THE 4TH GEOLOGICAL CONFERENCE OF THE GEOLOGICAL SOCIETY OF TRINIDAD AND TOBAGO

June 17-22, 2007, Hilton Trinidad & Conference Centre, Port-of-Spain, Trinidad and Tobago

"Caribbean Exploration – Planning for the Future"

ABSTRACT

ANISOTROPIC PP AND PSv PRESTACK DEPTH MIGRATION OF 4C (OBC) SEISMIC DATA, PAMBERI, OFFSHORE TRINIDAD

Tony Johns*, Carmen Vito*, WesternGeco and* **Raul Sarmiento***, EOG Resources.*

In November 2004, EOG Resources acquired an ocean-bottom cable (OBC) 4C swath survey across the Pamberi-1 well location in the Lower Reverse L block of the Colombus basin, eastern offshore Trinidad. The purpose of the 4C test survey was to evaluate the potential of long-offset multicomponent technology for resolving lithology and stratigraphic detail in an area perturbed by shallow gas, over-pressure and illumination shadows from normal regional faults and major anticlinal ridge trends acting as pressure seals. The motivation from EOG for attempting this was because a conventional 3D towed-streamer survey acquired the previous year failed to adequately image the target reflectors comprising the reservoir under the main growth fault.

Details of the P- and PS_V-wave processing of this dataset through anisotropic prestack time migration were previously described (Johns, et al., 2006) in which it was demonstrated there existed a qualitative correlation between derived parameters and attributes from P and Sv anisotropic migration velocities and known regional geology. This observation was quite remarkable considering only a limited effort to constrain or validate parameters (in this case, velocities to the Pamberi-1 well checkshots) was performed. Under the "Future work" section of the previous publication, it was suggested that further data quality enhancement in preparation for more quantitative rock property classification, calibrated to wells, could only be achieved after prestack depth imaging.

In this paper, we present precisely that next phase in the 4C processing, advancing the P- and PSv-wave data through anisotropic prestack depth migration, using cell-based tomography with a top-down pseudo layer-stripping approach. The Pamberi-1 well information was used to constrain the anisotropy in the shallow section, with the deeper, spatial trend away from the proximity of the well determined from the anisotropy derived previously in the time processing.

Prior to proceeding with the anisotropic depth imaging, the magnitude of shear splitting (or, birefringence) from the presence of azimuthal anisotropy (HTI) is first examined to assess its potential impact on the radial rotated P-S signal. The shear-wave splitting analysis revealed a principal angle of polarization that was closely aligned with the regional stress direction delineated by the major faults blocks acting as pressure seals.

Introduction

The OBC multicomponent 4C swath, acquired by WesternGeco at the end of 2004, comprised of two parallel 15-km receiver lines separated by 400m, with a receiver station interval of 25 m. Twelve source lines, with crossline separation of 100 m, were shot into the two cables with a recorded maximum split-straddle offset of 10,000 m and a nominal inline fold of 133.

The 4C survey, situated in the Lower Reverse L block of the Columbus basin, Trinidad, traverses the Pamberi-1 well location. EOG is currently not producing from this well, but consider the location which is comprised mainly of Plio-Pleistocene sands and shales, to have high prospectivity potential. The objective of the 4C acquisition and processing is to characterize the lithology and reservoir potential of the events directly under the well in the 10,000 to 14,000-ft depth range. On previous conventional seismic data this target zone, in the upthrown side of the fault, suffered from a problematic illumination shadow despite the existence of several well-imaged strong reflectors in a downthrown fault trap that form the basis of the prospect.

The original processing, as previously described in detail (Johns et al., 2006) adopted a fairly conventional P- and PS_v-wave signal processing flow prior to imaging through curved-ray Kirchhoff prestack migration. Data quality was very good with improved imaging at the target level from both wave modes. To match equivalent events the PS section was compressed to pseudo P-P time using the derived vertical V_p/V_s ratio (γ_0). The preference, however, is to process in the depth domain to facilitate the registration of P- and PS_v-wave events in depth through important incorporation of anisotropy calibrated to available well data. Previous papers have been published describing the registration of P- and PS_v-wave data in depth from anisotropic prestack depth imaging. Nolte et al. (1999), Crompton et al. (2005) and Kommedal et al. (2006) are a few that exemplify the evolution of the technology. This paper continues in that premise by describing the prestack depth migration (PrSDM) work flow and velocity modeling for P- and PS_v-wave data, with inclusion of well control and anisotropy. Results of the final depth migrations are shown compared to the previous prestack time migration (PrSTM) results.

Before embarking on the anisotropic PrSDM for both wave modes, it was decided to examine another form of anisotropy, HTI (or azimuthal anisotropy), and its possible effect on PS_v imaging and data quality as a consequence of shear splitting.

