# Diagenetic Imprints and Their Effect on Porosity Modifications in Bassein Limestone: A Case Study Near Neelam Field, Mumbai Offshore Basin*

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Search and Discovery Article #10323 (2011)
Posted June 3, 2011

*Adapted from extended abstract presented at GEO-India, Greater Noida, New Delhi, India, January 12-14, 2011

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## Abstract

Hydrocarbon occurrence has already been proved in the Middle-Late Eocene Limestone of Bassein Formation in different structures of the Heera-Panna-Bassein block of Mumbai Offshore Basin. The present work is an outcome of sedimentological study of the five wells A, B, C, D and E covering microfacies analysis, diagenesis and porosity modifications in the Bassein Formation. Foram wackestone to foram-bioclastic packstone characterizes the Bassein Formation. Stylolaminations along with selective dolomitization, partial sparitization of matrix with development of microspar and dissolution process are dominant diagenetic imprints observed in these microfacies. Good secondary porosity is observed in the form of solution vugs observed at certain levels in wells A, B and C due to karstification and leaching/dissolution of grains. The porosity in other structures of the area under study has been occluded by sparitization as well as filling of solution channels by blocky spary calcite. Subsequent dissolution of the spary calcite has generated minor secondary porosity in some intervals at a later stage. In general, reservoir characteristics in terms of development of porosity in Bassein Formation is poor to moderate except in the paleohighs where Bassein Formation was subjected to prolonged subaerial exposures resulting in karstification and localized development of porosity.

## Introduction

Mumbai Offshore is surrounded by the Deccan Trap outcrops to the east, Bombay High East Fault to the west, Ratna North Fault to the south and Diu Fault to the north (Figure 1). The study area lies east and northeast of the Neelam structure in the Heera-Panna-Bassein tectonic block of Mumbai Offshore Basin and has been explored extensively in recent years for Panna, Bassein and Mukta pays. In this block, commercial production has been established from Bassein, Neelam , Bassein East and Bassein West fields. In the studied area hydrocarbon indications are known from few wells. The present study is taken up to understand the microfacies, porosity development and reservoir characters of the sediments in the area east of Neelam Field.

## Methodology

Six conventional cores comprising 32 meters of core length from the 5 wells A, B, C, D and E (Figure 2) have been studied for detailed lithology, microfacies and porosity assessment. A correlation profile at the top of Mukta Formation was also prepared covering all the five wells. Megascopic and thin section studies were carried out to understand the different facies developed in this area and the effect of diagenesis on reservoir quality. SEM studies of selected samples were carried out to decipher the reservoir characteristics and XRD analyses have also been carried out to determine the type of carbonate minerals.

## Geology and Stratigraphy

The Western Continental Margin of India is described as a “passive margin” (Biswas, 1982 and 1987) and its evolution related to the breaking up of Gondwanaland in Late Triassic to Early Jurassic time and the subsequent rift drift history. Faulting along the Precambrian basement trend developed the major West Coast Fault (Dessai and Bertrand 1995) and also developed the structural mosaics of the Bombay Platform.

Widespread Deccan volcanism in the Western Continental Shelf is considered to be a late synrift event (Whiting et al., 1994). The post-rift stage between Late Paleocene/Early Eocene to Recent witnessed deposition of a very thick sedimentary succession on the faulted floor of Deccan basalts and isolated inliers of metamorphic basement. The Deccan basalt constitutes the technical basement for the sediments of this area and the sediments range in age from Late Paleocene/Early Eocene to Recent (Figure 3). The Late Paleocene/Early Eocene sediments are represented by the Panna Formation comprised of claystone, shale, siltstone and at places very fine-grained sandstone which is absent in the studied wells. The overlying Bassein Formation is characterized by thick foraminiferal and algal wackestone, packstone and occasional grainstone facies. In a few wells the Bassein Formation directly overlies the basaltic basement.

The Mukta Formation, which unconformably overlies the Bassein Formation, is characterized by the presence fossiliferous limestone with shale intercalations. The Alibagh Formation (Upper Oligocene-Basal Miocene) overlying the Mukta Formation is separated by an unconformity and consists of greenish gray splintery shale interspersed with thin limestone bands. The Bombay Formation (Lower Miocene) consists of thick limestone interspersed with thin shale and unconformably overlies the Alibagh Formation.

