Euregio Meuse-Rhine (EMR): Active Seismic Experiences - Campaign 2022

First results and recommendation for future campaigns

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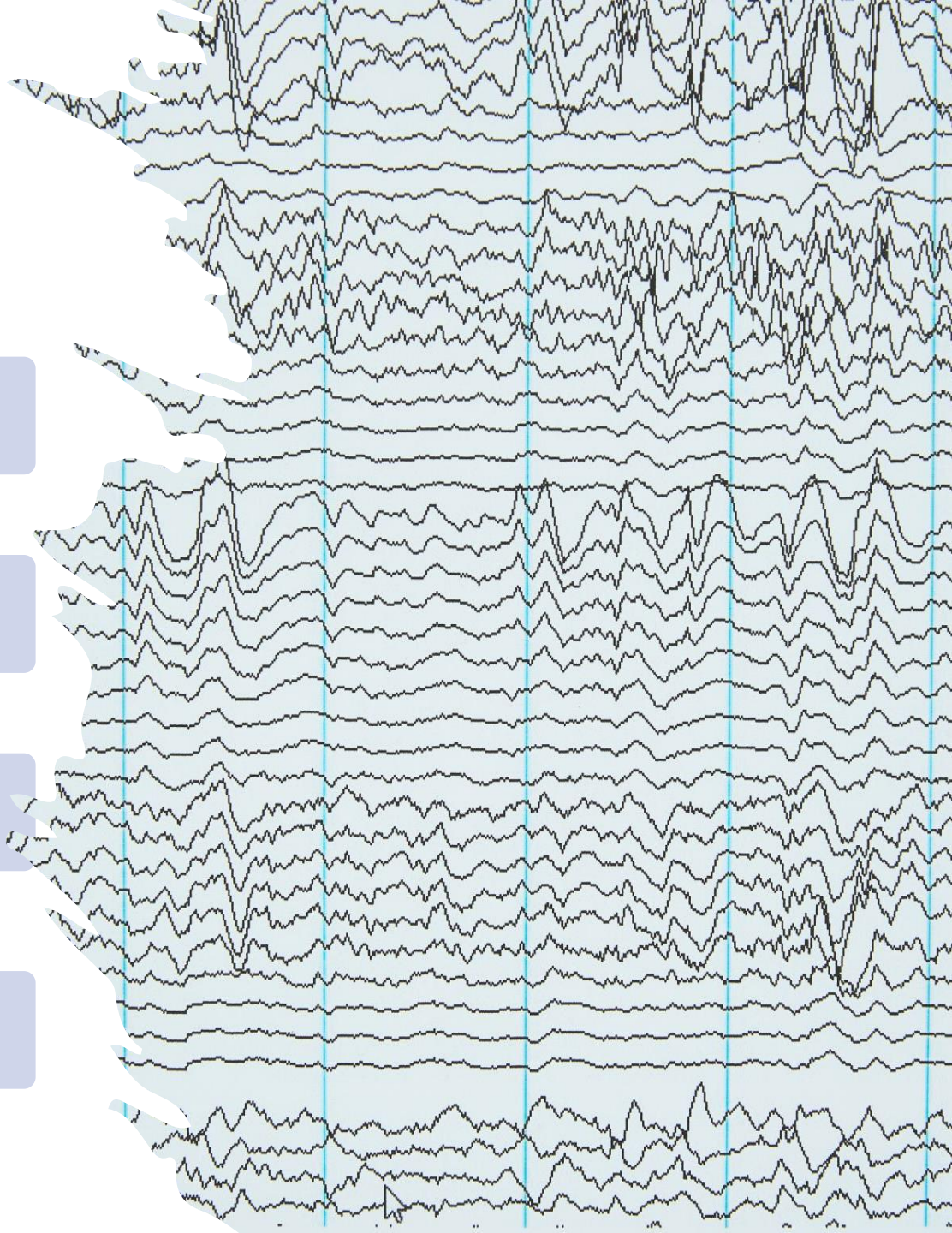
E-TEST Einstein Telescope EMR Site & Technology

Interreg Euregio Meuse-Rhine European Regional Development Fund

EUROPEAN UNION

Outline

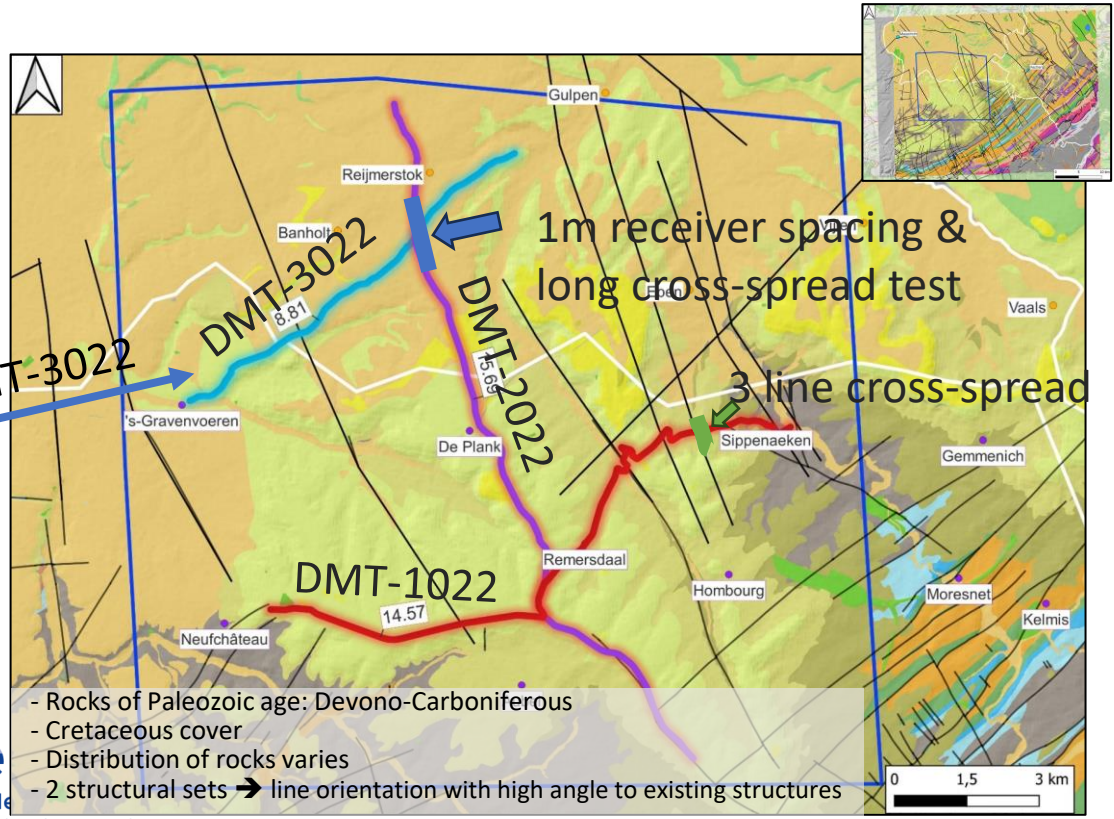
- Overview about the active seismic campaign 2022
- Seismic processing challenges
- Comparing results of different seismic processing vendors
- Recommendations for future acquisition campaigns



2D Seismic Survey

- Data acquisition: September 2022
- Dual purpose: Geothermal exploration and Einstein-Telescope

	Electro-Vibe Test	1-3 M12 Vibro-Seis
Frequency range	2-100 Hz	6 – 90 Hz or 10 – 90 Hz
Sweep time	24 s	16 s
Listening time	3s	4 s
Number of sweeps	2	4
Receiver spacing	5 m*	10 m*
Source point interval	5 m*	20 m*



Data & Processing Step Examples

Challenges of Near Surface Imaging (0-500m)

General

- High velocity contrast at ~ 150m depth (Cretaceous Unconformity)
  - from ~1500-2000m/s to 3000-3500m/s

  ➔ limits reflection energy to enable imaging events below the contrast

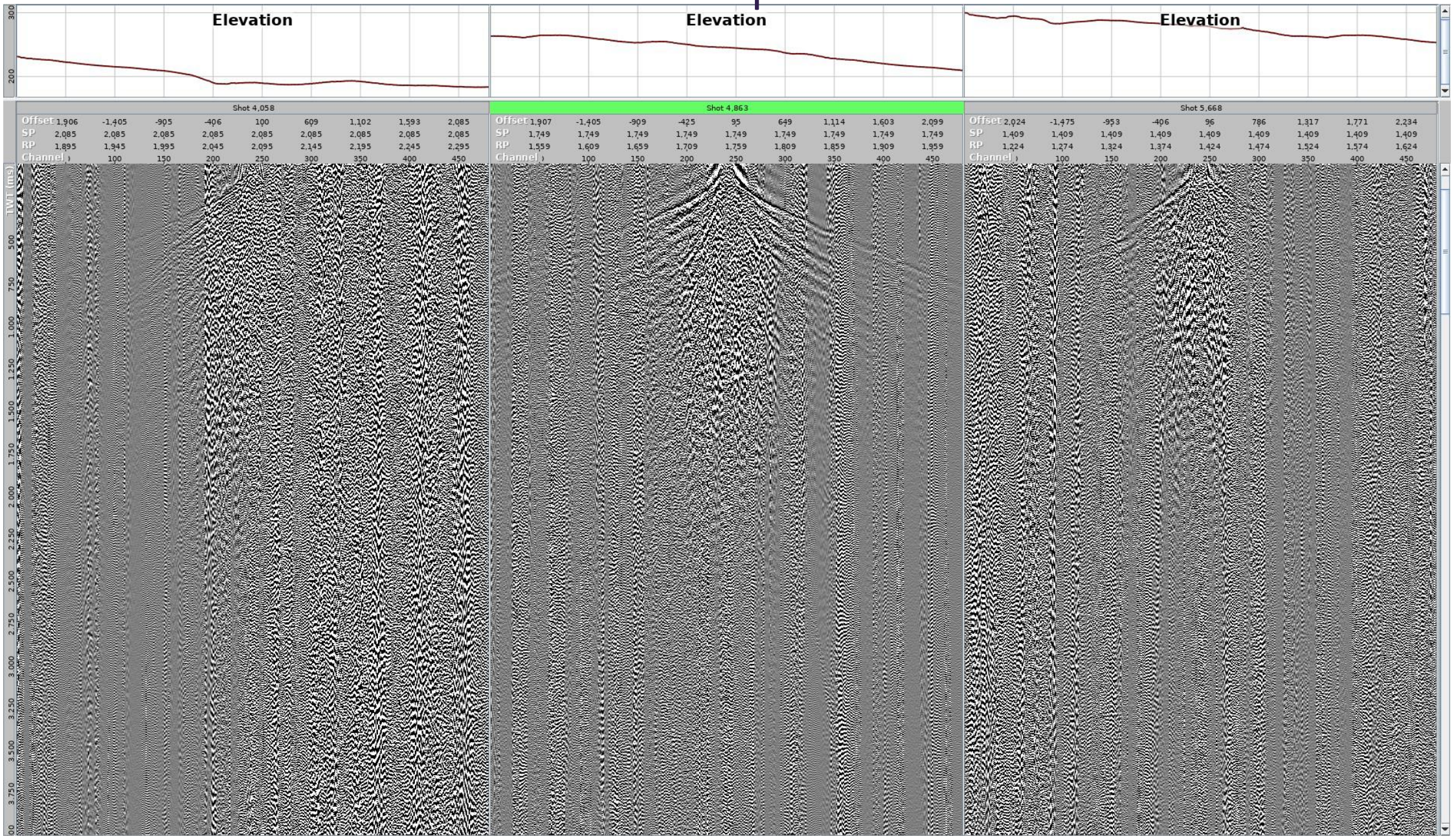
Specific to the 2D acquisition campaign in 2022 with DMT

- Sparse sampling
- Strong ground-roll
- 3 vibes simultaneously going leads to strong noise interference

➔impacts first break picking and the near surface tomography model

➔Impacts stacking velocity analysis,….

