Time vs Depth Imaging: Improving Seismic-well Correlation and AVO Modeling for a Heterogeneous Shallow Marine Reservoir: Example from Krishna-Godavari Basin

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ABSTRACT

This paper reviews the concept, process and workflow for comparison of time and depth imaging for improved identification of reservoir scale geobodies using seismic pre-stack inversion. The study area is located in the Krishna-Godavari basin along the east coast of India, which covers the deltaic and inter-deltaic areas of the Krishna and Godavari rivers and extends into the offshore. The basin evolved through crustal rifting and subsequent drifting during Mesozoic time, followed by major fluvial and marine Tertiary sedimentation (Sharma et. al., 2010). The present study involves Cretaceous sedimentary sequence of the basin.

As the survey encompasses very shallow to deep water, a 3D Q-marine seismic survey was acquired using a special survey design having a short nominal near offset in order to favor further processing. An undershoot technique was also used to record seismic information beneath the numerous installations that are present within the area. The raw field data were extremely noisy due to the presence of rigs, vessels and fishing activities that were going on during acquisition as well as the nature of multiples that varied considerably from shallow to deeper water.

The preprocessing of the data incorporates extensive noise attenuation and QC followed by the Generalized Surface Multiple Prediction (GSMP) method to remove complex surface related multiples. A combination of XT and Tau-p domain deconvolution was used to attenuate shallow water multiple reverberations.

Prior to this study, a total of eleven exploratory wells were drilled in the area, but due to the complex stratigraphic uncertainty only two wells encountered reservoir facies. To better assess reservoir distribution, seismic inversion and lithocube volumes are used as the main drivers for delineating and modeling of the reservoir geobodies (Sharma et. al., 2010). The current seismic volume needed to be better suited for seismic inversion studies.

Kirchhoff Pre-stack Time Migration CMP gathers clearly exhibited the presence of complex moveout in the area and thereby strongly suggested the need for depth imaging. Kirchhoff Isotropic Pre-stack Depth Migration gathers showed improved imaging of energy and the amplitude vs offset relationship was better defined. However the ‘hockey-stick’ effects in the depth domain gathers and well-log information clearly exhibited presence of anisotropy in the area. Epsilon and delta values were calculated using two vertical wells present in the area and final VTI Anisotropic depth migration solved the complex moveout problem present in the area leading to a better well-tie and increased confidence in inversion results.

1. Introduction

Krishna-Godavari (KG) basin is proving to be one of the largest gas basins of India. This pericratonic rift basin has multiple proven petroleum system of Mio-Pliocene, Upper and Lower Cretaceous age. The present study is focused on the better imaging and delineation of Upper Cretaceous sediments for improved well-tie and AVO-modeling exercises. The investigated area is located in the offshore KG Basin, East coast of Indian peninsular, near the north eastern bank of Godavari Delta (Fig. 1).

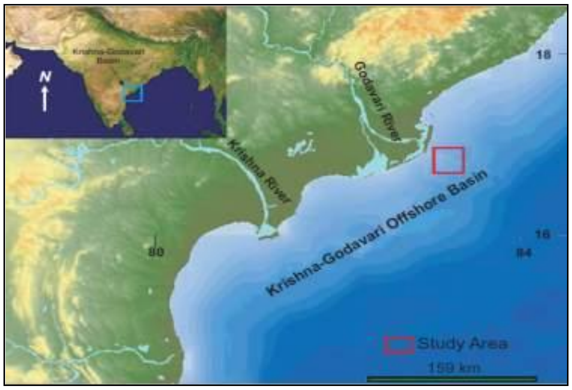

Figure 1: Location map of KG-Basin showing the area under study (highlighted in red square box)

1.1. Preconditioning of seismic data

Due to the presence of numerous seismic, drilling and fishing activities within and by the side of the survey, raw data was contaminated with substantial marine noise and multiples. To get a better imaging result, an extensive suite of noise and multiple attenuation methods were adopted. As the water bottom depth varied greatly from very shallow to deep, hence the nature of the multiples changes substantially. All noise and multiple attenuation processes were designed to preserve the AVO signature of the data.

