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An Integrated analysis of Seismic Impedance with Petro-Physical Data for identification of Porosity Behaviour in Oligocene Lime Stone of D18 Area Of Western Offshore, India

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Summary

3D seismic inversion in integration with petrophysical properties has been qualitatively and quantitatively used in reservoir characterization of Oligocene Limestone reservoir in D18 area which lies in the southern part of Bombay High-DCS of Mumbai Offshore Block, Western Offshore Basin of India. Hydrocarbon accumulations have been established from three different levels of Oligocene Limestone reservoir in a number of wells while a few wells are dry. The aim of study was to define the limits of these pays and to separate out the tight carbonate zones to avoid dry hole drilling. Seismic inversion was carried out over PSTM seismic data enhanced for higher resolution using 'Spectral Bluing' technique. Top of Pays could be accurately correlated using impedance data. Petro physical study was carried out by cross plotting different reservoir parameters with well impedance and inverted impedance volume was calibrated with reservoir parameters. Porosity volume was computed by acoustic impedance using multi-attribute analysis algorithm with EMERGE and was used to find out distribution of porosity in the area. The study could define the limits of Oligocene pays and also could separate tight carbonate zones and may be a good guide for further hydrocarbon exploration targets.

Introduction

Reservoir characterization requires building a spatial model of the reservoir by using appropriate data gathered from different studies. This spatial model is then used in flow simulators, which can predict reservoir performance. An accurate and reliable reservoir characterization study is indispensable in reservoir management. Seismic inversion has been used for several decades in the petroleum industry, both for exploration and production purposes. During this period, seismic inversion methods have progressed from the initial recursive inversion method to the present plethora of methods/software packages available to transform band-limited seismic traces to impedance traces. The application of seismic impedance data has also progressed from qualitative assessments of prospects to the quantitative description of reservoir properties necessary for reservoir characterization. Seismic inversion still remains a powerful tool in defining reservoir, if integrated judiciously, with geological, petrophysical and production data.

The study is a part of detailed G&G study in D-18 field located on westerly dipping, gentle homoclinal part of Bombay High-DCS block (Fig.1). Exploratory drilling in D-18 field commenced during the year 1985 and a total number of nine wells have been drilled so far. Out of these, hydrocarbon at levels of Oligocene Limestone reservoir has been established.. A complete knowledge of distribution of Oligocene pays and favorable reservoir properties along with structure has been felt necessary before further exploration and development of the field.

The present study covers approximately 800 sq. km. of PSTM seismic volume and wire line logs of 9 drilled wells.

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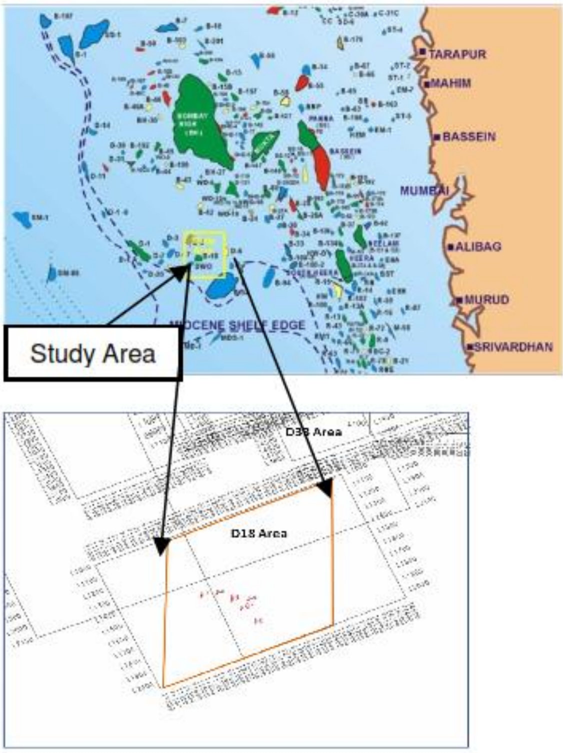

Fig.1: Location Map

Methodology

Seismic data enhancement (Spectral Blueing):

The quality of PSTM seismic data was fairly good. However, restricted seismic resolution imposes limits on the detection of subsurface geological features using surface seismic data. Despite great improvements in acquisition and processing techniques in recent years, seismic data still suffer from its limited resolution problem. We have attempted to enhance the surface seismic data resolution using the spectral blueing technique. Well log data generally show a blue spectrum with higher amplitudes at the higher frequencies than the generally assumed white reflection series. By designing and applying one or several operators to post-stack data it has been possible to better match the reflectivity series and improve resolution (Fig.2,3,4). Seismic inversion with spectrally blued data helped in resolving the pay zones vertically.

