An Integrated Workflow for Seismic Data Conditioning and Modern Pre-stack Inversion Applied to the Odin Field

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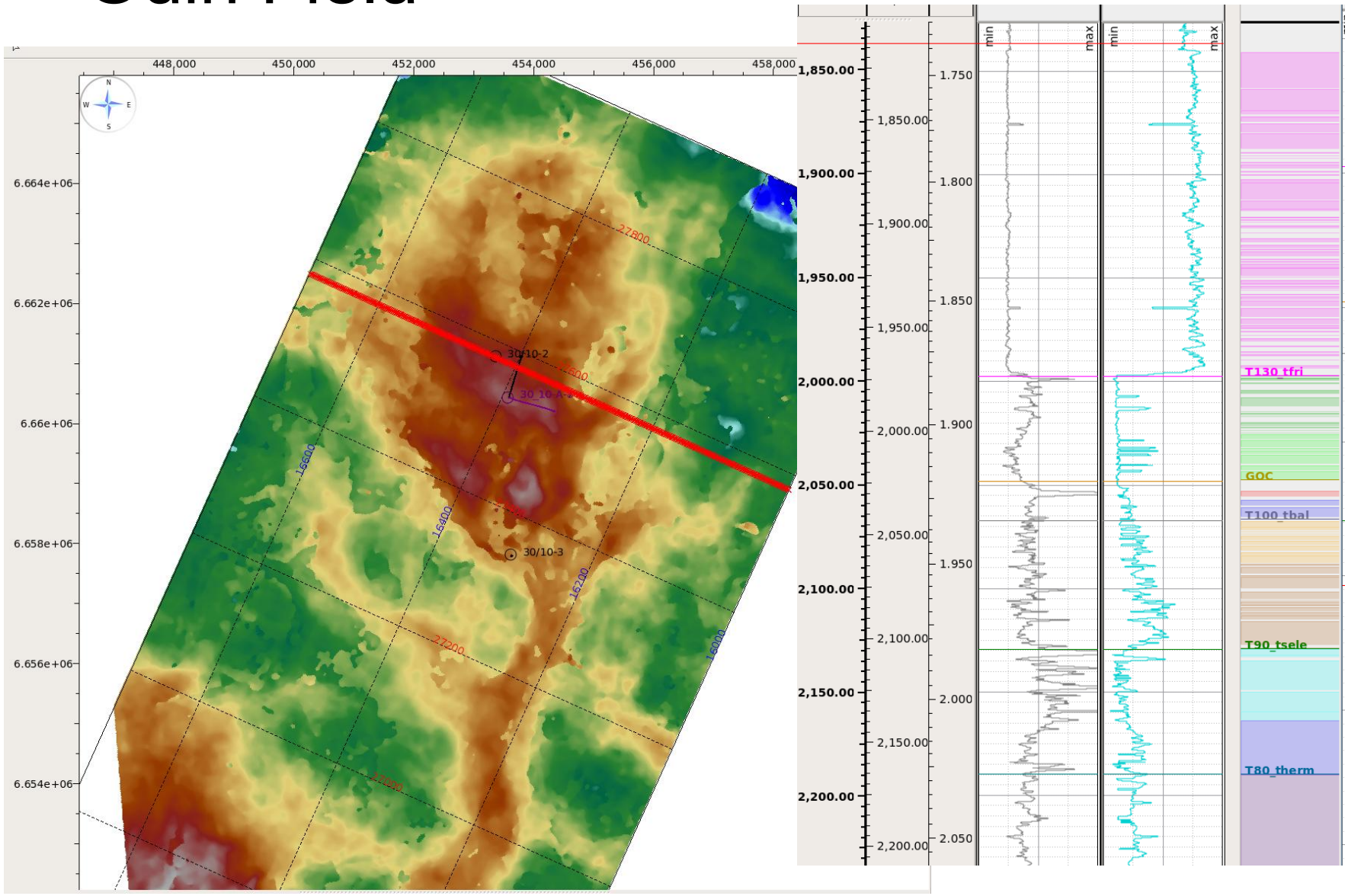
sharpreflections
INTERACTIVE PRE-STACK

Talk Outline

- Introduction
- Motivation
- Introducing Pcube+
- Gather Conditioning
  - Workflow
  - Conditioning
  - Interpretation support
- Summary, Conclusions

Odin Field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452,000
454,000
456,000
458,000
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6.662e+06
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6.654e+06
30/10-2
30/10-A
30/10-3
27800
27600
27400
27200
27000
16600
16400
16200
16000
1,850.00
1,900.00
1,950.00
2,000.00
2,050.00
2,100.00
2,150.00
2,200.00
1.750
1.800
1.850
1.900
1.950
2.000
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max
min
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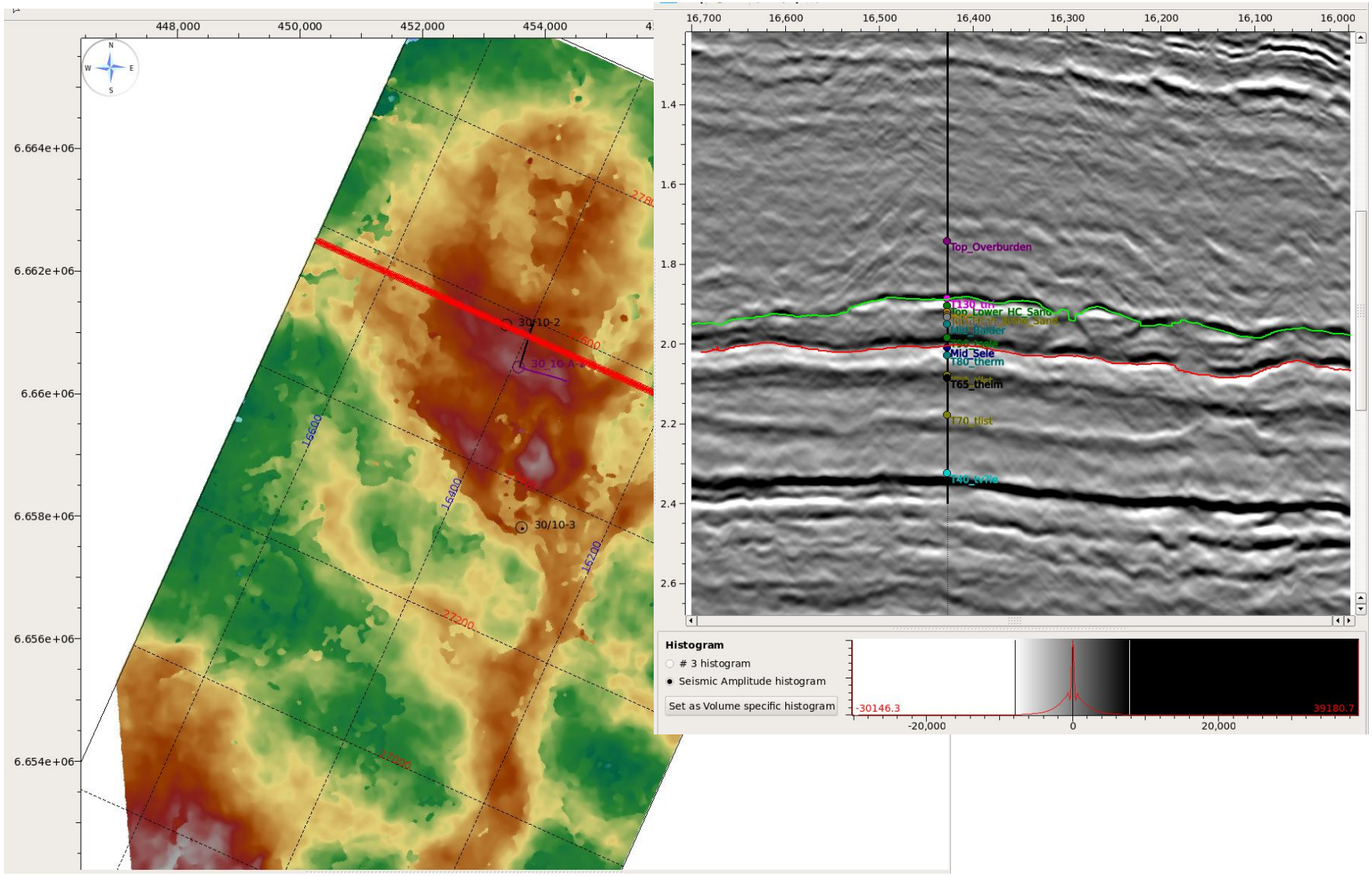
T130_tfri
GOC
T100_tbal
T90_tsele
T80_therm

