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Delineation of Geobodies from Seismic Attribute and Log Response Relationship in 3D Space- A case Study of Complex Lithological Environment in Clastic Regime

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Abstract:

Seismic attribute is sensitive to lithological variation within the sequence. P & S velocity combined with density governs the seismic expression. Bandwidth limited acoustic impedance log is reliably derived from the near stack seismic data, through post stack inversion process. The same acoustic impedance log is derived through log suites of sonic & density log at very high vertical resolution. The variation of impedance log along with other log suite is a function of lithology and fluid contained in it. A feasibility study needs to be carried out to see the possibility of predicting petrophysical parameters from seismic attribute. If the relationship between seismic attribute and log response can be established at log scale than, this relationship can be used to derive petrophysical parameters in 3D space and used for delineation of Geobodies.

Present study deals with identification of reservoir Geobodies, and the spatial distribution with the help of 3D seismic data and log response in terms of reservoir property in complex clastic regime of a giant onland oil and gas field of India. A multi-mineral approach has been adopted in petrophysical evaluation for estimation of petrophysical parameters, minerals volume and fluid contents. Various cross plots between P-Impedance & Vp/Vs and other log attributes have been taken to identify the different lithologies with fluid type. Since the reservoir is very much heterogeneous in terms of variation in lithology & mineralogy, histogram of various log response along with facies and fluid have also been taken to demarcate the sand, shale distribution.

The cross plot between P-impedance & Vp/Vs and P-impedance & NPHI shows a clear demarcation of reservoir facies. Another marked observation was that Cross plot of P-impedance & NPHI log was giving the similar response as P-impedance & Vp/Vs for identifying facies and associated fluid.

A Geostastical method has been adopted to predict Neuton Porosity from Seismic attribute with in the whole volume for enable us to delineate geobodies, prone to the pay sands.

This methodology and workflow with a combination of log property & seismic attribute has given a lead for exploration & exploitation strategy in a very difficult reservoir in optimal way.

Introduction:

The Cambay basin is a rift basin located on the western margin of Indian platform. The Kalol field is one of the largest onland oil and gas fields which is under exploitation since 1961. It is a one of the major oil producing field of Western onland basin. The field is credited with multilayered reservoir and is at plateau stage of its production.

The field was discovered in the year 1961 and put on production in 1964. Hydrocarbons are encountered in Olpad, Cambay Shale and Kalol formations of paleogene age. Till date more than 700 wells have been drilled to exploit hydrocarbons from 11 Kalol pay sands viz. K-II to K-XII from top to bottom. This field has OIIP of 150 MMt, out of which only 10 % has been produced so far.
The middle Eocene pay sand in Kalol field is one of the most prolific oil producers. Large volume of reserves has been booked in the reserves but the recovery factor is poor. The reservoir has widespread distribution in entire field. Thus there is a need to understand the lithological variations, reservoir characteristic and identification of hydrocarbon

charged geobodies. In the present study an attempt has been made to understand the spatial distribution with the help of 3D seismic data and log response in terms of reservoir property with petrophysical data and core information integration. The study will be helpful in understanding the reservoir and its extension for better oil recovery from the field.

Study Area:

Kalol field (Fig:1) is located around 20 Km NNW of Ahmedabad city. The field is spread over 300 sq Km. and is situated in the Ahmedabad–Mehsana tectonic block and the most prolific HC producer of the basin. Kalol field is a doubly plunging anticline with longitudinal and transverse faults. The field had pay zones from K-II to K-XII where K-IX &K-X are main producer with K-VII being next best layer.

In the present study more than 400 wells are taken, till dates about 700 wells are drilled in Kalol field targeting different pays. Logs of 350 wells were processed using multi mineral optimization technique. The well numbers shown in the figures are replaced with imaginary names.

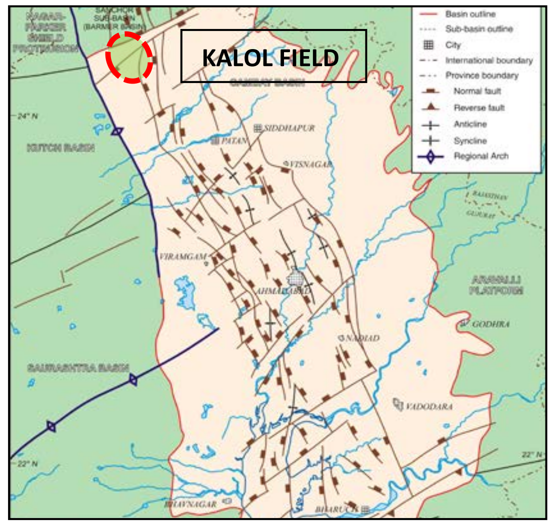

Fig-1: Location Map

Methodology adopted:

In order to achieve the objective of the project, a detail G&G study was carried out with an objective to predict the extension of all pay sand units especially, in the west and southwest side of a major fault trending NNW-SSE. Post stack seismic inversion and Multi-attribute analysis based on Artificial neural networking technology has been adopted to predict Neuton Porosity from Seismic attribute approach to characterize the lithology pattern of the reservoir facies and to discriminate the fluid type present in the area of study. The following workflow has been designed to achive the objective of the project.

Multi mineral Log processing approach:

The lithology of the area is complex in nature and most of the logs show high value of GR on logs. Since natural radioactivity is not always associated with shale alone. Radioactive minerals which are rich in uranium or thorium (zircon, allanite, torite, uranite, phosphate etc) as well as uranium rich sapropelic and above all, humic organic matter can have a considerable influence on the gamma ray response and may completely mask variations in clay percentage. Natural Gamma Ray Spectroscopy logs recorded in selected wells indicate high thorium concentration against sandstone /siltstone layers having high GR activity. Photoelectric Factor log generally reads high against these highly radioactive layers suggesting presence of heavy mineral. Other non-radioactive minerals like ilmenite, siderite, pyrite etc have been reported in core studies. Based upon the above fact wireline logs were studied to characterize for the porosity, clay volume and water saturation estimation of the reservoir. Once the Petrophysical model has been finalize, it will be applied for estimation of the reservoir parameters i.e. Effective Porosity (Φ), Water saturation (Sw) and Volume of Clay (VCL) using multi-mineral least square optimization technique. From this technique the effect of conductive/nonconductive, heavy minerals, radioactive minerals and different clay contents has been taken in to account Fig 2.

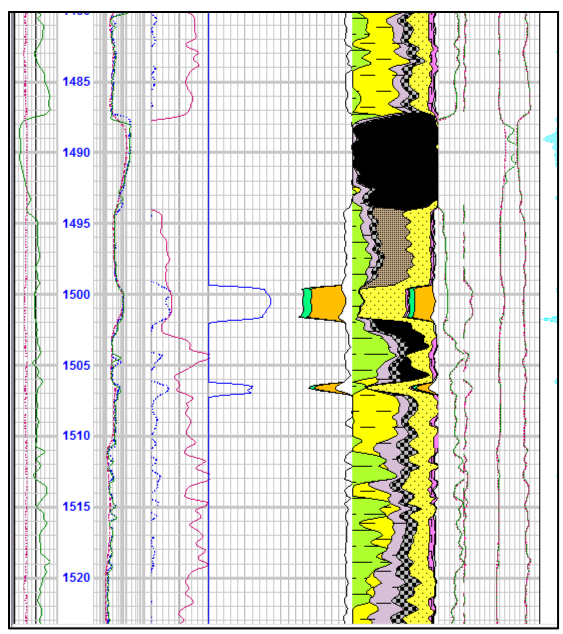

Fig-2: Multi-mineral log processing

Facies identification and creation:

Based on Sedimentological and core studies which have been carried out in many core samples of various wells, cross plot analysis and log responses five main facies sand, shale, silt, shaly sand coal have been identified. These identified facies have been created in more than 400 wells with the help of log and processed log data Fig.3. The creation of the facies has been correlated with the lateral facies distribution in the entire area as shown in Fig.4

