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Integrated Analysis for Facies distribution and Porosity development within Middle-Late Eocene Bassein carbonates in south-western DCS platform area, Mumbai Offshore Basin

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Summary

Integrated analysis of electrologs, sedimentology and 3D seismic data has been carried out bringing out the microfacies and porosity development within Middle-Late Eocene Bassein carbonates in DCS area of Mumbai Offshore basin. Litho-facies analysis shows mainly carbonate development in the study area along with mixed carbonate-clastic litho facies in the east. Sedimentological analysis indicates foraminiferal wackestone and packstone, foraminiferal algal grainstone and dolomitic wackestone microfacies for the Bassein carbonates. SEM studies indicate poor to fair porosity development represented by solution vugs, channels and often blocked by sparitisation. Petrophysical analysis indicates good porosity development at the top of both Bassein Upper and Lower in the southern part. Seismic inversion studies indicate poor to fair reservoir facies development in the north-eastern and fair to good in central part, and good reservoir facies in the south and south western part. The wedge out plays of Bassein Lower and Upper in the north-eastern part are likely to be promising exploratory targets for pursuing hydrocarbon exploration in this area.

***Keywords**: Facies analysis, Bassein Carbonates, Porosity development, Foraminiferal Packstone, Wackestone, Trace element and isotope study, SEM Study, Petrophysical study, Seismic inversion*

Introduction

Mumbai Offshore Basin, located on the western continental margin of India, is a pericratonic rift basin and is the largest among the West Coast sedimentary basins of India (Biswas, 1987). It is the most important producer among the Cenozoic hydrocarbon basins of India, mainly from the carbonate reservoirs stretching between the Deep continental shelf (DCS) structure in west to shallow waters in the east. The basin is bounded by the Deccan trap outcrops to its north and east, Kori-Comorin ridge to its west and Vengurla arch to its south, covering an area of about 1,48,000 sq. km up to 200m isobaths.

The study area lying within Bombay High-DCS block is basically a broad extending platform (Fig.1) with a prominent low to the south. In the north, the platform is bounded by a major east-west trending fault downthrown to north, known as Diu fault. The platform is bounded by the Miocene shelf edge to the west running in NNW-SSE direction. The study area is known to have hydrocarbon accumulation in the carbonates of Oligo-Miocene sequence. However, the Middle-Late Eocene Bassein carbonates are yet to be established as a major hydrocarbon play in this area. The discovery of oil within Bassein Lower few years back, has provided impetus to the exploration of Middle-Late Eocene carbonates of Bassein Formation. The present study attempts to bring out facies distribution and porosity development of Middle-Late Eocene Bassein carbonates with an integrated analysis of electrologs, laboratory and seismic data.

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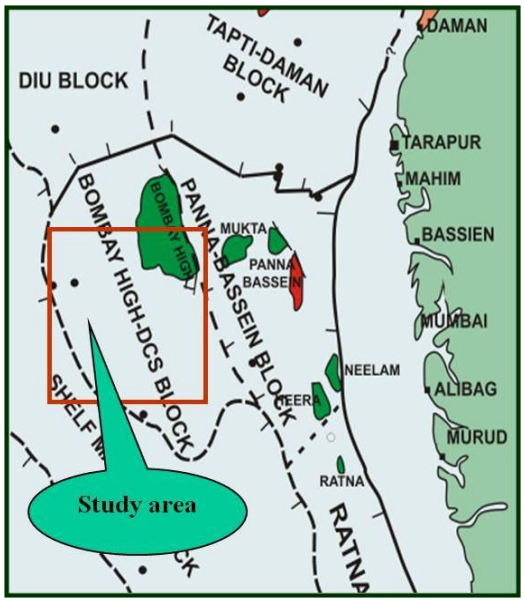

Figure 1: Location map showing study area

Methodology

Integrated analysis of well data, electrologs, sedimentology, trace element and isotope, and 3D seismic data has been carried out to bring out the microfacies and porosity development within the carbonates of Middle- Late Eocene carbonates of in this area. Electro-log correlations have been prepared to understand lithological and thickness variations. Laboratory studies including Sedimentological, Trace element, and Isotope studies havebeen incorporated to bring out the microfacies, diagenesis, and porosity development. Litho-facies analysis was carried out based on electro log and sedimentological inputs. 3D Seismic data was tied up with electro logs with the help of synthetic seismograms. Seismic inversion of 3D volume was carried out and acoustic impedance volume was generated to bring out the litho-facies variation and porosity development in the study area.

