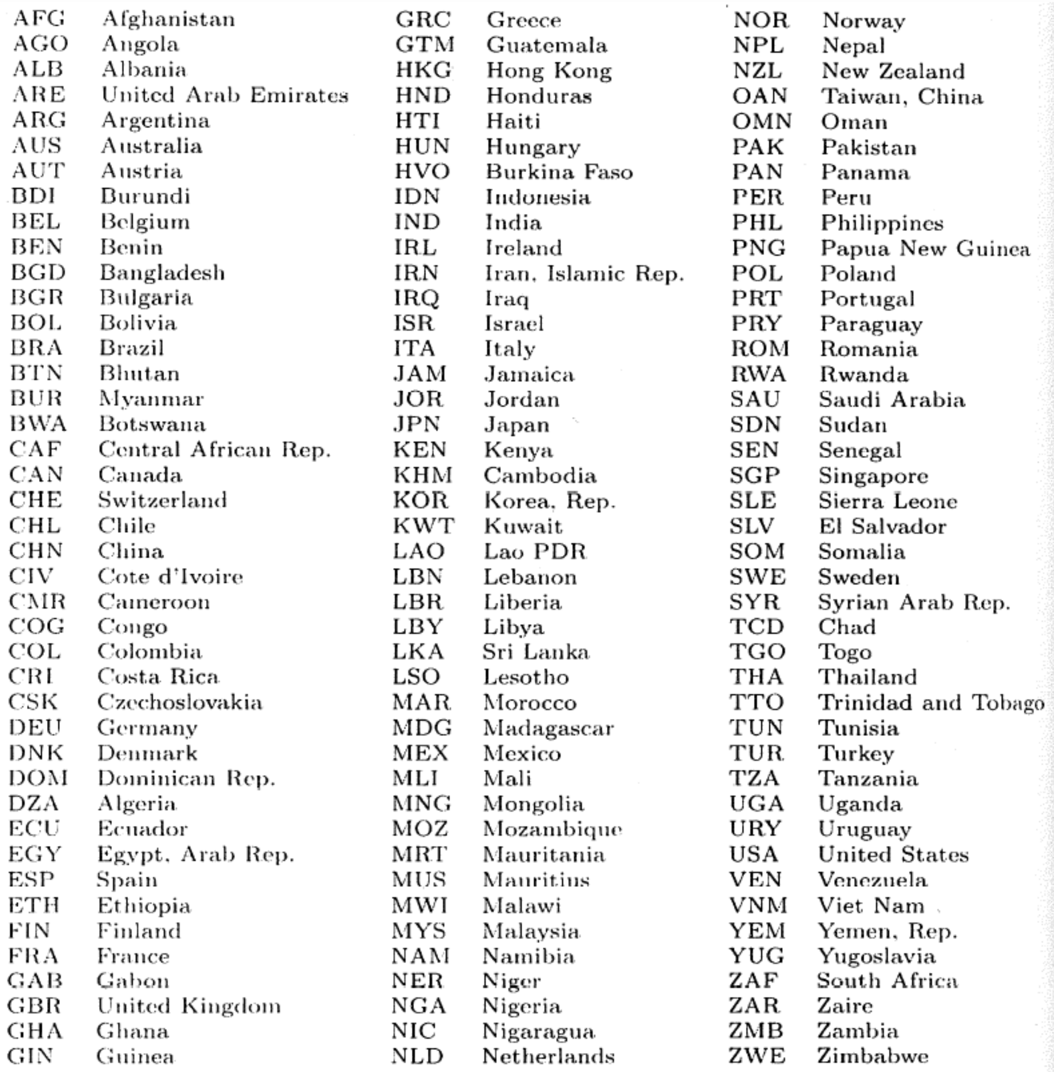
But we want to “organize” those attributes into something meaningful in the subsurface!



Example of Classification of "Attributes" – T. Kohonen

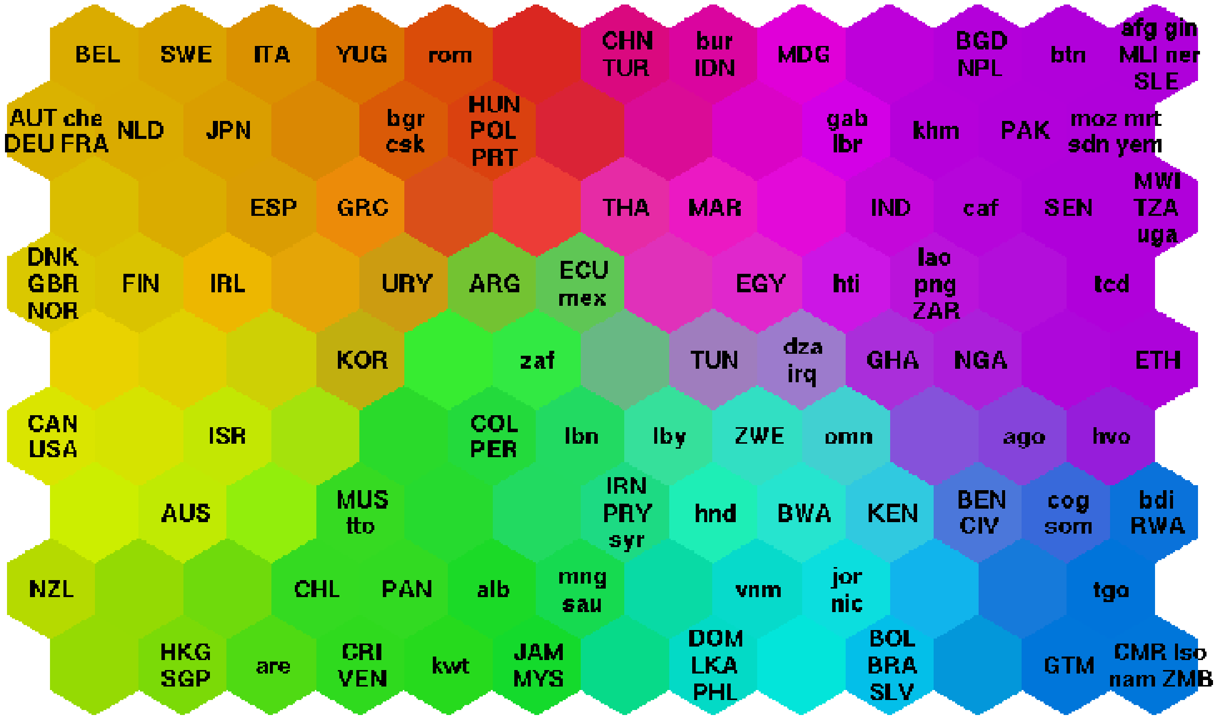
This example shows how the classification process can group clusters of similar information. Using this method with seismic attributes results in a more clear view of the subsurface stratigraphy than can be done in a conventional wavelet interpretation. Using the data in SAMPLE statistics, allows fine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



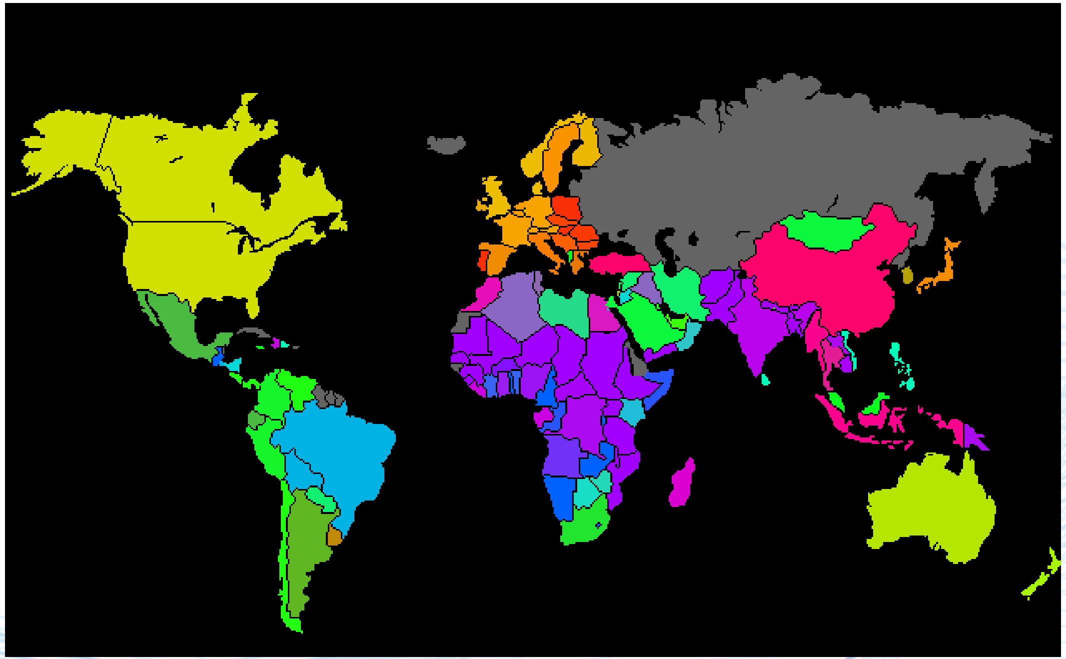
AFG	Afghanistan
AGO	Angola
ALB	Albania
ARE	United Arab Emirates
ARG	Argentina
AUS	Australia
AUT	Austria
BDI	Burundi
BEL	Belgium
BEN	Benin
BGD	Bangladesh
BGR	Bulgaria
BOL	Bolivia
BRA	Brazil
BTN	Bhutan
BUR	Myanmar
BWA	Botswana
CAF	Central African Rep.
CAN	Canada
CHE	Switzerland
CHL	Chile
CHN	China
CIV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

Slide courtesy of Dr. Tom Smith



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

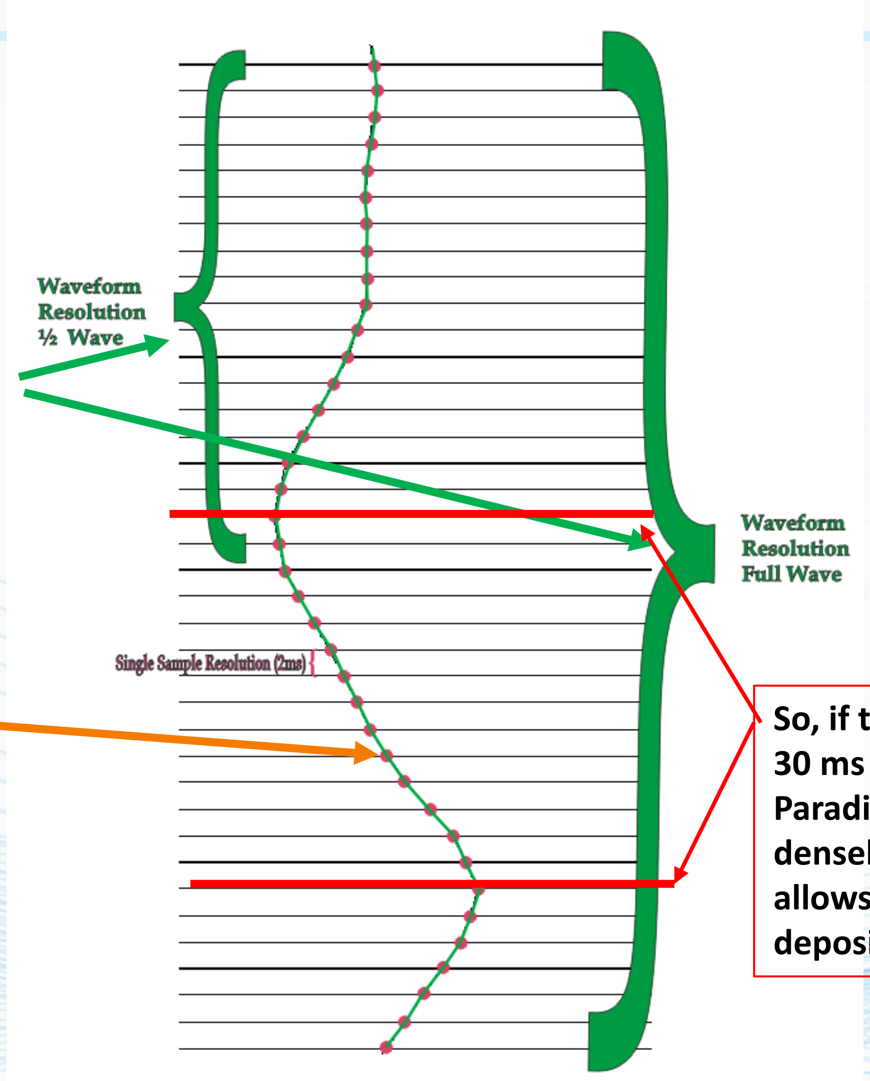
9X13 hexagonal neuron topology (117 neurons)

T. Kohonen, 2001

Slide courtesy of Dr. Tom Smith

“Single Sample Resolution” – number crunching!

All other ML software use Waveform Resolution of either ½ or Full Wave Resolution to minimize Data Processing requirements



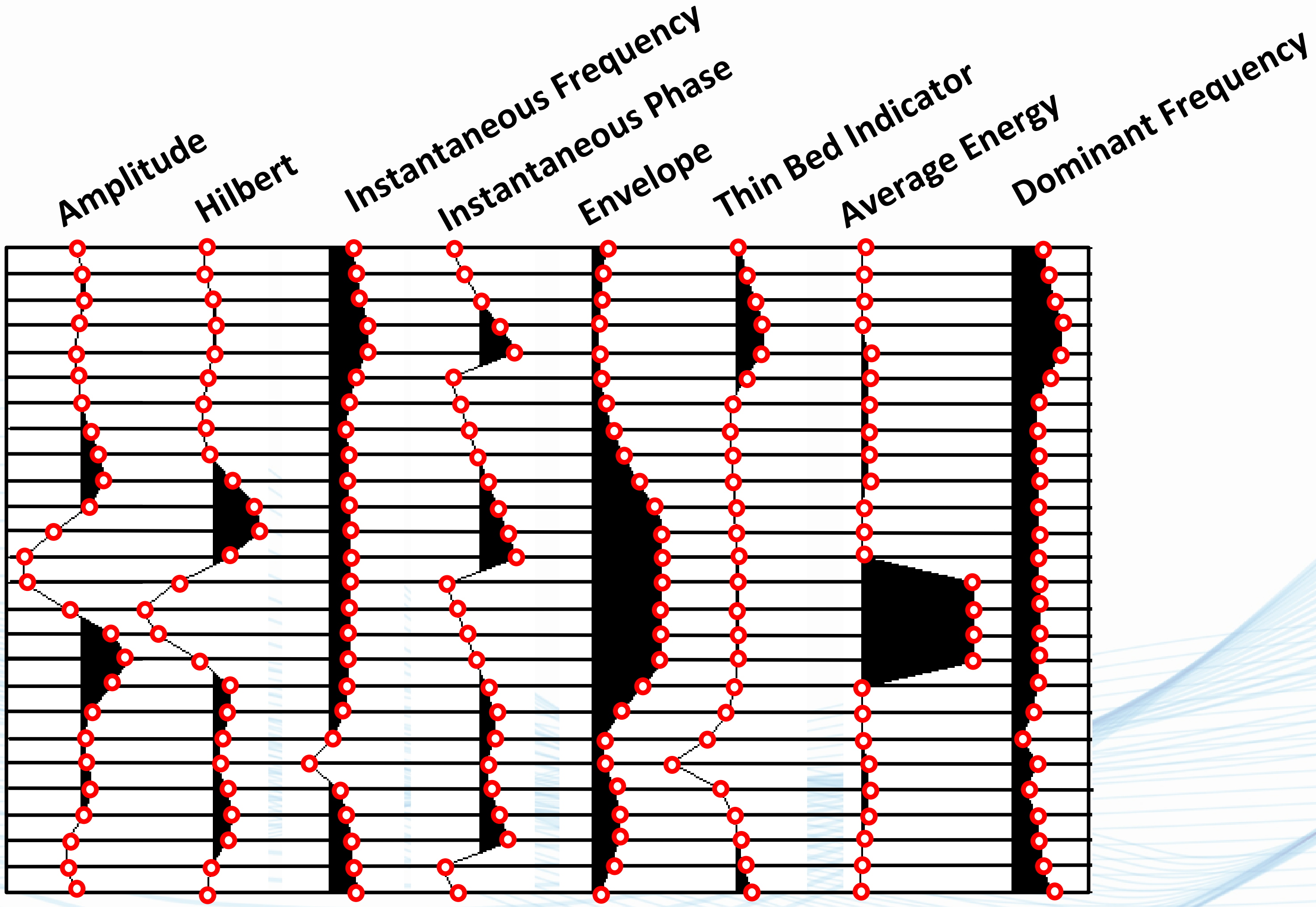
This Software uses Single Sample Resolution In order to enhance the Neural Cluster Process

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!

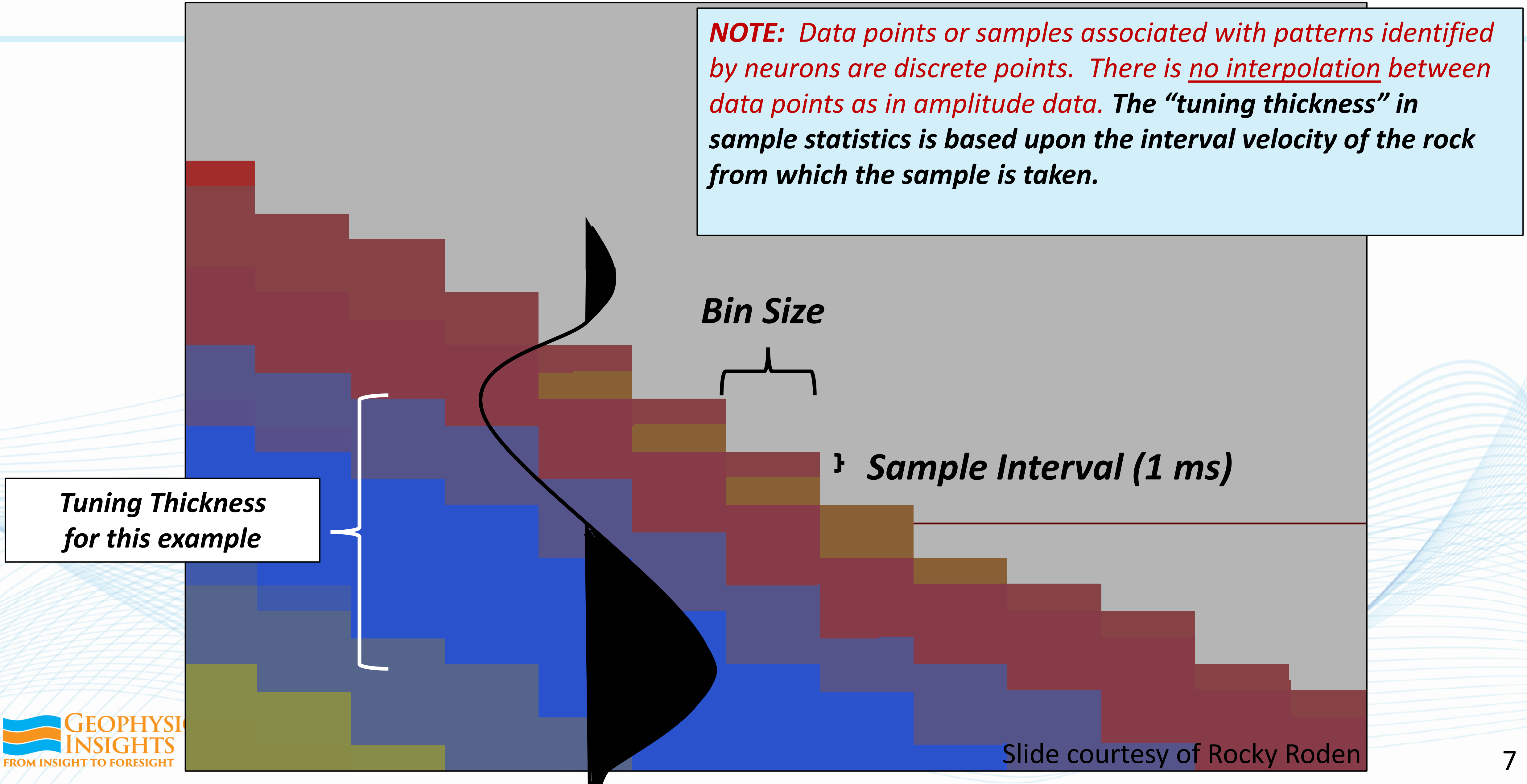
Slide courtesy of Blaine Taylor

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.

Slide courtesy of Rocky Roden

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

Proof of concept challenge

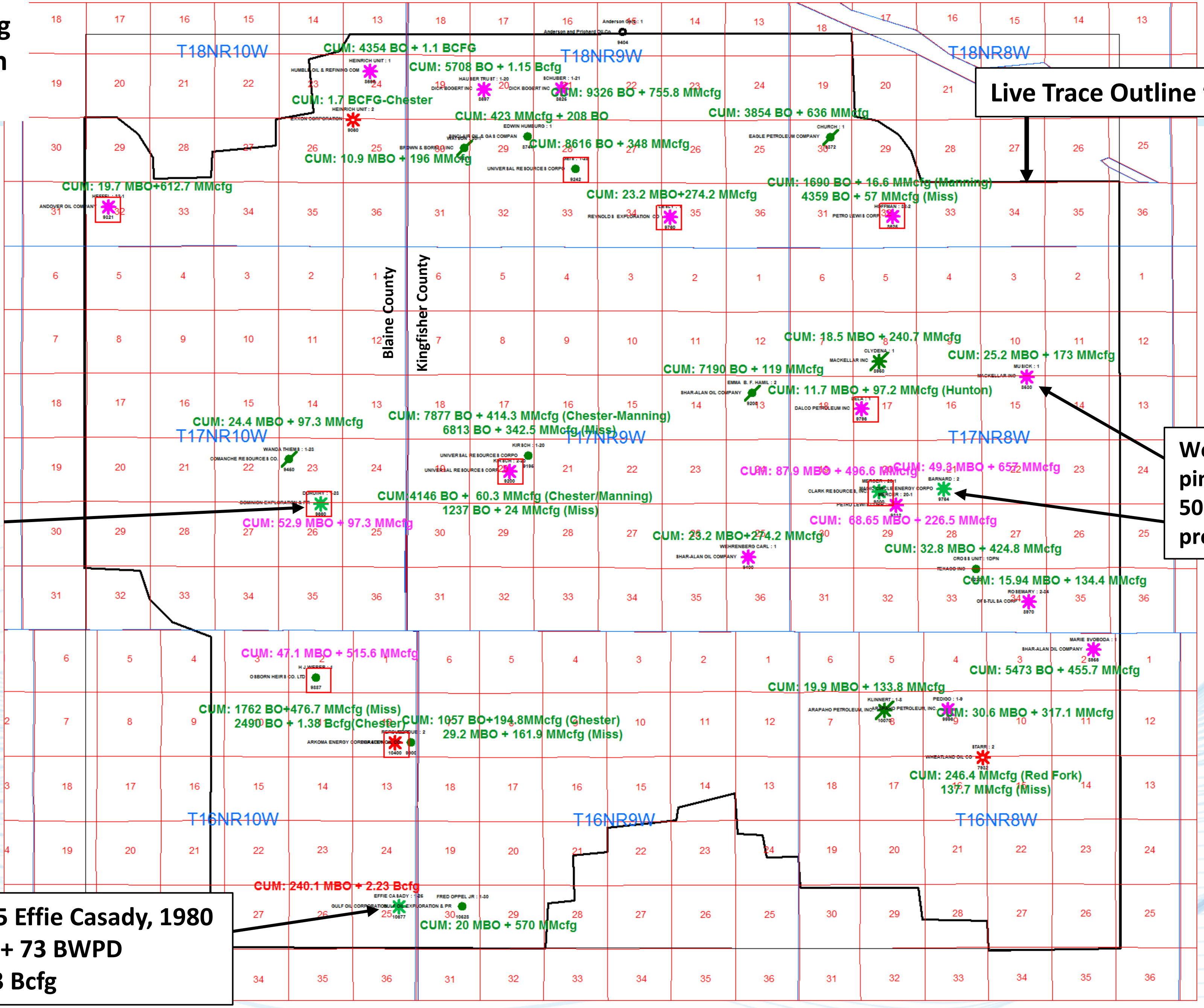
Project Objectives:

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.



Live Trace Outline ~ 196 sq mi

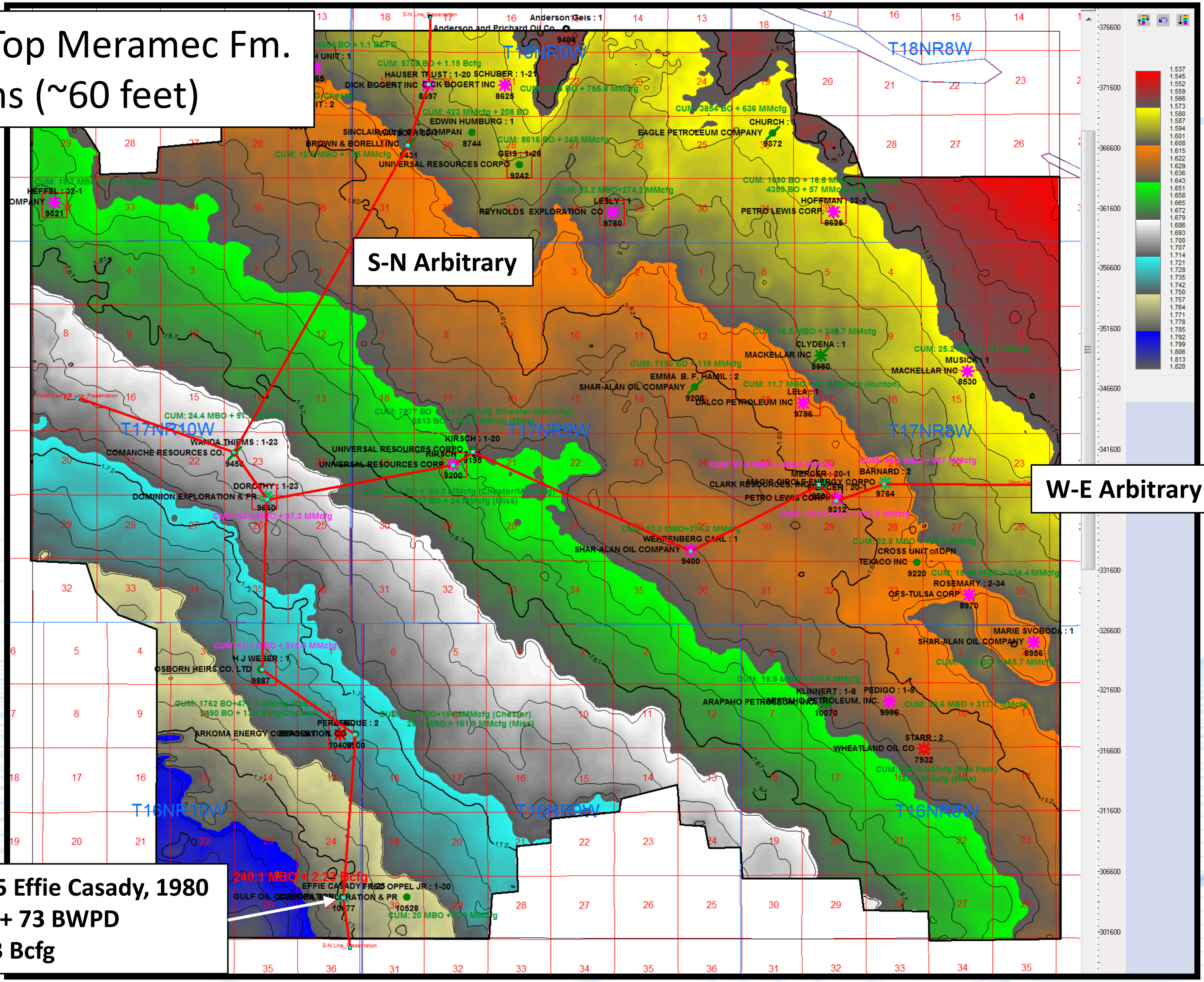
Square boxes represent those wells in which synthetic seismograms were created to tie the data. In all, 10 synthetic ties were created.

Wells with production numbers in pink have produced near or over 50 MBO. Those in green have produced 35 MBO or less.

