Seismic Attributes for Prediction of Reservoir Architecture and Hydrocarbon Prospectivity: A Case Study of Zubair Formation in Bahrah Area, North Kuwait*

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Abstract

The spectral decomposition for seismic thin bed reservoir characterization (Partyka et al, 1999) and the seismic inversion (Pendrel, 2001) for mapping the distribution of clastic reservoir facies, play an important role in identifing the hydrocarbon accumulation. The interpretation of PSDM seismic data, in a structurally complex area and the use of seismic semblance, amplitude variance attribute and its visualization are crucial to understanding the fault system as well as hydrocarbon entrapment conditions. In this article, seismic attributes are pragmatically used to analyze the gross depostional environment of the Zubair Formation to mitigate the challenges of reservoir facies distribution in Bahrah area, North Kuwait.

A sequence stratigraphic approach was adapted to understand the reservoir characteristics of Zubair Formation, which was deposited in a fluvial to deltaic environment with considerable marine influence. The PSTM and PSDM seismic data, covering ~385 km^2, was used to carry out the project. The structural mapping, using PSDM data, exhibits anticlinal features with subtle highs and lows; the structure accompanied by seismic amplitude variance, coherency-based semblance attribute shows NW-SE, NE-SW and E-W orientations of the faults. The post-stack seismic inversion was carried out using PSTM seismic data to obtain the P-impedance volume. The well logs and the petrophysical interpretation show the lowering of the P-impedance across the sand facies interval identified with the lowering in the gamma ray log. These are tied to the inverted seismic data in the relative P-impedance domain within estimated seismic frequency band (5-65 Hz). The spectral decomposition methodology was adapted to understand the characteristics of thin sand features within Lower Zubair (LZ) and Middle Zubair (MZ) intervals. The analysis

of whole range of frequency (5-65 Hz) evident with 55 Hz dominant higher frequency amplitude distribution depicts the thin sand facies distribution in MZ and LZ intervals.

Thus, the P-impedance property against the reservoir sand facies facilitates characterization of the Zubair sand distribution (as deltaic deposits). The spectral characteristics improve the understanding of the MZ and LZ thin-bed depositional pattern. Moreover, the structural interpretation supports the understanding of traps and reservoir architecture. Based on this study, several potential exploration areas have been identified; and exploratory drilling locations have been proposed.

Selected References

Partyka, G.A., J.M. Gridley, and J. Lopez, 1999, Interpretational Applications of Spectral Decomposition in Reservoir Characterization: The Leading Edge, v. 18/3, p. 353-360.

Pendrel, J., 2001, Seismic inversion - The best tool for reservoir characterization: CSEG Recorder, v. 27/01. Website accessed October 2, 2016, http://csegrecorder.com/articles/view/seismic-inversion-the-best-tool-for-reservoir-characterization.

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A Case Study of Zubair Formation in Bahrah Area, North Kuwait"

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SEG
Society of Exploration Geophysicists
The international society of applied geophysics
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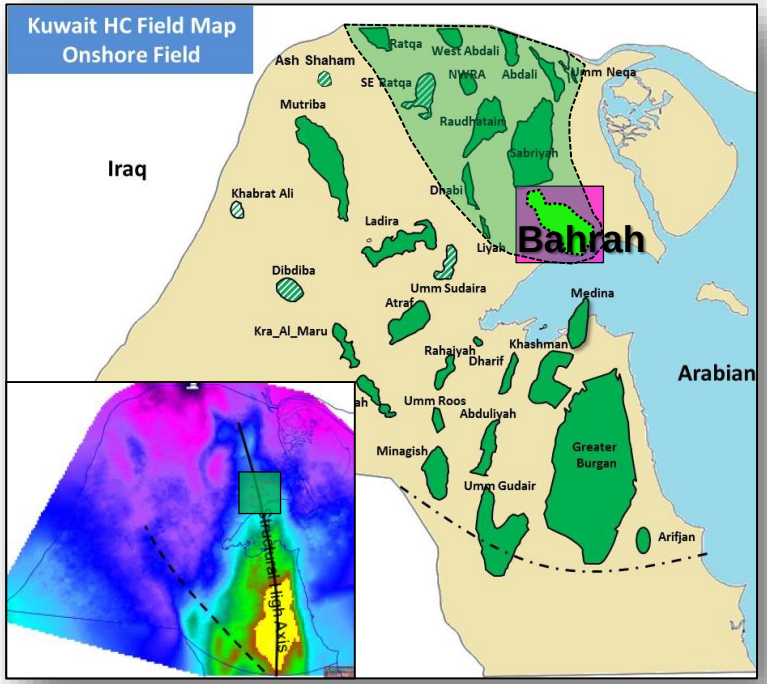
Outline

- Introduction
- Challenges
- Brief geology
- Data Availability
- Methodology (Structural Interpretation, Sequence Stratigraphic Framework, Spectral Decomposition, Seismic Inversion Data Analysis)
- Reservoir Architecture
- Conclusion

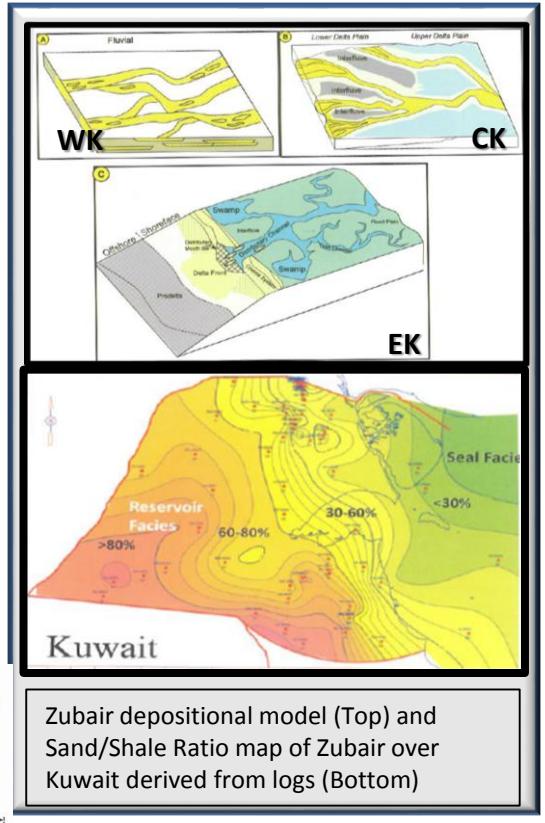
Introduction



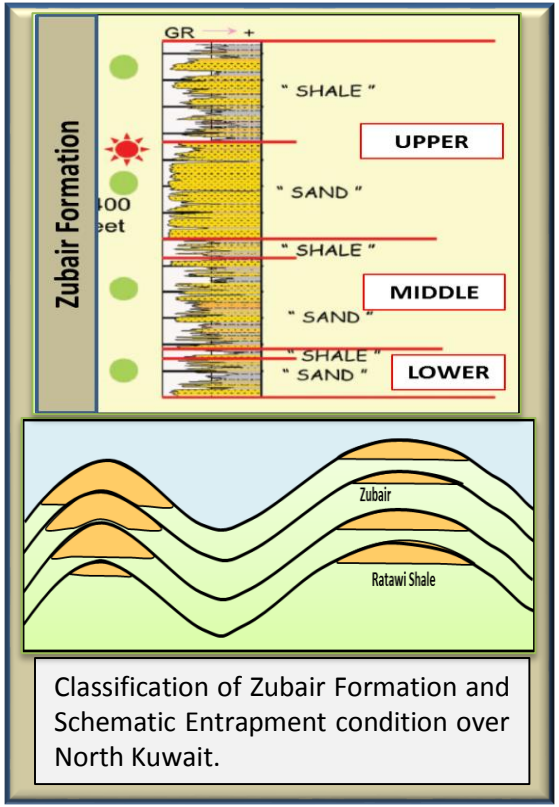
- 1st exploratory well drilled in Kuwait (in Bahra area) to yield minor oil shows.
- During 1936-37 few wells drilled target the Cretaceous reservoirs.
- Only 5 Jurassic wells penetrated through Lower Cretaceous section.
- Till now, Lower Cretaceous is in early phase of exploration in Bahrah area.

The Study area is located to the Southeast of Sabriyah & Raudhatain area. In addition to Sabriyah & Raudhatain, Abdali, Ratqa and Sudaira are main producers from Zubair Formation in North Kuwait.

Zubair Formation



Zubair depositional model (Top) and Sand/Shale Ratio map of Zubair over Kuwait derived from logs (Bottom)



Classification of Zubair Formation and Schematic Entrapment condition over North Kuwait.