Odin Field


448,000
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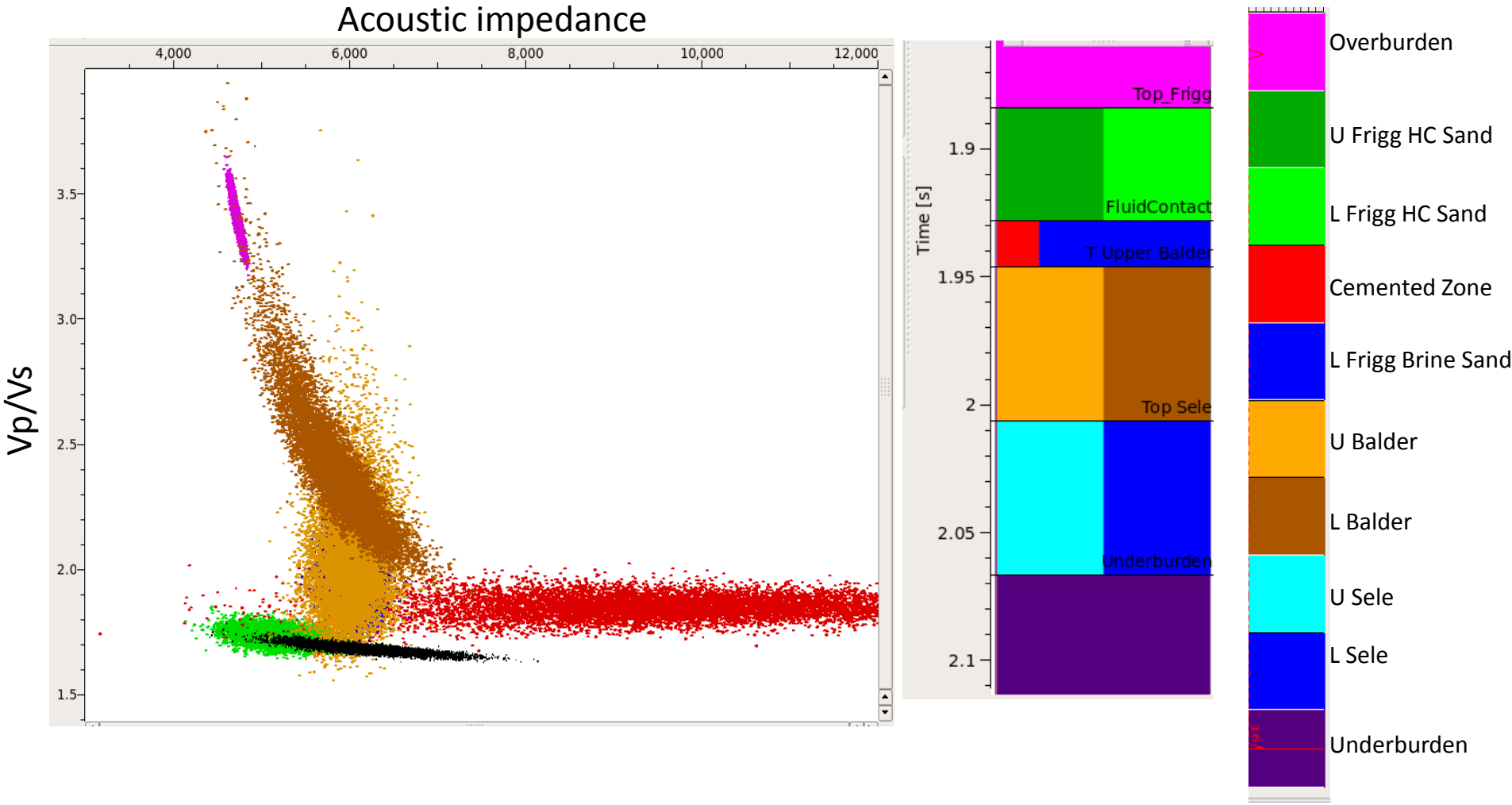
6.654e+06
30/10-2
30/10-3
16600
16400
16200
27200
16,700
16,600
16,500
16,400
16,300
16,200
16,100
16,000
1.4
1.6
1.8
2.0
2.2
2.4
2.6
Top_Overburden
T130_tim
Top_Lower_HC_Sand
Mid_Balder
Mid_Sele
T80_therm
T65_therm
T70_Hist
Histogram
3 histogram
Seismic Amplitude histogram
Set as Volume specific histogram
-30146.3
39180.7
-20,000
0
20,000

PCube+ Introduction

- PCube developed by Statoil & NR* ~9 years ago
- Pcube+ latest developments
  - LFC (Litho Fluid Classes) to define rock/fluid
  - Illegal vertical transitions – geological rules
- Bayesian inversion
  - Updating prior probabilities with seismic amplitudes
  - Updating model layer thicknesses
- Inputs
  - Partial stacks
  - Seismic horizons
  - LFCs
  - Wavelets

**NR – Norwegian Computing Centre*

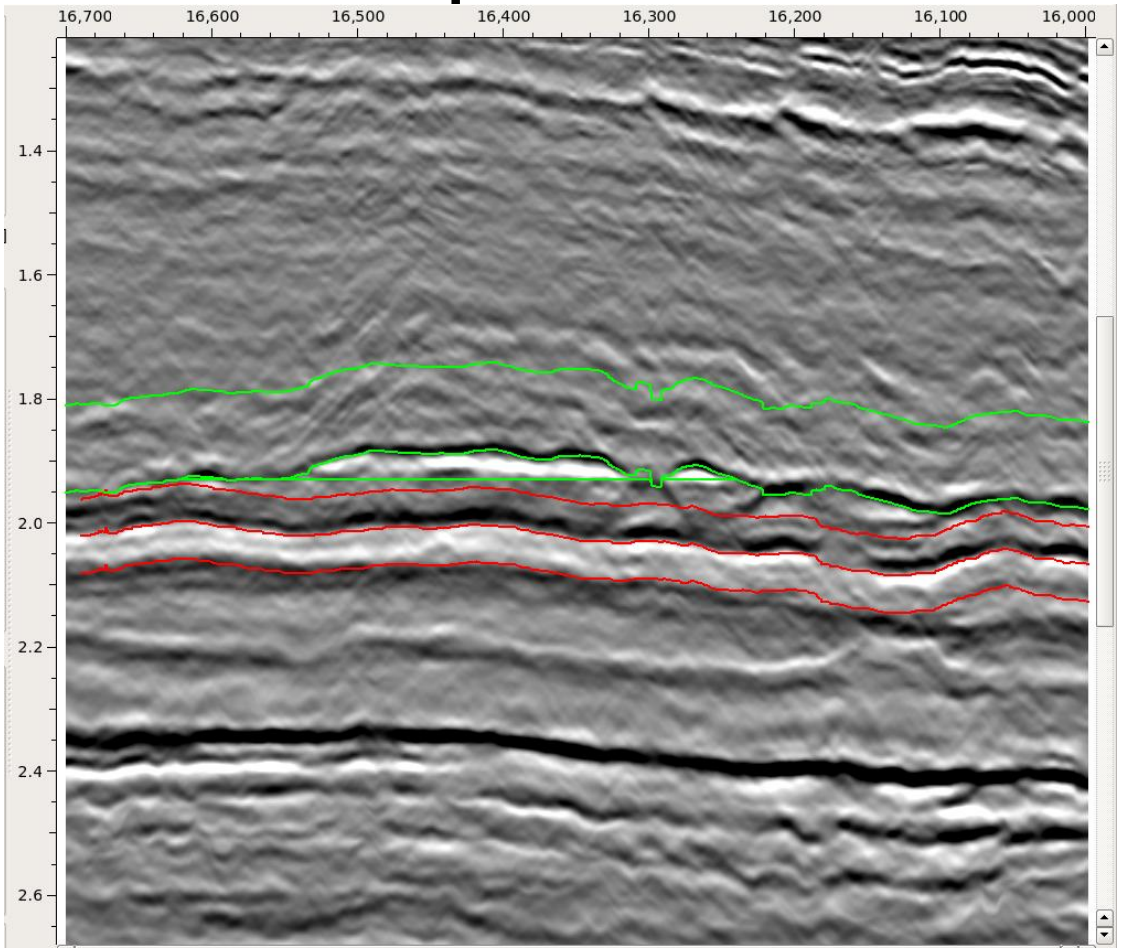
Concept Model: LFCs

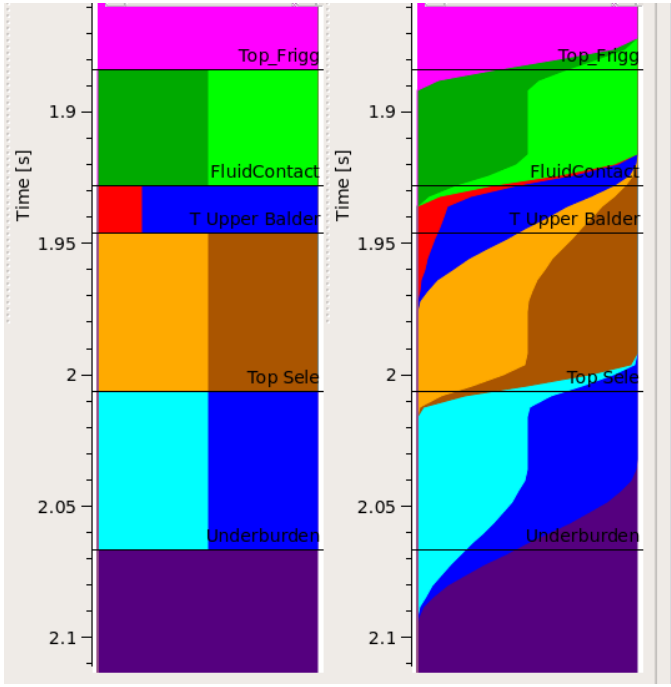


LFCs are derived from well data. Within each zone, a 3D Gaussian is fitted to the elastic properties.

A layer model is populated with prior probabilities for each LFC.

Concept Model: Horizons

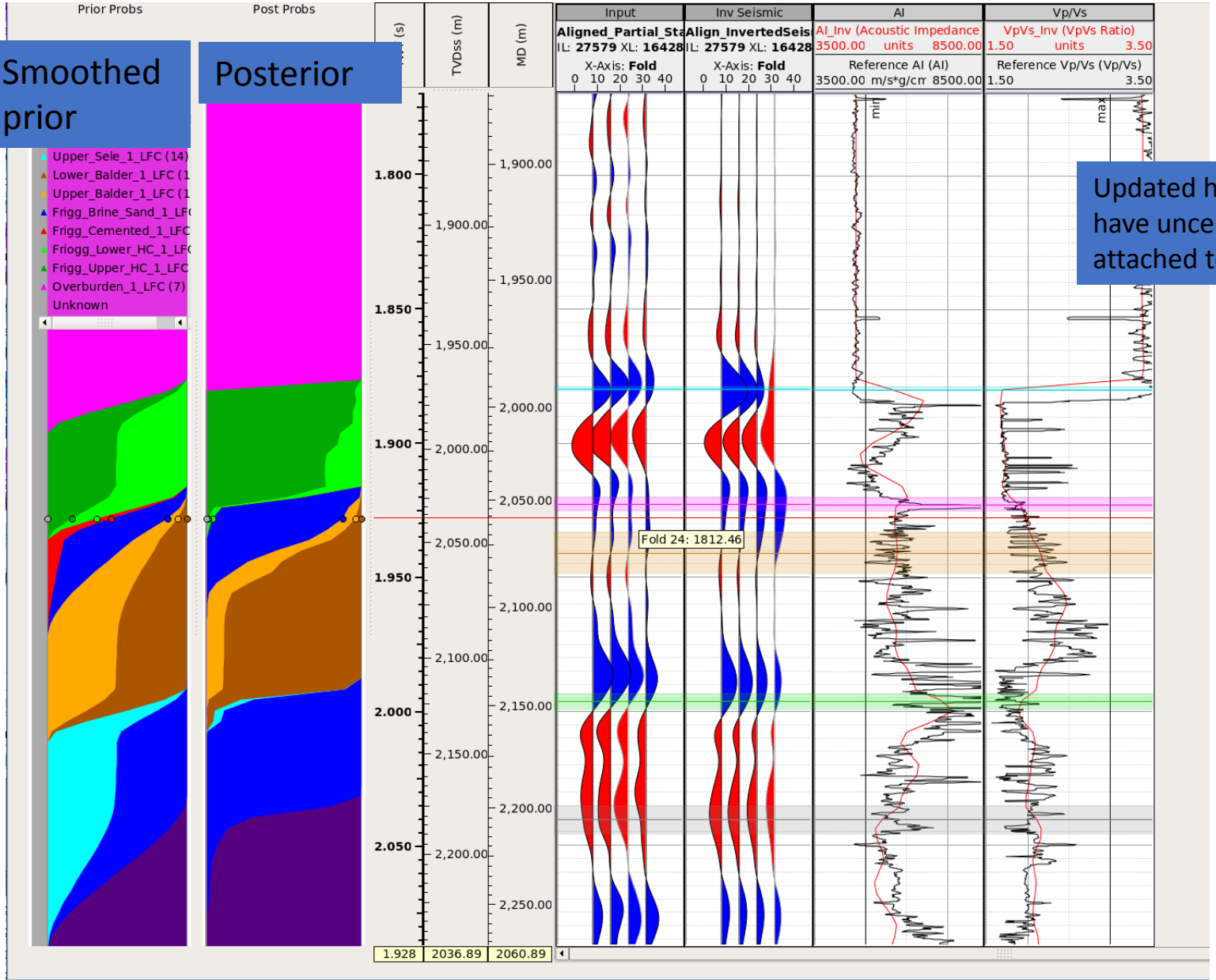




Slave horizons are parallel to a few interpreted horizons. The concept model is smoothed vertically due to prior uncertainty in the horizon position.

