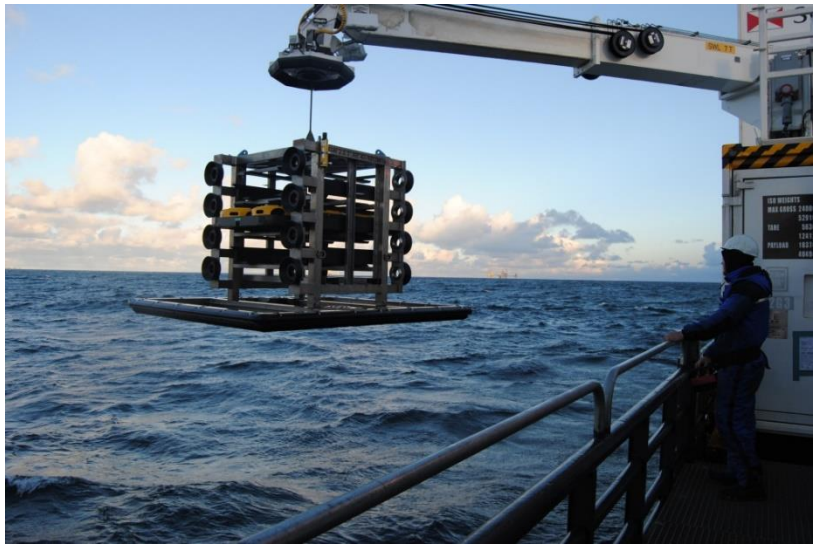
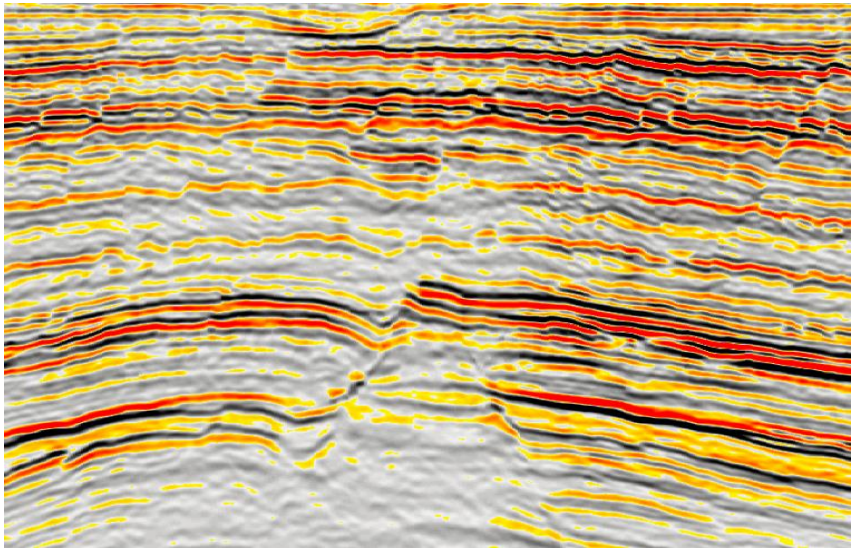




Snatching victory from the jaws of defeat—Dan field seismic monitoring node survey

1 CGG

2 MAERSK OIL

3 Seabed GEOSOLUTIONS

Dan field, North Sea Danish sector



- Chalk reservoir
- 45 m water depth
- Complex structure
- Water injection

- Baseline survey streamers including two vessel undershoot
- 2012 4D monitoring survey: combined streamers and nodes

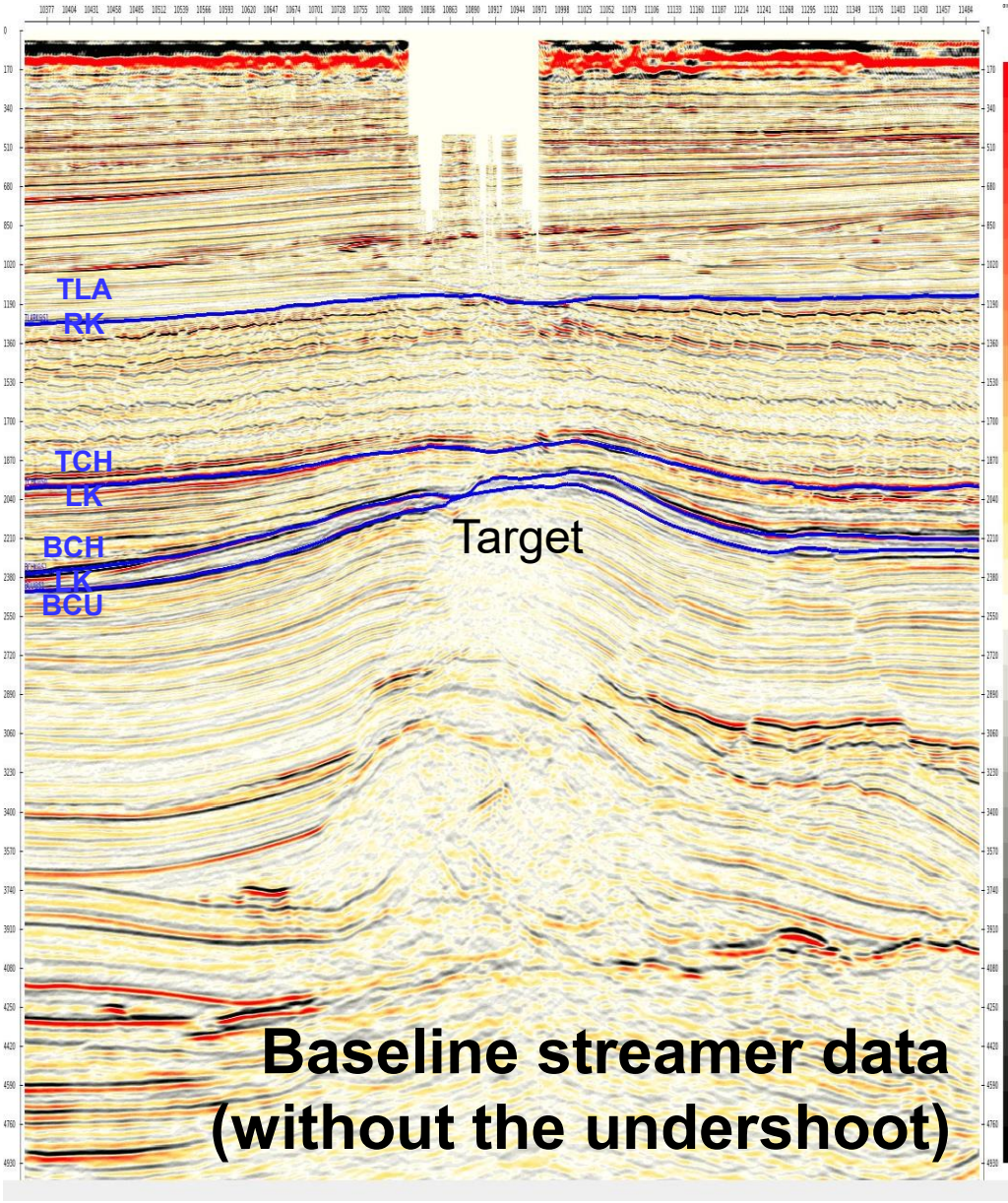


Dan 2012 monitor survey: combined streamer and nodes

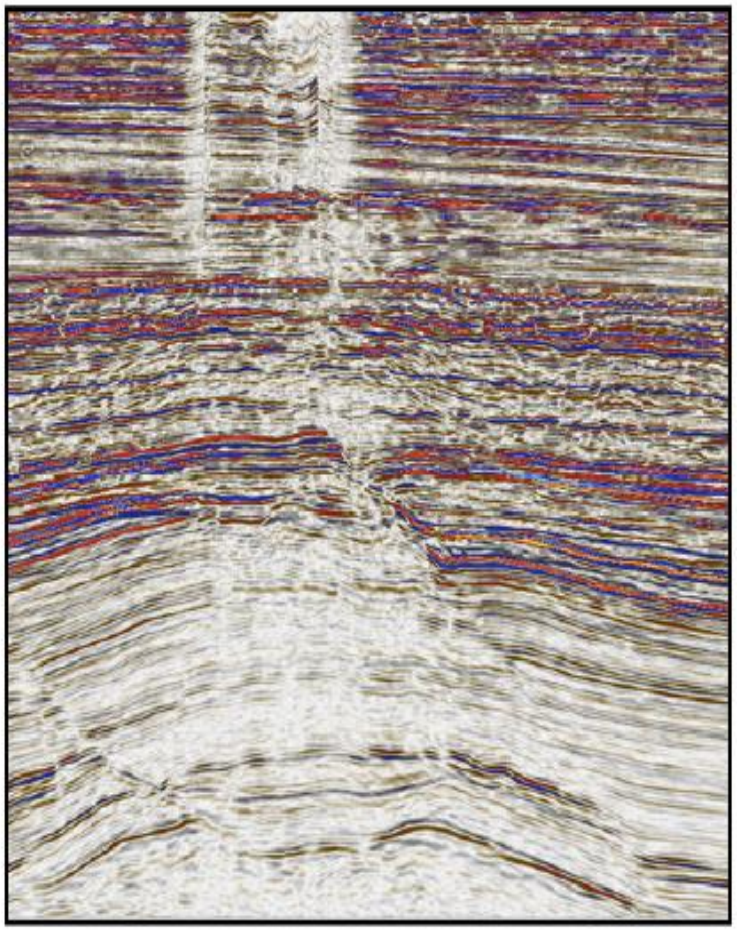
- Obstructions, Full azimuth, Shear waves. 4D repeatability



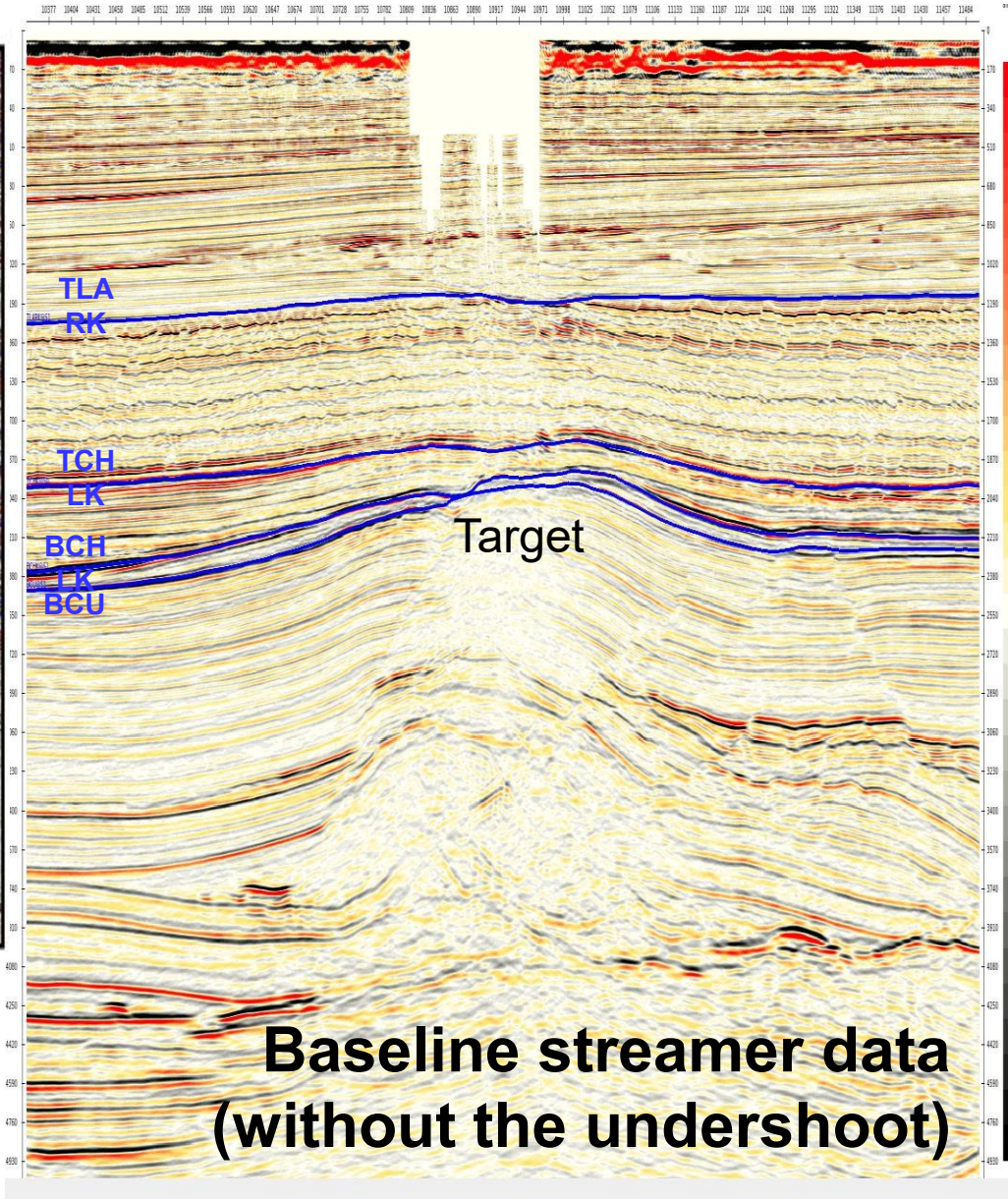
- Streamers and dual vessel undershoot
- Node survey covering the reservoir including the obstructed area



The undershoot helped, but not enough for D & P

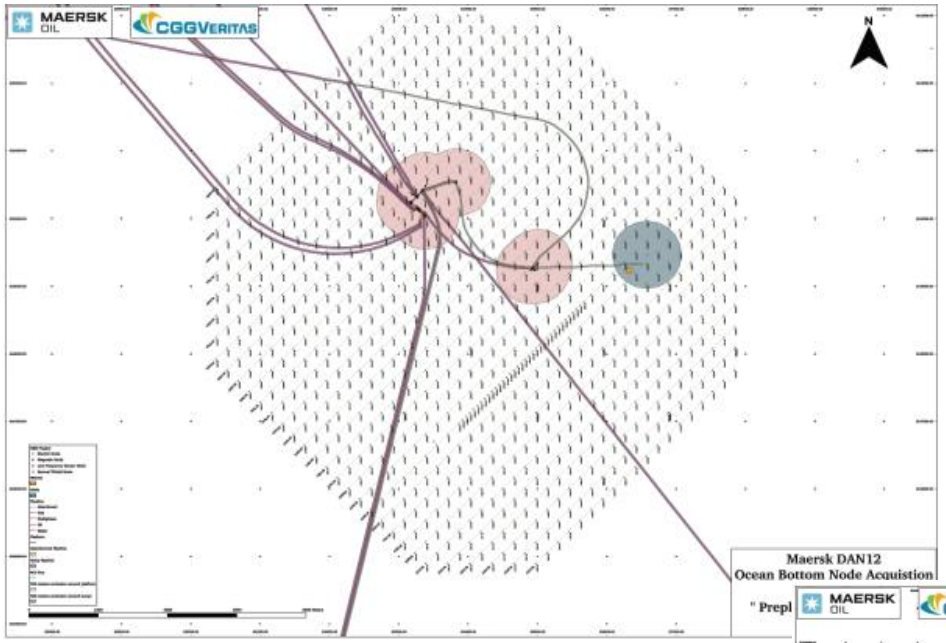


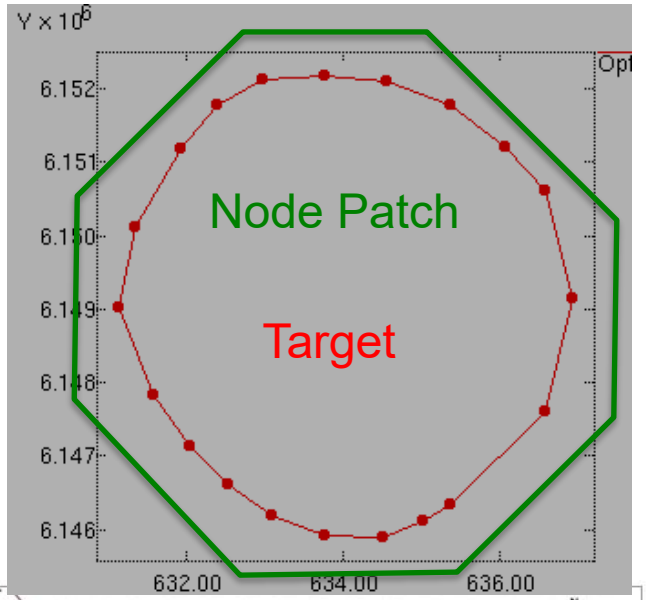
Baseline streamer data (with the undershoot, more reprocessing)



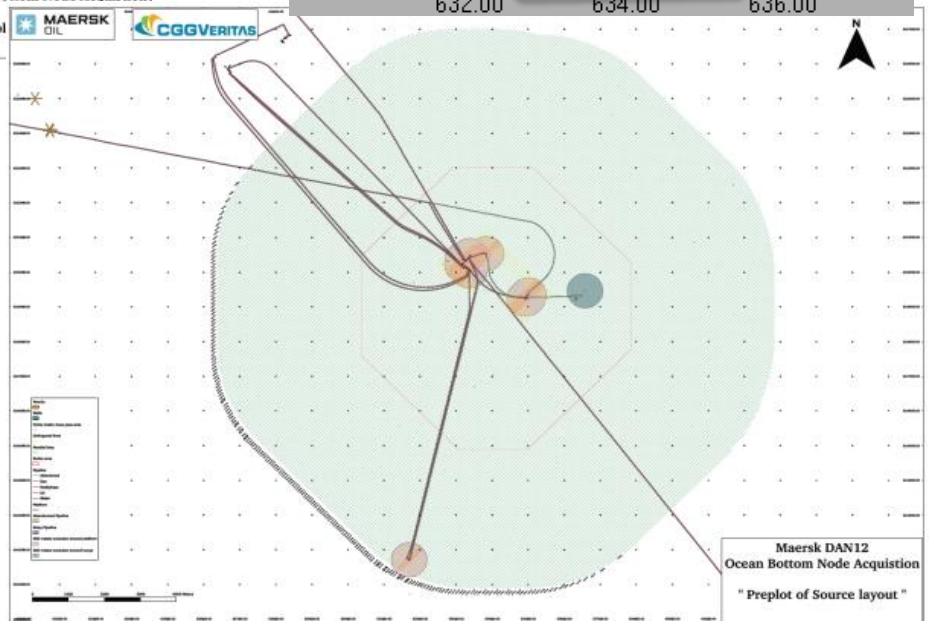
Baseline streamer data (without the undershoot)

Survey design





- 225 x 225 m node interval
- 37.5 x 37.5 m shot interval
- Abundance of caution
- Maersk first OBN survey
- Following Total Angola
- Not Shell/BP GoM 400x400 node and 50x50 shot intervals



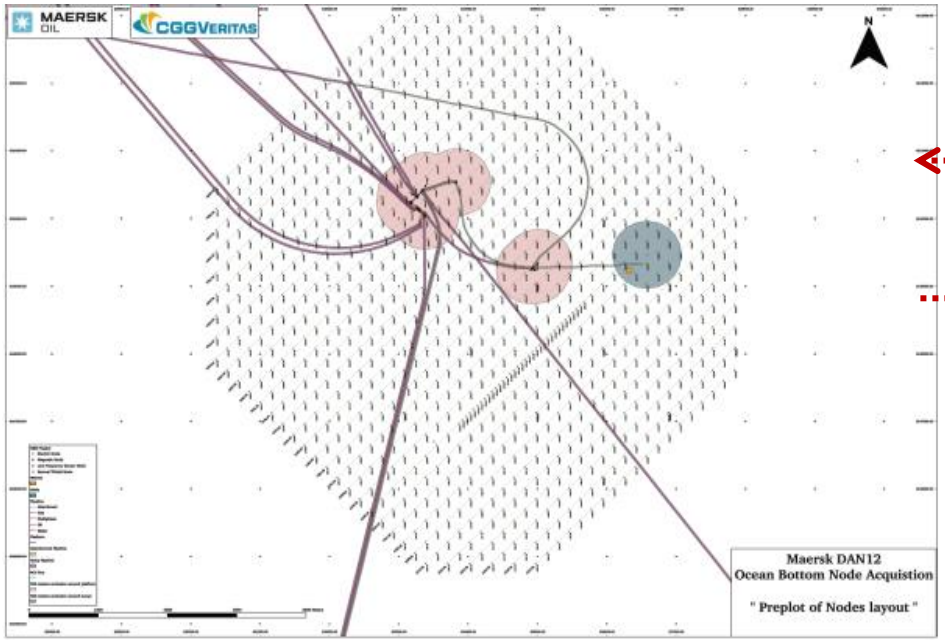
Dan 2012 OBN monitoring survey

- Streamers: summer
- Nodes: October-December (up to 8m swell)
- No major safety incidents
- Completed reasonably on schedule “by Christmas”





