Reservoir Characterization From Seismic Attributes- A Case Study

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ABSTRACT:

After inclusion of cdp stack and digital processing to remove unwanted effects in reflection seismology, the image enhancement capabities of reflection methods have improved steadily over the years. Now new developments in seismic technology can provide high quality data in which there is far more information than just a time (depth) of reflection. The waveform analysis has been extremely valuable tool in prediction of facies and depositional environments. The high data sampling provided by 3D seismic further enables to map finer geological details leading to refinement of reservoir model for planning delineation and development wells in the field under development.

A case study dealing with reservoir delineation is presented in this paper. 3D seismic data has been used to map the structure and stratigraphy in the area where identification of reservoir facies is a major challenge to plan delineation and development drilling. Seismic attributes have been used to characterize the reservoir and a channel filled with sands is mapped at Kalol-IX level which is a producer of hydrocarbons. This interpretation was validated by drilling a number of wells afterwards. The Kalol-IX sequence belongs to one of the units of Kalol formation of Middle Eocene age. The Kalol formation is characterized by coal, shale, silt and sand sequences deposited in a slow subsiding but oscillating basin conditions. High variabihty in thickness and reservoir facies development is observed in the area.

INTRODUCTION

The characterization of reservoirs requires the integration of different types of data to define reservoir model. Seismic data can contribute to a well defined geometric description of structural and stratigraphic aspects of the reservoir. Presently the challenge before upstream petroleum industry is to accrete reserves from stratigraphic prospects. Exploration and exploitation of these prospects need careful and cautious planning. In this respect, 3D seismic has come in a big way to reduce the risk of drilling dry wells. The task of detecting finer structural and stratigraphic details was successfully completed in one such prospect using 3D seismic data. The results obtained are discussed in this paper.

GEOLOGY

The area of study is situated in Cambay Basin which is one of the major hydrocarbon producing basins in India. This basin is a pericratonic rift graben situated in the western part of the Indian subcontinent and forms the northern extension of the large Bombay offshore basin.

The basin came into existence during Late Mesozoic era with the development of major tensional faults along pre-existing basement trends following widespread extrusion of Deccan trap basalt. This basaltic floor formed the basement for the deposition of huge thickness of Tertiary-Quaternary sediments in the basin. The basin has been divided into a number of blocks based on recognisable basement fault trends. Considerably thick sequence of black to dark grey Cambay shale was deposited during Paleocene which is considered to be the main source of hydrocarbon generation. During Middle Eocene period, Kalol Formation was deposited and is one of the major hydrocarbon producer in this area. The environments of deposition for Kalol formation are fluvial/deltaic, plain/interdelta, marsh, backshore, lagoon/tidal flat and gulf having coal, shale, silt and sand lighologic assemblages. The major drainage systems are identified to be from north bringing coarser elastics. Upper Eocene to Oligocene mark the regional transgression hav

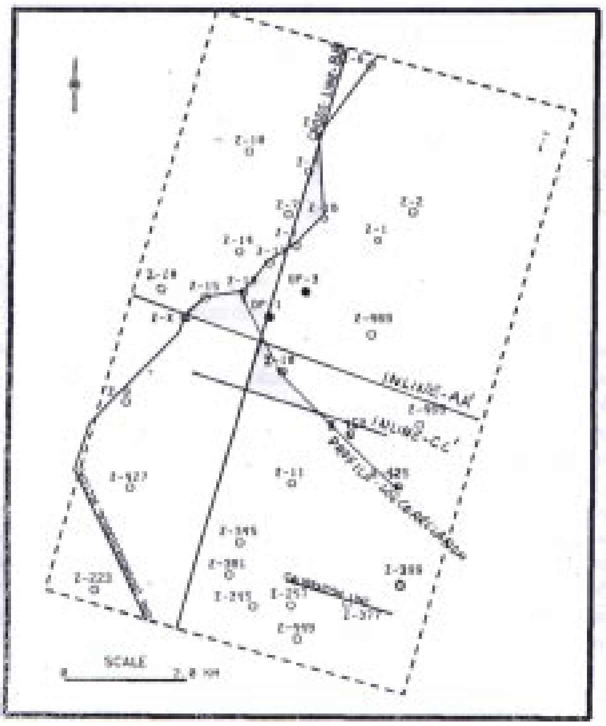

Fig 1: Location map showing 3-D survey, drilled wells, calibration line, seismic inlines and crosslines, seismological and electrolog correlation profiles.

ing deposited mainly shale. Lower Miocene is represented by shale with carbonaceous streaks and thin limestone bands with occassional sand association.