These horizon positions are updated in the inversion.

Inversion Output



Likelihood Ratio

Posterior probability

Prior model

$$\frac{P(m \mid d)}{P(m)} = \frac{P(d \mid m)}{P(d)}$$

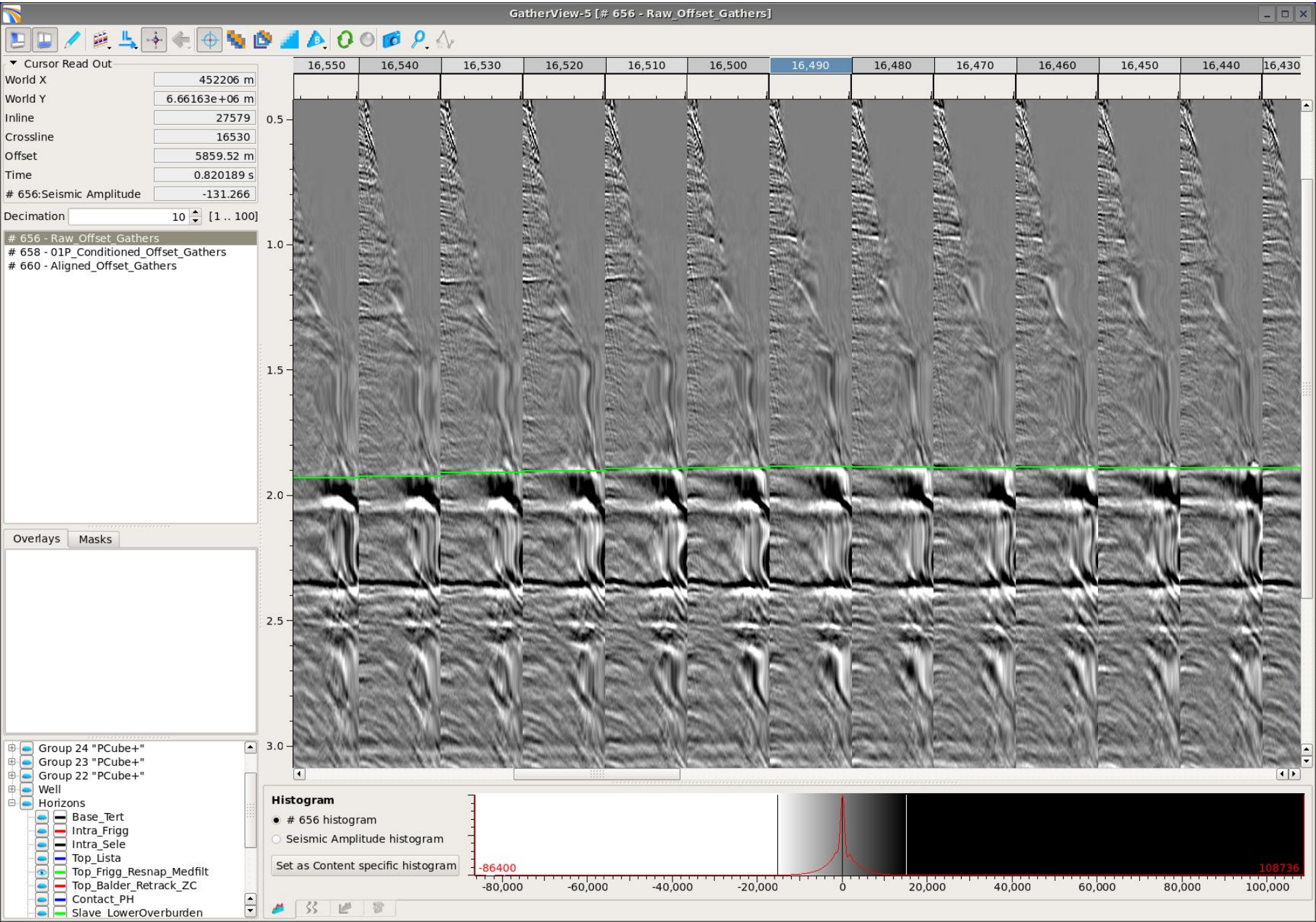
If this ratio is much different from 1, then the data are driving the result away from the prior model.

This is a useful QC

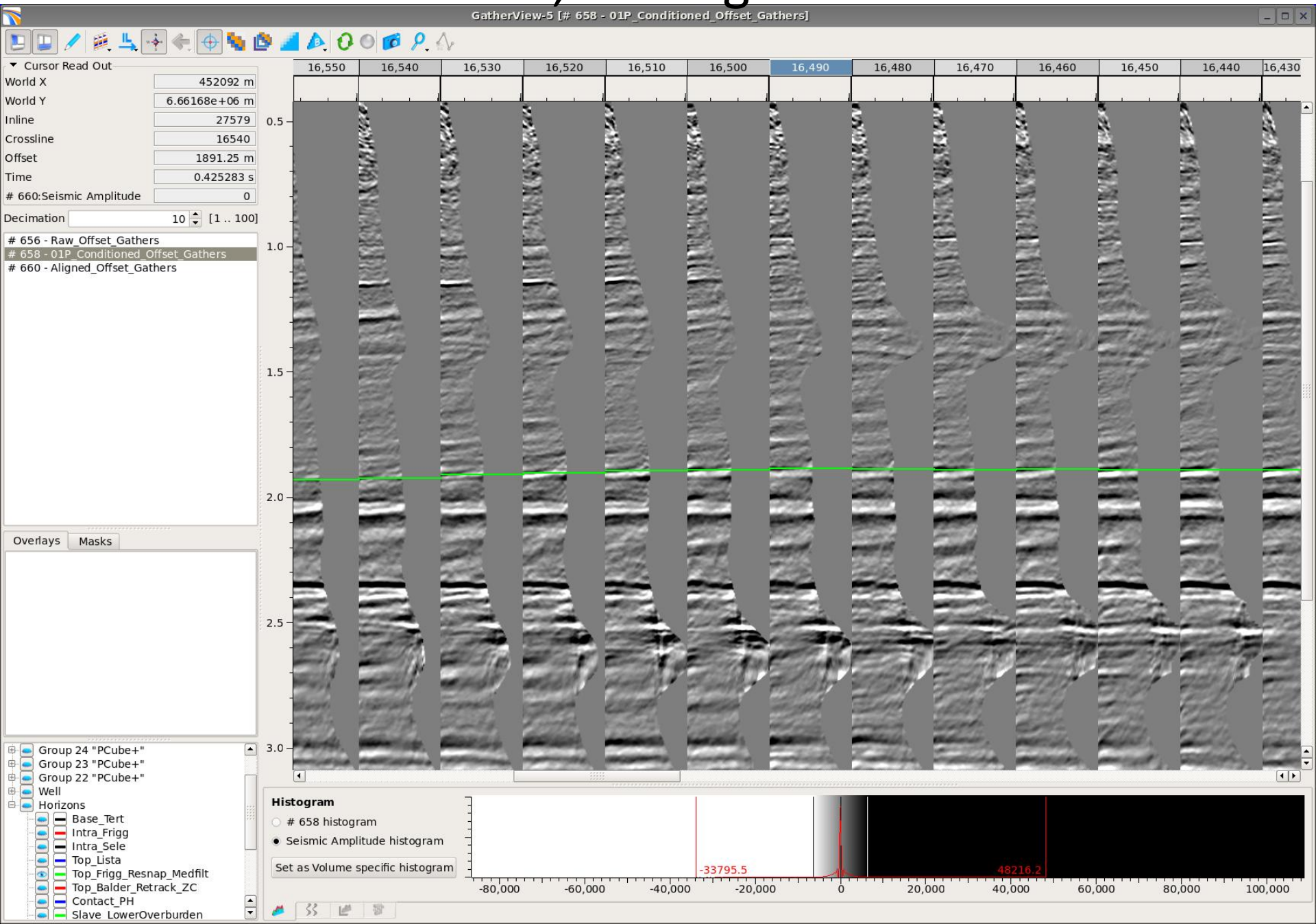
Seismic Data Conditioning

- Processes applied to the raw (time-migrated) gathers summarised below:
  - Angle mute at 50°
  - Radon de-multiple
  - Linear Radon noise reduction
  - Random noise reduction
    - Output conditioned gathers without alignment
  - Gather event alignment
    - Output conditioned gathers with alignment
- Partial stacks and Inversions on:
  - Raw Gathers
  - Conditioned gathers NO alignment
  - Conditioned gathers WITH alignment