There were at least ten different types of marine noise present in the area which required careful attenuation and extensive QC in order to maintain the AVO signature of the data. A Generalized Surface Multiple Prediction (GSMP) approach was used to attenuate highly complex surface related multiples and XT and Tau-p domain multiple attenuations were used to remove interbed and peg-leg type of multiples, especially in the shallow areas (Fig. 2, 3, 4, 5).

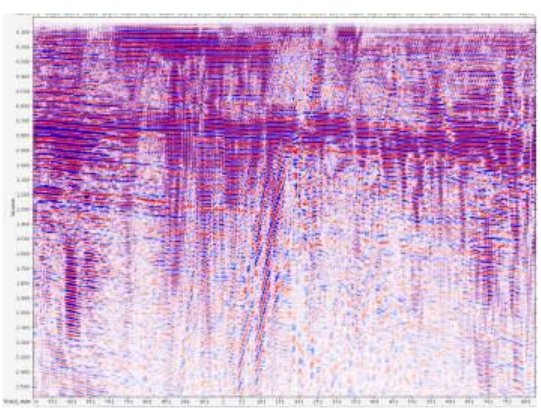

Figure 2: A shallow line from the western part of the survey showing raw navmerged data contaminated with noise and multiples

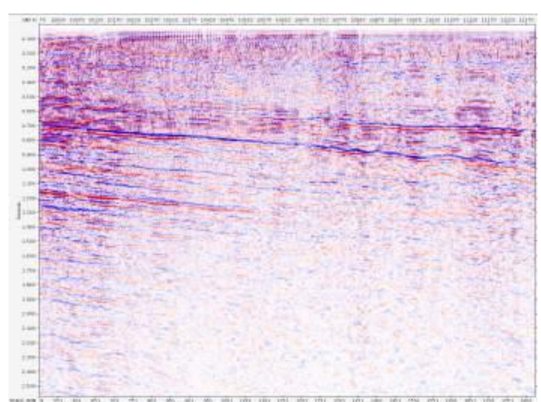

Figure 3: Same line as shown in Fig.2 after preconditioning showing improved S/N ratio

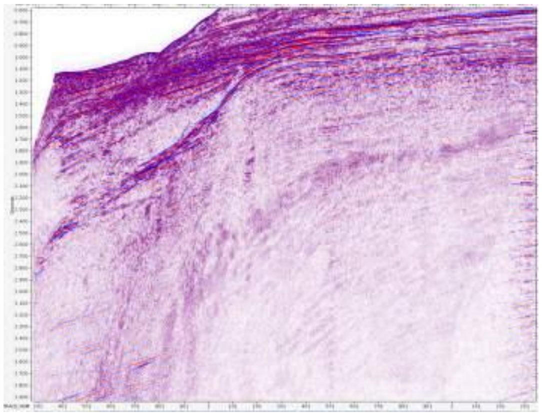

Figure 4: A line from eastern part of the survey showing varying water bottom and contaminating noise and multiples

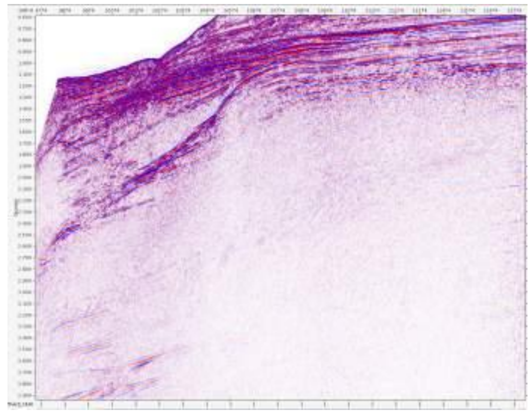

Figure 5: Same line as shown in Fig. 4 after preconditioning showing improved S/N ratio

2. Velocity modeling – Issues

As was evident from the available interpretation (Fig. 6; Petrotel, 2007) and known geological settings, the area is extremely heterogeneous exhibiting strong lateral velocity variation (Fig. 7) which acts as a challenge in delivering a good time image, as Kirchhoff time migration algorithm assumes the ray-path to be symmetric.