SEISMIC DATA:

The 3D survey was conducted in an area covering. an area of 70 sq km. Twenty four fold coverage was achieved for about 75 percent of the surveyed area with a bin size of 15x60m. Fig. I shows 3D survey area with drilled wells. Although the seismic data is good, the quality deteriorates considerably in the north.

Seismic to well matching was established though CVLs and synthetic seismogram using a number of wells. A series of continuous reflectors are observed due to presence of coal units. The thin sand units (<10m) are not descernable on seismic section directly, due to thichness limitations. However,their .position with respect to coal markers on sections are identified. The delineation of these sands has been attempted using attributes and horizon slices in the area.

INTERPRETATION

The 3D seismic data was interpreted on an interactive workstation. Six key horizons (Ktop, KIV, KV, KVI+VII, KIX and KX) were interpreted and mapped using their seismic continuity and adequate seismic to well correlation. The results obtained from interpretation of only one horizon K-IX are presented in this paper.

Two seismic sections AA' (Inline) and BB' (Crossline) are shown in Figs. 2 & 3. Correlation of horizon KIX is shown on the sections. Time and depth structure maps (Figs. 4, 5) are prepared using Zmap+mapping package of Landmark workstation. Depth map preparation was done using 3D seismic final migrated velocity grid corrected suitabily with well velocity data. The time and depth structure maps are in conformity, thus indicating no depth anomaly due to velocity.

Seismic attribute analyses were carried out for facies mapping. Vertical and lateral varia

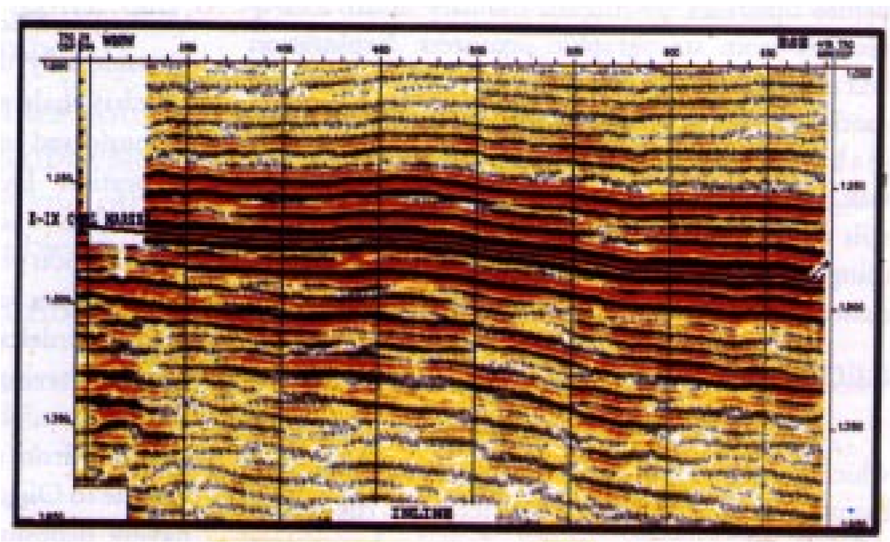

Fig 2. Seismic line AA'(Continuous and series of reflections between 1250 and 1500 msecs correspond to different units of Kalol formation K-IX horizon pertaining to study is correlated and annotated

