UNIVERSITY OF CALGARY

POST-STACK INVERSION OF THE HUSSAR LOW FREQUENCY SEISMIC DATA

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CREWES

2012 Sponsor's meeting | Banff | November 30th

OUTLINE

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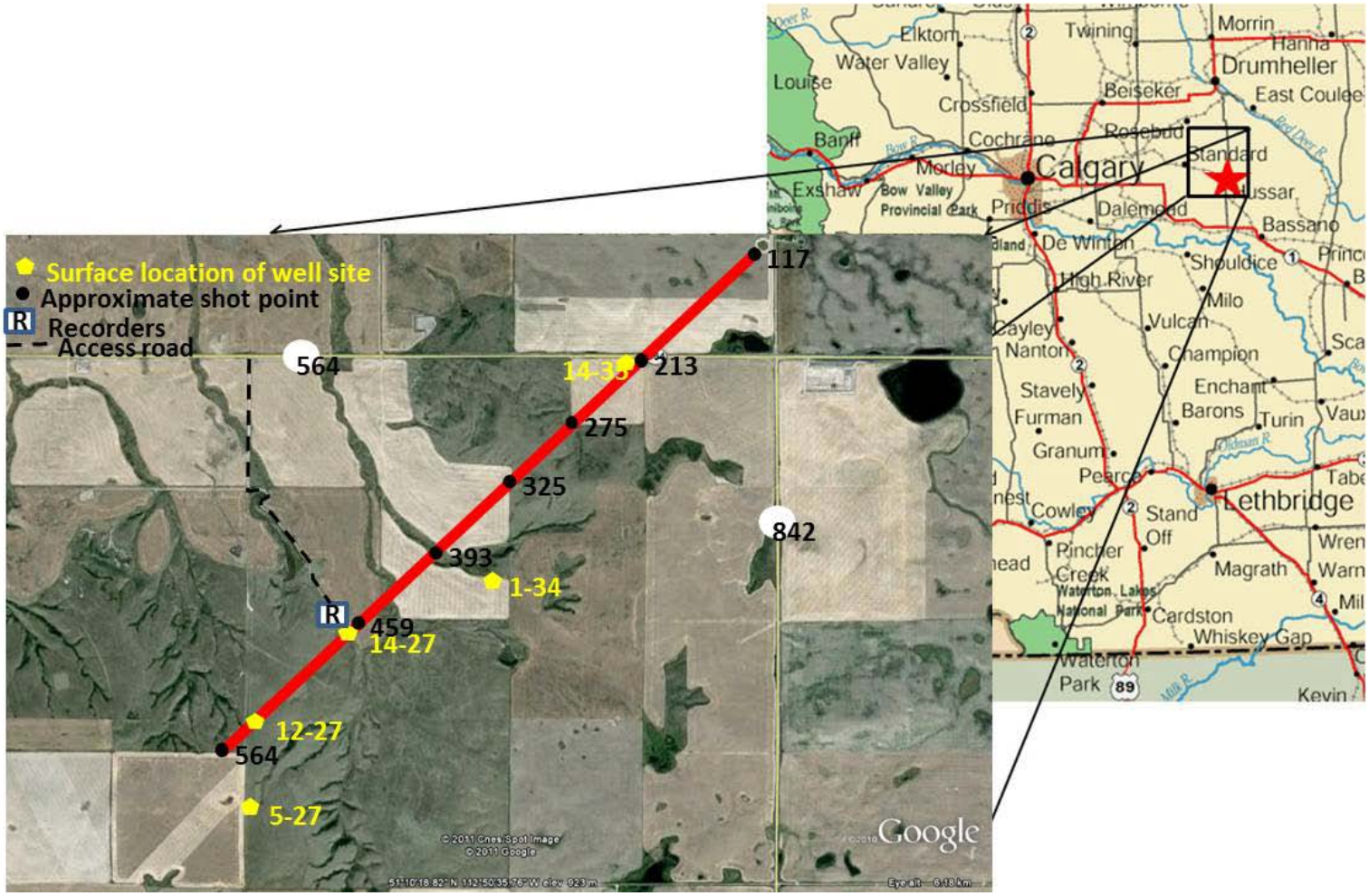
OBJECTIVE

Evaluate the effect of using the Hussar low frequency seismic data in a post-stack inversion study with a commercial software

Determine the lowest possible cut-off for the initial inversion model

AREA OF STUDY

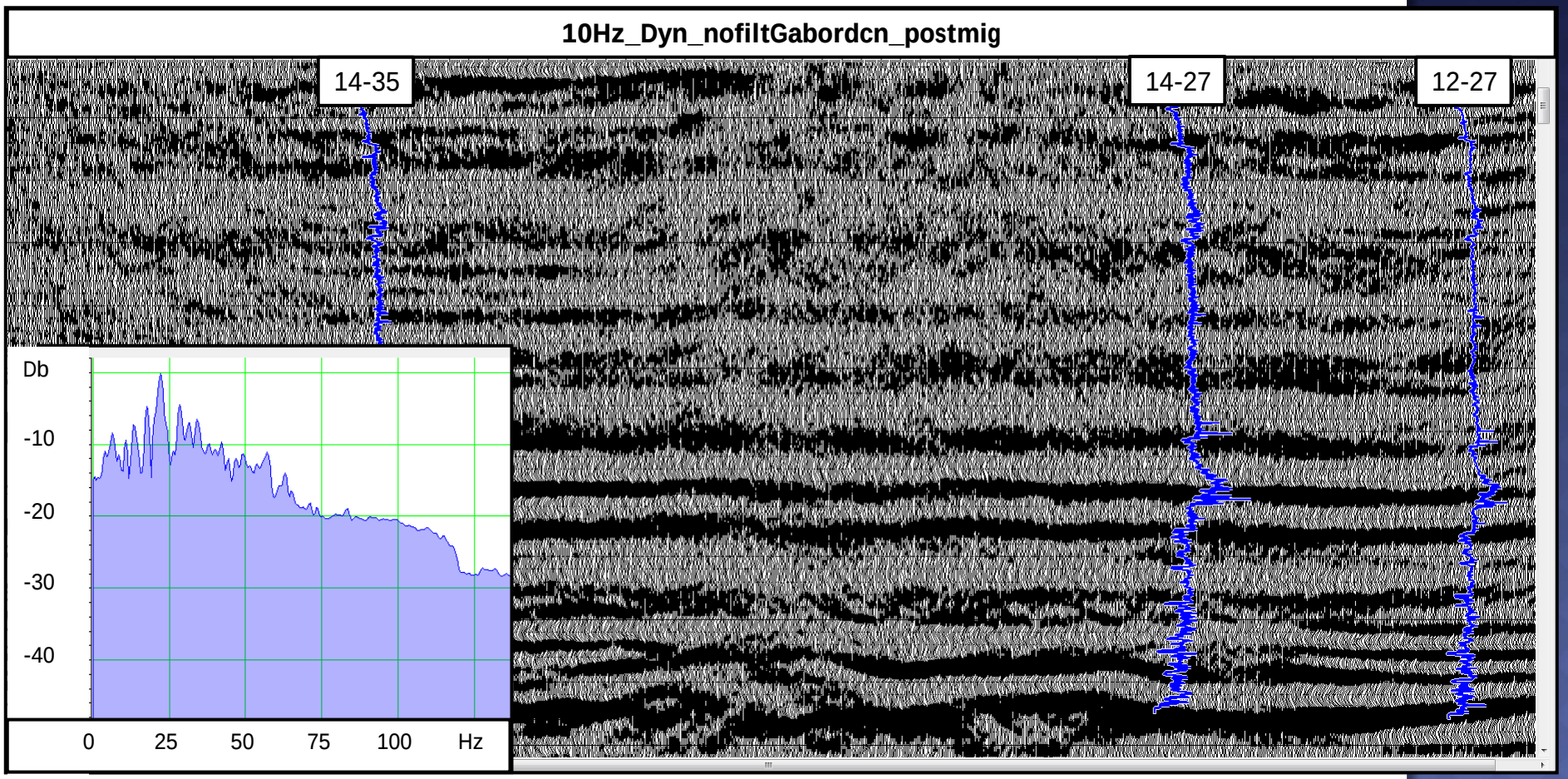
Seismic data



(modified from Margrave et al., 2011)

