Broadband 4D processing and analysis using multi-sensor streamers

Force seminar: 30 years of 4D on the NCS

Ross Milne, Julien Oukili November 2018

Outline

- Multi sensor streamers in 4D
- Example 1: Hod Field
- Example 2: Bøyla Field

4D monitoring with dual sensor streamers

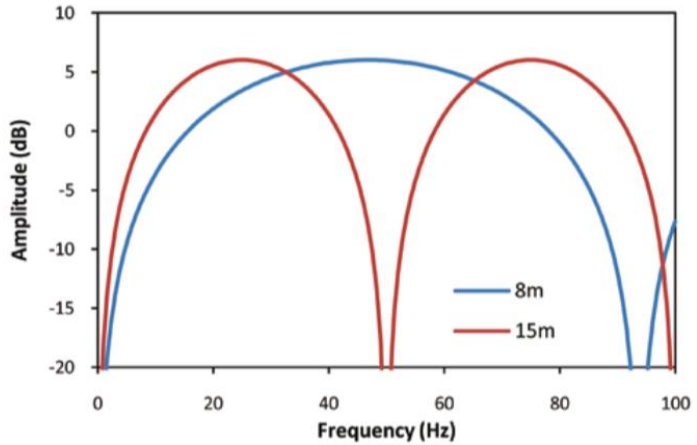


Figure 4 *Normal incidence amplitude spectra of the receiver ghost functions for 8 and 15 m recording depth.*

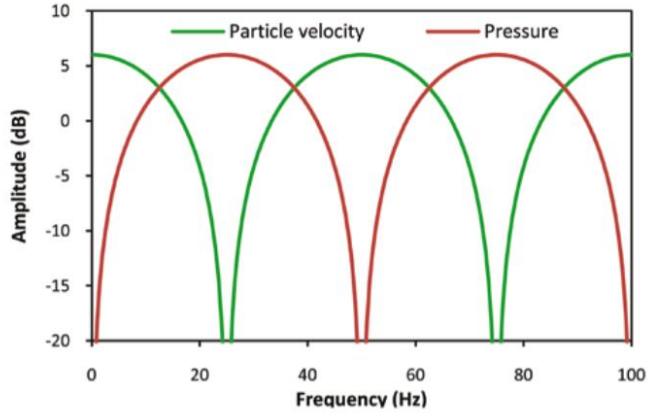


Figure 5 *Normal incidence amplitude spectra of the receiver ghost functions at 15 m recording depth for a pressure and particle-velocity sensor.*

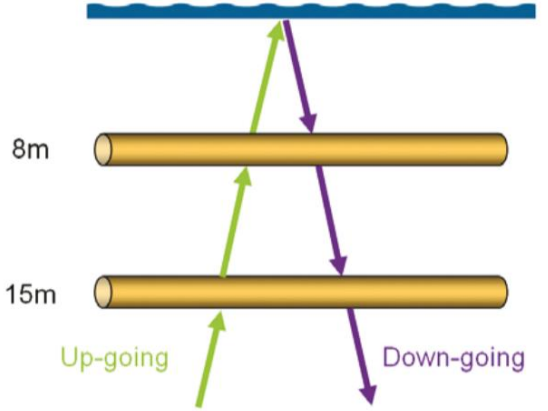


Figure 6 *Schematic representation of the procedure for reconstructing total pressure field data at a different datum level to the recording depth.*

Time-lapse acquisition with a dual-sensor streamer over a conventional baseline survey

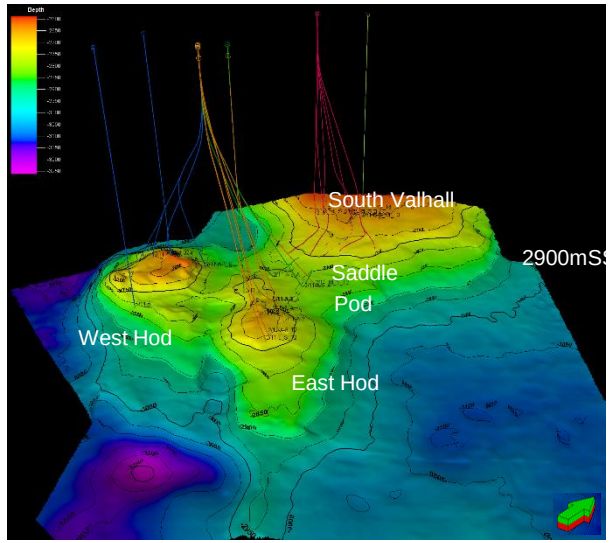
Anthony Day,* Martin Widmaier, Torben Høy and Berit Osnes, PGS, describe an experiment to validate the use of a dual-sensor streamer for time-lapse acquisition.

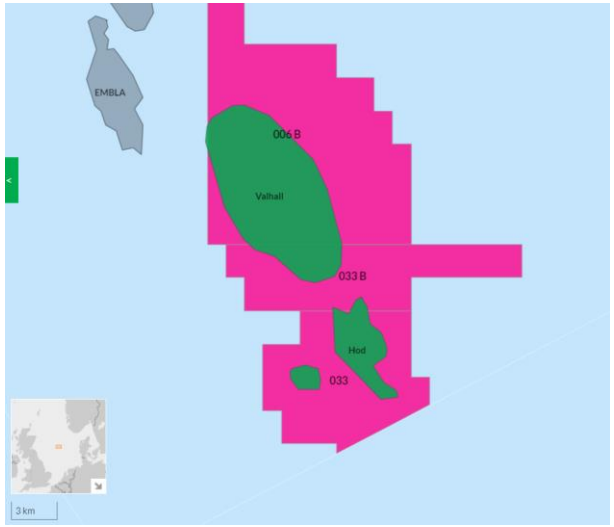
first break volume 28, December 2010

Example 1: Hod drive-by 4D

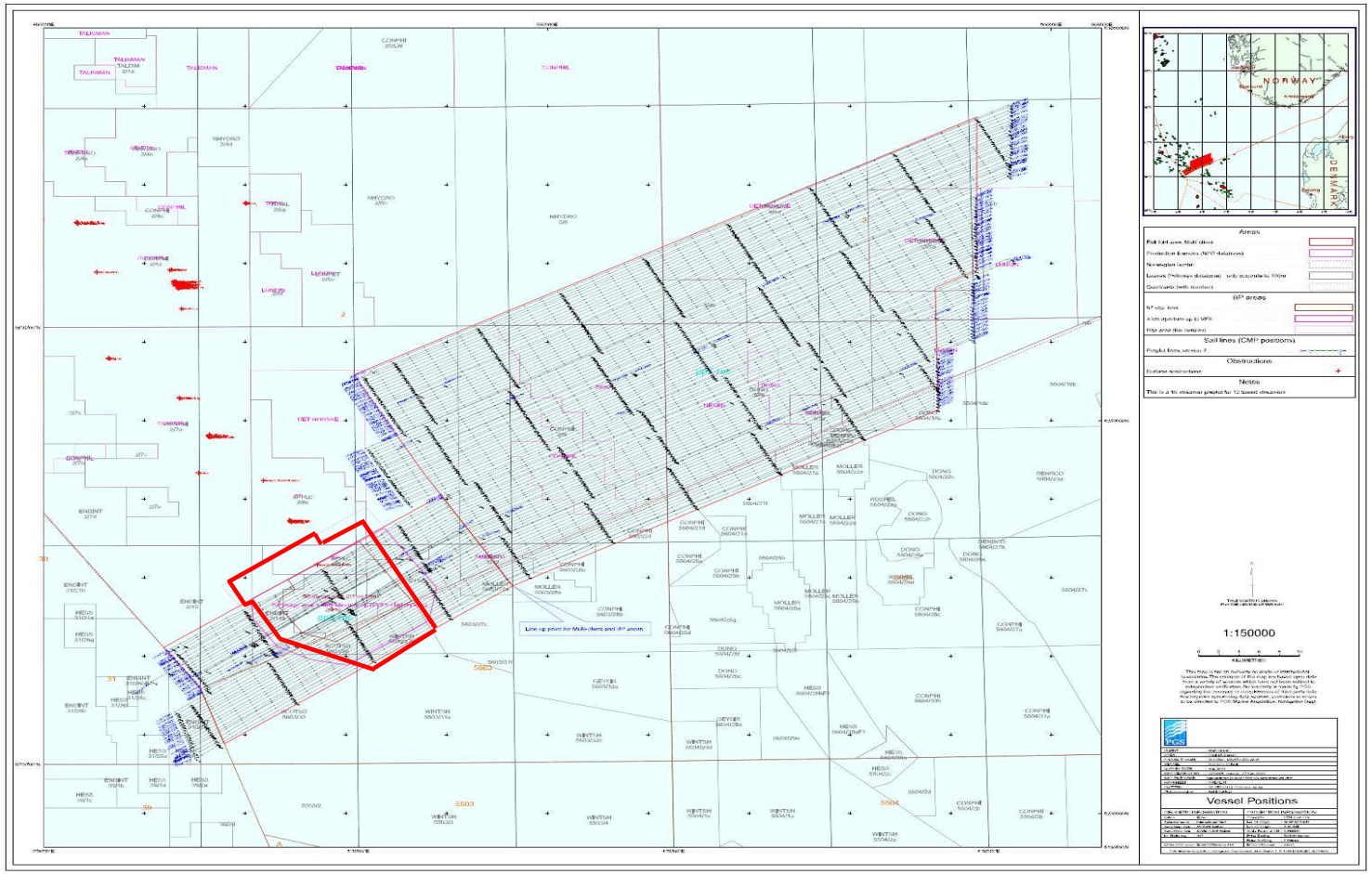
Hod field

- License awarded in 1968
- Discovered in 1974 and appraised with 10 wells
- Production start-up in 1990
- Chalk reservoir in Tor and Hod formation
- Recovery by pressure depletion / compaction
- Analogous to Valhall: gas cloud in West Hod, presence of hard ground in East Hod
- Produced 64m bbl

