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Reservoir characterization of thin sand below K-IX Coal in Wadu-Paliyad Field of Cambay Basin, India.

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Abstract:

The study area comprising Wadu-Paliyad field and part of north Kalol field is located in Ahmedabad block of Cambay Basin. The area is flanked by Nardipur low to the east, Nandasan field to the west, Kalol field to the south and Langhnaj-Wadasma field to the north **(Fig.1**). Commercial hydrocarbon accumulations have been established in multiple Kalol reservoirs (K-IV, V, VI+VII, VIII, IX and X) in addition to silt/ silty shale reservoir of Wadu pay in Younger Cambay Shale. Kalol formation generally being tight and silty in this part of the basin, it is very difficult to map the discrete sands individually. Practically K-VI, VII, VIII could not be mapped individually in the conventional seismic data.

The integrated 3D seismic study was aimed to decipher the different pay zones by repeated interaction of the originally interpreted seismic data volume and the inverted impedance volume. The study is based on reprocessed seismic data in PSTM domain. Keeping in view the discrete nature of the sand bodies, the 3D seismic volume was wavelet processed for improved resolution **(Fig.2).**

In this area, hydrocarbon entrapment is strati-structurally controlled with stratigraphic component playing the major role in entrapment; hence presence of reservoir facies seems to hold more significance in accumulation of hydrocarbon. The fact that the wells structurally down are producing oil, is a clear indication of the dominance of stratigraphic control over the structural control on the entrapment of hydrocarbon in the area. Therefore; mapping of reservoir facies is critical in delineation of sand bodies for exploitation and further in exploration, to identify areas of possible pool extension/new pool. The present study has been focused on seismic inversion to identify the reservoir facies in K-IX unit.

An attempt has been made to understand the reservoir facies distribution, through seismic inversion study of the 3D seismic data. The seismic inversion study has brought out channel pattern and it is possible to identify the reservoir facies distribution. On analyzing the impedance section, it has been observed that K-IX coal layer with intervening thin shale varying in thickness. The present study has been focused on seismic inversion to identify the reservoir facies in K-IX unit.

Introduction:

The Kalol formation represents the progradation of a fluvial dominated delta system, which was fed from an igneous and metamorphic source in the North. During periods of low clastic input and relatively high base level, coals and carbonaceous shales were deposited in swampy plains. Kalol formation is late Middle Eocene in age and is conformably overlain by the Tarapur Shale. Kalol formation is 200-300m thick in the study area and generally found tight and silty in this part of the basin .The pay zone K - IX consists of alternate coal - silt / sand and shale bands. Hydrocarbon bearing reservoir facies are developed below the K- IX coal. Thickness of coal beds varies from 10 to 15m, whereas that of pay zone ranges from 2.5 to 8m.

The seismic study was aimed to map different reservoirs in Kalol formation in time volume as well as in impedance volume. The electro log data, various seismic attributes and other sub surface data are to be integrated to provide a comprehensive updated geological model to support the field development and reservoir management activities in the Wadu-paliyad Field.

It was possible to identify the K-IV+V, K-VI+VII, K-IX and K-X as individual unit on the seismic data for correlation while is not possible to map K-VIII (Fig.4). After seismic inversion study it was possible to correlate the coal/shale, coal/sand and sand/shale interface in the impedance volume with greater confidence. In this paper K-IX sand mapping has been focused, which was deposited in deltaic environments marked by coal, shale, sand and silt. Electro log correlation has been carried out in this area to understand the deposition of K-IX sand **(Fig.3**). The log motif indicates that the K-IX sand deposited in deltaic environment. This log profile in general describes the nature and quality of sand in this area. The hydrocarbon producing zones from Kalol reservoirs viz. Kalol-X, IX, VII+VI, V and IV, as developed and designated from bottom to top, ranging from siltstones to fine to medium grained sandstones, exhibit an abrupt facies change laterally

Wavelet Processing:

The wavelet processing has been carried out to improve the resolution on 3D Seismic data. After wavelet processing comparison of both the volumes before and after wavelet processing, It was observed that the wavelet processed data is much better than the PSTM data **(Fig.4 & 5).**

Methodology:

Integrated 3D seismic interpretation was carried out on PSTM data. Seismic Synthetic seismograms were generated to tie up well and seismic. The different depth levels of the sands/horizons encountered in the wells were calibrated on the time domain seismic data with the help of available VSP data and synthetic seismograms prepared for wells, spread over the field. Synthetic seismograms for well-F and well-J **(Fig.6 & 7)** show good match with the seismic data. Seismic correlation was done at the top of kalol formation and other marker, respectively **(Fig. 8**) on wavelet processed data Total five horizons viz. K-X, IX, VI-VII, IV and Kalol top *were* calibrated and mapped.

