The Petrofacies and Depositional Model of Kalol-VII Reservoir in a Tidal Flat Complex in Kalol Field, Cambay Basin, Gujarat, India*

K.K. Das[1], Sayan Biswas[2], Bharti Jagtap[2], and Vasudev Issrani[3]

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[1]ONGC, RGL,Western Onshore Basin, Vadodara (kamal_das@rediffmail.com)
[2]ONGC, RGL,Western Onshore Basin, Vadodara
[3]Forward Base Ahmedabad, ONGC, Chandkheda, Ahmedabad

Abstract

The Kalol Formation in Cambay basin is informally composed of eleven pay sands, namely K-I to K-XI from top to bottom with intervening shale (Mehrotra et al., 1980). The K-I to K-V belong to Wavel Member, K-VI and K-VII to Kansari Shale and K-VII to K-XI to Sertha Member of Middle to Late Eocene age (Pandey et al., 1993). The K-VI and K-VII are the main hydrocarbon producing reservoirs in Kalol Field. The individual units are developed over a wide area having thickness ranging from 2 m to 15 m. The reservoir facies of K-VII have been divided into three depositional cycles by some workers and designated as Units –I, II, and III on the basis of their log motif. The geometry of the K-VII sands as brought out in sand isolith maps reveal shifting of channels with time.

A detailed sedimentological study of selected conventional cores belonging to K-VII reservoir unit has been carried out. The study includes documentation of the petrofacies (litho and micro-facies), textural attributes, mineralogy and sedimentary structures. The main objective was to map the distribution of litho-subunits and decipher an area based depositional model of K-VII pays.

The K-VII sediments are characterized by a mixed facies of shale-sideritic shale, laminated siltstone-shale, and fine grained sandstone with thin coal, deposited in a peritidal environment. It is apparent from the study that the deposition of the K-VII has taken place over a wide spread tidal flat, traversed by a number of tidal channels. There is development of reservoir facies close to tidal channels, whereas, away from the channel there is gradual deterioration. The imprints of tidal environment could be recorded in the core with the help of characteristic sedimentary structures and palynofloral evidences in wells Kalol #A, B, C, D, E, F, G, and H from northwest to southeastern part of Kalol Field. Accordingly, three tidal flat sub-environments were demarcated in the area, which include, subtidal channel complex; intertidal levee/sand flat/mixed flat complex, and supratidal mud flat complex after Reineck and Singh (1980).

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Discussion

In Kalol Field, the subtidal channel facies comprise fine grained and moderately sorted but immature sandstone having a few anatomizing argillaceous laminae and burrows. The microfacies is quartzwacke having coarse silt to fine grained quartz having kaolinite matrix. The porosity is moderate to good and mostly intergranular. The intertidal sand flat and mixed flat facies close to channels is characterized by thinly laminated siltstone, fine grained sandstone, and shale having sedimentary structures like lenticular structure, flaser structures, ripple laminations, cross laminations, and burrows. The microfacies here is argillaceous quartzwacke comprising coarse silt size angular to subangular quartz and dominance of argillaceous matrix and secondary siderite. The siltstone is alternating with irregular shale and often present as lenses (Figures 2 and 3). Occasional carbonaceous laminae are also present. The porosity is mostly intergranular and often destroyed by increasing argillaceous constituents. The mud flat and supratidal complex comprises mainly partially sideritic and carbonaceous shale and silty shale with minor coal. Petrographically, the microfacies is silty shale having irregular carbonaceous laminae and higher percentage of disseminated fine grained siderite.

The study indicates that in the northwestern part of the field, there is better development of fine grained sandstone facies in well Kalol #D (Figures 2 and 4) which represents channel/sand flat facies. The microfacies is quartzwacke having fine grained, moderate to well sorted and point contact quartz having moderate percentage of kaolinite matrix. In well Kalol #A, there is good development of sandflat sandstone overlying the greyish fissile shale. The sandstone is quartzwacke having fine grained point contact quartz in argillaceous matrix. In well KL #B, 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 overlain by sandstone of 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 facies from distal part to the close proximity to channel with time. The microfacies is quartzwacke having higher percentage of argillaceous matrix in laminated siltstone and is less in sandstone. The prominent sedimentary structure is flaser bedding and burrows. In well Kalol # C, however, the lithofacies is mainly laminated siltstone-shale which grade upward in to silty shale and shale. Sideritic nodules and bands are very prominent. The laminated and lenticular bedding is prominent in the basal part of the core. The petrographic study reveal silty quartz floating in an argillaceous ground mass. The laminated siltstone and shale facies in the basal part represents an intertidal mixed flat environment which grades upward in to silty shale and sideritic shale deposited in mudflat environment, thereby, suggesting a gradual lateral shift away from a channel which is more prominent in well Kalol #D.

