

FWI velocity models for quantitative interpretation of a deep water GOM dataset

Cobo Yannick, Calderon-Macias Carlos, Chi Shihong, ION

Summary

Full waveform inversion (FWI) has become the method of choice for deriving shallow velocity models that potentially improve interpretation of images in complex geologically settings. Recently, a combination of diving waves and reflections is being used resulting in an increase of depth range for updating the model. In this work, we evaluate the potential for utilizing velocities from FWI as a background model for quantitative interpretation. Our results show that using a velocity model as a low frequency model (LFM) with a higher vertical and lateral resolution obtained from the FWI process results in a higher quality post-stack inversion compared to the traditional approach that uses sparse well velocities extrapolated within a structural framework as a LFM.

Authors

Introduction

Full waveform inversion (FWI) is becoming an essential step in the model building flow for imaging relatively complex geology (e.g., Virieux and Operto, 2009). FWI produces a more exact shallow velocity model than it is typically possible from more traditional approaches such as estimation of V_{rms} velocities and the use of reflection tomography. The main purpose of the FWI inverted velocity has been to produce a final migrated image for interpretation and quantitative interpretation. In some recent deep water applications (e.g., Peng et al., 2018; Vigh et al., 2016; Routh et al., 2017), both diving waves and reflections are being utilized for improving the model with FWI methods. The resulting velocities from these approaches have the potential of becoming a more interesting product for other studies such as for impedance inversion, pore pressure prediction and 4D characterization studies.

In this work, we analyze the feasibility of applying post stack inversion for a sand characterization using velocities obtained from a conventional FWI followed by reconstructed wavefield inversion (RWI) for an offshore field in the Mexican side of the GOM. The area under investigation is characterized by folding and faulting, an anticline structure flanked by sand gas bearing channels. The inputs to the post stack inversion are the migration stack alongside the final FWI+RWI velocity model, which is directly used to replace the traditional background model from well data. This result is compared with a post stack inversion with a background velocity obtained from extrapolating the well velocity following the structure of the migration stack seismic volume.

Methodology

For model building, a smooth velocity model was obtained with reflection tomography. This smooth velocity model was then used as starting model to an iterative diving wave FWI algorithm. Diving wave FWI produced a higher resolution shallow velocity model compared to the initial tomography result. These inverted velocities served as the starting model for incorporating reflections with the reconstructive wavefield inversion (RWI) method (Chao et al., 2017), which updated the model starting at the deepest part of the model updated by the previous step. An advantage of the reconstructive wavefield method is that it does not rely on any additional a priori information such as the knowledge of density or reflectivity to incorporate the reflections into the inversion. The final velocities were found to be in good agreement with velocities measured at two wells. The frequency band used by these two methods ranges between 4 to 10Hz (Cobo and Calderon-Macias (2018)). The final FWI+RWI velocity model for an inline section coinciding with one of the available wells is shown in Figure 1a. These final velocities were then inverted with a post stack inversion algorithm commonly used in quantitative interpretation, with densities computed from empirical relations. Results of this inversion are shown in Figure 1c. The result displayed on Figure 1b was obtained with the same algorithm but using as reference velocity the well velocity extrapolated following horizons interpreted from the migration stack image.

Interpretation of results

The study area is centred on a gas/wet gas discovery located around 125 km off the coast of Mexico's Veracruz state. The water depth is about 2000 m. The area is of interest due to the large gas accumulations in structural plays causing rapid velocity variations. Gas accumulation can be interpreted from the inverted velocity model shown in figure 1c, alongside the delineation of the potential reservoir extension.

Assuming that the FWI+RWI methodology produces a more accurate velocity trend with increasing depth as well as a higher resolution model which is confirmed from comparing the inverted velocity with the well velocity at the target depth, the FWI+RWI inverted velocity can be used to constrain the low frequencies needed for a more accurate post-stack inversion that results in improved predictions of rock properties. The post stack inversion result of Figure 1c shows that the top of the reservoir is conforming to the structure from the seismic migration stack and the base of the reservoir is fairly flat, which might indicate a gas water contact, and it also shows lateral variations indicating presence of gas-bearing channels. The post stack inversion making use of the extrapolated well velocity produces what is most likely an incorrect velocity away from the well from simply extending the reservoir and the velocity anomalies away from the well location. Furthermore, the shallow velocities from the well are too fast as this was observed from overcorrected common image gathers after depth migration indicating that the overburden velocities at the well were in error. The seismic well tie process also indicated that the well velocity were too fast up shallow.

Conclusions

Our staged FWI+RWI workflow produces a detailed high resolution velocity model by taking advantage of diving and reflection waves. In this study, rather than carrying out a high frequency waveform inversion, a post-stack inversion was used to provide more details after capturing the low frequency trend in the model produced by the FWI+RFWI method.

Using the FWI+RWI velocity model (Figure 1a) as the background model not only incorporates the geology variation contained in the seismic data, but also bypasses some of the conventional geological interpretation. This approach potentially overcomes some of the pitfalls one might obtain from lack of enough well velocity constrains for a background velocity model built as in a standard inversion process. Inversion and interpretation of these results show that our FWI+RWI velocity model has advantages over an industry standard inversion for reservoir characterization.

Acknowledgements

We thank ION management for permission for publishing these results. We thank our colleagues Chao Wang, David Yingst, Ian Jones and John Brittan for their contribution to this work. (Data processed by ION in partnership with Schlumberger, who holds data licensing rights).

