

Seismic reflection inversion with basis pursuit

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Outline

- Motivation
- Basis Pursuit Algorithm
- Wedge dictionary
- Field data
- Conclusions

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Motivation

- Help interpretation
 - Structure
 - Identify thin layer
 - Map micro-structure
 - Lithology
 - Tie seismic with well-log with detailed scale
 - Detect local impedance change

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- Motivation
- Basis Pursuit Algorithm
 - Objective Function
 - Linear Program
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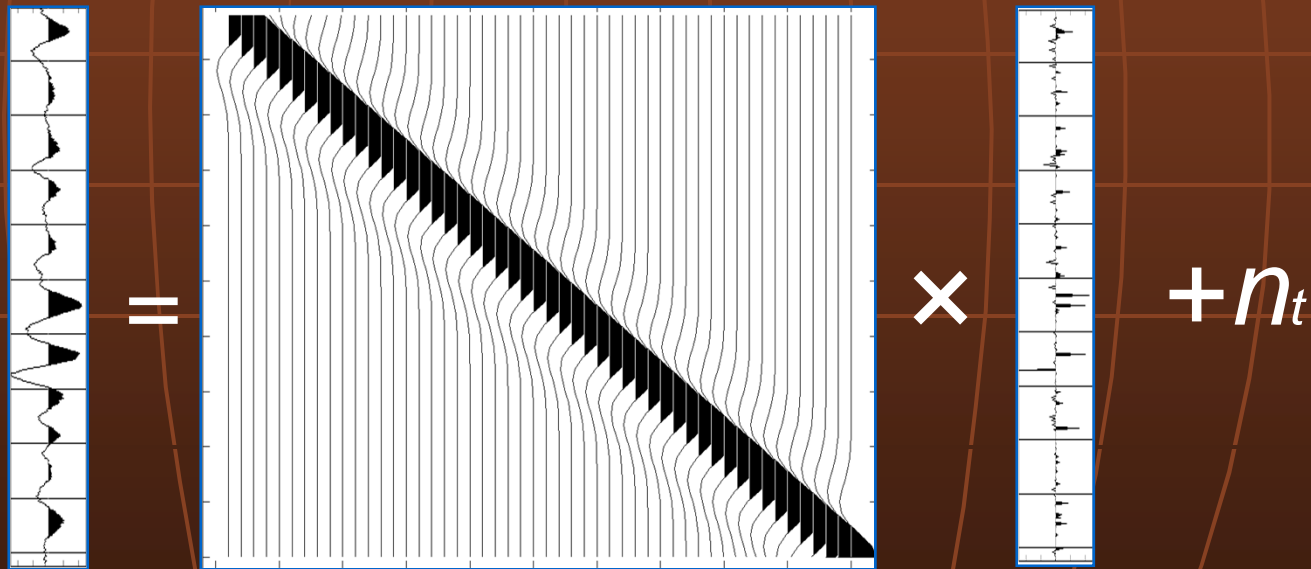
Objective Function

L1 norm minimization least square solution

$$\min \|r\|_1$$

Subject to

$$\min \|s - W \times r\|_2$$



r: reflectivity

W: kernel wavelet matrix

s: seismic image trace

λ : trade-off factor (positive)

$$\min \|s - W \times r\|_2^2 + \lambda \|r\|_1$$

Linear Program

$$\min \lambda \|r\|_1 \quad \text{subject to} \quad \min \|s - W \times r\|_2$$

$$\begin{aligned} A &= (W \quad -W) \\ b &= s \\ c &= \lambda \begin{pmatrix} 1 \\ 1 \end{pmatrix} \\ x &= \begin{pmatrix} u \\ v \end{pmatrix} \\ r &= u - v \\ u &\geq 0; v \geq 0 \end{aligned}$$

$$W * r = s$$

$$(W \quad -W) \begin{pmatrix} u \\ v \end{pmatrix} = b$$

$$\min \|A \times x - b\|_2$$

$$\min \|r\|_1$$

$$\|r\|_1 = \|u - v\|_1 \leq \|u + v\|_2$$

$$\min c^T x$$

$$\min c^T x$$

Subject to

$$Ax = b, x \geq 0$$

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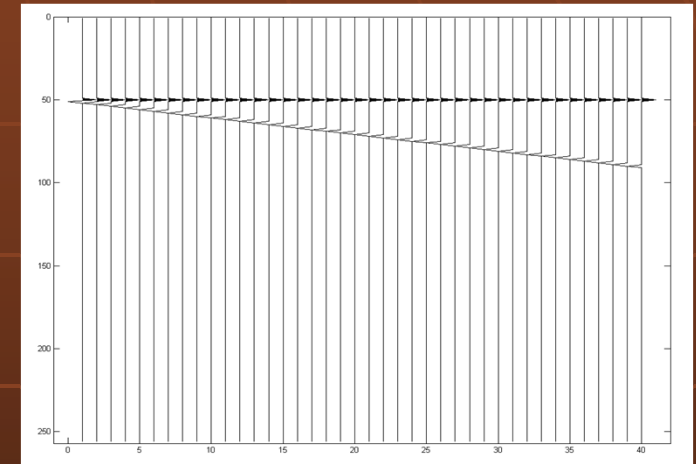
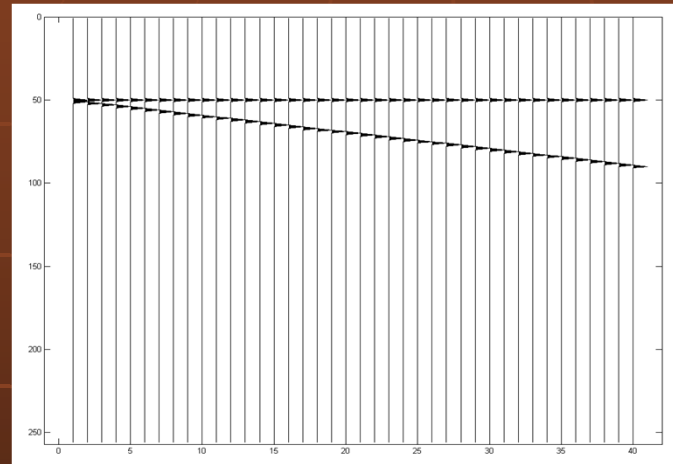
Wedge Matrix



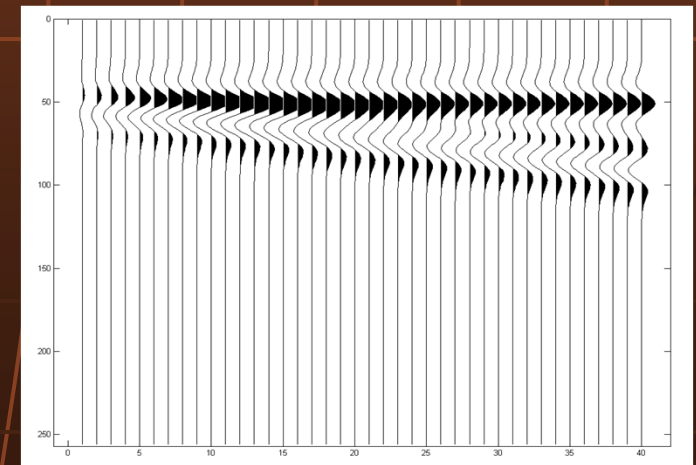
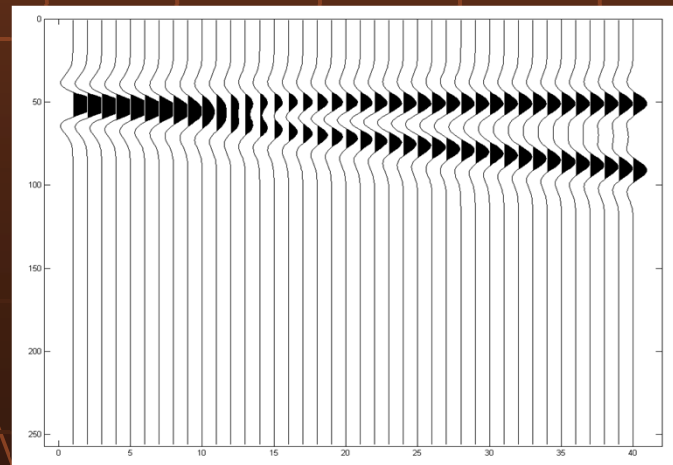
Even

Odd

Wedge reflectivity



Wedge seismic response



Wedge Matrix

Wedge reflectivity matrix

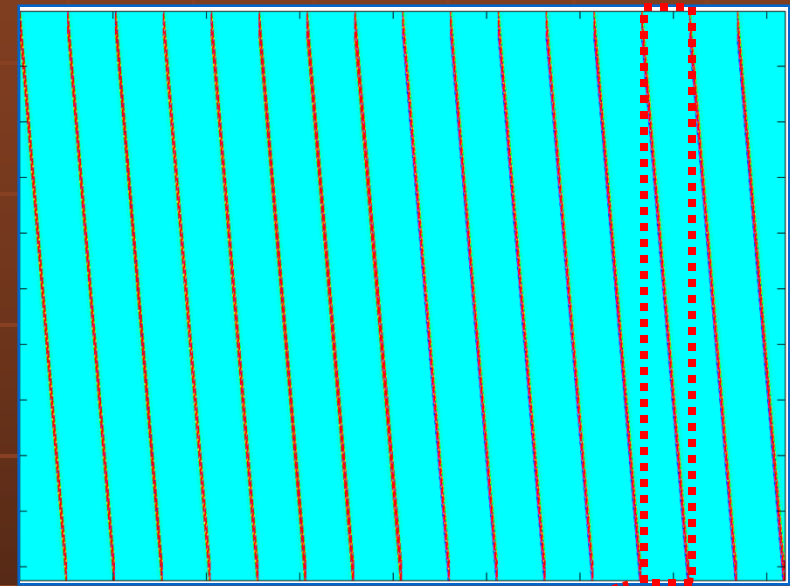
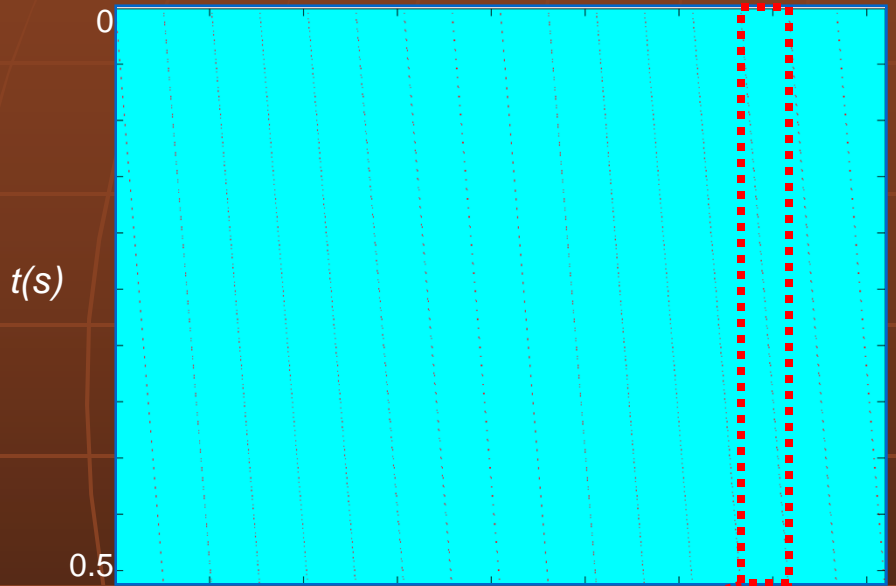
Even