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

FROM INSIGHT TO FORESIGHT

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



S-N Arbitrary

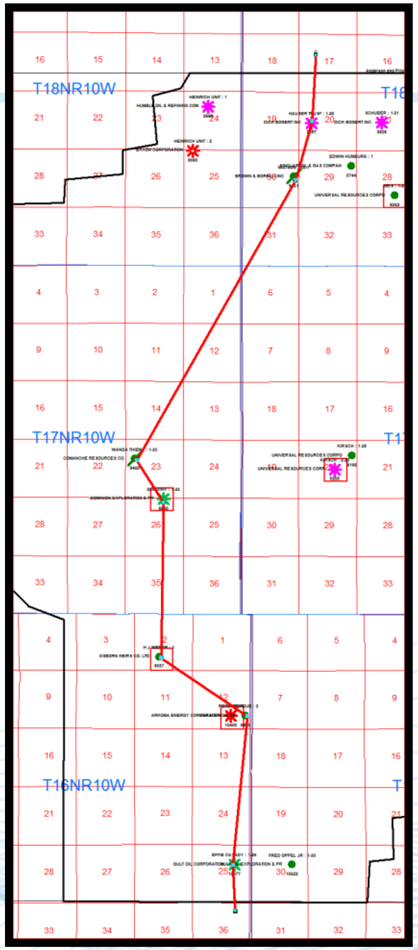
W-E Arbitrary

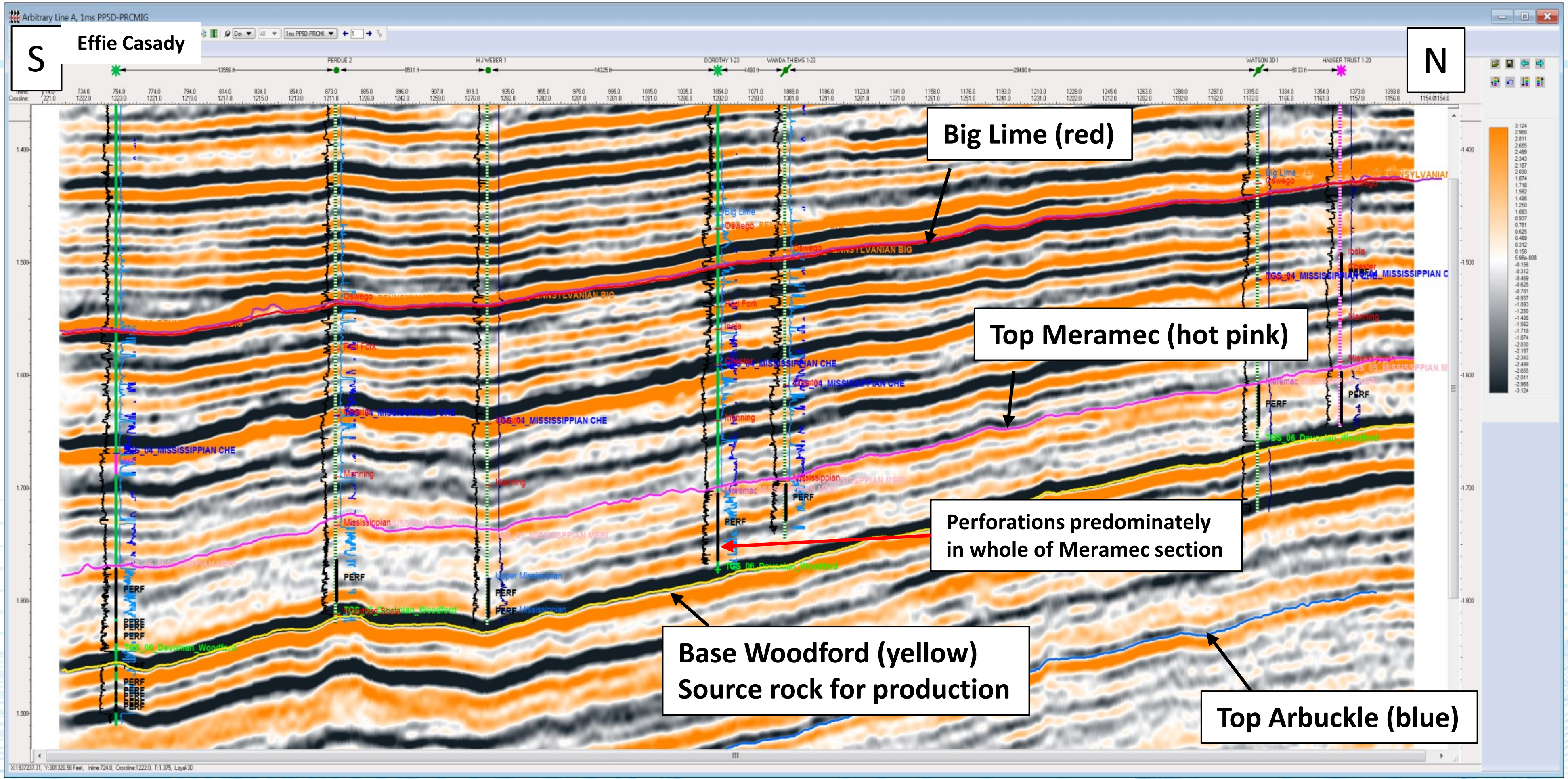
Best Well – Gulf Oil #1-25 Effie Casady, 1980
IPF: 890 BO + 1979 Mcfg + 73 BWPD
Cum: 240.1 MMBO+ 2.23 Bcfg

FROM INSIGHT TO FORESIGHT

S-N Arb Line

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





Effie Casady

Big Lime (red)

Top Meramec (hot pink)

Perforations predominately in whole of Meramec section

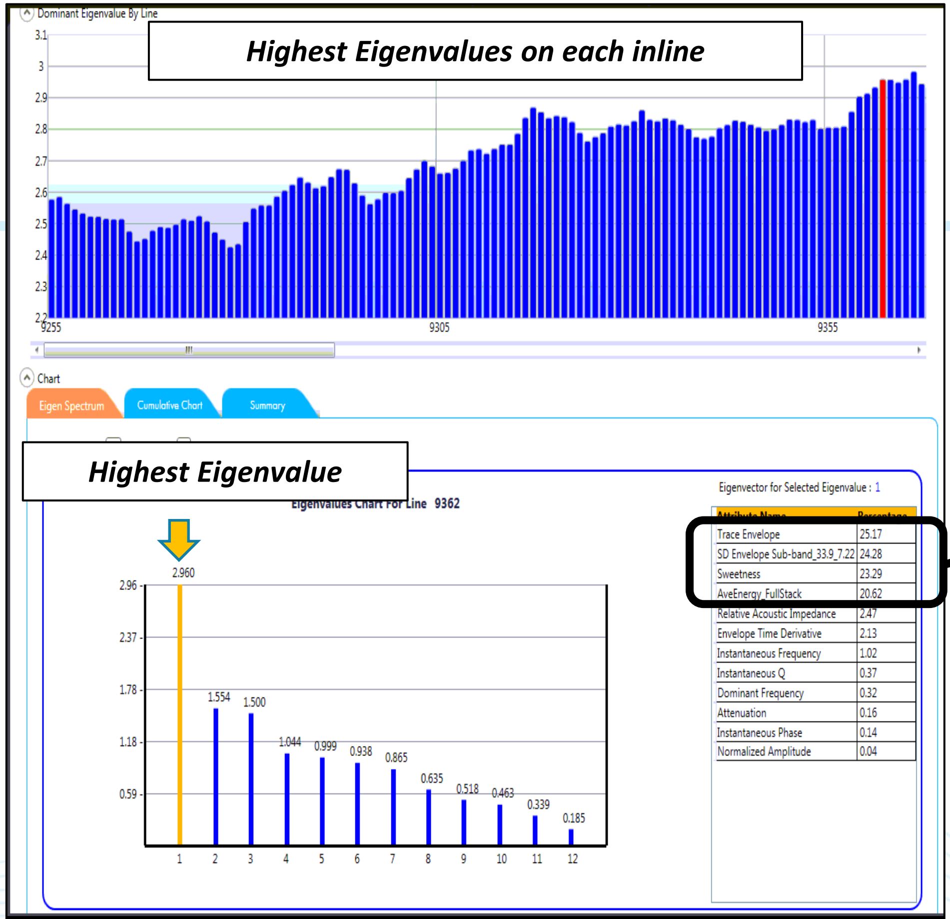
Base Woodford (yellow)
Source rock for production

Top Arbuckle (blue)

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)



Highest Eigenvalues on each inline

Highest Eigenvalue

Eigenvector for Selected Eigenvalue : 1

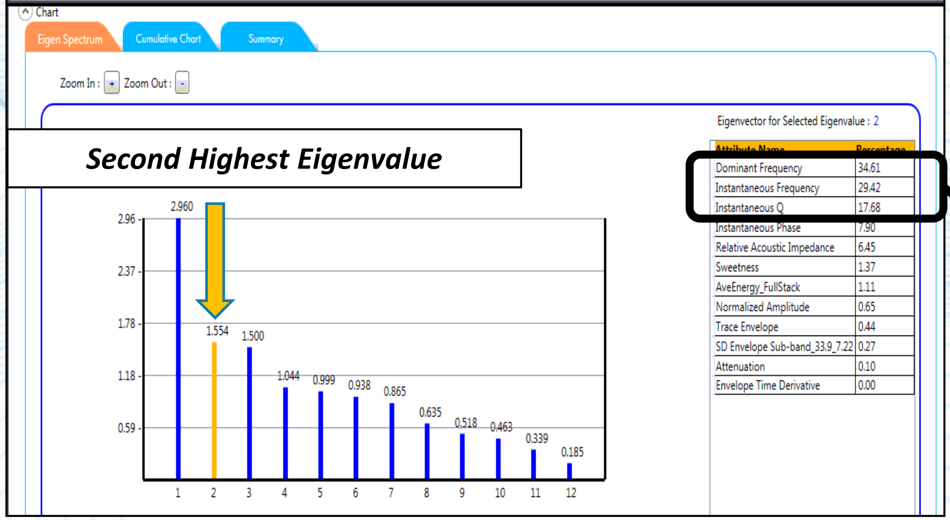
Attribute Name	Percentage
Trace Envelope	25.17
SD Envelope Sub-band_33.9_7.22	24.28
Sweetness	23.29
AveEnergy_FullStack	20.62
Relative Acoustic Impedance	2.47
Envelope Time Derivative	2.13
Instantaneous Frequency	1.02
Instantaneous Q	0.37
Dominant Frequency	0.32
Attenuation	0.16
Instantaneous Phase	0.14
Normalized Amplitude	0.04

<u>FIRST PRINCIPAL COMPONENT</u>

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 Highest Eigenvalue

Eigenvector for Selected Eigenvalue : 2

Attribute Name	Percentage
Dominant Frequency	34.61
Instantaneous Frequency	29.42
Instantaneous Q	17.68
Instantaneous Phase	7.90
Relative Acoustic Impedance	6.45
Sweetness	1.37
AveEnergy_FullStack	1.11
Normalized Amplitude	0.65
Trace Envelope	0.44
SD Envelope Sub-band_33.9_7.22	0.27
Attenuation	0.10
Envelope Time Derivative	0.00

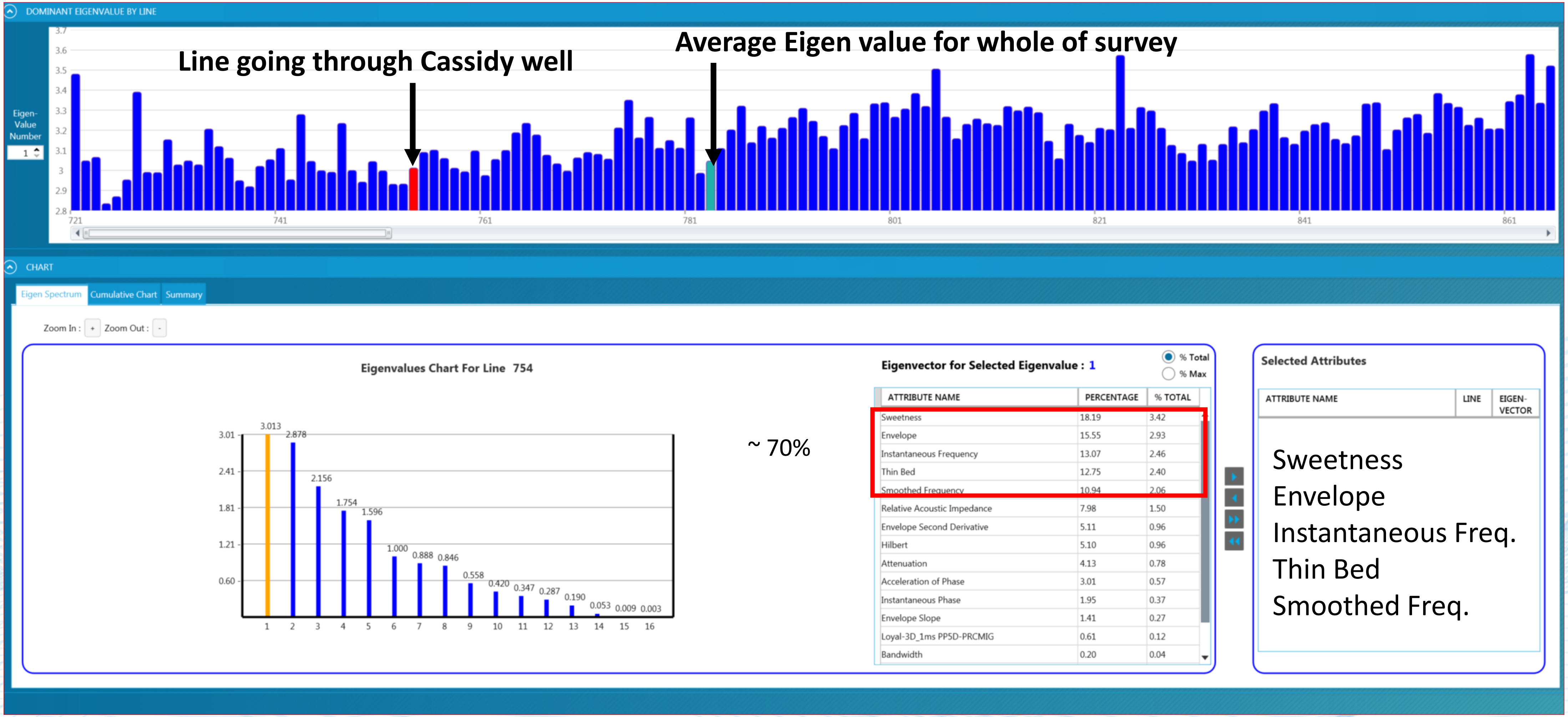
<u>SECOND PRINCIPAL COMPONENT</u>

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.



Line going through Cassidy well

Average Eigen value for whole of survey

Eigenvalues Chart For Line 754

~ 70%

Eigenvector for Selected Eigenvalue : 1

● % Total
○ % Max

ATTRIBUTE NAME	PERCENTAGE	% TOTAL
Sweetness	18.19	3.42
Envelope	15.55	2.93
Instantaneous Frequency	13.07	2.46
Thin Bed	12.75	2.40
Smoothed Frequency	10.94	2.06
Relative Acoustic Impedance	7.98	1.50
Envelope Second Derivative	5.11	0.96
Hilbert	5.10	0.96
Attenuation	4.13	0.78
Acceleration of Phase	3.01	0.57
Instantaneous Phase	1.95	0.37
Envelope Slope	1.41	0.27
Loyal-3D_1ms PP5D-PRCMIG	0.61	0.12
Bandwidth	0.20	0.04

Selected Attributes

Sweetness
Envelope
Instantaneous Freq.
Thin Bed
Smoothed Freq.

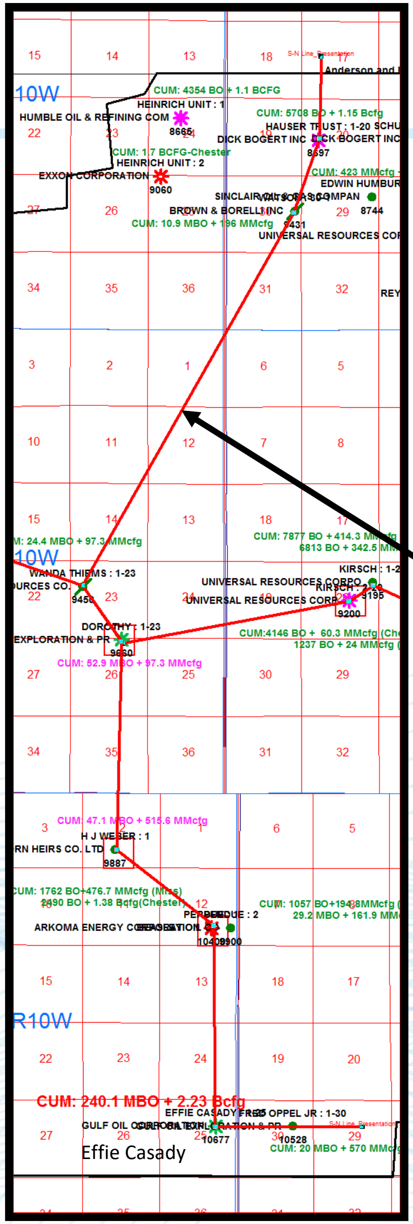
PCA: Eigen Vector 1 – Instantaneous Attributes through Line 754 (going through best well)
Window of focus was 10 ms above Meramec Fm. and 10 ms below Base Woodford Fm.

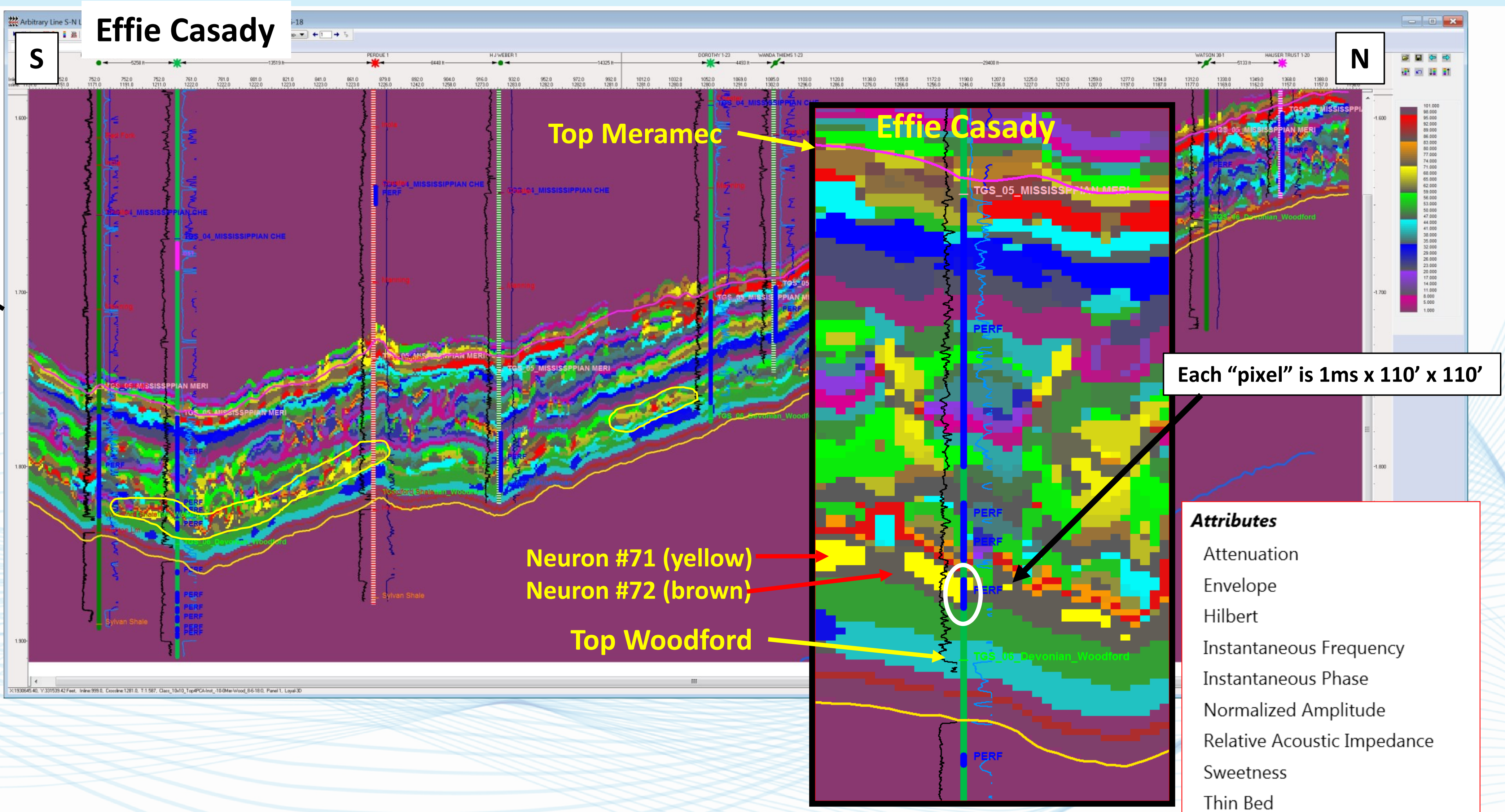
GEOPHYSICAL INSIGHTS
FROM INSIGHT TO FORESIGHT

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)





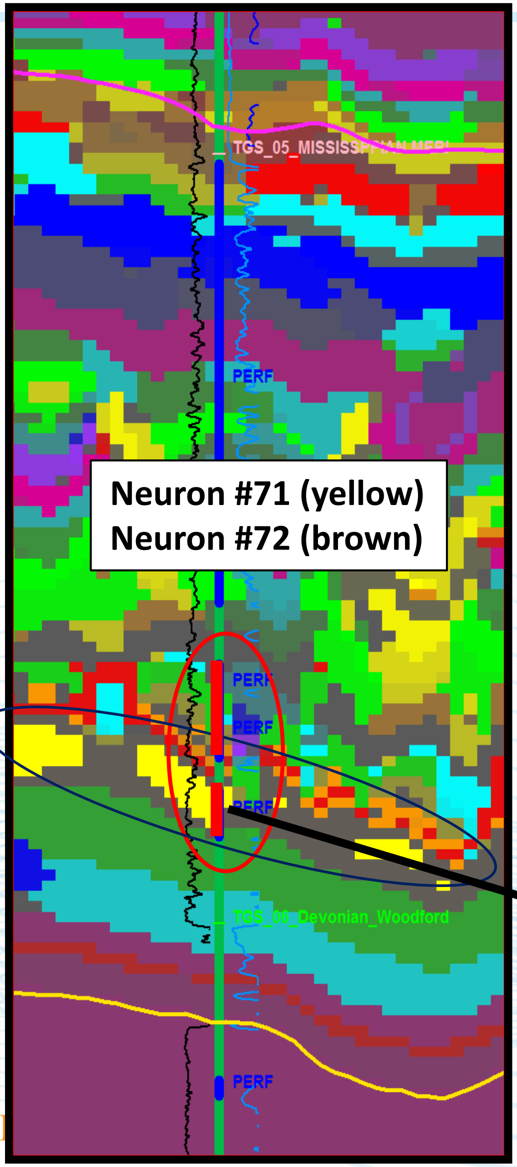
Attributes

- Attenuation
- Envelope
- Hilbert
- Instantaneous Frequency
- Instantaneous Phase
- Normalized Amplitude
- Relative Acoustic Impedance
- Sweetness
- Thin Bed

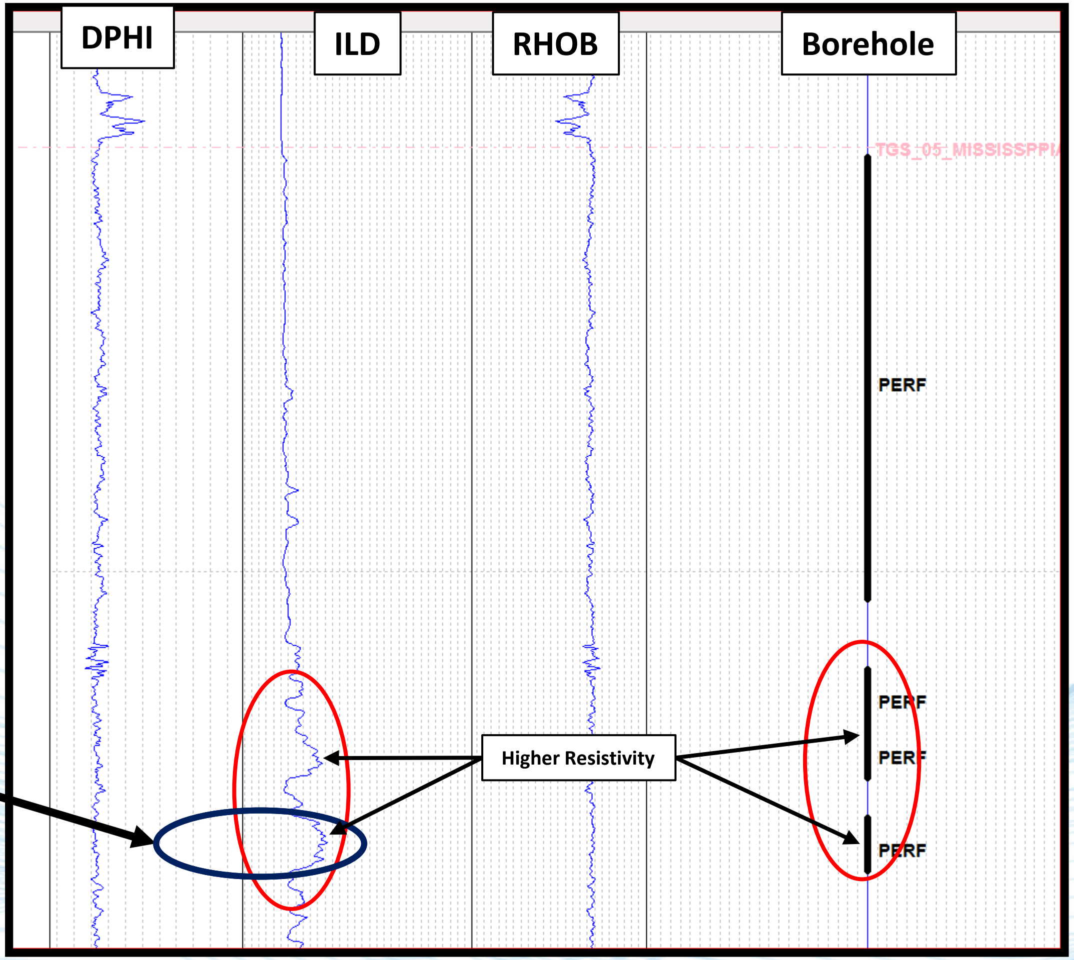
GEOPHYSICAL INSIGHTS
FROM INSIGHT TO FORESIGHT

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

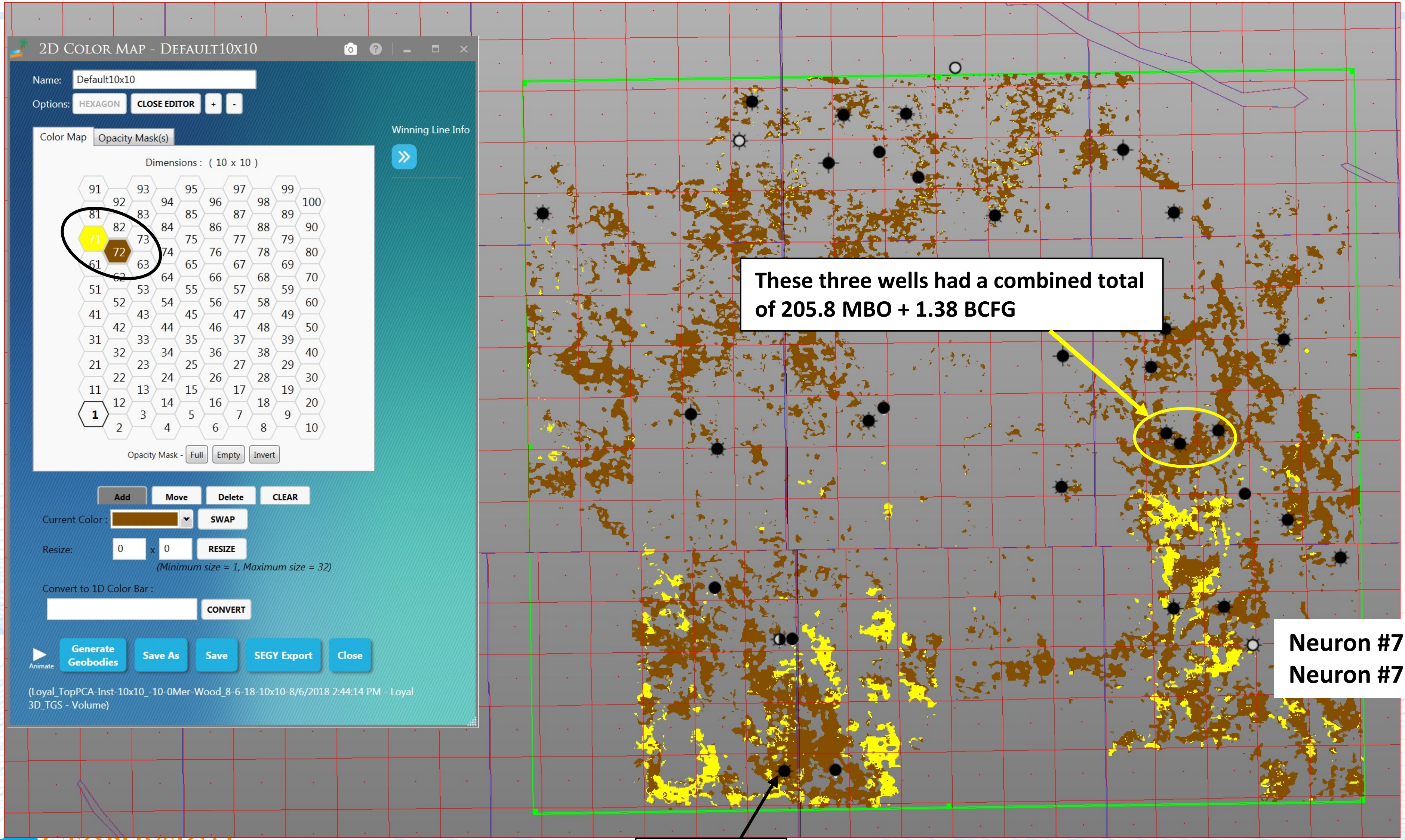


Effie Casady logs



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


2D Color Map - Default10x10

Name: Default10x10

Options: HEXAGON · CLOSE EDITOR

Dimensions : (10 x 10)

Current Color :

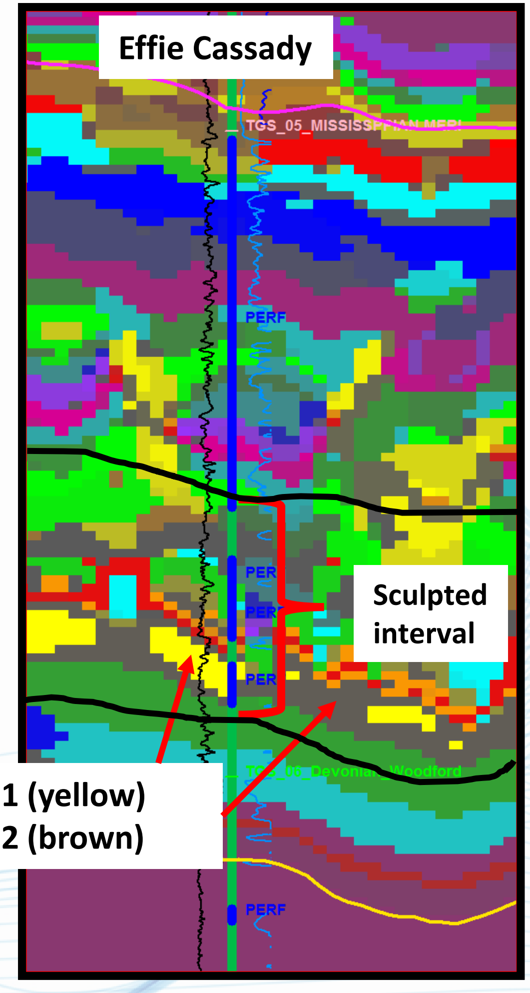
Resize: 0 x 0 (Minimum size = 1, Maximum size = 32)

Convert to 1D Color Bar :

(Loyal_TopPCA-Inst-10x10_-10-0Mer-Wood_8-6-18-10x10-8/6/2018 2:44:14 PM - Loyal 3D_TGS - Volume)

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

Casady Well



Effie Cassady

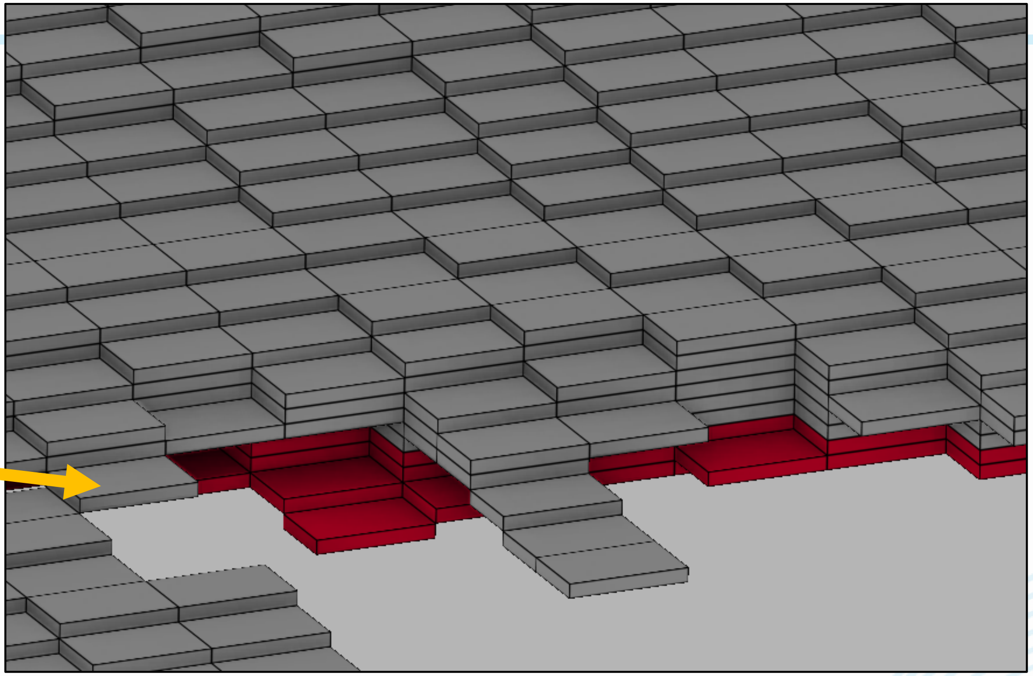
Sculpted interval

Neuron #71 (yellow)
Neuron #72 (brown)

GEOPHYSICAL INSIGHTS
FROM INSIGHT TO FORESIGHT

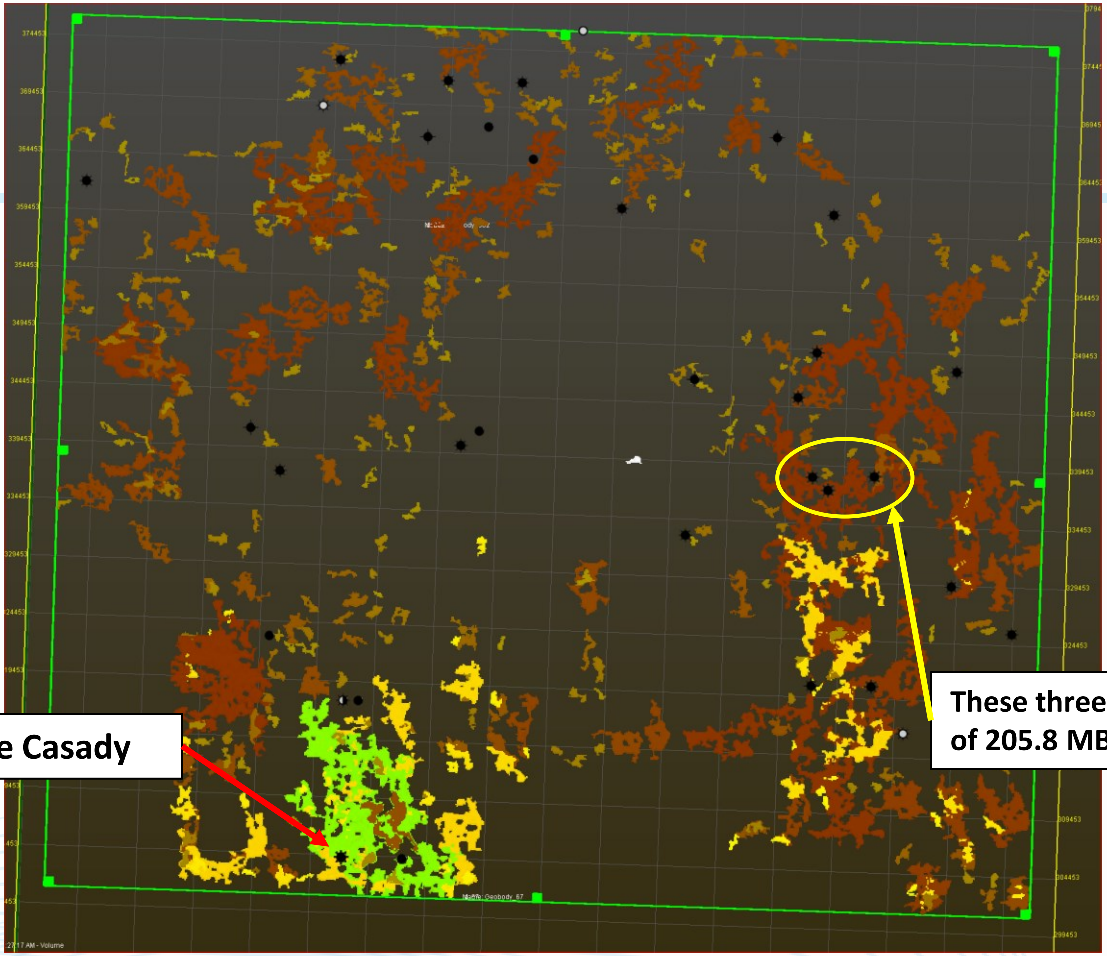
Geobodies are on a scale of bin X sample increment, therefore, geobodies can be quantified.