Line 2022 - Raw Data Example

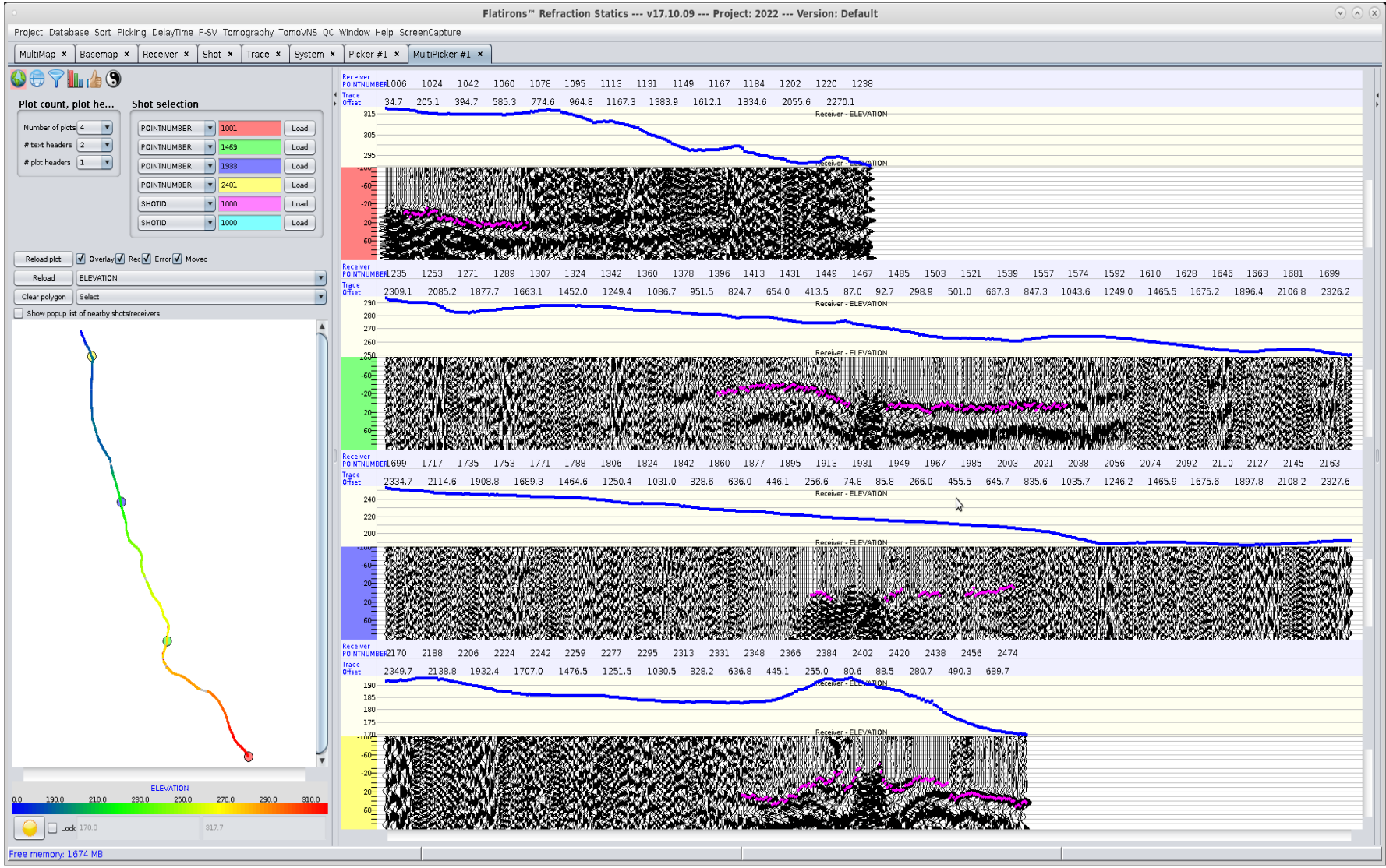


First break picks for refraction statics

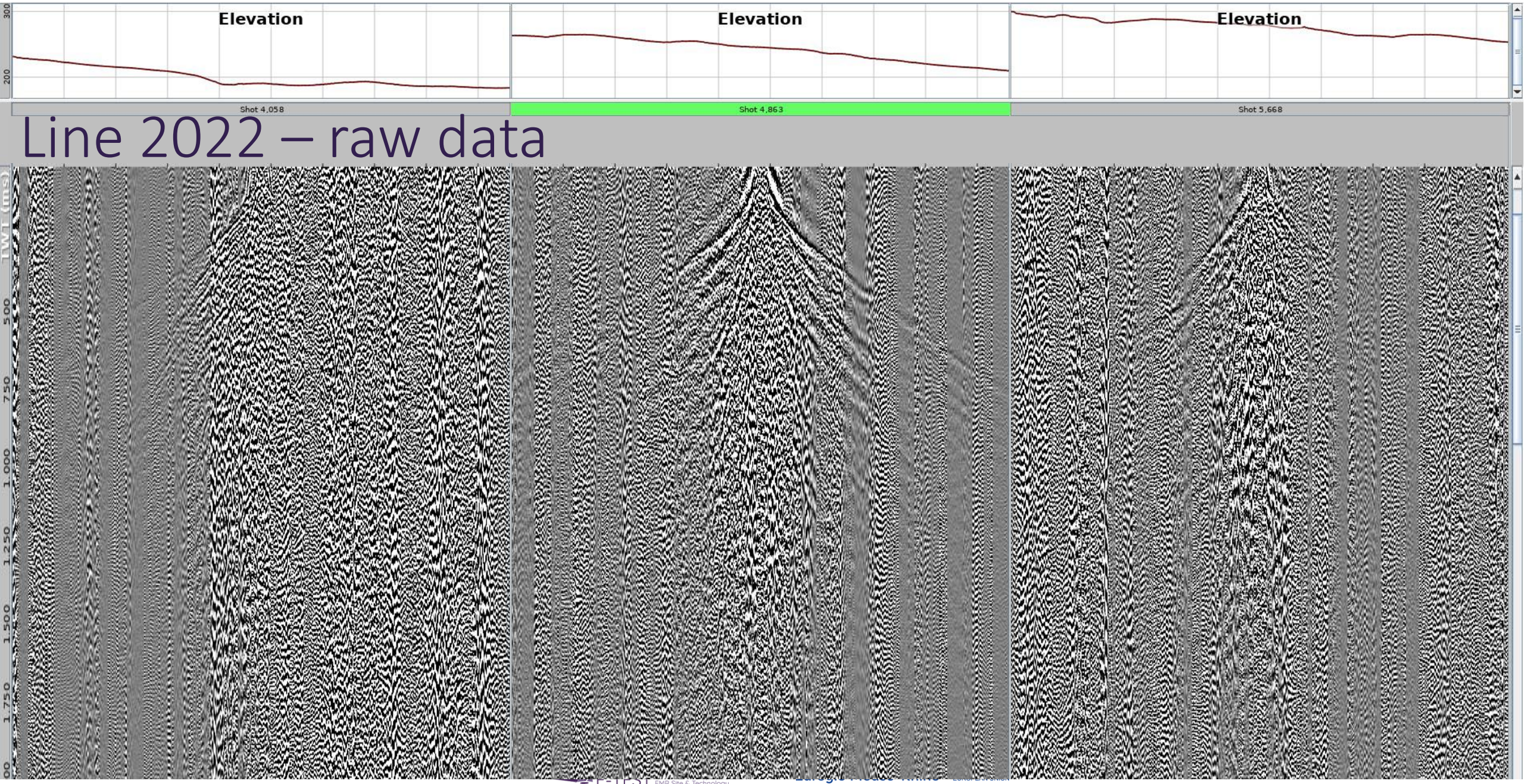
- First break picking is challenging
- Only possible in the near offset range (~500-600m)

➔Low quality refraction statics

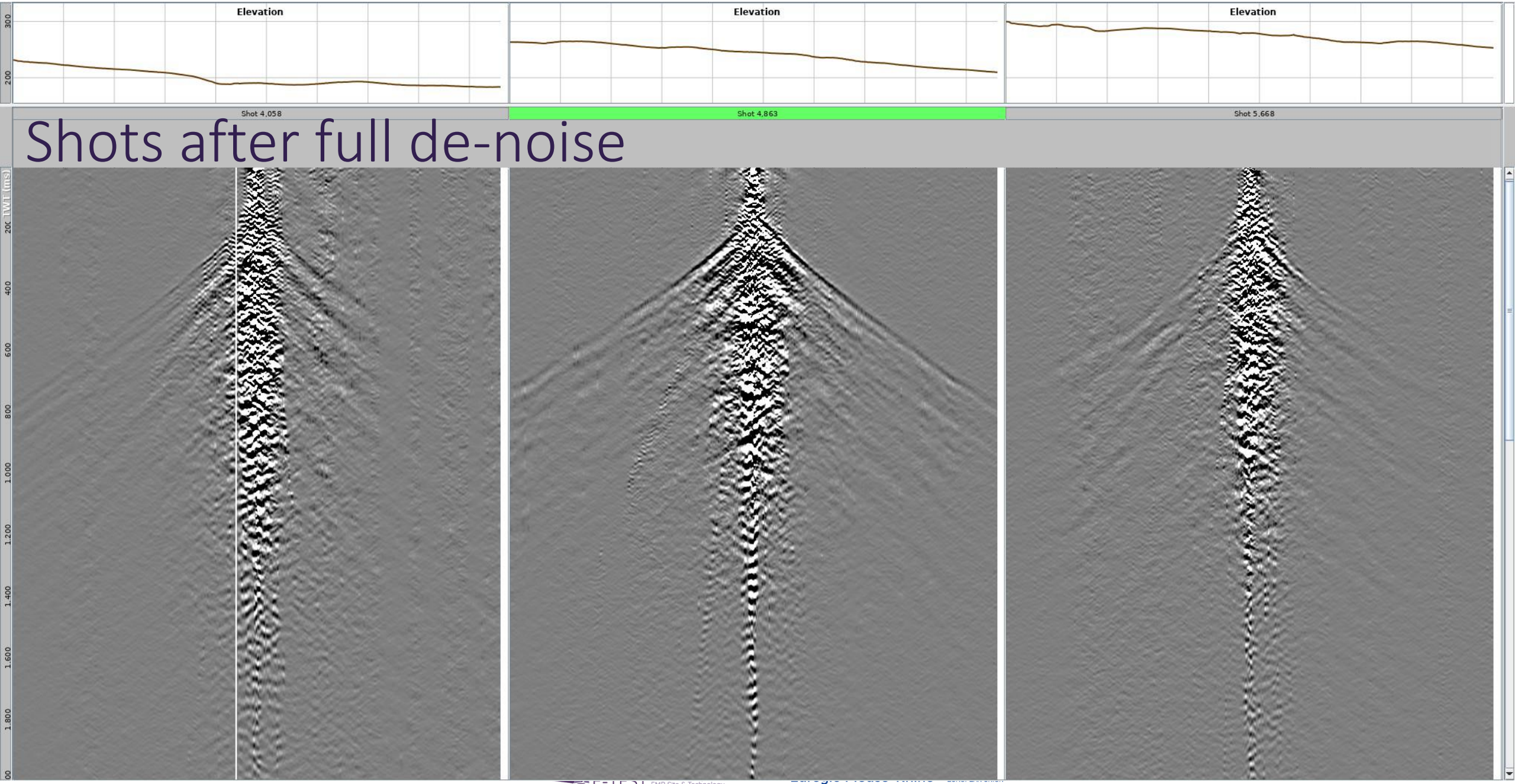
➔Low resolution near surface velocity model



