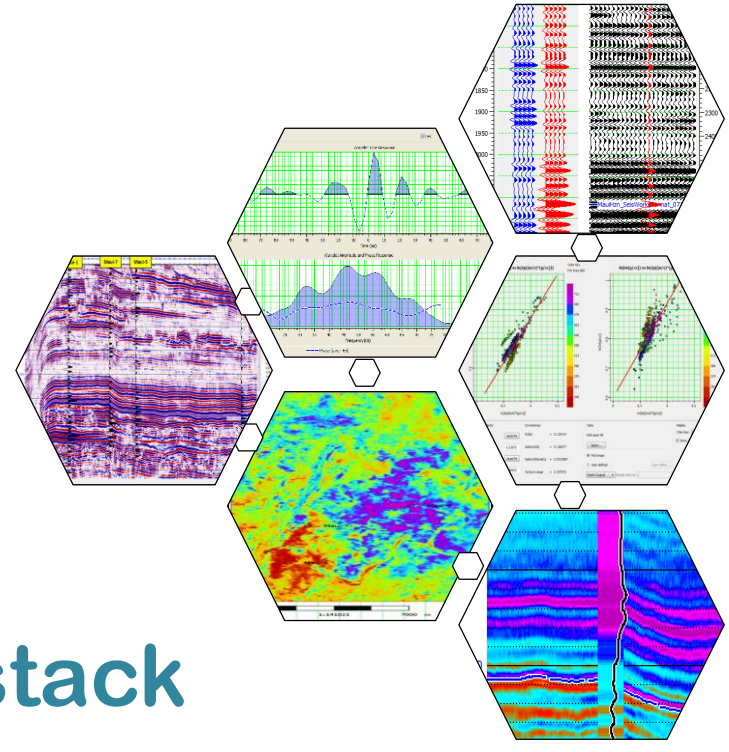

AVO Analysis
Post-stack & Pre-stack
Seismic Inversion

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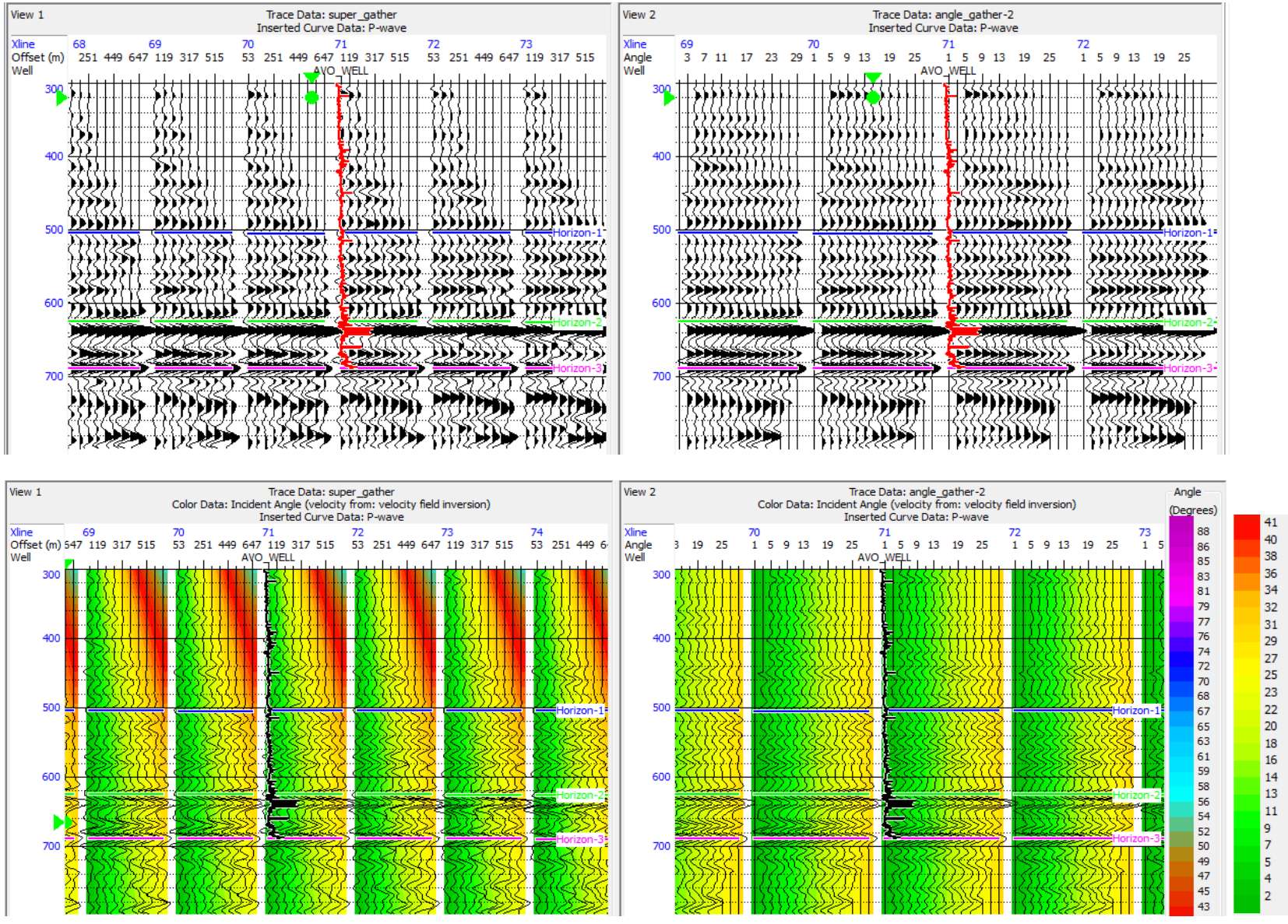
Outline

Presentation has divided into 3 parts:

- **AVO Analysis**
  Using the Geoview tutorial dataset
- **Pre-stack Inversion**
  Using the Geoview tutorial dataset
- **Post-stack Inversion**
  Seismic Data: Maui 3D
  Well Data: Maui 1, Maui 5, Maui 6 and Maui 7

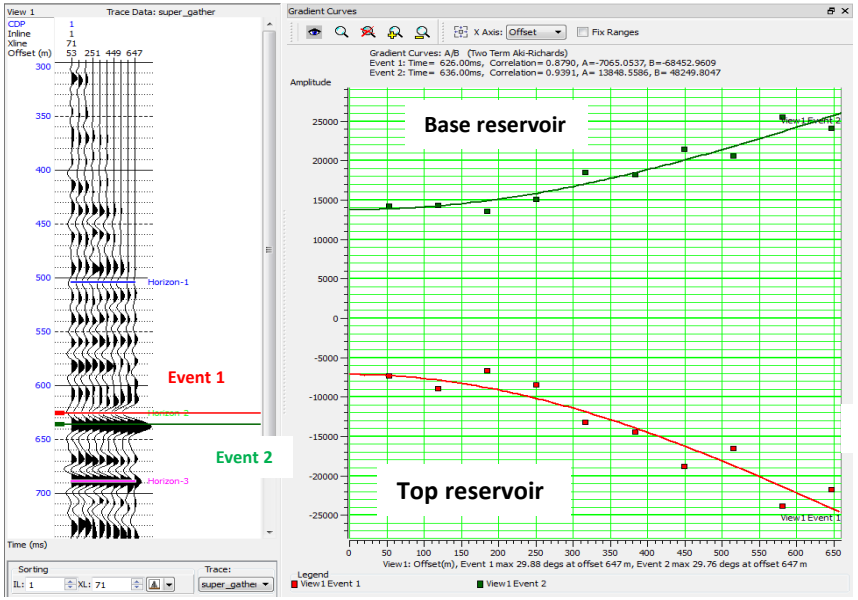
1. AVO Analysis
(Geoview tutorial dataset)

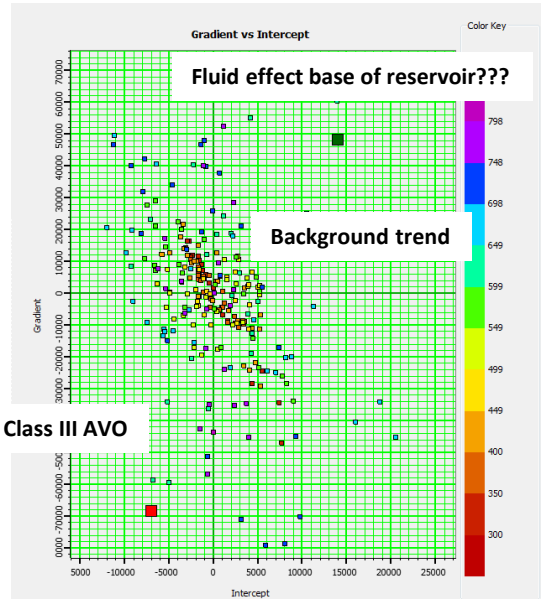
Angle Gather

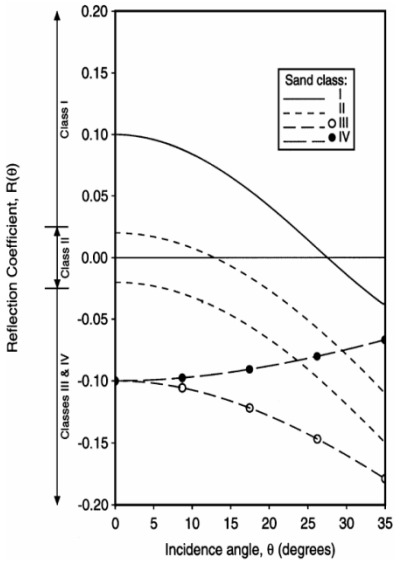


- Color data represent the incident angle and maximum angle for Angle Gather is 30 degree.
- Since data volume is small we select single log as source to create velocity field to transform offset to angle.

AVO Gradient Analysis



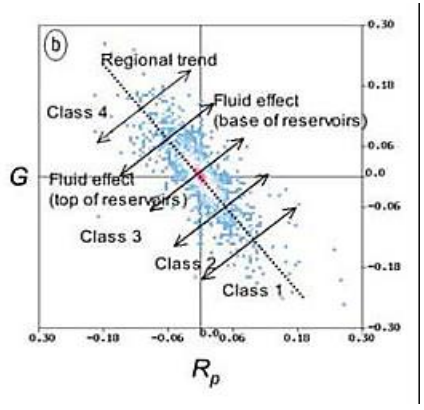


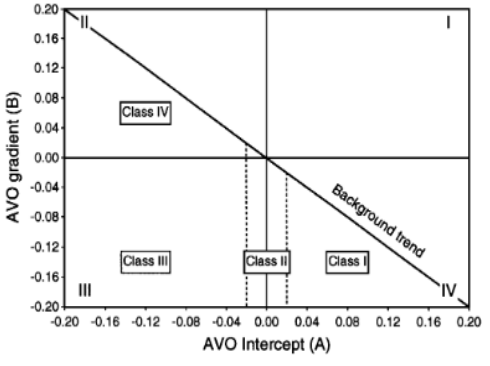



```
Analysis Volume: super_gather
Gradient Curves: A/B   (Two Term Aki-Richards)

Event 1: Time=  626.00ms,  Correlation= 0.8790, A=-7065.0537, B=-68452.9609, Max Angle= 29.88
Event 1: Vint= 2536.09, Vrms= 2180.62
Event 2: Time=  636.00ms,  Correlation= 0.9391, A= 13848.5586, B= 48249.8047, Max Angle= 29.76
Event 2: Vint= 2574, Vrms= 2187.08
```

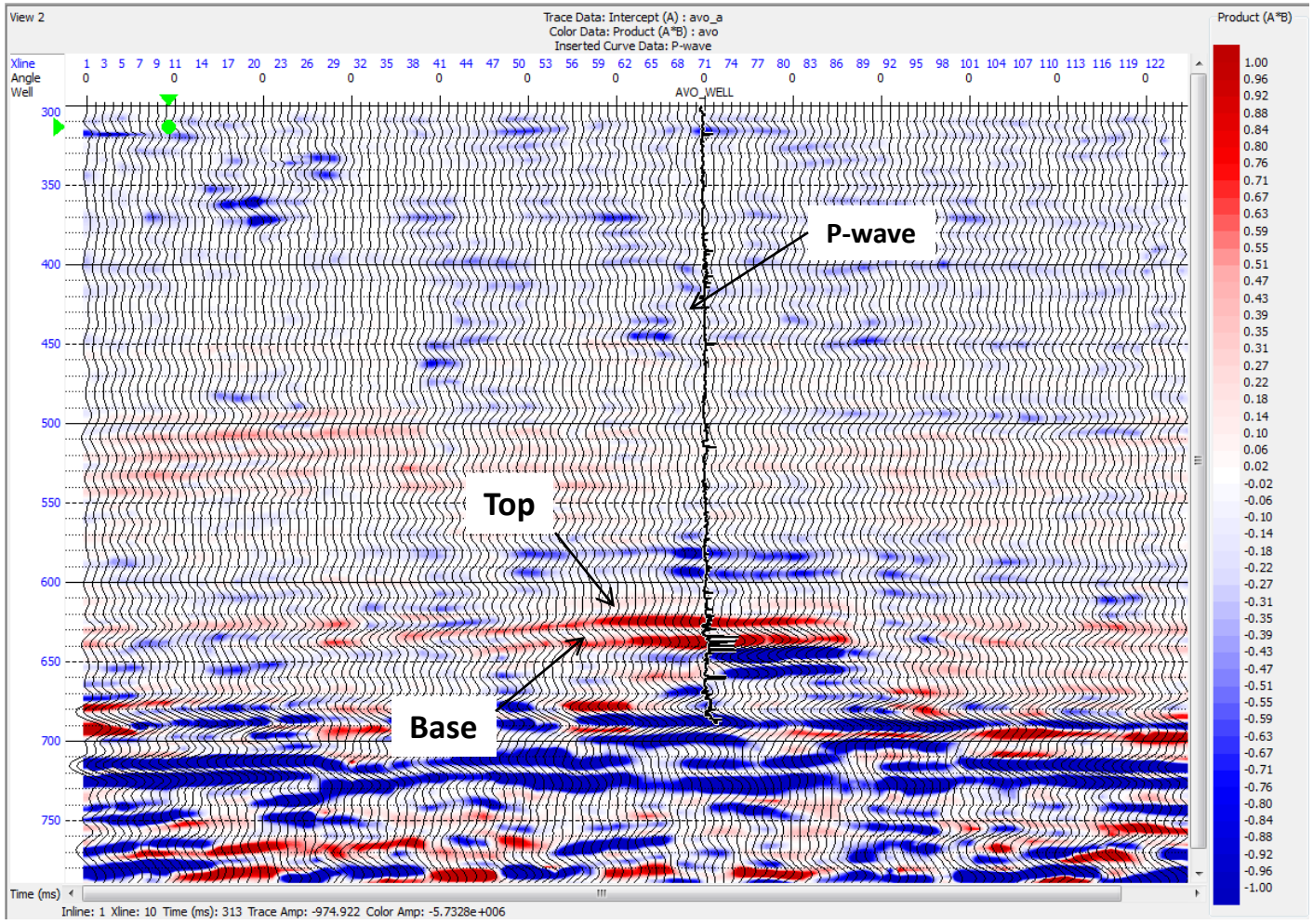
#	<Offset(m)>	<Amplitude Event 1>	<Amplitude Event 2>
1	53	-7263	14334
2	119	-8821	14414
3	185	-6567	13659
4	251	-8364	15138
5	317	-13085	18571
6	383	-14307	18341
7	449	-18706	21516
8	515	-16463	20735
9	581	-23713	25638
10	647	-21701	24230





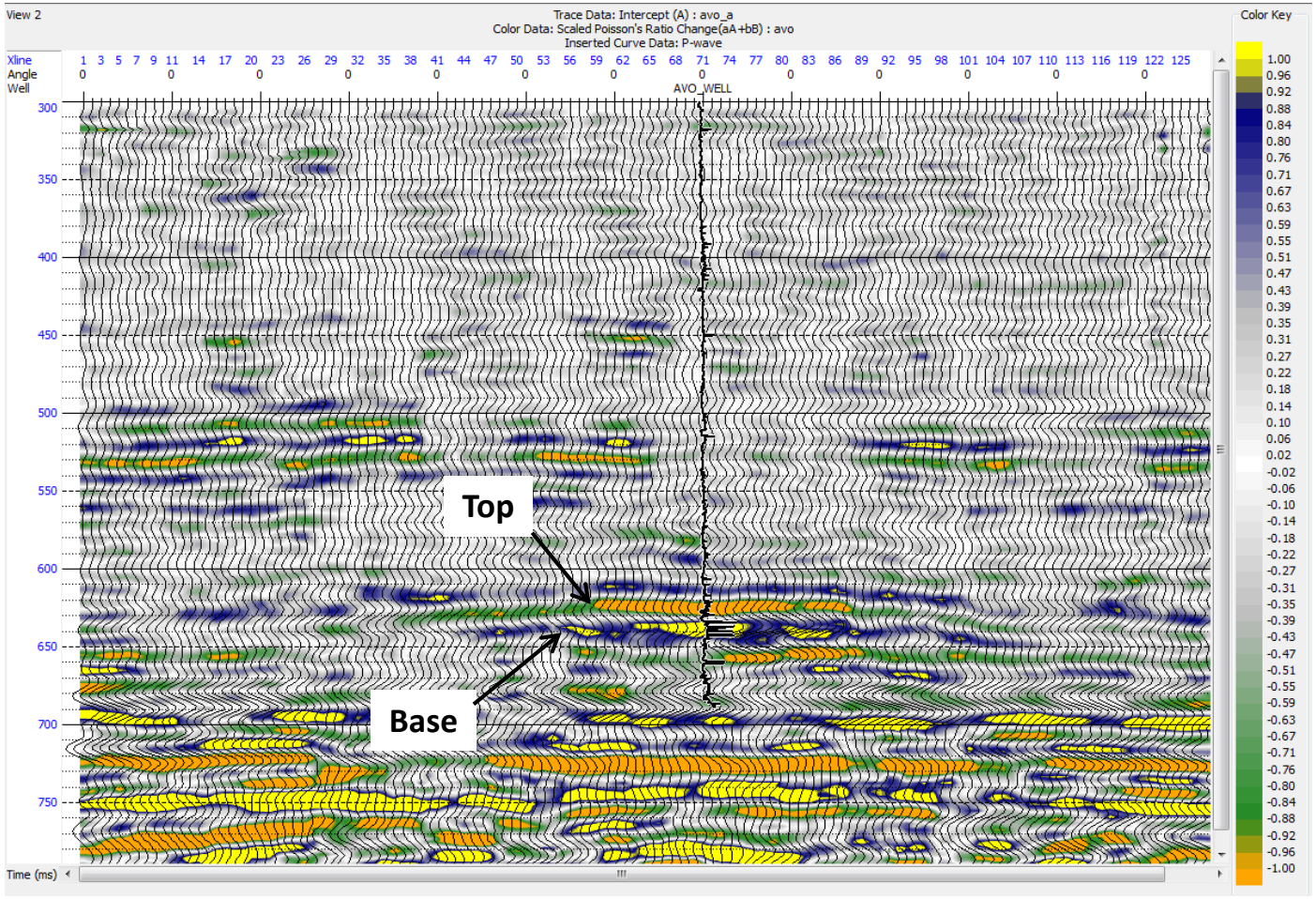
- Class III AVO anomaly with amplitudes increasing for both the trough at the top of the sand (red) and the peak at the base of the sand (green).
- The fit of the AVO curves is extremely good. Correlation for event -1 is 87% and event-2 is 93%.

