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Seismic attribute analysis and Neural network application for reservoir characterization in Lanwa Field, India ; A case study

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Summary

Delineation and development of thin reservoirs with conventional interpretation techniques have been a tough task due to limitations of seismic signal bandwidth. The objective of this study is to differentiate reservoir/non reservoir units with seismic tools. An integrated study of Lanwa field in Cambay basin, India has been carried out for reservoir characterization combining the 3D seismic, geological, petro-physical and reservoir data. Lanwa Field has unconsolidated sandstone reservoirs of Eocene age saturated with heavy oil. Different type of attributes was used to understand subsurface geology. Post stack seismic inversion has been carried out to understand various facies in the well logs and their expression on the seismic. The reservoir facies pattern derived from the impedance volume consists of alternations of low and high impedance zones indicative of shale and porous sands respectively. To delineate and resolve thin sand reservoirs, an effort has been made to extract the different seismic attributes (Taner, 1995, Brown, 1996, Hart, 2008, Srivastava, 2003) from a 3D seismic data volume and utilize them along with results from inversion and Probabilistic Neural Network technique using Emerge software of Hampson Russell.

***Keywords**: Seismic inversion, Acoustic impedance, Neural Network application*

Introduction

Changes in lithology, the presence of laterally continuous shale stringers, or faults can hamper the free flow of oil and reduce productivity significantly. Seismic data can help resolve the reservoir characteristics. A number of horizon and window based seismic attributes - derivatives of seismic data are generated for two purposes, feature detection and to predict (usually quantitatively) physical properties of interest. There is a well-developed interest in using "physically significant" attributes to predict subsurface physical properties. These attributes are mainly related to relative changes in amplitude, frequency and phase of seismic data. For efficient oil recovery it is essential to extract information from seismic data to delineate subtle features, to map faults and to define accurate reservoir model. In this paper attributes used for characterizing reservoirs are:

1) Complex attributes for mapping subtle faults and for stratigraphic layer interpretation

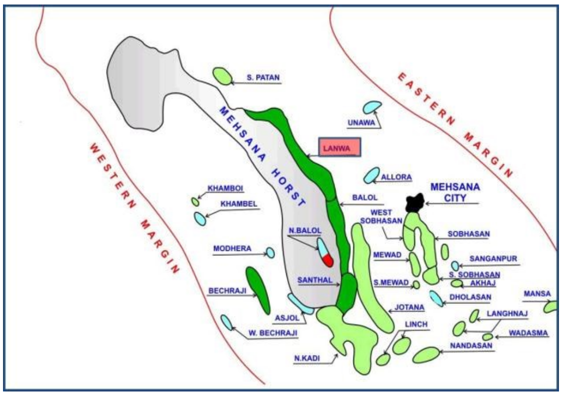

Figure1: Oil and Gas Fields of Mehsana Petroleum Province showing location of Lanwa Field.

2) Acoustic impedance and neural network application (Rainer, 2002) for facies analysis. The study area-Lanwa field is located in the Mehsana Block of Cambay Basin and covers an area of 21 Sq Km. It forms the northern most part of the heavy oil belt and lies on the Eastern flank of Mehsana Horst with Balol field in the South. (Fig.1). The field was discovered in 1971 and put on production in 1986. The general structural trend is of a homocline with the pay sands

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terminating against the Mehsana Horst towards the West and gently dipping towards the East. The crestal part of the structure is in the central part of the field close to the Mehsana Horst. The highs and lows are trending NW-SE.

Theory and Method

Geologic background

Cambay basin is an aborted intracratonic rift graben situated in the western part of the Indian sub-continent which came in to existence during Late Cretaceous. The basin is 40-60 km wide and running N-S to NNW-SSE direction. The interplay of transform faults trending ENEWSW and reactivation of basement faults have given rise to horsts and later development of the structures by differential compaction of sediments. During Middle Eocene and late Eocene period, Kalol formation was deposited and is one of the major hydrocarbon producer in this area. In the study area the main producing sands are Upper Suraj Pay (USP), Kalol Sand-I and II Pay Sands of Eocene age. The average sand thickness of KS-I varies from 1 to 44 Mts. The pay sands are separated from each other by shale of varying thickness. The pay sands abut against the Mehsana Horst in the West and are connected through an aquifer in the East. The field has an active edge water drive with OWC varying from 944 to 1043mts (MSL).