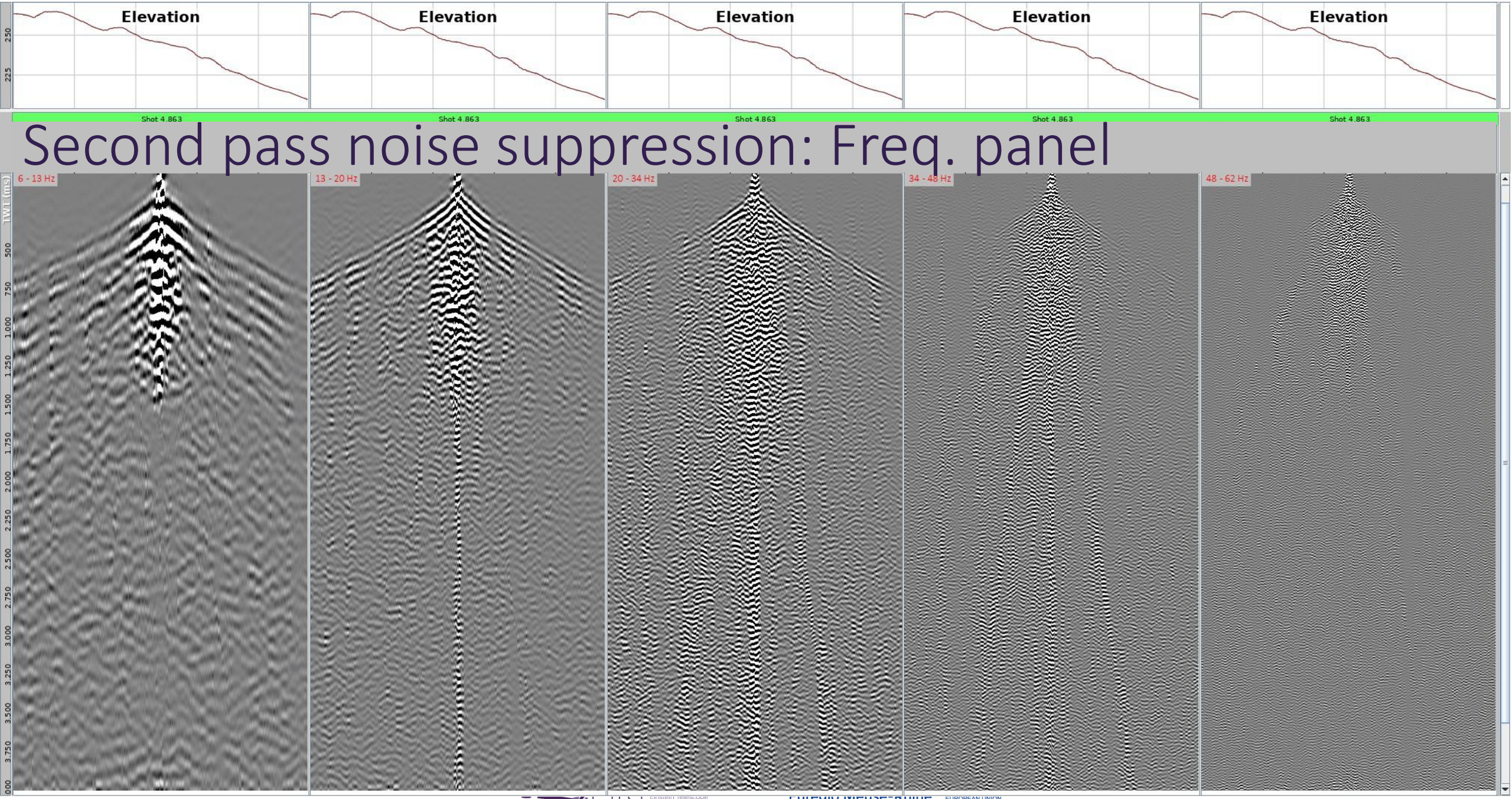
Line 2022 – raw data



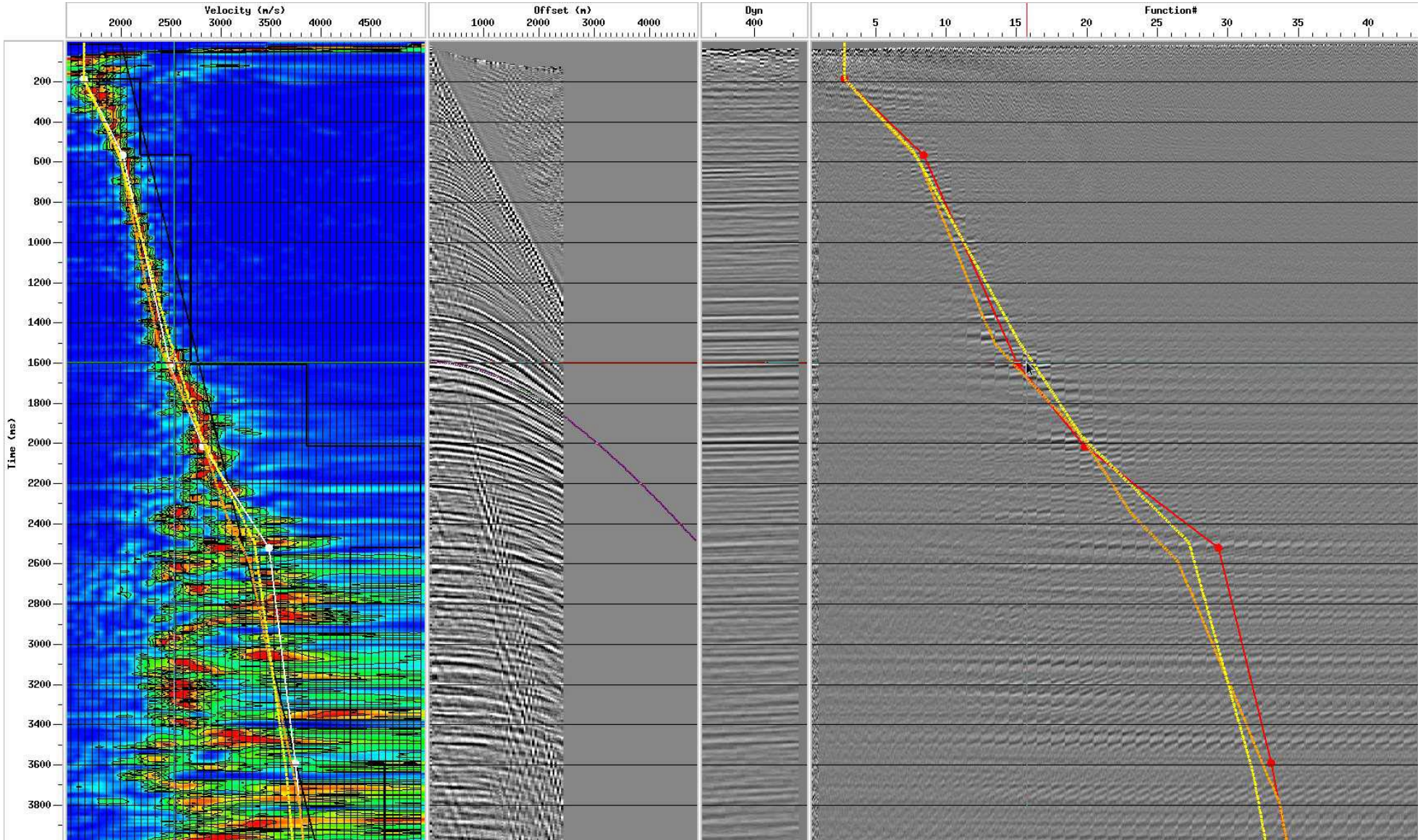
Shots after full de-noise



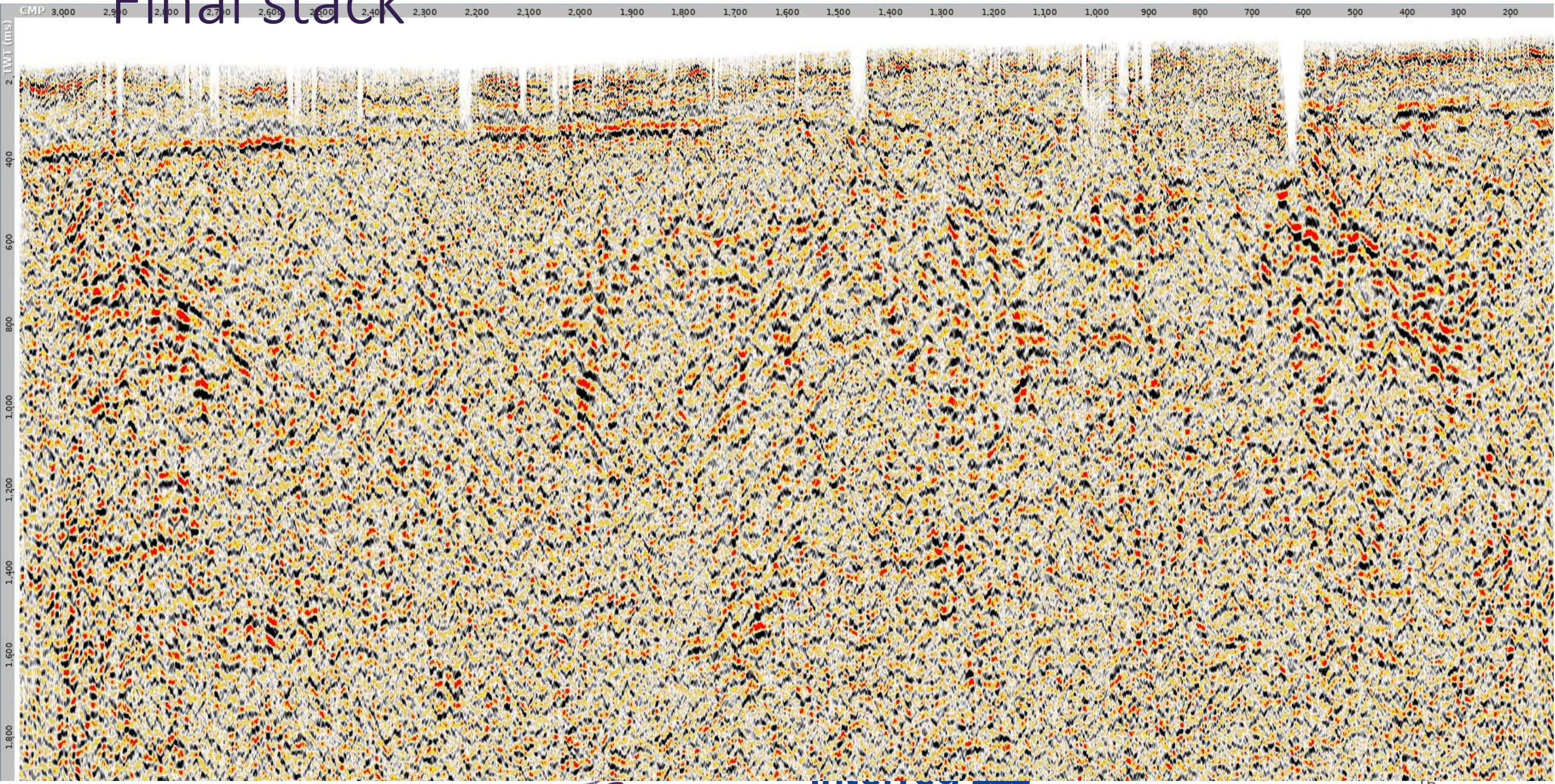
Second pass noise suppression: Freq. panel



Velocity analysis



Final stack

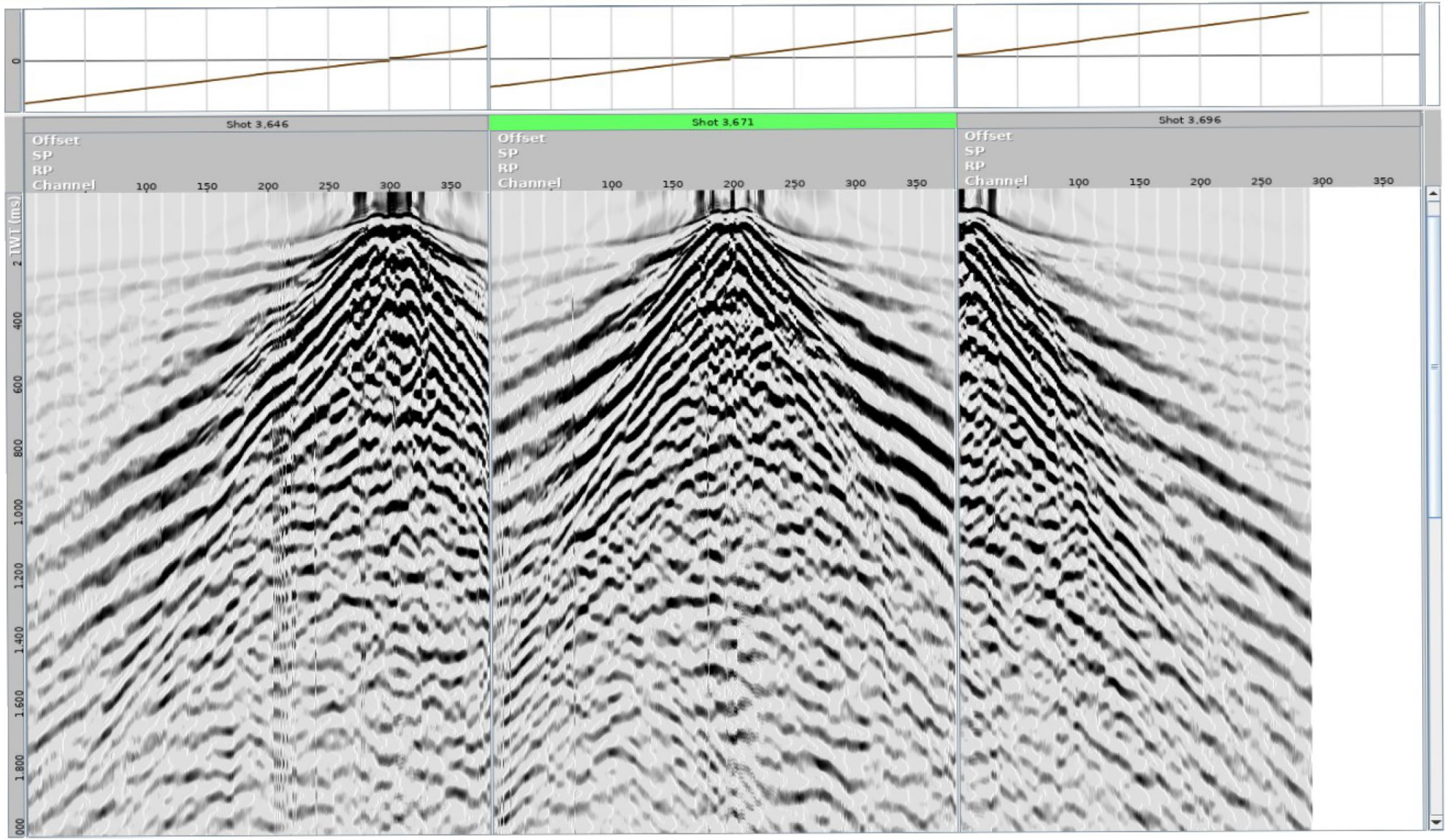

CMP
3,000
2,900
2,800
2,700
2,600
2,500
2,400
2,300
2,200
2,100
2,000
1,900
1,800
1,700
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
TWT (ms)
400
600
800
1,000
1,200
1,400
1,600
1,800