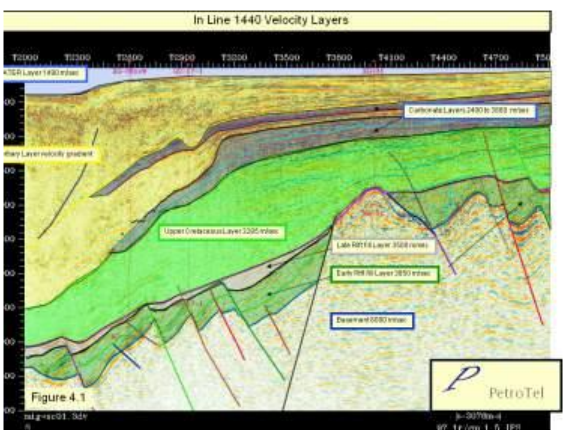

Figure 6: Interpretation showing heterogeneity and their corresponding lateral velocity variation (Petrotel, 2007)

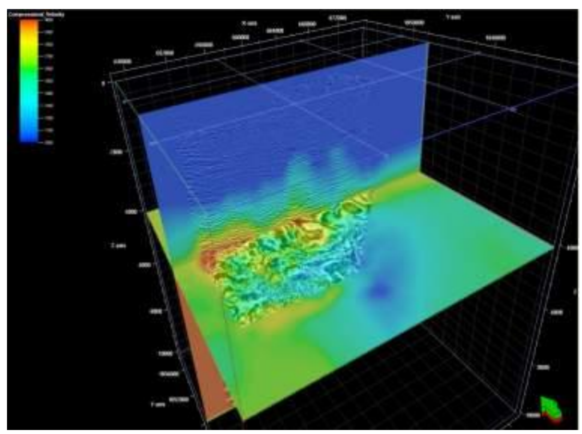

Figure 7: Timeslice through reservoir section showing strong lateral velocity variation

This is in turn causes non-flat events on the gathers after Pre Stack Time Migration which results in poor AVO character thereby deriving incorrect rock properties. This has a huge impact on drilling decisions and well path design. In order to mitigate this problem, final time migration velocity field was taken to create the simplistic initial depth velocity model and was updated using hybrid/gridded tomography approach (Fig. 8, 9). Series of isotropic updates have been run which showed significant improvement over pre-stack time migrated image in terms of gather flatness, significant changes of structural plane, faults focusing and positioning. Using information from two vertical wells in the target area, parameters for anisotropic depth migration - epsilon and delta were computed and used for velocity model updating and the final anisotropic prestack depth migration. Final VTI anisotropic depth migrated gathers and stacks showed significant improvement over isotropic results (Fig. 10, 11, 12) and brought another significant improvement in gather flattening, structural interpretation and understanding of the geological setting. These results thereby improved confidence and certainty in AVO modeling and rock properties derived from inversion. In the target area, lateral movement of the faults and main structures were observed as large as 600 meters which will definitely affect the drill path design and will reduce risk as well.

