PaperID **AU458**

Author **SUBHASH KUSHWAHA , CEWELL,ONGC , India**

Co-Authors **V L N Avadhani, P P Deo**

Facies Analysis and mapping for Reservoirs characterization and depositional variations

Abstract:

Every log curve has a unique response and characteristics against a formation. A large set of petro-physical data of a particular interval can be analyzed simultaneously to know the depositional behavior of the reservoir facies in the field and can be interpreted into a meaningful lithological facies and depositional trend. Facies analysis is a technique which correlate the features of prominent log characteristics of reservoirs of the wells in two dimension. There are many algorithms which are based on statistical, non-parametric and unsupervised techniques that can analyze multi dimension data structure of particular interval and segregate data in clusters in two dimension that provide valuable information about the electro-litho facies from the data structure itself. MRGC (multi resolution graph based clustering), SOM (Self-Organizing Maps), AHC (Ascendant Hierarchical Clustering) etc. are some of the algorithms based on this principle. A set of Well log data of a particular interval can be thought of multidimensional data structure and can be analyze with these methods to resolve best electro-facies. These generated electro-facies can be Identified and validated with the available high-tech information and well testing results that refines the electro-facies characteristics. In this paper, a study of 170 wells log data of the Sanand field of the Cambay basin using MRGC methodology for identifying and mapping of prolific reservoir facies has been presented. The effective reservoir facies thicknesses of the wells are estimated in TVD and mapped to understand its depositional variation in the field.

General Geology and Litho-stratigraphy of the Study Area

Study area is located in Sanand of Ahmedabad-Mehsana Tectonic block of the North Cambay Basin. It is an intra-basinal doubly plunging anticline ridge structure extending from Sanand High in the South to Jhalora in the North of the basin. In the South, the western margin of the Sanand high steeply dipping towards west side and in the northern Jhalora side gradually dipping toward west side of the basin. Towards East and North-Eastern side Sanand-Jhalora ridge gradually dipping towards Wamaj low.

Deccan trap of Late cretaceous is assumed to be a technical basement which is uncomfomably overlain by Olpad formation of Late Paleozoic to early Eocene period which consist of trap derivative materials, exhibits a typical alluvial fan complex and having moderate reservoir facies. The basin experienced first marine transgression during lower Eocene time led to the regional deposition of lower Cambay shale, rich in organic content conformably overlain the Olpad formation. This is the main organic source kitchen for generation and migration of hydrocarbon toward various strati-structural entrapment of the basin. During early Eocene upliftment of the basin is marked by regional unconformity between Lower Cambay shale and Upper Cambay shale. In this time some minor regression is traced by development of arenaceous sequence (Chhatral, Mehsana and Mandhali) in the Northern part of the Basin.