Odd

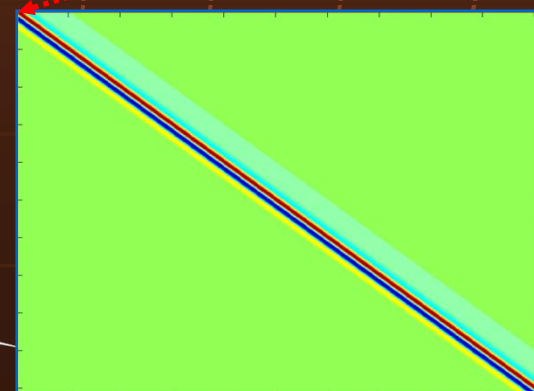
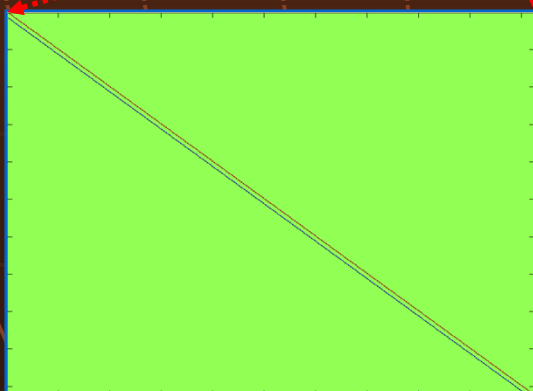
Wedge waveform matrix

Even

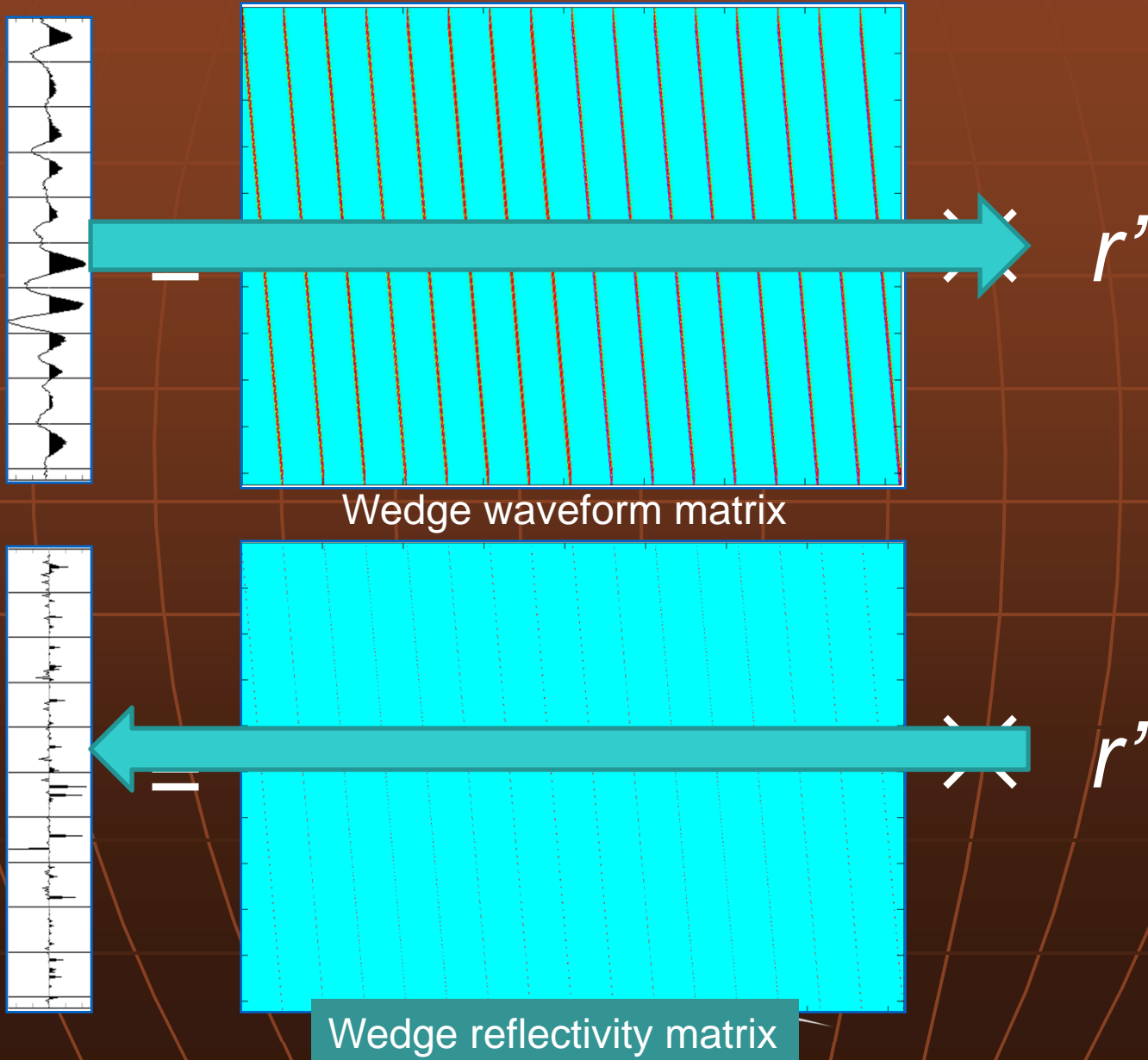
Odd



1 8 1 8



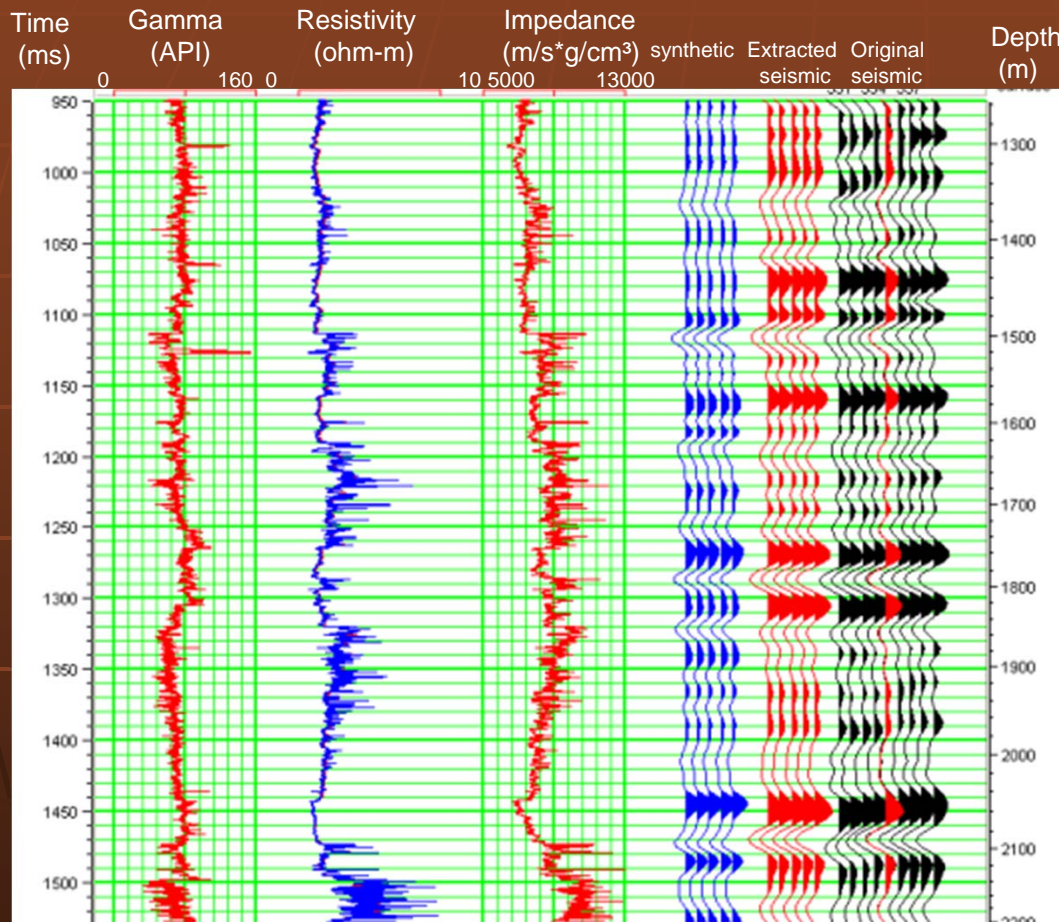
Wedge Matrix



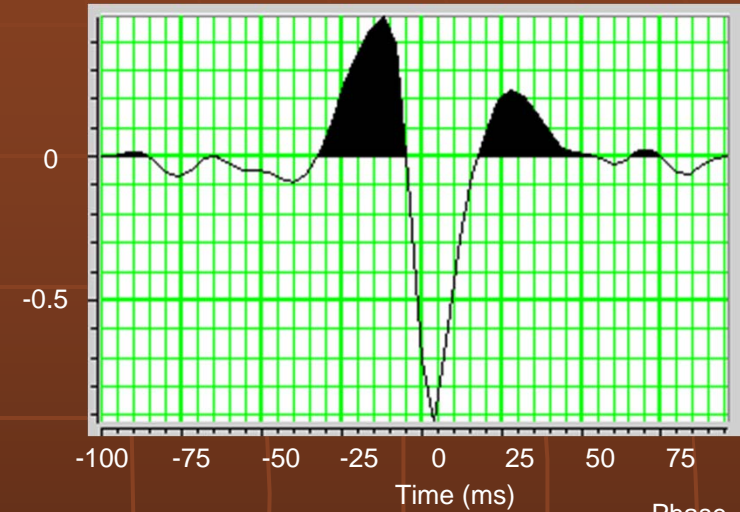
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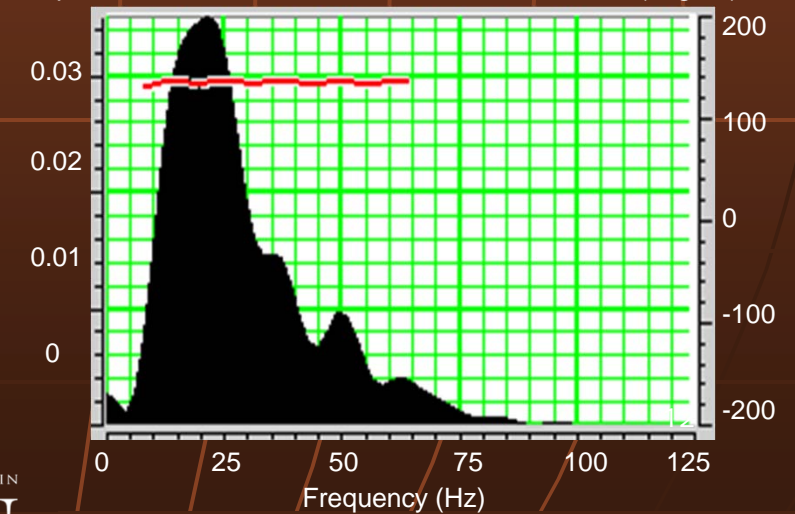
Seismic Well Tie