INPUT DATA

Seismic data

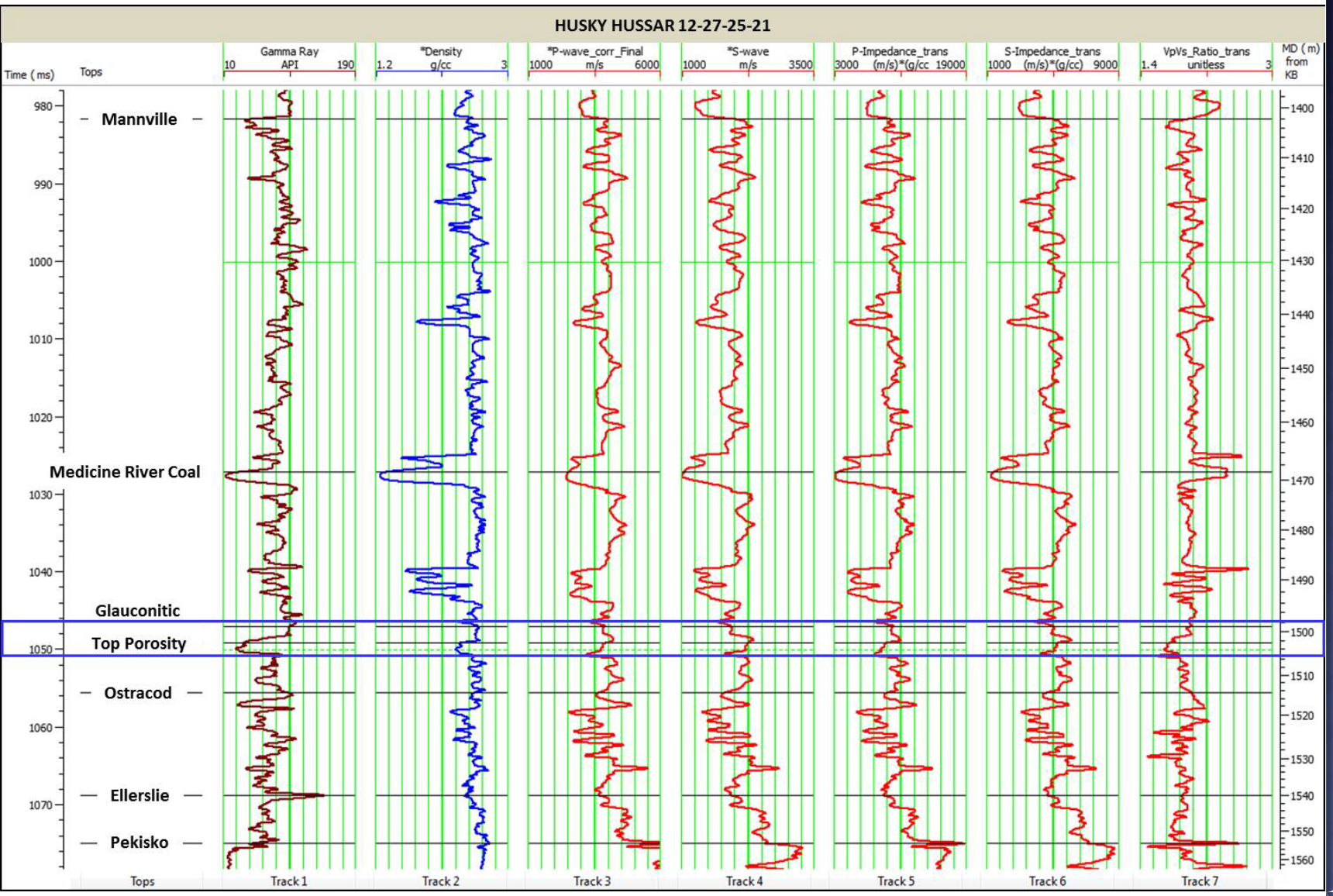


Seismic line:
2 kg of dynamite and
3C 10 Hz geophones
600-1100 ms

3 wells (Husky Energy):
14-35-25-21W4M
14-27-25-21W4M
12-27-25-21W4M

INPUT DATA

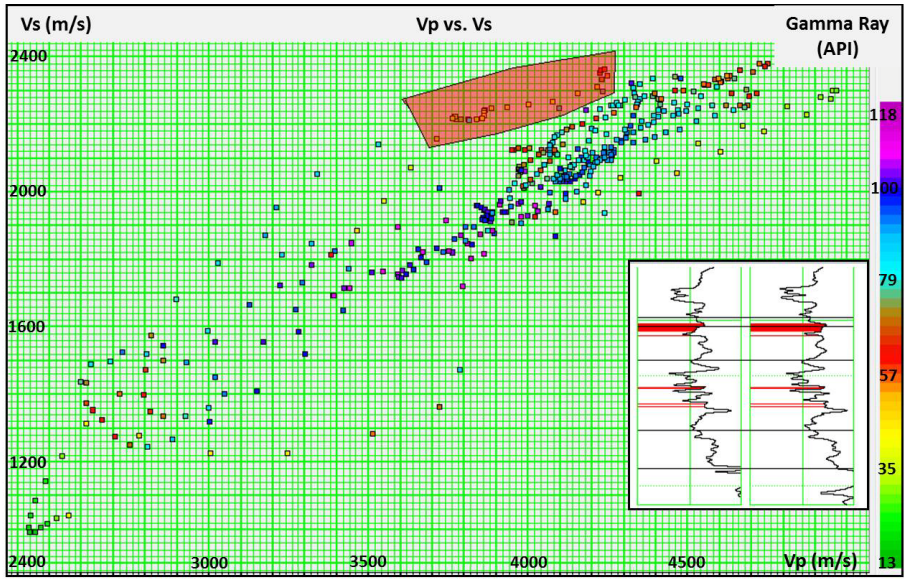
Well logs

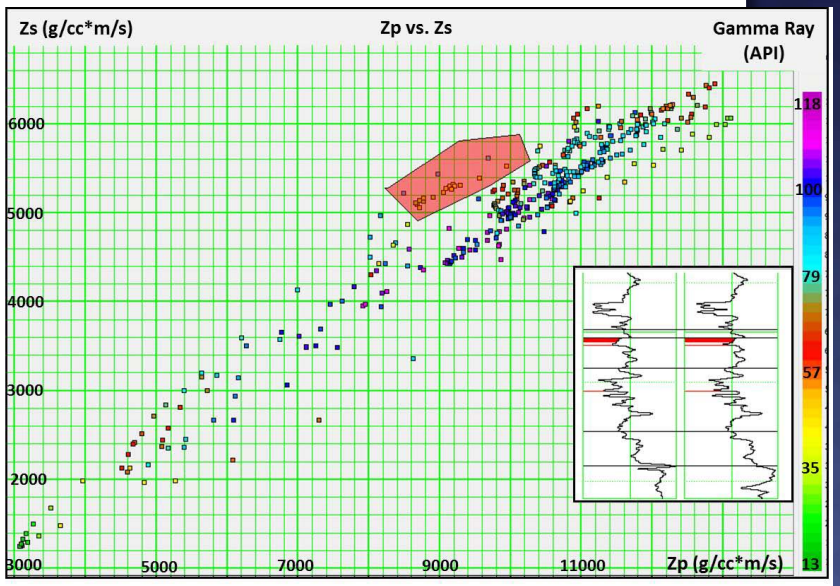


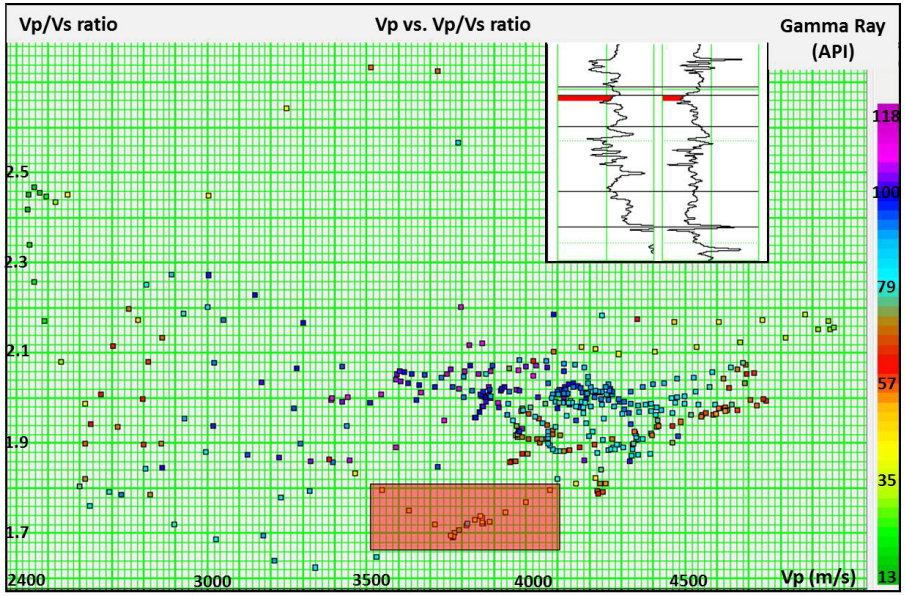
INPUT DATA

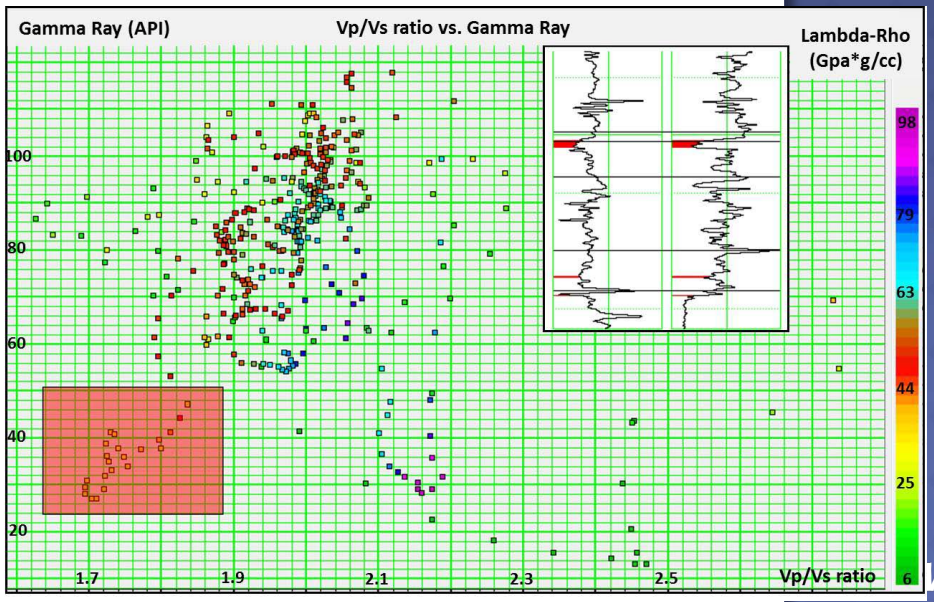
Cross-plot analysis @well 12-27-25-21

The red polygon highlights the target Formation





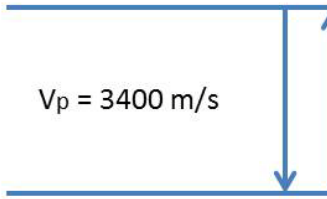




INPUT DATA

Seismic resolution

Dominant frequency = 40 Hz
Min. thickness = 15 m
Max. thickness = 24 m

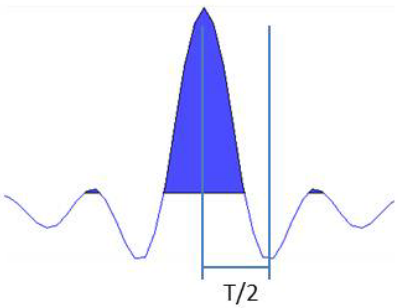


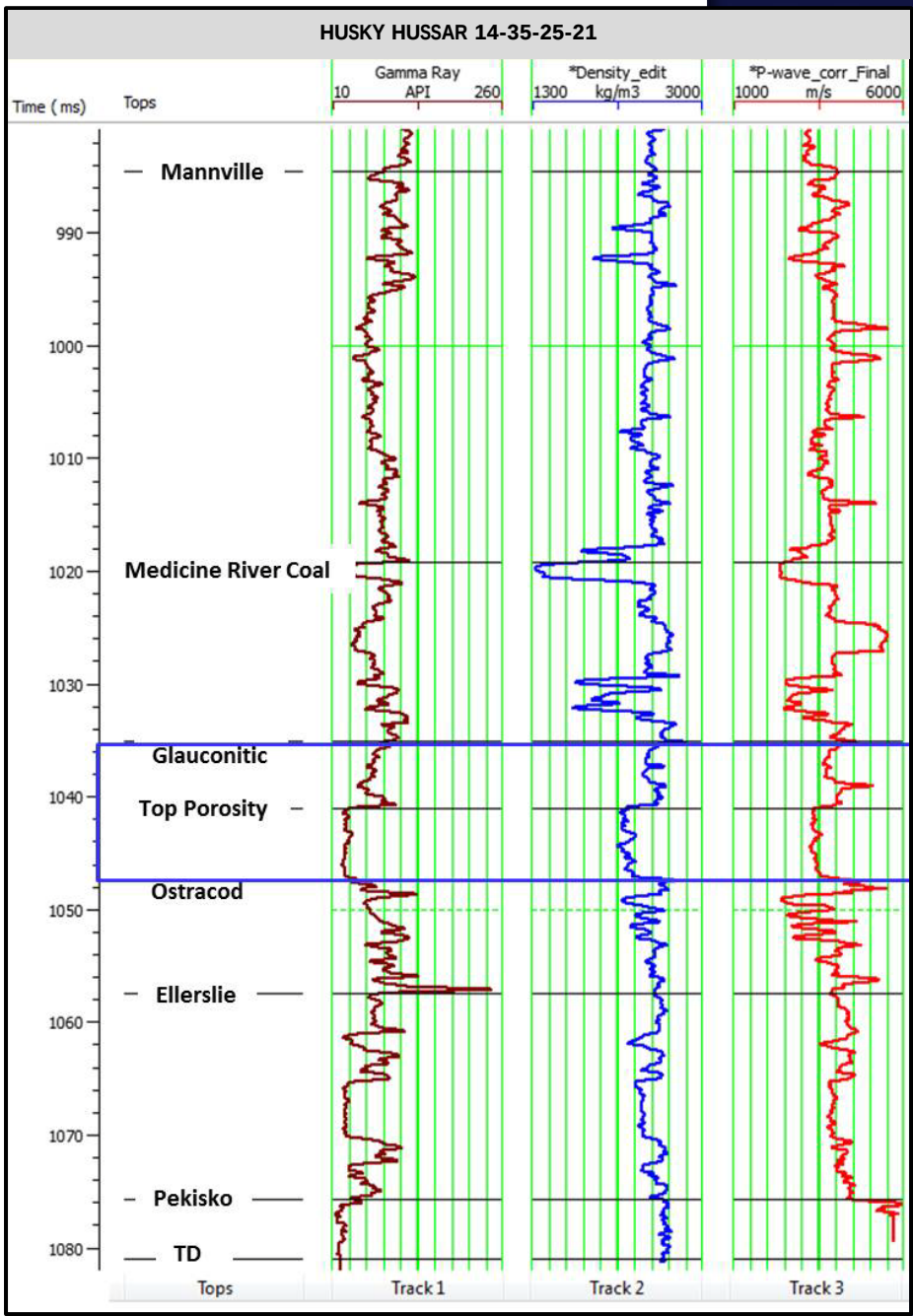
