Seismic Acoustic Impedance Inversion in Reservoir Characterization Utilizing gOcad

Boonsville Field – Central Texas
Data Made Public Thru
The Bureau of Economic Geology

- 5.5 sq. Miles of 3D seismic data
- Vertical seismic profile (VSP) near center of survey
- Digital well logs from 38 wells
- Well markers for the Bend Conglomerate Group
- Perforations, reservoir pressures, production and Petrophysical data for the 38 wells

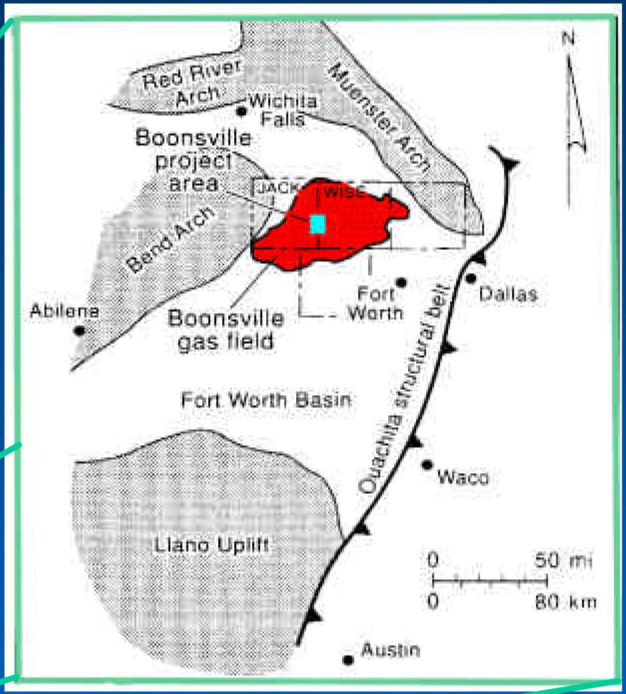
Contributing Companies and Organizations to This Public Domain Dataset

Arch Petroleum

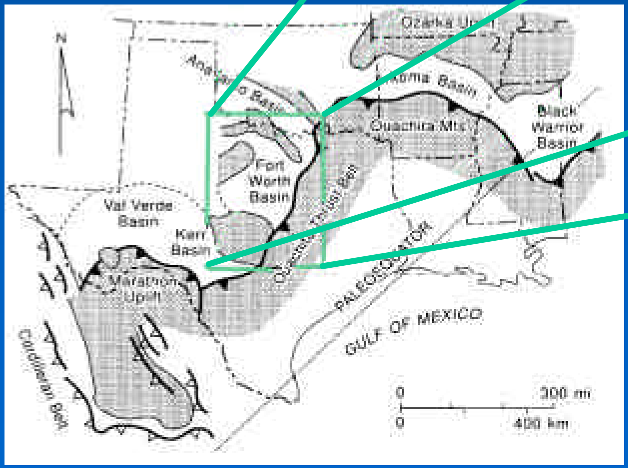
Enserch

Boonsville Field Location Map

Middle Pennsylvanian Paleogeography map Showing the Fort Worth Basin and the Boonsville project area

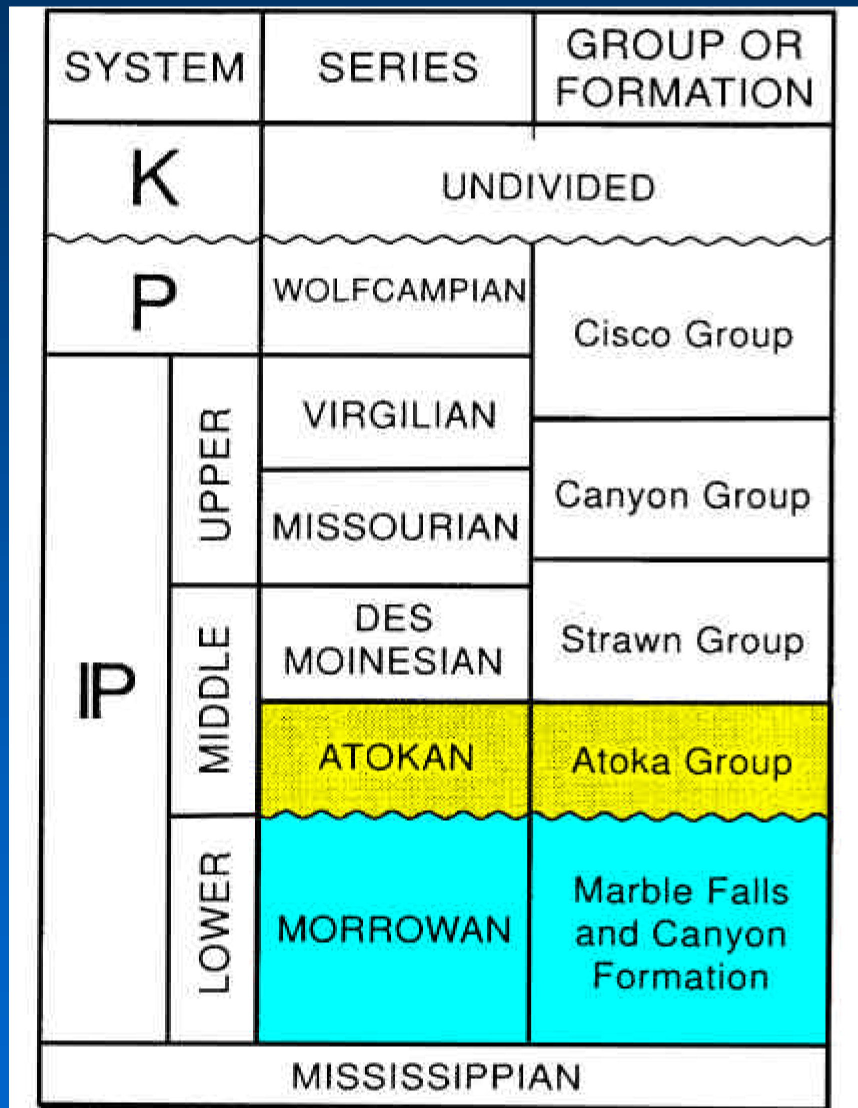


Modified from
Lahti and Huber (1982)



Modified from
Thompson (1982)

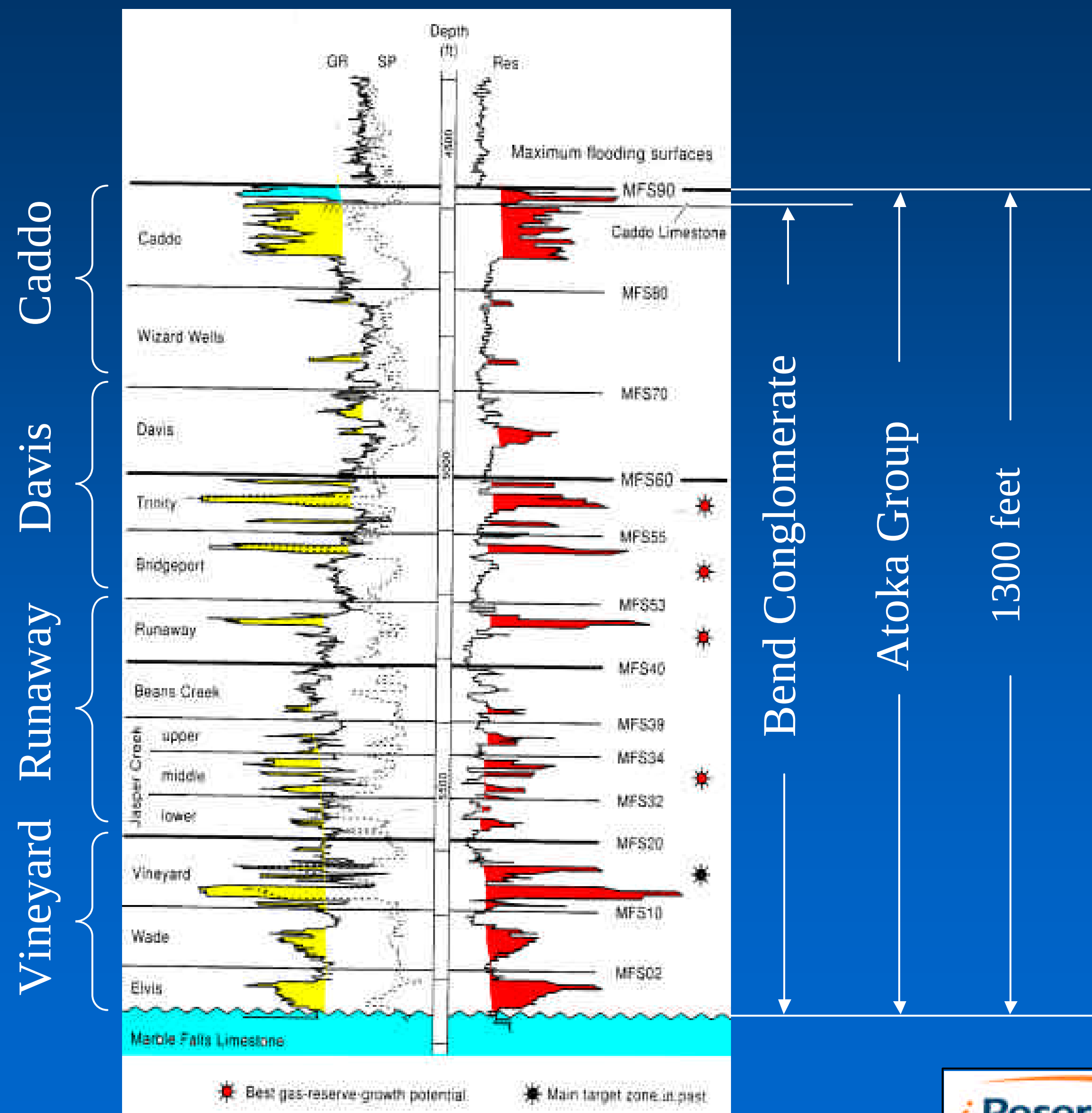
Stratigraphic Column



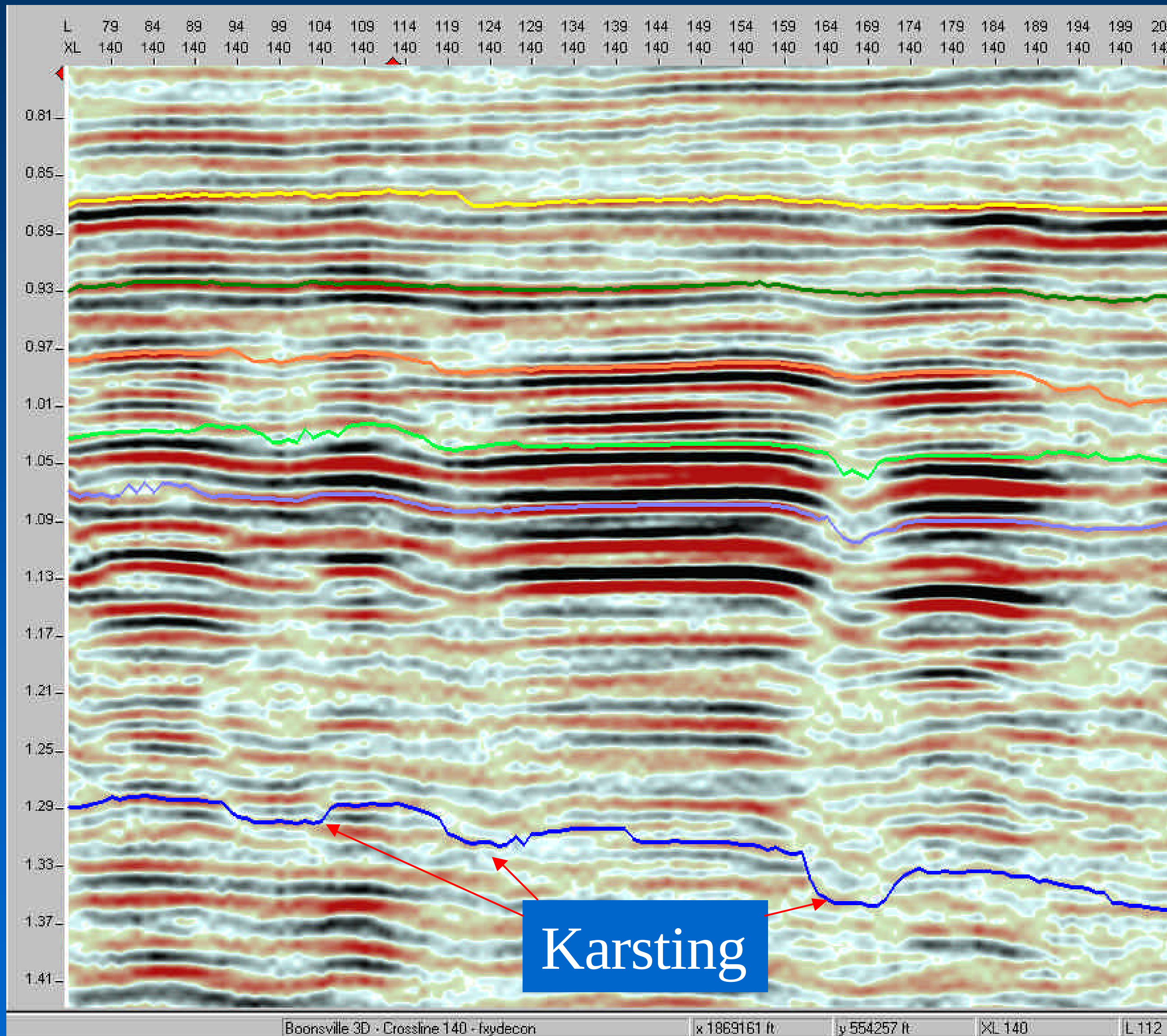
Gas from Bend Conglomerate Group

Type Log and Stratigraphic Nomenclature

BEG Sequence nomenclature to define Bend Conglomerate genetic sequences in Boonsville field



