Filling in the missing 2-10 Hz gap for impedance inversion

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Summary

Seismic inversion is routinely used in the prediction of reservoir porosity, lithology, and mechanical response to hydraulic fracturing. Since seismic data typically range between 10 and 100 Hz, the low-frequency trend needs to be estimated by other means, most commonly by gridding the low-frequency content of sparse well control, or by using migration-driven interval velocity analysis coupled with a statistical velocity/density relationship. In this study, we first tested a workflow proposed by Mesdag et al. to fill the low frequency gap in seismic inversion. Then propose a new algorithm which employs the interval velocity to build low frequency trend in seismic inversion.

Mesdag et al from Fugro have proposed an inversion workflow for the low frequency modeling for seismic inversion. They concluded that with correct low frequency model, seismic inversion can get a high fidelity results (Figure 1).Inspired by their work, we performed a two-stage initial model building process and tested P-impedance inversion on different models (Figure 2 – Figure 6). This turned out to be a failed attempt, which motivated us to explore new possibilities to accomplish this goal.

Reflection tomography constructs an estimated of the subsurface velocity distribution based on a series of measurement of travel times or amplitudes associated with seismic reflections. Sayers et al . (2005) first calibrated the velocity from tomography with velocity from well logs, then use the calibrated velocity to perform pore pressure prediction. Inspired by Sayers's ideal, by employing the empirical equation between velocity and density, we can build the low frequency model with the inverted interval velocity model.

Iterative model ng

Conventional P-impedance inversion

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Calculate the P-impedance contrast for high contrast layers

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Update the initial low frequency model by adding the contrast from step 2

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Run inversion again using the updated low frequency model

Chart 1: Workflow for suppressing sidelobe effect caused by high impedance contrasts.

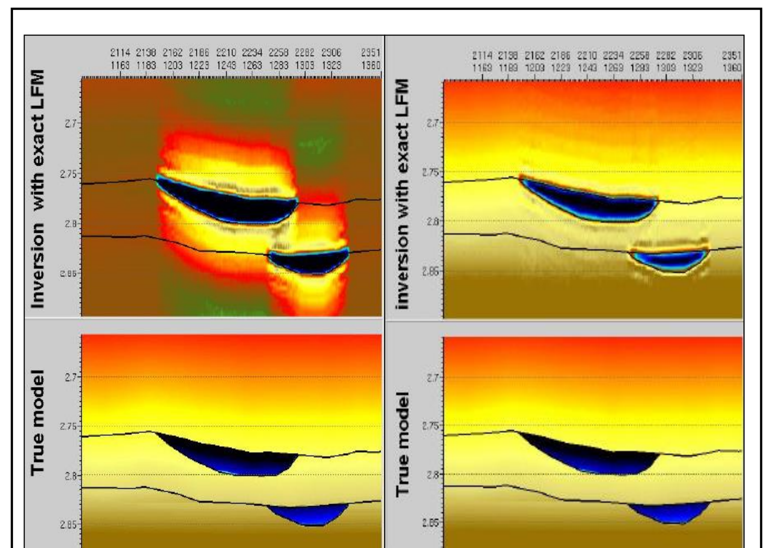


Figure 1: Model test of P-impedance inversion result for two sand channels using original low frequency model (left) and updated model (right). Note the sidelobe effect in neighboring layers are suppressed when using the updated model.

Courtesy of Mesdag (Fugro)

A Failed Attempt

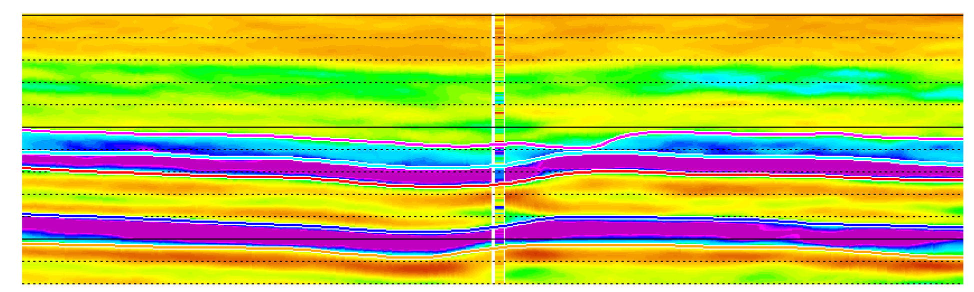
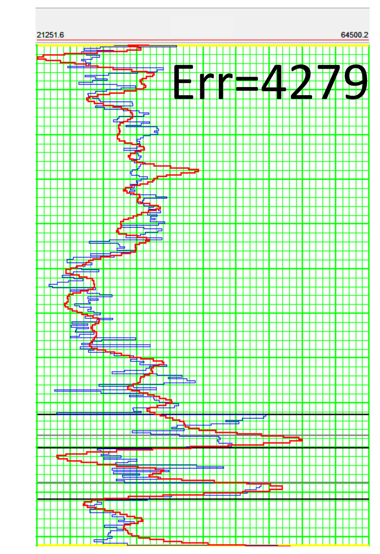



Figure 2: (top) Inversion result using an initial model of 0 – 5Hz. (right) Correlation error (Err) between inverted impedance and computed impedance from well logs.