Amplitude



Amplitude

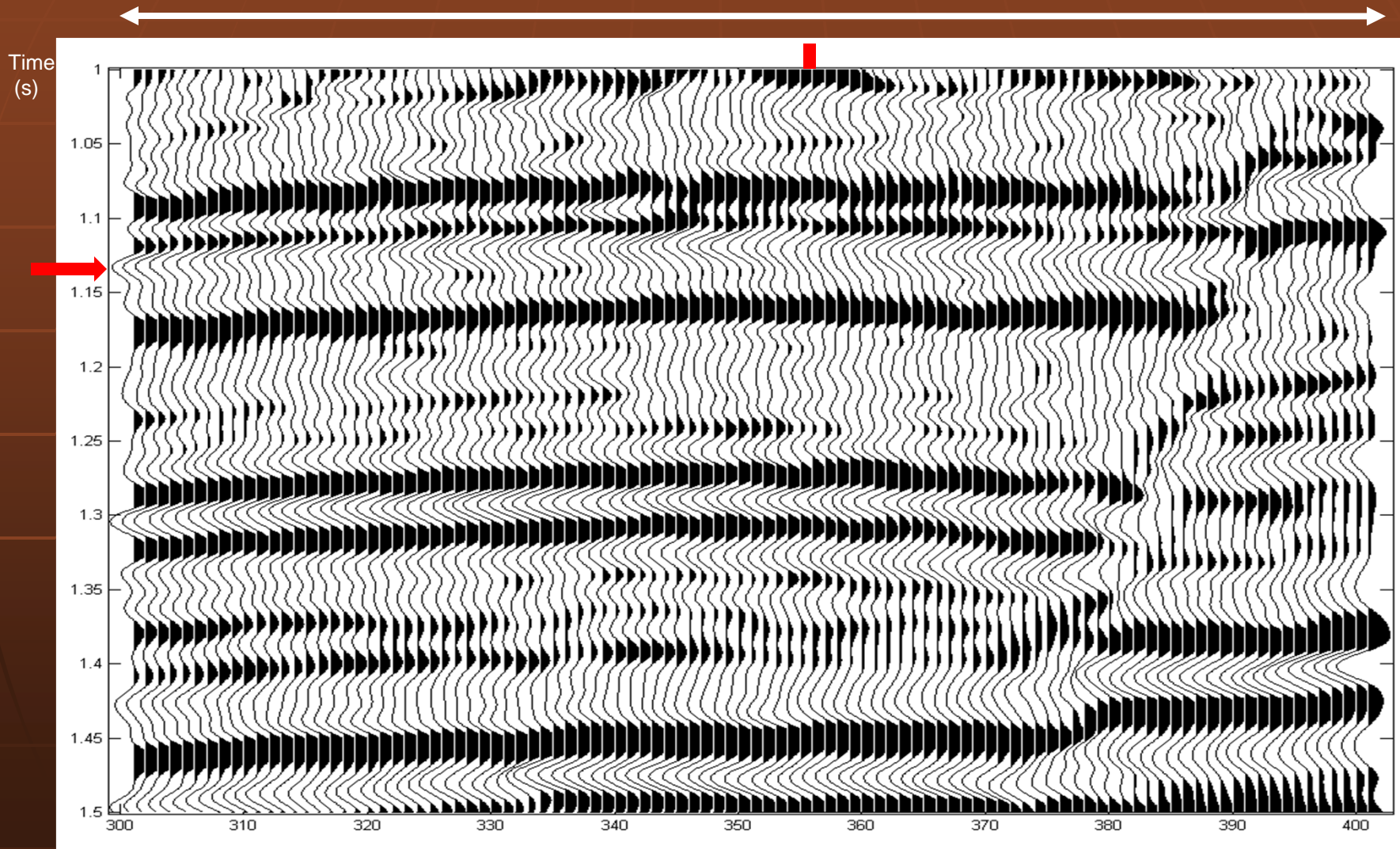


Phase (degree)

