



Seismic Attribute Analysis-A valuable tool for accurate Placement of Horizontal Drainhole: An Elucidation through a case study

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Summary

The structural style and lithofacies architecture dictate the reservoir heterogeneity of Mumbai High field in western offshore, India. The complex geology of the platform carbonate set-up in conjunction with the temporal and spatial distributions of the reservoir properties and the production assisted by water injection affected the in-place hydrocarbon in a big way. Besides this, it has got its own impact on the drainage characteristics of the sub-layers of the L-III reservoir under study.

Seismic attributes are the only tools which can give an idea of the vertico-lateral variations of the reservoir in the subsurface. The authors made an attempt to utilize the attributes judiciously by preparing a well track model containing the placement of the landing point and the horizontal track through the reservoir in the Mumbai Field. This paper deals with the case study of a well in Mumbai High South in which the authors have shown how the Relative Acoustic Impedance and Amplitude Envelope attribute maps of sub layer B, had played an important role in steering the drain holes in good reservoir facies. The wells were drilled and the models prepared on the basis of Attributes met with great success.

Introduction

The success of the ongoing field rejuvenation programme depends on the placement of horizontal drainholes along the ‘sweet’ areas of the target reservoirs. This is achieved by using the application of 3D seismic data, new generation technologies, real-time data monitoring, etc. Pre-job modelling of the geological structure of the target reservoir is of utmost importance for planning the trajectories of the drainholes. A post-job analysis of the acquired well log & reservoir data helps in concretizing the reservoir characterization for fine-tuning the model.

The structural configuration, thickness, petrophysics and production data are available at discrete points in the drilled well path. 3D Seismic data and its attributes act as a bridge in the area between the drilled wells and it decodes the different Petrophysical parameters. It is an aid to select the area for placement of horizontal wells. Basically, in seismic data we get the composite response of various layers / lithologies in terms of amplitude, phase and frequency. These responses are the combined effect of

lithology, porosity, fluid content, lithification or cementation and depth of burial.

The new location dealt in this paper was planned to maximize the productivity of the platform and thus in totality of the field. Before drilling these locations it was of paramount importance to study the reservoir for its petrophysical, structural and related characters in order to be able to put the landing point and subsequently the drain hole in the good reservoir part.

Recently reprocessed seismic data, i.e., Pre-stack Depth Migration coupled with the well and production data around the platform in which new wells were located was considered for the study. A suite of attributes which are supposed to possess the capability to predict the lateral facies variation were generated. The analysis of each attribute along with other available geoscientific data was done to unfold any complexity of reservoir facies. The analysis shows that two attributes namely Relative Acoustic Impedance (RAI) and Amplitude Envelope to be the best fit among the lot for predicting the relative



Petrophysical character of the reservoir. The analysis of RAI attribute depicts relatively better facies in the form of lower negative to lower positive values. Similarly analysis of Amplitude envelope depicts lower amplitude values as better facies.

Three wells were to be drilled as horizontal in B layer of L-III reservoir of Mumbai High Field. There are already four existing horizontal oil wells in the same platform in B layer. The attribute maps were matched with production profiles of these wells. The areas of better reservoir facies were identified on the attribute maps, keeping adequate spacing between the planned wells from the existing wells to avoid the interference of the drainage area and production of each well. While deciding the drain hole the structural disposition is also taken care of along the drainhole path. The three wells A, B & C were completed successfully one after other as per the schedule. These well A, B & C started with production of 1103, 1448 & 639 bopd respectively. The results validated and upheld the veracity of the attributes map in the placement of drilled horizontal wells. This success gave a boost for using these attributes as a tool for further horizontal well placement in Mumbai High Field.

Seismic Attributes have all the information obtained from seismic data, either by direct measurements or by logical or experience based reasoning (Taner M T, 2001). A seismic attribute is a quantitative measure of a seismic characteristic of interest. Good seismic attributes and attribute-analysis tools mimic a good interpreter. Over the years we have witnessed the development of seismic attributes tracking the breakthroughs in oil industry. The study and interpretation of seismic attributes provide us information about the geometry and the physical parameters of the subsurface. We define all seismically driven parameters as Seismic Attributes. They can be velocity, amplitude, frequency, phase and rate of change of any of these in time and space and all attributes are developed as a classification scheme based on their computational characteristics. The principal objective of attributes is to provide accurate and detailed information about the reservoir. The usage of seismic attributes depends on the knowledge and understanding and for what reason it is being used. Seismic attributes are commonly used for depicting the lateral facies variation and reservoir property. The main functions of acoustic impedance and amplitude attributes are to identify the lithology, porosity, unconformity, discontinuity etc. Commonly used acoustic impedance attributes in the industry are relative acoustic impedance (RAI), absolute acoustic impedance and elastic impedance whereas RMS amplitude, amplitude envelope, total amplitude, total energy, instantaneous amplitude etc are amplitude attributes.

