Future active and passive seismic imaging campaigns in the EMR-region

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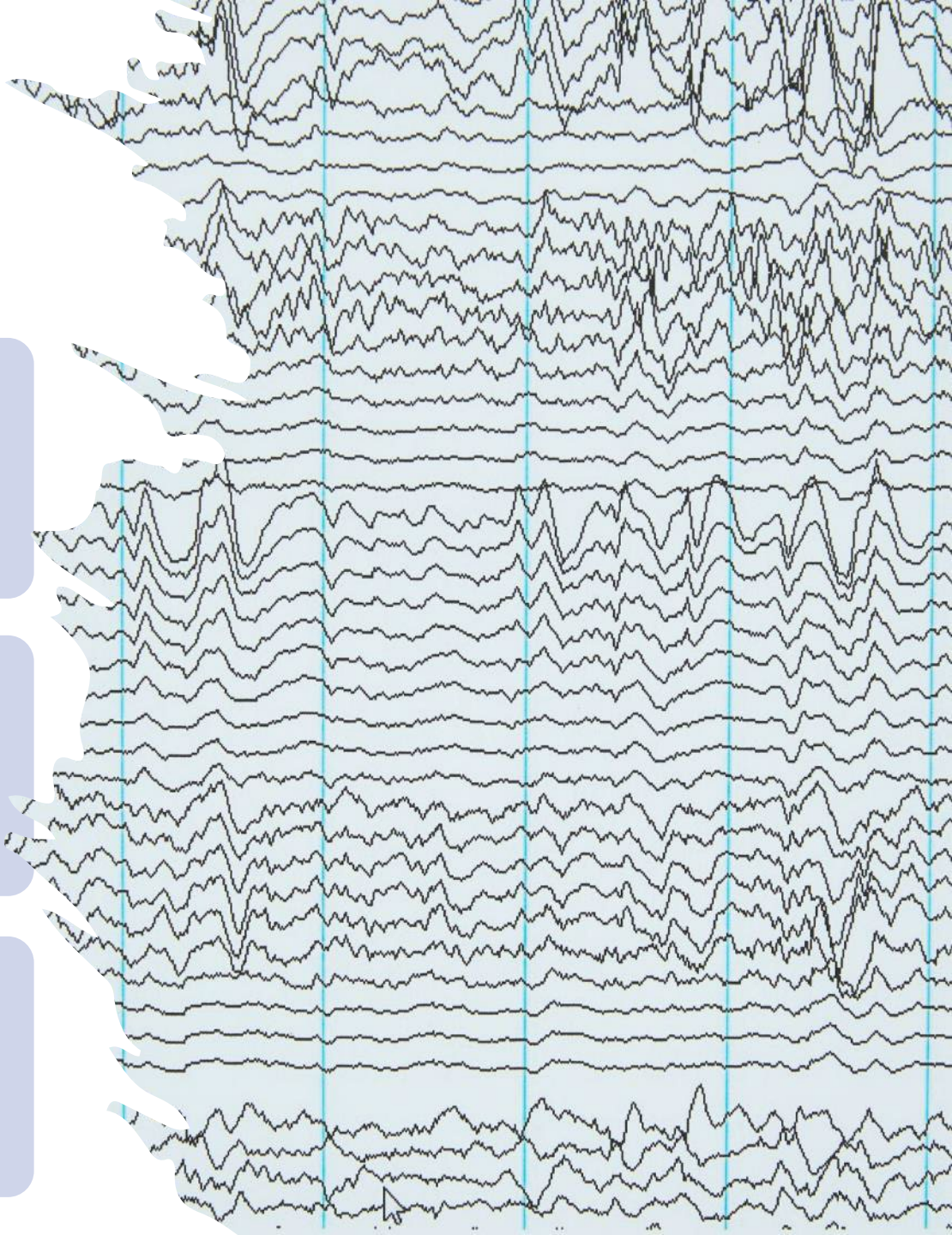
Outline

Learning from experience
- 2022 active and passive seismic campaigns
- 2023 DAS-VSP and 2D surface seismic

Seismic plans Q4-24/Q1-25
- 2D and/or 3D surface seismic
- Passive & Active Seismic
- DAS-VSP’s

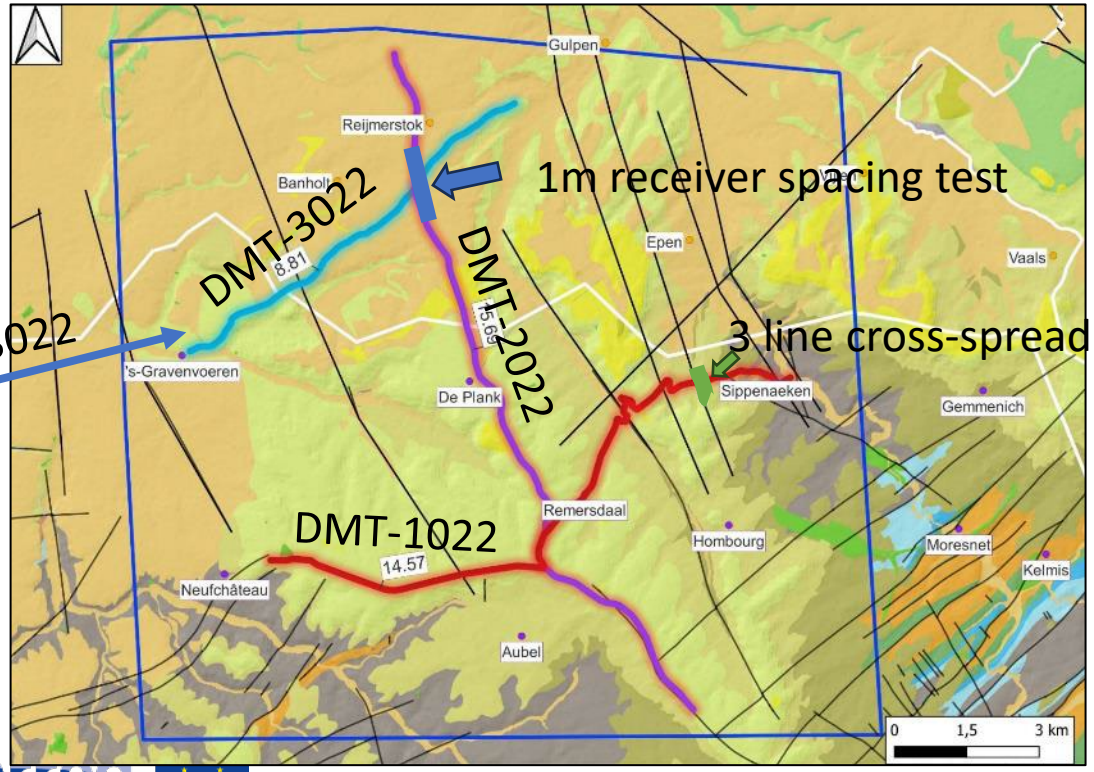
Collaboration with the Geological Services in Belgium and Northrhine-Westphalia (Germany)



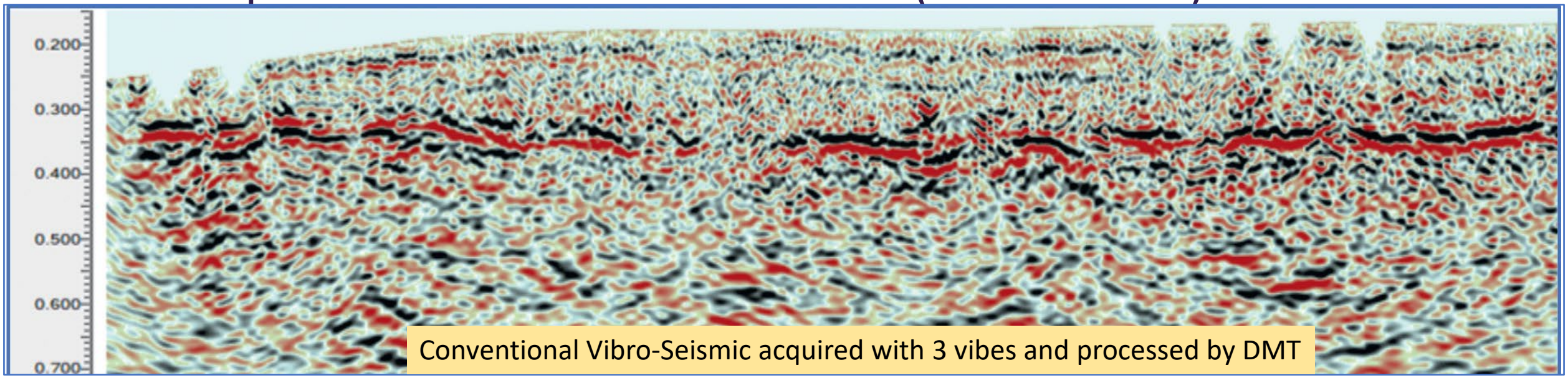
2D Seismic Survey

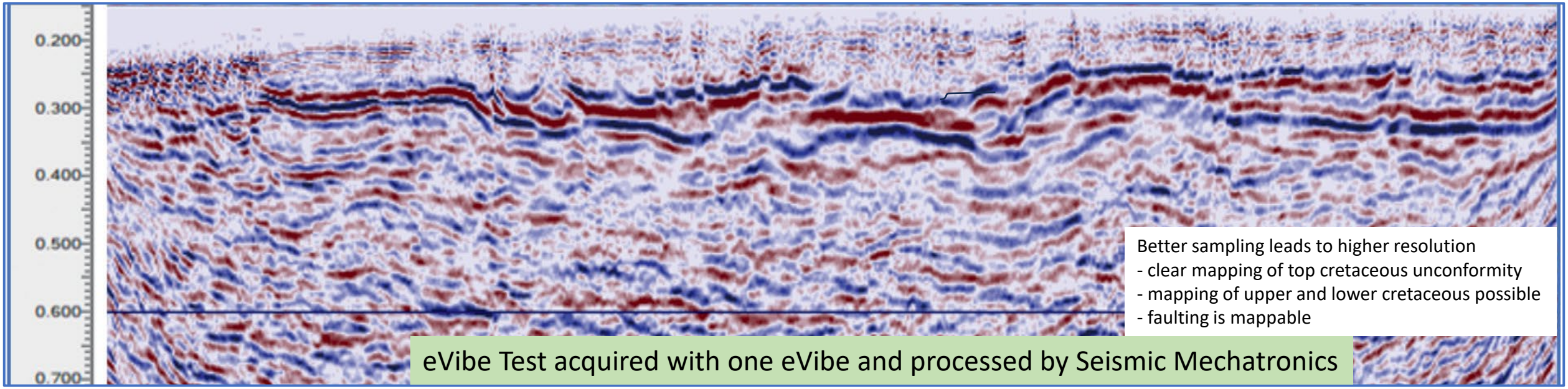
- Data acquisition: September 2022
- Dual purpose: Geothermal exploration and Einstein-Telescope

	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*



Comparison of the shallow (0-700ms) results





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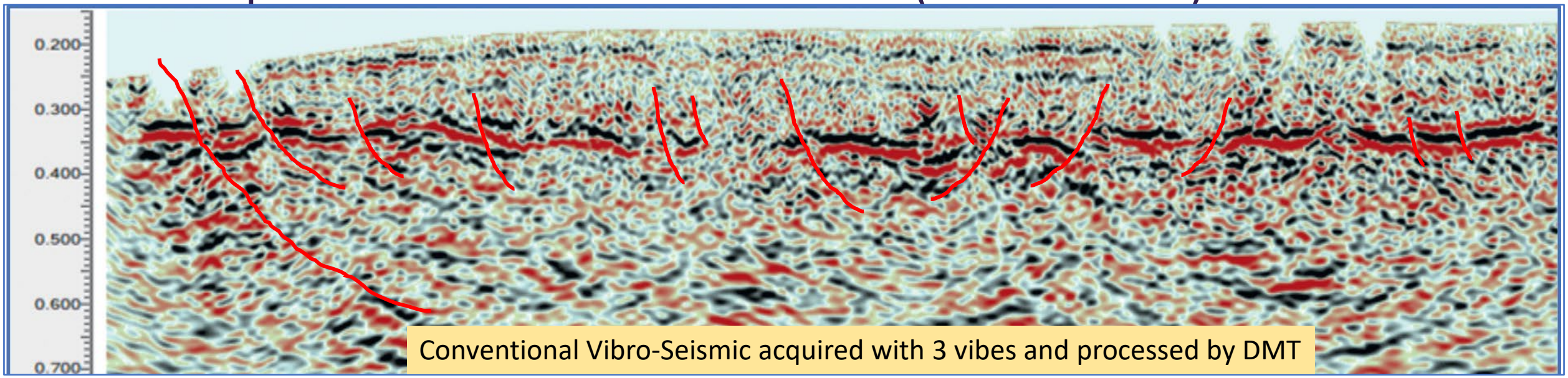
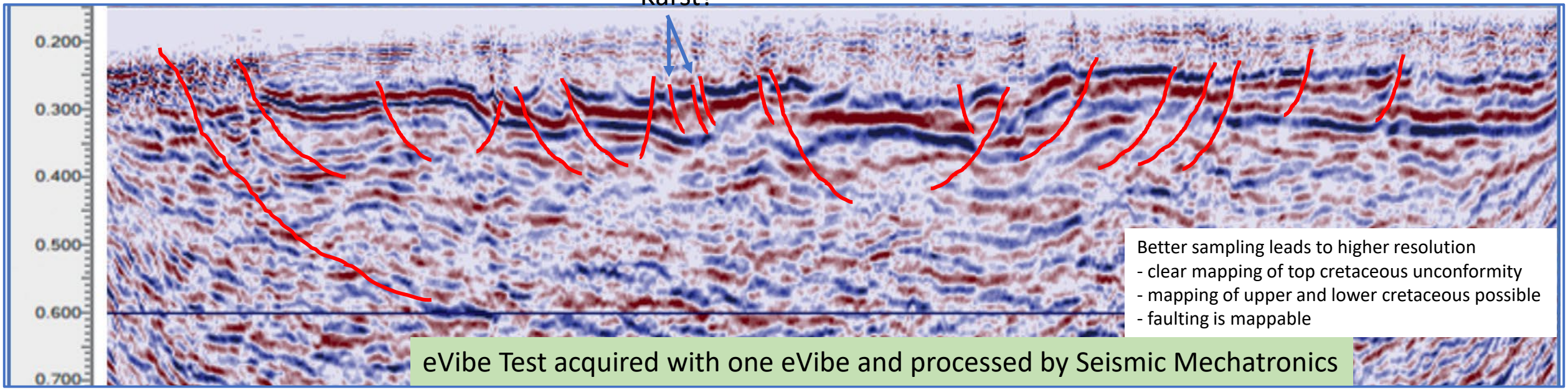


