Complex Imaging

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Abstract

The past couple of years have seen a tremendous increase in the acquisition of wide azimuth (WAZ) surveys that provide improved subsalt imaging. We have seen a step change improvement in image quality compared to conventional narrow azimuth (NAZ) surveys, even when using minimal processing and existing, conventional-survey velocity models. The improvement in image quality is taken to the next level when the wide azimuth data are combined with other seismic and non-seismic measurements to build ever more highly constrained models, and then more accurately migrated with two-way wave-equation methods.

In this presentation we will show examples of WAZ data processed with the latest technology such as true azimuth 3D multiple attenuation using the general surface multiple prediction (GSMP), wave equation based multiple attenuation (WEM MOD) and reverse time migration (RTM). We will also discuss development of our next generation of velocity model building tools and techniques such as full waveform inversion (FWI).

Introduction

In our current methodology, we apply general surface-related multiple prediction to our rich or wide-azimuth data sets (Dragoset et al., 2008). VTI or TTI sediment models are built as required, using both diving-wave and reflection-seismic grid tomography, always honoring the acquisition azimuths. We begin with regional trends for ε and δ, which are used with well information to derive smoothly varying scalars for correcting our starting velocities to vertical velocities. (see figure 1). Repeated iterations of tomography are performed, updating vertical Vp only or simultaneously updating various combinations of vertical Vp, ε and δ with well constraints. Well mis-ties and VSP traveltime measurements are used as constraints; scans may be performed to fine-tune ε and δ.

After sediment model properties are determined above salt, we interpret top salt, perform a salt flood, interpret base salt, and finally perform subsalt sediment tomography from gathers or scans. Anisotropic Kirchhoff, Beam, WEM, or RTM migration algorithms are used as appropriate (see figure 2).

Method

In geologically complex areas these existing methods for building velocity models still have shortcomings in providing accurate velocity models for imaging. In the future geomechanical and basin modeling studies may be incorporated as constraints (see figure 3, Bachrach et al., 2008).
Where data cannot constrain the model, interactive migration may be useful. Also, multi-azimuth grid tomography may be used to quantify uncertainties in anisotropic seismic models, which may then be mapped into error bars on image structures (Osypov et al., 2008).

One of the most advanced tools for velocity model building is full waveform inversion (see figure 4). Prestack full waveform inversion is a highly challenging task due to the non-linearity and non-uniqueness of the solution. Combined with compute intensive forward modeling and residual wavefield back propagation, the method is resource and time consuming, especially for 3D projects. The availability of increased compute power and faster two way wavefield propagation algorithms along with improved illumination and signal to noise ratio provided by wide azimuth data acquired with enhanced low frequency bandwidth facilitates the building of accurate velocity models with full waveform inversion.

Conclusions

The combination of wide-azimuth data and two-way wave-equation migration algorithms such as RTM can provide a step change improvement in salt flank and subsalt imaging. The improvement depends on continuing progress in building more accurate velocity models. The addition of information from well logs, VSP's, gravity and magnetotelluric surveys, and geomechanical modeling to our seismic data will further constrain our data-driven model-building methodologies, improving the model accuracy required for subsalt imaging.
We are currently performing full waveform inversion to further improve the accuracy and efficiency of building velocity models; we plan to show results in our talk at the congress.

References

Bachrach, R., M. Sengupta and A. Salam, 2008, Using geomechanical modeling and wide-azimuth data to quantify stress effects and anisotropy near salt bodies in the Gulf of Mexico, 2008: 78th Annual International Meeting, SEG, Expanded Abstracts.

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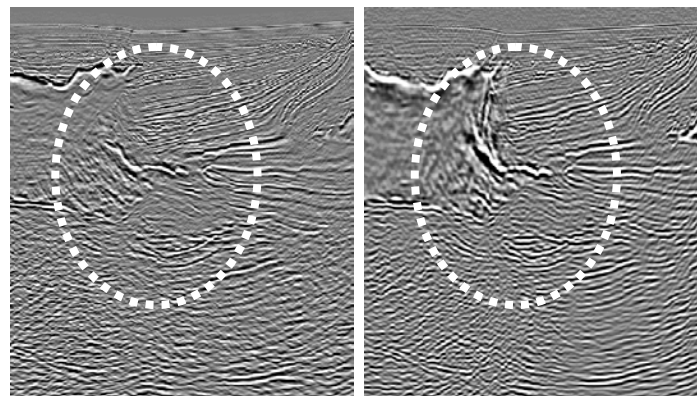
Figure 2: Salt flank and subsalt imaging improvements obtained by RTM

Stress and Velocity relations
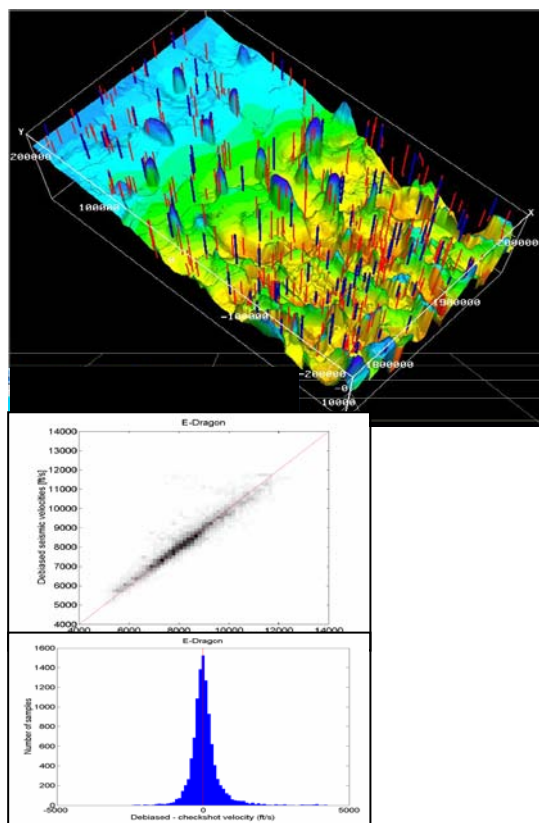
Validating Tomographic velocities