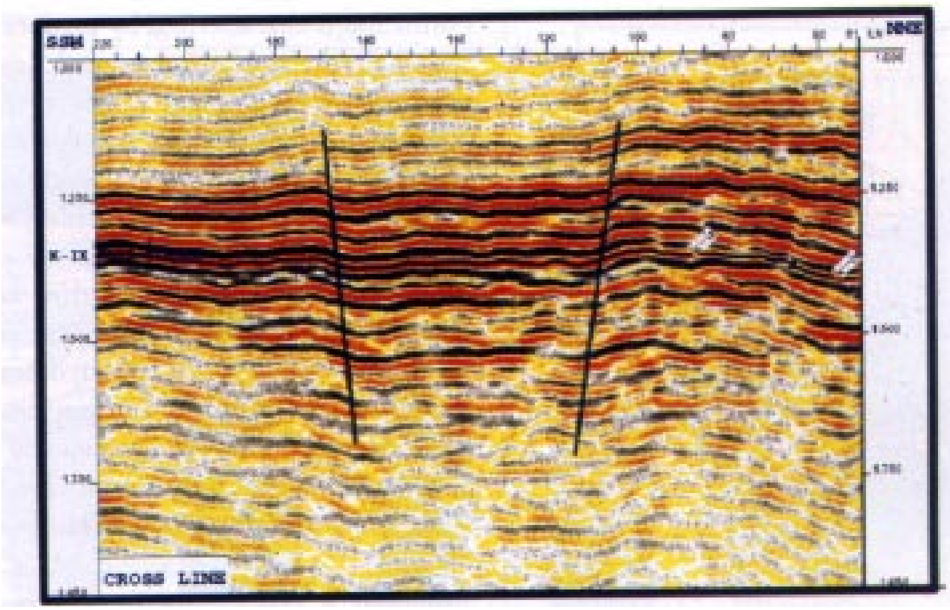

Fig 3. Cross line BB'(Correlation of faults and K-IX horizon shown).

tions in attributes (amplitude, frequency, phase) were analysed using inline, crossline, reconstruction outline, time slice and horizon slice from 3D data volume integrated with well data. Apart from the original seismic data volume different volumes (both flattened and normal) of attributes were generated to study time slices and horizon slices. Flattenning was done at K-IX horizon which lies just above the target reservoirs. Time slices and horizon slices were analysed at every 2ms interval in the zone where presence of reservoir (sand) was established from seismic calibration. Finer structural details and seismic attributes derived from 3D data were integrated with well data and prospective areas were identified.

Fig 4. Time structure map at K-IX horizon(yellow color indicates a high and green color indicates lows and terrace feature).

ATTRIBUTE INTERPRETATION:

Attributes based interpretation offer a more efficient representation for taking advantage of the wealth of information in the data. It is important to note that attribute interpretation supplements conventional structural interpretation and the descriminating properties of the attributes set may be critically checked for its relevance for a particular problem of a prospect.

DISCUSSIONS:

The structural configuration mapped from 3D seismic (Figs. 4,5) has changed considerably compared to the existing maps prepared based on 2D seismic data. A number of E-W trending cross faults in addition to a NE-SW trending fault are mapped. Fault correlation on section has been shown in Fig 3. Post dipositional fault control structure foming is evident in the area. The structure maps indicate NW-SE trending high and low features in the north and SW-NE trending low in south with terrace feature In

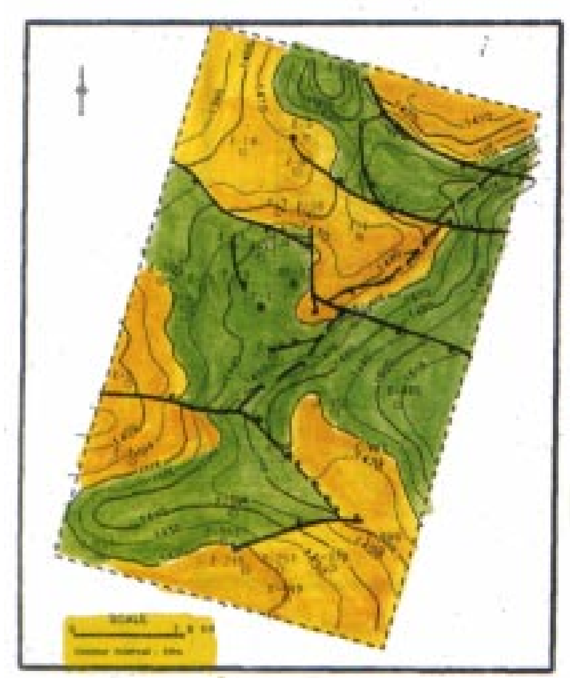

Fig 5. Depth structure map at K-IX horizon(yellow color indicates high and green color indicated lows and terrace feature).

the central part of the area. The observation of cross faults and complexities in structural disposition especially juxtaposing high/terrace features against low' indicate complex tectonic movement in the area. A seismogeological section in the NNE-SSW orientation is shown in Fig. 6 which highlights the general structural trend and stratigraphic development in the area.

Lithostratigraphy variation corresponding to Kalol Formation is characterized by predominance of coal and shale facies with restricted development of siltstone/sandstons. Seismic events are relatively strong due to high contrast interfaces between coal/shale and coal/sand units. An electrolog correlation profile is shown in Fig. 7. Thick widespread to thin discontinuous coal development are observed. The occassional development of thin sands are also observed. These sands encased in an overall coal-shale sequences are good producer of hydrocarbon. Seismic attributes have helped to delineate one such sand in K-IX sequence which was encountered in a few wells prior to 3D survey. A course of channel filled with sands is identified from seismic attributes.