References

- Chao, W., Yingst, D., Farmer, P., Jones, I., Martin, G., and Leveille, J., 2017, Reconstructed waveform inversion with the extended source, SEG International Exposition and 87th Annual Meeting, 1450-1452.
- Cobo, Y., and Calderon-Macias, C. 2018. Extending model depth and resolution using diving waves and reflections with full-waveform inversion for a GOM dataset, submitted to 80th Conference and Exhibition, EAGE.
- Peng, C., Wang, M., Chazalnoel, N., and Gomes, A., 2018, Subsalt improvement possibilities through a combination of FWI and reflection FWI, TLE, 52-57.
- Routh, P., Neelamani, R., Lu, R., Lazaratos, S., Braaksma, H., Hughes, S., Saltzer, R., Stewart, J., Naidu, K., Averill, H., Gottumukkula, V., Homonko, P., Reilly, J., and Leslie, D. 2017. Impact of high-resolution FWI in the Western Black Sea: revealing overburden and reservoir complexity, TLE, 60-66.
- Vigh, D., Jiao, K., Cheng, X., Sun, D., and Lewis, W. 2016. Earth-model building from shallow to deep with full-waveform inversion, TLE, 1025-1030.
- Virieux, J., and S. Operto, 2009, An overview of full-waveform inversion in exploration geophysics: Geophysics, **74**, 127–152.

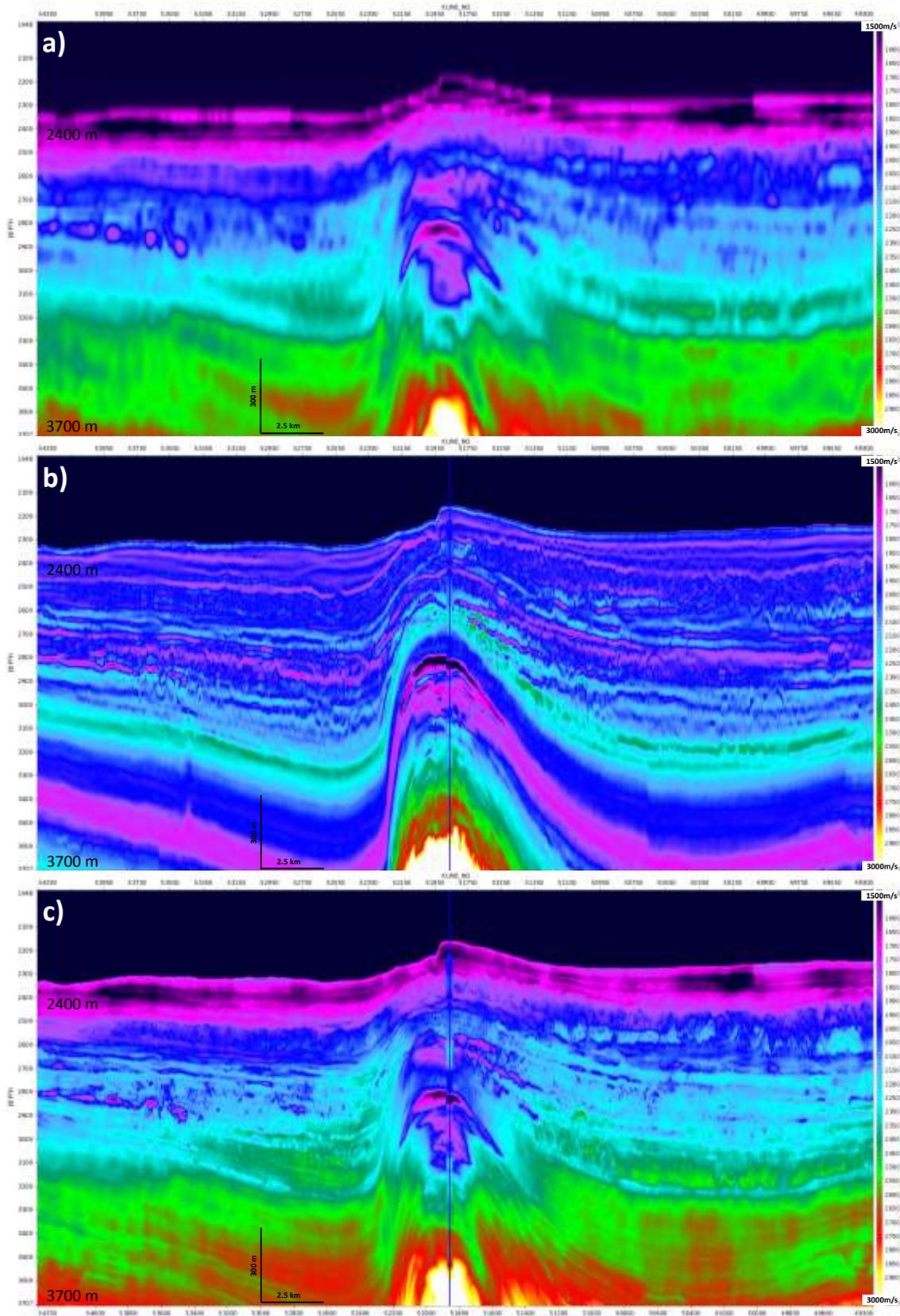


Figure 1: Inline section a) FWI+RWI Pwave velocities, b) Inverted Pwave velocities using well velocities for background model, c) Inverted Pwave velocities using FWI+RWI Pwave velocities for background model. (Data processed by ION in partnership with Schlumberger, who holds data licensing rights).