Impact of the Receiver Spacing

3 shots into Nikhef 1 m receiver nodes

2-4 Hz filter and T gain applied

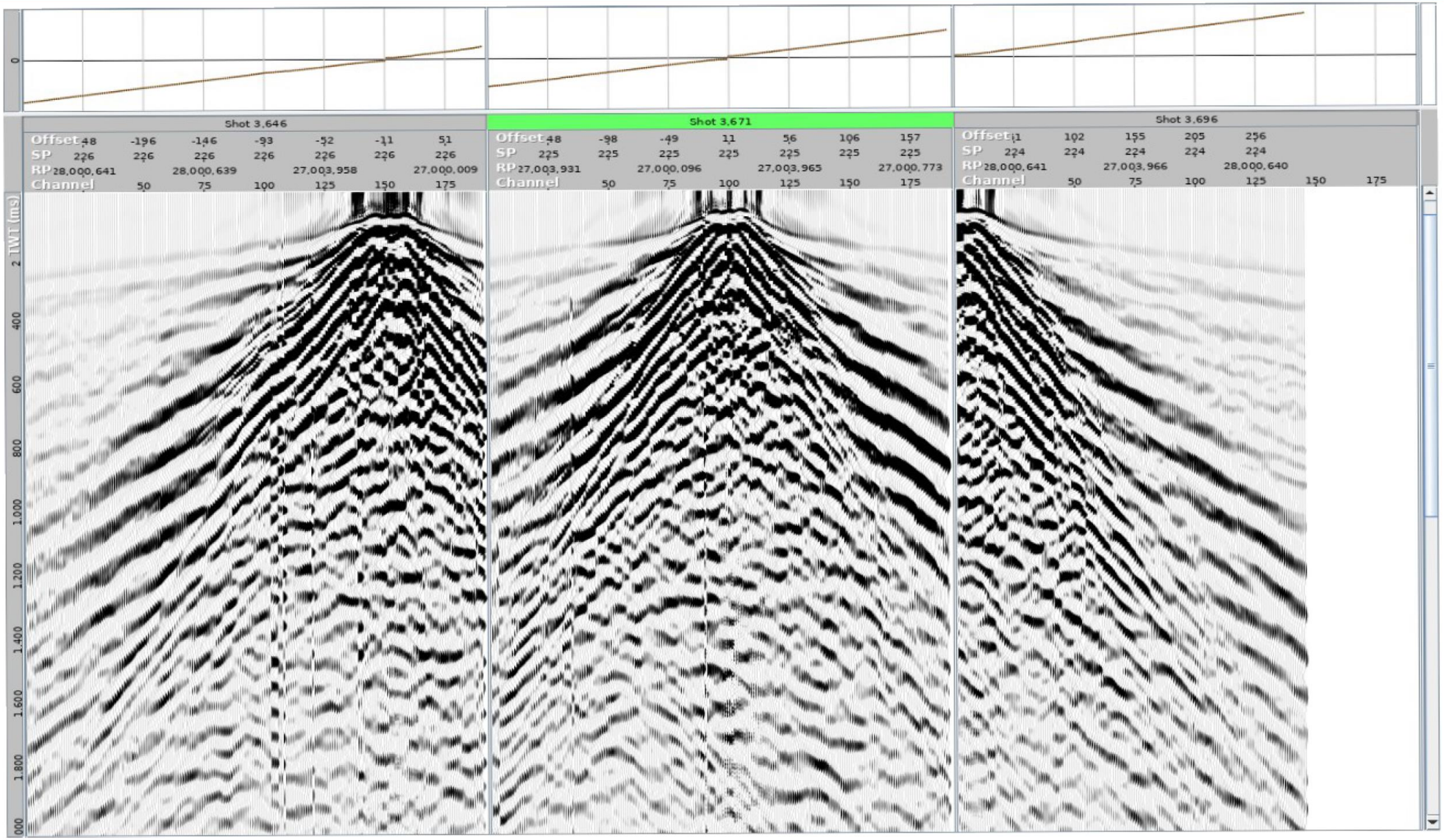
offset



3 shots into Nikhef 2 m receiver nodes

2-4 Hz filter and T gain applied

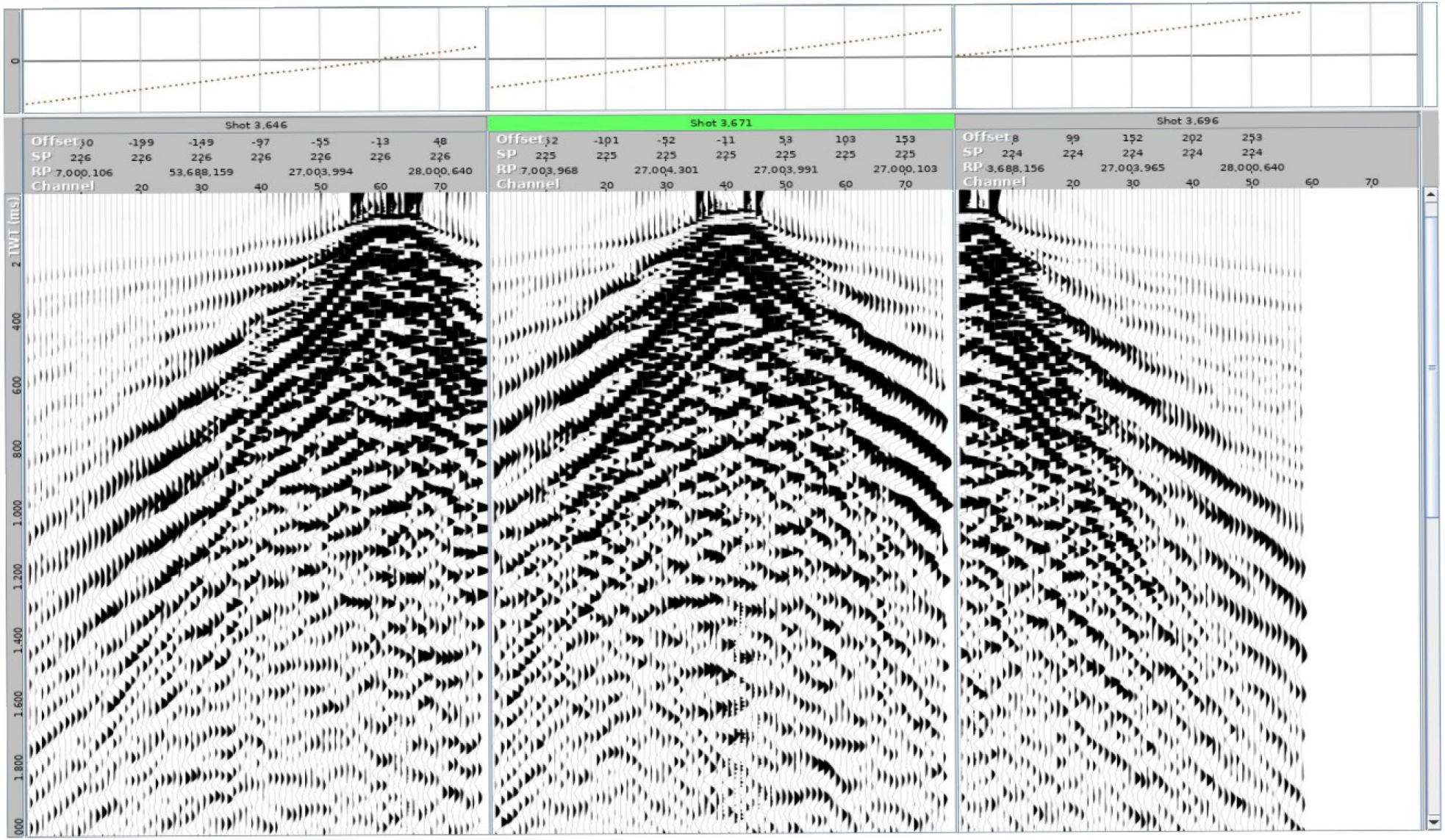
offset



3 shots into Nikhef 5 m receiver nodes

2-4 Hz filter and T gain applied

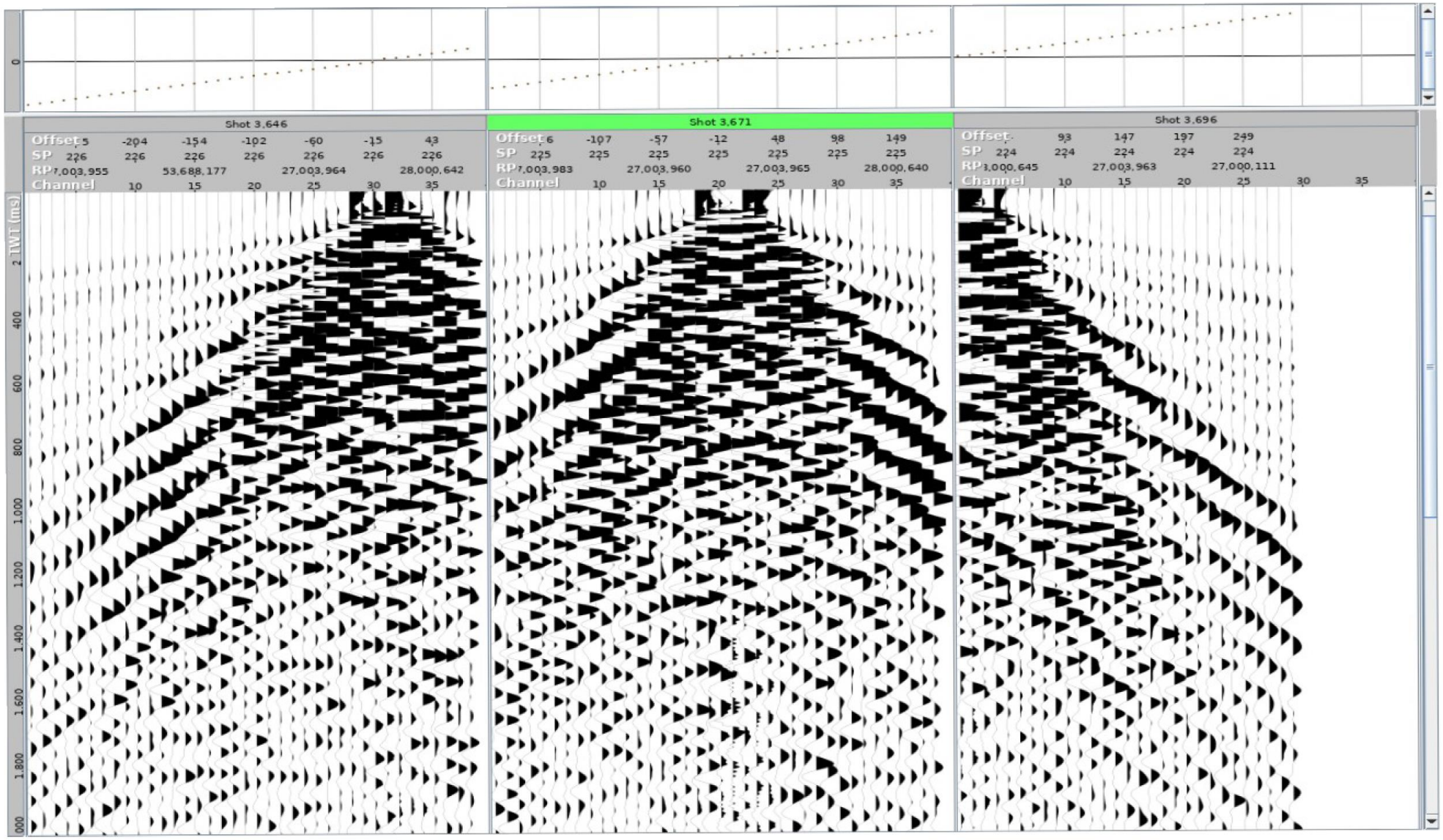
offset



3 shots into Nikhef 10 m receiver nodes