Conventional Vibro-Seismic acquired with 3 vibes and processed by DMT



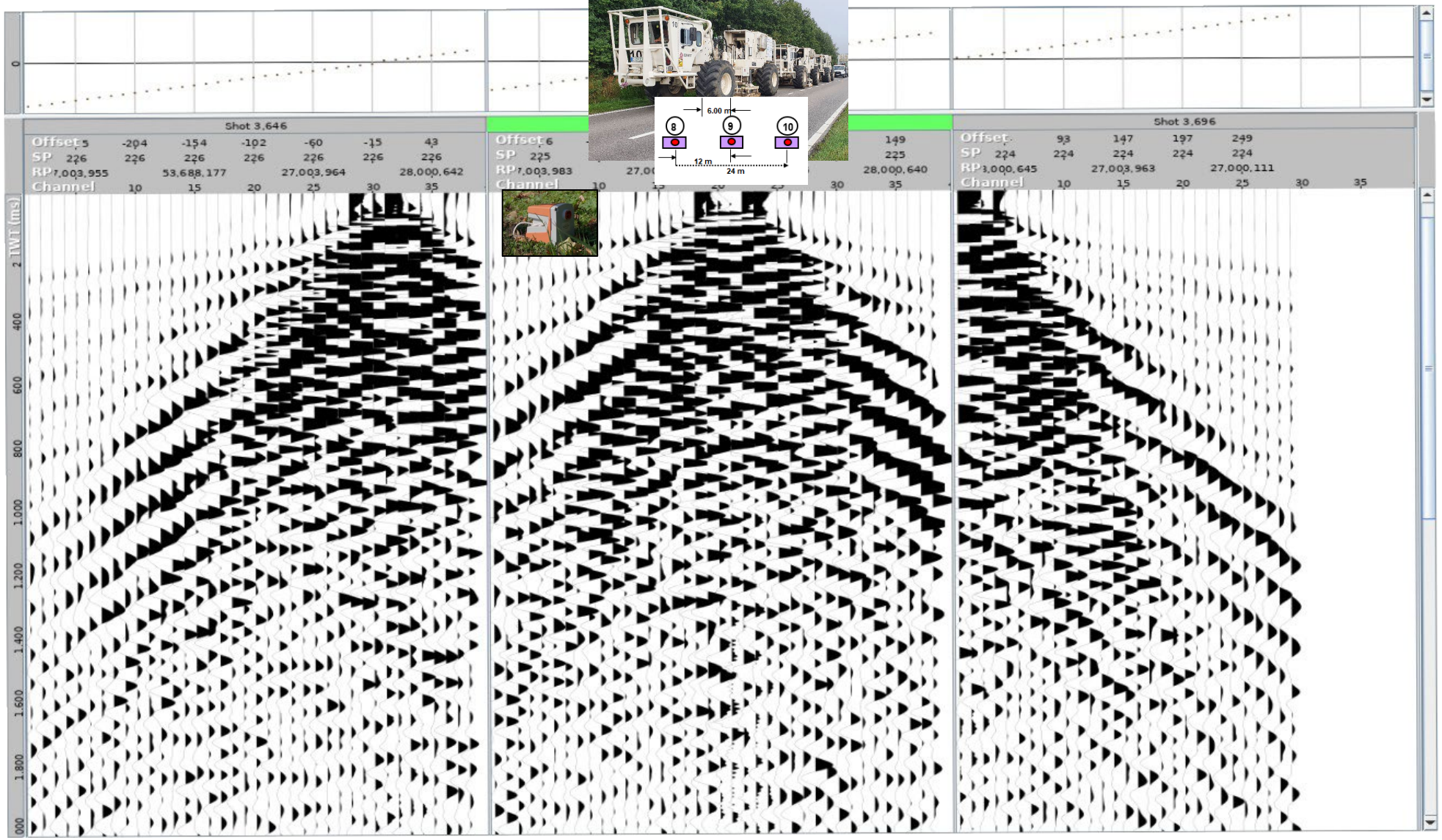
Better sampling leads to higher resolution
- clear mapping of top cretaceous unconformity
- mapping of upper and lower cretaceous possible
- faulting is mappable