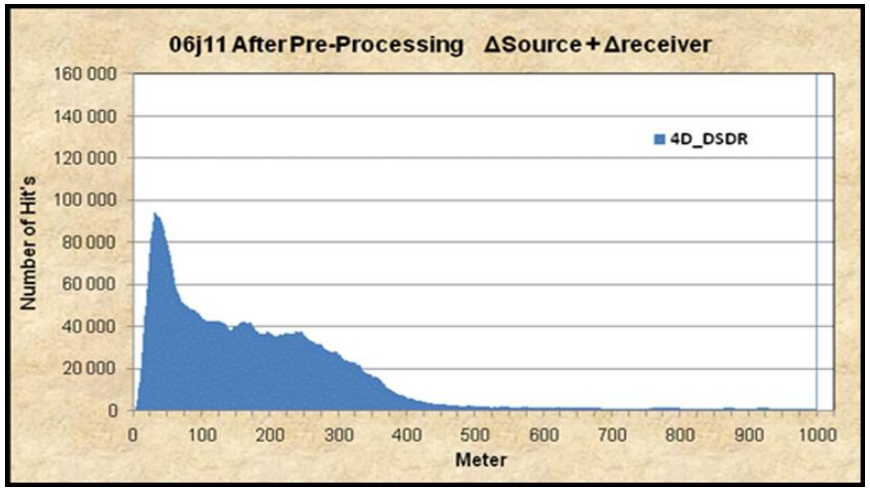




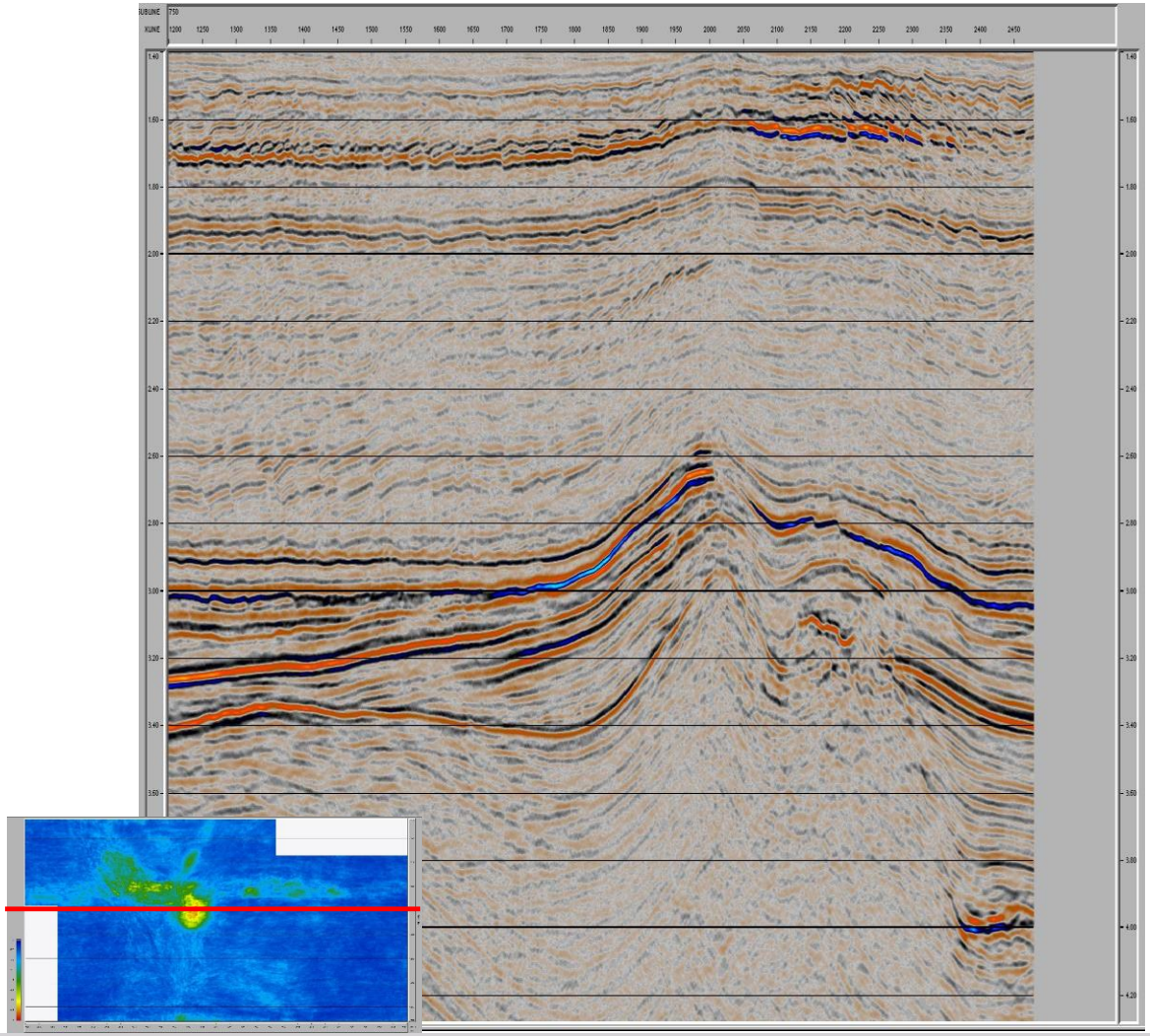
Hod field: Drive-by MC 4D monitor

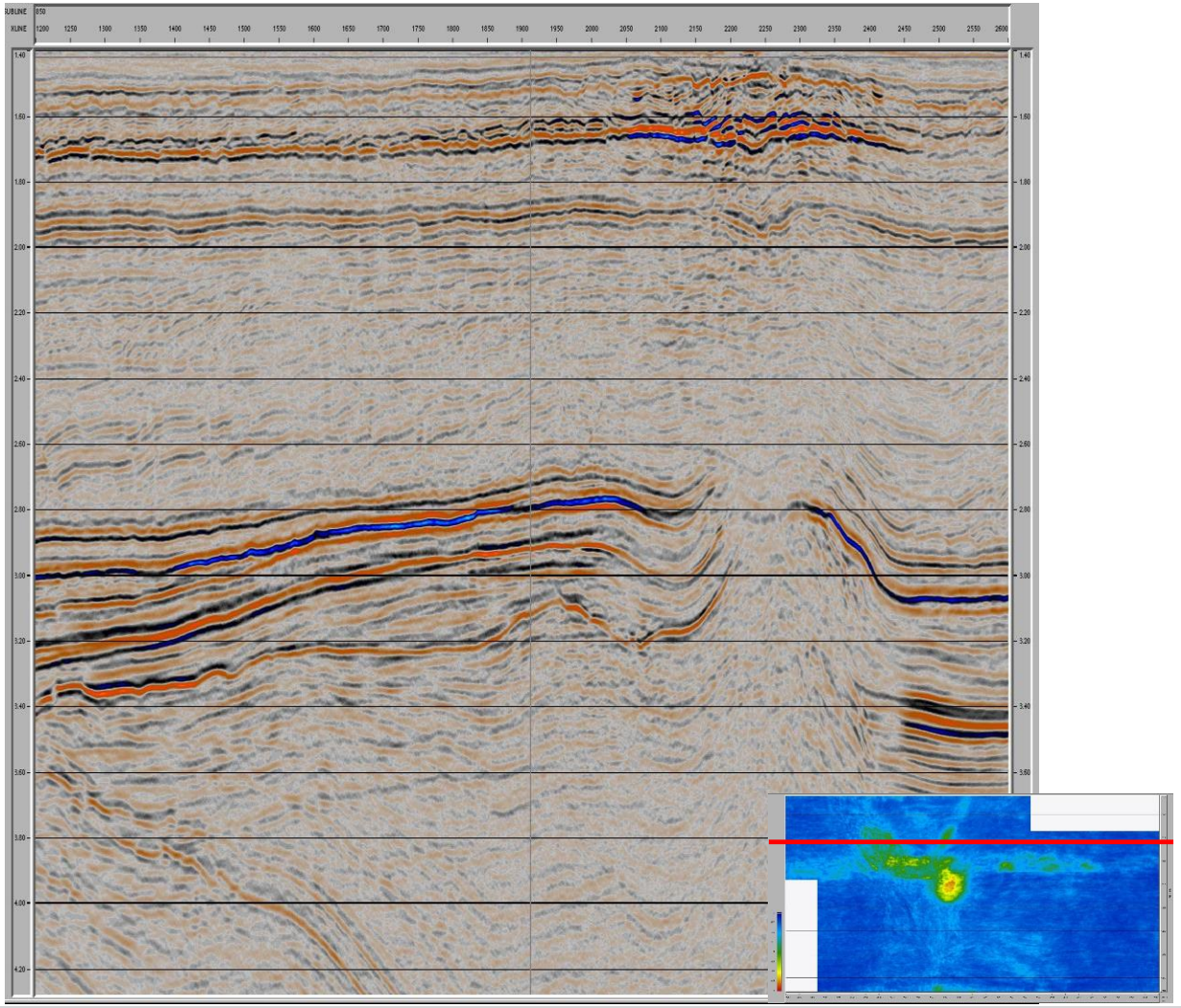


	RITA 90	CGR2010
Cables	2 x 3.6km	12 x 6km (10)
Cable separation	100m	75m
Guns	2	2
Gun separation	50m	37.5m
Shot interval	25m flip-flop	18.75m flip-flop
Group interval	25m	12.5m
Acq. Bin size	25m x 12.5m	18.75m x 6.25m
Shot depth	5m	7m
Cable depth	8m	15m
Undershoot	Yes	Yes, wider
Bearing	**70°**	**70°**

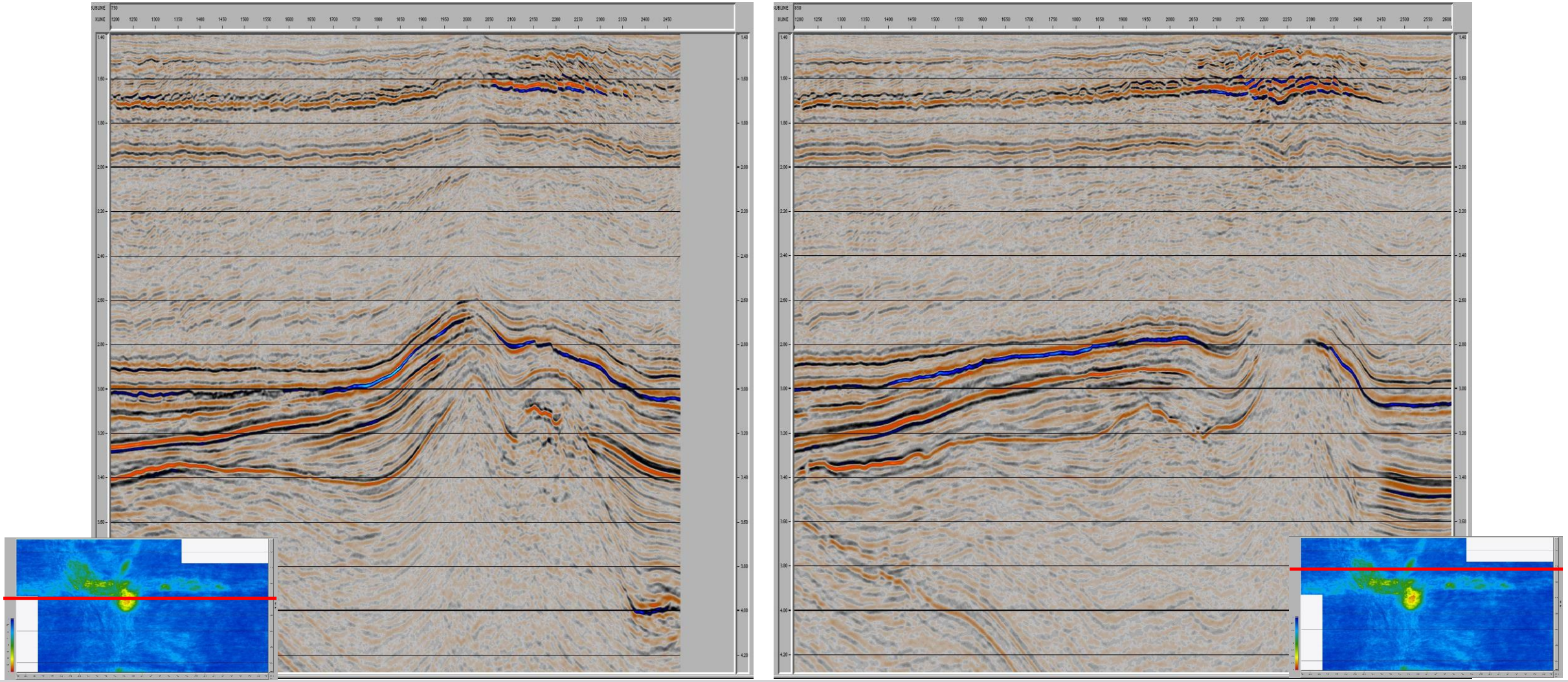


Vertical QCs RITA90 (baseline)

