Paper ID: 2011212

Geological Modeling of K-IX, K-X and K-XI Pays, Kalol Field: An Integrated Approach to Re-development of Existing Asset

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Abstract

In Kalol Field, K-IX, K-X and K-XI pays are developed within Sertha Member of Kalol Formation of Middle Eocene age. The last geological model was prepared long back for K-IX+X Pays and also for K-XI Pay. Since then, more than 200 wells have been drilled and production history of the existing and new wells is also available. In Addition to above, 2D and 3D Seismic data have been acquired and processed/reprocessed. In view of large quantity of new data, the need was felt to study and update the geological models of K-IX and K-X Pays. The geological data suggest K-IX and K-X pays are separate reservoirs and mapped separately. Later on, the scope of work was extended to further refine the existing geological model of K-XI Pay.

The integrated study included structural mapping of all the pays after incorporating new fault pattern mapped through interpretation of newly acquired 3D seismic data. isopach and sand/silt isolith maps were prepared. ELAN processing on 79 selected wells was carried out and the results were incorporated for preparation of isopay maps for each pay. The ELAN processed reservoir parameters have been used for calculation of in-place volume. The study has also upgraded OIIP and reserves for K-IX, K-X and K-XI Pays. Earlier approved OIIP for K-IX+X is 55.75 MMt. After splitting the layer K-IX & K-X and estimating them separately, the new reserves estimated to be much higher as compared to earlier estimates. This translates into an accretion of about 3 MMt for K-IX and K-X reservoirs. Additionally, re-mapping of K-XI Pay has also resulted in accretion of more than 2.5 MMt oil with re-estimated oil in-place of about 7 MMt against earlier estimated 4.5 MMt.

The outcome of the study has opened up new area in the Kalol Field to explore and produce more oil by infill drilling and zone transfer. The paper portrays a better understanding of geological model by the re-evaluation and re-assessment of G&G data which has helped in exploration/development of untapped /by-passed hydrocarbons and enhancement of production from the Field.

Introduction

Cambay Basin is one of the most extensively explored sedimentary basins of India. The study area Kalol Field is located in Ahmedabad tectonic block of Cambay Basin. Kalol Field, one of the major oil producing areas in Ahmedabad Asset, is surrounded by Wadu-Paliyad in the north, Nardipur low in the east, Motera Field in the south and Wamaj low in the west & southwest. The Field was discovered with the drilling of well Kalol #1 in June 1961 and put on production in 1964. In Kalol Field, hydrocarbons have been encountered in various reservoirs ranging from Olpad, Cambay Shale and Kalol Formation of Paleogene sequences (Fig. 1). Within Kalol Formation, K-II to K-V sand belongs to Wavel member whereas K-VI to K-XI belongs to Sertha member. The major hydrocarbon producing layers within Kalol Formation are K-XII, K-IX, K-X, K-VII, and K-III+IV. Kalol Field lies in the median high trend as well as in the adjacent low and known for its oil and gas production. A large number of wells have been tested and completed initially or at a later stage as producer from K-IX, K-X and K-XI pays. Overall recovery is poor from the field (<10% of in place oil) and the reservoir heterogeneity is the main factor for its low recovery besides many other technical reasons. Based on recovery factor achieved so far, still good potential remains in the area, for further exploitation.

The last geological model for K-IX+X Pays and K-XI Pay was prepared long back (Fig.2). Since then, more than 200 wells have been drilled and production history of the existing and new wells is also available. In Addition to above, 2D and 3D Seismic data have been acquired and processed/reprocessed. In view of large quantity of new data, the need was felt to study and update the geological models of K-IX and K-X Pays. The geological data suggest K-IX and K-X pays are separate reservoirs and mapped separately. Later on, the scope of work was extended to further refine the existing geological model of K-XI Pay.

In the present study, structure contour and pay maps of K-IX, K-X and K-XI have been prepared based on the new well data and log correlation of all drilled wells. Estimations of inplace volumes and reserves of oil and gas have been upgraded and presented in this study. The present study will help in further delineation of these reservoirs and to identify locales for future exploration and exploitation.

