A case study for salt model building using CFP full azimuth data

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Summary

We present a case study of the salt model building for a Gulf of Mexico area with a full azimuth (FAZ) dataset that was created by merging two orthogonal 3D wide azimuth (WAZ) surveys, the Kepler and Justice orthogonal WAZ surveys (Figure 1), using the Common Focus Point (CFP) technology (Berkhout, 1997 and Cai et al., 2011). Our results show that the merged full azimuth data keep the benefit of illumination from both original surveys. Both salt boundary image and signal-to-noise (S/N) ratio of imaging beneath the salt bodies are improved while resource cost and run time are significantly reduced as there is only one dataset need to be processed.

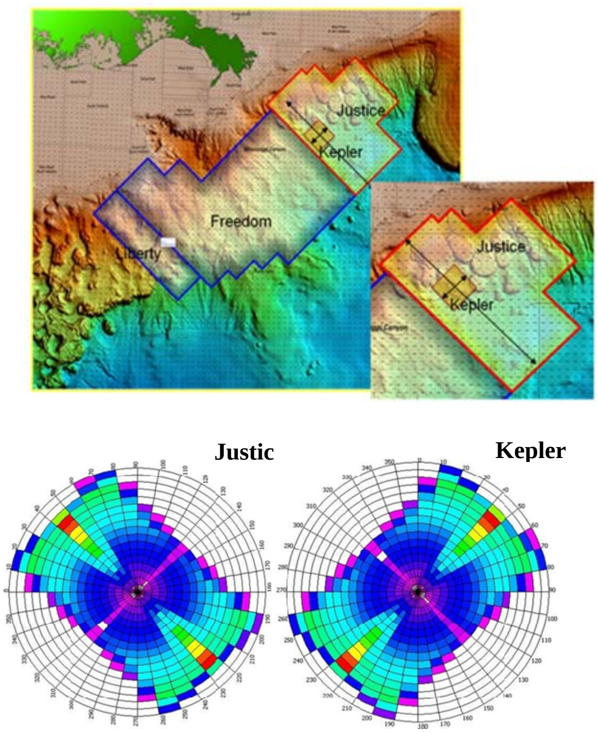

Figure 1: Location of the Kepler and Justice orthogonal surveys and their azimuth coverage diagrams.

Introduction

The more recent recognizable improvements on imaging the complex geologic structures and imaging illumination beneath the salt bodies primarily benefit from the wide azimuth acquisition, the accuracy of the Reverse Time Migration (RTM) and the new algorithms for imaging as well. The rapid processing of many large scale 3D wide azimuth projects is assured with the quick advancements in the computer hardware technologies such as the large memory chips, large disks, fast CPU, high speed network and GPU. Following these encouraging advances in imaging algorithms and computer hardware, the use of multiple large scale 3D wide azimuth surveys, for example, the orthogonal wide azimuth acquisitions, have been increasingly applied in challenging imaging areas in the Gulf of Mexico as they provide the better illumination on the complex geologic structures. It is clear that the full azimuth acquisition will deliver the best illumination of the subsurface and higher S/N ratio images in the complex geologic regions as its uniform and isotropic configurations on both sources and receivers reduce migration artifacts and coherent noise in data.

Many new acquisition technologies have been developed to achieve FAZ coverage. One such example is provided by the Kepler and Justice orthogonal WAZ surveys (Baldock et al., 2012) acquired by TGS in the Gulf Mexico in 2010. These two orthogonal WAZ surveys provide an efficient way to obtain nearly full azimuth data over an existing WAZ area (Figure 1). The two orthogonal WAZ surveys can be merged to a single full azimuth survey on regular grid by CFP method for imaging (Cai et al., 2011). When used for imaging, the created FAZ data provides a unique and improved subsurface image. It will be interesting to see if the combined FAZ data will aid in velocity model building.

