Rapid, High-Resolution Imaging via Real-Time Processing-Driven Acquisition

Onshore Northern Caspian: Gran Field

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Introduction

Data processing & acquisition in parallel, rapid delivery & optimised acquisition parameters

- Overlap ***acquisition*** and ***processing*** stage to enable real-time field verification and allow dynamic survey adaptation.
- Apply processing solutions to further mitigate field modifications.
- Compress project timelines by delivering processed datasets almost concurrently with raw field records at survey completion.
- Provide robust, immediate datasets ready for velocity modeling, structural interpretation, and scoping subsequent full-integrity sequences

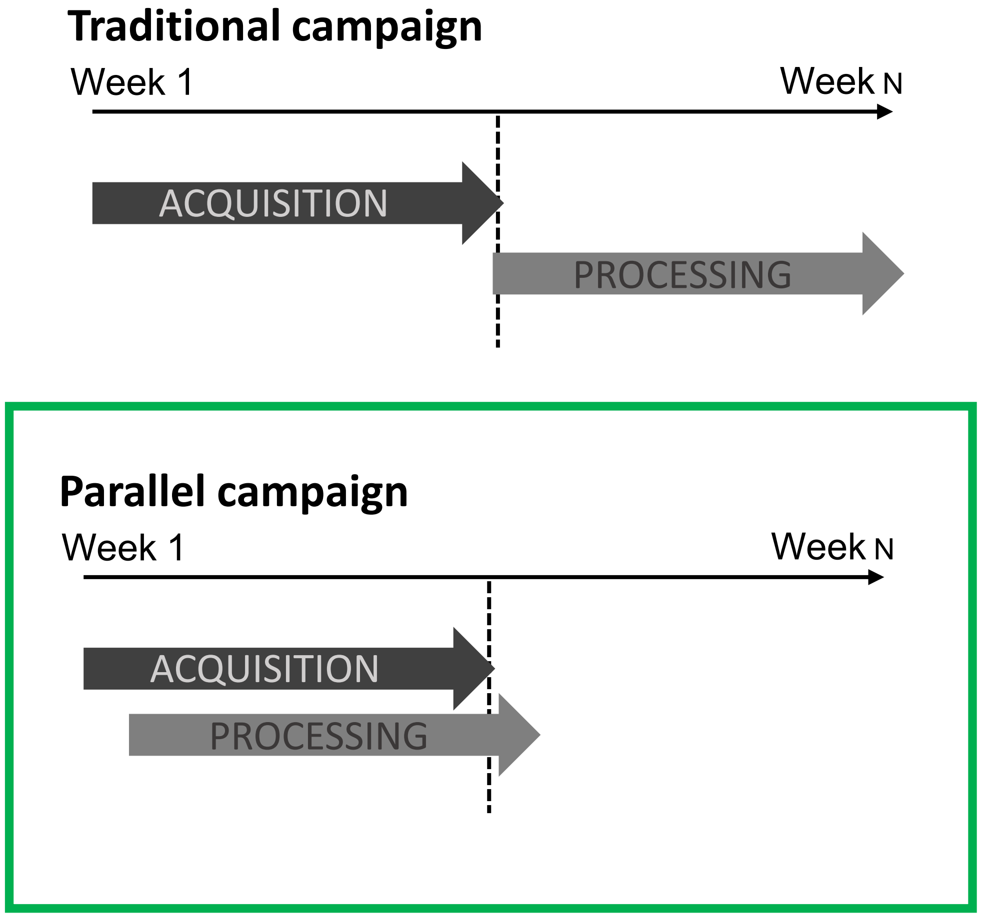

Figure 1: Visual of timeline for seismic field operations & processing, with and without compressed timeline

Background

A mature brownfield lacking modern seismic

- Located in the Atyrau/Emba province (first oil 1899), Gran Field was formally licensed in the 1990s.
- The field is a mature, post-peak brownfield with extensive existing exploration and production wells.
- Current operator initiatives to focus on maximising recovery factor of remaining reserves.
- Significant structural uncertainty remains around complex suprasalt reservoir configurations & deeper geometric features; legacy seismic lacks spatial resolution required to image the former

Figure 2: Photograph on location at the gran field for seismic operations team, courtesy of Samga Group

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Gran Field: salt-controlled traps in the Pre-Caspian Basin

Atyrau region, northern Caspian coastal Kazakhstan

- Lower Permian Kungurian evaporite divides the section into subsalt and suprasalt domains
- More than one thousand salt domes generate a complex system of traps and structural compartments (Ulmishek, 2001)
- Key Target: Jurassic and Lower Cretaceous sandstones, sands and siltstones on the flanks and crests of salt structures

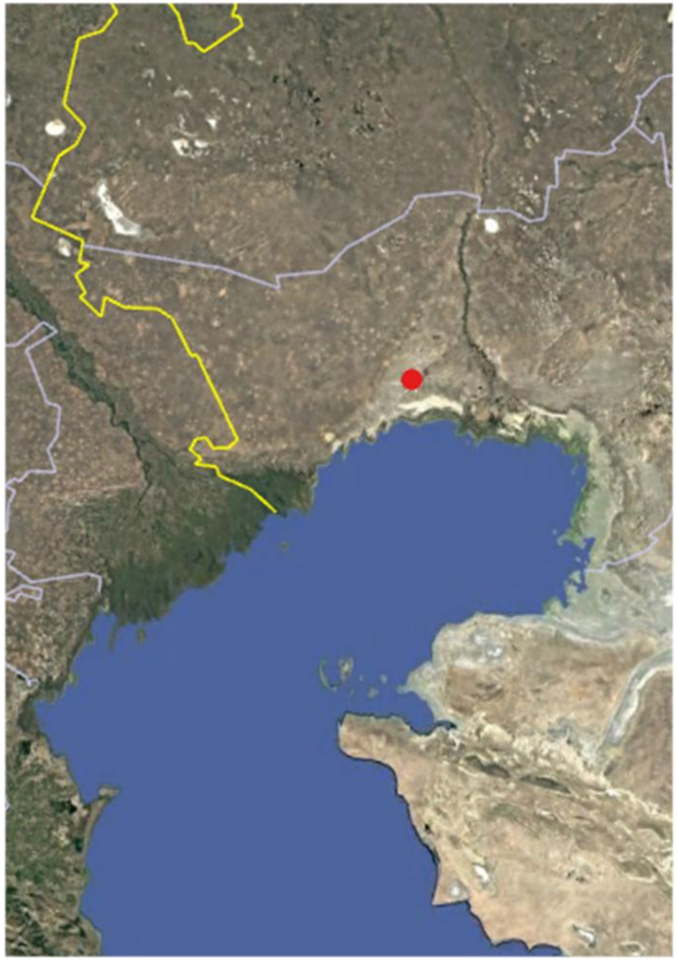

Figure 3: Satellite location map and zoom showing location and layout & size of the survey

The imaging challenge: shallow targets, complex structure

Atyrau region, northern Caspian coastal Kazakhstan

- Primary target lies in this shallower section <1 km depth; specifically, imaging of and around salt domes by flanks & crest.
- Secondary targets exist, but are much deeper, commanding a source with the energy to penetrate that with reasonable SNR.
- To achieve this, a small but focused high-density survey was carried out using 500kg weight drop (multiple drops).

200 – 850 m

Suprasalt reservoir interval

~4000 m

Deeper Palaeozoic potential

> 1000

Salt domes across the region

High-density nodal survey design

Dense spatial sampling for the shallow suprasalt interval

Survey size	5.7 × 2.5 km
Source type	500 kg weight drop (multi drops)
Receiver type	Wireless node (2 ms)
Source line	50 m
Source points	12.5 m
Receiver line	50 m
Receiver points	12.5 m
Binning	6.25 × 6.25 m
Traces	~400,000,000
Data size	1.2T