Theory

Acoustic Impedance is the product of density and seismic velocity, which varies among different rock layers and commonly symbolized as Z . The difference in acoustic impedance between rock layers affects the reflection coefficient. It is also a measure of the ease at which the seismic waves can pass through the earth. At a well, it usually is calculated using DT and RHOB logs.

Estimated relative acoustic impedance is calculated by integrating the trace, then passing the result through a low-pass Butterworth filter (Jorge Granados SIS Mexico). We assume that the seismic data has been processed to have minimum noise and minimum multiple contaminations and that it contains zero phases, wide band wavelet illumination etc. Based on this assumption the seismic trace represents the band limited reflectivity series and can be expressed as:

$$f(t) = \frac{1}{2} \frac{\Delta \rho v}{\rho v}$$

Where, ρ = Density & v = seismic velocity

This is:

$$f(t) = \frac{1}{2} \Delta \ln(\rho v)$$

Therefore, by integrating the zero phase trace, we get the band-limited estimate of the natural log of the acoustic impedance. Since it is band limited, the impedance will not have absolute magnitudes and the stack section is usually the estimate $\ln(\rho v) = 2 \cdot \int_{-T}^T f(T) dt$ of zero offset reflectivity; hence it is called relative acoustic impedance.

Computation is a simple integration followed by a low pass filtering, without any exhaustive inversion. It reflects physical property contrast, hence it is a physical attribute effectively utilized in many calibration procedures.

Relative acoustic impedance shows band limited apparent acoustic impedance contrast. It relates to porosity. High contrast indicates possible sequence boundaries, unconformity surfaces, and discontinuities.

Amplitude Envelope is the Instantaneous Energy of analytic Signal i.e., the complex trace, independent of Phase. Mathematically, it is defined as

$$\text{Amplitude Envelope} = \sqrt{(f^2 + g^2)}$$

Where: f = real seismic trace and g = quadrature seismic trace

It is also known as 'Instantaneous Amplitude', 'Magnitude', 'Reflection Strength' or 'Absolute

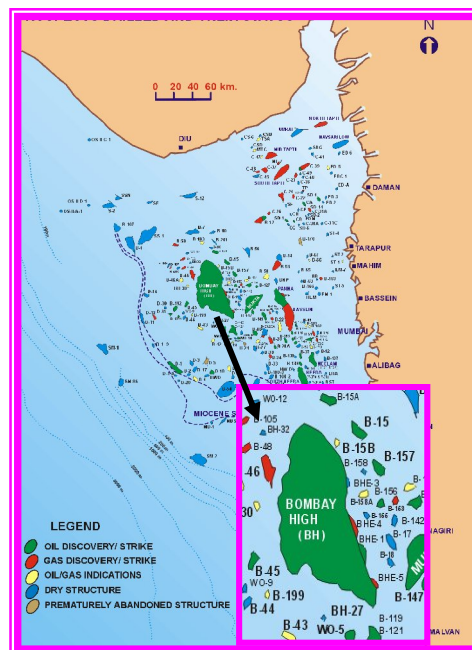


amplitude'. It replaces all samples with the absolute value of the original sample. The zone of high acoustic impedance changes becomes more visible.

Conceptualization of the Methodology

The conventional 3D seismic mapping is not ideal for carbonate reservoir characterization. Carbonate reservoirs are largely controlled by original depositional environment or facies and, importantly, alter over later diagenetic changes. In carbonates, unlike in clastics, porosity and permeability are strongly dependent on diagenesis that does not necessarily follow facies boundaries. This can make carbonate reservoirs extremely heterogeneous and unpredictable in the subsurface. In addition, facies changes in carbonates can be subtle and overprinted by multiple stages of diagenesis, making identification of reservoir boundaries by any means a challenge. The ultimate goal of seismic imaging techniques is to locate hydrocarbons, because diagenetic complications can make the distribution of porosity and permeability in carbonates difficult to predict (Christine Skirius et al., March 1999). Therefore, a tool that could map lateral and vertical variations in porosity and/or permeability from 3-D seismic data would be extremely useful in delineating a carbonate reservoir. Seismic amplitude maps traditionally have been used as tools for delineating porosity in 3-D carbonate data sets. A seismic attribute along a horizon is dependent upon how the interpreter has picked the horizon and sometimes may be subjective also. This should be kept in mind when interpreting attribute horizon maps because picking poorly defined or discontinuous reflectors of some carbonate units can be difficult. However, extracting an attribute along an interpreted horizon should best encompass the geology of the unit. The alternative is to take attribute time slices that could indiscriminately cut through geology that may be dipping or otherwise structured which is not a true representative of the horizon of interest.