End of survey QC: only 87.5% acceptable nodes



840/959 accepted = 12.5% failed, Contract: up to 2%

- 2.7% 26 nodes: 1 flooded, 5 bad sensors, 17 incomplete data ← Bad!
- 3.5% 34 nodes were taken and 3 moved by a *trawler
- 2.5% 23 nodes without final clock synchronization ← Bad!
- 3.8% 36 nodes were rejected by CGG's dedicated processing center

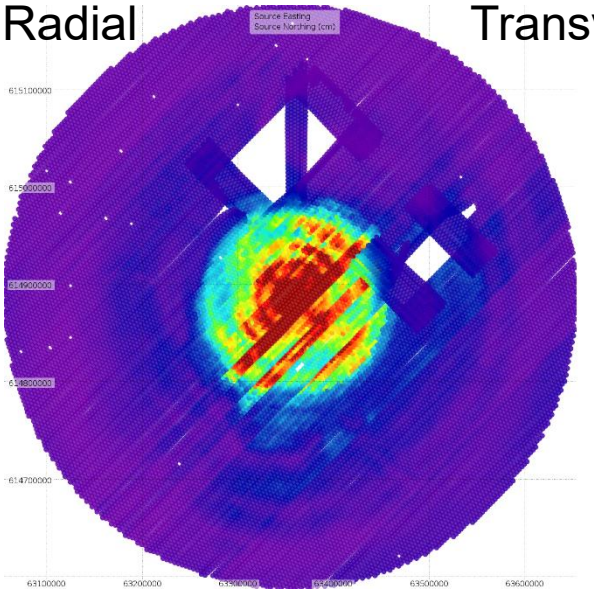
* A Dutch trawler, her AIS turned off, came at night, during crew change, passed between two Maersk-paid guard vessels (!) Went west to east, turned, and then went east to west and went away with 34 nodes

Trawler

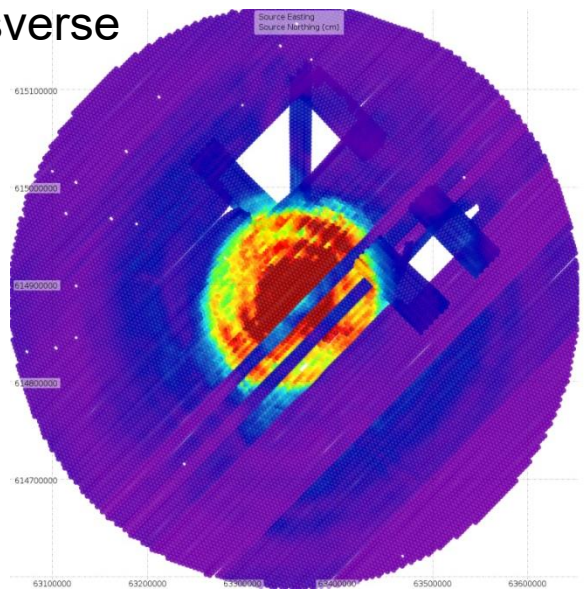


34 nodes were not found by the ROV
3 more nodes were moved as seen on the data.

Radial



Transverse

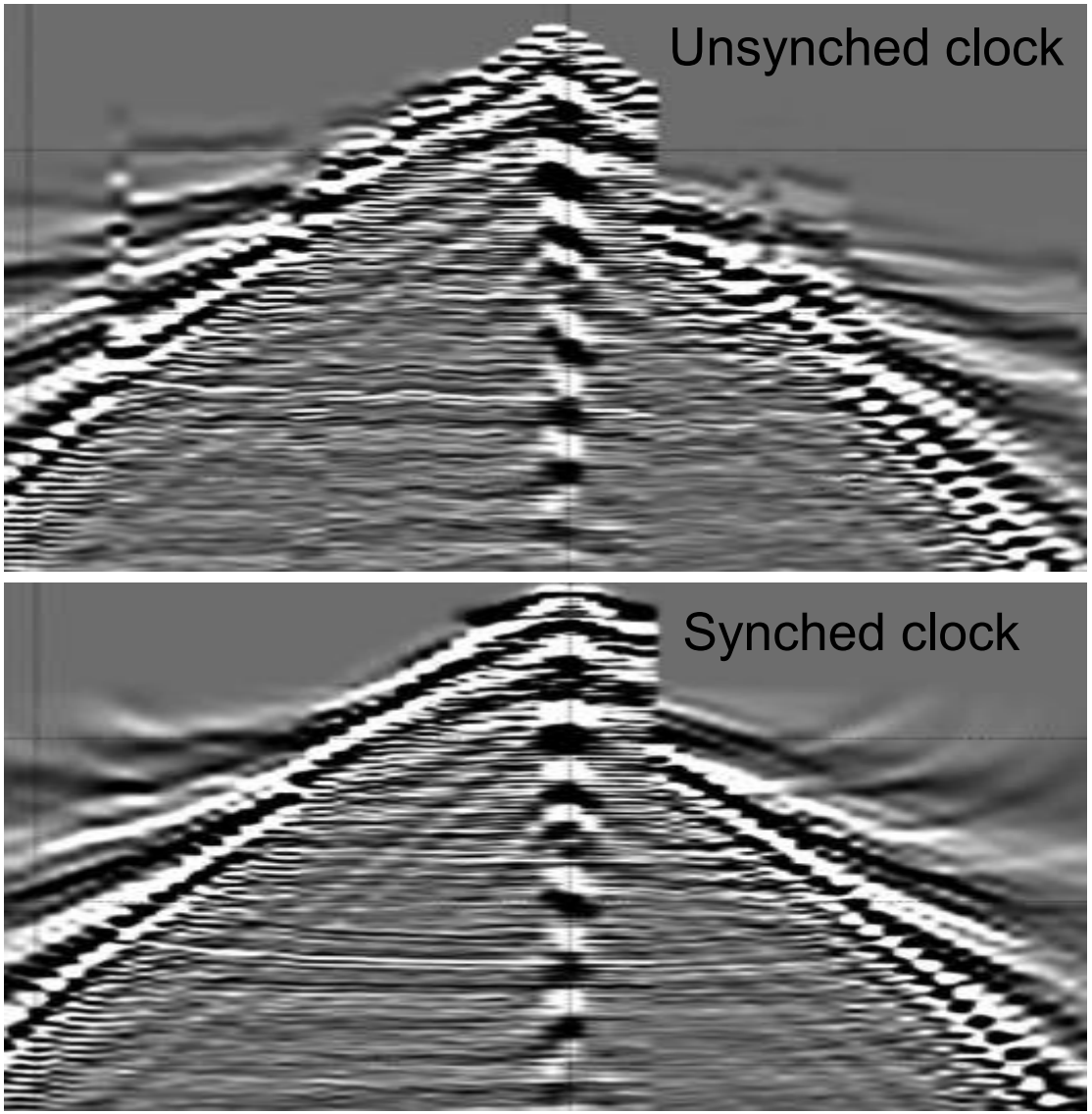


RMS maps of horizontal components around the onset of the first break for a node that has been moved and rotated by the trawler.

← Picture taken in den Helder. Surrendered after some detective work (AIS records and bluffing)

Unsynched clocks

- According to contract, clocks are synchronized just after deployment and again just before retrieval
- The drift is linear if the reason is clock frequency inaccuracy which is typical to the clock
- Failure: 23 nodes were retrieved without final synchronization
- These nodes were out of specification and not acceptable initially



Dan Survey onboard and post survey actions

1. Fast track processing of the 840 accepted nodes (Haacke in Crawley)
2. Data processing fixing of the 23 nodes without final clock synchronization (Noss in Copenhagen)
3. Reload data and review the QC reports of all nodes that were rejected before Noss got to Copenhagen
4. Found the trawler. Maersk had to admit that it was their responsibility/fault



Dan Survey onboard and post survey actions

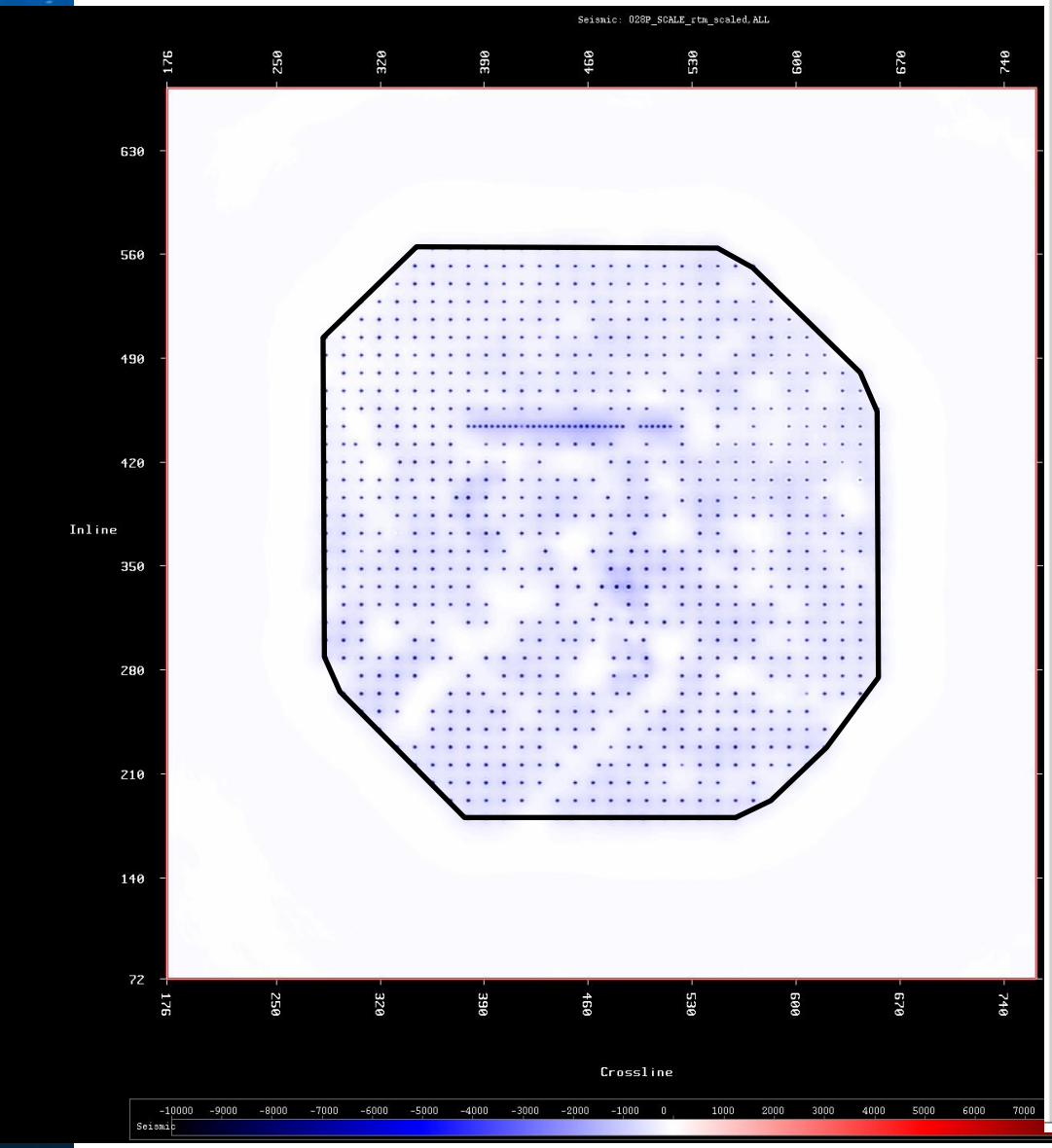
- 12.5% failure rate

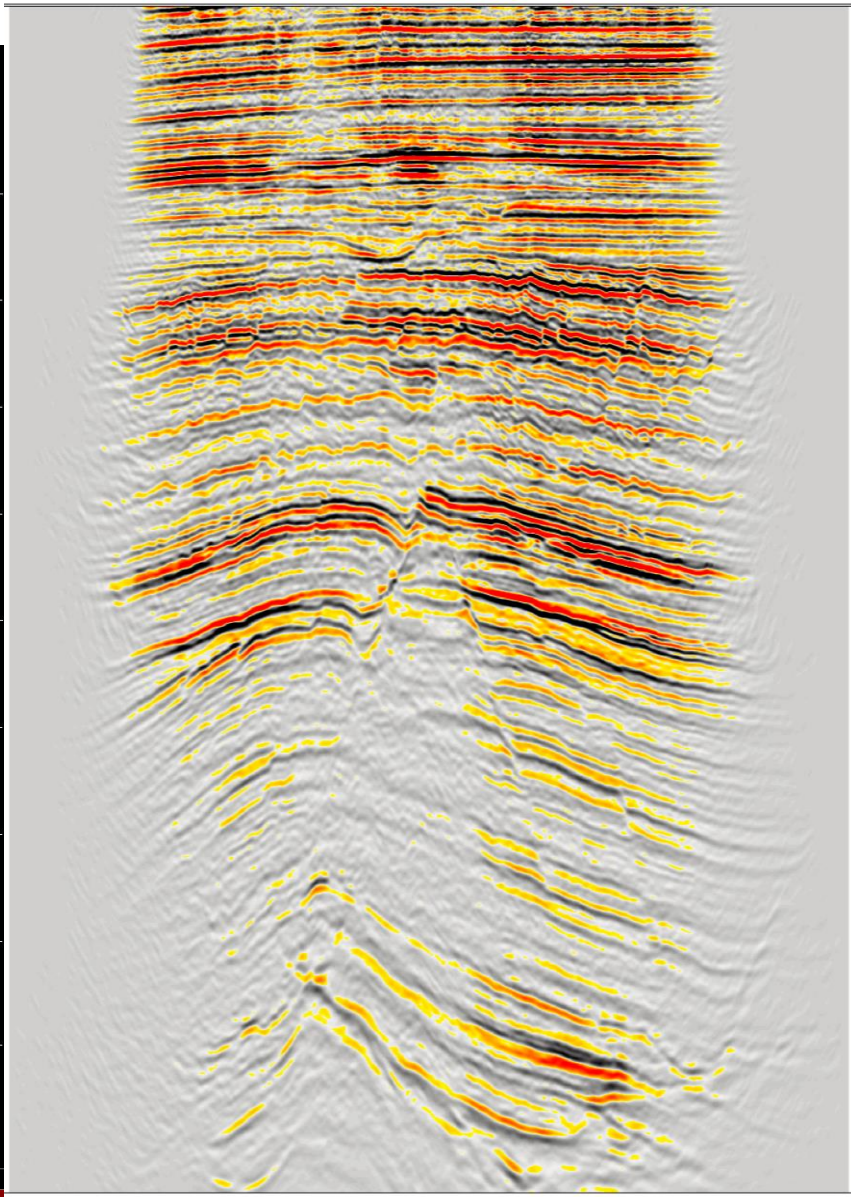
Actions:

1. **Fast track processing of the 840 accepted nodes**

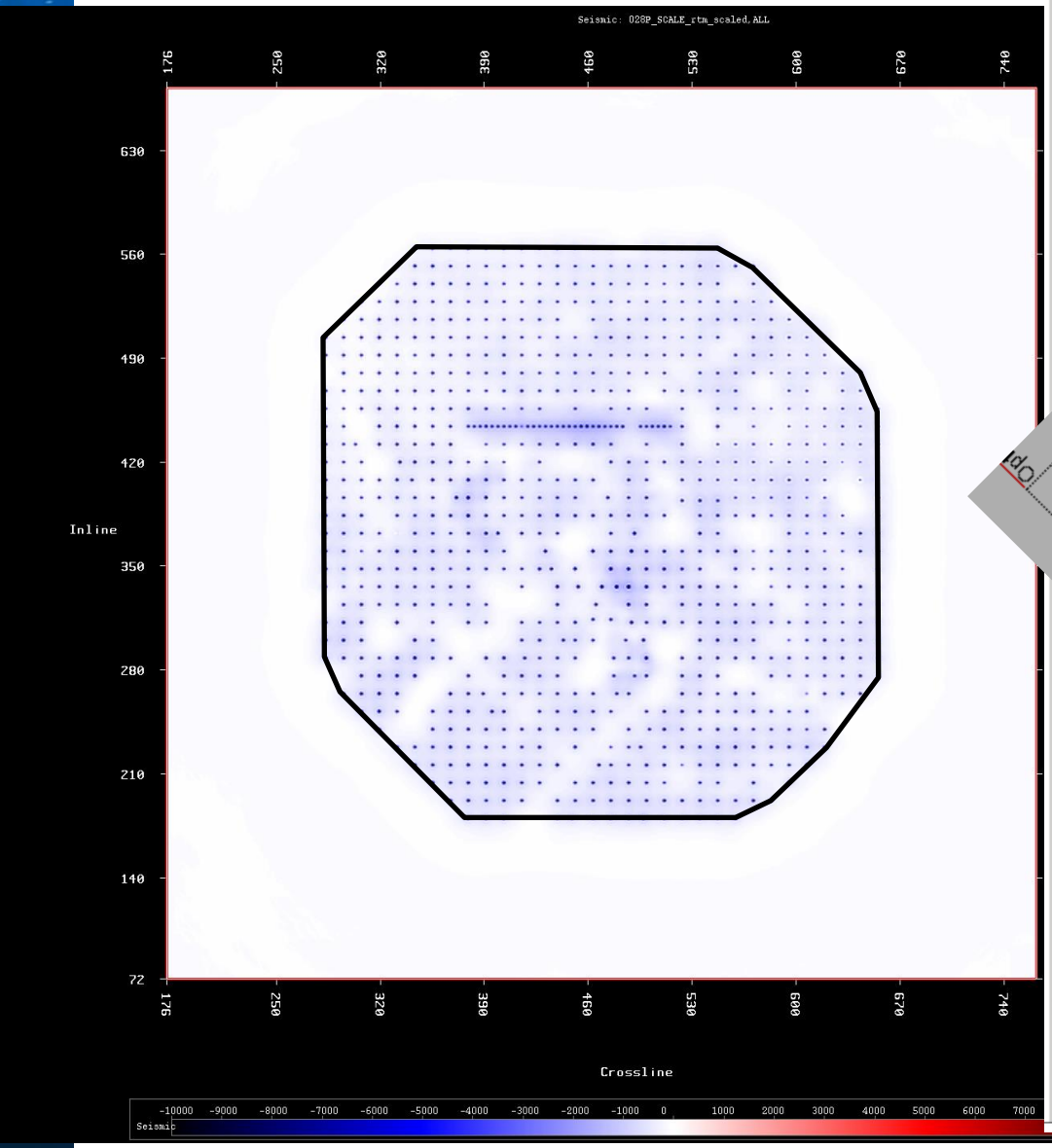


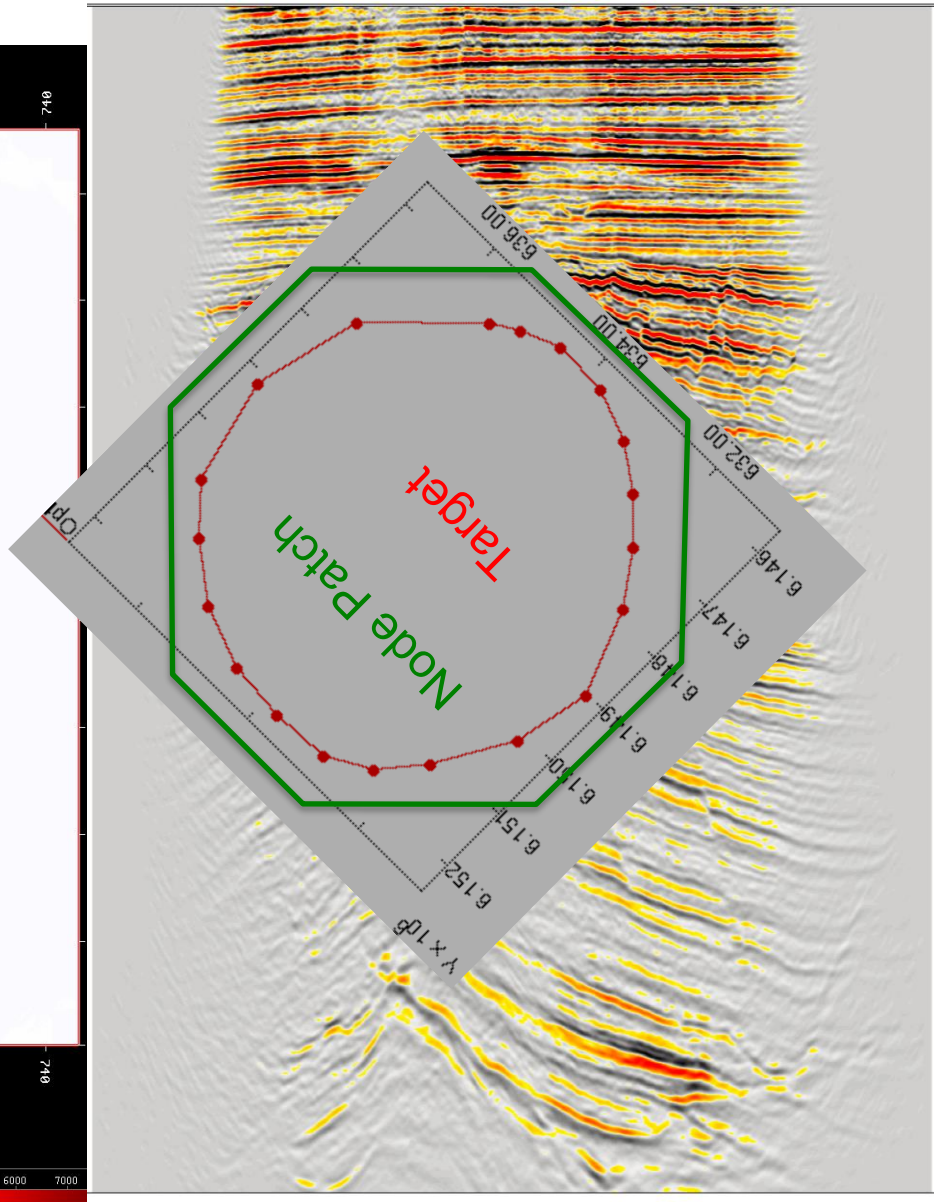
Time slice at 70 miliseconds



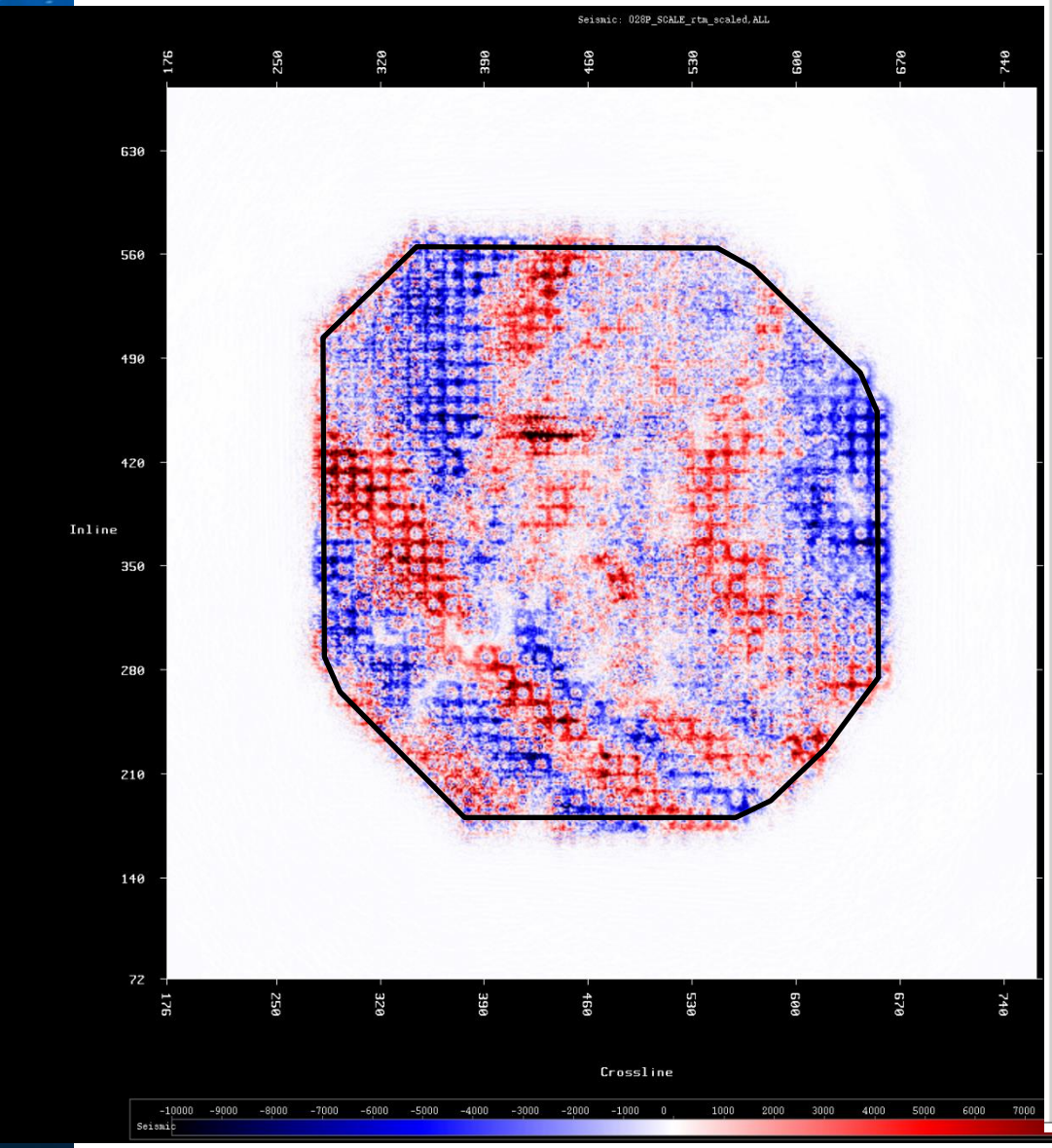


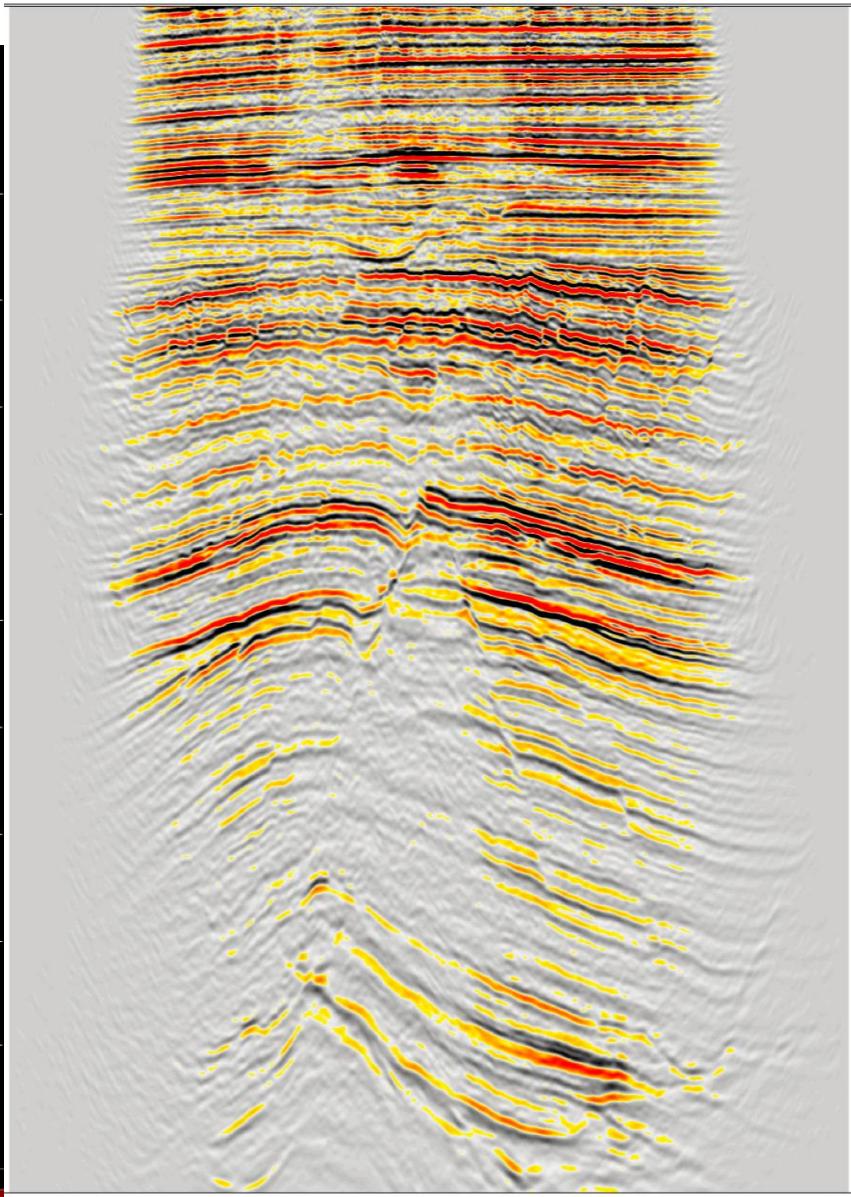
Time slice at 70 miliseconds



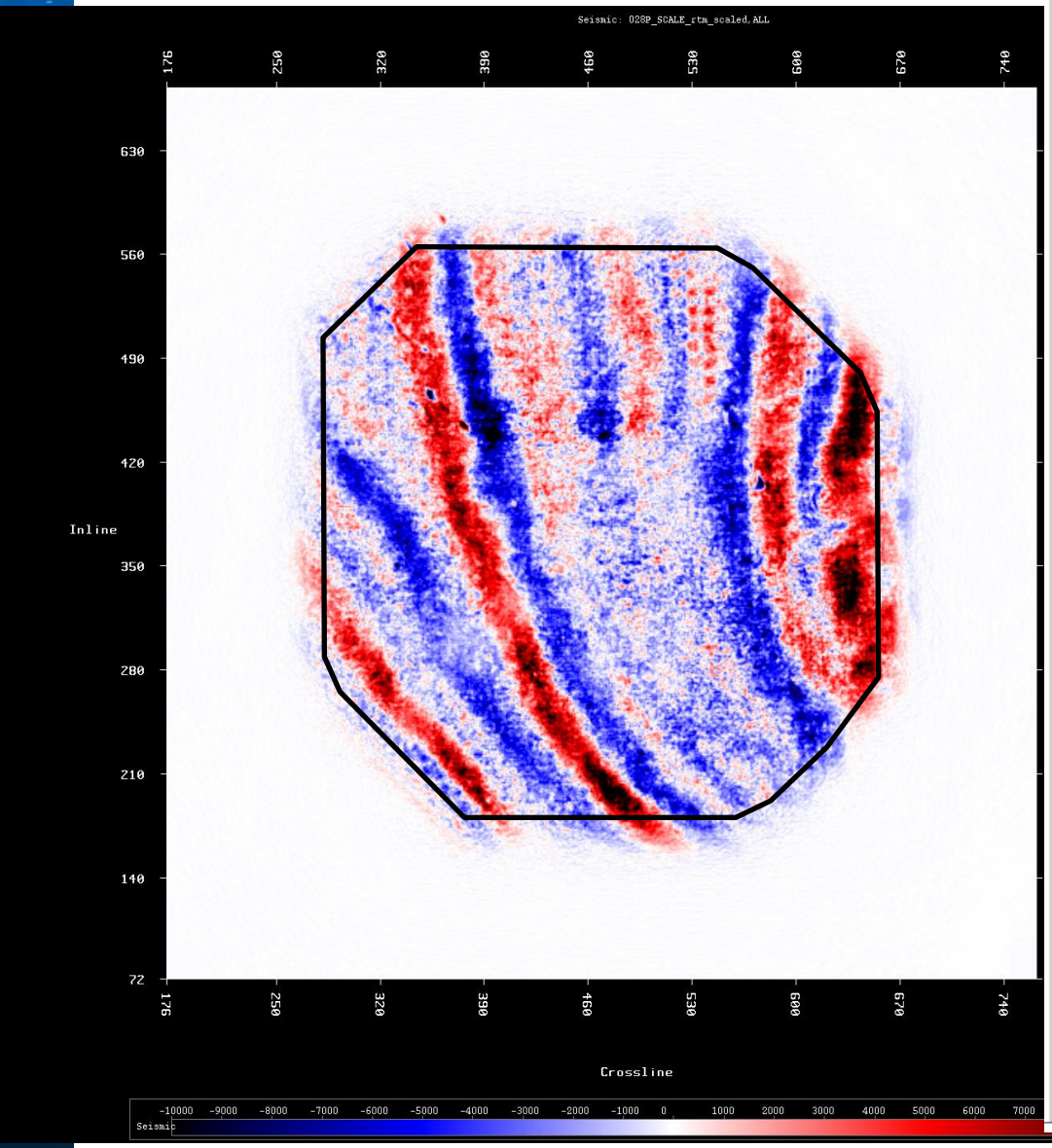


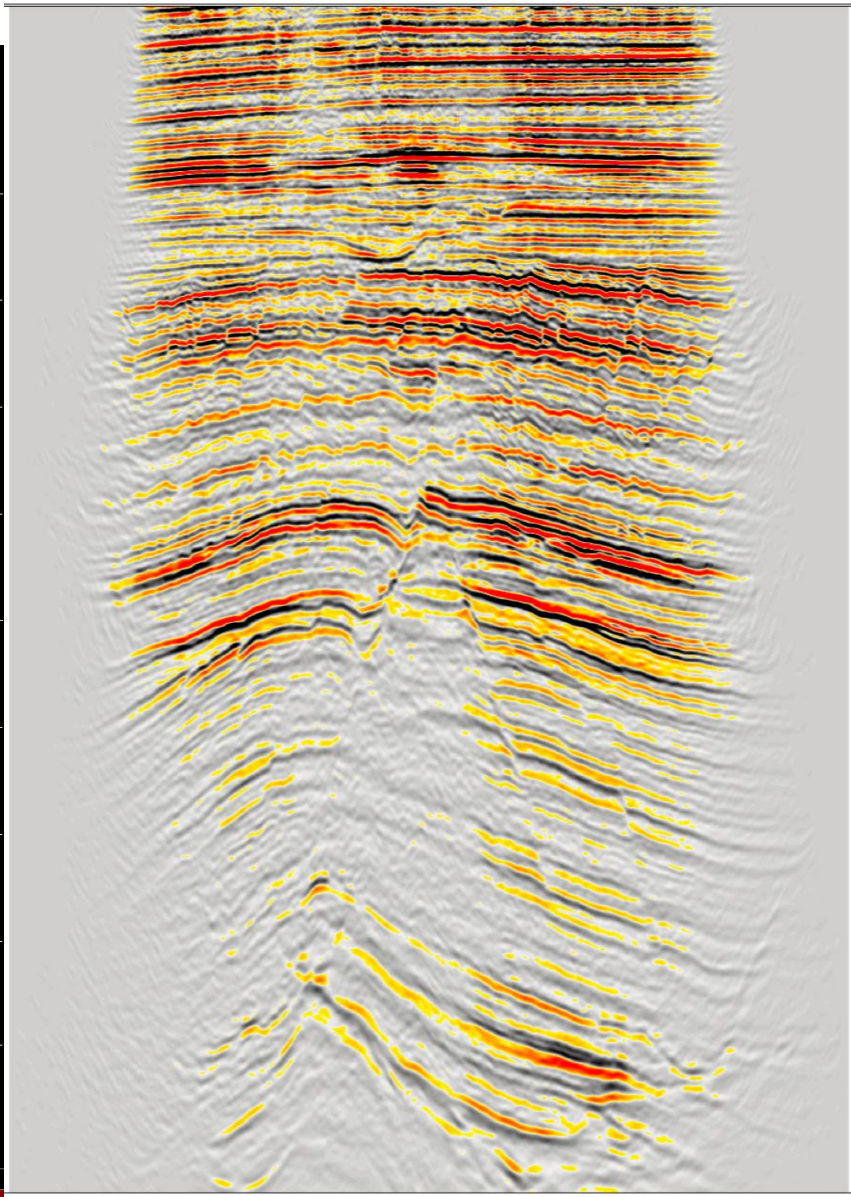
Time slice at 0.4 seconds



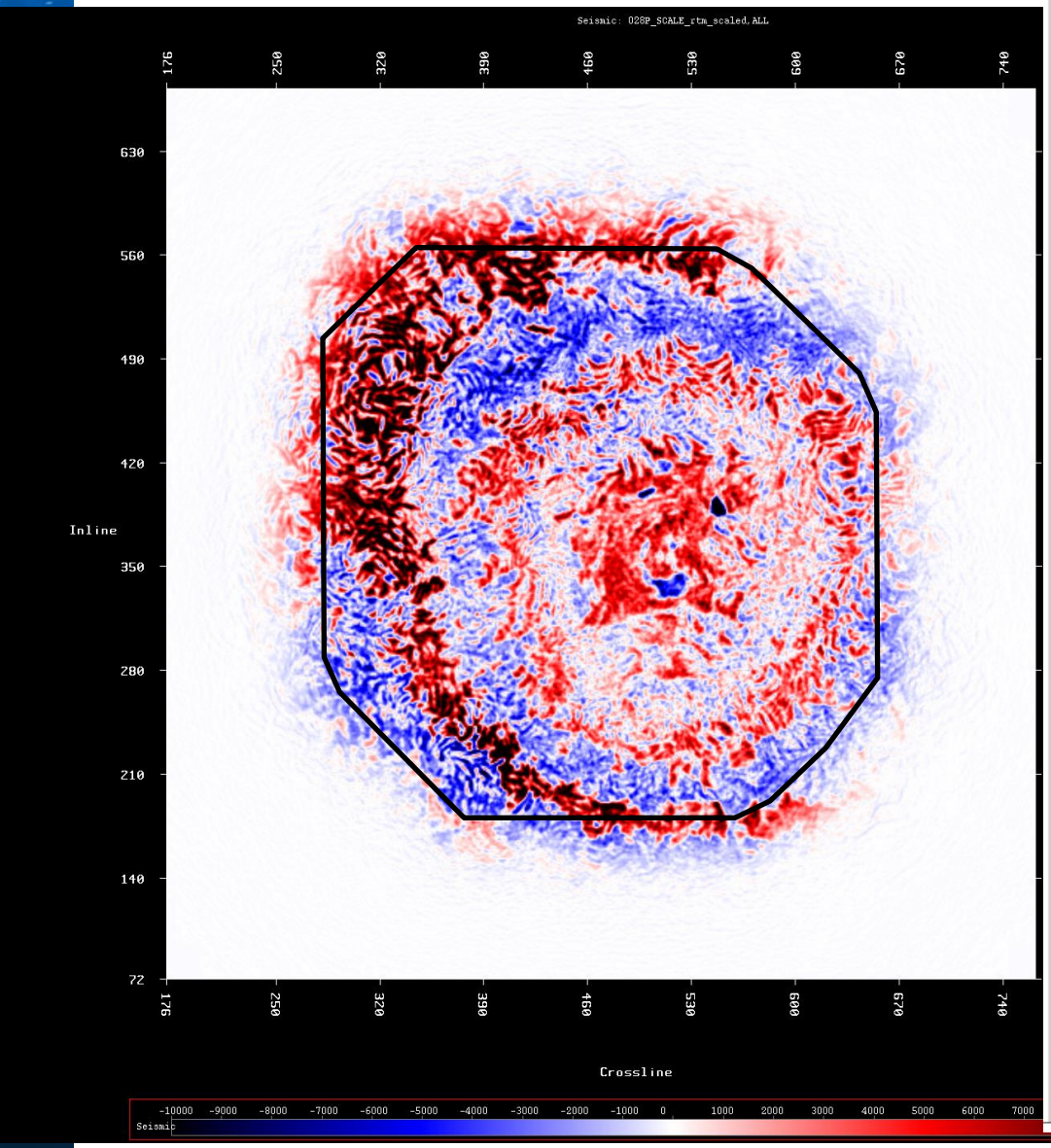


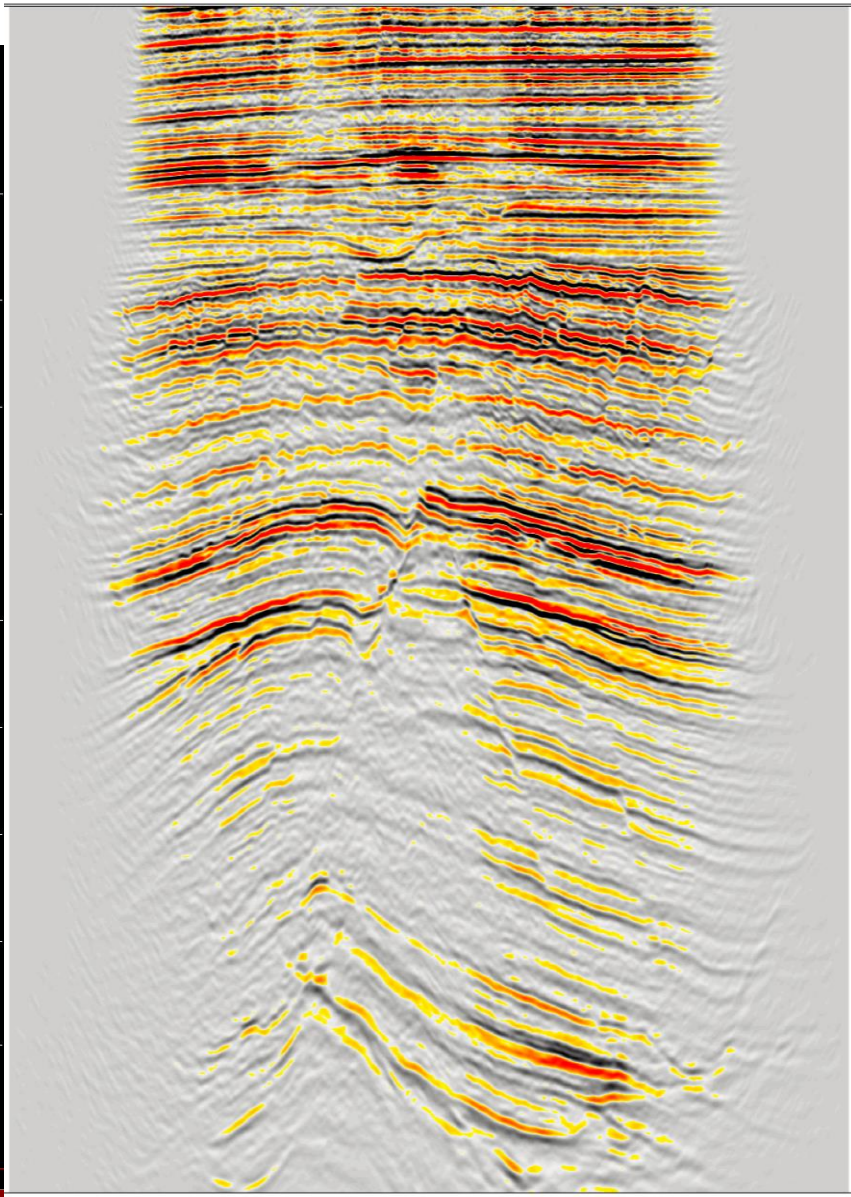
Time slice at 0.8 seconds