AVO Attribute Volume: (A*B)



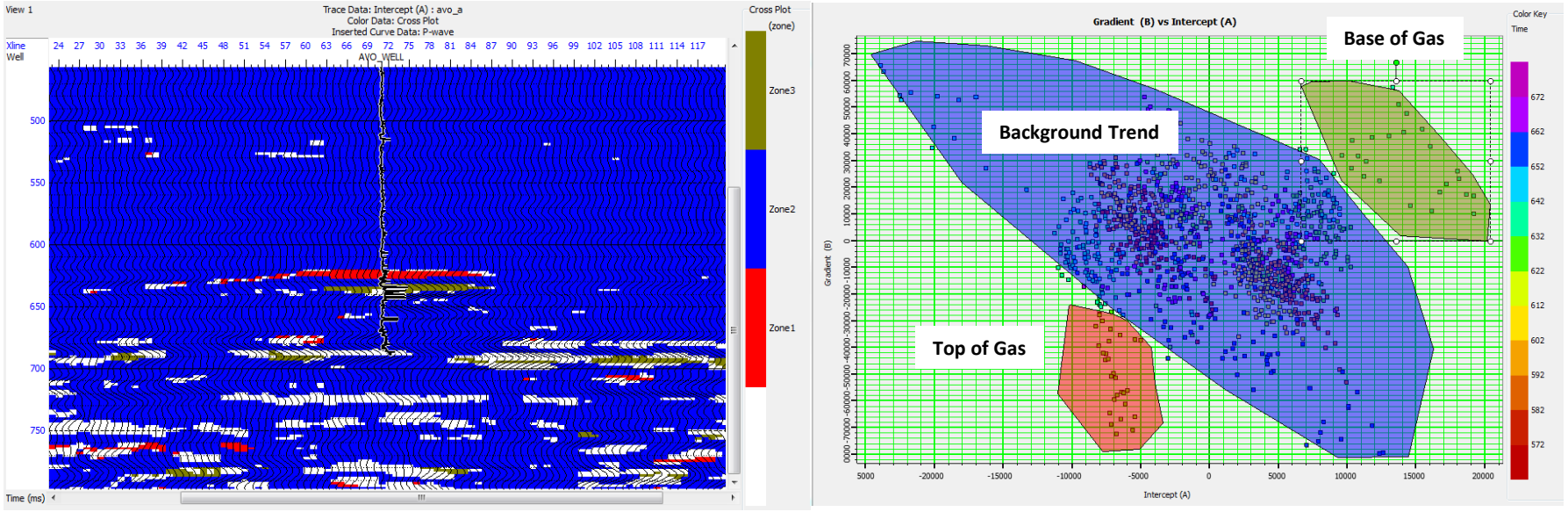
- The color data is currently the product of intercept and gradient (A*B).
- Since this is a class 3 AVO anomaly (High negative gradient and intercept), we can see a strong positive response at the top and base of the reservoir at 630 ms.

Scaled Poisson's Ratio Change (Aa+Bb)



- Sum of A+B is propositional to the change in Poisson's Ratio.
- At the top of the reservoir shows strong negative response (orange), indicating a drop in Poisson's Ratio (gas bearing zones have very low Poissson's Ratio), while at the base of the reservoir a positive response (yellow), indicating an increase in Poisson's Ratio.

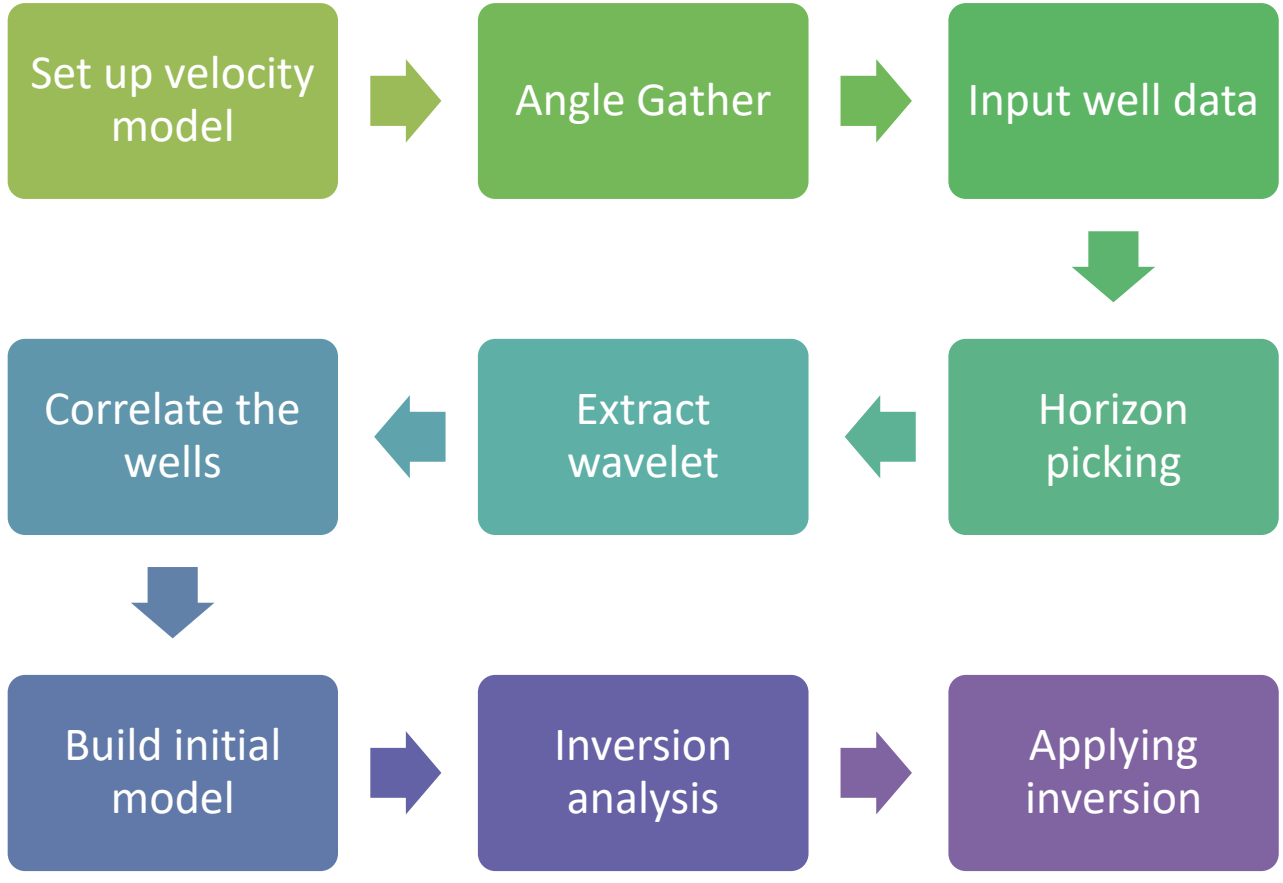
Cross-Plotting: Intercept vs Gradient



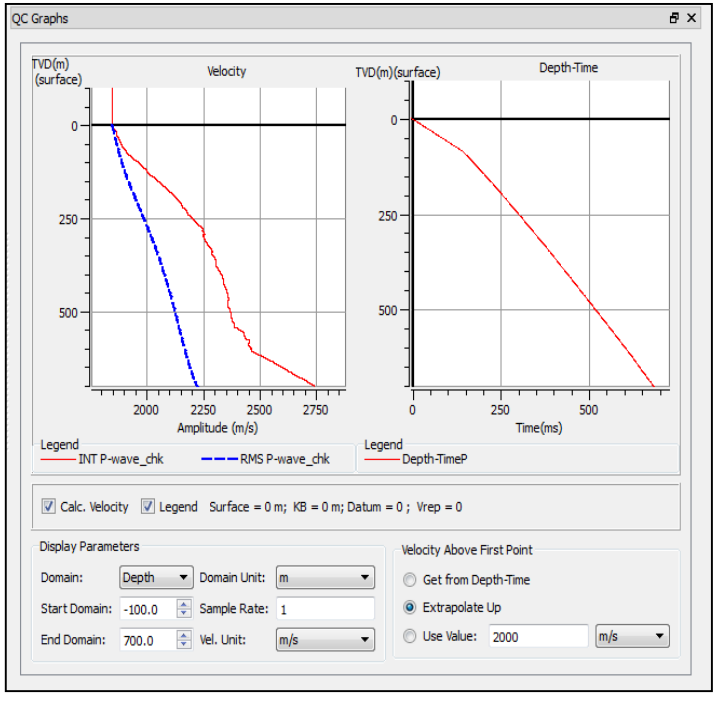
Cross-plotting the intercept versus the gradient (B), as shown on the left. As seen in the figure below, the highlighted zones correspond to the top of gas sand (red), base of gas sand (blue) and background trend (green).

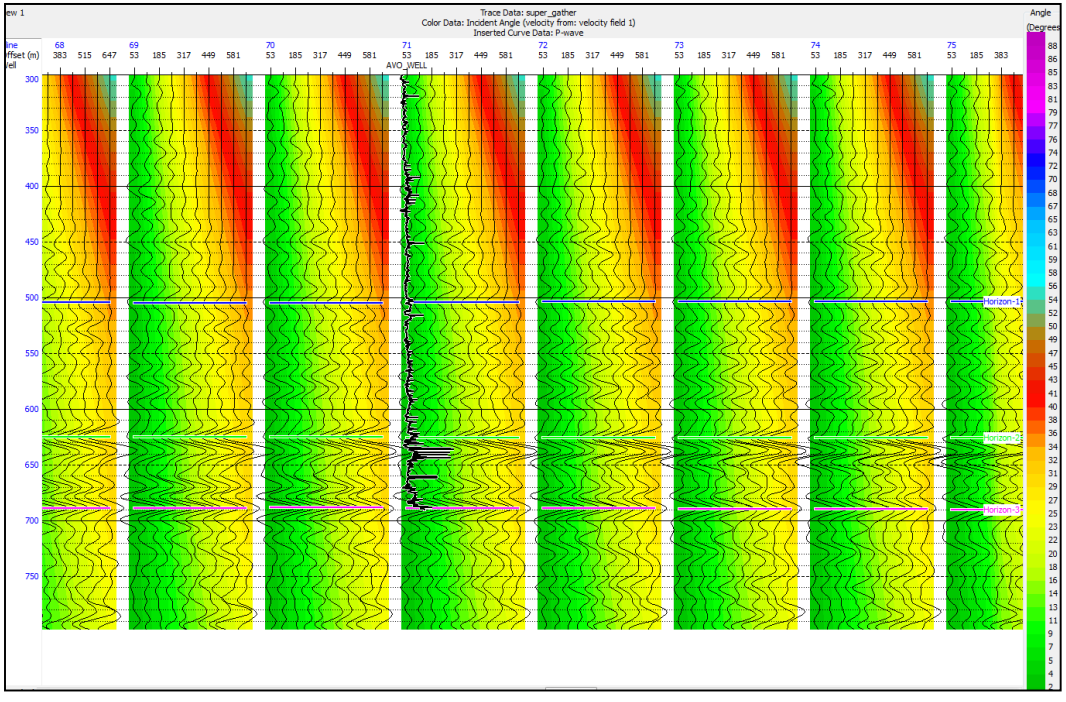
2. Pre-stack Inversion
(Geoview tutorial dataset)

Pre-stack Inversion Workflow



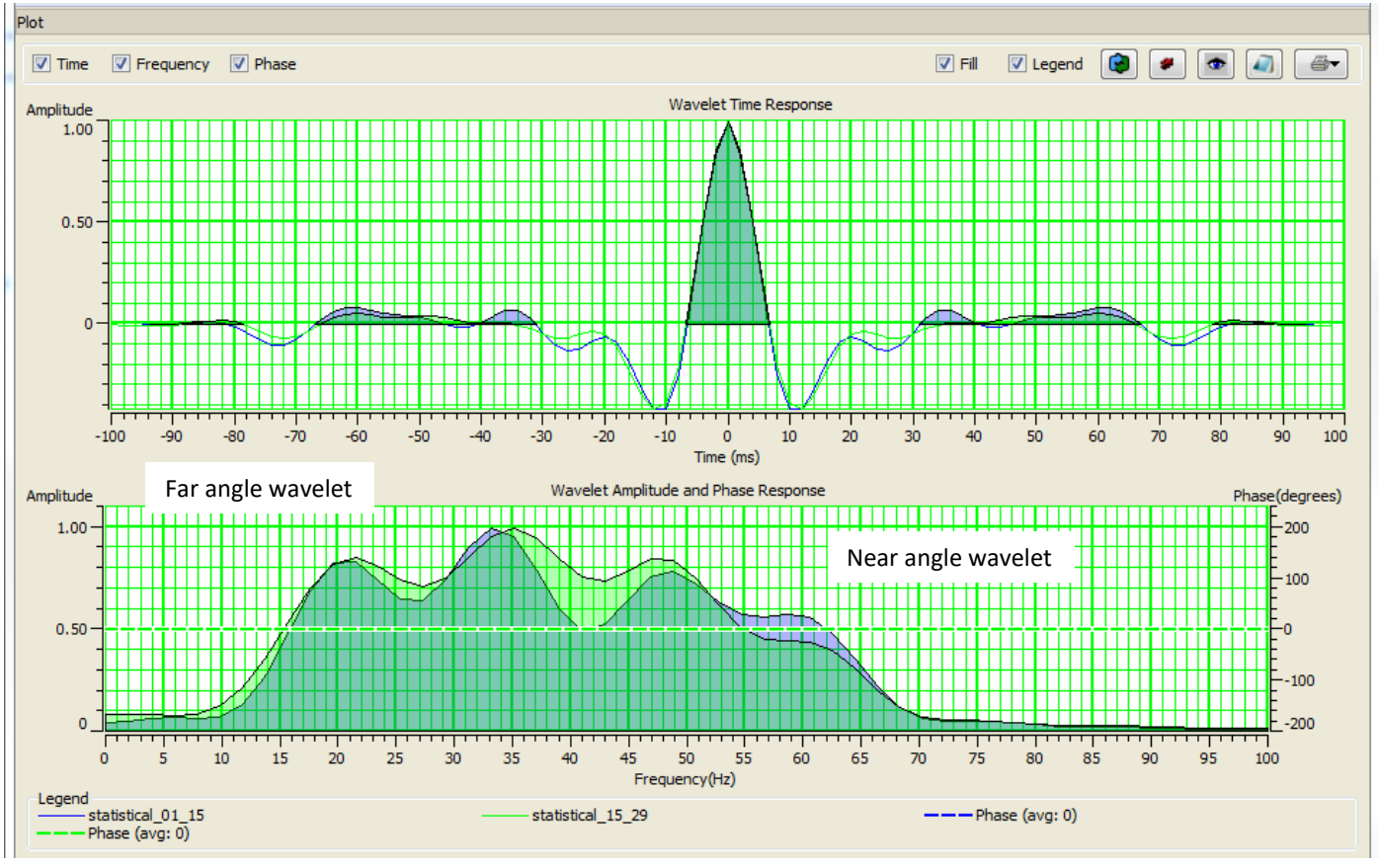
Velocity Field Model





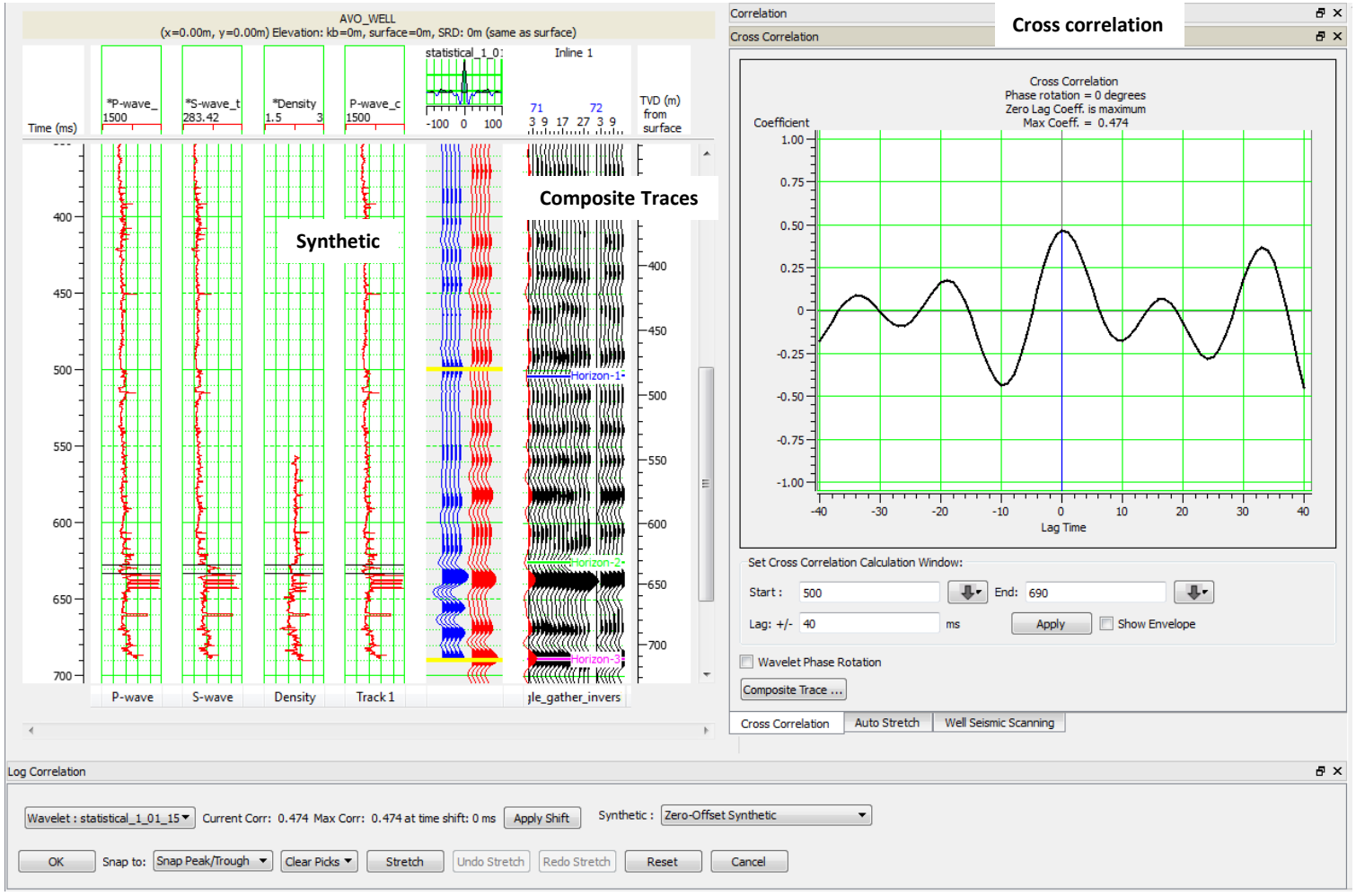
- The purpose of this step is to define a velocity model, which will be used to transform the offset dependent super gather into an angle gather.
- Color display shows usable angles at the zone of interest out to about 30 degrees and trace data is super gather.

