Processing and analysis of data recorded from a buried permanent seismic source

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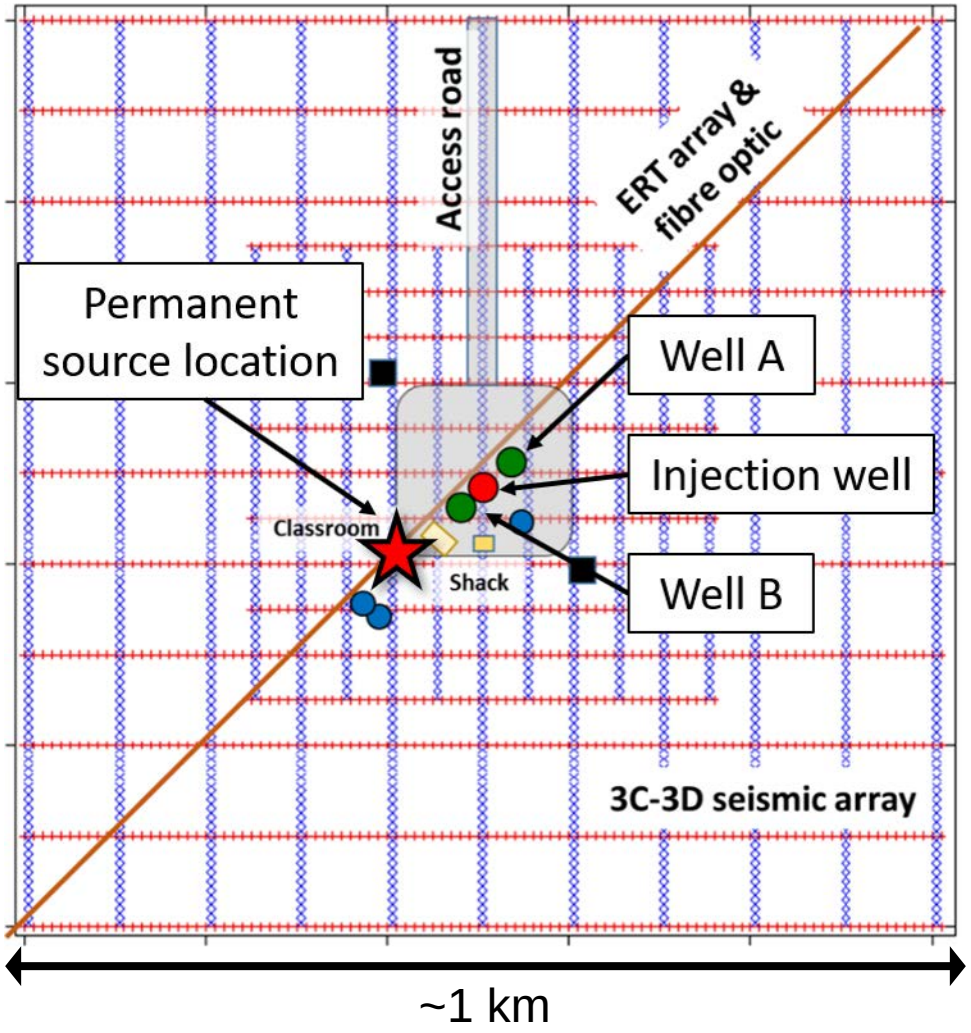
Motivations

- Monitoring is of great importance in various types of projects
- Time-lapse seismic surveys typically performed 1+ years apart
- Desire high quality, rapidly acquired seismic data for geophysical monitoring projects

Site description



- CaMI.FRS in Newell County, Alberta
- Small CO_2 storage site testing various monitoring techniques
- Permanent sources located ~110 m SW of Well A, ~60 m SW of Well B

GPUSA linear vibrators

- Eccentric mass rotating over chosen sweep of frequencies
- Axle coupled with ground
- Force on axle:

$$F_c = mr\omega^2$$

- By Newton's Third:

$$A = A(\omega^2)$$

GPUSA linear vibrators

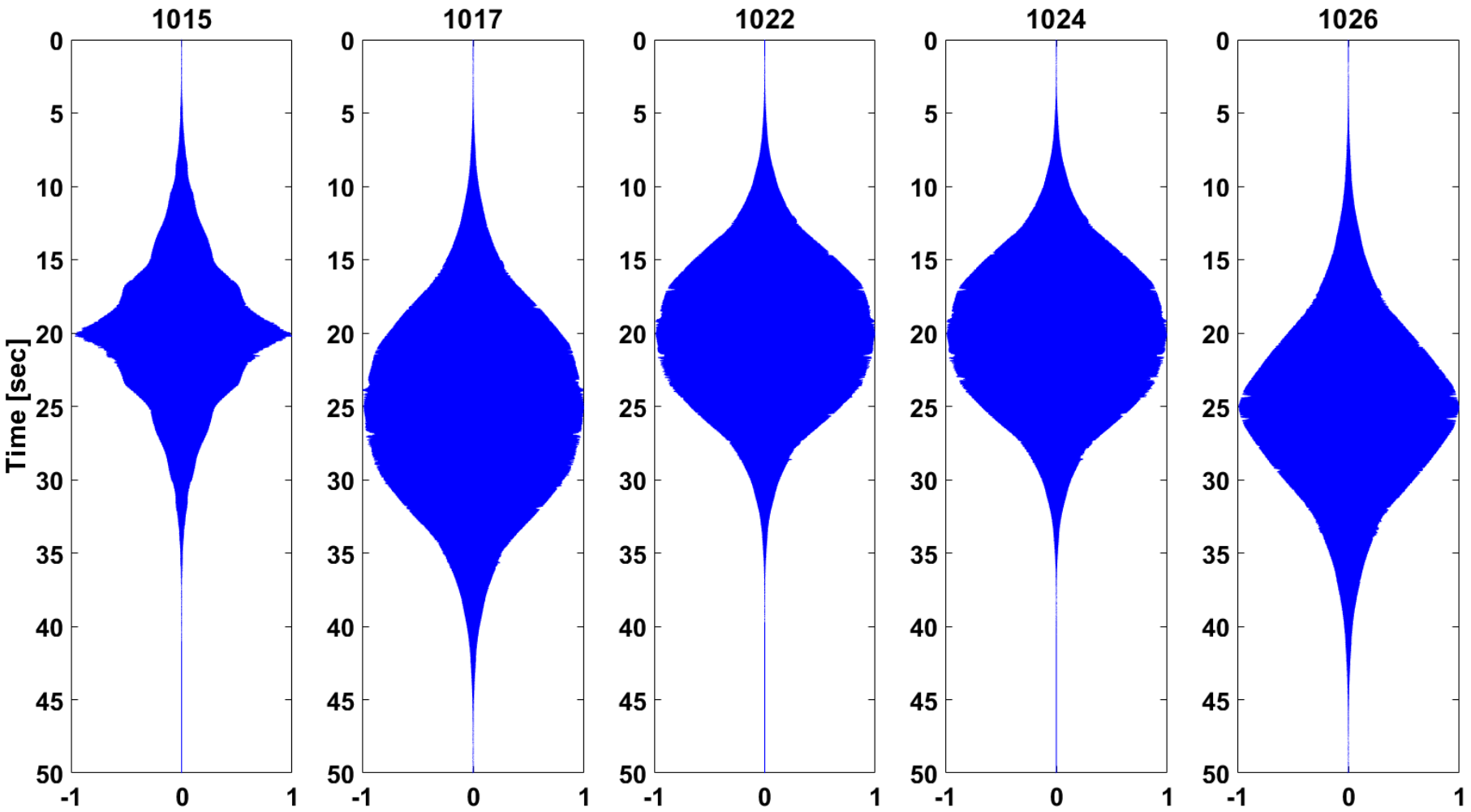
Source name	Frequency range (Hz)	Peak force (lbs.)
Borehole linear vibrator	0-200	4,500
Surface linear vibrator	0-200	4,500
Surface linear vibrator (“orange vibe”)	0-100	11,000