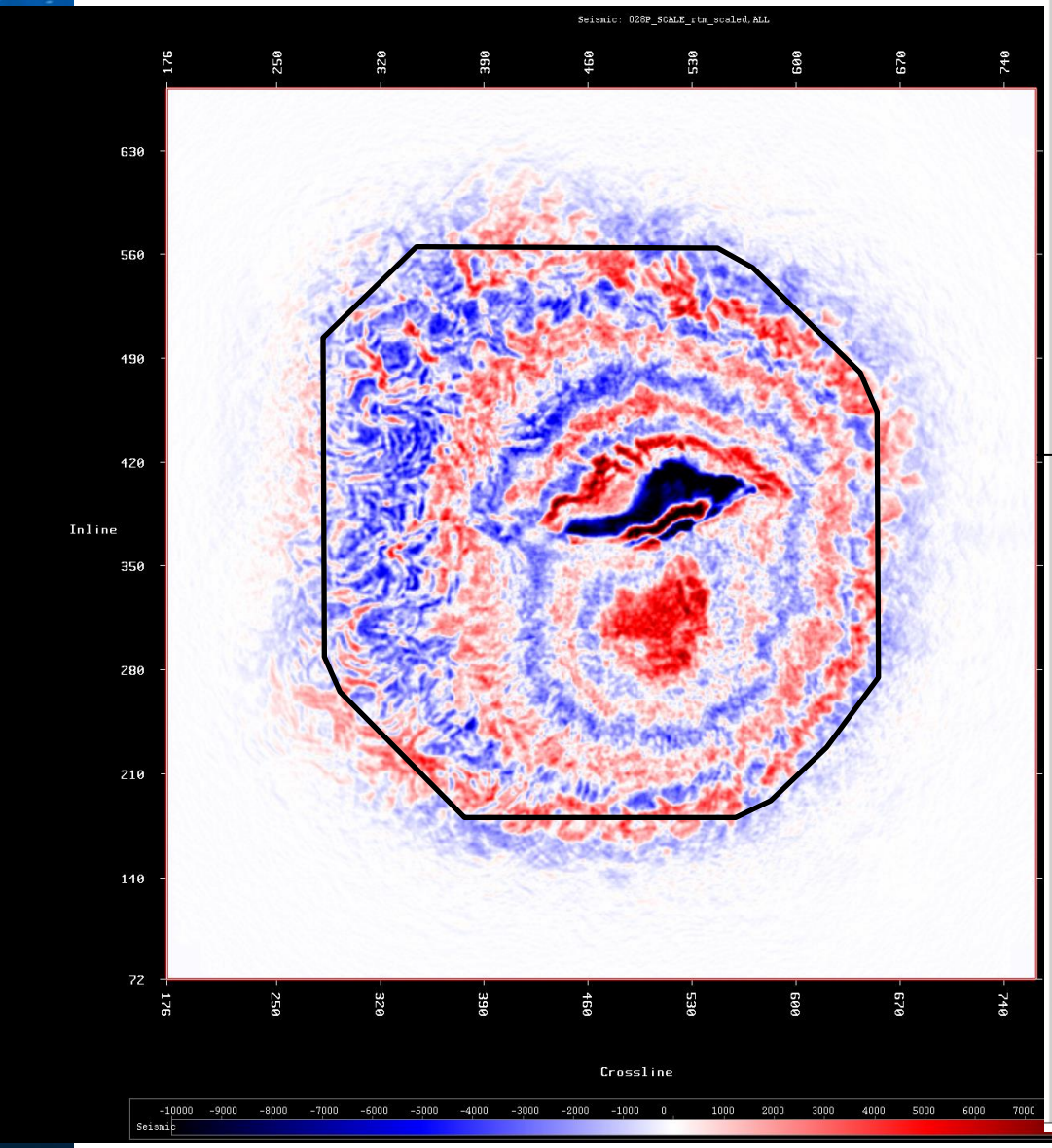


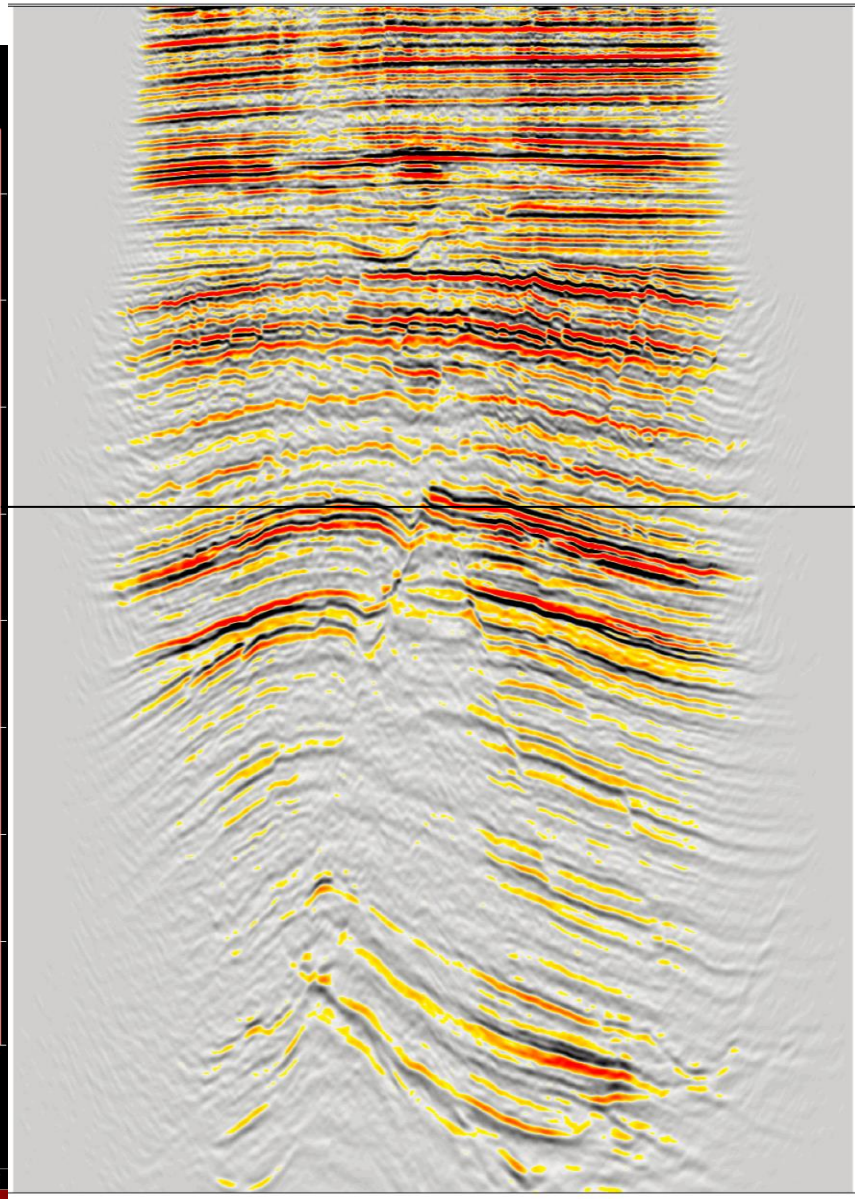
Time slice at 1270 miliseconds



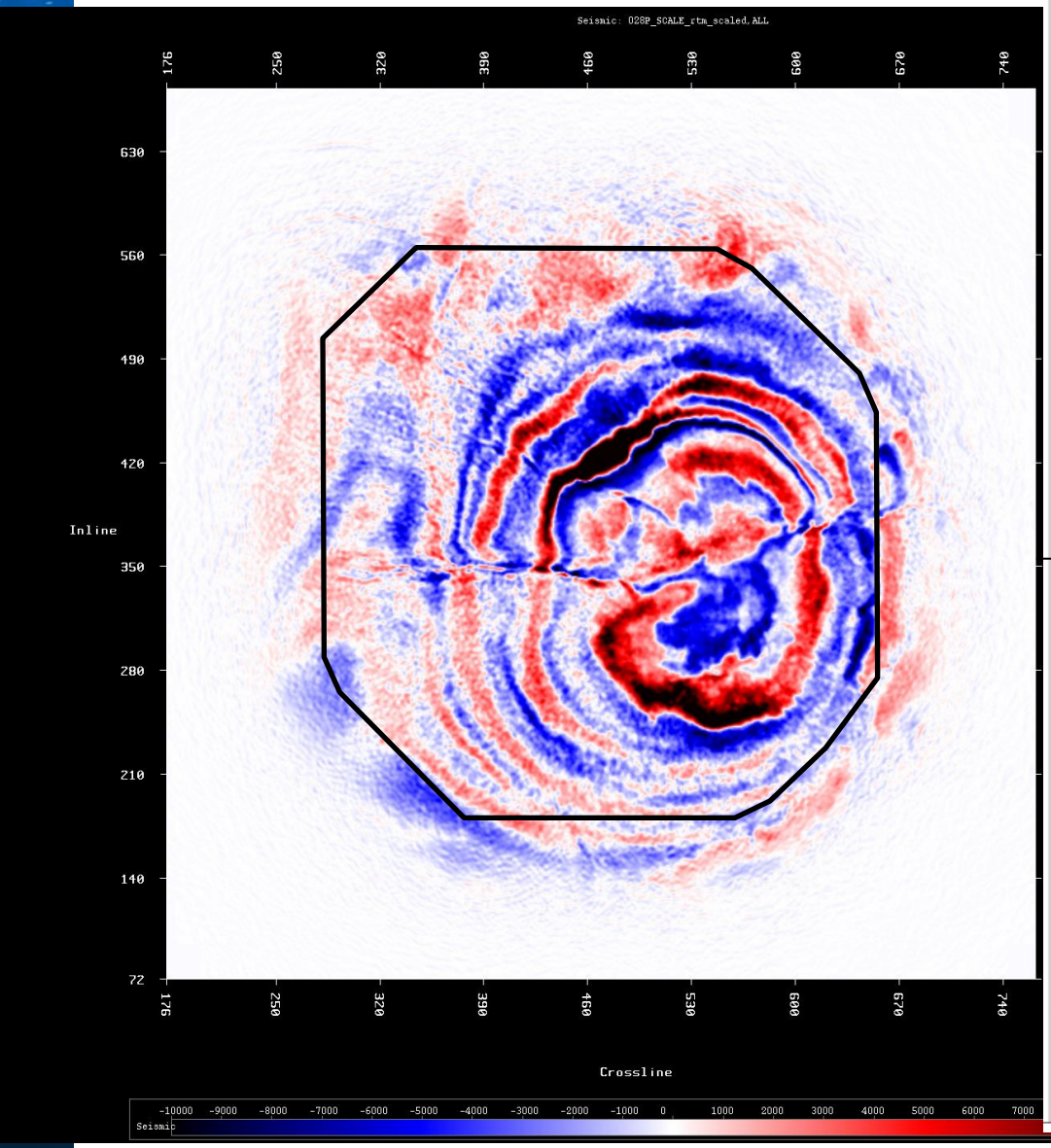


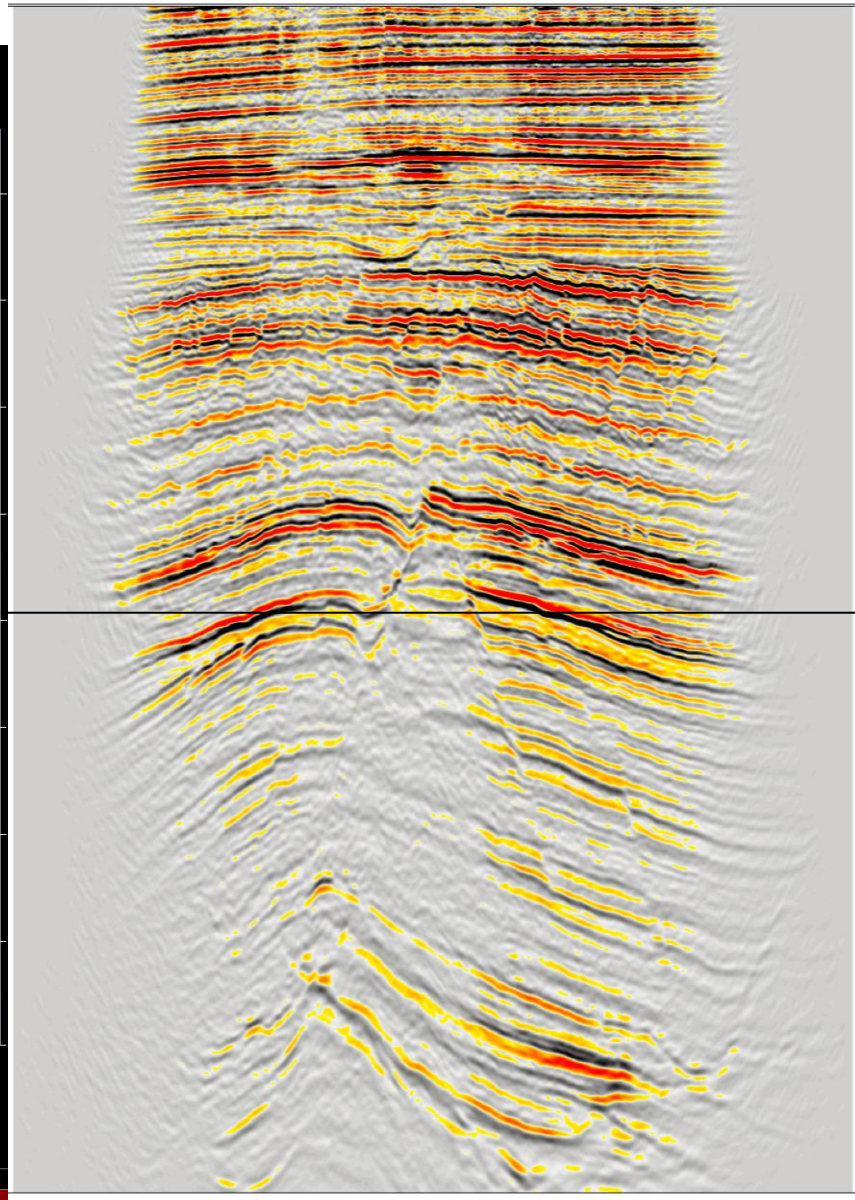
Time slice at 1740 miliseconds



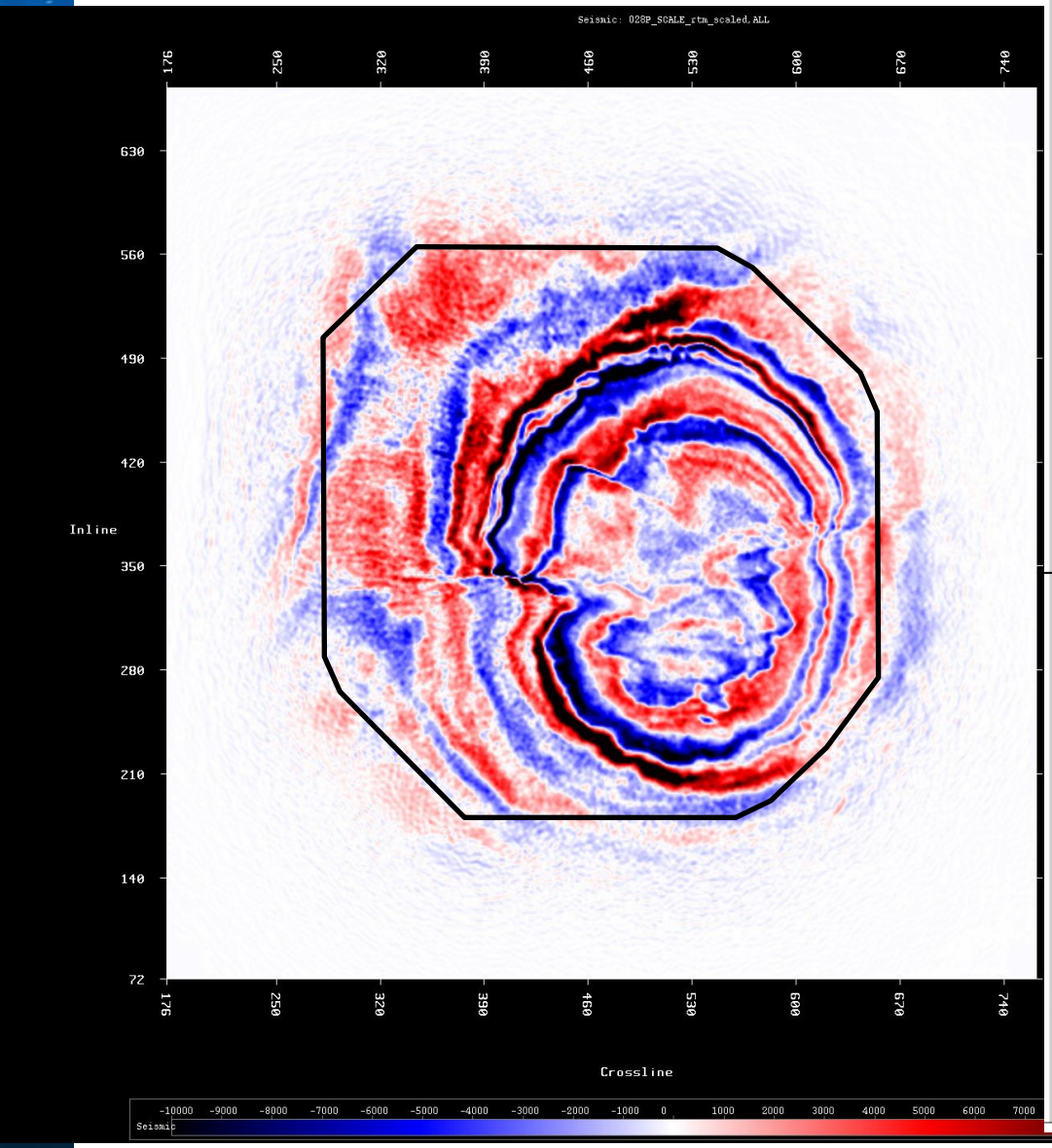


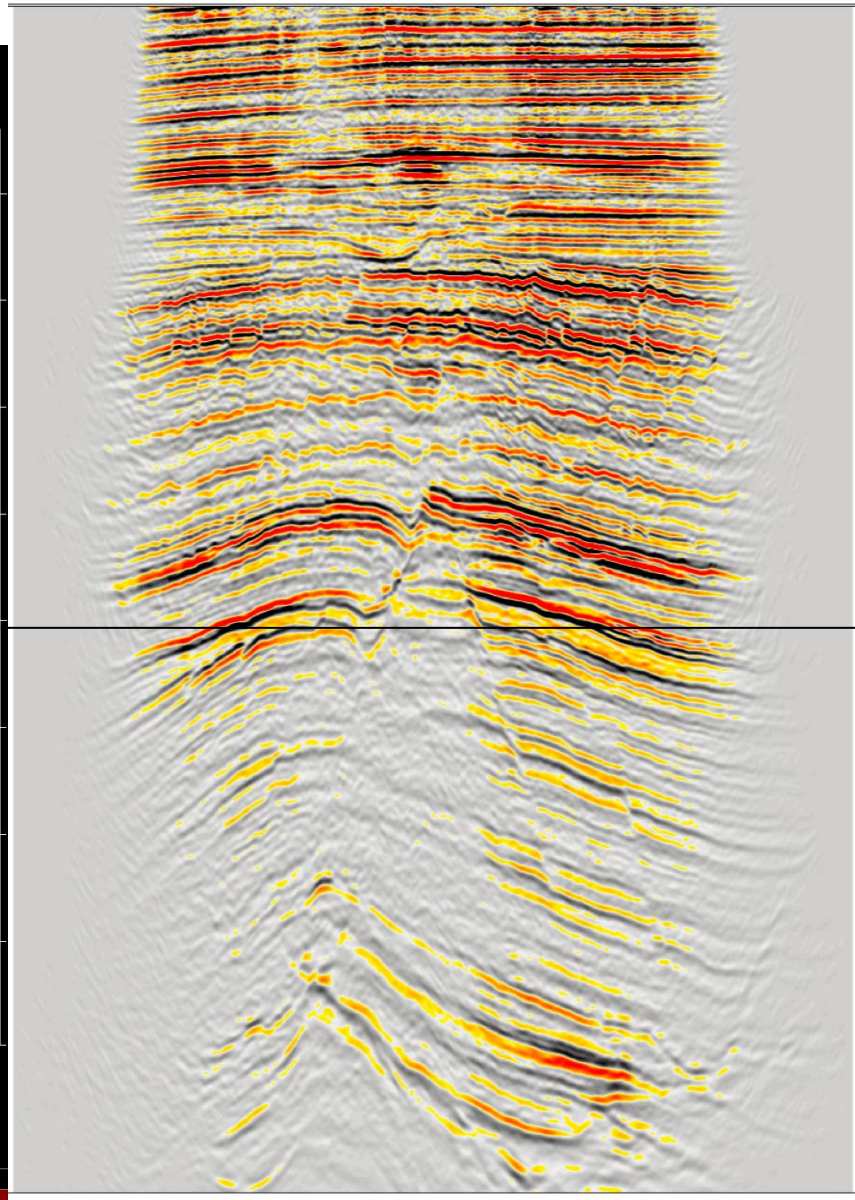
Time slice at 2 seconds



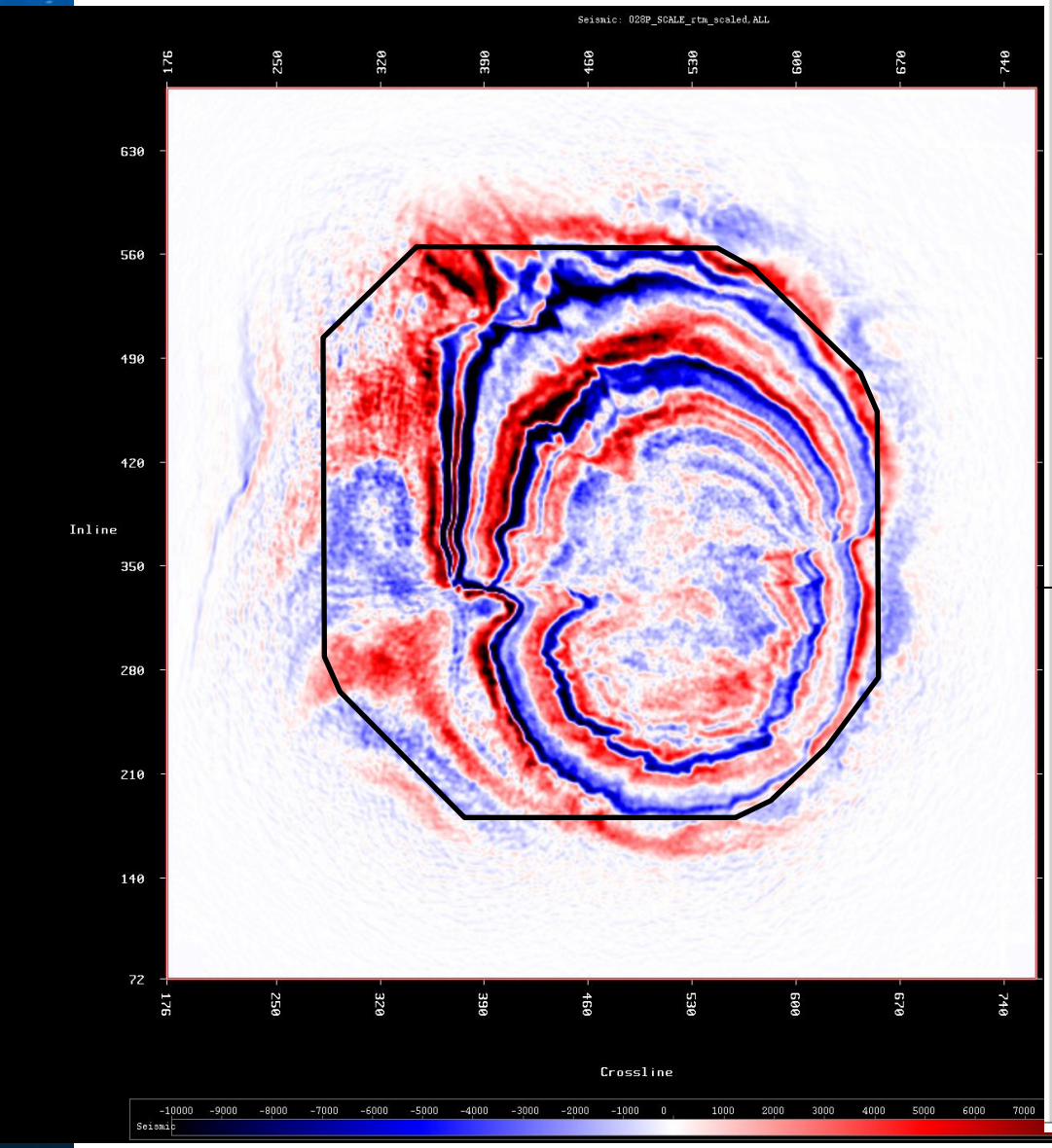


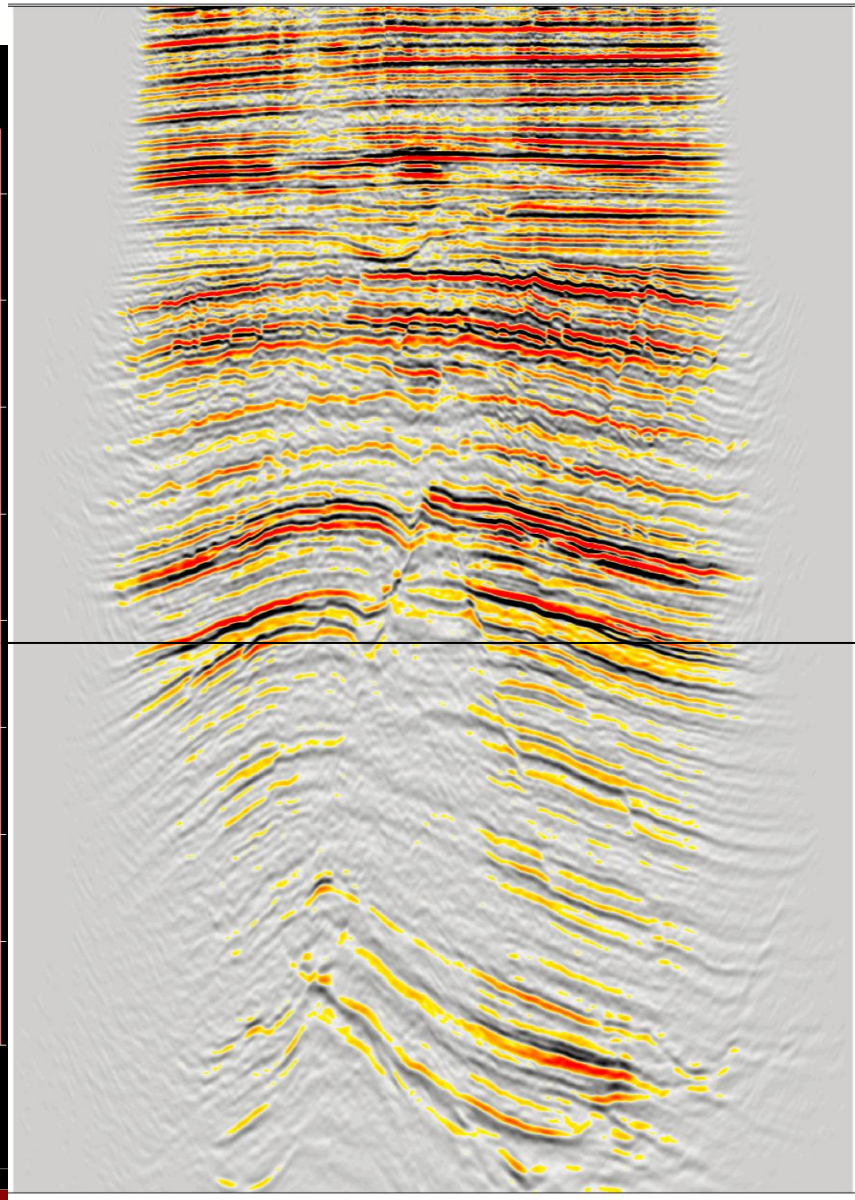
Time slice at 2070 miliseconds



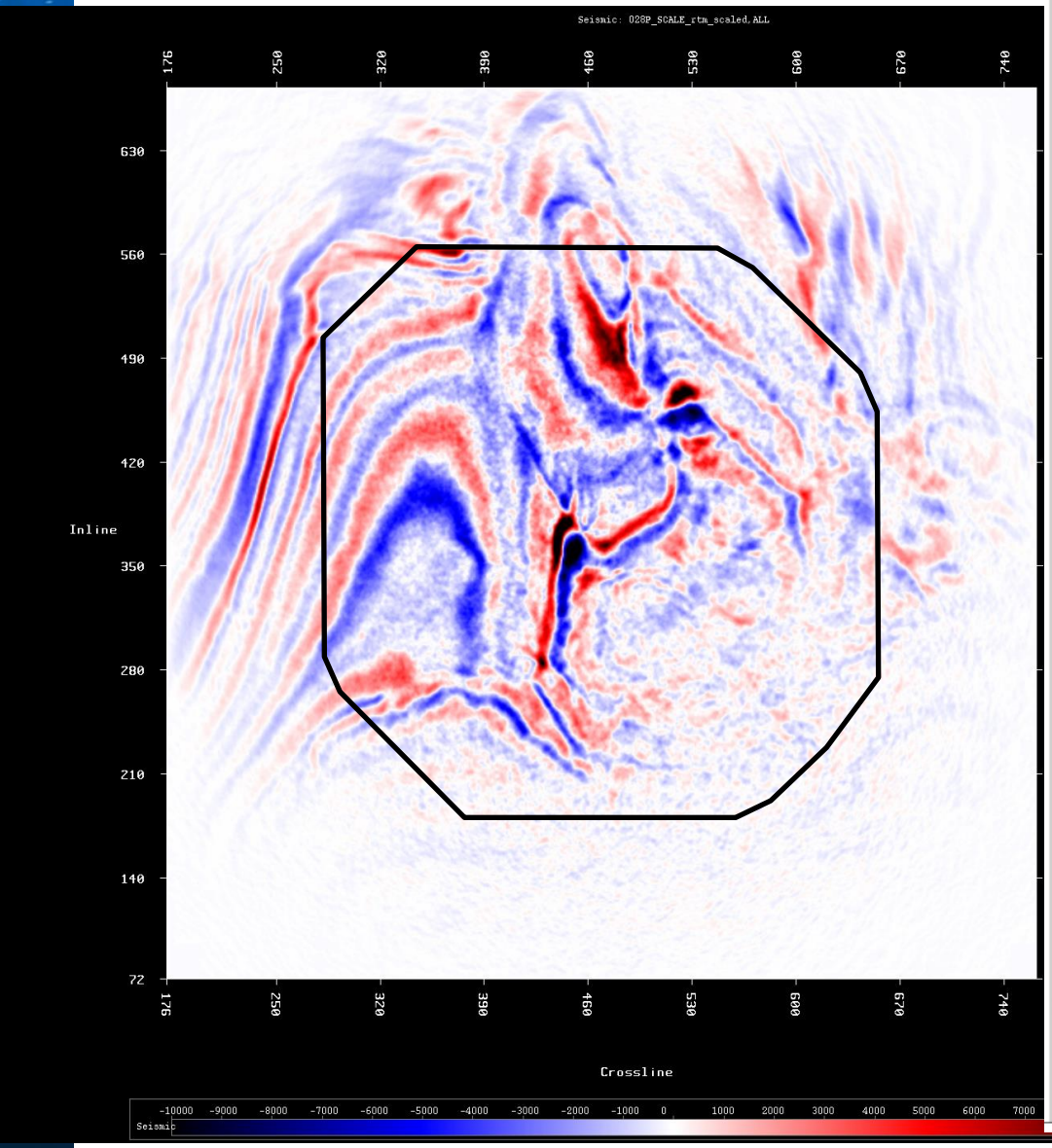


