Improved imaging below the Deccan Trap: An attempt to see sub-trappean Mesozoic sediments

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Keywords

Interval velocity reversal, Mesozoic sediments, model-based approach

Summary

Imaging below the Basalt which is highly heterogeneous and having rugose interface is difficult due to loss of seismic energy, attenuation, absorption, scattering and mode-conversion. Reprocessing of vintage 2D lines with improved processing techniques considerably improved the image quality. The stack section guided by interval velocity reversal successfully identified Deccan Trap and sub-trappean Mesozoic sediments below the trap. Well to seismic calibration was carried out for interpreting internal stratigraphy and geometry of structures accurately. This methodology may be helpful in mapping and modelling sub-basalt Mesozoic sequences in entire Western Offshore Basin. Thus interval velocity function can be used as one of the effective seismic tools to confirm imaging below Basalt.

Introduction

The sedimentary basins adjoining the west coast of India from north to south are Kutch Offshore Basin, Cambay Basin, Saurastra Basin, Surat Basin, Mumbai Offshore Basin (collectively termed Northern Basins) and Kerala Konkan Basin (Fig. 1). The Northern Basins have greater hydrocarbon potential than the Kerala Konkan Basin resulting in more intensive research and better understanding of their sedimentation history (Mathur & Nair, 1993; Singh et al, 1999).

Kutch Offshore Basin, Cambay Basin, Saurastra Basin, Surat Basin are situated in the north of West coast of Peninsular India. In Kutch Offshore the rift evolution and syn-rift sedimentation continued through Jurrasic-Cretaceous and subsequently in passive margin set-up. Here a significant amount of Mesozoic sediments is present in addition to tertiary sediments. Recent discoveries proved presence of hydrocarbon in both Mesozoic and Tertiary sequences.

In the South of Kutch-Saurastra, Mumbai High and associated hydrocarbon bearing fields are producing hydrocarbon from established Plio-Mio-Eocene Clastic and Carbonate plays. Below Paleocene, Mesozoic play couldn't be established so far in Mumbai Offshore Basin.

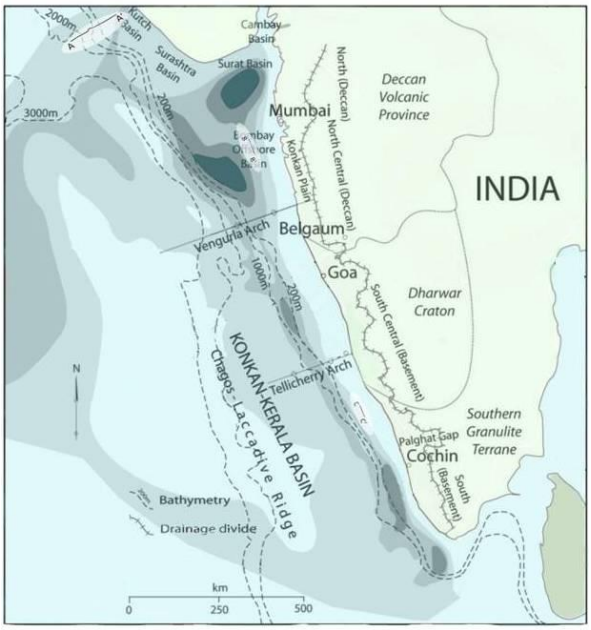

Figure 1: Western Offshore Basin showing present study area

Further south, there lies Kerala-Konkan Basin. The Vengurla/Goa Arch separates Kerala-Konkan Basin from Mumbai Offshore Basin. Continental shelf of Kerala-Konkan Basin is only 50km wide, whereas the northern Basins are characterized by a shelf, which gradually widens from the southernmost offshore Mumbai Basin to 300km northwest-wards till the Saurastra Arch.

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Vengurla/Goa Arch obstructed the Tertiary sediment supply from northern river system to further south and therefore attributed a diminished Tertiary prospectivity for Kerala-Konkan Basin. So exploration strategy in Kerala-Konkan Basin shifted from Tertiary to Mesozoic.

