Let there be light

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Banff 10Dec19

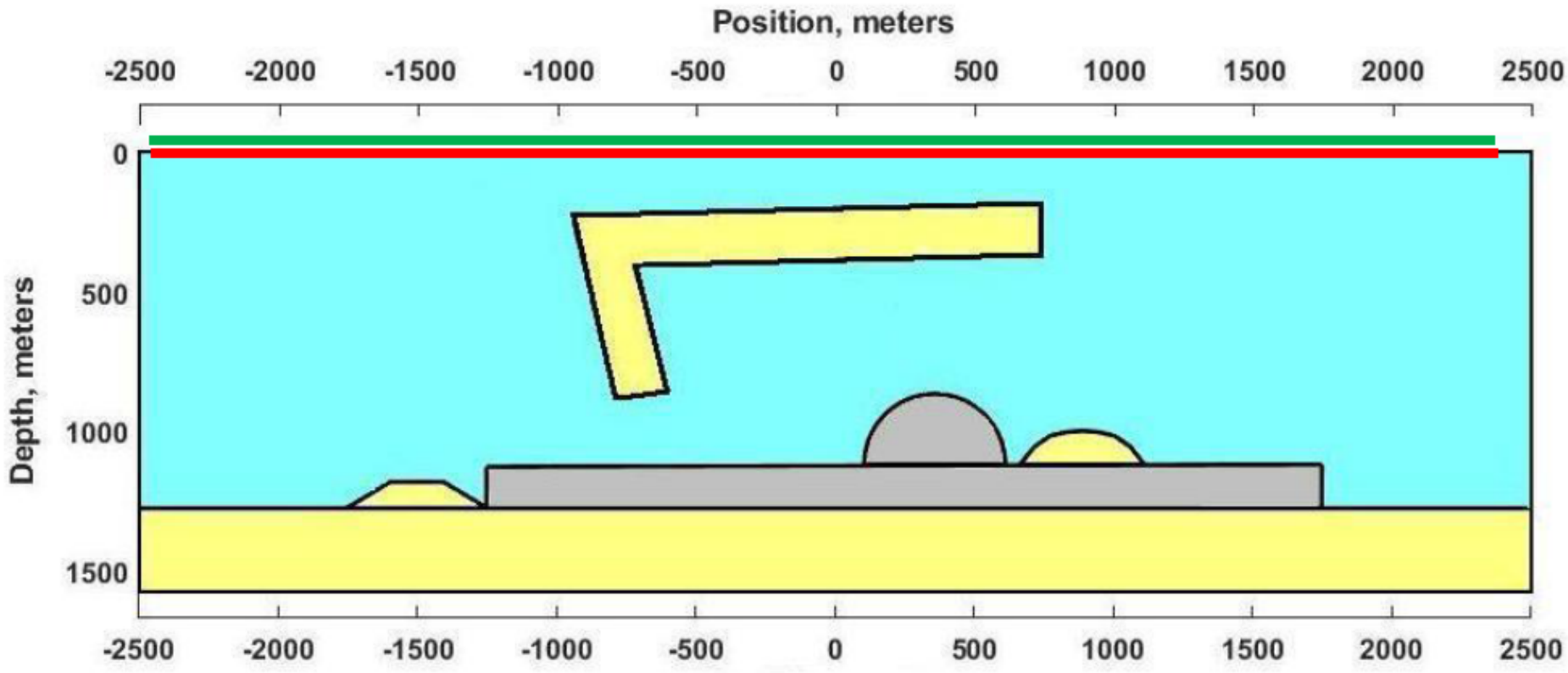
Outline

- Introduction
- Physical model
  - Purpose
  - Model details
- Seismic illumination
  - Surface only
    - ***2D multi-fold survey***
    - ***Zero-offset “sonar” survey***
  - Subsurface
- Analysis and comparison
- Conclusions

Purpose of physical modeling

- Study effective illumination of geological features
- Test scenarios for ‘recording while drilling’
- Explore what can be determined about model using only ***surface illumination***

The model


Position, meters
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
Depth, meters
0
500
1000
1500
SRC Line
RCR Line
Water: Vp = 1485 m/s, ρ= 1000 kg/m3
PLX: Vp = 2745 m/s, ρ= 1190 kg/m3
PVC: Vp = 2350 m/s, ρ= 1300 kg/m3

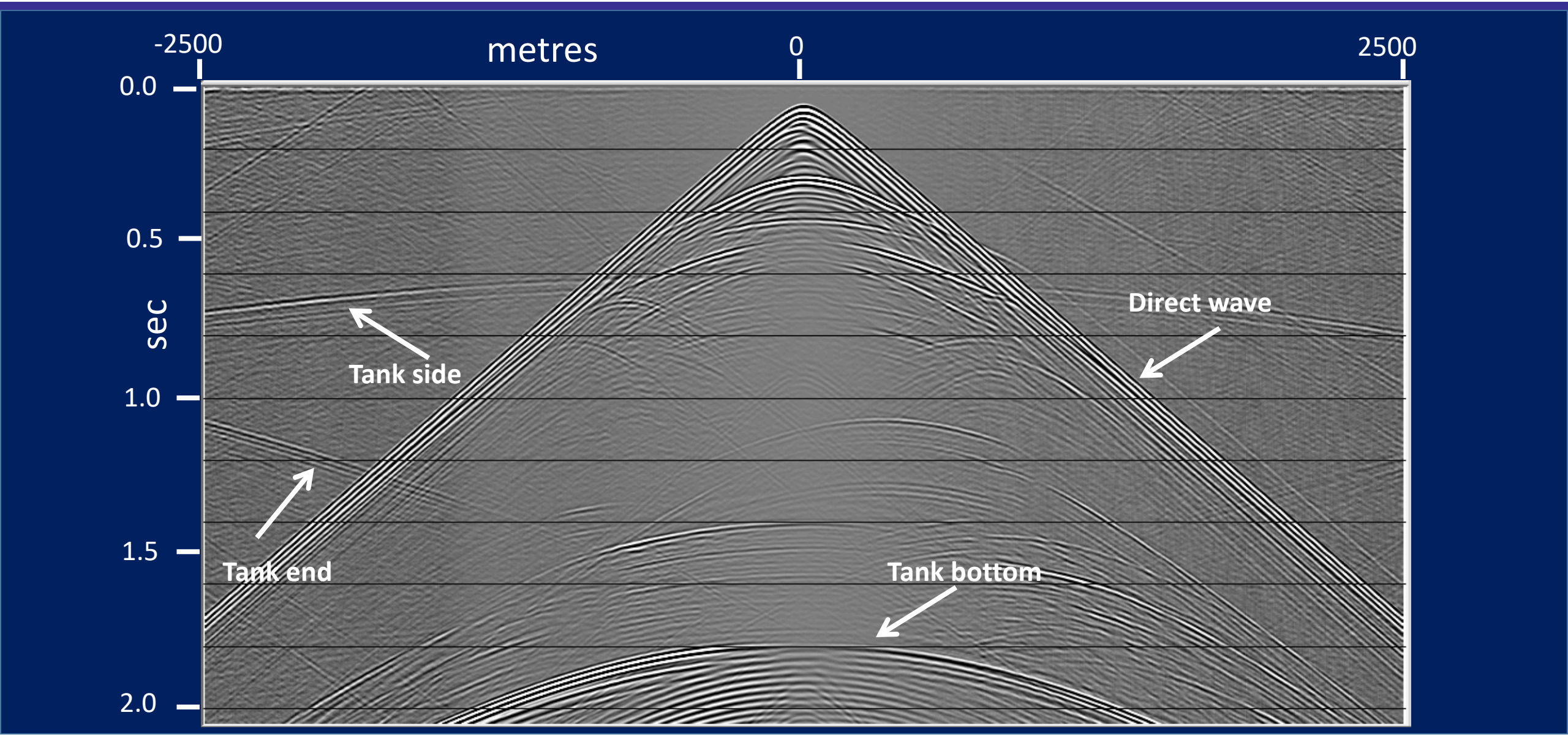
2D multi-fold CMP survey

- 101 shots into 1001 receivers
- Receiver position spacing 5m
- Source position spacing 50m
- CMP (trace) spacing ***2.5m***
- Maximum fold 100

