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Robust Low Frequency Model is the key to improve the accuracy of Pre-stack Inversion results: Case study from Contai, Bengal Basin, India

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Abstract

Seismic Inversion process adds missing low frequency information below the seismic band and extends the bandwidth, improves the resolution. Lacking of low-frequency components loses the basic information of geological structure, which brings difficulties on quantitative prediction of rocks elastic properties. Compensation of low frequency information is very important to get the absolute value of the rock properties in subsurface. In the LFM, creates structural grid by using interpreted Horizons and then use well logs to populate with back ground trend of elastic properties. There is always uncertainty in the interpolation and extrapolation in the area, where doesn't have well control.

We proposed an innovative approach to improve the accuracy of LFM model by first combining the seismic RMS velocity, additional Horizon layers and log information as a priori information in the model to get the absolute elastic properties. First pass simultaneous inversion was run using the initial LFM model. Inversion outputs were applied Hi cut filter (10/15 Hz) and were used as trend for rebuilding the model again to be used in simultaneous inversion as second pass. This approach has improved the Pre-stack inversion results, especially at the southern part of study area where doesn't have well control.

Introduction

In pre-stack seismic inversion, conditioned seismic gather data are inverted to generate the elastic rock properties, which are qualitatively used to predict reservoir rock properties. Calibrations between elastic and reservoir rock properties are used to make predictions away from well control. Quality and reliability of these predictions depends on seismic gather data quality, amount of Impedance variations in rock properties, the quality of parameters input to the Inversion, well to seismic Tie, wavelet and the Low frequency Modelling to add the missing low frequency content in the seismic data.

Conventional seismic data are generally band limited and lack low and high frequency components. Missing of high frequency components limits the resolution of seismic data while lacking of low-frequency components lose the basic information of geological structure, which poses difficulties on quantitative prediction of elastic properties through pre-stack simultaneous inversion. Compensation of low frequency information is very important for obtaining the absolute value of the rock properties. All seismic inversion methods require knowledge of the low frequency trends corresponding to the required elastic properties – usually P Impedance, Vp/Vs and Density. Typically, this low frequency band ranges from 0Hz to 10 Hz. Seismic RMS/Interval velocities derived from stacking velocities can often be used to compensate the lowest 2 or 3Hz band and at the same time it can provide the trend for interpolation of elastic logs during model building.

The study area is Contai block which is located in in the southern part of onland Bengal Basin, India (Fig.1). Bengal basin is a poly cyclic basin evolved through two distinct tectonic episodes. It initiated as intra-cratonic rift basin within Gondwana land during the Paleozoic-Mid- Mesozoic time. After separating from Gondwana land, it kept on moving northwards and in second phase collided with Eurasian plate causing folding and thrusting of Tethian sediments to build Himalayan orogenic belt. Four exploratory wells were drilled in the Contai area to explore the Hydrocarbon potential of Palaeogene sequence. Two wells encountered Palaeocene play and flowed 100m^3 gas during testing of one well.

The study area consists of three wells and merge 3D seismic gather of two seismic investigations. Recorded shear-wave logs were available in two wells and it was generated through rock physics modeling for the third well. Pre-stack simultaneous inversion was carried out to explore the hydrocarbon potential of the block in terms of elastic properties like P-impedance, Vp/Vs and Density.