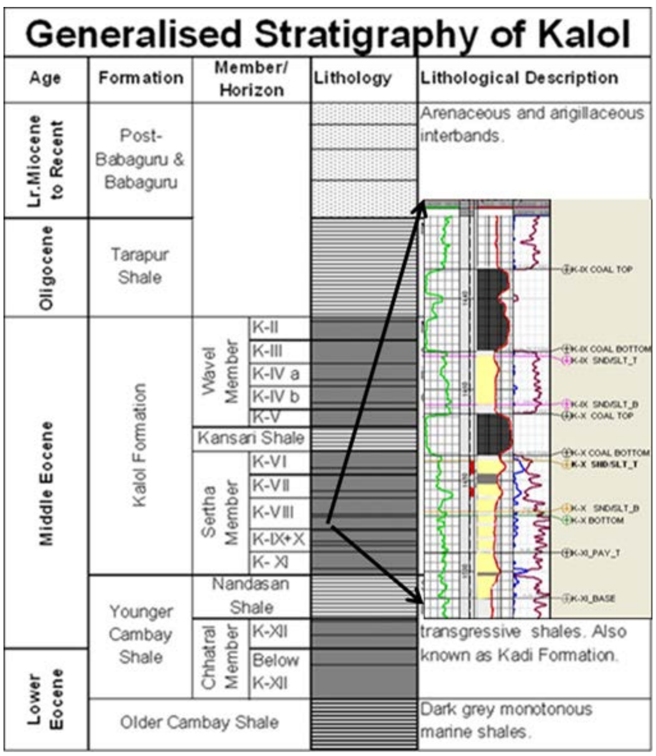


Fig. 1: General Stratigraphy of Kalol Field & Representative Log Motif of K-IX, K-X and K-XI Pay zones

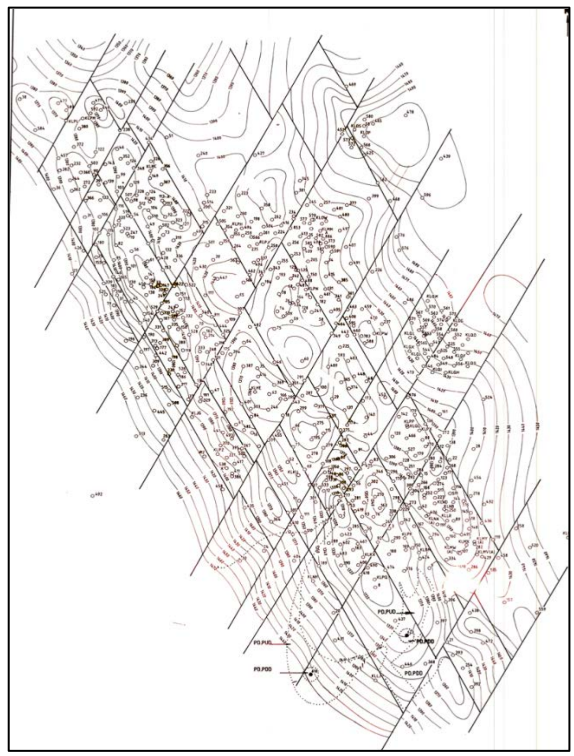


Fig. 2: Structure contour map on top of pay zone Kalol-IX+X with old fault pattern

Lithology of pay units

The dominant lithological assemblages of Kalol Formation are shale/ carbonaceous shale, sandstone, siltstone and coals. Thick coal layers have been found to be present on top of K-IX and K-X siltstone/ silty-shale layers. The reservoir distribution patterns indicate maximum spread for K- IX + X pay sands deposited mainly in deltaic setting. Total eleven thin reservoir layers (numbered from top to bottom as K-I to K-XI) separated from each other by thin shale and/or coal have been identified in Kalol Formation. These pay zones mainly consist of siltstone/sandstone have low resistivity, moderate to poor effective porosity & permeability and varying hydrocarbon saturations. Log response of different pays varies from area to area. However, there are distinct log patterns which are fairly correlatable laterally in Kalol Field. The shale and silty–shale layers are not very prominent markers in the area hence it is difficult to correlate laterally without the help of coal layers. The coals, however, have better continuity and correlatability throughout the area. The pay zone K-XI is the lowermost pay of Kalol Formation and is marked by a monotonous shale/silty-shale near the top, siltstone layer and coal in the middle and a shale layer towards bottom. The overlying K-X unit consists of siltstone/silty-shale layers having low resistivity and higher gamma count with a coal layer (K-X coal) at the top. K-X unit is overlain by K-IX unit consisting of siltstone and silty shale and has thick coal layer (K-IX coal) at the top of the unit (Fig.1).

