An Integrated Geostatistical Approach to ascertain the Porosity of Bassein Limestone in HPB Sector

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Geostatistics, Cross-plot, Density Porosity, Sonic Porosity, Neutron Porosity, Effective Porosity

Summary

More than 50 percent of the hydrocarbon reserves of the world have been proven in Carbonate rocks. Among all the reservoir parameters, Porosity is the most critical parameter and plays vital role in the assessment of carbonate reservoir. Contrary to clastic rocks where porosity mainly occurs in the inter-granular pore spaces, in carbonate rock its genesis is more complicated.

In the HPB sector of Mumbai Offshore Basin which is a part of shelfal horst graben complex, the Bassein Formation is of immense importance because many structures have proven hydrocarbon and till date the exploration is still going on.

Bassein Formation bounded by the H3B marker at the top and H4 marker at bottom, is primarily represented by wackestone and mudstone with appreciable porosity developed due to the sub-aerial exposure during the Late Eocene and also by late burial digenesis due to the movement of the corrosive fluids along the fault plane. Porosity development is mostly confined to upper unit of Upper Bassein and is mainly vuggy, dominantly connected by solution channels with isolated pin point vugs, molds and leached porosity patches.

HPB sector, mostly hydrocarbon saturated zones are situated in the upper unit of the upper Bassein and some of the localized hydrocarbon saturated zone in the lower Bassein.

This study is focused mainly on the upper unit of the upper Bassein (just below the 50 meter from the Bassein top) and Lower Bassein. Geostatistical approach has been adopted to ascertain the porosity of Bassein limestone. This approach include such tools as cross-plot, variogram, collocated co-kriging. The main purpose is to use 3D impedance volume as a secondary variable to extrapolate well data throughout the area. This analysis was done to generate the density porosity, sonic porosity, neutron porosity and effective porosity maps for both the zone and calculated the error grid for each porosity maps. The generated porosity map of each respective level reflecting the minimal error as their error grid are lying within the limit of 5to10%. So even away from the well control data, the predicted porosity is likely to be accurate. Porosity maps for both the zone show comparatively lower porosity in the western region of the HPB sector and higher porosity in the eastern region. As exploration has already been done in the eastern corridor to a great extent, this Geostatistical approach highlights some promising areas in western corridor of HPB sector

Introduction

The Heera-Panna-Bassein of Western Offshore Basin is one of the most petroliferous sectors of Mumbai Offshore Block. The area has three major producing fields: Bassein, Heera and Neelam, besides number of smaller fields. Commercial hydrocarbon has been proven from Panna, Bassein, Mukta and Heera Formations with oil and gas, whereas indications/ shows have been encountered in Basement, Alibag and Bombay Formation. However major accumulation occur within the upper unit of the Bassein Formation and dominantly structural controlled.

In this area fifty two percent of the established resources have been converted into reserves, leaving a major chunk in Yet-to-Find (YTF) category. Most of the larger structures and easy to find pays have been discovered and put on production thereby shifting the focus on discovering smaller prospects in "Near Field Exploration" that could be easily monetized using available nearby facilities.

The main aim of the study is to explore the potential of Bassein Formation especially in the area west of the Bassein East Fault and western corridor of the HPB sector where porosity decreases gradually and wells produce good amount of hydrocarbon from upper unit of the Upper Bassein and few wells produce from the Lower Bassein. 203 Exploratory wells were used for the detailed porosity mapping throughout the HPB sector.

Study Area and Prospectivity Analysis

The study area, Heera- Panna –Bassein sector is bounded by Mumbai High East fault in the west , the coastal belt in the east ,Tapti -Daman and Ratnagiri sector to the north and south respectively (Figure:1). It is situated around 100 km away from Mumbai coast with bathymetry varying from 20m to 120m.The Heera-Panna-Bassein platform situated over the western shoulder of the Central Graben where hydrocarbon bearing anticlinal structure (B-28, B-28A, B-22, B-193,B-80 and B-149) are present.

