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CREWES

South Komie 3D Seismic Analysis of Fractured Reservoirs

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NSERC CRSNG

Motivation

Information related to ***fracture intensity and orientation*** is vital for the development of unconventional reservoirs

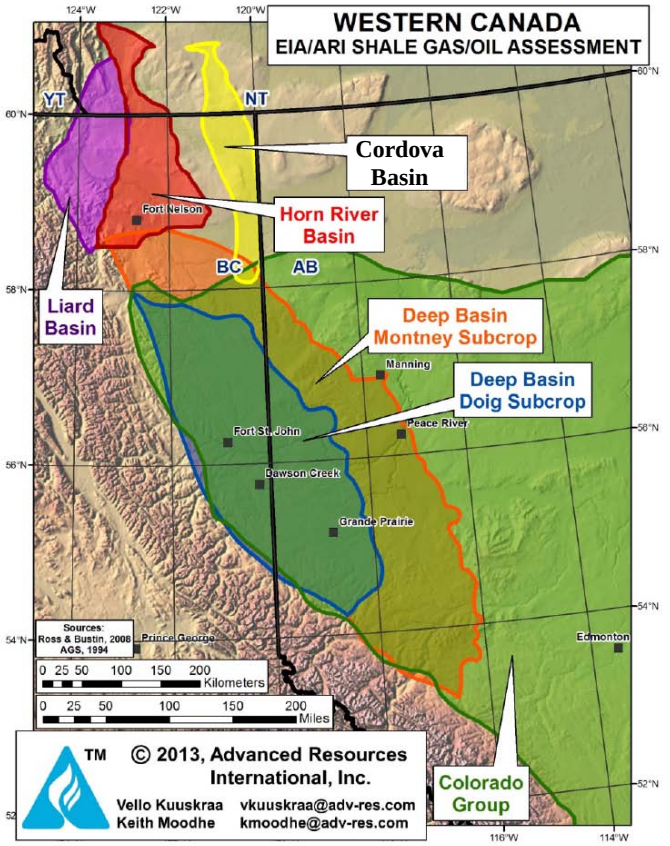
Outline

- Introduction
  - Horn-River Basin
  - Data acquisition & processing
- South Komie 3D data analysis
  - Post stack inversion
  - Post-stack attributes
  - Pre-stack COCA
  - Pre-stack AVO and AVAZ
- Conclusions

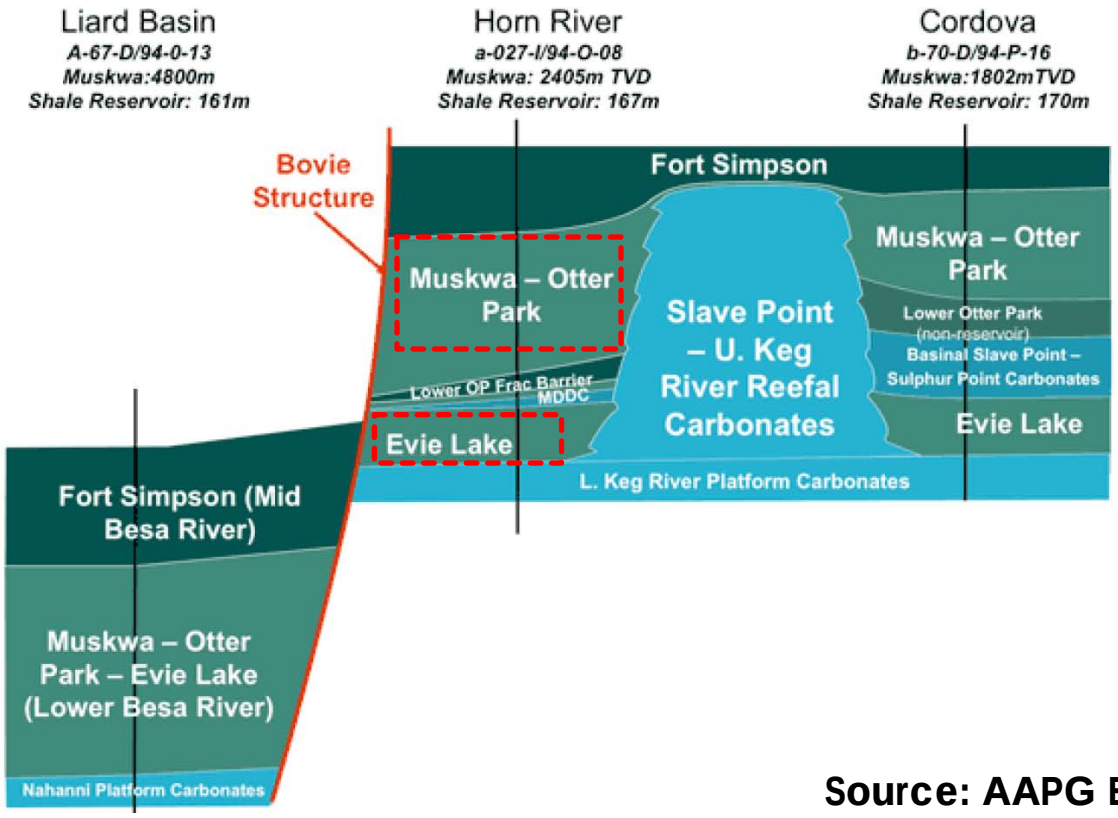
Horn River Basin

- **Location: Northeast BC & Southwest NT**
- **Area: 18,000 km^2**
  Producing well: 200 (Feb 2014)
- **OGIP: 500 Tcf**

Compare to: Cordova: 200 Tcf;
Montney: 2000 Tcf



Stratigraphy

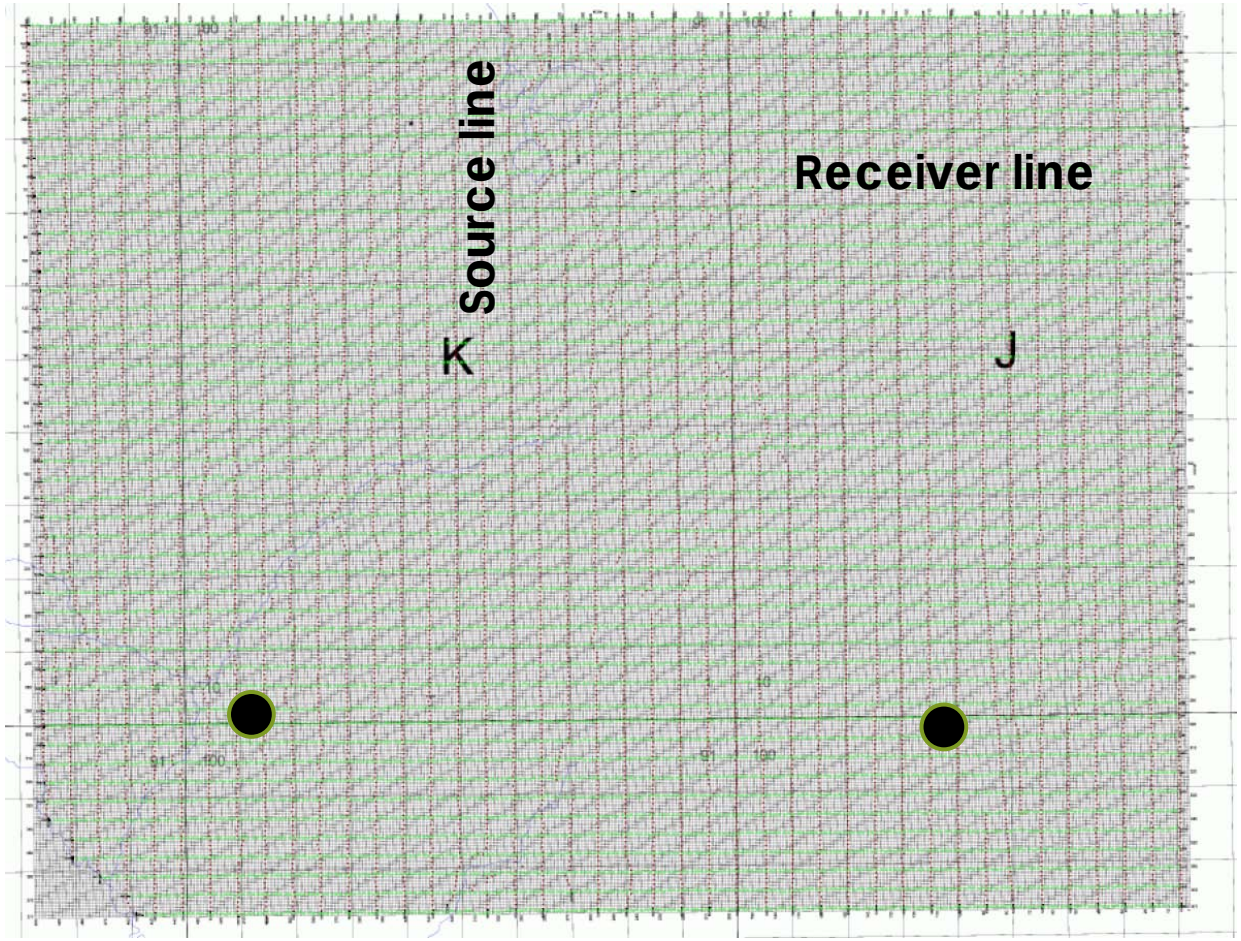


Source: AAPG Explorer, Horn River Basin Keeping Canada Hot

Data Acquisition

- **Acquisition data: 12-29 March 2009**
- **Source: Dynamite (single hole)**
  2 kg at 15 m depth
- **Receiver: single 3-C**
- **Sample interval: 2 ms**
- **Source interval: 60 m Receiver interval: 60 m**
- **Source Line orientation: N-S**
- **Source Line spacing: 360 m**
- **Receiver line orientation: E-W**
- **Receiver line spacing: 240 m**

