7th International Conference & Exposition
on Petroleum Geophysics

"HYDERABAD 2008"

P - 254

Sub Basalt Imaging Through Grid Based Tomography- A Case History from Western-Offshore Basin, India.

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Summary

Tomography is a method for refining the velocity /depth model when Pre Stack Depth Migration is performed with an improper velocity model. The degree of non-flatness of the resulting depth gathers determines the measure of error in the model. Tomography uses these measures of non-flatness as input, and attempts to find an alternate model to minimize the errors. The area under study belongs to south western offshore basin of India where potential exploration targets of Mesozoic sediments are overlain by Early Paleocene Deccan basalts. The rough and uneven nature of these basalts deteriorates seismic imaging of underlying Mesozoic sediments. Seismic expression of sub basalt section is of very poor quality data infested with multiples, high velocity diffractions and other noises making it very difficult to pick the horizons.

In areas of complex structures or of poor quality data which hinder interpretation and model building, Grid Based Tomography (GBT) enables to refine the depth images. Since Grid-Based Tomography does not require a complete model as input (meaning that not all horizons need to be part of the depth model, only the horizons that can be interpreted), it is useful in those cases where model-based tomography cannot be applied. Where it is difficult to pick the horizons clearly, GBT uses tomography segments on depth section/volume. These picks are performed in the velocity panel or section window and serve as guidelines for the tomography. The required inputs for grid-based tomography are depth gathers an initial velocity section or a residual move out section and tomography picks. The output of GBT is a new updated velocity section/volume.

The present paper describes the methodology, velocity model building to get Pre-Stack depth gather and depth images, picking of the tomographic events to get the updated velocity section/volume and finally the Pre-Stack depth images after refining velocity depth model using grid based tomography.

Introduction

The area under study falls in south western offshore basin of India (Fig-1). Even though Petroleum exploration efforts in the basin are on since 1970's, till recently they were mostly focused on to the post-trap Tertiary section confined to the shelfal shallow waters. Of late, sub-basalt Mesozoic sediments are viewed as potential exploration targets and extensive efforts are on to try map these sediments. Deccan basalts of Paleocene age which overlay these Late Cretaceous section play a detrimental role in seismic imaging of underlying Mesozoic sediments. Due to the rough nature of basalts, most of incident seismic energy tends to get scattered and as such, seismic expression of sub basalt section is that of very poor quality data infested with multiples, high velocity diffractions from basalts and other noises. Hence, state of the art techniques in seismic data acquisition and processing are warranted to improve the sub-basalt surface imaging.

The study area has been covered by closed grid 2D Seismic grid acquired during 1996 and 2002 by different agencies. Studies carried out in the area indicate presence of structural and strati-Structural features in post-basalt Tertiary and sub-basalt Mesozoic levels. As the sub-basalt events are not clearly discernable though basic processing, few lines in the area were identified (Fig-2) to **carryout PSTM/PSDM** with specific **objective of improving sub-basalt imaging** (Fig-2a: Line AA' and GG').

Methodology

Detailed analysis of acquisition and earlier basic processing parameters were carried out to understand the salient features. Close interaction between processor and interpreter helped to understand the Geological complexity. The processing efforts include basic processing, PSTM & PSDM processing using Promax and Focus/Geodepth software. PSTM and PSDM processing was attempted specifically to improve the sub-basalt imaging on two sets of data acquired during 1996 and 2002 with broad acquisition parameters as mentioned below:

Parameters	SET A	SETB
No of channels	96	184
Offset Near/Far (m)	222 / 2597	150 / 4725
Group Interval/ Shot interval (m)	25 / 25	25 / 25
Sample interval (ms)	2	2
Record length (sec)	6 / 7	7
Gun depth / Streamer depth (m)	6 / 10	6 / 8
Filters LC(Hz)/HC	3.5/ 128	1.98/ 205.9

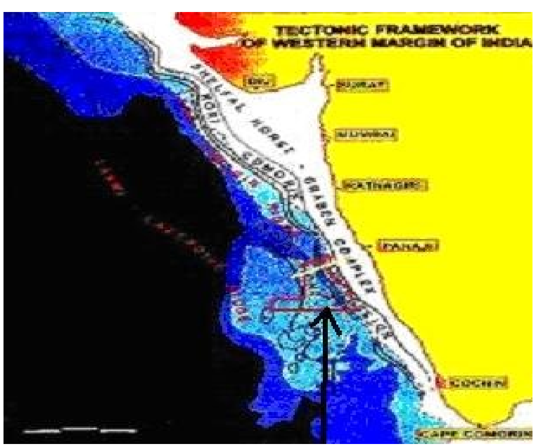


Fig-1: Tectonic frame work of western margin of India And location of area under study

Line AA', BB' & CC' are recorded by ONGC vessel in 1996 and DD', EE', FF',GG' are recorded by M/S Large in 2002.