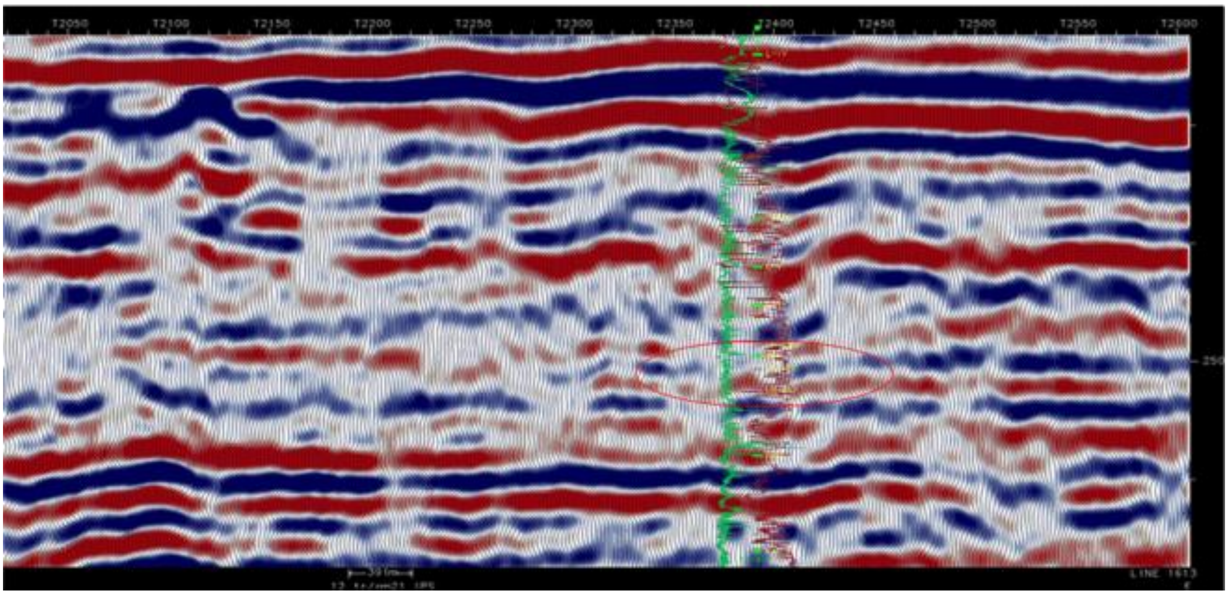

Fig.2: In Line 1613 from PSTM 3D seismic data

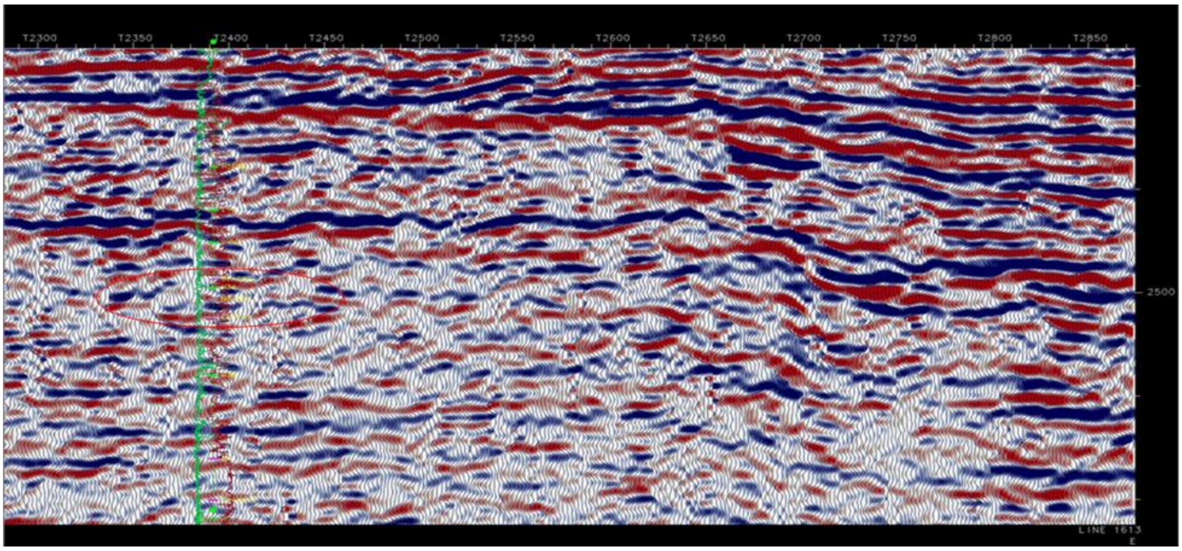

Fig.3: In Line 1613 after applying Spectrum Blueing on PSTM 3D seismic data

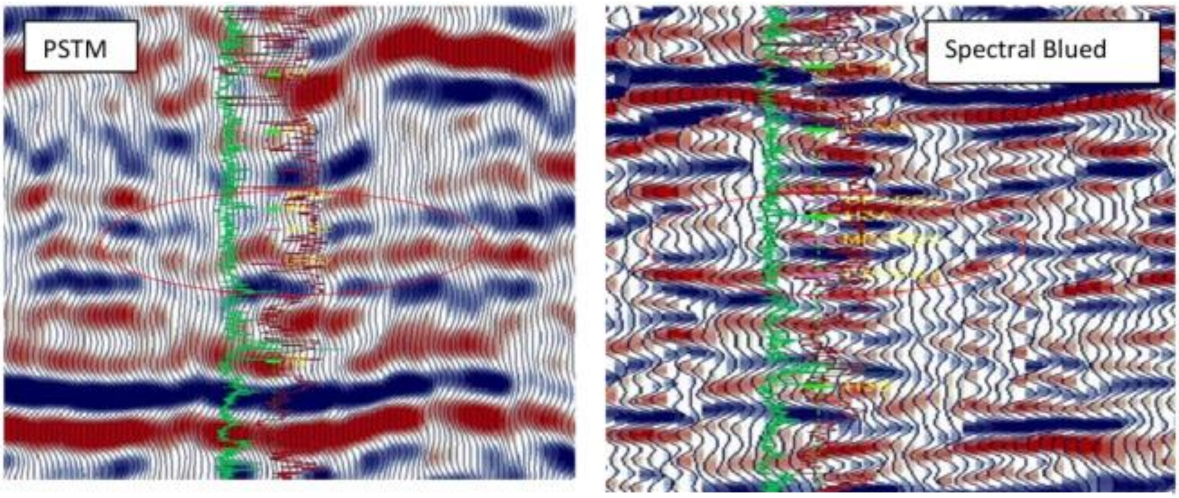

Fig.4: Zoomed sections of In Line 1613. Comparison for frequency enhancement after applying Spectral Blueing

Seismic Inversion

Model based post stack seismic inversion was carried out using spectrally blued seismic 3D volume. Horizons, correlated and mapped for G&G study, were used as geological constrains. Total six horizons were used in preparing initial model. It was not possible to correlate and map the tops of three Oligocene Limestone pay layers in normal seismic volume. However, these layers were tracked over inverted impedance volume and quite accurately correlated. Incorporating these additional horizons, a new model was created and data was again inverted with the new model. Low frequency trend was extracted from nine wells in the area having Sonic and Density logs. Synthetic