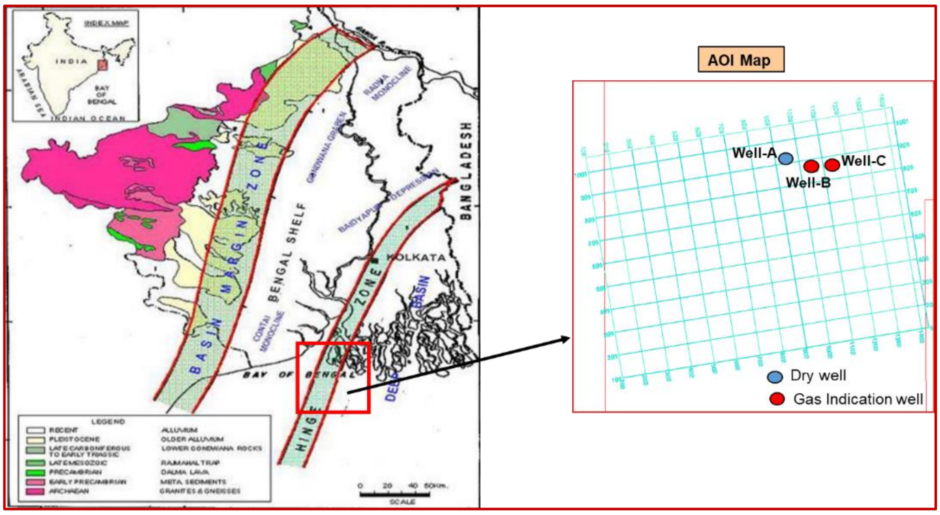

Figure.1 Basemap of the study area

The seismic data coverage along with the available wells in the study area are shown in (Fig.2). Merge PSTM gathers are available with usable offsets of 100 to 2400m and having frequency range of 8 to 50Hz at -12dB. Four partial angle stacks, namely 3^0- 12^0, 10^0-19^0, 17^0-26^0 & 24^0-33^0 were generated after conditioning of gathers and were used in pre-stack simultaneous inversion to generate the elastic properties.

An innovative approach was adopted to improve the of low-frequency model by first combining the seismic RMS velocity, additional horizons and log information as a priori knowledge. First pass pre-stack inversion was run using the above low frequency model. Low frequency model was again improved by using the Hi cut filter (10/15Hz) applied first pass pre-stack inversion results (P-Impedance, S-Impedance, Vp/Vs ratio, density) as a trend in co-kirging. The approach accounted the lateral geological changes and made the model much more realistic. The present case study shows the improved pre-stack inversion results which may be attributed to the improvement in the low frequency model.

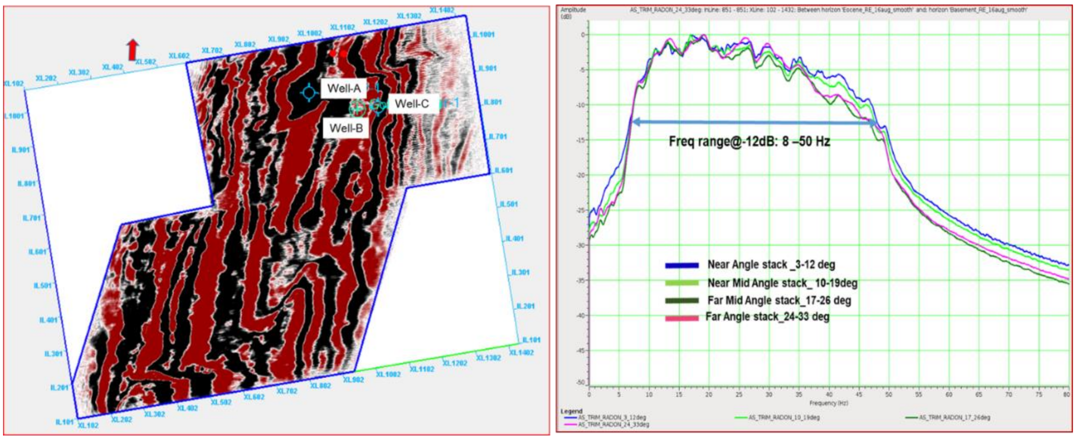

Figure.2 Map showing (left) Seismic coverage and drilled wells in the study area and right side showing Frequency Amplitude spectrum of Four angle stacks used in the Pre-stack simultaneous inversion.

