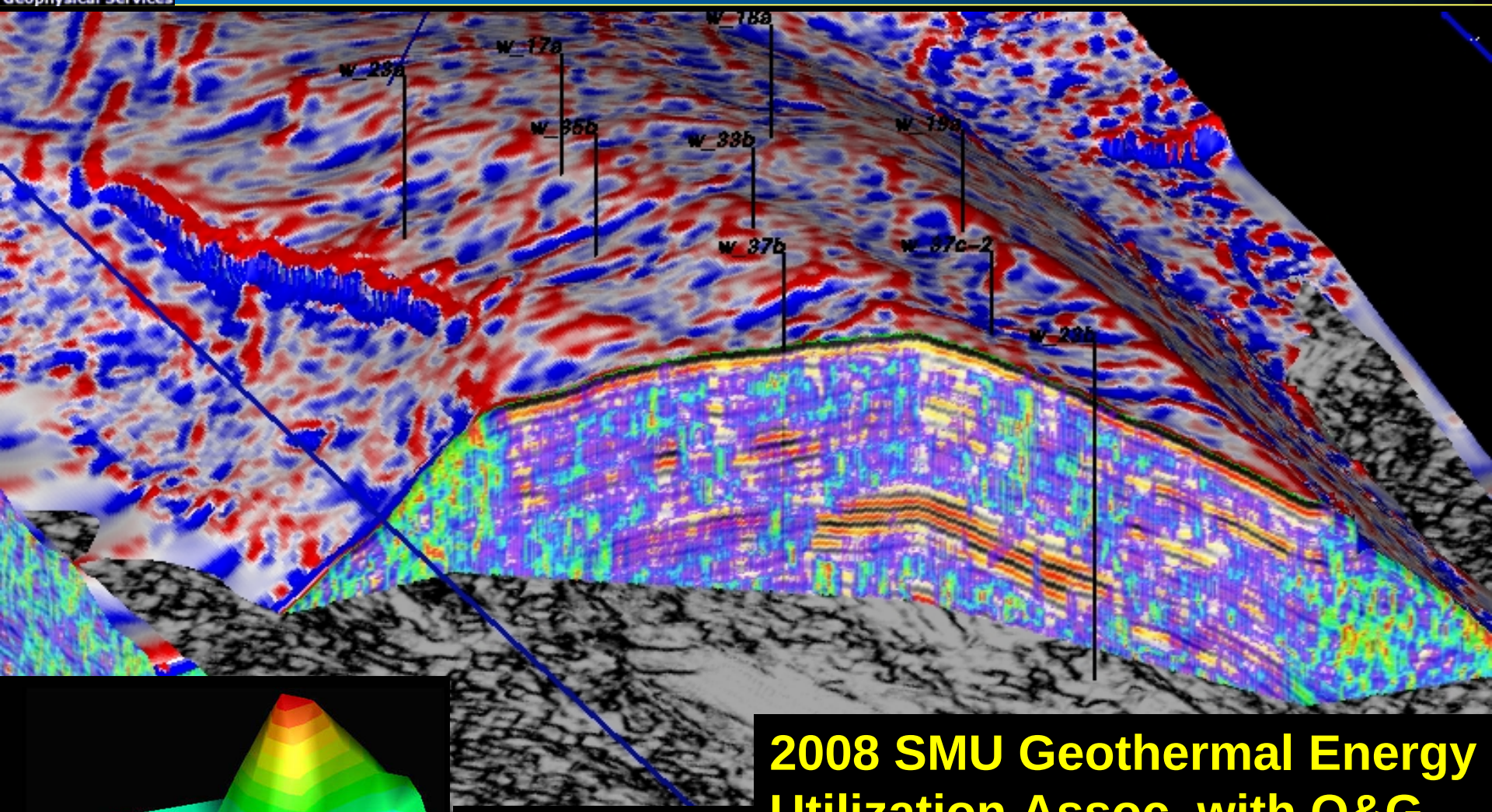
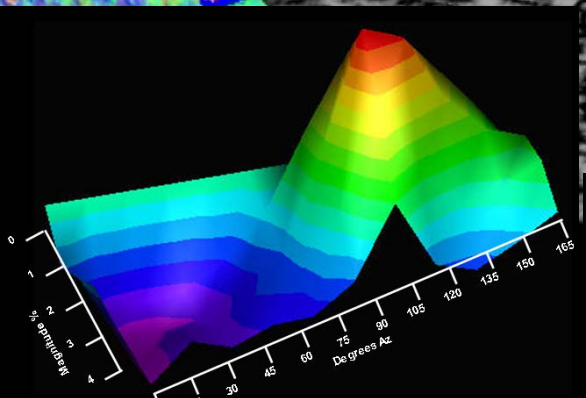
Seismic Processing for Fracture Prediction

Global Geophysical Services

Weinman GeoScience



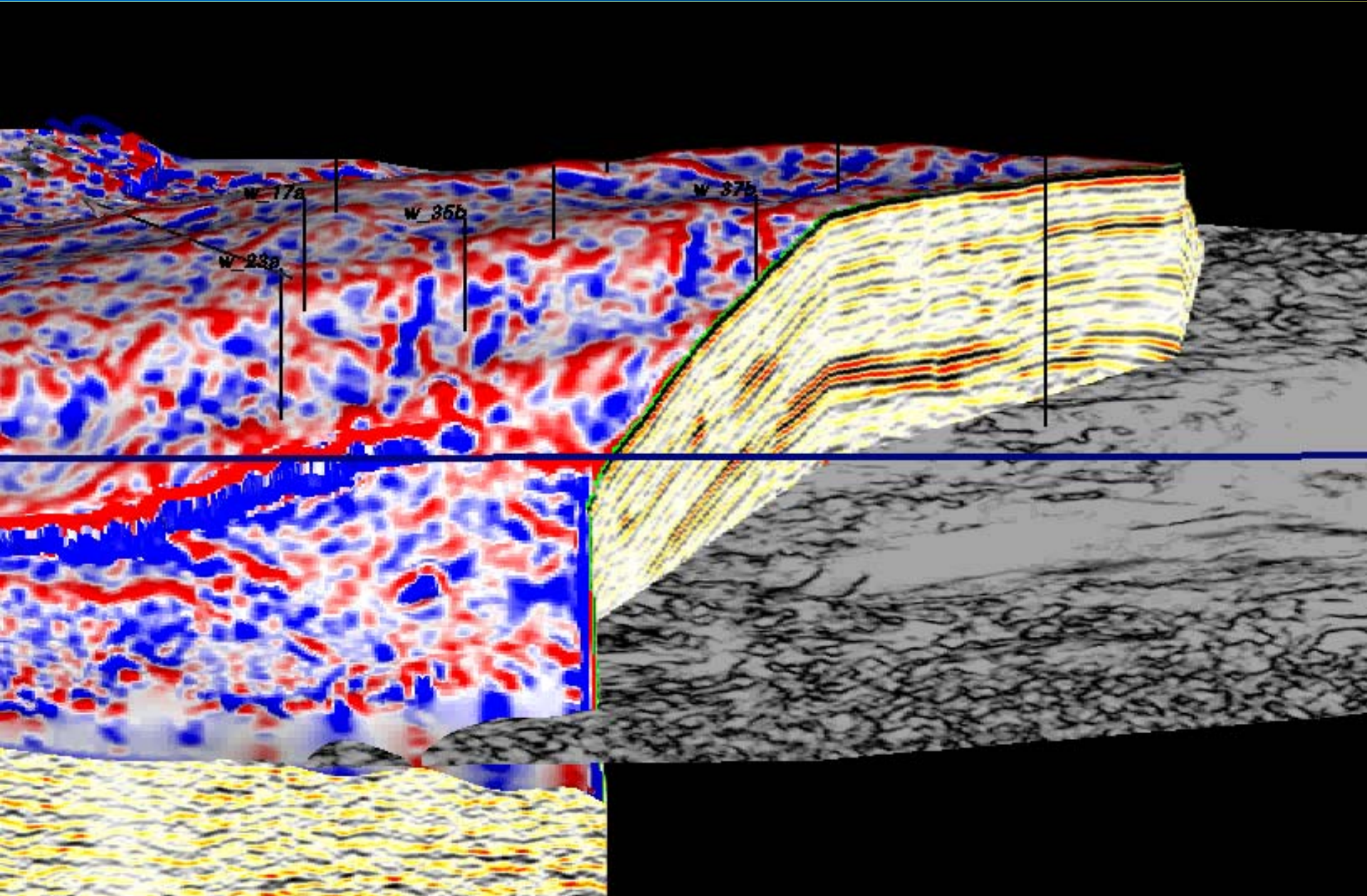


2008 SMU Geothermal Energy Utilization Assoc. with O&G

***Galen Treadgold**
Charles Sicking
Victoria Sublette
Gary Hoover

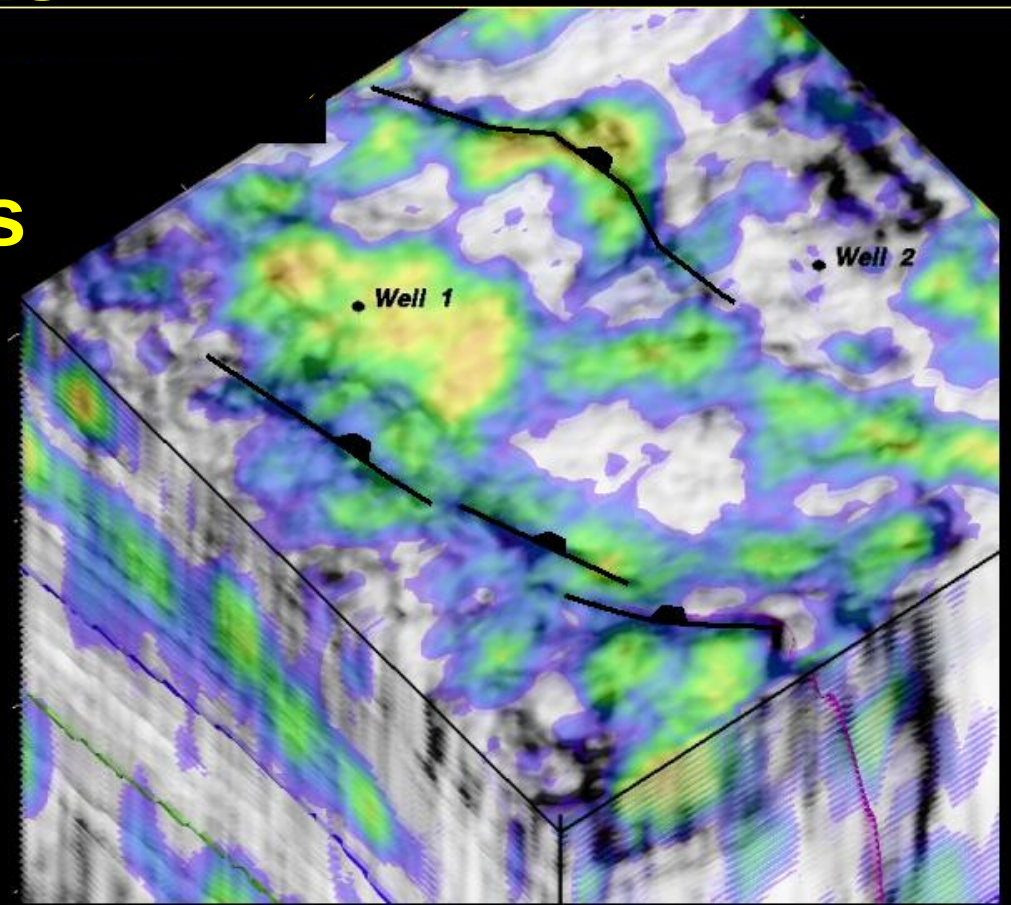
***Speaker**

Curvature and Coherence

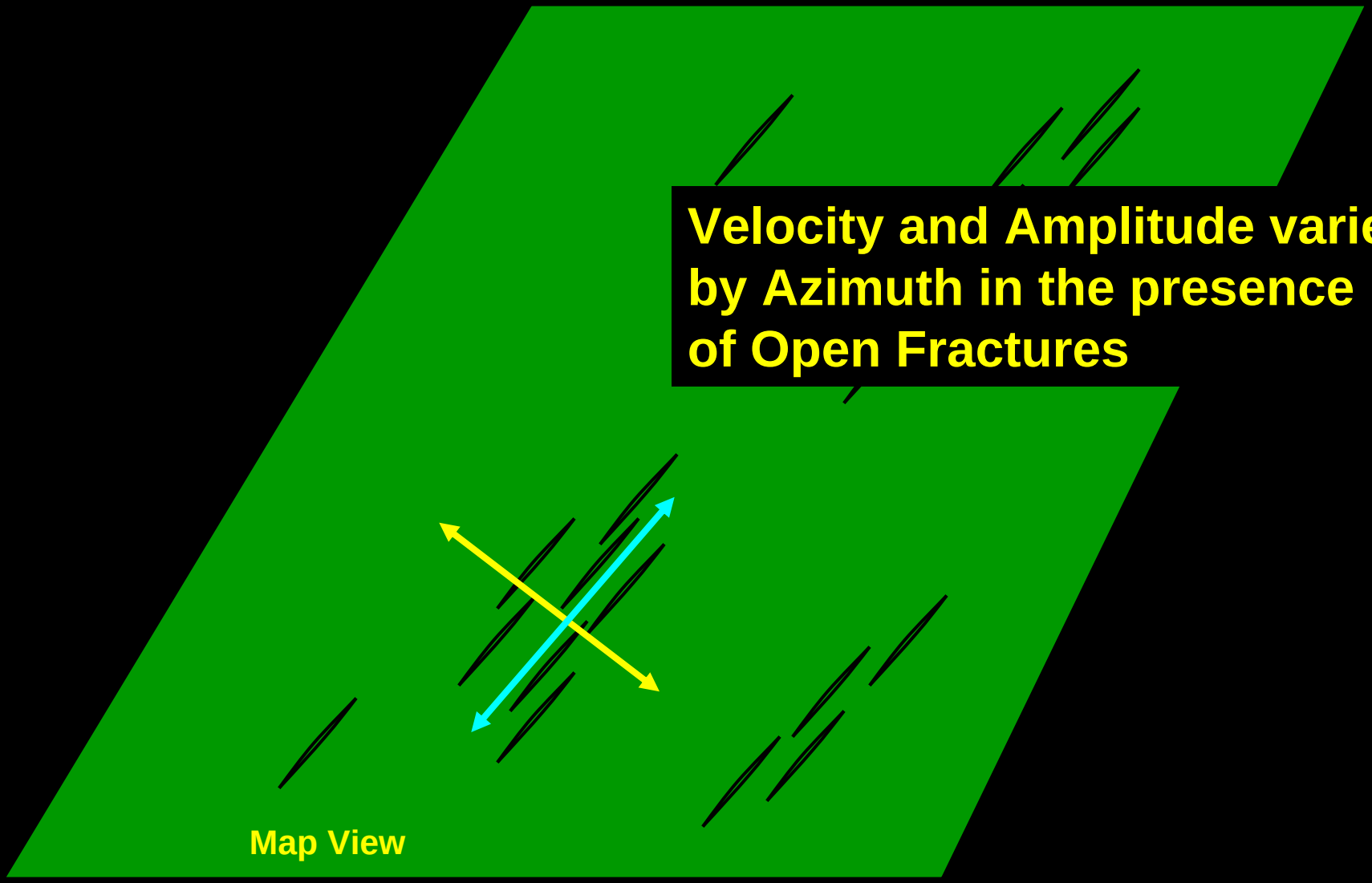


Outline

- Seismic and Fractures
- Velocity and Anisotropy
- Azimuthal Analysis
  - Methods
  - Imaging Results



Azimuthal Velocity Variations



Seismic Based Fracture Prediction Technologies

- Multi-Component – Shear Wave Splitting
- Azimuthal Analysis - TIME
  - Pre-Migration Azimuthal Analysis
  - Migration based Azimuthal Velocity Analysis
    - Option 1 – Sectored Azimuthal Migrations
      - Suffers from poor sampling
    - Option 2 – Isotropic Migration into azimuth and offset bins
    - Option 3 – Azimuthal Migration
  - Migration based Azimuthal AVO
- Azimuthal Analysis - DEPTH
- Post-Stack:
  - Curvature Analysis
  - Coherence Analysis
  - Inversion – Amplitude and Velocity Information

Best Seismic Technology for Fracture Detection???

?

