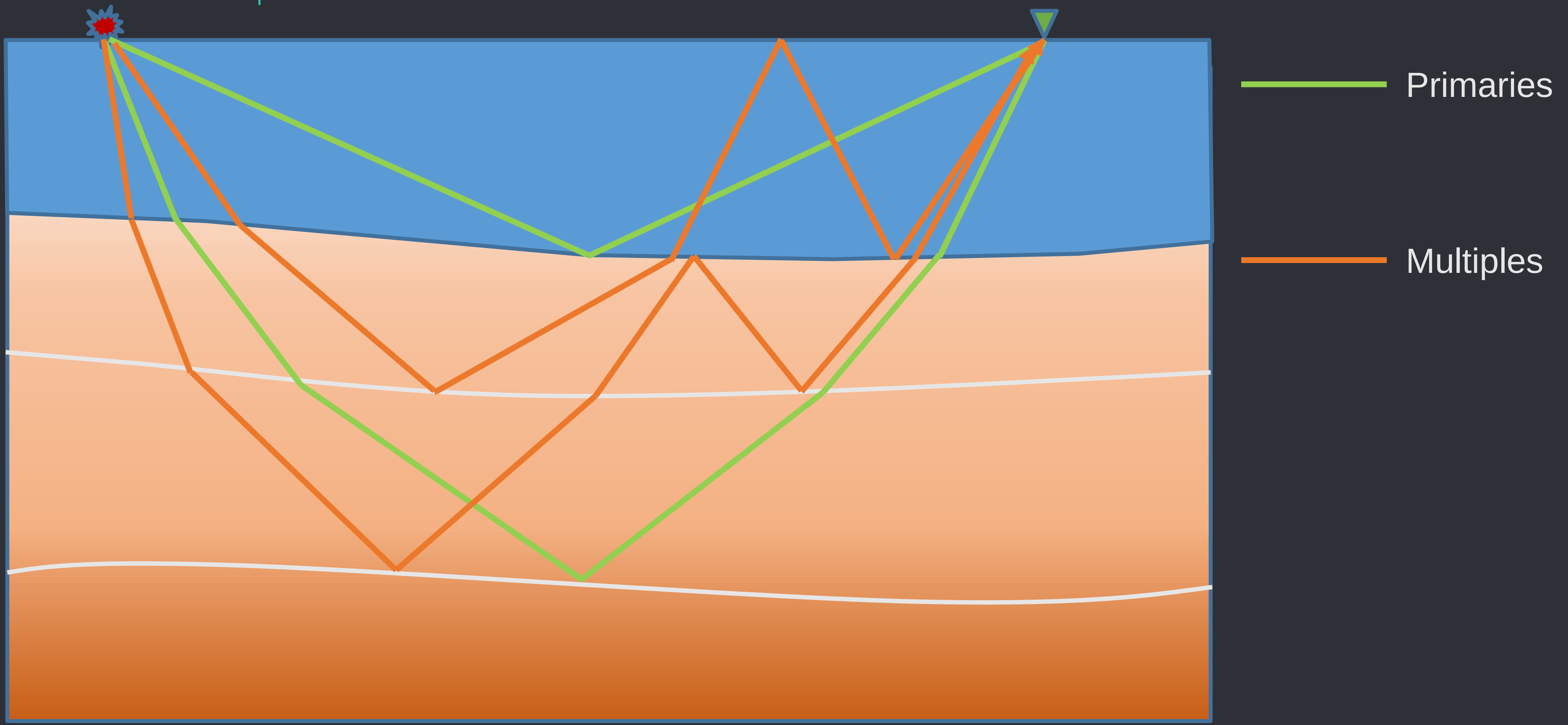
Zero-Offset Demultiple – Efficient Demultiple of Near-Offset Marine Seismic Data in RadExPro

Problem of Multiple Waves



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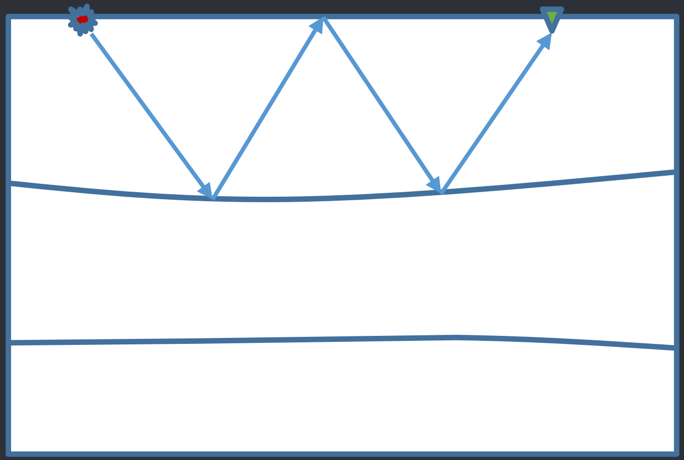
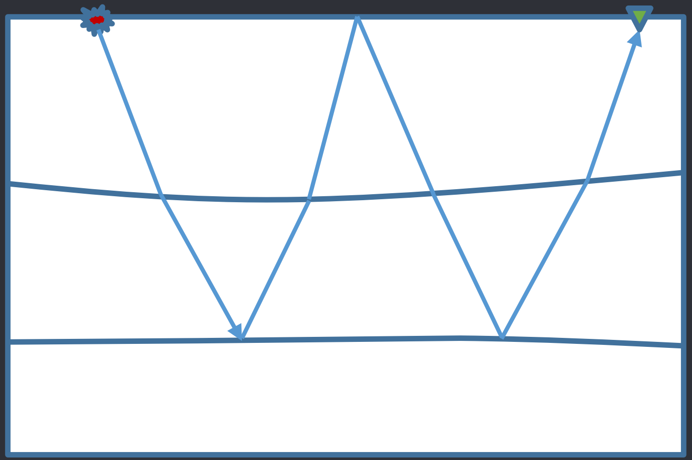
Types of Multiples

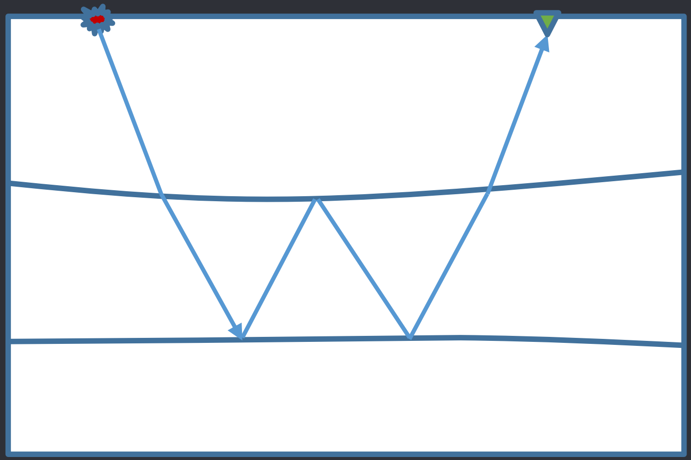
Water bottom multiple



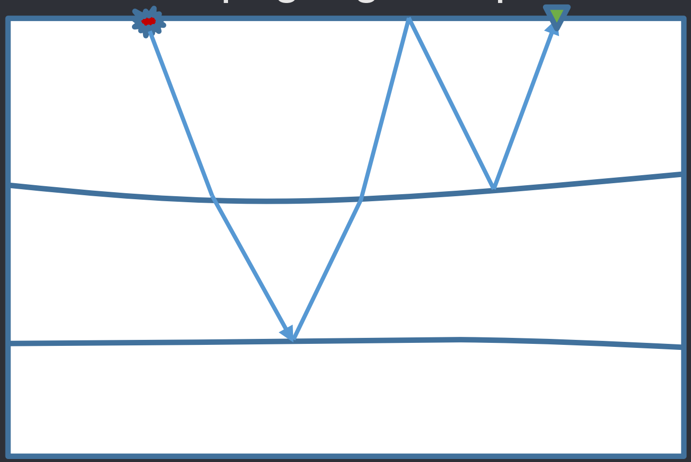
Reflector multiple



Internal multiple



Reflector peg-leg multiple



Multiple Elimination

- **Main Multiple Elimination Techniques**

1. Periodicity of Multiples – **Deconvolutions**

2. Different Move-Out between Multiples and Primaries -- **Radon/F-K/Tau-Pi demultiple, slant-stack, etc.**

3. Wavefied Prediction and Subtraction – **SRME**

RadExPro seismic software

Multiple Elimination

- **Main Multiple Elimination Techniques**

~~1. Periodicity of Multiples – **Deconvolutions**~~
-- very limited usability: flat seafloor only, very shallow water, not very efficient

~~2. Different Move-Out between Multiples and Primaries -- **Radon/F-K/Tau-Pi demultiple, slant-stack, etc.**~~
-- fail for near offset seismic data (Yilmaz, 1989)

3. Wavefied Prediction and Subtraction – **SRME**
-- work well for multi-channel data, time-consuming

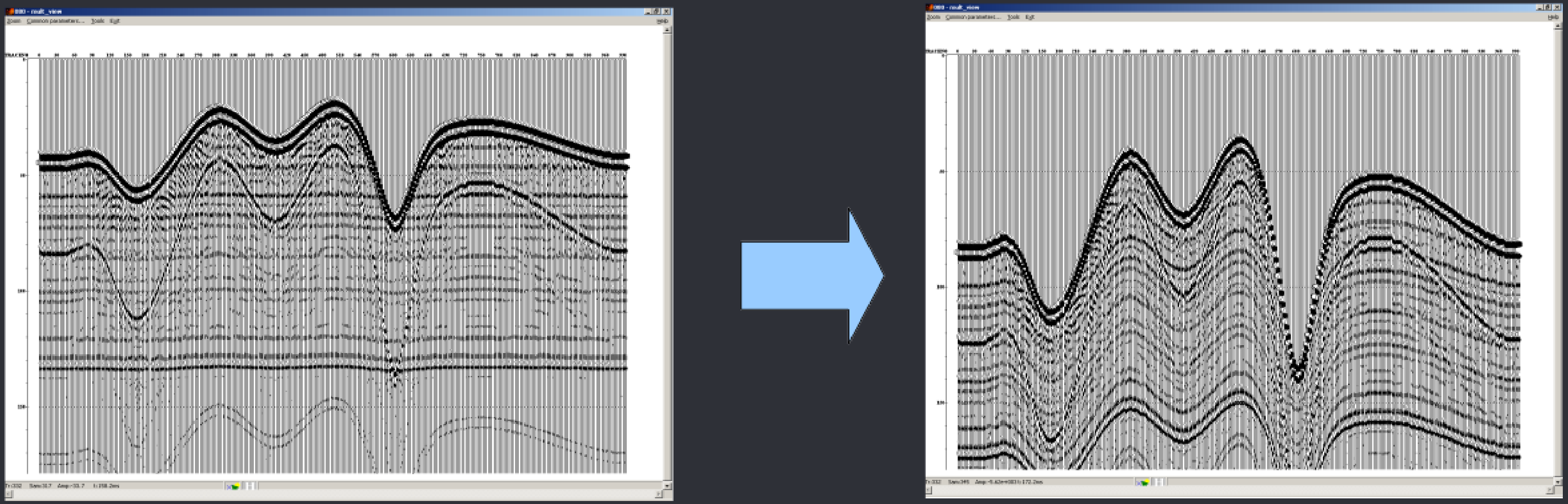
HR/URH specific – **Zero-Offset Demultiple**
-- for single-channel near-offset data

Multiple Elimination: Zero-Offset Demultiple

Zero-offset demultiple theory

1. An approximate model of multiples created from data itself:

- Statics shift to the time of seafloor reflection **– model of peg-leg multiples**



Zero-offset demultiple theory

1. An approximate model of multiples created from data itself:

   - Autoconvolution of each trace

Zero-offset demultiple theory

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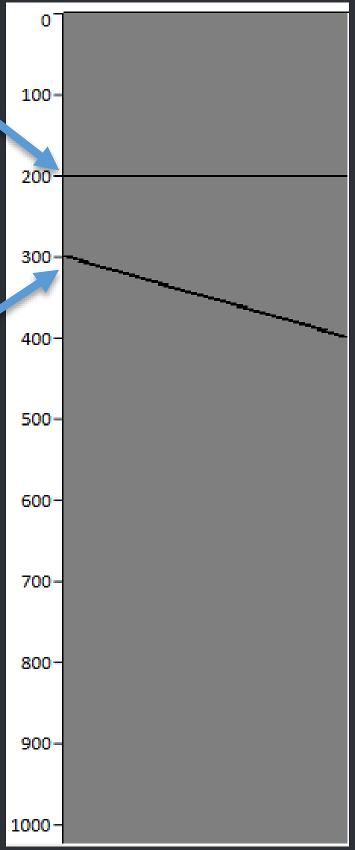
Water bottom