Base Map



Data processing

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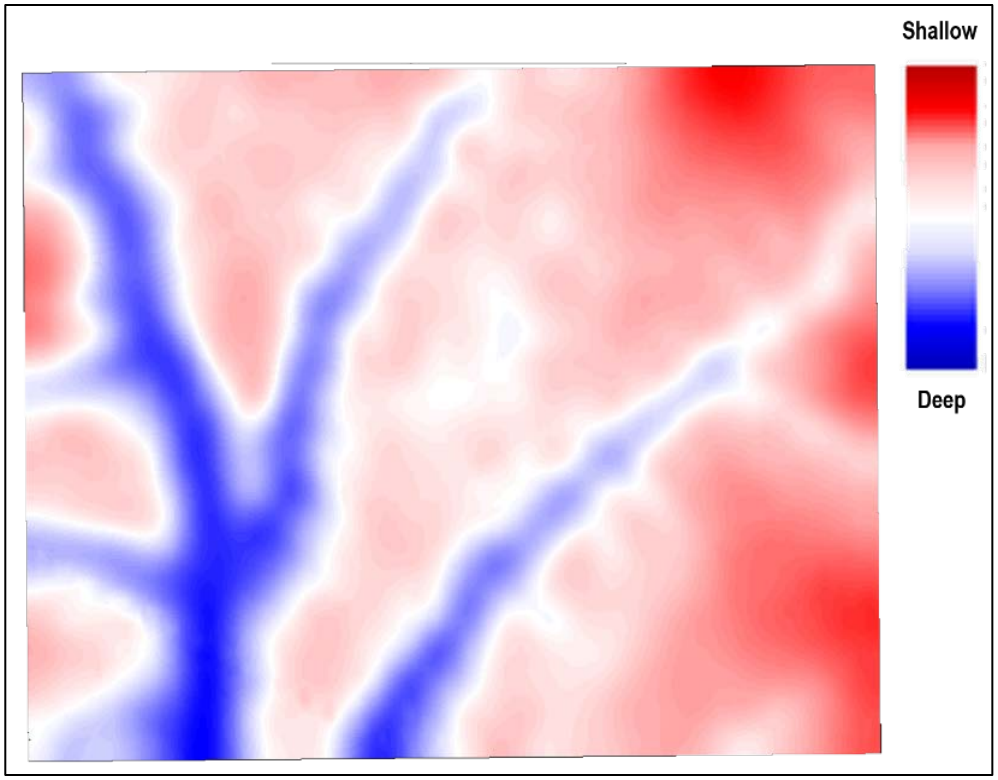
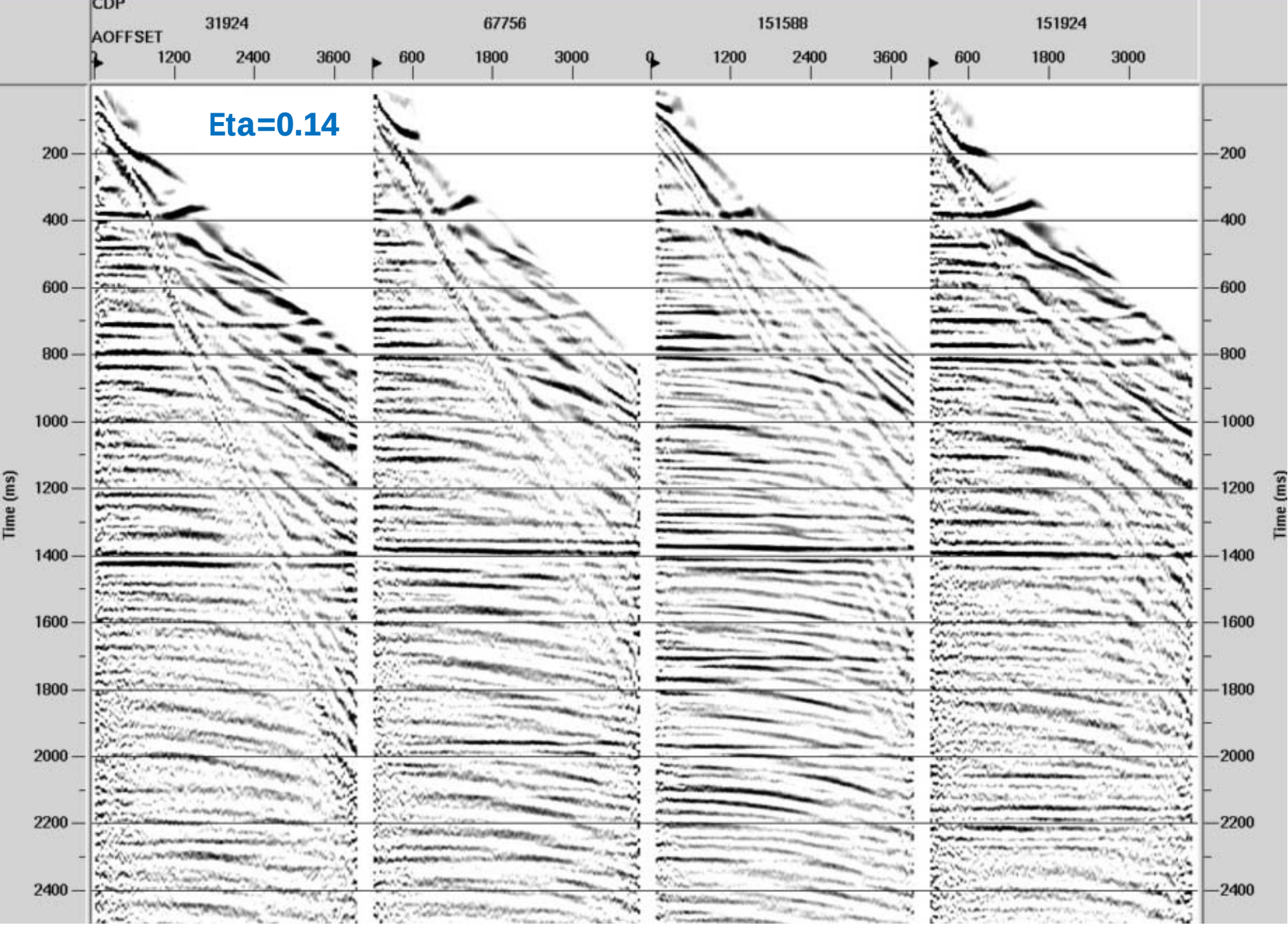
- Geometry
- Amplitude recovery
- Refraction Statics Correction
- Other statics
- Linear-noise attenuation
- Surface-consistent Decon
- Noise suppression
- NMO
- 3D COV Binning
- Migration Velocity Analysis
- 3D PSTM

Near-surface: 2nd refractor



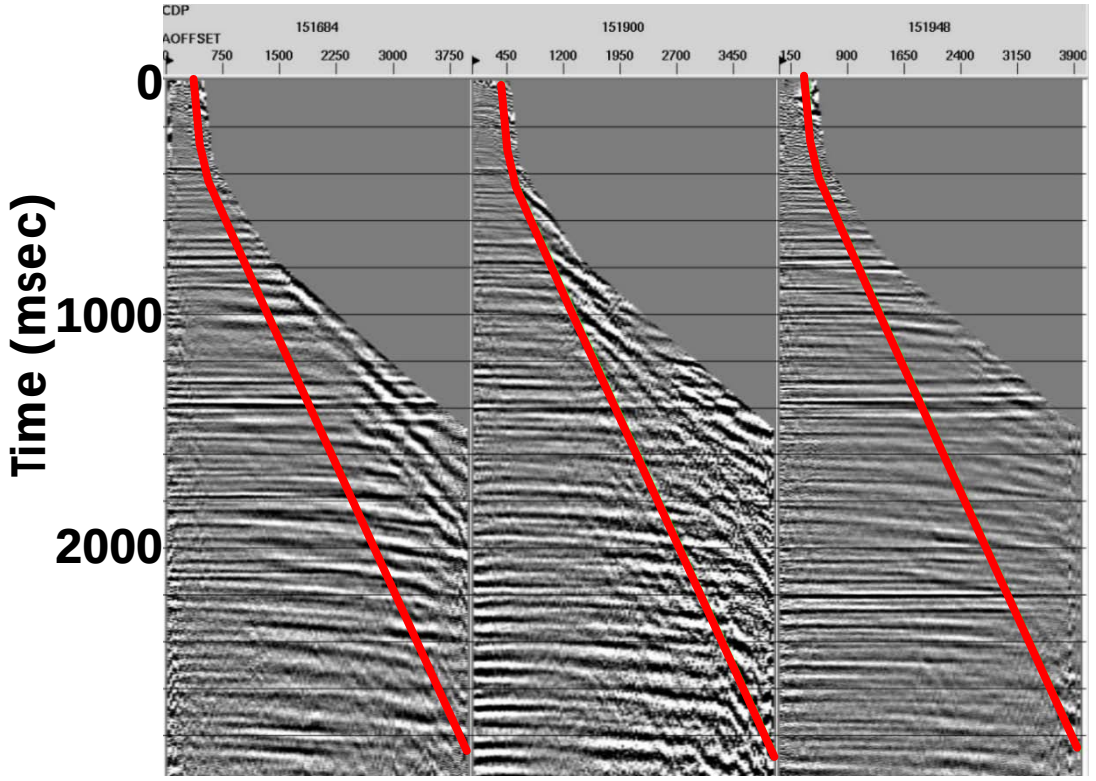
2nd refractor elevations:

A significant channel system within the near surface is observed.

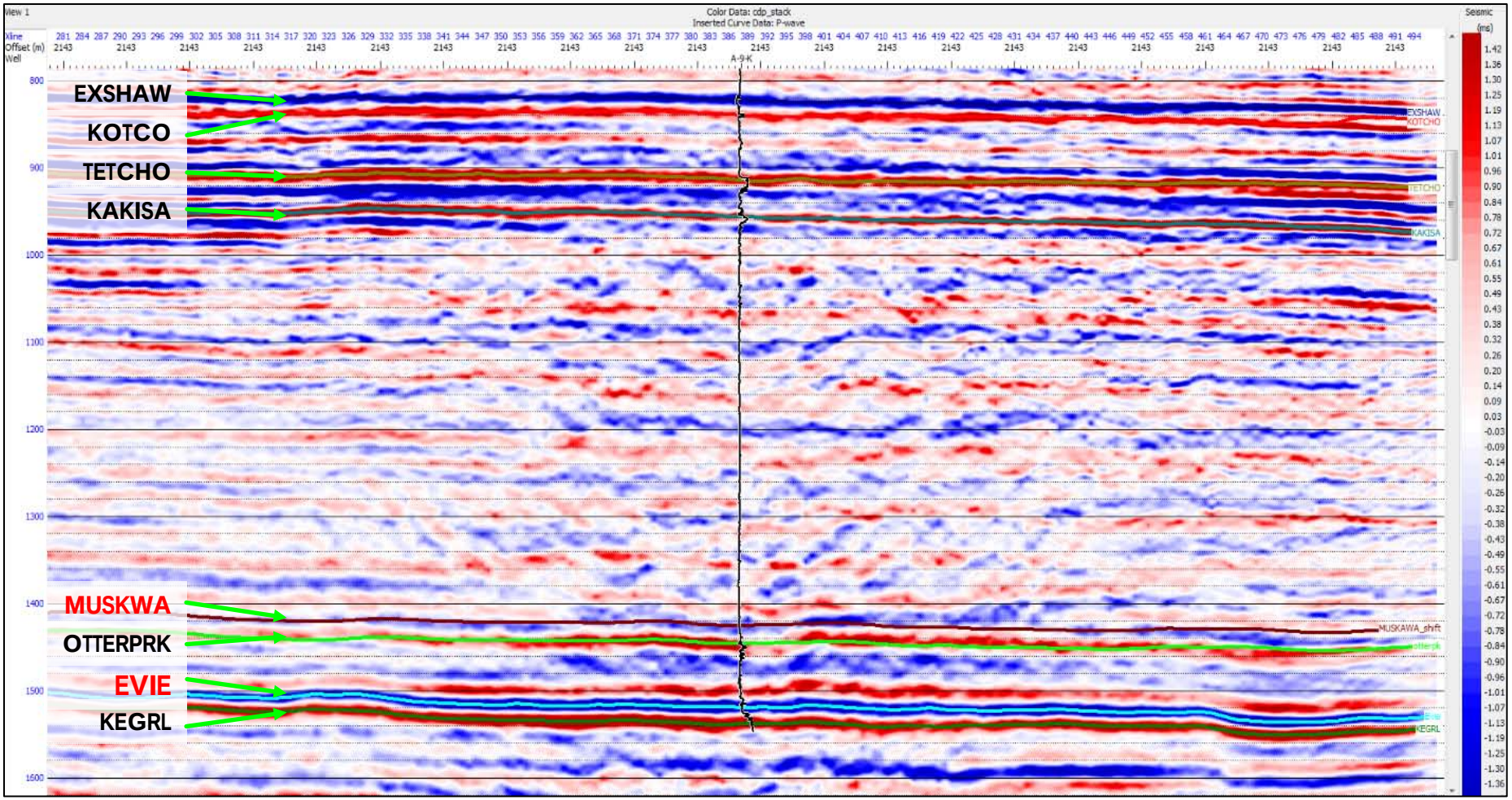

CDP
31924
67756
151588
151924
AOFFSET
0
1200
2400
3600
600
1800
3000
Eta=0.14
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Time (ms)