Wavelet Extraction



- Statistical wavelet assuming zero phase data.
- Since it is expected that high frequency energy continuously loss from near to far offset trace by trace, but practically wavelet extraction per 15 degrees is sufficient.
- Two wavelet are extracted for per 15 degrees, because the current angle gather range is 15 to 30 degrees.

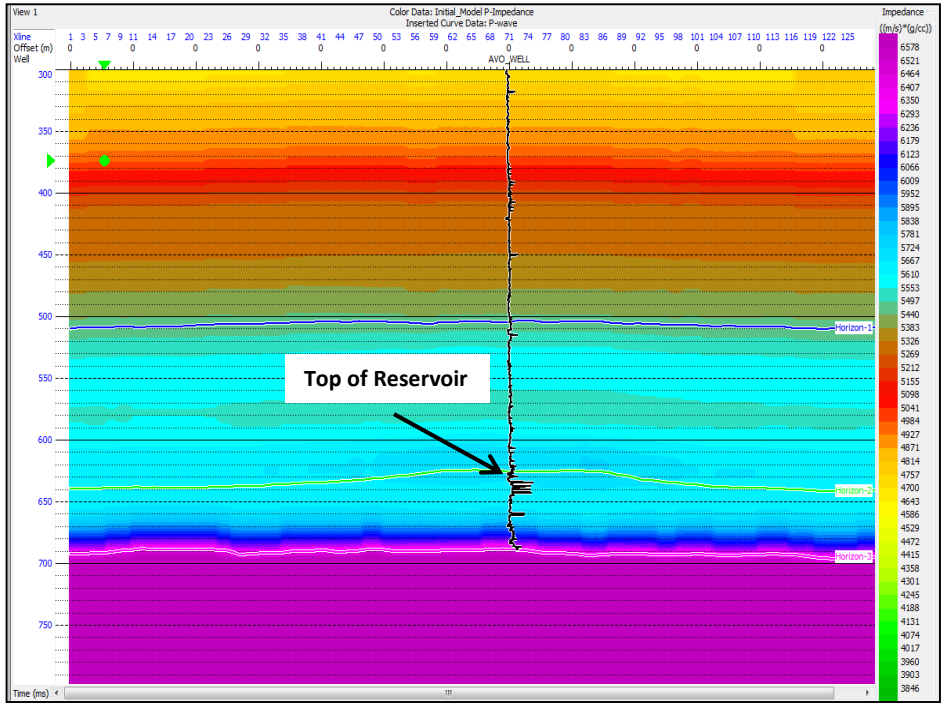
Log Correlation



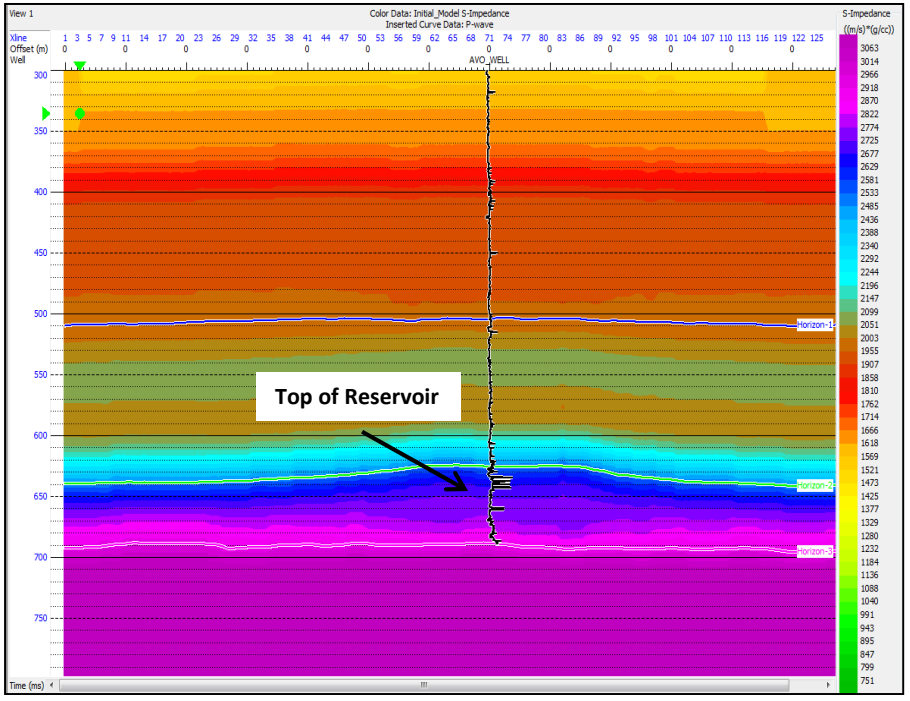
We limit the window from 500-690ms considering our target location. Then correlation window suggest lag 40ms for maximum correlation to get maximum correlation (47%).

Initial Model

P Impedance



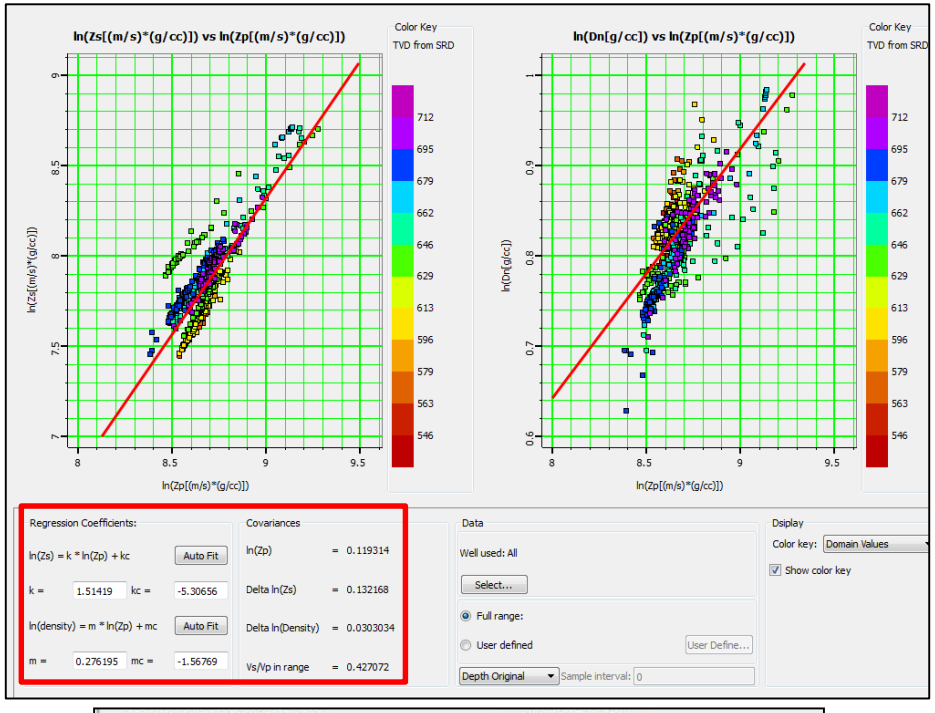
S Impedance

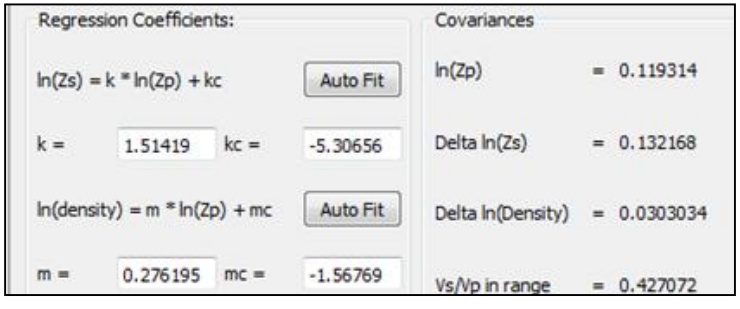


10/15 Hz high cut frequency filter has applied.

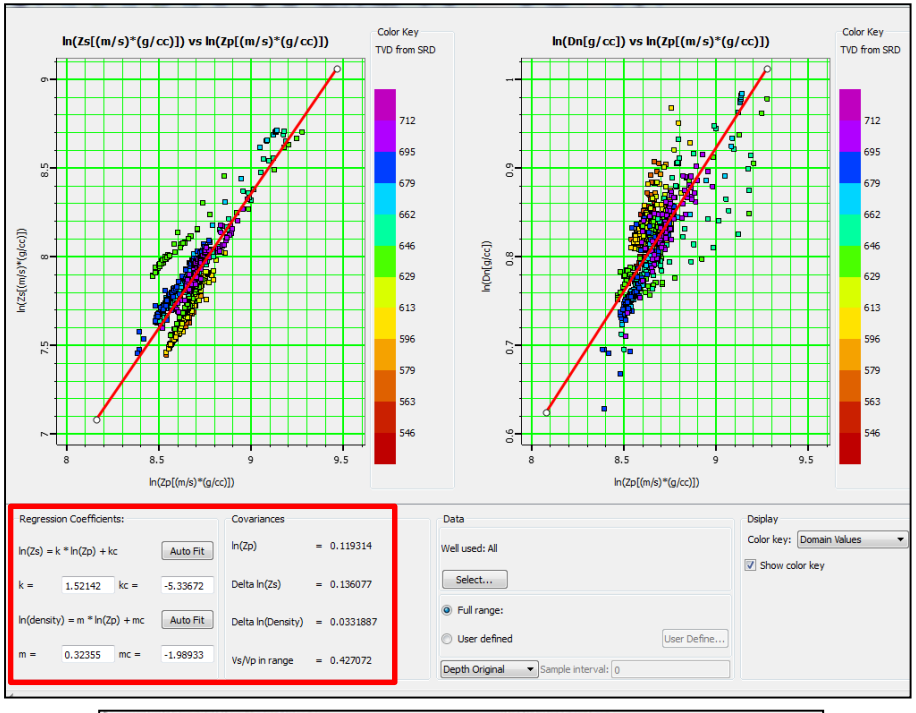
Inversion Analysis

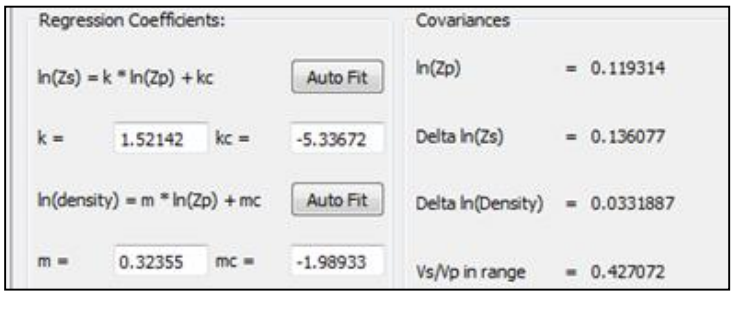
Automatically derived trend lines





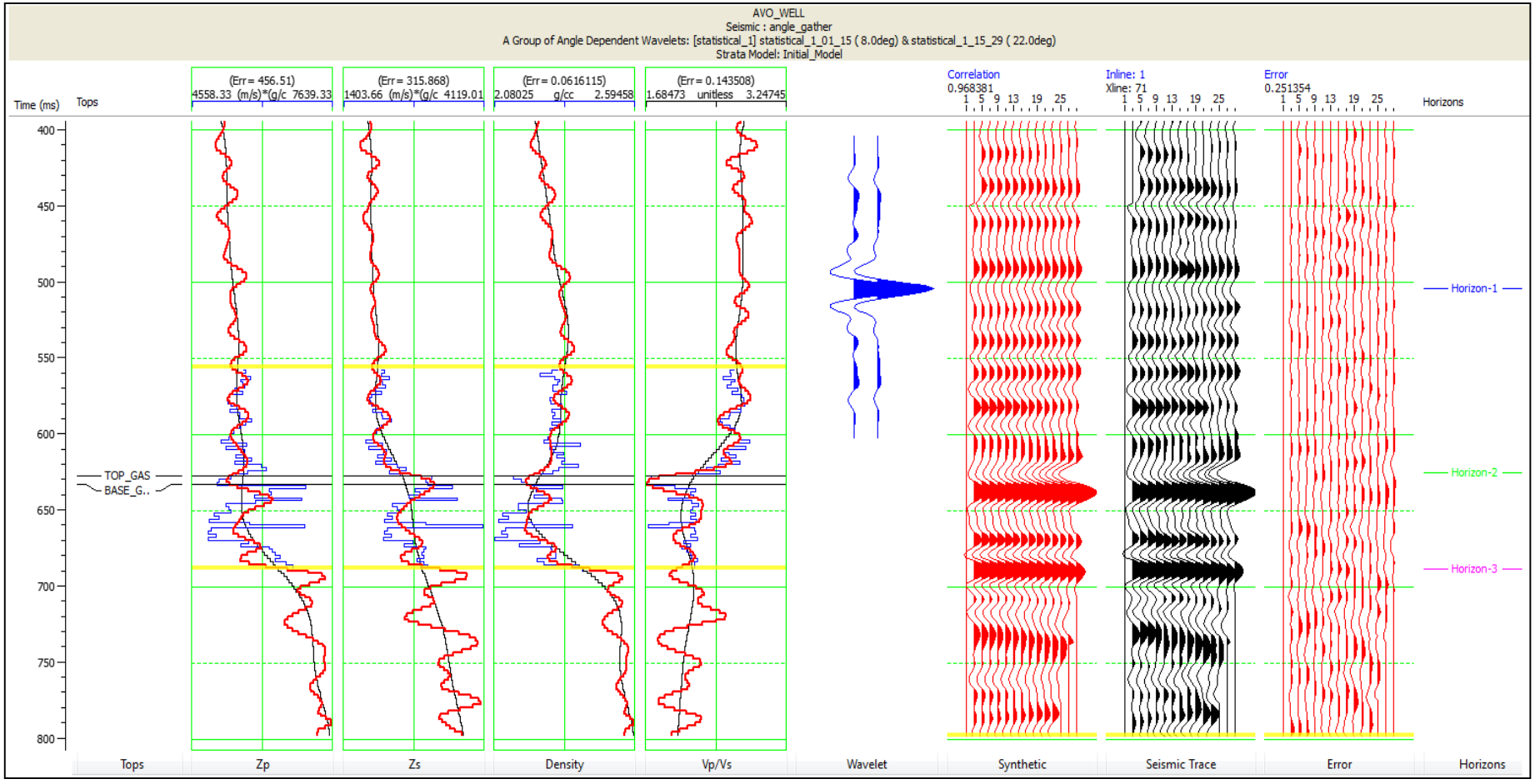
Manually adjusted trend lines





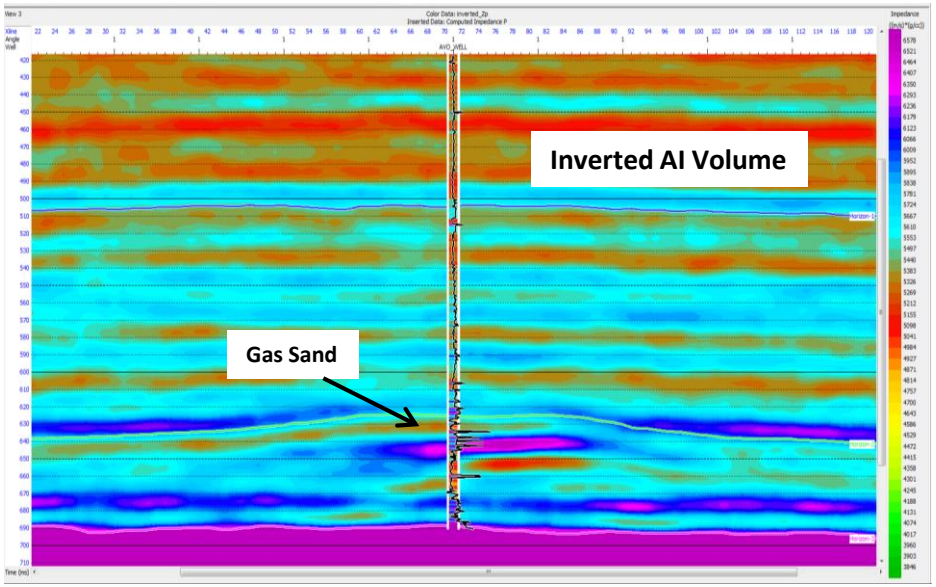
- The red lines indicate the current linear trend and background trend relating the variables Zp, Zs, and density.
- Geoview use this trend to reduce the non-uniqueness of the Pre-stack inversion process.