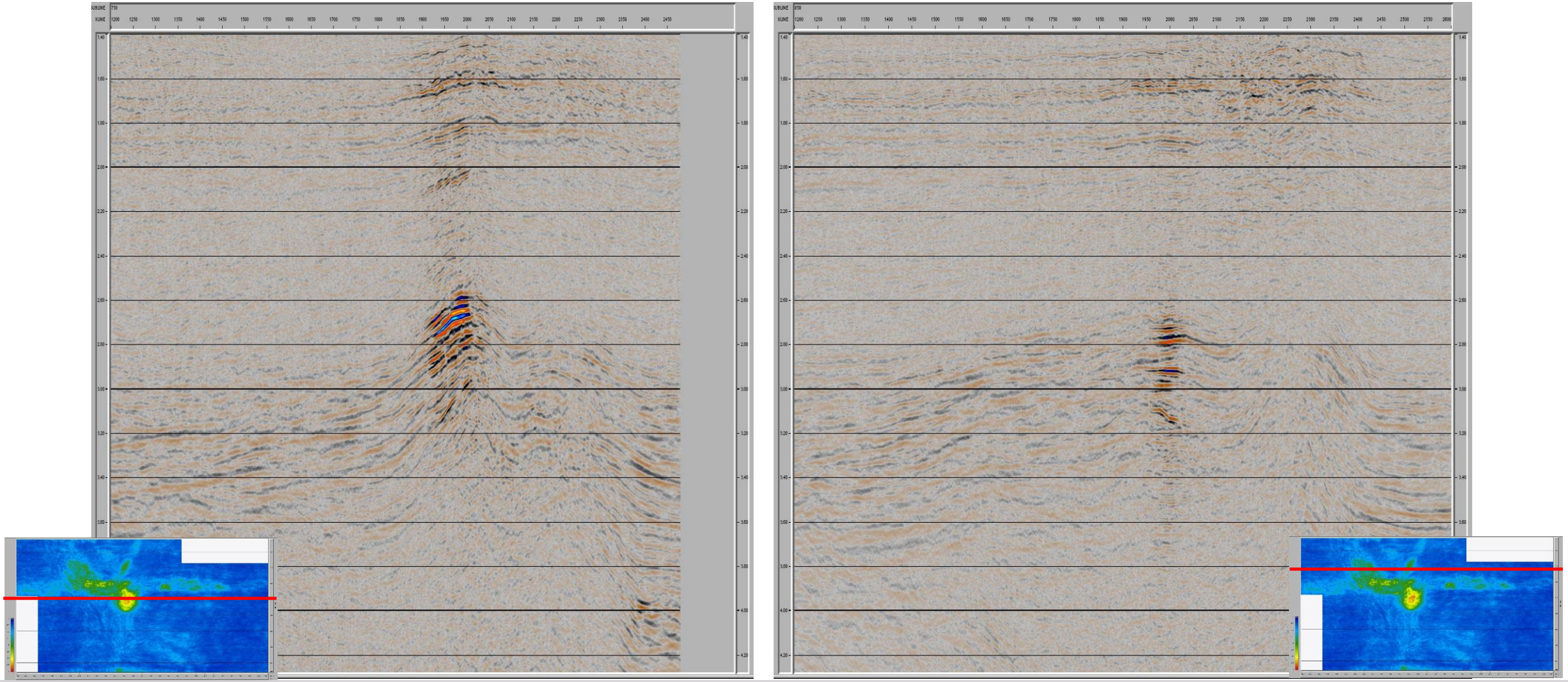




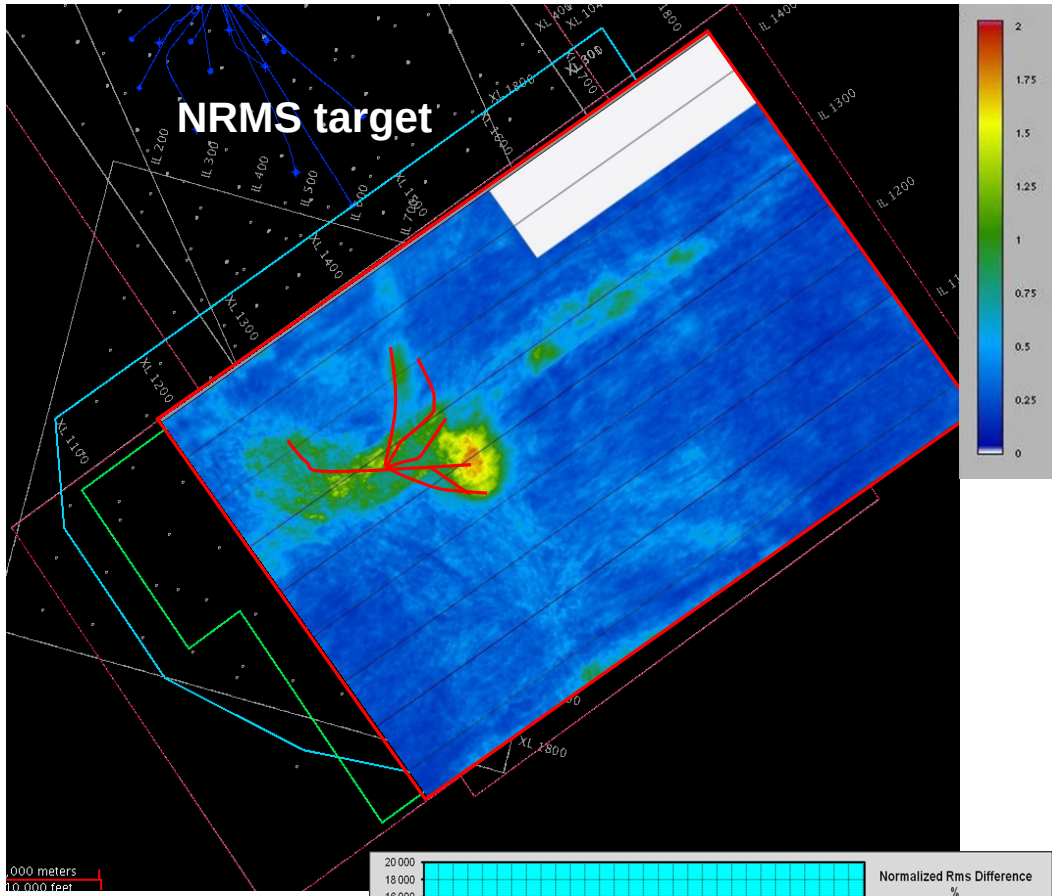
Vertical QCs CGR2010 (monitor)