PSTM Gathers

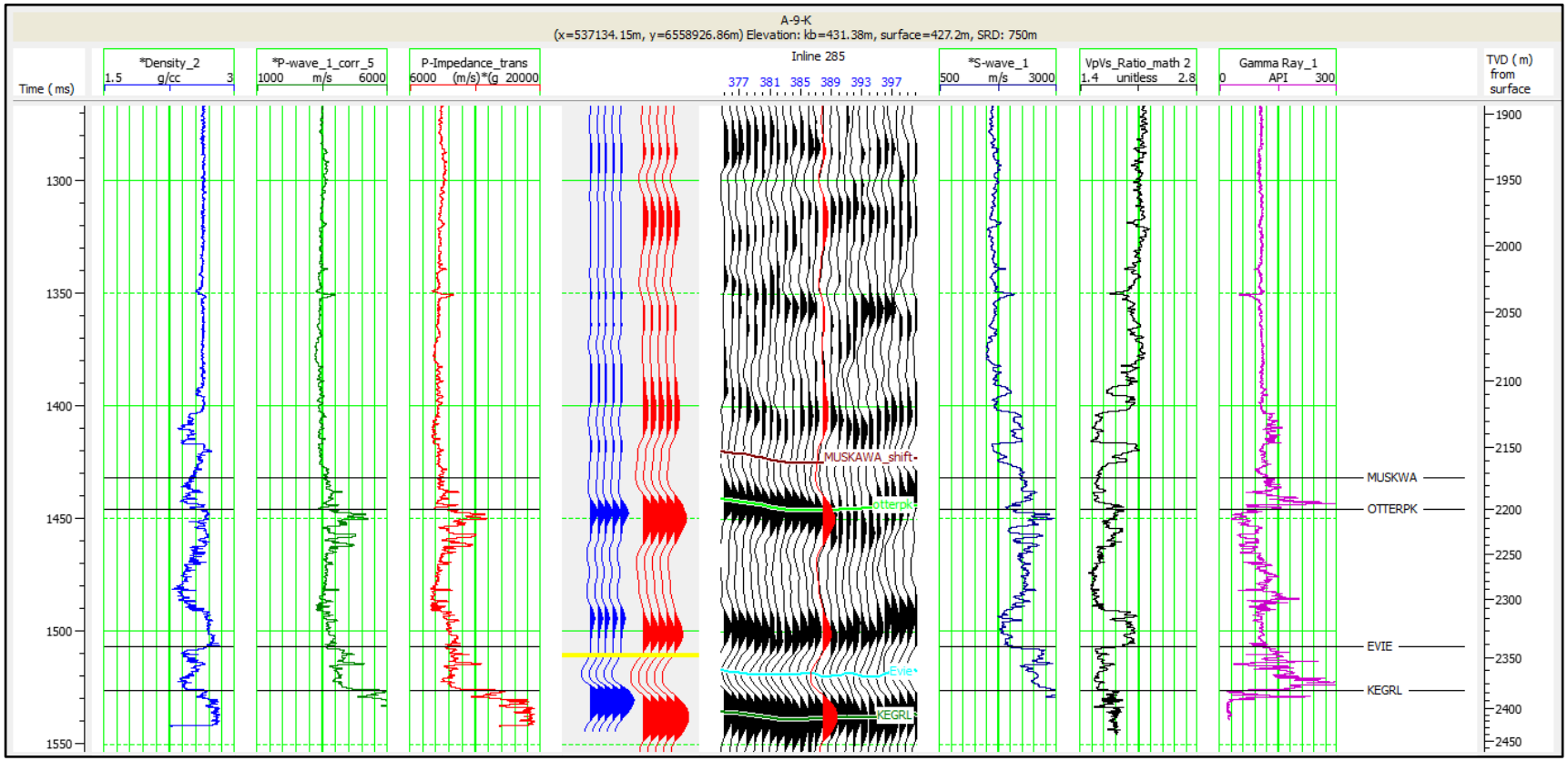
PSTM image gathers with an outer mute function indicated by green



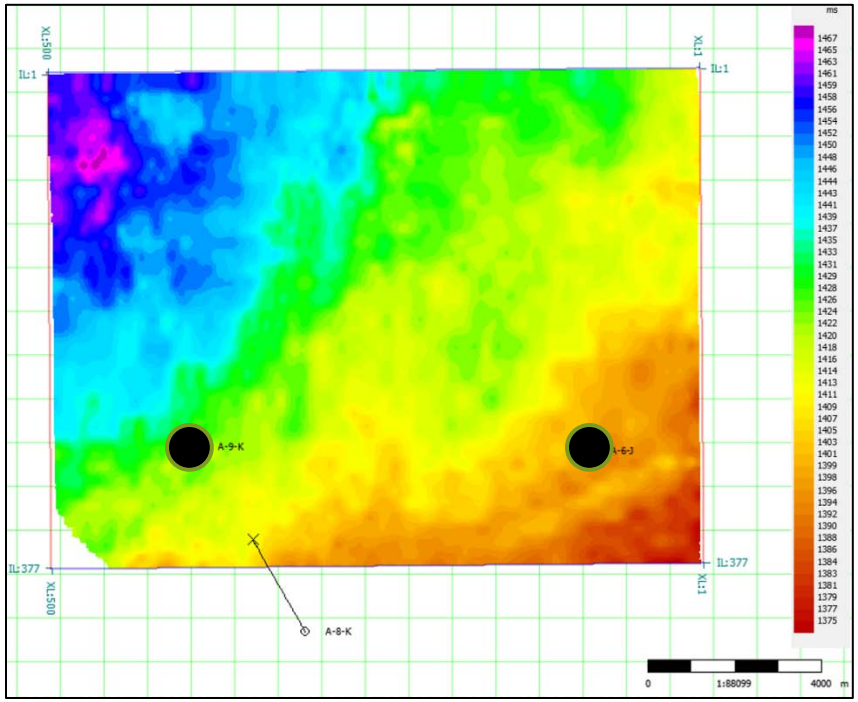
PSTM Stack & Picked Horizons

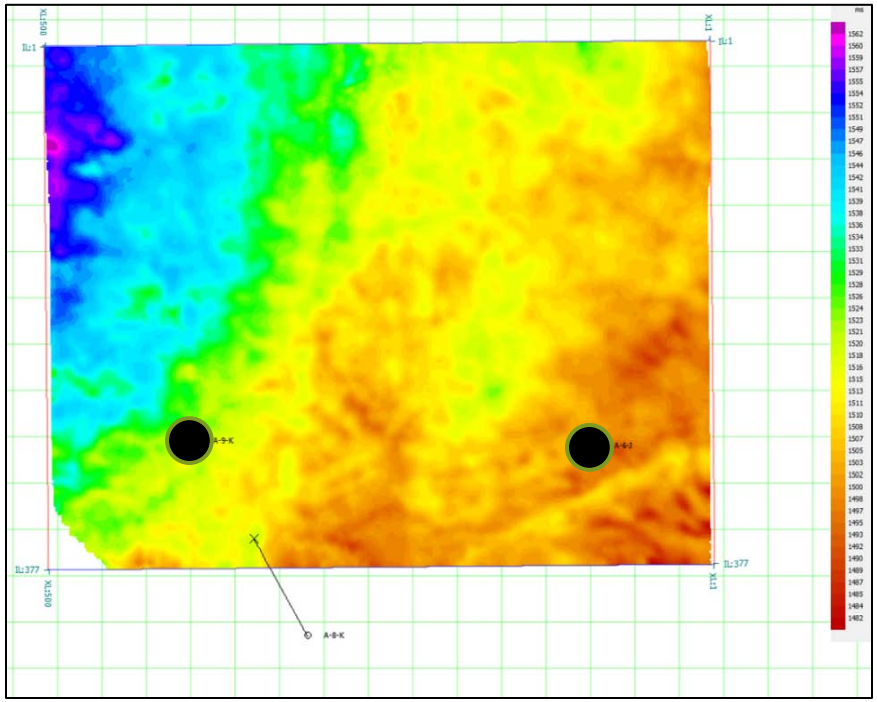


Well Log Correlation

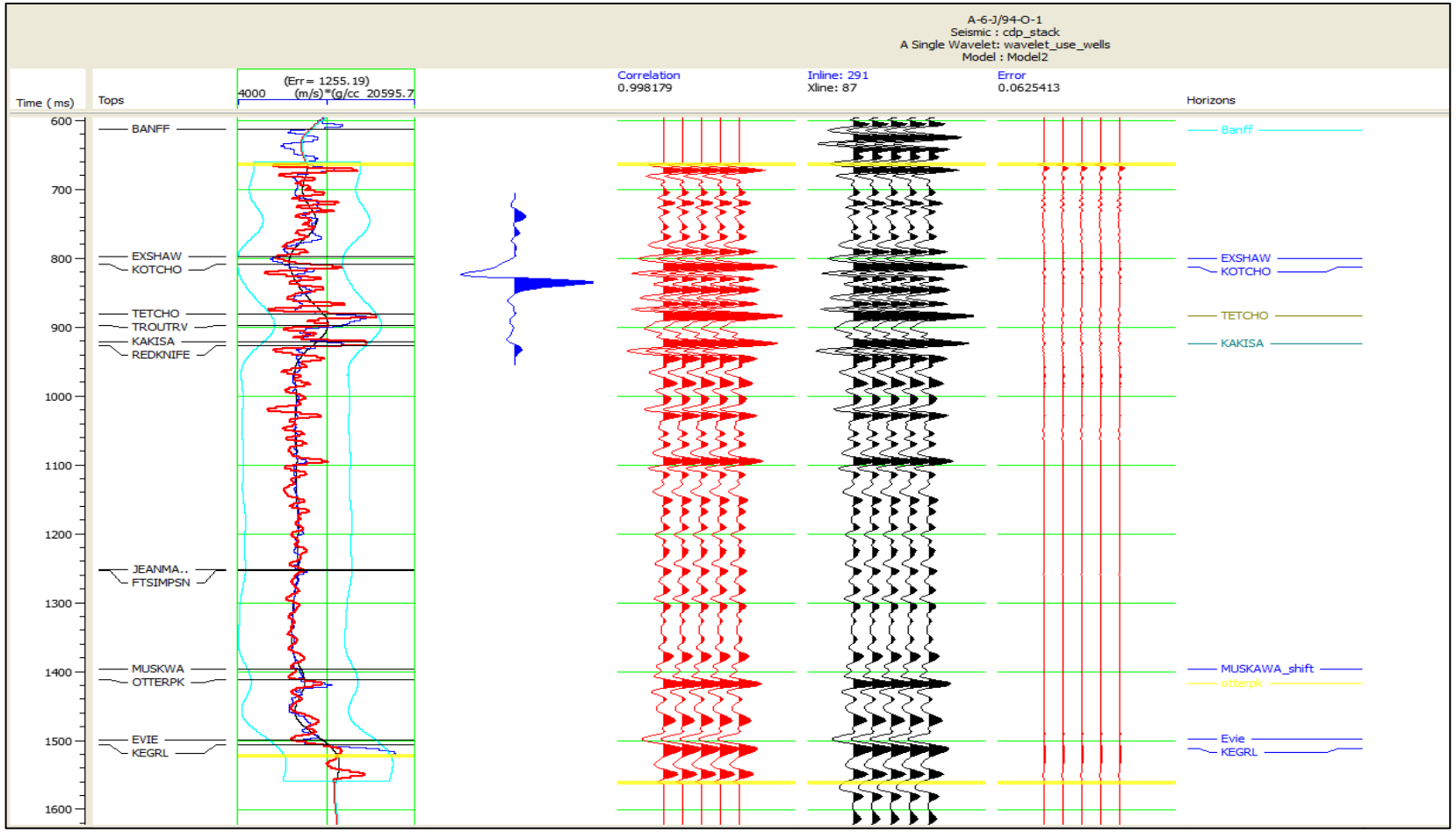


Target horizons: Muskwa (left) & Evie (right)

