

OBN and FWI - Significant Change in Subsurface Image, Case Study from Heera Field, Western Offshore Basin, India

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Keywords

Velocity Pitfalls, Pseudo Structural Sags, Anisotropic Pre-Stack Depth Migration (APSDM), Multicomponent Seismic Data Processing, Full Waveform Inversion (FWI), PP & PP-PS Joint Tomography, 4C-3D OBN Full Azimuth Seismic Data

Abstract

The present case study is from the Heera field of Western Offshore Basin, India. In this field, the shallow low velocity anomaly zones cause the velocity pushdown effect which results in pseudo structural sags in the time domain seismic data. Proper depth conversion through advanced imaging techniques may reveal the true structures that are masked in the time domain seismic data. The velocity model derived from the legacy seismic data of Heera field, recorded in 1999, with limited far offset, was not accurate enough to remove the effect of shallow low velocity anomalies from the subsurface image even after anisotropic Pre-Stack Depth Migration (APSDM). These shallow velocity anomalies cause the structural sags even in the deeper sections in anisotropic PSDM image which results in false imprints of low structure bounding faults. Advanced multicomponent seismic data processing, high resolution velocity modeling using Full Waveform Inversion (FWI), PP & PP-PS joint tomography and anisotropic PSDM of recently acquired 4C-3D OBN full azimuth seismic data brought out high resolution sub-surface image as compared to the anisotropic PSDM of limited offset and low fold old seismic data. The imprints of shallow low velocity anomalies, which cause pseudo structures in time domain seismic data, are minimized in OBN 4C-3D depth domain PSDM seismic data.

Introduction

Mumbai Offshore Basin, a pericratonic rift basin, lies in western continental margin of India. Towards NNE it continues into the onland Cambay Basin. It is bounded in the northwest by Saurashtra Peninsula and in the north by Diu Arch. Its southern limit is marked by east-west trending Vengurla Arch to the South of Ratnagiri and to the east by Indian craton. Five distinct structural provinces with different tectonic and stratigraphic events can be identified within the basin viz. Surat Depression (Tapti-Daman Block) in the north, Heera-Panna-Bassein Block in the east central part, Ratnagiri in the southern part, Mumbai High / Platform-Deep Continental Shelf

(DCS) in the mid-western side and Shelf Margin adjoining DCS and the Ratnagiri Shelf.

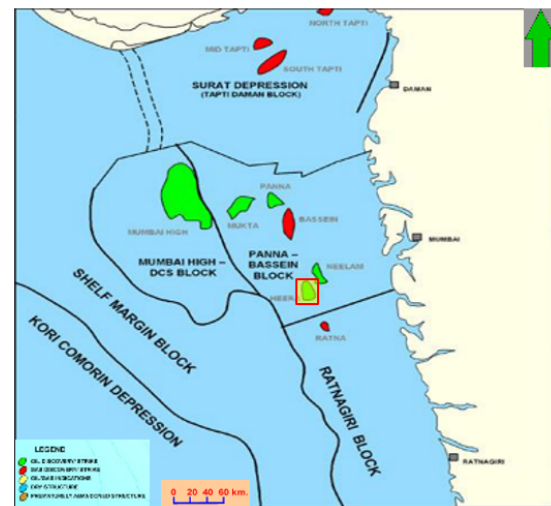
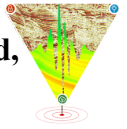


Figure-1: Index map of Western Offshore Basin

Heera field is the second largest oil field in Heera-Panna-Bassein block of Mumbai Offshore Basin. The field is located at about 70 Km south-west of Mumbai city and 140 km south-east of Mumbai High (Figure-1). The average water depth in the area is ~50 m. The field was discovered in 1977 by the drilling of first exploratory well. South Heera field is towards the south of Heera field and was discovered in 1990. Heera and South Heera fields were subsequently delineated with 11 and 7 exploratory wells and put on production in 1984 and 1995 respectively. Both fields proved to be major hydrocarbon bearing structures with a number of reservoirs of commercial oil and gas accumulations. The entire sedimentary succession is from Paleocene to recent comprising Panna, Bassein, Mukta, Heera, Alibag, Bombay, Bandra and Chinchini formations. In Heera Field, hydrocarbon bearing pays are Basement, Panna, Bassein, Mukta, and Heera formations (oil & gas) and Bandra Formation (free gas). In South Heera field, oil accumulation encountered in Panna, Bassein, Mukta and Heera formations. At present there are 25 production



platforms and more than 600 wells including exploratory, development, sidetracks and water injectors in the field.

