Understanding the Root Cause of Poor Seismic Data Through Modelling*

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Abstract

Enabled by ongoing advances in computer technology and processing algorithms, pre-acquisition feasibility studies using synthetic data are becoming more and more accepted in the marine environment. For marine acquisition the near-surface is relatively simple acoustic medium which simplifies the computational task for synthetic modelling, enabling large-scale 3D seismic simulations for various scenarios to be run within a reasonable time frame. In comparison with onshore acquisition the near surface is a much more complex elastic medium which makes finite- difference simulation modelling significantly more compute intensive.

Through developments in modelling and inversion technology a suite of tools are now available which allow us to build complex near-surface models without having to revert to full elastic finite-difference modelling. Consequently multiple near-surface models may be generated in a relatively short period of time.

This article demonstrates how it is possible to gain an understanding of the onshore near-surface in absence of direct measurements, such as uphole surveys. We can utilize the existing seismic data to support near-surface model building and the generation of realistic synthetics.

By varying the parameters of the Earth model and comparing synthetic data with the real seismic data, it is possible to gain an understanding of the mechanisms behind the noise trains visible on the real seismic data. We can then analyze how to optimize selection of acquisition parameters and data processing schemes with respect to both signal and noise.

Such analyses can include evaluation of the effects of geometry, fold, arrays and noise interference introduced by high productivity techniques. The article gives a case-study example of such a workflow approach where it was used to uncover the potential root cause of poor legacy seismic data quality.

Reference Cited

Jack, I., 2013, Progress in land seismic technology: Finding Petroleum, Oil Voice Forum, London, 7 March, 2013. 41p. Website accessed September 27, 2016, http://64be6584f535e2968ea8-7b17ad3adbc87099ad3f7b89f2b60a7a.r38.cf2.rackcdn.com/Jack.2013.OilVoiceForum.March.Rev3.pdf.

Understanding the root cause of poor data through modelling

Anastasia Poole & Peter van Baaren

Presented by John Quigley

GEO2016 08th March 2016, Bahrain

WesternGeco

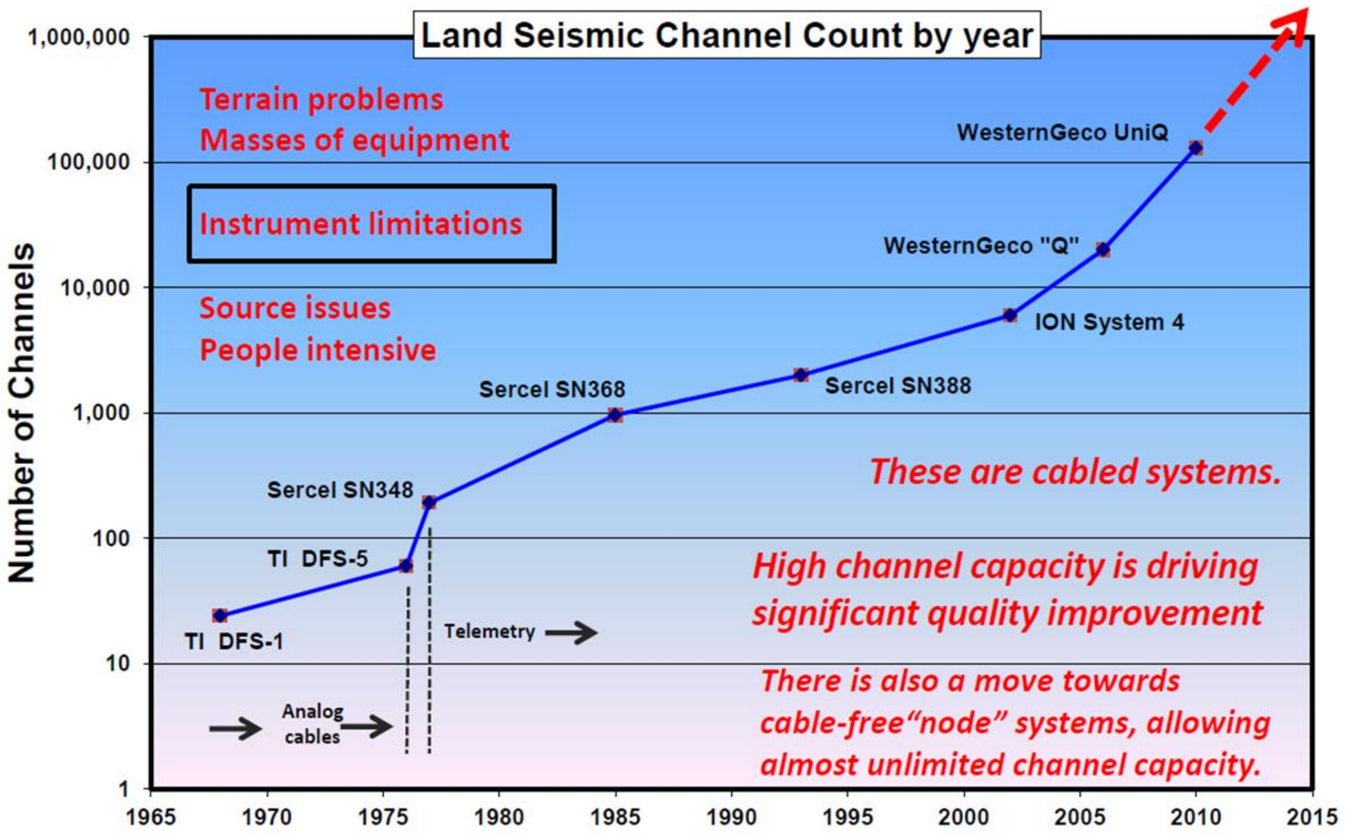
Conclusions

Modelling allows:

- Separation of contributing factors
  - Signal
  - Coherent noise
  - Ambient noise
- Test both acquisition and processing schemes together
- Test different hypotheses
- Quantify errors

Towards “better” data

- Increased fold
- Full azimuth
- Broadband energy
- Point source
- Point receiver
- High trace density

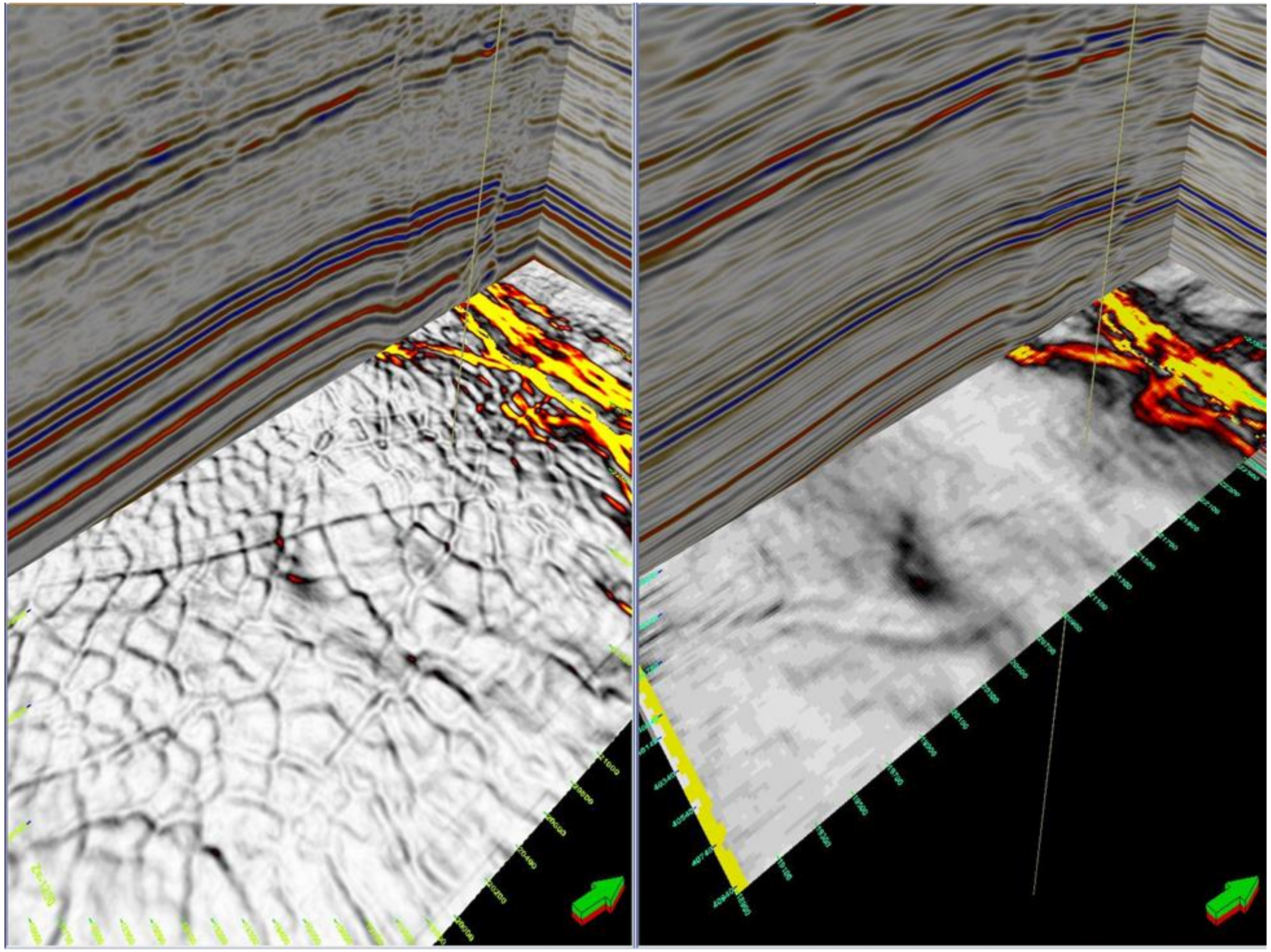


Ian Jack, ‘Progress in land seismic technology’, Finding Petroleum, Oil Voice Forum, London, 7th March 2013