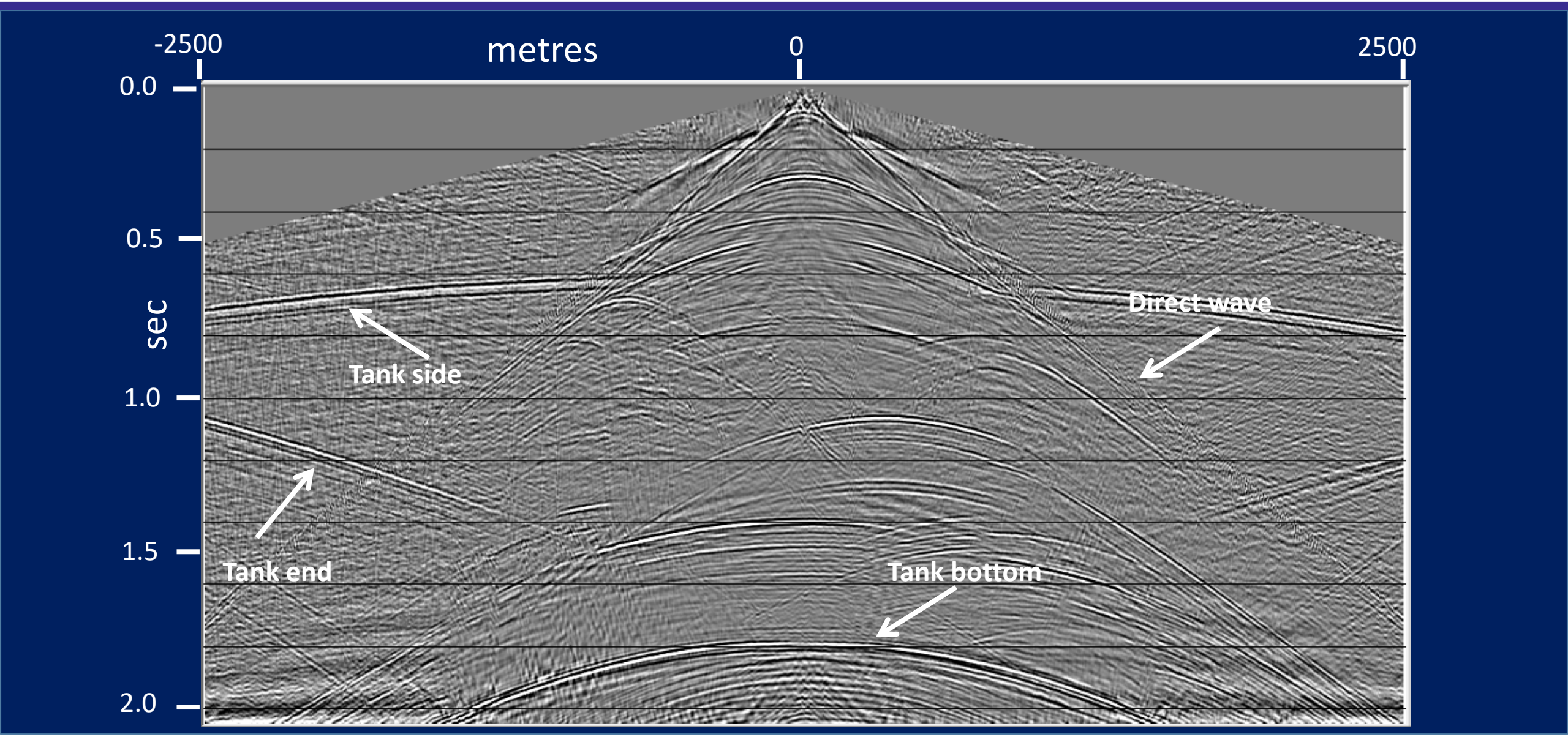
Processing for CMP survey

- Remove direct wave on source gathers by radial trace filter
- Gabor deconvolution to broaden spectrum, shorten wavelet
- Remove tank reflections on common-offset gathers by median mix and subtract
- NMO correction with water velocity
- CMP stack

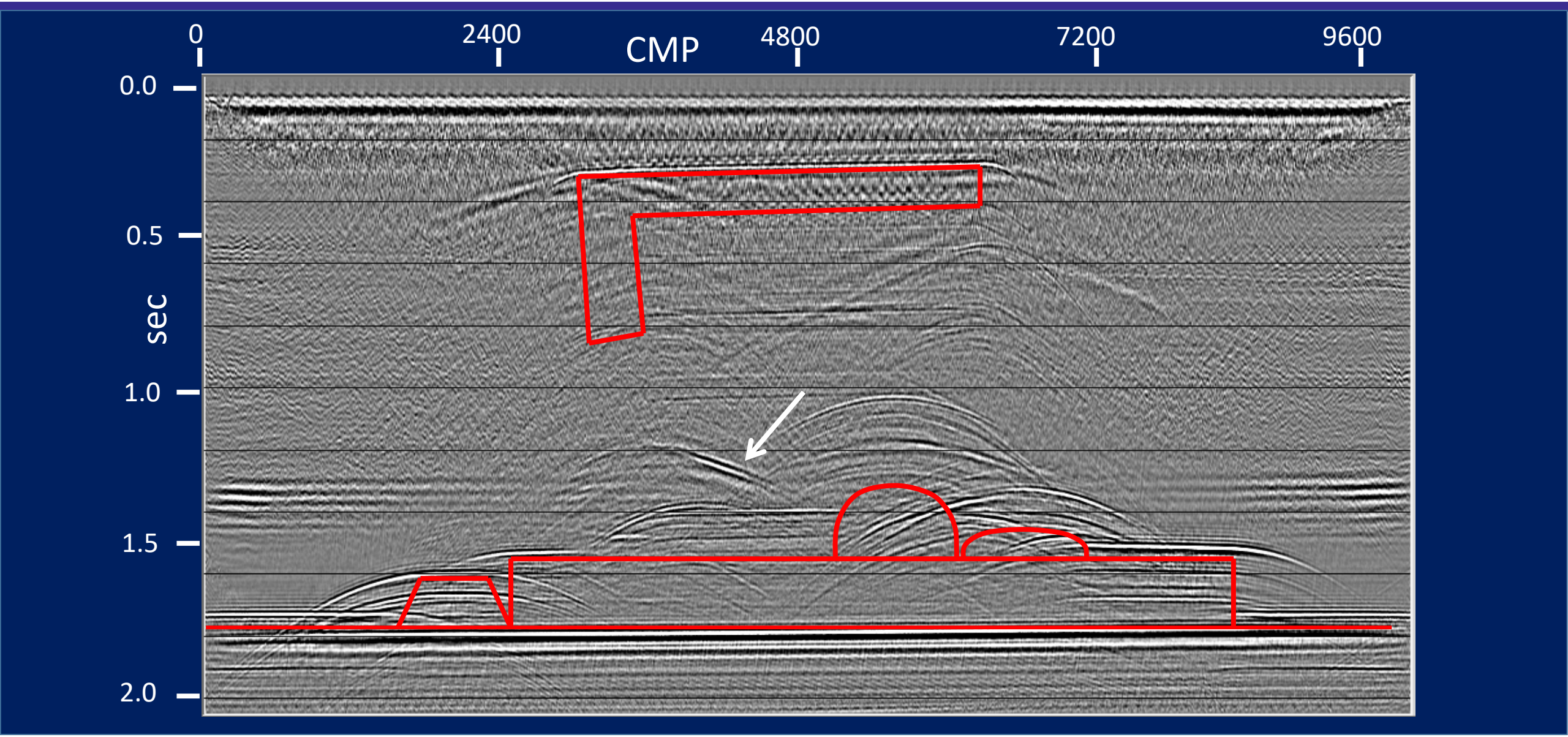
Typical source gather



Source gather after filter and deconvolution



CMP stack



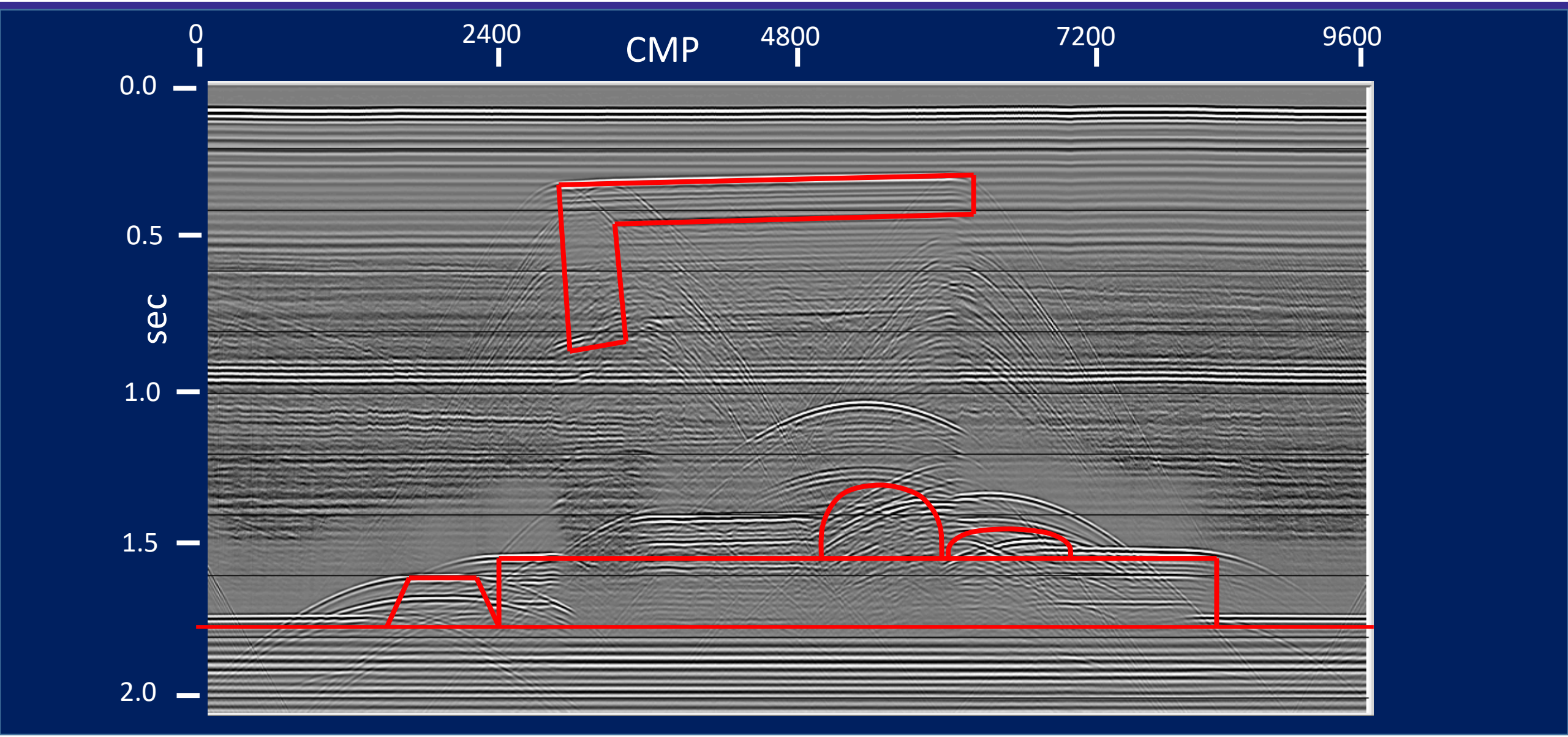
Zero-offset “sonar” survey

- 992 shots into single receiver
- Source/receiver position (trace) spacing ***5m***
- Maximum fold 1

