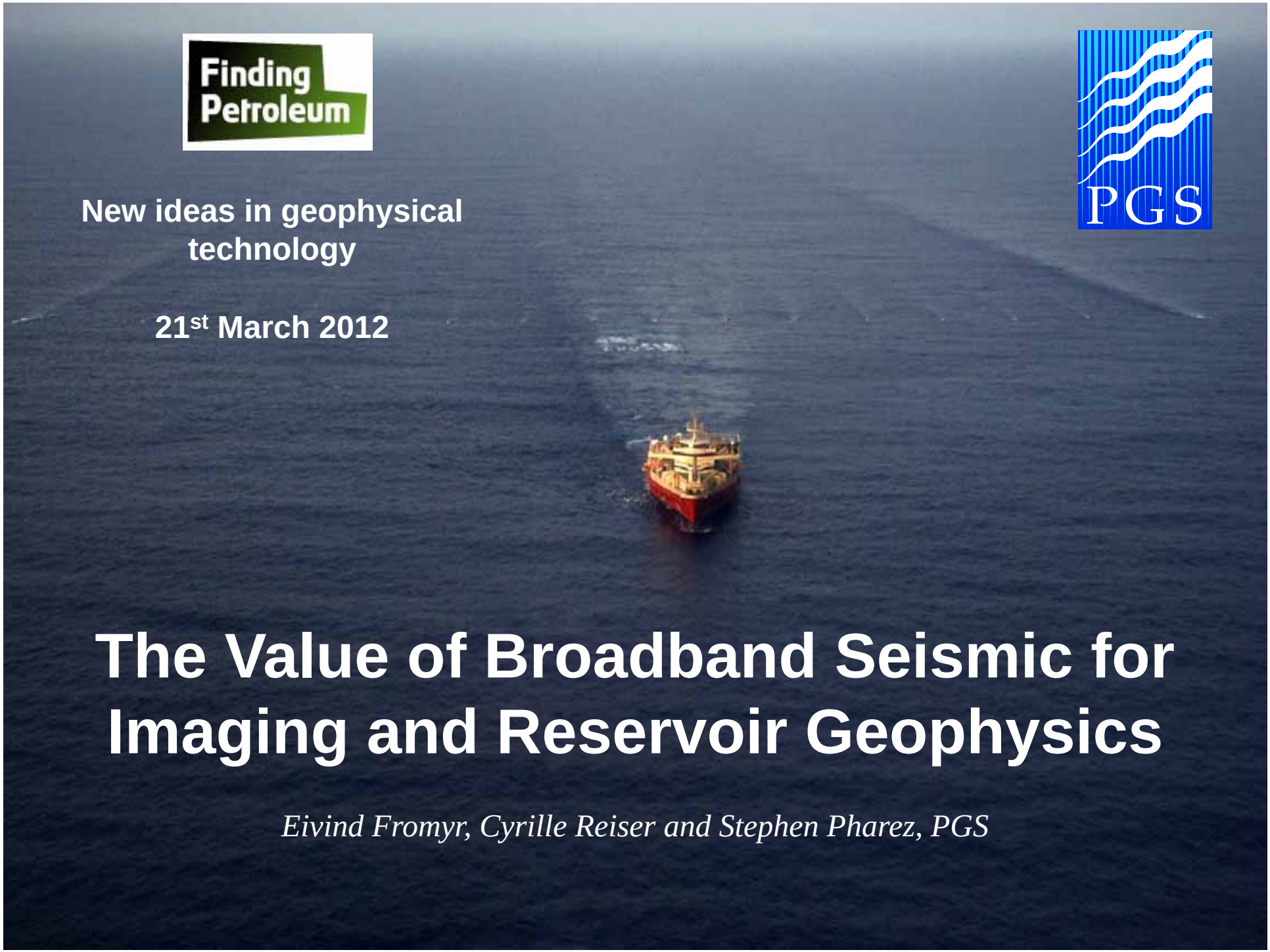


Finding Petroleum

PGS

New ideas in geophysical technology

21st March 2012

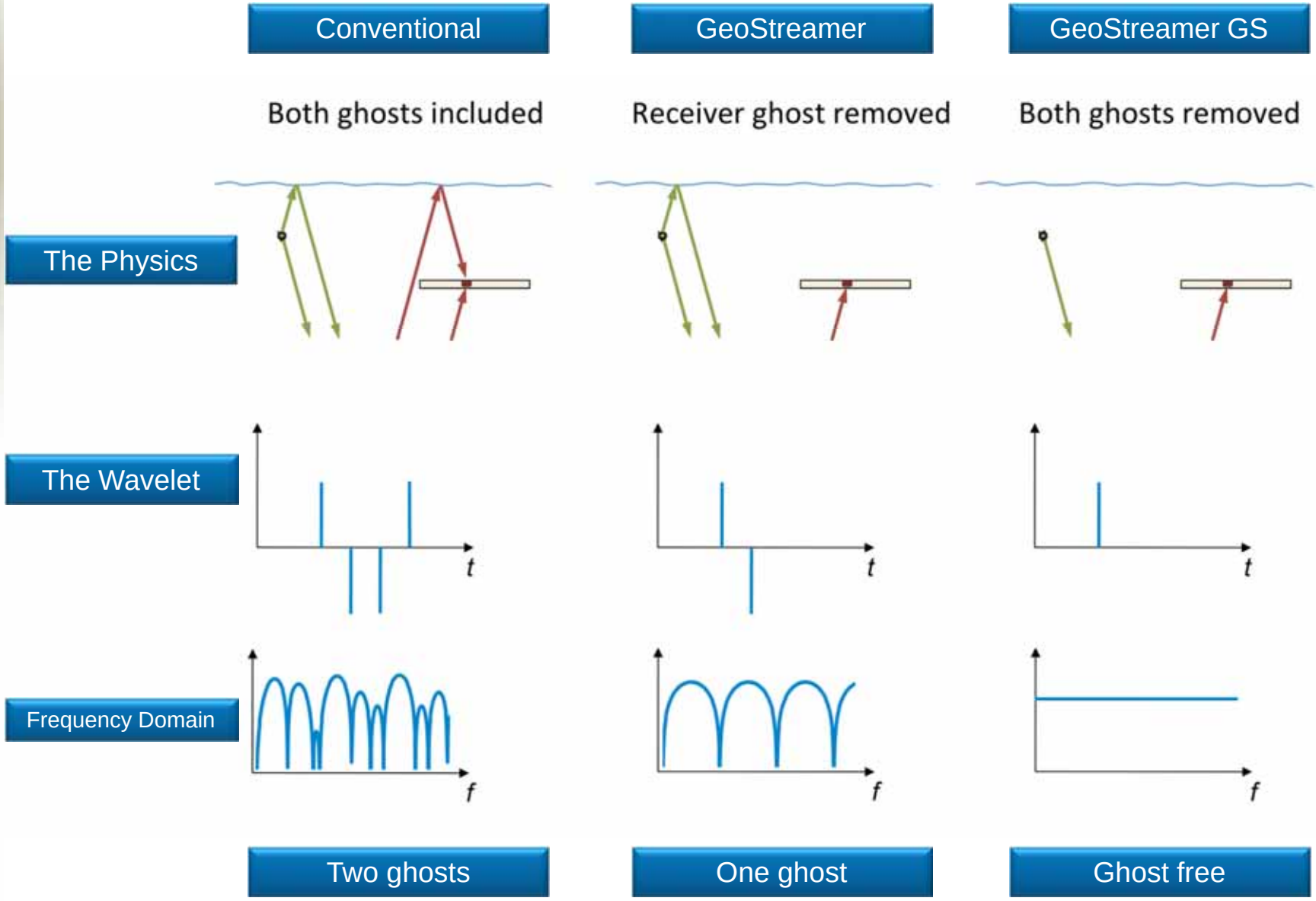
The Value of Broadband Seismic for Imaging and Reservoir Geophysics

Eivind Fromyr, Cyrille Reiser and Stephen Pharez, PGS

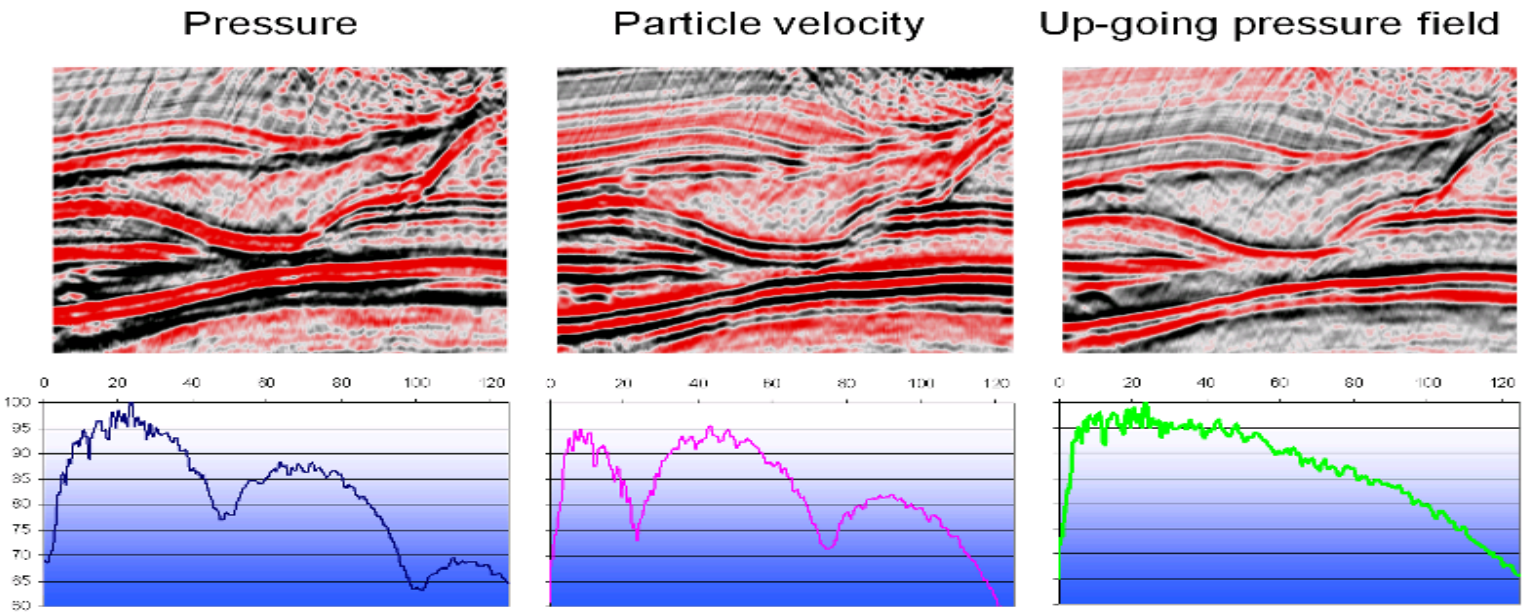
Outline

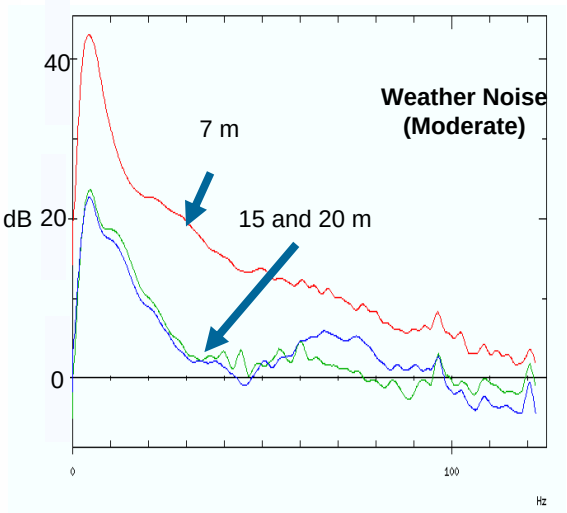
- Introduction
- GeoStreamer
  - Impact of the sea surface reflection
  - Dual-sensor technology
  - Experience and data examples
  - Reservoir characterization
- What about the source side – GeoStreamer GS
  - Principles
  - Revealing the true earth response
  - Data examples
- Imaging with separated wavefields
- Towed streamer electromagnetics

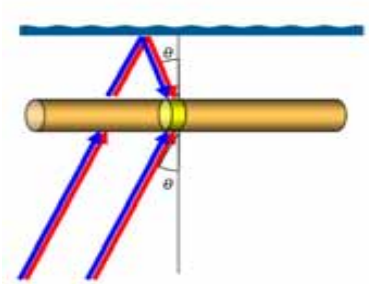
The motivation for new acquisition technology

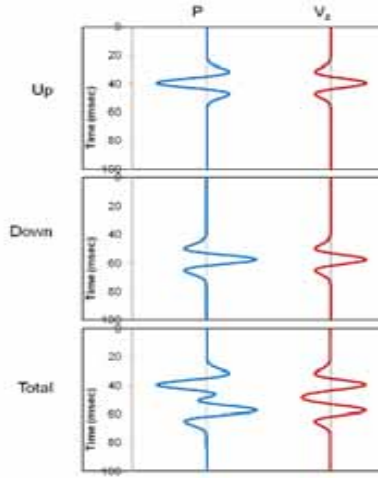


GeoStreamer – Removing the receiver ghost and separating the wavefield at the receiver





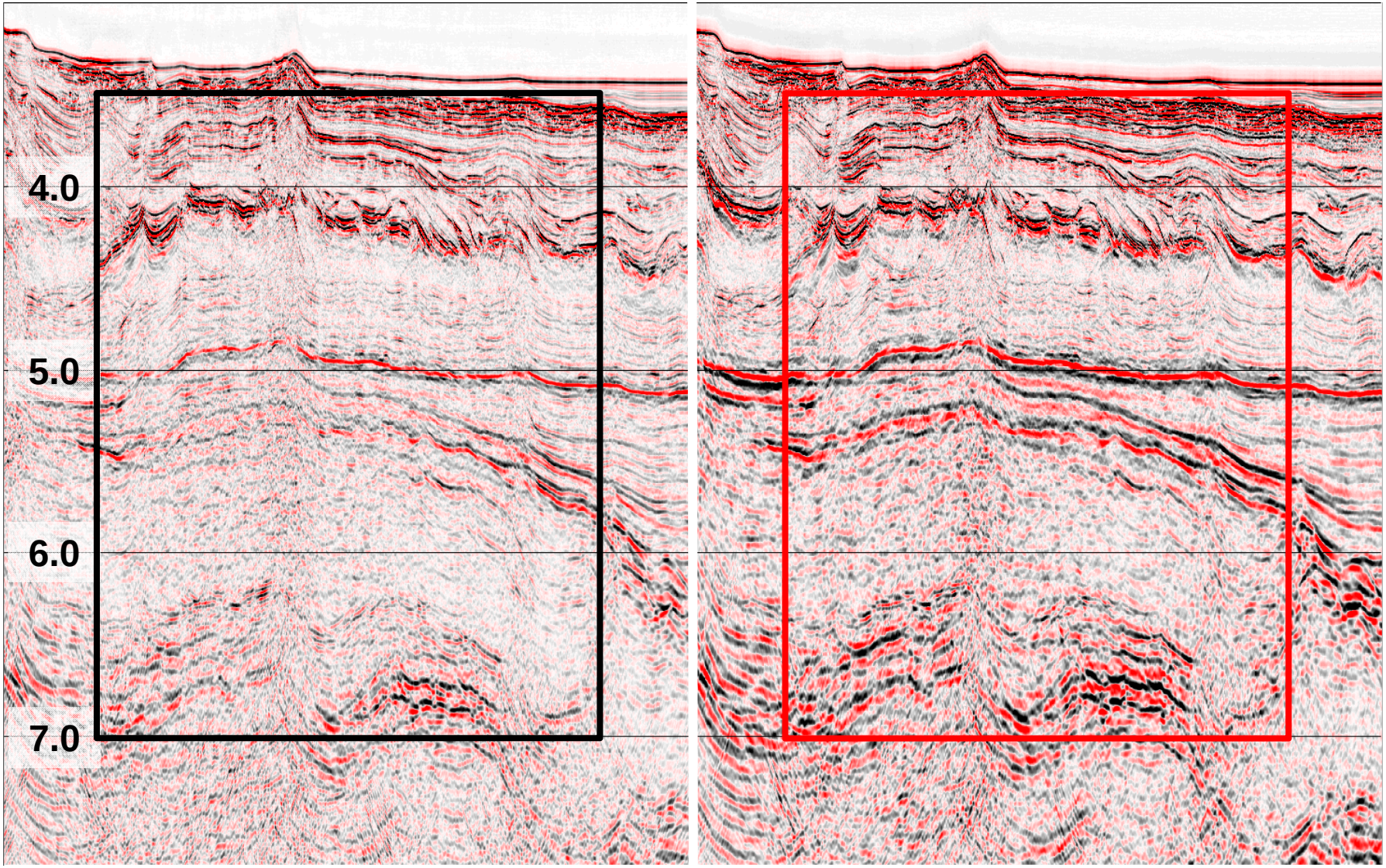




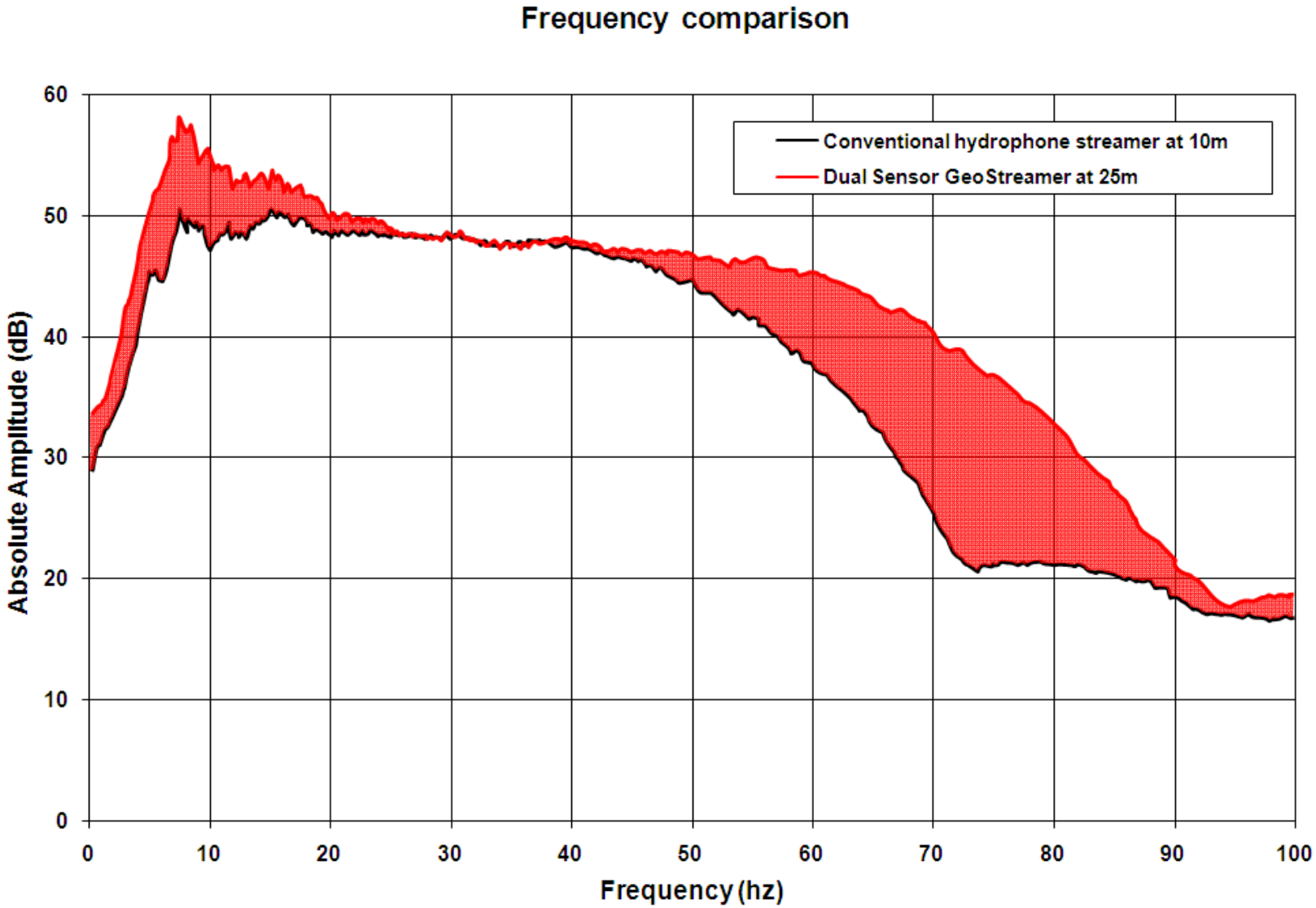
$$P^{up} = \frac{1}{2}\left(P - \frac{\rho c}{\cos\theta} V_z\right)$$

$$P^{down} = \frac{1}{2}\left(P + \frac{\rho c}{\cos\theta} V_z\right)$$

Direct comparison, 10m vs. 25m



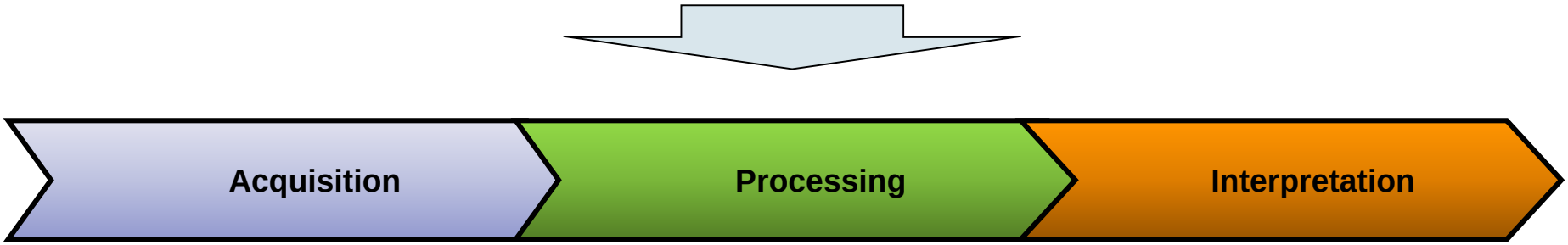
Amplitude spectrum comparison 10m vs. 25m



GeoStreamer benefits throughout the value chain

- Colocated pressure and velocity sensors
- Deep Tow

- Wave-field separation
  - Up and downgoing P and V



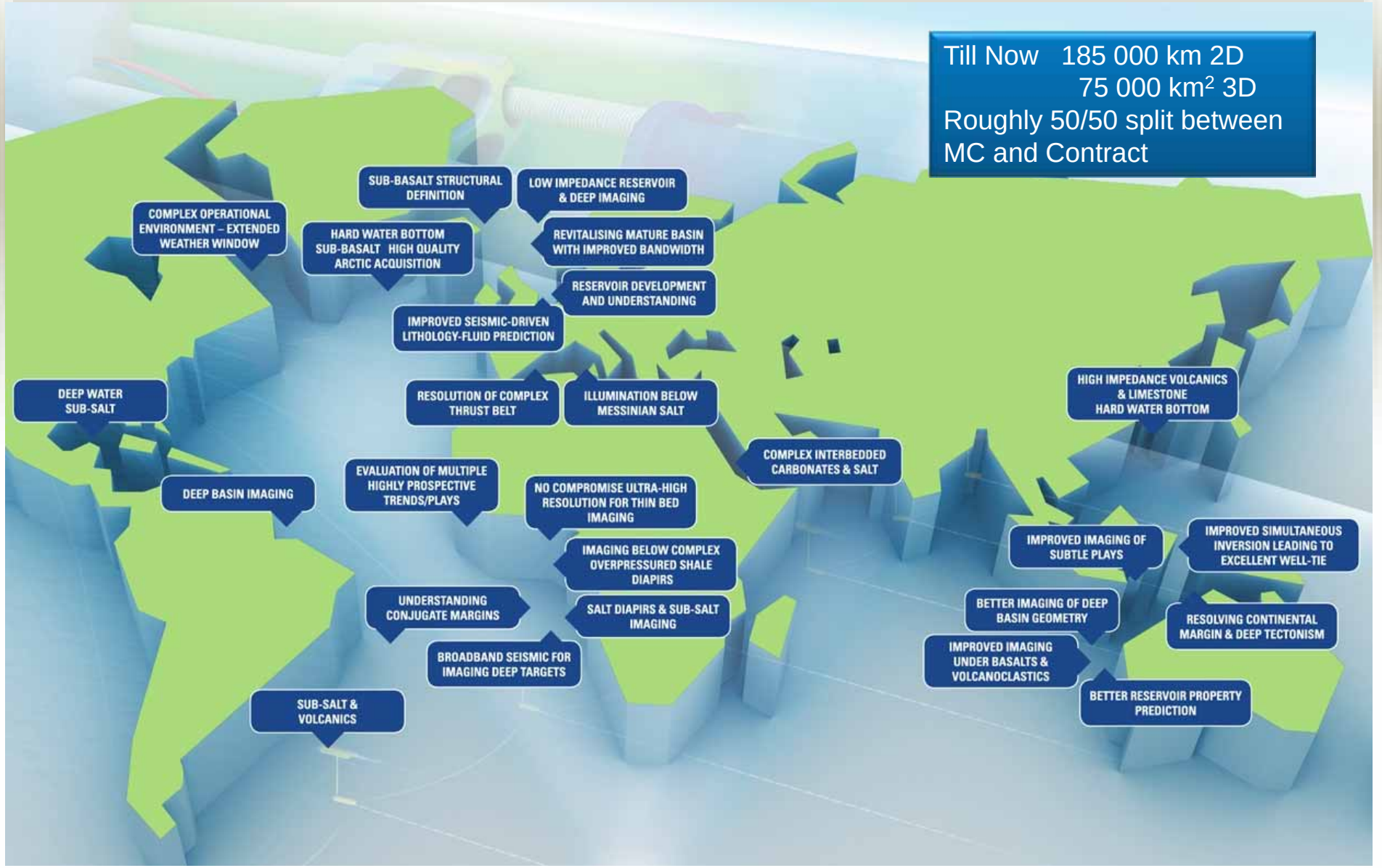
- Operational efficiency
- S/N
- Sea surface effects
- Seismic interference