eVibe Test acquired with one eVibe and processed by Seismic Mechatronics

3 shots into Nikhef 10 m receiver nodes

2-4 Hz filter and T gain applied

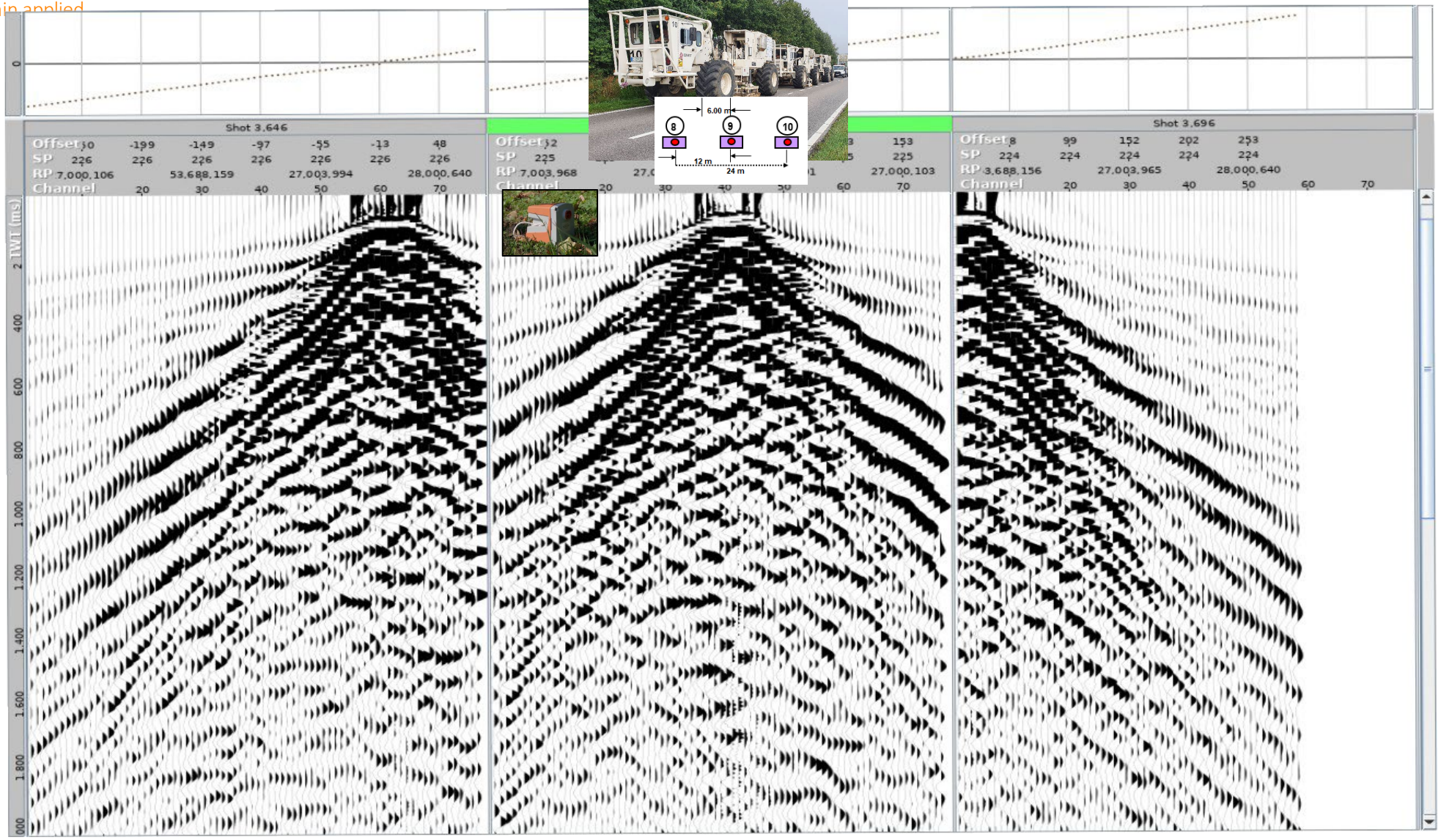
offset



3 shots into Nikhef 5 m receiver nodes

2-4 Hz filter and T gain applied

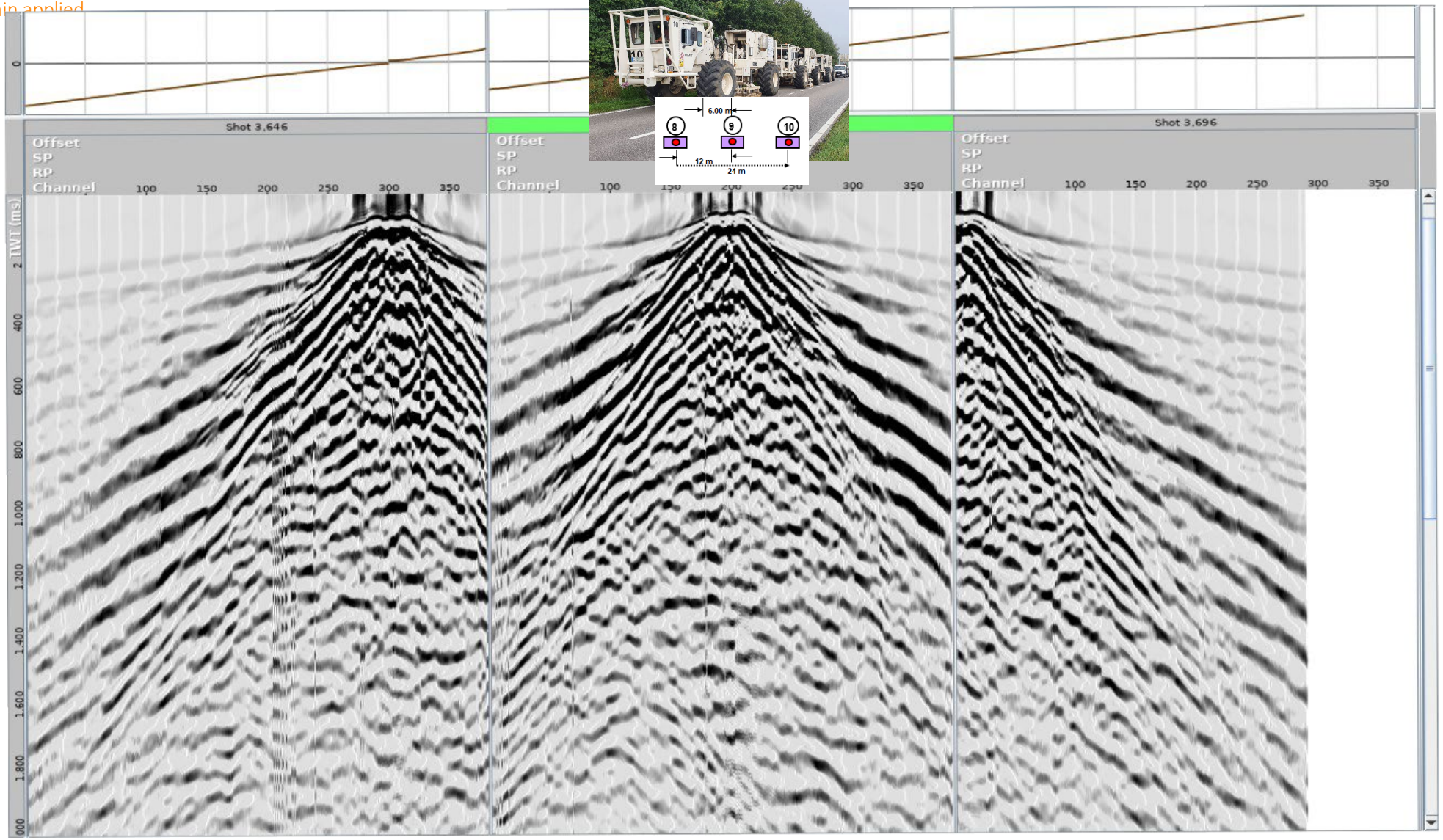
offset



3 shots into Nikhef 1 m receiver nodes

2-4 Hz filter and T gain applied

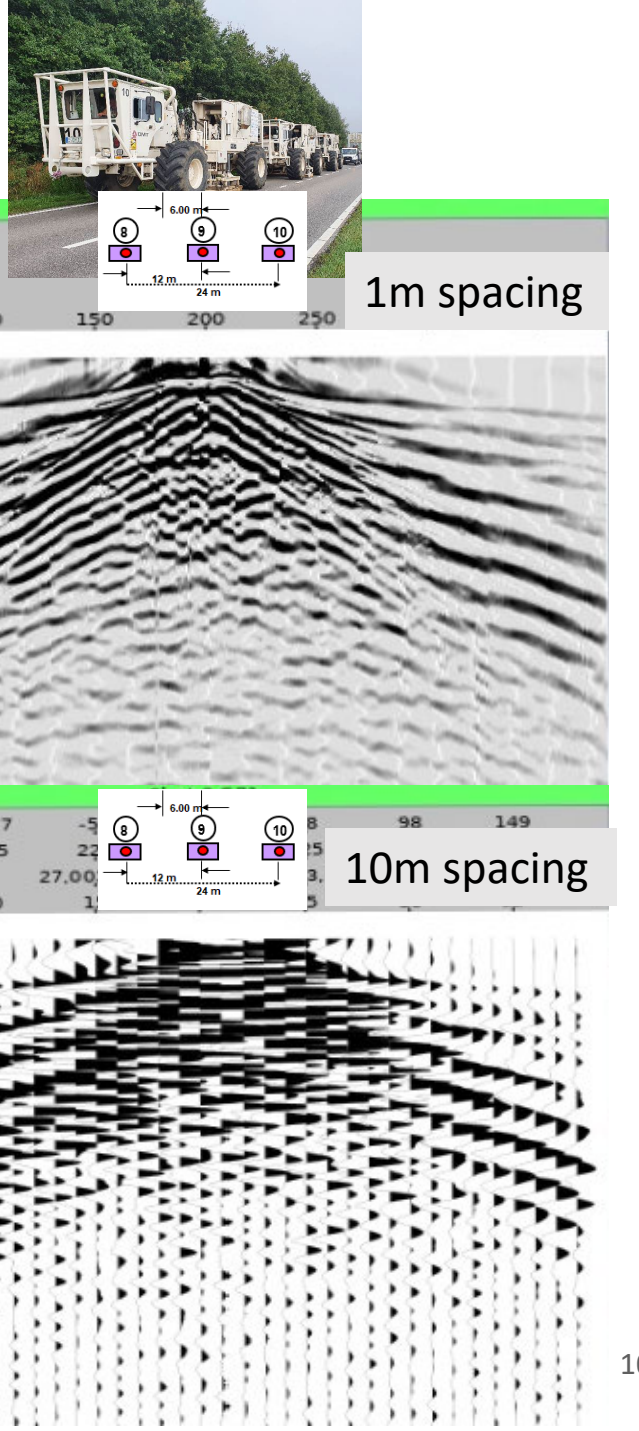
offset



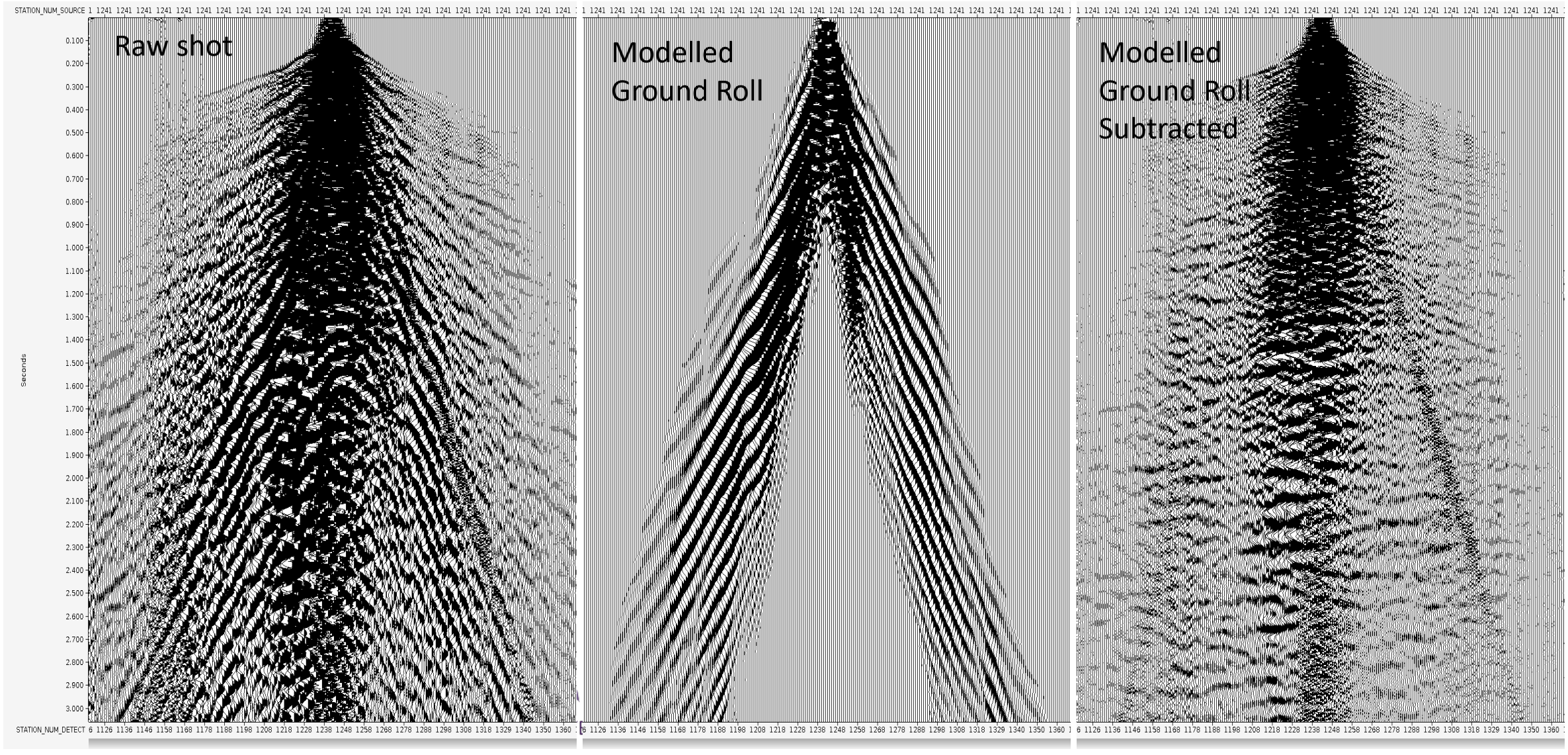
Summary Active Seismic

- Structural interpretation enabled
- The noise of the 3 Vibs is interfering
  - ➔ Difficult to remove
- 10 m receiver spacing too sparse sample the noise

➔ Recommendation for future acquisitions
- Reduce receiver spacing and source point spacing (~3-5m)
- Using only a single (e)Vib at reduced power
- Starting the sweep at a lower frequency

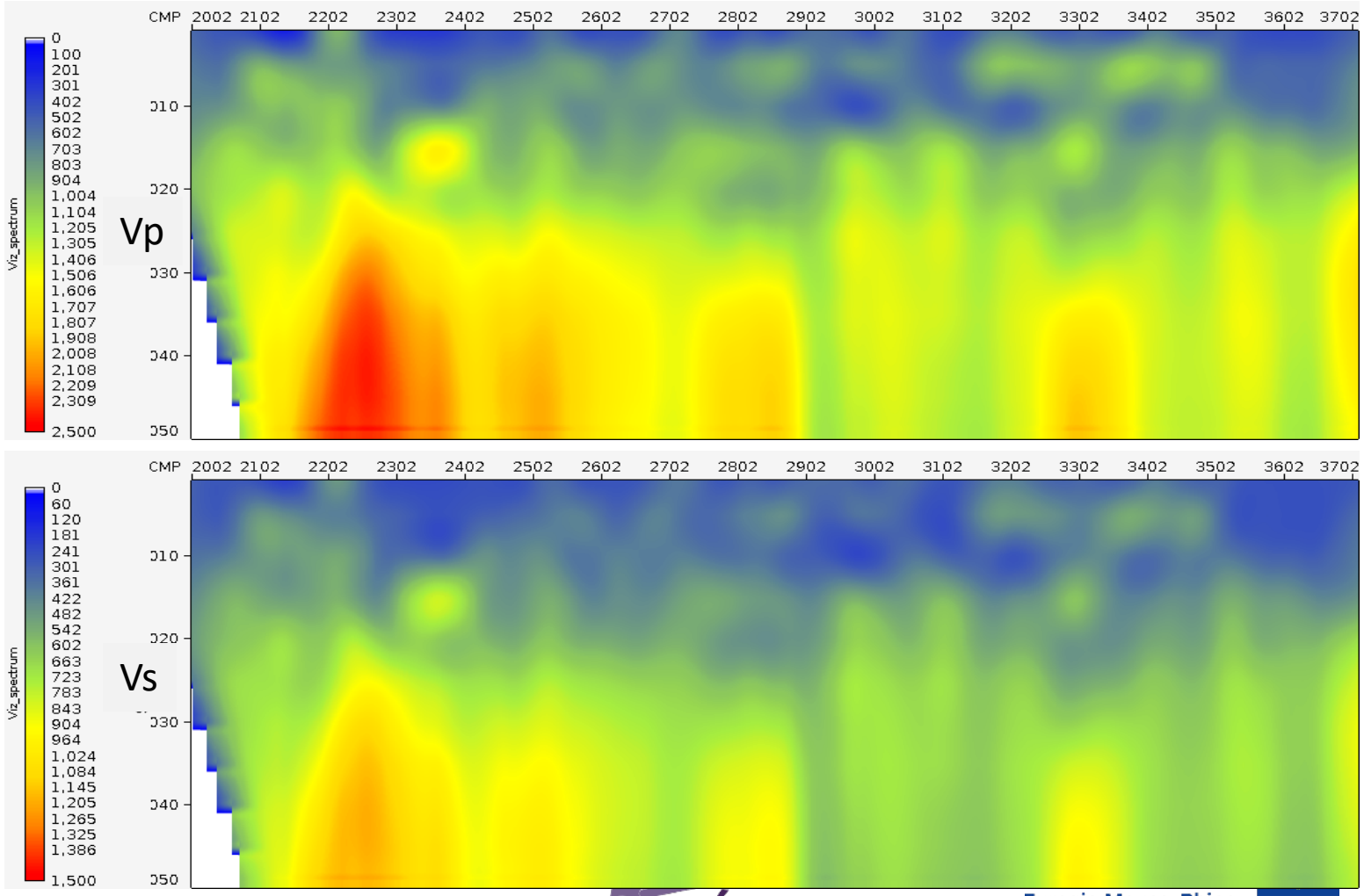


Surface wave analysis and modelling



Surface wave inversion to obtain Vp & Vs

Selection of competent seismic contractor is essential

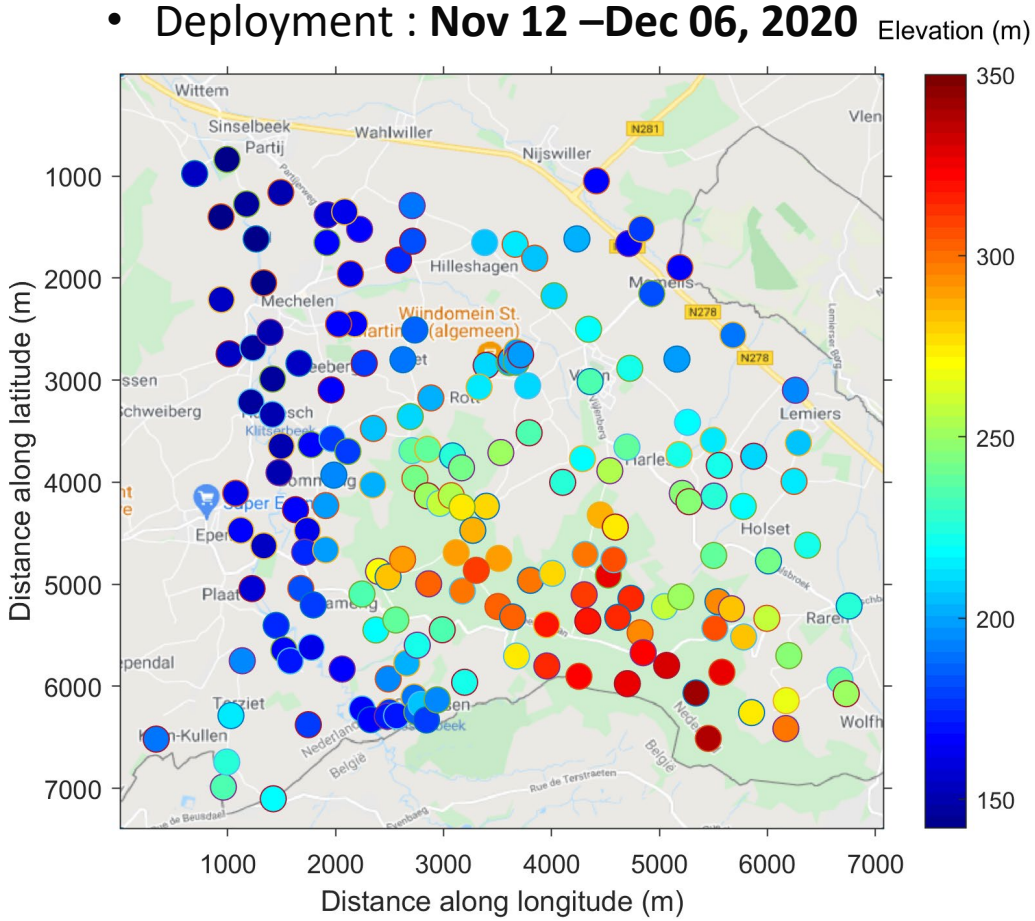


Surface wave analysis, modeling, and inversion enables extraction of the phase velocity characteristics per frequency from the surface waves to facilitate both velocity model building and advanced coherent noise attenuation.

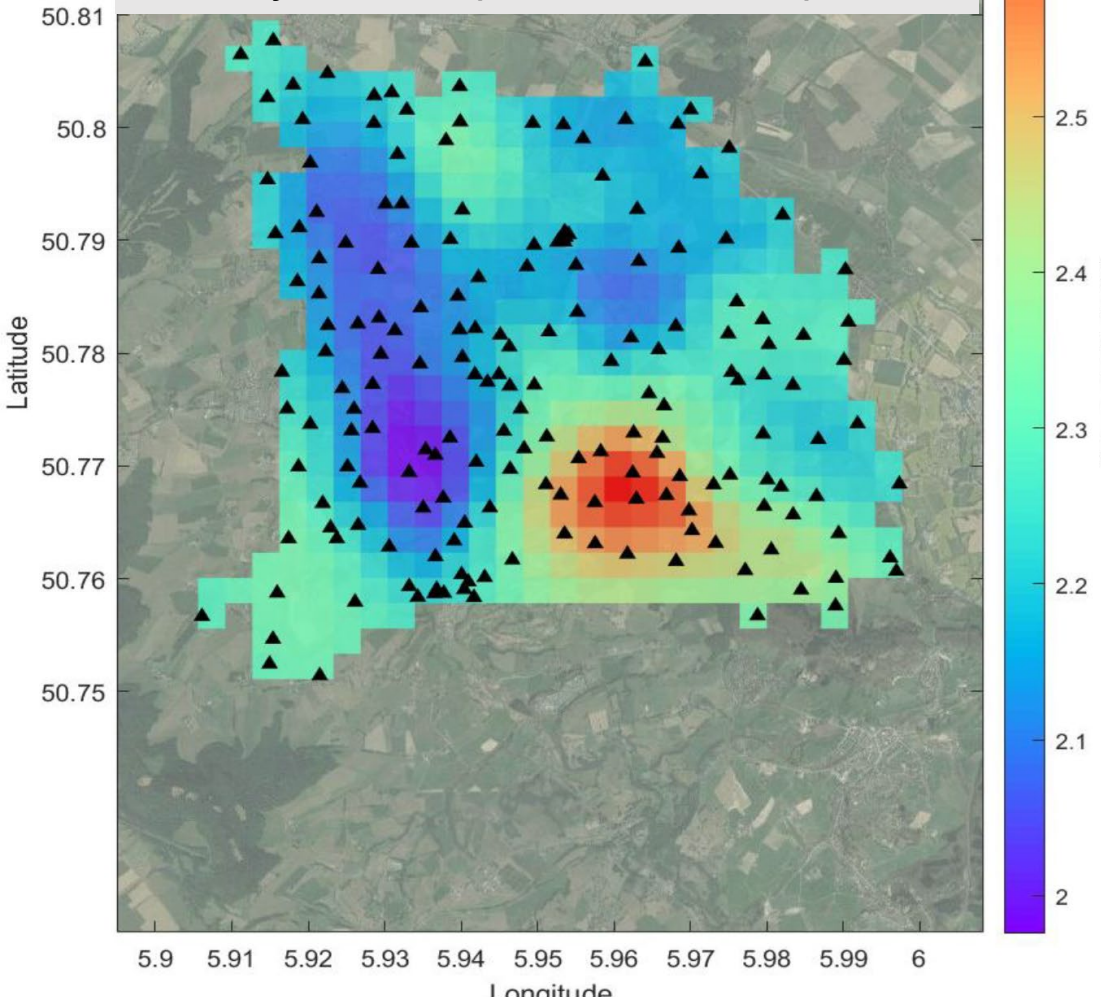
Passive Seismic

Sensor Array 1

- **183** stations ~ covering 6km*6km
- Quantum Geophones 1C –5Hz
- Distance between stations : **200 m to 7.91 km**
- Deployment : **Nov 12 –Dec 06, 2020**