The structural style and lithofacies architecture dictate the reservoir heterogeneity of Mumbai High field (Fig. 1) in western offshore, India. The complex geology of the





Methodology Adopted

The Pre-stack Depth Migration and well data was loaded in Landmark Workstation; different horizons were correlated including the target layer B to know the structural configuration. The portion of SEG Y data around the platform under consideration was exported and loaded in Petrel along with the well data and horizons. Out of many attributes under usage in the industry a few attribute volumes generated were, Relative Acoustic Impedance, Amplitude Envelope, Dominant Frequency and Cosine of Phase. To understand the areal distribution of the facies, the arithmetic mean map of the target layer B was prepared out of the volume attribute. The attribute maps were examined in detail with well production data. The analysis suggests that two attributes i.e., RAI and amplitude envelope are giving better match and can be used for lateral facies prediction (Fig. 3 & 4). Based on the statistical analysis it is revealed that lower ranges of RAI value and amplitude envelope corroborates nicely with the well performances. This has enabled the identification of attribute character predicting the good to poor reservoir facies on the basis of the performances of the well. Accordingly drain holes were planned considering the structural configuration of B layer (Fig. 2) and locale of favorable reservoir facies. Based on above consideration three horizontal wells A, B & C with their laterals were placed in the favorable facies areas as guided by the attribute maps (Fig. 3 & 4).

Discussion

As already said in heterogeneous carbonate reservoir the RAI and amplitude envelope attribute analysis has proved to be an effective tool for placement of drainholes in good reservoir facies and with greater accuracy. The analysis of RAI and amplitude envelope attributes, coupled with production profile of existing well in the platform suggests

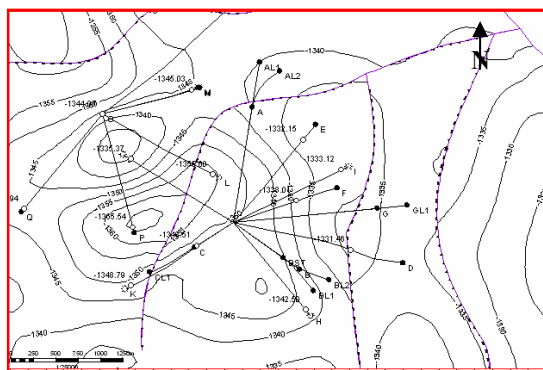


Fig. 2: Structure contour map around the platform, where well-A, B & C were drilled

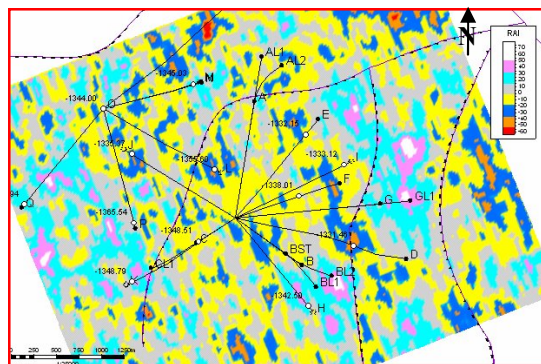


Fig. 3: RAI map of layer B around the platform, where well-A, B & C were drilled

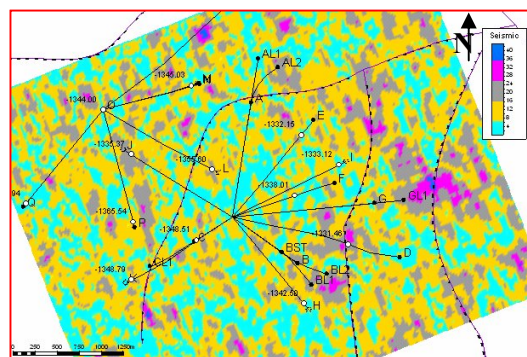


Fig. 4: Amplitude Envelope map of layer B around the platform, where well-A, B & C were drilled

that lower RAI values (-20 to +30) and lower amplitude envelope values (upto 16) correspond to good reservoir (Fig. 3 & 4). The RAI and amplitude envelope attributes were extracted along the laterals of well A, B & C and were superimposed along with the log motif of respective wells. The portion of gamma ray logs showing tight or non carbonate units are circled and show good matching with the corresponding RAI and amplitude envelope attribute (Fig. 5 to 7). However, smaller changes in the attribute values within same litho unit carbonate are not reflected in gamma ray logs, but have a bearing on porosity log; the good patches were having porosity values 'between' 22 to 28 which was nicely revealed in the facies map extracted along the lateral. Thus the integrated analysis of the attributes along with well data has enabled the identification of good reservoir facies.

