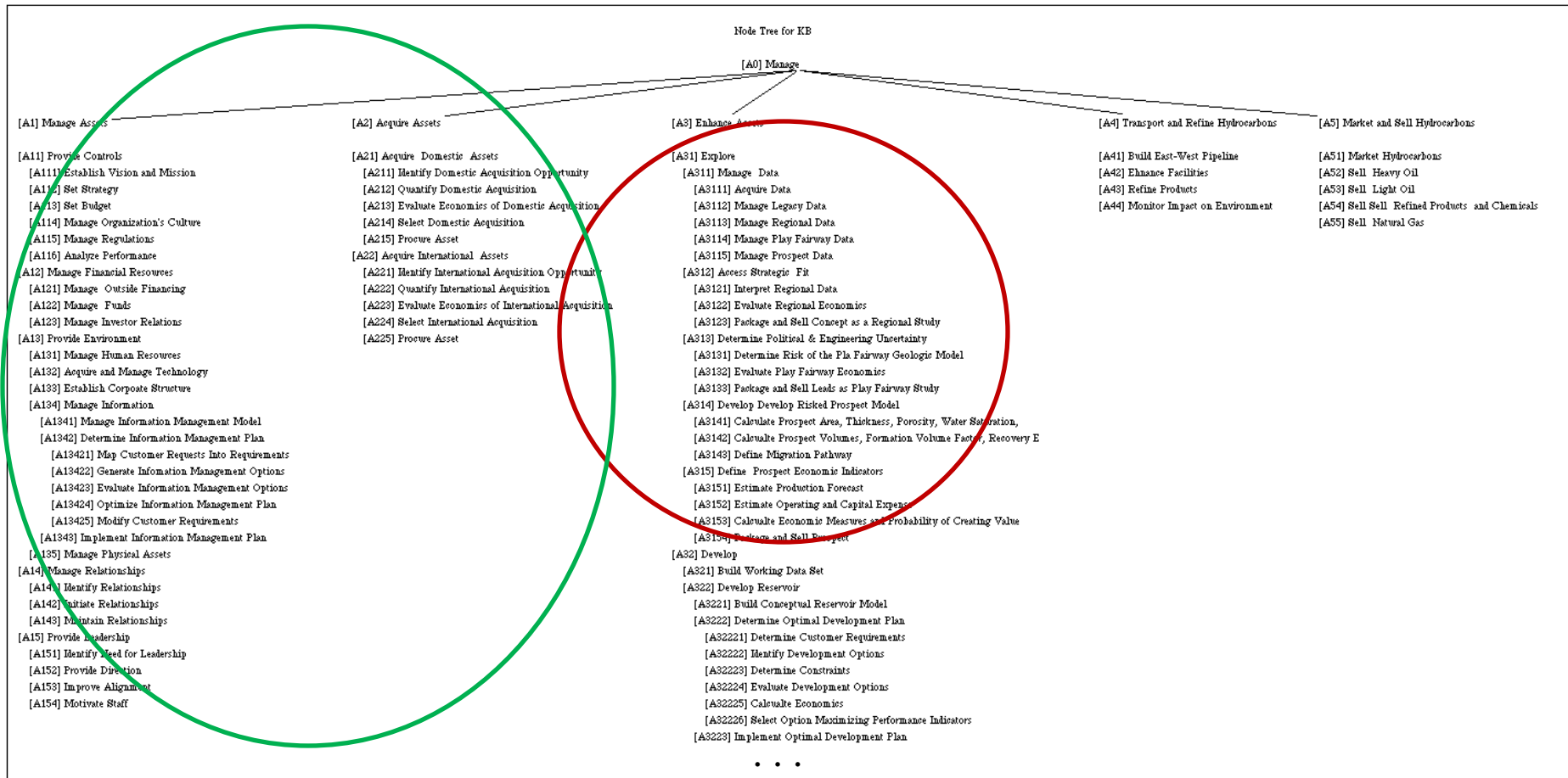# Relating Seismic Acquisition, Processing, and Interpretation

H. Roice Nelson, Jr.

Day 1 Session 2

- Relationships between seismic acquisition, processing, and interpretation
- Proven strategies in survey design
  - Wavelength
  - Resolution
  - Multi-Component
  - P-Wave vs. S-Wave & multi-component seismic
  - Amplitude preservation & migration
  - Binning
  - Zero Phase vs. Phased Data
  - 2D, 3D, and 4D time-lapse design
  - Wavelet Extraction and Inverse Modeling
- Design Considerations
  - Basement tectonic trends
    - Enhancing fracture trends
  - Anisotropy
    - Wide azimuth
  - Stratigraphic morphology
    - Multi-component
- Seismic processing
  - Binning and Phase
  - Velocities
  - Amplitudes preservation and migration
  - PSTM and PSDM
  - Wavelet Extraction and Inverse Modeling
  - Introduction to Attributes: wavelet & curvature & AVO & AVA
- Reflection seismic prediction of subsurface properties

3-D Seismic Interpretation - with an emphasis on carbonate terrains

Business and Geology Relate Seismic Acquisition, Processing, and Interpretation

Node Tree for KB

[A0] Manage

[A1] Manage Assets

[A11] Provide Controls
  [A111] Establish Vision and Mission
  [A112] Set Strategy
  [A113] Set Budget
  [A114] Manage Organization's Culture
  [A115] Manage Regulations
  [A116] Analyze Performance
[A12] Manage Financial Resources
  [A121] Manage Outside Financing
  [A122] Manage Funds
  [A123] Manage Investor Relations
[A13] Provide Environment
  [A131] Manage Human Resources
  [A132] Acquire and Manage Technology
  [A133] Establish Corpoate Structure
  [A134] Manage Information
    [A1341] Manage Information Management Model
    [A1342] Determine Information Management Plan
      [A13421] Map Customer Requests Into Requirements
      [A13422] Generate Infomation Management Options
      [A13423] Evaluate Information Management Options
      [A13424] Optimize Information Management Plan
      [A13425] Modify Customer Requirements
    [A1343] Implement Information Management Plan
  [A135] Manage Physical Assets
[A14] Manage Relationships
  [A141] Identify Relationships
  [A142] Initiate Relationships
  [A143] Maintain Relationships
[A15] Provide Leadership
  [A151] Identify Need for Leadership
  [A152] Provide Direction
  [A153] Improve Alignment
  [A154] Motivate Staff

[A2] Acquire Assets

[A21] Acquire Domestic Assets
  [A211] Identify Domestic Acquisition Opportunity
  [A212] Quantify Domestic Acquisition
  [A213] Evaluate Economics of Domestic Acquisition
  [A214] Select Domestic Acquisition
  [A215] Procure Asset
[A22] Acquire International Assets
  [A221] Identify International Acquisition Opportunity
  [A222] Quantify International Acquisition
  [A223] Evaluate Economics of International Acquisition
  [A224] Select International Acquisition
  [A225] Procure Asset

[A3] Enhance Assets

[A31] Explore
  [A311] Manage Data
    [A3111] Acquire Data
    [A3112] Manage Legacy Data
    [A3113] Manage Regional Data
    [A3114] Manage Play Fairway Data
    [A3115] Manage Prospect Data
  [A312] Access Strategic Fit
    [A3121] Interpret Regional Data
    [A3122] Evaluate Regional Economics
    [A3123] Package and Sell Concept as a Regional Study
  [A313] Determine Political & Engineering Uncertainty
    [A3131] Determine Risk of the Pla Fairway Geologic Model
    [A3132] Evaluate Play Fairway Economics
    [A3133] Package and Sell Leads as Play Fairway Study
  [A314] Develop Develop Risked Prospect Model
    [A3141] Calculate Prospect Area, Thickness, Porosity, Water Saturation,
    [A3142] Calcualte Prospect Volumes, Formation Volume Factor, Recovery E
    [A3143] Define Migration Pathway
  [A315] Define Prospect Economic Indicators
    [A3151] Estimate Production Forecast
    [A3152] Estimate Operating and Capital Expense
    [A3153] Calcualte Economic Measures and Probability of Creating Value
    [A3154] Package and Sell Prospect
[A32] Develop
  [A321] Build Working Data Set
  [A322] Develop Reservoir
    [A3221] Build Conceptual Reservoir Model
    [A3222] Determine Optimal Development Plan
      [A32221] Determine Customer Requirements
      [A32222] Identify Development Options
      [A32223] Determine Constraints
      [A32224] Evaluate Development Options
      [A32225] Calcualte Economics
      [A32226] Select Option Maximizing Performance Indicators
    [A3223] Implement Optimal Development Plan

• • •

[A4] Transport and Refine Hydrocarbons

[A41] Build East-West Pipeline
[A42] Ehnance Facilities
[A43] Refine Products
[A44] Monitor Impact on Environment

[A5] Market and Sell Hydrocarbons

[A51] Market Hydrocarbons
[A52] Sell Heavy Oil
[A53] Sell Light Oil
[A54] Sell Sell Refined Products and Chemicals
[A55] Sell Natural Gas

Ranking a Study Area

- A client provided a list of 10 Nigerian lease blocks he was looking at bidding on: OPL-135; OPL-233; OPL-239; OPL-241; OPL-259; OPL-313; OPL-315; OPL-317; OPL-318; and OPL-915.

- The request was for a ranking of the potential of these blocks.

- On file were studies done for the Asuokpu, Atala, Eremor, Ibigwe, Ogedeh, Umusati, Umutu, and Uquo Marginal Fields.
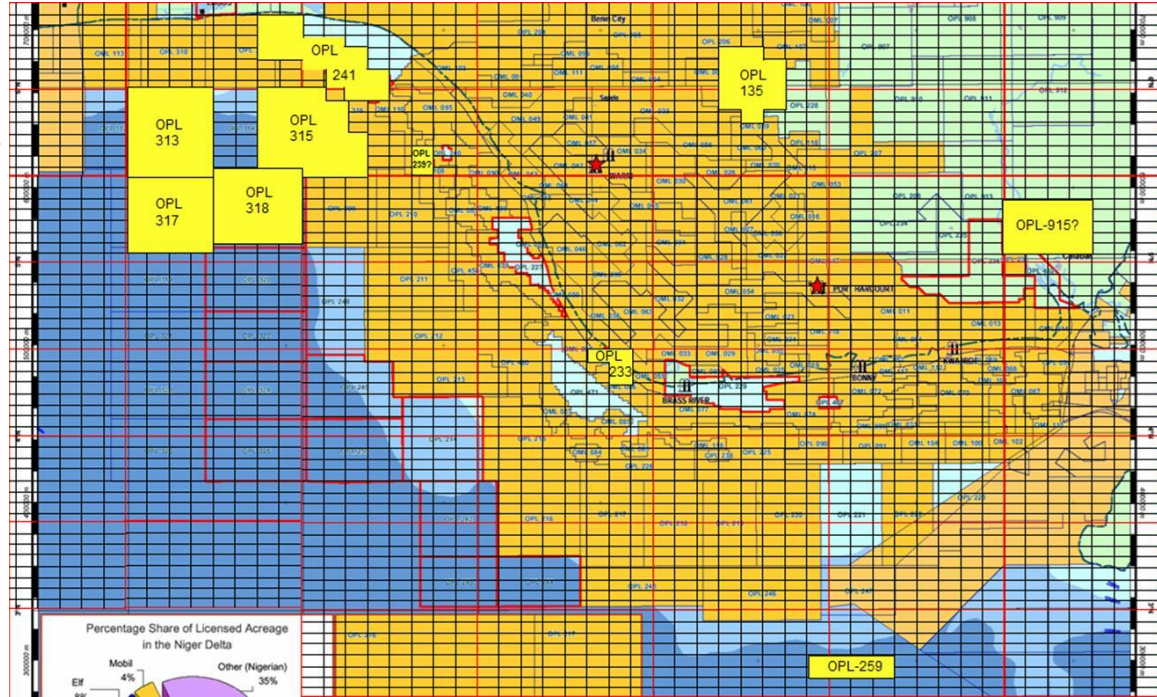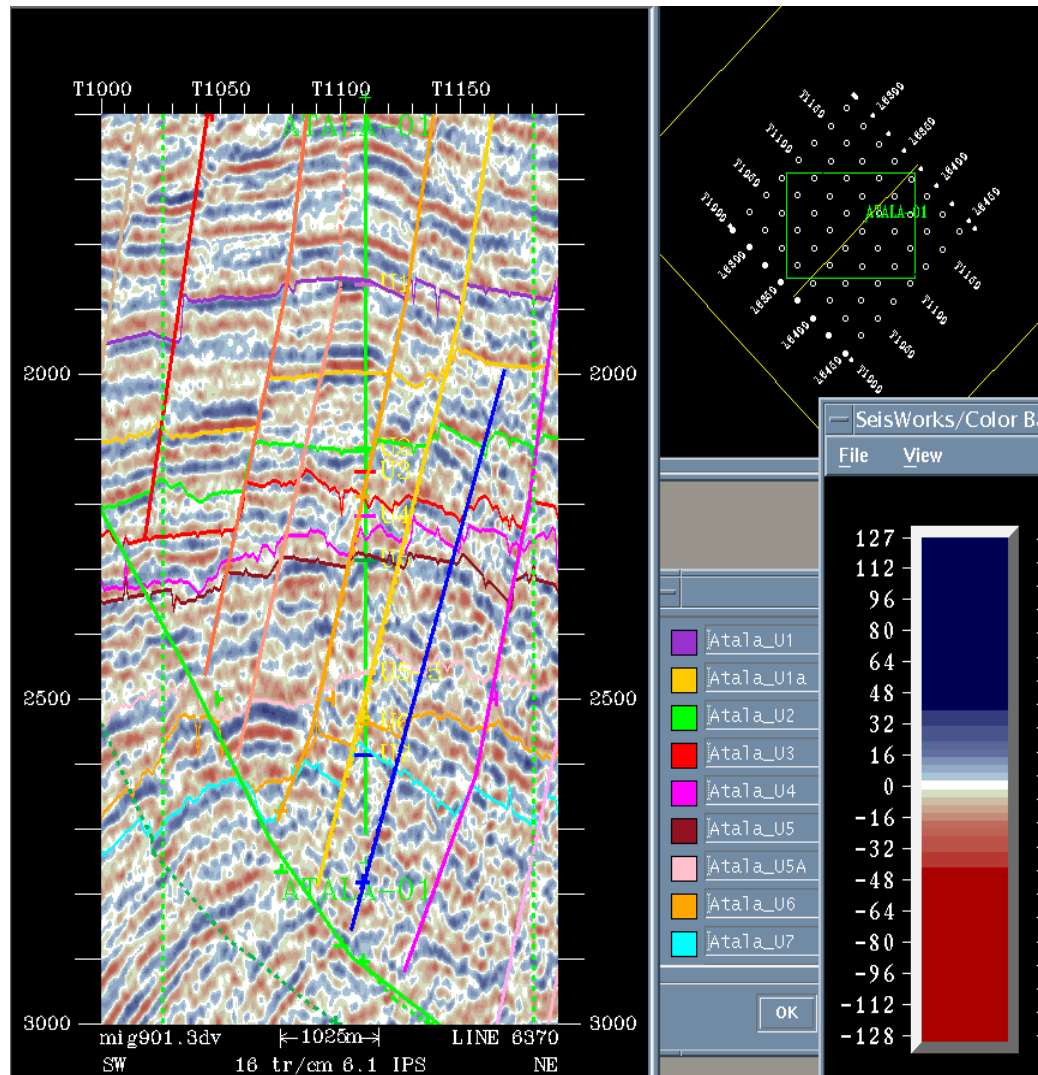

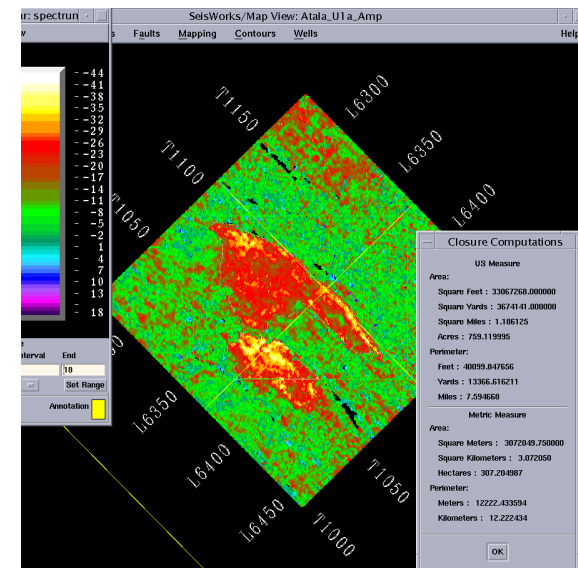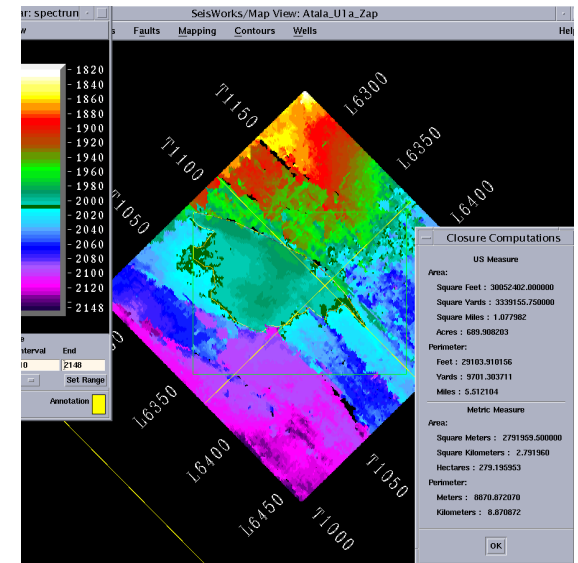**Step 1. Review the existing seismic and well data on file for the area.**

Asuokpu Marginal Field with 3-D
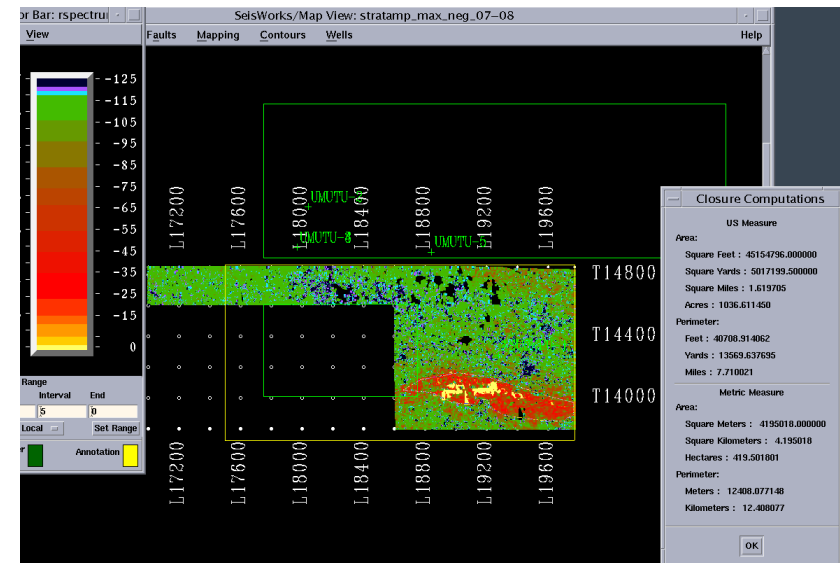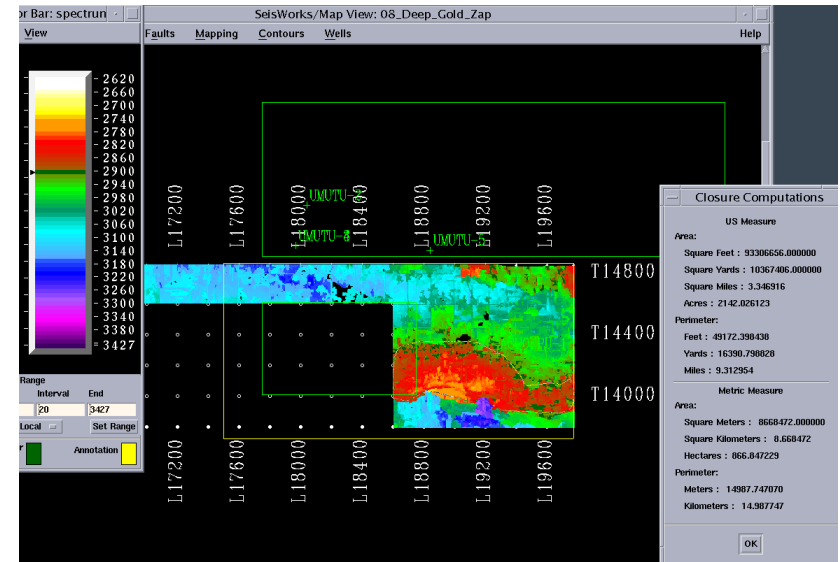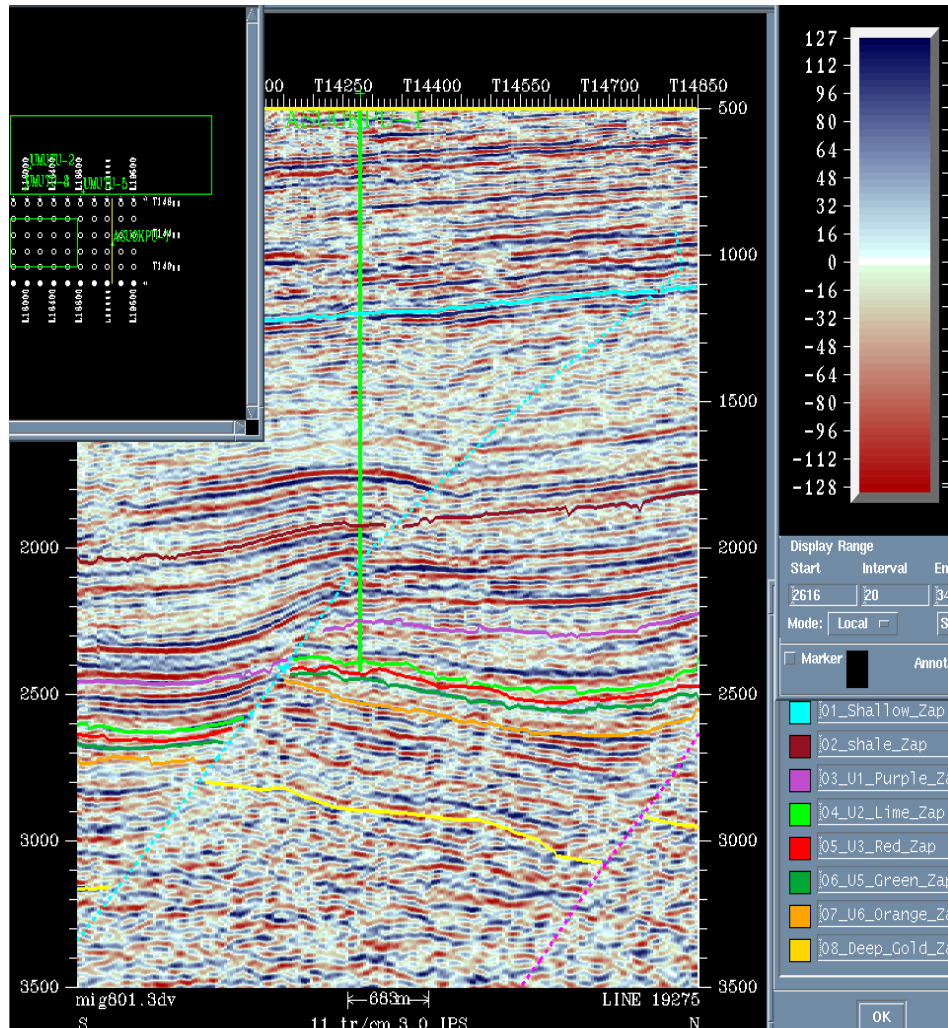
FLASH: 3.0105149

