

RockWave

Factor 50: a simple way to ensure you don't get burned by ultra high-resolution seismic

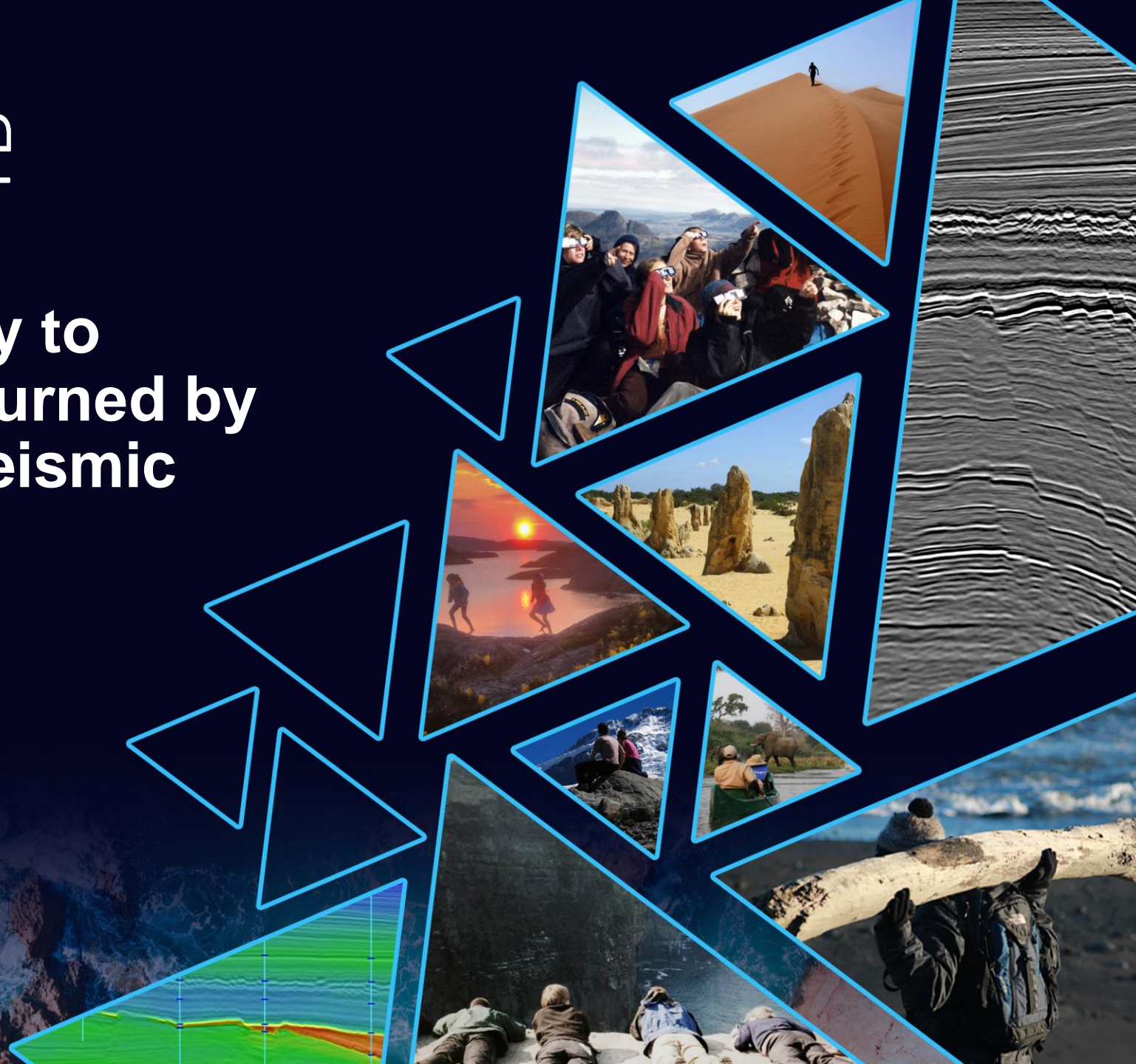
Nick Woodburn*

(RockWave)

Dave Monk

(ACTeQ)

May 2024









Factor 50

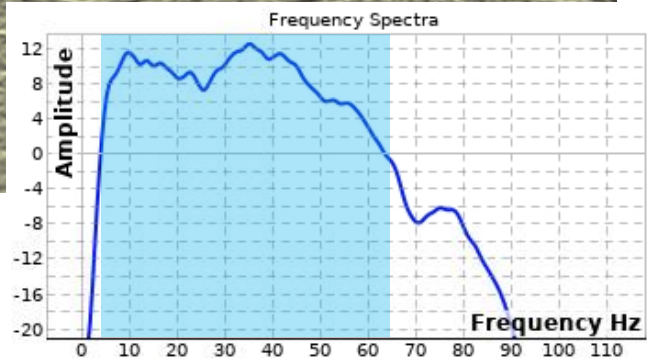
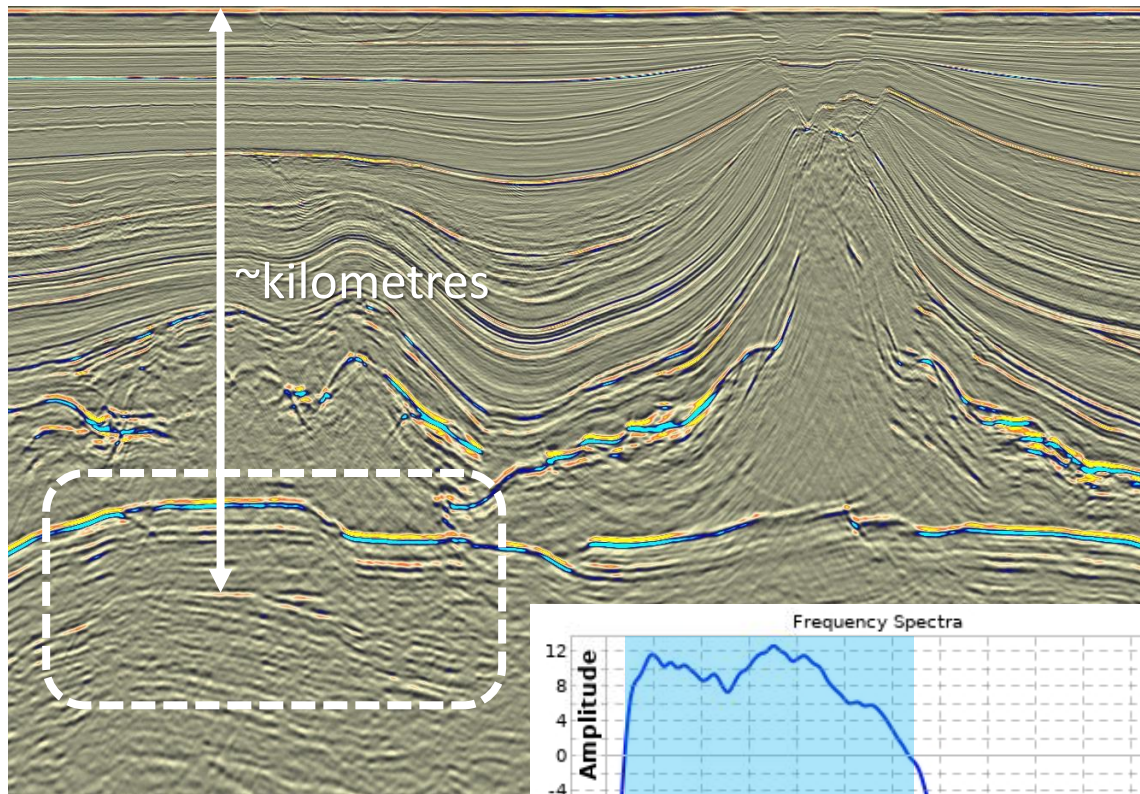
95%
recycled
bottle

A 3D seismic data visualization showing a complex geological structure. The image is a perspective view of a seismic volume, with a central vertical axis and two horizontal axes. The data is color-coded, with a prominent blue and orange layer at the top, and a purple and blue layer at the bottom. The central part of the image shows a complex, layered structure with various colors (yellow, orange, red, blue, purple) representing different geological units. The overall appearance is that of a high-resolution seismic scan of a subsurface geological formation.

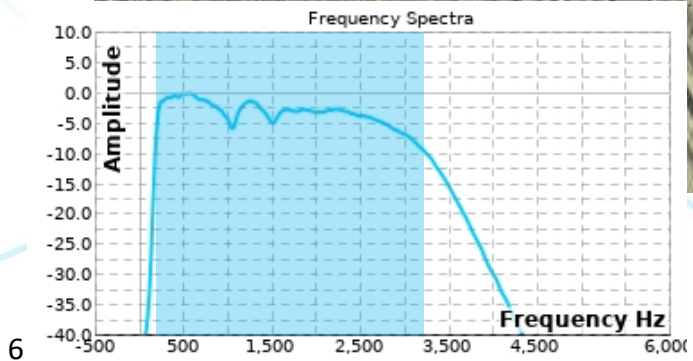
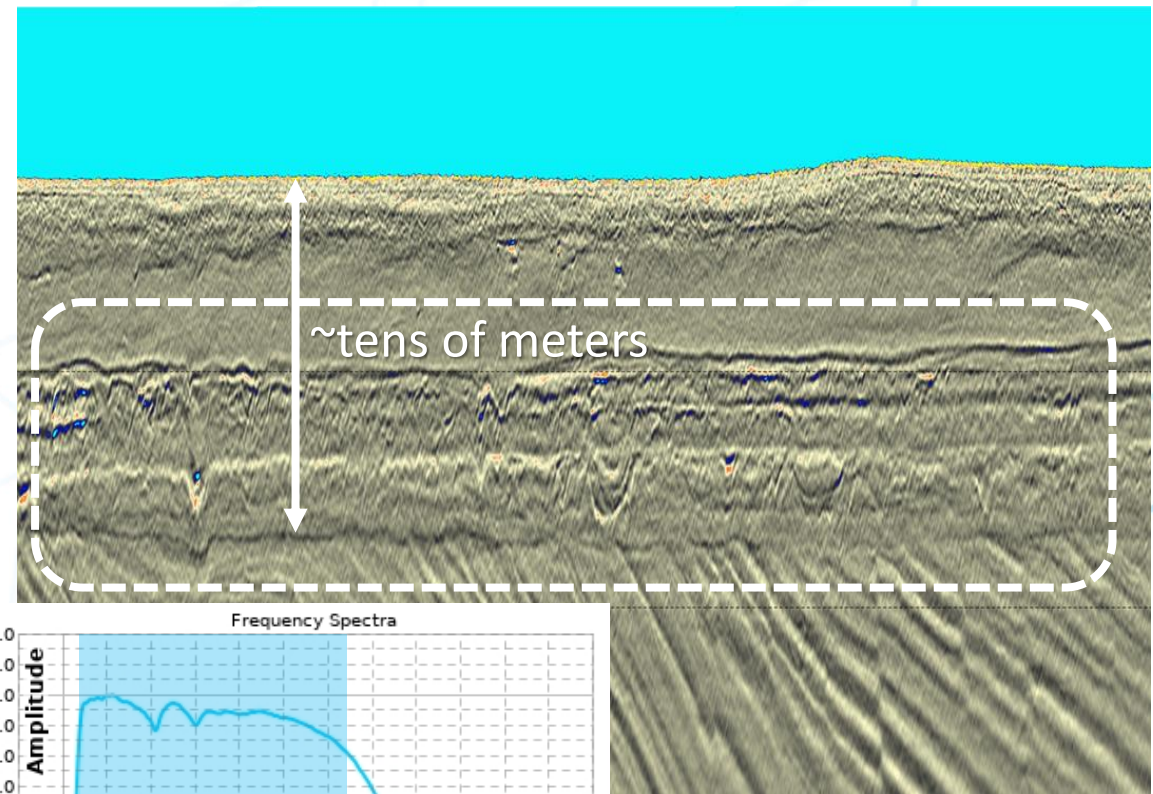
Summary:

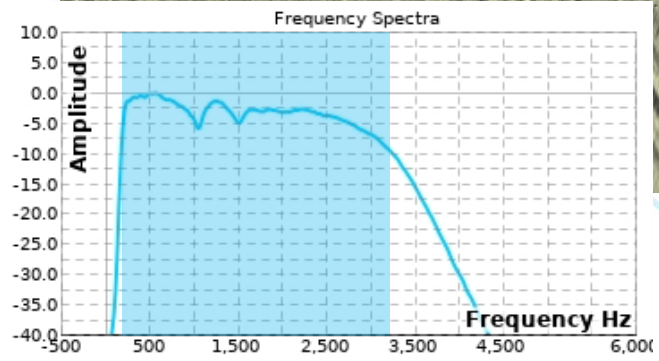
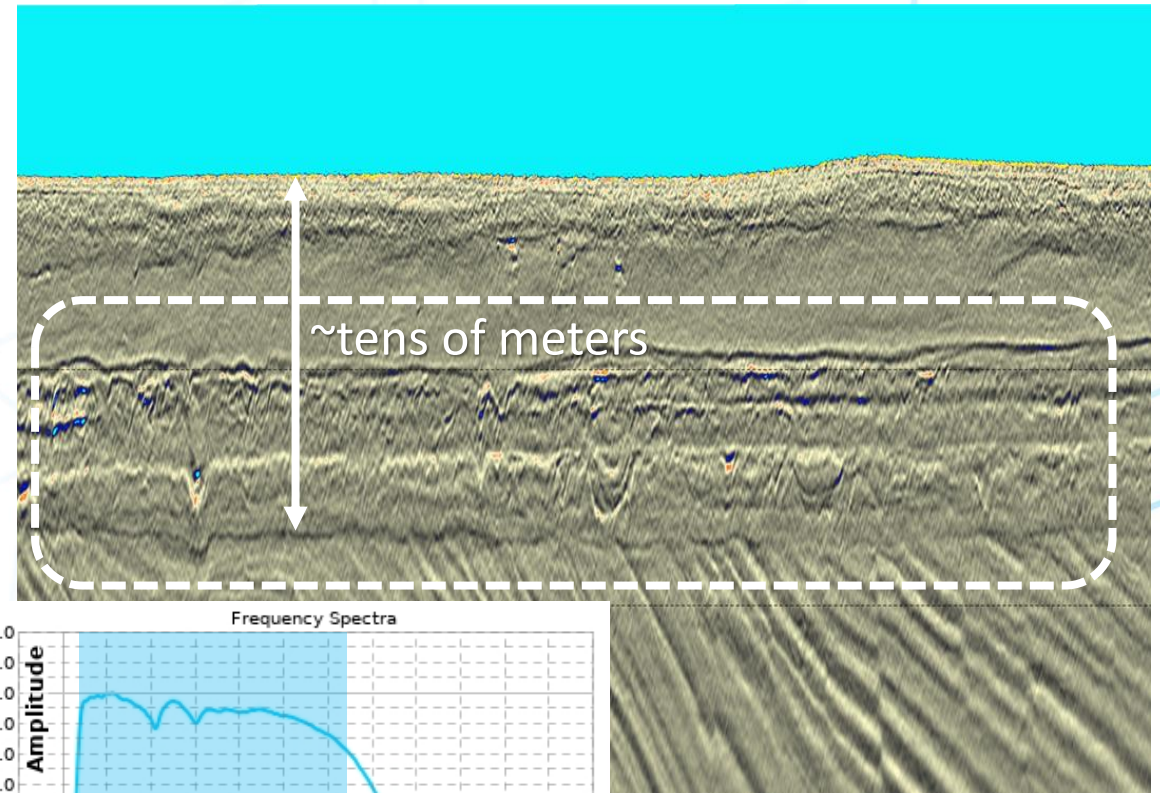
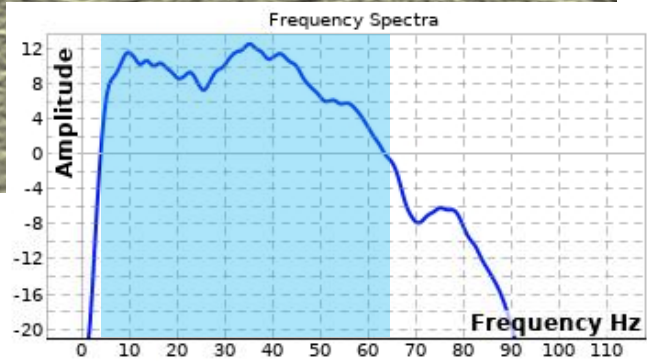
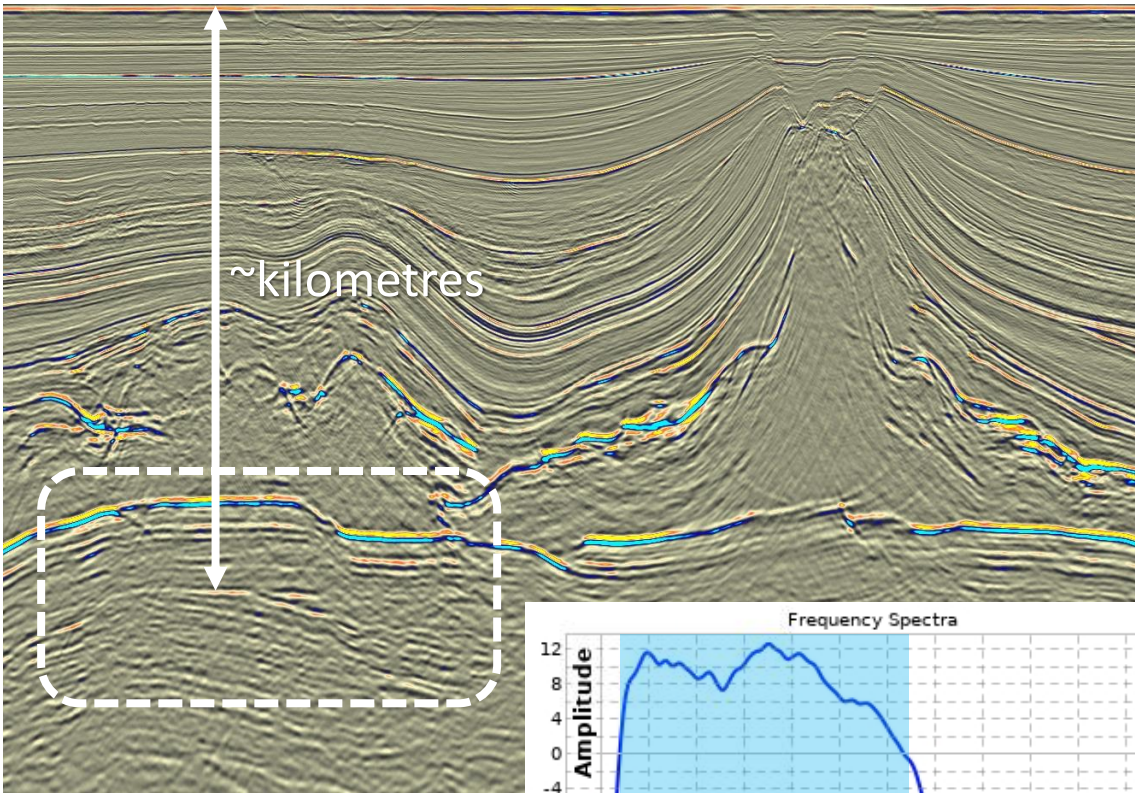
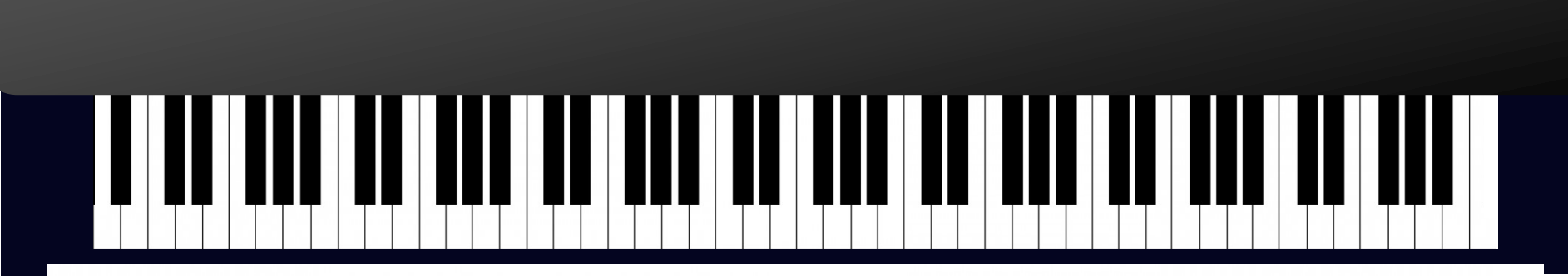
1. Introducing *Factor 50*
2. Interrogate the 3D ultra high-res seismic (UHRS) experiment
(Implications for seismic processing)
3. Implications for seismic interpretation
4. Conclusions