2-4 Hz filter and T gain applied

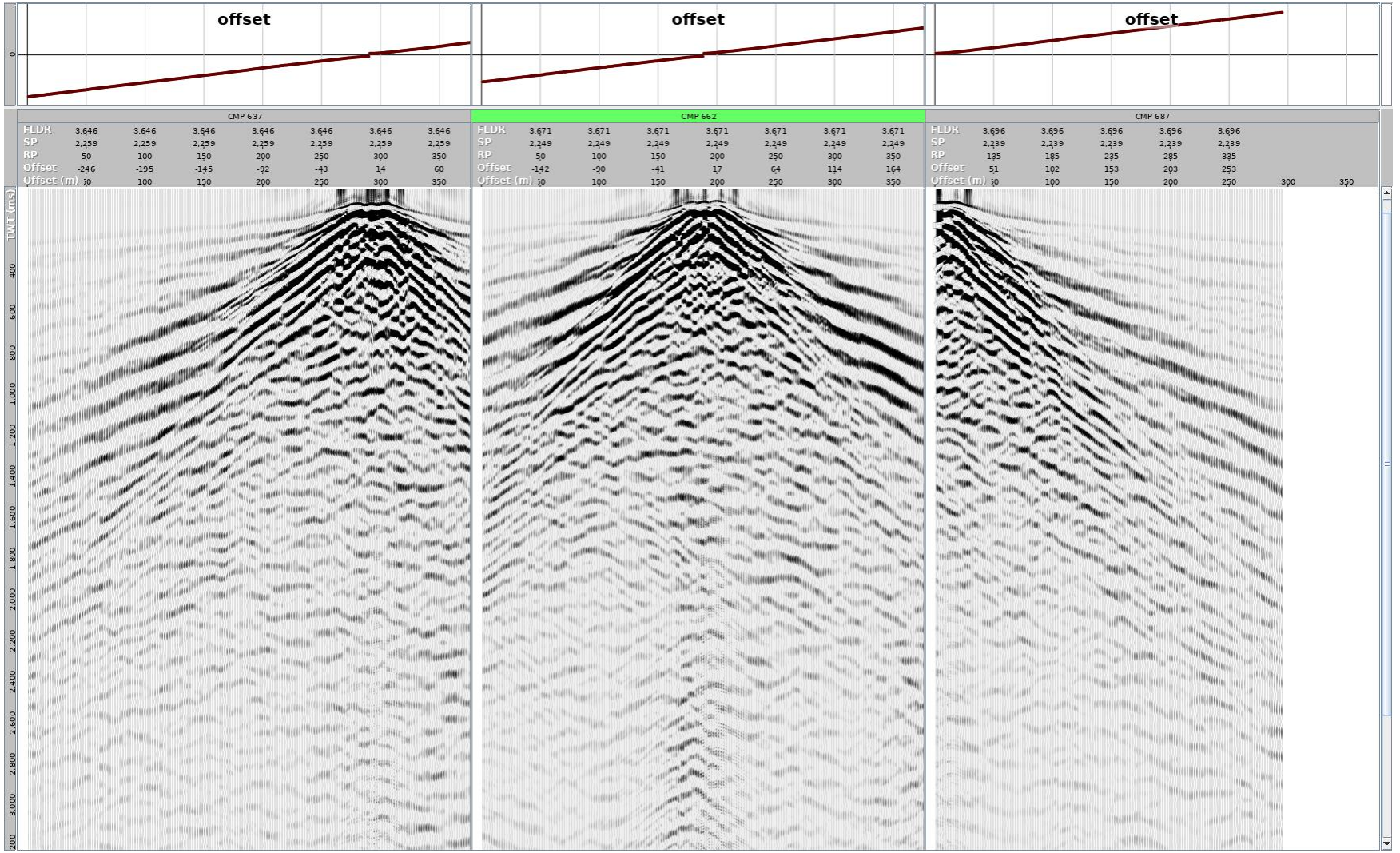
offset



Testing Interpolation to “de-alias” Data

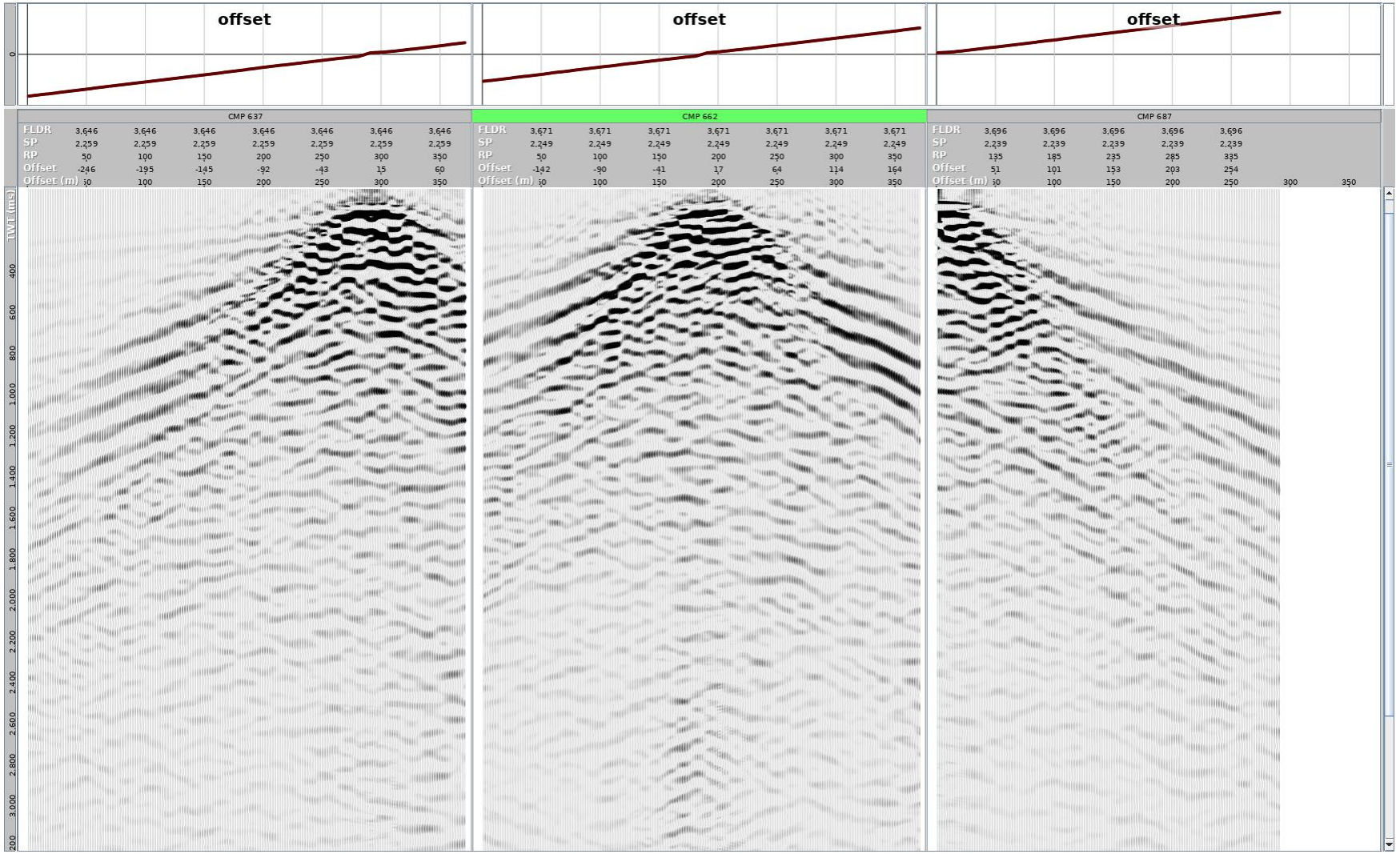
3 shots into Nikhef 1 m receiver nodes

2-4 Hz filter applied and T gain applied. Channel sorted.



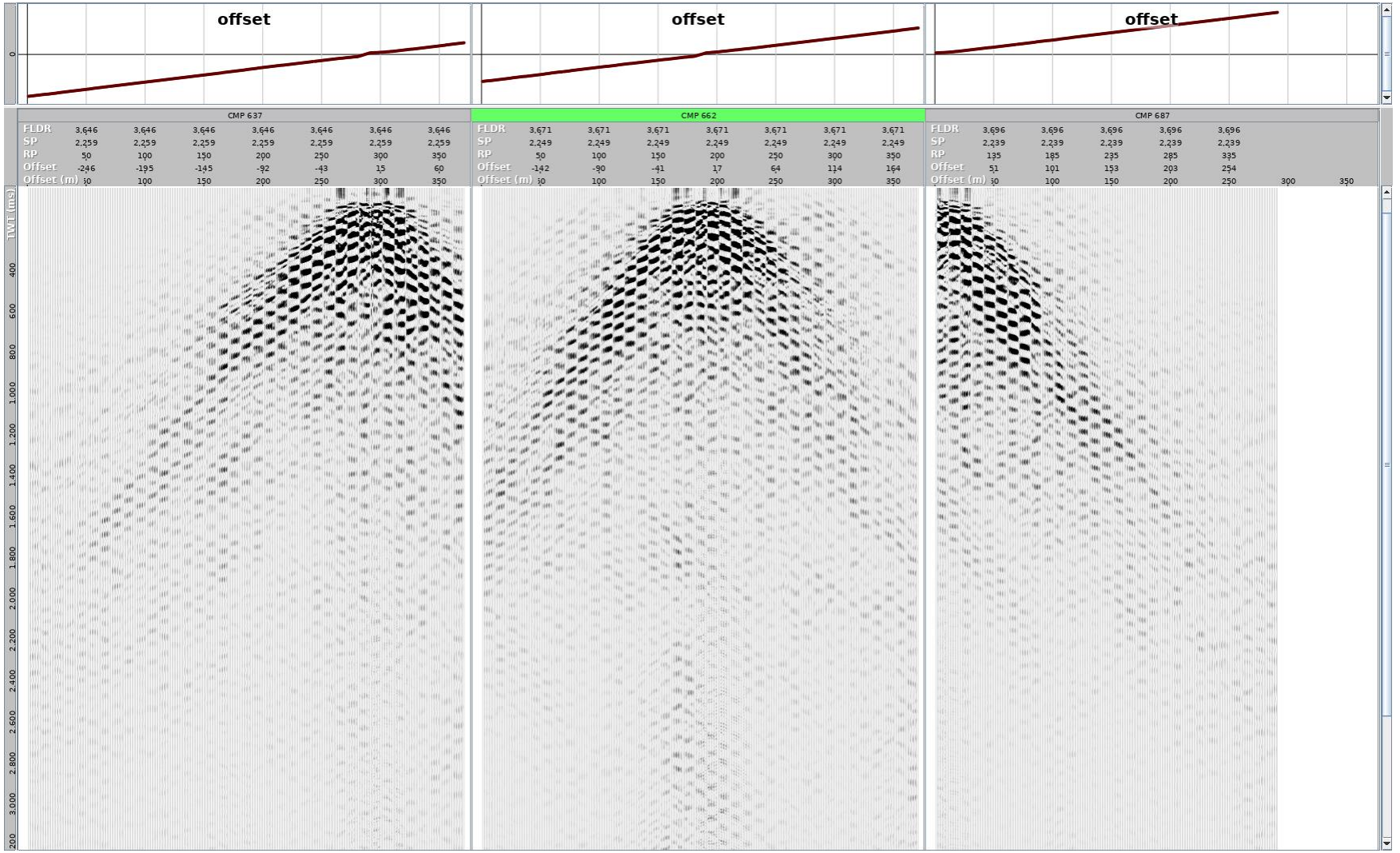
3 shots into Nikhef 10 m receiver nodes with 1 m interpolation

2-4 Hz filter applied and T gain applied. Channel sorted.