It is to be noted that Mesozoics are the largest contributors of recoverable hydrocarbons worldwide. Although in Indian context, apart from Kutch Offshore, Mesozoic plays couldn't be established so far.

Due to large impedance contrast at sediment-basalt interface and presence of breccias or vesicles within the lava flows, the primary reflections are masked by coherent noises such as multiples, diffractions, scattering and mode-conversion. This makes imaging below Basalt very difficult.

With due course of time, seismic processing techniques have improved considerably. In the present study, old vintage 2D seismic lines were reprocessed with improved processing techniques. Low frequency part of the seismic data can be preserved in a better way. Model based multiple attenuation approach eliminates multiples more effectively. Finally, incorporating the temporal as well as spatial velocity changes in migration algorithm, the output image quality enhances. Mesozoic sequences can be seen in the reprocessed output clearly.

Methodology

In the current study, three representative vintage 2D seismic lines, 'AA'' from Kutch Offshore, 'BB'' from Mumbai Offshore and 'CC'' from Kerala-Konkan Offshore were reprocessed (Figure 2).

The processing work-flow is shown in Fig 3. Special processing techniques like designature/debubbling, demultiple processes were adopted on each of the dataset. As 2D lines were old, gun signature was not available with the data. Source signatures were prepared using direct arrival event in seismic data to eliminate the bubbling effect.

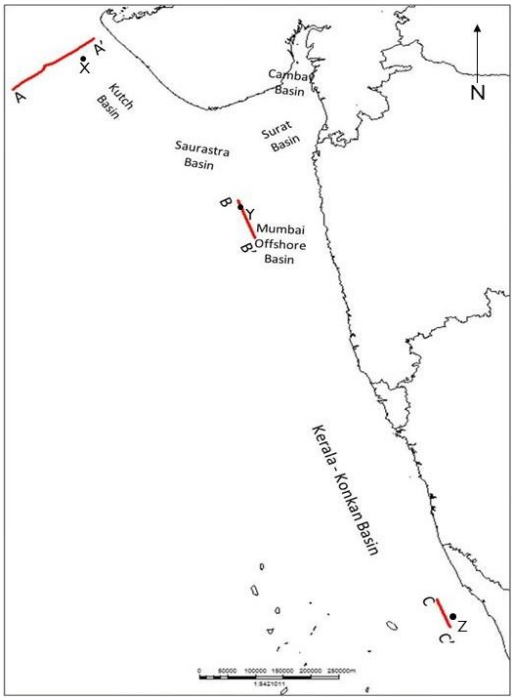

Figure 2: Location of the 3 seismic lines under study

Following is the acquisition geometry of the 2D lines:

Line	AA' & BB'	CC'
Record length	6sec	5sec
Shooting Pattern	End-On	End-On
No of channels	96	48
Group Interval	25m	50m
Shot Interval	25m	25m
Near offset	222m	265m
Far Offset	2597m	2605m