Case History

In Heera field, the legacy 3D seismic data was recorded in 1999 with nominal fold of 60, bin size of 12.5 m X 25 m, sample rate of 2 millisecond, record length of 4 second and far offset of ~2200 meters. With the limitation of the available far offset as well as low fold of the seismic data, the velocity model derived from the legacy seismic data was not accurate enough to remove the effect of shallow low velocity anomalies from the subsurface image even after anisotropic Pre-Stack Depth Migration (APSDM). These shallow low velocity anomalies cause the velocity push down effect or structural sags even in the deeper sections in anisotropic PSDM image which results in false imprints of low structure bounding faults at several places in Heera field.

So, with an objective to have latest seismic data in brown fields (viz. Neelam & Heera) with ~40 production/ injector platforms & ~1000 exploratory /development / sidetrack / injector wells and to address challenges like accurate subsurface imaging, karst delineation in Neelam field, fracture characterization of Basement of Heera field & advanced reservoir characterization (PP-PS joint inversion) to locate the bypass oil, 4C-3D full azimuth OBN seismic was acquired in 2019. The area of operations was ~750 km². The survey was designed with a total of 27,425 nodes. The multicomponent data was recorded with dual airgun as the seismic source, nominal fold of 400, sample rate of 2 millisecond, record length of 12 seconds, bin size of 25m x 25m and SEG Normal Polarity (i.e., increase in impedance represented by a peak).

Advanced multicomponent seismic data processing, high resolution velocity model using 5 band Full Waveform Inversion (FWI) & joint PP-PS tomography was carried out to get high resolution sub-surface image. The workflow adopted for advanced velocity modelling includes initial model building, five band FWI, model merging, four iterations of PP CIP reflection time tomography and three iterations of PP-PS joint reflection time tomography. The details of the adopted workflow are shown in figure 2.

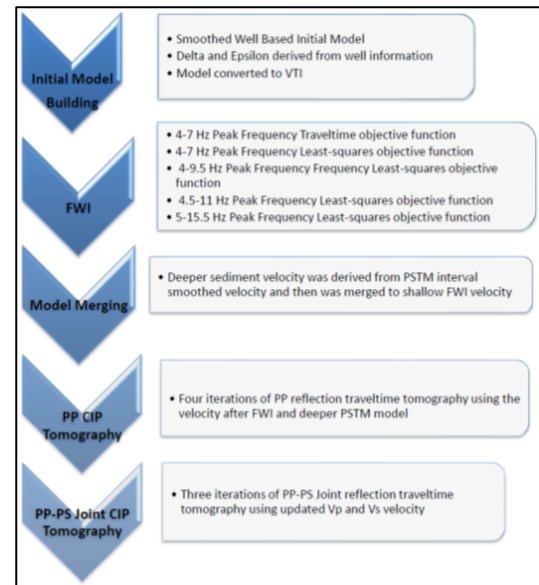


Figure-2: Adopted workflow for advanced velocity modelling

For a crossline, the initial vis-a-vis final velocity overlay on depth stack are shown in Figure-3 (a) and (b) respectively. It is clear that low velocities zones in shallow sections are properly captured in final velocity and their imprints in final depth stacks are minimized. Interpreter may put structure bounding faults in the highlighted area as per figure 3(a), but actually there are no/very less imprints of such faults in final PSDM stack as shown in figure 3(b).

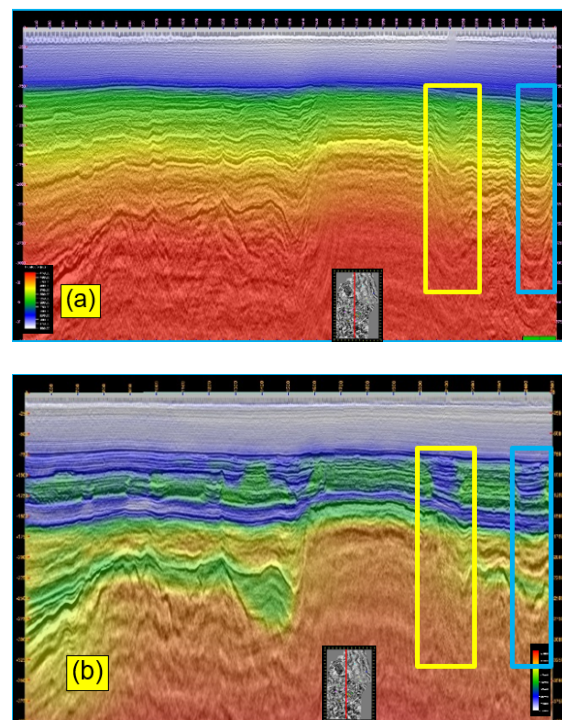
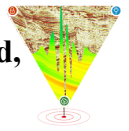