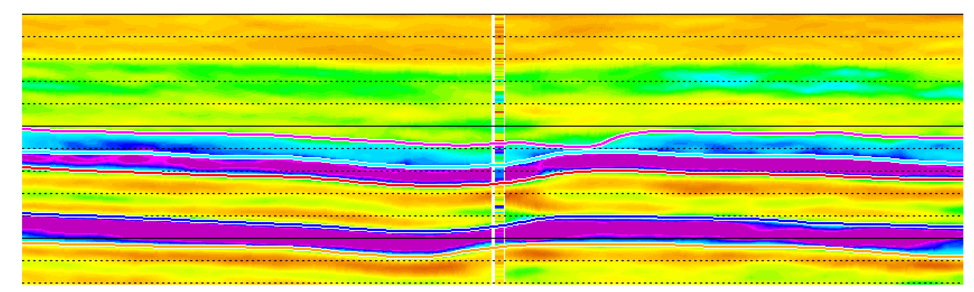
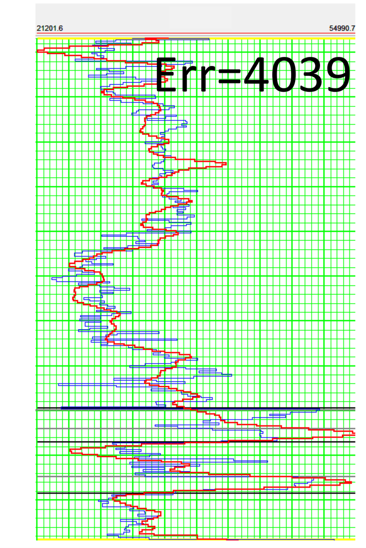
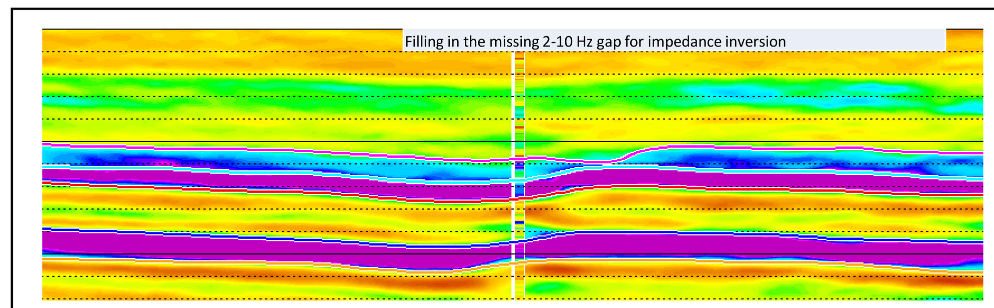



Figure 3: (top) Inversion result using an initial model of 0 – 10Hz. (right) Correlation error (Err) between inverted impedance and computed impedance from well logs.



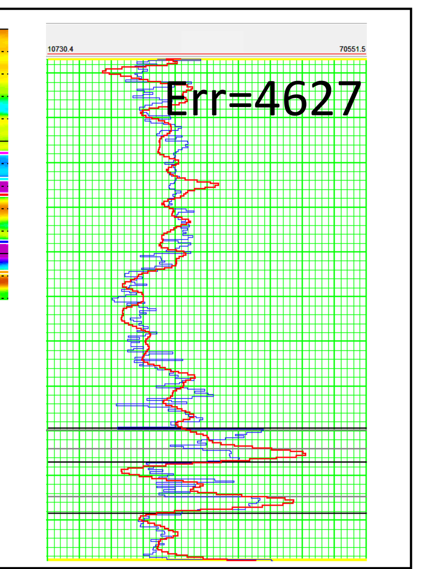


Figure 4: (top) Inversion result using a 0 – 10Hz low-pass filtered inversion result from Figure 3 as initial model. (right) Correlation error (Err) between inverted impedance and computed impedance from well logs.