Modelling allows investigating these beliefs before acquiring data

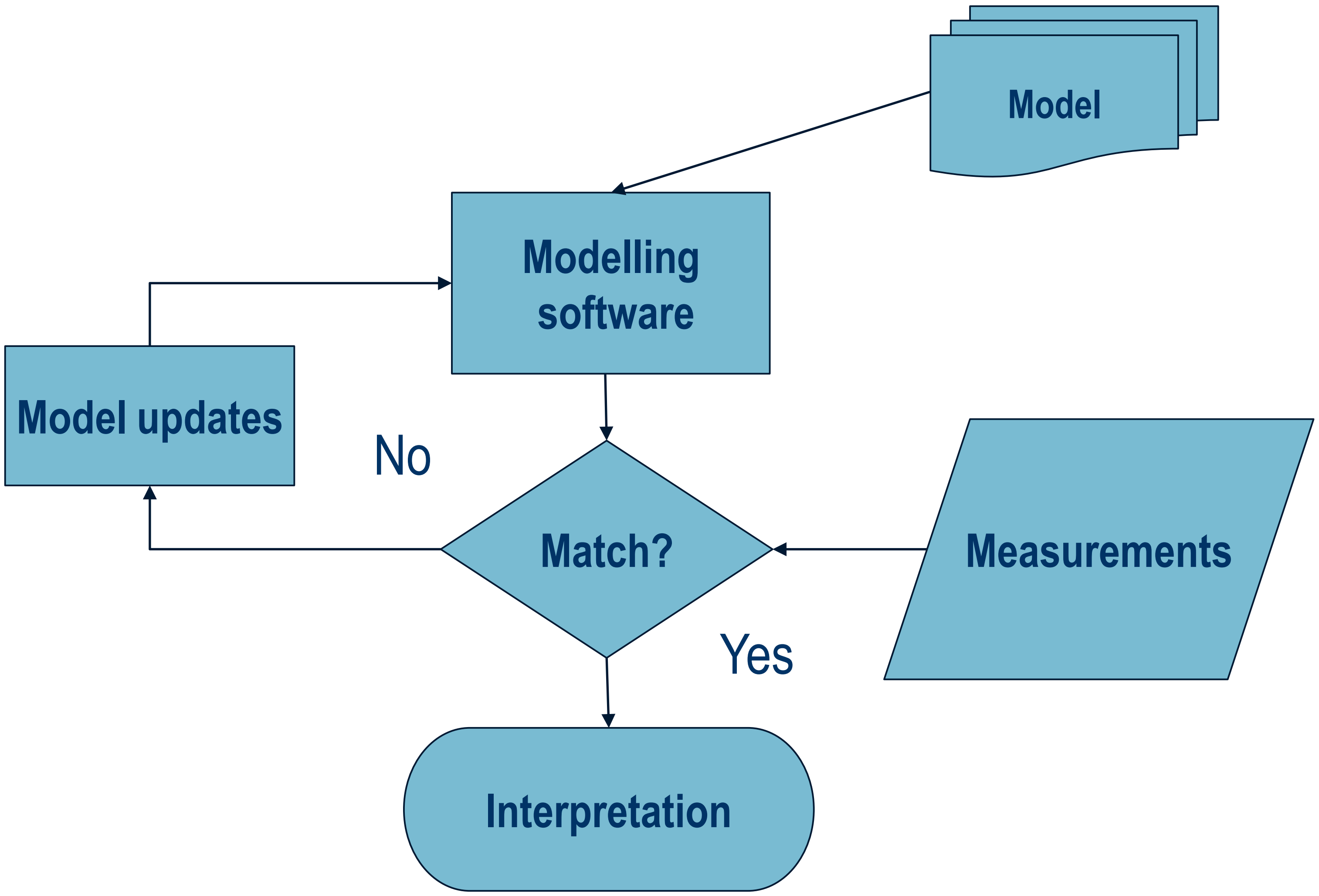
Better data

- Good well ties
- Stable wavelet
- Fits geologic model

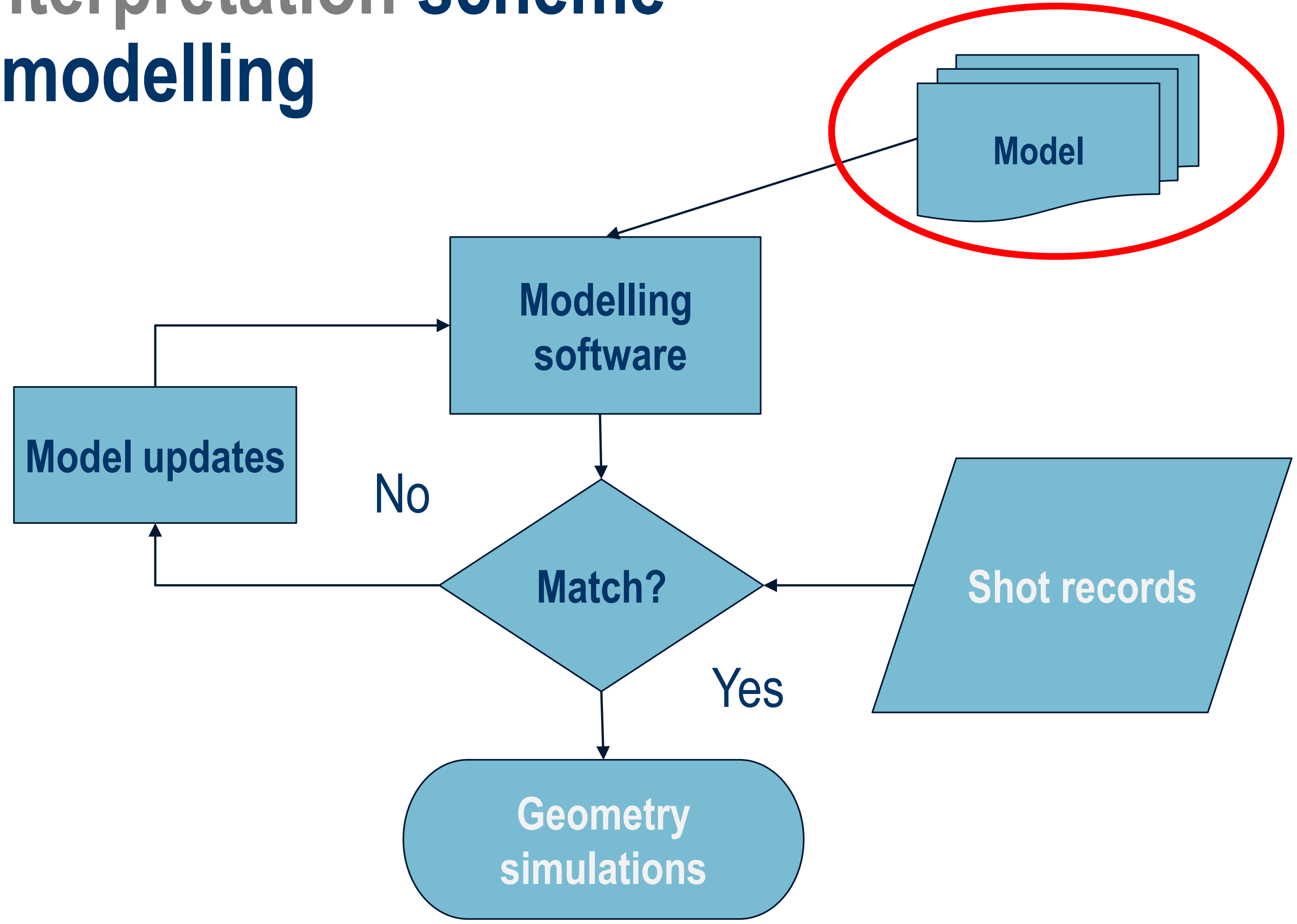


PSPR Full Offset & Azimuth   Legacy Array Limited Offset & Azimuth

Iterative interpretation scheme



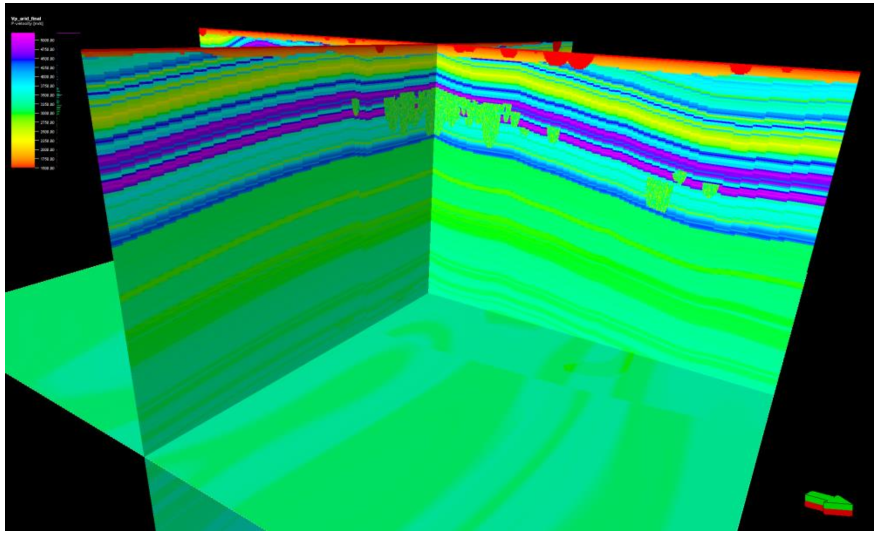
~~Iterative interpretation~~ scheme
Forward modelling



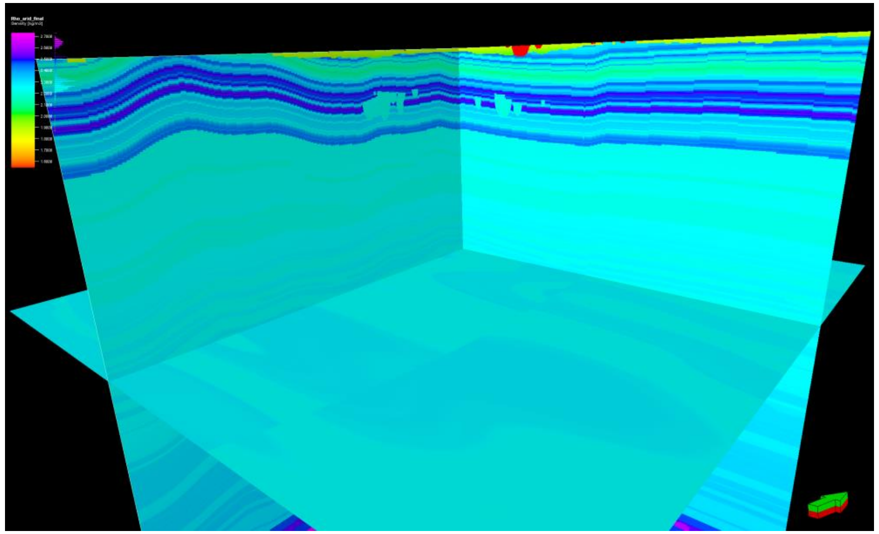
Full elastic models - Example 3D model

SEG SEAM Arid Model - 3D depth model with following properties:

Vp, Vs, Rho/Density, HTI alpha, HTI delta, HTI gamma, HTI azimuths, Qp



Vp

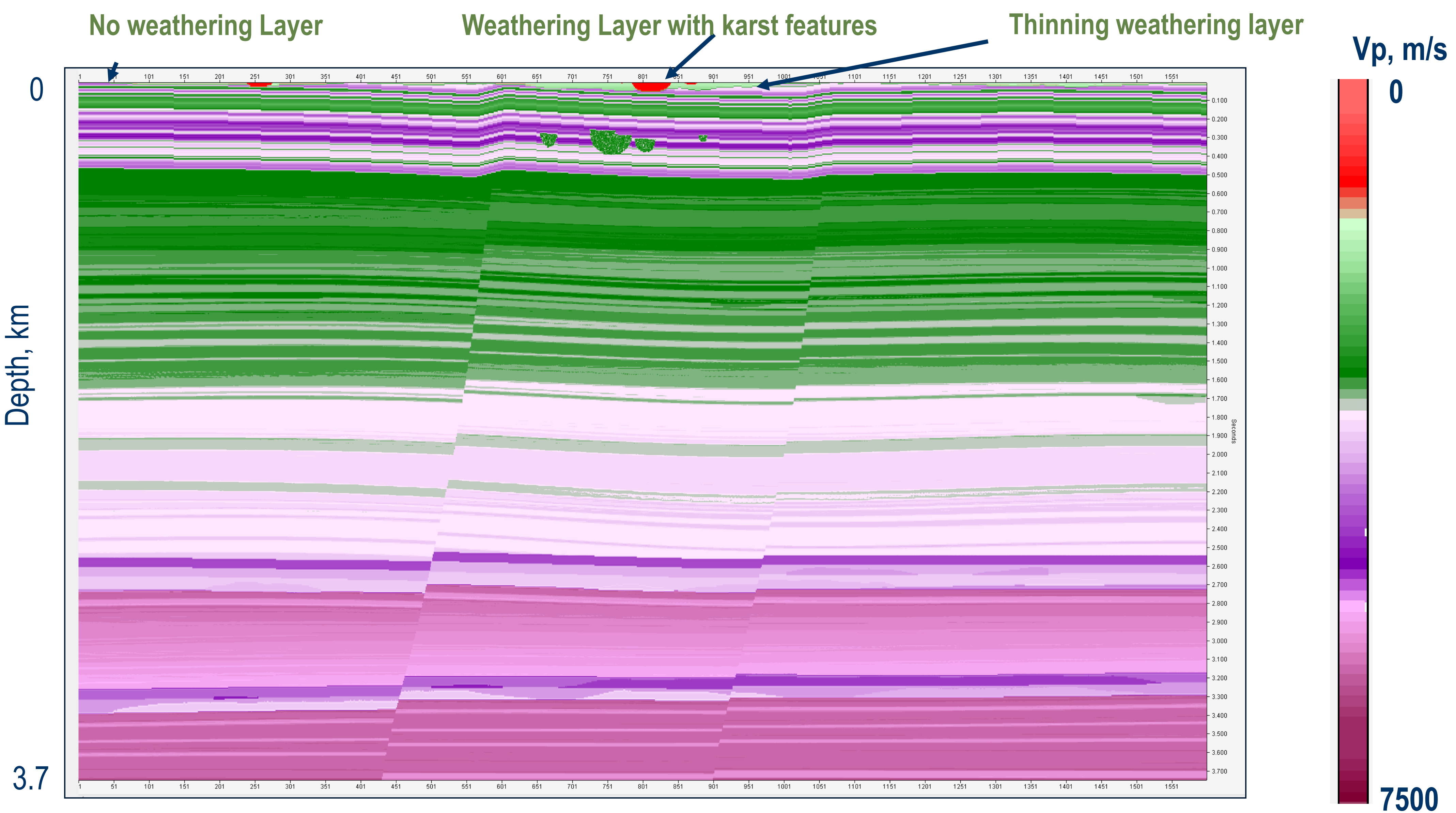


Rho / Density

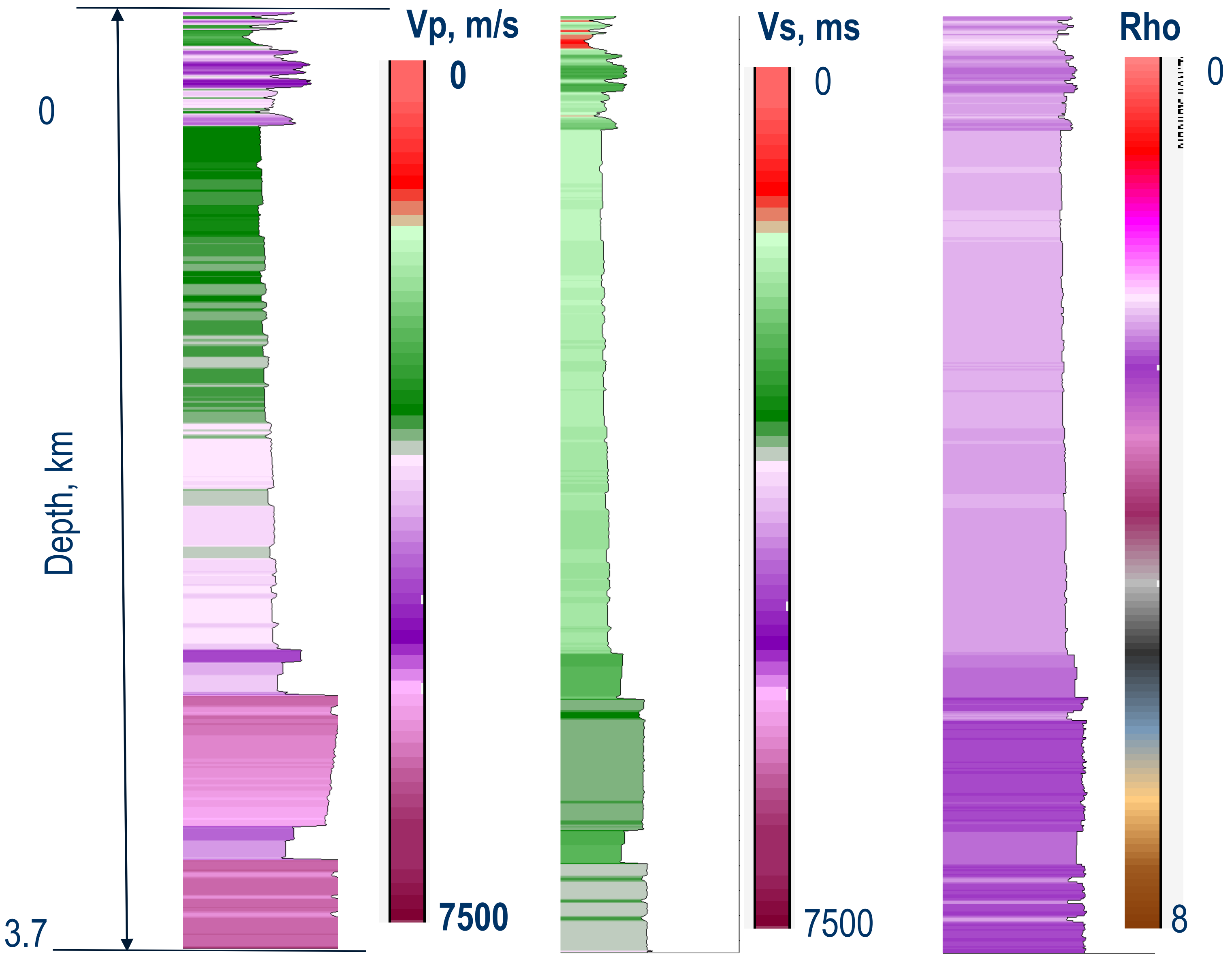
SEG Arid Model, courtesy of SEAM Phase II