Mapping of Additional Horizons

Total five Horizons (H1 to H5) have been interpreted using the merge PSTM stack. Apart from the five interpreted horizons, 4 more surfaces (H1A to H4A), in the zone of interest, were mapped using artificial intelligence-based tool named Seisnetics. It uses the power of genetic algorithms and artificial Intelligence (AI) to segment & organise 3D seismic data into “genetically” similar wavelet packages called Geopopulations (figure 3). Finally, nine horizons were incorporated in low frequency model building which provided more confidence in the process.

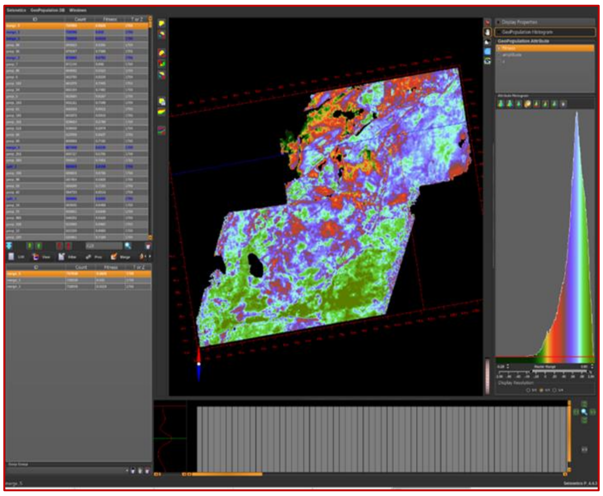

Figure.3: Fitness map of extracted Horizon H2A, indicates the seismic waveform variability and confidentity of Geopopulated Horizons.

Low Frequency Modelling

Conventional seismic data is band limited where both low and high frequencies are absent. Low frequency model is added to fill the lower part of frequency band. Usually, low frequency model provides the low frequencies trend and absolute value to the inversion results. Seismic velocity provides information up to 2-3 Hz in general. Seismic RMS velocity was used to compensate this low frequency component during first pass low frequency model building with high cut filter 10/15Hz, along with 3 wells and 7 number of horizons within the zone of interest, followed by pre-stack deterministic inversion.

The elastic properties volumes, P-Impedance, S-Impedance, Vp/Vs and Density were generated during first pass simultaneous inversion. High cut filter of 10/15 Hz was applied on the first pass inversion results and were used as a trend to update the low frequency model again. The workflow adopted is shown in Fig.4.

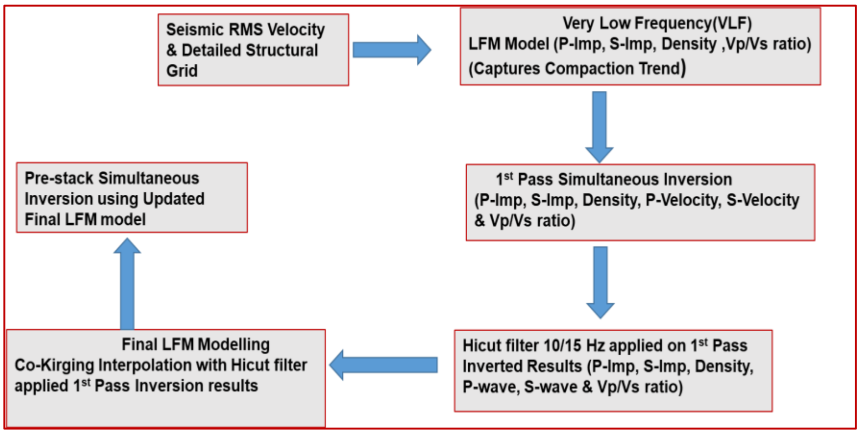

Figure.4: Working process for Low Frequency Modelling

Arbitrary sections of modelled elastic properties from the two successive passes are shown in Figure 5a & 5b. Highlighted portions of final LFM section shows significant improvement, especially in those areas, where there is no well Control, i.e. in the southern part of study area.