Figure-3: (a) Initial velocity section vis-à-vis (b) final velocity section overlaid on depth stack along a cross-line



To analyze the effects of such shallow low velocity anomalies, the time domain PSDM & depth domain PSDM seismic sections were scanned throughout the area. A crossline from time domain PSDM & depth domain PSDM seismic are shown in figure 4(a) & 4 (b) respectively and it is very much clear from these two figures that effect of these shallow low velocity features is very much present in time sections because of the inherent limitation of the time domain seismic data but their imprints are minimized in PSDM depth sections. The deepest horizon in blue circled area is structurally low in time domain seismic section while the same represents a structure high in depth domain seismic section. The highlighted zone in time section indicates the presence of structure bounded faults but same areas in depth section clearly depicts the absence of such faults.

As fault plays an important role in entrapment of hydrocarbon, understanding the hydrodynamic behavior & distribution of fluids and defining the facies/permeability barrier across different compartments in the field, fault interpretation in time domain seismic data with pseudo structure sags and appearance of pseudo structure bounding faults may led to false interpretation of subsurface. Therefore, fault interpretation was attempted in time domain as well as in depth domain PSDM seismic data to ascertain the sanctity of the faults and its further utilization in maps & subsequent use in static model.

For detailed analysis, discontinuity attributes were computed for both time as well as depth domain PSDM seismic data. The slices were extracted from discontinuity volumes derived from both time & depth PSDM stacks. The time, depth and horizon slices corresponding to various formations were analyzed in detail before finalization of fault framework. Figure 5(a) & (b) represent the discontinuity slices corresponding to Basement Formation derived from time & depth domain PSDM seismic respectively. It is evident from both the figures viz. 5(a) & (b) that imprints of E-W trending faults highlighted with red, yellow & blue polygons are very much prominent in time domain seismic derived discontinuity slice because of inherent nature of time domain seismic data while their imprints are minimized in depth domain PSDM seismic derived discontinuity slice because of utilization of advanced velocity modelling techniques viz. FWI during processing.

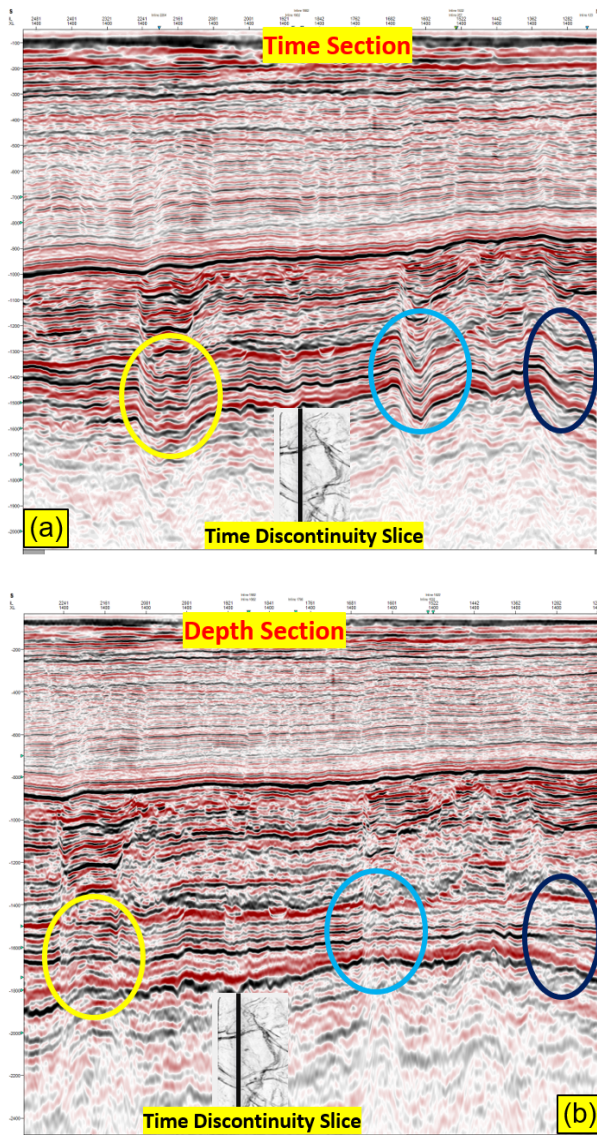


Figure-4: (a) Time Scaled PSDM and (b) PSDM depth stack sections along a cross-line

