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Applied Spatial Data Analysis Technique on Petrophysical Properties of MA Unit of Mishrif Formation / Noor Field

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Abstract

Noor oil field is one of smallest fields in Missan province. Twelve well penetrates the Mishrif Formation in Noor field and eight of them were selected for this study. Mishrif formation is one of the most important reservoirs in Noor field and it consists of one anticline dome and bounded by the Khasib formation at the top and the Rumaila formation at the bottom. The reservoir was divided into eight units separated by isolated units according to partition taken by a rounding fields.

In this paper histograms frequency distribution of the porosity, permeability, and water saturation were plotted for MA unit of Mishrif formation in Noor field, and then transformed to the normal distribution by applying the Box-Cox transformation algorithm. The spatial correlation of the transformed parameters were estimated and modeled in appropriate equation, and then the spatial distribution of the reservoir parameters were specified through Geostatistical methods.

Keywords: Statistical analysis, Variogram, Mishrif formation, Noor field.

Introduction

Most geostatistical methods assume that the parameters under study were normally distributed such that the deviations from this assumption lead to skewness in estimation [1], to avoid this problem, histograms of the porosity, permeability, and water saturation frequency distribution were plotted for reservoir MA unit in Mishrif formation, and then transformed to the normal distribution by applying the Box-Cox transformation. The spatial correlation of the transformed parameters were estimated and modeled in appropriate equation, and then the spatial distribution of the reservoir parameters were specified through Geostatistical methods.

Experimental

Decriptive Statistics

Geostatistical simulation require the data to be approximately normally distributed (close to a bell-shaped curve) and stationary (mean and variance do not vary significantly in space), Significant deviations from normality and stationary can cause problems, so it is always best to begin by looking at a histogram to check for normality and a posting of the data values in space to check for significant trends [2]. Dealing with samples that are symmetric and that show narrow spread is always easier than dealing with highly skewed samples with a large spread [3].

Frequency distribution histogram and its summary statistics were made for characterizing porosity, water saturation, and permeability at each zone in Mishrif formation to investigate the symmetry and the spread of the data [4].

The histogram in Figure 1-a characterizes porosity, the total number of points are 320, limited between 0.0001 and 0.21. The average porosity is greater than that of the most frequency, indicating that the distribution is skewed positively to the right. The coefficient of variation (Cv) is close to one, indicating that the variation of porosity in MA unit is approximately low.

As shown in Figure 1-b, which represents the histogram of water saturation, the value of water saturation ranging from 0.122 to 1, the average value equal to 0.71, i.e, less than the mode value which indicating negative skew (to the left), and the coefficient of variation is close to zero indicating the variation of water saturation in MA unit is low.

Although the permeability value of MA unit range from 0.002 md to 51.6647md, as shown in Figure 1-c, the majority of the values are at the lower end of the range where the permeability distribution is positively skewed (to the right). The coefficient of variation is greater than one, indicating that the variation in permeability for MA unit is approximately high and should be treated with care when estimating values at un sampled locations.

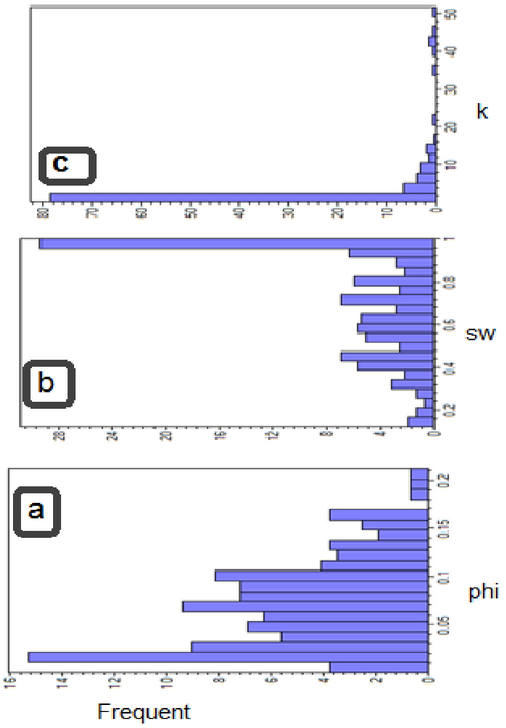

Fig .1: Petro physical properties histogram for MA unit, (a) Phie, (b) Sw, (c) k

Data Tranformation

When data is skewed or has extreme high or low values; estimated variograms often exhibit unorganized behaviors [5].