Atala Marginal Field with 3-D

FLASH: 0.30105149

Eremor Marginal Field with 3-D
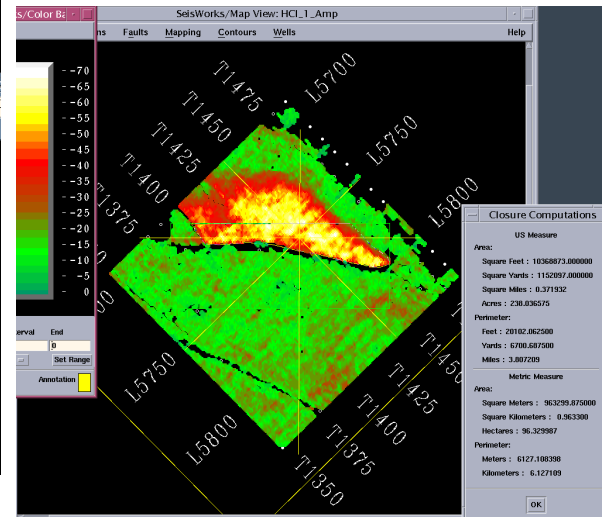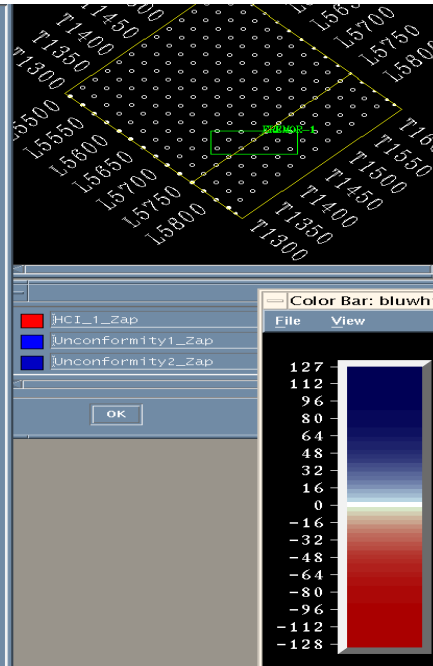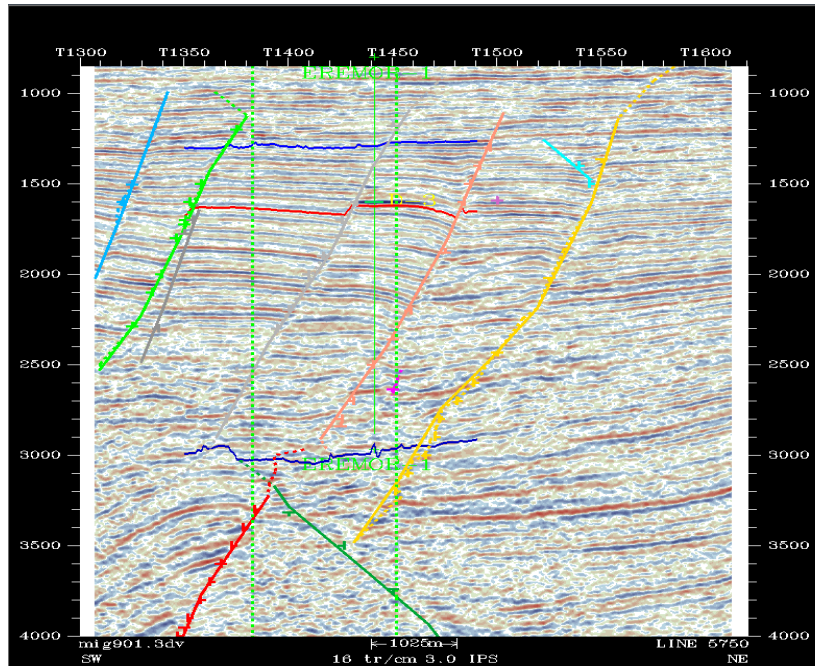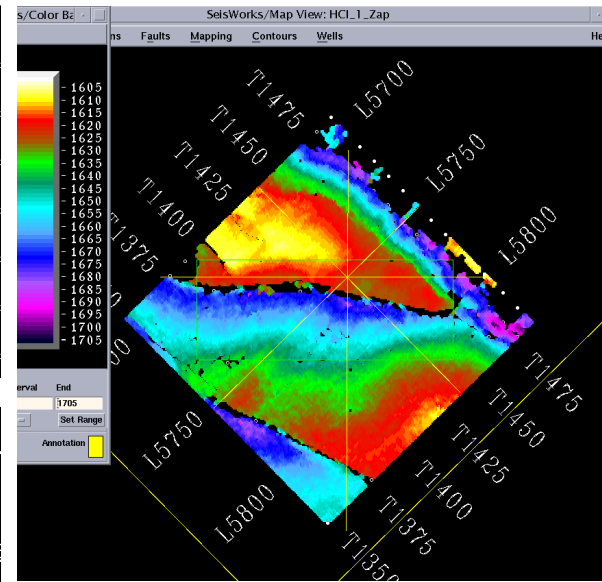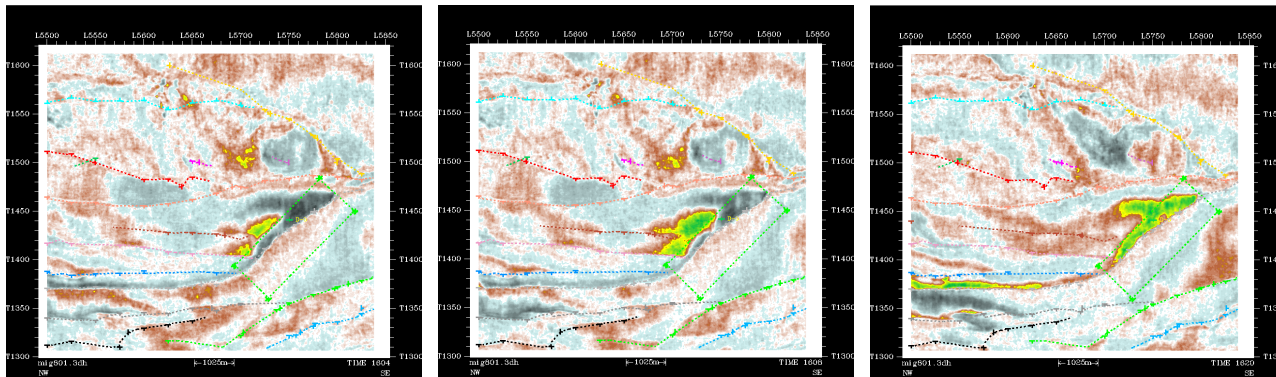
FLASH: 0.11900000

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Ibigwe Marginal Field with 3-D
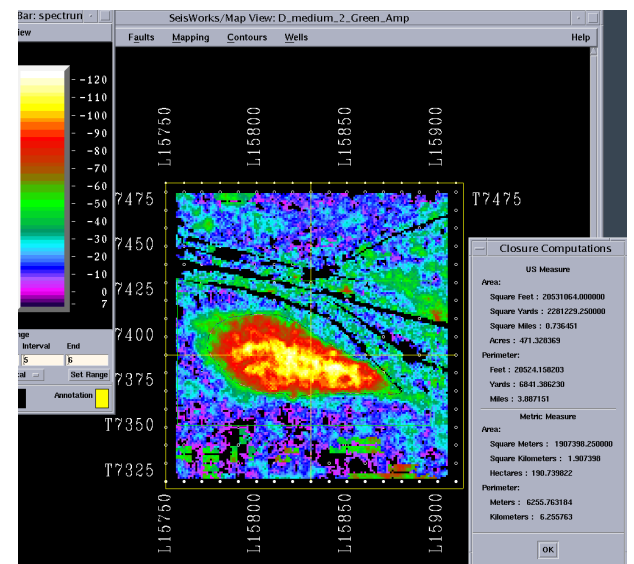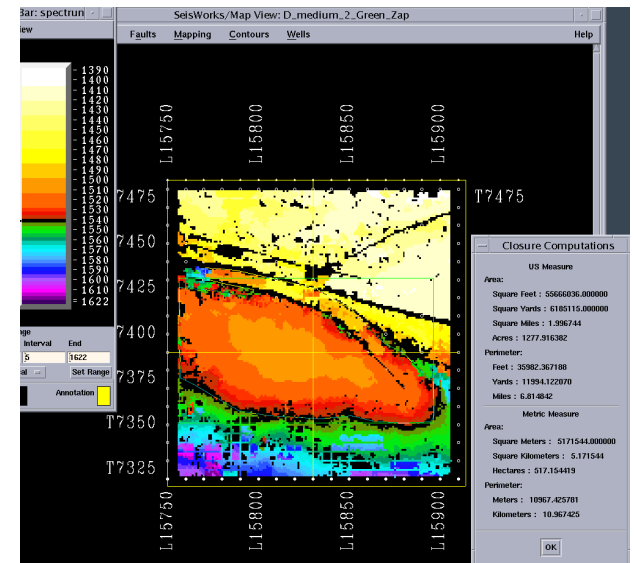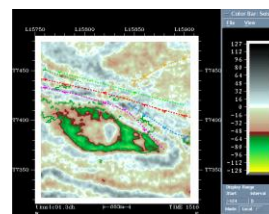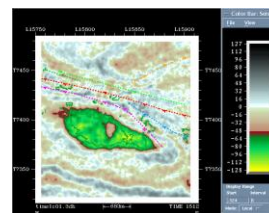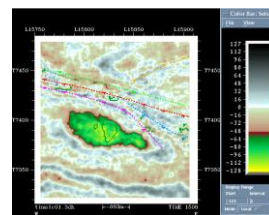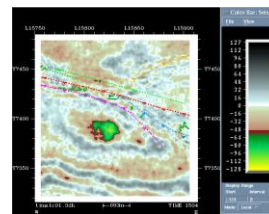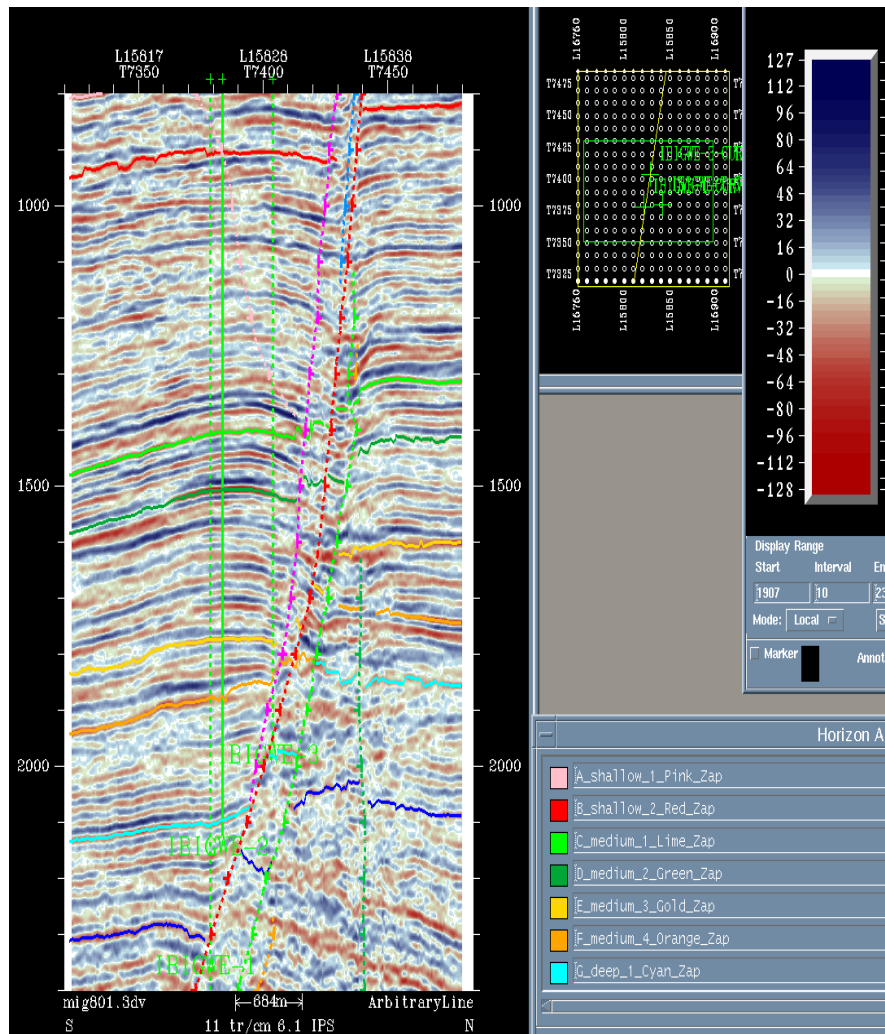
FLASH: 0.90819724

Ogedeh Marginal Field with 3-D

FLASH: 0.00783957

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Umusati Marginal Field with 3-D
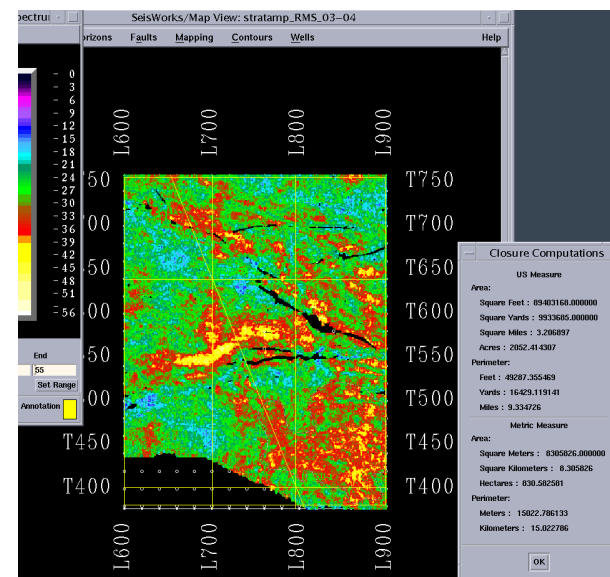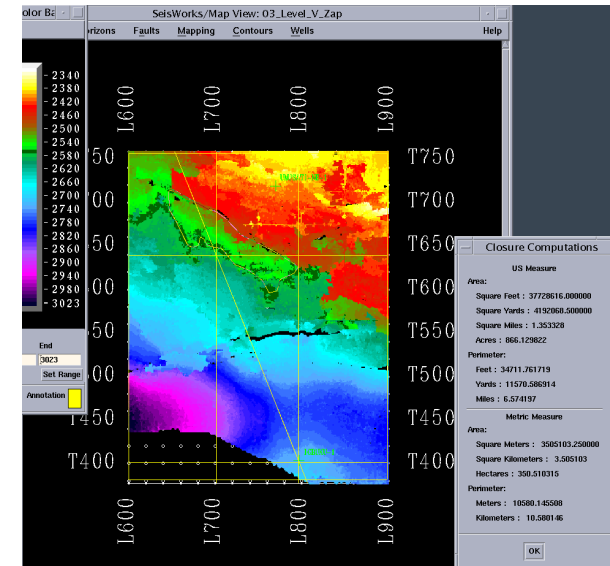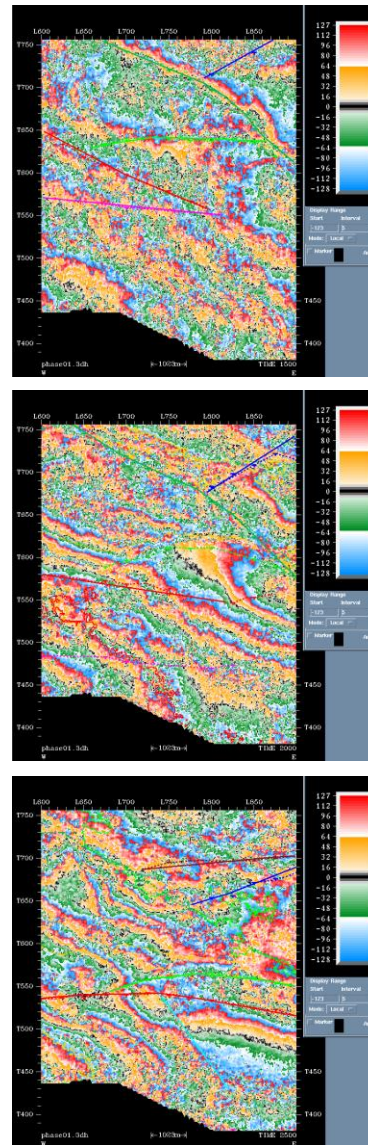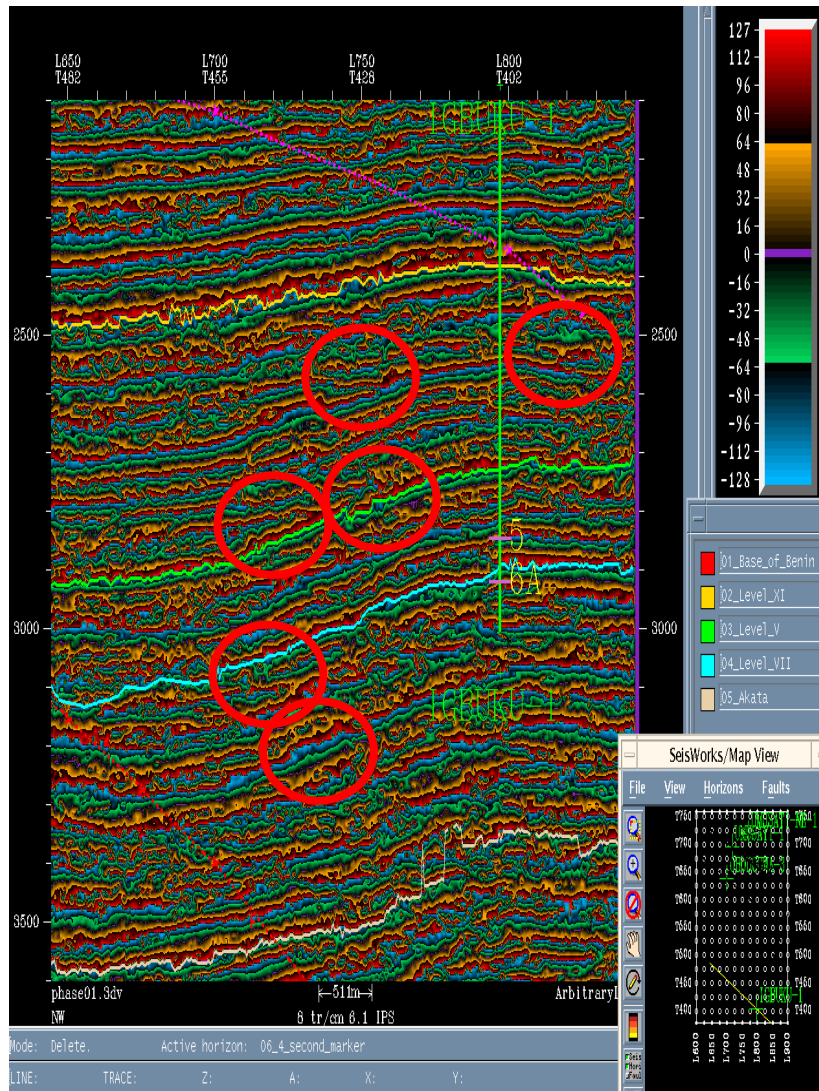
FLASH: 7.05505642

Umutu Marginal Field with 3-D

FLASH: 0.47157683

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terrainsCopyright © 2011 Walden 3-D, Inc.

Uquo Marginal Field with 2-D
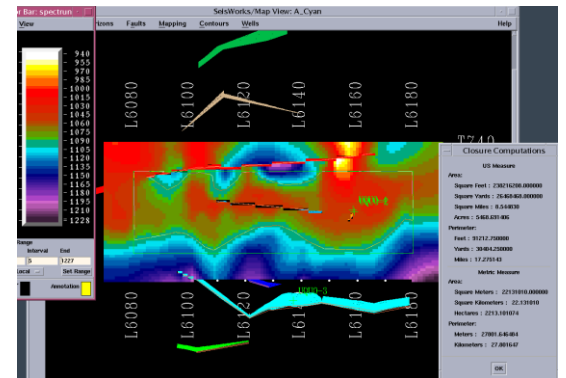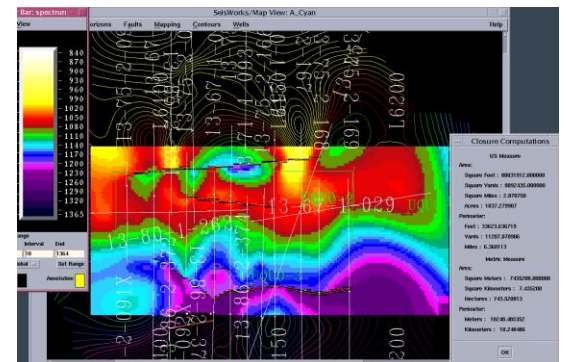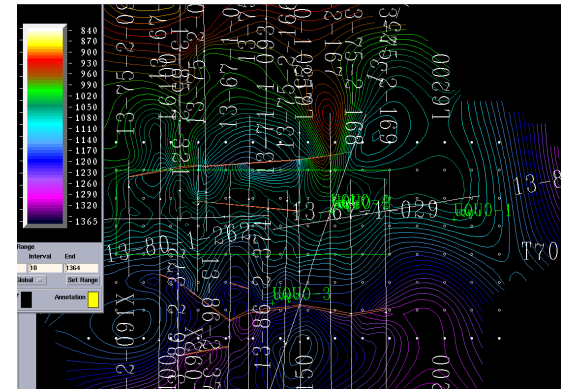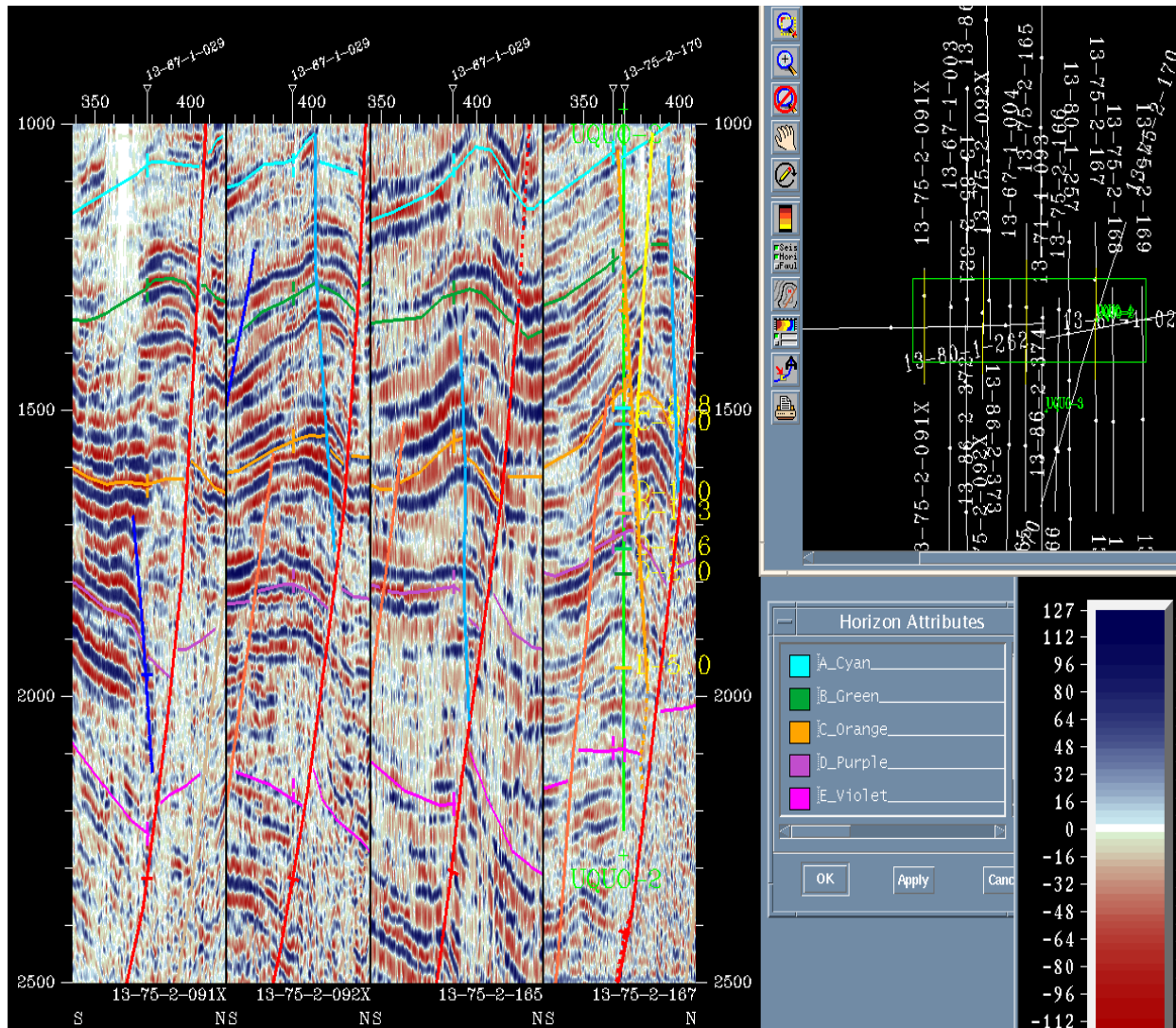
FLASH: 0.58222314