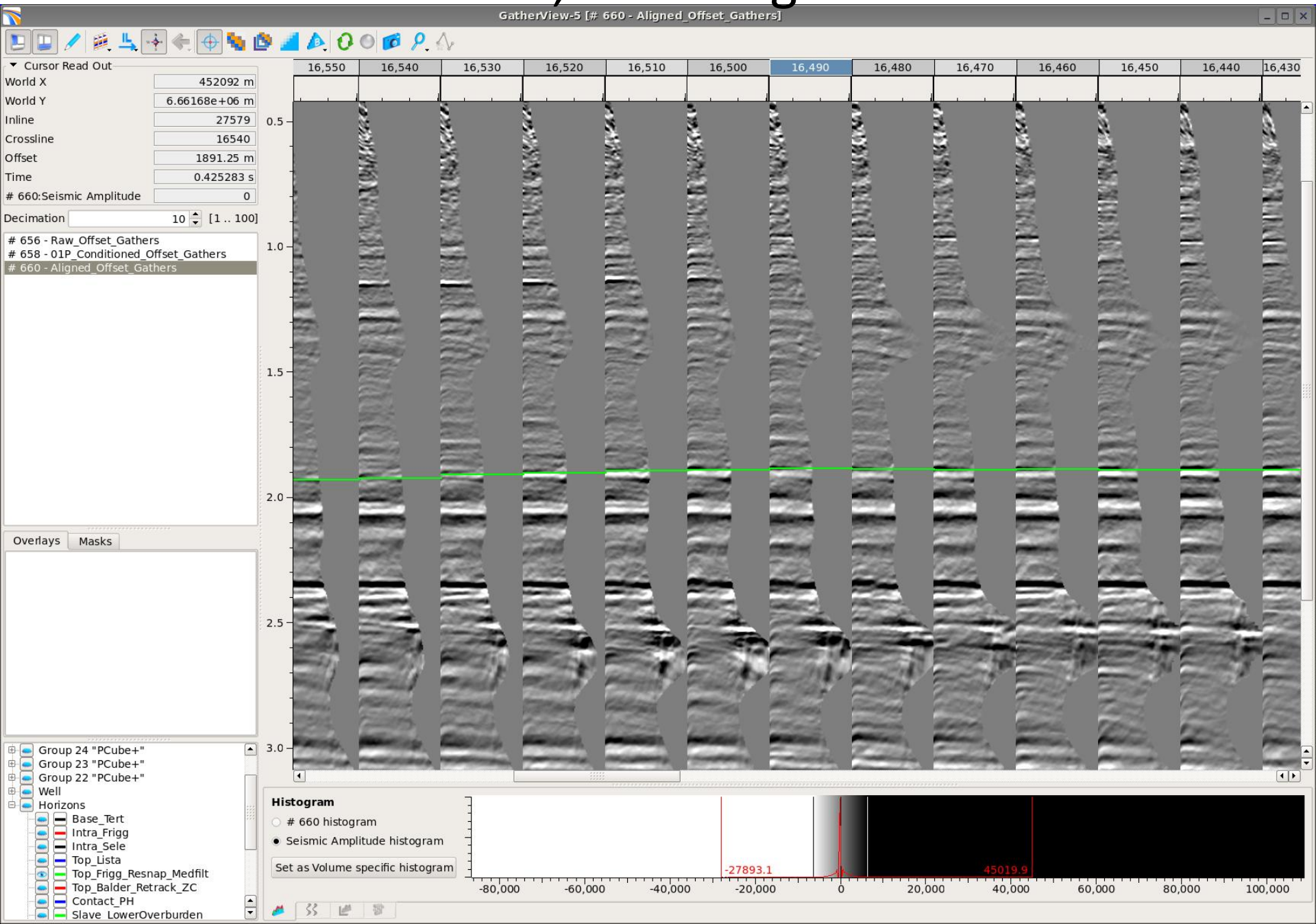
Raw Gathers


GatherView-5 [# 656 - Raw_Offset_Gathers]
Cursor Read Out
World X 452206 m
World Y 6.66163e+06 m
Inline 27579
Crossline 16530
Offset 5859.52 m
Time 0.820189 s
656:Seismic Amplitude -131.266
Decimation 10 [1 .. 100]
656 - Raw_Offset_Gathers
658 - 01P_Conditioned_Offset_Gathers
660 - Aligned_Offset_Gathers
Overlays
Masks
Group 24 "PCube+"
Group 23 "PCube+"
Group 22 "PCube+"
Well
Horizons
Base_Tert
Intra_Frigg
Intra_Sele
Top_Lista
Top_Frigg_Resnap_Medfilt
Top_Balder_Retrack_ZC
Contact_PH
Slave_LowerOverburden
16,550
16,540
16,530
16,520
16,510
16,500
16,490
16,480
16,470
16,460
16,450
16,440
16,430
0.5
1.0
1.5
2.0
2.5
3.0
Histogram
656 histogram
Seismic Amplitude histogram
Set as Content specific histogram
-86400
108736
-80,000
-60,000
-40,000
-20,000
0
20,000
40,000
60,000
80,000
100,000

Conditioned Gathers, No Alignment



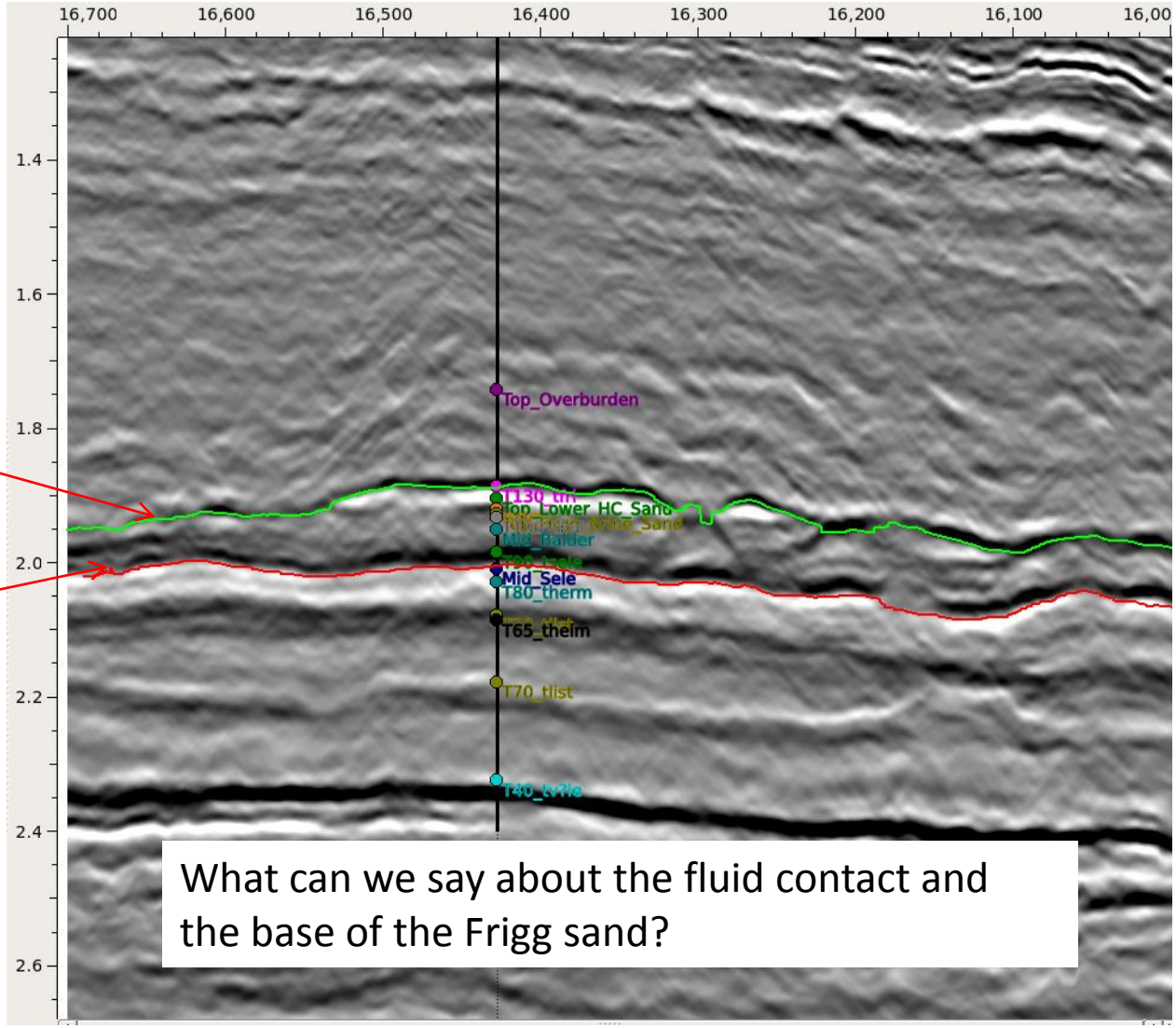
Conditioned Gathers, With Alignment



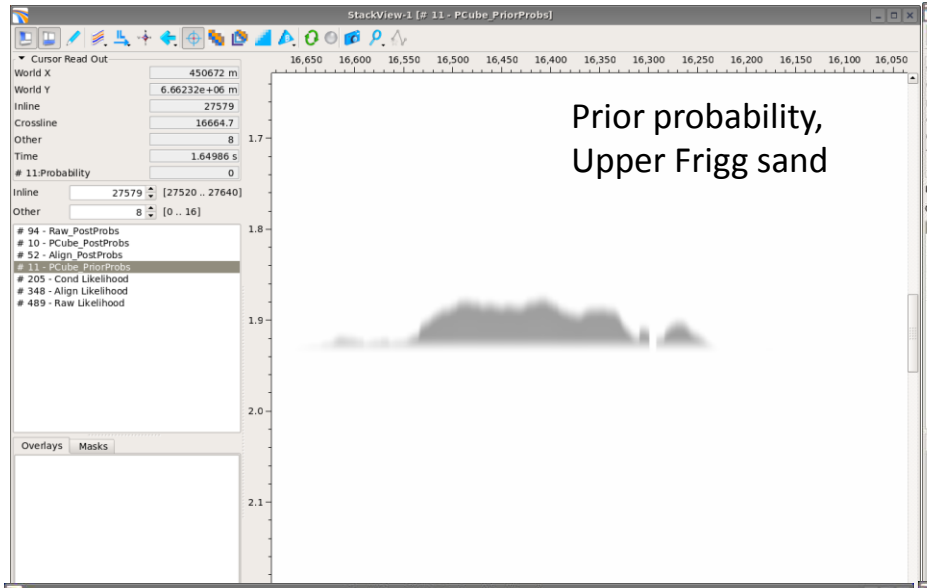
Conditioned Partial Stack, With Alignment