Borehole linear vibrator tests

- Field tests of borehole linear vibrator in September 2018
- Five sweeps with various parameters
- Receiver geometry:
  - 24 3C geophones in geophysics well (58 m offset)
  - 24 1C surface geophones, centred on source borehole

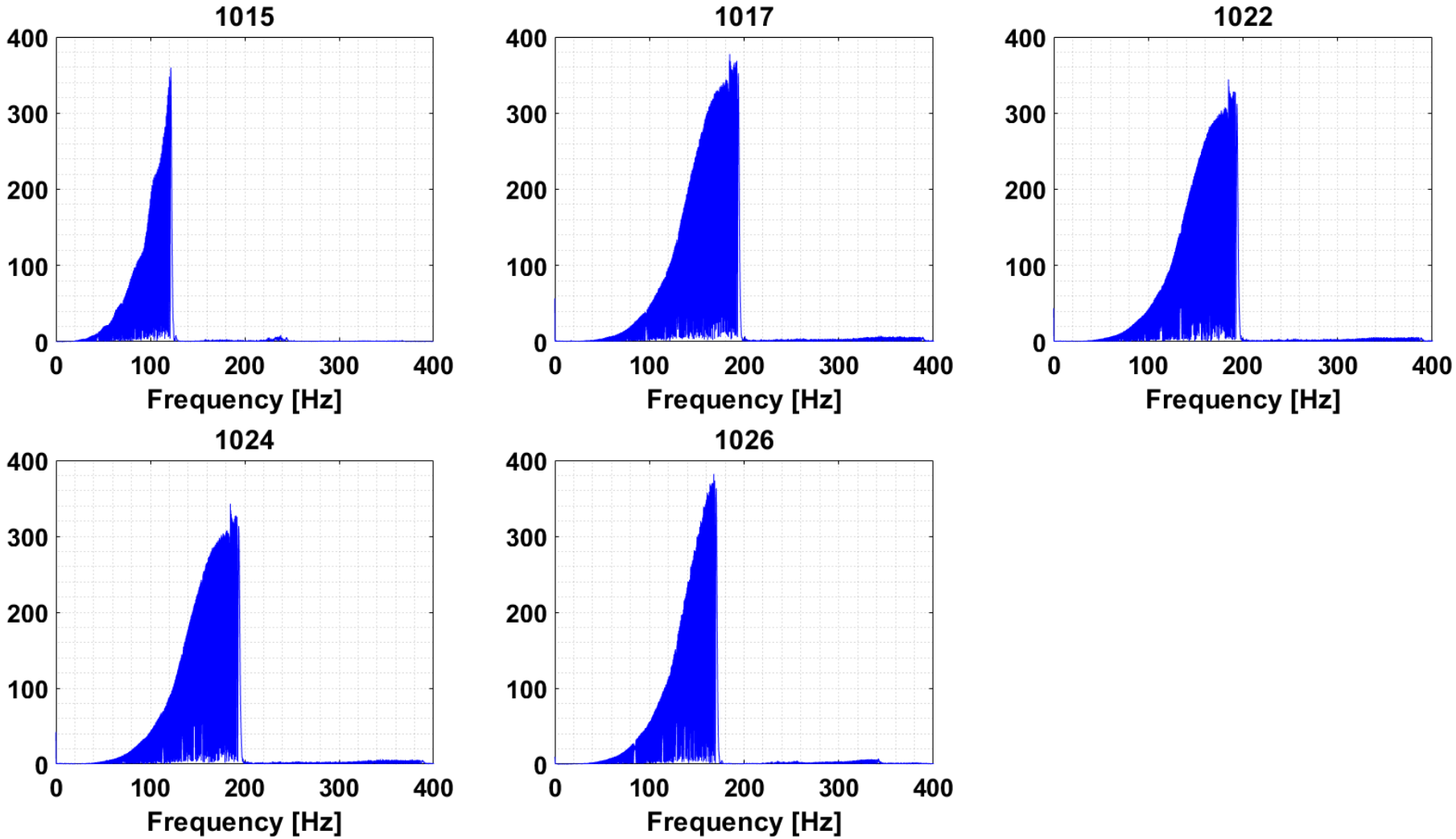
Sweep number	Maximum frequency (Hz)	Upsweep/downsweep time (s)
1015	125	20
1017	200	25
1022	200	20
1024	200	20
1026	175	25

Borehole linear vibrator tests



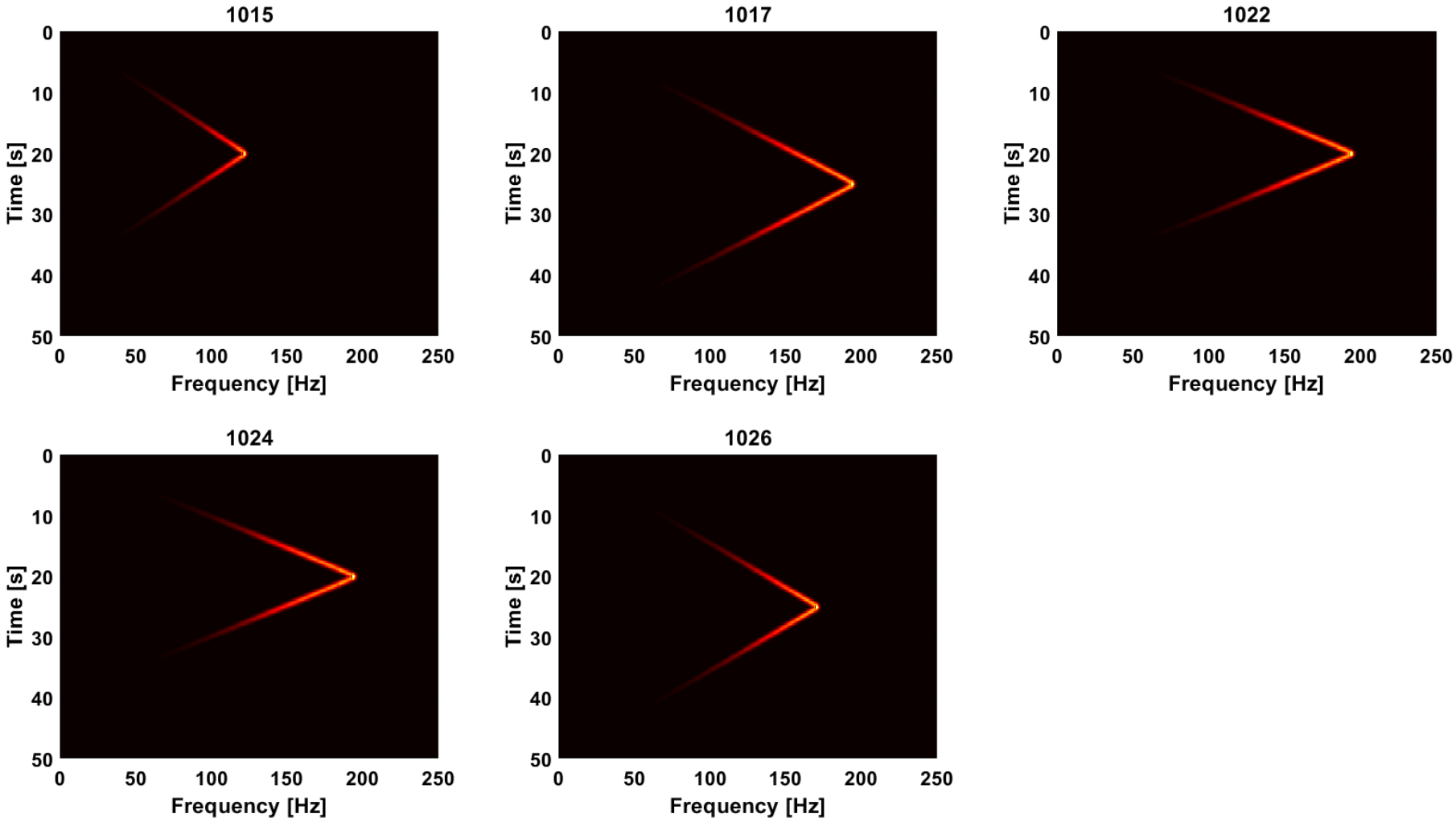
Uncorrelated traces from surface geophone nearest source borehole (station 36)