Methodology

Well data, including newly drilled wells and well logs were loaded in IIWS after quality check using “Petrel” interpretation software. The base map of Kalol Field was updated incorporating GPS data of old wells and recently drilled wells. Formation and pay zone boundaries of all the drilled wells were included and correlated for interpretation. Ten log markers, i.e., K-IX Coal top, K-IX Coal Bottom, K-IX Silt Top, K-IX Silt Bottom, K-X Coal Top, K-X Coal Bottom, K-X Silt Top, K-X Silt Bottom , K-XI Pay Top and K-XI Pay Bottom were identified from the study of log motifs and correlated along and across the field. More than sixty electrolog correlation profiles were generated for understanding lateral facies variation, lithological variation and/or facies change. For structural analysis, 3D seismic data was interpreted with Team Interpretation at Block-II, Baroda to finalize and adopt fault pattern at K-IX top level. The same fault pattern was adopted for K-X and K-XI mapping. Isopach maps for all the mapped units were also generated. Around sixty wells across the field were subjected to ELAN processing by Well Logging Section to arrive at net pay thickness data of K-IX and K-X pays. Oil isopay maps have been prepared for K-IX, K-X and K-XI levels and the volumetric estimations of in-place reserves were carried out. Prospectively maps were generated and potential areas have been identified.

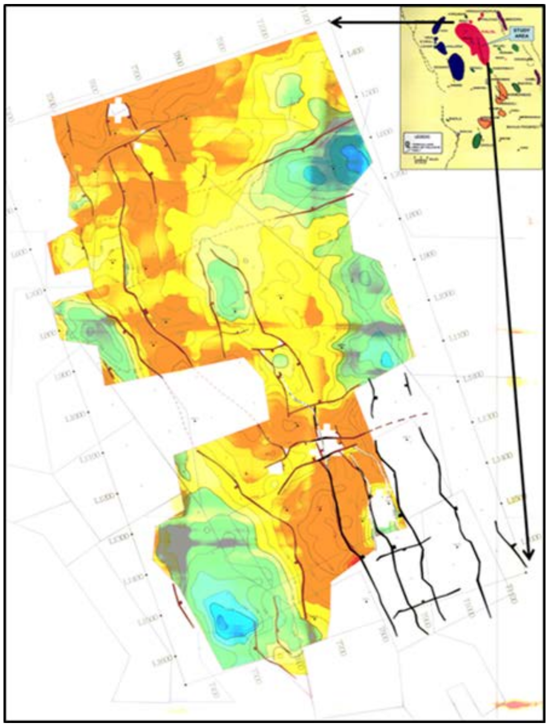
Interpretation and Discussions

Structural Style:

On the basis of reprocessed 2D and 3D seismic data, time structure map on top of K-IX coal was prepared (Fig. 3). The structure contour map was prepared from well data taking structural configuration as derived by time structure mapping on near to the top of K-IX coal unit. There is a good match in structural trends between time- and depth- structure maps corresponding to K-IX, K-X & K-XI horizons indicate a prominent high trend which is parallel to NNW-SSE trending Dharwarian trend.

Structurally, the Kalol Field represents broadly a doubly plunging anticline having NNW-SSE axis and separated by north plunging low area towards Jhalora in the north and a low area in the south. There is no major variation in the structural elements from K-XI pay top to K-IX pay top. These structural features remain intact with time (K-XI to K-IX) and hence indicate that the present structural configuration of the area has come into play post K-IX depositions. Eastern limb of the anticline is culminated in Nardipur low in the east while Wamaj/Warosan lows lie in the west (Fig. 4). The crestal part of the anticline lies in the southern part of the structure. Several NNW-SSE to N-S longitudinal faults and ESE-WSW trending cross faults divide the area into different blocks. Based on production and pressure data, these faults seem to be generally non-sealing type as the oil properties and pressures in the wells across the faults are more or less matching. The longitudinal faults have throws in the easterly or westerly directions and are responsible for originating smaller lows and highs in the area.

Apart from NW-SE trending longitudinal faults, a few ENE-WSW trending cross fault have also been mapped. One such set of fault to the south of main Wadu Field act as barrier for Hydrocarbon movement. This is evident from gas accumulation in area located towards south of the main fault. To the north of this fault, at higher structural levels, oil accumulations have been found while at the lower structural level in the southern part, gas accumulation is reported. The hydrocarbon entrapment seems to be more controlled by facies variation rather than by structural configuration. In the south-eastern part of Wadu Field where a gas cap at lower level and oil at higher structural level across the fault brought out both structural and facies control (strati-structural) for the hydrocarbon accumulation.