Subbottom reflector



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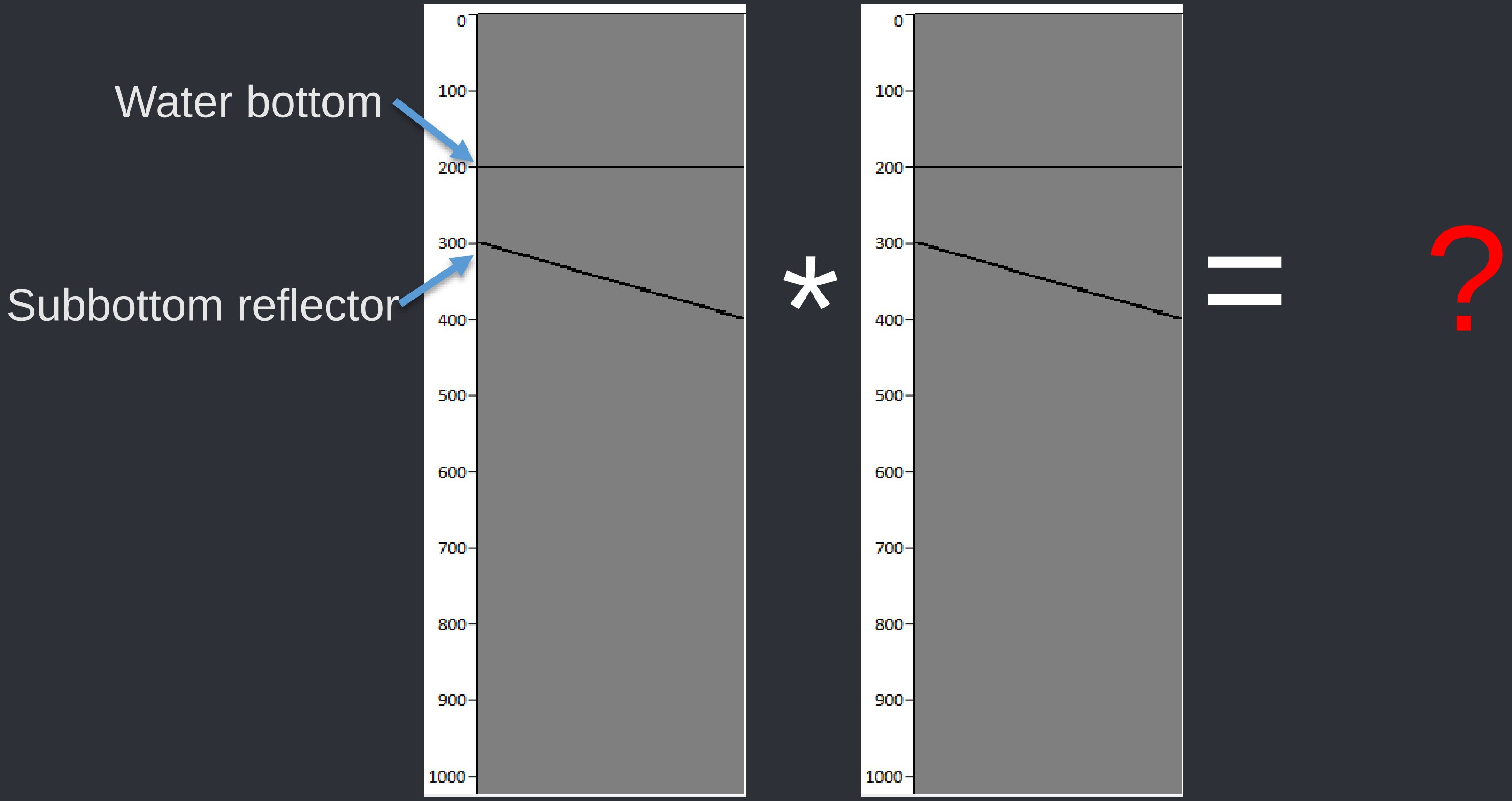

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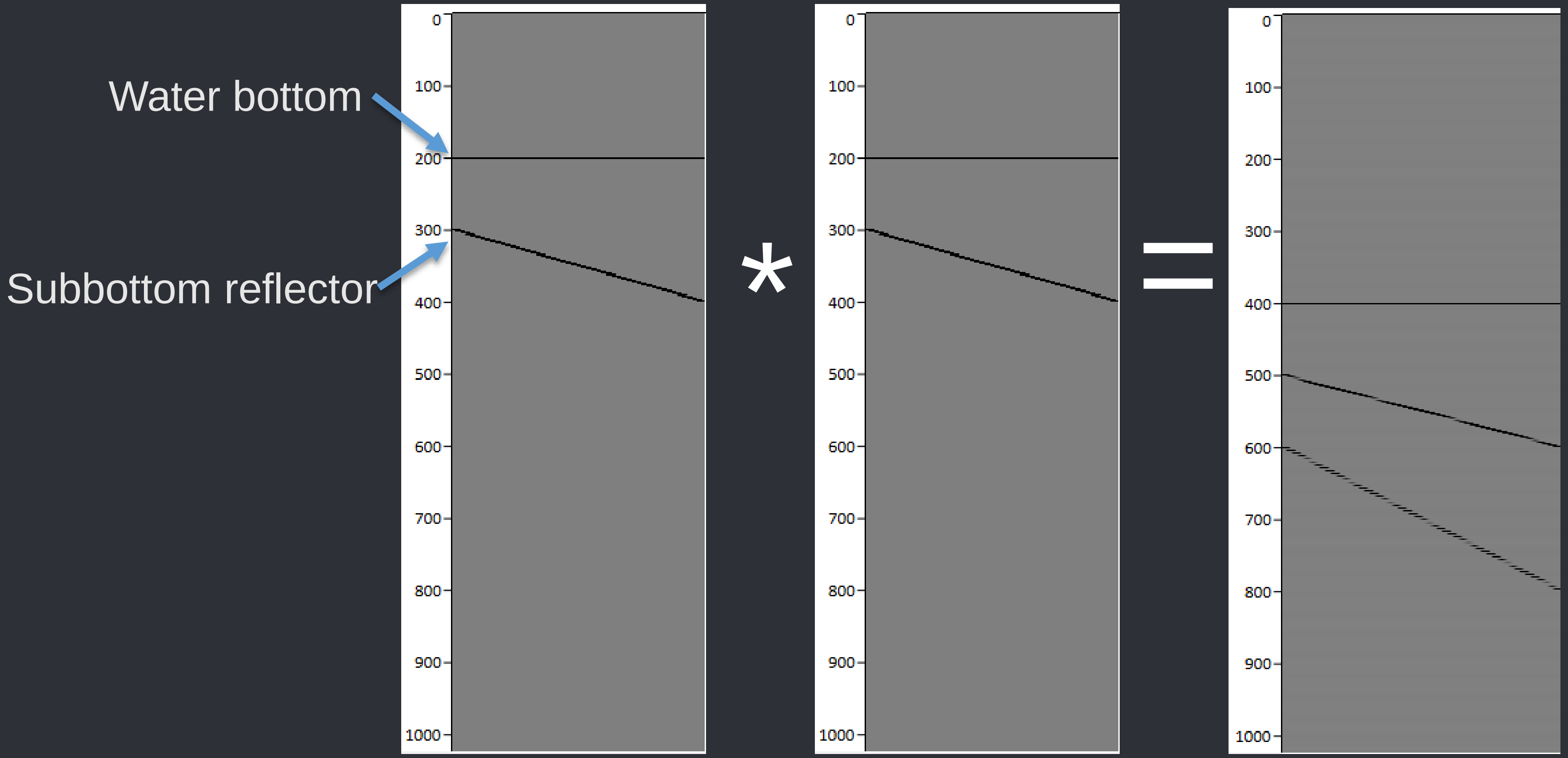

Multiple Elimination: Zero-Offset Demultiple

Zero-offset demultiple theory

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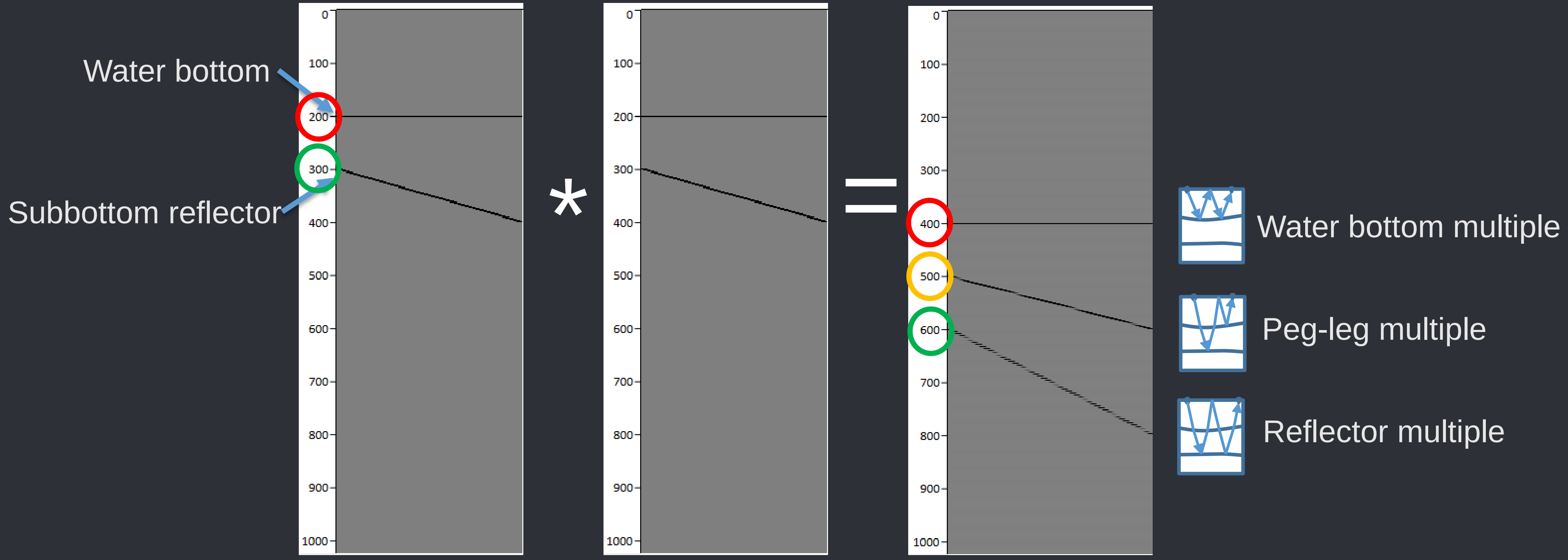