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



Sample Volume (Time)	**Calculated (Bin X * Bin Y * Bin Z(Sample in time/msec. * velocity))**
Depth Conversion Velocity	**5 Digit Value from User: 12000 Feet/sec (survey units)**
Gross Rock Volume	**GRV = Sample Volume * Sample Count**
Net Rock Volume	**NRV = GRV * Net Rock Factor (0-1)**
Pore Volume	**PV = NRV * Porosity**
Hydrocarbon Pore Volume (HPV)	**HPV = PV * (1-Sw)**
Porosity	**0-1 (from user)**
Water Saturation	**Percentage (by user from log data)**

GEOPHYSICAL INSIGHTS
FROM INSIGHT TO FORESIGHT



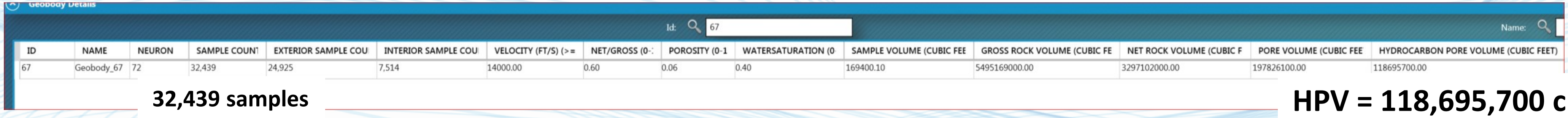
Effie Casady

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-:	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

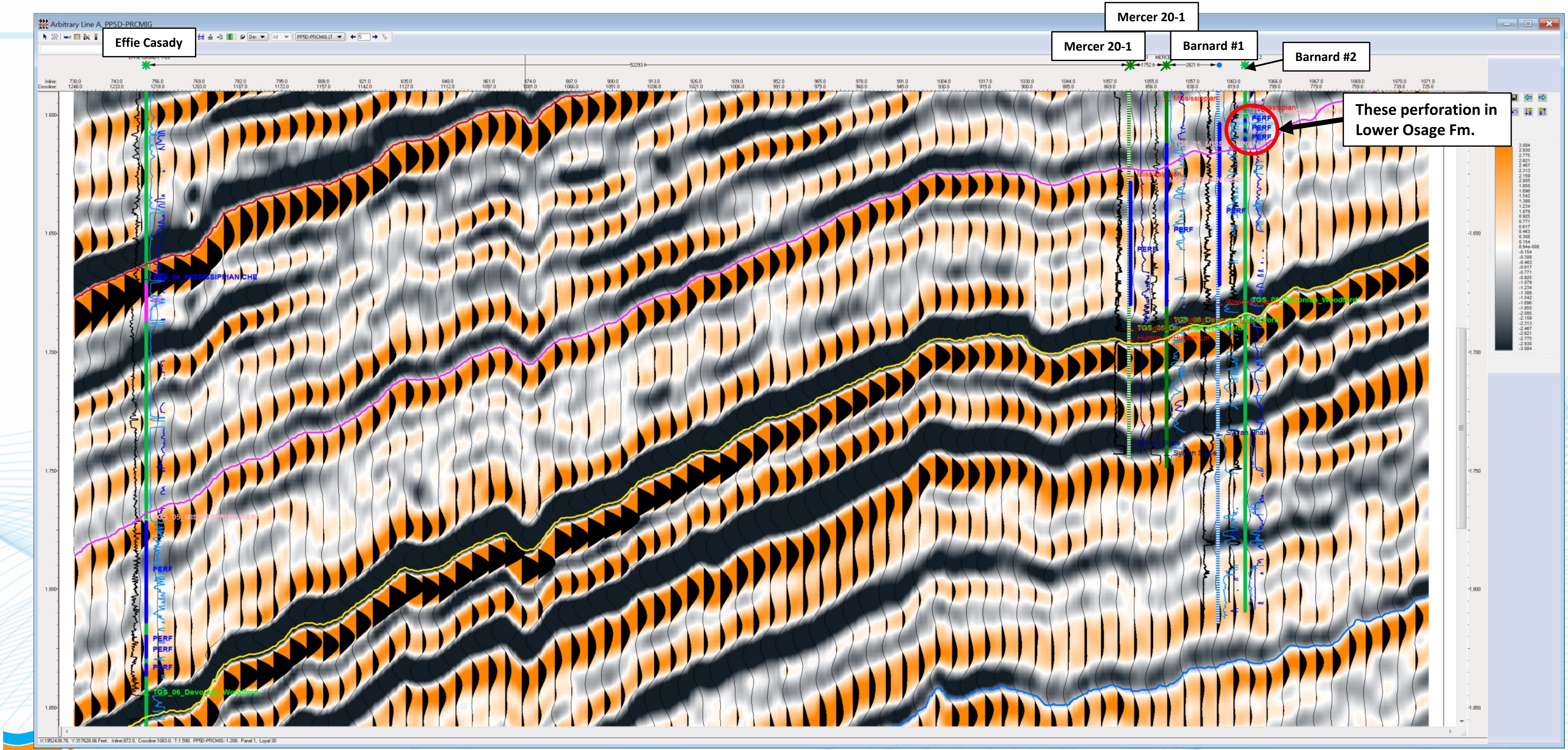
32,439 samples

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

GEOPHYSICAL INSIGHTS
FROM INSIGHT TO FORESIGHT

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



Effie Casady

Mercer 20-1

Mercer 20-1

Barnard #1

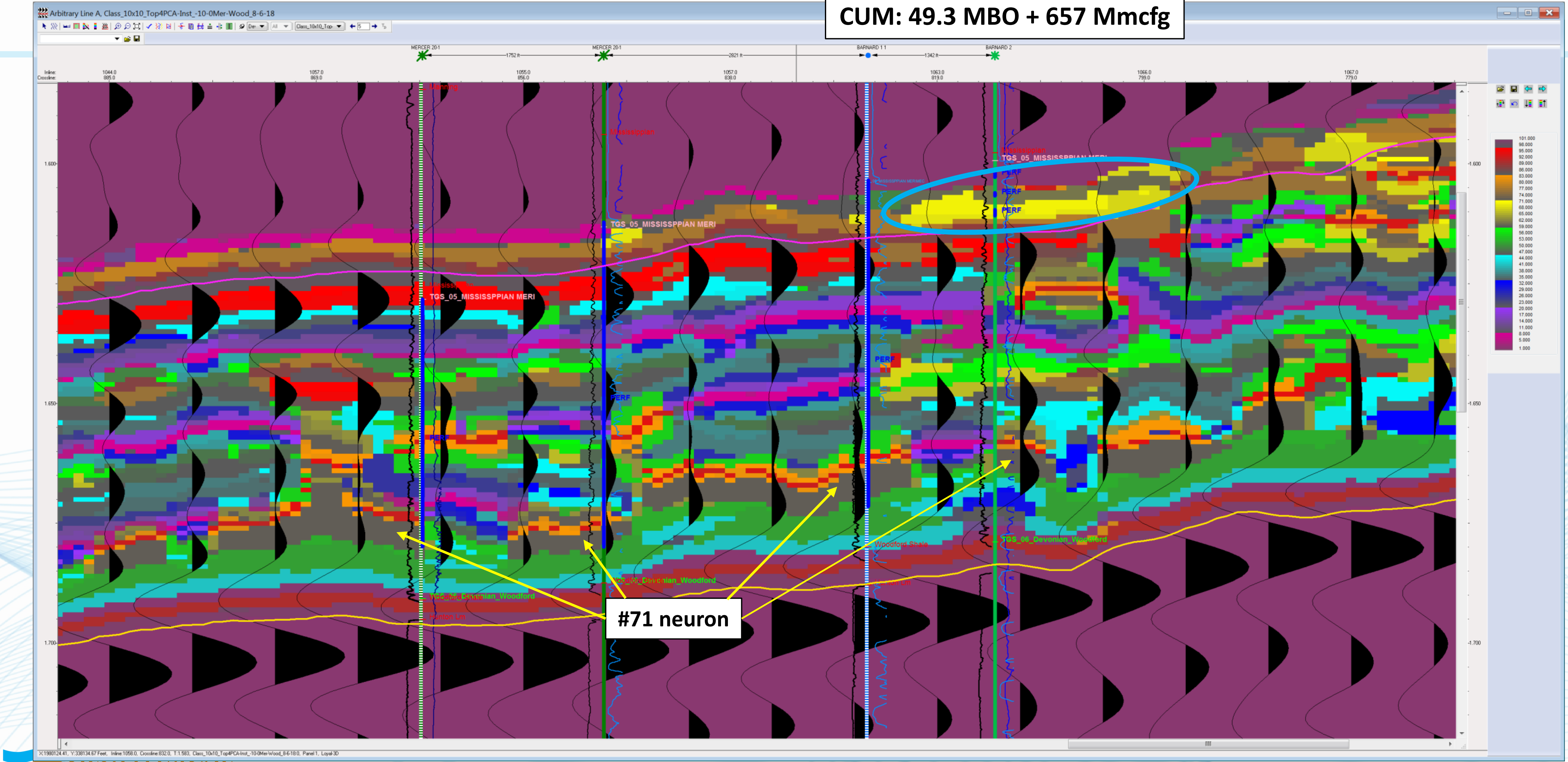
Barnard #2

These perforation in Lower Osage Fm.

X:1952438.78, Y:317628.06 Feet, Inline:872.0, Crossline:1083.0, T:1.590, PP5D-PRCMIG:-1.208, Panel 1, Loyal-3D

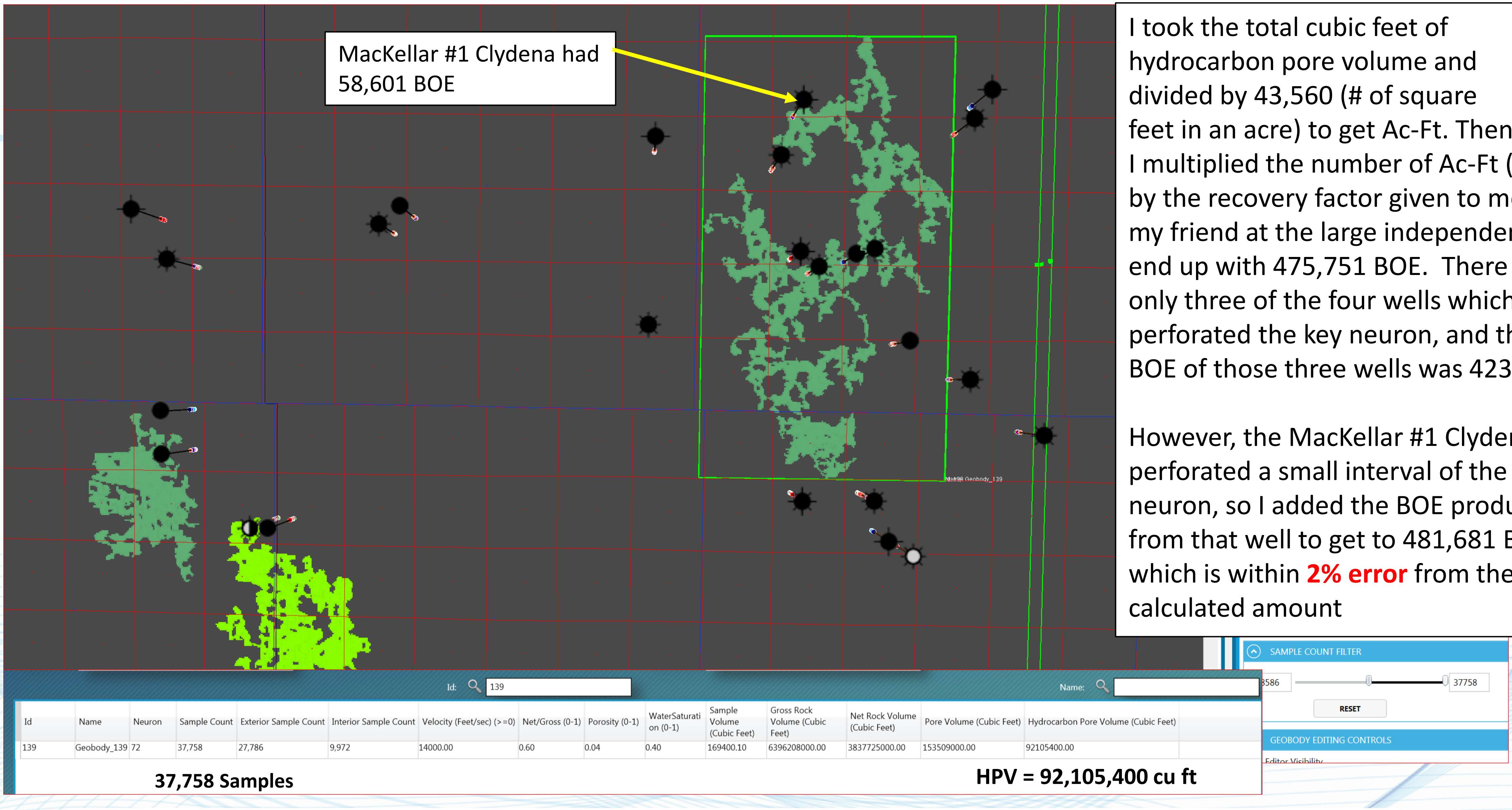
Enlarged section from previous line in Paradise SOM

Barnard
CUM: 49.3 MBO + 657 Mmcfg



X:1980124.41, Y:338134.67 Feet, Inline:1058.0, Crossline:832.0, T:1.583, Class_10x10_Top4PCA-Inst_-10-0Mer-Wood_8-6-18.0, Panel 1, Loyal-3D

#71 neuron



MacKellar #1 Clydena had 58,601 BOE

Id: 139

Name:

Id	Name	Neuron	Sample Count	Exterior Sample Count	Interior Sample Count	Velocity (Feet/sec) (>=0)	Net/Gross (0-1)	Porosity (0-1)	WaterSaturation (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

3586 – 37758

37,758 Samples

HPV = 92,105,400 cu ft

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.

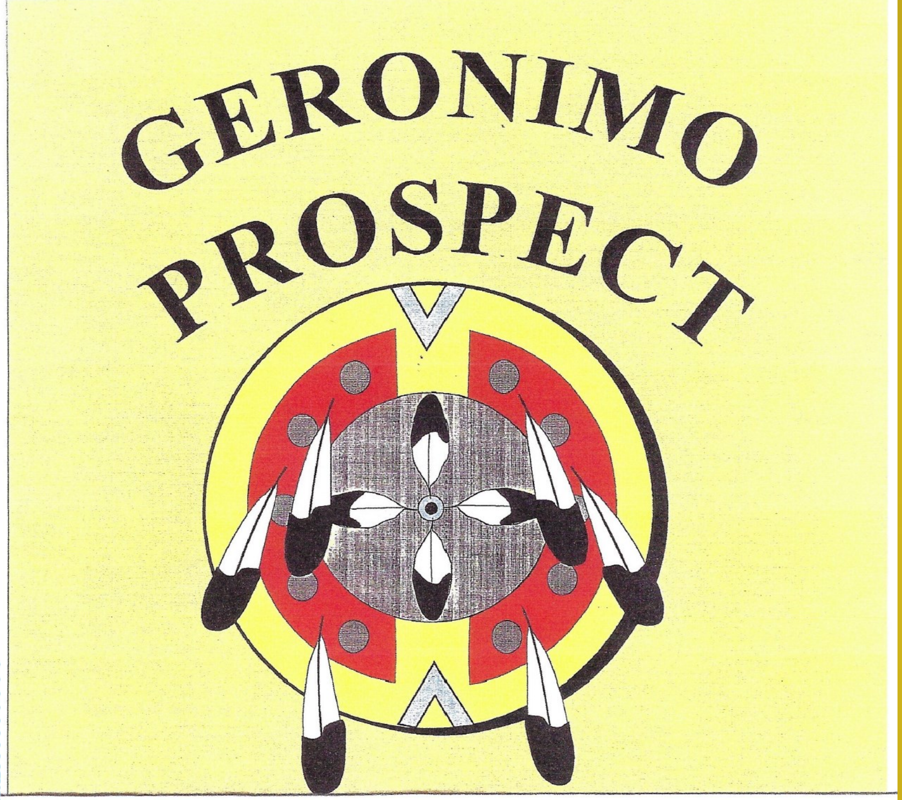
However, the MacKellar #1 Clydena perforated a small interval of the key neuron, so I added the BOE production from that well to get to 481,681 BOE, which is within **2% error** from the calculated amount

92,105,400/43,560 = 2114.4 Ac-Ft x 225 BOE/Ac-Ft = 475,751 BOE

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

PALADIN PETROLEUM III, LLC

GERONIMO PROSPECT



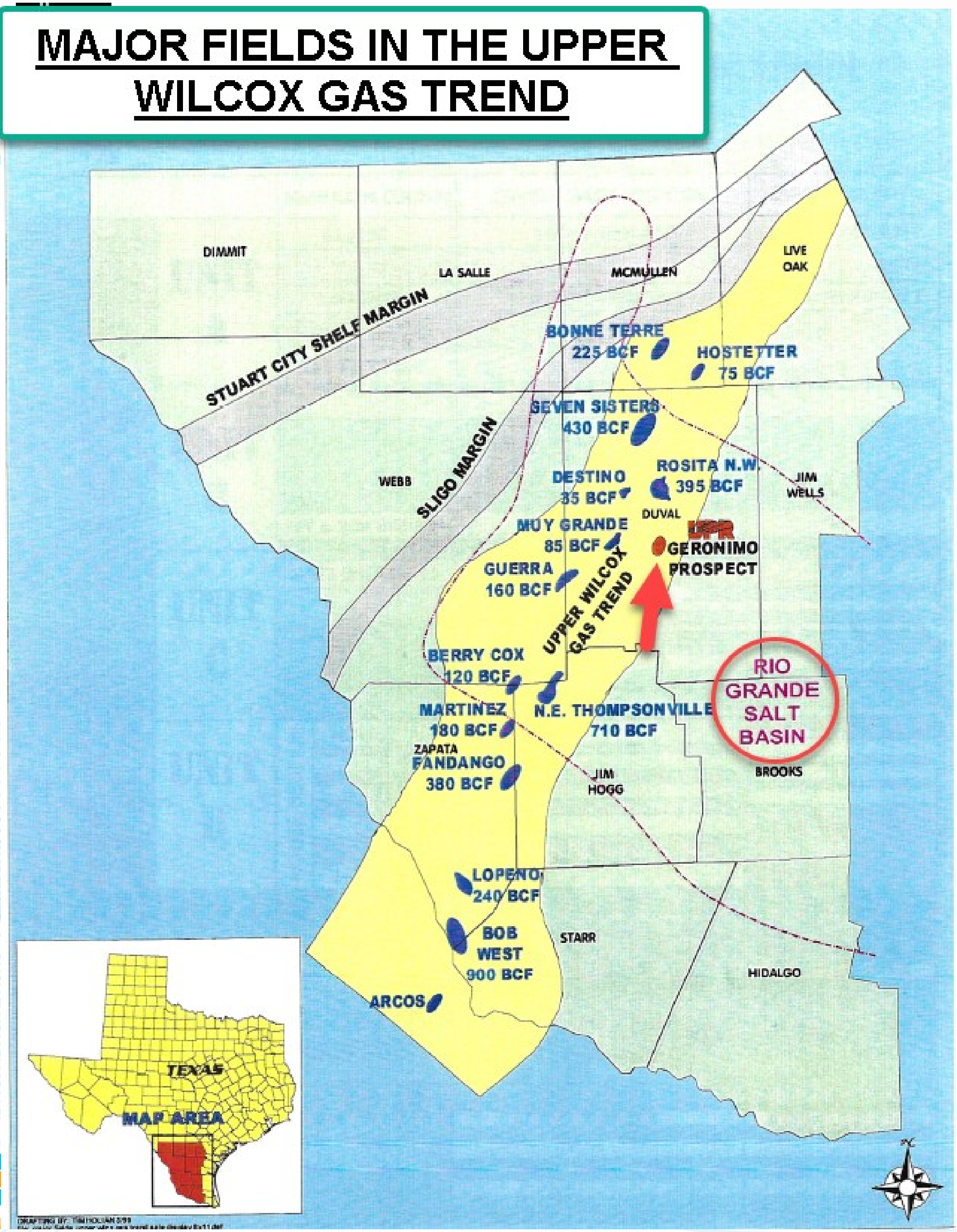
An "M.L. Driven" Prospect

Upper Wilcox & Queen City Targets

Duval County , TX

ORR ENERGY GROUP

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.

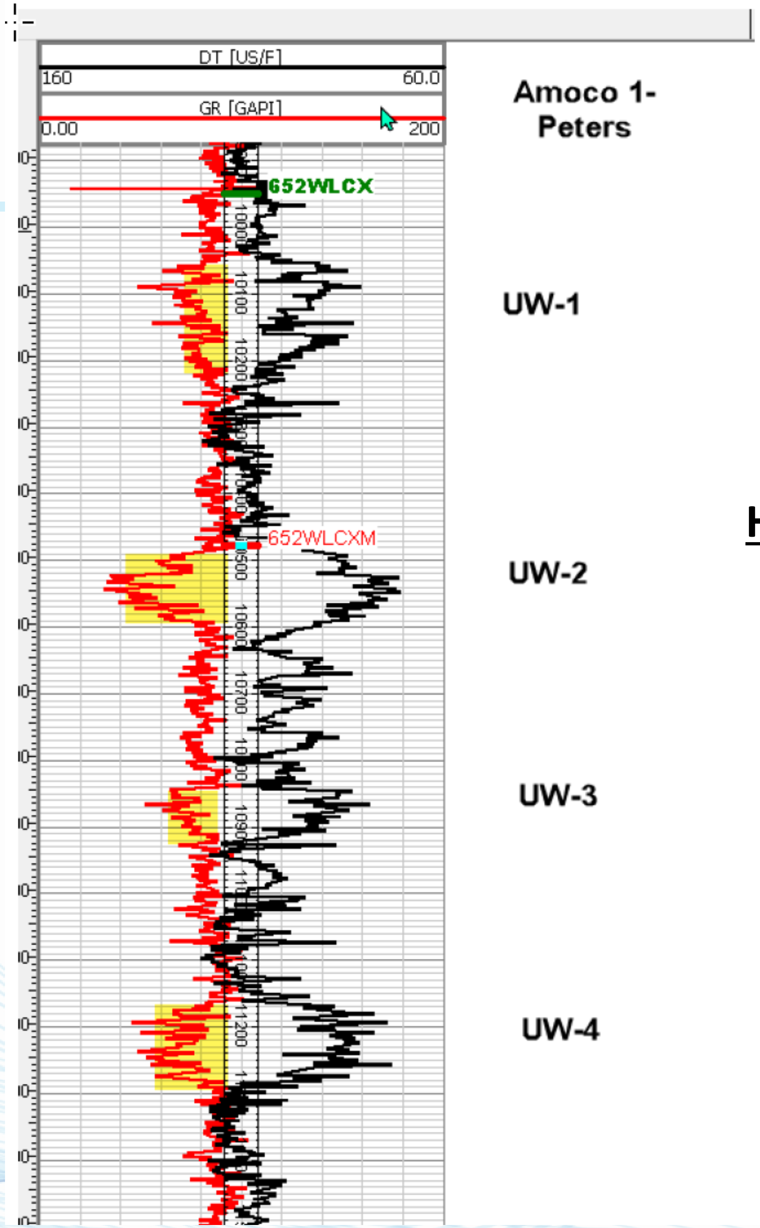
Additional potential can be seen in the Queen City Fm., which would be a non-pipe test at about 9000 feet.

