Integration of Dispersion Curve and Full Waveform Inversion Techniques for Onshore Velocity Model Building – Inner Mongolia Study

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Summary

We develop an integrated velocity model building workflow for prestack depth imaging in onshore settings with a complex shallow subsurface. This workflow incorporates dispersion curve inversion and full waveform inversion into a single framework to optimize the advantages of each. An accurate near-surface velocity is derived using the dispersion curve inversion technique that overcomes limitations of traditional traveltime tomography. This velocity is then incorporated into layer-stripping full waveform inversion. We illustrate the workflow on an experimental data set from Inner Mongolia, whose long-offsets and low-frequency content provide the necessary input for both the dispersion curve and full waveform inversion techniques.

Introduction

In onshore areas with complex shallow settings, a detailed near-surface velocity model needs to be properly taken into account for accurate imaging of deeper targets. As conventional traveltime tomography (TT) has limits with regards to the maximally resolvable spatial wavelength, Ernst (2007) proposed to incorporate guided waves into the (mainly) long-wavelength statics solution by applying Dispersion Curve Inversion (DCI). Here, our objective is to incorporate this solution into the complete macro-model building workflow based on the acoustic Full Waveform Inversion (FWI) that retrieves the deeper part of the subsurface (Plessix et al. 2010).

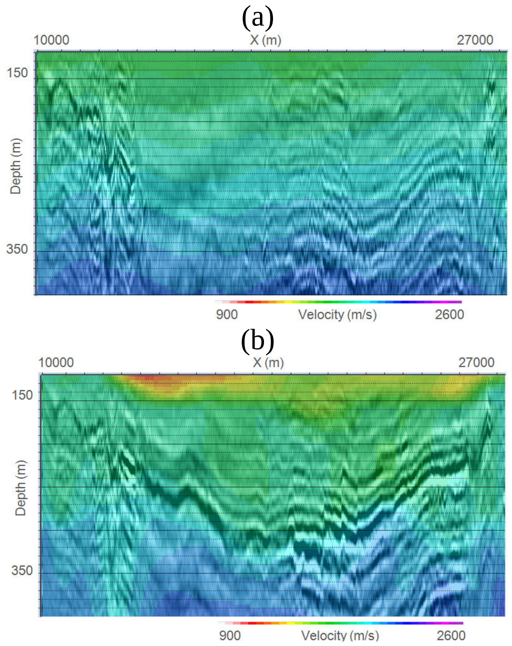


Figure 1 *Velocity models overlaid by stacked depth migrated sections: (a) TT and (b) DCI-FWI.*

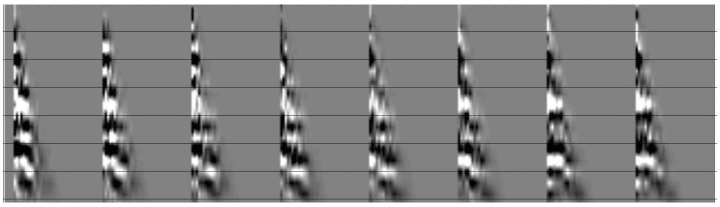
Methodology

Following Ernst (2007), the near-surface guided waves are used to retrieve shallow velocity anomalies. The near-surface DCI analysis is based on the dispersion curves extracted in the ω-p domain. Next, the final DCI velocity model is incorporated into a layer-stripping FWI approach in which an initial model is built successively from the top down. Before applying acoustic FWI, the waveform preserving common-shot data pre-processing is applied (Plessix et al. 2010), including f-k domain ground roll attenuation, filtering of high-frequency scattering noise, and compensation for the geophone response. In FWI, we first invert the lower frequencies to avoid local minima and progressively include higher frequencies in the inversion to increase the velocity resolution.

Results

The hybrid methodology is demonstrated on the densely sampled single sensor land data set from Inner Mongolia acquired by BGP in 2009. In Figures 1 and 2, we compare depth migrated sections by using different velocity models. Since DCI resolved the shallow velocity anomalies, migration using the DCI-based velocity updating shows a clear indication of effectiveness of our layer-stripping approach. When one compares migration using the global TT and DCI-FWI velocity models in Figure 1, the improved stack power of the DCI-FWI velocity is noticeable. Similar improvements are also observed in flatness of migrated gathers (Figure 2). Moreover, the updated DCI-FWI model in Figure 1b shows significant improvement in depth mistie near the well location.

(a)



(b)

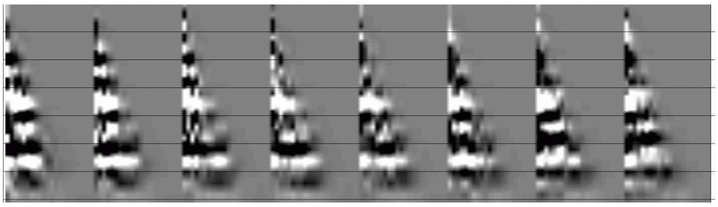


Figure 2 *Selected image gathers: (a) DCI-TT and (b) DCI-FWI layer stripping.*

Conclusions

We have developed an integrated model building methodology that is well suited for accurate velocity model building in onshore areas with a complex shallow structure. We have shown how the DCI near-surface model can be incorporated into the layer-stripping FWI procedure. Using the low-frequency and long-offset experimental data set from Inner Mongolia, we have demonstrated the efficacy of this methodology in determining both the macro-velocity model and near-surface velocities. Application of our hybrid approach has enabled us to incorporate short wavelength anomalies in the problem areas while preserving lateral velocity consistency in well-resolved areas.

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References

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Plessix, R-E., Baeten, G., de Maag, J. W., Klaassen, M., Zhang, R. and Tao, Z. [2010] Application of acoustic full waveform inversion to a low-frequency large-offset land data set. *SEG Expanded Abstracts*, **29**, 930-934.