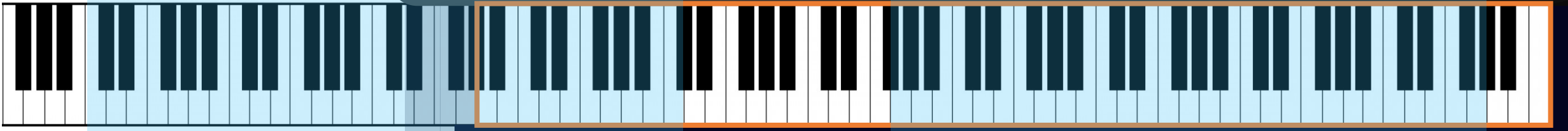
'Conventional' seismic



Ultra high-resolution seismic





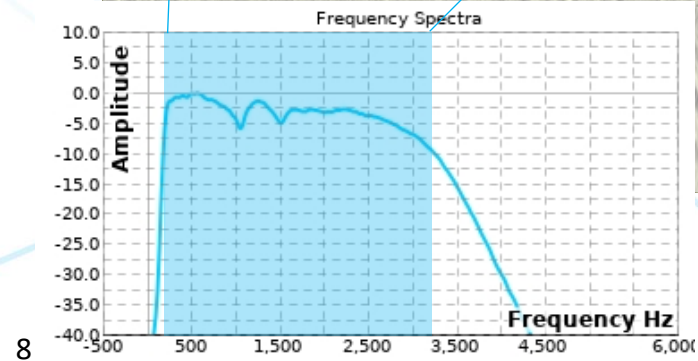
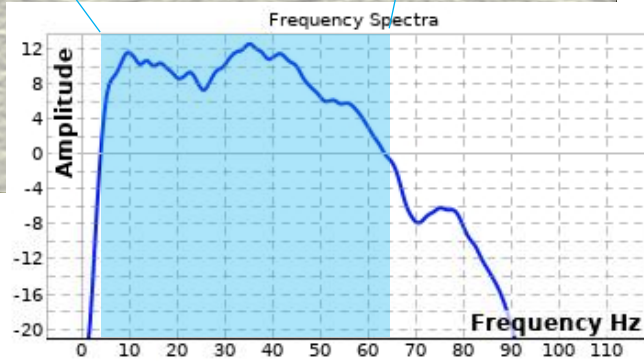
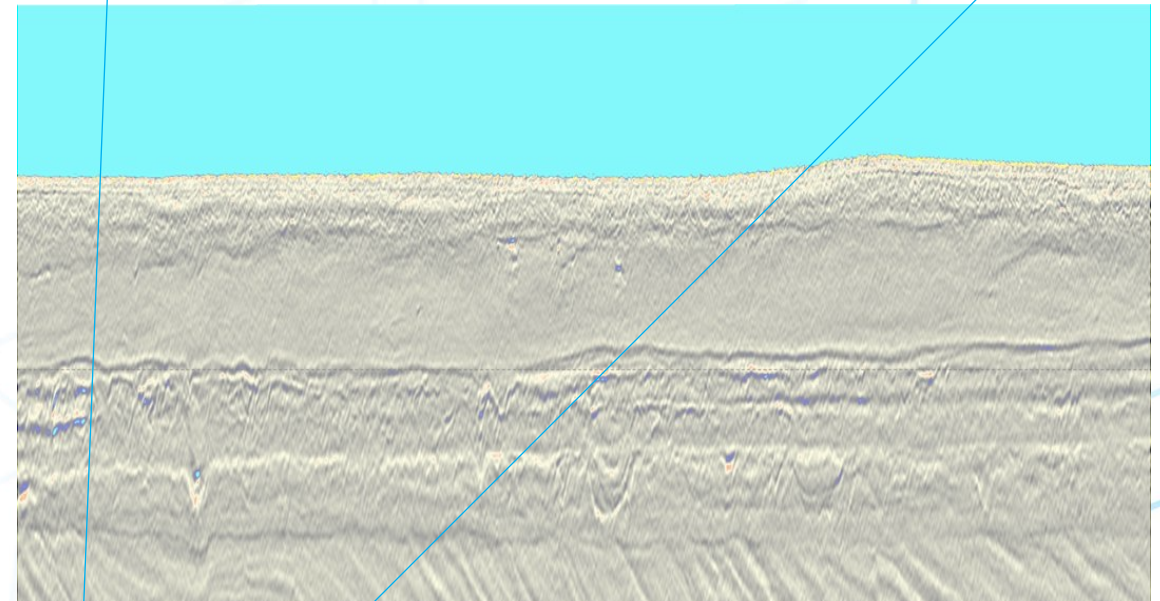
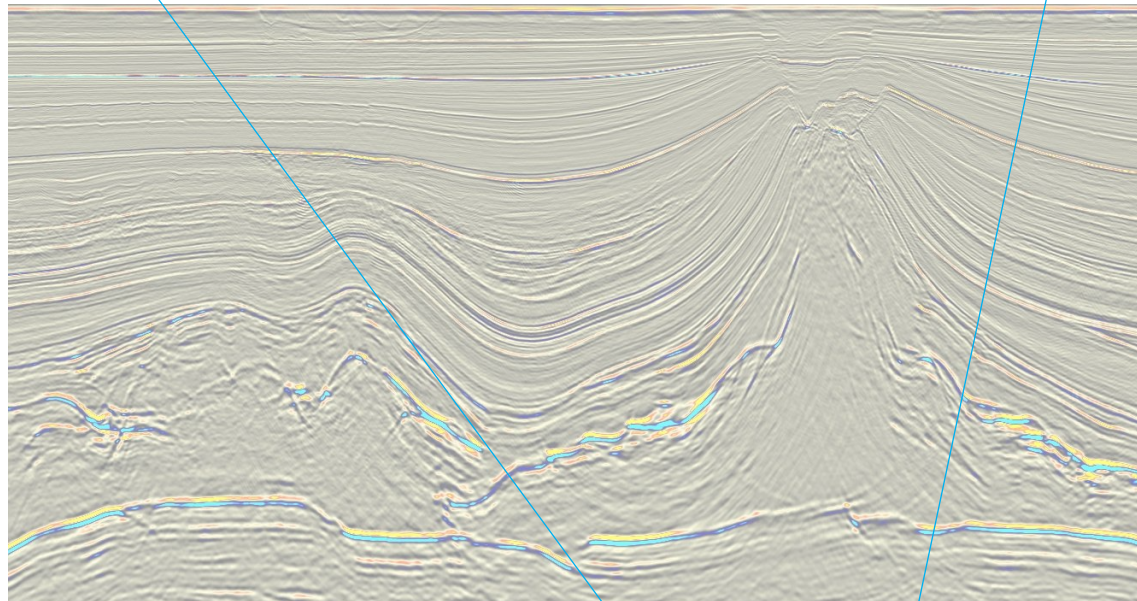


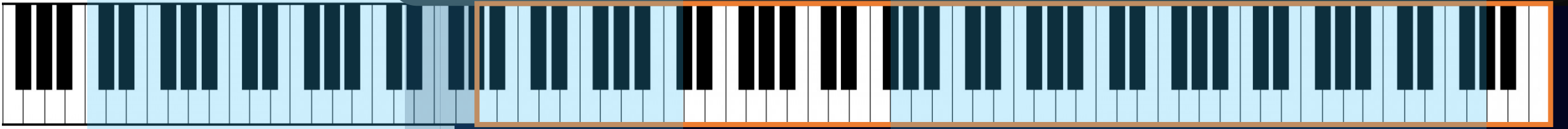
4 Hz

64 Hz

200 Hz

3,200 Hz





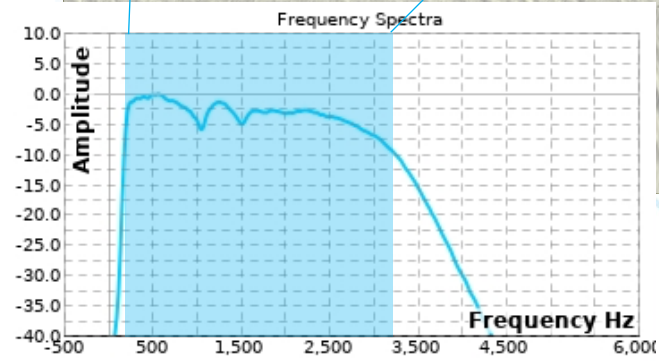
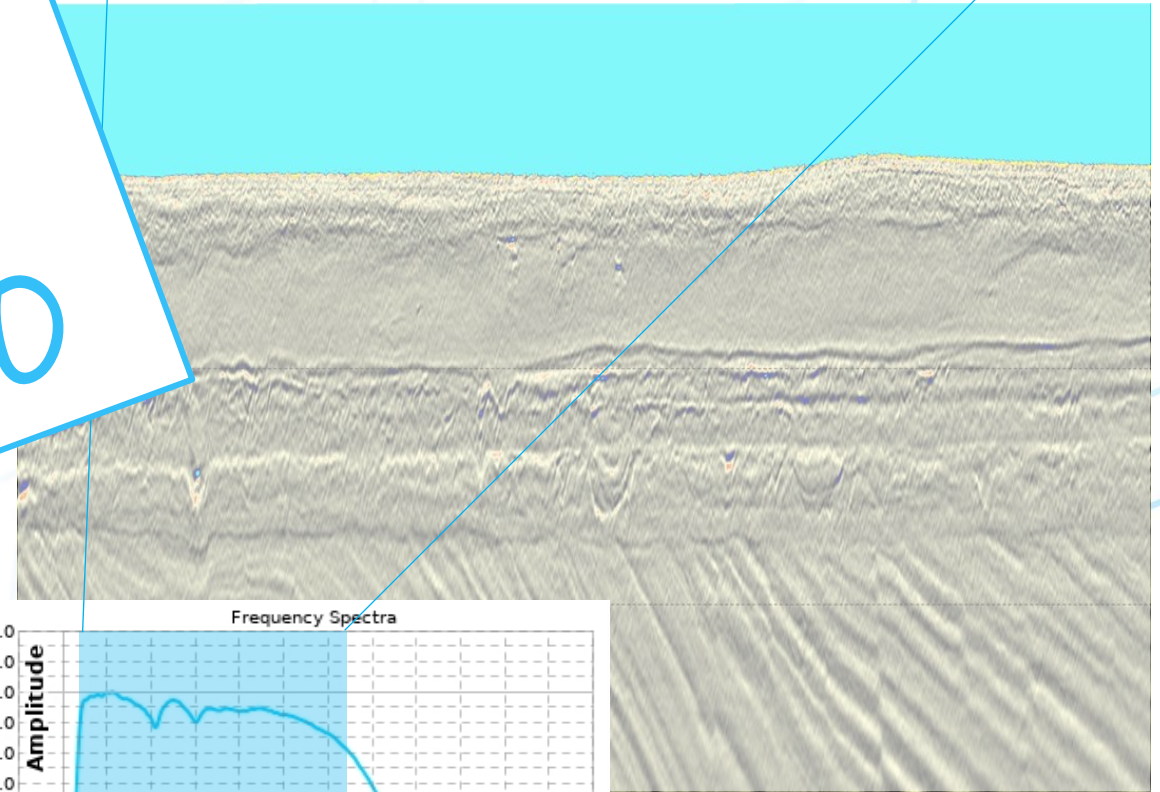
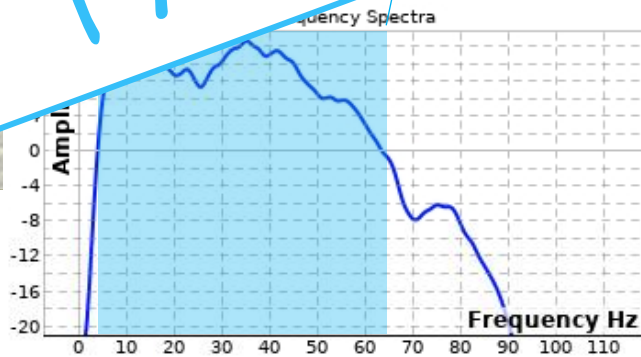
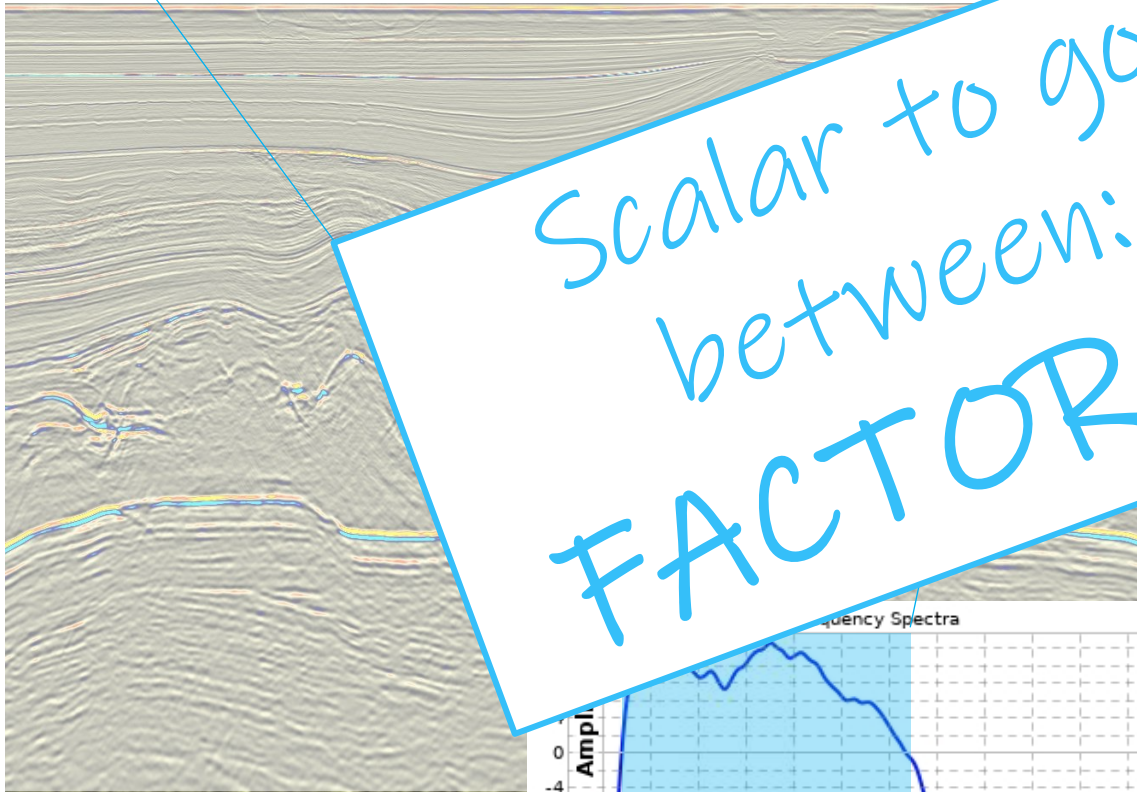
4 Hz

64 Hz

200 Hz

3,200 Hz

Scalar to go
between:
FACTOR 50





4 Hz

64 Hz

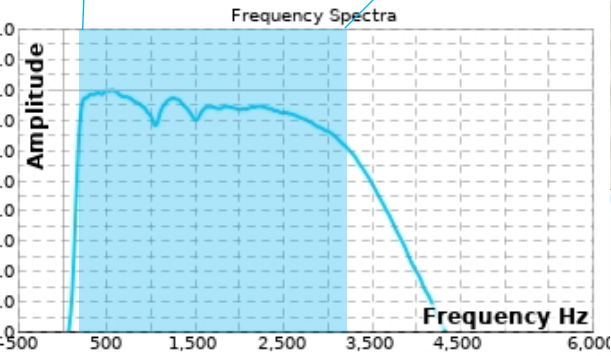
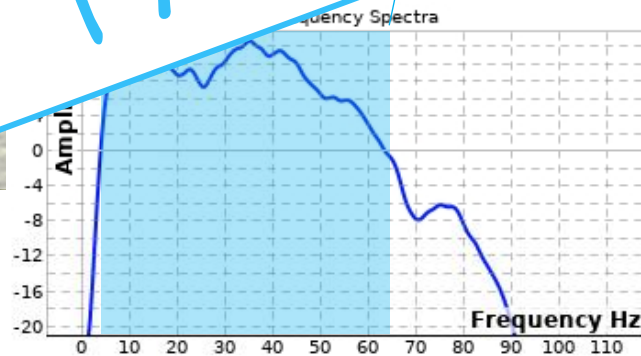
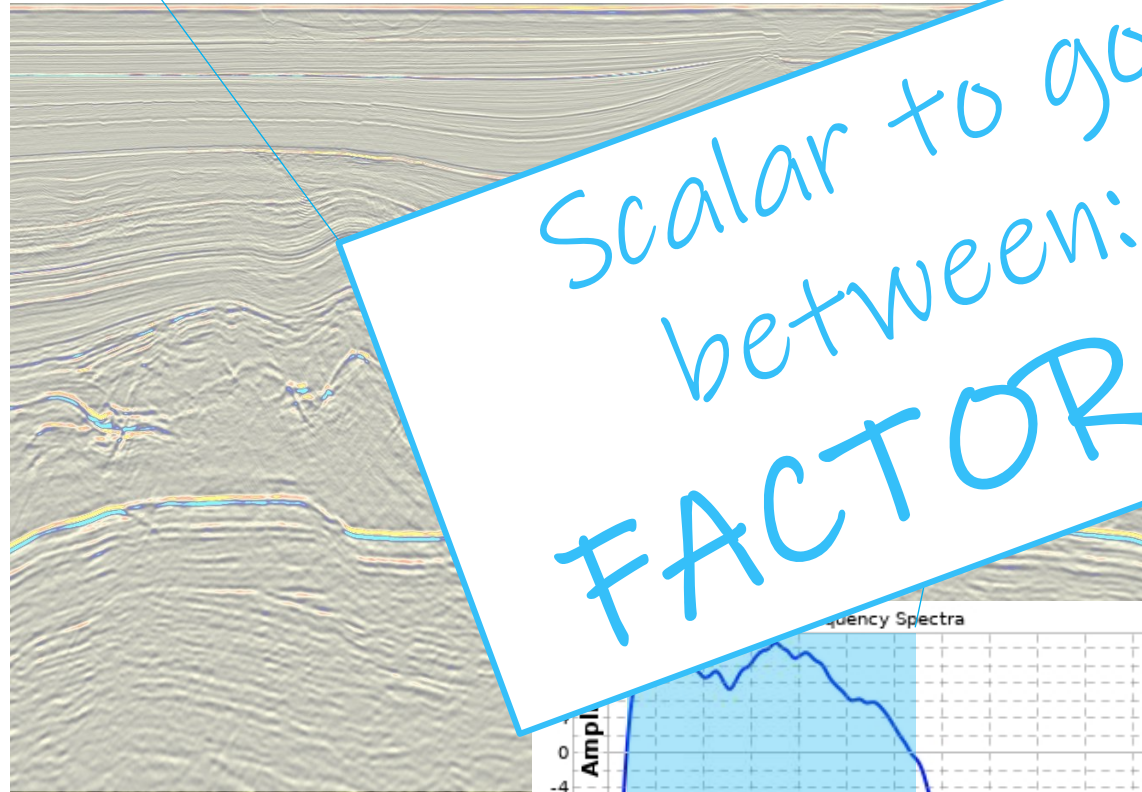
200 Hz

3,200 Hz

Scalar to go
between:
FACTOR 50

Applicable to:

- a) the spatial and temporal dimensions of the recorded UHRS,
- b) the apparatus used to acquire the seismic, and
- c) the environmental conditions encountered in the field

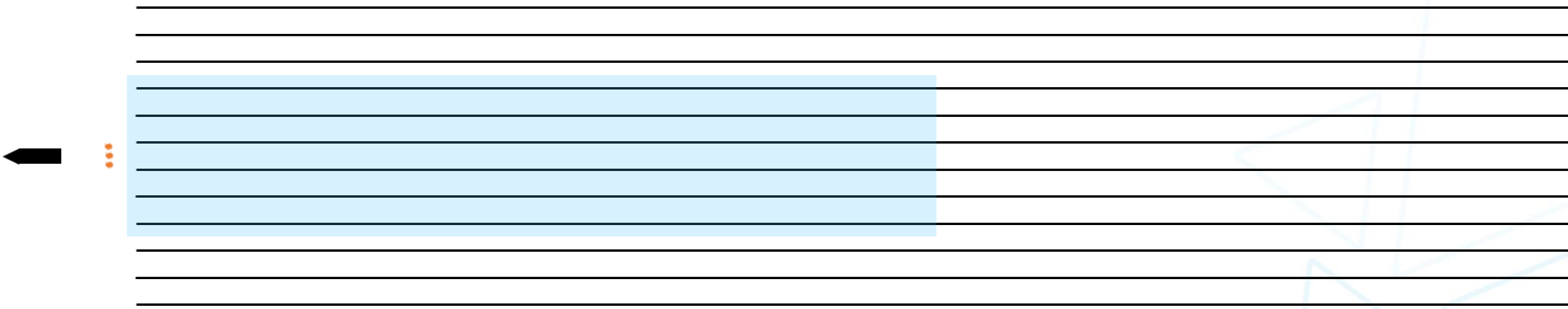


A 3D seismic data visualization showing a complex geological structure. The image is a perspective view of a seismic volume, with a central vertical axis and two horizontal axes. The data is color-coded, with a prominent blue and orange layer at the top, and a large purple and blue region at the bottom. The seismic data is represented by a series of wavy, layered patterns. A semi-transparent white box is overlaid on the left side of the image, containing a list of four items. The background is a dark, textured surface.

Summary:

1. Introducing *Factor 50*
2. Interrogate the 3D ultra high-res seismic (UHRS) experiment
(Implications for seismic processing)
3. Implications for seismic interpretation
4. Conclusions

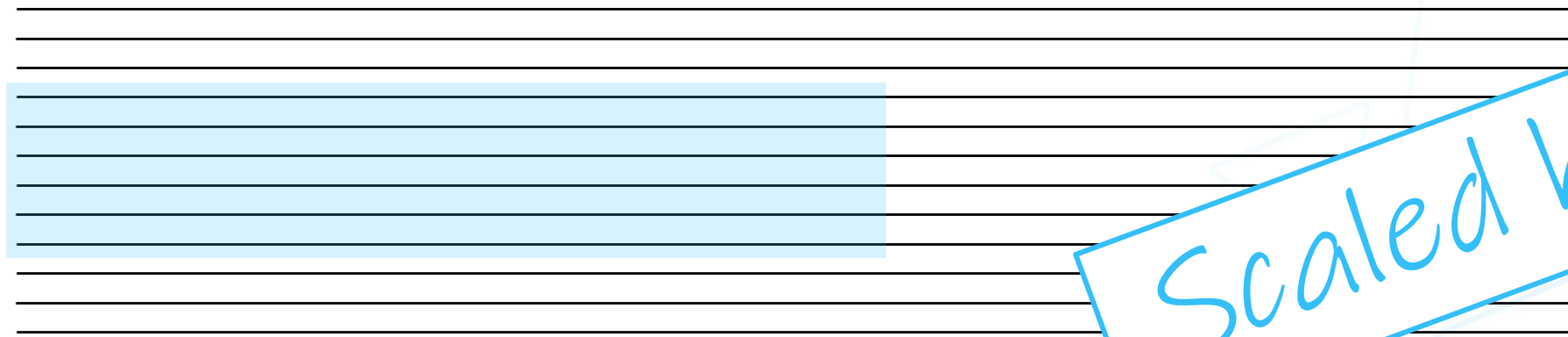
'Conventional' 12-streamer 3D seismic acquisition set-up



Conventional NAZ spec:

| | | | |
|-------------------|-------|---------------------|--------------|
| Cable length | 8000m | Triple source | |
| Cable spacing | 150m | Shot point interval | 18.7m |
| Channel spacing | 12.5m | Source depth | 7m |
| Cable depth | 9m | Source array length | 8m |
| Near trace offset | 150m | Bin size (il x cl) | 6.25 x 12.5m |
| Sample rate | 2ms | Sub-surf footprint | 4000 x 825m |

'Conventional' 12-streamer 3D seismic acquisition set-up



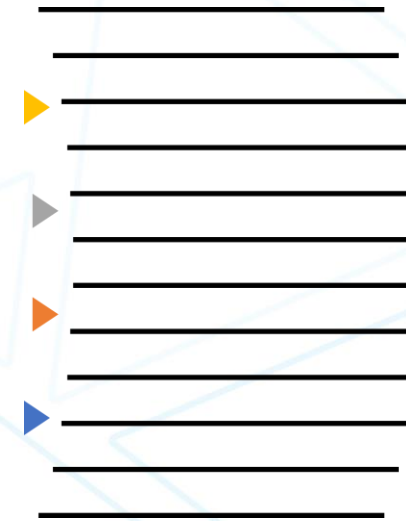
Conventional NAZ spec:

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| Near trace offset | 150m | Bin size (il x cl) | 6.25 x 12.5m |
| Sample rate | 2ms | Sub-surf footprint | 4000 x 825m |

Scaled by 50 for equivalent UHRS spec:

| | | | |
|-------------------|--------|---------------------|---------------|
| Cable length | 160m | Triple source | |
| Cable spacing | 3m | Shot point interval | 0.38m |
| Channel spacing | 0.25m | Source depth | 0.14m |
| Cable depth | 0.18m | Source array length | 0.16m |
| Near trace offset | 3m | Bin size (il x cl) | 0.125 x 0.25m |
| Sample rate | 0.04ms | Sub-surf footprint | 80 x 16.5m |

Cost-effective 3D UHRS 12-streamer acquisition set-up



Actual cost-effective UHRS spec:

| | | | |
|-------------------|---------|---------------------|---------------|
| Cable length | 75m | Quad source | |
| Cable spacing | 12.5m | Shot point interval | 0.78m |
| Channel spacing | 1.56m | Source depth | n/a |
| Cable depth | 2m | Source array length | 1.8m |
| Near trace offset | 2m | Bin size (il x cl) | 0.78 x 1.56m |
| Sample rate | 0.125ms | Sub-surf footprint | 35 x 110.93m* |

*includes missing bins; swath move-up can be 89.06m

Cost-effective 3D UHRS 12-streamer acquisition set-up

Scaled by 50



Scaled by 50 for equivalent 'conventional' data spec

Actual cost-effective UHRS spec:

| | | | |
|-------------------|--------|---------------------|-------------------|
| Cable length | 3,750m | Quad source | |
| Cable spacing | 625m | Shot point interval | 39.1m |
| Channel spacing | 78.13m | Source depth | n/a |
| Cable depth | 100m | Source array length | 90 |
| Near trace offset | 100m | Bin size (il x cl) | 39.1 x 78.1m |
| Sample rate | 6.25ms | Sub-surf footprint | 1,750 x 5,546.8m* |

| | | | |
|-------------------|---------|---------------------|---------------|
| Cable length | 75m | Quad source | |
| Cable spacing | 12.5m | Shot point interval | 0.78m |
| Channel spacing | 1.56m | Source depth | n/a |
| Cable depth | 2m | Source array length | 1.8m |
| Near trace offset | 2m | Bin size (il x cl) | 0.78 x 1.56m |
| Sample rate | 0.125ms | Sub-surf footprint | 35 x 110.93m* |

*includes missing bins; swath move-up can be 89.06m

Cost-effective 3D UHRS 12-streamer acquisition set-up

Scaled by 50

But my linear noise will be aliased above 10Hz!