- Velocities
- Multiple attenuation
- Q estimation
- Imaging

- 4D
- Inversion
- Reservoir Characterization

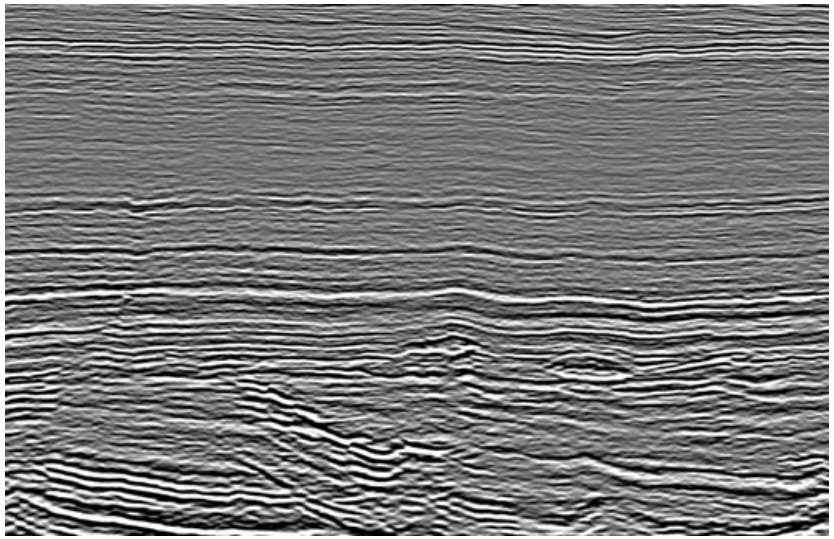
A Broader Bandwidth without restricting assumptions

Global Experience – 2D and 3D

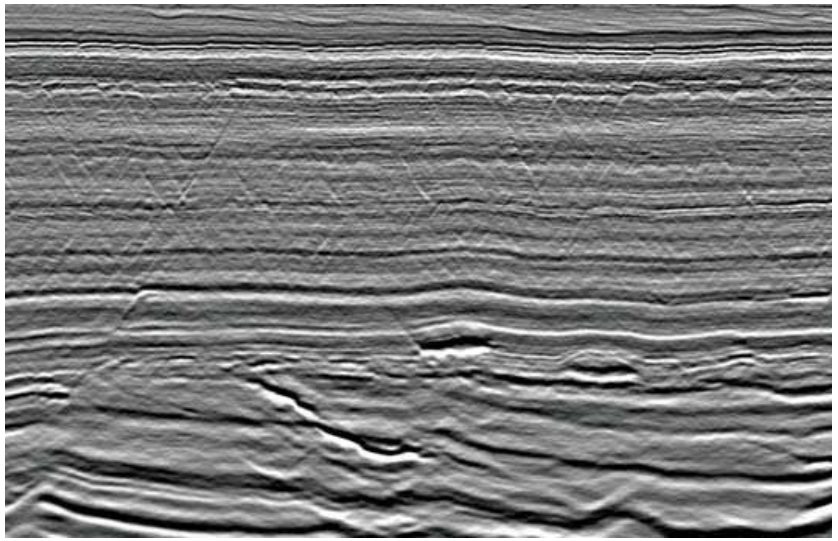


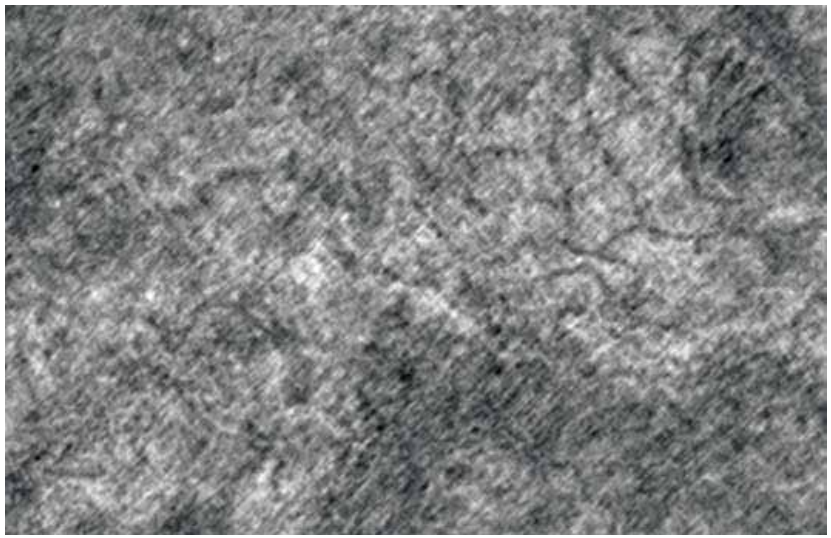
Browse Basin, Australia

Conventional Final Migration

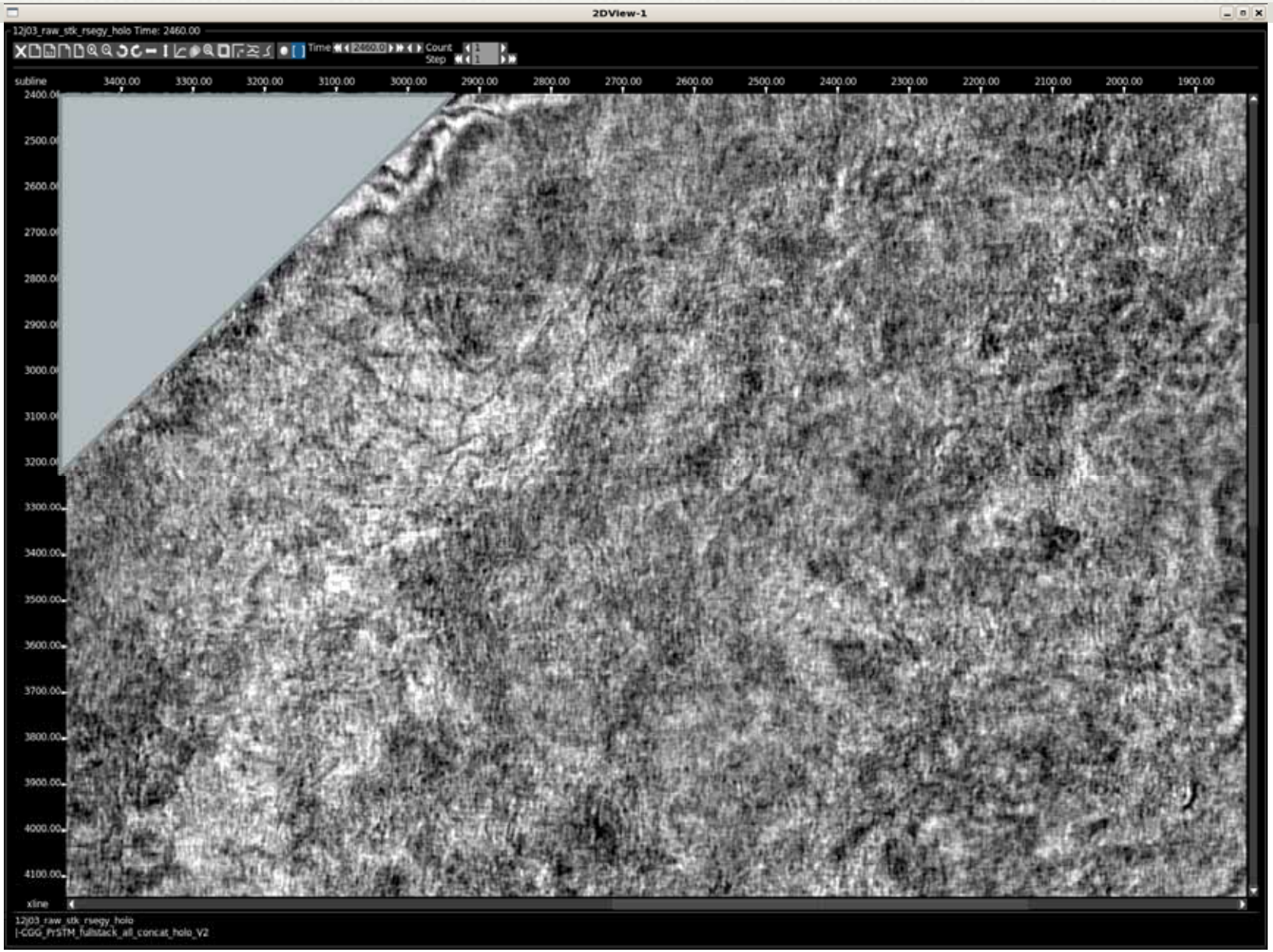


Dual-sensor Raw Migration

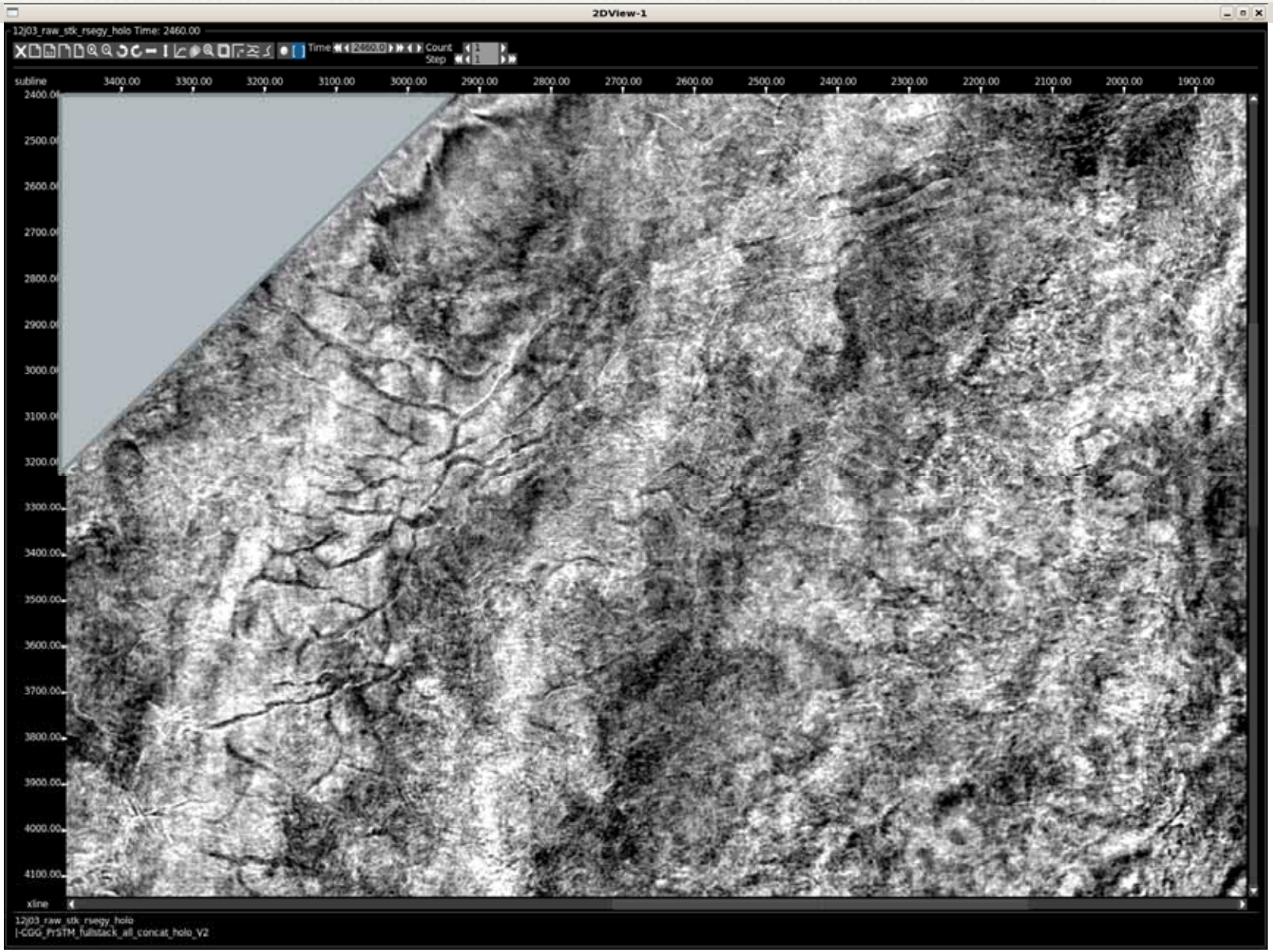




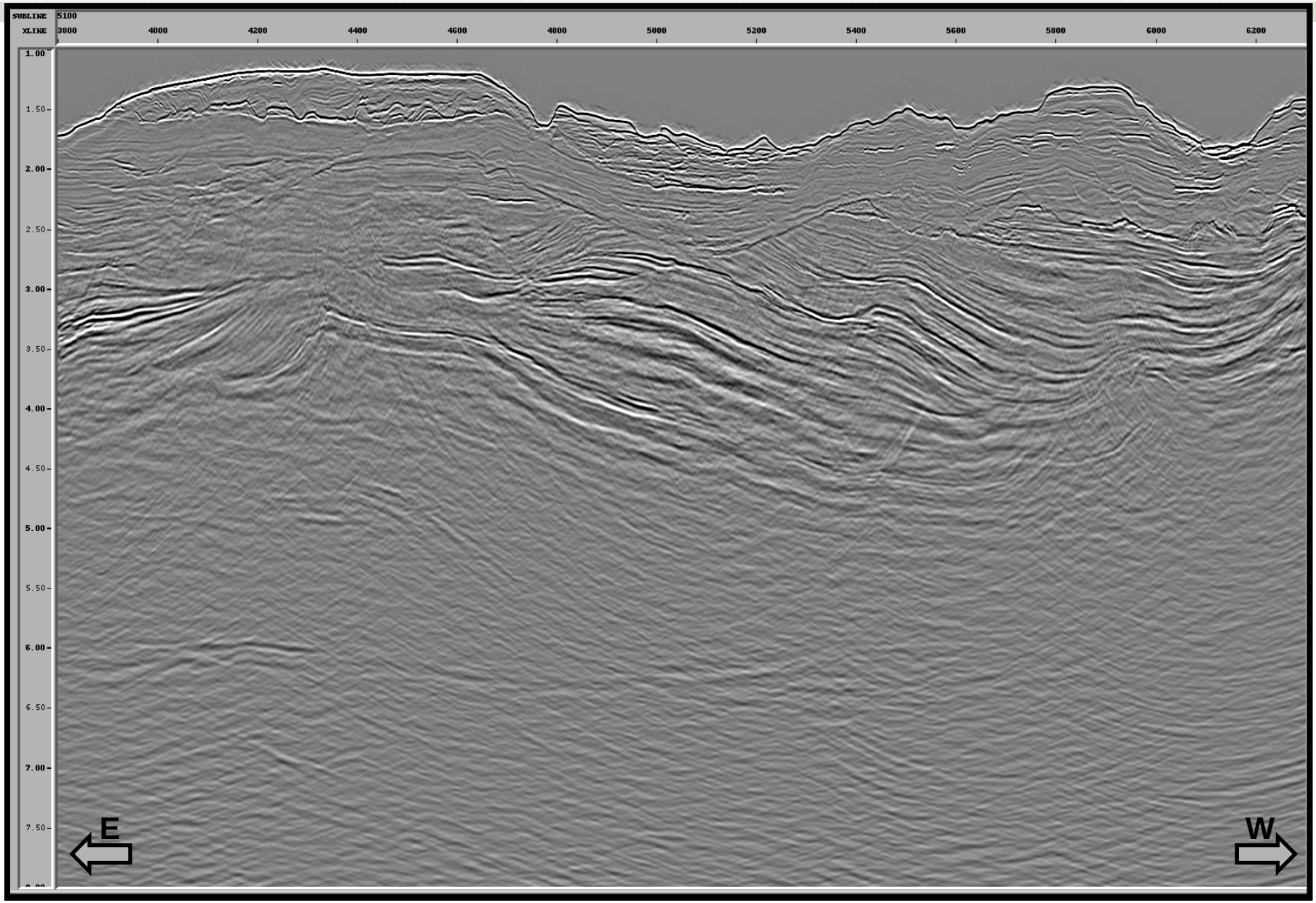
Time Slice 2460ms - Conventional



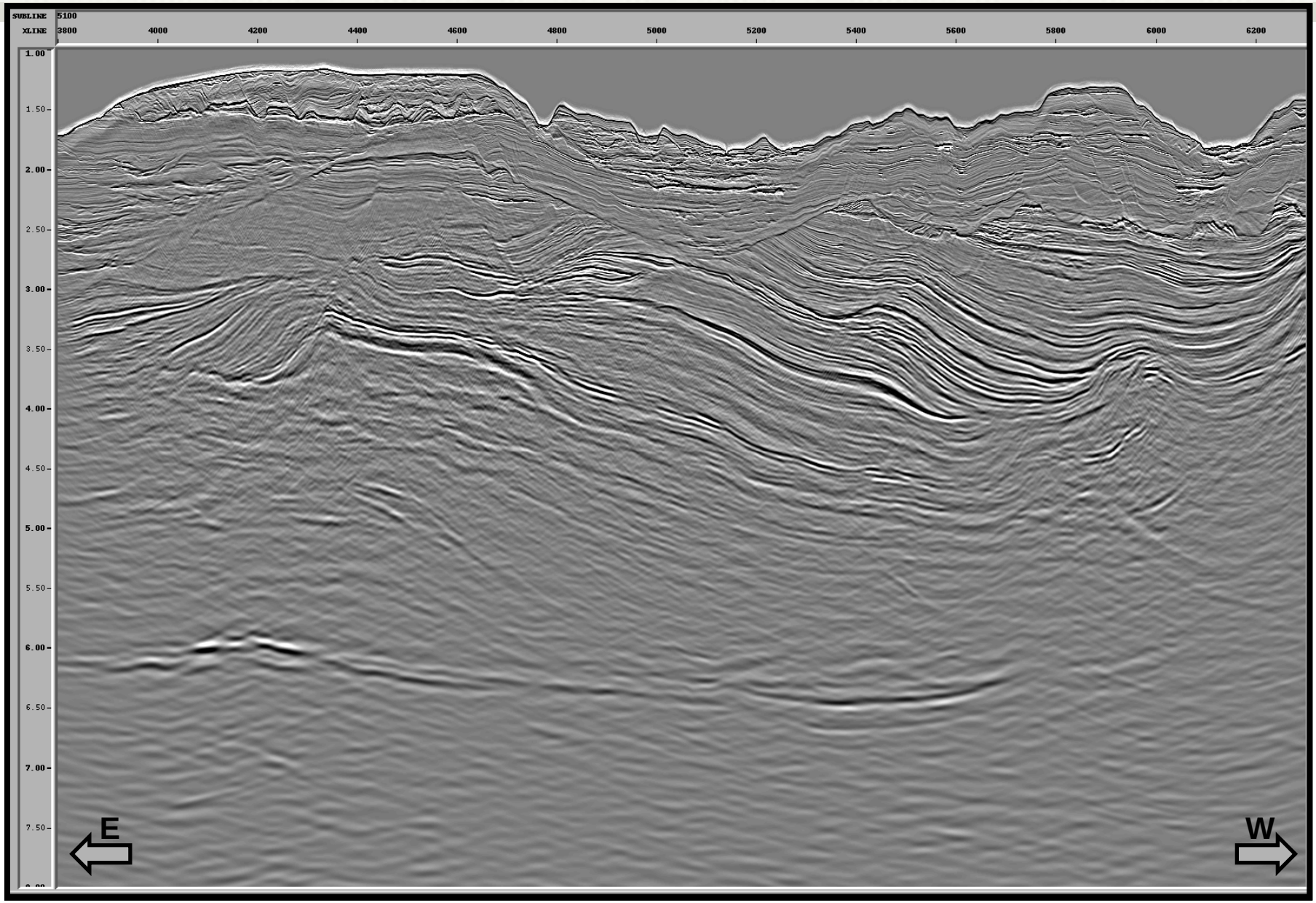
Time Slice 2460ms – Dual-sensor Streamer



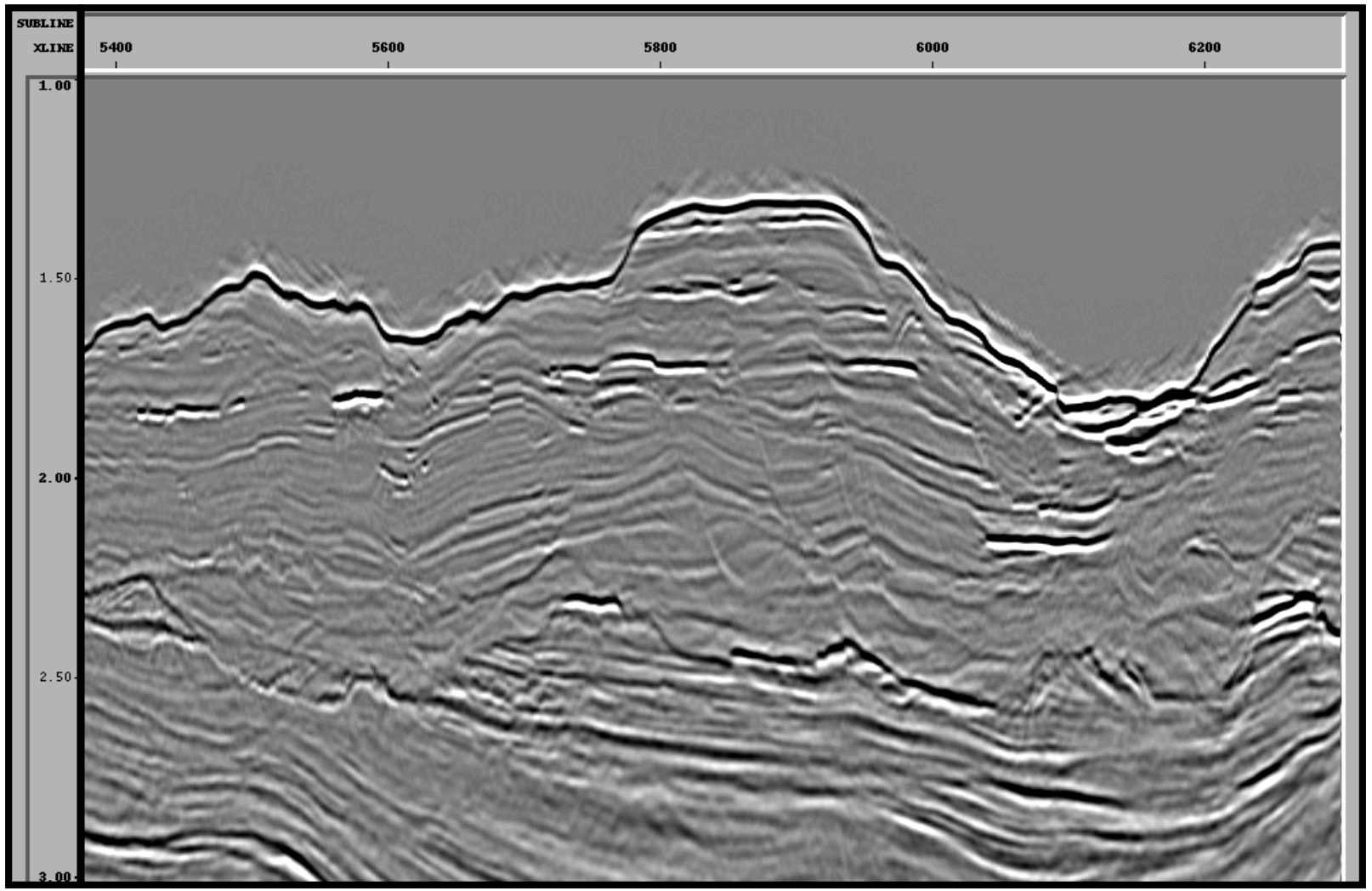
Conventional – example subline



Dual-sensor Streamer – example subline



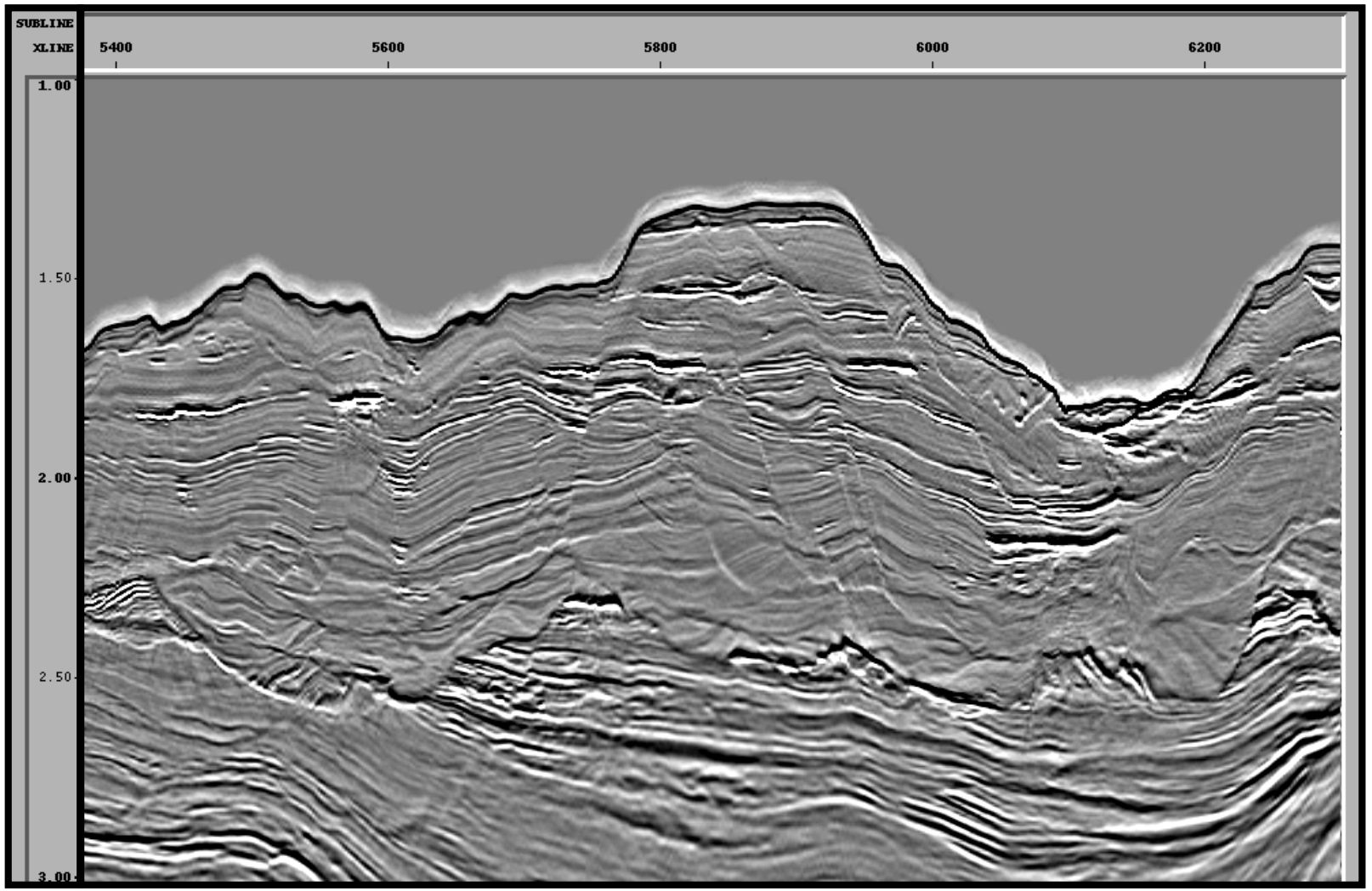
Conventional – shallow data zoom (1)