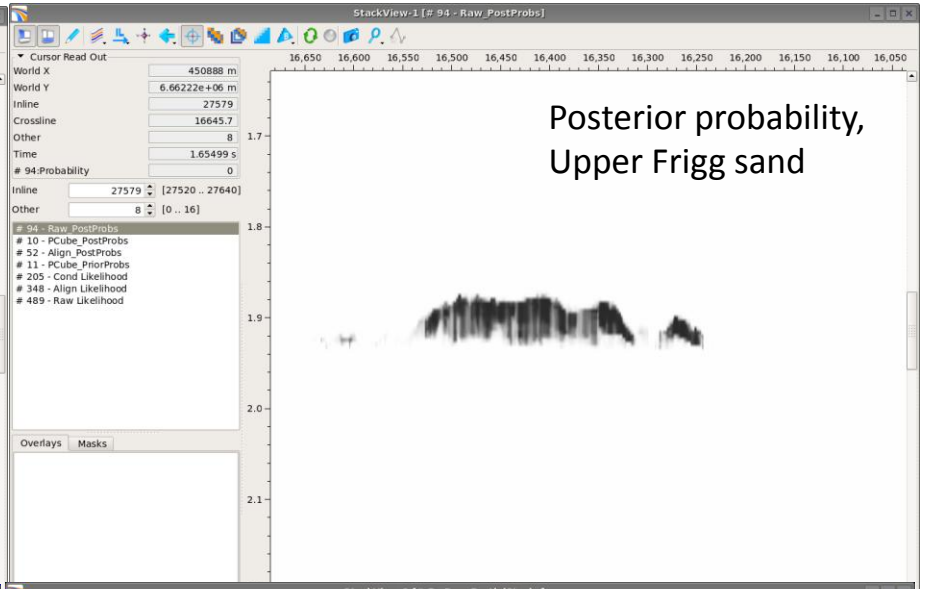
Top Frigg

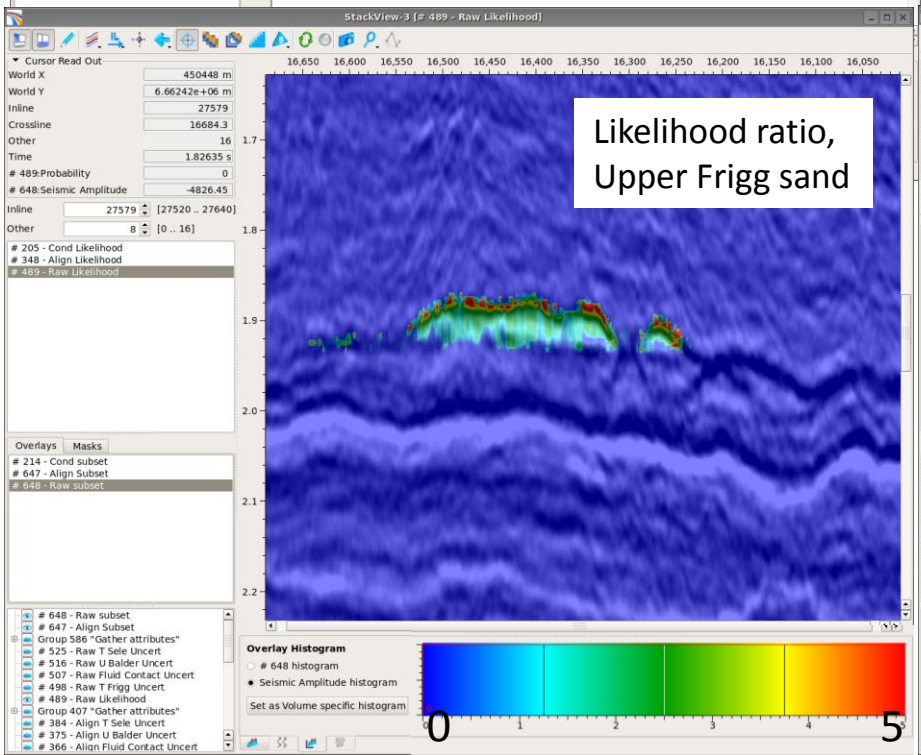
Sele

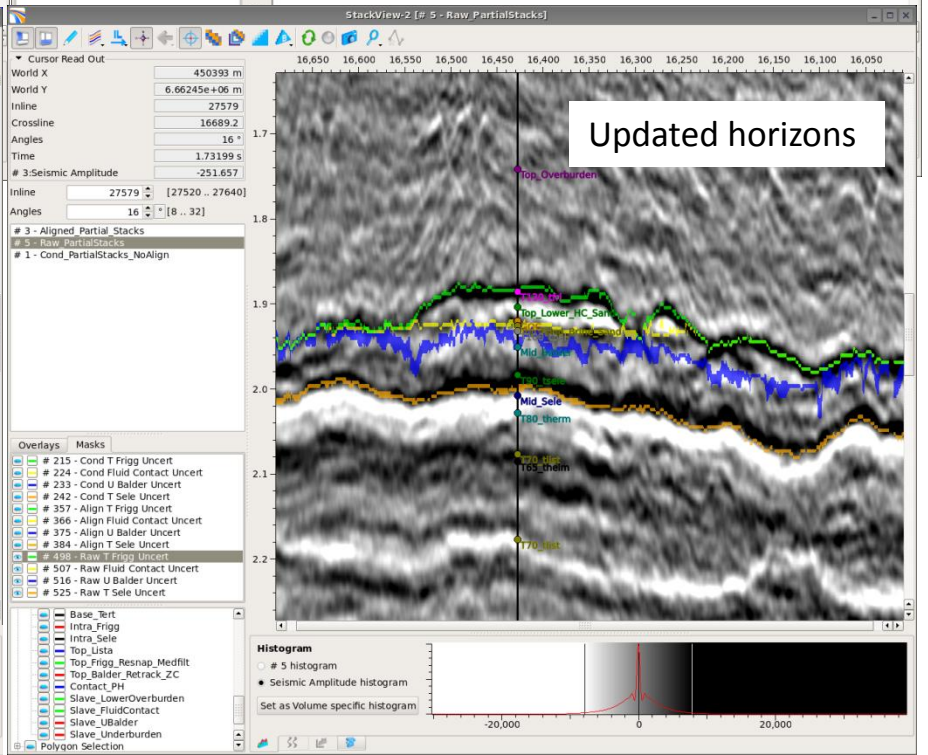


Results: No Gather Conditioning

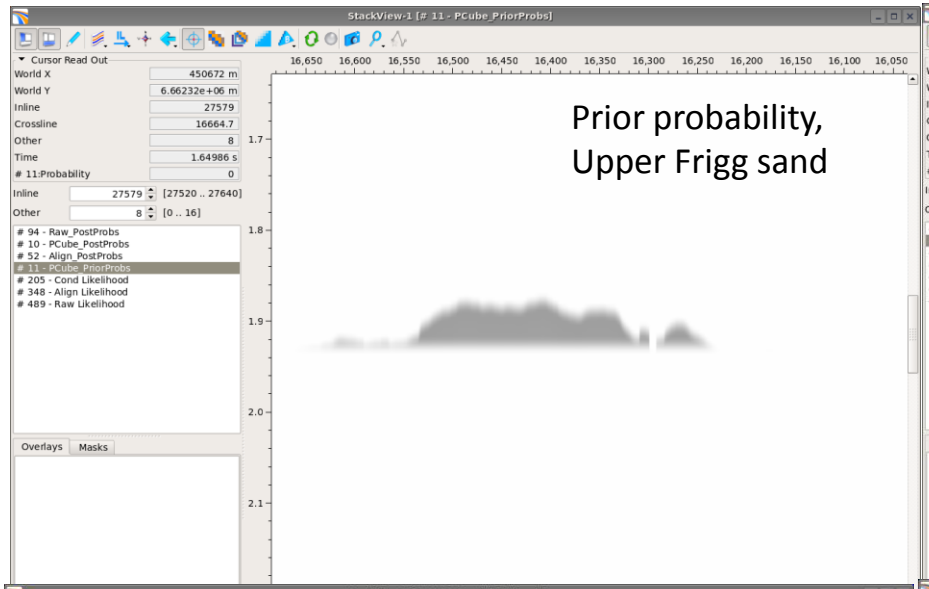


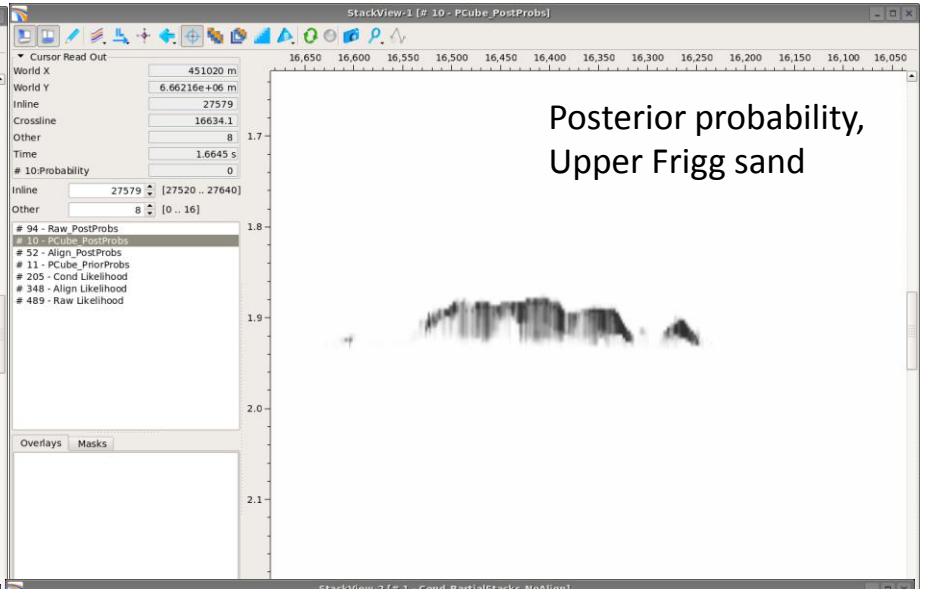


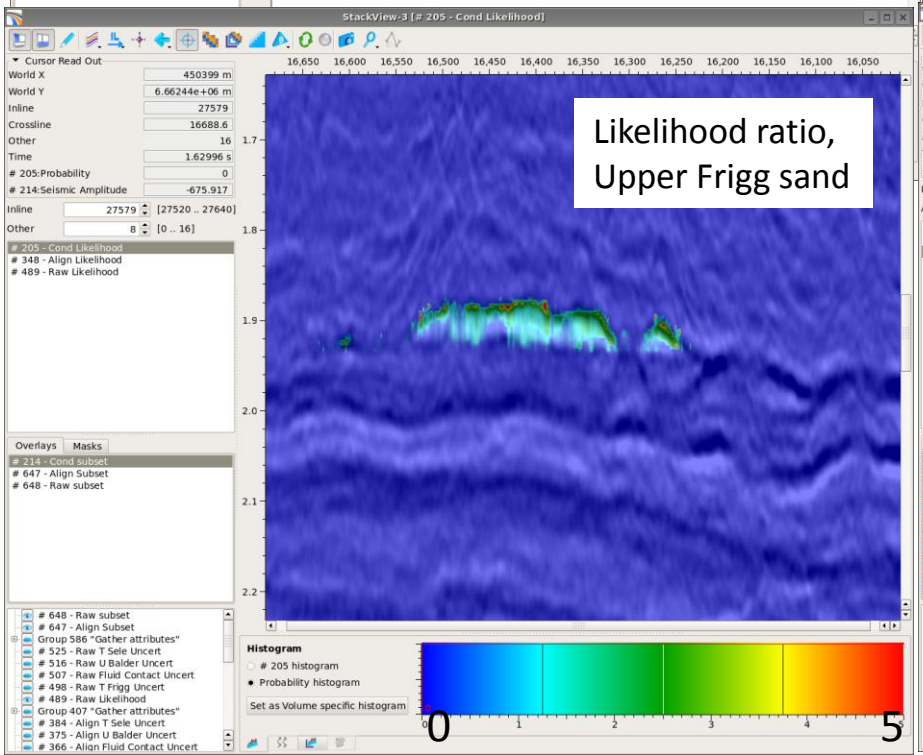


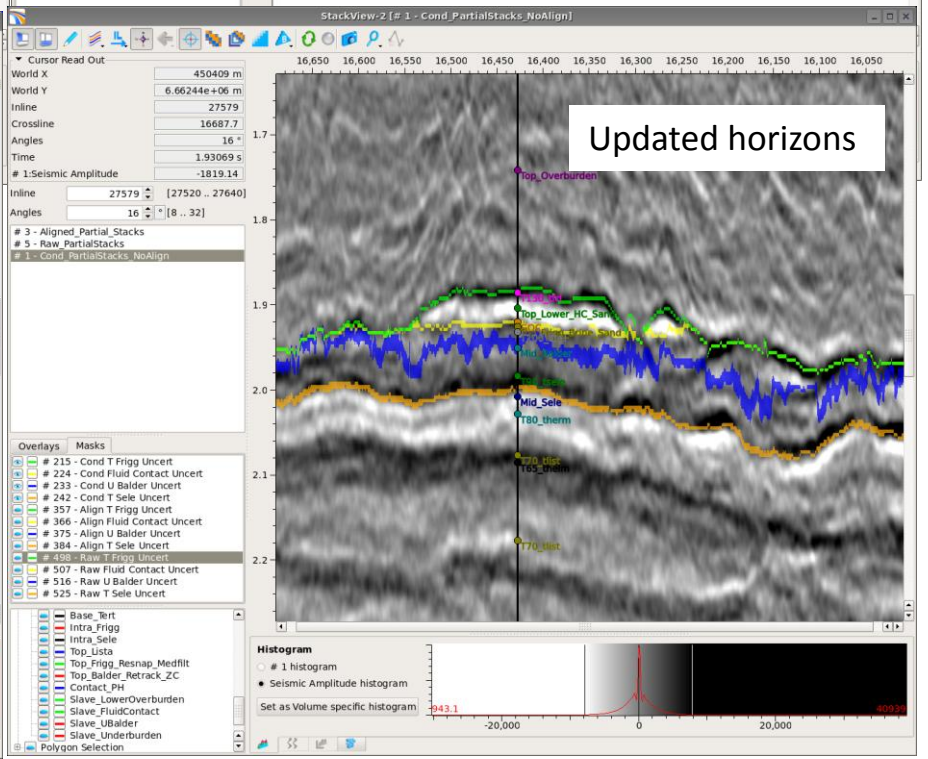


Results: Gather Conditioning, No Alignment

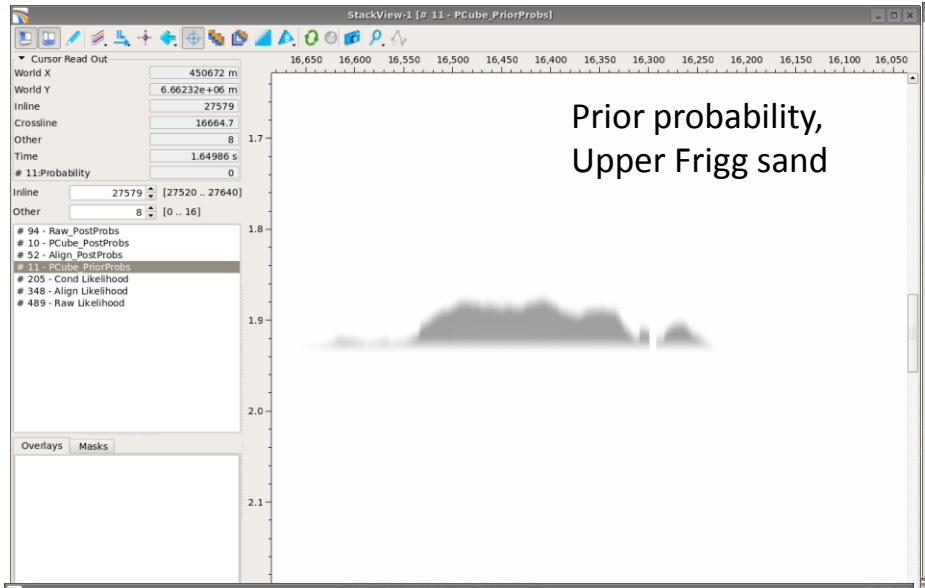


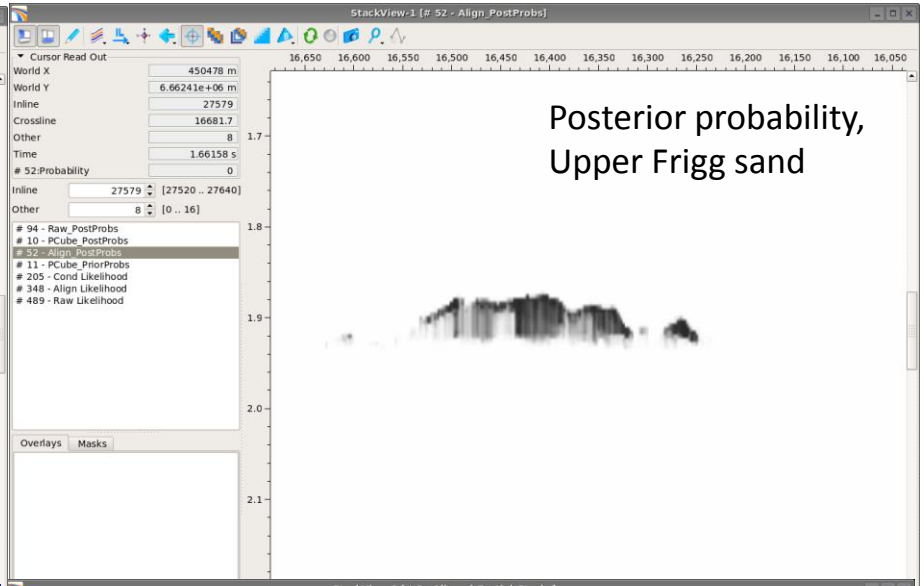