Example Seismic Line



3500 ft

Caddo

Davis

Runaway

Vineyard

Marble Falls LS

Ellenburger LS

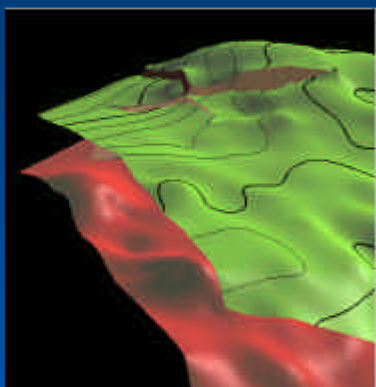
2.75 miles

BEG’s Major Conclusions

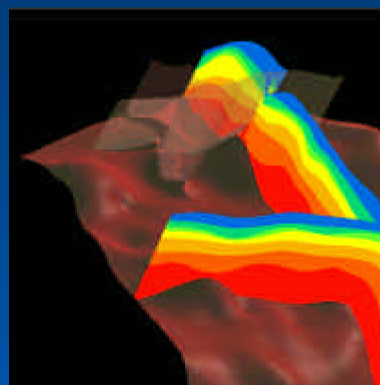
- Karsting from Ellenburger carbonates cause collapse features compartmentalizing the reservoir.
  - Large range of compartment sizes
- Need 3D seismic to image the collapse features.
- Seismic attributes can sometimes predict the reservoir facies
  - Upper Caddo: Amplitude
  - Lower Caddo: Inst. Frequency
  - Lower Bend Conglomerate sequences not definitive
- Reservoirs often exist as stacked compartments of genetic sequences.

Overview of Reservoir Modeling

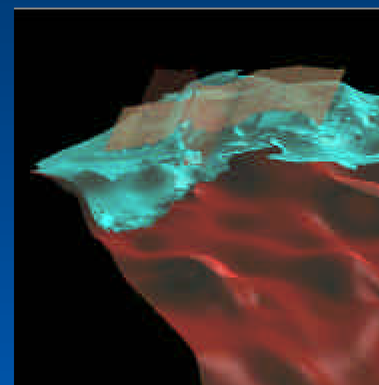
Structural Framework



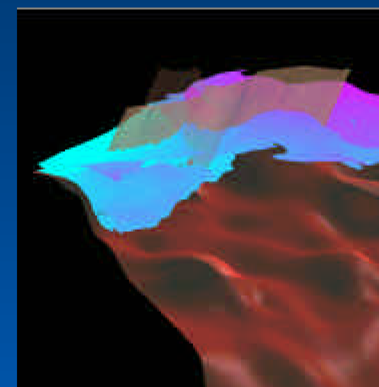
Stratigraphic Gridding



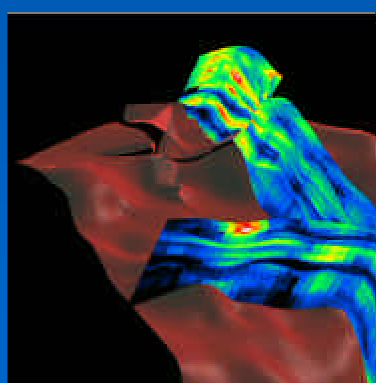
Lithology and Facies Mapping



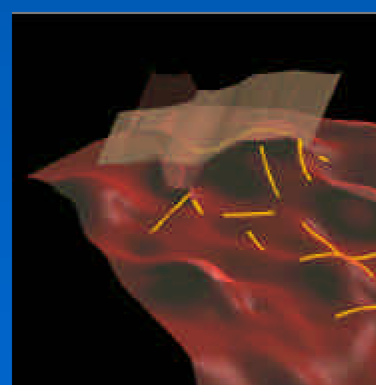
Pressure Field



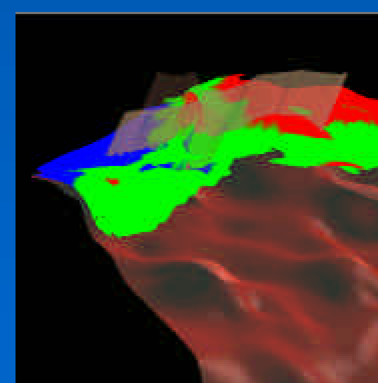
Rock Properties



Fracture Network & Stress Field



Reservoir Fluids & Dynamic Response



Motivation for Reservoir Modeling
- Technical -

- Integration of all relevant and available data.
- Merge data of different scales.
  - Cores.
  - Well logs.
  - Seismic.
  - Production.
- Dynamically update the model as new information becomes available.
- Measurement of errors and uncertainty as well as expected value.
- Specific workflows dependant on number and type of data available.

Motivation for Reservoir Modeling
- Business Case -

- Integration of different disciplines in team.
- Earth model serves as the focal point of inter-disciplinary communication.
- Better assessment of risk:
  - Lowering of risk.
  - Proper risk assessment.
- Make better business decisions.

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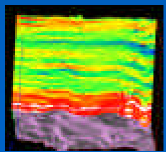
Rock Properties Workflow

Input Data

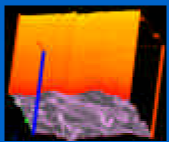
Well Logs
(sonic, density, RT, porosity)

Seismic Amplitude Data

Background AI

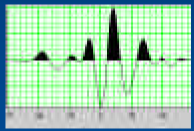


Velocity Field

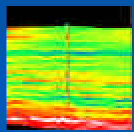


Process

Seismic to Log Calibration



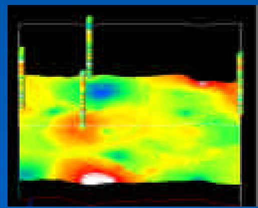
Inversion To Acoustic Impedance



Depth Conversion for Correlation to Logs

Product

Rock Property Model of Reservoir in Depth Containing Detailed Seismic Information and Faulted Network



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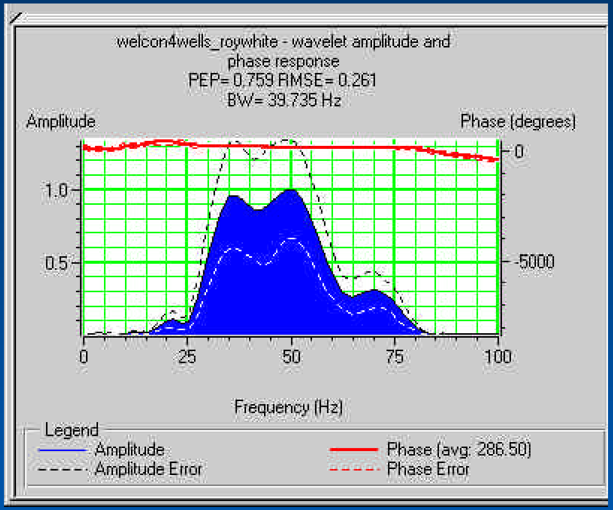
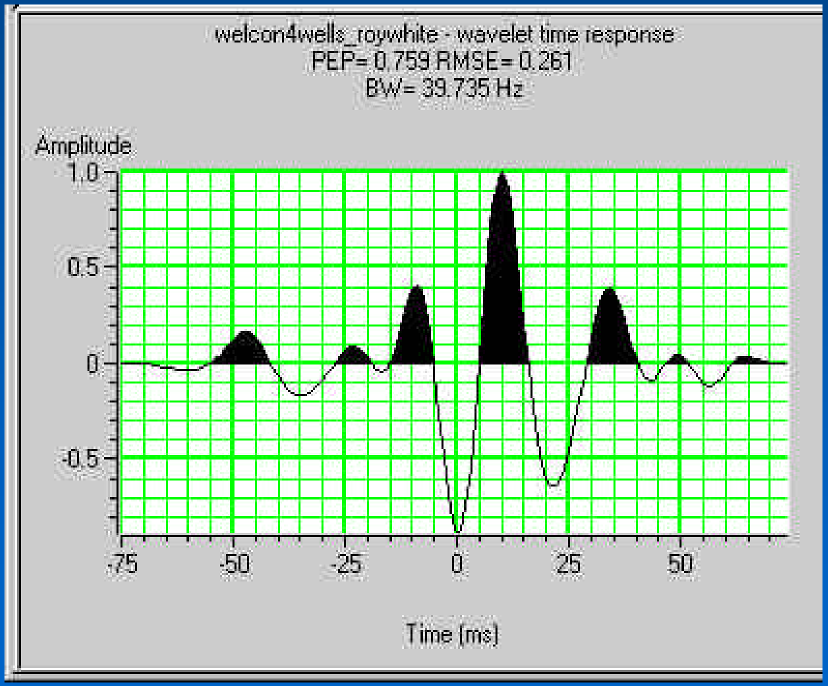
Seismic to Log Calibration

Amplitude Spectrum (linear scale)