Merging Two Orthogonal WAZ Surveys into One Full Azimuth Data

The CFP technique was first introduced by Berkhout (1997), and was used to merge and regularize surveys by Cai et al. (2011). The method of the data driven 3D true azimuth CFP data regularization is a tool of processing multi-dimensional data regularization. The CFP-based approach to merge the surveys preserves the azimuth information for each trace. It can be used as a general tool to merge multiple surveys pre-stack, including, for example, orthogonal Wide Azimuth (WAZ) surveys, different Narrow Azimuth (NAZ) surveys, or a combination of the two. An example of the shot locations before (A) and after (B) regularization is shown in a dataset for creating one CFP shot data made of at least sixteen shots records (C) and the created CFP dataset for a shot (D) in Figure 2.

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For certain potential prospect areas, there can be many surveys of different acquisition geometries acquired over time.
By merging the two existing orthogonal Kepler and Justice surveys, we obtain a full azimuth dataset in that the sources and receivers are uniformly distributed in the surface with the denser shot point spacing (from 150x600m and 600x150m shot intervals to a combined 150x150m shot interval), which covered an about 18 OCS blocks.

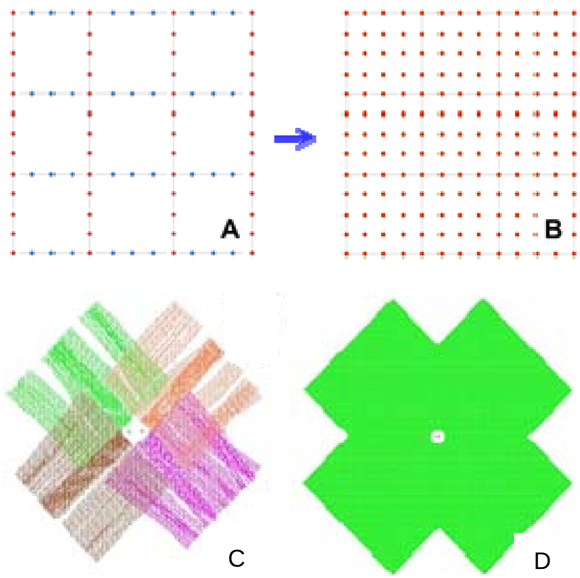

Figure 2 example of making a shot-receives CFP dataset and pattern of the contributing shots vs. the CFP shots.

The 3D True Azimuth Multiple Elimination (TAME) data of the Kepler WAZ survey and the Justice WAZ survey are the input for the merging (Figure 3) as TAME technique, a 3D extension of SRME, may better preserve the primary energy while still effectively eliminate multiply energy. In this CFP dataset there are the configuration of shots of 150m by 150m and the pattern of receivers of 37.5m by 37.5m. As both the sources and receivers are uniformly distributed in the surface the raypaths will be homogenous and isotropic for any spatial location within the survey and then the 3D binning is not necessary. It is prospect that this CFP dataset will deliver the better illumination and high S/N ratio for challenging imaging areas than before. In this case there is only one dataset that will be used for migrations of the Kirchhoff PSDM and RTM.

Velocity Model Building Workflow

The initial TTI velocity model is from the calibrated VTI model of the Justice WAZ project and the Kepler Plus Justice WAZ project and the the initial dip parameters are estimated based on their final RTM stacks.

In order to extensively and equally exploit the azimuth information of the full azimuth dataset in the heterogeneous and anisotropic earth the CFP Kepler dataset is split into six azimuth sectors for the Kirchhoff PSDM and each azimuth data will be equally used on the velocity model updates of tomography.