Zubair is mainly clastic reservoir

The **Lower Zubair** was deposited in complex estuarine and marine environment.

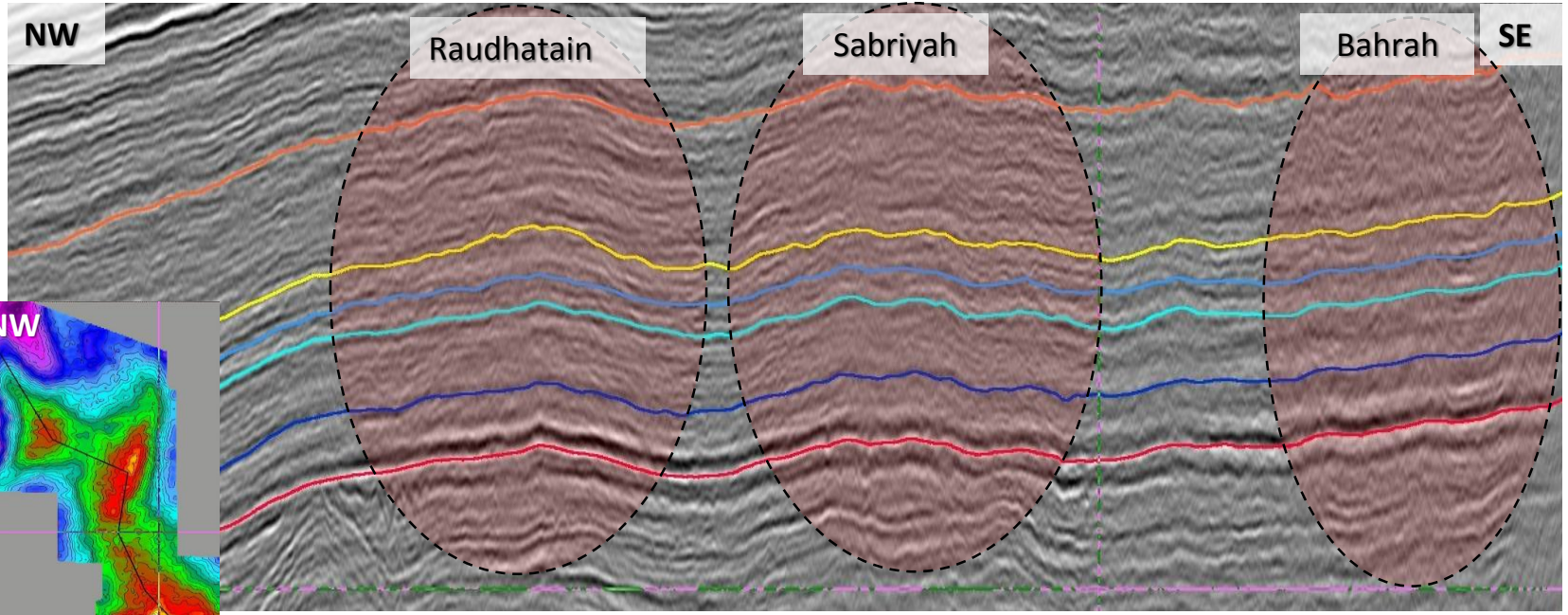
The **Middle Zubair** dominantly displays fluvial and estuarine environment of deposition generally more landward compared to the Lower Zubair.

The **Upper Zubair** was deposited in deltaic to estuarine environment with strong marine influence.

Challenges

- Lack of Complete data set
- Entrapment Condition
- Reservoir Facies
- Extent of the Reservoir

Introduction

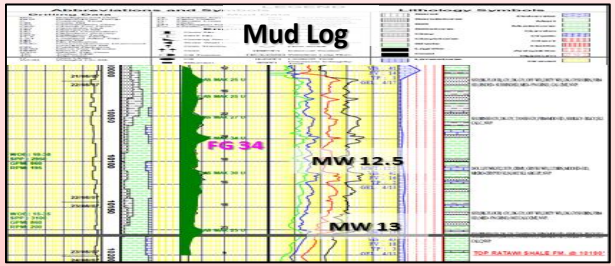


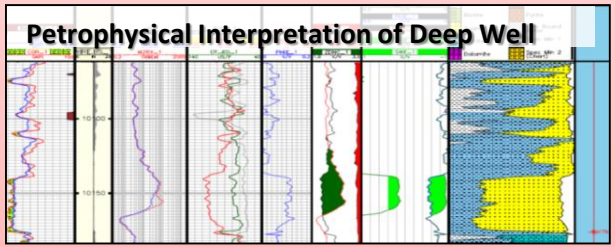
The seismic section from the NW to SE direction shows the structure is in the up-dip direction which is following in the same trend with the Kuwait arch.

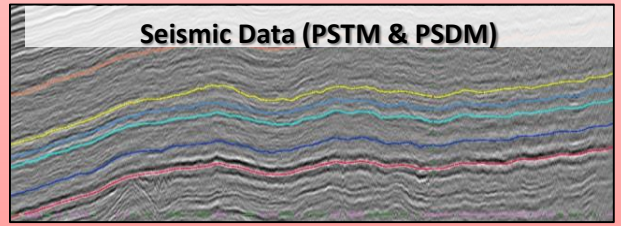
Data Availability

Well Info	Logs	Seismic
Recently drilled deep wells showed good to moderate gas shows within Zubair formations in the mud logs with mud weight information.	This triggered desire to review the logs for HC indication. Logs show better porosity & resistivity.	Both the PSTM & PSDM 3D and 2D data available with good qualities with inherent limitation. It is good to start in the prospectivity analysis to consider the structural complexities.

Integration is the Key







Methodology

Structural Interpretation

Horizon Interpretation (PSTM & PSDM)

Fault Interpretation (PSDM, Seismic Variance, Semblance, Combo-Mambo)

Seismic Sequence Stratigraphy

Interpretation of Top Zubair, Upper Zubair (UZ), Middle Zubair (MZ) and Lower Zubair (LZ)