Workflow

A critical element of present study is seismic tie with well data. All the wells having sonic logs were tried for this purpose. Only those wells which showed good correlation between synthetic generated with sonic and density log with seismic data, were used for correlation purpose (Figure2).

For fault mapping time slices (Figure.3) were generated from volume based attributes viz. difference cube, dip azimuth cube structure cube of coherency volume and window based attribute- spectral decomposition and studied.

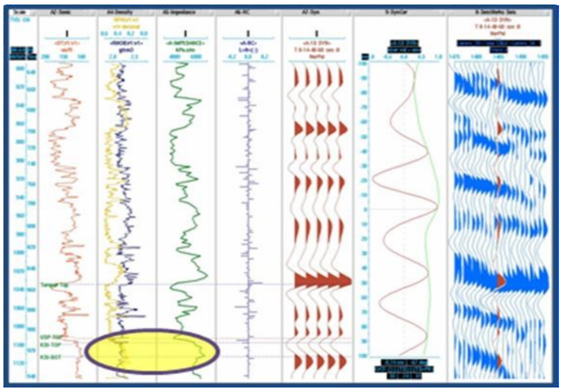


Figure2: Synthetic seismogram of Well-A showing high impedance at pay sands.

The amplitude of a seismic reflection, whether it be measured on pre- or post-stack data, is a function of only acoustic or elastic properties when there is no interference from adjacent reflections. Different amplitude attributes were studied for pay sands- KS-I. These attributes show almost same pattern of distribution of facies hence Maximum trough amplitude within KS-IA has been considered for detailed study.

Detailed stratigraphic interpretation of fully processed post stack seismic data to delineate stratigraphic subtle units quantitatively includes its transformation into acoustic impedance. An important aspect of the inversion process is the extraction of the wavelet required to remove its effect from the seismic volume for converting the interface to layer property. Wavelet estimation was an iterative process that improved as the correlation between synthetic and seismic trace improved. Interpreted horizons and impedance logs were used to create a model which, in turn, was used to invert the seismic volume. The seismic wavelet extracted from 12 wells was used for inversion. For the initial impedance model, two main horizons were interpreted – Tarapur top & KS-I top (Figure.4), and 13 wells were used to build the initial model and inverting the seismic volume.

Neural network technique is a powerful tool for prediction of log property from seismic data. That property may be any measured log type such as velocity or porosity, density, gamma ray etc.. In this process well data is the main key to establish the relationship between logs and seismic data, thus generating non-seismic 3-D cube from seismic 3-D data. This technique was used for predicting P-wave velocity and porosity logs from seismic attributes. Two types of attributes are used here –internal attribute and external attribute.