Figs. 8, 9 and 10 are the two panel displays of the same seismic section CC' selected In an area where channel is relatively wider due to its E-W orientation. Normal and flattened (at K-IX horizon) sections shown in Fig. 8 indicate channel marked by arrows in yellow colours. The flattened section has confirmed the paleolow and course of channel flow. Fig. 9 represents the display of the normal section (dual polarity) and reflection magnitude attribute of seismic section CC'.

The channel is clearly indicated. Instantaneous frequency and phase attributes sections are shown in Fig. 10. The low frequencies and wider cycles are visible in frequency and phase attribute sections corresponding to the channel area.

The horizon slices generated from both amplitude and frequency attribute data volumes

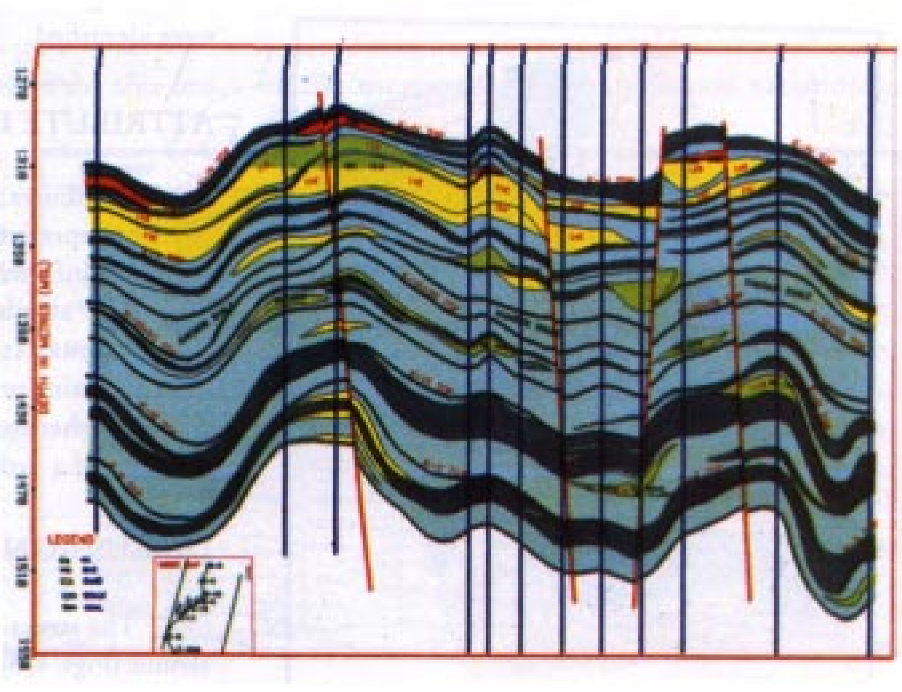

Fig 6. Siesmological section showing lithological and structural attitudes of Kalol formation. Coal, Shale, sand and oil sands are shown in black, light blue, yellow and green colors respectively. Faults are amrked in red color.

