Click to see poster presentation

Lithofacies and Semi-Quantitative Analysis by XRD/SEM for Evaluating the Impact of Mineralogy on Reservoir Quality of Organic Shale in Cambay Basin*

P.T. Prathimon[1], Swati Sharma[1], Amrita Roy[1], and Jagmohan Singh[1]

Search and Discovery Article #11083 (2018)**
Posted June 11, 2018

*Adapted from extended abstract based on poster presentation given at 2017 AAPG Asia Pacific Region Geosciences Technology Workshop, Oil and Gas Resources of India: Exploration and Production Opportunities and Challenges, Mumbai, India, December 6-7, 2017

[1]Oil and Natural Gas Corporation, India (T_PrathimonP@ongc.co.in)

Abstract

This work presents findings of sedimentological studies on twenty-seven cored sections from six wells: Gandhar#GAG, Wadu#EF, Mahelaj#AE, Linch#ACB, Kalol#GAB and S. Kadi#AFC. The main objective of this study is sedimentological analysis of various members/horizons of the Cambay shale section encountered in the wells being drilled for delineation of the shale Gas/oil reservoirs in the study area to facilitate fracture stimulation jobs and for future regional correlation. The detrital assemblages in the studied Cambay Shale samples, as determined from thin section and qualitative X-Ray Diffraction analyses comprise quartz, feldspar (plagioclase and K-feldspar), clay minerals (kaolinite and illite), dolomite and organic matter. No biogenic silica, either in form of radiolarian tests or sponge spicules, was observed. Quartz cement is seen as patches of microcrystalline quartz (crystal size up to 10 µm), commonly occurring as scattered patches of euhedral crystals. Possible sources for quartz authigenesis include: (i) dissolution of unstable framework grains and (ii) mass transfer of silicon ions into the pore water from the interbedded fine-grained sediments. Petrographic, including microscopic as well as Scanning Electron Microscopic studies, reveal presence of euhedral crystals and overgrowths of kaolinite, chlorite and silica. A few primary intra granular pores associated with the body cavities of fossils such as foraminifera are present. However, most fossil-related, primary intra particle pores are filled with clays, silica, and/or pyrite cement. Clay minerals form a dominant part of the finer grained detrital component, with a mix of illite/smectite, chloritic and kaolinitic clays, apparent from qualitative X-Ray Diffraction analysis. The occurrence of nano pores is typically associated with detrital grains, disseminated organic matter, and authigenic euhedral quartz and pyrite crystals, whereas the secondary porosity exists in the form of micro fractures. These micro fractures are a common feature in all studied wells, which are found mostly in association with sideritic shales. When compared to the wells Gandhar#GAG and S.Kadi#AFC, the samples from wells Wadu#EF, Linch#ACB, Mahelaj#AE and Kalol#GAB show poor silica content with higher amount of clay minerals, which are dominantly ferruginised in nature. The wells Gandhar#GAG and S.Kadi#AFC show high silica content, evident in photomicrographs, Scanning Electron Microscopic images and X-Ray Diffraction data. It has been widely accepted that the mineralogy and texture can be a critical component in the resource potential of shales. Rocks with high silica

(quartz) and or sideritic nature along with low clay content make them more brittle, more prone to natural fractures and are good candidate for fracture stimulation.

Introduction

Shale gas is natural gas, primarily methane, generated in organically rich, fine grained, shale having very low porosity and permeability. In India, Potential sedimentary basins are being identified and the relevant geochemical, geological and geomechanical data are being generated /or assimilated from conventional exploratory studies for prioritizing the zones towards location of sweet spots where it would be most beneficial to drill. One amongst such potential areas is the petroliferous Cambay Basin in the western India (Figure 1A), where Cambay and Tarapur shale along with shale of Ankleshwar/Kalol Formations and those within the Miocene section in the Broach depression have acted as source rocks for generation of oil and gas in the basin (Banerjee et al., 2002). The mineralogy of shale has direct bearing on the effectiveness of hydro fracturing for optimum production. The presence of certain minerals favours the generation of natural fractures. These create permeability pathways that connect the micro pores and allow gas to flow. Natural fractures are more prevalent in silica-rich and carbonate-rich shale. The brittleness of the shale is the key factor in carrying out successful hydro fracturing and the operation can be monitored by micro seismic survey (Padhy and Das, 2013).