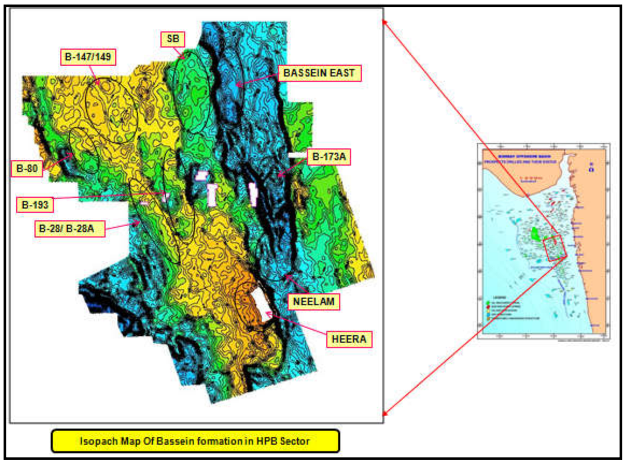

Figure 1: Location Map Of the study area

Electrolog Correlation:

Bassein Formation has been divided into three units,namely Lower Bassein, Middle Bassein and Upper Bassein (Figure 2).Two well developed markers in electro-logs were used for the study. B-Middle marker below H3B (Bassein Top) is a low porosity carbonate zone which is almost persistent in HPB Sector. B-Lower marker is taken below the prominent argillaceous carbonate developed above H4 (Panna/Devgarh Top).

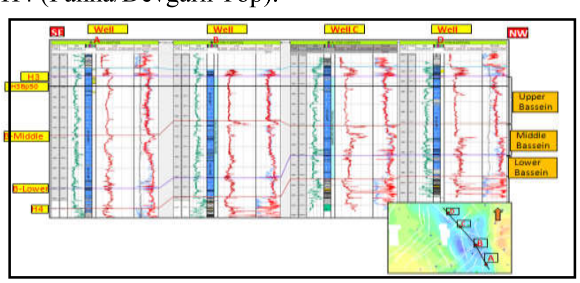

Figure 2: Type well showing the subdivision of the Bassein

Methodology for Generation of the Porosity Map

- Porosity Logs were derived from Density and Sonic Logs. Later, Porosity Logs were converted to a point data which contain the average porosity value. Extract the porosity from the genrated point data pertaining to zone of interest at each well location.
- Extract the impedance from modeled impedance volume of that particular zone through out the area
- Generate the cross-plot between porosity extracted at each well location and impedance extracted for that particular zone and analyzed the correlation coefficient
- Variogram analysis on the basis of well data
- Used collocated co-kriging method to populate the porosity throughout the HPB sector
- Calculate the error grid, if it is within the permissible limit, the output was considered otherwise iterations done to get the feasible output

Density Porosity Map

To calculate the porosity from bulk density, it is necessary to know the mineralogy of the grain framework. In case of Carbonate, the grain density of the Limestone is 2.71g/cm3 and the fluid density is 1.1g/cm3.

The equation mentioned below has been used to extract out the porosity from Bulk Density-

Porosity $Ø = (\rho ma – \rho b)/(\rho ma - \rho f)$

Where,ρma =matrix(or grain) densityρf = fluid density and ρb = bulk density (as measured by tool). The Porosity logs converted into point data, imported to HRS and a cross-plot generated between porosity (derived from Density Log) and impedance pertaining to zone of interest and a very good correlation coefficient (more than 60%) obtained for each interval of the Bassein Formation (the black point in the cross-plot represent the individual well ,Figure:3). Afterwards,Variogram was generated based upon well data (Figure:4). The collocated co-kriging method was used to populate the derived Porosity throughout the HPB sector where Variogram has been taken as first and impedance as a secondary variable. To strengthen the analysis, the error grid was generated to find the permissible limit away from the well, if data does not honour the permissible limit then revisit the Varigram model. Othrewise, the output is taken for further analysis.

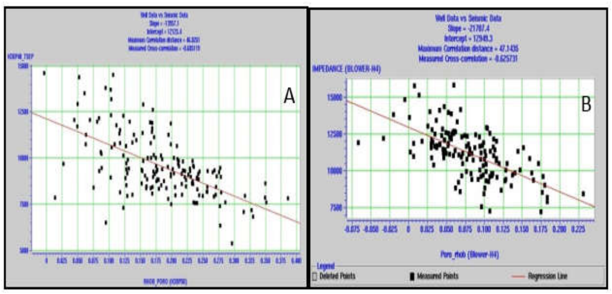

Figure 3: Cross-plot between density derived porosity and impedance: A) upper unit of upper bassein, B) Lower Bassein

