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Complex Imaging

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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) and further improvements in acquisition design to provide better illumination using our novel 2x4 Coil acquisition design. This design records all azimuths with 14km long offsets.

In our current processing 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. 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. (See figure 1).

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).

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, Bachrach et al., 2008).

Where data cannot constrain the model, interactive migration may be useful. Also, multiazimuth 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 3). 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.

Proper implementation of the FWI technology is dependent on recording low frequencies, long offsets and illuminating the complex subsalt sediments. Survey evaluation design performed with full finite difference modeling has shown us that we can efficiently acquire full azimuth data with

14km offsets using 2 recording and 4 source vessels (2x4) in a Coil configuration (see figure 4)

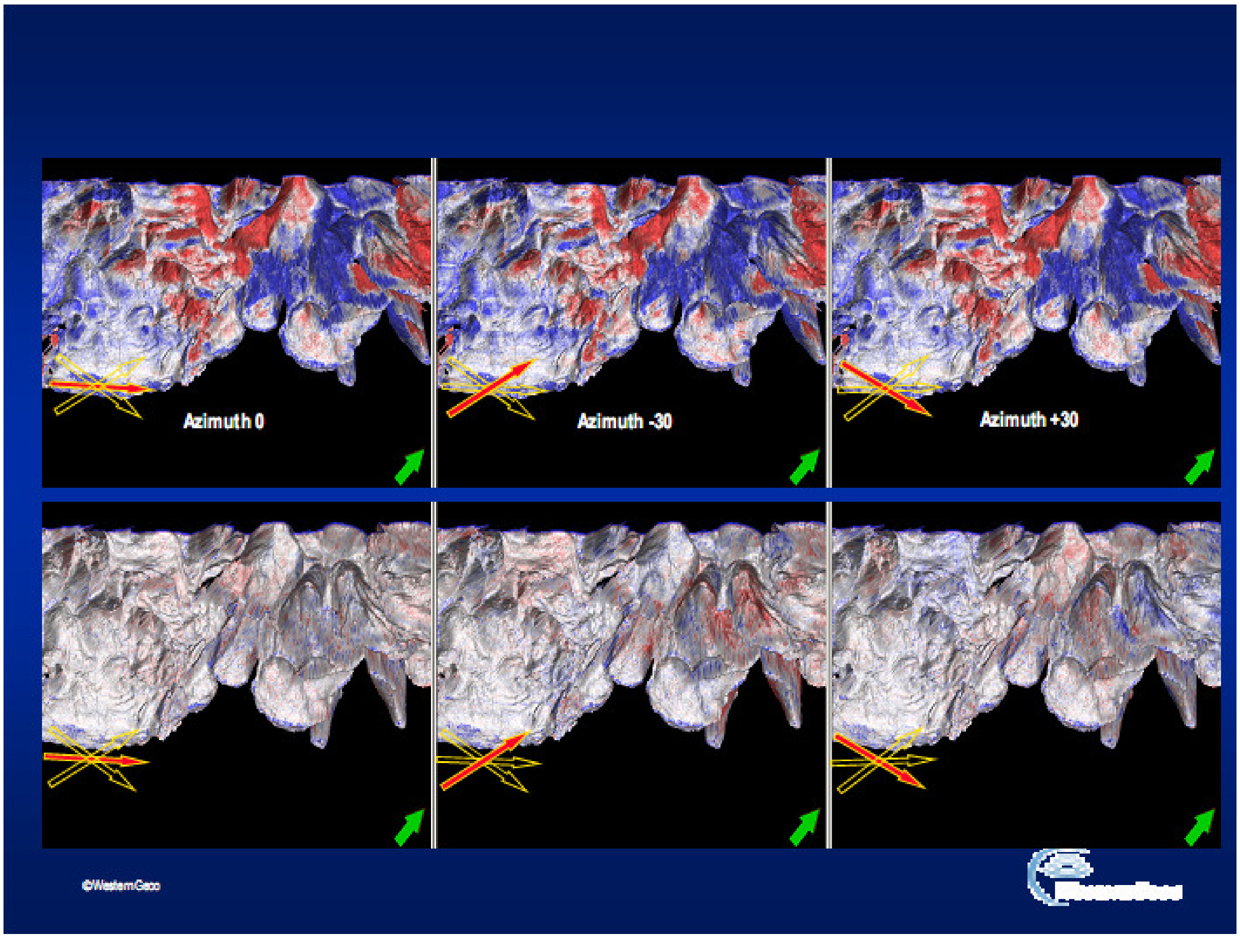

Figure 1: Gamma values representing residual moveout before (top) and after (below) multi azimuth tomography on top salt horizon

