USE OF QUANTITATIVE SEISMIC ANALYSIS TO DEFINE RESERVOIR ARCHITECTURE AND VOLUMES

AN EXAMPLE FROM THE JOHAN SVERDRUP FIELD

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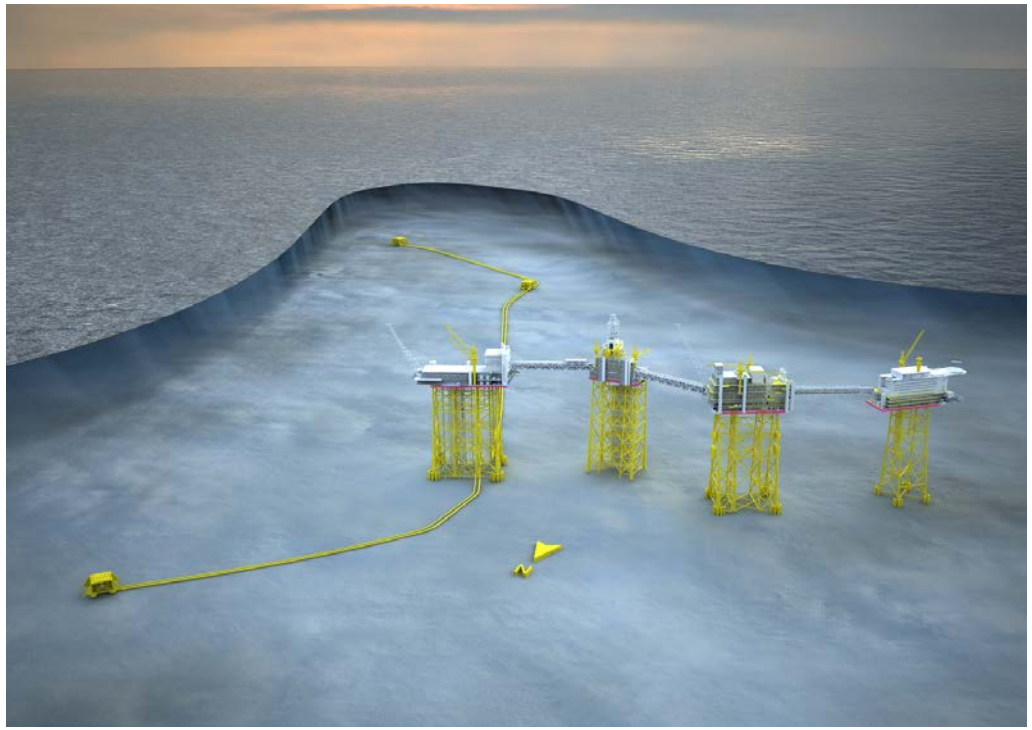

NPF Conference – Stavanger
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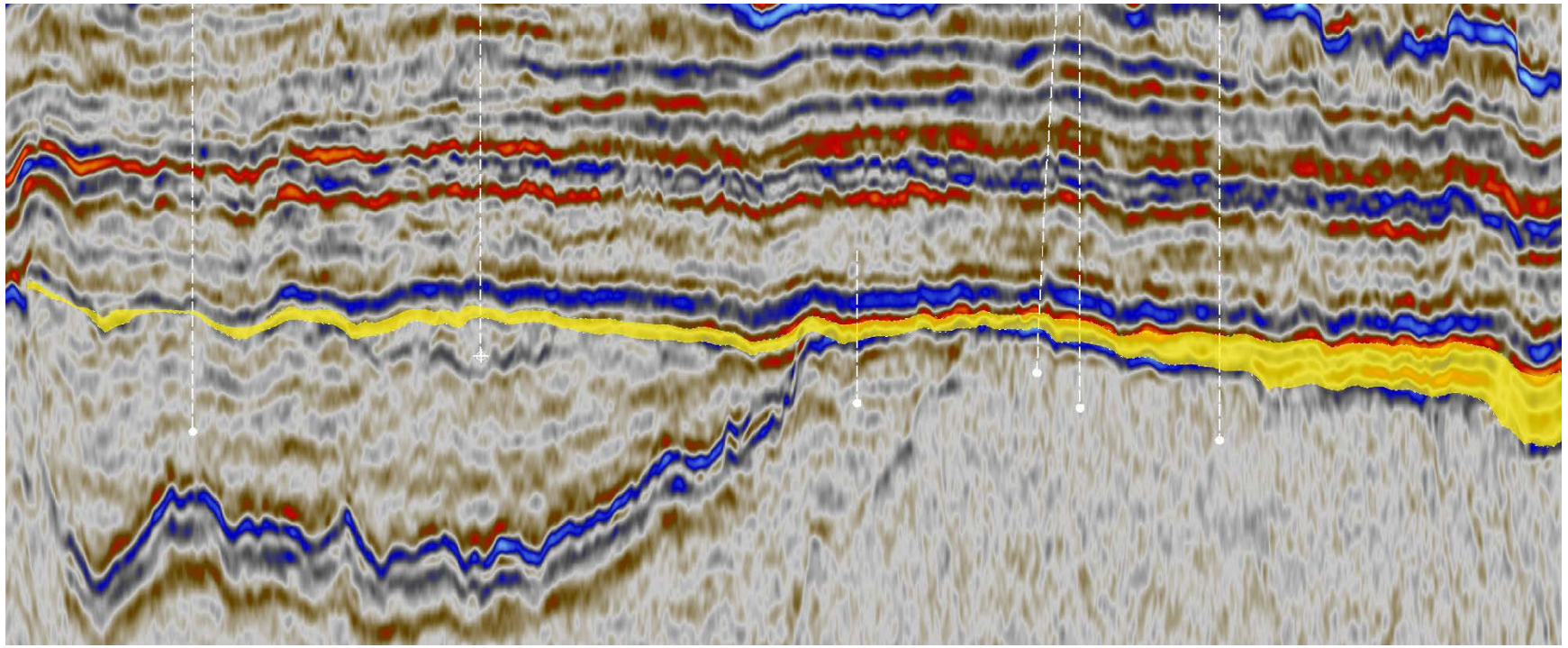
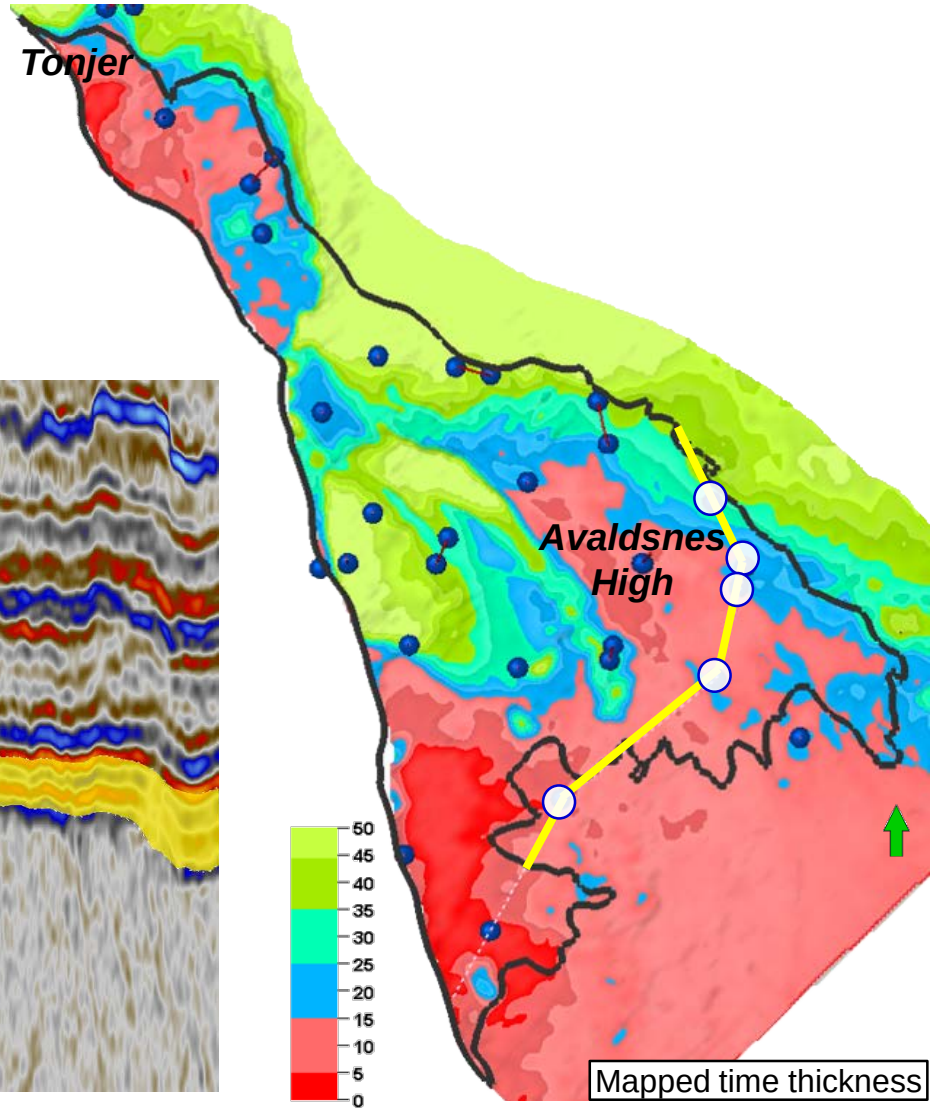
Johan Sverdrup Reservoir
– a challenge for seismic resolution

Imaging of the reservoir is in large parts impaired by tuning and interference from other strong reflectors.

"We strive to provide **complementary** insights, more informative than a single view of the data."

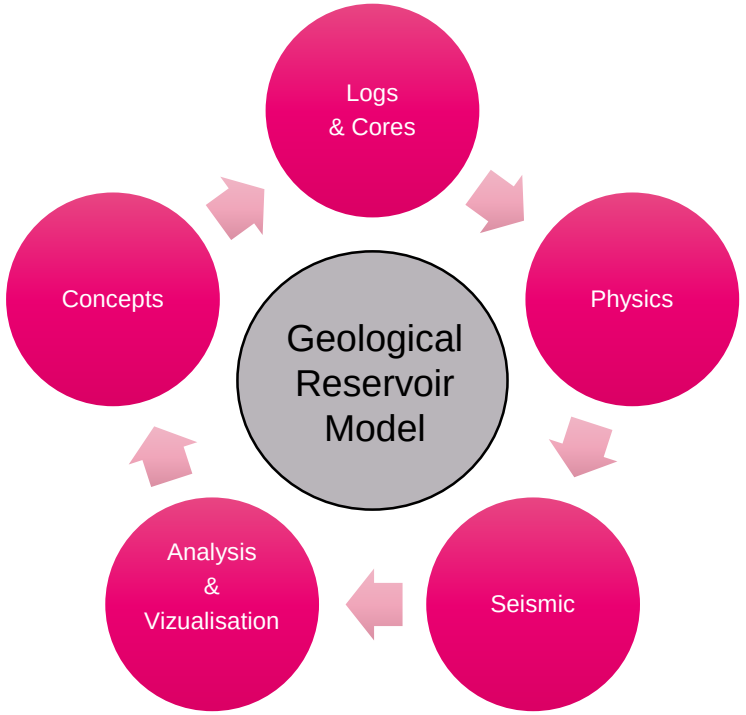




Outline

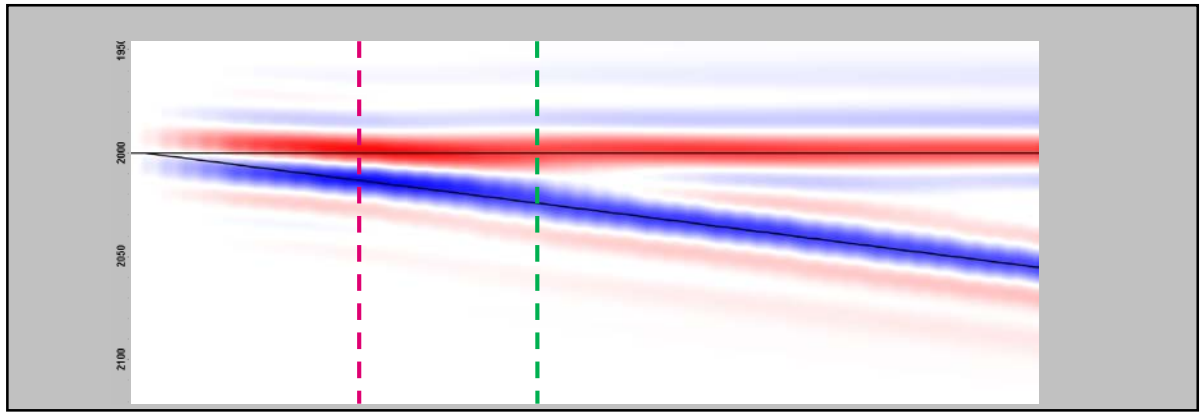
Seismic resolution – first order challenge in reservoir characterization

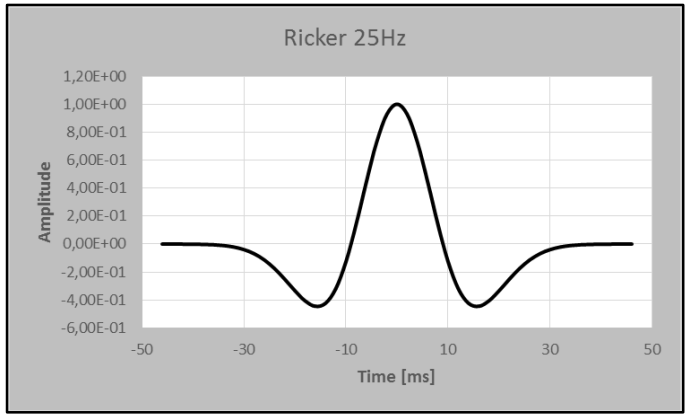
- Introduction
- Basic principles
- Options for visualizing thin bedded resolution
- Examples - Visualizing internal layering
- Verification
- Conclusions

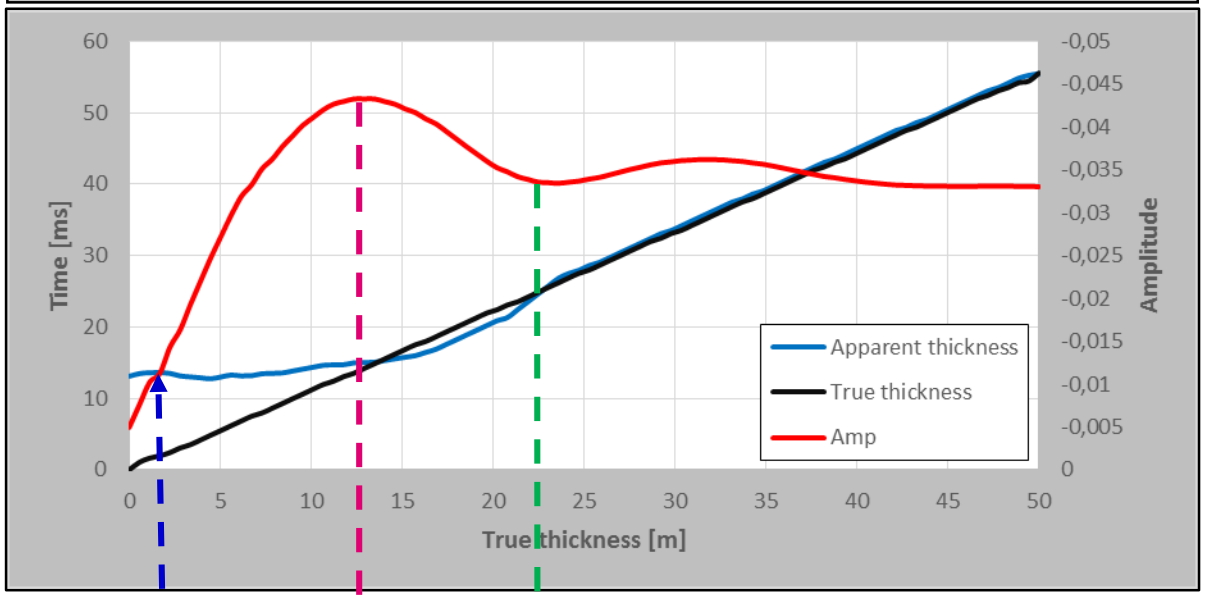


Thickness and Seismic Tuning

– the simple perspective with a binary model







Over predict thickness

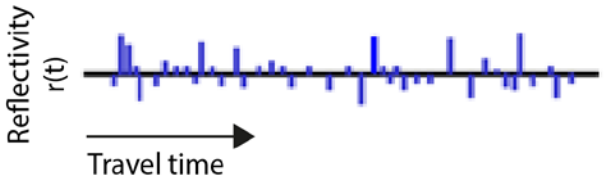
Max tuning

Onset of interference/tuning

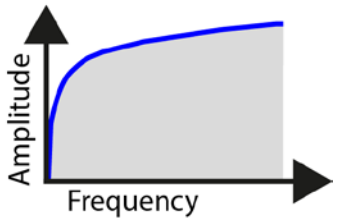
- Tuning Thickness is λ/4 – 15 ms or 1/¼ fmax
- Below tuning, thickness is over-predicted
- Below tuning we may use amplitude or inversion to predict true thickness