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

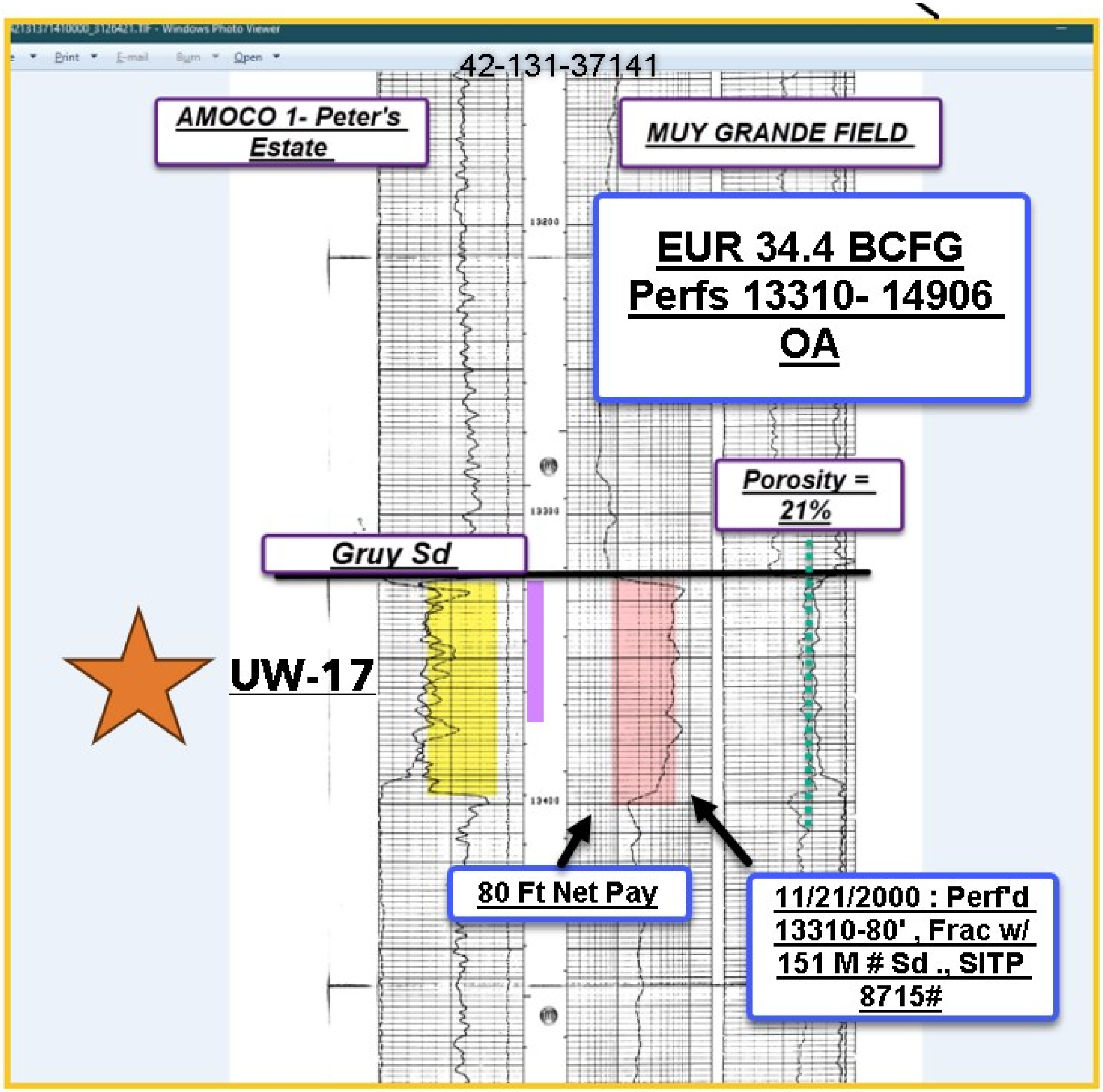
UW-3

UW-4

HINNANT SAND SERIES

Sonic Porosities : 22-28%

ANALOG UW – 17 PAY FOR WEST LOCATION



42-131-37141

AMOCO 1- Peter's Estate

MUY GRANDE FIELD

EUR 34.4 BCFG
Perfs 13310- 14906 OA

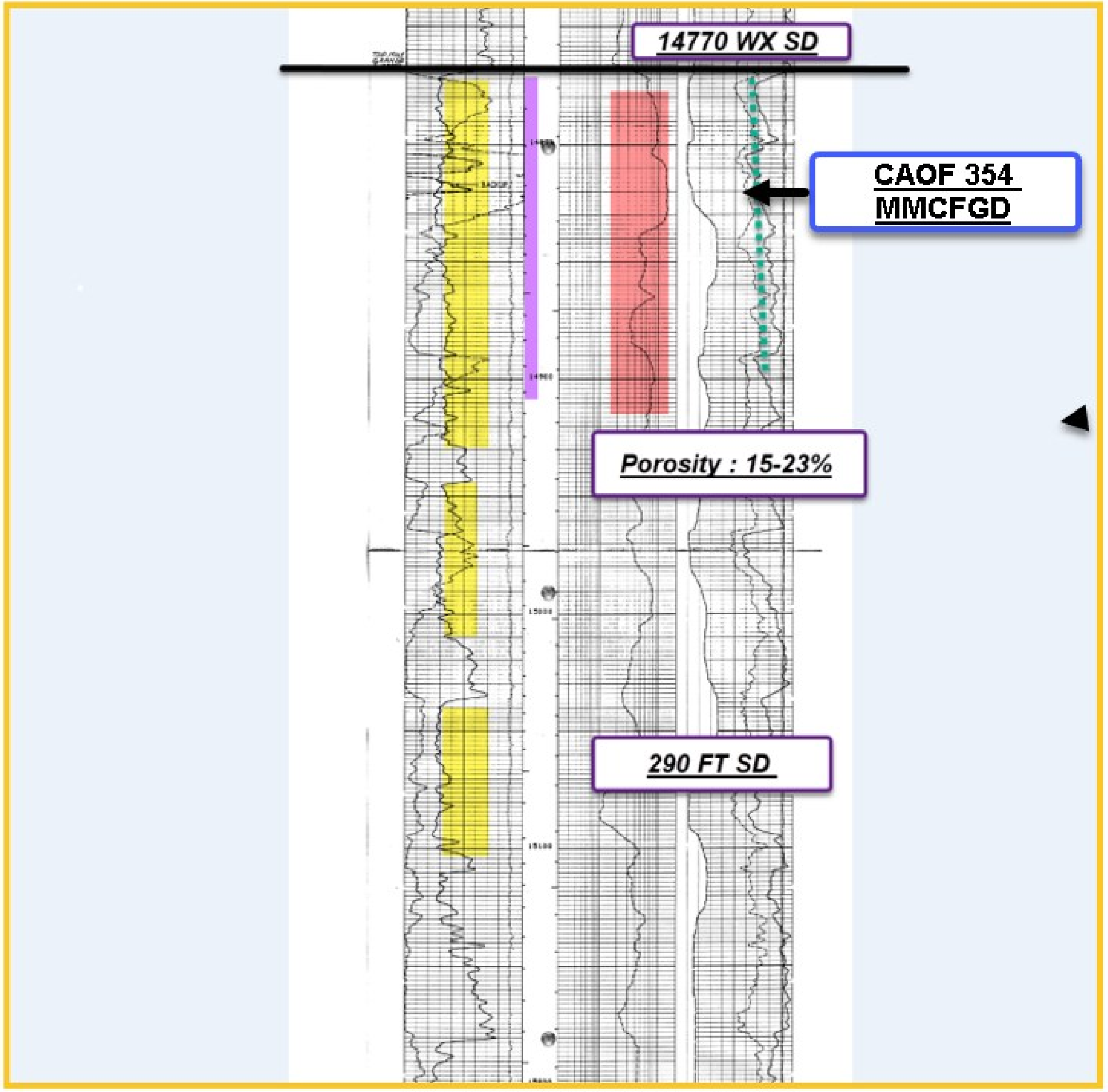
Porosity = 21%

Gruy Sd

UW-17

80 Ft Net Pay

11/21/2000 : Perf'd 13310-80' , Frac w/ 151 M # Sd ., SITP 8715#



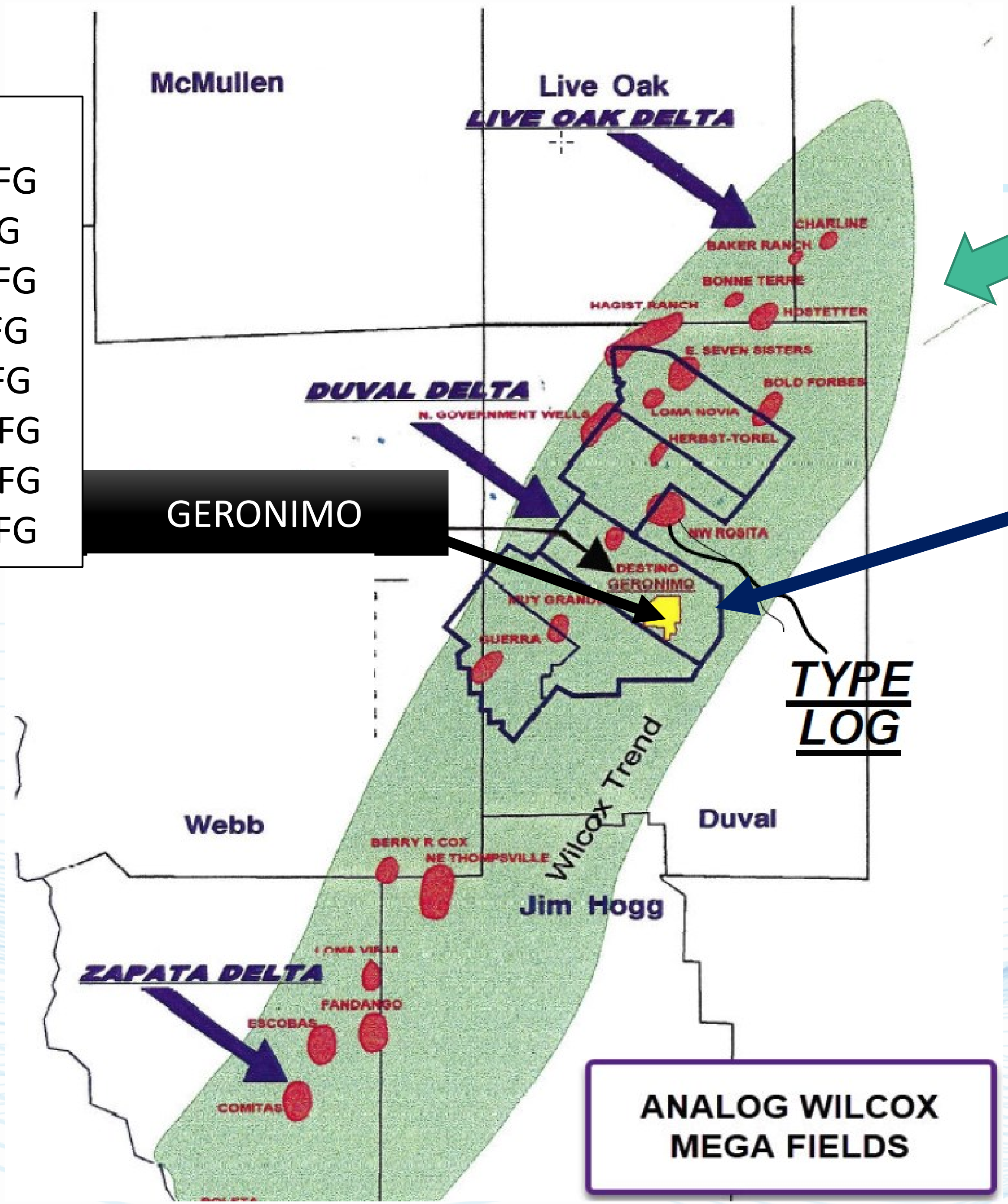
14770 WX SD

CAOF 354 MMCFGD

Porosity : 15-23%

290 FT SD

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



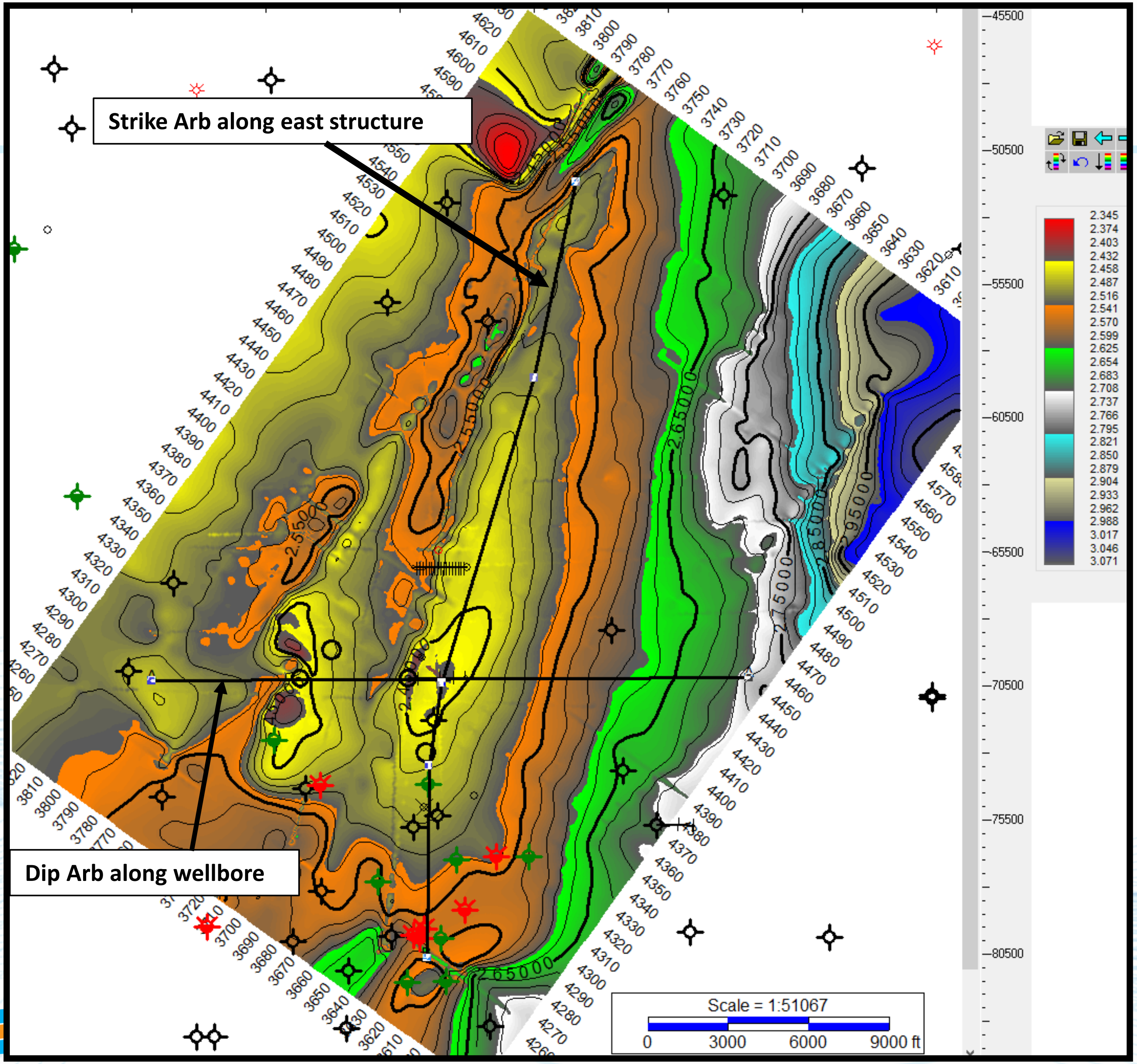
GERONIMO

TYPE LOG

ANALOG WILCOX MEGA FIELDS

WILCOX TREND SOUTH TEXAS

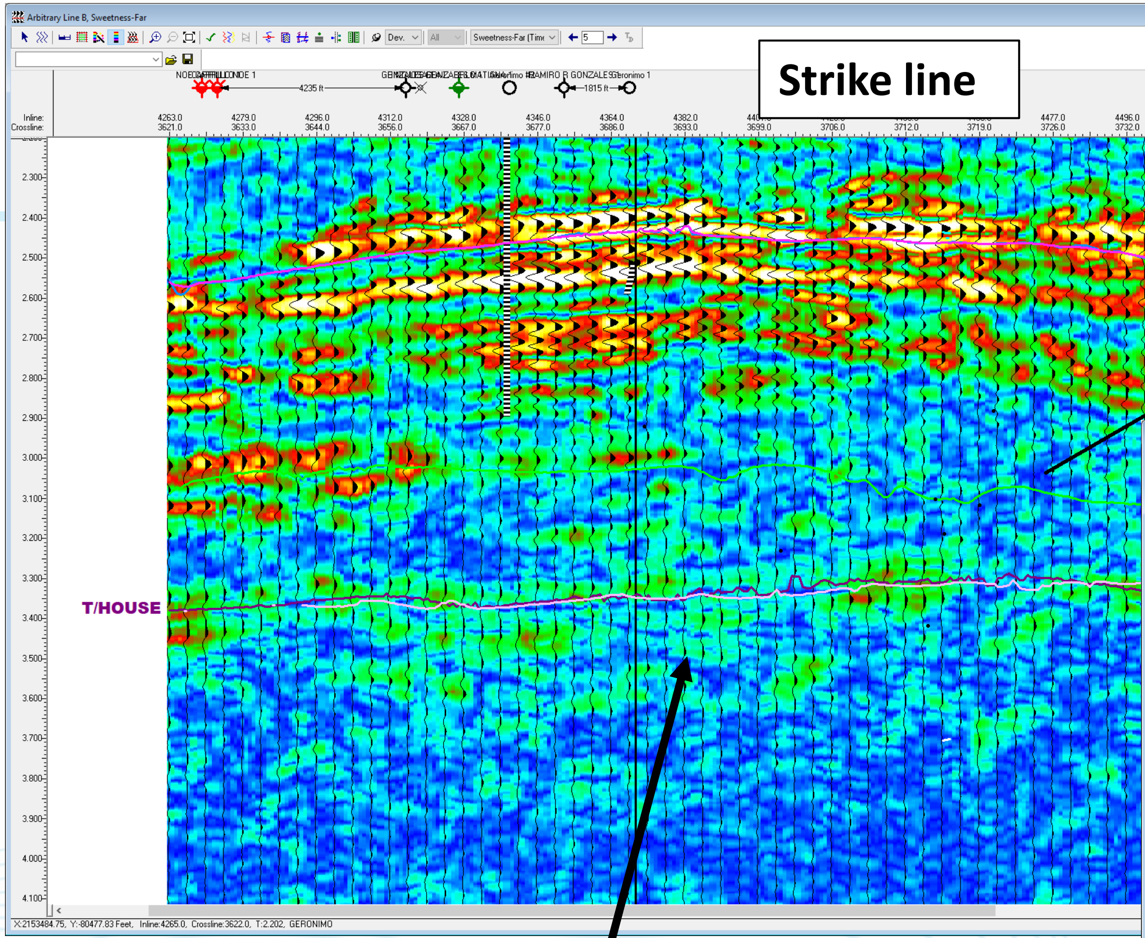
650 Sq.Mi Western Geco 3D Spec Shoot

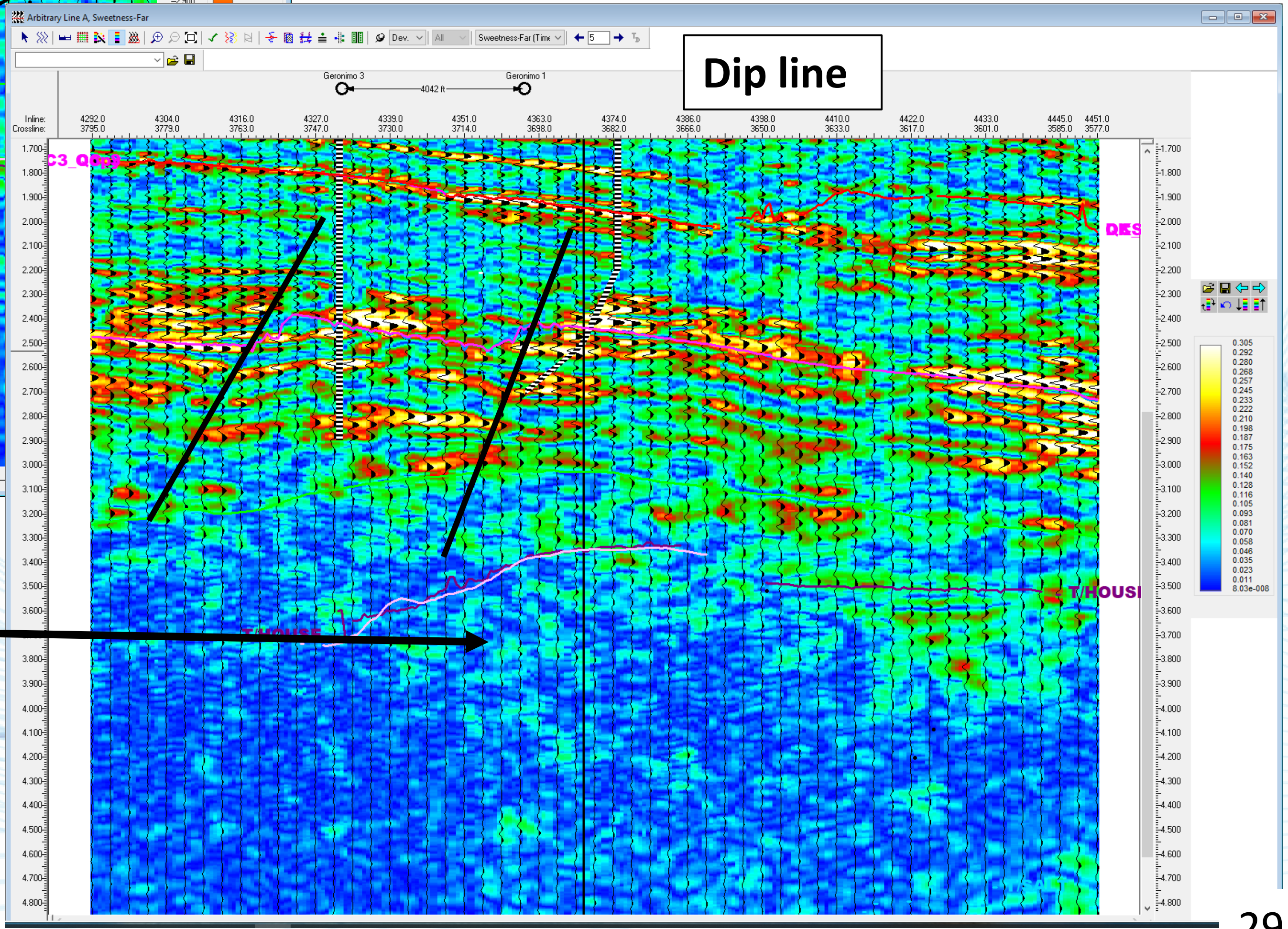


Time Structure Grid of Near Top Wilcox

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.





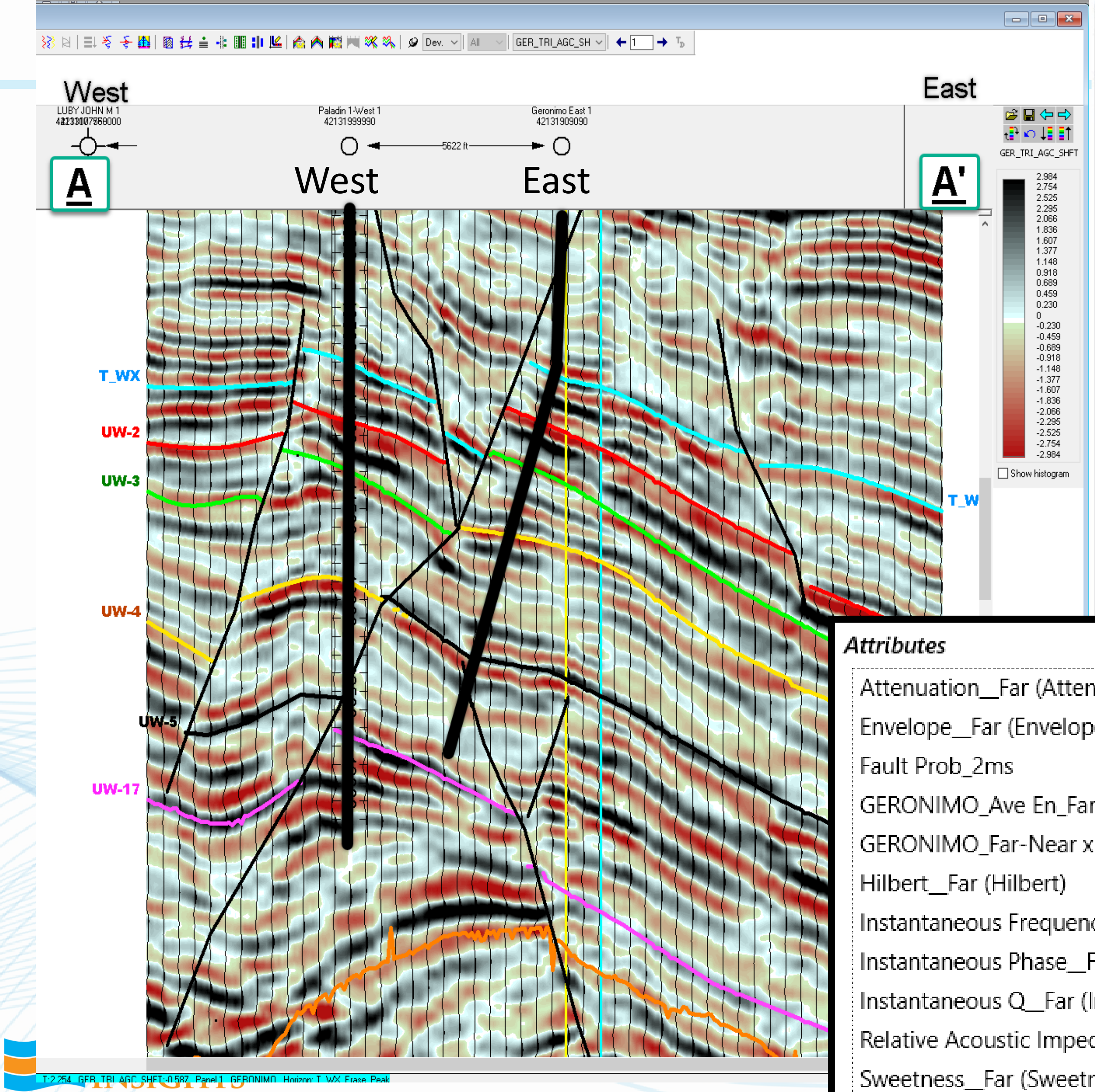
Presence of Upper Wilcox Sands by use of **Sweetness Attribute**. Sweetness is derived by taking the Envelope and dividing by square root of the frequency.

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

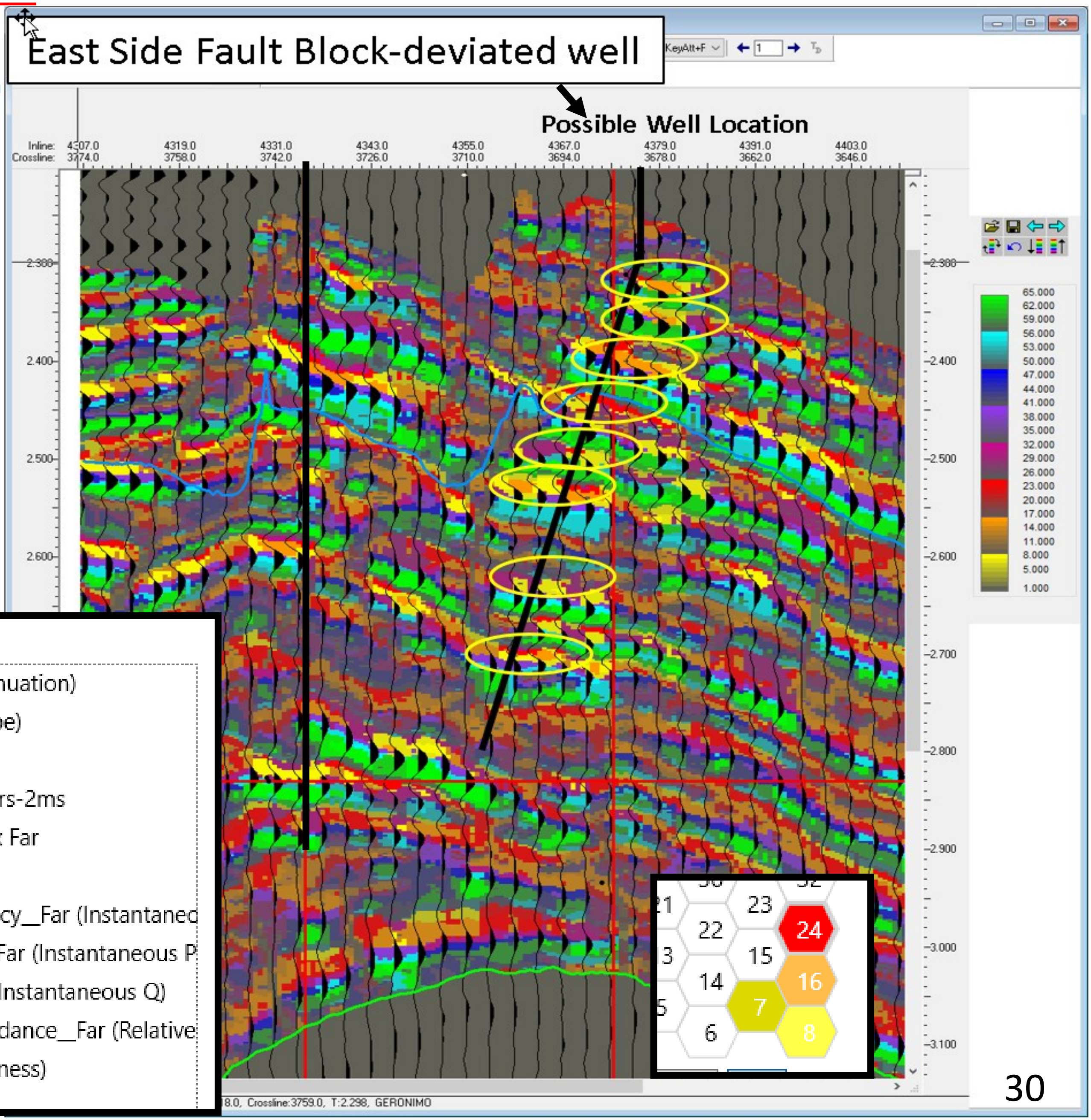
GEOPHYSICAL INSIGHTS
FROM INSIGHT TO FORESIGHT

Dip Line along proposed well bore

Tricon PSTM



Paradise ML Software

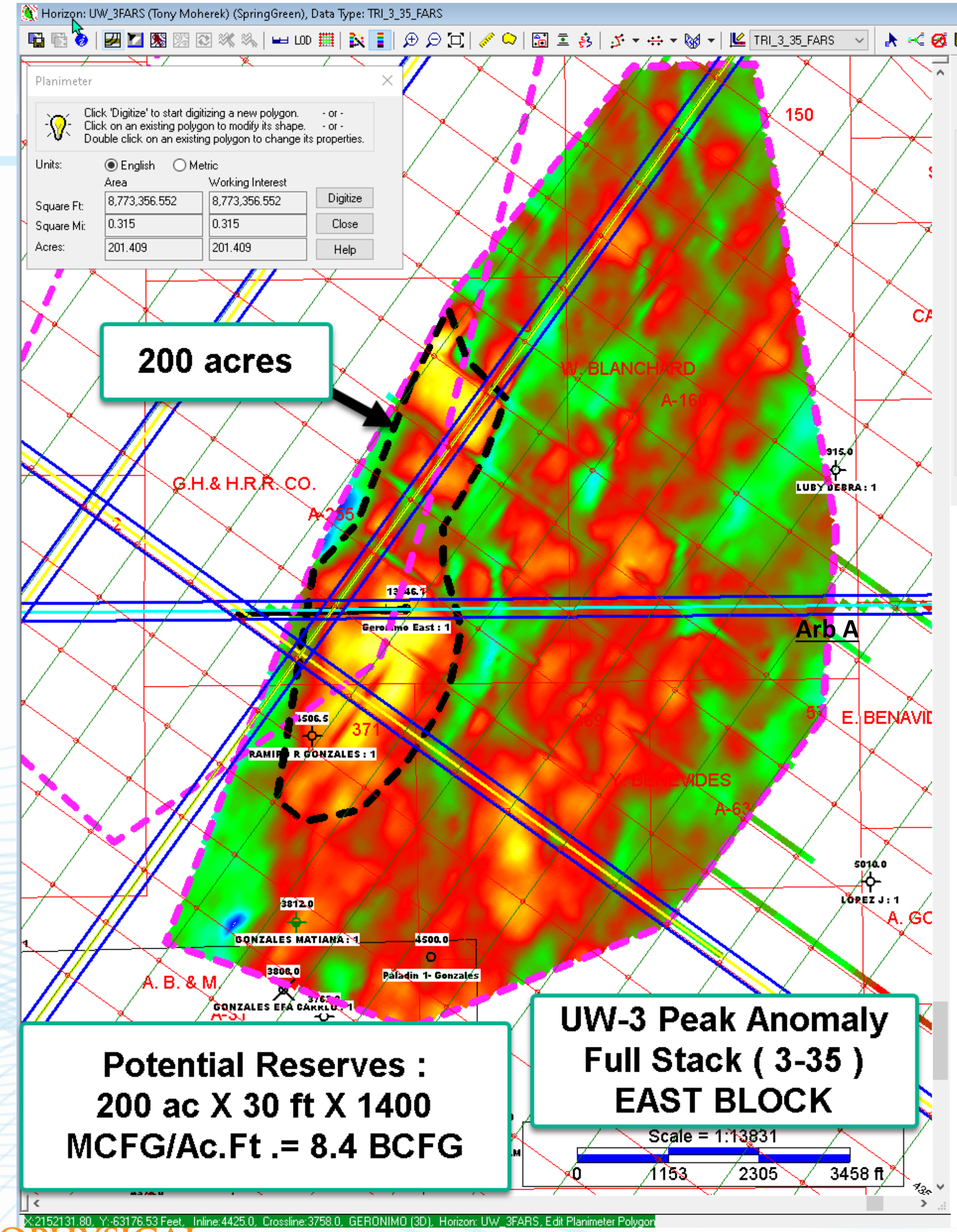


East Side Fault Block-deviated well

Possible Well Location

Attributes

- Attenuation__Far (Attenuation)
- Envelope__Far (Envelope)
- Fault Prob_2ms
- GERONIMO_Ave En_Fars-2ms
- GERONIMO_Far-Near x Far
- Hilbert__Far (Hilbert)
- Instantaneous Frequency__Far (Instantaneo
- Instantaneous Phase__Far (Instantaneous P
- Instantaneous Q__Far (Instantaneous Q)
- Relative Acoustic Impedance__Far (Relative
- Sweetness__Far (Sweetness)



Planimeter

Click 'Digitize' to start digitizing a new polygon. - or -
Click on an existing polygon to modify its shape. - or -
Double click on an existing polygon to change its properties.