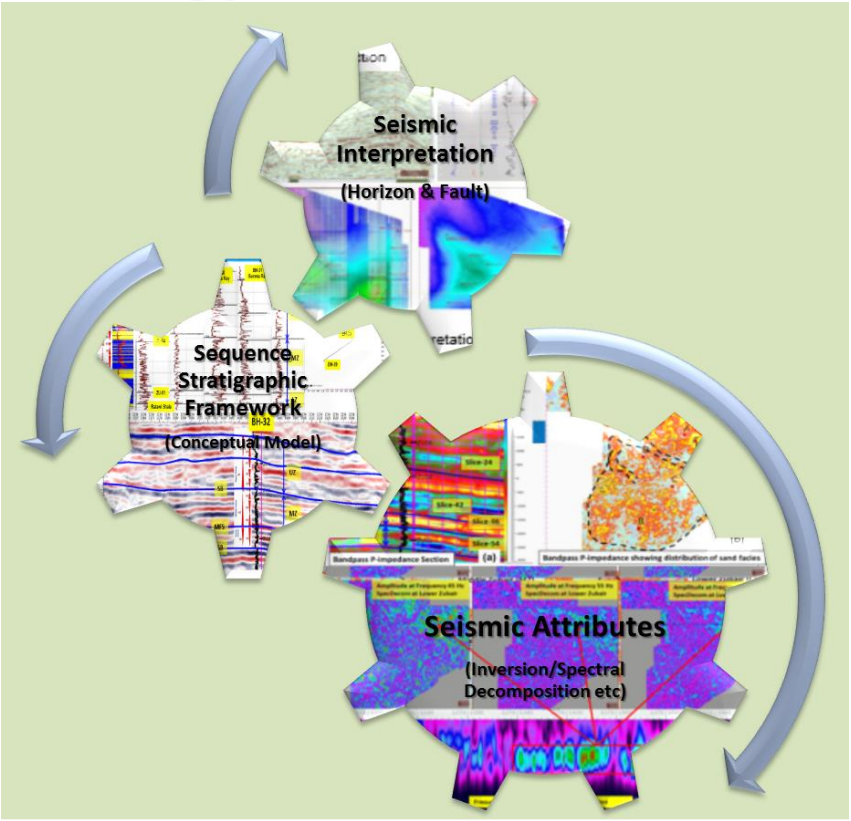
Spectral Decomposition

Spectral Decomposition Tuning Cube – DFT

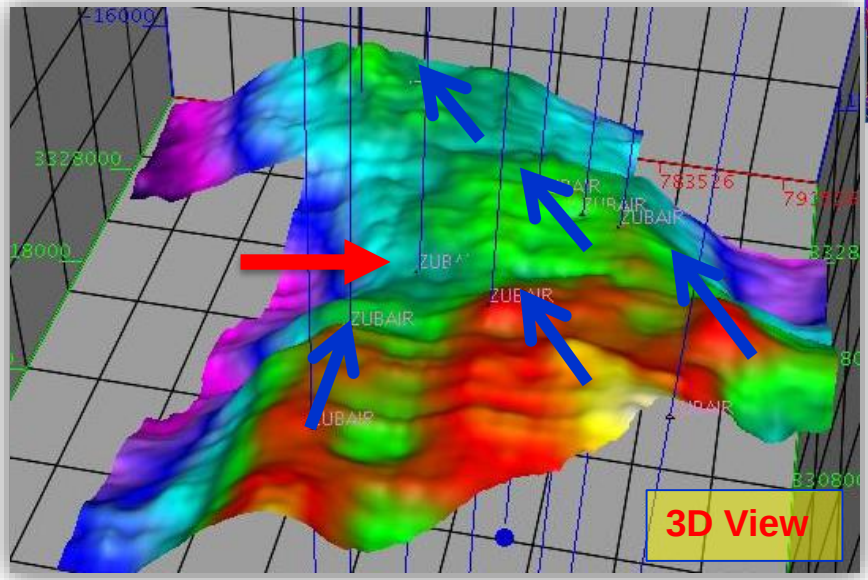
Bed thickness identification

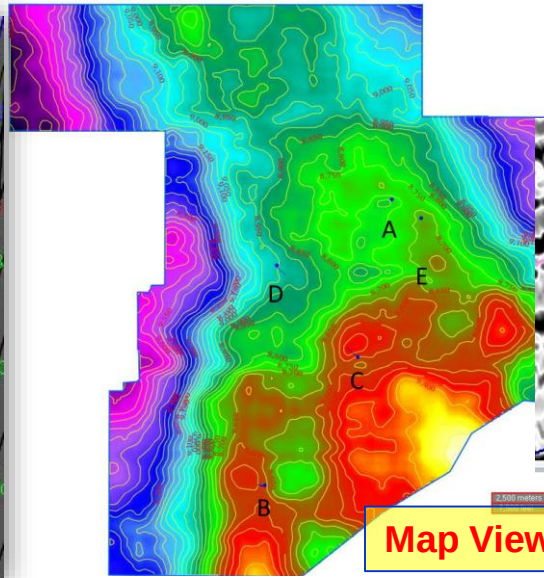
Seismic Inversion (Reservoir Characteization)

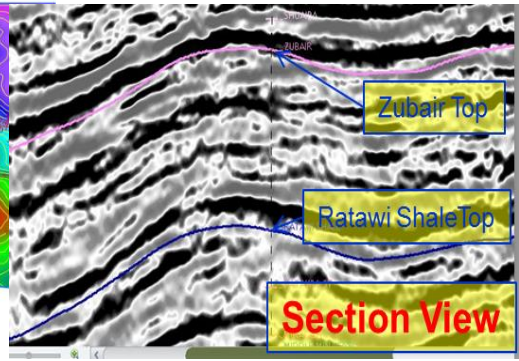
PSTM seismic data inversion to identify reservoir facies distribution and depositional pattern.



Structural Interpretation

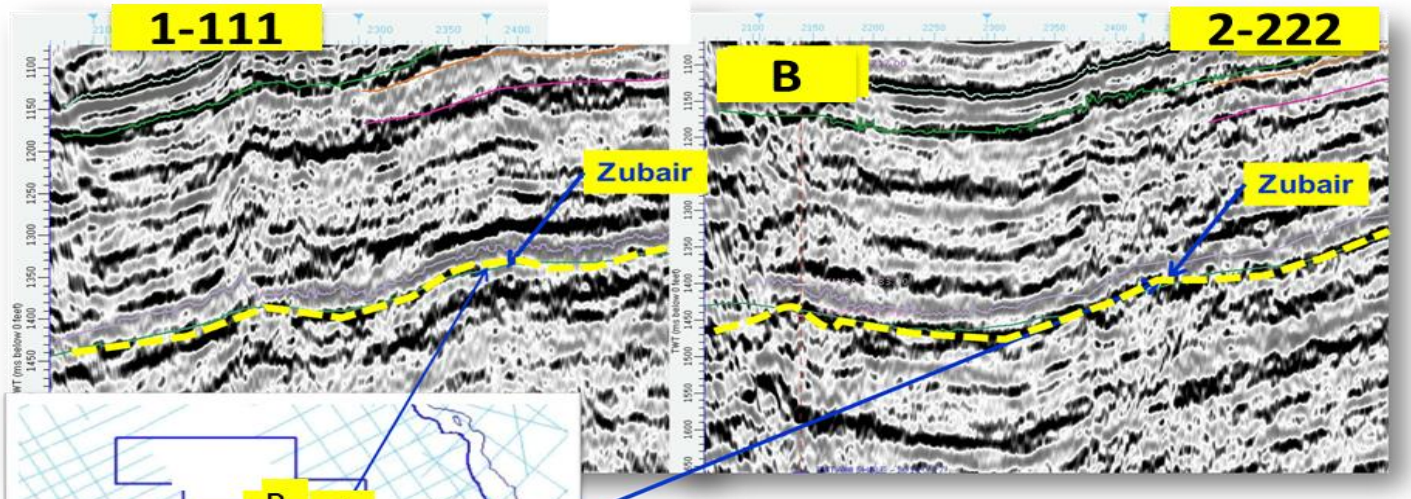






Three structural high trends are observed in the 3D gridded data of the Zubair top surface--one through well B, another through well C and another towards the east.

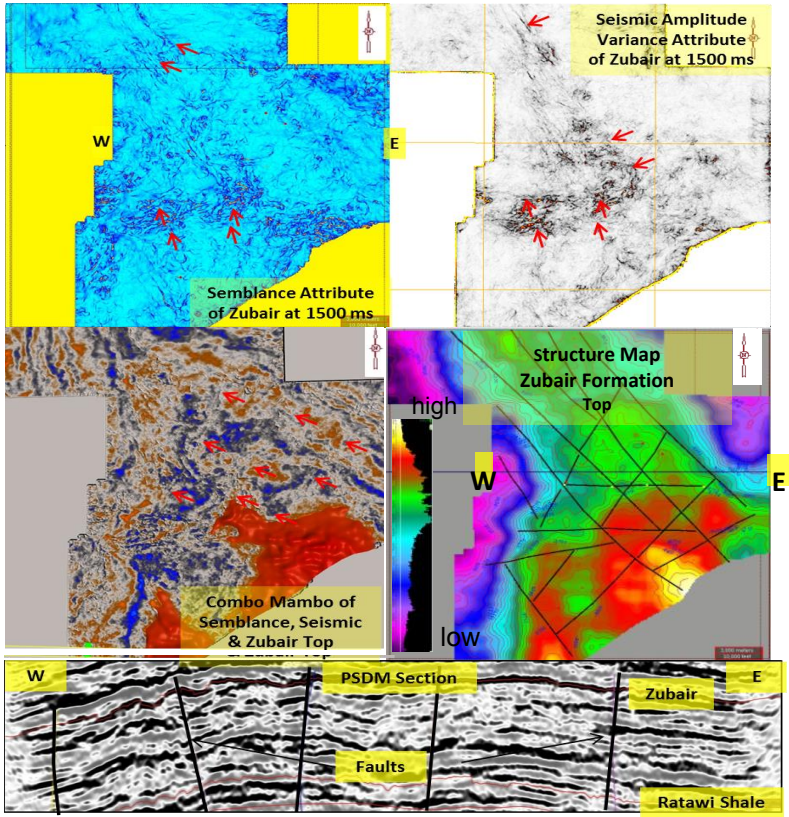
Seismic 2D Lines



L line passing through area near well B shows structural anticlinal feature in line no 1-111.

2-222 line shows structure towards south-east direction over the bay area.