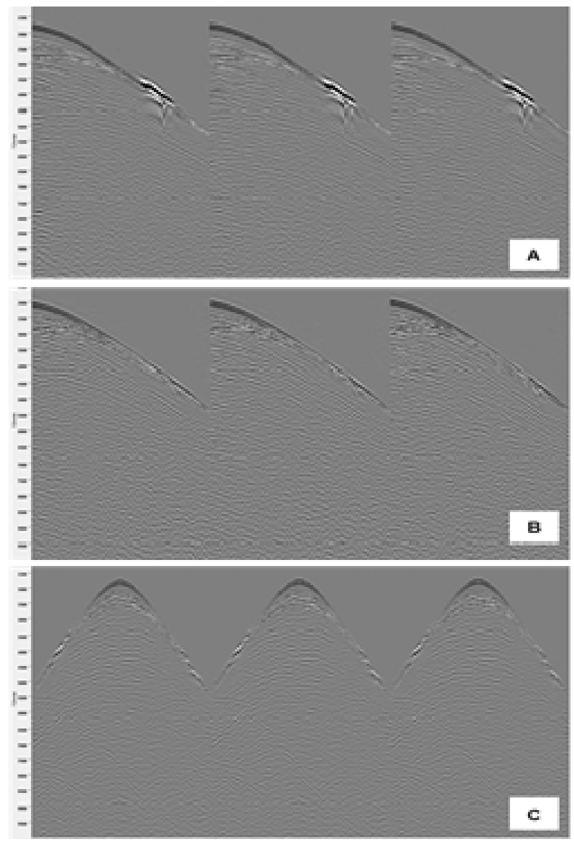

Figure 3 Examples of the contributing shot gathers (A: Kepler and B: Justice) and the created CFP gathers (C).

Furthermore in order to better estimate the velocities and reduce the uncertainty in the inversion of tomography the combined tomographic inversion with the six azimuth sector tomographic datasets in equal weight is conducted.

The sediment velocity model updates are made by using the Kirchhoff migration results. For salt interpretation both Kirchhoff migration and RTM are used to define the salt geometry. The salt model is built from the top down: shallow salt body, overhang salt and deeper salt body. Top of salt 1 (TOS1) was picked on the sediment flood migration volume of Kirchhoff PSDM; base of salt 1

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(BOS1) was picked on TOS1 salt flood migration volume of Kirchhoff PSDM and RTM; TOS2 was picked on salt body 1 (TOS1-BOS1 enclosed) migration volumes of Kirchhoff PSDM and RTM after an overhang tomography update in the region just below BOS1 and above TOS2. BOS2 was picked on TOS2 salt flood migration volumes of Kirchhoff PSDM and RTM. Similar to define the TOS2-BOS2 procedures, TOS3-BOS3, …, are interpreted (Figure 4).

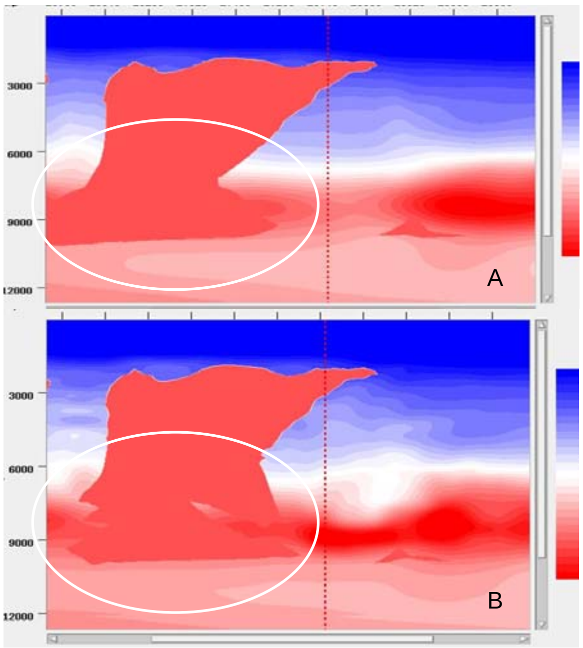

Figure 4: Salt model interpretations from Kepler-Justice orthogonal project (top) and CFP full azimuth project (bottom).