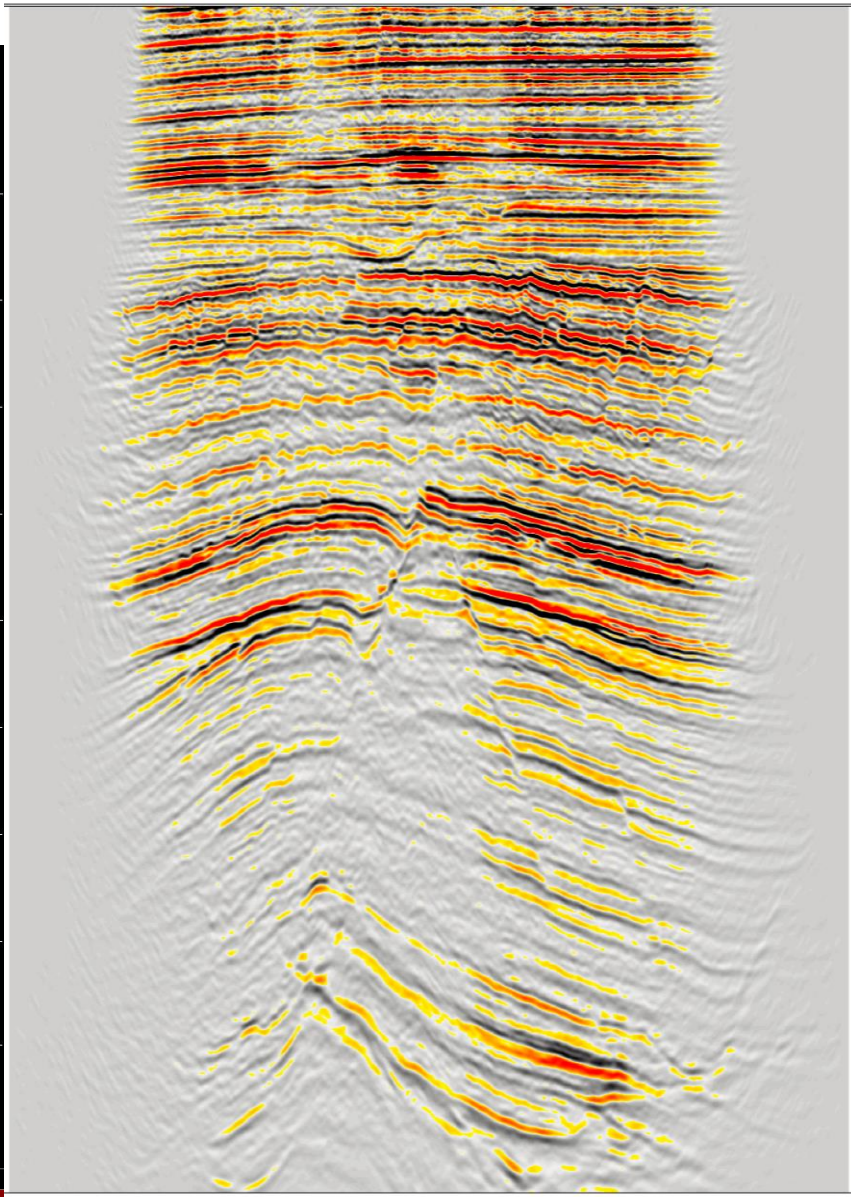
Time slice at 2140 miliseconds





Time slice at 3.2 seconds





Dan Survey onboard and post survey actions

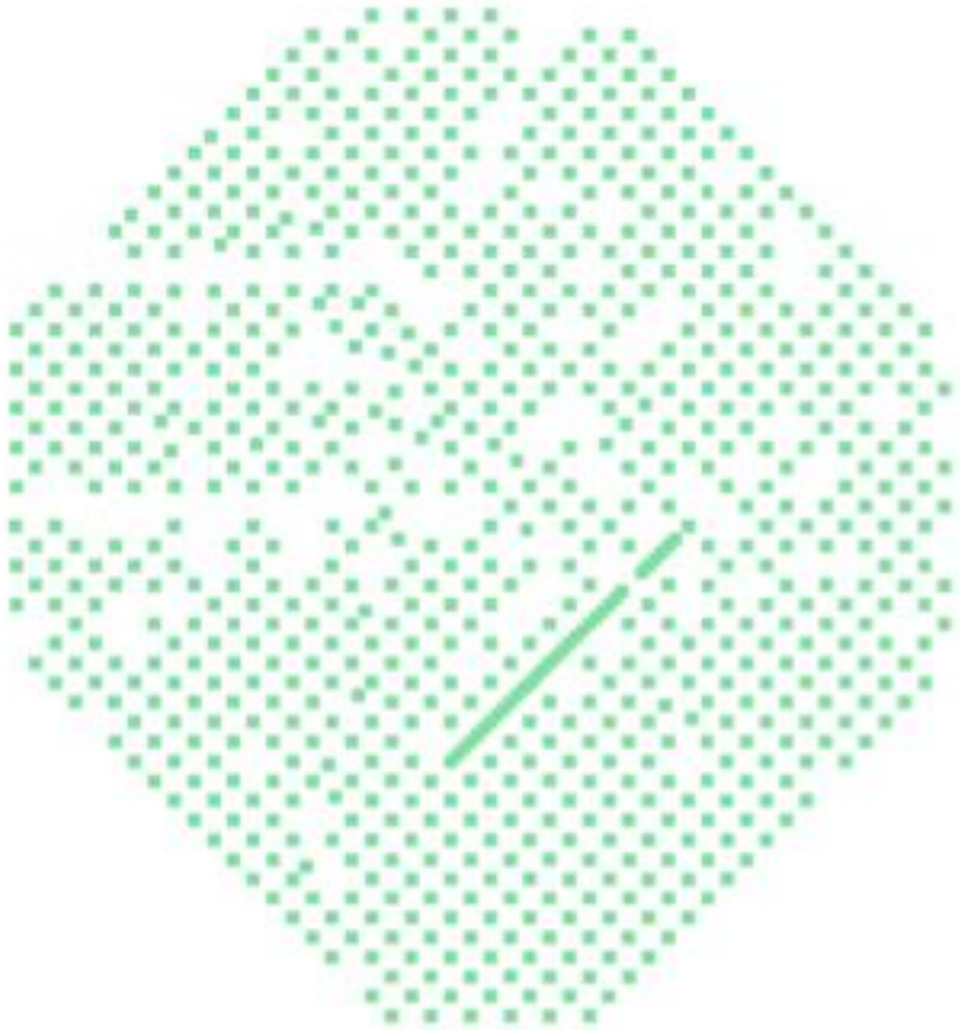
- 12.5% failure rate

Actions:

1. **Fast track processing of the 840 accepted nodes**

Result:

- No geometry footprint of the unacceptable nodes. Thanks to the 225 m node interval overkill
- Huge effect on Maersk Asset
  - Partner's meeting
  - "It is not a failure"
  - In fact, it looks really good!

