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Technique Improves Deep Shelf Images

By August Lau,
Laurie Geiger
and Duryodhan Epili

HOUSTON–Repeat imaging using grid tomography and new well information was used in two subsalt fields in the Gulf of Mexico to resolve complex imaging challenges. The goal of repeat imaging with prestack depth migration using detailed studies of prospects as new information is made available is to generate new locations for both development and exploration targets.

The 3-D seismic data used in this project was part of a 3,200-square mile multiclient survey designed to improve the imaging of the deep section of the Outer Continental Shelf, where oil and gas companies are drilling to depths greater than 15,000 feet. Survey specifications included long offsets and long record lengths to improve data acquisition in the deeper section and final image quality, employing the latest prestack time and depth migration processing techniques.

The first field (Field H) consists of angular beddings truncating at the base of a thick salt. The second field (Field T) consists of sediments under a salt of unknown thickness, where well control showed only thin salt penetration. The updip potential of the pay sands for both prospects had not been shown clearly in previous depth processing work. A careful model building approach with automated residual move-out estimation and 3-D grid tomography in the suprasalt area enabled the sediment velocity to be properly estimated. This helped the operator to reinterpret the top of salt and base of salt, as well as enhance the subsalt reflections.

Poor subsalt imaging is a major hindrance for efficient exploration in the Gulf of Mexico, where the salt canopy system underlies many blocks in the Central and Western planning areas. In the case of these two fields, the interest was in improving the structural images of deep sediments beneath salt with repeat imaging using velocity model building and prestack depth imaging to take advantage of new well information as it became available.

Deep Targets Beneath Salt

The exploration target in Field H lies below the salt in a zone between 15,000 and 17,000 feet. The updip potential of the sand units that were trapped beneath the salt was not clearly resolved in previous data processing work. The improvement resulted from picking a different top of salt compared with the earlier prestack depth migration interpretations. This was directly related to a better estimation of suprasalt sedimentary velocity using grid tomography.

Field T has two pay zones located below the salt in a zone between 12,000 and 18,000 feet. Previous processing had failed to clearly illuminate the updip potential of the pay sands as they tracked up under the salt. New information based on well control showed that a shale zone overlying the salt had abnormally low velocity, which was not included in the original sediment velocity model.

In order to obtain a better image for the suprasalt and subsalt regions, noise editing, multiple attenuation, several iterations of grid tomography and Kirchhoff prestack depth migration were run to improve the image quality of both prospects.

Five velocity model-building iterations were performed to obtain the velocity model for final prestack depth mi-

FIGURE 1A
Sediment/Salt Velocity Model (Field H)

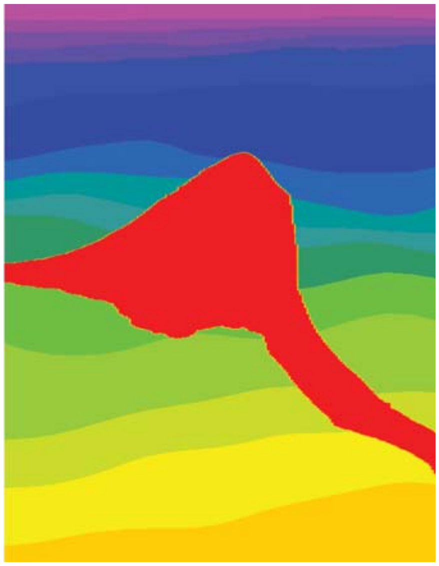


FIGURE 1B
Tomographic Model (Field H)

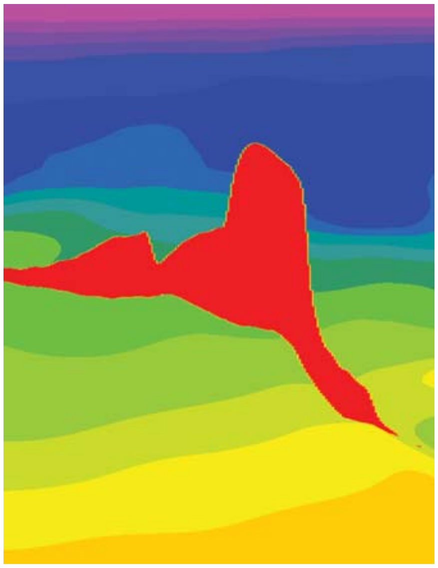


FIGURE 2A

WEM Image (Field H Sediment/Salt Velocity Model)