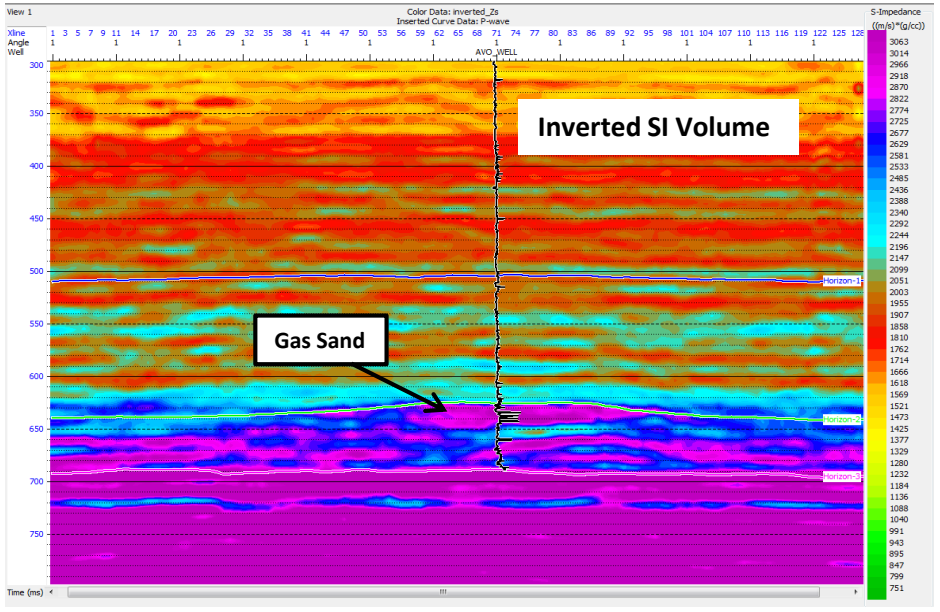
Inversion Analysis



From left to right, the display shows the inversion results (in red) overlaying the original logs (blue). To the right, we see the synthetic traces calculated from these inversion (in red) followed by the original seismic (in black). Finally, we see the error, which is the difference between the two previous results. The error is small which indicate that the inversion is mathematically correct.

Inverted volume: AI and SI



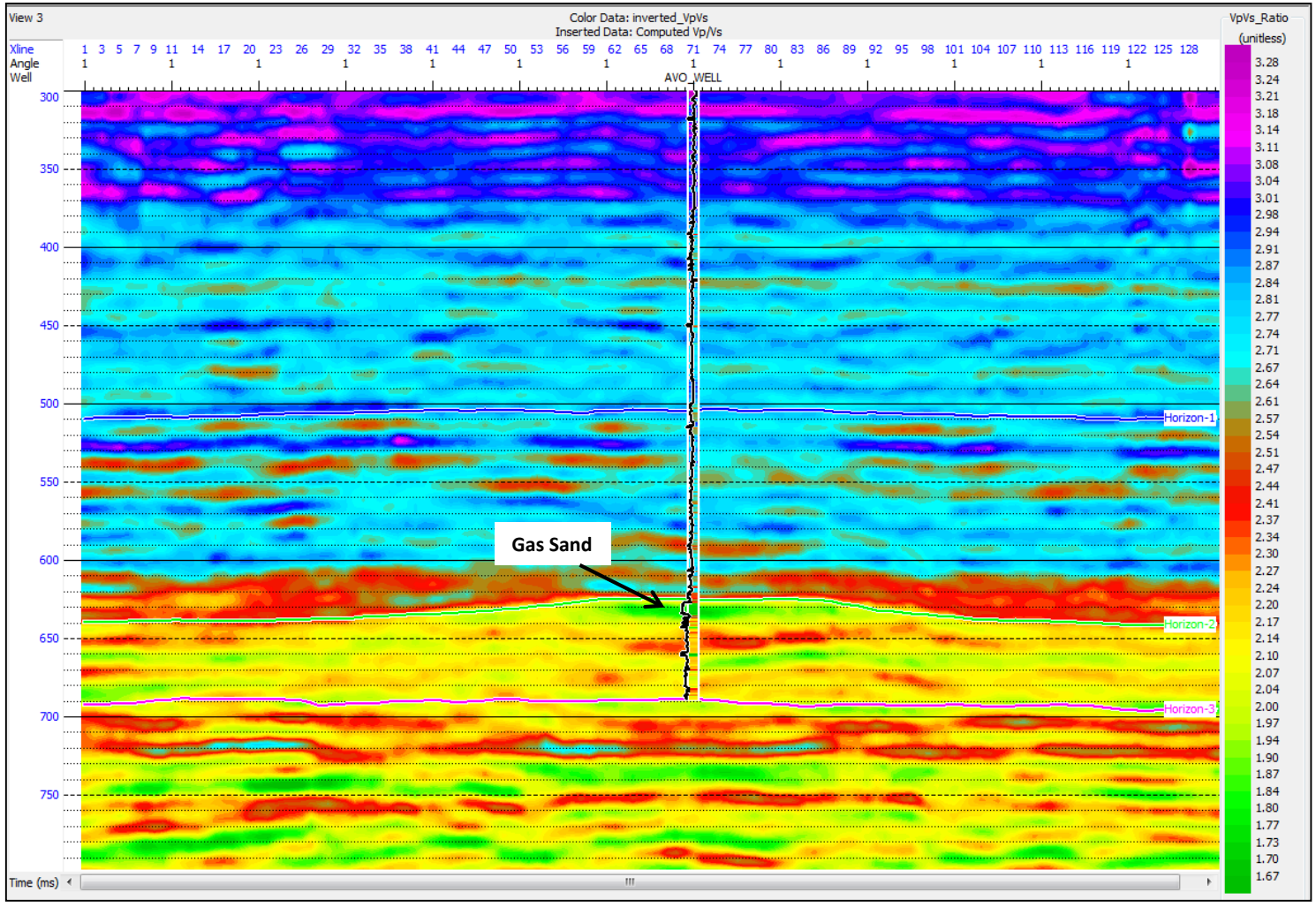


- AI and SI representative of Vp and Vs. Magnitude of the velocity (velocity controlled by modulus) play high role than density in impedance calculation.

$$AI = \rho V_P$$
$$SI = \rho V_S$$

- The low AI below Horizon 2 represents the gas sand. But SI value increase because Vs doesn't response to fluid.

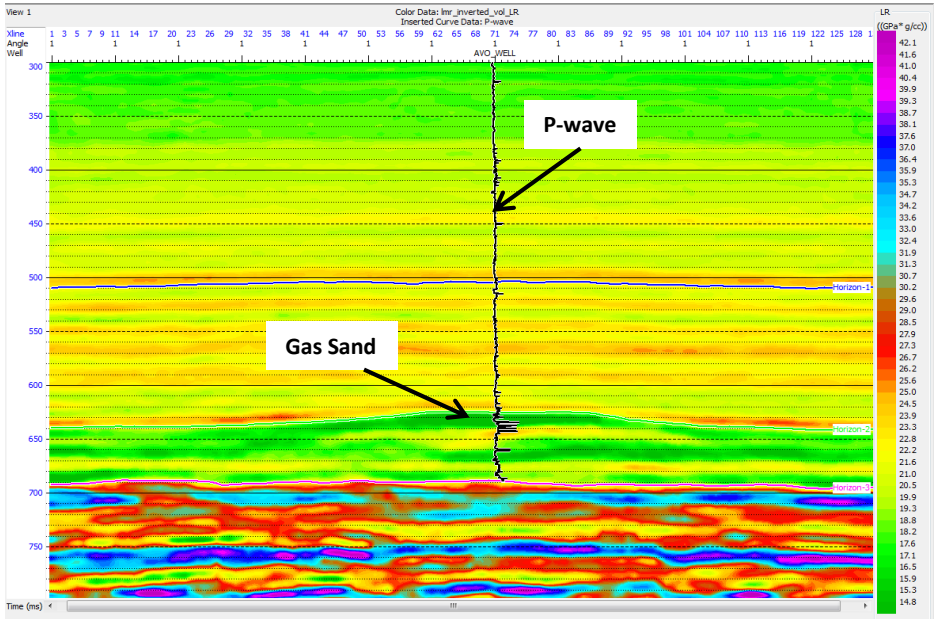
Inverted volume: Vp/Vs



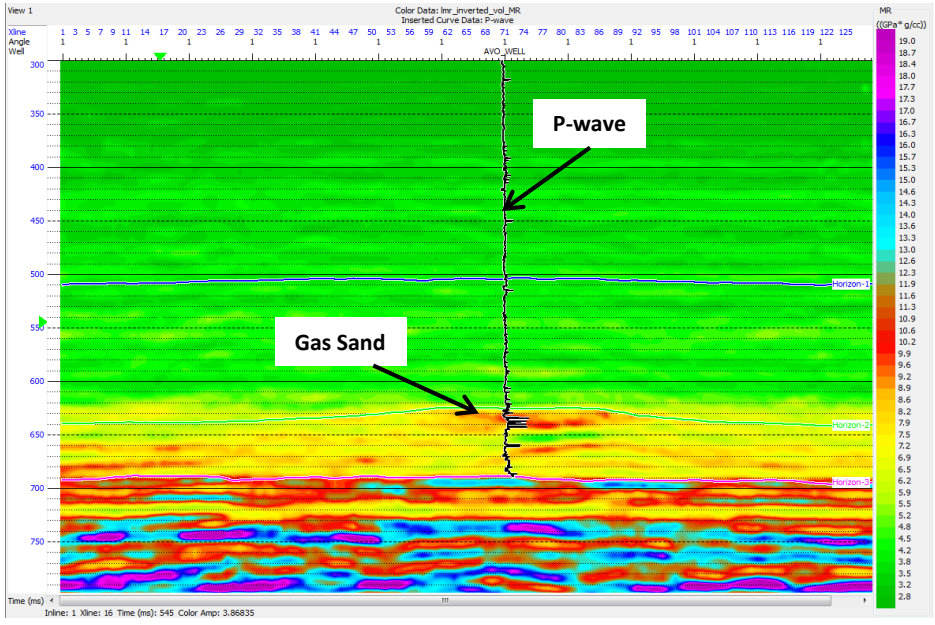
- Here is the ratio of P to S velocity. Notice the low ratio at the gas sand.

Inverted volume: Lambda-mu-rho

Inverted Lambda-rho (LR)



Inverted Mu-rho (MR)



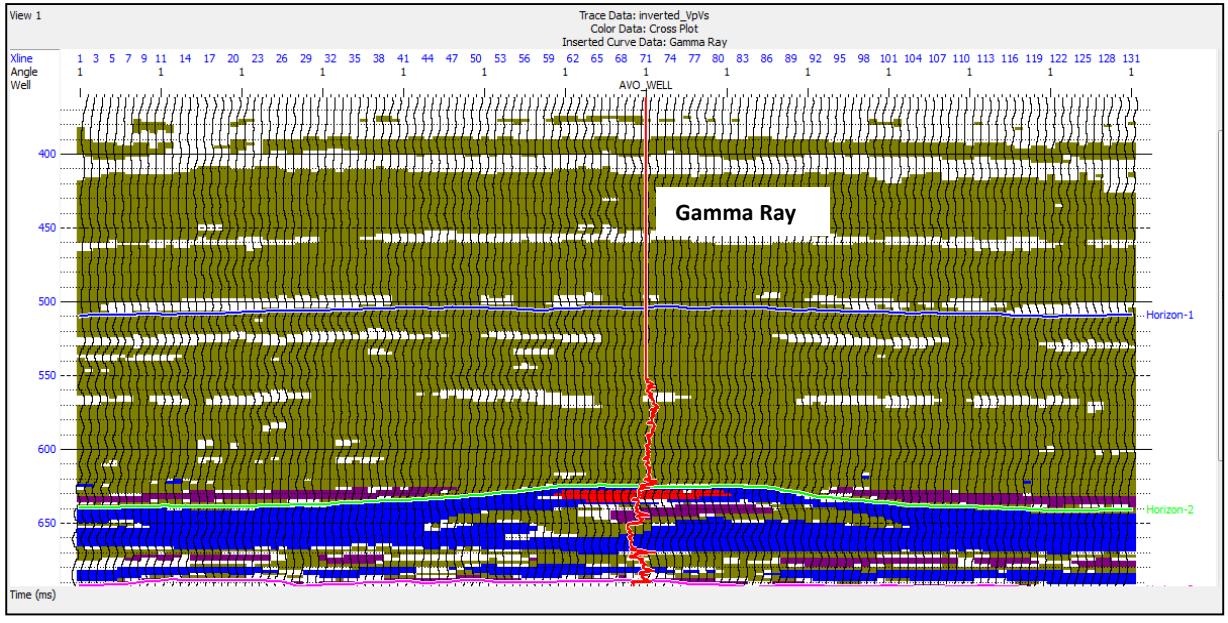
- The LR and MR sections derived from the AI and SI inverted sections.

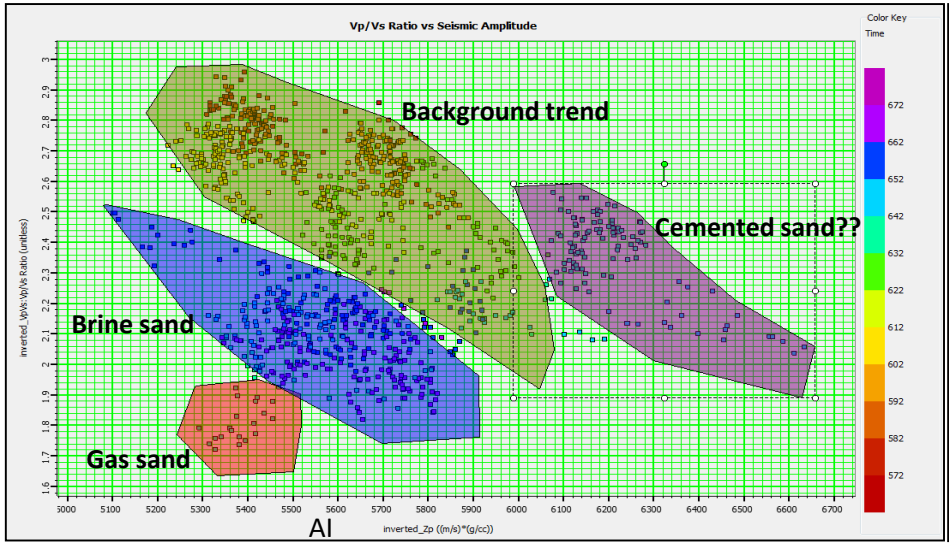
$$\mu\rho = SI^2$$

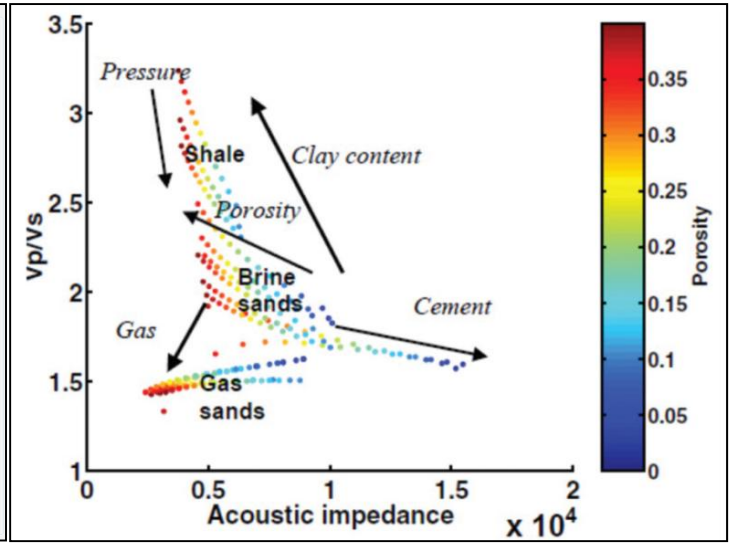
$$\lambda\rho = AI^2 - 2SI^2$$

- Mu-rho gives the matrix value of the rock and LR the fluid value.
- The decrease in LR and the increase in MR at the gas sand zone.