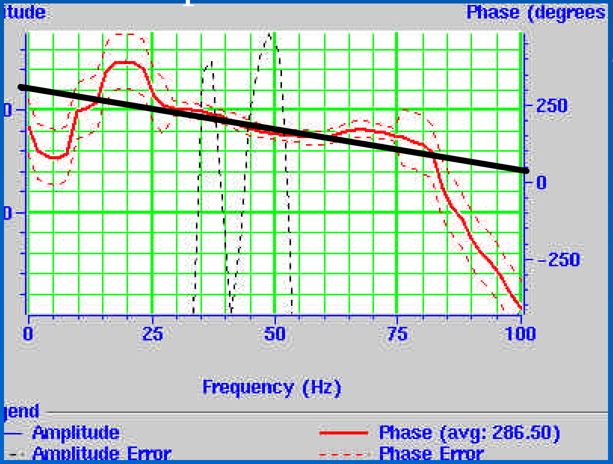


Final Seismic Wavelet
Average of 4 Well Ties

Time Domain Wavelet

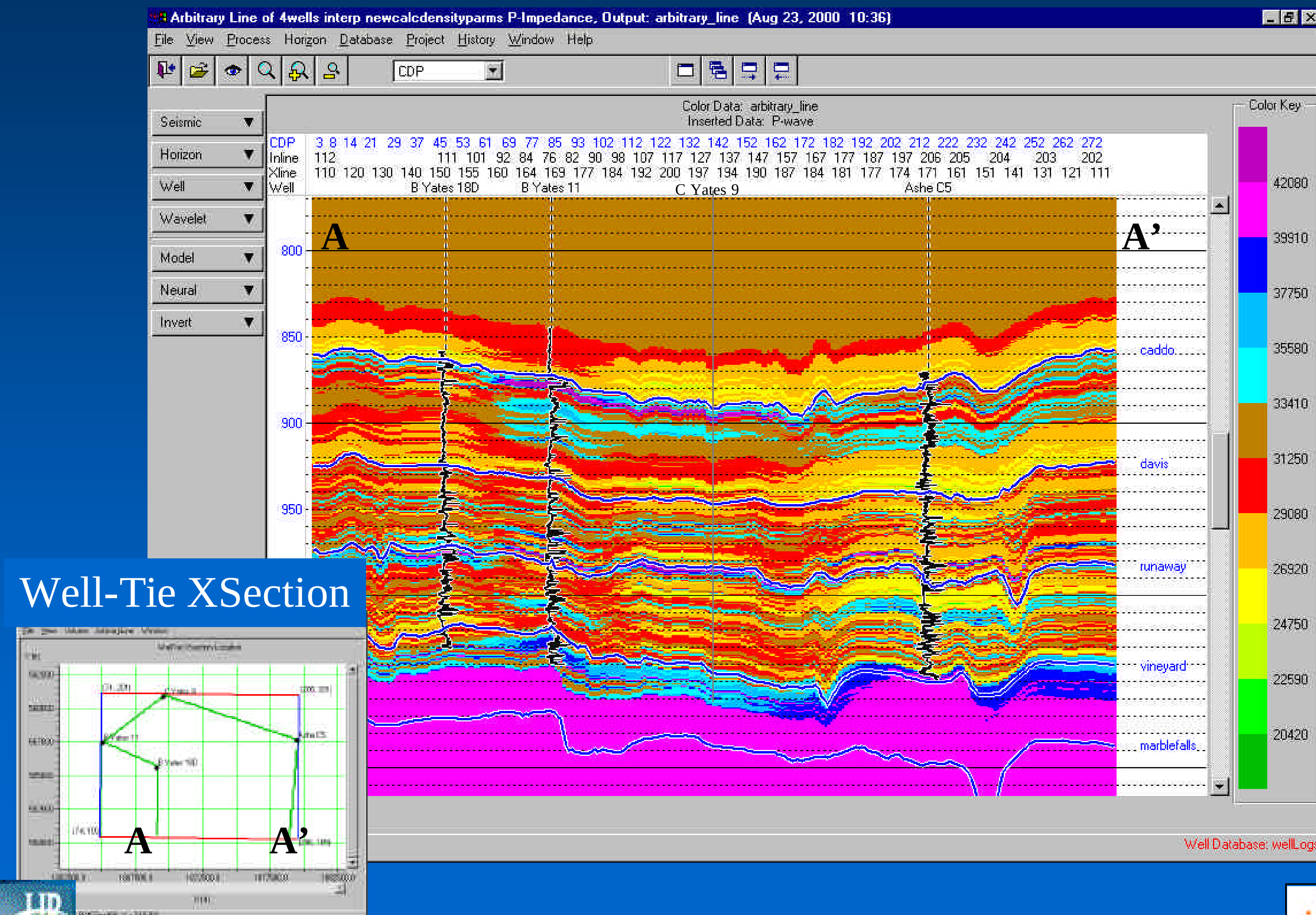


Phase Spectrum

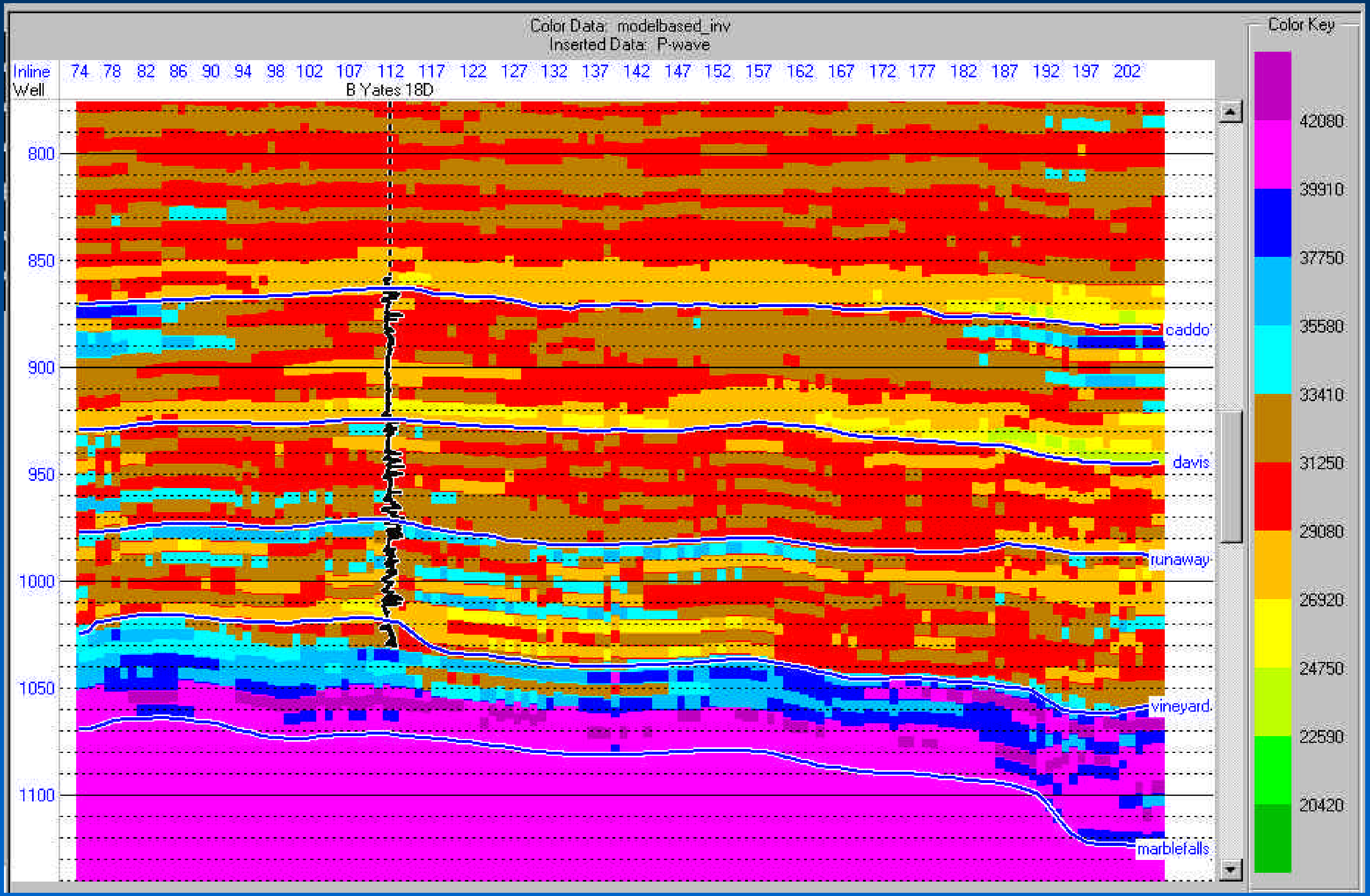


Avg. Phase
285^{o}
(or –75^{o})

Background AI Model From 4 Wells (Simple Gridding)

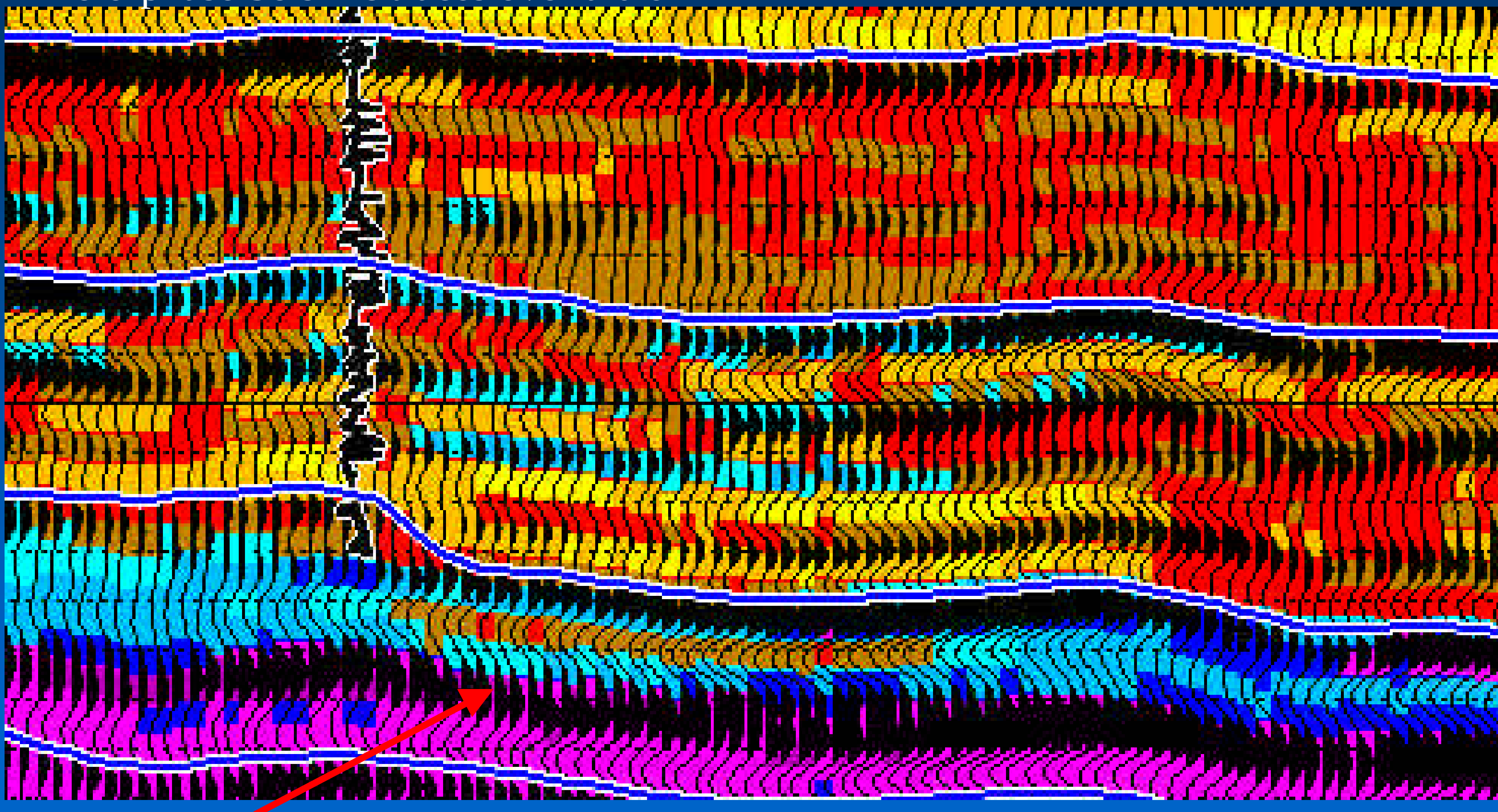


Model Based Inversion to Acoustic Impedance (AI)



Model Based Inversion to Acoustic Impedance (AI)