## Facies Analysis and Diagenetic Imprints

The Bassein Formation (Middle-Late Eocene) constitutes a thick (225- >500 m) massive limestone with occasional thin streaks of shale. Six conventional cores from the five wells A, B, C, D and E have been studied to understand the reservoir's diagenetic aspects. Most of the cores were taken in the upper part of the Bassein Formation, except in Well C where the cores belong to the lower part of this formation. The megascopic study reveals that the upper part of the Bassein Formation in Well A is karstified limestone giving a chalky appearance and foram-coral packstone to wackestone with some argillaceous matter in the other wells (B, C, D and E). The visual porosity is moderate to good in these wells except in Well E where it is poor due to sparitization. Wackestone facies show extensive karstification and generation of good secondary porosity in wells A and B (Figures 4a-b). The main microfacies in these wells are foram bioclastic wackestone, foram-algal packstone, and algal coral packstone facies, argillaceous and dolomitic at places, except in Well E where the microfacies are represented by foram packstone with very poor porosity (Figure 5f). Pyritic encrustation of fossil chambers is common.

These facies are characterized by partial sparitization of matrix and skeletal grains with development of microspar. Porosities are moderate to good and mostly present in the form of vugs and molds. Patches of ferruginous matter and presence of large vugs and cavities indicate subaerial exposure common in the upper part of Bassein Formation. At places good vuggy porosity is generated due to dissolution of grains and spary calcite in the lower part along stylotitic seams. Porosity in the Bassein Formation is heterogeneous and is destroyed at places due to blocky calcite spar filled in fossil chambers, earlier generated vugs/cavities and neomorphic development of microspar with in the matrix (Figures 5b-c). Compactional features are abundant and include irregular solution seams, grain breakage, etc. Dolomitization is associated with higher matrix content. Two stages of cementation are observed, first stage displayed by isopachus rimcement followed by large equant spary calcite cement. The facies represent low to medium energy environment for the sediments, with rare high energy conditions.

## Reservoir Characterization

X-ray diffraction (XRD) and SEM studies are carried out to understand the mineralogy of the carbonates and their reservoir characteristics. The limestone of Bassein Formation shows calcite as the dominant carbonate mineral with subordinate dolomite (Figure 6). Samples studied under SEM show the presence of smaller solution vugs, organic porosity and micro porosity enhanced by solution activity. In Well C isolated vugs, channels and intergranular pores are filled with equant spary calcite which has occluded the secondary porosity. The sparitization of grain is accompanied by presence of clay floccules (kaolinite – Figure 5h)

## Diagenetic Effects on Porosity Developments

During diagenesis, carbonate sediments may gain or lose porosity. With increasing depth of burial there is generally a decrease in porosity, but there are late processes of dissolution and fracturing which can create higher porosity. The understanding of porosity creation and deterioration is major aim of diagenetic studies. Textural criteria indicating a burial origin of spar include broken and collapsed micritic envelopes present within calcite spar, fracture grains and sutured or concavo-convex contacts between grains.

The Bassein Formation is represented by bioclastic wackestone, foram-algal packstone, and algal coral packstone facies with extensive karstification in wells A and B, along with moderate to good vuggy porosity in Well B formed due to dissolution of grains and spary calcite. Partial sparitization of matrix and skeletal grains are common diagenetic process responsible for deterioration of porosity. Dolomitization is observed in the argillaceous limestone in the lower part of the Bassein Formation as well as along stylolites. A correlation profile (Figure 7) at top of the Mukta Formation shows the variation of thickness of the Bassein Formation which varies from 225 m in Well B to 506 m in Well E.

Subaerial exposure at the top of Bassein Formation resulted in the development of a karstified zone creating better porosity pods in the upper part. Additional porous layers are observed in the lower part of this formation wherever it lies over the paleohighs or locales with lesser thickness of Panna clastics as observed in wells A, D, B and C. The porosities in the Lower Bassein are generated during late burial diagenesis due movement of corrosive fluids along the faults. This is evident from the log motives of Well B, as well as from the core data of Well C where only 2 meters ov core was recovered against the 18 meter cored section suggesting that a major part of the core was washed out in the porous zone. This type of localized porosities is developed in the areas whereever this formation either lies over the paleohighs or with locales with lesser thickness of Panna clastics.