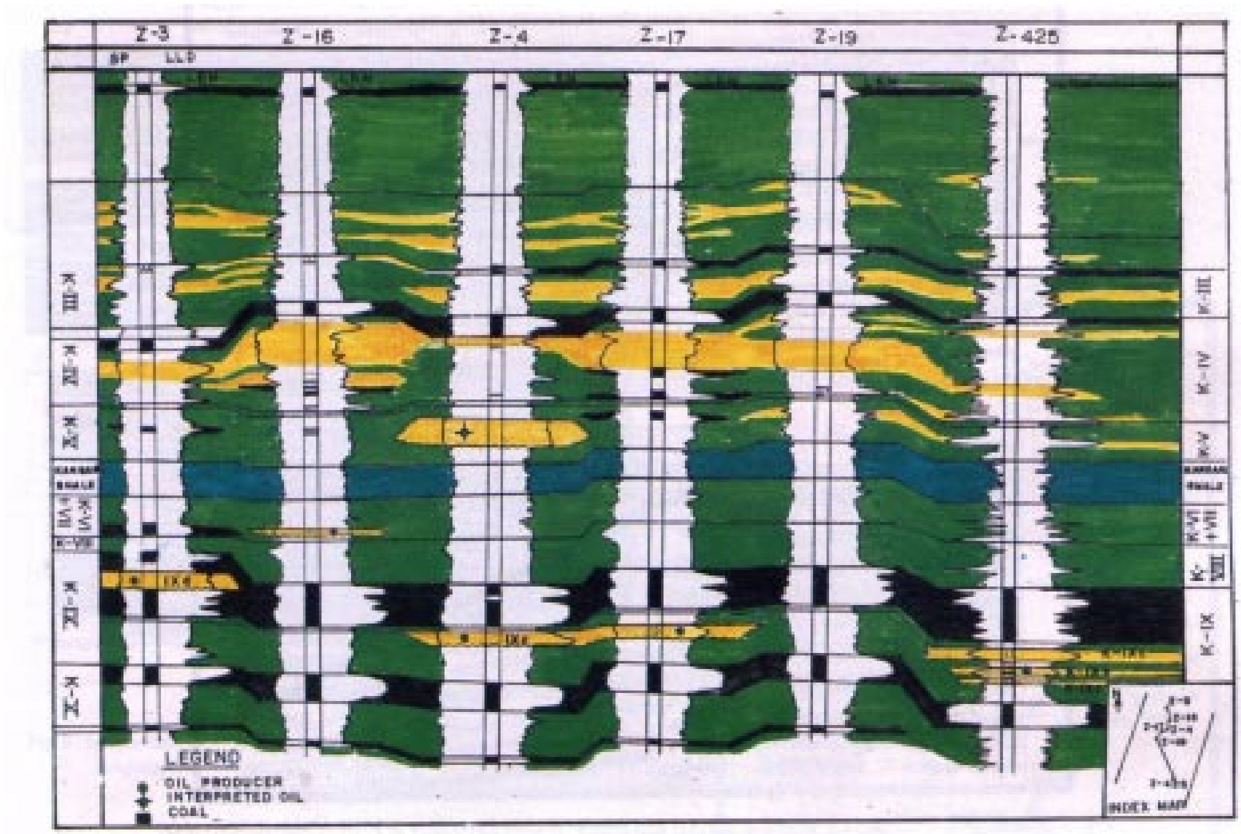

Fig 7. Electrolog correlation profile(flattened at LRM marker). Black and yellow colors represent coal and sands whereas green and blue colors represent shale lithology.

are shown in Figs. II, 12. A NW-SE oriented channel has been observed from amplitude attribute '(Fig. II) and the same is also confirmed from frequency attribute horizon slice (Fig. 12). Negative amplitudes of higher magnitude (blue colour) and relatively low frequencies of the order of 20 to 28Hz (red colour) are observed corresponding to the course of channel. It is observed that the frequency attribute data brings out some additional area in between wells Z-17 and Z-469 as compared to amplitude data. The channel mapped from attributes are found in conformity with the well data. Based on the channel mapped from attribute a geological model integrating further well data are prepared and shown in Fig.13. An electrolog correlation, showing finer subdivision of K-IX units is also shown in Fig. 14 which explains the fluid distribution in different reservoir units.

CONCLUSIONS:

The interpretation of 3D seismic survey has provided a detailed structural and stratigraphic interpretation of the reservoir previously unattainable with 2D seismic and well data. The delineation of thin pay sands using seismic attributes has been attempted and a visibly clear channel has been mapped from both frequency and amplitude attributes. It is observed that the different sand units of Kalol Formation need careful study to chase the reservoir facies development especially utilizing attributes information and horizon slices interpretation. Though target sands are .thin and limited in areal extent deposits, they are found very attractive for their economic value of hydrocarbon production due to high production rate and economic drilling in the area. The channel mapped at K-IX level has been proved by drilling a number of wells after this 3D interpretation.

ACKNOWLEDGEMENTS:

The authors are grateful to Mr. A.G. Pramanik, GGM(E) & Head GEOPIC, and Mr. S.N. Badola, DyGM & Head INTEG, for their constant guidance and encouragement during the