from these well logs were correlated with seismic data at well locations. A good correlation, of the order of 85% to 90% was obtained (Fig.5). A full waveform wavelet was used for making synthetic trace.

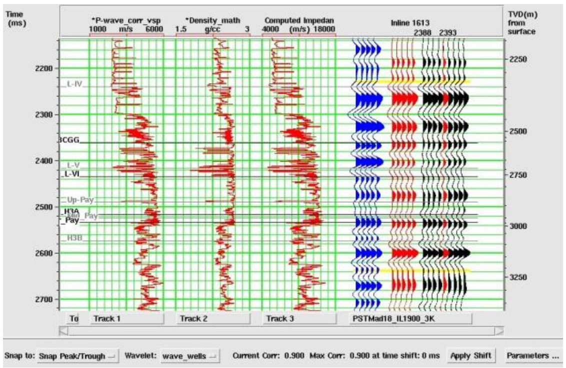

Fig.5: Calibration of seismic data with well logs & generation of synthetic trace. Correlation is 90%

The output of inversion was acoustic impedance volume which was able to describe horizontal as well as vertical variation in lithology and reservoir properties we (Fig.6,7,8). The reservoir layers at three Oligocene pays were well resolved vertically (Fig. 6 & 7). Window based acoustic impedance maps at three pay levels were prepared to study the distribution of reservoir properties at these levels. These maps could very well define the limits of Oligocene pays and could also separate out tight lime stone zones which can avoid drilling dry holes. Fig. 8 shows the distribution of acoustic impedance at Upper Pay level. High AI, mostly in north eastern part indicates zone of tight lime stone.