Table1: Recording parameters

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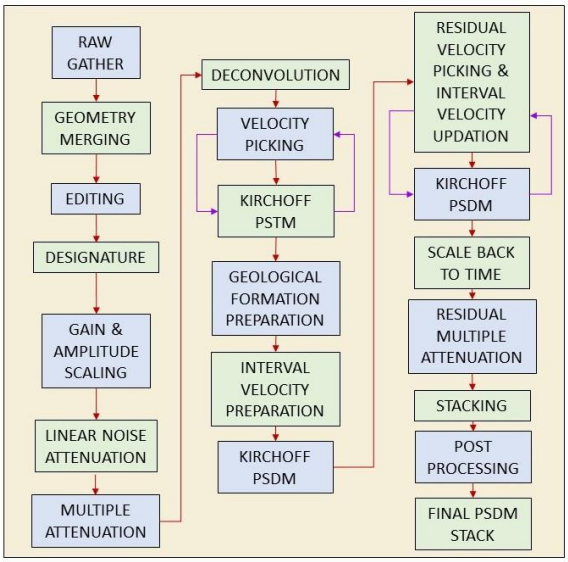
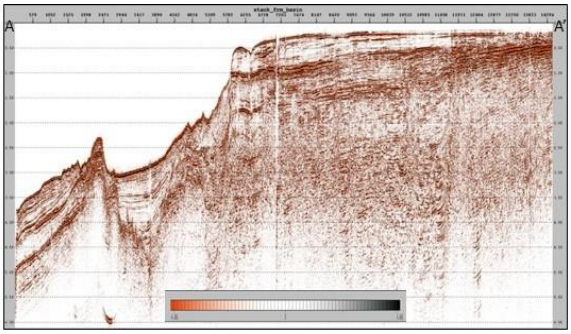
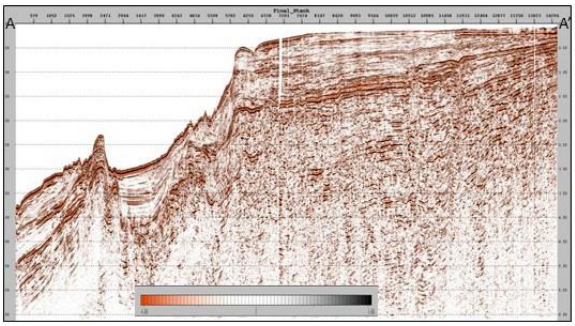


Figure 3: Special Reprocessing workflow

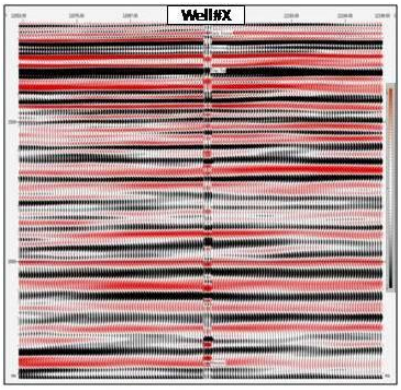
Marine seismic data is heavily contaminated with multiples like Surface Related Multiples, Ghost, Peg-Leg Multiples etc. Model based approach was incorporated in all the demultiple processes (like wave equation multiple attenuation, deghosting & surface related multiple attenuation). In addition to that Deghosting method broadens the frequency spectrum by removing Source and Receiver Multiples. Thus lower part of the frequency spectrum is preserved and enables the seismic interpreter to see below the high density Basalt more confidently. Deconvolution is applied on the data in Tau-p domain which effectively exploits the periodically occurring nature of the multiples. Finally parabolic radon demultiple was used to remove move-out based multiples.