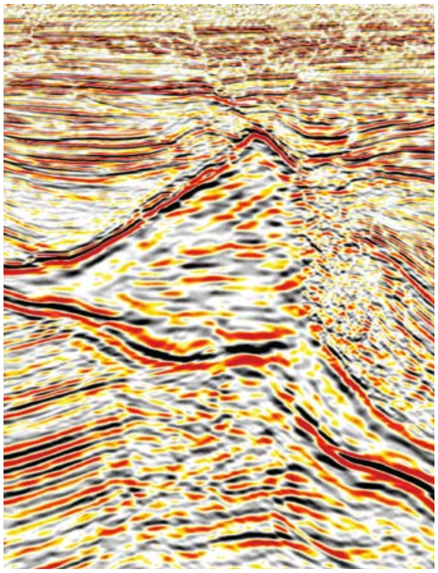
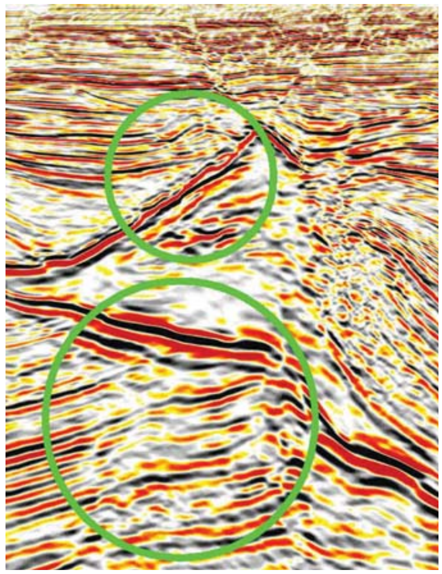


FIGURE 2B

WEM Image (Field H Tomographic Model)



gration. For the initial sediment velocity model, the 1-D updated velocities obtained from the prestack depth-migrated gathers from a previous multiclient project were used. It is important that the velocity volume be free of any salt influences for building the initial sediment velocity model. This was achieved by masking the velocities under and around the salt, and interpolating with the sedimentary velocities.

A Kirchhoff prestack depth migration was then run to generate offset gathers, which were then converted to angle gathers. In both fields, an automatic volumetric depth residual move-out picking was used, followed by 3-D grid-based tomography to derive the sediment velocity updates.

A simplified process flow for the velocity model building included:

- Running the suprasalt tomography;
- Building the salt body velocity model;
- Updating the subsalt velocities; and
- Running the final migration.

Tomography Process

The tomography process measures the residual move-out (RMO) and performs a global inversion to update the 3-D velocity field. Data preparation was a main component in the grid-based, post-migration tomography work. Data preparation included:

- Near offset stack (or stack along RMOs) and skeleton preparation;
- In-line and cross-line dip estimation and filtering;
- Common image gathers preparation and conditioning; and
- RMO computation with skeleton as seed points (no horizon interpretation), filtering and quality control.

The tomography process flow included de-migrating the CIGs' significant reflection events, migrating the zero-offset events, and reconstructing the complete CIGs through the updated model, tomographic inversion, and regularization of the updated velocity field.

FIGURE 3A

Sediment/Salt Velocity Model (Field T)

These tomography steps were then repeated until convergence was obtained. This loop is referred to as internal tomography iterations. A mask horizon, preferably the top of salt, was interpreted, mainly to stabilize the tomographic back projection by discarding all rays striking it. In this way, the velocity update was compensated only as a result of sediment velocity error.

Figures 1A and 1B show the final sediment/salt velocity models, which were derived without and with grid tomography for the Field H area (Figure 1A is the 1-D updated sediment/salt velocity model for field H, while Figure 1B is the tomographically updated sediment/salt velocity model).