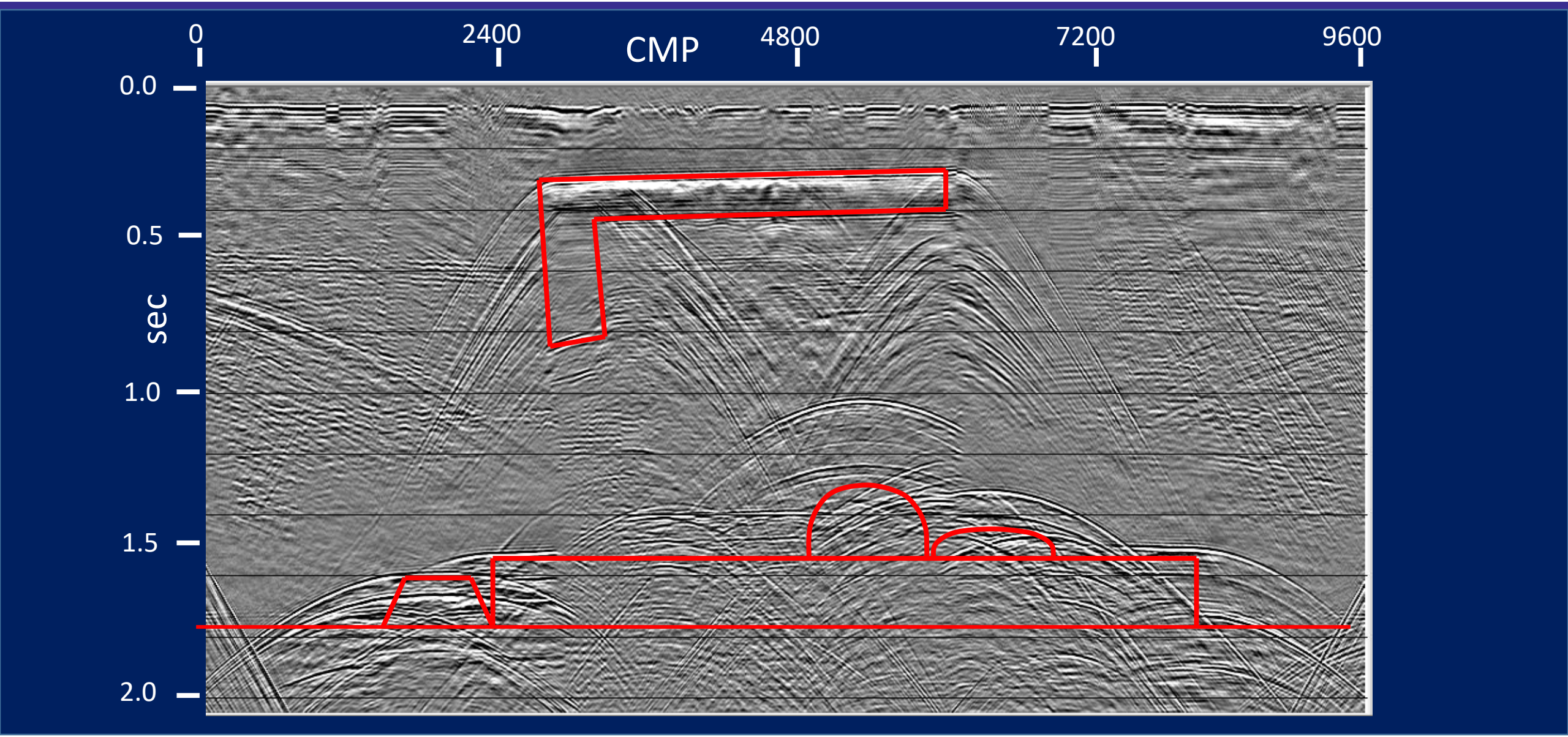
Zero-offset “sonar” survey processing

- Estimate and subtract tank reflections
- Gabor deconvolution
- Demultiple (gapped deconvolution)
- FX deconvolution

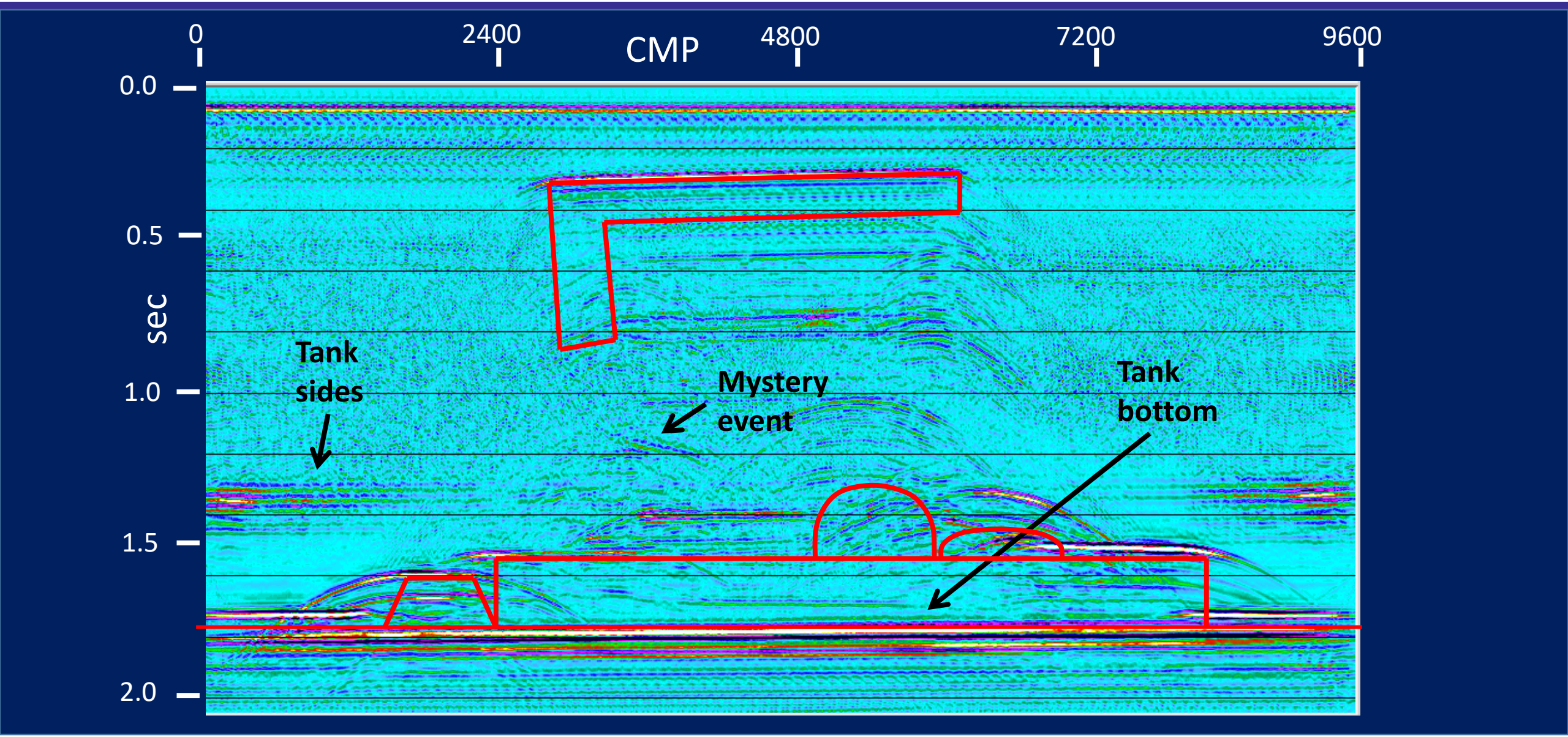
Raw zero-offset survey, AGC only



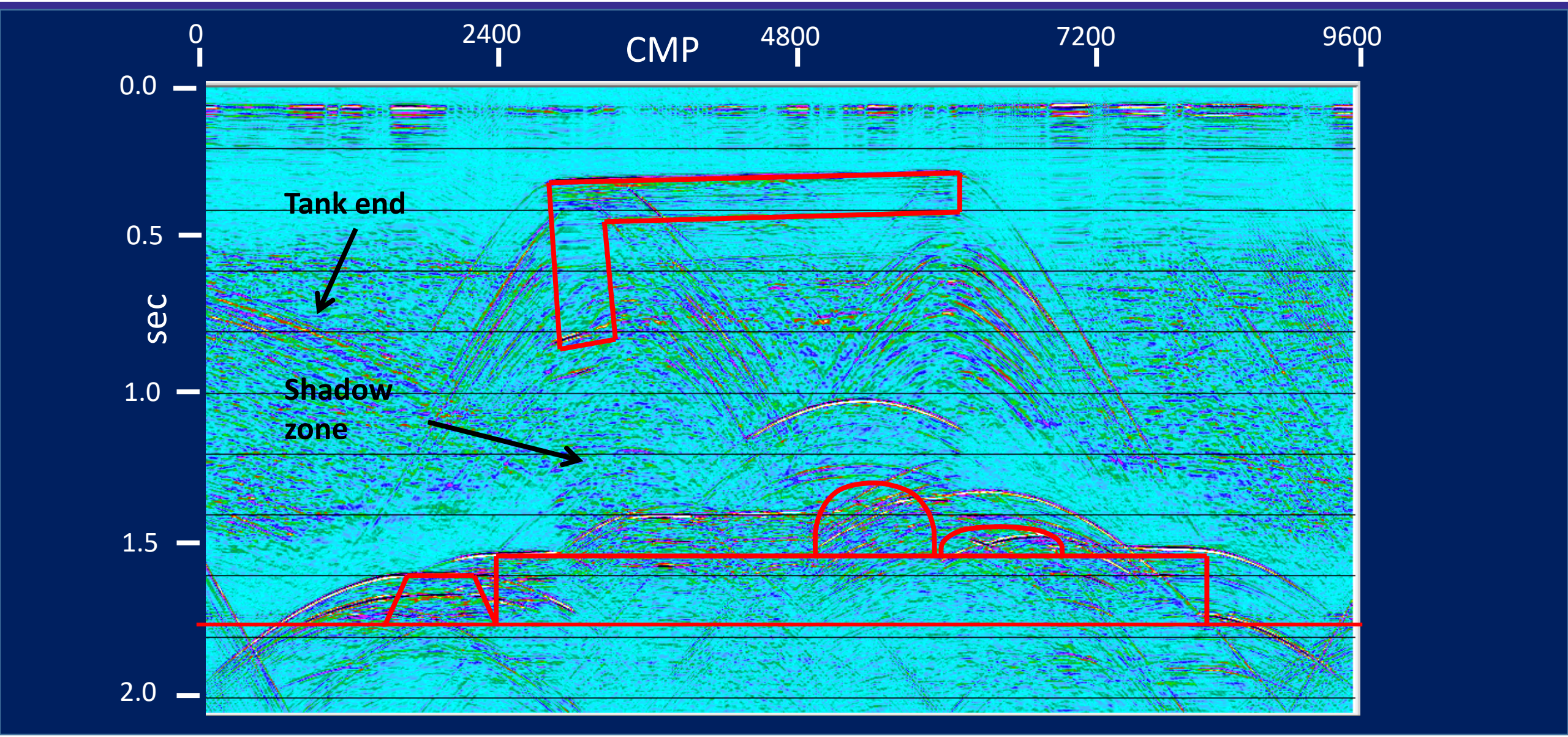
“Sonar” survey—after processing



CMP multi-fold stack in colour



“Sonar” survey in colour



Summary

- Sometimes simple is superior
- Reconnaissance may not require the best “image”
- ***Reflections are not the only indicators of subsurface features***
- Analyzing ***image*** features can lead to ***model*** features