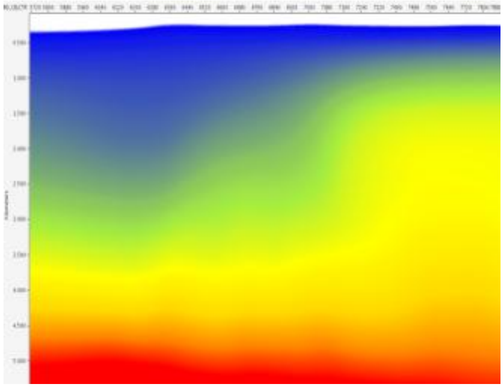

Figure 8: Section showing smooth time migration velocity

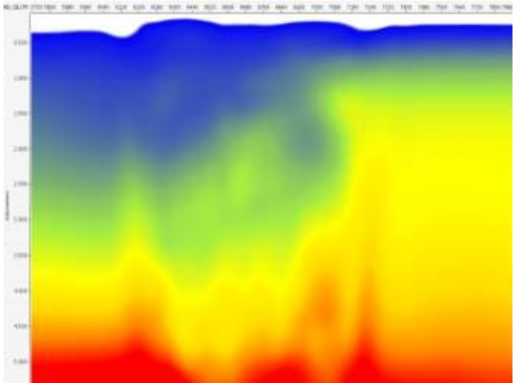

Figure 9: Section showing depth imaging velocity model having lot more vertical and lateral variation corresponding to the geology of the area

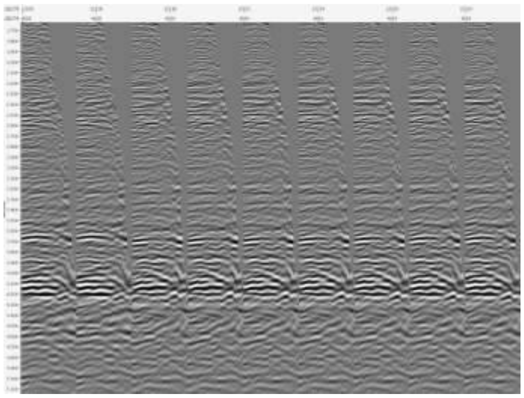

Figure 10: KPSTM CMP gathers showing non-resolved complex moveout on events resulting in non-flatness of events

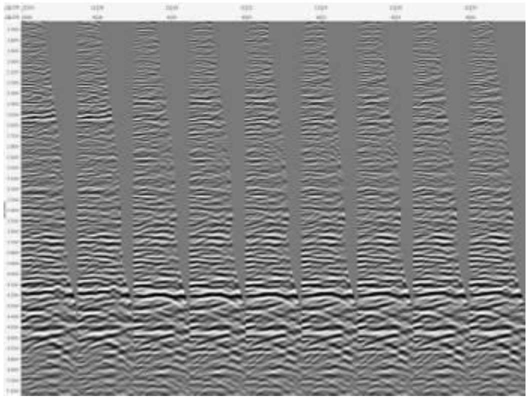

Figure 11: Isotropic KPSDM CMP gathers showing complex moveout on gathers partially resolved and exhibiting better flatness than PSTM gathers

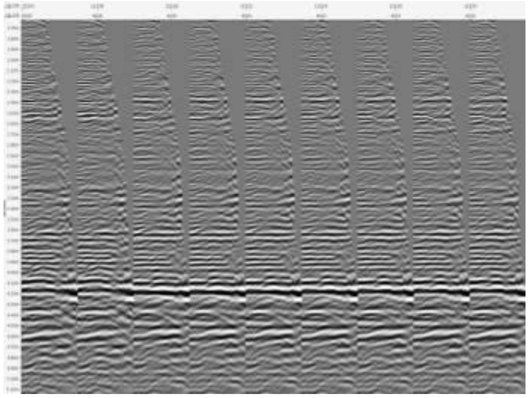

Figure 12: Anisotropic KPSDM CMP gathers showing complex moveout on gathers resolved resulting in flat events

3. Well ties and AVO modeling

The anisotropic depth migrated results were matched with VSP data and anisotropic CMP gathers showed a substantially better match compared to time migrated gathers. Inversion and AVO studies showed better correlation and similarity between seismic and petrophysical data thereby increasing the confidence in static modeling of the reservoir (Fig. 15, 16).