Robert Taylor - Halliburt

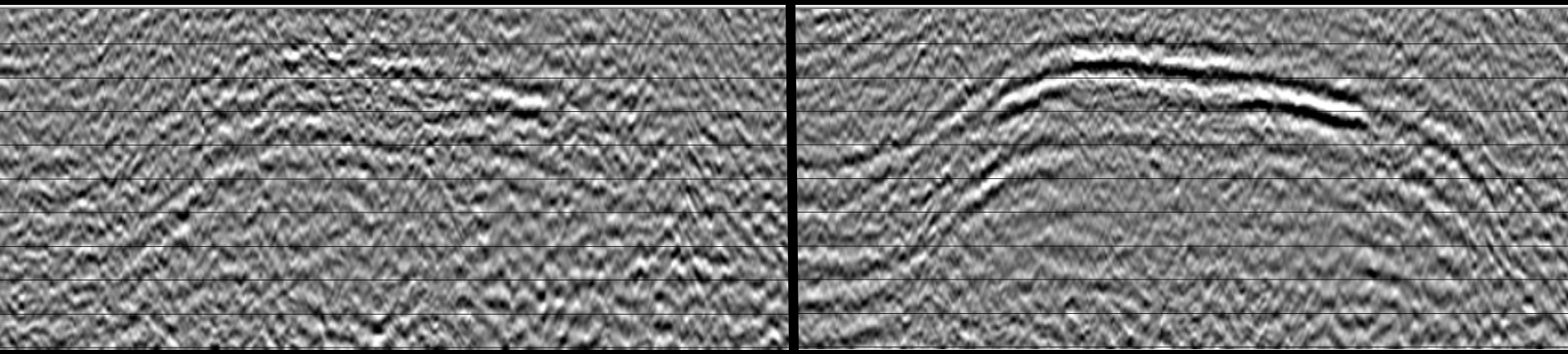
Bakken Fractures

Depends on:

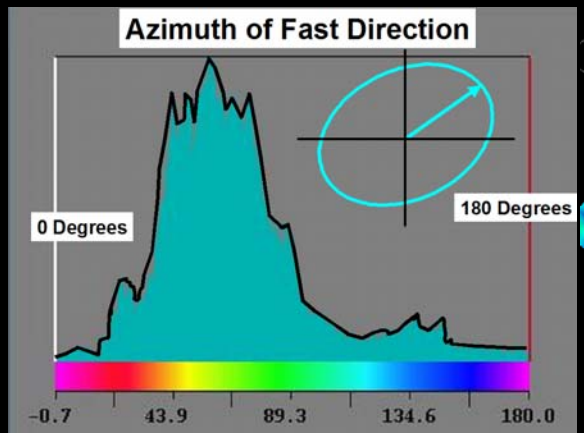
- Acquisition….
- Target Lithology
  - Sandstones….
  - Carbonates….
  - Shales….
- Structural Setting….
- Nature of Fracturing

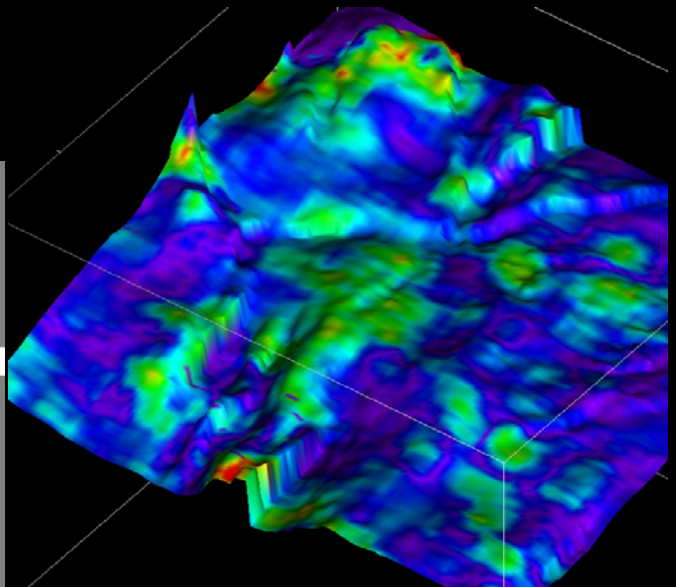
Goals for Azimuthal Analysis

- **Better Image**



- **Reservoir Information**





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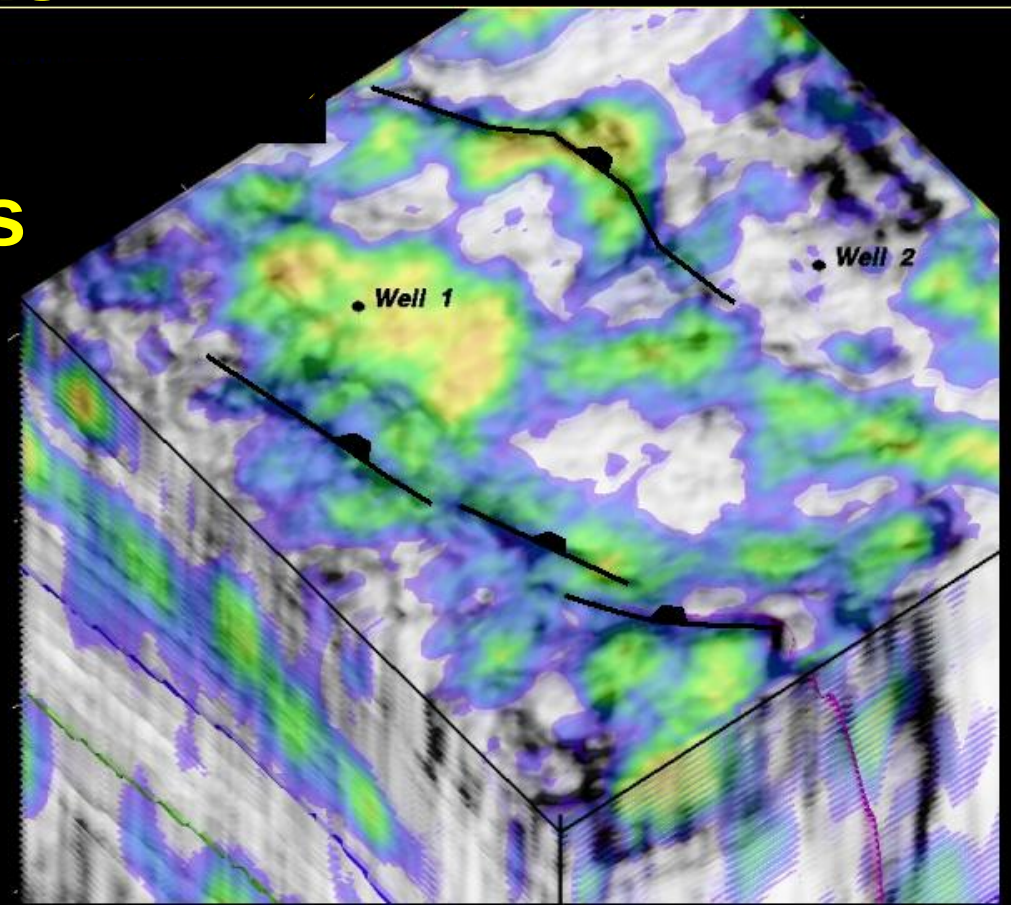
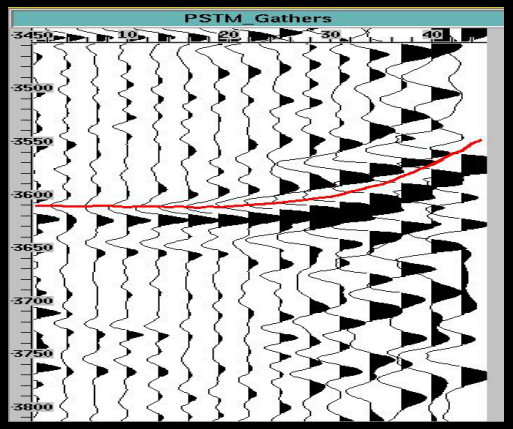
  - Methods
  - Imaging Results
- Azimuthal AVO



Some Definitions

- **VTI - Vertical Transverse Isotropy**

Offset, Time and Dip Dependent
Layer Anisotropy



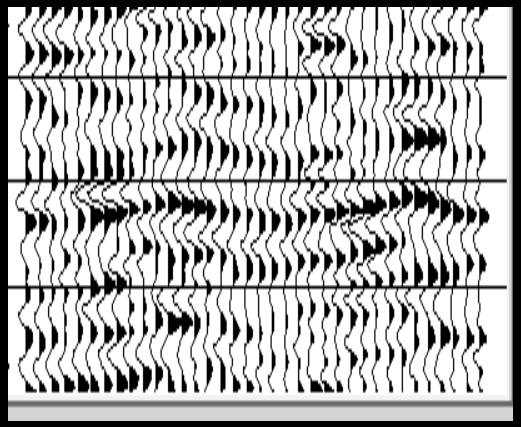
Migrated Gather
Sorted by Offset

- **HTI – Horizontal Transverse Isotropy**

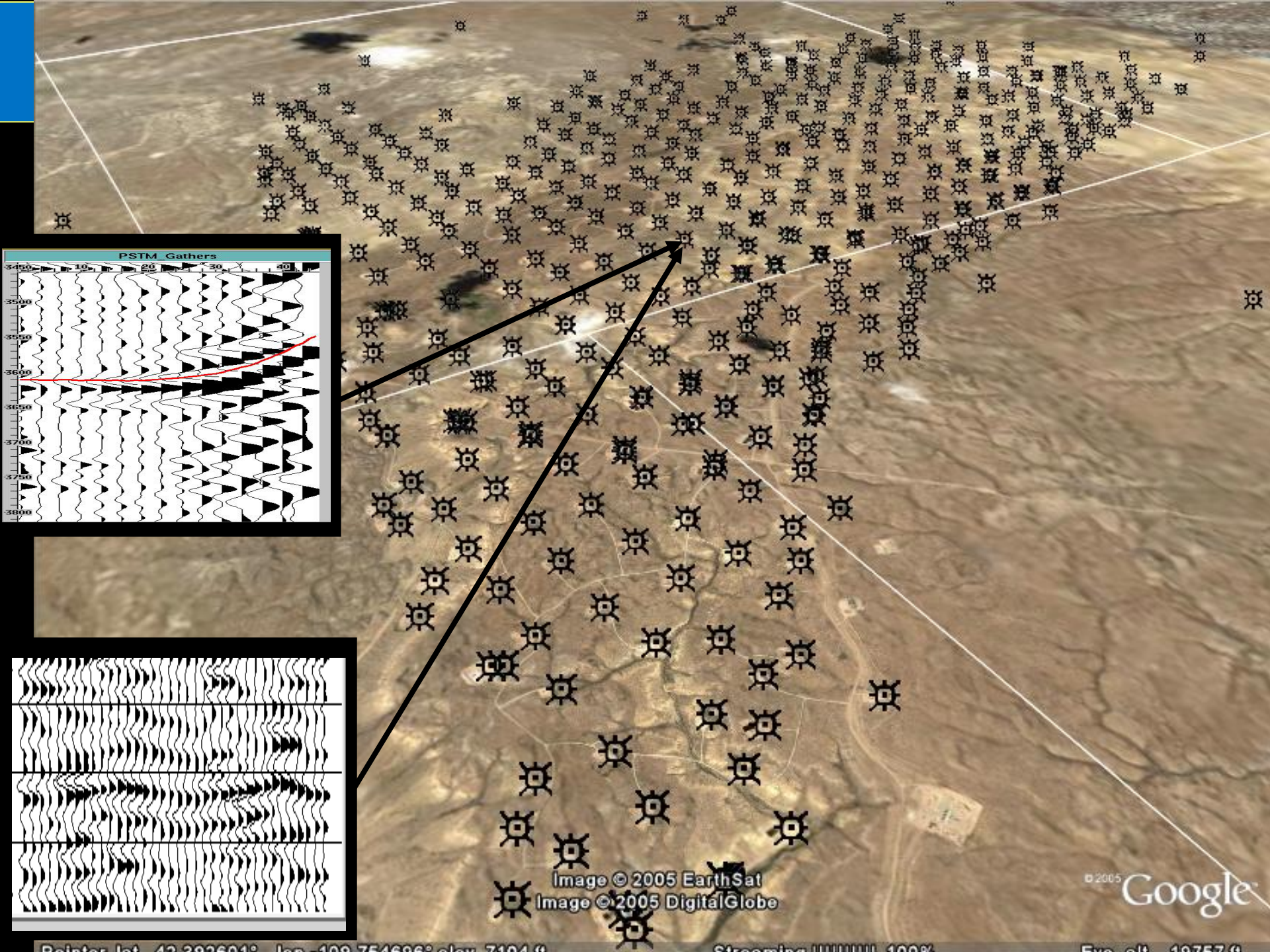
Offset, Time and Azimuth Dependent
Stress and Fracture Sensitive

"Sinusoids"

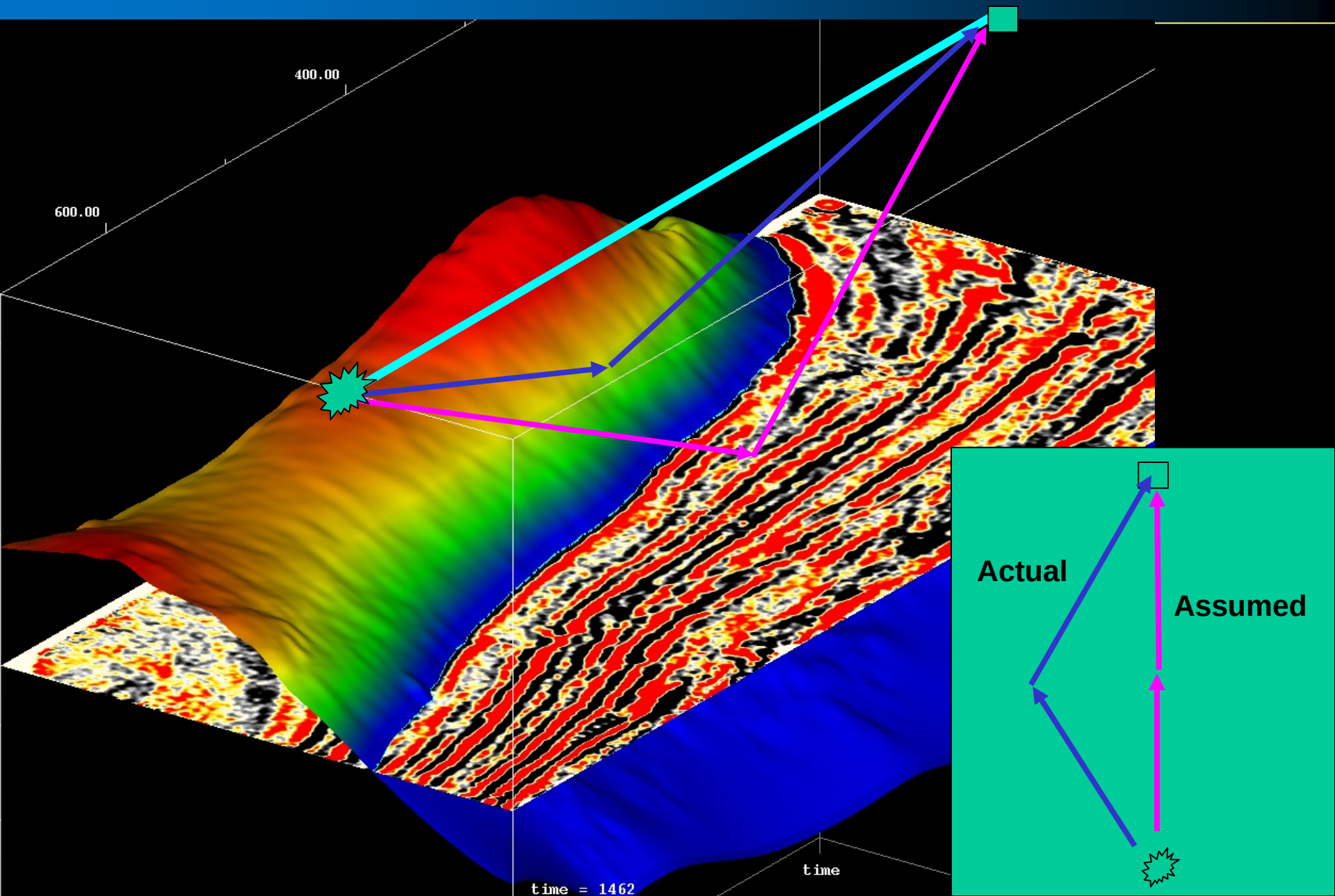
0 360



Unmigrated Gather
Sorted by Azimuth

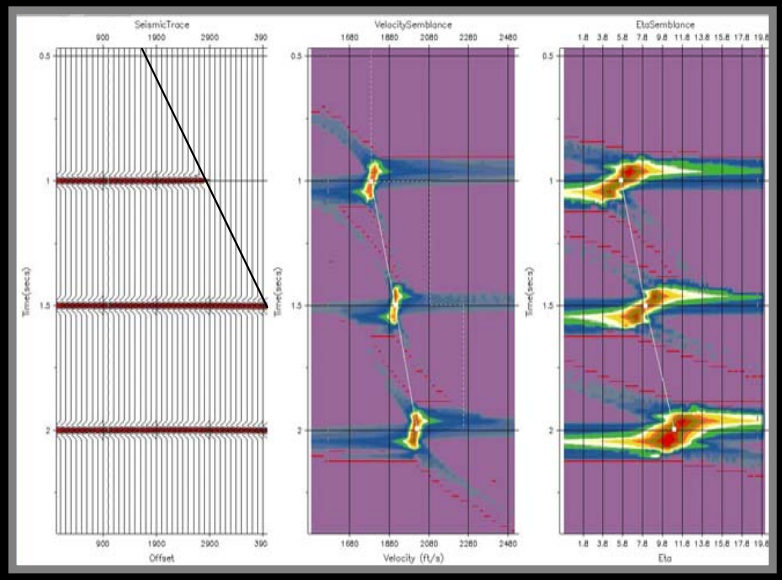

PSTM_Gathers
Image © 2005 EarthSat
Image © 2005 DigitalGlobe
© 2005 Google

What Azimuth?