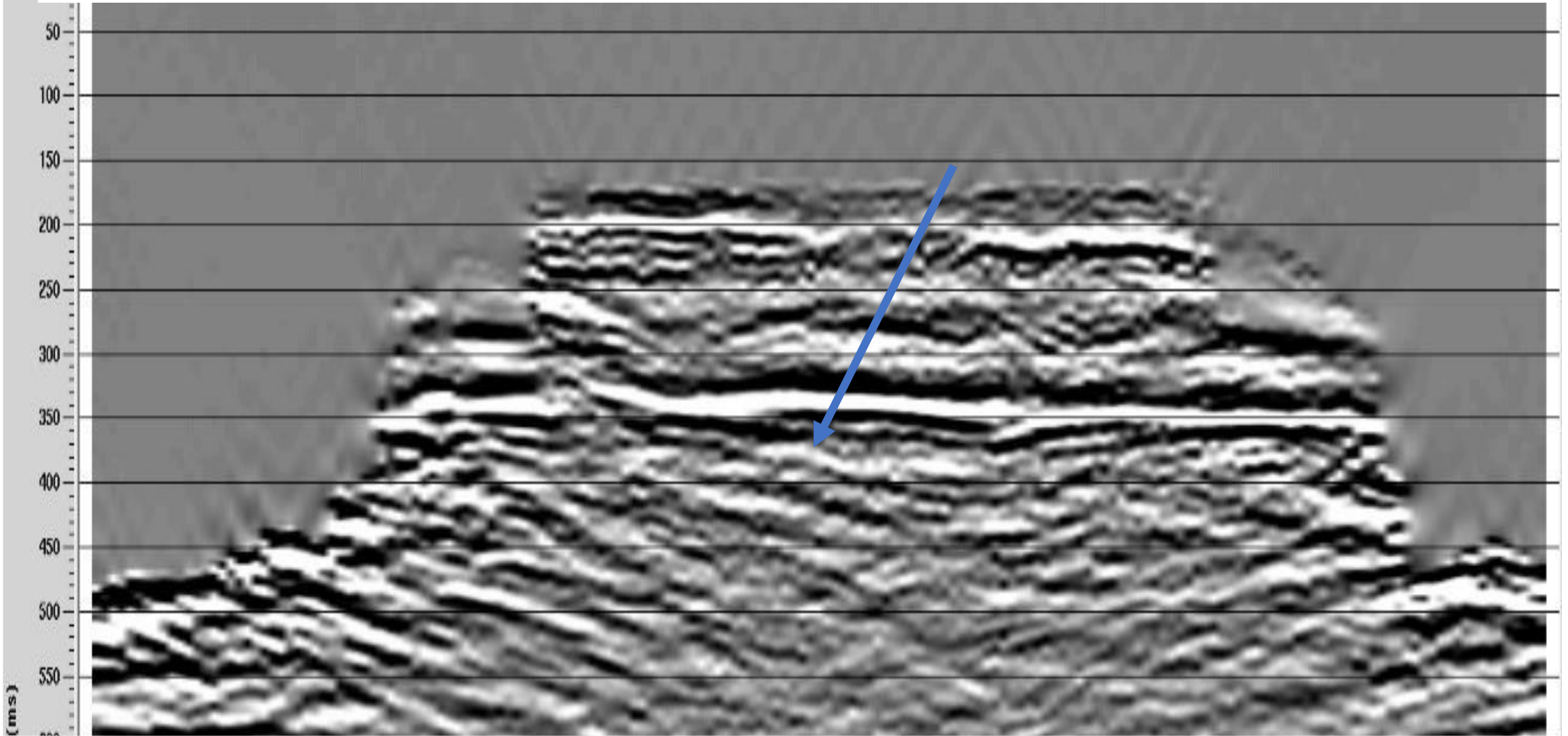


3 shots into Nikhef 10 m receiver nodes with 1 m interpolation – difference

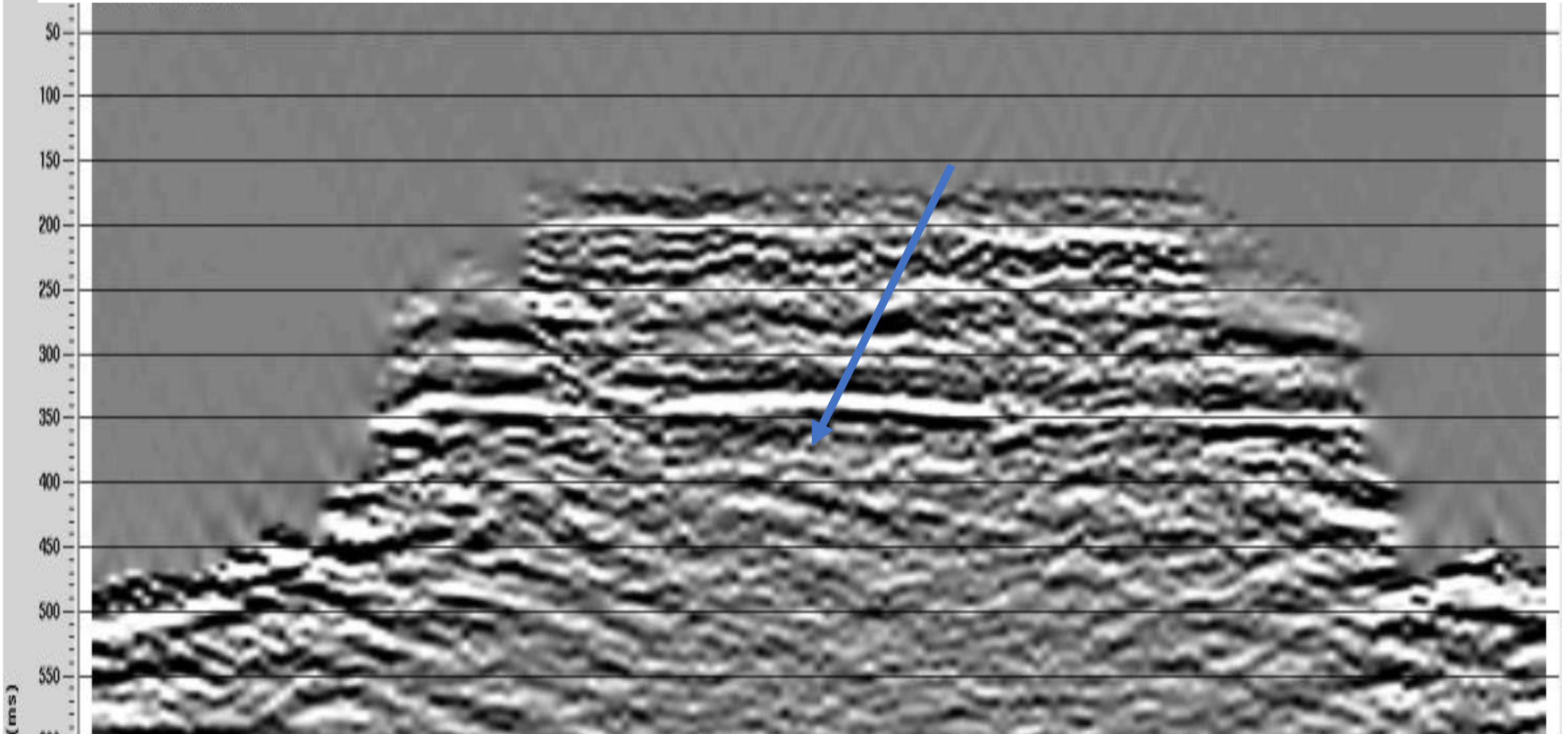
2-4 Hz filter applied and T gain applied. Channel sorted.



DMT Enhanced Stack – RI 1 m – Dense 2D on L2022

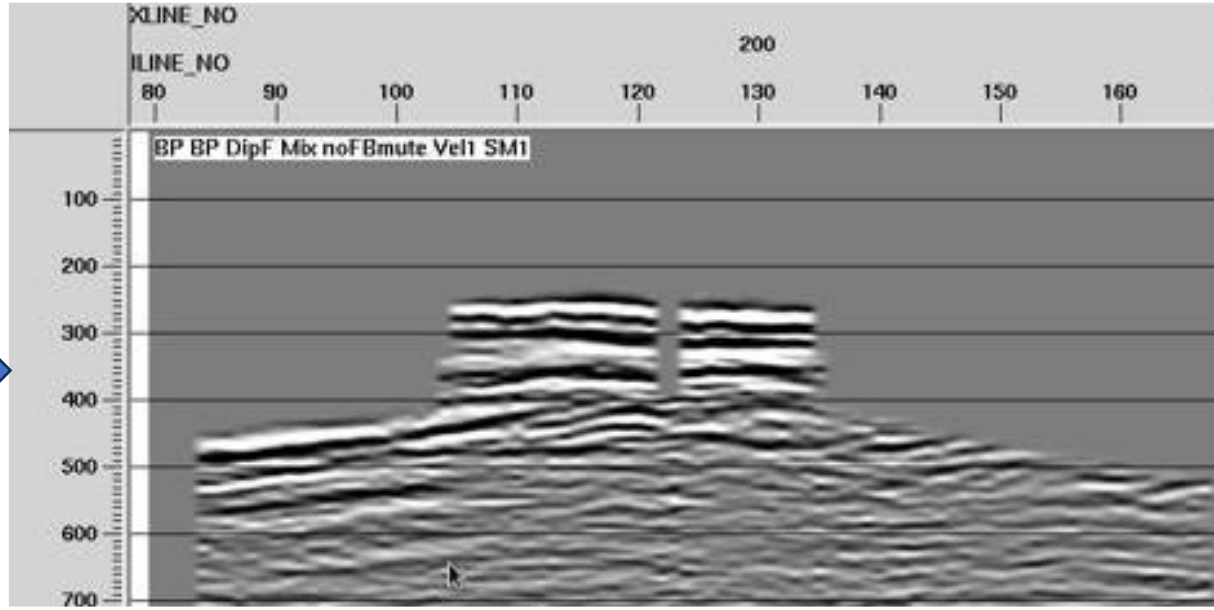


DMT Enhanced Stack – RI 10 m – Dense 2D on L2022



Summary of the acquisition tests

- The 2D dense test layout with 1 m receiver interval was used to simulate different receiver intervals of 1m, 2m, 5m, and 10m by eliminating un-needed traces. The comparison of the stack and migration results shows 1m RI and 2m RI yield very similar quality, whereas 5 m RI and even more 10 m RI resulted in less continuity of reflected events and higher noise levels in the stacks and migrations.
- The fat 3D cross-spread test resulted in an approximately single fold coverage of the 5 m x 5 m bin grid with visible imaging of shallow reflectors around the intersection point of source and receiver layouts.
- For the long 3D cross-spread less than single fold resulted on average on the 5 m x 5 m bin grid and the visibility of shallow reflections was limited.

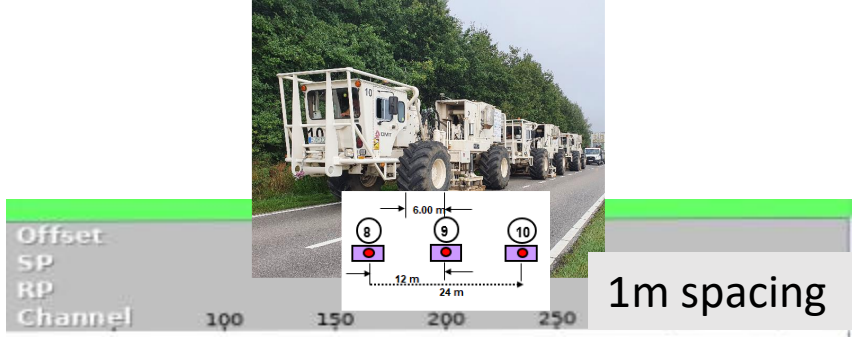


A sparse 3D cross-spread is likely to produce a better image than dense 2D

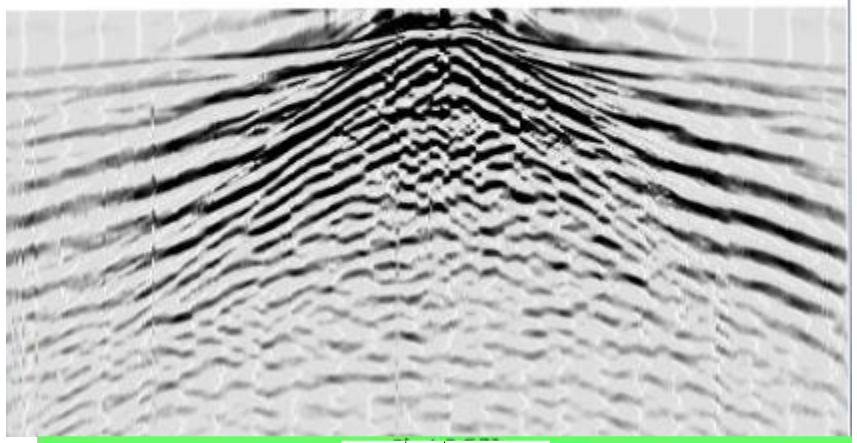
2022 Acquisition Review

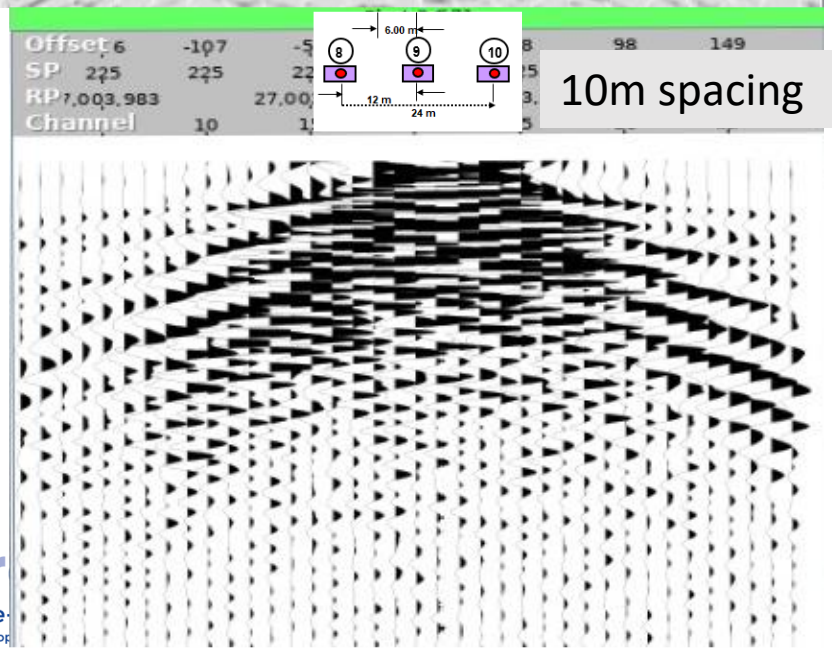
- 1-3 Vibs: 12m plate dist/
  - Pattern length: 24m
  - Sweeps per VP: 4-6
    - “1”: 6-90 Hz “2”: 10-90 Hz
- The noise of the 3 Vibes is interfering ➔
  - Difficult to remove
  - Separation of VP-points in processing
    - chosen vendors cannot do it
- Receiver:
  - Spacing: 10m
  - Too sparse to sample the noise

- Recommendations for future acquisition campaigns:
  - Use only a single Vibe to avoid noise (& signal) interference
    - Start the sweep at a lower frequency ~ 2Hz
    - Reduced „amplitude“
  - Sample signal and the noise sufficiently to enable separation
    - Densify receiver (~2-5m)
    - Densify source point (~5-10m) spacing