Results

Preliminary prestack analysis of the raw and radial rotated converted-wave data indicated evidence of mild shear splitting from azimuthal anisotropy attributable, in part, to dominant

regional stress fields delineated by major fault blocks. The advantage of the detectors exhibiting near-perfect cross-component vector fidelity and orientation facilitated the identification and measurement of principal azimuths of shear-wave polarization on the PS data. It was encouraging to observe that the principal azimuth of polarization agreed closely with known regional lateral stress field orientation for the area. The polarization to S_1 and S_2 was restricted to a rotation of 15° or less from the survey's natural acquisition orientation, and appeared to have minimal detrimental impact on the final radially rotated PS data quality. From a theoretical standpoint, Alford rotation to principal azimuths of polarization following a layer-stripping approach could most certainly compensate for the differences and yield an incremental improvement, but was outside the scope (and budget) of this project.
After several iterations of constrained cell-based tomography with progressively smaller scale lengths (smoothing) and the necessary incorporation of anisotropy (VTI), the resultant P- and PS_v-wave PrSDM sections exhibit an enhancement in structural detail and continuity together with improved PP to PS_v correlation of target events across the main fault (Fig. 1). The inclusion of anisotropic (VTI) properties from the previous time processing, subsequently updated after well control and P-P to P-S event registration, significantly improved the final PSv imaging; more so than that noted in the P-wave migration. Improvements in imaging compared to the time-processed PrSTM sections, are also observed on the downthrown side of the fault away from the well. Furthermore, better flattening of the PS_v CIP gathers across the entire positive and negative 10-km offset range are evident, which is important for future AVO/inversion work in the extraction of rock property attributes. Although raypath asymmetry (Thomsen, 1999) and lateral heterogeneity is causing significant variation in the PS_v reflectivity, structurally there is a better depth consistency match between the positive- and negative-offset PrSDM sections compared to time-processed data, increasing confidence in the PS_v depth interpretation.

Conclusion

In this paper, we demonstrate for the Pamberi area of the Columbus basin of offshore eastern Trinidad, that further to the improvement over the conventional 3D towed-streamer time imaging from 4C anisotropic prestack time migration, (Johns, et al., 2006) significant enhancement is also possible with anisotropic PrSDM of the P- and PS_v-wave data, using cell-based tomography calibrated to well information.

Work currently in progress is now taking advantage of the improved PP to PS_v event correlation of the enhanced anisotropic depth-migrated gathers to quantitatively classify, using additional nearby well control, the lithology and rock properties of the target interval from joint pre and poststack inversion. Despite the acquisition being limited to a single swath, the potential for future work is huge, both in terms of interpretation and processing. The next challenge is to further increase resolution of the P- and PS-wave imaging via enhanced preprocessing, advanced migration algorithms and more interactive anisotropic velocity modeling tools. Any improvement from the compensation of observed azimuthal anisotropy is also a consideration.

Acknowledgements

The authors thank the Trinidadian Ministry of Energy (MOEEI) and EOG Resources for granting show-rights to publish this paper and colleagues at WesternGeco for assistance in processing.

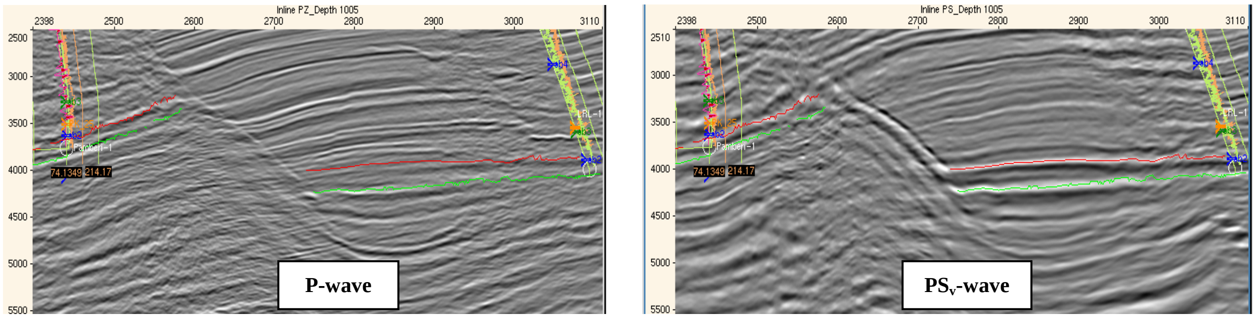

Figure 1. Central inline PZ P-wave (left) and PS_v-wave PrSDM sections with correlated depth horizons and well log overlays. The Pamberi-1 well is on the left. The PSv section shows a series of bright events on the downthrown (red and green horizons) which are not clearly visible on the PZ data. A good example of where this 4C dataset has identified potential new leads