Repeat imaging using grid tomography and new well information: application to two sub-salt fields in the Gulf of Mexico

August Lau, Kyle Stewart and Chuan Yin, Apache Corporation; Duryodhan Epili, Laurie Geiger, Elizabeth Beal and Steve Hightower, TGS-NOPEC Geophysical Company*

Summary

The goal of **repeat imaging** (detailed studies of prospects as new information is available) using PSDM is to generate new locations for both development and exploration targets. We present two case studies of **repeat imaging** and grid tomography in the Gulf of Mexico acreage. 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 shows only thin salt penetration. The up dip potential of the pay sands for both prospects had not been shown clearly in the previous depth processing. A careful model building approach with automated residual moveout estimation and 3-D grid tomography in the supra-salt area enabled us to estimate the sediment velocity properly. This helped us to reinterpret the top salt and base salt and enhance the sub-salt reflections. We provide two examples of the velocity model building and depth imaging in this area.

Introduction

Poor sub-salt imaging is a major hindrance for efficient exploration in the Gulf of Mexico. We are interested in improving the sub-salt images in two fields in the Gulf of Mexico (Figure 1) with **repeat imaging** using PSDM when new well information is available. The first field, field H, lies below the salt in a zone between 15000-17000 feet. The up dip potential of the sand units that were trapped under the salt was not clearly resolved with previous processing. The improvement is due to picking a different top salt compared to previous PSDM. This is due to better estimation of supra-salt sedimentary velocity using grid tomography. The second field, field T, lies below the salt in a zone between 12000-18000 feet with two pay zones. The up dip potential of the pay sands, as they track up under the salt, had not been shown clearly in the previous processing. New information based on well control shows that a shale zone overlying the salt has abnormally low velocity, which was not included in the original sediment velocity model.

In order to obtain a better image for the supra-salt and sub-salt region, noise editing, multiple attenuation, and several iterations of grid tomography and Kirchhoff PSDM were run to improve the image quality of both prospects.

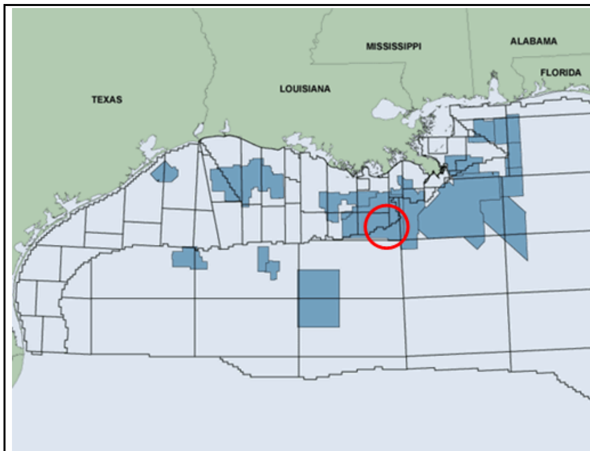

Figure 1: Map showing the location of the survey area.

Velocity Model Building

A total of five velocity model-building iterations were performed to obtain the velocity model for final pre-stack depth migration. For the initial sediment velocity model, we converted the root mean square (RMS) velocities obtained from the pre-stack time migrated (PSTM) gathers to interval velocities. For building the initial sediment velocity model, it is important that the velocity volume be free from any salt influences. This was achieved by masking the velocities under and around the salt and interpolating with the sedimentary velocities. We then ran a Kirchhoff pre-stack depth migration to generate offset gathers and converted offset gathers to angle gathers. Xu et al. (1998) showed that scattering angle, rather than offset, is the domain of choice for the analysis of Common Image Gathers (CIG). We used an automatic volumetric depth residual moveout picking similar to the one used in Dirks et al. (2005) followed by a 3-D grid based tomography (Epili et al., 2007) to derive the sediment velocity updates.

The tomography process measures the residual moveout (RMO) and performs a global inversion to update the 3D velocity field (Stork 1992, Wang et al., 1995). The main components of our grid based post migration tomography are as follows.