Figures 2A and 2B are the corresponding wave equation migration (WEM) images for Field H, with Figure 2A showing the wave equation migrated image using the 1-D updated sediment/salt velocity model (Figure 1A) and Figure 2B showing the wave equation migrated image using the tomographically updated sediment/salt velocity model (Figure 1B). Using tomography for velocity model building has enhanced the sediment above salt. In the latest model, the top of salt has been picked deeper than it was in the previous model. Because of this, sediments are now visible in the green circled areas in Figure 2B that had previously been interpreted as salt.

Better Focused

With an improved top-of-salt interpre-

FIGURE 3B

Tomographic Model (Field T)

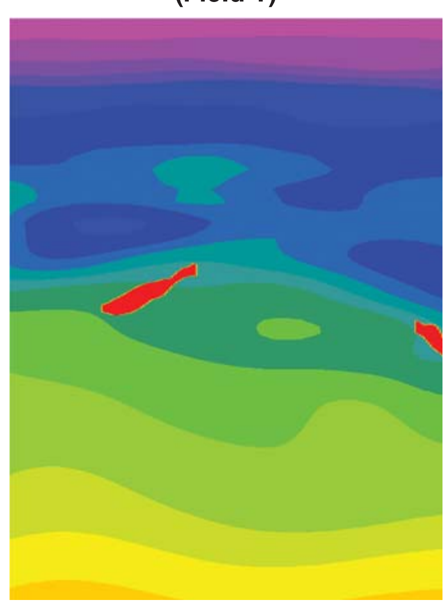


FIGURE 4A

WEM Image (Field T Sediment/Salt Velocity Model)

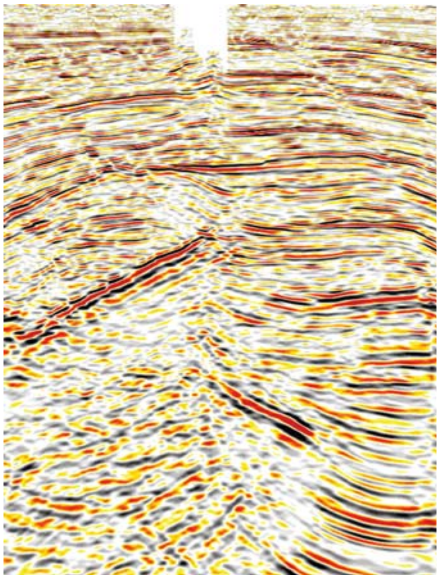
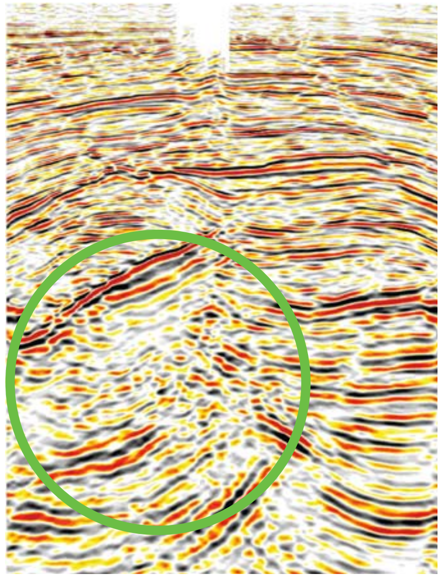


FIGURE 4B

WEM Image (Field T Tomographic Model)



tation, the base of salt and the subsalt events also become better focused. The truncation of the sediments into the base of salt is well imaged. In addition, events that appeared to be possible faults in the subsalt region have now become more coherent and continuous.

Figures 3A (1-D updated sediment/salt velocity model) and 3B (tomographically updated sediment/salt velocity model) show the final sediment/salt velocity models for the Field T area. Figures 4A and 4B are the corresponding wave equation migration images, again derived with and without grid tomography. A velocity inversion above the salt was detected by the wave equation migrated tomographic update shown in Figure 4B. Because of this addition to the model, the imaging of the events above and below the salt was improved, as shown in the circled area.

Following the insertion of salt into the model, and in order to further improve the images below salt, subsalt move out-based tomography and subsalt wave equation migration scans were run. Both methods yielded marked improvements in the image. Fairly clean gathers with a good range of angles allowed for adequate move-out picking, which is required for the tomography.