Besides the Kirchhoff-based tomographic velocity updates for the subsalt regions the recently developed RTM-based velocity estimation methods will be used in this case study. The angle information from RTM angle gathers provide the initial shooting direction for ray tracing from the reflection point to ensure the repeating of wave paths during imaging. Subsalt tomography based on the RTM angle gathers takes advantage of the superior accuracy of RTM propagation with the efficient ray-based tomography for velocity updates (He et al., 2012). The angle gathers that created by the RTM partial images will be used to estimate the time delay that is similar to the Kirchhoff migration gathers.

And the RTM-based Delayed Imaging Time (DIT) scans developed by Wang et al. (2009) for the subsalt velocity updates or other low S/N areas have been successfully applied to many 3D projects. This velocity estimation technique is based on RTM image-based perturbation scans rather than velocity-based perturbation scans, since only a single RTM pass is required it significantly reduce computational cost and run time. It is performed to finalize the final velocity model for the final production in this study. The DIT process can help to identify possible residual multiples if a region with large negative model updates is found in the delta velocity field.

Image Improvements

Final comparisons are made with a legacy field data set. The legacy data set is 3D orthogonal wide azimuth, migrated with anisotropic RTM of the two orthogonal 3D wide azimuth datasets separately and summed with the coherent weight (Baldock et al., 2012). This data is shown on top in Figures 5-8. The results of the CFP full azimuth data set migrated with an anisotropic RTM are shown on bottom in Figures 5-8. The CFP FAZ RTM image clearly shows that better illumination, high S/N ratio and better continuity beneath salt body (Figure 5-6) and clear salt boundary on deep salt body and steep-dip salt flank (Figure 7-8) between orthogonal WAZ data and CFP FAZ data.

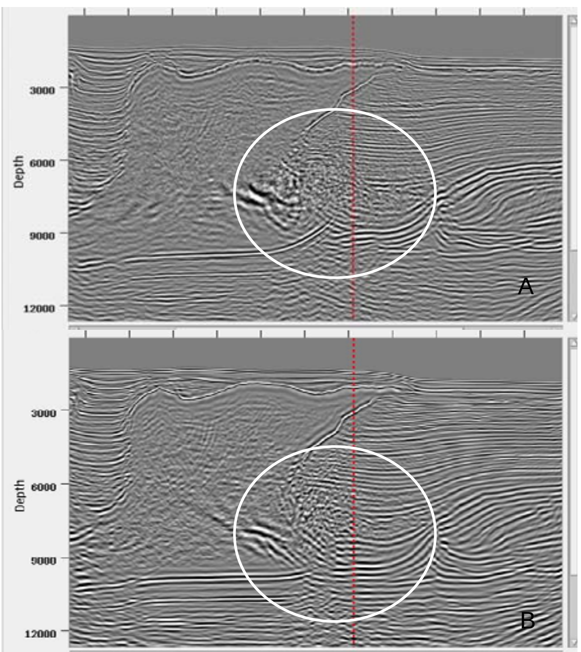

Figure 5: Comparison between the weighted sum stack of orthogonal WAZ RTM and the CFP RTM stack seen from the Justice Survey direction.

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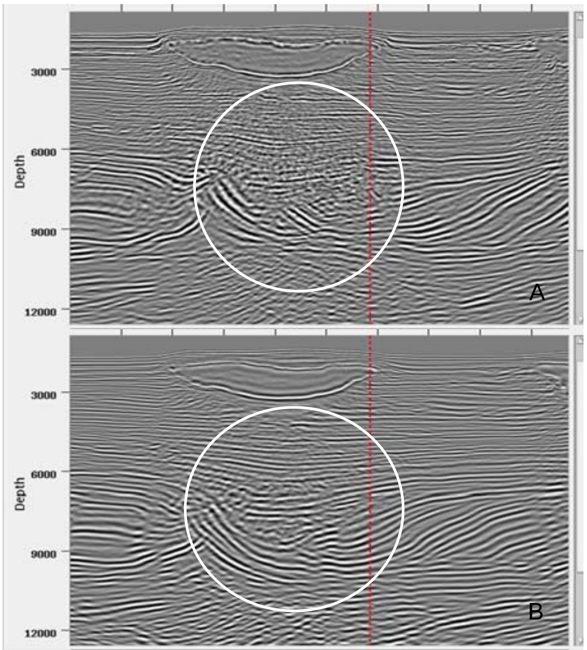

Figure 6: Comparison between the weighted sum stack of orthogonal WAZ RTM and the CFP RTM stack seen from the Kepler Survey direction.