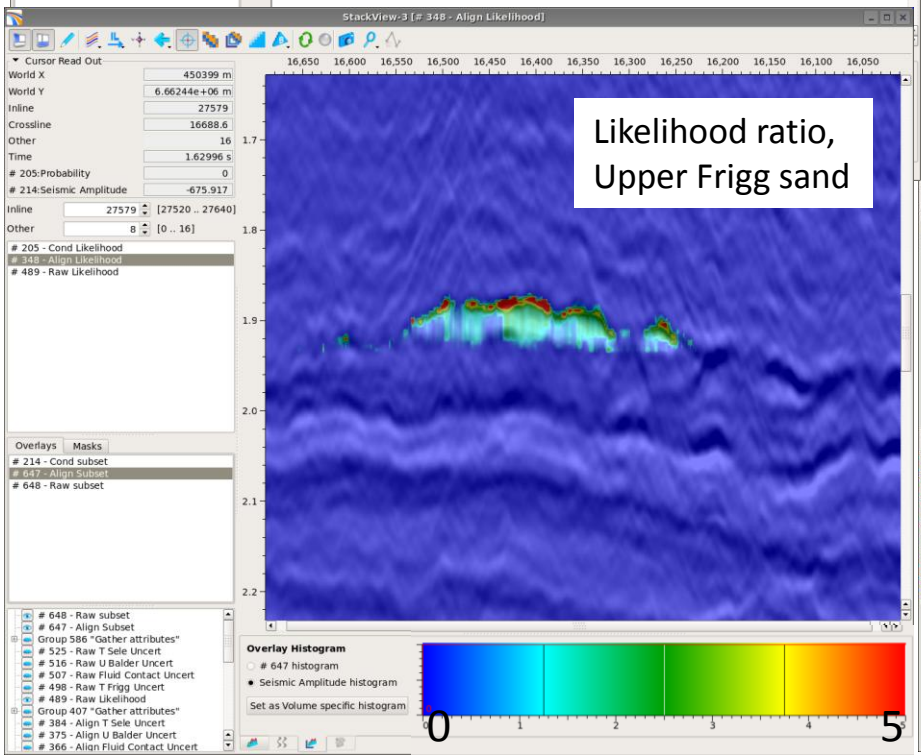


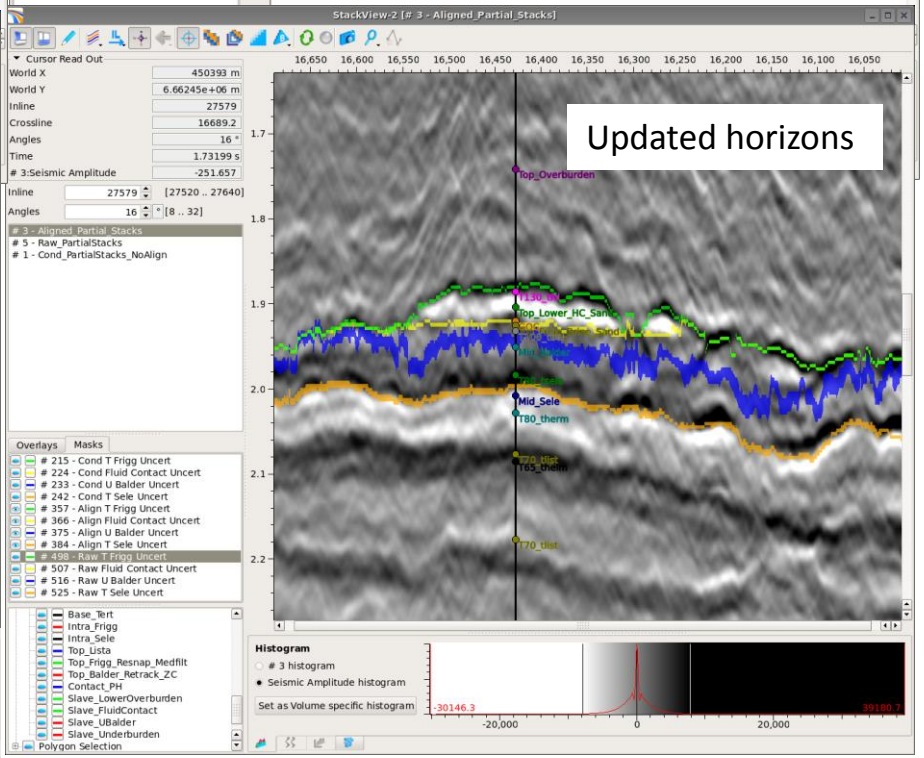


Results:Gather Conditioning and Alignment

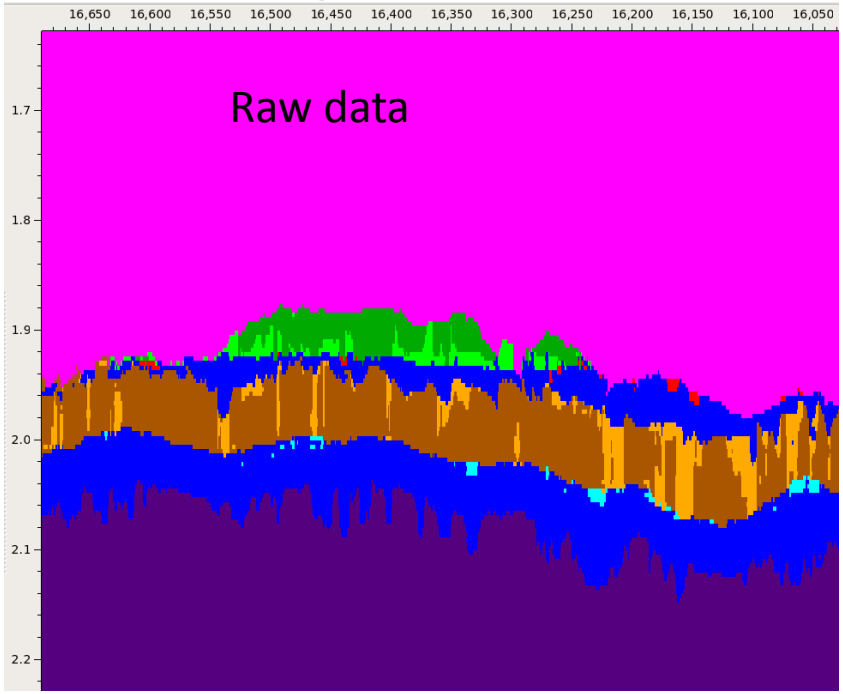


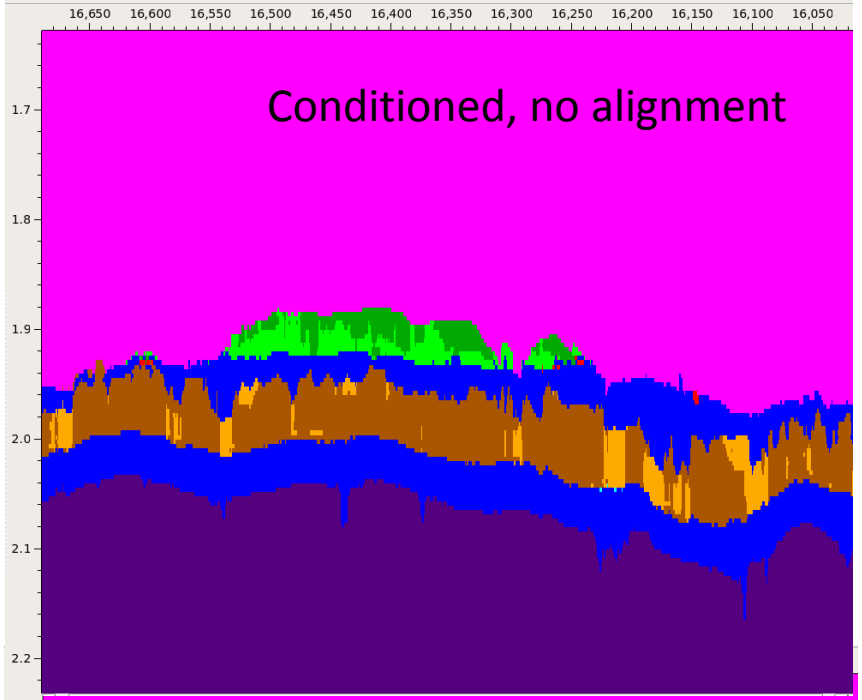


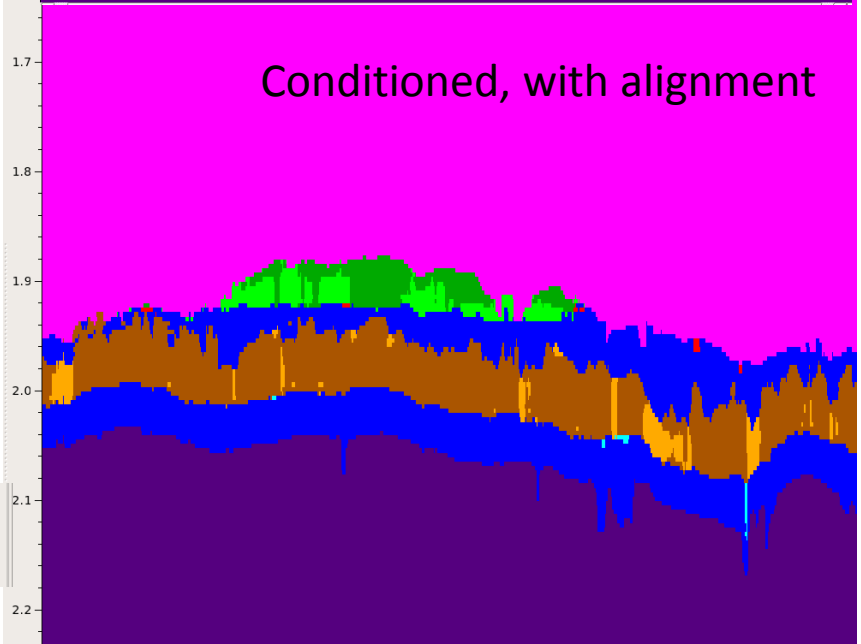


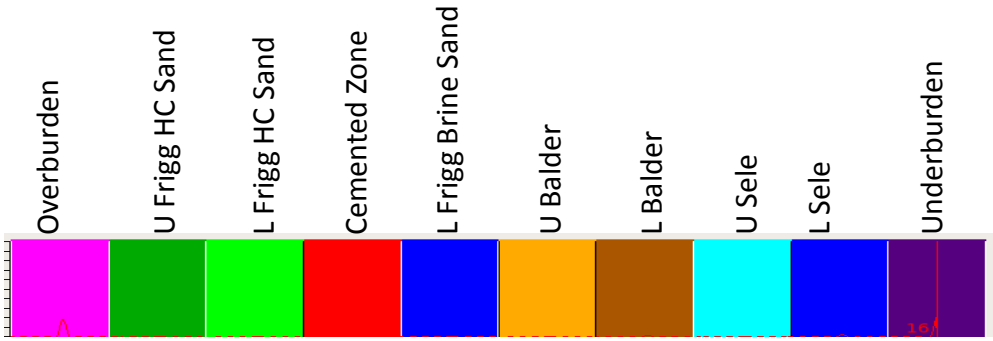


Most likely LFC

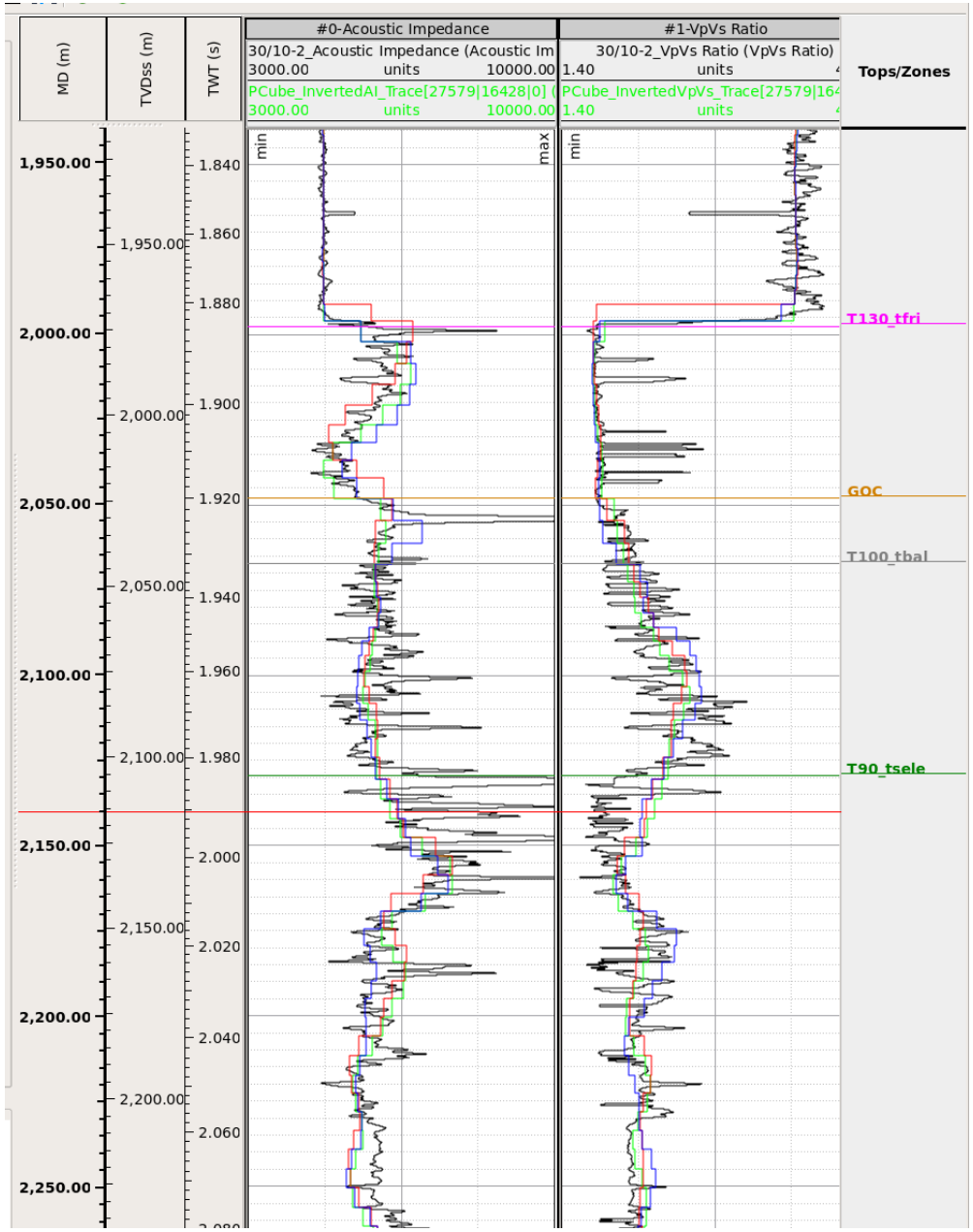


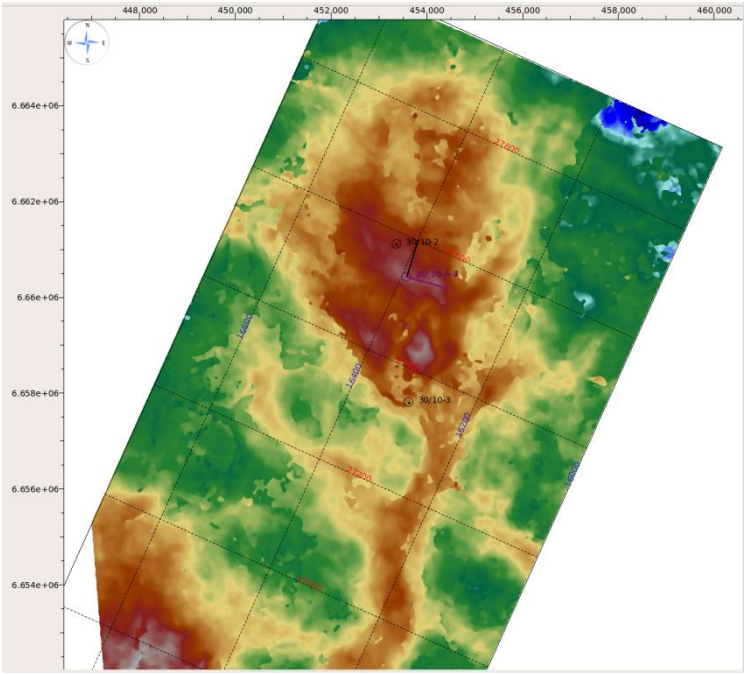






Elastic properties at well



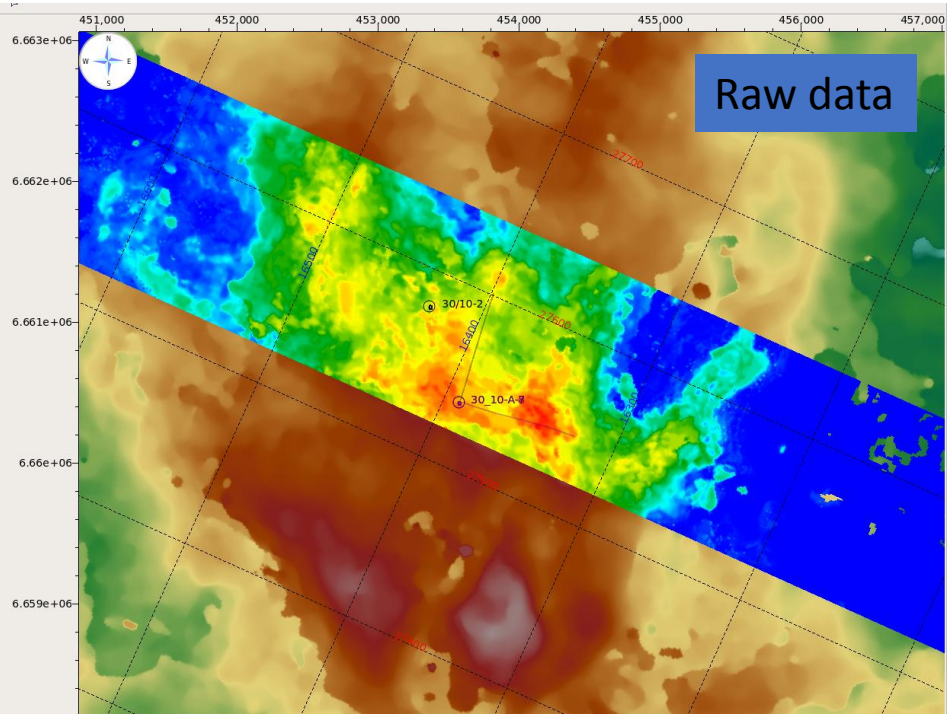


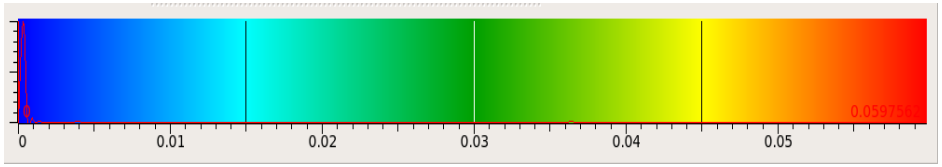