Figure 1: Left plot shows location of wells and on the right calibration of seismic velocities derived from tomography against checkshot velocities.
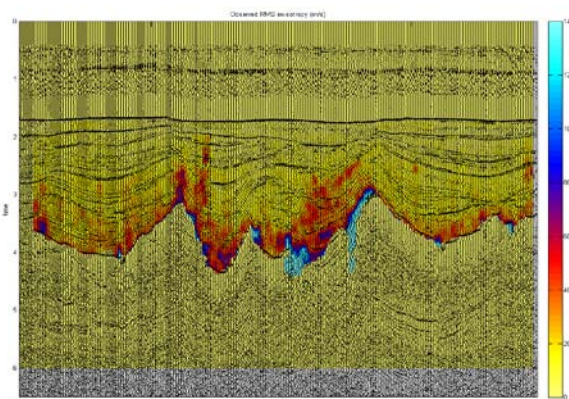

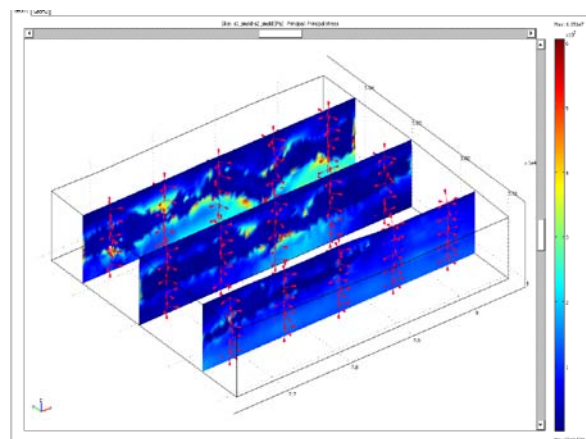**Figure 3a:** Observed RMS velocity anisotropy from WAZ seismic data analysis in the GoM

Figure 3b: Modeled stresses (SH-Sh) from Geomechanical model for GoM
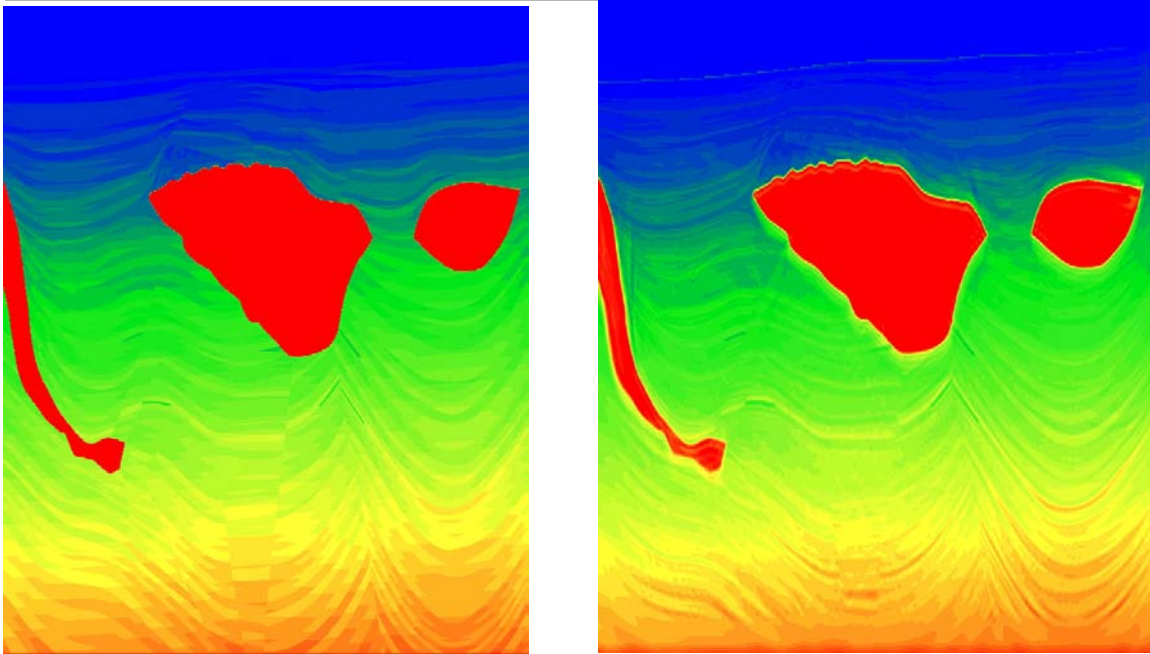
Figure 4: On the left, the Velocity Model and on the right, the FWI Velocity model. This shows the ability of FWI to delineate the Pluto salt model including the subsalt velocity inversions.