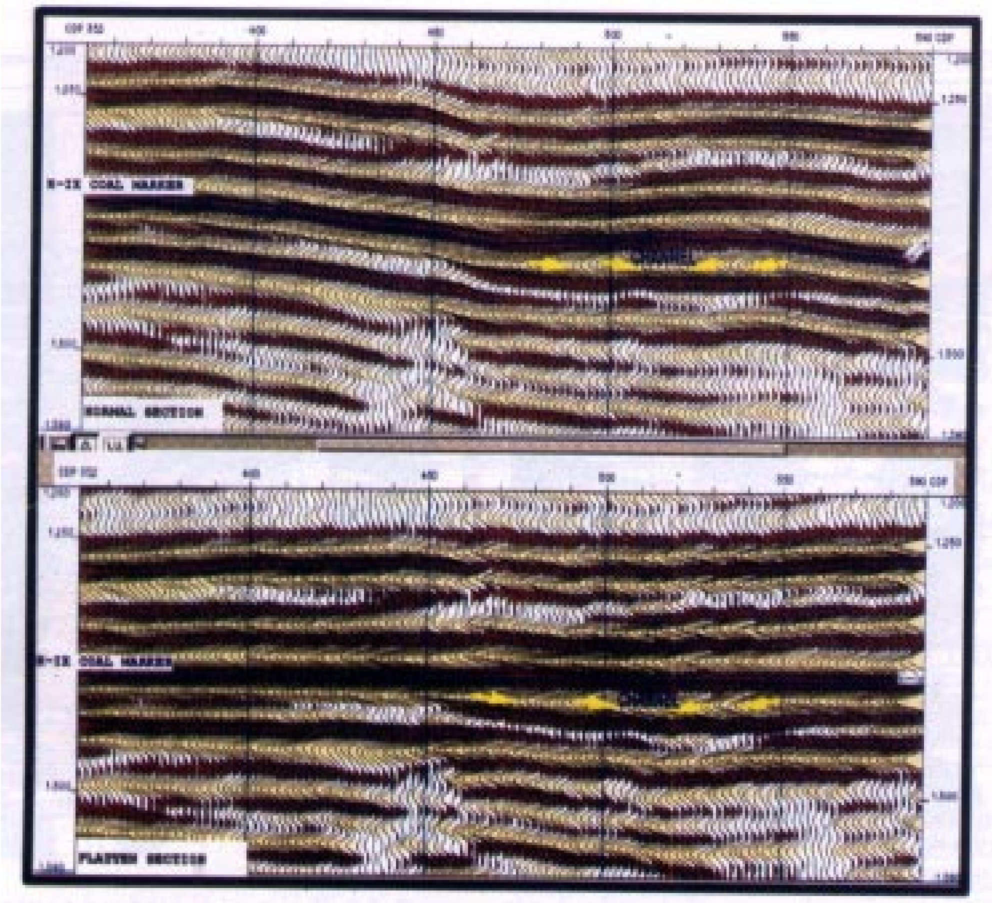

Fig 8. Seismic line CC' section above is normal and below is after flattening at K-IX(Coal marker) level. Yellow color arrows indicate channel.

course of .work and preparation of this paper. The support provided by Workstation Management Group of INTEG is thankfully acknowledged. The authors are also thankful to ONGC for giving permission to publish this paper.

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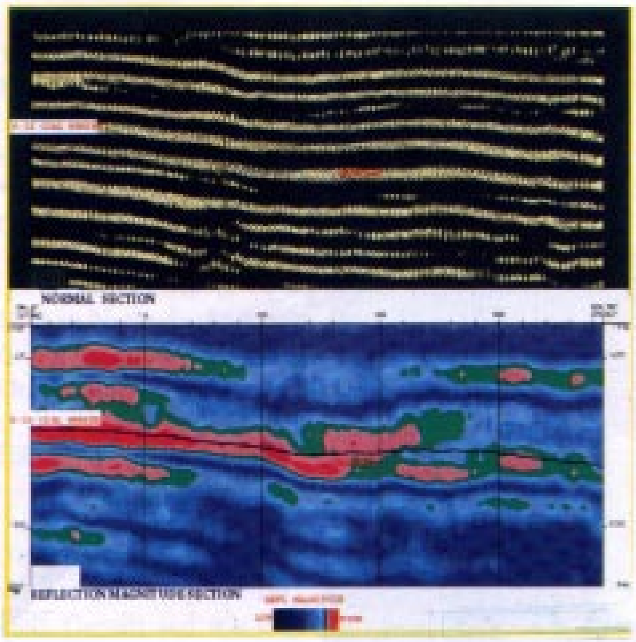

Fig 9. Seismic line CC'. Above is normal and below one is Reflection magnitude attribute section. (red color is high and blue low magnitude.)