In the central part of Kalol Field, there is moderate development of the reservoir facies. In well Kalol #E, there is repetition of development mud flat carbonaceous shale facies both at the top and bottom with intervening mixed flat laminated siltstone-shale facies (Figure 3). The petrographic characteristics are similar to that observed in wells in northwestern part. In the well Kalol #F, however, the entire core section having sideritic shale representing mud flat facies.

In the southeast part of the Kalol Field, in well Kalol # G, there is development of the basal coal suggesting a marshy condition over which silty shale is deposited having thin silty laminae. The silty laminae are irregular and have no regular pattern. In well Kalol #H, the cored facies is mainly dark grey to brownish grey fissile and sideritic shale at the bottom and laminated mixed flat laminated siltstone towards the

top. The siltstone laminae are wavy at time, lensoid and often have flaser structure (Figures 2 and 3). Both ripple and cross laminations are also preserved.

The recorded palynoflora in the cores were mainly dominated by different varieties of low salinity water plant complex, 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.

Conclusion

It is well evident from the study that in the northwest part of the field there is good development of reservoir facies in the form of sand flat and laminated mixed flat facies in proximity to tidal channels, probably originating from southeast. The sandstone-siltstone is quartzwacke having floating to point contact quartz and has moderate to good intergranular porosity. In the central part of the field, however, there is moderate development of the reservoir facies as laminated mixed flat tidal facies. In the southeast part of the Kalol Field, there is gradual deterioration of reservoir facies. The better development of mixed flat laminated siltstone facies in southeast suggests presence of a possible tidal channel further to the east (Figure 1). However, the reservoir characteristics are likely to be relatively poor.

The mapping of tidal flat facies in Kalol Field helped in understanding the distribution of lithofacies in relation to the depositional setup. The area in proximity to the tidal channels as indicated here will be suitable for development of reservoir facies. The mapping of tidal channels and reinterpretation of sand isolith maps will help in opening new area for exploration and better evaluation of reservoir parameters of Kalol-VII pays in Kalol Field.

Selected References

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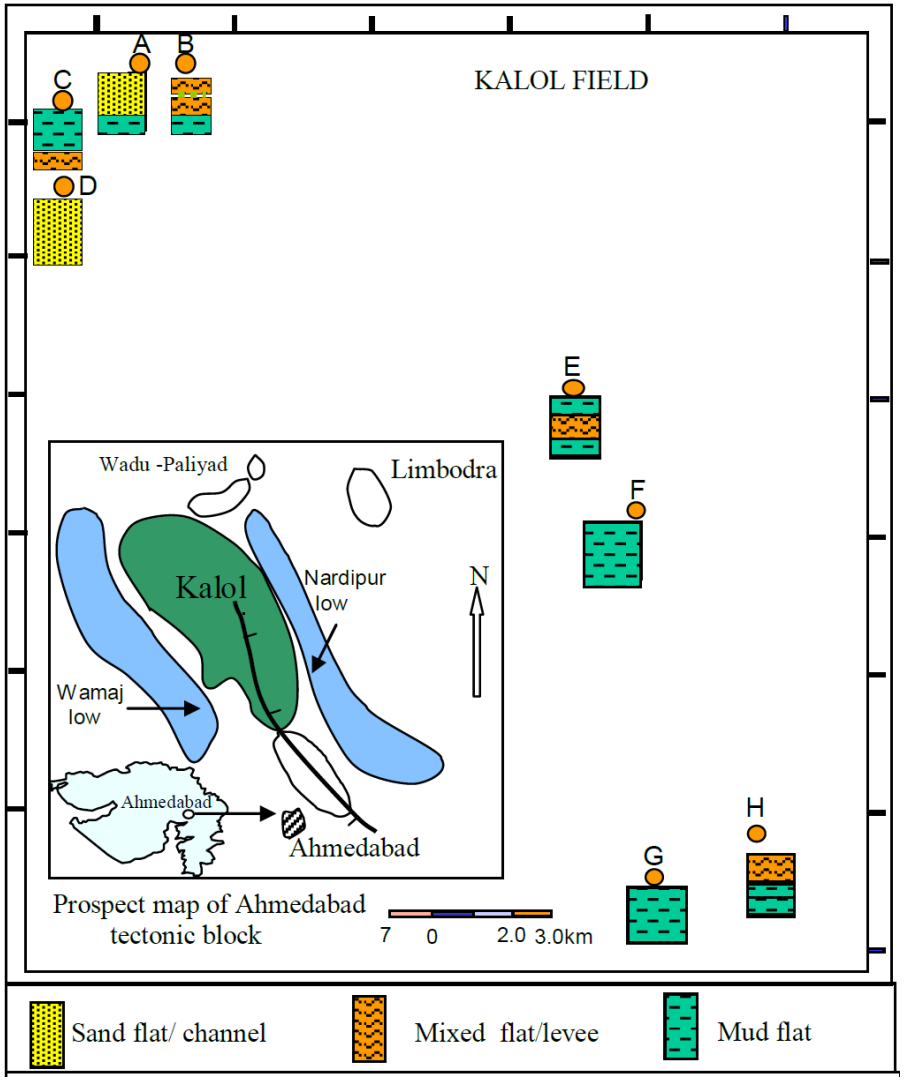