Average velocities measured in between all pairs of stations are inverted using Travel Time Tomography to obtain the group velocity at each point of the maps



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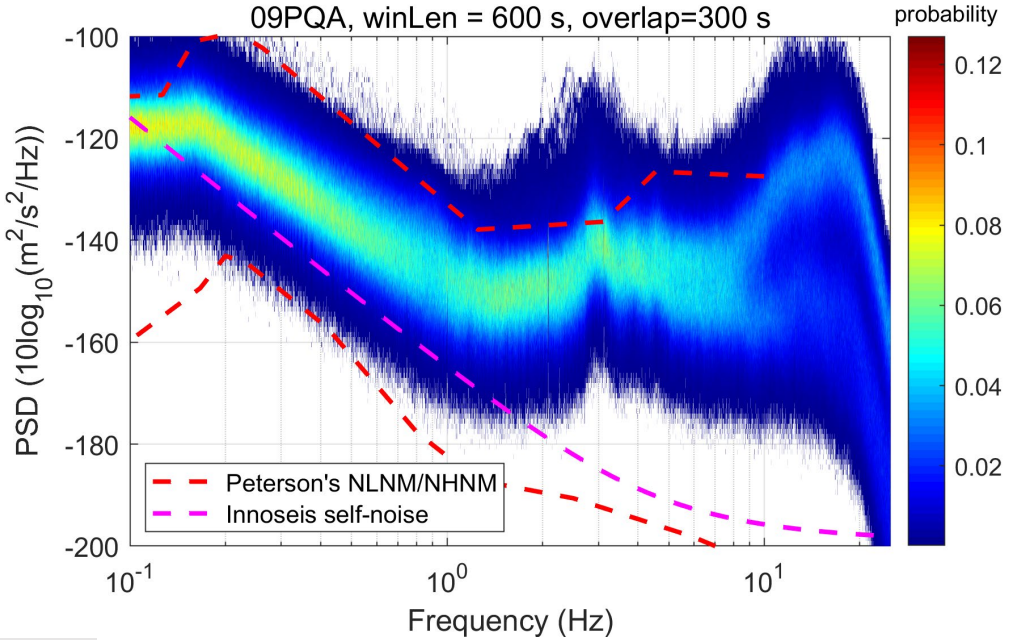
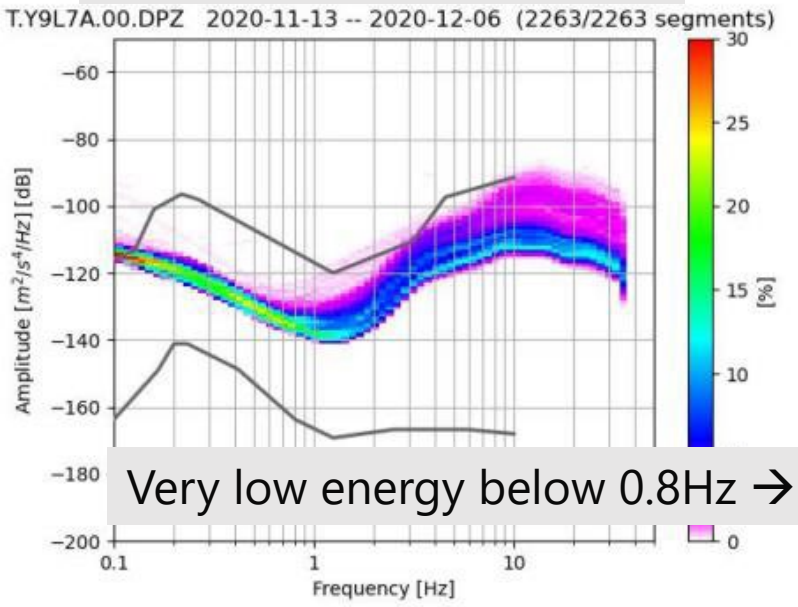
Quality Check of Raw Data

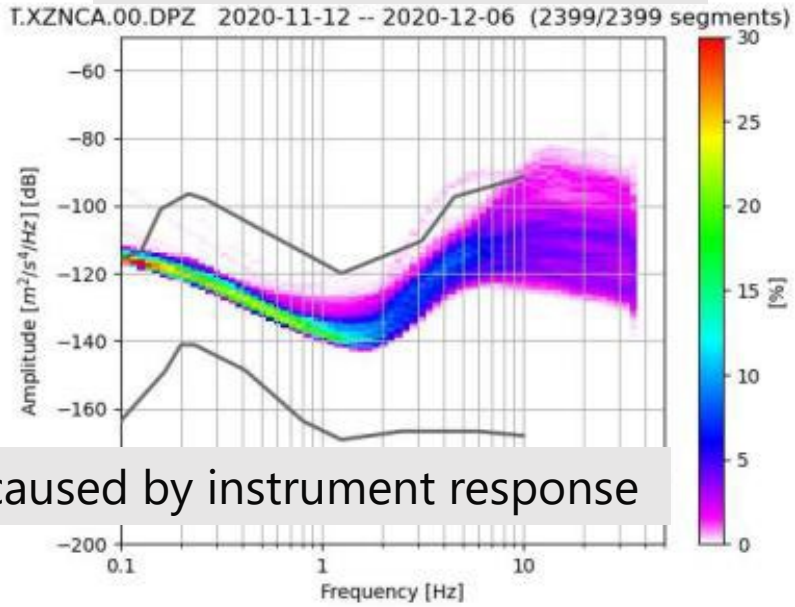
- Noise characteristics: Most stations measure a noise comparable to or more than the Peterson's high noise model



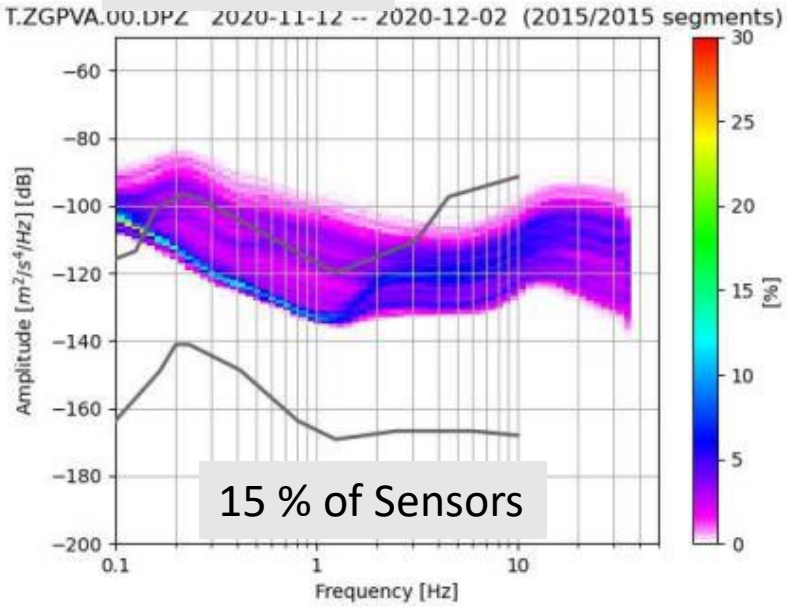
Low variability of noise level



High variability of noise level



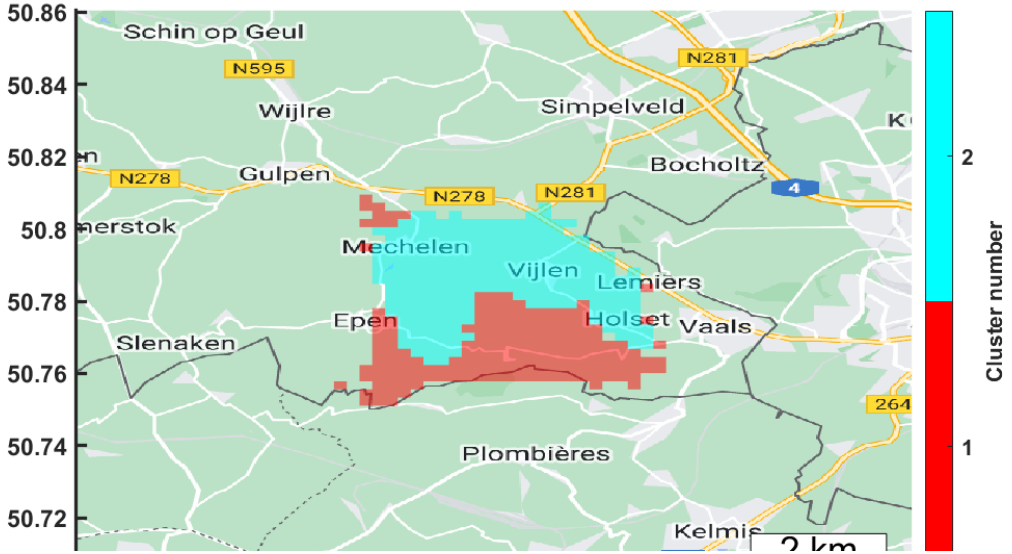
Bad coupling

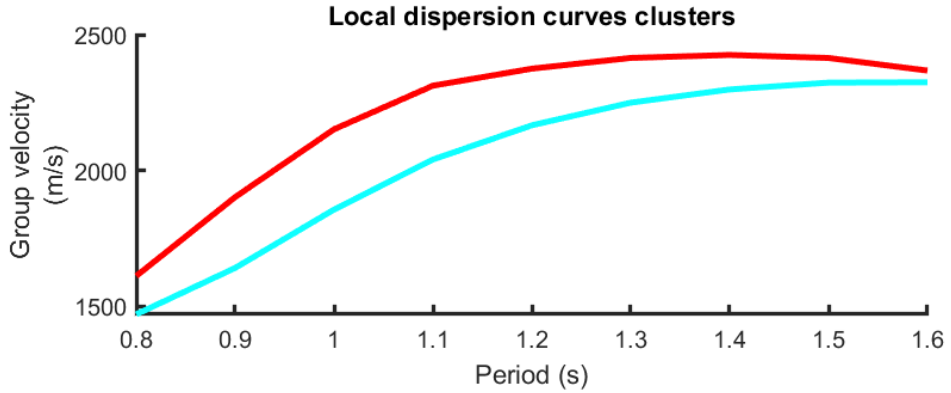


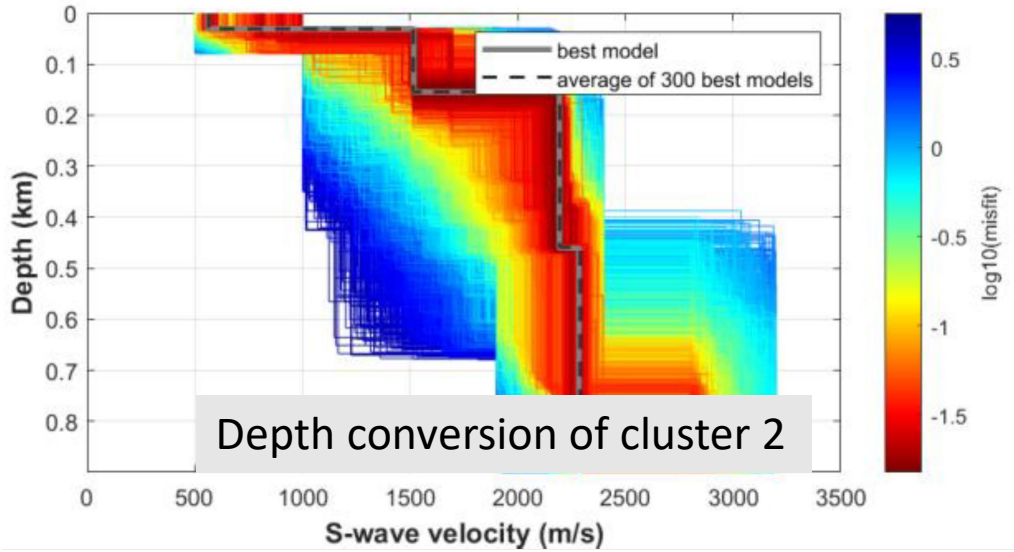
Very low energy below 0.8Hz → caused by instrument response

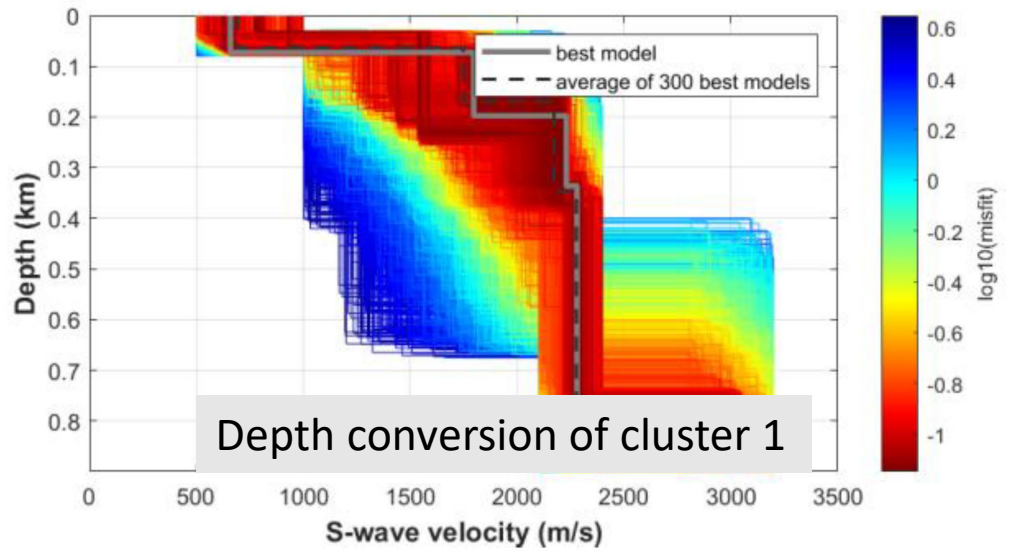
15 % of Sensors

Clustering (K-Means)