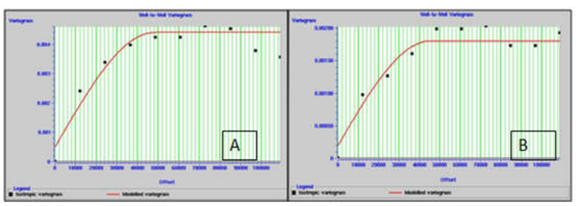

Figure 4: Variogram model generated from well data A) Upper unit of the Upper Bassein, B) Lower Bassein

Sonic Porosity maps

To derive the porosity from the sonic log following equation has been used:

$\Delta t = Ø\Delta tL + (1-Ø)\Delta tMA$ (Wyllie et al., 1956)

Ø = porosity, Δt = interval transit time ΔtL = transit time of interstitial fluid), ΔtMA = transit time of matrix material.

In case of Carbonates, the transit time for material is 47.6 and transit time for the interstitial fluid is 189 micro sec/foot. To bring out the relationship between Impedance (used as secondary variable) and Porosity, the cross-plot was made, more than 70% of the correlation coefficient was obtained for each of the interval (Figure 5). Afterwards, the collocated co-krigging method used to populate the sonic porosity with Variogram model based on the well data used as Primary (Figure 6) and Impedance as a secondary variable.

Neutron Porosity Map

The same methodology mentioned above, has been followed in other maps too. Cross-plot analysis between the Porosity extracted at each well location and Impedance shows a good correlation (correlation coefficient more than 60%) shown in Figure 7. Variogram model based on the well data has been used to populate the property throughout the HPB sector.(Figure 8*)*

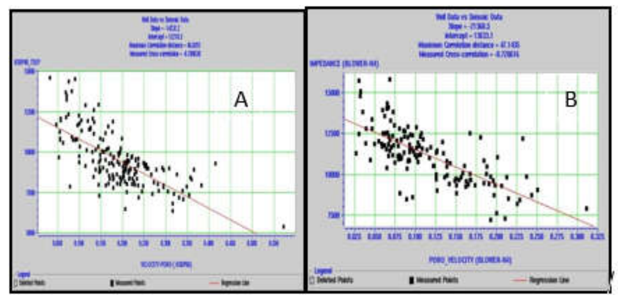

Figure 5: Cross-plot between Sonic porosity and impedance: A) upper unit of the Upper Bassein, B) Lower Bassein

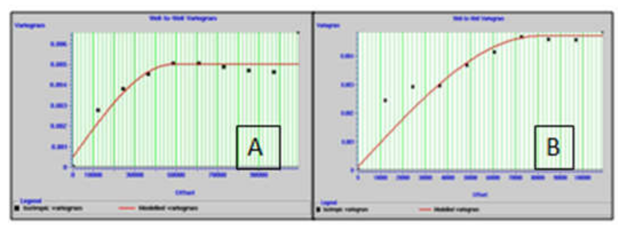

Figure 6: Variogram model generated from the well data A) Upper unit of the upper Bassein, B) Lower Bassein

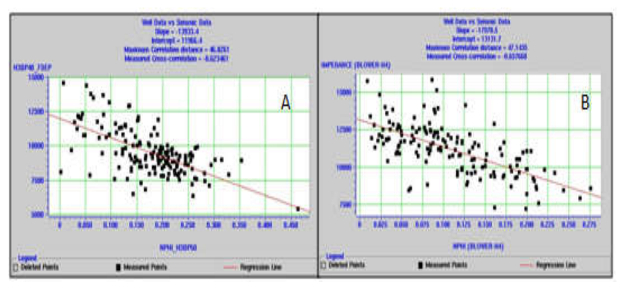

Figure 7: Cross-plot between Neutron Porosity and Impedance A) Upper unit of the upper Bassein, B) Lower Bassein

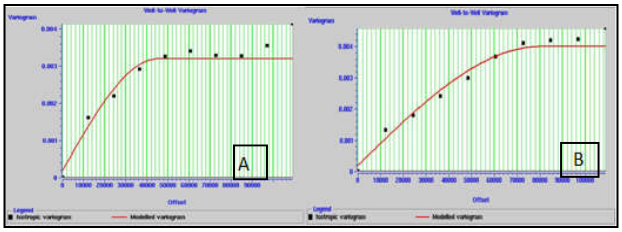

Figure 8: Variogram model generated from the well data, A) Upper unit of the upper Bassein, B) Lower Bassein

Effective Porosity Map

Same procedure has been followed to bring out the relationship between effective porosity and impedance of zone of interest, cross-plot generated and used Variogram model as primary variable (Figure:9& Figure:10.)

