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Statistical Analysis of Core Porosity of Benin's Offshore Coastal Sedimentary Basin Reservoir Formations

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Abstract:- The reservoir formation porosity is one of the main reservoirs petrophysical properties required for fields characterization. The study aims to verify whether the core porosity of Benin's offshore petroleum block 1 reservoir formations depends significantly upon the nature of reservoir formations and to determine the porosity ranges, the average porosities and the porosity percentiles (P10, P50 and P90) of these formations. The results have shown that Benin's Petroleum block 1 reservoir formations core porosities depend significantly on the horizons and the nature of formations. Moreover, the core porosities range from 2.1 to 27.8 percent with averages between 12.31 and 18.95 percent. H9 Albian sand has the highest porosity and H8 Albian sand the lowest one. Abeokuta reservoir formations porosities are respectively 16.95 and 17.77 percent for H6 and H6.5 horizons. They have 50 and 90 percent of chance to be respectively greater than 12 and 5.84 percent no matter the formation. Abeokuta formation core porosity has high chance to be more than 17.3 percent.

Keywords:- *Statistical Analysis; Reservoir Formations; Core Porosity; Benin's Offshore; Coastal Sedimentary Basin.*

I. INTRODUCTION

Over oil and gas fields exploration and development phases, geoscientists and petroleum engineers have to characterize the potential or discovered reservoirs or fields. This help to compute the initial hydrocarbon (oil or natural gas) in place in oil (or natural gas) reservoirs and fields. Determining the reservoir formations petrophysical properties through direct and indirect methods are part of fields characterization [1]. The direct methods rely on laboratory analysis of formations cores. The reservoir formation porosity is one of the main reservoirs petrophysical properties required for fields characterization. It is defined as the ratio of the pore volume to bulk volume of reservoirs [2].

In the framework of Seme oil field exploration and development activities, cores have been collected from exploration and development wells and laboratory analysis have been performed thereon. Among these analyses, core porosities have been determined on a great number of cores.

The study aims to verify whether the core porosity of Benin's offshore petroleum block 1 reservoir formations depends significantly upon the nature of reservoir formations and to determine the porosity ranges, the average porosities and the porosity percentiles (P10, P50 and P90) of these formations.

II. MATERIAL AND METHODS

A. Material and Data Description

The materials used for this study is Microsoft Excel, Python Notebook of Anaconda software and cores data collected on some Benin's offshore petroleum block 1 reservoir formations over Seme oil filed exploration and development operations. MS Excel has been used to gather core porosities from core laboratory analysis reports and Python notebook has served for reservoir formations porosity ranges, average values and percentiles computation with python programming.

Core porosities of eight Seme oil field wells (S2, S4, S5, S9, S11, SC1, SC2 and SC3) has been gathered from well conventional core analysis study reports of the reports of [3] to build the dataset. This dataset is composed of porosities of a total of 758 cores from three formations (Abeokuta, Agwu and Albian sand) and six horizons (H5, H6, H6.5, H7, H8 and H9). Table 1 shows the number of samples for horizons and formations.

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Table 1 Number of Samples for Horizons and Formations

Horizon	Formation	Number of samples
H5	Agwu	3
H6	Abeokuta	410
H6.5	Abeokuta	68
H7	Abeokuta	13
	Albian Sand	39
H8	Albian Sand	223
H9	Albian Sand	2
Total		758

B. Methods

➢ *Four main Tasks have been Performed in this Study:*

- Data manipulation.
- Verification of Benin's offshore petroleum block 1 reservoir formations core porosity dependency upon the nature of formations.
- Determination of formations porosity ranges and averages.
- Determination of formations porosity percentiles (P10, P50 and P90).

➢ *The Methodology Adopted for that Purpose is Presented as follows.*

- *Data Manipulation*

It has consisted of (i) cleaning the dataset and (ii) creating new formations terminology on the basis of the horizons and formations of the dataset.

Data cleaning task has been carried out by identifying the porosity dataset odd values and outliers and replacing them by appropriate values with the technique proposed [4]-[5].

- *Verification of Benin's offshore petroleum block 1 reservoir formations core porosity dependency upon the nature of formations*

The significant dependency of Benin's offshore petroleum block 1 reservoir formations core porosity upon the nature of formations is checked through a statistical test for dependency called one-way analysis of variance (ANOVA) test. It is a statistical method developed by the statistician and eugenicist Ronald Fisher in order to examine how the averages of multiple samples differ from one another [6]. One can refer to [7]'s work to get the details on one-way ANOVA test. The main aspects to highlight here are the test hypotheses for the verification of formations porosity dependency and how to conclude from the test results.