## Conclusions

● Occurrence of foram bioclastic wackestone, foram-algal packstone, and algal coral packstone in the Bassein Formation are suggestive of shallow water platform carbonate origin in the studied area.

● Porosity in the Bassein Formation is generated mainly due to karstification in the upper part represented by solution vugs/channels and molds.

● Additional porous layers are observed in the lower part wherever it lies over the paleohighs or locales with lesser thickness of Panna clastics. The porosities in the Lower Bassein are generated during late burial diagenesis due to the movement of corrosive fluids along the faults.

● Diagenetic imprints like sparitization, presence of blocky calcite in earlier generated vugs/cavities and neomorphic development of microspar with in the matrix are responsible for deterioration of porosities.

**Acknowledgements**

The authors are grateful to Mr. D.K. Pande, Director (Exploration), ONGC for granting permission to publish this paper. Authors are thankful to Mr. P.K. Bhowmick, ED-HOI-KDMIPE for his valuable guidance and suggestions during the course of the present study. The views expressed in the present paper are solely of the authors and not necessarily of the organization they belong.

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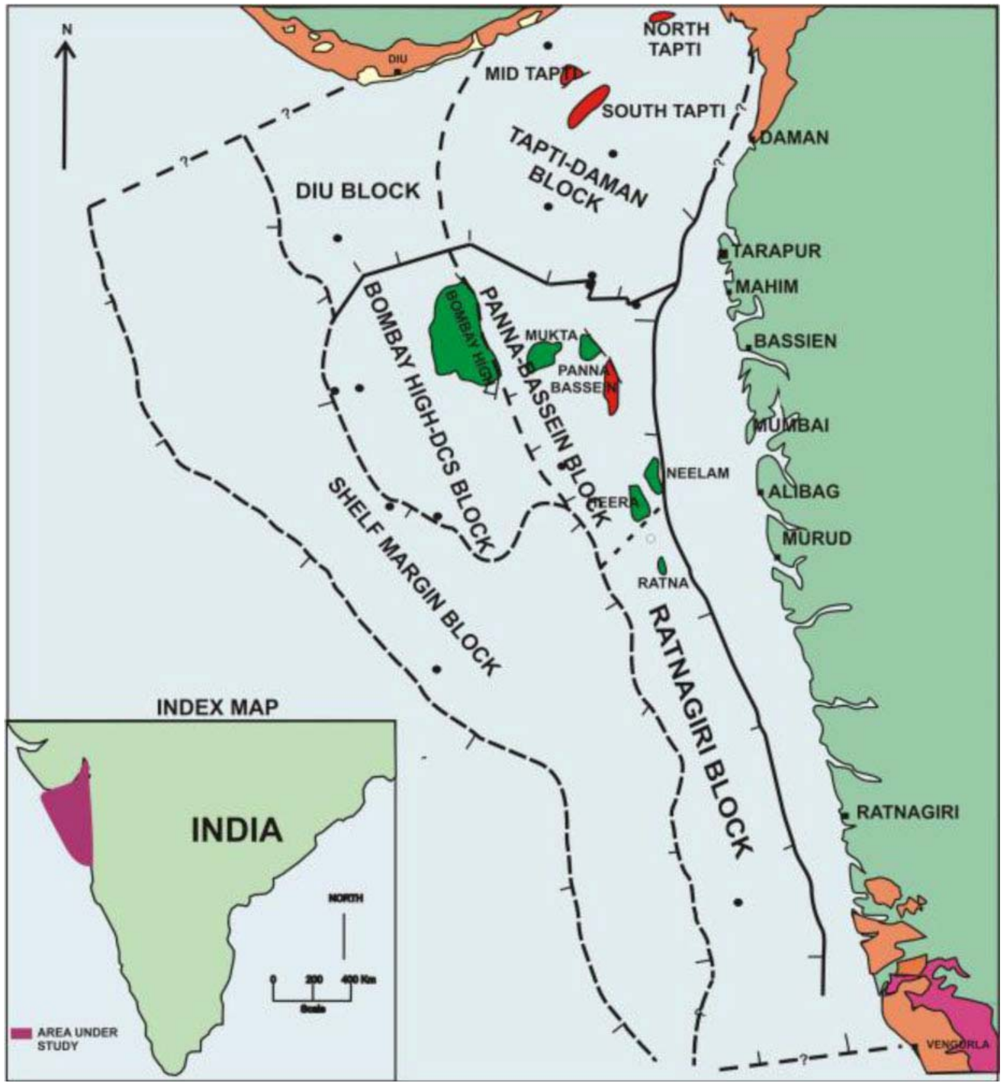


Figure 1. Tectonic map of Western Mumbai Offshore Basin (after Pandey et al., 1998).