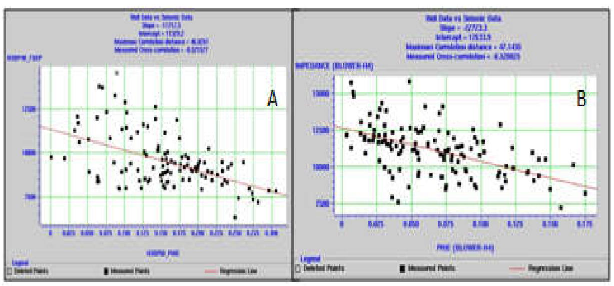

Figure 9: Cross-plot between Effective Porosity and Impedance, A) Upper unit of the upper Bassein, B) Lower Bassein

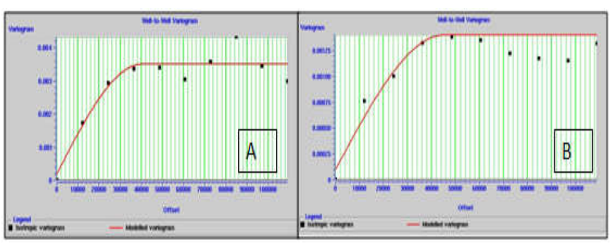

Figure 10: Variogram model generated from the well data, A – Upper part of the upper Bassein, B- Lower Bassein

An integrated porosity map Analysis of Upper Unit of the Upper Bassein Formation

Porosity mapping is an important aspect in evaluation of the Carbonates for hydrocarbon exploration. Porosity prediction in the limestone is quite difficult and tricky where no well data is available. All Porosity maps are depicting a NS and NNW-SSE high porosity trends with a porosity varying from 15 to 31%. The high porosity area encompasses all the major and marginal oil and gas fields like Bassein, South Bassein, Neelam, Heera, B-149, B-147, B-173 area. These fields have favorable structural elements as well as having good porosity, above 15%. There are some small structural closures belong to B-193, B-147, B-149, Bassein, B-22(SW of the South Bassein field) having good average porosity between 16 to 19 % and these structures are hydrocarbon bearing. Few of the isolated structures in B-28 and B-28A are hydrocarbon bearing in upper unit of the Upper Bassein and in all the Porosity maps, it is showing porosity range between 10 to 13 %. On detailed analysis of Electrologs, some high porosity intervals were identified having porosity more than 20% referred to as the Pay Zones but the average porosity is low because of the large low porosity interval. On the western side of the HPB sector, the low porosity zones observed with porosity less than 10% and most of the well drilled in this area does not show any encouraging result.

Comparison of the density porosity (Fig: 11A) with sonic porosity (Fig: 12A) is a very good tool for the fracture identification. The Density Log records the Bulk Density and it include both the intergranular and fracture porosity. Whereas Sonic Log measures only the intergranular porosity. On comparing the maps of South Bassein, Neelam, B-147, B-149 and Bassein field show slightly higher Density Porosity than Sonic Porosity indicating the presence of fracture in the upper unit of the Upper Bassein. Likewise, Neutron porosity map (Fig: 13A) showing lowering of porosity in south Bassein, while Density, Sonic and Effective Porosity show higher porosity. As this structure is mainly gas bearing so causes lowering in Neutron Porosity. Coming to Eastern side of Neelam Field, the Effective porosity map (Fig: 14A) shows the lower porosity whereas all three Porosity maps depicting higher porosity in this area. Probably the presence of Clay is a main contributor for causing lowering in Effective Porosity. Although a very good development of Overall Porosity is observed towards the Ratna Low (below Heera Field) and SW corridor of the Heera High.

To strengthen the study, the error grids generated for each porosity map showing permissible error within the study area. For the Density porosity and Sonic Porosity error grid (Fig: 11B, 12B) varies in between 3 to 4 % away from the well point, whereas Neutron porosity and Effective Porosity it (Figure 13B, 14B) shows the variation between 1 to 3%.