Cell size = 6.25 x 6.25 x 6.25 m

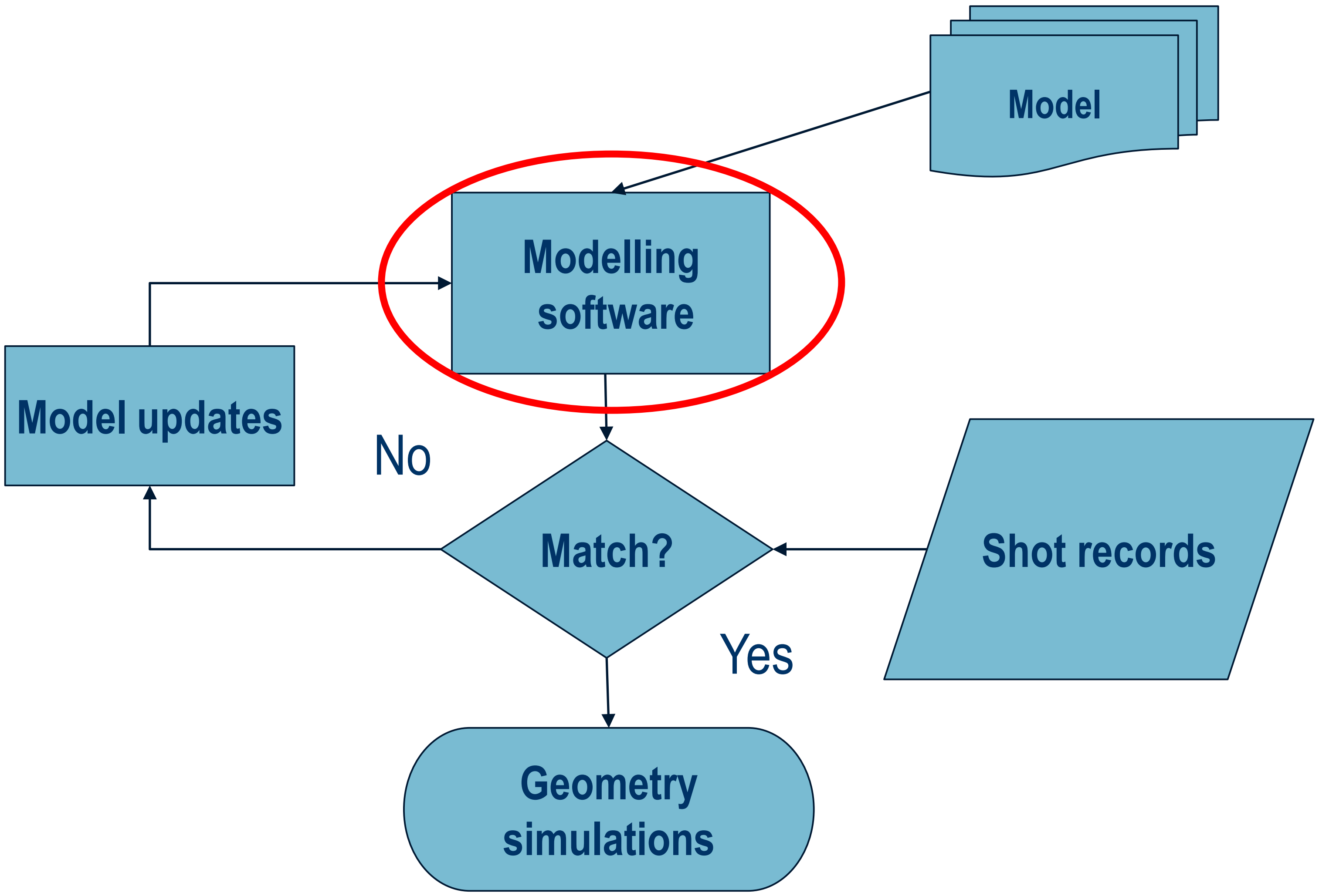
Model subset - 2D line from SEAM Arid Model (Vp shown)



Example 1D model extracted from SEAM Arid Model



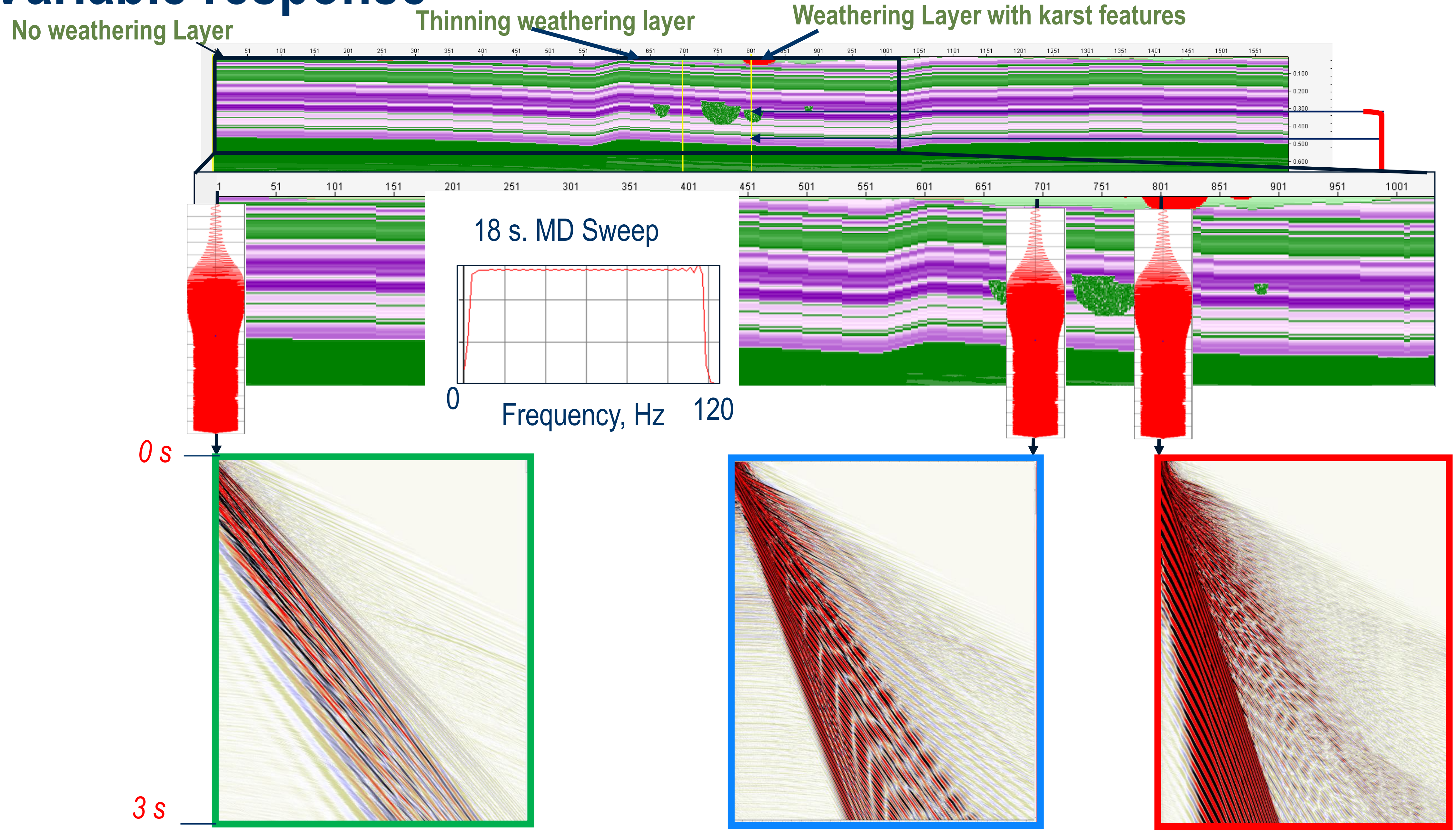
Forward modelling scheme



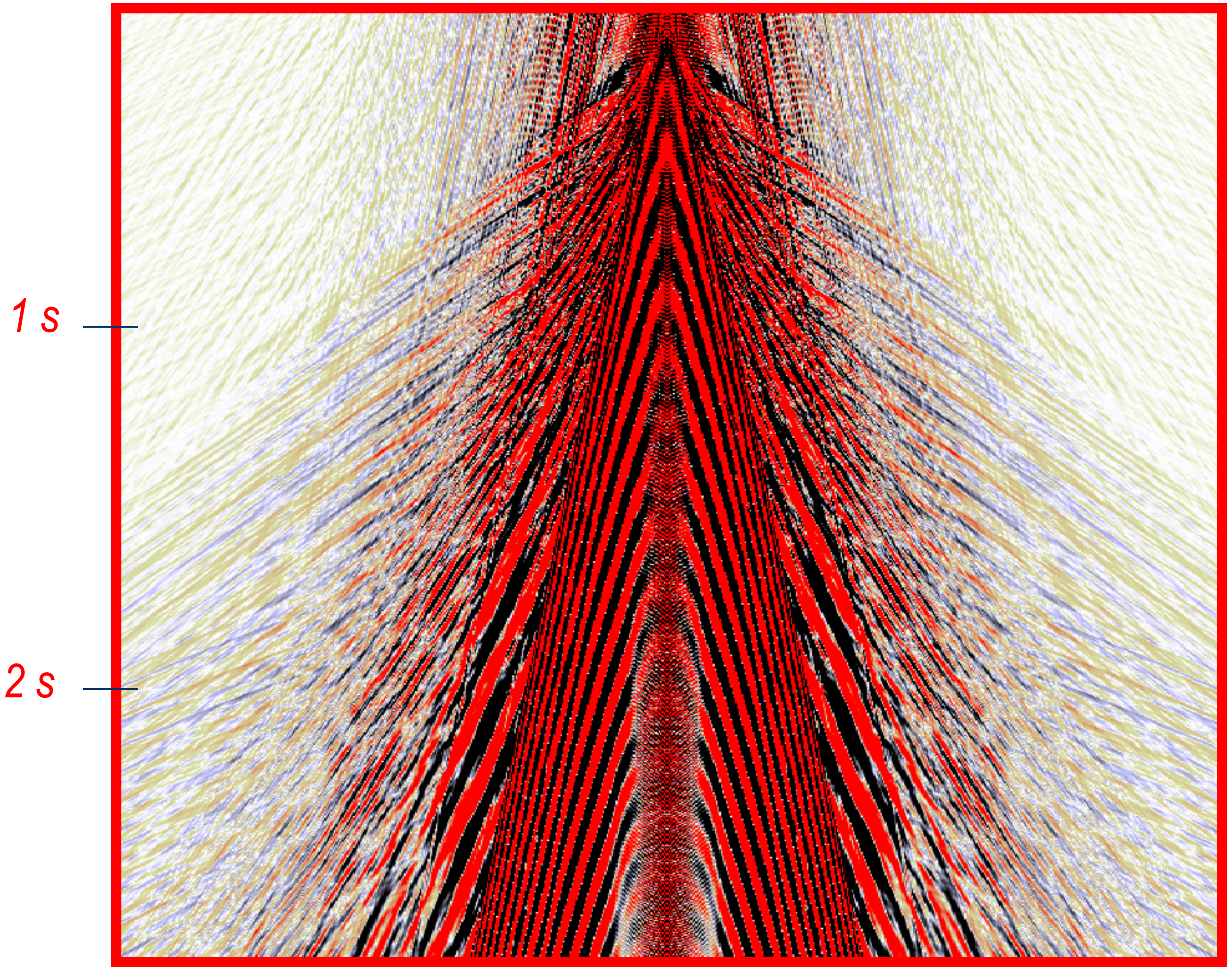
Elastic wavefield modelling tools

Method	Description	Limitation	Speed
3D Full Elastic	Full 3D Finite-Difference wavefield propagation		Excessive run time for Land 3D models with realistic frequency ranges
2D Full Elastic	Finite-Difference	No out-of-plane energy No out-of-plane scattering	Weeks
1D Full Elastic	ANIVEC (Kennett algorithm)	Layer cake geology No scattering	Days