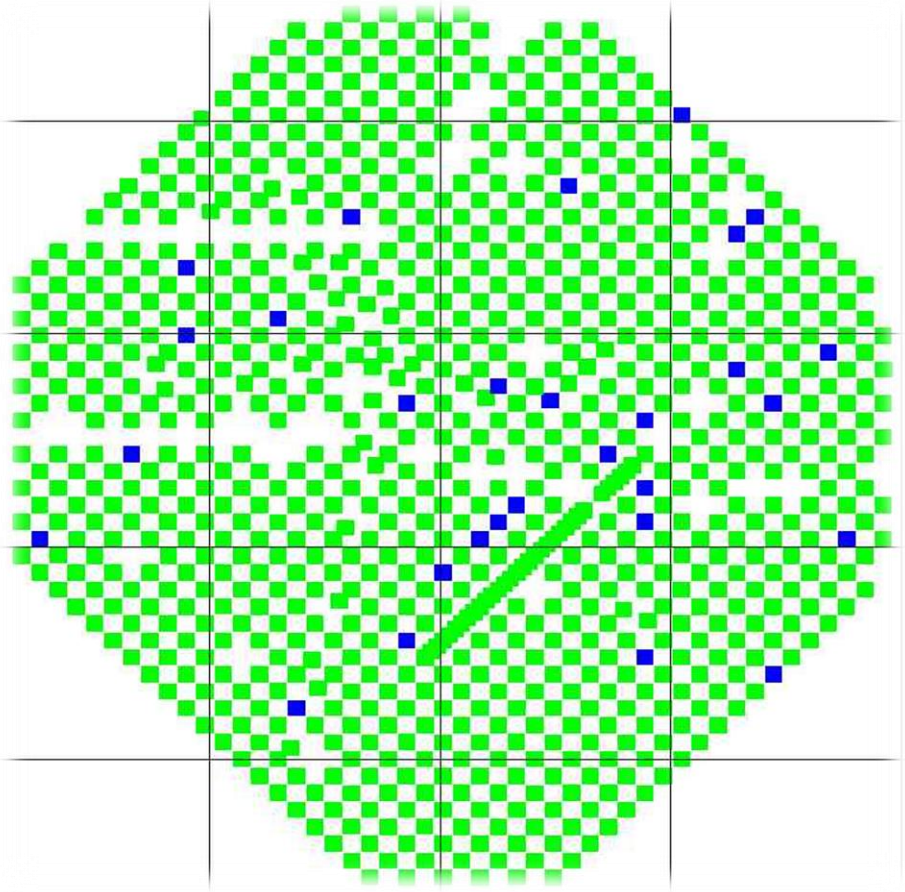


Fast track processing summery

- 12.5% failure rate

Actions:

1. Fast track processing of the 840 accepted nodes
2. **Data processing fixing of the 23 nodes without final clock synchronization**
3. Reload data and review QC reports of the 62 nodes that were rejected for other reasons
4. Retrieval of the trawled nodes

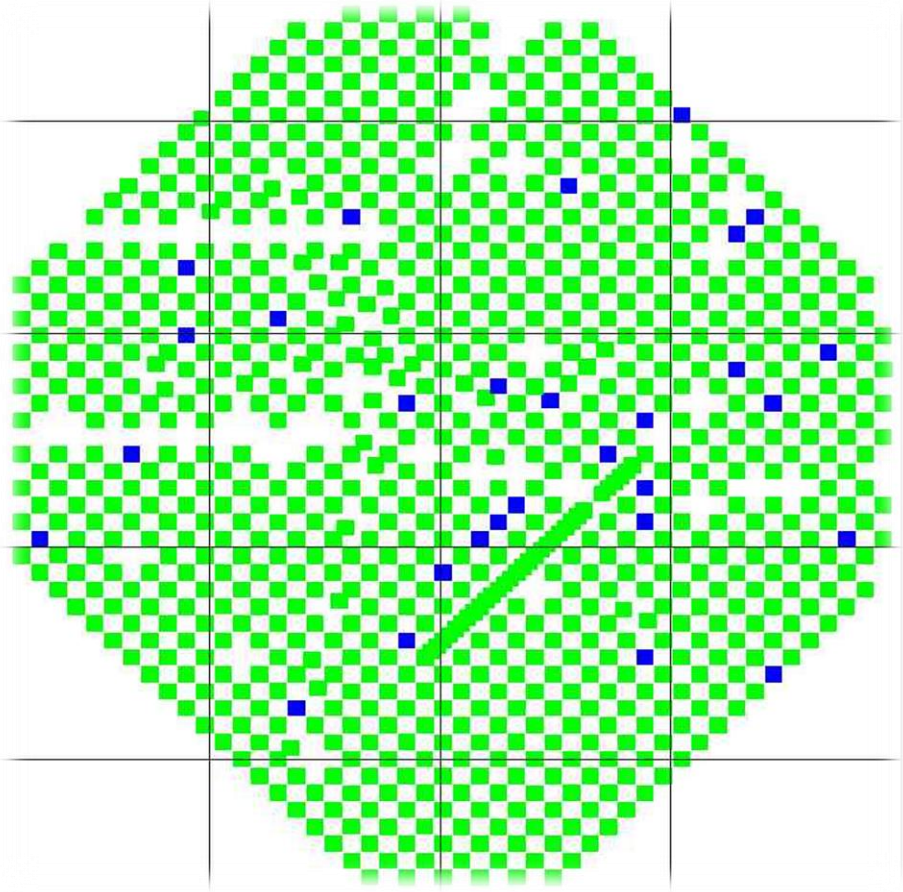


Clock synchronization in processing

- Previous experience was with deep water, where first breaks are direct arrivals
- The Dan field is in shallow water 45 m water depth

Actions:

1. Nevertheless use direct arrivals which are not first breaks
2. Develop/Implement a method based on reflections
3. Not done: passive data



Method: time consistent residual statics

- (Land and) Node data always go though a process called surface consistent static shifts
  - Accounting mainly for velocity variations under the receivers (and the sources when applicable)
  - There are various methods to estimate statics
- We extended surface consistent to time and consistent statics
  - We chose two simple methods
  - There are other methods, more sophisticated, that may work better
  - We did not optimized the methods too much as time was limited
  - Data processing will get better results than this presentation shows
  - At this stage it is important to demonstrate that at lease one method works well enough for the client to accept the data without taking a risk that the damage from the clock sync failure is damaging

Time consistent statics

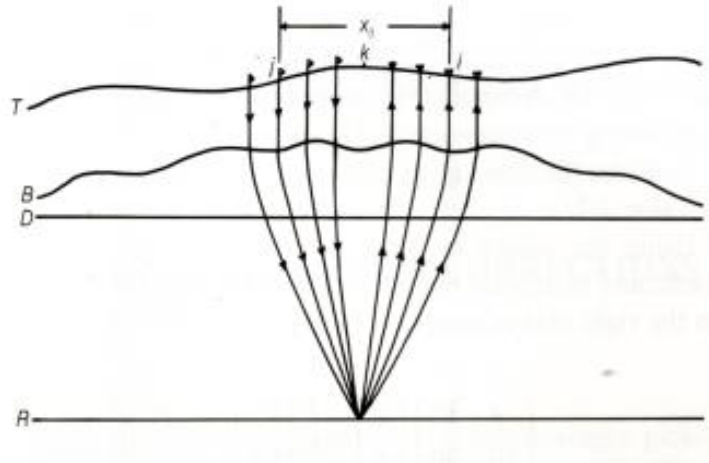


Figure 1. Surface-consistent statics model (after Yilmaz, 1987,p.201).

$$S_i + R_j + G_k + M_k X_{ij}^2 = T_{ij}$$

Surface consistent static shifts

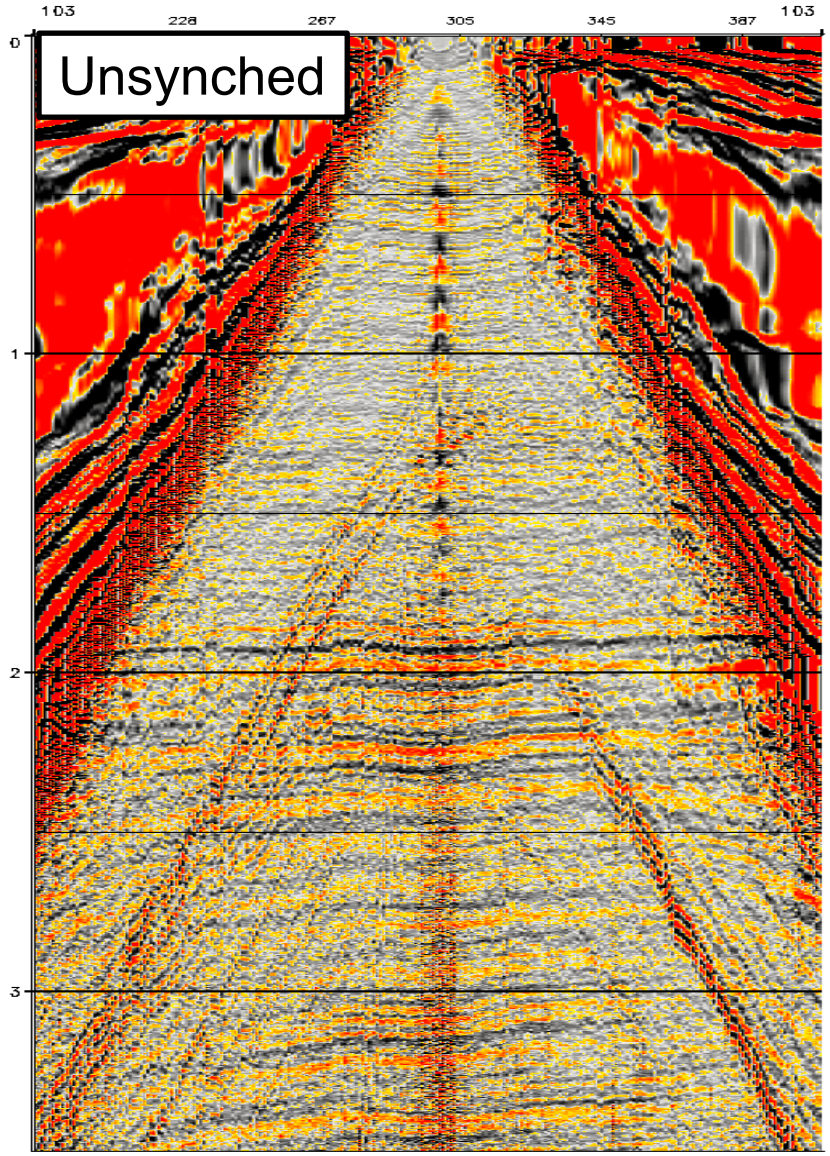
- Shot *i*, Receiver *j*,
- Image point k, Offset *Xij*
- *Tij* = static shift
- *G* = Geology
- *M* = Slowness^2 ($M^{-1}=V^2=VV$)

Time and Surface consistent static shifts

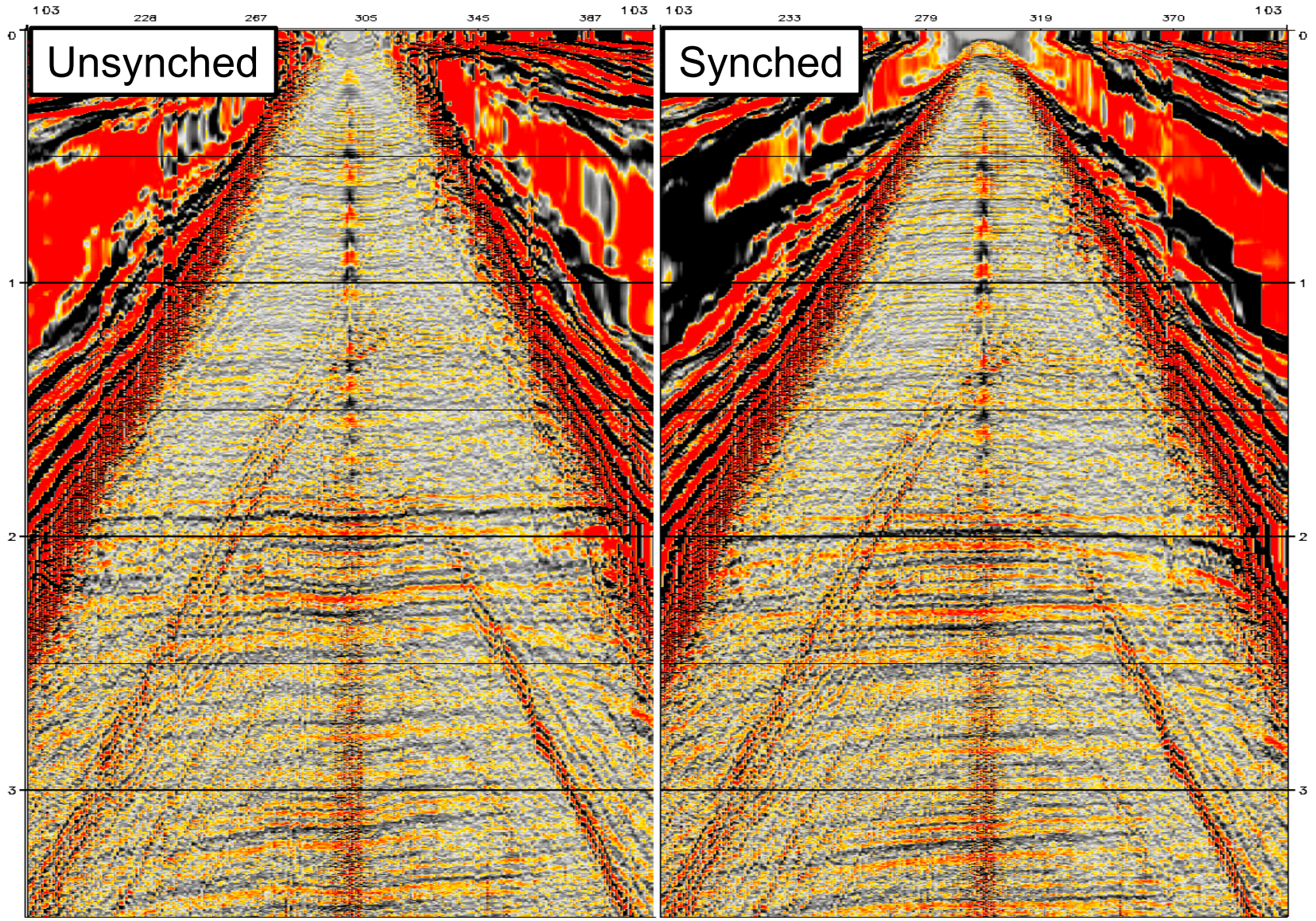
- The Receiver term becomes time dependent (linear or non linear)