Physical Modeling of Seismic Illumination and SWD (Seismic While Drilling)

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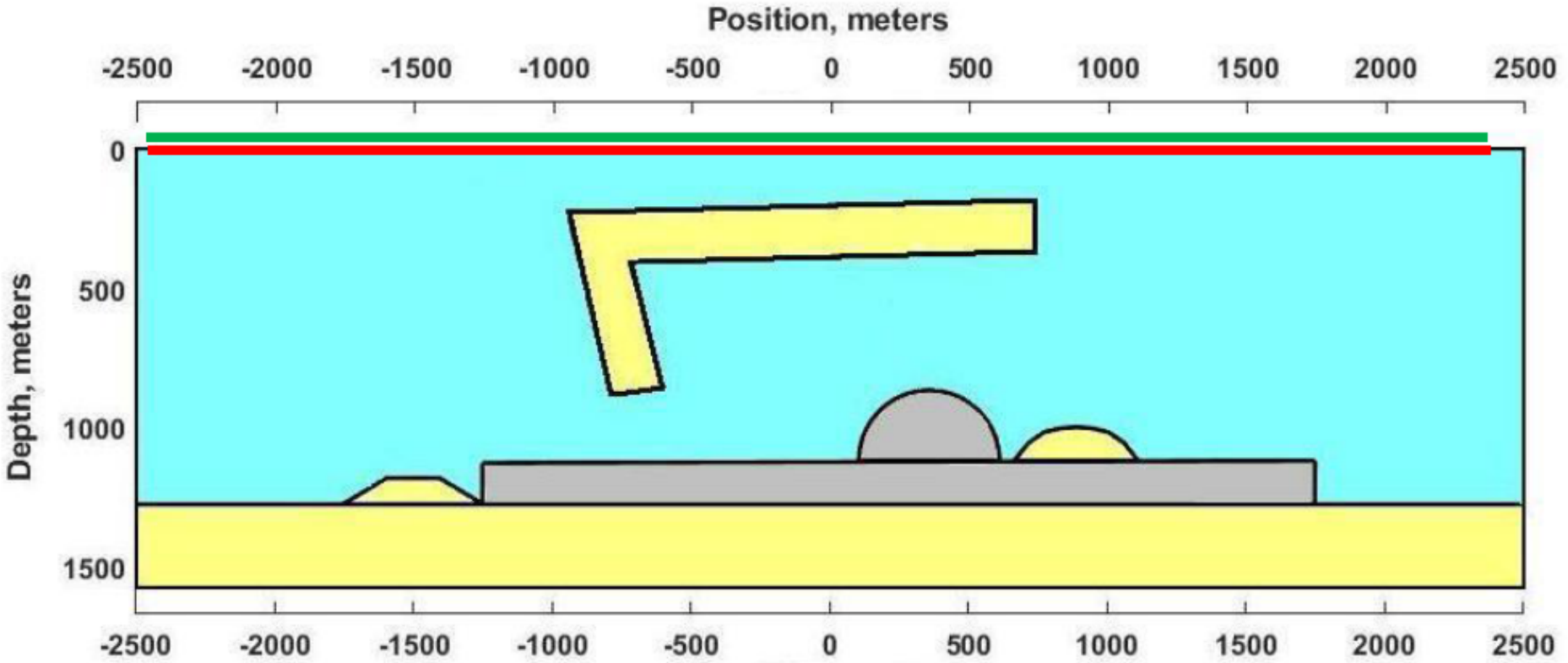
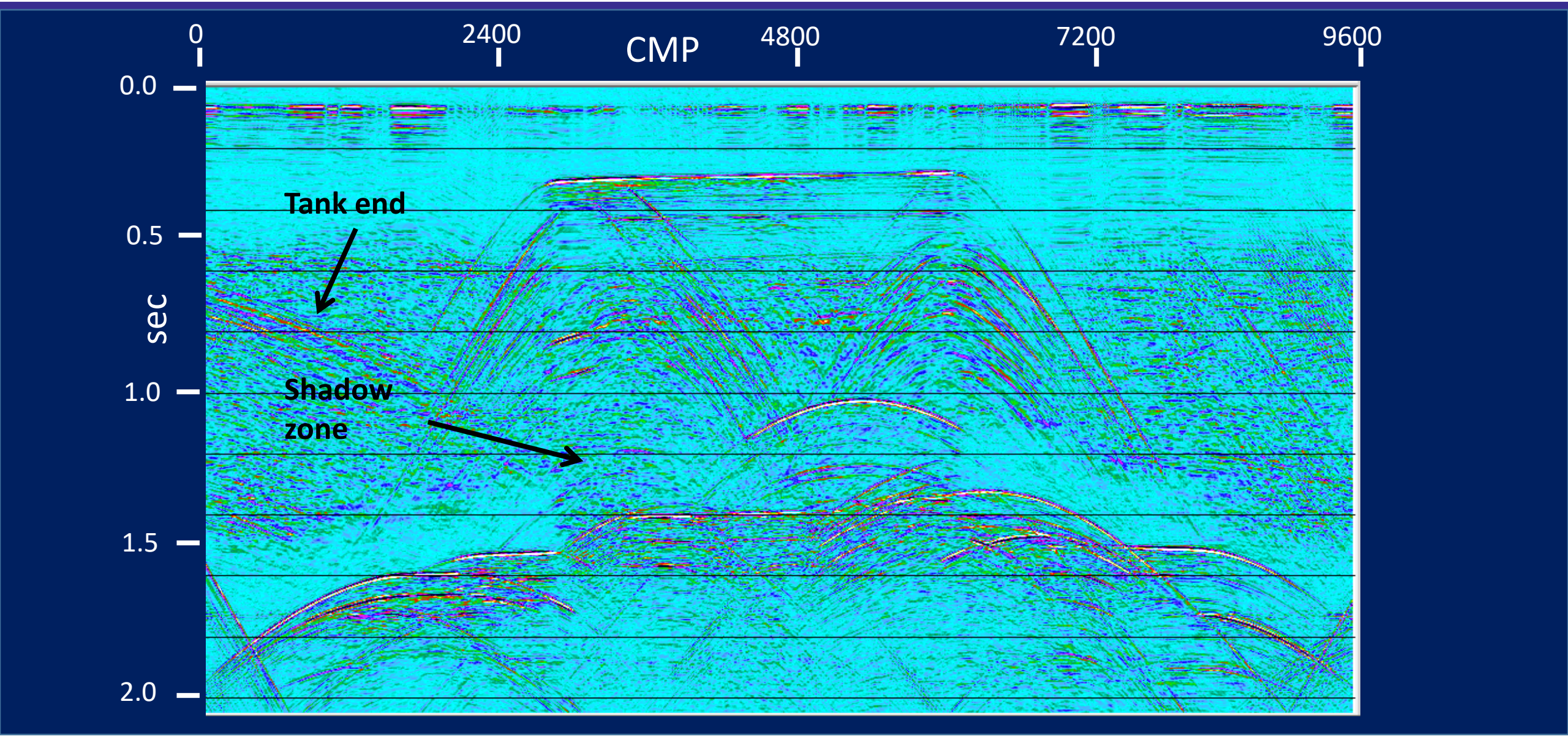
UNIVERSITY OF CALGARY