Scaled by 50 for equivalent 'conventional' data spec

Actual cost-effective spec:

| | | | |
|-------------------|--------|---------------------|-------------------|
| Cable length | 3,750m | Quad source | |
| Cable spacing | 625m | Shot point interval | 39.1m |
| Channel spacing | 78.13m | Source depth | n/a |
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| Near trace offset | 100m | Bin size (il x cl) | 39.1 x 78.1m |
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| | | | |
|-------------------|---------|---------------------|---------------|
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| Cable depth | 2m | Bin size (il x cl) | 39.1 x 1.56m |
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| Sample rate | 0.125ms | | |

*includes missing bins; swath move-up can be 89.06m



Cost-effective 3D UHRS 12-streamer acquisition set-up

Scaled by 50

You want me to deghost data with a cable this deep!

Scaled by 50 for equivalent 'conventional' data spec

Actual cost-effective:

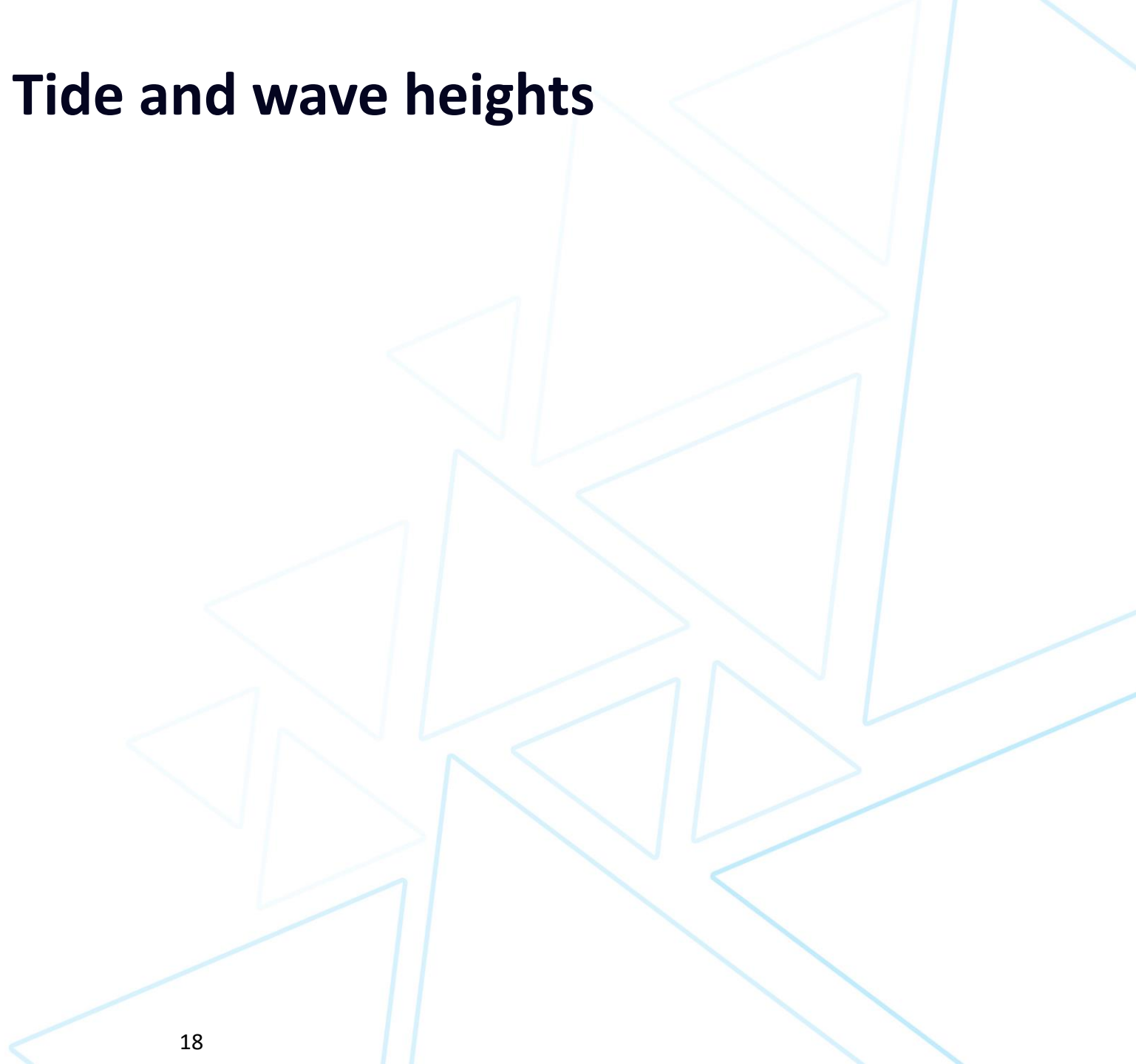
| | | | |
|-------------------|--------|---------------------|-------------------|
| Cable length | 3,750m | Quad source | |
| Cable spacing | 625m | Shot point interval | 39.1m |
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| Cable depth | 100m | Source array length | 90 |
| Near trace offset | 100m | Bin size (il x cl) | 39.1 x 78.1m |
| Sample rate | 6.25ms | Sub-surf footprint | 1,750 x 5,546.8m* |

| | | | |
|-------------------|---------|--------------------|---------------|
| Cable length | 75m | | |
| Cable spacing | 12.5m | | 0.78m |
| Channel spacing | 1.56m | | n/a |
| Cable depth | 2m | | 1.8m |
| Near trace offset | 2m | | 0.78 x 1.56m |
| Sample rate | 0.125ms | Sub-surf footprint | 35 x 110.93m* |

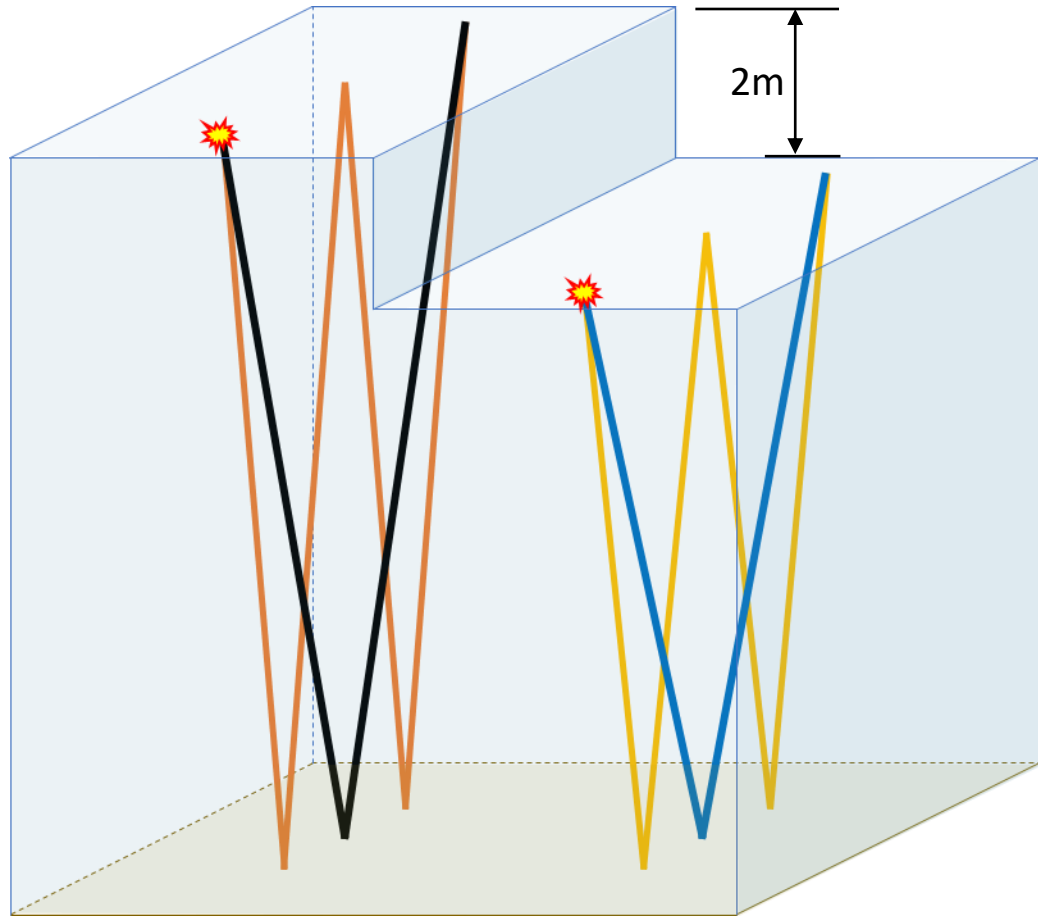
*includes missing bins; swath move-up can be 89.06m



Environmental conditions: Tide and wave heights

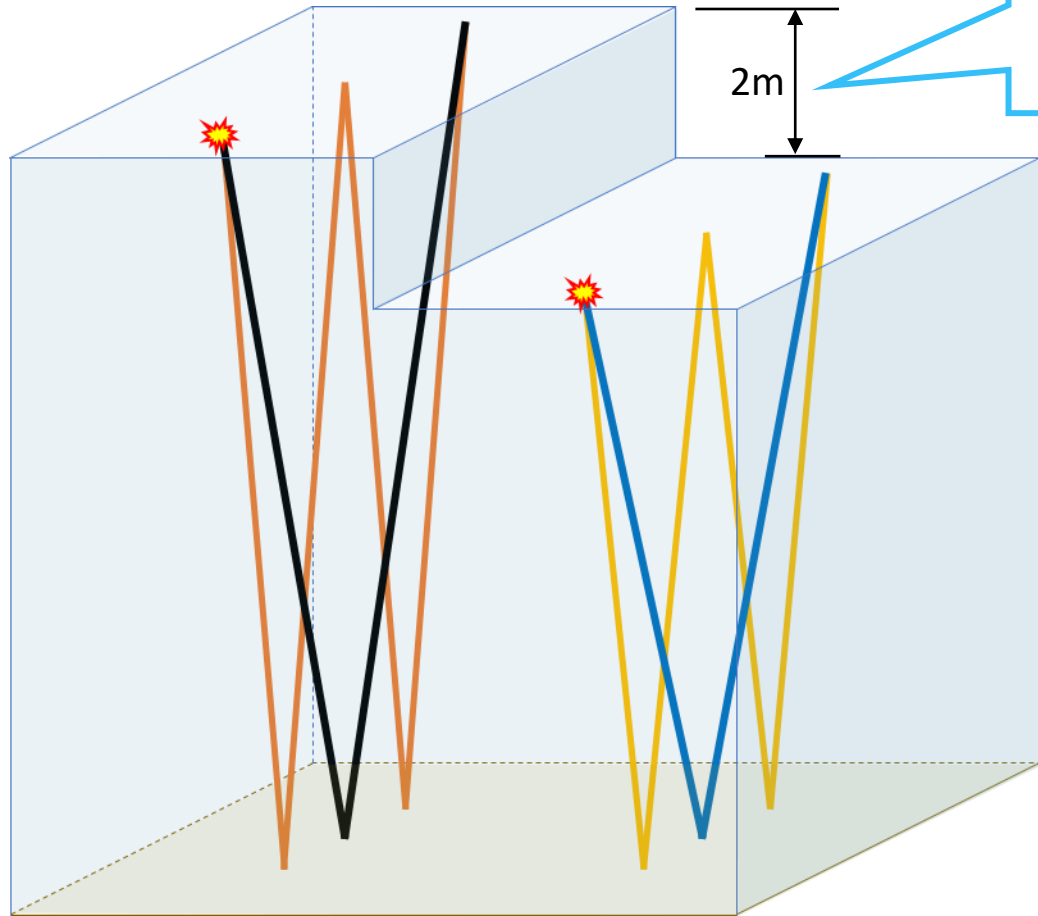


Environmental conditions: Tide and wave heights



Environmental conditions: Tide and wave heights

Scaled by 50

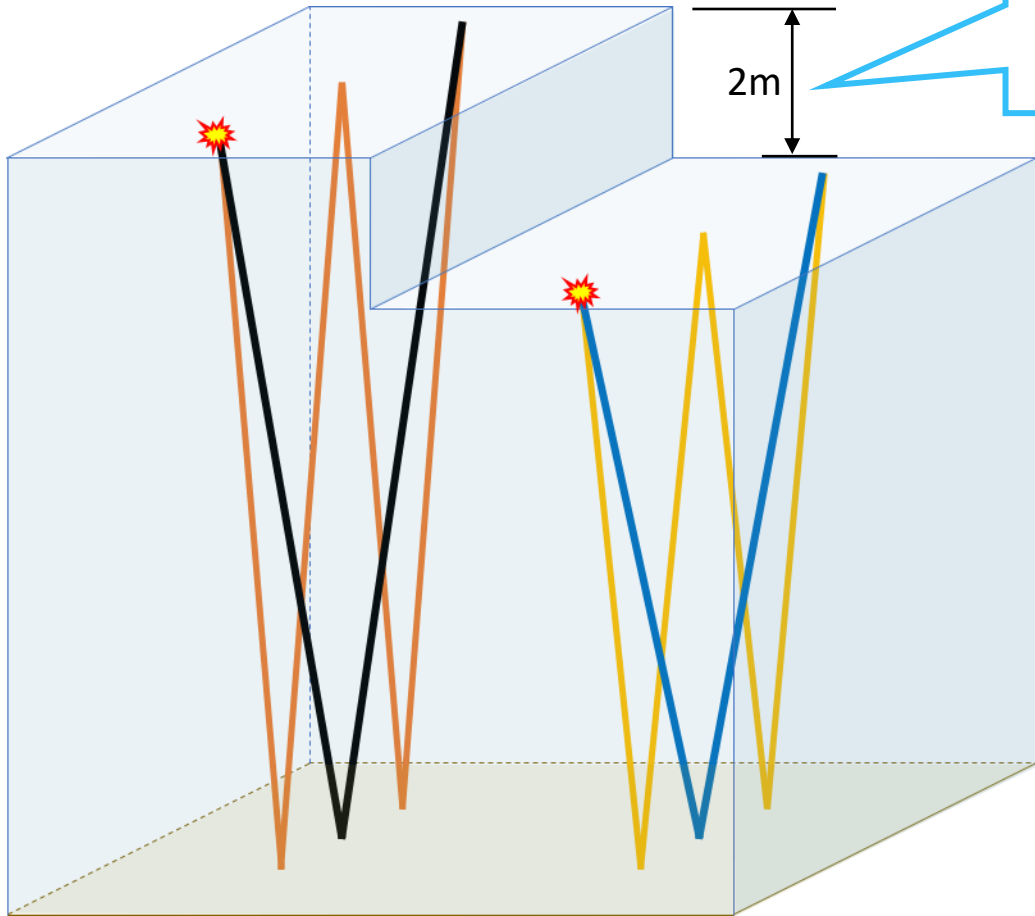


Tidal range of 2m in UHRS would be the equivalent of **100m** in conventional 3D seismic

Environmental conditions: Tide and wave heights

Scaled by 50

Tidal range of 2m in UHRS would be the equivalent of **100m** in conventional 3D seismic



What does this mean for building, and subtracting, 3D SRME models

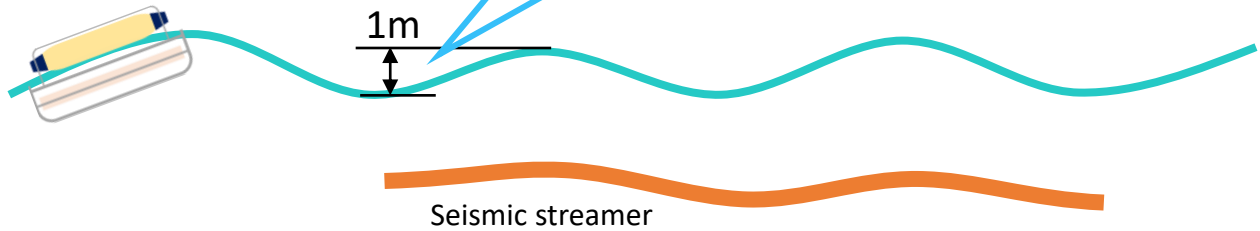


Environmental conditions: Tide and wave heights

Scaled by 50

Wave height of 1m would be the equivalent of **50m** in 'conventional' 3D seismic!

Sparker source

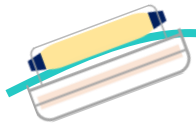


Environmental conditions: Tide and wave heights

Scaled by 50

Wave height of 1m would be the equivalent of 50m in 'conventional' 3D seismic!

Sparker source



1m



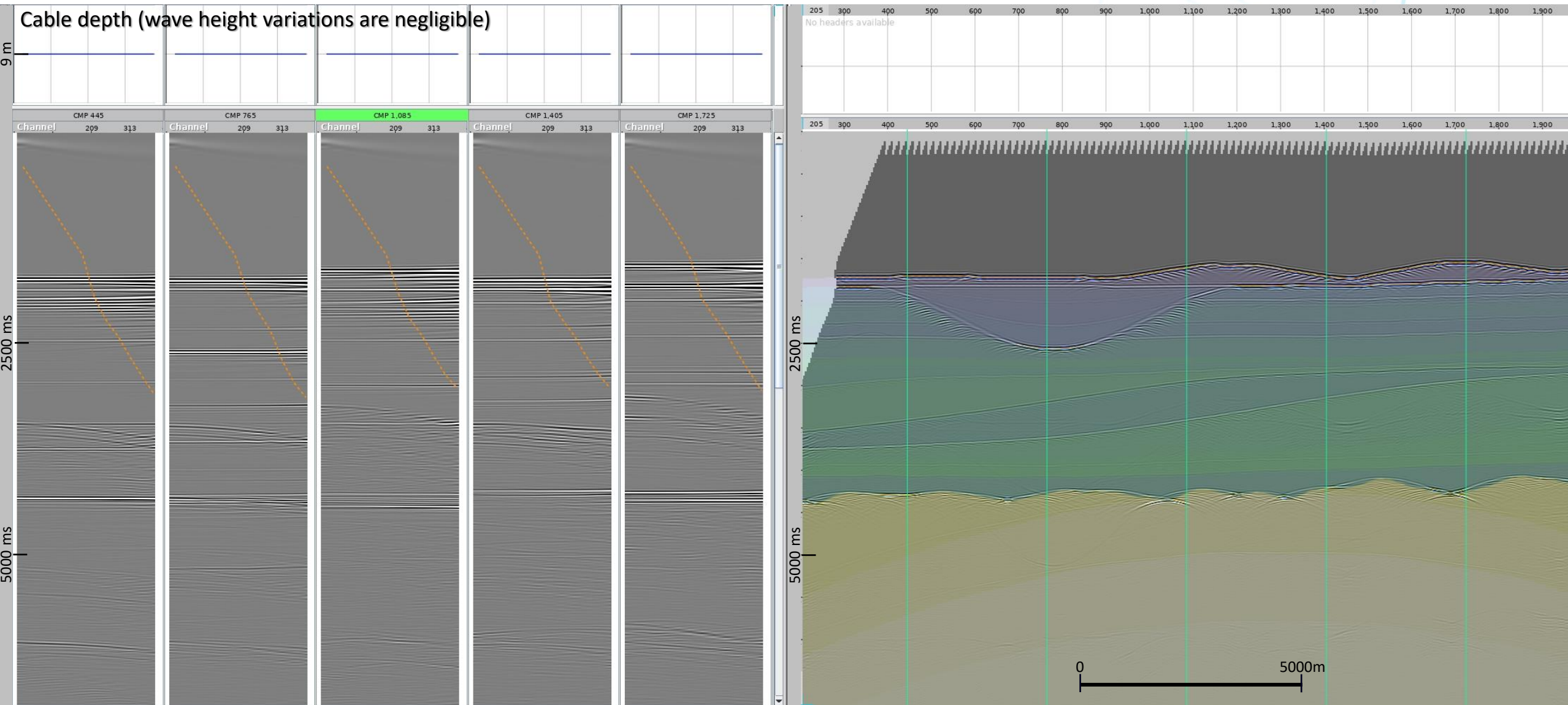
Seismic streamer



Can you make deghosting any harder!?!?

And what about statics...?