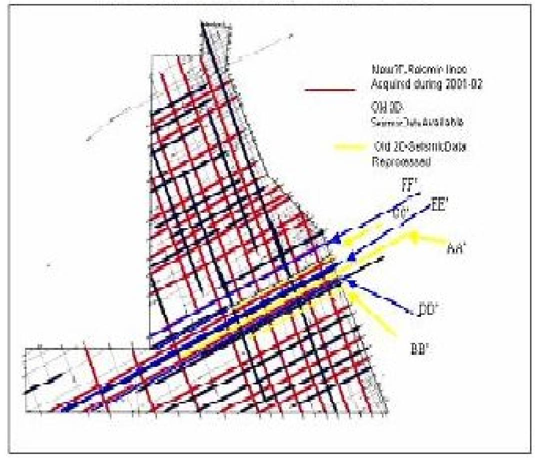


Fig-2: Seismic Location Map

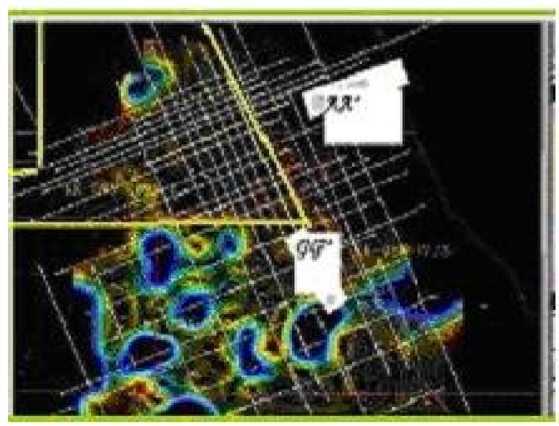


Fig-2a: Location Map of the Lines under study(AA'& GG')

Recent advances in computer–based processing systems have significantly reduced the processing time while improving the images in time and depth domain. Grid based Tomography was carried out on all the selected lines and with the help of accurate velocity depth model, PSTM/PSDM processing has produced spectacular results in terms improved subsurface images. In the present case, the whole data set was processed after removing the multiples to bring out the sub basalt events. Processing flow chart for basic and PSTM is shown in the flow chart below.

- Data reformatting from SEG Y to Promax format.
- Geometry application on the raw data
- Editing.
- Static application
- True amplitude recovery
- Band pass filter application
- Deconvolution Operator length / Gap - 240ms/12ms

Then the above input CMP gathers were exported in Geodepth software for PSTM/PSDM processing. After velocity picking, the velocity picks were exported in

Promax software for multiple attenuation. Comparison of CMP gathers with and without multiple is shown in Fig-3. The multiple attenuated CMP gathers were again exported to Geodepth software for PSTM. The processing flow for PSTM is given below:

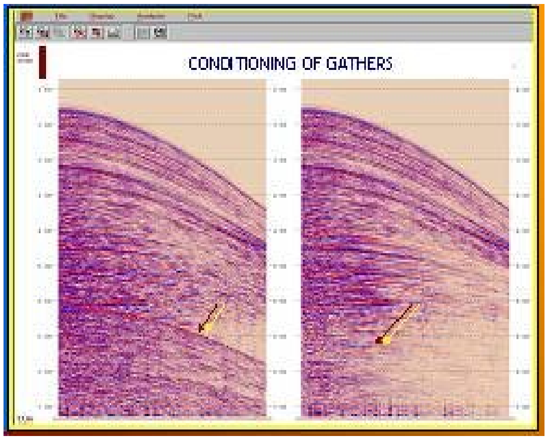
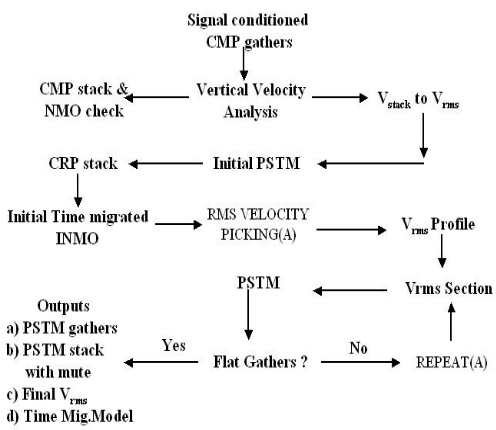


