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Depositional Environment and Lithofacies Analysis with Petropysical input for Effective Reservoir Characterization of Kalol Pay (K-VII) -Kalol field, Cambay Basin.

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Abstract

In this paper, attempts have been made to explain complex depositional environment leading to difficult lithofacies distribution. The interpreted lithology and facies property is mapped across the field. The integration of the open hole logs analysis, advance logs (FMI etc) interpretation, with the core data has given a lead for defining depositional environment and spatial facies distribution. The depositional pattern has also been identified from the spatial distribution of reservoir facies also through geostatistical method.

Introduction

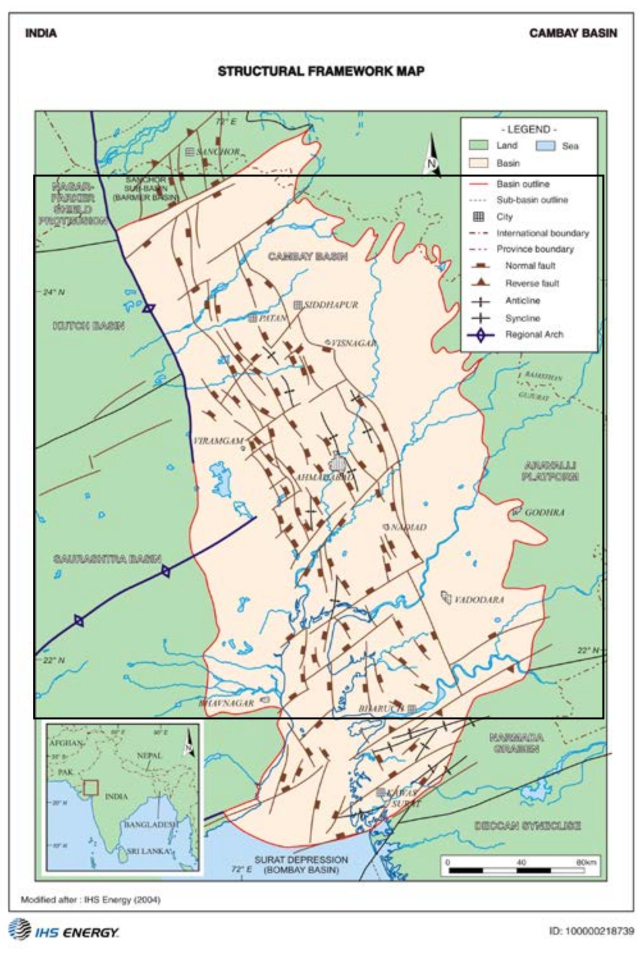
The Cambay basin is well explored rift basin located on the western margin of Indian platform. The Kalol field is one of the biggest onland field which is under exploitation since 1961. It is a one of the major oil producing field of Western onland basin. The field is credited with multilayered reservoir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

The middle Eocene pay sand (K-VII) in Kalol field is one of the most prolific oil producers. Large volume of reserves has been booked in the reserves but the has widespread distribution in entire field. Thus there reservoir characteristic and evaluation of depositional characteristic with petrophysical data and core inform in understanding the reservoir for better oil recovery fr

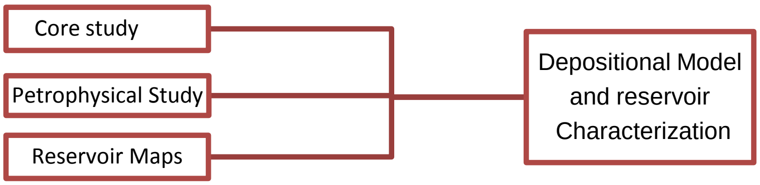
Study Area:

Kalol field (Fig:1) is located around 20 Km NNW Ahmedabad city. The field is spread over 300 sq K and is situated in the Ahmedabad–Mehsana tecto block and the most prolific HC producer of the bas Kalol field is a doubly plunging anticline with longitudi and transverse faults. The field had pay zones from K to K-XII where K-IX &K-X are main producer with K- being next best layer. The OIIP of pay K-VII is about MMTOE with a poor recovery of about 7%.

