Interdisciplinary Approach To Maximize Benefits of Prestack Depth Migration

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SUMMARY

The advent of massively parallel computers has made the use of fast, efficient, accurate, 3D prestack depth migration (PSDM) a viable option for the exploration and production of hydrocarbons. However, it is still a significant investment in terms of computer resources, time, money, and personnel to carry out this process. Therefore, we need a methodology to intelligently utilize this new tool and to manage the associated technical risks and expectations. In this paper, we suggest an integrated, staged approach to both predict where it's beneficial, and to anticipate its results within an acceptable confidence level. Thus we avoid the temptation to abuse PSDM as a brute force tool on all imaging problems and instead maximize our potential benefits by knowing how to apply it judiciously.

INTRODUCTION

We summarize some of our learnings from this interdisciplinary, staged application of 3D PSDM to several subsalt prospects in the Gulf of Mexico. We know that prestack depth migration produces accurate subsurface images even in the presence of strong lateral and vertical velocity variations. PSDM with the correct velocity model produces offset-consistent, flat gathers after migration even when the moveout is non-hyperbolic. It accomplishes this by removing the raypath distortion that is caused by the focusing and de-focusing of rays due to the salt body. The migrated output can also be used to help refine the associated velocity model.

The incorporation and analysis of all available velocity data is essential to establish initial velocity models for 3D PSDM. A process that starts with time migration, then moves to poststack depth migration, and finally prestack depth migration allows us to establish the need for higher-end processing and to continually update and refine the velocity model prior to 3D PSDM. Other factors which are also relevant to its success and need to be considered before its use include: illumination problems, primary signal attenuation through the salt, and any unwanted multiple energy. The active involvement of other experts in seismic modeling, gravity and magnetic modeling, together with the seismic processor and interpreter, provides the requisite insight to help resolve issues and explain the presence or absence of key seismic reflections. This progressive use and integration of technology allows us to not only build the velocity model but also to determine the critical image area and some parameters for PSDM.

VELOCITY ESTIMATION AND MODELING

It is well-known that the velocity models for most subsalt prospects in the Gulf of Mexico generally consist of a high-velocity salt body surrounded by the slower, mildly varying background velocity of the sediments. There are several ways to estimate the background velocity field and determine the geometry of the salt body. Prestack time migration works well for areas with mild, lateral velocity variations. Thus, for the sediments above and away from the salt, prestack time migration can be used to estimate the associated interval velocities. Correct imaging velocities for the sediments produce flat, offset-consistent gathers after prestack time migration. Depending on the exact geometry of the top of salt, velocities derived from prestack time migration are exactly the same as velocities derived from prestack depth migration, just determined less expensively. DMO velocities are usually less accurate, but can serve as a good starting point. It is important to compare the seismically derived velocities with those from any wells, checkshots, and VSPs. While the imaging velocities do not necessarily have to match those from other sources, the trends usually do.

To determine the geometry of the salt body, we perform recursive 3D poststack depth migration, i.e. we carry-out several iterations of poststack depth migration until the salt boundaries have been properly identified and incorporated into the velocity model. For most salt environments, a total of three iterations is needed, one to image the top of salt (with a sedimentary velocity model), one to image the base of salt (with a salt half-space or flood model), and an final iteration (with the composite model) to preview the seismic data after depth migration. This assumes that the sedimentary velocities have been extended from the areas outside of the salt to the area underneath the salt. When the salt bodies have highly irregular geometries, or when very precise subsalt velocities are needed, the velocity model from this process may not have the desired accuracy. In these cases, the analogous process needs to be performed with prestack depth migration.

Since 3D PSDM is a long and expensive process, it is worth investing some time to identify areas for potential illumination problems. Using the same acquisition patterns as the seismic data and the final velocity model from poststack depth migration, ray-trace modeling can uncover problems which cannot be addressed by PSDM. If the modeling shows gaps in the illumination of the key reflectors in the areas of exploration interest, PSDM will not have the necessary data to properly image those reflectors. Thus, the entire strategy for the project may need to be re-examined. Occasionally, there are questions about the position of the top or base of salt due to lower signal strength. Gravity and magnetic modeling can, in a broad sense, assist in the definition and interpretation of regional salt geometries.

Just as we need to clarify any illumination issues, we need to verify that there is sufficient primary signal in the area of interest, and that it is not hopelessly corrupted by multiple energy. Since PSDM is needed only to properly position the salt and subsalt reflections, we rely on the cheaper, conventional processing methods to answer these questions.

3D PRESTACK DEPTH MIGRATION

An assessment of all these issues, including the modeling results, together with the initial interpretation from the time and poststack depth migration, provides the necessary information to decide if PSDM is warranted and what areas should be prestack depth migrated. This assessment phase sets the technical expectations for the PSDM results and determines how the prestack depth migration is to be carried out.

Inspection of the travel-times should be done to verify that there are no problems in the specification of the velocity model or the computation of the travel-times. First-arrival travel-time calculators can produce arrival times that correspond to undesirable refractions, instead of reflections, and cause problems in the imaging process.

Some parameter analysis for the production 3D PSDM can be made with the initial 3D time migrations, 2D PSDM, or smaller, target-oriented 3D PSDM runs to determine anti-alias filtering parameters, aperture, amplitude corrections, and multiple attenuation. Since the computations for PSDM can be ordered by area of highest interest or specific offsets, the continual monitoring of the accumulated output can be used to QC the migration or alter the strategy of the migration.

Limiting the offsets or aperture, in addition to reducing the output image locations, can be quite useful if PSDM is required to iteratively develop the velocity model for the salt base or subsalt reflectors. Our experience indicates that good results can be achieved with 3D PSDM when the velocity model is within a few percent of the actual imaging velocities.

CONCLUSIONS

Even with the advances in massively parallel computing, 3D PSDM projects are still relatively expensive and long in duration. For these reasons, we established a process and methodology using an interdisciplinary, staged approach to 3D PSDM to maximize its benefits while minimizing the technical risks and costs. While this process was developed for Gulf of Mexico subsalt prospects, the notion of tightly integrating the technical work from several disciplines and conducting technical assessments at key times in the process is certainly valid for other areas. It can be modified and used for imaging complex structures in other parts of the world.