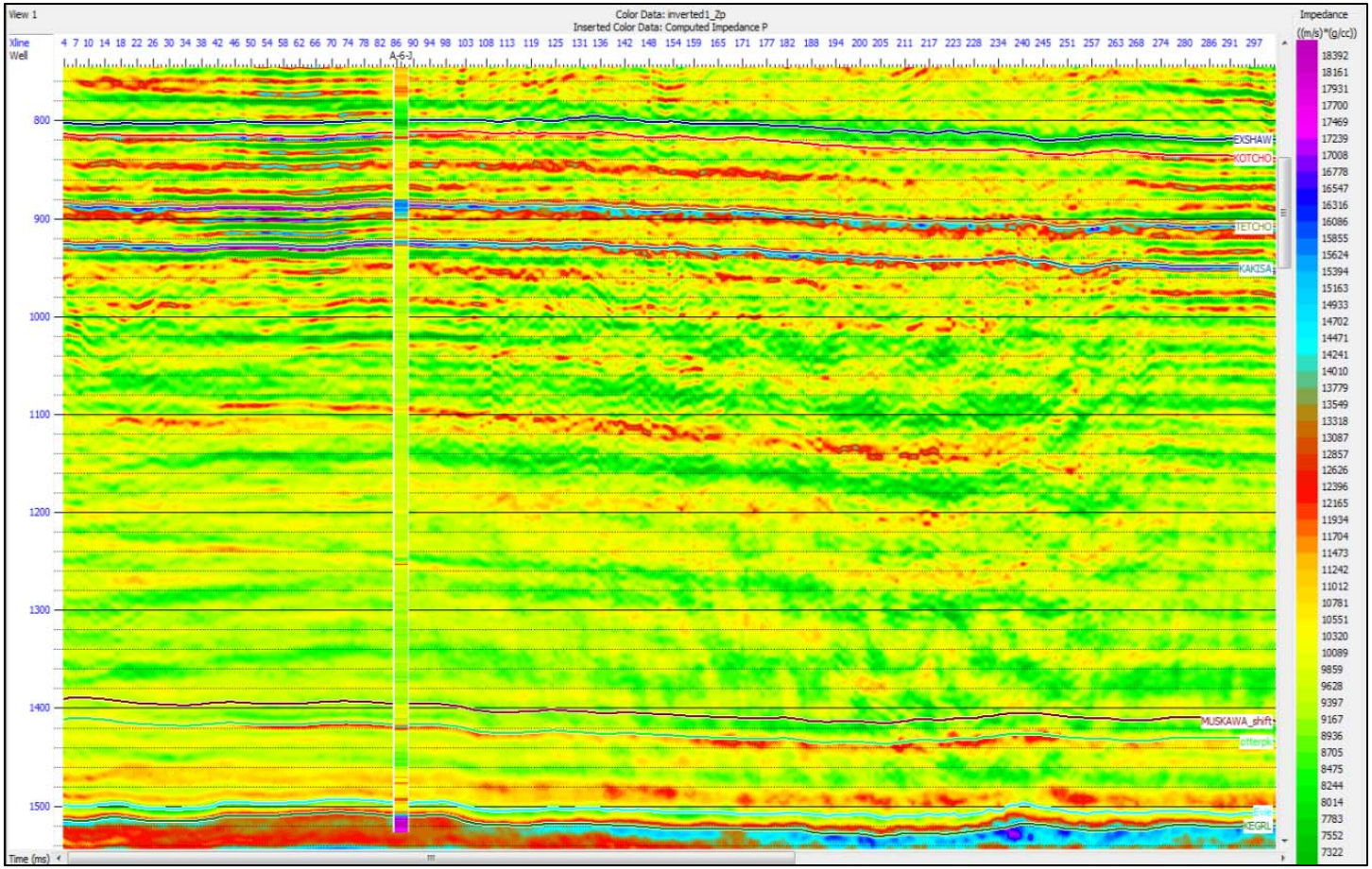




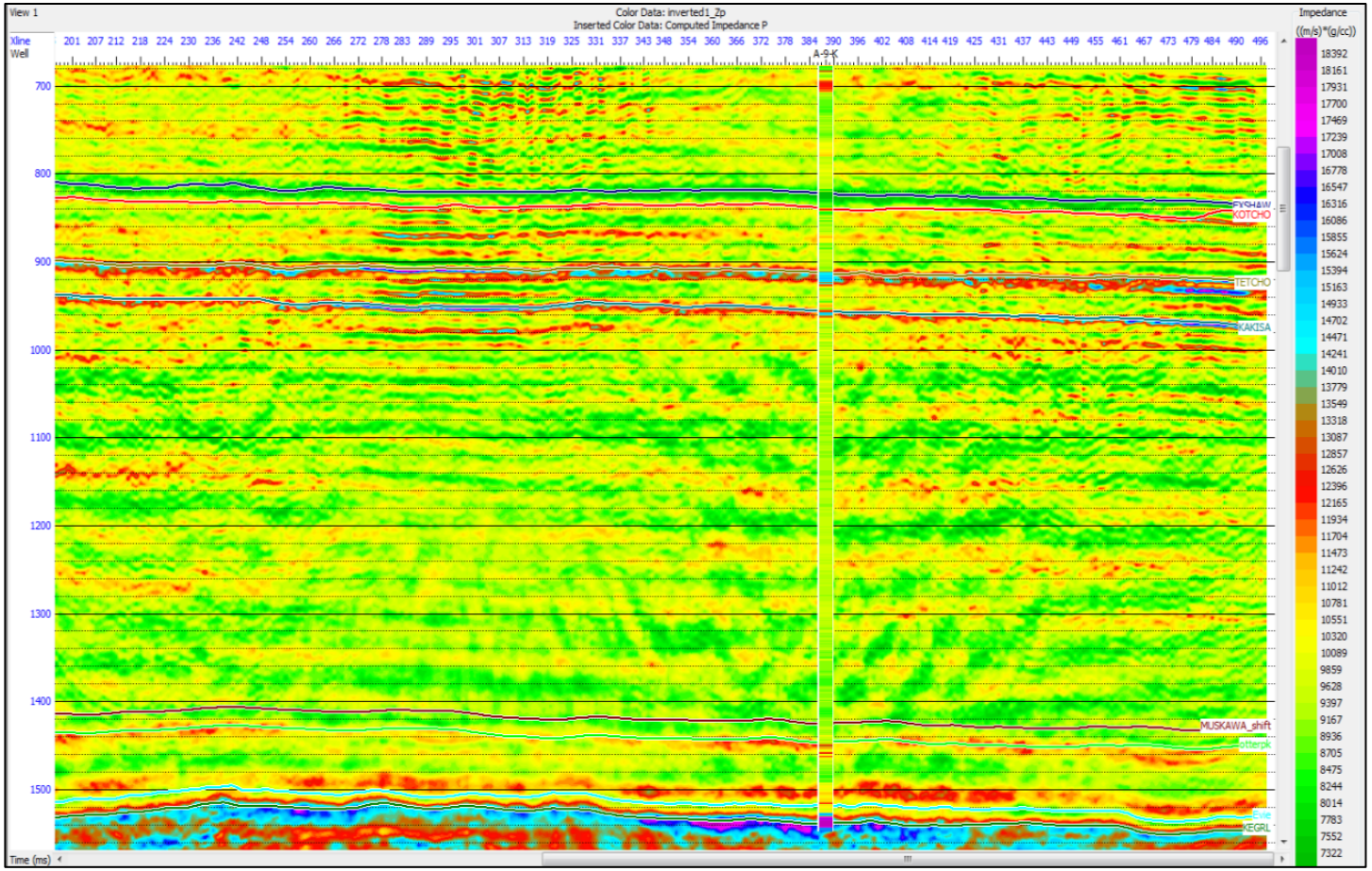
Post-stack Inversion



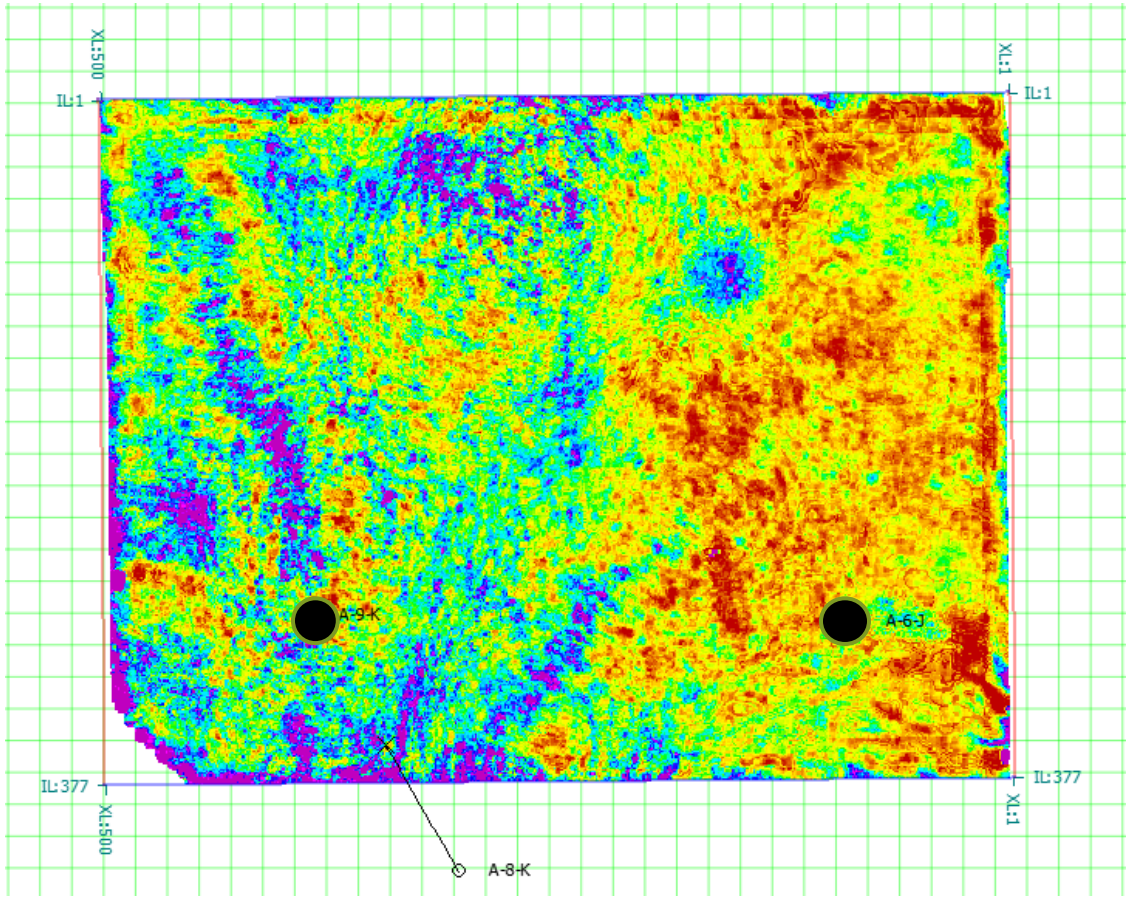
Impedance


View 1
Color Data: inverted1_2p
Inserted Color Data: Computed Impedance P
Xline
Well
A-6-J
Impedance
((m/s)*(g/cc))
EXSHAW
KOTCHO
TETCHO
KAKISA
MUSKAWA_shift
otterpk
KEGRL
Time (ms)

Impedance

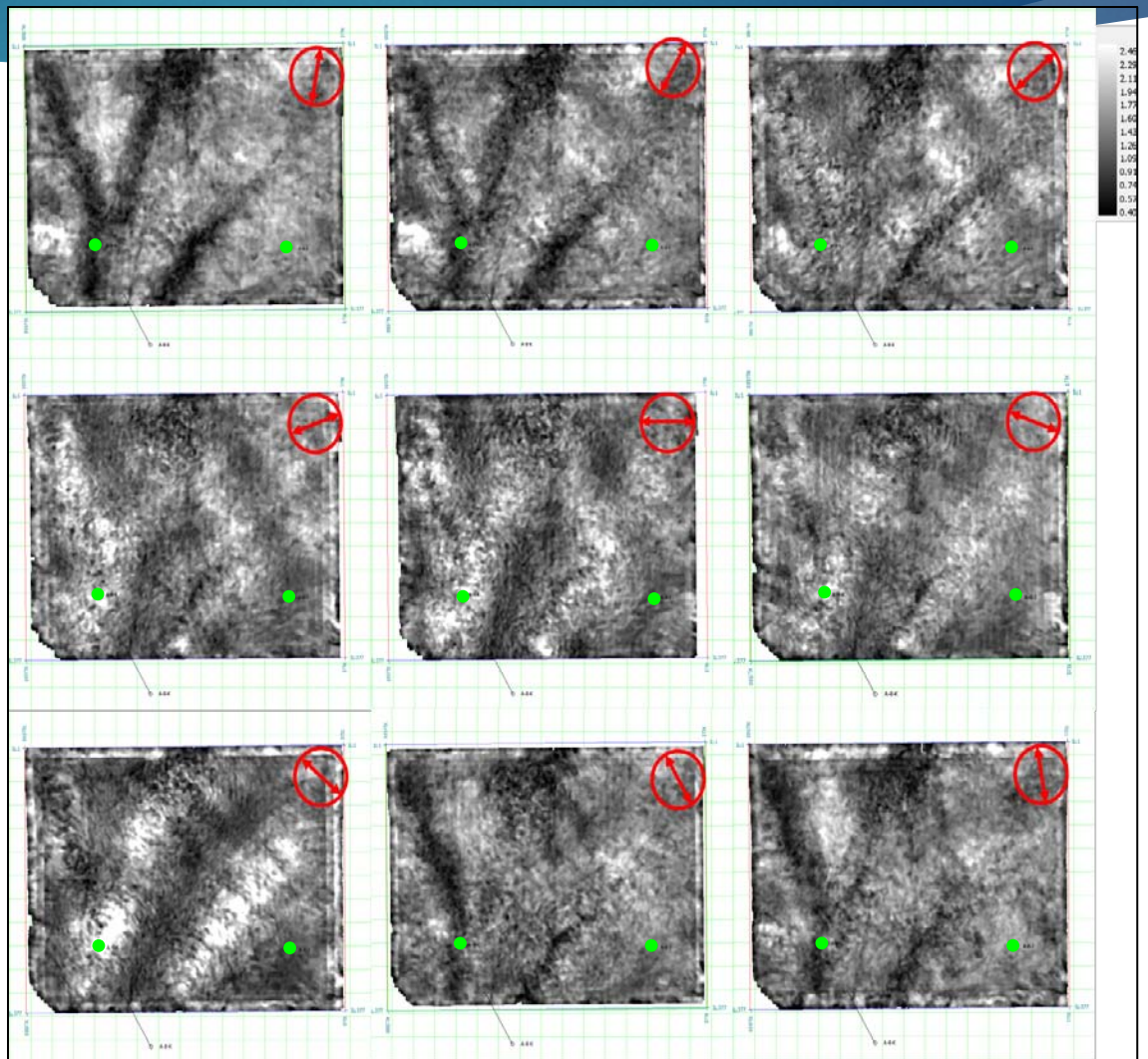

View 1
Color Data: inverted1_Zp
Inserted Color Data: Computed Impedance P
Xline
Well
Impedance
((m/s)*(g/cc))
Time (ms)
FYSHAW
KOTCHO
TETCHO
KAKISA
MUSKAWA_shift
otterpk
KEGRL