Rayleigh's resolution criterion:

$$\Delta t \geq \frac{T}{2} = \frac{1}{2f_d}$$

$$\Delta t = 2t_p = \frac{2Z}{V_p} \geq \frac{T}{2}$$

$$Z \geq \frac{V_p}{4f_d} \geq \frac{3400\ m/s}{4 * 40\ Hz} \geq 21m$$

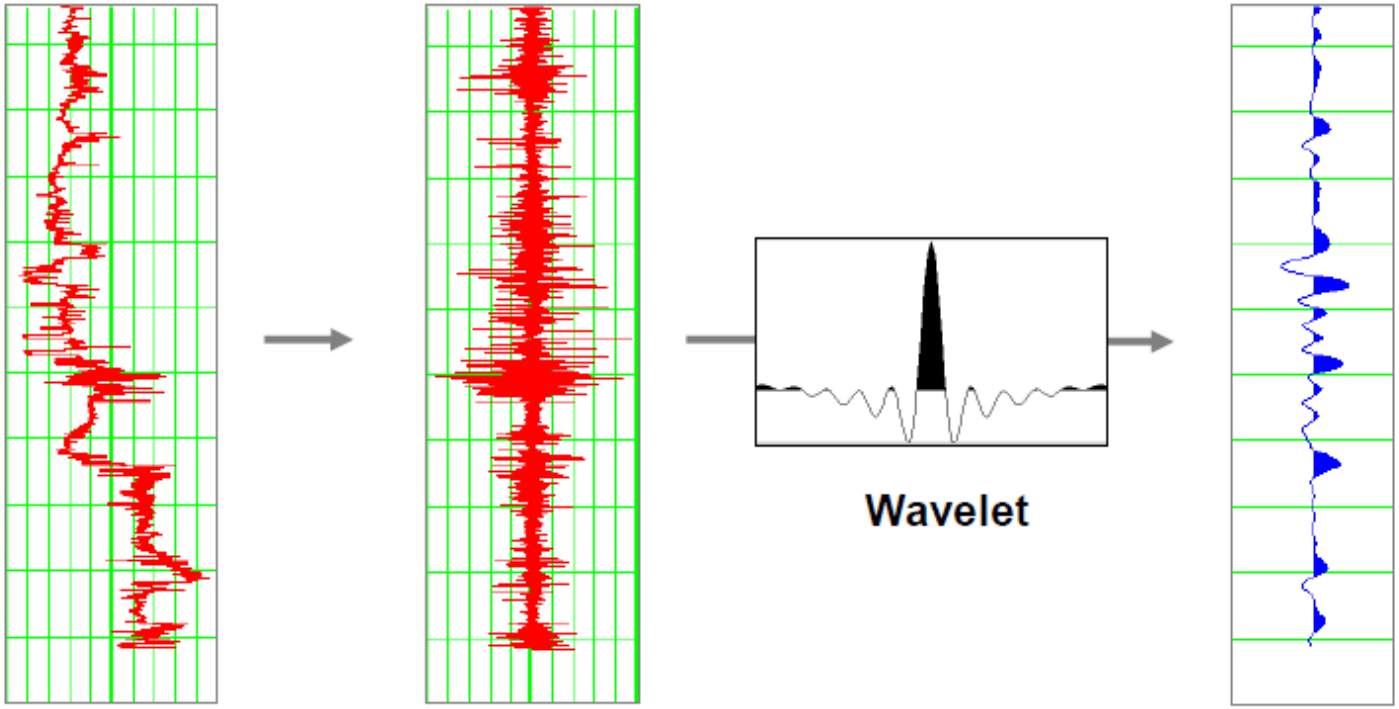




POST-STACK INVERSION TEST

Definition

- Inversion is the process of estimating impedance from the seismic trace



$$Z_P = \rho V_P \longrightarrow R_i = \frac{Z_{i+1} - Z_i}{Z_{i+1} + Z_i} \Rightarrow S = W * R + Noise$$

Inversion

POST-STACK INVERSION TEST

Model-based inversion

First approach:
Band-limited impedance inversion, Lindseth (1979)

$$Z_{i+1} = Z_i \left(\frac{1 + R_i}{1 - R_i} \right)$$

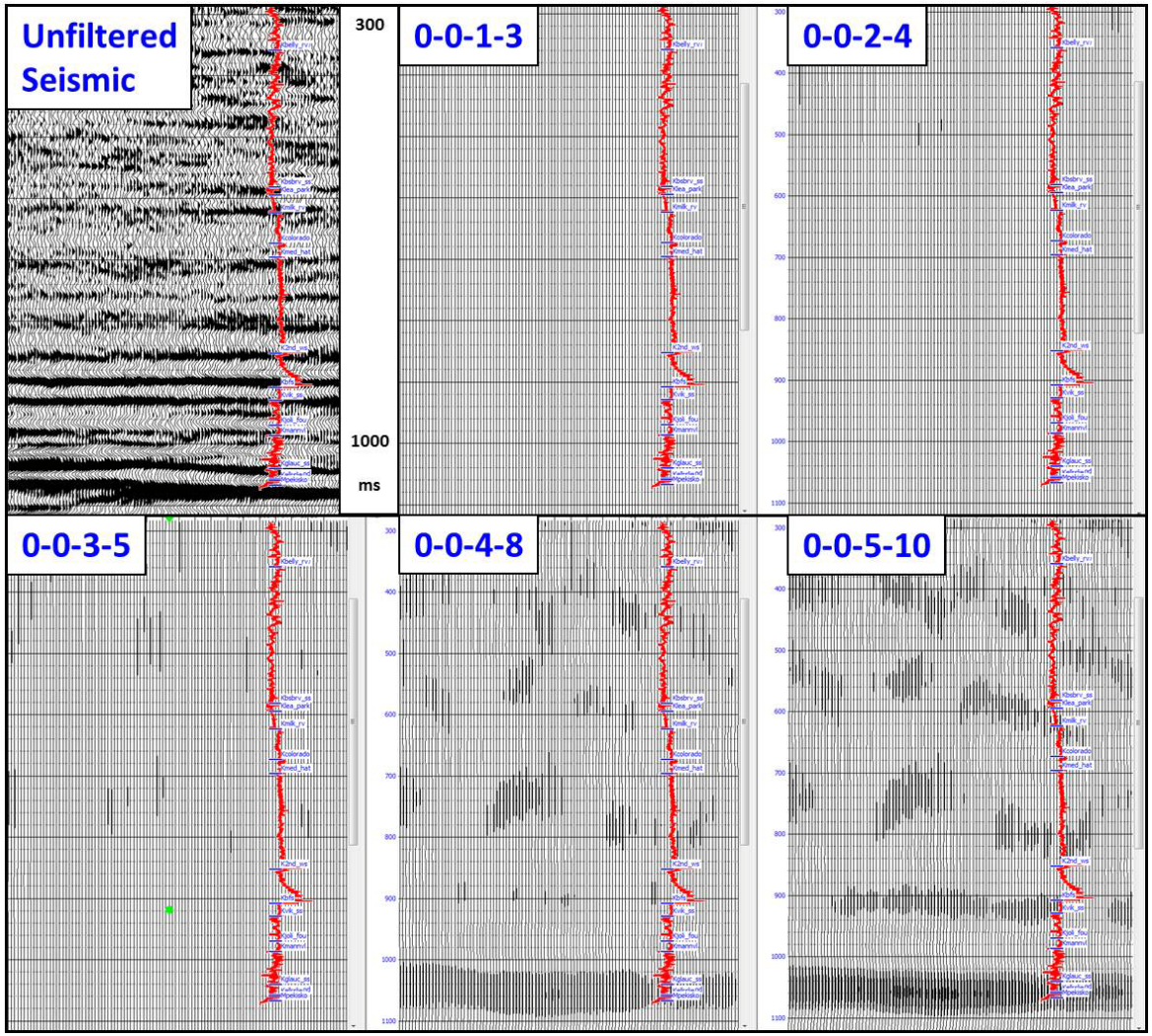
The initial value of Z is required to be known