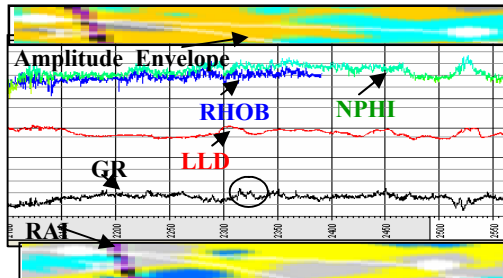


Fig. 5a: Correlation of Log data with the Seismic attribute along lateral-1 for well-A

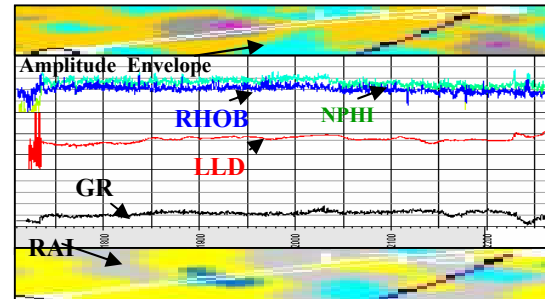


Fig. 7: Correlation of Log data with the Seismic attribute along lateral-1 for well-C

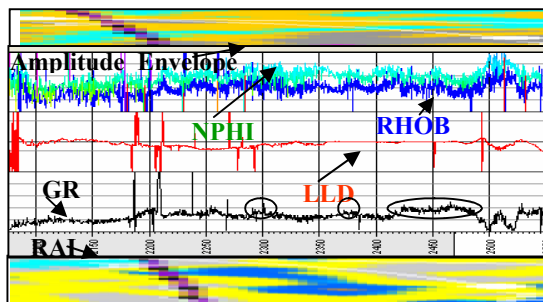


Fig. 5b: Correlation of Log data with the Seismic attribute along lateral-2 for well-A

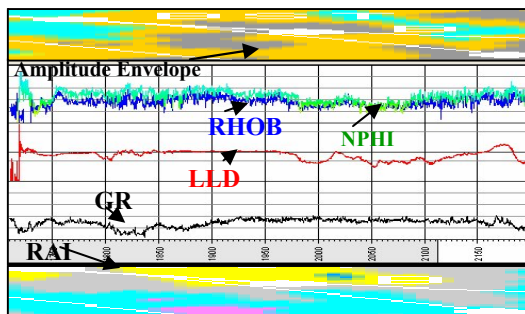


Fig. 6a: Correlation of Log data with the Seismic attribute along lateral-1 for well-B

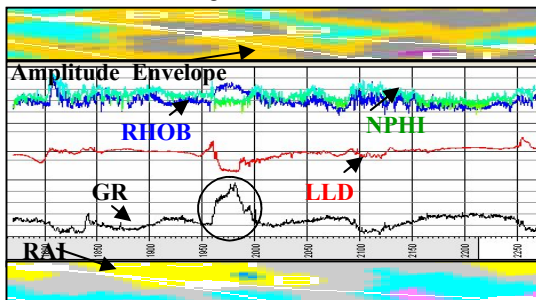


Fig. 6b: Correlation of Log data with the Seismic attribute along lateral-2 for well-B

Conclusion

Though there are many attributes available in the industry, judicious use of them is warranted. The structural style and lithofacies architecture dictate the reservoir heterogeneity of Mumbai High field. The matching of attribute maps with production profile of the well is most important phase for confidence building to adopt an attribute for facies prediction. The successful placement of these well A, B & C gave a confidence on RAI and amplitude envelope attribute and same can be used in other areas. The ever increasing of energy demand has to be met with increased production only from existing assets. An attempt to get more from what we already know should be an essential part of our development plans. But it's not easy to do. Successful optimization of mature assets – particularly offshore – will require skilled application of the most advanced technologies. And there is no "one-size-fits-all" solution. The modeling of well path on basis of seismic attributes prior to drilling of a well is of paramount importance in order to produce optimally. Thereby, reducing the uncertainties of predictions made for focused exploitation of hydrocarbons.

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