Figure 4: Acquisition parameters for the survey

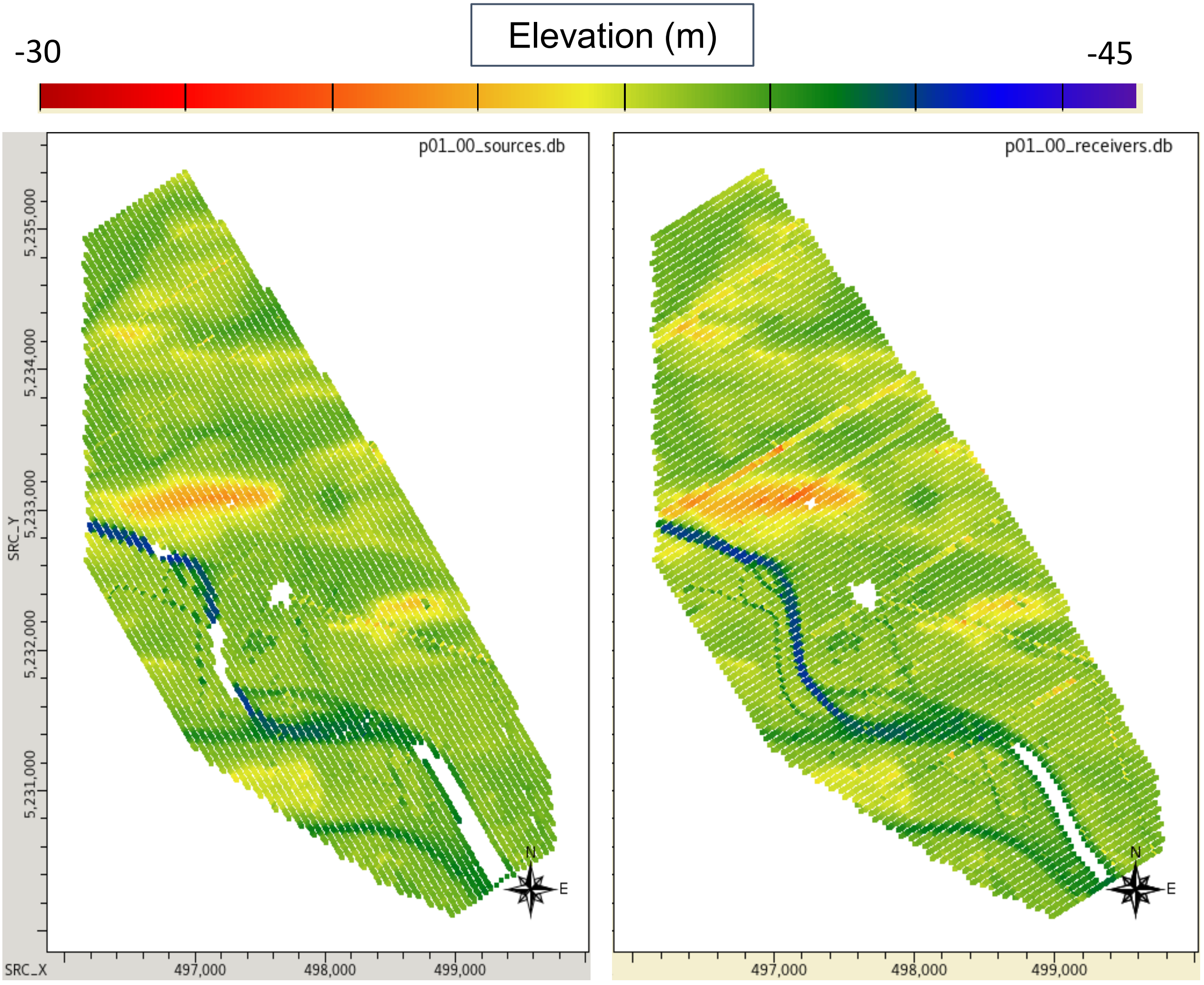

Figure 5: Source & Receiver maps from the field data

Processing on the edge

Acquisition hardware as a field processing asset

- The same hardware that harvests and reconstructs field data from continuous nodal records
- Deploy a processing environment on the edge, during idle or low-rate usage, the processing can be executed piece wise to fill gaps.
- Remotely accessible by the processing team located outside the country
- Provides ultra-fast turnaround imaging products and can be used as a feedback loop, to apply operational changes near real time.

1. **Acquire**
   Continuous nodal records, multiple stacked 500kg weight drops
2. **Harvest & process on site**
   Same hardware, idle capacity
3. **QC & adapt**
   Decisions while the crew is still in the field

Acquisition real-time decision: halving the source effort

Source testing — 12 drops per location, decimated and analysed for S/N

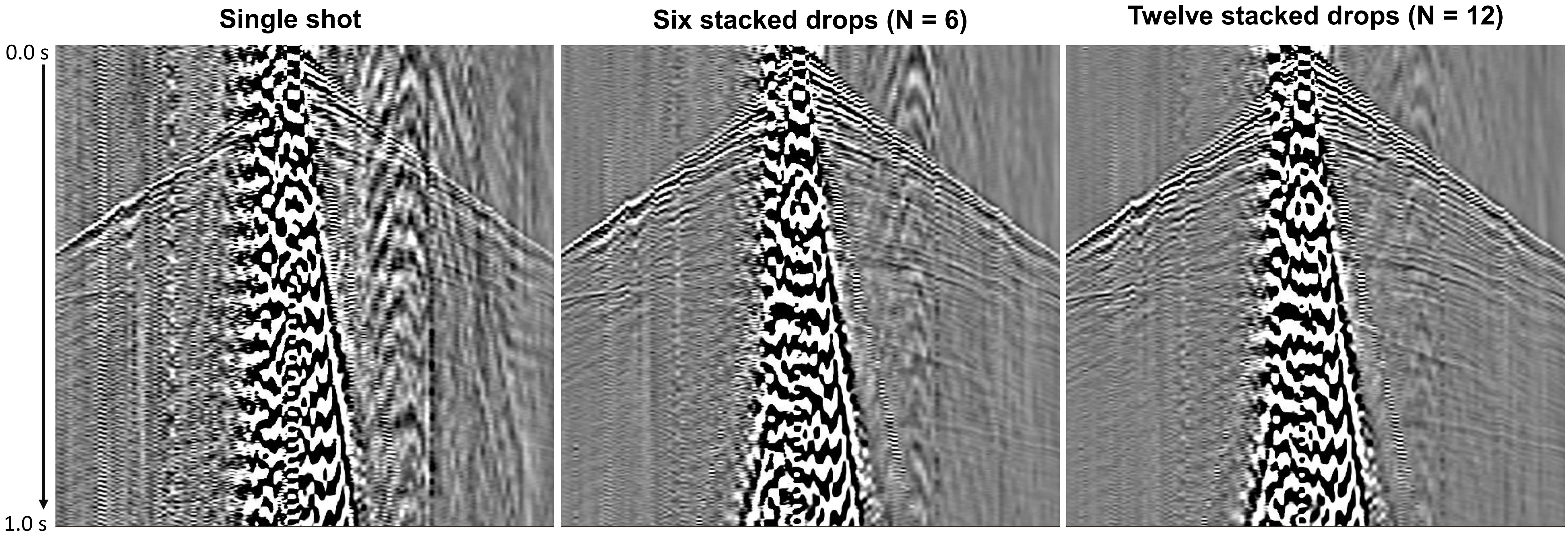

Figure 6: Stacked shot gathers showing N shots stacked together (1, 6, 12)

50% reduction in planned source effort, ~like-for-like data quality

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Processing real-time decision: "pop statics"

- To further enhance the shot data and provide some mitigation of the halving # shots - we can apply subtle shifts to data before summing.

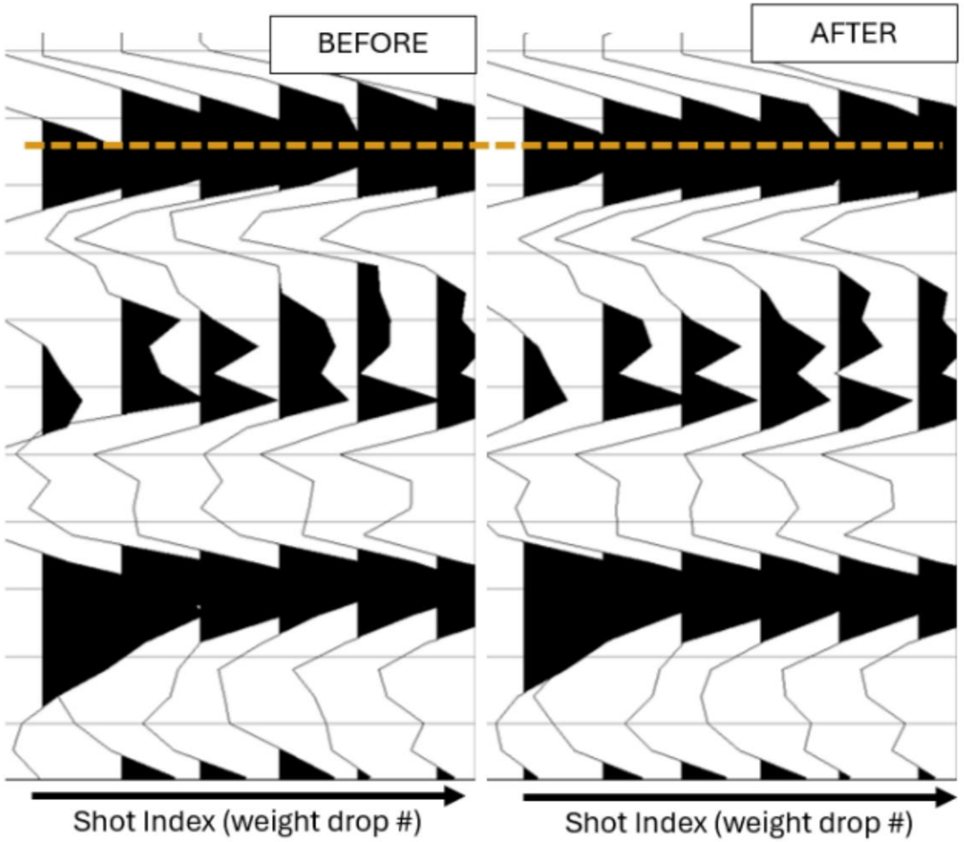

Figure 8: Example of data before & after pop statics correction to better align multiple shot gathers prior to stack

Figure 7: Photos from the field acquisition with example of softer ground conditions, courtesy of Samga Group

Advanced processing sequence, executed at the edge

1. Multiple passes of denoise
2. Refraction tomography
3. Residual statics
4. Pseudo-5D interpolation
5. Surface Consistent Deconvolution
6. Kirchhoff pre-stack time migration

Velocity analysis carried the emphasis.

Manual picking on regularised data, refined with 50 m auto-picks on pre-conditioned semblance gathers. Data were migrated with the process repeated several times to optimise imaging velocities which was felt essential given the structural complexity at target.