- **Data Preparation**
  - Near offset stack (or stack along RMOs) and skeleton preparation
  - Inline and cross line dip estimation and filtering
  - CIG preparation and conditioning
  - RMO computation with skeleton as seed points (no horizon interpretation), filtering, QC

- **Tomography**
  - Demigration of CIGs' significant reflection events
  - Migration of the zero-offset events and reconstruction of complete CIGs through updated model
  - Tomographic Inversion
  - Regularization of updated velocity field

We repeat the tomography steps above until the convergence is obtained. We refer to this loop as internal tomography iterations. A mask horizon, preferably the top of salt, is interpreted, mainly to stabilize the tomographic back projection by discarding all rays striking it. In this way the velocity update is compensated only due to sediment velocity error.

Data Examples

Field H: Figures 2 and 3 show the final sediment/salt velocity models which have been derived without and with grid-tomography for the field H area. Figures 4 and 5 are the corresponding Wave Equation Migration images. Use of tomography for velocity model building has enhanced the sediment above salt (Figure 5). In our latest model (Figure 3), the top of salt has been picked deeper than it was in the previous model. Because of this, sediments are now visible in the area (Figure 5) that was previously interpreted as salt. With the improvement in the top of salt interpretation, the base of salt and the sub-salt events are now better focused. The truncation of the sediments into the base of salt is also well imaged. In addition, events that appeared to be possible faults in the sub-salt region have now become more coherent and continuous.

Field T: Figures 6 and 7 show the final sediment/salt velocity models, which have been derived without and with grid-tomography for the field T area. Figures 8 and 9 are the corresponding Wave Equation Migration images. A velocity inversion above the salt was detected by the tomographic update. Because of this addition to the model the events above and below the salt have improved.

Conclusions

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 quite modest compared to drilling a deep well at 15-35 million dollars dry hole cost. The drilling cost has gone up significantly even for shallow water exploration.

We have outlined the processing history and given depth imaging examples for two fields in the Gulf of Mexico. Several iterations of grid-tomography and Kirchhoff PSDM improved the accuracy of sediment velocity around and beneath the salt bodies. Because our grid tomography is automated, this approach reduces the project cycle time by replacing people's effort and promises to be faster and more accurate.

Acknowledgments

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REPEAT IMAGING

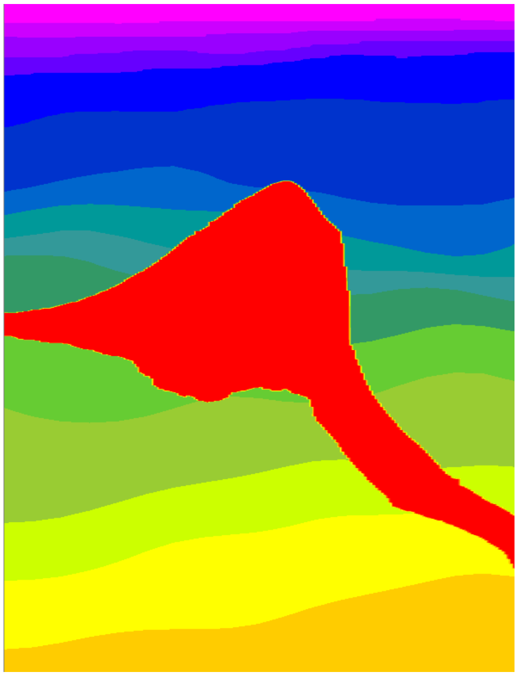

Figure 2. 1-D updated sediment/salt velocity model for field H.