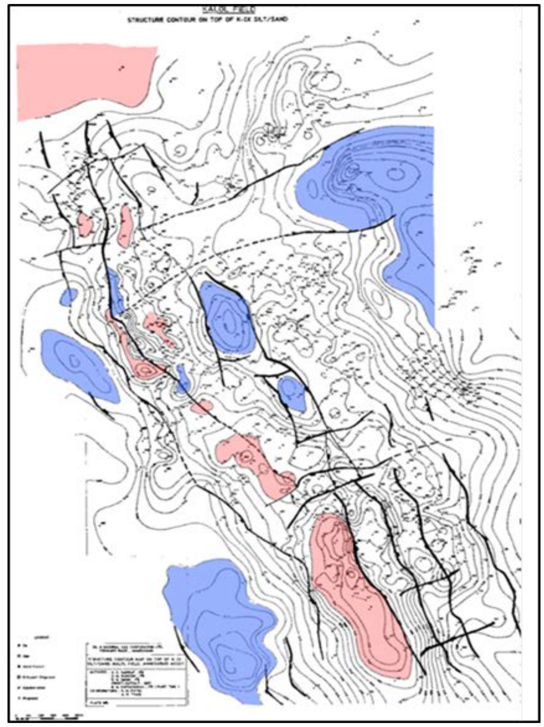


Fig. 3: Time structure map close to K-IX top, Kalol Field showing structural framework & faults

Fig. 4: Structure contour map on top of K-IX silt/sand. Kalol Field

Depositional Pattern:

Isopach map of the all the sequences show marginal thickness variations indicating low relief at the time of deposition and negligible subsidence. Isopach map prepared for K-IX pay unit shows major depocentre in the north-eastern part; central part; in the northern part (Fig. 5). Thickness along the NNW-SSE high trend axis is generally less (in the range of 1.5m to 5m) as compared to adjacent Nardipur and Wamaj Lows. In most of the wells of the study area, K-IX thickness varies from 10m to 20m. Similar depositional trends have been observed for K-X and K-XI pay units in the area.

Lithological Distribution and Facies Variation:

The isolith patterns of K-IX pay zone (Fig. 6) indicated major entries from North and NE through Wadu Field and branch out towards SW and southern parts. In the northern part K-IX silt is better developed as compared to the southern part of the field. In the eastern part of the field though the thickness of K-IX pack is higher, the shaliness also is more, so for this area ELAN derived data and well behavior in few tested wells have been used for estimating sand/silt thicknesses.

The sand/silt distribution pattern of K-X Pay zone (Fig. 7) indicates two major entries from the North and NE part, which are separated from each other by absence of coarser clastics facies. These areas are located in the Central and NW part of the field. On the contrary SE part has no silty reservoir in K-X section. The facies here is shaled out. Better reservoir characteristics seem to have developed wherever facies is good along the axial parts of the channels.

A significant observation indicates that wherever K-X sands/ silts are better developed, K-IX sand/ silt has relatively poorer or no sand/silt development. This may be due to availability of space due to subsidence/compaction difference of shale and silt lithologies. On the contrary, the low silt/sand development areas of K-X, especially in the southern part, have better reservoir facies development than in K-IX pay unit.

The Sand/silt isolith map of the K-XI pay zone (Fig. 8) shows that the spread of this unit is extended in the entire field except in the central and eastern parts. The entry for the sediments has been envisaged from North to NE directions, which extend into southern part through narrow channels. Branching out of this channel at a few places is responsible for a few sand/silt minima or bypass areas.