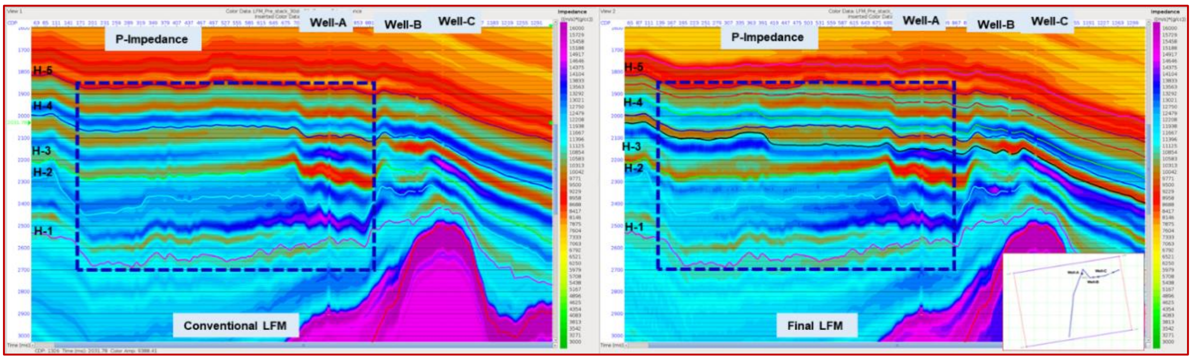

Figure.5a: RC section of conventional LFM P-Impedance (left) and Final LFM P-Impedance with innovative method, Highlighted box shows significant improvement in the modelling low frequency information.

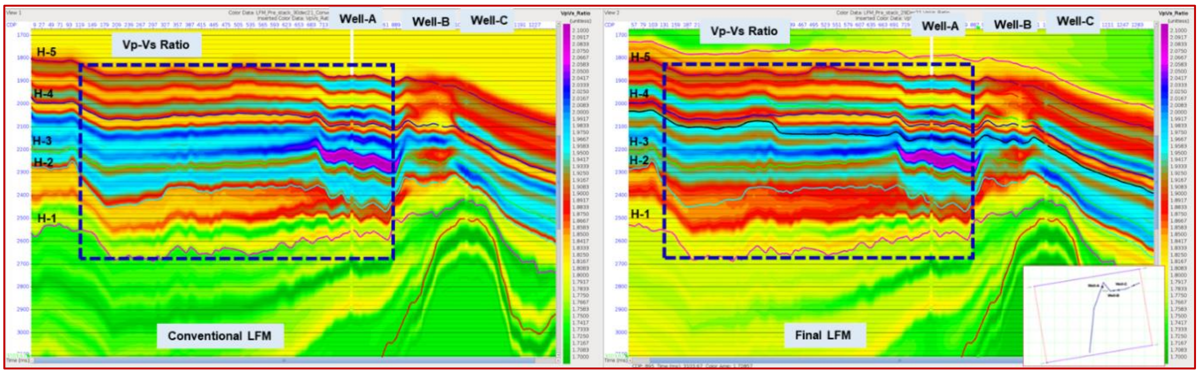

Figure.5b: RC section of conventional LFM Vp-Vs ratio (left) and Final LFM Vp-Vs ratio with innovative method, Highlighted box shows significant improvement in the detailing of low frequency information.

Results

The first pass conventional low frequency modeling and simultaneous inversion followed by second pass low frequency model building and pre-stack simultaneous inversion improved the results significantly in terms of absolute values of generated elastic properties and better definition of the features. The improvements in the inverted results, especially in the southern part of study area where there is no well control are shown in Fig.6 & 7.