Zero-offset demultiple theory

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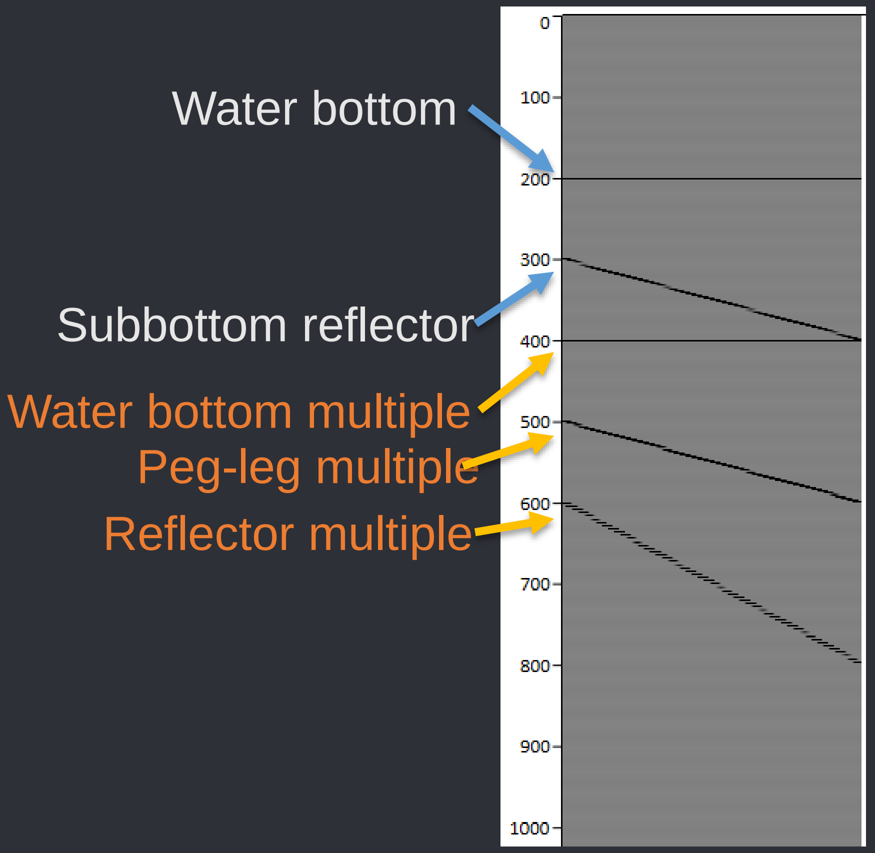
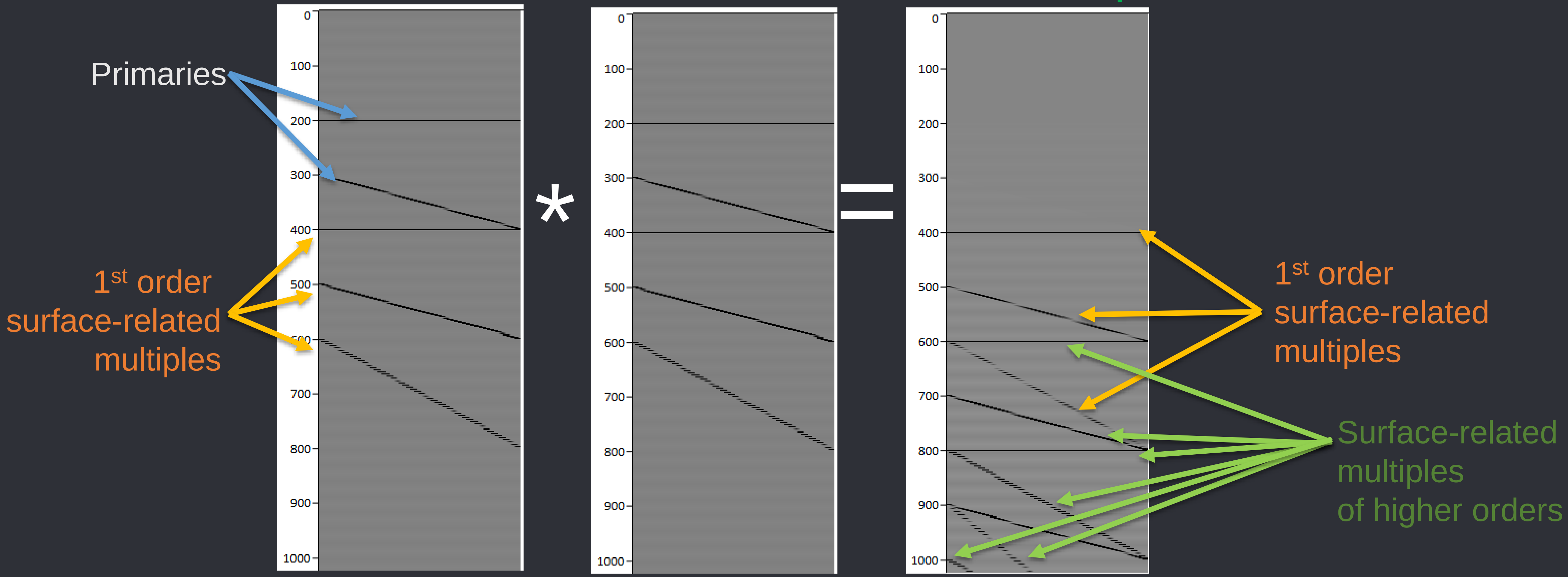


Zero-offset demultiple theory

1. An approximate model of multiples created from data itself:

- Autoconvolution of each trace **– model of all surface-related multiples**

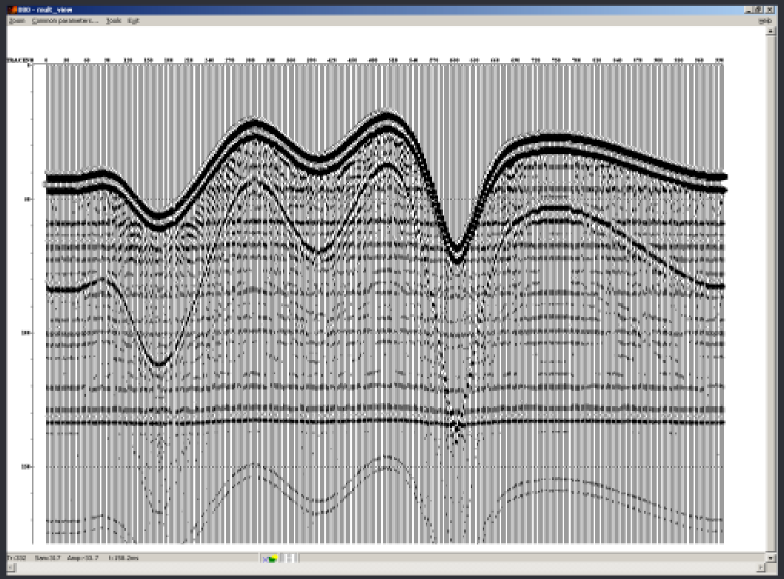


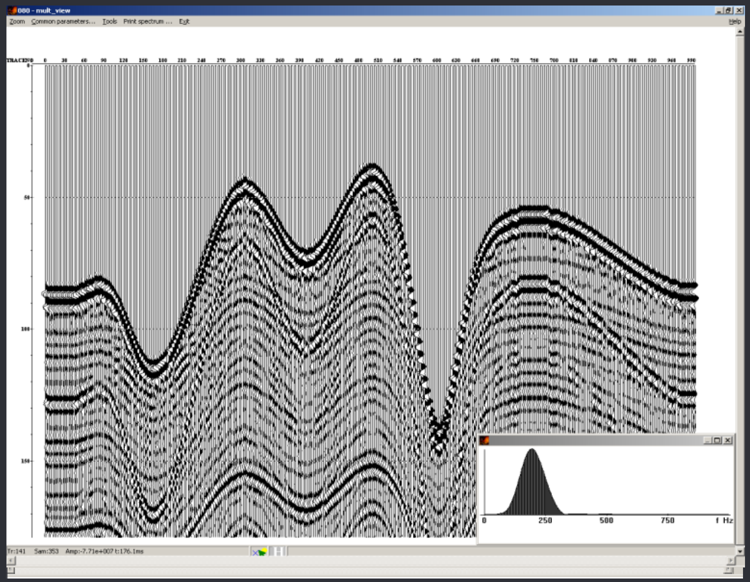
Multiple Elimination: Zero-Offset Demultiple

Zero-offset demultiple theory

1. An approximate model of multiples created from data itself:

- Autoconvolution of each trace – **model of ALL surface-related multiples**





Zero-offset demultiple theory

2. Model is subtracted from the data

Zero-offset demultiple theory

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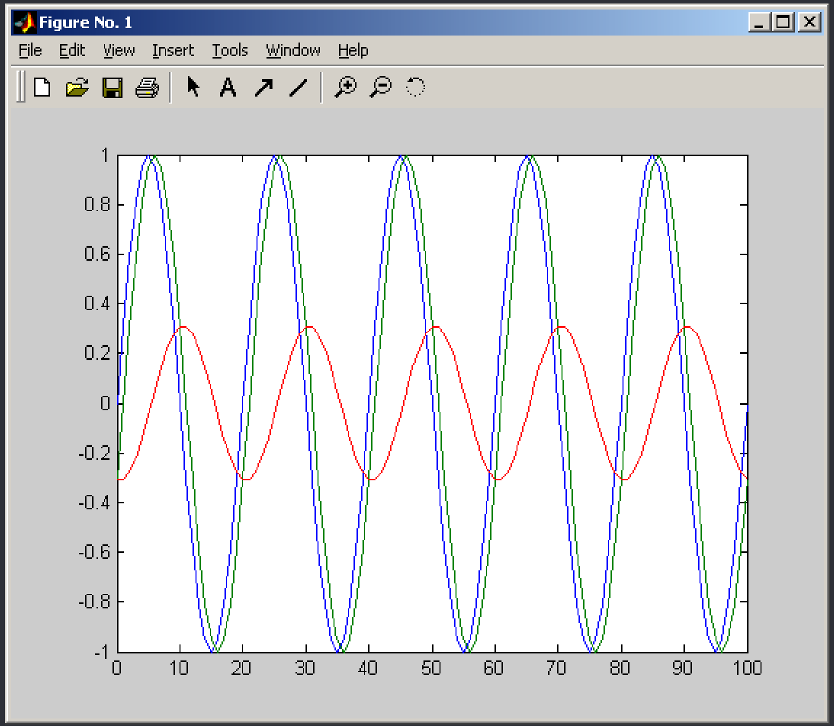
- Our model is **inaccurate**, both in kinematics and in dynamics.

Can we simply subtract it?

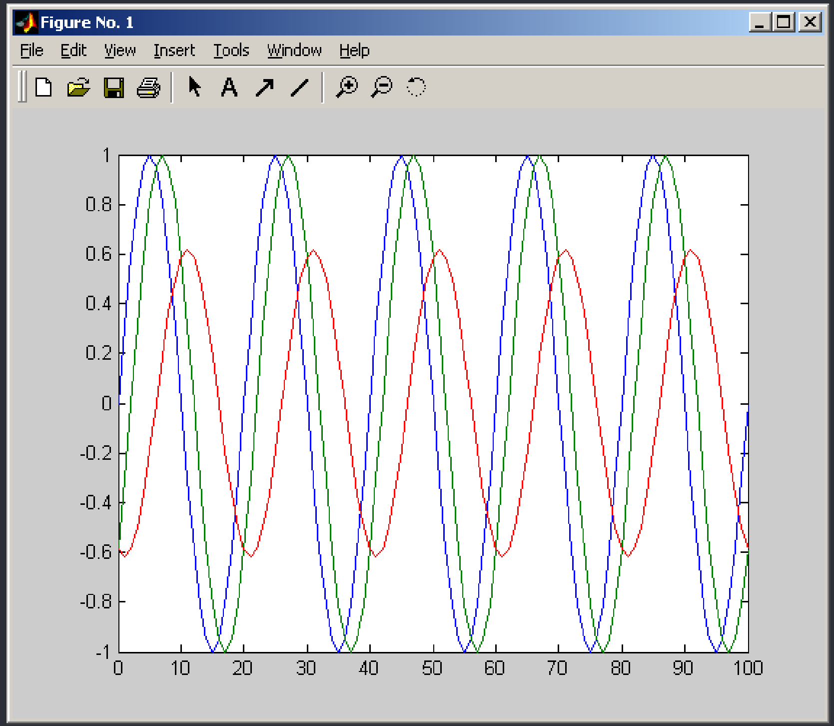
Zero-offset demultiple theory

2. Model is subtracted from the data

- Subtracting with inaccurate kinematics:



Shift of 1 sample

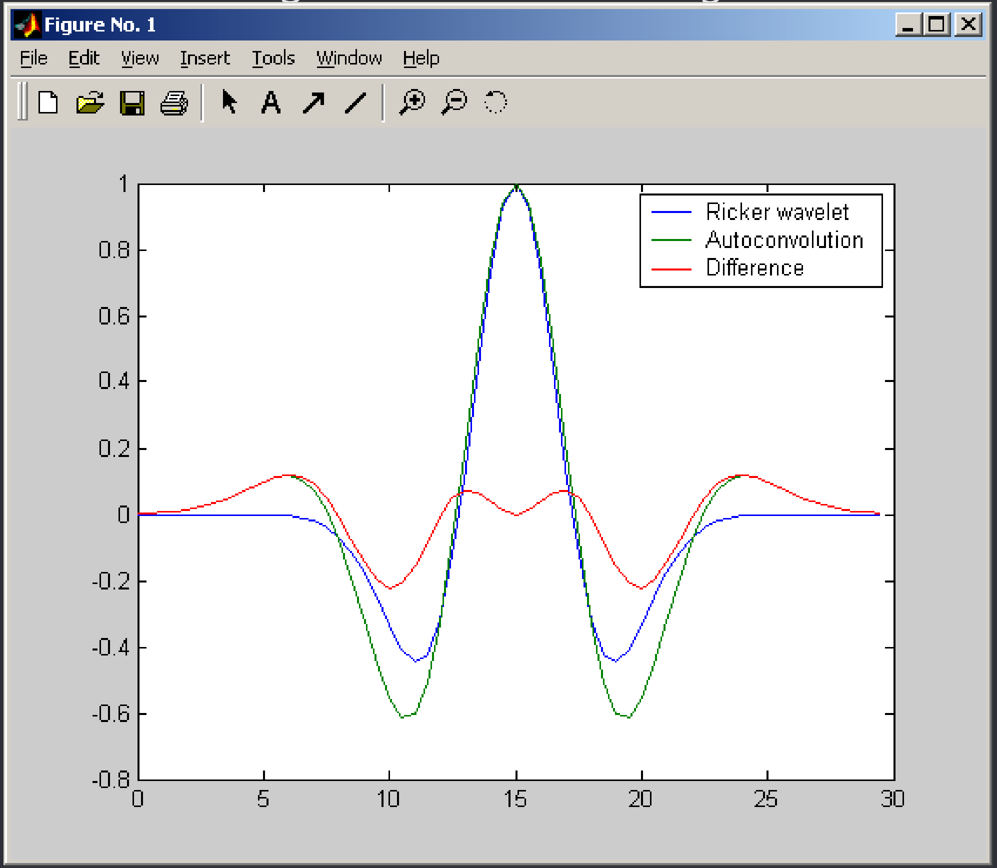


Shift of 2 samples

Zero-offset demultiple theory

2. Model is subtracted from the data

- Subtracting with inaccurate dynamics:



- Autoconvolution results in change of wavelet
- Adequate amplitude decay compensation is difficult to achieve

Zero-offset demultiple theory

2. Model is to be subtracted from the data **ADAPTIVELY**

Zero-offset demultiple theory – **Adaptive Subtraction Algorithm**

The task of adaptive subtraction of the model of multiples from the initial wavefield is posed in the following way: for each trace it is required to define *f(x,t)* minimizing in RMS sense the following functional:

$$J = \sum_t \left(Z(x,t) - \sum_{k=-M}^{M} f\ (x-k,t) * K\ (x-k,t) \right)$$

f(x,t) are filters instead of coefficients, this description of distortions is essentially more general and includes waveform fluctuations caused by, particularly, frequency-dependent attenuation as well as amplitude variations

$Z(x,t)$	Current trace of the original wavefield
$K(x,t)$	Initial model of multiples for this trace
x	Current trace number
k	Index of a neighboring trace from the current trace (from –*M* to *M*)
t	TWT time

This task can be solved with the help of standard techniques, particularly with the help of Wiggins-Robinson-Levinson algorithm for multi-channel filters.

Zero-offset demultiple theory – **Adaptive Subtraction Algorythm Used**

<u>As a result of this step:</u>

For each trace X we calculate a filter *f(x,t)*

This filter minimizes everything that is in common between the original trace and the model of multiples at traces within the neighborhood *(x-M, x+M)*

STRONG SUPPRESSION OF MUILTIPLES

Zero-offset demultiple theory – **Adaptive Subtraction Algorythm Used**

As a result of this step:

For each trace X we calculate a filter *f(x,t)*

This filter minimizes everything that is in common between the original trace and the model of multiples at traces within the neighborhood *(x-M, x+M)*

STRONG SUPPRESSION OF MUILTIPLES

Final step:

We assume that the filters *f(x,t)* shall not be changing too abruptly from trace to trace.

So we average the filters over *N* neighboring traces:

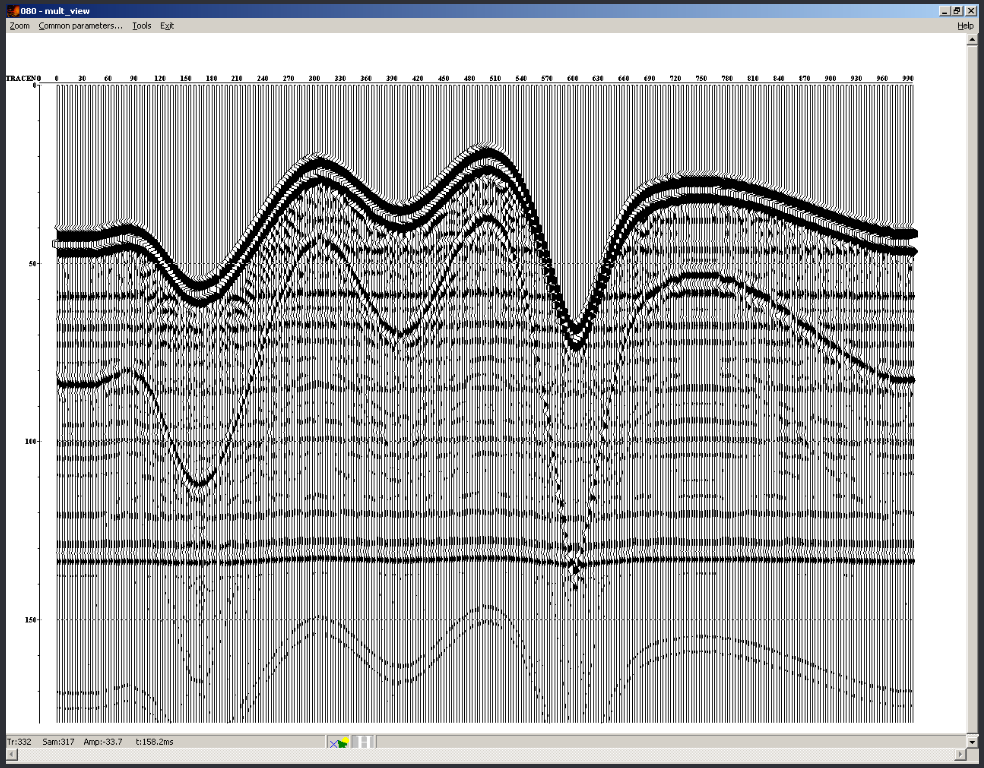
$$f_{final}(x,t) = \frac{\sum_{j=-N/2}^{N/2} f\ (x-j,t)}{N+1}$$

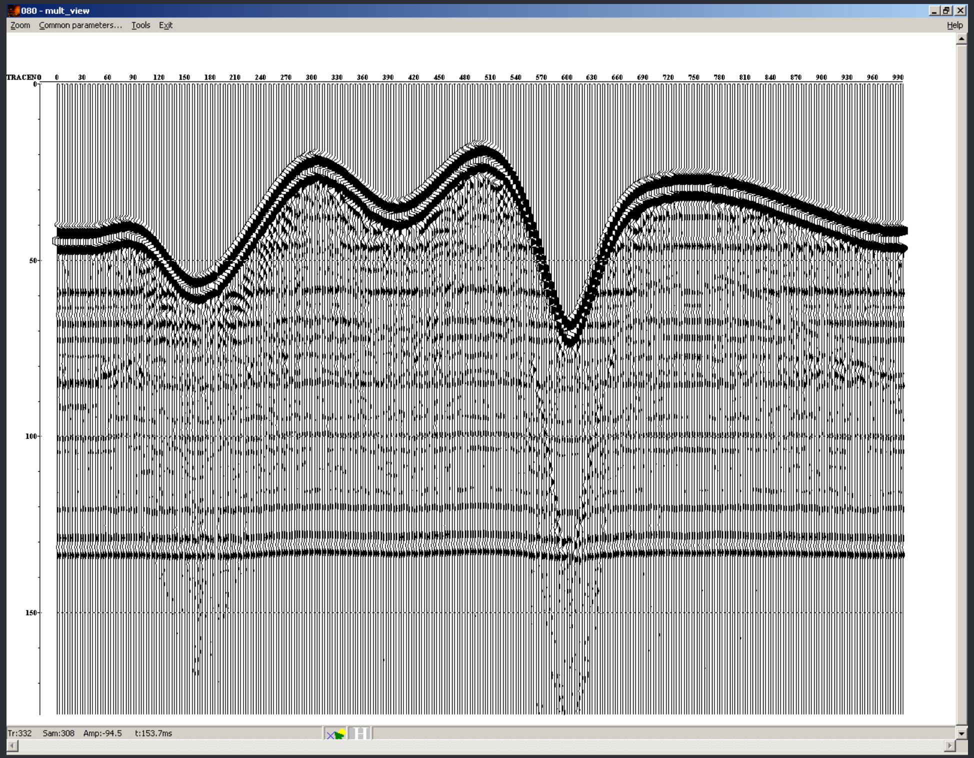
THIS STEP HELPS PRESERVING PRIMARIES

Multiple Elimination: Zero-Offset Demultiple

Zero-offset demultiple theory

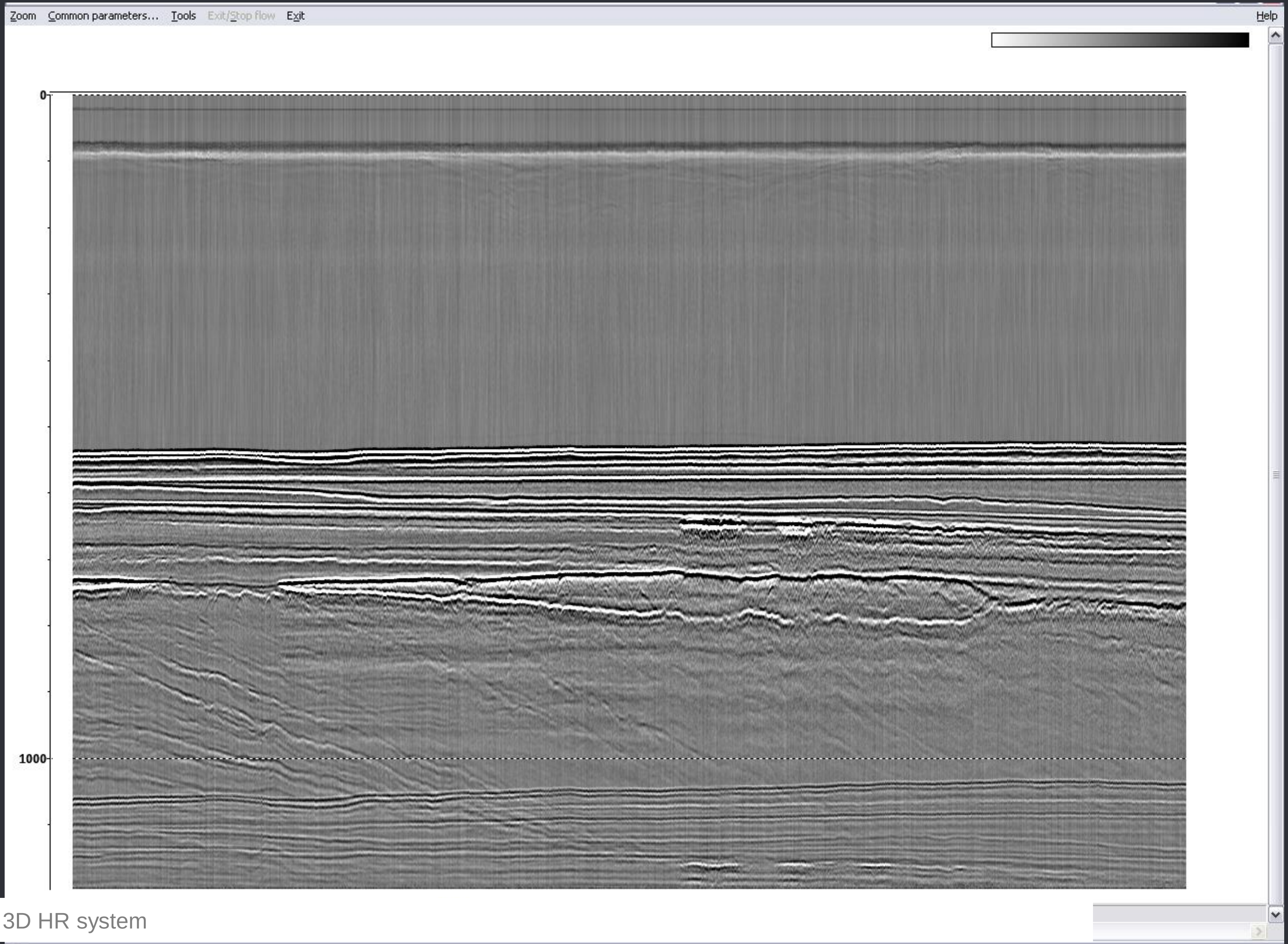
2. Model is subtracted from the data **ADAPTIVELY**