Box and Cox [6] developed a procedure to identify an appropriate exponent (lambda) to use for skewness removal and transforming data into a normal shape. The final algorithm is:

$$y(\lambda)=(y\lambda-1)/\lambda,\ \lambda\neq0 \qquad \ldots(1)$$

$$y(\lambda)=\log(y),\ \lambda=0 \qquad \ldots(2)$$

Lambda (λ) expresses the degree of skewness and y(λ) is the transformed value of the original observation (y). The Box-Cox transformation coefficient using any statistical package or by hand to estimate the effects of a selected range of λ automatically [7]. The λ can take on an almost infinite number of values. One can theoretically calibrate a transformation to be maximally effective in moving a variable toward normality, regardless of whether it is negatively or positively skewed. This family of transformations incorporates many traditional transformations [7]:

λ = 1.00: no transformation needed; produces results identical to original data.
λ = 0.50: square root transformation.
λ = 0.33: cube root transformation.
λ = 0.25: fourth root transformation.
λ = 0.00: natural log transformation.
λ=-0.50: reciprocal square root transformation.
λ=-1.00: reciprocal (inverse) transformation.

Data transformations are commonly-used tools that can serve many functions in quantitative analysis of data, including improving normality of a distribution and equalizing variance to meet assumptions thus constituting important aspects of data cleaning and preparing for statistical analyses[8].

The Lambda (λ) has been estimated depending on statistical packages in Petrel software, where Cox-Box transformation technique was applied on porosity, water saturation and permeability data for checking what if the data need to transform or not and making the necessary transformation if need [4].

The square root transformation was selected to improve the distribution behave of porosity data in MA unit since the estimated lambda equal to 0.5, the transformation result are shown in Figure 2.

The estimated λ was equaled to 1, when Cox-Box transformation was applied on water saturation data in MA unit, as a result there is no need to make transformation since it will produce results identical to original data as shown in Figure 3.

Natural log transformation was selected to transform the permeability data in MA unit where the estimated λ was equaled to 0.00, as shown in Figure 4.

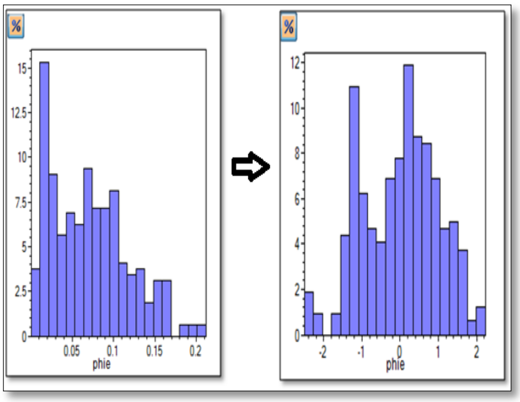

Fig. 2: Porosity transformation for unit MA

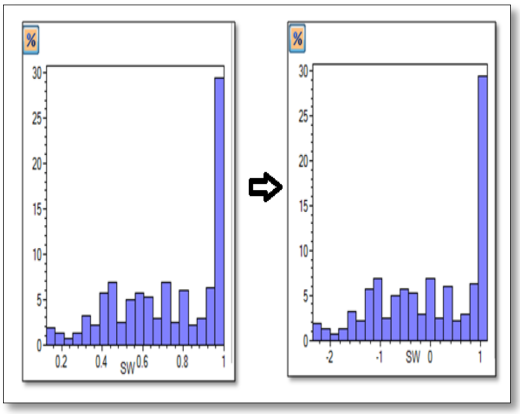

Fig. 3: Water saturation transformation for unit MA

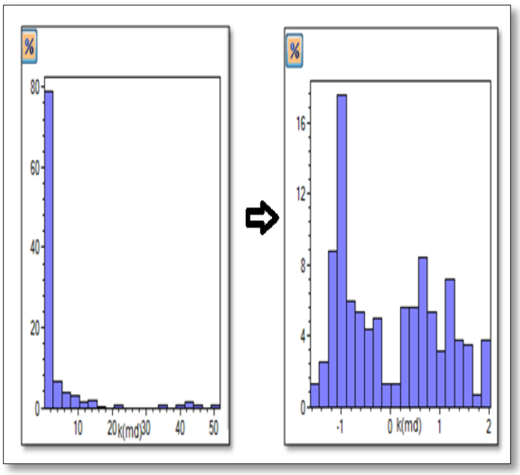

Fig. 4: Permeability transformation for unit MA

Variogram Analysis

Variogram is a measure of correlation between rock properties at two locations [9]. The variogram is mathematically defined as [10]:

$$(\vec{h})=1/2\mathrm{Var}[(\vec{x}+\vec{h})-(\vec{x}) \qquad \ldots(3)$$

The principle of the variogram is that two closely located samples have less dissimilarity than two samples far away from each other [11]. The variogram is a critical input to geostatistical studies, it is a tool to investigate and quantify the spatial variability of the phenomenon under study, and the underlying techniques behind most geostatistical estimation or simulation algorithms require an analytical variogram model which they will honor [12]. In the construction of 3D high-resolution numerical models of reservoir properties, the variogram reflects some of our understanding of the geometry and continuity of petrophysical properties, and can have a very important impact on predicted flow behavior and consequent reservoir management decisions[12].

For the variogram analysis of Mishrif formation, porosity, permeability and water saturation, were utilized to calculate corresponding experimental variograms [4].

The experimental variogram was computed and plotted for petrophysical properties after defining the major and minor areal directions of the variogram depending on 2D variogram map [13] which is a plot of experimental variogram values in a coordinate system with the center of the map corresponding to the variogram at lag equal zero. Figure 5 Represents the 2D variogram map calculated from water saturation where the elliptic shape indicates geometric anisotropy occurs in the areal direction.

The location map, Figure 6-a, represent the wells location and the major direction of the areal variogram where the orientation of the major direction equal to 183°. The orientation of the Minor direction is perpendicular to the major direction and equal to 93° in our study as shown in Figure 6-b. The search radius equal to 6000 m which represent the maximum distance between two samples of dataand the number of lags were chosen to be 20 lags with lag distance equal to 362.3 m.

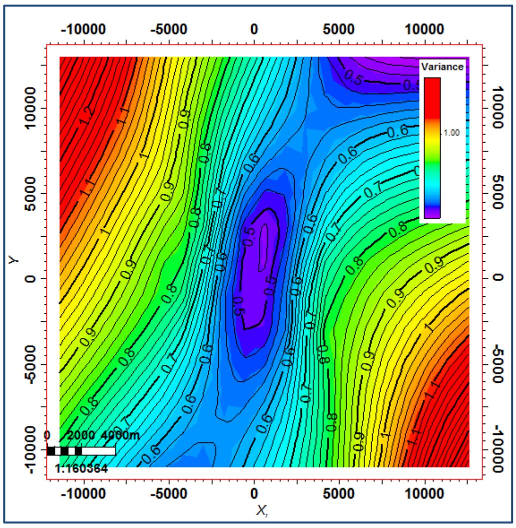

Fig. 5: 2D variogram map calculated from water saturation

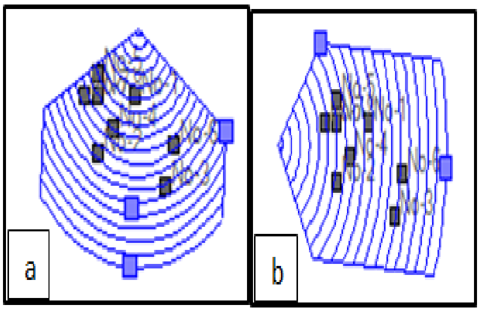

Fig. 6: Location map; a) major direction and b) minor direction

Porosity Variography

The experimental variogram of normalized porosity indicates a behavior that can be described as a combination of exponential variogram where the variogram change very gradually at the origin, and dampened hole-effect (cyclic) variogram [12] which observed after reaching a sill value where the experimental variogram alternated from positive correlations to negative correlations at a length scale directly linked to the geologic cycles as shown in Figure 7, which represents the experimental variogram for normalized porosity of MA unit in three directions.

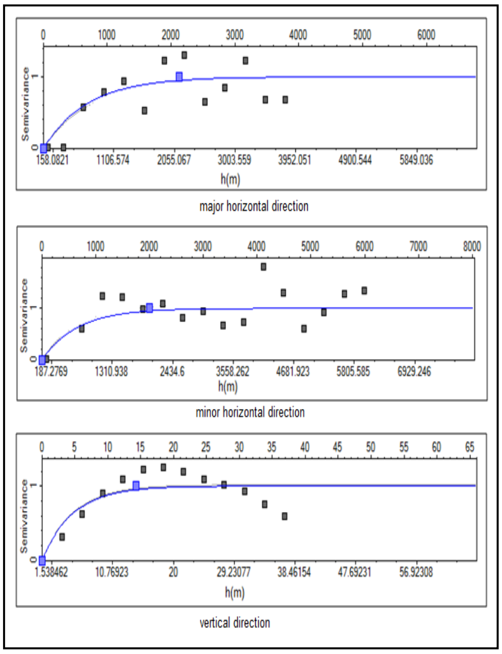

Fig. 7: Experimental variogram of normalized porosity, MA unit

The final model for the horizontal and vertical variability of porosity variograms of MA unit in Mishrif formation is summarized as given in Table (1).