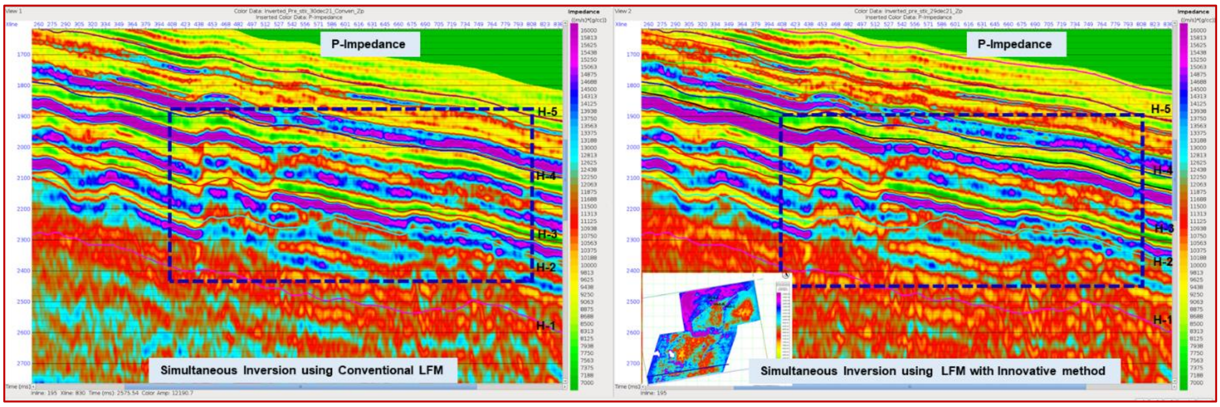

Figure.6: IL section of conventional inverted P-Impedance (left) and Inverted P-impedance using LFM with proposed method (right) shows significant improvement in the inverted results, improves the detailing of sub layers.

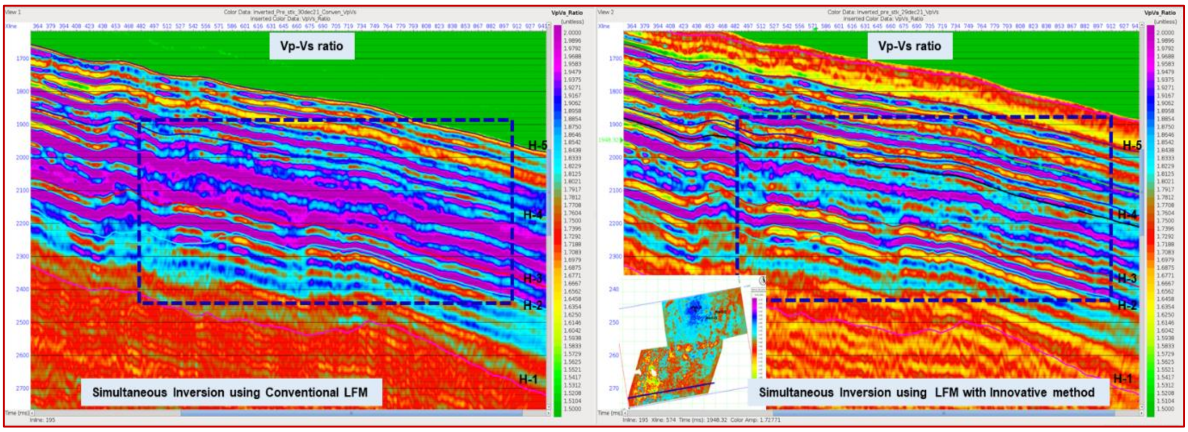

Figure.7: IL section of conventional inverted Vp/Vs ratio (left) and Inverted Vp/Vs using LFM with proposed method (right) shows significant improvement in the inverted results, improves the detailing of sub layers.

Data slices extracted from inverted P-impedance & Vp/Vs ratio volumes using both the approaches along Paleocene play time equivalent horizon with window 20ms centred shows better reservoir facies disposition in the proposed approach data slice as per geological understanding of the area, especially in the southern part, where there is no well control and it is shown in Figure.8 & 9.