Units: ● English ○ Metric

	Area	Working Interest
Square Ft:	8,773,356.552	8,773,356.552
Square Mi:	0.315	0.315
Acres:	201.409	201.409

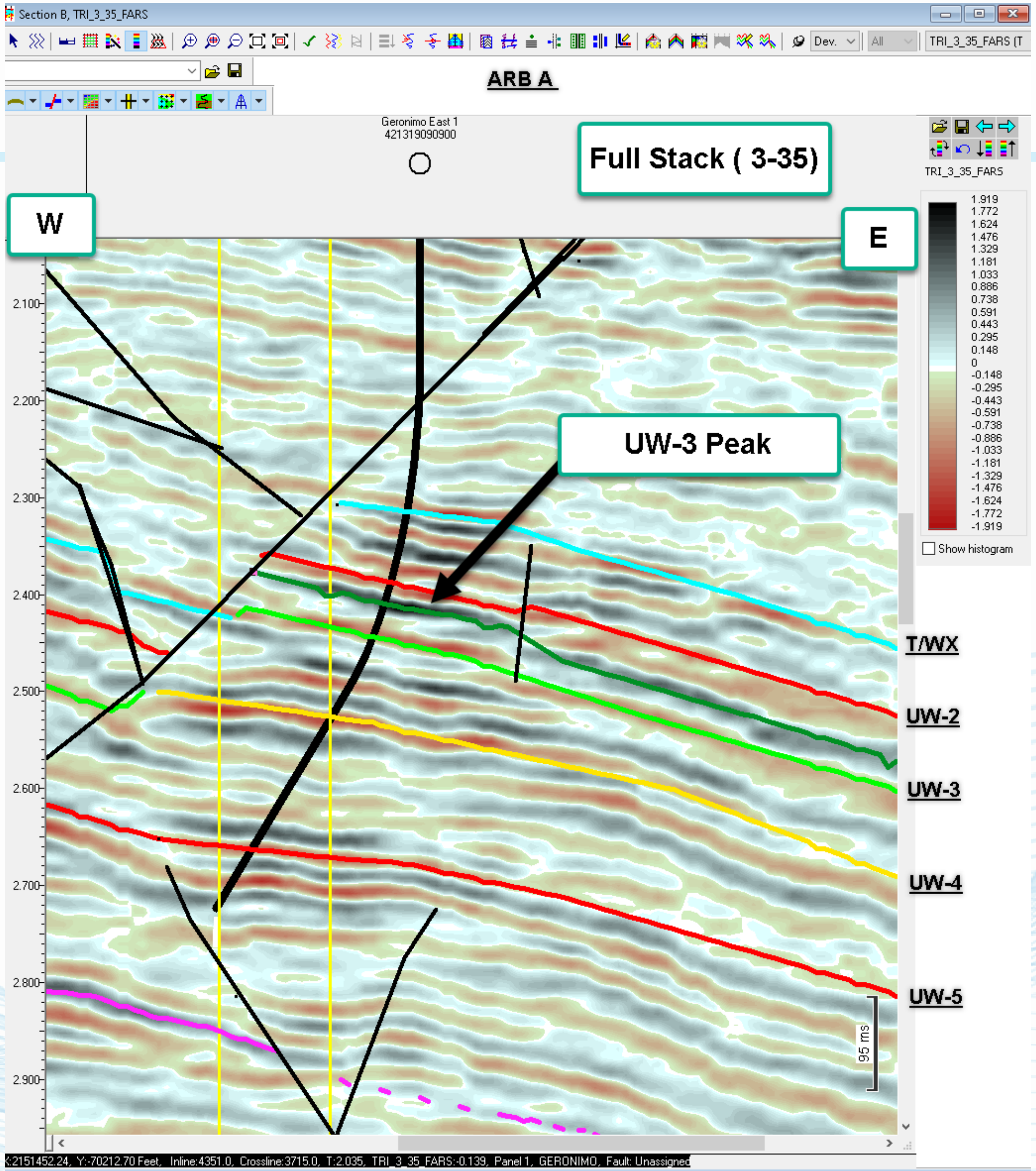
Digitize
Close
Help

X:2152131.80, Y:-63176.53 Feet, Inline:4425.0, Crossline:3758.0, GERONIMO (3D), Horizon: UW_3FARS, Edit Planimeter Polygon

200 acres

Potential Reserves :
200 ac X 30 ft X 1400 MCFG/Ac.Ft .= 8.4 BCFG

UW-3 Peak Anomaly
Full Stack (3-35)
EAST BLOCK



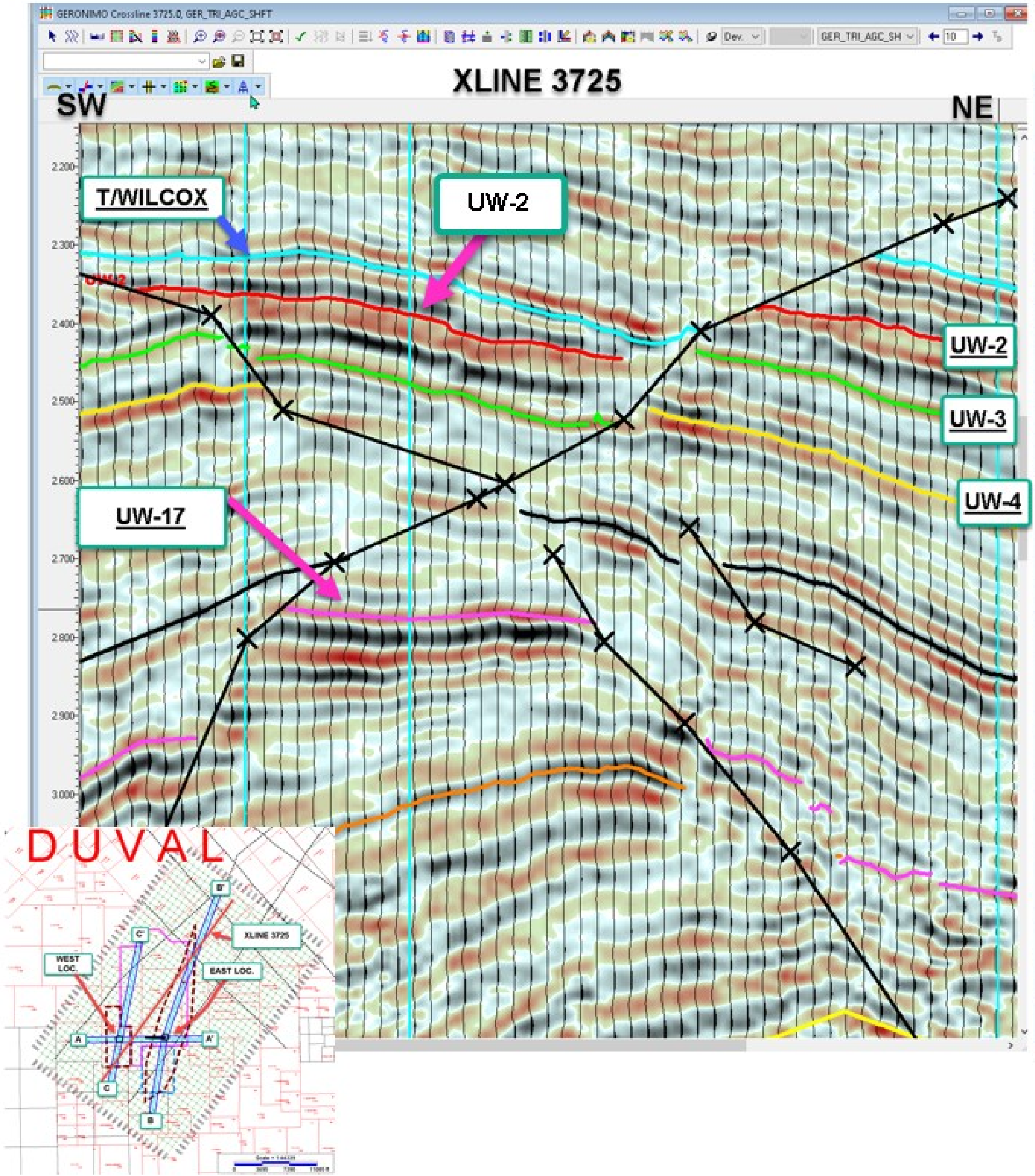
X:2151452.24, Y:-70212.70 Feet, Inline:4351.0, Crossline:3715.0, T:2.035, TRI_3_35_FARS:-0.139, Panel 1, GERONIMO, Fault: Unassigned

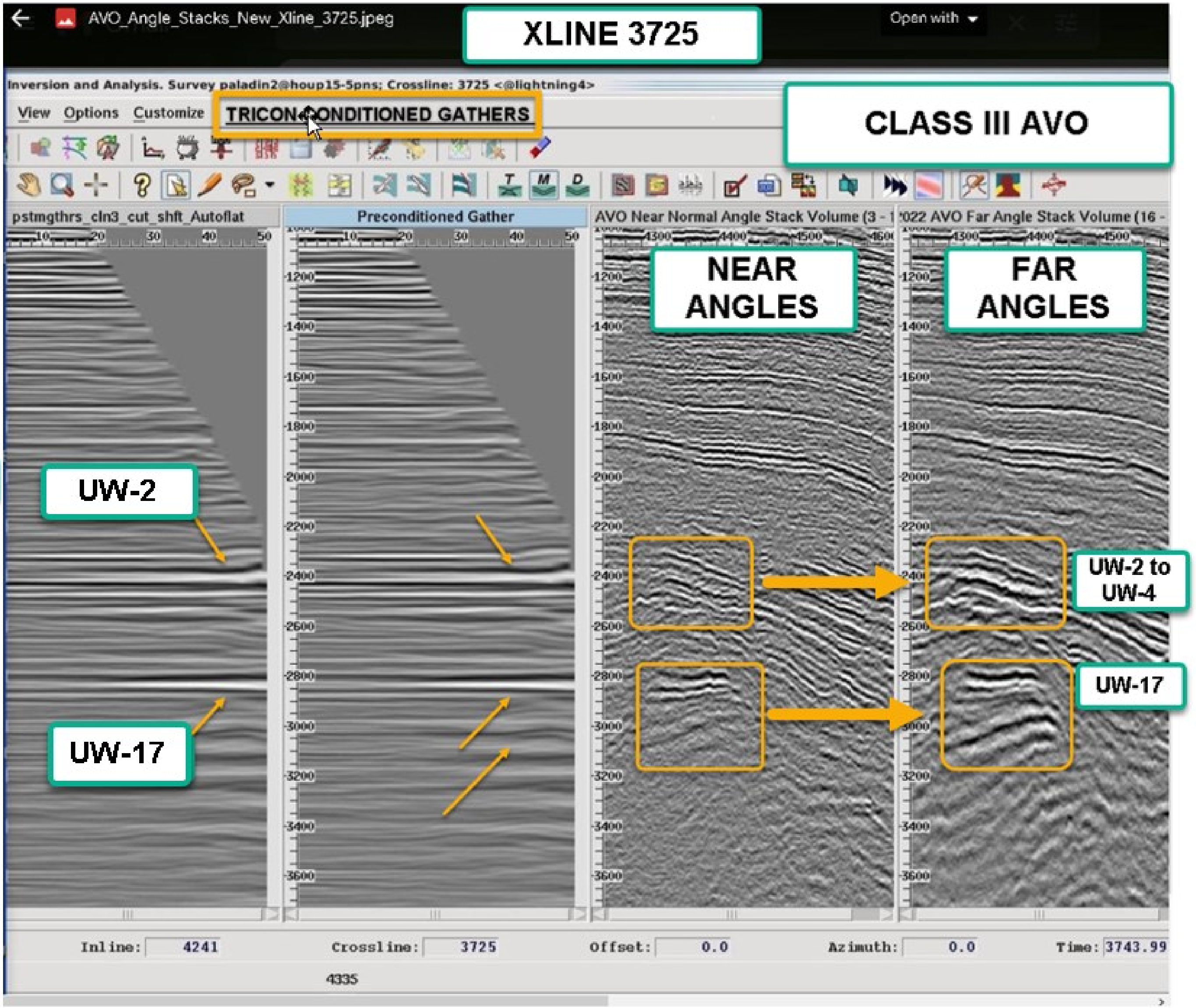
Full Stack (3-35)

UW-3 Peak

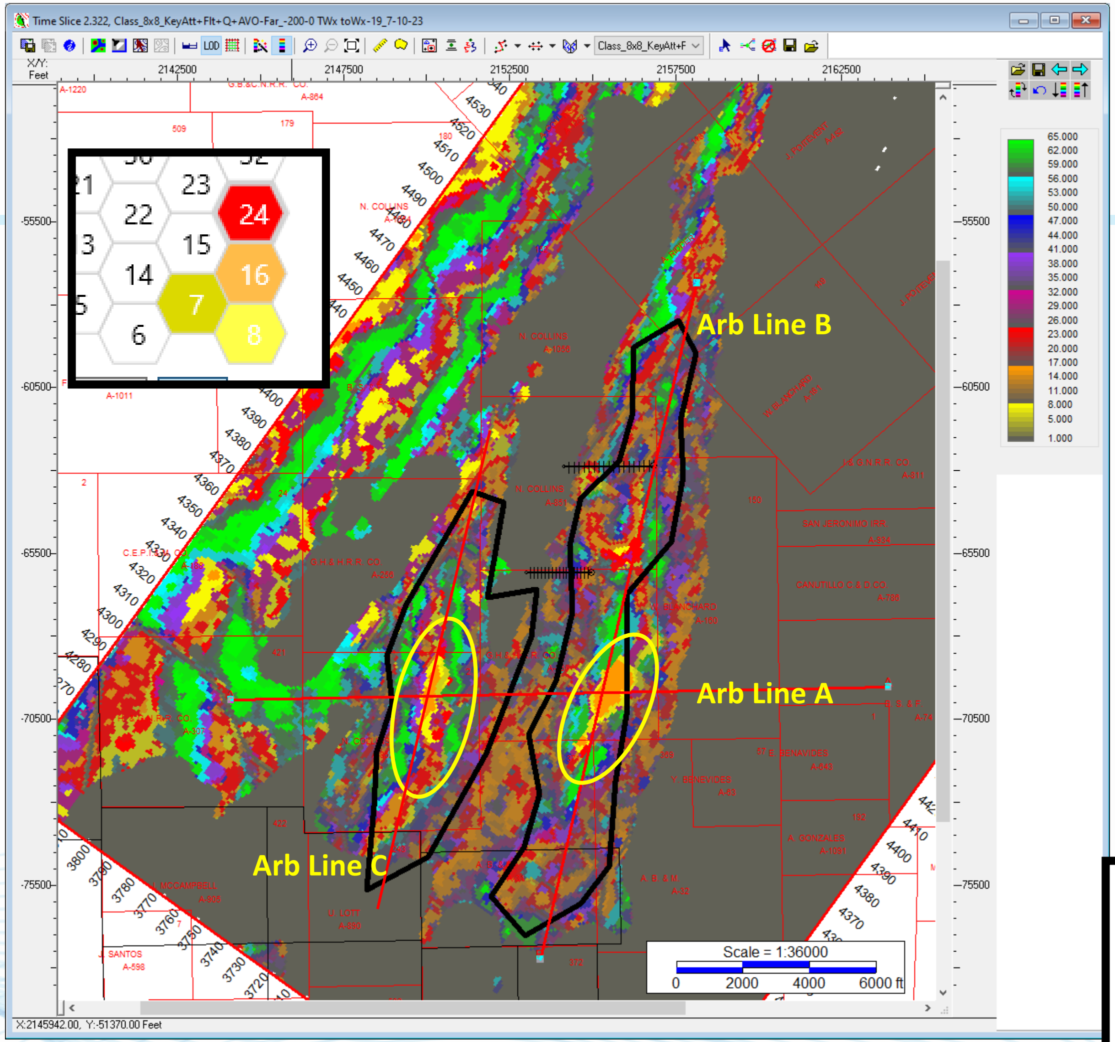
GEOPHYSICAL INSIGHTS
FROM INSIGHT TO FORESIGHT

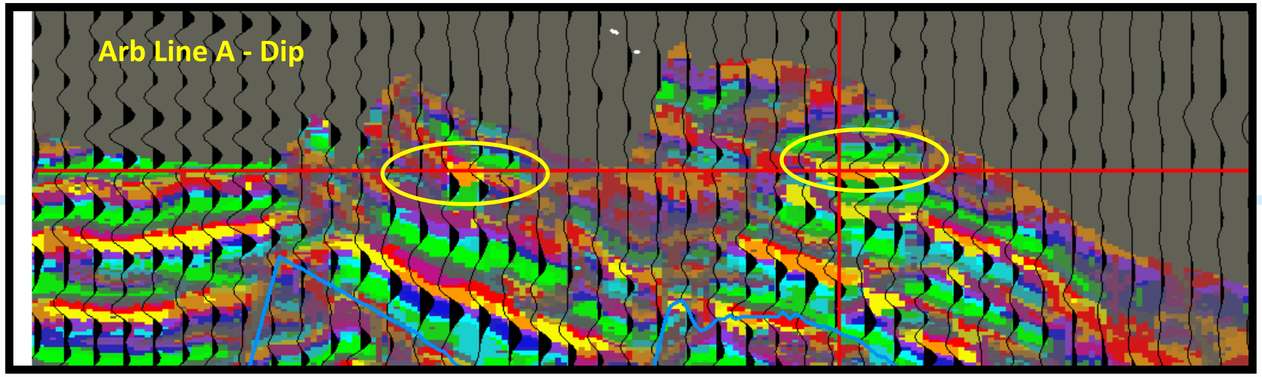
CLASS III AVO Signature Along XLINE 3725

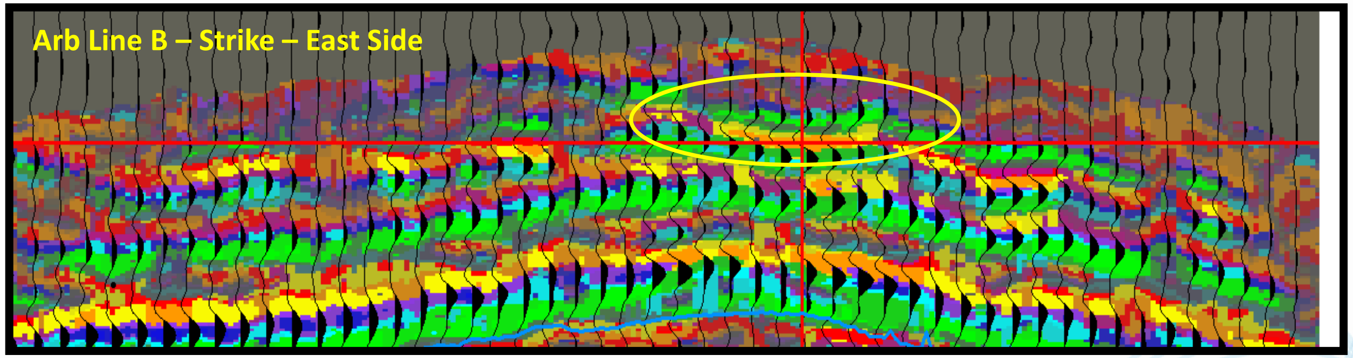


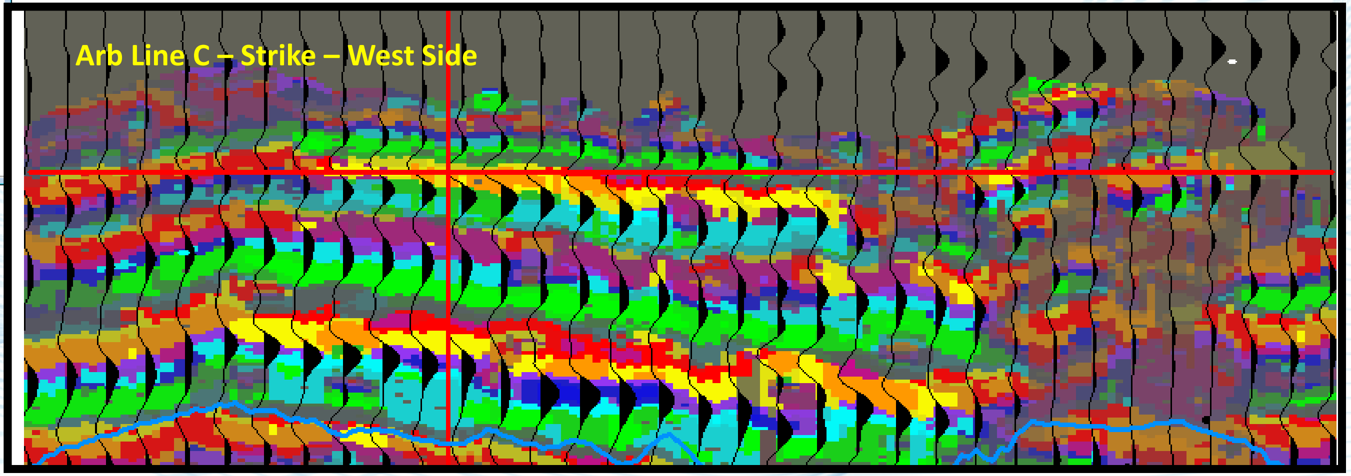


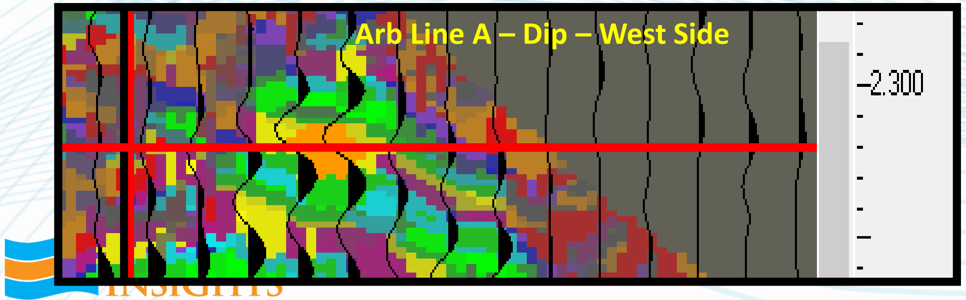
Inline: 4241
Crossline: 3725
Offset: 0.0
Azimuth: 0.0
Time: 3743.99
4335


Time Slice 2.322, Class_8x8_KeyAtt+Flt+Q+AVO-Far_-200-0 TWx toWx-19_7-10-23
Class_8x8_KeyAtt+F
X/Y: Feet
2142500
2147500
2152500
2157500
2162500
-55500
-60500
-65500
-70500
-75500
21
23
22
24
3
15
14
16
5
7
6
8
Arb Line B
Arb Line A
Arb Line C
Scale = 1:36000
0
2000
4000
6000 ft
65.000
62.000
59.000
56.000
53.000
50.000
47.000
44.000
41.000
38.000
35.000
32.000
29.000
26.000
23.000
20.000
17.000
14.000
11.000
8.000
5.000
1.000
X:2145942.00, Y:-51370.00 Feet

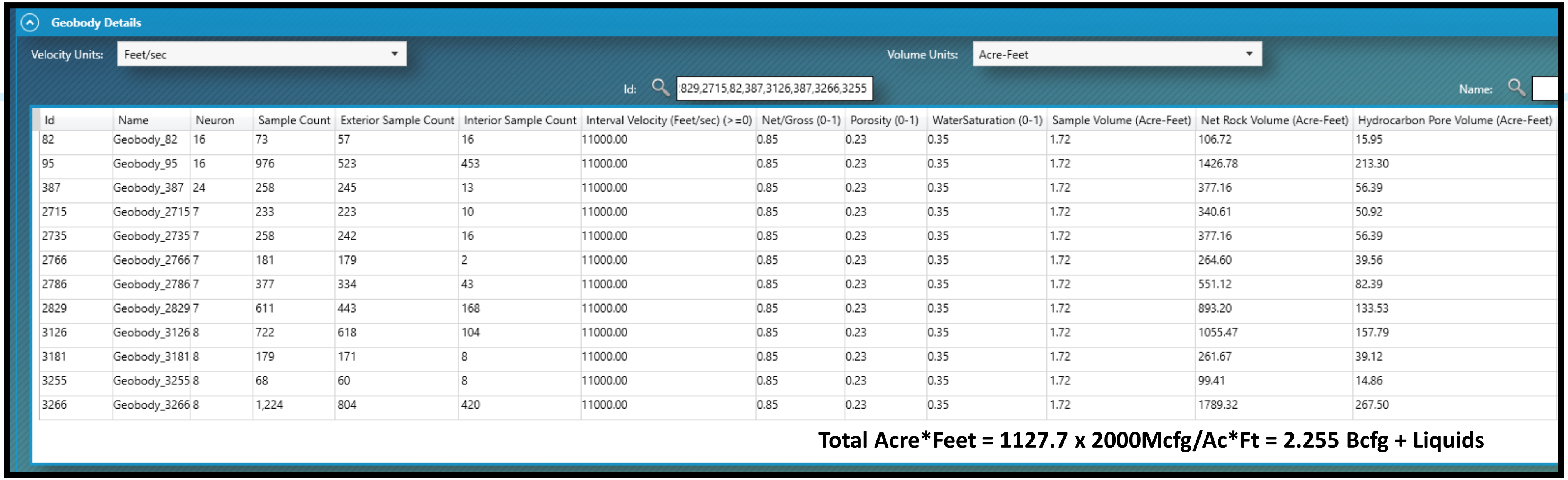

Arb Line A - Dip


Arb Line B – Strike – East Side


Arb Line C – Strike – West Side


Arb Line A – Dip – West Side
-2.300

Upper Sand – West Side



Velocity Units: Feet/sec

Volume Units: Acre-Feet

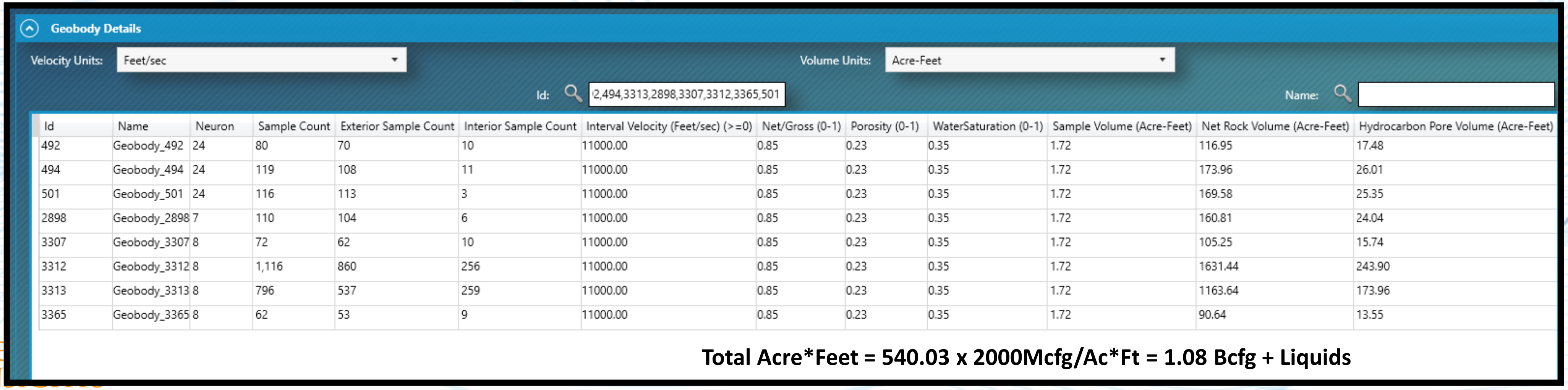
Id: 829,2715,82,387,3126,387,3266,3255

Name:

Id	Name	Neuron	Sample Count	Exterior Sample Count	Interior Sample Count	Interval Velocity (Feet/sec) (>=0)	Net/Gross (0-1)	Porosity (0-1)	WaterSaturation (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



Velocity Units: Feet/sec

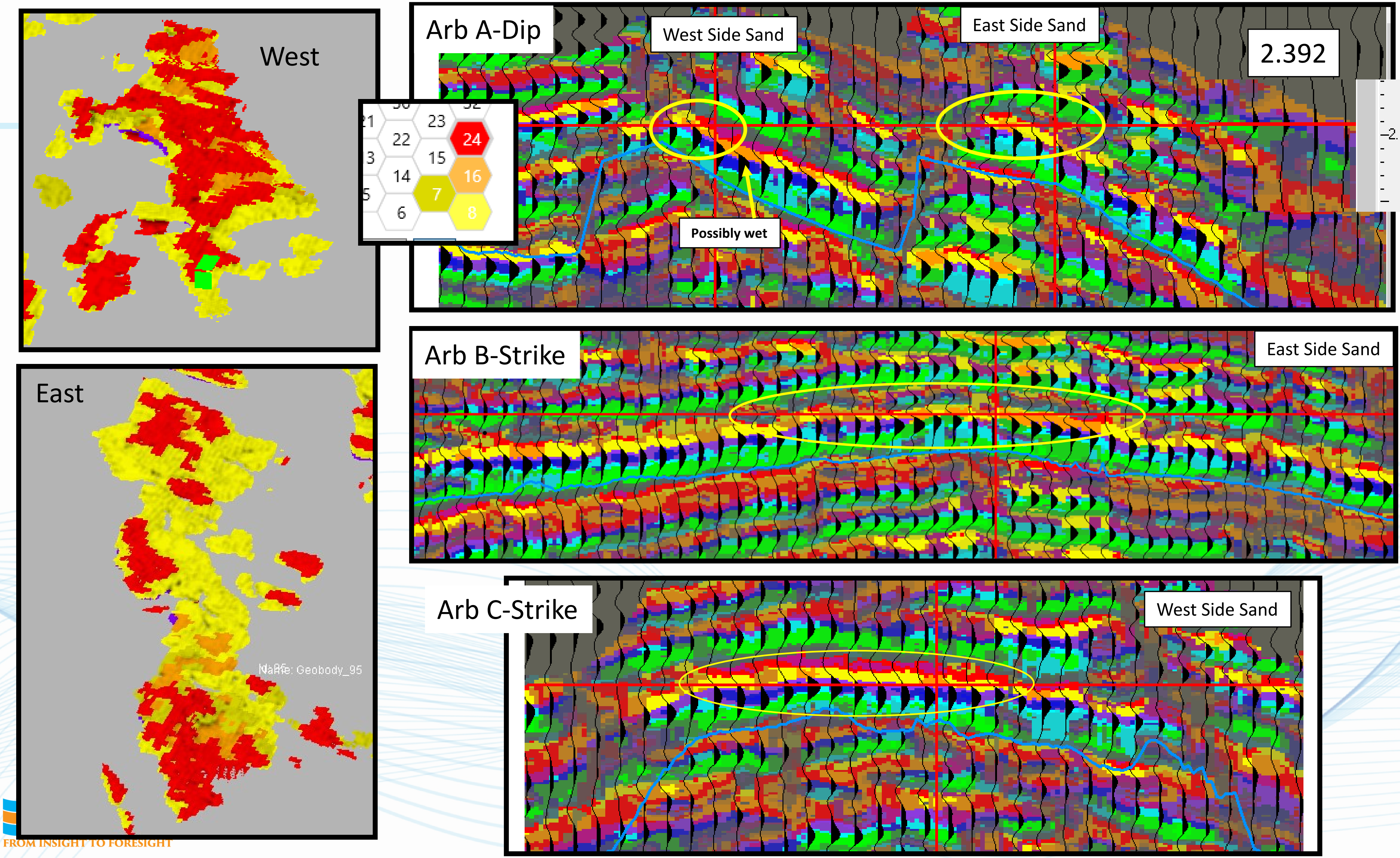
Volume Units: Acre-Feet

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)	WaterSaturation (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