Borehole linear vibrator tests



Amplitude spectra from borehole linear vibrator test pilot traces

Borehole linear vibrator tests

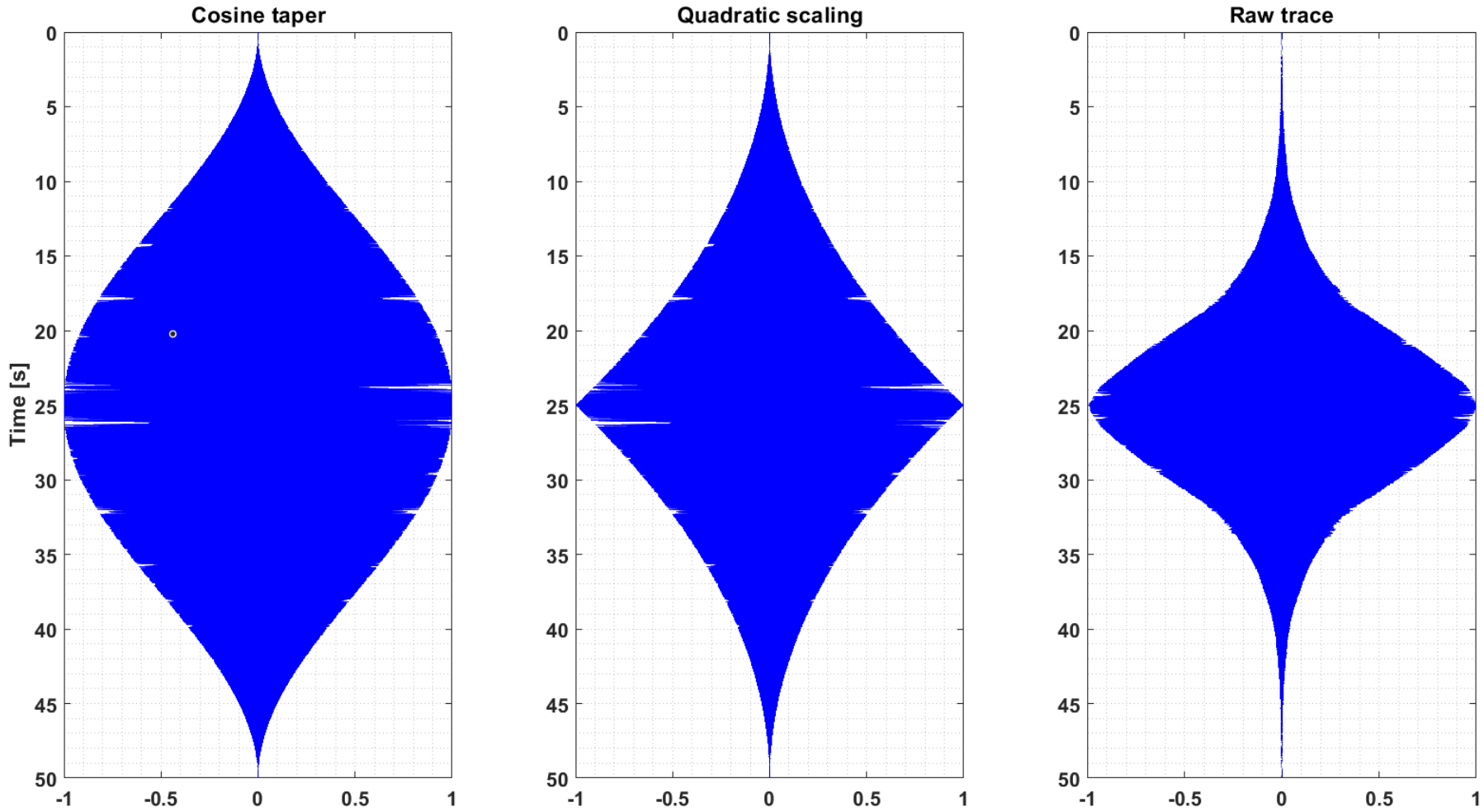


Gabor transform of borehole linear vibrator test pilot traces

Correlation

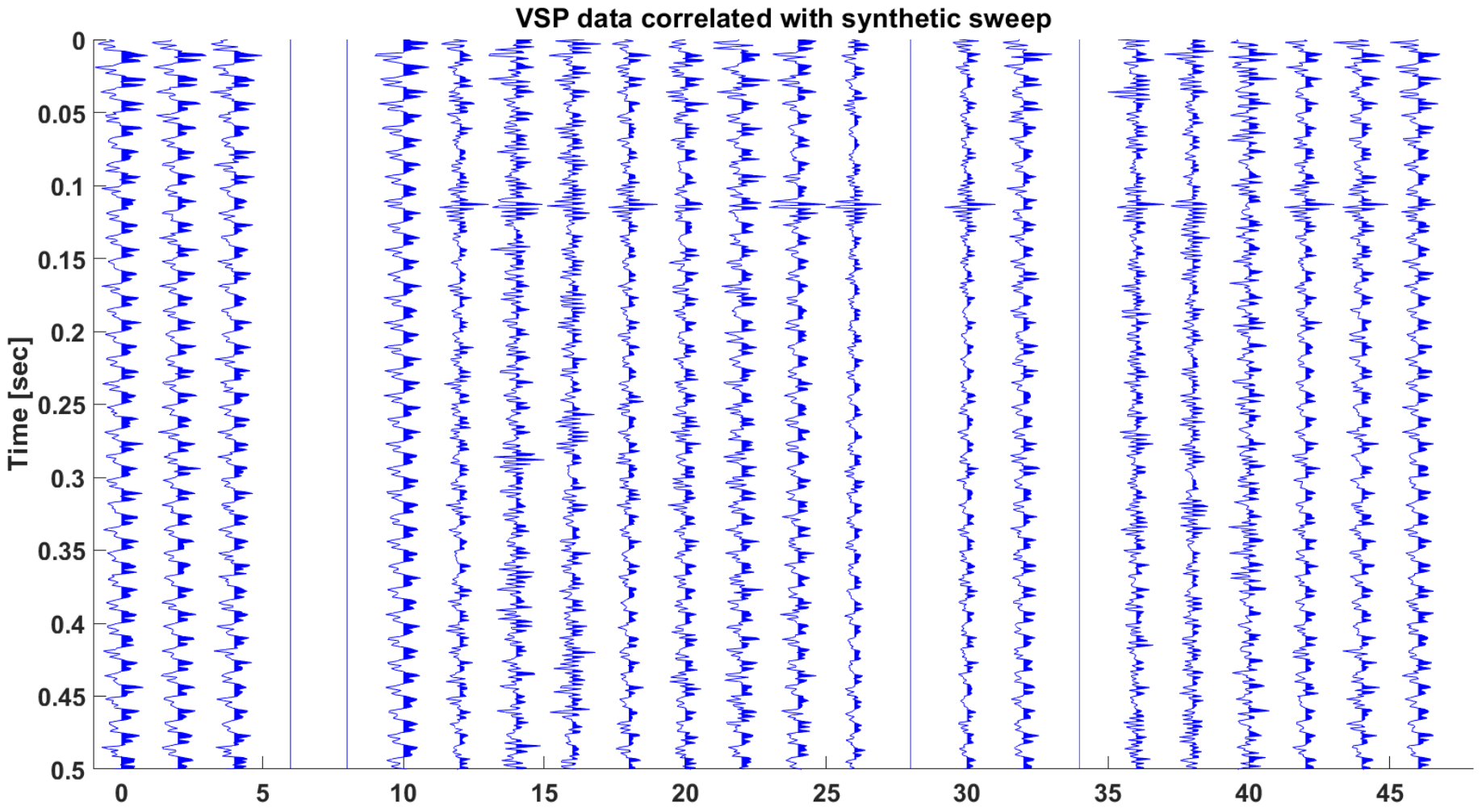
- Ideally record ground motion with accelerometer on source
- Source accelerometer failed during testing
- To create correlated sections:
  1. Correlate with geophone closest to source location (i.e. pilot trace)
  2. Correlate with synthetic sweep