Fault Identification



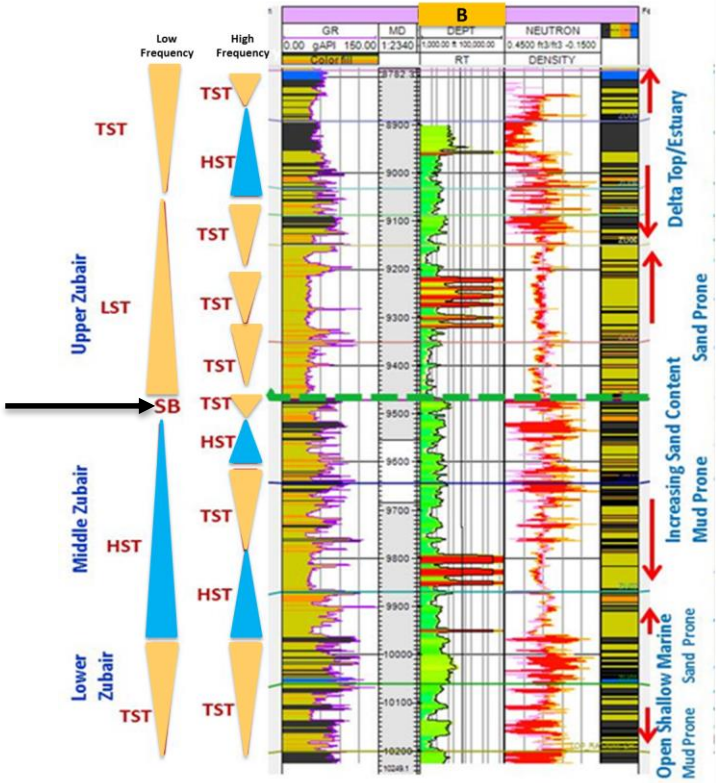
To identify the complexity of the faults the following seismic attributes are taken into consideration

- Seismic Variance
- Semblance
- Combo-Mambo
- PSDM Seismic Data

The red arrows are showing three sets of faults. These are mostly

- NW-SE
- SW-NE
- E-W

Sequence Stratigraphy and implication on Reservoir distribution



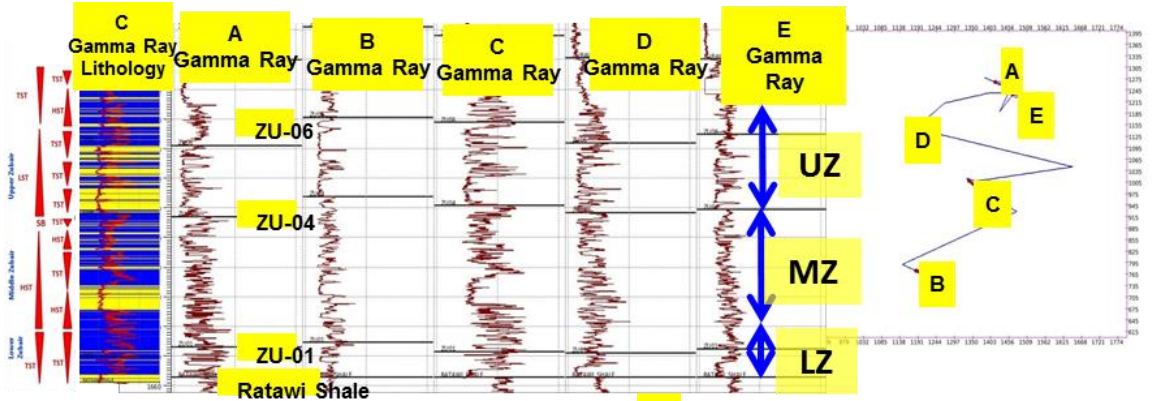
- General upward trend from sand to mud-prone deltaic deposits interbedded with minor distributary sandbodies to increasingly more open marine deposits…… indicate high frequency flooding surface
- Good reservoir associated with deltaic channel fill ,most commonly isolated single stray distributive network

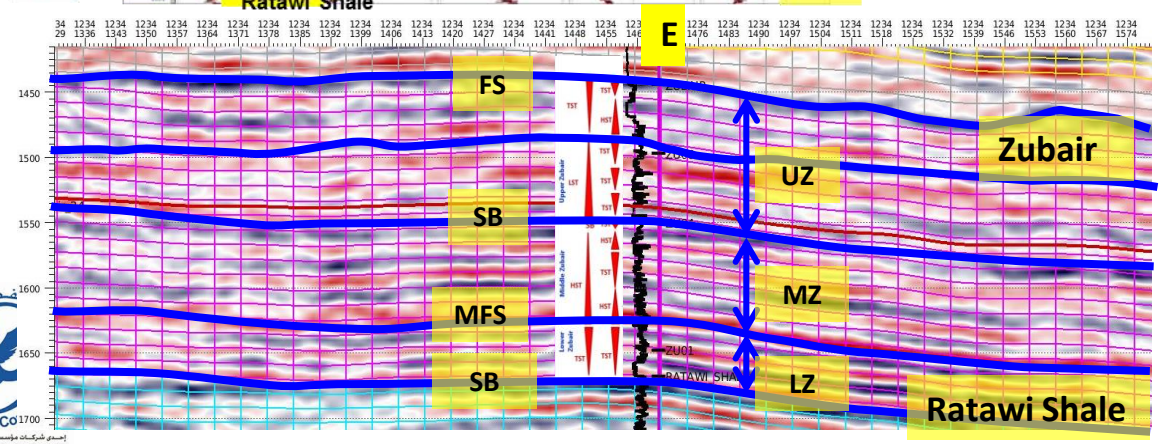
- This LSt bounded by SB at base and mfs at the top.
- Characterized by multistory estuarine channel and interbedded mud-prone abandonment deposits.
- This marine deposits show some marine character ,may be formed in response of flooding events which define the reservoir zonation within this interval
- Reservoir quality within channel very good to excellent

- This HST has two high frequency HST separated by TST
- Muddy open marine at base of LMZ & MMZ ,widespread, and act as seal .supported by pressure data in Raudhatain field
- Several channels generated either isolated or vertically stacked show excellent reservoir potential. Channel seems to be oriented NE-SW

- Basinal mudstone of underlying Ratawi Fm. and deltaic influenced deposits of LZ… therefore indicate SB (Carruthers et al., 1997)
- LZ characterized by laterally widespread mud-prone delta top facies—act as baffles
- The backstepping character of LZ sand suggests sandbodies less extensive laterally towards the top of LZ

Sequence Stratigraphic Framework





This methodology is used to understand the spatial distribution of the sediments.

Based on the sequence stratigraphic understanding from the well data, the seismic data have been interpreted.

The Top and Base of the Zubair Fm. have been interpreted, apart from that the Upper Zubair (UZ), Middle Zubair (MZ) and Lower Zubair (LZ) have also been interpreted.

The framework was built using the parallel layering approach to Top and Base of Zubair.