Zero-phase Seismic traces overlaid on AI

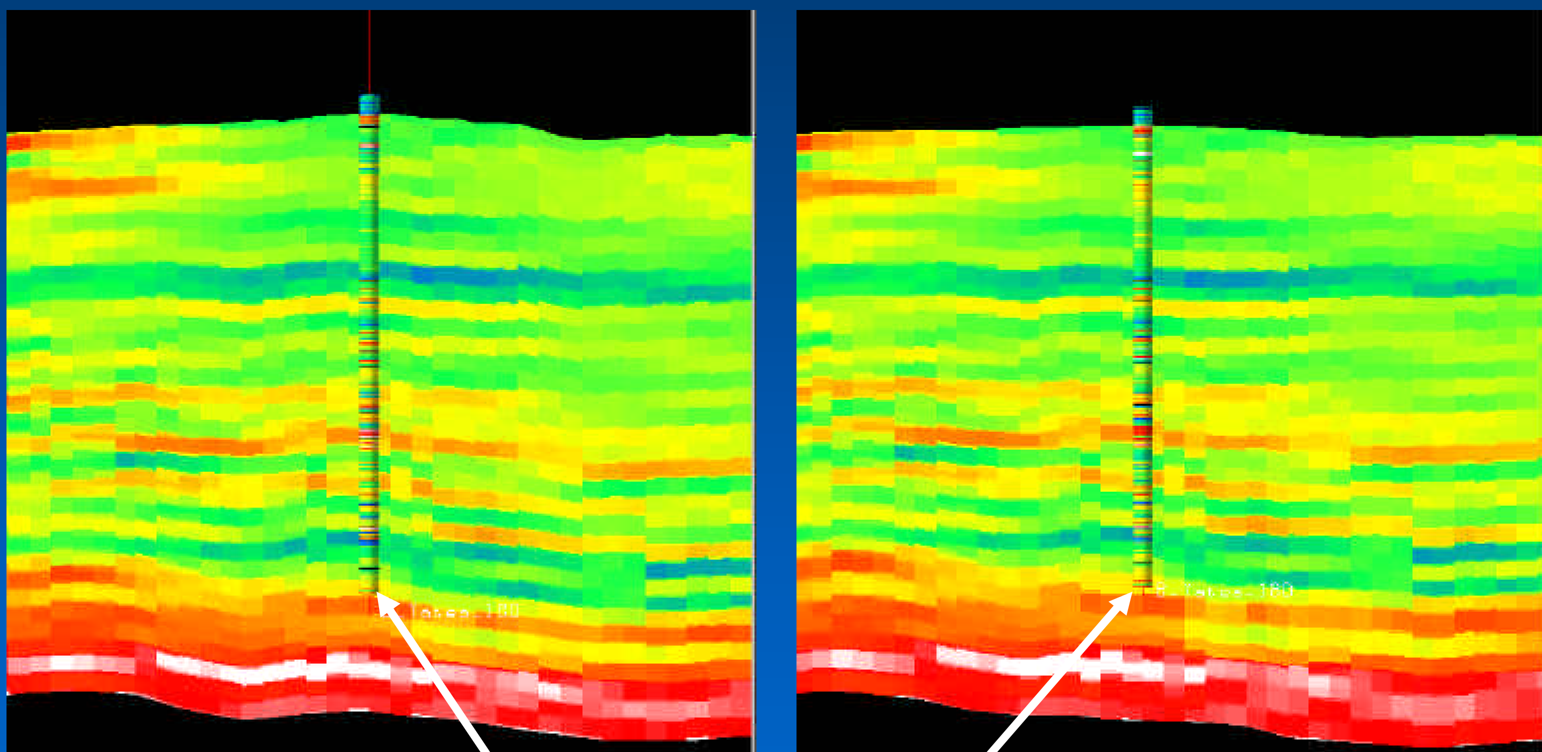


Note: Reflections
Are at layer
boundaries

Check on Inversion and Depth Conversion at Well: Yates 18D

Time Domain

Depth Domain



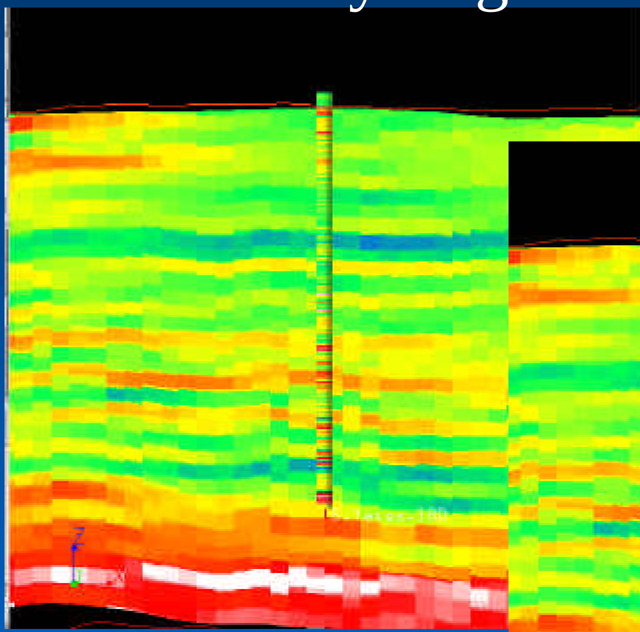
Caddo

Marble Falls LS

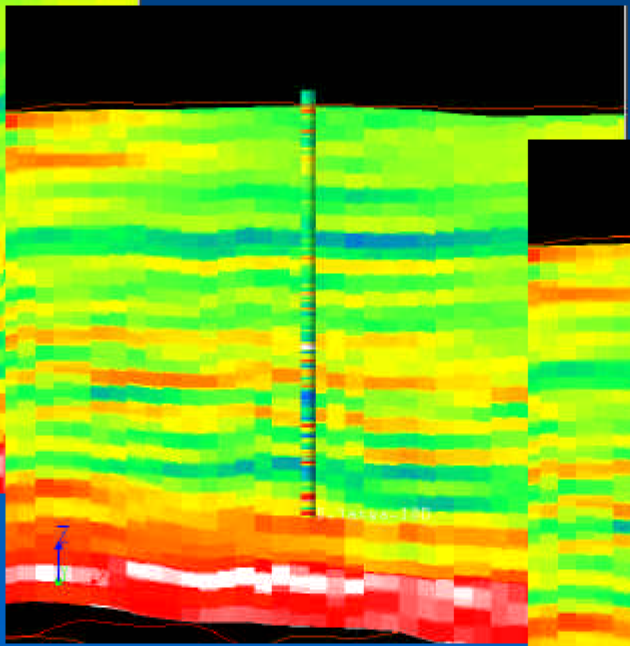
AI from Well Log

Well Log & Seismic AI
Cross-Section at well: Yates 18D

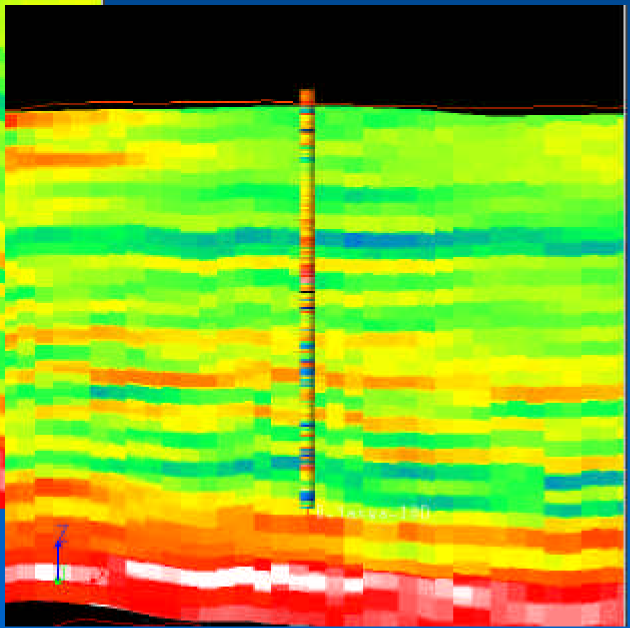
Gamma Ray Log



RT



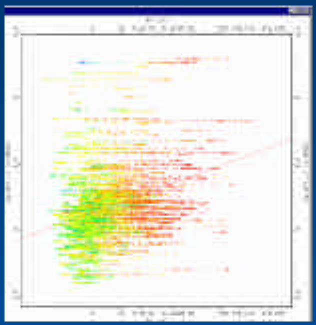
NPHI



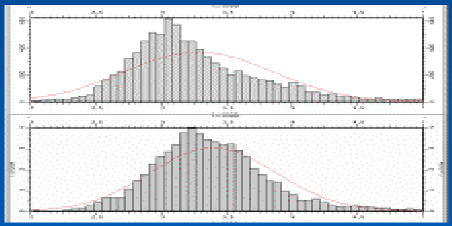
Depth Domain

Correlation of Seismic Inverted AI to Log Properties (Simple Gridding Model)

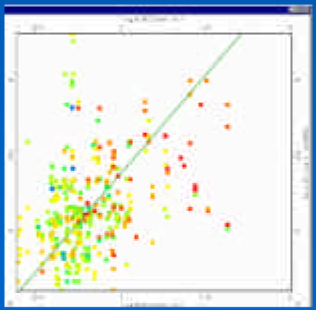
- Log scale properties cross-plotted with lower resolution seismic AI: (RT x AI) CC=0.31



- Seismic resolution is a lowering of variance
  - Loss of 25% of rock property variance.



- Necessitates that the well logs be smoothed to the common resolution scale of the seismic data
  - Smoothed logs over 20ft: (RT x AI) CC=0.41
  - Still low Correlation Coefficient from sub-optimal seismic inversion.



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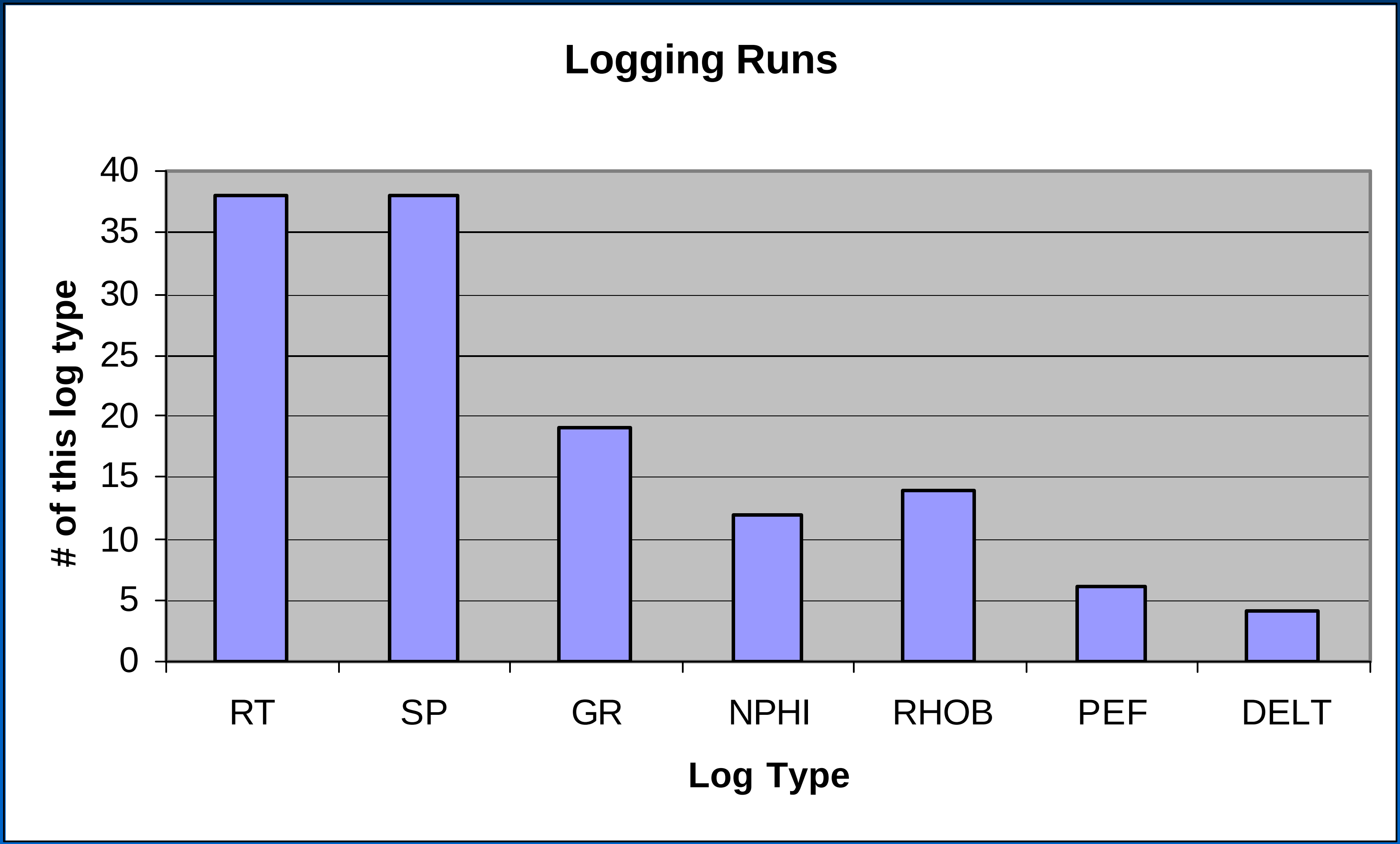
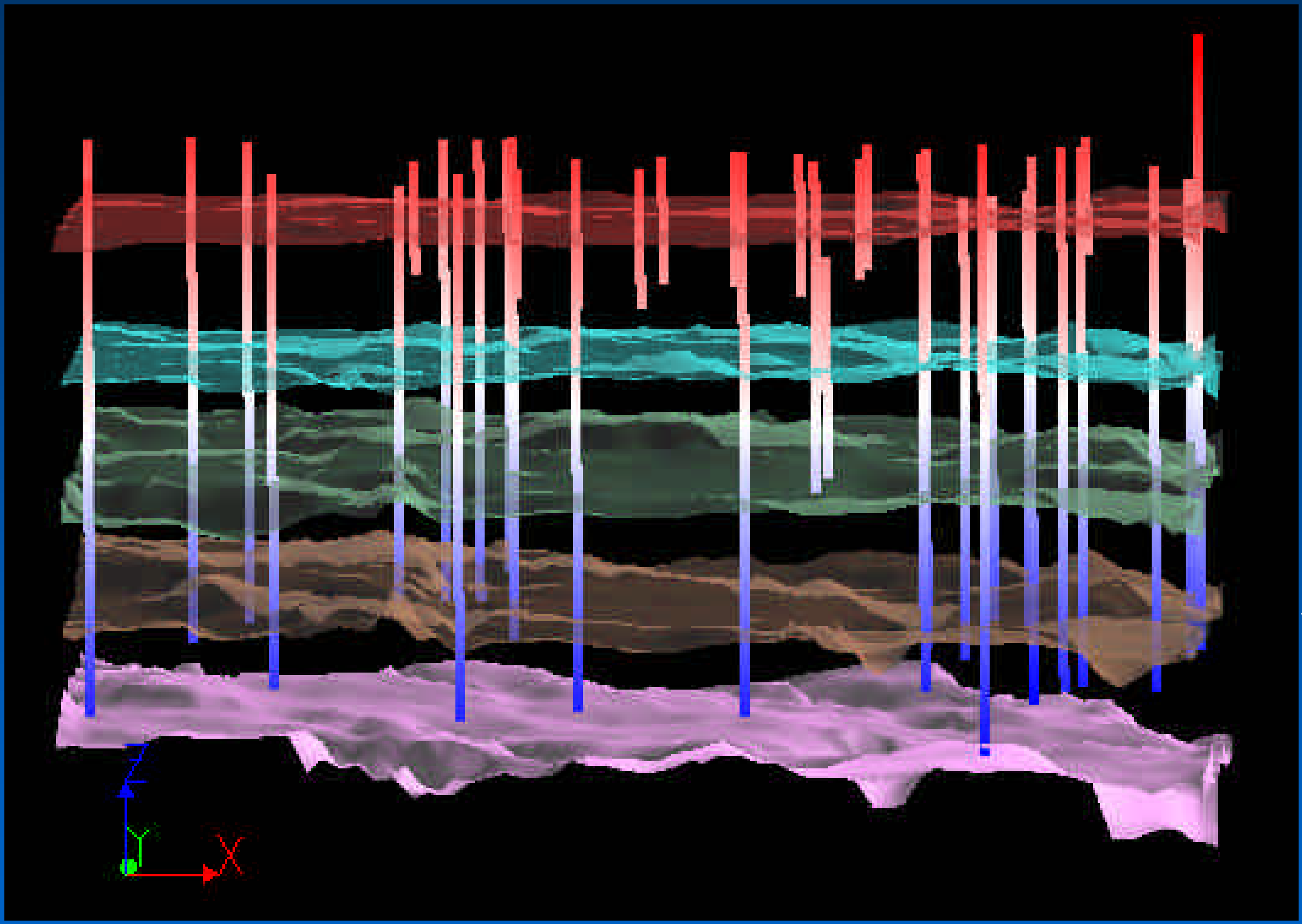
Logging Runs in Boonsville Project Area