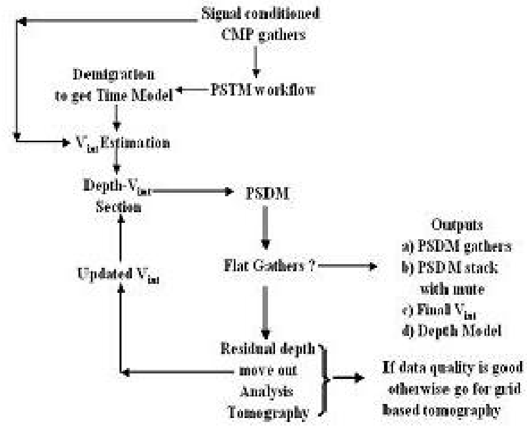
Fig:3 CMP Gathers with and without multiple

Simplified Workflow for Pre Stack Time Migration



For PSDM we need Interval Velocity and CMP gathers free from multiple. The interval velocity can be obtained either from RMS velocity by Dix conversion method or coherency inversion method. In the present case, the initial interval velocity depth model for selected horizons (traceable) was performed through coherency inversion method. By running Pre Stack Depth Migration, PSDM gathers and PSDM stacks were obtained. Detailed flow chart for running PSDM is given below.

Simplified Workflow for Pre Stack Depth Migration



The PSDM gathers with the initial interval velocity are flat for the interpreted horizons above basalt section. There are many ways to update interval velocity in depth by picking residual moveout along depth horizons, updating the model, and applying different types of tomography ie. Horizon based and grid based. Both are global solutions, they solve the matrix for all the horizons in one pass Tracking the horizons below the basalts were unreliable due to their poor standout and continuity. So it is difficult to pick horizons and build a depth model after migration The patchy events below the trap gives improper interval velocity and was not possible to carry out horizon based residual depth moveout analysis. (Horizon based tomography). In such a situation where data quality is very poor or geology is very complex , Dan Kosloff (1999) , Andy Furnish (2000) and Frank Dumanoir etal (2007) have published very good papers for updating the velocity section through Grid based tomography in which the input is interval velocity and PSDM gathers and the output is an updated velocity section , meaning that the tomography updated velocity section which is grid type of representation of the model.

To perform the grid-based tomography, reflection events are picked on pre-stacked depth images with significant amplitude (Fig.4) between the last correlatable horizon and a deepest level on the depth section below which velocity will not be updated., however at this stage there is no requirement to perform a geological interpretation or to associate the events with formation boundaries in a subsurface model. This is an advantage over horizon based tomography in cases where it is difficult to build a consistent model. The tomography internally creates correlated panels for all the CRPs of the tomography picks. The panels are muted automatically where the mute depends on the amount of residual moveout and signal to noise ratio. GBT can calculate residuals directly from the gathers or use a residual depth section as input . Ray tracing uses either a structural model or picked segments .The steps to be followed in carrying out grid based tomography are shown in Fig-5. GBT is an iterative process to update the velocity section, so , repeat the process until and unless satisfied with the velocity and output depth gathers (Fig-6: a.b,c). After optimizing the velocity (Final Grid interval velocity is shown in Fig-6d) run the final Pre Stack Depth migration to get the PSDM gathers and migrated images. (Fig-7) shows the update grid interval velocity and migrated PSDM gathers.