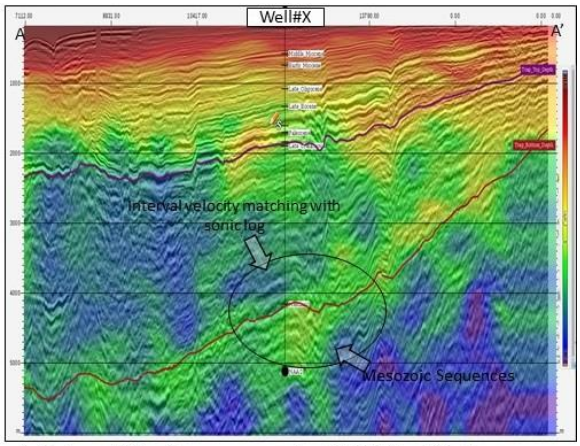
4.a Vintage PSTM Stack Section



4.b Reprocessed PSTM Stack Section



4.c Well-to-seismic tie at Well#X



4.d Interval Velocity superposed on PSDM Stack Section

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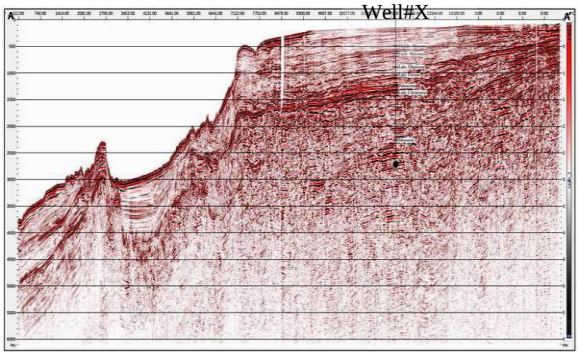
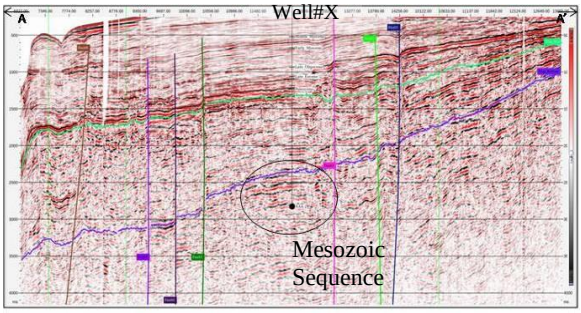


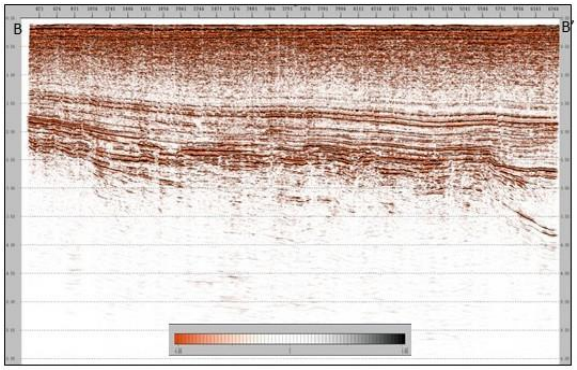
4.e PSDM Stack Section(Scale to time) shows Mesozoic sequences



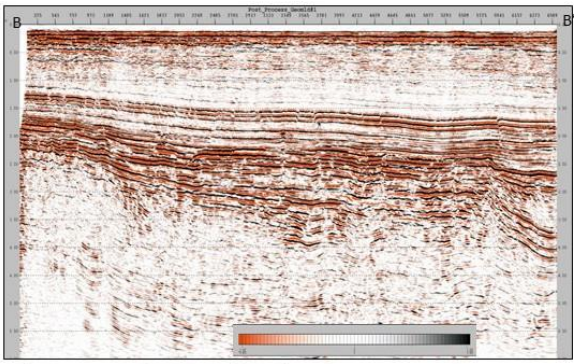
4.f Reprocessed PSTM Stack Section shows Mesozoic sequences (Zoomed Section)

Figure 4: Seismic line AA' showing Mesozoic sequences

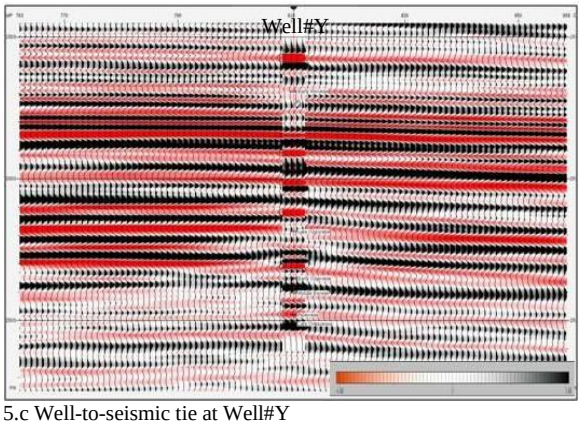
Pre-Stack Depth Migration was carried out with updated interval velocity. PSDM takes care of temporal as well as spatial velocity changes. (PSTM only considers temporal velocity changes). So, events can be positioned more accurately and image quality improves. For this approach, model-based Interval velocity was calculated from RMS velocity using Constrained Velocity Inversion method over simple Dix formula