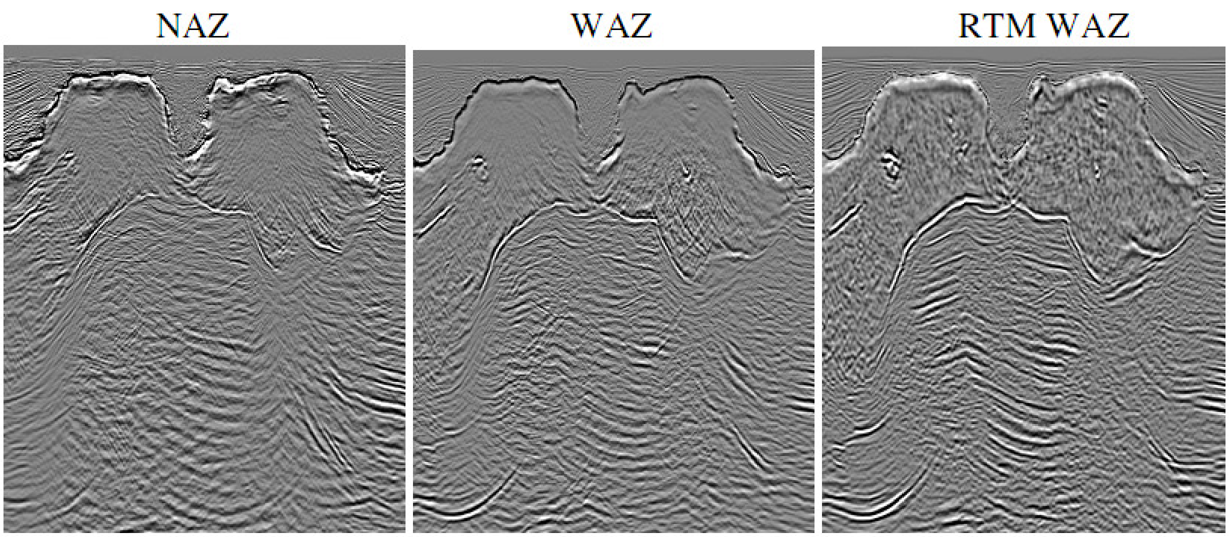

Fig 2: Subsalt imaging improvements obtained by WAZ and RTM

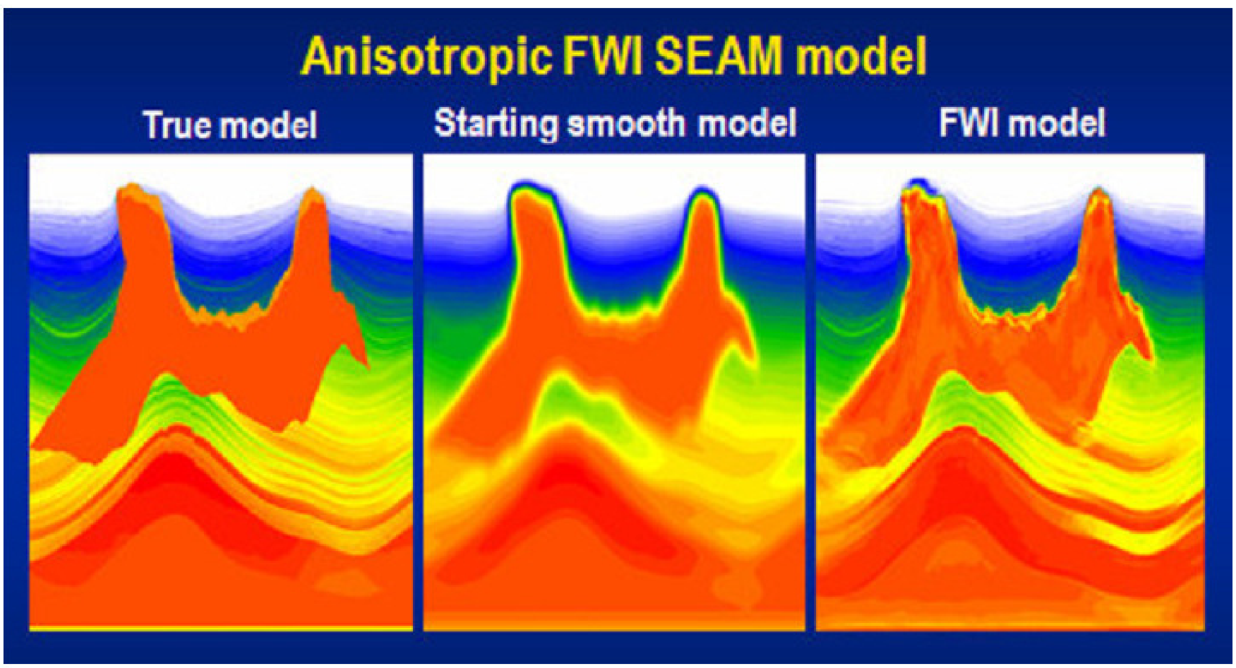

Figure 3: Shows the ability of FWI to delineate the SEAM model including the subsalt velocity inversions

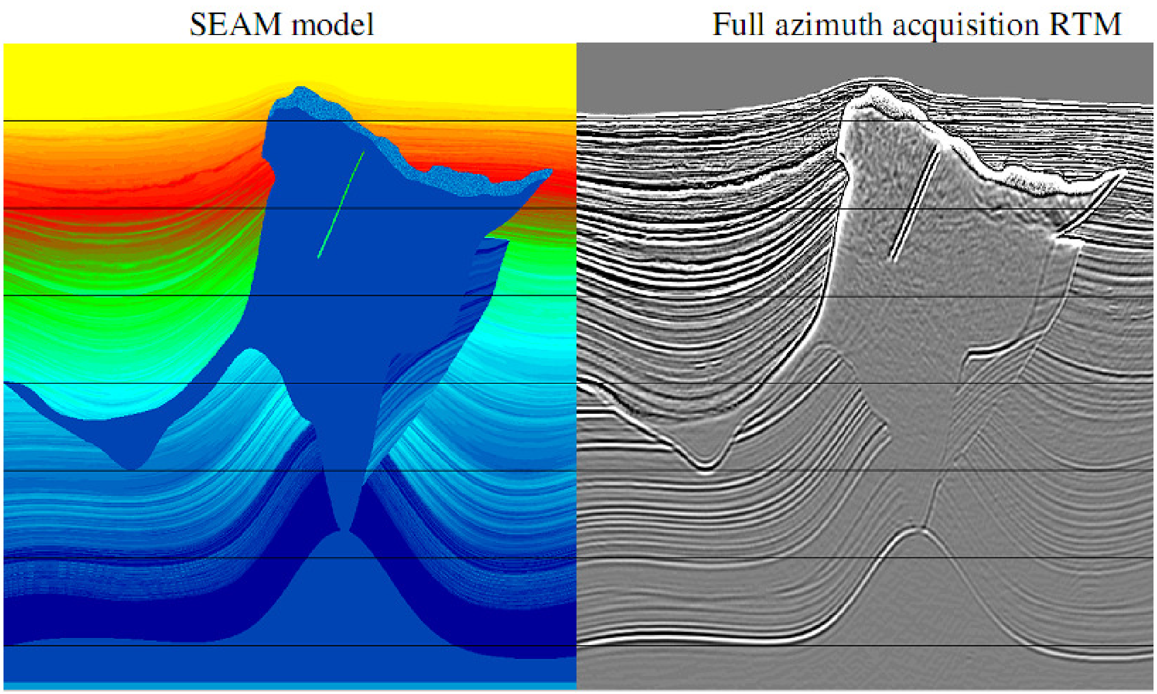

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Figure 4: The next generation full azimuth acquisition design with 14km offsets provides excellent illumination of complex subsalt sediments

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 magnetolluric surveys, and geomechanical modeling to our seismic data will further constrain our datadriven 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 are also planning on acquiring a new survey with the next generation Coil acquisition design using two recording vessels and two additional source vessels.

References

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