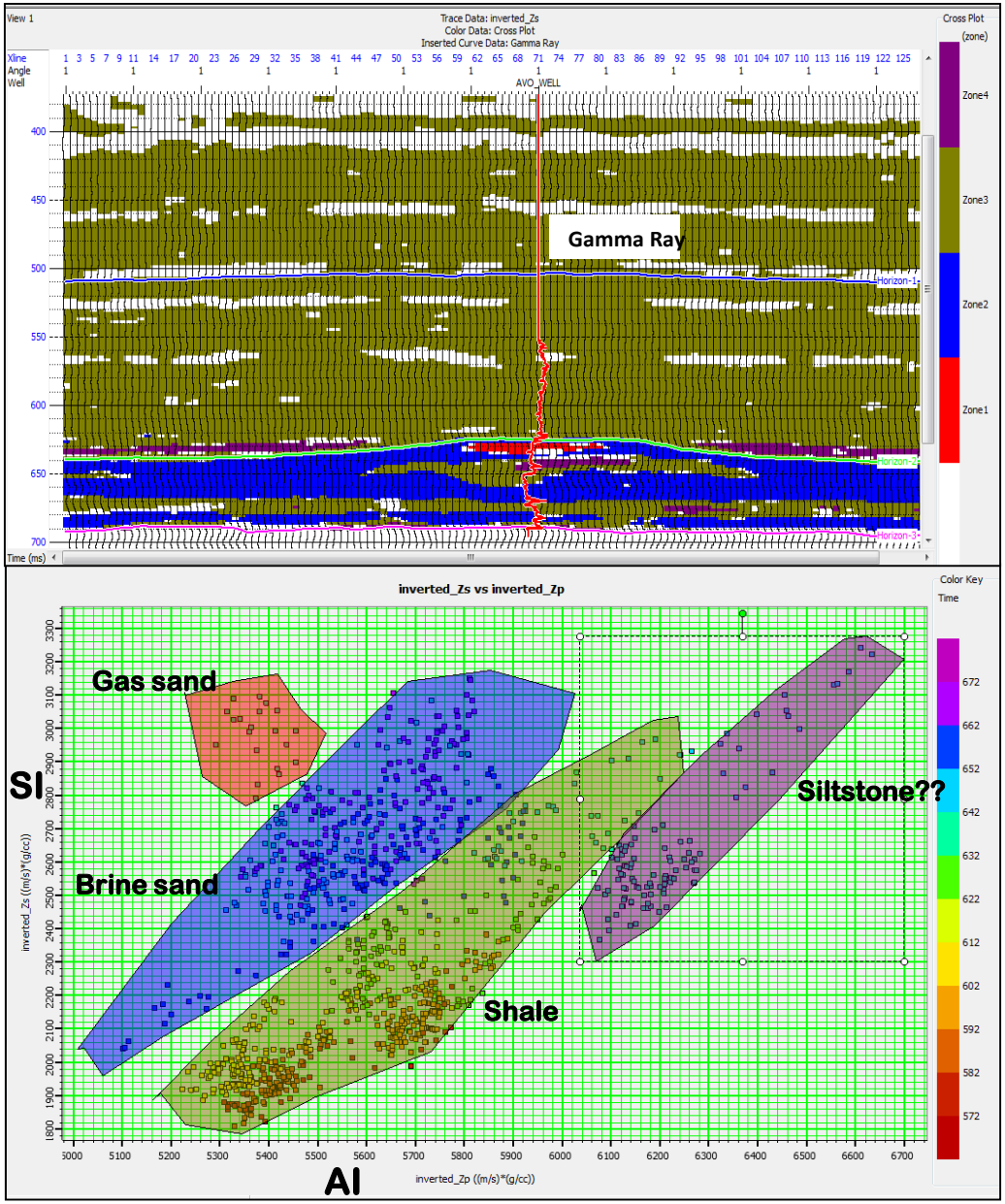
Cross plot: AI vs. Vp/Vs







Cross plot: AI vs. SI

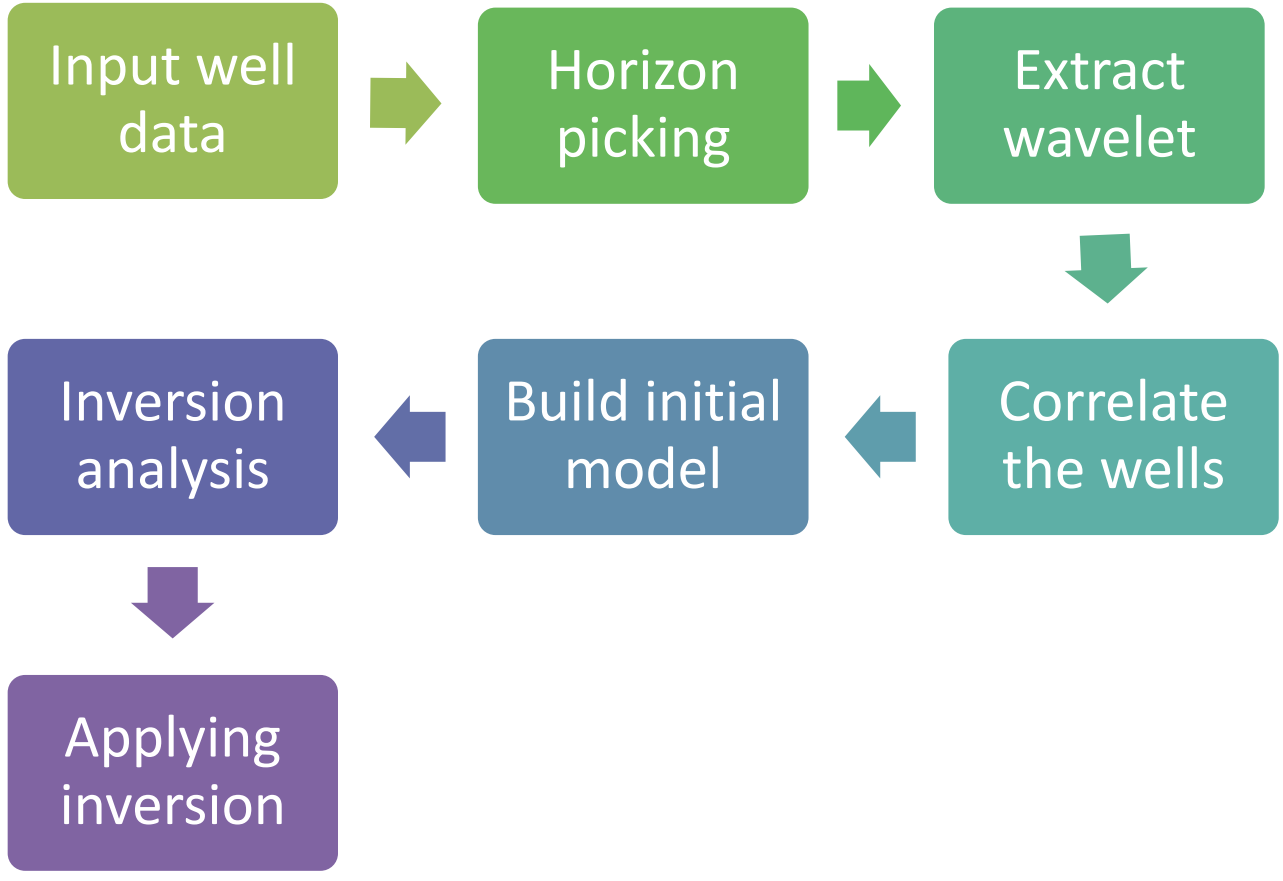


3. Post-stack Inversion

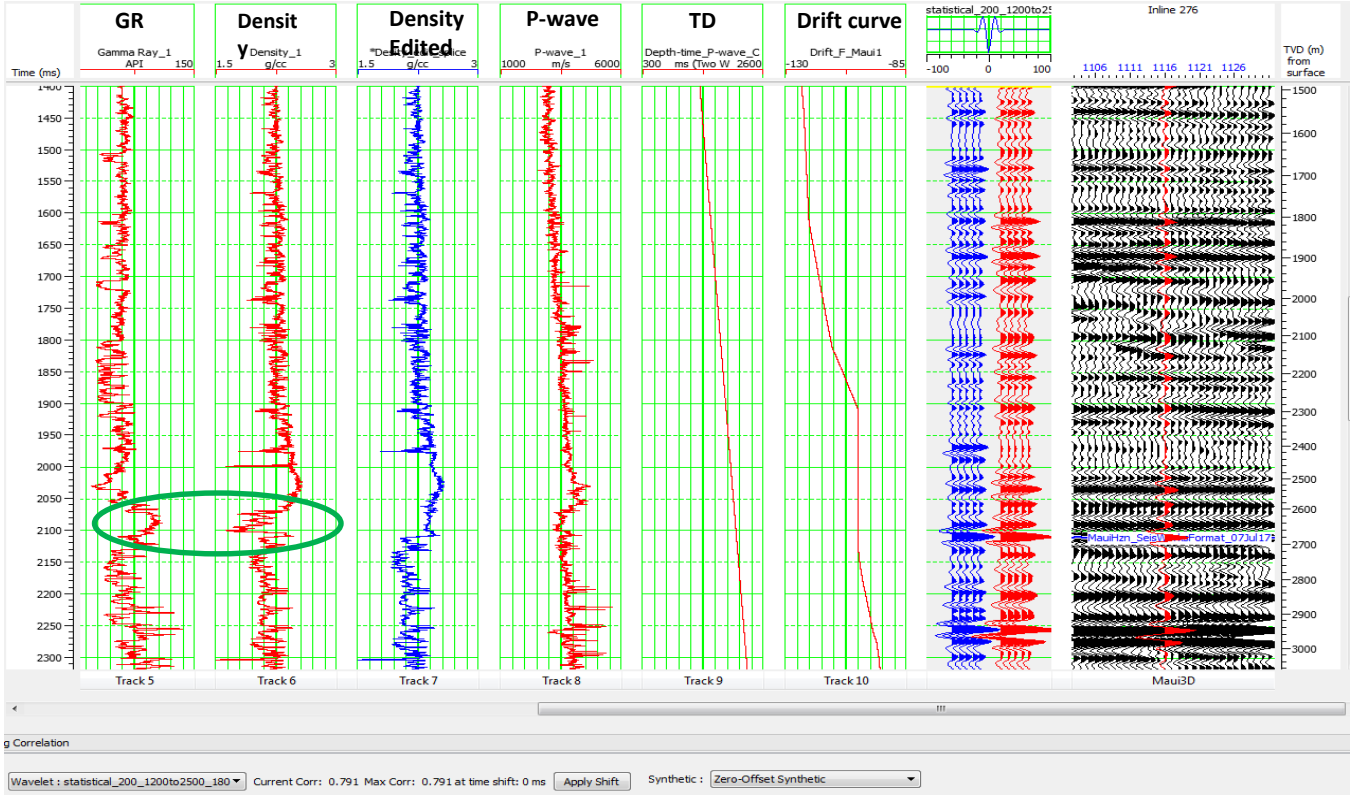
Seismic Data: Maui 3D

Well Data: Maui 1, Maui 5, Maui 6 and Maui 7

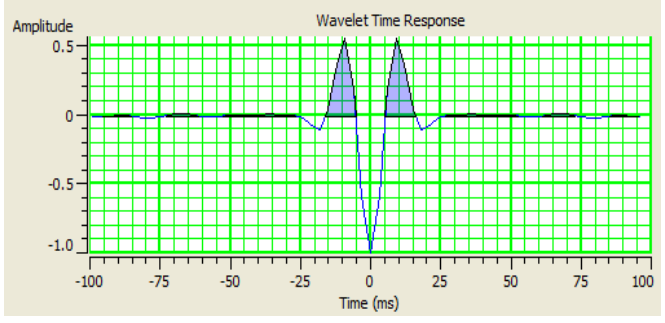
Post-stack Inversion Workflow

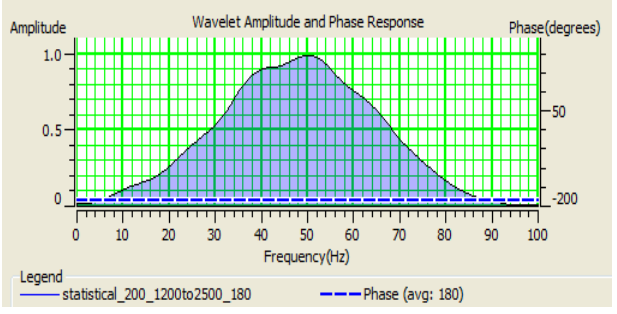


QC and Well Tie: Maui 1

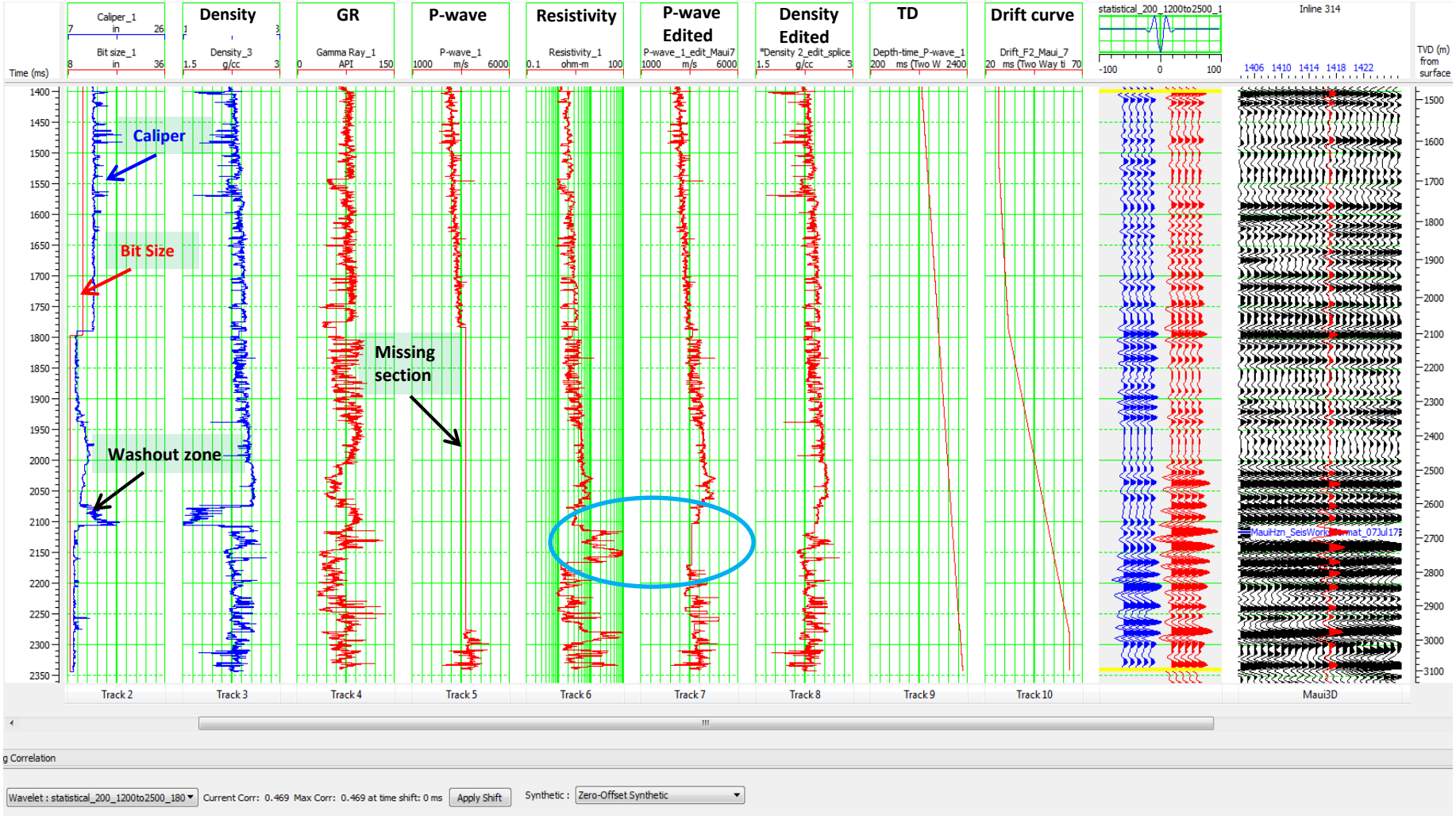


- Wavelet were extracted by statistical method.
- Time window 1200ms to 2500ms and phase -180 degrees.
- Correlation coefficient is 0.79
- Density log edited using Gardner's Empirical equation.