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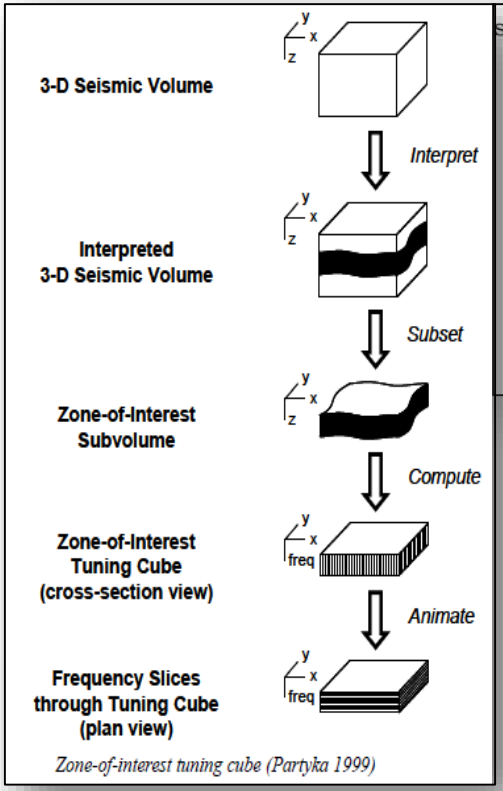
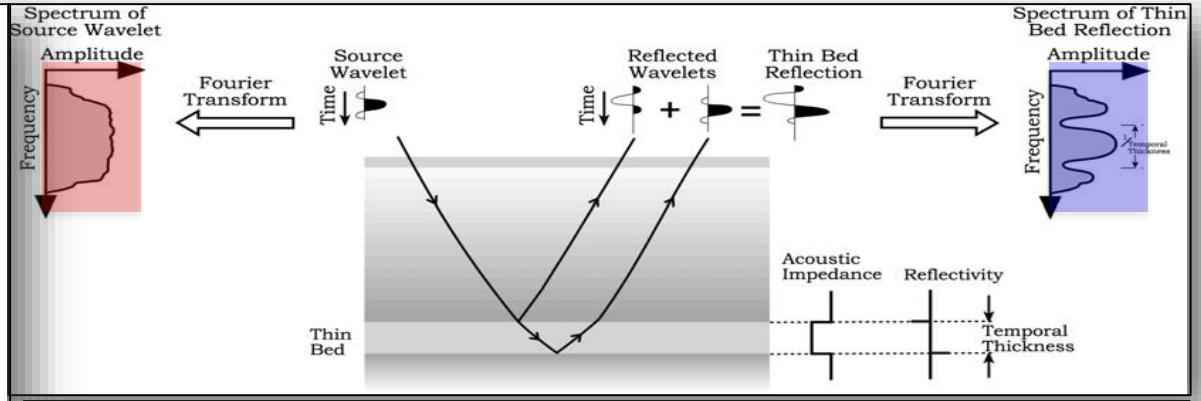
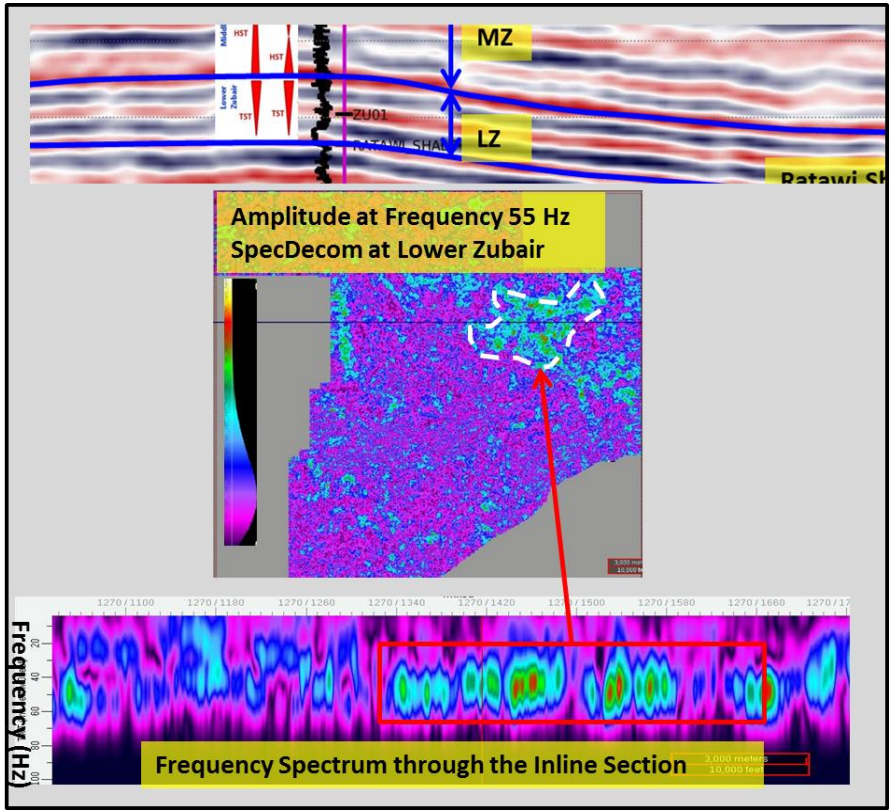
Spectral Decomposition





Spectral Decomposition transforms the seismic data into the frequency domain via a Discrete Fourier Transform (DFT) .
The transformed (phase independent) **amplitude spectra** are used to delineate temporal bed thickness variability, while the phase spectra are used to indicate lateral geologic discontinuity.
This technique has proven to be a robust approach for thickness estimation and fault definition.

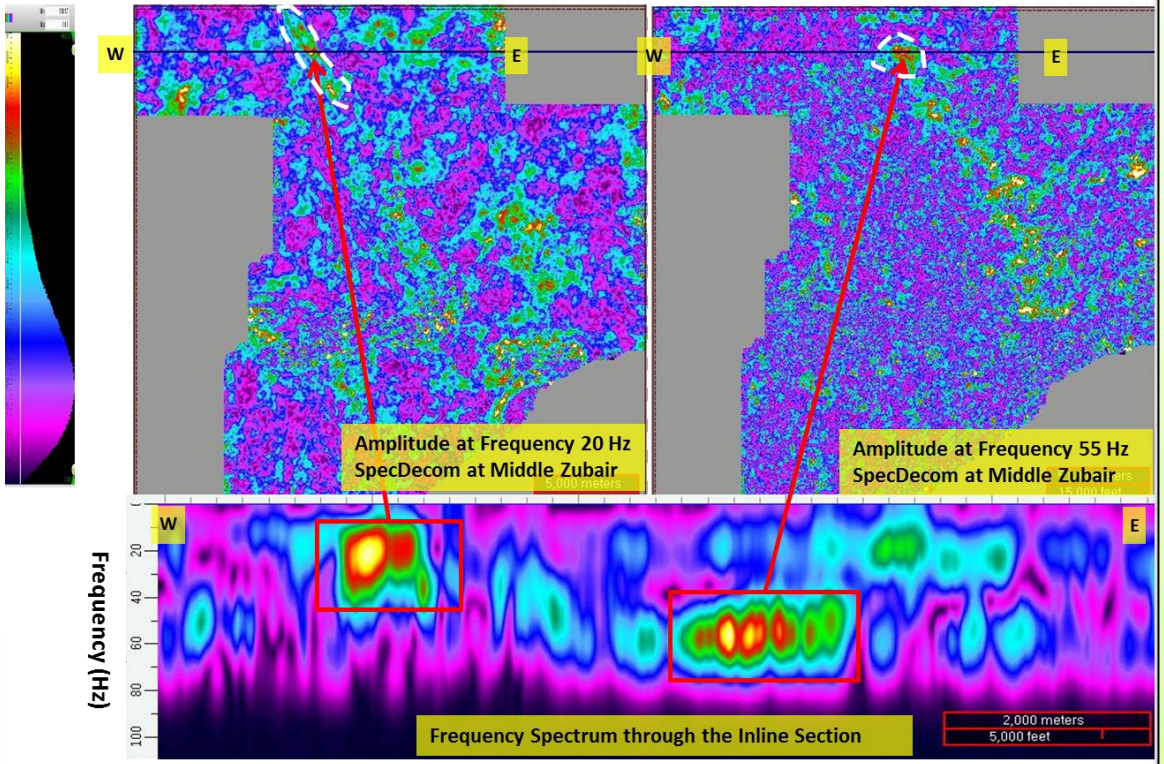
Spectral Decomposition for Lower Zubair



Spectral Decomposition of the Lower Zubair Interval shows the predominant high frequency.

The high frequency anomaly is seen in the eastern part of area. So the anomaly in the eastern part is comparatively less thick.

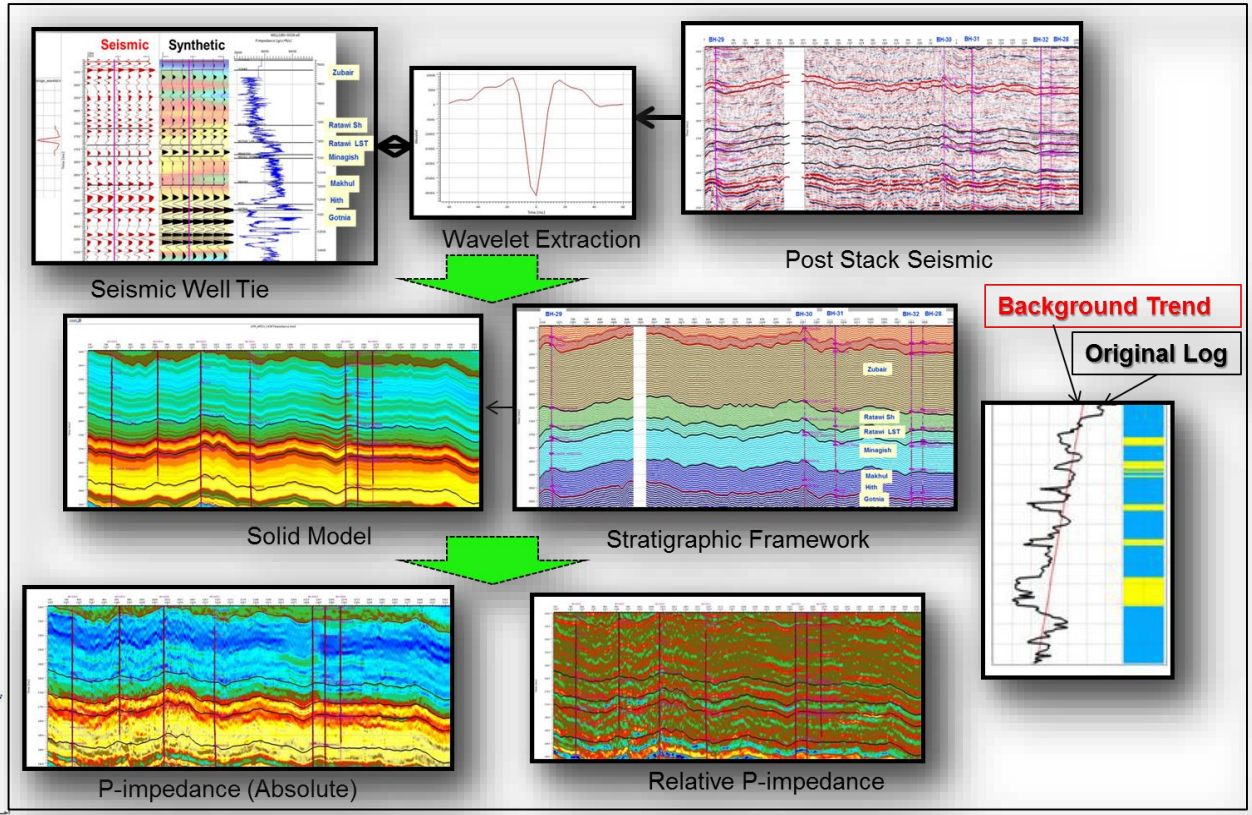
Spectral Decomposition for Middle Zubair



The Low frequency anomalies are seen in the west part of the Bahrah area. The bed thickness in the west part is quite moderate in thickness.