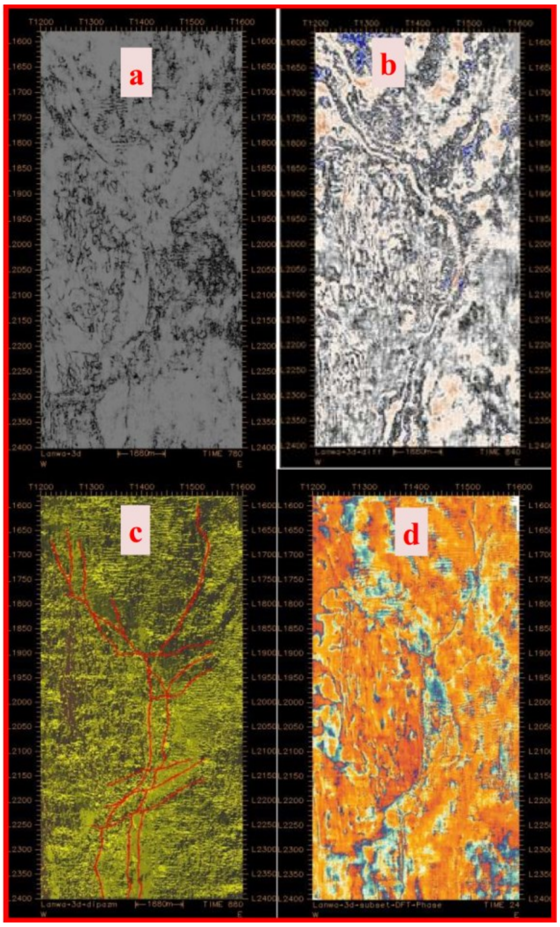


Figure.3: Multi attribute slices - a) time slice at 780ms through structure cube, b) time slice at 840ms through difference cube, c) time slice at 880ms through azimuth cube(showing fault alignment) and d) horizon slice through 24-Hz spectral phase component.

The original 3D seismic volume was taken as internal attribute while inverted volume was taken as external attribute. To improve the result multi attribute analysis was carried out which try to discriminate subtle features on the target logs.

In the first stage, target log and seismic data were analyzed to derive a statistical relationship between them. In the second, application stage, the derived relationship was applied to the entire volume to create log values throughout the seismic volume. A validation test was carried out to check whether the neural network performed well.

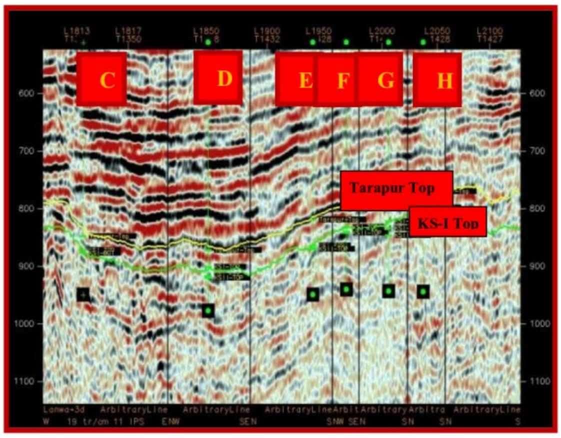


Figure. 4: R C Line passing through wells - C, D, E, F, G & H.

Results and Discussions

All the attributes not only depicted major fault trends but also deciphered footprints of minor faults. Major faults have been identified and mapped (Figure.3). The most dominant fault trends are oriented in NNW-SSE and the fault near the Mehsana horst block coincides with the pinch out limit of sands. Other faults run parallel to this with similar trend. Cross faults having ENE-WSW trend seem to be younger in comparison to the longitudinal faults. Synthetic seismogram (Figure 2) Shows good tie between log data and seismic and indicate that the event corresponding to KS-I sand is a trough.

Maximum trough amplitudes were generated for two time windows 0-5msec and 0-20 msec below KS-I Top. Pay sand KS-I indicate low to moderate amplitude depicting development of good porosity while high amplitudes correspond to poor porosity development. Generally sands correspond to moderate – high amplitude, here low amplitudes may be attributed to poor quality of data in the vicinity of wells as most of the wells are placed near Mehsana horst/fault. Maximum trough amplitude maps at different time windows indicate that deeper window has higher mean amplitude of maximum trough in comparison to shallower window, showing gradational change in the gross lithology from sand rich facies (low to moderate amplitudes) to shaly-sand facies (moderate to high amplitudes). Thus the vertico-lateral variations of the amplitudes give an idea of thickness and areal extension of the reservoir facies.