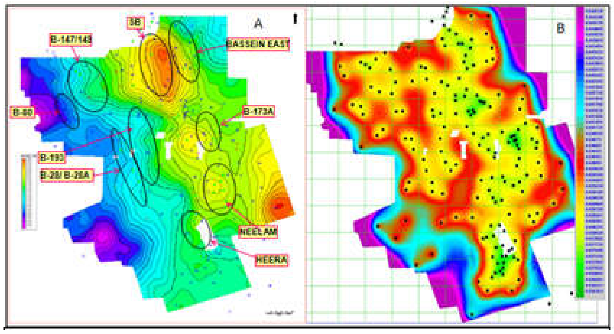

Figure:11 A) Density porosity map of the upper unit of the upper Bassein , B) Error Grid

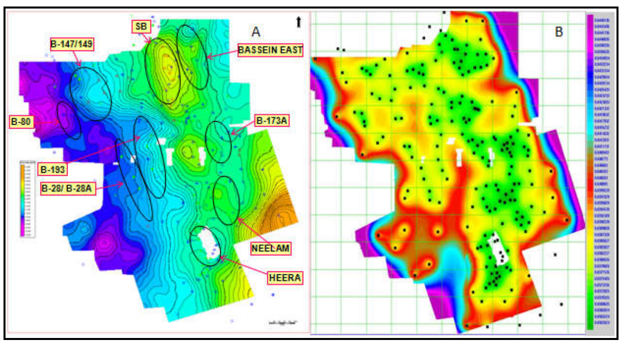

Figure 12 A) Sonic Porosity map of the upper part of the upper Bassein, B) Error Grid

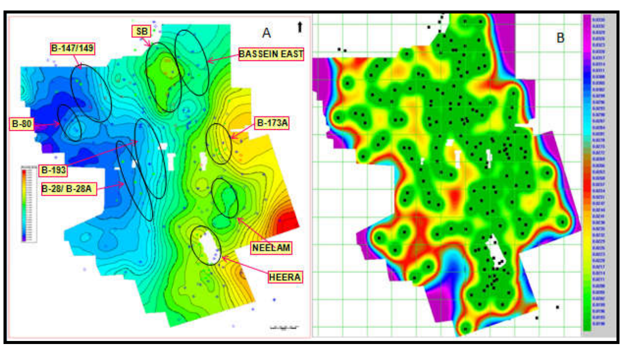

Figure 13 A) Neutron Porosity Map of the upper part of the upper Bassein, B) Lower Bassein

An Integrated porosity map Analysis of the Lower Bassein Formation:

Density porosity (Figure 15A), Sonic Porosity (Figure 16A), Neutron Porosity (Figure: 17A) and Effective porosity map (Figure: 18A) show a good development of the porosity across the South Bassein, Bassein, B-22(south west of the Bassein field) and B-147, B-149 structure whereas the western corridor of the HPB sector and B-172 area show low porosity in the range of 3-8%. For the exploration point of view the Lower Bassein is very tricky. Few of the well from B147, B-149, B-22, SB, B-180, B-38 structure produce from the Lower Bassein. The computed error grid for the Density Porosity (Figure:15B) and Sonic Porosity (Figure:16B) varies in between 1 to 2 percent whereas error grid computed for the Neutron Porosity(Figure:17B) and Effective porosity (Figure:18B) show the variation in between 1 to 3 percent.

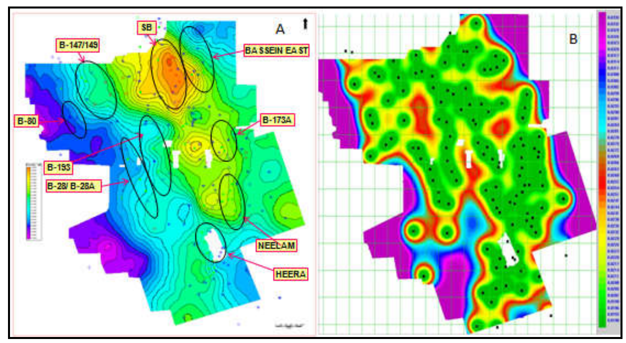

Figure:14 A) Effective porosity map of the upper unit of the upper Bassein, B) Error Grid