Geological Framework

Tectonically, the Mumbai basin has evolved from a rift basin, a continuation of the Cambay rift to the south with a lateral shift. The structural style in the area is dominated by extensional tectonics with faulting and horst and graben morphology. The Precambrian igneous and metamorphic rocks, in general, form the basement in the northern part of the study area. In the southern part, Deccan Trap volcanic of Late Cretaceous Age constitutes the basement rock. The basement is overlain by Panna Formation of Paleocene to Early Eocene Age. The generalized stratigraphy of Mumbai offshore Basin is given in figure 2, (Zutshi et al., 1993).

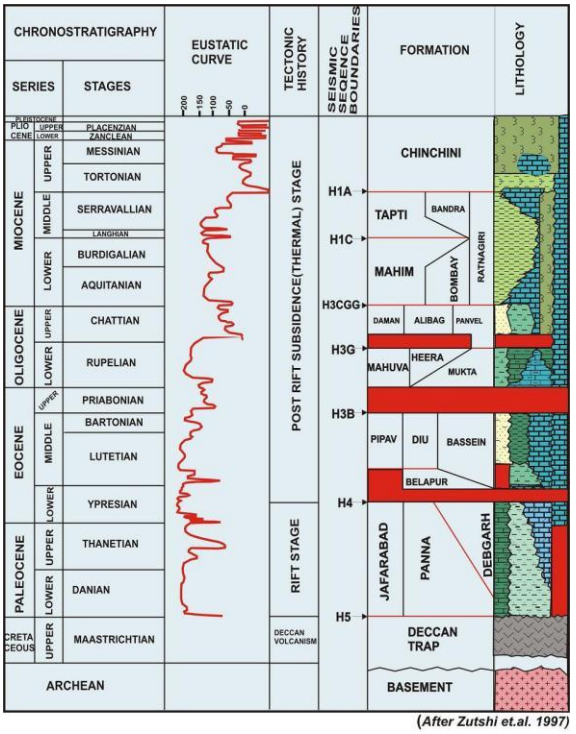

Figure 2: Generalized Stratigraphy of Mumbai Offshore basin

Two sequences are identified within the Cenozoic succession, based on the tectonic evolution. The Early Paleocene succession is dominantly fluvial, intertidal to shallow inner shelf clastic with subordinate carbonates and trap derivatives as graben fills during synrift. The upper sedimentary succession of Late Paleocene to Recent represents the post-rift succession. The Late Paleocene- Early

Eocene represents the first widespread Cenozoic marine transgression in the basin. The succeeding Middle – Late Eocene succession (Bassein Formation) has a very large areal extent over the basin, except Mumbai High platform. During this period, a large part of the basin witnessed widespread carbonate sedimentation in a shallow inner shelf setup. The upper boundary between Eocene and Oligocene is highly dichronous covering a span of 3-6 million years in Middle and Late Eocene chronospans. Wide variation in lithofacies is observed. In the northern areas of Tapti–Daman, finer clastics dominate, while in other parts of the basin, limestone and shale with minor clay are the dominant facies.

Data Analysis

Electro-log correlations along various profiles (Fig.3a & b) show a distinct thickness variation from the shelf edge set up to wedge out area in the north-central part of the study area. Stratigraphically older units gradually reduce in thickness and wedge out up-dip from west to east. Paleocene- Early Eocene sequence comprising Panna and Devgarh formations present in the west, wedge out to the east. Bassein Lower is underlain by basement with thin column of clastics in the central part, while Bassein Lower wedges out to the east.