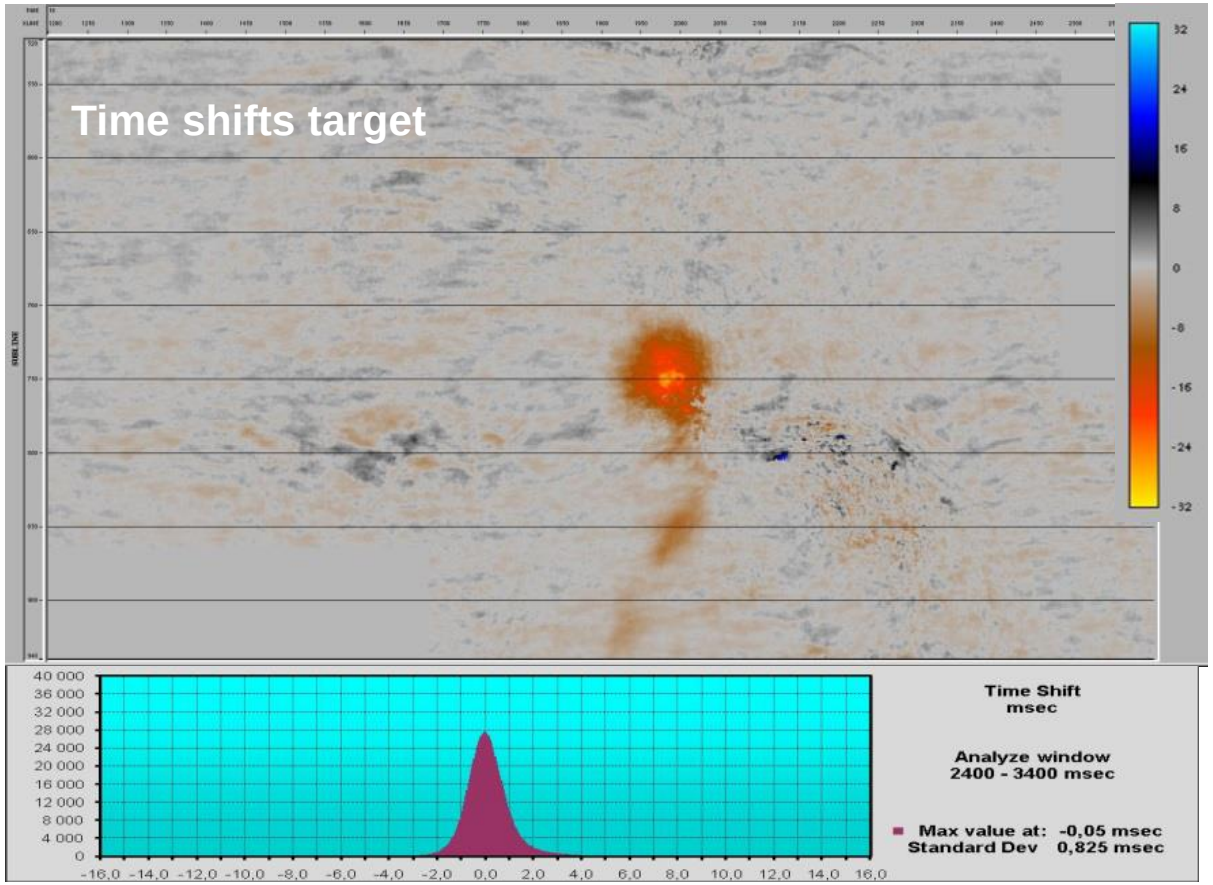


Vertical QCs Monitor-Baseline 4D

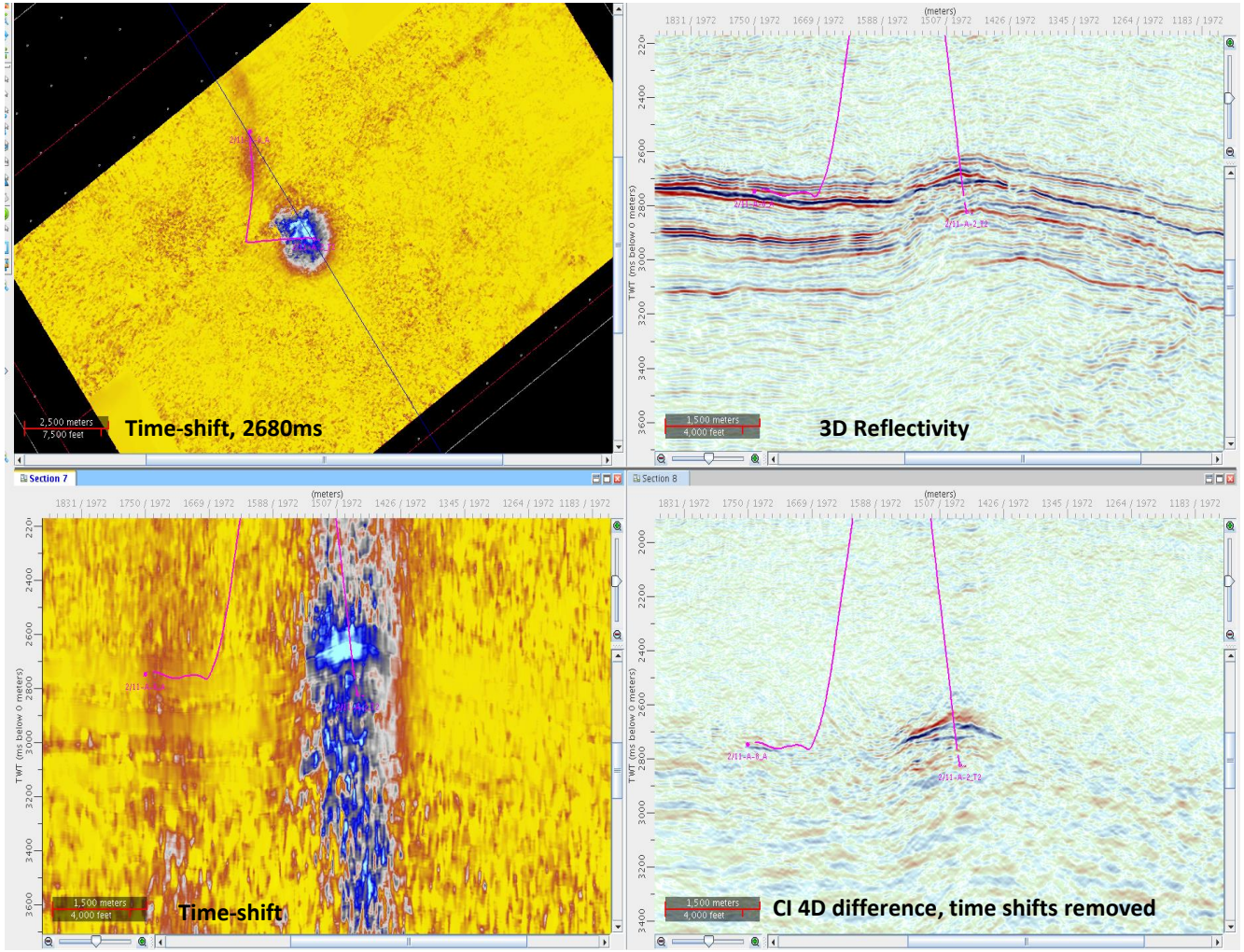


Hod drive-by 4D: 4D QCs





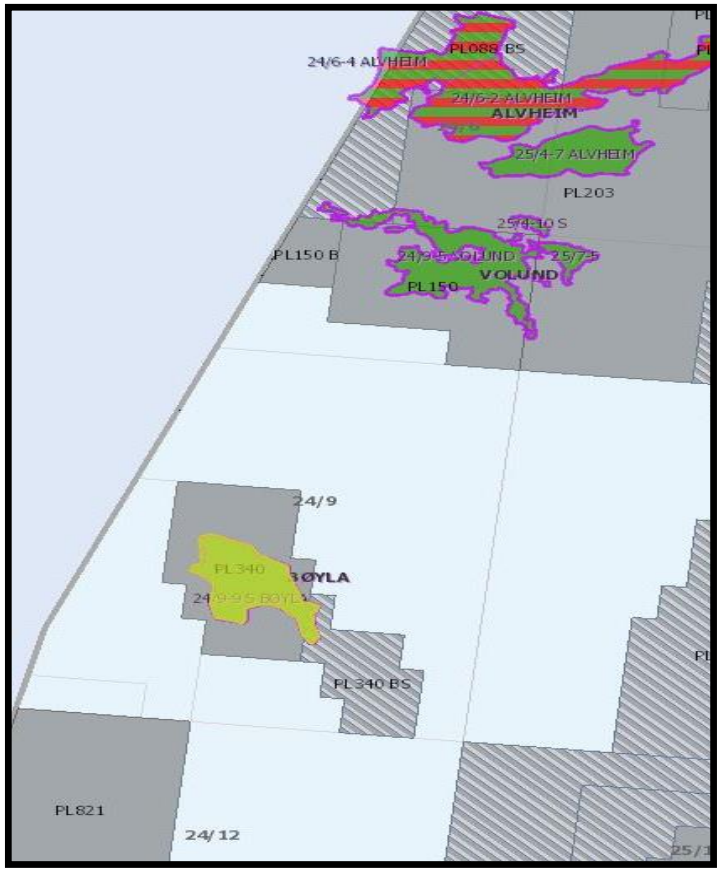
Hod field: 4D interpretation



- High quality 4D seismic images produced by matching dual sensor to conventional TS, despite large differences in acquisition geometry
- Validated the wave-field separation and re-datuming of dual-sensor for 4D
- **4D Interpretation approach** : 4D time-shifts at the crest (up to 10ms) used as a primary guide for placing new wells, in order to avoid stress arching related to subsidence.

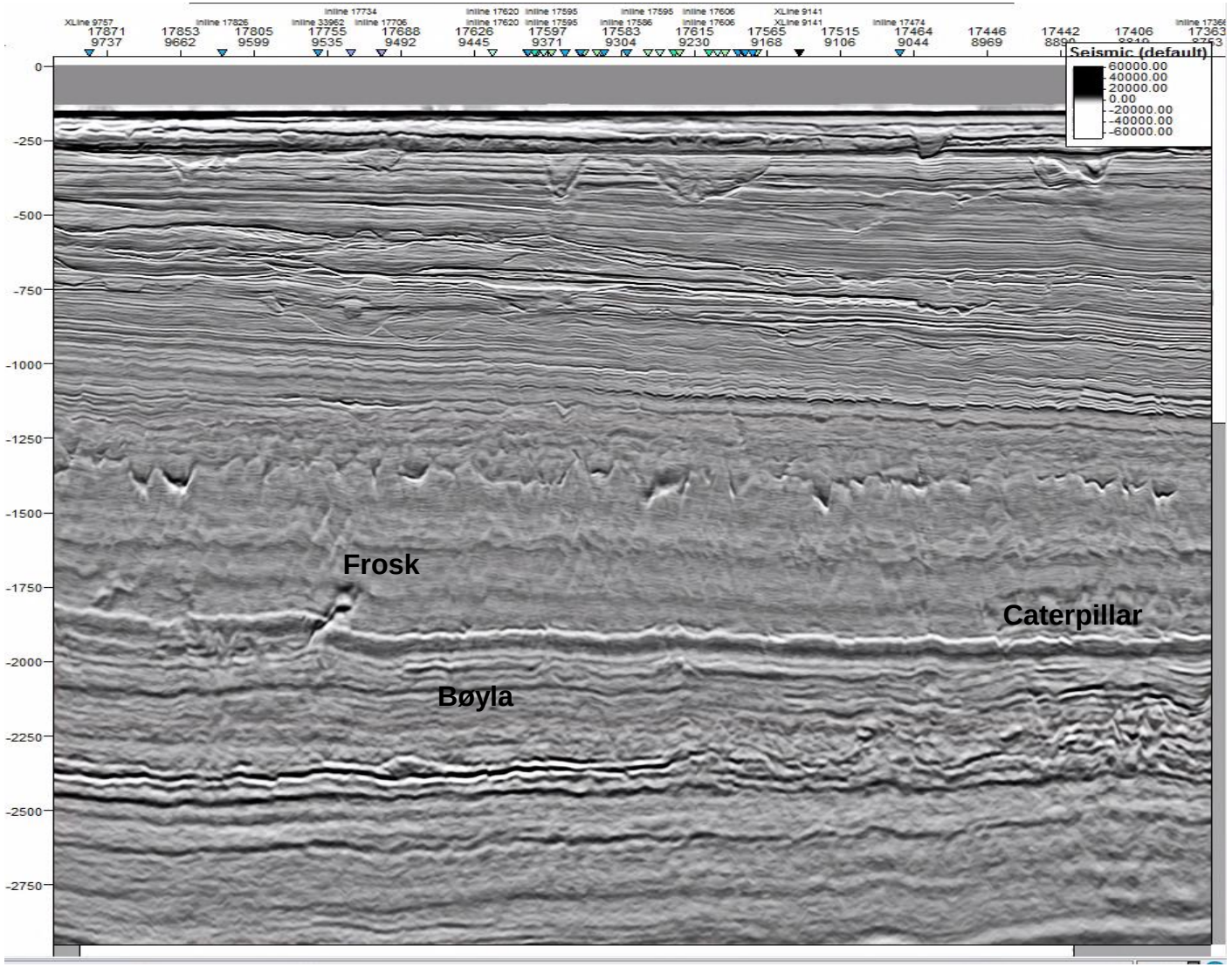
Example 2: 2017 Bøyla field

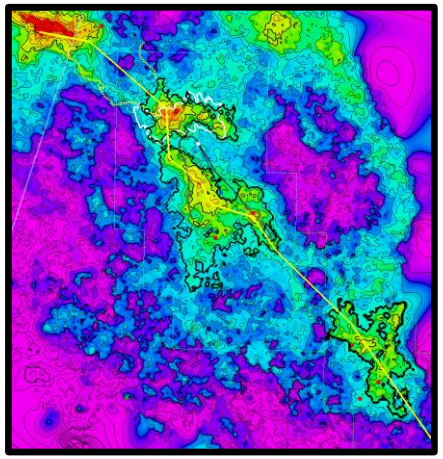
The Bøyla field

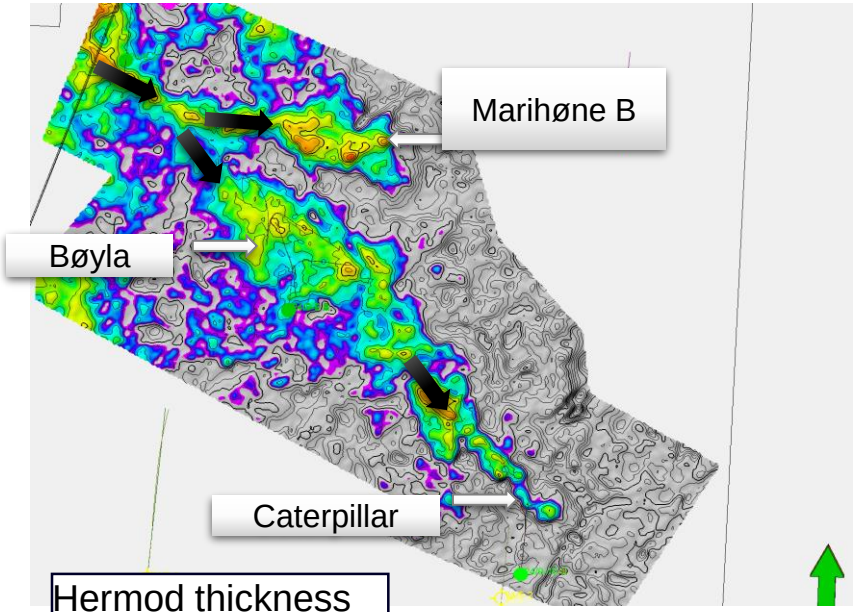


- Oil field discovered in Sep 2009 with first oil production in Jan 2015
- 225km west of Stavanger in block 24/9 in the North Sea (NCS); 28km south from Alvheim
- Developed as a subsea tie-back to the floating production, storage and offloading (FPSO) facilities of the Alvheim (2 horizontal seabed production wells and one water injector well)
- Oil from sandstone of late Paleocene to early Eocence age in the Hermod Formation
- Produced with pressure support from water injection, started 2 months after production start-up
- 4D monitor survey shot in 2017