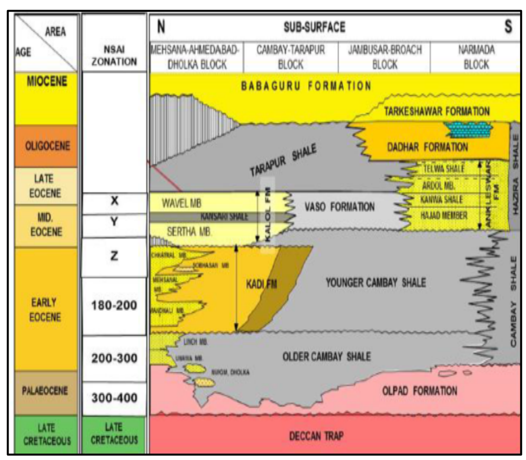


Figure 1: General Litho-Stratigraphy of the Cambay Basin

The middle Eocene is characterized by a phase of distinct fluvial deposition. This is represented by large scale deposition of arenaceous sequence, in the Northern part of the basin identified by Kalol formation and in the Narmada and Jambusar - Baroch Block is by Hazad member. In the north Cambay basin Kalol formation is identified by its unique fluvial intertidal swampy and cyclic transgression regression environment. Due to its unique feature of deposition, Kalol formation is composed of sands, silt, thin laminated shale, and carbonaceous layer with content of heavy mineral like siderite, pyrite etc. Thickness of the Kalol formation varies from 100m to 150m in the Sanand field and regionally upto 300m.The Kalol formation segregated into Wavel, Kansari and Sertha members on the basis of its depositional environment and characteristics. K-III and K-IV reservoirs, which are presently studied are considered under Wavel member, these are characterized by sandy and silty-shaly compositions, which vary throughout the field. K-III reservoirs are better developed in the central and northern part of the field, whereas K-IV reservoirs are developed in the southern region.

During Late Eocene the basin witnessed a major transgression phase in which Tarapur shale was deposited, which act as a regional cap rock of the basin. During Neogene period a regional unconformity identified as post Kand deposition developed under fluvial environment in the Northern part and fluvial to inter tidal in the Southern part of the basin.

Electro-Facies Analysis

Theory:

There are many algorithms like MRGC (Multi-resolution Graph based clustering), AHC, and SOM etc. which are based on statistical, non-parametric, unsupervised methods that analyze multi dimension data structure and summarize the results into number of clusters of data in the random sets, which gives valuable information about the electro-litho facies from the data structure itself. The main work of analysis is to identify appropriate number of representative clusters which can be interpreted as electro-facies to litho-facies. All the algorithms optimize the clusters using Euclidian distance theorem. MRGC module is also an algorithm which works on the principle of Euclidian distance theory and Dendogram, a graphical tree presentation of minimum dispersed cluster.

In this project electro facies generation and analysis of K-III and K-IV reservoirs of the Sanand Field have been done with MRGC module. For generation of electro-facies conventional log data viz. GR, NPHI and ZDEN have been used. Analysis and validation of the generated electro-facies logs have been done with high tech NMR porosity log and well testing results. Primarily electro-facies generation, analysis and validation are performed on Model wells where all the required data were available for the integration. The resultant model facies characteristics are propagated in the rest of the modern wells of the Sanand field for the identification of the similar facies.

Methodology:

Initially Model wells A and B were selected for the electro facies generation, analysis and validation, since these wells have all the conventional as well as high tech log data. The convention al log data viz. GR, NPHI and RHOB were used for the electro facies generation because most of the lithological information, porosity and probably the expected permeability which are essential parameter for the identification of the reservoir can be extracted. These log data were preprocessed for the depth correction, trained and normalized for the facies generation. The MRGC module in default generated minimum 12 facies, which scale down to five (05) identifiable electro-facies on the basis of log characteristics and well testing results. These facies are identified into five colors Grey- Good, Brown-Moderate, Black- Coal, Red- High Density and Blue- Non reservoir

(Figure 2). Resultant facies are again fine-tuned with free fluid NMR porosity log, SP logs and with well testing results.

