# Full Waveform Inversion for Detailed Velocity Analysis

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## EXTENDED ABSTRACT

### Introduction

**An accurate earth model is key to any successful depth imaging effort and to help increase drilling success and reduce drilling risk. Full-waveform inversion (FWI) is an advanced velocity model building process that uses the full two-way wave equation. Existing methods use a ray-tracing approach to distribute velocity errors within the model. In this presentation, we will show examples of seismic data processed with the latest technology, including earth model building with full-waveform inversion.**

**The industry has moved to using two-way wave-equation migrations commonly known as reverse-time migration (RTM), especially in areas of complex geology. The velocity model, including velocity anisotropy, is key to any depth migration effort. 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. Full-waveform inversion (FWI) uses computer-intensive forward modeling of the seismic measurement combined with residual wavefield back propagation to iterate to a final velocity model (Fig. 1), which can provide greater detail than tomographic ray-tracing approaches.**

### Method and Theory

**Although first introduced in the 80s (Tarantola, 1984), only recently 3D FWI has been applied on real datasets in marine (Plessix, 2009; Sirgue et al., 2009; Vigh et al., 2009, 2010; Kapoor et al., 2012) and land (Plessix et al., 2010) environments. These works demonstrate that FWI can be used for velocity updates if the acquired data have enough low frequencies and long offsets. Particularly, the shallow part of the model could be significantly enhanced by use of FWI and can result in a more improved depth image over all including deeper objectives.**

**We have implemented a 3D time-domain tilted transverse isotopic (TTI) anisotropic acoustic version of full-waveform inversion using the two-way wave equation with an elastic correction factor to model seismic data using an initial best guess of the earth**

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**model. This can be a depth model from a previous processing effort and/or calibrated to well logs and any other seismic or non-seismic measurements.**

**The modeled seismic data are compared to the real prestack seismic measurement, and errors are backwards propagated into the velocity model, iterating to a final detailed model. Care must be taken in data preparation to preserve the refracted, diving wave, and prism wave energy recorded on the far offsets of these datasets to help FWI build a detailed velocity model and then allow RTM to image them properly.**

## Results

**FWI has been performed to build velocity models on several real 3D projects in the Gulf of Mexico, North Sea, offshore Australia, West Africa, Brazil, Malaysia, Mediterranean, and a few onshore projects in China and the Middle East. As with the deployment of any new data processing solution, FWI was initially applied and tested on synthetics. Encouraging results were obtained by performing FWI on the BP Valhall model. Starting with a smoothed version of the Valhall velocity model, FWI was able to delineate the gas pockets of the true model (Fig. 2). Figure 3 shows results from a FWI project with the starting model from tomography on the left and the FWI model on the right, and reveals the ability of FWI to add detail and delineate both high velocity and low velocity channels.**

## Summary

**Prestack full waveform inversion is a challenging and compute-intensive task, especially for 3D projects on real data. 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 complex structures.**

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