Id no. 2004963

Causative of low resistivity Paleogene pay sands in North–Eastern part of Cambay Basin- A case study

S. Uppal and K.K. Das

KDM Institute of Petroleum Exploration, ONGC, Dehradun, India

Presenting author, E-mail: *uppal_s@rediffmail.com*

Abstract

In this paper, an attempt has been made to determine the cause of low resistivity, which will help in reservoir characterization and development of interpretation model for petrophysical evaluation of complex lithology/low resistivity pays in North Eastern part of Cambay Basin. The study is mainly based on the high resolution sedimentological techniques. SEM studies and SEM-EDX analysis of Mandhali and Mehsana members in Kadi and Kalol formations show presence of significant amount of iron and titanium in the form of ilmenite and rutile attributed towards low resistivity. Presence of chlorite clay and tiny siderite crystals in the pore spaces, grains coated with sideritic cement and ferruginous clayey matrix also have an added effect on low resistivity.

Introduction

The study area falls in the north eastern part of Mehsana block of Cambay Basin and covers Mansa and Langhnaj fields (Fig.1). The Mansa field is located on the eastern flank of block and Langhnaj field is located on the ENE-WSW trending Linch-Nandasan-Langhnaj cross trend in the Southern part of block. The stratigraphy of the area is well established with a good number of wells drilled in and around the area. The Deccan Trap forms the technical basement and the overlying sedimentary sections consist of Olpad, Cambay Shale, Kadi, Kalol, Tarapur Shale and other younger formations in ascending order. Kadi Formation is further differentiated into Mandhali, Mehsana and Chattral Members (Fig.2). In the Cambay Basin the accumulations of hydrocarbons have been established in Kalol Formation, Mehsana & Mandhali members, and also in Older Cambay Shale and Olpad formations. In Mansa-Langhnaj area (Fig.1) the complex lithology and low resistivity of the different pays creates problem for the proper evaluation of the pay sands. The objective of the present study is to find out the microfacies, mineralogy and clay minerals which are considered to be the main cause of low resistivity of the different formations. The study has been carried out for reservoir characterization and development of interpretation model for petrophysical evaluation of pays in North Eastern part of Cambay Basin.

Experimental Details

The study has been done on the 63 core plugs of about 11 different wells in Mansa- Langhnaj fields (Fig.1) in North Eastern part of Cambay Basin, covering Olpad, Older Cambay Shale, Kadi (Mandhali, Mehsana members) and Kalol formations. Selected samples are studied for petrographic analysis, to understand the mineralogy and texture. The SEM –EDX and XRD studies are also carried out for reservoir characteristics, mineral identification and clay mineralogy. The petrographic studies of selected samples and formation wise lithology of different cores is given in the Table-1.

Results and Discussion

The high-resolution sedimentological studies show that problem of low resistivity of each formation is different. In the ***Olpad Formation*** against the cored interval 1022.2-1026.2m of well Mansa-A, log shows the low resistivity of around 2 ohm-m. It is mainly due to complex lithology of claystone, sandstone and trapwacke and the lower part is mostly consists of trapwacke very similar to weathered trap (Fig.3).

The ***Older Cambay Shale*** is dominantly consist of shale and siltstone/fine grained sand stone in the interval 972-981m of well Mansa-N and in the interval 1524.0-1526.5m of well Mansa-Z. Older Cambay Shale is developed at a very shallow depth w.r.t to the central part of the Cambay Basin. Petrographic study of selected samples show that microfacies is quartz wacke (Fig.3) consisting of fine to medium grained, sub-angular to angular quartz gains 50%, detrital grains 25%, chloritic matrix 20%, and biotite (<5%). Presence of good amount of chloritic clay as matrix could be one of the reason for low resistivity in Older Camay Shale. The ***Mandhali Member*** of Kadi Formation in the studied wells Mansa-S and Langhnaj-C is consisting of sandstone with interbedded shale and carbonaceous shale respectively. The petrographic study of selected samples of well Mansa-S shows that microfacies are sideritic siltstone and quartz wacke with ferruginous clayey matrix along with sideritic cement (Fig.4). The resistivity against the studied interval (1273-1278m) in well Mansa-S is less than 2 ohm-m and SEM-EDX analysis shows the presence of well-developed crystals of ilmenite (Fe TiO_2) which could be one of the reasons of low resistivity (Fig.4).