E

W

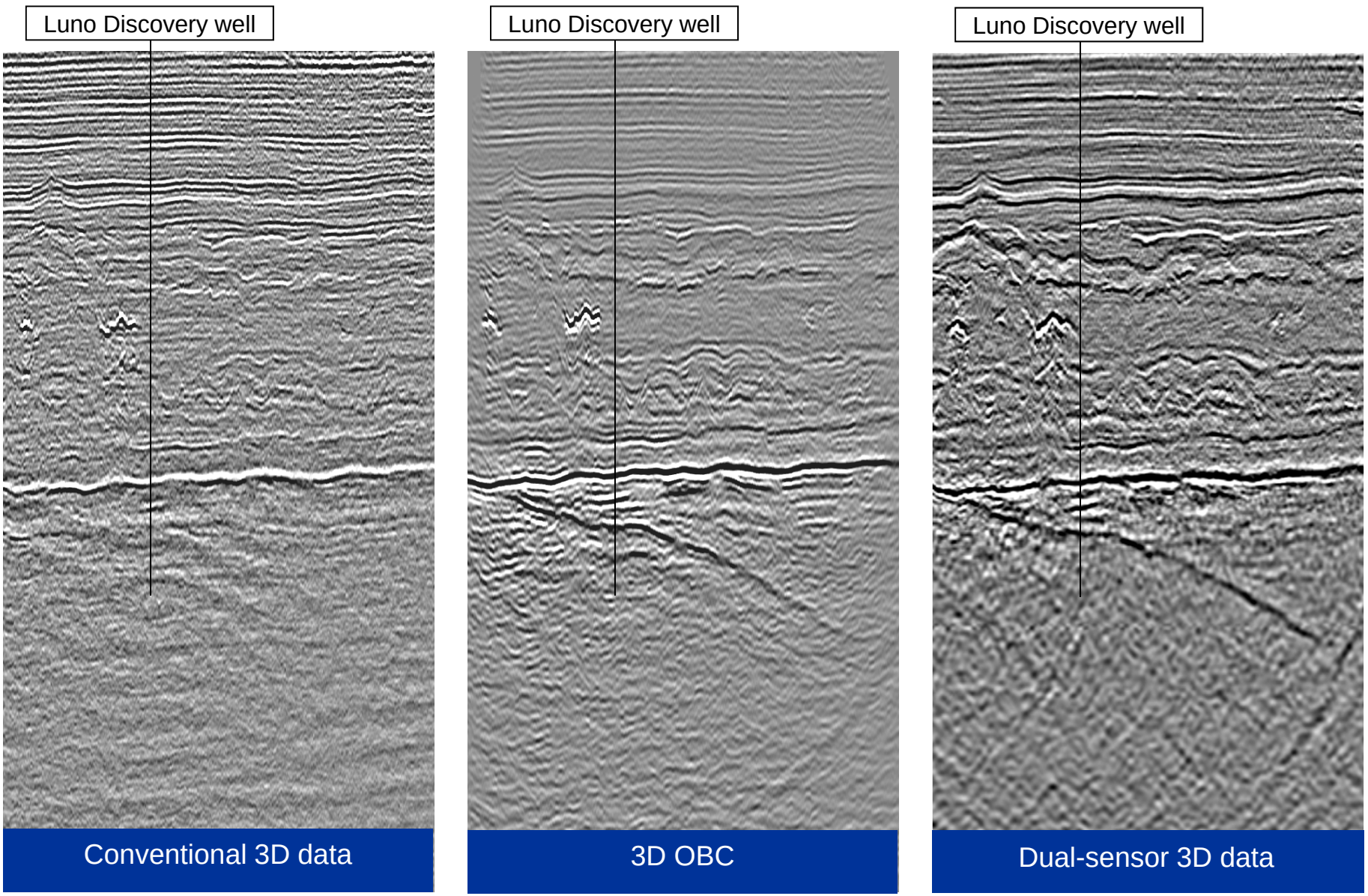
Dual-sensor Streamer – shallow data zoom



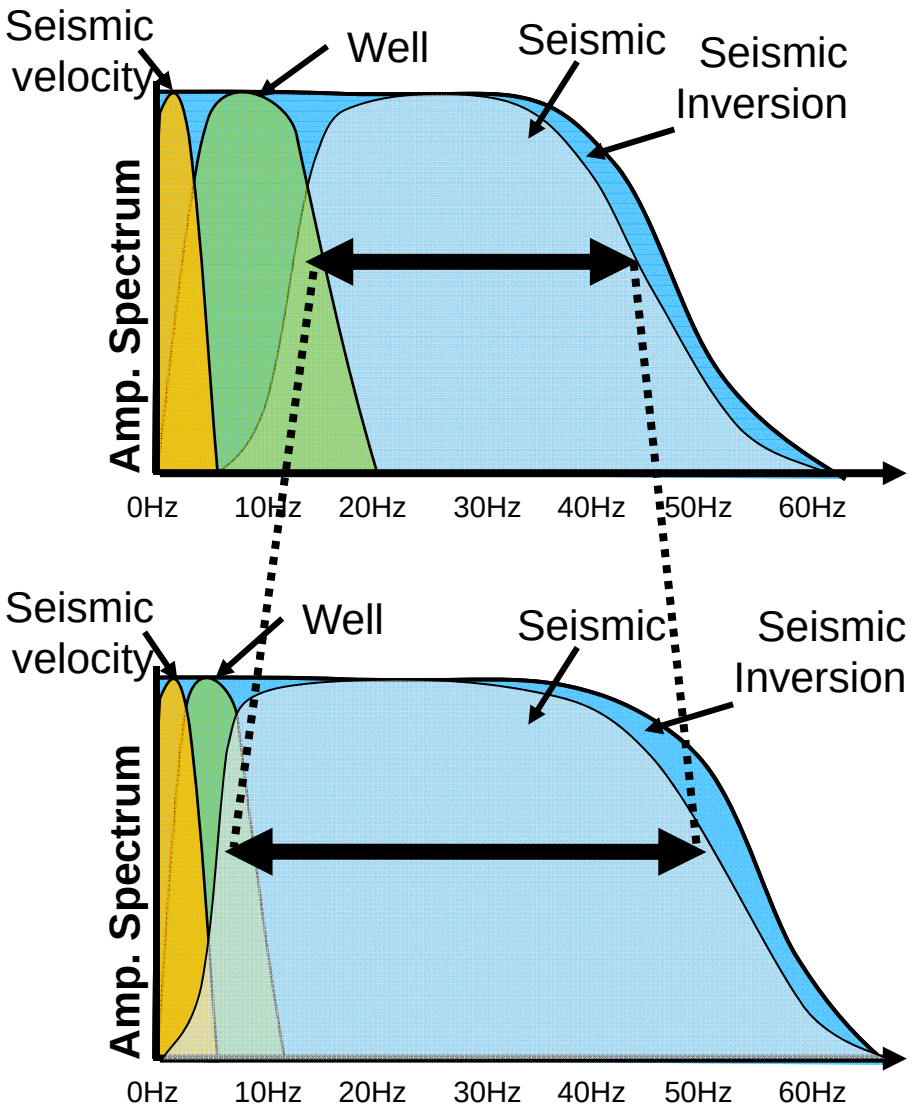
E

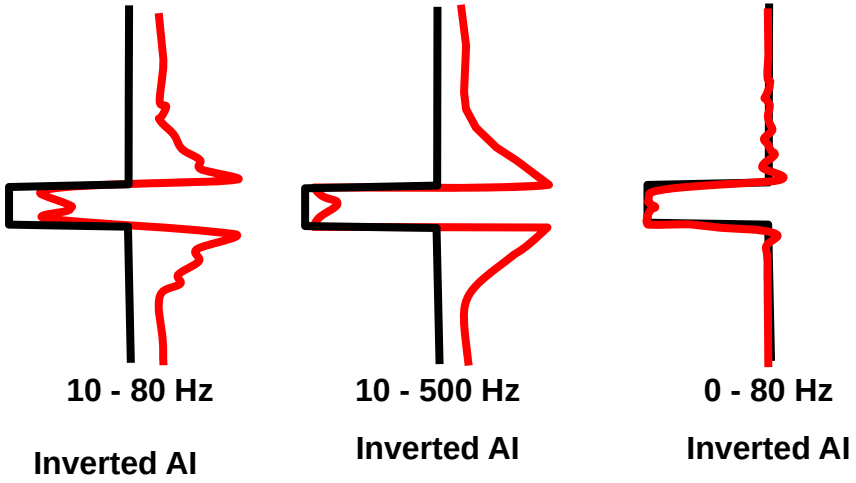
W

Data Quality



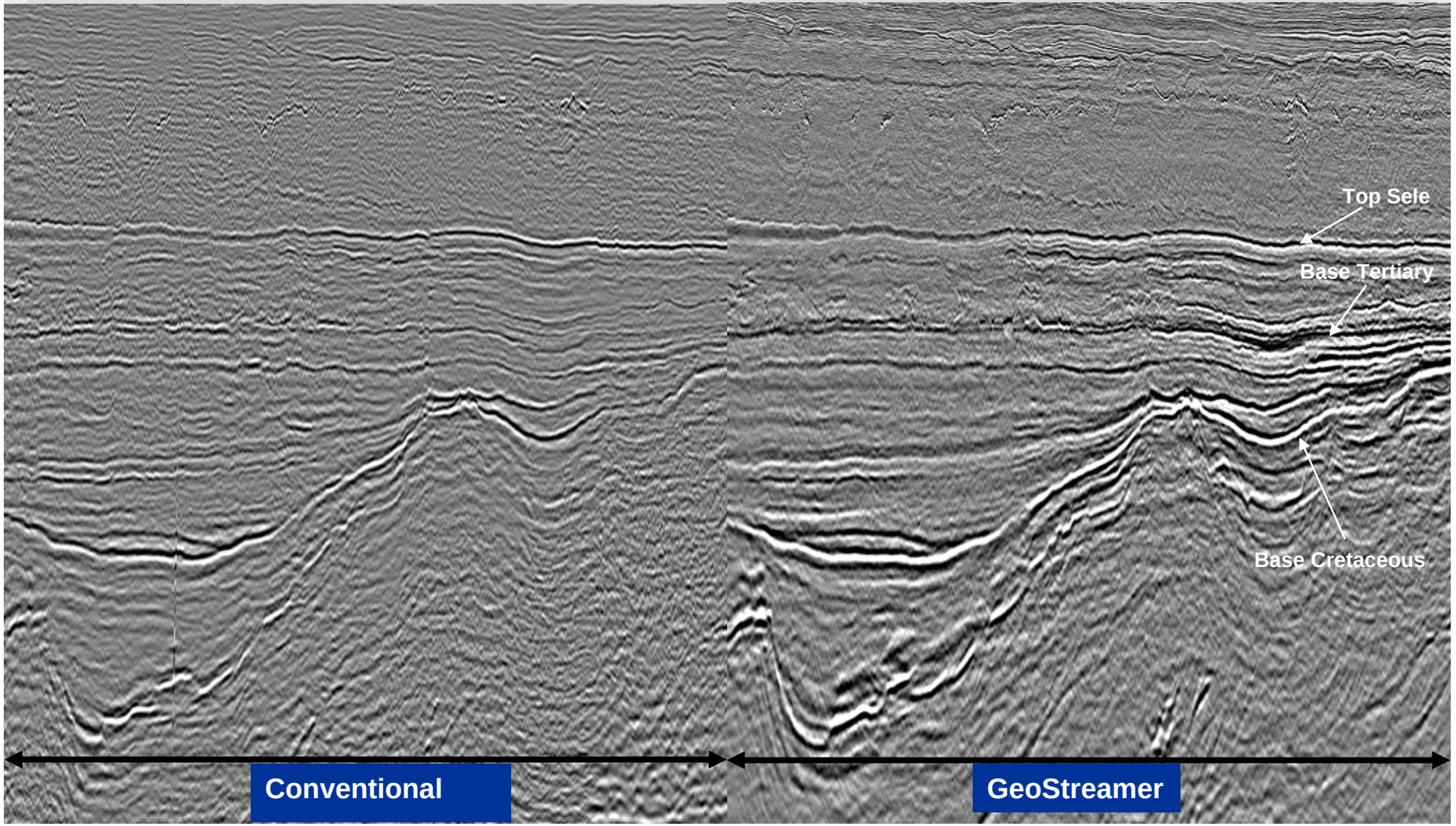
Common issues for the Rock Properties Estimation



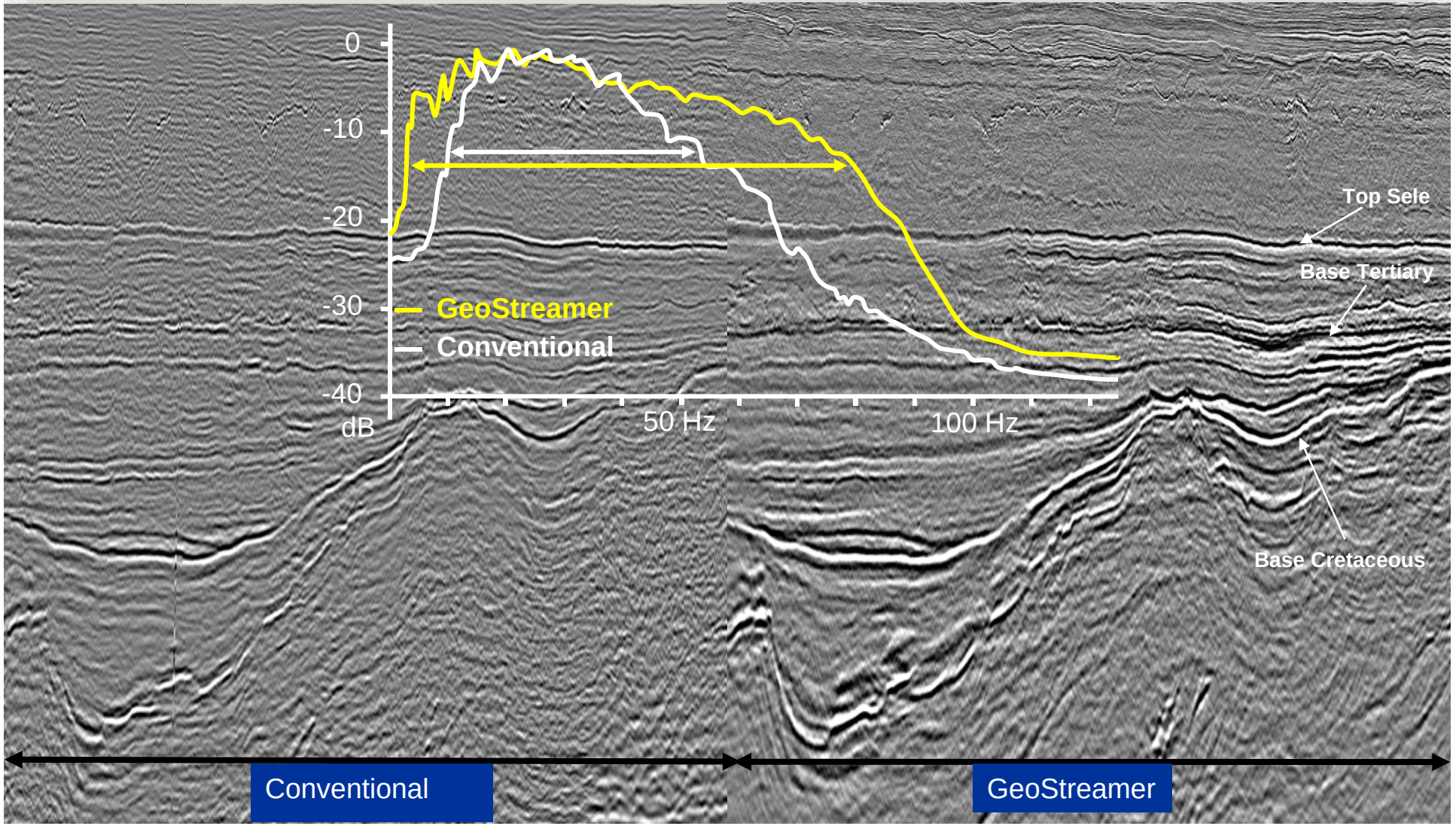


- **Bandlimited seismic**: Not enough low frequency for the seismic inversion with conventional streamer
- **Filling of the frequency gap** by using well and seismic velocity information
- **Heavy a priori knowledge** can be provided by injecting too much well information into the inversion scheme.
- **Bias estimation** of the elastic properties / Litho-Fluid prediction by the well data and the geometry / locations of them

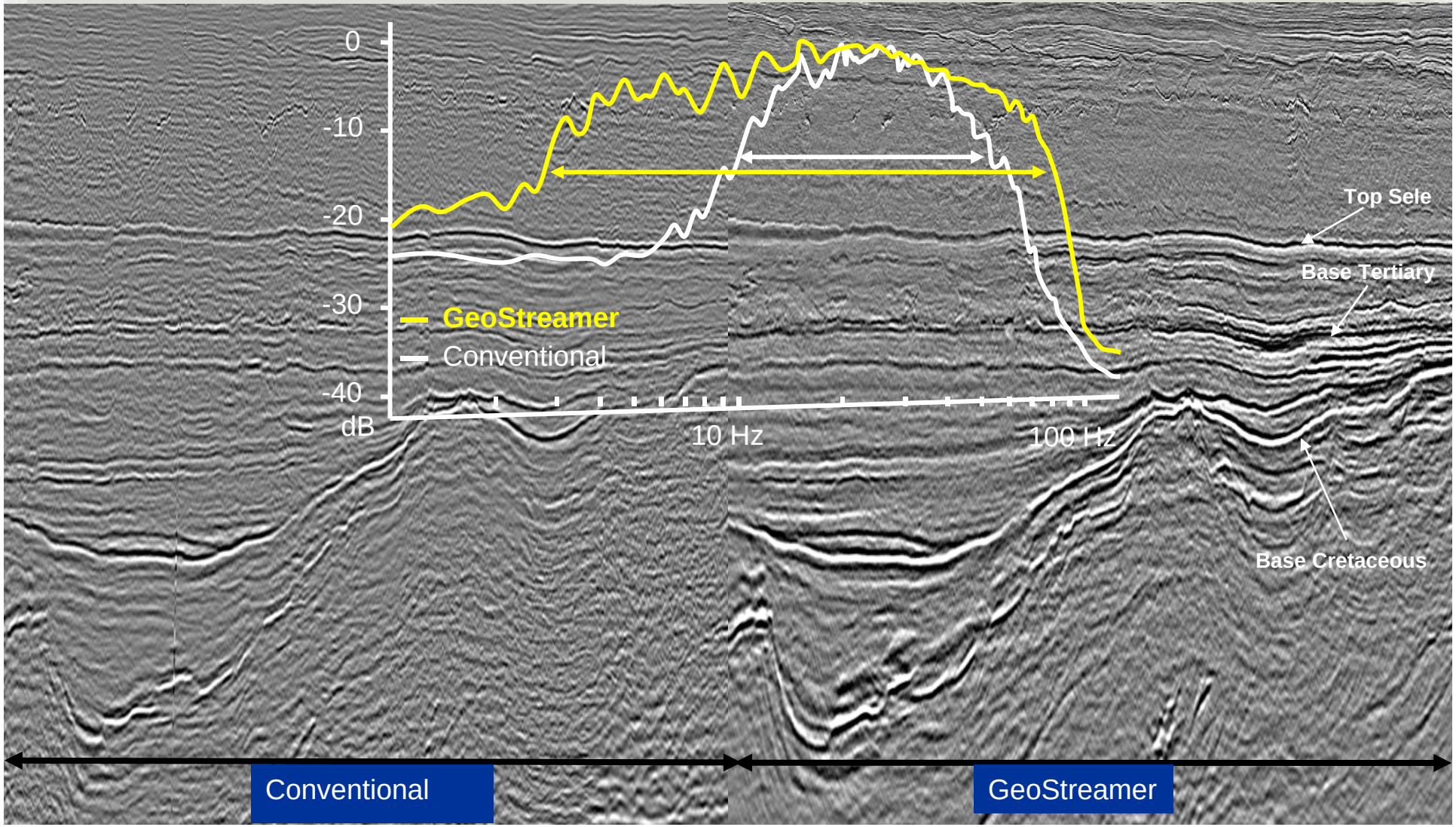
Seismic comparison Conventional versus GeoStreamer



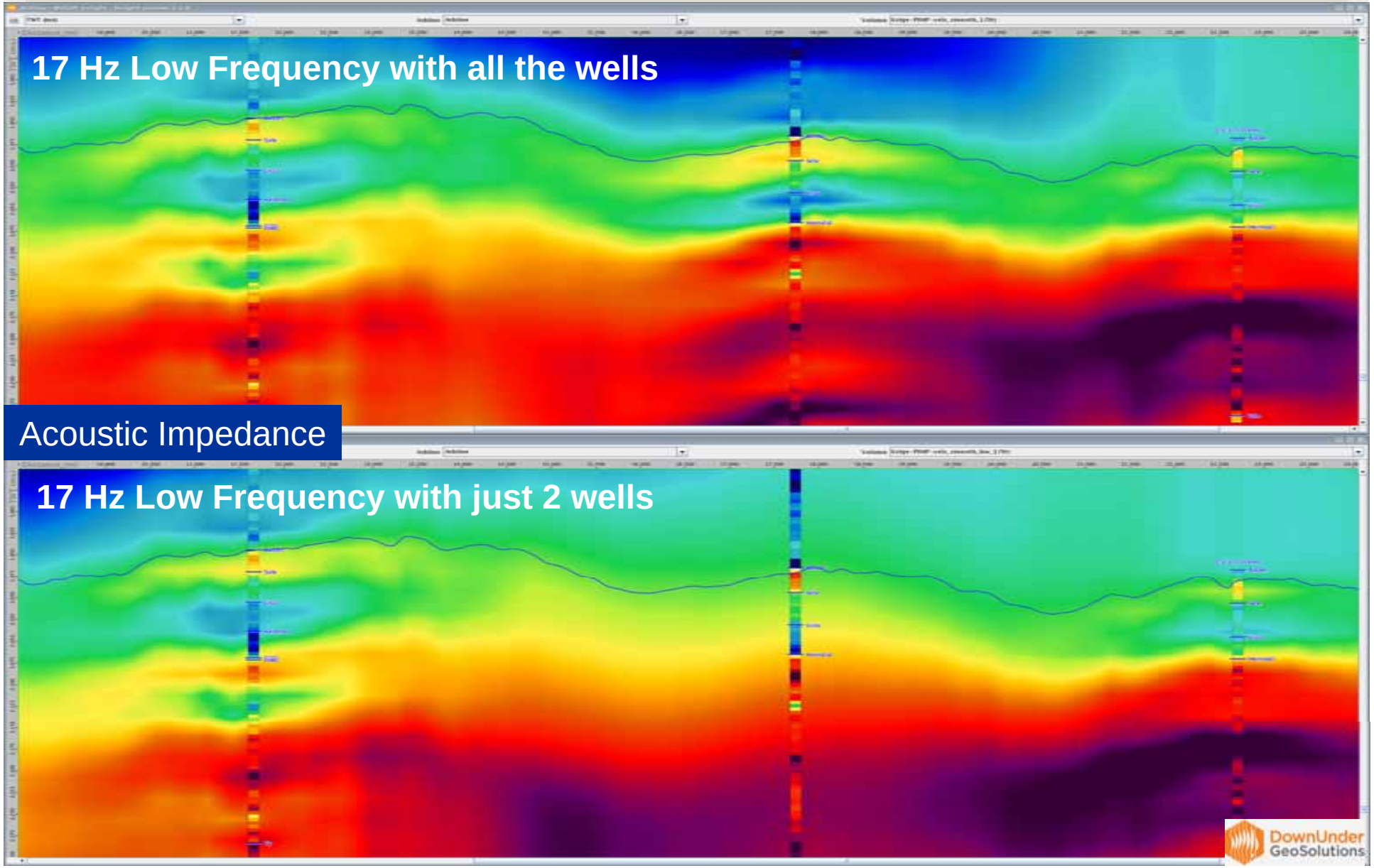
Seismic comparison Conventional versus GeoStreamer