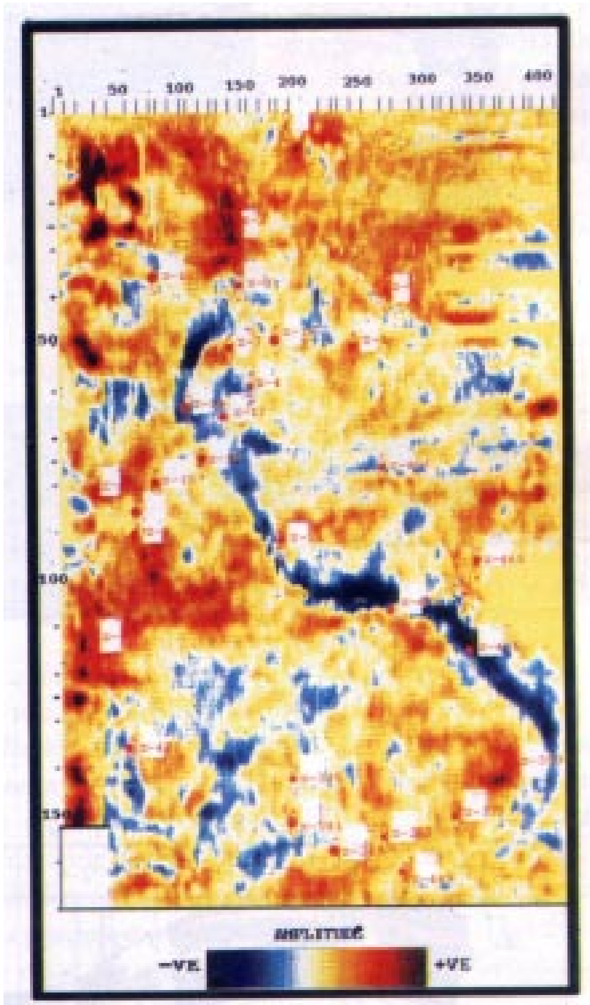

Fig 11. Horizon slice corresponding K-IX reservoir from amplitude attribues data.(blue color higher negative amplitude values and red positive amplitude values)

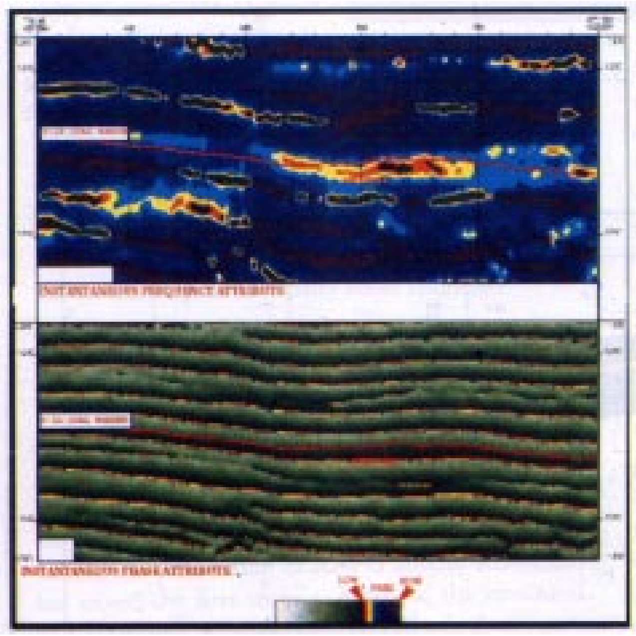

Fig 10. Seismic line CC'. Above is Instantaneous Frequency and below one is Instantaneous phase attributes(red color low frequencies and blue is high frequencies)

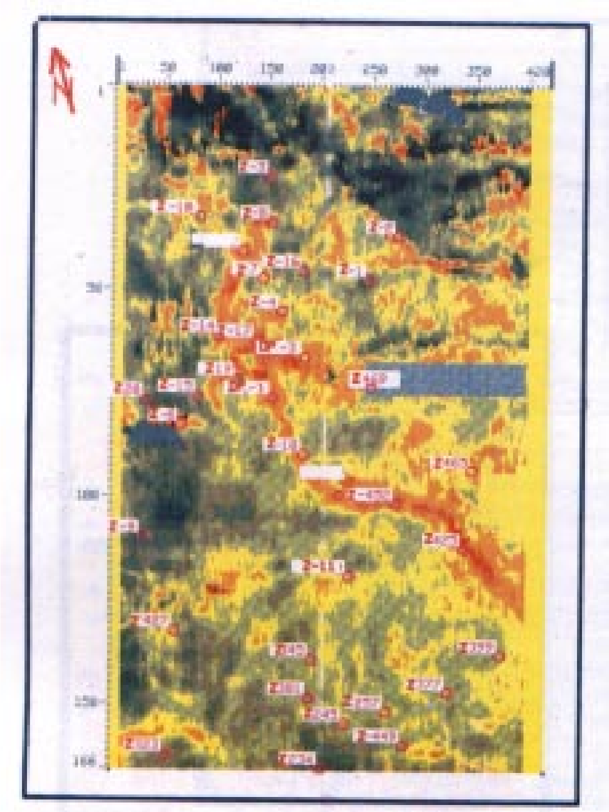

Fig 12. Horizon slice corresponding K-IX reservoir from frequency attributes data (red color low frequencies and black color high frequencies)