Multiple Elimination: Zero-Offset Demultiple

Zero-offset demultiple examples: before



Data acquired by P-Cable 3D HR system

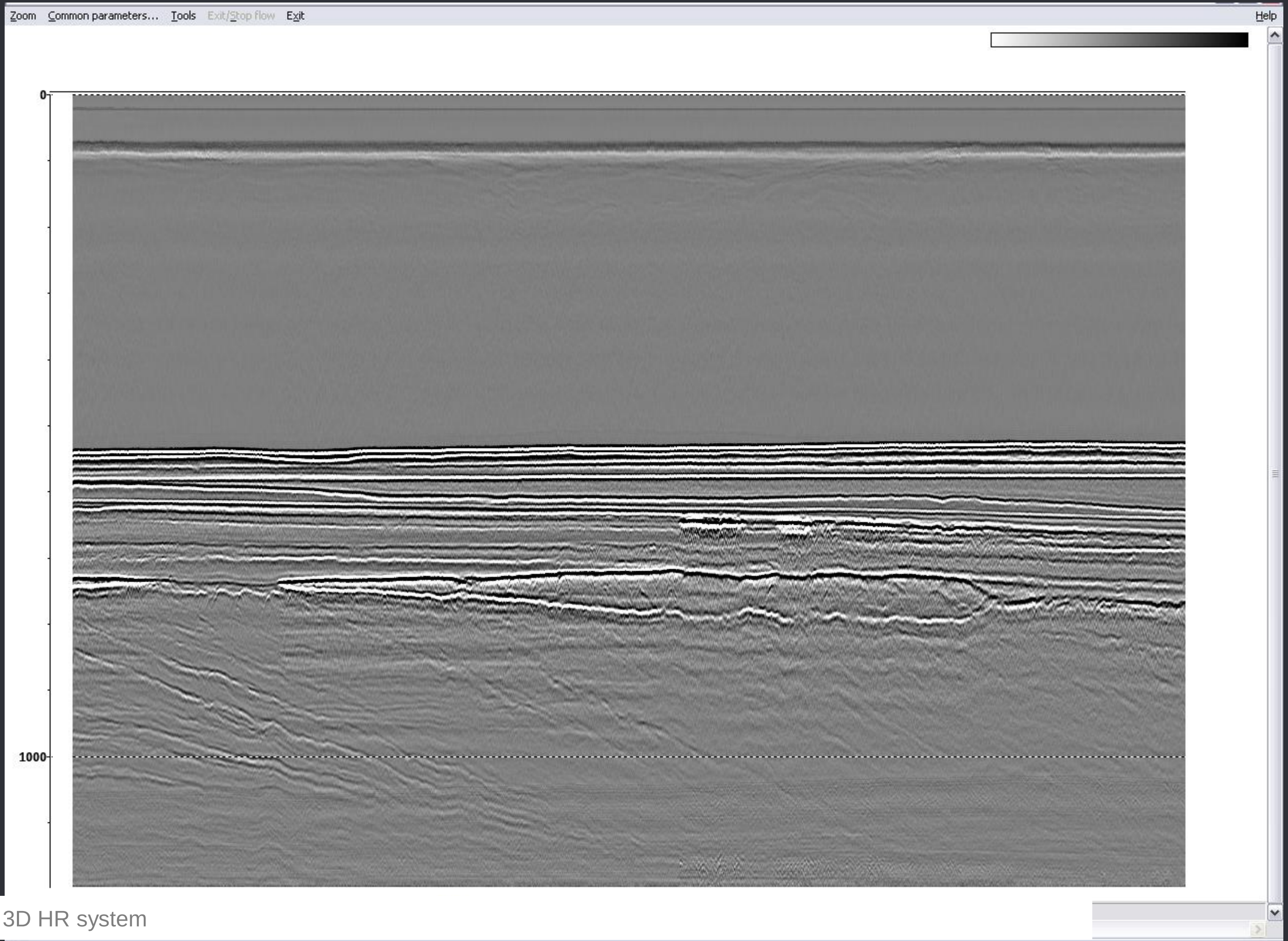
Multiple Elimination: Zero-Offset Demultiple

Zero-offset demultiple examples: multiple model

Data acquired by P-Cable 3D HR system

Multiple Elimination: Zero-Offset Demultiple

Zero-offset demultiple examples: subtraction result



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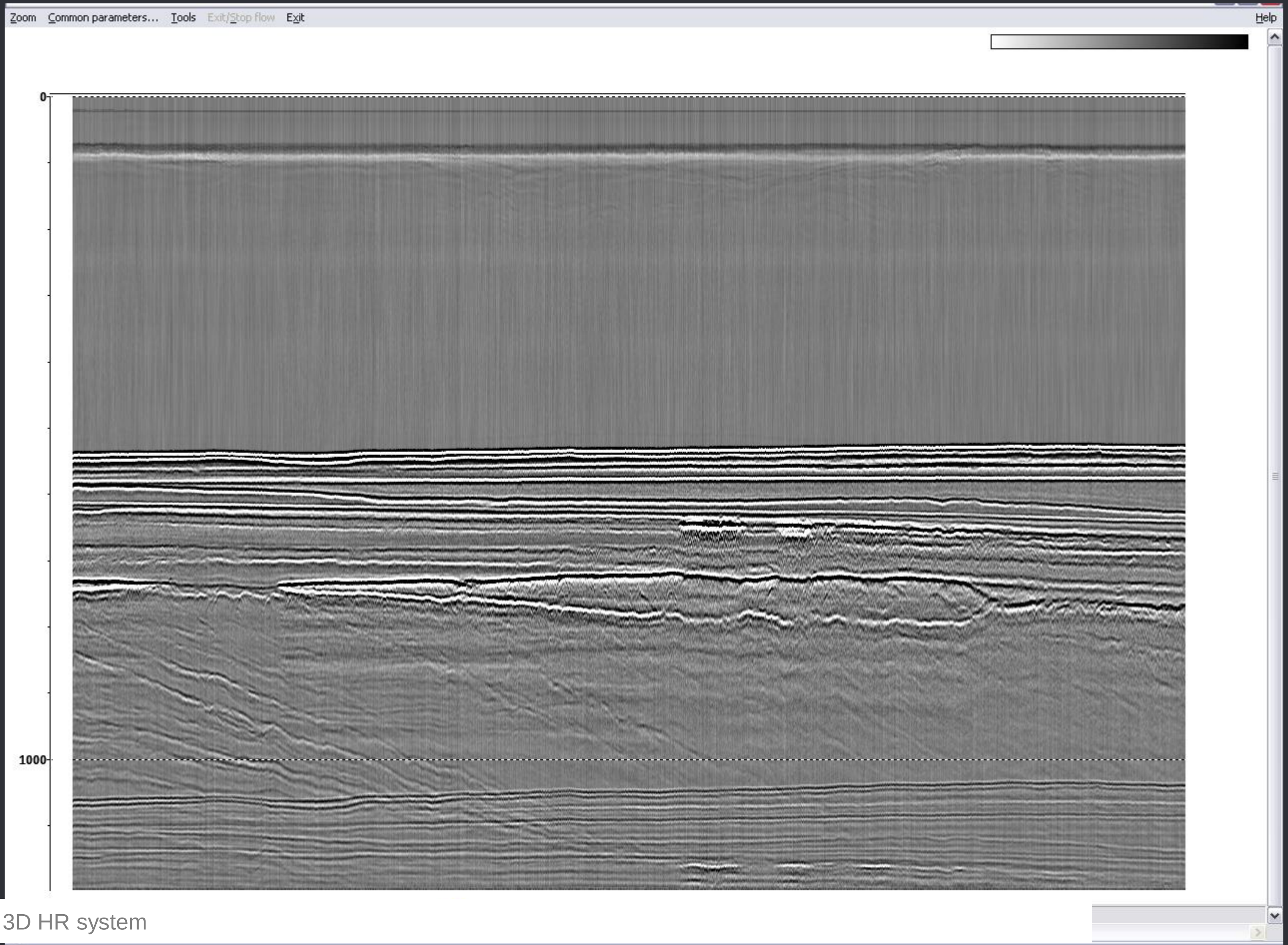
Multiple Elimination: Zero-Offset Demultiple