The ***Mehsana Member*** of the Kadi Formation in the wells Langhnaj-C and Mansa-V comprises brownish grey, moderately soft, poorly fissile, non-calcareous shale/siltstone, carbonaceous at places and dark grey, hard, compact, siltstone respectively. Thin section study in the interval 1901.87m of well Langhnaj-C reveals quartzwacke microfacies, consisting of silt size to very fine grained, sub-angular to sub-rounded quartz grains embedded in ferruginous clay matrix along with carbonaceous matter. The log response against the studied interval (1900.4-1904.65m) of the well Langhnaj-C has resistivity of the order of 2-3 ohm-m (Fig.5). SEM-EDX analysis also shows the presence of mixed layer clay along with siderite and minor amount of TiO_2. Though XRD analysis shows presence of kaolinite clay with some amount of smectite clay but SEM study indicate presence of pore fill chlorite clay which also have the impact on the resistivity.

Varied types of lithology have been observed in wells Mansa-D&E and Langhnaj-A&D in the different pays of ***Kalol Formation***. In Mansa area, Kalol Formation is developed at very shallower depth as compared to the wells drilled in Langhnaj area. The studied interval (579.2-588.2m) of Mansa-D dominantly comprises brownish grey moderately soft, micaceous and non-calcareous claystone; whereas the interval (878.5-887.5m) in well Mansa-E is mainly consist of brownish grey, moderately compact, fissile, micaceous and non-calcareous shale, carbonaceous at places. The bottom part of this core consists of brick red coloured, hard and compact ferruginous claystone (Fig.6). SEM-EDX analysis of the ferruginous claystone in the bottom part (884.7m) of well Mansa-E indicate the significant amount of iron present in the form of siderite and illmenite crystals which is probably the main cause of low resistivity. The log response in the studied section also shows the resistivity less than 5 ohm-m (Fig.6)

The studied interval (1317.0-1326.0m) in well Langhnaj-A is dominantly consist of carbonaceous shale which is poorly fissile and non-calcareous in nature, whereas interval (1327.4-1334.7m) represents K-(III+IV) in well Langhnaj-D consists moderately hard and compact, fine to medium grained sandstone, non-calcareous in nature. The reservoir facies is present only in the interval 1327.4-1334.7m of Langhnaj-D and petrographic studies of the selected samples show that microfacies is quartz arenite consisting of fine to coarse grained, poorly sorted, angular to sub-angular quartz (85%) embedded in ferruginous clay matrix (10%) along with presence of pyrite, chlorite and siderite at places, which could be the reason of low resistivity (Fig.7). SEM study shows the presence of mixed layer clay and tiny siderite crystals in the pore spaces reducing the porosity and grains coated with sideritic cement are also observed. SEM-EDX analysis also confirms the presence of siderite (Fig.7)

Conclusions

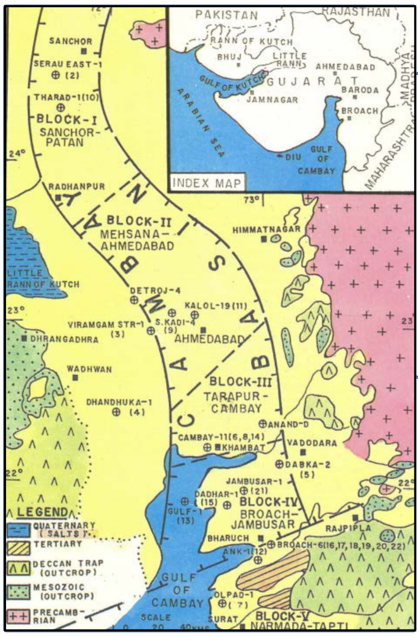
- The Olpad Formation in the studied wells represents mainly silty claystone, trapwacke and weathered basalt with olivine crystals and other ferromagnesian minerals.
- Older Cambay Shale Formation is dominantly of shale and siltstone/ fine grained sandstone and XRD analysis shows the presence of kaolinite and smectite clay.