Correlation=0.78

Original Seismic

3000m



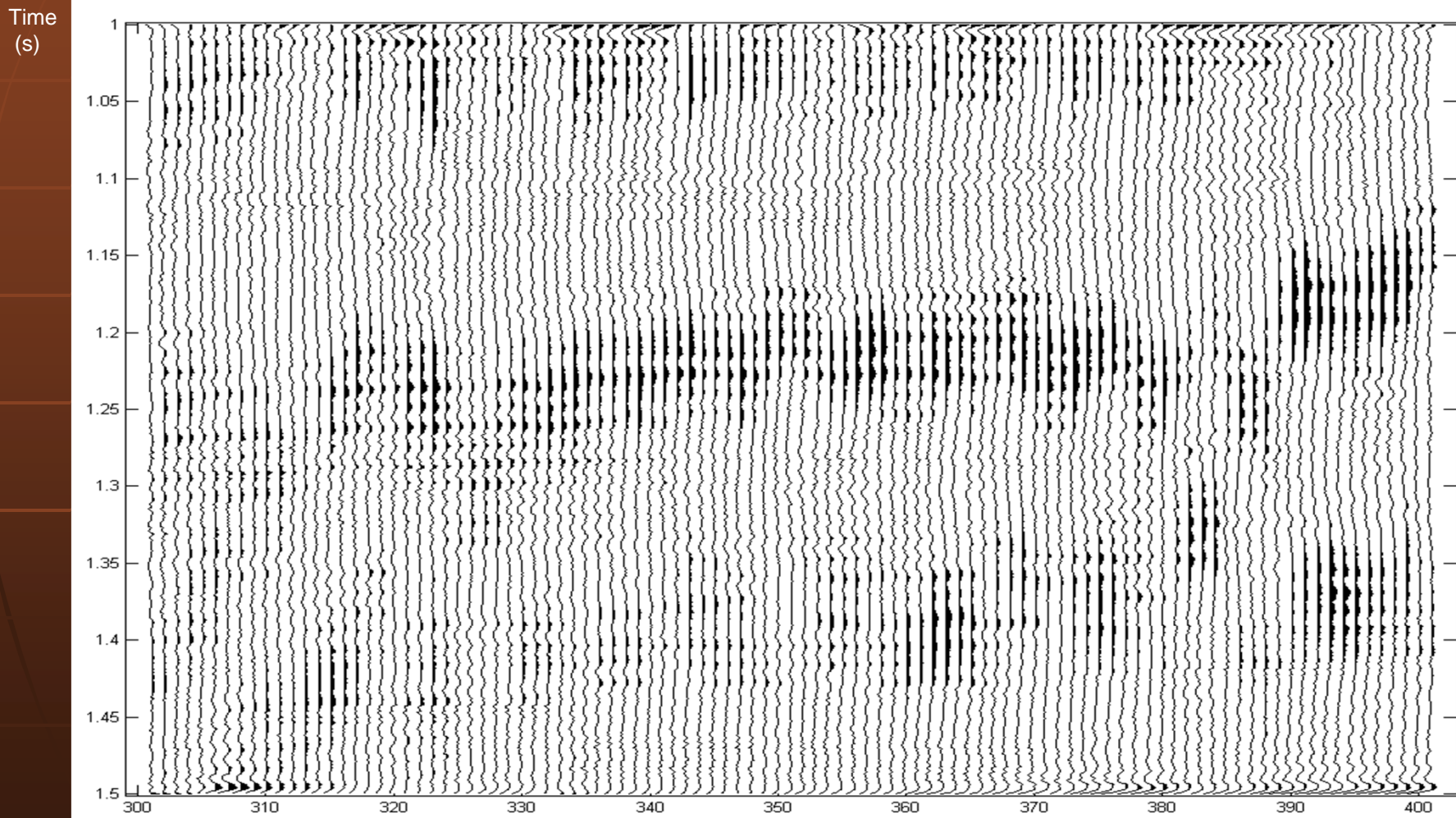
$$RMS = 6.1 \times 10^4$$

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BPI inverted RC



Residuals

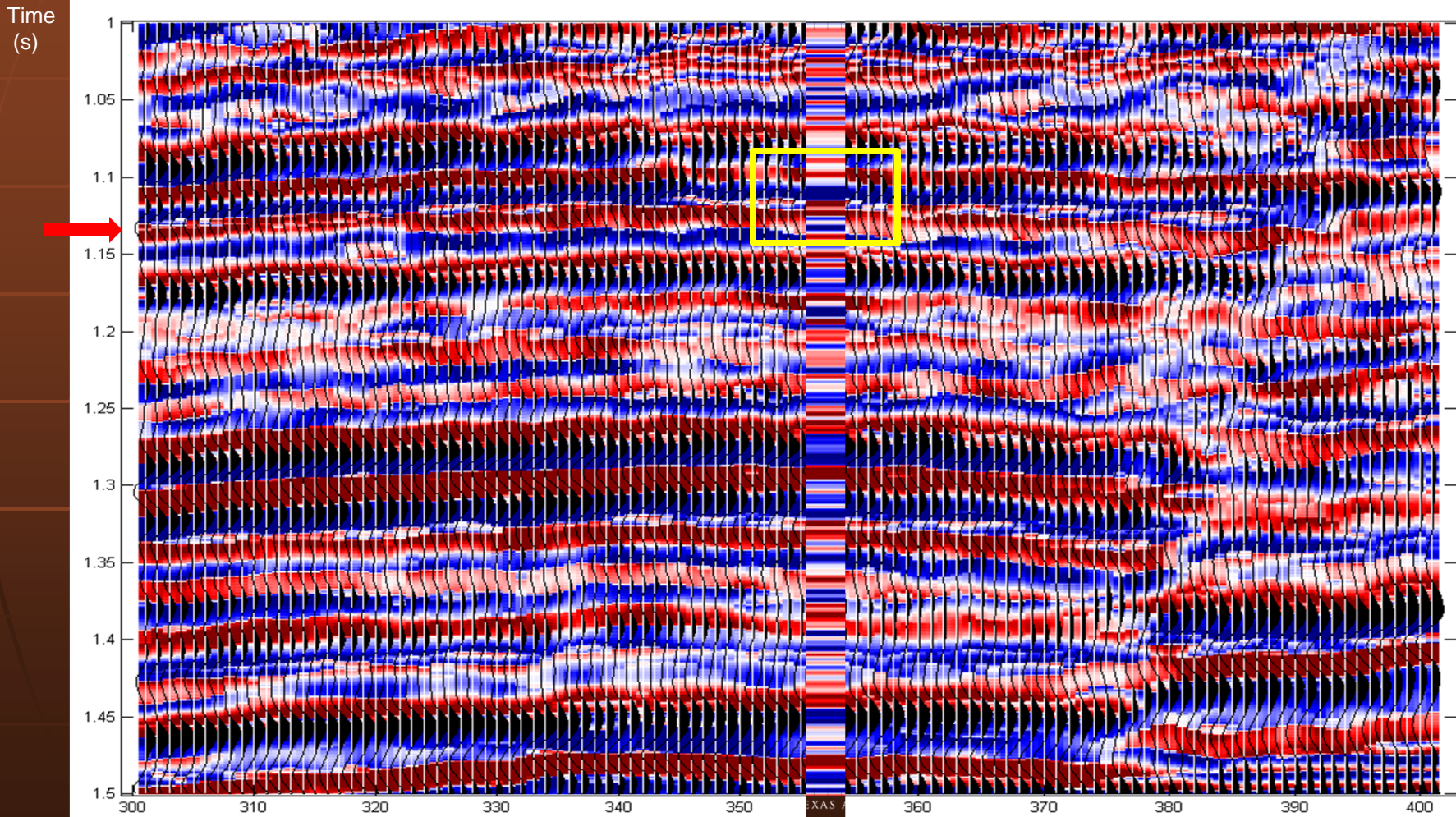


$$RMS = 2.2 \times 10^3$$

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BPI inverted Impedance