5.a Vintage PSTM Stack Section



5.b Reprocessed PSTM Stack Section



5.c Well-to-seismic tie at Well#Y

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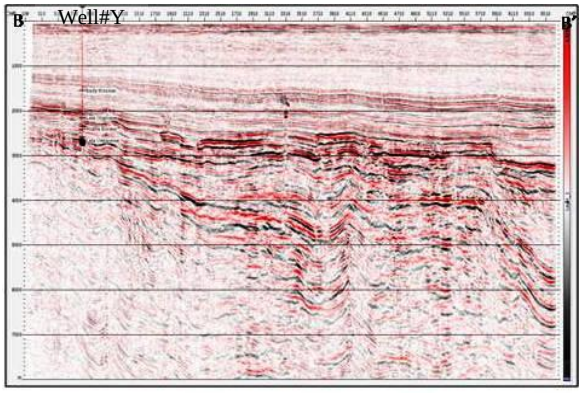
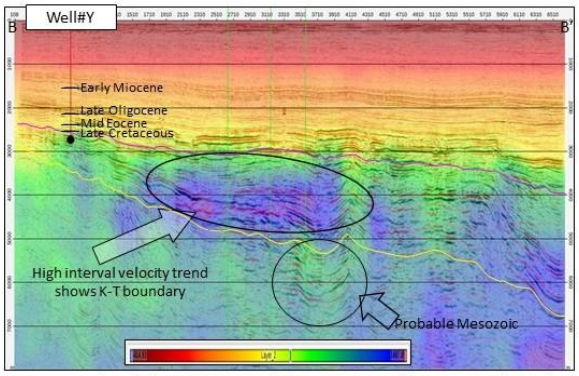


5.d Reprocessed PSDM Stack Section



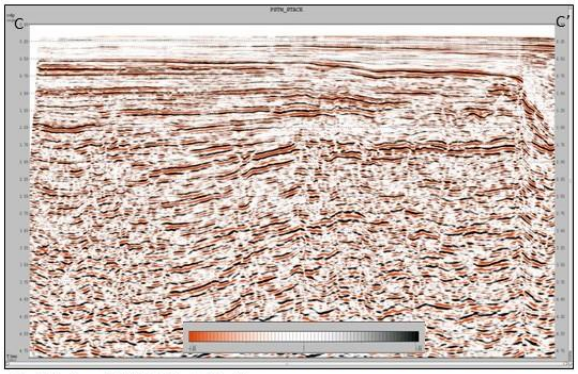
5.e Interval Velocity superposed on Reprocessed PSDM Stack Section

Figure 5: Seismic line BB' showing Mesozoic sequences

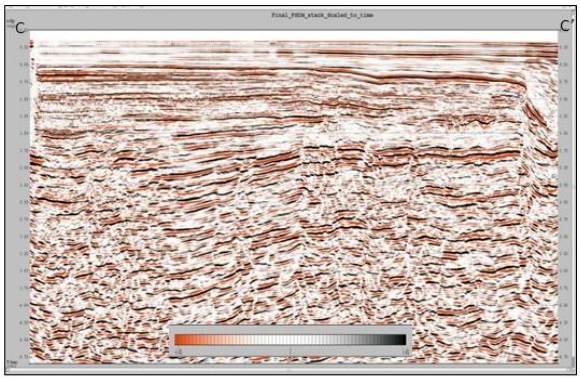
Figure 4, 5 & 6 are showing old vs newly processed sections along with interval velocity sections and synthetic seismograms of three 2D lines AA', BB' and CC' falling in three different areas of Western Offshore Basin respectively.

The interval velocity which incorporates the layer property of different formations, at places shows velocity reversal; this velocity reversal is due to transition of acoustic wave from high-density basaltic layer to comparatively low-density deeper Mesozoic/Cretaceous layer. In all the seismic sections velocity reversal is clearly visible. This indicates presence of Trap as well as Mesozoic sequences below.