Alternatives

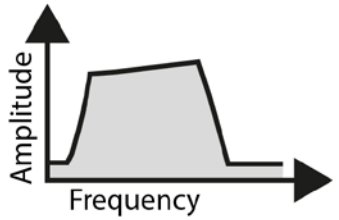
Blueing: Shape the wavelet to match the reflectivity ”colour” of geology



Reflectivity Log (geology)

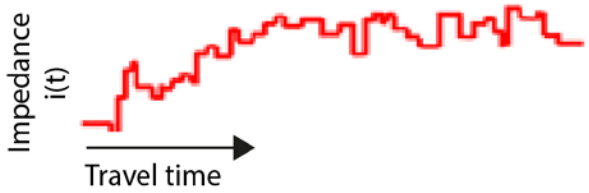


The blue “colour” of geological reflectivity

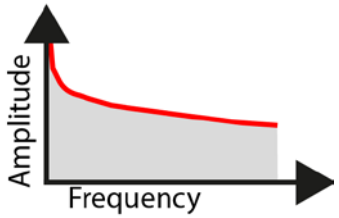


Reflectivity matched to the ”colour” of geology

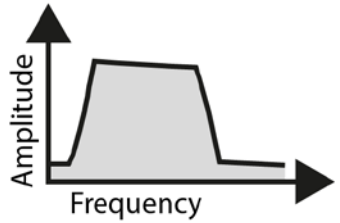
Coloured Inversion: Shape the wavelet and phase to match the impedance ”colour” of geology



Acoustic Impedance Log (geology)

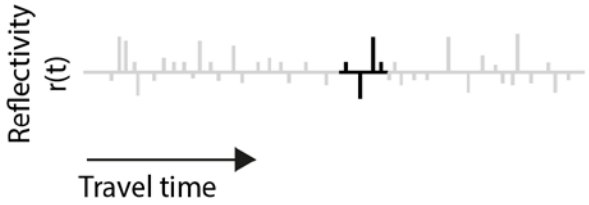


The red “colour” of geological Impedance

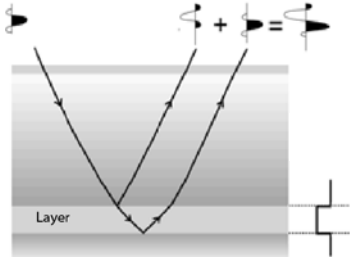


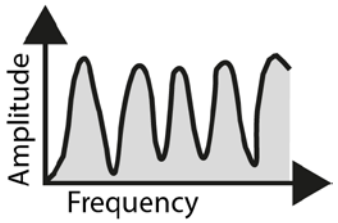
Impedance matched to the ”colour” of geology

Spectral Inversion: Remove the wavelet and analyse the spectral behaviour of the reservoir to complement the time analysis

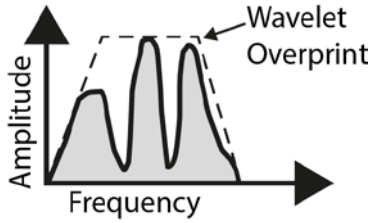


Detailed analysis





Spectral behavior of thin layering



Spectral behaviour of thin layering seen in seismic

Adding spectral decomposition to our analysis

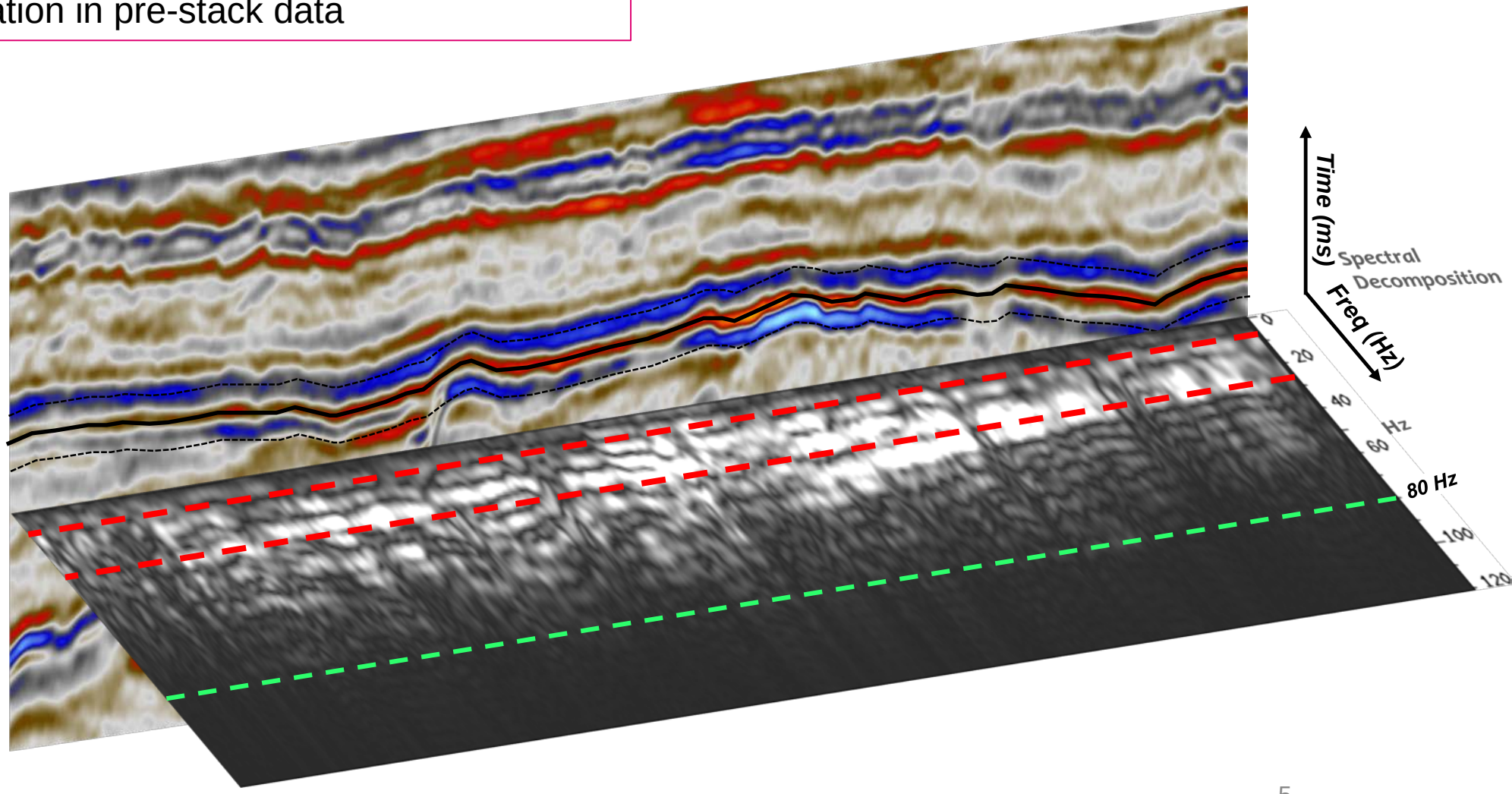
- Looking only at the time section – conceals details
- Analogy to information in pre-stack data

Zone of interest

Frequency spectra from a 200ms window

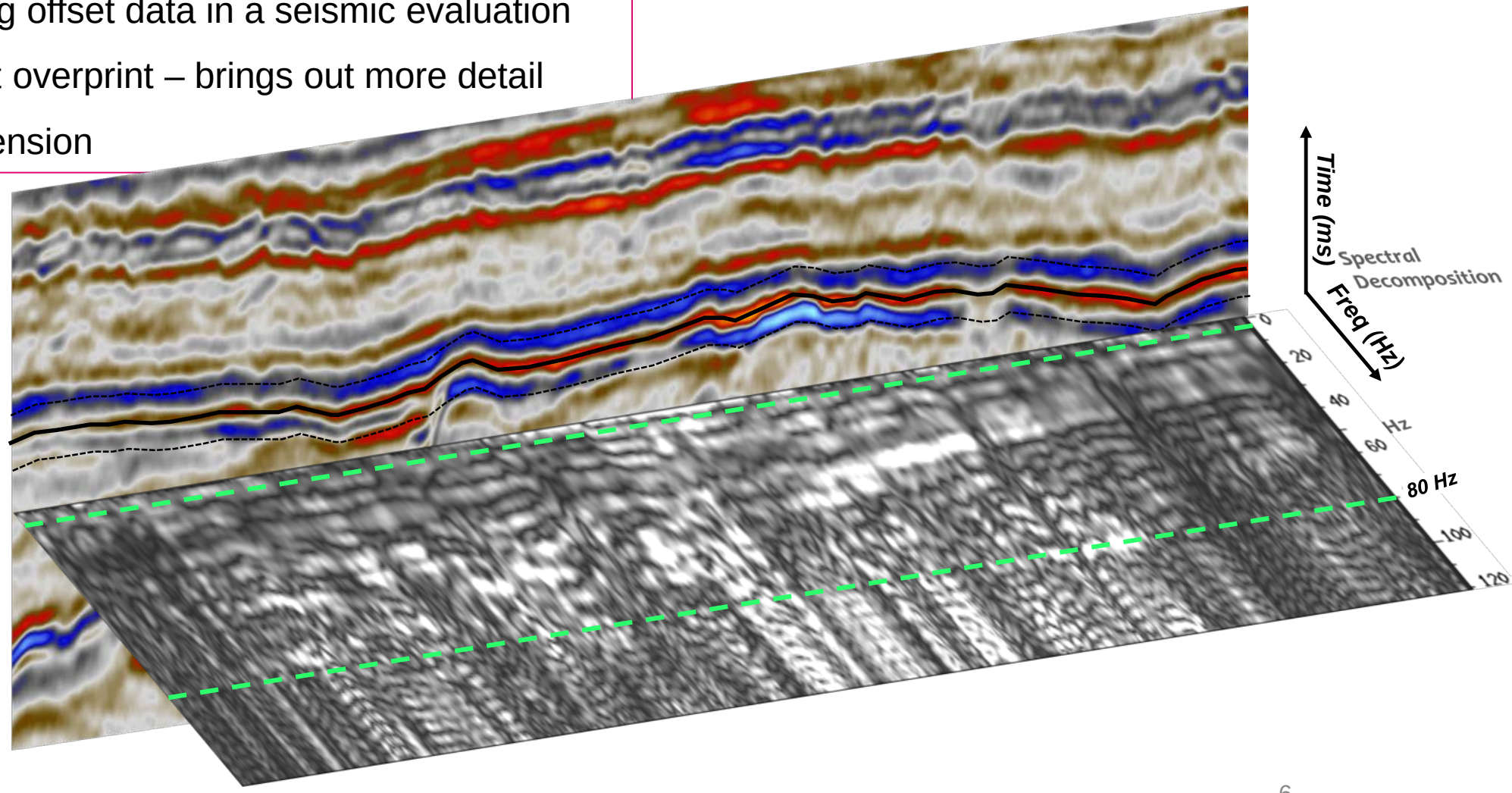
Signal extends from 3-to-80Hz

Dominant frequency ~7-to-25Hz



Removing the wavelet overprint

- Looking only at the time section – conceals details
- Analogy to ignoring offset data in a seismic evaluation
- Removing wavelet overprint – brings out more detail
- No bandwidth extension



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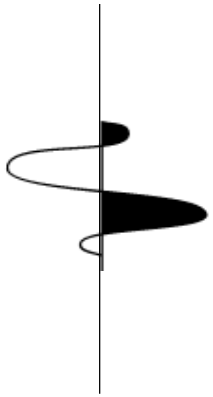
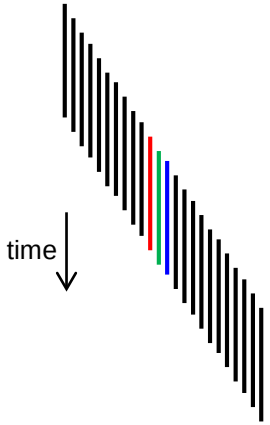
Spectral Inversion