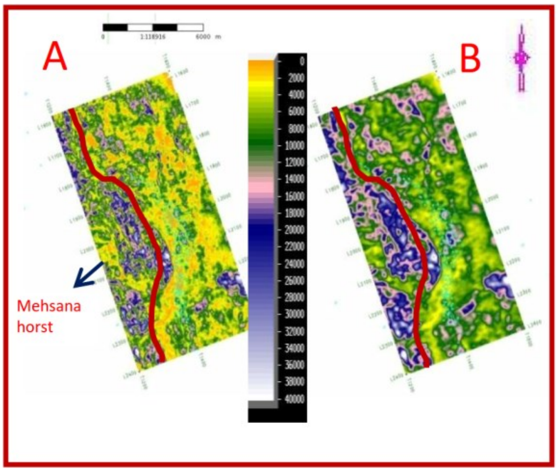


Figure.5: Maximum Trough Amplitude map of KS-I Top for 0-5ms (A) and 0-20ms (B) below KS-I Top

The lateral variations in the amplitude distribution at both the windows point towards a possible change in the lithological environment. The statistical distribution of amplitudes exhibits a pattern particularly in west of study area where relatively high amplitudes were observed indicating different depositional settings. The red line marking the change in amplitude pattern clearly shows change in facies and matches well with the pinch out limit of Kalol sands.

As the normal seismic section images the interface boundaries and acoustic impedance images the layer itself, the impedance section helps in the detailing of subsurface geology. 3D seismic data acquired over the Lanwa field has been subjected to model based post stack seismic inversion. Sands are well brought out on impedance response arrived after inversion (Figure.6).

Results of inversion were examined by overlaying the impedance logs for wells on seismic sections passing through these wells (Figure.6). The match between log derived impedance and inverted section is quite good. The data slice generated from impedance volume shows quite high impedance in the northern part over producing area (Figure. 7) indicating poor porosity. Producing sands in the crestal part of Lanwa field generate impedance in the range of 4800 to 5500 (m/s)*(g/cc). Sands are characterized by higher impedance than shale as seen on well log data (Figure.2).

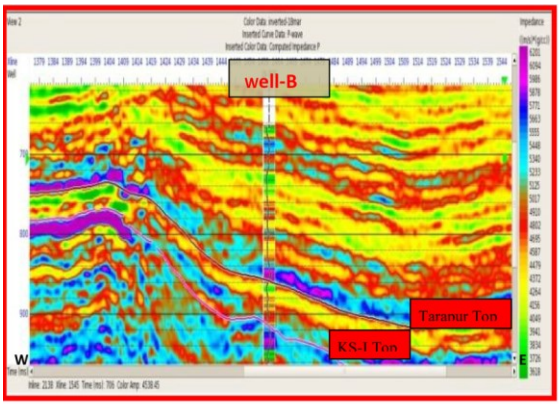


Figure.6 : Impedance Section passing through Well –B

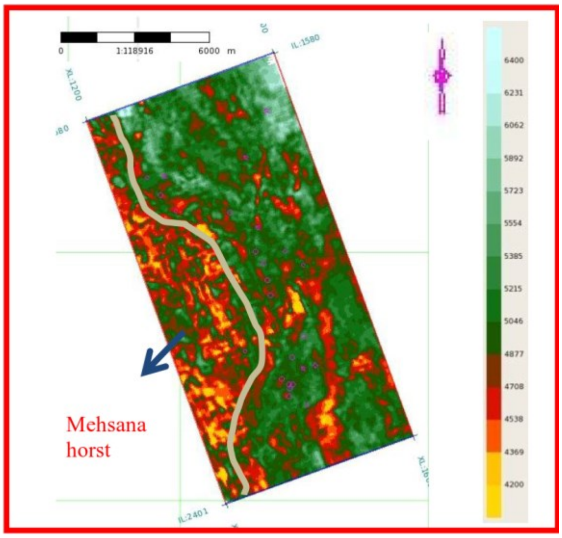


Figure.7: Arithmetic mean Amplitude (Inverted Volume) of Horizon Slice of Pay Sand KS-I & a Window of 5ms Down.