DN15M01 final stack depth full

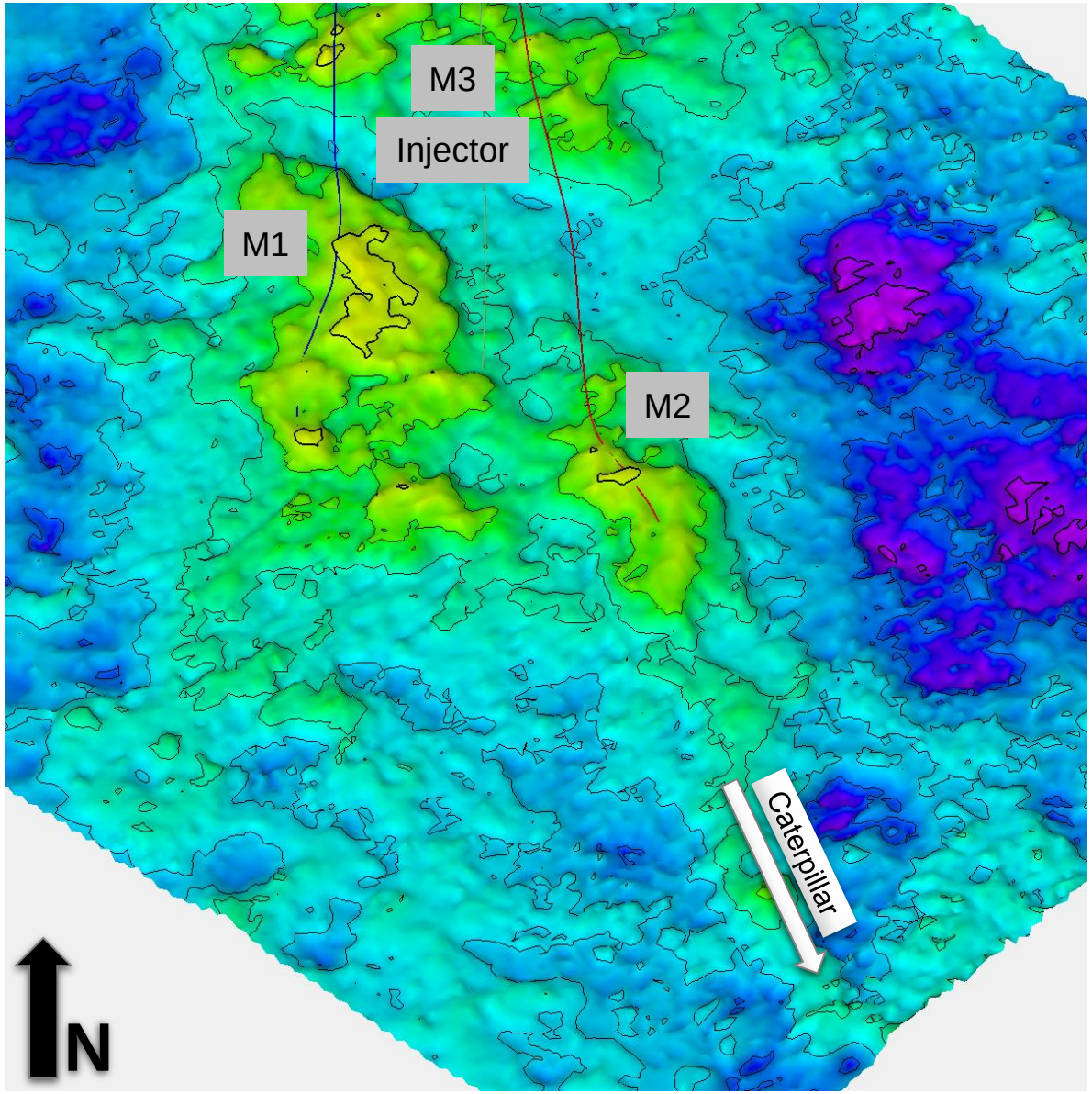




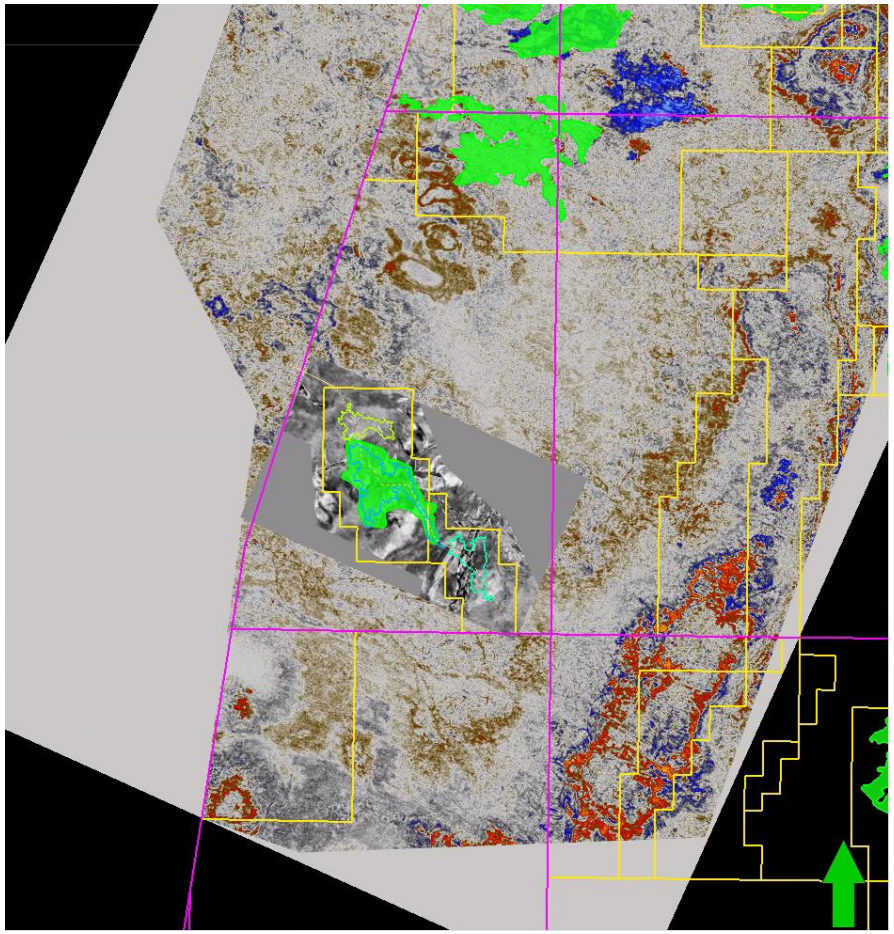


Main challenges Bøyla

- Injector does not support both producers
  - M1 producer is supported but M2 is not
  - → barriers?
- Understand communication on field
- Understand communication to Caterpillar



Broadband 4D acquisition



- 2011 Baseline from a subset of MC3D-SVG2011 Geostreamer survey
- 2017 monitor acquired using multi-sensor streamer

	MC3D-SVG2011	ABP17002
Cables	6, dual-sensor	12, triple sensor
Cable separation	100 m	75 m
Guns	2	2
Gun separation	50 m	50 m
Shot interval	18.75 (flip-flop)	18.75 (flip-flop)
Shot depth	6 m	6 m
Cable depth	15 m	18 m
Bearing	114.28º/ 294.28º	114.28º/ 294.28º

Seismic processing

Summer 2017

3,5 months

Spring 2018

4D Fast-track

raw data P/Vz
Denoise
2-C Wavefield Separation
Source Deghosting
Model-based broadband Demultiple
3D regularization
Q-PSDM

4D Full Integrity

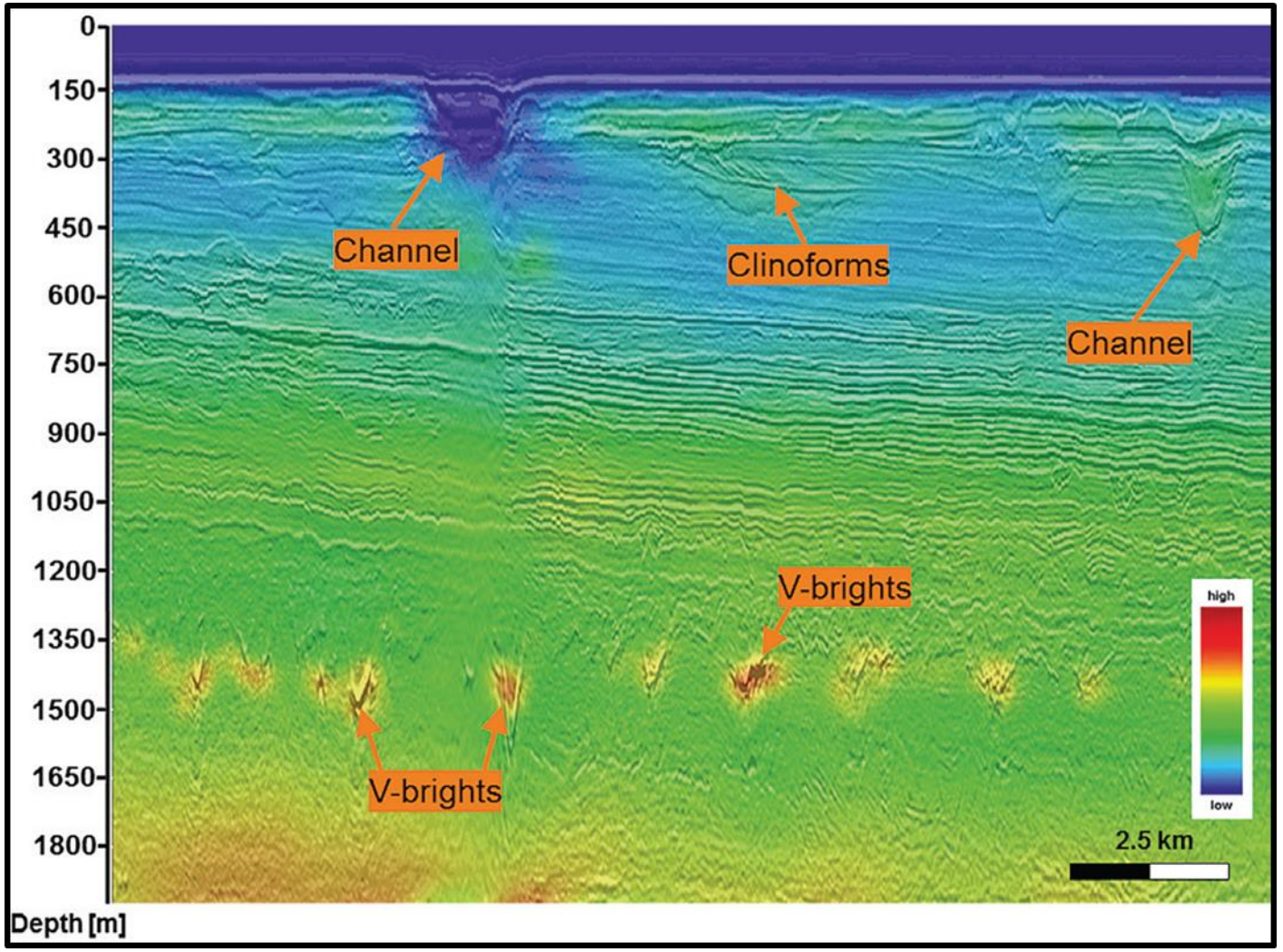
+

Additional 4D Sailline corrections & matching
Final 4D regularization
Final 3D Q-PSDM
Post-processing

3D High-Res
(3 ms)

Not discussed here

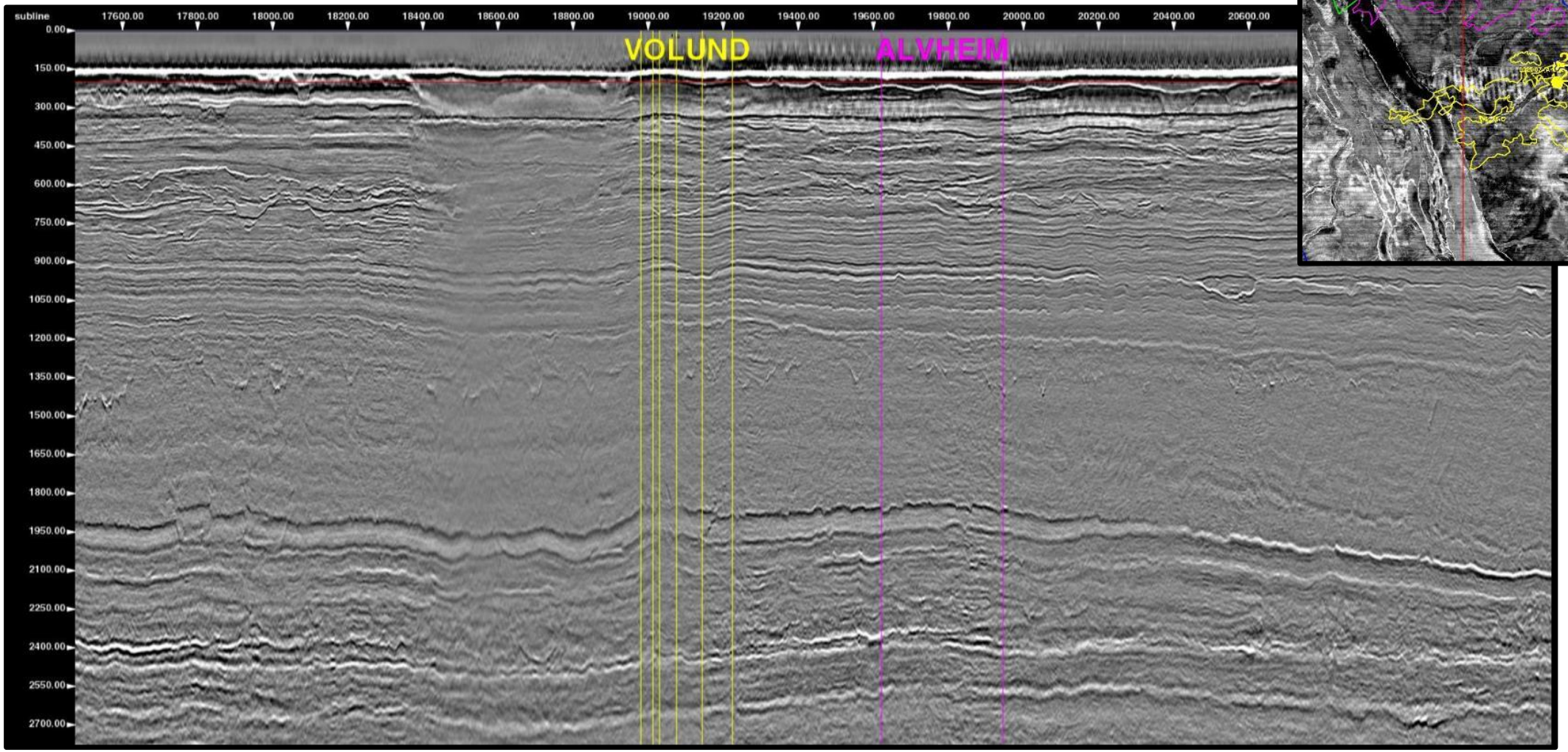
Detailed and geologically consistent migration model

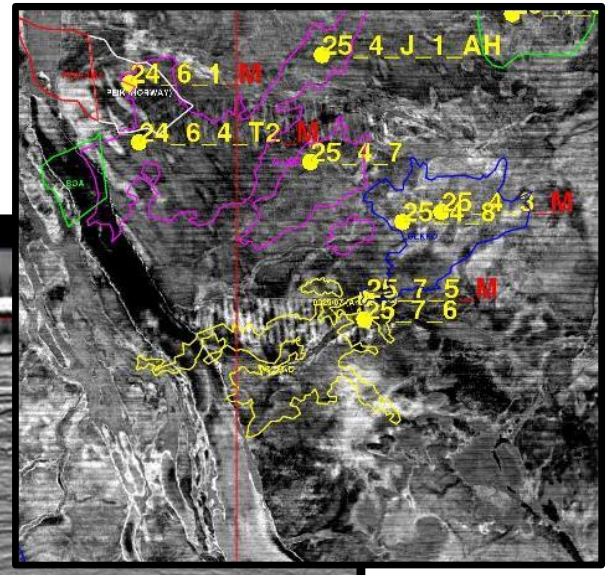


- Utilise existing depth velocity model from most recent MC processing
- FWI for shallow section: fast/slow channels and more..
- V-brights (geobodies) mapped with coherency attribute. A priori scaling followed by high resolution tomography.