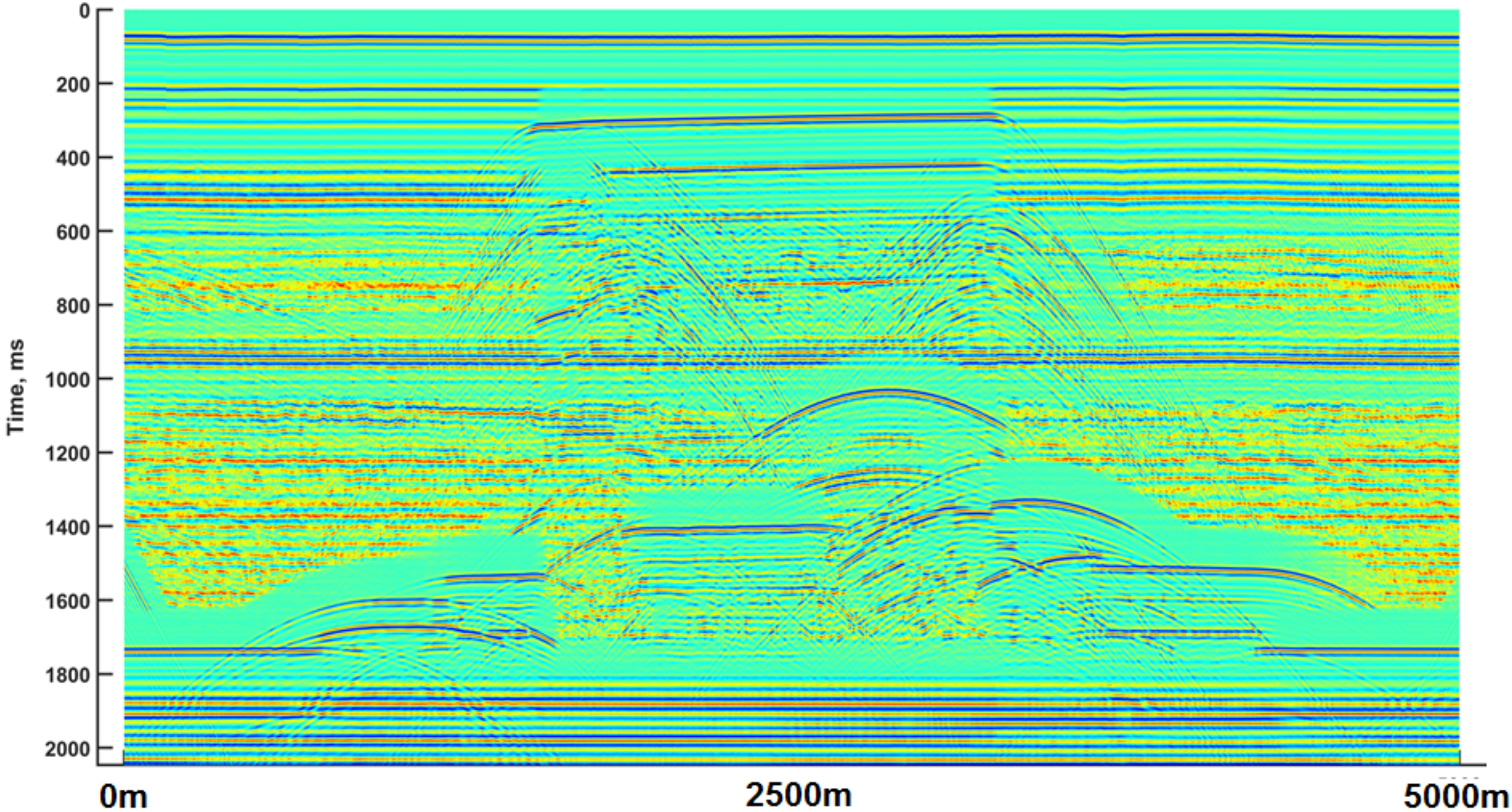
Part 1

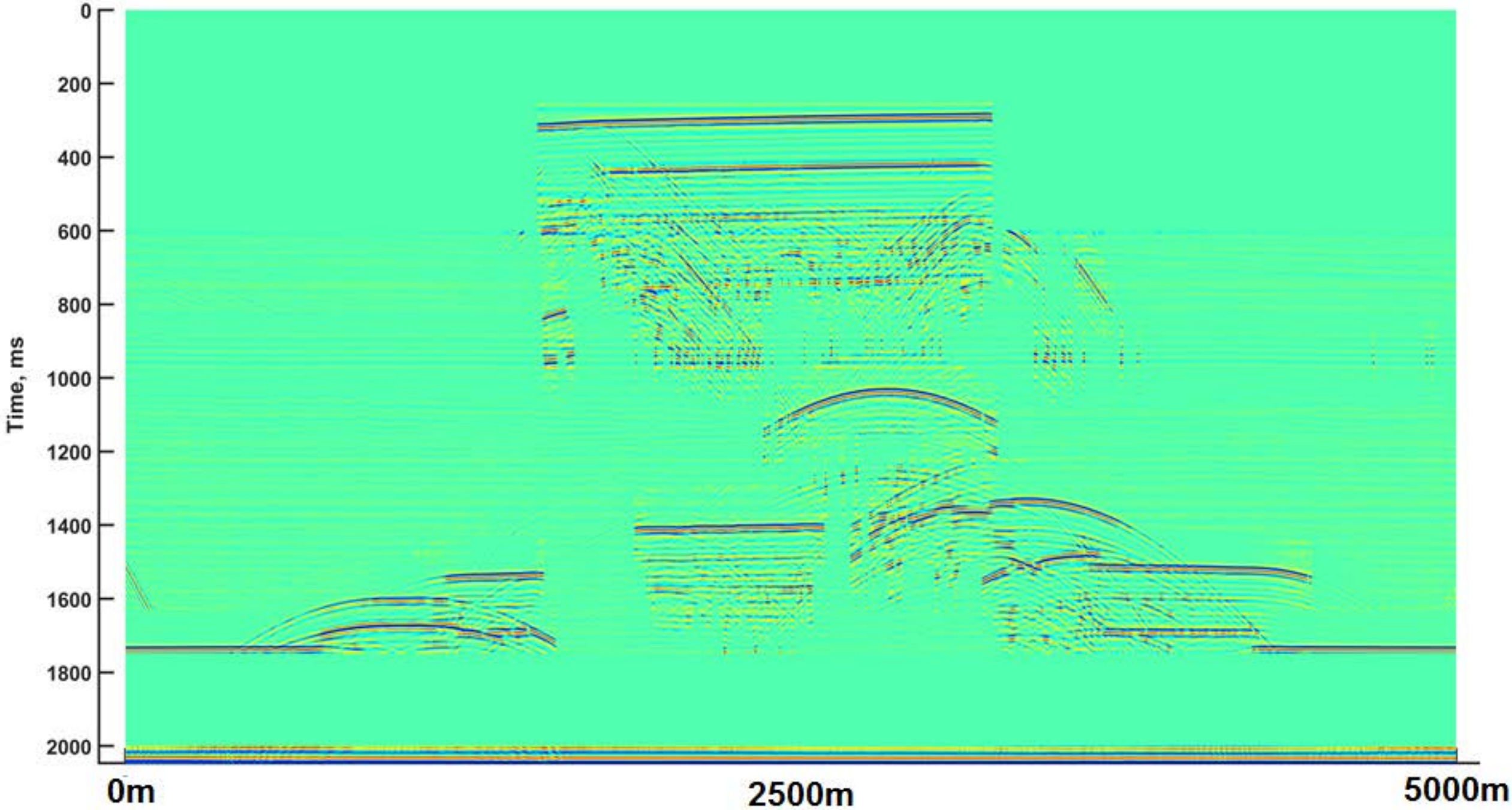
Seismic Illumination (reprised)