An attempt has been made to predict P-wave values and porosity from post stack seismic data. The attribites used for estimation of P wave and porosities were selected by

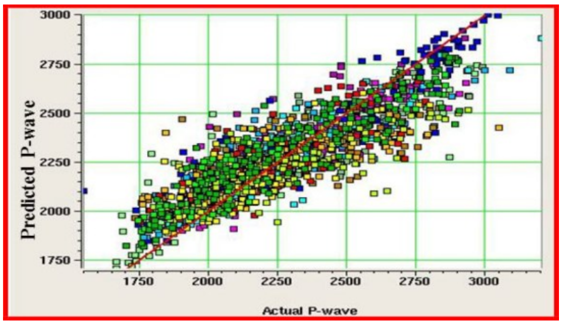
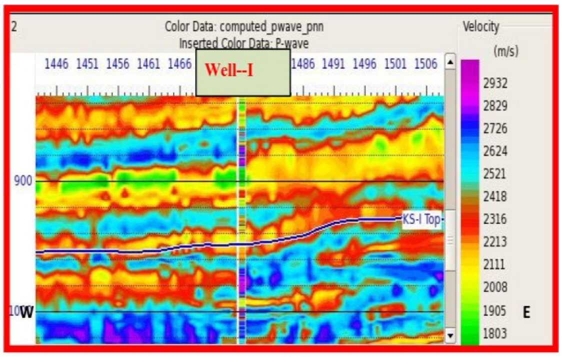
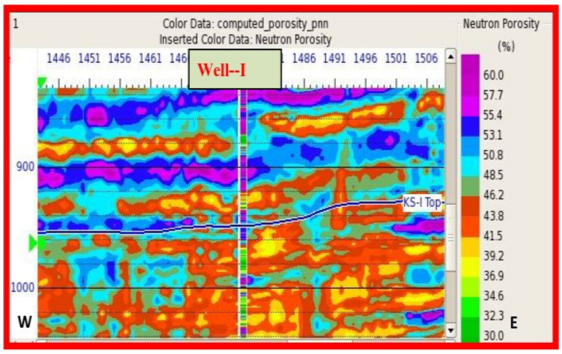


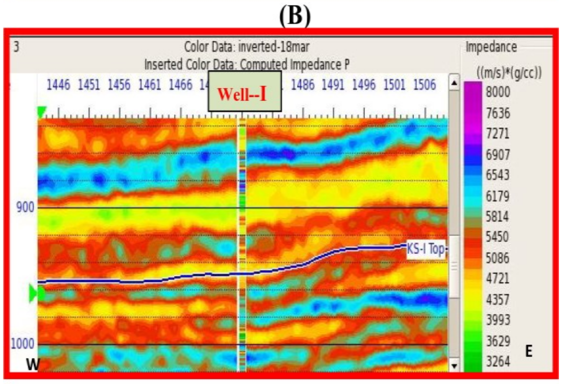
Figure.8: X plot of predicted P-wave values versus actual P-wave values



(A)



(B)



(C)

Figure.9: Display of P-wave section (A) and porosity section (B) corresponding to vertical impedance section (C) overlain by corresponding logs.

To quality check the Neural network technique predicted Pwave values were plotted against actual P-wave values (Figure.8). The cross plot shows a good correlation between predicted and actual values. Neural network application enhanced the resolution as compared to post stack inversion (Figure.9).

Vertical section (Figure.10) passing through P-wave cube shows variation in facies. Low velocities indicated by yellow, green colour corresponds to shale, red blue color corresponding to moderate velocities associated with silty sandy facies, blue color corresponding to moderate to high velocities associated with sandy facies and dark blue, purple colour representing high velocities indicate tight sand.

