Multi-Source Towed Streamer Acquisition Techniques

Finding Petroleum : New Geophysical Approaches

London
March 9, 2017

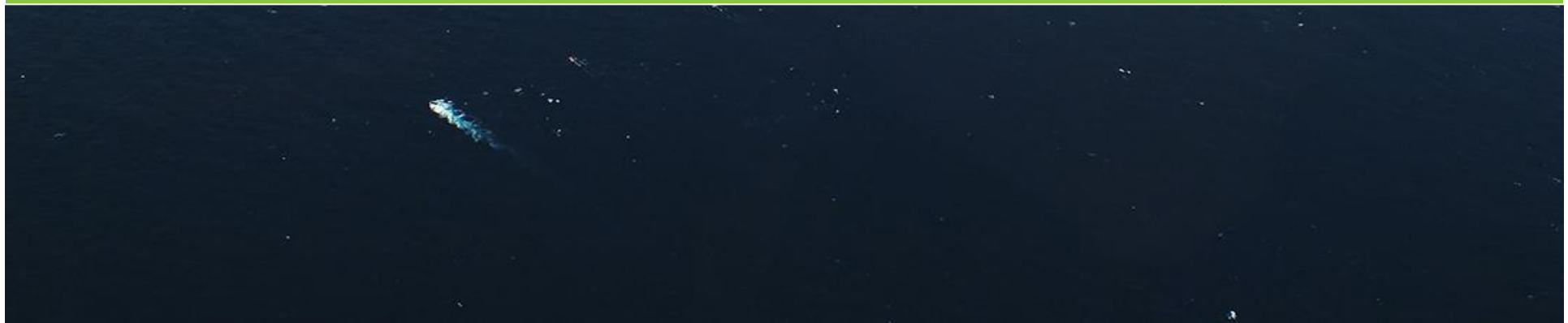
Phil Fontana
Chief Geophysicist, Polarcus

Polarcus

Enhancing Operational Efficiency and Overall SeismicTrace Density

Leveraging De-Blending of Overlapping Shots

Enhanced In-Line and Cross-Line Sampling with Extra Sources



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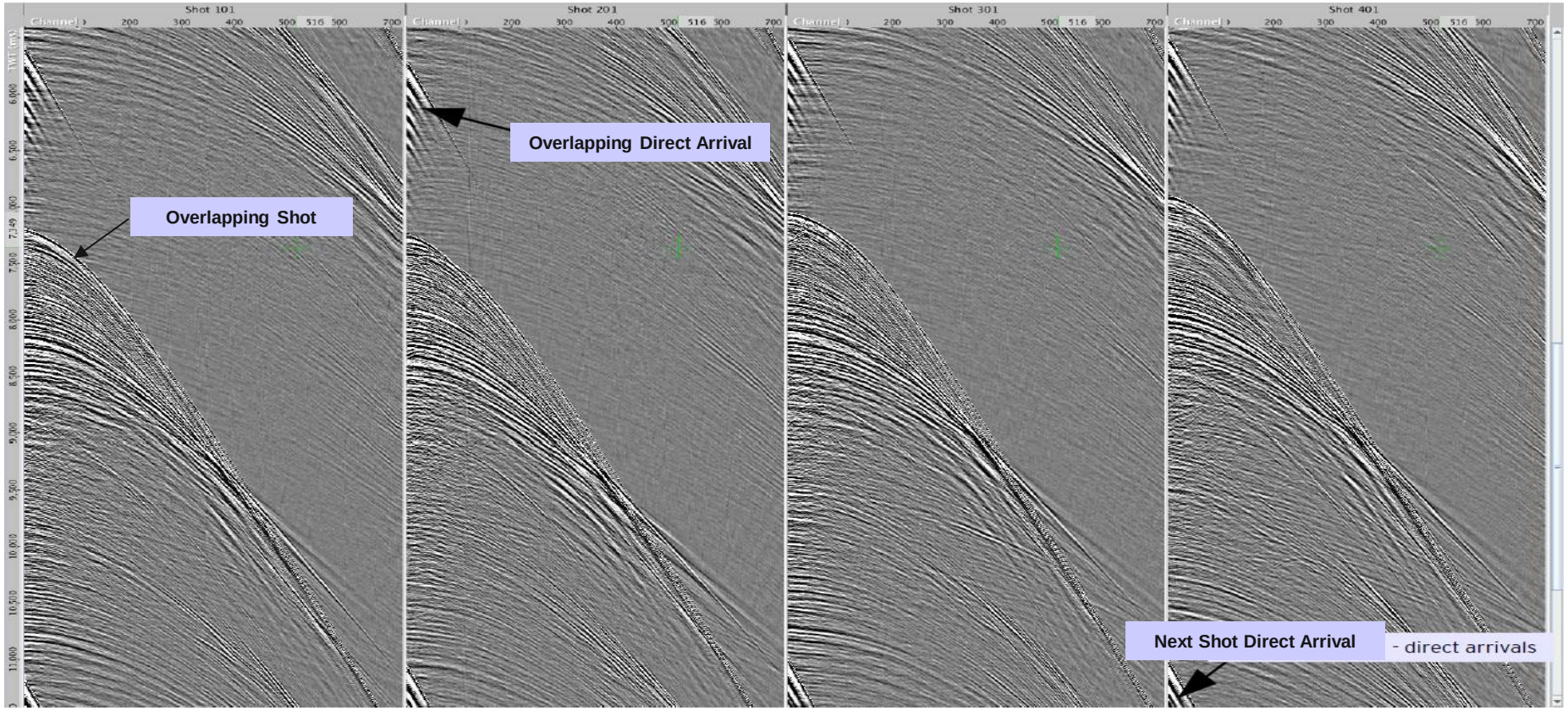
Overlapping Shot Records

Raw 12-second Shot Records



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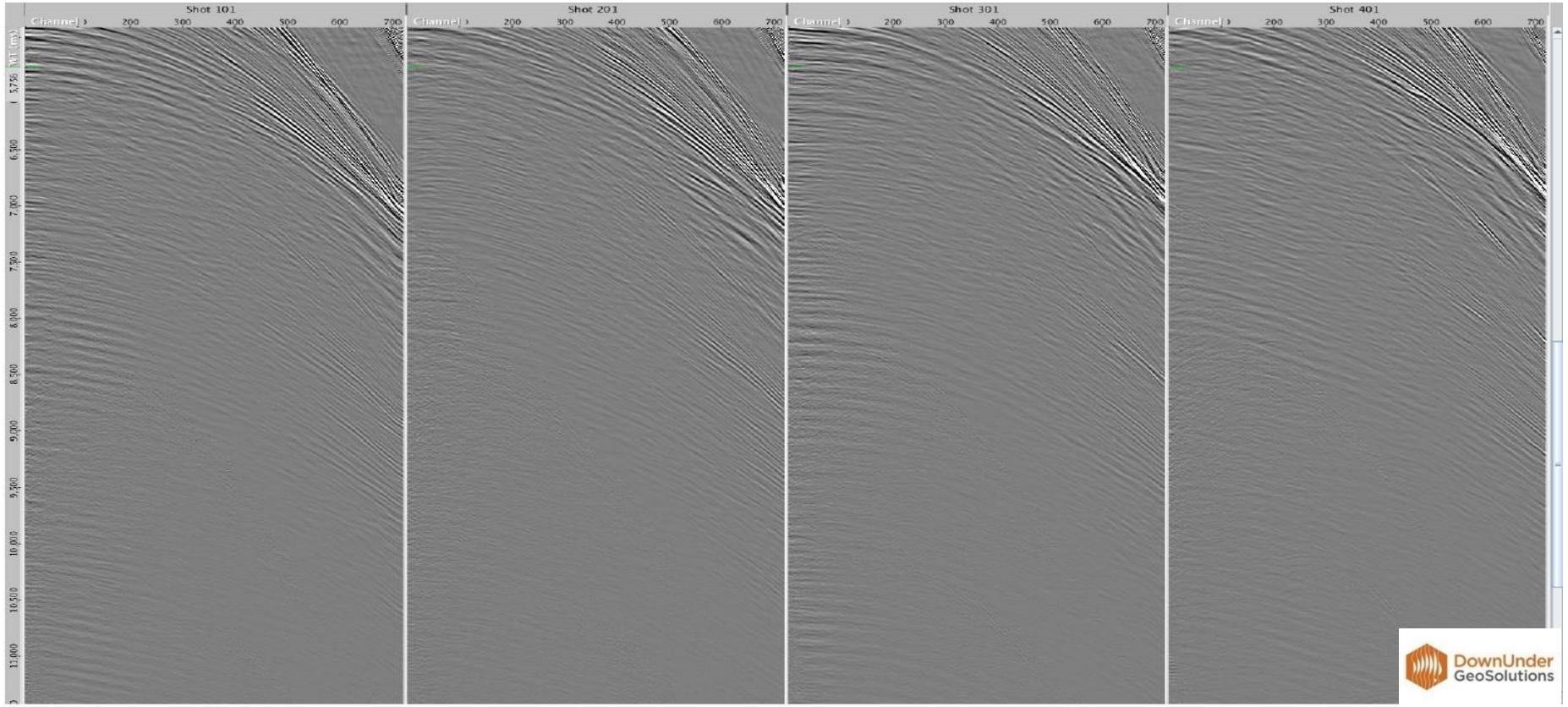
Overlapping Shot Records

Deblended 12-second Shot Records



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De-Blending Technology

2016 Session at SEG

- **- SPNA 1 - Deblending and Marine Noise Attenuation**

Inversion-based 3D deblending of towed-streamer simultaneous source data using sparse Taup and wavelet transforms
Can Peng, Jie Meng
pp. 4607-4611 (5 pages)
http://dx.doi.org/10.1190/segam2016-13866688.1
Abstract | References | PDF (5234 KB) | PDF w/Links (1511 KB) | Permissions

± Show Abstract

Focal deblending using smart subsets of towed streamer 5D data
Apostolos Kontakis, Dirk Verschuur
pp. 4612-4617 (6 pages)
http://dx.doi.org/10.1190/segam2016-13945960.1
Abstract | References | PDF (1221 KB) | PDF w/Links (1228 KB) | Supplemental Material | Permissions

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Towards better deblending: Application of wave equation based demigration
Chao Peng, Yuan Yao
pp. 4618-4622 (5 pages)
http://dx.doi.org/10.1190/segam2016-13872538.1
Abstract | References | PDF (5953 KB) | PDF w/Links (5954 KB) | Permissions

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Data studies of simultaneous source separation using robust linear algebra
Ian Moore, Robin Fletcher, Craig Beasley, Clara Castellanos
pp. 4623-4627 (5 pages)
http://dx.doi.org/10.1190/segam2016-13779503.1
Abstract | References | PDF (1521 KB) | PDF w/Links (1525 KB) | Permissions

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Rank-reduction deblending for record length extension: The example of the Carnarvon basin
Margherita Maraschini, Audrey Kielius, Sergio Grion
pp. 4628-4632 (5 pages)
http://dx.doi.org/10.1190/segam2016-13685251.1
Abstract | References | PDF (1683 KB) | PDF w/Links (1687 KB) | Permissions

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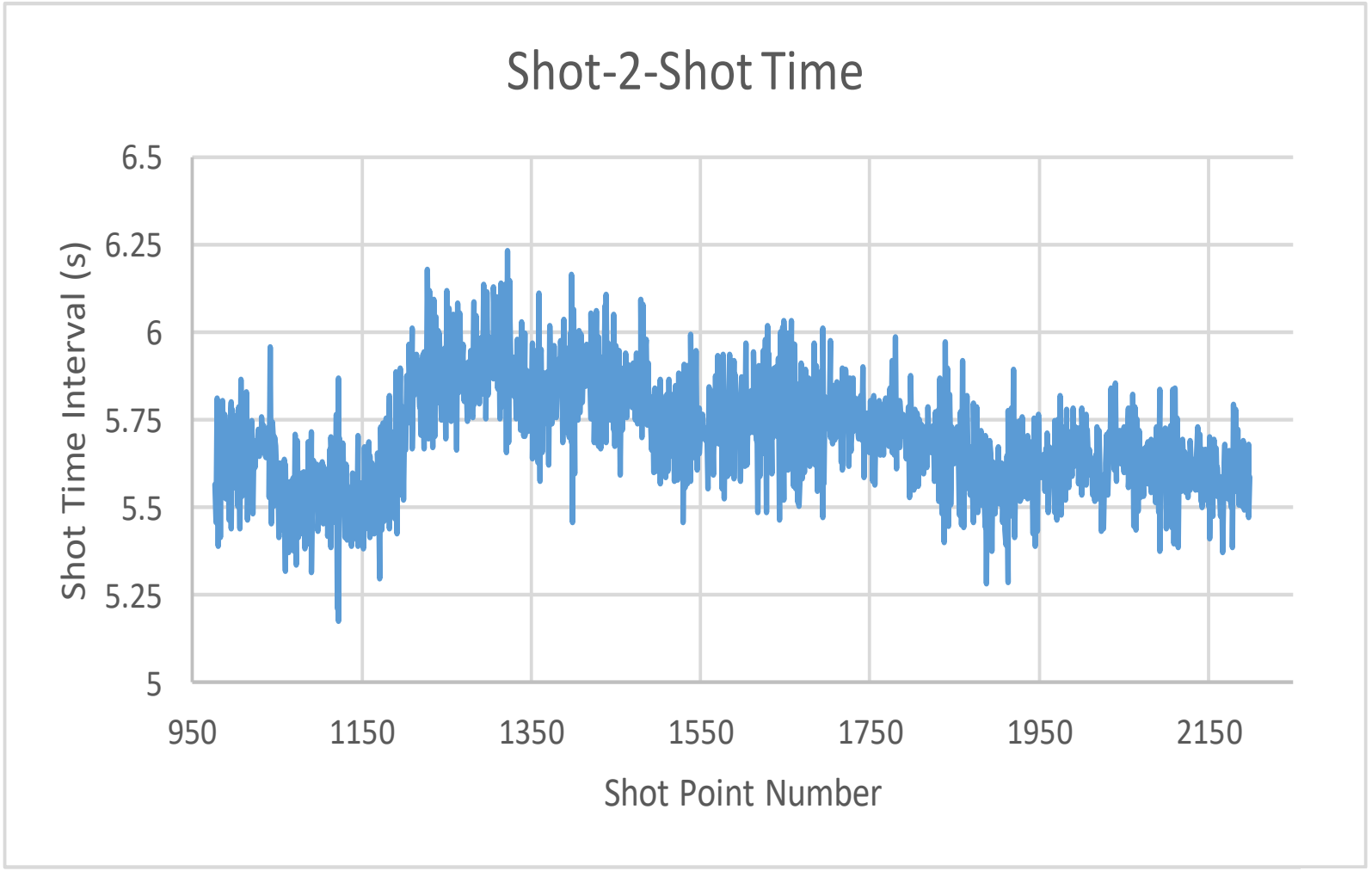
Shot-to-Shot Time Variations