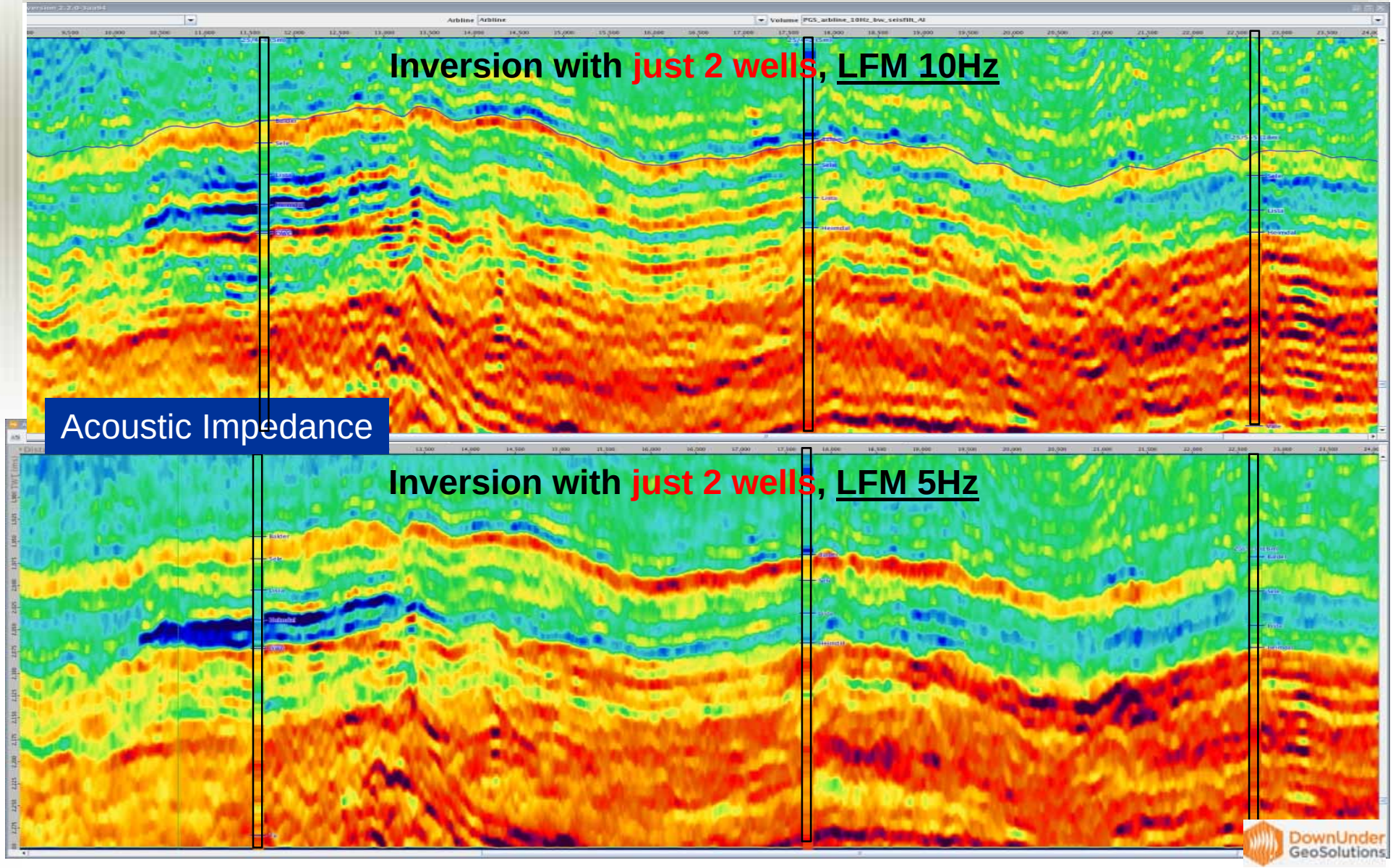
Seismic comparison Conventional versus GeoStreamer



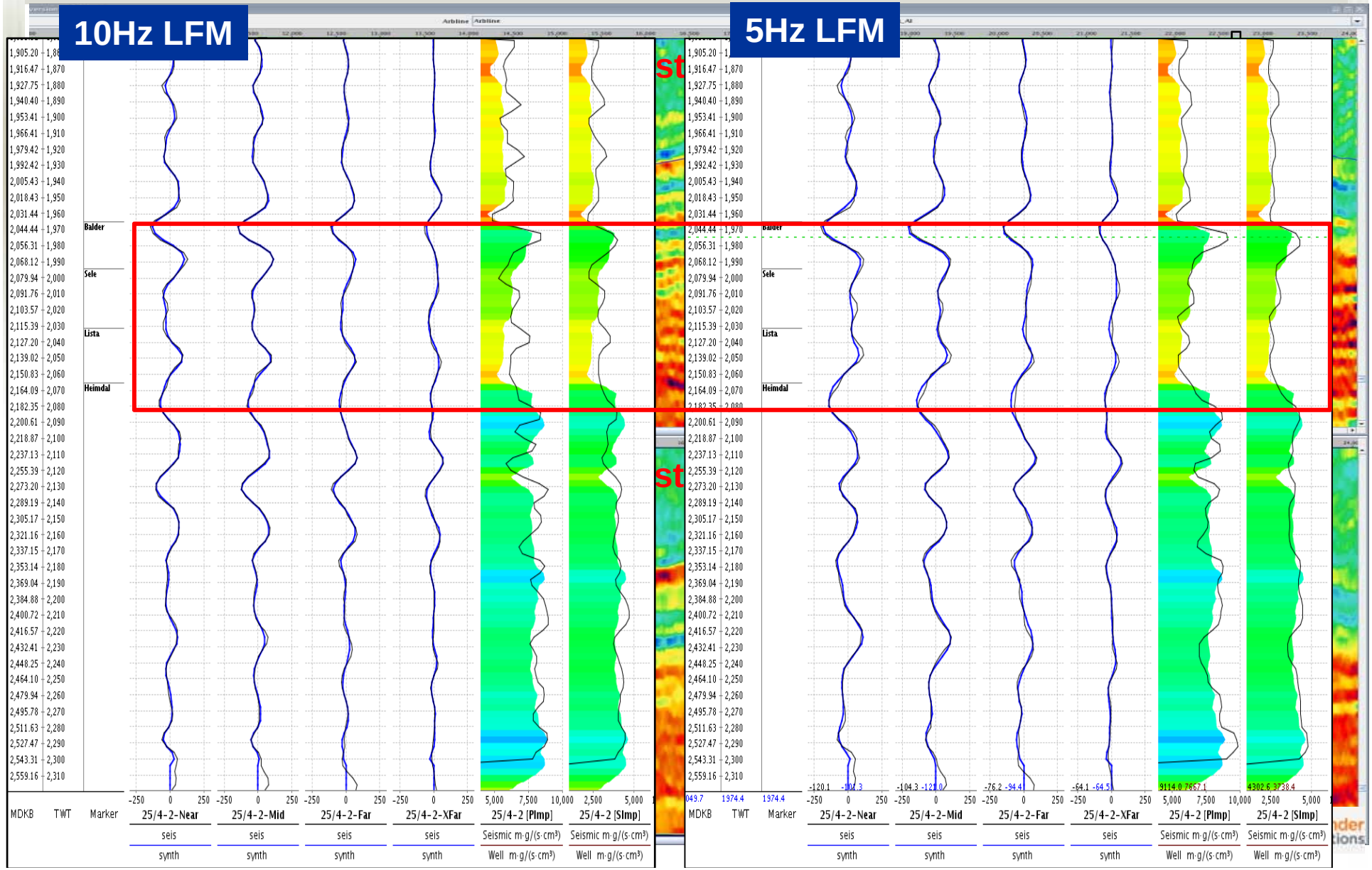
Impact of the Low Frequency on Elastic Properties Prediction



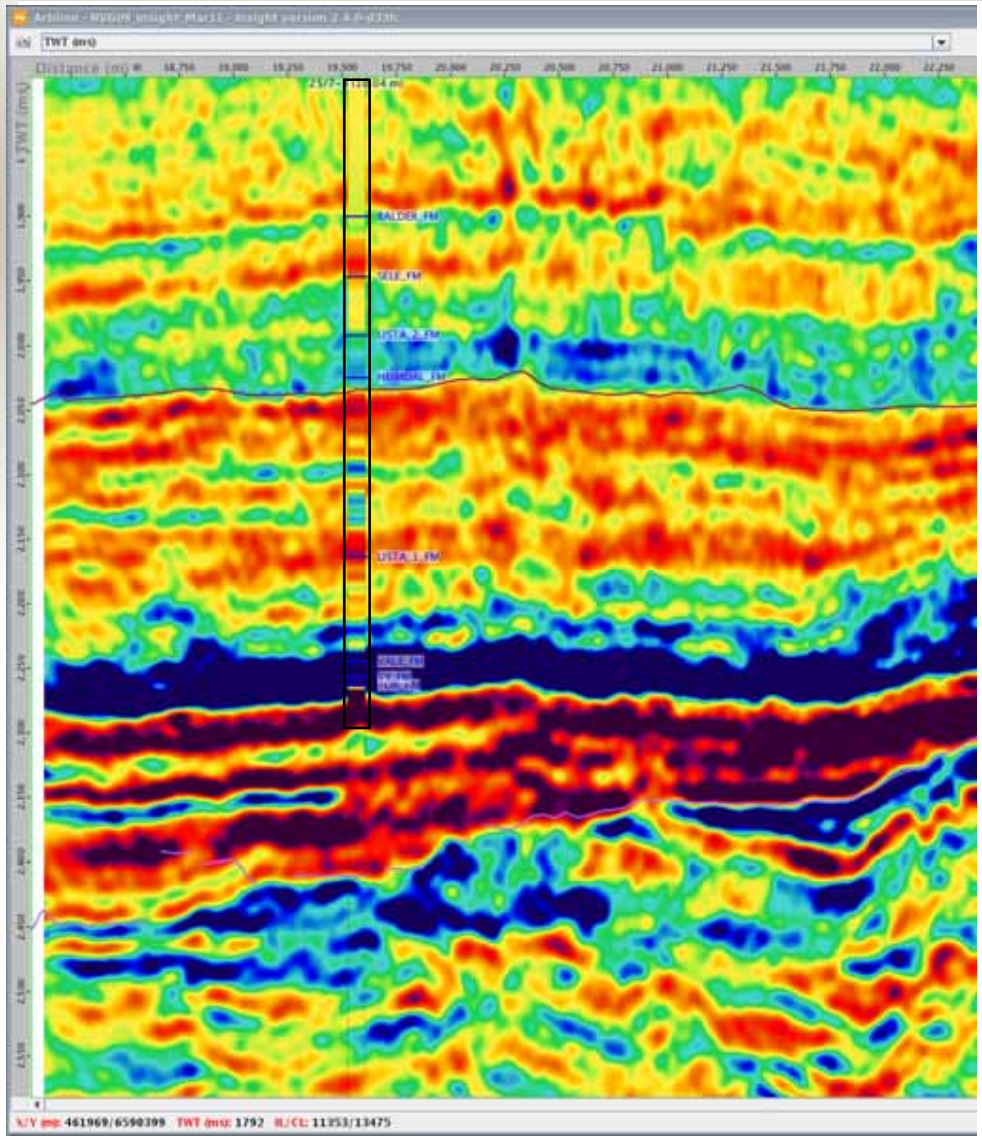
Impact of the Low Frequency on Elastic Properties Prediction

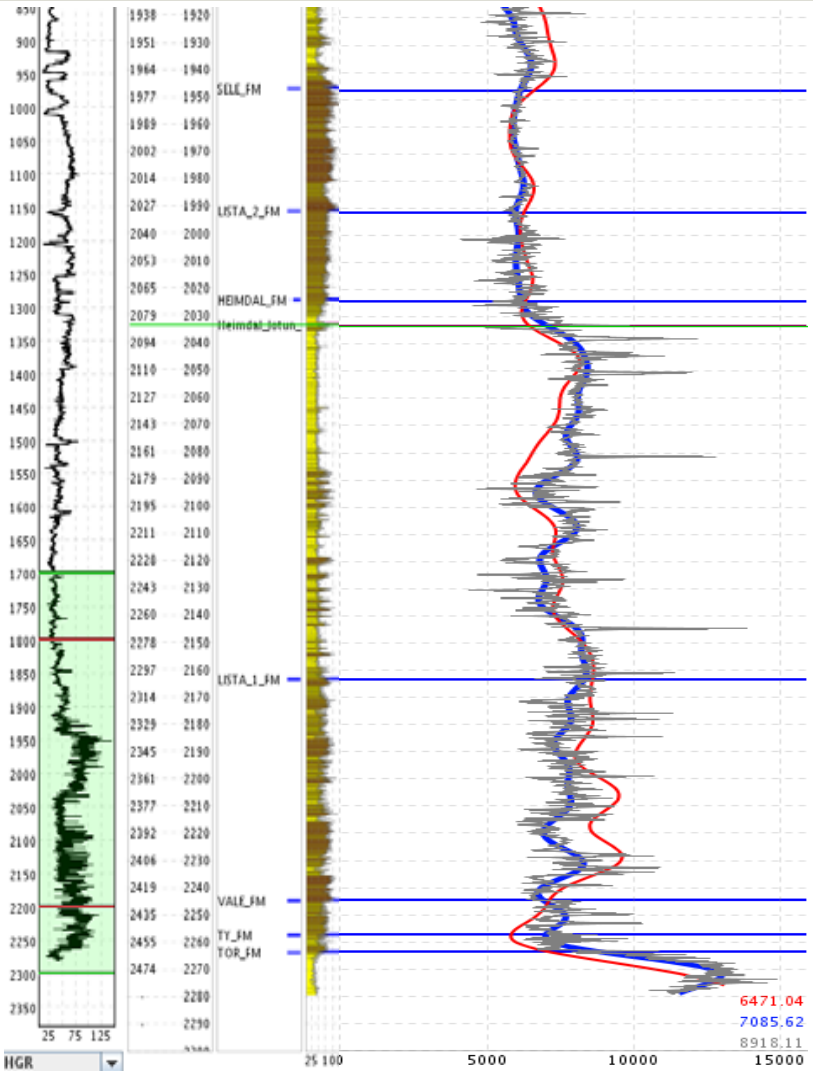


Impact of the Low Frequency on Elastic Properties Prediction



NVG09-10-05, Well 25/7-3

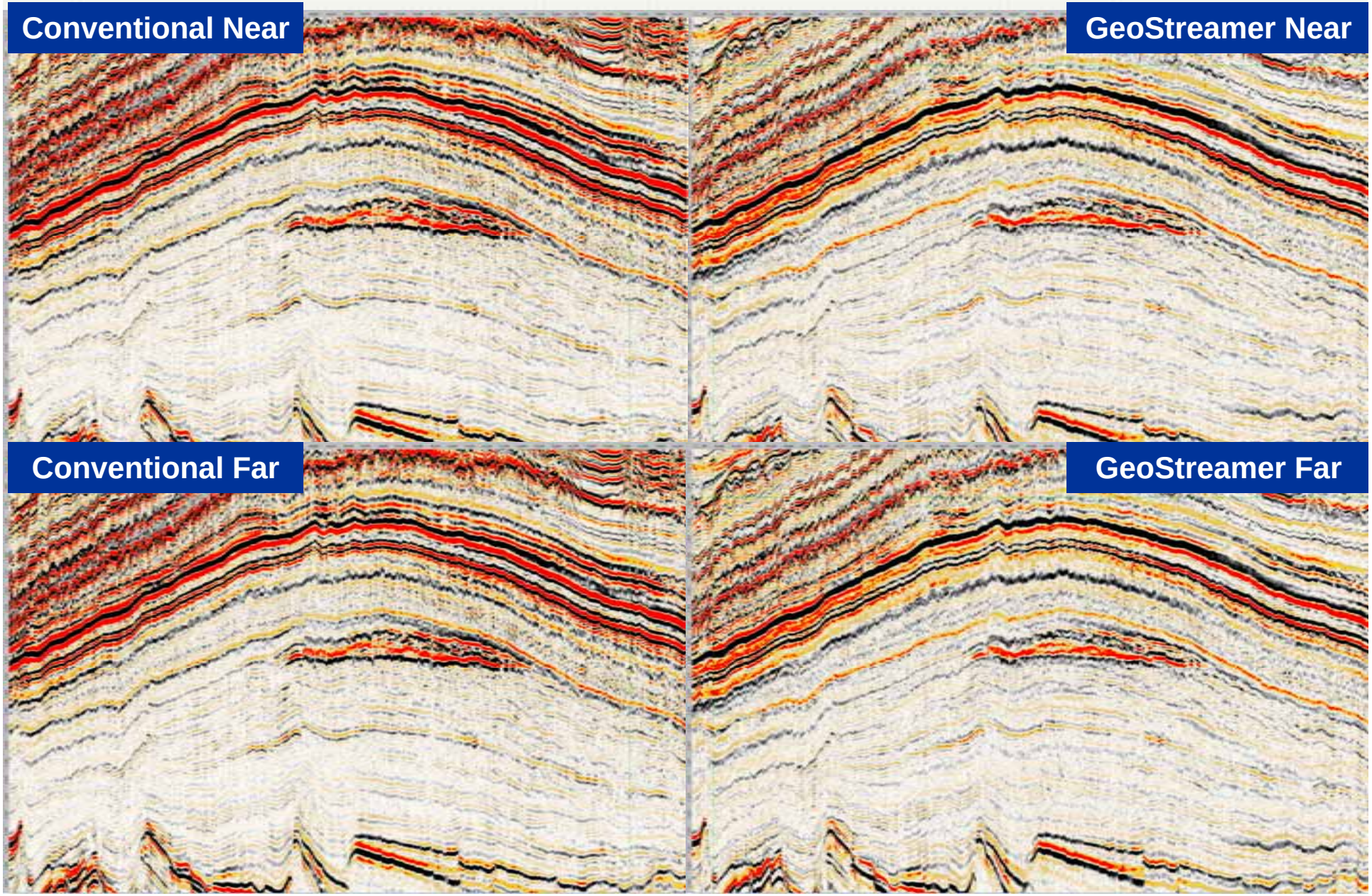




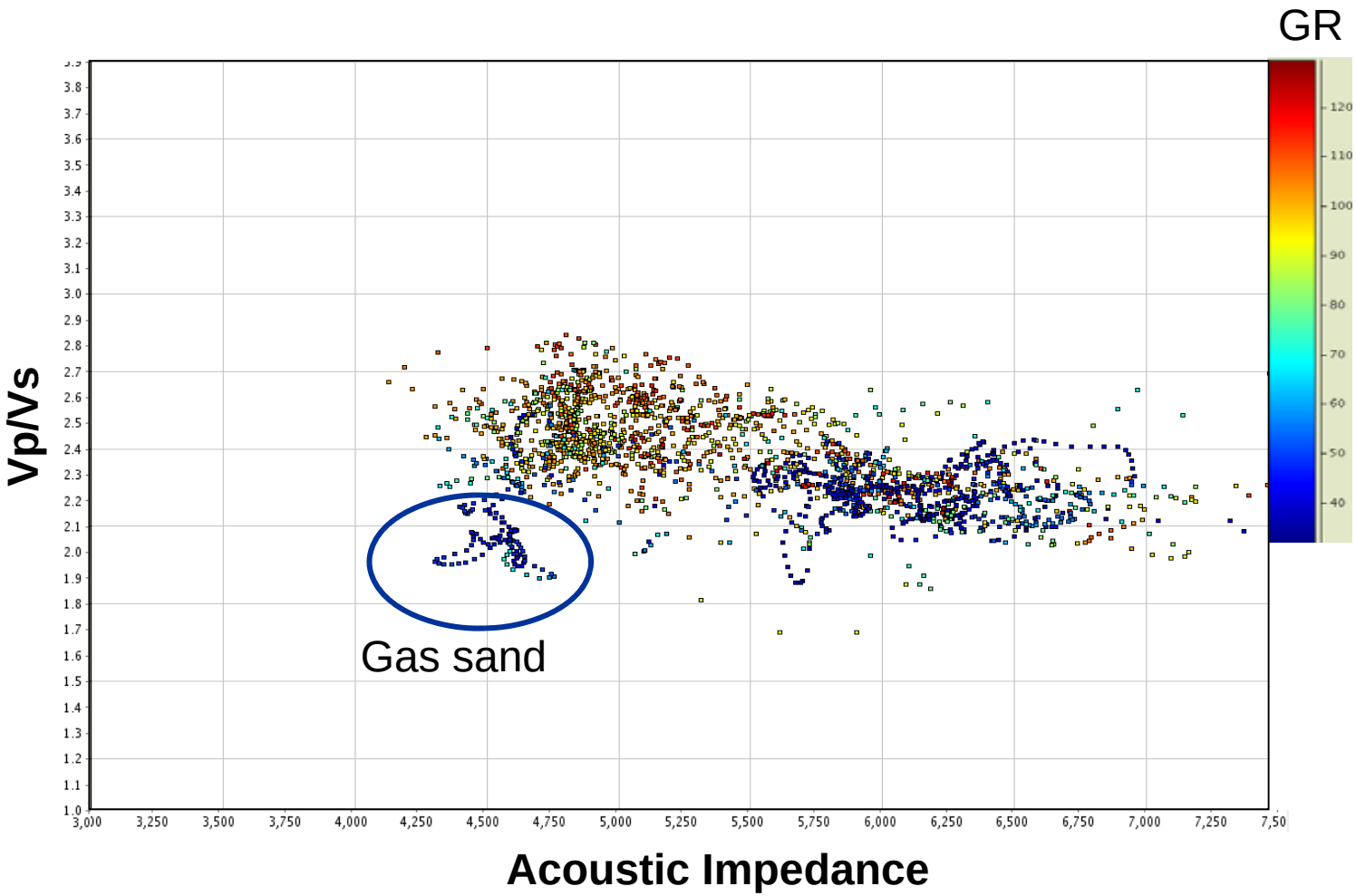
Ip = Rel(IP)+Vint*2.35

Log filtered in the seismic bandwidth

Pre-stack Seismic Comparison – Near / Far Stack



Cross-plot analysis - Well 2 – Ip *versus* Vp/Vs



Cross-plots analysis between the 2 streamer types:

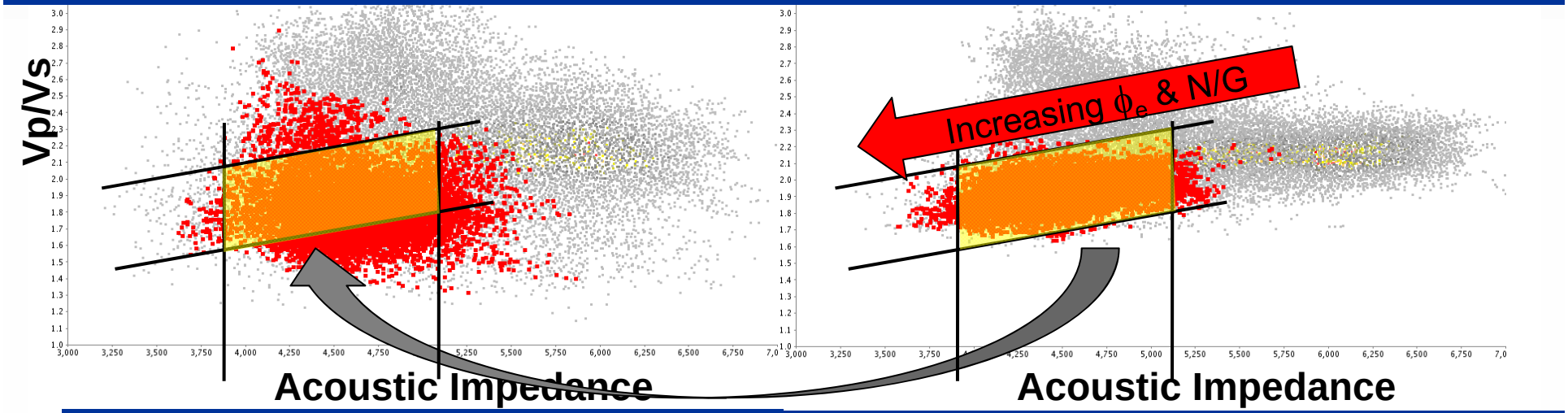
- **Acoustic Impedance domain: Equivalent distribution**
- **Vp/Vs domain: Significantly less scattering with the Broadband Streamer**

=>Increased reliability in the Pre-stack AVO inversion i.e:

1 - Improved amplitude fidelity in the pre-stack data

2 - Preserved AVO Amplitude behaviour with the Broadband streamer.