In the present study 350 wells are taken, till dates ab 700 wells are drilled in Kalol field targeting differ pays. Logs of 350 wells were processed using m mineral optimization technique. The well numb shown in the figures are replaced with imaginary name



Methodology:



A. Core data analysis:

In order to understand the petrofacies variation, reservoir characteristics and finally the depositional environment of the K-VII Pay, the study of eight representative conventional cores carried out by Regional Geoscience Laboratory, Vadodara is incorporated. The representative samples of four well in the **north western part,** three wells in the **central** and one wells in the **southern** part are considered.

North West area: The study indicates that predominant fine grained sandstone in well no **A** represents Channel/ sand flat facies. In well **B**, the laminated siltstone and shale facies in the basal part represents a mixed flat intertidal facies away from the channel, which is overlain a gradual transition from laminated siltstone – shale to dominantly shale facies representing gradual lateral shifting away from a channel to the distal part of mixed flat to mudflat facies. Here there is a repetition of depositional cycle. In well **C**, the predominant Mud flat / Flood plain shale facies is overlain by mixed flat laminated siltstone – shale facies. In well **D**, there is a repetition of facies starting from mud flat / flood Plain silty shale at the base, followed up by mixed flat laminated siltstone-shale facies; then sandstone channel / sand flat facies and finally mud flat facies at the top. The vertical disposition of the facies clearly suggests a lateral migration of the channel from distal part towards the proximity to channel.

It is well evident that in the NW part of the field, there is good development of channel / sand flat / mixed flat facies having better reservoir characteristics and is suitable site for mapping the tidal channel and associated reservoir facies.

Central area: The Central part of the field, three wells were studied and there is moderate development of the reservoir facies here. In well **E**, there is development mud flat facies overlain by mixed flat laminated siltstone-shale facies in equal proportion. In the well **F**, the entire core section having sideritic shale represents mud flat facies. In well **G**, there is repetition mud flat facies both at the top and bottom with intervening mixed flat laminated siltstone - shale facies.

South-East area: One well was studied. In well **H**, the coal at the base marks a marshy condition in a stagnated reducing environment and also suggests an end to a depositional cycle. It is followed up by laminated shale / siltstone facies, of mixed flat and initiation of fresh cycle of deposition of typical tidal flat reservoir facies.

The recorded palynoflora in the cores were mainly dominated by different varieties low salinity water plant complex of associated with palm plant complex and a very few mangrove pollen grains. The assemblages suggest that the sediments were deposited under coastal to tidal swampy conditions of deposition as interpreted on the basis of sedimentological studies.

B. Petro physical analysis

In this study 350 well with basic log suite have been considered and processed logs have been derived using multi mineral technique. The reservoir for K-VII has wide spread distribution in the area. The top of K-VII unit is marked with a thin coal layer or carbonaceous shale. The K-VII pack is distinct on the electro log motif and a number of Para sequences can be observed (FIG: 2), thickness of these sequences

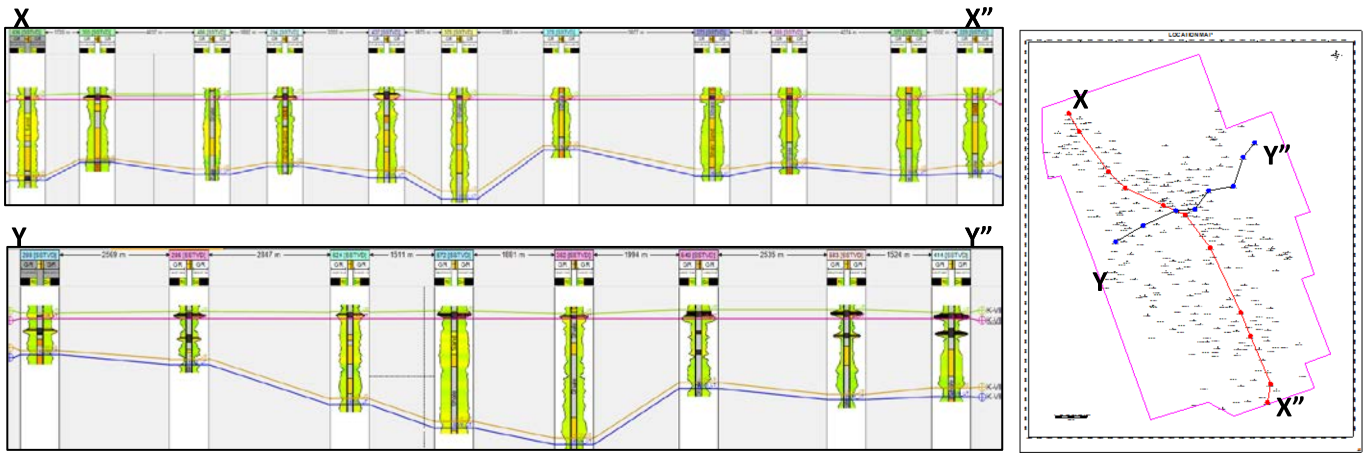


Fig-2: GR-GR plot along NW-SE and W-E profile; serrated cylinder shapedcorresponding to tidal channel deposit