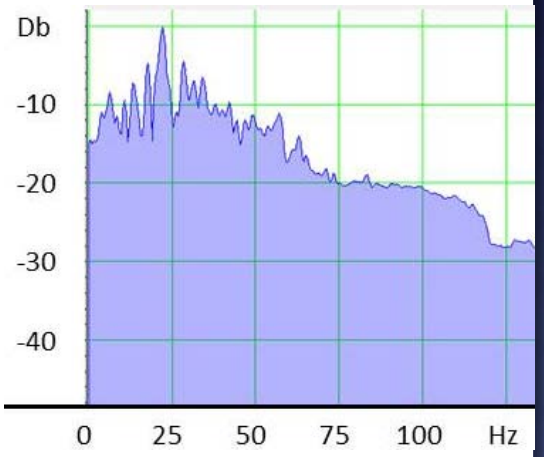
Others approaches:
Sparse-spike, model-based, etc., Russell and Hampson (1991)

$$J = weight_1 \; x \; (S - W * R) + \; weight_2 \; x \; (M - H * R)$$

POST-STACK INVERSION TEST

Initial model



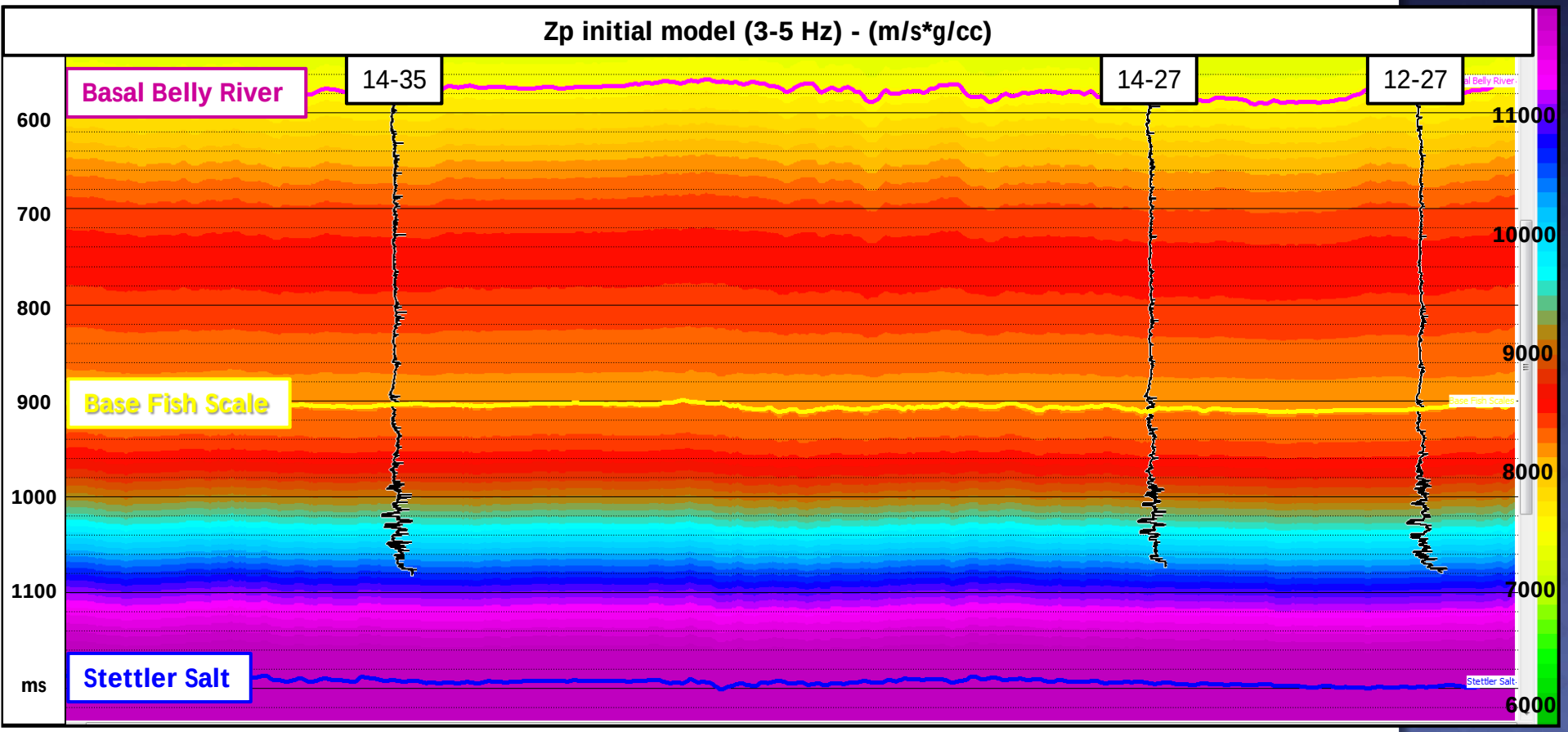


Signal band 10-60 Hz
Dominant freq. 40 Hz

(Isaac and Margrave, 2011)

POST-STACK INVERSION TEST

Initial model



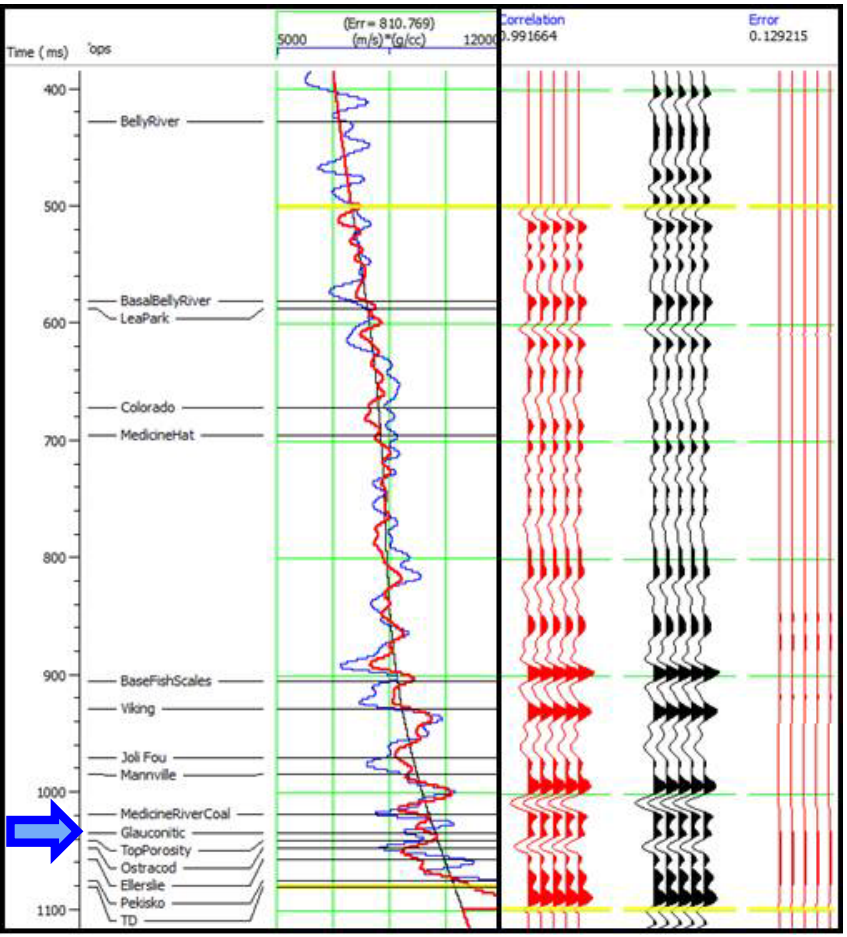
3-5 Hz model

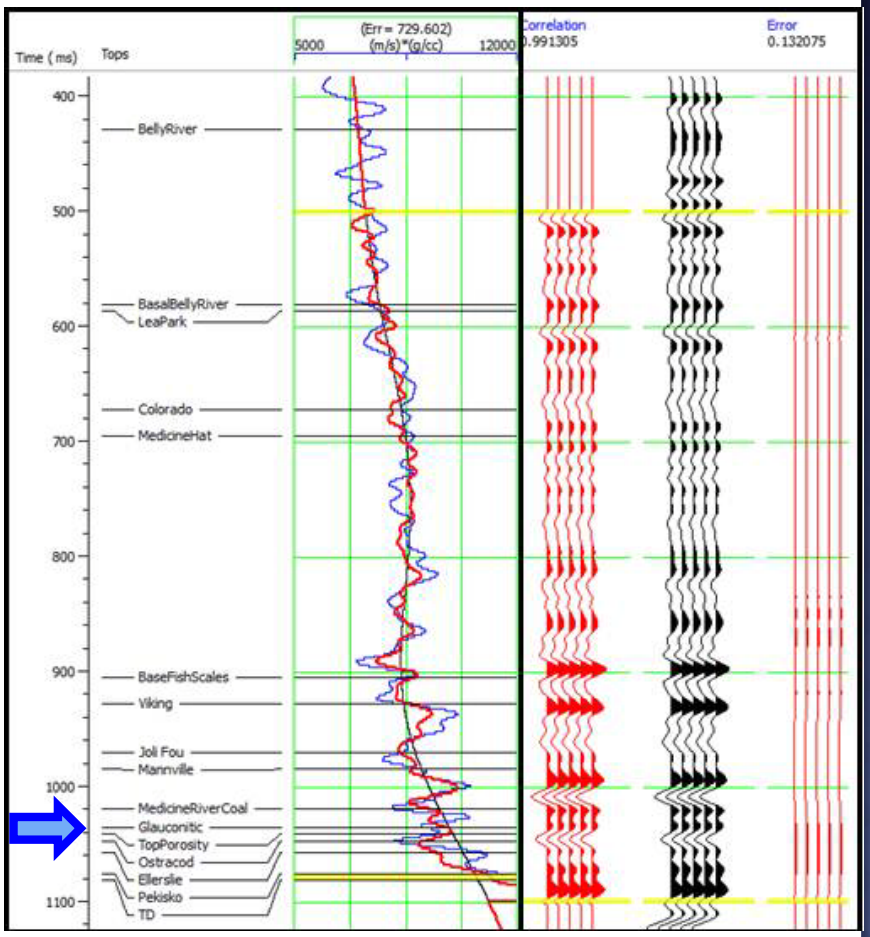
Well 14-35-25-21

3 horizons: Basal Belly River, Base Fish Scale and Stettler Salt.