Step 2. Map Locations and FLASH Values

(Faults, Lithology, Amplitudes, Stratigraphy, and Horizons)

Atala FLASH: 0.30105149

Eremor FLASH: 0.11900000

Ibigwe FLASH: 0.90819724

Umutu FLASH: 0.47157683

Asuokpu FLASH: 3.0105149

Ogedeh FLASH: 0.00783957

Umusati FLASH: 7.05505642

Uquo FLASH: 0.58222314
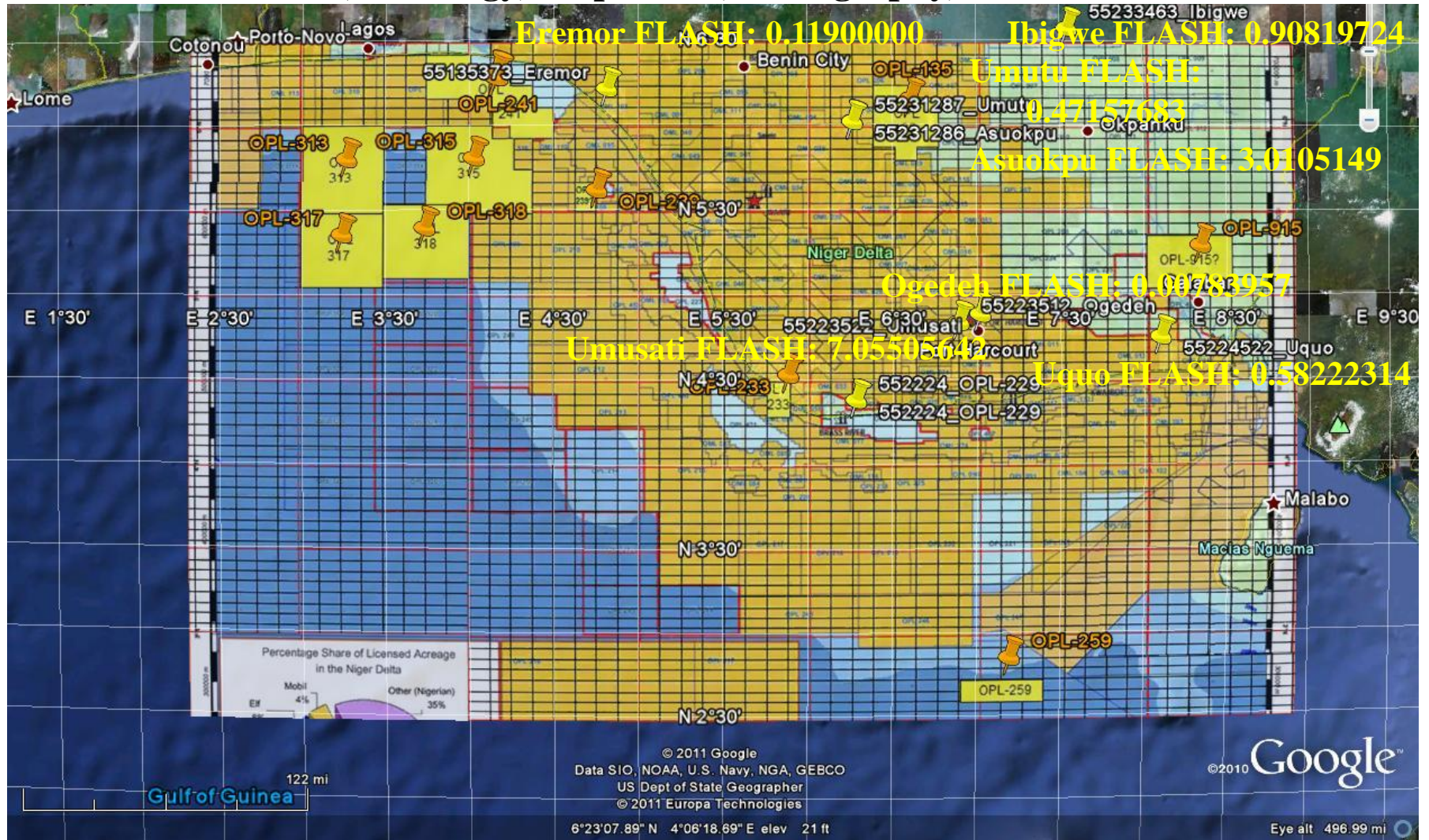
Step 3. Collect & Organize Public Data
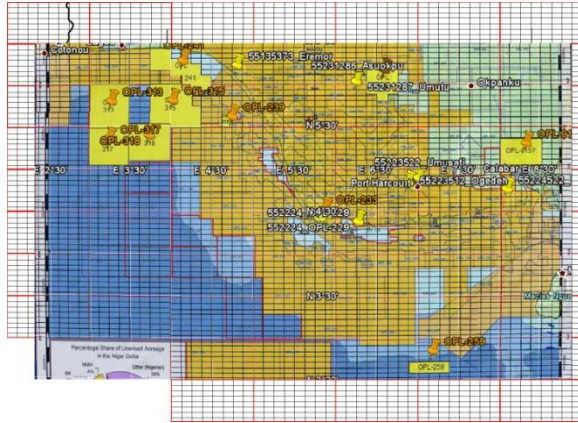
Locations
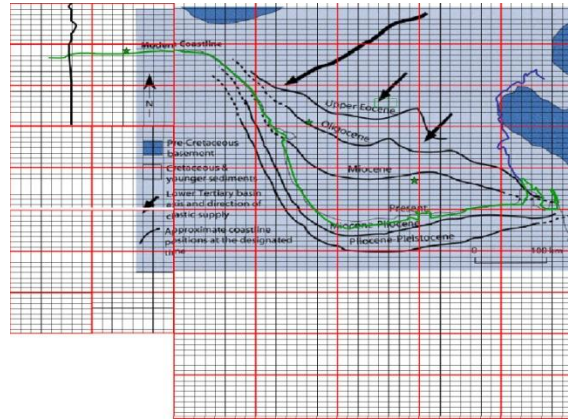
Geologic Age
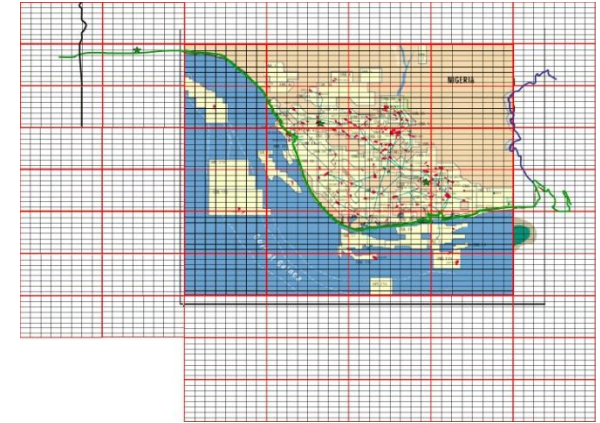
Existing Oil Fields
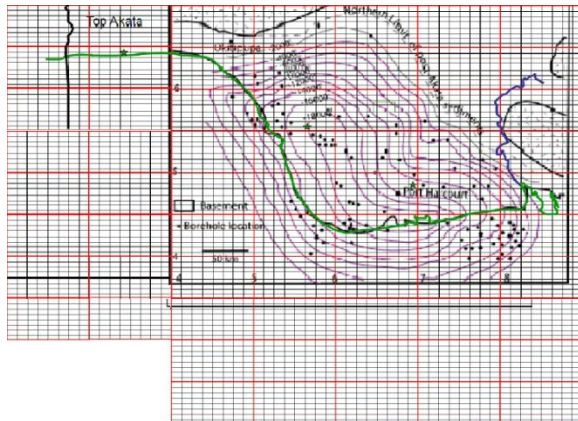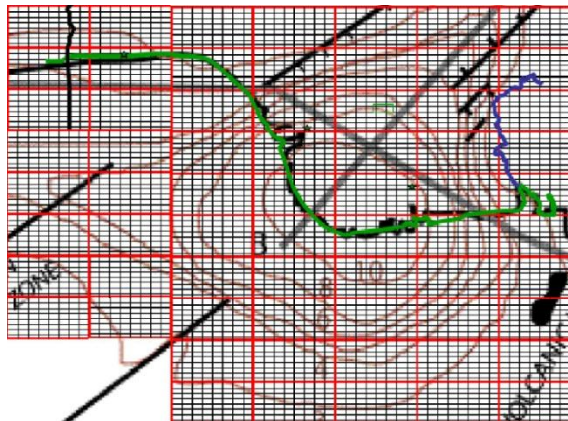
Top Akata

Sediment Thickness
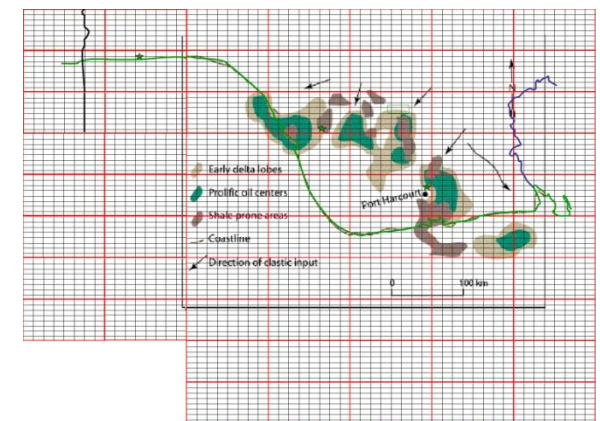
Producing Trends

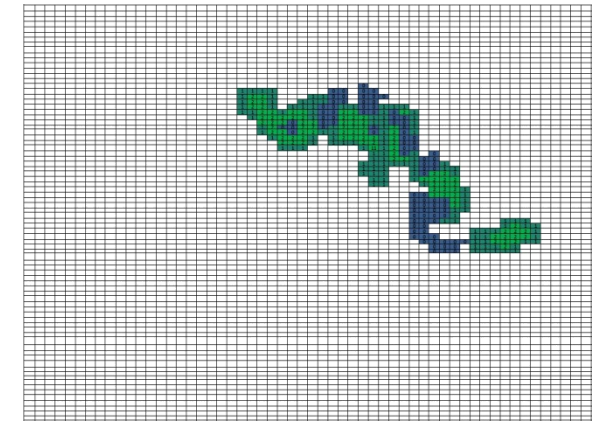# Step 4. Put Data in Common Format
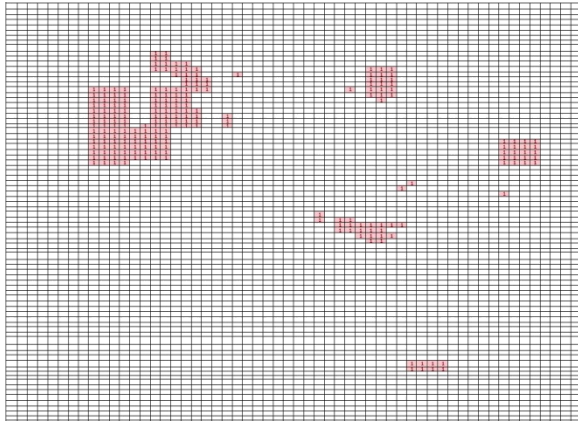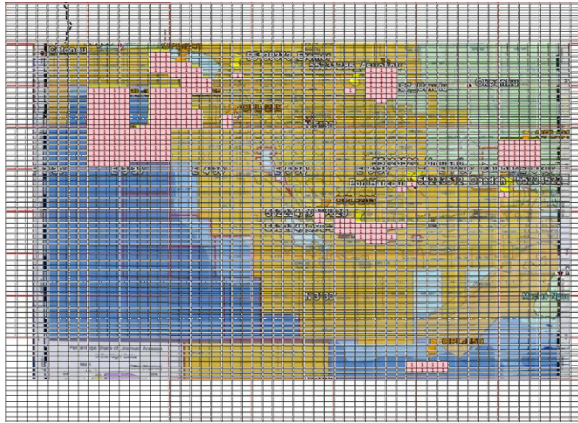

Locations
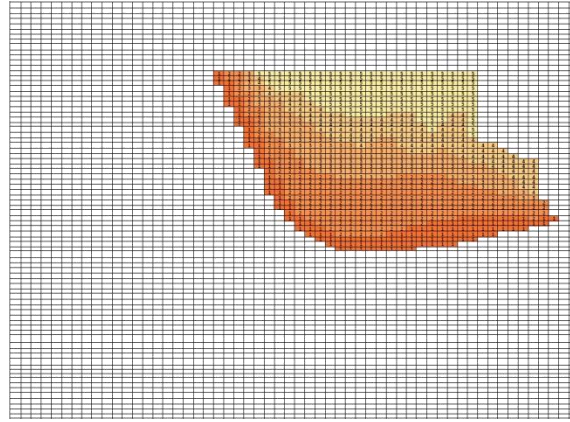
Geologic Age

Existing Oil Fields

Top Akata

Sediment Thickness

Producing Trends

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terrainsCopyright © 2011 Walden 3-D, Inc.
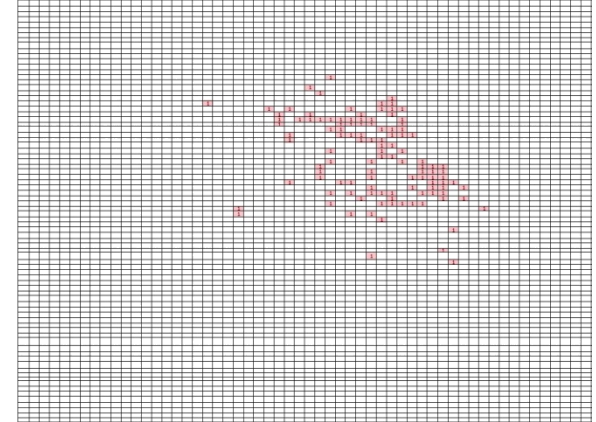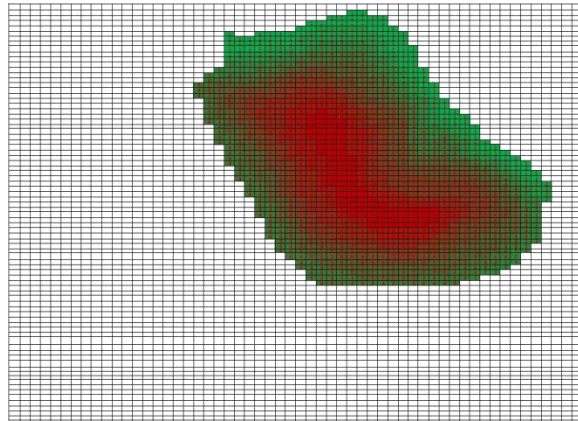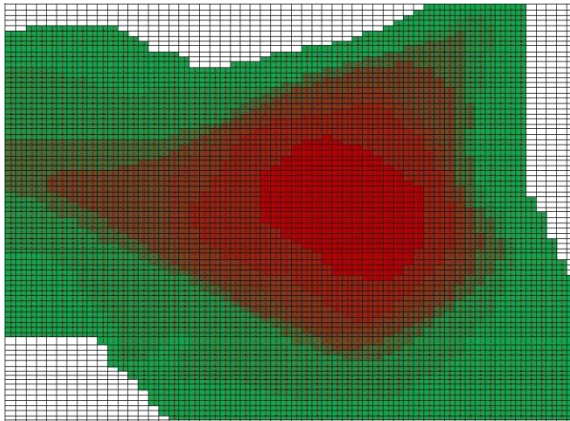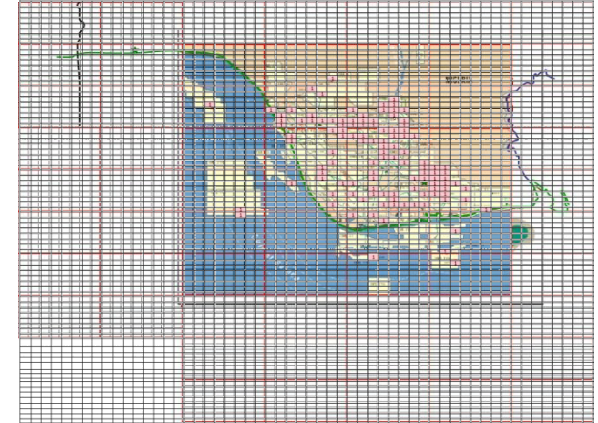
Step 5. Check Against Original Format
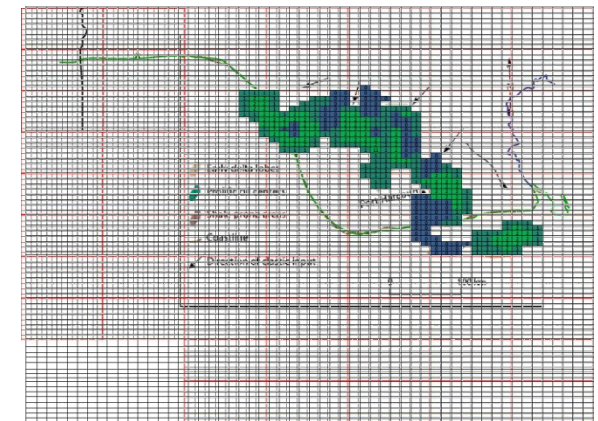

Locations
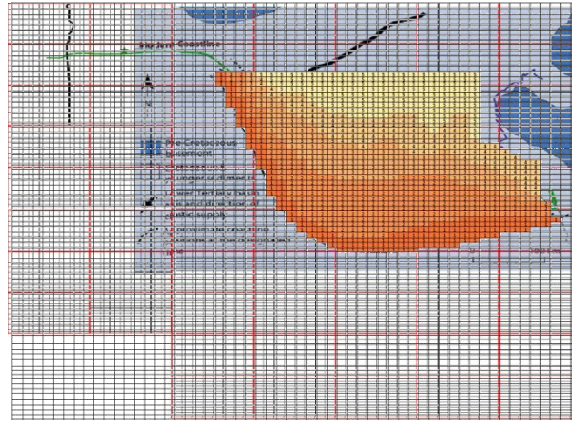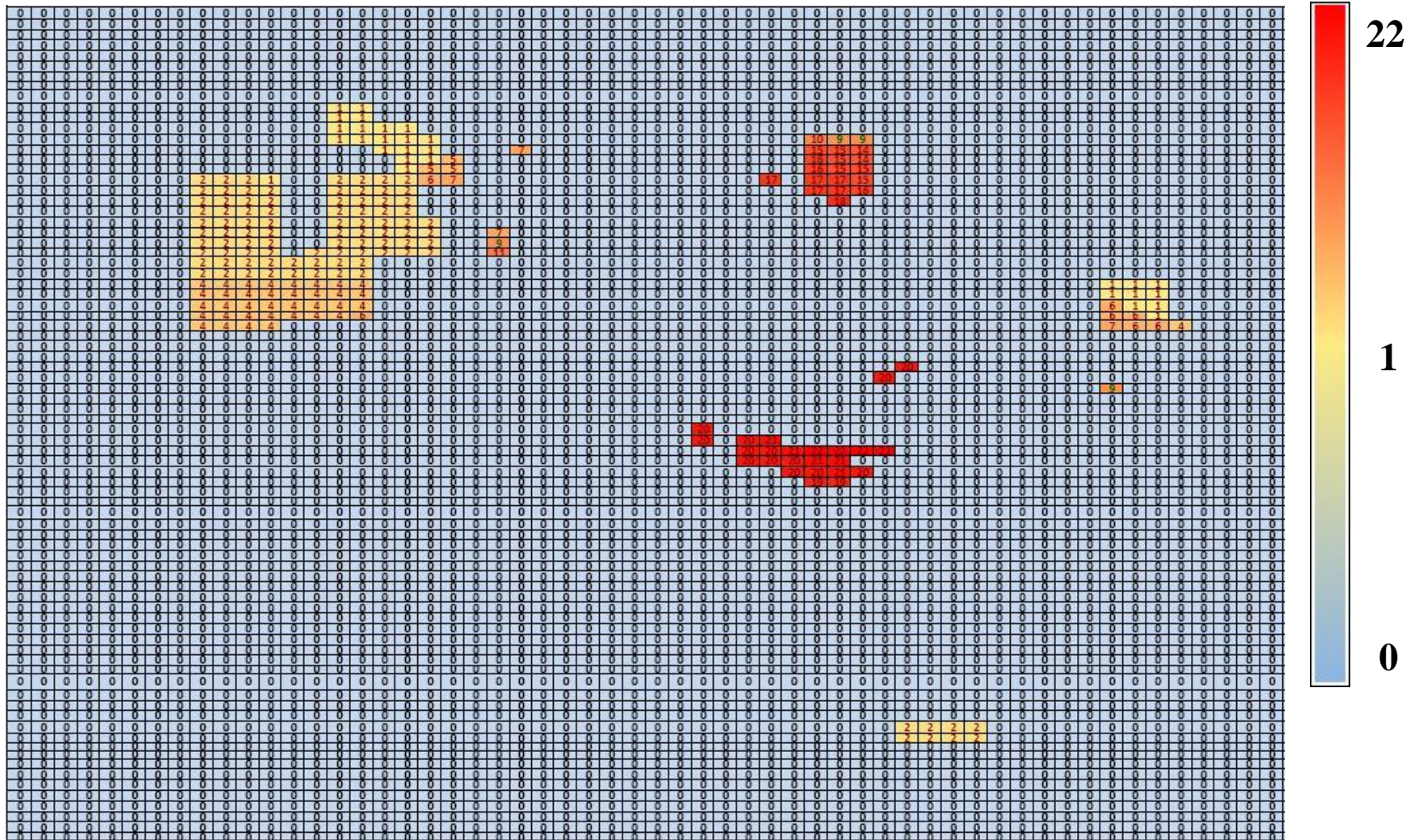

Geologic Age

Existing Oil Fields

Top Akata

Sediment Thickness

Producing Trends

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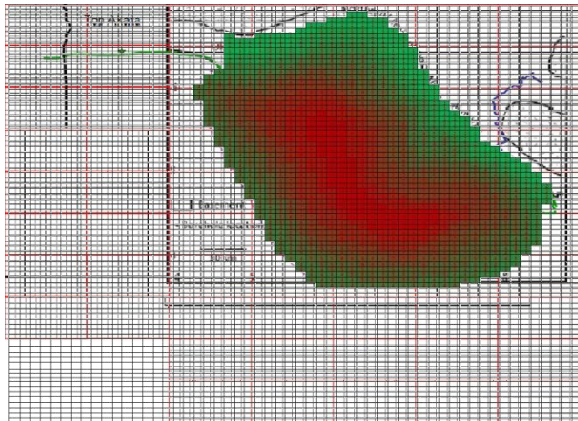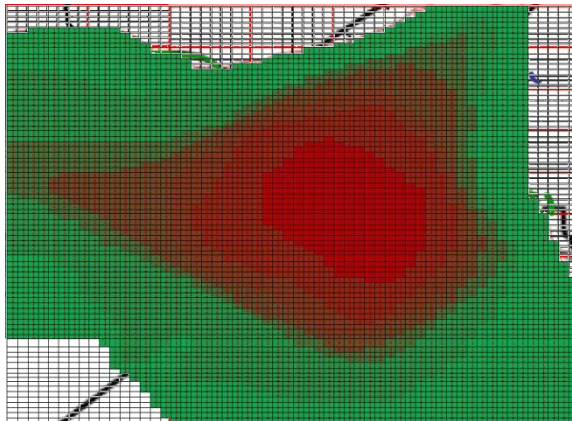
Step 6. Develop Ranking Algorithm

Cell Value = (Location *Age)+(Location*Oil Field)+(Location*Top Akata)+
(Location*Thickness)+(Location*Production Trend)

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terrainsCopyright © 2011 Walden 3-D, Inc.