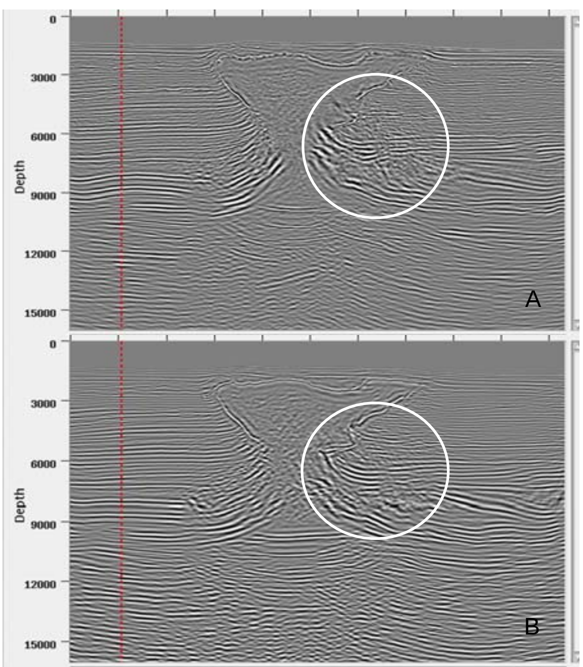

Figure 7: Comparison between the weighted sum stack of orthogonal WAZ RTM and the CFP RTM stack seen from the Kepler Survey direction.

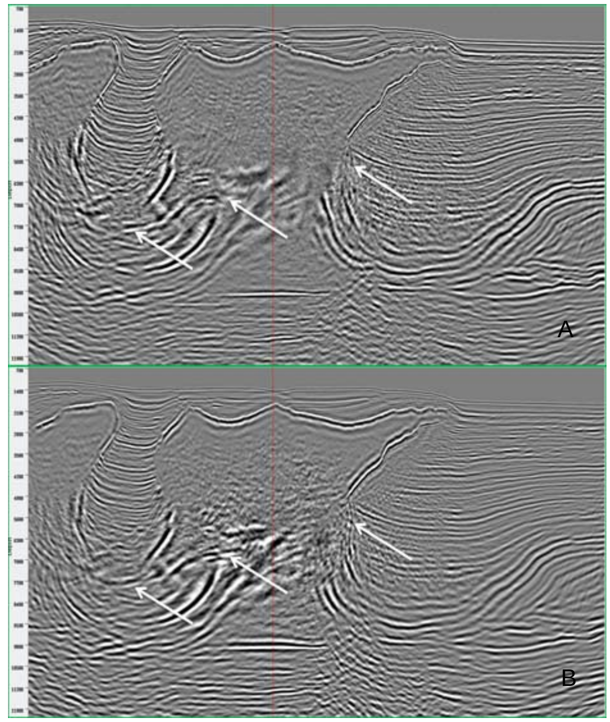

Figure 8: Comparison between the weighted sum stack of orthogonal WAZ RTM stack and the CFP RTM stack seen from the Kepler Survey direction.

Conclusions

Both illumination of imaging beneath salt bodies and S/N ratio in imaging are obviously improved and salt geometry more confidently is defined by using the CFP data for velocity model estimation and migration. The calculation time and cost of RTM in all iterations of this case is cut about a half with only one CFP data as input. It is prospect that processing with the CFP full azimuth data will provide the possibility for a more detailed salt geometry definition and the better image for challenging imaging in the complex geologic structure areas with the better illumination and high S/N ratio.

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EDITED REFERENCES

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