Arb A-Dip

West Side Sand

East Side Sand

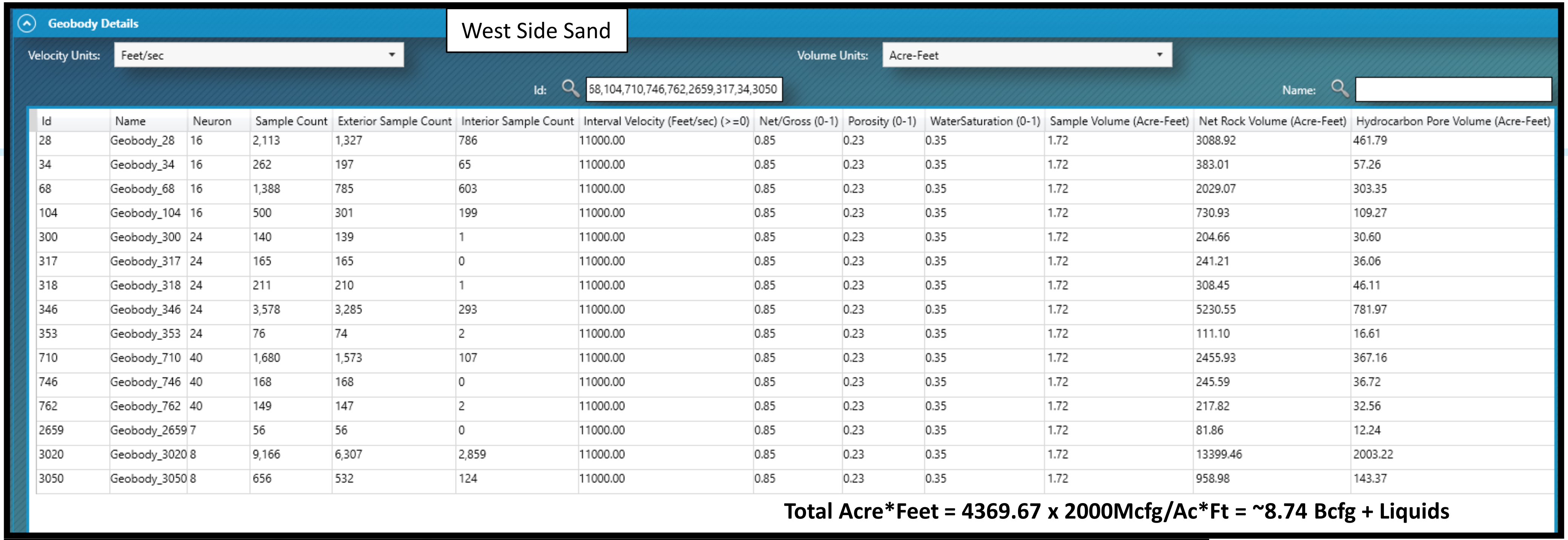
Possibly wet

Arb B-Strike

East Side Sand

Arb C-Strike

West Side Sand



Velocity Units: Feet/sec

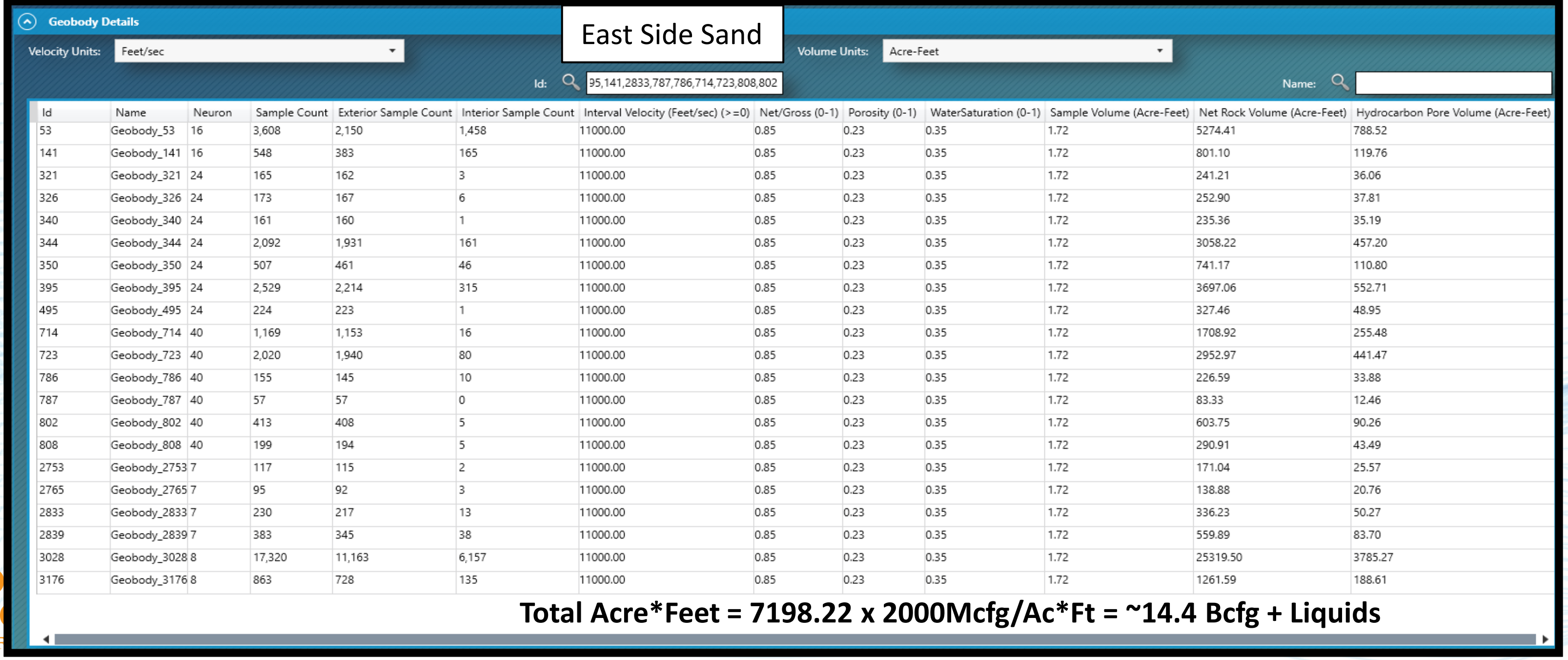
Volume Units: Acre-Feet

Id: 68,104,710,746,762,2659,317,34,3050

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



Velocity Units: Feet/sec

Volume Units: Acre-Feet

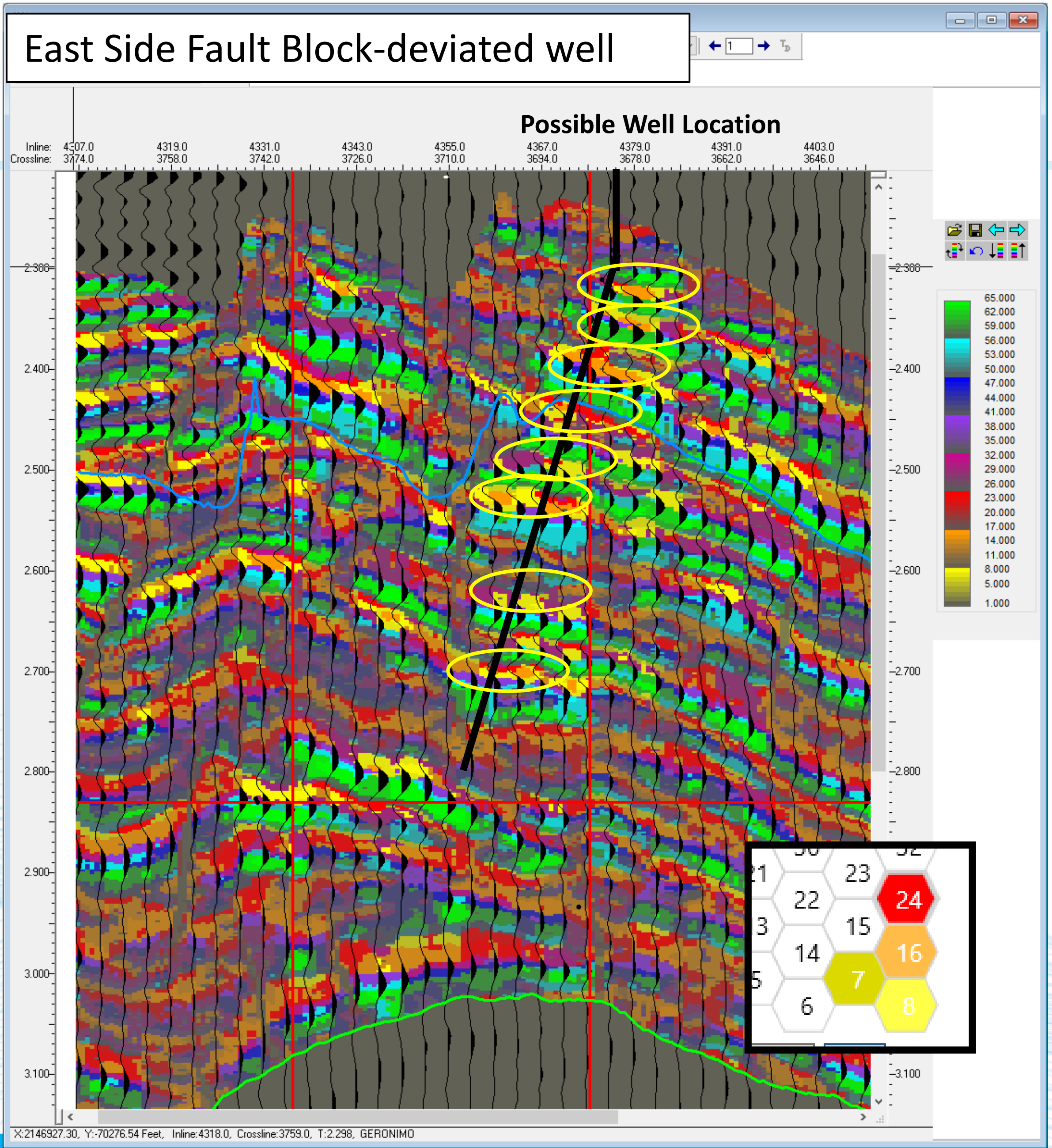
Id: 95,141,2833,787,786,714,723,808,802

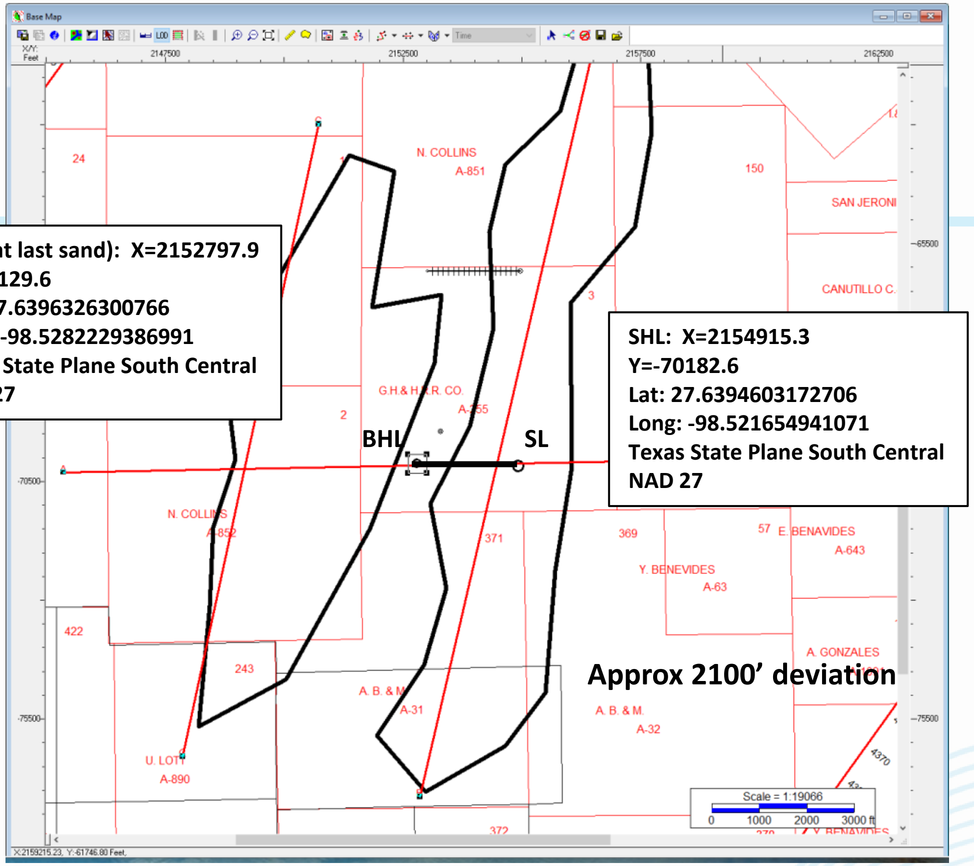
Name:

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





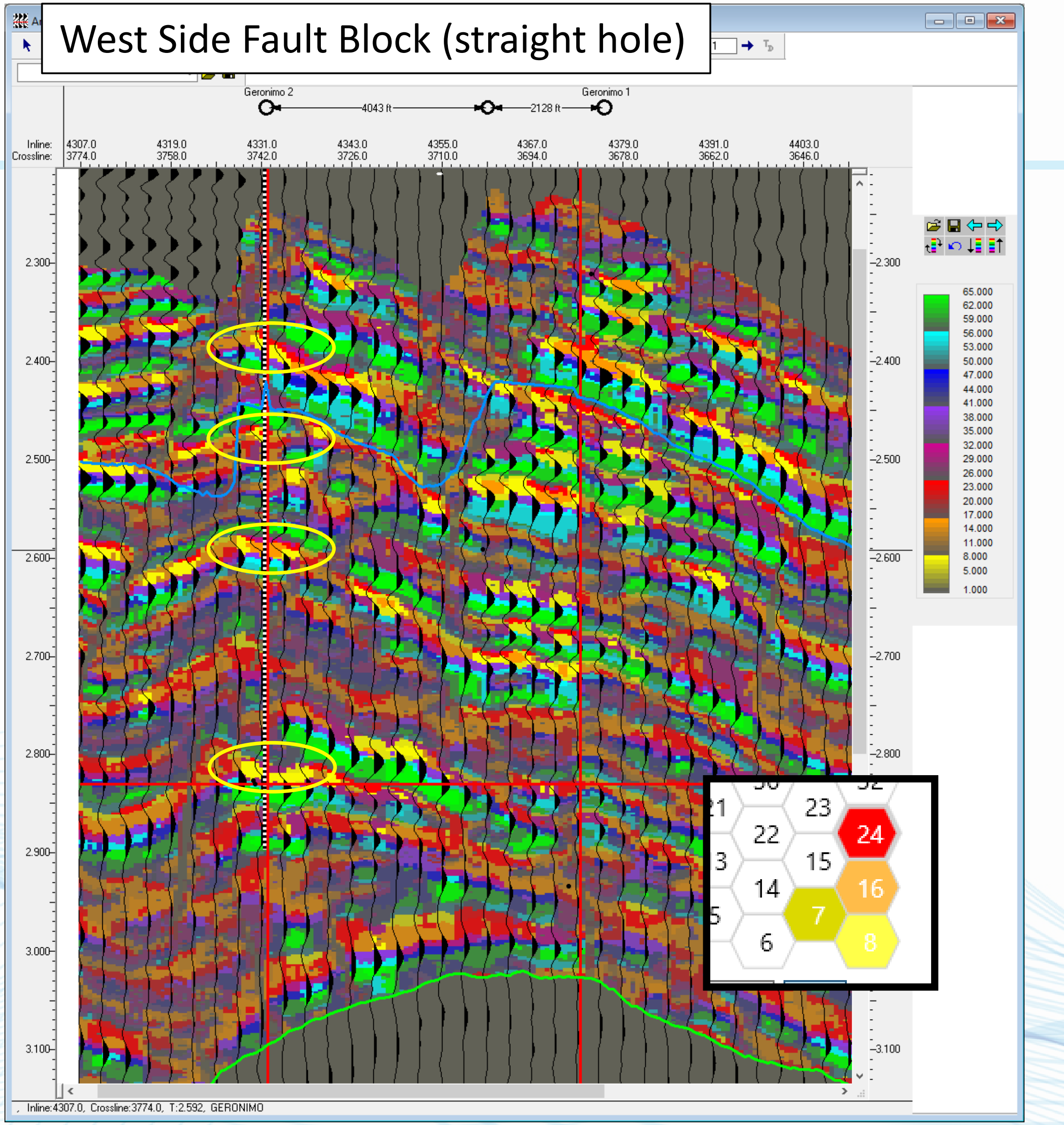
BHL (at last sand): X=2152797.9
Y=-70129.6
Lat: 27.6396326300766
Long: -98.5282229386991
Texas State Plane South Central
NAD 27

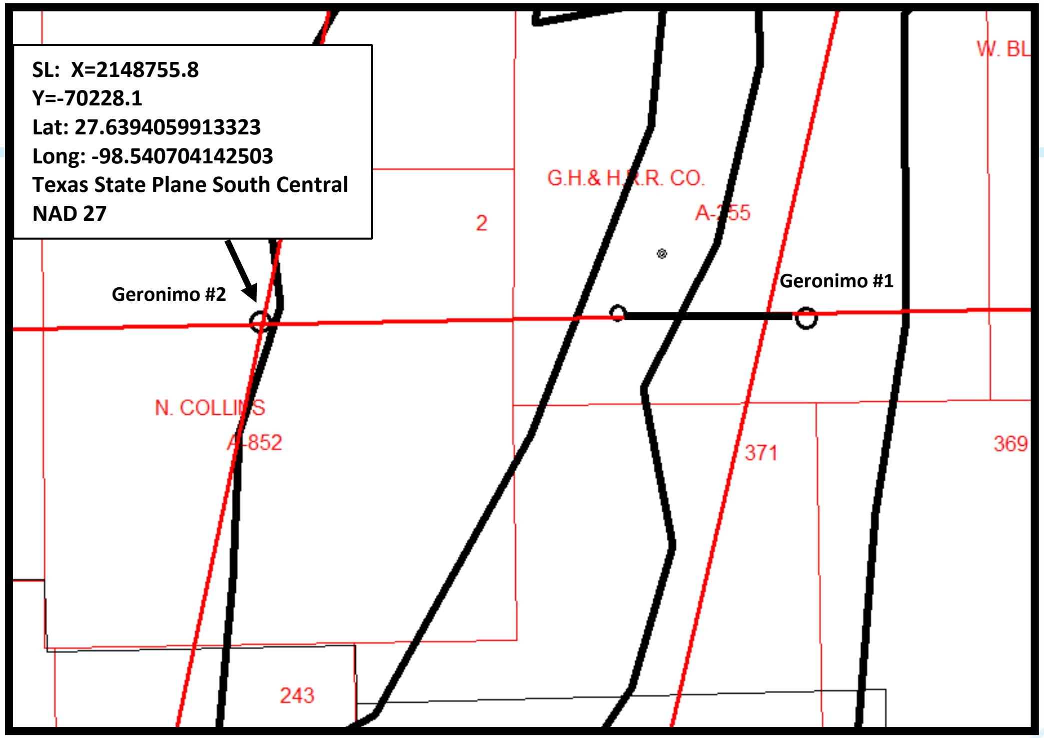
SHL: X=2154915.3
Y=-70182.6
Lat: 27.6394603172706
Long: -98.521654941071
Texas State Plane South Central
NAD 27

Approx 2100' deviation

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

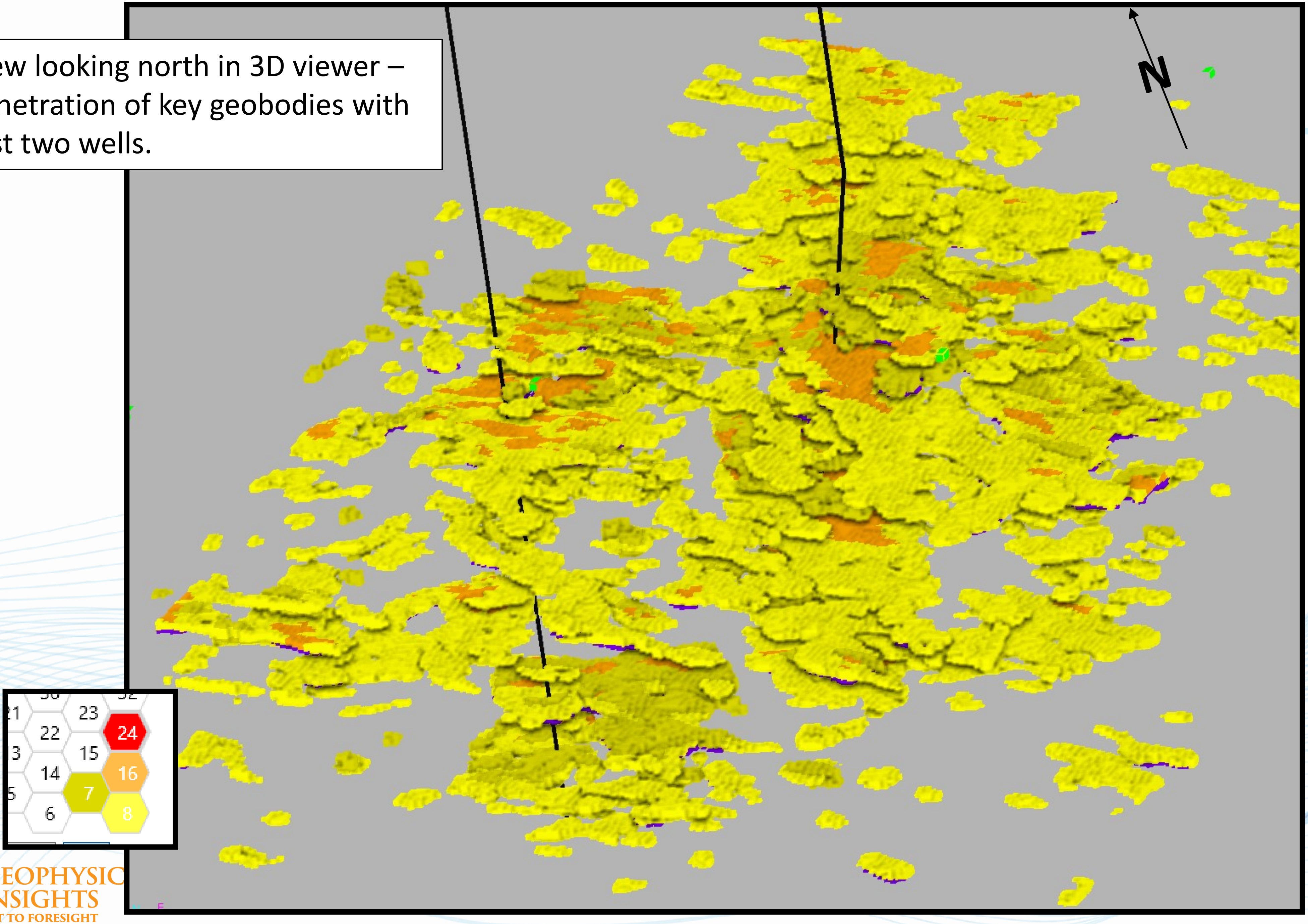
West Side Fault Block (straight hole)




SL: X=2148755.8
Y=-70228.1
Lat: 27.6394059913323
Long: -98.540704142503
Texas State Plane South Central
NAD 27

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

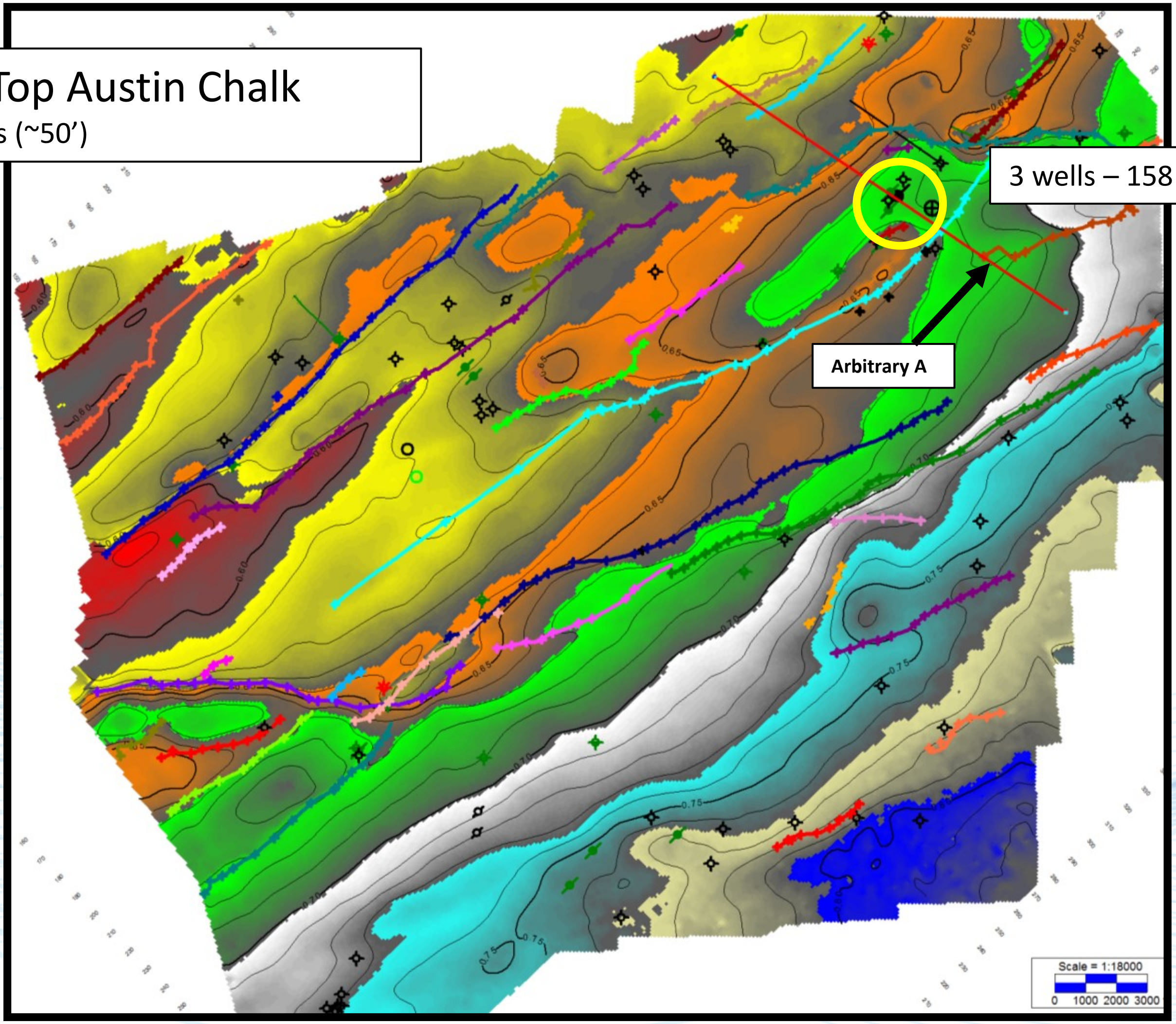
View looking north in 3D viewer – penetration of key geobodies with first two wells.



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

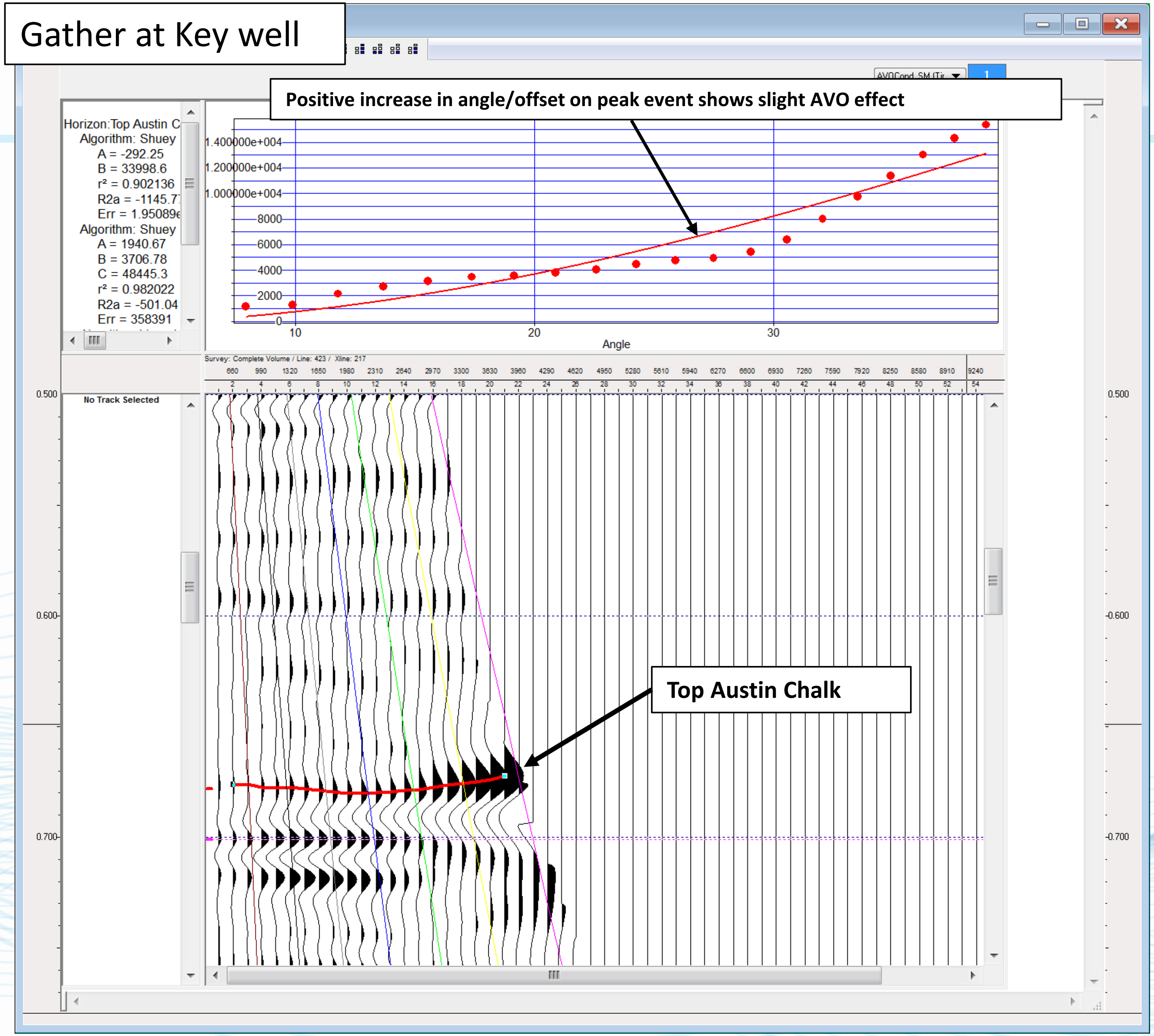


Time Structure Map – Top Austin Chalk
CI = 10 ms (~50')

3 wells – 158 MBO at 2100 feet!