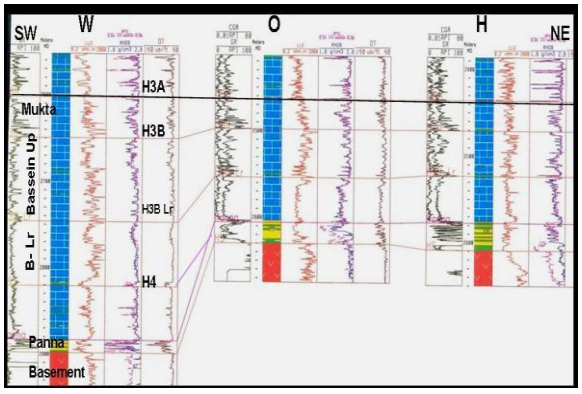

Figure 3a: Log correlation of Bassein carbonates in NE-SW profile

Further, the electro-log correlation profiles indicate fair porosity development within Bassein Lower in the west and good porosity development in the central part, while it is mostly wedged out in the east. Similarly, the log correlation indicates fair porosity development within Bassein Upper in the west and central part, while it is mostly tight in the east and to the further west it is wedged out.

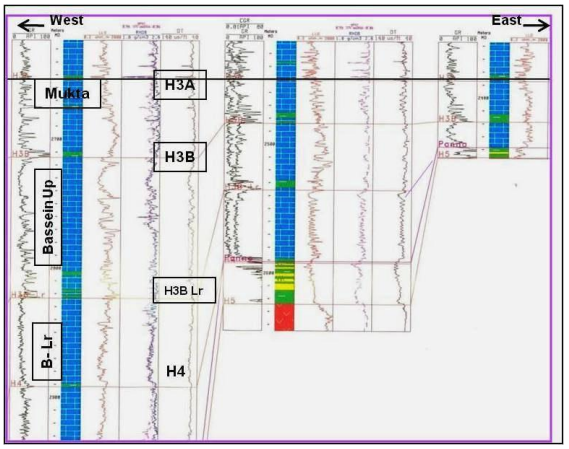

Figure 3b: Log correlation of Bassein carbonates in E-W profile

Sedimentological Microfacies analysis of Bassein Lower based on side wall core (SWC) data indicates mud dominated foraminiferal packstone showing fair porosity along fractures (Fig.4a) and foraminiferal wackestone showing poor porosity (Choudhary P.K et al, 2005). SEM studies of another SWC reveal presence of secondary porosity in form of thin channels and isolated vugs. At places selective leaching has also generated porosity in patches. In well Q, sidewall core within Bassein Lower indicates foraminiferal algal grainstone microfacies. Conventional core in Bassein Lower in one of the well W in the central part shows a dirty white to brownish grey, hard and compact limestone having microfacies algal foraminiferal wackestone. Porosity is poor and represented by isolated solution vugs and at times solution channels. SEM studies of CC reveals poor to moderate porosity in the form of solution vugs and at times channels.

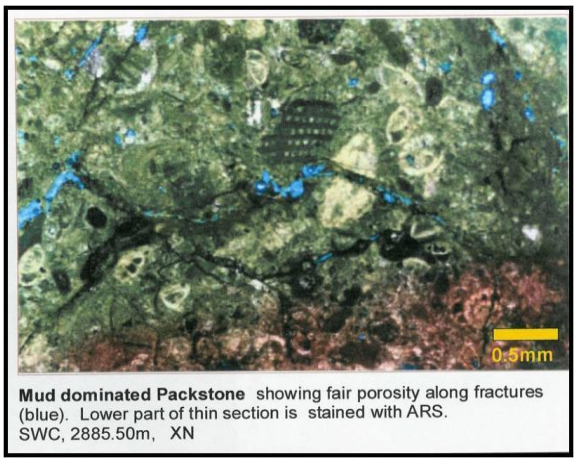

Figure 4a: Microfacies of Bassein Lower in well E

Litho-facies distribution of Bassein Lower (Fig. 4b) shows overall development of carbonates in the whole area except for the clastic- carbonate buffer zone close to the wedge out limit. The formation wedges out to the north-eastern part. Foraminiferal wackestone microfacies are developed in the west and in the eastern part, where the reservoir development is poor.