- SEM studies and SEM-EDX analysis of Mandhali Member, Mehsana Member and Kalol Formations show the significant amount of iron present in the form of siderite and illmenite and titanium in form of rutile crystals, could be probably cause of low resistivity. Presence of Fe-rich clay and pore fill chloritic clay also has the impact on lowering of resistivity.
- Based on the finding of these minerals the log evaluation parameters can be redefined for better computation of resistivity values of the pay sands.

Table 1: Detailed lithology and Petrographic analysis of selected plug samples.

Formation/ Member	Well	Core	Core Interval(m)/Rec.%	Lithology	Petrography
Kalol	Mansa-E	CC-2	878.5-887.5 (89.2)	Shale- Brownish grey, soft, moderately compact, fissile, micaceous, non-calcareous, and carbonaceous, whereas bottom part (Plug. No.28) is Ferruginous claystone- Brick red, hard and compact, non-calcareous.	Depth 884.7m: Ferruginous claystone- Dark brown with red crystals of rutile
	Mansa-D	CC-1	579.2-588.2 (71)	Claystone- Brownish grey, moderately soft, micaceous, non-calcareous.	
	Langhnaj-A	CC-1	1317.0-1326.0 (88.4)	Carbonaceous Shale- Brownish grey, soft, moderately compact, poorly fissile, non-micaceous, non-calcareous, and carbonaceous in nature.	
	Langhnaj-D	CC-1	1327.4-1334.7(30.1)	Sandstone- Light dirty brown, moderately hard and compact, fine to medium grained, non-micaceous, and non-calcareous.	Depth 1328.19 to 1328.64m: Quartz arenite- Fine to coarse grained, poorly sorted quartz grains, angular to sub-angular having point to line contact embedded in ferruginous clay matrix. Quartz 85%, Matrix 10% along with pyrite, chlorite and siderite.
Mehsana	Langhnaj-C	CC-1	1900.4-1904.65(99.8)	Shale - Brownish grey, moderately soft, compact, incipient fissile, non-calcareous, and carbonaceous. Siltstone - Brownish grey, moderately hard and compact, and non-calcareous, along with few carbonaceous flakes.	Depth 1901.87: Quartz wacke- Silt size to very fine grained, sub-angular to sub-rounded quartz grains embedded in ferruginous clay matrix along with carbonaceous matter.
	Mansa-V	CC-1	1338.0-1344.75 (31)	Siltstone- Dark grey, hard, compact, and non-calcareous.	Depth 1339.72m: - Silt size to very fine grained, cryptocrystalline quartz formed due to diagenesis along with some carbonaceous matter.
Mandhali	Mansa-S	CC-2	1273.0-1278.0 (82.5)	Sandstone interbedded with shale: Sandstone - Dirty grey, moderately hard and compact, fine to medium grained and non-calcareous with presence of clay clasts. Shale -Dark brown, soft, fissile, non-micaceous, non-calcareous, and carbonaceous in nature.	Depth 1273.76-1273.97m: Quartz wacke- Fine to coarse grained, poorly sorted quartz grains, angular to sub-angular having point to line contact embedded in chloritic clay matrix and bonded by sideritic cement. Quartz 65%, chloritic clay matrix 25%, siderite 5%, pyrite<5%, and mica in traces along with sideritic siltstone have around 50% siderite.
	Langhnaj-C	CC-2	2079.10-2086.90(95.3)	Carbonaceous Shale- Brownish grey, soft, compact, poorly fissile, non-calcareous, and carbonaceous.	
OCS	Mansa-Z	CC-1	1524.0-1526.5(88.4)	Shale - Dirty brownish grey, soft, moderately compact, poorly fissile, non-calcareous, and slightly silty in nature.	