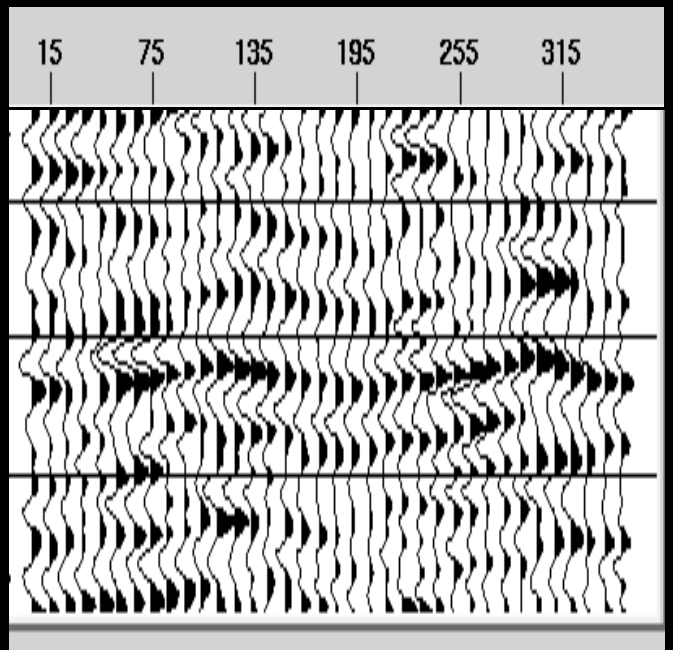


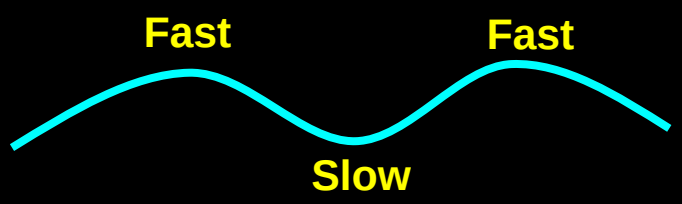
Velocities

- NMO – Normal Move-Out
- Ray Tracing – Higher Order NMO
- VTI – Higher Order NMO



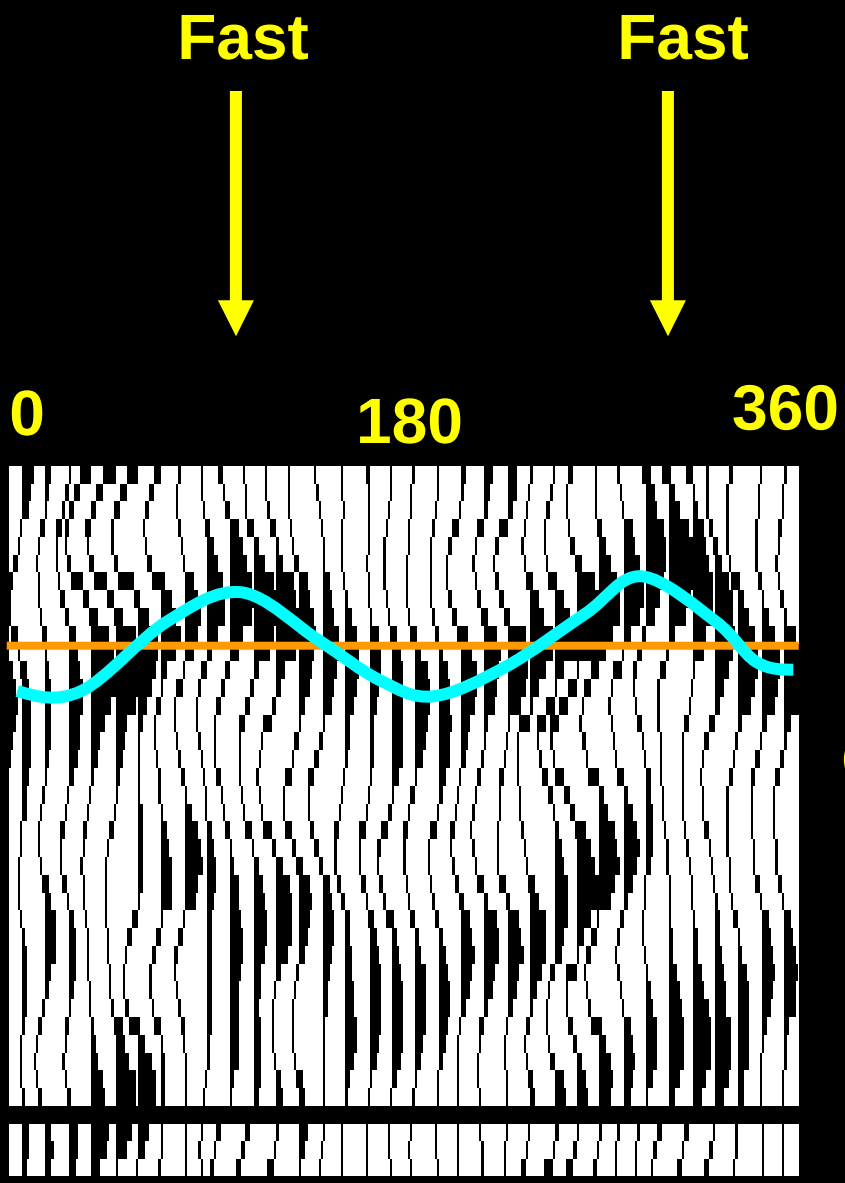
- Azimuthal

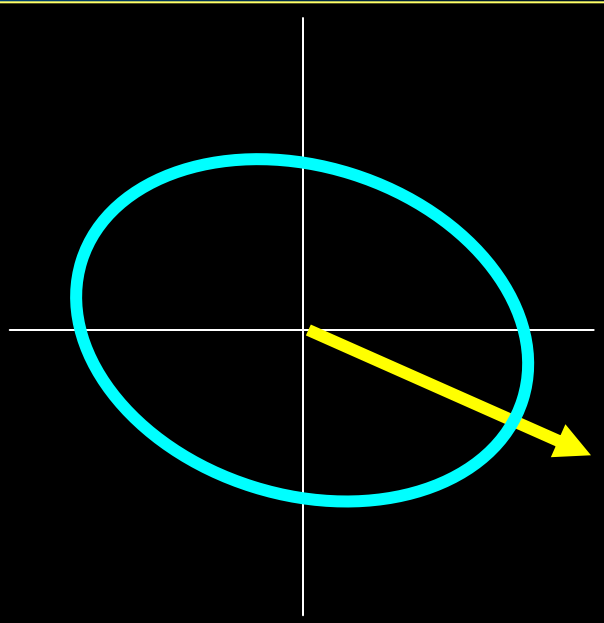




Azimuth

Why Azimuthal Processing





Gather Sorted by Azimuth

Robert Taylor - Halliburton

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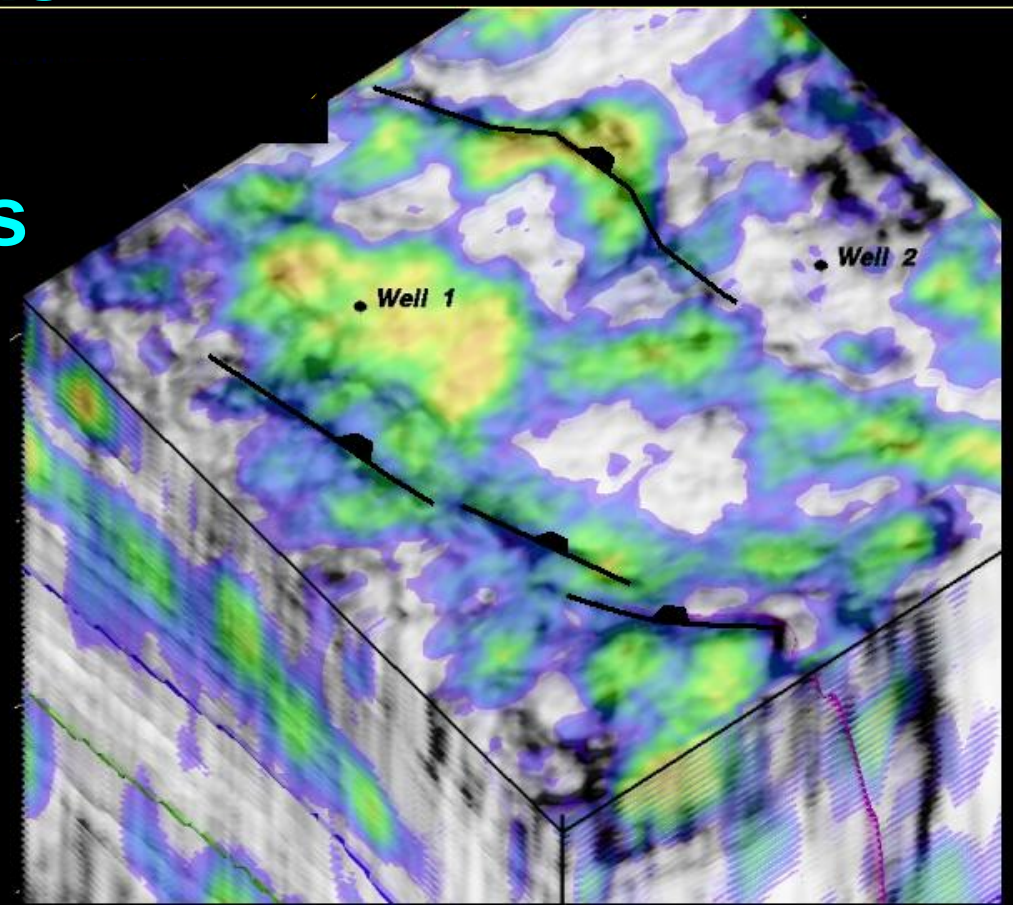
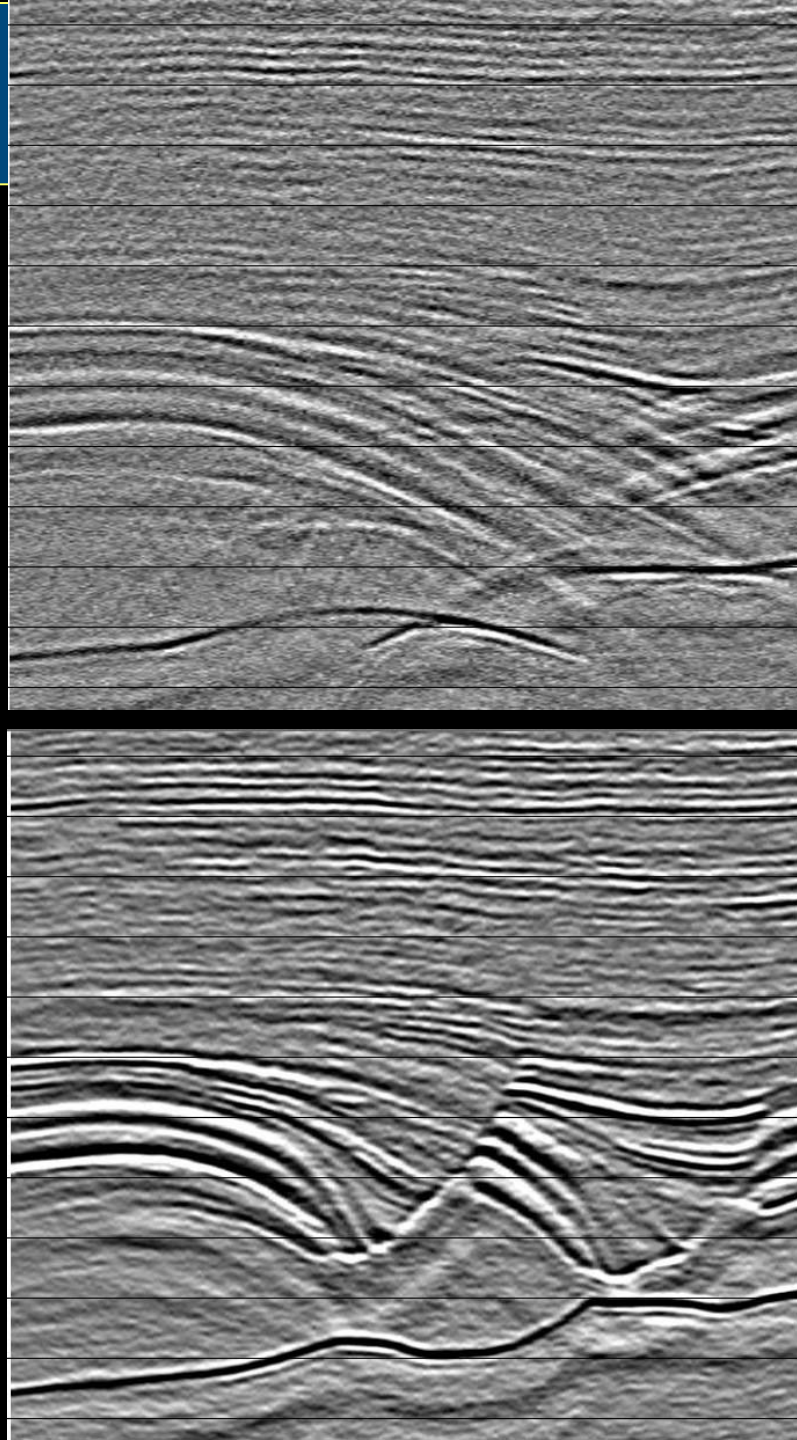


Azimuthal Velocity Analysis

No Migration

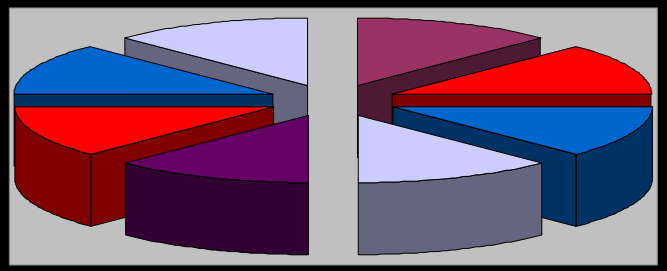
Migration



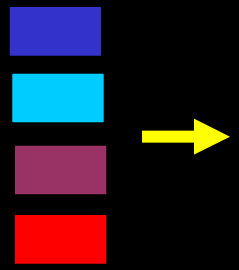
Azimuthal Migrations

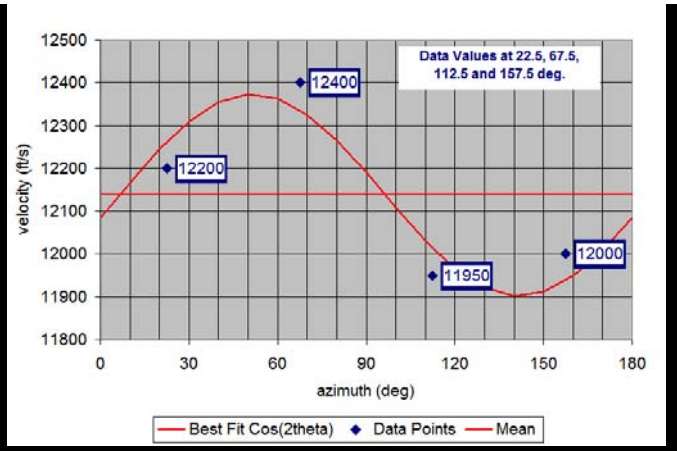
From Walt Lynn, Lynn Inc.
SEG/San Antonio 2007 Annual Meeting

- **Input Sectoring**



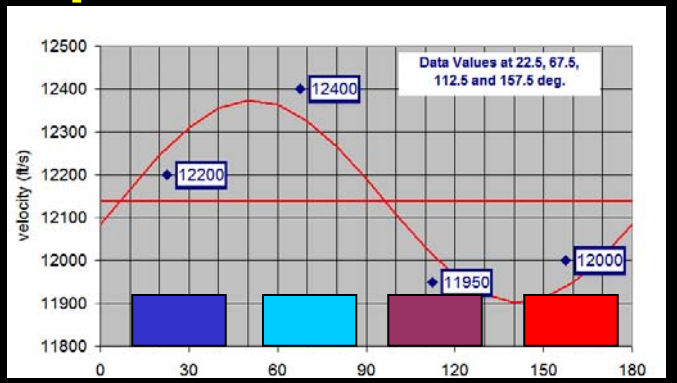
4 Migrations





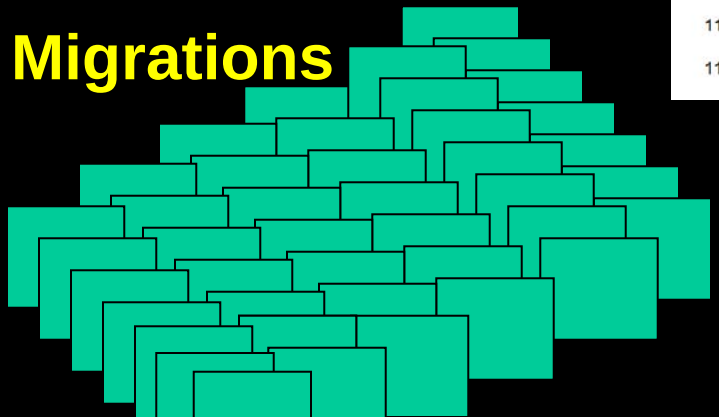
- **Imaging into Azimuth and Offset Space**

