Pre-Stack Full Waveform Inversion for Velocity Model Building

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Abstract

An accurate earth model is key to any successful depth imaging effort. Full waveform inversion is an advanced velocity model building process which uses the full two way wave equation. Existing methods use a ray tracing approach to distribute velocity errors, computed from the residual move-out in Image gathers, into the model.

In this paper we will briefly introduce the full waveform inversion theory and show some results from synthetic and real data studies.

Introduction

The industry has moved to using two-way wave equation migrations, especially in areas of complex geology such as the salt bodies in the Gulf of Mexico and offshore Brazil. The natural next step is to use the two-way wave equation for velocity model building. One of the most advanced tools for velocity model building using the two-way wave equation is Full Waveform Inversion(FWI).

Method

Full waveform inversion uses the two-way wave equation to model seismic data using an initial best guess of the earth model. This can be the smoothed time-velocity model or a depth model from a previous processing effort.

The modeled seismic data is compared to the real pre-stack seismic measurement, and errors are backwards propagated into the velocity model, iterating to a final detailed model (Figure 1).

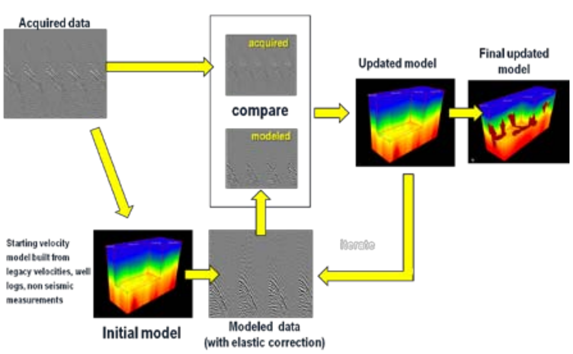

Figure 1 Full Waveform Inversion workflow.

Results

As with the deployment of any new technology, full waveform inversion was initially applied and tested on synthetics. Encouraging results were obtained by applying Full Waveform Inversion to the SEG SEAM model. Starting with a smoothed version of the model, we were able to recover a significant amount of the original detail (Figure 2).

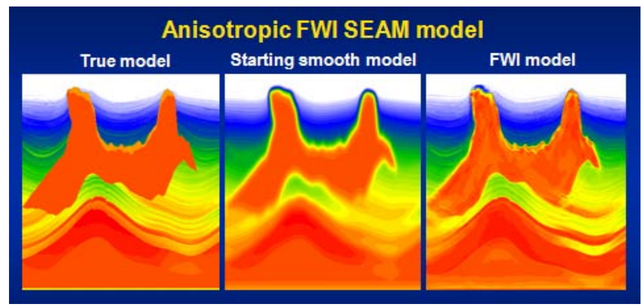

Figure 2 FWI is able to capture the thin layer of higher velocities just above the salt and the slow velocity over-pressured sediments below the salt.

To date FWI has been applied on several real projects in GOM, North Sea and Brazil and is currently being applied on a 30,000 km^2 reprocessing project in the GOM. In all cases results are very promising. Figure 3 shows comparisons of RTM images produced with a tomography velocity model versus the FWI model. The migration with the FWI model better defines the structural closure and enhances the detail in the sediments.

RTM with Velocity Model from tomography | **RTM with velocity model from FWI**

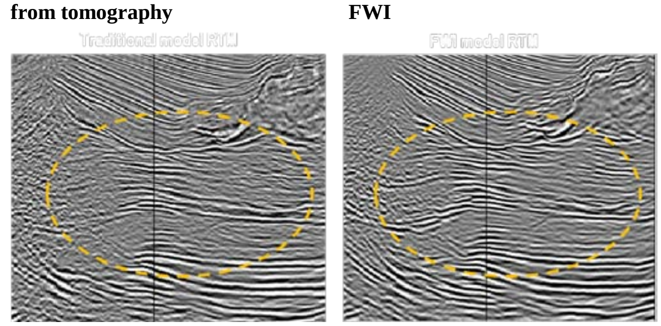

Figure 3 Comparison of RTM images using a velocity model produced with tomography and FWI. The FWI image on the right improves the structural closure and enhances the detail in the sediments

WG are currently performing FWI on a wide-azimuth dataset from the Gulf of Mexico and initial results are very encouraging in the ability of FWI to delineate salt reflectivity starting with a sediment velocity model derived from a conventional tomography approach (Figure 4)

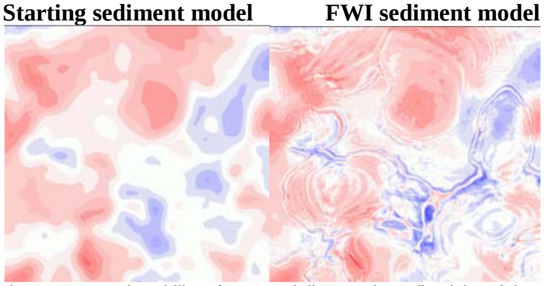

Figure 4. Note the ability of FWI to delineate the reflectivity of the salt horizon

Figure 5 details a comparison of the sediment flood migration (left) and the difference between the starting model migration and FWI migration. This demonstrates the capability of FWI to delineate the top salt.

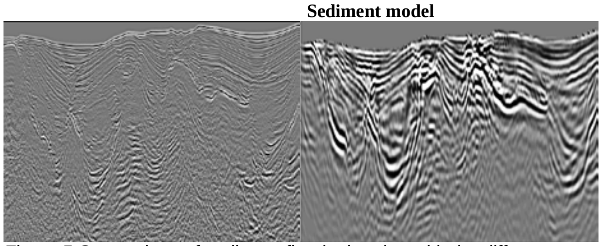

Figure 5 Comparison of sediment flood migration with the difference between the FWI velocity model and the starting sediment velocity model, which shows the capability of FWI to delineate the top salt.

Conclusions

Prestack full-waveform inversion is a highly challenging task due to the non-linearity and non-uniqueness of the solution. Utilizing compute-intensive forward modeling and residual wavefield back propagation, the method is resource and time consuming, especially for 3D projects (Vigh et al., 2009). However with the availability of increased compute power and faster two-way wavefield propagation algorithms, it is now realistic to apply full waveform inversion as part of the imaging effort. Applications to date have universally shown uplift, with more detail in the velocity model and better definition of the pre-salt events.

Acknowledgments

References

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