varies laterally and merge into each other. The thickness of the pack reduces on both western and eastern flank of the Kalol anticline. The thickness of the pack from NW to SE is almost uniform along its anticline axial trend. The K-VII pack thickness is maximum in the central part of the field.The GR-GR curves in Fig: 2 shows repetition of the facies.The funnel shapes on the Gama ray log correspond to coarsening upward sequences, interpreted to have been deposited in prograding shoreline. At places the GR-GR curve is serrated cylinder shaped corresponding to tidal channel deposit.

Lithofacies for 350 wells were created based on the basic & ELAN processed logs. They were posted on the location map (Fig: 3) to understand the lithofacies distribution across the field. The better sand facies is developed in the north western part and in the central part. The silt/sand grades into shale/ carbonaceous shale on both east and west margins of the study area. There is development of thin coal layers mainly along the flanks of the main structure. The better reservoir facies are developed in the NW-SE trend.

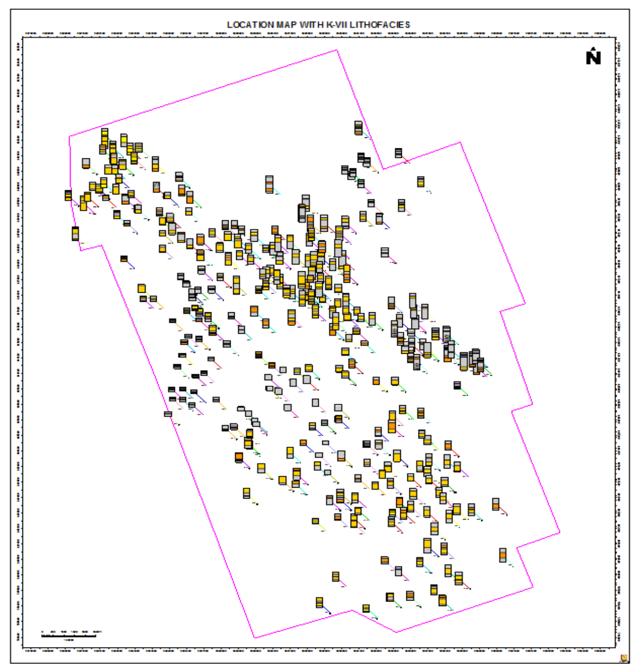


Fig-3: Litho-facies distribution across the field

Image logs

Image logs in the north western and central-eastern part of the field were studied. The K-VII pack contains several coal, shale and silt layers. The sediment flow direction in the north western and in the central-eastern part is found to be NW to SE. Signature of tidal influence is noticed in the study area.

The log motif of well **AA** in the central-eastern part of the field (Fig: 4) represents K-VII (1495-1522m) contains several coal beds, shale and silt layers. Flow direction in this case is found to be NW. Signatures of tidal influence is noted around 1505 m. Slope patterns mostly reaffirm to slope in

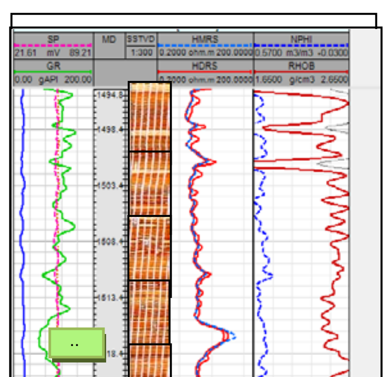


Fig:4 –Log motif of well AA for K-VII pack

a channel having axis oriented in NW – SE direction. NE flow direction and bar feature combination is noted around 1521 m. Oil bearing silt layer occurring in between1516 – 1518 m displays different flow direction NE to SE with signature of tidal influence in the middle part at 1517m.