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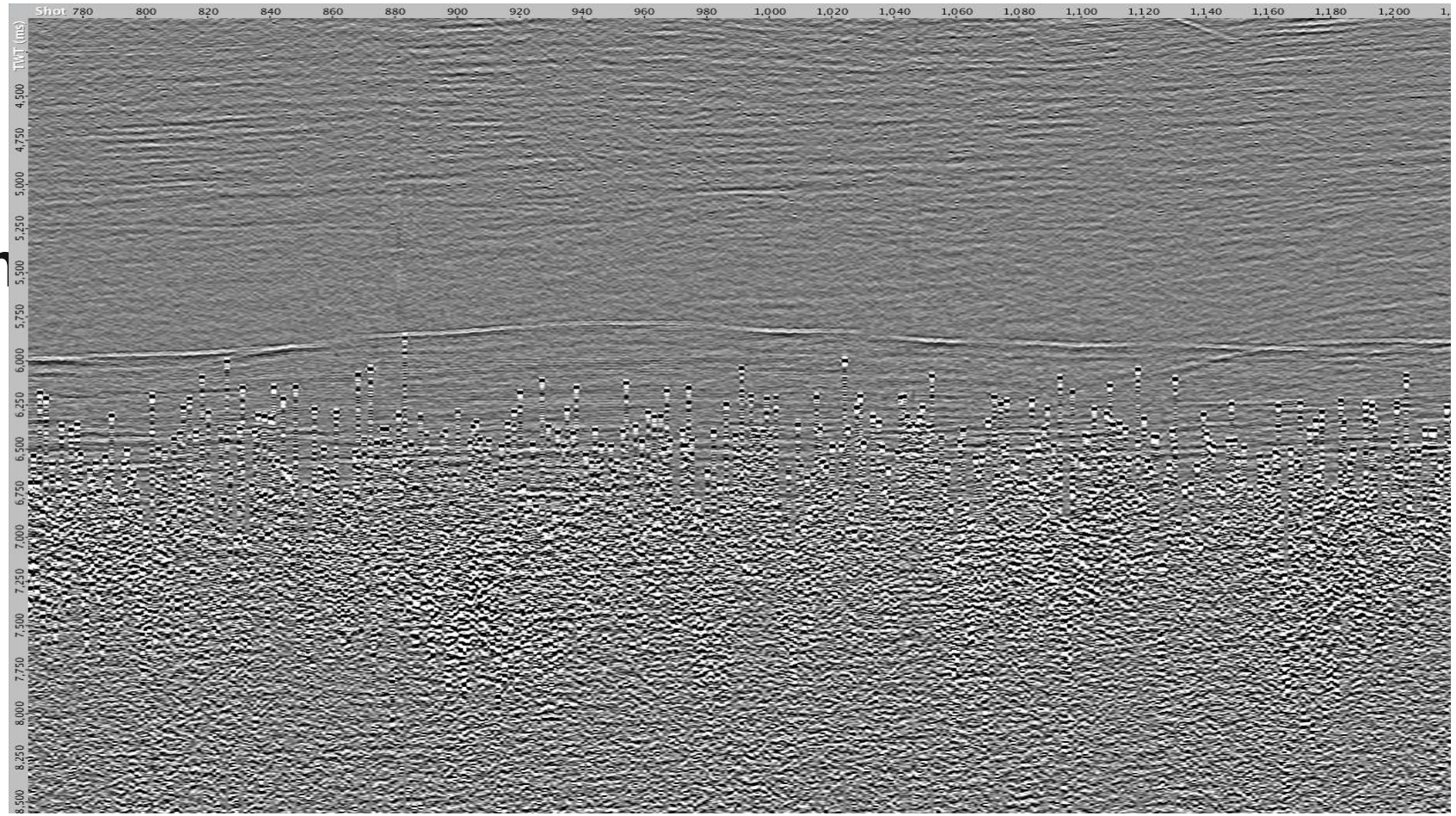
Overlapping Shot Records

Channel Display : Input Channel 130

4.2s



8.7s

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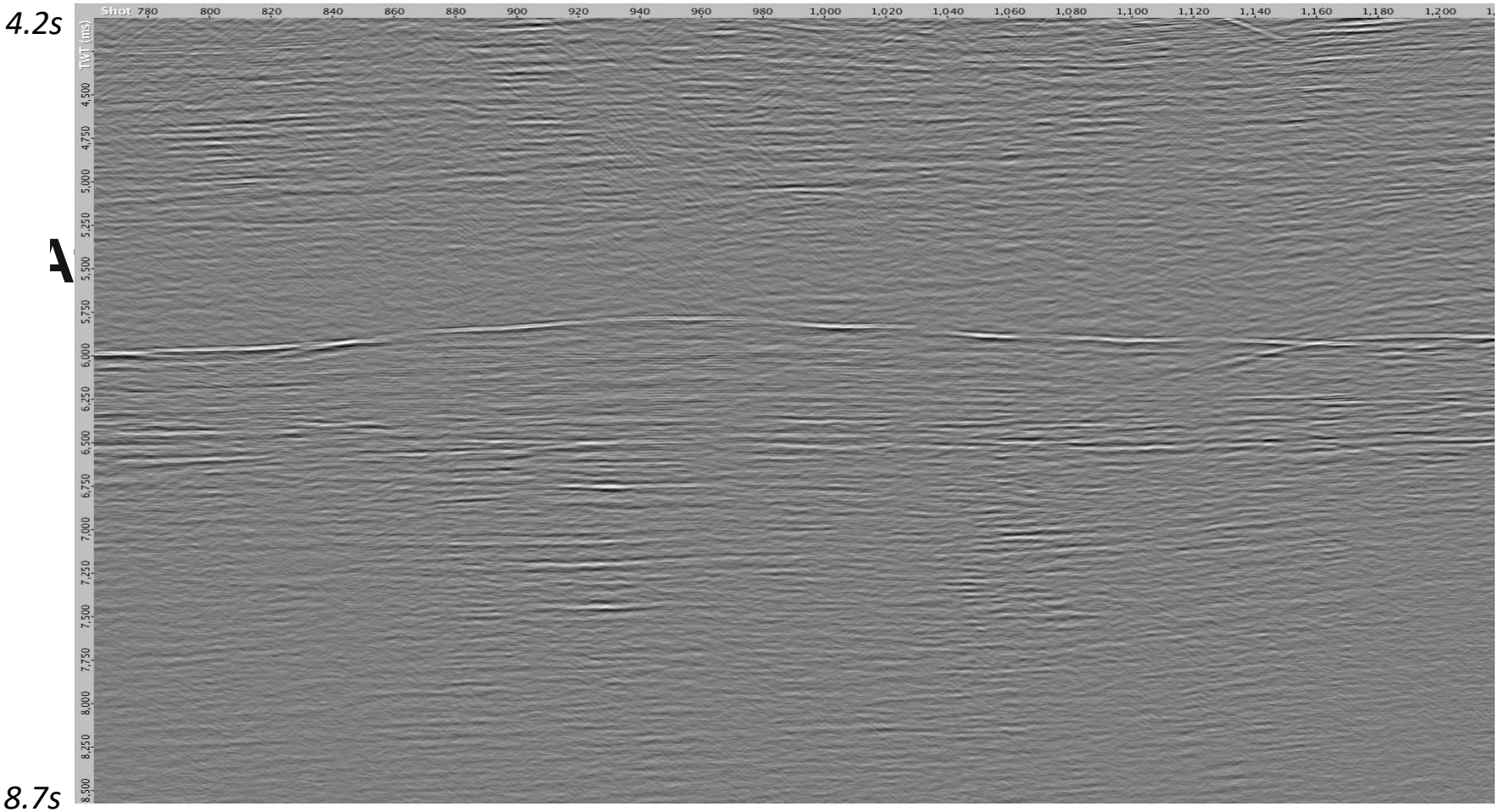
Overlapping Shot Records

Channel Display : After Deblending Channel 130



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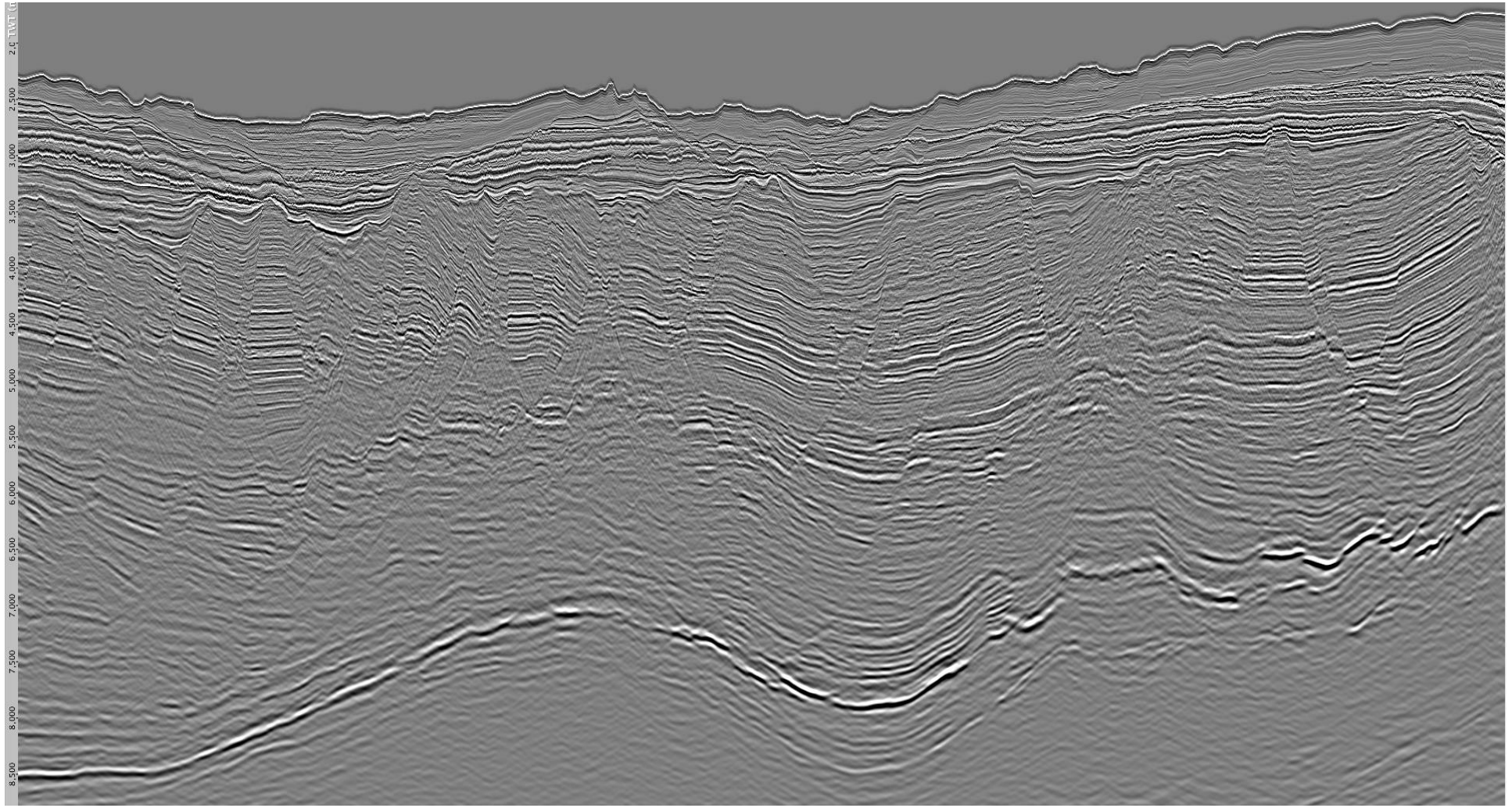
De-Blended Migrated Section



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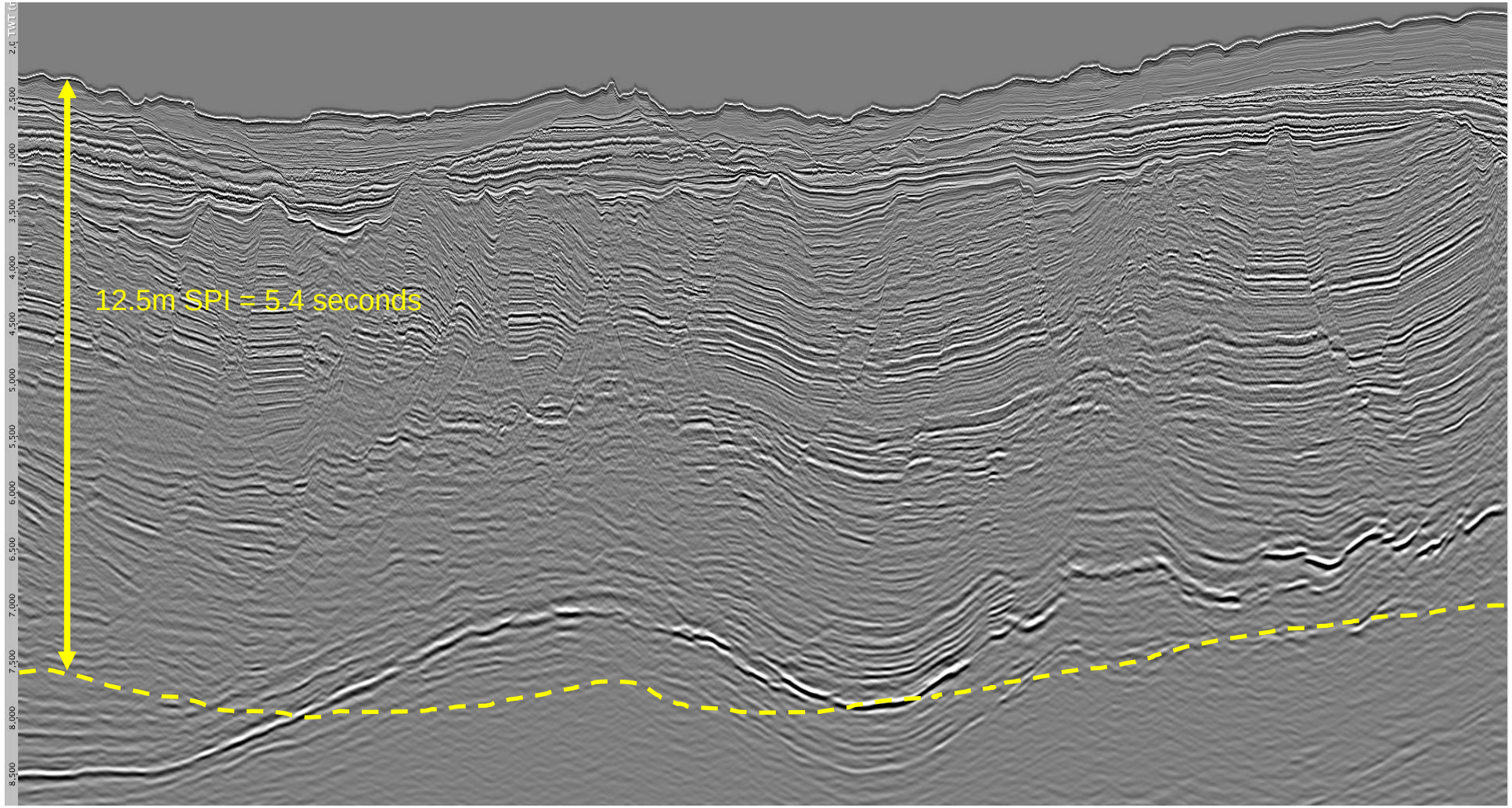
Deblended Migrated Section

Shot Record Overlap Determined by Shot Point Interval



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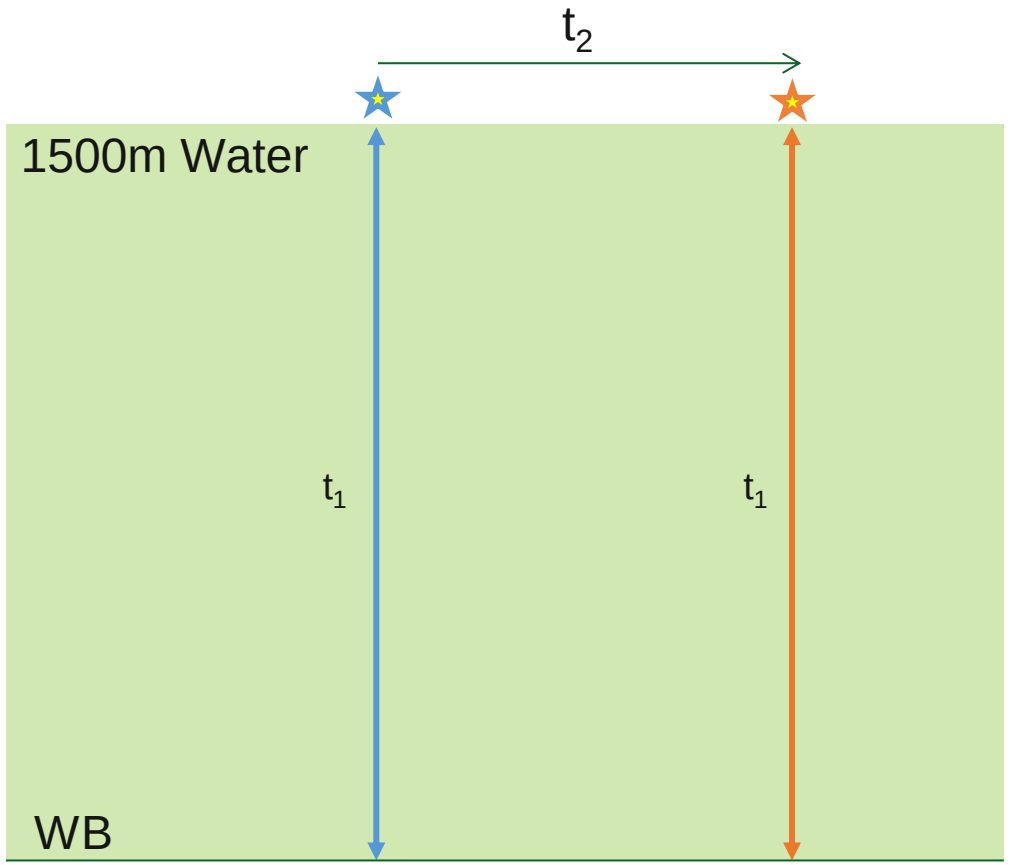
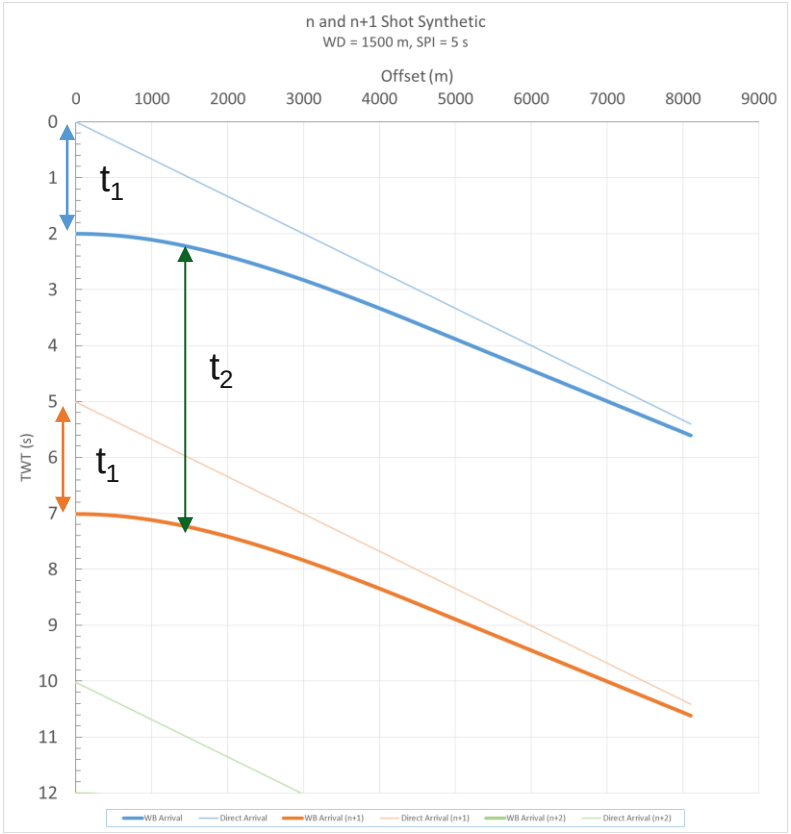
Shotpoint Interval and Overlap