=>Gas sands reservoir interval is better isolated in the Broadband Streamer cross plot analysis compared to the cross-plot of conventional data



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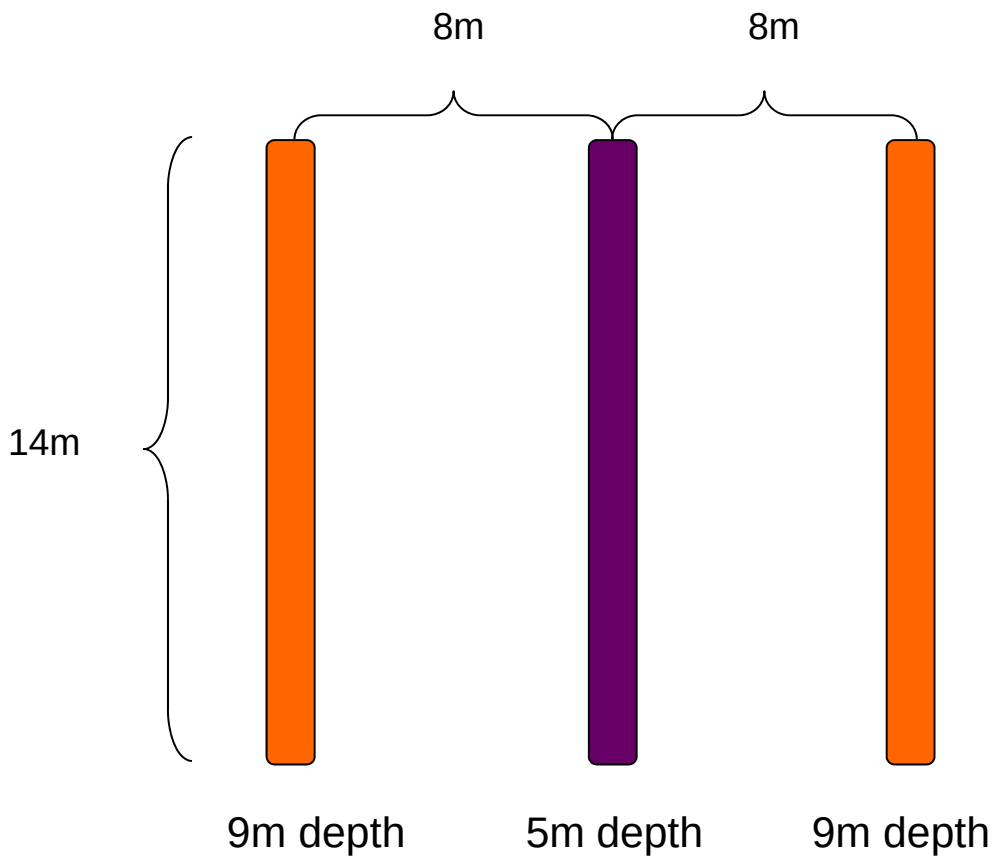
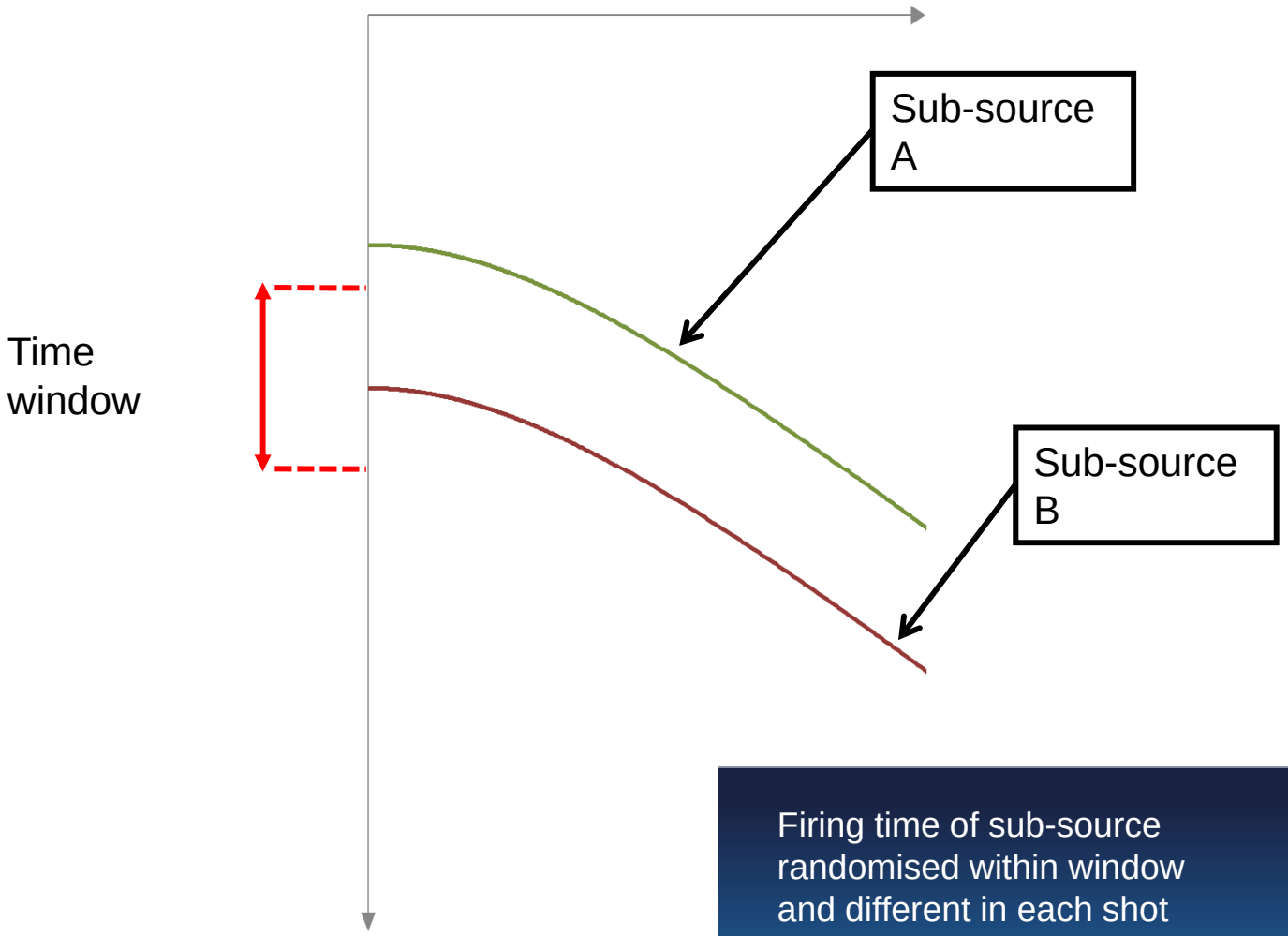
GeoSource layout example



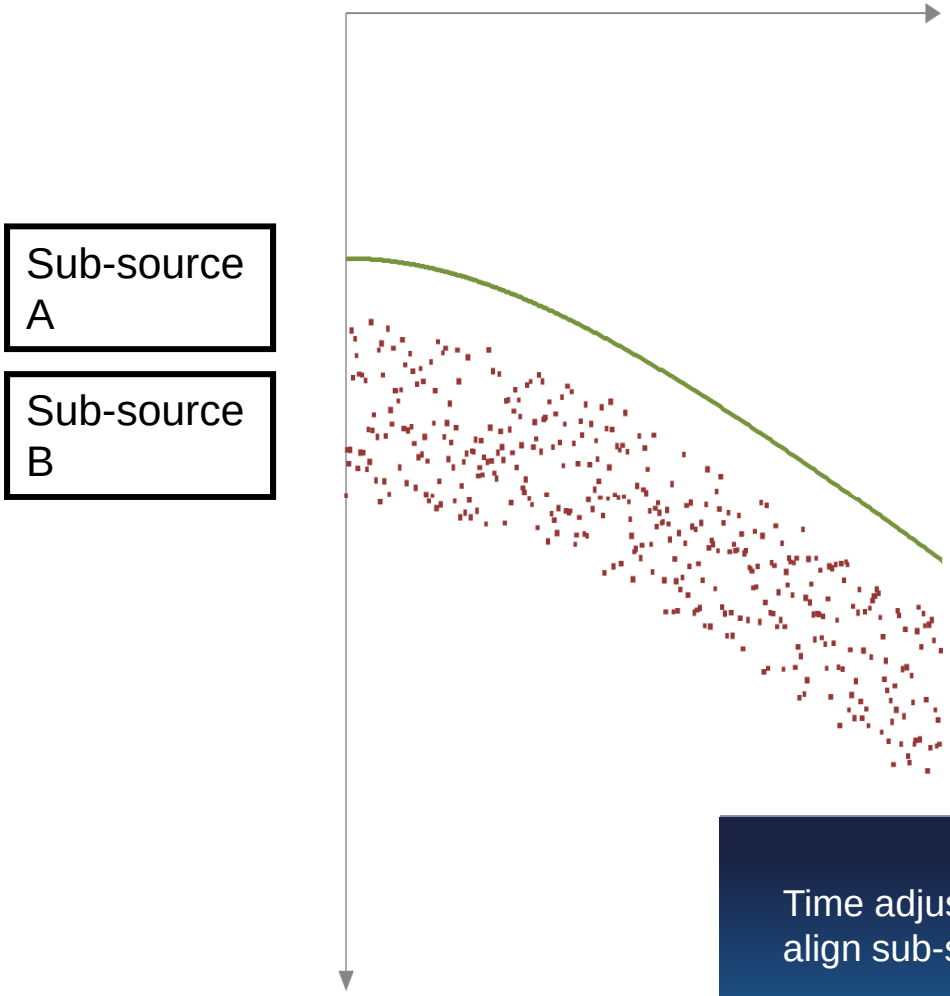
9m sub-arrays fired together at time 0
5m sub-array with randomised delay 250 -1000msec

Shot domain



Firing time of sub-source randomised within window and different in each shot

Common receiver domain – Sub-source A aligned

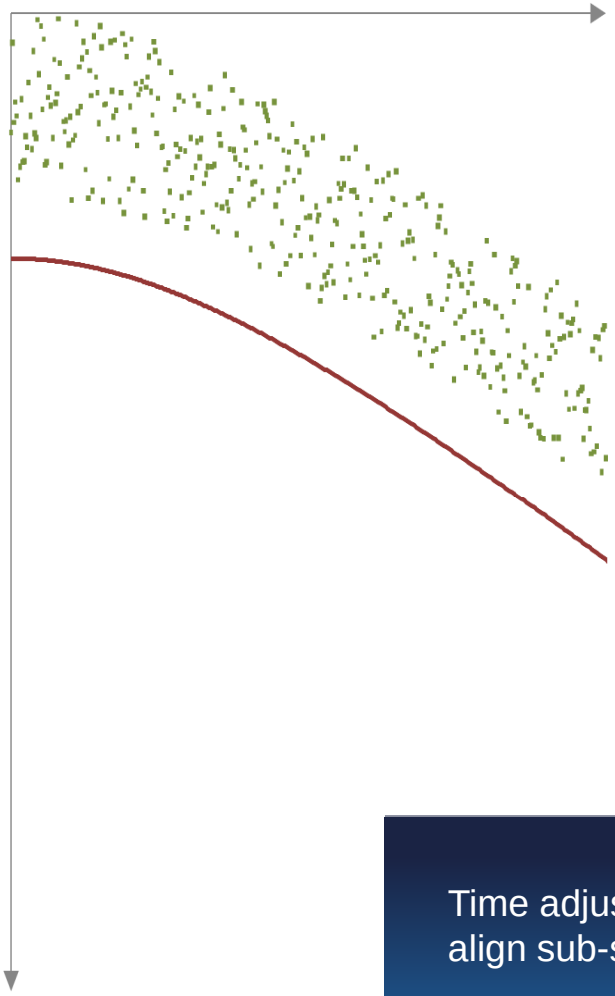


Time adjusted to
align sub-source A

Common receiver domain – Sub-source B aligned

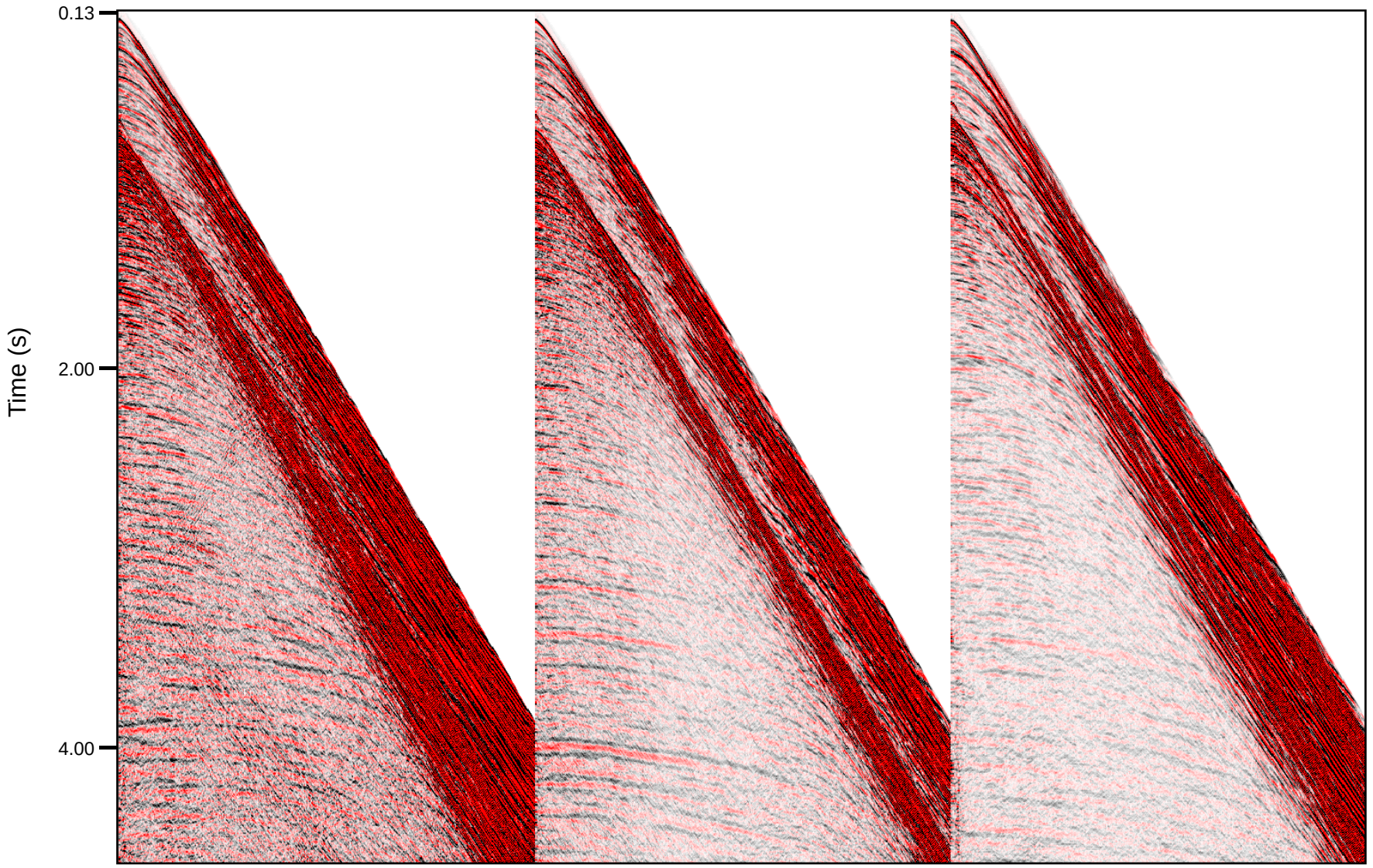
Sub-source A

Sub-source B

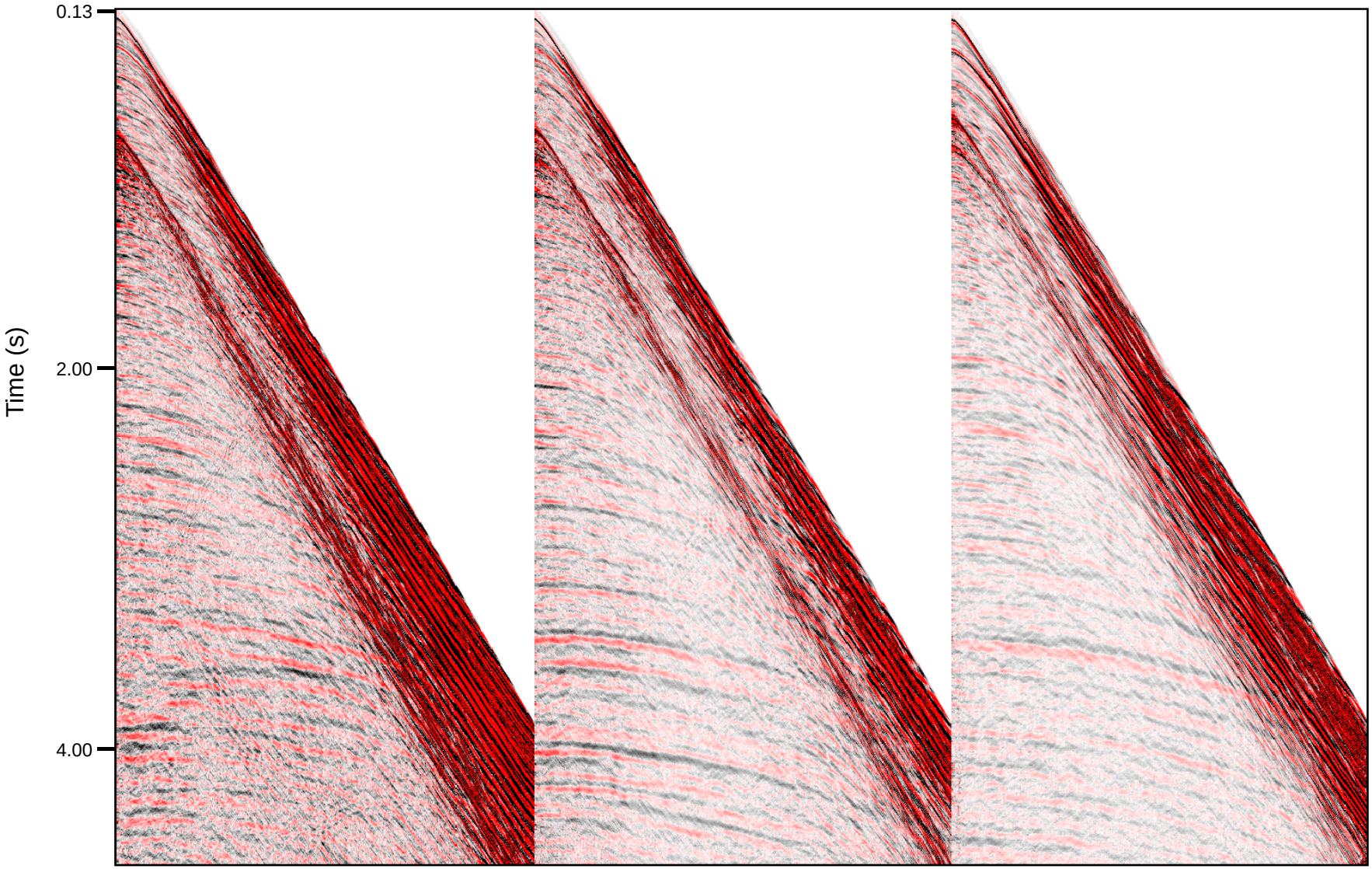


Time adjusted to align sub-source B

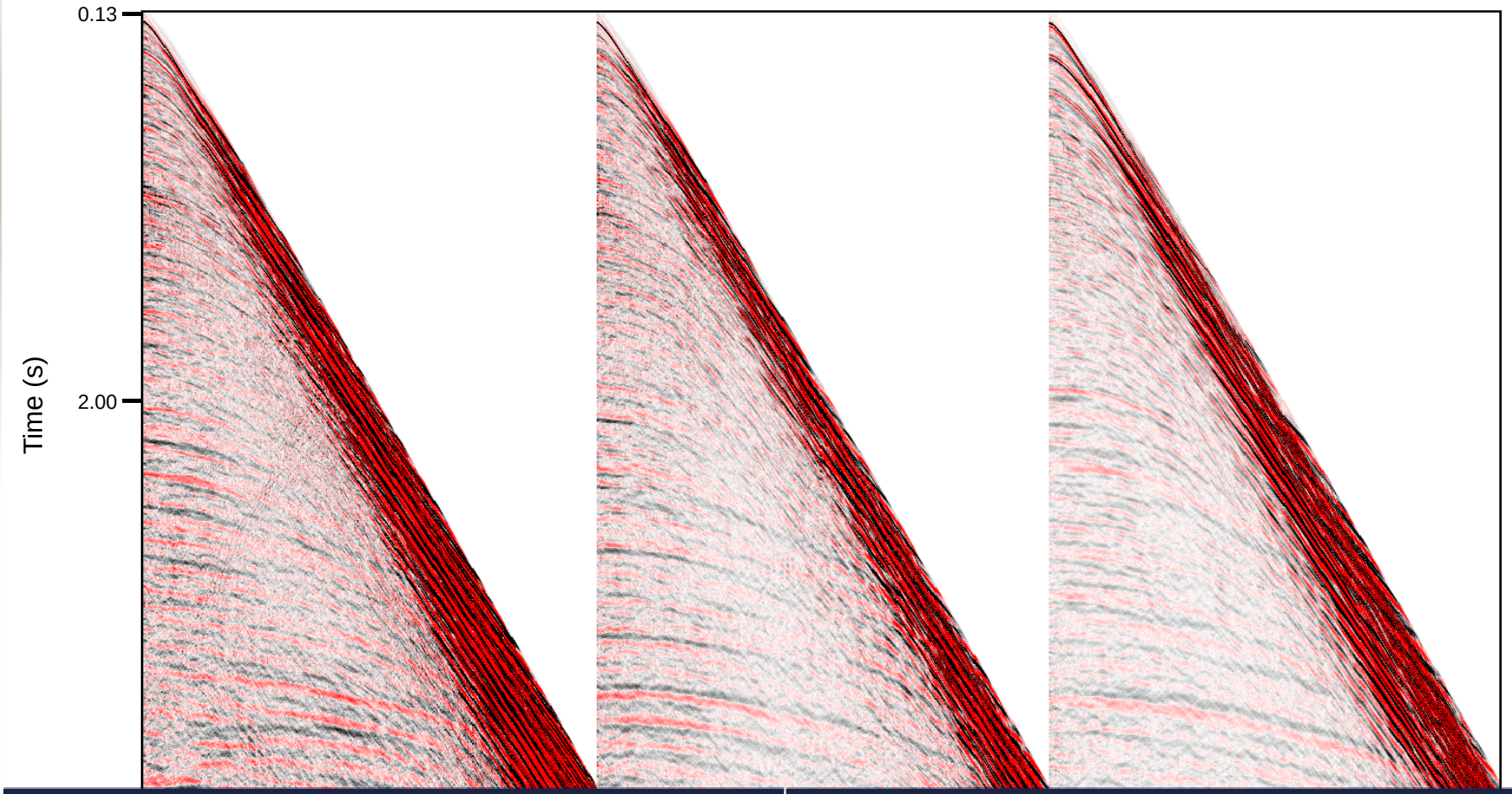
Shot files (9m/5m GeoSource)



Shot files after source de-ghosting



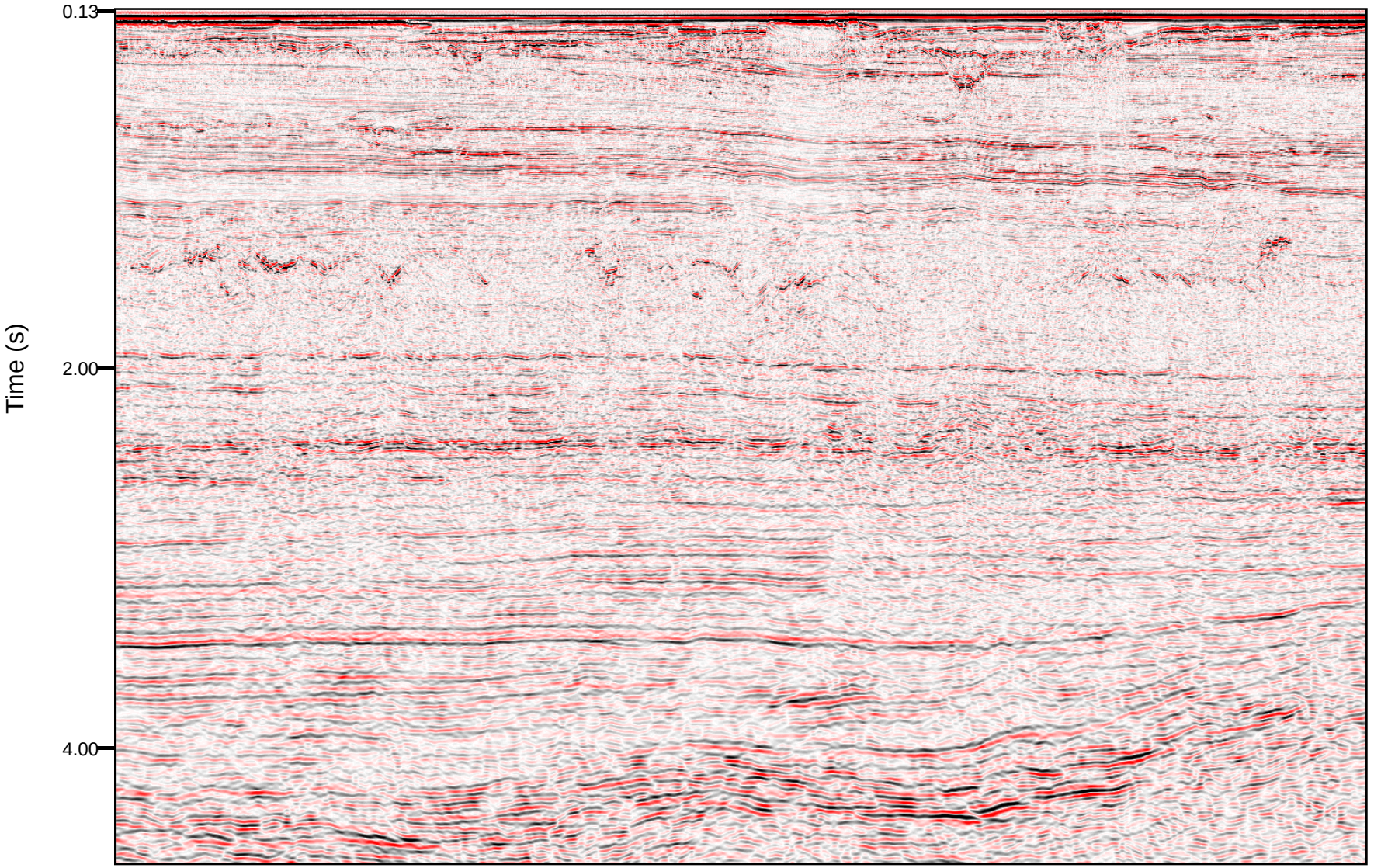
Shot files – source de-ghosting + source separation