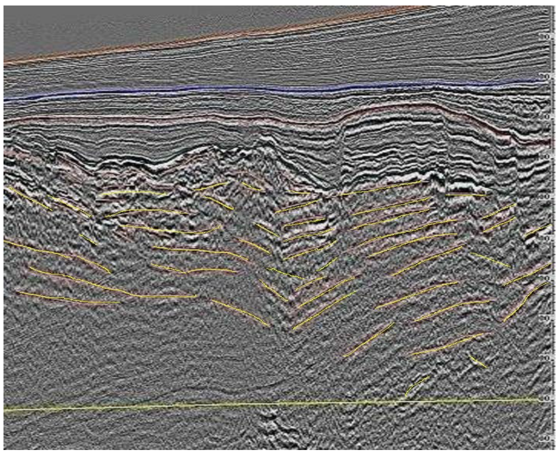


Fig-4:Grid Tomographic Picks on Migrated section

TO PERFORM GRID BASED TOMOGRAPHY
(2D TOMOGRAPHY)
SET THE PARAMETERS AS FOLLOWS
INPUT PICKS: TOMOGRAPHIC PICKS
INPUT DATA: DEPTH GATHERS
MAX DEPTH: MAKE SURE THAT BOTH THE INPUT AND OUTPUT IS THE VALUE FOR DEEPEST PICKS.
INPUT FILE: INPUT SHOULD BE FROM PREVIOUS ITERATION
OUTPUT : INTERVAL VELOCITY(GRID) AND PERFORM PSDM TO GET OUTPUT GATHERS AND MIGRATED IMAGES IN DEPTH DOMAIN.

Fig-5 Flow of grid base tomography

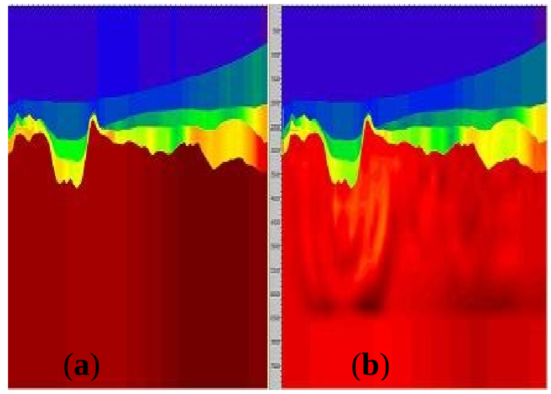


Fig-6 Interval Velocity- Initial (a) and after 1st Grid Tomography(b)

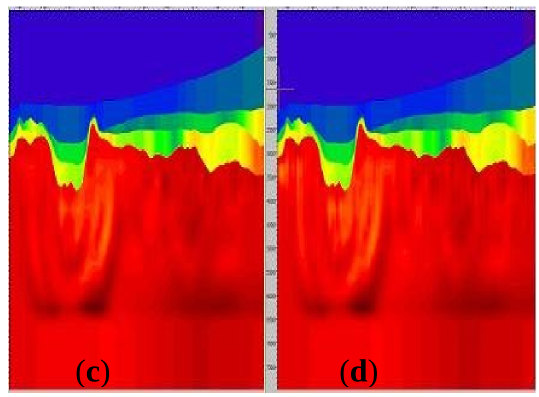


Fig-6 Interval Velocity after 2nd (c) and 3rd Grid Tomography(d)

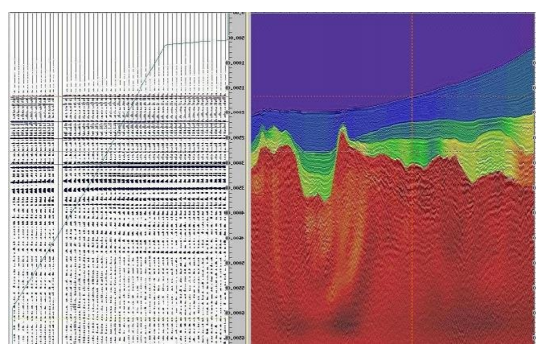


Fig-7: PSDM Gather with updated tomo-velocity

Observations and suggestions

Following are the observations made after running the grid based tomography for final depth images.

- The final interval velocity field (Fig-6d) particularly for the sub-basalt is more realistic compared to first stage interval analysis (Fig.6a) .
- The sub-basalt events are more easily discernable. Better structural configuration and fault definition have been brought out (Fig-8). PSTM section based on PSDM velocity and analysis shows marked improvement compared (Fig-9) earlier PSTM(Fig-10).
- Confirmation sub trap events enable the interpreter to re-define the horizons (Fig-11&12).
- Application of Grid based Tomography on Long Offset Seismic data specifically acquired for sub-basalt imaging would have brought more spectacular results.