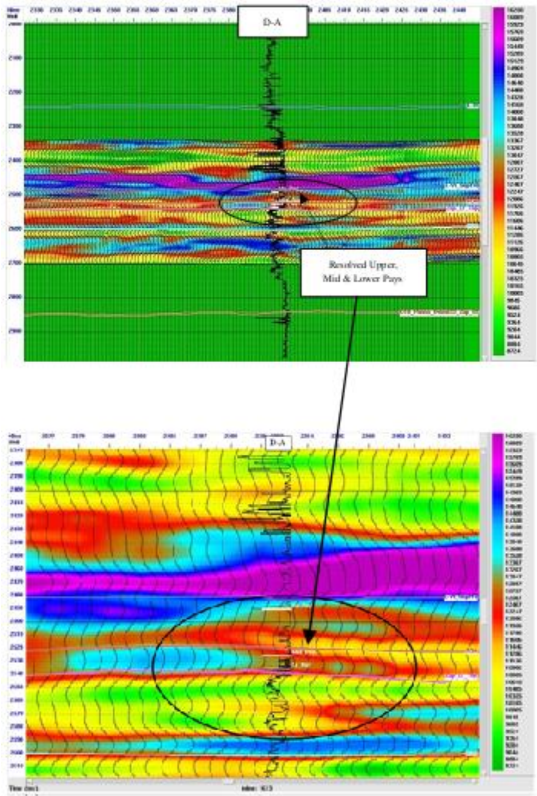

Fig.6: Acoustic Impedance section through well D-A. Three reservoir layers are well resolved

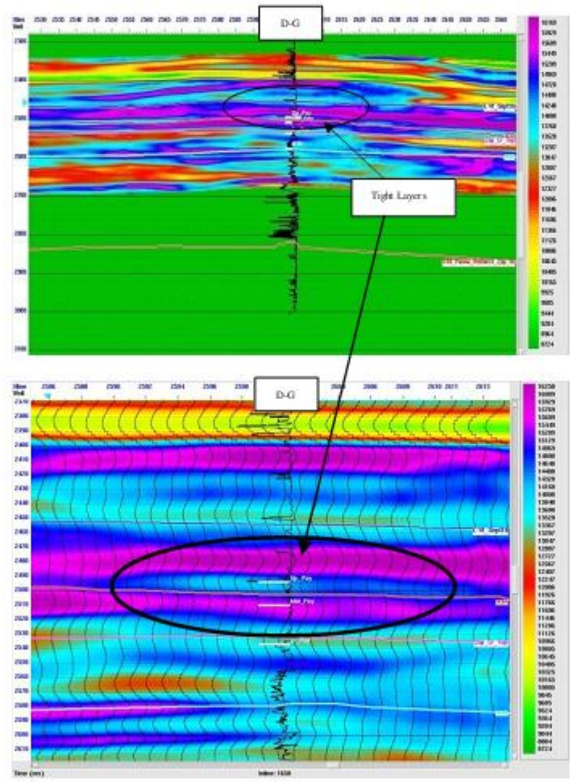

Fig.7: Acoustic Impedance section through well D-G. High AI values shows tight lime stone.

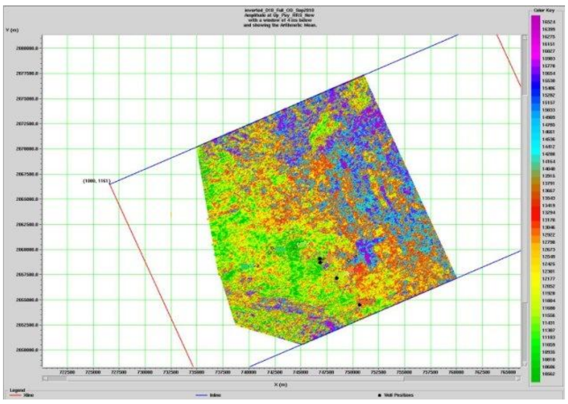
Fig.8: Distribution of acoustic impedance for Upper Pay. Violet to blue patches indicates high AI values and tight lime stone.