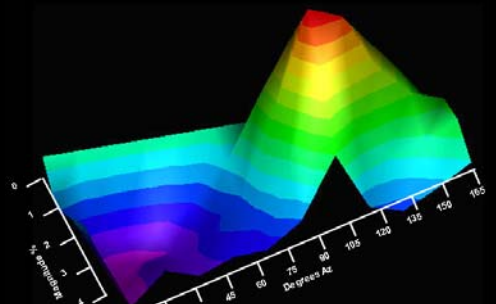
1 Migrations



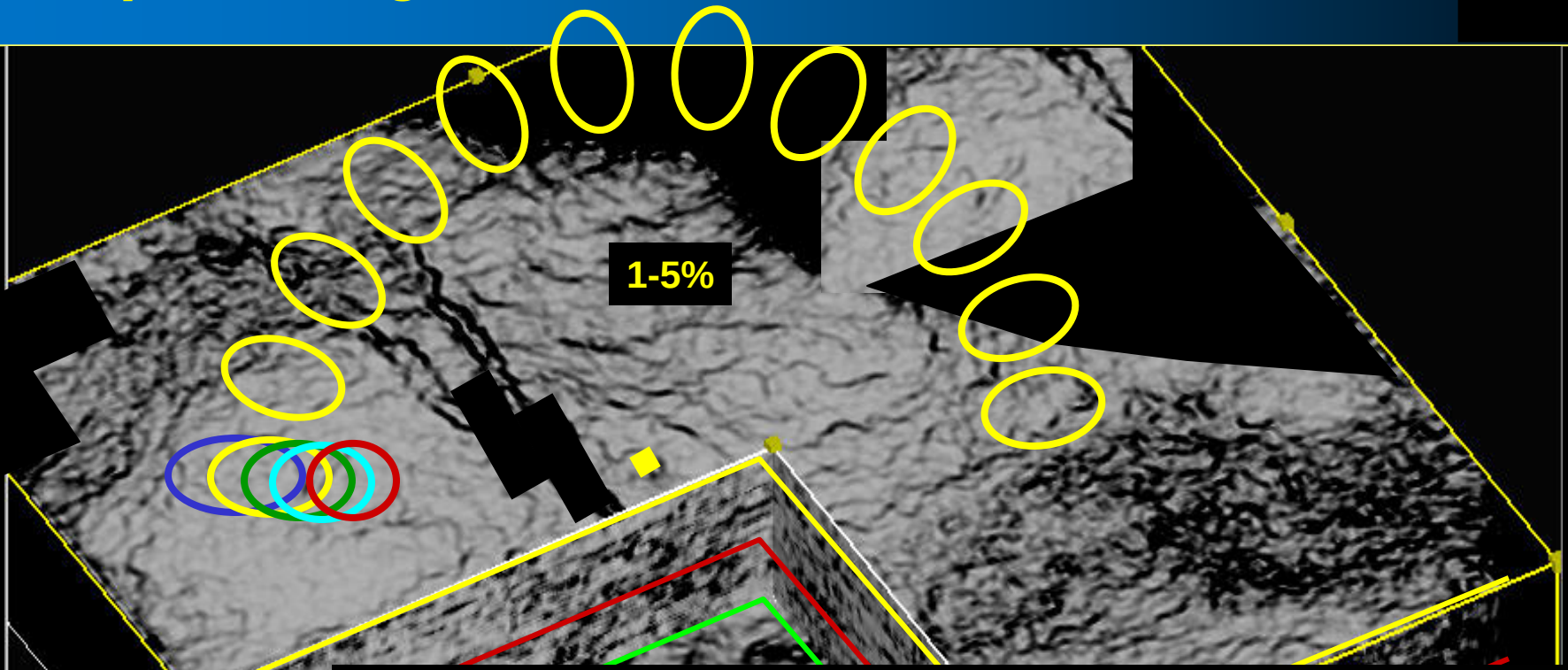
- **Azimuthal Migrations**

60-144 Migrations



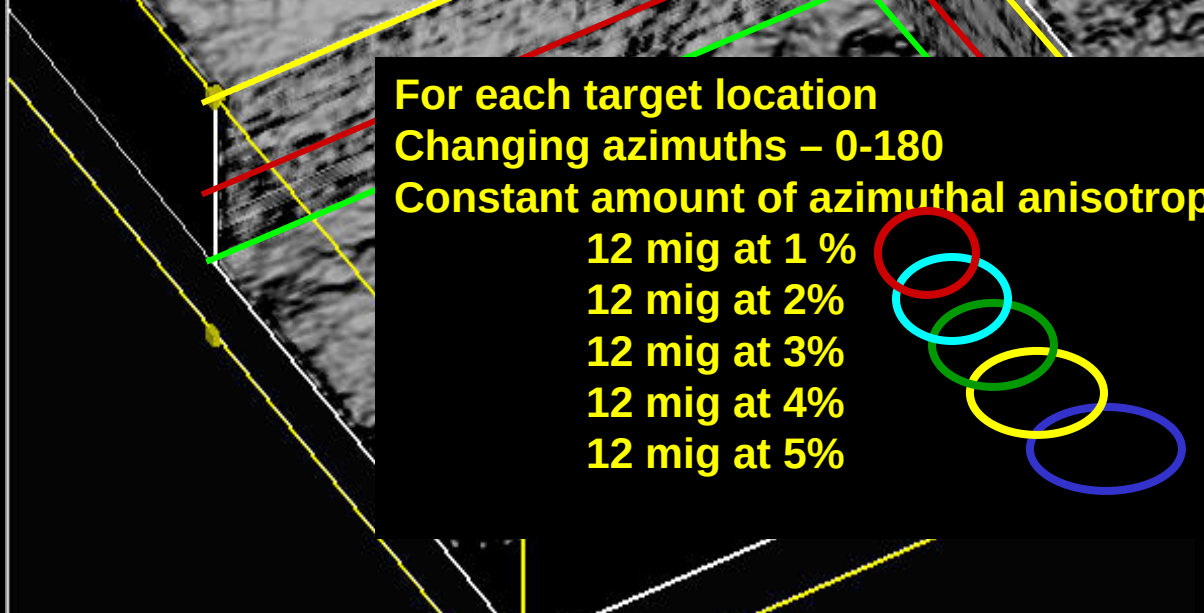


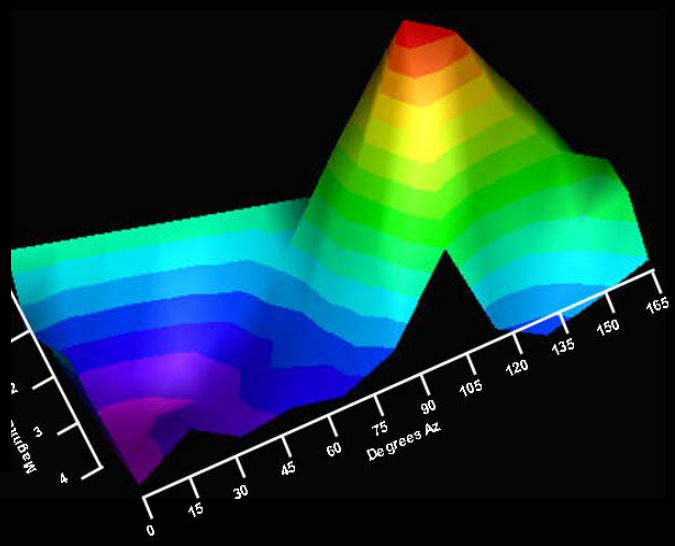
Elliptical Migrations



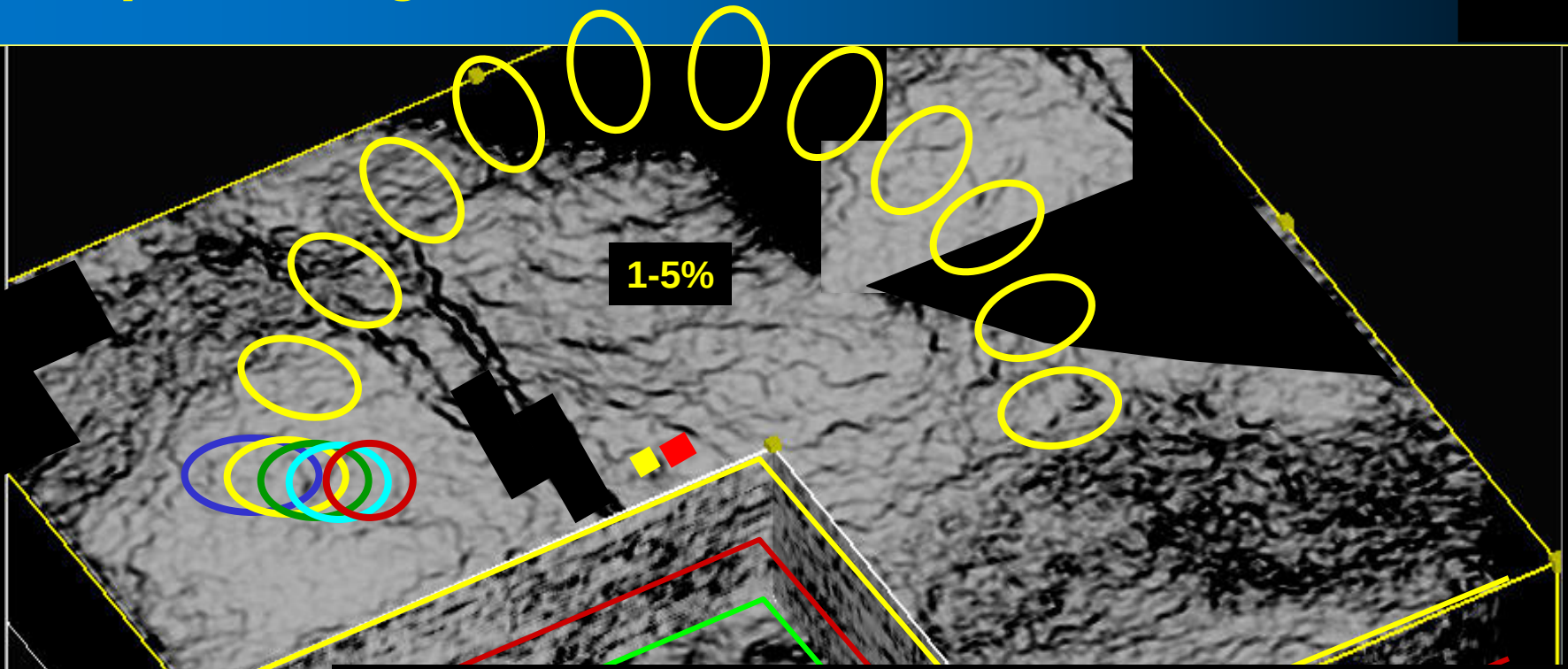
For each target location
Changing azimuths – 0-180
Constant amount of azimuthal anisotropy

- 12 mig at 1 %
- 12 mig at 2%
- 12 mig at 3%
- 12 mig at 4%
- 12 mig at 5%





Elliptical Migrations



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12 mig at 1 %
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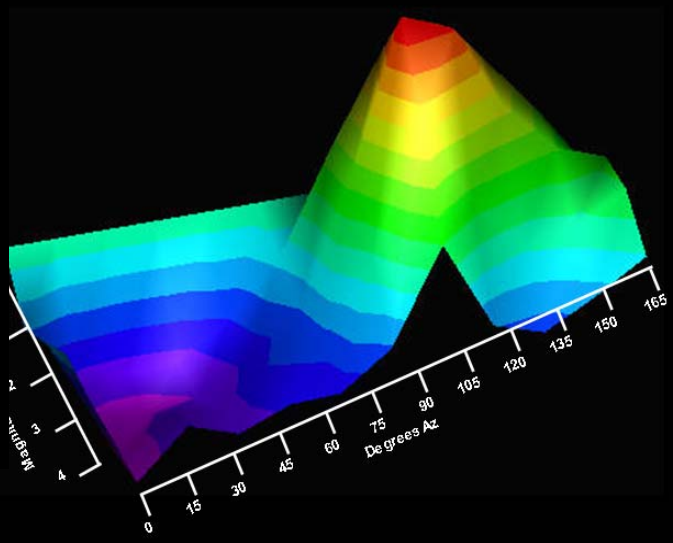
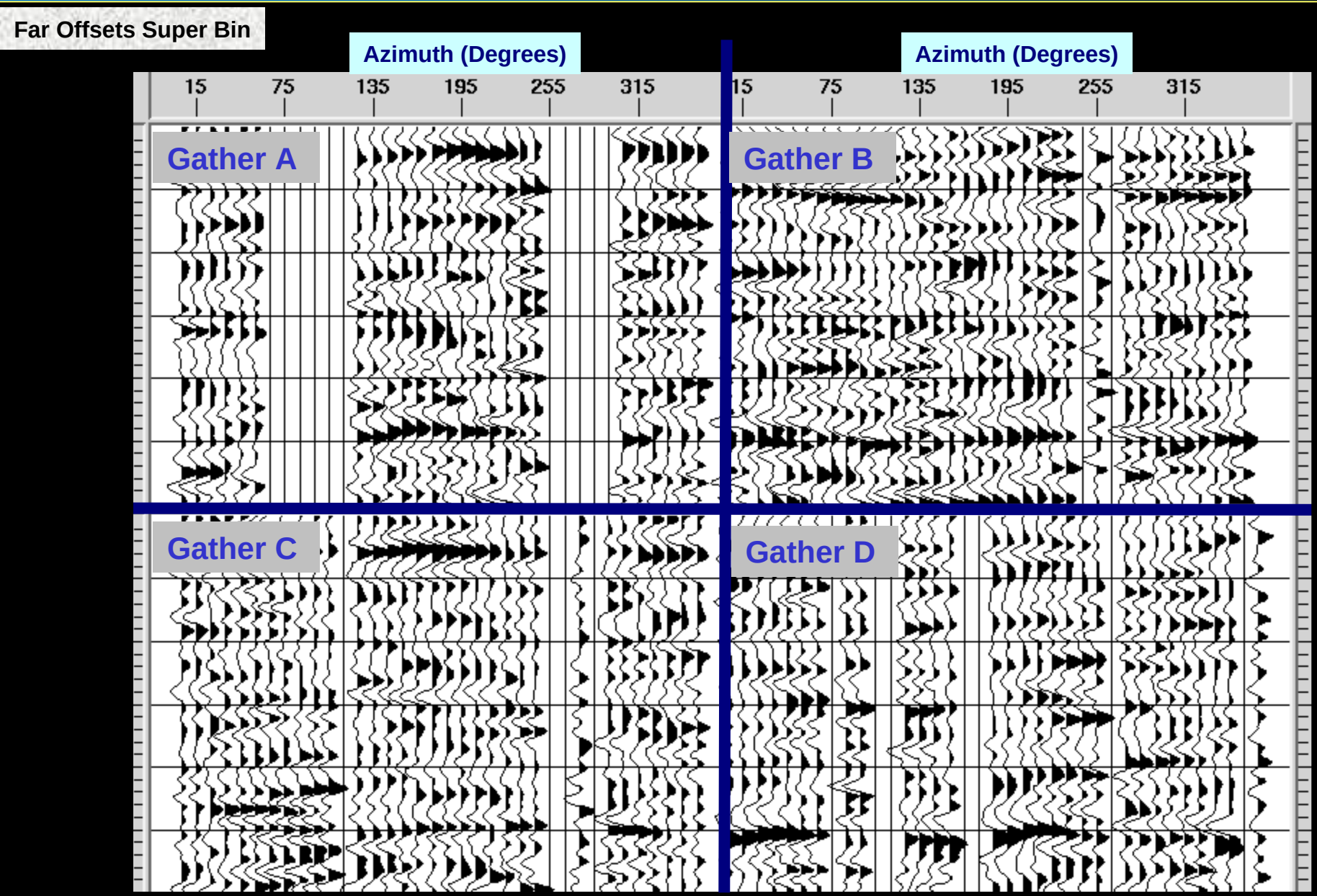


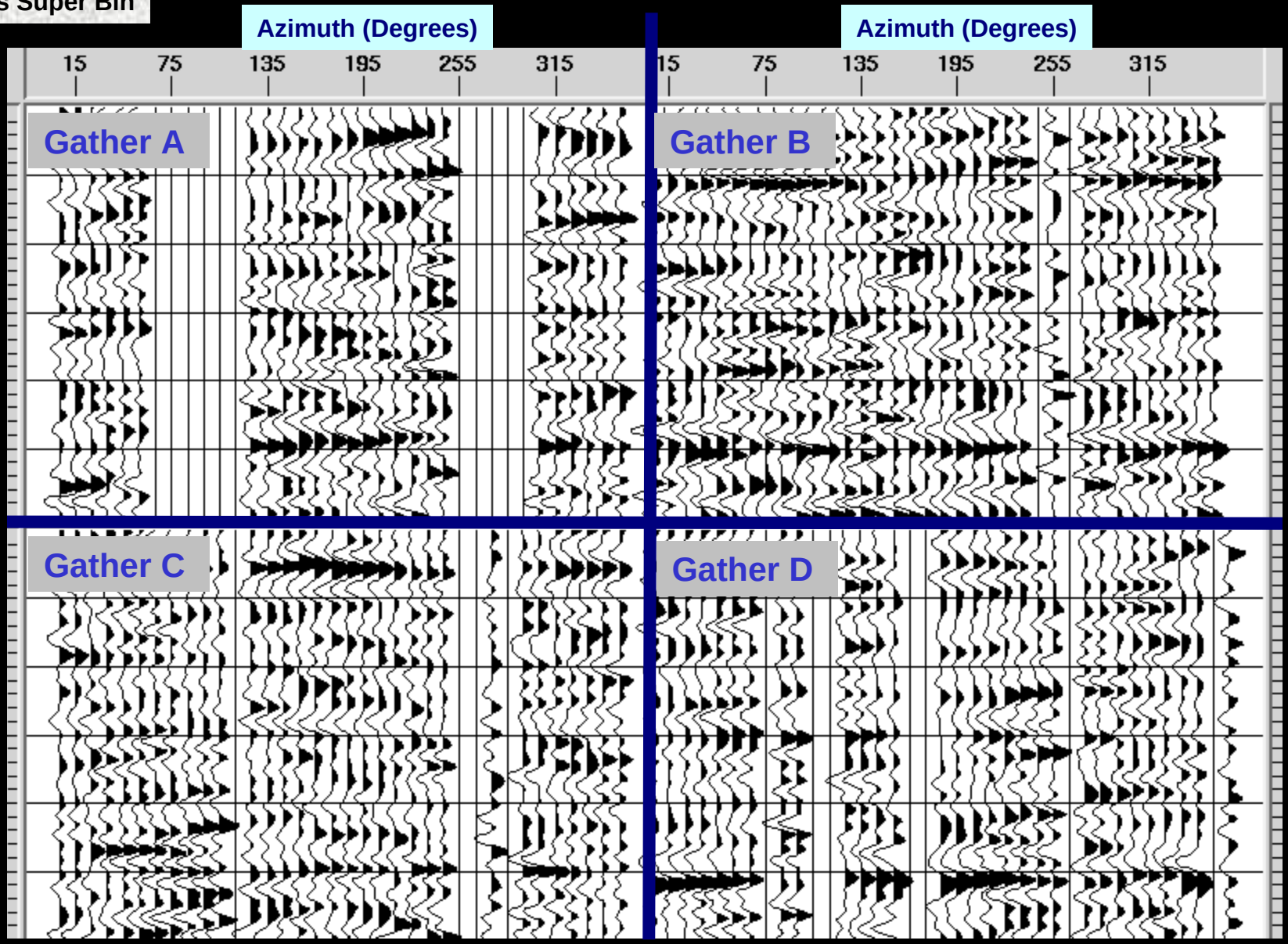
Far Offsets Azimuth Gathers – Isotropic NMO