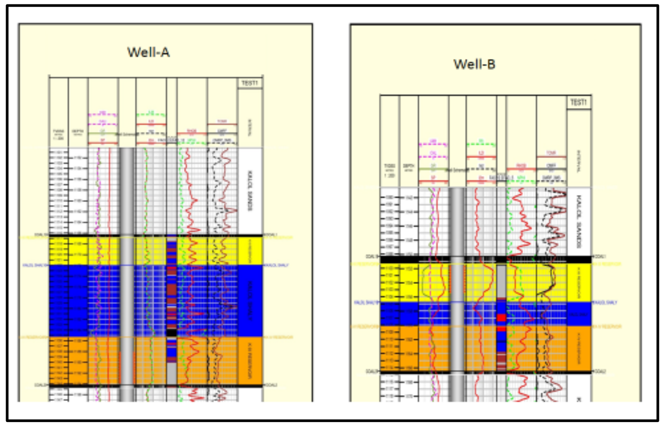


Figure 2: Identified electro-facies between K-III and K-IV Coal Markers

The model wells A and B are exploratory wells, drilled in the Southern part of the Sanand field to explore K-III and K-IV horizons. The K-III and K-IV reservoirs of the wells A and B are characterized and segregated according to results of the NMR porosity logs and well testing results. Good facies (Grey color) of K-III reservoir of the well B (Figure 3) is fairly matching with NMR free fluid porosity logs and well testing results. Cross plot between Neutron porosity and Density of the K-III reservoir interval indicate the points to be concentrating towards sandy matrix. Whereas the K-III horizon of the well A appear to be of non-reservoir characteristics and NMR free fluid results also indicates very poor facies against the zone.

Figure 3: Electro-facies correlation between wells A and B

The zone between K-III and K-IV in both the wells is showing non-reservoir characteristics. Cross-Plot between Neutron and Density is showing a matrix of Smectite, Chlorite, Illite and Kaolinite clay minerals along with some constituents of carbonaceous matter, almost same things are pointed out in the core studies also. Electro-facies of K-IV of the well A (Figure 4) is showing good reservoir facies. In Neutron-Density Cross-Plot of the interval, points are shifting towards sand matrix. The zone produced hydrocarbon on testing. K-IV reservoir of the well B (Figure 5), is showing non-reservoir facies. In the Neutron and Density Cross plot, points are concentrating towards shaly matrix.

Figure 4: Cross Plots NPHI vs RHOB against K-III, K-IV and Shaly intervals of the well A

Figure 5: Cross Plots NPHI vs RHOB against K-III, K-IV and Shaly intervals of the well B

After proper analysis and validation of the electro-facies of K-III and K-IV reservoirs, the characteristics of the reservoirs is propagated into rest of the well log data to identify similar electro-facies.

Facies Mapping:

Delineated tops of K-III and K-IV reservoir facies of each wells have been mapped in the MSL to know its structural variation in the field. The color codes on the map are varying spectrally between Blue to Red according to depth of the reservoirs top. Blue shading is showing top of the K-III reservoir facies at deepest and red at shallowest depth respectively and in between the color code of K-III tops of other wells are varying accordingly. The black dots on the map are the points where data of the wells are not available. All the wells having good reservoir layers of K-III are located on the rising flank area of Wamaj low while the K-IV reservoir is having producible reservoirs on the top of Sanand high with moderate reservoir facies (Figure 6).

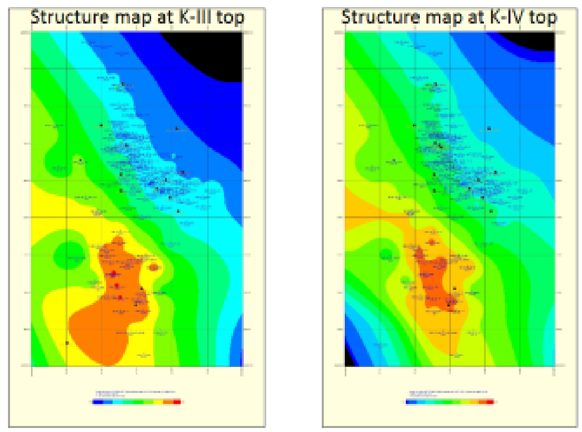


Figure 6: Structure Map at K-III & K-IV Tops

K-III & K-IV Electro-Facies Thickness Mapping:

Delineated K-III, K-IV reservoir facies of the wells have been valued in actual facies thickness to know it depositional variation in the field. In the facies analysis, it has been observed that the K-III and K-IV reservoirs are mostly characterized by both Good and Moderate facies and several wells are having only one facies either Good or Moderate. Some reservoir facies are containing coal along with non-reservoir facies also. It shows inhomogeneity in depositional environment. Before making Effective reservoir facies thickness maps, Elan processed results have been incorporated to verify the methodology for its robustness (Figure 7).