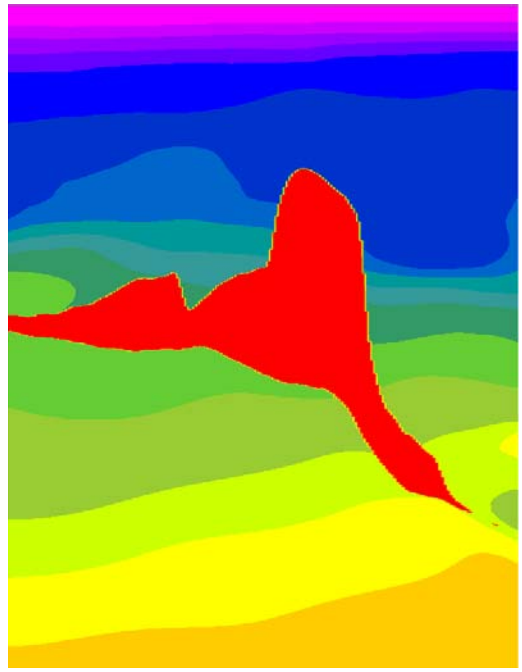

Figure 3. Tomographically updated sediment/salt velocity model for field H.

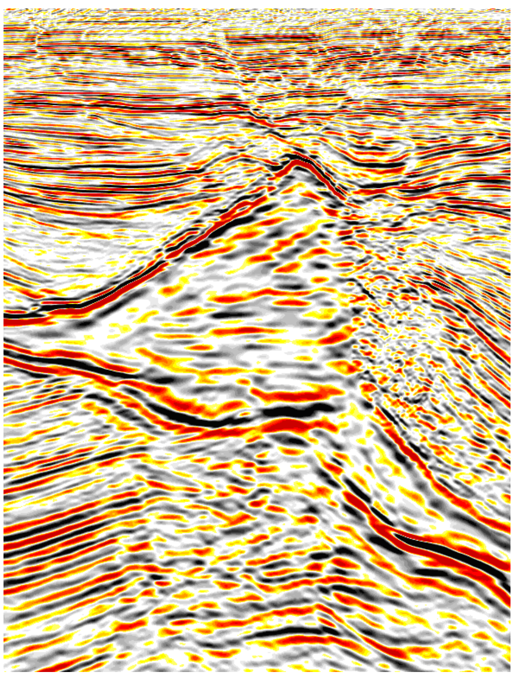

Figure 4. Wave equation migrated image using 1-D updated sediment/salt velocity model for field H.

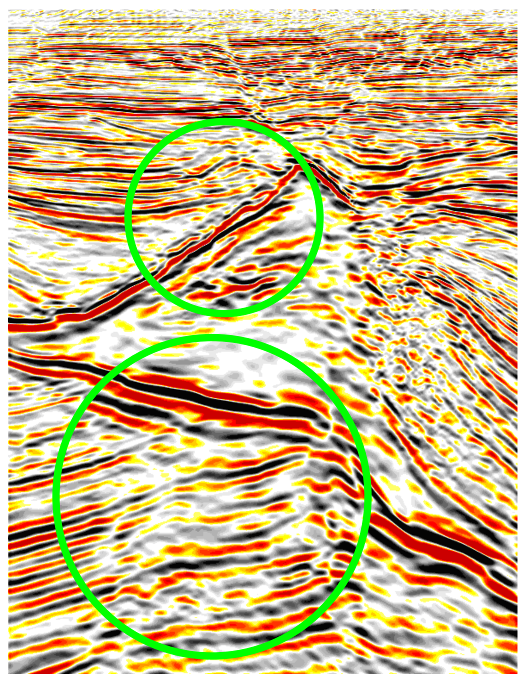

Figure 5. Wave equation migrated image using tomographically updated sediment/salt velocity model for field H.

REPEAT IMAGING

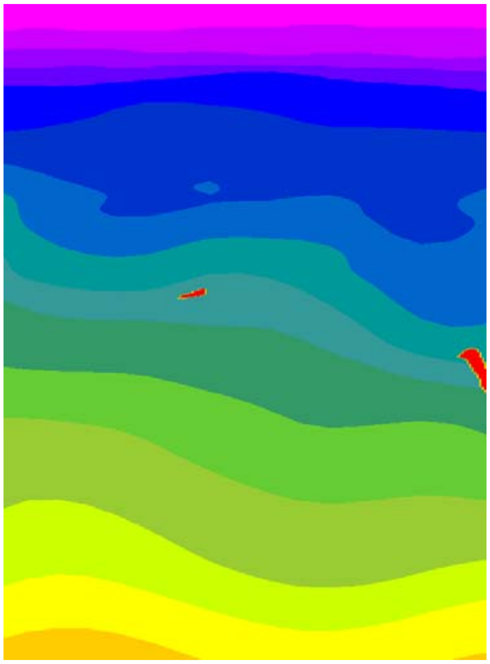

Figure 6. 1-D updated sediment/salt velocity model for field T.