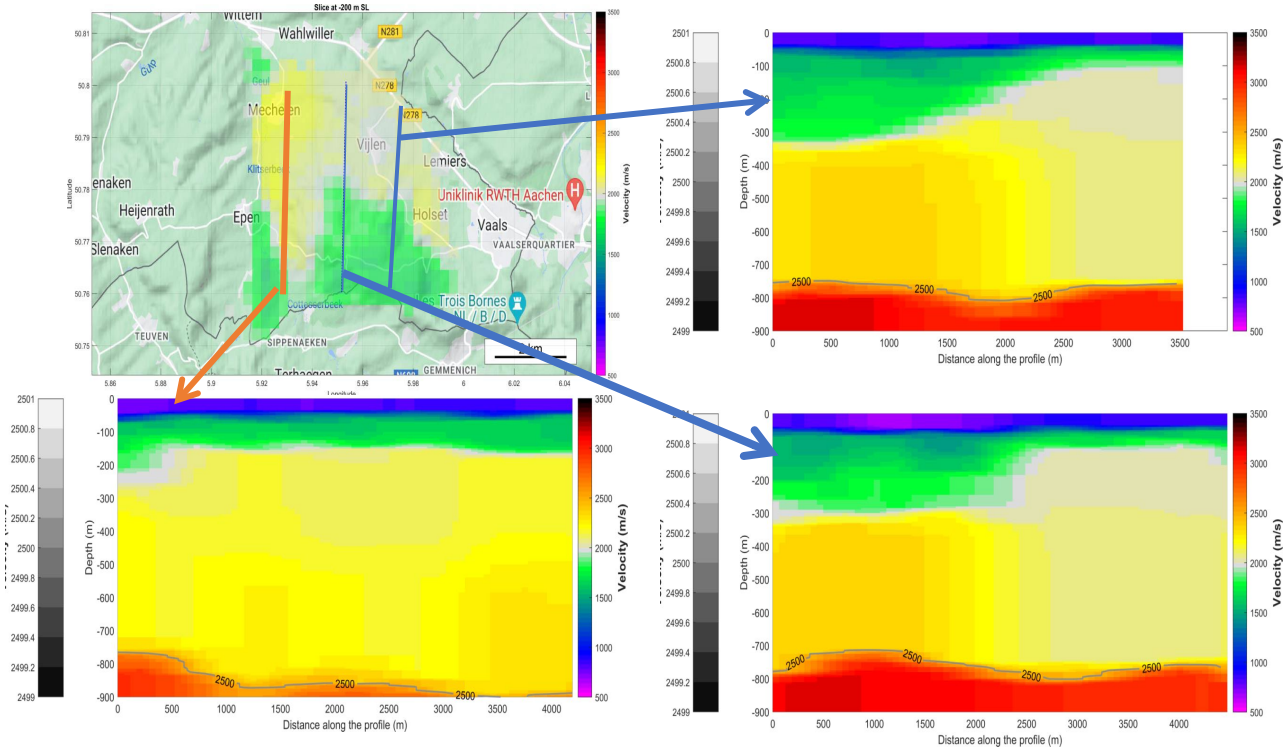


- Data are represented in form of black error bars
- The color curves are the tested models
- The color represents the misfit

Summary: Passive Seismic

- Very low-quality dataset
  - Picking difficult →sensors not sensitive under 0.8Hz, overtones interfering with fundamental mode around 3Hz
  - Local sources of noise
  - Less than 10% of the correlations have been used
  - Not well resolved group velocity maps (low variance reduction)
- Results
  - Two different velocity zones separated by clustering before the depth inversion
  - The final velocity model is resolved between 40–700 m
  - The misfit is low
  - Model : low velocity for the first layer (around 900 m/s) and then velocity increasing with depth (until 3200 m/s)
- Recommendation
  - Improve the array design to better resolve the 0-500m depth range
  - Use 3C geophones with higher sensitivity
  - Bury the geophones

Depth inversion: Group Velocity at 3 profiles

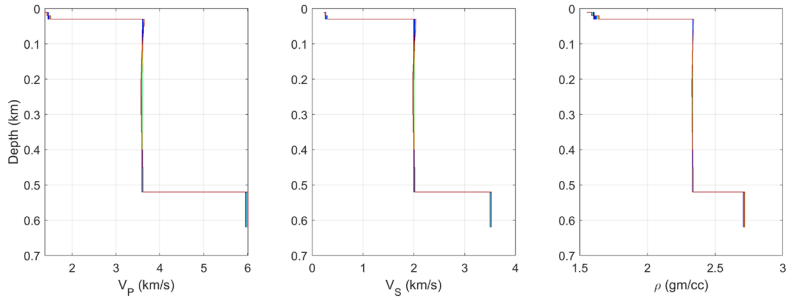


- First layer: 50 m thickness and 700 -1000 m/s
- Second layer: 50 –250 m thickness and 1700 m/s
- Third layer: 400 –700 m thickness and 2300 m/s
- Fourth layer: 3000 m/s

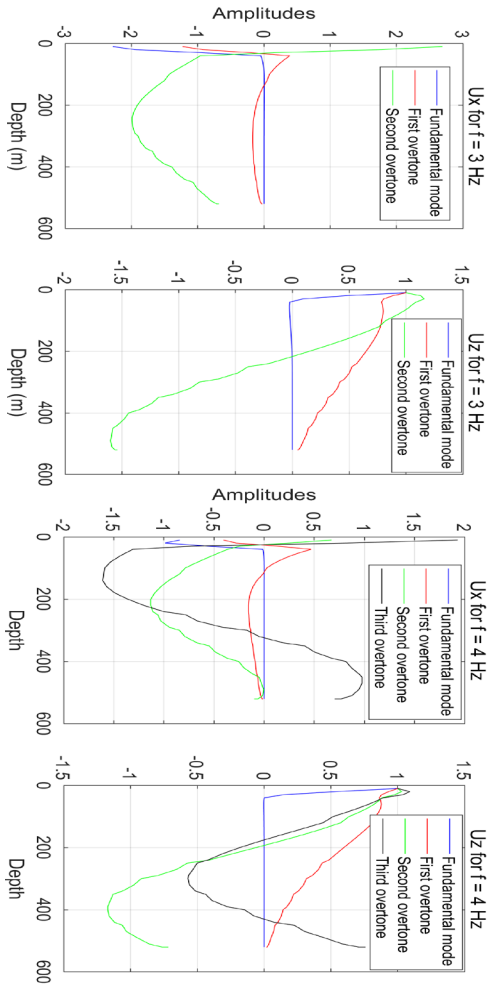
400 3C SmartSolo Geophones getting calibrated at KNMI Site

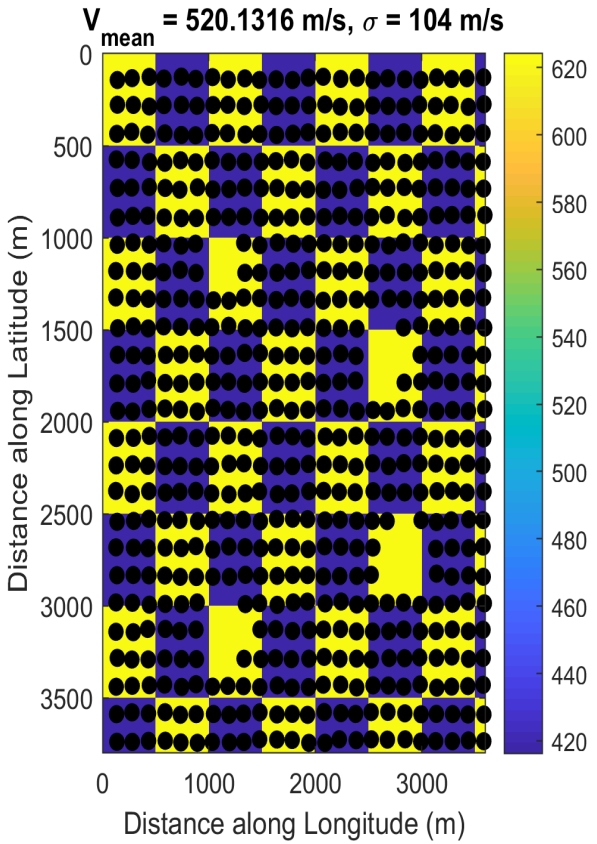
Simple modelling and checkerboard test:

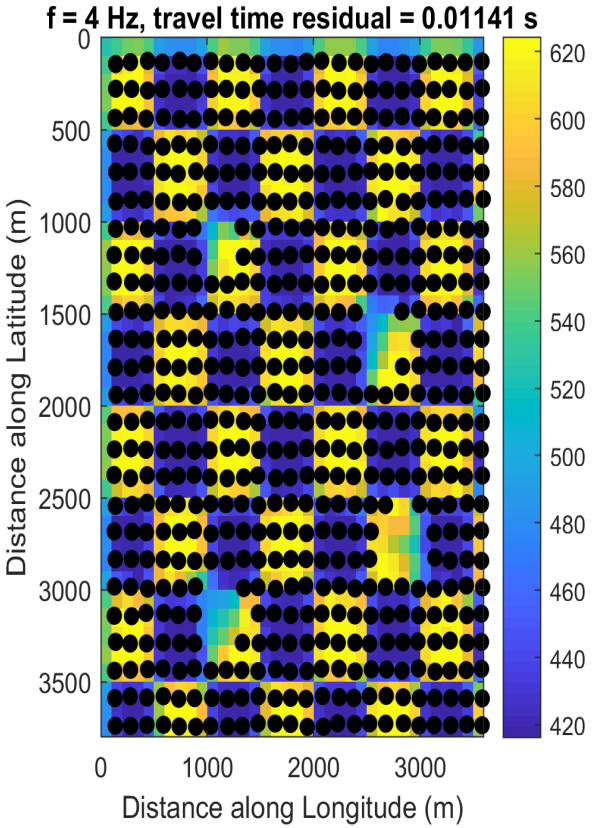
Rayleigh wave phase velocity of 520 m/s at 4 Hz with voids

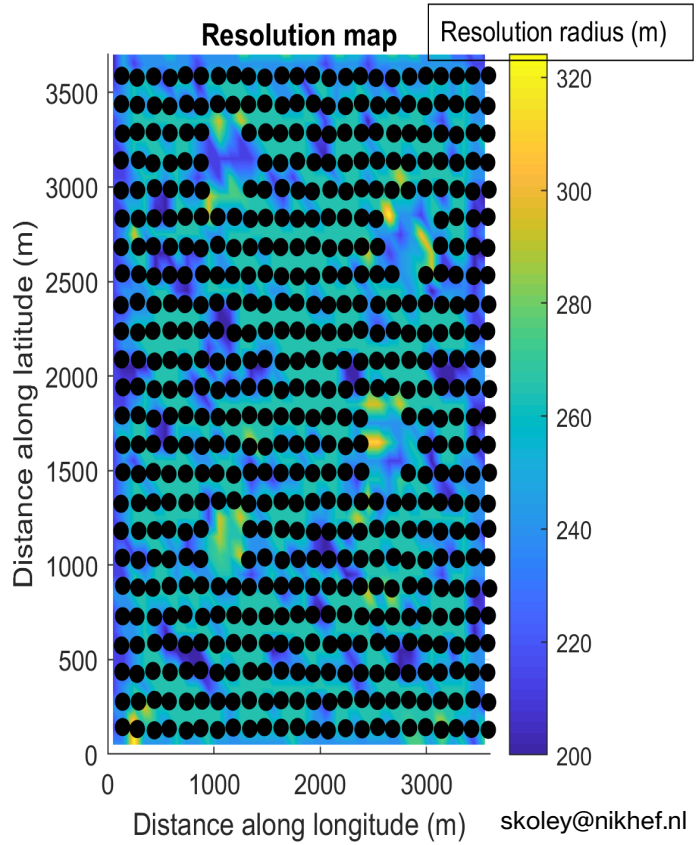


Station spacing of 150 m, grid size = 100 m, minimum resolving power = 200 m, total stations = 600
Velocity perturbation of about 100 m/s (20%), each ray has **45%** probability of getting selected, station separation of at least 1 wavelength and maximum 4 wavelengths









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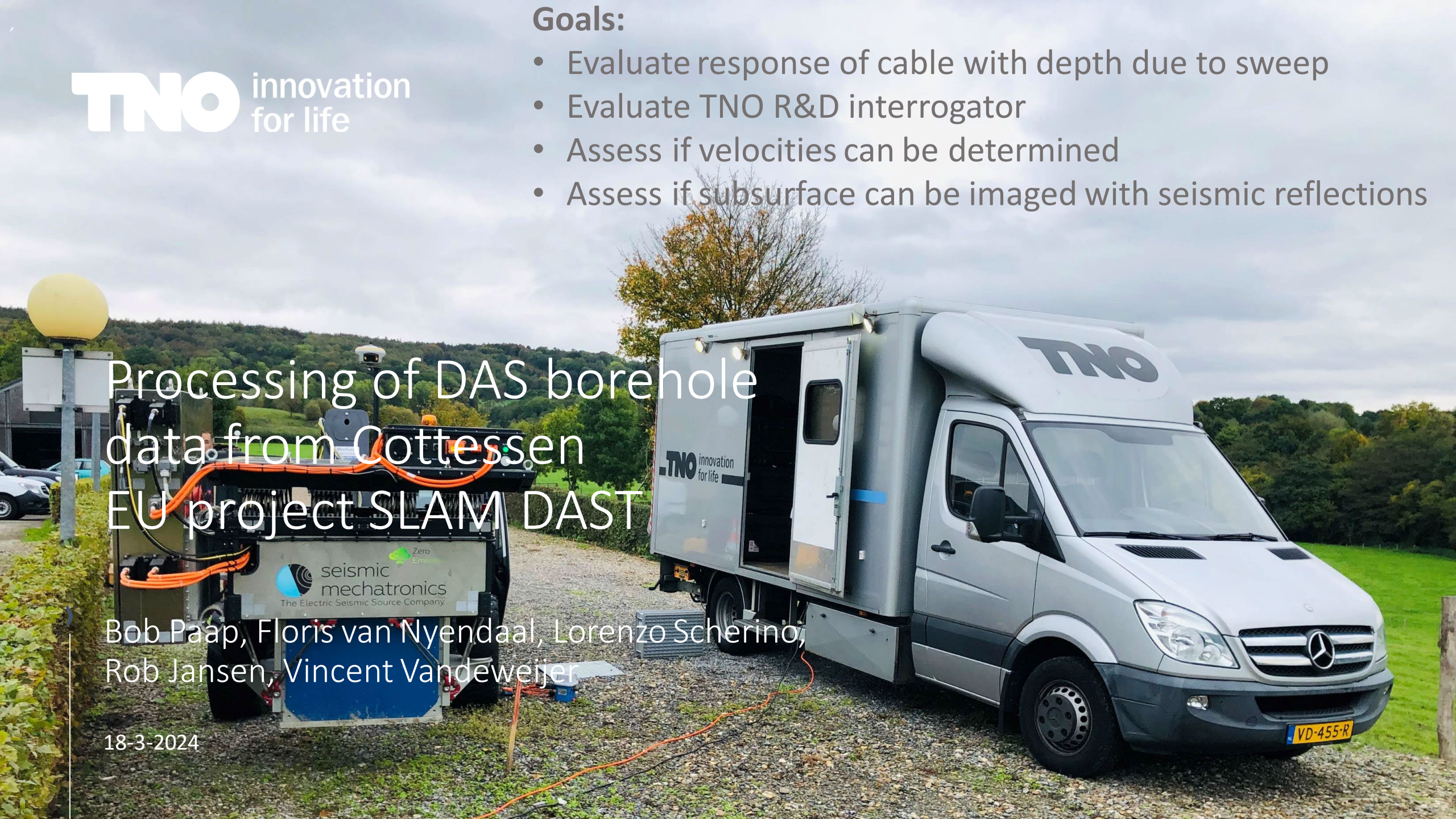
Goals:

- Evaluate response of cable with depth due to sweep
- Evaluate TNO R&D interrogator
- Assess if velocities can be determined
- Assess if subsurface can be imaged with seismic reflections

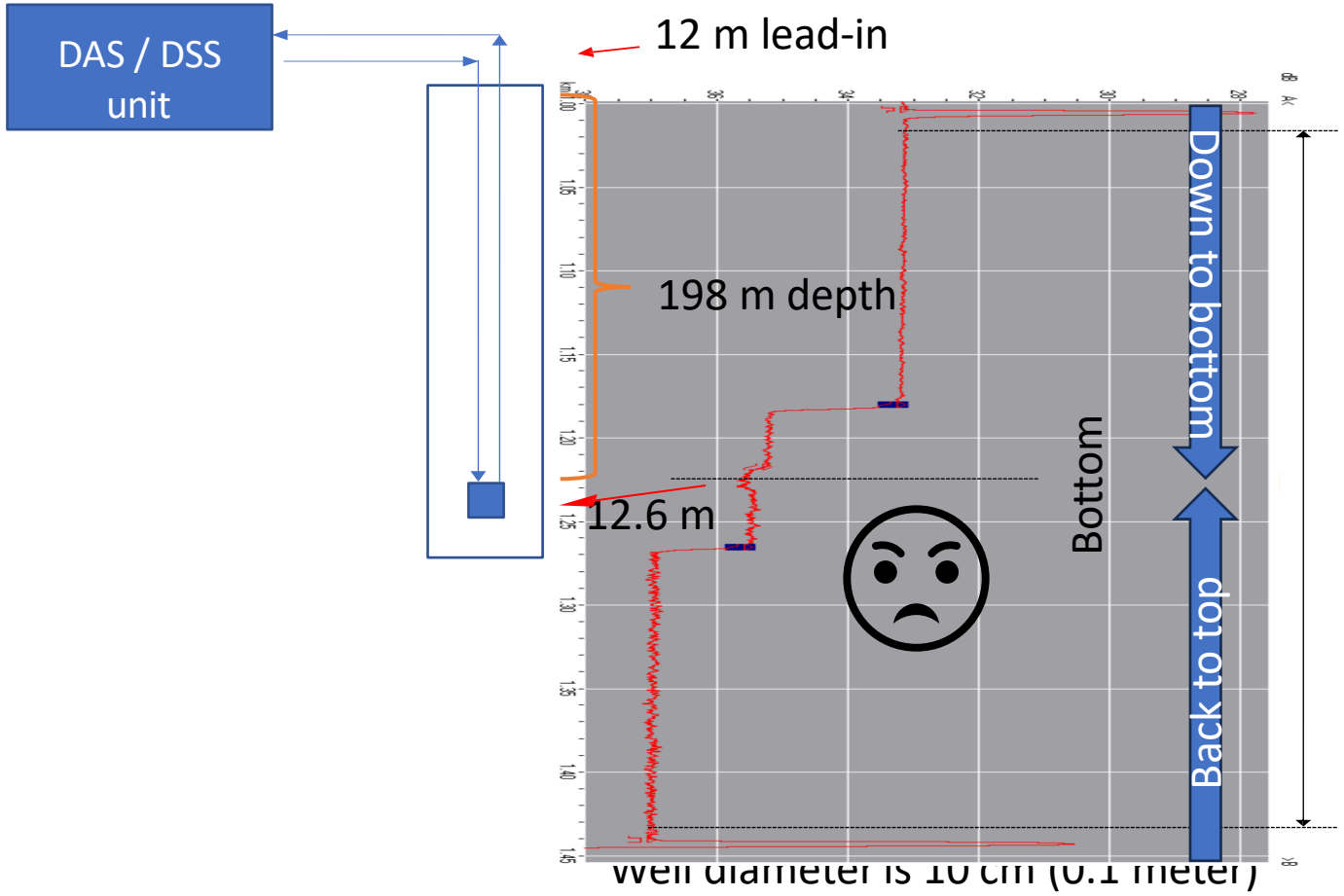


Processing of DAS borehole data from Cottessen EU project SLAM DAST

Bob Paap, Floris van Nyendaal, Lorenzo Scherino, Rob Jansen, Vincent Vandeweijer

18-3-2024

Fiber layout Cottessen survey well



Length from Fiber Optic unit to well surface is 12 meters

Length of Fiber Optic cable in Cottessen well is 198 meters.

Note: two fibers inside so total length is 396 meters.

Length of delay line is 12.6 meters

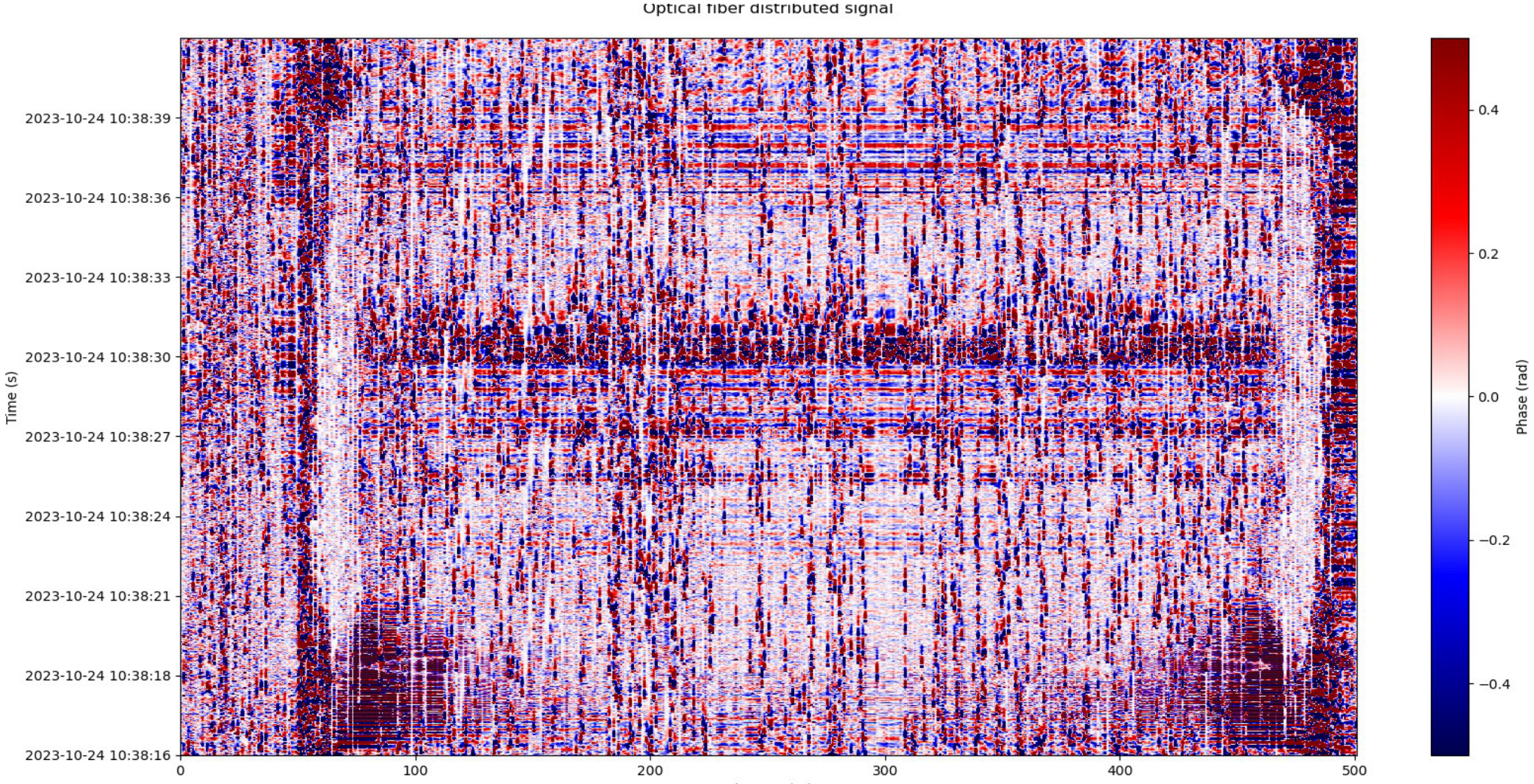
The trace measured through the OTDR shows an attenuation of the both fibers in the same point. This attenuation was already registered after cementing.

- Cable was stretched at a faultzone?

7 kn Vibrator Force

Location 1, stack of 3 preprocessed sweeps

- Problem encountered with the processed DAS data of the TNO R&D interrogator.
- Around 30 to 35% of the DAS data contains incorrect readings / false traces.
- Datasets have been cleaned by applying a filter (filter was set at low pass at 0.4 Rad)
- Consequence is reduced stacking power and therefore poorer imaging resolution.

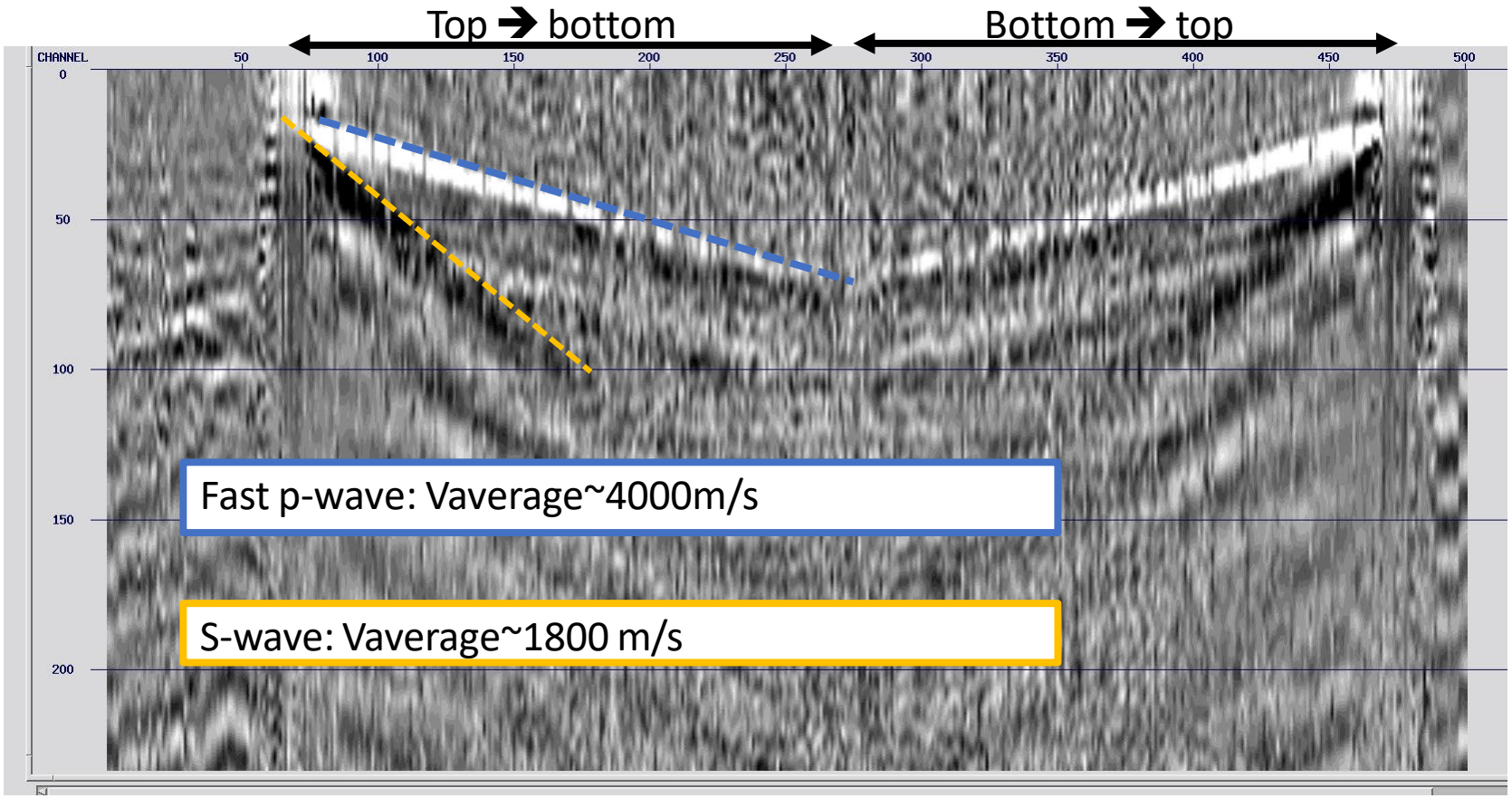


7 kN TNO cc all traces, preliminary result

Location 1, 3 sweeps stacked, bandpass 2-130 Hz, AGC (250ms)