Synthetic data with 'conventional' seismic dimensions

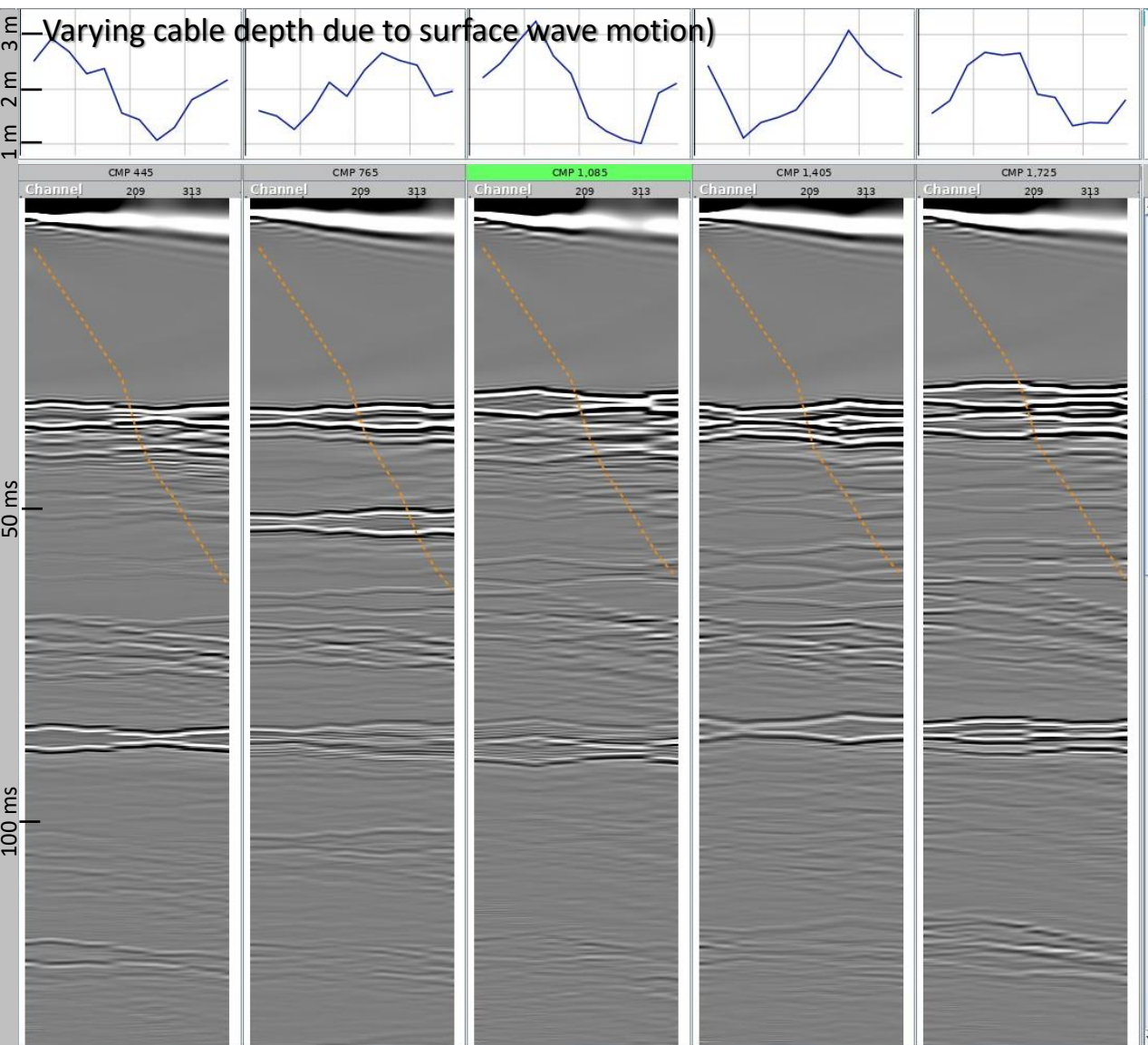


Example NMO corrected CMPs (orange line = stack mute)

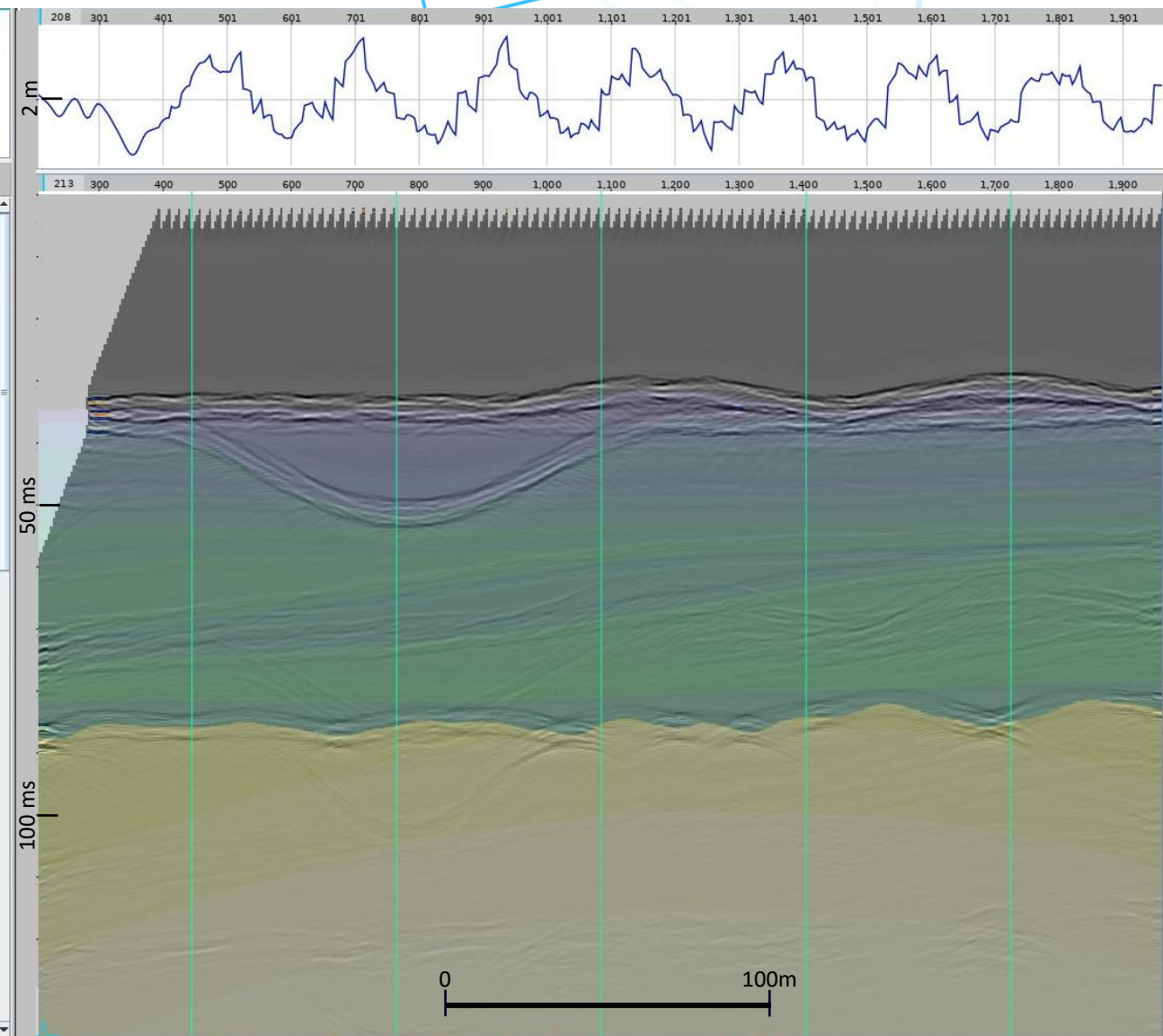
Raw stack, with velocity overlay (green lines show location of CMPs)

Synthetic data with UHRS seismic dimensions

Scaled by 50



Example NMO corrected CMPs (orange line = stack mute)



Raw stack, with velocity overlay (green lines show location of CMPs)

What about positional errors?

For a Gaussian distribution of positional errors*:

A 10cm standard deviation of positioning leads to 7.8dB attenuation of signal at 3.2kHz

Scaled by 50

A 5m standard deviation of positioning leads to 7.8dB attenuation of signal at 64Hz

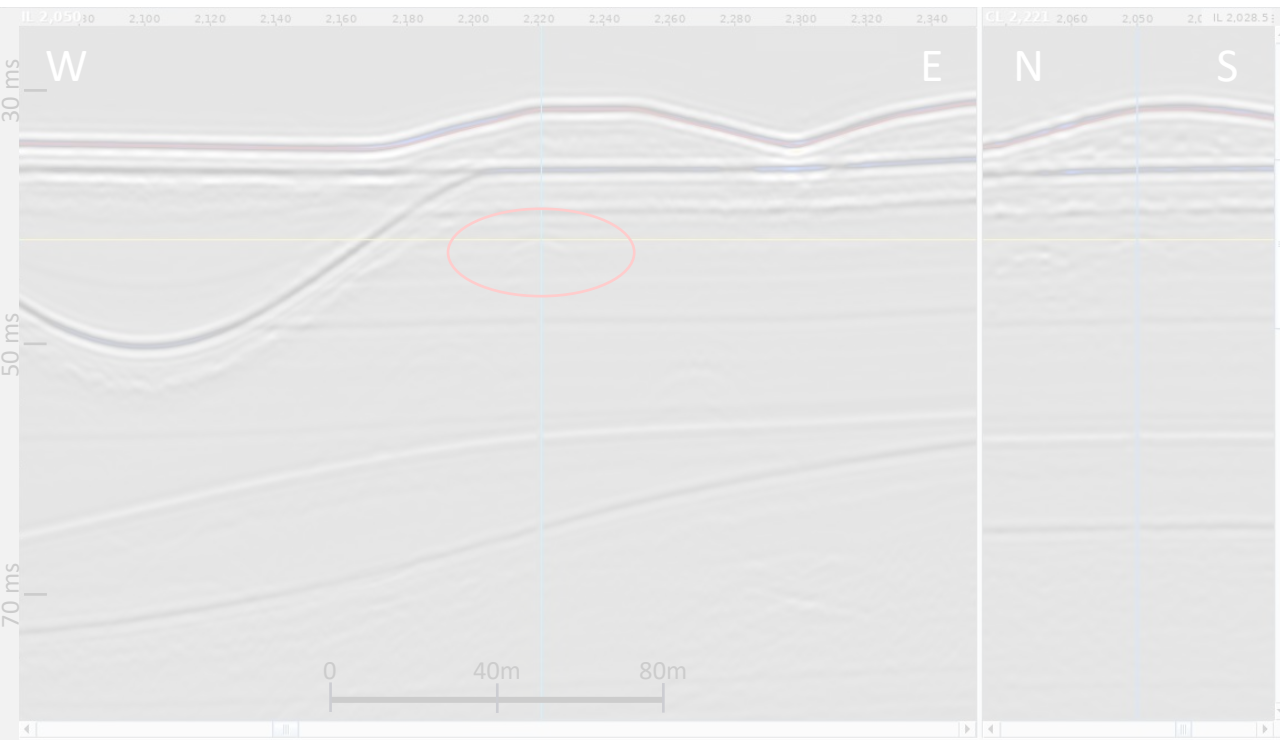
$$* F_{(-NdB)} = \frac{\sqrt{N}}{13.08\delta}$$

Where δ is the standard deviation (in time); F is the frequency that you are N dB down

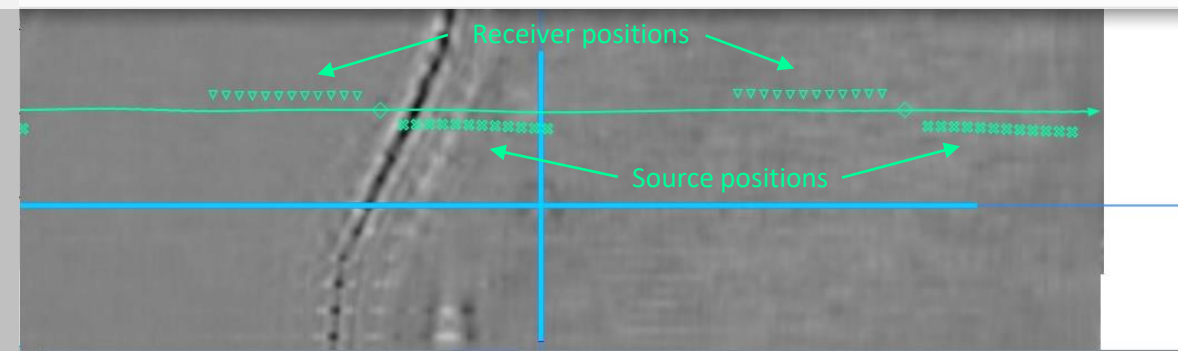
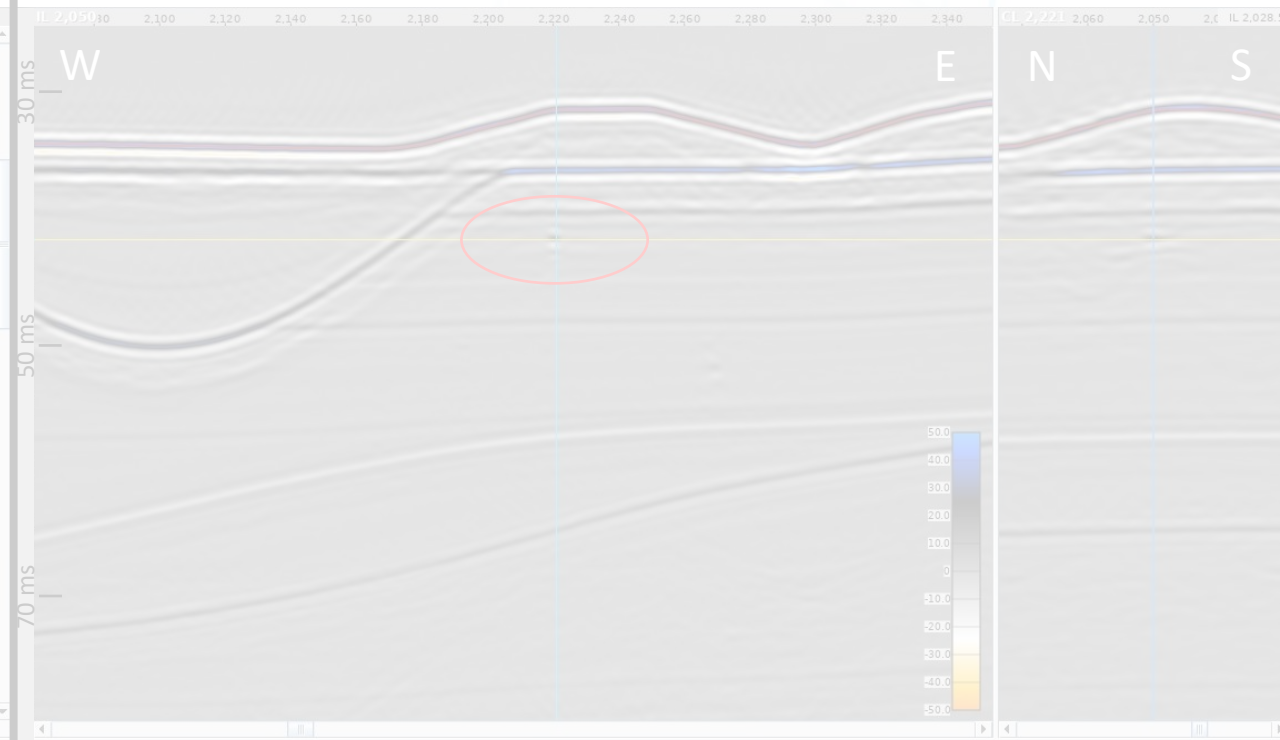
(Equation A1.16 in *Survey Design and Seismic Acquisition for Land, Marine, and In-Between*. (Monk, 2020))

Evaluation on synthetic data: NO navigational errors

REGULARIZED DATA (BEFORE MIGRATION)

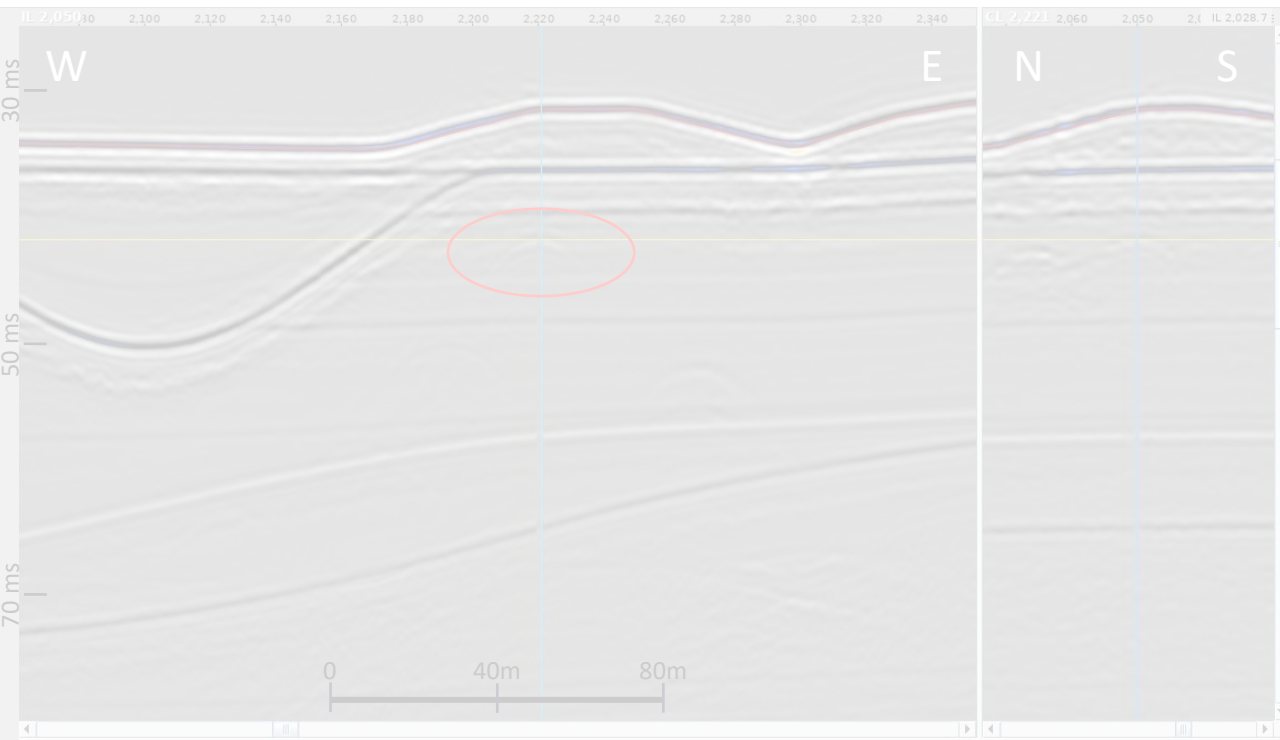


PRE-STACK TIME MIGRATED

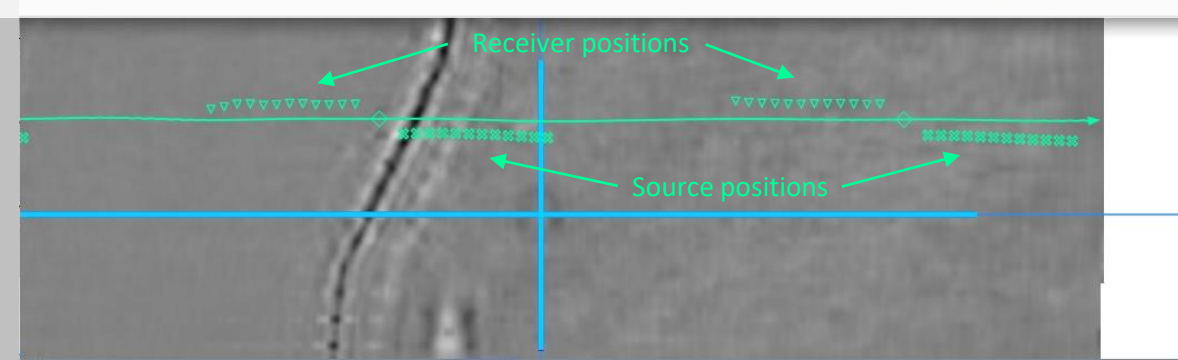
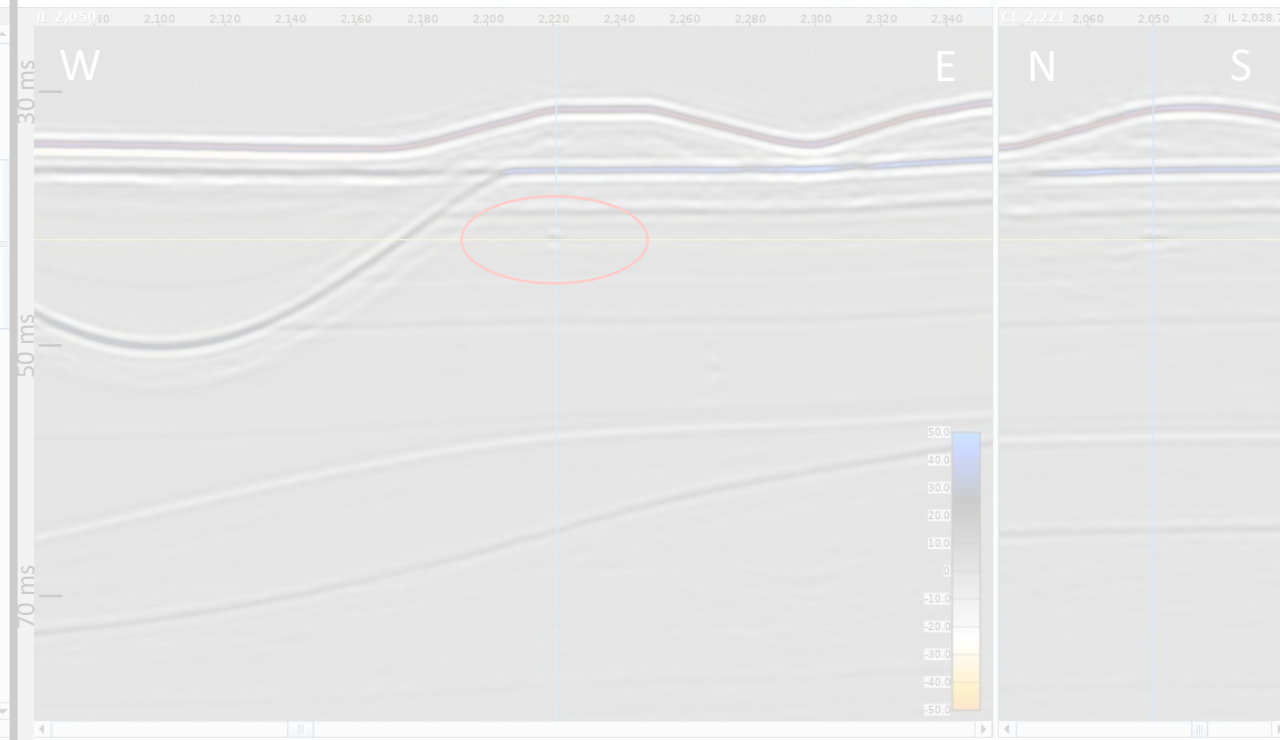


Evaluation on synthetic data: Average 40cm nav-error on recvrs

REGULARIZED DATA (BEFORE MIGRATION)