1500 m water depth, 5 s shot interval time





t_2 = shot interval time = “unblended” zone = SPI / vessel speed

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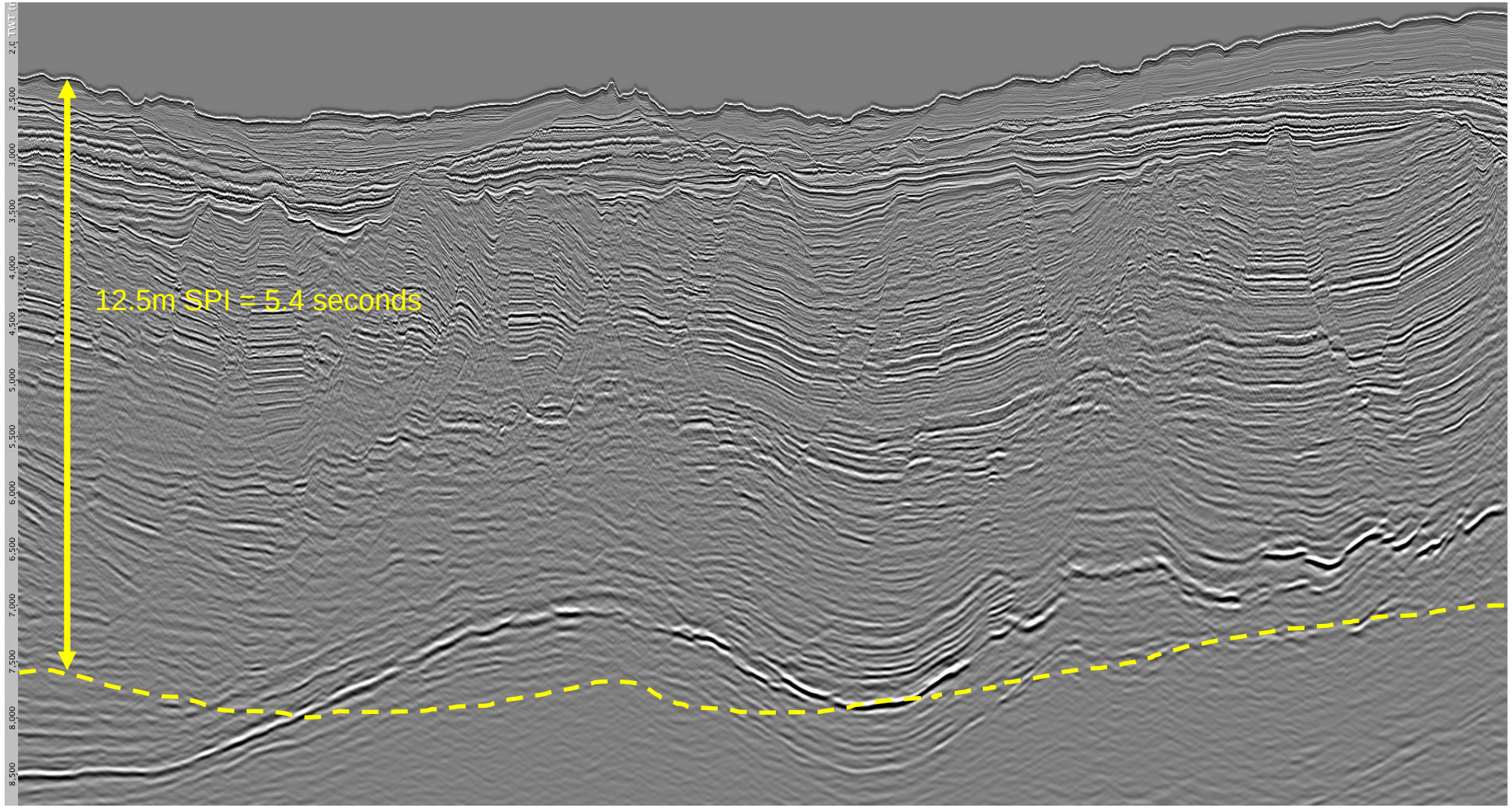
Shot Interference Zone

- Time of shot 1 = 0 = t_0
- TWT of shot 1 water bottom reflection = 2D/V =t_1
- Time of shot 2 = Shot Distance / Vessel Ground Speed = t_2
- TWT of shot 2 water bottom reflection = t2+ 2D/V = t_3
- Time of shot interference = t_3-t_1 = (t2+2D/V)-(2D/V)
- = t_2 = time between shots

- Water depth cancels out.

Deblended Migrated Section

Shot Record Overlap Determined by Shot Point Interval



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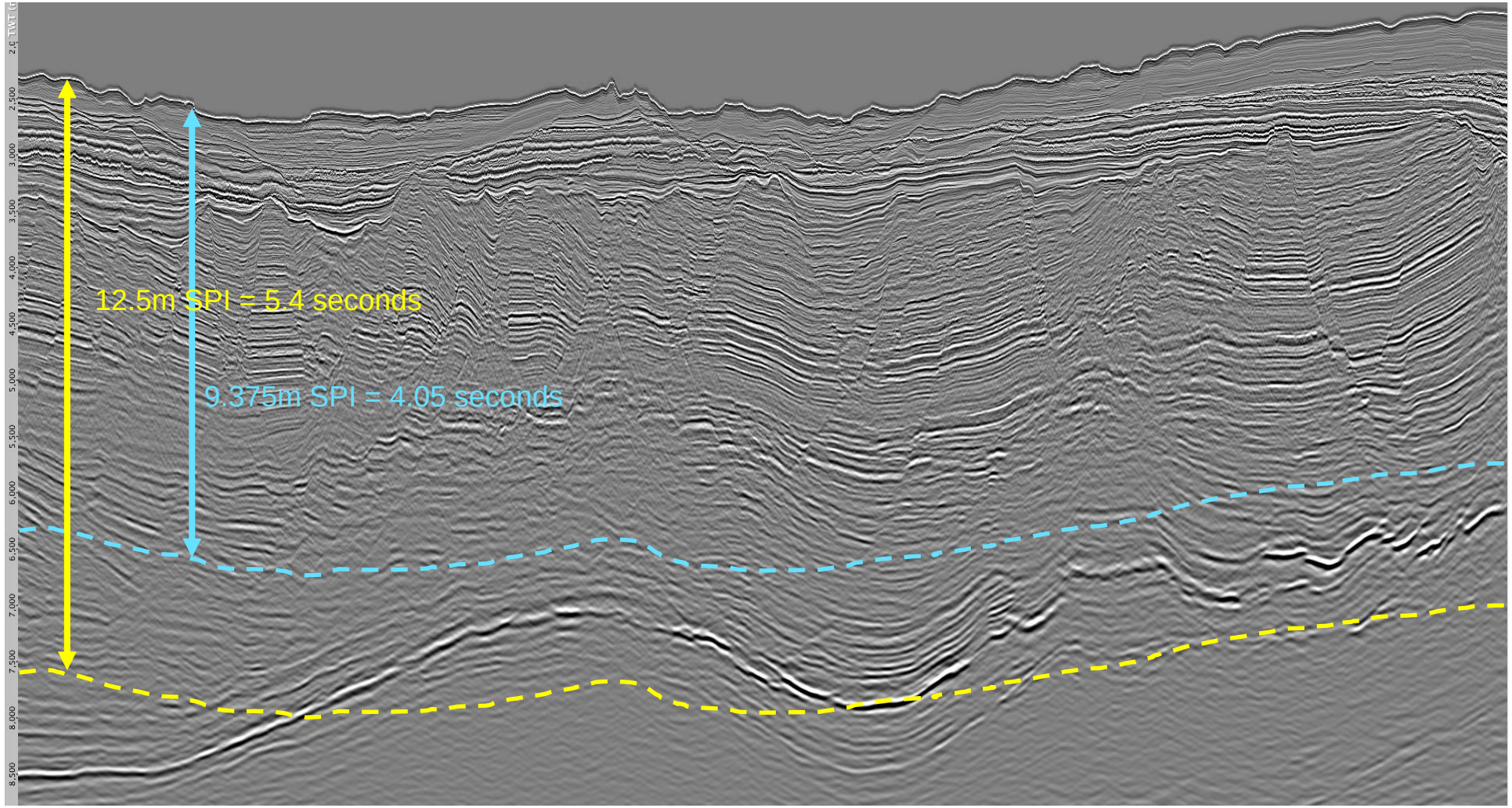
Deblended Migrated Section

Shot Record Overlap Determined by Shot Point Interval



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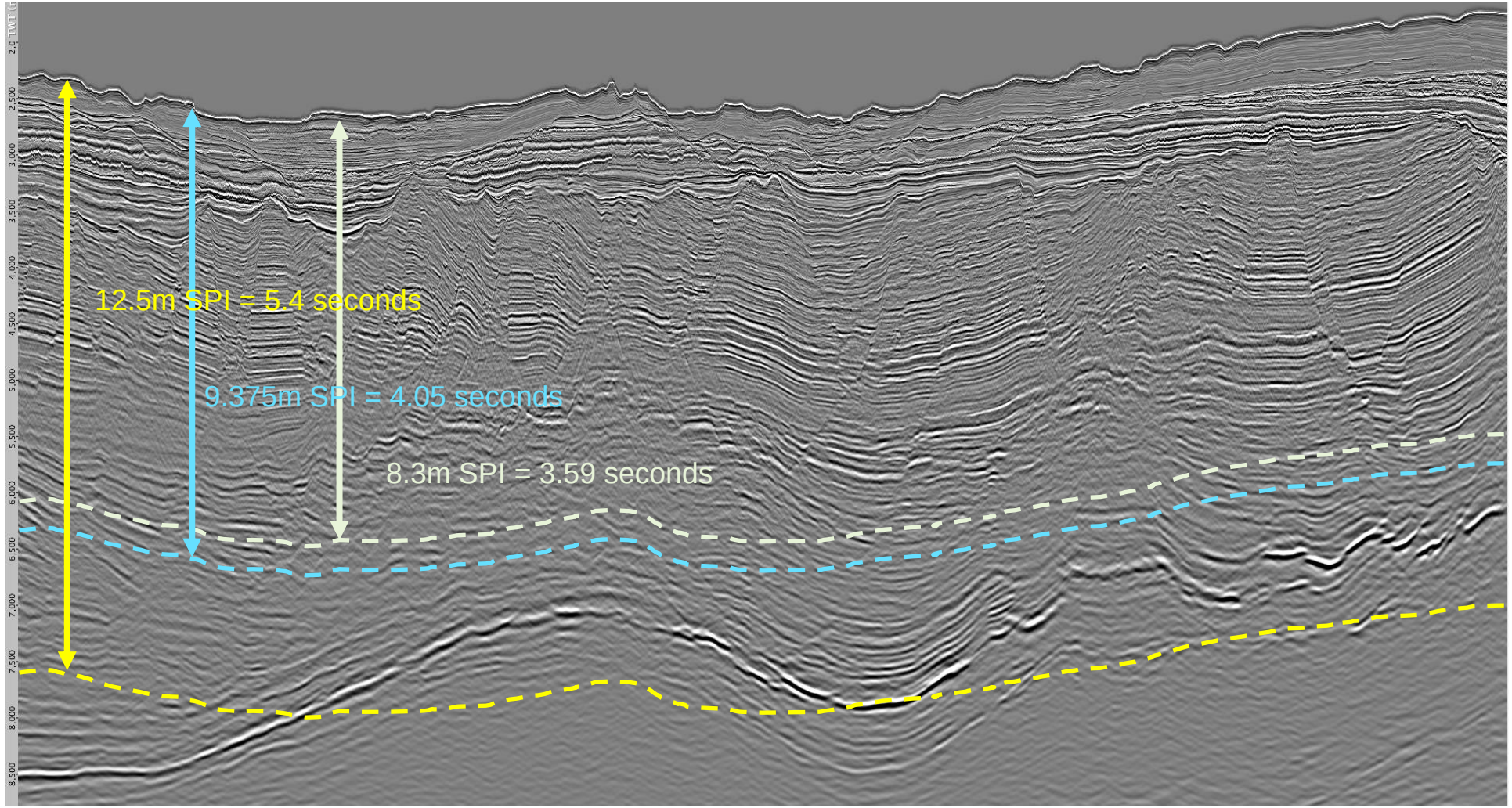
Deblended Migrated Section

Shot Record Overlap Determined by Shot Point Interval



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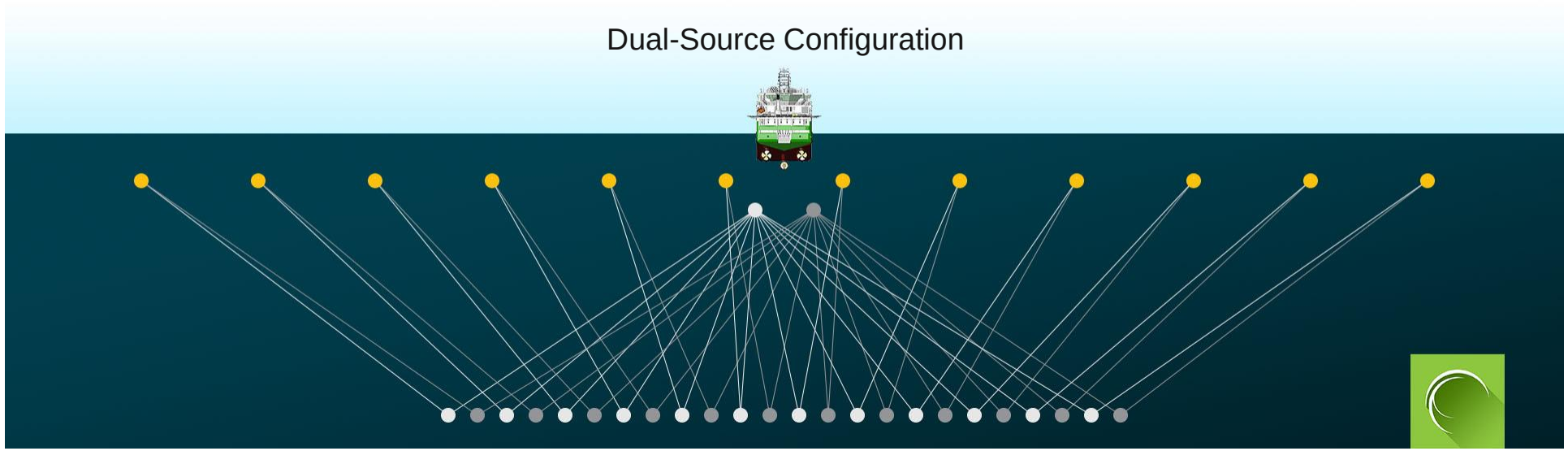
Dual-Source