➔ No visible subsurface reflections

➔ Not (yet) suited for time-to-depth conversion and tying formations



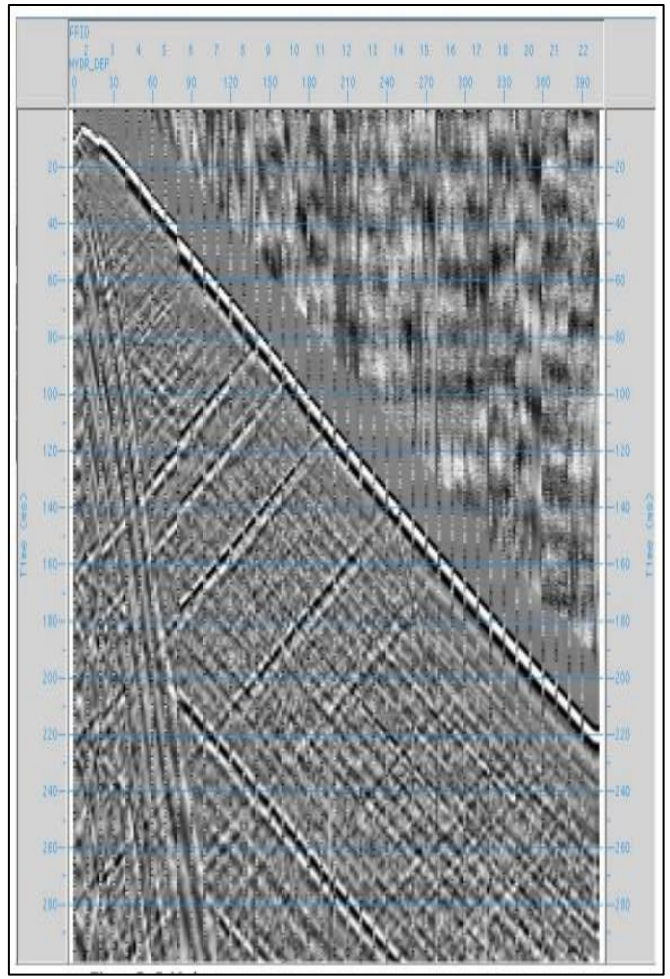
Let's see if we can still measure the attenuation at the low freq. range (1.5-12Hz)

Example of VSP near Nederweert

Quaternary/tertiary

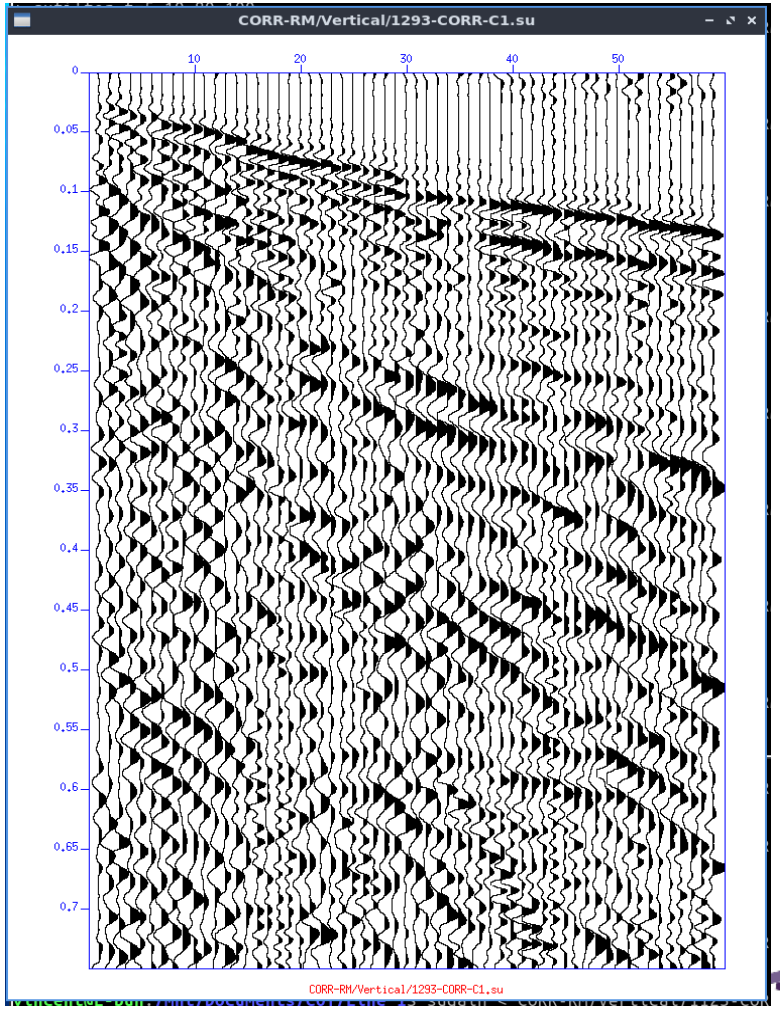
Vp=1831m/s

(Dortland, 2004)



Summary of 2D surface line

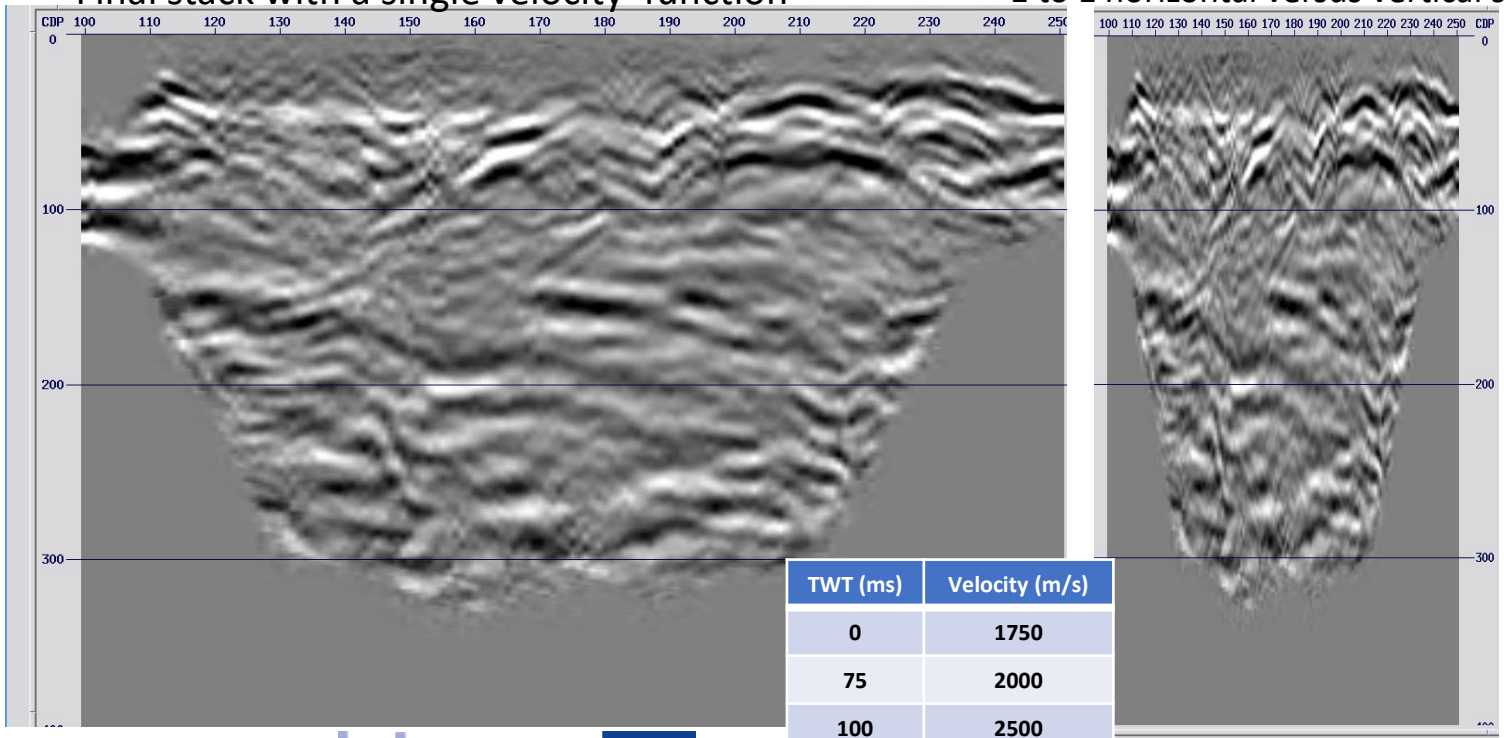
Raw Shot, P-component



- 59 active nodes (3C) were deployed
- 89 source locations used
  - 3 sweeps at each location
- Source and receiver interval: 5m
- Total line length: 450m

Final stack with a single velocity function

~1 to 1 horizontal versus vertical scale



TWT (ms)	Velocity (m/s)
0	1750
75	2000
100	2500
150	3000
200	3500

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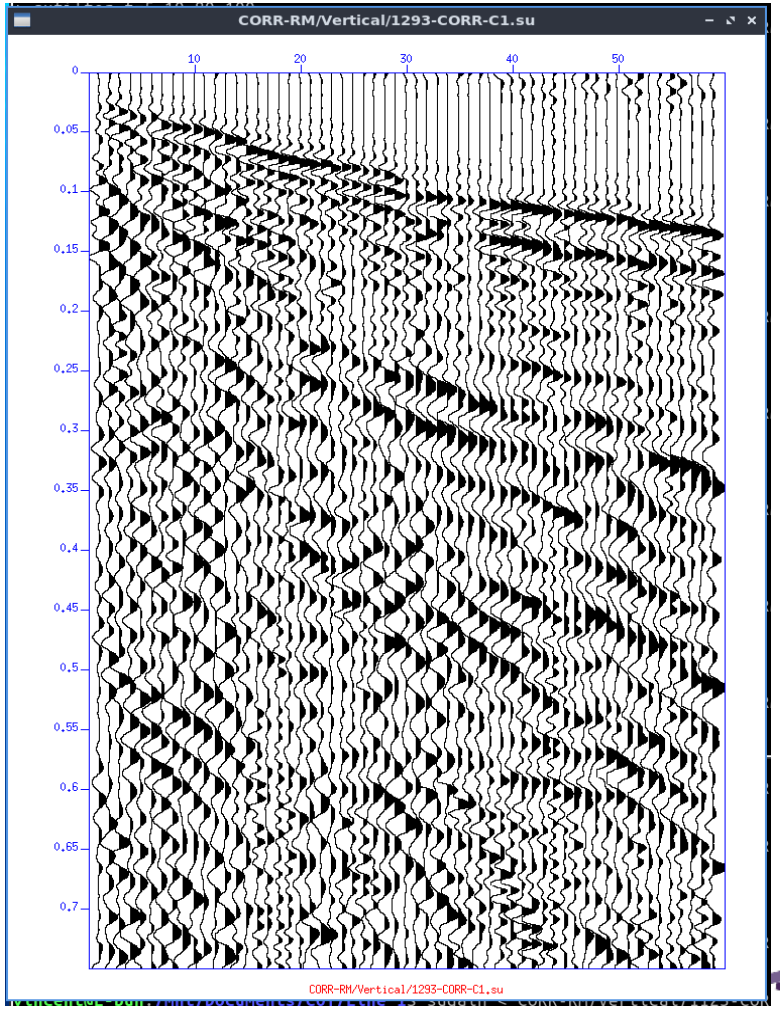
Summary of 2D surface line

Raw Shot, P-component



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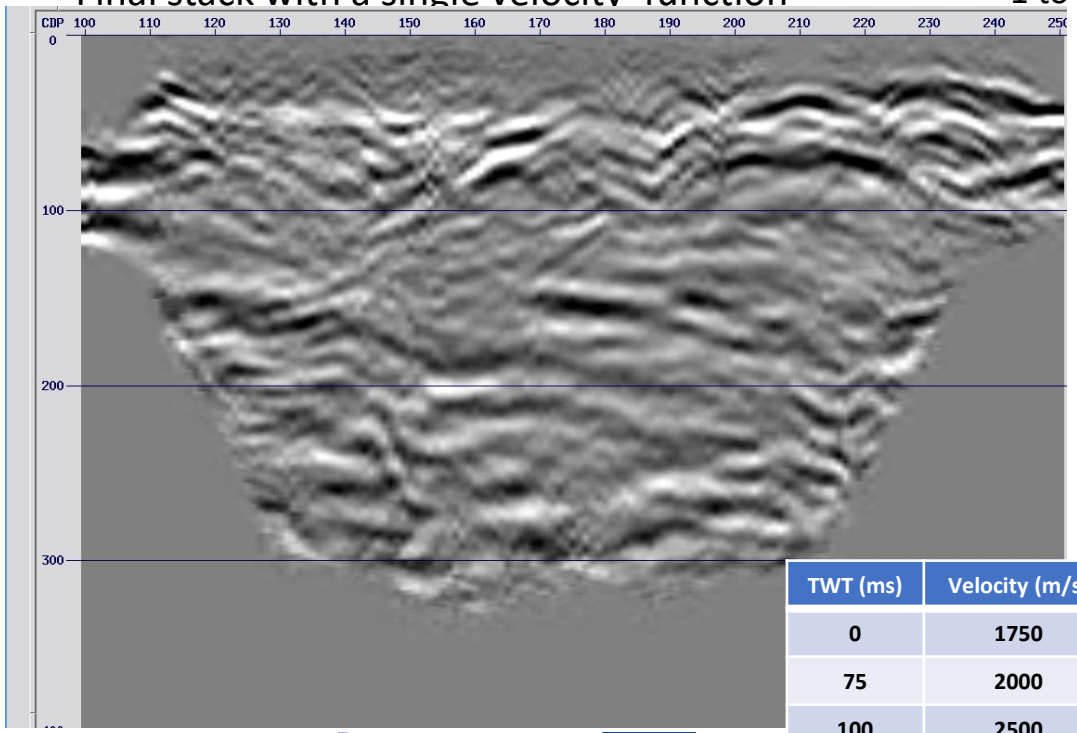

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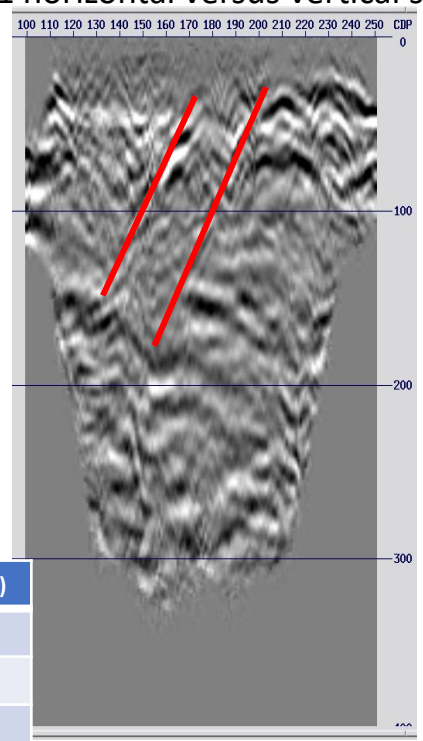