Table 1: Variogram analysis of porosity for MA unit in Mishrif formation

Sill	**Nugget**	**Major Range (m)**	**Minor Range (m)**	**Vertical Range (m)**
0.994	0.00	2126.6	1997.6	14

Water Saturation Variography

Since the experimental variogram of normalized water saturation rises rapidly for a given range, the Spherical model was chosen to be a good option to model the variogram, Figure 8 represent the experimental variogram for normalized water saturation of MA unit in three directions.

The final model for the horizontal and vertical variability of water saturation variograms of MA unit in Mishrif formation is summarized as given in Table 2.

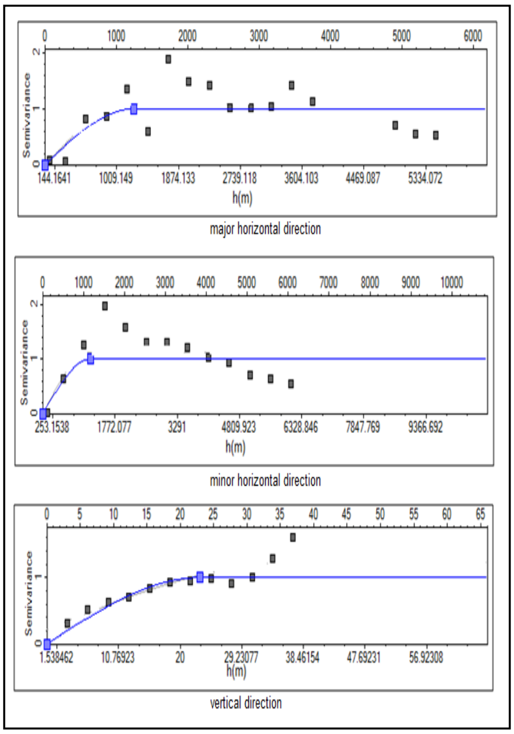

Fig. 8: Experimental variogram of normalized water saturation, MA unit

Table 2: Variogram analysis of water saturation for MA unit in Mishrif formation

Sill	**Nugget**	**Major Range (m)**	**Minor Range (m)**	**Vertical Range (m)**
1.12	0.00	1243.6	1171.4	23

Permeability Variography

The experimental variogram of normalized permeability is similar to the pattern found for normalized porosity as a resultthe exponential model was chosen to be a good option to model the variogram, Figure 9 represent the experimental variogram for normalized permeability of MA unit in three directions.

The final model for the horizontal and vertical variability of permeability variograms of Mishrif formation is summarizedas given in Table 3.

Table 3: Variogram analysis of Permeability in Mishrif formation

Sill	**Nugget**	**Major Range (m)**	**Minor Range (m)**	**Vertical Range (m)**
1.00	0.0	3502.2	3305.3	22