	Mansa-N	CC-1	972-981 (64.22)	Silty shale - Greyish brown, soft, compact, poorly fissile, non-calcareous. Siltstone - Siltstone is dark brown, soft, moderately compact with shale lamina and abundant clay matrix.	Depth 975.3m: Quartz wacke- Fine to medium grained, sub-angular to angular quartz gains 50%, detrital grains 25%, chloritic matrix 20%, and muscovite and biotite in traces(<5%)
Olpad	Mansa-J	CC-3	869-872 (94)	Silty Claystone- Dirty yellowish grey, soft, moderately compact, and non-calcareous.	
	Mansa-A	CC-4	1022.2-1026.2 (85)	Trap wacke: Reddish brown with black and white spotted fillings, hard, compact, feebly calcareous trap wacke along with some black coloured volcanic fragments	Depth 1022.35m: Microfacies is weathered Basalt, showing basaltic texture, large olivine crystals and plagioclase laths. At places altered basalt showing Palagonite grains formed by hydration of basalt giving pseudo-look of oolites



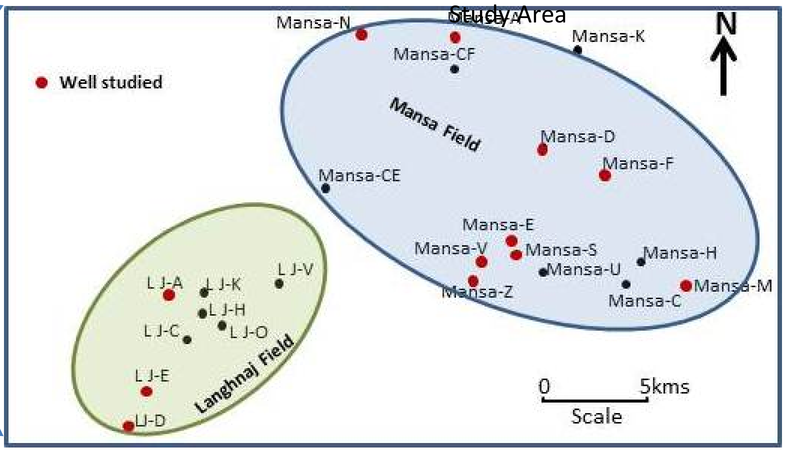


Fig.-1 Tectonic Map of Cambay Basin and area of study in North Cambay basin showing well locations

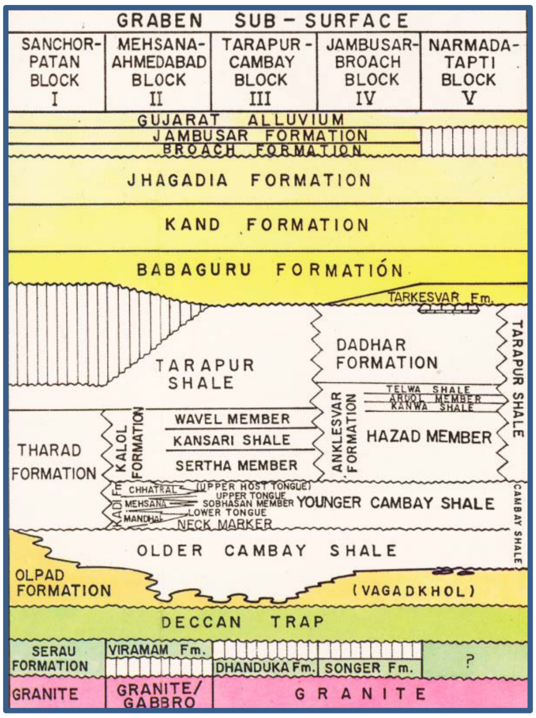


Fig.-2 Generalized Stratigraphy of Cambay Basin

(After Pandey et al)