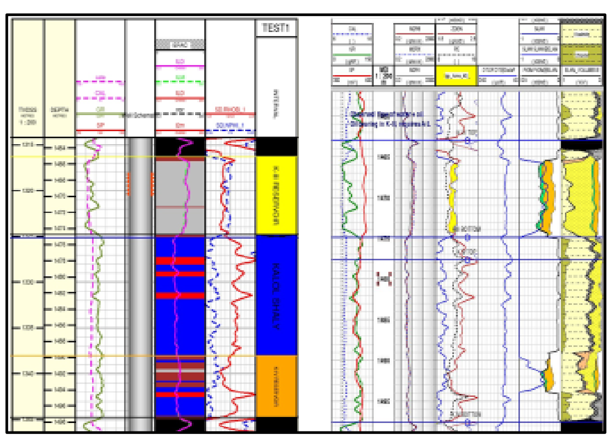


Figure 7: Effective reservoir thickness comparison between electro-facies analysis and Georame-Elan processed results.

In the effective reservoir thickness estimation both Good and Moderate facies of the reservoir section has been considered in the calculation. The total effective thickness of the reservoirs facies has been calculated as the total sum of Good and Moderate facies as the moderate facies have also given good amount of hydrocarbons.

Reservoir effective thickness mapping of K-III and K-IV horizons have been done for 'GOOD (Grey color-sandy),'MODERATE (Brown color-silty)' and total (GOOD + MODERATE). The color codes on the map are varying spectrally between Blue to Red according to thickness of the reservoirs (Figure 8).

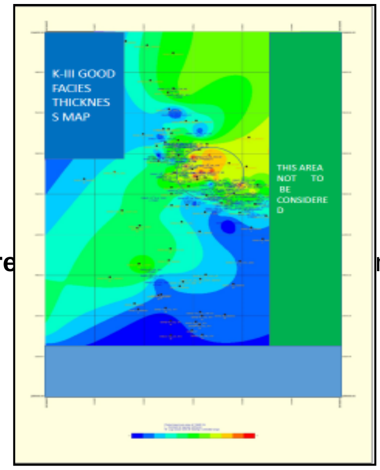


Figure map

A region of highest thickness of Good K-III reservoir facies has been observed in the mid of the Sanand field and aligned in the NW-SE direction.

The effective thickness (Grey + Brown) of K-III reservoir facies have been calculated for all the wells and projected on the map (Figure 9). The color codes on the map are varying spectrally between Blue to Red according to total effective thickness of the reservoirs intervals. Black dots on the map showing wells which are absent with the reservoir facies.

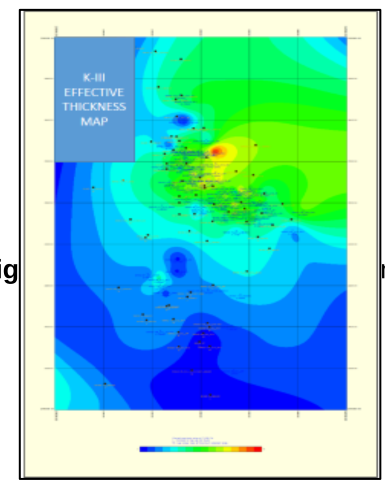
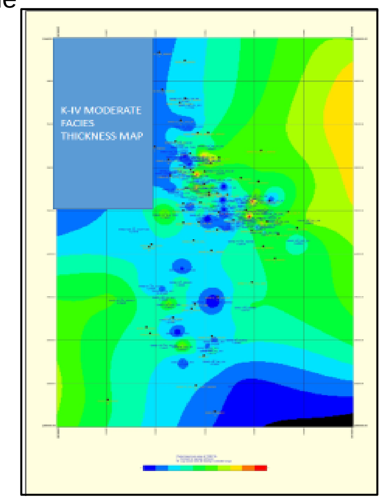


