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# FILTER BASED SIMULATION: APPLICATION IN RESERVOIR CHARACTERIZATION HATCH FIELD NIGER DELTA

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**Abstract**

Many models in the Niger Delta are built without recourse to model validation. It is based on these shortcomings that the Filter Based Simulation (FILTERSIM) technique was applied in Hatch Field, Niger Delta. The method was chosen based on its ability to reduce disorderliness in realizations and the ability to honour training image statistics. Training images obtained from simulation of porosity and permeability with grid dimension of 204x120x5 using Sequential Gaussian Simulation of the field together with evaluated petrophysical properties from well logs were used in the study. A simulation grid of 204x120x5 was built. The evaluated porosity and permeability were upscaled and property distributed using FILTERSIM algorithm. Modeled porosity and permeability in the field ranges from 0.1844-0.4 and 189.6-7467mD which are good prospects for hydrocarbon accumulation. The model results show closeness in training image and model realization statistics. The Mean Absolute Percentage Error (MAPE) shows that the model error for mean and variance is 3.24% and 2.94% for porosity and 2.32% and 1.92% for permeability. The implication of this statement is that 96.76% and 97.06% of porosity and 97.68% and 98.08% of permeability can be explained by the model. The correlation coefficient ($R^2$) of the model realization for porosity ranges from 96.22-99.48, while that for permeability ranges from 93.87-99.97. The model will assist management in making a firm decision in developing the field.

***Keywords***: *Training image; Disorderliness; Property; Filter based simulation; Simulation grid.*

## 1. Introduction

Reservoir modeling aims at showing spatial heterogeneity and distribution of reservoir facies architecture and calculated petrophysical properties across a selected field. These petrophysical properties can be porosity and permeability and data such as core analysis report; well log data, seismic data could be combined to build a robust reservoir, static model. Offshore Niger delta is characterized by a series of complexities in the deposition of sediments as a result of distortions associated with the depositional cycles in the depobelt. Due to this complexities the delta is highly heterogeneous in such that two point statistics, variogram based techniques alone cannot adequately describe the complexities associated with this depobelt. It is based on this shortcoming that the researcher applied the Filter based Simulation (FILTERSIM), a multiple point geostatistics (MPG) approach in characterizing petrophysical property of porosity and permeability in the field.

In order to produce curvilinear structures with data conditioning with hard and soft data that the MPG approach was proposed [1]. The MPG approach initially proposed by [2-3] combines the strength of variogram based algorithms [4]. Basically, the Gaussian simulation is used to predict petrophysical properties. The major setback of the Gaussian simulation is that it reproduces the "maximum degree of disorderliness of patterns" or "maximum randomness structures" [5].

### 1.1 Geologic setting and stratigraphy

The Hatch Field is an oil field located in Offshore Depo belt Niger delta Fig. 1. The Niger Delta is divided into three formations, representing prograding depositional facies that are distinguished by most authors on the basis of sand-shale ratios. The type sections of these formations are described in [6], and the summary is given in numerous papers [7-9]. The stratigraphic units are the Benin Formation that is recent in geological age, the Agbada Formation was deposited in the Eocene, and the underlying Akata Formation was deposited in the Paleocene.