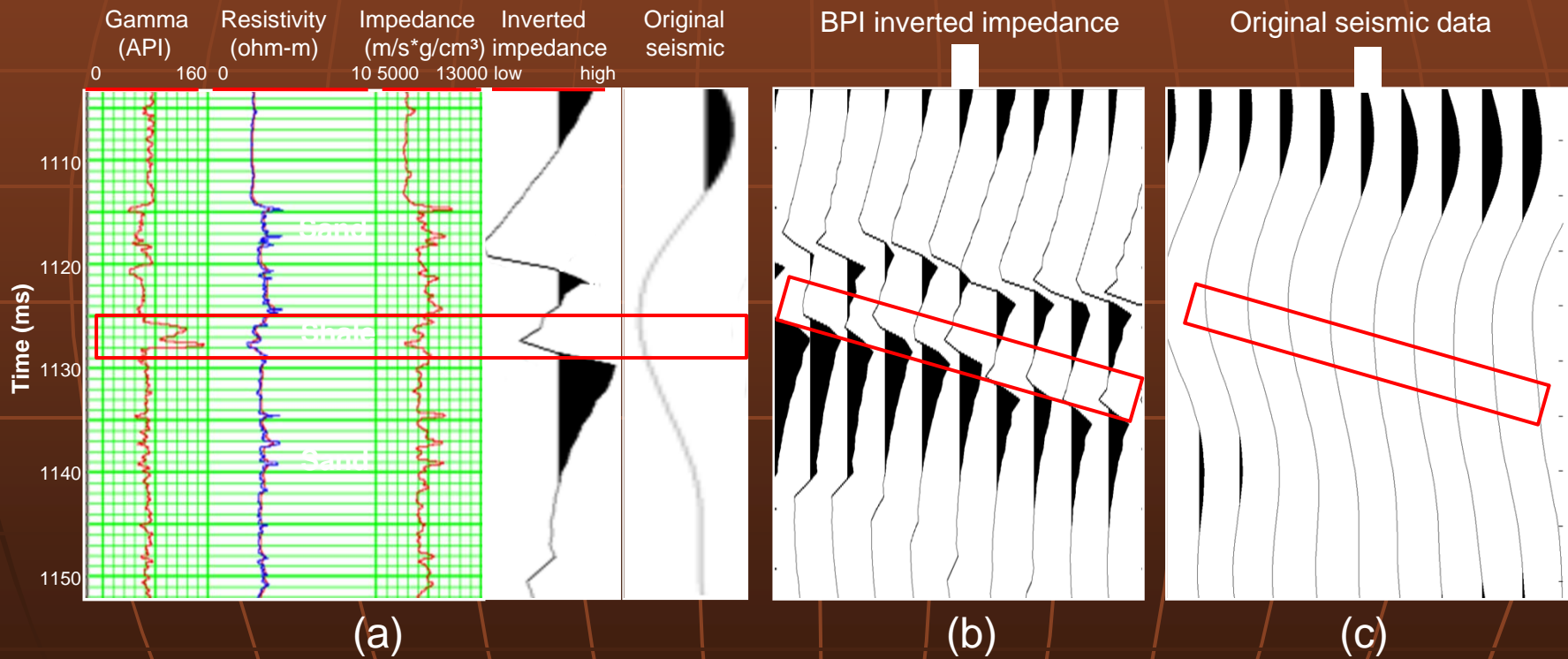
Well-log



$$\int RI = e^{2 \int RC(t) dt}$$

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BPI inverted Impedance

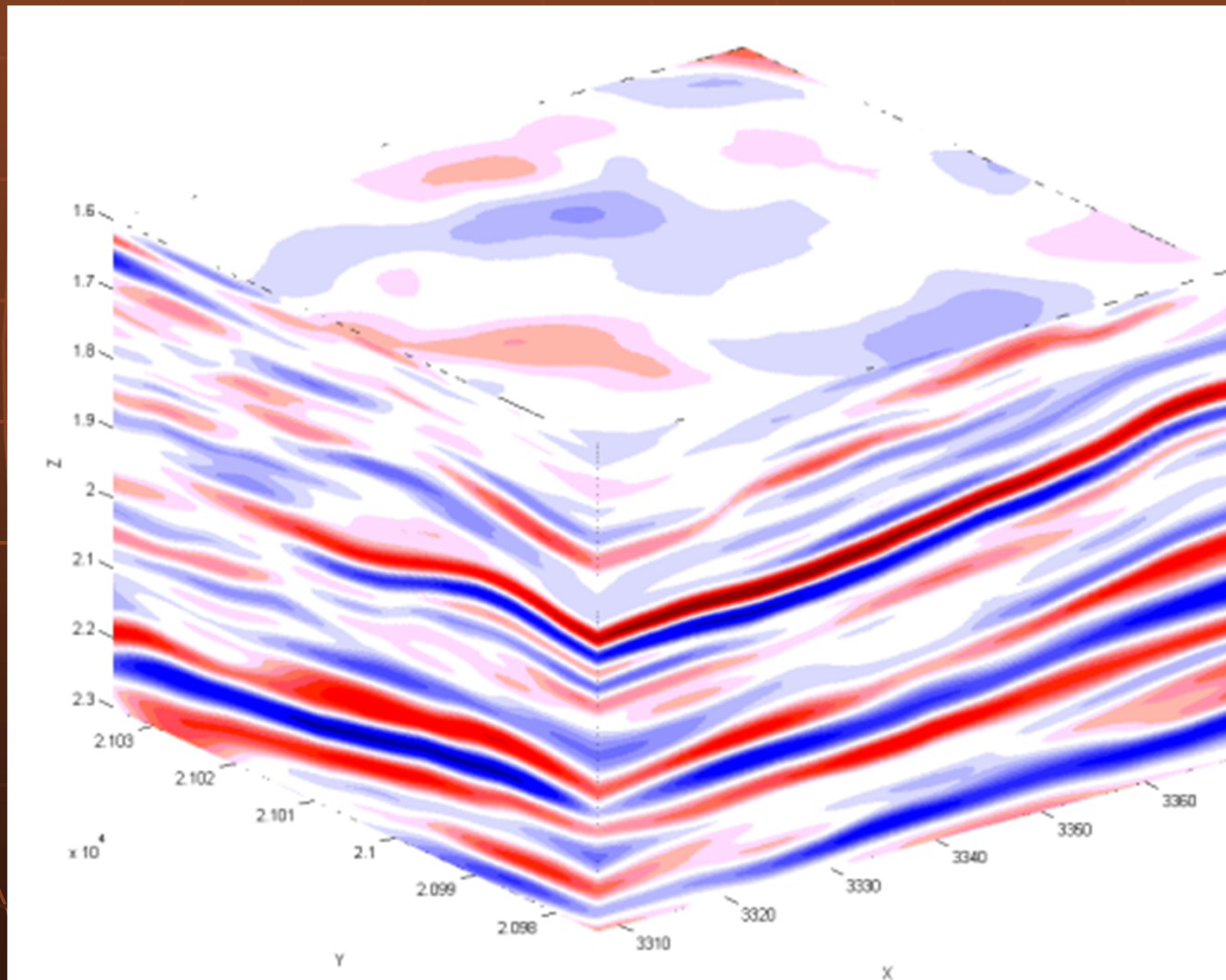


■ : Well-log location

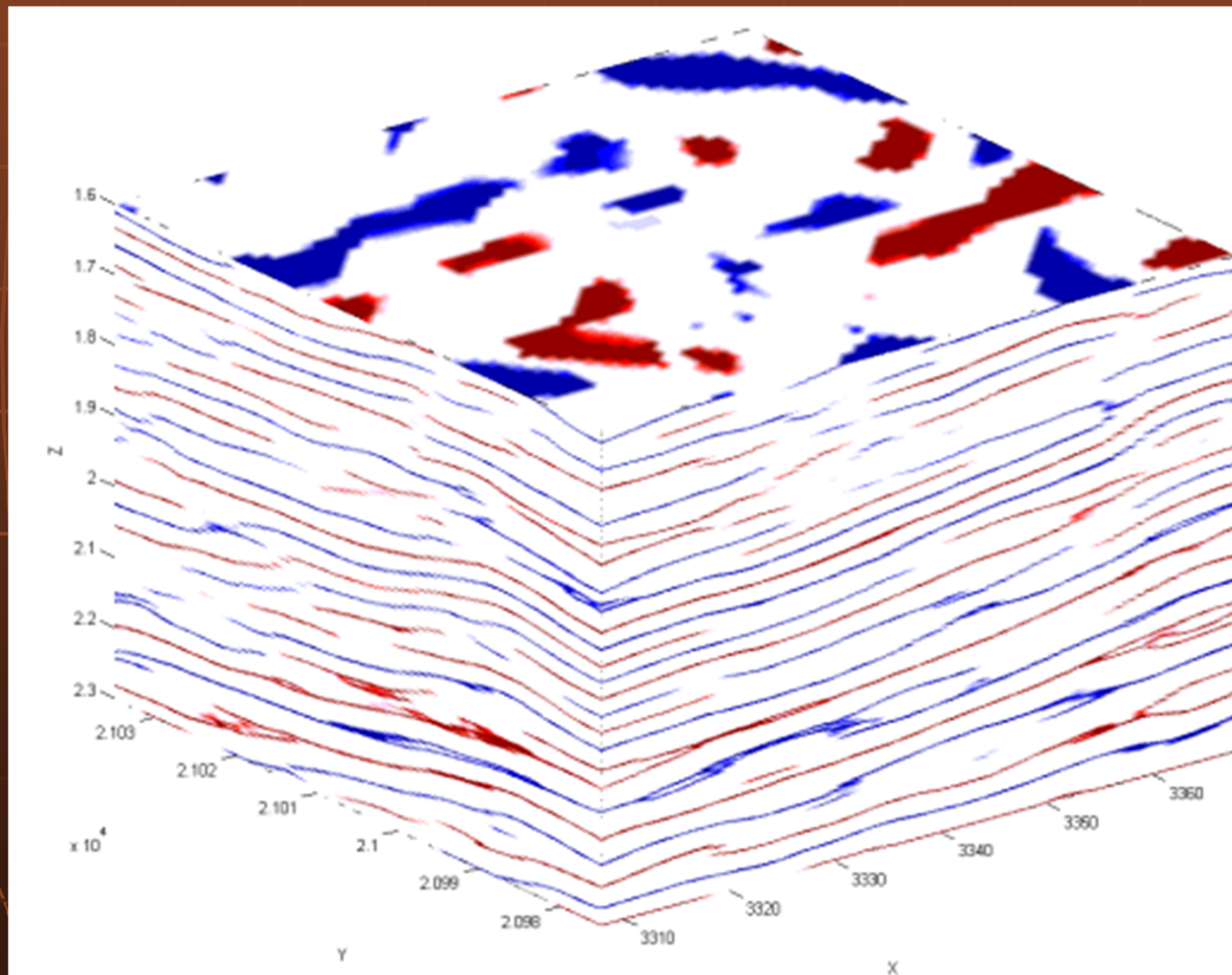
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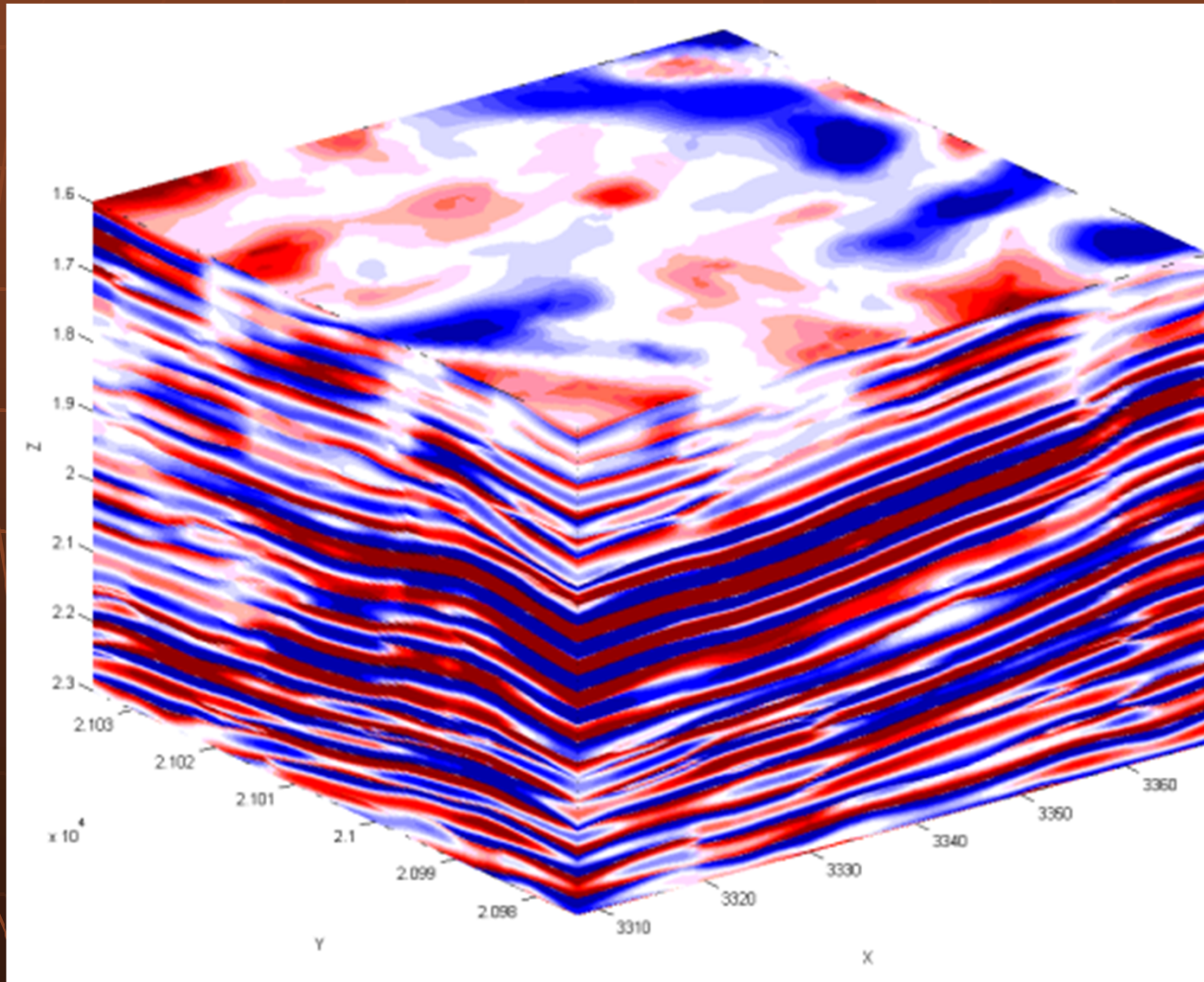
3-D Dataset