Advanced processing sequence, executed at the edge

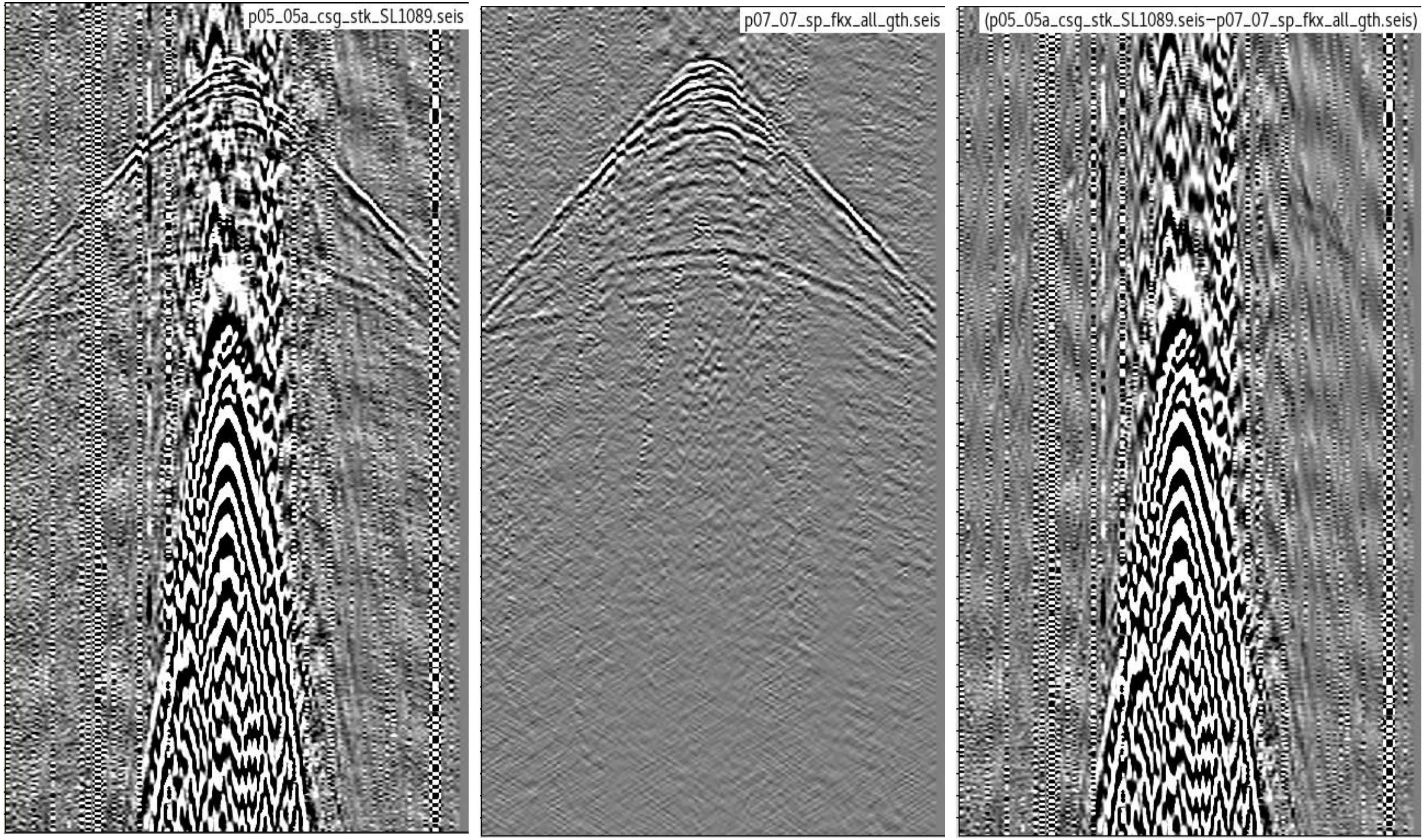

Figure 9: Shot gather example with and without denoise, including difference

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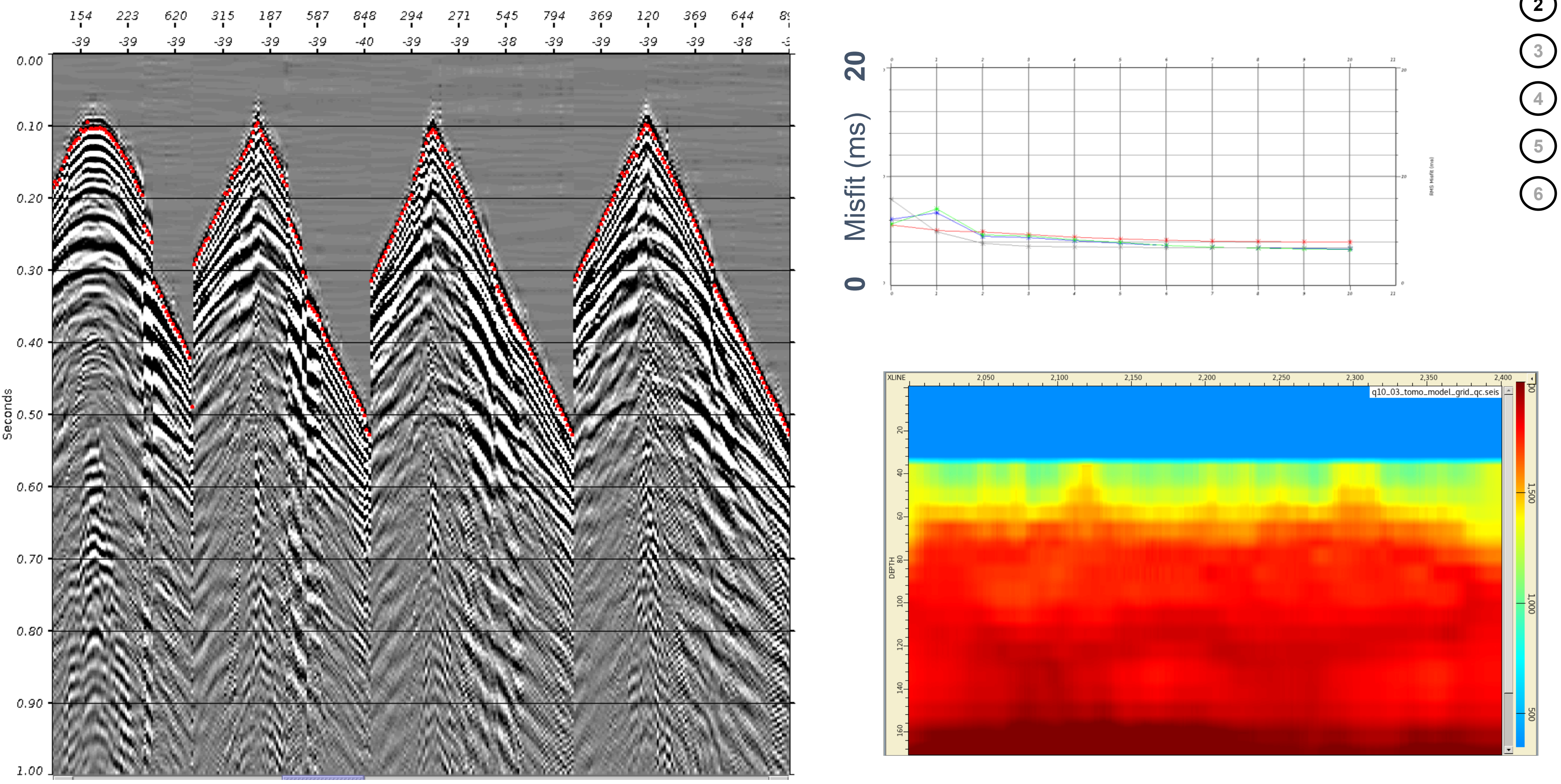

Figure 10: Snaps from tomographic static solution with first breaks on shots, RMS misfit after inversion & resulting near surface model

Advanced processing sequence, executed at the edge

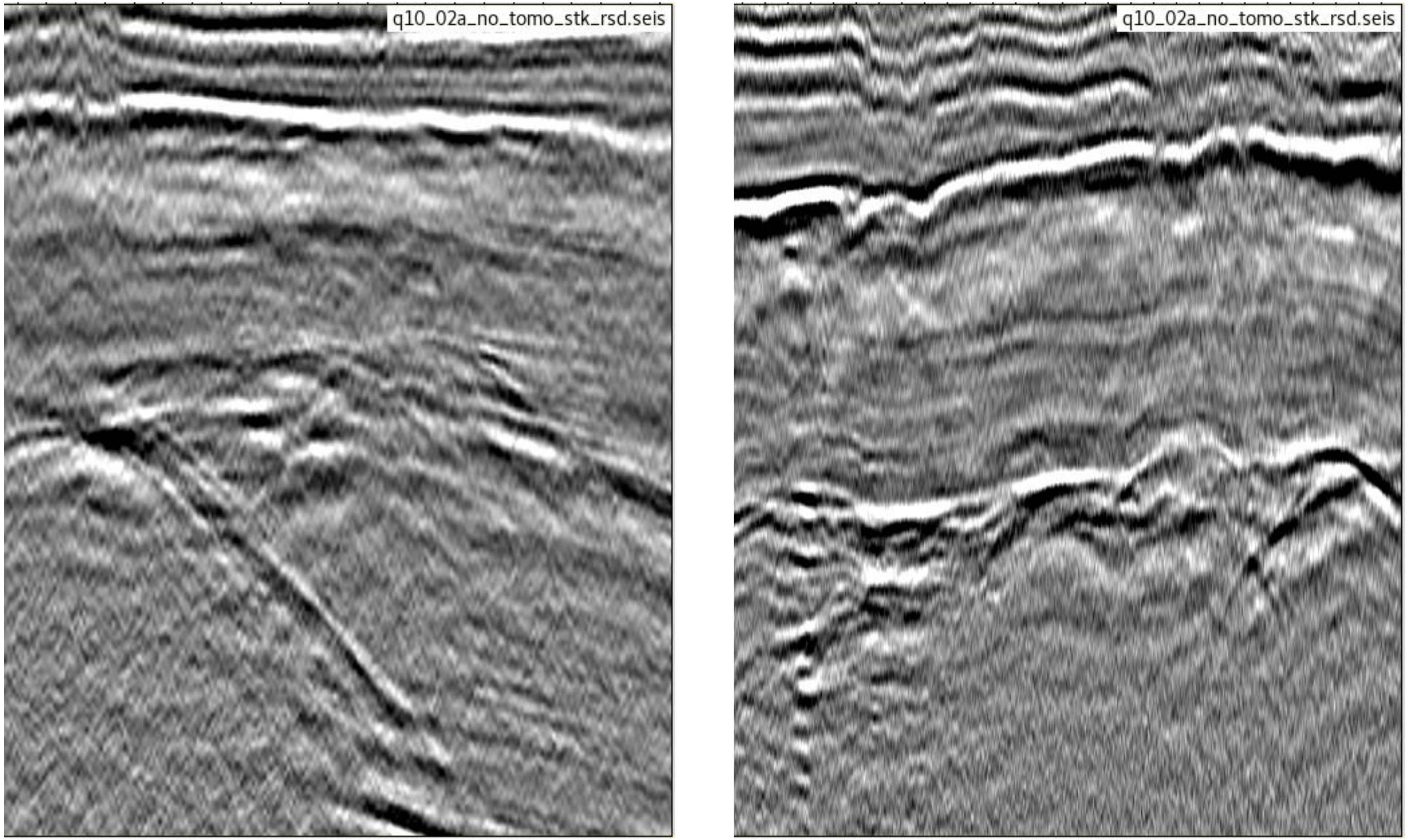

Figure 11: Stack examples before / after application of refraction statics & residual statics (compared with elevation)