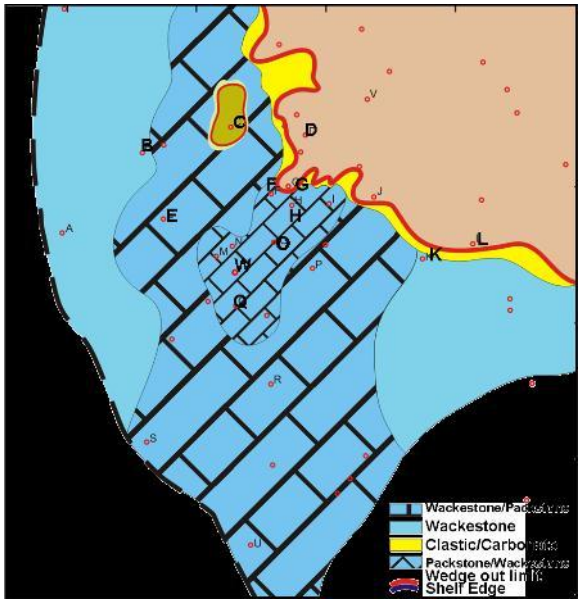

Figure 4b: Litho-facies distribution of Bassein Lower in study area

Foraminiferal packstone/ wackestone facies are developed in the central part of the study area with better reservoir facies. At places, foraminiferal grainstone microfacies is also developed. Porosity development within Bassein lower is mostly restricted to upper part. The lithofacies distribution indicates poor to fair reservoir facies development in the north-west, fair to good in the north-central, while good reservoir facies development in the central and excellent reservoir development is observed in the southern and south-western part of the study area.

Microfacies analysis *of Bassein* Upper indicates foraminiferal wackestone microfacies showing poor porosity based on side wall core of well E. SEM studies of another SWC reveal that sparitisation has blocked the porosity completely by development well developed blocky spar crystals. At few places partly open channels are seen. Minor amount of porosity is contributed by leaching activity. Petrographic studies of conventional core (CC) within Bassein Upper at well Q indicate foraminiferal wackestone and foraminiferal dolomitic wackestone microfacies. SEM studies of core indicate that sparitisation has almost completely destroyed the preexisting porosity. Remnants of porosity are seen as isolated partly open vugs and channels. Minor dolomitization is noted in the close vicinity of channels. The SWC data at well Q indicate foraminiferal packstone microfacies with poor porosity (Fig.5a). Conventional core in well W in Bassein Upper indicates buff to light brown, hard and compact limestone. Microfacies of the core comprise foraminiferal wackestone Pre-existing thin fractures filled with spar are seen at many places. SEM studies indicate porosity in general to be poor to fair, represented by solution vugs, channels and at times organic framework porosity. At places, this porosity is partially blocked by sparry calcite crystals.