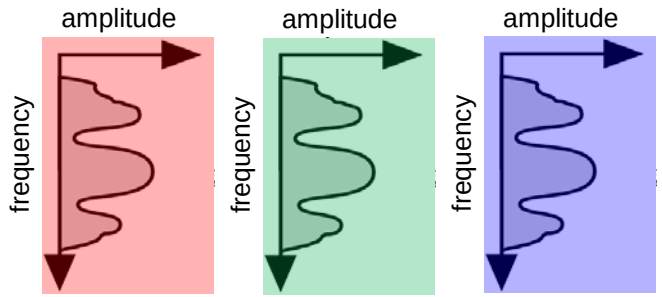
Input data



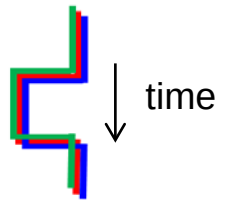
Overlapping Analysis Windows

Spectral Decomposition

Amplitude Spectra from Input data

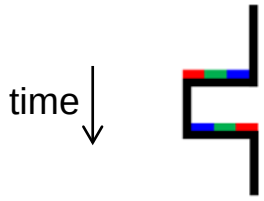


Spectral Inversion



Layering

Summation of solutions

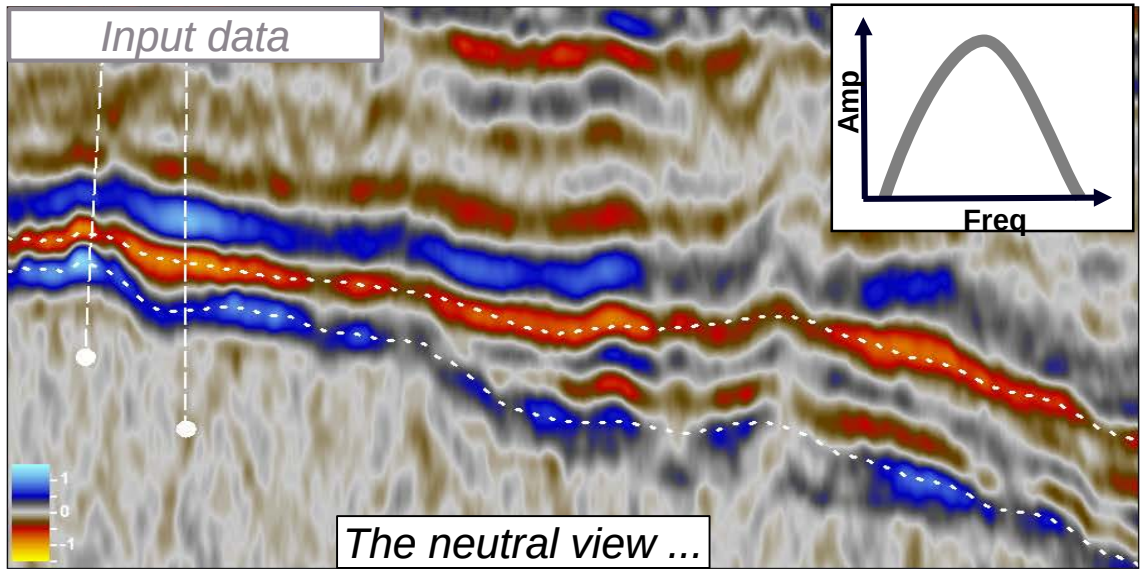


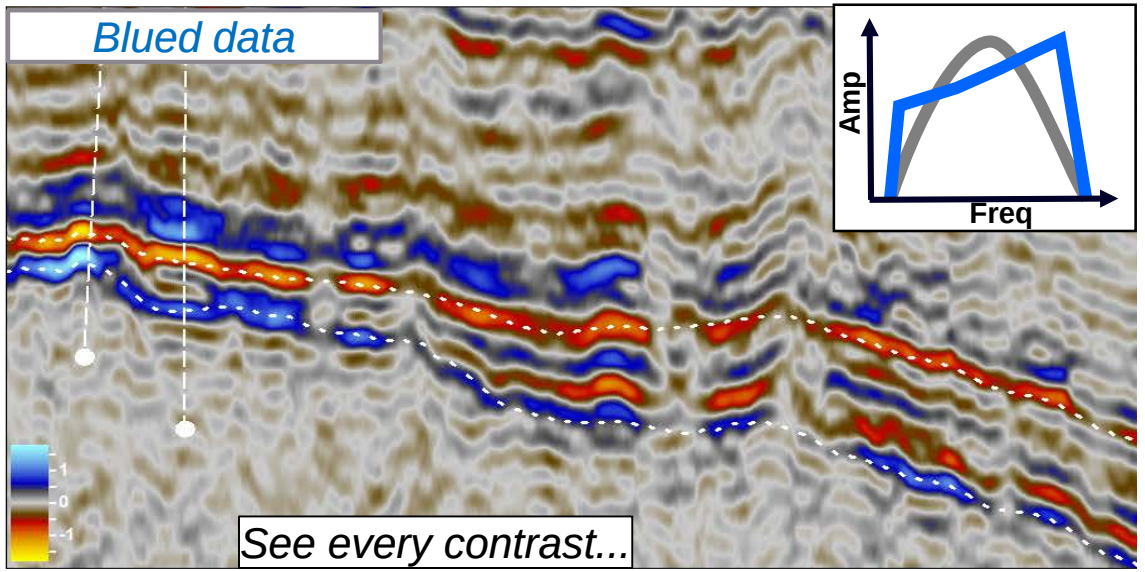
Summed Layering

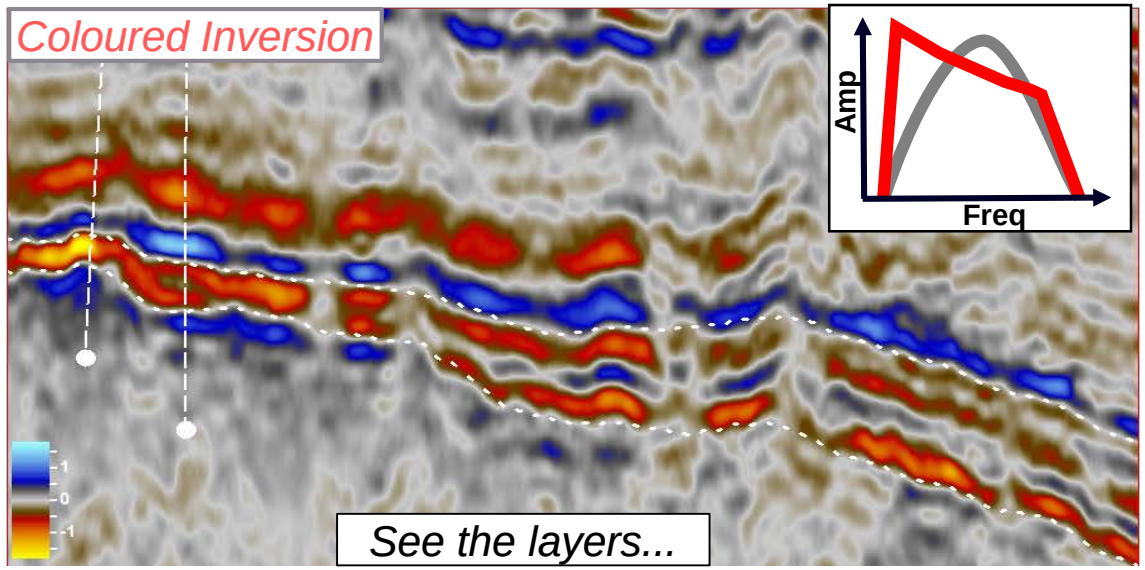
Amplitude represents confidence in layer prediction

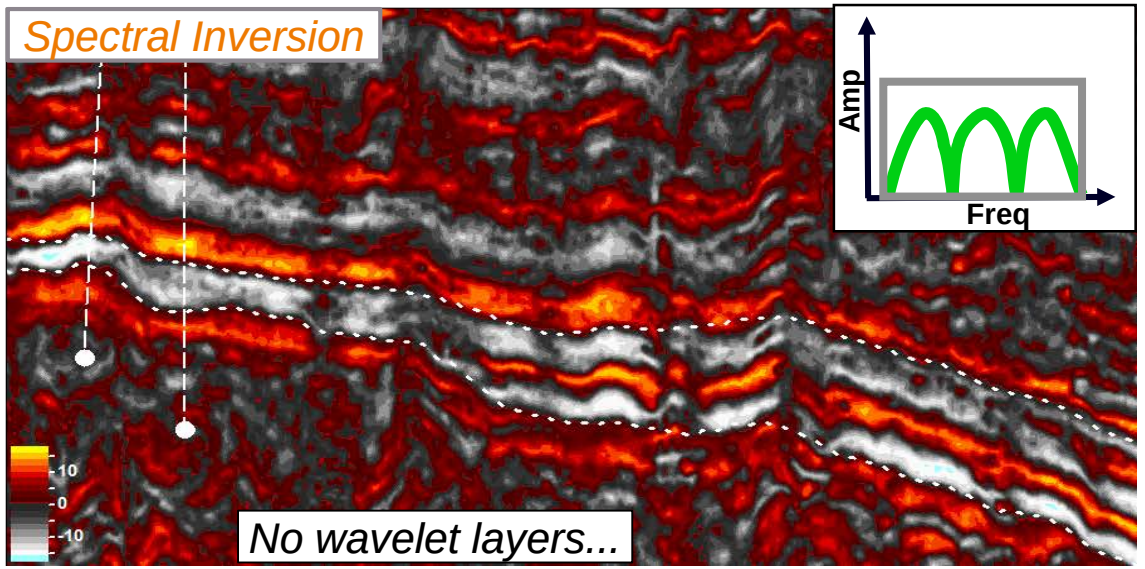
- Layering architecture defined from amplitude spectra
- Layers are defined as “soft” or “hard”
- No background model required

Complementary view

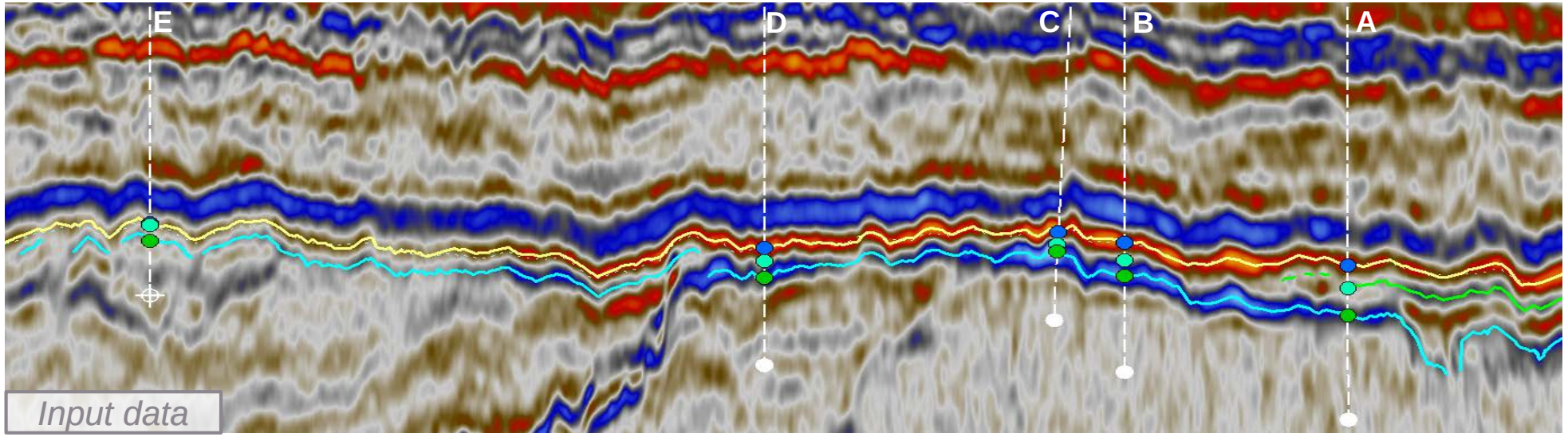


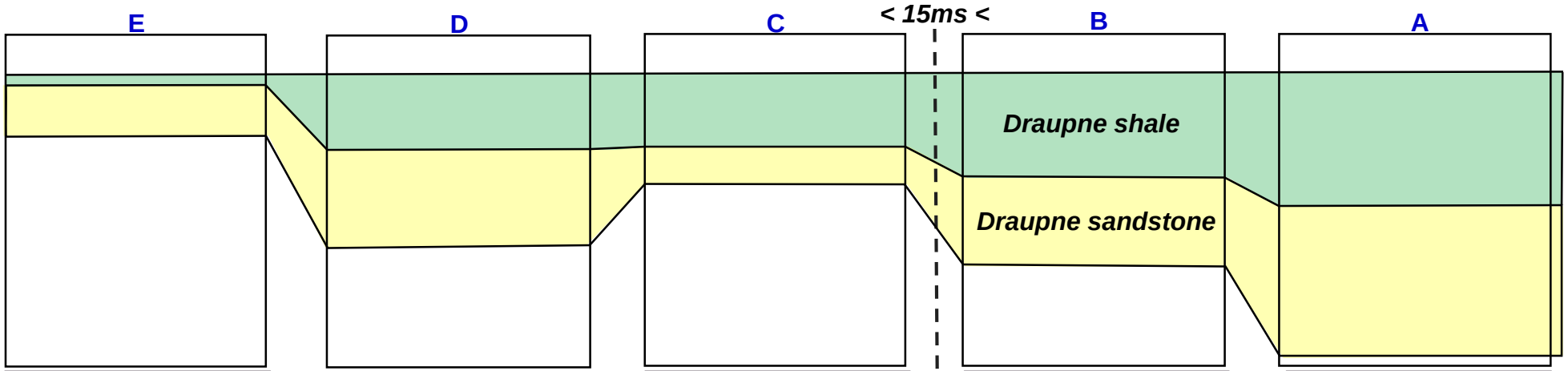






A tour across southern Johan Sverdrup





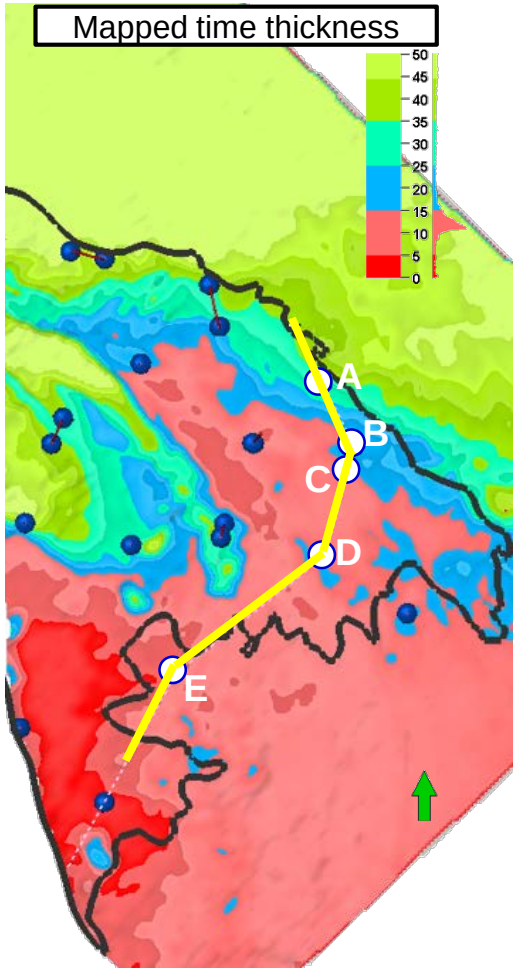
Well E	
Thickness	ms
Shale	1
Sandstone	5

Well D	
Thickness	ms
Shale	8
Sandstone	9

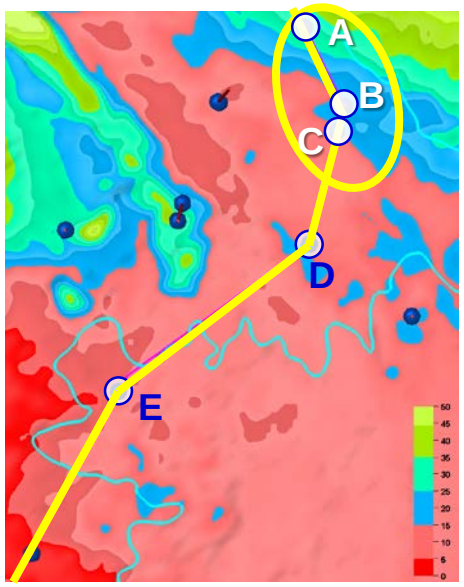
Well C	
Thickness	ms
Shale	7
Sandstone	4

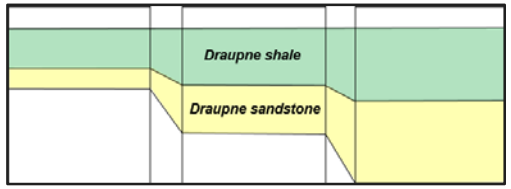
Well B	
Thickness	ms
Shale	10
Sandstone	9

Well A	
Thickness	ms
Shale	13
Sandstone	14



From thick to thin reservoir





C	ΔZ ms
Shale	7
Sandst	4

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Shale	10
Sandst	9

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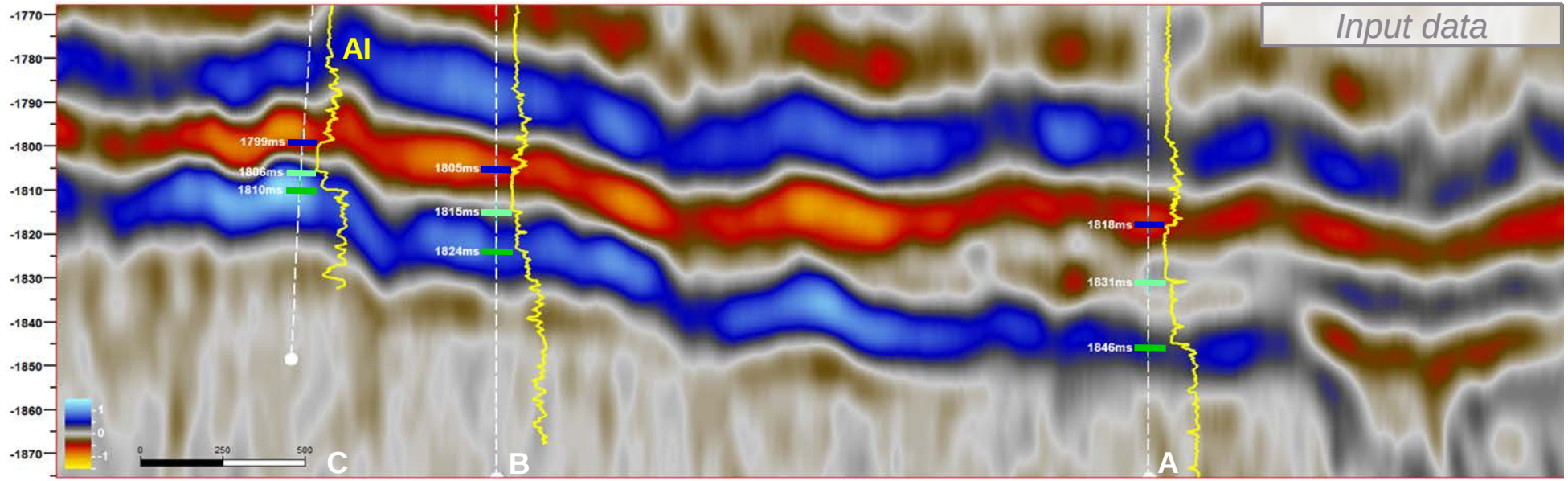
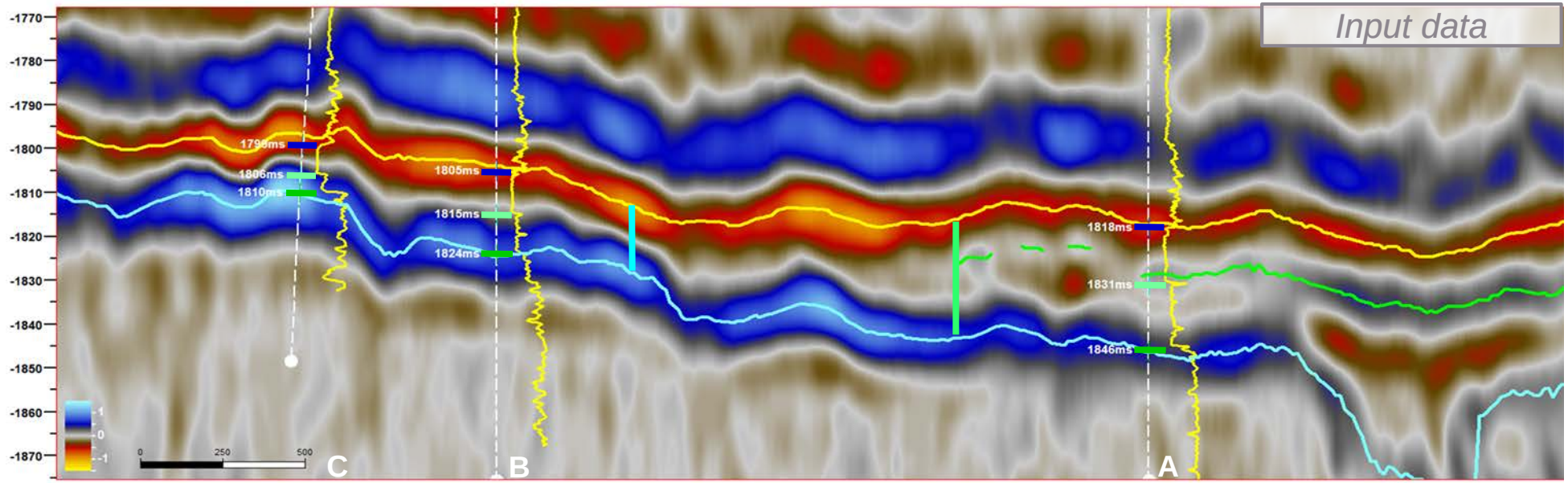
Sandst	14