Well Penetrations



Caddo

Davis

Runaway

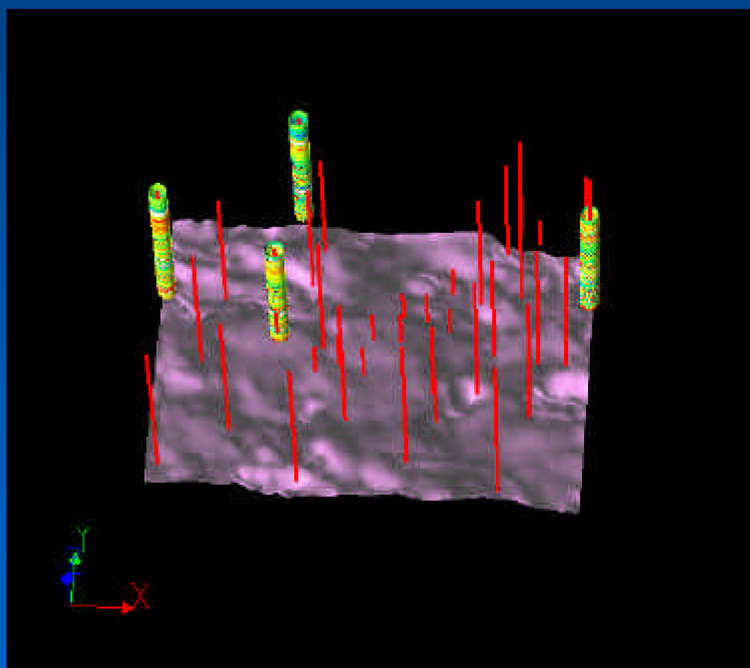
Vineyard

Marble Falls LS

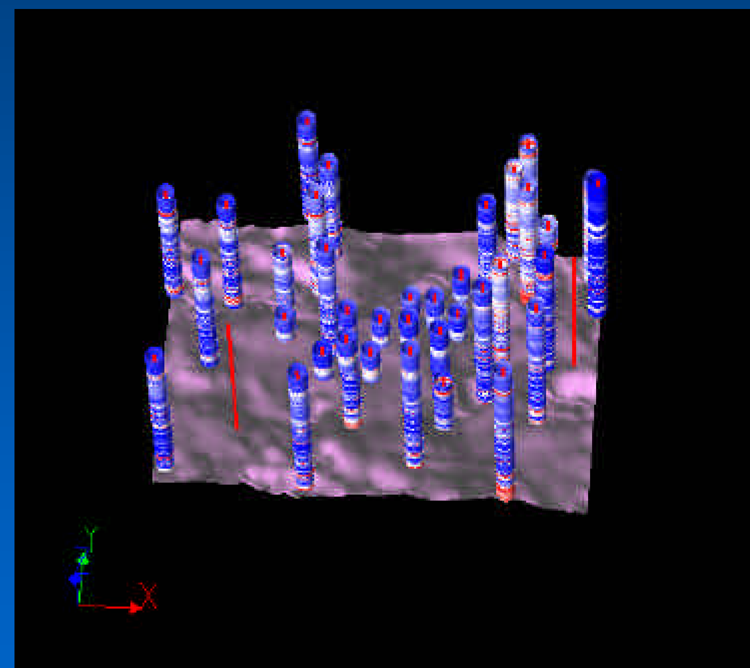
Many Caddo penetrations gives good log data coverage.
Fewer Vineyard penetrations needs seismic data to constrain modeling

Build a Better Background Impedance Model

AI Logs (only 4 wells)



RT Logs – many more wells



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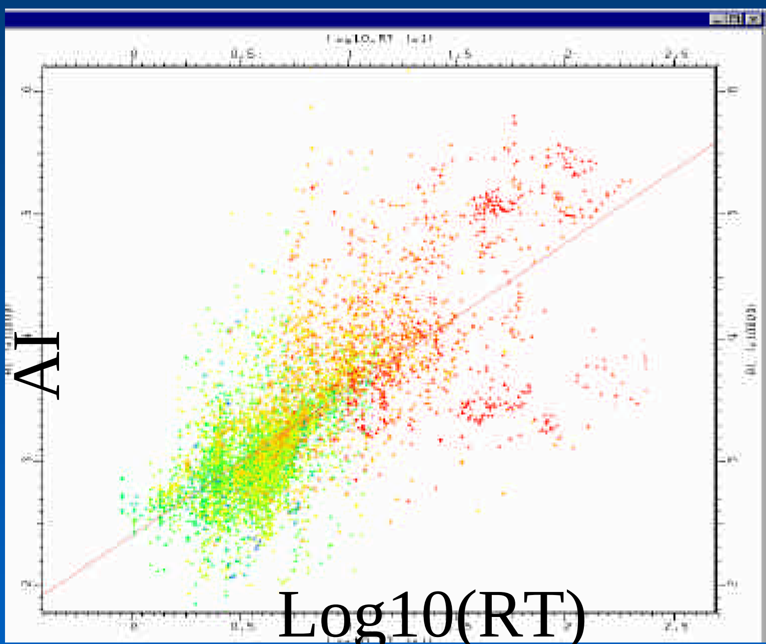
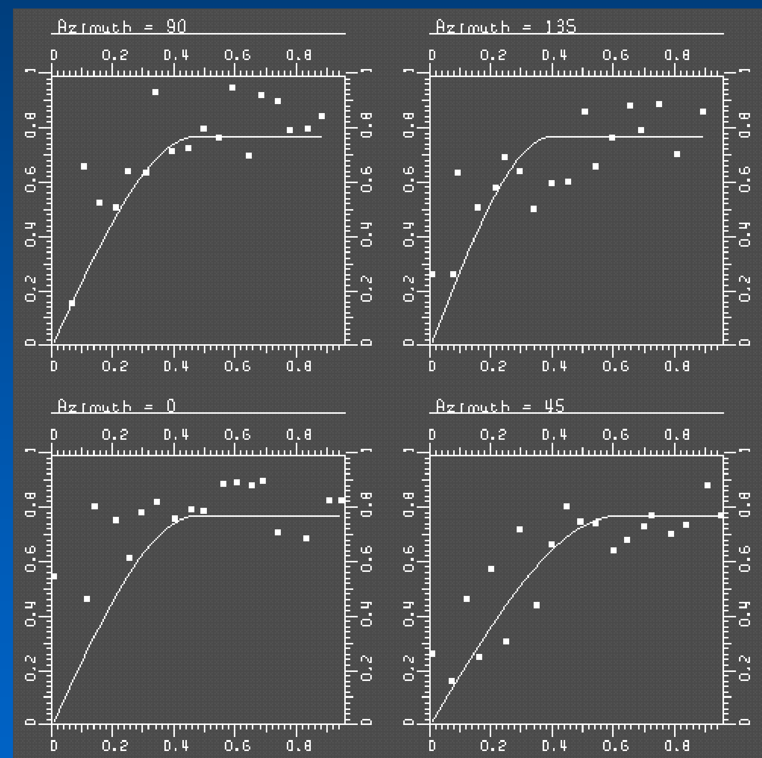
Build a Better Background Impedance Model

Use RT as a proxy for AI



CC = 0.72
(from well log data)

Variogram Model for RT Logs



Variogram Parameters
- Anisotropy Direction N45E
- UVW Space Transform
- Ranges = 0.6 & 0.4
- Sill = 0.8 (normalized)

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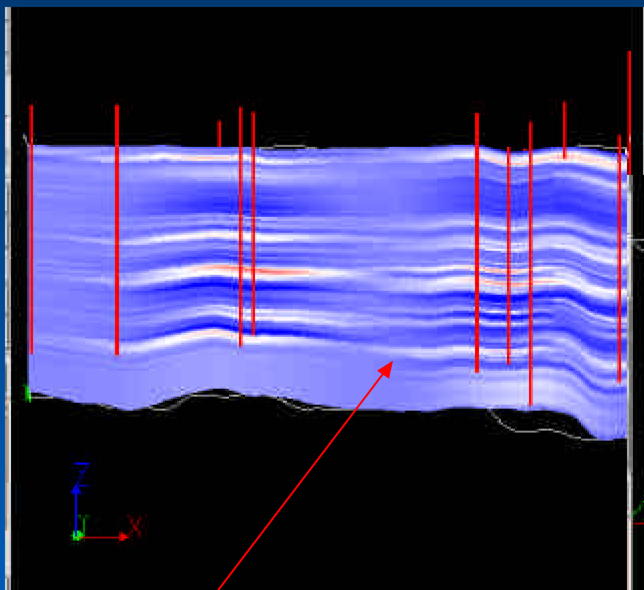
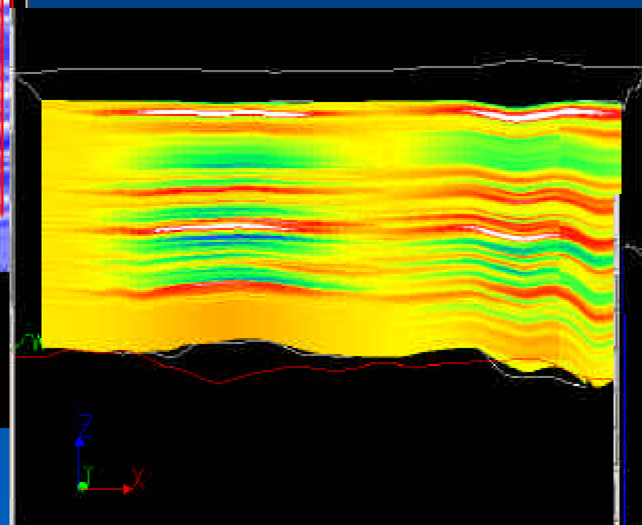
Co-Kriging the RT and AI Log Data

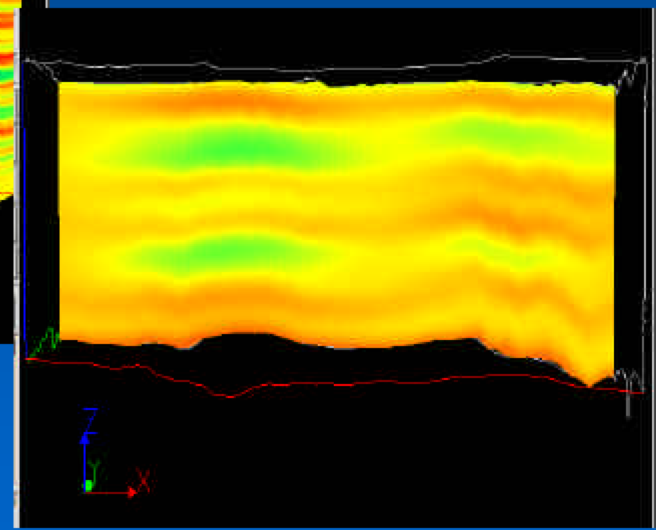
Log_{10}(RT) Kriged Model



Co-Kriged to AI

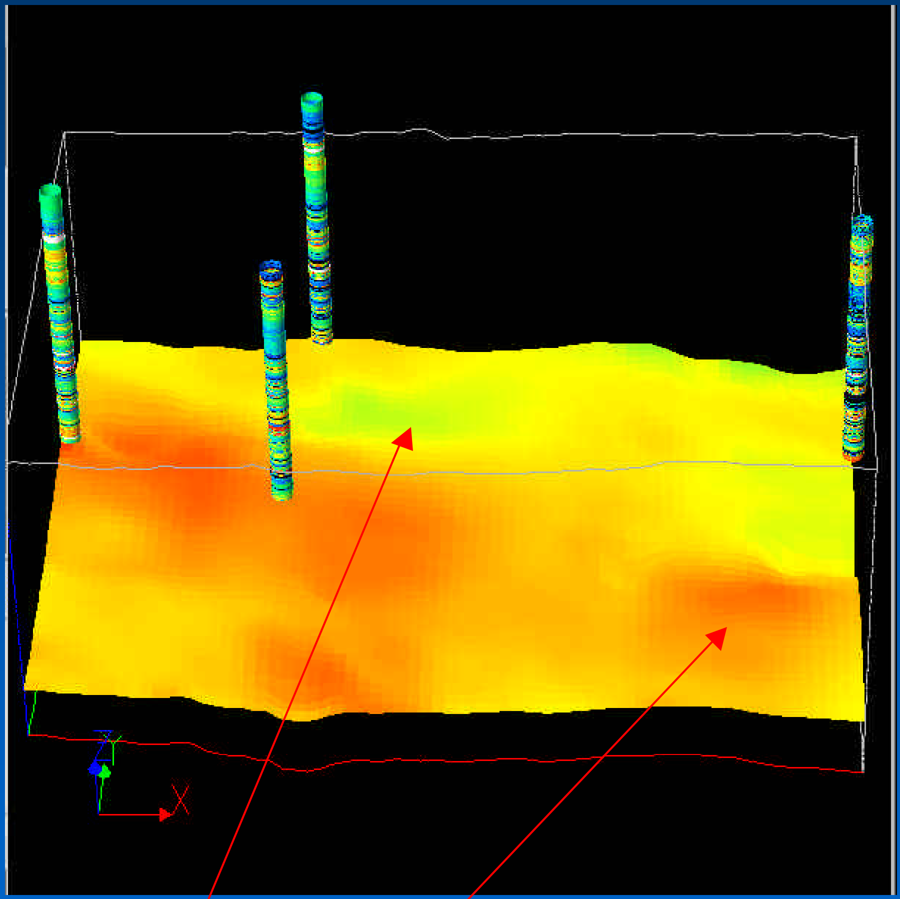


Filtered back to 0-20Hz



Subdued response due to far distance from well control

AI Model From Co-Located Co-Kriging of Well Log RT and AI Data (Filtered back to 0-20 Hz)