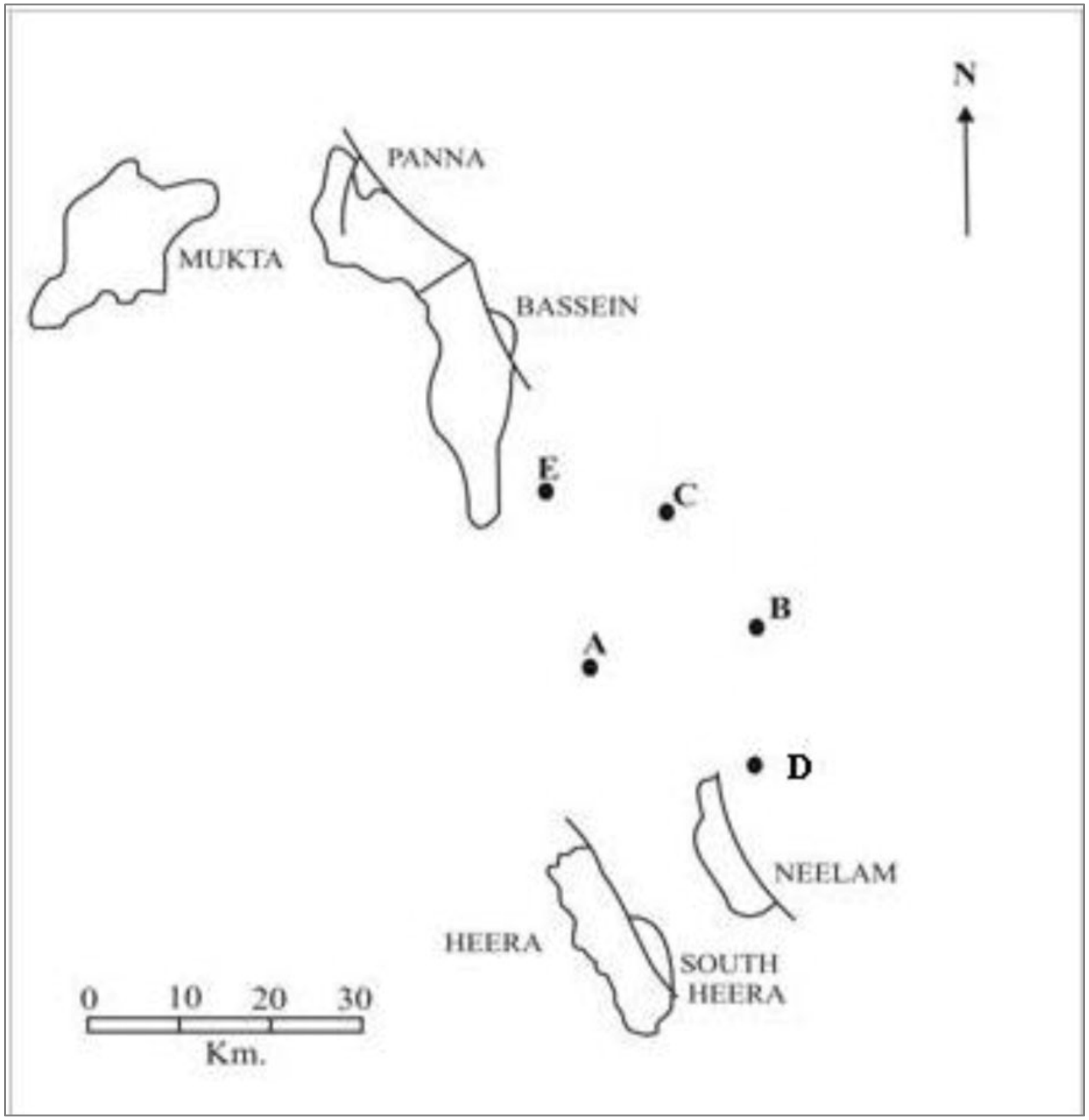


Figure 2. Location map of studied wells.

