Significant Improvements in Subsalt Imaging

New processing algorithms are leading to impressive imaging results.

Contributed by TGS

Keeping up with the latest wide-azimuth processing methods will be a popular topic at the SEG this year. TGS-NOPEC Geophysical Co. (TGS) plans to participate by showcasing results using data from a recent wide-azimuth survey. These data are jointly owned by TGS and WesternGeco. Known as Freedom WAZ, this survey is located in the Gulf of Mexico's Mississippi Canyon, an area well known for its subsalt discoveries and imaging challenges.

TGS used three key techniques in a wide-azimuth work flow to achieve significant improvements in subsalt imaging. The first one, data regularization, prepared the data for multiple attenuation and imaging. The next method, 3-D multiple attenuation, allowed for the removal of multiple energy, particularly complex multiples beneath salt. Finally, the application of a suite of high-end migration algorithms yielded the final image of the subsurface.

Data regularization

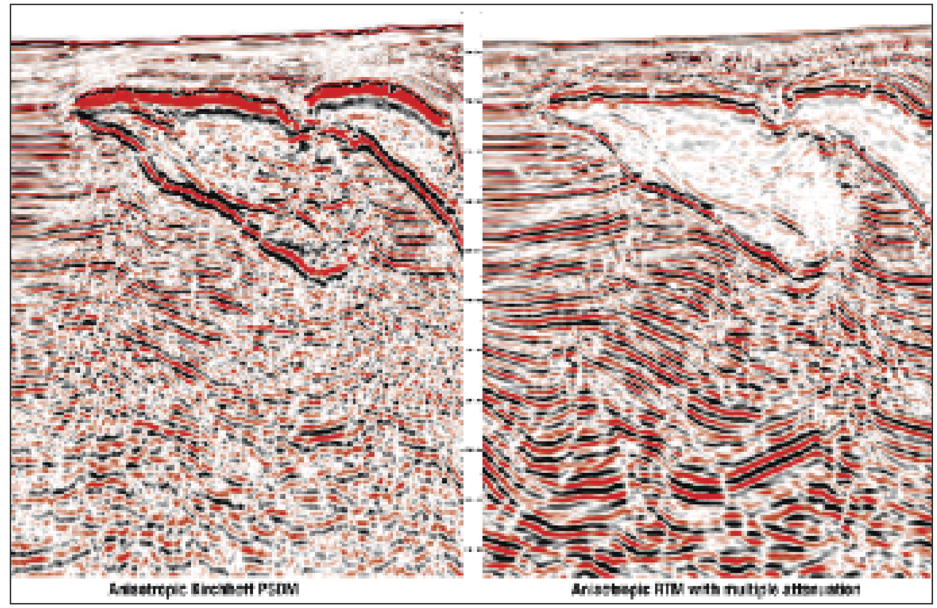
Supershots form the basic processing unit for much of the wide-azimuth processing flow. In a perfect world, the supershot would consist of a regular array of receivers; however, cable feathering, cable and gun dropouts, and infill give rise to holes as well as areas of duplicate coverage.

Regularization is used to improve the receiver sampling in preparation for 3-D surface-related multiple elimination (SRME) or wave-field extrapolation (WFE) multiple attenuation. By reducing the cable spacing, aliased noise in both the WFE and 3-D SRME models is attenuated. Regularization can be used to interpolate data where there is no receiver coverage and regularize data where duplicate receivers or irregular coverage exists due to cable feathering. Used in this way it provides a completely regularized supershot that can be used as input to reverse-time migration (RTM), for example.

Multiple elimination techniques – 3-DSRME and WFE

Despite the early promise that the additional crossline offsets in wide-azimuth data would do away with the need for multiple attenuation, experience has shown that multiple attenuation is still required in practice. Furthermore, in the presence of large crossline offsets, conventional approaches, such as radon and 2-D SRME, are ruled out. Three-D multiple removal schemes must bear most of the weight of multiple attenuation on wide-azimuth data.

There are two main approaches for 3-D multiple prediction: data-driven 3-D SRME and model-based WFE. Data-driven techniques have traditionally been used in both narrow- and wide-azimuth processing to create a 3-D prediction of surface-related multiples. TGS has implemented a true-azimuth, fully data-driven, convolution-based approach to 3-D SRME that utilizes high-fidelity regularization routines to reduce aliasing.



A comparison of Kirchhoff versus RTM for wide-azimuth data shows the uplift that comes with using a high-end migration algorithm in conjunction with data regularization and 3-D multiple elimination techniques. Complex subsalt structures can be identified on the RTM data, while the multiple elimination work flow has also attenuated subsalt multiples. Both algorithms incorporate VTI anisotropy. ***(Image courtesy of TGS-NOPEC)***

WFE techniques provide an alternative to data-driven approaches. Since they work shot-by-shot, they are particularly well suited for wide-azimuth data, in which the receiver density is higher and the shot density lower than for conventional narrow-azimuth acquisition.

The WFE technique used here is a shot-based process that extrapolates a surface shot record down to a target depth and back to the surface. In one pass, it generates a 3-D prediction of all surface-related multiples. A high-resolution depth migration is used to generate the reflectivity model. Once the multiples are modeled, an adaptive subtraction process is applied to remove the modeled multiples from the original shot record.

In certain cases, the strengths of the 3-D SRME and WFE techniques complement one another. In these cases, uplift can be achieved by combining the two models. Both models are input into the adaptive subtraction step, and for each adaptation window, the model that has the highest correlation to the multiples in the data is selected.

Leading-edge imaging

While preprocessing, regularization, and multiple attenuation schemes are important, the single biggest uplift in wide-azimuth data comes in the imaging step through the additional illumination provided by increased azimuth coverage.

Since they provide an efficient way to take advantage of wide-azimuth acquisition's relatively sparse shot distribution, shot-based wave-equation techniques, such as wave-equation migration and RTM, are best suited to image wide-azimuth data. Additionally, Kirchhoff and beam migrations are also used during the model-building phase (Figure 1).

TGS will feature its wide-azimuth processing results at exhibit booth and paper presentations throughout the convention. Visit TGS Booth 2226 for more details. ■