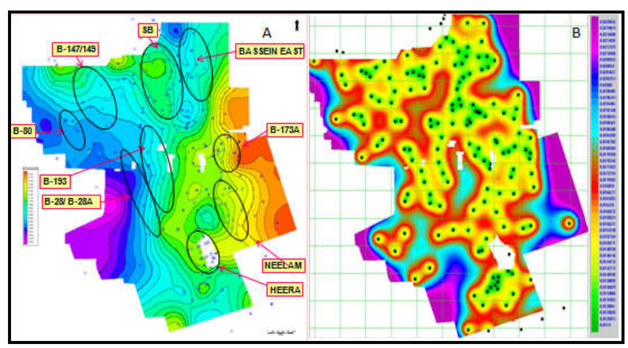

Figure 15A)Density Porosity Map of the Lower Bassein, B) Error Grid

Conclusion: An integrated study was carried out to predict the porosity of the Bassein Limestone and identification of the prospective areas where Upper unit of the Upper Bassein and Lower Bassein is the main pay of the area. Geostatistical method was used for the porosity mapping and generation of Error Grid gives better confidence for the porosity prediction away from the wells. Porosity map of the upper unit of the upper Bassein depict a NS and NNW-SSE porosity trends which are dominantly hydrocarbon bearing. Porosity map of the Lower Bassein shows a good development of the porosity in the SE part of the HPB sector and across the South Bassein, Bassein, B-147, B-149 corridor. The promising areas identified from this study are lying in the SW of Heera Field in Upper and Lower Bassein. Similarly, in South Bassein, only one well shows commercial hydrocarbon from Lower Bassein, the porosity map shows its further extension in the area which can be a part of future exploration. This work flow has helped to generate regional scale porosity maps which may be used to infer temporal distribution of porosity and identify prospective locals for exploration.

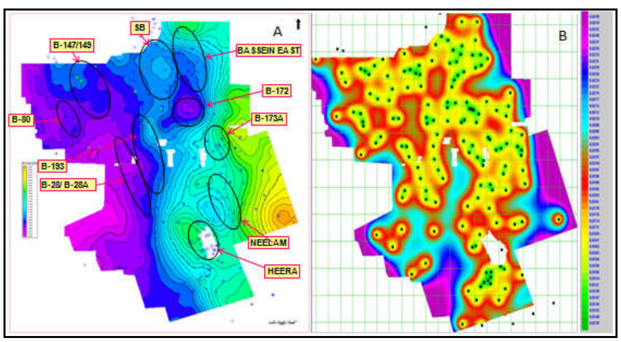

Figure 16A- Sonic Porosity Map of the Lower Bassein, B- Error Grid

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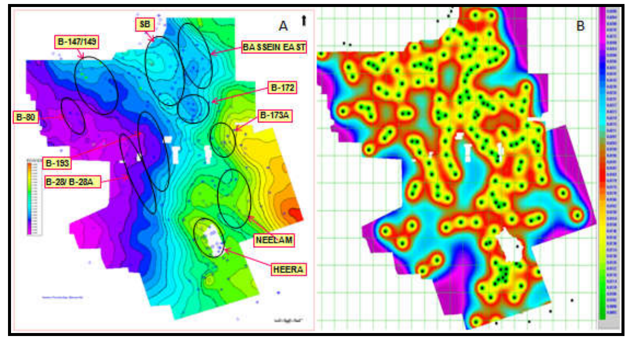

Figure 17 A- Neutron Porosity Map of the Lower Bassein B- Error Grid

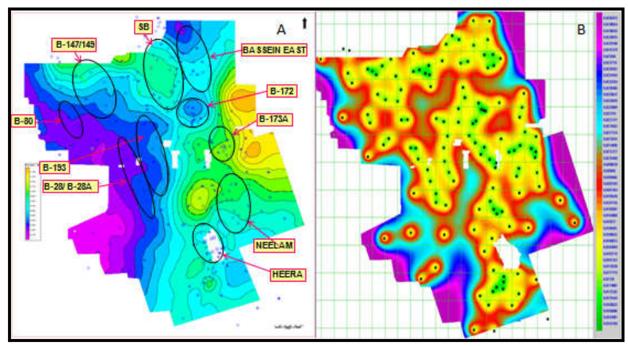

Figure 18A - Effective Porosity Map of the Lower Bassein, B) Error Grid

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