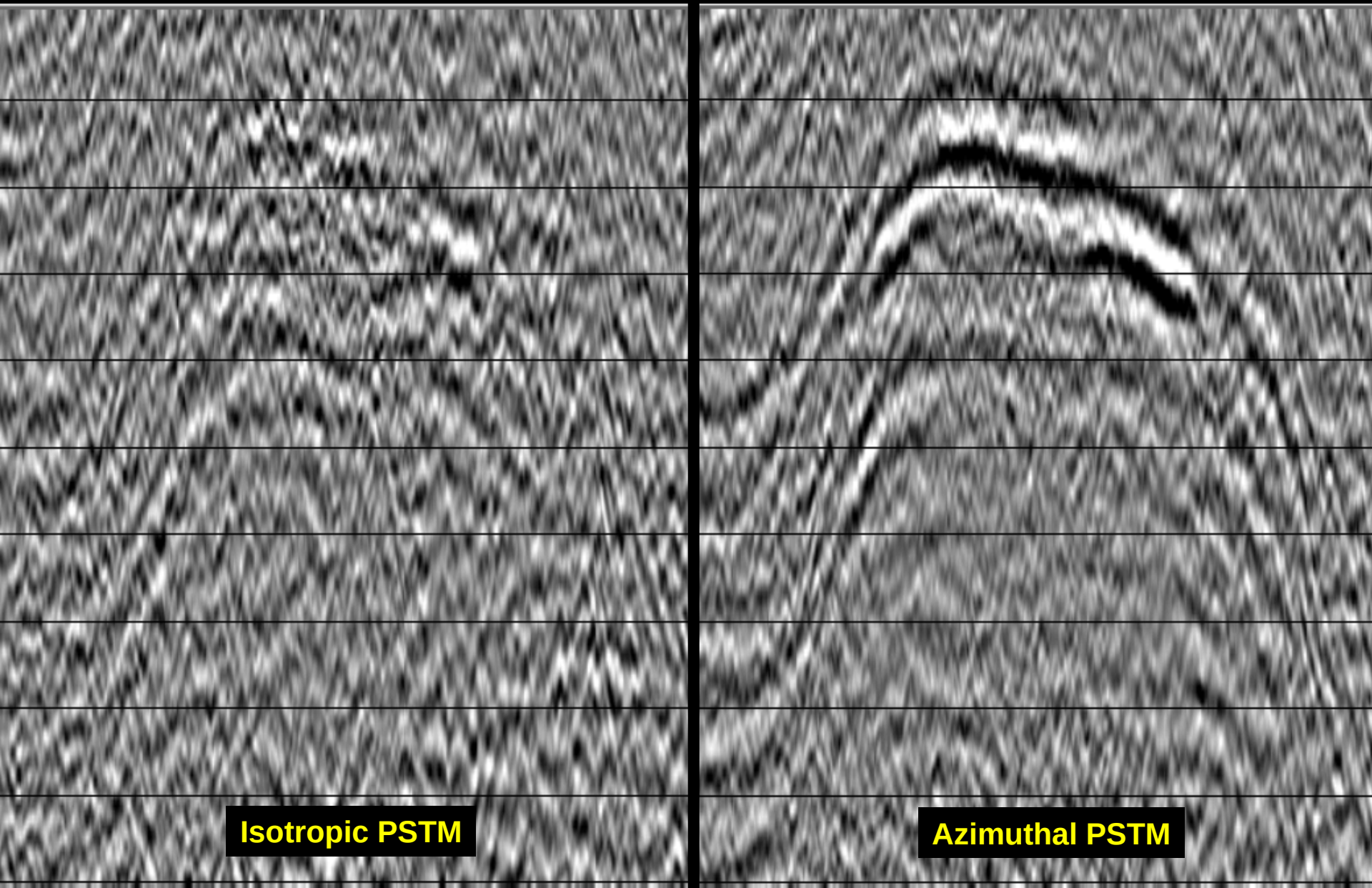
Far Offsets Azimuth Gathers – Azimuthal NMO

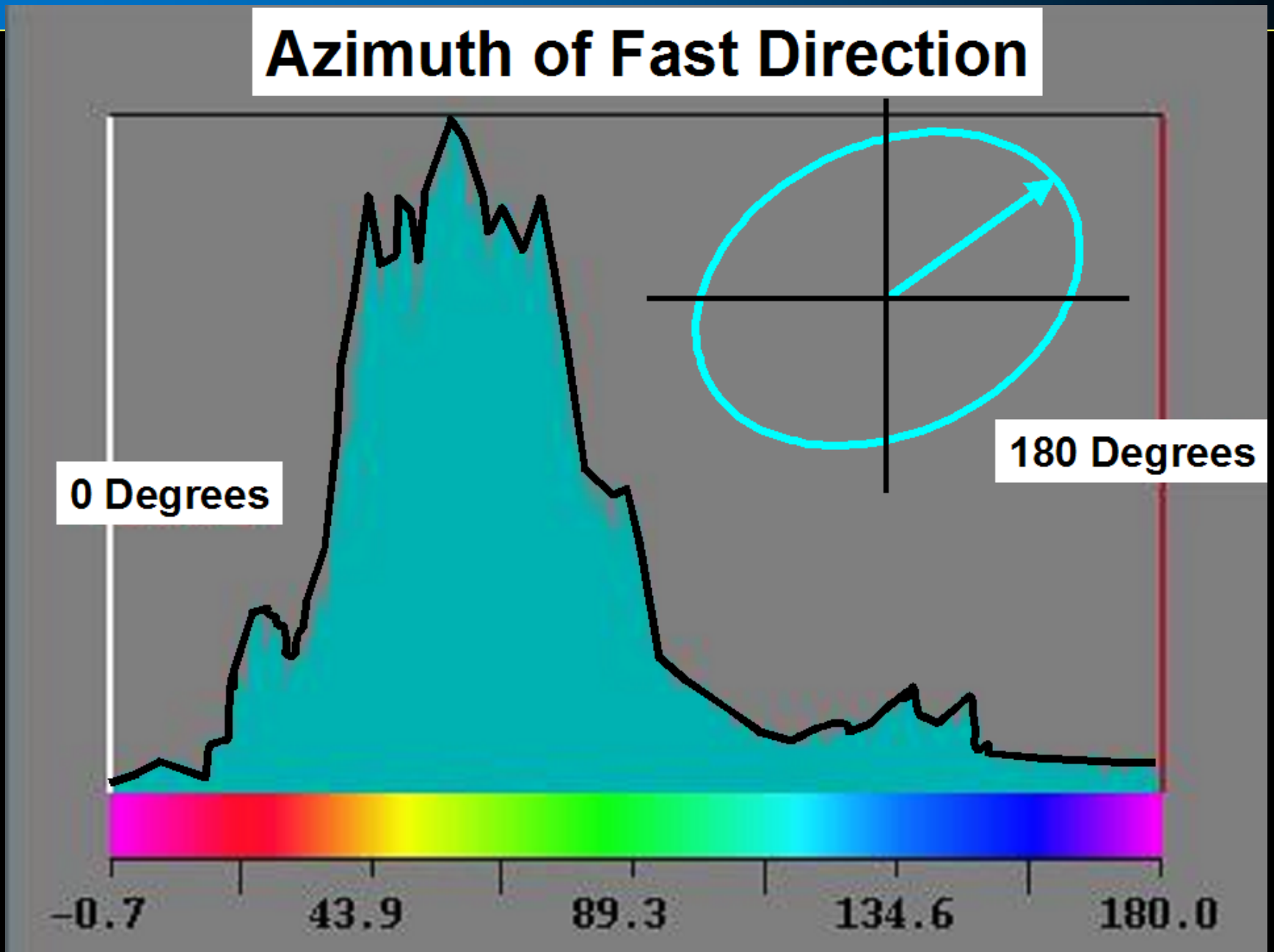
Quality Check on Derived Parameters

Far Offsets Super Bin



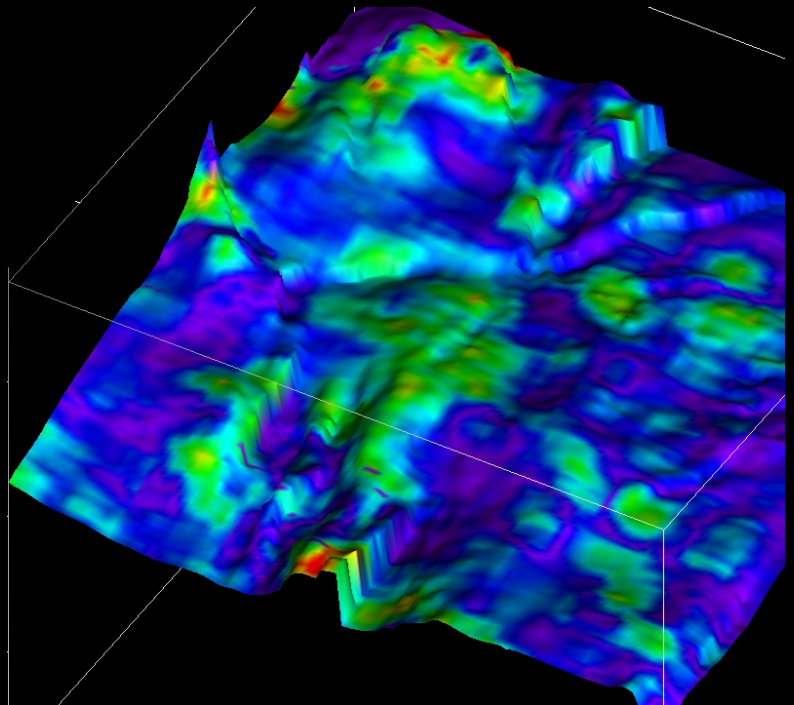
Far Stack Comparison
Isotropic Imaging versus Azimuthal Imaging