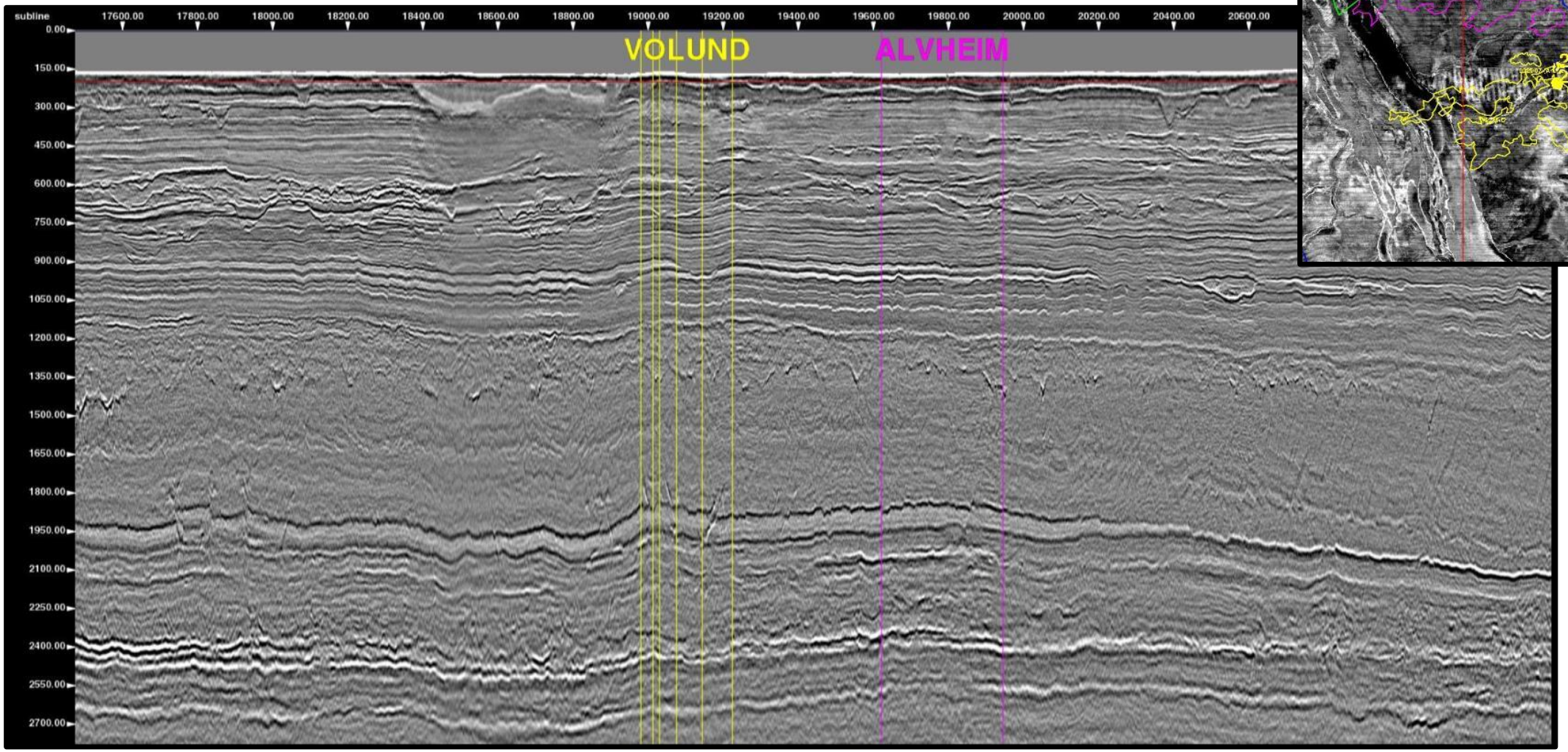
Ciotoli et al, First break volume 34, September 2016

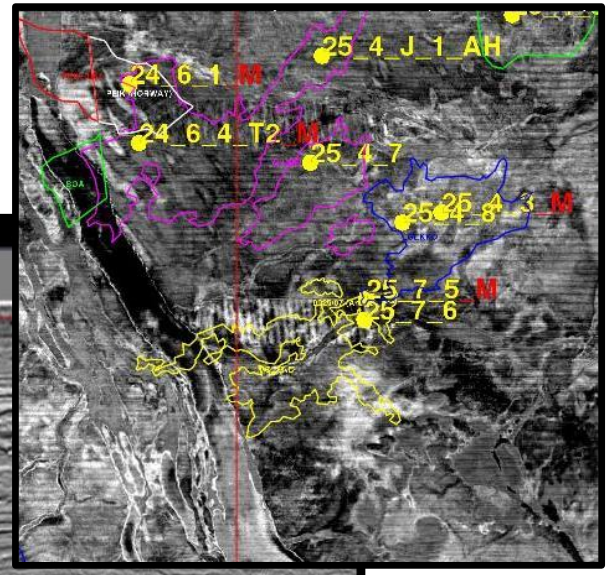
MC3D N/SVG merge – Vintage PSTM



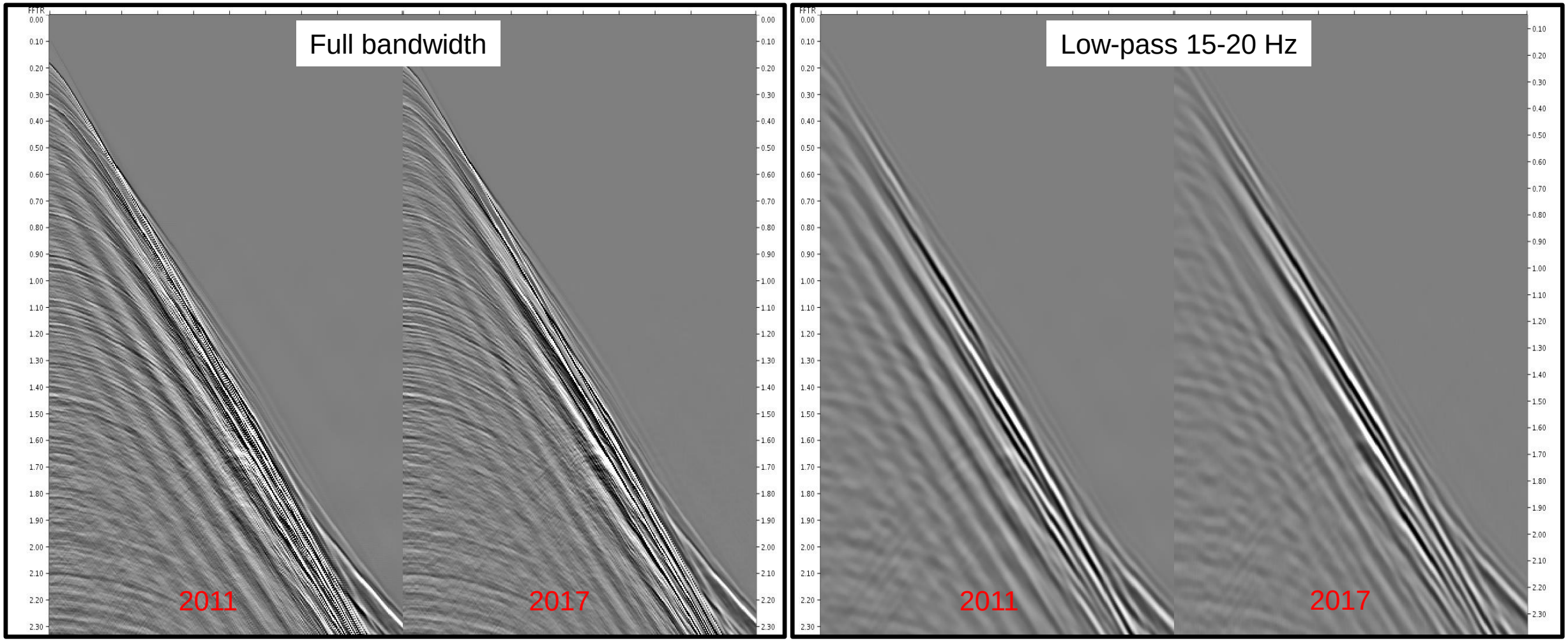


MC3D N/SVG merge – CWI PSDM (time domain)