Hampson-Russel software was used to invert the seismic volumes into impedance volume. A few wells evenly distributed in this area were taken for correlation of formation boundaries with seismic markers. Subsequently all wells having good sonic log and calibrated with seismic data, have been taken up for the creating the initial model i.e. impedance model. On analyzing the impedance section it has been observed that K-IX coal layers with low impedance can be clearly identified and K-IX sand developed immediately below the coal layer can be mapped**.** In Well-D the extension of the sand can be seen. This sand body having limited aerial extent has produced very nominal quantity of oil **(Fig. 9)**. Sand developed below coal in well -H can be observed in the inverted line **(Fig.10**). Sand development in well- K observed on seismic is tight in nature (**(Fig.11)**.With lower impedance at well-M sand development observed having shaly facies . **(Fig.12).**

The study area falls in a major cross trend zone separating Mehsana and Ahmedabad block. This cross trend has the influence on structural style of the area, which has been brought out by study on the latest PSTM data. The structural set up of the area is characterized by two sets of faults, one longitudinal and the other transverse. These near vertical faults have throws in the order of 5-20 msec**.**

Mapping of K-IX sand:

In this area, structure is not solely playing the role in hydrocarbon entrapment; rather presence of reservoir facies seems to hold more significance. Therefore, identification of reservoir facies is critical for delineation of K-IX sands for development planning. Hence seismic inversion was attempted to achieve higher resolution on the impedance volume by integration of well data. K-IX sand is marked by a thick coal unit deposited at the top which gives rise to a prominent peak on the seismic section. Thin shale and sand units beneath the coal get obliterated and are not resolved. Hence seismic inversion was attempted to achieve higher resolution. On analyzing impedance sections it can be seen that the K-IX coal layer with low impedance has been clearly brought out. K-IX sand is developed below the K-IX coal with intervening thin shale varying in thickness. To remove the effect of coal, the correlation was again done on impedance section on K-IX coal base (K-IX sand top).The sand distribution has been brought out by taking horizon slice in impedance volume (Within 0 to 6ms) because pay sands are varying from 2.5m to 8m below K-IX coal. The prospective area of KIX has been identified **(Fig.13)**.

Analysis & Findings:

On the basis of this study, K-IX sand seems to have extension in eastern part of the field. The orientation of K-IX sand unit is North-South oriented and wells producing from K-IX are located within this area. In the Western part the sand is not developed but sporadic high impedance can be inferred as very limited sand development. The sand distribution has been brought out by taking horizon slice in impedance volume with 0 to 6ms intervals.

After seismic inversion, thin sand body development can be mapped, which are having limited aerial extension. Well D in impedance section clearly indicates the sand body, while the impression of the sand in the horizon slice is clear. K-IX reservoir can be classified to three major facies on the impedance range of the horizon slices. The wells G, M and L K-IX are having shales in general and this zone has not contributed to the production (shaly facies). The AI of this shaley facies ranges between18000~20200 (ft/s gm/cc). Wells A, B, D, I and H K-IX sand is developed with moderate shale content, so these wells have contributed marginally in terms of production (shaley sand). The AI range for this facies is between 202000~22000. The AI beyond 22000 to 23700 has contributed in general to the production from K-IX (sandy facies). Wells C and J, K-IX sand is very well developed and contributed better than other wells. The impedance range beyond 23700 as seen in wells E and K for K-IX sand seems to be very tight, which after stimulation jobs (acid job, HF job and other applications) has produced to some extent. Attempt has been made by seismic inversion process to resolve facies with certain limitation which was not possible in normal seismic data. Structure map of K-IX in conjunction with the facies classification will help to understand the hydrocarbon habitat of this area thereby facilitating the field development **((Fig.14.).**

Conclusions and Recommendation

It was not possible to infer the reservoir facies below K-IX coal from normal seismic data.However It could be possible only after seismic inversion study. Seismic inversion has produced a broad band, high frequency image of the subsurface even in the presence of thick K-IX coal layer above and enabled mapping of the underlying thin reservoir of K-IX leading to identification of facies distribution to the possible extent.

References :

1. C.C.M.Rao et.al “ Report Integration Interpretation of merged PSTM 3D data in Wadu – Paliyad area.” By Western Onshore Basin, Vadodara, 2014.