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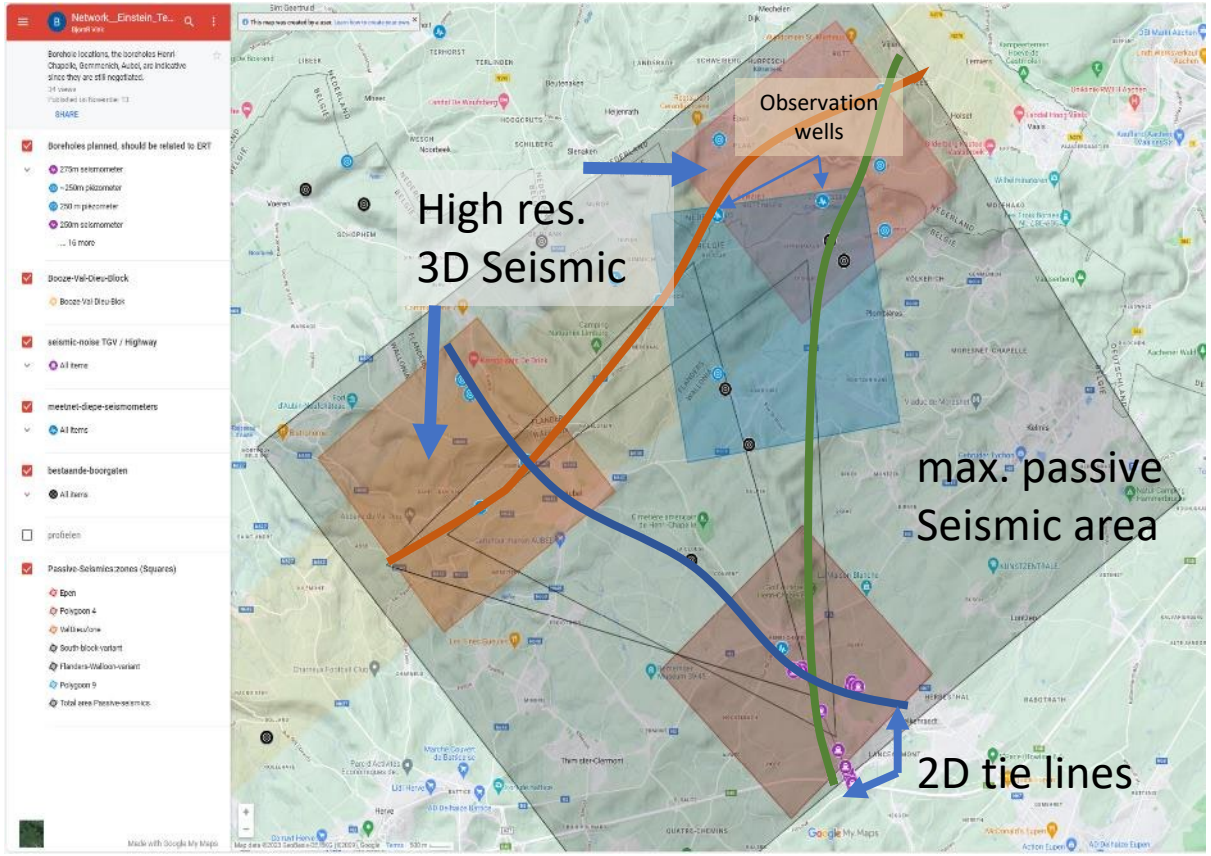
Plans for a next seismic campaign in Q4-24/Q1-25

- 3+ high res. 2D seismic tie-lines between envisioned corner-points
  - Tying into most instrumented wells
  - ➔ crooked lines, total of ~ 50-60km. single vibe (1-100Hz), >=5m source, >=5m receiver, offset ~1000m, image depth range 0-600m
  - Rough cost estimate: ~ € 10k/km ➔ €500-600k
- 3 high res. 3D seismic surveys (cross-spread based) at potential corner points
  - Each ~1km*1km, 50m source/receiver line spacing, 10m source spacing, 10m receiver spacing ➔ 10k source & receiver positions, 20-line km
  - Rough cost estimate: ~ € 15k/km ➔ ~€900k
- Simultaneously acquire 2D/3D DAS-VSP's at instrumented wells
- 3D passive seismic to delineate Booze Val-Dieu block with Vp, Vs
  - Cover the area (~100 - 225km2) encompassed by the corner-points
  - Rough cost estimate: ~€500 - 1200k
- Fiber optical cable to be installed for DAS-VSP, noise, strain, temperature measurements in the seismic observation well

	Date of completion	Well depth
Observation well	[dd/mm/yy]	[metres]
Teuven	~ 07/06/24	~ 275
Obsinnich	~ 24/6/24	~ 275
Henri Chapelle	~ 02/7/24	~ 400
Vijlen	~ 19/7/24	~ 275
Aubel	~ 08/08/24	~ 275

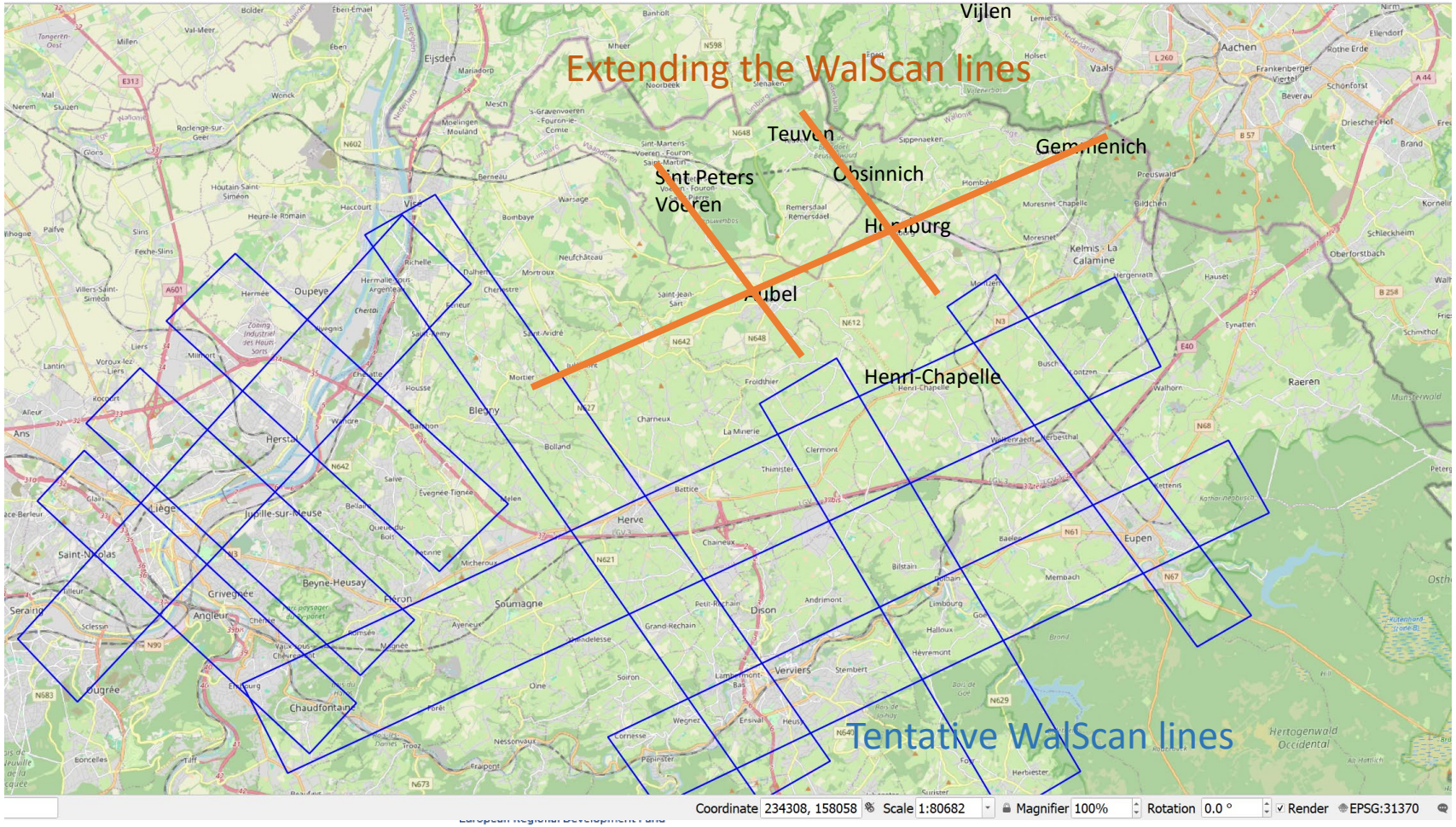


Conceptual outline. Ongoing well campaign will inform actual survey locations, etc.

Collaboration opportunities with the geological service of Belgium and Nordrhein-Westfalen (GD-NRW)

Geothermal Exploration

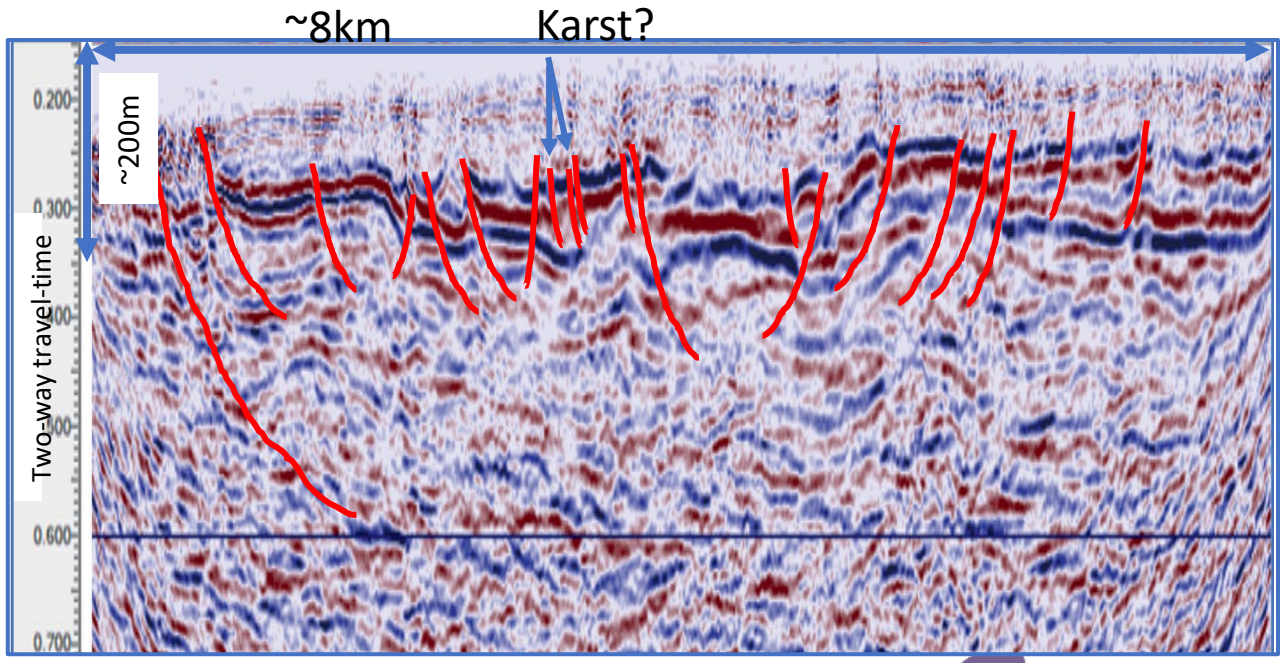
- WalScan in Belgium
- Eschweiler (East of Aachen)



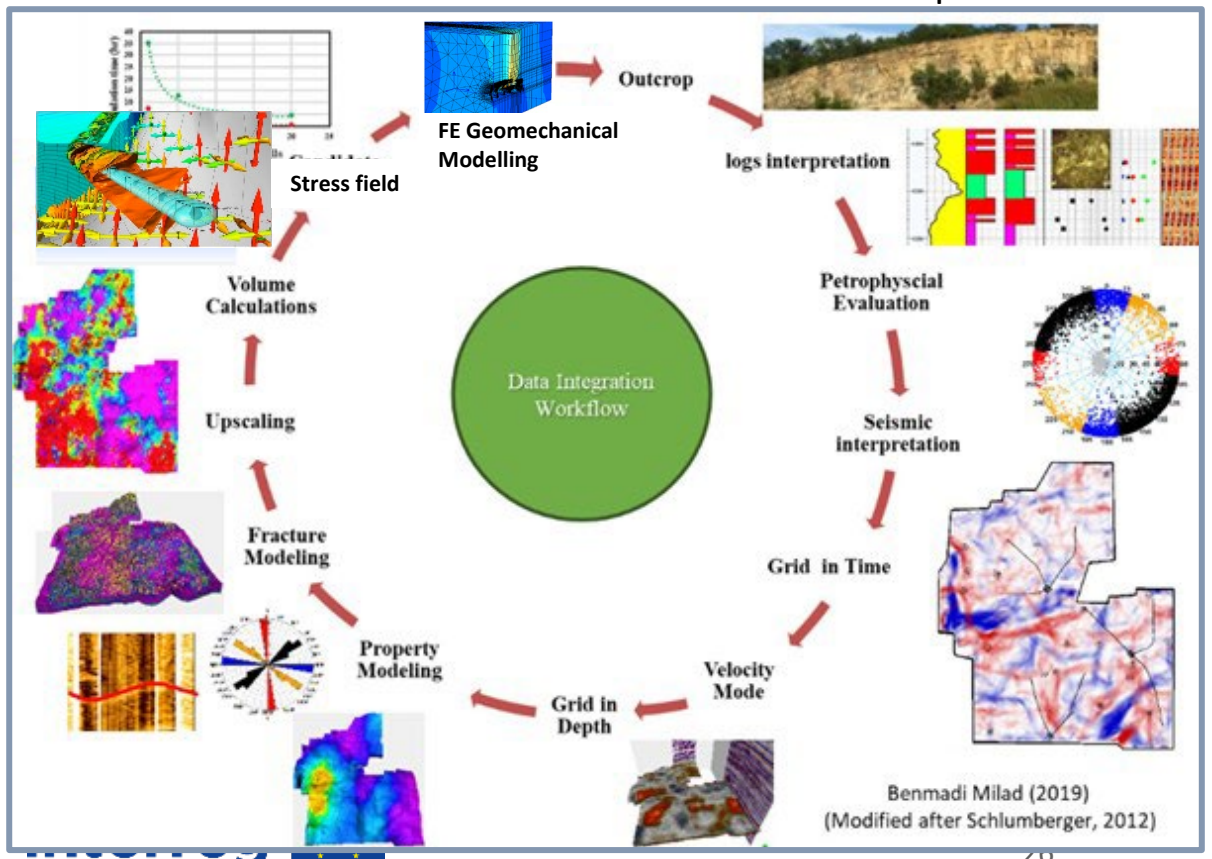
Summary:

Active and passive seismic programs to delineate a suited “rigid” rock formation for ET-construction is in planning

- Active seismic to delineate top of the geological Famenian unit
- Identify faults, karst, etc.



Integrated model building: From outcrop and well information to 3D dimensional model with seismic, ERT & gravity data to support a safe and cost-effective construction of the Einstein Telescope



Questions?