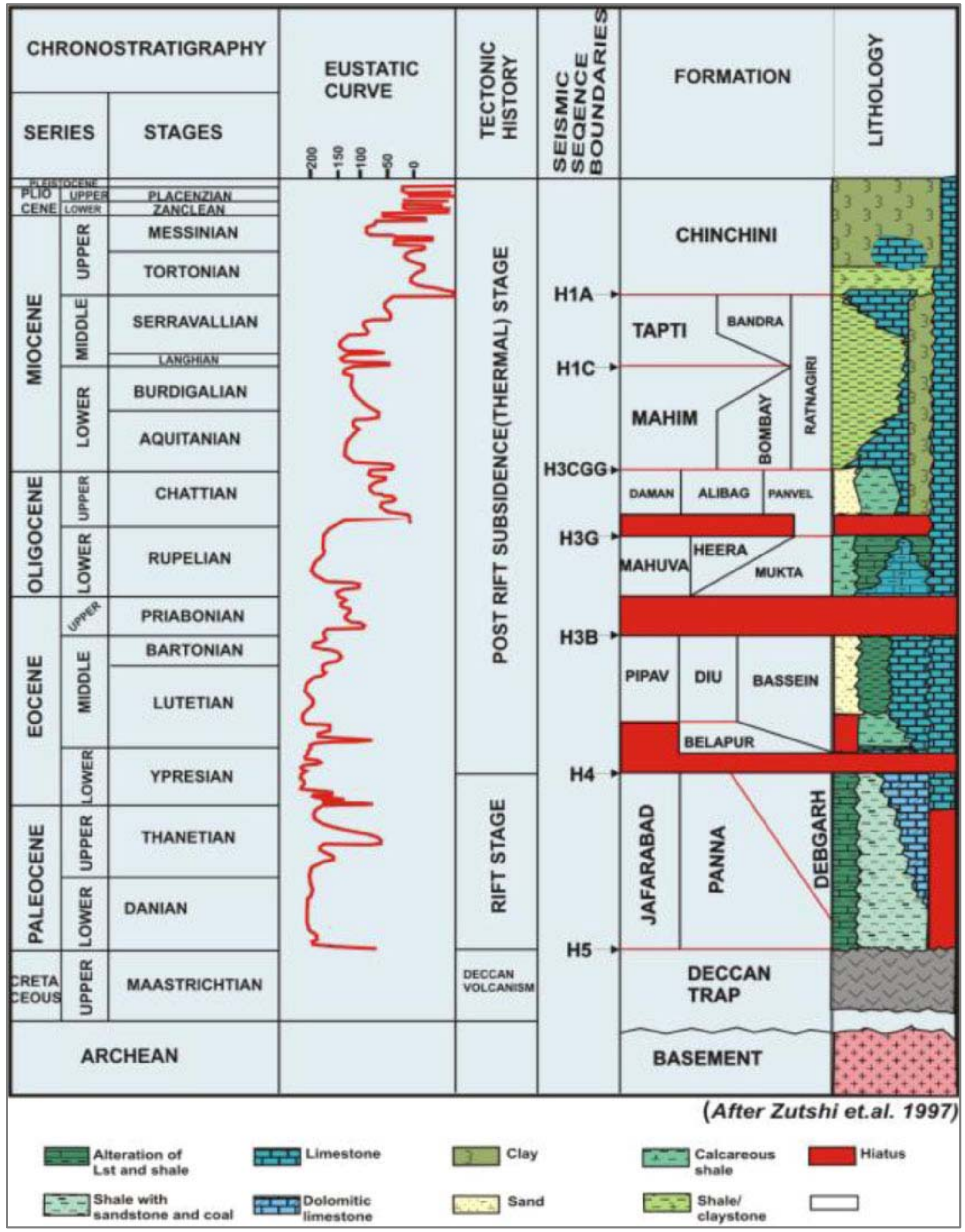


Figure 3. Stratigraphy of Mumbai Offshore Basin.