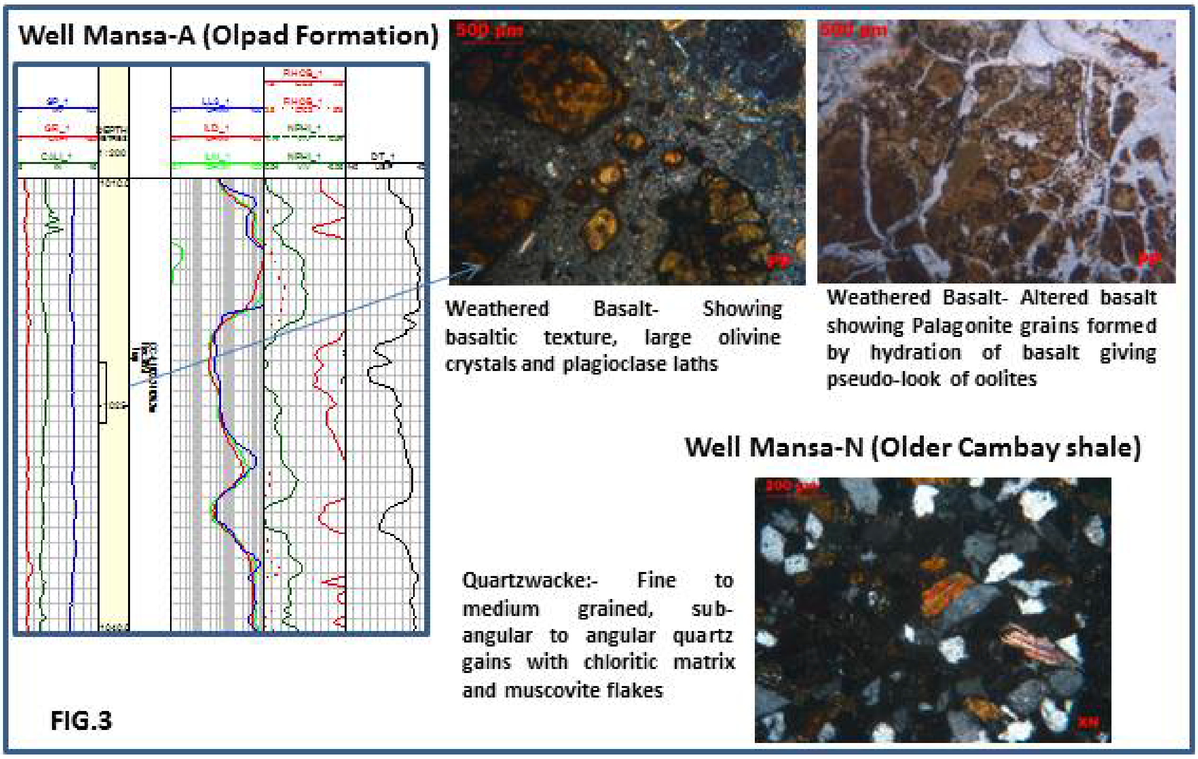


Fig.-3 Microfacies of Older Cambay Shale, Olpad Formation and log signature of Olpad

Well Mansa-S (Mandhali Member)