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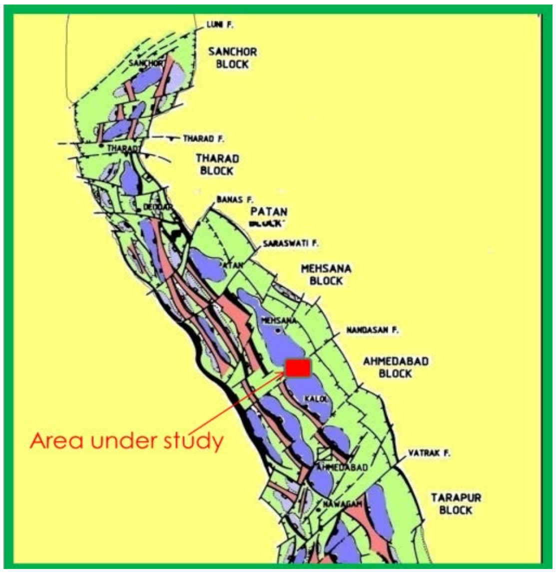

Fig.1 Tectonic framework of Cambay basin

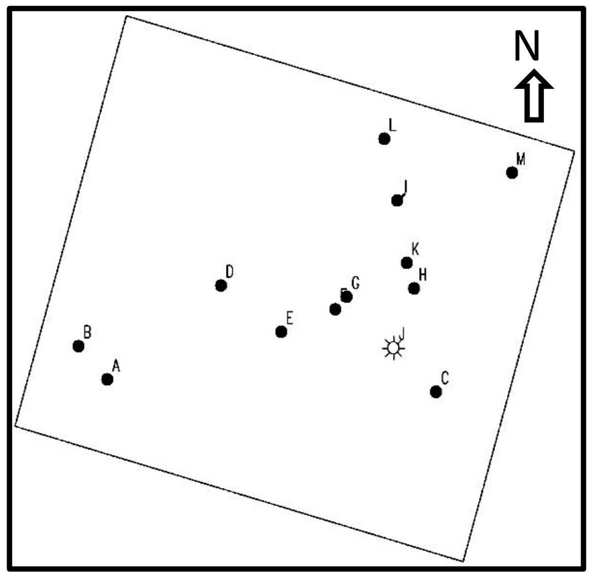

Fig.2 Location map of the study area

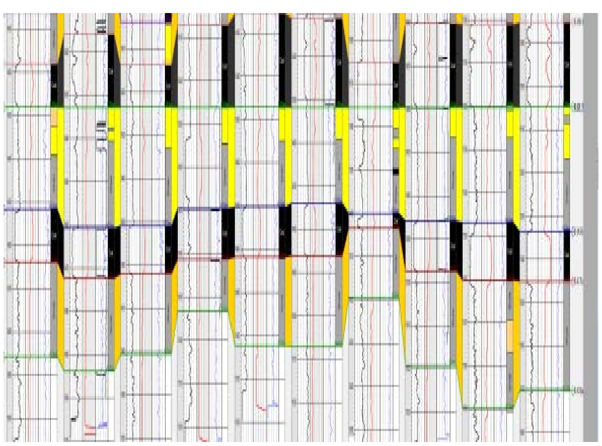

Fig.3 General sand dispersal of K-IX sand in the area

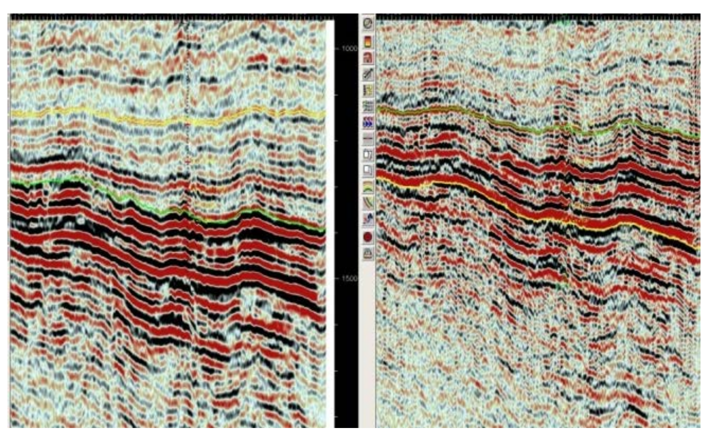

Fig.4 Wavelet processed section: before and after

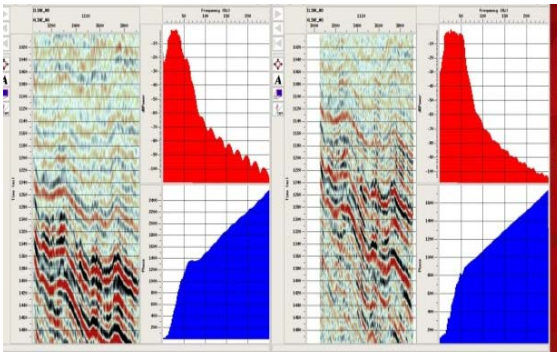

Fig.5 Wavelet processed: before and after (Band width)