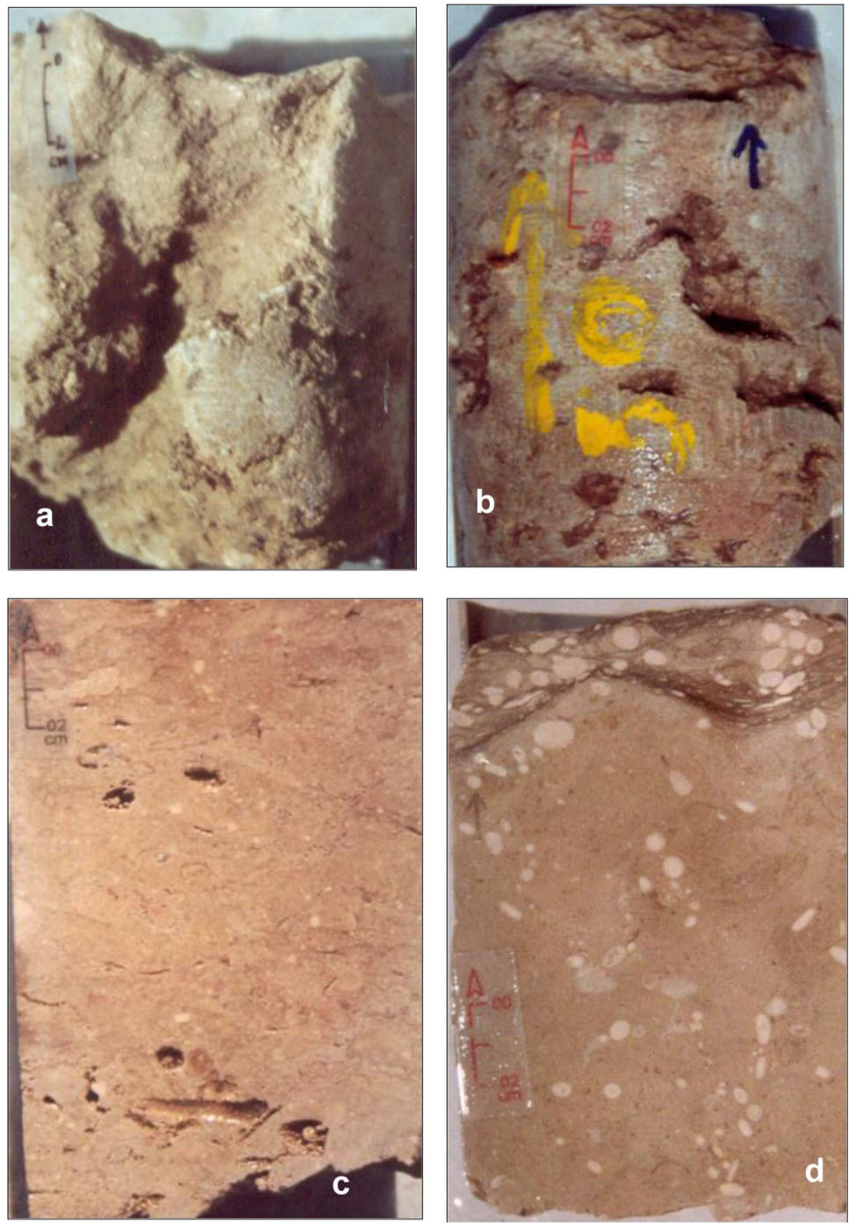

Figure 4. a) Well A, highly porous chalky wackestone facies showing karstification. b) Well B, coral-foram wacke/packstone facies, ferruginous, highly leached with generation large vugs and cavities. c) Well D, coral-foram packstone facies having good moldic and organic porosity. d) Well C, foram (larger) packstone facies with argillaceous matter at the top.