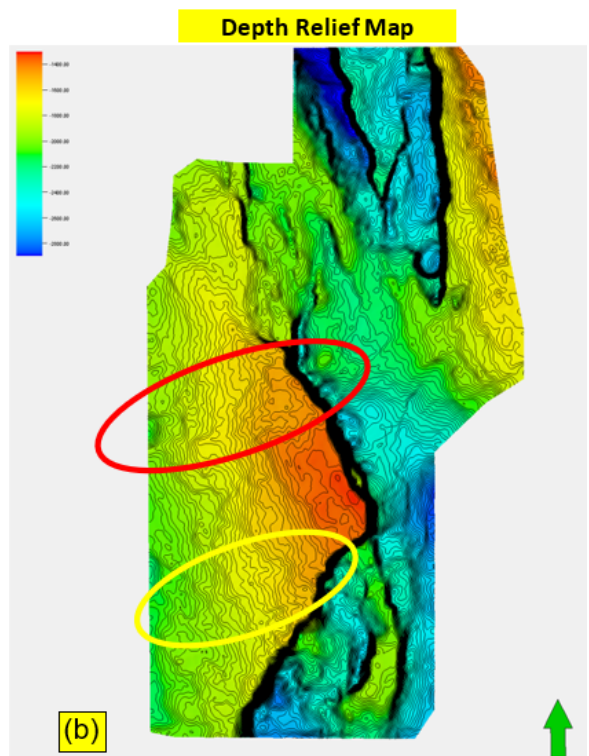
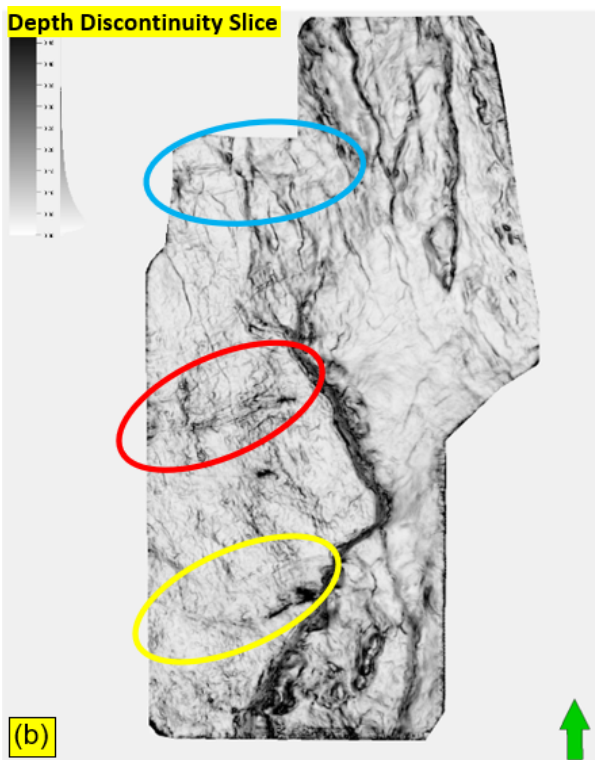
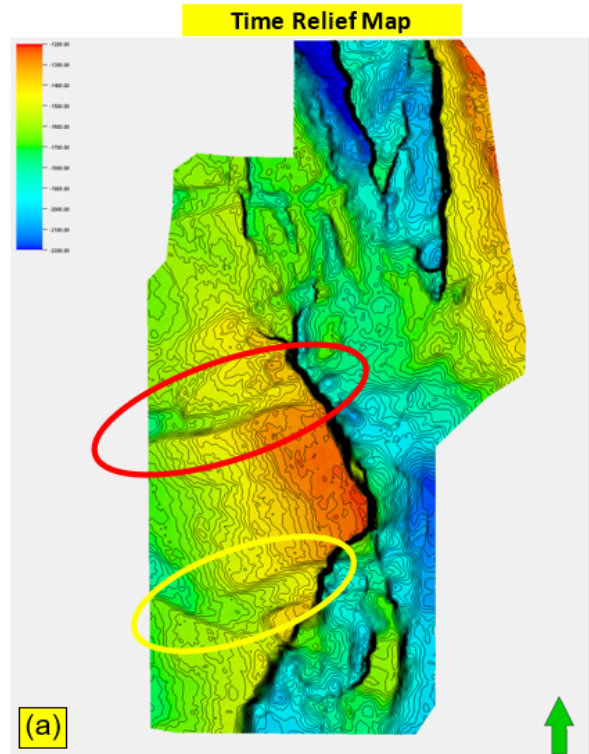
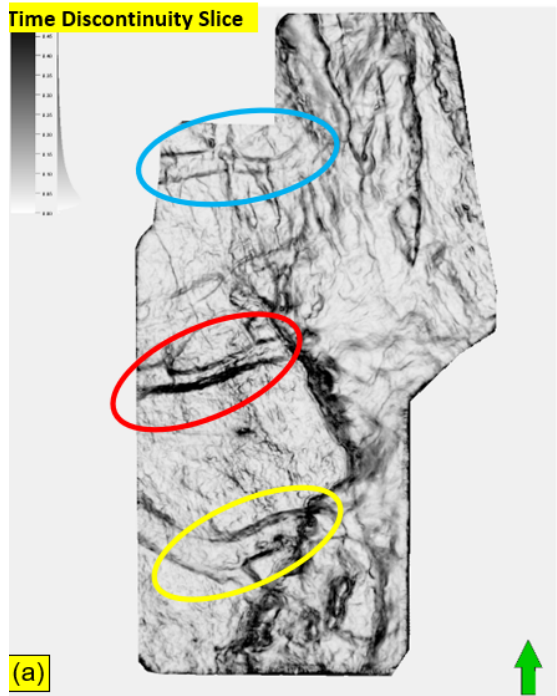
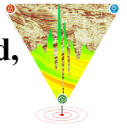
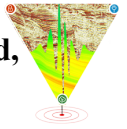