Step 7. Integrate and Develop Strategy

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terrainsCopyright © 2011 Walden 3-D, Inc.

Acquisition, Processing, & Interpretation
Related Since the Start of Exploration

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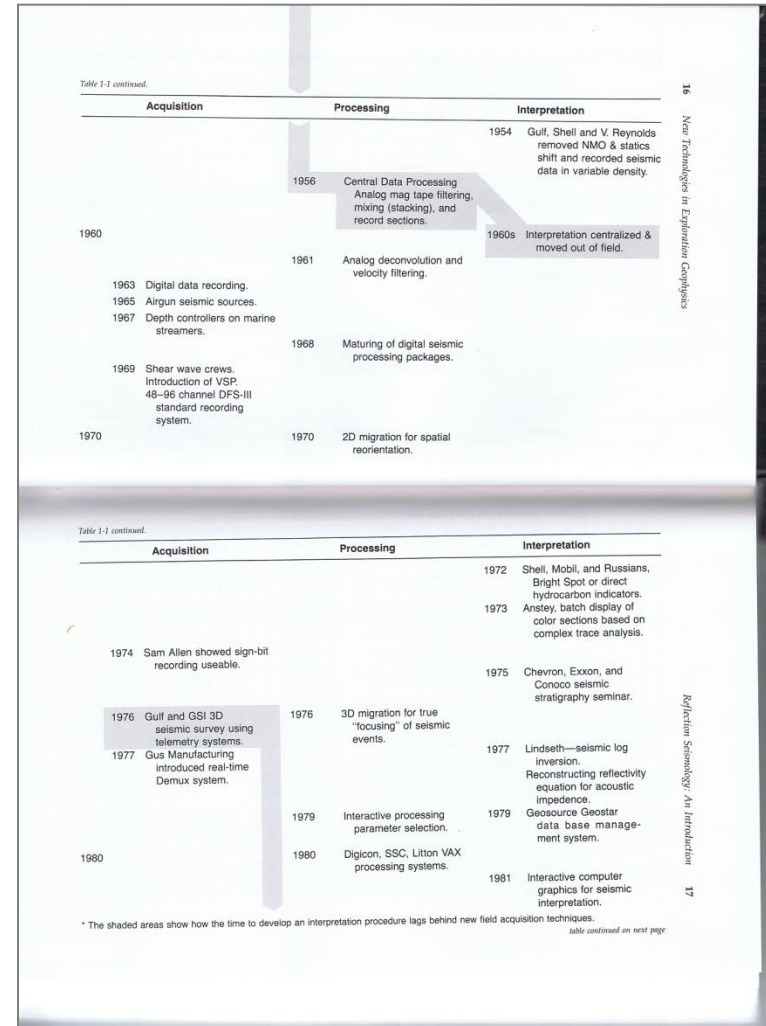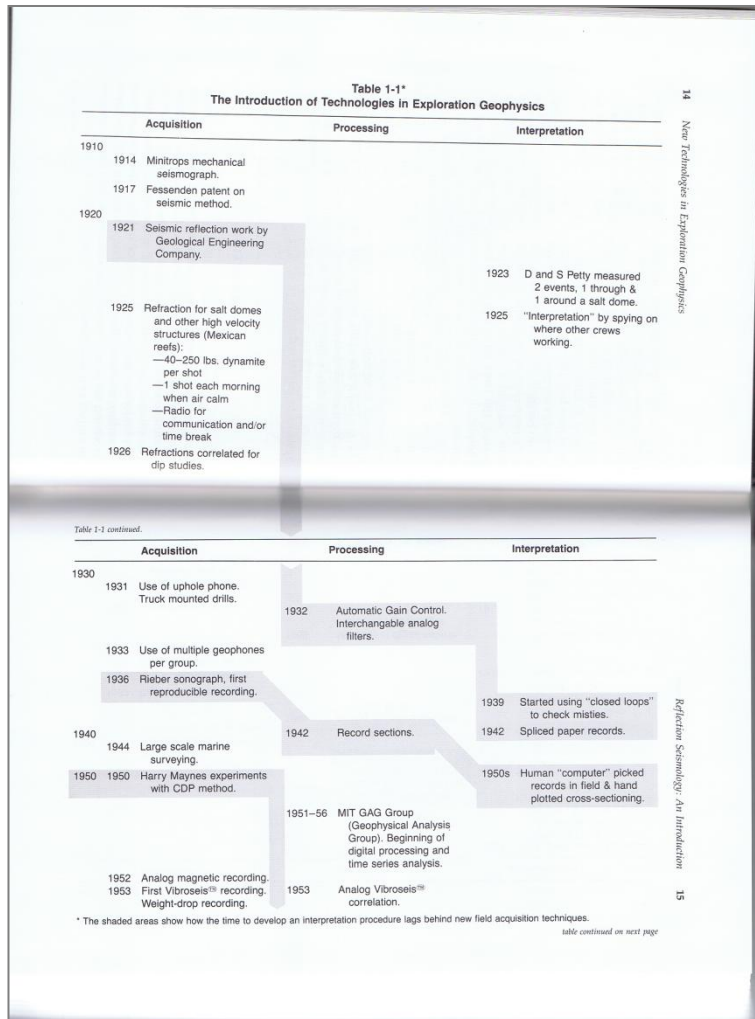
New High Frequency Sensors Survey Design

(hp logo)

February 15, 2010 03:00 AM Eastern Daylight Time

Shell and HP to Develop Ultrahigh-resolution Seismic Sensing Solution

A Leap Forward in Oil and Gas Exploration

LONDON--(BUSINESS WIRE)--At International Petroleum Week 2010, HP (NYSE:HPQ) and Shell today announced a collaboration to develop a wireless sensing system to acquire extremely high-resolution seismic data on land.

The oil and gas industry requires high-quality seismic data to accurately assess exploration prospects for commercial viability and to effectively monitor producing reservoirs. By delivering a much higher channel count and a broader sensor frequency range than are currently available, the new system promises to vastly improve the quality of seismic data.

> "These advances in technology to discover energy resources could transform the ability to pinpoint abundant new oil and gas reserves"

HP and Shell will use their complementary knowledge and experience to produce a groundbreaking solution to sense, collect and store geophysical data. The system is designed to integrate seamlessly with Shell's high-performance computing and seismic imaging environment and to be deployed safely and more cost-effectively than current systems.

"We think this will represent a leap forward in seismic data quality that will provide Shell with a competitive advantage in exploring difficult oil and gas reservoirs, such as sub-salt plays in the Middle East or unconventional gas in North America," said Gerald Schotman, executive vice president, Innovation/Research and Development, Shell. "As a result of this exciting collaboration, we expect to fully realize the potential of Shell's processing and imaging technology on land."

The new system reflects the breadth of HP's portfolio. It will be delivered by HP Enterprise Services and includes a recent breakthrough in high-performance sensing technology from HP Labs – the company's central research arm – and the company's Imaging and Printing Group. Additionally, the system uses HP ProCurve networking products along with HP storage, computation and software products.

"These advances in technology to discover energy resources could transform the ability to pinpoint abundant new oil and gas reserves," said Joe Eazor, senior vice president and general manager, HP Enterprise Services. "HP is uniquely positioned to offer Shell a complete sensor system that delivers innovation to address key technical seismic challenges."

This strategic relationship with Shell is a cornerstone in HP's blueprint for an information ecosystem that empowers people to make better, faster decisions to improve safety, security and environmental sustainability while transforming business economics. Sensing solutions are positioned to provide a new level of awareness through a network of sensors, data storage, and analysis tools that monitor the environment, assets, and health and safety.

Additional information about the sensing system from HP and Shell is available in an online press kit at www.hp.com/go/sensingsolutions.
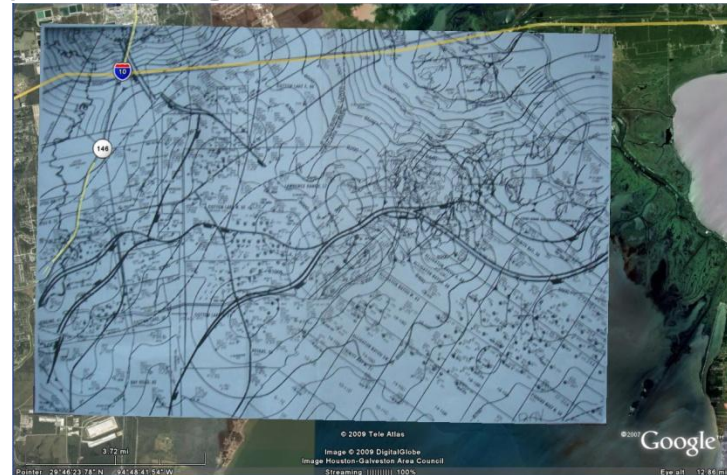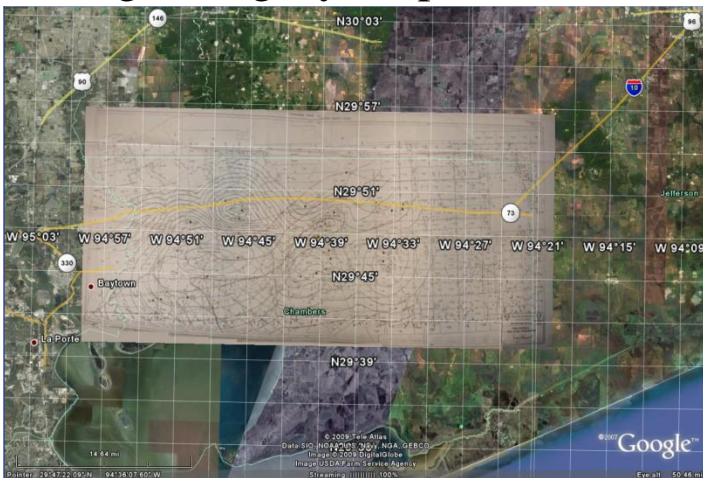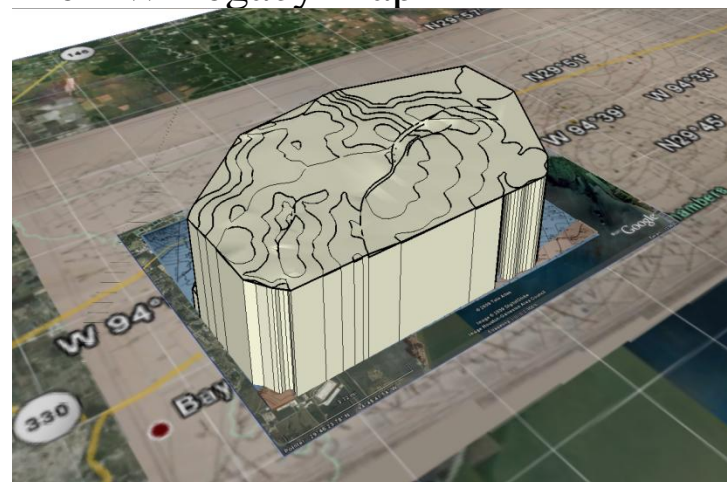
Alligator Bayou
3-D Survey Design

Marg-A Legacy Map

Tex-W Legacy Map

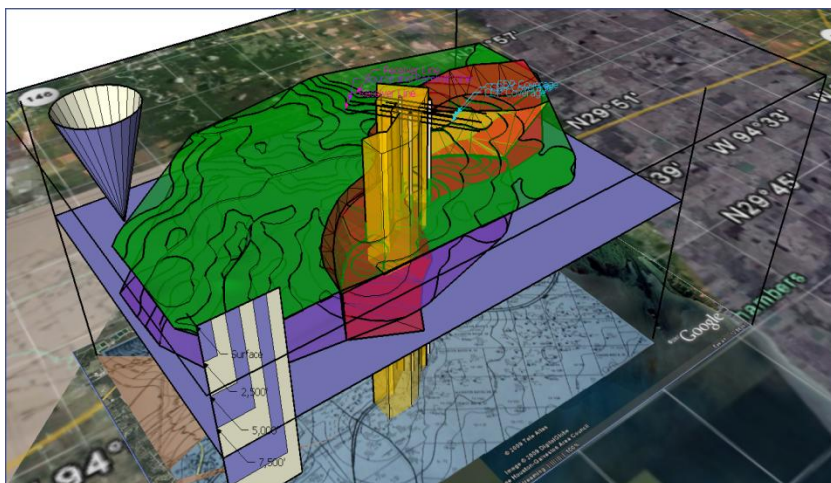Frio Isopach Legacy Map

Marg-A 3-D Model

3-D Seismic Interpretation - with an emphasis on carbonate
terrainsCopyright © 2011 Walden 3-D, Inc.

Outline of Possible 40 sq.mi. 3-D
3-D Survey Design

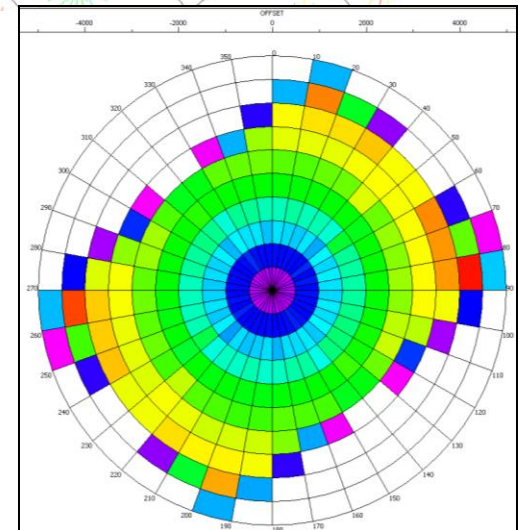3-D Seismic Interpretation - with an emphasis on carbonate
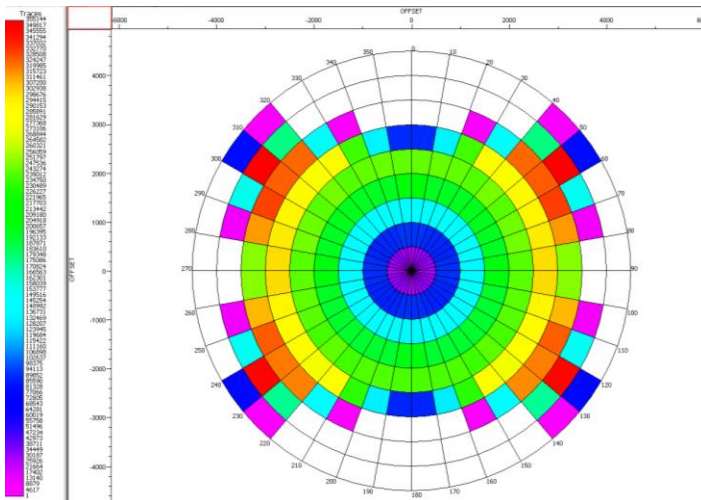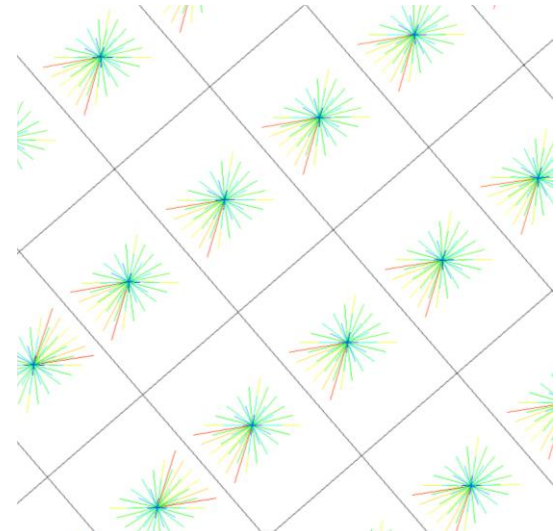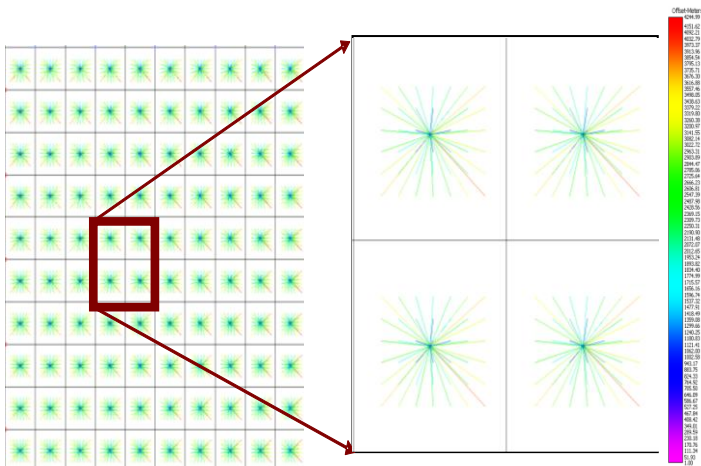terrainsCopyright © 2011 Walden 3-D, Inc.
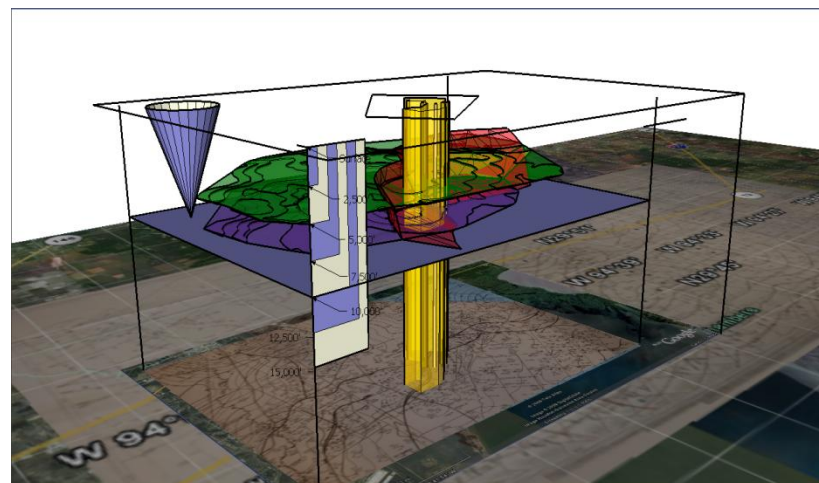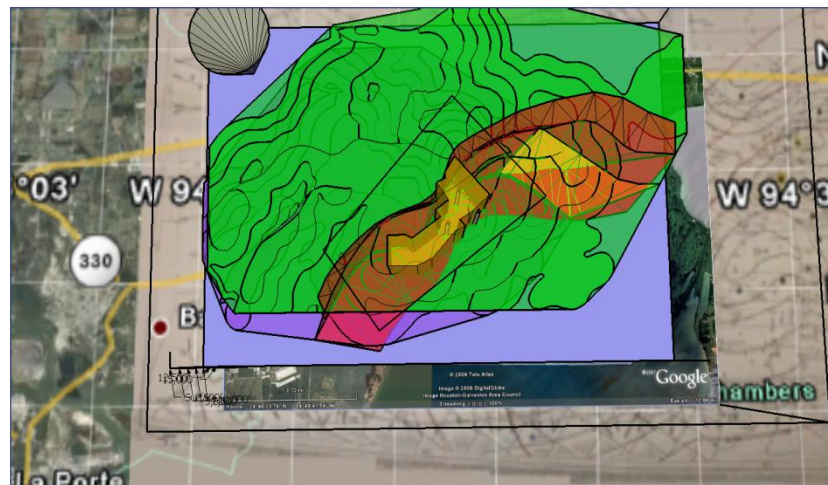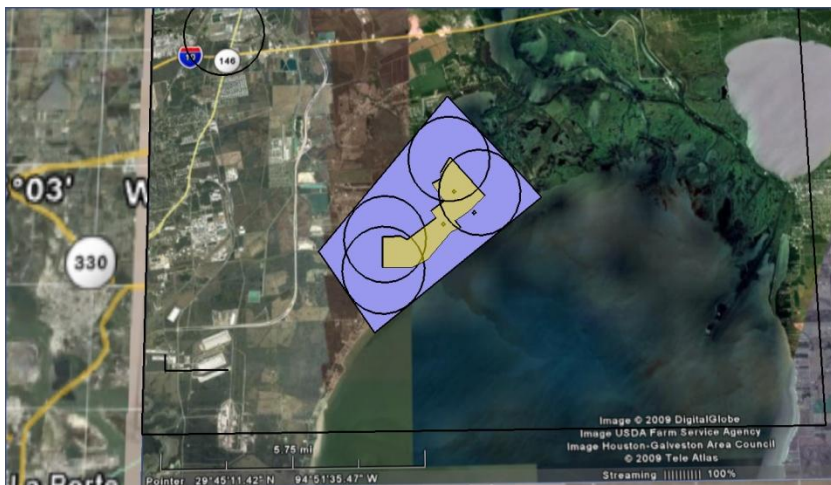
Alligator Bayou
## Alternate 2-D Survey Design

Azimuth Distribution
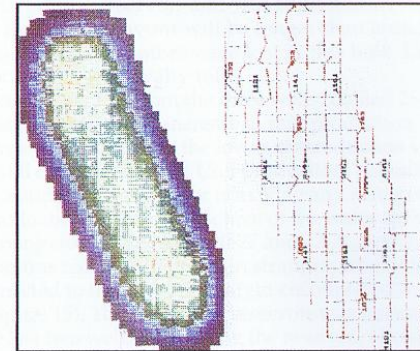# Two Recent Survey Designs

Design Considerations

- Wavelength
- Resolution
- Multi-Component
- P-Wave vs. S-Wave & multi-component seismic
- Amplitude preservation & migration
- Binning
- Zero Phase vs. Phased Data
- 2D, 3D, and 4D time-lapse design
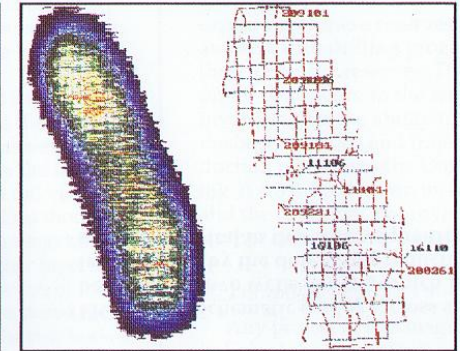- Wavelet Extraction and Inverse Modeling