For the scans, the sediment velocities below salt were scaled to create seven models, and a wave equation migration volume was then run with each. After using this "brute force" approach and picking the best events on the seven stacks, a new model was created and we migrated again. Both the move out-based tomographic update and the WEM scans update below salt pro-

AUGUST LAU *is senior scientist at Apache Corporation in Houston. He received a B.S., an M.S. and a Ph.D. in mathematics from the University of Houston. His professional work has included academic research, aerospace engineering for NASA, and geophysical research. Lau has maintained research interests in topology (nondifferentiable systems) and semigroups (noninvertible operators).*

LAURIE GEIGER *is a senior processing geophysicist in depth imaging at TGS-NOPEC Geophysical Company in Houston. She holds a B.S. from Texas A&M University. She began her career at WesternGeco in 1994, and has served in the depth imaging group at TGS since 2006. Her main professional interests are tomography, depth migration, knowledge sharing, and training in the production environment.*

DURYODHAN EPILI *is research adviser at TGS-NOPEC Geophysical Company in Houston. He received an M.S. in geophysics from the Indian Institute of Technology and a Ph.D. in geophysics from the University of Western Ontario. Before joining TGS in 2005, Epili served with India's Oil & Natural Gas Commission, the University of Texas at Dallas, the University of Tulsa, Green Mountain Geophysics, and CGG. His primary interests are velocity model building using tomography, and advanced imaging algorithms.*

FIGURE 5A

Image Before WEM Scan

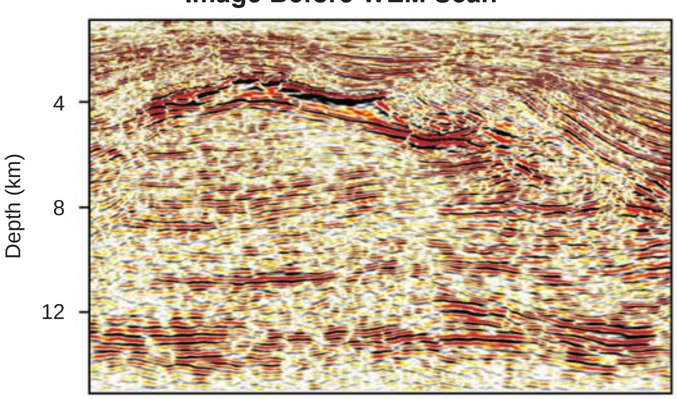
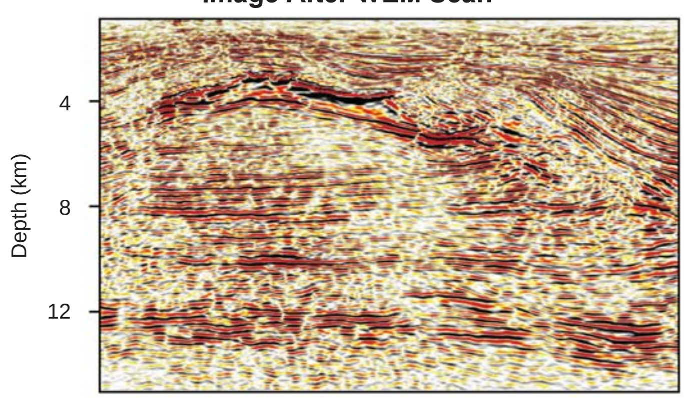


FIGURE 5B

Image After WEM Scan



vided an improved image and showed dips very close to what the client saw from well data. Figures 5A and 5B show image updates both before and after the WEM scans.

The economics for repeat imaging with depth migration based on new well information are favorable. Grid tomography expedites the velocity updates and provides a more accurate velocity model. The cost of repeat imaging is modest compared with drilling a deep well at $15 million-$35 million in dry hole cost. Average drilling costs have gone up significantly over the past few years, even for shallow-water exploration wells.

As illustrated in repeat imaging and grid tomography processing in these depth imaging examples from two fields in the Gulf of Mexico, several iterations of grid tomography and Kirchhoff prestack depth migration improved the accuracy of sediment velocity around and beneath salt bodies. Because the grid tomography is automated, this approach reduces the project cycle time and promises to be faster and more accurate. After the insertion of the salt body into the velocity model, further improvement in the subsalt sediments was achieved from move out-based tomography and subsalt WEM scans, leading to more accurate imaging. ❒

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