The high frequency anomaly is seen in the eastern part of area. So the anomaly in the eastern part is comparatively less thick.

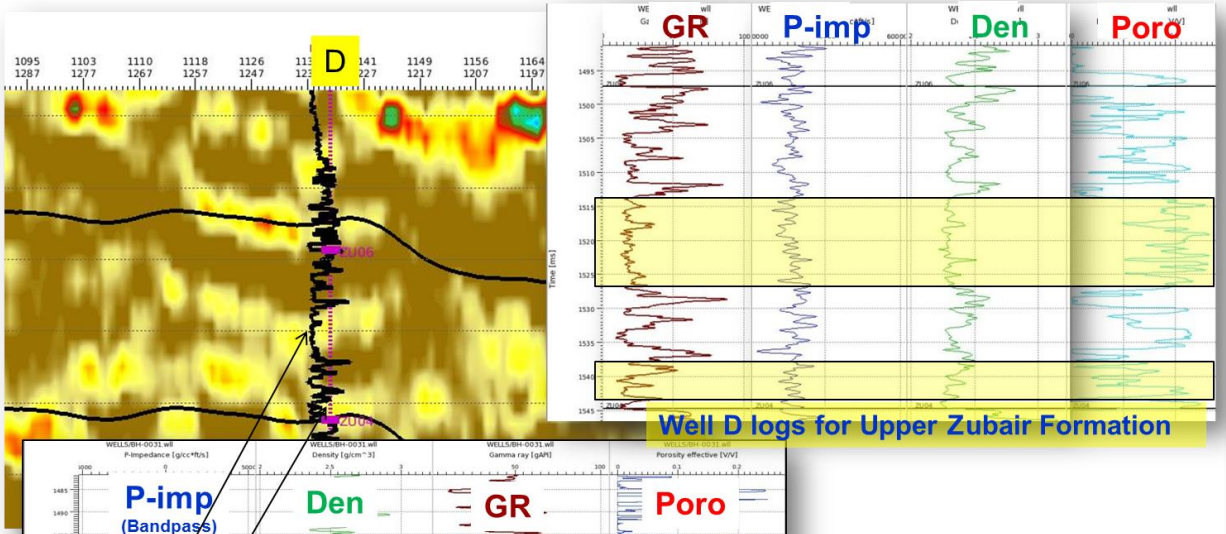
Post-Stack Seismic Data Inversion Workflow



The P-impedance log is showing the characteristic log feature.

If we remove the background shale trend, the log will be the relative impedance log. This relative impedance log will enhance & indicate the reservoir characteristics.

Upper Zubair Reservoir Identification

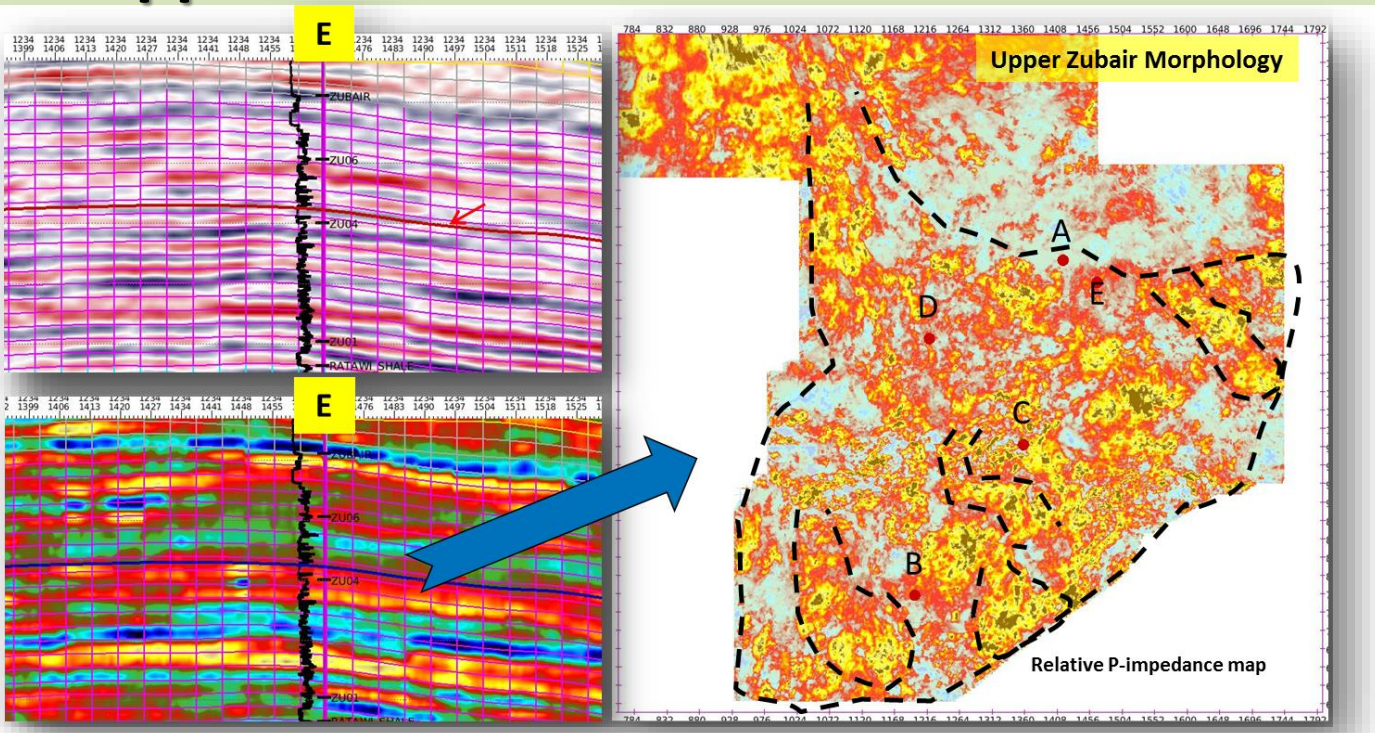


Lowering in the Gamma Ray log shows the sand facies.

Lowering in the density and P-impedance matches the porosity development.