Data Analysis

The geology laboratory data has been generated to establish the litho-facies and semi-quantitative mineralogy of various members/horizons for evaluating the impact of mineralogy on reservoir quality of Cambay shale formation. Sedimentological studies include detailed lithofacies by megascopic studies, microfacies by thin section, mineralogy by X-Ray Diffraction method and reservoir characteristics by Scanning Electron Microscopic Study. The semi-quantitative assessments make the identification of individual minerals in shale gas samples much more valuable. The studied samples from wells J#EE, G#GAO, G#GAG, G#FIH, G#GAB, G#GOH and G#GOO (Figure 1C) of South Cambay Basin, reveals that the entire core is Silty Shale and Shale (Figure 2A). The Shale is dark grey color, moderately indurated, moderate to poorly fissile and highly carbonaceous in nature whereas the silty Shale shows grey to dark grey color, moderately hard and poor fissility with silt size quartz grains. Silt is observed as micro laminations. Siderite bands observed at places with varying thickness from 2 cm to 7cm. Petrographic analysis of representative samples also suggests that the entire core is silty shale with silt sized quartz grains (Figure 2B) which are bounded by argillaceous matrix. Scanning Electron Microscopic analysis of the representative samples from silty shale and shale reveals that Kaolinite, the most common clay that occurs as a replacement product of feldspar diagenesis and as a minor pore filling clay, associated with quartz cement. The semi quantitative analysis (Figure 2F) of the representative samples reveals that the silty shale dominates with quartz subordinate with clays and ferruginous minerals. The micro pores are observed in association with organic matter and authigenic minerals like Pyrite framboids and authigenic quartz grains. The secondary porosity mainly observed in silty shale as in the form of micro fractures and dissolution structures. Nano-to micro inter crystalline pores within pyrite framboids vary with the size of the framboids.

Results

The representative samples from the wells LN#ACB, SK#AFC, WD#GAB, and MY#AE (Figure 1D) of North Cambay Basin show mainly

sideritic shale and shale lithology. The sideritic shale is grey to brownish grey color, hard, poorly fissile, sideritic and feebly calcareous in nature. Siderite nodule with short diameter is observed throughout the cores. The petrographic study shows sideritic shale with secondary porosity exists in the form of micro fractures (Figure 3B, C and D) which are filled by non-calcareous and calcareous secondary minerals. Scanning Electron Microscopic study reveals that most of the micro-pores are associated with pyrite framboids (Figure 3E and F) and authigenic quartz in association with organic matter or fossil material. Vermicular form of Kaolinite is the main clay mineral observed in association with organic matter. A few primary intra-granular pores associated with the body cavities of fossils such as foraminifera are present. However, most fossil-related, primary intra-particle pores are filled with clays, silica, and/or pyrite cement. The semi quantitative analysis by X-Ray Diffraction method reveals that the siderite is the most dominant and quartz is the second most abundant mineral in the sideritic shale section (Figure 3G).

The organic rich shale, silty shale and sideritic shale are fine-grained rocks with a complex mineralogy (variable amounts of detrital, diagenetic and biogenic components) that affect reservoir quality, which ultimately governs the shale well performance. The presence of non-clay minerals and ferruginous minerals favours the generation of natural fractures. These create permeability pathways that connect the micro pores and allow gas to flow. When compared to the shales from South Cambay Basin, the shale from North Cambay Basin shows poor silica content with higher amount of ferruginous and clay minerals.

Conclusions

From these studies, we observed that the mineralogy and texture can be a critical component in the resource potential of shales. Rocks with high silica content (Quartz) and or sideritic nature along with low clay content make them more brittle, more prone to natural fractures and are good candidate for Hydro-fracture stimulation jobs. The presence of nano-quartz may outline potential cleavage planes within organic matter, and therefore may represent the first open and permeable pathways between HC-filled intra-organic nano-pores and stimulated fractures connected to the well bore. In this case, authigenic nano quartz may behave as a natural proppant. More work is needed for the interpretation of textural variations in organic shale/silty shale through additional integration of cores, logs and other data.