Multi-Source Acquisition : Higher Geophysical Fidelity

- Designed to provide closer cross-line sampling and more unique ray-paths than dual sources on the same streamer configurations
- Dual-source cross-line sampling = 1/4 of streamer separation
- Triple-source cross-line sampling = 1/6 of streamer separation



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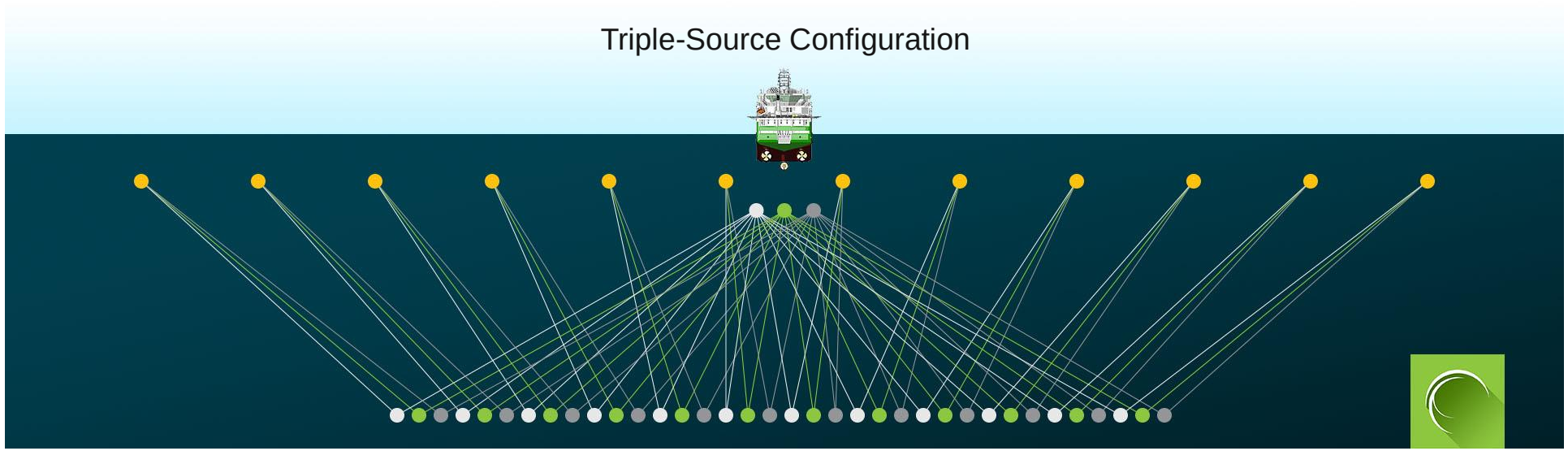
Triple-Source

Multi-Source Acquisition : Higher Geophysical Fidelity

- Designed to provide closer cross-line sampling and more unique ray-paths than dual sources on the same streamer configurations
- Dual-source cross-line sampling = 1/4 of streamer separation
- Triple-source cross-line sampling = 1/6 of streamer separation



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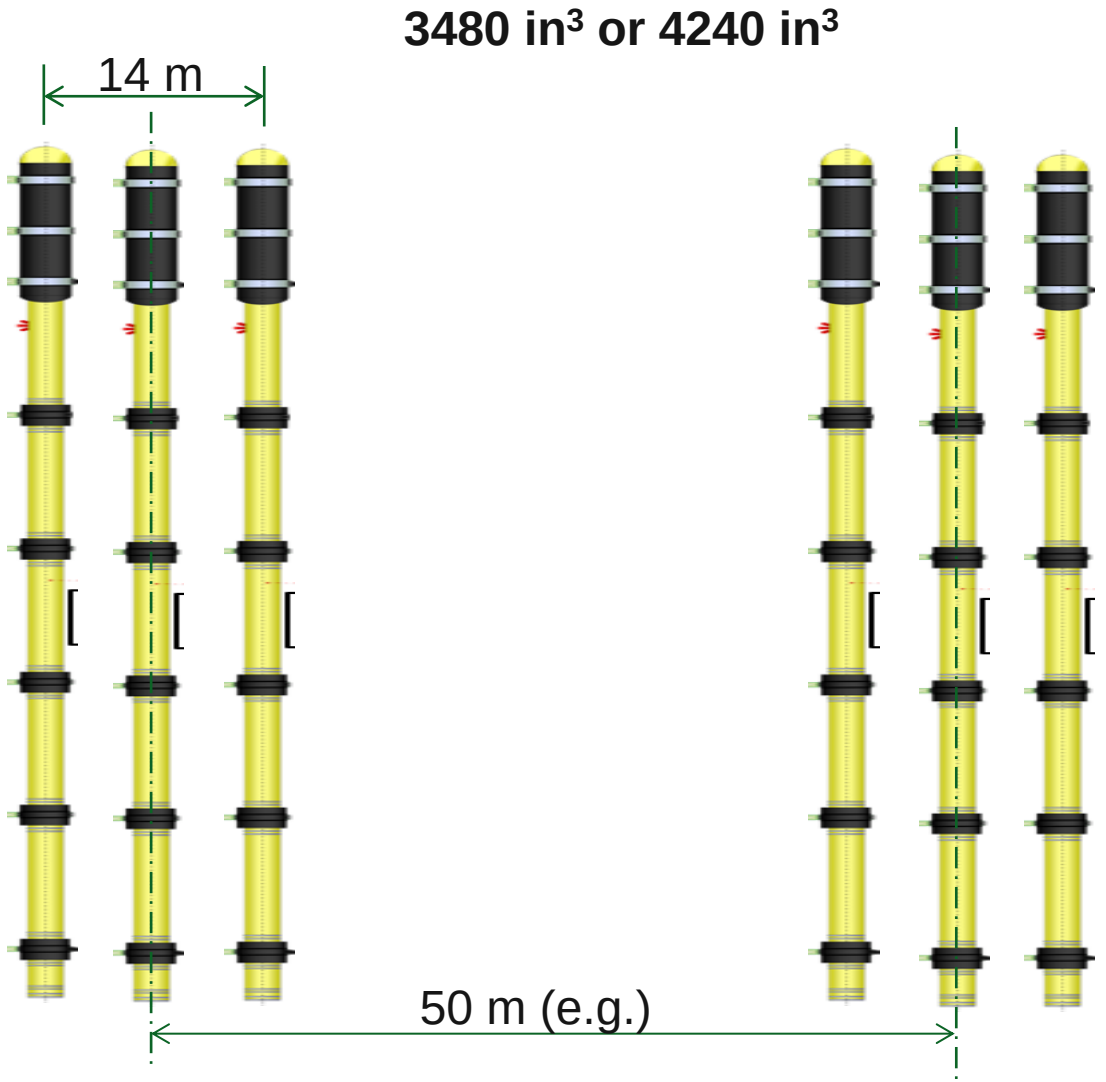
Dual-Source Array Configuration



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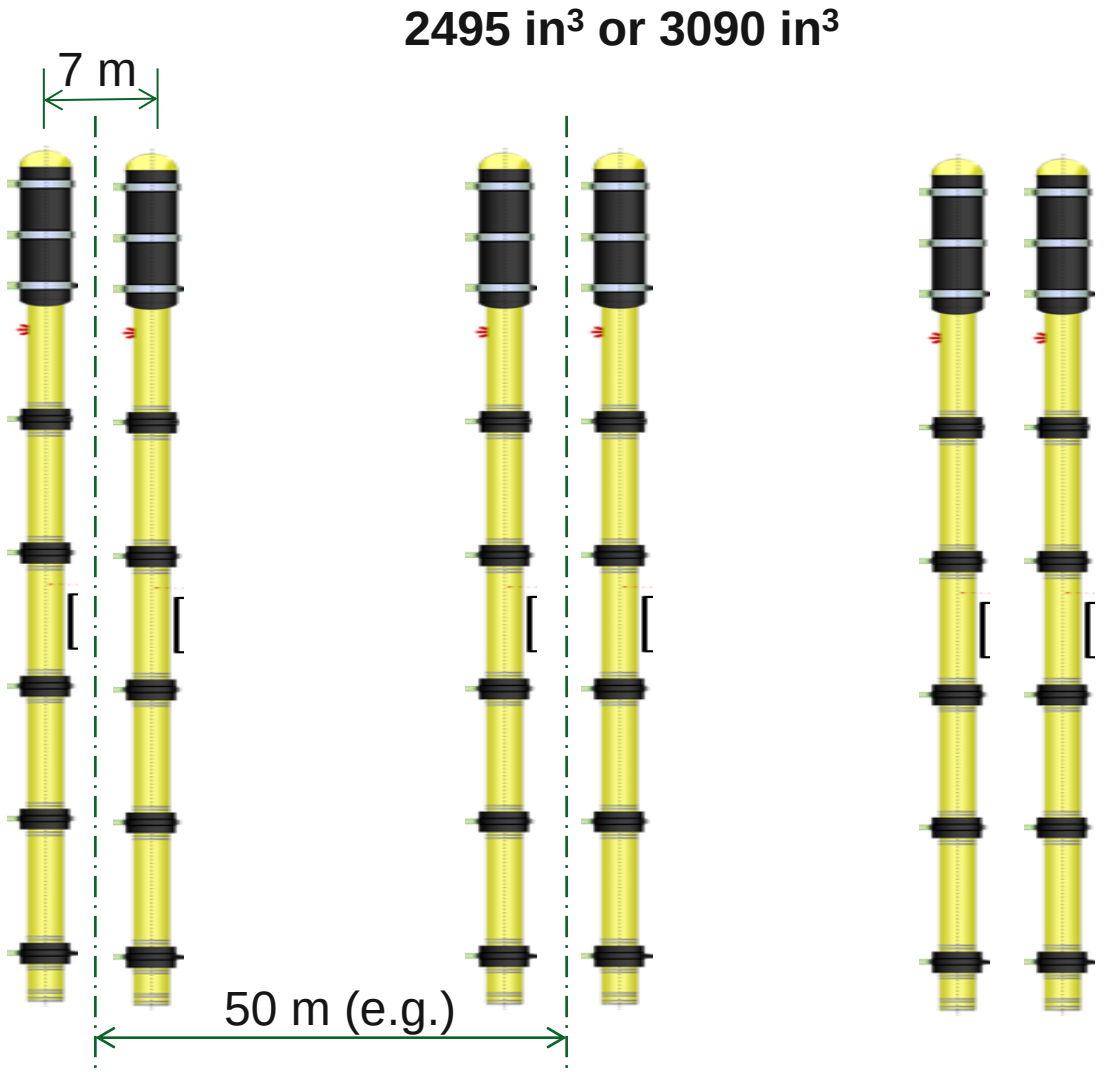
Triple-Source Array Configuration



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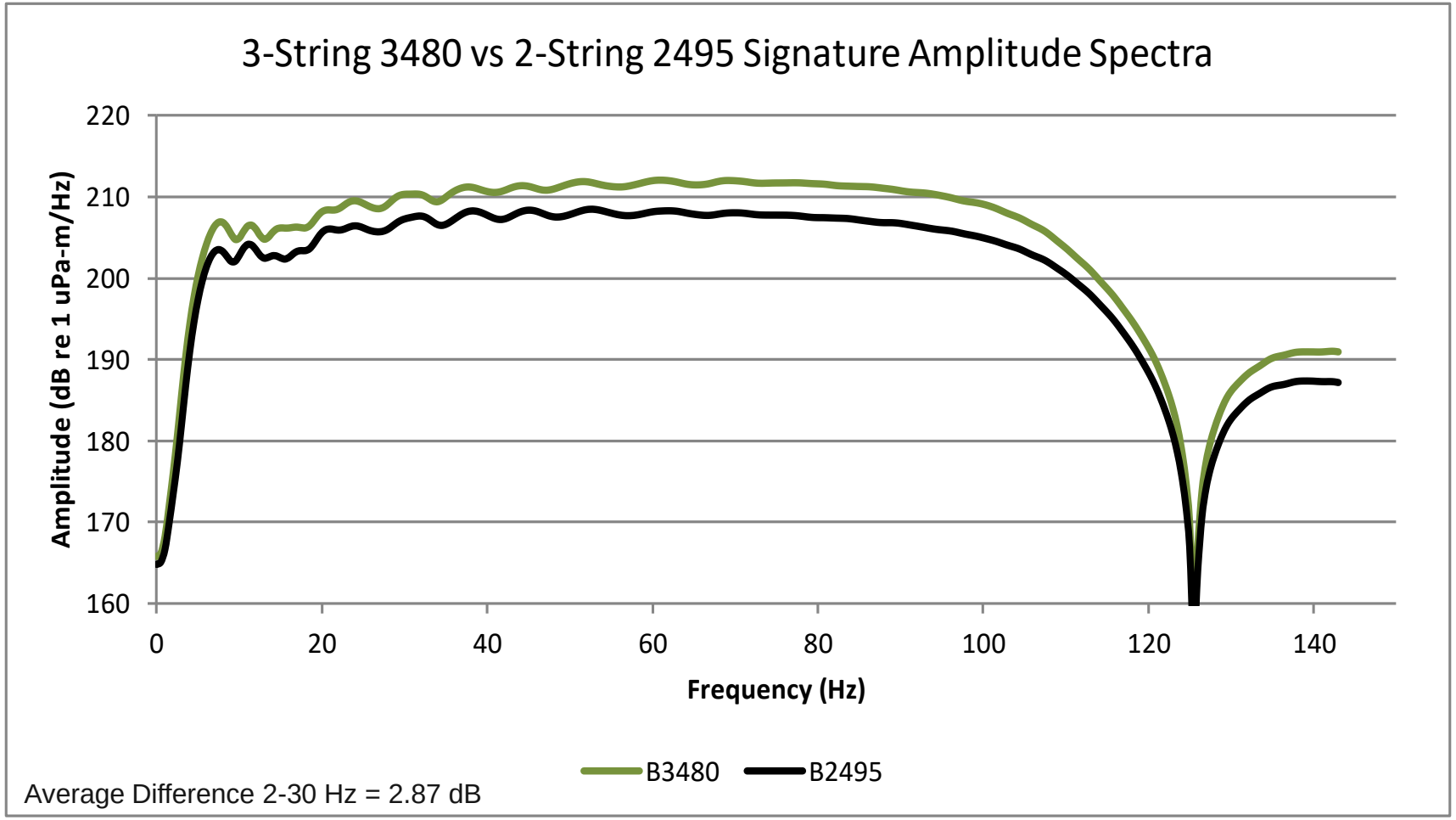
Bolt 3480 vs Bolt 2495 Signature Amplitude Spectra
6m Tow Depth and DFS-V Filter



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Dual vs Triple Sources

MADRID 2015
1-4 June 2015 I IFEMA Madrid

We N101 06

Triple-Source Simultaneous Shooting (TS3), A Future for Higher Density Seismic?

J. Langhammer* (TGS) & P. Bennion (TGS)

SUMMARY

The use of triple-sources in marine seismic streamer acquisition has been tested in the past, but with no significant commercial success compared to dual-source acquisition. With the introduction of new and better low noise streamers, in addition to the ability to record and deblend simultaneous source data, it is time to revisit the use of triple-sources in marine seismic exploration for decreased crossline bin-size leading to better spatial resolution. The data from the triple-source configuration flip-flop-flap sequential firing mode, is similar in quality compared to flip-flop conventional dual-source acquisition mode. When firing off the triple-sources in simultaneous mode, giving reduced shot-point interval, the results appear to be better than for dual-source flip-flop mode mainly due to increased fold and less aliasing of pre-stack gathers. A triple-source configuration can find its application in shallow and deeper water areas for imaging of targets where reduced crossline spacing and higher fold may be required.