Correlation

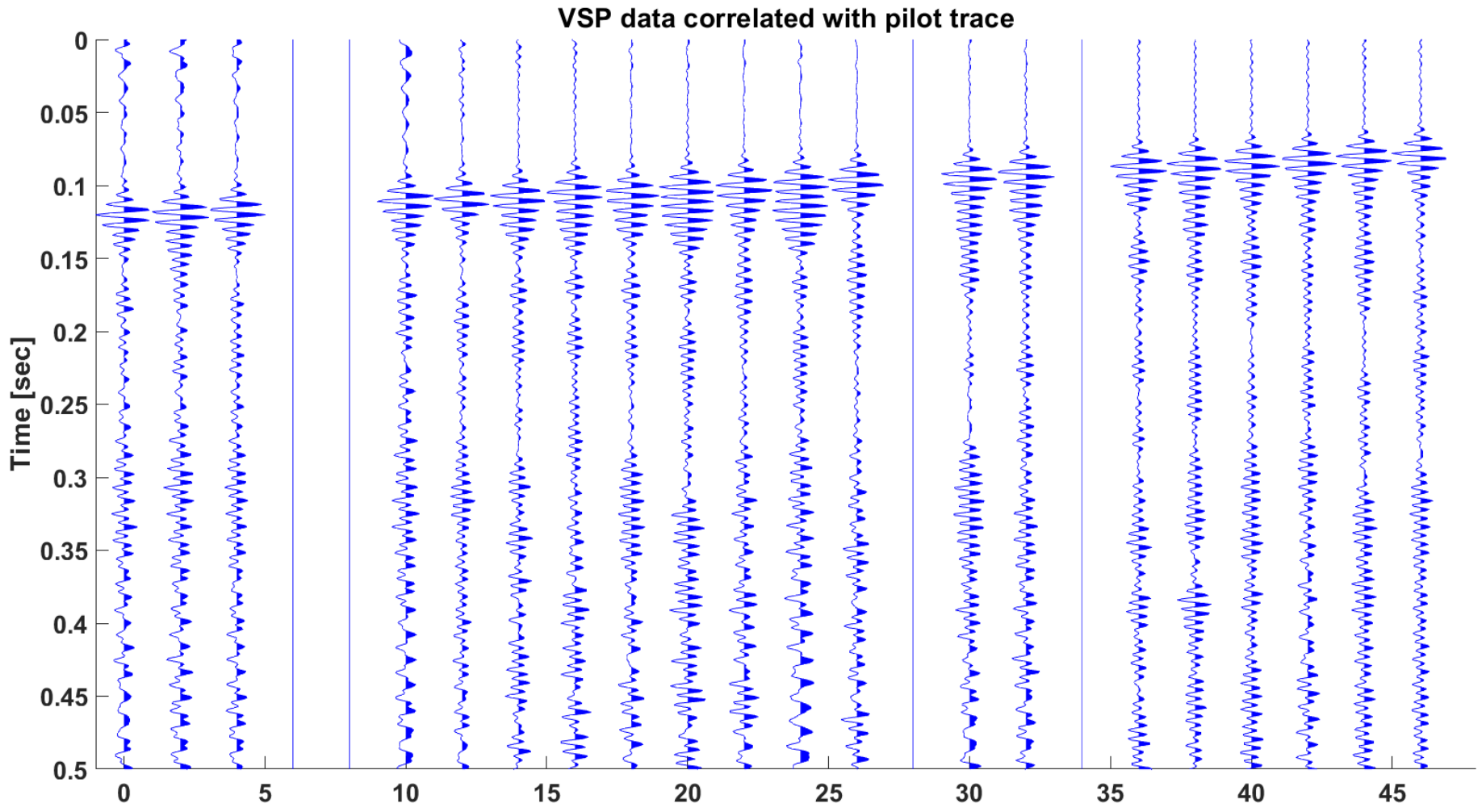


Traces used in correlation tests: synthetic sweep with cosine taper (left), with quadratic scaling (centre), and pilot trace (right).