Acknowledgement

The authors express their deep gratitude to Oil and Natural Gas Corporation, India for granting permission to present and publish this study.

References Cited

Banerjee, A., S. Pahari, M. Jha, A.K. Sinha, A.K. Jain, N. Kumar, N.J. Thomas, K.N. Misra, and K. Chandra, 2002, The effective source rocks in the Cambay Basin, India: AAPG Bulletin, v. 86/3, p. 433-456.

Padhy, P.K., and Shishir Kumar Das, 2013, Shale Oil and Gas Plays: Indian Sedimentary Basins: Geohorizons, v. 18, p.20-25, Web Accessed May 27, 2018, https://www.spgindia.org/geohorizon_junuary_2013/junuary_2013_shale_oil_and_gas_plays_indian_scdimentary_basins.pdf

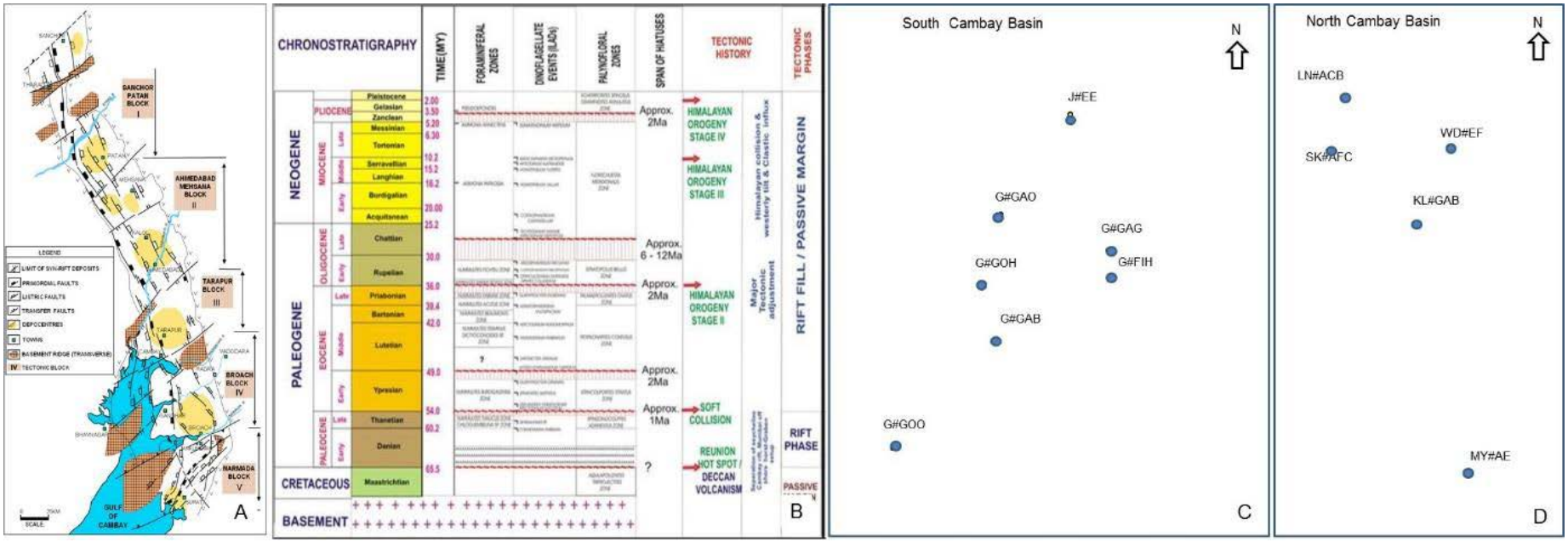

Figure 1. A) Prospect Map of Cambay Basin; B) Sequence stratigraphic scheme in Cambay Basin (after Pandey et al., 1993); C) Location map of south Cambay Basin; and D) North Cambay Basin.