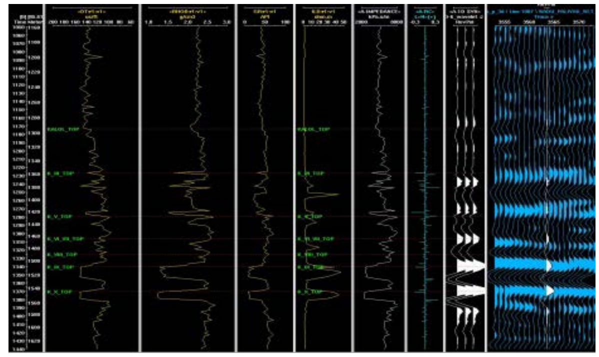

Figure. 6 Synthetic Seismogram at well-F

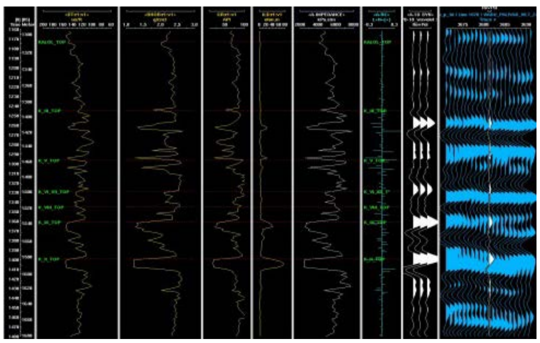

Fig. 7 Synthetic Seismogram at well-J

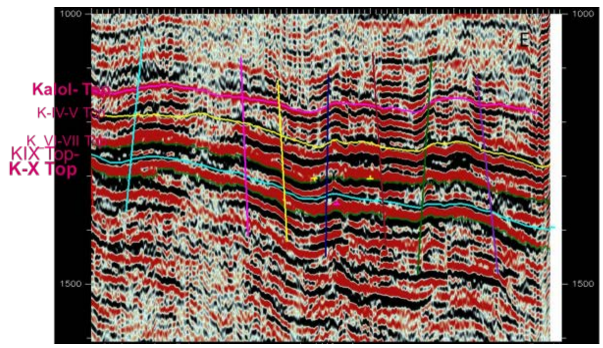

Fig.8 seismic correlation of K-IX & K-X in Wavelet processed data

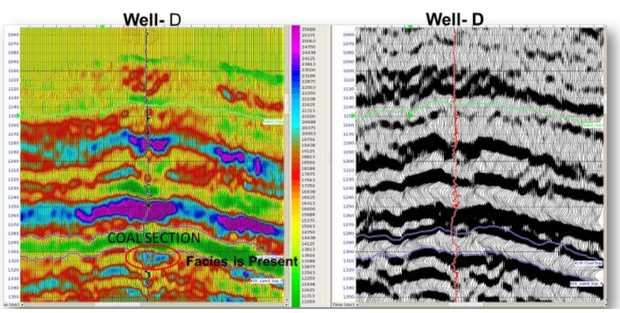

Fig.9 Impedance & Normal section through Well- D

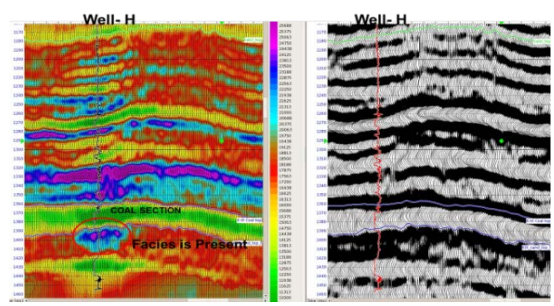