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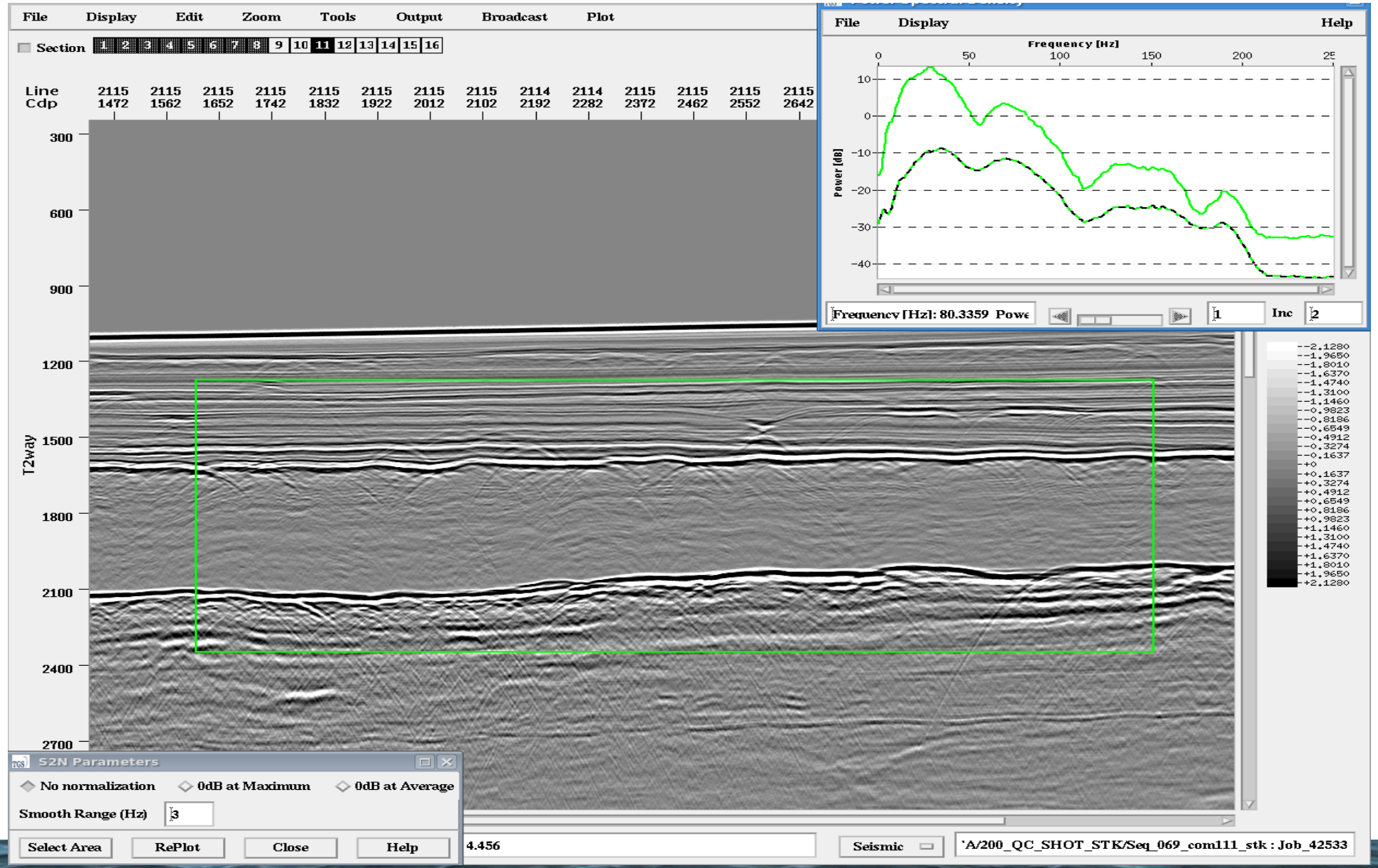
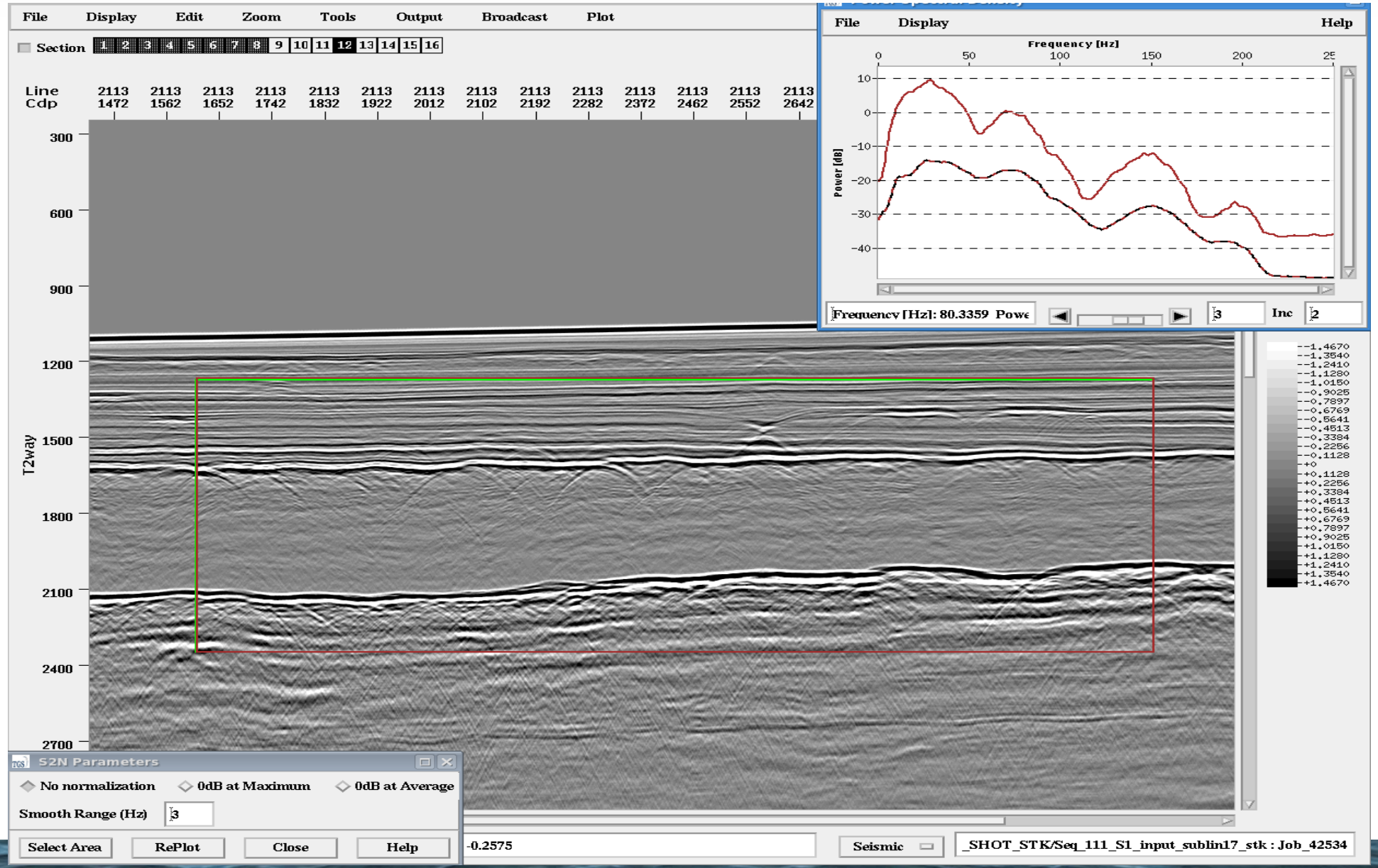
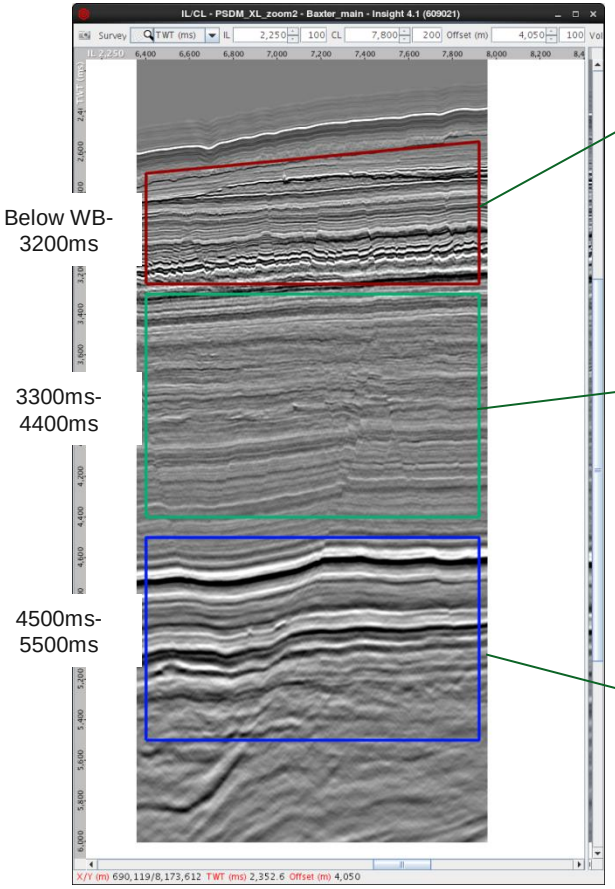
Seq 069: Stack Dual-Source Flip-Flop Sequential



Seq. 111: Stack Triple-Source Flop-Flop-Flap Sequential



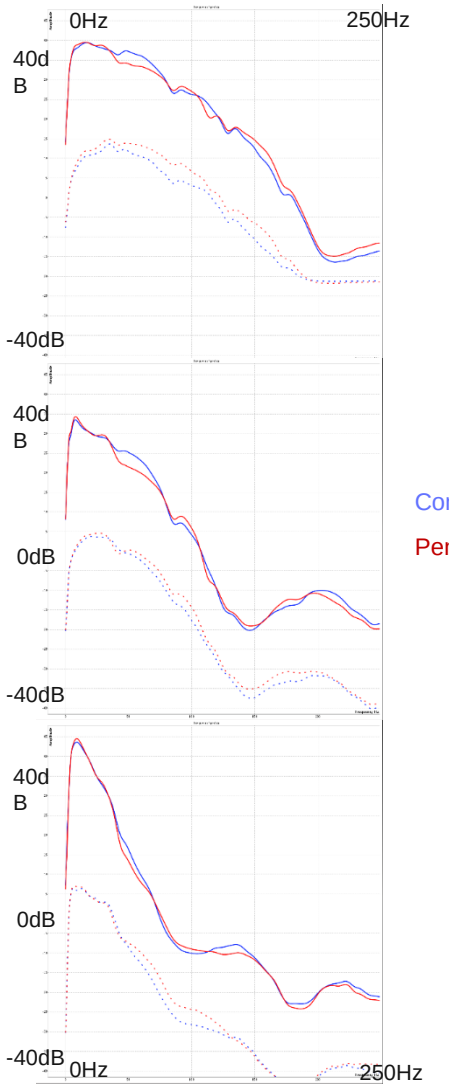
Estimated S/N PSDM processing



Below WB-3200ms

3300ms-4400ms

4500ms-5500ms



Conventional

Penta Source

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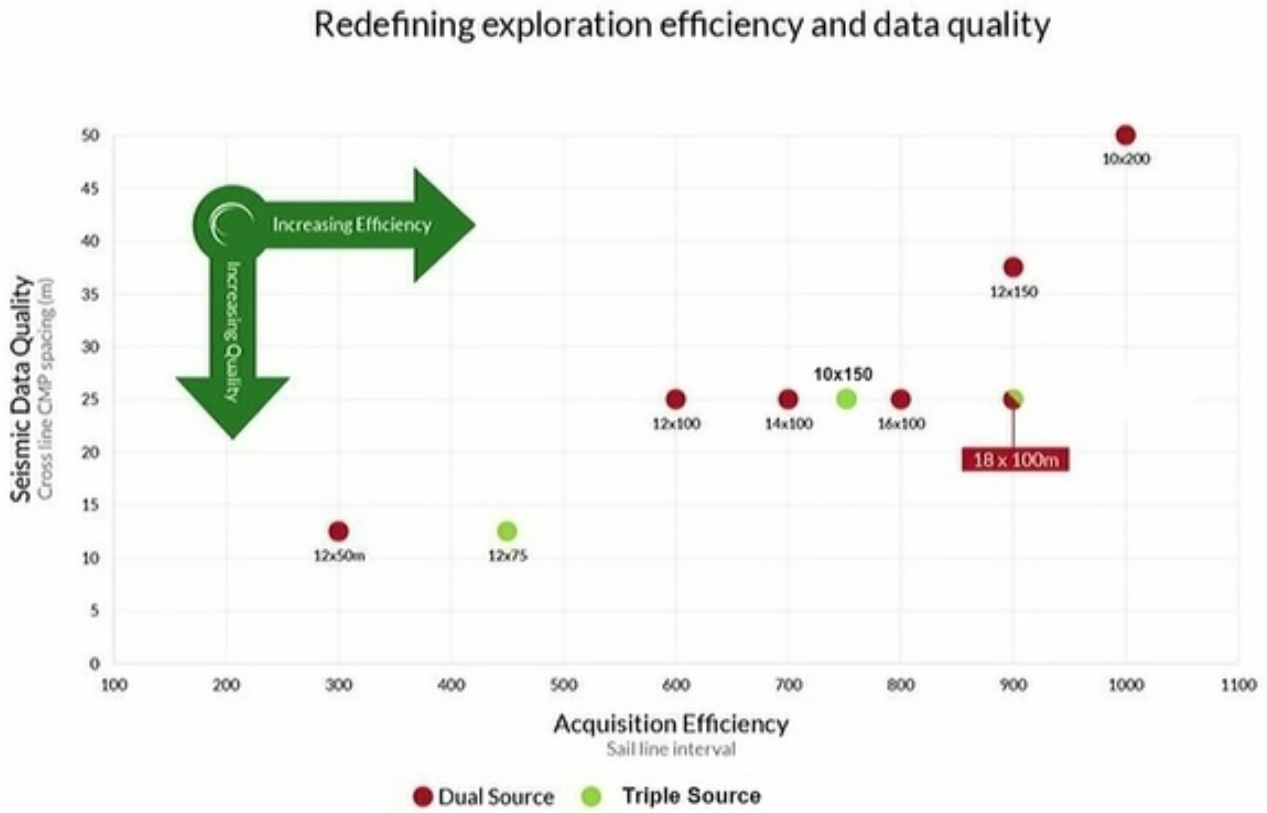
Triple Source Efficiencies



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Triple Source Efficiencies

Reduced Operational Risk and HSE Exposure

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Comparative Fuel Consumption: 12x100 Dual Source vs 14x100 Dual Source vs 10x150 Triple Source

		12x100x8 100 Dual Source	10x150x8 100 Triple Source	14x100x8 100 Dual Source
Sail line interval	(km)	0.6	0.75	0.7
Sail lines		100	80	85
CMP/sail line km	(CMP/km)	24	30	28
Estimated Towed Drag @ 4.5 knot	(kN)	875	957	999
Estimated Hull Drag @ 4.5 knot	(kN)	76	76	76
Total Drag @ 4.5 knot	(kN)	951	1,033	1,075
Propulsion Efficiency Factor @ 4.5 knot	(kW/kN)	6.2	6.2	6.2
Propulsion Power	(kW)	5,896	6,403	6,667
Generator Efficiency Factor	(g/kWh)	215	215	215
Propulsion Fuel Consumption	(ton/day)	30.4	33	34.4
Fixed Fuel Consumption	(ton/day)	13	13	13
Total fuel	(ton/day)	43.4	46	47.4
Relative consumption	(ton/day)	43.4	36.8	40.3
Reduced fuel consumption and emissions		**100%**	**85%**	**93%**

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Shot Interval vs Overlap Time vs Trace Density
14x100 Dual Source vs 10x150 Triple Source

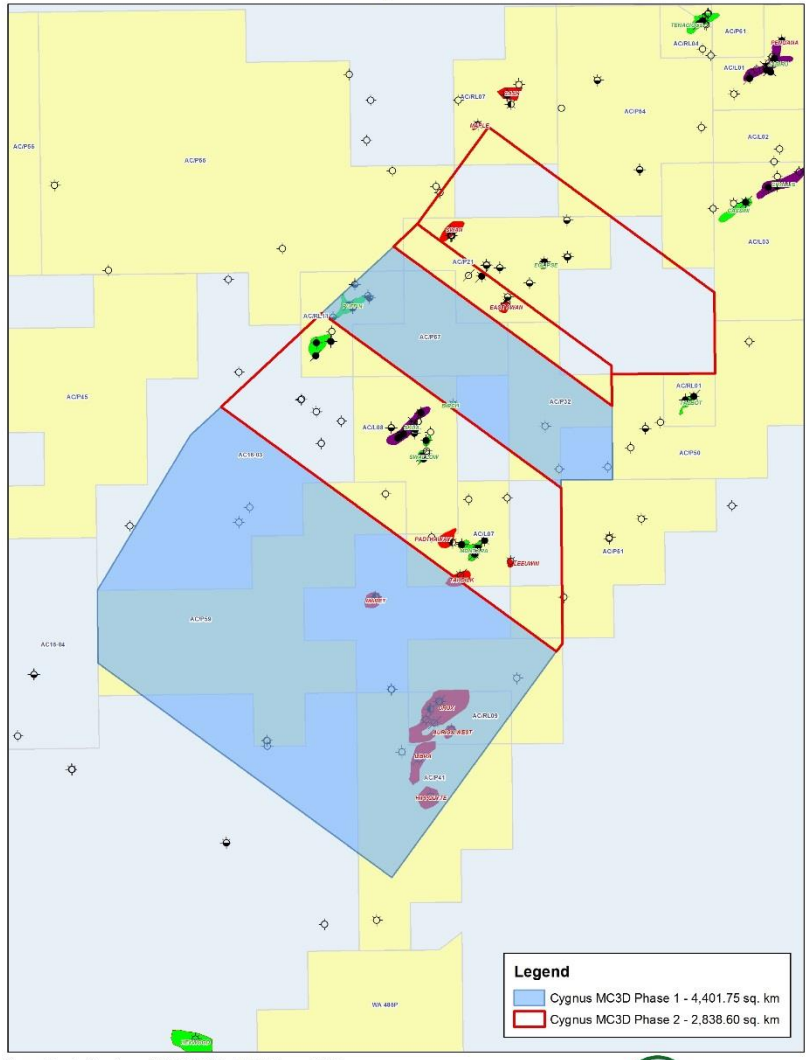
Streamer Spread	Number of sources	Source Separation (m)	Cross-line CMP (m)	Shot Interval (m)	Source Interval (m)	Nominal Bin Fold*	Shot Overlap Time (s)**	Sail-Line Interval (m)	Trace Density (traces/sq km)
Dual Source									
14x100	2	50	25	25.000	50.00	81	10.80	700	518,200
16x100	2	50	25	25.000	50.00	81	10.80	800	518,400
Triple Source									
10x150	3	50	25	12.500	37.50	108	5.40	750	691,028
10x150	3	50	25	9.375	28.13	144	4.05	750	921,371
10x150	3	50	25	8.300	24.90	163	3.59	750	1,036,957