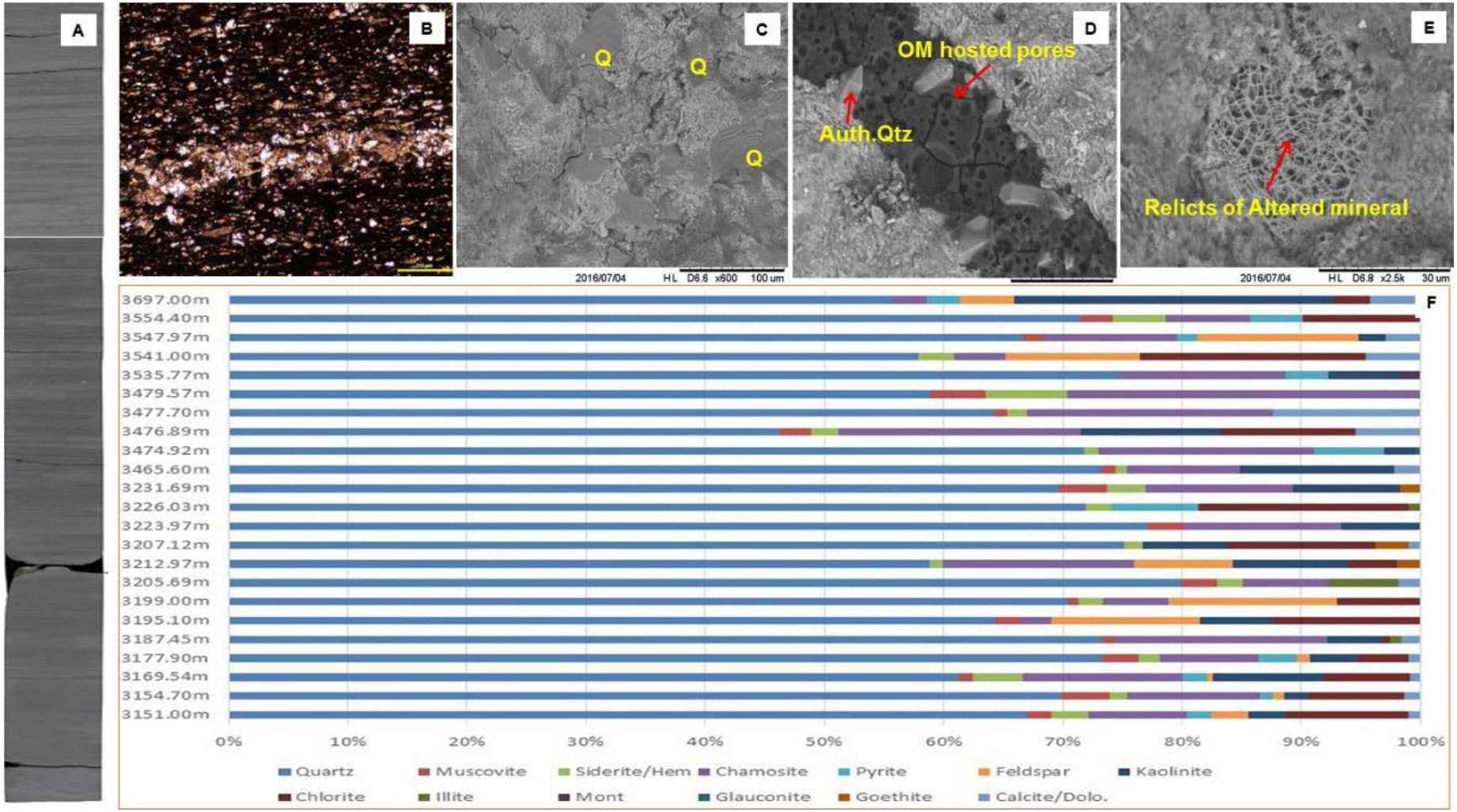

Figure 2. A) Slabbed core section; B) Petrographic study; C, D & E) Scanning Electron Microscopic Study; and F) Semi-quantitative analysis by XRD of representative samples from South Cambay Basin.