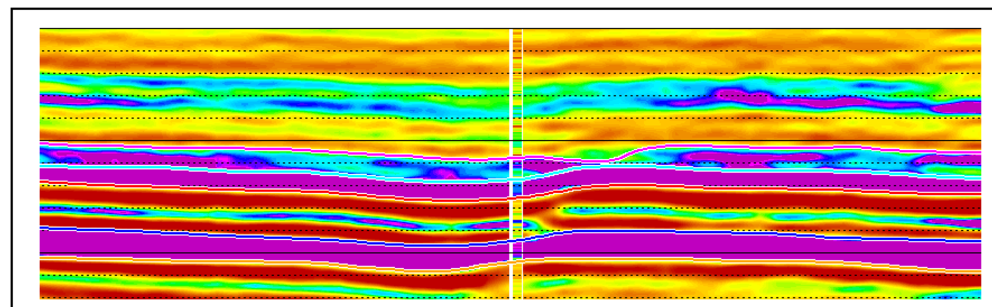
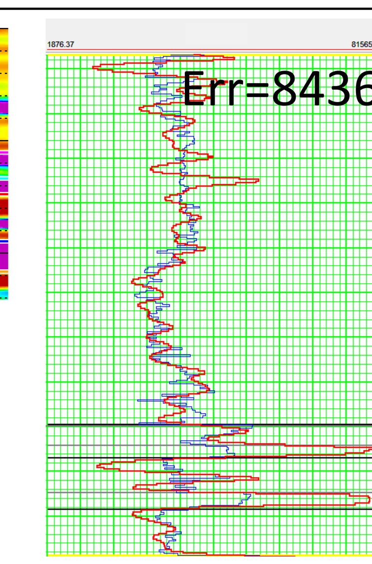



Figure 5: (top) Inversion result using a 0 – 15Hz low-pass filtered inversion result from Figure 3 as initial model. (right) Correlation error (Err) between inverted impedance and computed impedance from well logs.

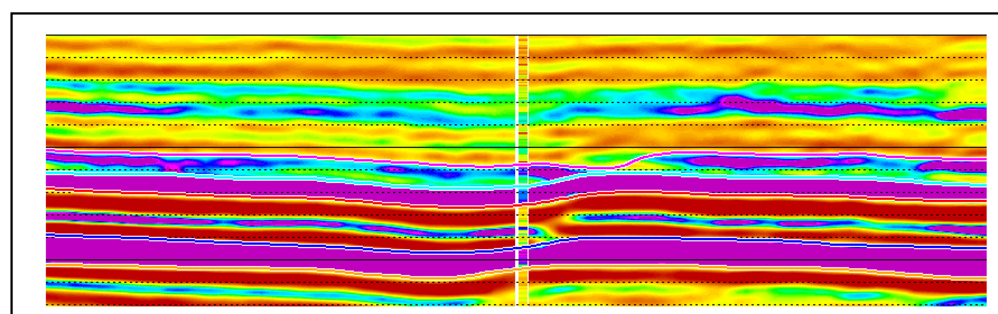
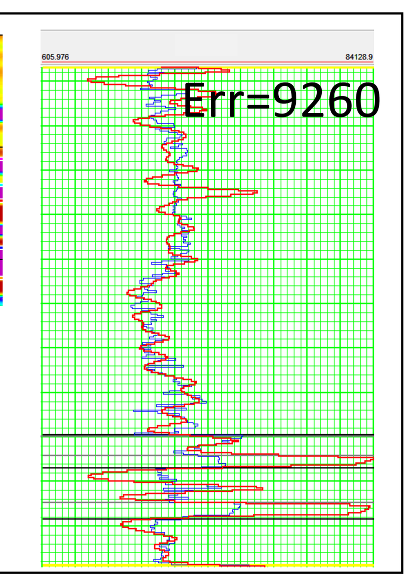



Figure 6: (top) Inversion result using a 0 – 20Hz low-pass filtered inversion result from Figure 3 as initial model. (right) Correlation error (Err) between inverted impedance and computed impedance from well logs.

We built several initial models and compared the inversion results to examine the feasibility of our two-stage initial model building workflow. Figure 2 and 3 are inversion results from traditional initial model with frequency limited to 5Hz and 10Hz, respectively; Figure 4, 5 and 6 are inversion results from our two-stage initial model building workflow, which used the impedance volume in Figure 3 with low-pass filters of 10Hz, 15Hz and 20Hz, respectively, as the new initial models.

By comparing the correlation error with wells, we can identify the impedance volume inverted from traditional 10Hz initial model has the least error, which means our proposed method is failed. We can also identify the introduced artifacts in Figure 5 and 6 which go beyond seismic resolution.

Conclusions

1) Low frequency model has a great effects on the last inverted impedance results. The error between the inverted impedance and that from well logs varies with low frequency models. In our test, 0-10 Hz low frequency model generates the most fidelity result.
2) It is not appropriate to build the low frequency model by simply low pass filter the introverted result.
3) If there exists large errors in the inverted results, we do not suggest build the low frequency from inverted results.

Future Work

Estimate interval velocity from reflection tomography

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Tie the seismic and well logs, then invert the velocity trend from check-shot

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Calibrate seismic interval velocity with velocity inverted from check-shot

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Employ the empirical equation to get density cube from interval velocity cube. Then Build low frequency

Chart 2: Future workflow for building low frequency initial model.

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