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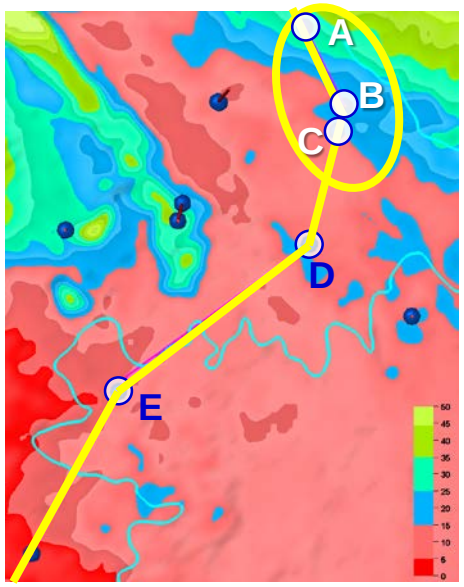

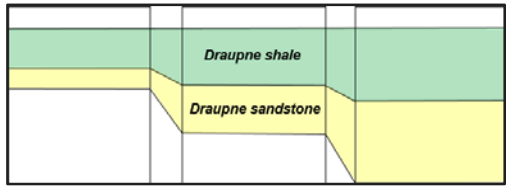

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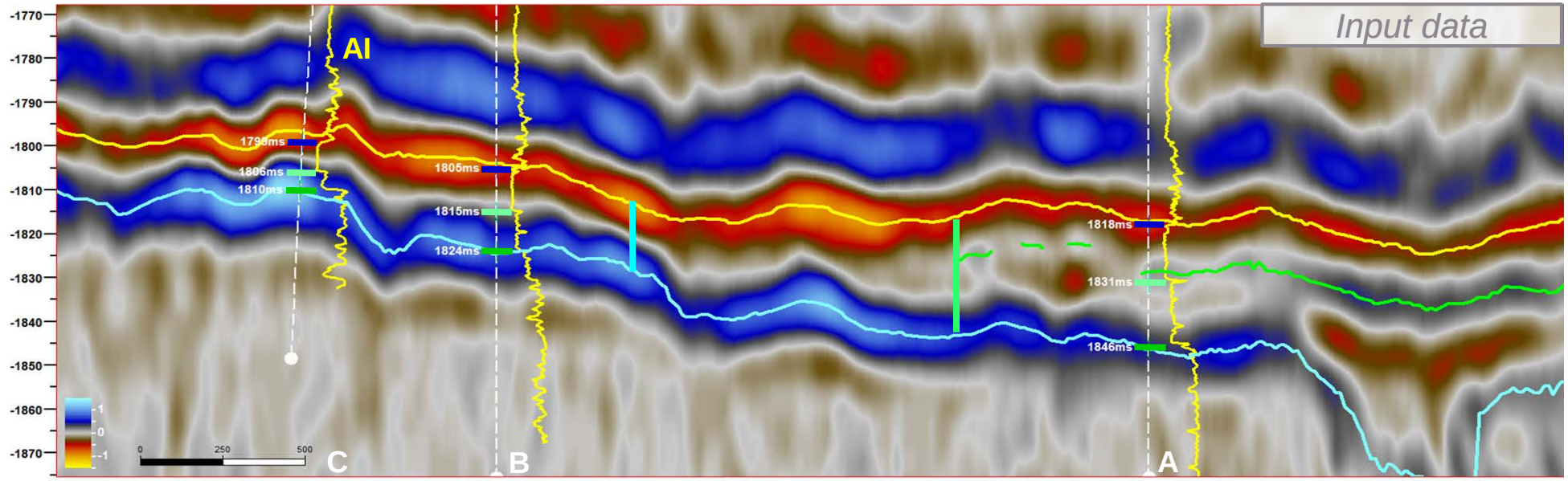

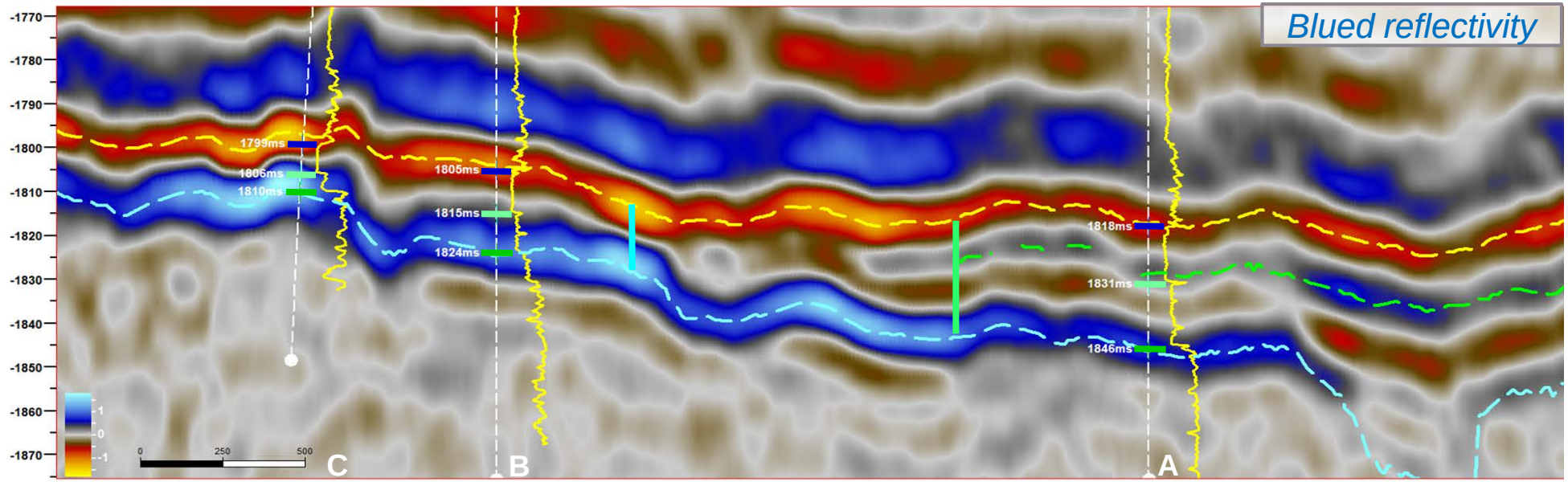

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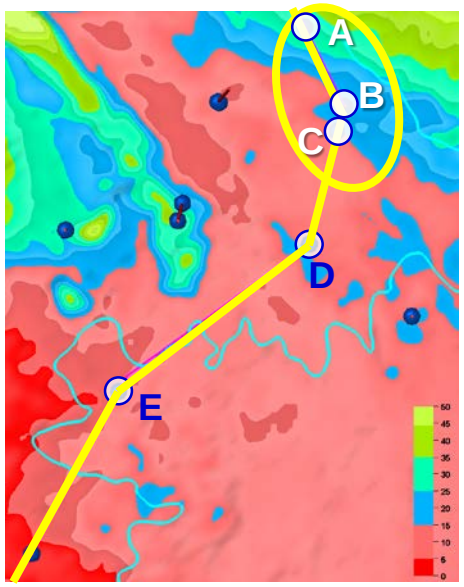

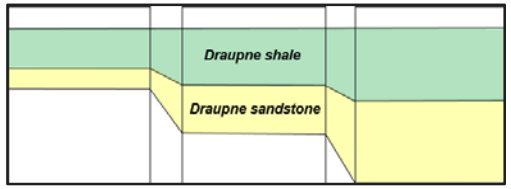

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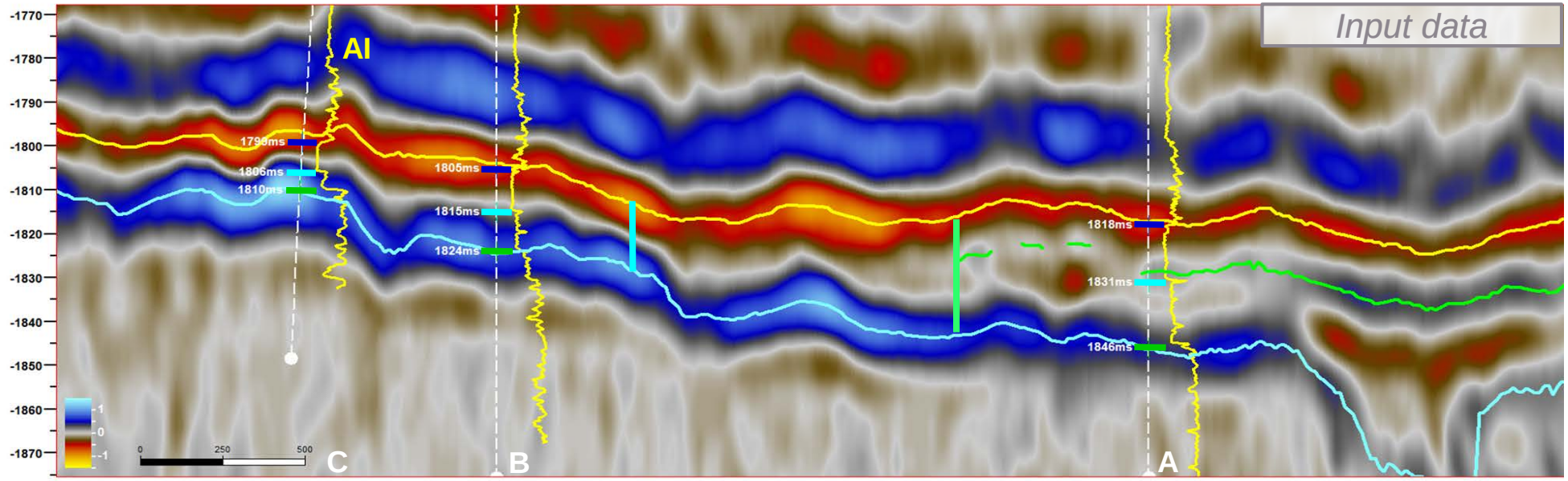