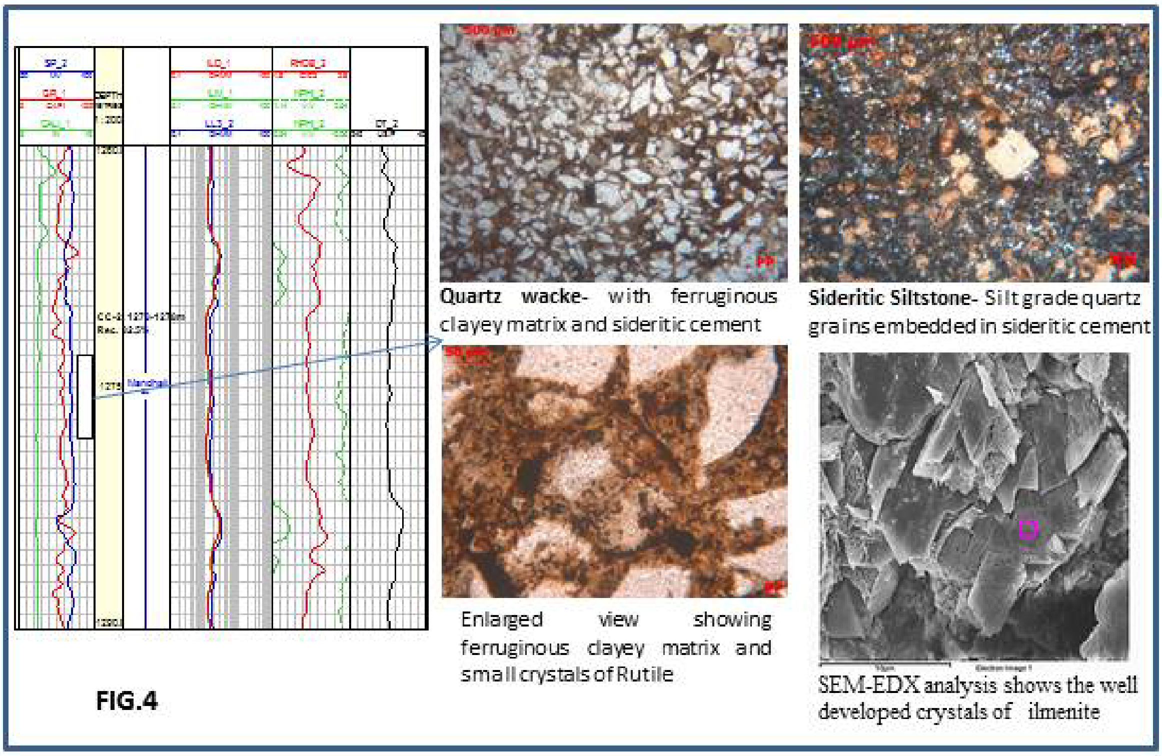


Fig.-4 Microfacies, SEM-EDX analysis and log signature of Mandhali Member

Well Langhnaj-C (Mehsana Member)

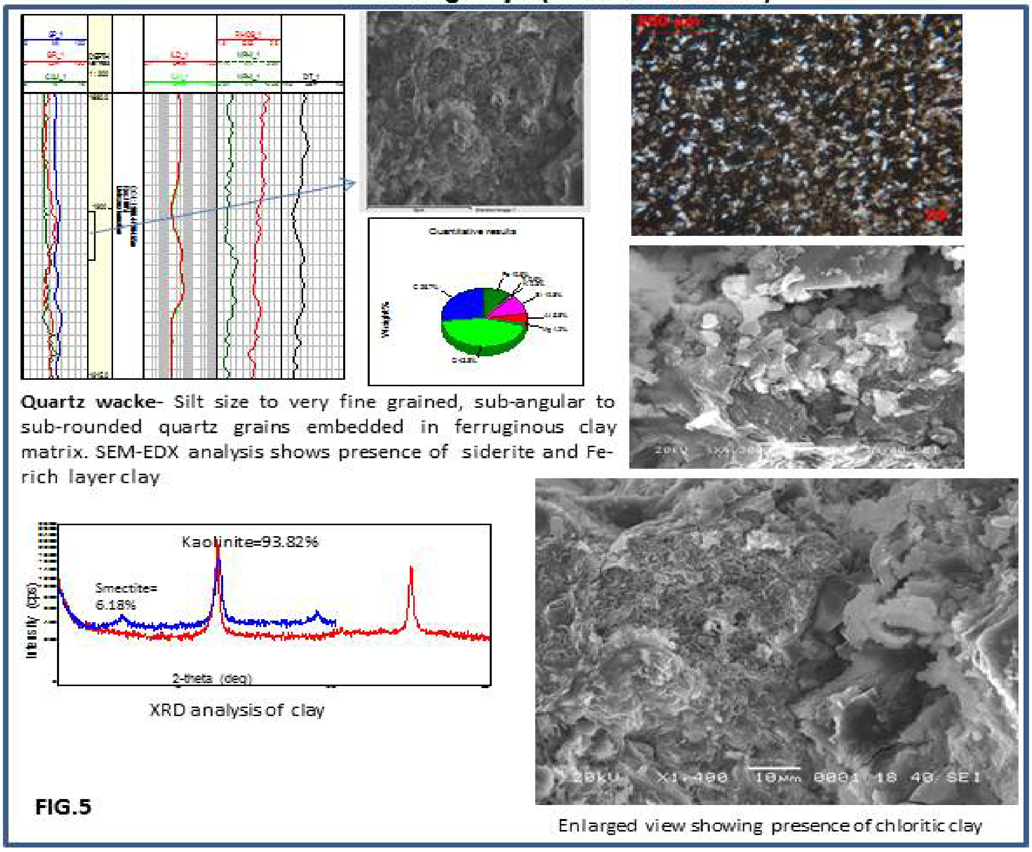


Fig.-5 Microfacies, SEM-EDX, XRD analysis and log signature of Mehsana Member

Well Mansa-E (Kalol Formation)