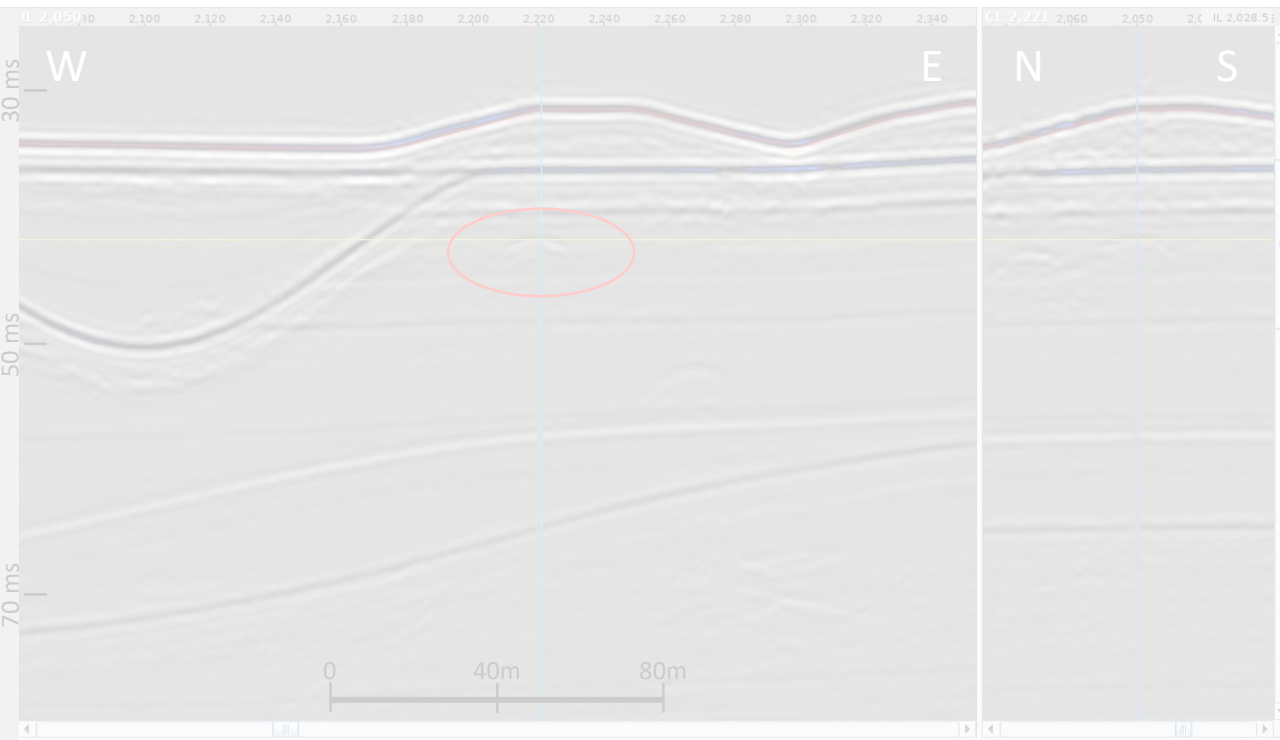


PRE-STACK TIME MIGRATED

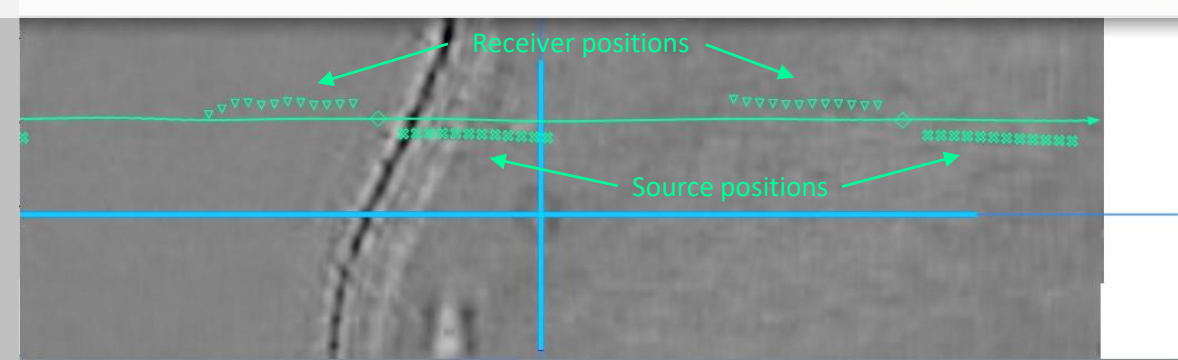
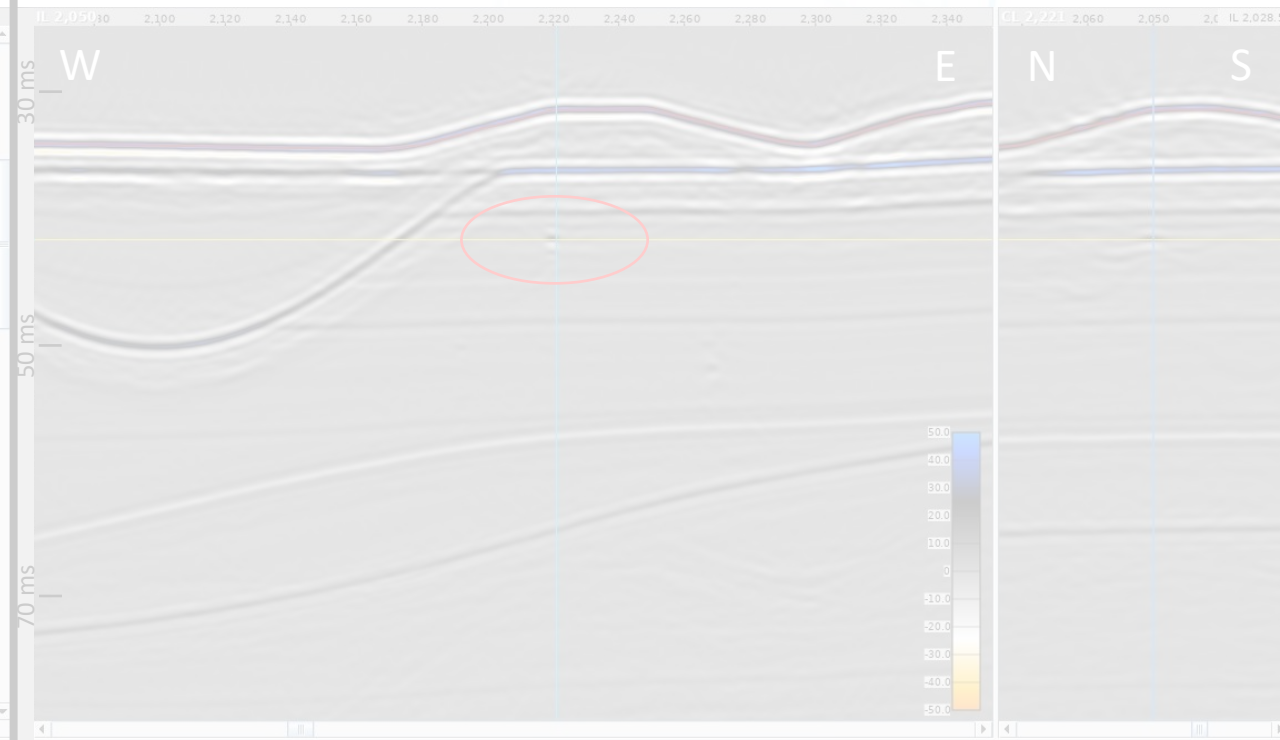


Evaluation on synthetic data: Average 80cm nav-error on recvrs

REGULARIZED DATA (BEFORE MIGRATION)

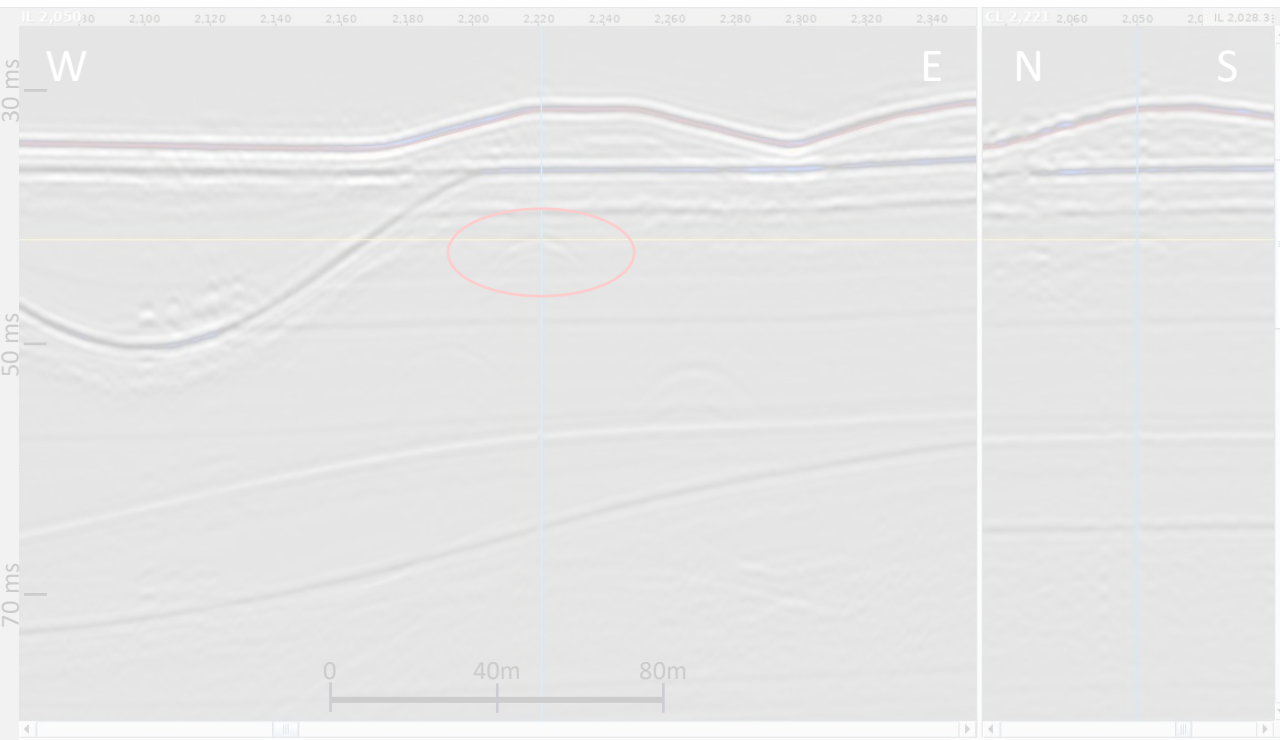


PRE-STACK TIME MIGRATED

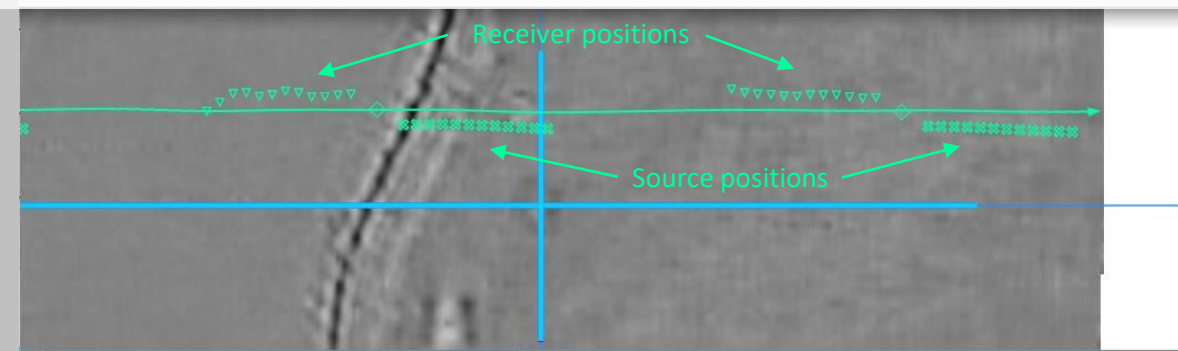
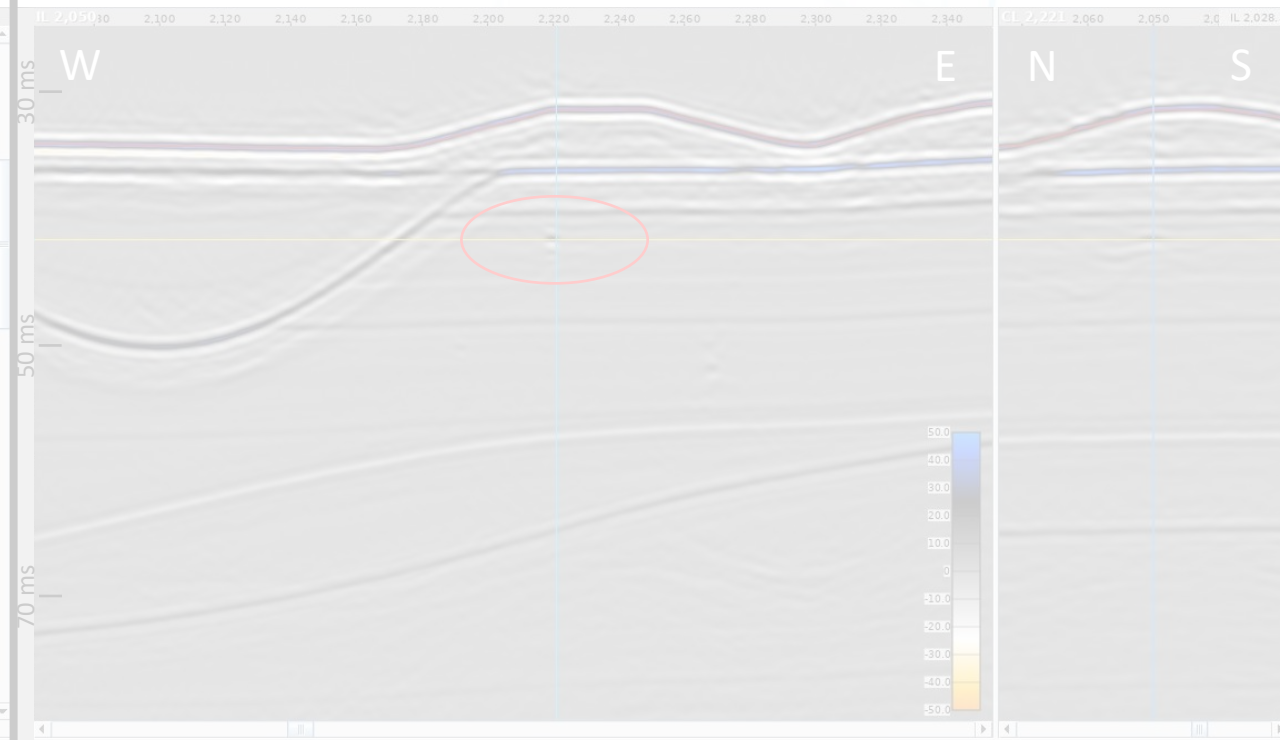


Evaluation on synthetic data: Average 1.2m nav-error on recvrs

REGULARIZED DATA (BEFORE MIGRATION)

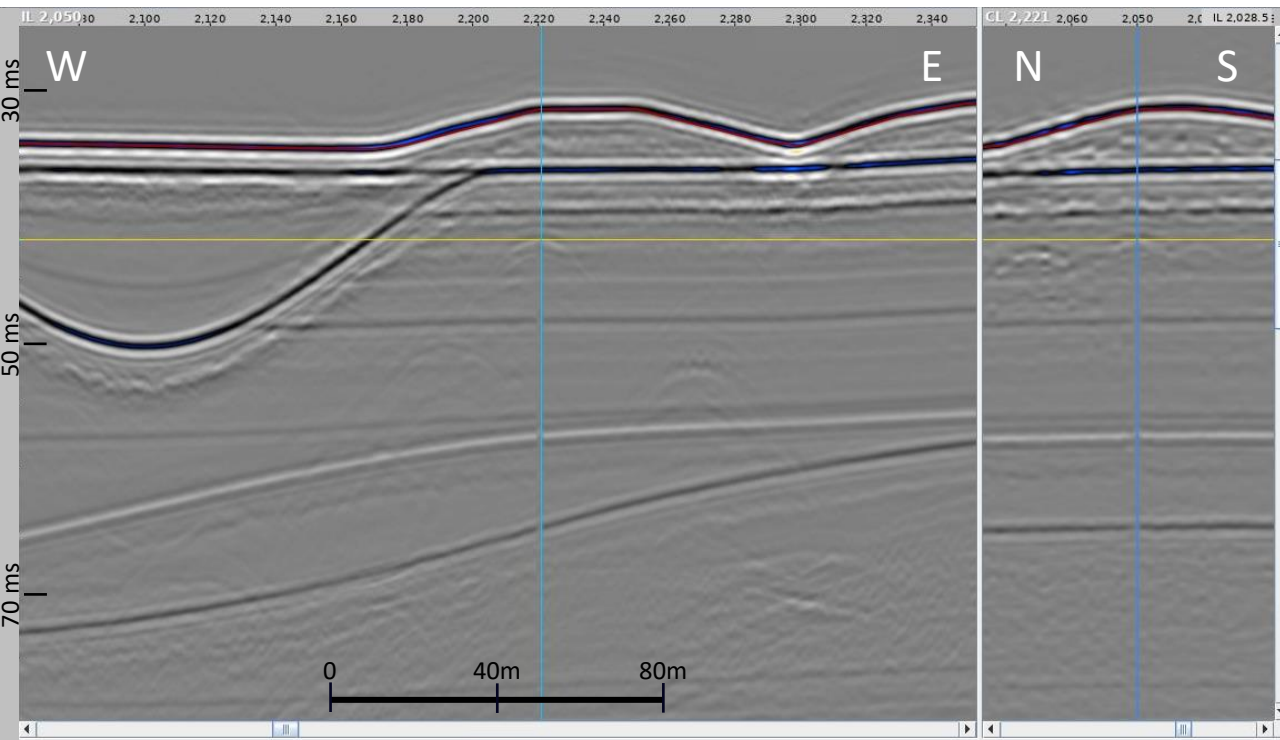


PRE-STACK TIME MIGRATED

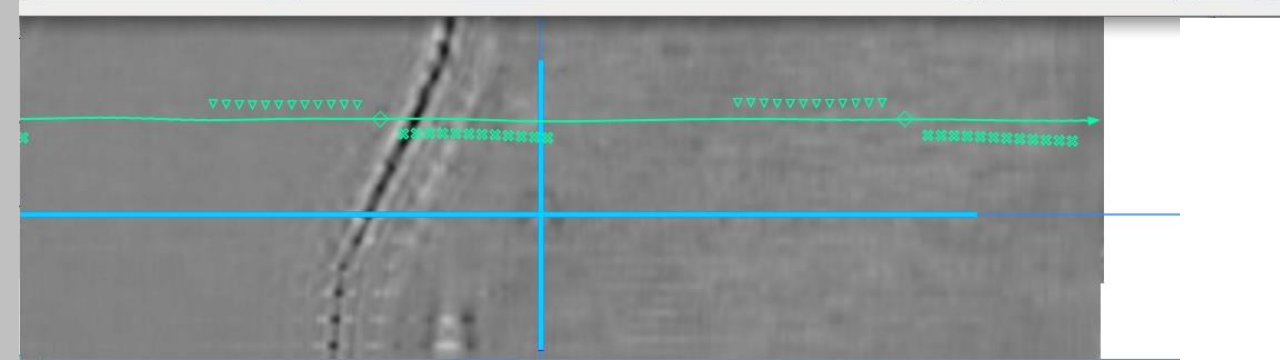
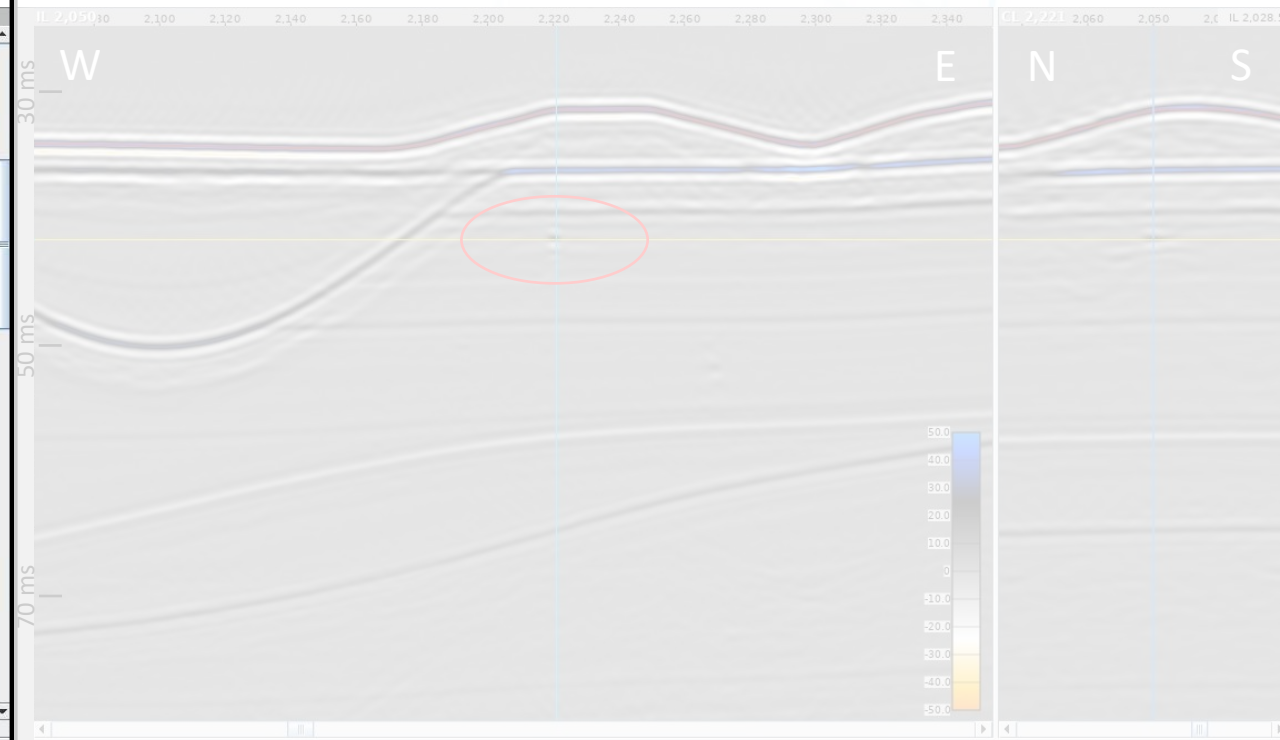


Evaluation on synthetic data: NO navigational errors

REGULARIZED DATA (BEFORE MIGRATION)