Impedance: Evie Map



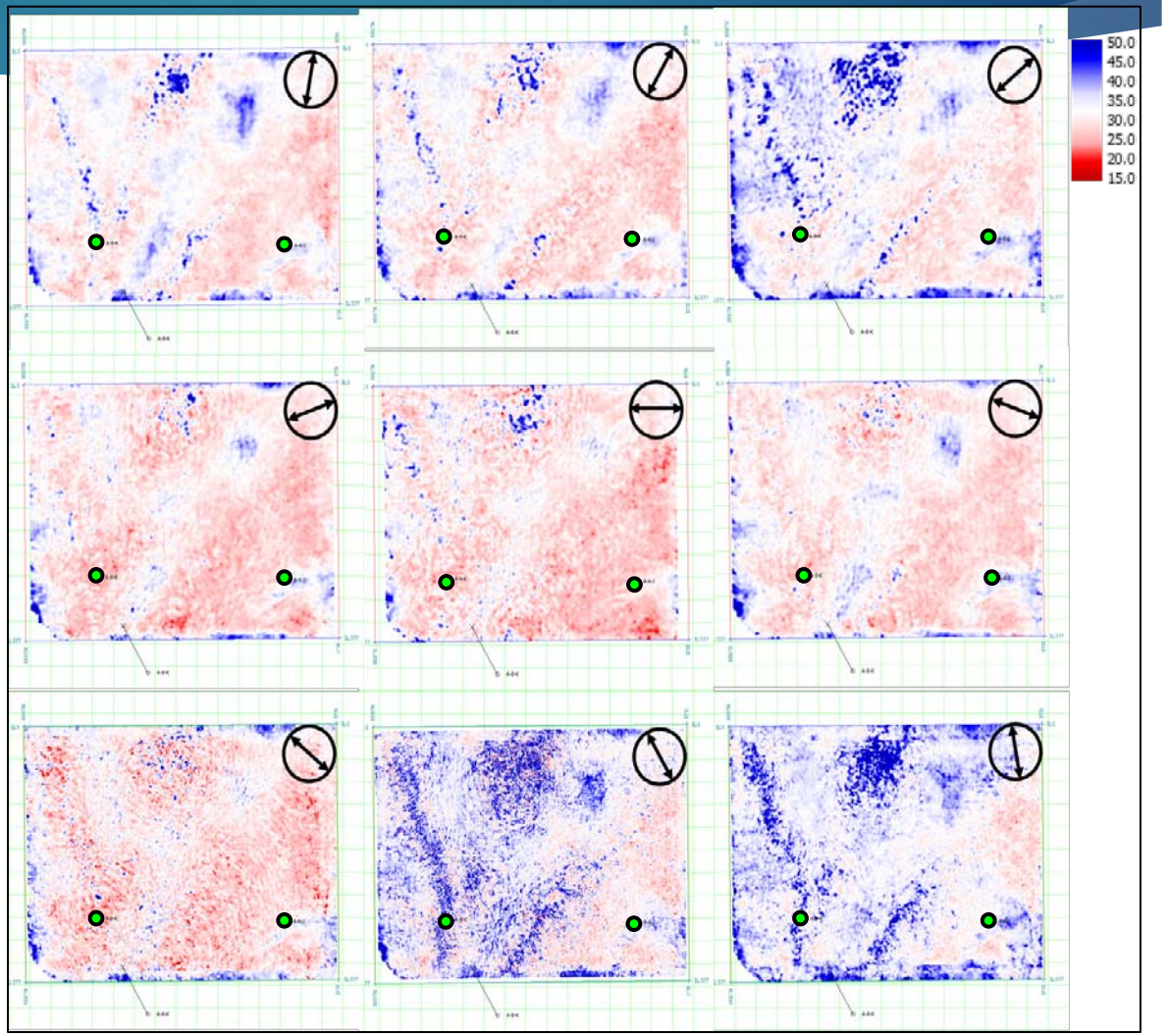
RMS amplitude at the Evie, sectored by S-R azimuth

Red arrows indicate azimuths. Black indicate lower amplitude values, or in another word lower impedance contrast. Therefore, it indicates the direction of fracture strike. Major directions are 0o (i.e. Well A-9) and 90o (i.e. Well A-6).

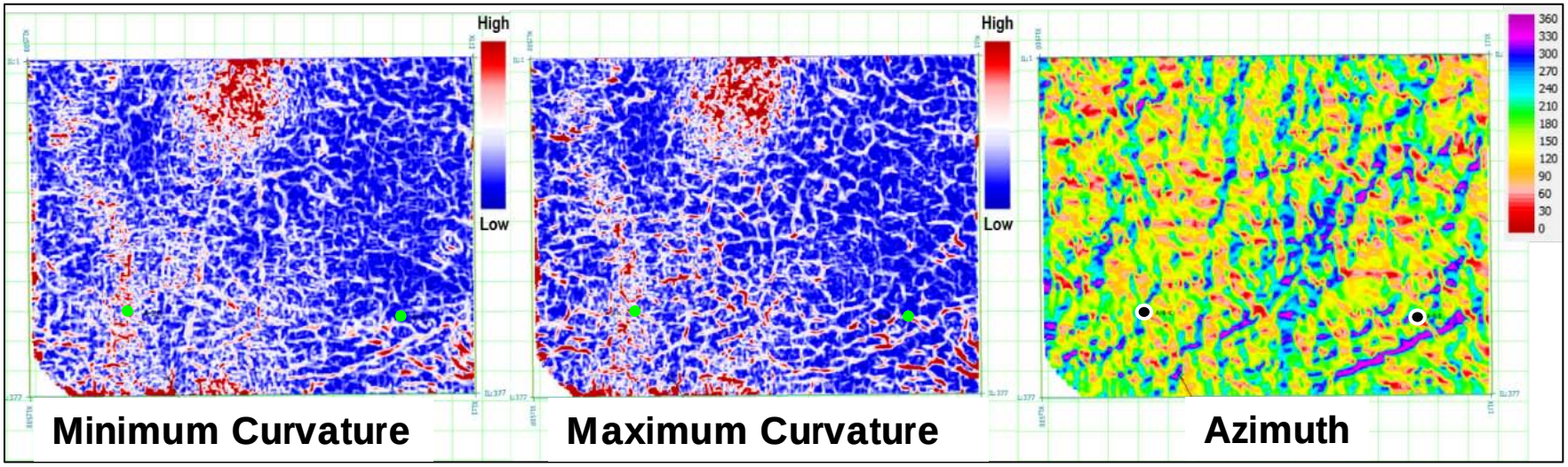


Instantaneous frequency at the Evie

Black Arrows indicate azimuth. Lower instantaneous frequencies see more fractures. Therefore, higher values indicate the fracture strike. Major direction are 90º

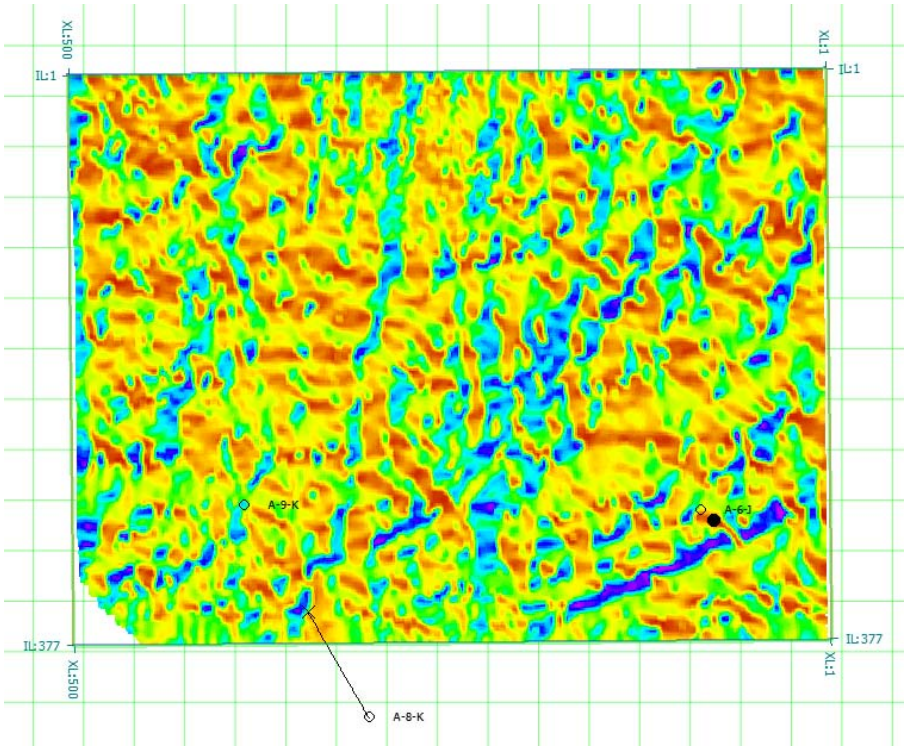


Curvature at the Evie

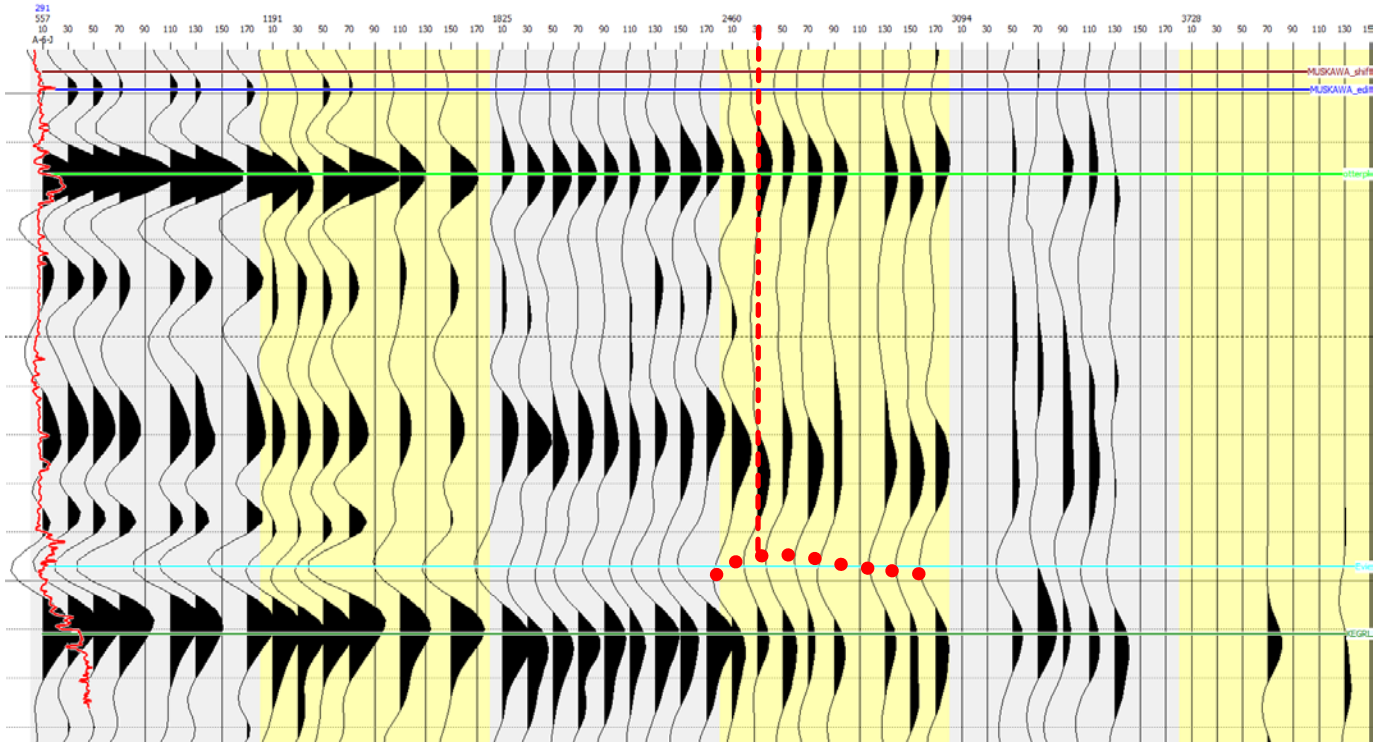


High curvature values indicate fractured zones. Azimuth map indicates that the major trends are about 0º and 40º.