Arbitrary A

Gather at Key well

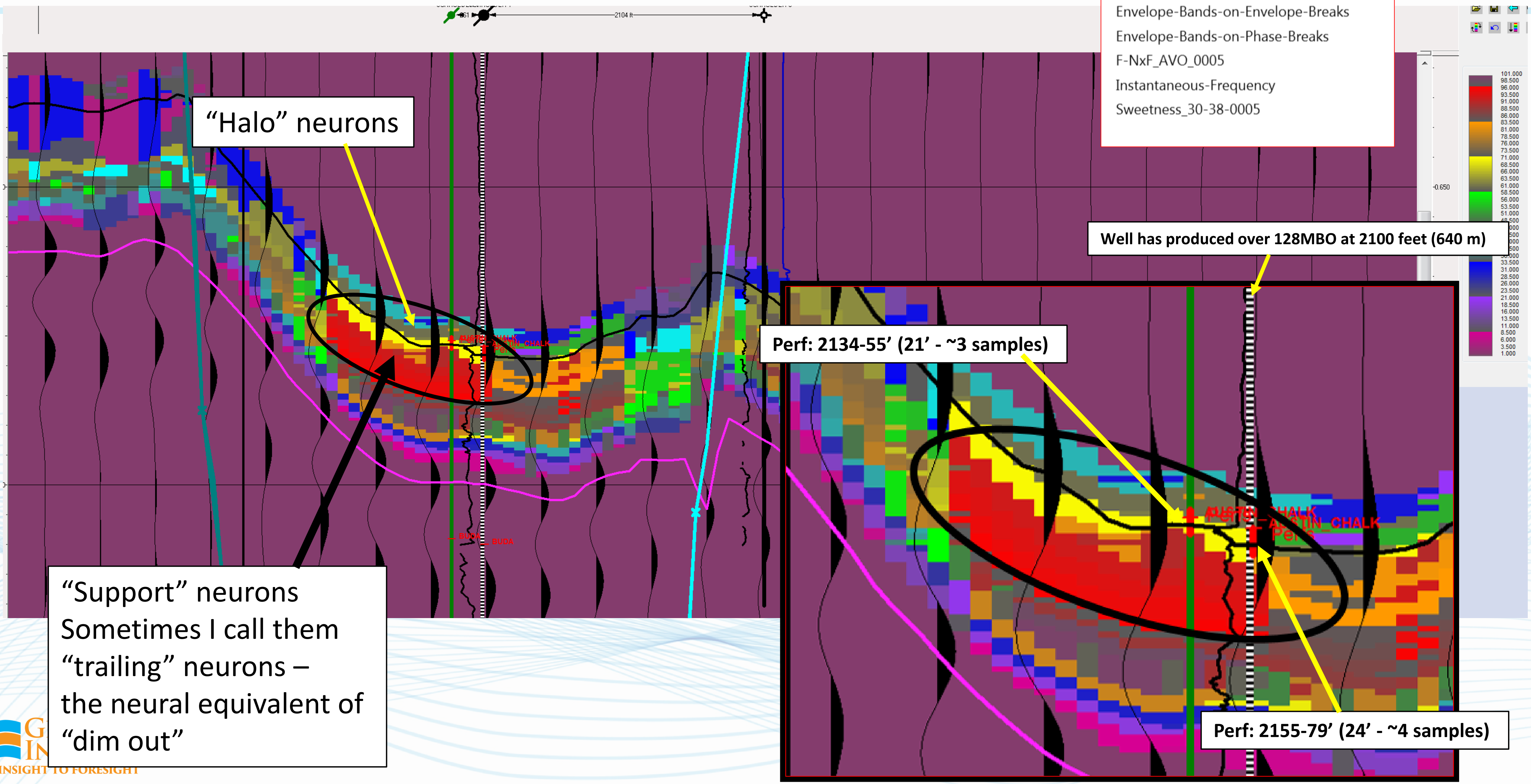


Horizon:Top Austin C
Algorithm: Shuey
A = -292.25
B = 33998.6
r² = 0.902136
R2a = -1145.7
Err = 1.95089
Algorithm: Shuey
A = 1940.67
B = 3706.78
C = 48445.3
r² = 0.982022
R2a = -501.04
Err = 358391

Positive increase in angle/offset on peak event shows slight AVO effect

Top Austin Chalk

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



Attributes

Complete Volume_AVOStk_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

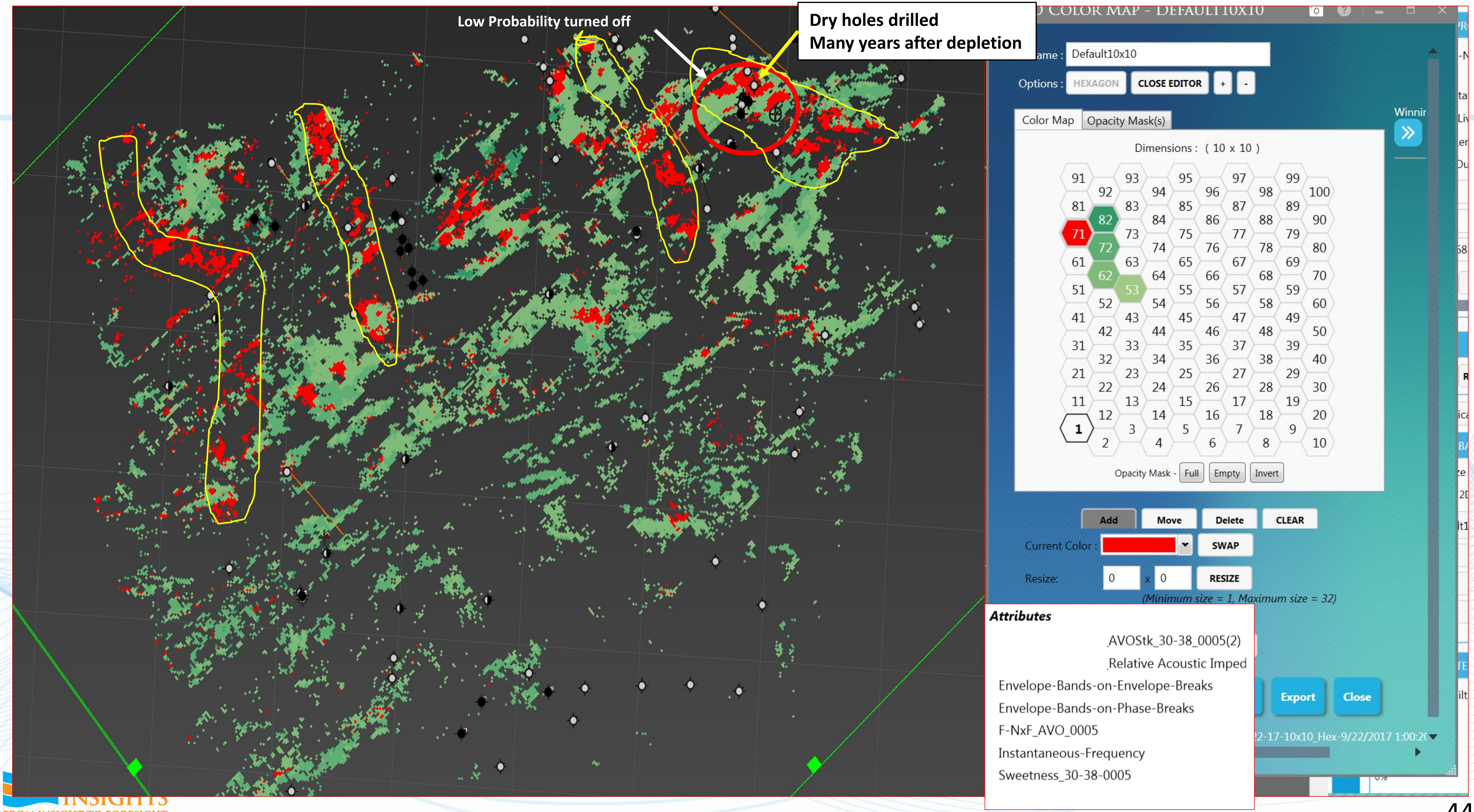
“Halo” neurons

“Support” neurons
Sometimes I call them
“trailing” neurons –
the neural equivalent of
“dim out”

Well has produced over 128MBO at 2100 feet (640 m)

Perf: 2134-55’ (21’ - ~3 samples)

Perf: 2155-79’ (24’ - ~4 samples)



Dry holes drilled
Many years after depletion

ame : Default10x10

Dimensions : (10 x 10)

Current Color : 🟥

Resize: 0 x 0

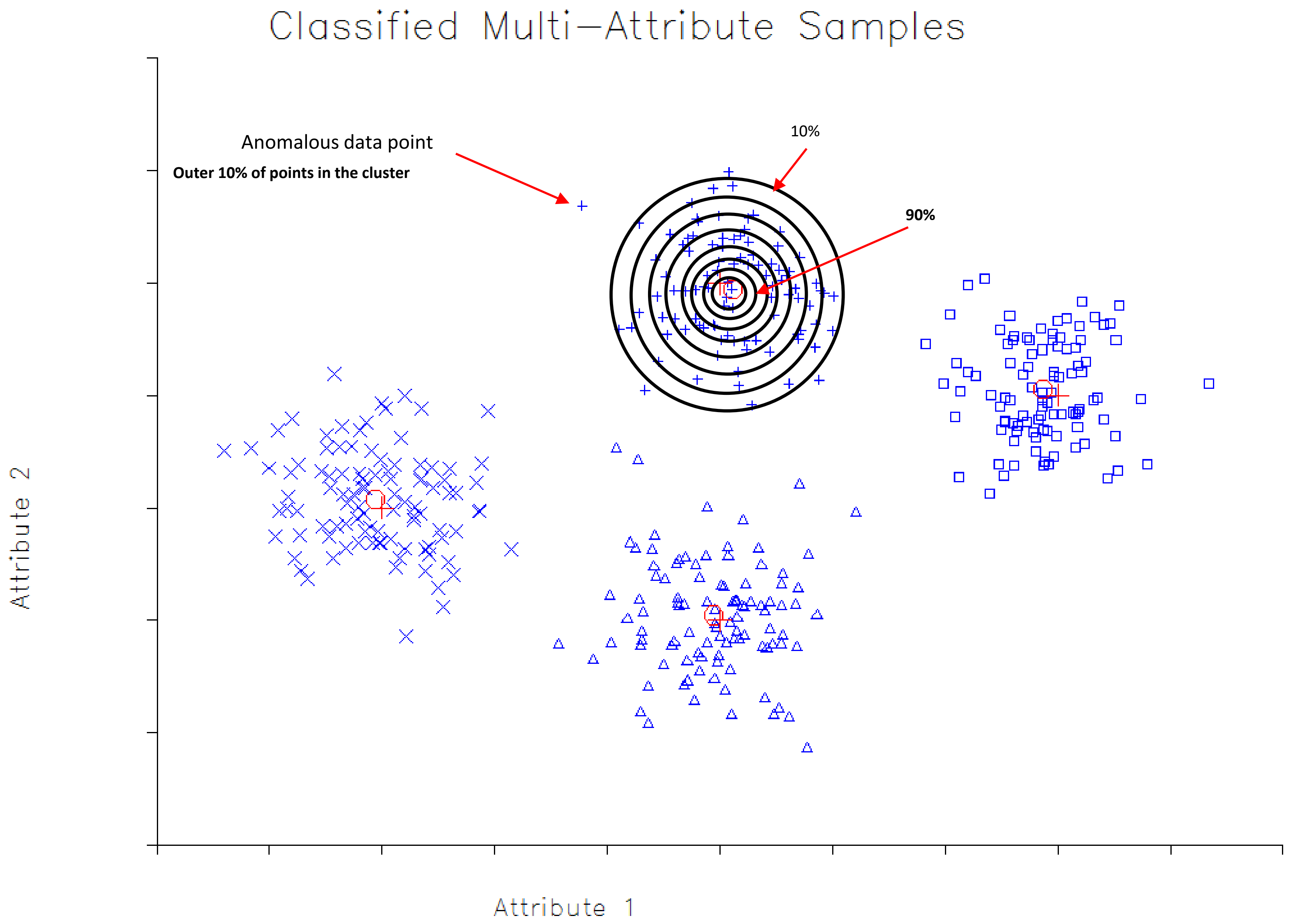
(Minimum size = 1, Maximum size = 32)

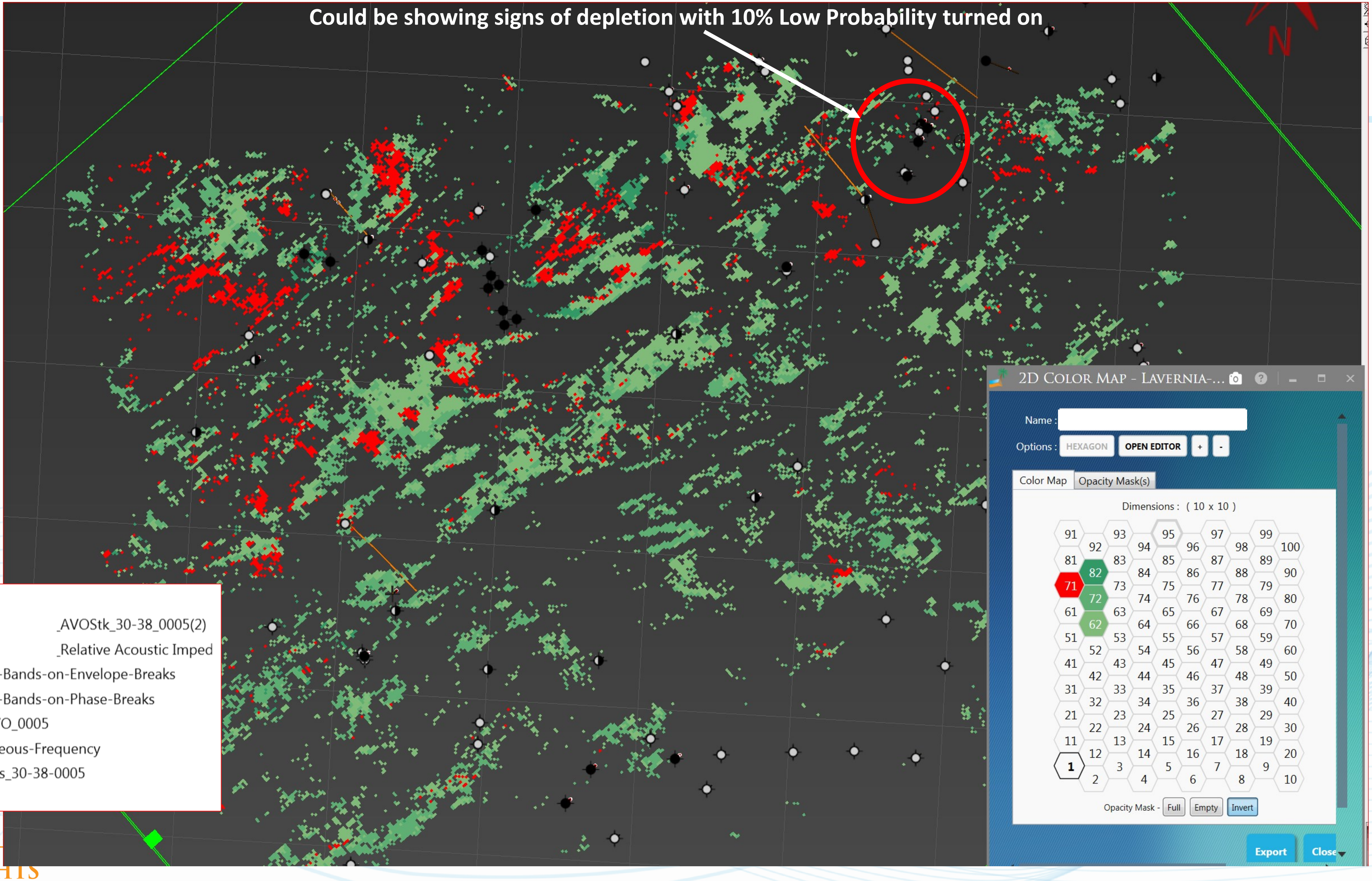
Attributes

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 1:00:2

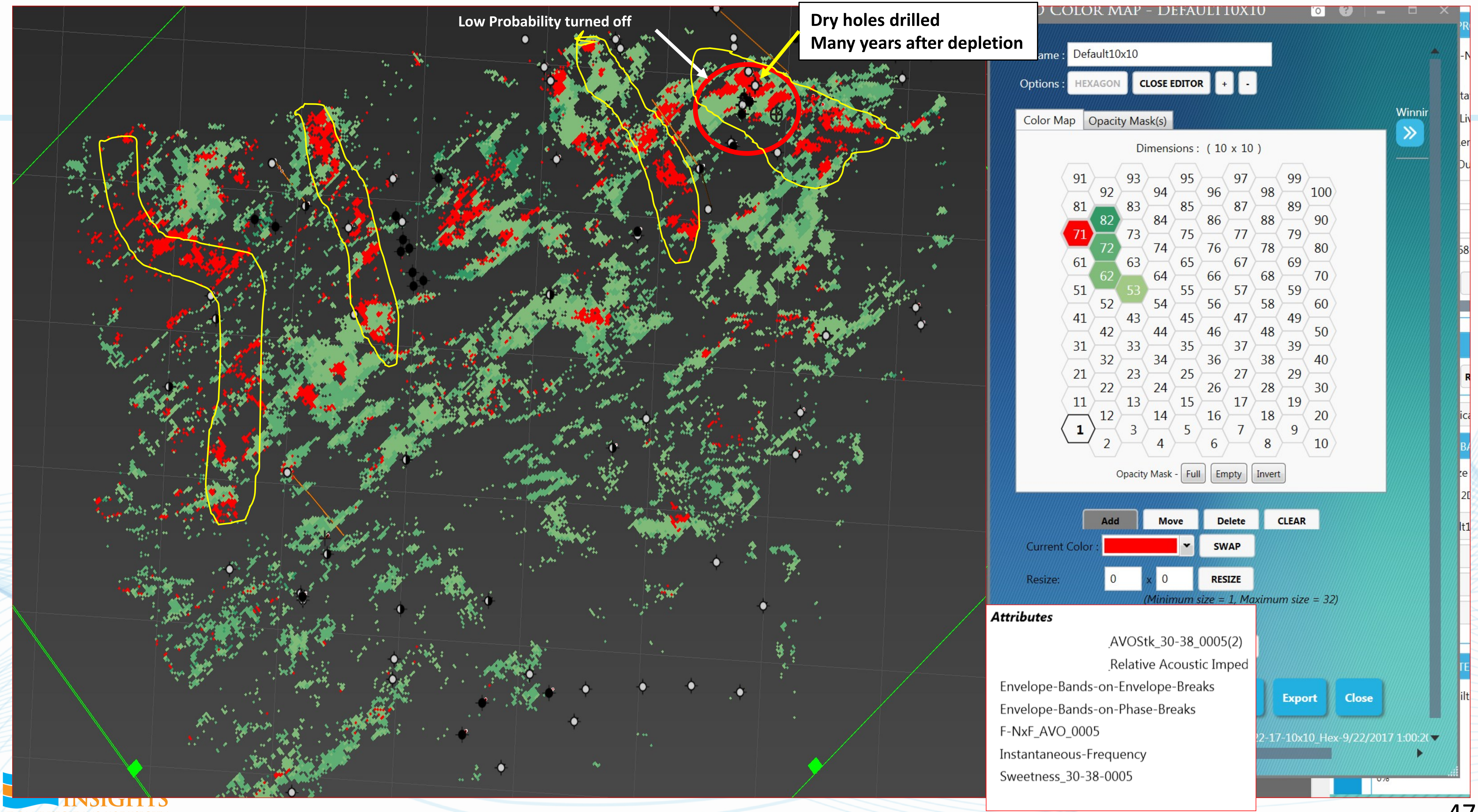
Low Probability Volume – outside “edge” of data points are furthest away from center of cluster – and are considered “most anomalous”. So, if attributes are used which are “hydrocarbon indicators” then the “low probability” anomalies could possibly be hydrocarbon indicators. At the very least, they would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





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

ame : Default10x10

Dimensions : (10 x 10)

Current Color : 🟥

Resize: 0 x 0

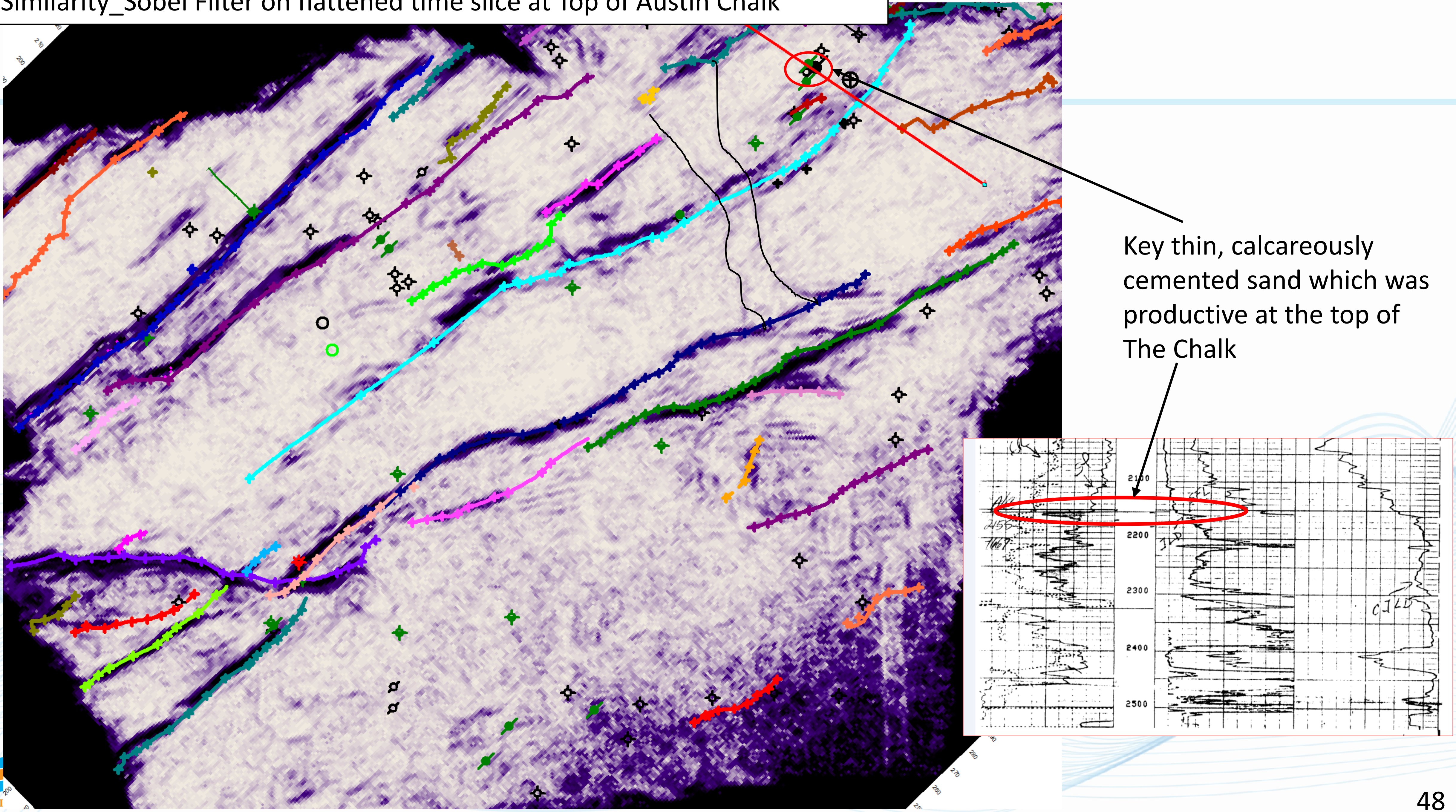
(Minimum size = 1, Maximum size = 32)

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

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

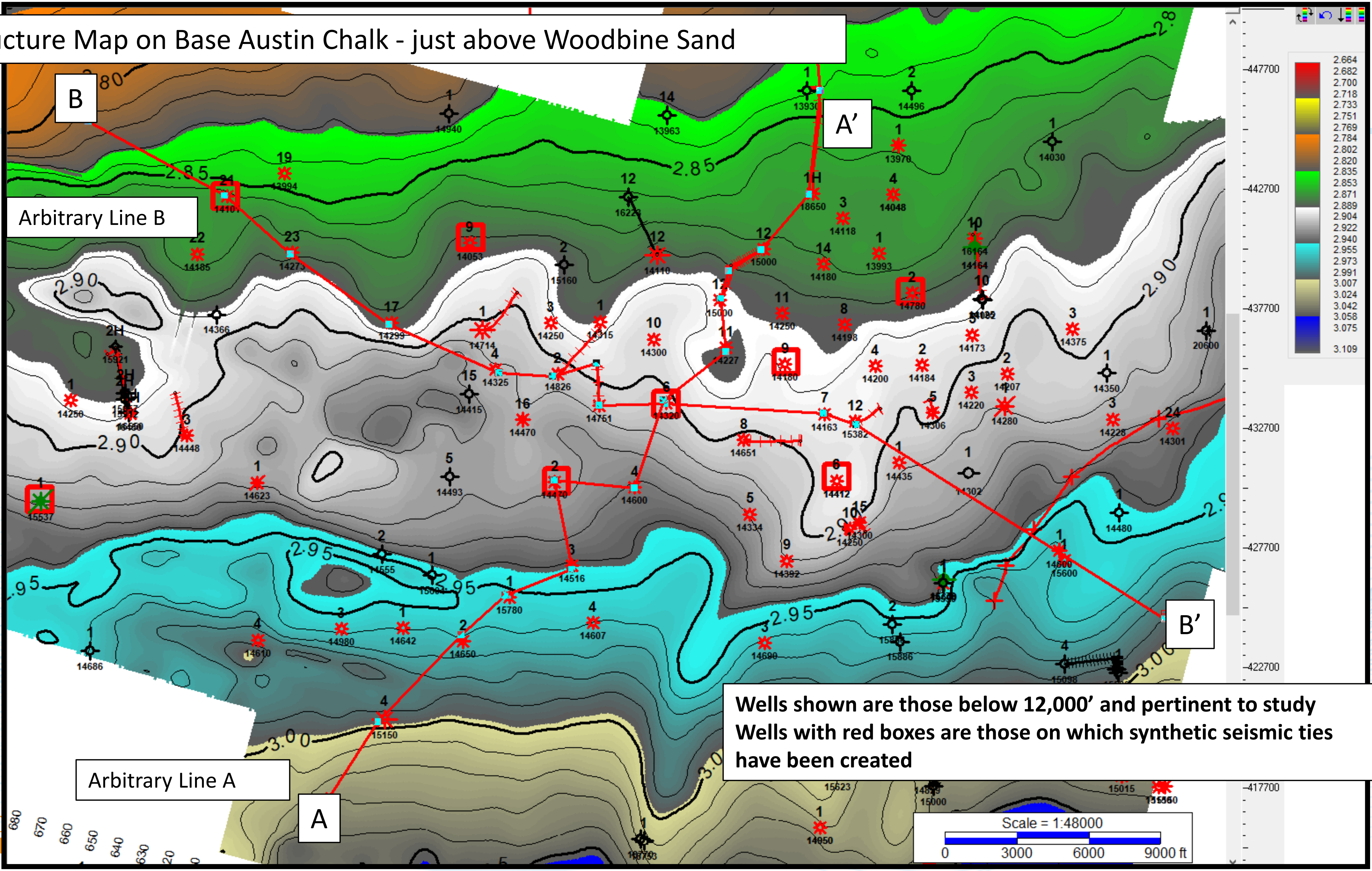
Similarity_Sobel Filter on flattened time slice at Top of Austin Chalk



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

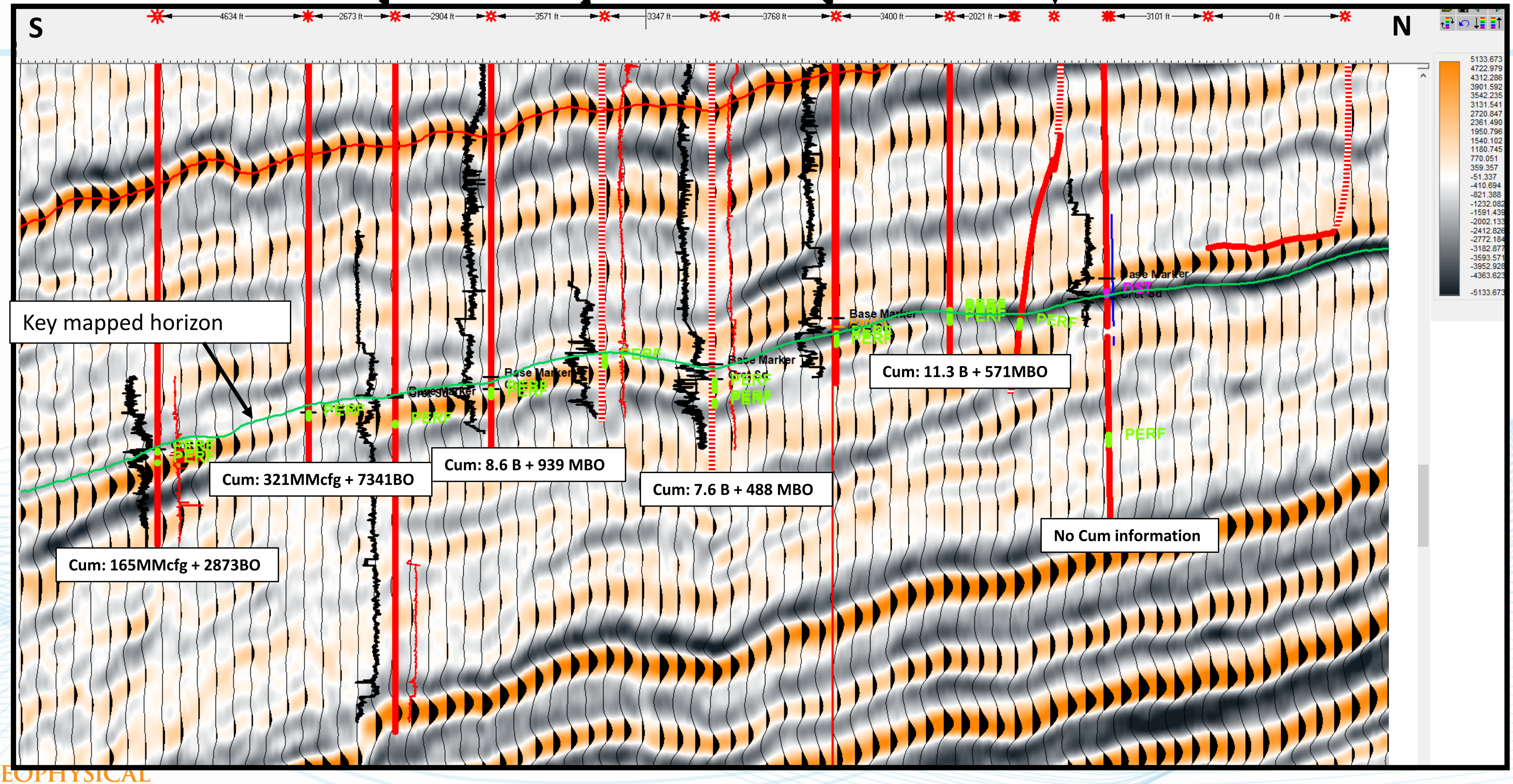


Arbitrary Line B

Arbitrary Line A

Wells shown are those below 12,000' and pertinent to study
Wells with red boxes are those on which synthetic seismic ties have been created