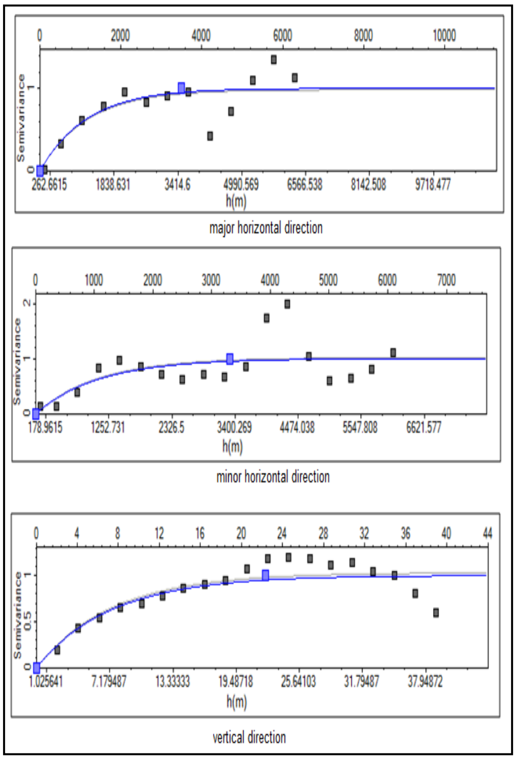

Fig. 9: Experimental variogram of normalized permeability, MA unit

Modeling of Petrophysical Properties

For porosity, water saturation, and permeability, the Sequential Gaussian Simulation technique was applied to interpolate data and to obtain multiple realizations [4] Where the distribution of petrophysical properties were characterized without the consideration of the rock type parameters as a possible guide where thirty (30) realizations were generated for describing the possible distributions of porosity, water saturation, and permeability, then the typical output image was obtained according to the accuracy in frequency distribution and summary statistics. Through using the porosity, water saturation, and permeability variogram models summarized as given in tables (1, 2, 3) respectively and Sequential Gaussian algorithm, the distribution of porosity, water saturation, and permeability were made as shown in Figure 10, Figure 11 and Figure 12 respectively.

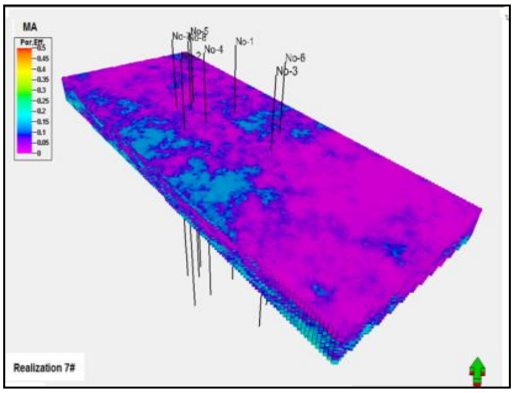

Fig. 10: porosity distribution of MA unit

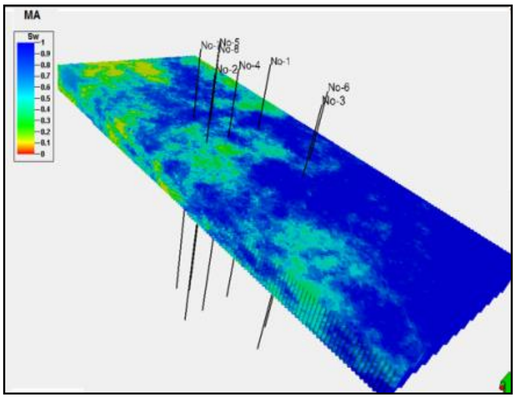

Fig. 11: Water saturation of MA unit

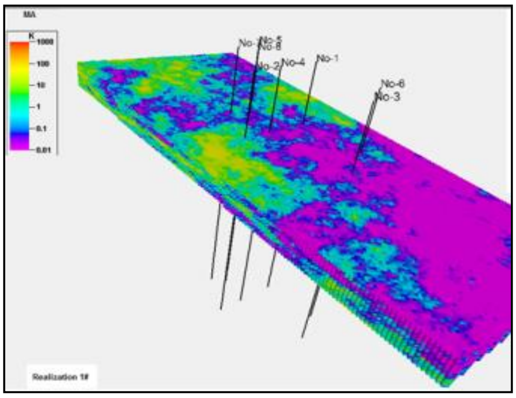

Fig. 12: Permeability distribution of MA unit

Conclusions

1. The descriptive statistics results indicate that MA unit has a symmetrical distribution of porosity while the distribution of water saturation was negatively skewed and the distribution of permeability was positively skewed.
2. Cox-Box transformation technique was removed the skewed behavior and improved the distribution of the petrophysical properties of MA unit

of Mishrif formation in Noor field toward the normal distribution.

3. Exponential model was applied to represent the variogram model of porosityand permeability, while spherical model was the best fitted for modeling the experimental variogramof water saturation in Mishrif formation.
4. The distribution of petrophysical properties in space has been done by using the Sequential Gaussian Simulation technique to interpolate data without the consideration of the rock type parameters as a possible guide.

Nomenclature

EDA=Exploratory data analysis.

Cv = the coefficient of variation.

λ=expresses the degree of skewness.

$(\vec{h})$=theoretical variogram.

$(\vec{x}+\vec{h})$, $(\vec{x})$ =random variables.

$\vec{x}$= position vector.

$\vec{h}$= distance between two points (lag).

Sill= the variance when the variogram levels out.

Nugget= the variance when the distance between two measured samples is very close to zero.

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