$$S_i + R_j(Time) + G_k + M_k X_{ij}^2 = T_{ij}$$

Clock drift QC: cross line after NMO

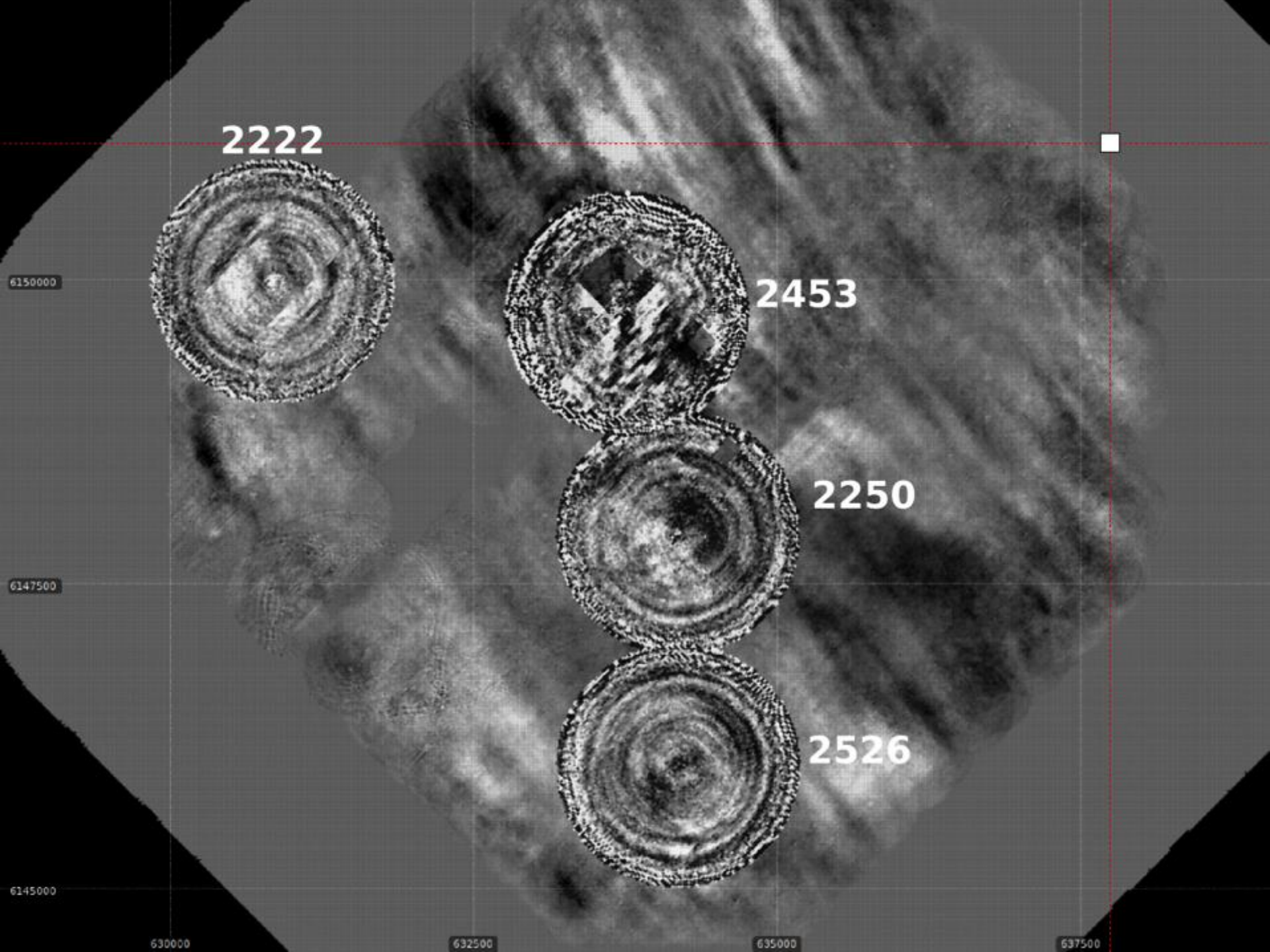


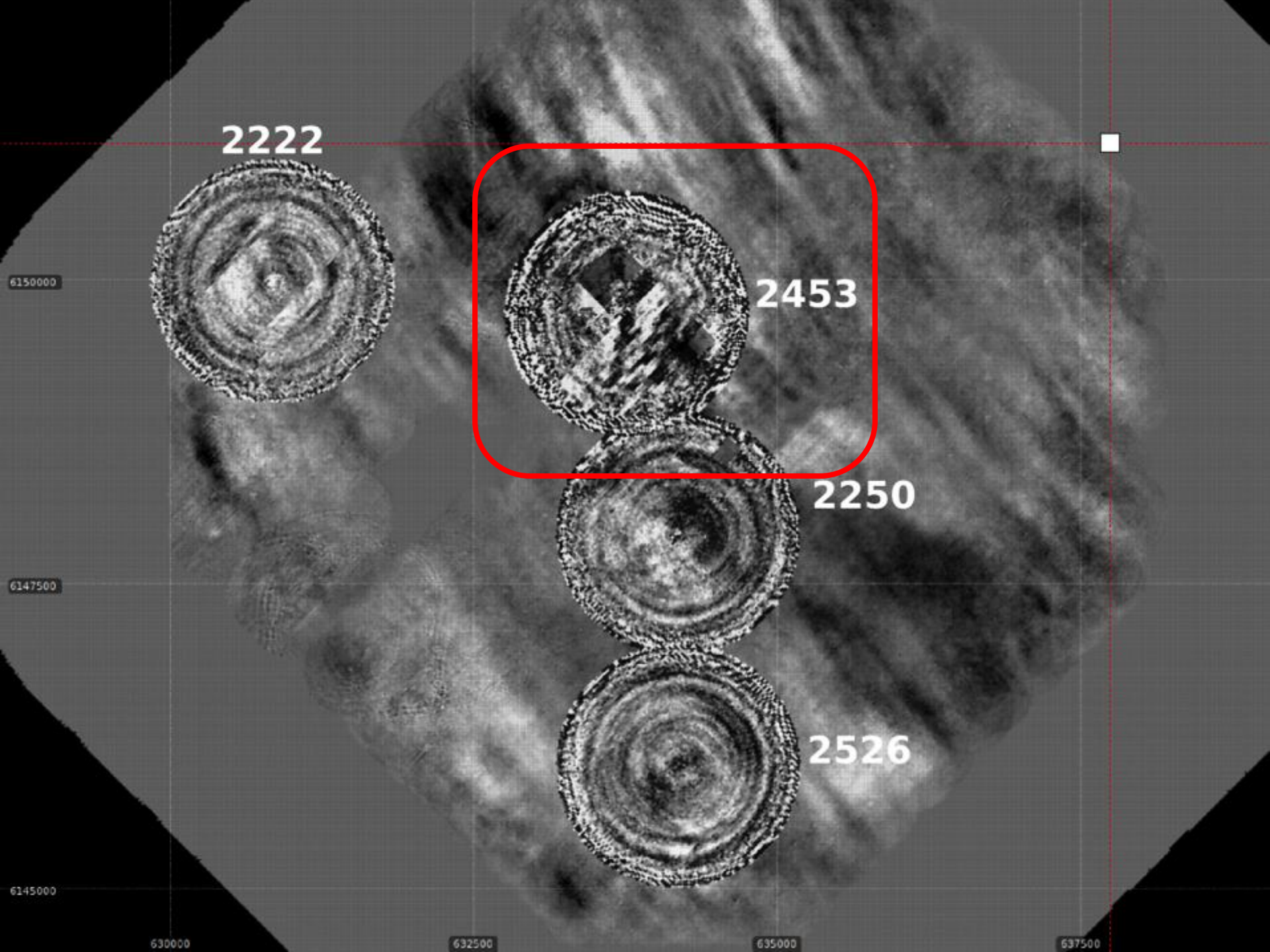
Clock drift QC: cross line after NMO



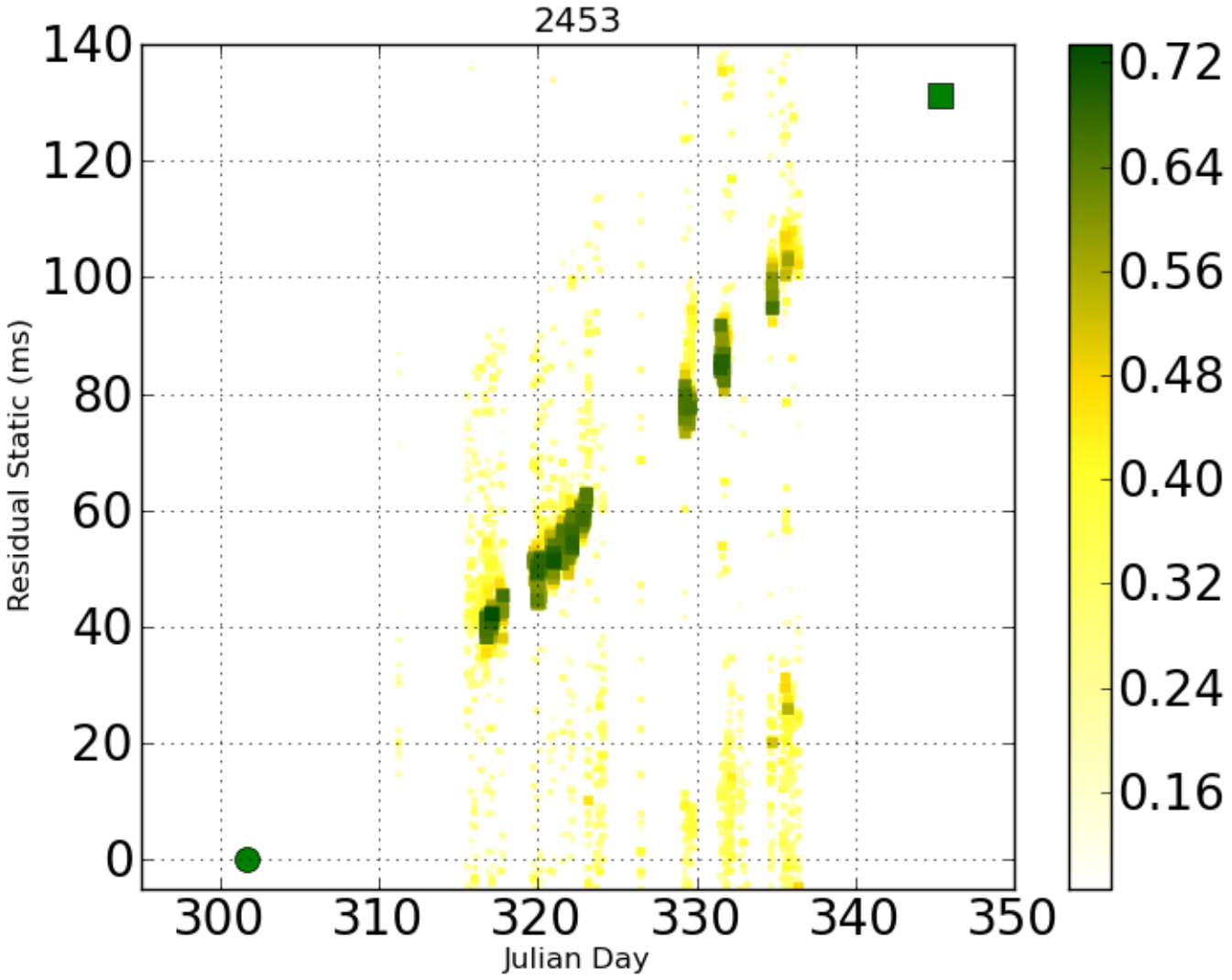
How do we know that the fix is perfect?

- To test the method we use control nodes
  - We selected a few good nodes with a variability of clock drift (positive/negative, small/large) to be control nodes
  - We generated a pilot: brute stack without the control nodes
  - We generated control nodes SEGY ignoring final sync (“Zero”)
  - We cross-correlated and picked pilot to “Zero”
  - We display the picked time shifts (milisecs) against time (days)
  - We calculate the skew ignoring the final sync
  - We regenerated SEGY with the “Calculated” skew
  - We QC all versions of the the control nodes SEGY data
    1. Original (“Retrieved”) used only in the QC
    2. “Zero”
    3. “Calculated”

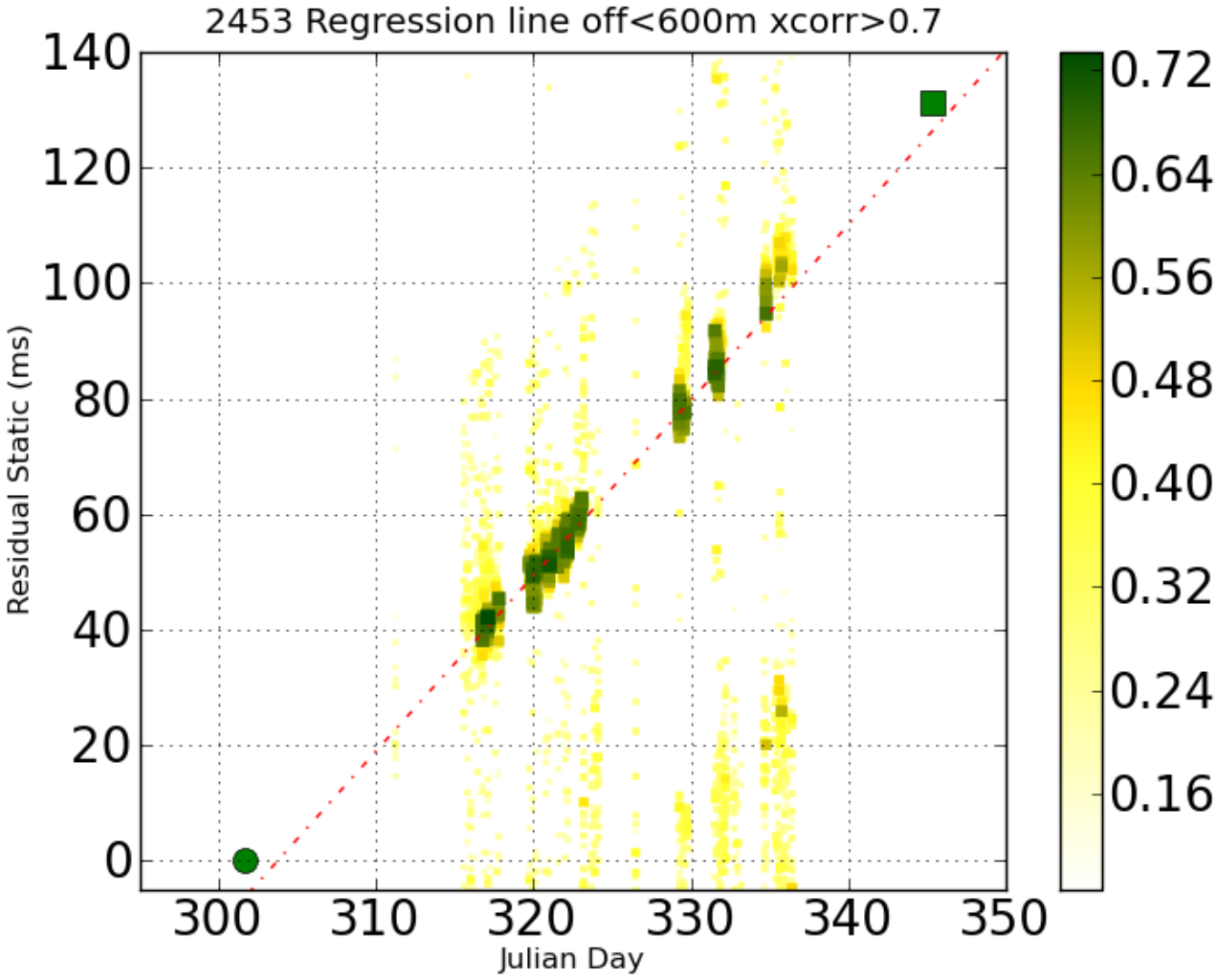

2222
2453
2250
2526
6150000
6147500
6145000
630000
632500
635000
637500

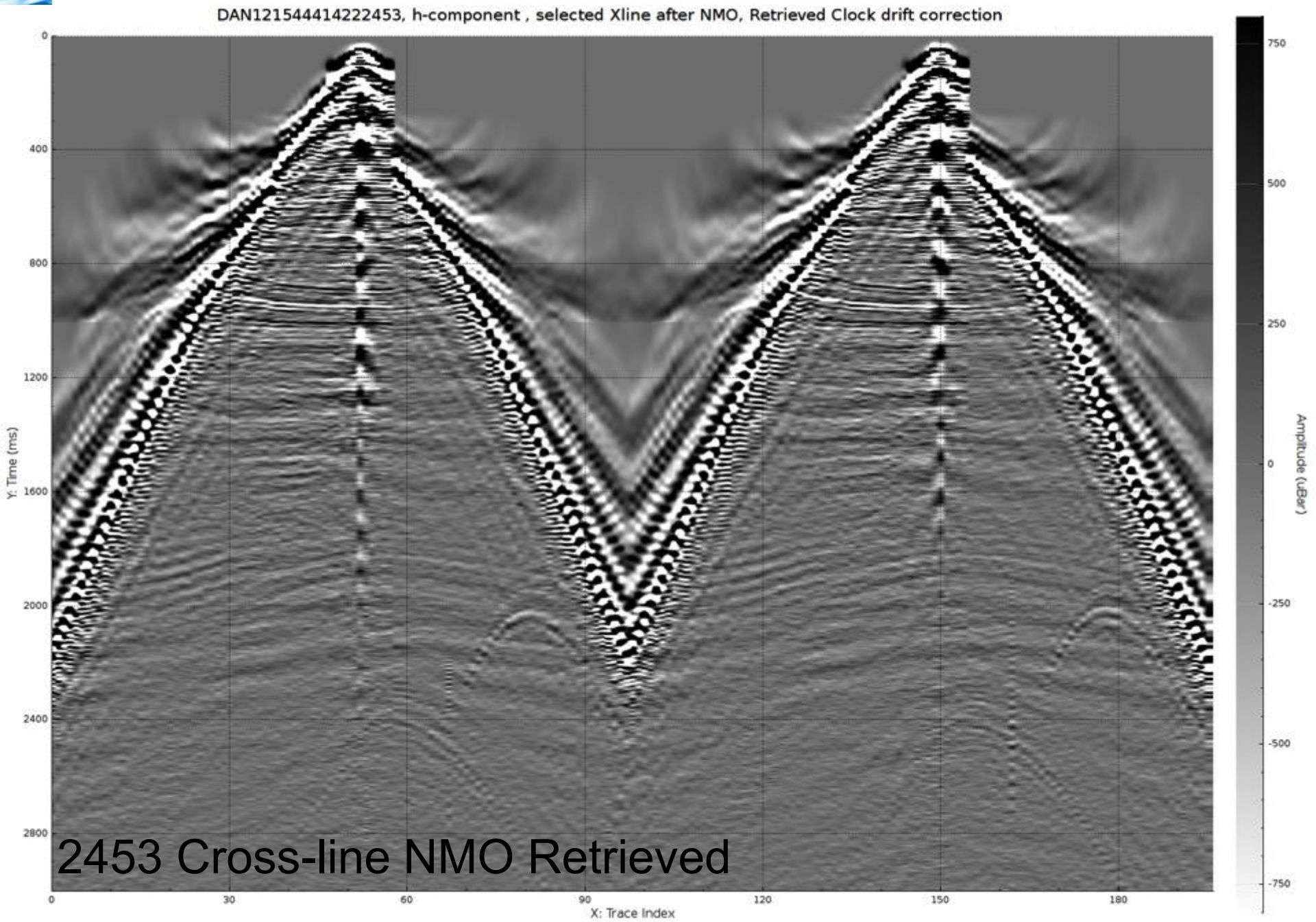

2222
2453
2250
2526
6150000
6147500
6145000
630000
632500
635000
637500

2453 clock drift cross plot (large positive)

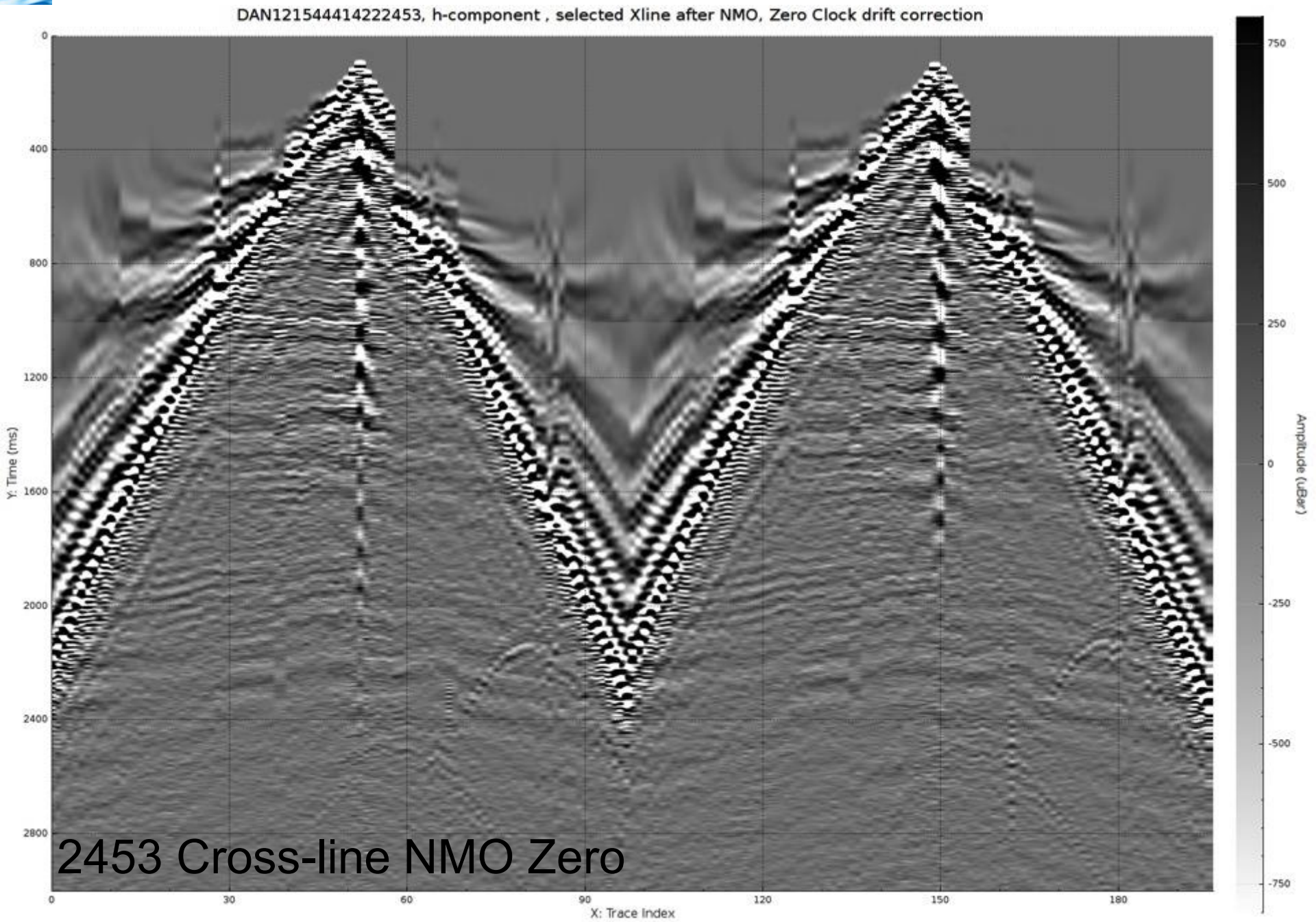


2453 clock drift cross plot (large positive)