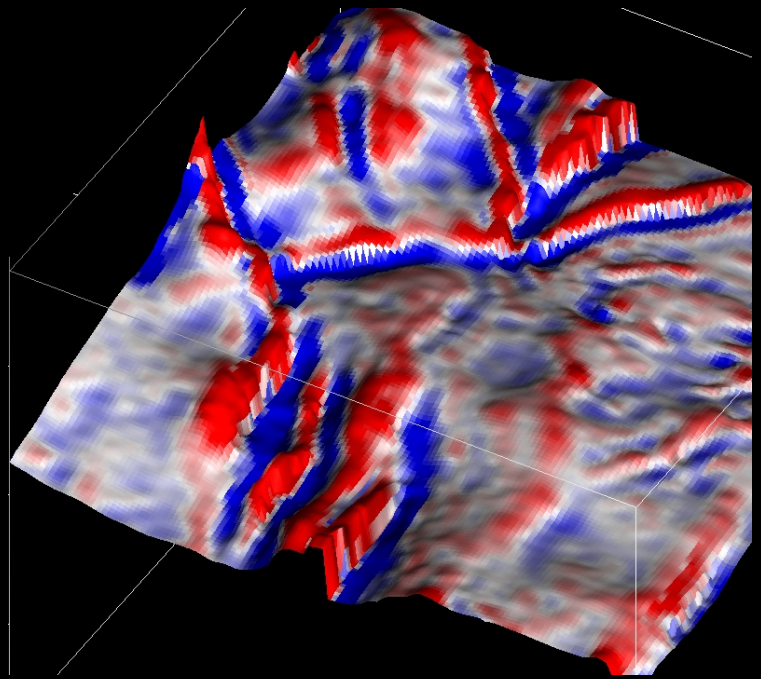

Azimuth of Fast Direction
0 Degrees
180 Degrees
-0.7
43.9
89.3
134.6
180.0

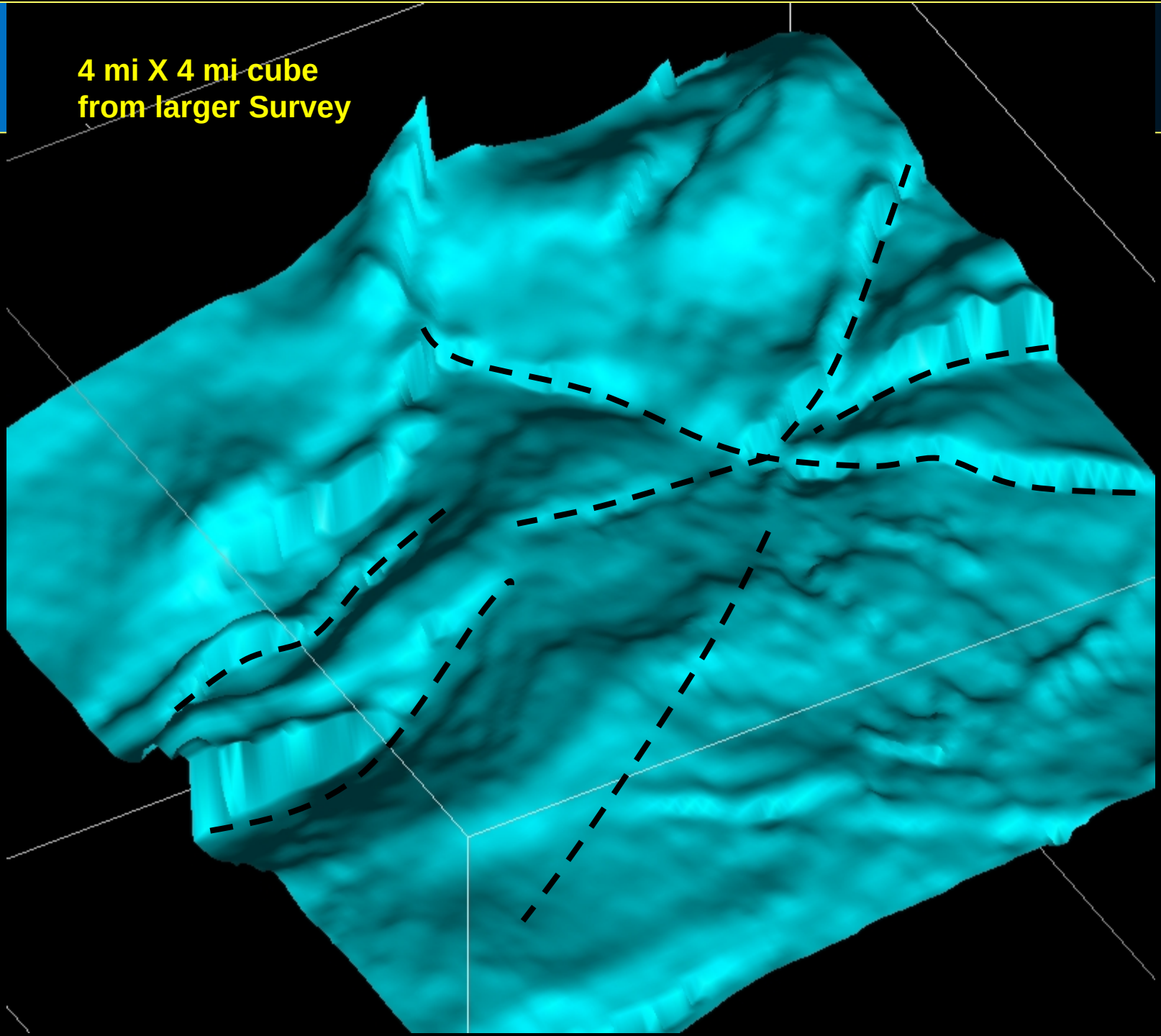
Complex Faulting
Carbonate Reservoir

Azimuthal Velocity Anomaly Volume

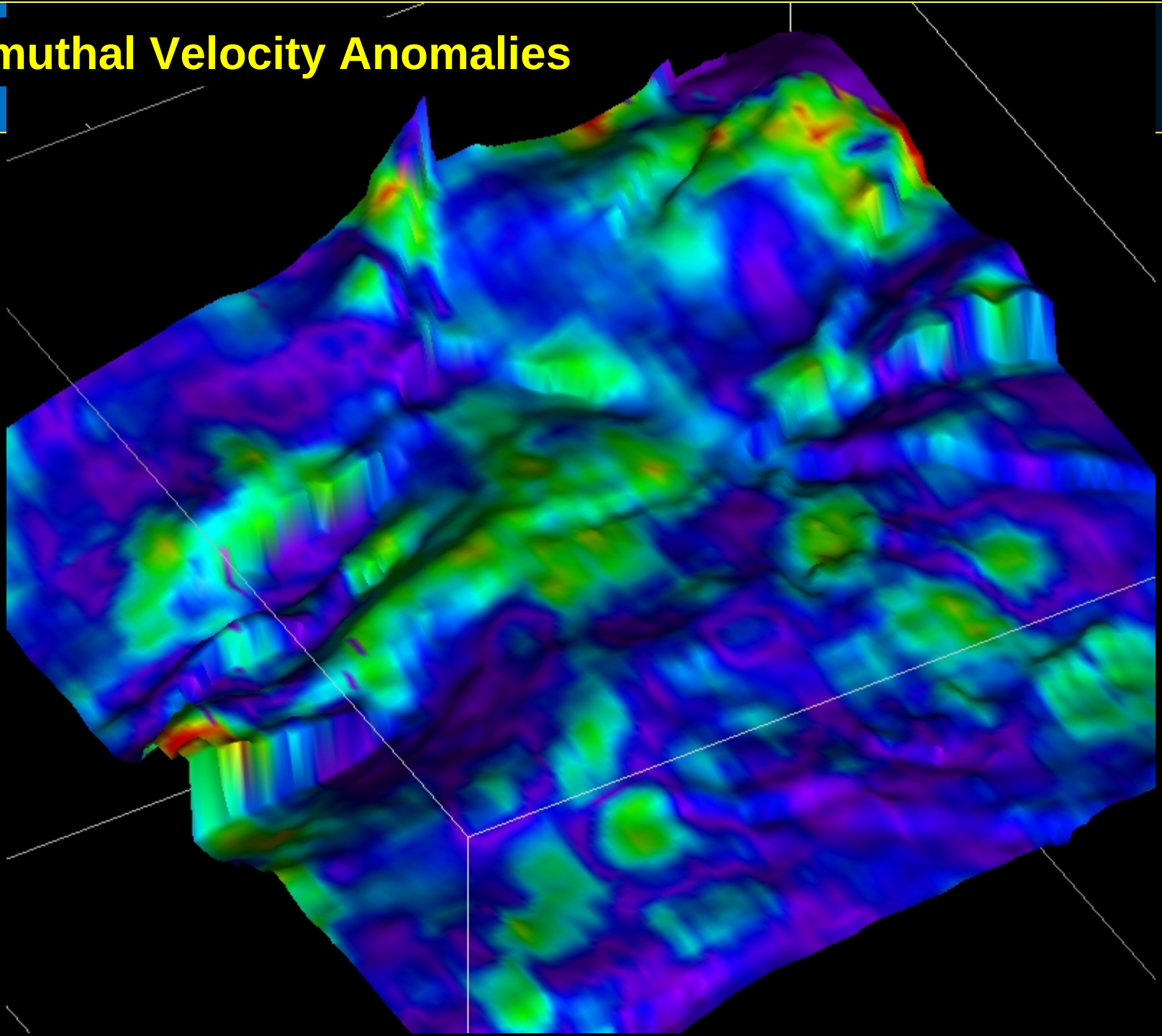


Curvature

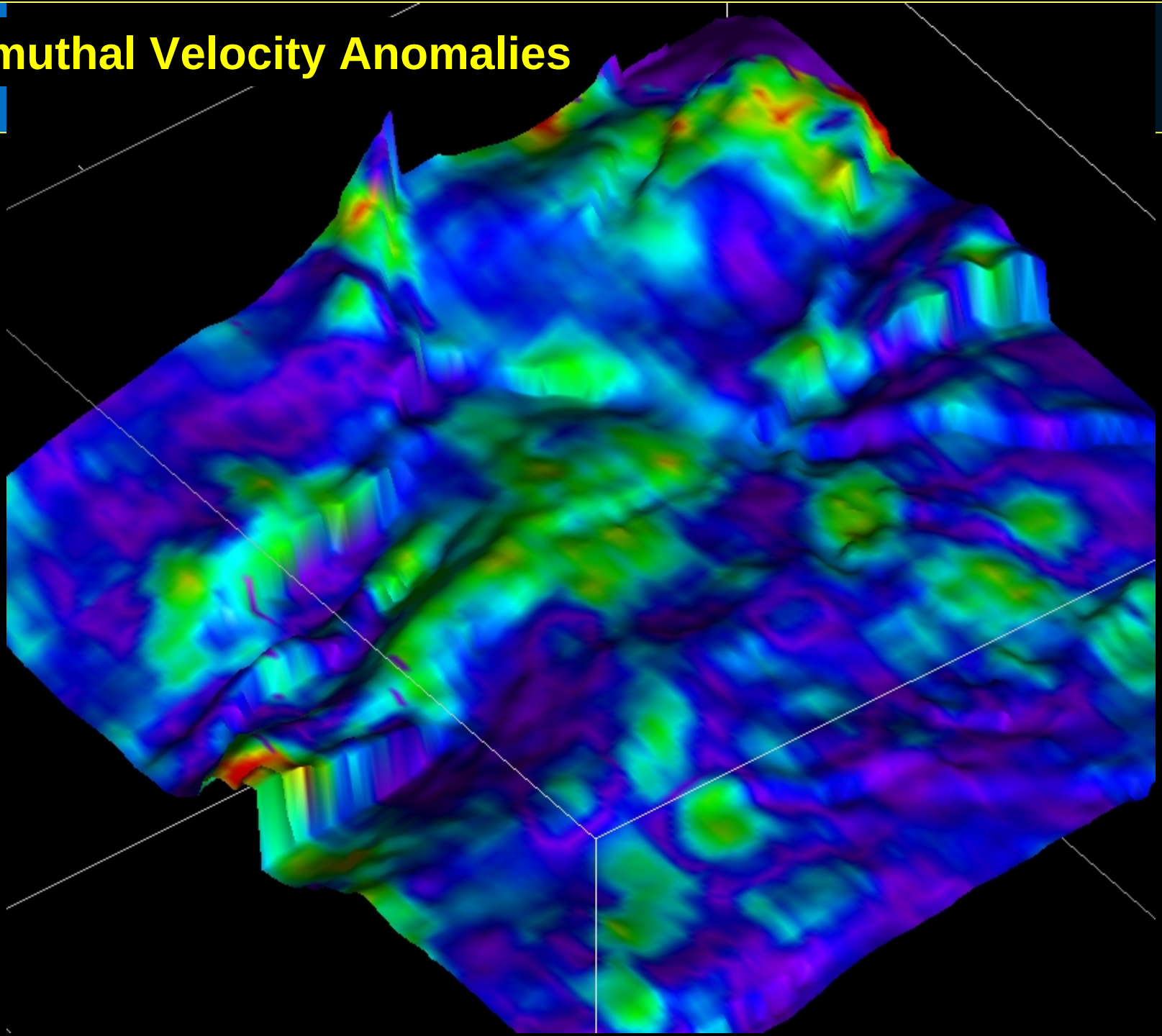



4 mi X 4 mi cube
from larger Survey

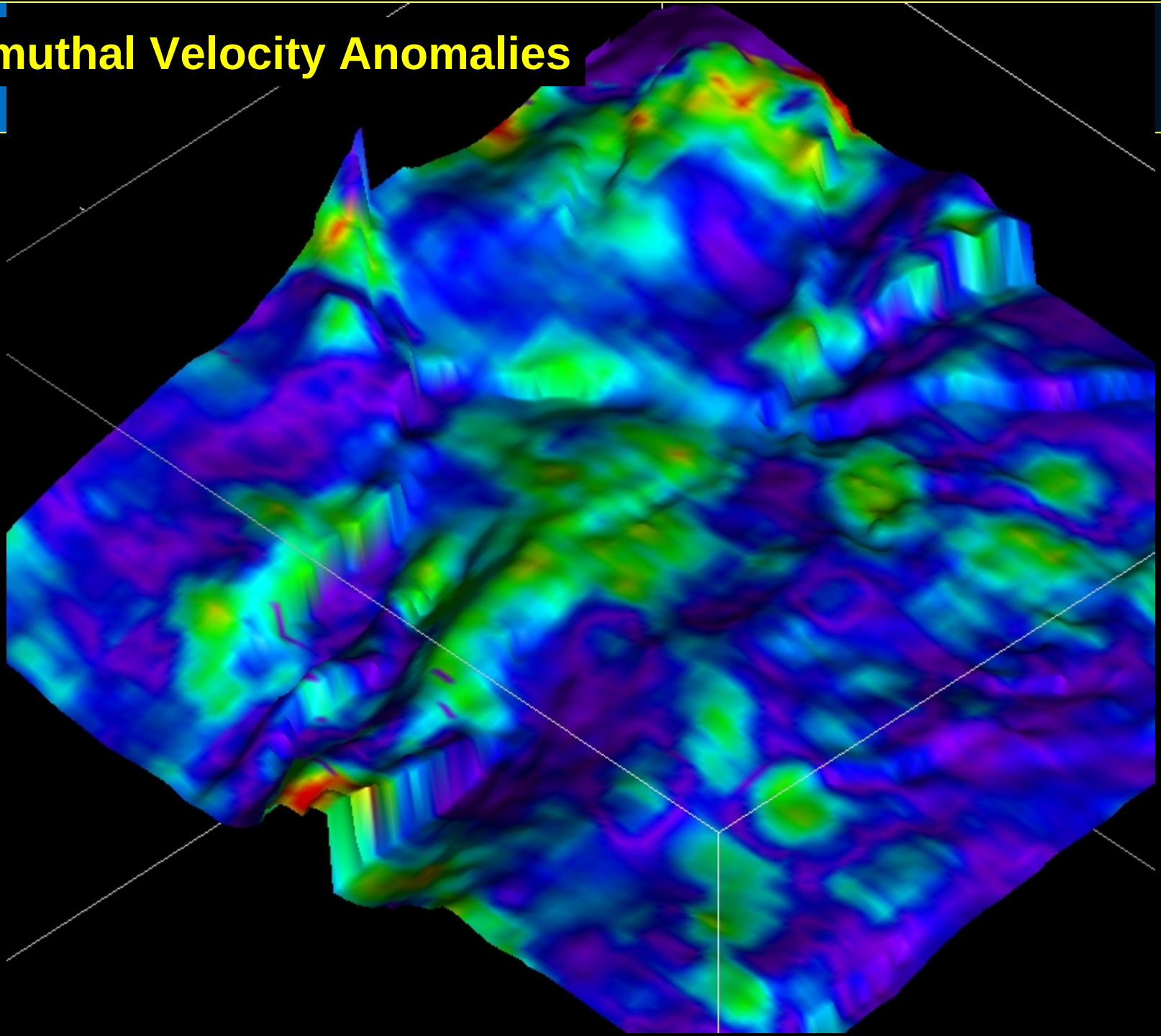
Azimuthal Velocity Anomalies



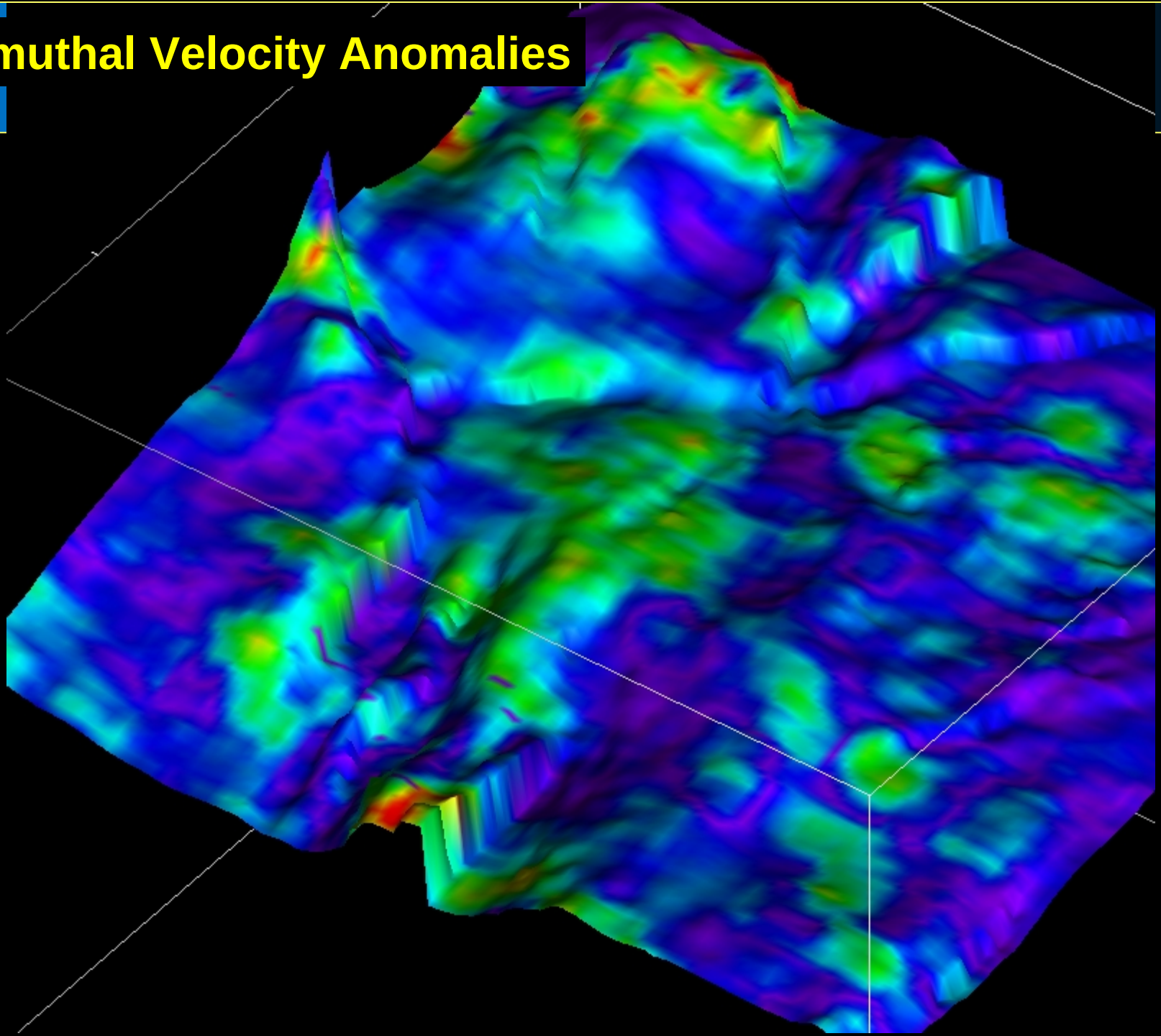
Azimuthal Velocity Anomalies

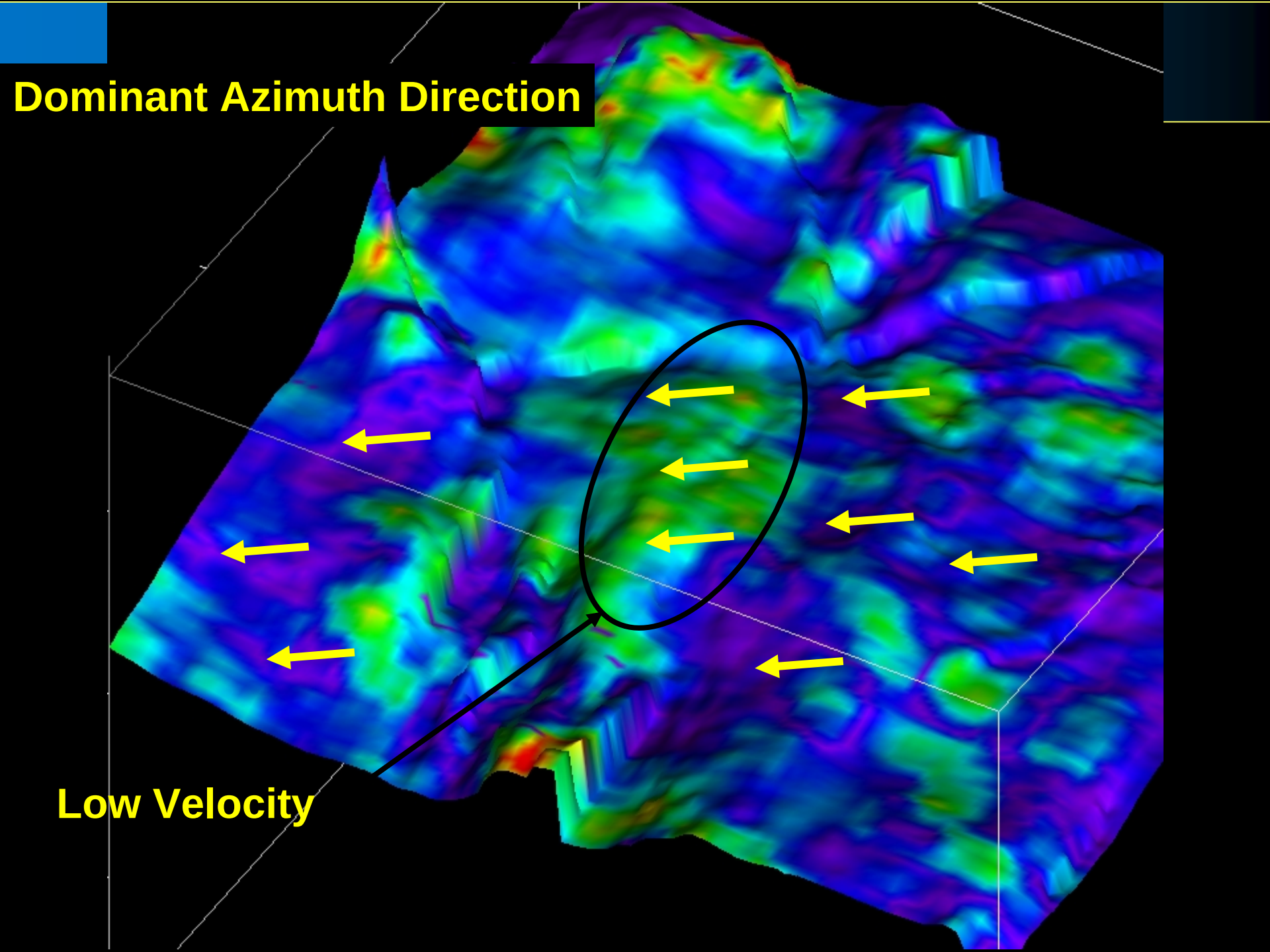


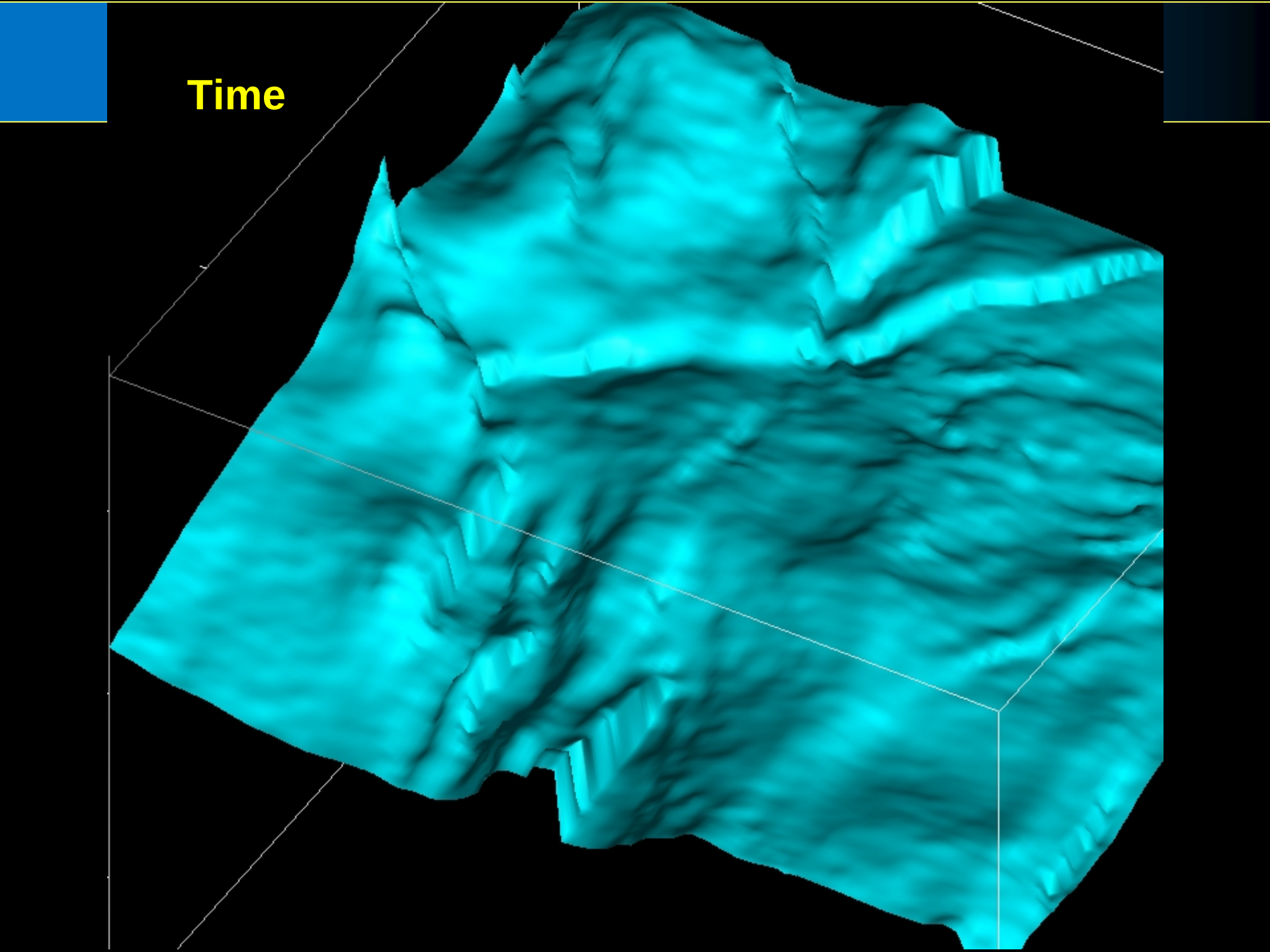
Azimuthal Velocity Anomalies



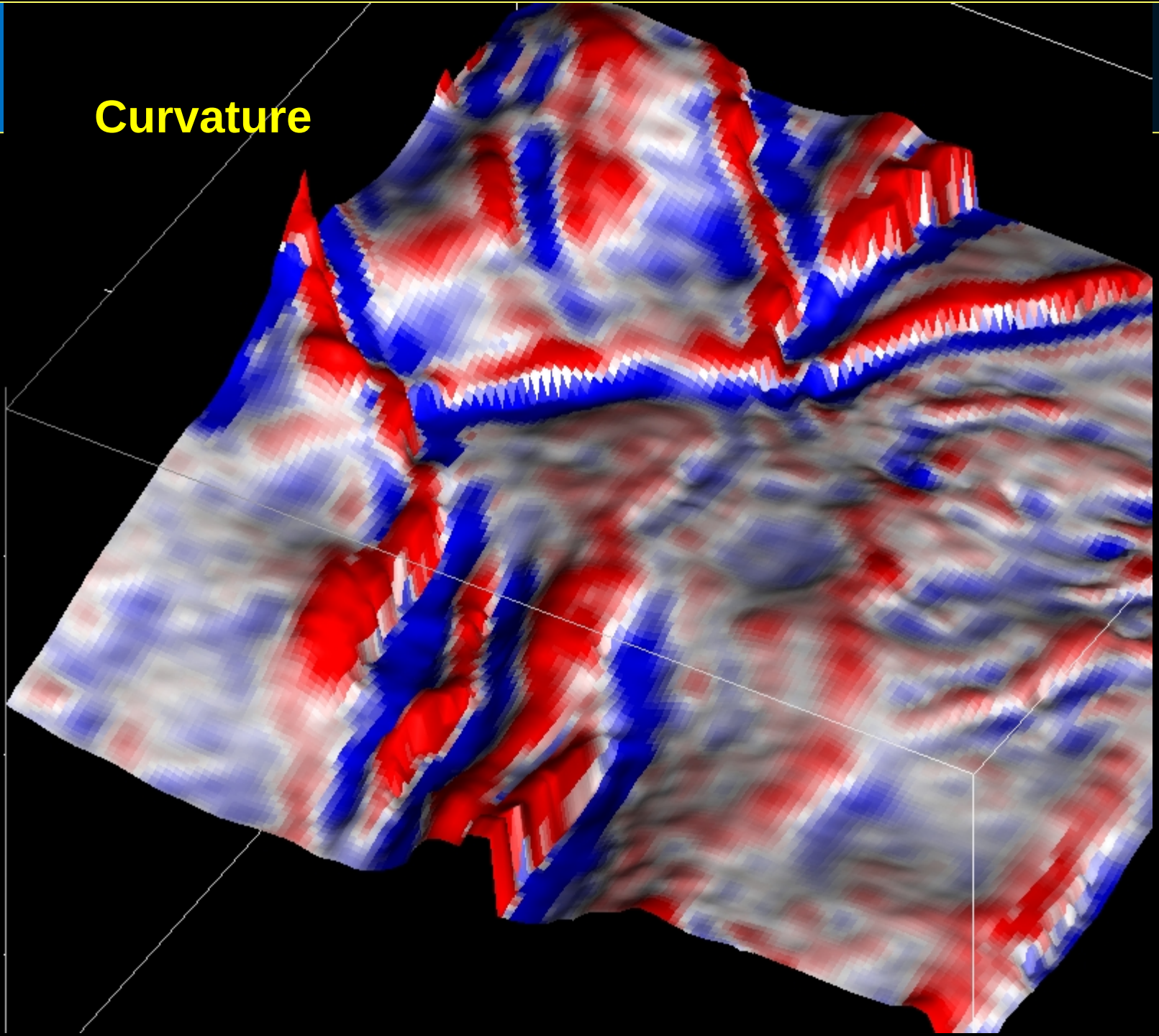
Azimuthal Velocity Anomalies




Dominant Azimuth Direction
Low Velocity


Time

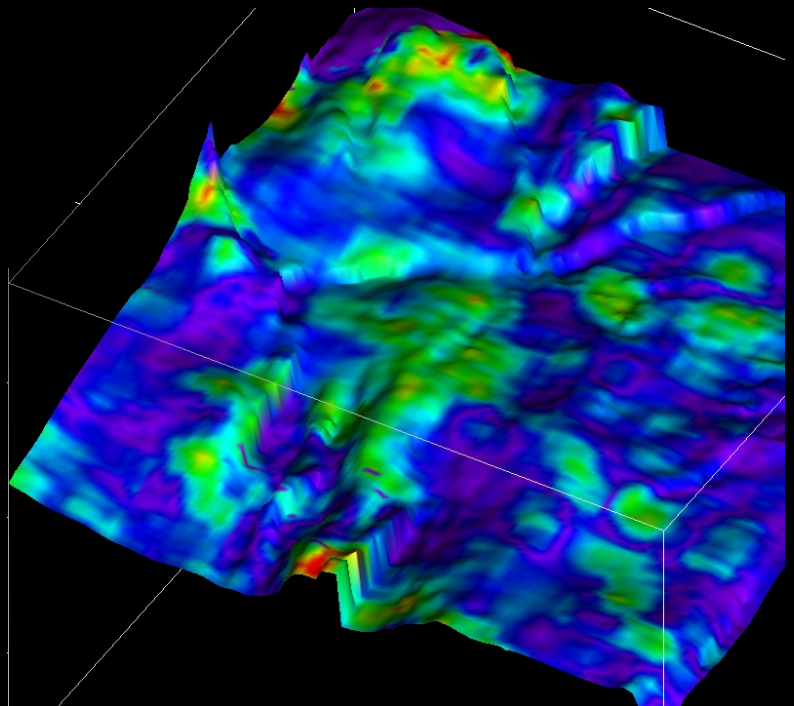
Curvature

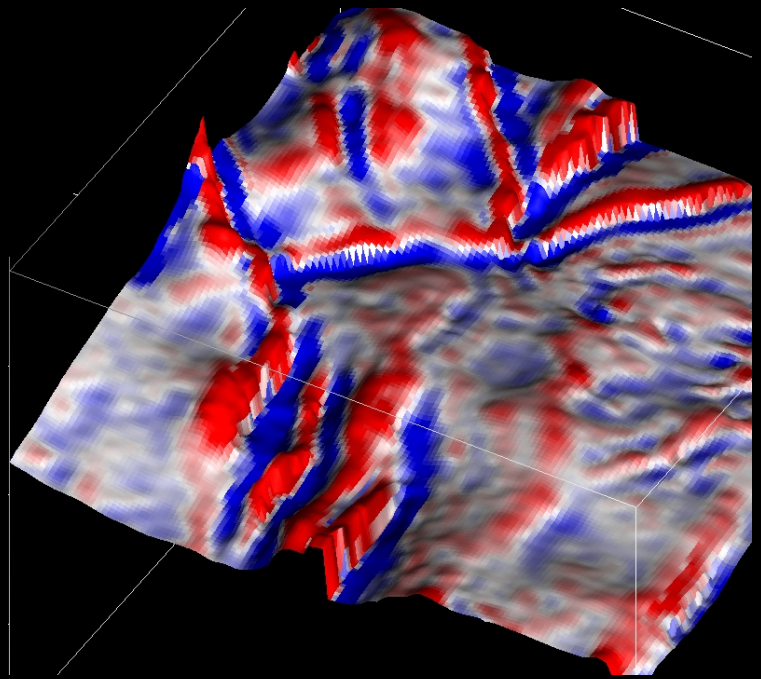


Complex Faulting Carbonate Reservoir

Azimuthal Results:

- **Minimal Imaging Impact**
- **Azimuthal Anomalies agree with some low velocity zones**
- **Azimuth Direction showed agreement with regional stress field**
- **Better anomalies don’t correlate with Curvature results**





Azimuthal Processing - Conclusions

- **Imaging Improvement ?**
  - **No difference→Huge Difference**
- **Fracture and Stress Field Prediction**
  - **Barnett, Marcellus, Bakken, Woodford, Fayetteville, Haynesville**
  - **Fractured Carbonates and Sandstones**
- **Future**
  - **Integration of Azimuthal Cubes into Reservoir Simulation**
  - **Simultaneous Inversion for VTI and HTI**
  - **Depth Migration and Azimuthal Analysis**

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Thanks!

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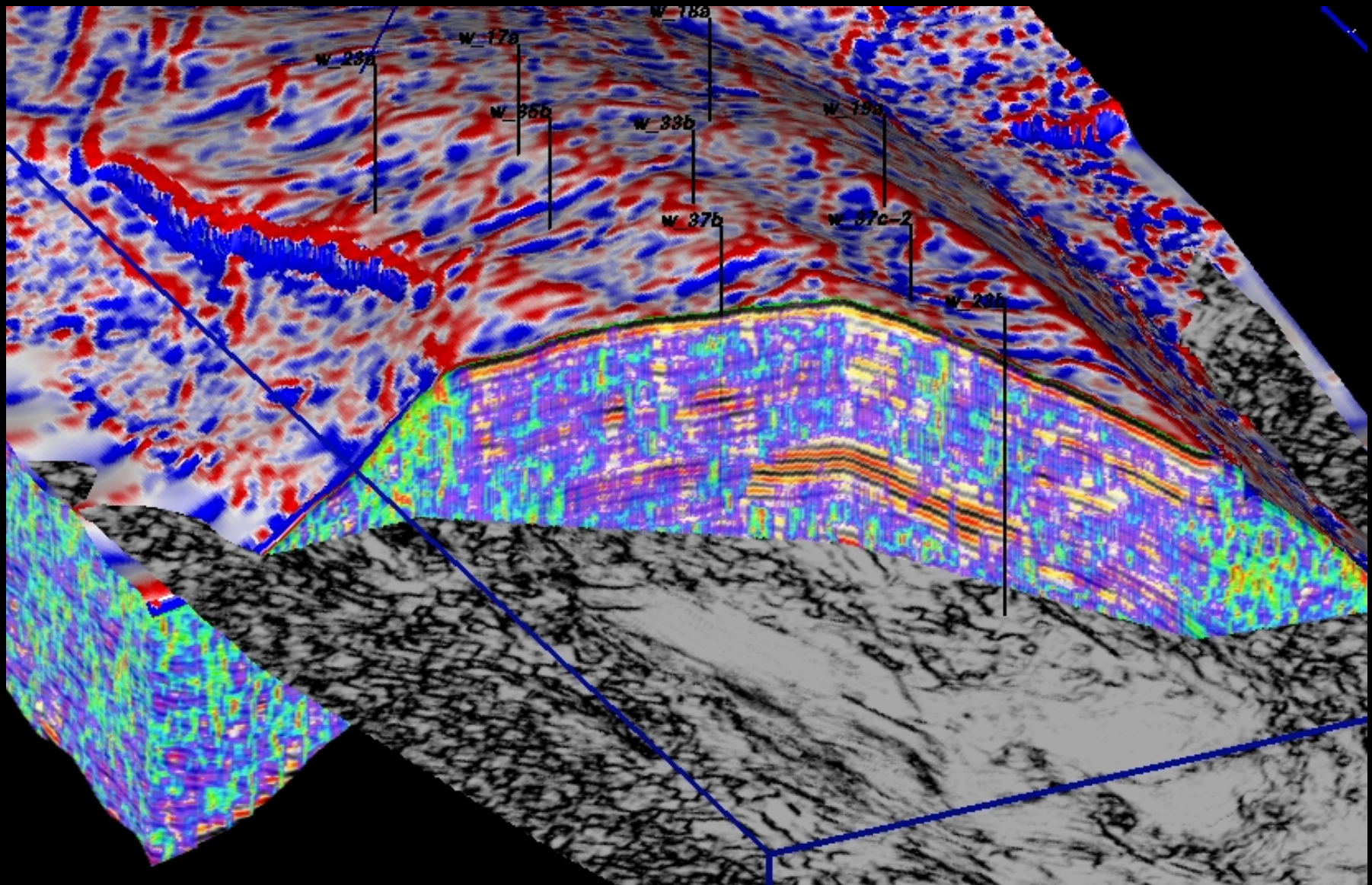
GeoScience



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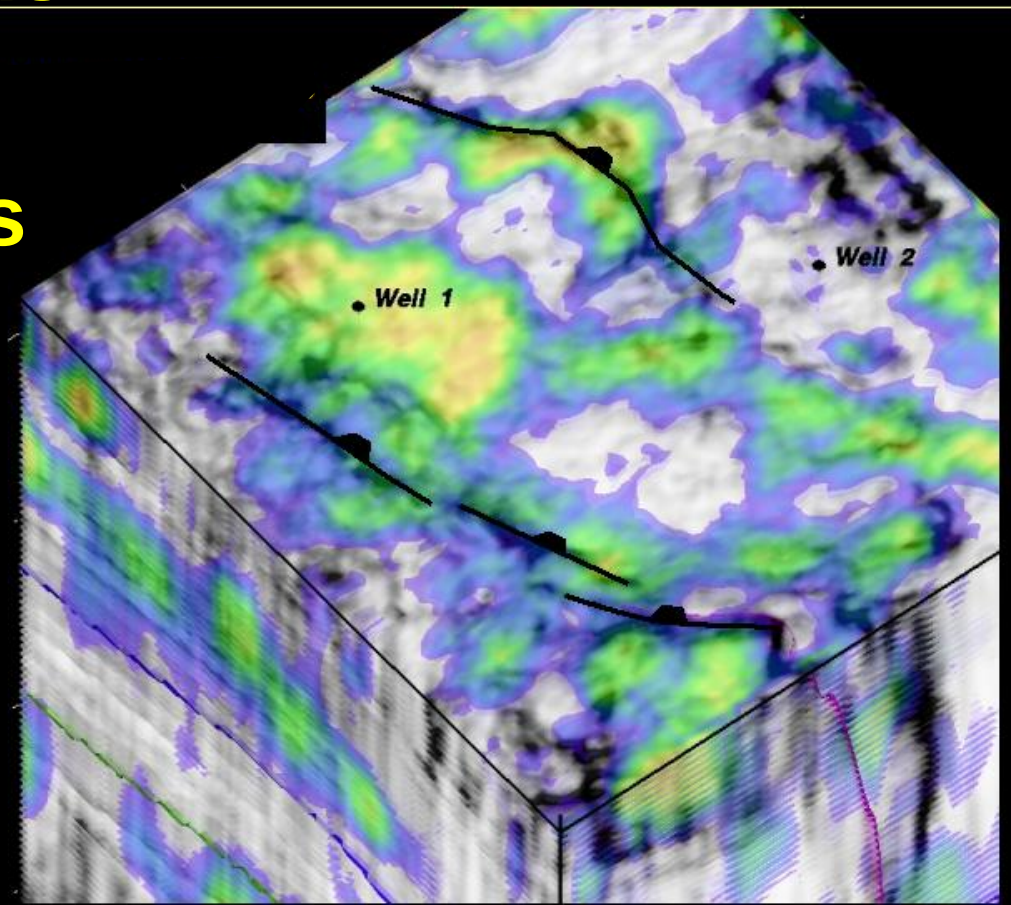