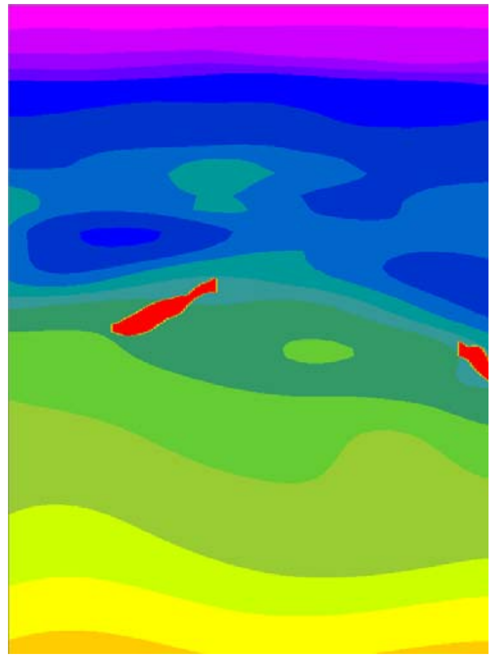

Figure 7. Tomographically updated sediment/salt velocity model for field T.

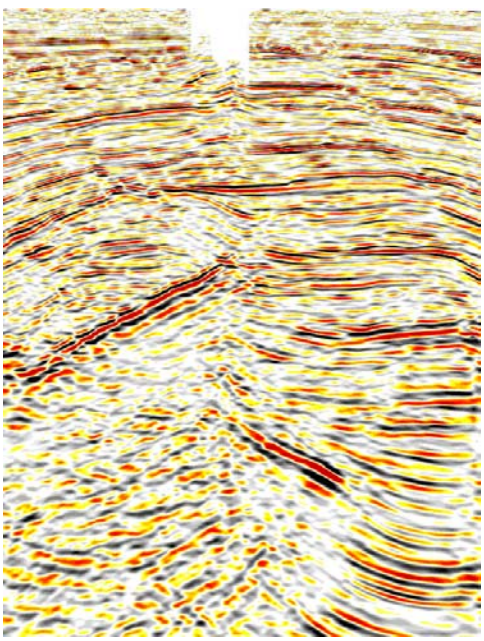

Figure 8. Wave equation migrated image using 1-D updated sediment/salt velocity model for field T.

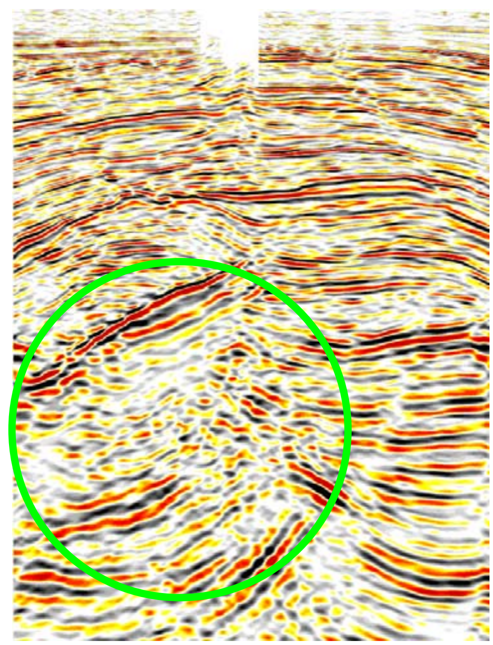

Figure 9. Wave equation migrated image using tomographically updated sediment/salt velocity model for field T.