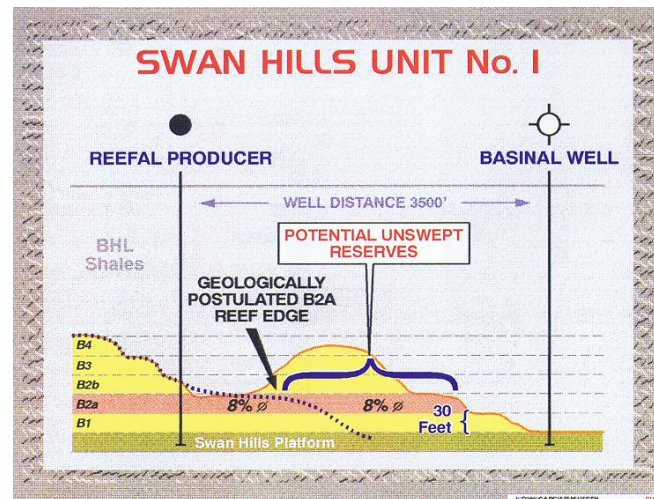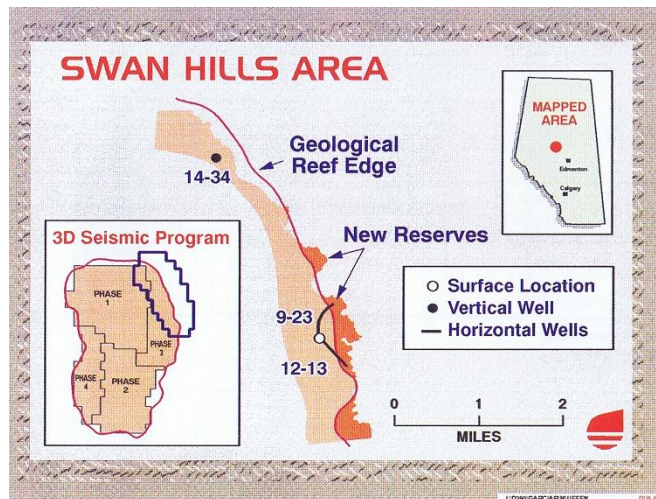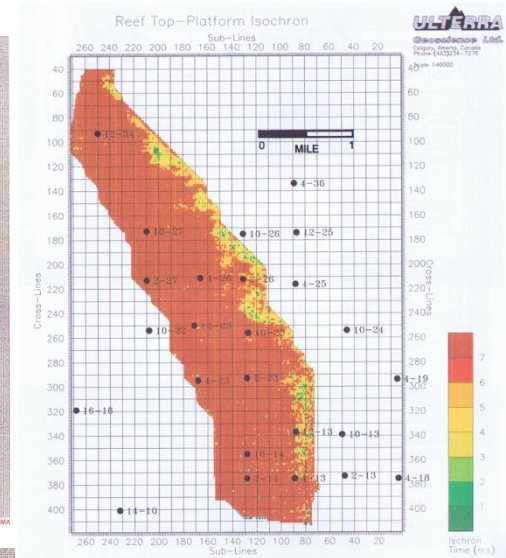# Reservoir Delineation and Characterization, Swan Hills, Alberta
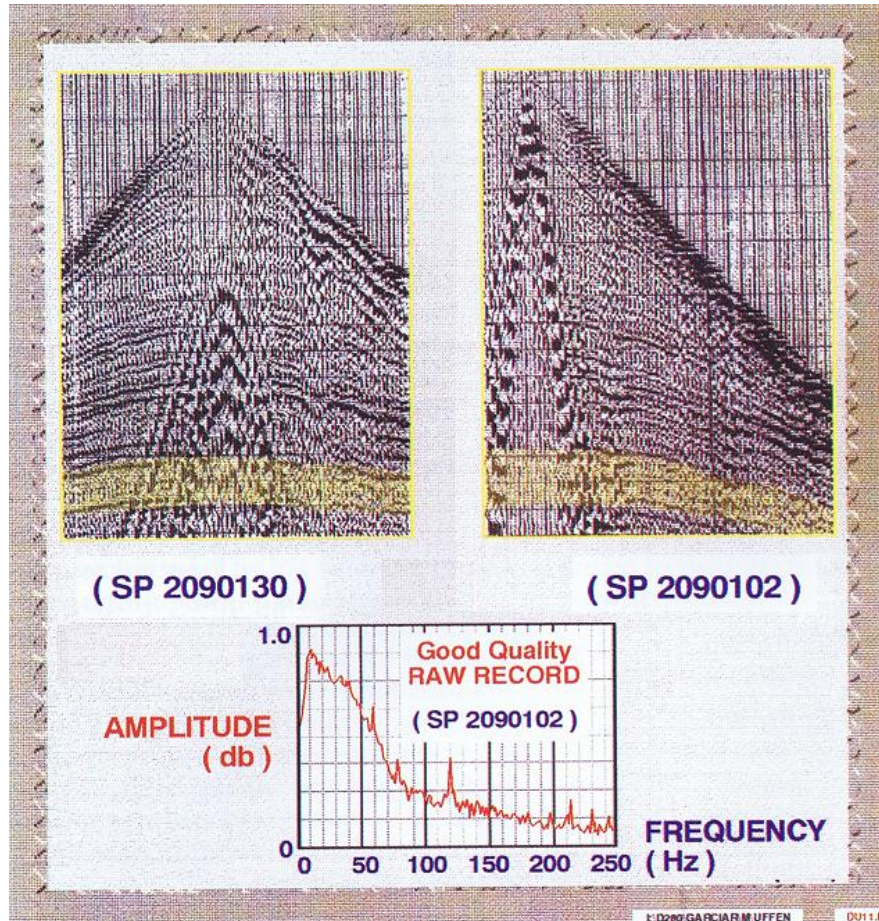
J. Douglas Uffen in **Application of 3-D Seismic Data to Exploration and Production**, pages 184-187, data from Home Oil Company and Swan Nills Unit partners, Alberta, Canada.

Reservoir Delineation and Characterization,
Swan Hills, Alberta
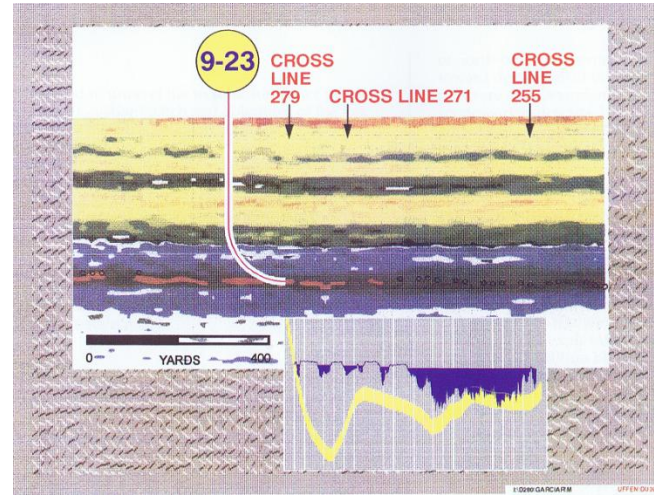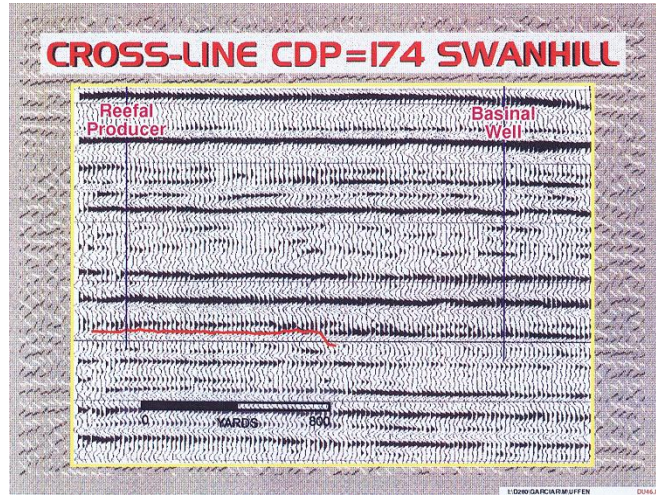
J. Douglas Uffen in **Application of 3-D Seismic Data to Exploration and Production**, pages 184-187, data from Home Oil Company and Swan Nills Unit partners, Alberta, Canada.
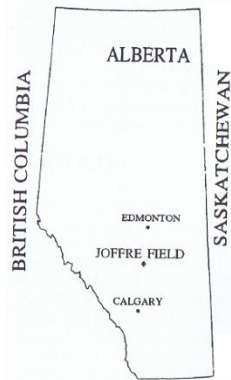
Joffre Field Leduc Reef,
Alberta, Canada
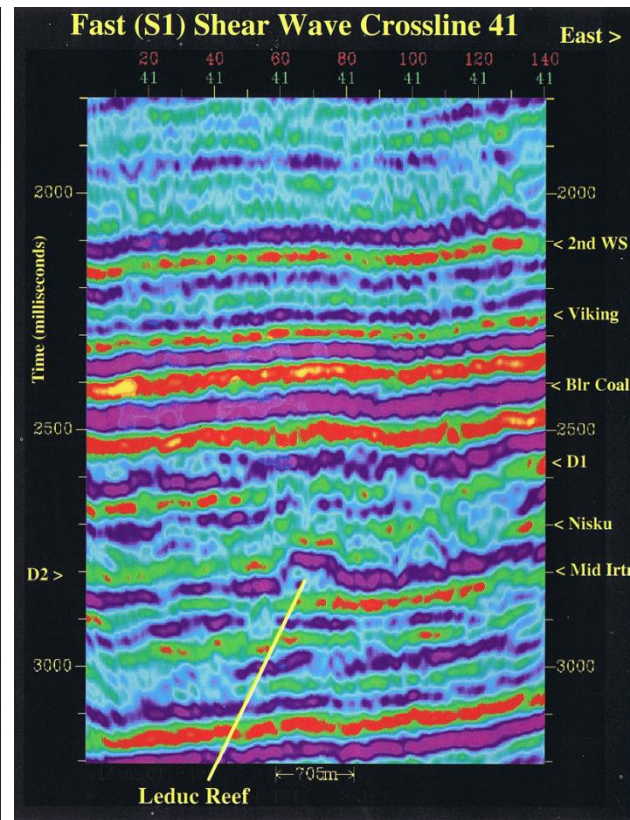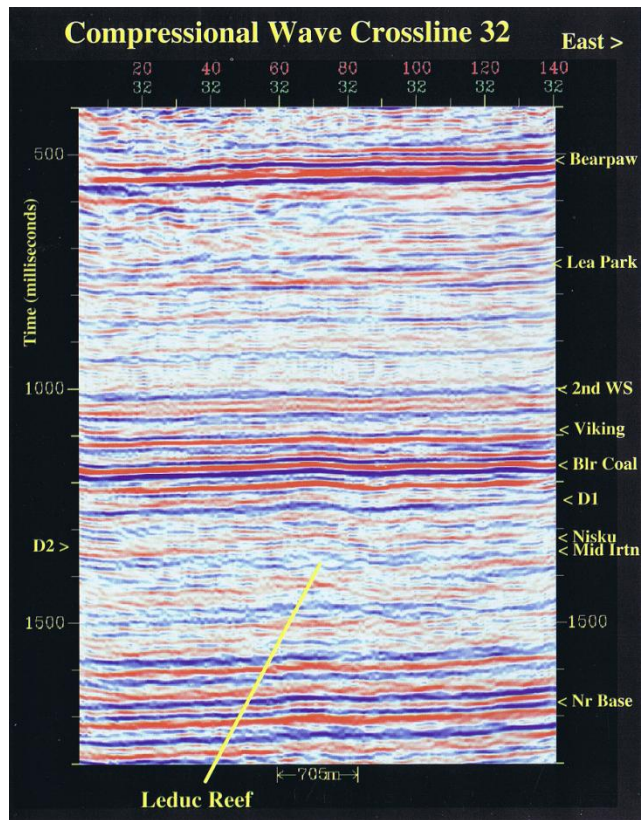

John F. Arestad, et. al., in **Application of 3-D Seismic Data to Exploration and Production**, pages 174-176, data from CSM RCP, Alberta, Canada.
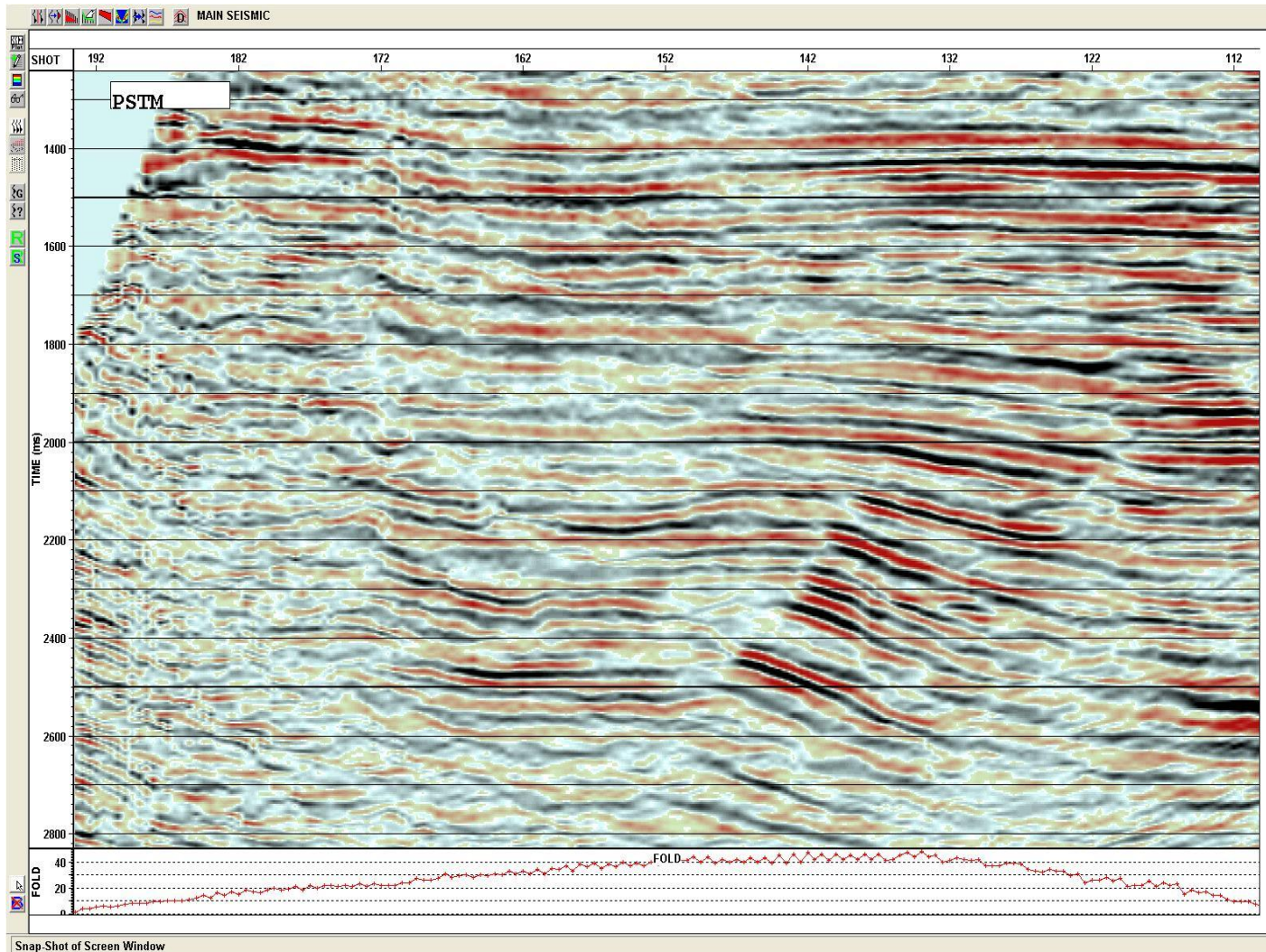
A Seismic Processing Workflow

DATA MERGE, PRE PROCESSING AND PSTM

- Survey Merge
- Data input and reformatting
- Trace edit
- Geometry definition and verification
- Gain recovery/spherical divergence
- OBC Summation (in case of Geophone and Hydrophone input)
- Deconvolution
- Spectral whitening and balance
- Refraction static corrections (OBC)
- 3D binning to 25m x 20m
- Interactive first velocity analysis
- 3-D normal moveout (NMO) corrections
- Mute
- Brute stack
- Intermediate stack
- 2nd interactive velocity analysis
- 3-D surface consistent residual static
- Prestack Noise Reduction
- Multiple Attenuation in CDP domain
- Branch to PSTM & PSDM

- Final Stack
- 3-D finite difference migration, FK or Omega X One pass post stack migration
- Final band-pass filter
- Post-Stack signal enhancement
- Prestack Time Migration (PSTM) flow
- Velocity analysis of prestack migrated target lines
- PSTM
- AVO stacks
- Residual Velocity analysis
- Final Phase Adjustment and Well Tie
- Final Stack

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Seismic Processing: PSTM
Texas Gulf Coast On-Shore

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Processing: PSTM over Interval Velocity
Texas Gulf Coast On-Shore

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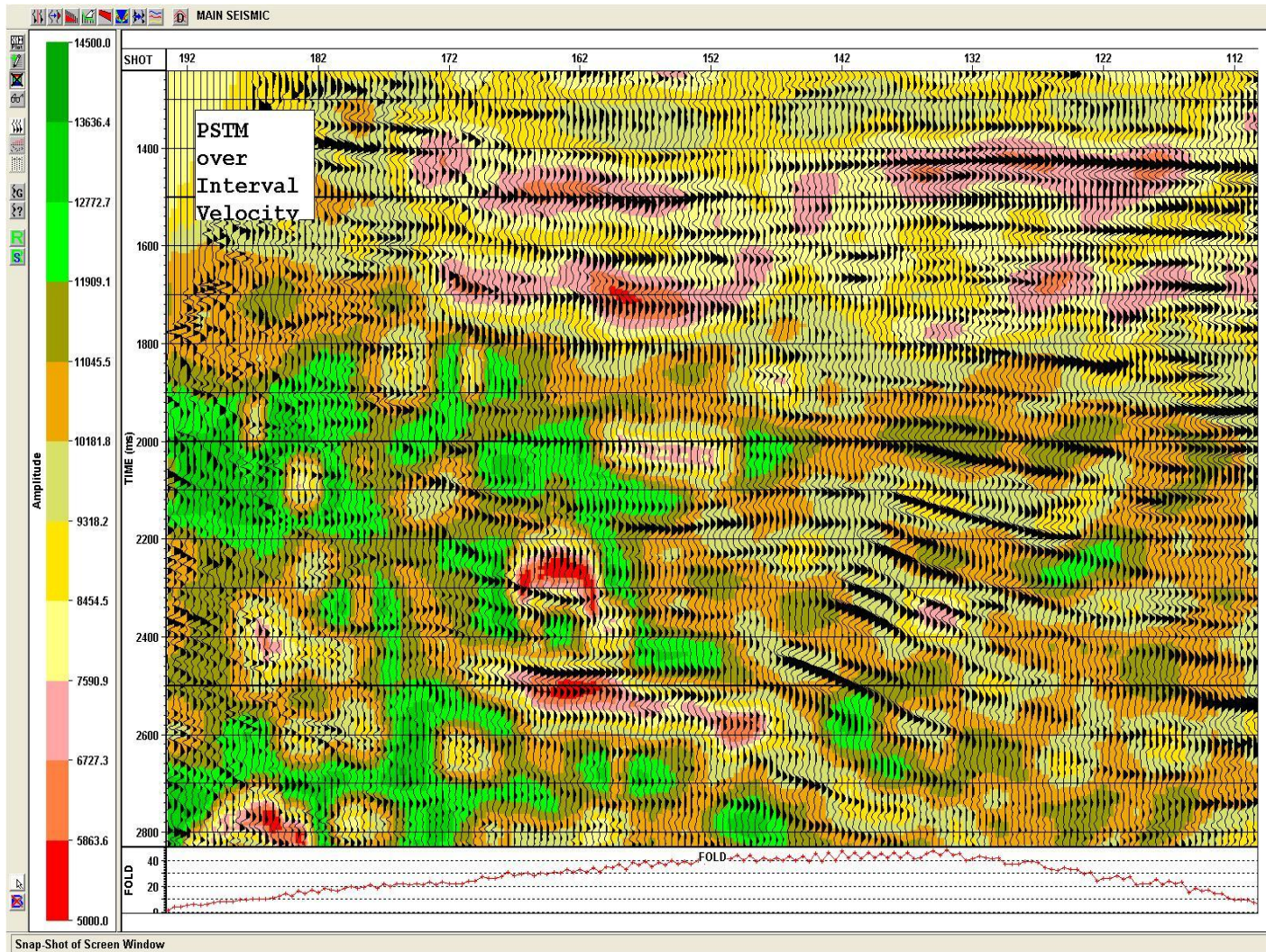
Seismic Processing: NMO Gathers
Texas Gulf Coast On-Shore

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terrainsCopyright © 2011 Walden 3-D, Inc.
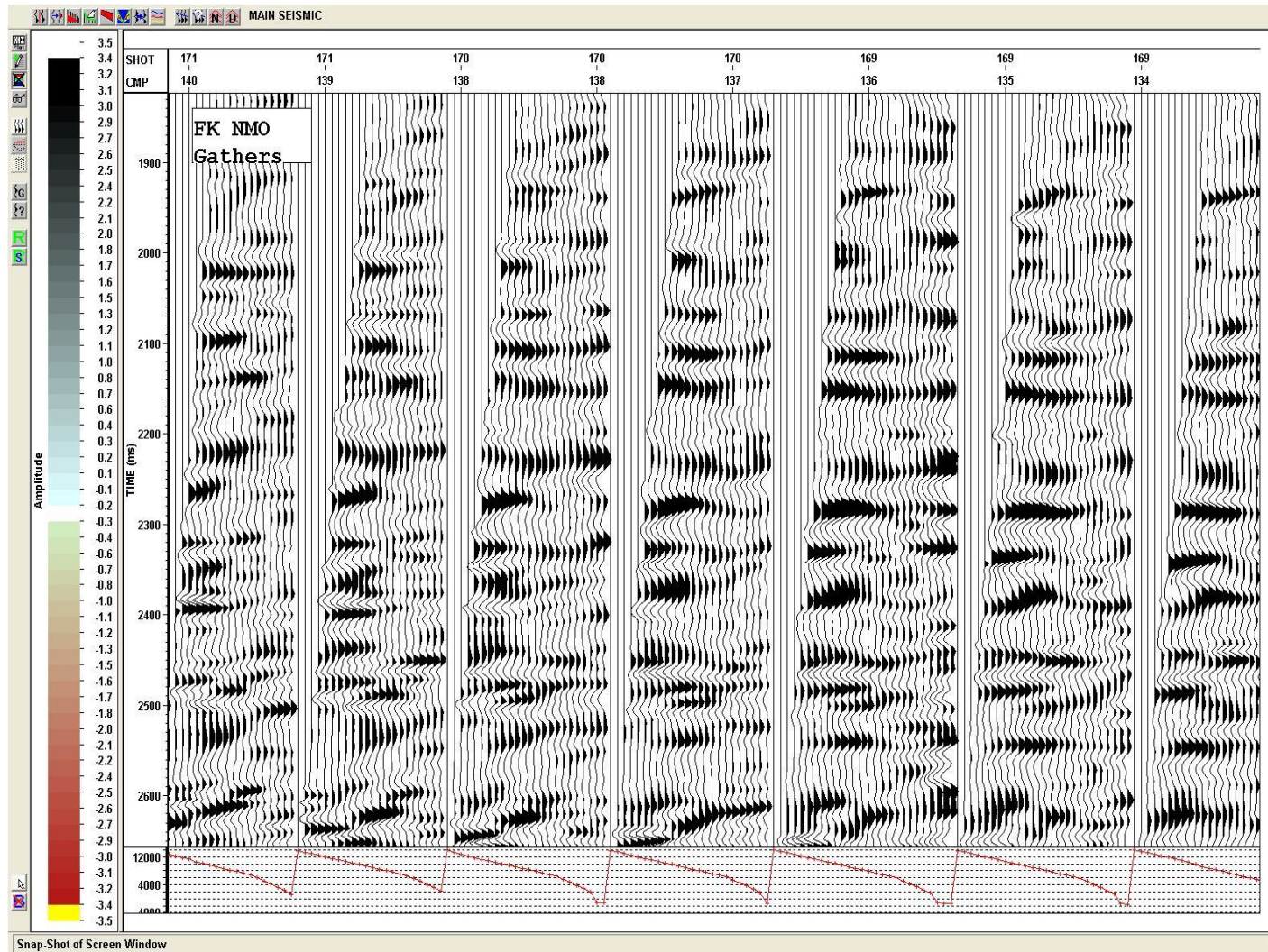
Seismic Processing: NMO Gathers colored
Texas Gulf Coast On-Shore