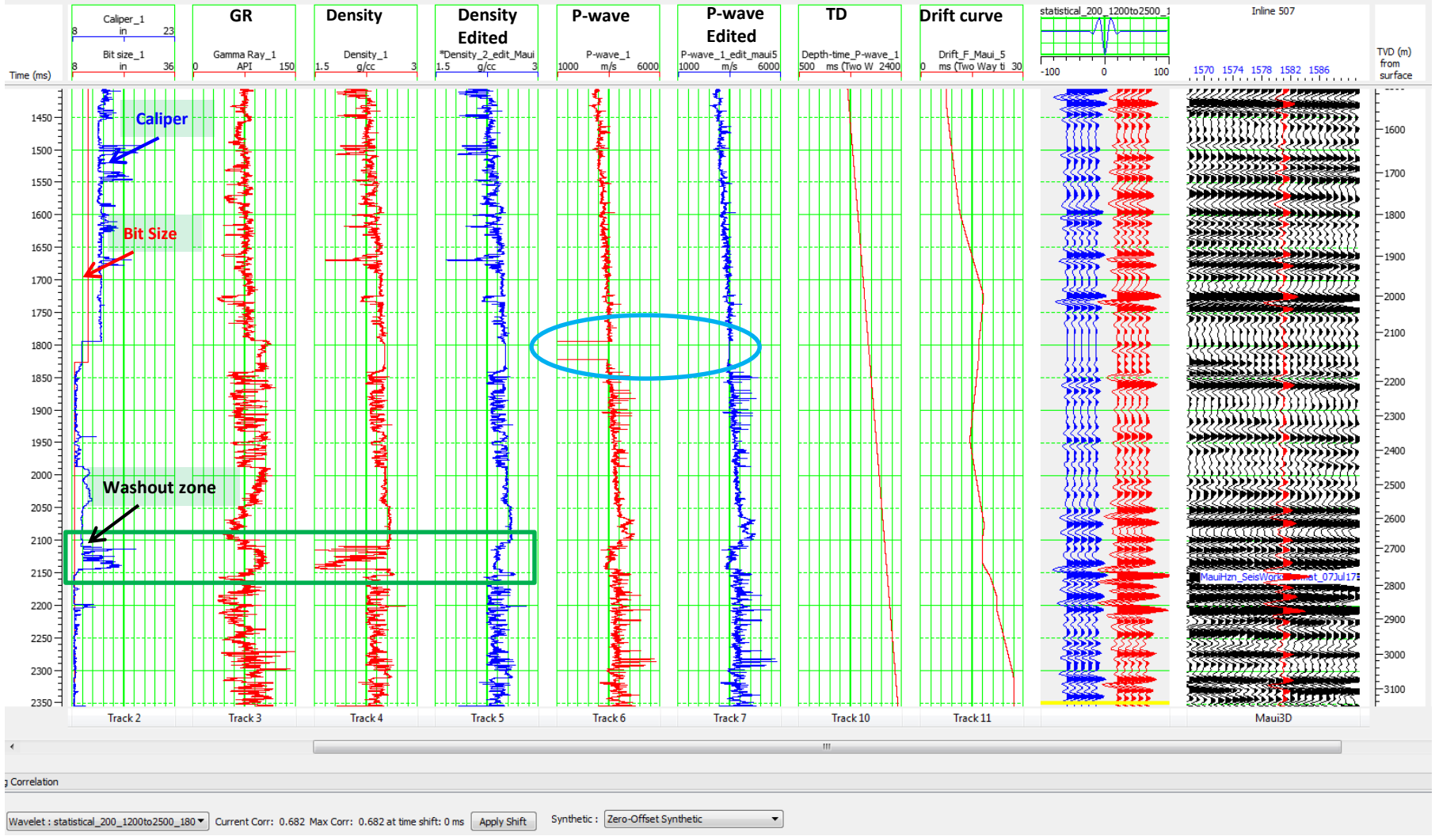


QC and Well Tie: Maui 7



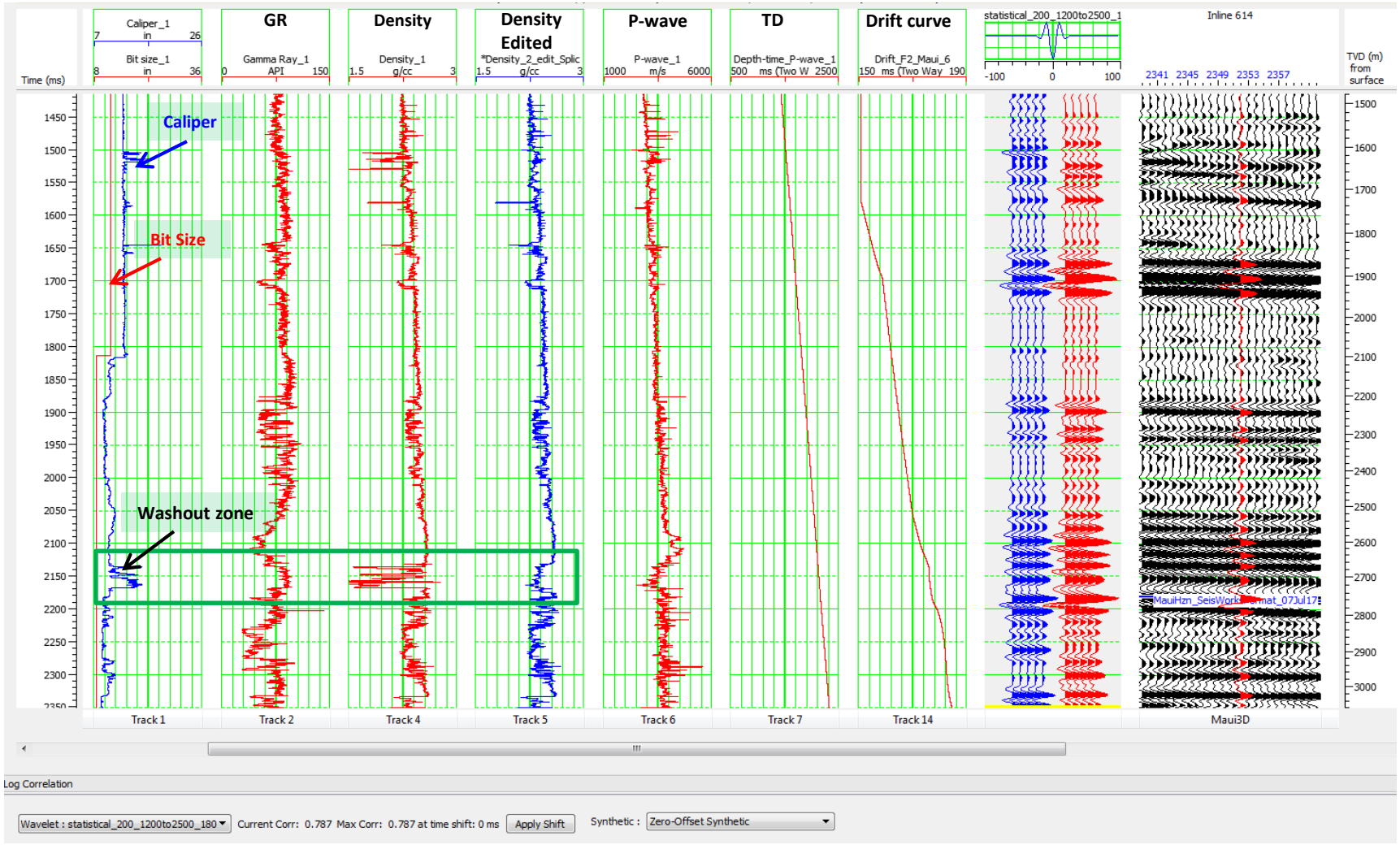
- Correlation coefficient is 0.46
- Density log edited using Gardner's Empirical equation.
- P-wave in missing section add by Faust's equation and manual editing.

QC and Well Tie : Maui 5



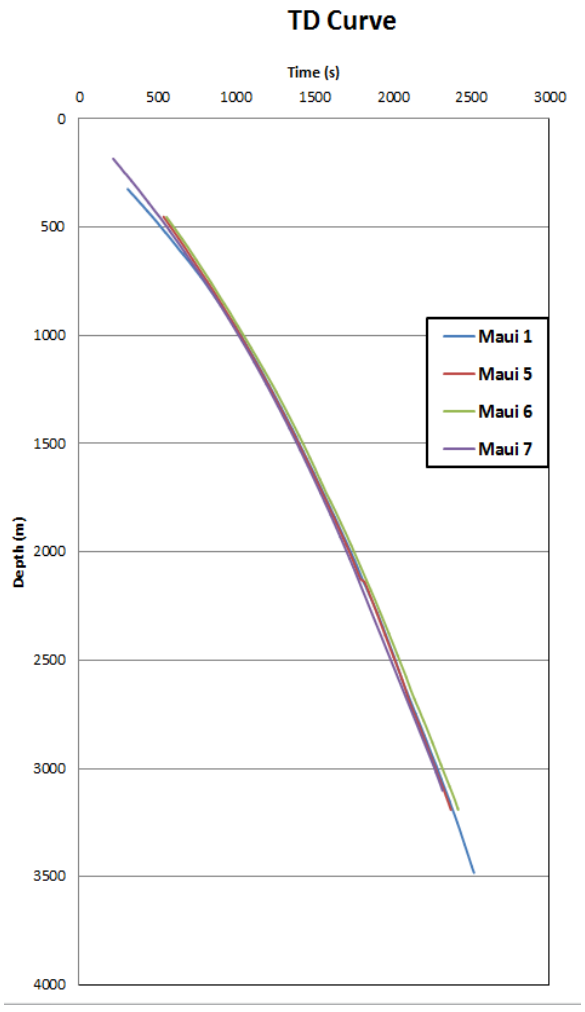
- Correlation coefficient is 0.68
- Density log edited using Gardner's Empirical equation.
- P-wave in missing section add by manual editing.

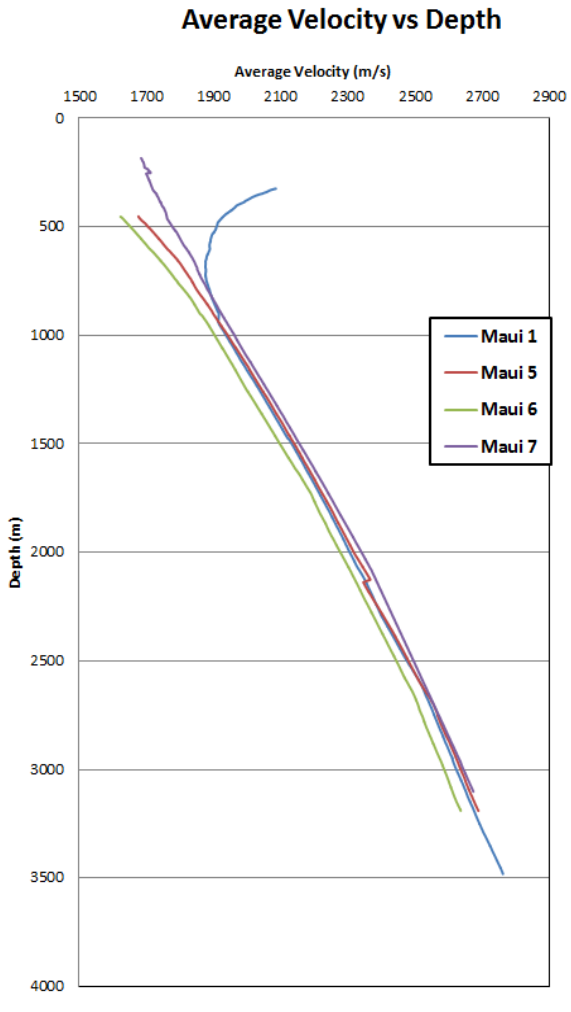
QC and Well Tie: Maui 6

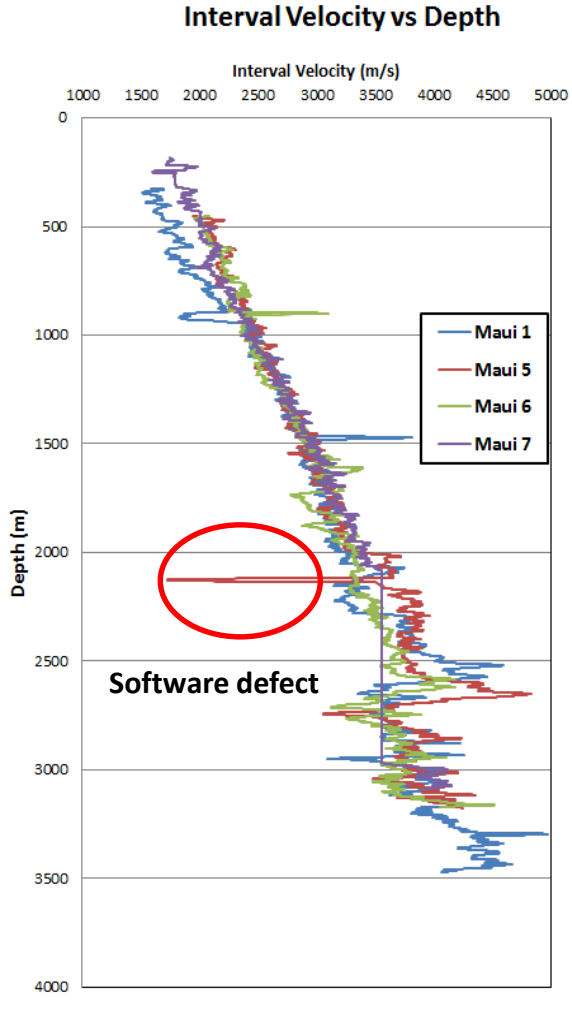


- Correlation coefficient is 0.78
- Density log edited using Gardner's Empirical equation.
- P-wave in missing section add by manual editing.

Time-Depth and Velocity-Depth Functions



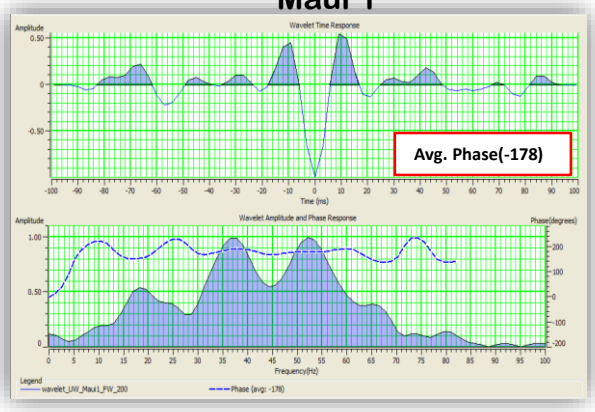




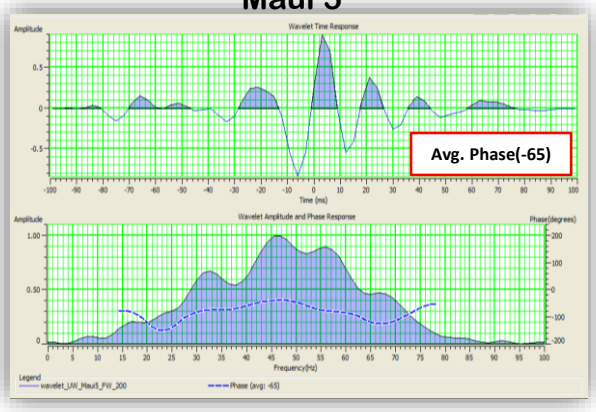
- All of the charts show the almost similar trend.
- Average velocity in Maui-6 gives the lower velocity compare to others wells. It may be because of younger formation at down dip location.