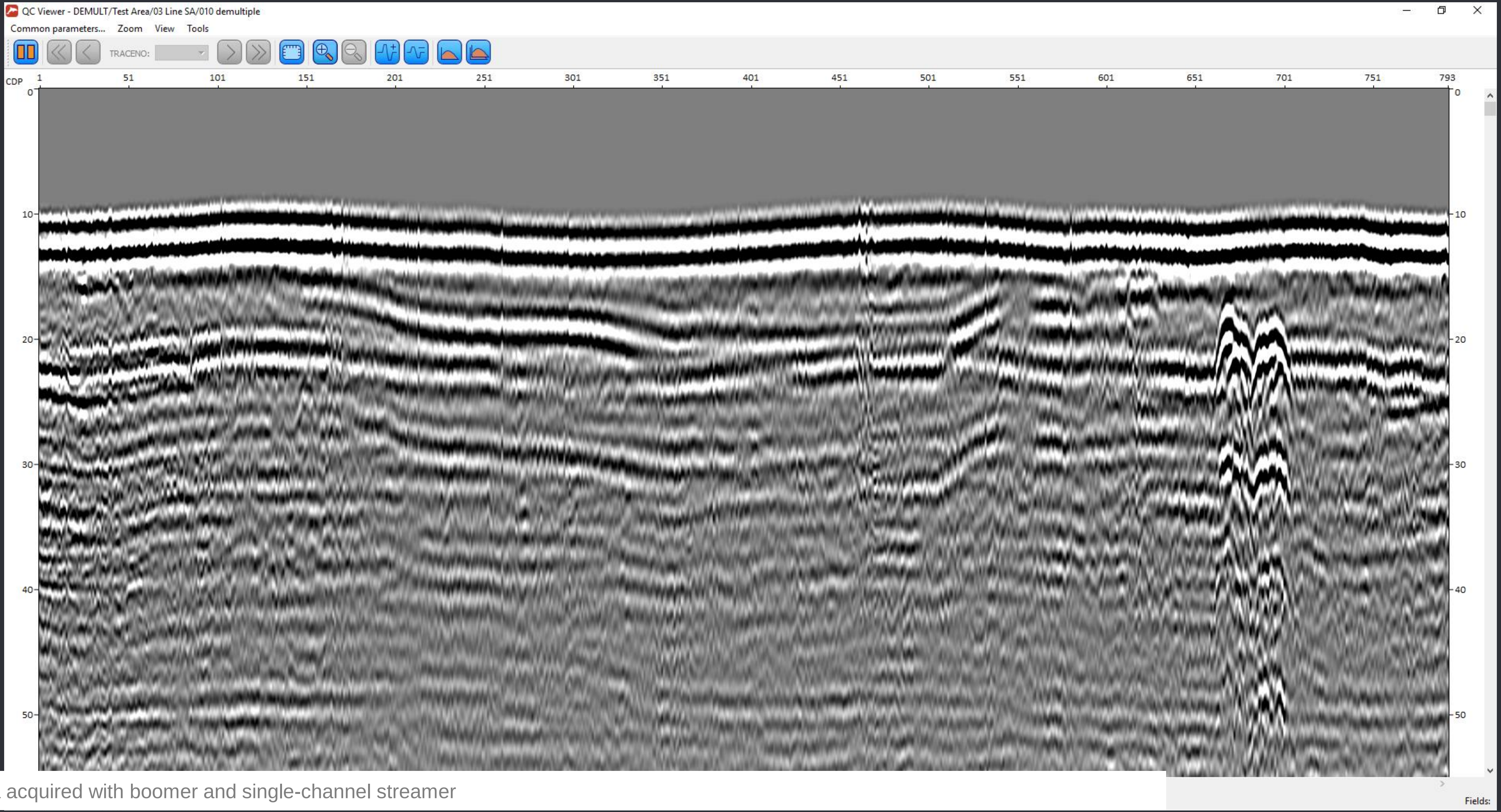
Zero-offset demultiple examples: before



Data acquired by P-Cable 3D HR system

Multiple Elimination: Zero-Offset Demultiple

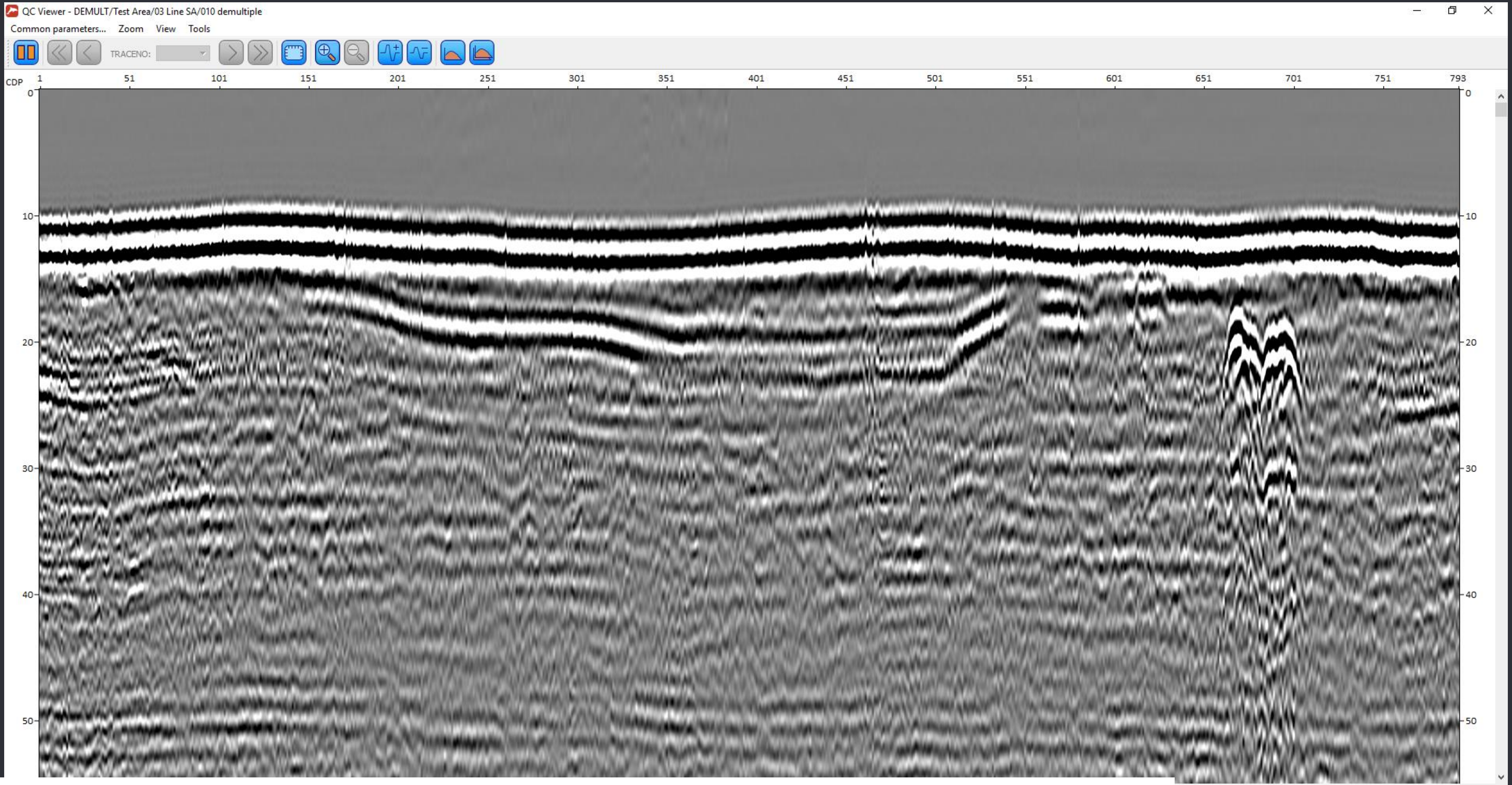
Single channel boomer data – before multiple elimination



Data acquired with boomer and single-channel streamer

Multiple Elimination: Zero-Offset Demultiple

Single channel boomer data – after zero-offset demultiple



Data acquired with boomer and single-channel streamer

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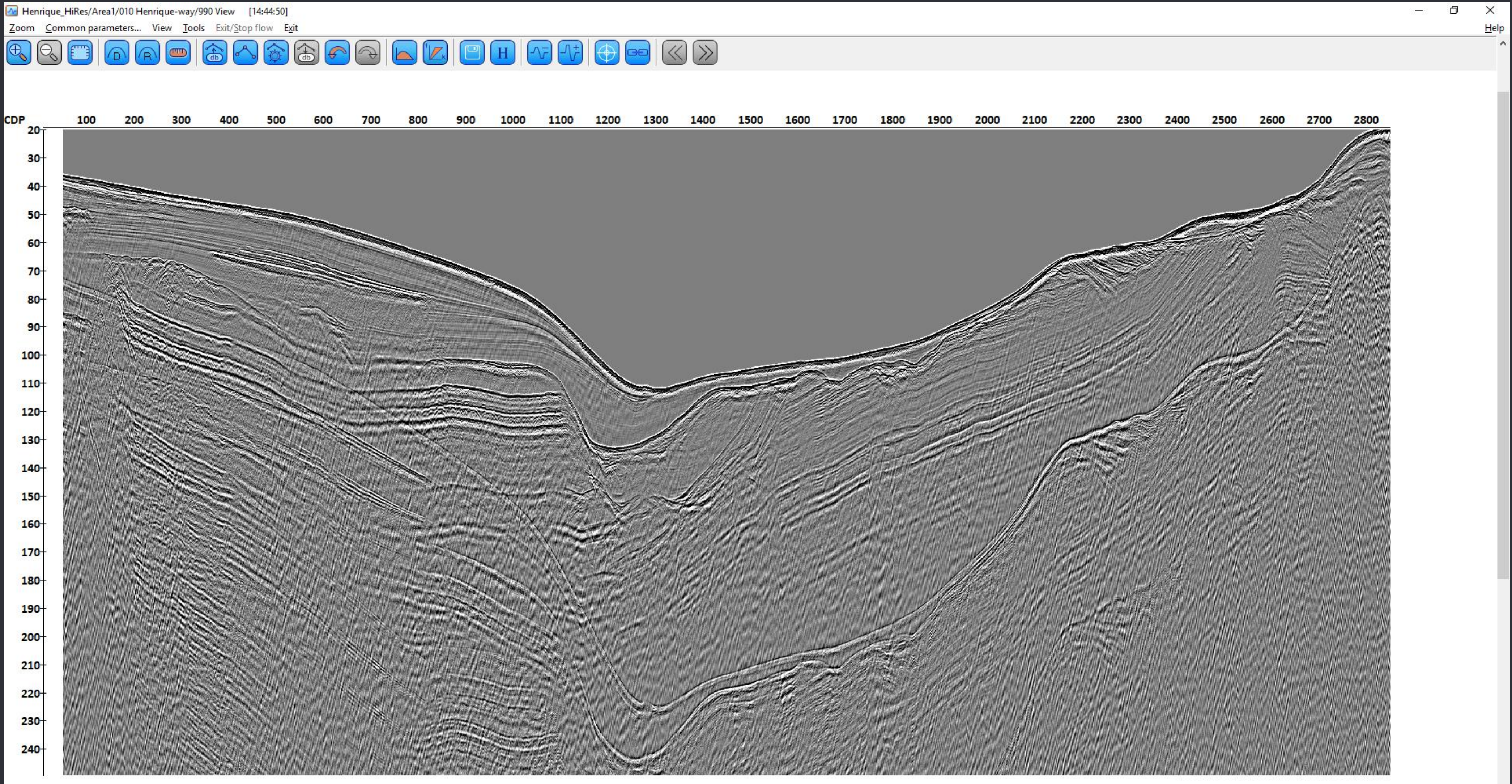
Multiple Elimination: Zero-Offset Demultiple

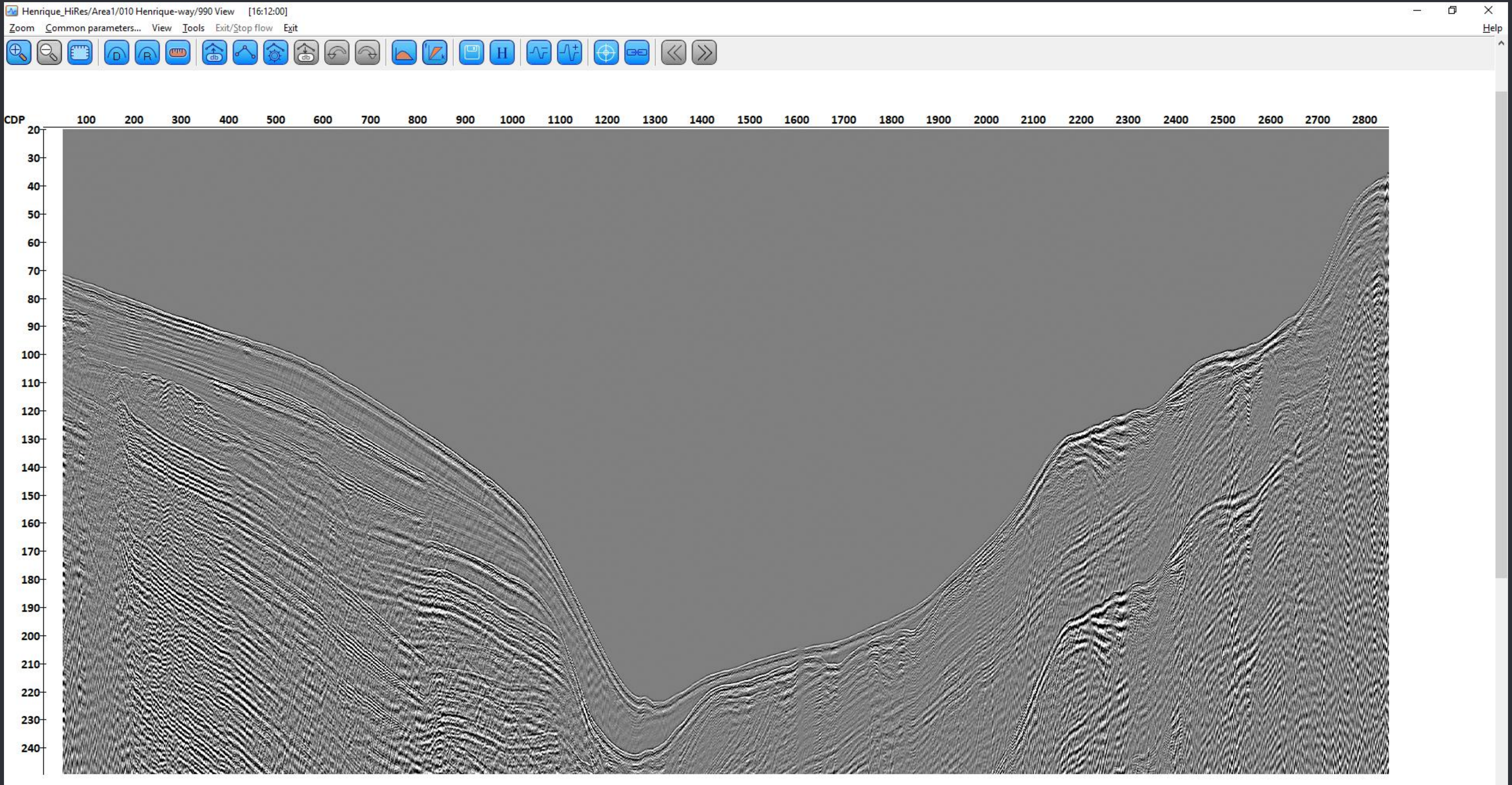
Before (stack of 16 channels)