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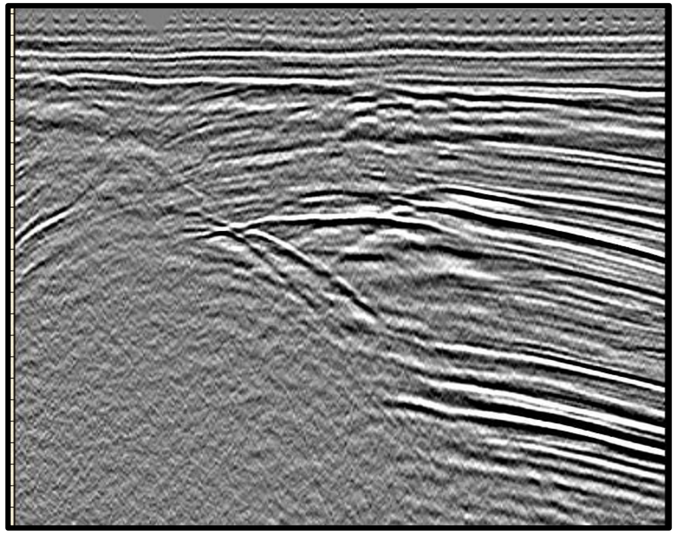
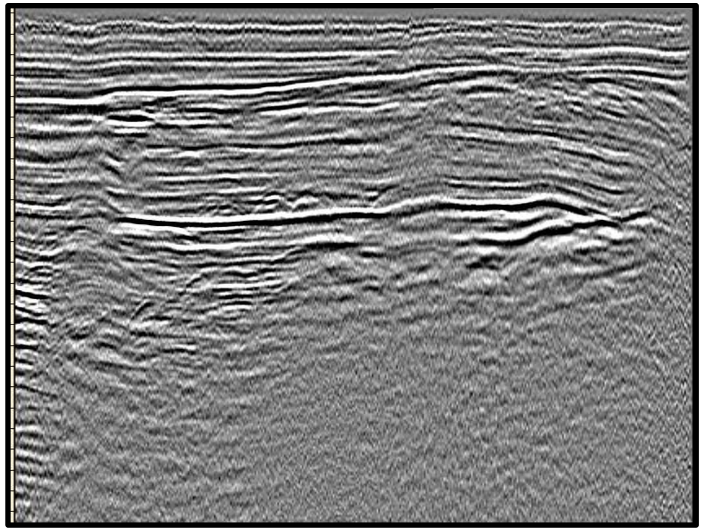
Pseudo-5D (3D interpolation by azimuth sector)





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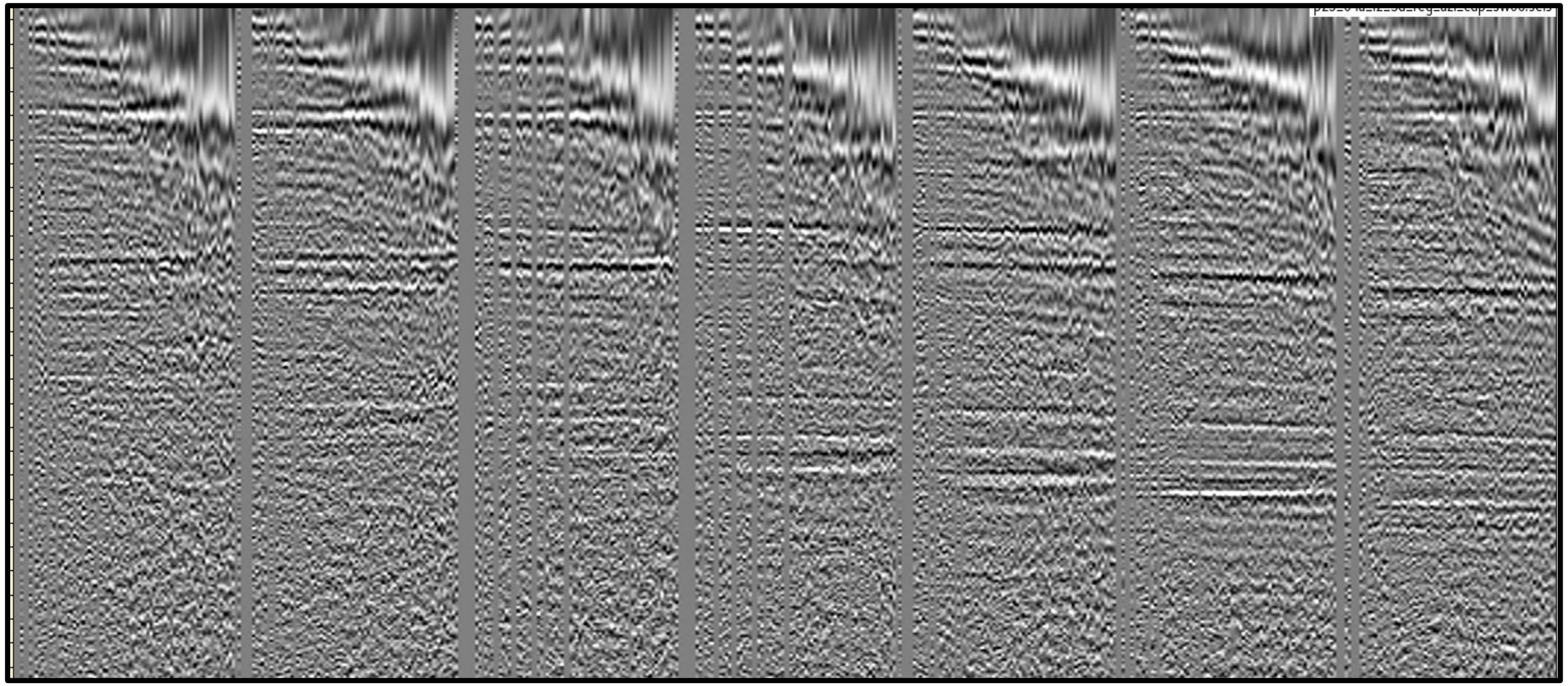

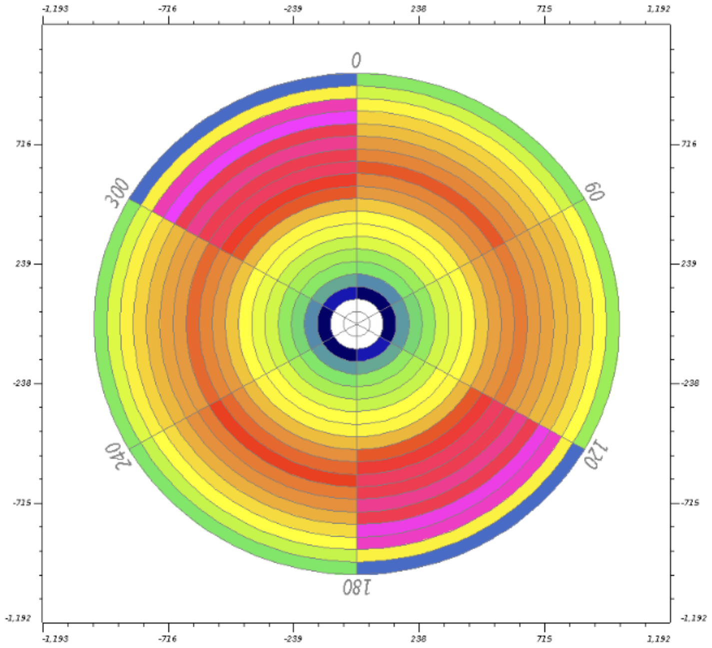

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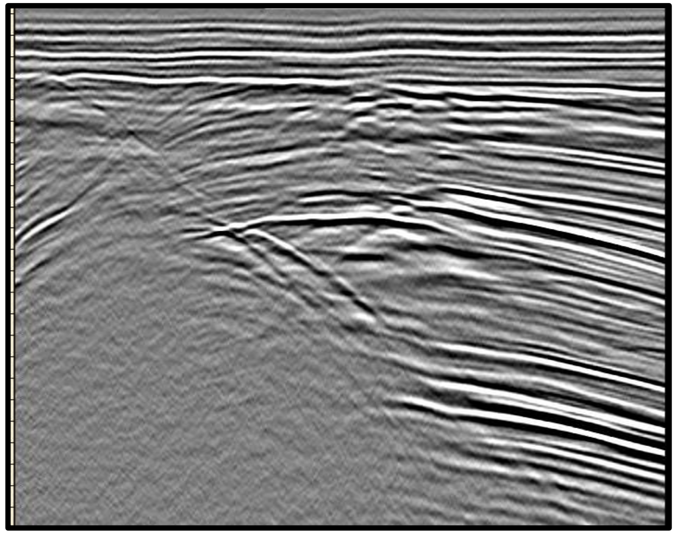