Fig map

The mapping of effective thickness of K-III reservoir facies of all the

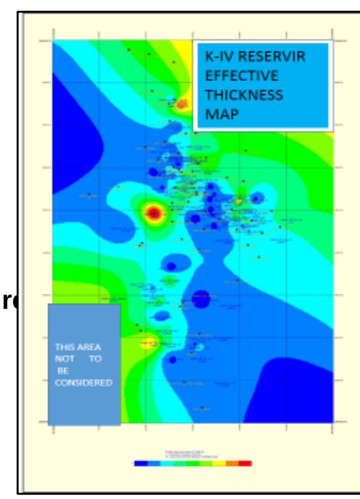


wells in the field indicates that the facies are almost aligned along the NW-SE master fault and concentrated mainly in the mid region and as the structure is rising towards West and South West absence of facies is noticed. This deterioration of facies is providing stratigraphic component of entrapment for K-III reservoir in this direction. Towards south and other side of the main fault also the facies appears to be gradually becoming thinner and poorer in character. This may be due to more carbonaceous grains in the matrix and heavy minerals content in the reservoir texture of the K-III, as it had been reported in the core report of the area.

The moderate facies thickness for the K-IV reservoir have been mapped as this facies are silty and producing nature in the Sanand field (Figure 10).

Figure 10: K-IV moderate facies thickness map

The effective thickness (Grey color + Brown color) of K-IV reservoir facies have been mapped for the Sanand field to understand its lateral variation from North to South in the field (Figure 11).



Figur map

The K-IV reservoir facies of normal thicknesses appear to be aligned in the NE to SW direction in the Sanand Field. In the NW to SE direction either side of this region K-IV facies is becoming thinner and poorer in character. In this region, well testing results of the K-IV reservoirs are very poor in terms of hydrocarbon production.

Conclusions:

- The prolific K-III reservoirs are mainly developed in the wells located on the rising flank of Wamaj low in the central part of the Field and characterized as a fining up sequence towards top of the anticlinal structure can be thought of a channel deposition which is oriented in NW-SE direction.
- The facies analysis also brings out that the better facies are developed in the central part of the channel and are almost aligned along Wamaj low.
- At the top of Sanand high K-III reservoir is having poor facies while moderate facies are developed in the Northern plunge side of the high.
- K-IV facies are poorly developed on the rising flank of Wamaj low while Moderate facies developed on Sanand high are having hydrocarbon potential.
- The K-III hydrocarbon entrapment in Sanand Field appears to have more Stratigraphic component.

Acknowledgement:

The authors are thankful to ONGC management for permission to publish the work.

References:

1. Exploration Potential of Syn-rift Olpad Play in the western rising flank of Warosan low, Mehsana Tectonic Block, North Cambay Basin. Varughese C.M.*, Das N.C., Arya O. P., Kumar Anil & Singh A. K.
2. COAL GEOLOGY Han Dexin, China University of Mining and Technology, Beijing, the People's Republic of China.
3. Reservoir Delineation of Lower Kalol Pays and Field Growth in Wadu and Paliyad Areas, Cambay Basin, India 1S Gupta, 1G Chakraborty*, 2U. S Kanungo, 1A harsakale and 1K Dattatraya 1KDMIPE, ONGC, Dehradun-248, 195, India2 CEC-OG, ONGC, New Delhi, India
4. Facies Distribution and Paleo - Depositional Model of Kalol Pay Sands in Nandej - Hirapur Area (Cambay Basin) 1C.P.Sharma*, S.P.Painuly*, S.K.Das*, N.K.Negi*, Ch.V.Satya Sai*.
5. Hydrocarbon Prospectivity in the Stratigraphic Traps within Cambay Shale, Broach, Sub Block, Cambay Basin, India. T.K. MATHURIA, A.C. JULKA, P.K. Dimri, P.B. Pandey, Block–I, Western Onshore basin, ONGC, Vadodara, India. Email: tarunnavita@yahoo.com