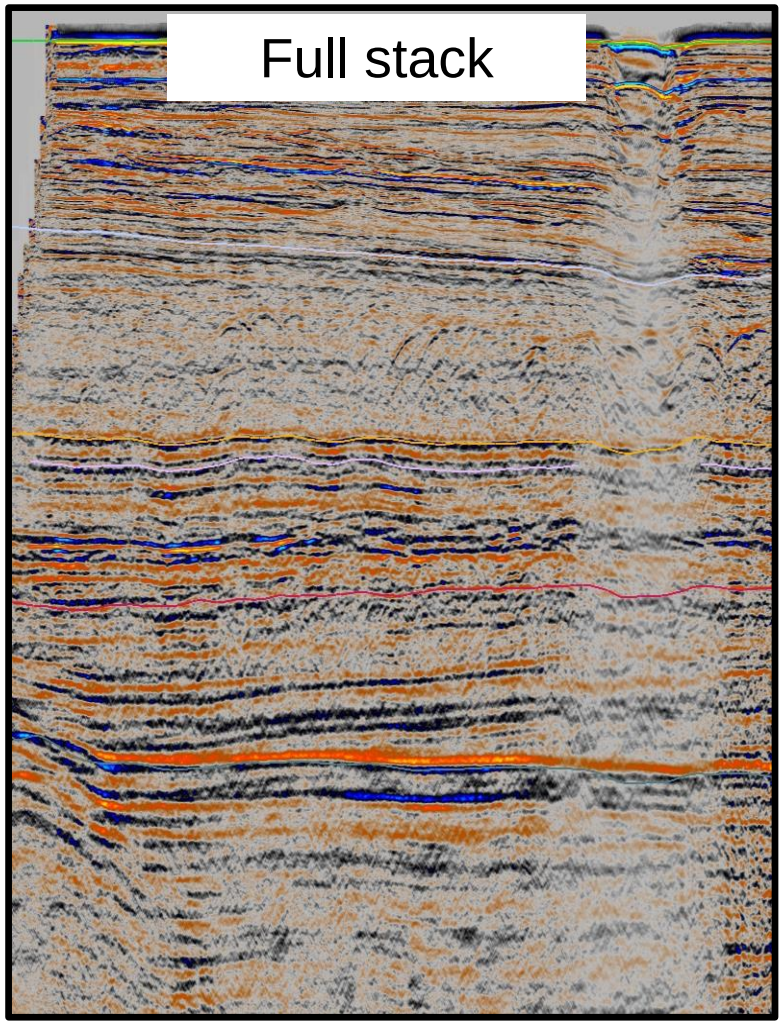


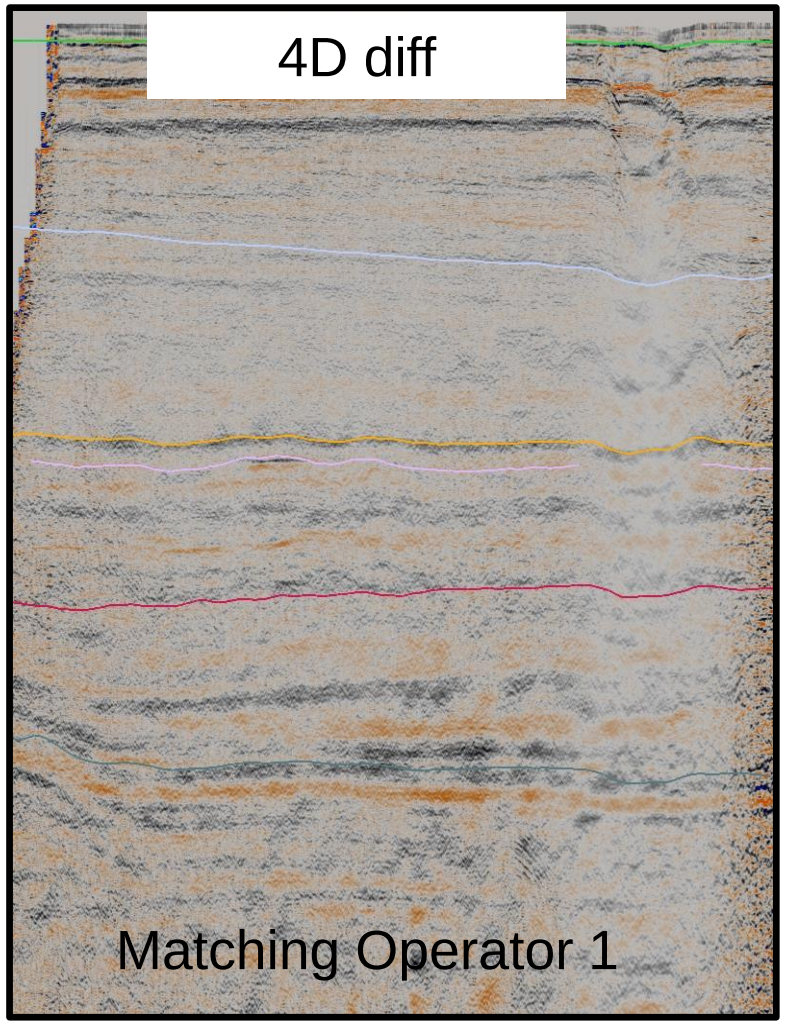


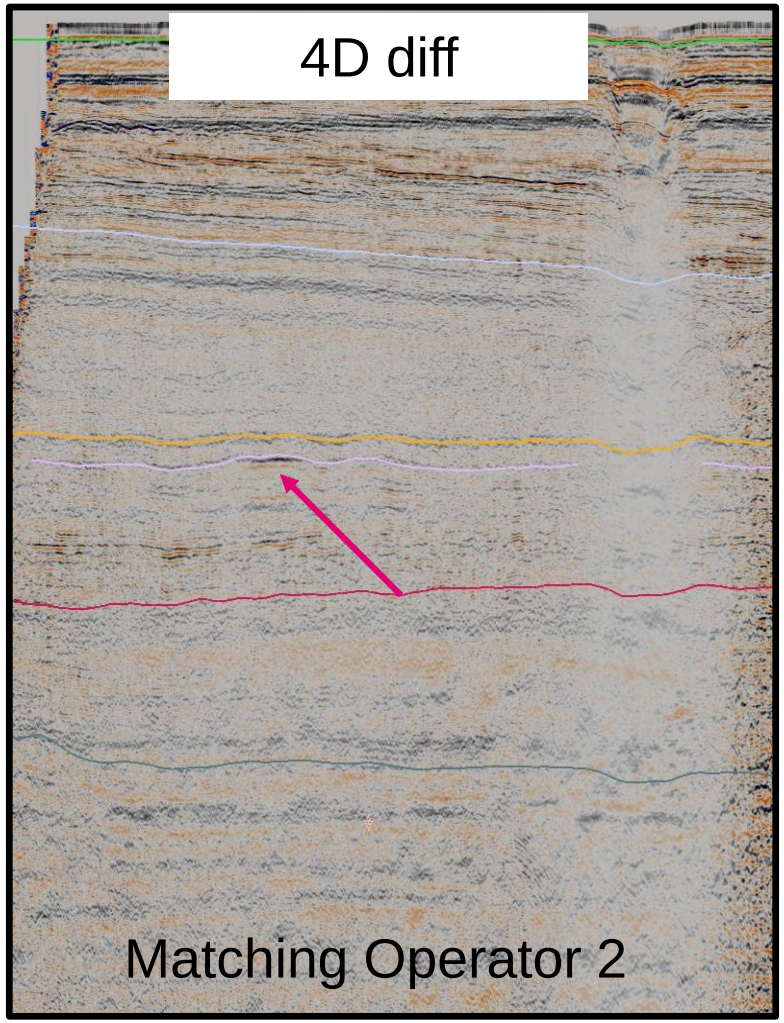
P-UP comparison – Wavefield Separation



Inline 2017 vintage and 4D difference – after denoise

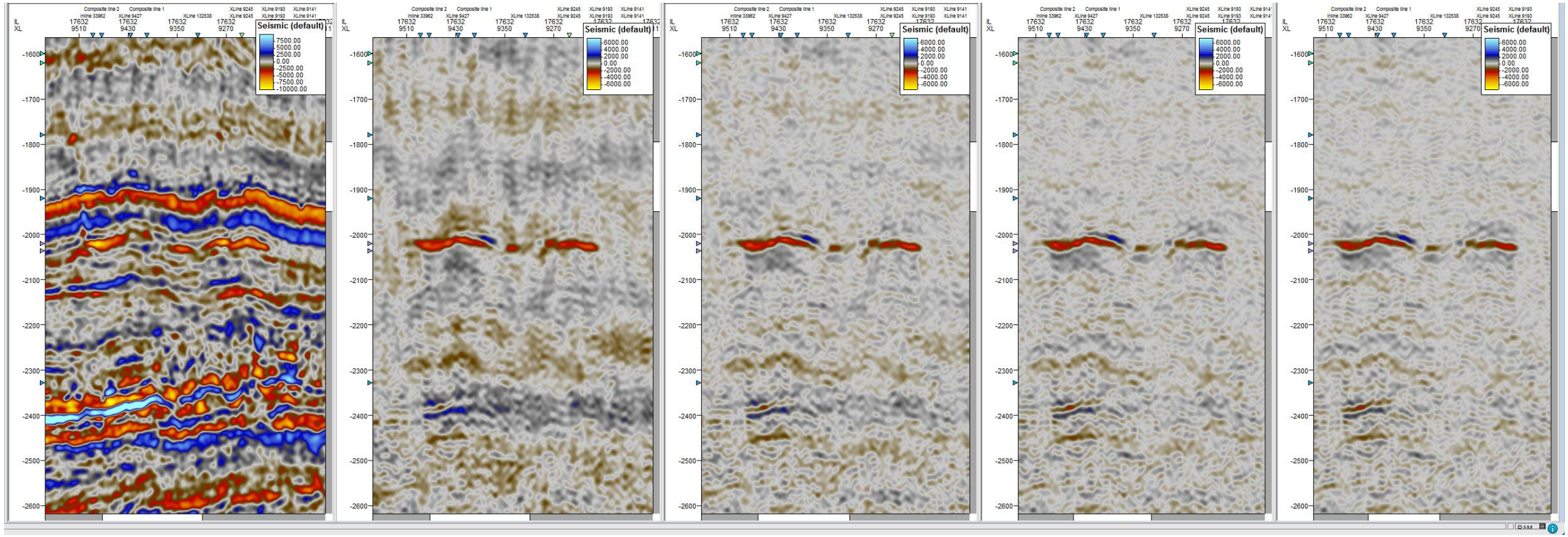




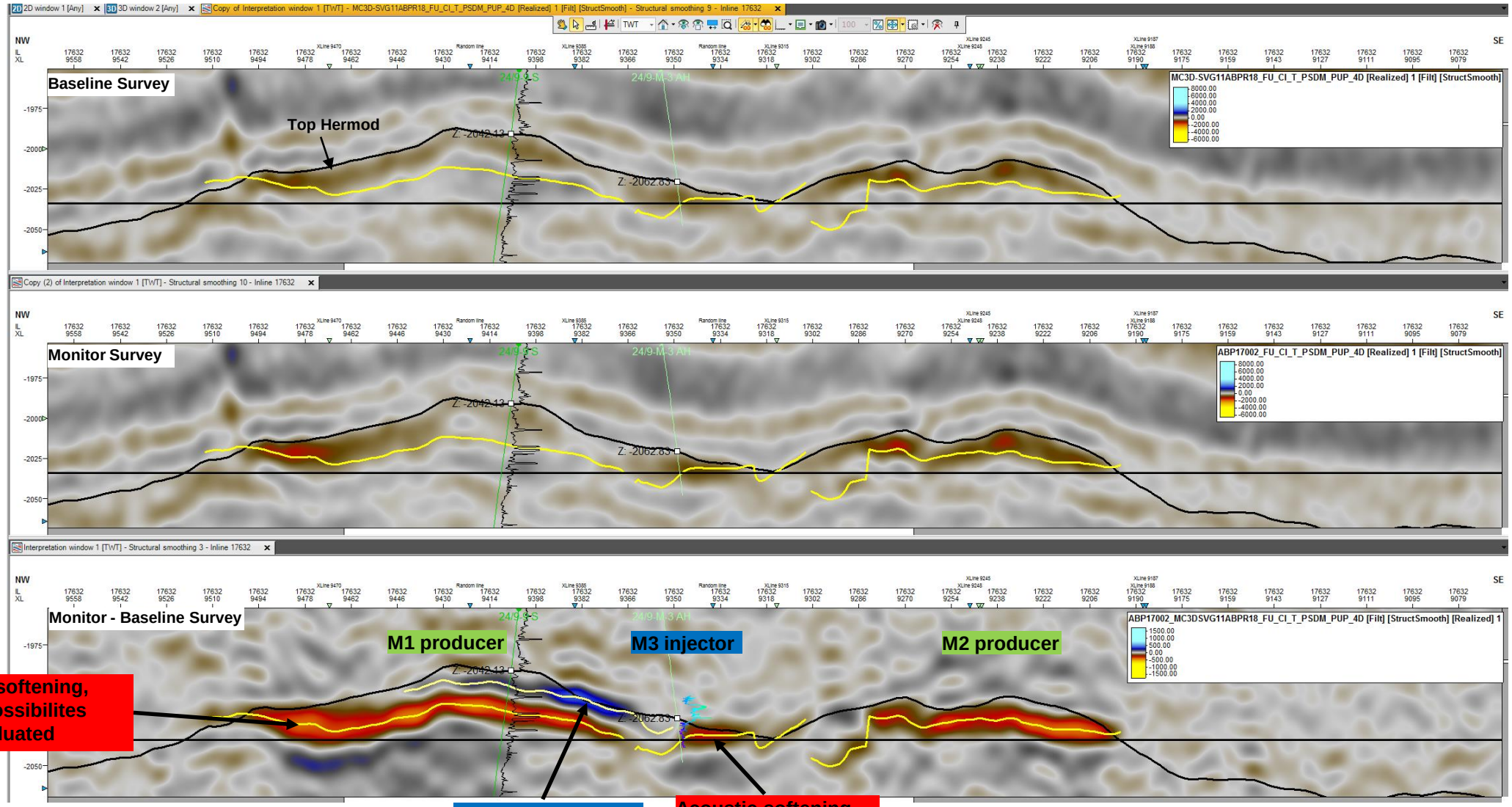


Coloured Inversion low cut testing

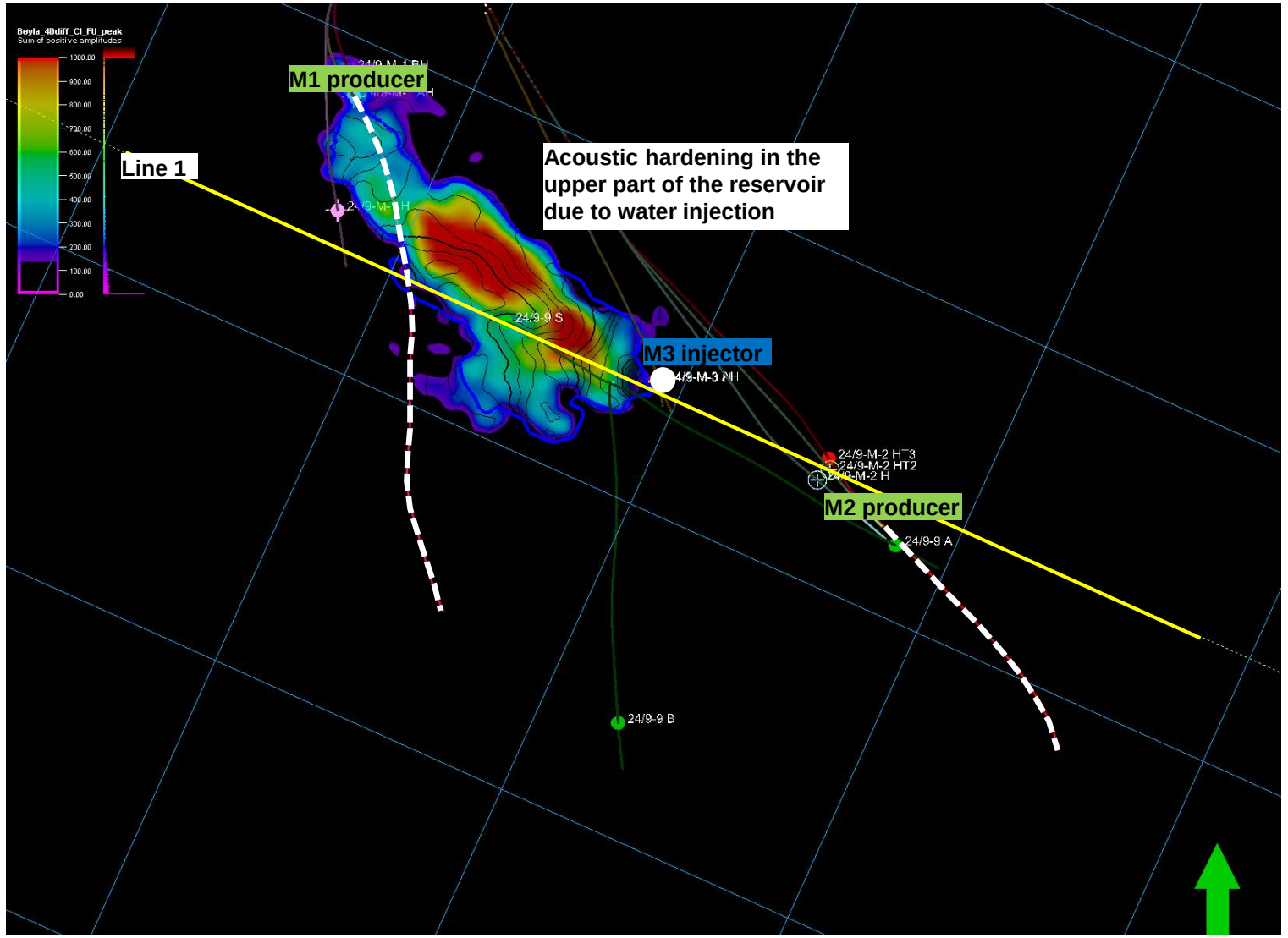
5Hz 3Hz 5Hz 7Hz 9Hz



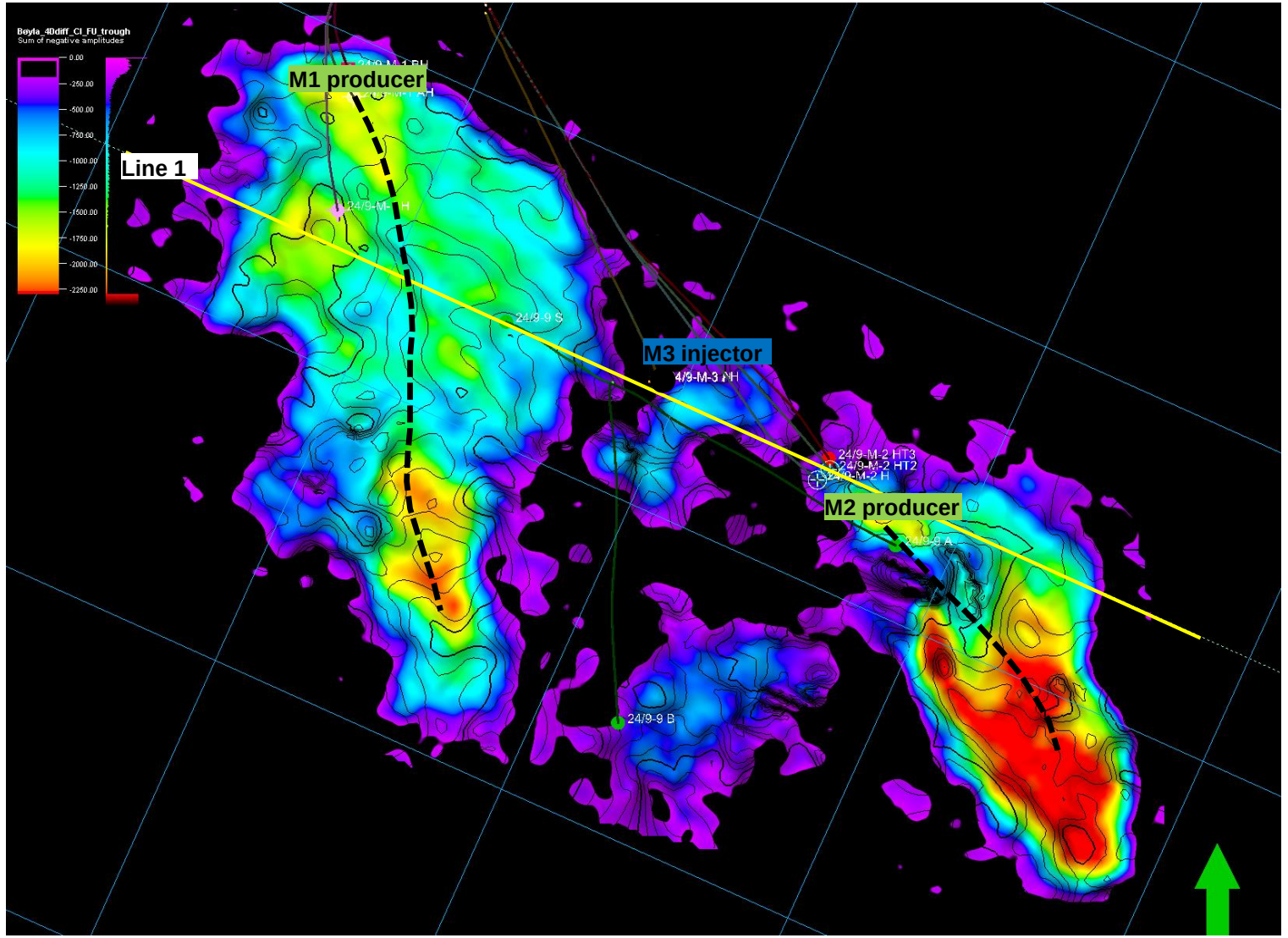
Results, Full offset, CI



Full offset CI difference – Sum of positive amplitudes

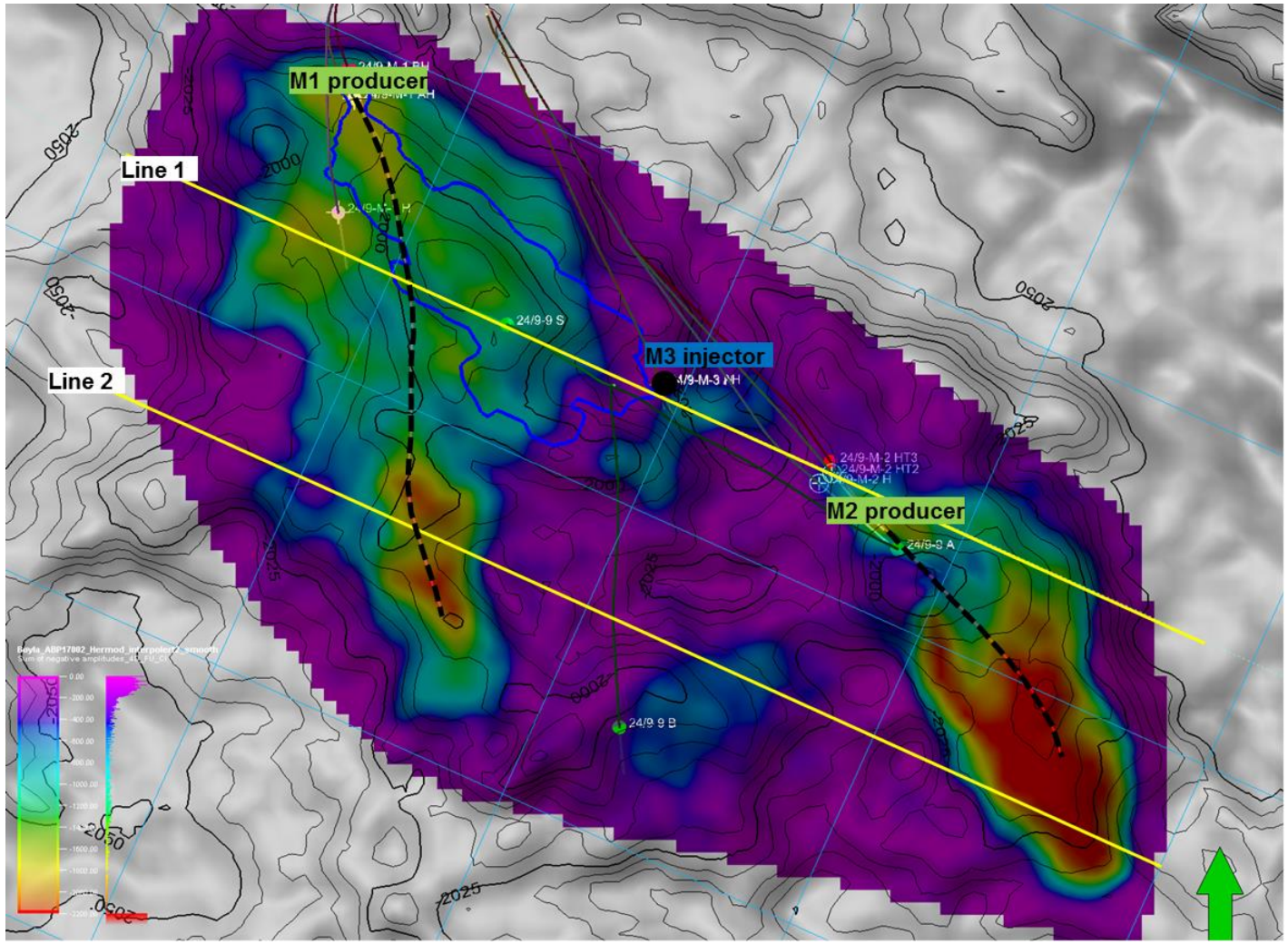


Full offset CI difference – Sum of negative amplitudes



Main challenges Bøyla

- Early stages of analysis, and conclusions are preliminary
- Injector does not support both producers
  - 4D being used as supporting evidence for understanding injector performance and potential infill opportunities
- Understand communication on field
  - Identified potential barriers/separate channels from 4D
- Understand communication to Caterpillar
  - No 4D evidence that area towards Caterpillar is being depleted



Summary

- Wavefield separation and re-datuming of multi-sensor streamer recordings is robust for 4D
- The value of existing regional MC datasets can be leveraged further via use as 4D baselines. Additional upside from recent re-processing and velocity model build
- Broadband 4D about to enter the mainstream, 3D broadband quality gains apply here

Acknowledgements

- Hod field partners AkerBP and Pandion Energy
- Bøyla field partners AkerBP, Lundin Norway and Point Resources
- Processing teams at PGS
- Colleagues: Olav Barkved, Einar Kjos, Jan Kommedal, Kent Andorsen, Tone Endresen

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