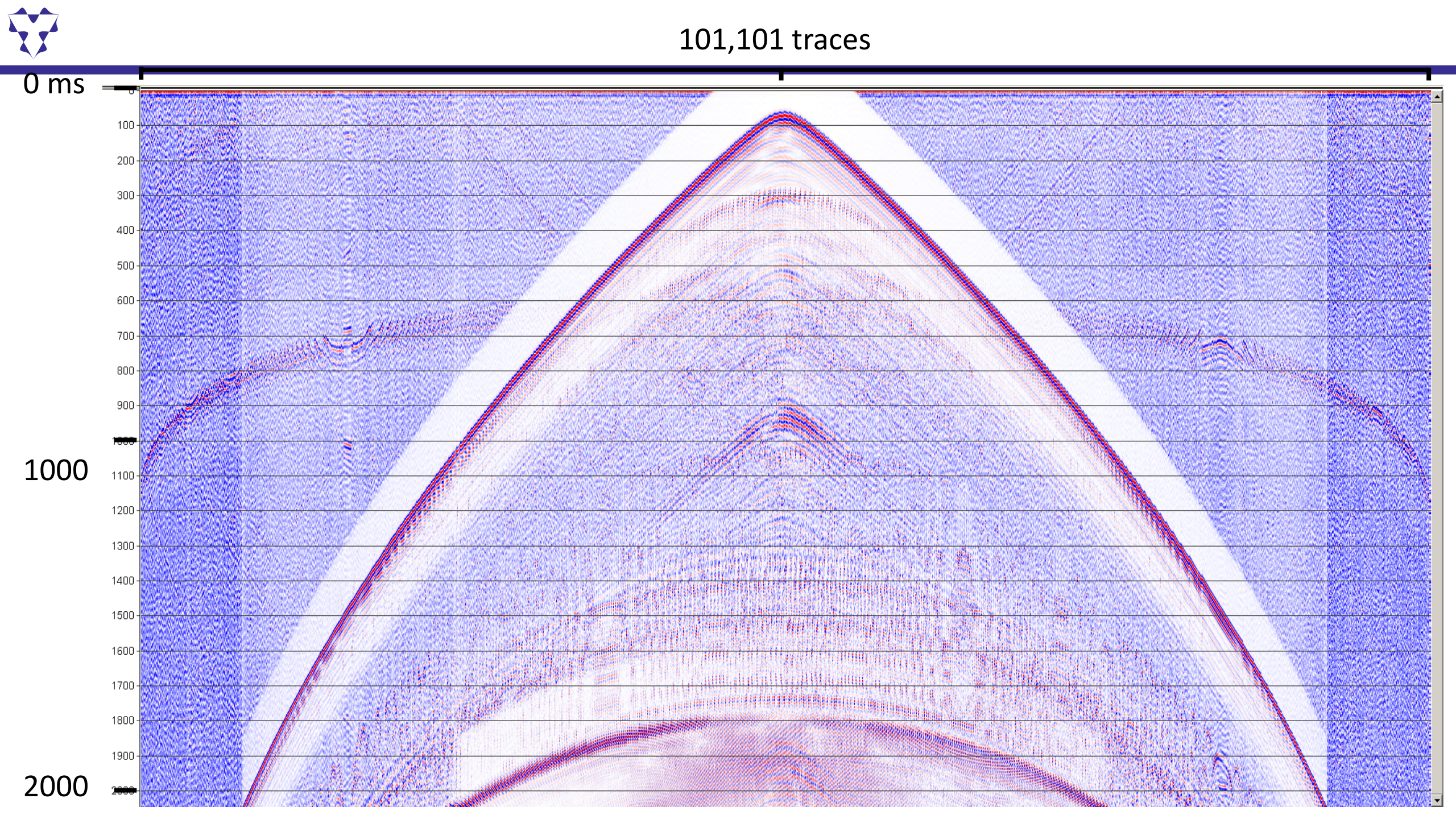


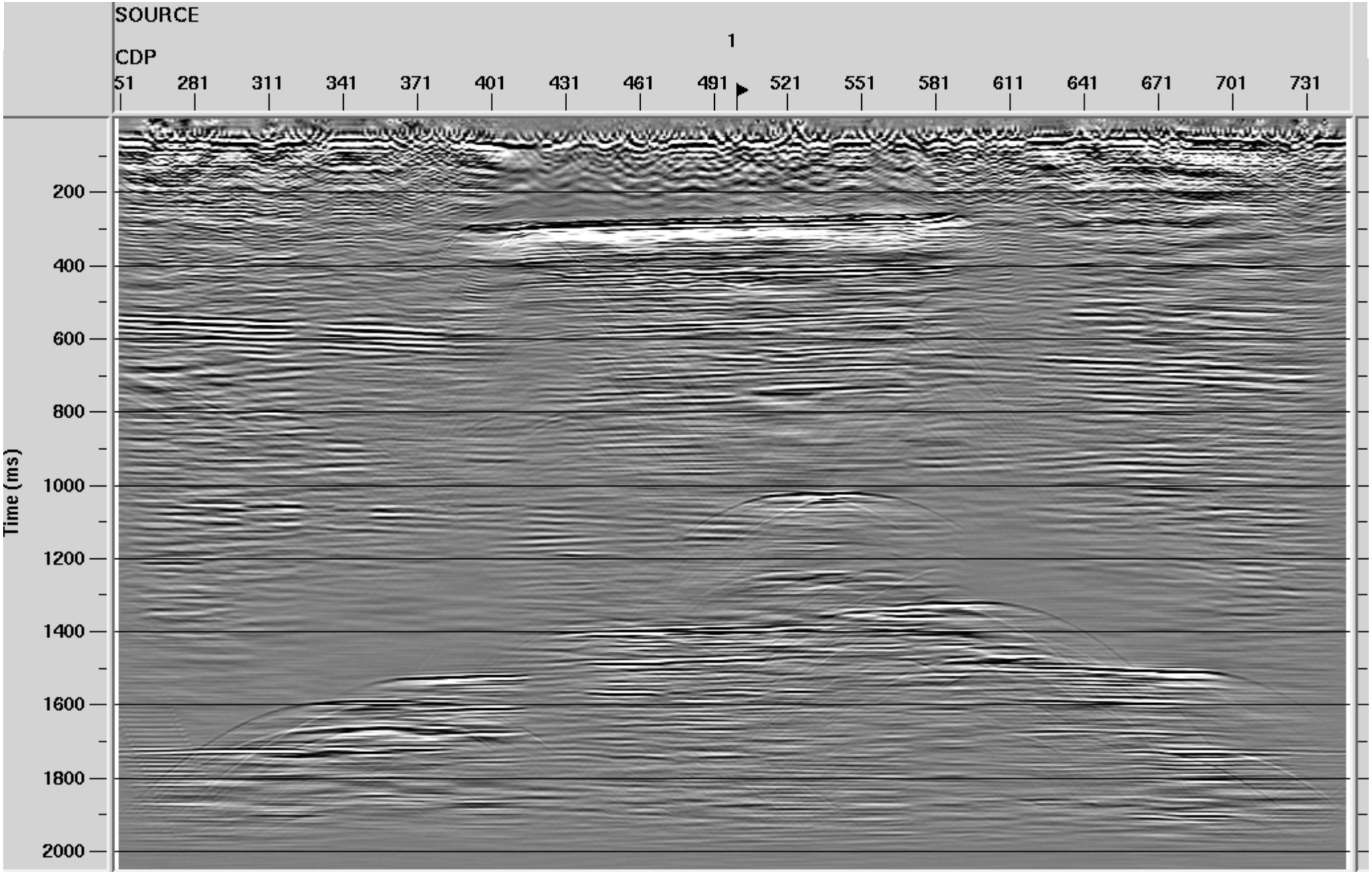
“Sonar” survey in colour

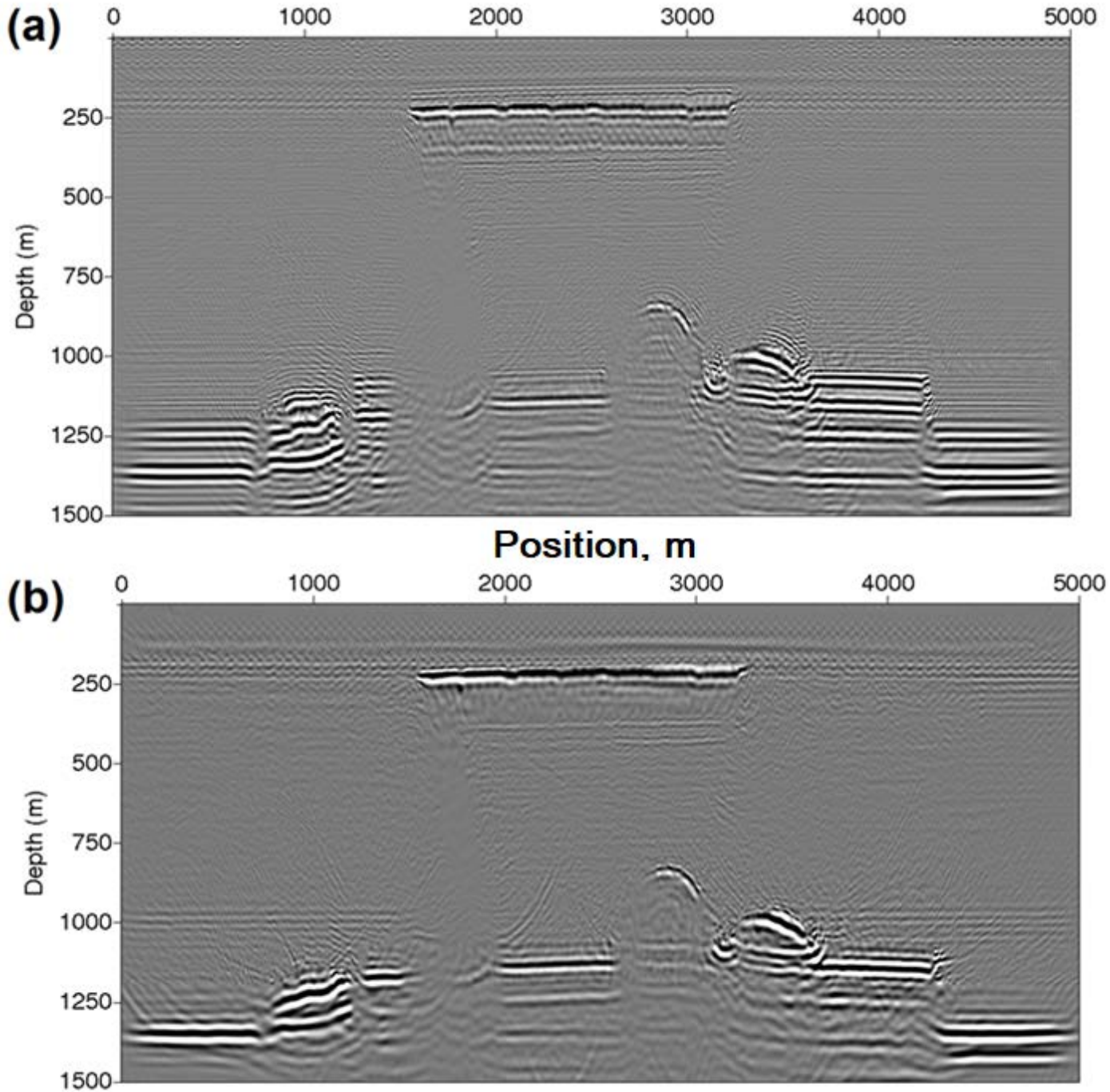



0
200
400
600
800
1000
1200
1400
1600
1800
2000
Time, ms
0m
2500m
5000m


0
200
400
600
800
1000
1200
1400
1600
1800
2000
Time, ms
0m
2500m
5000m


101,101 traces
0 ms
1000
2000
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000


SOURCE
1
CDP
51
281
311
341
371
401
431
461
491
521
551
581
611
641
671
701
731
Time (ms)
200
400
600
800
1000
1200
1400
1600
1800
2000

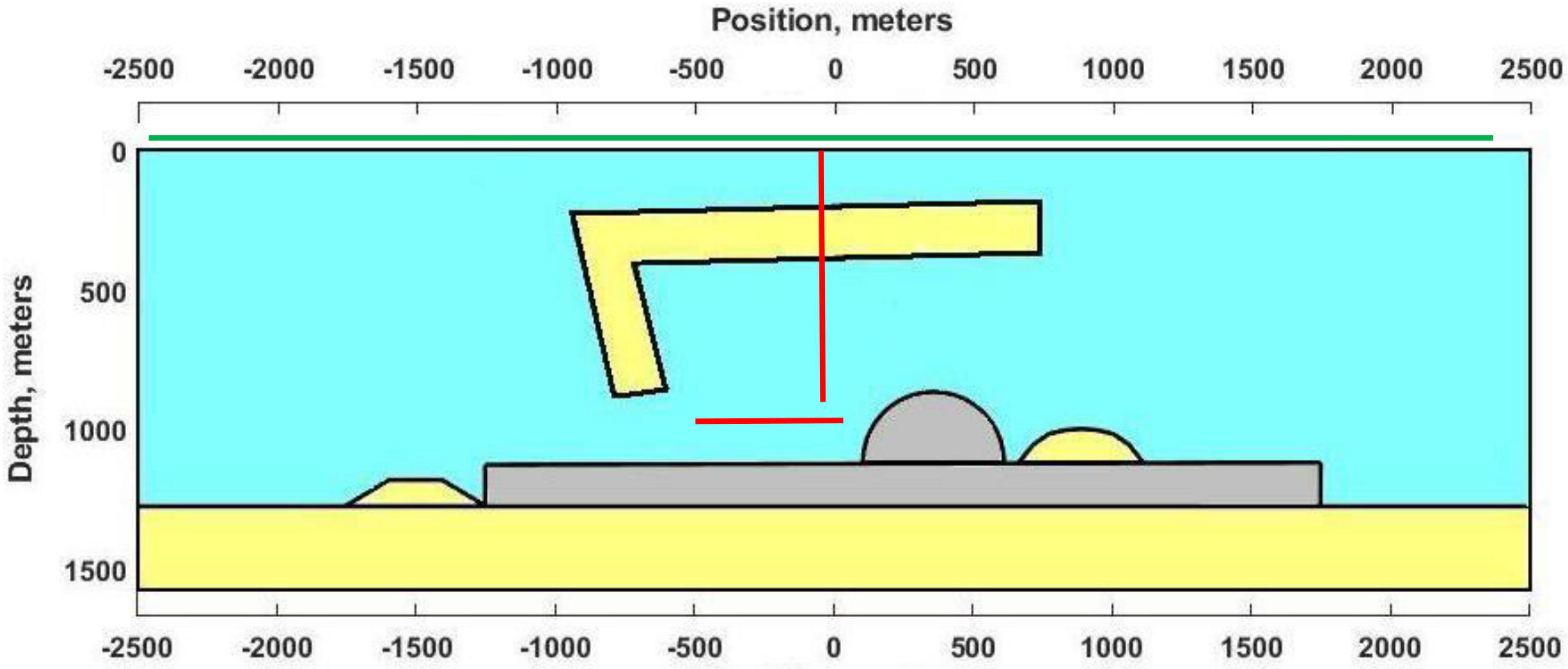

(a)
0
1000
2000
3000
4000
5000
250
500
750
1000
1250
1500
Depth (m)
Position, m
(b)
0
1000
2000
3000
4000
5000
250
500
750
1000
1250
1500
Depth (m)

Part 2

Seismic-While-Drilling (SWD)

Surface-only sources and receivers do not adequately illuminate sub-vertical interfaces and targets below blocking structures.