Fig.10 Impedance & Normal section through Well- H

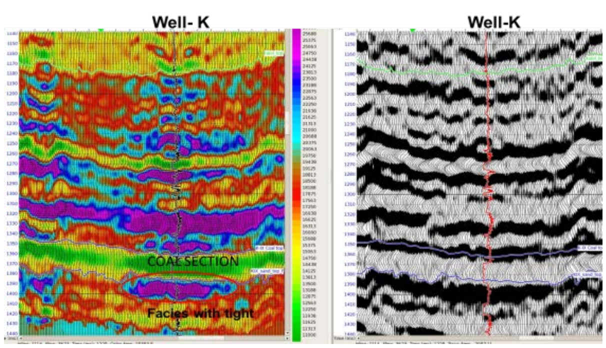

Fig.11 Impedance & Normal section through Well- K

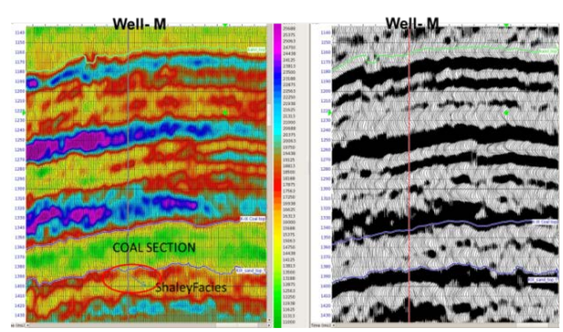

Fig.12 Impedance & Normal section through Well- M

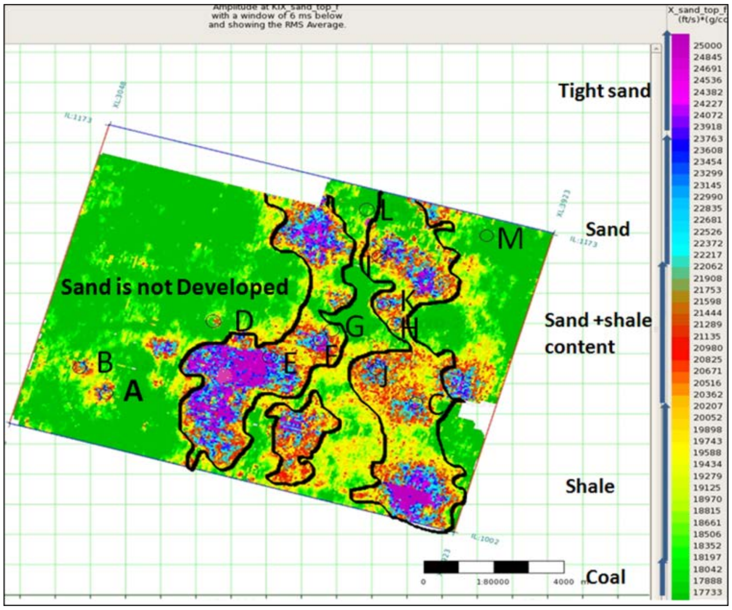

Figure.13 Average sand map over 6ms window K-IX sand top

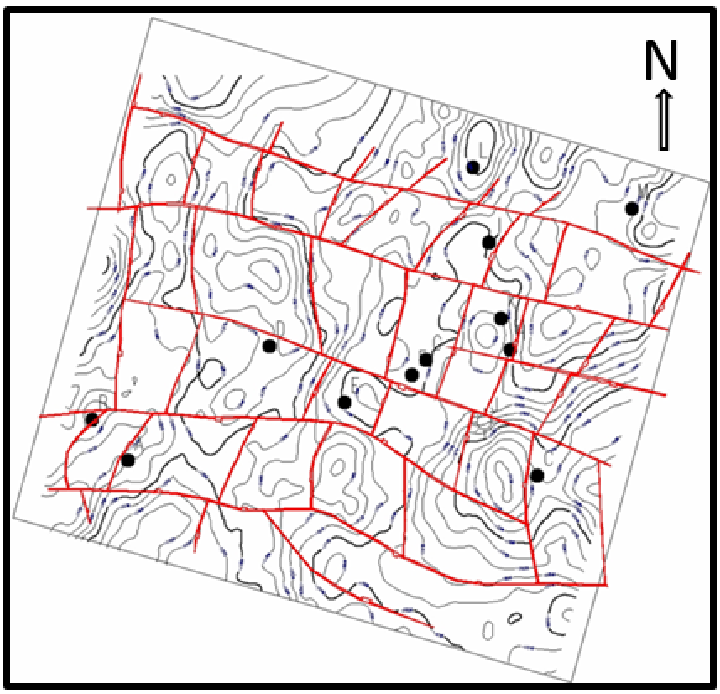

Fig.14 Structure Map on top of K-IX