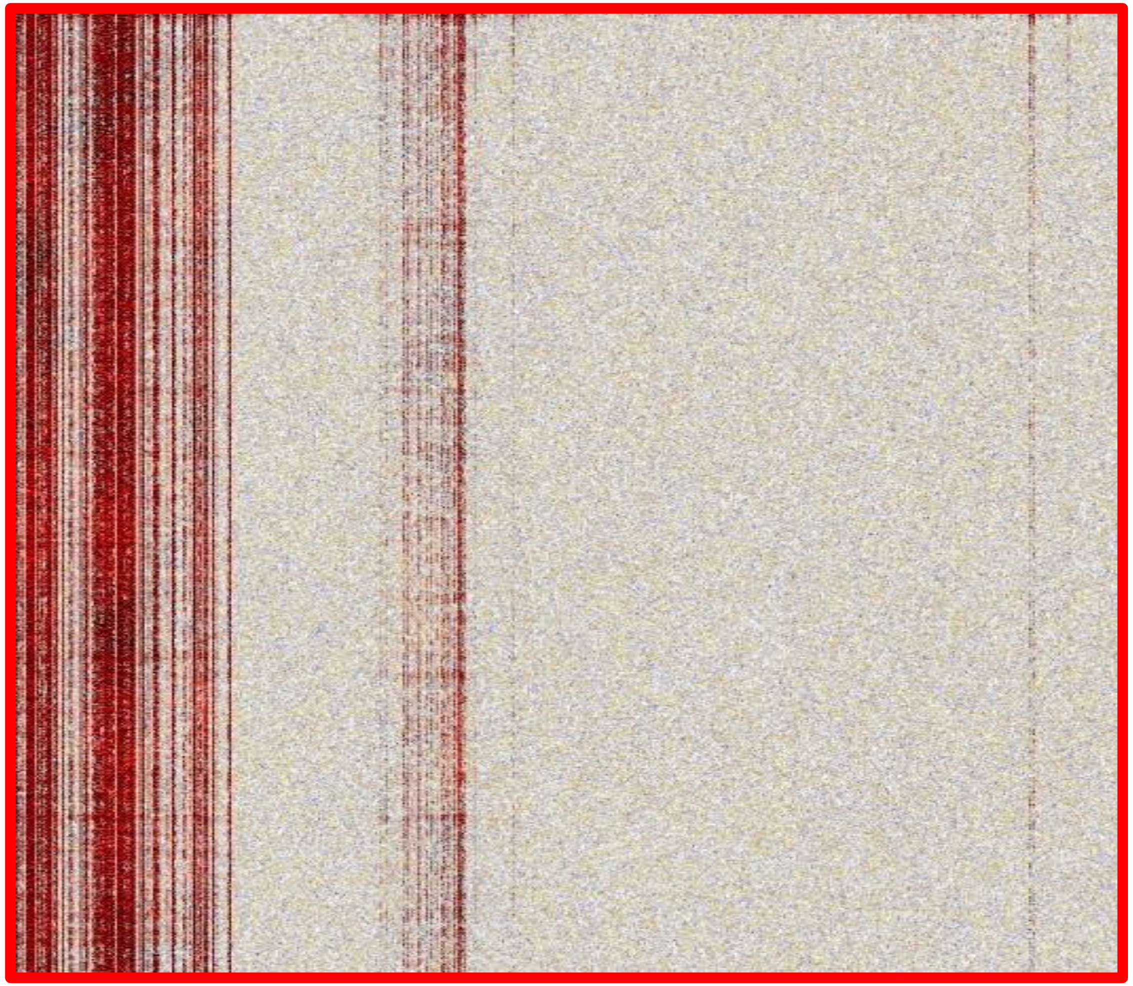
Variable response



Realistic synthetic shot records

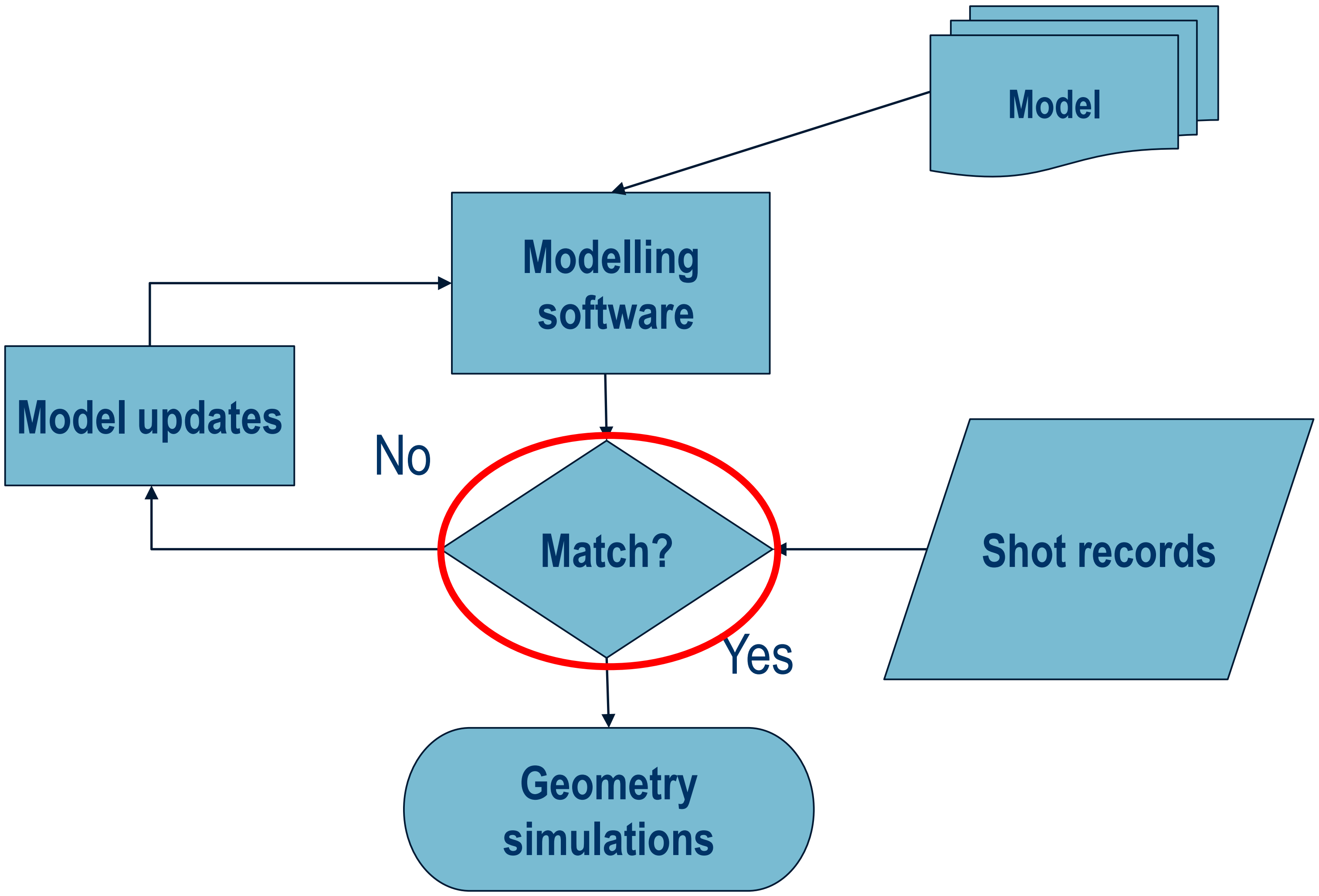


Point Source / Point Receiver synthetic signal

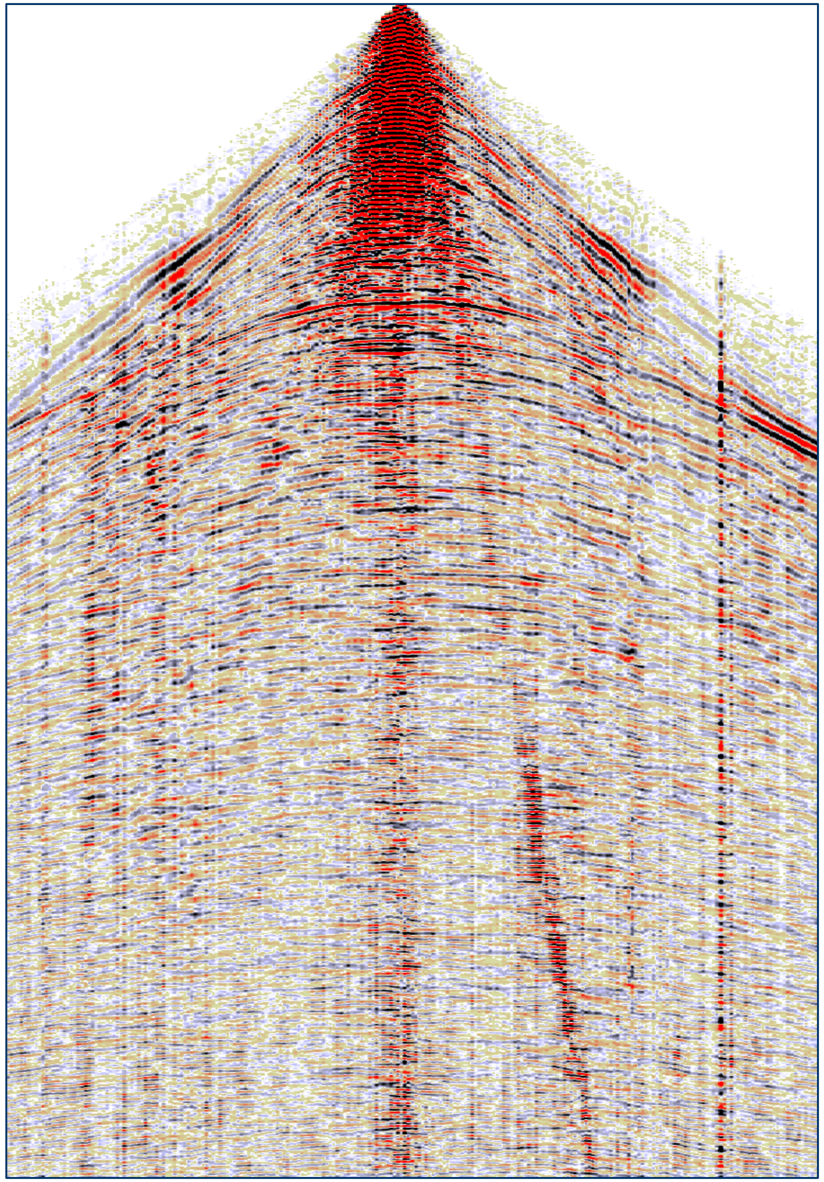


Synthetic ambient noise model

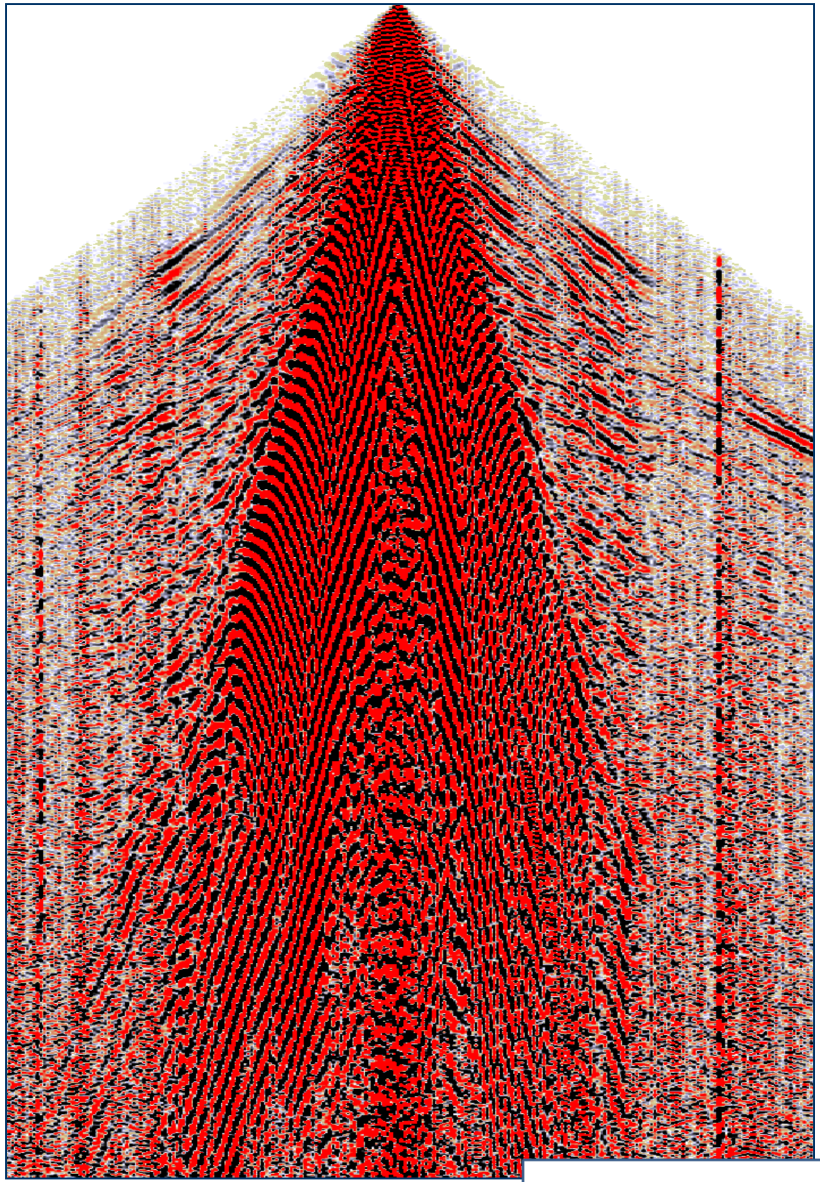
Forward modelling scheme



PSPR gather
After noise attenuation

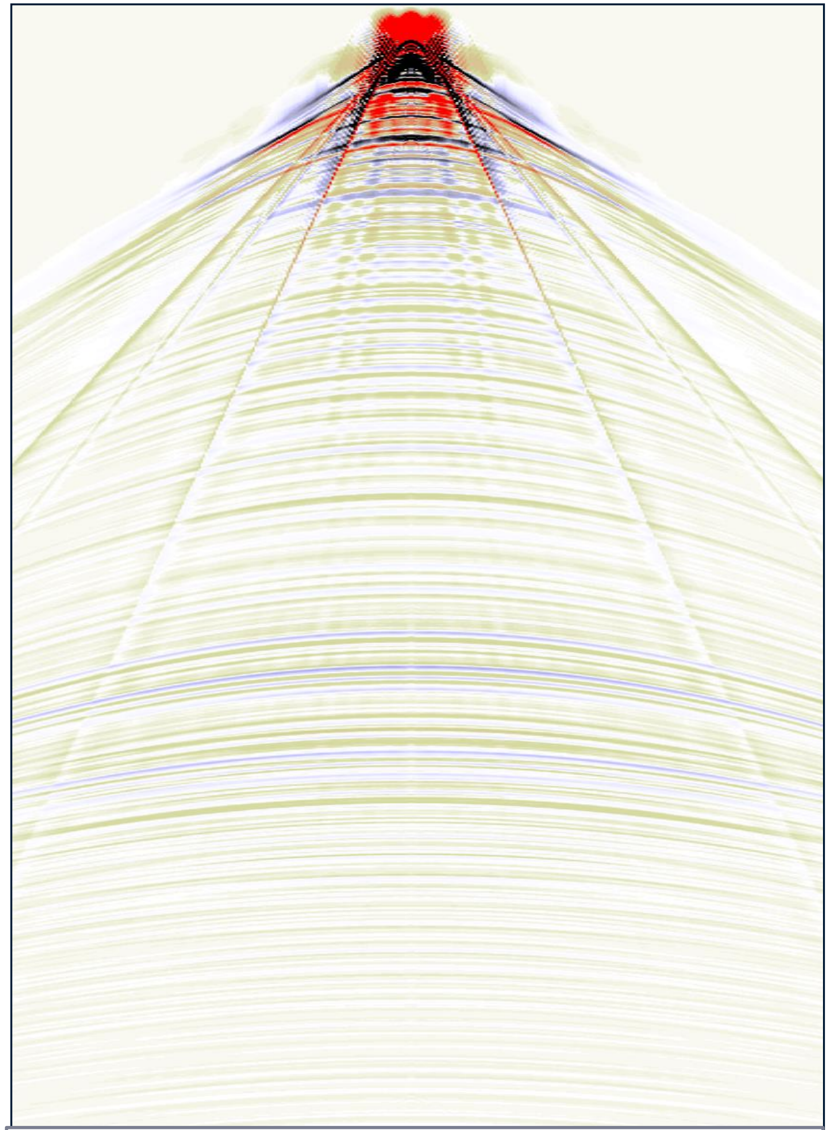


PSPR gather
Before noise attenuation

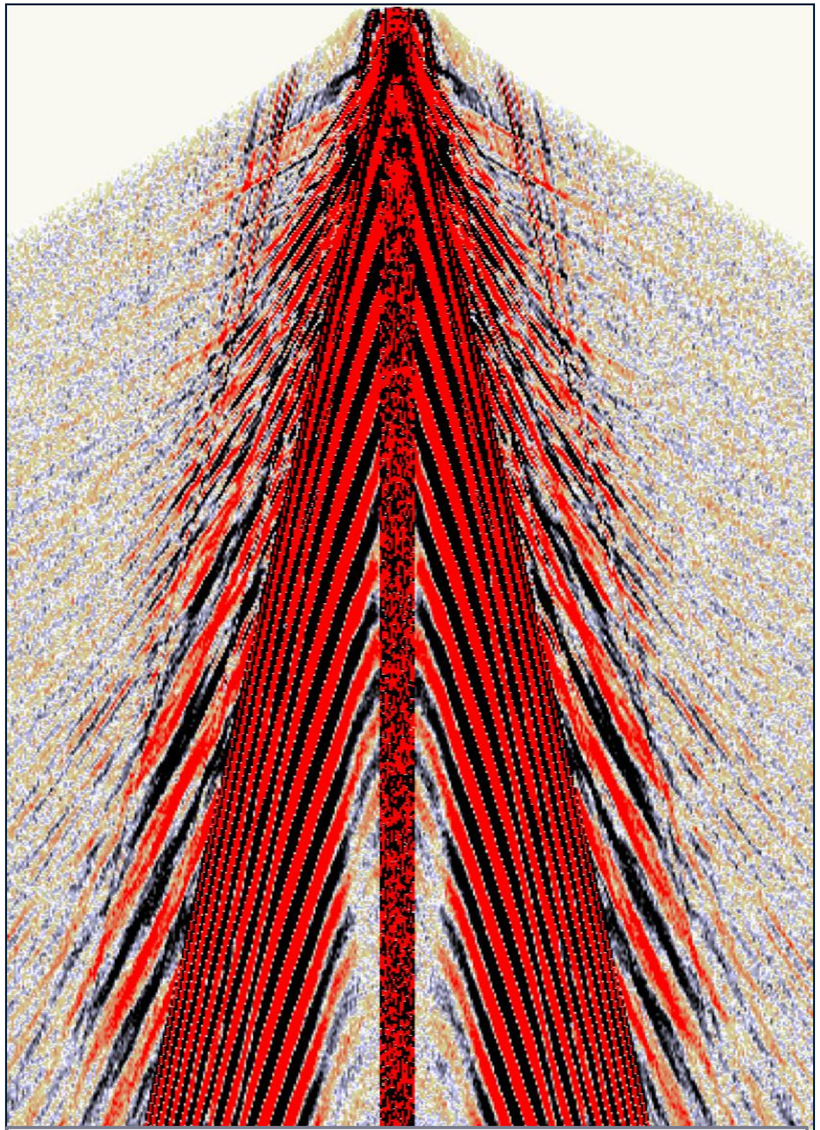


Data courtesy of APACHE Corporation

Point-Source / Point-Receiver synthetic generation

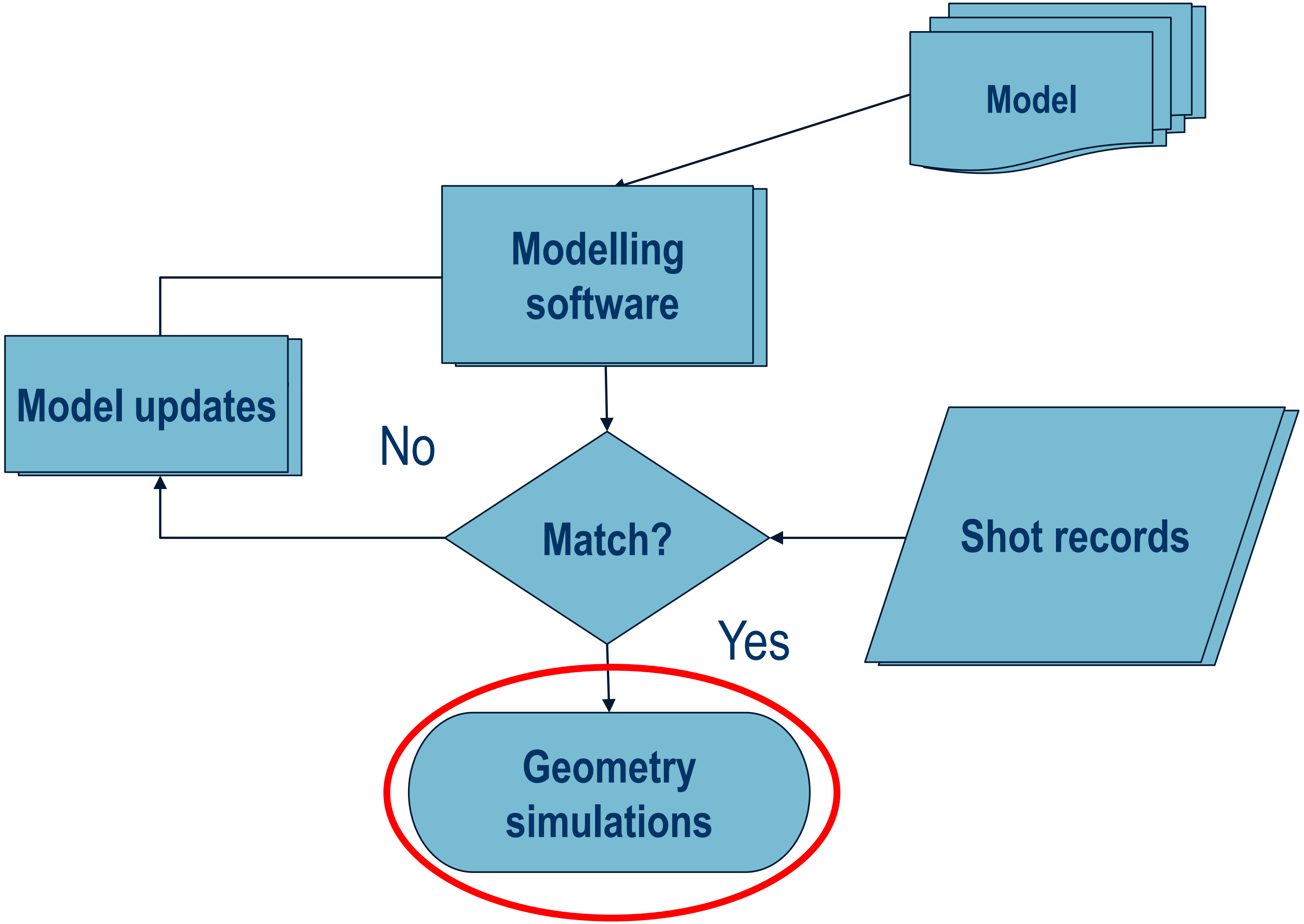


P-wave only response

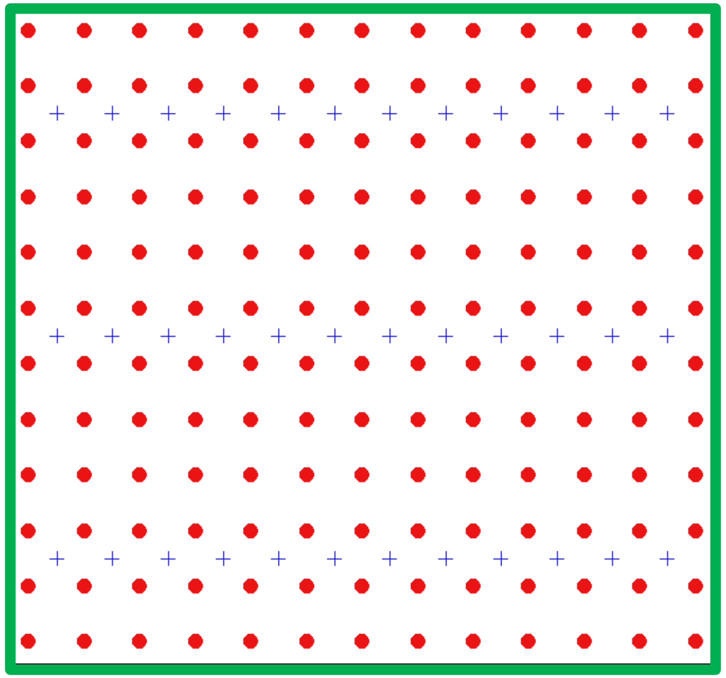


Full noise model

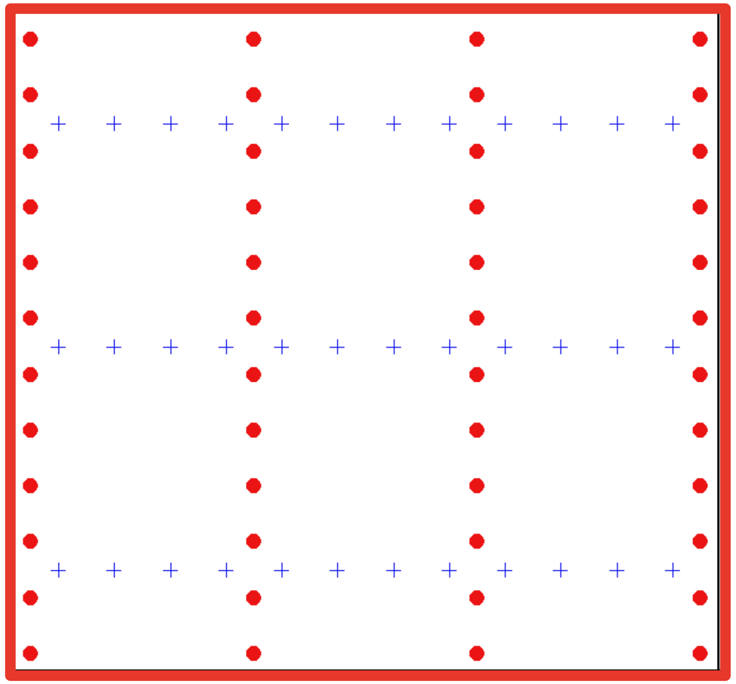
Forward modelling scheme



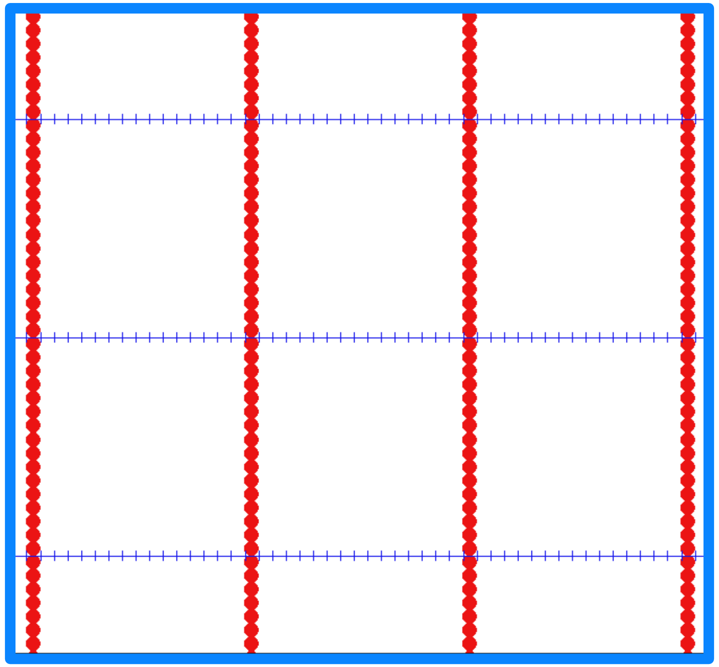