POST-STACK INVERSION TEST

Inversion analysis



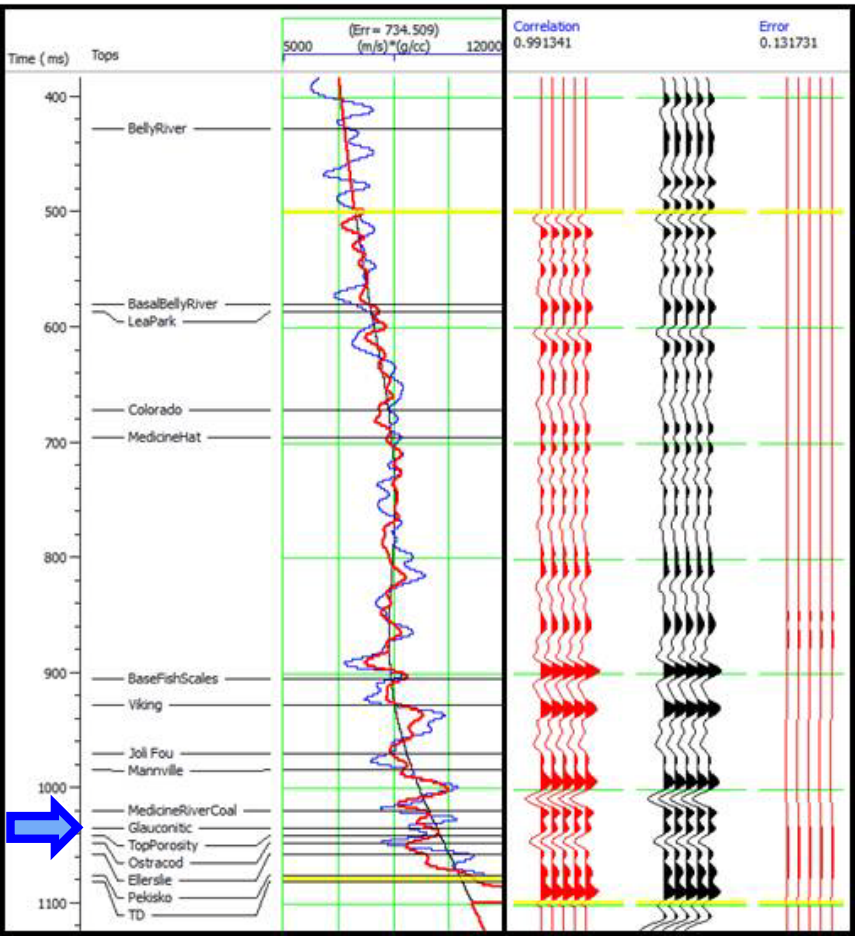


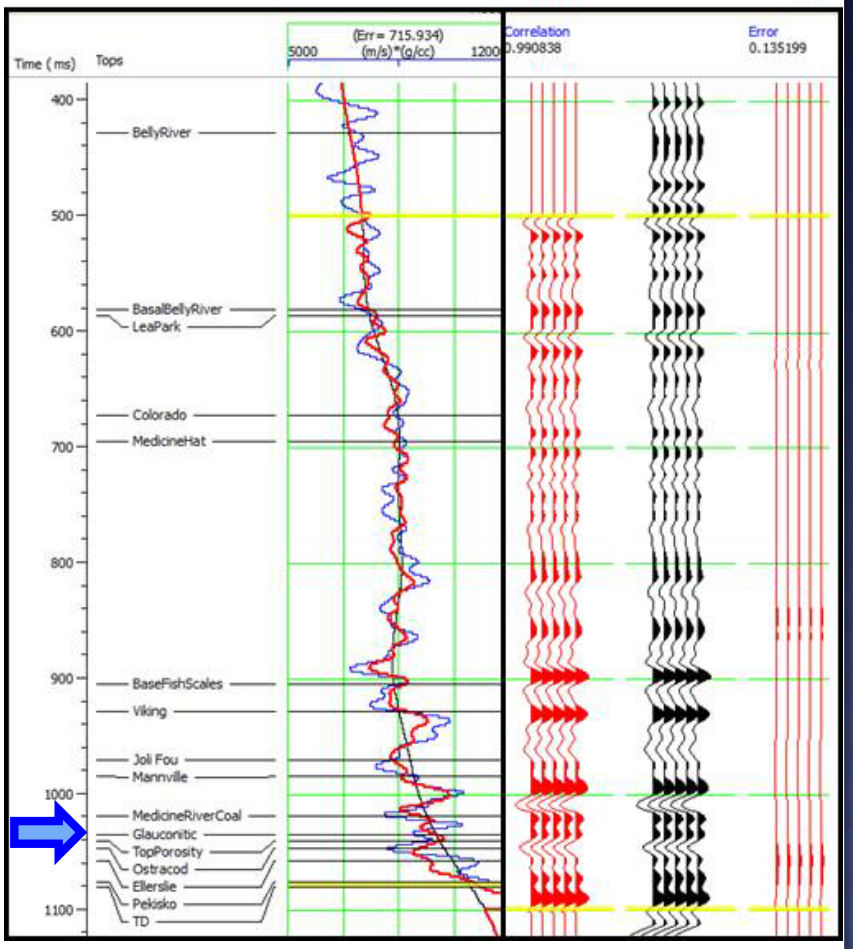
Post-stack inversion analysis
for each model:
Model 1-3 Hz (left)
Model 2-4 Hz (right)

Correlation ~99%
RMS Error: 715 - 811 m/s*g/cc

POST-STACK INVERSION TEST

Inversion analysis



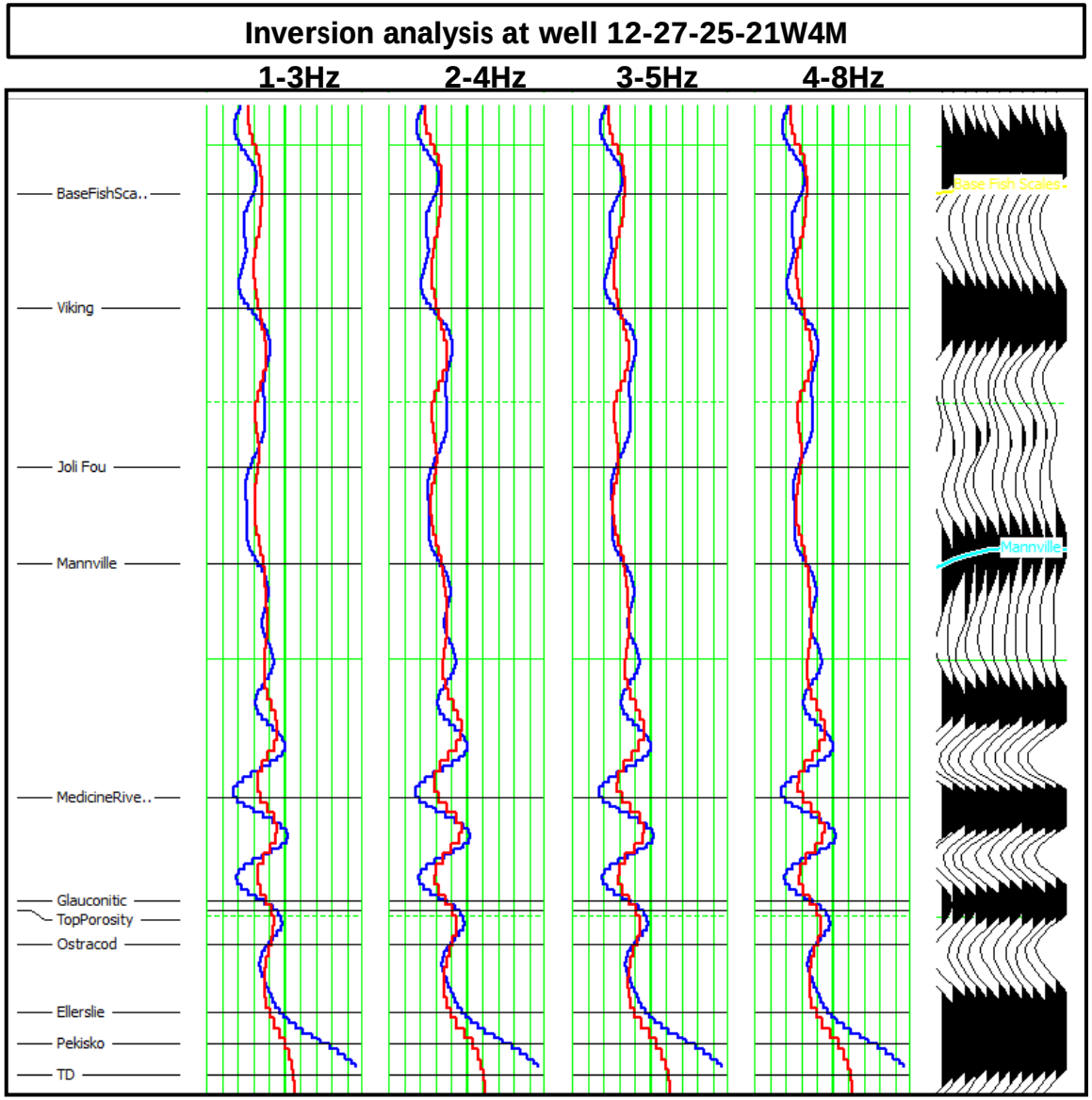


Post-stack inversion analysis for each model:
Model 3-5 Hz (left)
Model 4-8 Hz (right)