- ***Increase illumination by using subsurface sources.***
- ***Can we use the drill-bit cutting into rock as a subsurface source?***



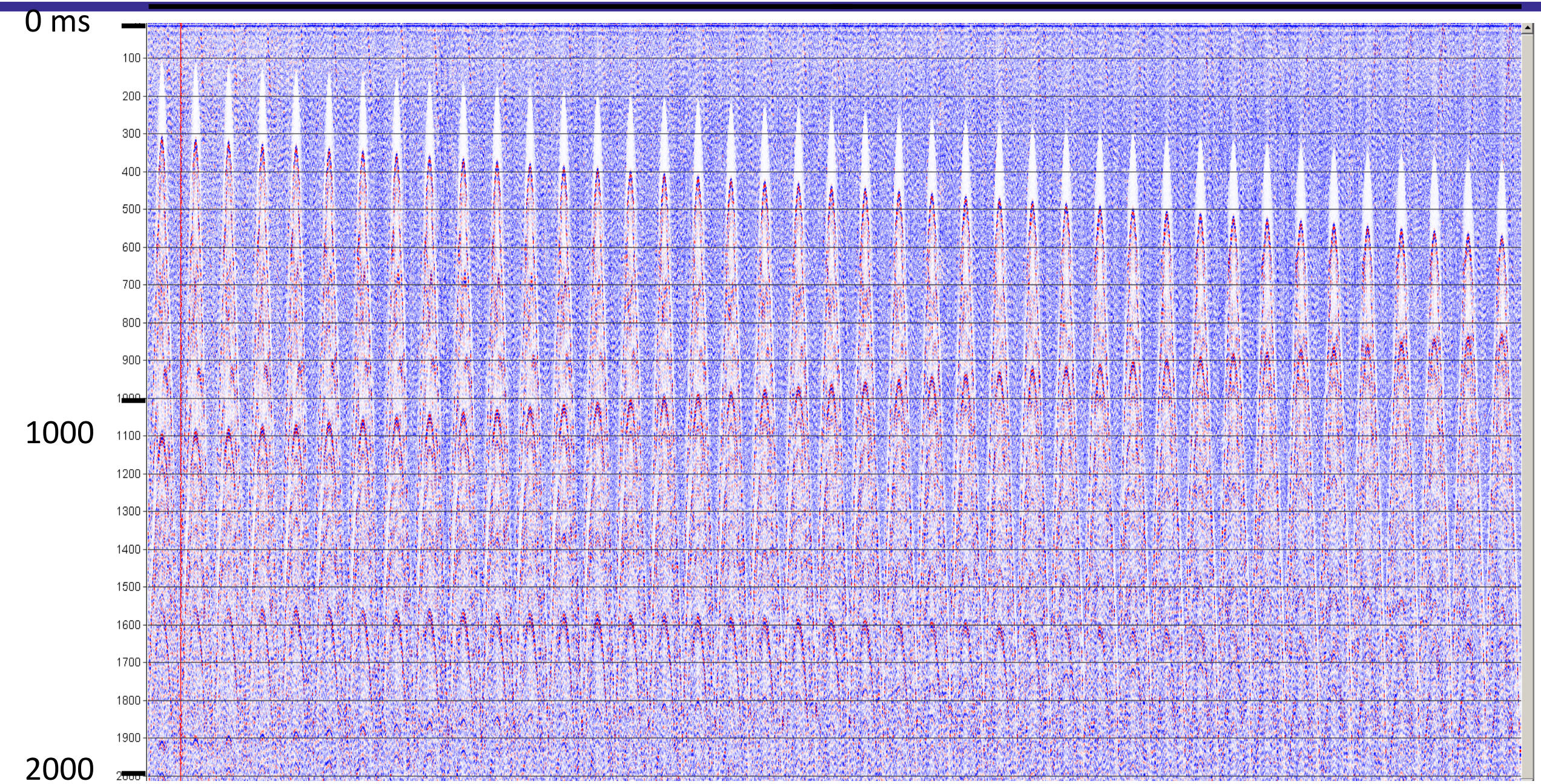
SRC Line

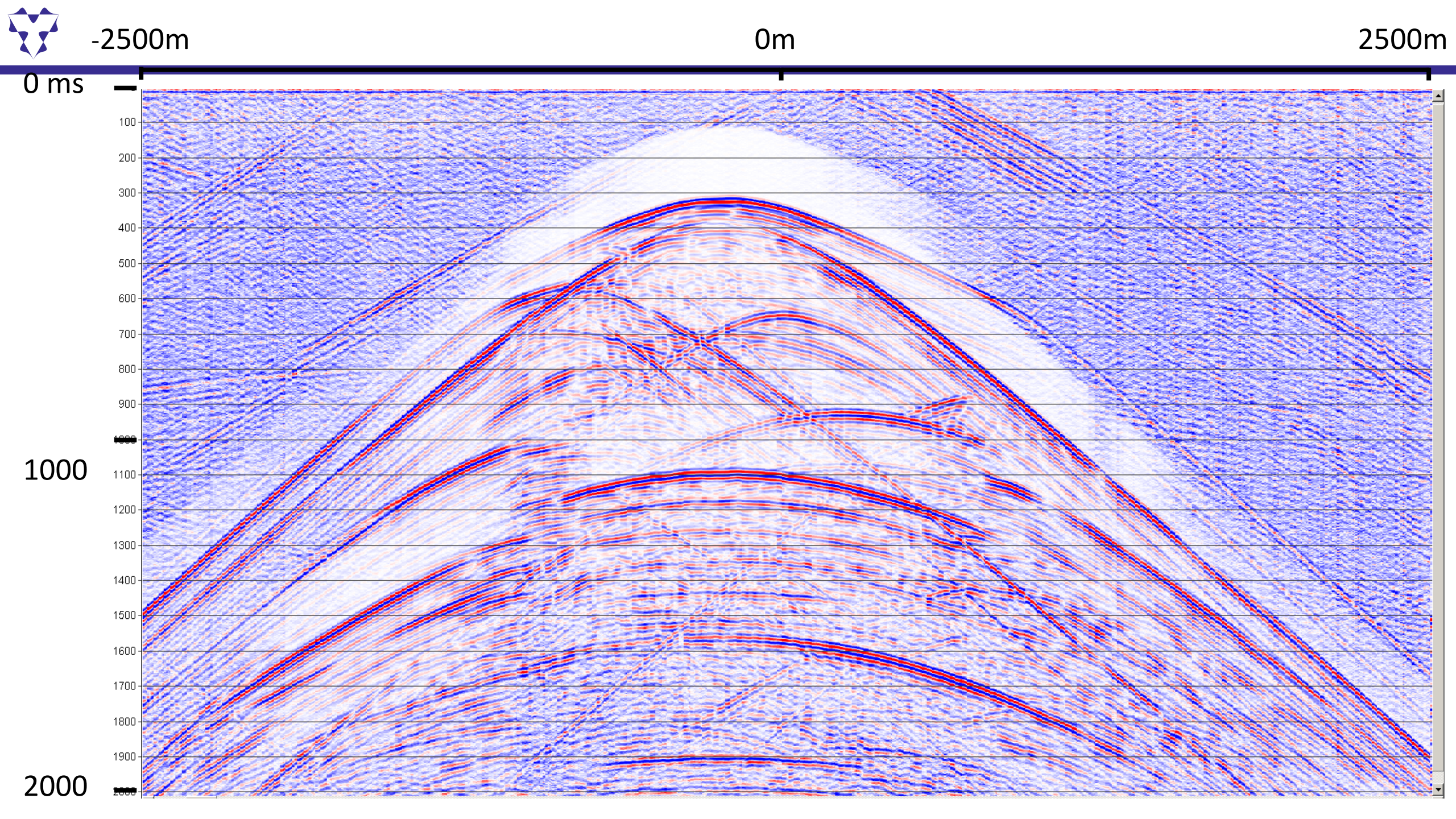
RCR Line

Enhanced illumination:

Acquisition with sub-surface sources and surface receivers.

41,041 traces




-2500m
0m
2500m
0 ms
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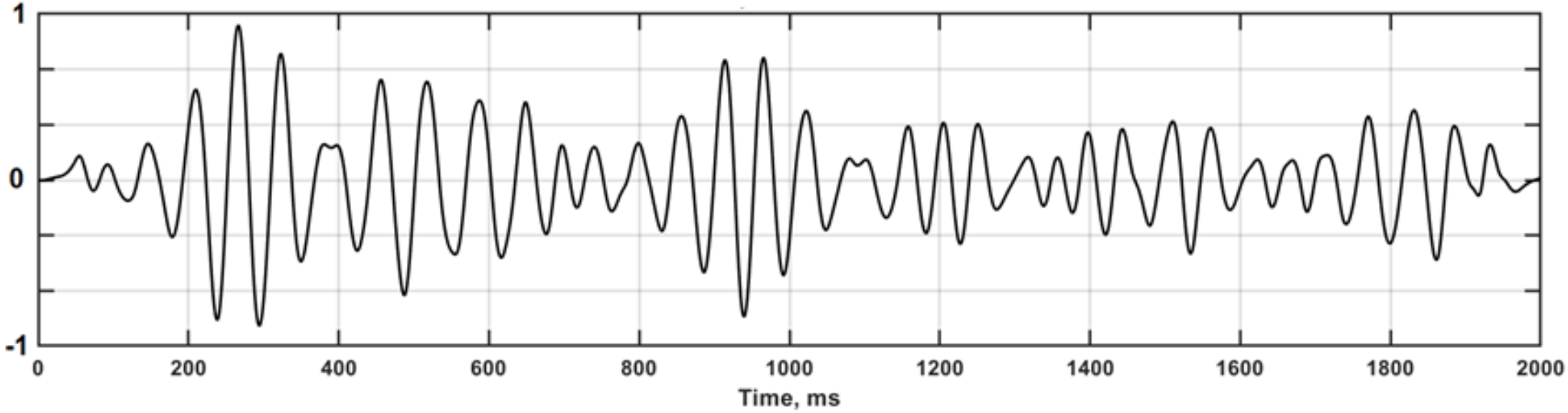
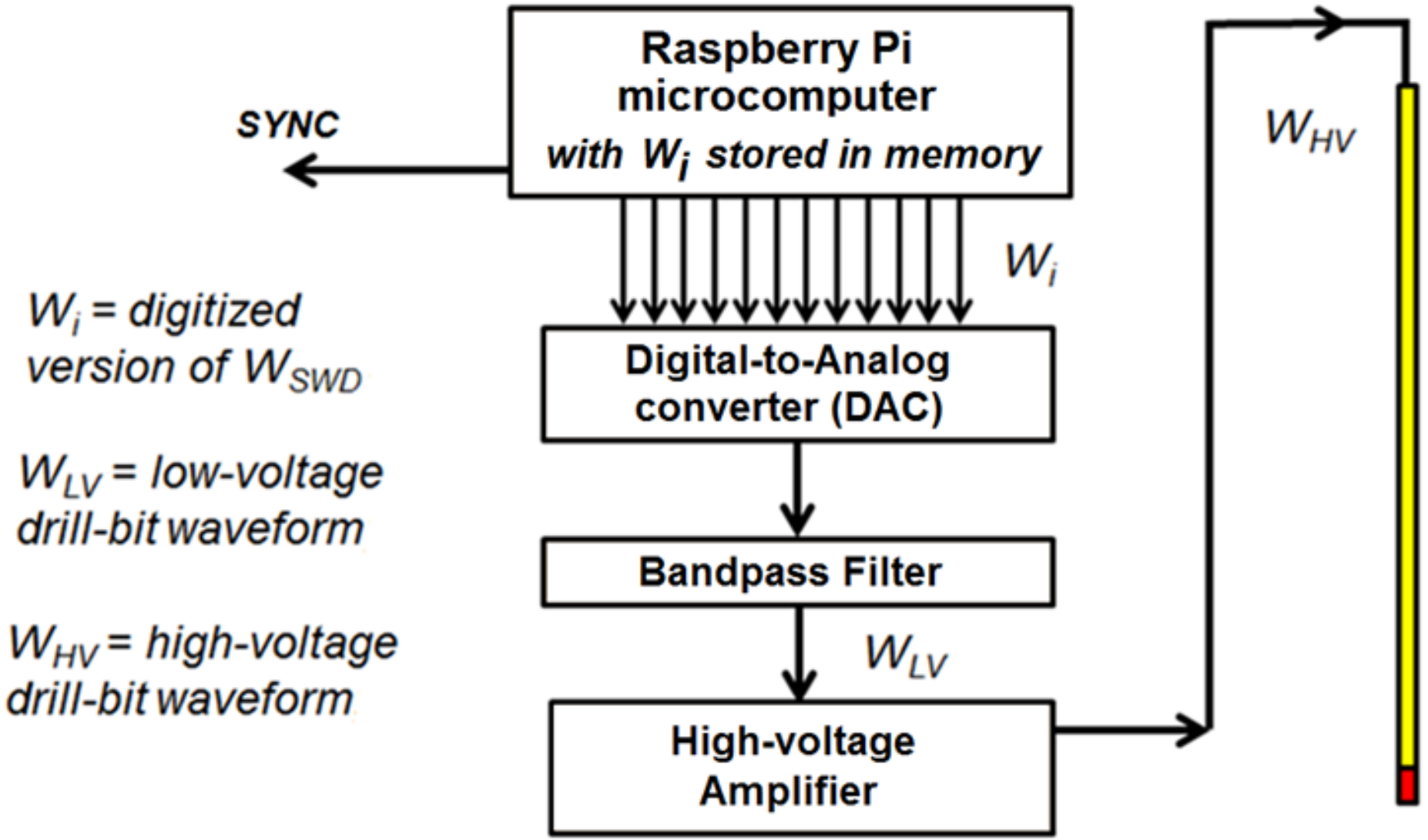
1700
1800
1900
2000