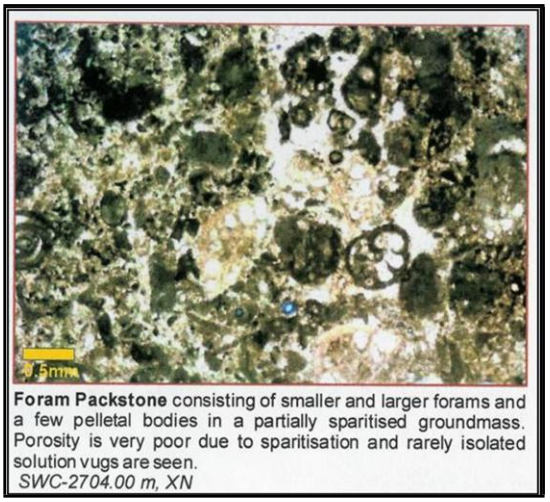

Figure 5a: Microfacies of Bassein Upper in well Q

Litho-facies distribution of Bassein Upper (Fig.5b) also shows similar overall development of carbonates in the most of the area and more clastic-carbonate facies in the eastern part. The wedge out limit of Bassein Upper is to further east and north-east compared to Bassein Lower. The eastern part of the study area shows presence of clastics mainly shale with minor siltstone close to wedge out area. Foraminiferal wackestone microfacies are developed in the west and eastern part. Foraminiferal wackestone/ packstone facies are developed in southern and south-central part. The vertical development of porosity within Bassein Upper is observed mostly in the upper part of Bassein Upper. Good reservoir facies development is observed in Bassein Upper in the central part and southern part. However, reservoir facies development reduces drastically to east and north-east and facies become tight in the drilled wells. Bassein top is represented by dark grey massive, hard and compact crystalline limestone with very poor porosity development, as observed in the conventional core of well L located to the eastern part of the study area.

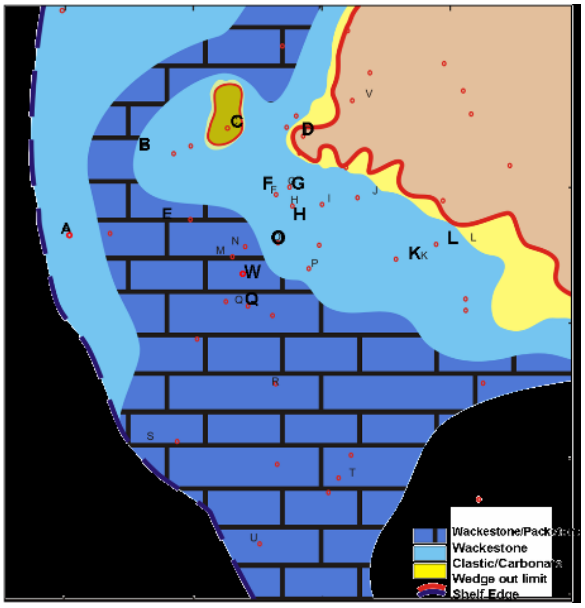

Figure 5b: Litho-facies distribution of Bassein Upper in study area.

Trace element and stable carbon and oxygen isotopic signatures (Fig.6) of Bassein Upper and Lower in well E indicates low strontium content, negative values for d13O and d13C suggesting meteoric diagenetic environment for the limestones (Sharma et al, 2008). However, the positive covariance observed between d13O and d13C suggest that these carbonates experienced a marine/meteoric water mixing zone. The isotopic data further suggest that Upper Bassein has undergone longer period of mixed marine-meteoric diagenetic environment, when compared to Lower Bassein section.

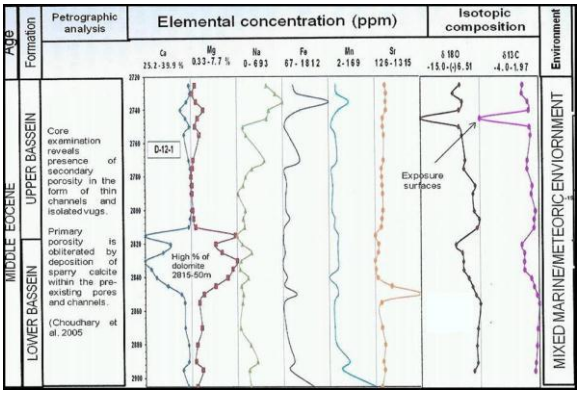

Figure 6: Trace element and isotopic study in well E

The seismic data in the 3D and 2D area was tied up with electro-logs with help of VSP data. Eight seismic reflectors H5 (Trap), H4 (Devgarh), H3B-Lr (Bassein Lower), H3B (Bassein Upper), H3A (Mukta), L-VI, L-III and L-II were correlated in the study area. Inline calibrated with well is shown in Figure 7.