Correlation ~99%
RMS Error: 715 - 811 m/s*g/cc

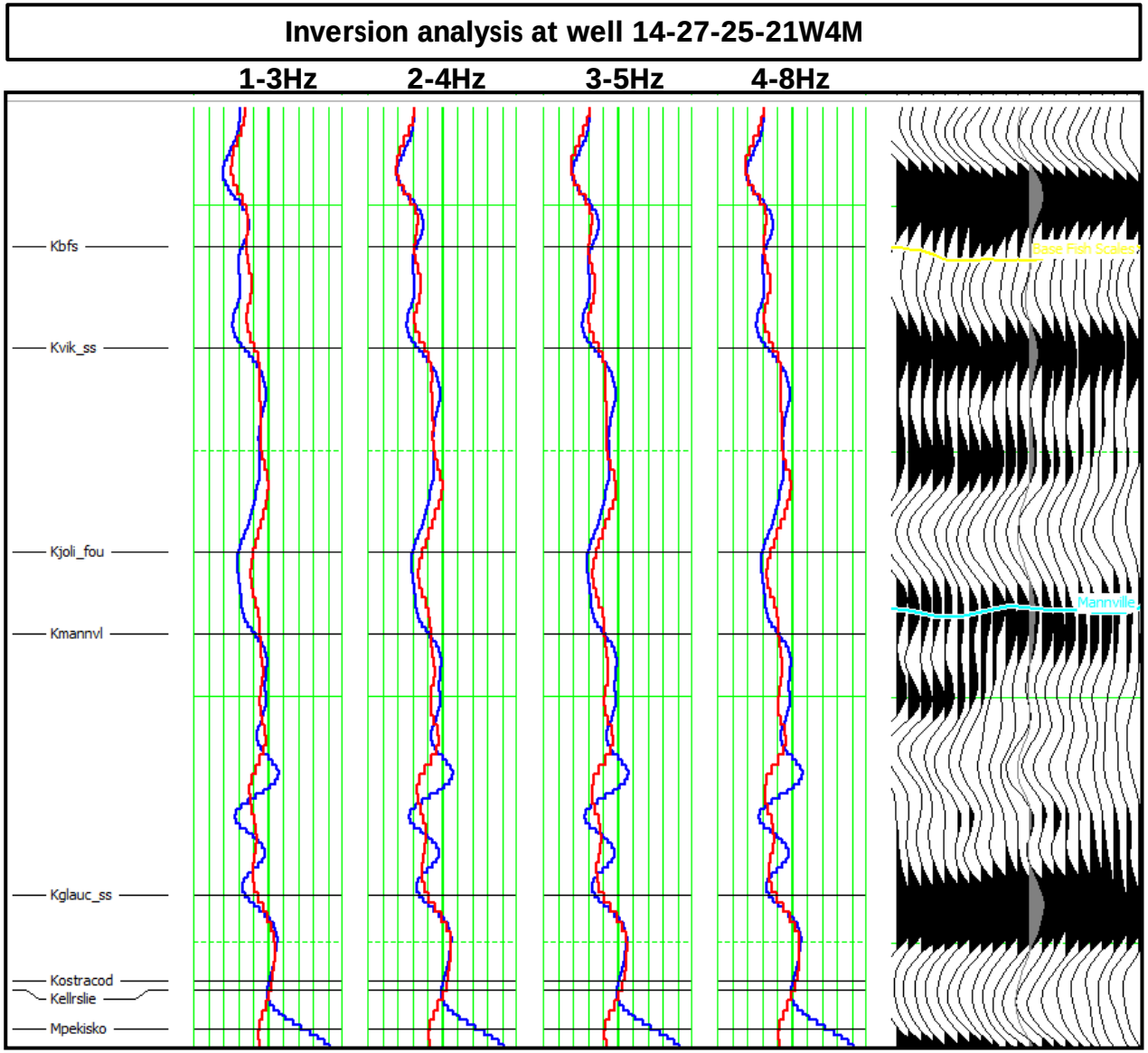
POST-STACK INVERSION TEST

Inversion analysis – blind test @well 12-27-25-21



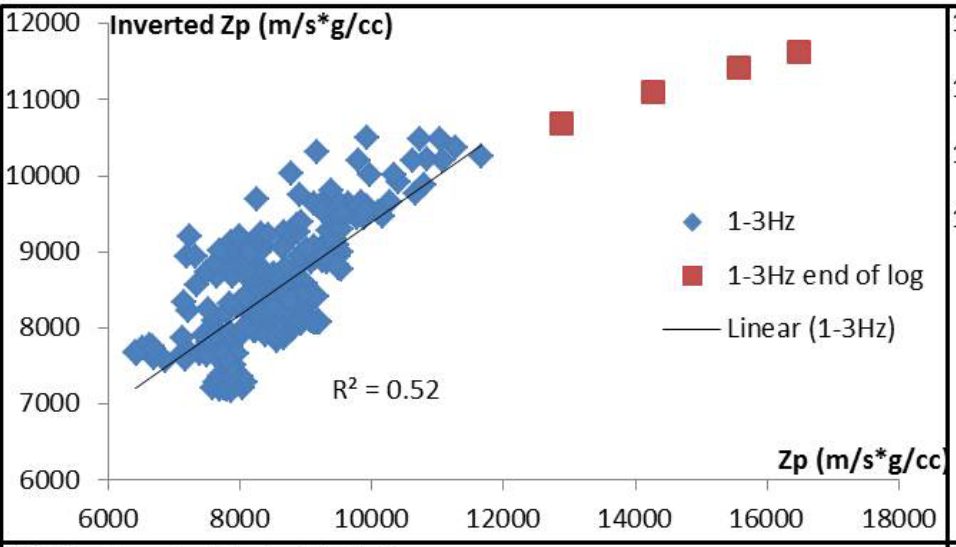
POST-STACK INVERSION TEST

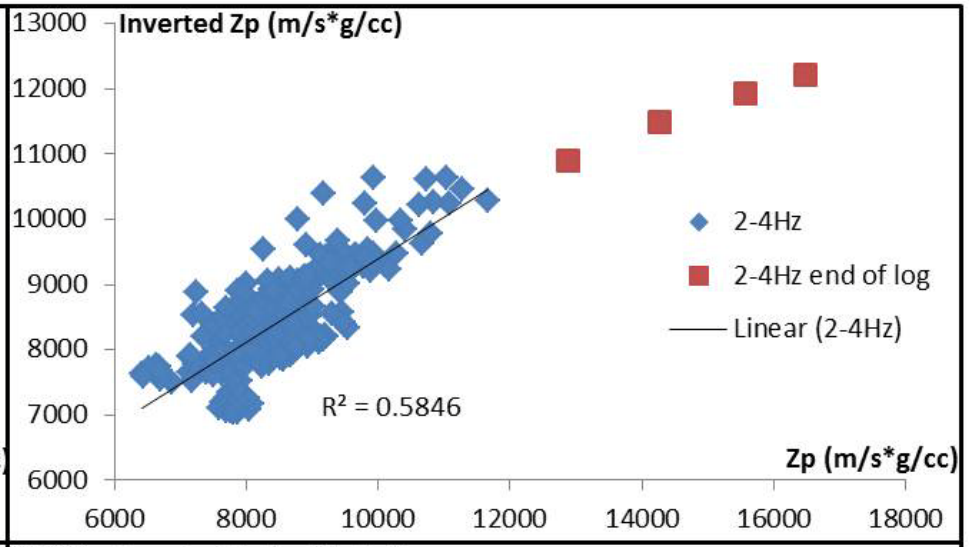
Inversion analysis – blind test @well 14-27-25-21

