Applying prestack depth migration to enhance subsurface assessments – Campos Basin, Brazil

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Abstract

The complex northern Campos Basin overburden, including seafloor canyons, buried channel complexes, fault shadows, carbonate rafts and salt, introduces structural artifacts and contribute to the poor quality of the in a prestack time-migrated (PSTM) image. Several approaches to time-to-depth stretching could not effectively resolve the overburden complexities, thus an anisotropic pre-stack prestack depth migration (PSDM) was applied to the data, leading into a high quality product that supported an enhanced interpretation of the underlying geology.

Introduction

The Campos basin is by far the most explored and prolific petroleum basin in offshore Brazil. Since its early exploration efforts in the 1970's hundreds of seismic surveys have acquired 2D and 3D datasets in the basin.

Over the years, we have seen a significant evolution of the seismic industry, not only improvements in acquisition parameters and the processing algorithms but also in the sophisticated interpretation platforms used to image the subsurface geology. This work highlights the value of a PSDM in correcting the effects observed on 3D PSTM seismic datasets acquired in the North Campos basin.

Even with all the technology applied into the seismic acquisition and data processing, there are still some geological features affecting the quality of the seismic data and providing complexity to the subsurface interpretations. In particular, the quality of the seismic image in this study area is highly affected by the overlying seafloor canyons. The canyons effects propagate downward into the subsurface disturbing not only the reflections geometries but also the seismic amplitude strengths.

Although the sea-floor canyons provide challenges to the seismic data, a complex subsurface stratigraphy also contributes to the poor image quality. In order to improve an overall subsurface assessment all other geological features in the overburden, such as buried canyons, high velocity contrast horizons such as the "Blue Marker", lithology changes (sandstones, shales and carbonates interactions) and body shapes (salt diapers and carbonate rafts) need to be considered and addressed during data processing.

Once the geological features were identified, reprocessing of the raw data through a pre-stack depth migration (PSDM) was performed to mitigate the overburden artifacts. The PSDM workflow focuses on solving shallow complexities first and works progressively into the deeper part of the section, resulting in an overall improved seismic image quality.

Time-to-Depth conversion

The initial subsurface interpretation was performed using the PSTM datasets containing the seismic artifacts described above. The main artifact affecting the structural interpretation was the lateral velocity variation introduced by the seafloor canyons and the associated buried canyons. Thus, all interpretation products, (structural and amplitude maps) once converted to depth, were highly affected by those artifacts. It was possible to identify the seafloor canyon velocity overprint in all of the structural maps as well as in the amplitude extracting along the stratigraphic column.

Several time-to-depth (T2D) models efforts were generated in an attempt to account for the canyons and other subsurface anomalies. As a general result, the T2D models had some positive impact in the shallower sections but minimal impact for the deeper section. The reason for this is that T2D velocity models assume a vertical ray path and cannot account for 3D effects caused by features that impose lateral and abrupt vertical variations in velocities, such as the canyons.

A need for a reliable subsurface assessment led us into an anisotropic pre-stack depth migration processing of the dataset.

Input dataset & processing

In order to perform a complete assessment of the area of interest a merger between three different 3D seismic surveys was proposed. Each input 3D survey was acquired by different acquisition campaigns that had different acquisition parameters. The pre-processing of the data had to match and integrate into into a single survey prior to migration. Another key step critical to enhancing the signal prior to migration was a model-based 3D free-surface demultiple.

The migration of the data was done by Chevron's proprietary Gaussian beam pre-stack technology, which is widely used in Gulf of Mexico for complex subsurface imaging, and this was used in Brazil for the first time. A more detailed description of the dataset and processing workflow of this dataset is presented by Vincent & Molinari (2011).

Pre-stack depth migration

The resulting PSDM covers an area of 2.900 km^2 in northern Campos basin, offshore Brazil, to address the lateral velocity variations and anisotropic properties affecting the structural interpretation of the area.

An accurate sediment velocity field and detailed subsurface body modeling enhanced the interpretation of velocity variability in 3D space, a critical factor in the velocity model definition.

The PSDM workflow requires geologic insight and input, solving shallow complexities first and working progressively into the deeper part of the section. Ultimately, all velocities were geologically consistent and mitigated the overprint of the subsurface complexities in the subsurface maps.

By applying this anisotropic velocity model into the PSDM a significant impact was obtained on the image quality when compared to the original time data.

A key part of enhancing the quality of the seismic was the de-multiple process, which was also performed along the data processing. A combination of Gaussian beam and radon multiple models predicted and removed the many multiples.

The final PSDM product resulted in a better quality seismic image that reproduces the geological framework in a more realistic matter by mitigating the artifacts related to a complex overburden.

Conclusions

Chevron has applied its leading edge technology developed in Gulf of Mexico for complex seismic imaging in Brazil for the first time. It resulted in a more geologically realistic structure leading to an enhanced subsurface assessment.

Given the model-based and iterative nature of the method, a successful PSDM demands the close integration of the geologist and geophysicist.

The PSDM enabled a more realistic risk assessment of the opportunities, increased the confidence of the subsurface interpretation and assisted with optimal well placement.

In the deepwater environments, where sparse well control doesn't capture all the subsurface complexities, improved seismic imaging leads to higher quality assessments and better decisions.

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References

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