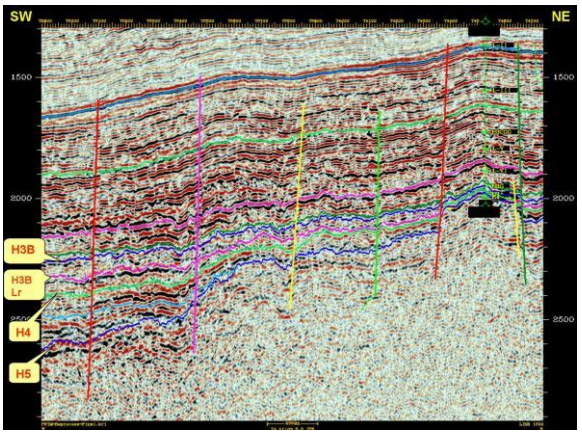

Figure 7: Inline showing main correlated reflectors in study area.

Seismic inversion of 3D volume was carried out and acoustic impedance volume was generated using Hampson-Russell software to bring out the litho-facies and porosity distribution in the area. Acoustic impedance variation along selected line passing through well O is shown in figure 8.

Crossplot of impedance and porosity generated at well E indicated a linear relation with porosity (fig. 9). Litho-facies distribution and porosity development was analysed on different horizons by extracting seismic attribute viz. RMS Impedance within the windows close to top of Bassein Lower and Bassein Upper formations.

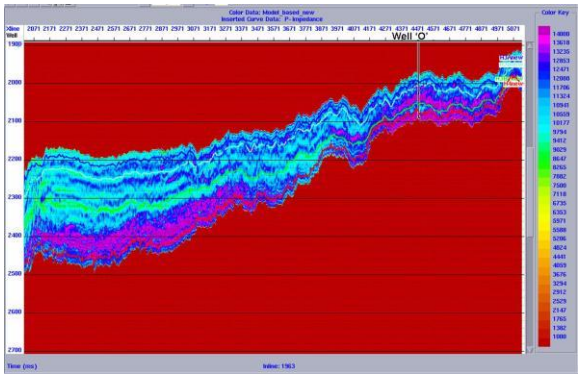

Figure 8: Acoustic Impedance variation along a selected line

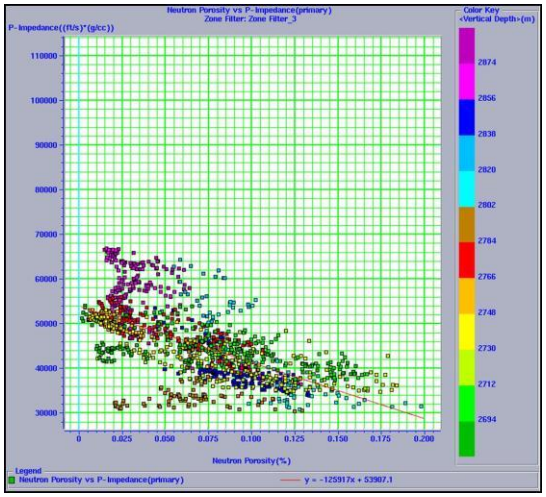

Figure 9: Crossplot of Impedance and porosity at well E

RMS average impedance near top of Bassein Lower (H3B Lr.) within a window of 10 ms below H3B Lr (Fig. 10) indicates relatively lower impedance values to the south central part and very low values in area to the south and south-western part, suggesting good reservoir facies development. This is also corroborated from the higher porosity values obtained in electro logs in well to the south-west. The area to the east and north-central part shows relatively higher impedance values indicating poor porosity development. However, the north-eastern part indicates relatively lower impedance values suggesting probable development of good reservoir facies within Bassein lower.