The null hypothesis (Ho) is "the formation porosity does not depend on the nature of formations" and the alternative (H1) is that "formations porosity depends on the nature of formations".

➢ *The Rules of Thumb for Concluding is as follows.*

If the test p-value is less that the preset confidence level then the null hypothesis is rejected and its alternative is accepted ([4] and [8]), that is, formations porosity depends on the nature of formations.

- *Determination of Formations Porosity Ranges and Averages*

Porosity ranges and averages have been determined for different formations on the basis of new formations terminology. The ranges are the sets of porosity values laying between samples minimum and maximum porosities while the averages are the mathematical expectancies of the porosity samples [7].

- *Determination of Formations Porosity Percentiles (P10, P50 and P90)*

Benin's offshore petroleum block 1 reservoir formation core porosity percentiles are the values of porosity that have a given probability of being less than the porosity of any other cores that will be collected from the formations. Indeed, P10, P50 and P90 of reservoir formation core porosity have respectively 10, 50 and 100 percent of chance to be smaller than any other core porosity.

➢ *Reservoir Formations core Porosity P10, P50 and P90 have been Determined as Follows.*

- For formations with large-size core porosity samples, the porosities P10, P50 and P90 have been determined using Monte Carlo Simulation, by generating randomly a large number of porosities from sample porosity random variable and determining 10^{th}, 50^{th} and 90^{th} percentiles of the generated samples as stipulated by [6] and [9]. The porosity random variable probability distribution is determined through the central limit theorem as proposed by [10] for sample with size more than or close to 30. P10, P50 and P90 are respectively 90th, 50th and 10th percentiles of the generated samples [10].
- Porosities P10, P50 and P90 have been determined by generating large-size porosity boostrap samples from the initial samples and computing determining 10^{th}, 50^{th} and 90^{th} percentiles of the generated samples, for the formations with core porosity sample size less than 30.

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Bootstrapping is a computer-based technique that can be used to infer the sampling distribution of almost any statistics via repeated samples drawn from the sample itself, as opposed to the hypothetical resampling from the population [11]. A boostrap sample $X^* = (x^*_1, x^*_2, \dots, x^*_n)$ is obtained by randomly sampling n times, with replacement, from the original sample X [12].

III. RESULTS AND DISCUSSION

A. Data Manipulation

The formations from the horizons and formations are Agwu_H5, Abeokuta_H6, Abeokuta_H6.5, Abeokuta_H7, AlbianSand_H7, AlbianSand_H8 and AlbianSand_H9. [Fig 1] shows the sizes of the new formations samples. One can see that it ranges from 2 to 410 with three samples having sizes less than 30.