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terrainsCopyright © 2011 Walden 3-D, Inc.
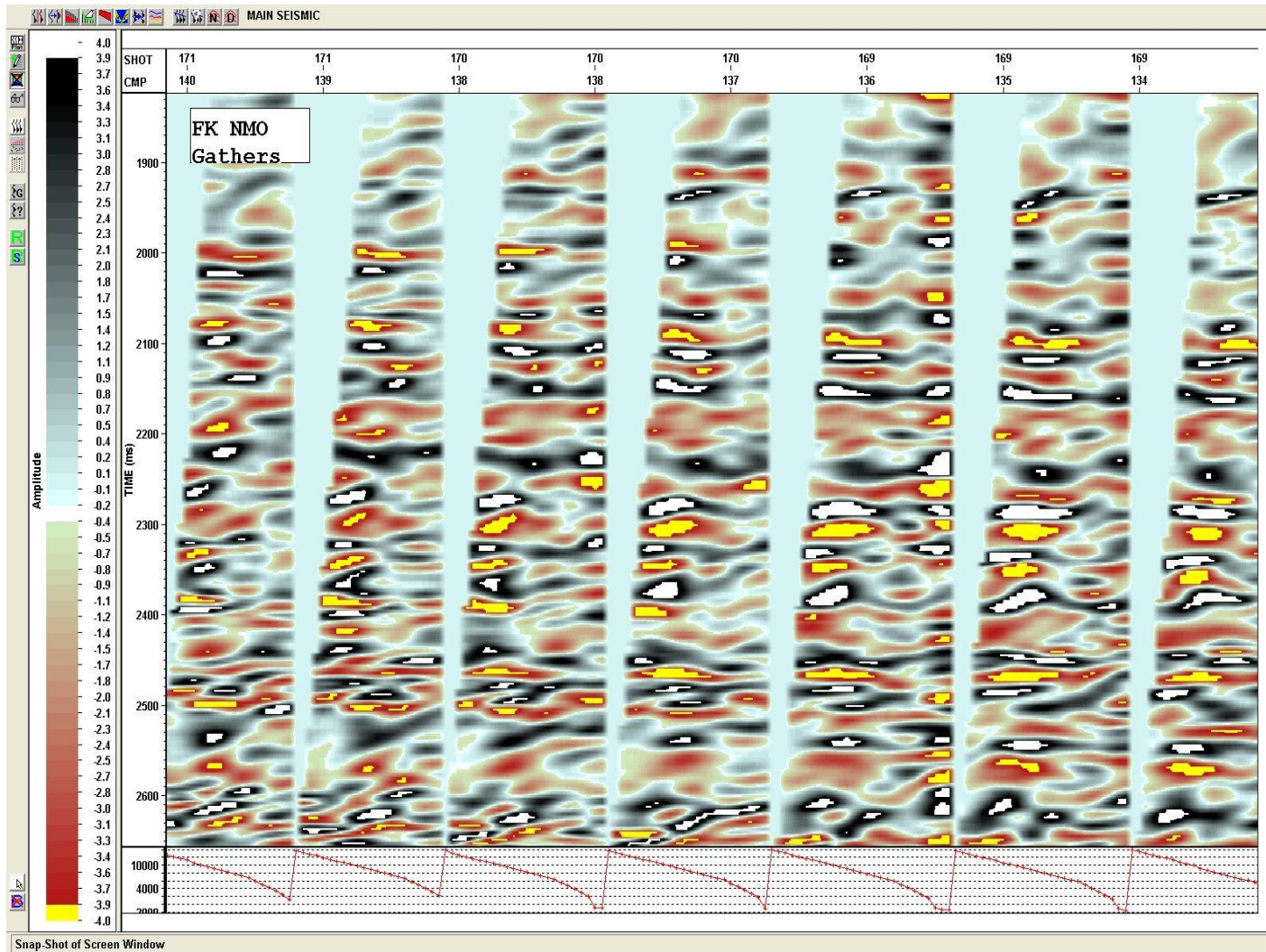
Seismic Processing: Near Angle Stack
Texas Gulf Coast On-Shore

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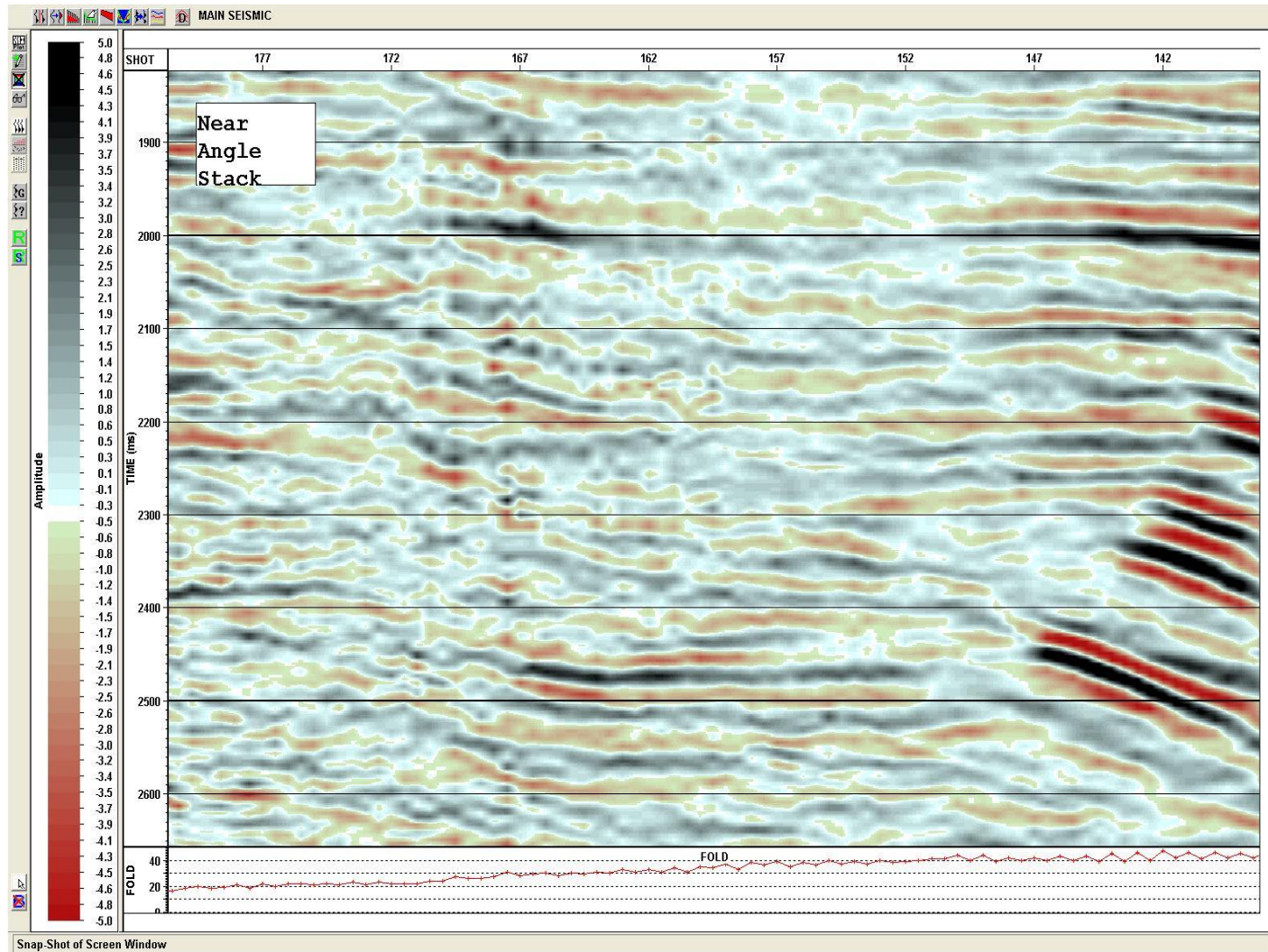
Seismic Processing: Mid Angle Stack
Texas Gulf Coast On-Shore

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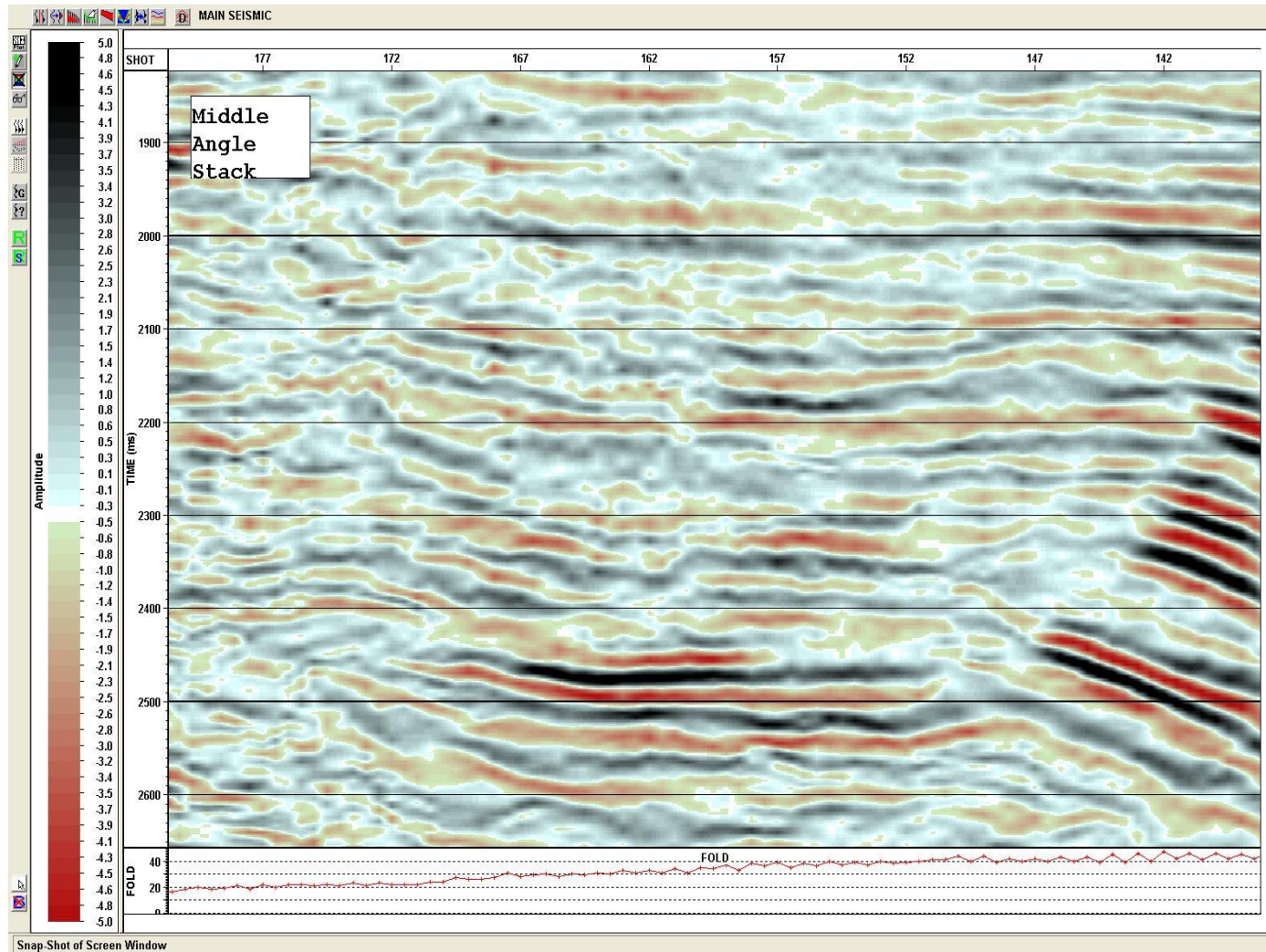
Seismic Processing: Far Angle Stack
Texas Gulf Coast On-Shore

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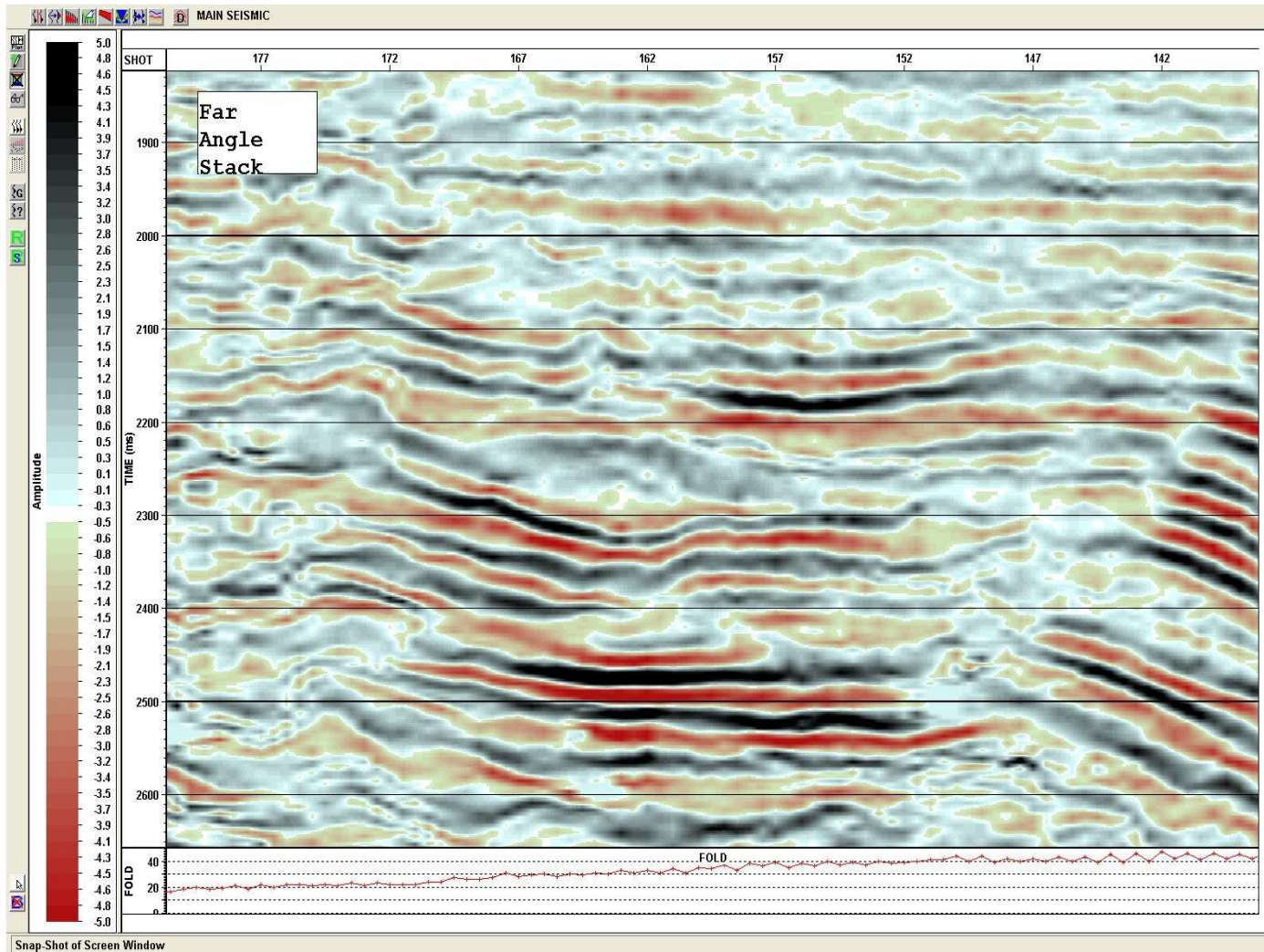
Velocities Key: Valhall Field, North Sea
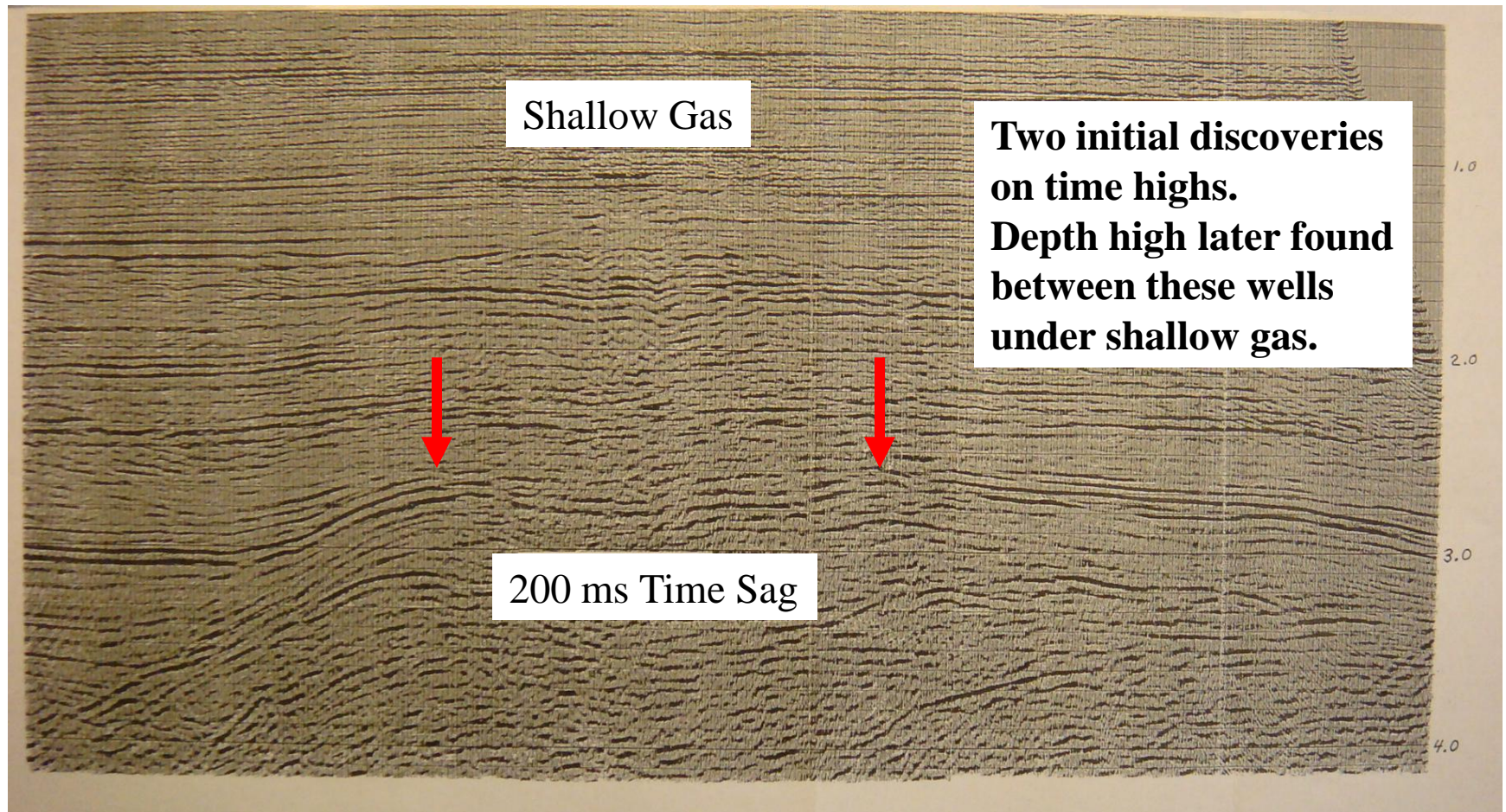
200 ms Sag on 1 Billion Barrel Field

Shallow Gas

Two initial discoveries on time highs.
Depth high later found between these wells under shallow gas.

200 ms Time Sag

Valhall Field, North Sea

200 ms Sag on 1 Billion Barrel Field

Shallow Gas

Two initial discoveries
on time highs.
Depth high later found
between these wells
under shallow gas.

200 ms Time Sag

Valhall Field, North Sea

200 ms Sag on 1 Billion Barrel Field

Shallow Gas

Two initial discoveries on time highs.
Depth high later found between these wells under shallow gas.

200 ms Time Sag

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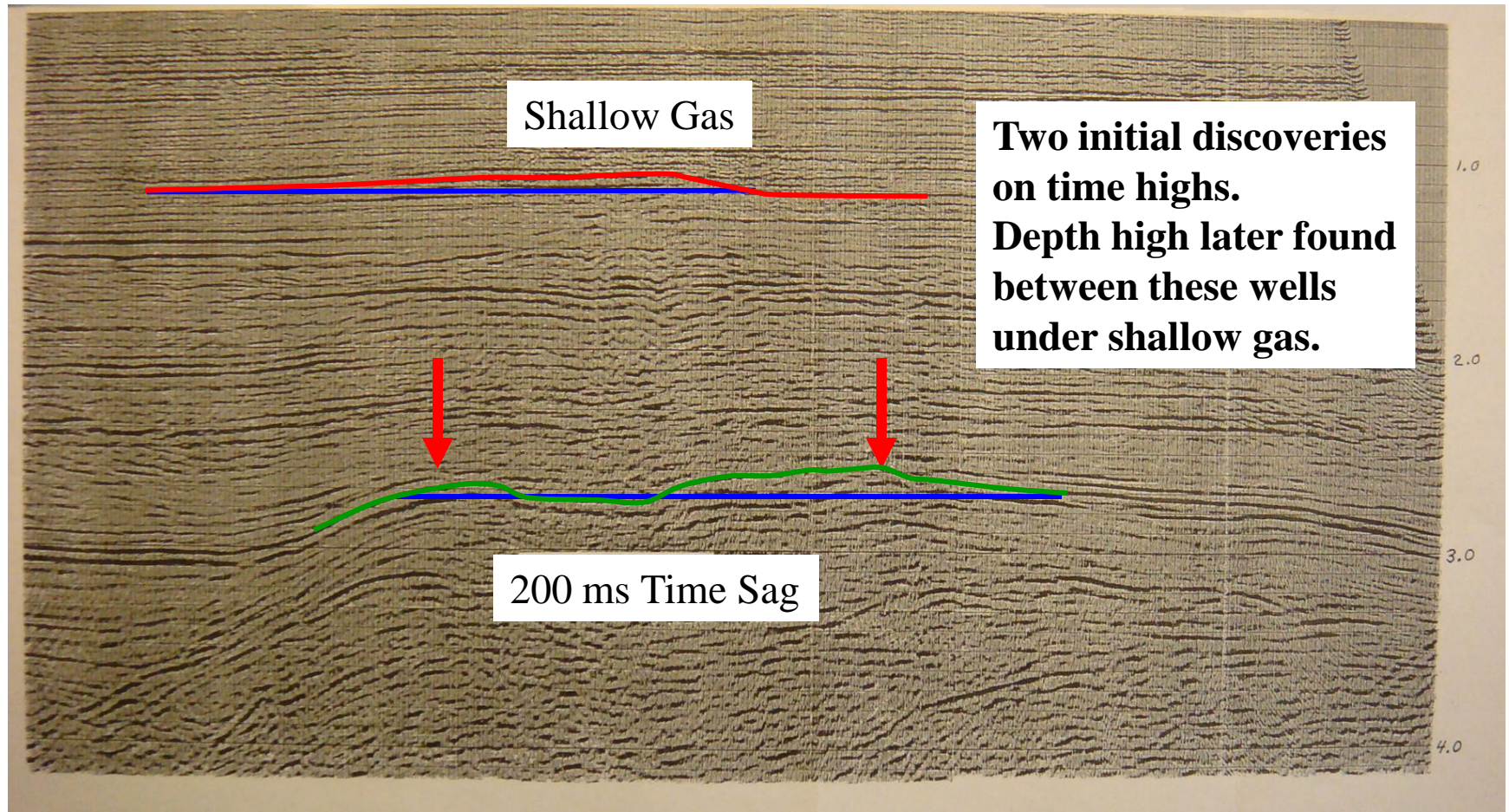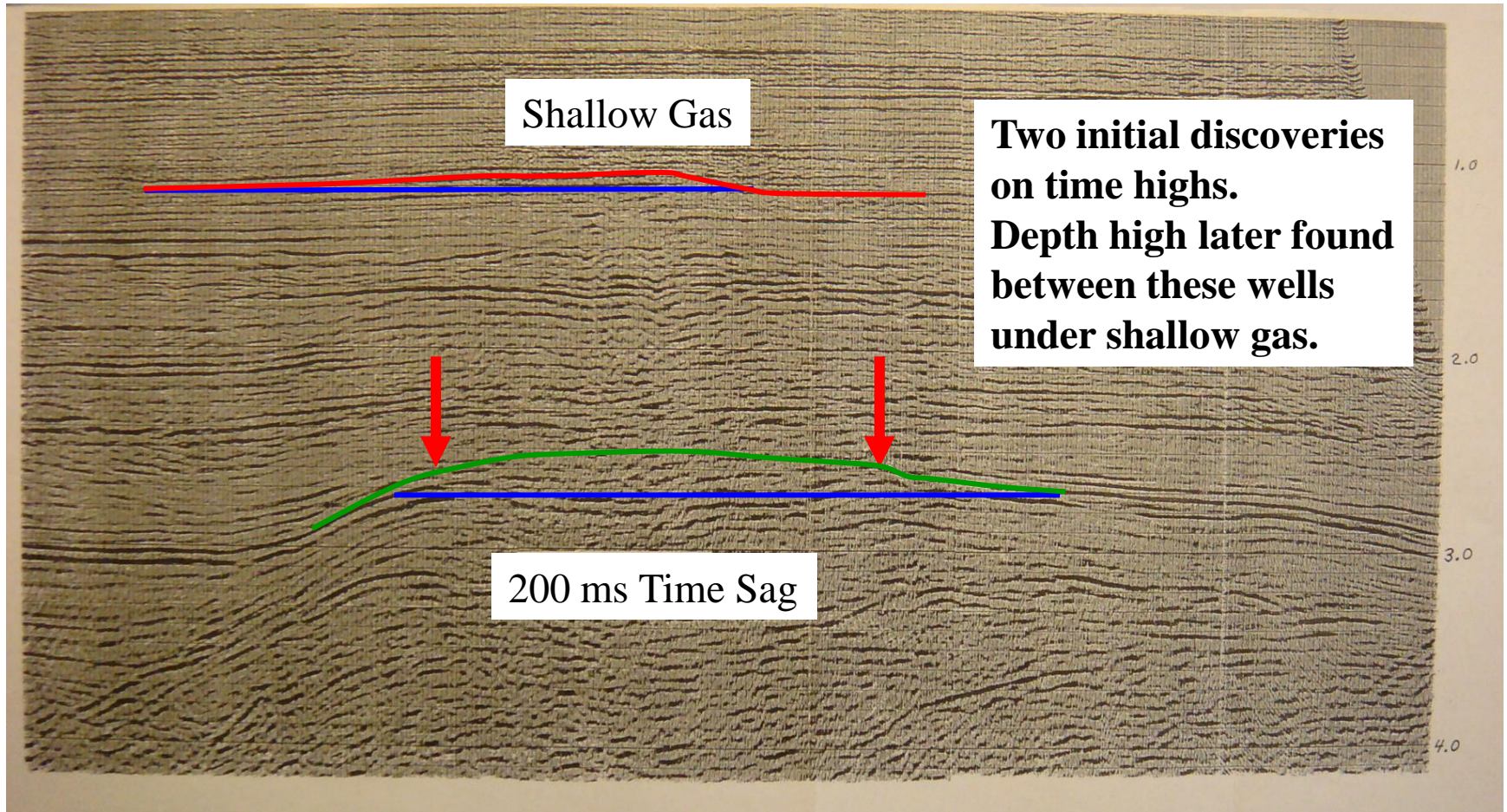
Velocity Study
South Louisiana