Map View with the 4 wells that have AI log data

Both Low and High AI areas captured by incorporating the RT logs in the modeling

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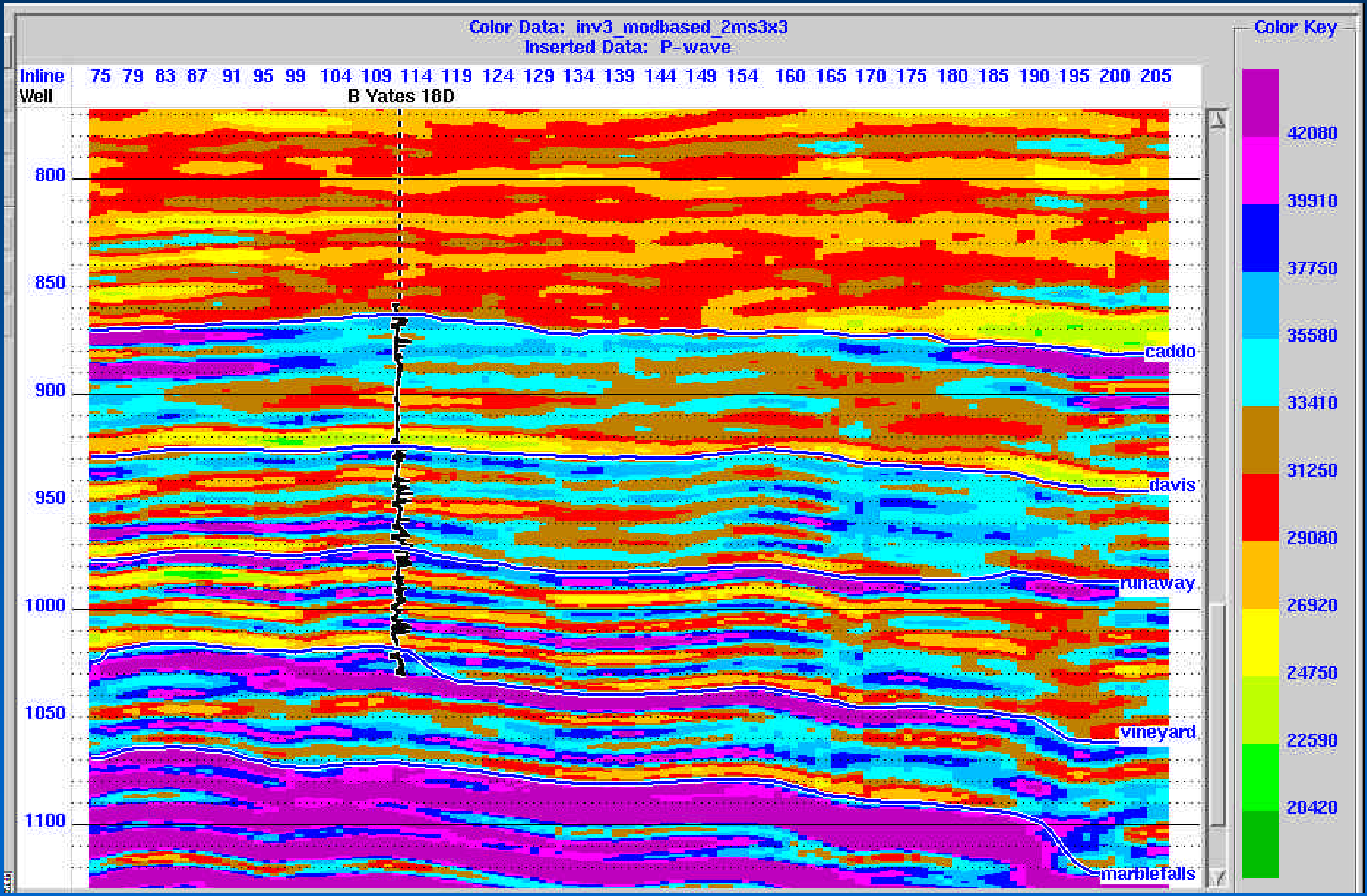
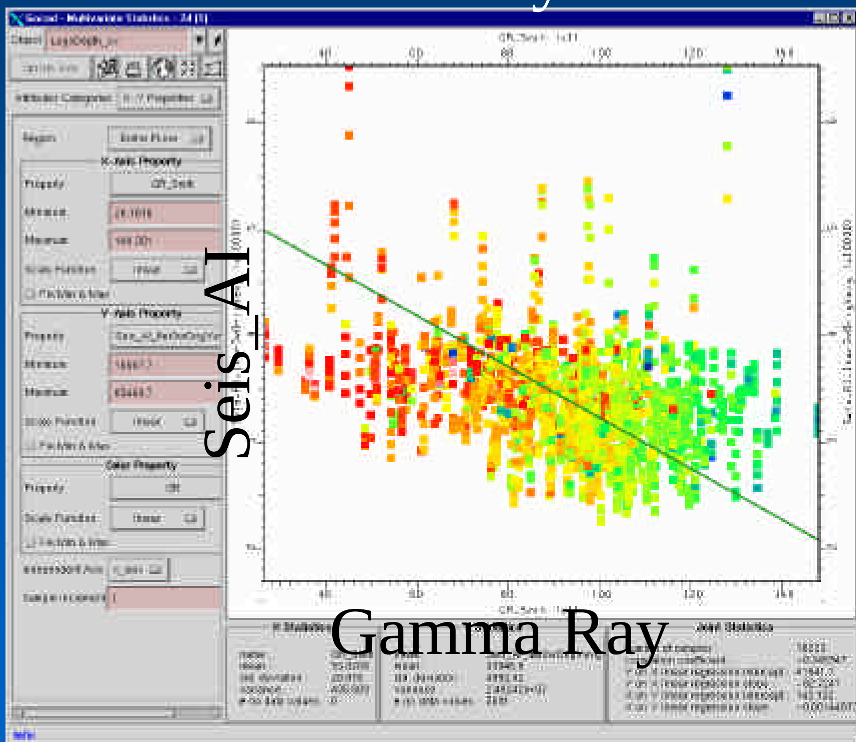
2nd Iteration:
Model Based Inversion to AI

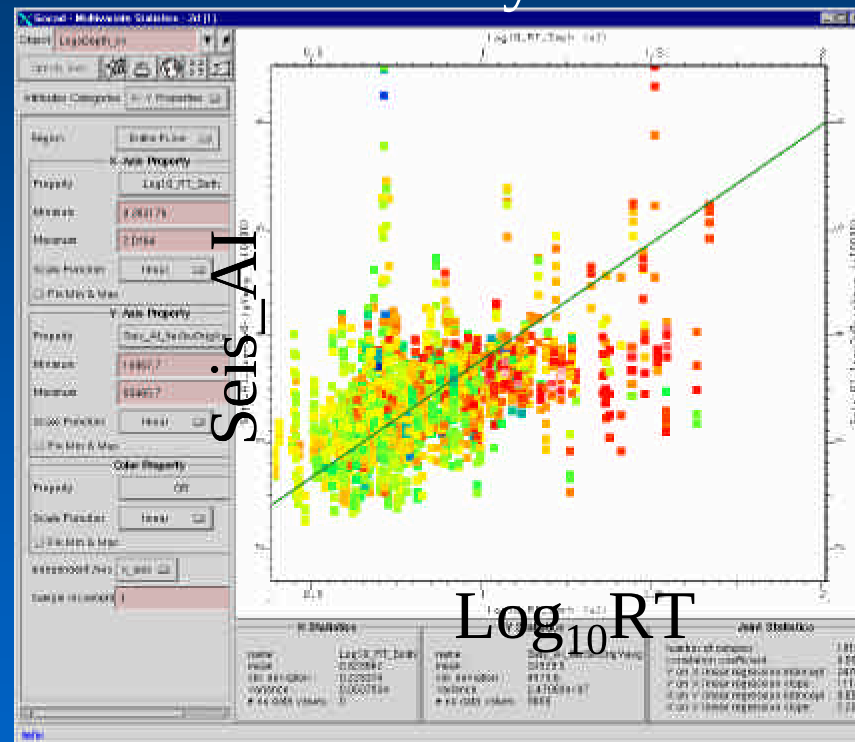


Correlation of Seismic Inverted AI to Log Properties

AI vs. Gamma Ray



AI vs. Resistivity



Colored by
Gamma Ray Log
(Red to Orange = Sand
Green to Blue = Shale)

CC=-0.35

CC=0.50

Smoothed Logs (20ft average)

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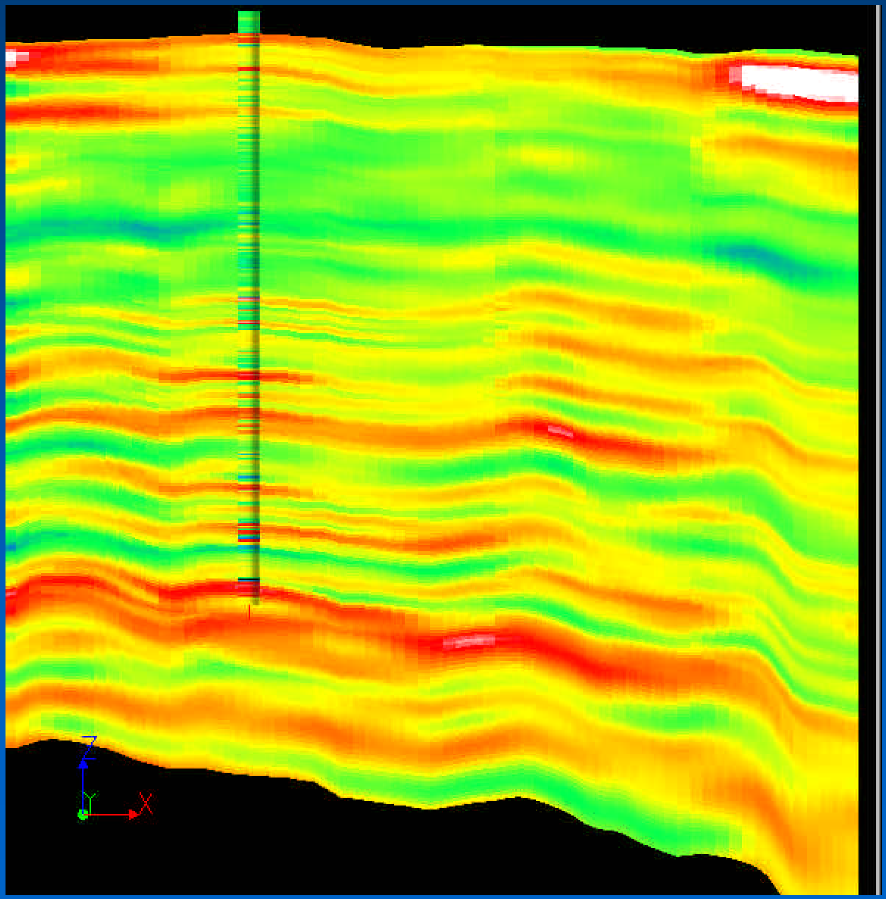
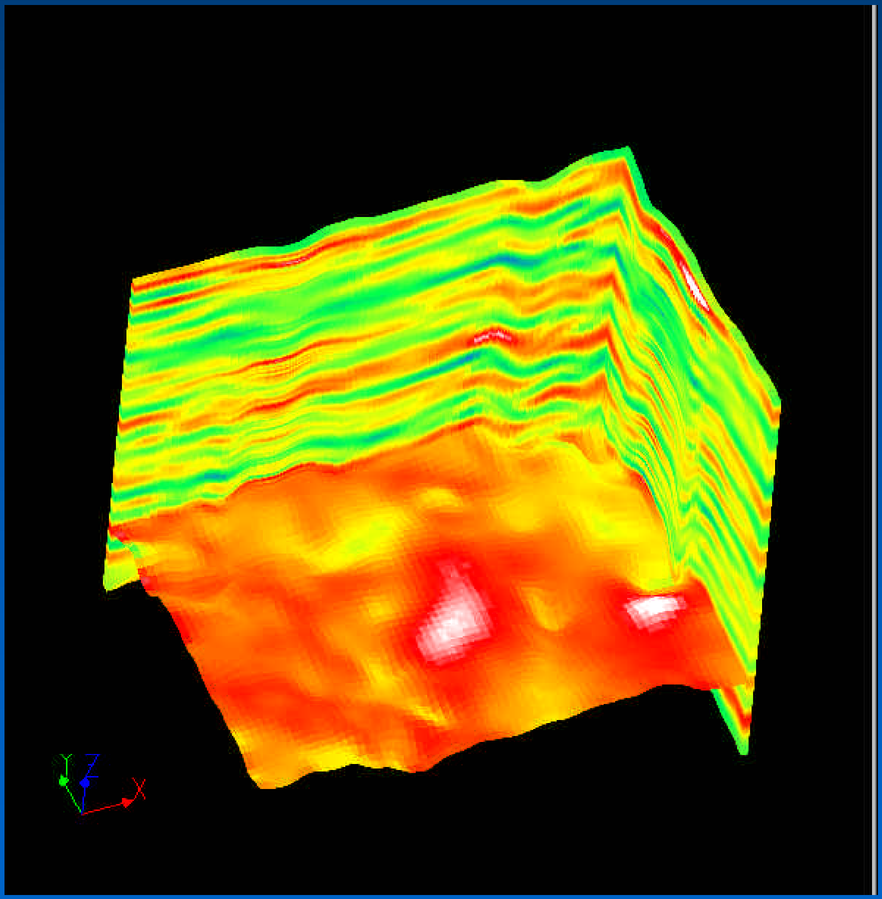
Building a Gamma Ray Model w/ Co-Located CoKriging Seismic AI