BLUE: Raw

GREEN: Conditioned, NO Align

RED: Conditioned WITH Align

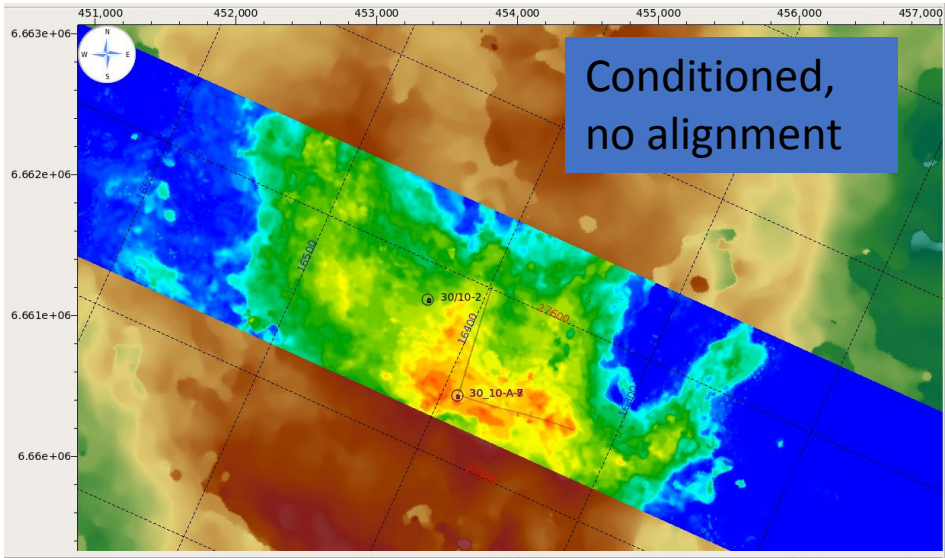
Reservoir time thickness

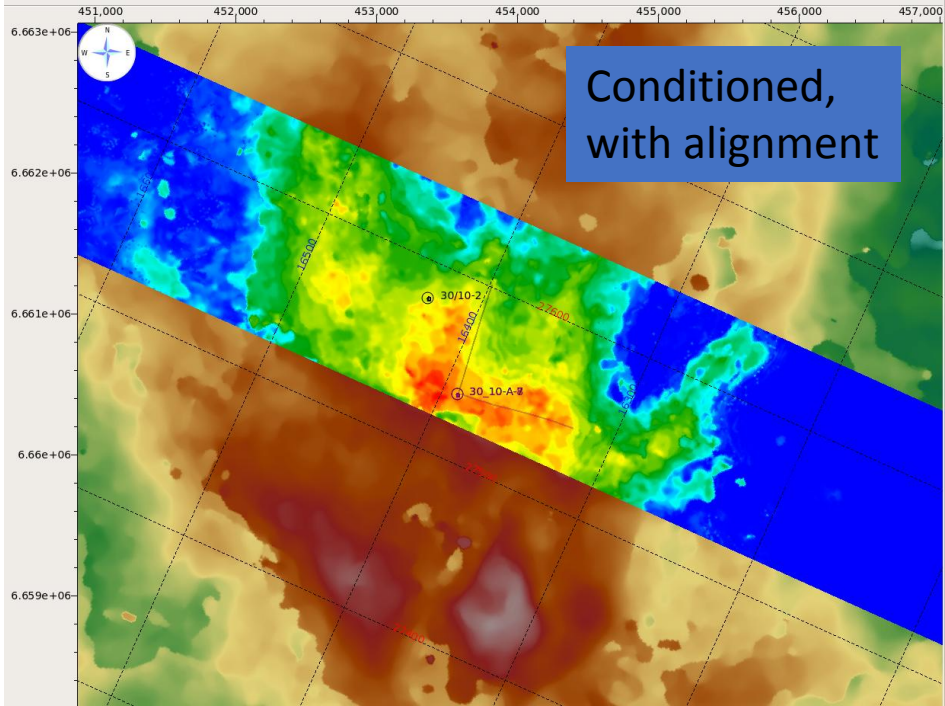




0

50 ms





Summary & Conclusions

- We describe a Bayesian pre-stack inversion that improves the characterisation of sand bodies in complex stratigraphy
- Comparing inversion results from raw and conditioned gathers demonstrates the benefits of the conditioning processes.
  - General de-multiple and de-noise processing improves the geological consistency of the results
  - Gather alignment sharpens the results, reducing uncertainty in thickness & and volumetric estimates, and improves the information supplied to the drillers.
  - It is important to close the loop from inversion results back to seismic gathers
- Quantification of probabilities could carry forward to reservoir modeling and flow simulation
- Pre-stack interpretation is providing new insights into likely rock property distribution