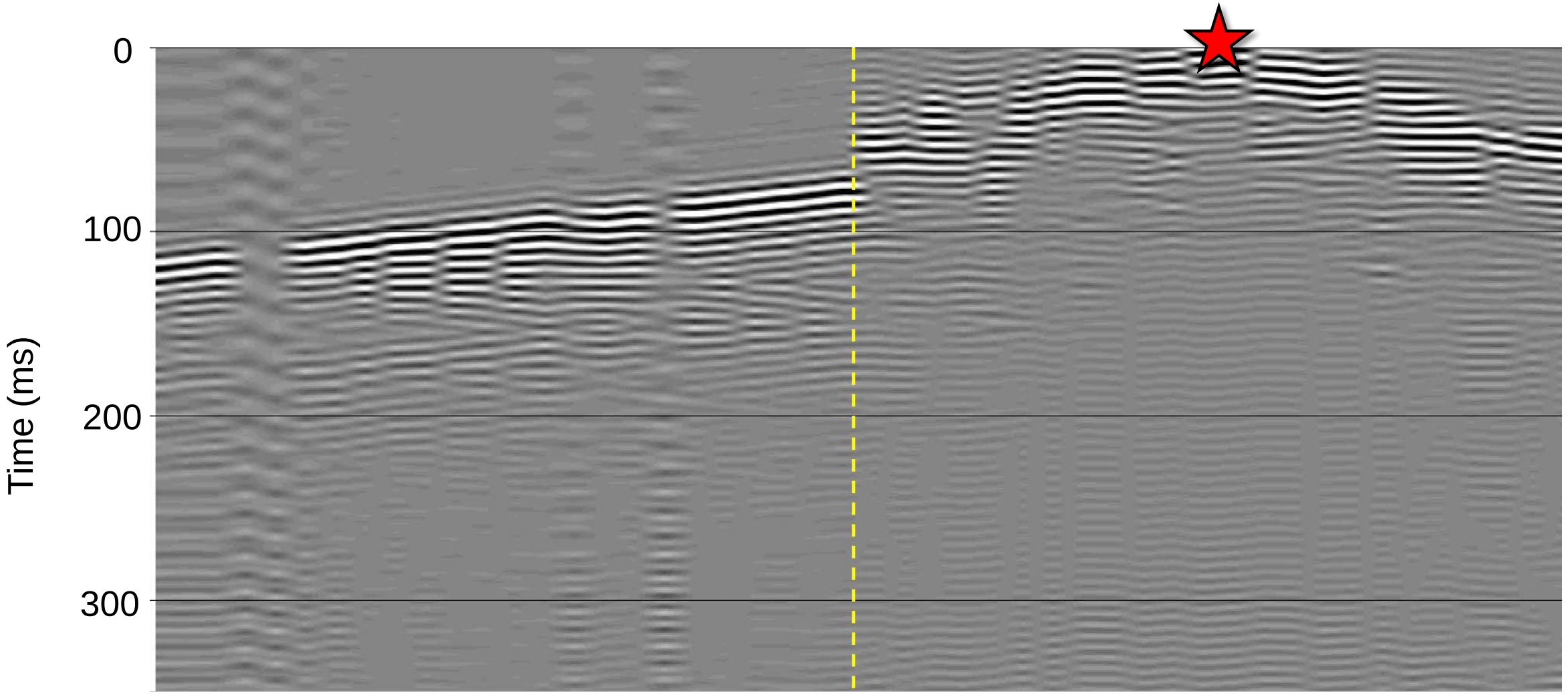
Correlation



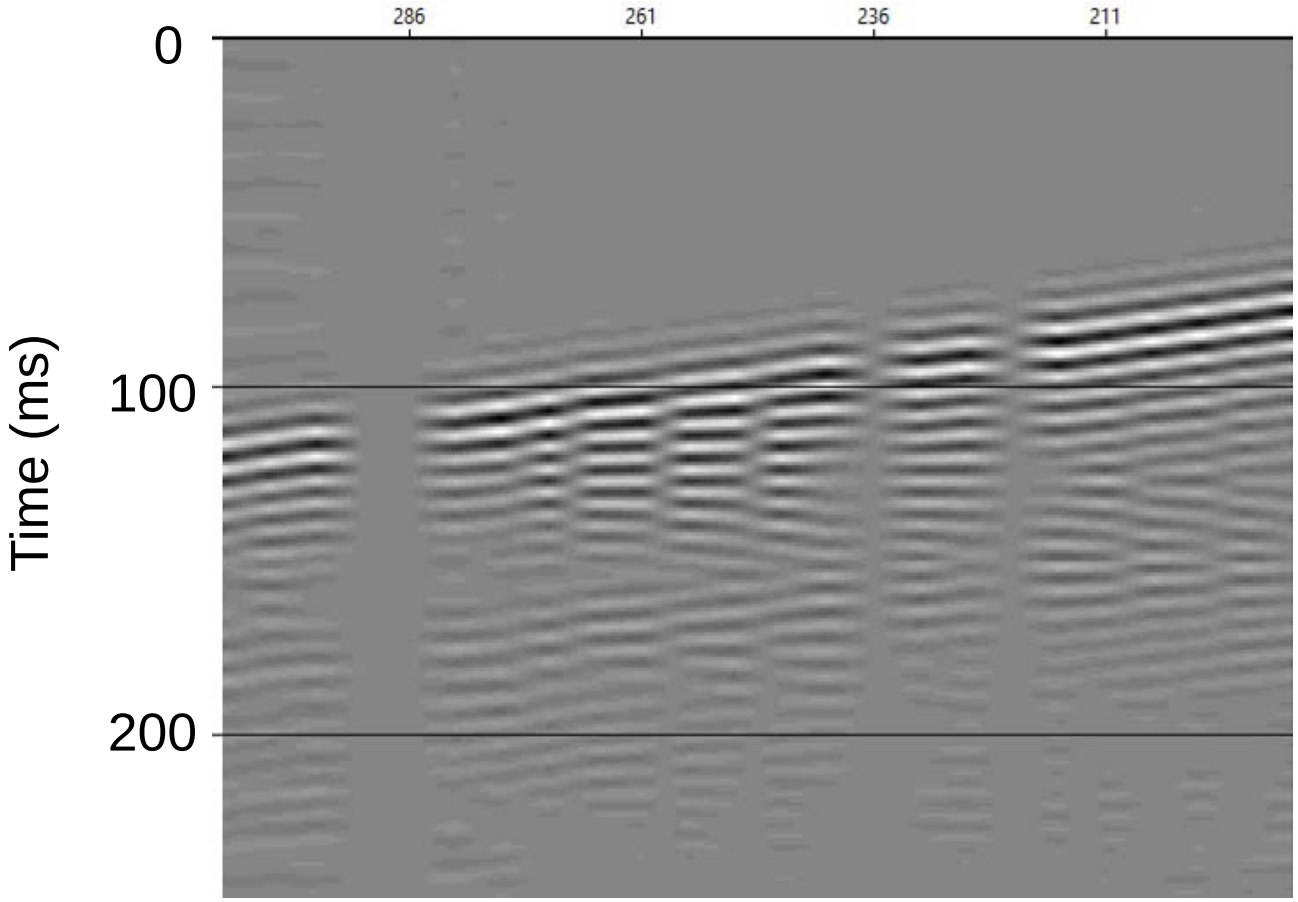
Correlation



Borehole linear vibrator data

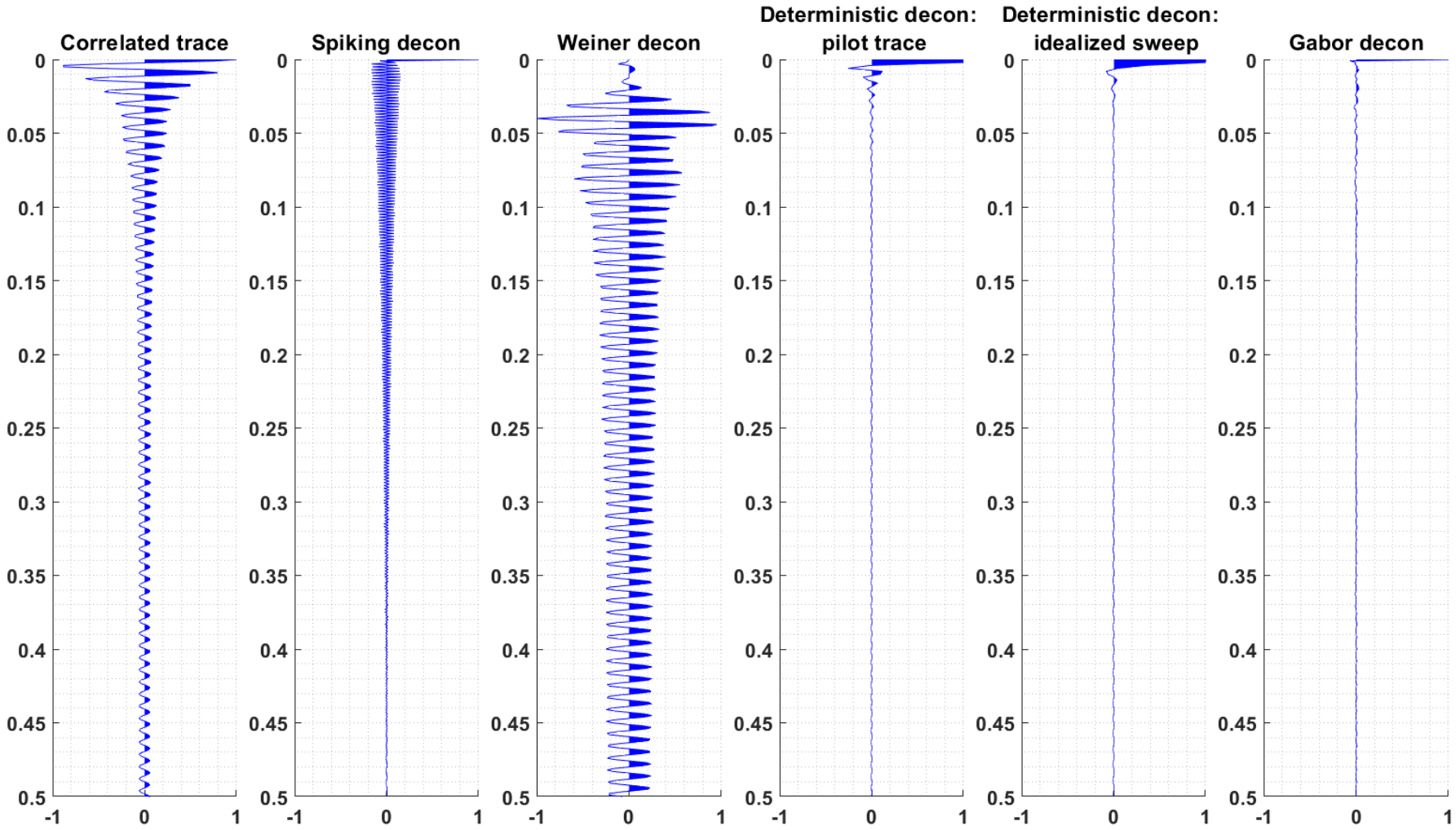