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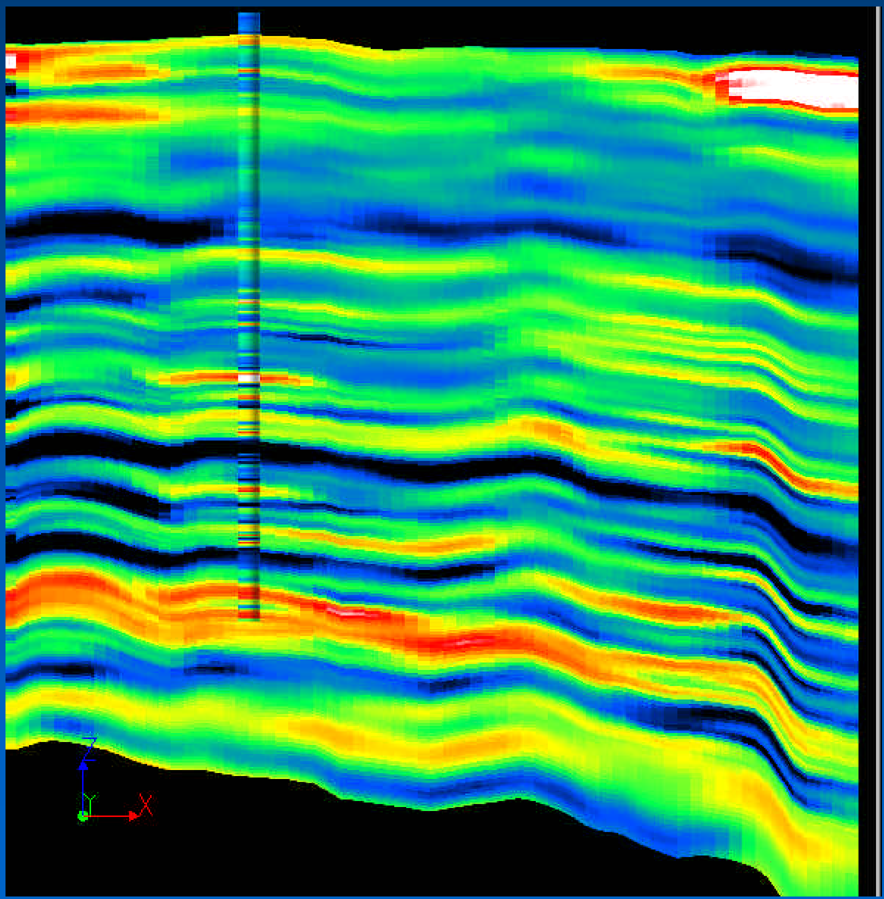
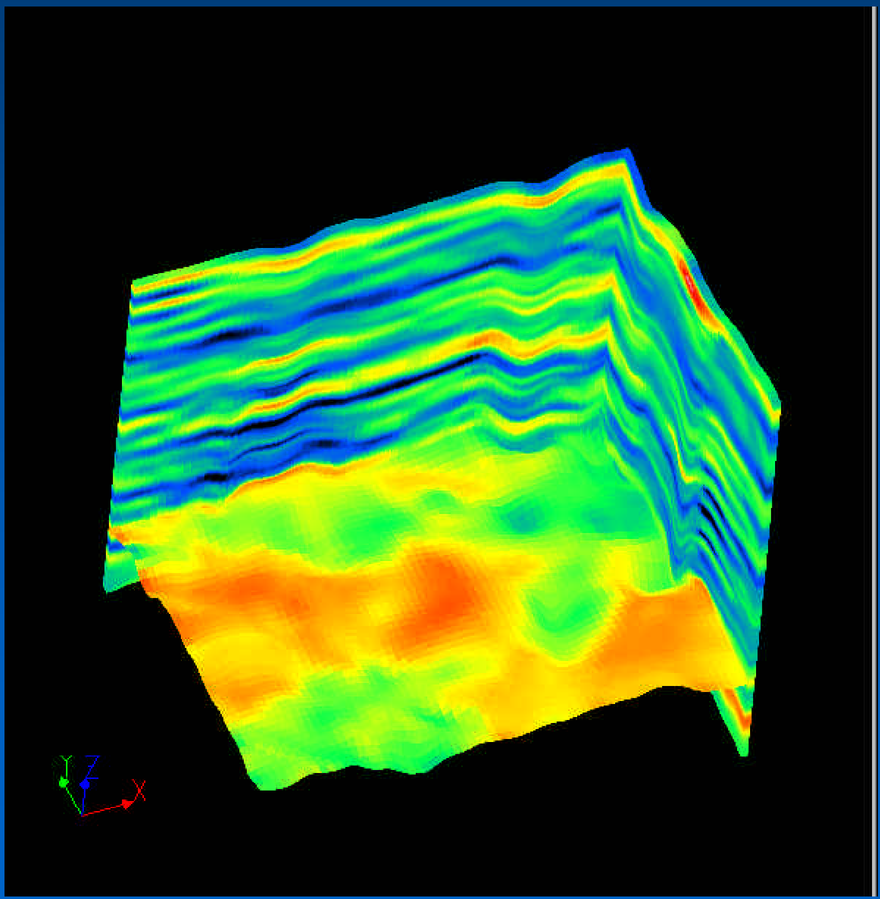
Building a Resistivity Model w/ Co-Located CoKriging Seismic AI





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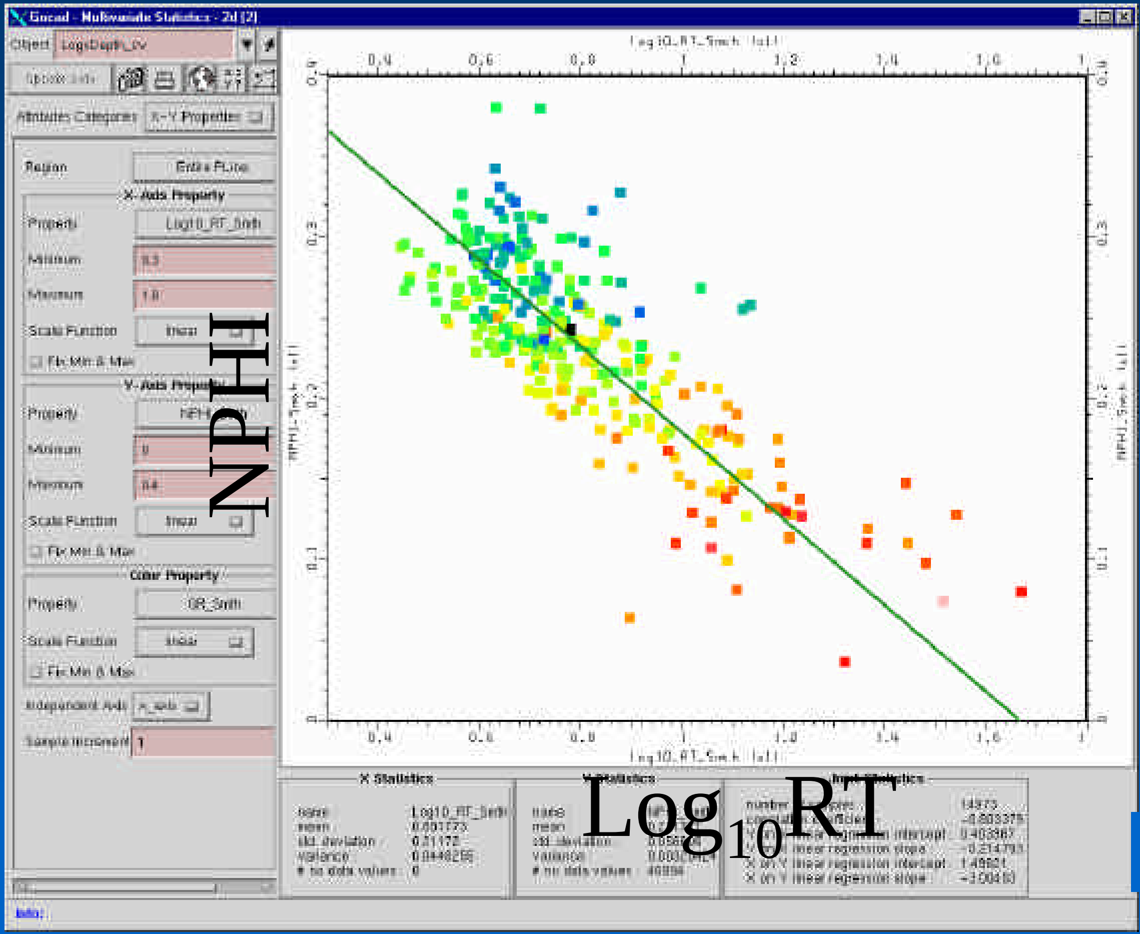
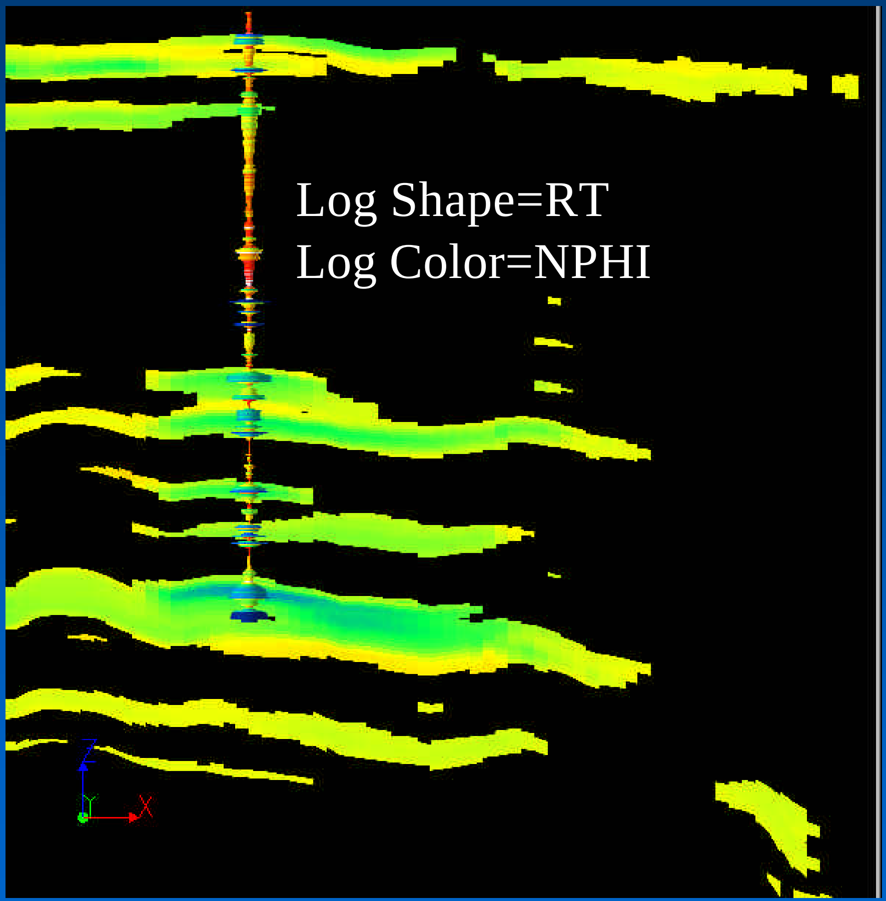
Relationship of Porosity to RT