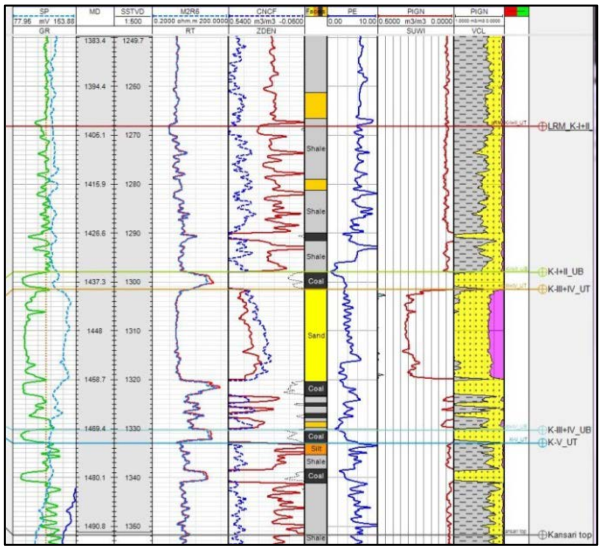

Fig-3: Facies log creation

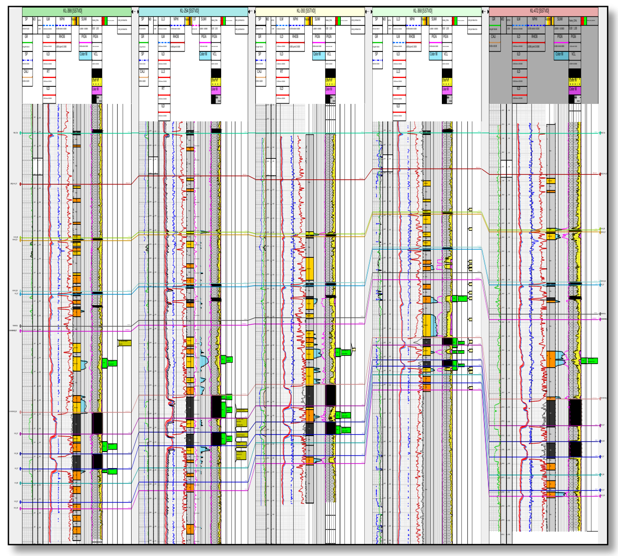

Fig-4: Facies log correlation

Feasibility study:

The cross plot between P-impedance and Vp/Vs shows a demarcation of the pay sand reservoir and non-reservoir facies shown in Fig: 5. The similar kind of response has been observed in many wells of the area while taking cross-plot between P-impedance and NPHI Fig: 6. Since there are few wells where shear sonic data is recorded therefore prestack inversion process will not be helpful for identification of geobodies in the entire area as it require calibration of the results in the different locations. Neutron porosity log is available in almost all the wells in the zone of interest therefore the relationship of NPHI with P-Impedance has been taken for population of the petrophysical property in the entire 3D area.

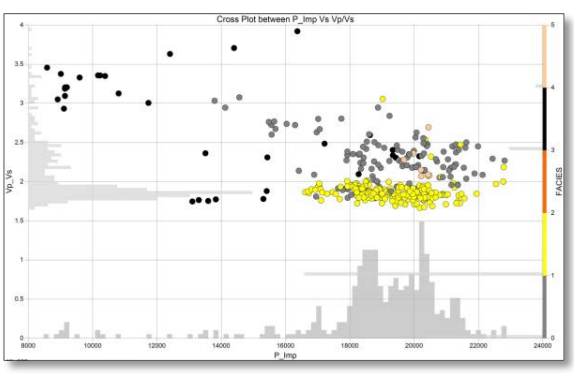

Fig-5: Crossplot between Pimp Vs Vp/Vs

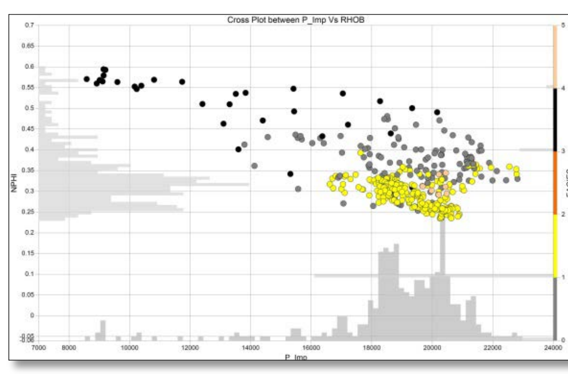

Fig-6: Crossplot between Pimp Vs NPHI

From these crossplots the following range has been identified for demarcation of the various reservoir and non-reservoir facies for population of the petrophysical properties.

Facies	P-Impedance Range	Vp/Vs Range	NPHI Range
Coal	8000 - 16000	1.5 – 3.5	.45 - .60
Sand	16000 - 22000	1.5 – 2.0	.20 - .35
Shale	15000 - 22000	2.0 – 3.0	.35 - .45

Seismic Impedance:

Seismic impedance has been generated in whole volume by model based inversion process incorporating the wavelet matching technique. Window based attribute analysis was carried out to see the reservoir facies within 20 ms from coal top. The response was clearly separate coal facies but sand and shale are falling with in same impedance range Fig.7. From this volume cross plots between P-Impedance and NPHI has been taken and the relationship established for property population.