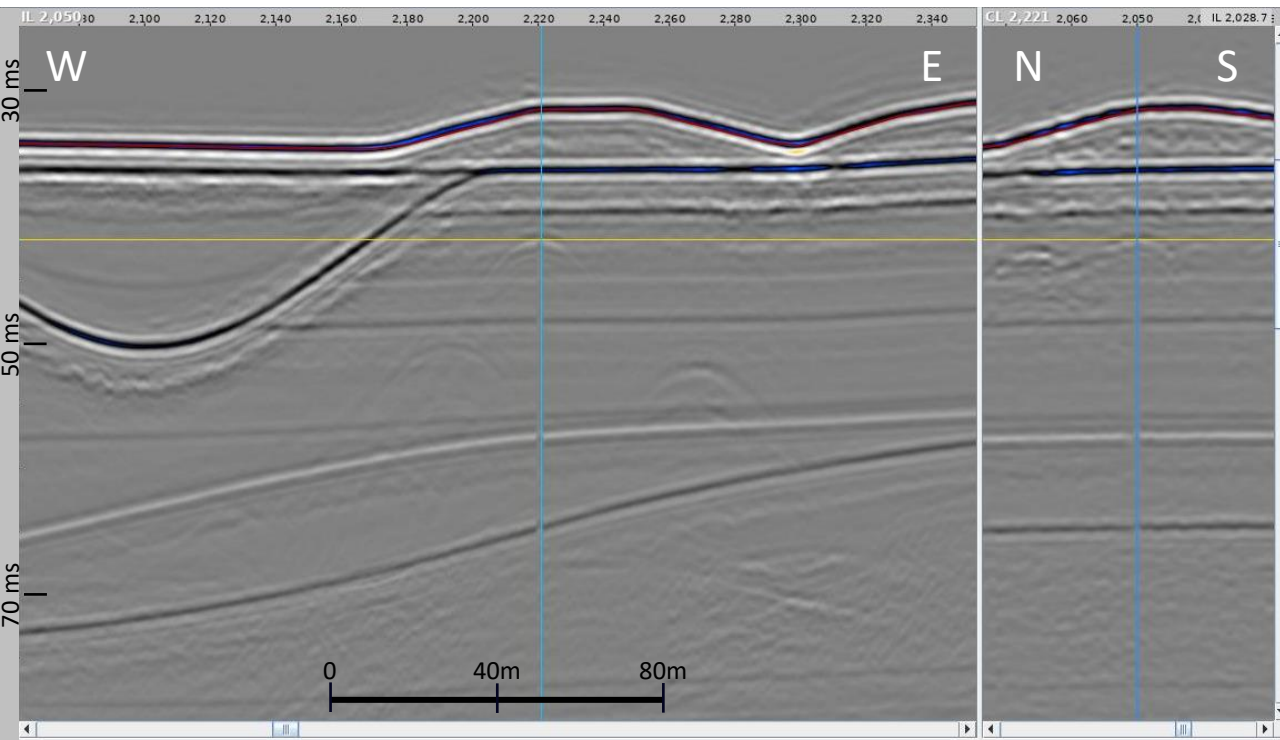


PRE-STACK TIME MIGRATED

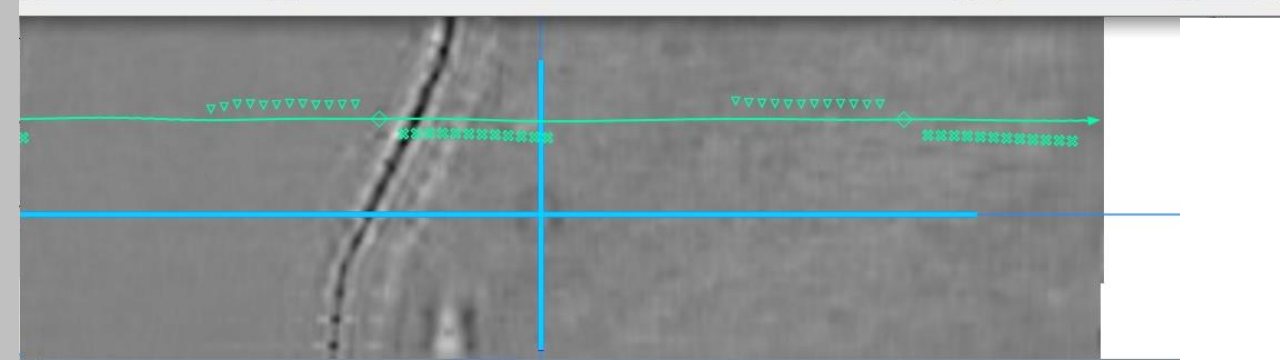
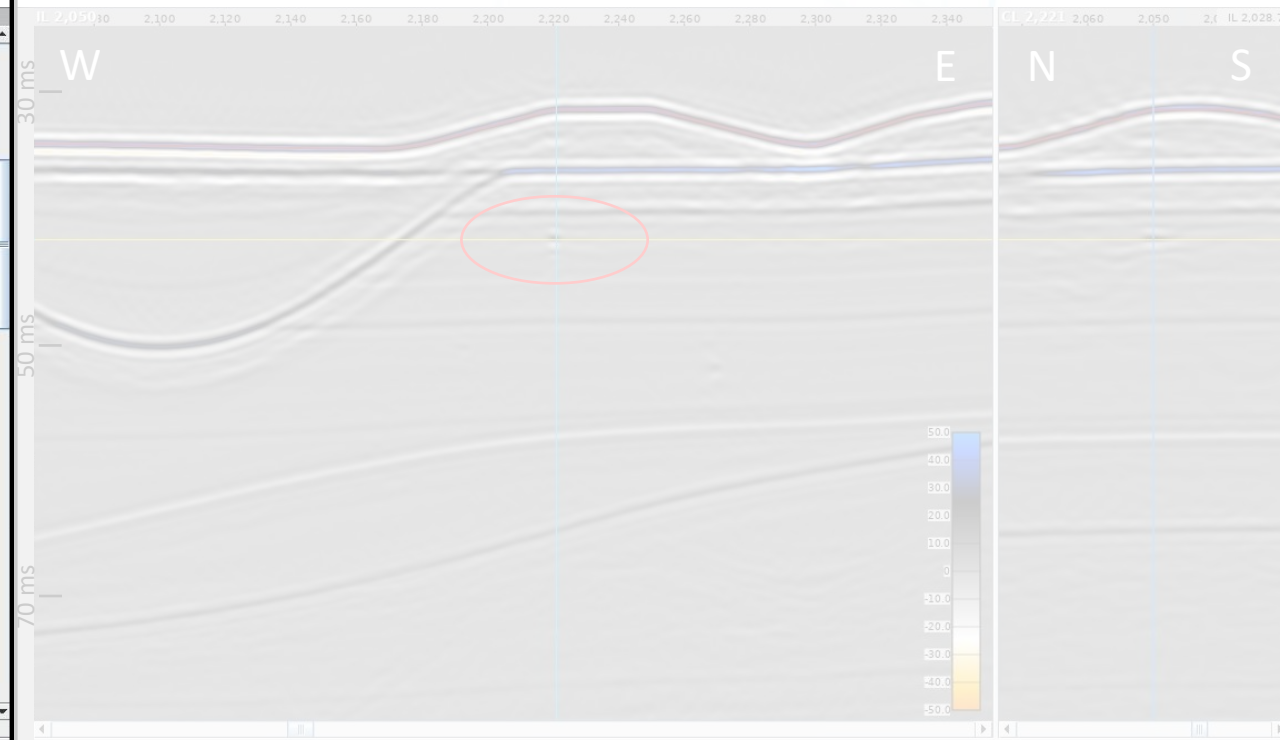


Evaluation on synthetic data: Average 40cm nav-error on recvrs

REGULARIZED DATA (BEFORE MIGRATION)

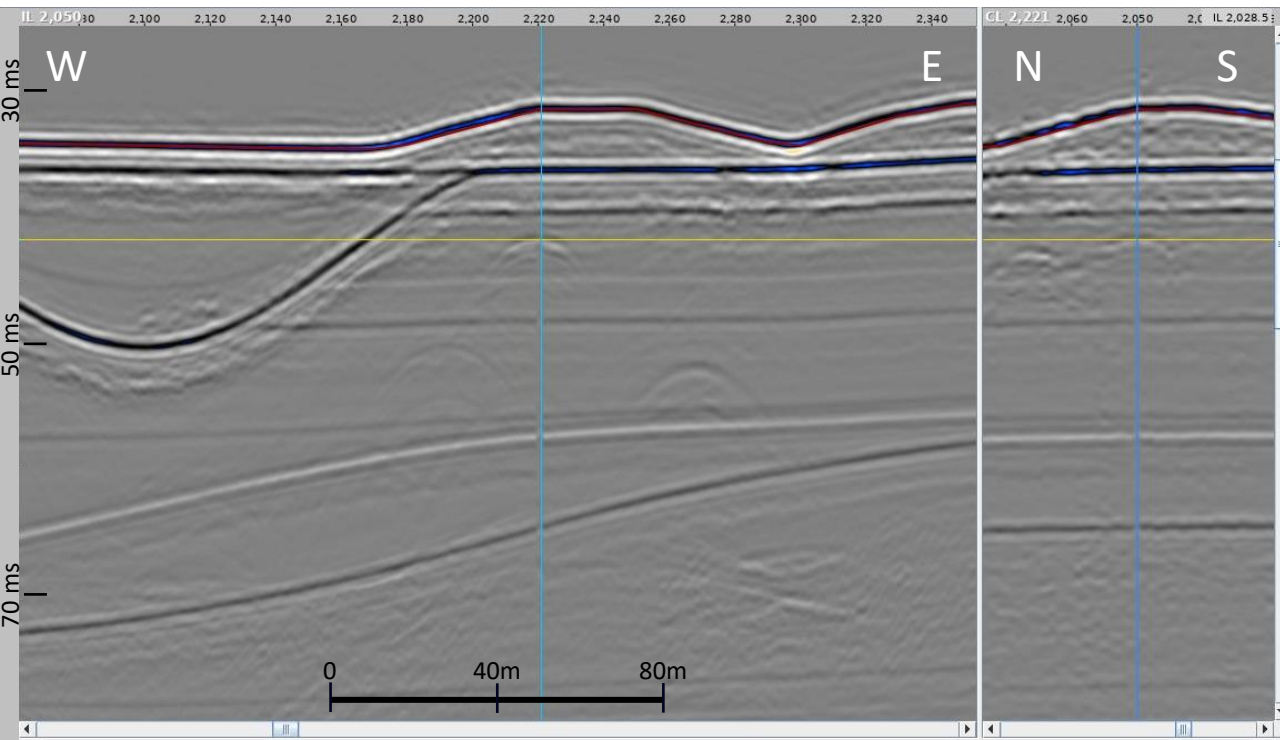


PRE-STACK TIME MIGRATED

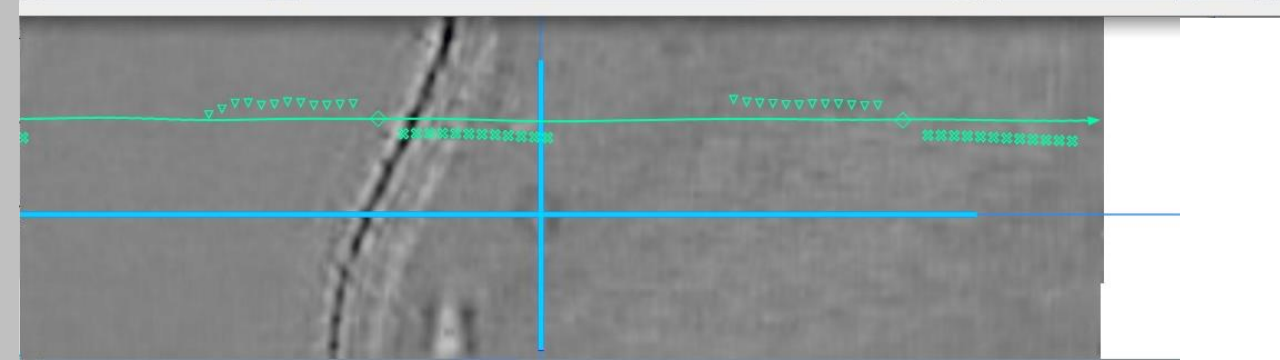
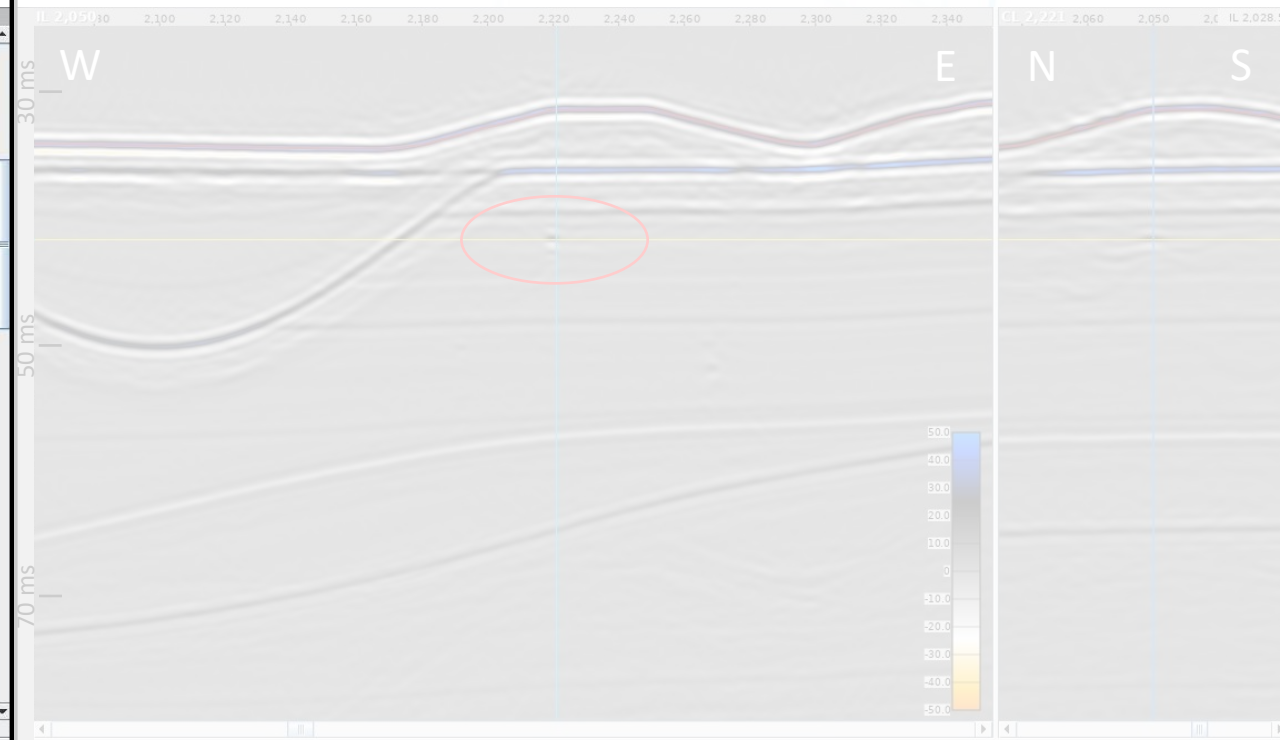


Evaluation on synthetic data: Average 80cm nav-error on recvrs

REGULARIZED DATA (BEFORE MIGRATION)

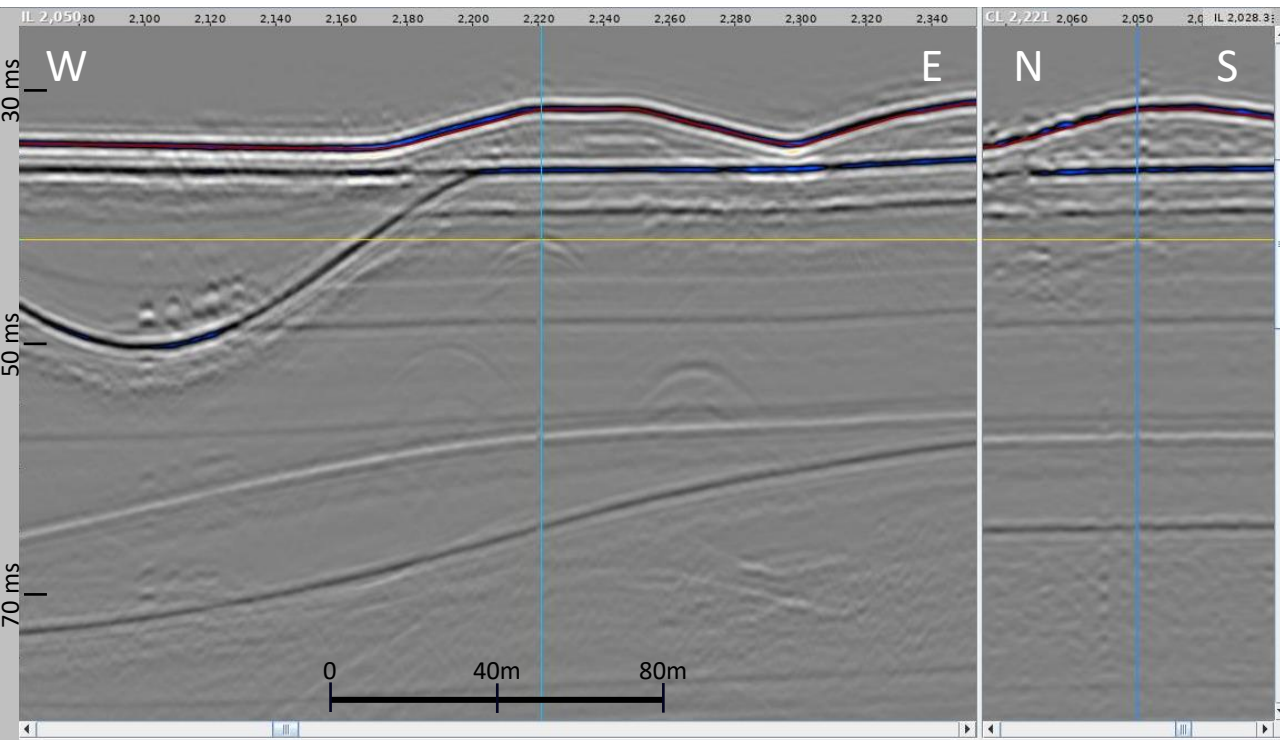


PRE-STACK TIME MIGRATED

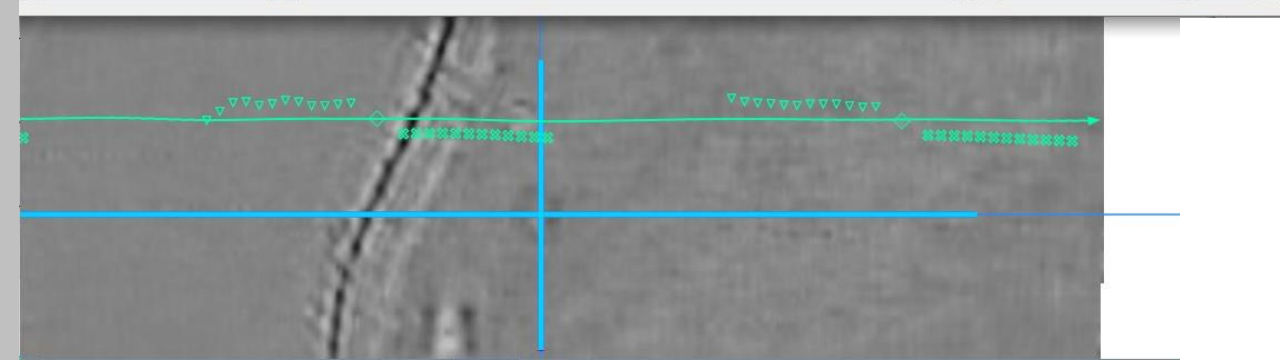
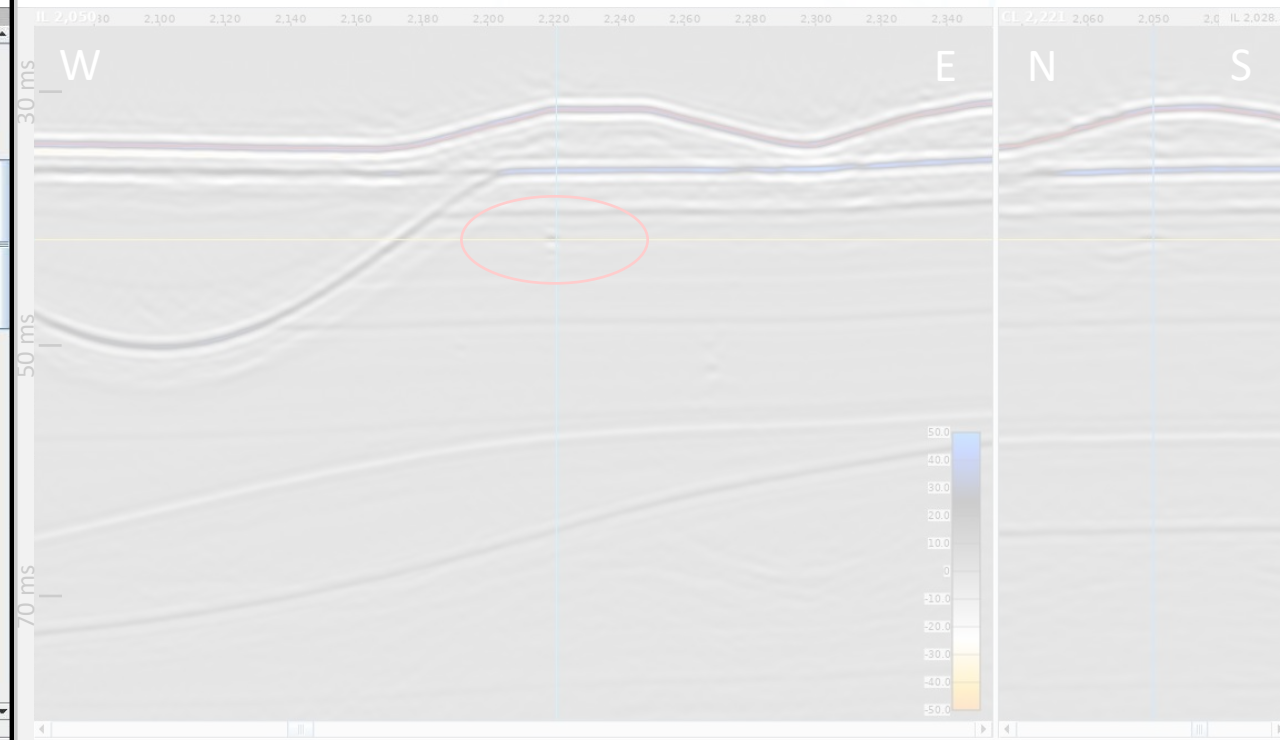


Evaluation on synthetic data: Average 1.2m nav-error on recvrs

REGULARIZED DATA (BEFORE MIGRATION)