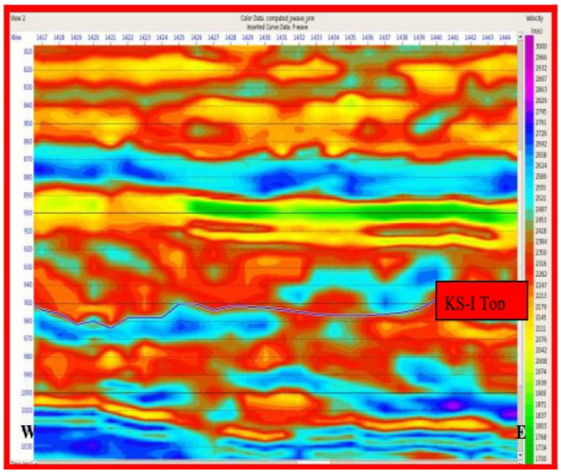


Figure.10: Vertical section passing through P-wave cube.

Window based attributes were generated from total porosity cube predicted from NPHI log for KS-I Top for different time windows (Figure.11). For deeper window(B) lateral facies variations were observed as compared to shallower window(A), depending upon the sand thickness in a particular well and the thickness of shale stringent discriminating different sand units. These attribute maps clearly validated the drilled data.

Conclusion

An integrated approach to reservoir characterization starting from seismic data, extracting seismic attributes and Neural network application for estimating log data from seismic data was presented in this paper. This analysis has successfully distinguished reservoir and non-reservoir shaly facies and demonstrated that reservoir parameters can be predicted from seismic data. Neural network techniques proved a good tool for this prediction. Seismic attribute studies have brought out vertico-lateral variation of KS-I sand facies in the area. The data slices generated from impedance volume and porosity cube clearly brought out the reservoir geometry.

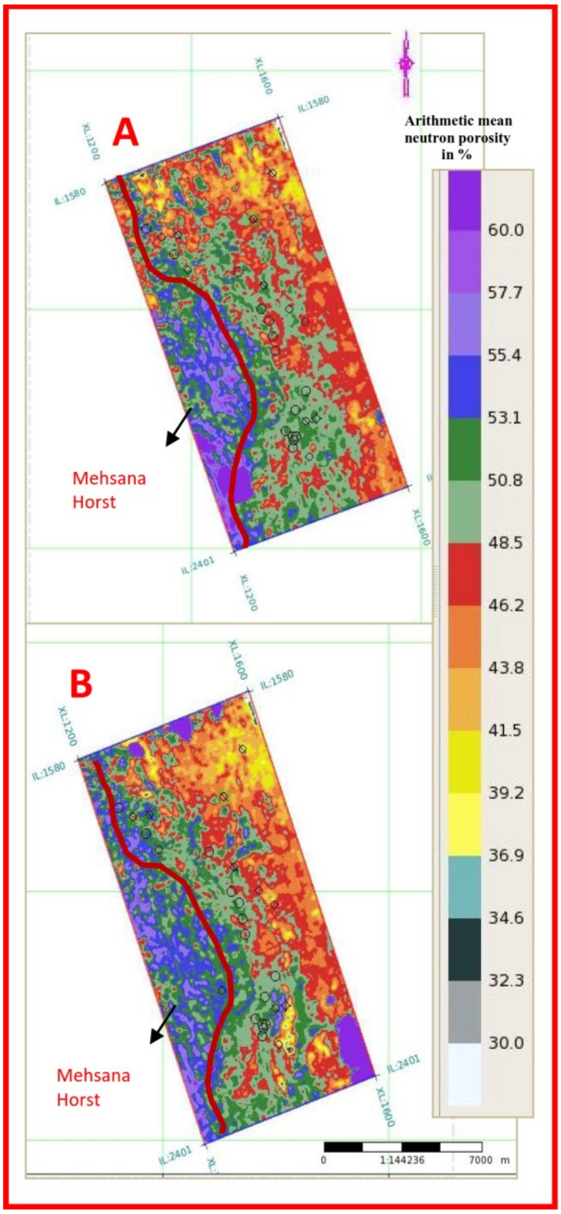


Figure.11: Arithmetic mean Amplitude (porosity cube) of Horizon Slice of (A)Pay Sand KS-I & a Window of 5ms Down and (B) Horizon Slice of Pay Sand KS-I+30ms & a Window of 10ms Down.

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