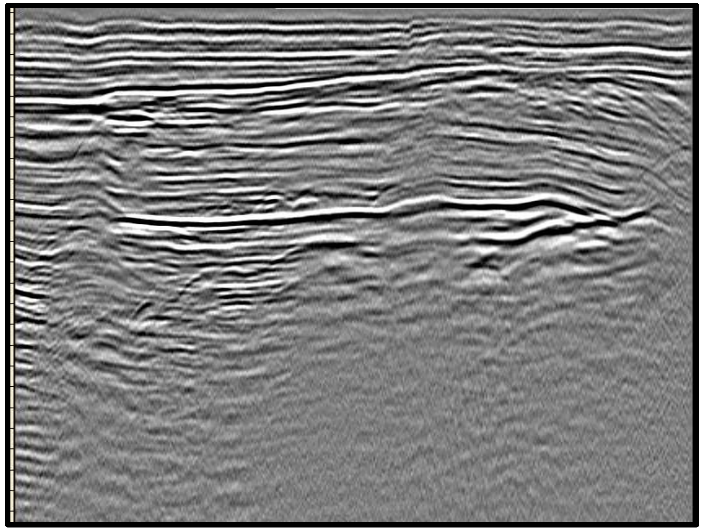

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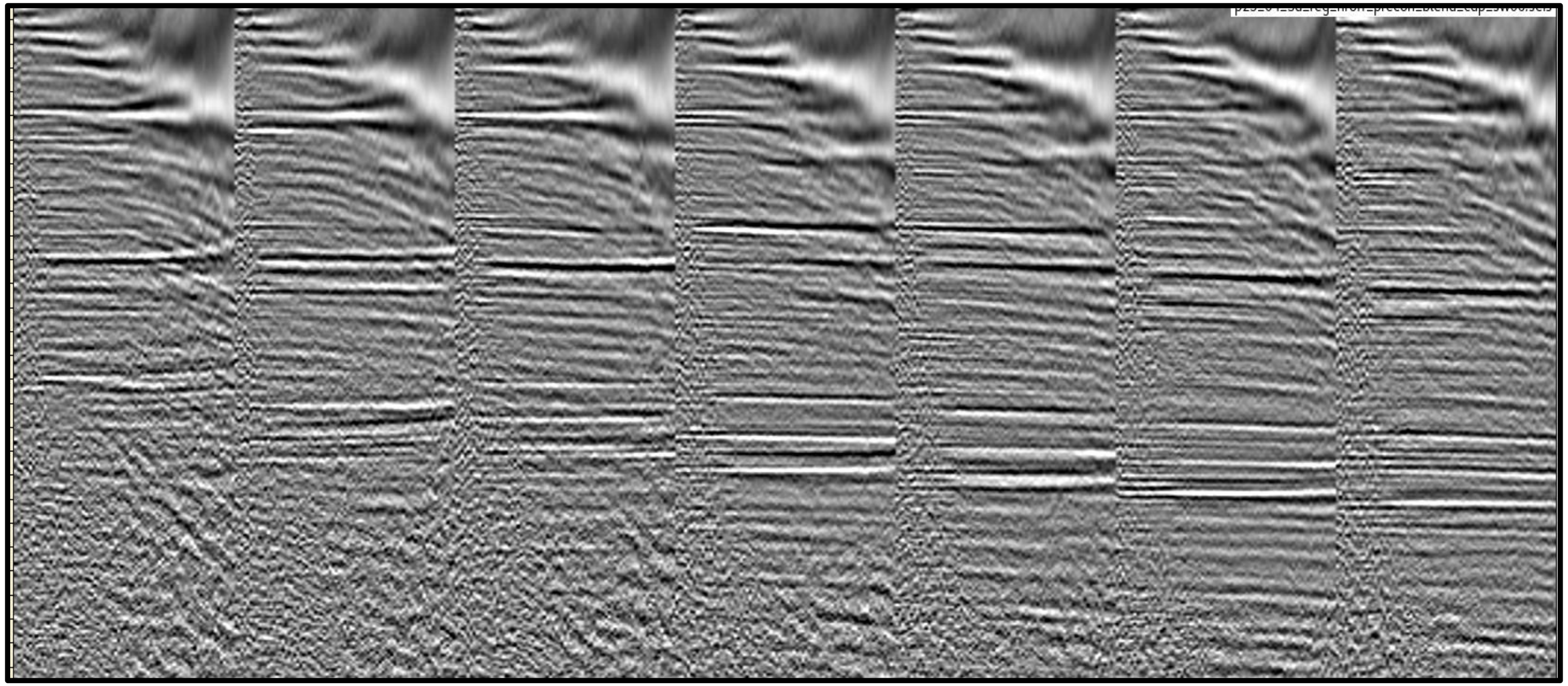
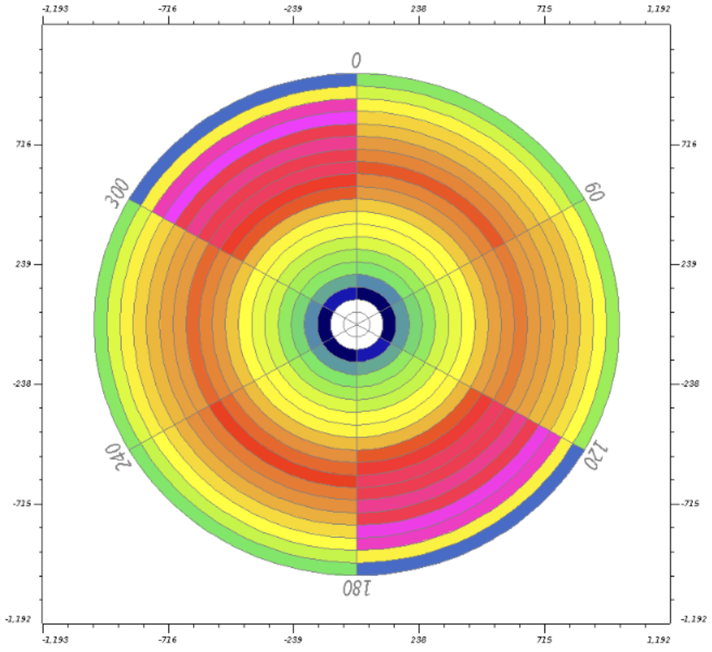
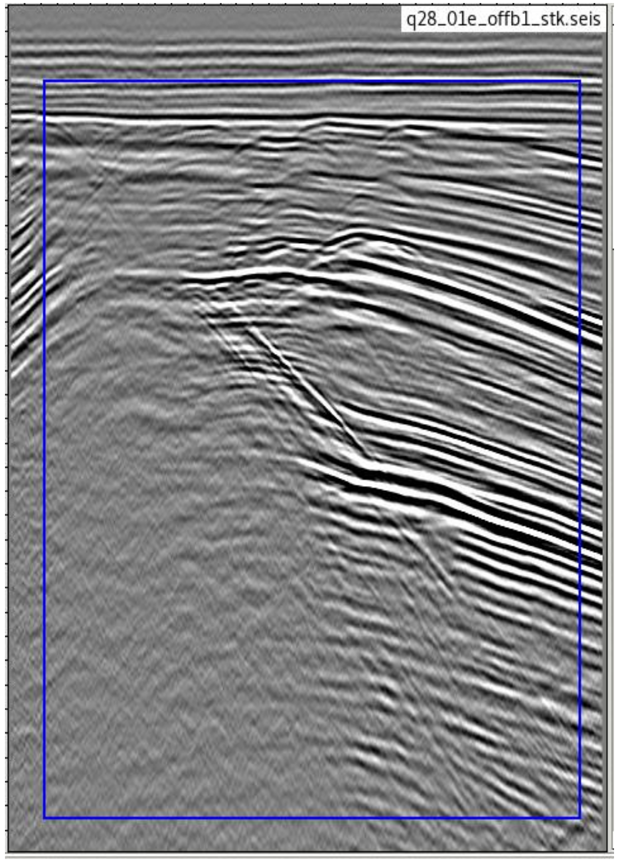
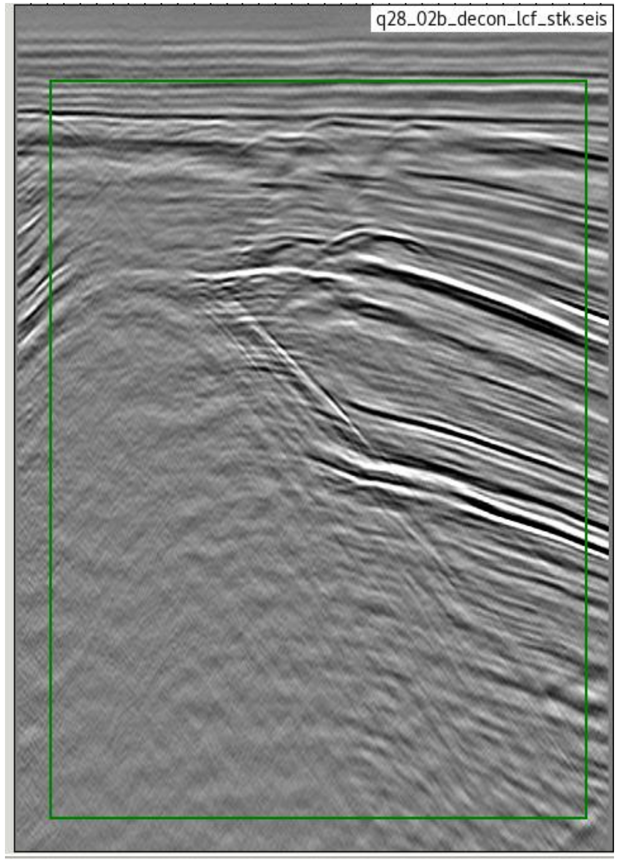
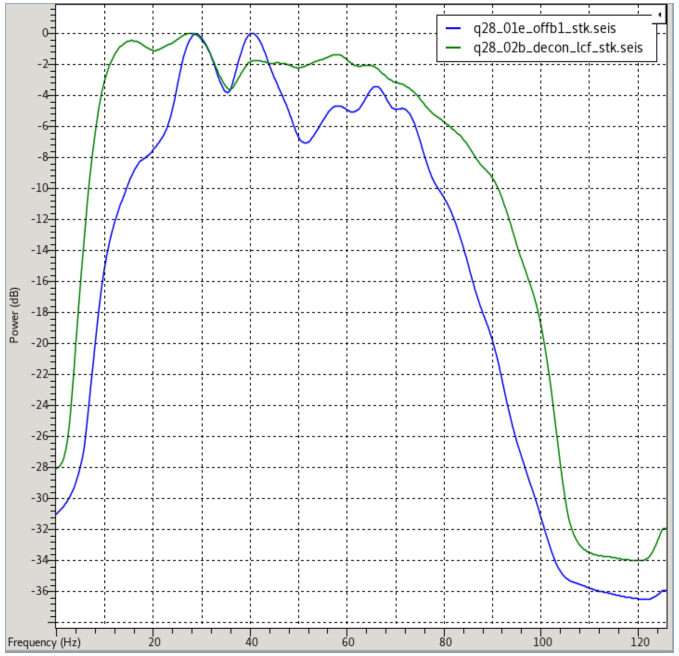