Curvature azimuth ~ 33



COCA Gathers



AVO vs AVAZ (Ruger's)

$$Rpp(\Theta) = A_{iso} + B_{iso}sin^2\Theta + C_{iso}tan^2\Theta sin^2\Theta$$

$$A_{iso} = \frac{1}{2}\left[\frac{\Delta Vp}{Vp} + \frac{\Delta\rho}{\rho}\right]$$

$$B_{iso} = \frac{1}{2}\frac{\Delta Vp}{Vp} - 4\left[\frac{Vs}{Vp}\right]^2\frac{\Delta Vs}{Vs} - 2\left[\frac{Vs}{Vp}\right]^2\frac{\Delta\rho}{\rho}$$

$$C_{iso} = \frac{1}{2}\frac{\Delta Vp}{Vp}$$

$$Rpp(\Theta,\emptyset) = A_{iso} + Bsin^2\Theta + Ctan^2\Theta sin^2\Theta$$

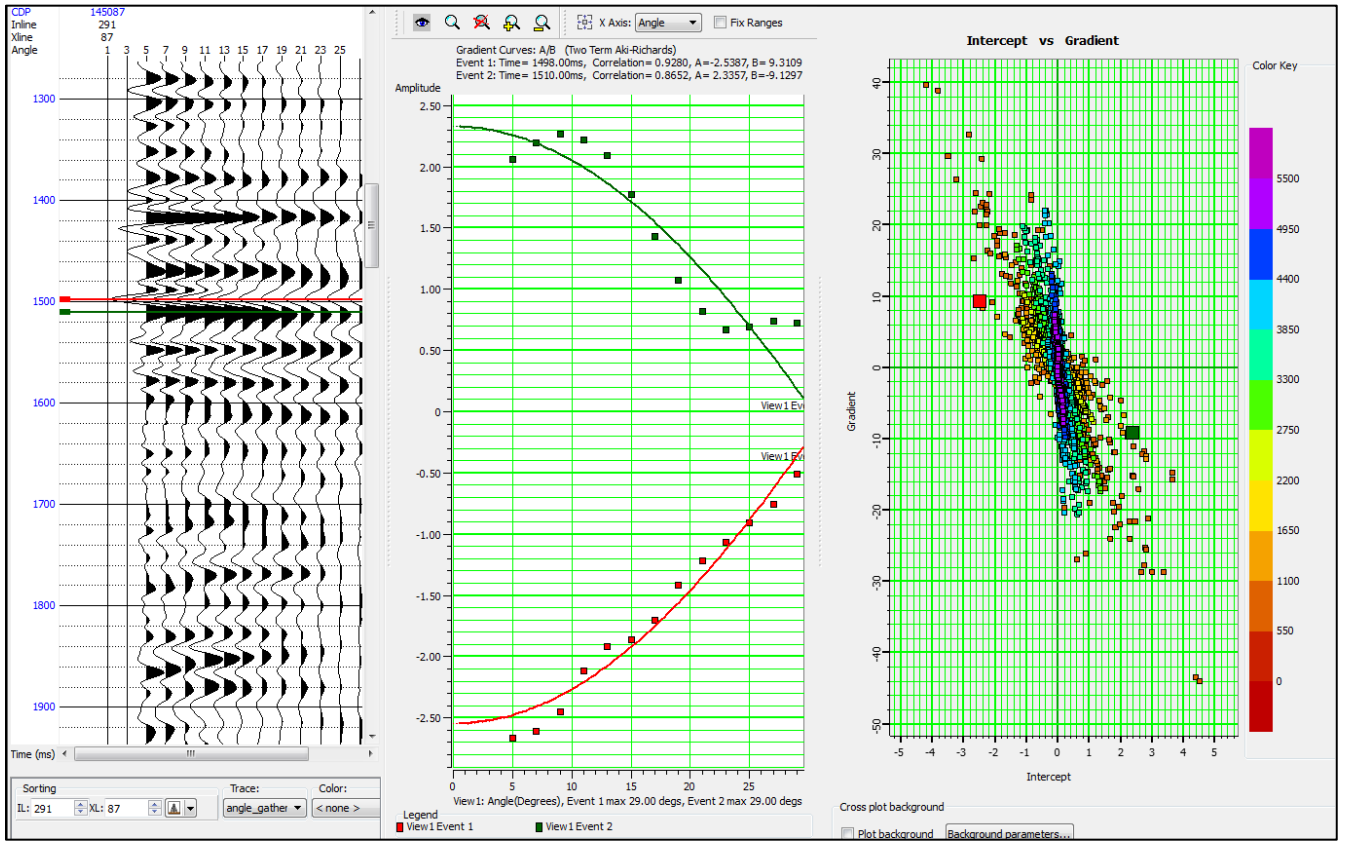
$$B = B_{iso} + B_{ani}$$

$$B_{ani} = \frac{1}{2}\left[\Delta\delta^v - 8\frac{Vs}{Vp}\Delta\gamma^v\right]$$

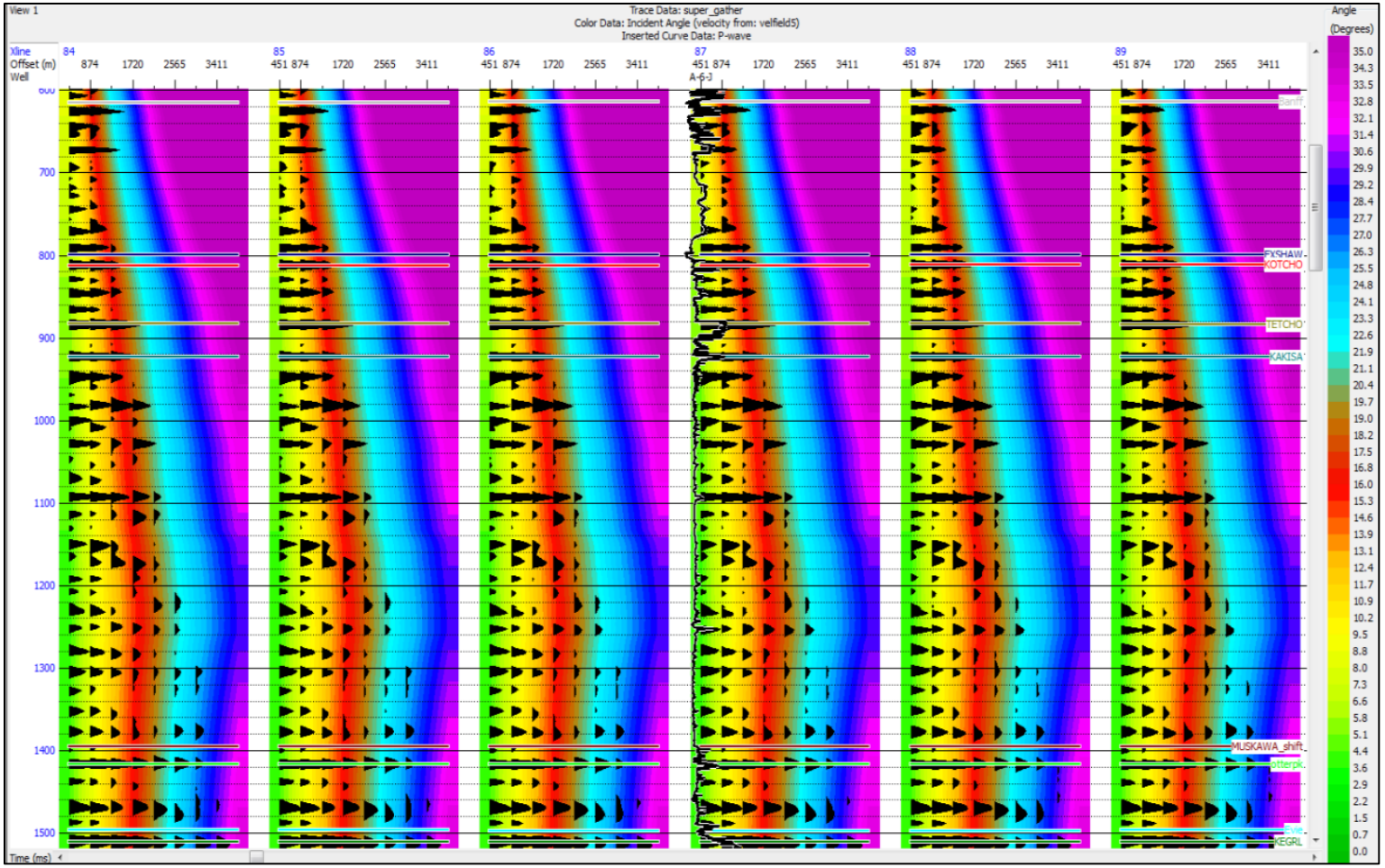
$$C = C_{iso} + \frac{1}{2}[\Delta\delta^v sin^2\emptyset + \Delta\epsilon^v cos^2\emptyset]cos^2\emptyset$$