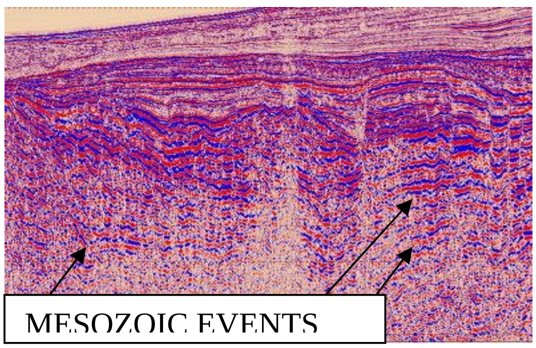


Fig-8: PSDM Stack with updated tomo-velocity

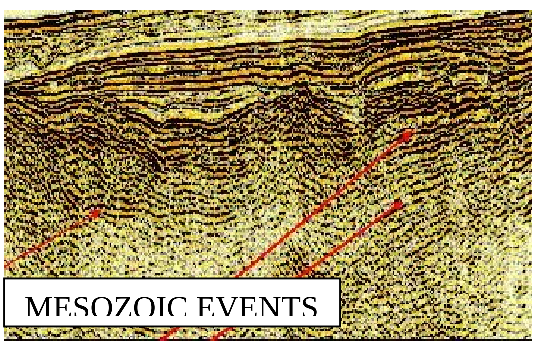


Fig-9: PSTM Stack with refined RMS velocity

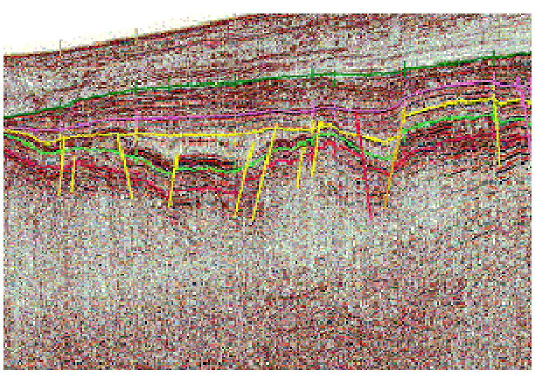


Fig-10: Earlier processed data line No AA'

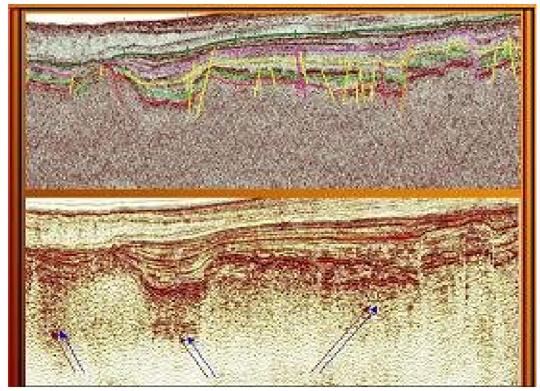


Fig-11: PSTM Stack of line no BB' showing Sub-basalt images

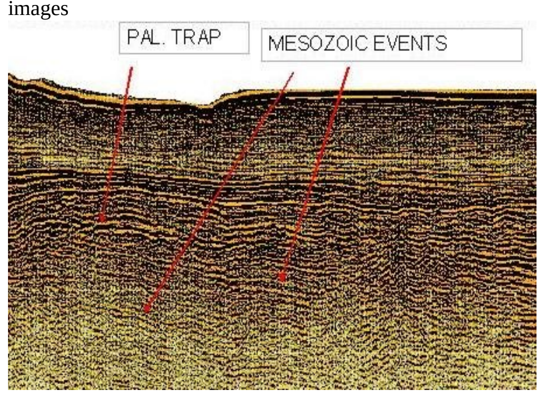


Fig-12: PSTM Stack of line no GG' showing Sub-basalt images

Acknowledgement

Authors are grateful to ONGC for providing opportunity and resources to work on this project. Authors are thankful to Director (E), ONGC for according his permission to present this work in present form. The authors are also thankful to those who are directly or indirectly helped in completing this paper Authors also state that views expressed here in are theirs and do not necessarily reflect the views of organization, they belong to.

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