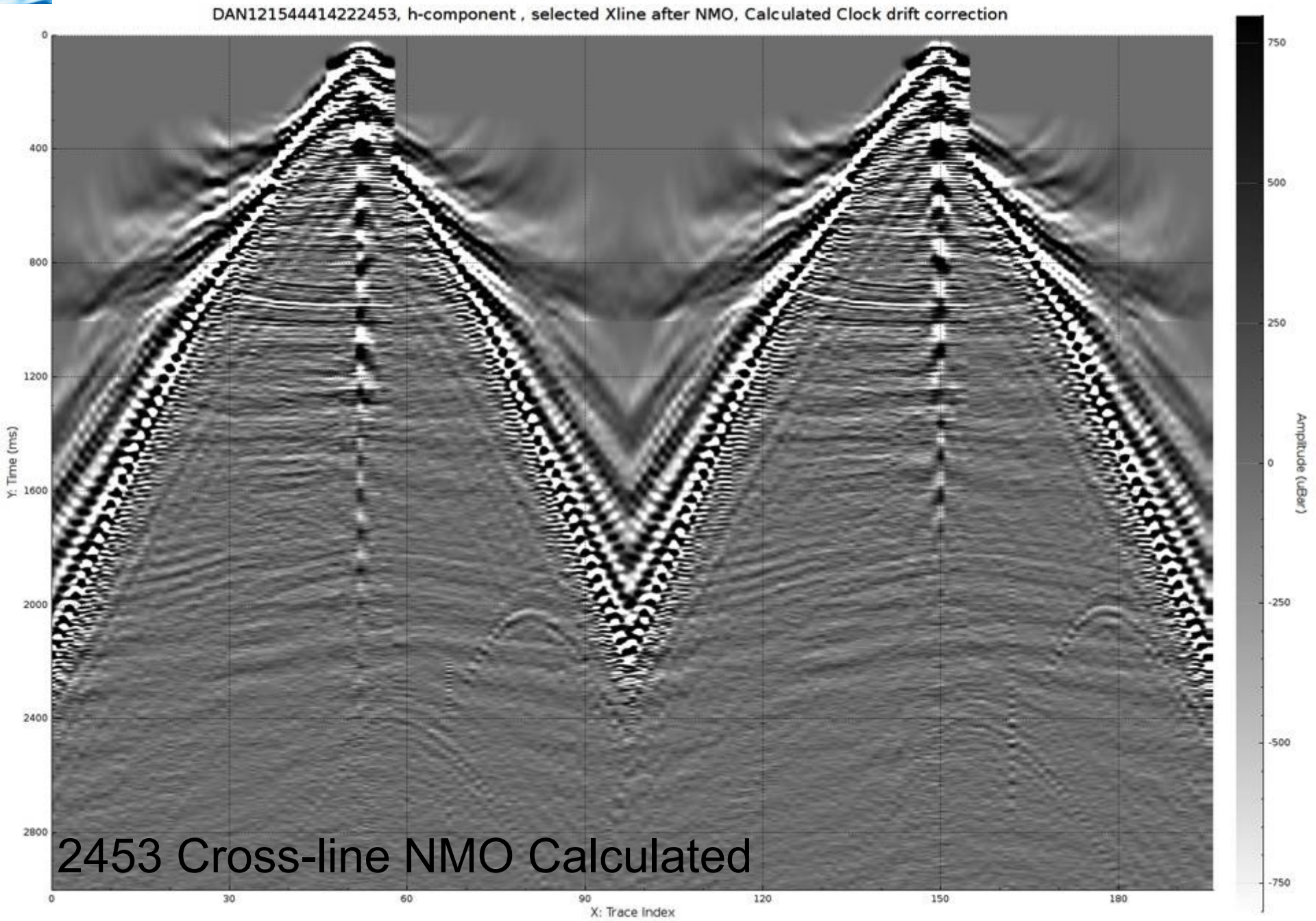




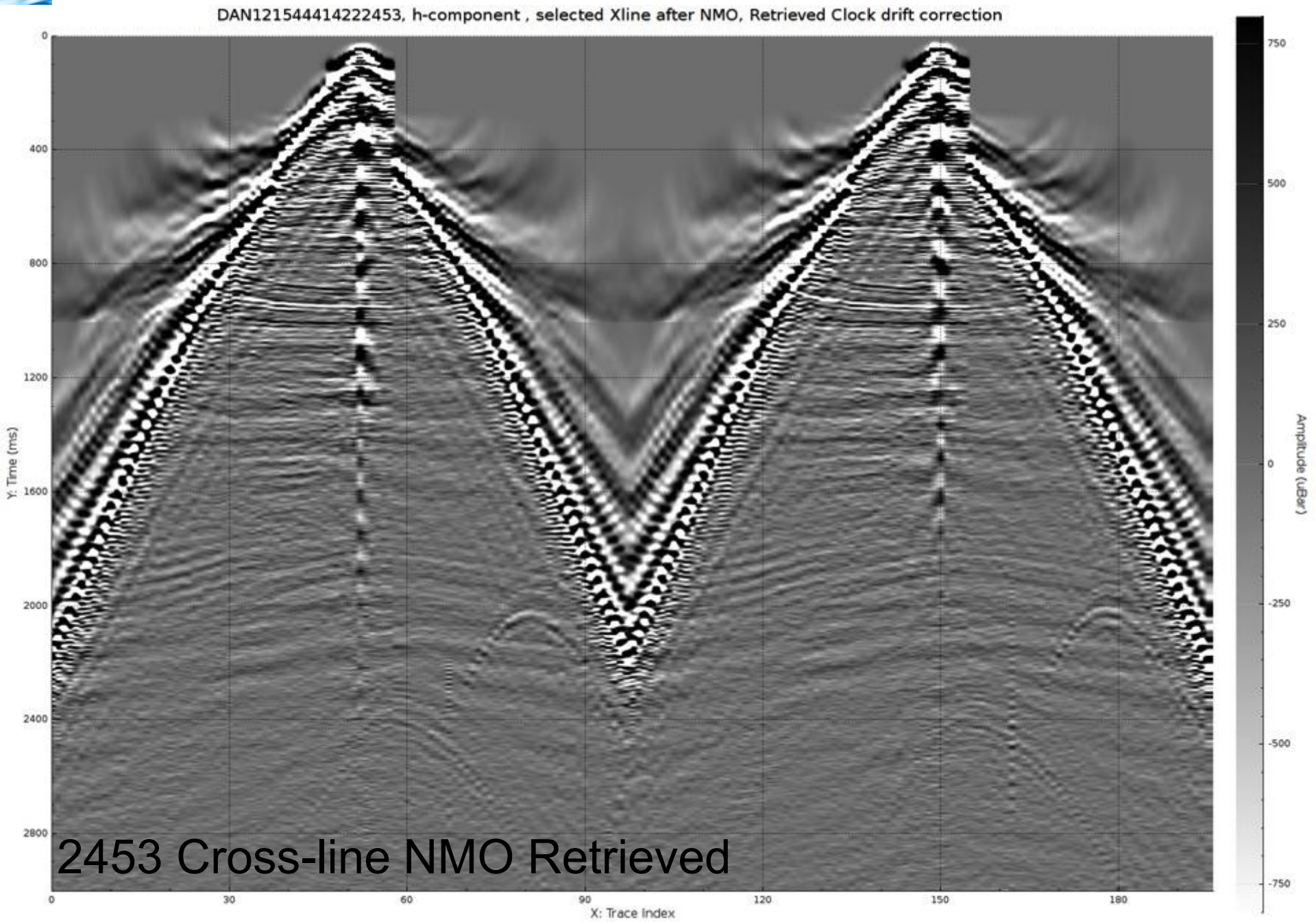
2453 Cross-line NMO Retrieved



2453 Cross-line NMO Zero



2453 Cross-line NMO Calculated



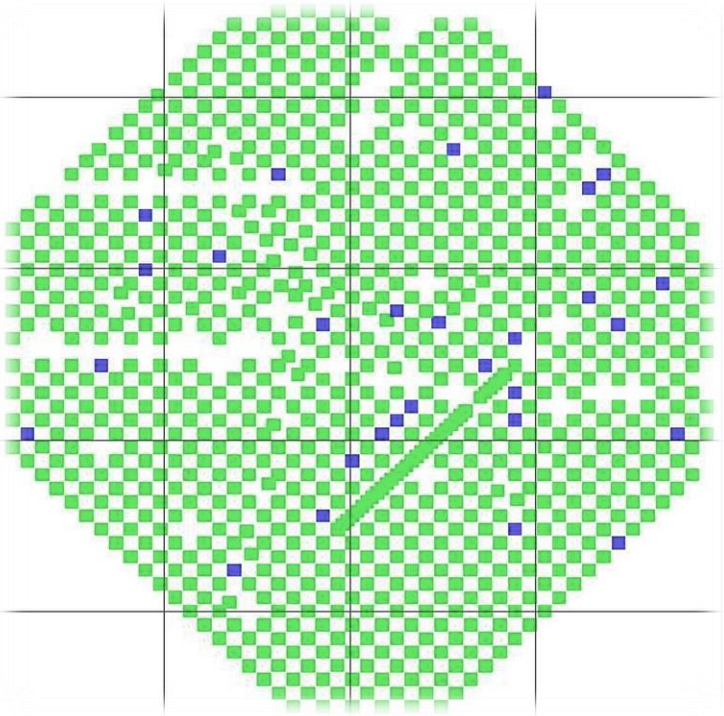
2453 Cross-line NMO Retrieved

Clock synchronization in processing summery

- 12.5% failure rate

Actions:

1. Fast track processing of the 840 accepted nodes
2. **Data processing fixing of the 23 nodes without final clock synchronization**
3. Reload data and review QC reports of the 62 nodes that were rejected for other reasons
4. Retrieval of the trawled nodes



➢ **Out of the 23 nodes without final synchronization, 21 were acceptable with data processing synchronization**

Miscellaneous processing fixes summery

- 12.5% failure rate

Actions:

1. Fast track processing of the 840 accepted nodes
2. Data processing fixing of the 23 nodes without final clock synchronization
3. **Reload data and review QC reports of the 62 nodes that were rejected for other reasons**
4. Retrieval of the trawled nodes

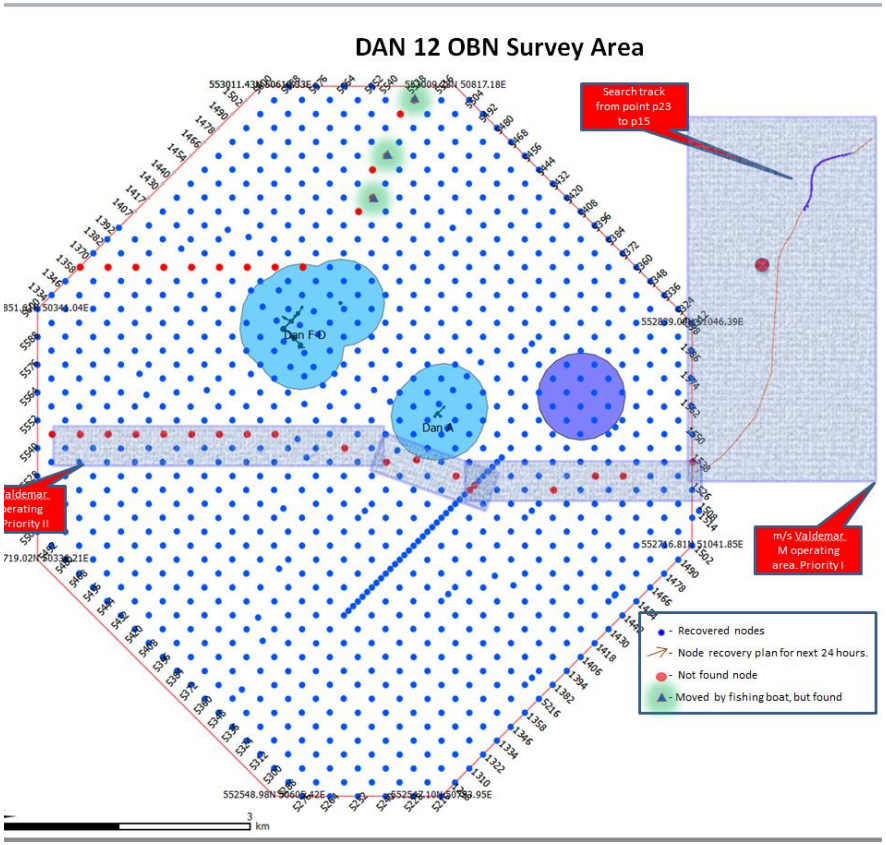
- **Out of the 62 nodes that were rejected for other reasons, only 16 were left unacceptable after data reloading and review of the rejections.**
- **Mostly over zealous QC by the processing center**
- **Onshore support, pulling the nodes apart, succeeded to load data from 11 nodes that the crew failed to load normally onboard**

Fast track processing summery

- 12.5% failure rate

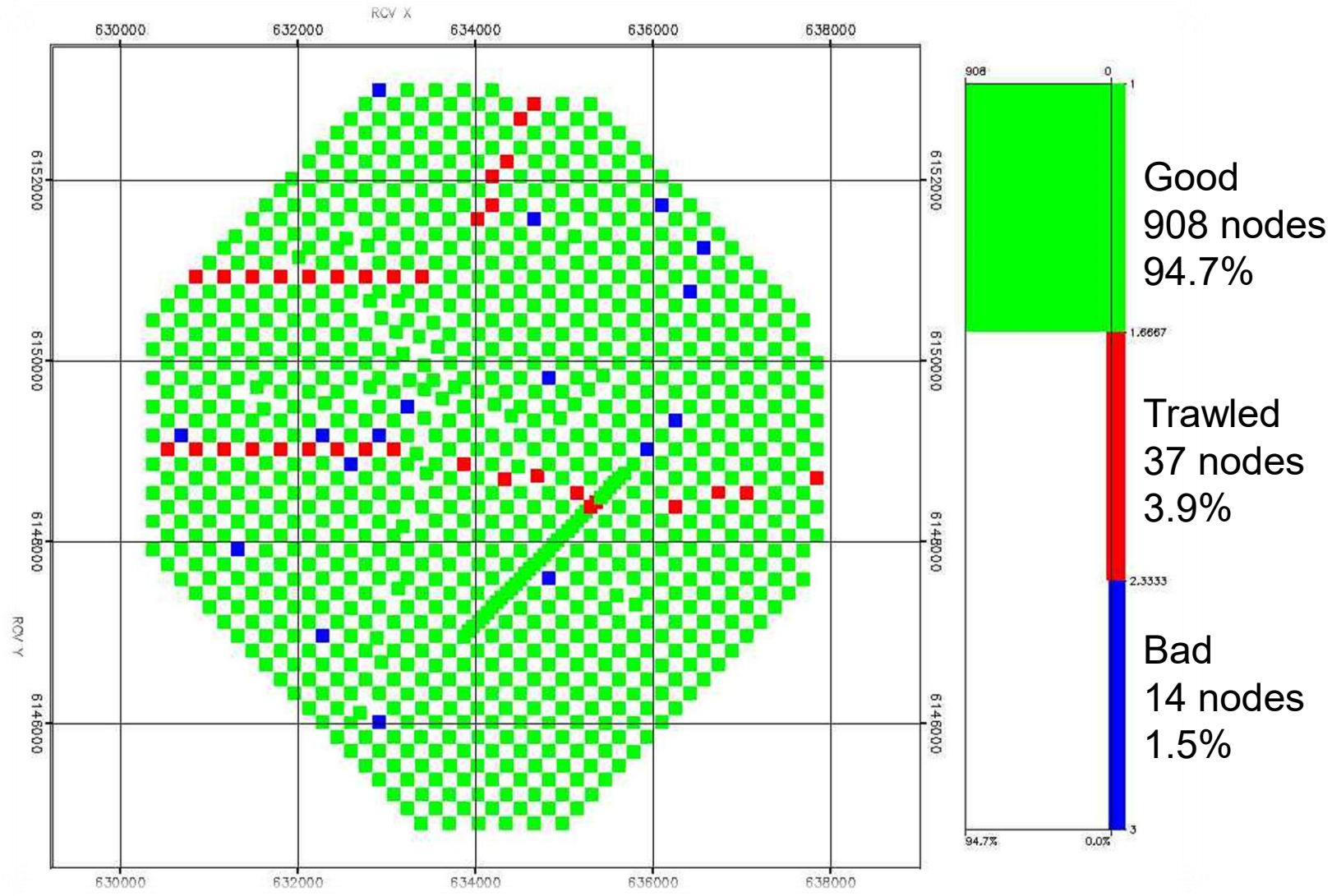
Actions:

1. Fast track processing of the 840 accepted nodes
2. Data processing fixing of the 23 nodes without final clock synchronization
3. Reload data and review QC reports of the 62 nodes that were rejected for other reasons
4. **Retrieval of the trawled nodes**



➢ **The crew and the trawler found 31 nodes out of 34 lost (bounty system with the trawler)**

Final node acceptance map



Final node acceptance

- 959 nodes total
- 908 accepted (94.7%) ← More than enough
  - 21 without field final synchronization were accepted with data processing synchronization
- 14 failed (1.5%) ← Seabed Geosolutions' fault < 2%
  - 6 memory (incomplete data)
  - 5 sensor problems (failed/ noisy hydrophones/geophones)
  - 1 flooded
  - 2 clock synchronization not accepted after Nossing (less than 2% anyway)
- 37 Trawled (3.9%) ← SBGS' guard vessel was made redundant
  - 3 moved by the trawler
  - 31 recovered (paid the Dutch trawler €2000 per node)
  - Data recovered from 21 node, but the data were not used for imaging
  - 3 Trilobits were never found. They are still down there, if not retrawled.

Discussion and Summary

- 3D PP imaging is very resilient to node failures: fast track with 12.5% failure rate provided better imaging than streamer data
- Data processing fixed most of the 12.5% failure nodes
- Would 4D and PS be affected more than 3D PP?
  - Yes, but how significant?
- Lessons learned
  - Guard vessel quality (our rep onboard)
  - Fast track is important for worst case scenario
  - Fast data processing fixes are important

Epilog

- Maersk presented Dan Case History at the EAGE

Streamer to Node comparison

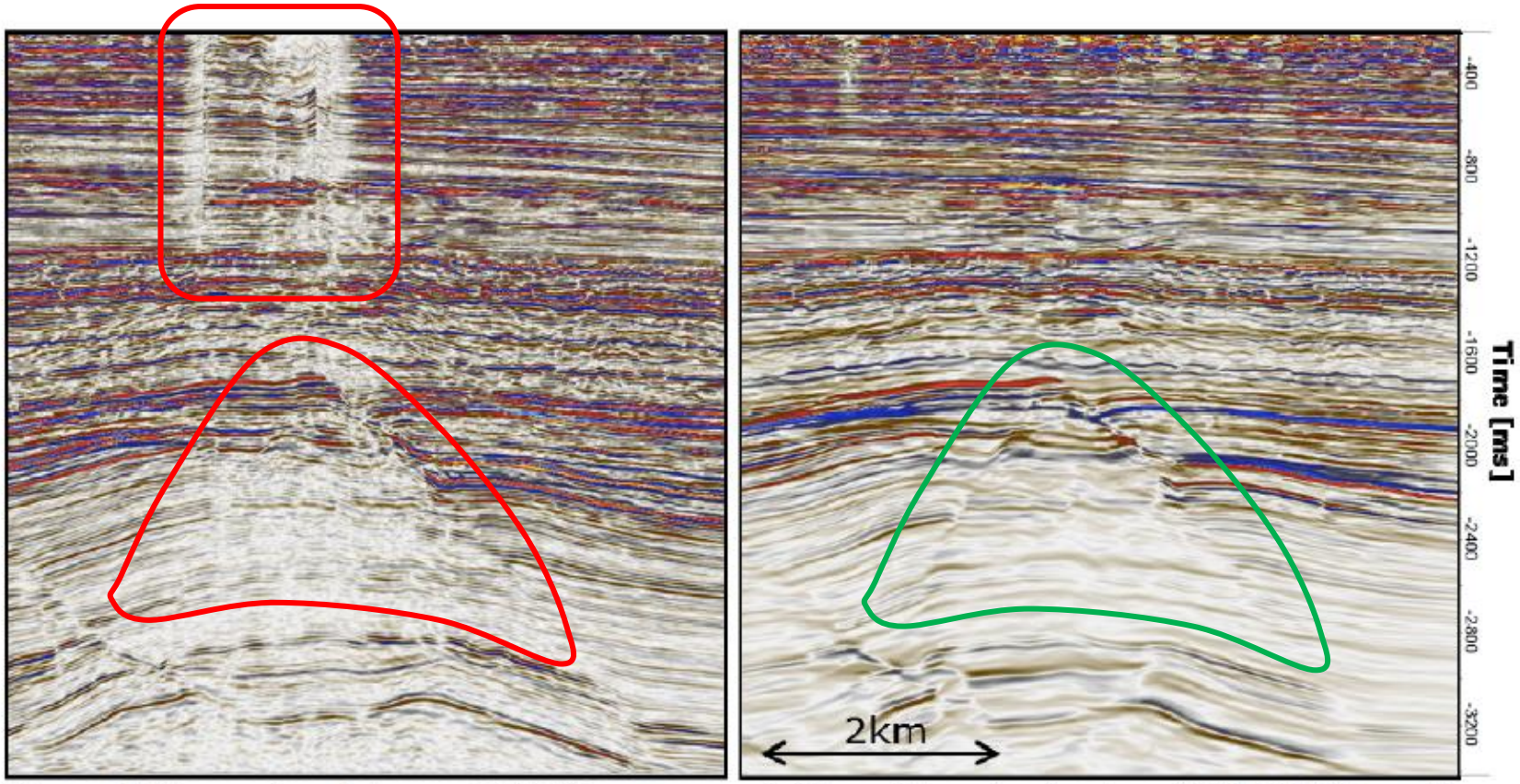


Figure 3 *Comparison between 2012 Streamer acquisition with undershoots and OBN RTM results along Line L2 shown in Figure 1. Left: Streamer, Right: OBN full frequency bandwidth. Faults and structure are better defined through the whole section. The OBN results show a wider frequency bandwidth.*

Epilog

- Maersk presented Dan Case History at the EAGE
  - No SBGS co-authors (maybe CGG)
- No mentions of the clock synchs and the trawler
  - Everything hunkey-dory
- No mention of their refusal to okay leaving the area
  - 31/12/2012 Maersk neither okayed nor demanded a reshoot
  - I think the lawyers were already in charge, and they knew they were at fault of the trawler. I know they thought we could not fix the clocks. Crawley had to send *Noss to Copenhagen to do it because the dedicated CGG processing center in Copenhagen said it could not be done (shallow water).
  - Maersk paid for the acquisition only after Noss proved (jury in mind) that the data processing synchs were perfect
  - No compensation to SBGS on the Trawler: time lost in retrieval, detective work including travel to den Helder, €2K / node bounty, and €10K / lost node
- Resolution end of 2013: Maersk wanted to present it at the EAGE
  - Survey done 31/12/2012 … lawyers 2013 ... Abstract Jan 2014

* Tony was available because his opposite rotation was kidnapped in Lagos. CGG processed Chevron Agbami monitoring data “in-country”.