Chimney Cloud

Abnormal Pressure

Major Pressure Increase
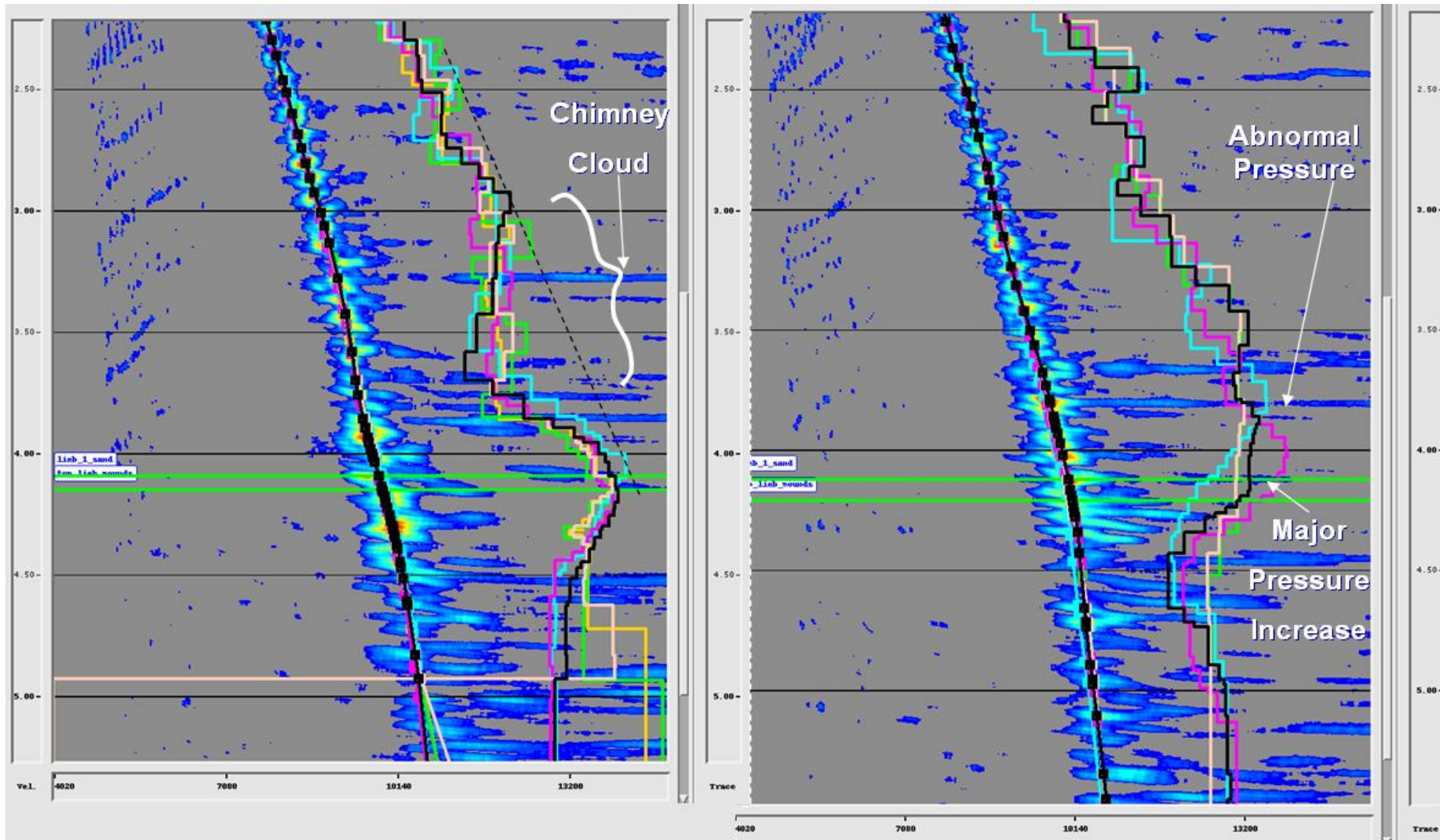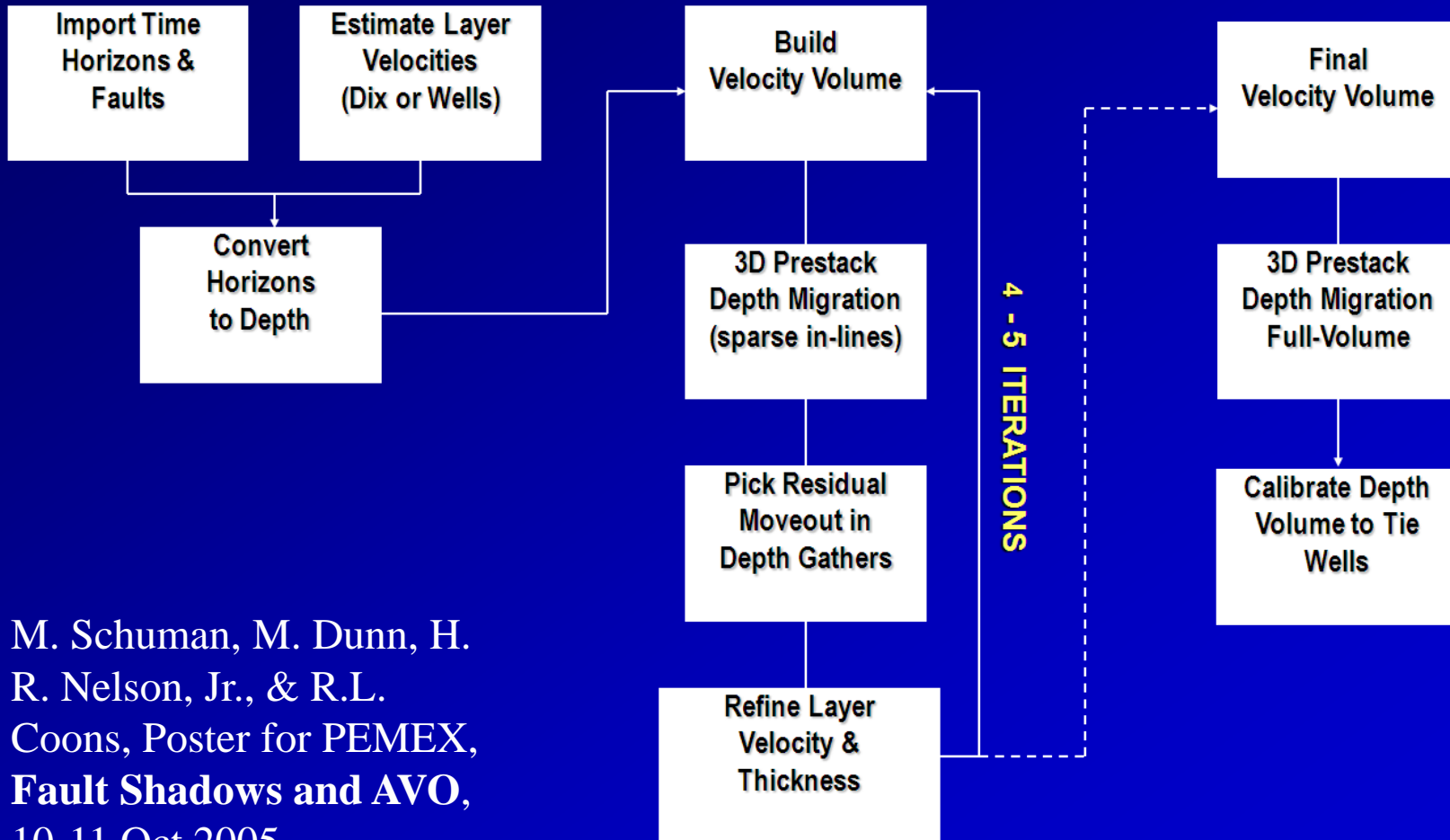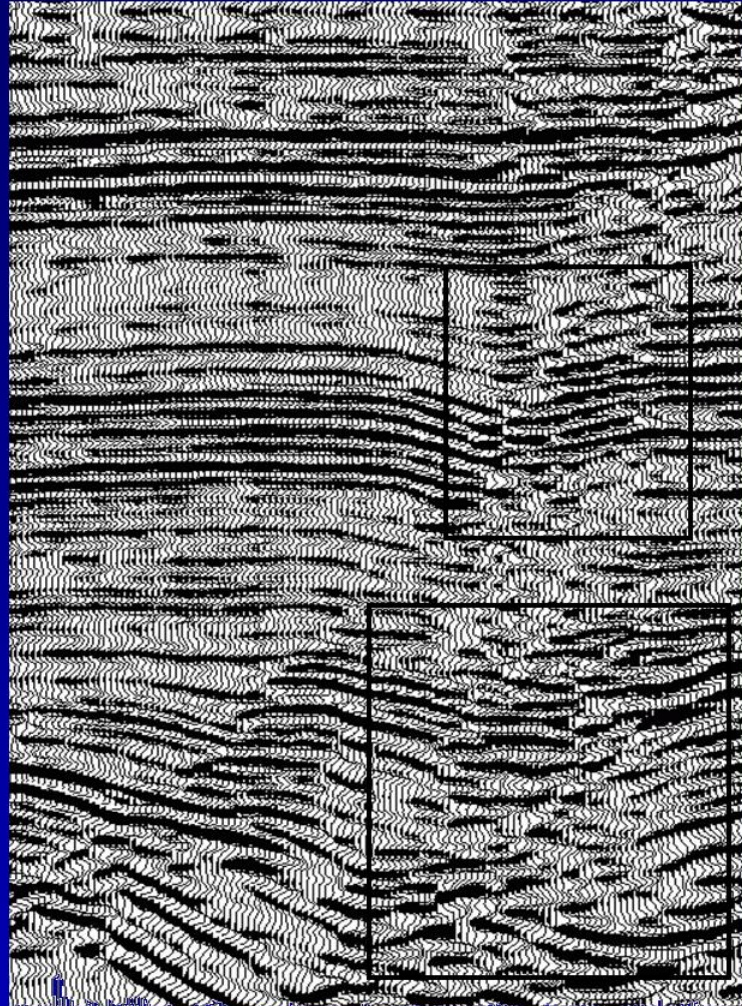
Fault Shadow Workflow
Seismic Processing

M. Schuman, M. Dunn, H. R. Nelson, Jr., & R.L. Coons, Poster for PEMEX, **Fault Shadows and AVO**, 10-11 Oct 2005.
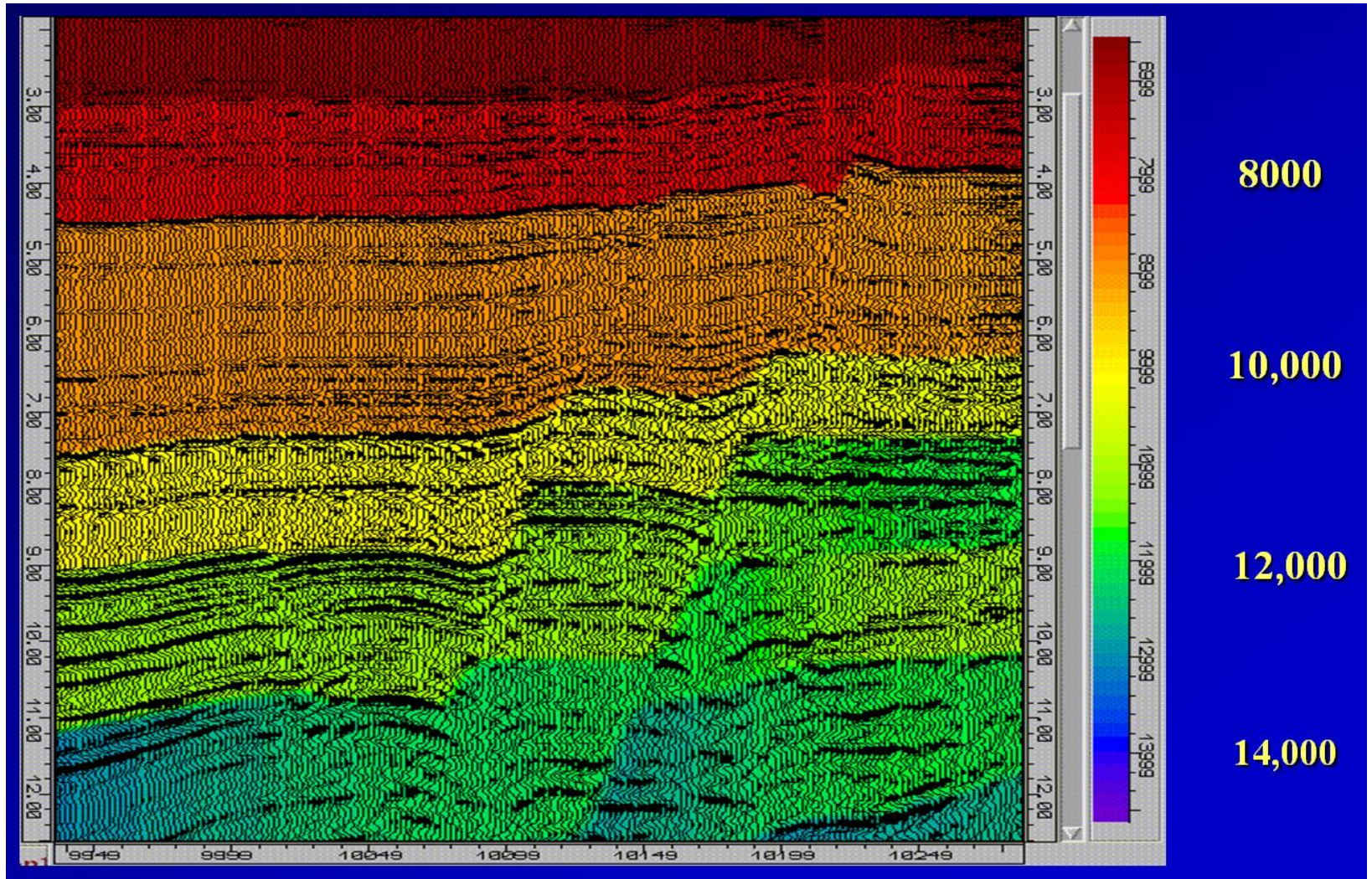
Fault Shadow False Structures
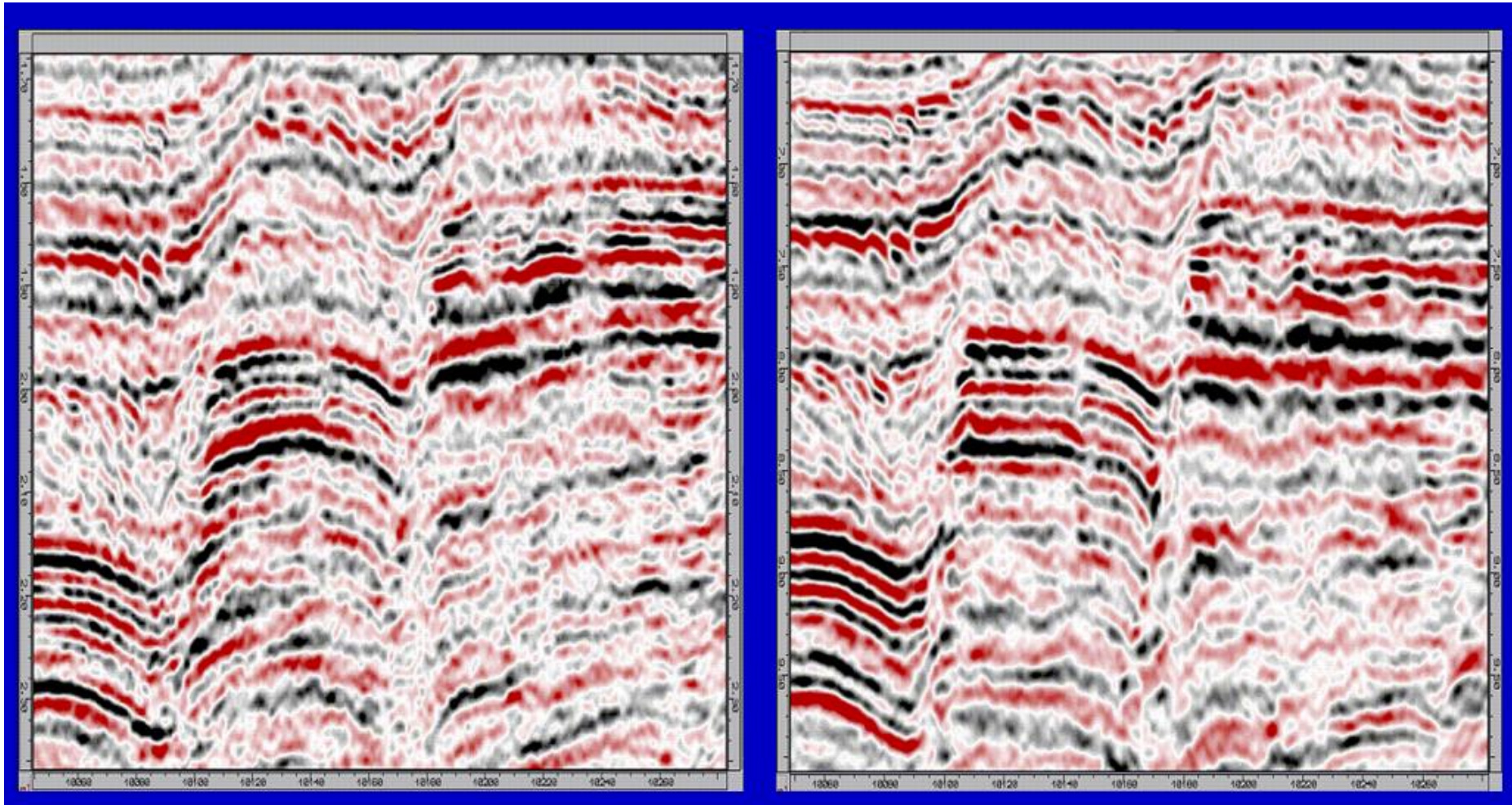# Seismic Processing

