Full Waveform Inversion

FULL WAVEFORM INVERSION FOR MORE ACCURATE VELOCITY MODELS

The promise of full waveform inversion (FWI) is the ability to derive high-fidelity Earth models that can be utilized for more accurate prospect evaluation and reservoir exploitation. FWI is a method which optimizes subsurface model estimates by minimizing the difference between field data and simulated data.

UNIQUE GXT WORKFLOWS

We have developed a proprietary version of FWI in order to leverage wave-based methodologies to generate fine scale Earth models and improve our clients' ability to resolve complex geologies. Our FWI solution provides algorithms that characterize the acquired wave-field using models that can be parameterized to include velocity, anisotropy, density and attenuation (Q). We can also invert for the source signature on a survey or shot-by-shot basis. The algorithm can utilize randomized shot sampling to provide a highly efficient model building sequence without introducing significant geometry related artefacts.

In the simplest workflow, a 3-D velocity model is updated to match the field data. At a higher level of complexity, for media with strong anisotropy, forward modelling is computed based on acoustic wave equations in vertical transversely isotropic (VTI) media. In VTI, we use a system of two coupled second-order partial differential equations in terms of P-wave vertical velocity, and the Thomsen anisotropy parameters, epsilon and delta. For physical materials that strongly attenuate seismic energy, such as gas clouds, visco-acoustic relaxation functions are applied with a superposition of standard linear solids to simulate the attenuation effects of real earth materials on wave propagation. A recent addition to the portfolio, has been the ability to simultaneously update (isotropic) velocity and density models.

In all workflows, the information in well logs is included when available. These well log data act as constraints by imposing a true velocity function. This allows for more useful and reliable recovery of Earth properties, allowing, for example, a better delineation of velocity at or close to well locations. Well constraints also stabilize the results of FWI and, more importantly, help accelerate the algorithm to a viable convergence solution.

BENEFITS

GXT offers multiple fit-for-purpose proprietary solutions for FWI depending on the physical properties of the media. GXT's FWI workflows are designed to support:

- → Allows us to start building a velocity model early in the processing sequence
- → Provides a high-resolution sub-surface model of the Earth
- → Produces a more accurate model for improved imaging

SYNERGISTIC TECHNOLOGIES TO RESOLVE COMPLEX GEOLOGIES

FWI is a promising solution to help refine small-scale velocity variations and improve the velocity model. However, in combination with other GXT technologies, it may become an even more powerful tool to help resolve complex geologies:

- → WiBand™ broadband processing workflows - GXT is able to capture extended low frequencies to improve data quality for seismic inversions, thus yielding a more accurate velocity model and ultimately, Earth model.
- → Tomography - GXT is able to generate more fine scale velocity models such that convergence to an accurate velocity model and ultimately Earth model can occur more rapidly.

EXAMPLE

The following are results for multi-parameter VTI FWI with well constraints using a data set from the Gulf of Mexico.

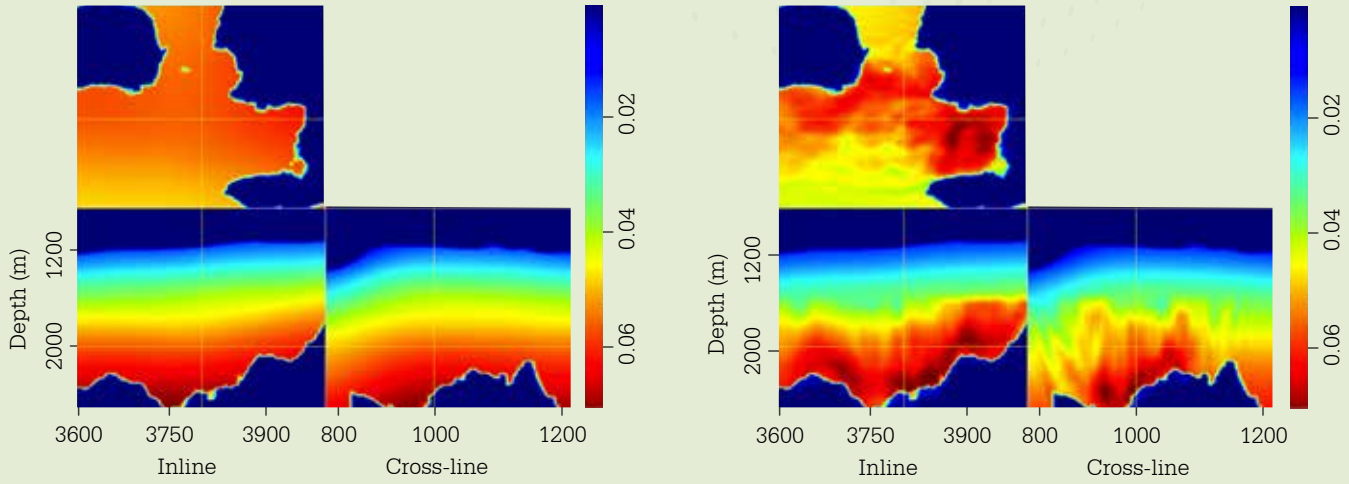

Figure 1. Initial epsilon model before anisotropic FWI (left). Updated epsilon model after anisotropic FWI. Upper left = depth slice, lower left = inline slice, lower right = crossline slice. Note the high resolution velocity model resulting from FWI showing significant detail in the horizontal and lateral variations of the velocity model.

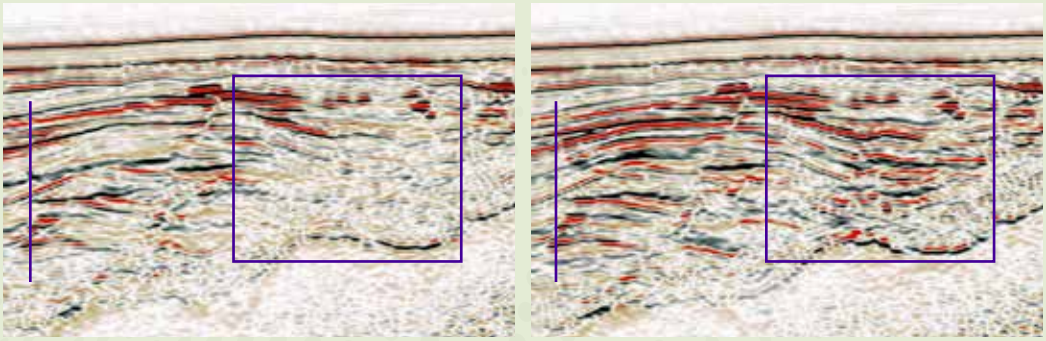

Figure 2. Stack image using the initial velocity model and the initial epsilon model before anisotropic FWI. (b) Stack image using the updated velocity model and the updated epsilon model after anisotropic FWI. Note that the image after FWI shows better focus and event consistency above the salt, especially in the area outlined in blue. Note that the fault in the structure is also delineated more clearly. The blue vertical lines indicate the well locations. Note that the velocity close to the well is more reliable due to the use of well constraints.