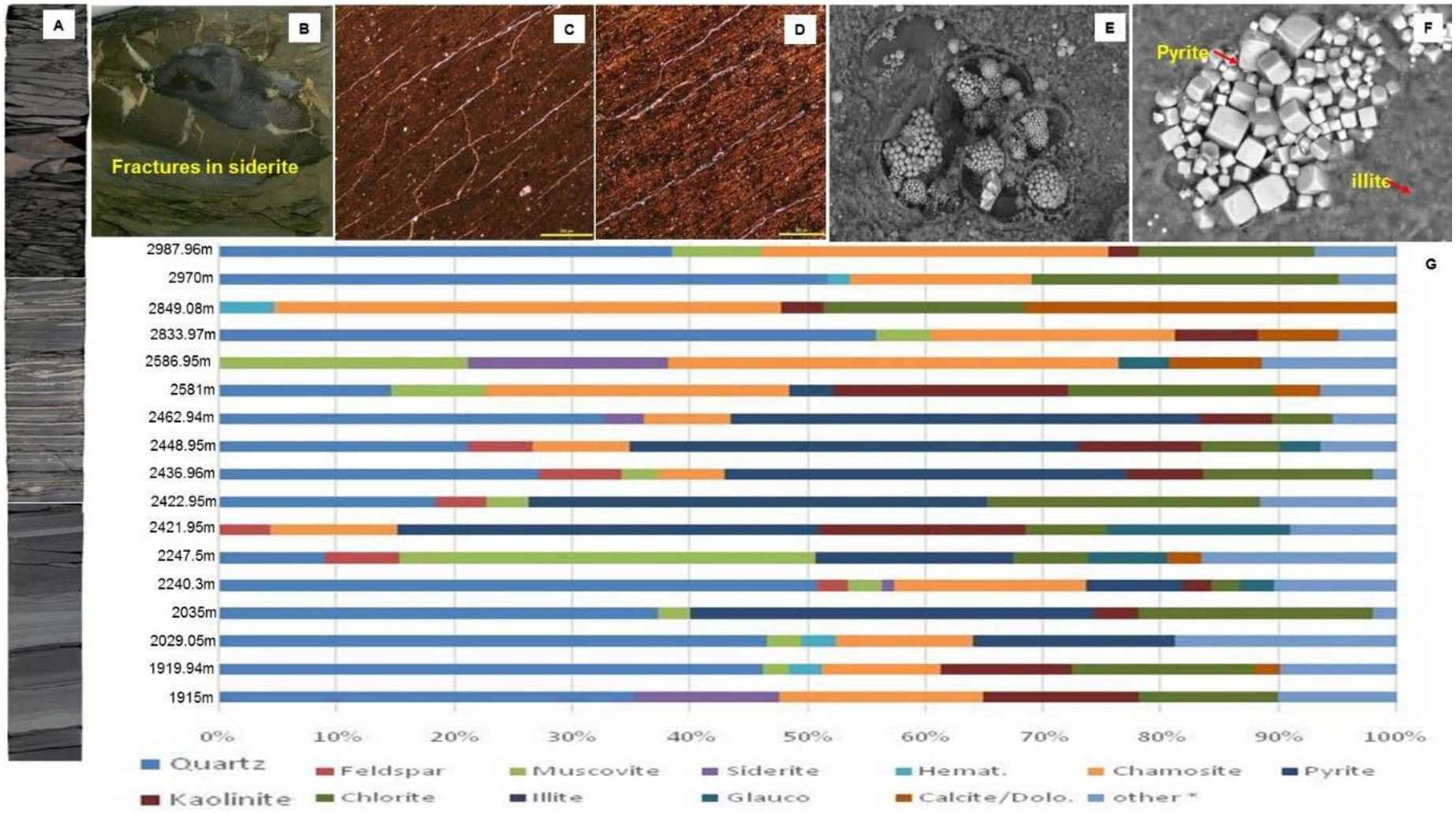

Figure 3. A & B) Slabbed core section; C & D) Petrographic study; E & F) Scanning Electron Microscopic Study; and G) Semi-quantitative analysis by XRD of representative samples from North Cambay Basin.

Click to view poster presentation