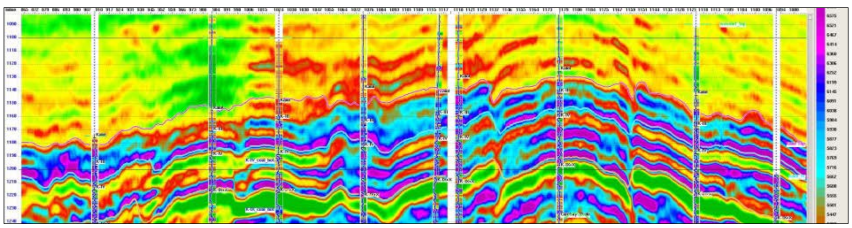

Fig.7: Inversion results along an arbitrary line overlaid with P-impedance logs

Reservoir Property Population:

The seismic derived P-Impedance volume has been taken as a guide for NPHI, facies & Effective Porosity (PIGN) population in the 3 D grid.

The population of these properties in 3D reservoir grid require geostatistical methods to ascertain the right value in the grid cell. Fig-8 shows the variogram analysis of the different facies to be use in sequential gaussian simulation (SGS) for its population.

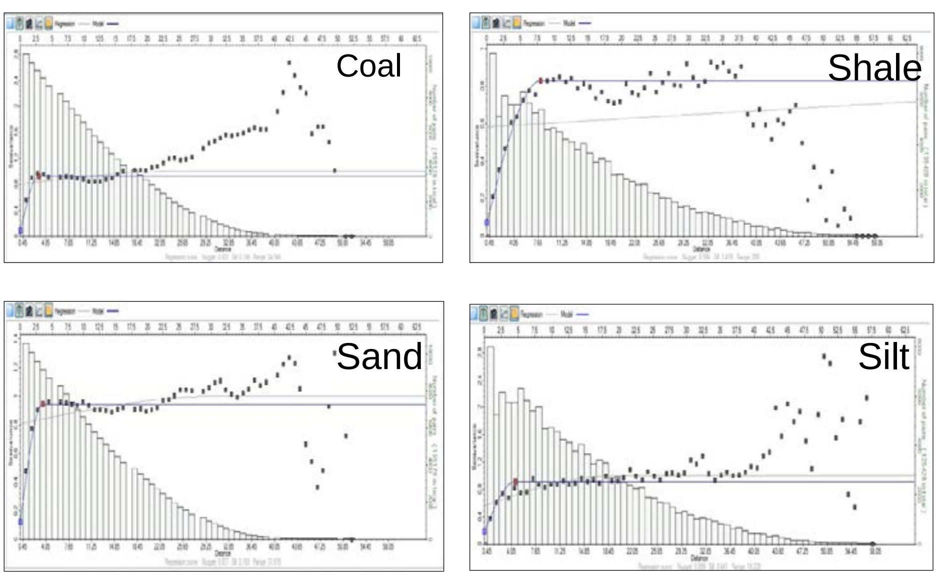

Fig-8: Variogram analysis for facieses population in 3D grid

These defined variogram has been have been used for property modelling in 3D reservoir grid. Fig. 9 shows the grid view of Facies, NPHI, P-Impedance, and PIGN. All the property are well corroborating at well locations. The high impedance sands are more prone towards the silt reservoir having porosity range of 12 to 17%. Fig-10 shows the cross section view of all the property in entire zone of study. This section also shows the lateral distribution of the variation of the properties.