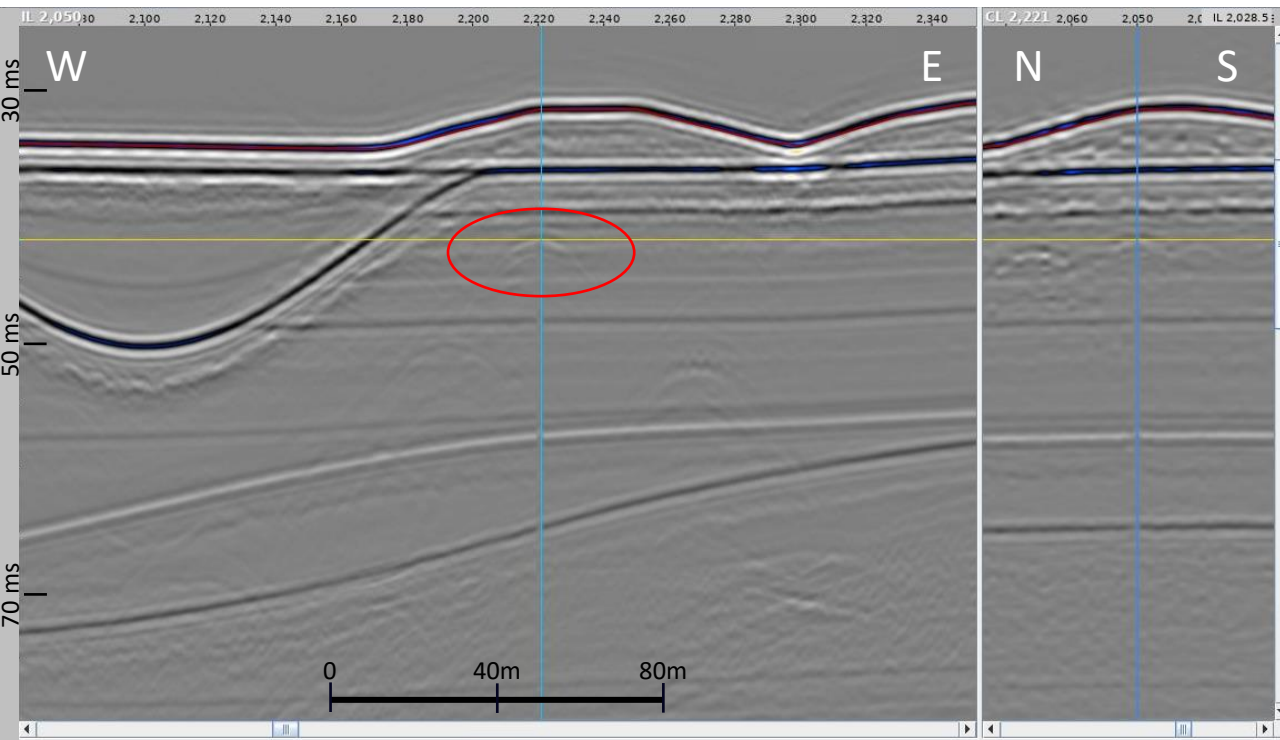


PRE-STACK TIME MIGRATED

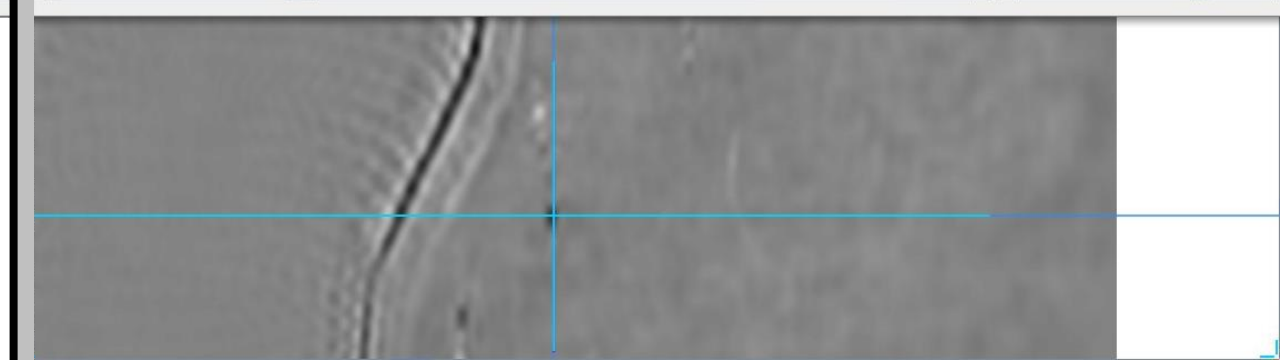
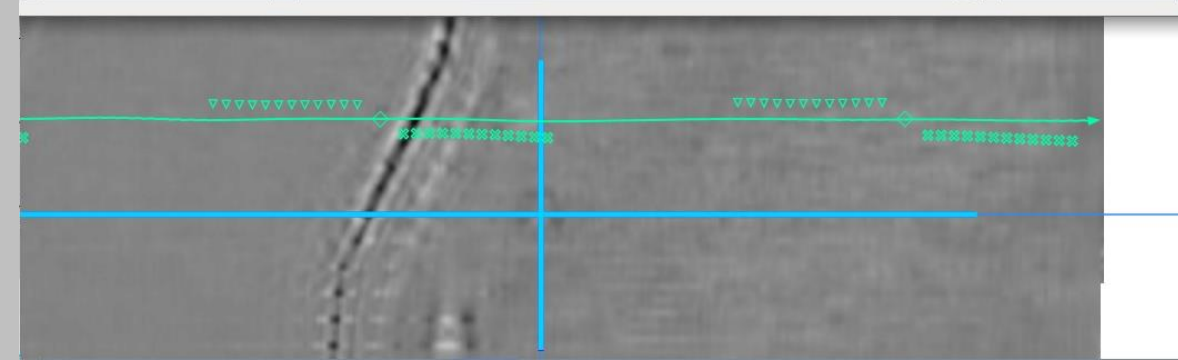
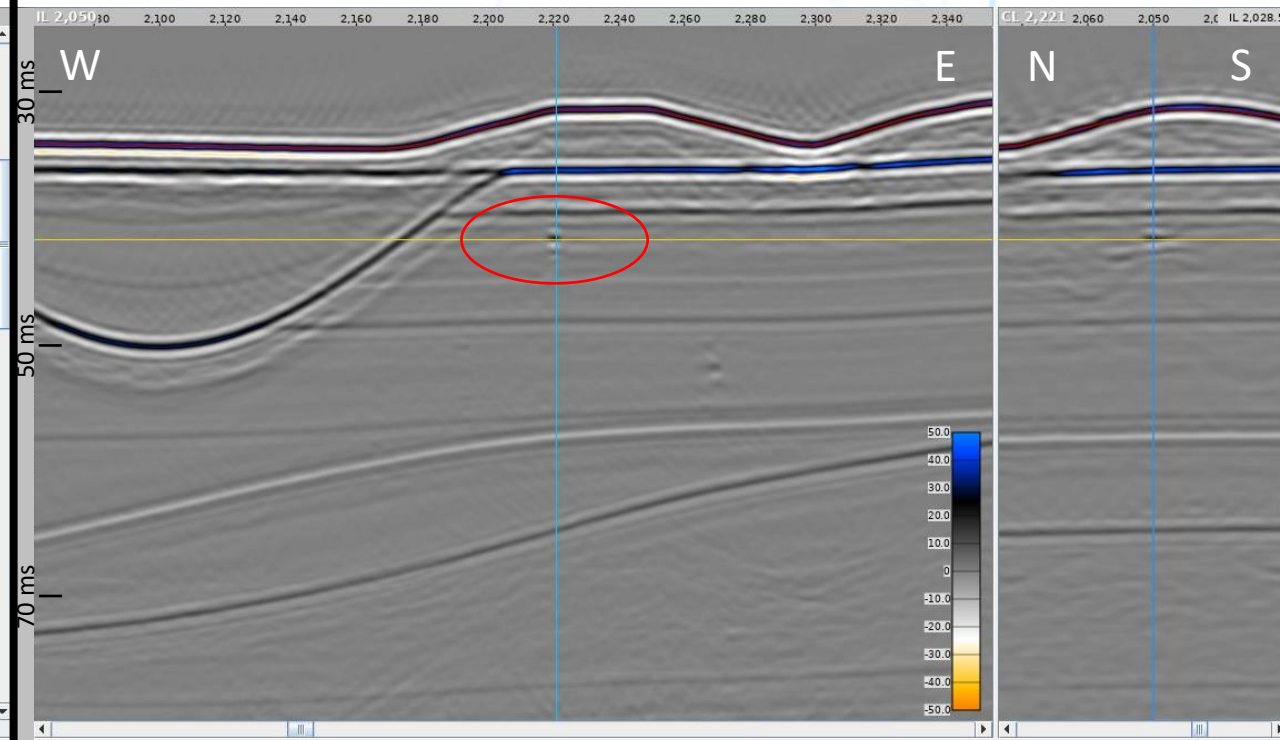


Evaluation on synthetic data: NO navigational errors

REGULARIZED DATA (BEFORE MIGRATION)

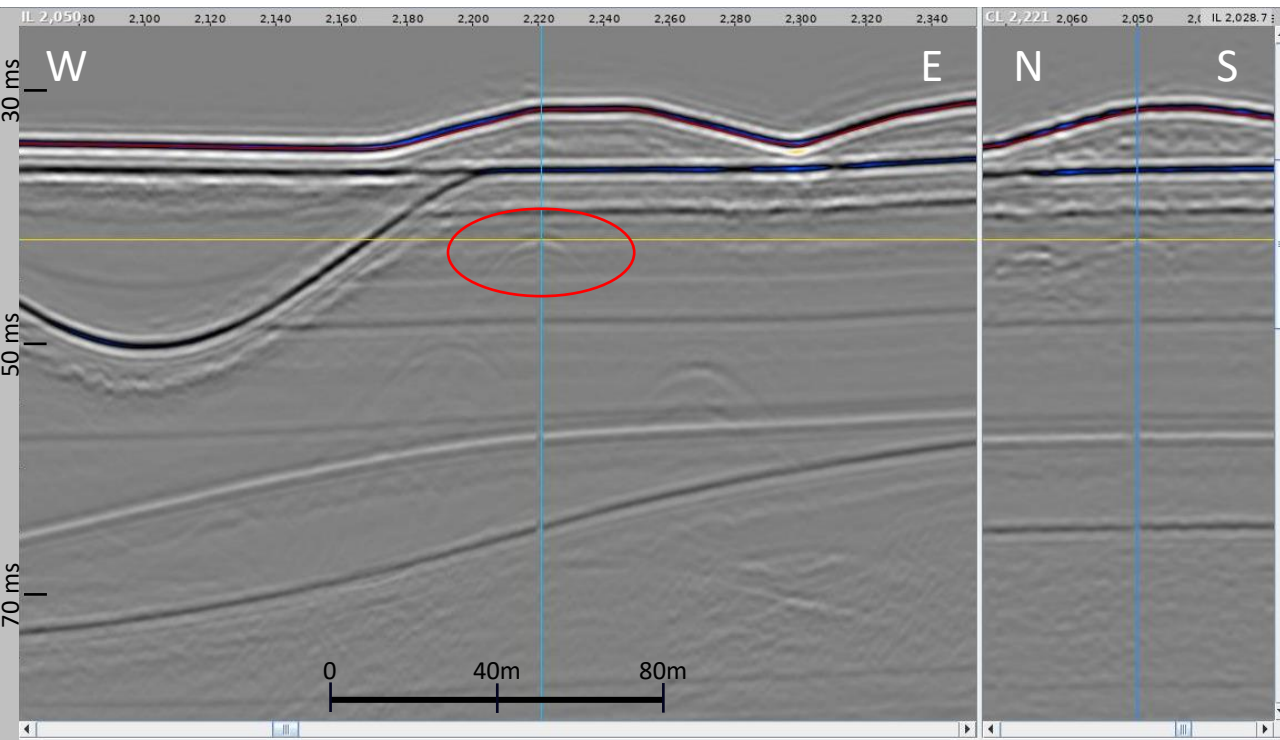


PRE-STACK TIME MIGRATED

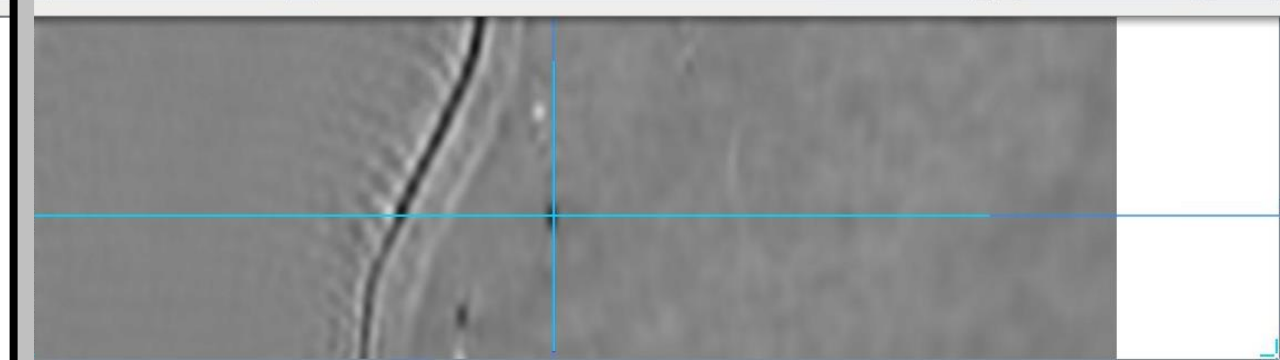
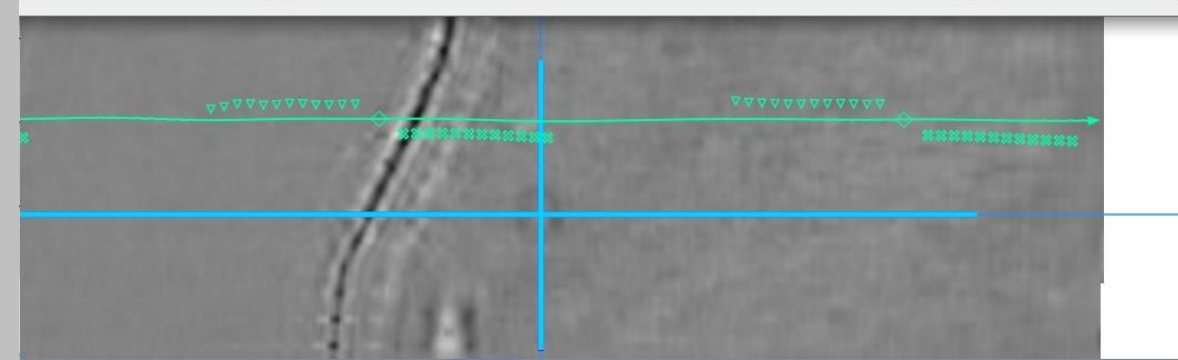
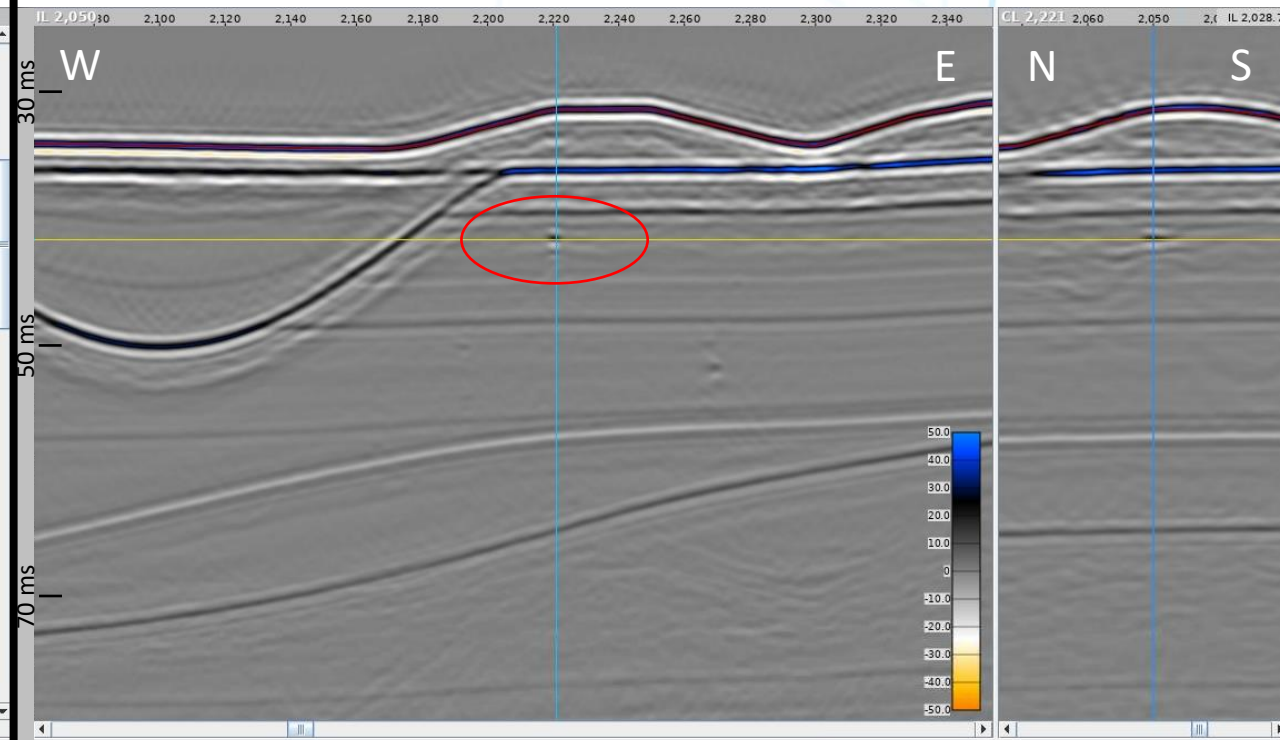


Evaluation on synthetic data: Average 40cm nav-error on recvrs

REGULARIZED DATA (BEFORE MIGRATION)

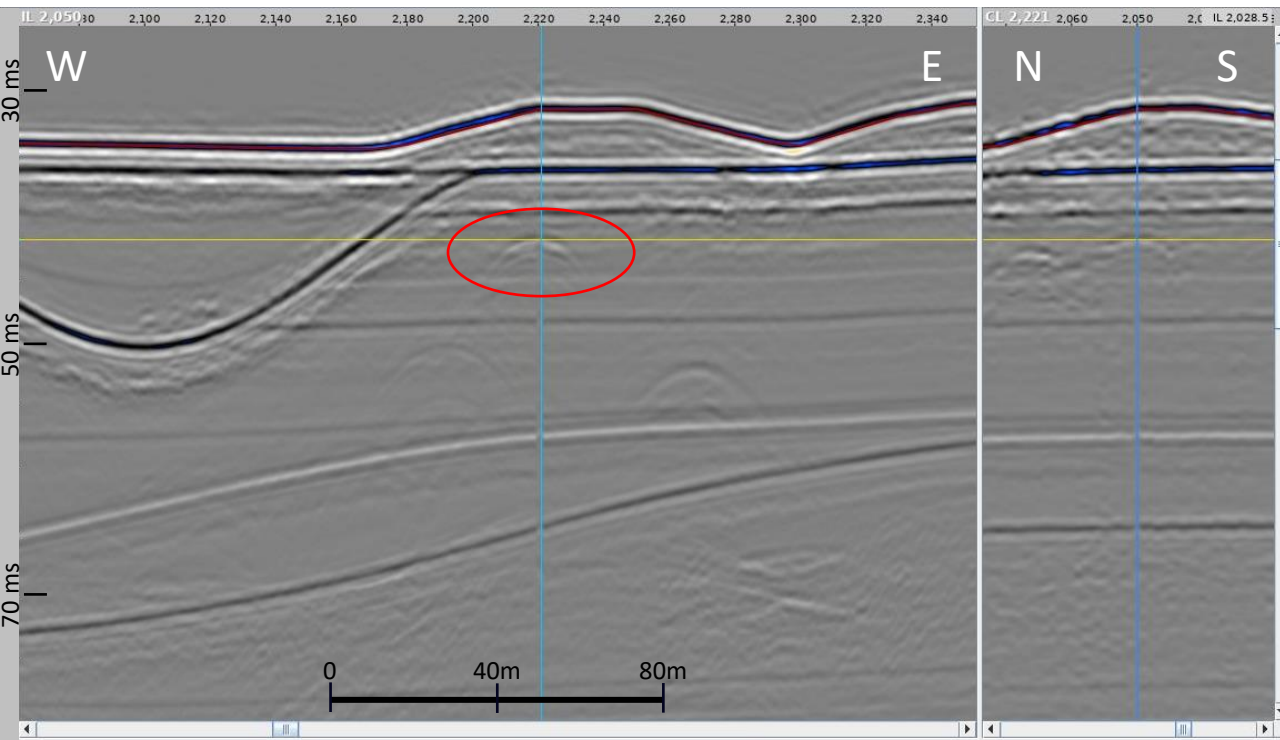


PRE-STACK TIME MIGRATED

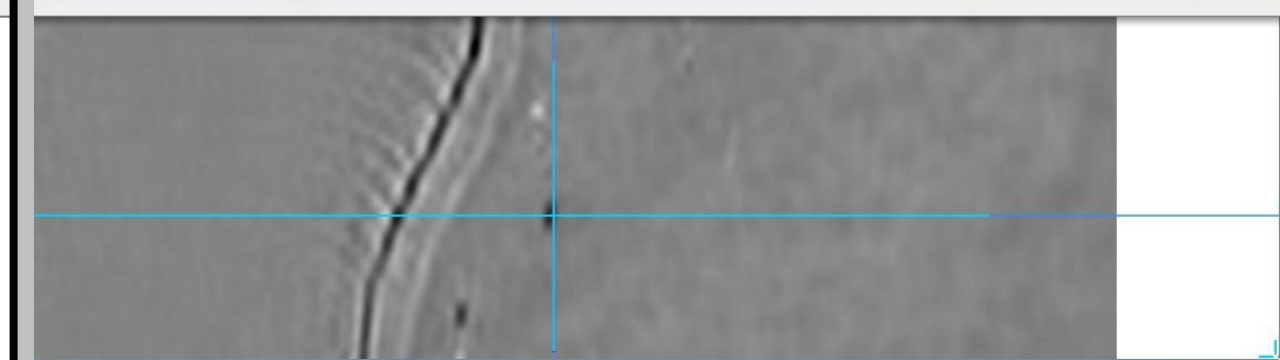
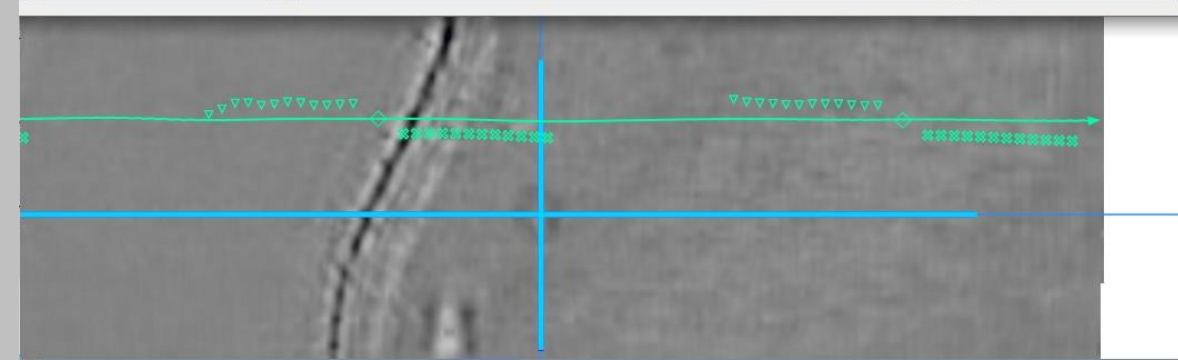
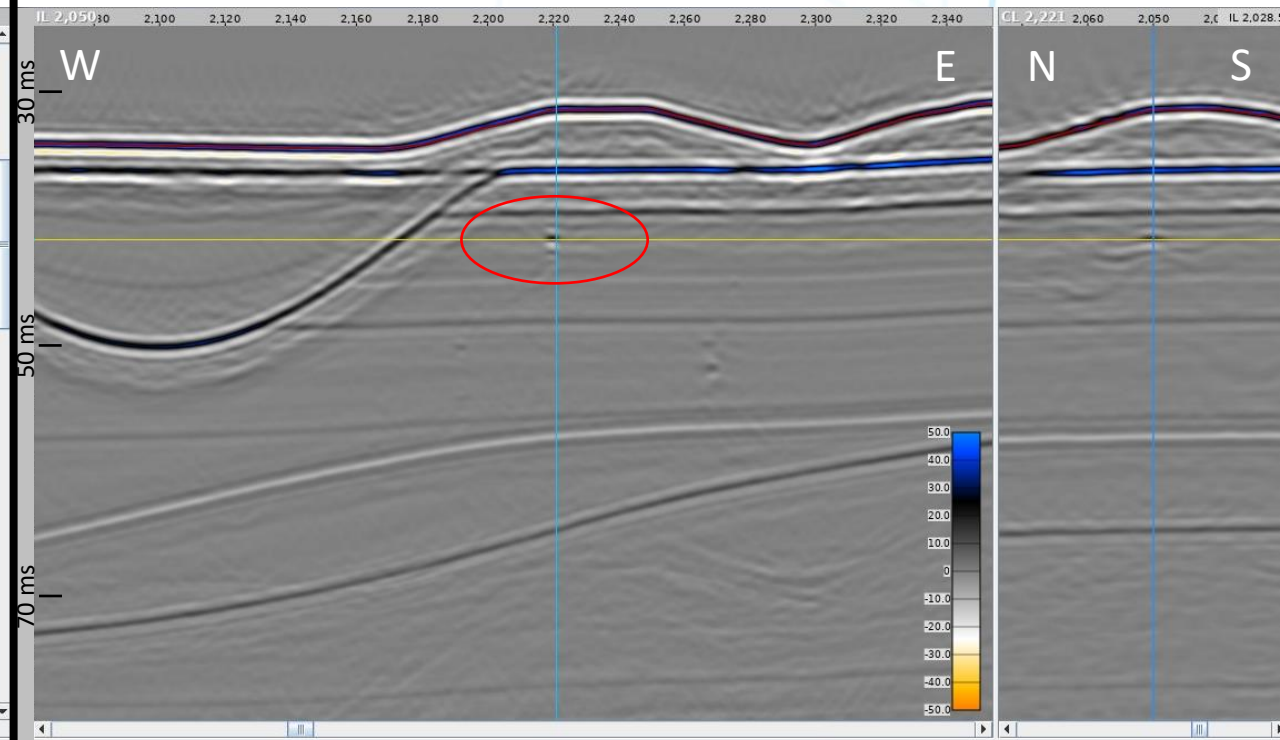