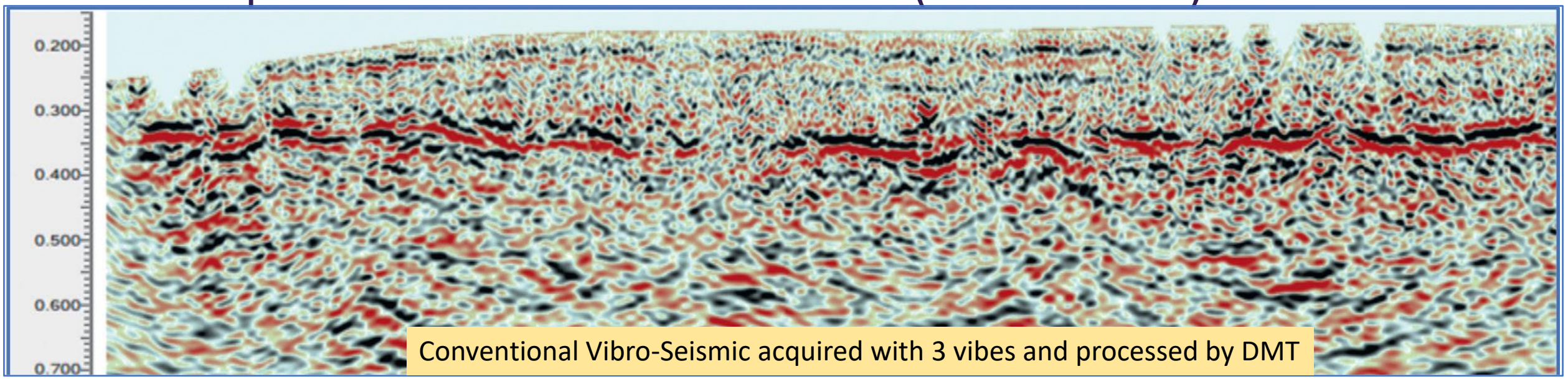
1m spacing

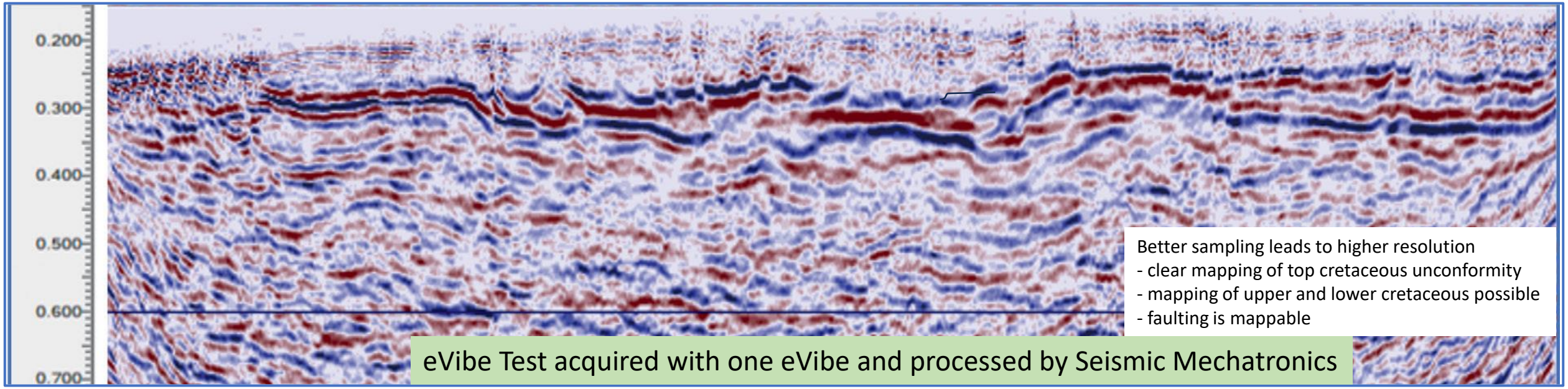




10m spacing

Comparison of the shallow (0-700ms) results





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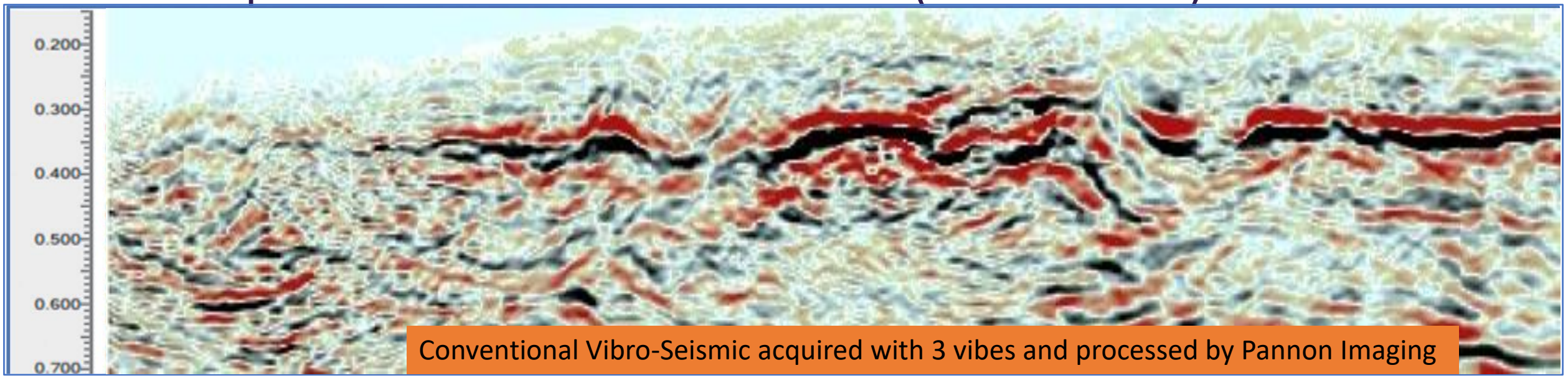

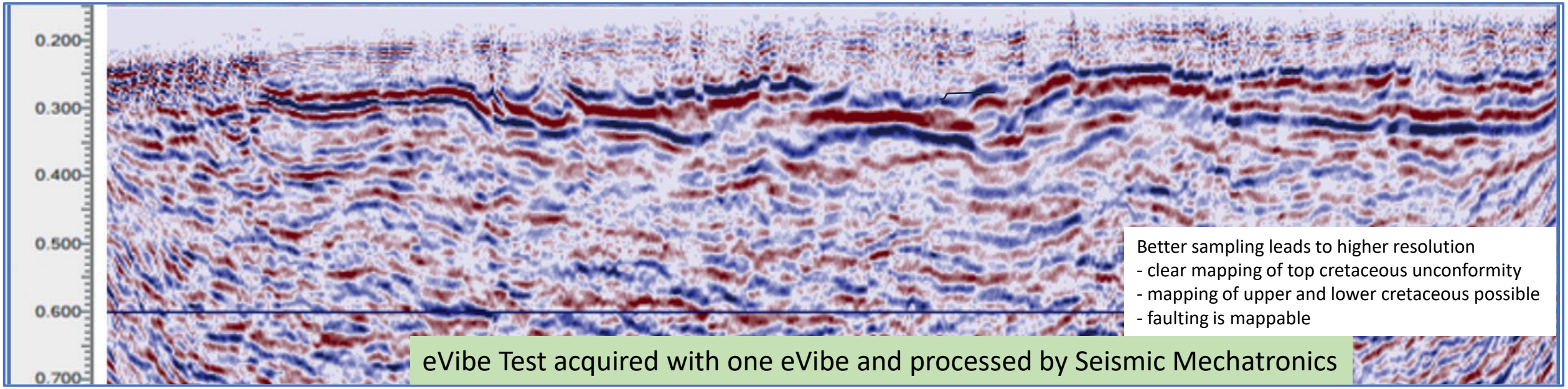

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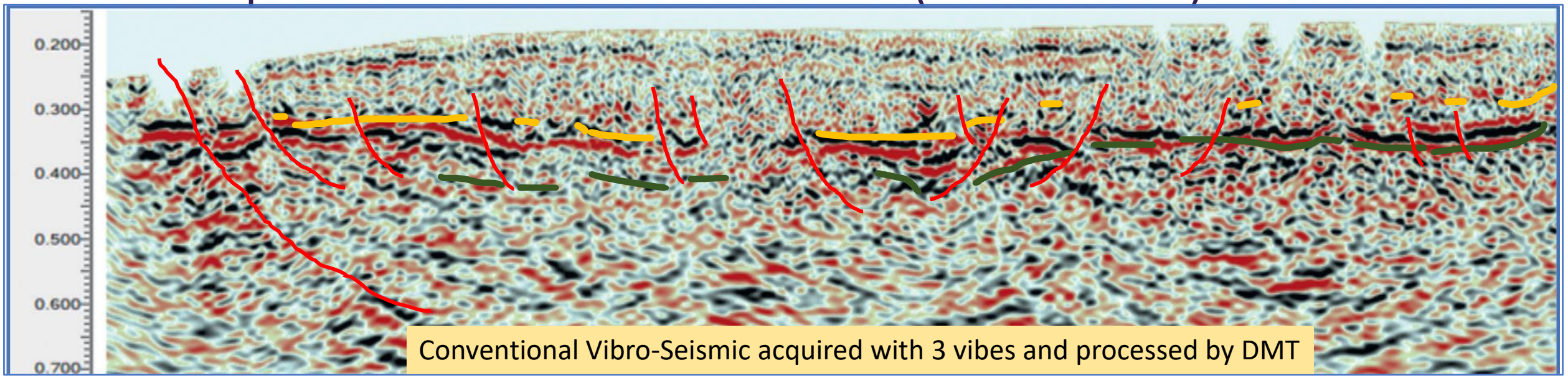

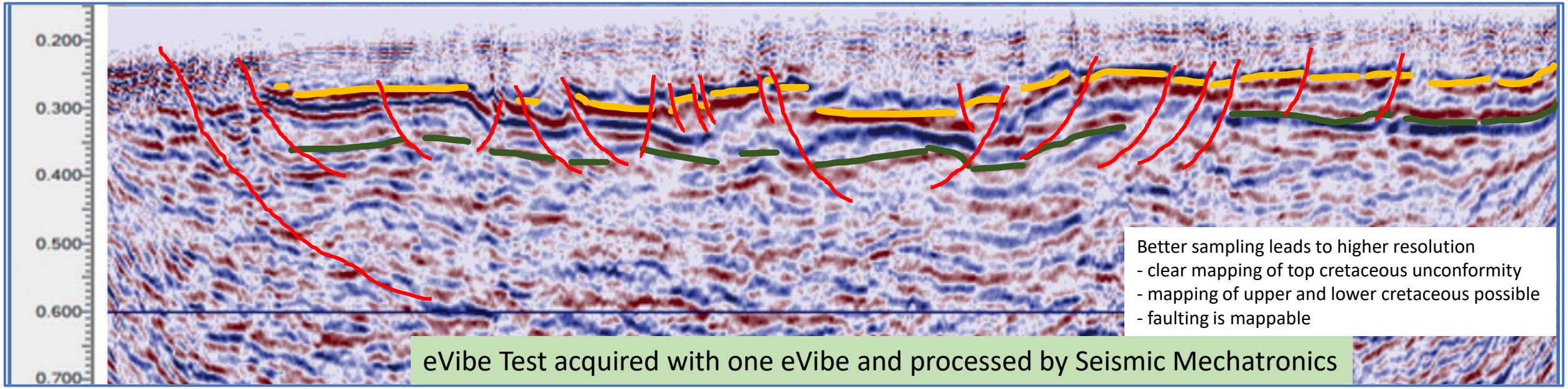

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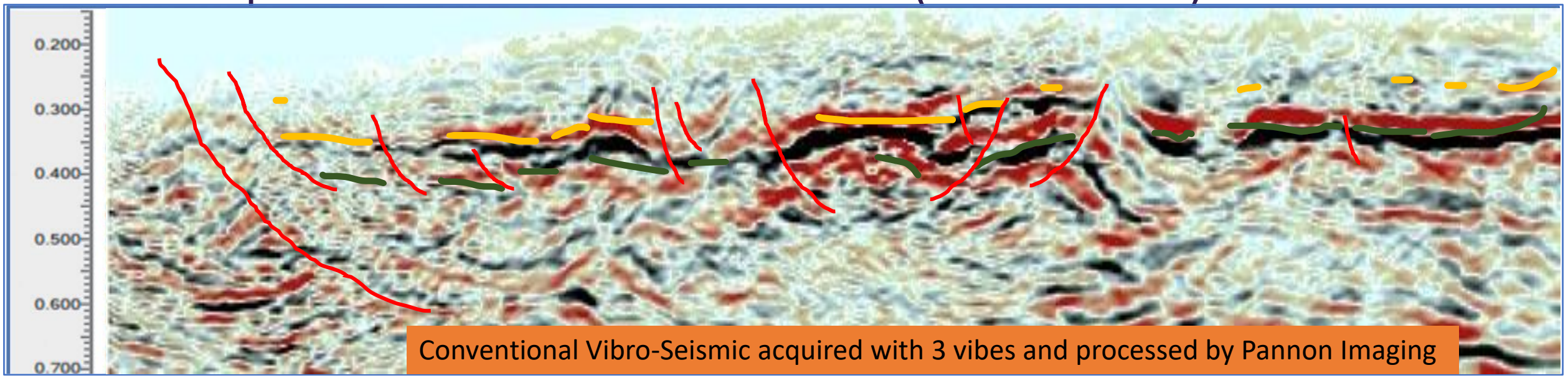
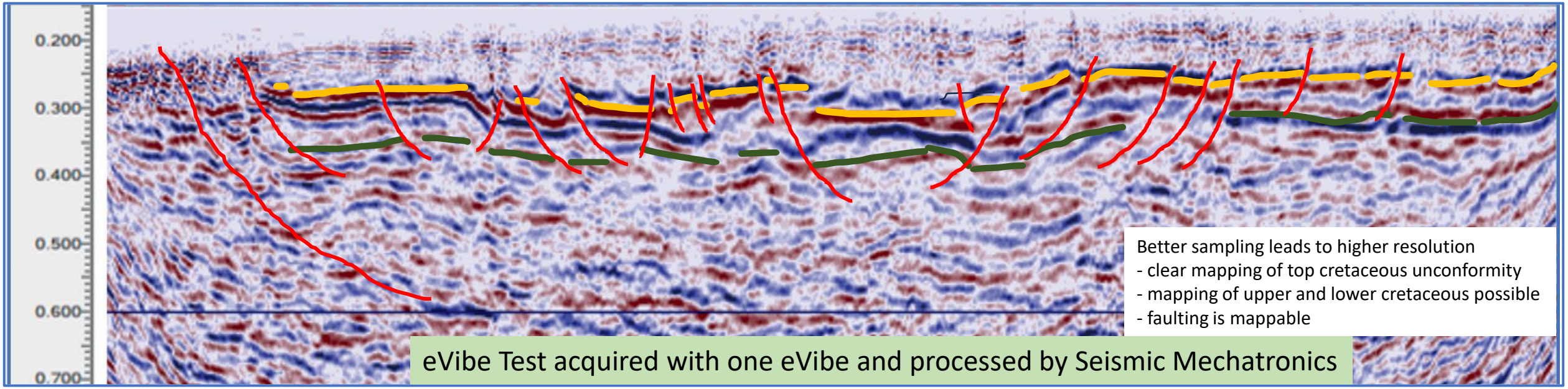
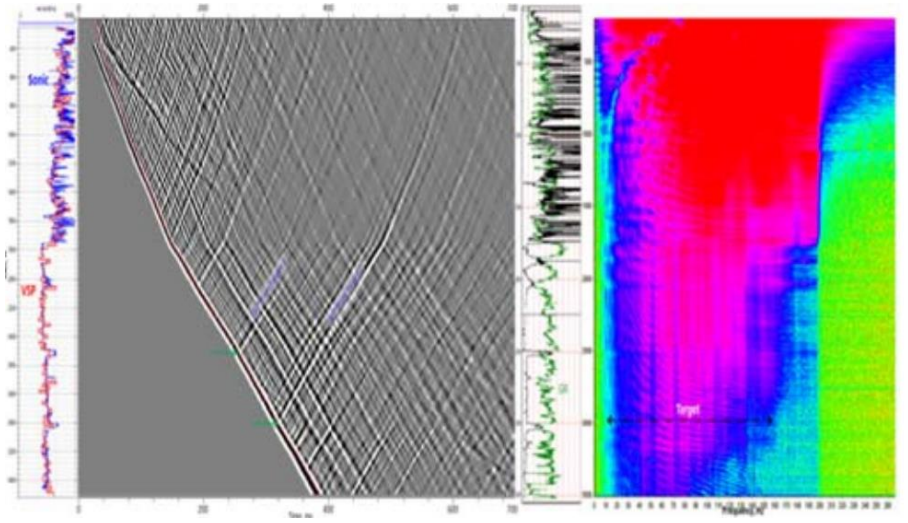