South to North Arbitrary Line B - PSTM



Cum: 12.63 B + 175.9 MBO

Cum: 1.78 B + 1.7 MBO

Cum: 24 B + 1.27MMBO

Cum: 6 B + 253.6MBO

Key mapped horizon

Cum: 11.3 B + 571MBO

Cum: 321MMcfg + 7341BO

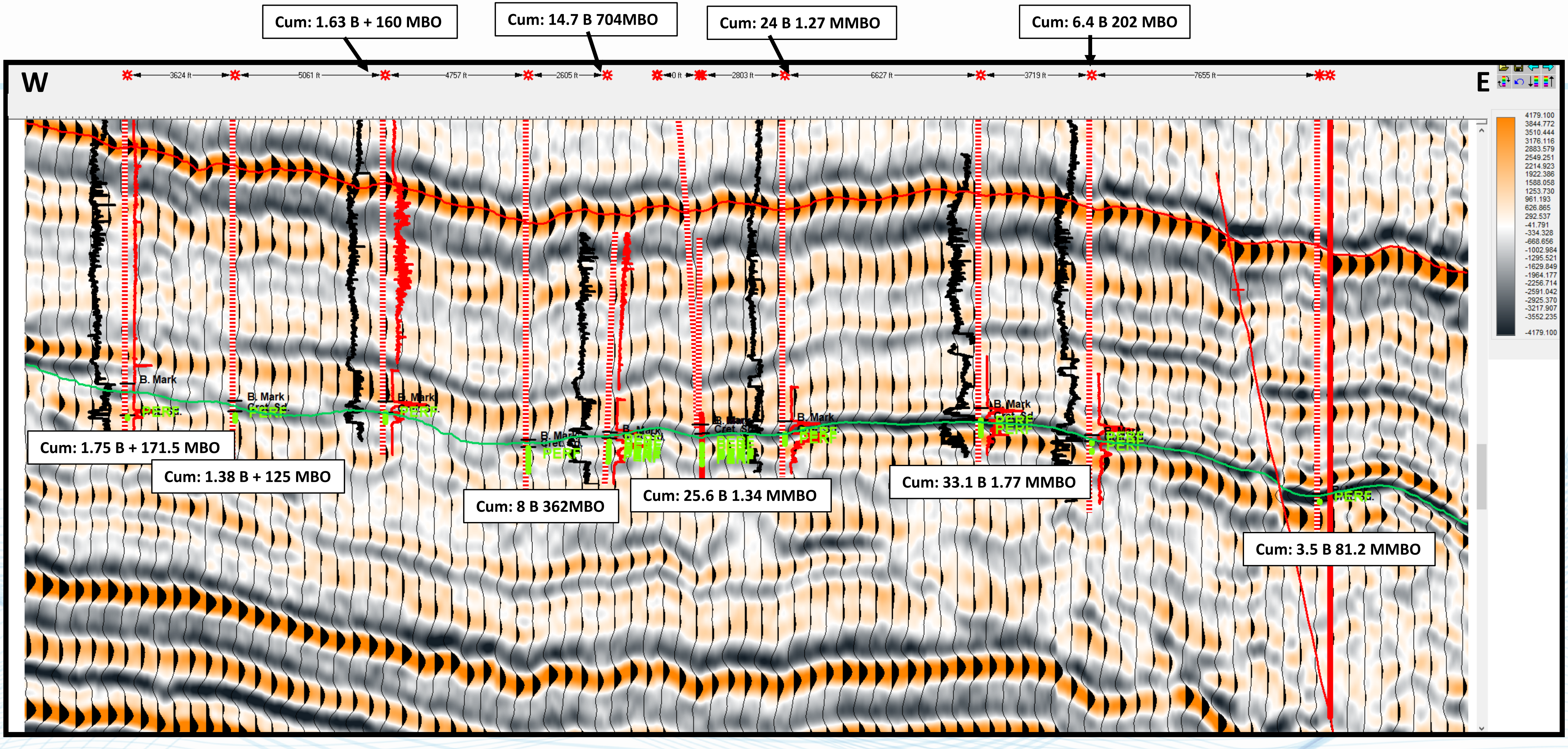
Cum: 8.6 B + 939 MBO

Cum: 7.6 B + 488 MBO

No Cum information

Cum: 165MMcfg + 2873BO

West to East Arbitrary Line A - PSTM


Cum: 1.63 B + 160 MBO

Cum: 14.7 B 704MBO

Cum: 24 B 1.27 MMBO

Cum: 6.4 B 202 MBO

Cum: 1.75 B + 171.5 MBO

Cum: 1.38 B + 125 MBO

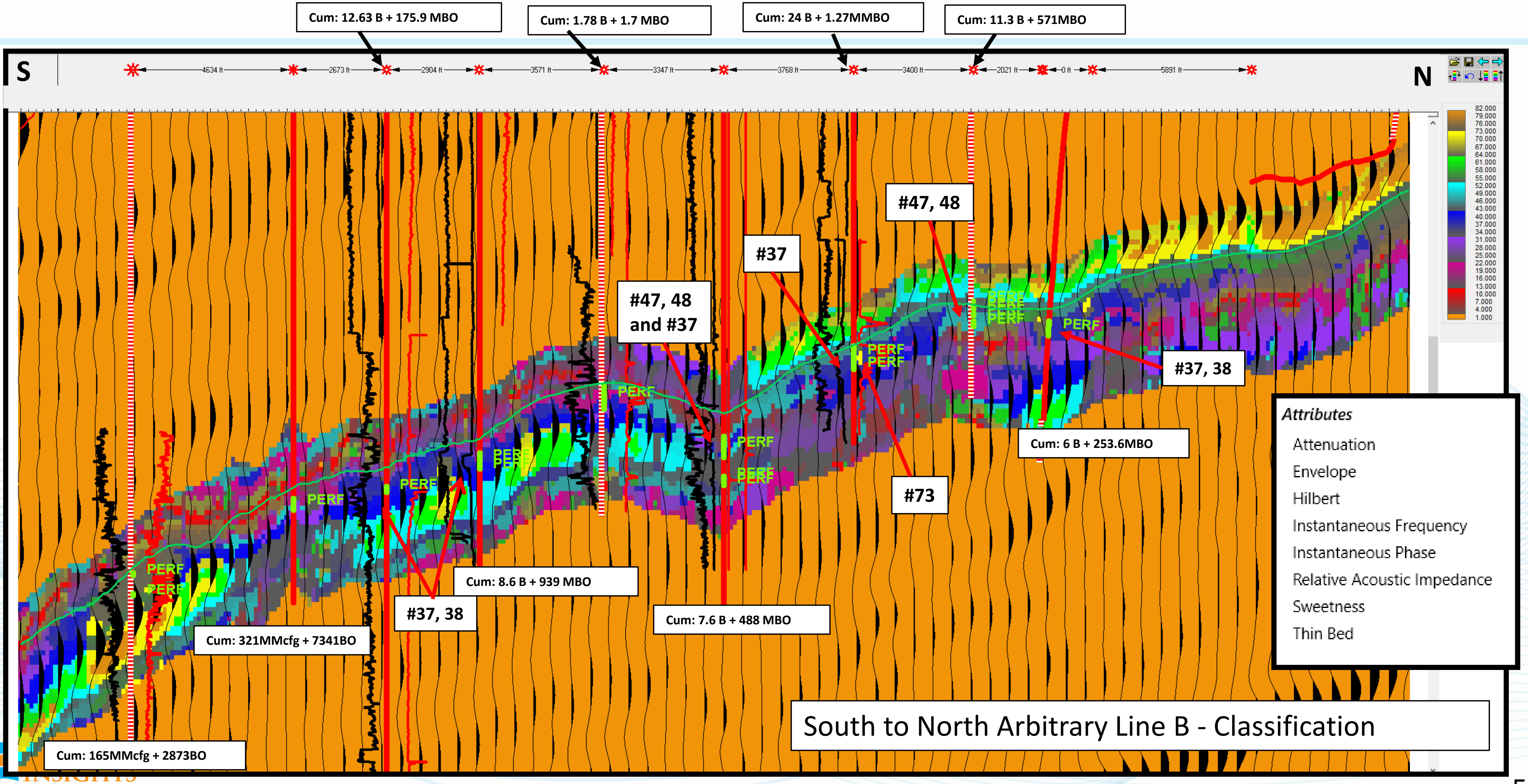
Cum: 8 B 362MBO

Cum: 25.6 B 1.34 MMBO

Cum: 33.1 B 1.77 MMBO

Cum: 3.5 B 81.2 MMBO

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



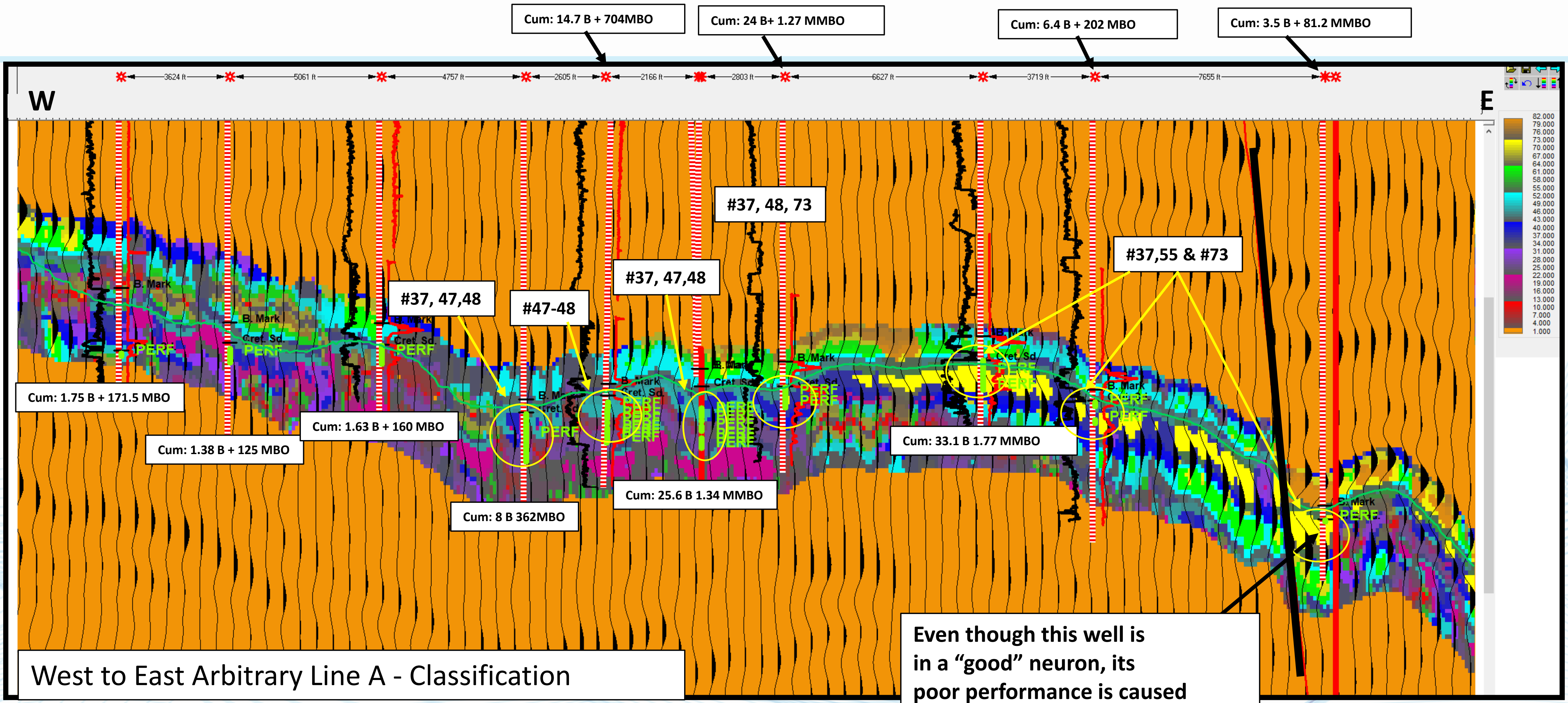
Attributes

- Attenuation
- Envelope
- Hilbert
- Instantaneous Frequency
- Instantaneous Phase
- Relative Acoustic Impedance
- Sweetness
- Thin Bed

South to North Arbitrary Line B - Classification

FROM INSIGHT TO FORESIGHT

This is more obvious when looking at the West to East



Cum: 14.7 B + 704MBO

Cum: 24 B+ 1.27 MMBO

Cum: 6.4 B + 202 MBO

Cum: 3.5 B + 81.2 MMBO

#37, 48, 73

#37,55 & #73

#37, 47,48

#37, 47,48

#47-48

Cum: 1.75 B + 171.5 MBO

Cum: 1.63 B + 160 MBO

Cum: 1.38 B + 125 MBO

Cum: 33.1 B 1.77 MMBO

Cum: 25.6 B 1.34 MMBO

Cum: 8 B 362MBO

West to East Arbitrary Line A - Classification

Even though this well is in a "good" neuron, its poor performance is caused by a structural element.

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

S

Well #1
#74,64
Poor

Well #2
#19,49
Poor

Well #3
#38,41
Good

Well #4
#28,38
Fair

Well #5
#13,20
Good

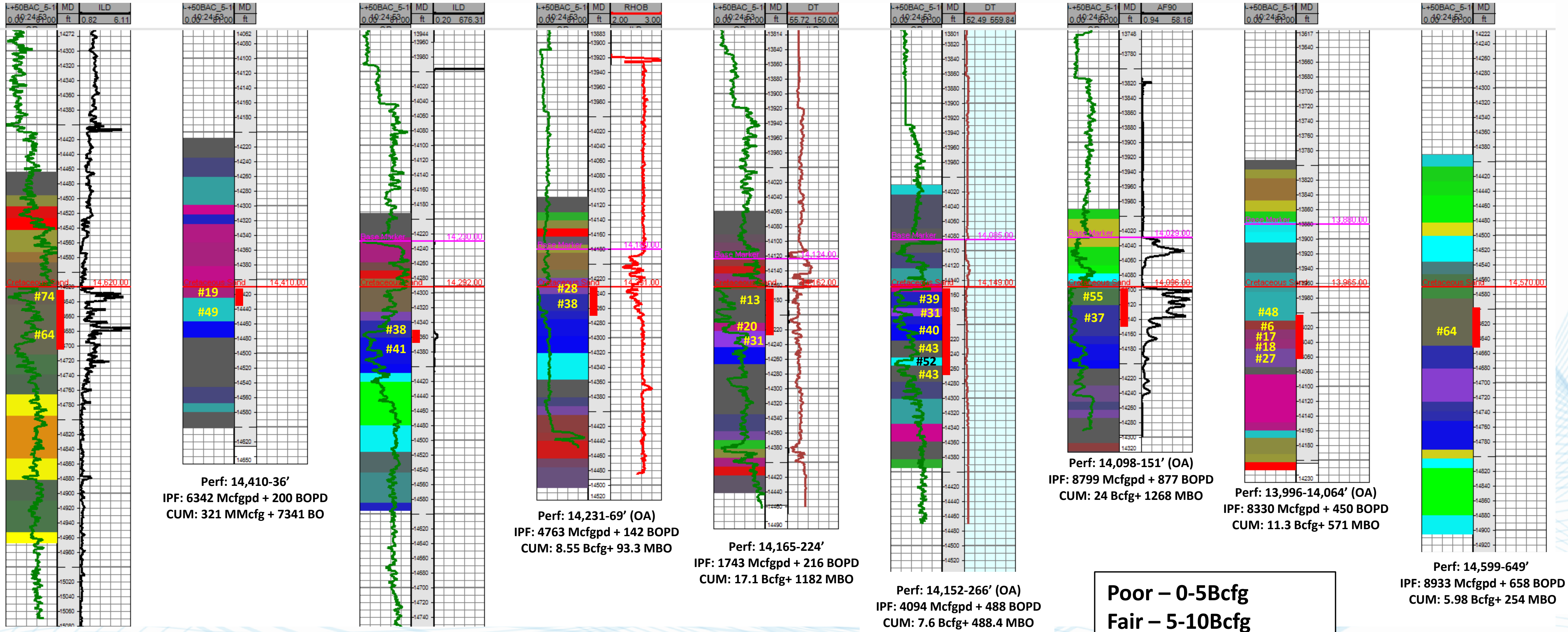
Well #6
#39, 31, 40
#43,52,43
Fair

Well #7
#37, 55
Great

Well #8
#48, 6, 17
#18, 27
Good

Well #9
#64
Fair

N



Perf: 14,628-708' (OA)
IPF: 336 Mcfgpd + 16 BOPD
CUM: 165.1 MMcfg + 2873 BO

Perf: 14,410-36'
IPF: 6342 Mcfgpd + 200 BOPD
CUM: 321 MMcfg + 7341 BO

Perf: 14,350-66'
IPF: 26 MMcfgpd + 100 BOPD
CUM: 12.6 Bcfg+ 175.9 MBO

Perf: 14,231-69' (OA)
IPF: 4763 Mcfgpd + 142 BOPD
CUM: 8.55 Bcfg+ 93.3 MBO

Perf: 14,165-224'
IPF: 1743 Mcfgpd + 216 BOPD
CUM: 17.1 Bcfg+ 1182 MBO

Perf: 14,152-266' (OA)
IPF: 4094 Mcfgpd + 488 BOPD
CUM: 7.6 Bcfg+ 488.4 MBO

Perf: 14,098-151' (OA)
IPF: 8799 Mcfgpd + 877 BOPD
CUM: 24 Bcfg+ 1268 MBO

Perf: 13,996-14,064' (OA)
IPF: 8330 Mcfgpd + 450 BOPD
CUM: 11.3 Bcfg+ 571 MBO

Perf: 14,599-649'
IPF: 8933 Mcfgpd + 658 BOPD
CUM: 5.98 Bcfg+ 254 MBO

🟥 Indicates zone of perforations

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

GEOPHYSICAL INSIGHTS
FROM INSIGHT TO FORESIGHT

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

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

W

Well #10
#50
Poor

Well #11
#30
Poor

Well #12
#36, 5
Poor

Well #13
#22, 26, 27
#40, 48
Fair

Well #14
#48, 15, 29
Good

Well #15
#47, 48
#15, 26
Great

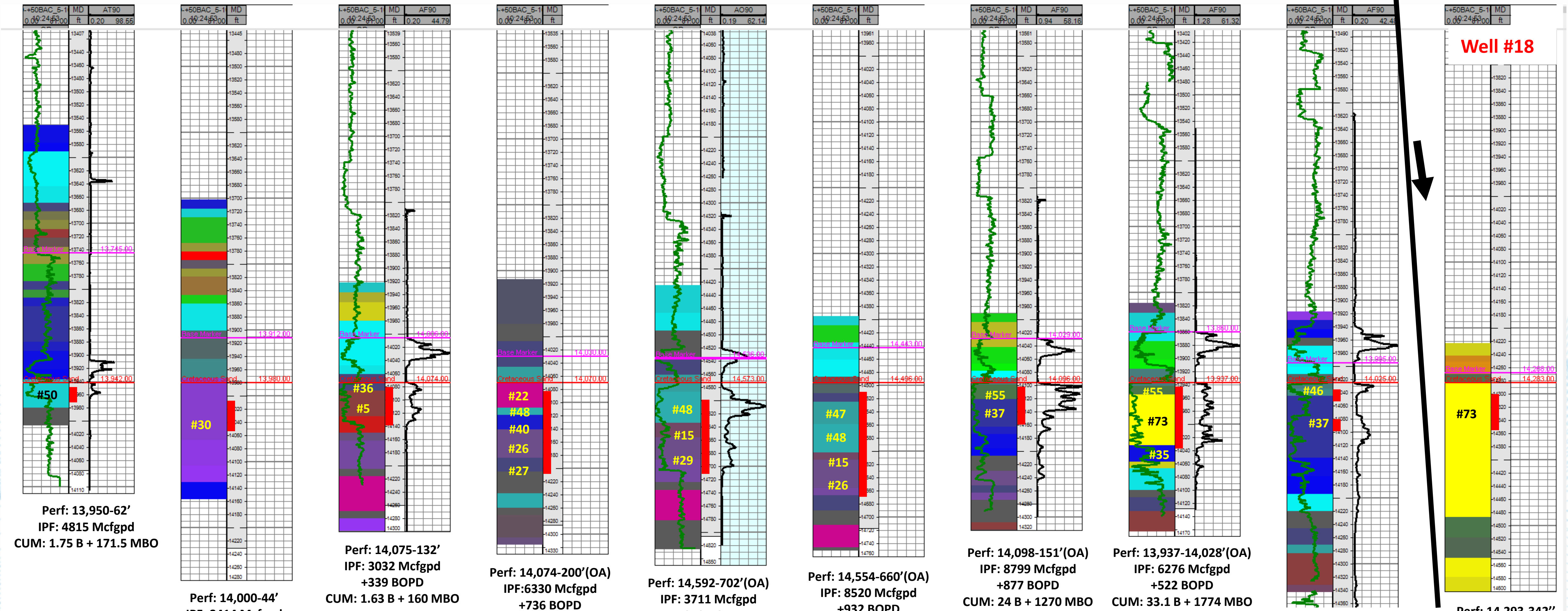
Well #7
#55, 37
Great

Well #16
#73, 37
Excellent

Well #17
#46, 37
Poor

#73
Poor

E



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

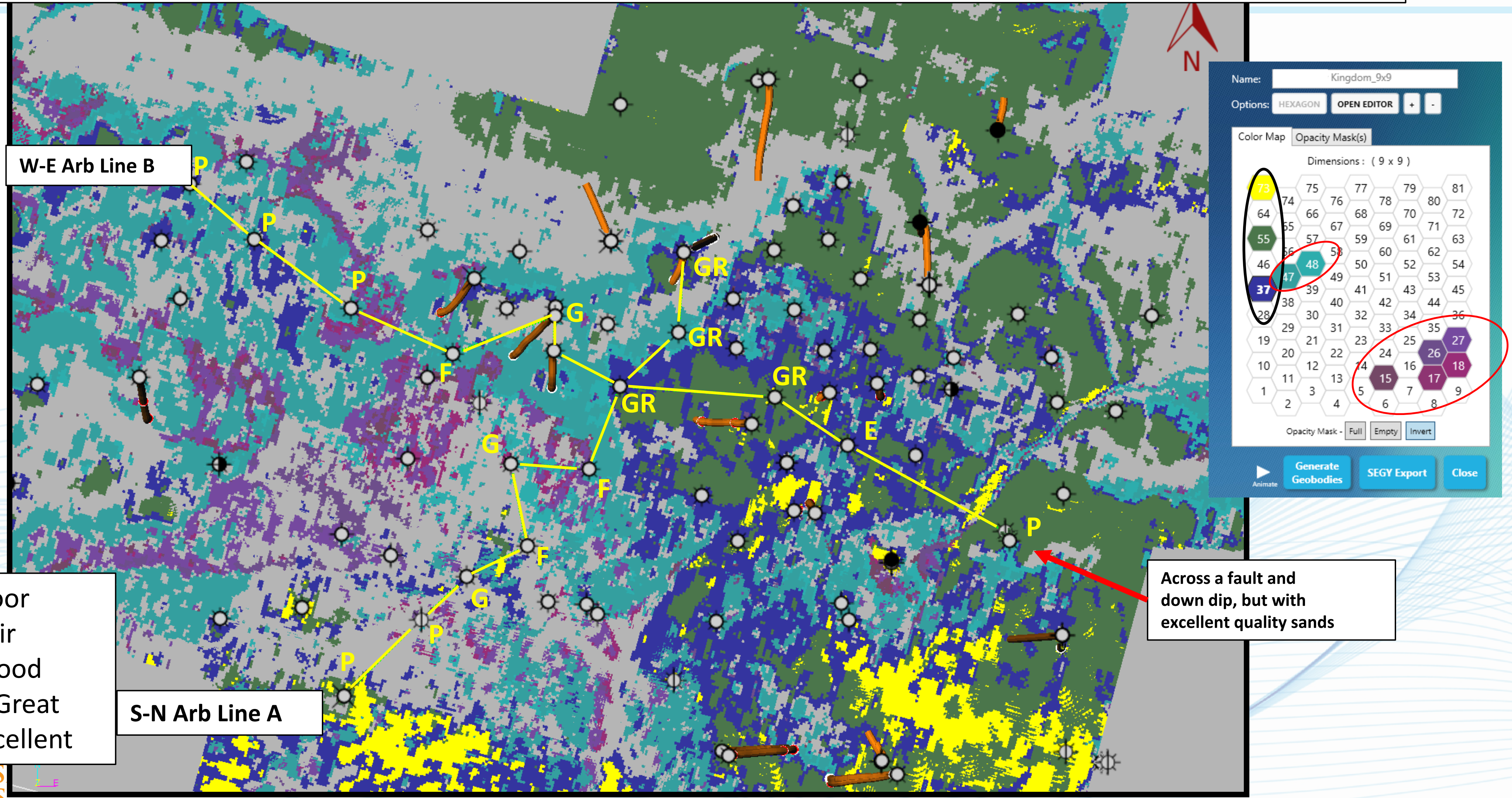
Perf: 14,293-342’’
IPF: 1543 Mcfgpd +55 BOPD
CUM: 3.5 B _81.2 MBO

🟥 Indicates zone of perforations

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

GEOPHYSICAL INSIGHTS
FROM INSIGHT TO FORESIGHT

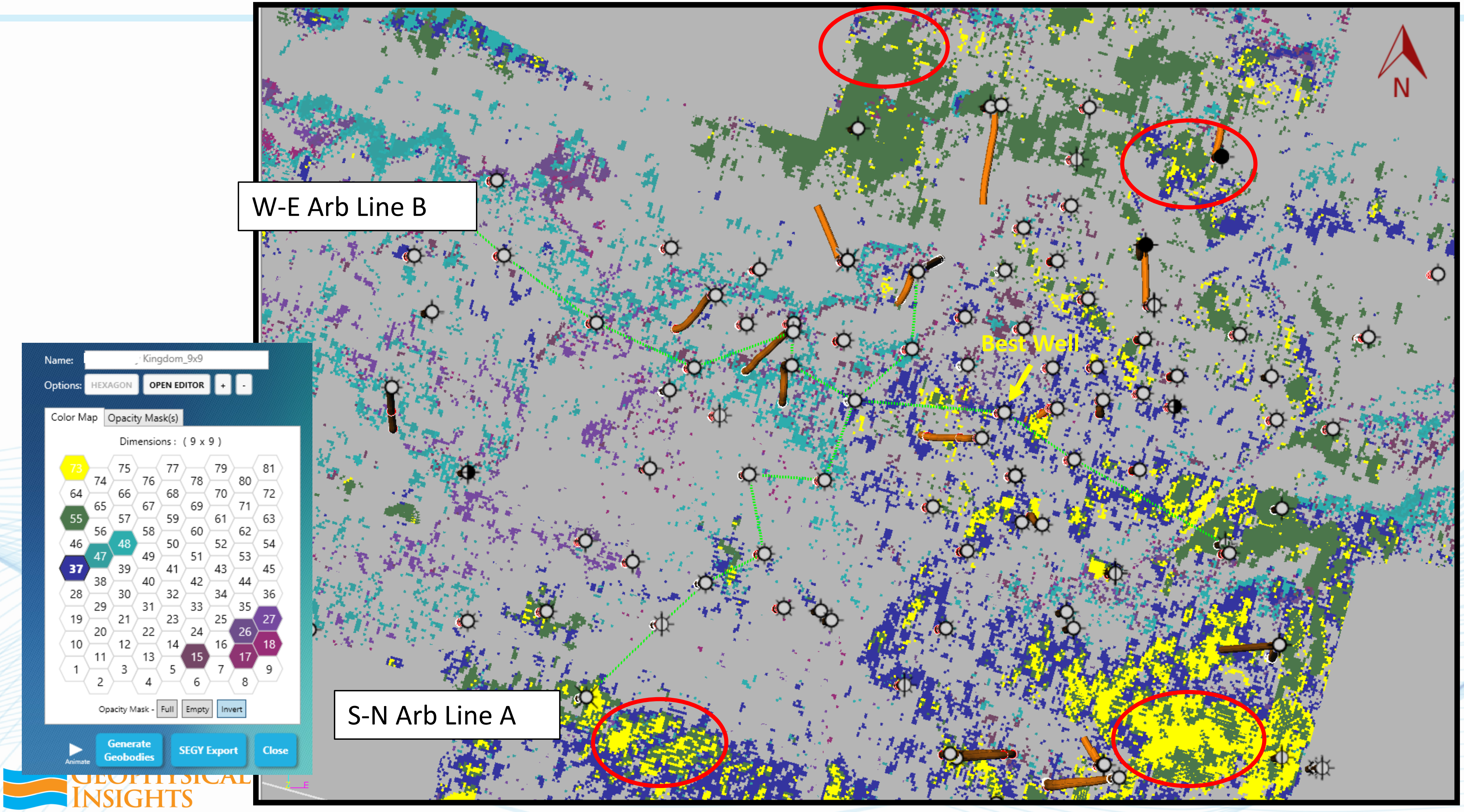
This is the areal extent of all Key neurons related to production turned on within a zone from the Key horizon down to 20 ms below the horizon. The neurons found at the perforations in the "Great" and "Excellent" wells are #37, 55 and 73, with other "Good" wells using Neurons #47 and 48. Neurons #15,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

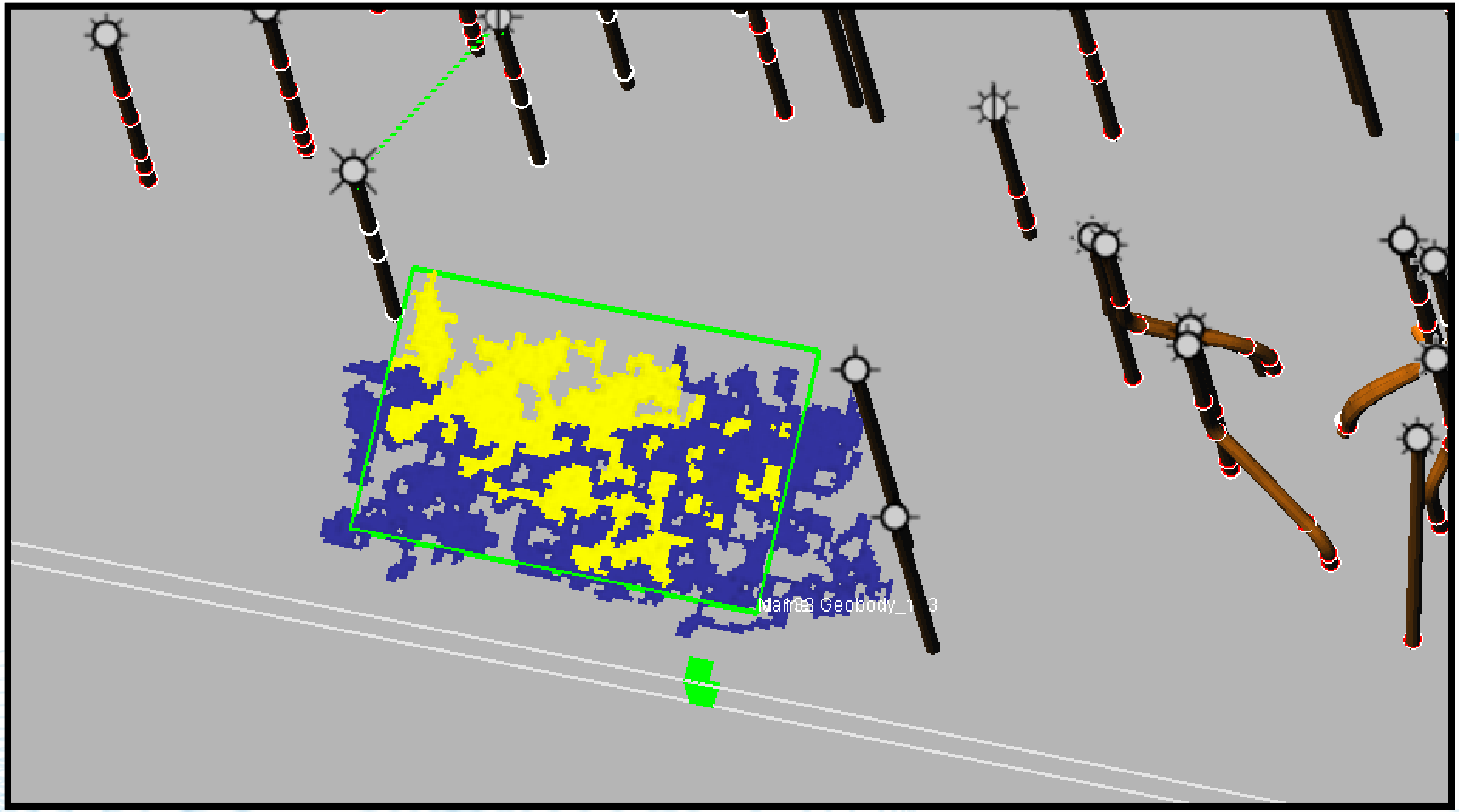


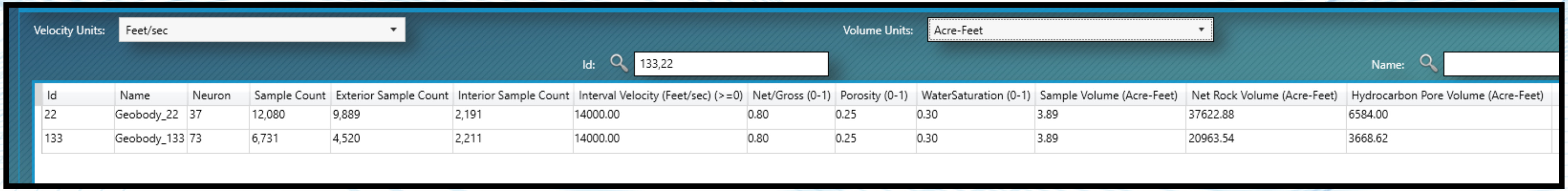
P = Poor
F = Fair
G = Good
GR = Great
E= Excellent

Across a fault and down dip, but with excellent quality sands

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.







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

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

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

GEOPHYSICAL INSIGHTS
FROM INSIGHT TO FORESIGHT