Figure 1. Location map of wells studied in Kalol Field showing distribution of tidal flat facies.

Core photograph showing fine grained well sorted sandstone developed in sand flat complex

Close up of selected core segments showing burrows and lenticular structures in intertidal sandflat complex

Close up of selected core segments showing laminated siltstone-shale developed in mixed flat complex.

Figure 2. Core Photographs and close up of selected segments depicting lithofacies variations and sedimentary structures. The well developed sandstone facies belong to sand flat facies deposited close to tidal channel. The laminated siltstone-shale facies depicting burrows and lenticular structures are developed in inter tidal mixed flat complex.

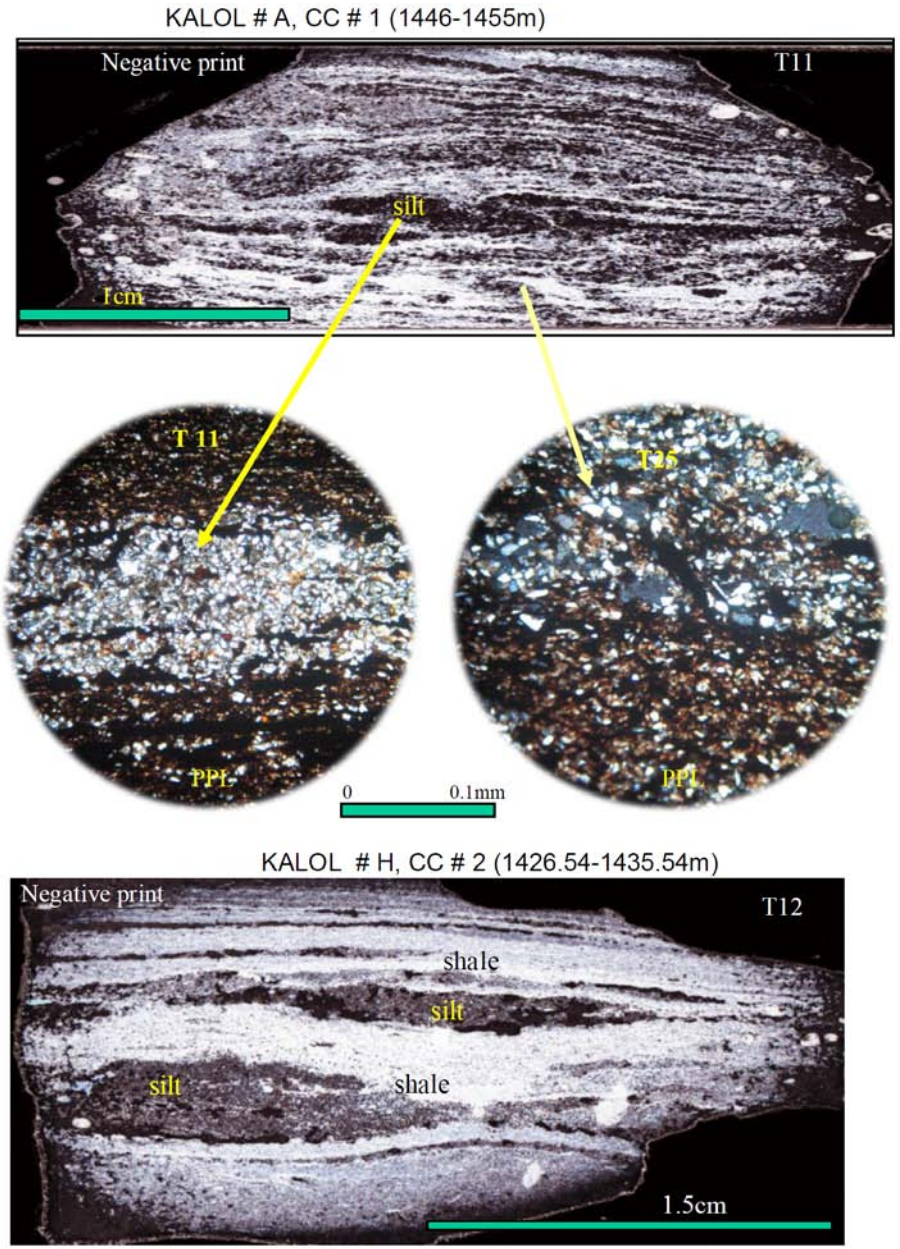

Figure 3. Microfacies details of Kalol-VII pay showing laminated mixed flat facies of siltstone and shale in wells Kalol #A and H. Note the lenticular nature of siltstone (darker portion in negative print) within shale.