Modelled acquisition geometries



Shot-Carpet



Orthogonal Array



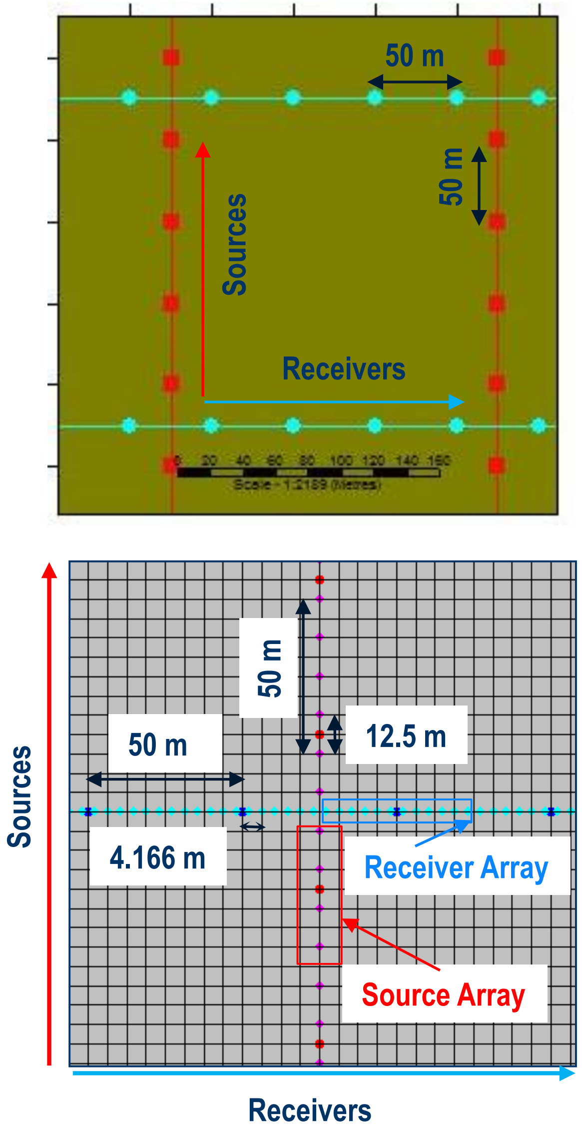
Point-Source Point-Receiver

Geometry simulations in numbers

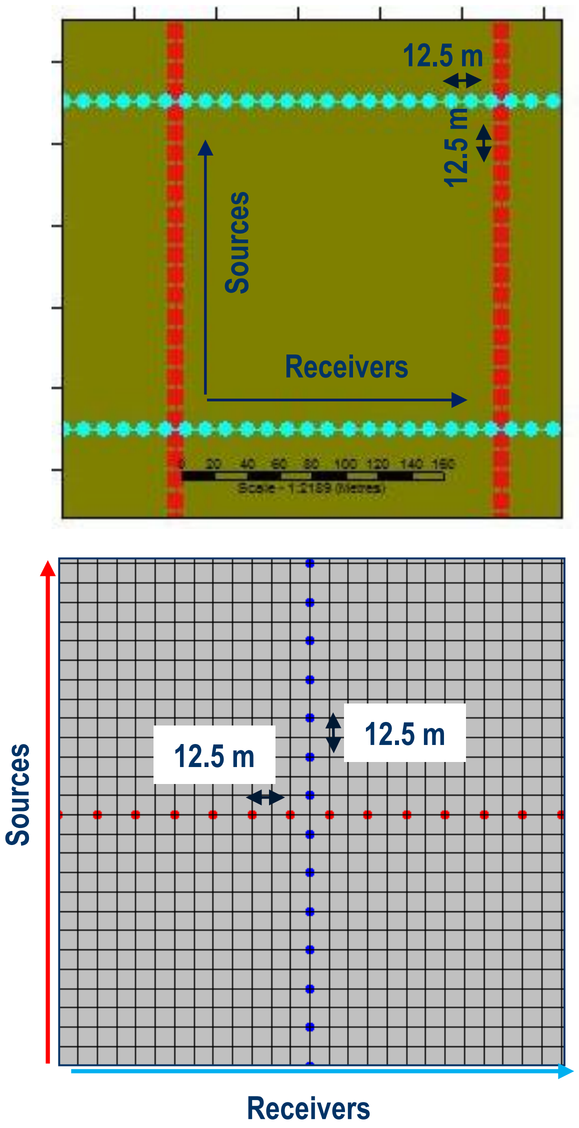
Parameter	Shot-Carpet	Orthogonal Array	PSPR
Source line spacing (m)	**50**	**200**	**200**
Receiver line spacing (m)	**200**	**200**	**200**
Shot point and receiver point spacing, (m)	**200**	**50**	**12.5**
Maximum IL/XL offset (m)	4400	4400	4400
Number of receiver lines	176	44	44
Number of receivers per line	176	176	704
Total active receivers/patch	30976	7744	30976
Natural fold	**1936**	**484**	**484**
Fold 25 m x 25 m bins	**1936**	**484**	**7744**
# Sensors per station	**12**	**12**	**1**
# Vibrators per shot point	**4**	**4**	**1**
Relative noise attenuation power √N	**+22.8**	**+16.8 dB**	**0 dB**