Data acquired by GEO MARINE 3D UHR system, with sparker

Multiple Elimination: Zero-Offset Demultiple

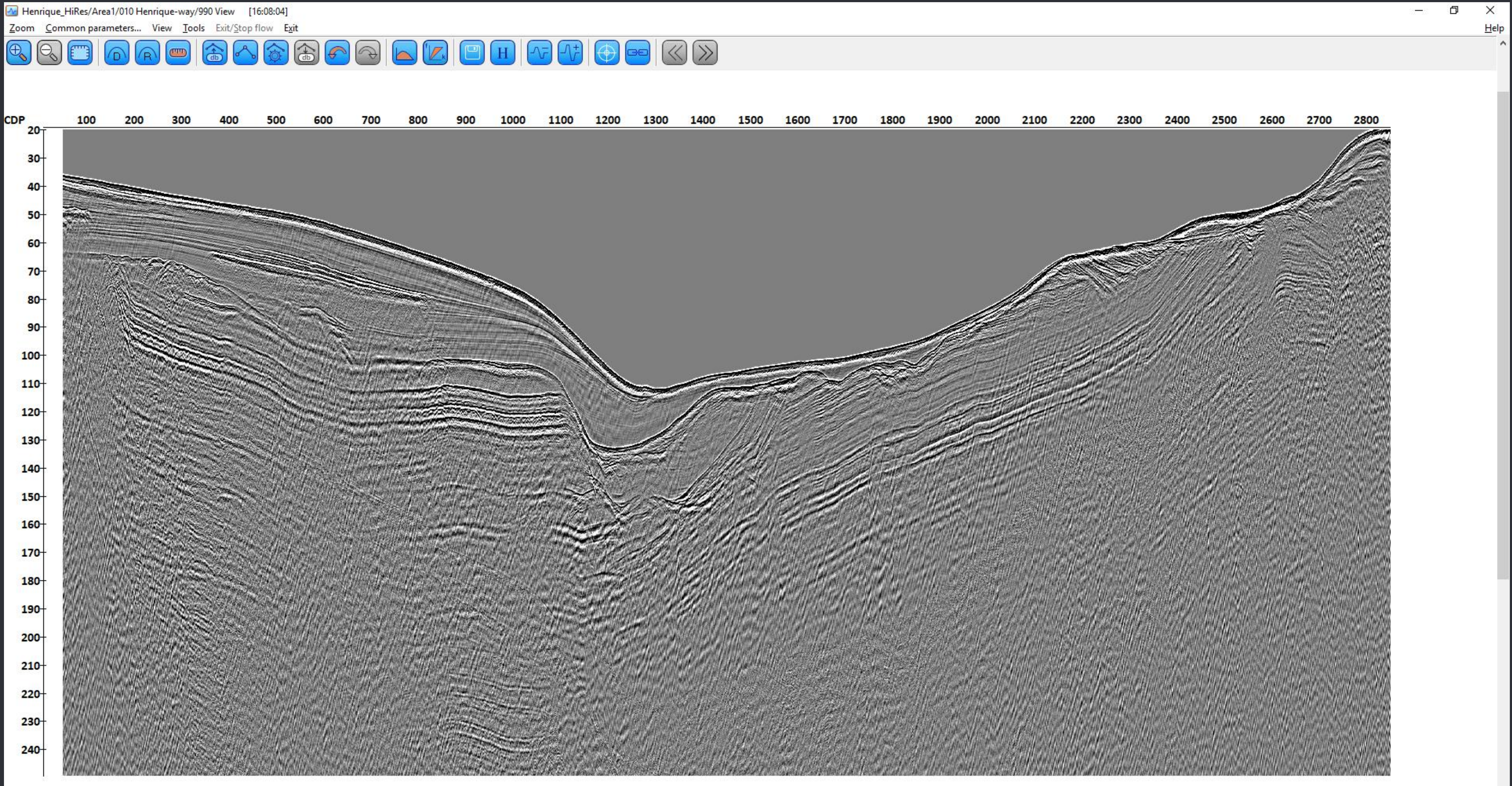
Model of Multiples (autoconvolution – post-stack)



Data acquired by GEO MARINE 3D UHR system, with sparker

Multiple Elimination: Zero-Offset Demultiple

Subtraction Resullt (post-stack)



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Multiple Elimination: Zero-Offset Demultiple

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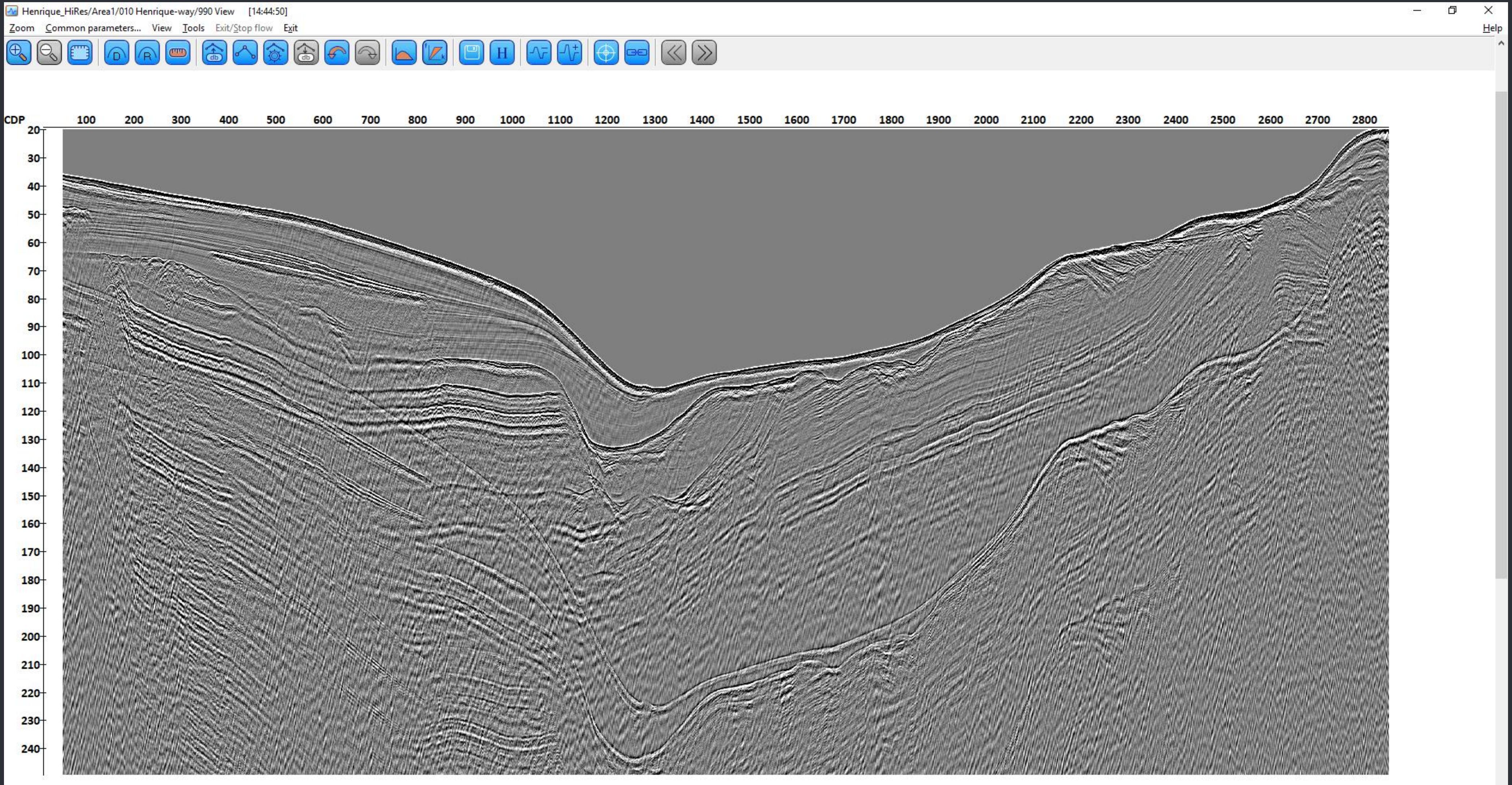
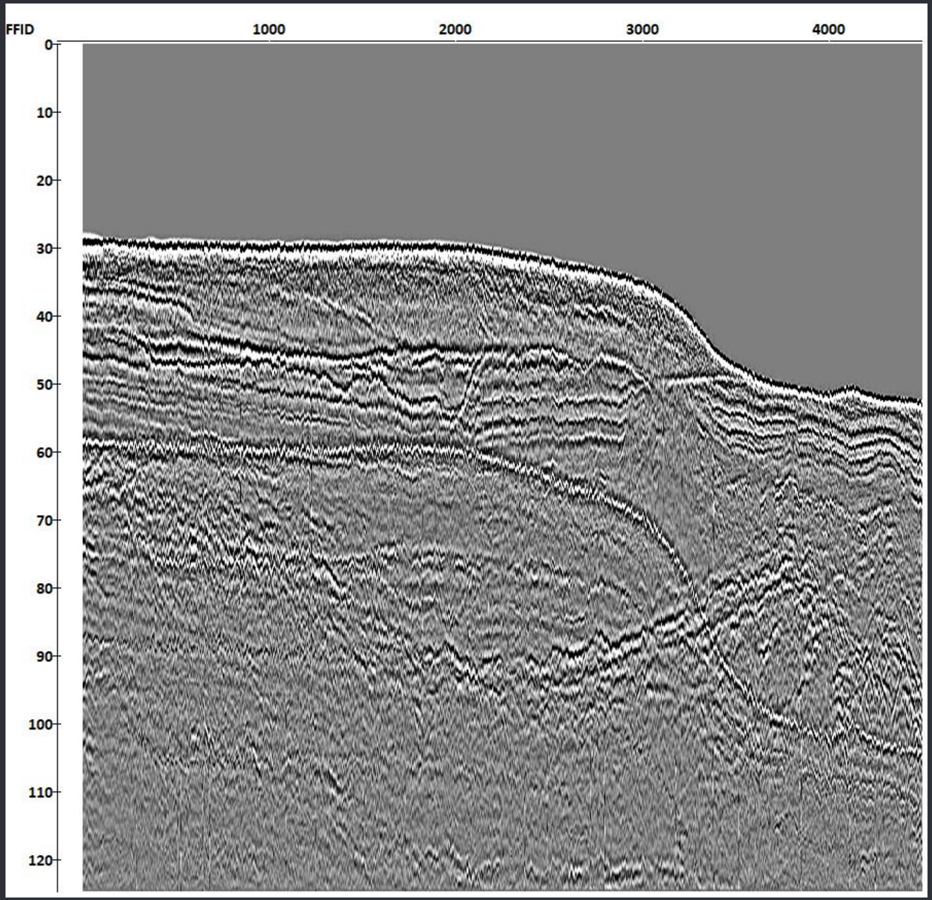


Data acquired by GEO MARINE 3D UHR system, with sparker

Multiple Elimination: Zero-Offset Demultiple

Data disturbed by sea swelling



Data acquired with Bubble Pulser (by Falmouth Scientific) and single-channel streamer

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Multiple Elimination: Zero-Offset Demultiple

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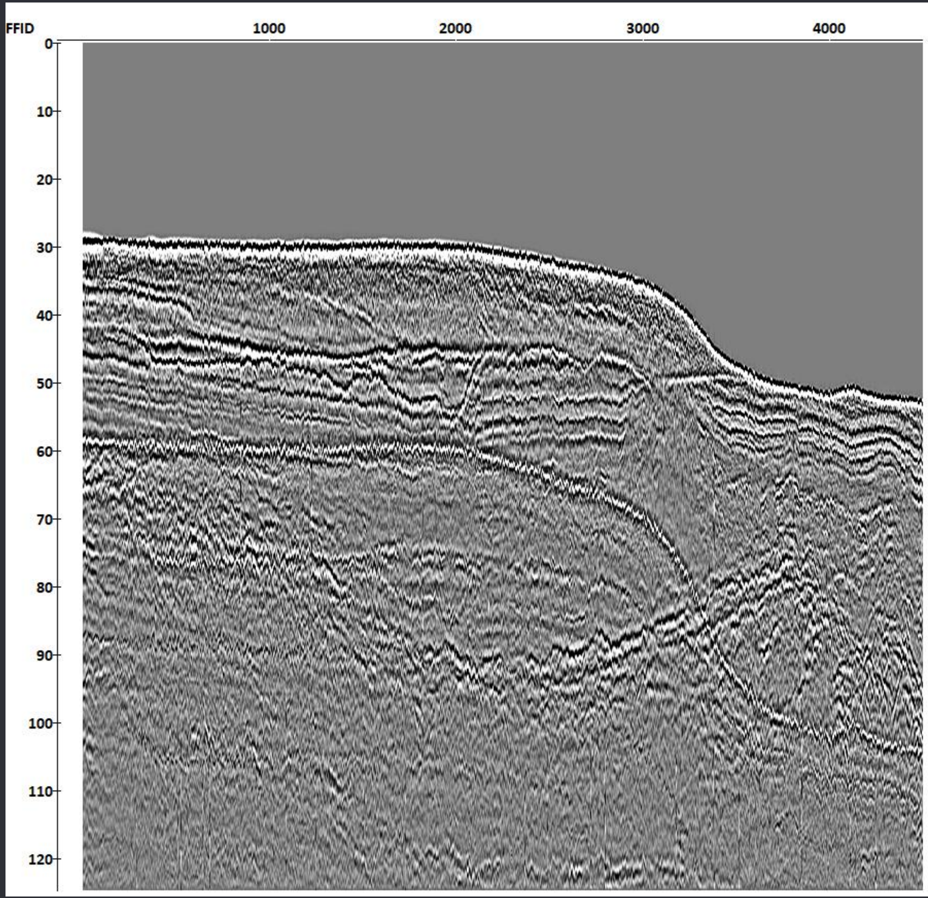
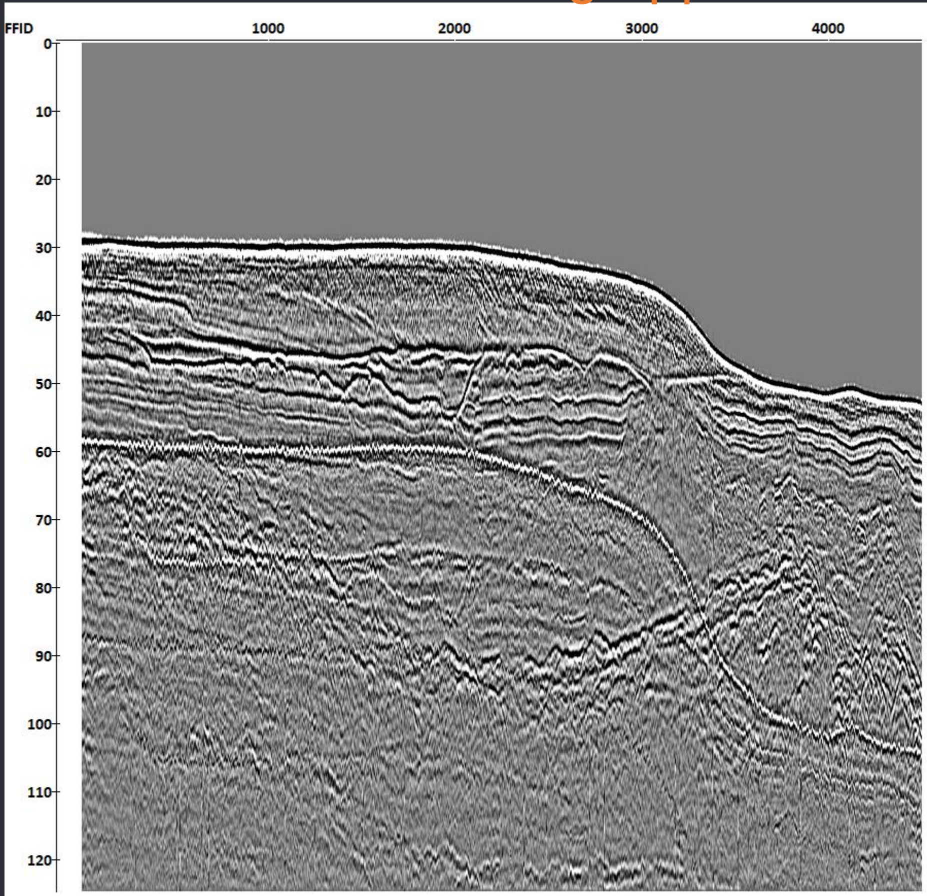