C. Porosity & Reservoir thickness Maps

Elan processed log of 350 wells were used in the study area. In order to interpret the facies variation in the entire area, processed log along with basic logs were used. The effective porosity and reservoir thickness data was taken from the processed log for creating reservoir thickness (Fig-5) and effective porosity map (Fig-6).Porosity and reservoir thickness are important reservoir parameters and have depositional characteristic. The reservoir thickness map was prepared using the data 350 wells. The reservoir thickness was considered as gross thickness of all the reservoir pack interpreted in the wells. The effective porosity data was taken from the ELAN processed logs.

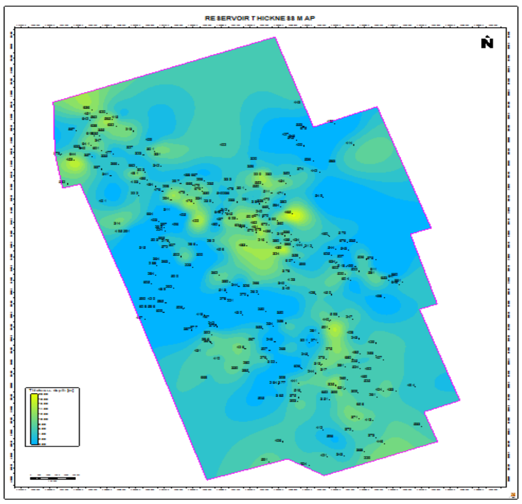


Fig-5: Average Reservoir thickness map

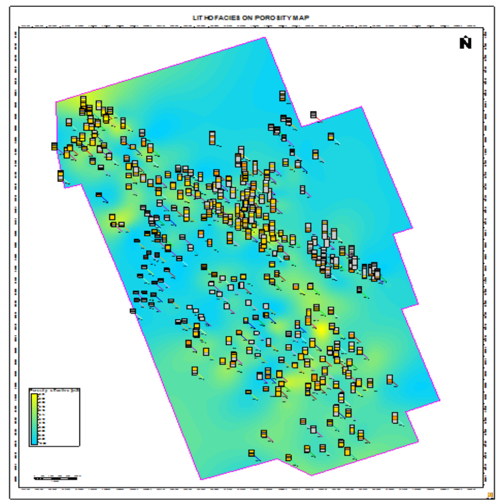


Fig-6: Porosity map with interpreted Lithofacies

Geostatistics offers strong tools for interpolation and extrapolation, spatial distribution analysis. The aim is to create a more realistic model of reservoir heterogeneity. Facies distribution map (Fig-7) and porosity (Fig-8) map of layer number 165 prepared after variogram analysis. These maps take into account the spatial anisotropy in data estimated through variogram thus define better spatial distribution of reservoir data.