Petrophysical Modelling:

As next step in the Reservoir Characterization Process, acoustic impedance was sought to be calibrated with reservoir properties from Petrophysics. To this end, cross plots between impedance values at different pay levels with gamma ray, porosity (PIGN) and fluid saturation (SUWI) were studied for all the wells in D18 area (Fig.9, 10).

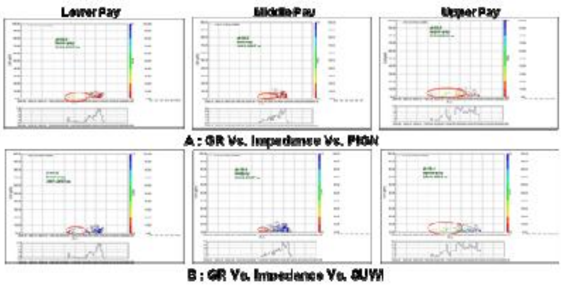

Fig.9: Cross plots between AI, GR and PIGN/SUWI for one of the wells in D18 area.

At well D-C the Upper Pay indicated an Impedance range of 8000 to 13000 from the seismic derived impedance, corresponding to Gas producing zone, this closely corroborates with cross-plots between Impedance, PIGN and SUWI. Low gamma ray with high impedance and low porosity indicates tight lime stone facies. While low gamma ray with low impedance and high porosity indicates porous lime stone.

However, no comparable change could be noticed between the impedance values vs. GR & SUWI, this indicates the fluid in the reservoir not effecting the impedance. Whereas, impedance is primarily depicting the porosity variation.

The cross plots also indicate that the GR per unit grain volume decreasing with increasing porosity and vice- versa. This in turn indicates the coherence between the grain size and porosity which is an indicator of presence of inter-granular porosity. There is also suggestion of presence of secondary porosity.

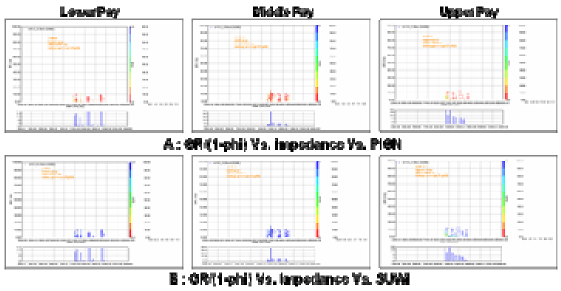

Fig.10: Cross plots between AI, GR/(1-phi) and PIGN/SUWI for one of the wells in D18 area

From the above it can be concluded that primary porosity plays a role in defining the reservoir quality here. The spread of gamma rays at low porosities is an indicator of original depositional grain sizes. The data also indicates that where low porosities have been noticed, loss of original porosity had occurred due to possible post deposition cementation.

By using this methodology the distribution of the porous zones is being identified within the Mukta(Oligocene) pays.

Computation of Porosity

Acoustic impedance volume was used for computing porosity using Multi Attribute Analysis algorithm of EMERGE software. Six seismic attributes including impedance were considered in the computation. Window based maps were generated at different pay levels from the output porosity volume. There was a good corroboration between computed porosity and well porosity. These maps were used to see the porosity distribution in the area at different levels (Fig. 10).

Results And Conclusions

Seismic inversion studies in conjunction with petro-physical analysis has helped in characterizing the reservoir facies in Mukta (Oligocene) pay zones.

Window based impedance maps have demarcated the limits of different pays.

Computed porosity has good corroboration with well porosity and hence its window based maps can be used to map the porous zones in the area.

Study shows that the south-western part of the area characterized by high porosity can be prospective area for further exploration and development.

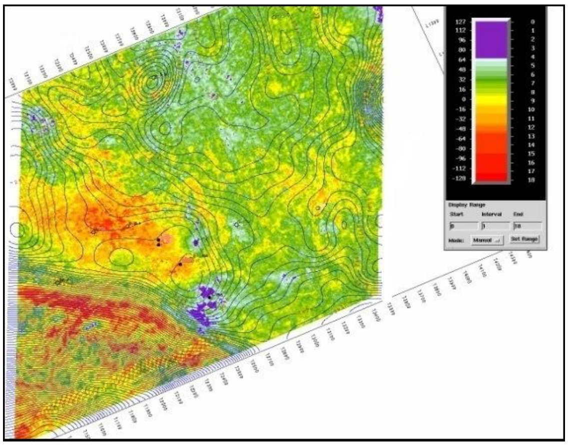

Fig.10: Computed porosity at Upper Pay level (Red to yellow colour shows higher porosity while green to blue represents lower porosity)

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