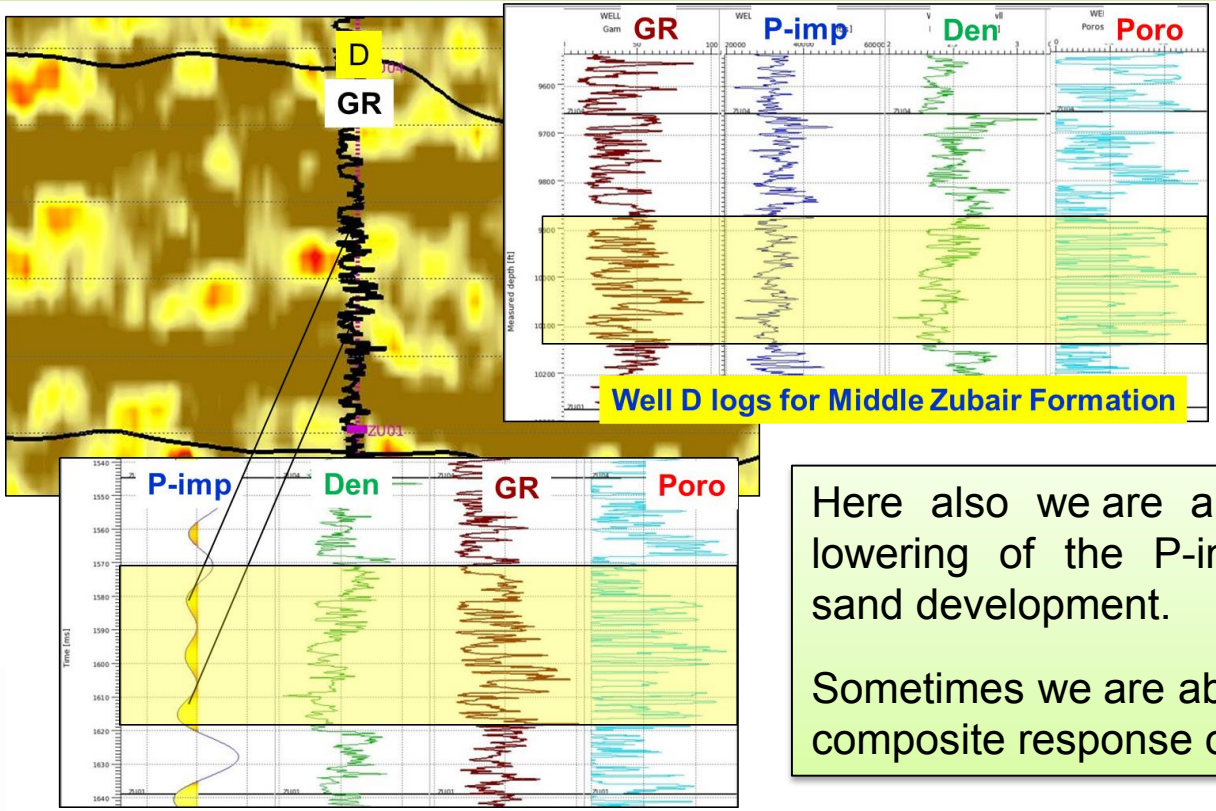
The bandpass P-impedance also matches the sand facies development.

Upper Zubair Reservoir Identification



Relative P-impedance map showing the distribution of the sand facies.

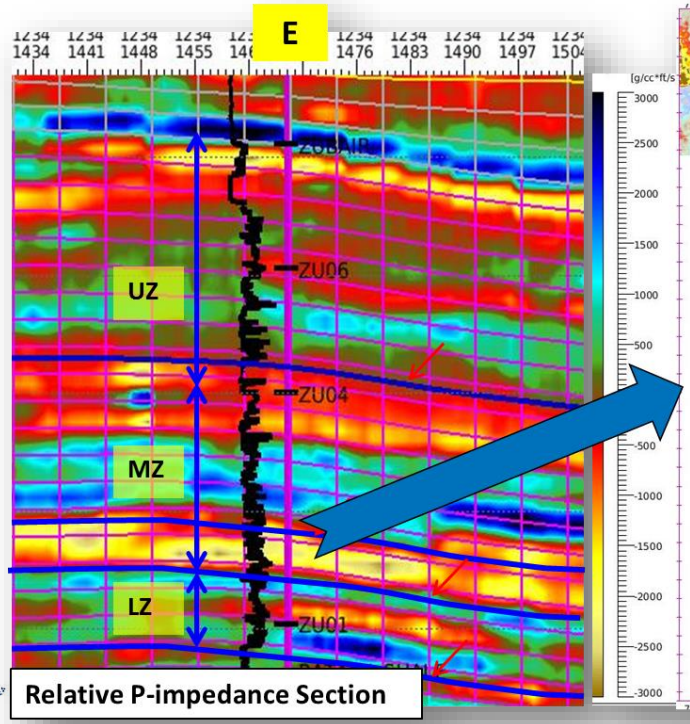
Middle Zubair Reservoir Identification

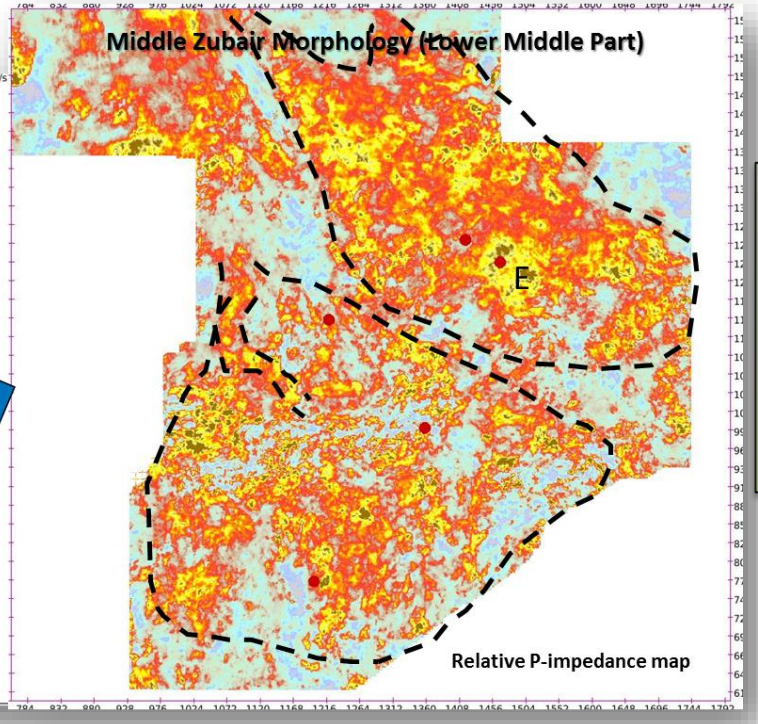


Here also we are able to see the lowering of the P-impedance across the sand development.

Sometimes we are able to observe the composite response of the sand.

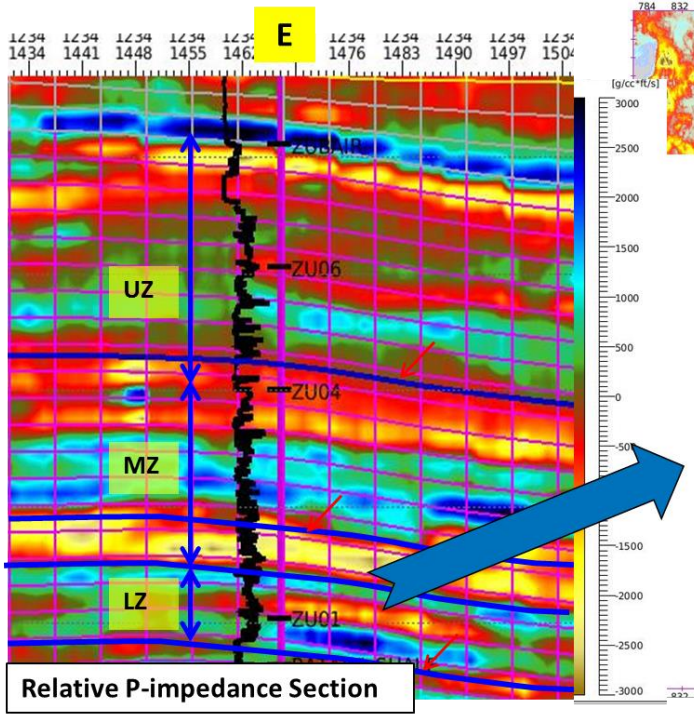
Middle Zubair Reservoir Identification



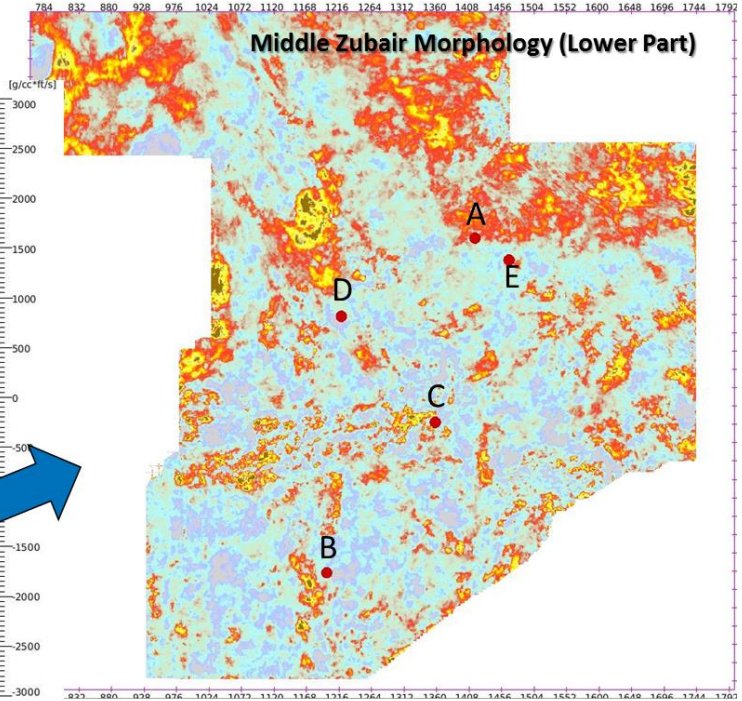


Relative P-impedance map showing the distribution of the sand facies in Middle Zubair.