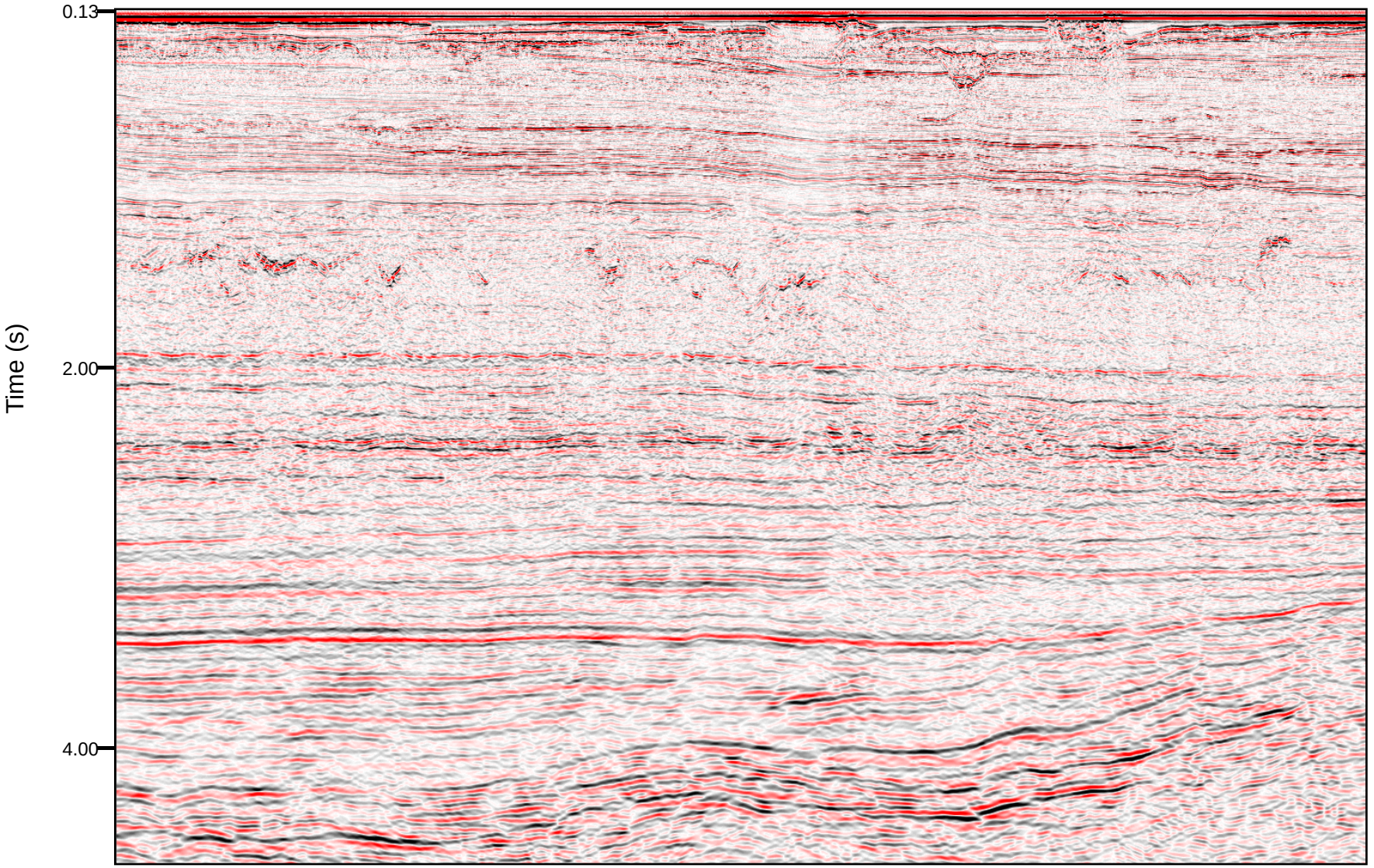
The accuracy of the source separation is within ~1dB throughout the bandwidth after pre-stack migration.

The source ghost removal process itself is a significant contributor to this accuracy.

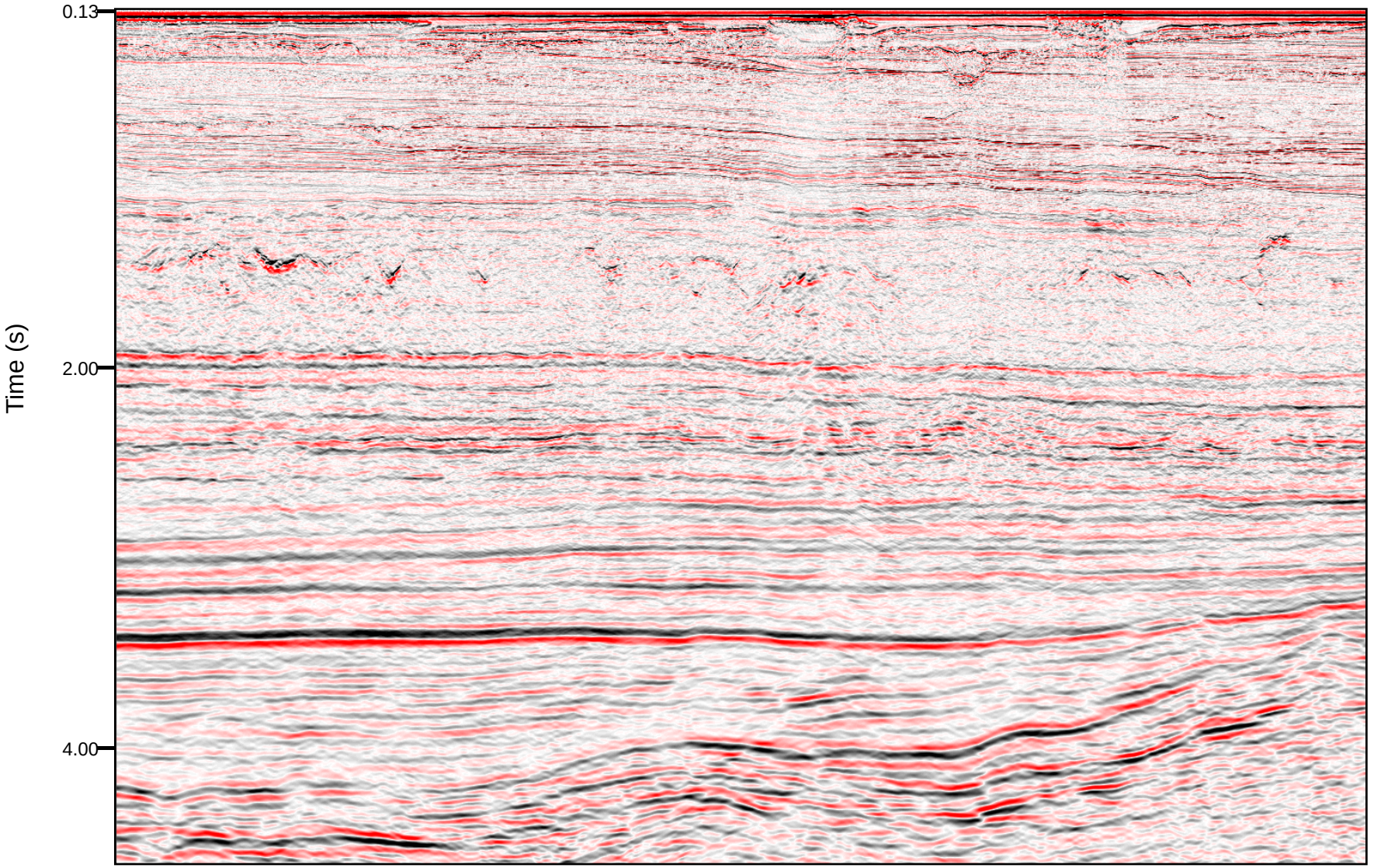
Final stack – Conventional source, Hydrophone