Borehole linear vibrator data

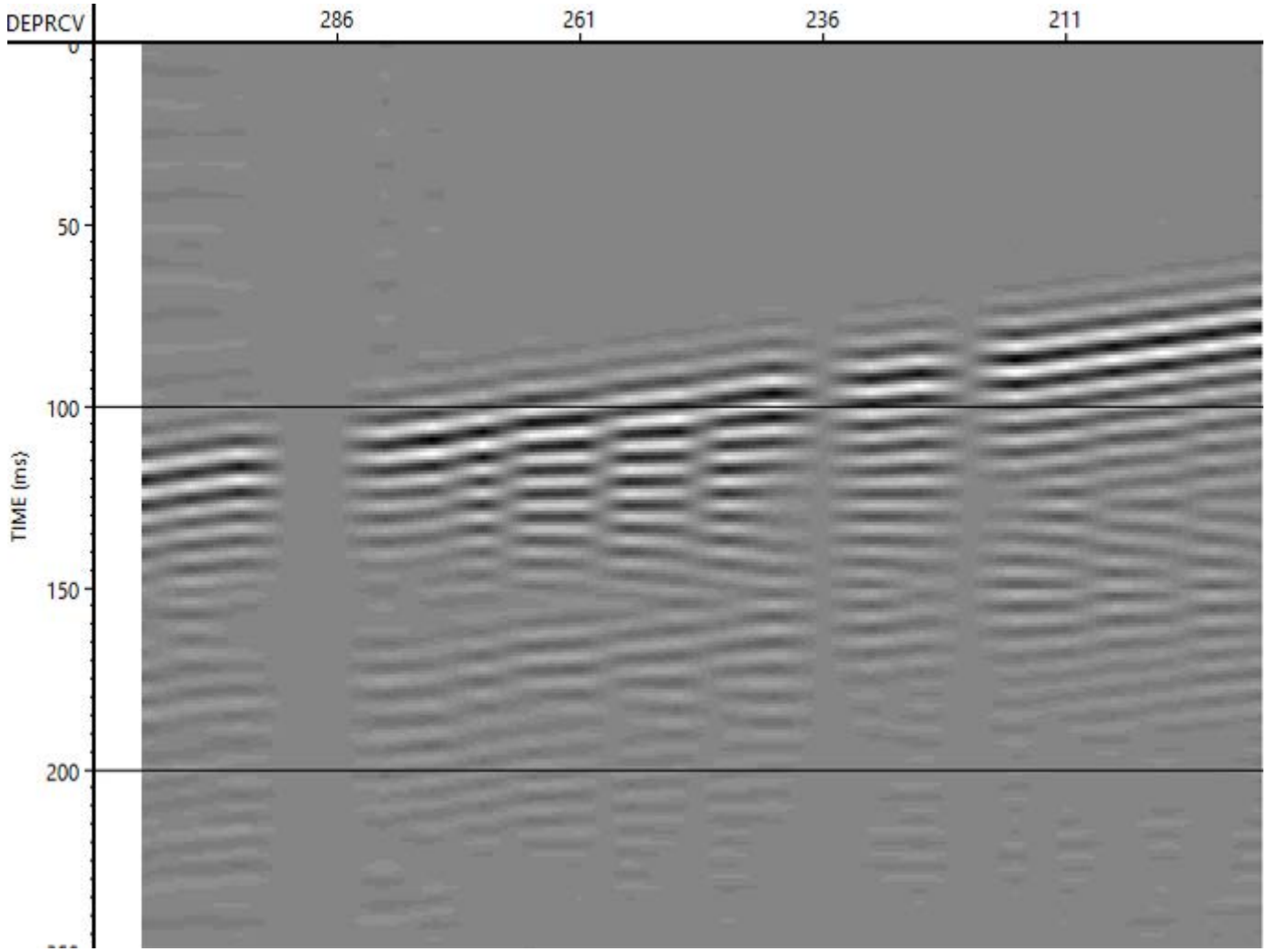


- VSP data, 0-175-0 Hz 50 sec. sweep
- Typical events recognizable
- Extremely ringy