Wavelet Extraction Using Well

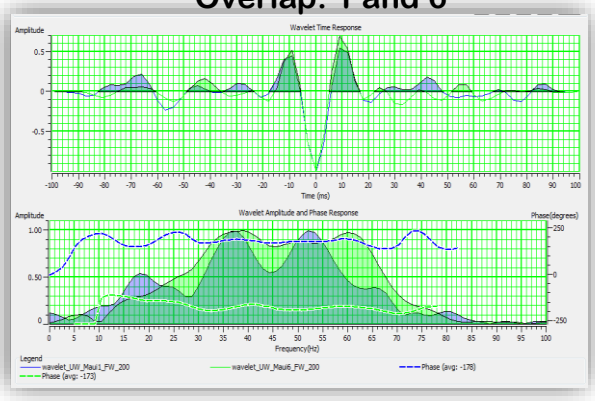
Maui 1



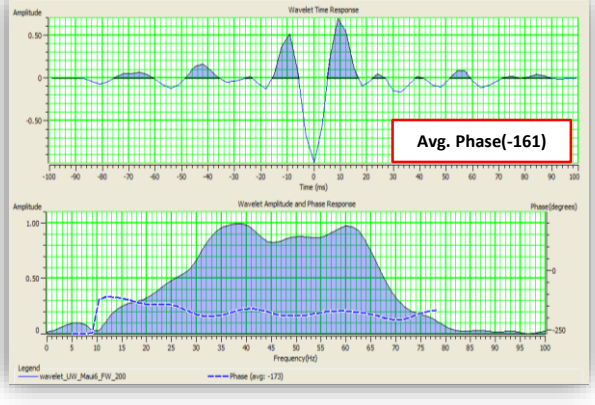
Maui 5



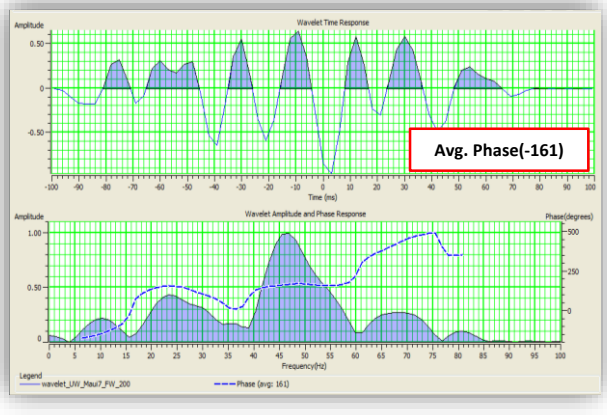
Overlap: 1 and 6



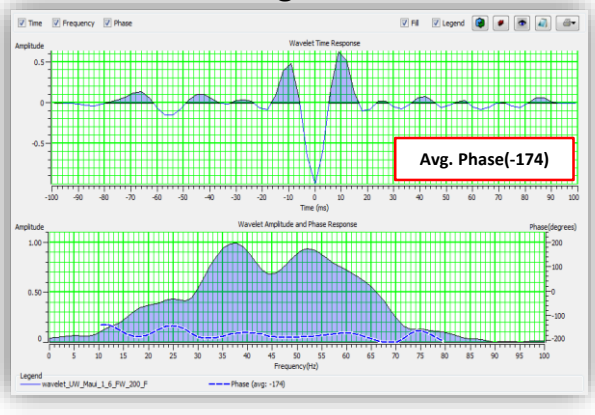
Maui 6



Maui 7

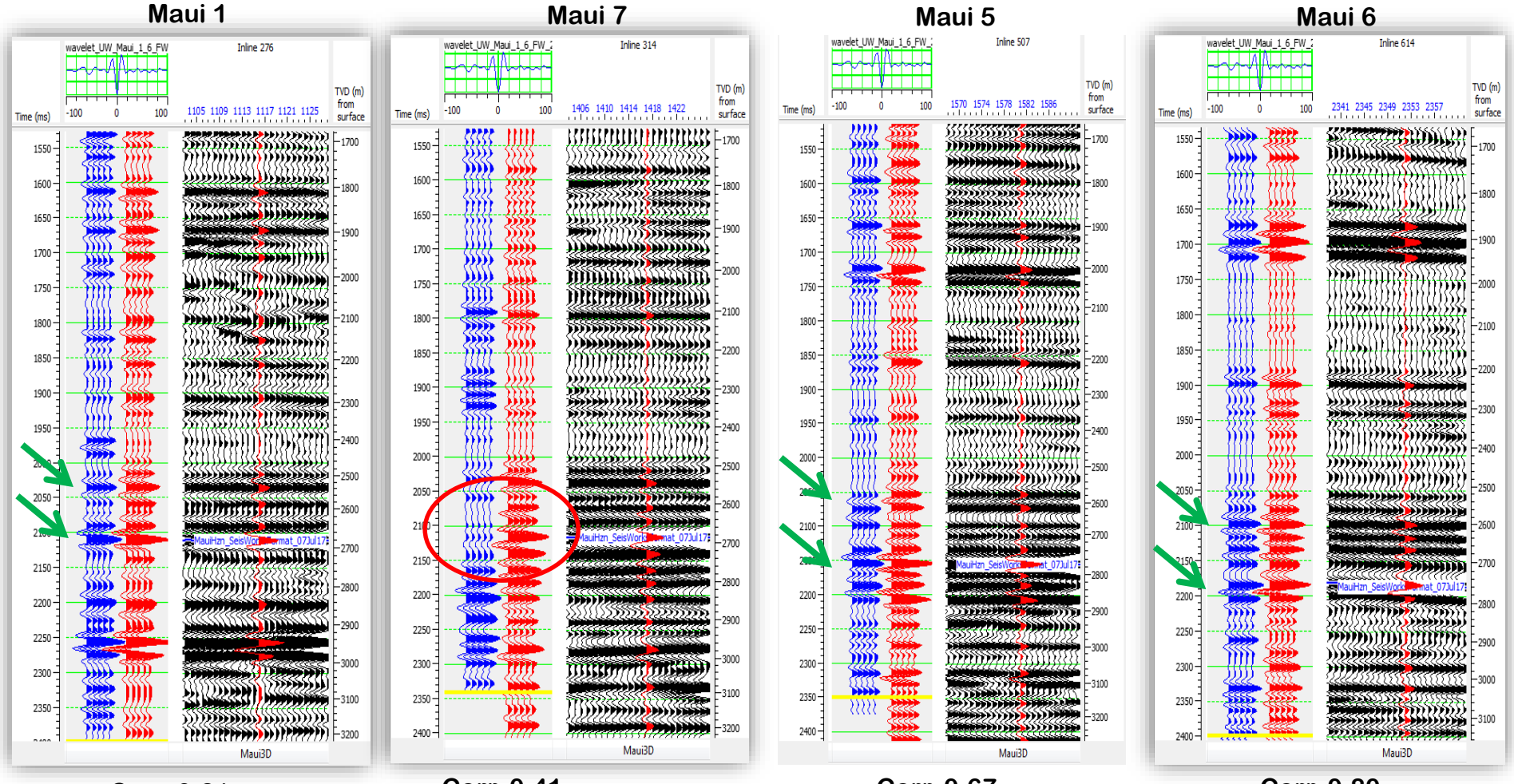


Average: 1 and 6



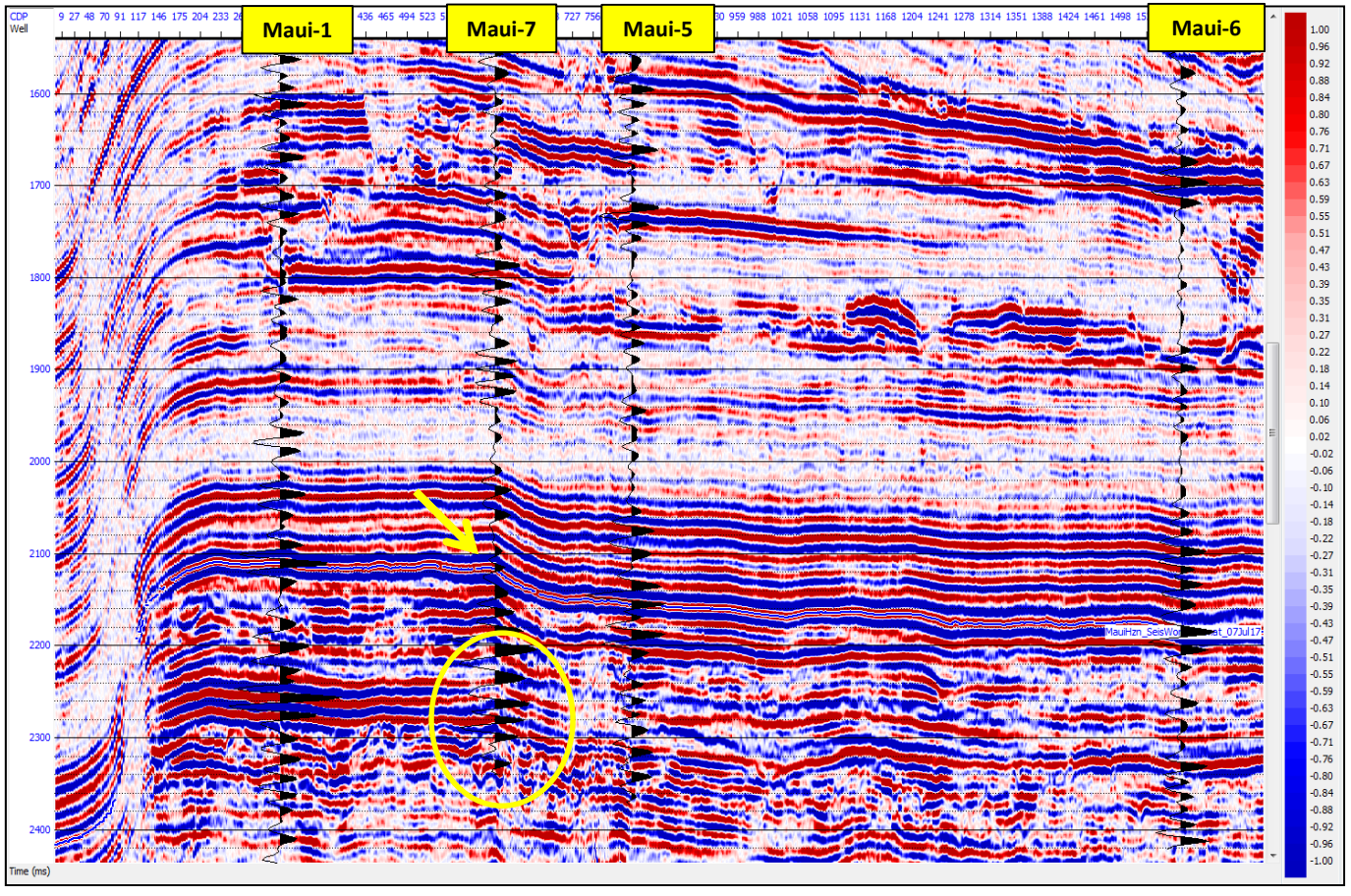
- Wavelet for each well has extracted along the well based on final corrected time-depth function for time window (1200ms to 2400ms.
- Phase in Maui 1 and Maui 6 are close to -180 and in Maui 7 is -161. But time and frequency domain are very worst (bad well logs).
- Average wavelet created using Maui 1 and 6 (Average phase is -174 degrees).

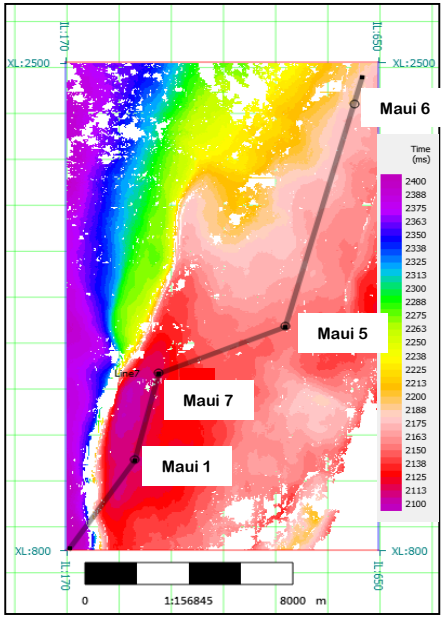
Well Tie: Using Average Wavelet



- Using average wavelet correlation coefficient slight increase in Maui 1, 5 and 6. But slight decrease in Maui 7.
- Correlation window: 1400ms-2400ms

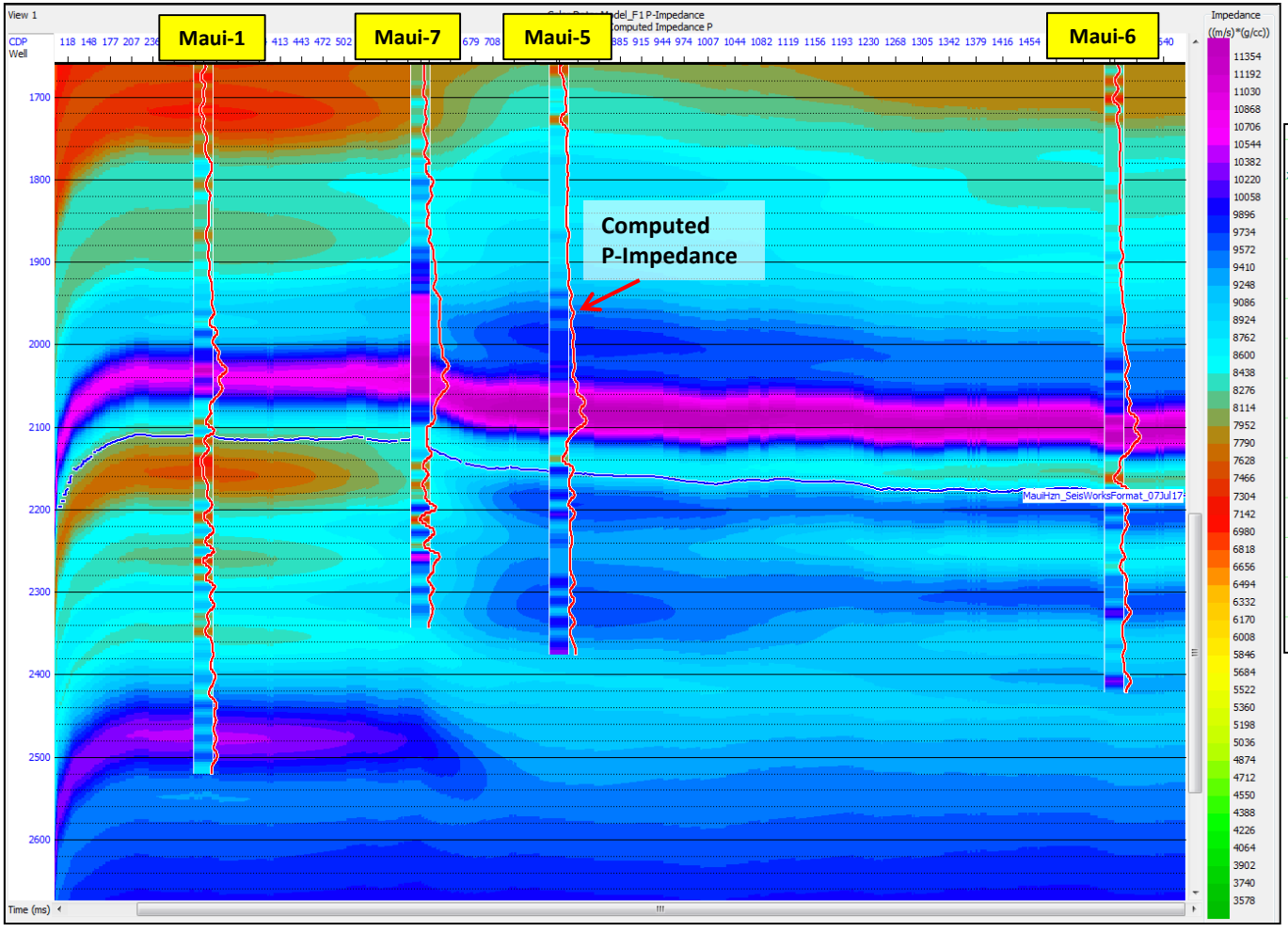
Seismic data with the synthetics

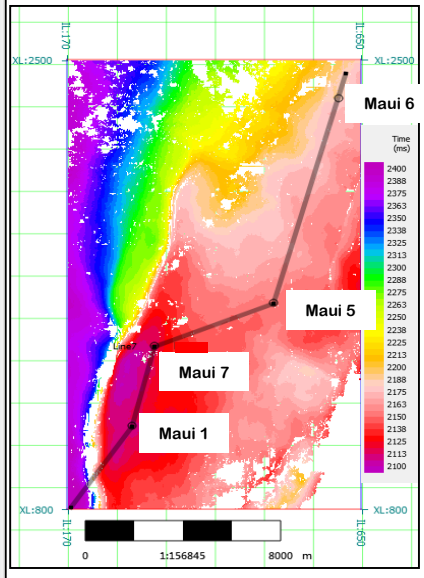




- Synthetic traces using Density and P-wave log from individual wells. Wavelet is average wavelet (-174 degree phase).
- Well 1, 5 and 6 show pretty well matching and poor matching in well 7.

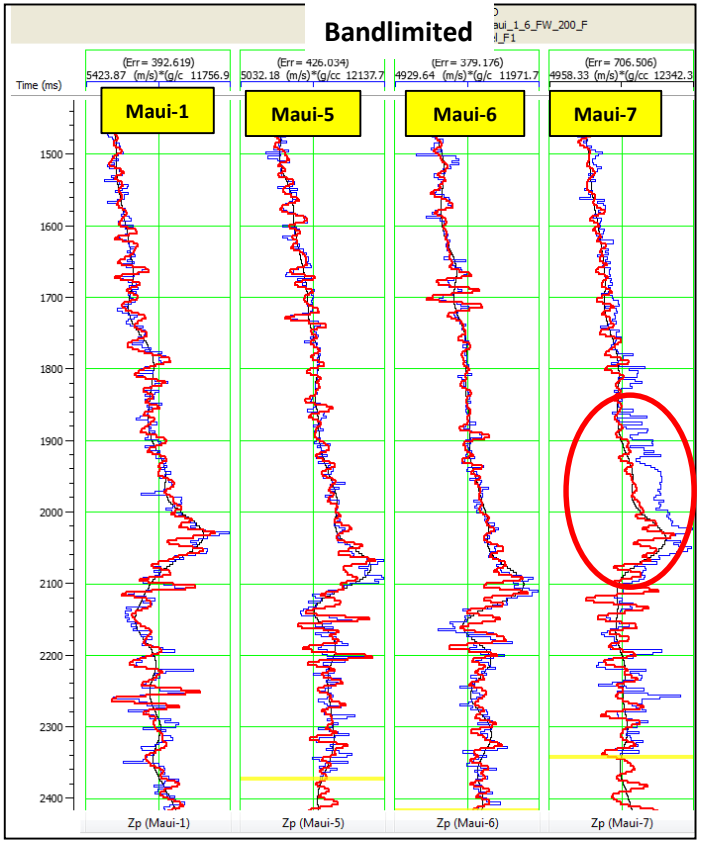
Low Frequency Model

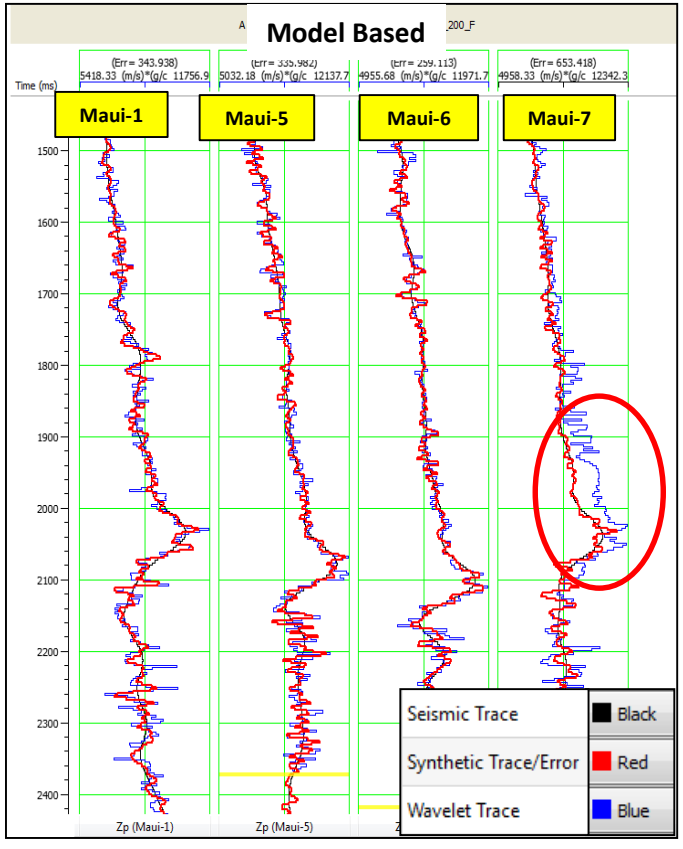




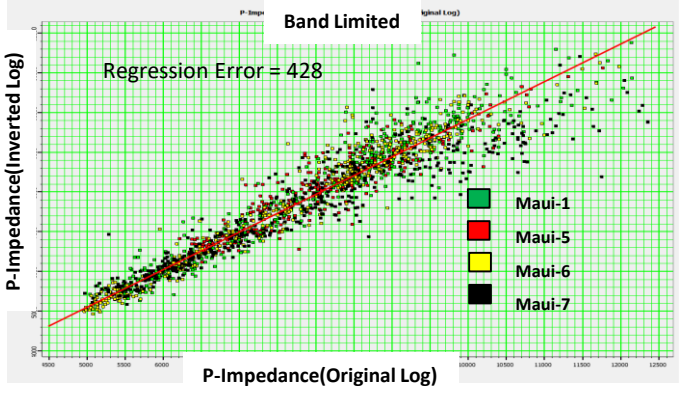
- Low frequency model of AI was generated by using corrected P-wave and density logs for time window 1000ms to 3000ms.
- High cut frequency 10/15 Hz
- Included wells to build model: Maui 1, Maui 5 and Maui 6