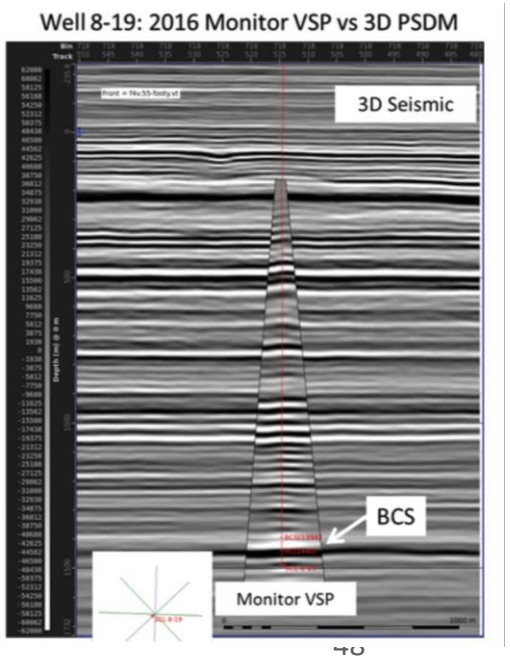


DAS-VSP at Cottessen Well in Collaboration with TNO

- Cottessen well is instrumented with a permanent DAS-Fiber:
  - Used for a VSP with
    - single eVibe (2-100Hz), 5m source spacing
    - 5m vertical sampling from ~0-300m depth through DAS-fiber
    - 5m lateral sampling with 3C geophones
      - ~440m offset
  - This allows:
    - Direct measurement of attenuation from 2Hz to 100Hz at each depth
    - Identification of ground-roll and other active seismic noise (generators)
    - Determination of seismic velocities
    - High resolution seismic image close to well bore (~200m lateral extend)
    - Time-to-depth conversion for seismic to well tie of the 2D surface seismic
- Processing to commence in January 2024

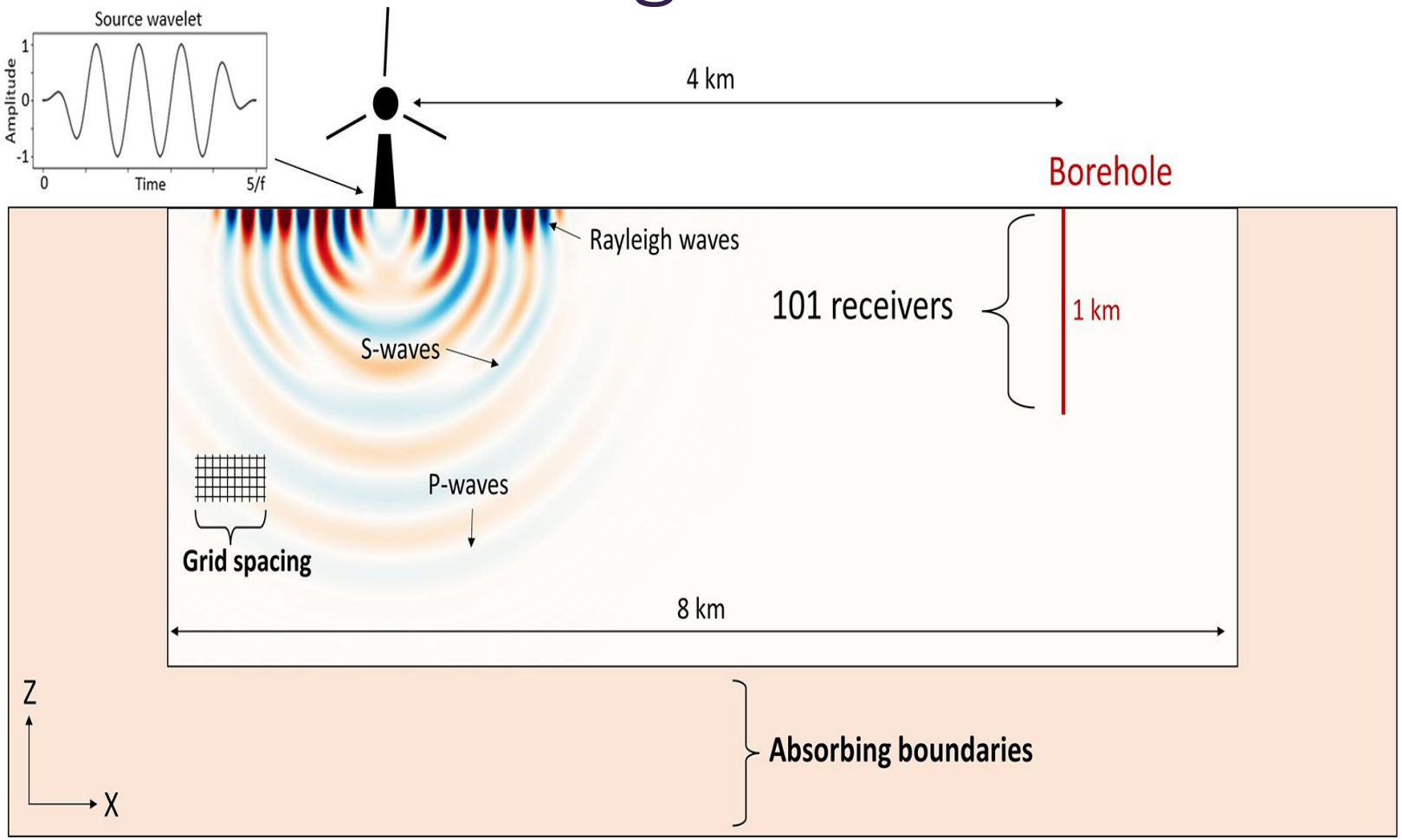


An Example for a SDAS Vertical Incidence VSP (VIVSP) raw stack waveforms with LWD sonic and gamma ray logs. Amplitude spectrum is shown on the right panel.
Teck Kean Lim et al. DAS-3DVSP Data Acquisition at 2018 Hydrate-01 Stratigraphic Test Well, 10th International Conference on Gas Hydrates (ICGH10), 2020



F. Limberger et al.: The impact of seismic noise, Solid Earth, 14, 859–869, 2023, https://doi.org/10.5194/se-14-859-2023

Noise modelling of wind turbines



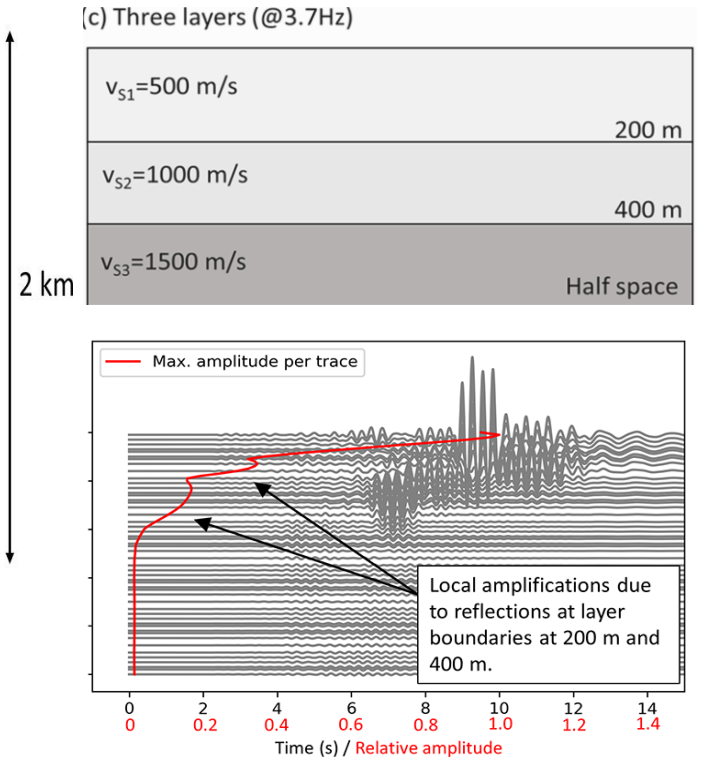


Figure 1. The numerical model includes a sinusoidal source wavelet, receivers located along a line from the surface to a depth of 1 km and a sufficient grid spacing (three elements per minimum wavelength of the simulation) as well as absorbing boundaries (2 times the maximum wavelength of the simulation). P waves, S waves and surface waves are simulated during the forward modelling. Synthetic seismograms are extracted at positions indicated by the red line (borehole).

Seismic Plans

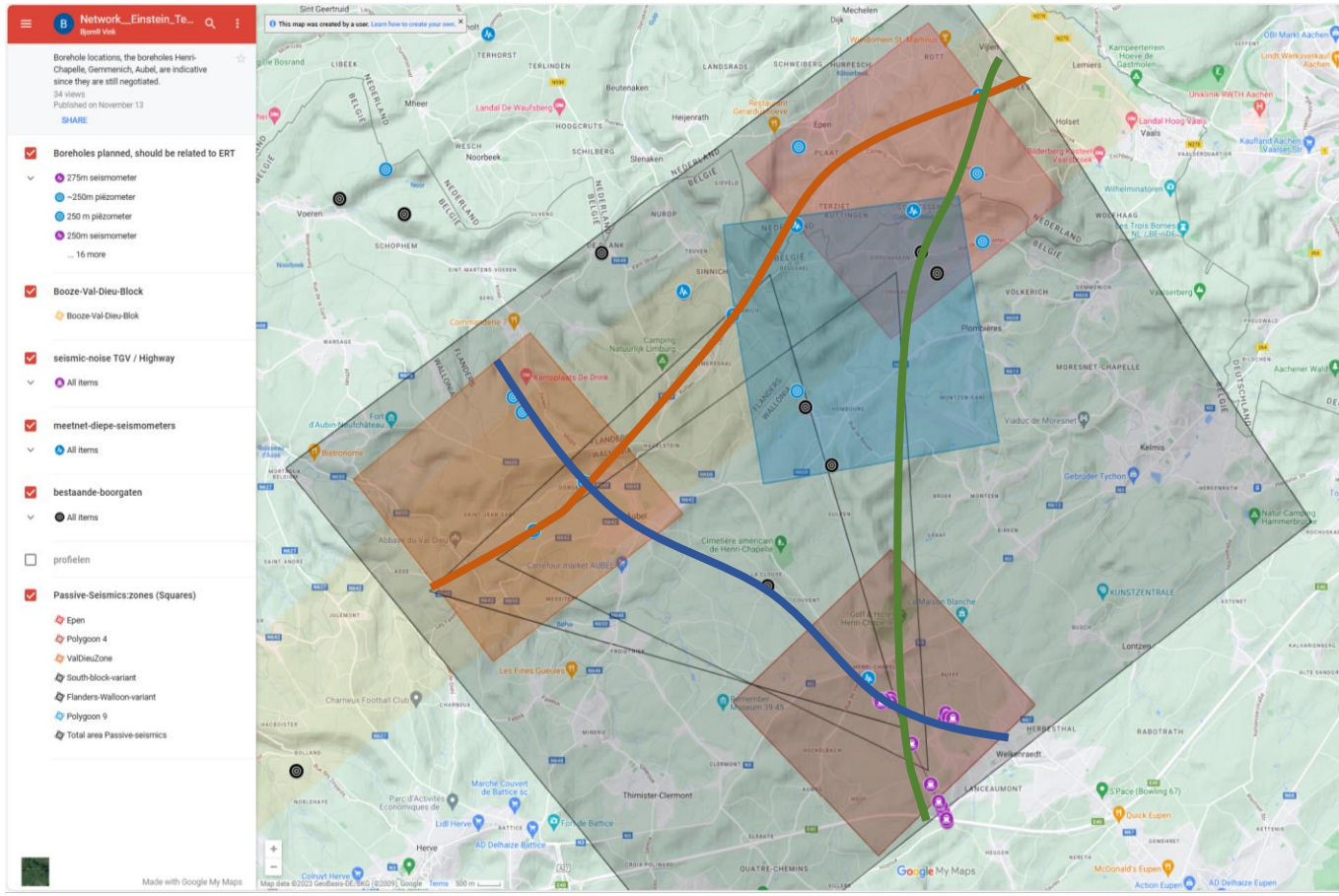
Active source

- 2D lines along possible legs
  - tying logged & instrumented wells
- “high-res” 3D cross-spreads
  - corner points +

Passive seismic

- corner points
- Booze Val-Deu block

- 2D/3D VSP’s in instrumented wells



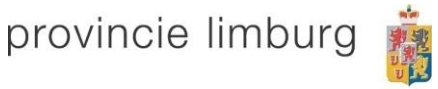
(Anthropogenic) Noise Measurements

- Permanent noise measurement in select well
  - 3C geophone
  - DAS fiber
- Noise sources today and in the future
  - Wind power – especially new designs with larger rotors and stronger coupling to ground
    - “Birds of prey” protection leads to strong vibrations with it short slow-downs of the rotation
  - Geothermal energy production – induced micro seismic
  - (High-speed) railway and motor highways
  - Other anthropogenic noise

Final Report „Windpower and Birds of Prey“ by H. Hoetker et. al. (in German)

Questions?

E-TEST is co-funded by the Regions:



E-TEST is also co-funded by the own-fundings of all Partners:

E-TEST partners

NMWP.
The Innovation Engineers.