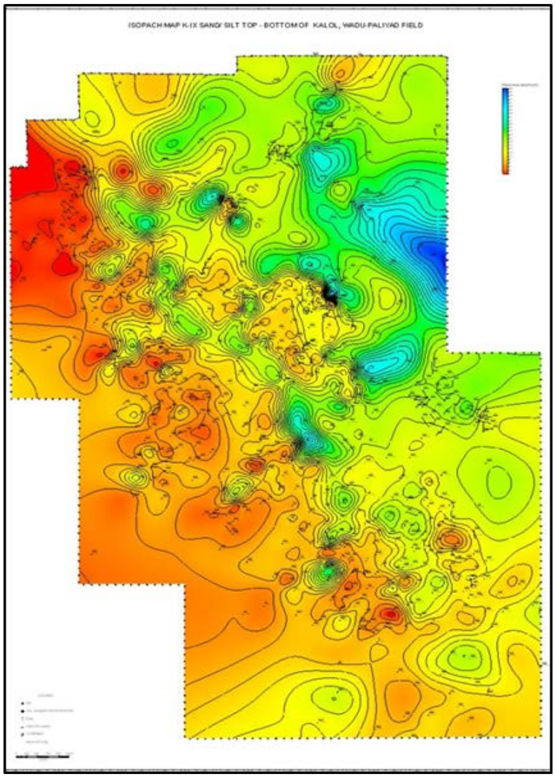


Fig. 5: Iso-pach map of K-IX pay zone, Kalol Field

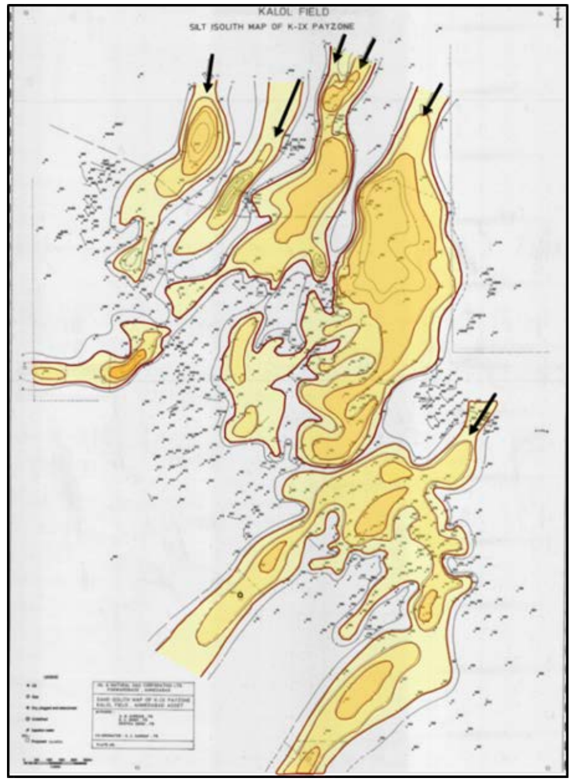


Fig. 6: Sand/silt isolith map of K-IX pay zone, Kalol Field

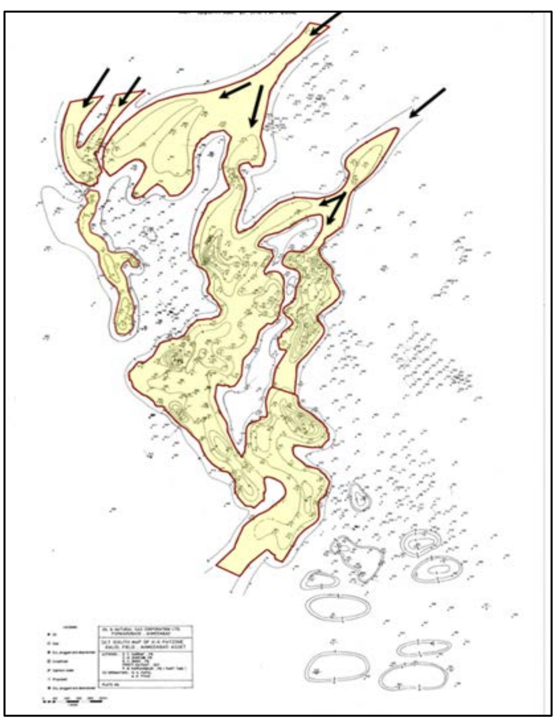


Fig. 7: Sand/Silt isolith map of K-X pay zone, Kalol Field

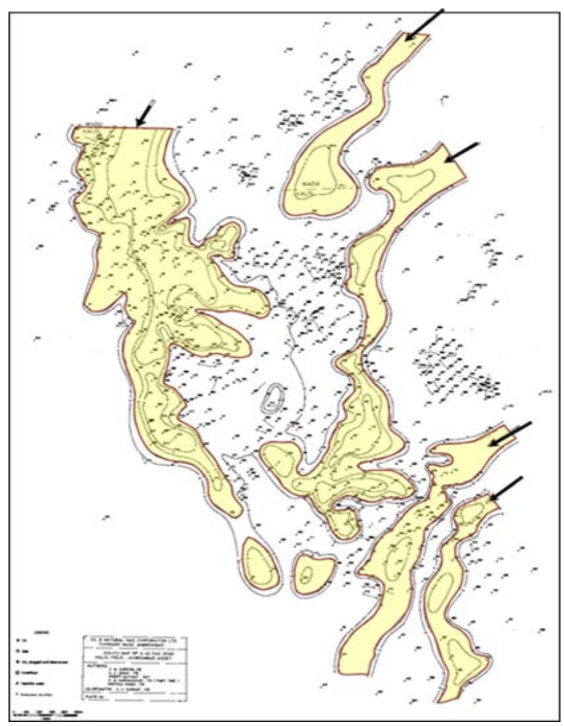


Fig. 8: Sand/Silt isolith map of of K-XI pay zone, Kalol Field

Hydrocarbon Distribution and Development Strategy:

Oil isopay map of K-IX Pay zone depicts a similar pattern of sand isolith pay map. For Oil and gas estimation, 2m isopay contour value has been taken as cut-off limit. The study brought out that eastern part has good potential and will open up a large area further NNE to northeast for exploration. An area of small gas cap has been mapped in the eastern part of the Kalol Field, this gas cap is due to facies variation and partly due to presence of fault, the gas cap is restricted around the well of Wadu Field only and not found in the northern part due to existence of fault to the north of this well. This fault acts as sealing fault as wells to north of this fault has oil on the higher structural level without any gas cap.

Oil isopay map of K-X pay zone depicts two main areas of oil accumulation along the channels which developed in NNW and central part of the field where better reservoir facies is developed along the axial parts of the channels. Central main channel and eastern channel is the main contributor for oil and gas due to good reservoir development. Most of the oil production from Kalol Field is from K-X layer which has better reservoir facies in the central part of Kalol Field. Even in some of the wells K-X pay having low resistivity (~5 ohm-m), on testing produced oil after HF.

Oil isopay mapping has been brought out for K-XI pay package in the area and only north-western channel has been estimated with cut-off limit of 2m. K-XI silt facies is developed in the entire field as shown in the silt/sand isolith map but hydrocarbon estimation has been restricted in the western part only where producers are available. Not many wells have been tested in the eastern and central channel tract hence the oil isopay does not include this area.

Results and conclusion