Middle Zubair Base

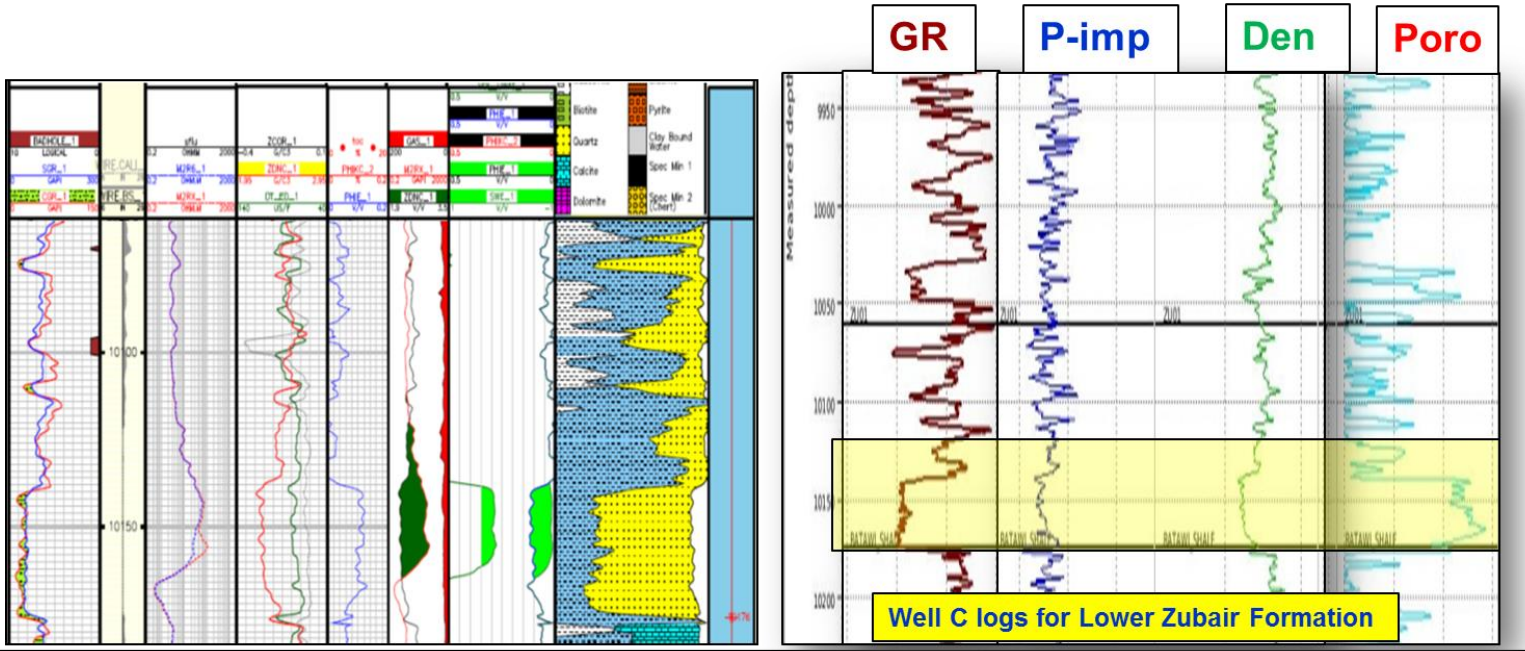


Relative P-impedance Section



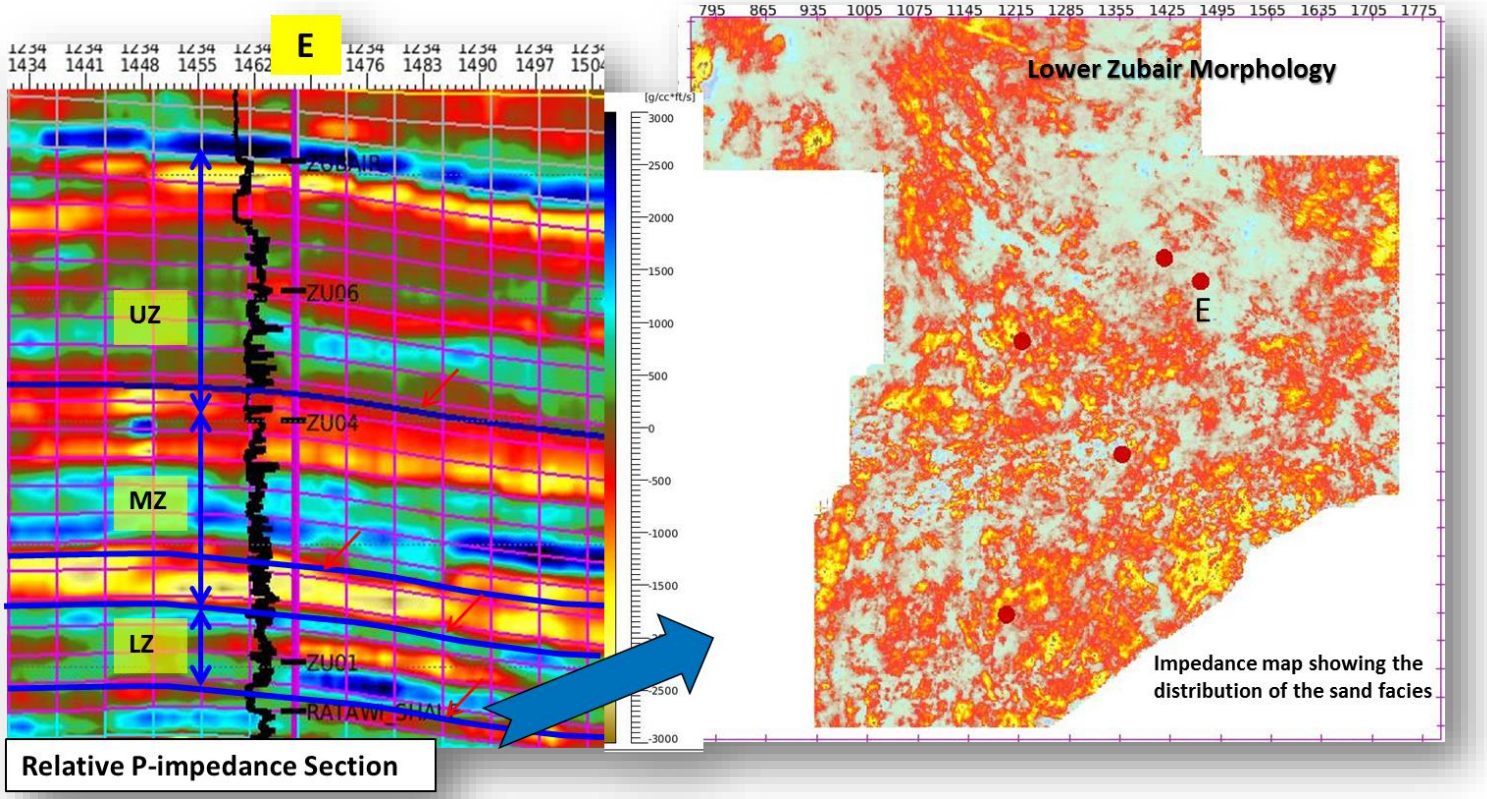
Relative P-impedance map at the base of the Middle Zubair, possibly indicating the MFS, which separates the Middle and Lower Zubair.

Lower Zubair Reservoir Identification



The Petrophysical interpretation is showing good hydrocarbon potential. The rock property showing the lowering of Gamma Ray, Density and P-impedance.These results validate the identification of the sand through the inversion.

Lower Zubair Reservoir Identification



Conclusions

- Zubair Formation was deposited in deltaic environment with strong marine influence
- The lowering of P-impedance indicates presence of reservoir facies and characterize the quality of reservoir
- The spectral decomposition improves the understanding of spatial distribution of the thinner sands within Middle and Lower Zubair.
- The structural interpretation supports the understanding of traps.
- The advance seismic attributes have facilitated the overall understanding of reservoir architecture and trapping mechanism.
- The study led to identification and generation of prospect and drillable locations in Lower Cretaceous in Bahrah area.