False Structures

Poor Focusing

Fault Shadow Velocity Overlay
Seismic Processing

PSTM (left) PSDM (right)
Seismic Processing

Fault Propagation Distortions
Seismic Processing

Fault Propagation Distortions are non-linear and can not be removed

Gas Charged Muds in the Fault Zone

24-30 Degree Stack Distortion

6-12 Degree Distortion

6-12 Degree

24-30°

Check Shots in Fault Gouge have shown 50% drop in velocity

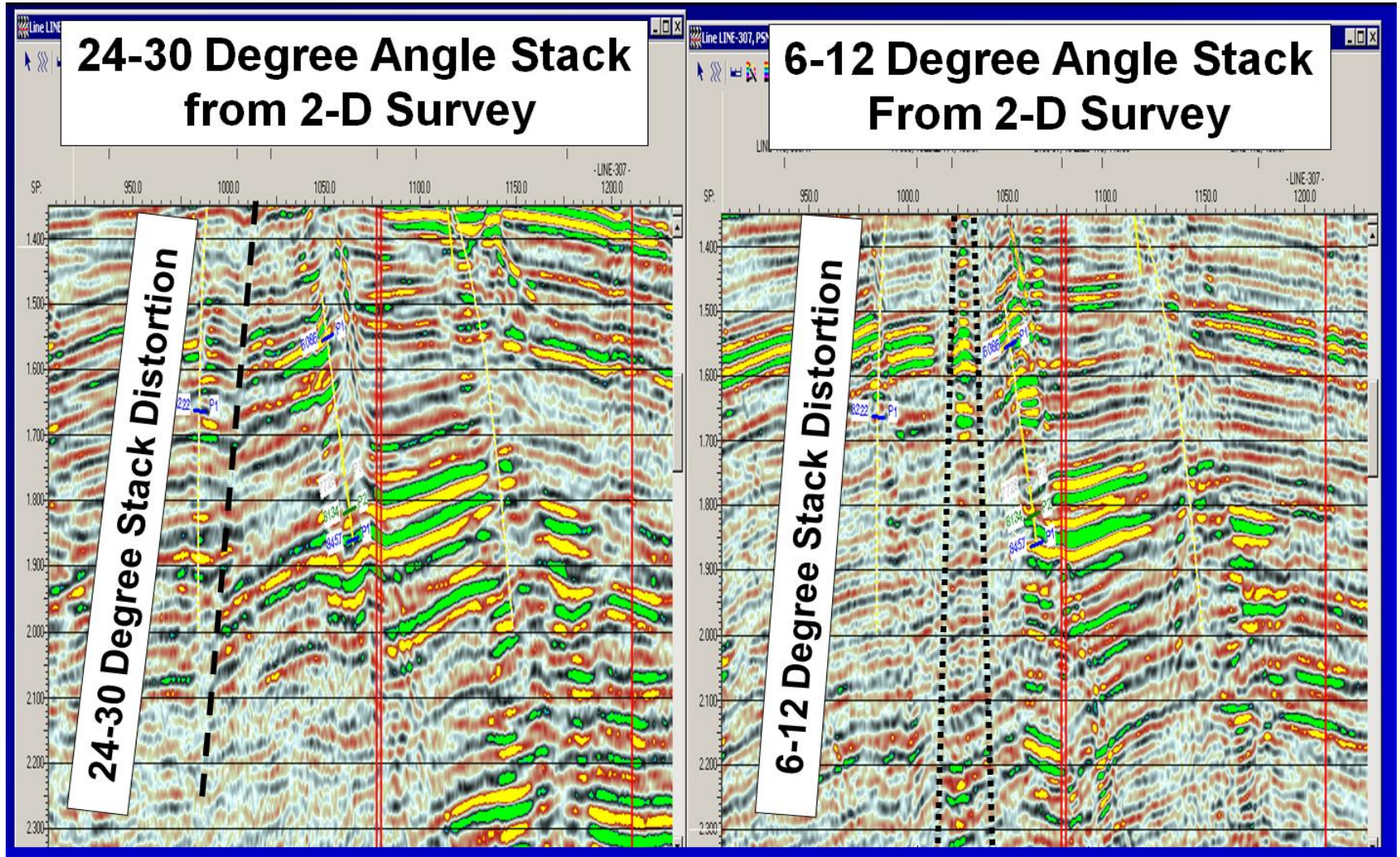# 2-D and 3-D Fault Distortions
Seismic Processing
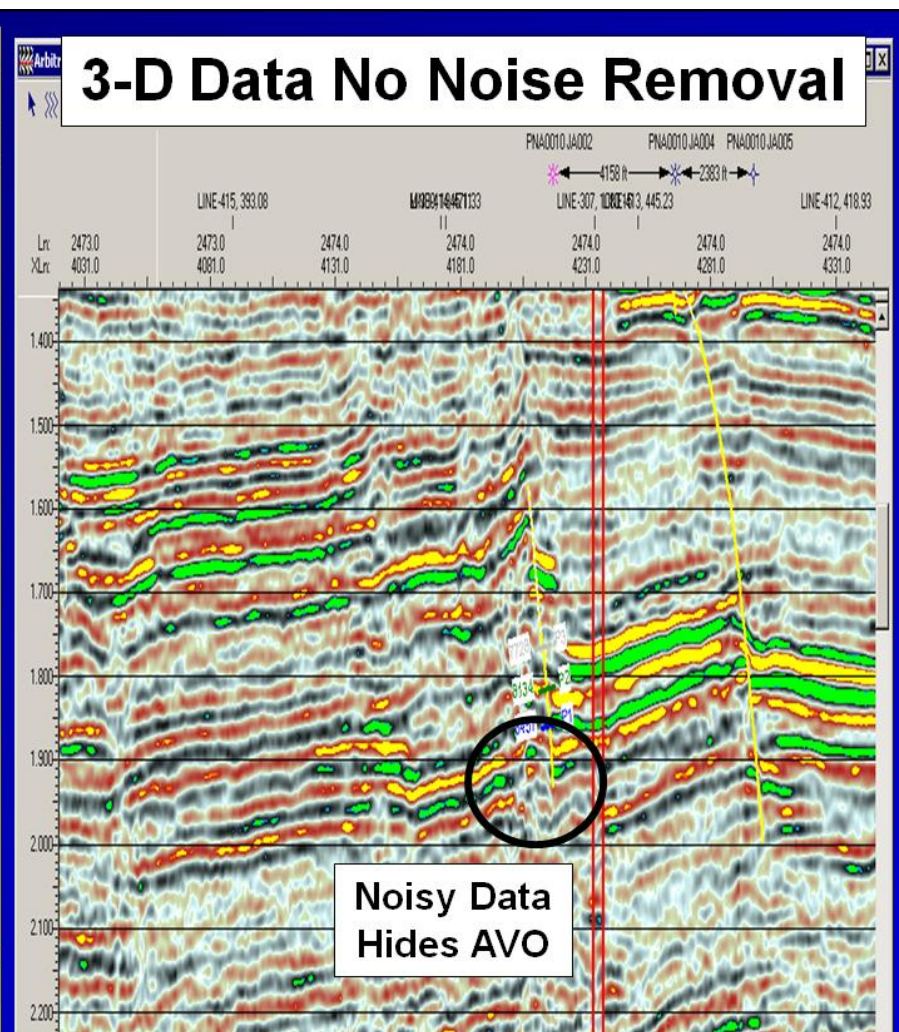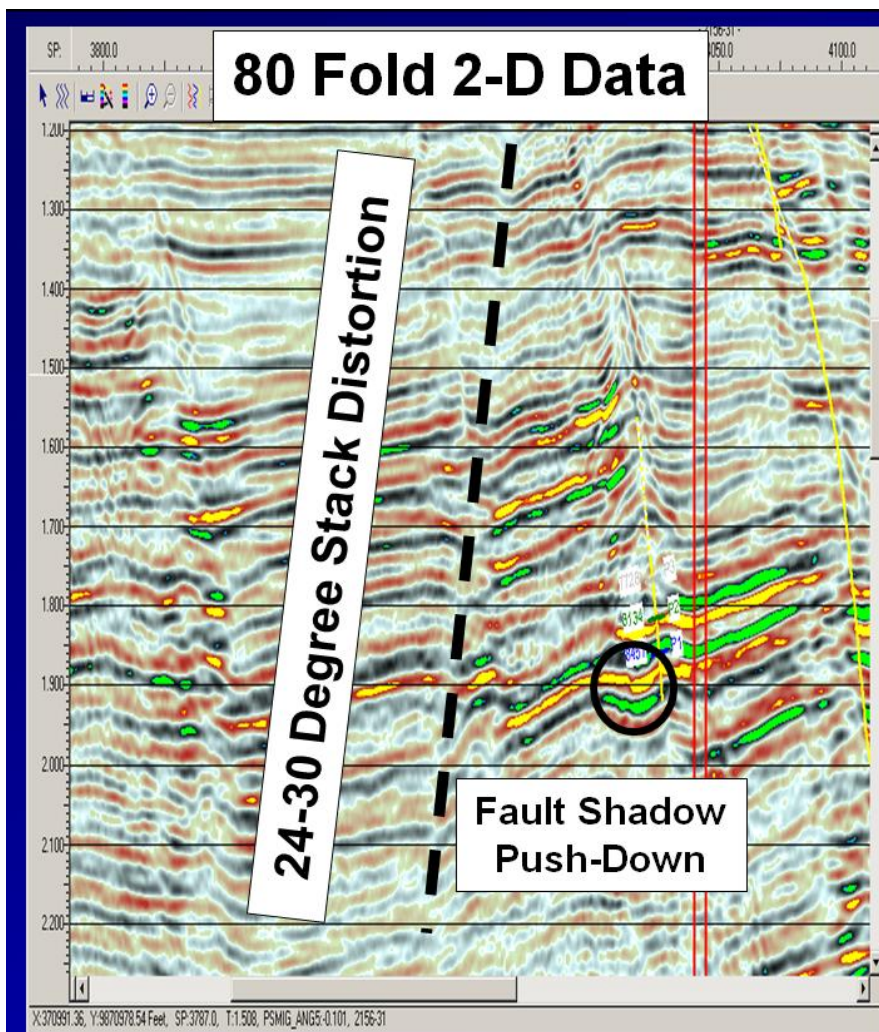
60 Fold 2D Fars vs. Nears Fault Distortions
Seismic Processing

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terrainsCopyright © 2011 Walden 3-D, Inc.

2-D Fars vs. 3-D Fars Fault Distortions
Seismic Processing

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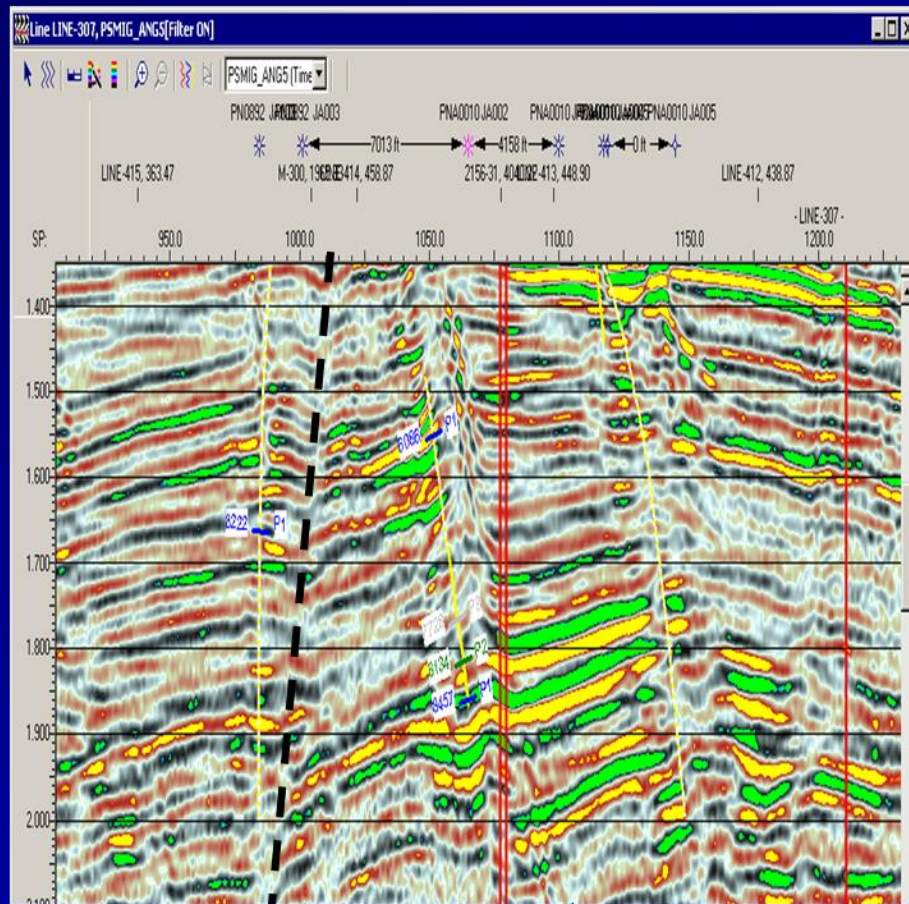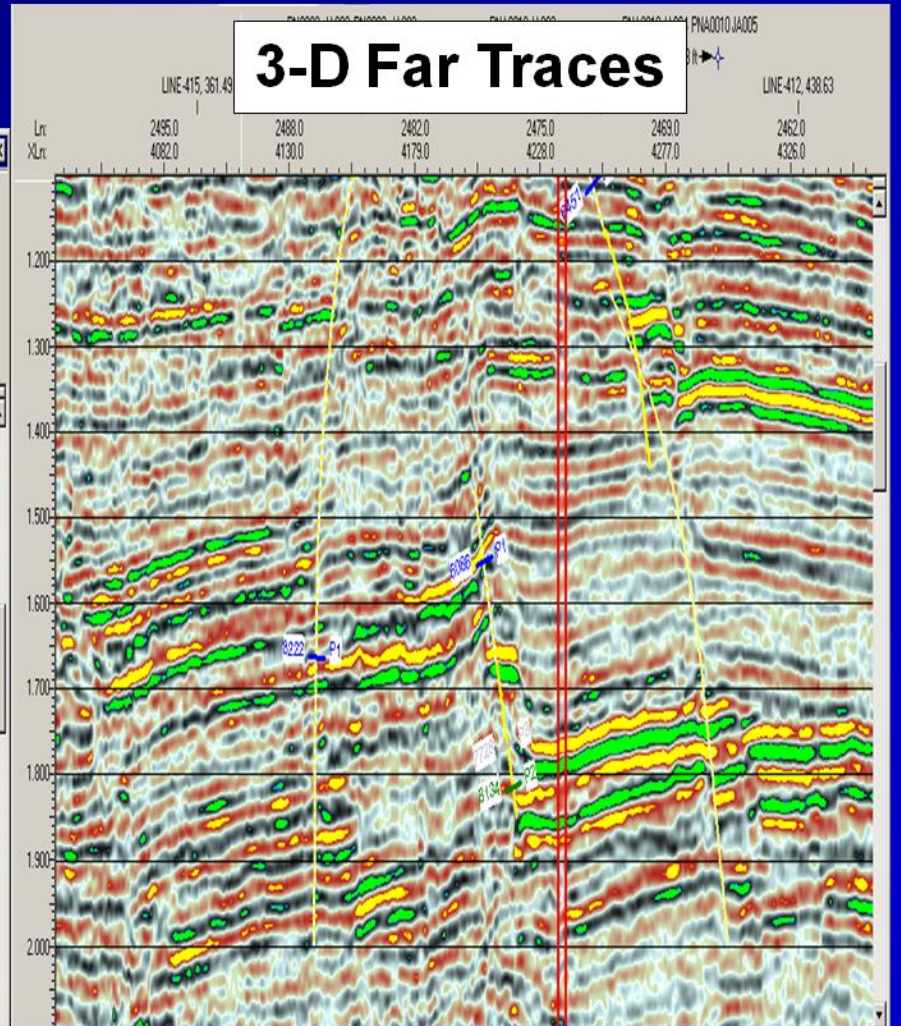
Ray Trace vs. Wave Equation Models
Seismic Processing

Vel   Den   Sd%

Ray Trace

Full Elastic
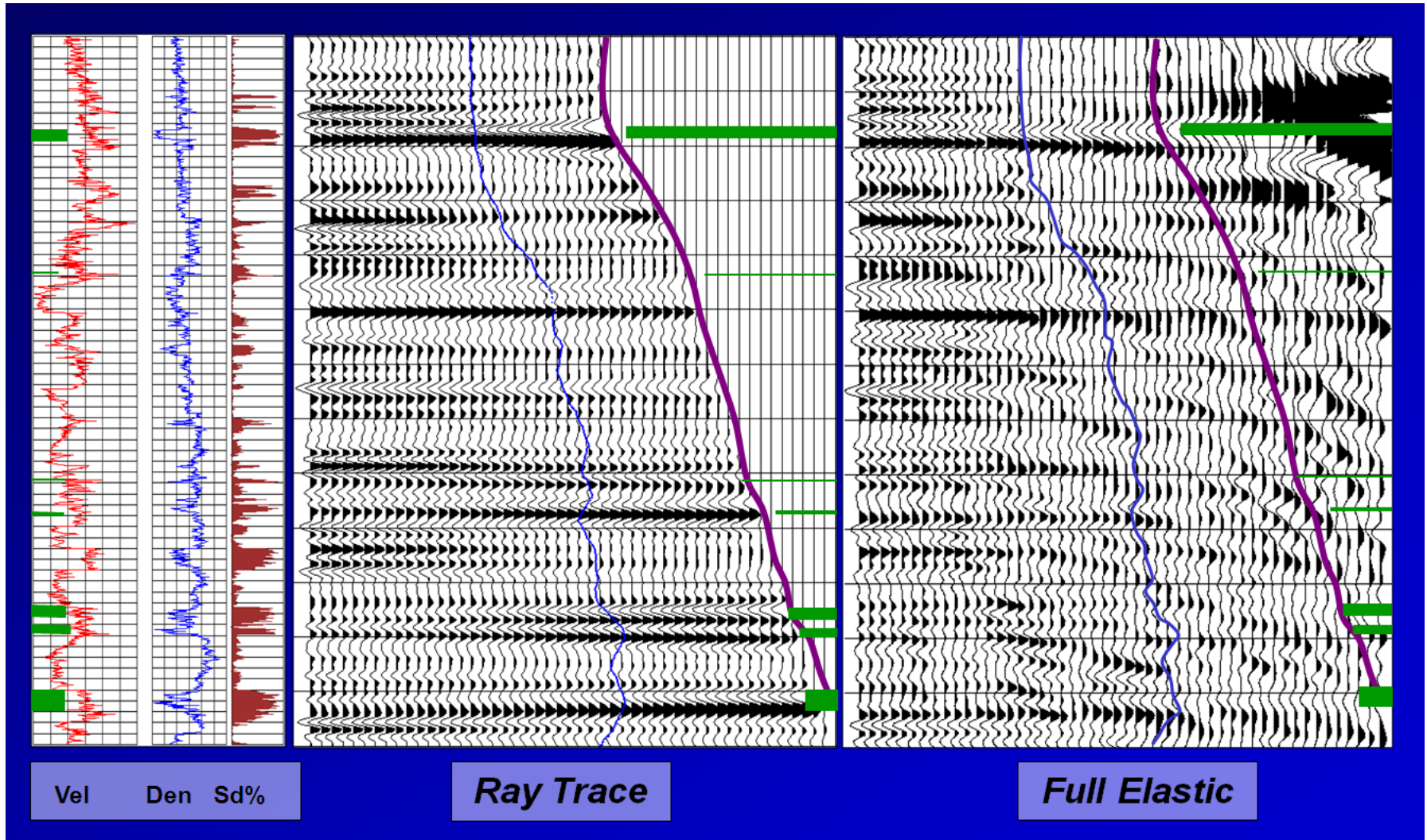
Processed Gathers and Fault Distortions
Seismic Processing

Hyperbolic +Linear Radon + Migration

Original Data

Hyperbolic Radon

Hyperbolic + Linear Radon

Fault Shadow

Pay
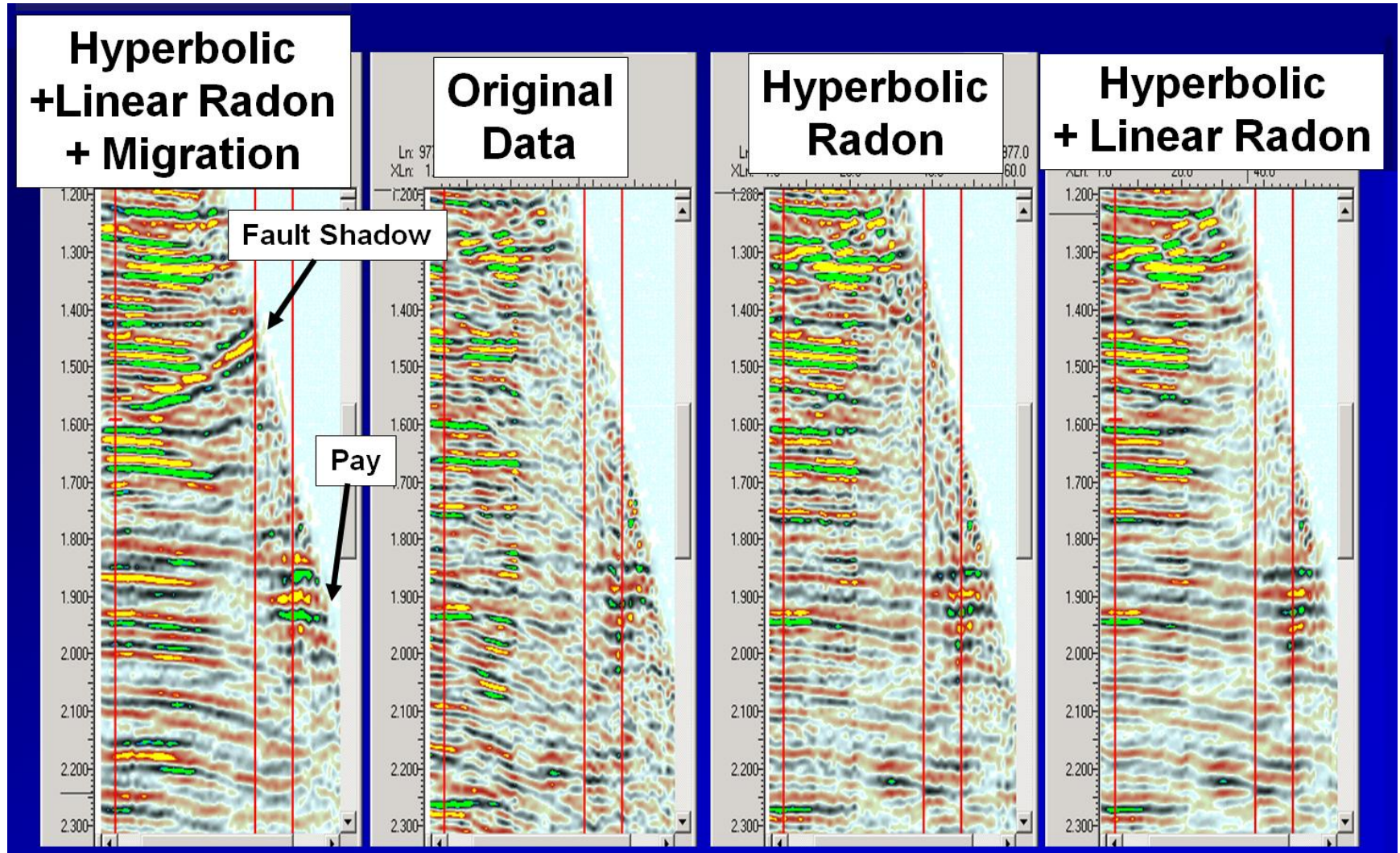
Predicting Subsurface Properties
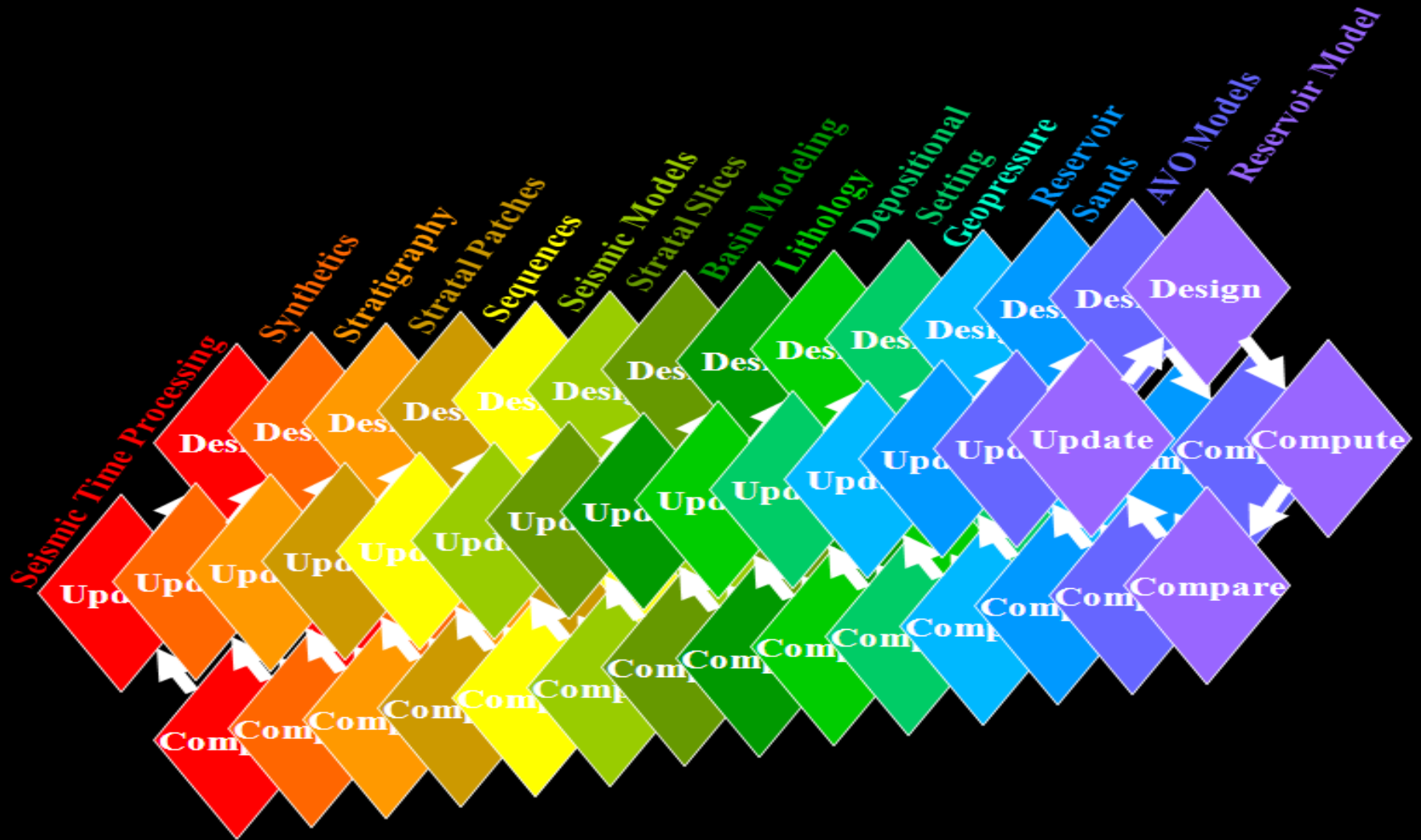
Pre-Program Questionnaire

- What is the role of seismic acquisition in integrated seismic interpretation?
  - What is the impact of basement tectonics on seismic acquisition design?
    - Fracture trends?
    - Anisotropy?
  - What impact does stratigraphic morphology have on seismic acquisition design?
  - What are the advantages of 2-D, 3-D, and 4-D seismic acquisition?
  - What is the advantage of wide azimuth acquisition?
  - What is the advantage of multi-component acquisition?
  - Are there special considerations for seismic acquisition across carbonates?
- What is the role of seismic processing in integrated seismic interpretation?
  - How do seismic velocities impact seismic processing?
  - What are the benefits of pre-stack time migration (PSTM)?
  - What are the benefits of pre-stack depth migration (PSDM)?
  - How does seismic processing impact interpretation?
  - Why does a seismic interpreter need to understand the implications of seismic processing assumptions?