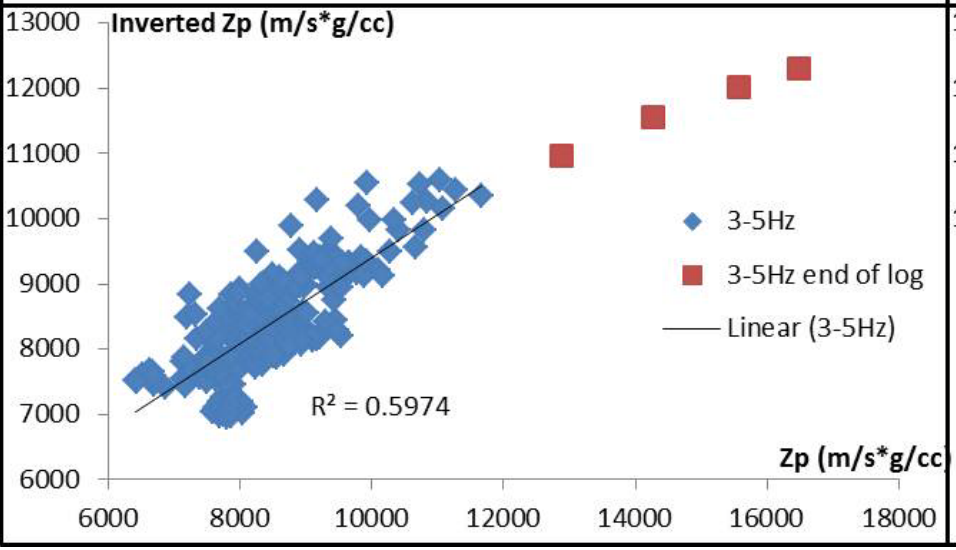


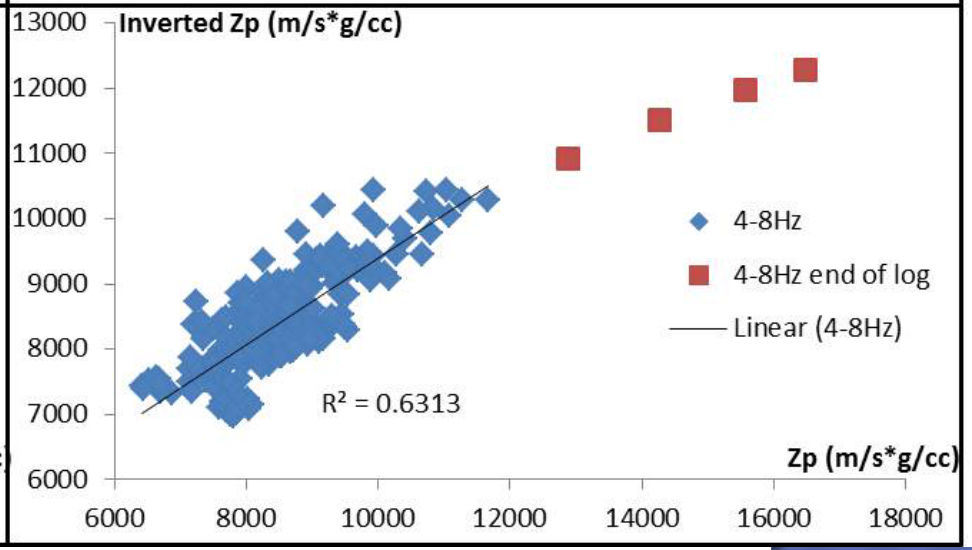
POST-STACK INVERSION TEST

Inversion analysis – cross-plot @well 12-27-25-21



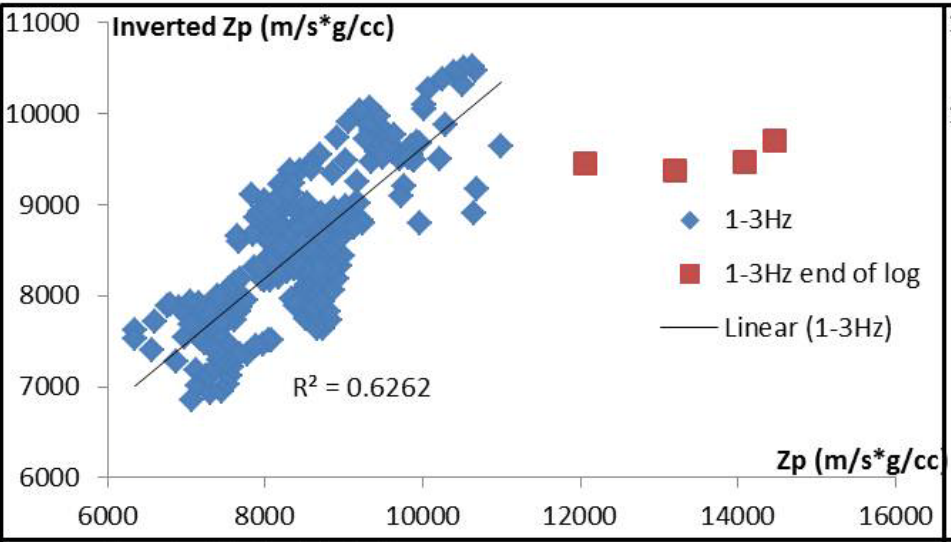


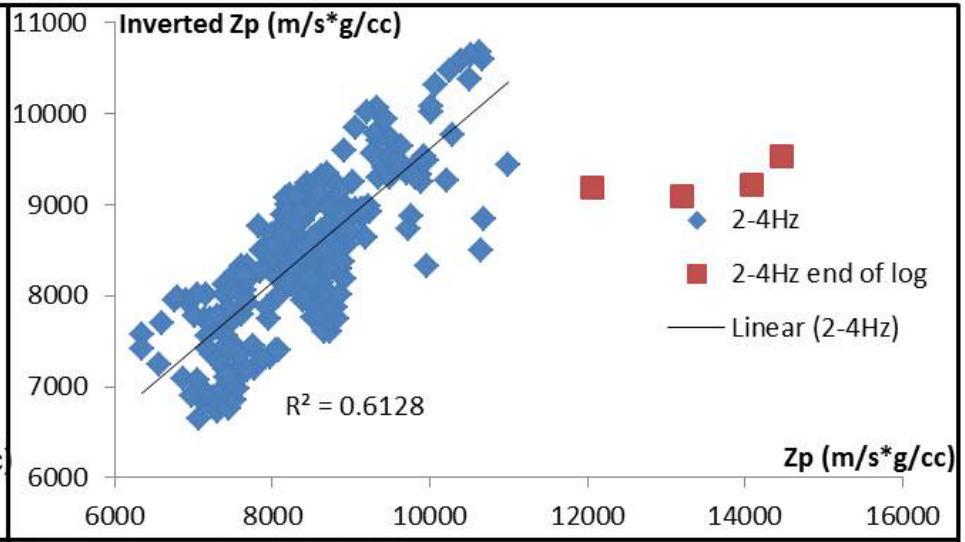


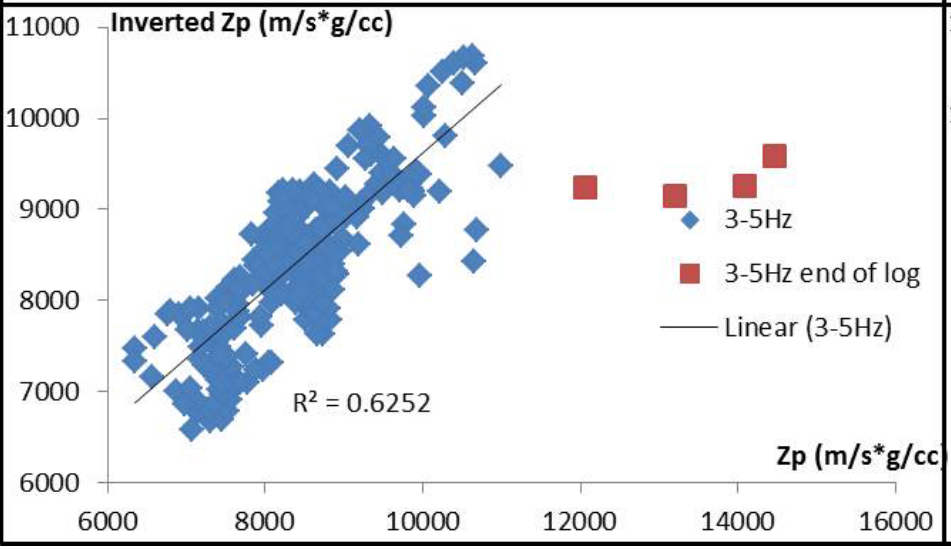


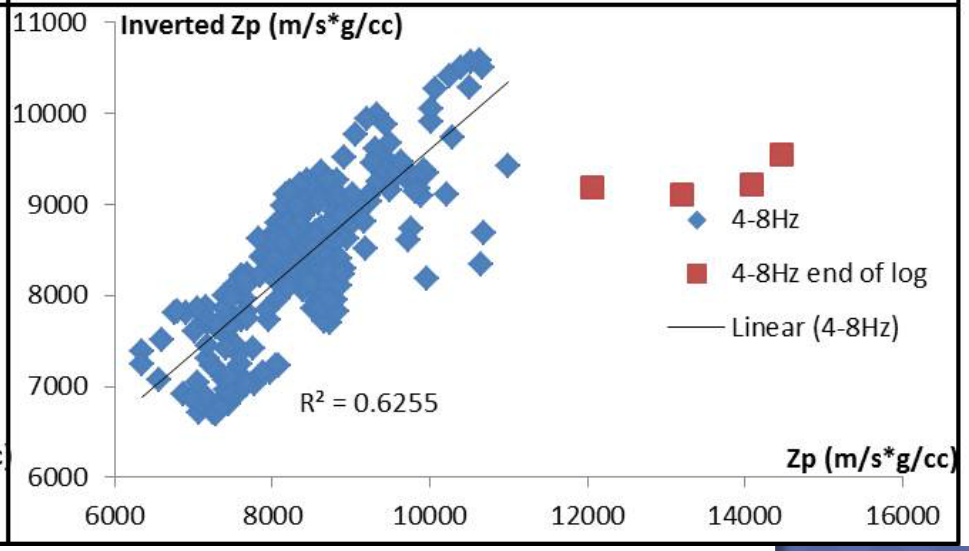
POST-STACK INVERSION TEST

Inversion analysis – cross-plot @well 14-27-25-21



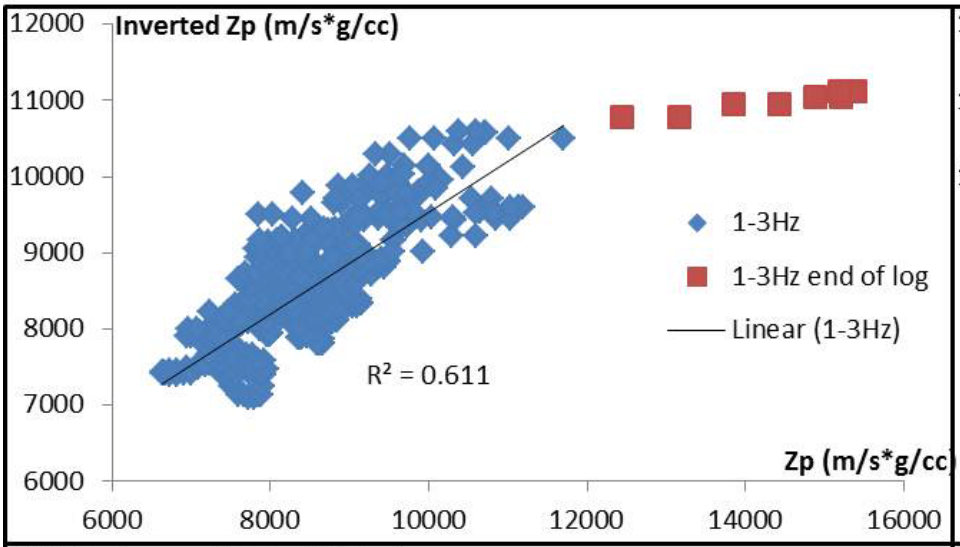


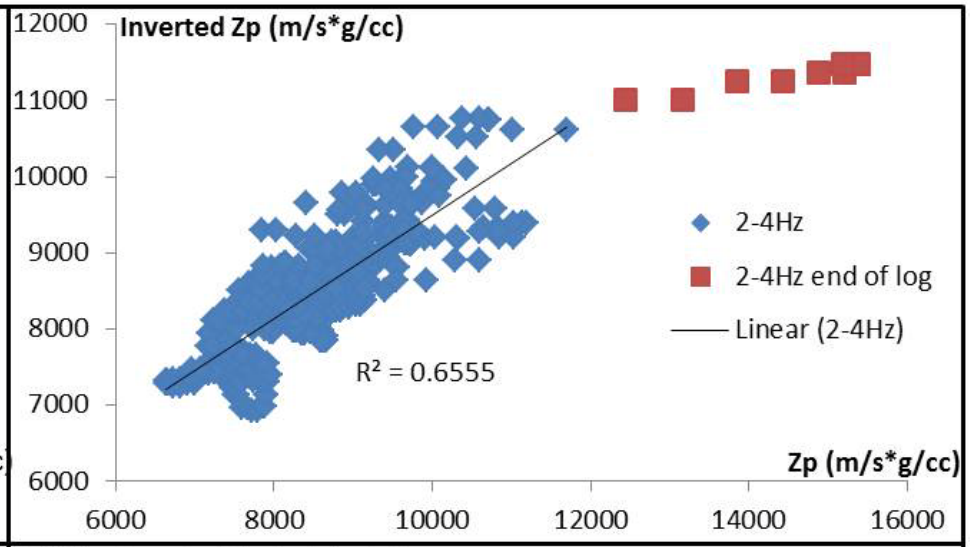


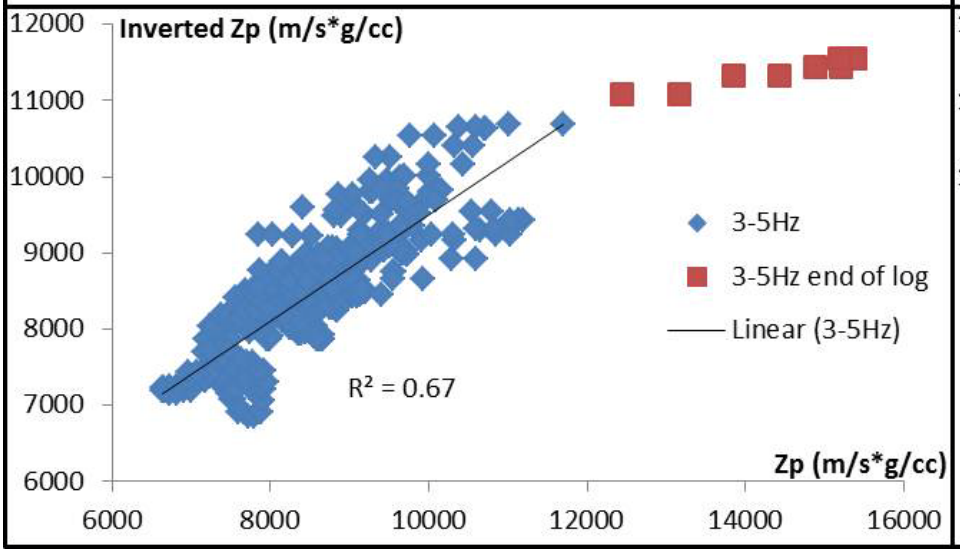


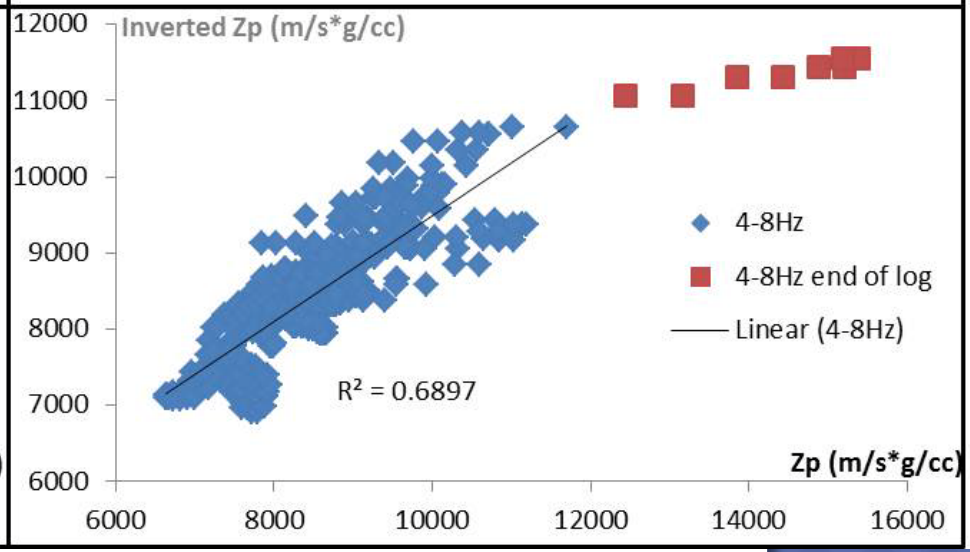
POST-STACK INVERSION TEST

Inversion analysis – cross-plot @well 14-35-25-21



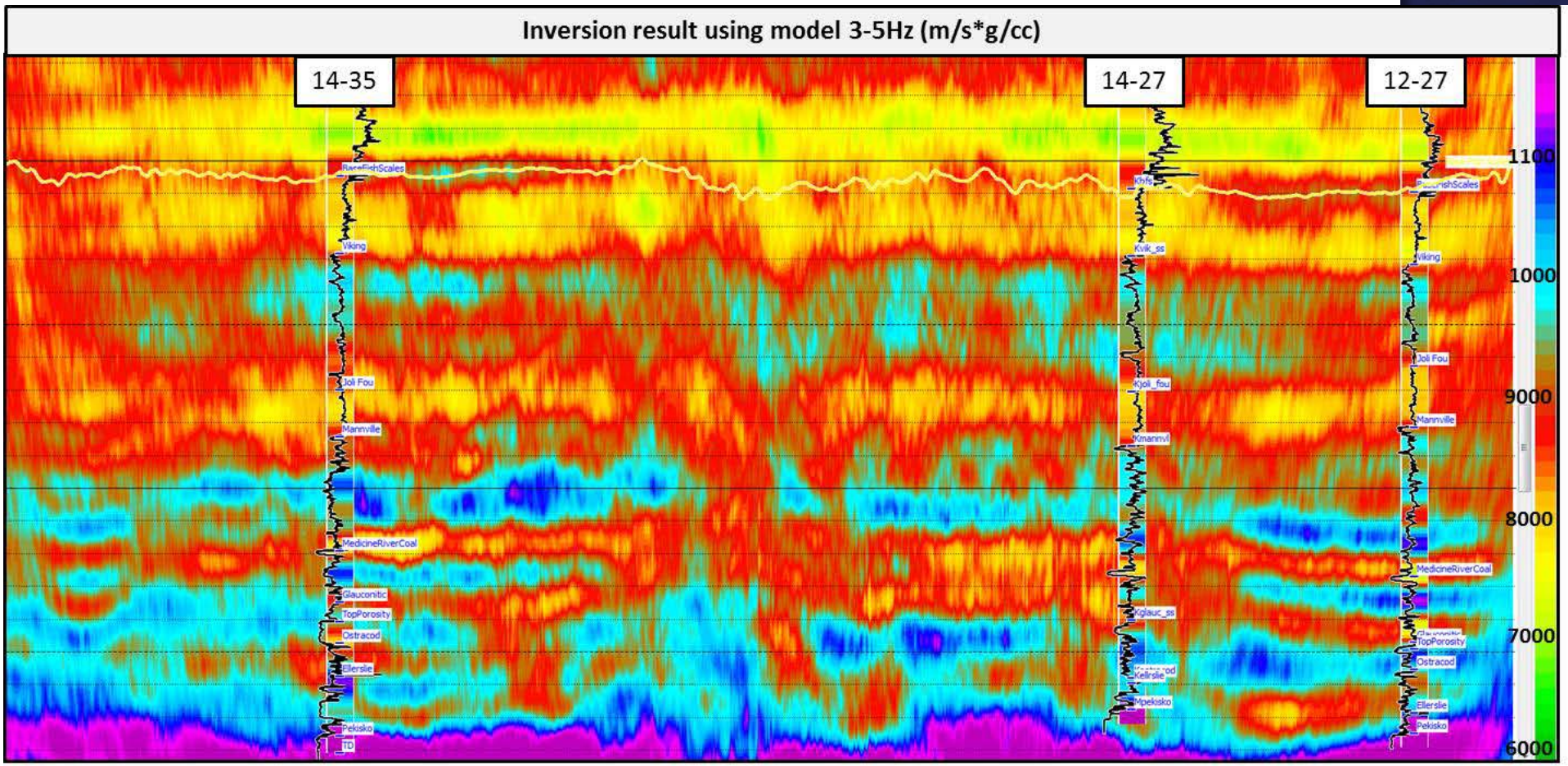






POST-STACK INVERSION TEST

Inversion result – Model 3-5 Hz

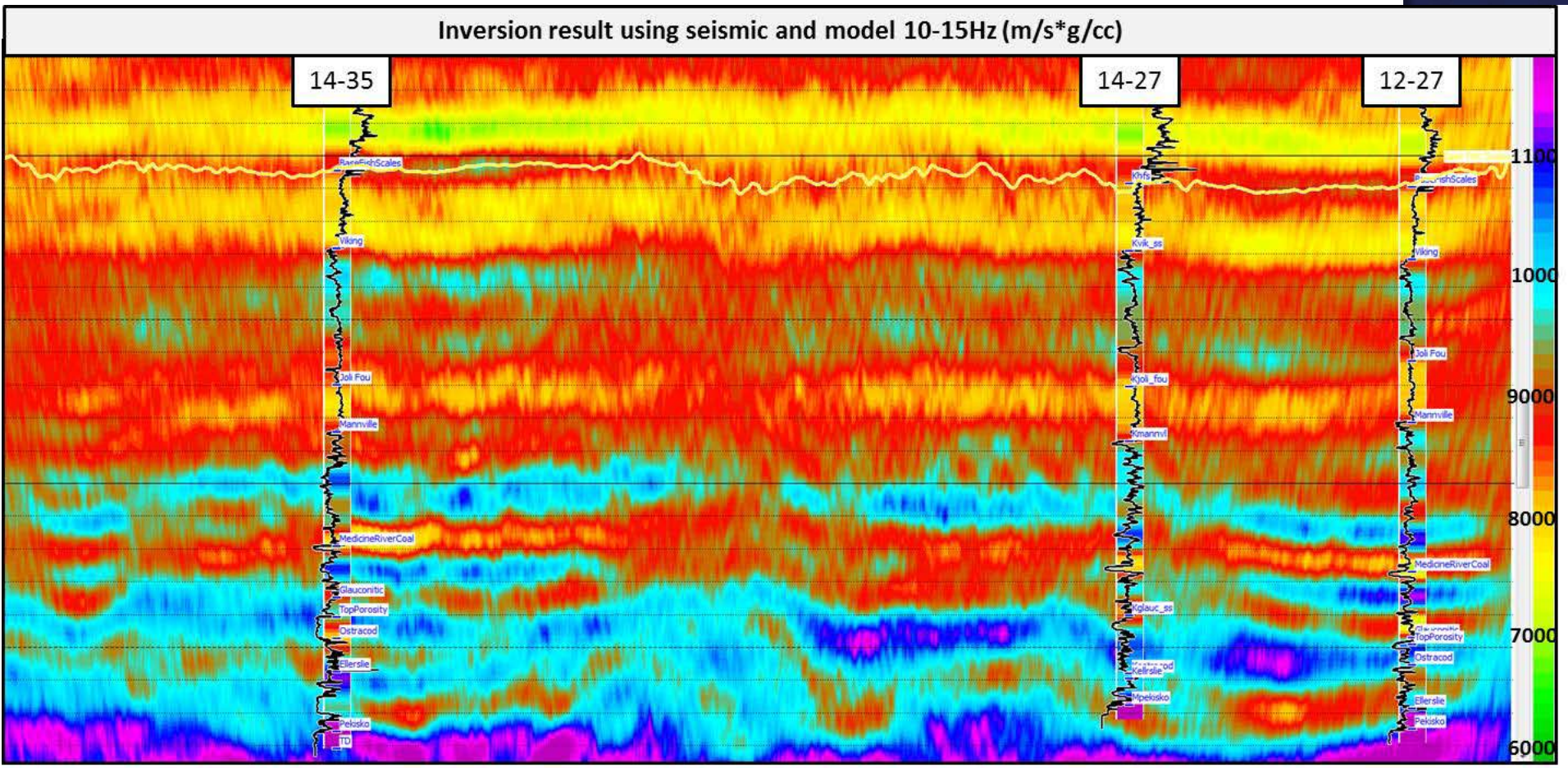


Black curve (gamma ray log)
Variable color (P-impedance log)

Window: 870 – 1080 ms

POST-STACK INVERSION TEST

Inversion result – Model 10-15 Hz / seismic data 10-15-60-85 Hz



Black curve (gamma ray log)
Variable color (P-impedance log)

Window: 870 – 1080 ms

CONCLUSIONS

- Initial inversion model 3-5 Hz showed better results and consistency with the seismic data.
- Blind test at wells 14-27-25-21 and 12-27-25-21 showed a correlation ~65% between the inverted impedance and the impedance log.
- The impedance determined from the inversion reflects lateral changes due to the seismic reflection data more than the influence of the initial model.
- The inverted impedance shows the general trend and relative variations which might allow monitoring changes in the reservoir.

CONCLUSIONS

- The inversion with the band-pass filtered seismic data and the model 10-15 Hz showed a good match at the well locations but,
- lateral variation and intensity of the events were subtle and resembled more the initial model character.
- The low frequency component gained during the Hussar experiment (4-10 Hz) adds valuable information to inversion studies.

ACKNOWLEDGEMENTS

- Husky Energy
- Geokinetics
- INOVA
- Hampson-Russell software
- CREWES sponsors, staff and students