Surface-Consistent Deconvolution







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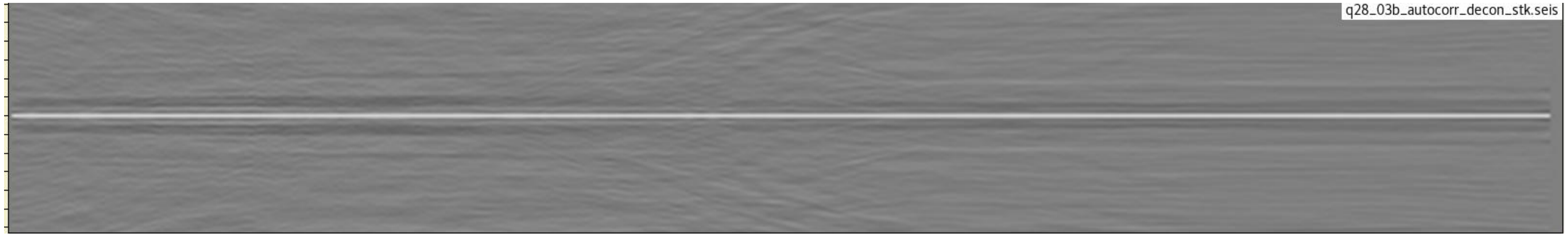
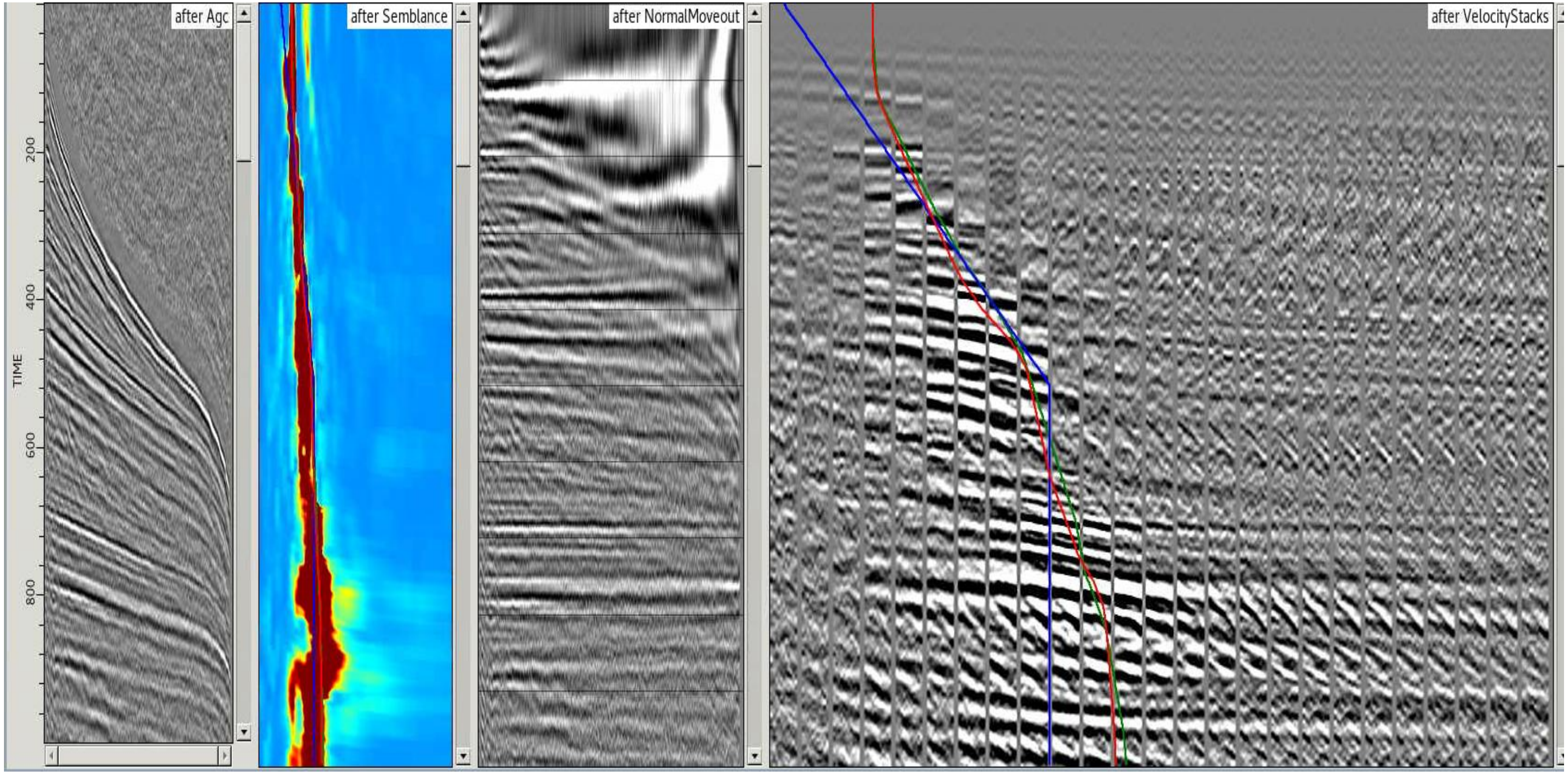