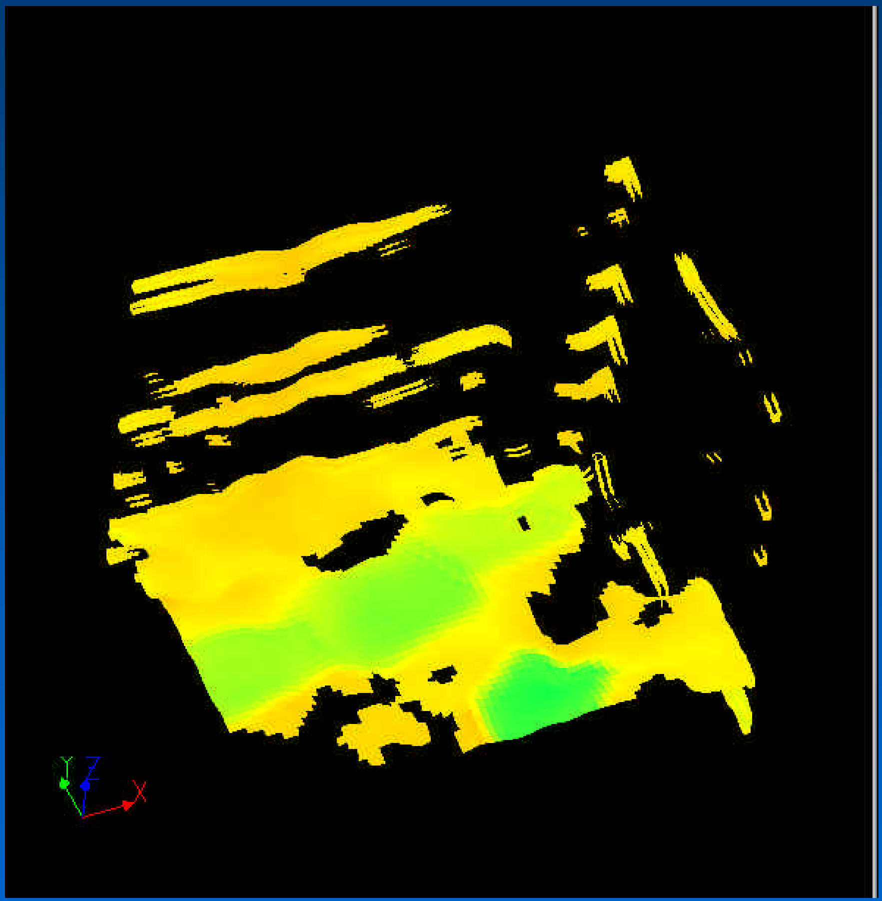


CC = -0.80

Smoothed Logs

Building a Porosity Model
CoKriging with $Log_{10}(RT)_{Smth}$ Model





Shales have porosity set=0%

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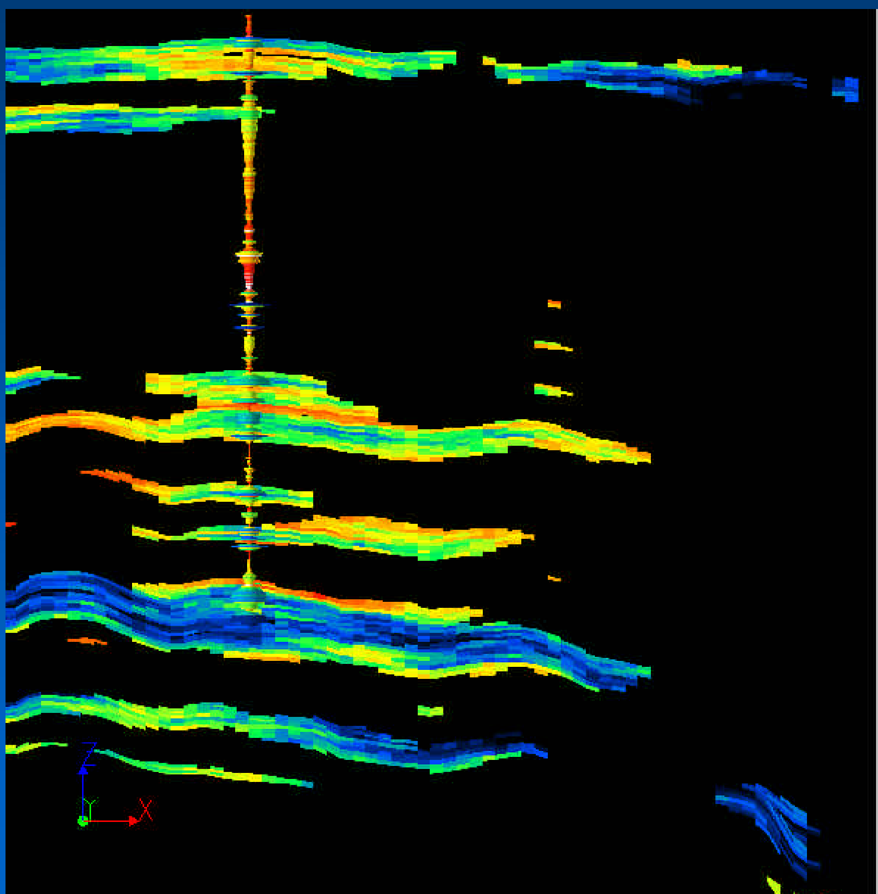
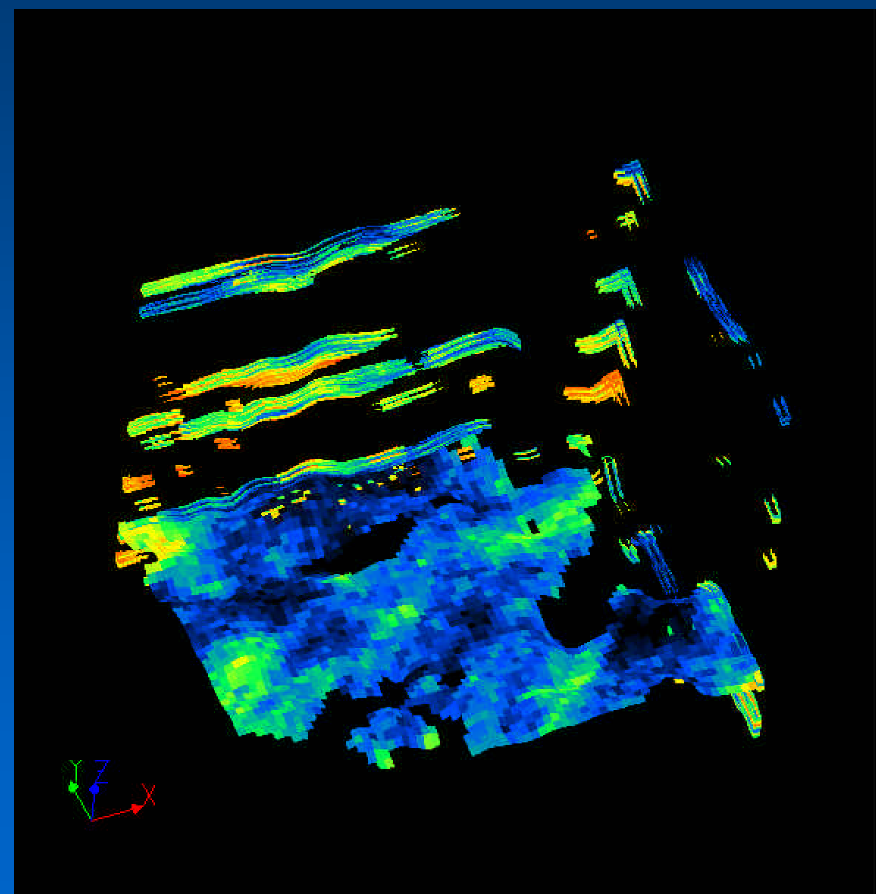
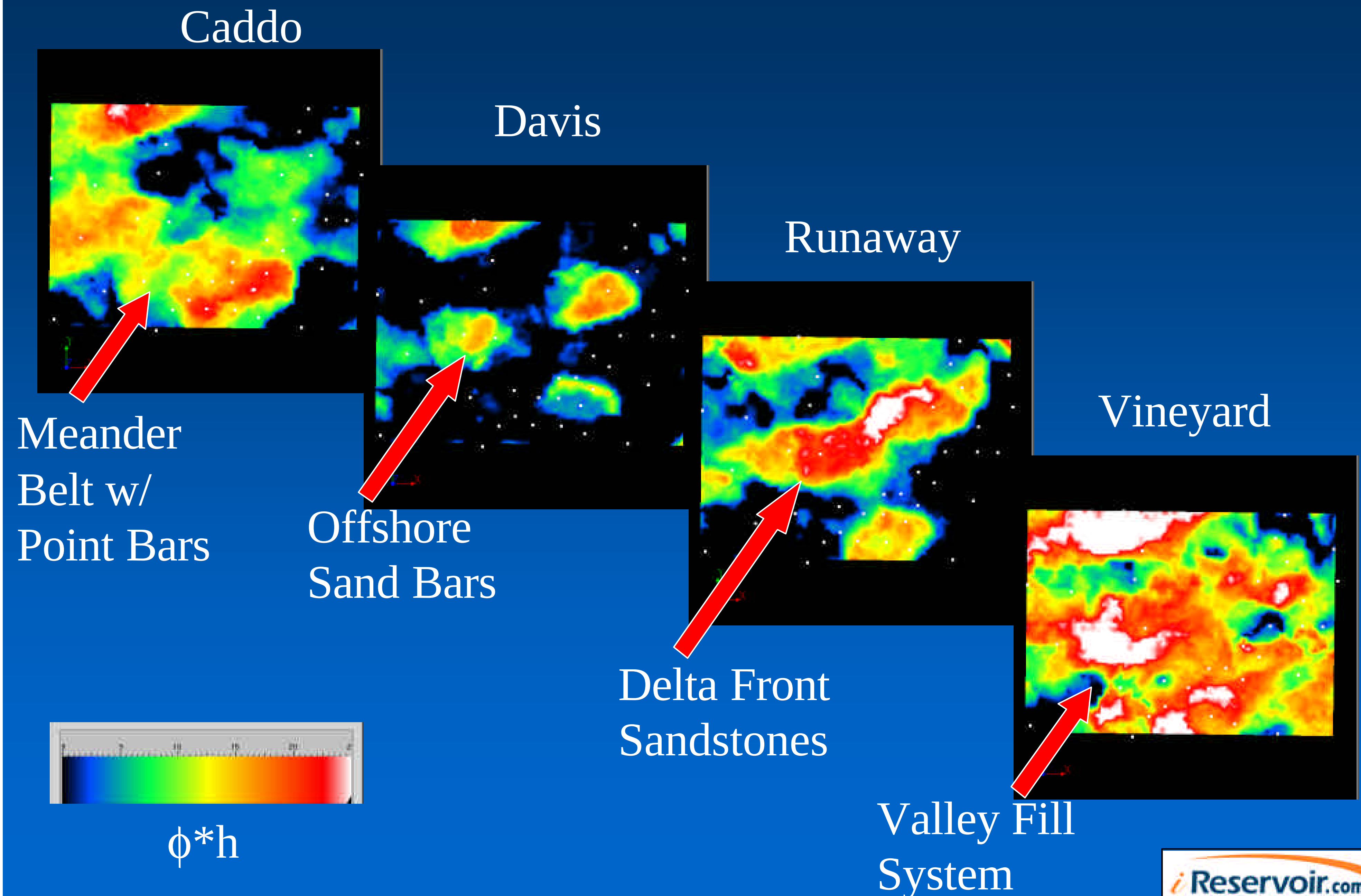
Sequential Gaussian Simulation (sGs) For Porosity Model



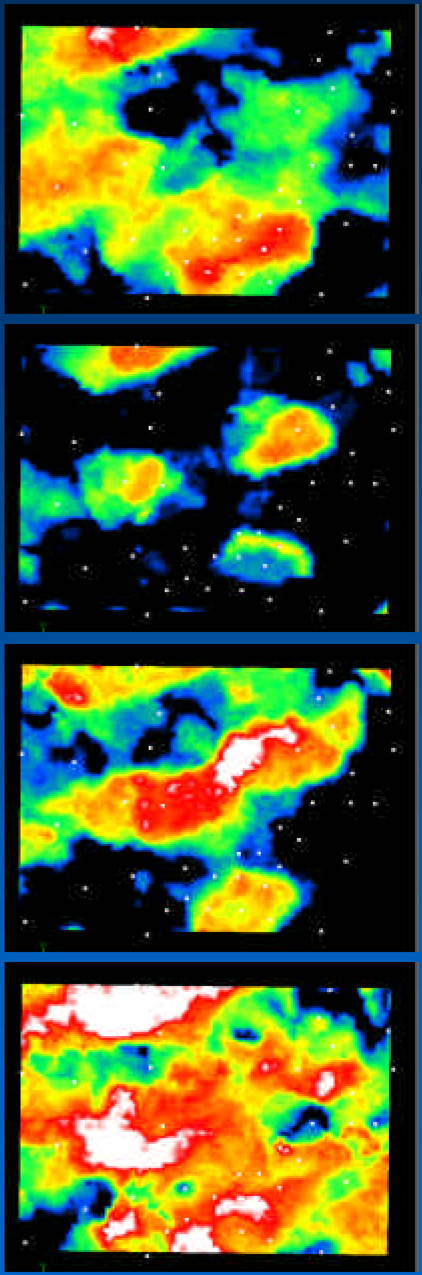


Interval Average ϕ*h Maps



Conclusions

- Seismic inverted acoustic impedance (AI) improves the interwell reservoir modeling.
- Integration of all the well log data improves the seismic inversion.
- Rock property modeling provides a detailed 3D model of this heterogeneous reservoir.



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