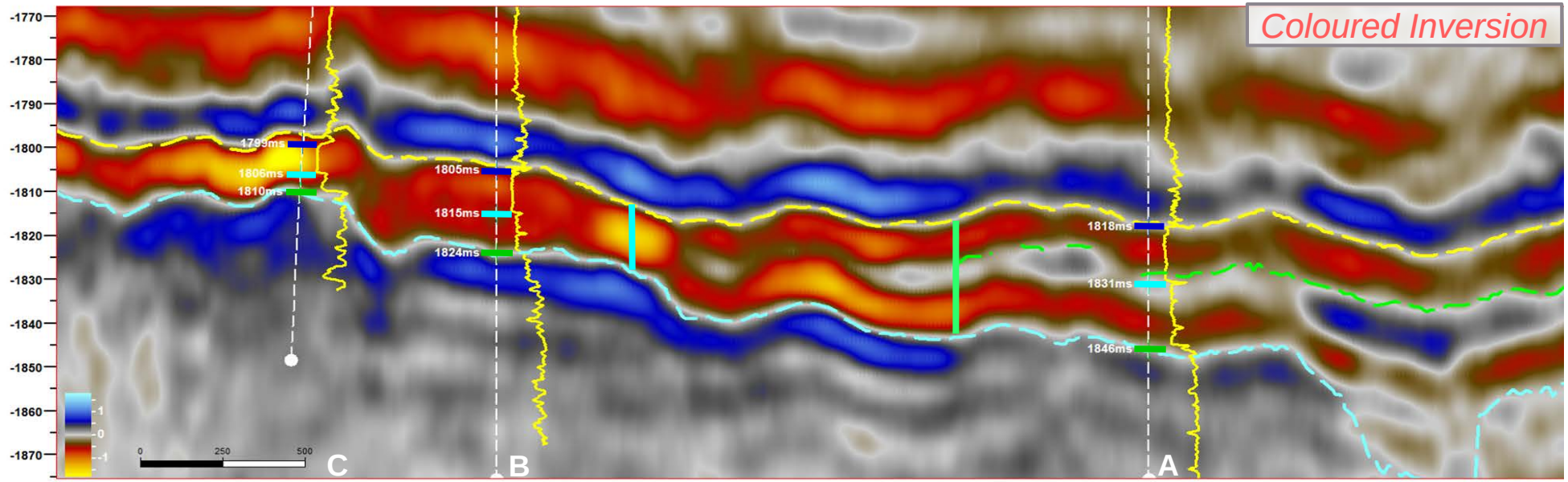

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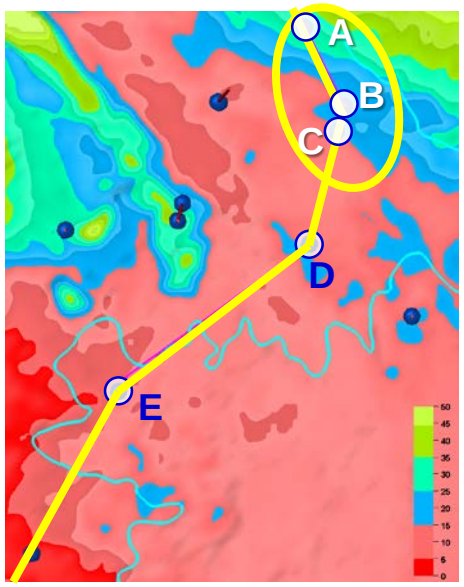
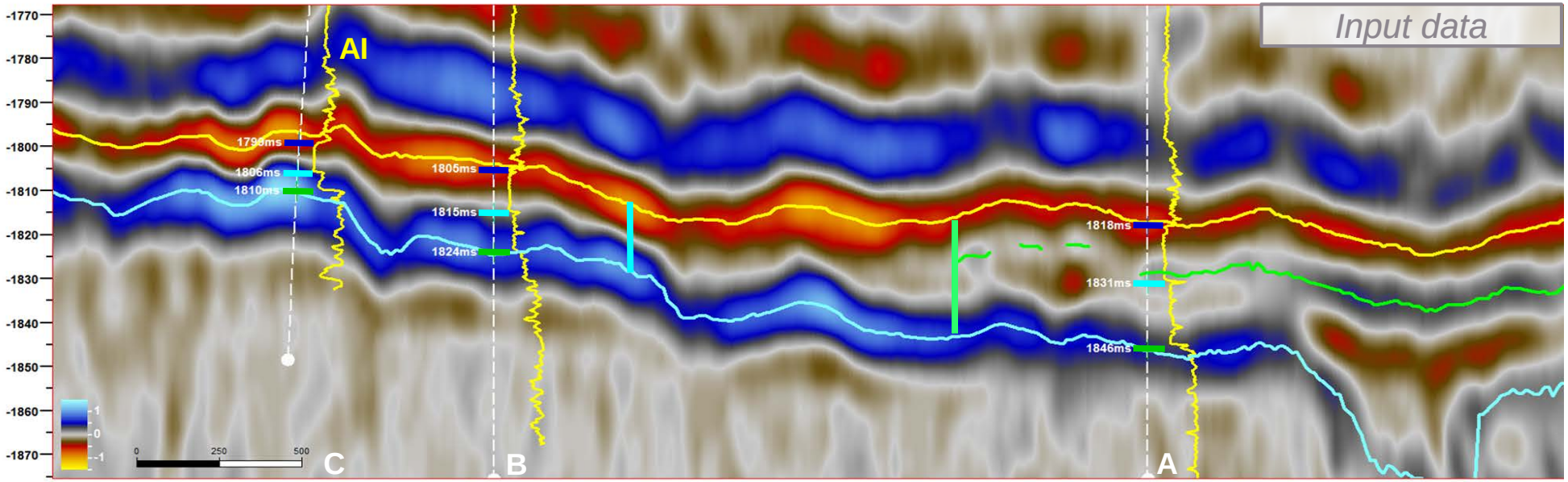
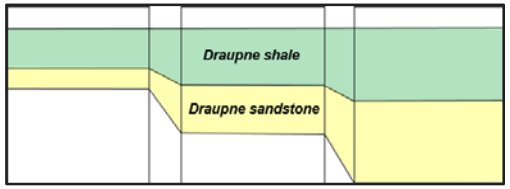
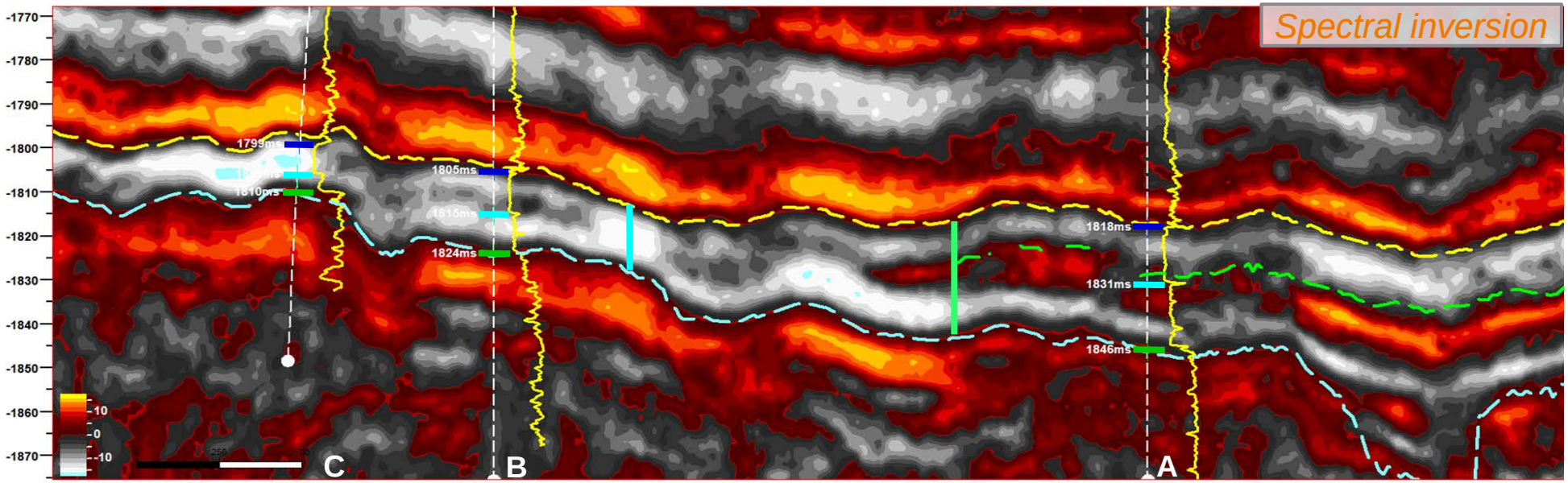






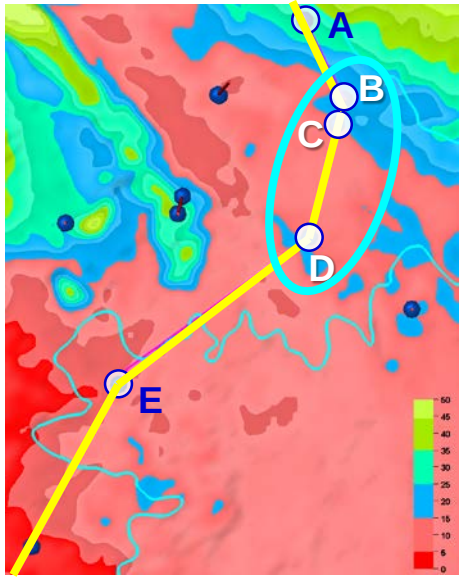


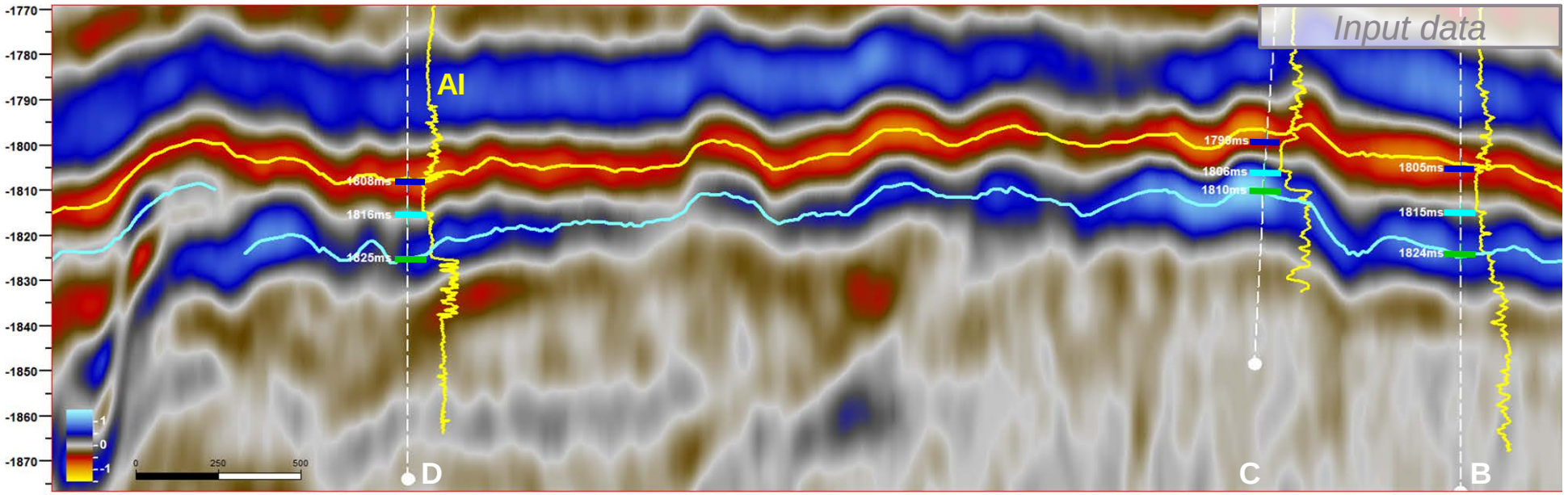
C	ΔZ ms
Shale	7
Sandst	4

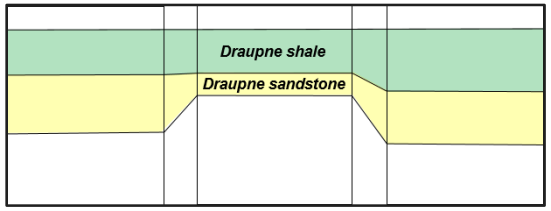
B	ΔZ ms
Shale	10
Sandst	9

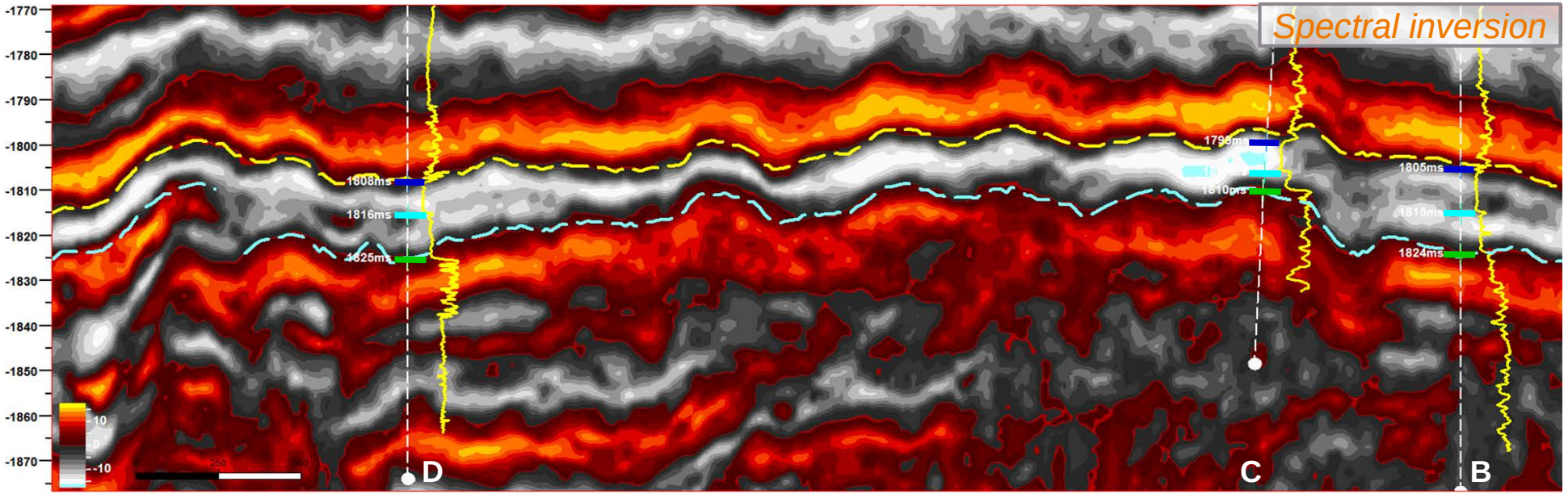
A	ΔZ ms
Shale	13
Sandst	14

Below tuning thickness over the Avaldsnes High







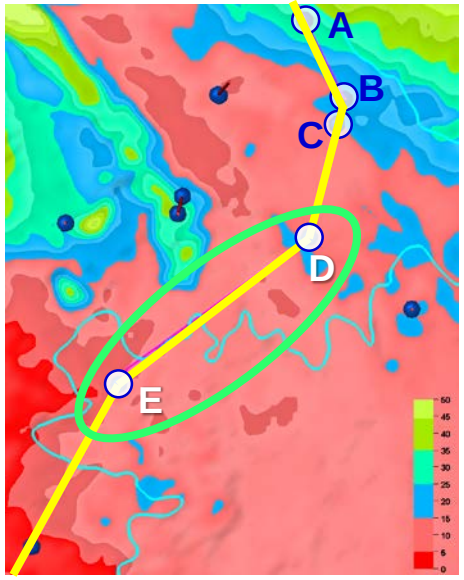


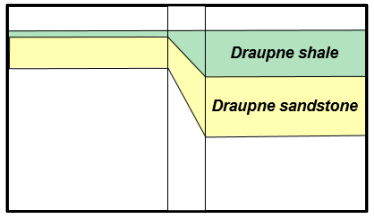
D	ΔZ ms
Shale	8
Sandst	9

C	ΔZ ms
Shale	7
Sandst	4

B	ΔZ ms
Shale	10
Sandst	9

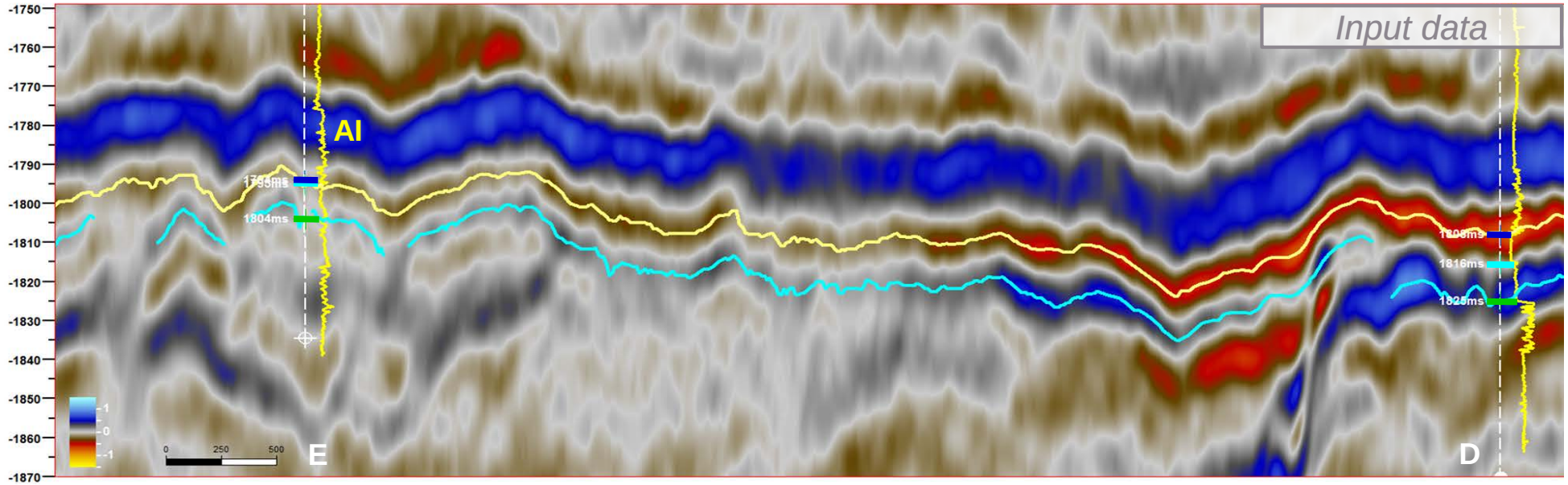
Thin Jurassic sand layer in southern Johan Sverdrup