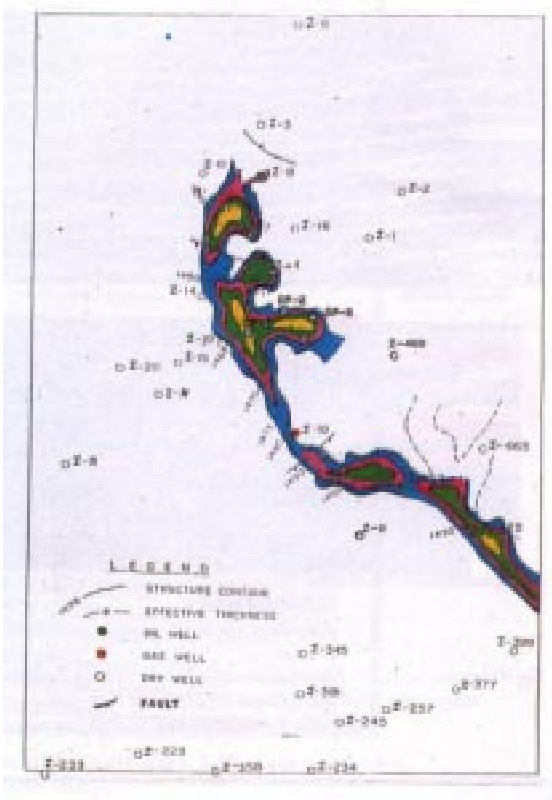

Fig 13. Geological model derived from channel course identified from seismic attributes integrated with well data. Sand isolith contours are drawn from well data. Structures are also overlaid.

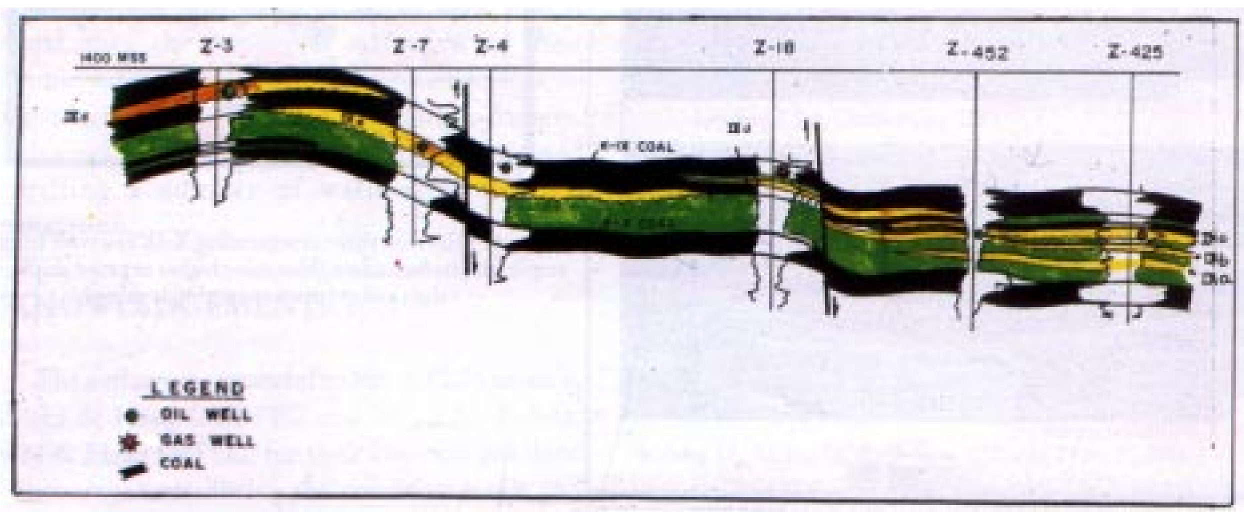

Fig 14. Log correlation of wells where K-IX reservoir sands are met. (Black colr is coal, green color is shale and yellow color is sands).