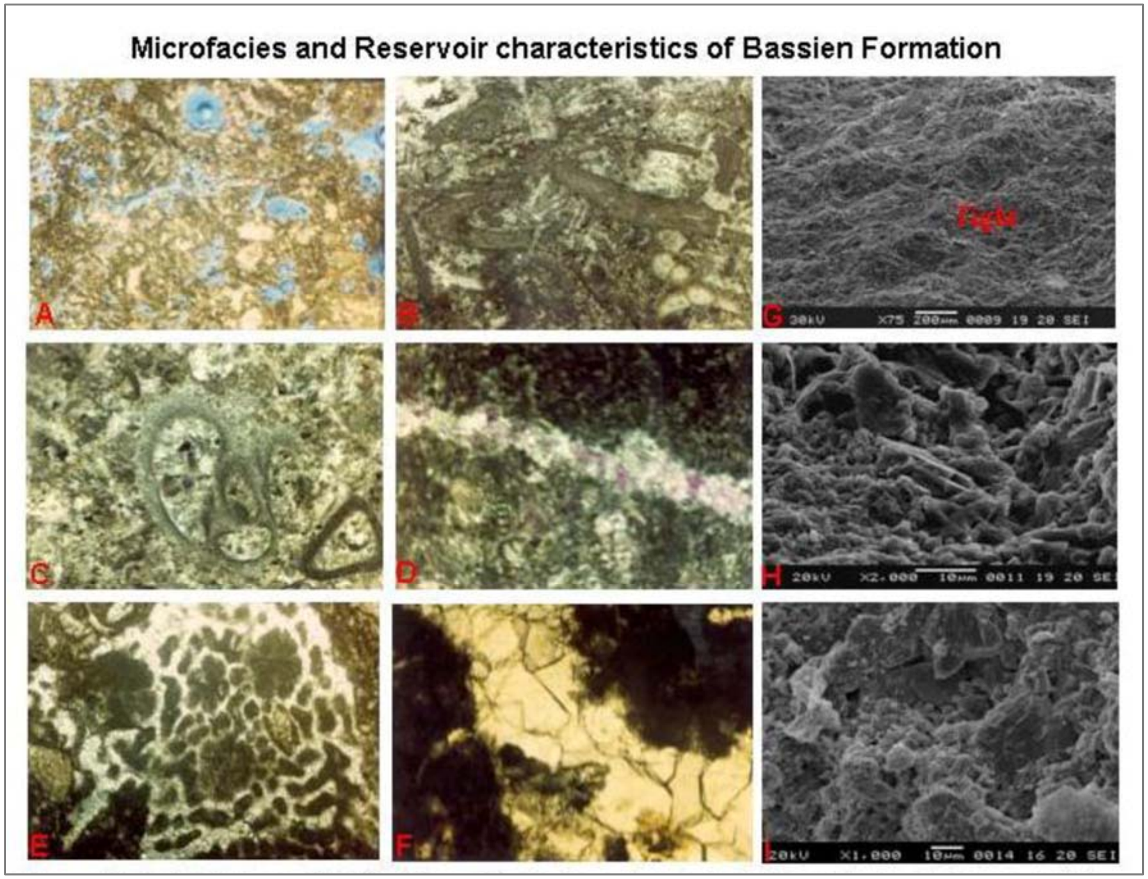


Figure 5. a) Well B, CC-3, coral-bioclastic wackestone facies with good vuggy porosity. b) Well C, CC-2, algal coral wackestone facies with sparitized grains. c) Well C, CC-1, foram wackestone facies showing sparitization with smaller spar inside the chamber. d) Well C, CC-1, argillaceous miliollitic wackstone facies, a large solution channel filled with blocky calcite spar. e) Well D, CC-1, coral-foram wackestone facies with sparitized coral chambers. f) Well E, CC-2, blocky calcite spar destroying porosity in foram packstone facies. g and h) Well C, CC-1, tight limestone with poor micritic porosity and showing small books of kaolinite. i) Well C, CC-2, enlarged view showing partial filling of vugs with calcite spar and clay coating on grain surface.

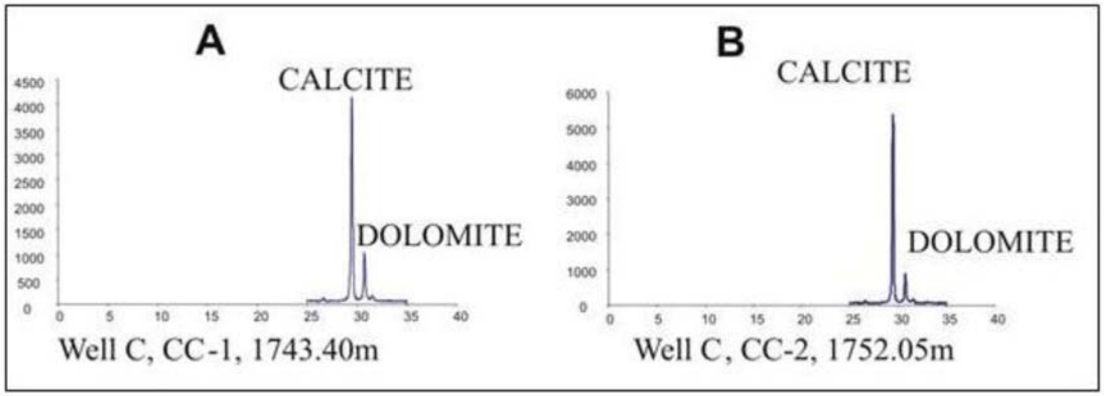


Figure 6. XRD analysis of Bassien Formation.