Orthogonal Array vs Point-Source / Point-Receiver geometry

Orthogonal Array

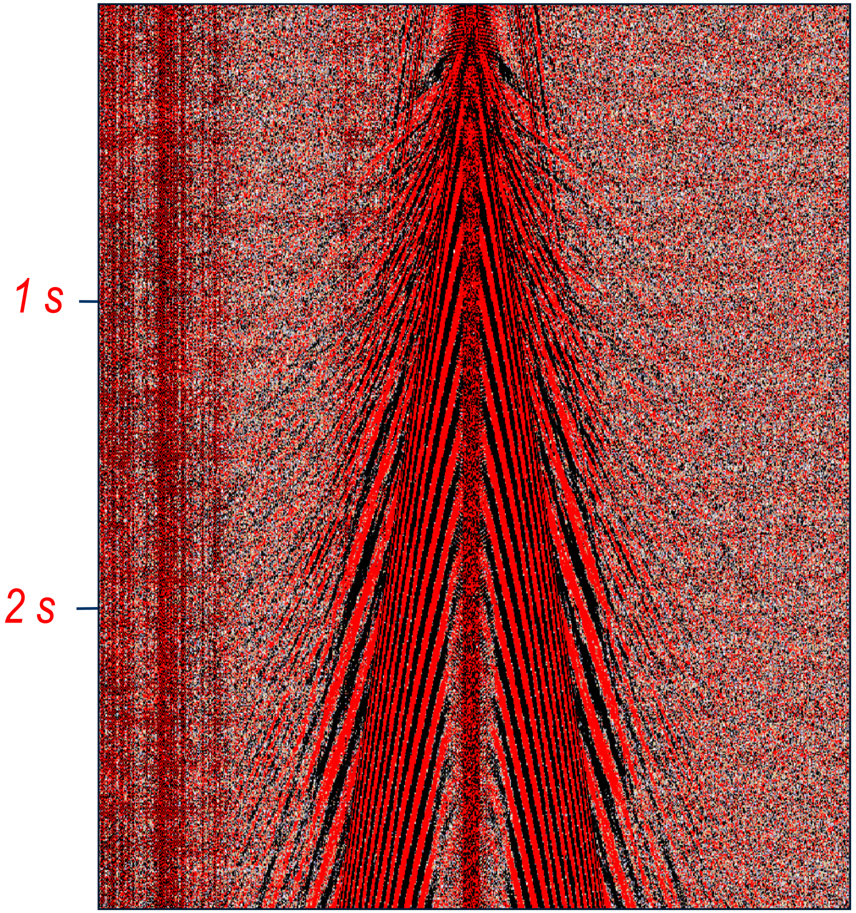


Point-Source / Point-Receiver

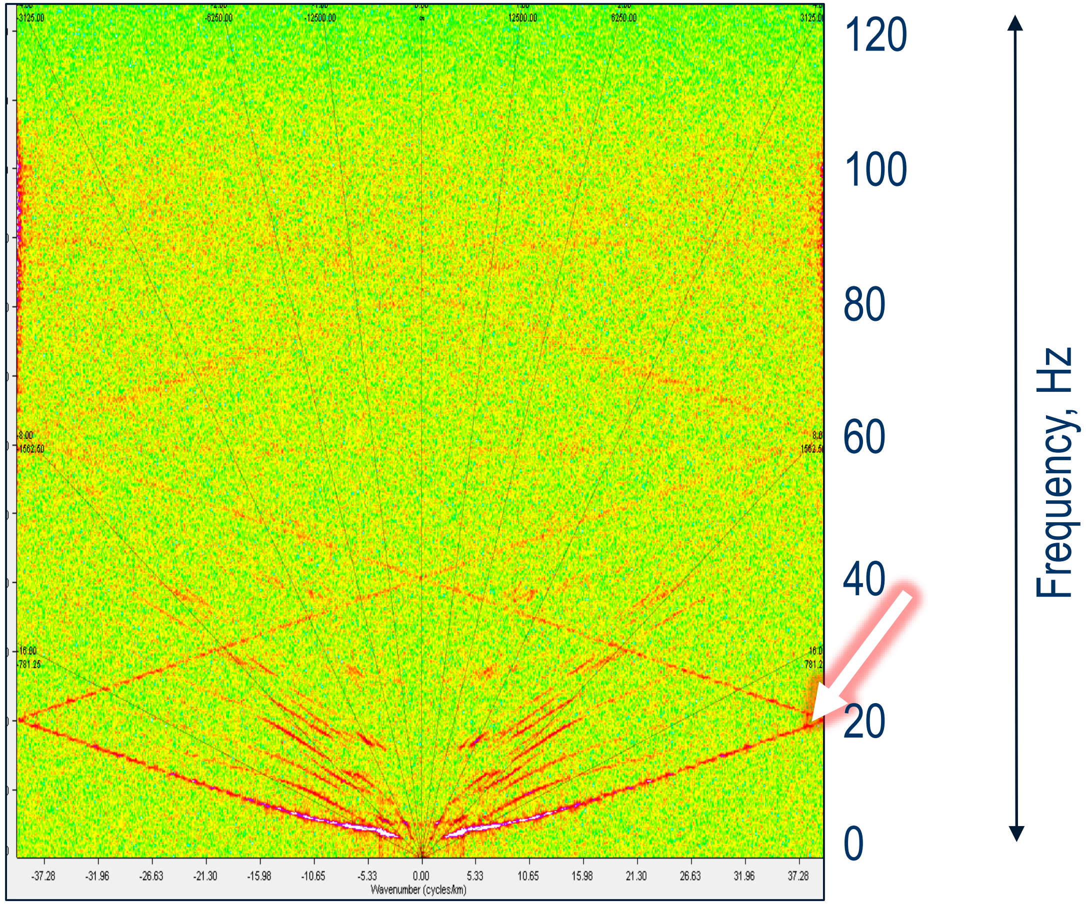


Point-Source / Point-Receiver synthetic data

Synthetic shot gather

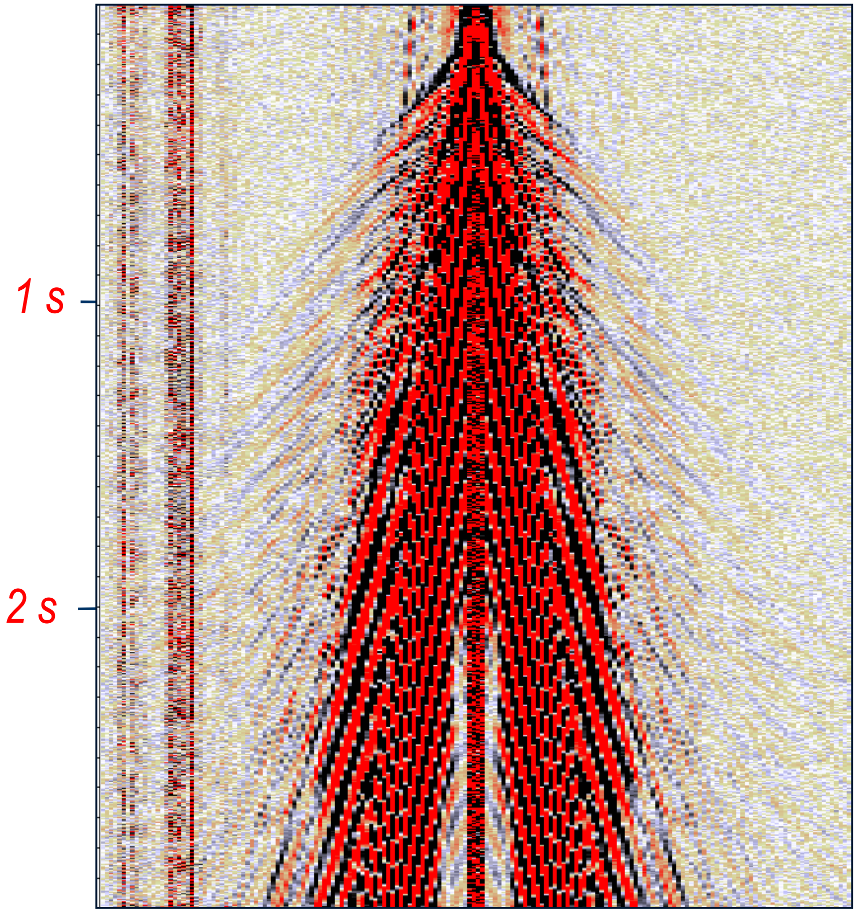


FK plot

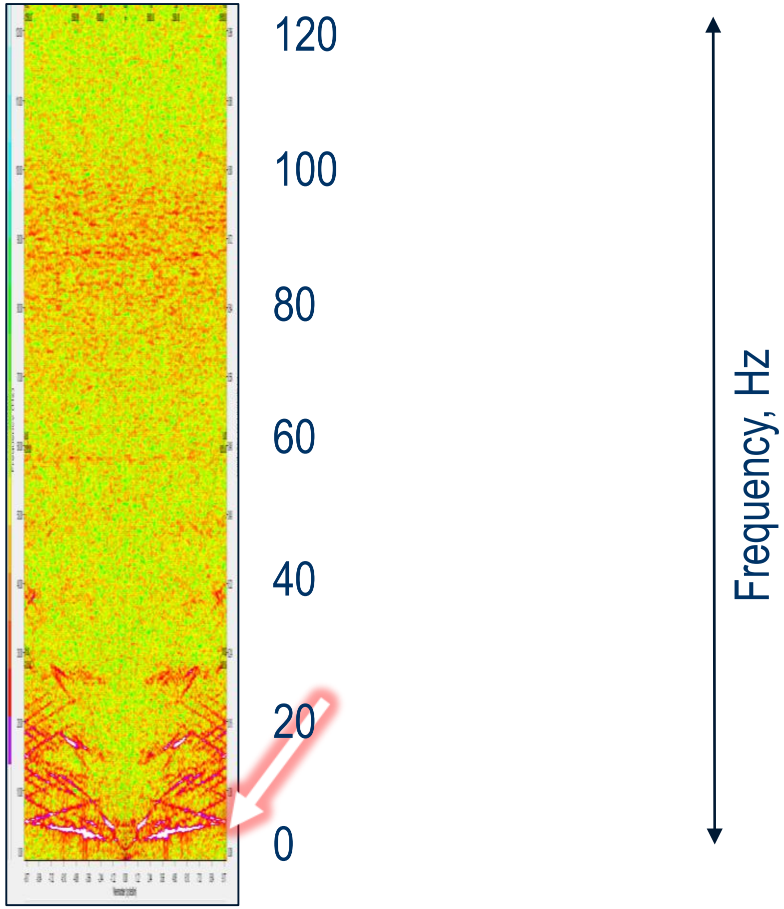


Orthogonal geophone array synthetic data

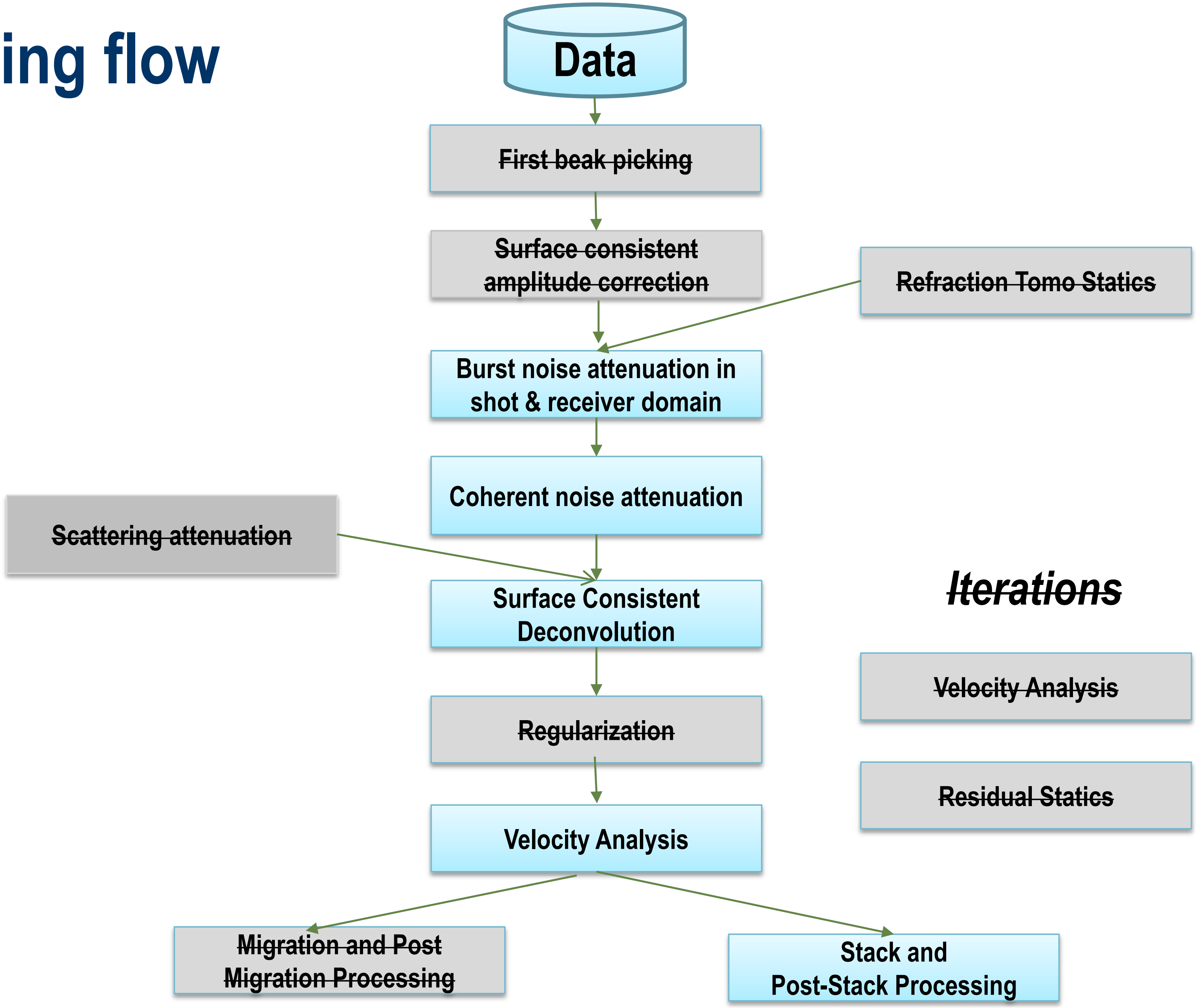
Synthetic shot gather



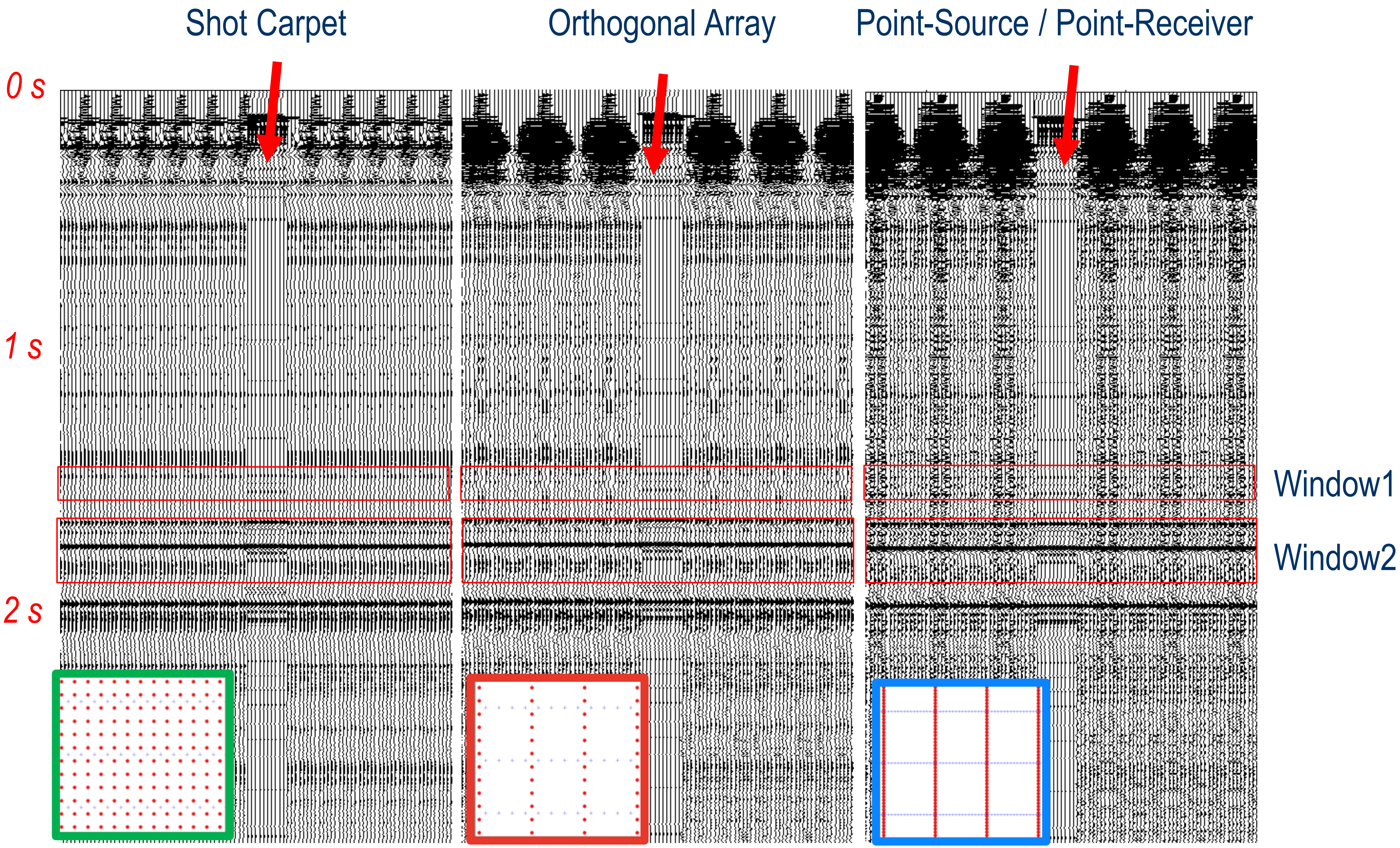
FK plot



Processing flow

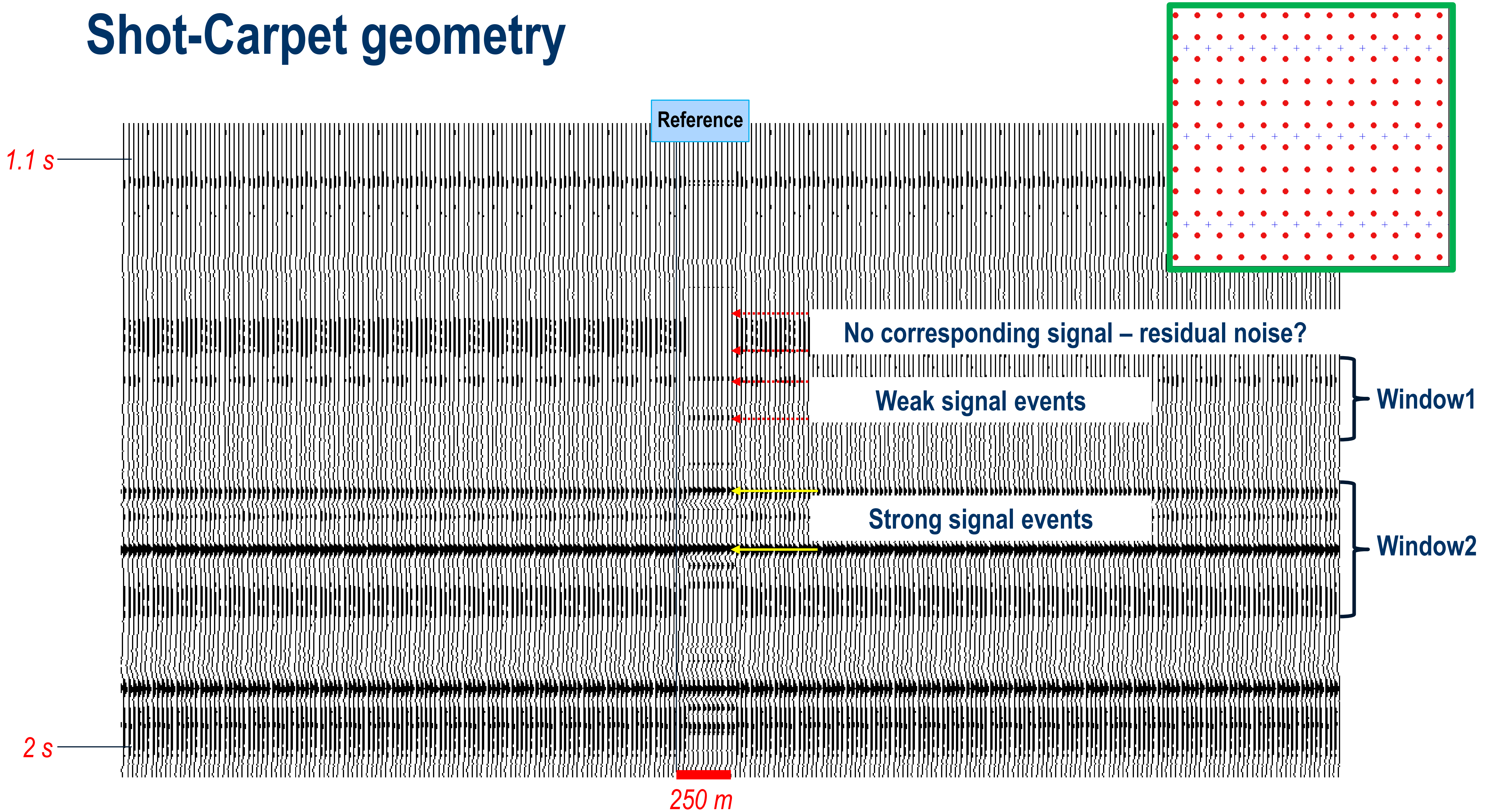