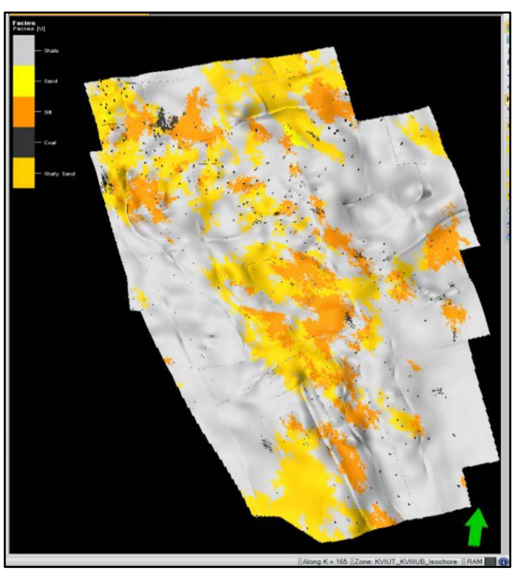


Fig-7: Facies distribution at layer no-165

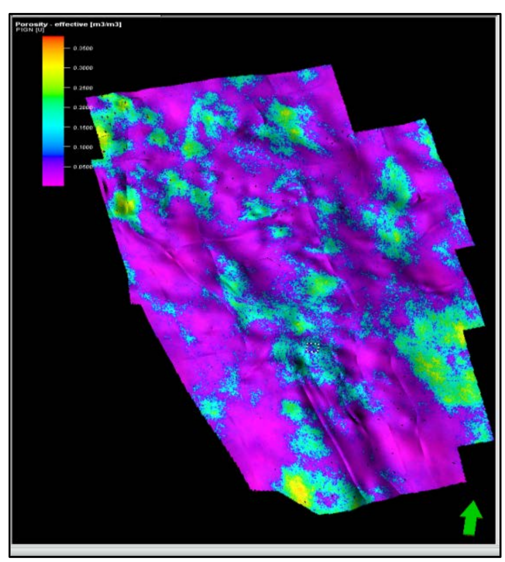


Fig-8: Porosity map at layer no 165

The average porosity value of the pack was used for making porosity map.The porosity map overlaid with lithofacies further supports the presence of good porosity in the areas where reservoir facies are developed. The reservoir facies spread has increased towards the southern part but the porosity values have reduced, indicating mixed tidal flat environment.

DEPOSITIONAL MODEL

The study indicates that the deposition of the K-VII pack has taken place on open coasts of low relief and relatively low energy (peritidal environment). The conditions necessary for development of tidal flats included low relief and relatively low energy and in protected areas of high-energy coasts associated with estuaries, lagoons, bays, and other areas lying behind barrier islands, traversed by a number of tidal channels. The conditions necessary for development of tidal flats include an effective tidal range and the absence of strong wave-induced currents.

Tidal flats are subdivided into intertidal and subtidal environments which control facies distribution. Parts of the tidal flat lying between high and low tide range, the intertidal zone, make up the major areal extent of the tidal flat. If a noticeable variation in sediment type is present throughout the flat, for example muds and sands, the intertidal area commonly possesses alternating layers of both textures. Where sand forms lenses in mud, the texture is called lenticular bedding, and where mud forms lenses in sand, the texture is called flaser bedding. Most tidal flats have a third zone, developed above the intertidal zone, called the supratidal zone.

Subtidal areas are important to the understanding of this environment because they are the part of the tidal flat most likely to be preserved. Most tidal-flat deposition results from lateral accretion in association with progradation of the flat and the point bar associated with meandering tidal channels. Therefore, a major part of the sedimentary record for most tidal-flat successions includes features associated with channel fills and tidal point bars.

Tidal flats that developed under progradational conditions, as in the case of shallowing upward cycles in carbonates, are characterized by a fining-upward succession, consisting of coarse sediments at the base and progressively finer sediments toward the top in an uninterrupted vertical sequence. This common relationship reflects decreasing energy in a progression from subtidal to intertidal parts of the tidal flats. Tidal channels are commonly substantially coarser than laterally equivalent parts of the tidal flat system. Where best developed, facies progression in a vertical sequence can be represented by:
A) A dominantly sandy subtidal zone of channel-fill, point-bar, and shoal sediments;
B) A mixed sand and mud intertidal flat deposit;
C) A muddy upper intertidal flat or salt-marsh deposit.

Sedimentological studies showed presence of palyno-flora which suggest that the sediments were deposited under coastal to tidal swampy conditions.

GR-GR log shape indicated existence of fluctuating environment from marshy environment to moderate energy environment. The shapes on the Gama ray log correspond to coarsening upward sequences, interpreted to have been deposited in prograding shoreline. The coarsening upward may be followed by fining upward without a well-defined boundary depending on the position in the delta. The reservoir quality interpreted from logs in the north western part and central part shows better facies development. This dominantly sandy facies indicated subtidal zone of channel fill and point bars.

The image log analysis indicates thin, parallel to oblique laminations with trough cross bedding thus confirming tidal environment. The blue pattern characterizes foreset beds which are used to define the direction of transport. The sediment flow direction in the north western and in the central-eastern part is found to be NW to SE. Blue pattern in a sandy interval corresponds to foreset beds. The red pattern reflect filling of a channel.

The reservoir thickness map reflects that the gross thickness is more in the north western and central part in the field. The sediment supply is thought to be NW-SE with high energy depositional activity to be more extensive in the northern and central part of the field.

Porosity map was prepared by taking average porosity value from the ELAN processed logs. It is observed that the porosity map had direct dependence of thickness map.

Conclusion

The study has clearly brought out that the Kalol-VII pay is characterized by a mixed facies constituted of shale/ sideritic shale, laminated siltstone- shale and fine grained sandstone with thin coal. Cyclic repetition of the three units indicates lateral shifting of the tidal sub environment. The area in the north western and central part of the field has better development of reservoir and is favorable locale for mapping the reservoir facies. This has not only given an idea of depositional pattern but also has given a lead for effective reserve characterization.

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