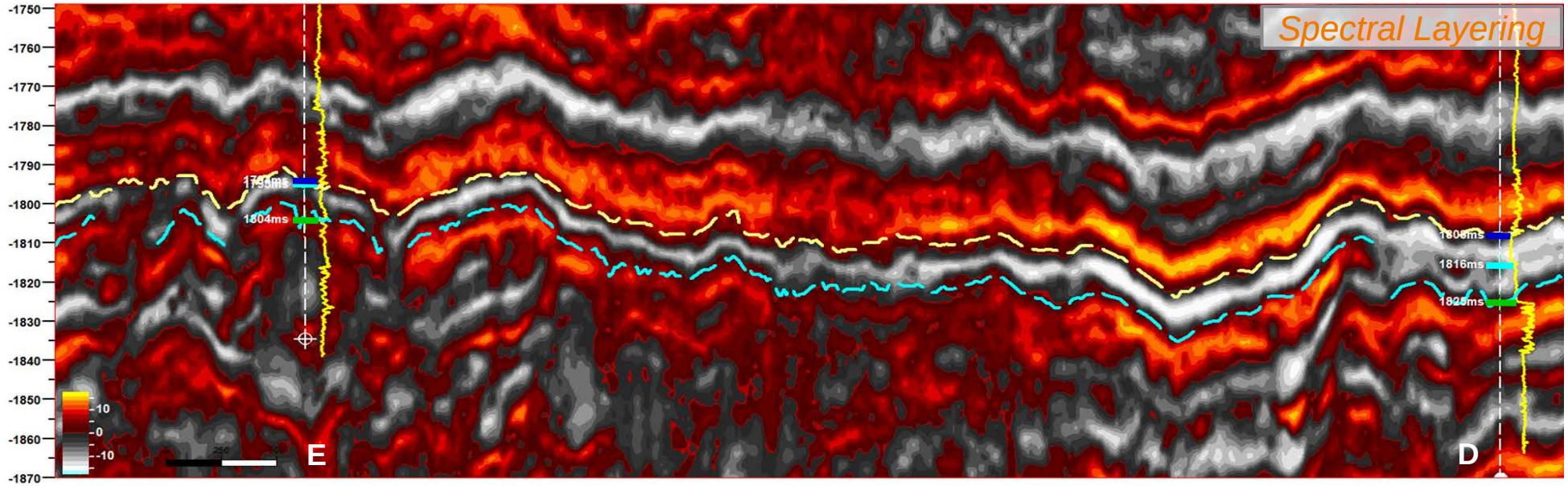




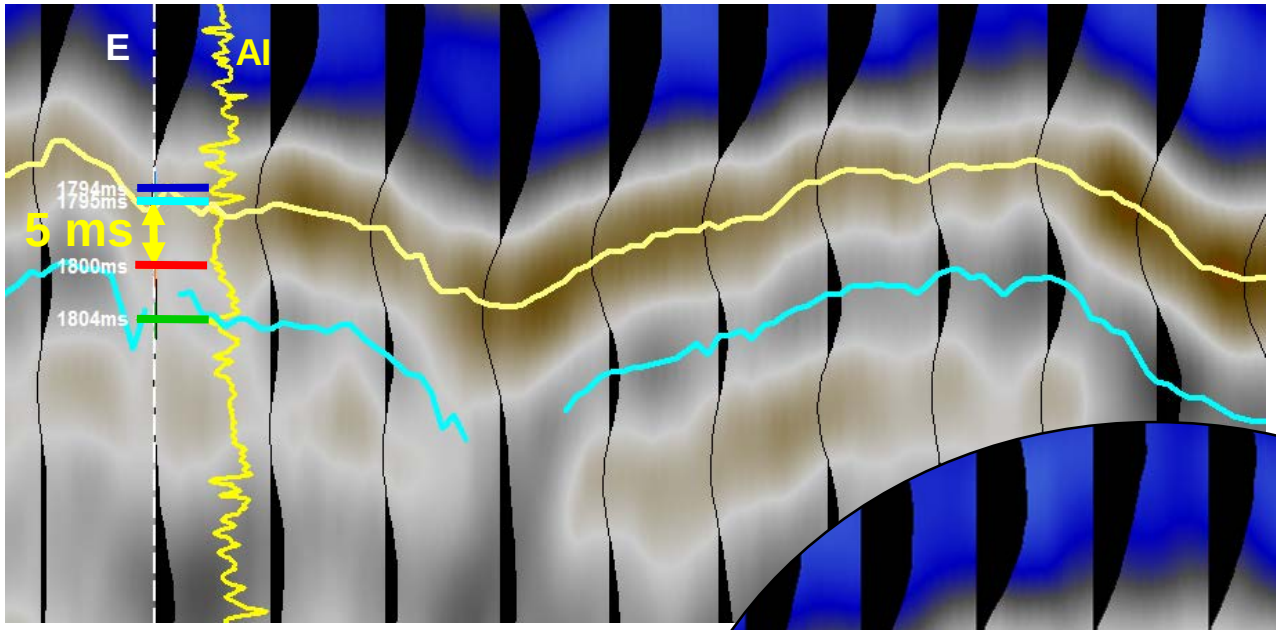
E	ΔZ ms
Shale	1
Sandst	5

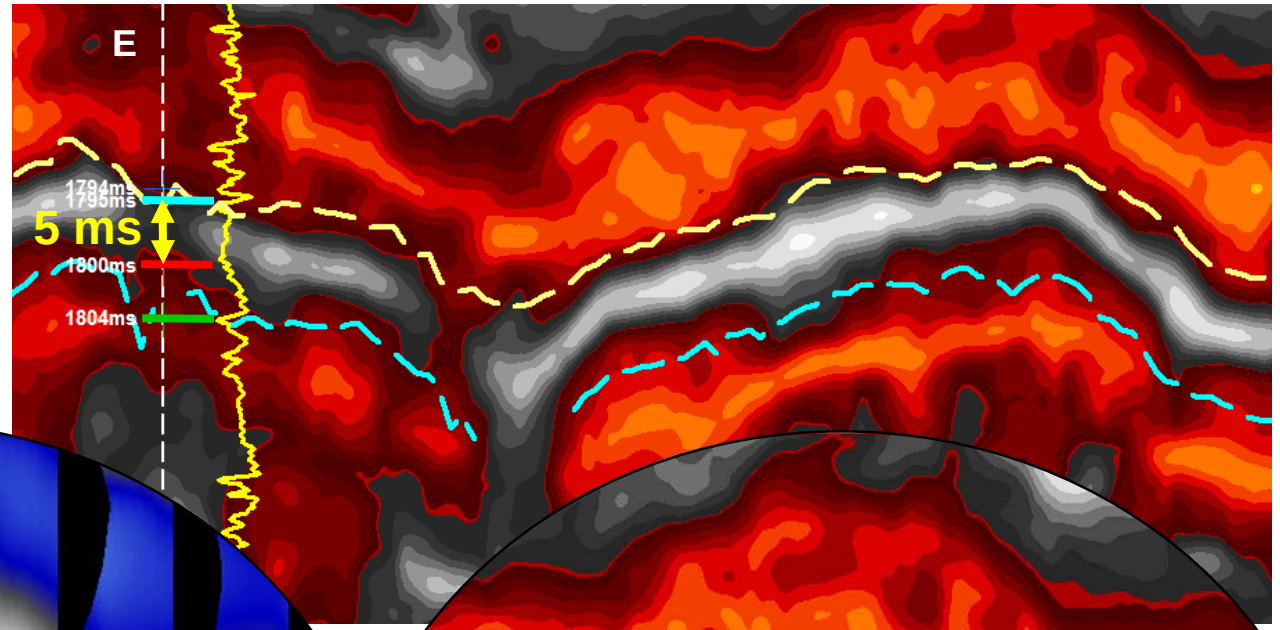
D	ΔZ ms
Shale	8
Sandst	9

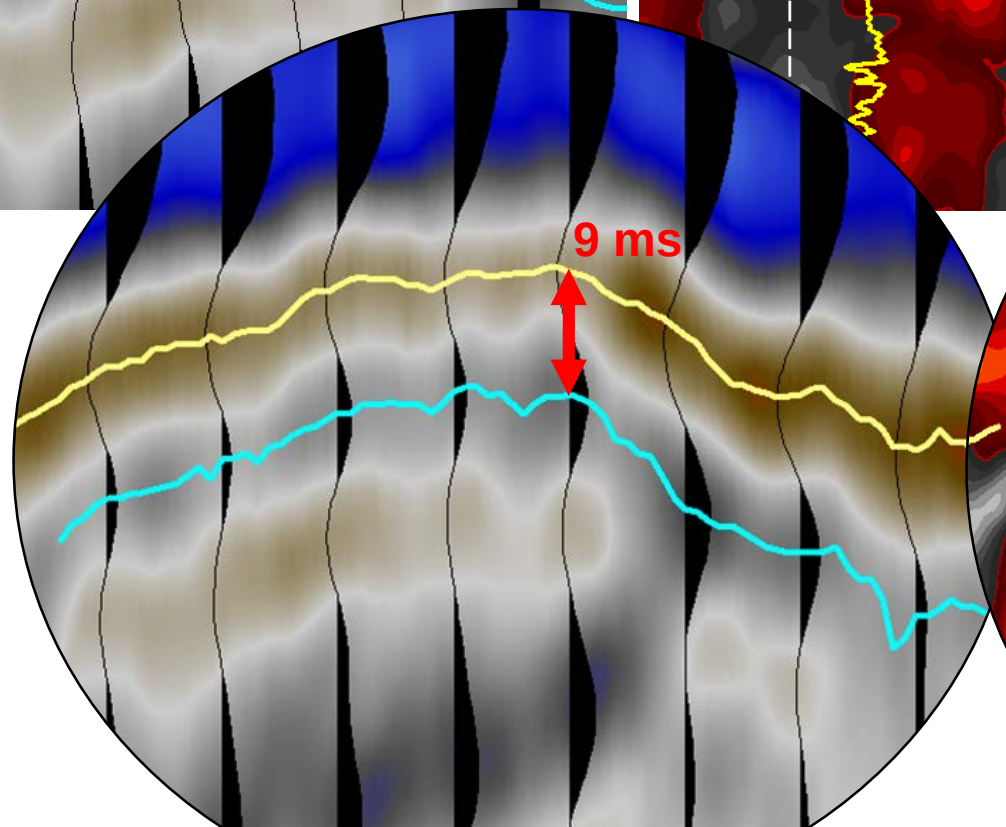


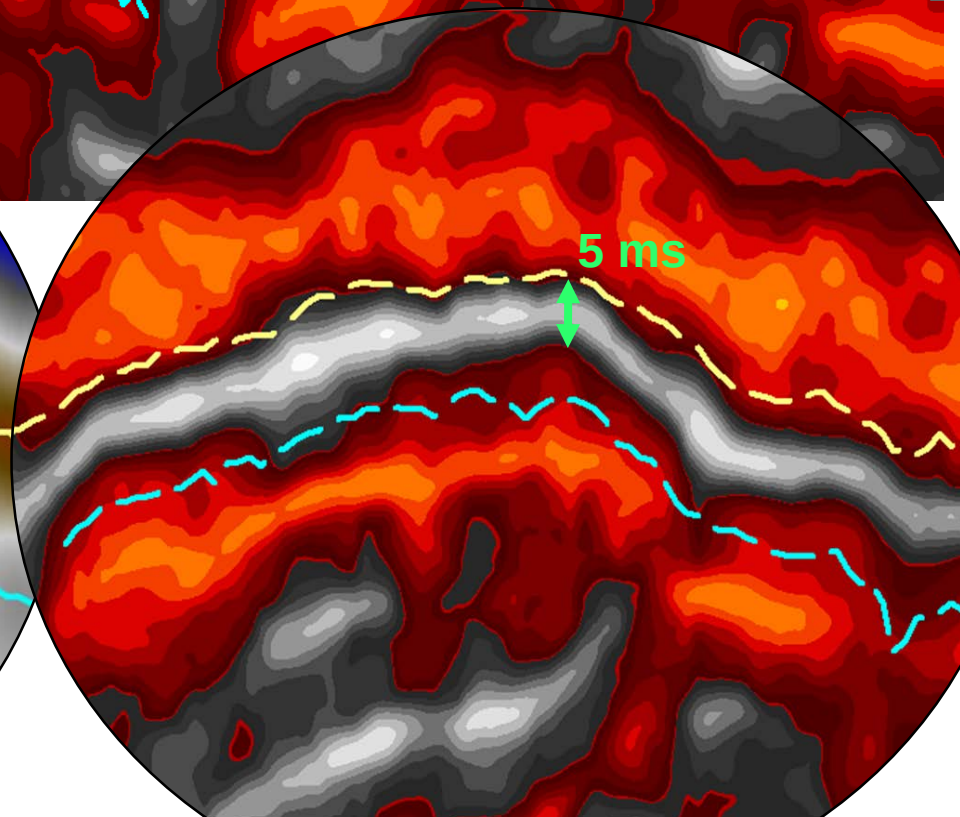


Eyeballing the thin layer







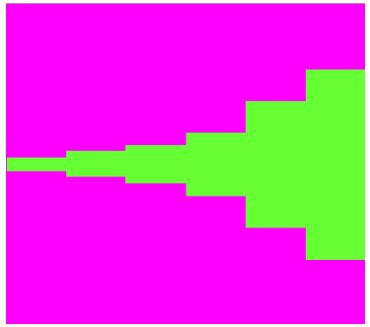


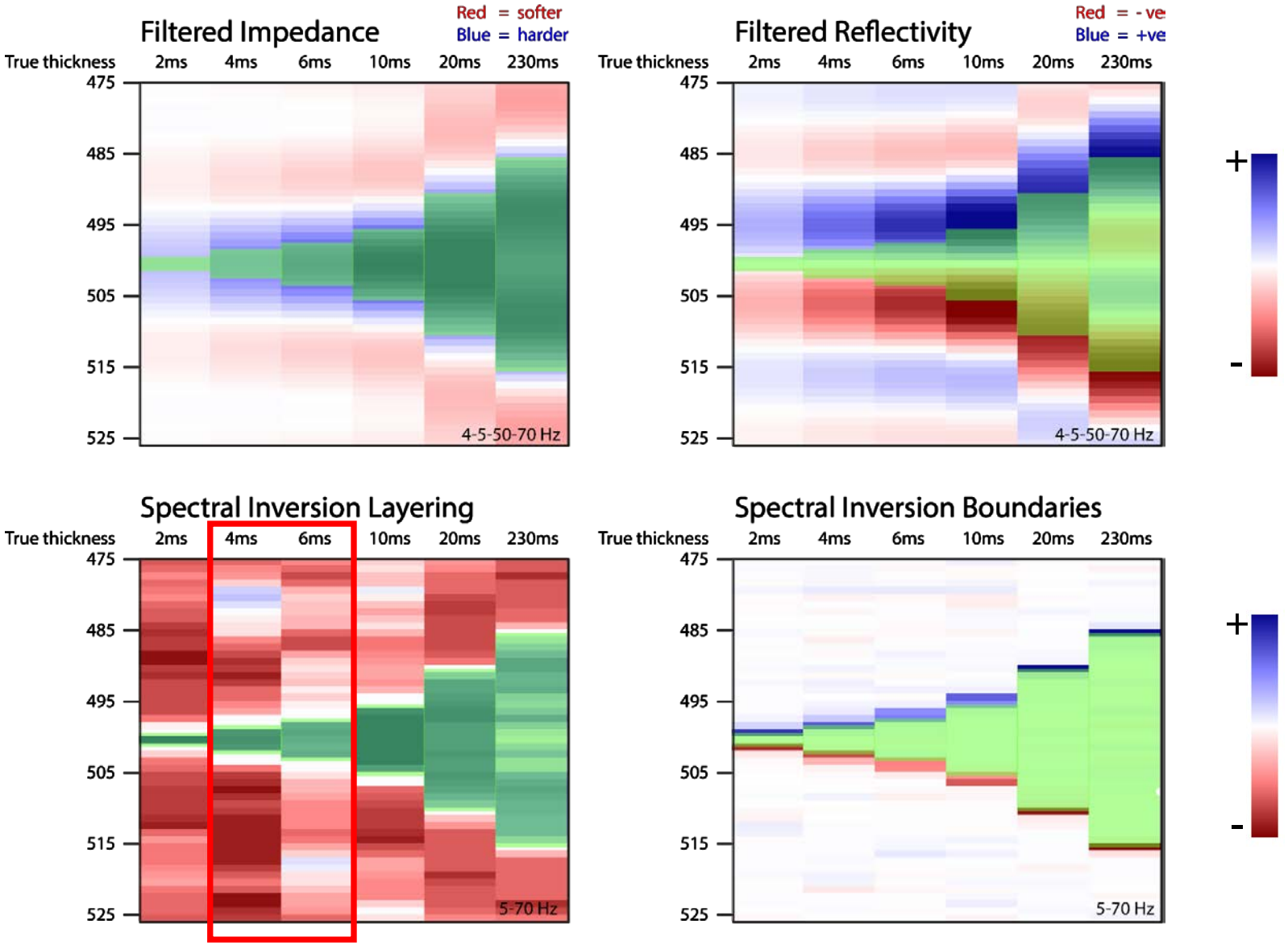
Conventional Seismic
Trough / peak ΔT = 9 ms