After swell filtering applied



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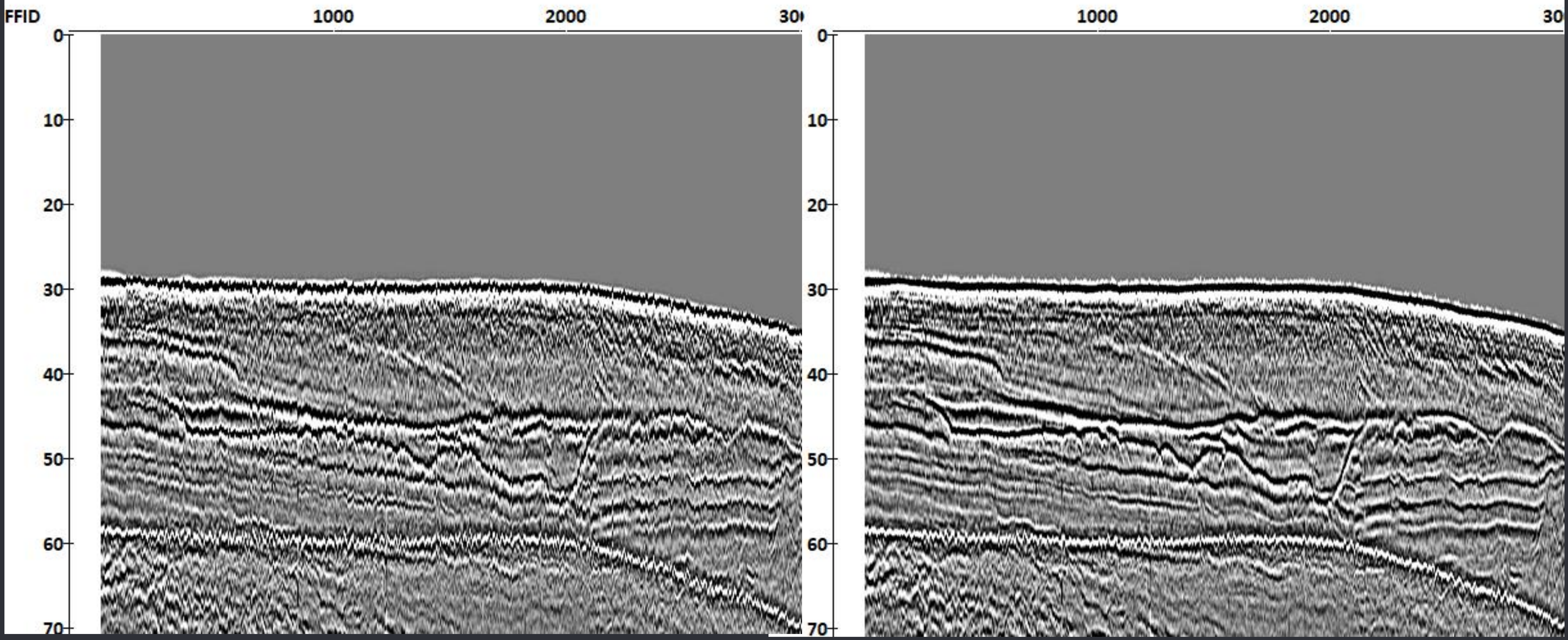
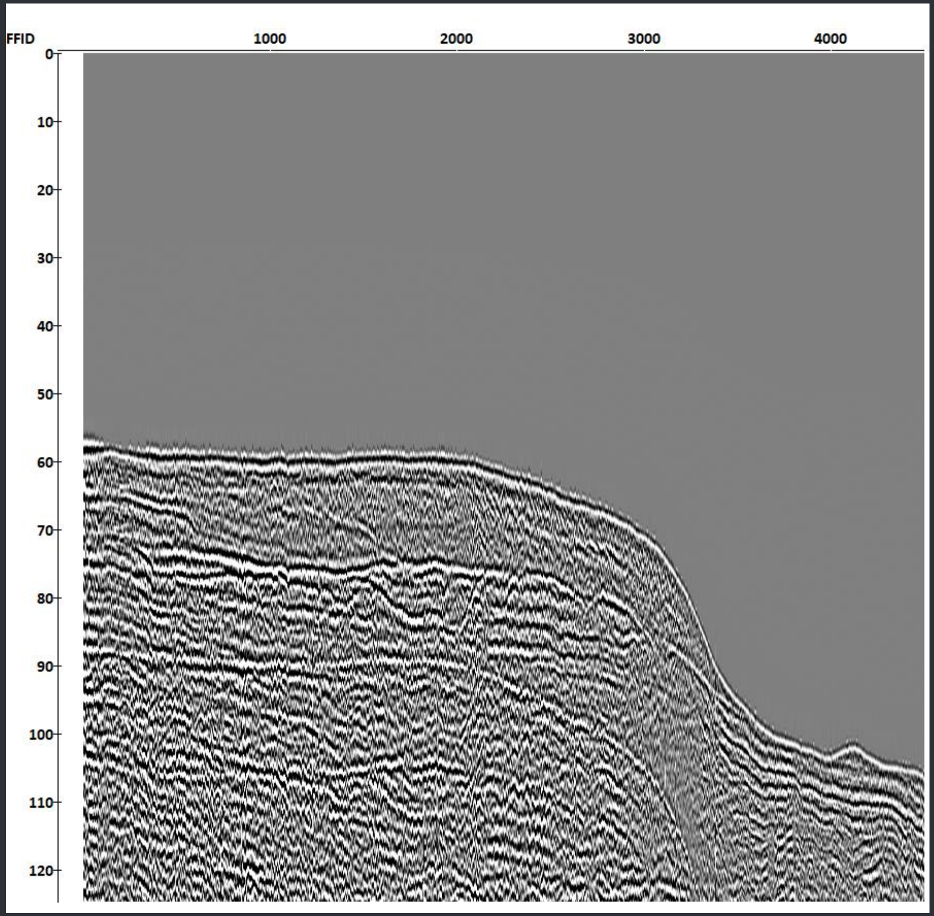


Multiple Elimination: Zero-Offset Demultiple

Data disturbed by sea swelling – model of multiples



Data acquired with Bubble Pulser (by Falmouth Scientific) and single-channel streamer

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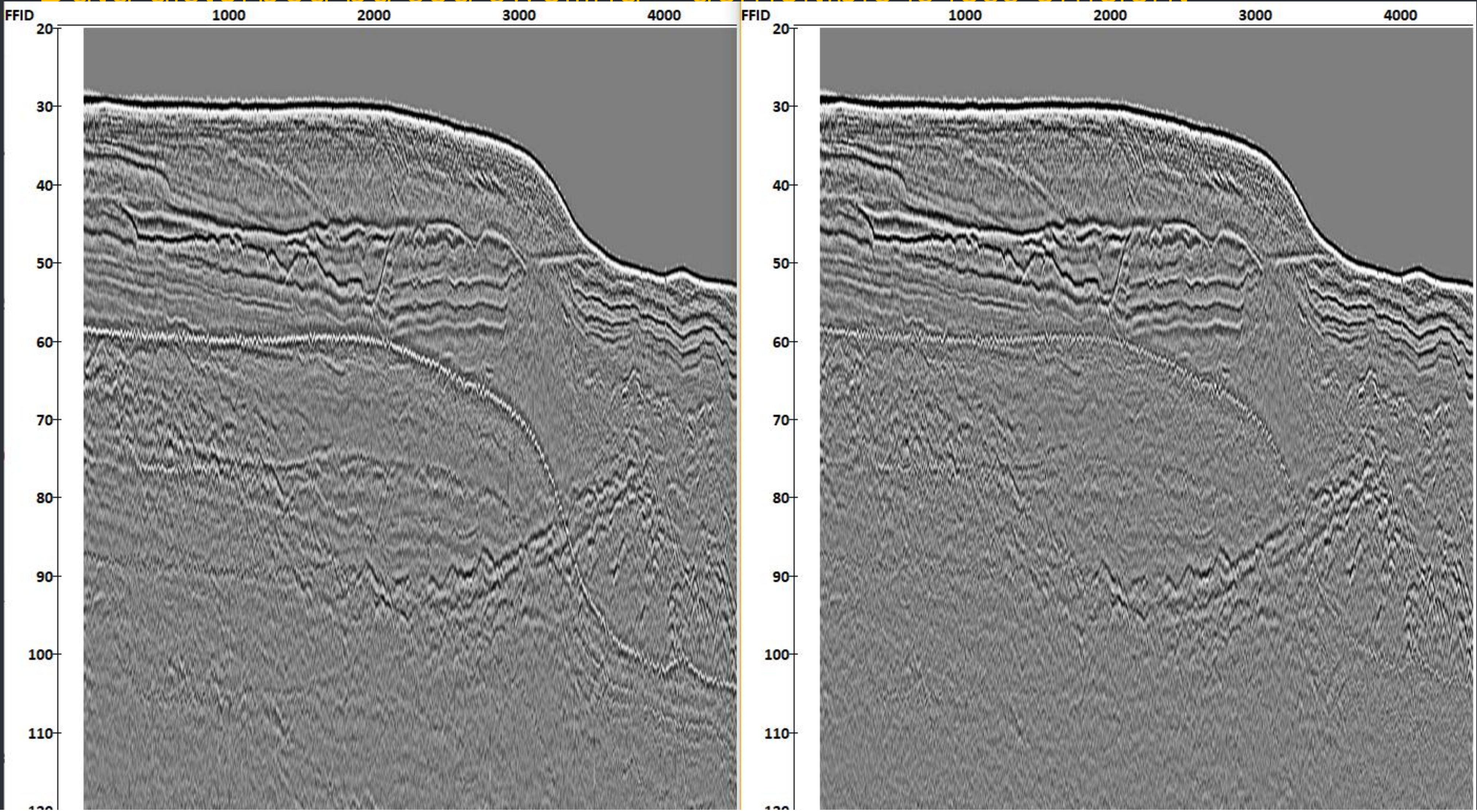
Multiple Elimination: Zero-Offset Demultiple

Data disturbed bu sea swelling – demultiple is less efficient



Data acquired with Bubble Pulser (by Falmouth Scientific) and single-channel streamer

- Zero-Offset Demultiple technique based on approximate modeling of multiples followed by adaptive subtraction, was implemented and tested.
- It was shown that the method can be very efficient for near-offset HR/UHR marine seismic data acquired with different types of sources.
- Greater offsets and sea swelling reduce the efficiency of the algorithm

Thank you for attention!

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