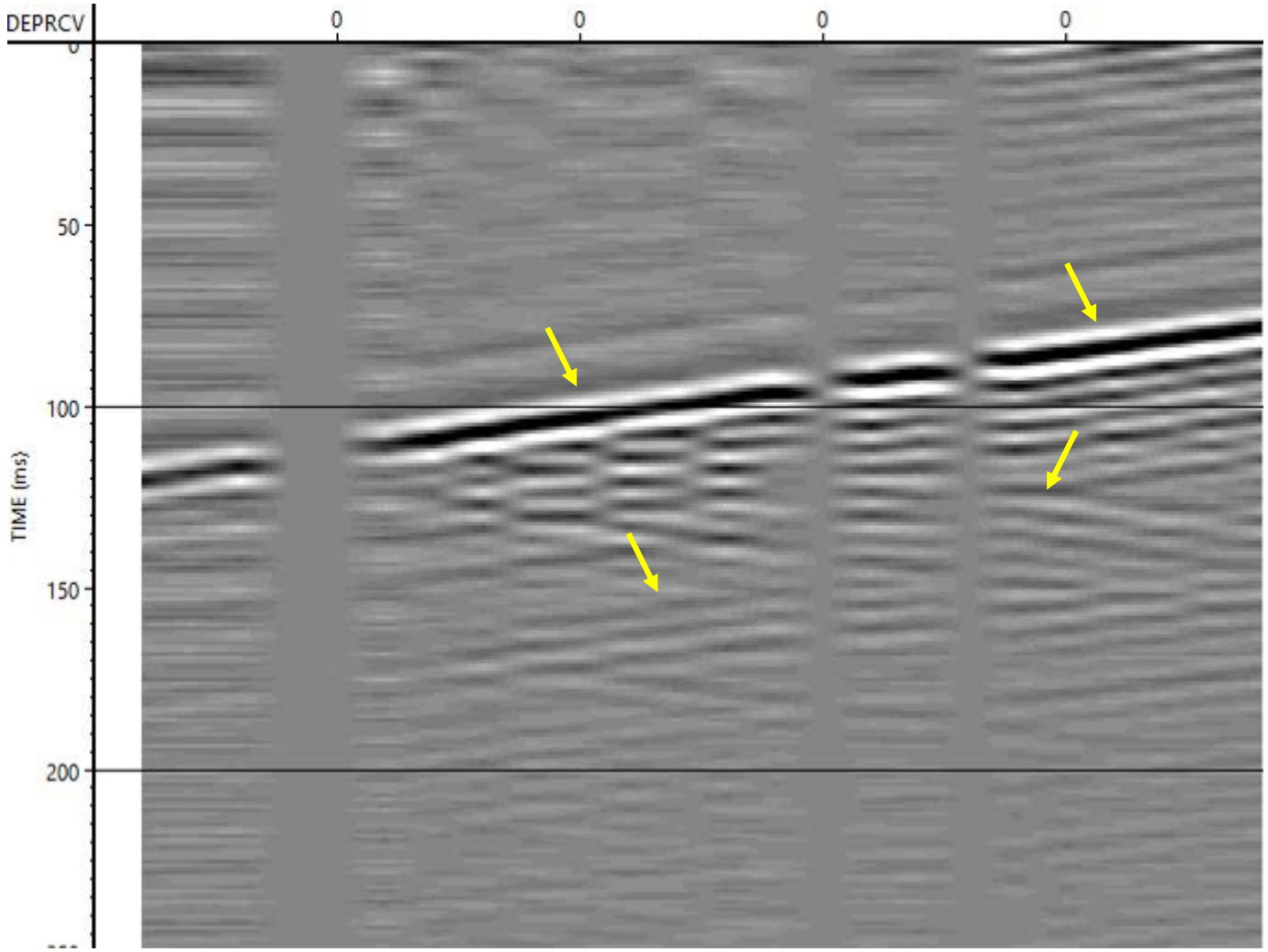
Deconvolution tests



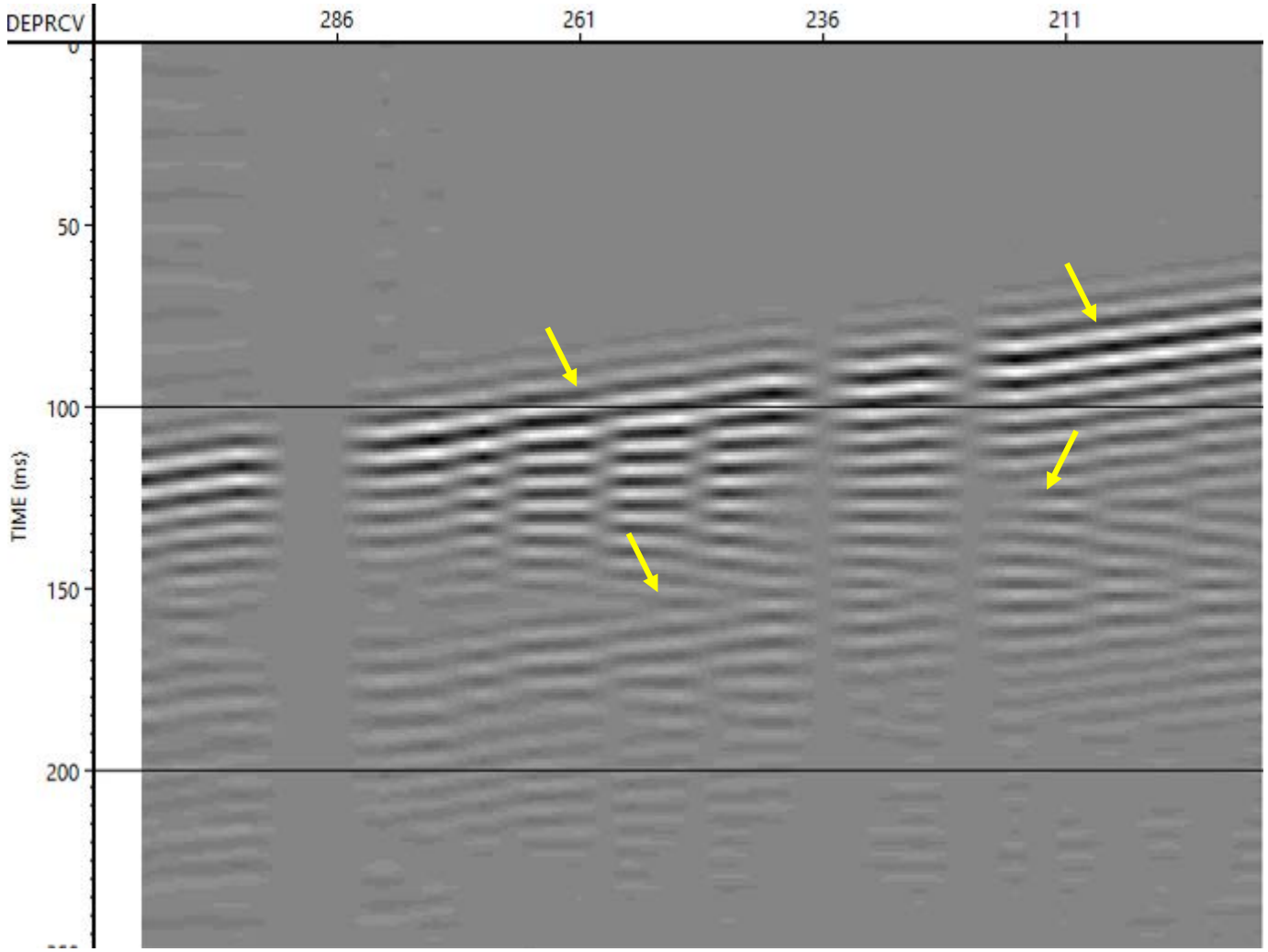
Borehole linear vibrator data – before decon



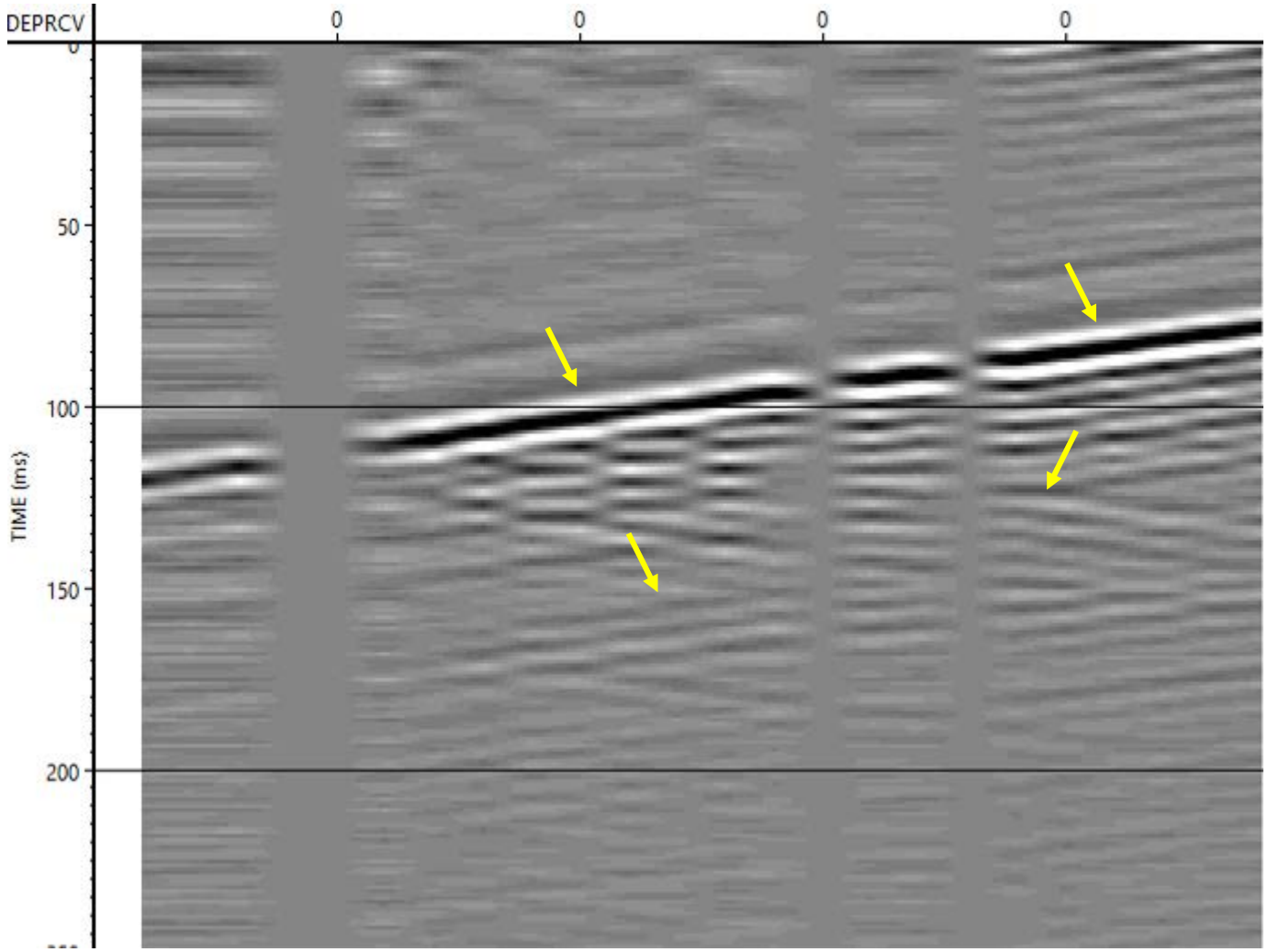
Borehole linear vibrator data – after decon