The last geological model for pays K-IX, X and XI was prepared in 1995. The study has also upgraded OIIP and reserves for K-IX, K-X and K-XI Pays. Earlier approved OIIP for K-IX+X is more than 55 MMt. After splitting the layer K-IX & K-X and estimating them separately, the new reserves estimated to be much higher as compared to earlier estimates. This translates into an accretion of about 3 MMt for K-IX and K-X reservoirs. Additionally, re-mapping of K-XI Pay has also resulted in accretion of more than 2.5 MMt oil with re-estimated oil in-place of about 7 MMt.

The current study also brought out that the Kalol pays in general and K-IX, X and XI pays in particular are low permeable, low resistivity and tight reservoirs. More effective hydro-fracturing may be needed to increase the permeability of these reservoirs to get good production from these silty/shaly reservoirs. Low resistivity reservoirs at places need to be tested in future. Siltstone just above K-X coal and siltstone immediately below the K-X coal appears interesting from logs and needs to be tested.

Coals at many places have been tested and produced hydrocarbons in commercial quantity. The possibility of exploiting from coals need to be worked out after re-looking and evaluating their log motifs and proximity to faults as fractured coals can also act as reservoirs.

The outcome of the study has opened up new area in the Kalol Field to explore and produce more oil by infill drilling and zone transfer. The study portrays a better understanding of geological model by the re-evaluation and re-assessment of G&G data which has resulted in identification of additional exploration area and locales for infill development drilling. More than 100 additional wells are required to be drilled to have better recovery with favorable techno-economics. The study has helped in exploration/development of untapped /by-passed hydrocarbons and enhancement of production from the field.

References

1. S.C. Sarraf, S.M. Qureshi, D.C. Singh and Deepika Singh “Integrated study to review and update geological model of K-IX, K-X and K-XI pays, Kalol Field” ONGC, Forward Base, Ahmedabad (Unpublished Report of ONGC Ahmedabad), 2012.

2. S.K.Biswas, “Regional Tectonic Frame work, structure and evolution of the weatern marginal basins of India” Tectonophysics 135 (1987) 307-327