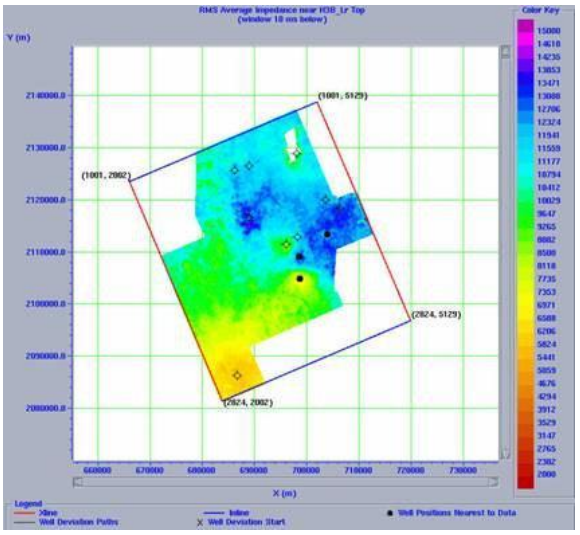

Figure 10: Acoustic Impedance slice near top of H3B Lr

RMS average impedance near top of Bassein Upper (H3B) (Fig.11) within a window of 10 ms below H3B indicates relative lower impedance values in the southern part and very low values in the south western part, suggesting good reservoir facies development. Similar to Bassein Lower, the impedance values reduce gradually to the south and south-west suggesting improvement of reservoir facies development. The north-western part shows higher impedance values with development of poor reservoir facies. The area to the north-east shows relatively lower impedance values, indicating possible development of fair to good reservoir facies within Bassein upper.

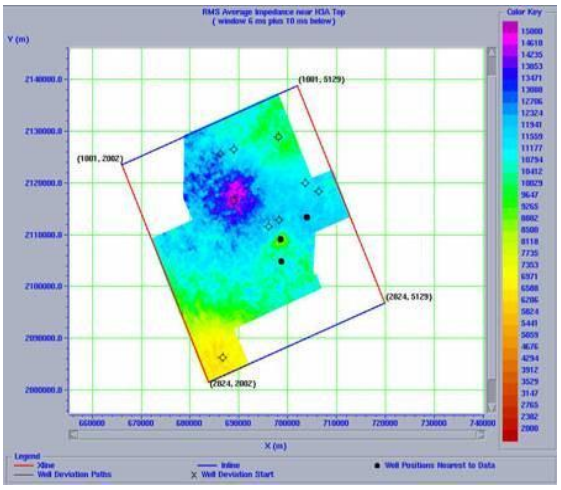

Figure 11: Acoustic Impedance slice near top of H3B Upr.

The exploration challenges in this area remain in establishing porosity pods within the Bassein carbonates. Based on the present study, it is envisaged that the wedge outs plays of Bassein Lower and Upper in the north-eastern part of the study area are likely to be promising exploratory targets for pursuing hydrocarbon exploration in this area.

Conclusions

Litho facies analysis of Bassein Formation indicates carbonate development in majority area along with carbonate-clastic mixed litho facies in the east.

Sedimentological microfacies analysis of Bassein Formation indicates foraminiferal wackestone, packstone, foraminiferal algal grainstone and dolomitic wackestone microfacies. Scanning Electron Microscope (SEM) studies indicate poor to fair porosity development represented by solution vugs, channels and often blocked by sparitisation.

Electrolog correlations along various profiles indicate progressive thinning and wedging out of older units to the east. Petrophysical analysis indicates good porosity development at the top of both Bassein Upper and Lower. Electrolog correlation and sedimentological studies indicate good porosity development in the central and southern part.

Seismic inversion studies indicate poor to fair reservoir facies development in the north-eastern and fair to good in central part, and good reservoir facies in the south and south western part.

Establishing porosity pods within Bassein carbonates remain as main exploration challenges in this area. Wedge outs of Bassein Lower and Upper in the north-eastern part are likely to be promising exploratory targets for pursuing hydrocarbon exploration in this area.

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