Nominal Bin Fold*	Based upon 8100m streamer length and 12.5m group interval
Shot Overlap Time (s)**	Shot interfernce occurs at this time below mud-line for 4.5kt vessel ground speed

Trace Density = Num of Streamer Channels x Num of Inline shots/km x Num of Crossline sail line/km

Cygnus – Triple Source

Cygnus Multi-Client 3D Survey
Vulcan Sub-basin, Western Australia



- **Cygnus 3D (7,240 km^2) Vulcan sub-basin**

- Survey located between Ashmore Platform and Londonderry High
- general structural trend is NE-SW
- parameters chosen to significantly enhance imaging from Paleogene to Permian

- **Existing data and reprocessing of it, is inadequate for the sub-surface imaging**

- **New Broadband 3D is required:**
  - Shooting in dip direction
  - Adding more shots (triple source); increased ray-paths (108 fold)
  - Narrower x-line bin size (18.75m)
  - Longer offsets (8,100m)
  - RIGHTBAND – de-ghosting to increase low-frequency resolution (6m source, 15m streamer)

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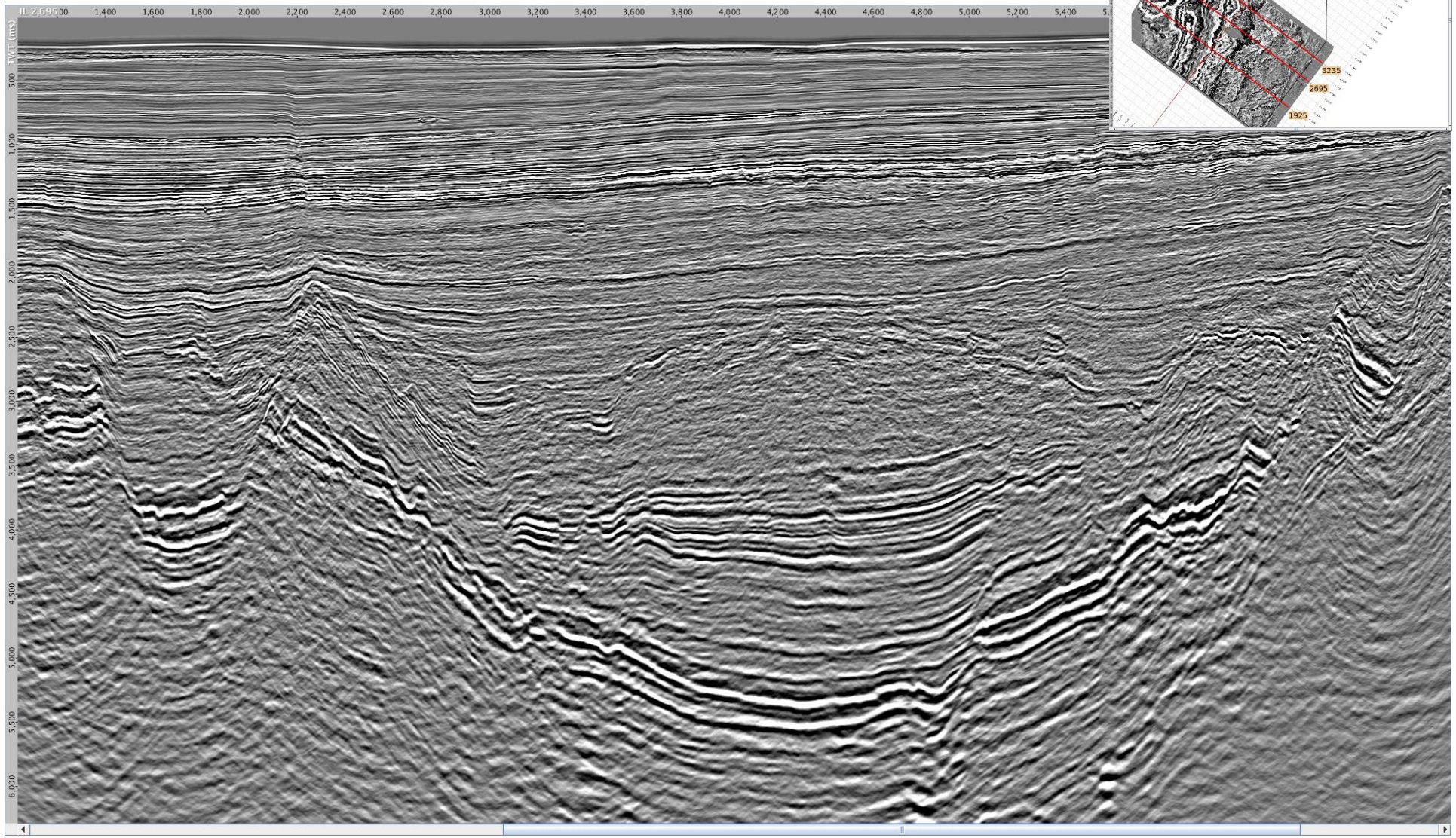
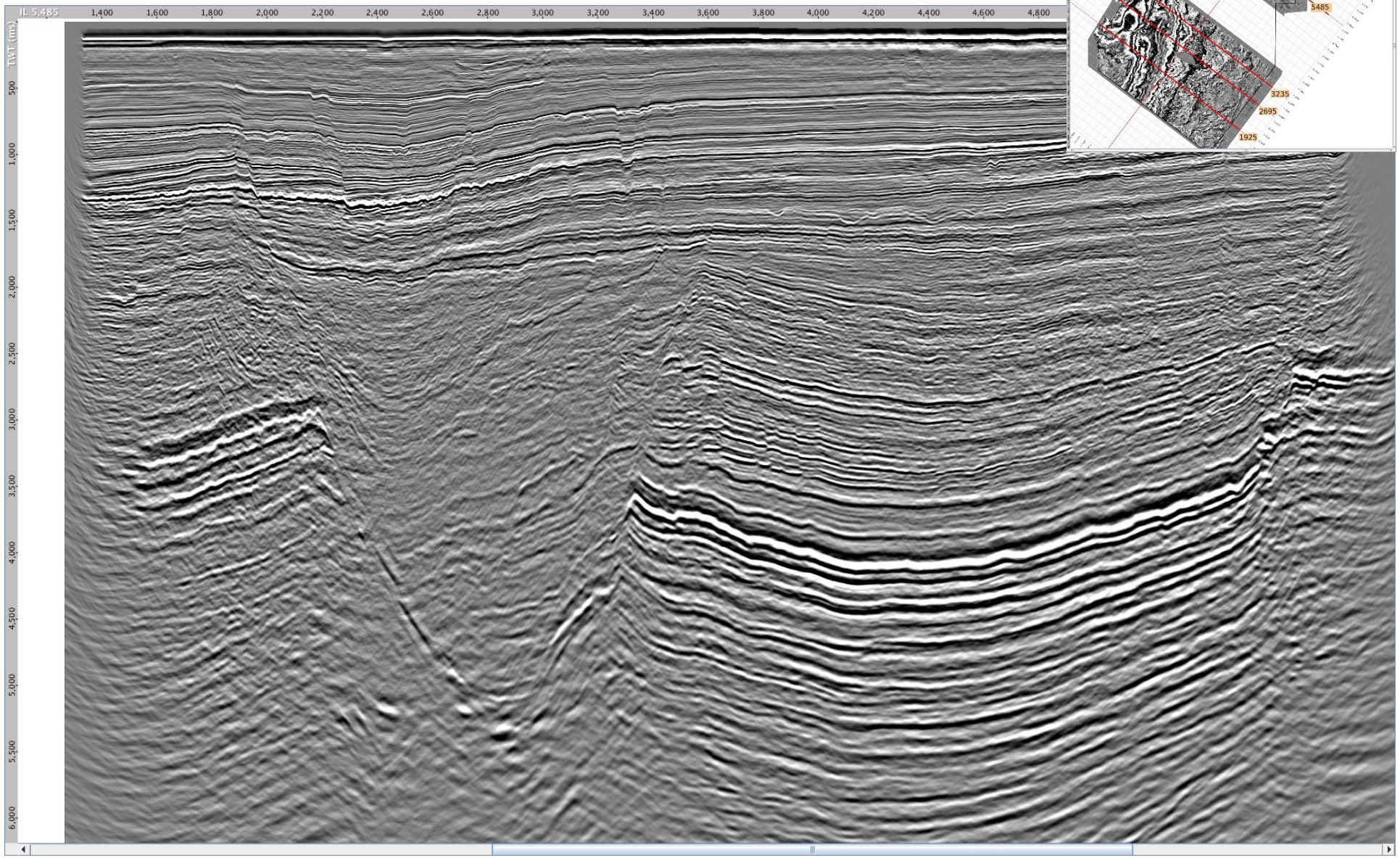
Final PreSDM, Inline 2695



Polarcus

Final PreSDM, Inline 5485



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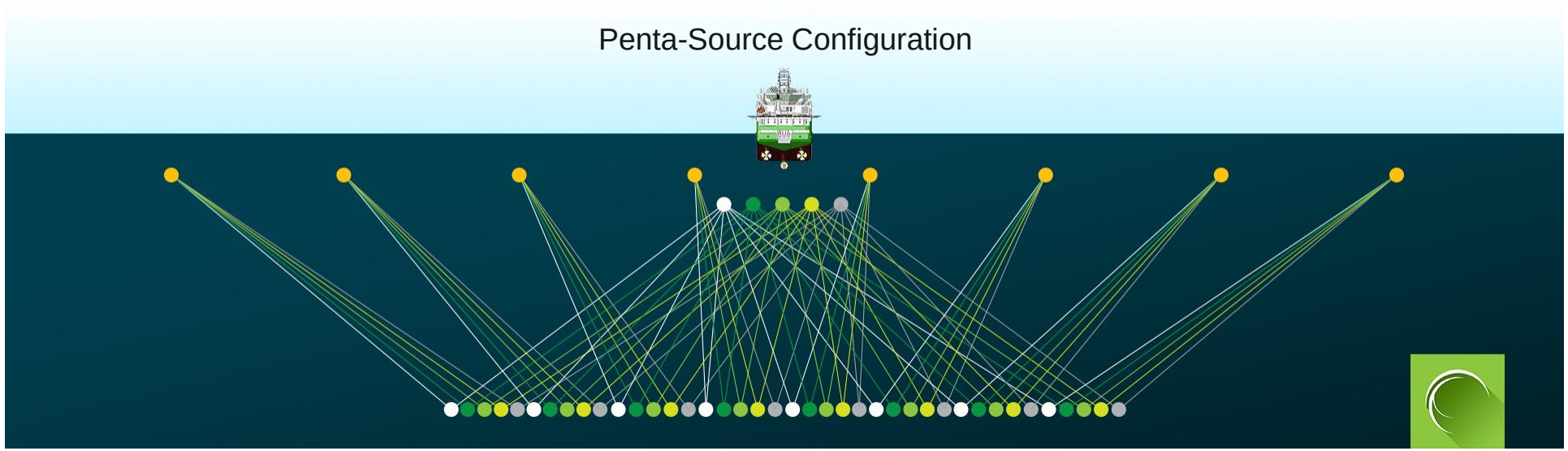
Penta-Source

Multi-Source Acquisition : Higher Geophysical Fidelity

- Designed to provide 6.25-meter cross-line sampling with real data using conventional streamers



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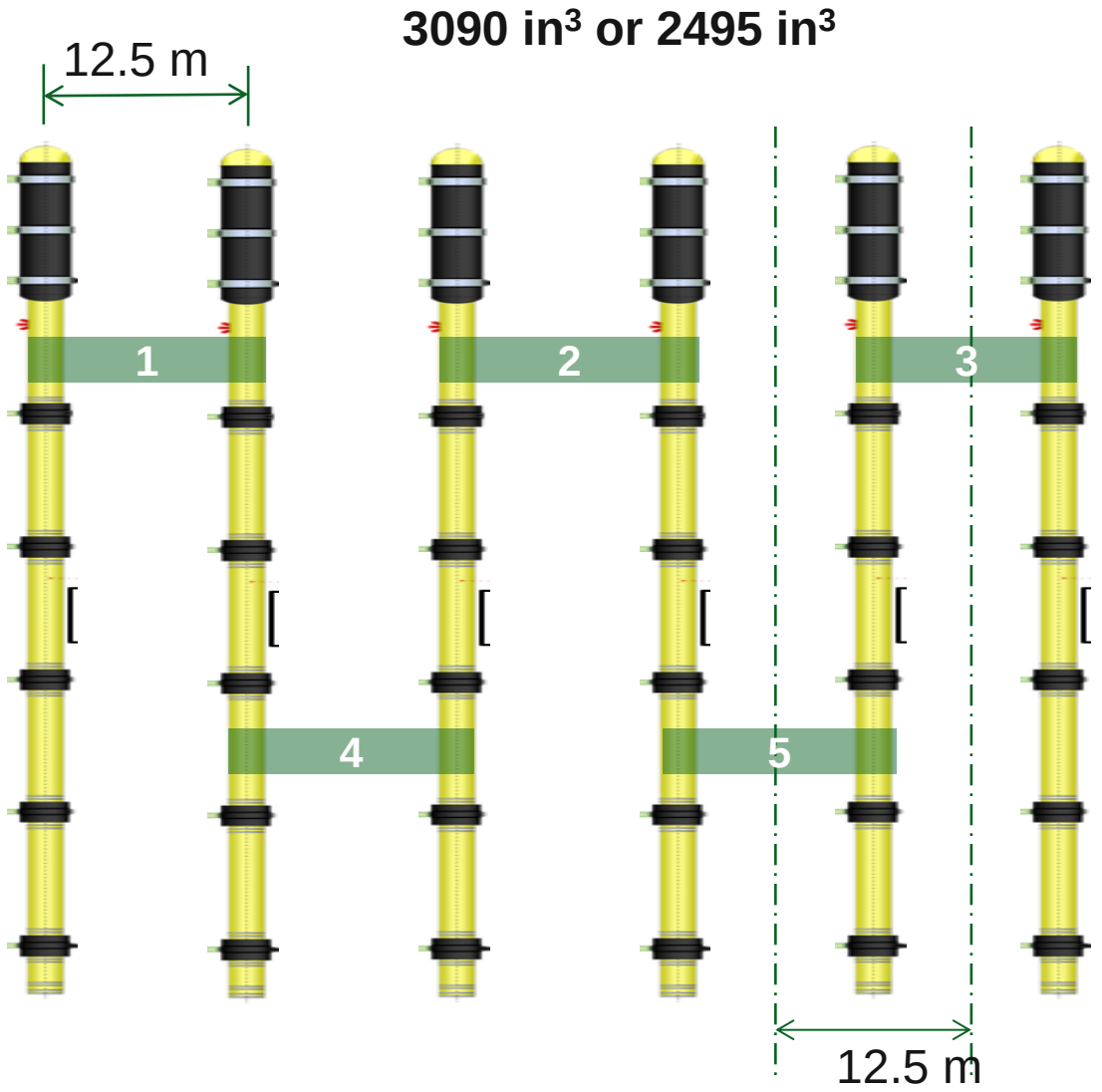
Penta-Source Array Configuration