Spectral Inversion
Trough / peak ΔT = 5 ms

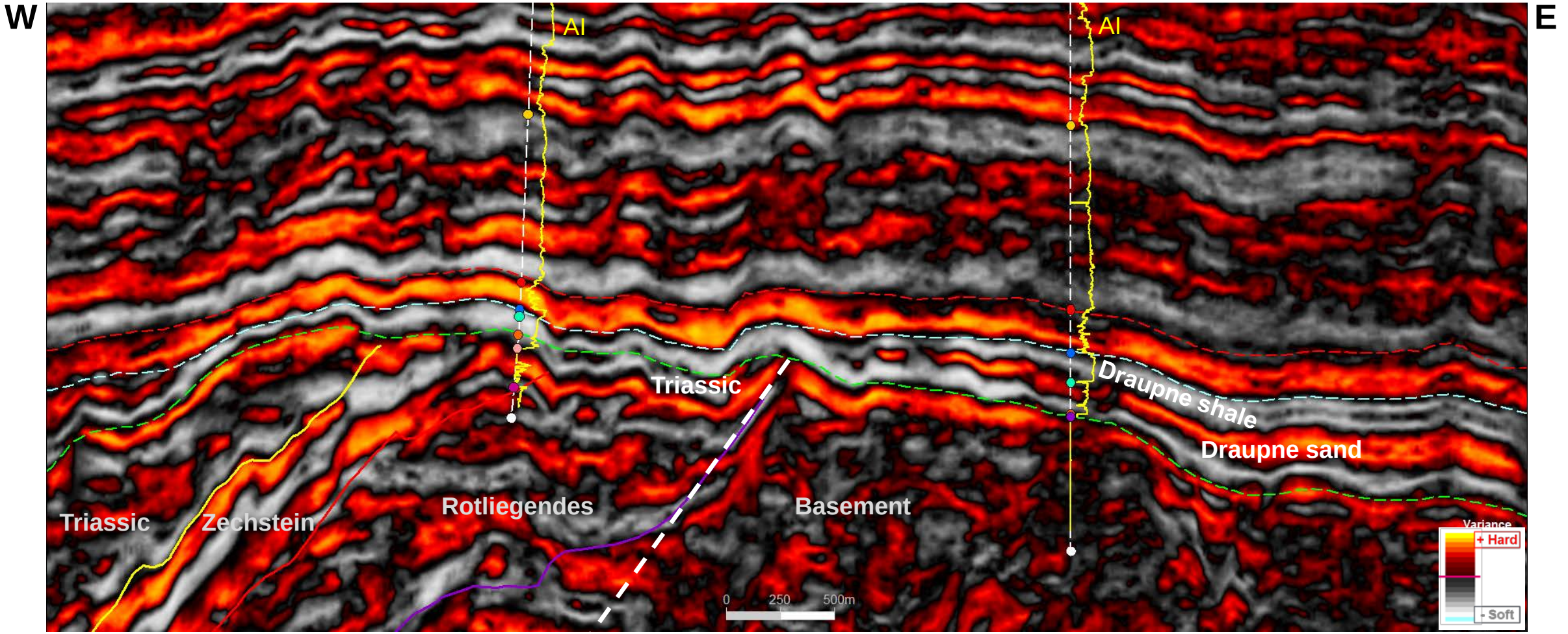
Confirmation through synthetic modeling

Model 1

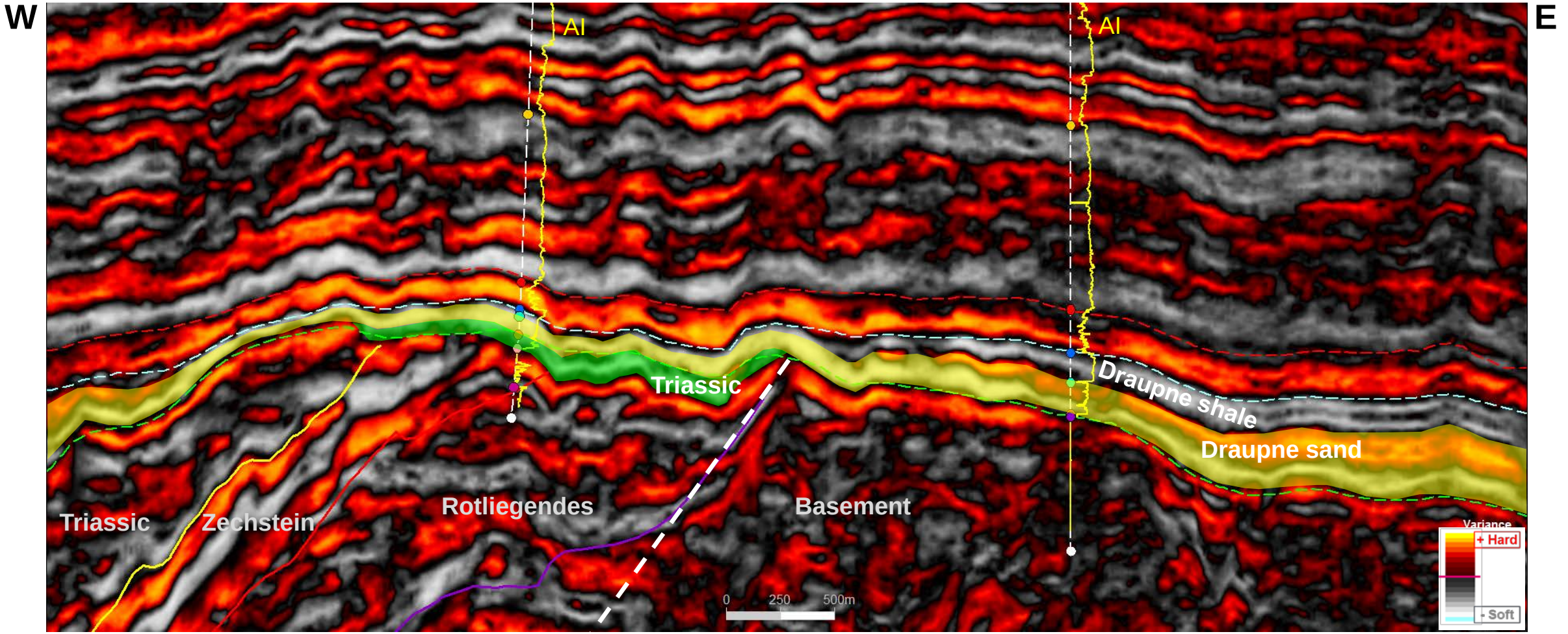




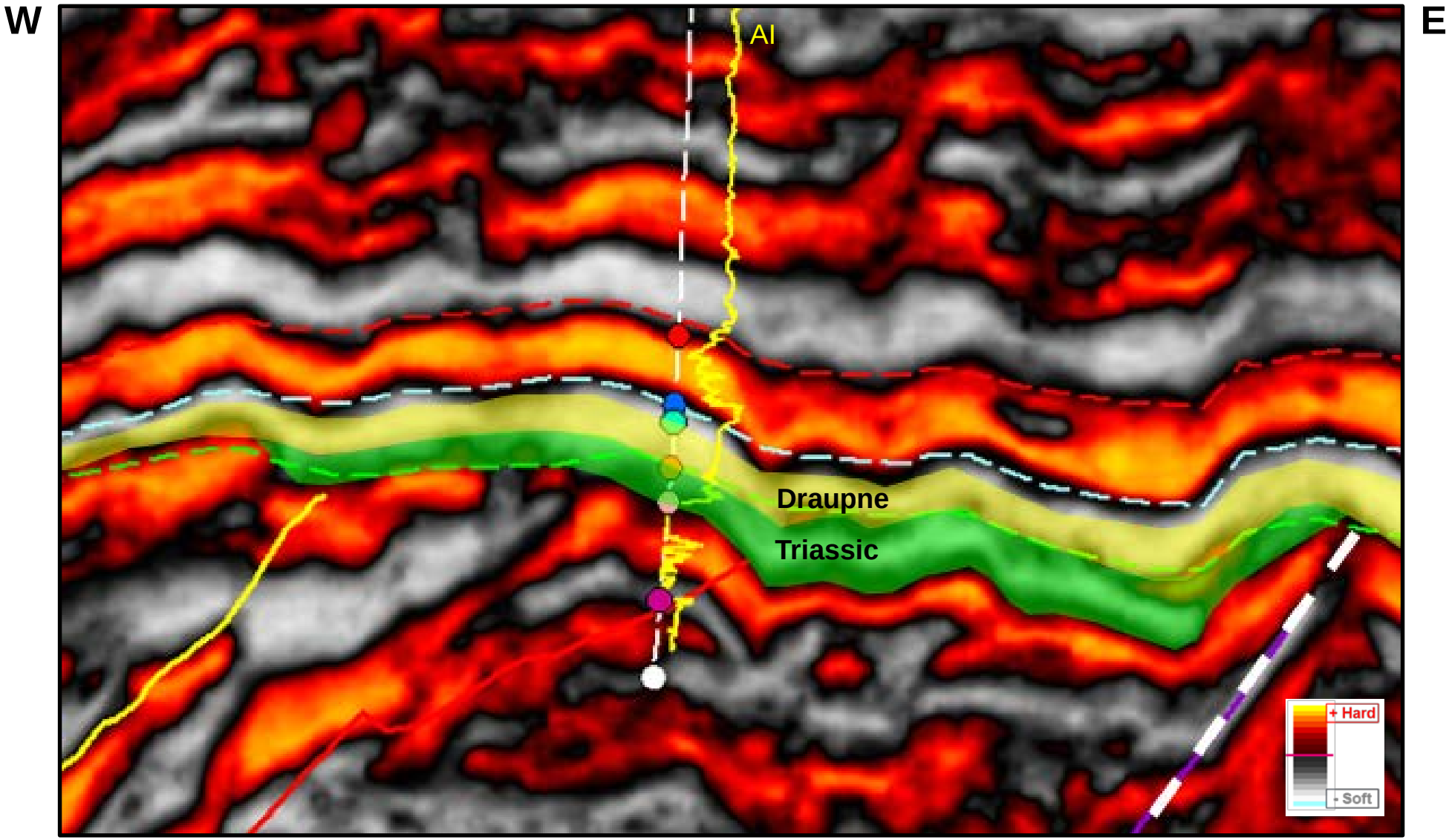
Spectral layering across the Avaldsnes High



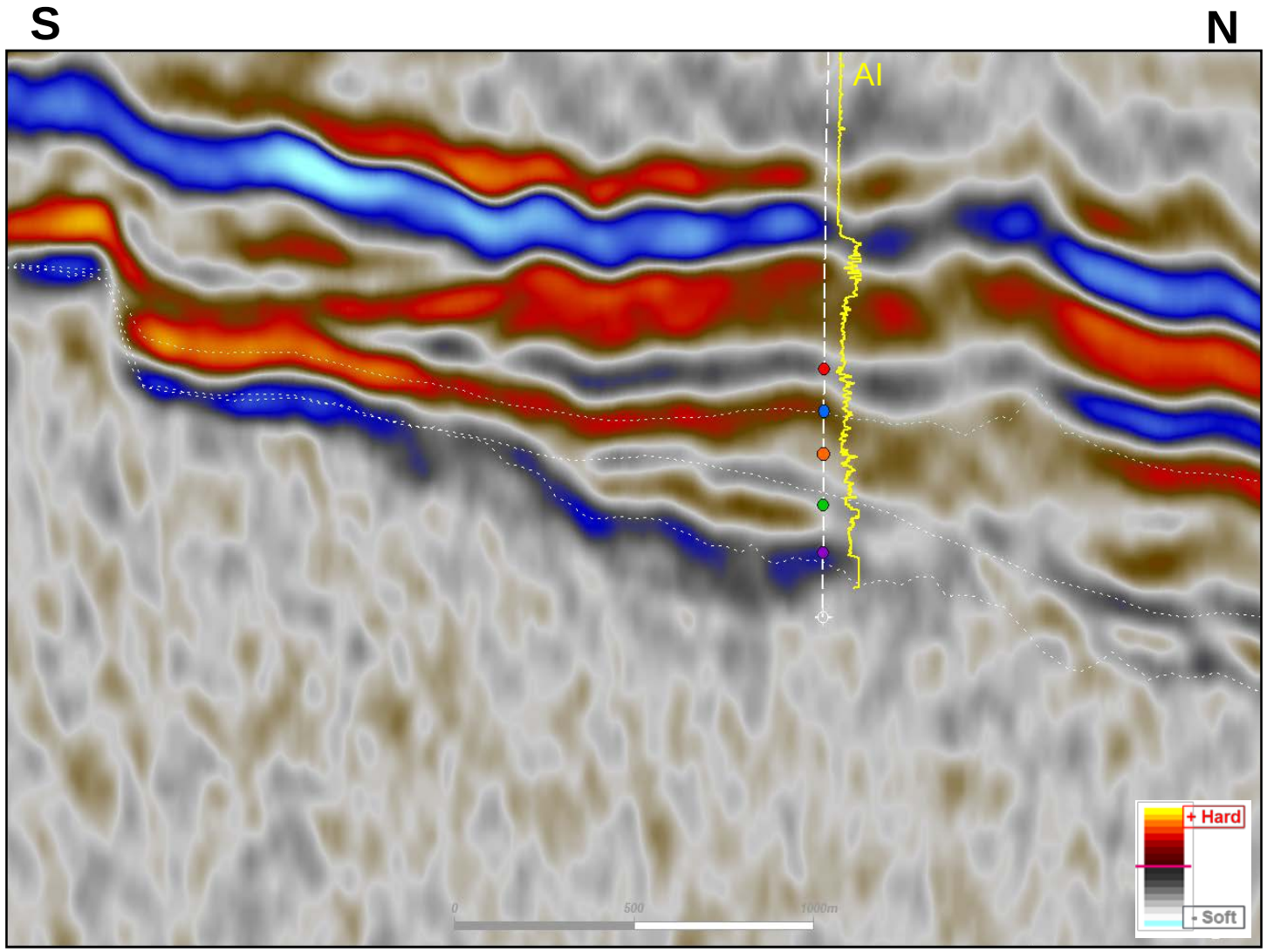
Spectral layering across the Avaldsnes High