AVO Analysis: Synthetic

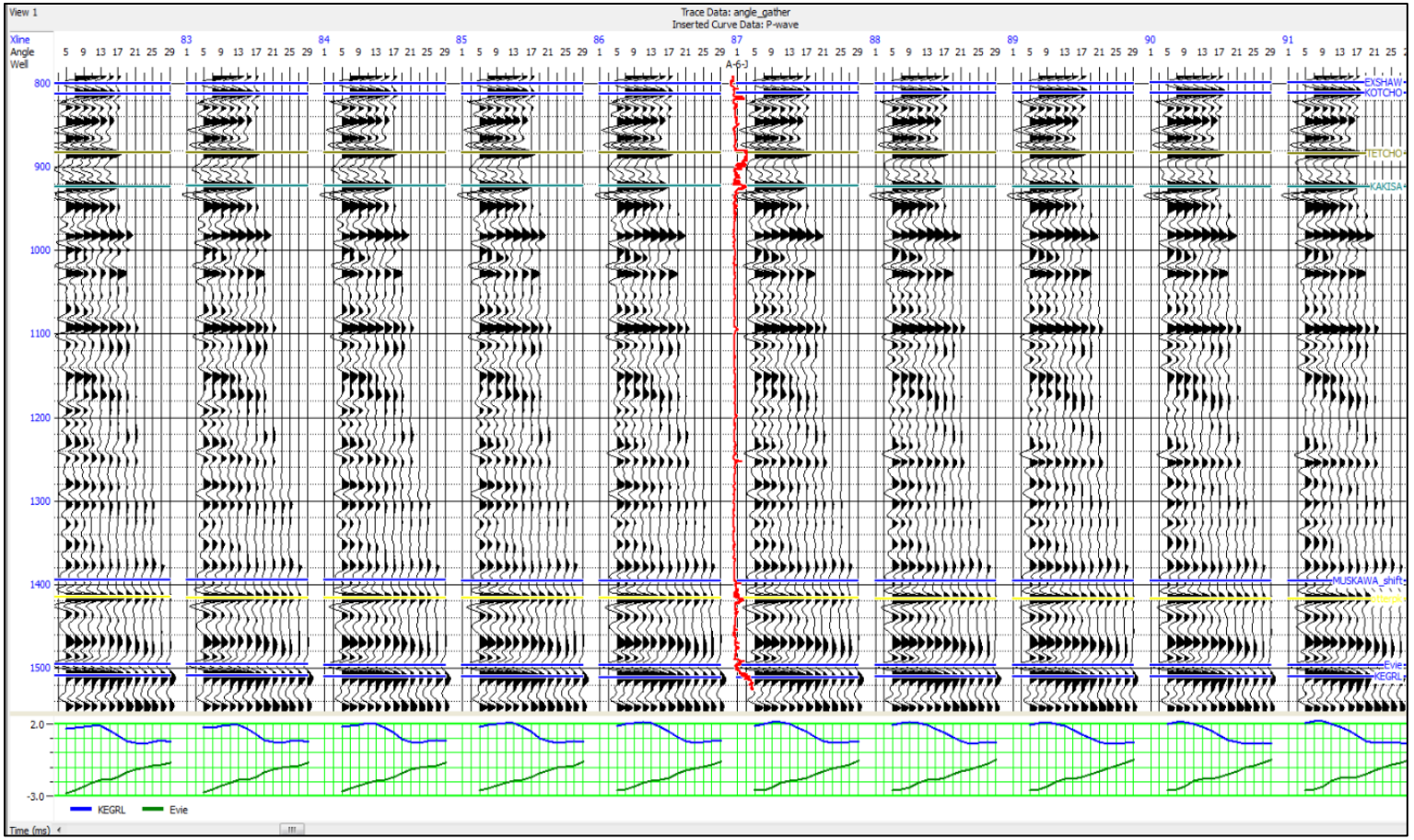
AVO modelling: synthetic angle gather (left), amplitude curves (middle), and intercept vs. gradient plot (right).



Super gathers

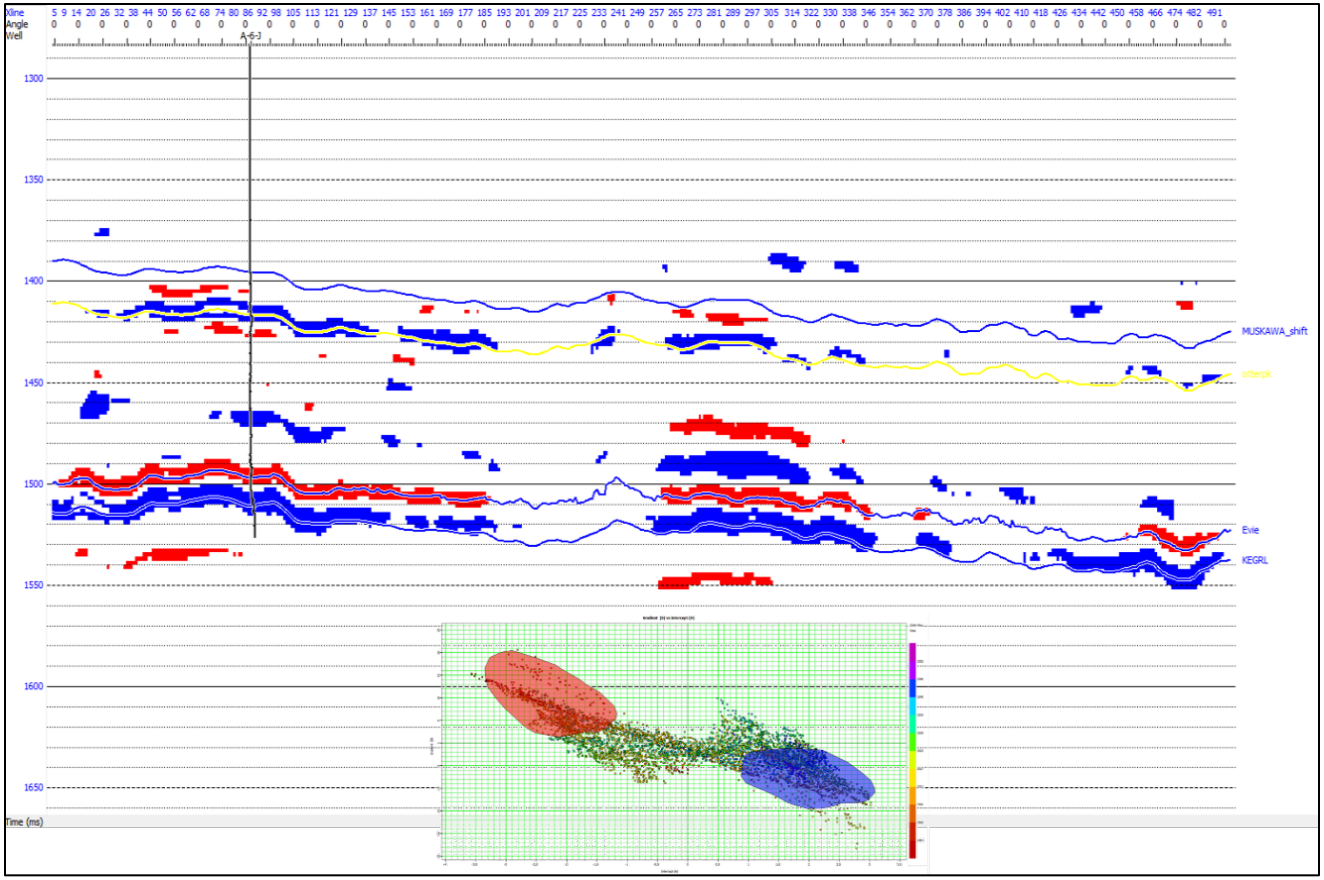


Angle gathers & Amplitude vs Angle

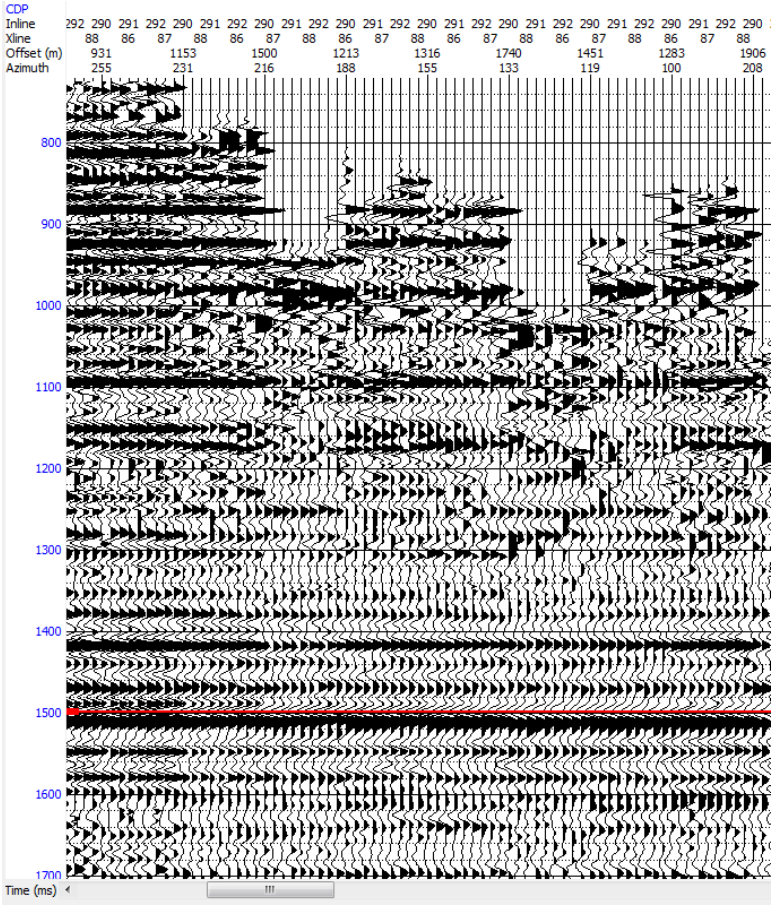


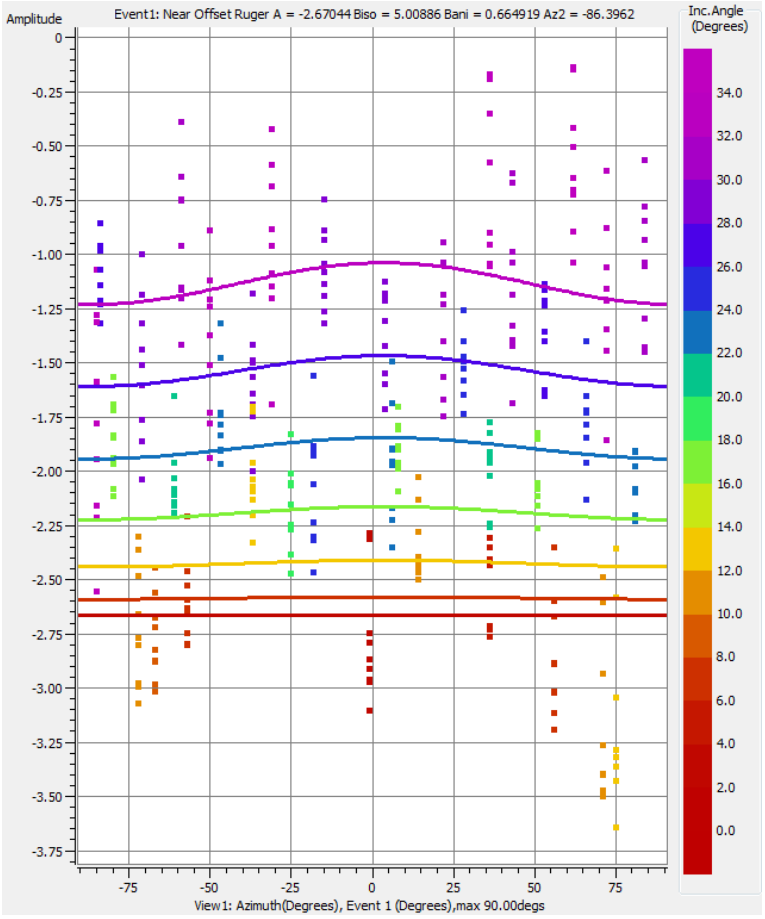
AVO

class IV reservoir. Red is top & blue is bottom of the reservoir.