Evaluation on synthetic data: Average 80cm nav-error on recvrs

REGULARIZED DATA (BEFORE MIGRATION)

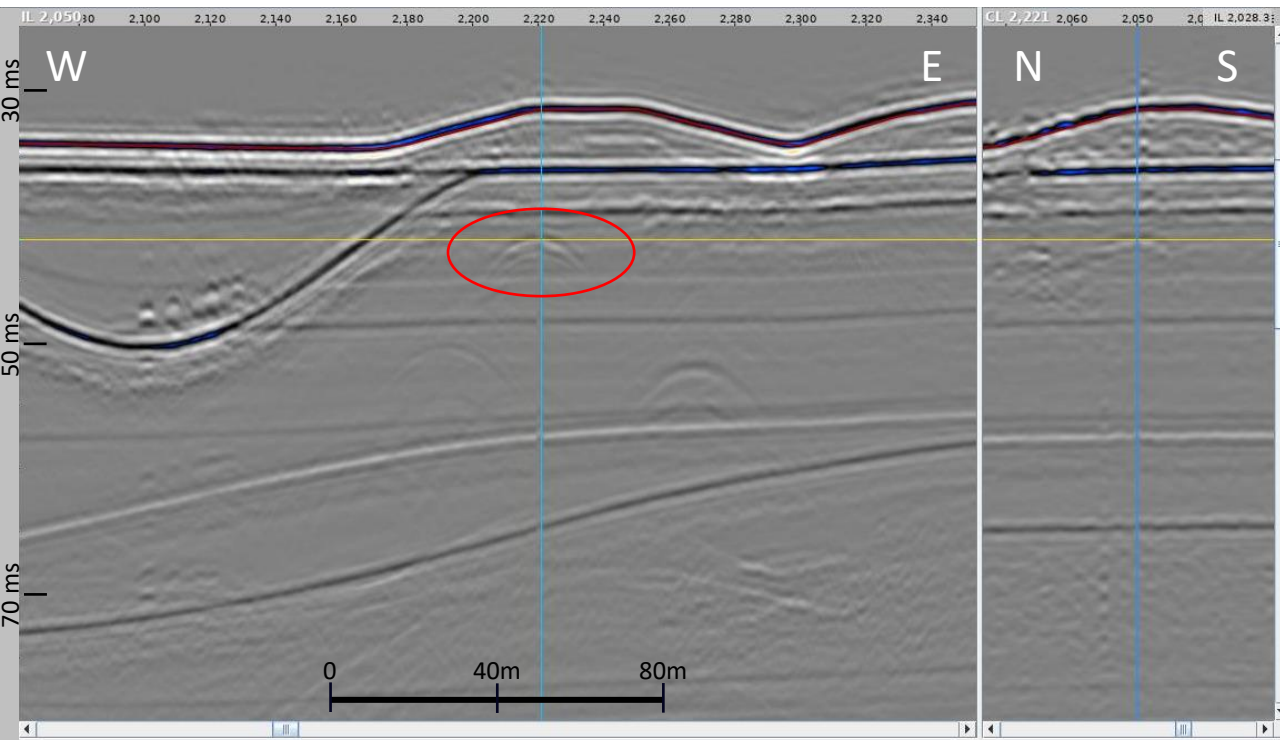


PRE-STACK TIME MIGRATED

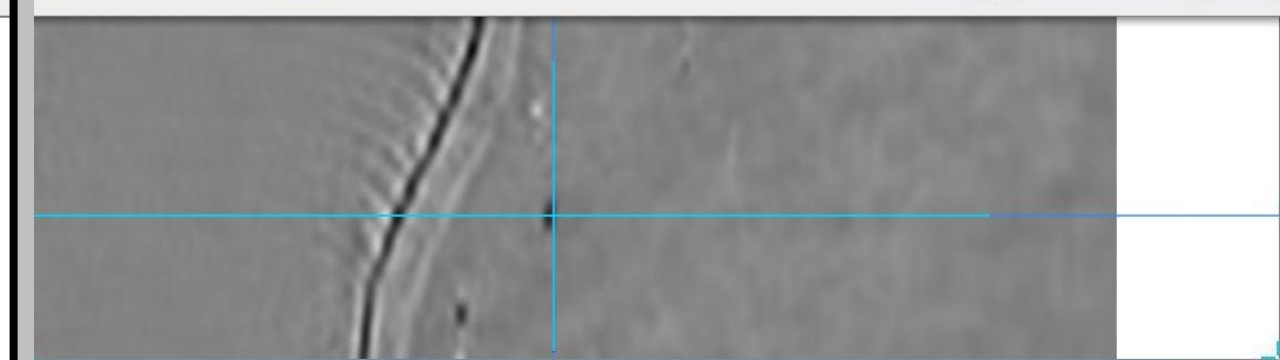
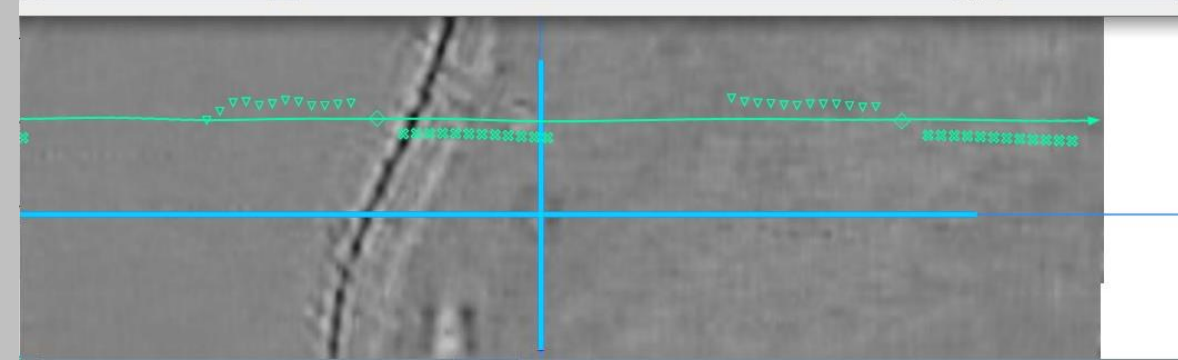
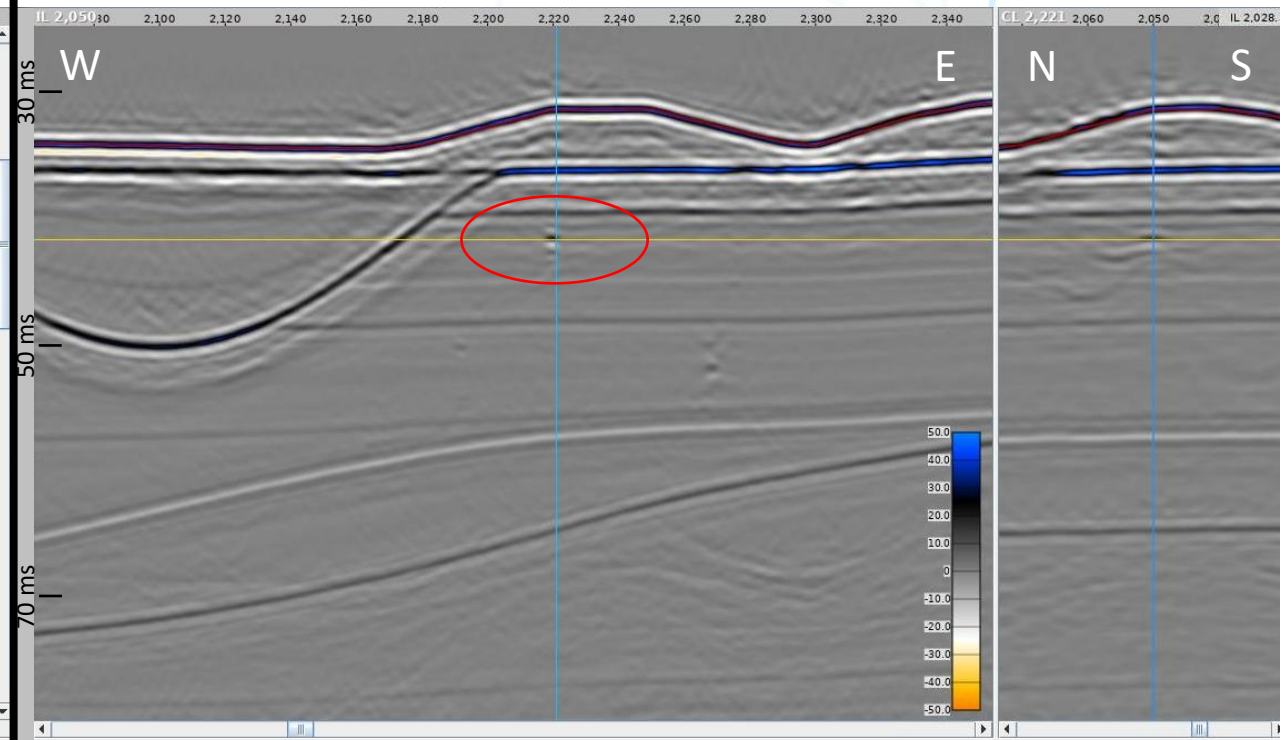


Evaluation on synthetic data: Average 1.2m nav-error on recvrs

REGULARIZED DATA (BEFORE MIGRATION)



PRE-STACK TIME MIGRATED



A 3D seismic data visualization showing a complex geological structure. The data is presented in a perspective view, with a central vertical axis and two horizontal axes. The seismic data is color-coded, with a prominent blue and orange layer at the top, and a large purple and blue region in the center. A semi-transparent white text box is overlaid on the left side of the image, containing a list of four items. The background shows detailed seismic wave patterns and structural features.

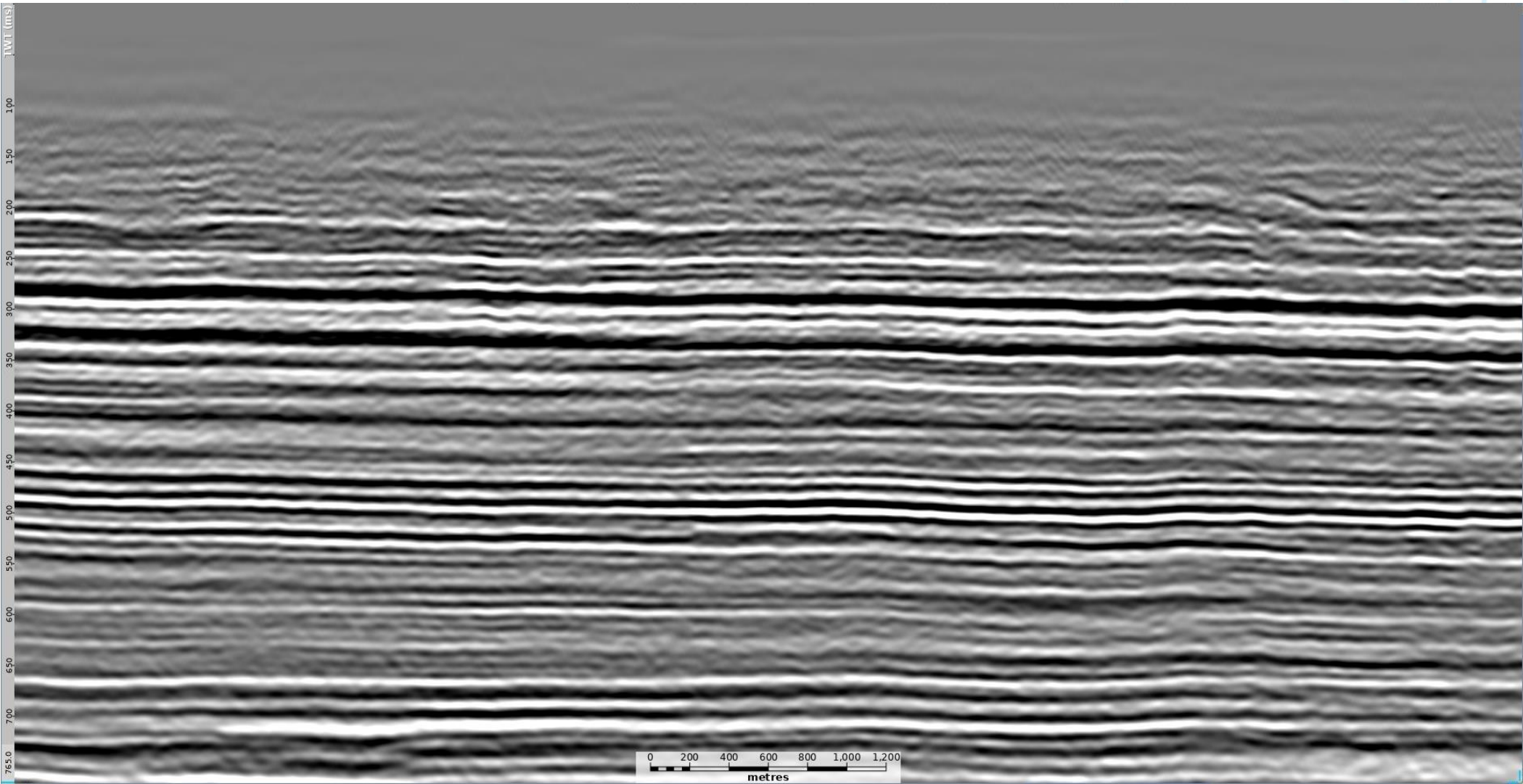
Summary:

1. Introducing *Factor 50*
2. Interrogate the 3D ultra high-res seismic (UHRS) experiment
(Implications for seismic processing)
3. Implications for seismic interpretation
4. Conclusions

Sample 'conventional' seismic

7.8km

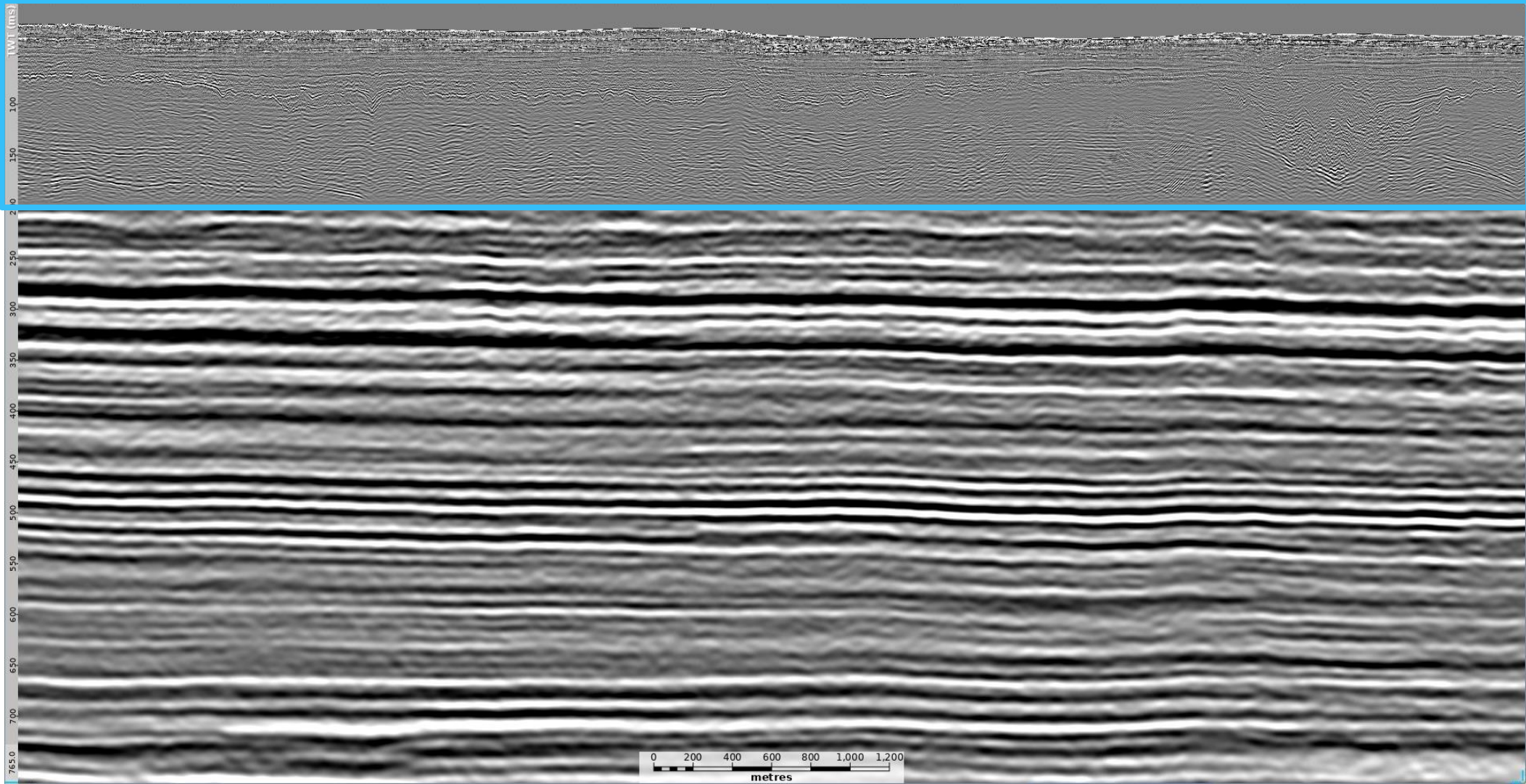
1km



With UHRS overlay

7.8km

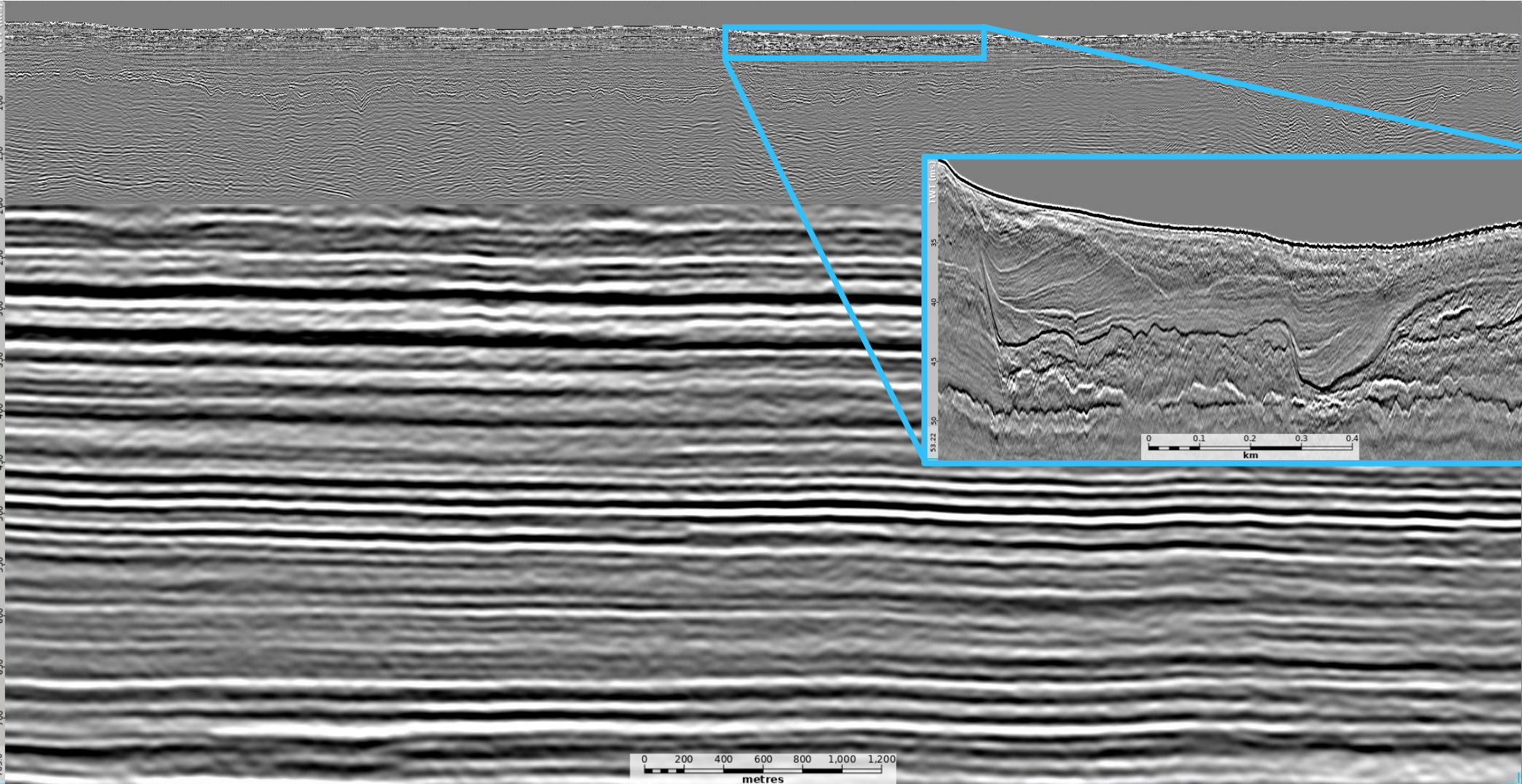
1km



UHRHS Zoom: 50 times as much information to interpret!

7.8km

1km



20m

Morven

- Concept/Early planning
- BP & partners
- 2.9 GW
- 191 Turbines



Morven

- Concept/Early planning
- BP & partners
- 2.9 GW
- 191 Turbines

After *Factor 50*:
2,700 x 800 km



Concluding statements:

1. *FACTOR 50*: applicable to
 - a) the spatial and temporal dimensions of the recorded UHRS,
 - b) the apparatus used to acquire the seismic, and
 - c) the environmental conditions encountered in the field
2. Tide heights and wave-motion have an ‘exaggerated’ effect on UHRS processing.
3. Spare a thought for those interpreting / building ground models at wind-farm sites.

Acknowledgements

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Thank You

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Velocities:

Not scaled by 50