Spectral layering across the Avaldsnes High

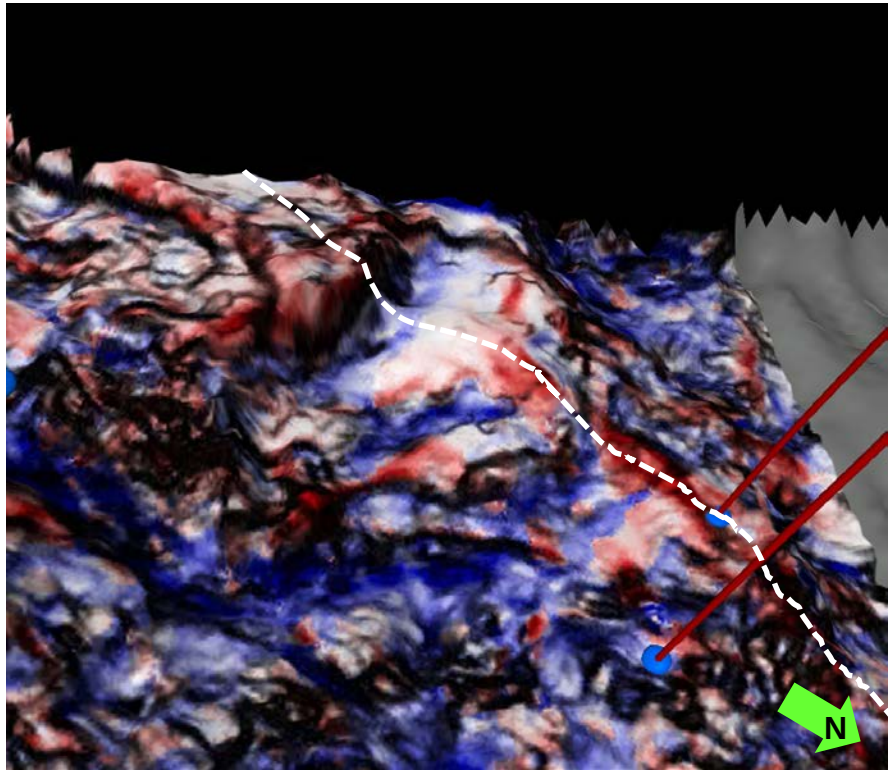


Section from the Tonjer fan to Torvastad

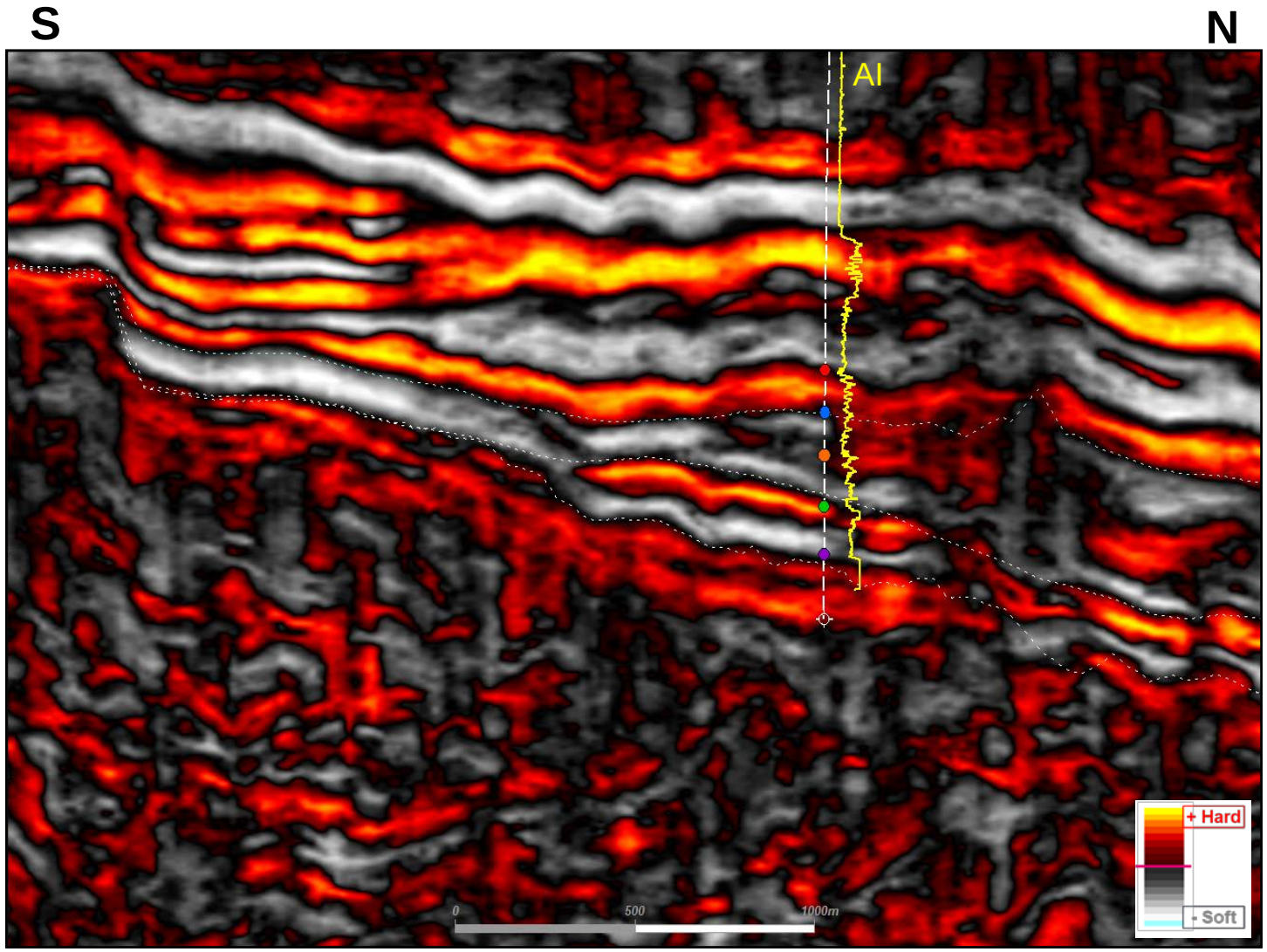


Conventional PSDM 3D seismic

3D curvature map near BCU

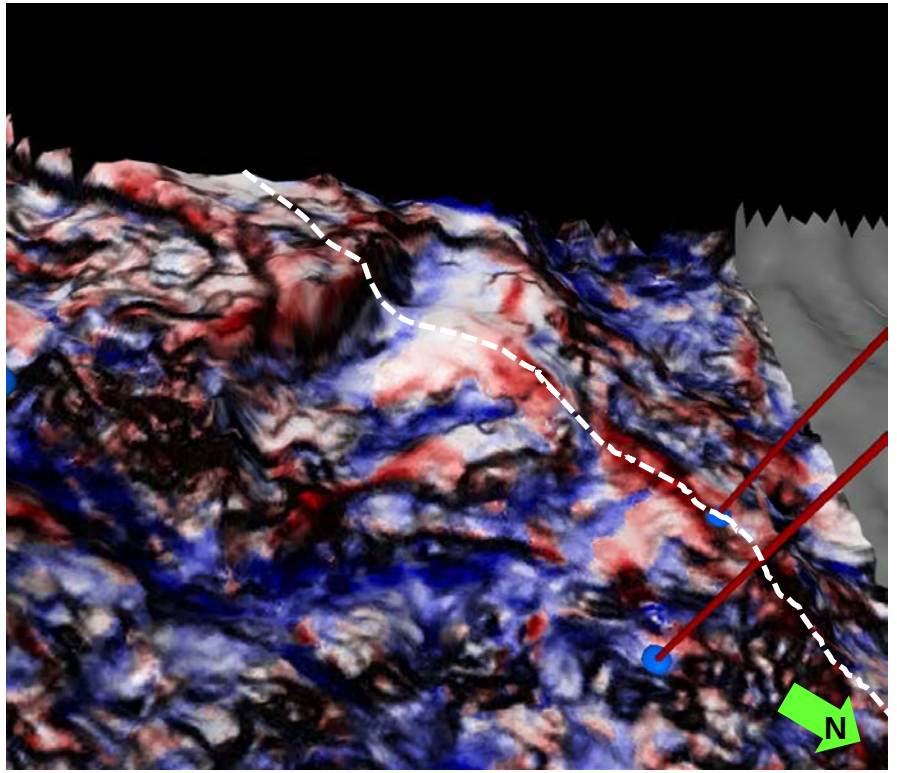


Section from the Tonjer fan to Torvastad

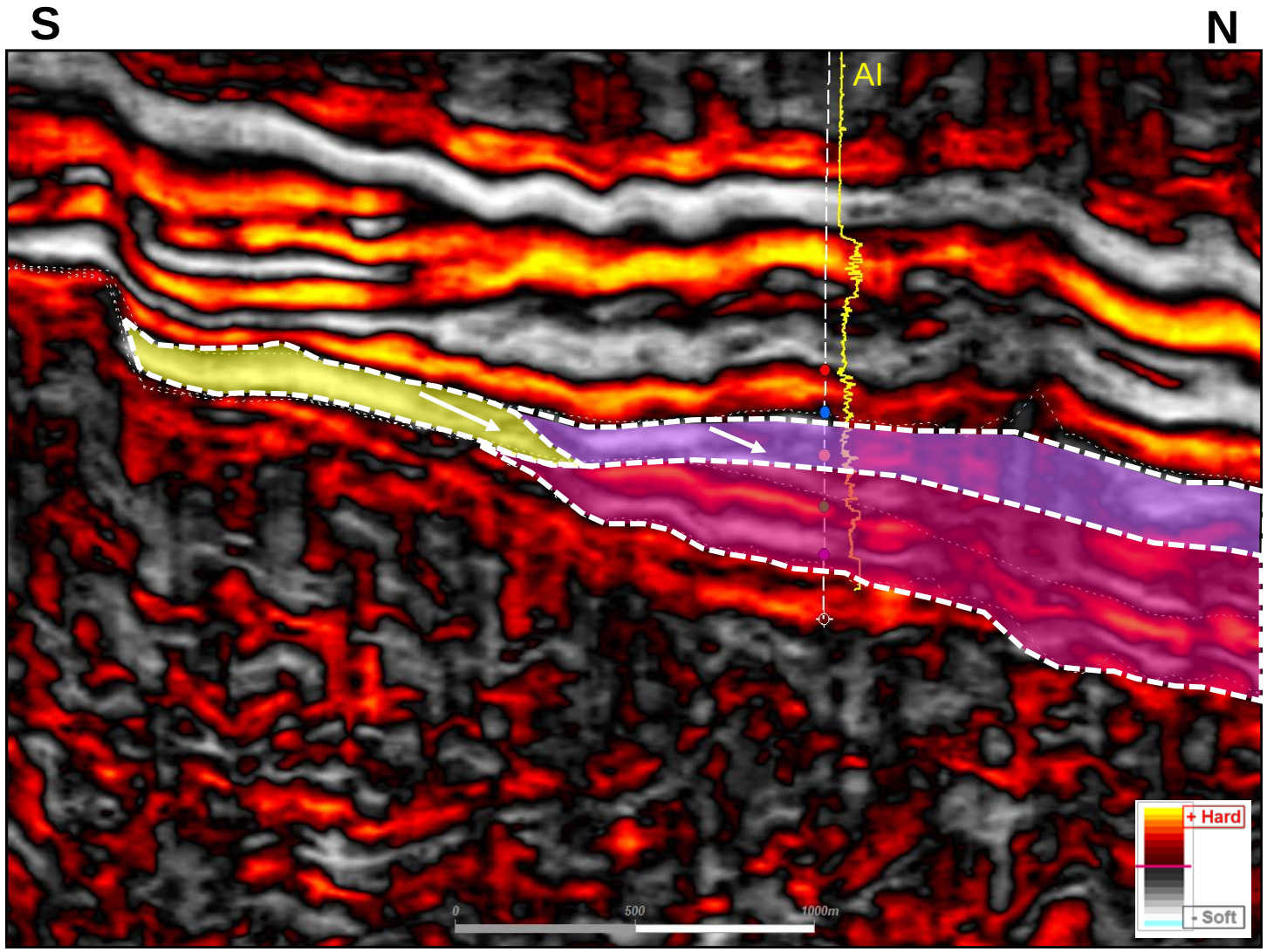


Spectral Inversion Layering derived from PSDM seismic

3D curvature map near BCU

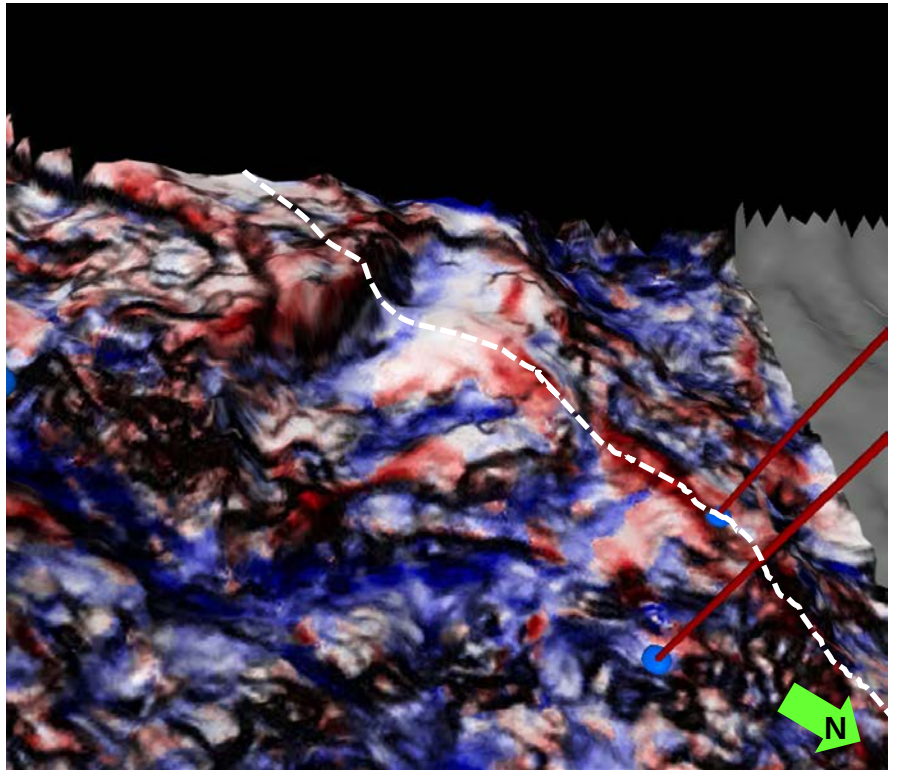


Section from the Tonjer fan to Torvastad

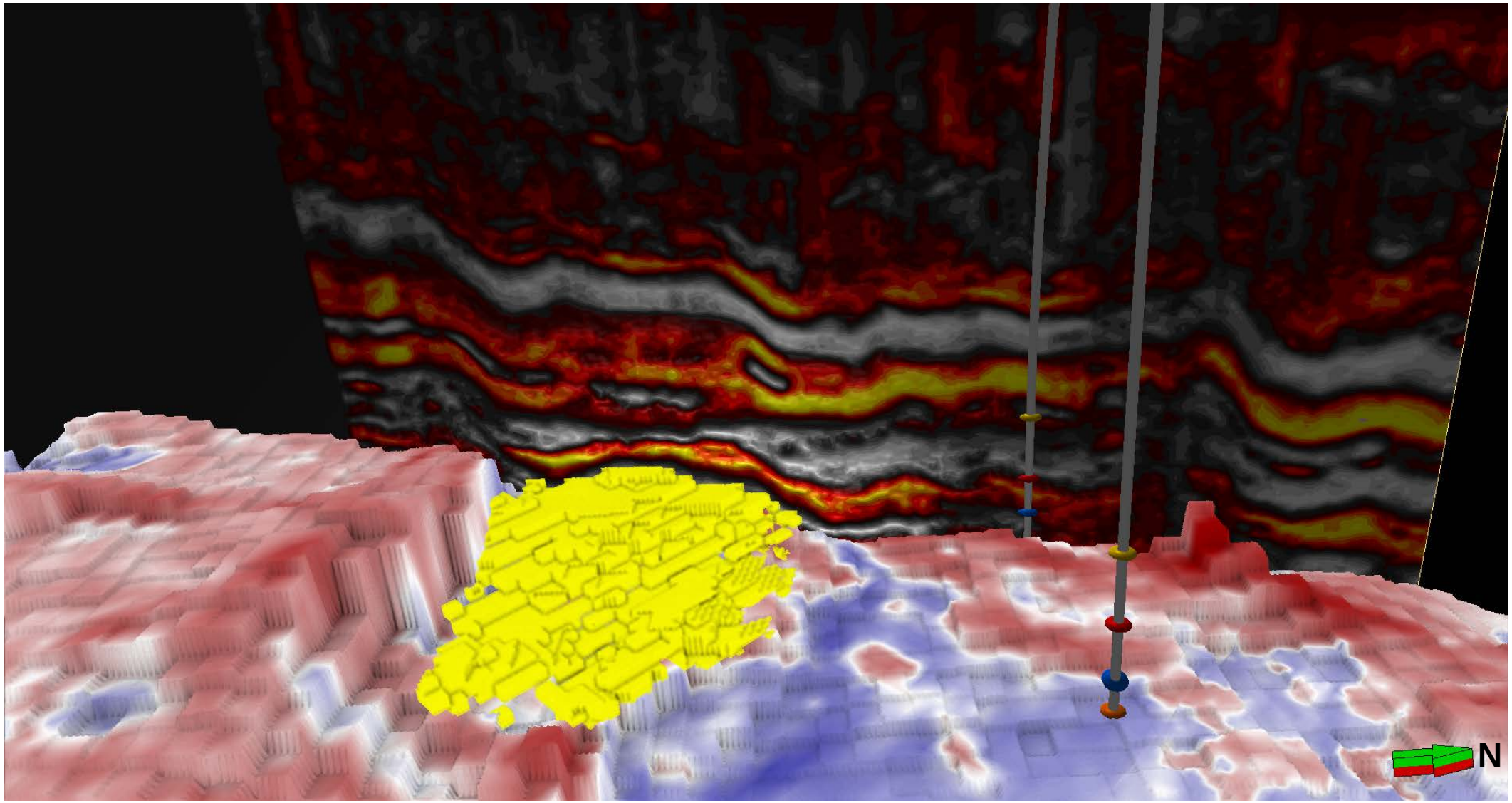


Spectral Inversion Layering derived from PSDM seismic

3D curvature map near BCU



Tonjer fan extracted as geobody
– a way to estimate volumes



Summing-up

- Exploit the available bandwidth
- View the data with “different colors”
- Analyze the data in different domains
- Spectral Inversion demonstrates resolution beyond the tuning thickness and resolves thin layers and geomorphology
- The resolution can be more than 40% higher than from conventional processed seismic data

Acknowledgements

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