Figure-5: Discontinuity slices from (a) Time scaled PSDM (b) PSDM depth stacks

Figure-6: (a) Time relief map and (b) Depth relief map of Basement Formation

Results and Discussions

Advanced multicomponent seismic data processing, high resolution velocity modeling using Full Waveform Inversion (FWI), PP & PP-PS joint tomography and anisotropic PSDM of 4C-3D OBN



full azimuth seismic brought out high resolution subsurface image as compared to the anisotropic PSDM of legacy seismic data. The imprints of shallow low velocity anomalies, which cause pseudo structures in time domain seismic data, are minimized in OBN 4C-3D depth domain PSDM seismic data.

Delineation of faults is of utmost importance during every phase of oil field cycle viz., exploration, appraisal, development and development. So, fault delineation in time domain seismic data with pseudo structure sags and appearance of pseudo low bounding faults may led to false interpretation. Therefore, fault interpretation was attempted in time domain as well as in depth domain PSDM seismic data to ascertain the sanctity of the faults and its further utilization in maps & subsequent use in static model.

In case of presence of velocity anomalies, it is recommended that fault interpretation has to be carried out in depth domain PSDM seismic data to get the real picture of sub-surface.

Conclusions

This case study focused on the Heera field of the Western Offshore Basin of India and addressed the challenges of accurate imaging the subsurface due to presence of shallow low velocity anomalies. The legacy seismic data recorded in 1999 with limited far offset and low fold was not able to remove the effects of these anomalies even after anisotropic Pre-Stack Depth Migration (APSDM). The shallow velocity anomalies caused structural sags and false imprints of low structure bounding faults in the seismic data.

To overcome these challenges, advanced multicomponent seismic data processing and high-resolution velocity modeling techniques were employed. Full Waveform Inversion (FWI), PP & PP-PS joint tomography, and anisotropic PSDM of recently acquired 4C-3D OBN full azimuth seismic data were utilized to improve the subsurface image. These techniques brought about a refined sub-surface image compared to the anisotropic PSDM of the legacy seismic data. The imprints of shallow low velocity anomalies, which caused pseudo structures in the time domain seismic data, were minimized in the OBN 4C-3D depth domain PSDM seismic data.

The study highlighted the importance of accurate fault interpretation in the presence of such shallow low velocity anomalies. Fault interpretation in time domain seismic data with pseudo structure sags and false low bounding faults may lead to inaccurate

structural interpretations. Therefore, it is recommended to attempt fault interpretation in the depth domain PSDM seismic data to obtain a more reliable representation of the subsurface.

Overall, the 4C-3D OBN seismic data and high-resolution velocity modeling using Full Waveform Inversion (FWI) provided a refined subsurface image of the Heera field in comparison to the legacy seismic data.

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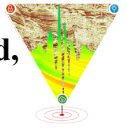
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However, the views expressed in the paper are those of the authors only.

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