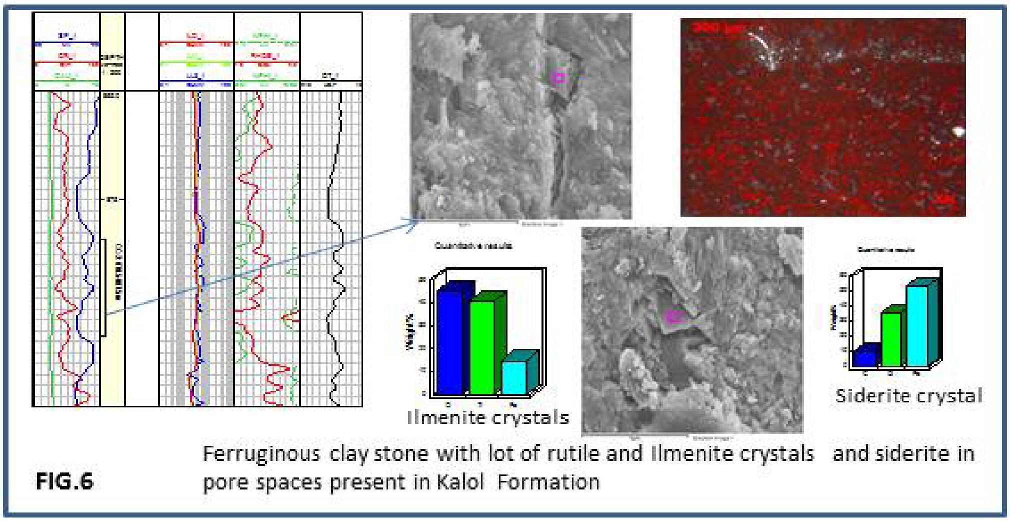


Fig.-6 Microfacies, SEM-EDX analysis and log signature of Kalol Formation

Well Langhnaj-D (Kalol Formation)

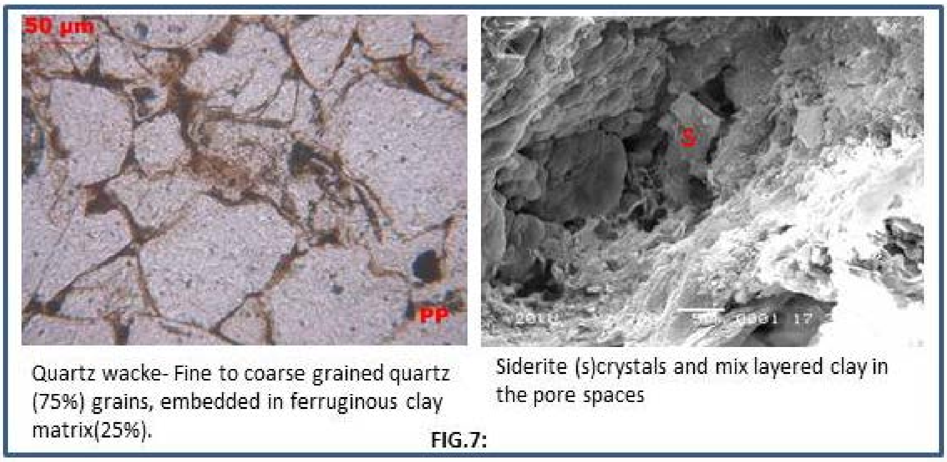


Fig.-7 Microfacies, SEM-EDX analysis and log signature of K III + IV (Kalol Formation)