3-D RC

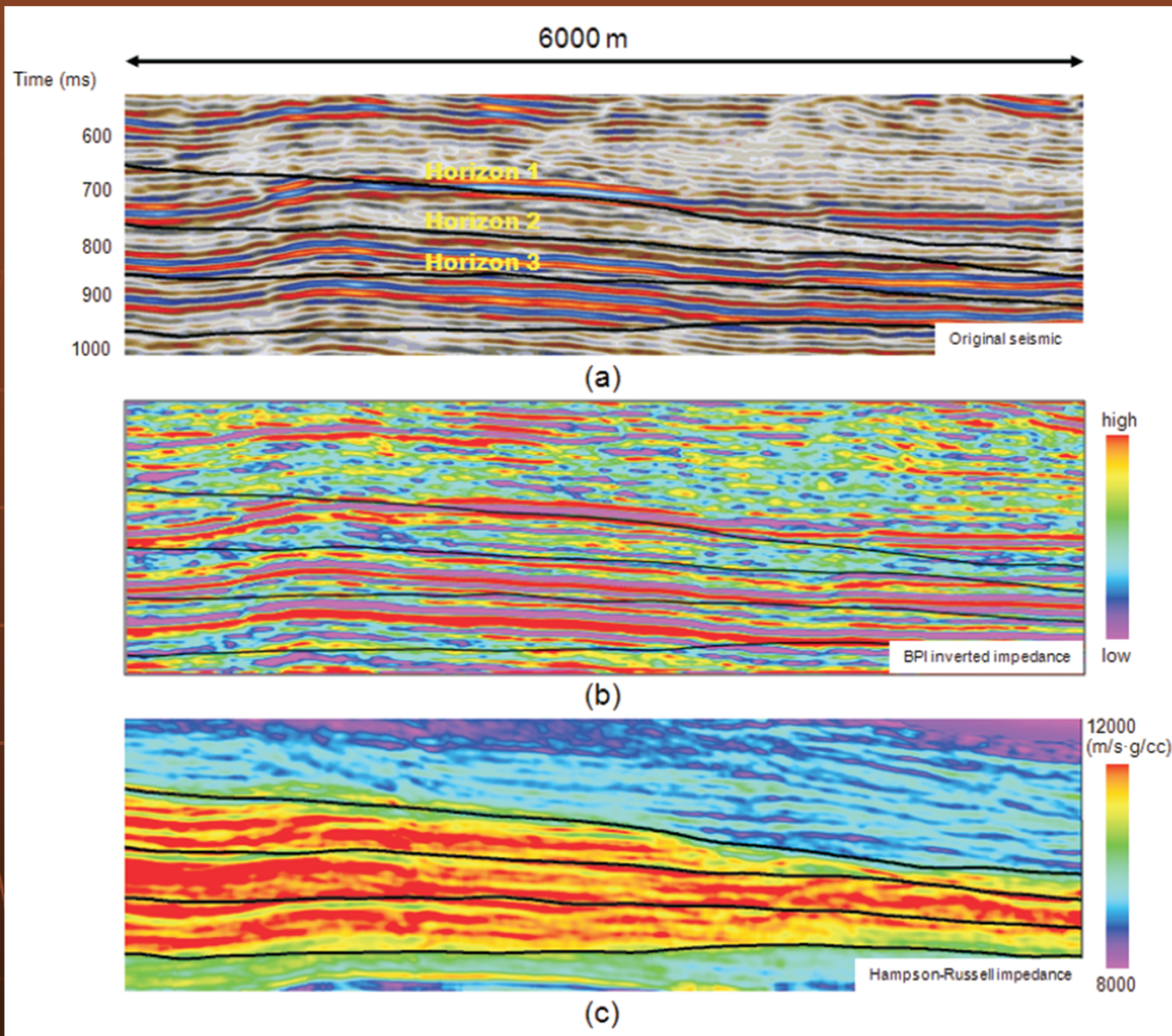


3-D RI

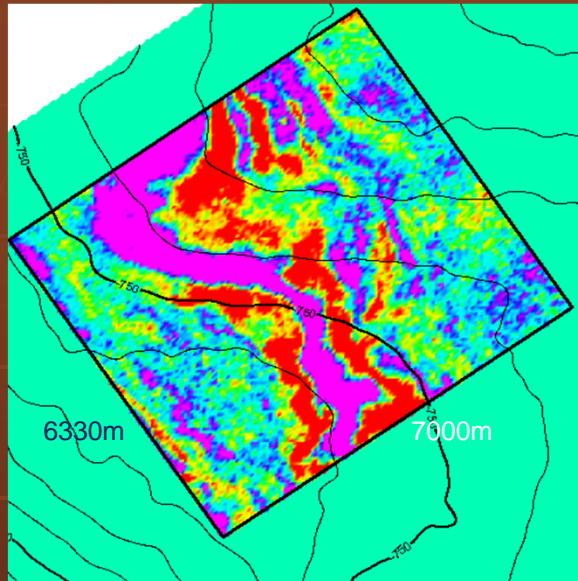


Outline

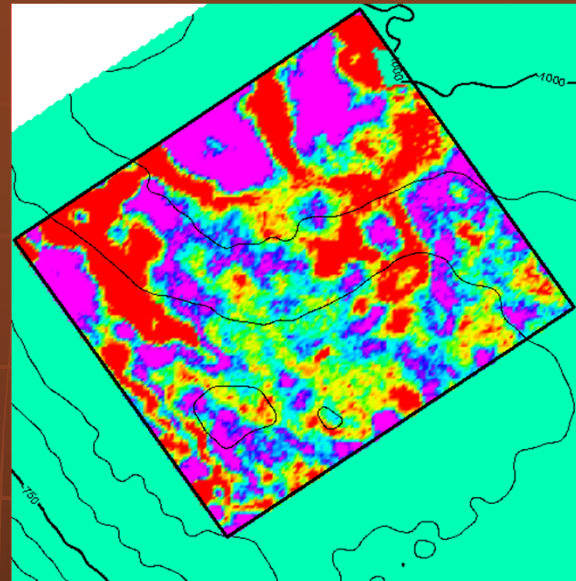
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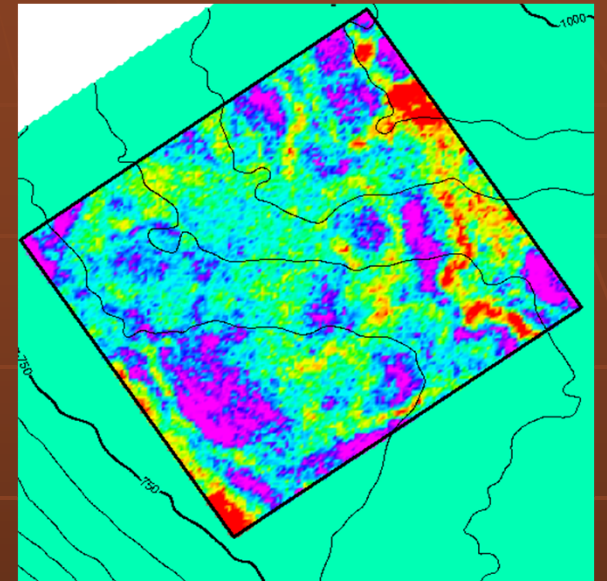
Horizon Slices



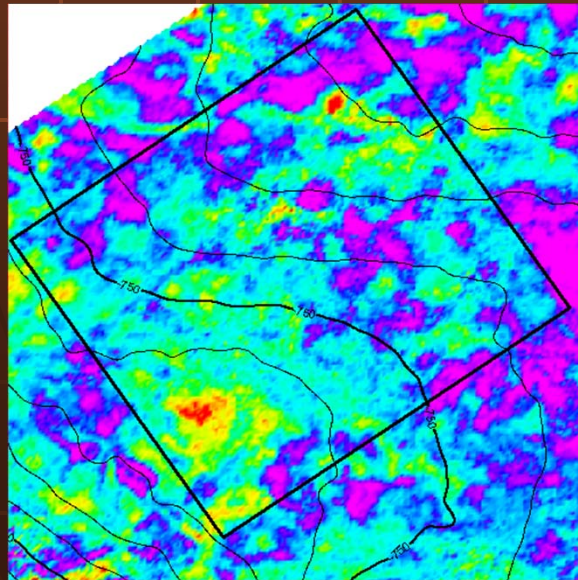
(a)



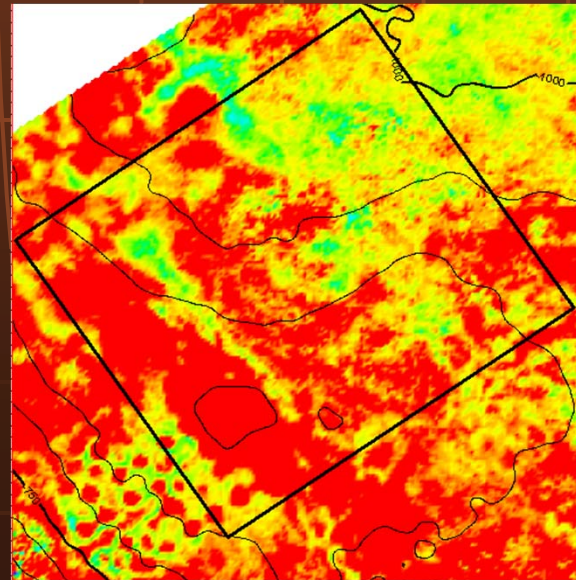
(b)



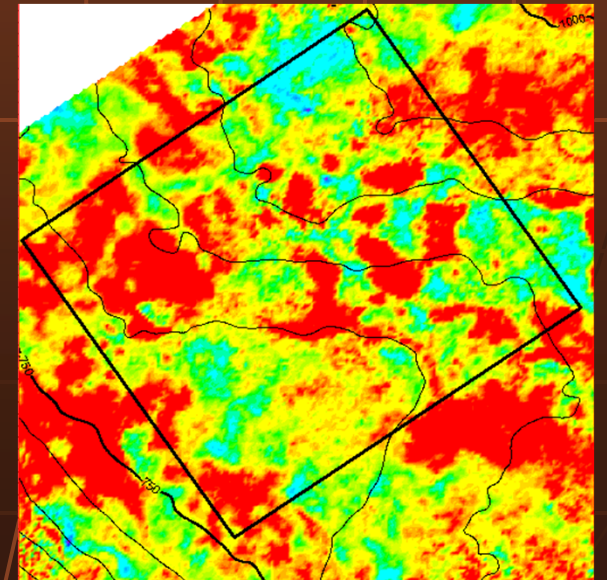
(c)



(d)



(e)

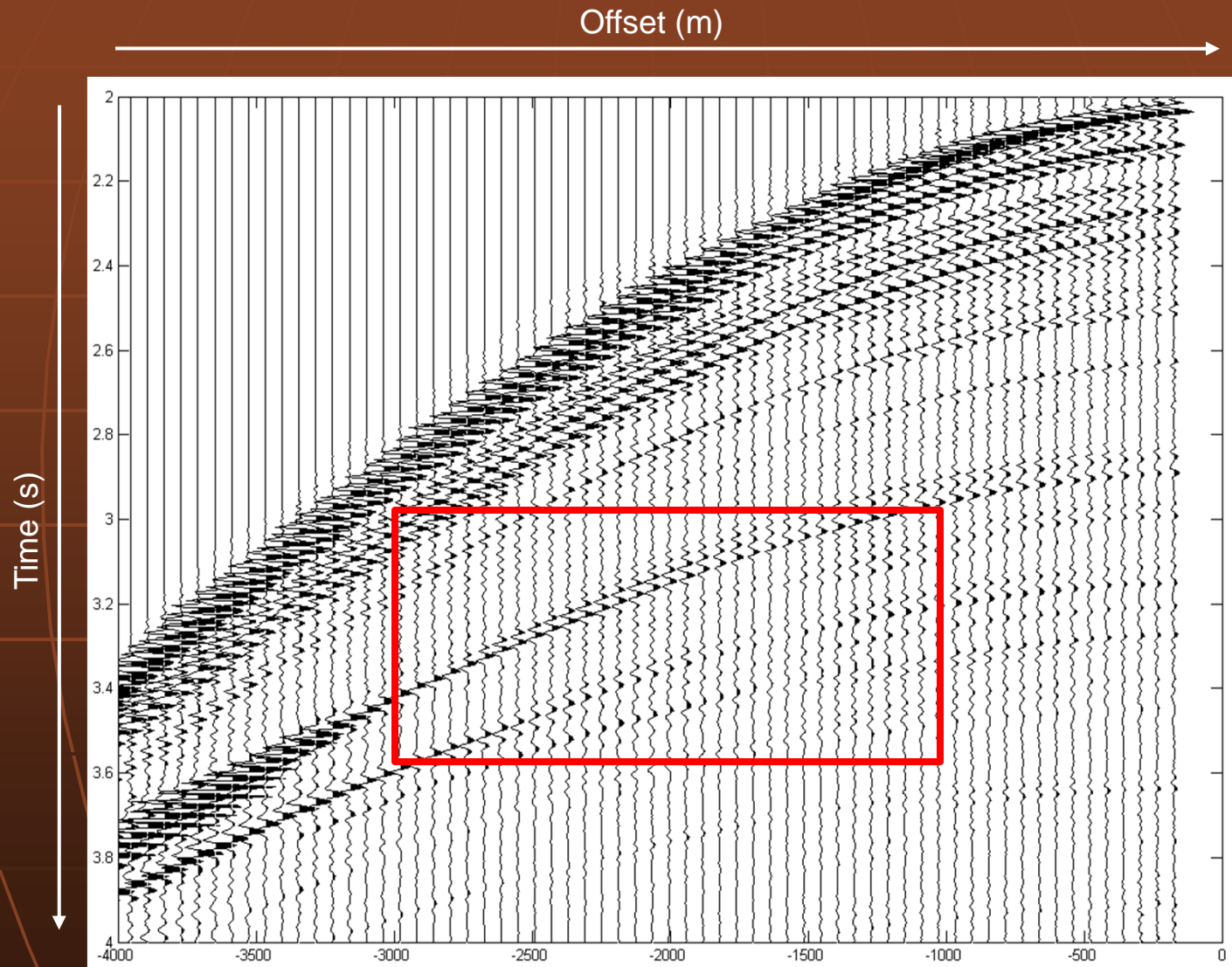


(f)