Designing Electronic Circuits for Generating the Drill-bit Source Waveform.

W_{SWD} = drill-bit waveform




Raspberry Pi microcomputer
with W_i stored in memory
SYNC
W_i
Digital-to-Analog converter (DAC)
Bandpass Filter
W_{LV}
High-voltage Amplifier
W_{HV}
W_i = digitized version of W_{SWD}
W_{LV} = low-voltage drill-bit waveform
W_{HV} = high-voltage drill-bit waveform

Mathematical model of SWD.

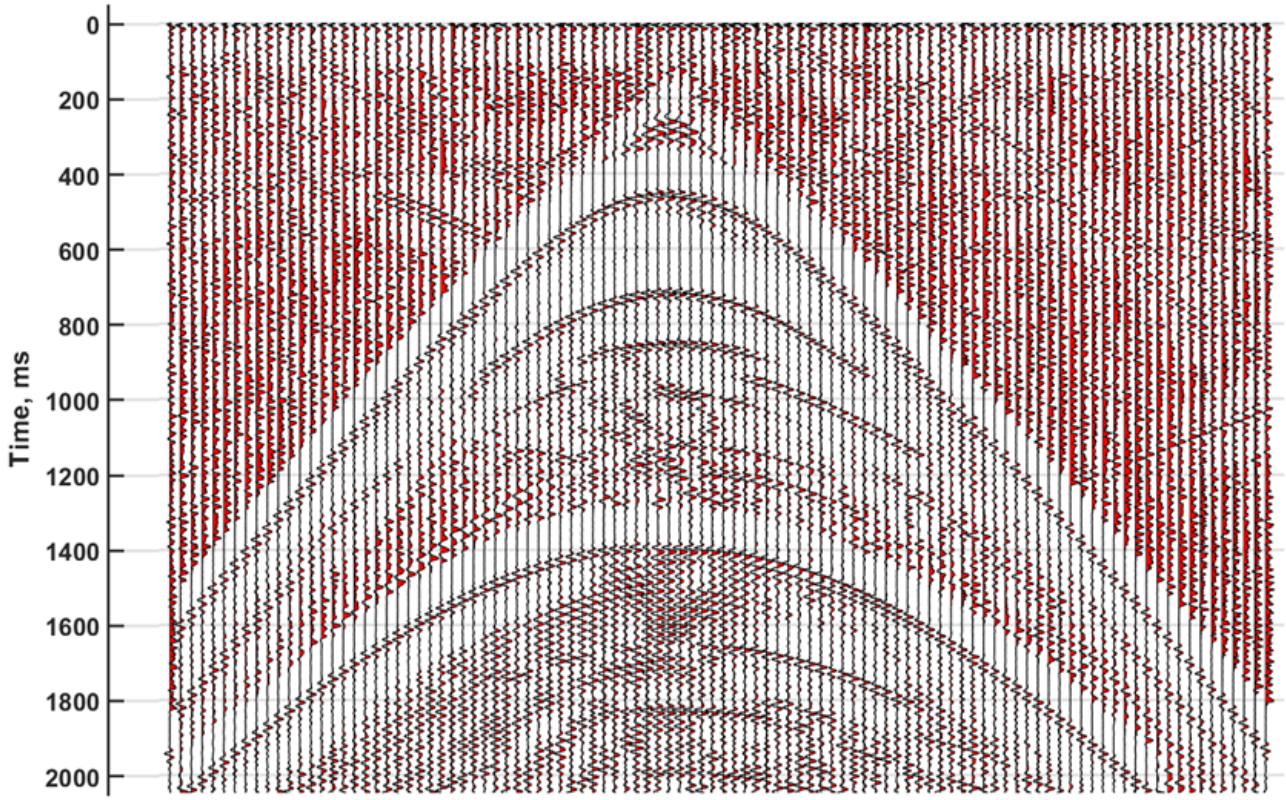
d_{imp} = *impulsive-source seismic data;*
W_{SWD} = *drill-bit waveform;*
d_{SWD} = *seismic field data acquired with drill-bit source;*
d_{est} = *estimated impulsive-source seismic data.*

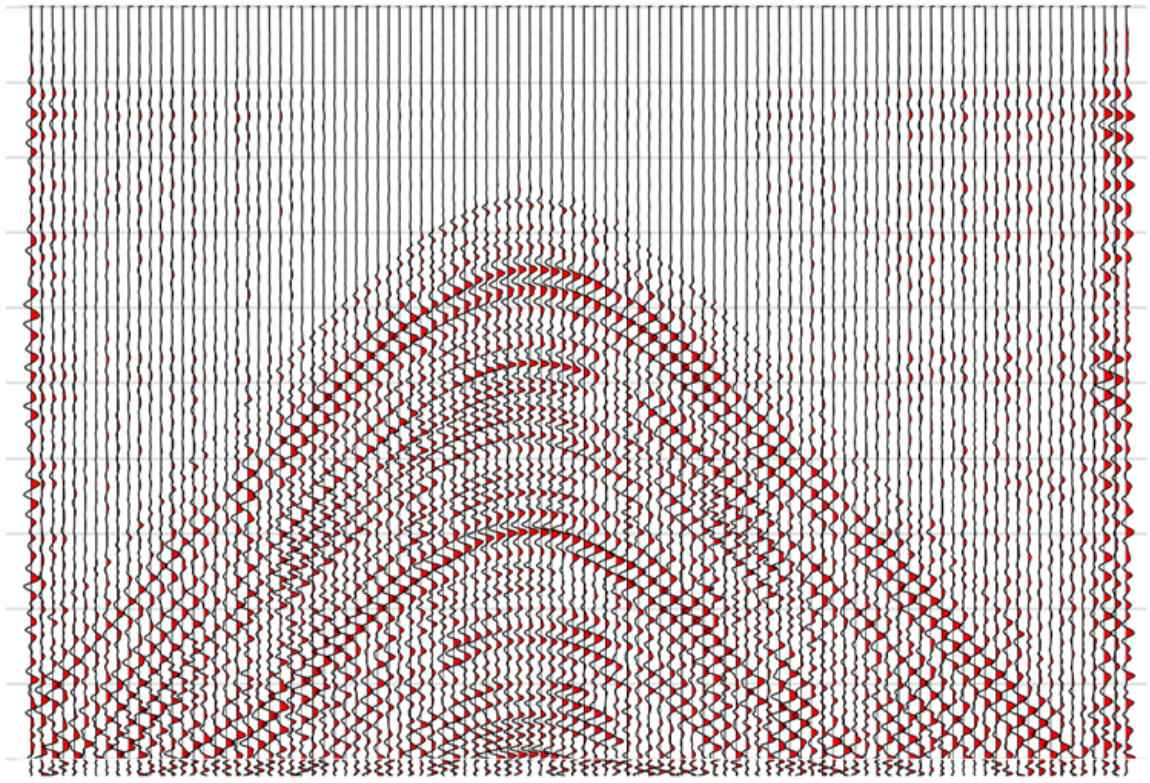
Convolution:

$$d_{imp} \otimes W_{SWD} = d_{SWD}$$

Deconvolution:

$$d_{est} = d_{SWD} \oslash W_{SWD}$$





Impulsive Source

Drill-bit Source

Summary and Conclusion

- ***We have conducted an impulsive-source survey to illustrate deficiencies in seismic illumination when surface-only sources and receivers are employed.***

- ***We mitigated the illumination deficiencies by also collecting data with subsurface sources that are stand-ins for drill-bits interacting with rock in a seismic-while-drilling (SWD) scenario.***

- ***To simulate SWD more fully, the subsurface piezopin sources must be driven by complicated waveforms mimicking vibrations produced by drill-bits cutting into rock. This remains to be done.***

ACKNOWLEDGEMENTS

We thank the sponsors of CREWES for continued support. This work was funded by CREWES industrial sponsors, NSERC (Natural Science and Engineering Research Council of Canada) through the grant CRDPJ 461179-13, and in part by the Canada First Research Excellence Fund.