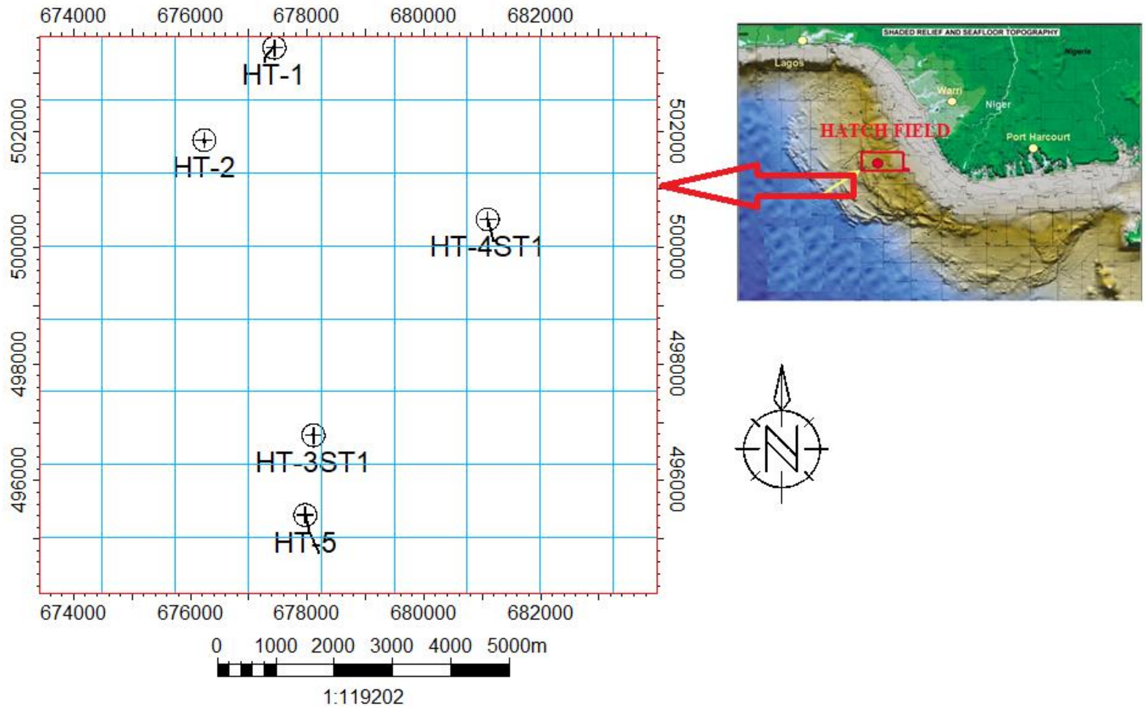


Fig. 1. Hatch Field oil field located in Offshore Depo belt Niger delta

## 2. Methodology

The FILTERSIM algorithm was applied to porosity and permeability data derived from the Hatch field Niger Delta. Training images obtained through Sequential Gaussian simulation of reservoir property of porosity and permeability. A template of 11*11*7 and an Inner patch of 7*7*3 was used to scan the training image from which patterns were obtained and stored in the pattern database from which similar pattern from the data was selected and pasted on the simulation grid with 204x120x5 until all the nodes in the simulation grid are populated. The mean absolute percentage error (MAPE) and correlation coefficient formular were applied to check for the accuracy of our model equations 1 and 2 [10].

$$MAPE = \frac{100}{n}\sum_t^n \left|\frac{A_t - M_t}{A_t}\right| \quad (1)$$

$$R^2 = 1 - {Var_{err}}/{Var_{act}} \quad (2)$$

where: A=actual value from training image; M=model realization value; n=number of realization; t=time; $Var_{err}$=difference in variance between TI variance and model; $Var_{act}$=actual variance of the training image.

## 3. Results

The simulation of porosity training image Fig. 2 and permeability training image Fig. 4 with data revealed variations of the reservoir properties of porosity Fig 3a-e and permeability Fig.5a-e across Hatch Field Niger Delta. The validation of our interpretation was carried out by comparing the mean and variance of our training image with that of our model realization for closeness (Table 1). The mean absolute percentage error was calculated and presented (Table 2). The correlation coefficient between training image variance and model variance revealed a very good correlation for both porosity and permeability (Table 3).

Table 1. Comparison of training image and FILTERSIM model realization statistics

| Training Image | | Reali- | Model Porosity | | Training Image | | Reali- | Model Permeability | |
|---|---|---|---|---|---|---|---|---|---|
| Mean | Variance | zation | Mean | Variance | Mean | Variance | zation | Mean | Variance |
| 0.297108 | 0.00258215 | 0 | 0.307324 | 0.00267987 | 2476.2 | 2757090 | 0 | 2468.47 | 2703910 |
| | | 1 | 0.307382 | 0.00266582 | | | 1 | 2518.11 | 2787260 |
| | | 2 | 0.308636 | 0.00259553 | | | 2 | 2516.9 | 2745500 |
| | | 3 | 0.307104 | 0.00272871 | | | 3 | 2611.66 | 2926010 |
| | | 4 | 0.303174 | 0.00262209 | | | 4 | 2537.11 | 2756150 |

Table 2. Mean absolute percentage error and mean square error for porosity and permeability model

| Model accuracy | Porosity model | | Permeability model | |
|---|---|---|---|---|
| method | Mean | Variance | Mean | Variance |
| MAPE | 3.24% | 2.94% | 2.32% | 1.92% |

Table 3. Correlation coefficient for porosity and permeability realization

| Model accuracy method | Realization 000 | Realization 001 | Realization 002 | Realization 003 | Realization 004 |
|---|---|---|---|---|---|
| $R^2$(porosity) | 96.22 | 96.80 | 99.48 | 99.32 | 98.45 |
| $R^2$(permeability) | 98.07 | 98.91 | 99.58 | 93.87 | 99.97 |