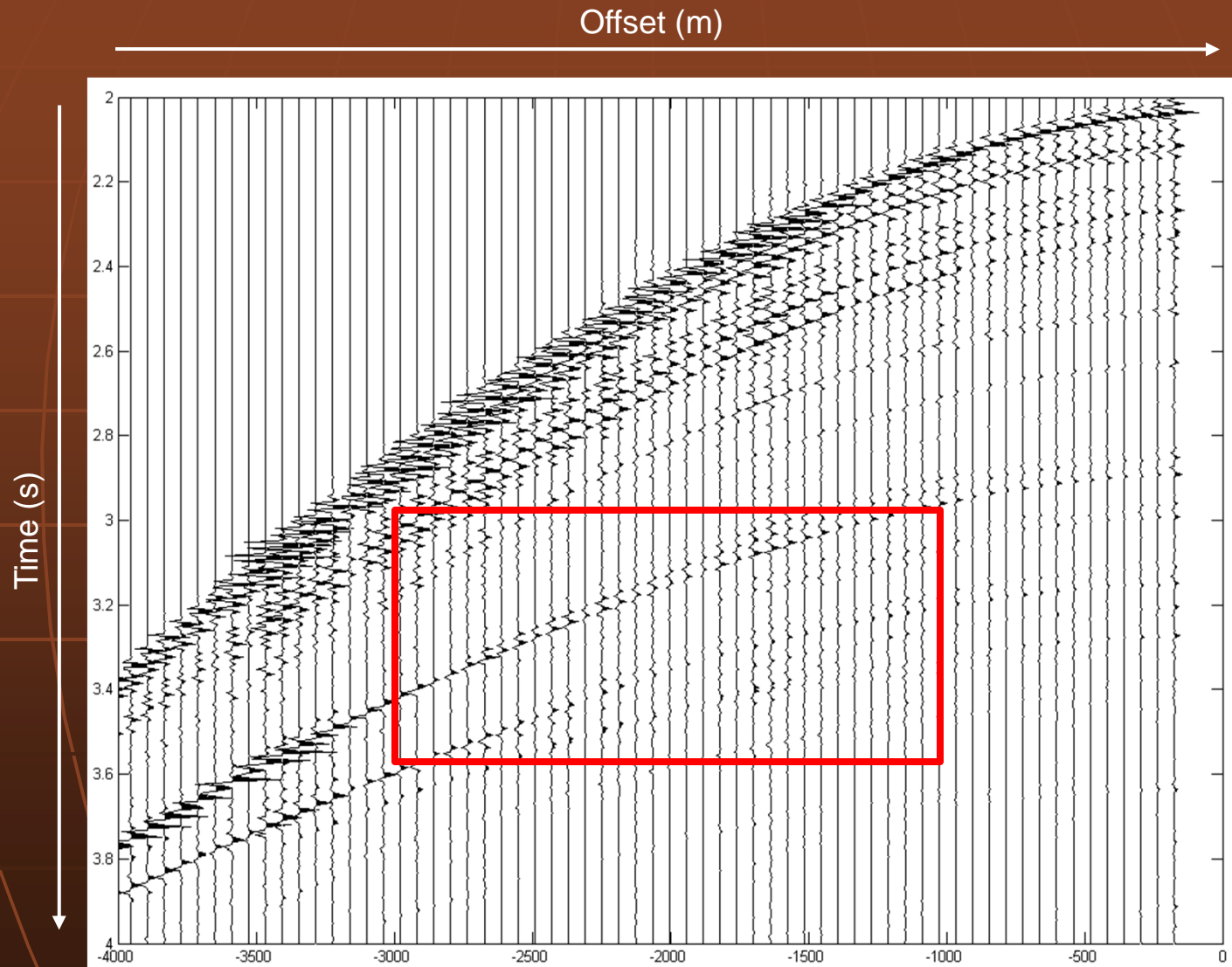
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Original CDP Gather

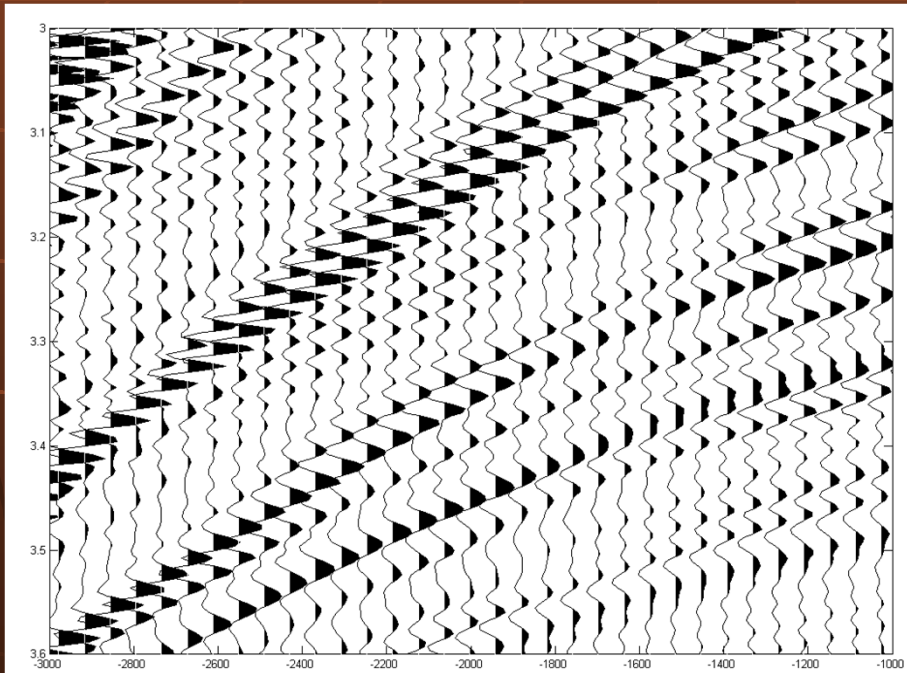


BPI inverted Gather



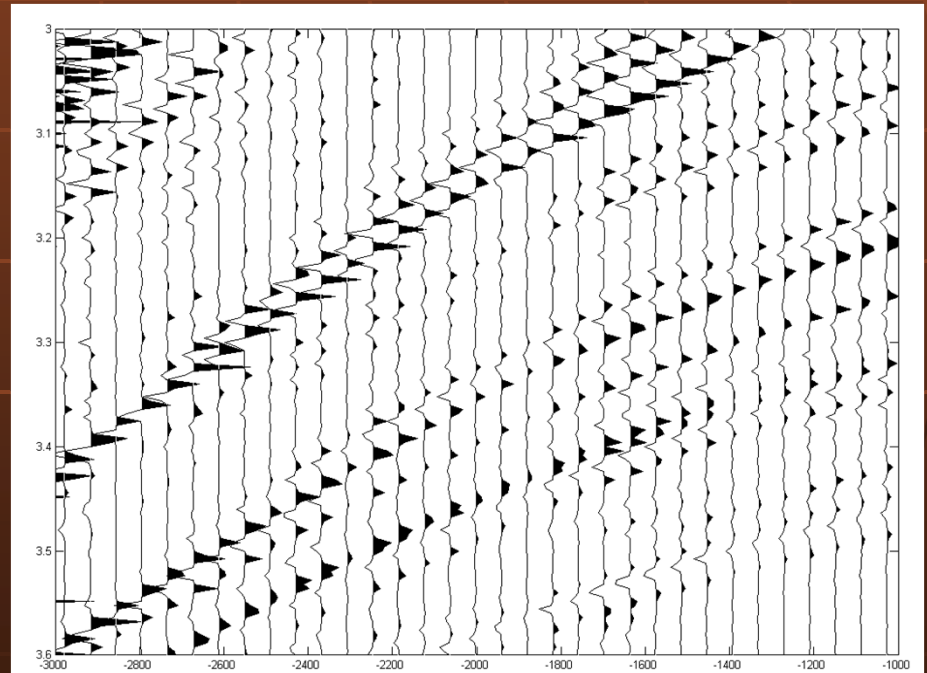
Comparison of Gathers

Original CDP gather



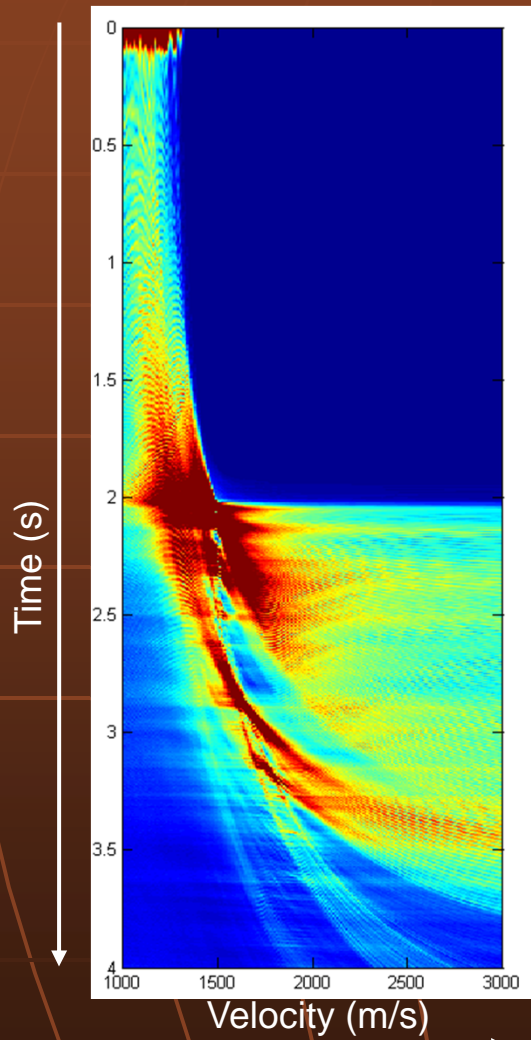
(a)

BPI inverted results

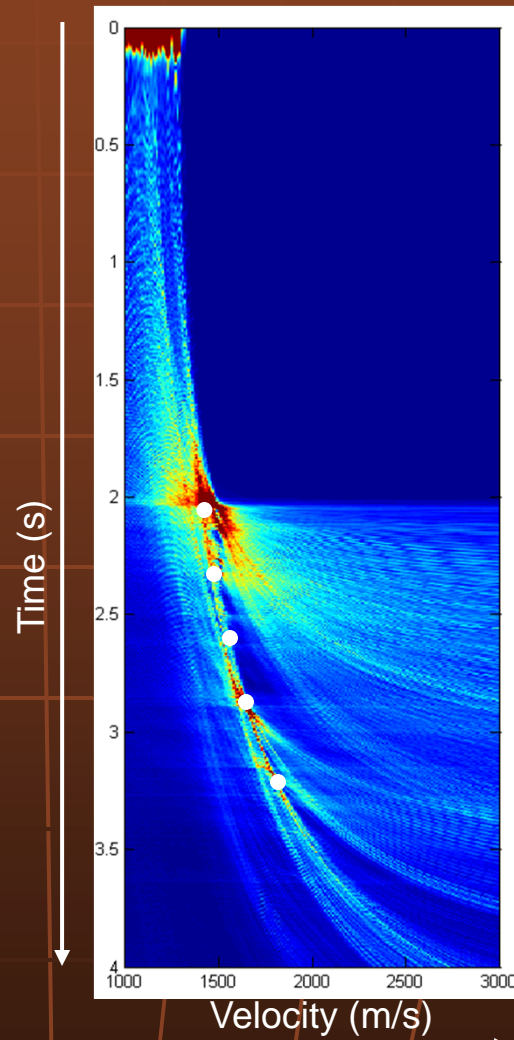


(b)

Comparison of Semblance



(a)