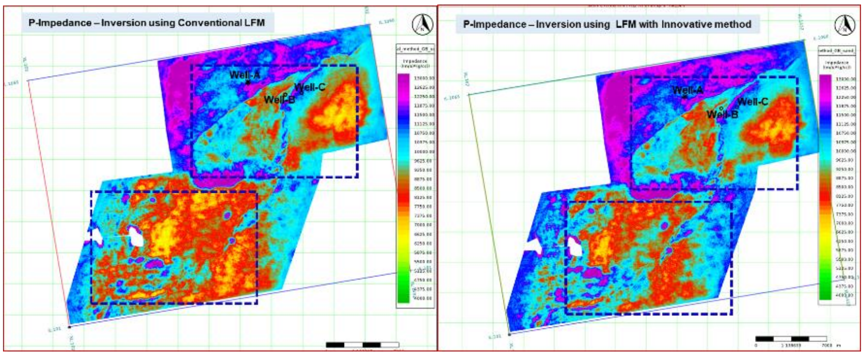

Figure.8: Data slices of Inverted P-Impedances generated from both the approaches extracted along the horizon Paleocene play time equivalent Top with 20ms centred window. Proposed method shows significant improvements in the reservoir facies disposition, especially at the southern part of study area, where well log information is missing.

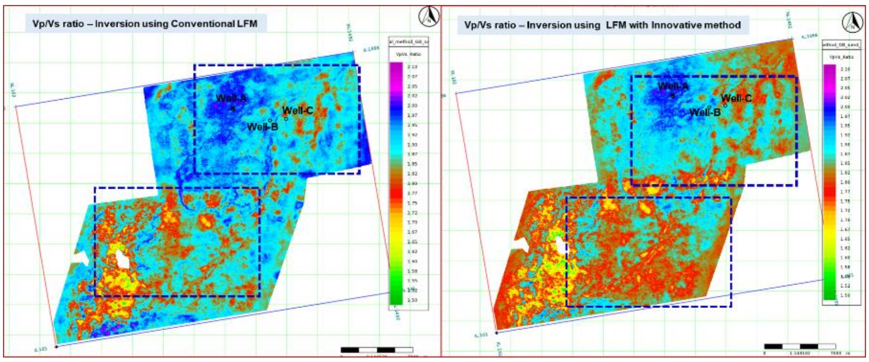

Figure.9: Data slices of Inverted Vp/Vs ratio generated from both the approaches extracted along the horizon Paleocene play time equivalent Top with 20ms centred window. Proposed method shows significant improvements in the reservoir facies disposition and open up new areas for further exploration.

Conclusions

A robust Low frequency model is important for good pre-stack simultaneous Inversion outputs. It helps to generate reliable Petro-physical properties of reservoirs from the elastic properties. The workflow minimises the risk of uncertainty in the interpolation and extrapolation of elastic properties in the limited well constrained area as demonstrated in the paper. The present approach of Low frequency Model building by integrating information from different sources like Wells, Seismic RMS velocity, more number of horizons, and trend from 1st pass Inversion makes the model robust and improves the absolute values of inverted elastic properties.

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References

Simon Voisey and David Monk, The building and application of seismic interval velocity used as an initial model in a pre-stack Seismic inversion, SEG New Orleans Annual Meeting, pp.3403 - 3407

Qilong Xia , Lixin Tian and Donghong Zhou, Low frequency model building based on relative impedance inversion to improve the accuracy of pre-stack simultaneous inversion：a case study from R oilfield in Bohai Bay, China, SEG Las Vegas 2012 Annual Meeting, pp.1 - -5

Vaughn Ball, Luis Tenorio, Christian Schiott , J. P. Blangy and Michelle Thomas, Uncertainty in inverted elastic properties resulting from uncertainty in the low-frequency model, The Leading Edge, Sep2015, pp. 1028 –1035

Brian cerney , David C. and Bartel, Uncertainties in low-frequency acoustic impedance models, The Leading Edge, January 2007, pp.1028 – 1035, pp 74 - 87

John Pendrel, Low frequency models for seismic inversions: strategies for success, SEG New Orleans Annual Meeting, 2015, pp.2703 - 2707

Patrick Connolly, Inversion of seismic data for reservoir properties: recent advances and the road ahead, SEG International Exposition and 87th Annual Meeting, 2017, pp.5267 - 5272