Final stack – Conventional source, GeoStreamer



Final stack – GeoSource, GeoStreamer

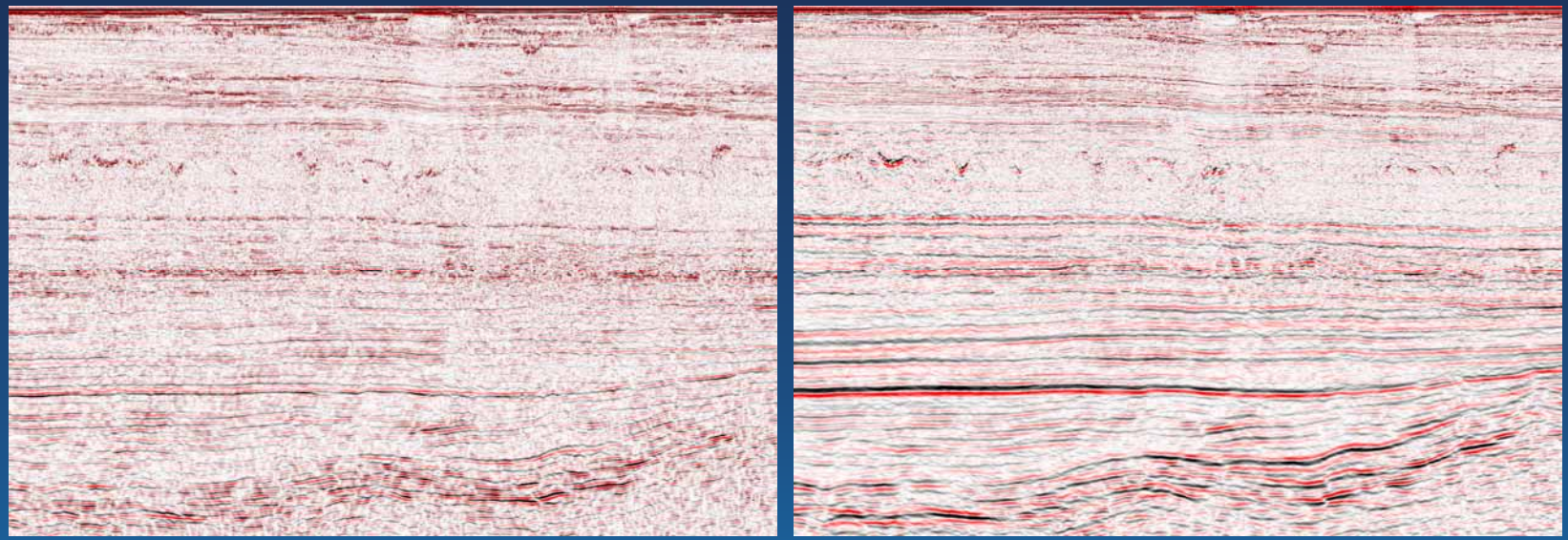


Conventional vs. GeoStreamer GS

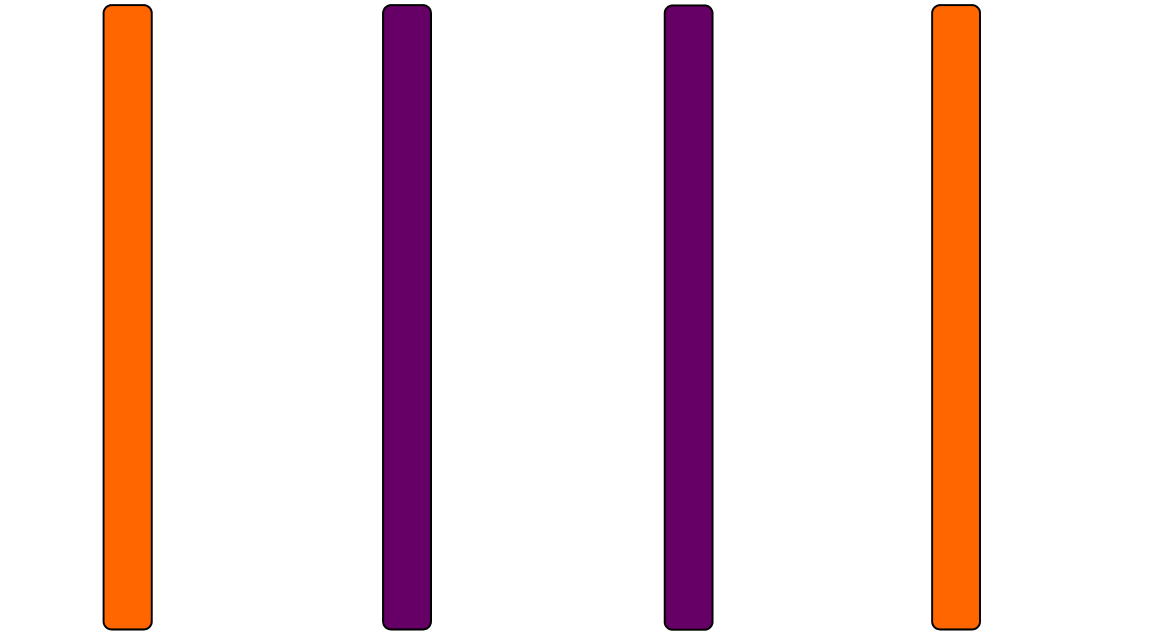
Same Hardware, Same processing

Conventional

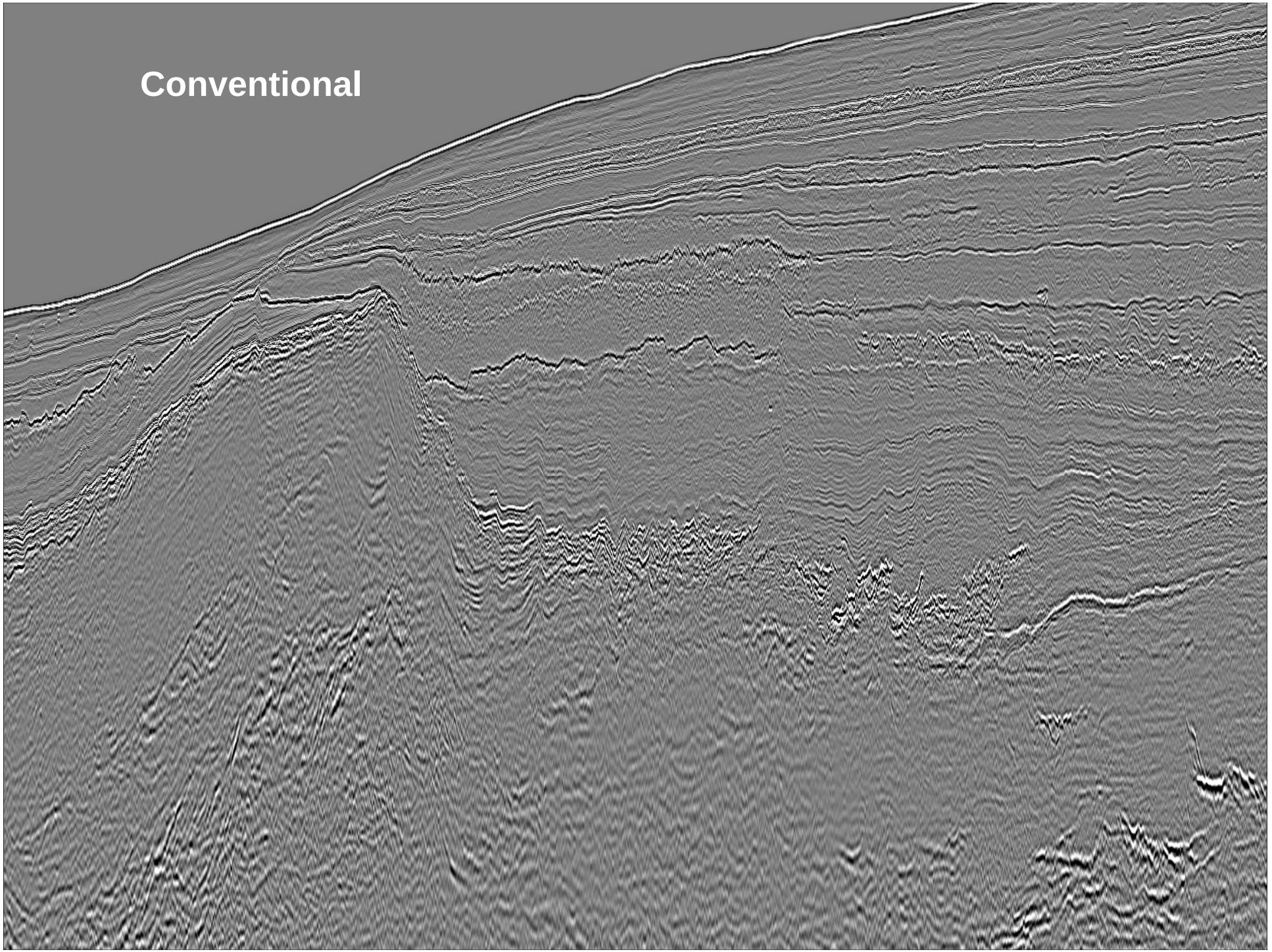
GeoStreamer GS™

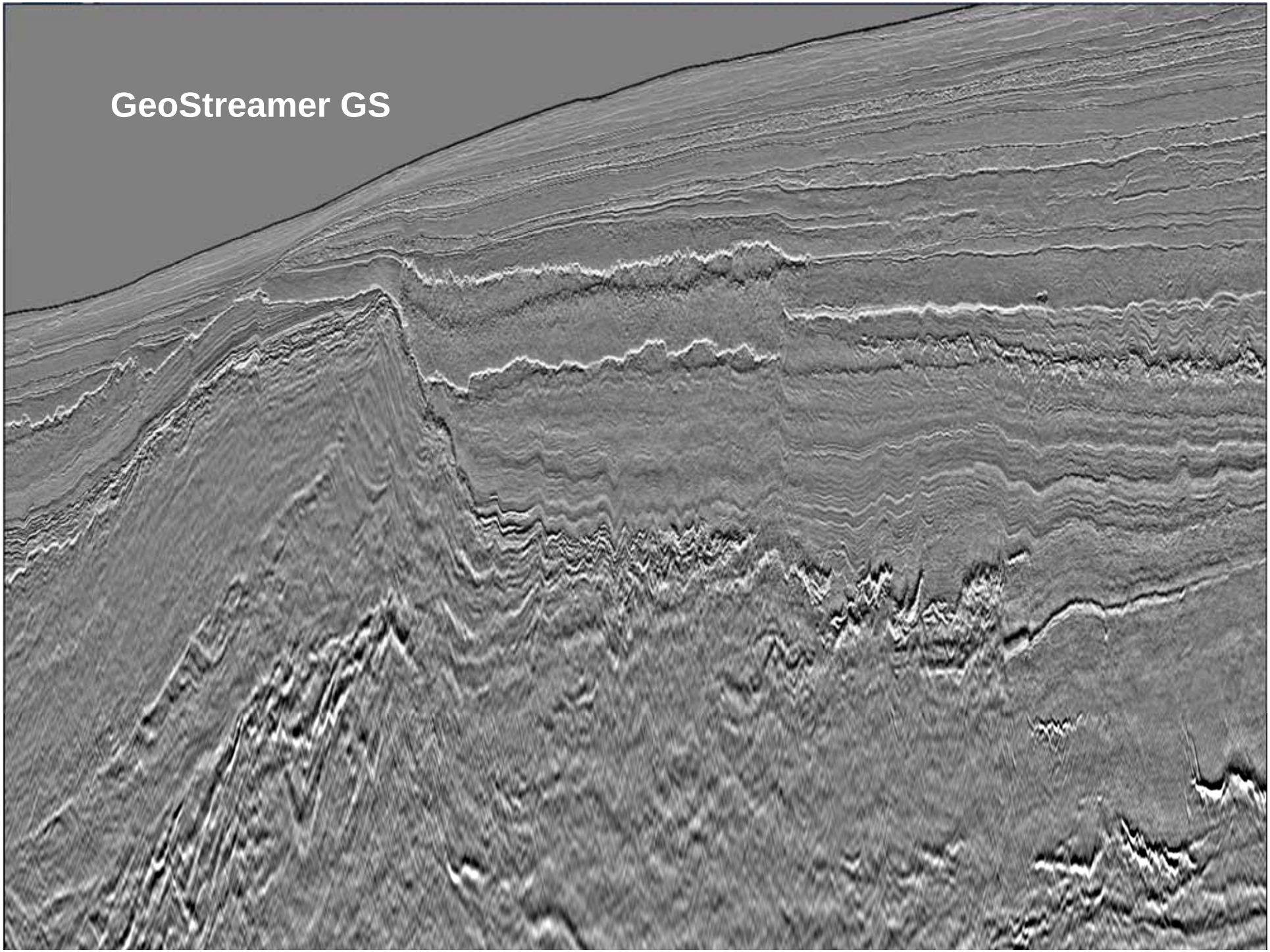


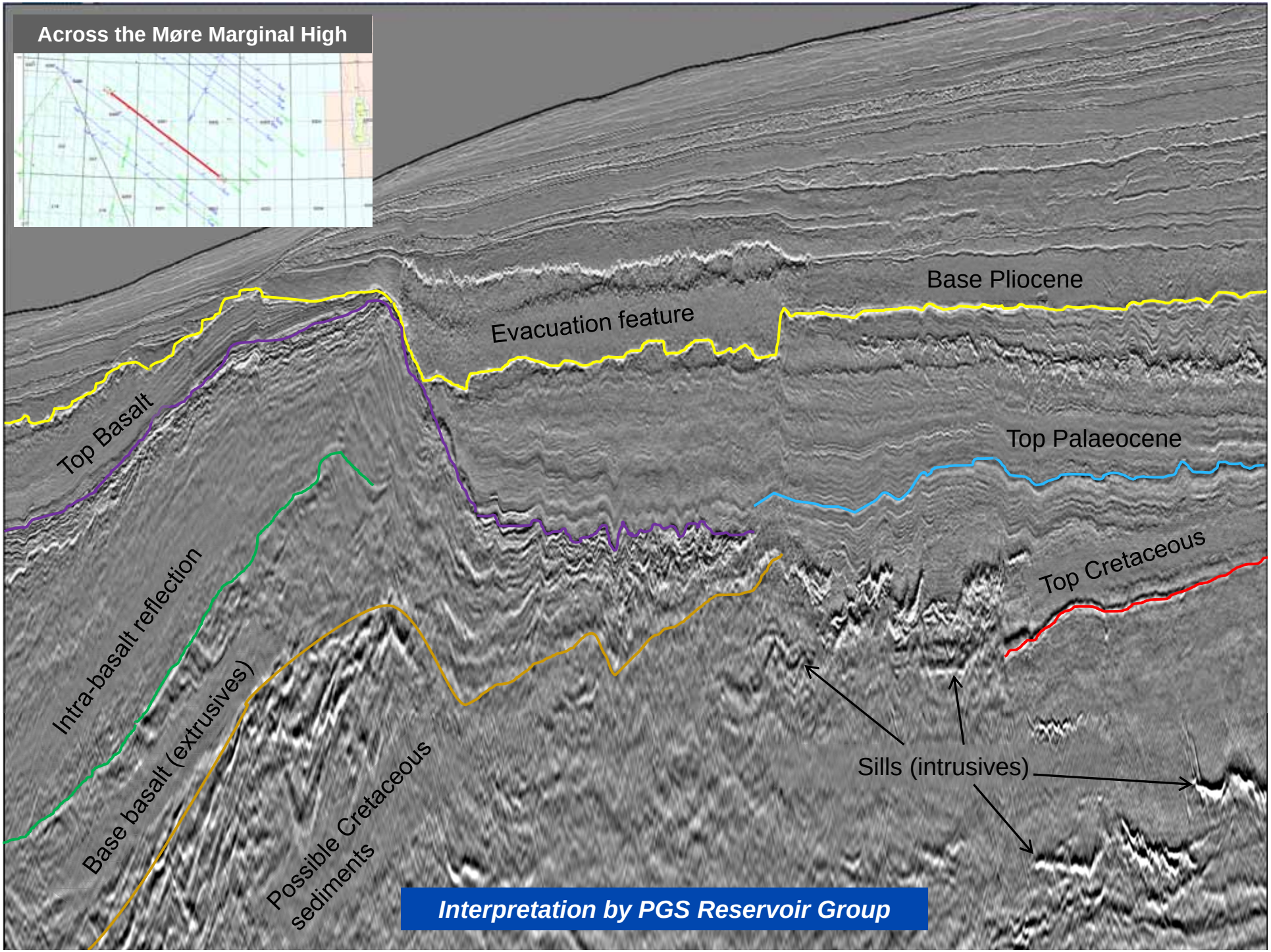
GeoSource layout in following examples



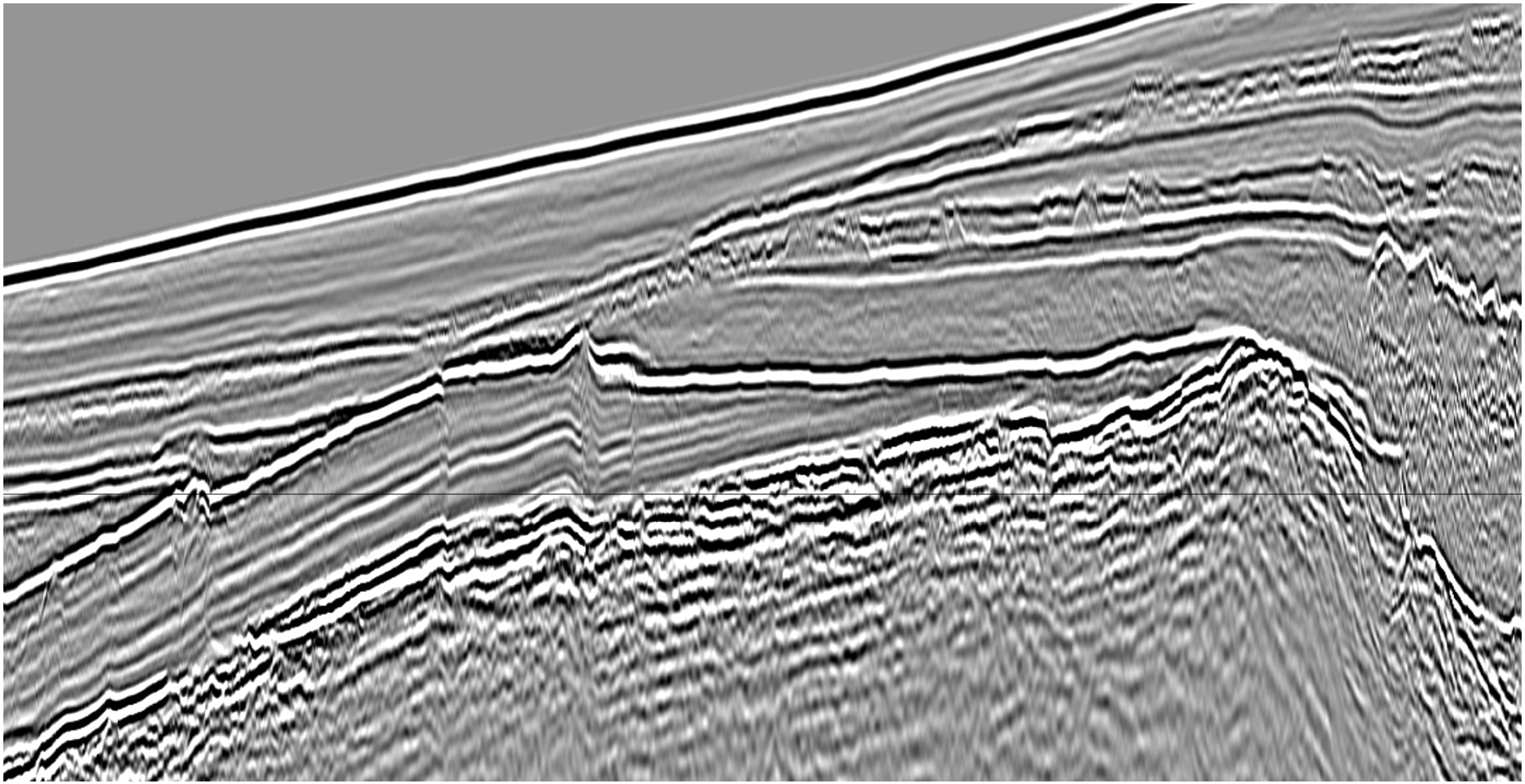
10m sub-arrays fired together with randomised delay 0-1000ms
14m sub-arrays fired together with randomised delay 0-1000ms


Conventional

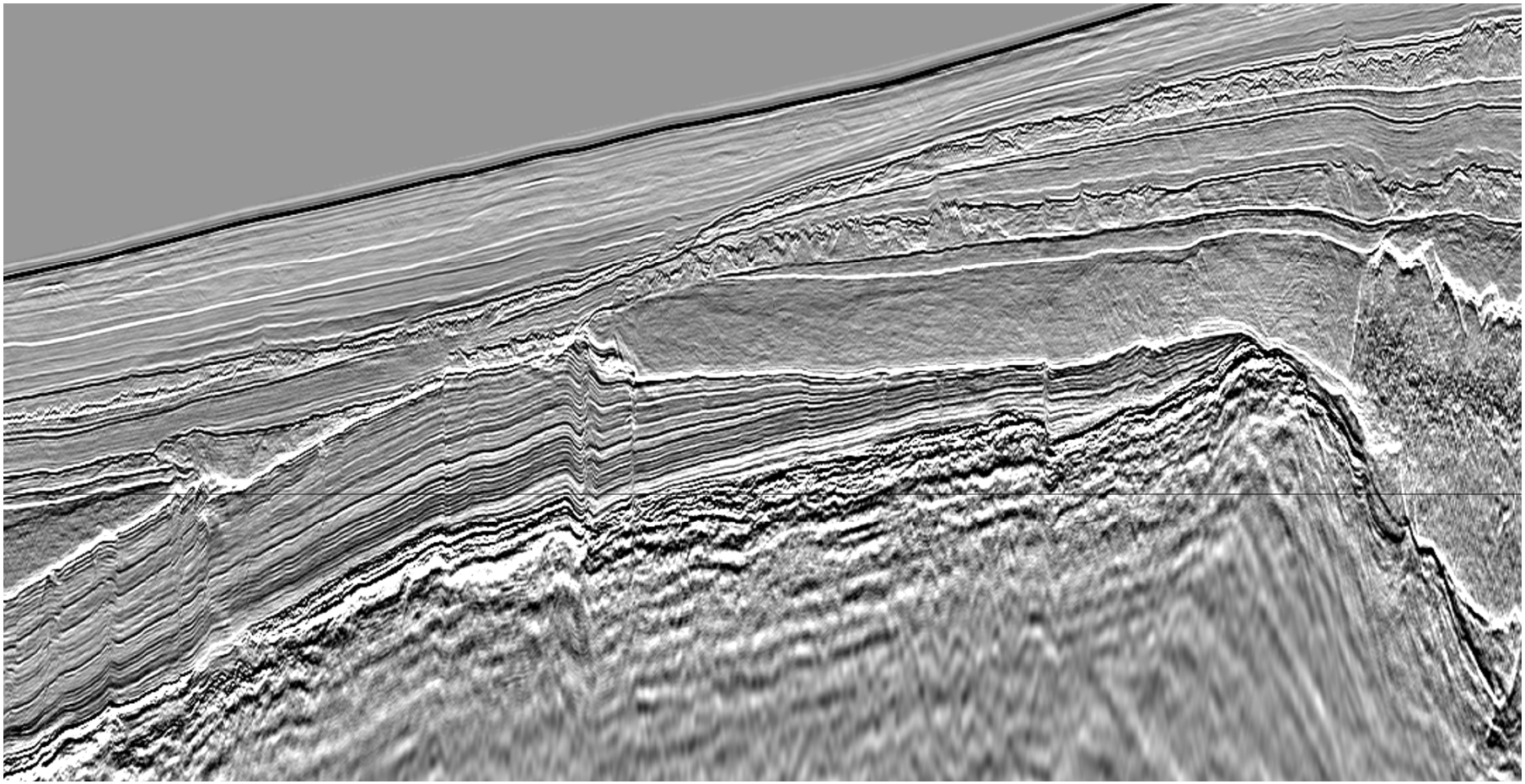

GeoStreamer GS


Across the Møre Marginal High
Base Pliocene
Evacuation feature
Top Basalt
Top Palaeocene
Top Cretaceous
Intra-basalt reflection
Base basalt (extrusives)
Possible Cretaceous sediments
Sills (intrusives)
Interpretation by PGS Reservoir Group

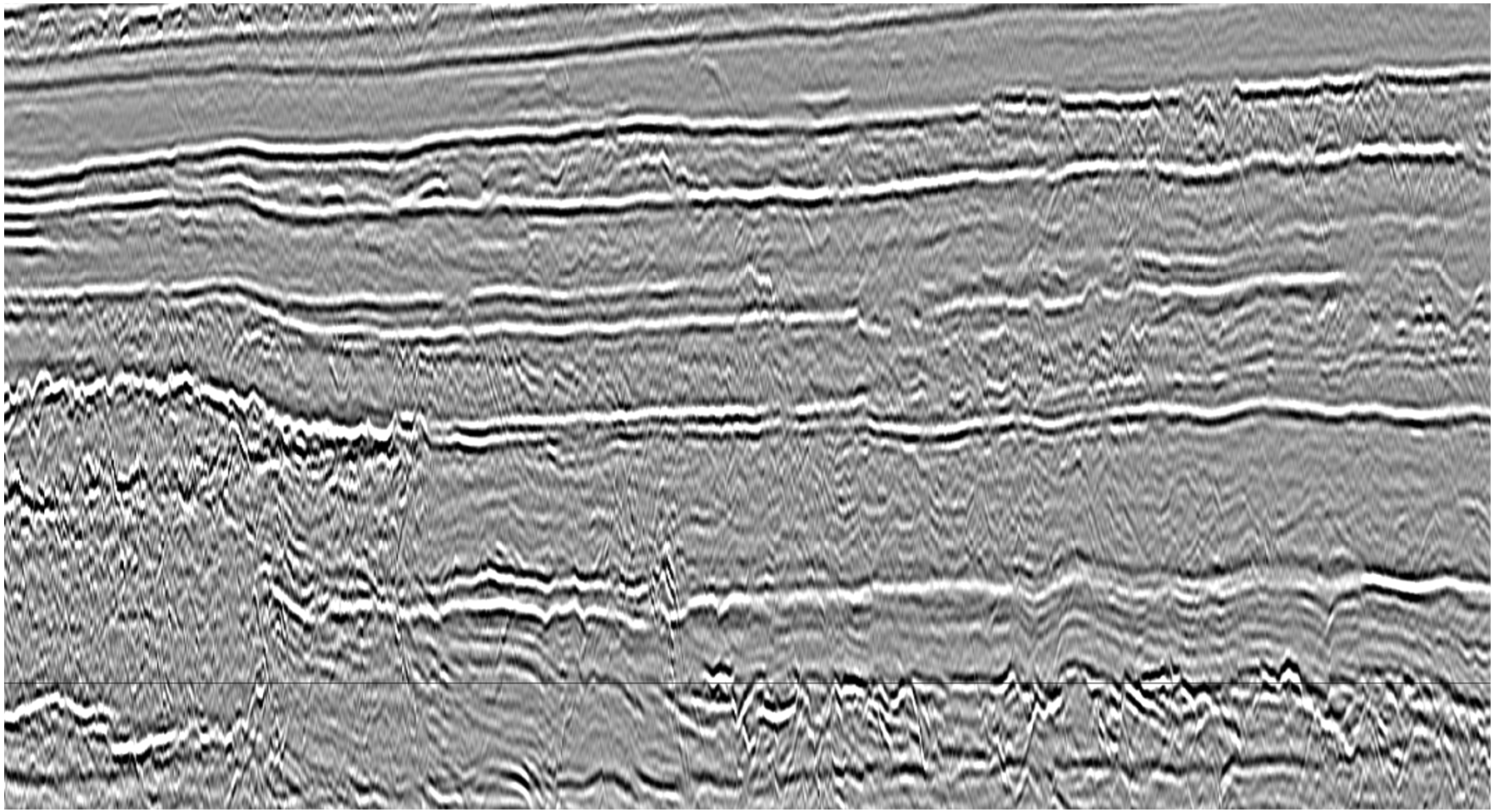
Legacy data



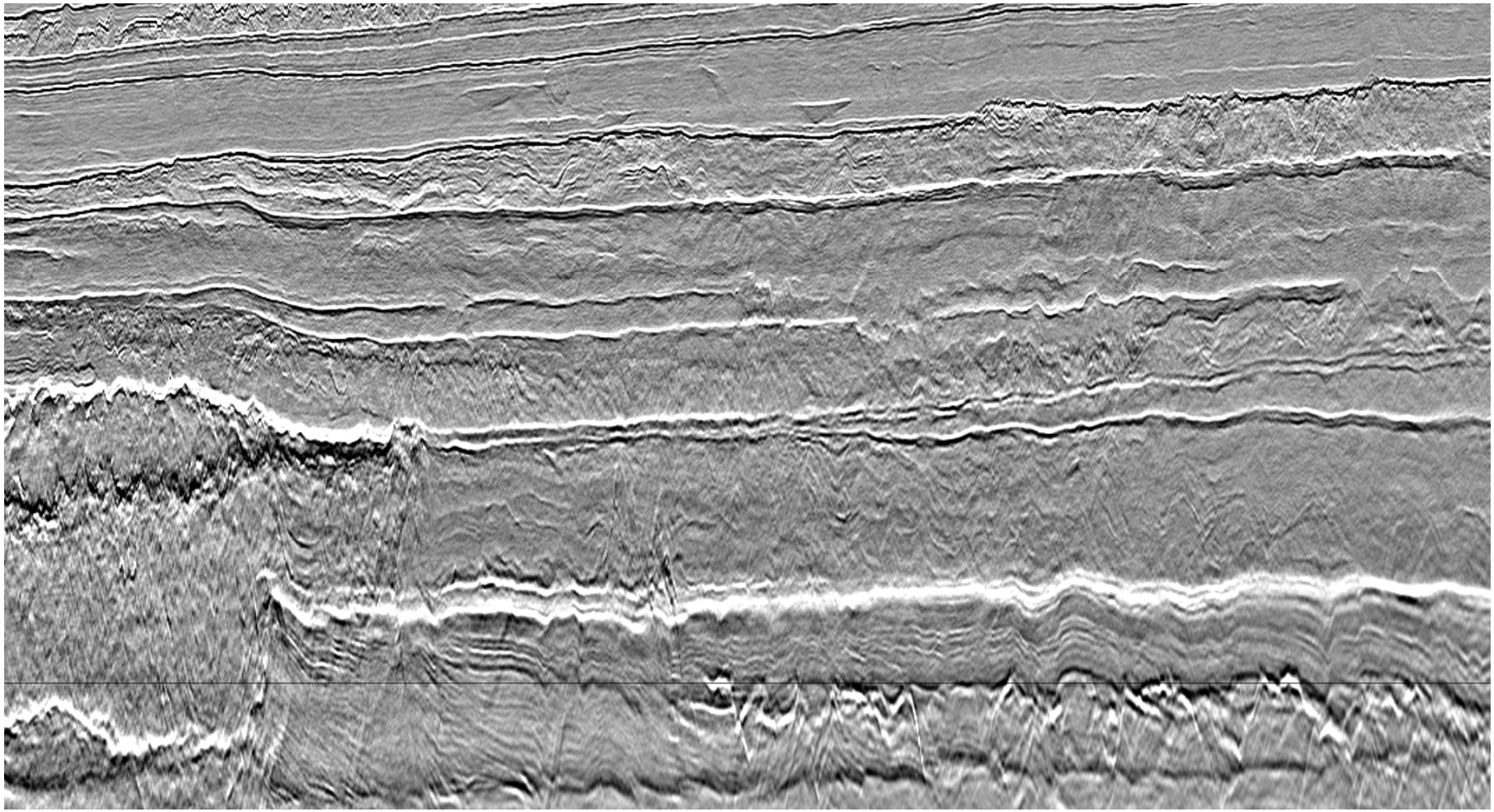
Ghost-free Acquisition



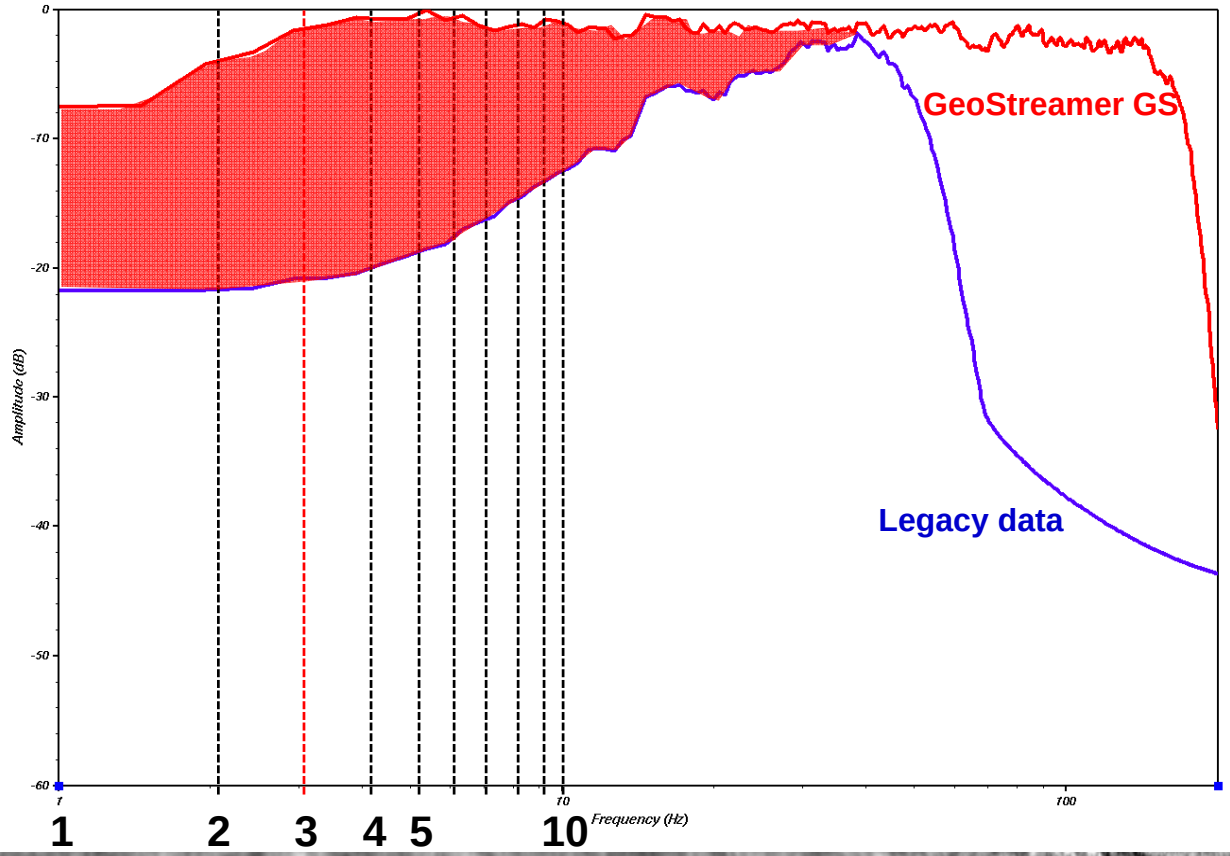
Legacy data



Ghost-free acquisition



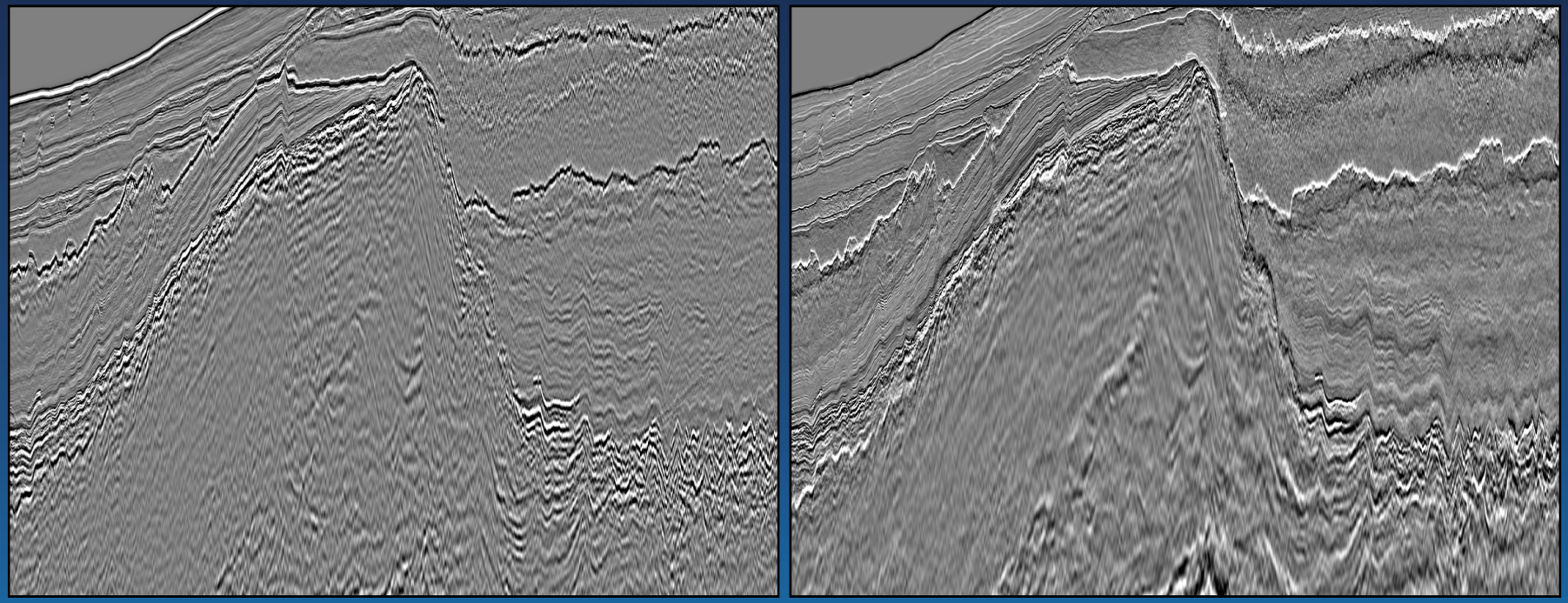
Frequency comparison – Log scale



Conventional vs. GeoStreamer GS

Conventional

GeoStreamer GS™



Outline

- Introduction
- GeoStreamer
  - Impact of the sea surface reflection
  - Dual-sensor technology
  - Experience and data examples
  - Reservoir characterization
- What about the source side – GeoStreamer GS
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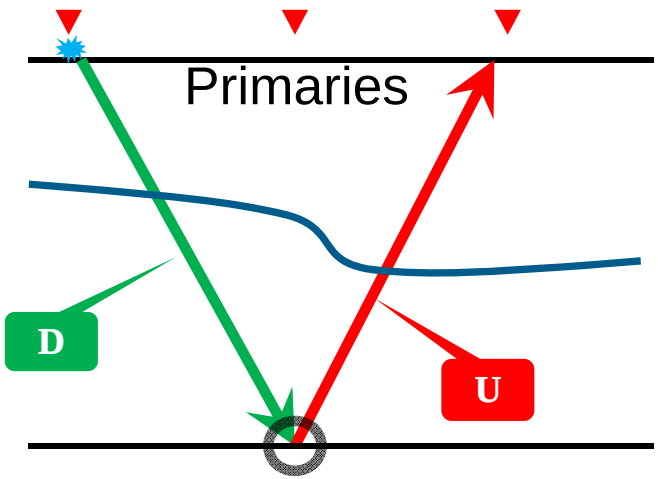
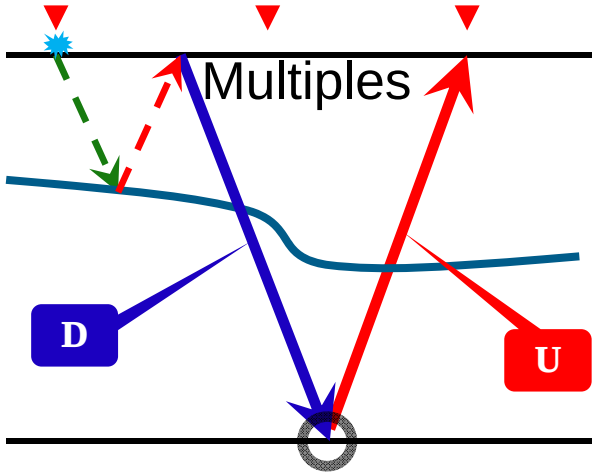
- Towed streamer electromagnetics

Imaging with separated wavefields from GeoStreamer data

1. Extrapolate Waves: For the multiples - substitute the source wavefield in normal WEM with the down-going wavefield at each receiver