Velocity Analysis



1 Multiple passes of denoise

2 Refraction tomography

3 Residual statics

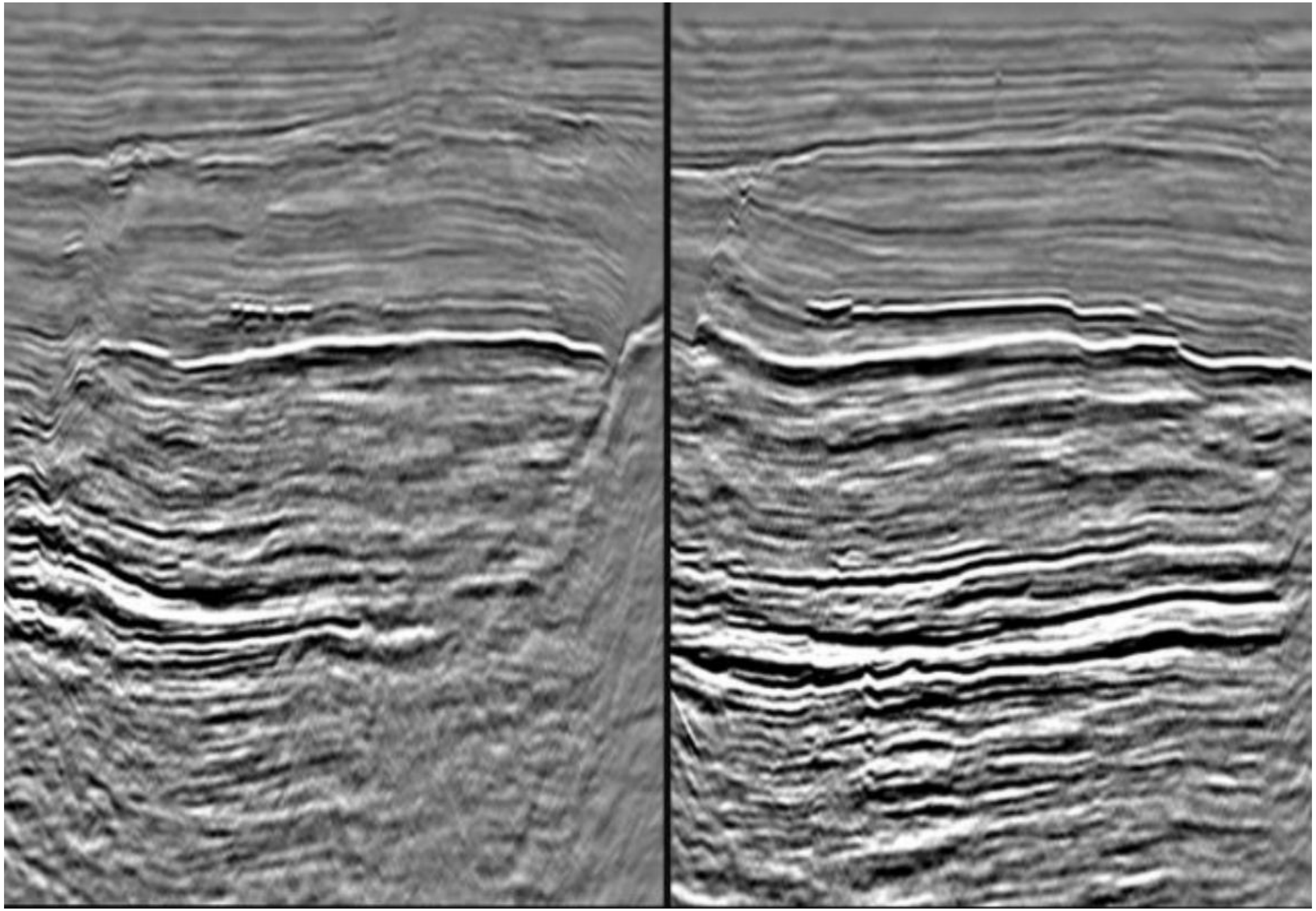
4 Pseudo-5D interpolation

5 Surface Consistent Deconvolution

6 Kirchhoff pre-stack time migration

Imaging

PSTM XLINE Stacks



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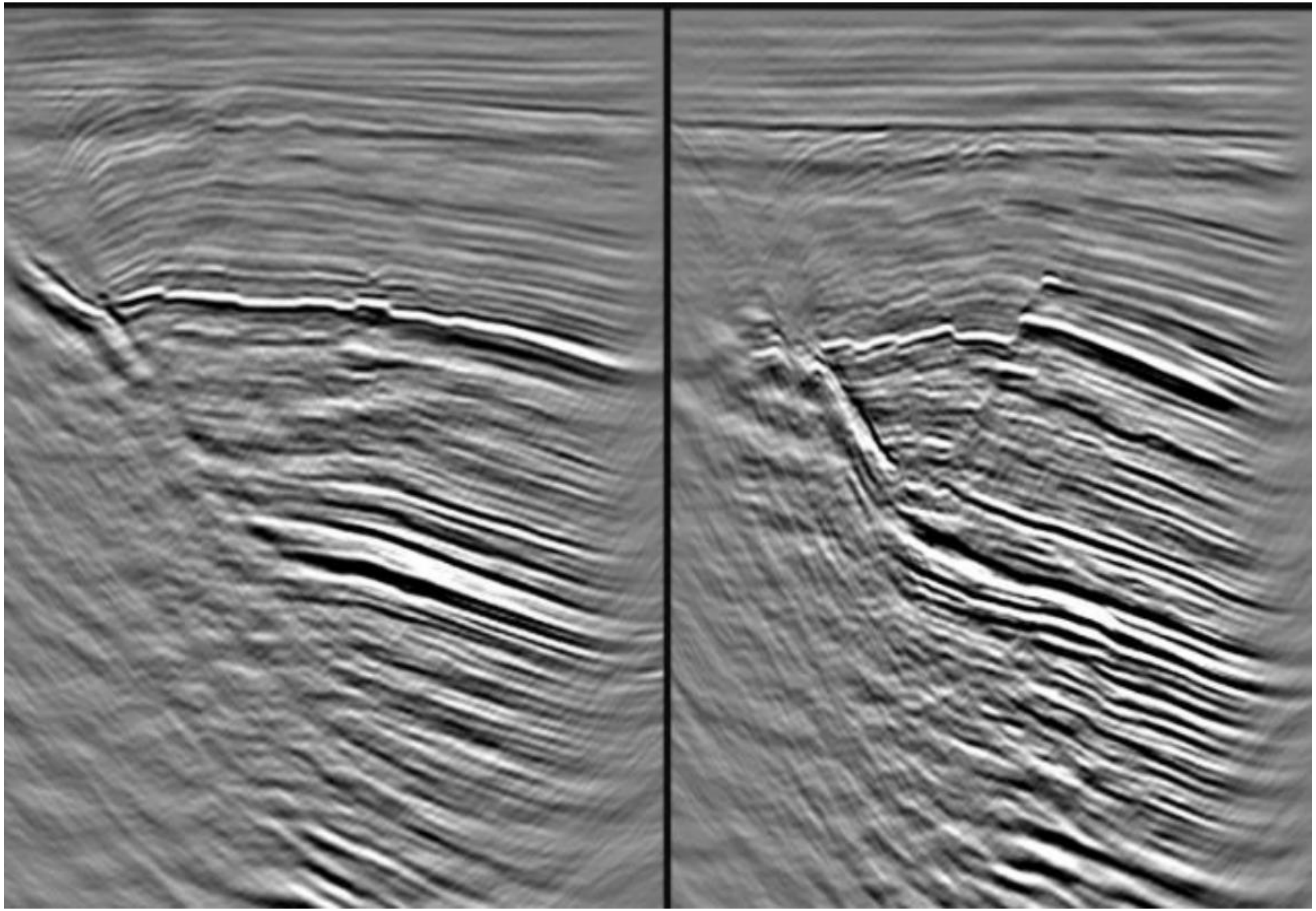

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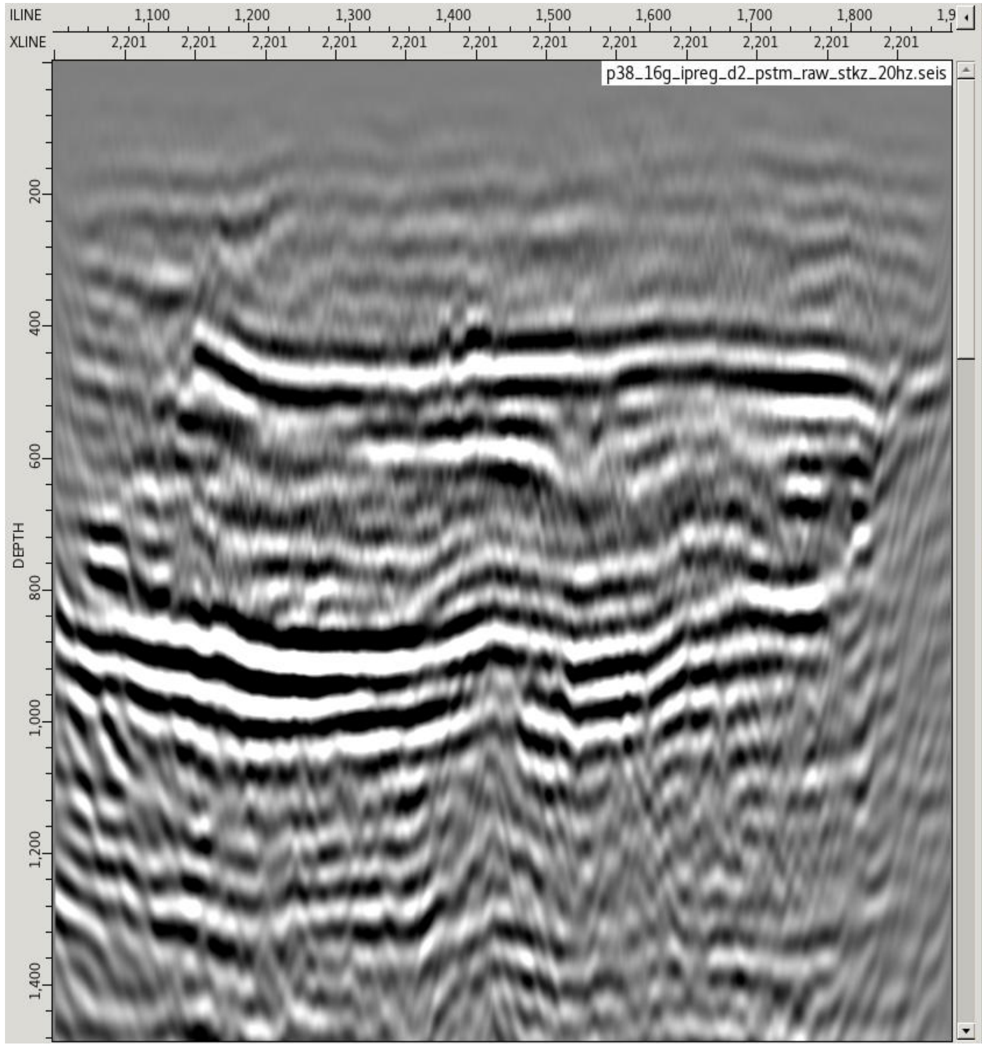
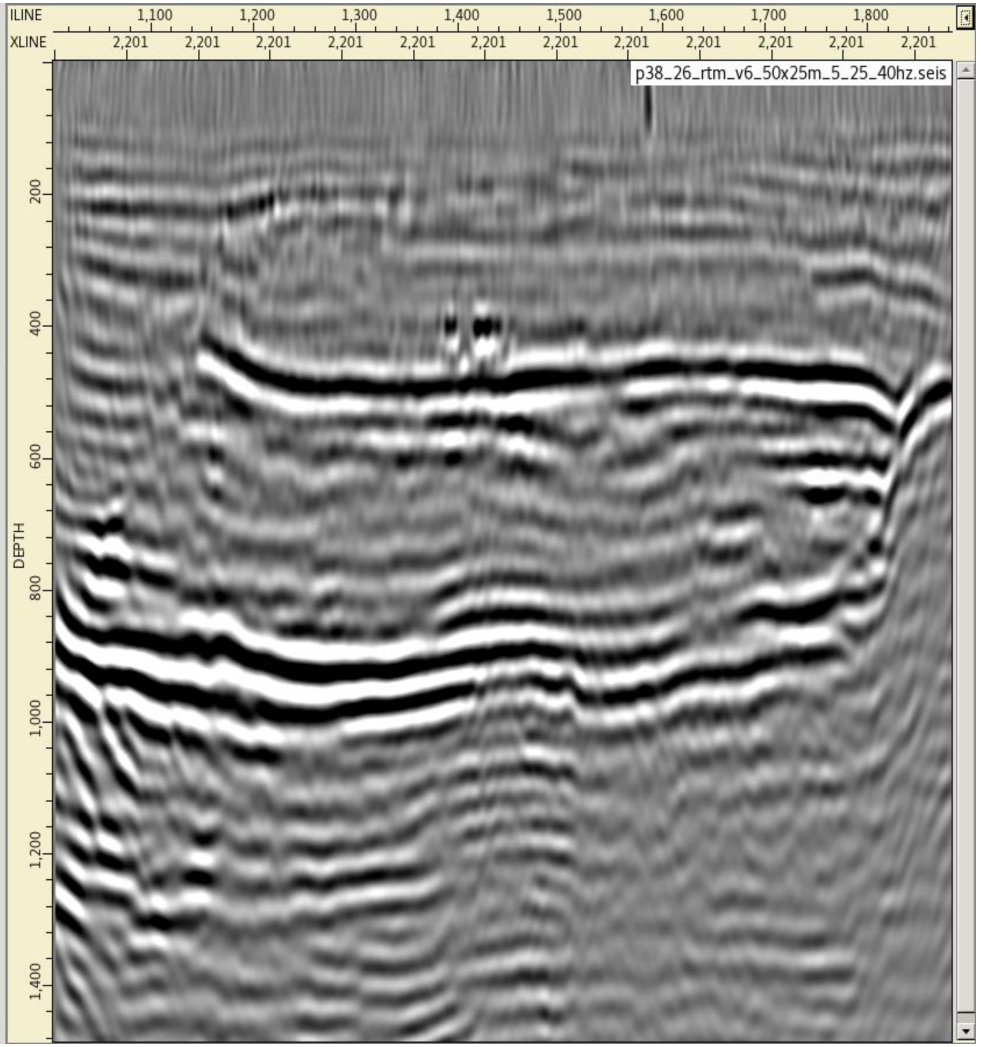
Imaging