AVAZ


CDP
Inline
Xline
Offset (m)
Azimuth
Time (ms)


Amplitude
Event1: Near Offset Ruger A = -2.67044 Biso = 5.00886 Bani = 0.664919 Az2 = -86.3962
Inc.Angle (Degrees)
View1: Azimuth(Degrees), Event 1 (Degrees),max 90.00degs

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CONCLUSIONS

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Conclusions

- **Post-stack P-impedance inversion is utilized to indicate sweet spots**
- **post-stack amplitude, instantaneous frequency, and curvature attributes are utilized for identifying fracture direction and intensity**
- **Pre-stack AVO show class IV AVO for some of Evie**
- **Pre-stack AVAZ is utilized to invert for A, Biso, Bani, Symmetry Angle**

Acknowledgments

- CREWES sponsors for their support
- NSERC for the grant CRDPJ 379744-08
- Seitel and Arcis for permission to use the data and publish the results
- Geophysical Sensor for time processing of the data
- CGGVeritas for the use of Hampson-Russell software
- Dr. Don Lawton, Dr. Faranak Mahmoudian, Nassir Saied, Jesse Kolb, Dr. Helen Isaac, and Dr. Pat Daley
- Saudi Aramco for PhD sponsorship of the first author

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Thank you

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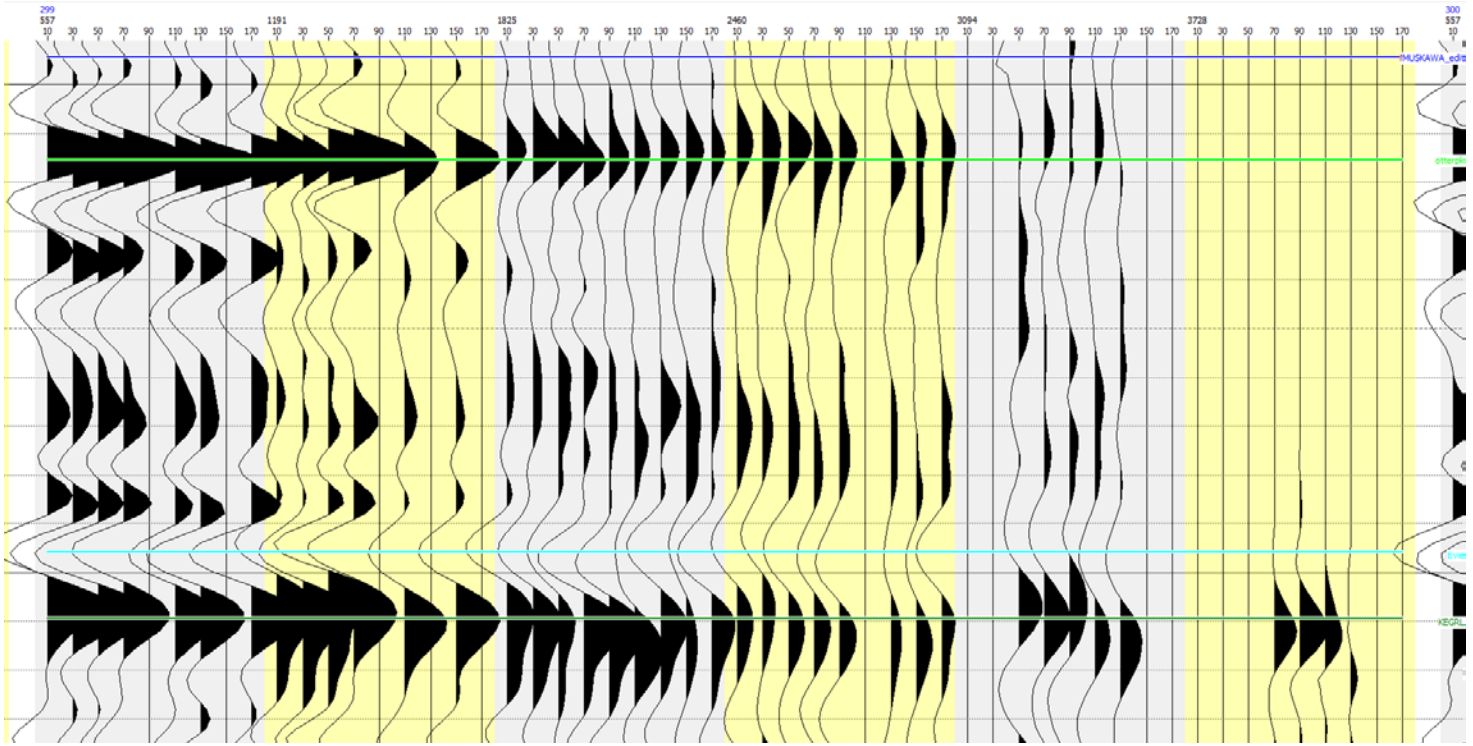
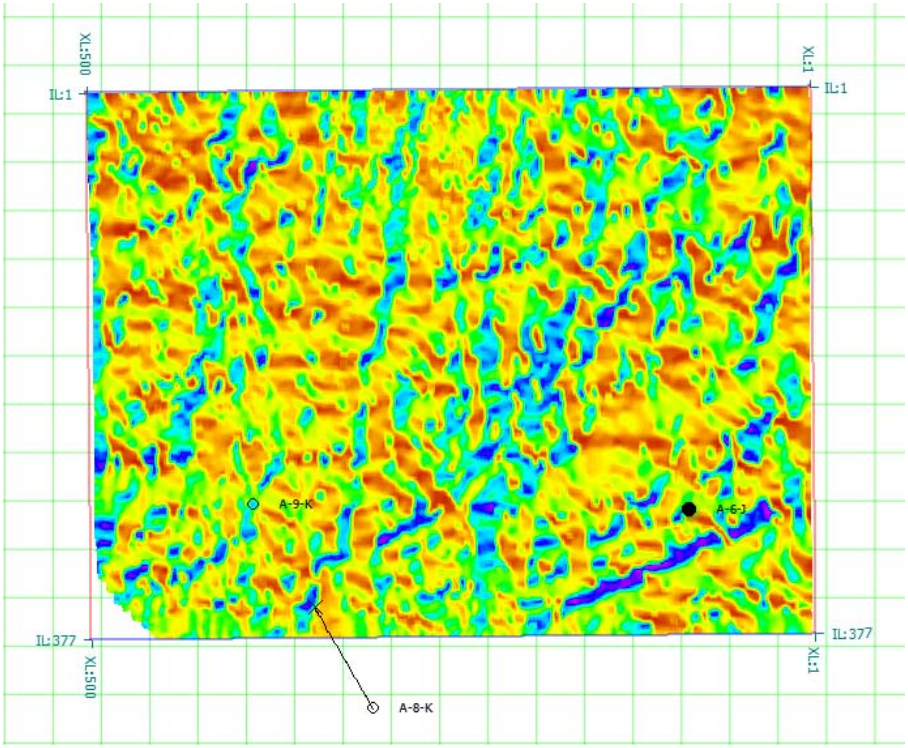
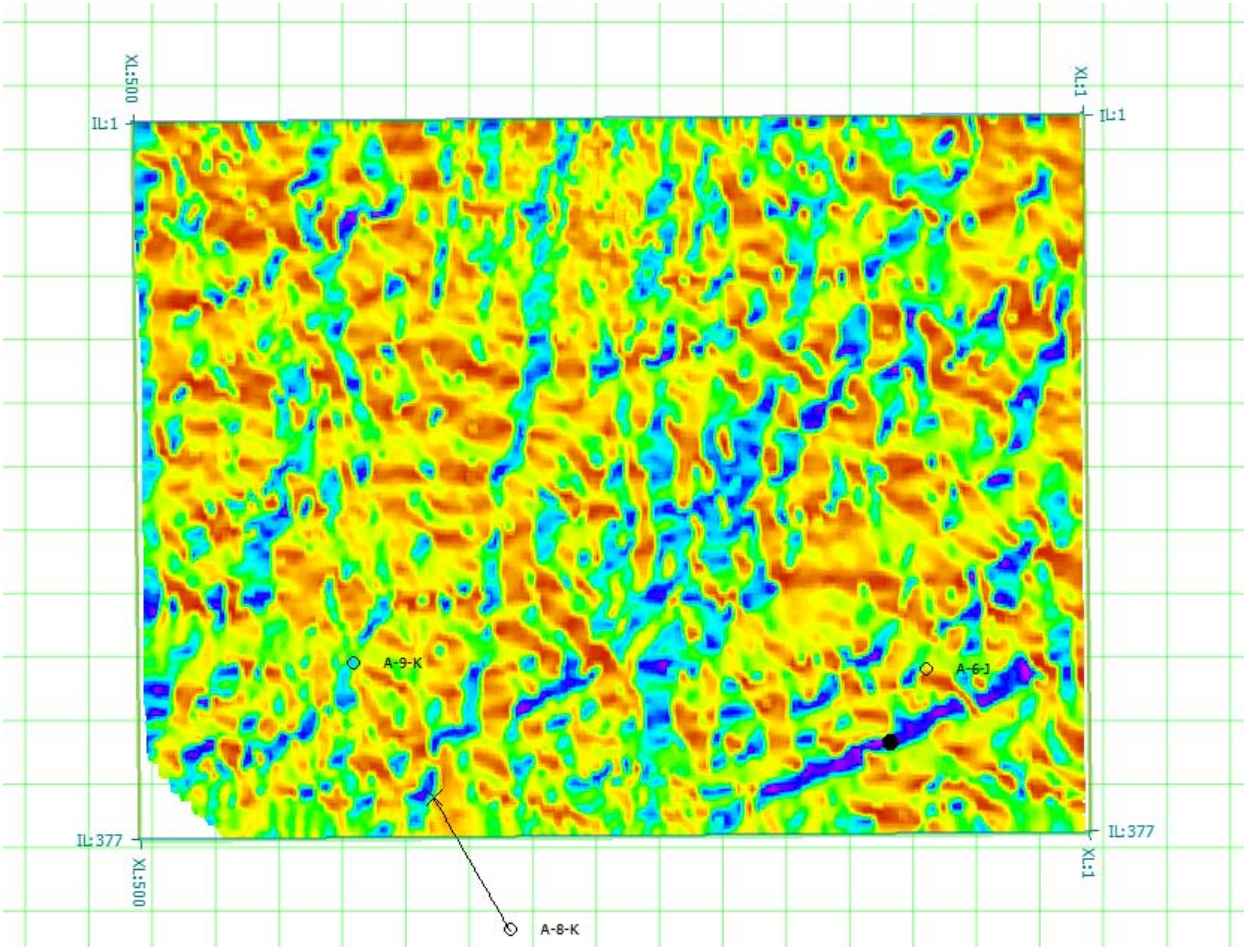
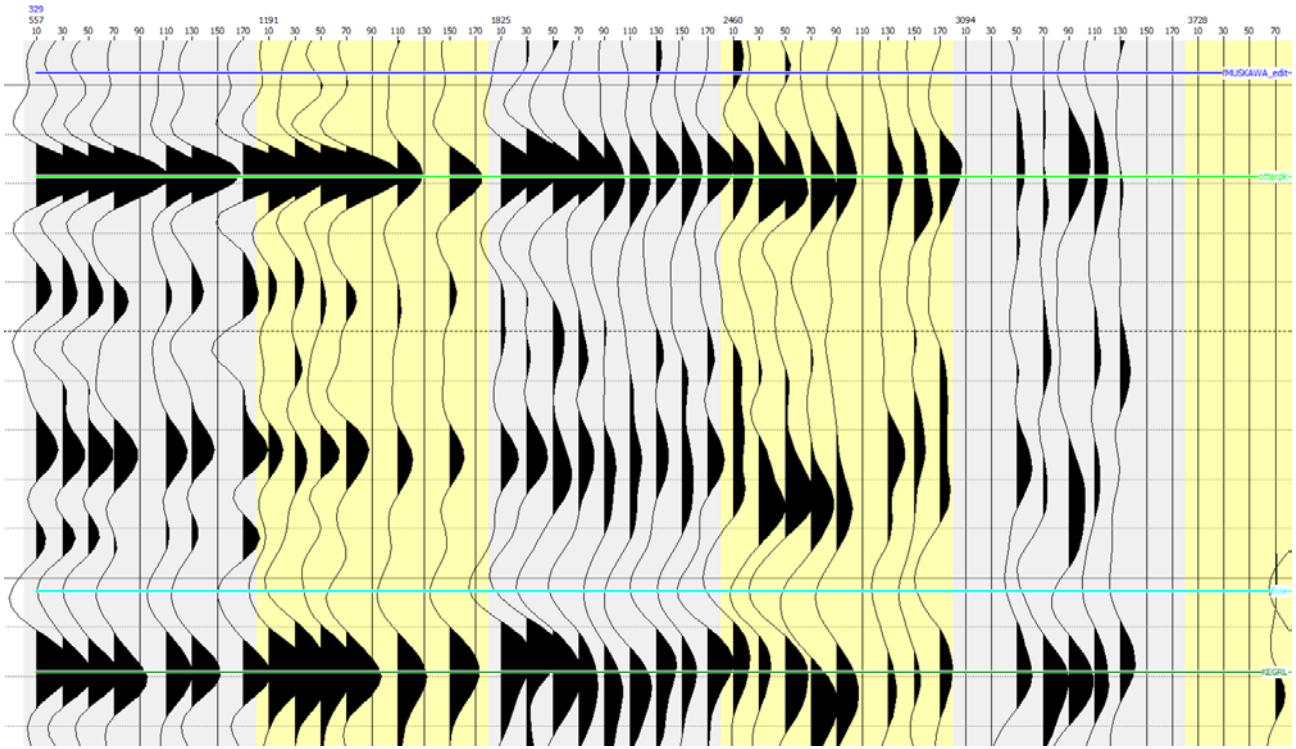


147




XL:500
IL:1
XL:1
IL:1
A-9-K
A-6-J
IL:377
IL:377
XL:500
XL:1
A-8-K

COCA Gather


329
557
1191
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MUSKAWA_edit
otterpk
Flue
KEGRL