Seismic Based Fracture Prediction Technologies

- Multi-Component – Shear Wave Splitting
- Azimuthal Analysis
  - Pre-Migration Azimuthal Analysis
  - Migration based Azimuthal Velocity Analysis
    - Option 1 – Sectored Azimuthal Migrations
      - Suffers from poor sampling
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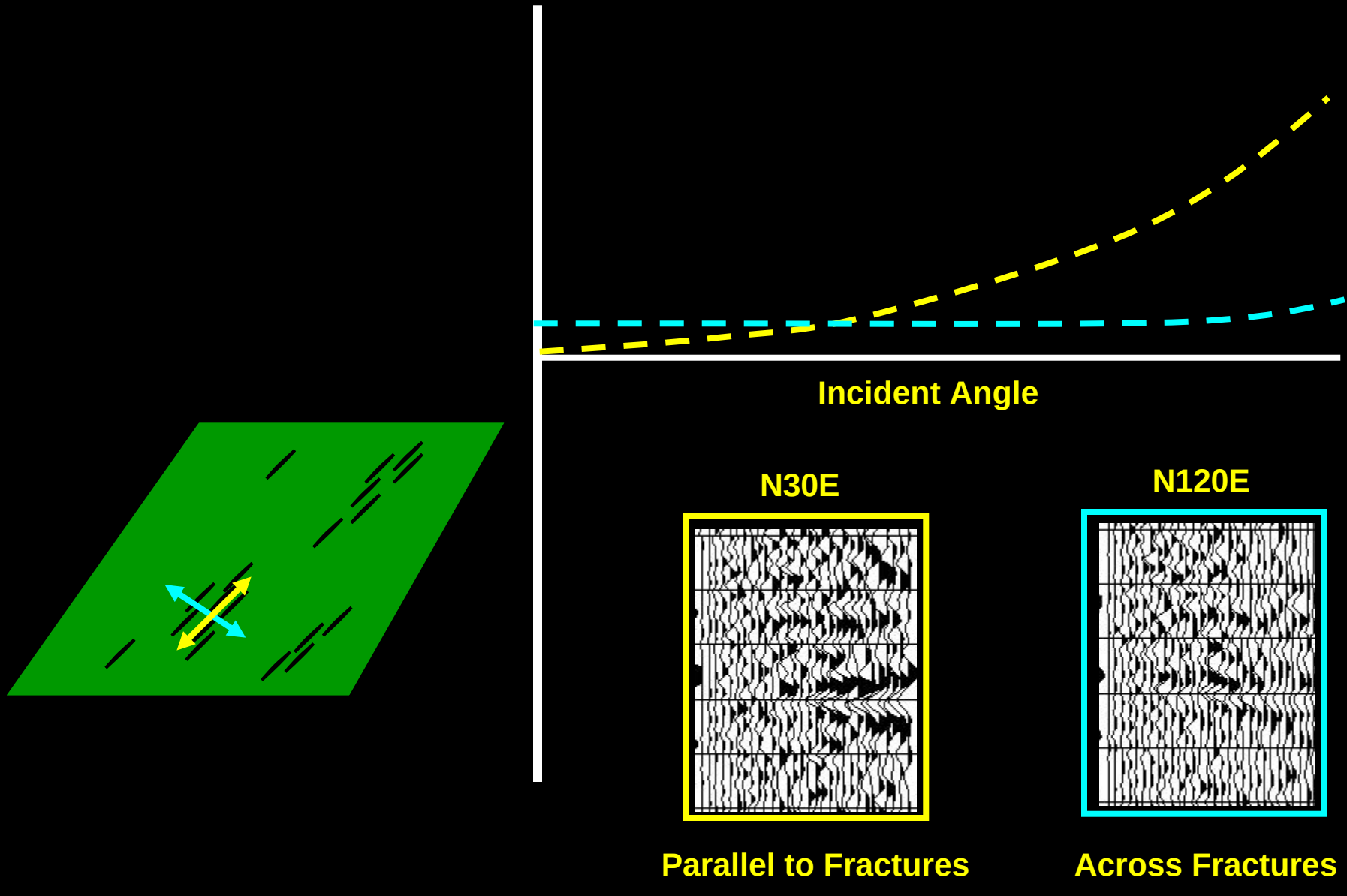
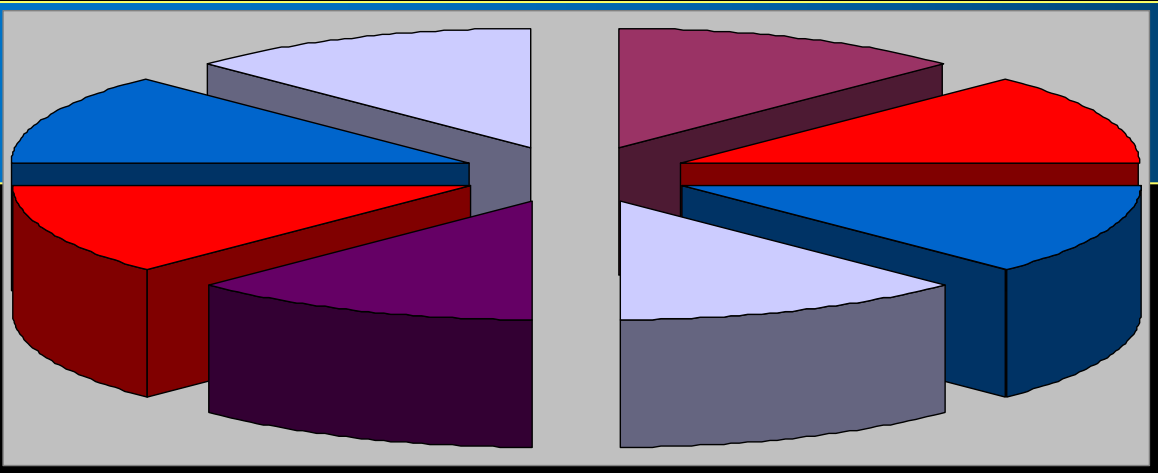
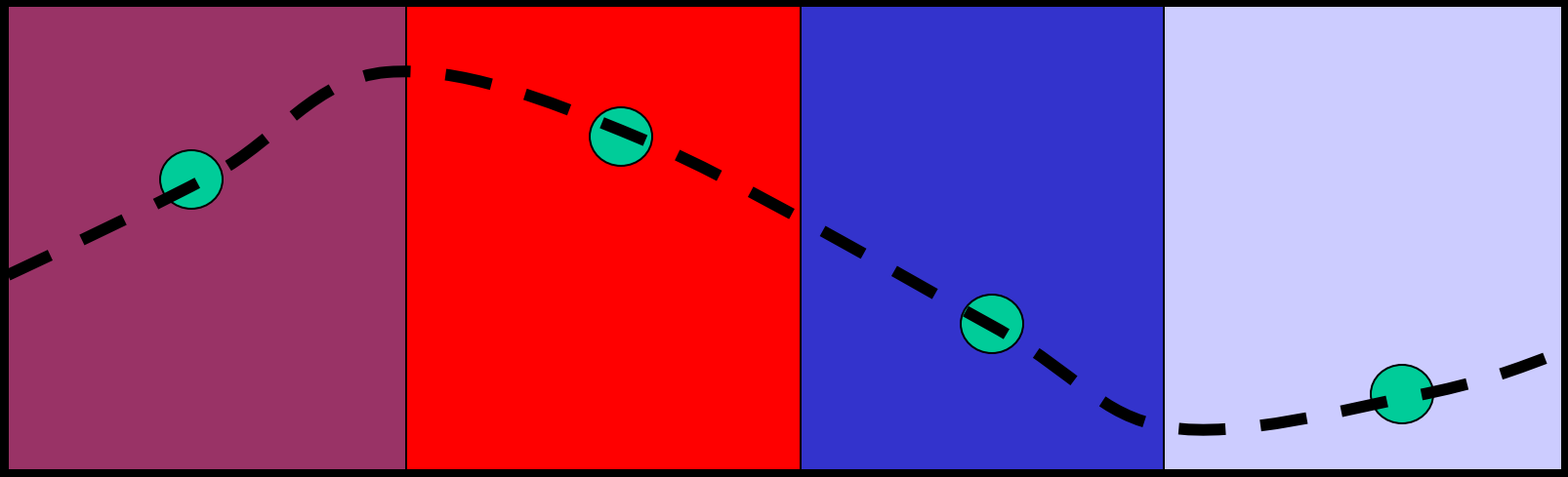
Azimuthal AVO





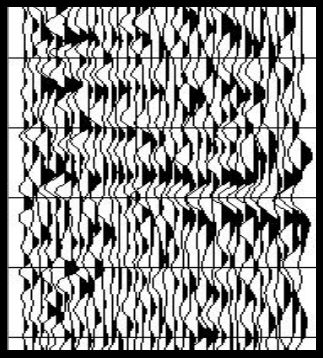


0

180

AVOA requires azimuth sectoring

Input Gathers

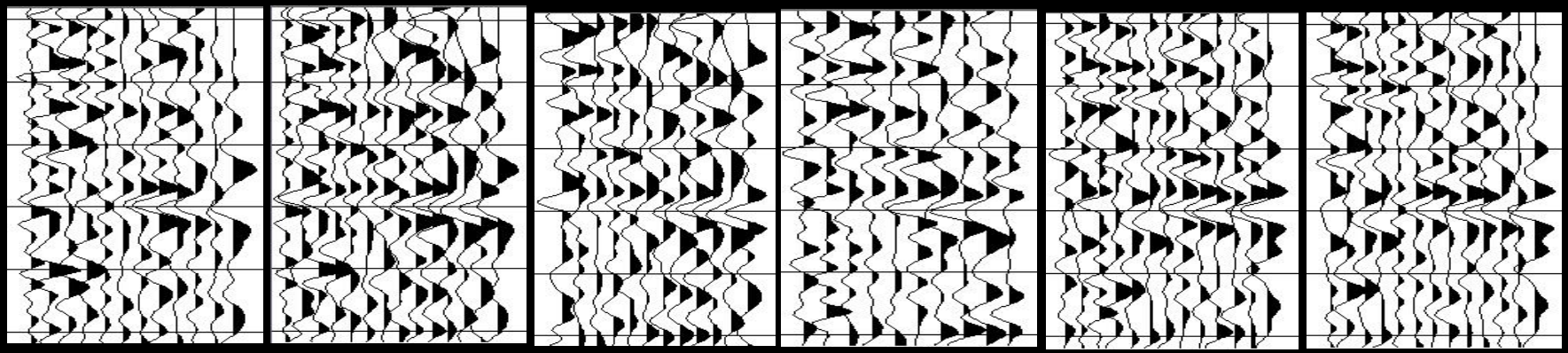


All Azimuths
In Gather

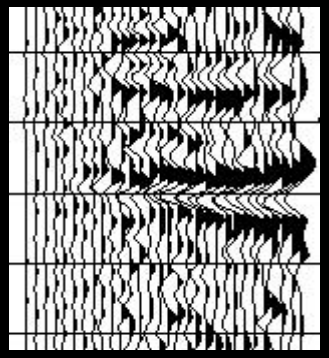
- CDP Gathers are Very Noisy – Sorting into Azimuth Ranges Makes the Analysis Very Difficult

Input Gathers for Azimuth Sort Ranges

30 60 90 120 150 180



Azimuthally Imaged Gathers

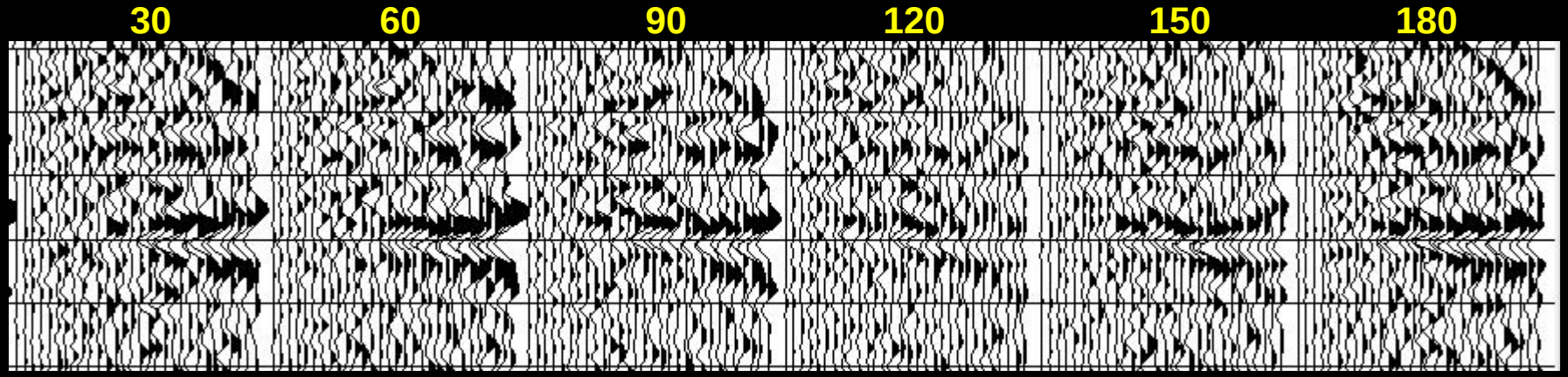


All Azimuths Imaged

Pre-Stack Azimuthal Imaging

- **Improves the Signal to Noise by a Factor of 10 or more**
- **Yields A Very Strong Signal for Velocity and AVO Analysis**

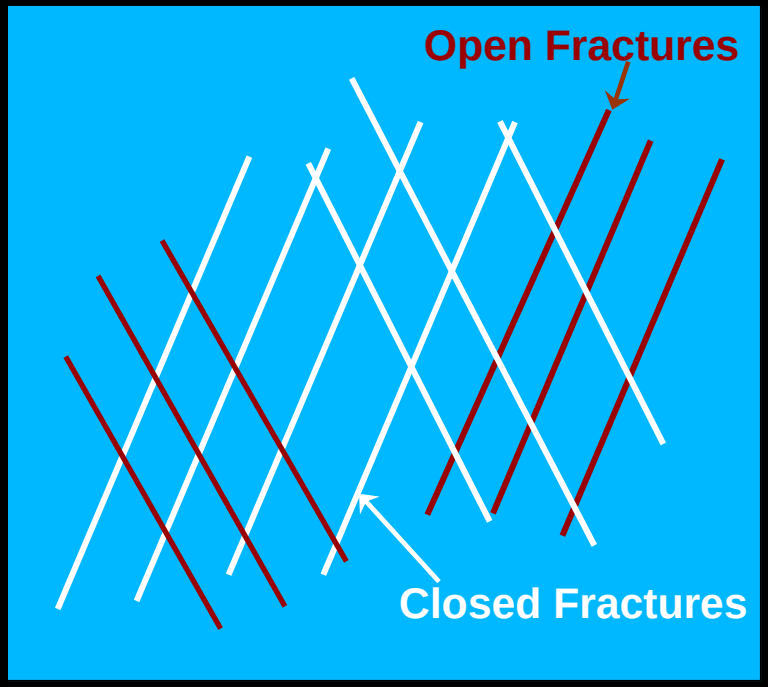
Imaged Gathers – Az (Degrees)



In Line With Fracture Direction

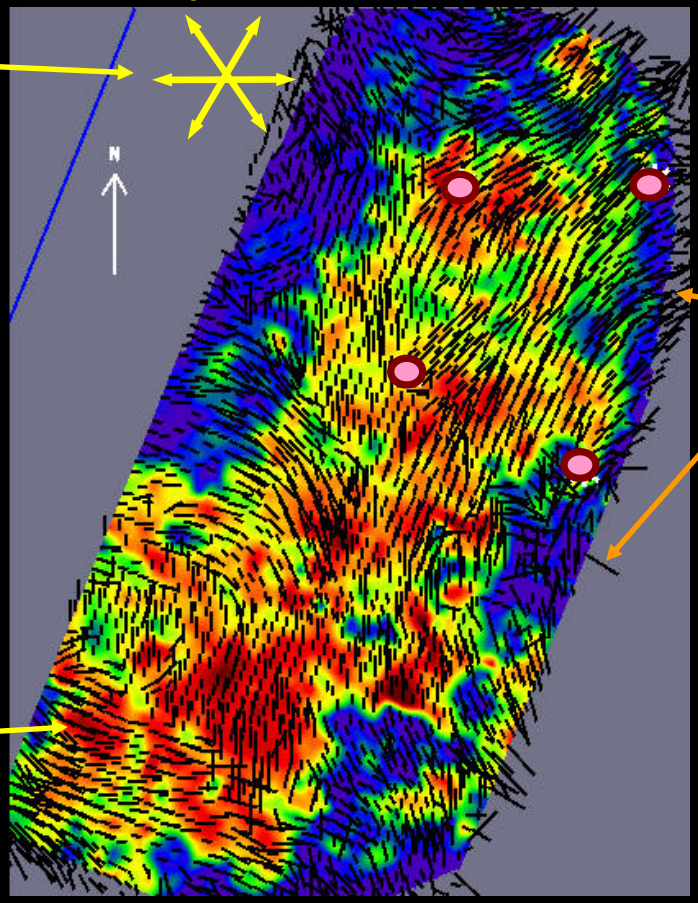
Cross Fracture Direction

Fracture Sets – Open Direction



- The Fractures Will Normally be Open in Only One of The Directions

PreStack Fracture Map –
All Azimuth AVO Analysis



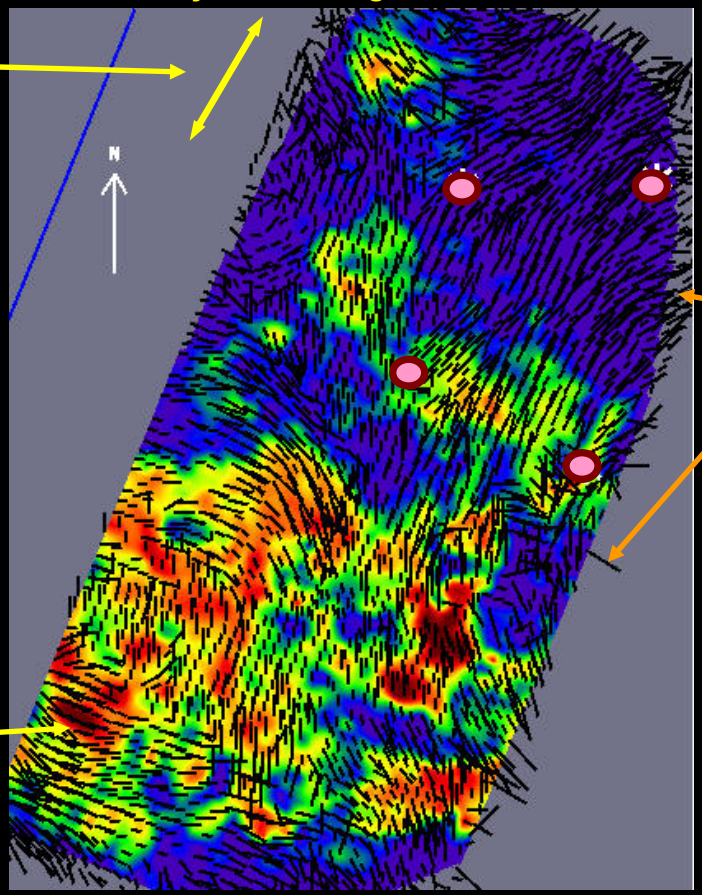
All Azimuth Analysis

Vectors:
Velocity Direction and Magnitude Auto-Picked in PSTM Azimuthal Analysis

Grid:
- Fracture Intensity Attribute From AVO Analysis

PreStack Fracture Map –
30 Degree Azimuth AVO Analysis

Direction Vectors From Azimuthal Analysis Correspond to Directional AVO



PreStack Fracture Map –
150 Degree Azimuth AVO Analysis

Direction Vectors From Azimuthal Analysis Correspond to Directional AVO