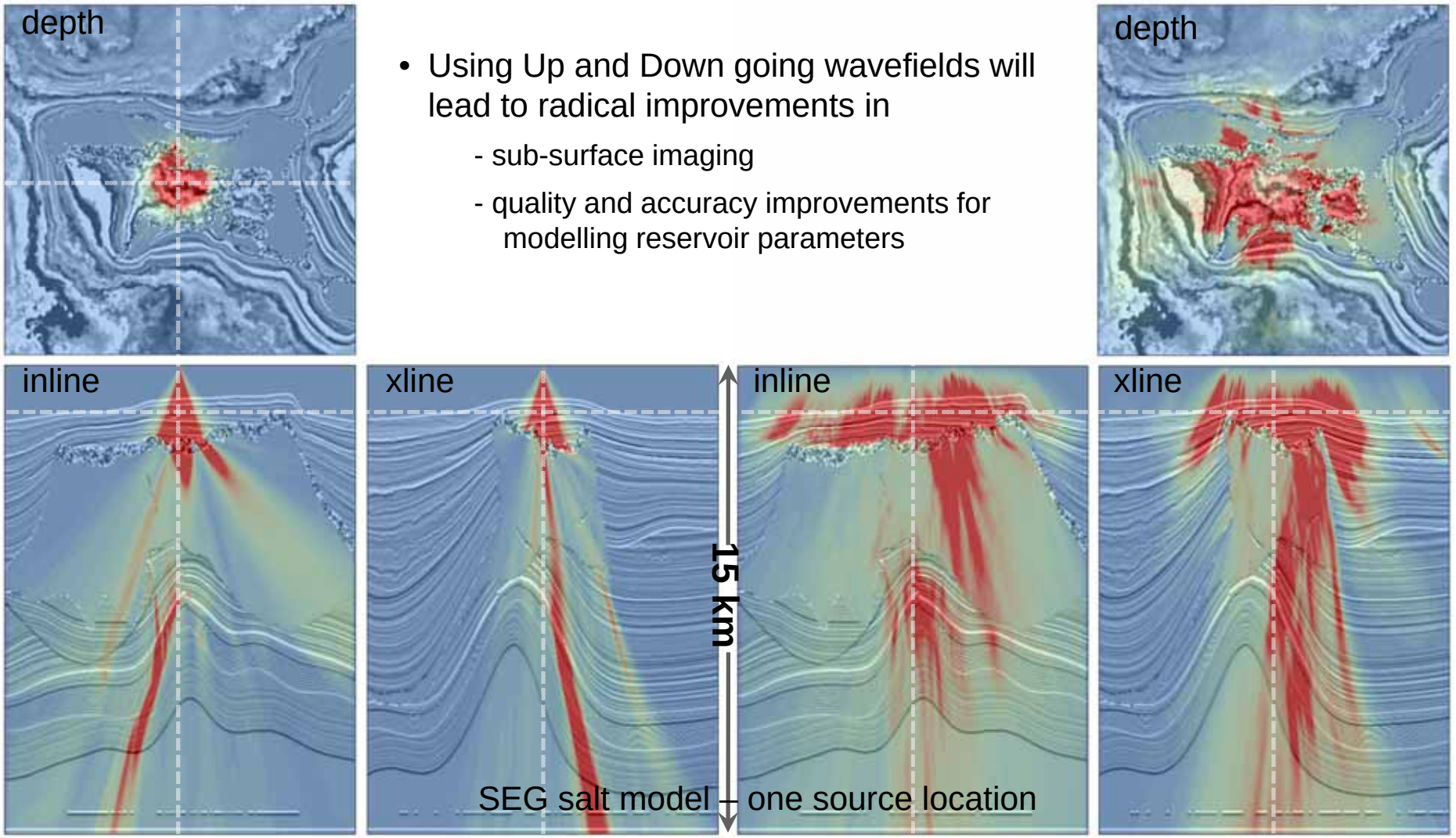


2. Apply Imaging Condition: either cross-correlation (stable but does not define reflectivity) or, preferably, smoothed deconvolution (defines the reflectivity)

See paper by Whitmore *et al*., Paper G005, EAGE 2011

Imaging with separated wavefields from GeoStreamer data

- Using Up and Down going wavefields will lead to radical improvements in
  - sub-surface imaging
  - quality and accuracy improvements for modelling reservoir parameters

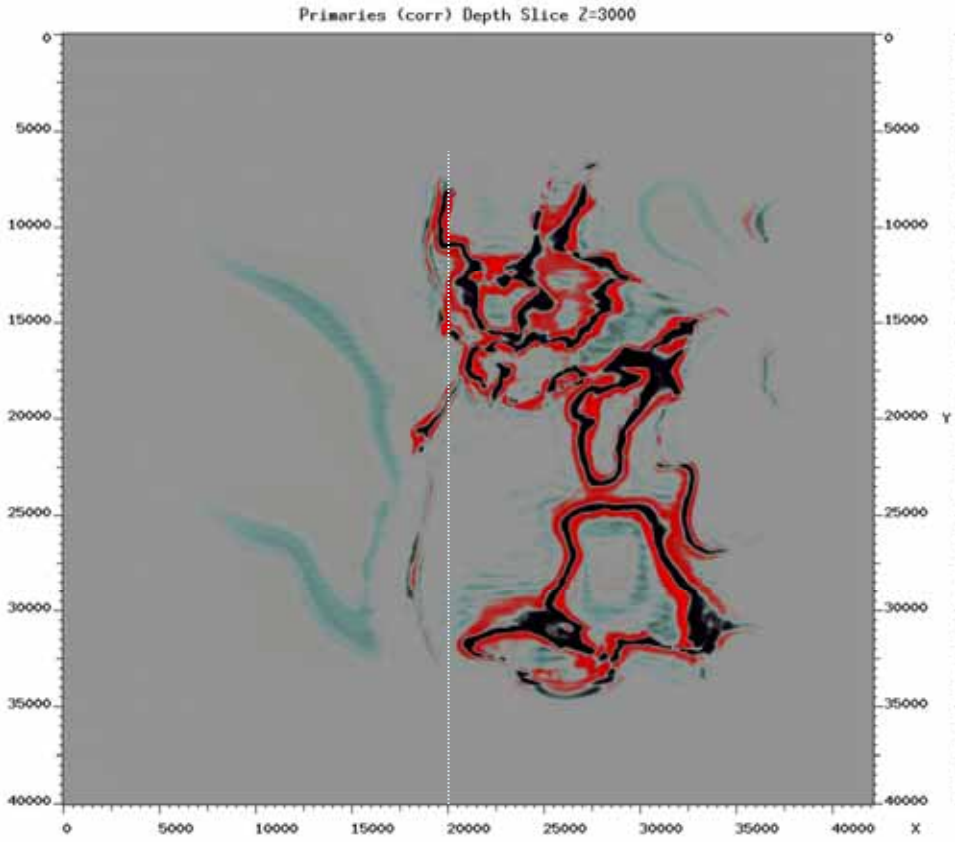


Illumination by Primaries

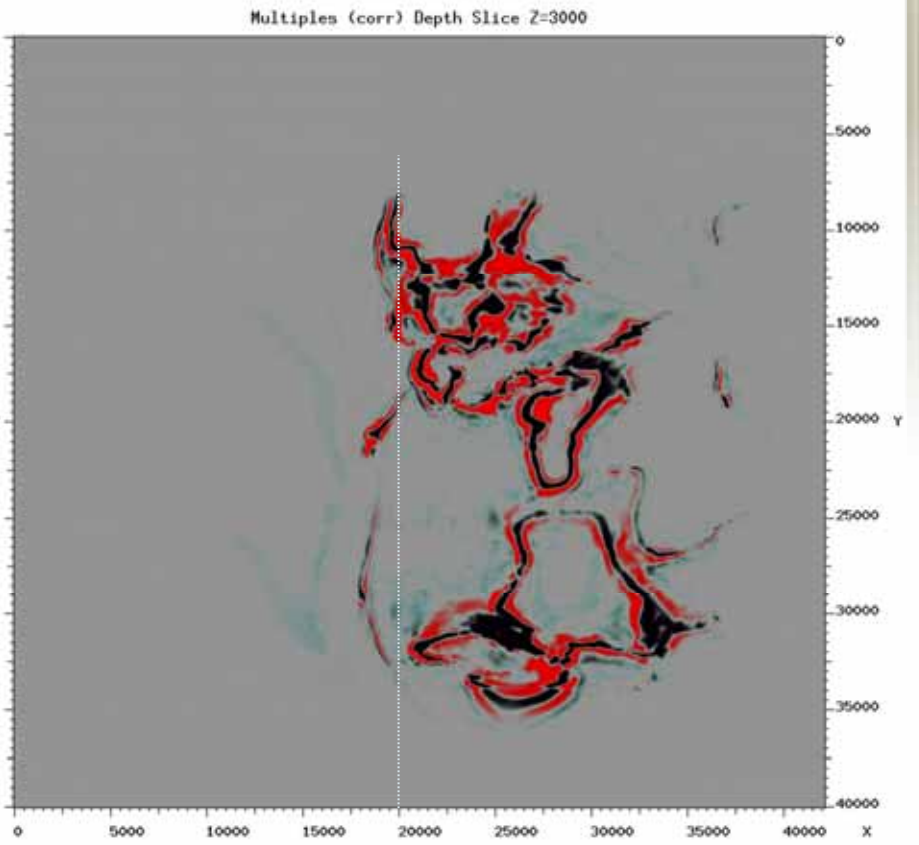
Illumination by Multiples

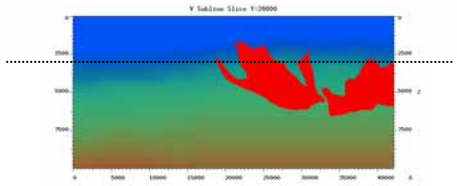
Depth slices - middle (z = 3000)

Imaging of Primaries



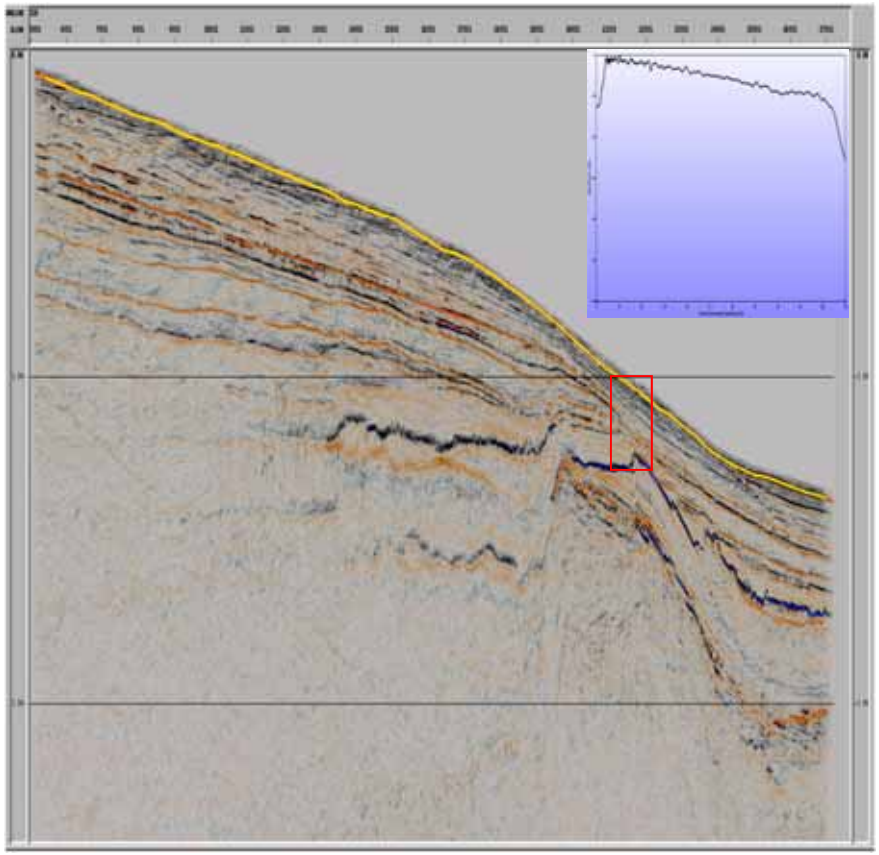
Imaging of Multiples



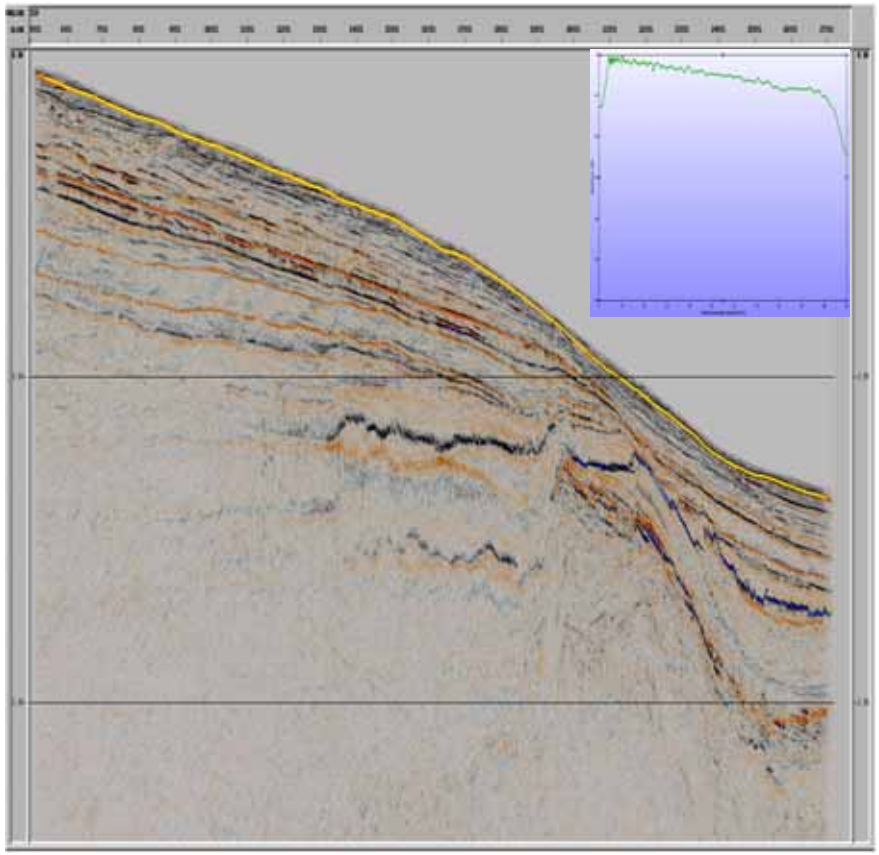


Depth slices - middle (z = 3000)

Imaging of Multiples



Imaging of Primaries



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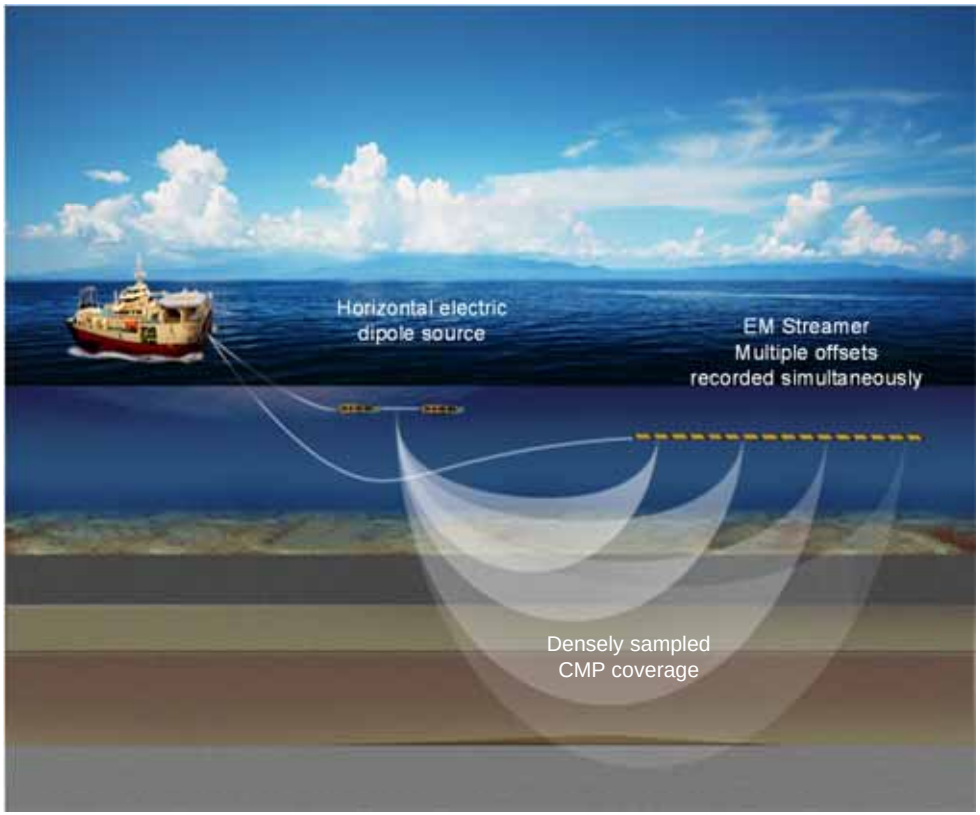
PGS Towed Streamer Electromagnetics

- PGS will acquire resistivity surveys during 2012
  - –North Sea for first surveys
  - –Data will be available to license
- A new system is being commissioned
  - –Significant upgrades from the prototypes
- What is different about “Towed EM”
  - –Acquisition speed between 4 and 5 Kts
  - –Same vessel as seismic acquisition
  - –Possible simultaneous seismic and EM ops.
  - –Dense data coverage
  - –Data analysis in context with seismic data
  - –Initial shallow water focus
  - –Next generation to go deeper



PGS Electromagnetic Streamer Development Timeline

2009

1st Offshore Trial:

Proof Of Concept

2010

Offshore Trial: Intermediate Proto-type

- < 400m water
- 1km target depth
- Increase source moment-I
- Processing & Modelling Alpha release

2011

Offshore Trial: Proto-type

-< 400m water

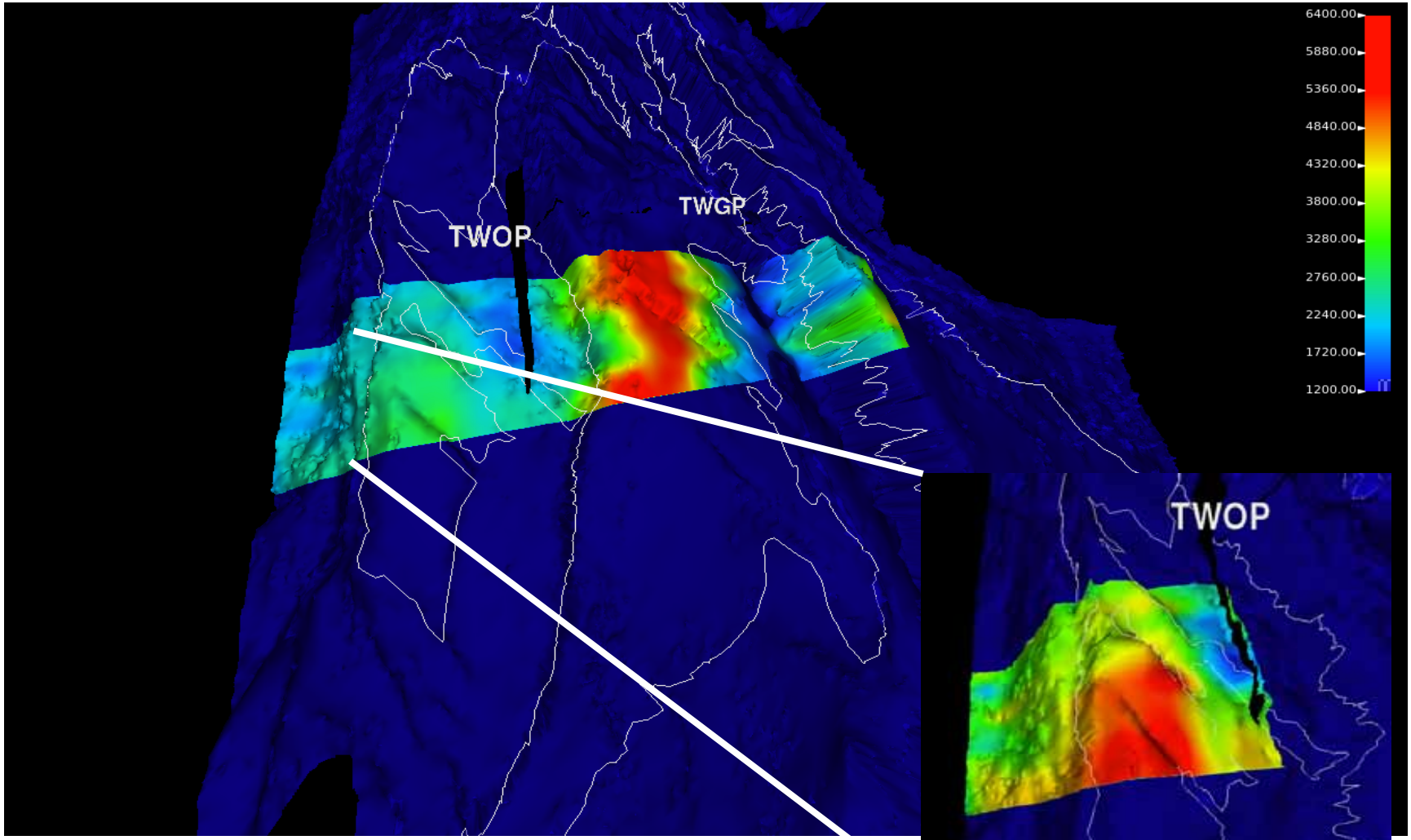
- 2 km target
- Increased source moment-II
- Processing & Modelling Beta Release

2012

Commercial System Commissioning

- Validation tests
- New Source
- 8Km Streamer
- Integrated QC/QA
- First data available before year-end

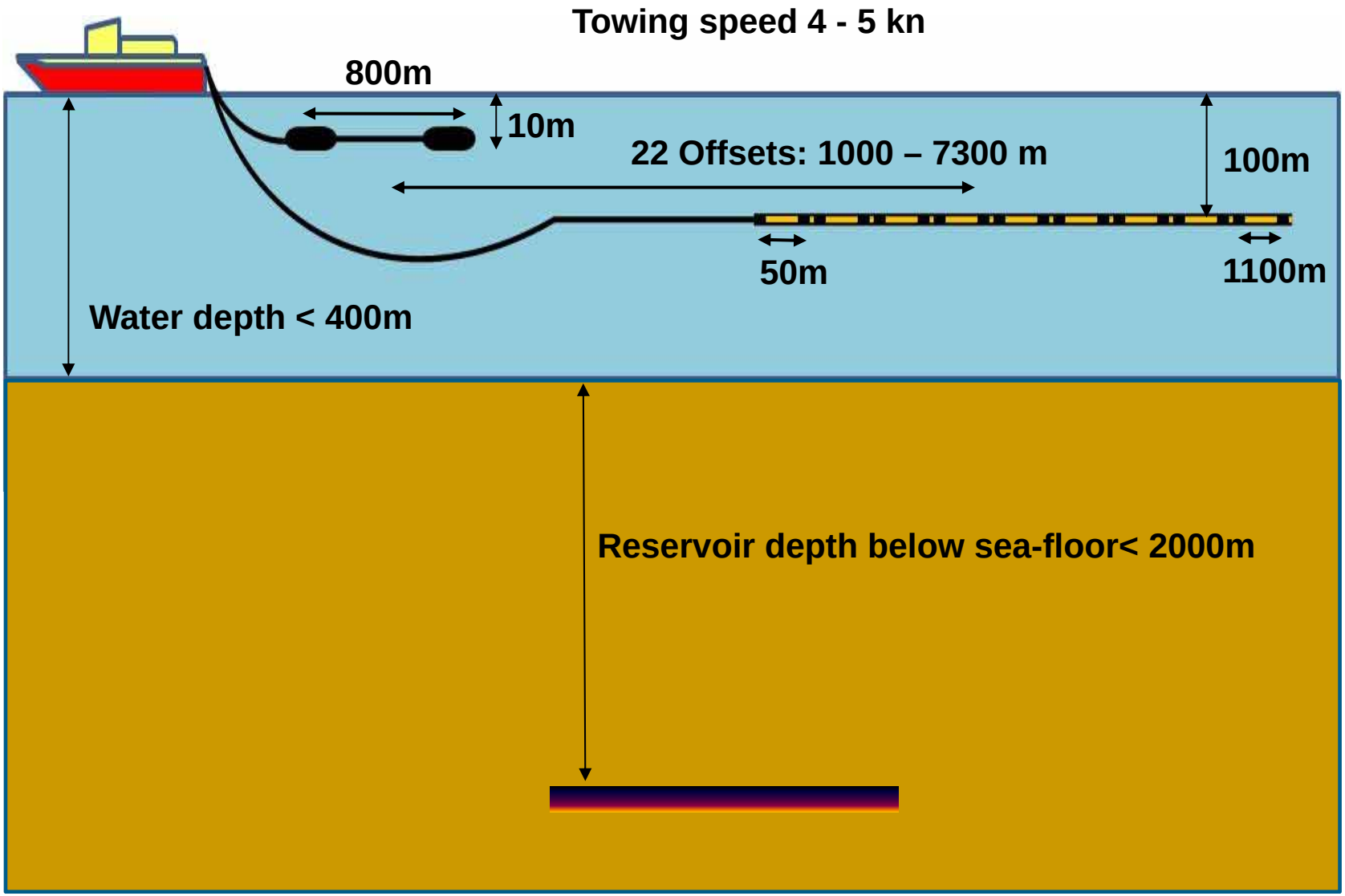
Resistivity from inversion – Troll Oil Province Delineated



Transverse resistance for 5120m offset inversion results plotted on the top reservoir horizon

Close-up of TWOP rescaled

Capability Analysis Results – First Generation System




PGS
Thank You for Your Attentio