Synthetic stack comparison

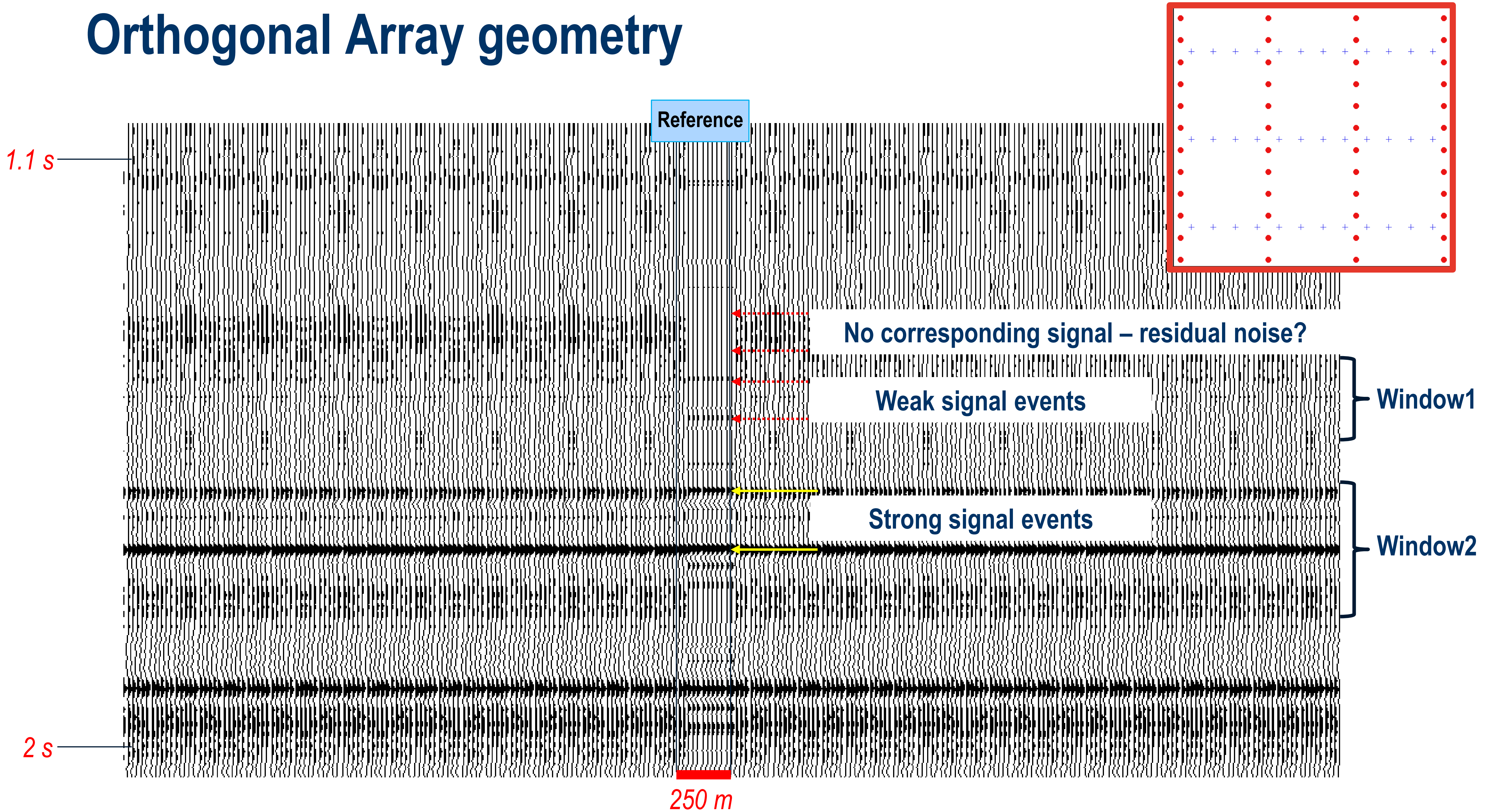


Orthogonal Array = 4:1 decimation of Shot Carpet

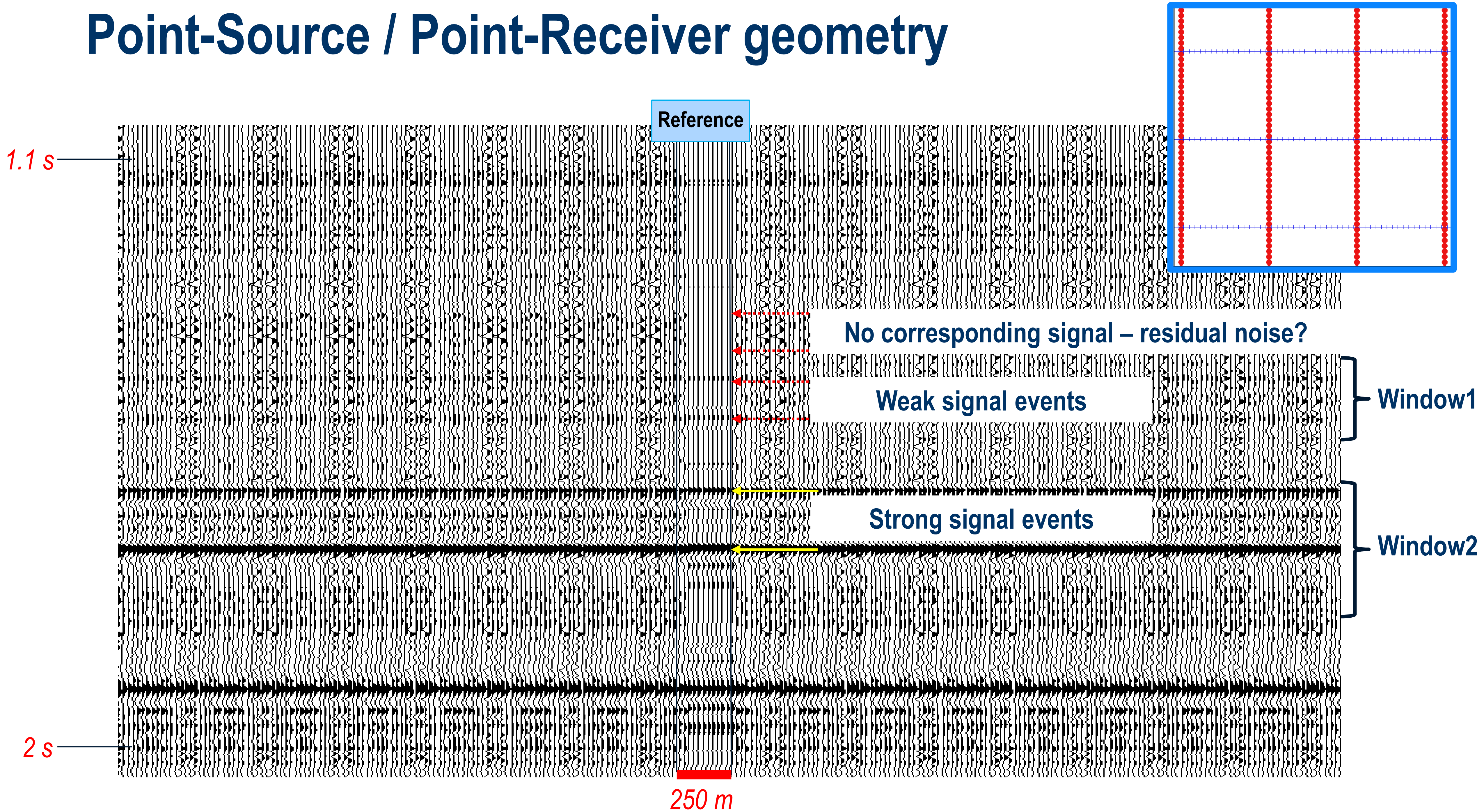
Shot-Carpet geometry



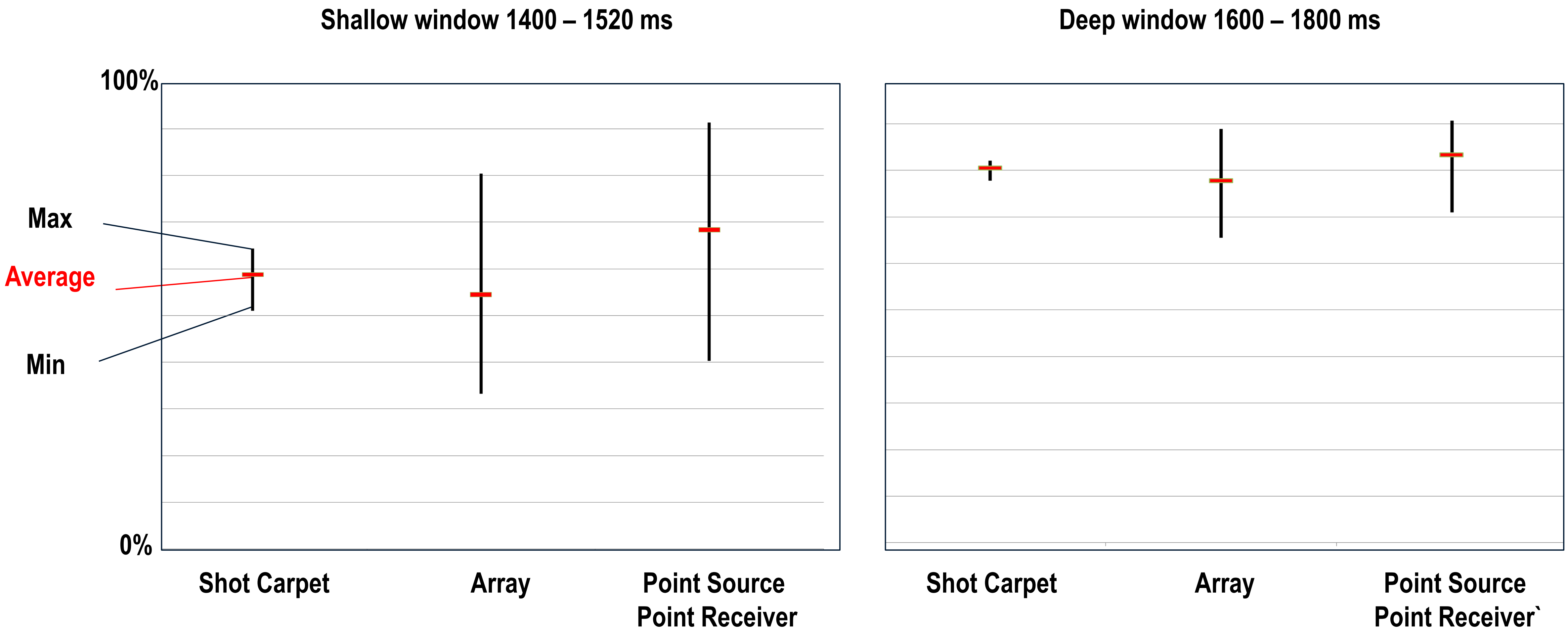
Orthogonal Array geometry



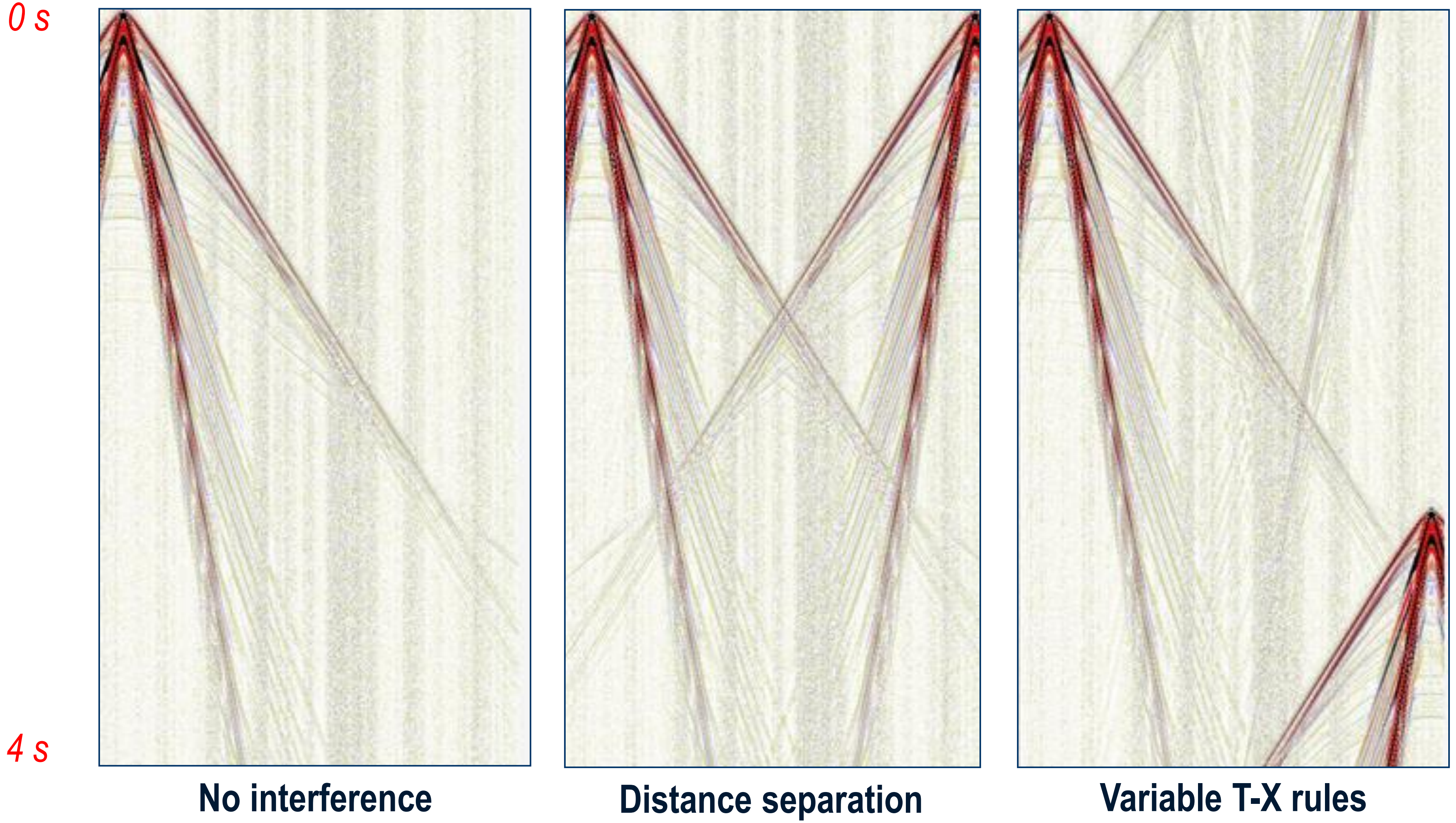
Point-Source / Point-Receiver geometry



Predictability metrics



Productivity enhancement - shot interference



Discussion

Methodology highlights many "features" of current acquisition and processing practices

- It is easy to create spurious coherent events
- Coherent noise attenuation is a key factor – none of the chosen geometries and coherent noise attenuation processing are fully effective in removing noise
- Using $\sqrt{N}$ to rank geometries appears not to provide the correct ranking of the geometries.

Conclusions

Modelling allows:

- Separation of contributing factors
    - Signal
    - Coherent noise
    - Ambient noise
- Test both acquisition and processing schemes together
- Test different hypotheses
- Quantify errors

Acknowledgements

Donnie Enns (OXY) and Scott Burns (formerly OXY) for extensive discussions

SEG Arid Model, courtesy of SEAM Phase II

Questions?