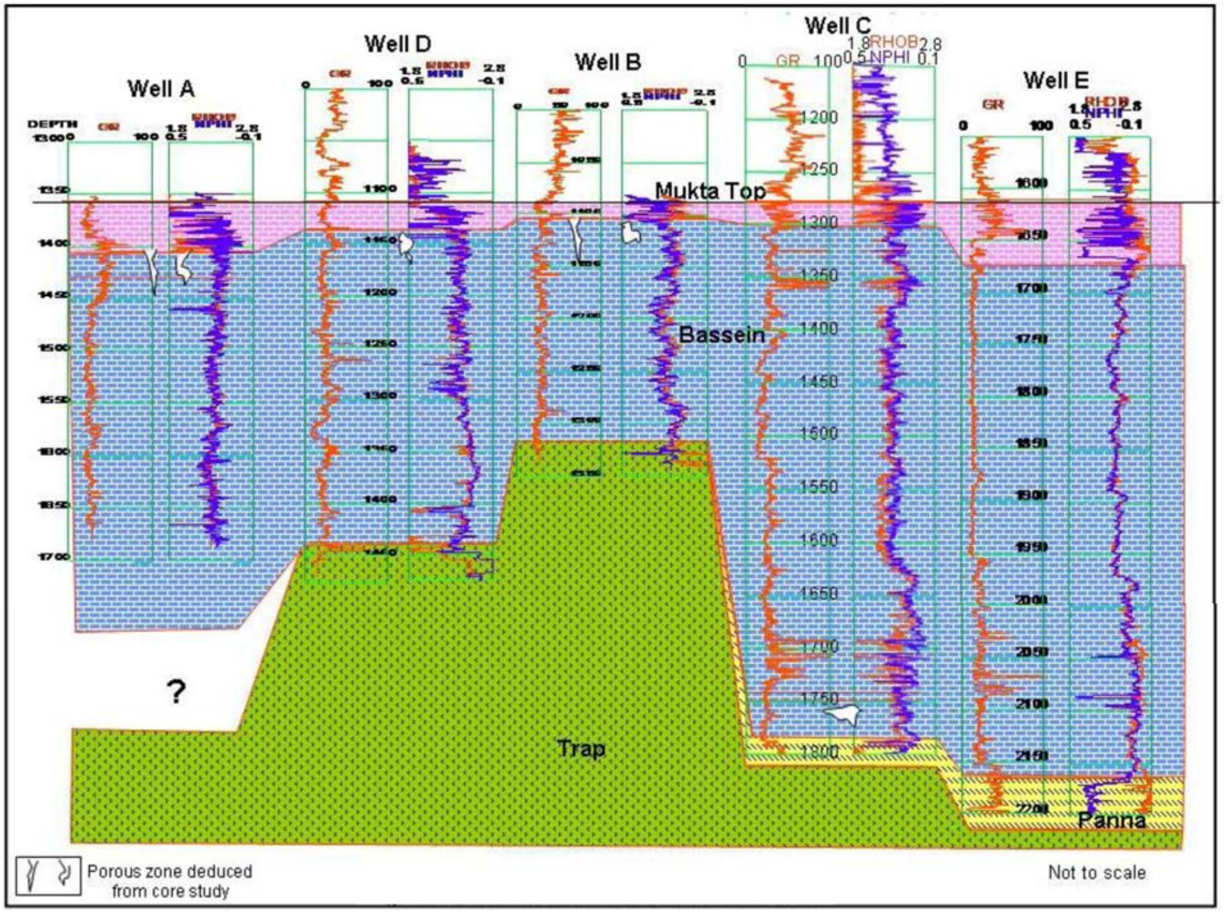


Figure 7. Electric log correlation of Bassein Formation.