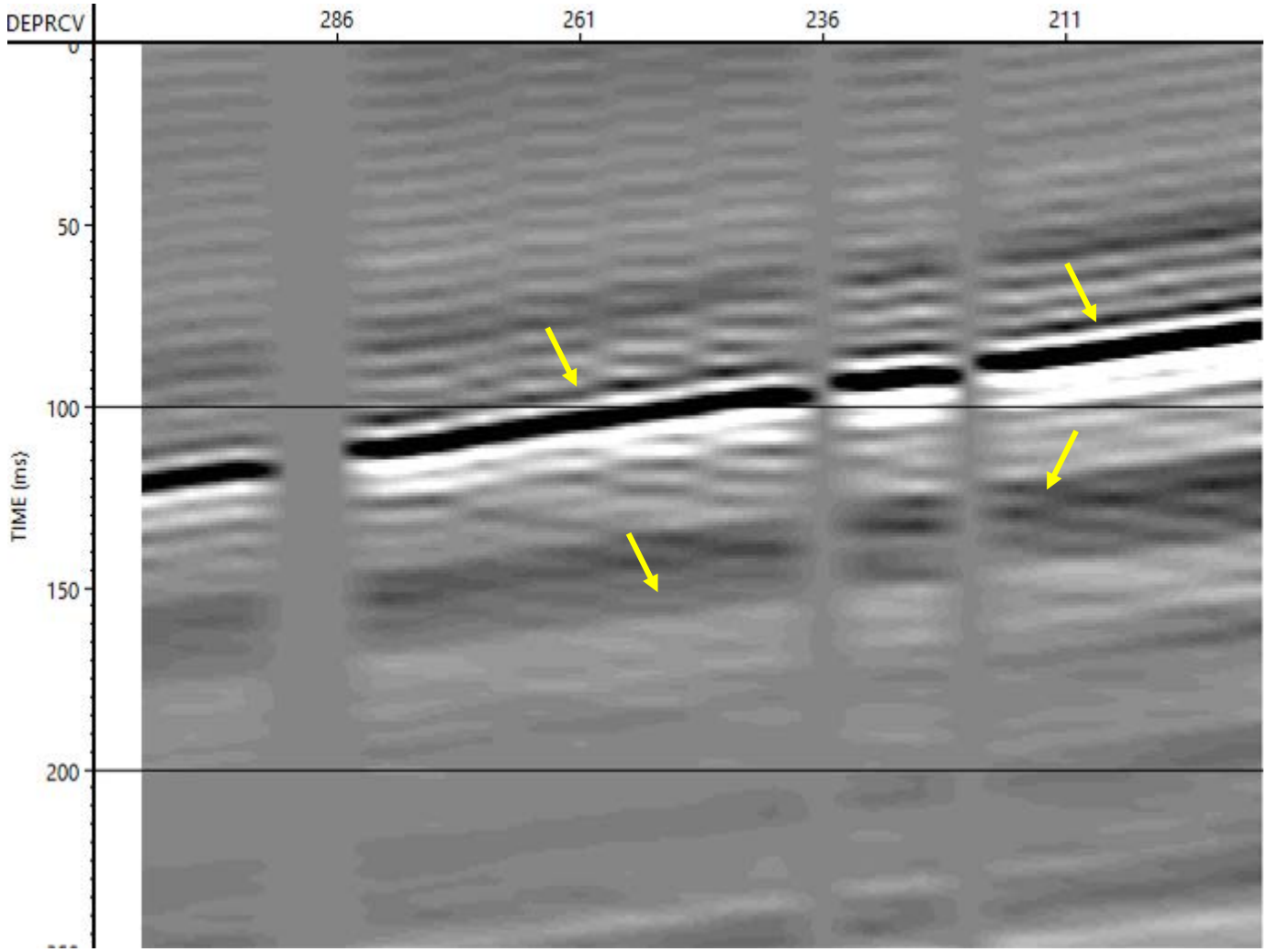
Borehole linear vibrator data – before decon



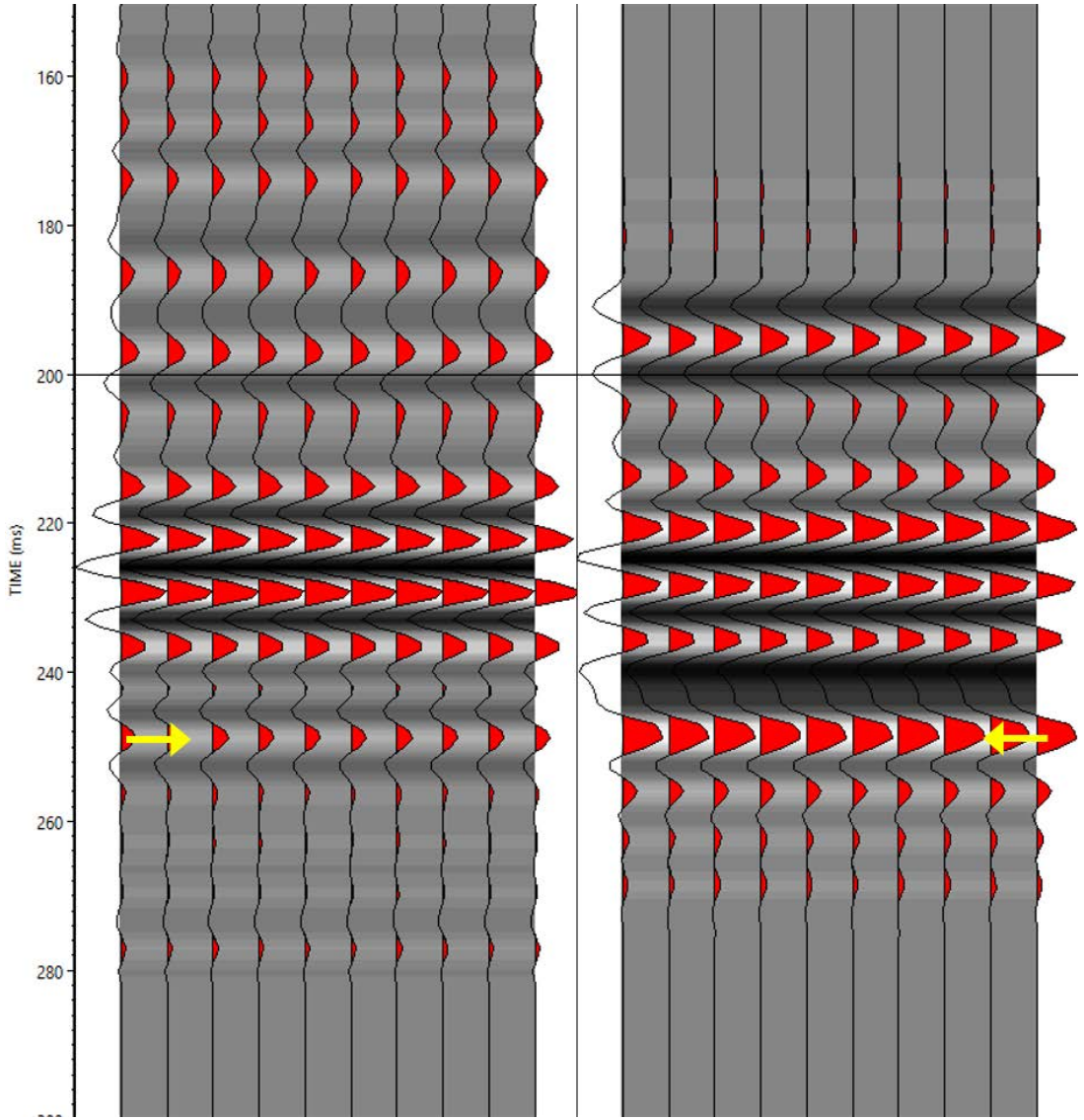
Borehole linear vibrator data – after decon



Vibroseis data – after decon



Corridor stack comparison



Corridor stacks of borehole linear vibrator (left) and Vibroseis (right) datasets.

- Borehole linear vibrator corridor stack compares well to Vibroseis corridor stack and FRS synthetic seismogram.
- Encouraging for further development of permanent sources as monitoring technique.

Conclusions

- Raw permanent source data may be correlated with pilot trace
- Application of Gabor deconvolution creates reliable datasets
  - Deterministic deconvolution may have more success if accelerometer data is available
- Resultant corridor stacks are comparable to Vibroseis

Going forward:

- Investigate effect of stacking on data quality
- Include processing of surface data
- Multiple source locations

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