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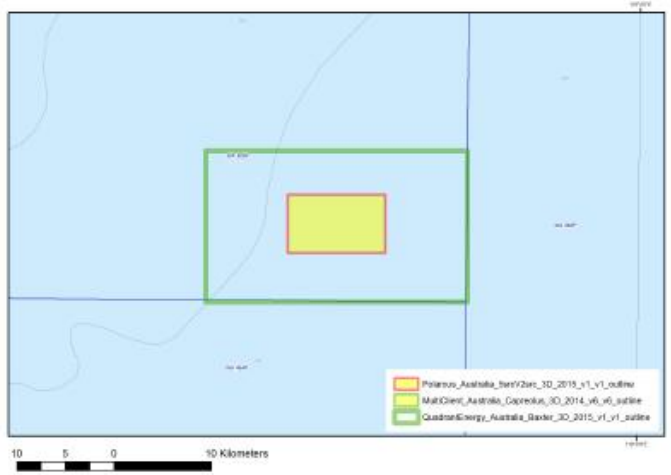
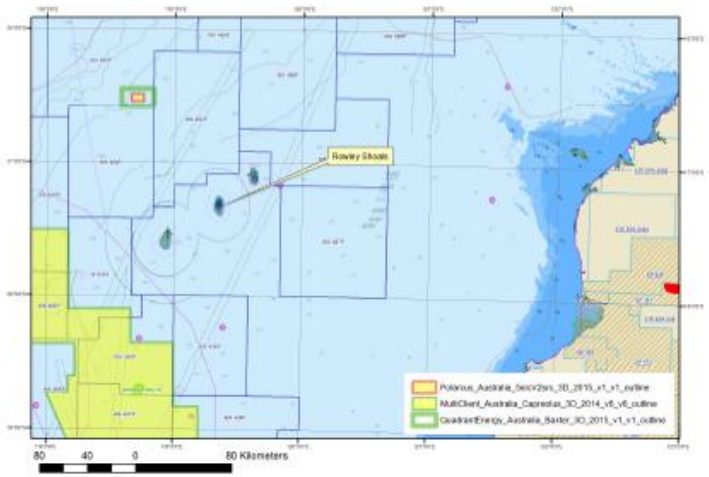
Baxter Five-Source Survey



Test Area



Main Area in Green = 417 km^2
Acquired with Penta-Source configuration for 6.25m cross-line with 9,000m streamers

Conventional “Control Area” in yellow = 60 km^2
Acquired with 10 x 100 x 9,000m and dual 3-string source arrays

SEG 2016 - Dallas

Baxter: a high-resolution penta-source marine 3D seismic acquisition

Ed Hager, Polarcus; Rob Kneale, Laurence Hansen, Quadrant Energy; Troy Thompson, DownUnder GeoSolutions

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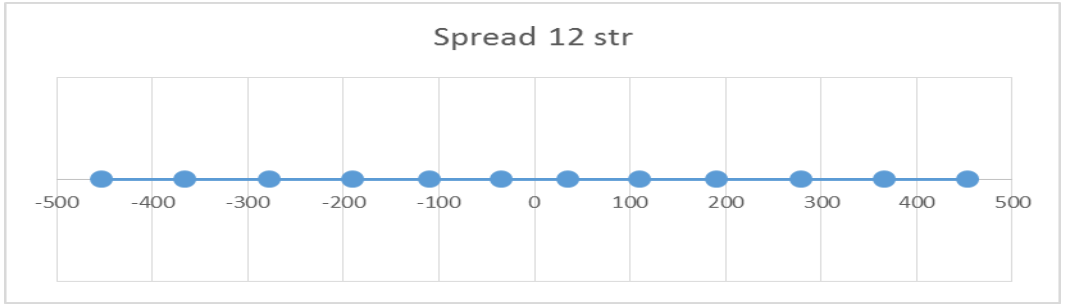
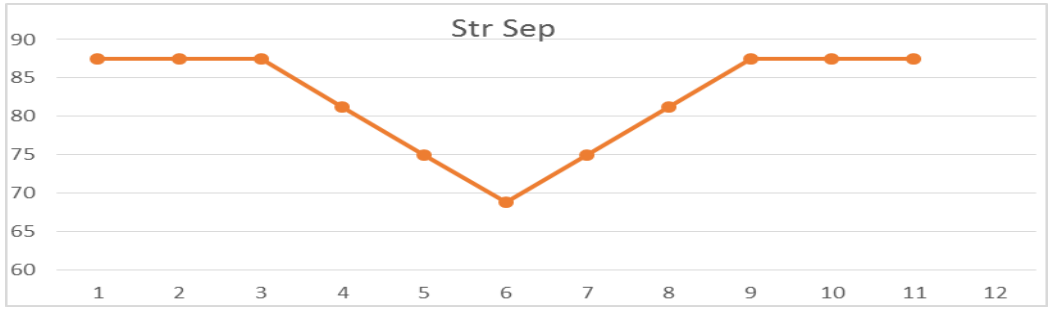
Streamer Separation

- Efficiency gained by hit-5 miss-2 sub-surface lines
- Closer separation on the inner cables, use wider on outer to give reasonably even coverage with fan





Streamer	Sep	#column (@6.25)
1		
	87.5	14
2		
	87.5	14
3		
	87.5	14
4		
	81.25	13
5		
	75	12
6		
	68.75	11
7		
	75	12
8		
	81.25	13
9		
	87.5	14
10		
	87.5	14
11		
	87.5	14
12		

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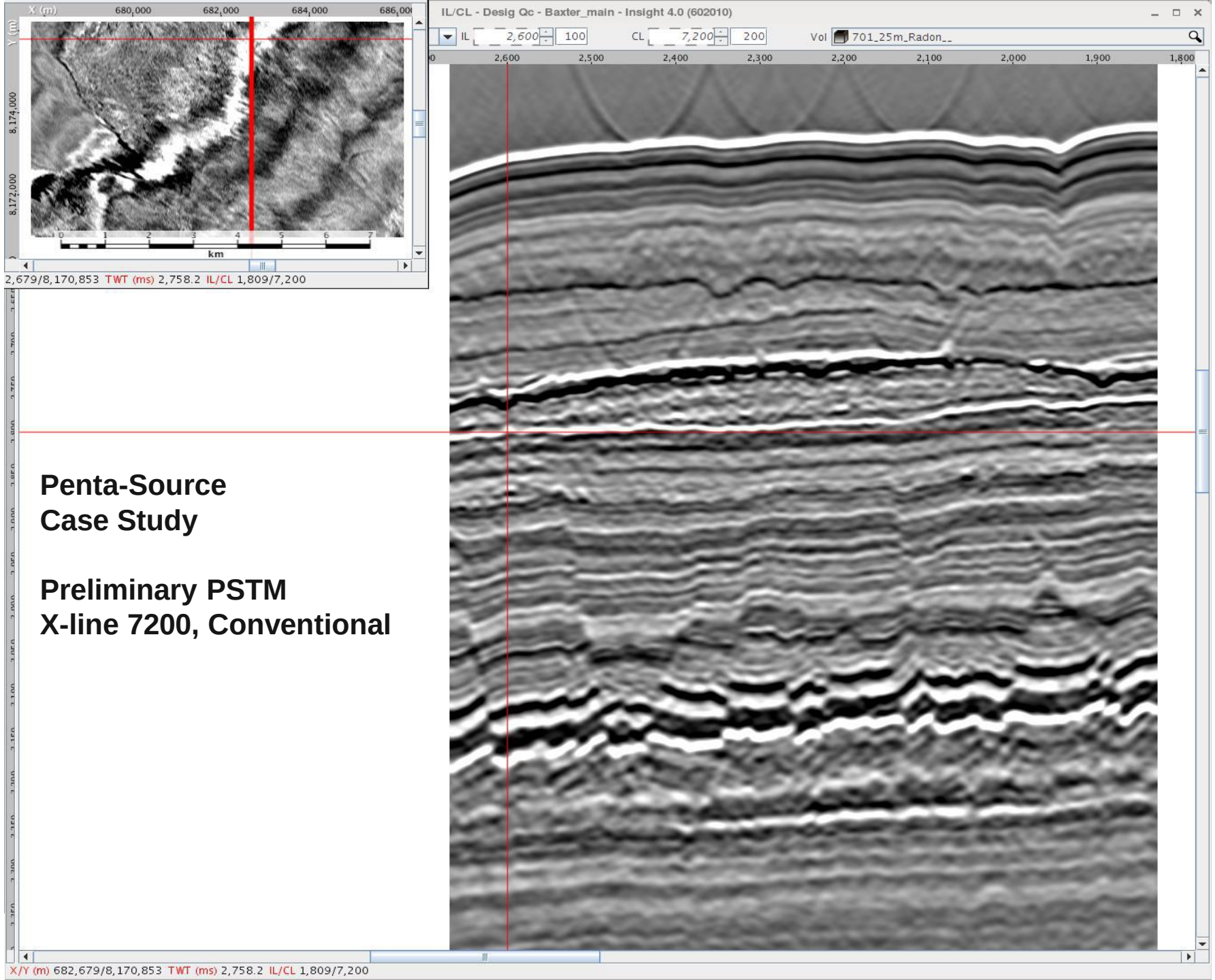

Penta-Source
Case Study

Preliminary PSTM
X-line 7200, Conventional

Quadrant Energy

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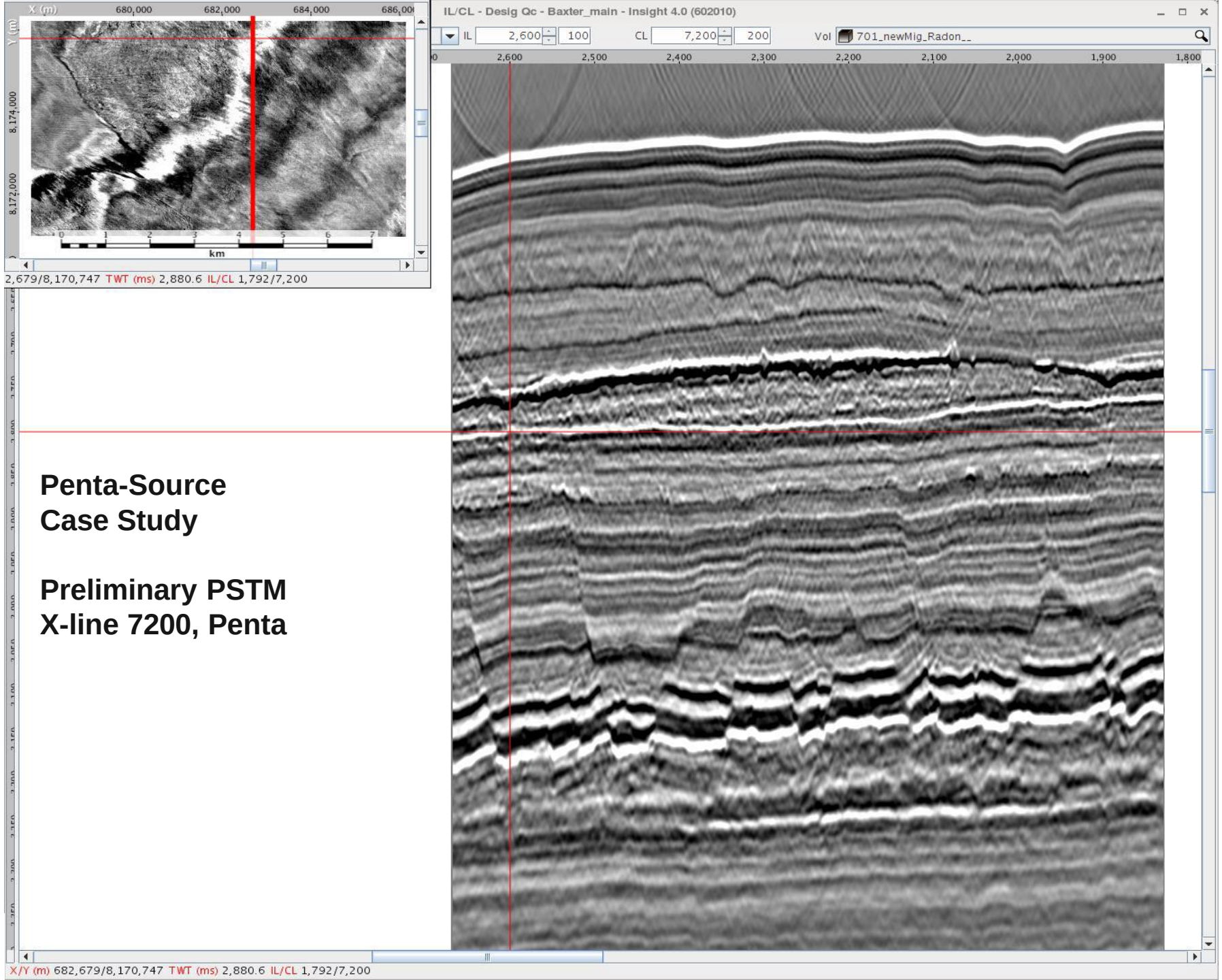

Penta-Source
Case Study

Preliminary PSTM
X-line 7200, Penta

Quadrant Energy

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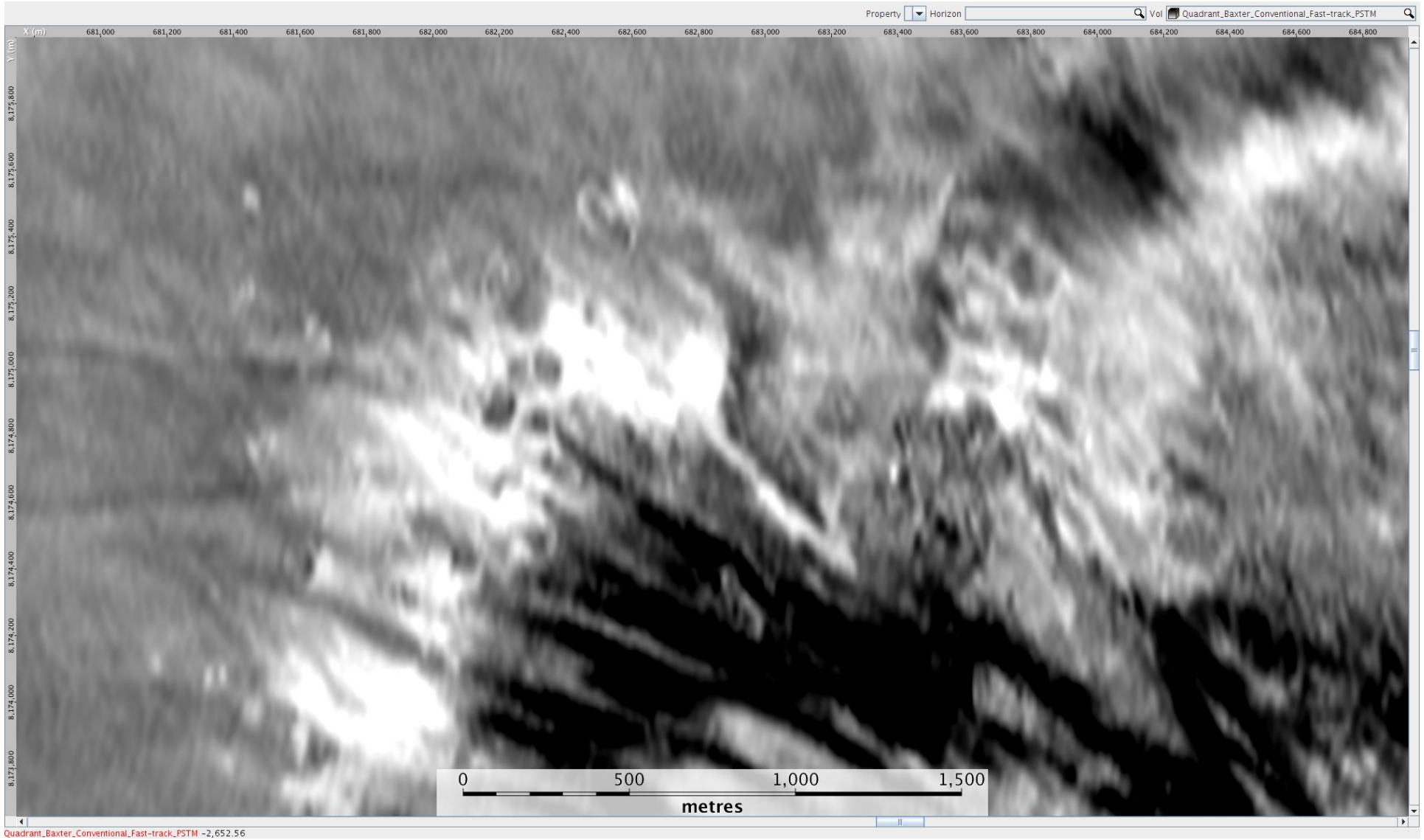
Penta-Source : Case Study : Time Slice 2720 ms, Conventional