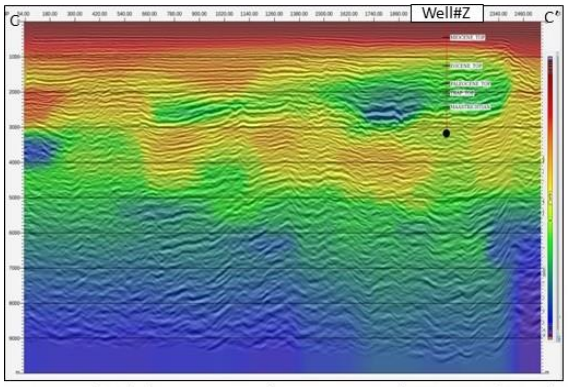
Well to seismic calibration with nearby wells (Seismic section AA' with Well#X, seismic section BB' with Well#Y and seismic section CC' with Well#Z) was carried out to validate the Mesozoic sequences. Wells are not falling exactly on the seismic lines (Offset between AA' and Well#X is 1.2km; Offset between BB' and Well#Y is 0.2km; Offset between CC' and Well#Z is 12km). Velocity trend of sonic log closely follows the seismic interval velocity.



6.a Vintage PSTM Stack Section



6.b Reprocessed PSDM Stack (Scaled to Time) Section



6.c Interval Velocity superposed on reprocessed PSDM Stack Section

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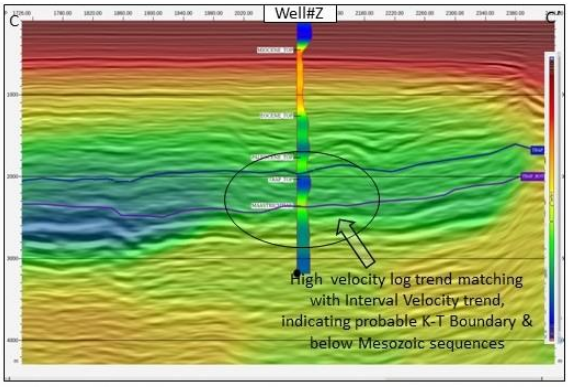

6.d Interval Velocity superposed on reprocessed PSDM Stack Section

Figure 6: Seismic line CC' showing Mesozoic sequences

Improved geological model, better processing techniques like use of various denoise/demultiple modules and adopting vertical as well as lateral velocity changes in the migration process significantly improve overall image quality. Thus presence of Mesozoic sequences can be identified below trap bottom.

Conclusions

Interval velocity reversal from Interval Velocity section along with newly reprocessed seismic section in the study area helps in mapping the Trap as well as in Mesozoic sequences. The methodology can be extended to the entire Western Offshore Basin and an integrated Mesozoic model can be prepared for prospectivity analysis.

Once the integrated Mesozoic model is prepared, the Mesozoic exploration strategy of Kutch-Saurastra Basin can be replicated in Mumbai Offshore Basin and as well as in Kerala-Konkan Basin.

Due to less offset in the vintage 2D data, image below Trap bottom is not clear at all the places. With better acquisition geometry and higher offset this limitation can be overcome.

Vintage 2D seismic lines have acquisition geometry constrain; but their reprocessed outputs give encouraging results. So reprocessing of old 2D lines at regular interval of time with improved processing techniques may lead the Geoscientists to new Hydrocarbon Exploration avenues.

Acknowledgement

Authors are thankful to Oil and Natural Gas Corporation Ltd. for providing the opportunity for this study. Sincere gratitude is expressed to Shri K Vasudevan, GGM-Basin Manager, WOB; and Shri S K Sharma, GGM-HGS, Mumbai for their technical guidance and support.

Authors are also thankful to Shri C P S Rana, GGM In-charge, SPIC and Shri M K Jain, CGM (GP), SPIC for their technical support and valuable suggestions.

Views expressed in this paper are that of the author(s) only and may not be necessarily of ONGC.

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