More advanced?





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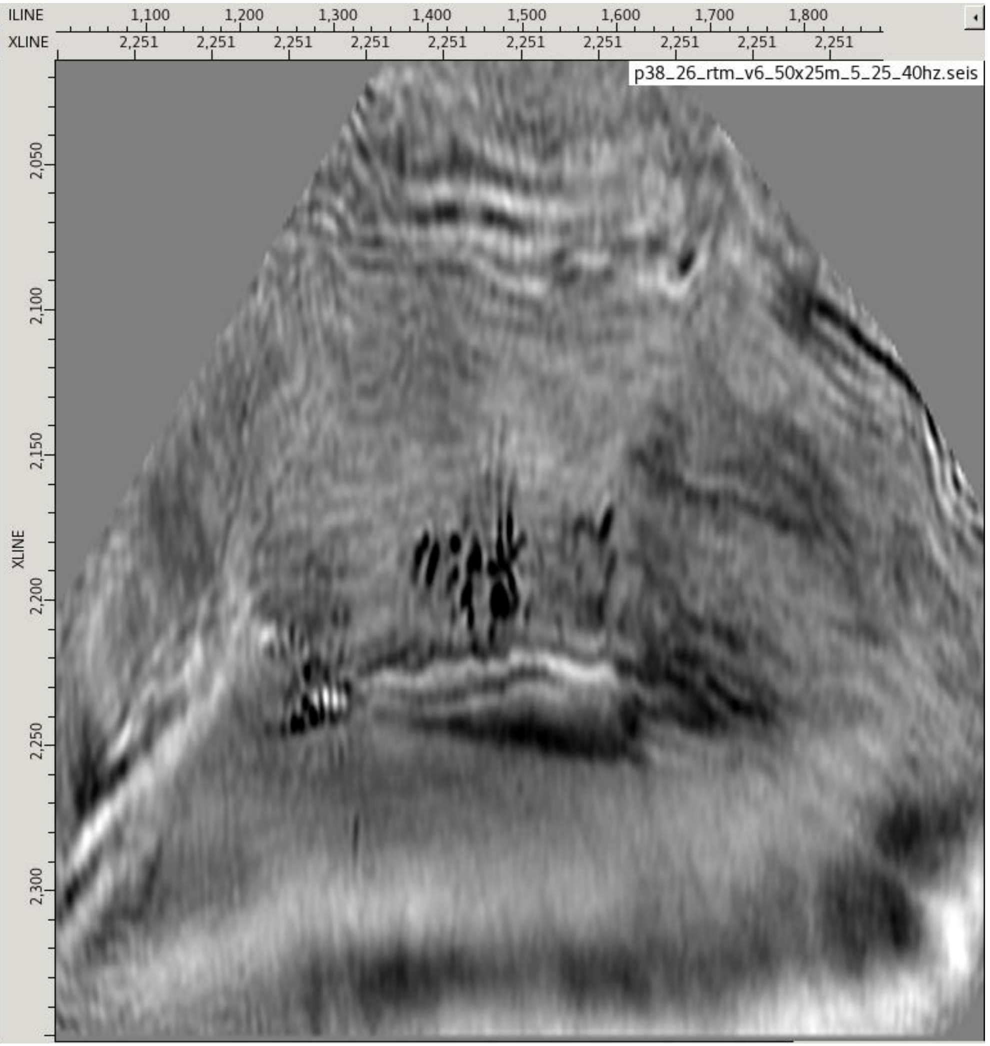
Imaging

More advanced?



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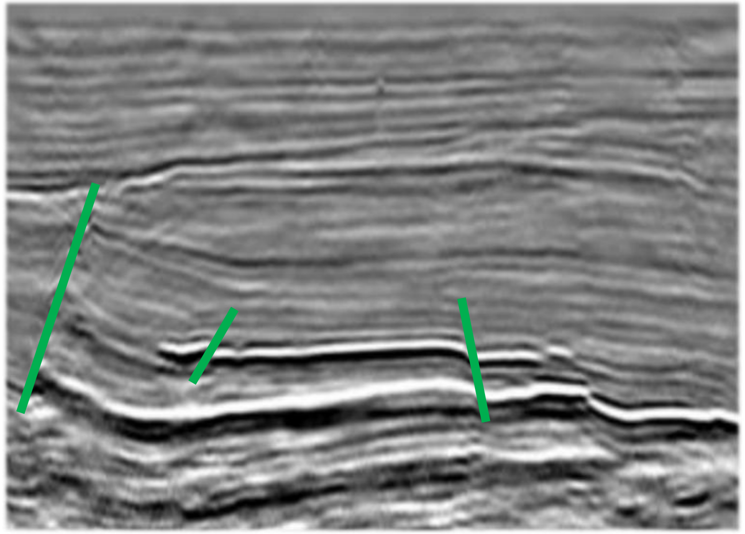
Limitations & what to change or improve

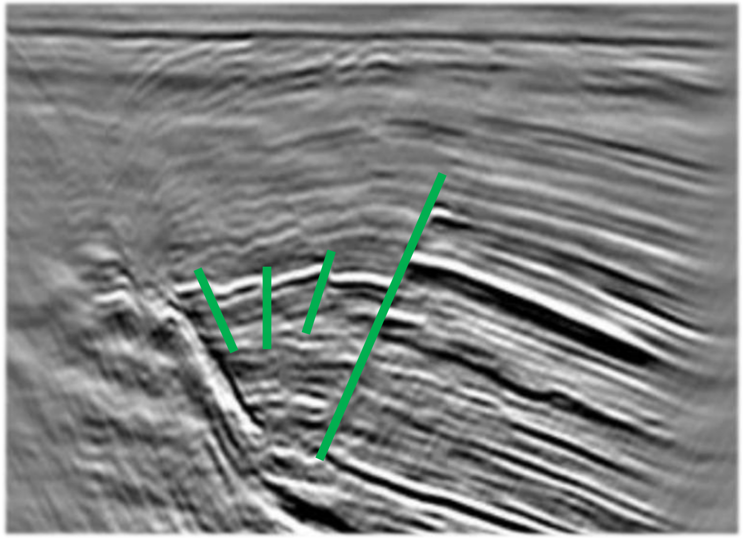
- **Offset Limitations**: Provided dataset is restricted to a maximum offset of 1350m; continuous wireless node records should be leveraged to reconstruct extended-offset gathers for advanced processing.

- **Processing Constraints**: Field-deployed hardware, while powerful, may lack the capacity for intensive full-integrity workflows involving multiple large-scale trials (e.g., velocity model building, large regularization, surface-consistent processing, or simultaneous 5D interpolation).

Conclusion

- By conducting processing remotely, on the edge and instantly, the source effort could be studied, leading to confidence in reducing immediately for the remaining survey reducing time, cost and risk for the acquisition duration.
- High density acquisition and a reasonable sequence yielded excellent imaging of the primary target of the <1km structural complexities around the salt flanks.
- A full processing could follow on from this, learning from, and use results to kick-start more advanced (VMB) regime with an already available velocity, static and image volume from the real-time proessing.
- Additionally, the lessons learnt can be applied as the “first pass” processing is already complete. (for example, larger offset range).





Thank you

Acknowledgements

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References

Ulmishek, G. F., 2001. Petroleum geology and resources of the North Caspian Basin, Kazakhstan and Russia. U.S. Geological Survey Bulletin 2201-B.