Quadrant Energy

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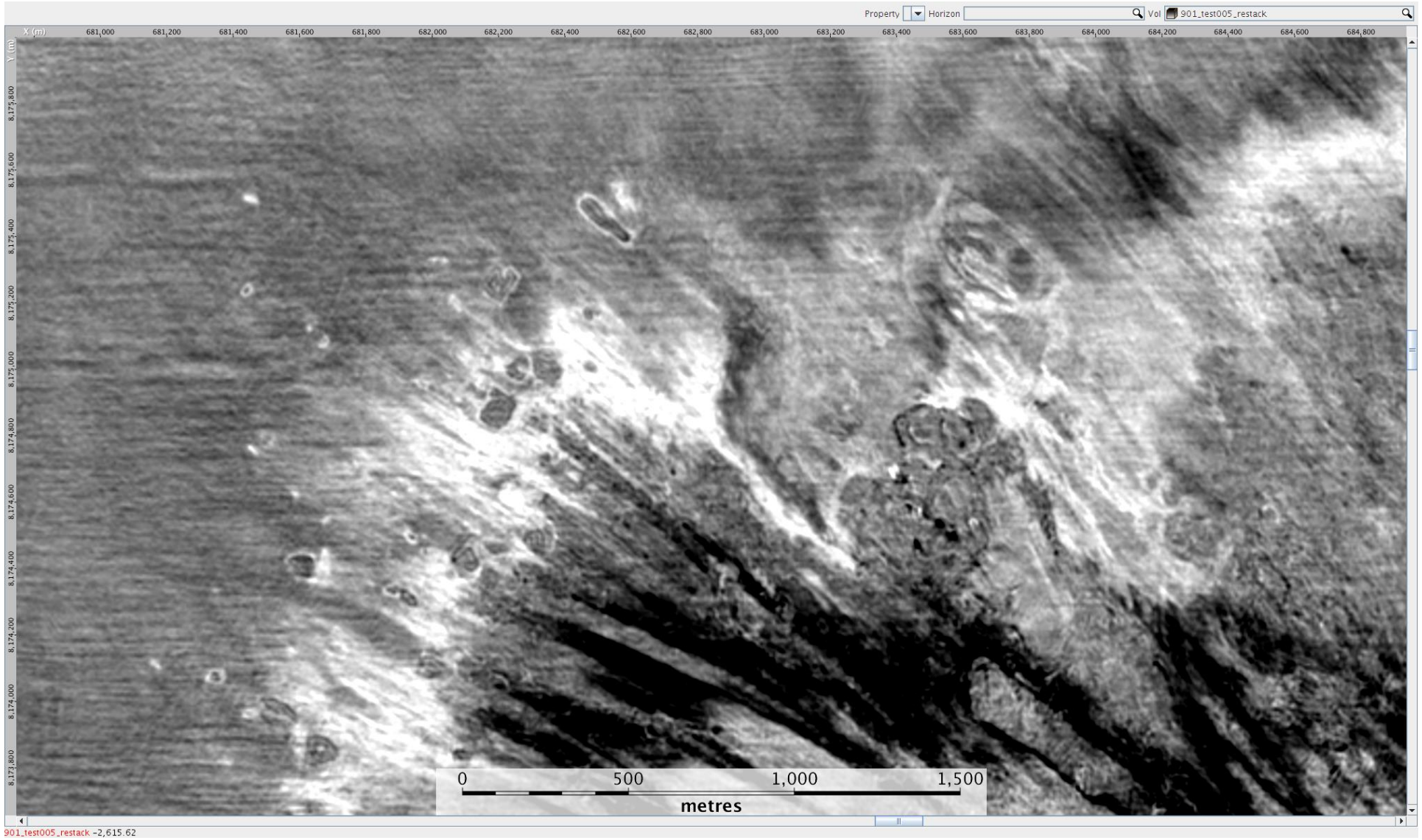
Penta-Source : Case Study : Time Slice 2730 ms, Penta-Source



Quadrant Energy

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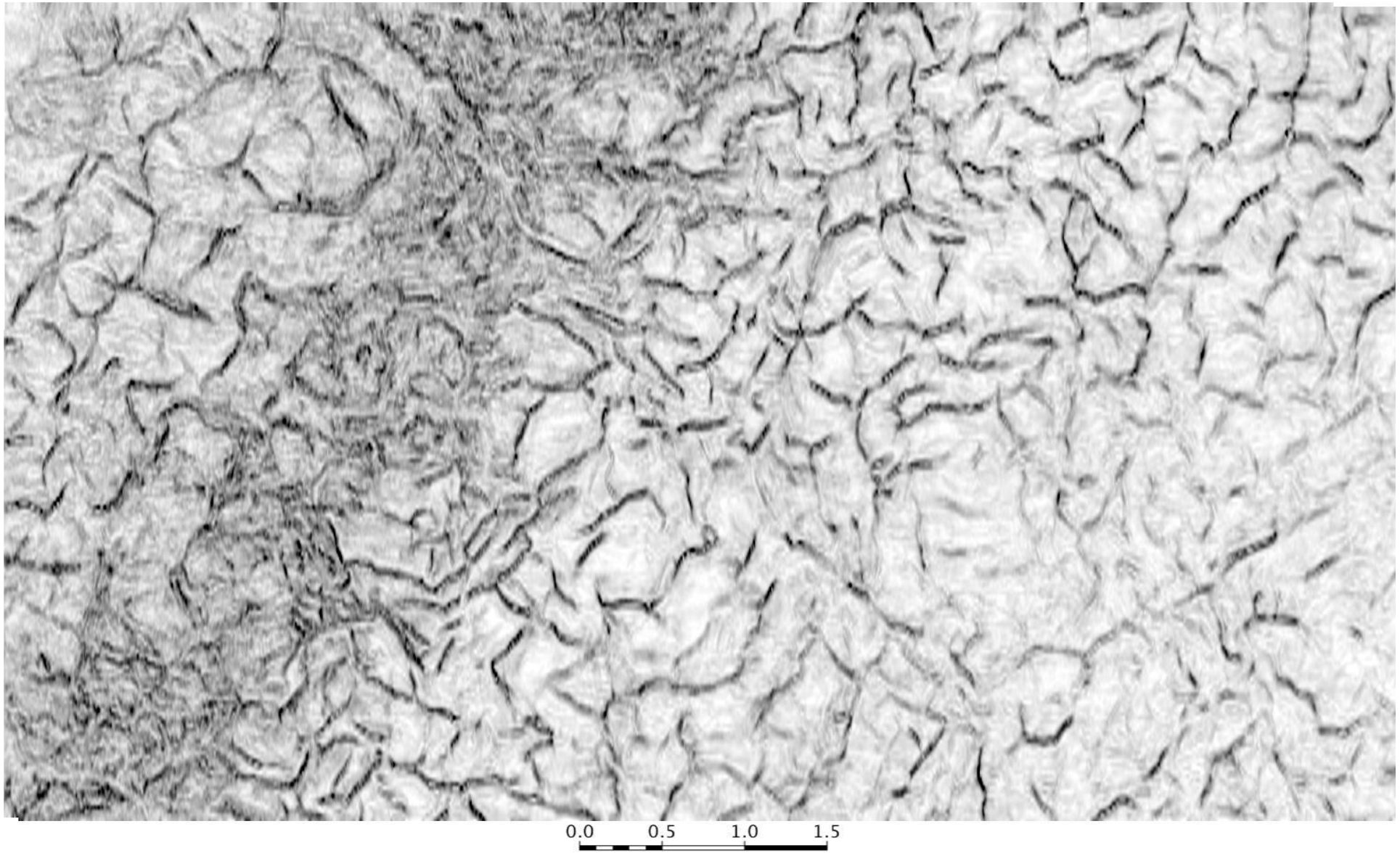
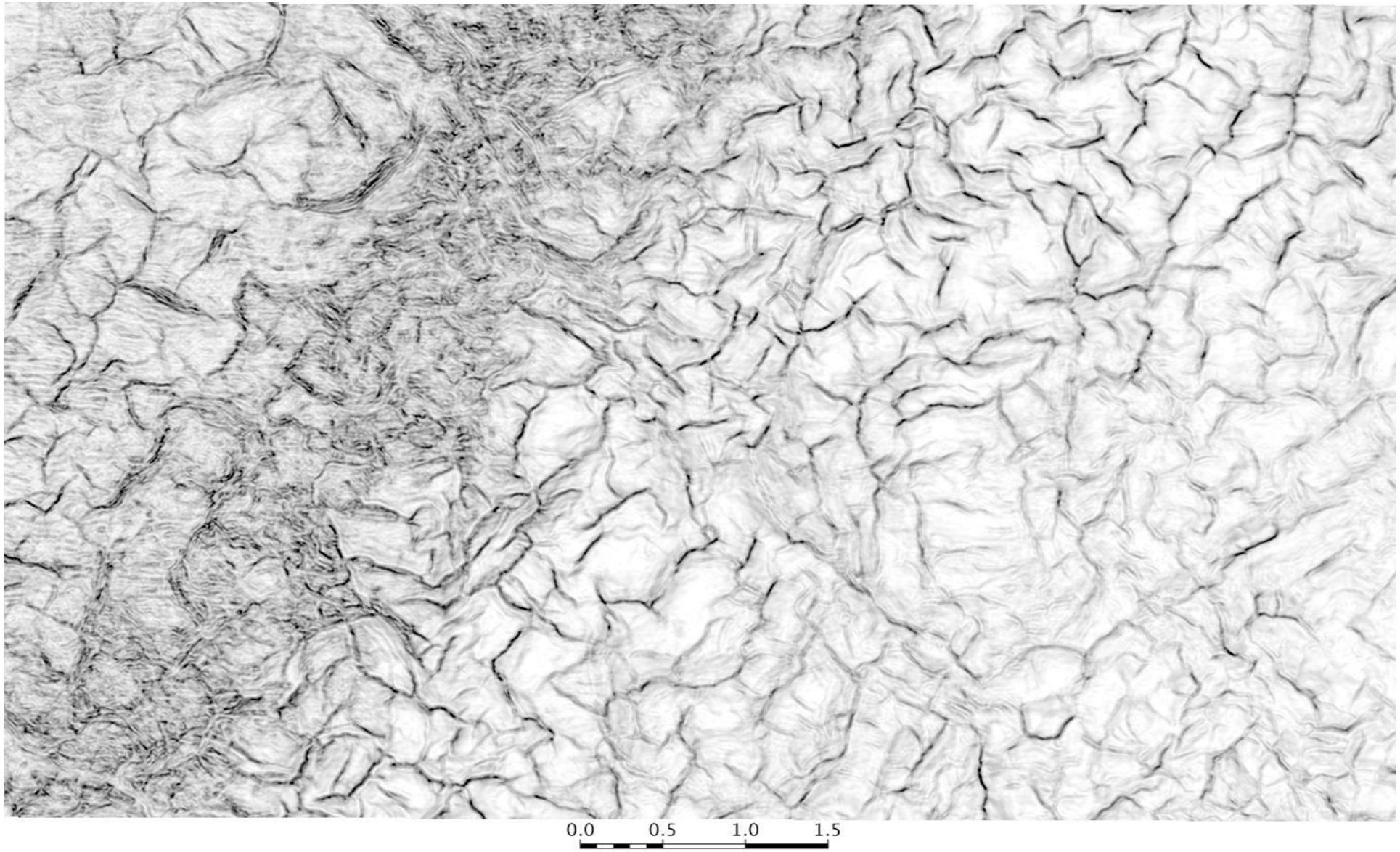
Penta-Source : Case Study : Coherency 3100 ms, Conventional



Quadrant Energy

Polarcus

Penta-Source : Case Study : Coherency 3100 ms, Penta-Source



Quadrant Energy

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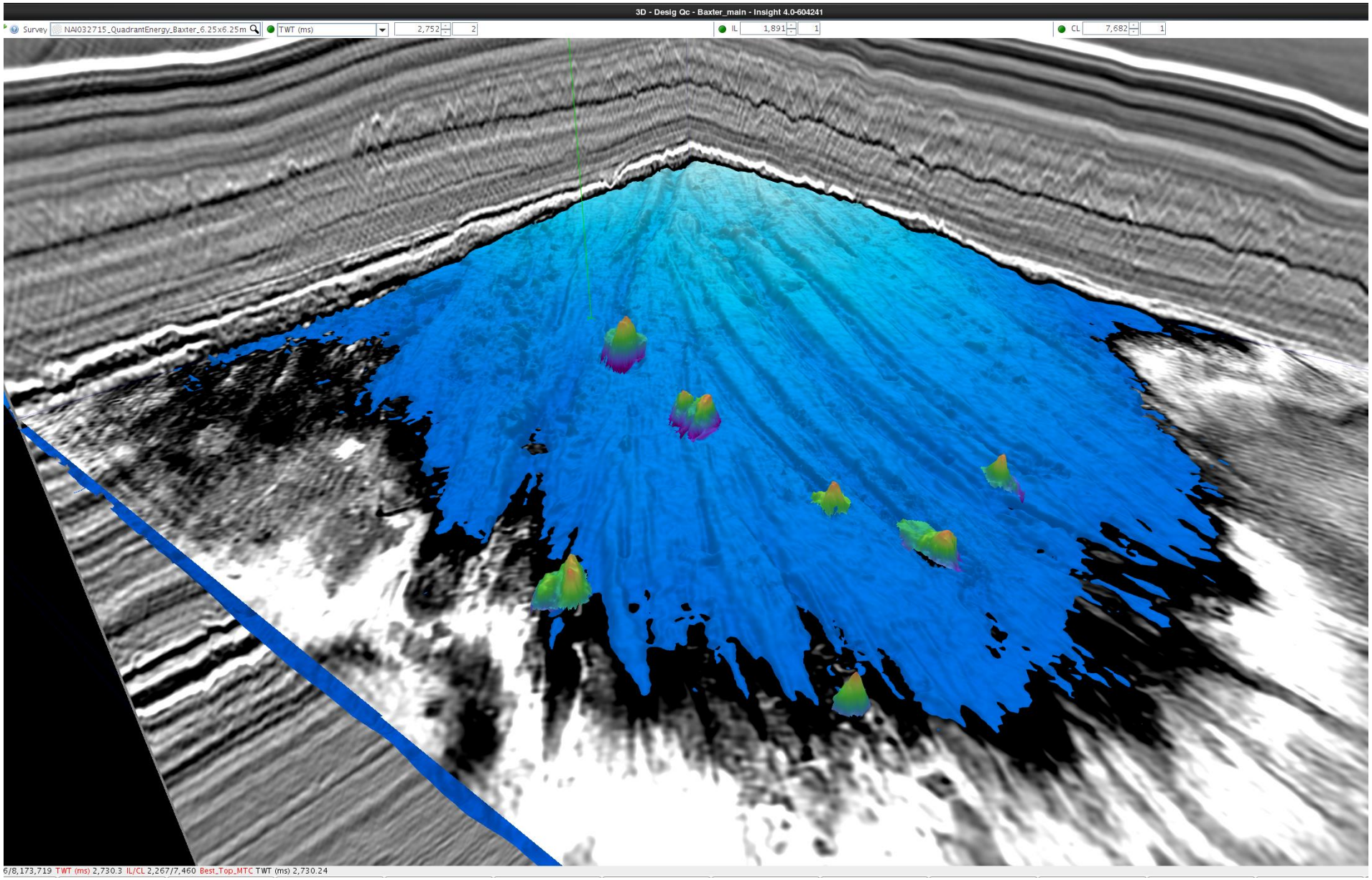

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Multi-Source Surveys

- Completed 2015 -2016 :
  - Triple Source, TGS Barents Sea
  - Triple Source, PLCS Cygnus
  - Triple Source, Apache Suriname
  - Triple Source, Ophir Indonesia
  - Triple Source, Edison Barents
  - Triple Source, Malta
  - Penta Source, Quadrant Australia

- Expected 2017:
  - Triple Source, Norway (30,000 sq km awarded)
  - Triple Source, Brazil
  - Triple Source, Ireland
  - Penta-Source, Arabian Gulf (tested)
  - Penta-Source, Netherlands

Conclusions

- Leveraging de-blending of overlapping shots provides the opportunity to sample 3D towed streamer seismic data with more sources and less streamers.
- Sources can be used to increase overall efficiency and/or increase inline and crossline trace sampling density.
- The reduction of the number of streamers provides a significant reduction in capital costs and risks, operational risks, and HSE exposure during deployment, retrieval, and daily streamer maintenance.
- Result - More, better, quicker!

Thank you for your time and attention

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