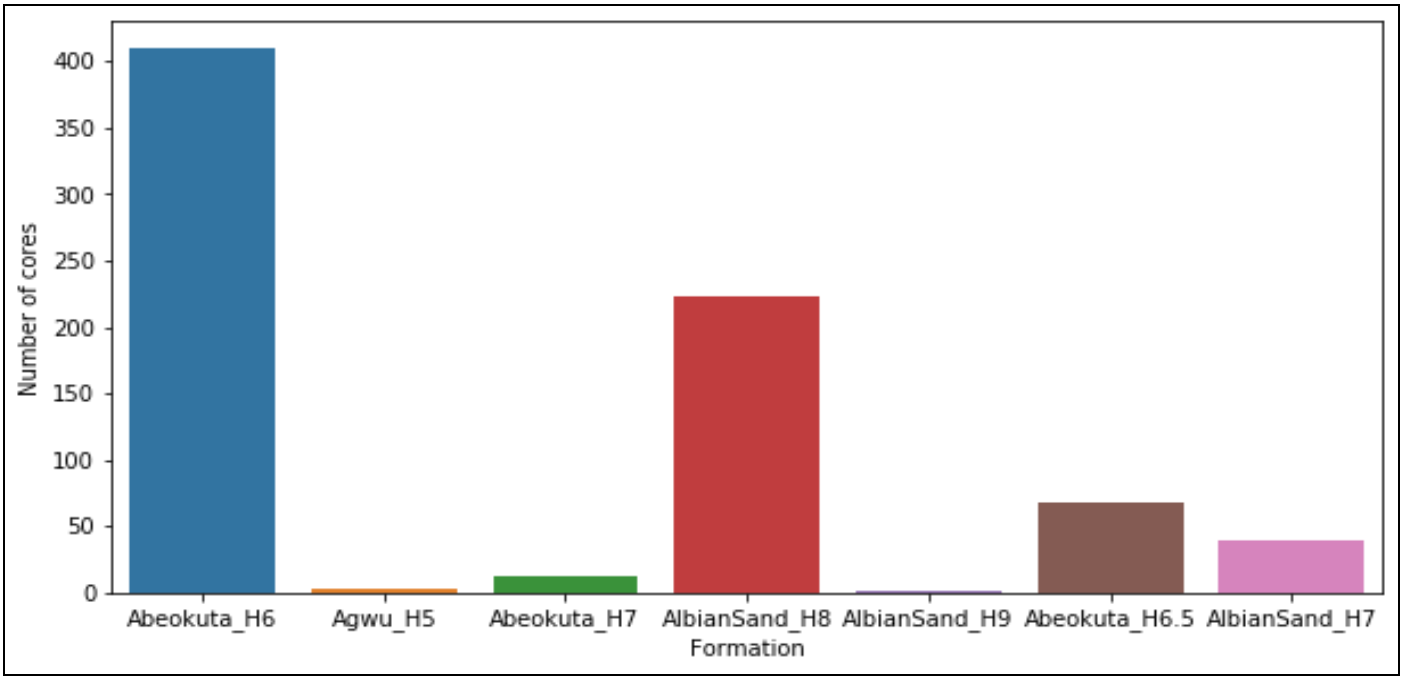

Fig 1 New Formations Samples Sizes

B. Verification of Benin's Offshore Petroleum Block 1 Reservoir Formations Core Porosity Dependency upon the Nature of Formations

The one-way ANOVA test performed on new formations porosity dataset show a p-value of $7.69*10^{-31}$, that is largely less than the confidence level of 5 percent. As a result, Benin's Petroleum block 1 reservoir formations core porosities depend significantly on the horizons and the nature of the formation.

C. Determination of Formations Porosity Ranges and averages

Table 2 summarizes the ranges and averages of formation core porosities determined on the basis of the methodology used. On can notice that the core porosities range from 2.1 to 27.8 percent with averages between 12.31 and 18.95 percent. H9 Albian sand has the highest porosity and H8 Albian sand the lowest one. Abeokuta reservoir formations porosities are respectively 16.95 and 17.77 percent for H6 and H6.5 horizons.

Table 2 Benin's Offshore Petroleum Block 1 Reservoir Formations Core Porosity Ranges and Averages

Formation	Min POR (%)	Max POR (%)	Mean POR (%)
Agwu_H5	14.1	15.9	15.23
Abeokuta_H6	2.1	27.4	16.95
Abeokuta_H6.5	8.9	25.5	17.77
Abeokuta_H7	11.4	27.8	18.93
AlbianSand_H7	3.1	23.6	13.55
AlbianSand_H8	3.0	27.3	12.31
AlbianSand_H9	12.2	25.7	18.95

D. Determination of Formations Porosity Percentiles (P10, P50 and P90)

Formations core porosities P10, P50 and P90 gotten are shown in Table 3. It reveals that core porosities have 50 and 90 percent of chance to be respectively greater than 12 and 5.84 percent no matter the formation. Abeokuta formation core porosity has high chance to be more than 17.3 percent.

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Table 3 Benin's Offshore Petroleum Block 1 Reservoir Formations Core Porosity P10, P50 and P90

Formation	POR P10 (%)	POR P50 (%)	POR P90 (%)
Agwu_H5	15.86	15.70	14.42
Abeokuta_H6	22.20	17.30	10.19
Abeokuta_H6.5	23.59	18.10	11.50
Abeokuta_H7	25.28	19.60	11.44
AlbianSand_H7	20.54	13.30	6.44
AlbianSand_H8	18.88	12.00	5.84
AlbianSand_H9	24.35	18.95	13.55

IV. CONCLUSION

The methodology adopted in the studies has helped to achieve the objectives of the studies. The results have shown that Benin's Petroleum block 1 reservoir formations core porosities depend significantly on the horizons and the nature of formations. Moreover, the core porosities range from 2.1 to 27.8 percent with averages formation between 12.31 and 18.95 percent. H9 Albian sand has the highest porosity and H8 Albian sand the lowest one. Abeokuta reservoir formations porosities are respectively 16.95 and 17.77 percent for H6 and H6.5 horizons. They have 50 and 90 percent of chance to be respectively greater than 12 and 5.84 percent no matter the formation. Abeokuta formation core porosity has high chance to be more than 17.3 percent.

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