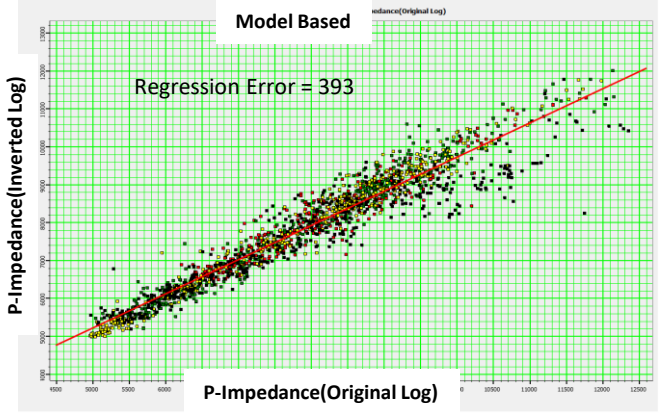
Inversion Analysis

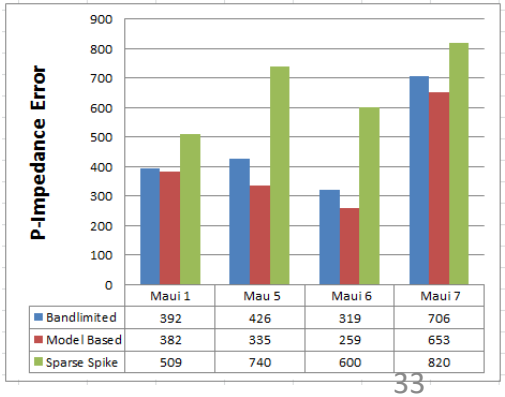




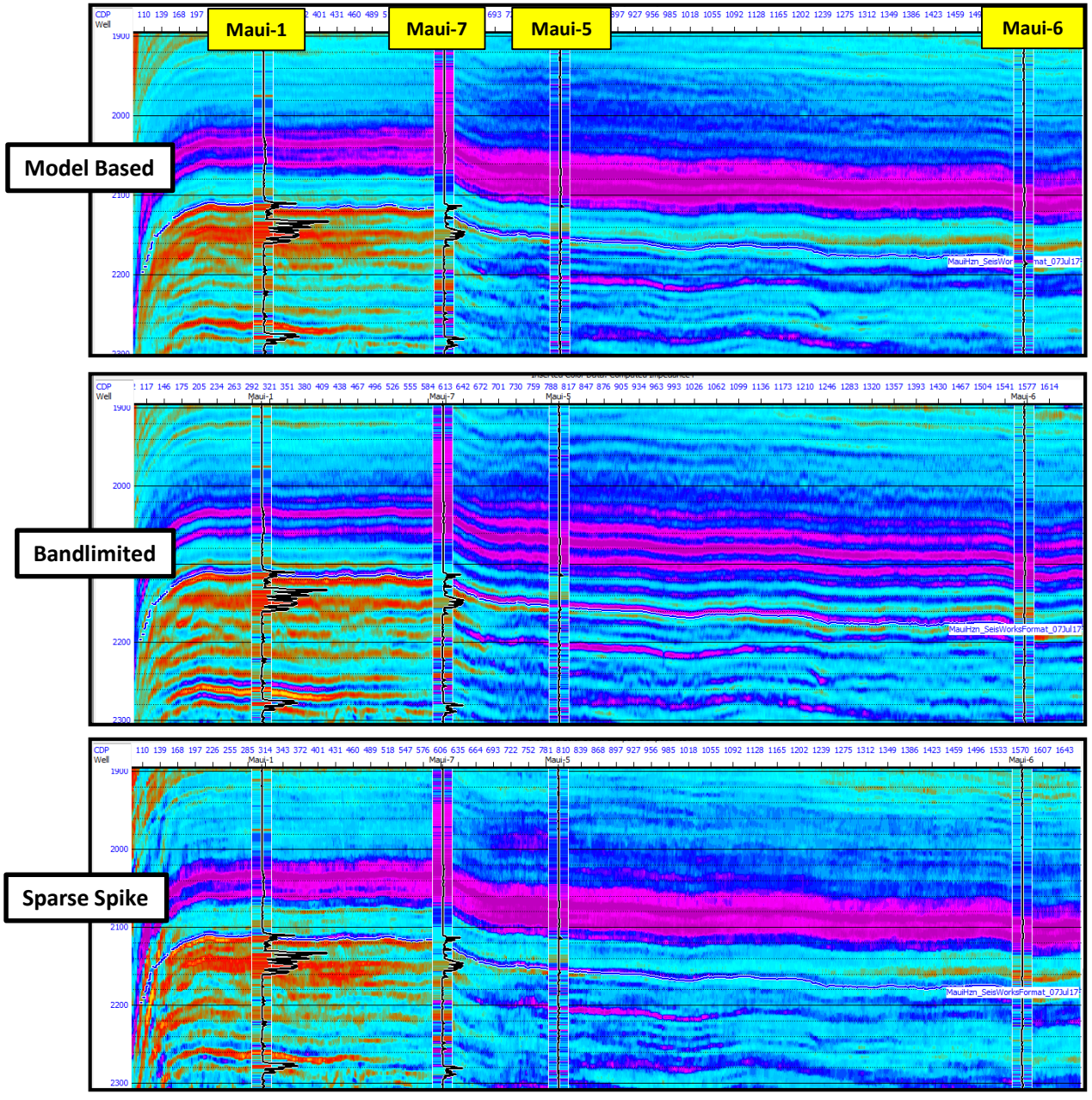
- Three inversion methods has been tested that are Model based, Bandlimited and Linear Sparse Spike.
- Model based and Bandlimited gave relatively low AI error.

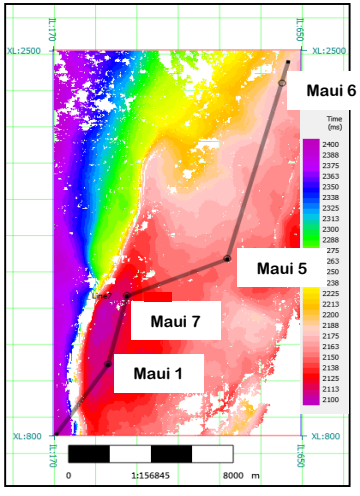






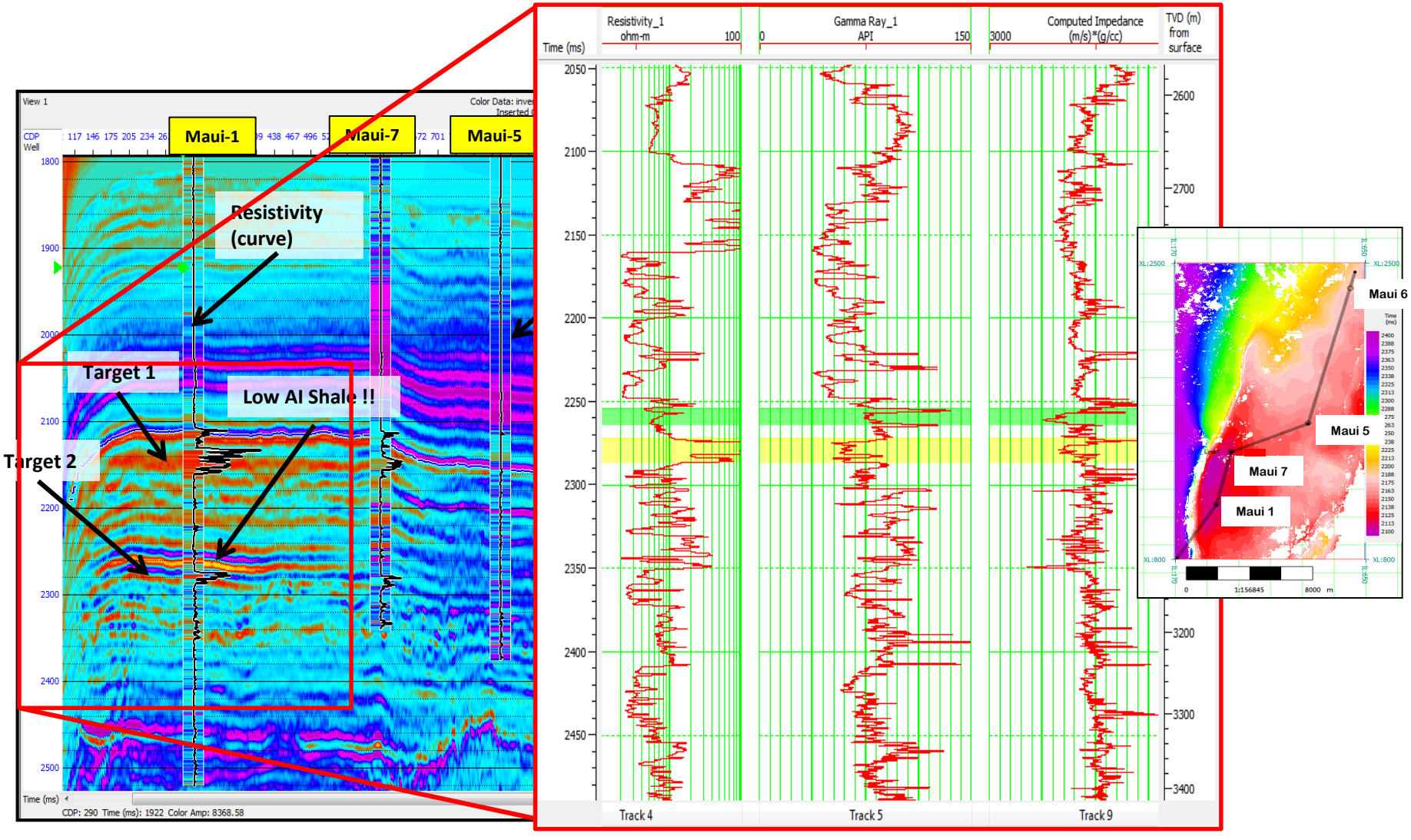
Inversion Results comparison





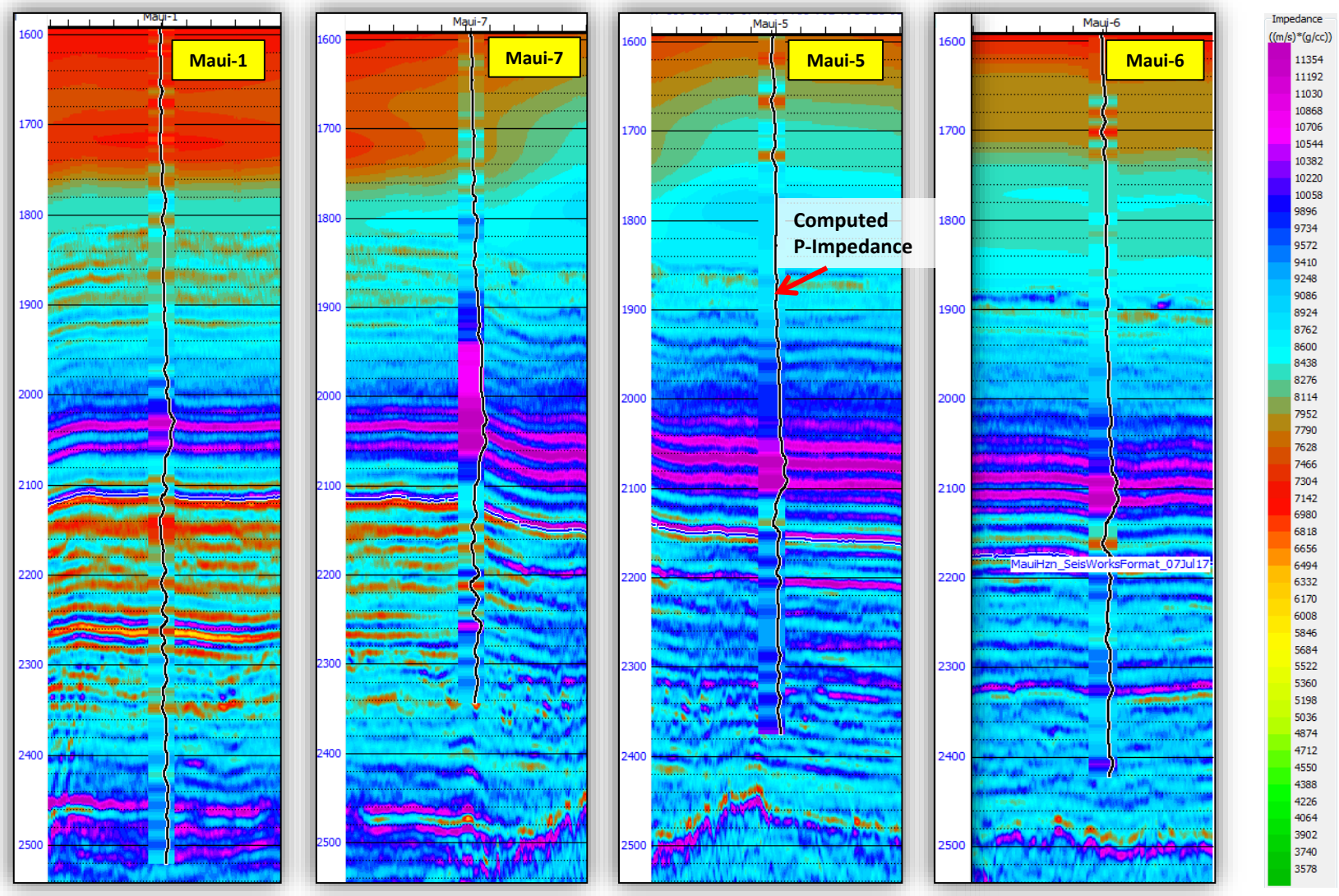
- Bandlimited provided the more details volume.

Inverted Section: Bandlimited



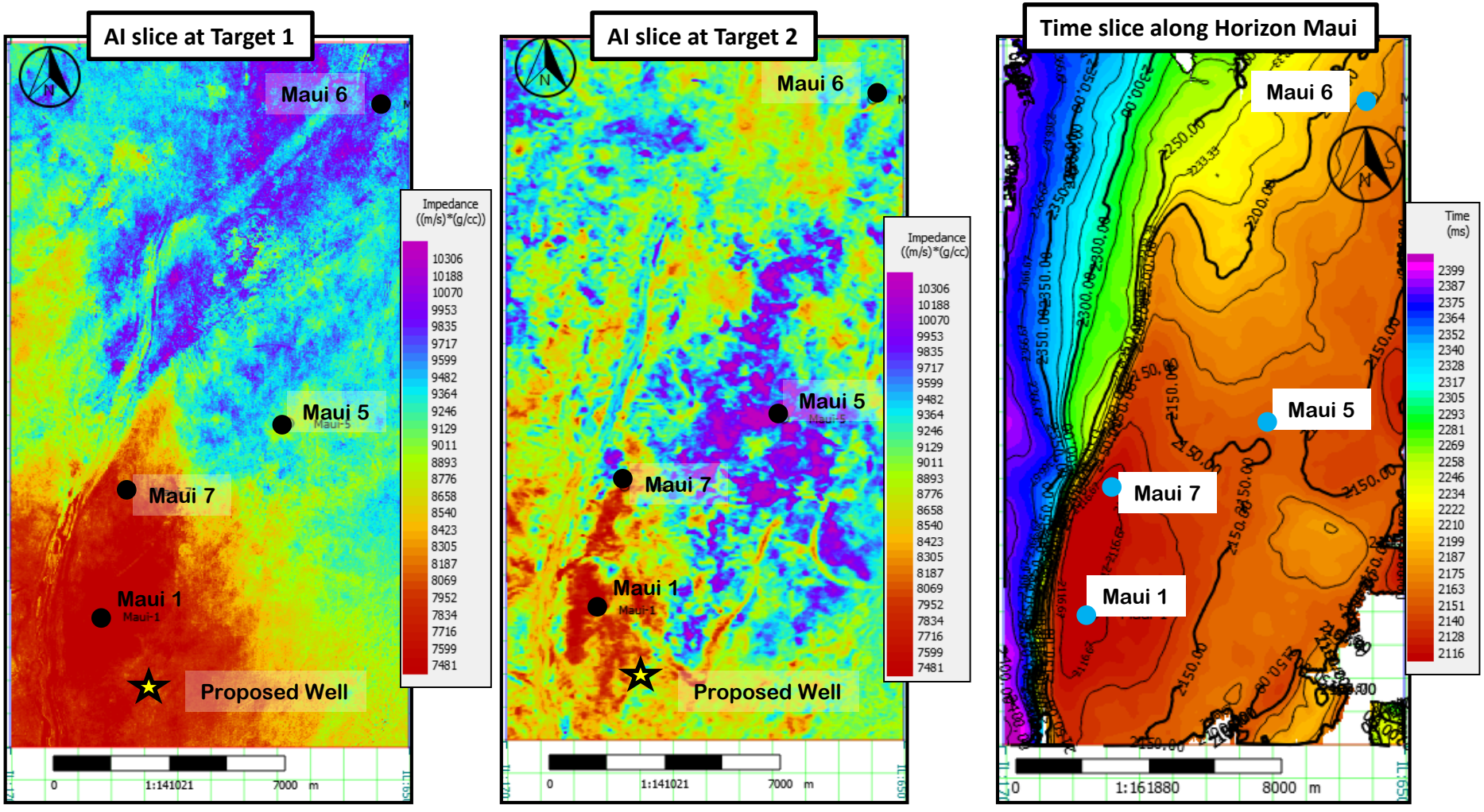
- Cross-section show inverted AI passing through four wells which are overlaid with calculated AI (color) and resistivity log.
- Target 1 and 2 both show the low AI and well log confirmed by high resistivity log.
- Slight above the Target 2 shows a very low AI shale !!!

Inversion at each well, with the AI log (High cut filtered)



- Applied High cut filter at well : 50/60 Hz
- The filtered AI at wells show the almost same results as Inverted result

Inversion Result: AI Slice



- Inverted AI slice maps along Target 1 and Target 2. Extended area of Target 1 is relatively bigger than the Target 1.
- Both target are related to structural high. Very low AI might related to gas sand. This result pretty similar with well result of well 1 and 7 that are high resistivity at same level.
- The proposed well based on low AI for both targets located at slightly down-dip and southeast direction from well Maui 1.

Thank You