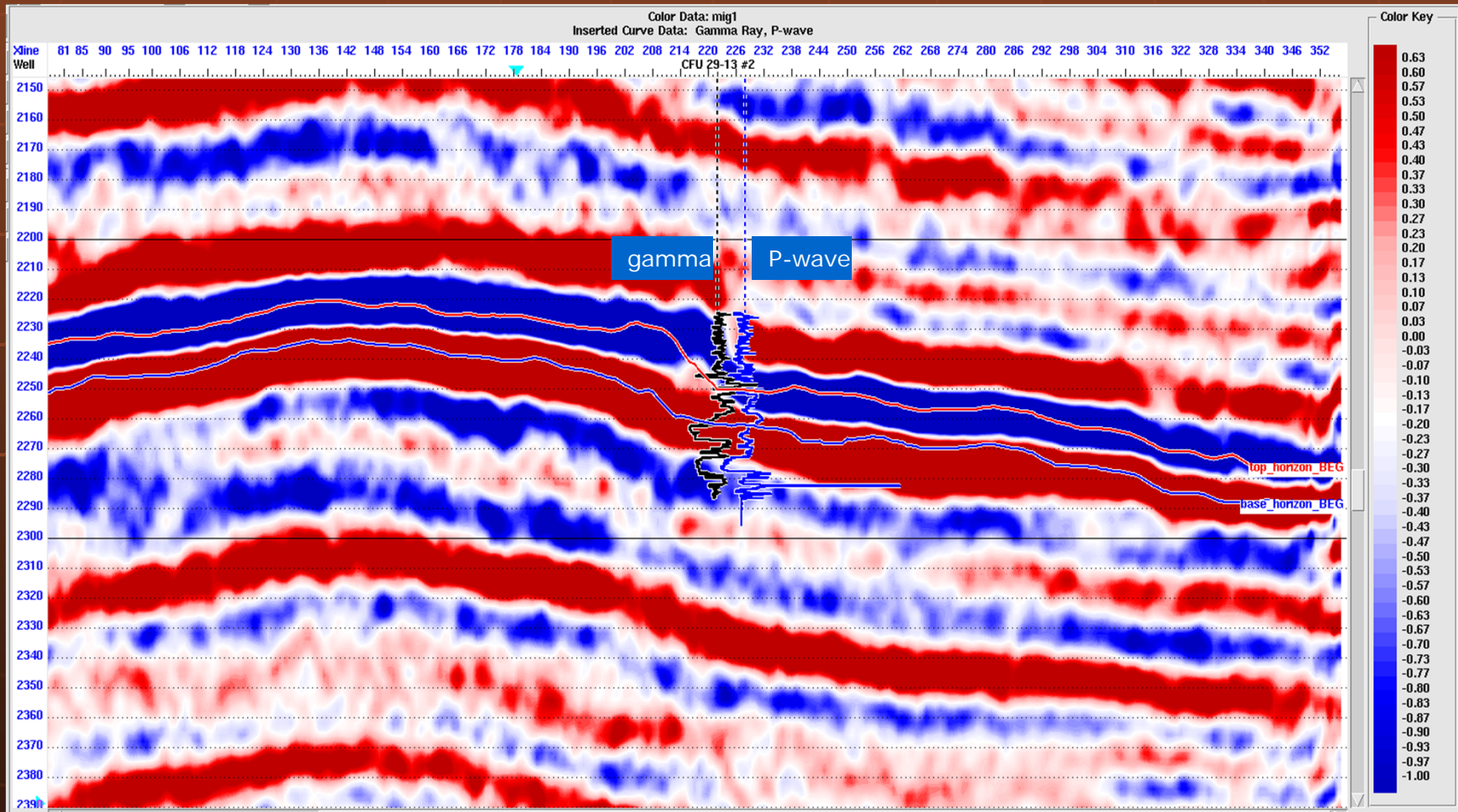


(b)

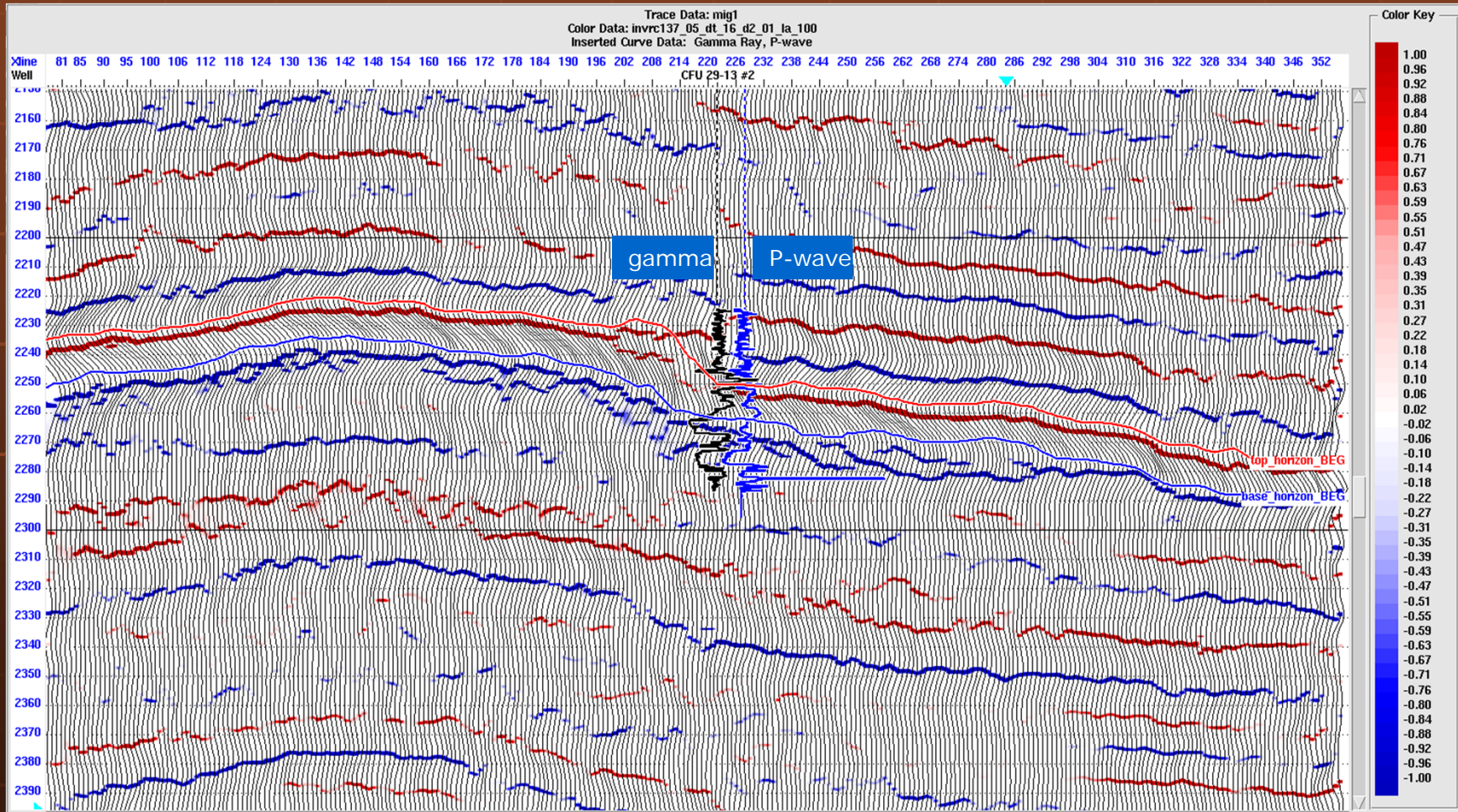
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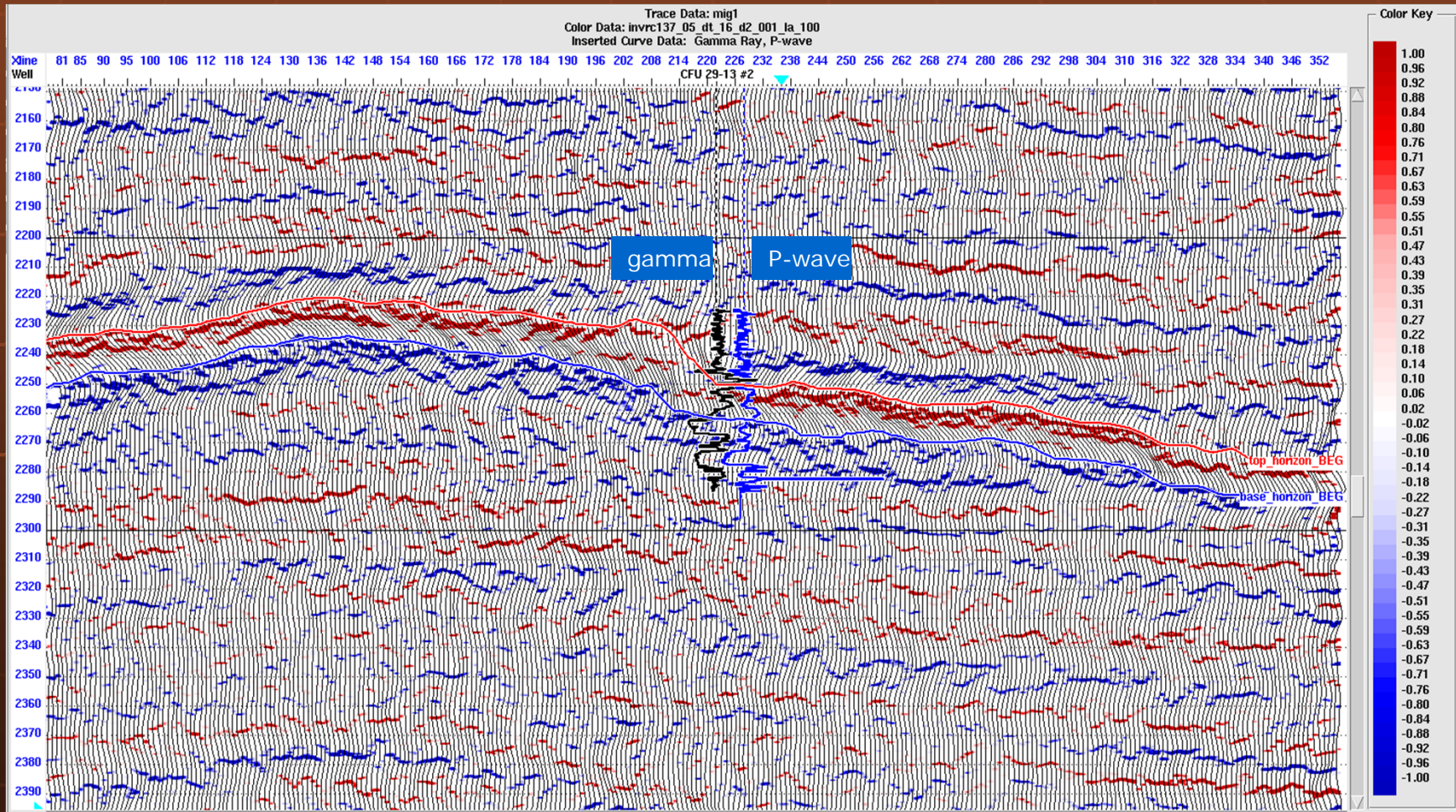
Crane field data



Crane field data-RC1



Crane field data-RC2



Conclusions

- BPI can produce spiky reflectivity and broadband relative impedance
- Wedge model is incorporated as basis
- Trade-off factor balances the resolution with noise level, best λ comes from tests.
- Speed

Future Work

- Migrate to Fortran and parallel
- Lateral continuity
- Incorporate with starting model
- Implementations with AVA inversion

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