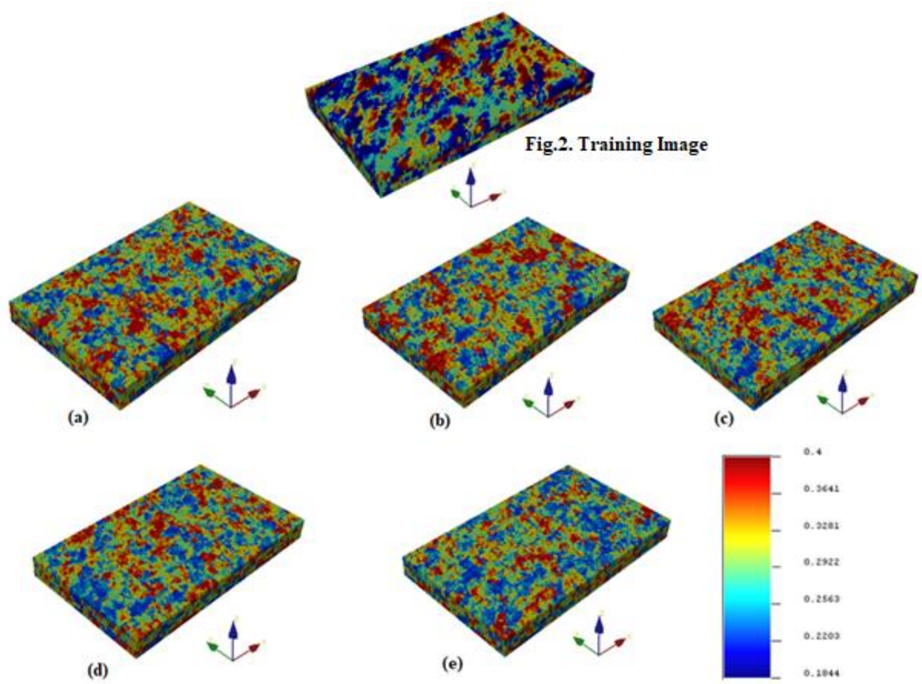


Fig. 3 a-e. Filtersim realization of porosity in hatch field Niger Delta

## 4. Discussions

The results from the analysis show porosity and permeability variability in the field Fig.3a-e and Fig.5a-e Areas of high porosity and permeability are targets for the development of the hydrocarbon field. The results show closeness in the mean and variance of the training image and realized model (table 1). The validation of our model using mean absolute percentage error shows that the model error for mean and variance for porosity is 3.24% and 2.94% while that of the permeability is 2.32% and 1.92%. The implication of this statement is that 96.76% and 97.06% of porosity and 97.68% and 98.08% of permeability can be explained by the model and vice versa. The correlation coefficient of our model realization for porosity ranges from 96.22-99.48 wile that for permeability range from 93.87-99.97. The training image and model correlation coefficient shows very good correlation and confidence for porosity and permeability model realization.

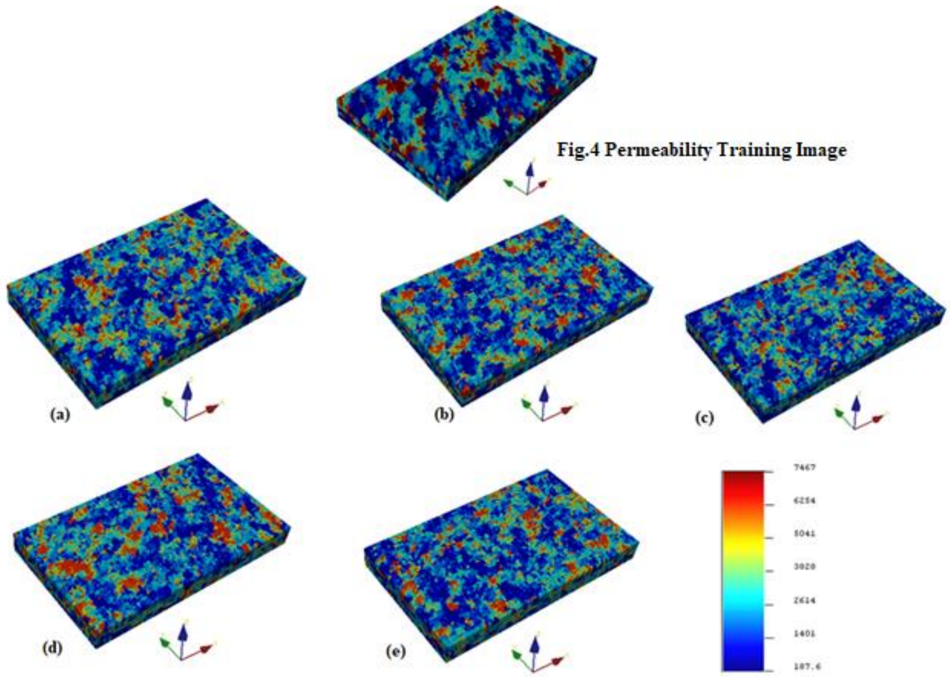


Fig. 5 a-e. Filtersim pemeability realization for Hatch field Niger Delta

## 5. Conclusion

The final model of porosity and permeability developed showed heterogeneity in reservoir E-Hatch Field Niger Delta. These properties will assist management in making a decision on further development of the Field. Areas with high porosity and permeability will be the major targets when developing the field. Validation of the results simply implies that FILTERSIM algorithm is a good method for reservoir characterization of porosity and permeability.

### *6. Acknowledgement*

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