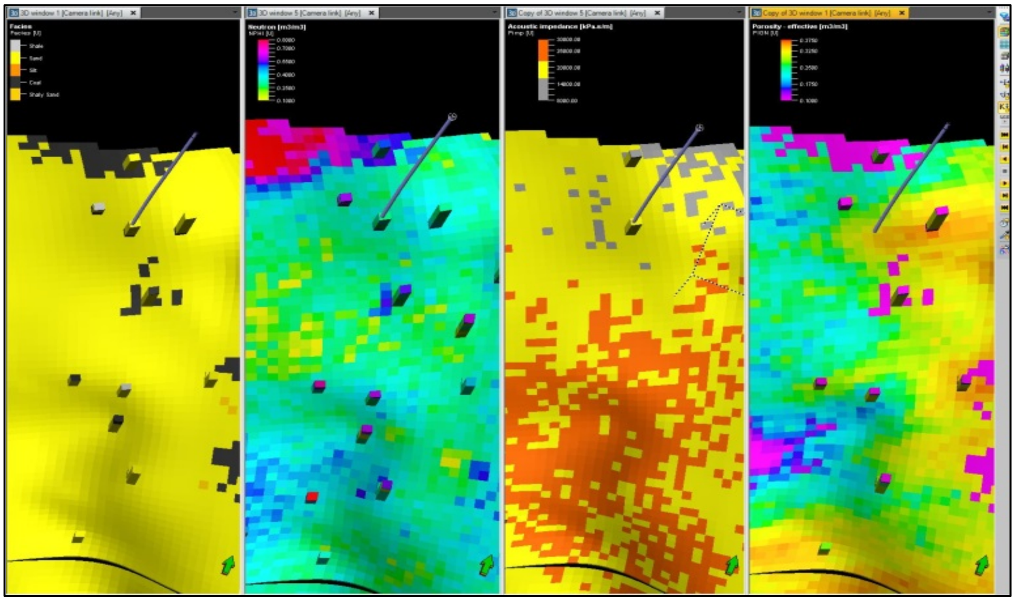

Fig-9: Property population (Facies, NPHI, Pimp & effective porosity respectively) Map view

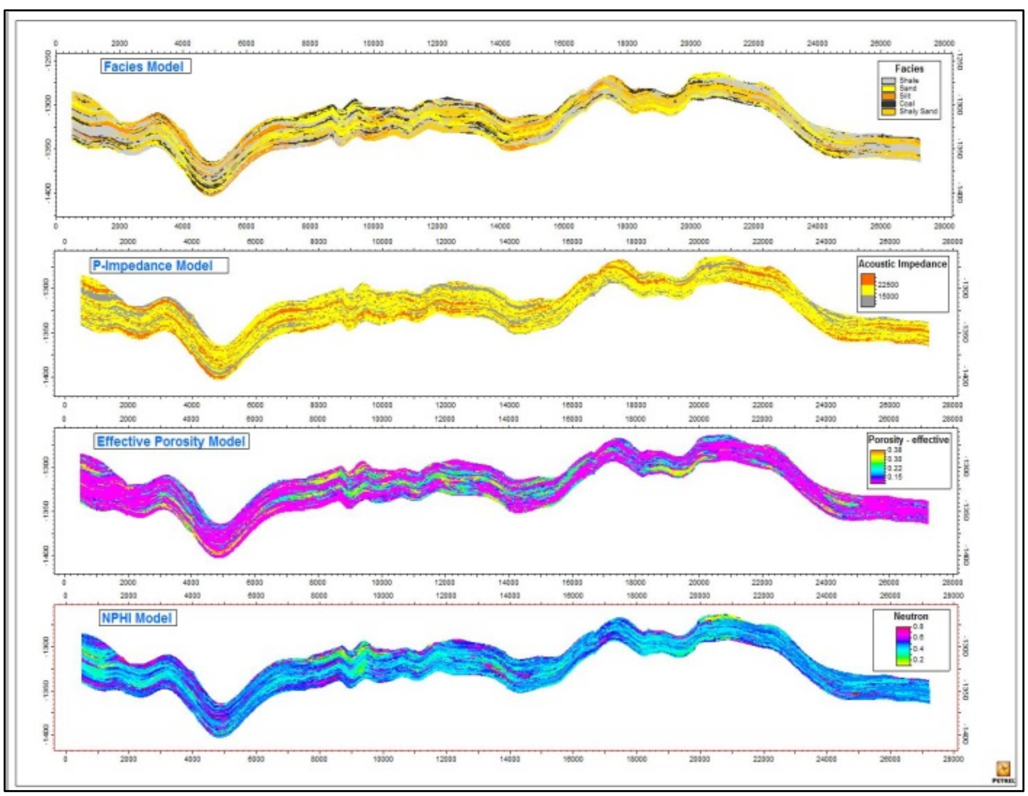

Fig-10: Property population (Facies, NPHI, Pimp & effective porosity respectively) Cross-section viw

Conclusions:

The present study has clearly brought out the identification of reservoir Geobodies, and its spatial distribution with the help of 3D seismic data and log response in terms of reservoir property in complex clastic reservoir in judicial way using Seismic and geo-statistical techniques. The workflow has not only given the lead for exploration in unknown area but also reduce uncertainty for exploitation strategy and development plan. The geo-statistical tools which allow pixel based stochastic modelling has produces multiple equally probable realization for facies output, out of which the most likely results has been considered for property population (Porosity, Saturation and NTG and for reserve estimation.

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