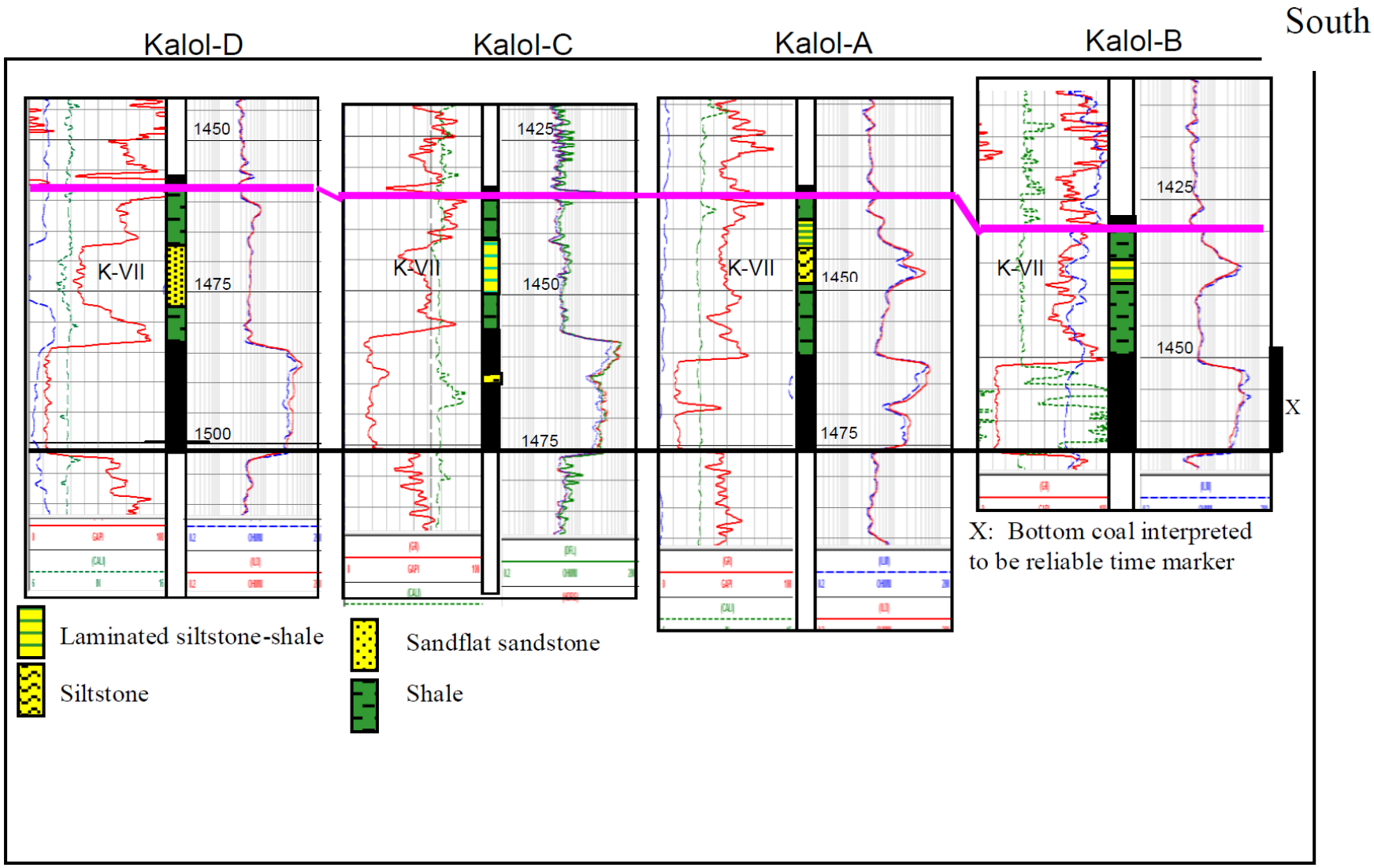

Figure 4. Development of relatively better tidal flat facies from north to south in northwestern part of Kalol field. The top and bottom coal delimit the K-VII unit. There is laminated mixed flat facies developed in Kalol-B, A and C, whereas, sand flat facies, close to tidal channel is developed in well Kalol-D.