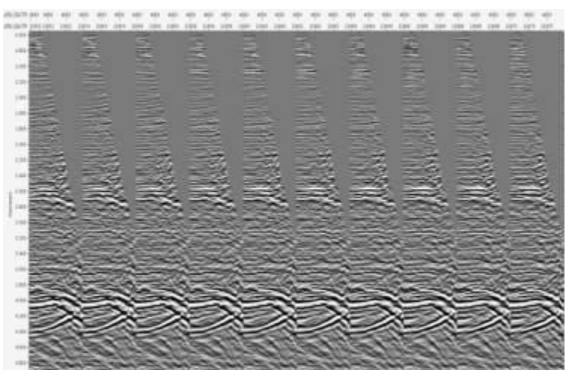

Figure 13: Another example of time migrated gathers showing non-resolved complex moveout and poor amplitude vs offset correlation

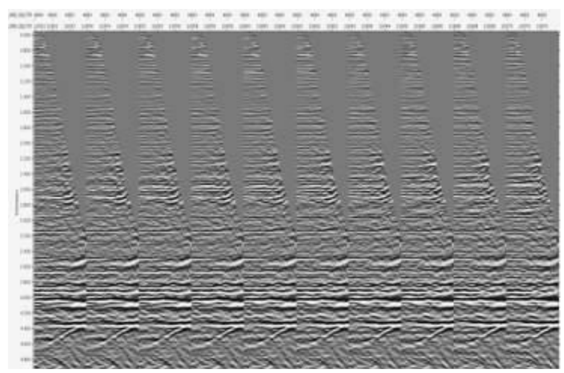

Figure 14: Same gathers as shown in fig. 13 after depth imaging showing better flatness of events and better amplitude vs offset correlation

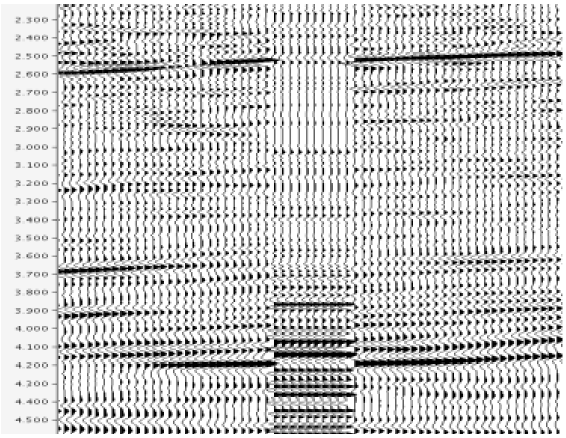

Figure 15: Seismic section showing non-correlation between VSP and PS**T**M data

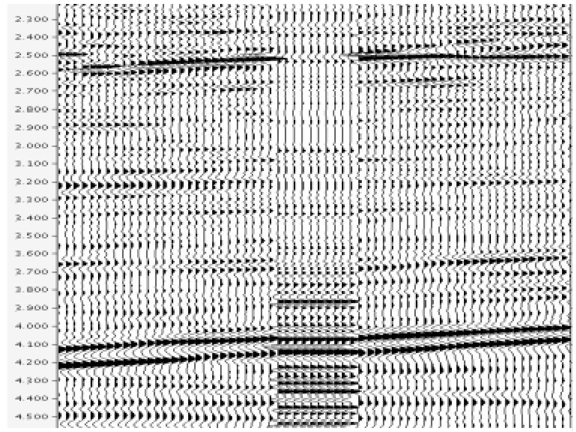

Figure 16: Seismic section showing good correlation between VSP and PS**D**M data

4. Conclusion

This project clearly underscores the substantial structural imaging improvement benefit and the need for the application of modern techniques like depth imaging in complex sedimentary structures such as seen in the Krishna-Godavari basin offshore India. The presence of a wealthy amount of well information helped the understanding and constrained the anisotropy parameters in the area. With the huge lateral movement of energy as exhibited by this dataset volume , it can be concluded that depth migrated seismic datasets will provide a superior reference point with which to derive rock properties for characterization and for ultimately designing the well location accurately and hence minimizing risk.

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Reference

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