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Investigation of P_2O_5% and Fe_2O_3% Geostatistically within Abu Tartour Phosphate Deposit, Western Desert, Egypt

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Authors' contributions

This work was carried out in collaboration among all authors. Author HAF designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MAG and MAY managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Geostatistical techniques play an important role to study the mineralization behavior within the ore deposits. When preparing the phosphate deposits for marketing, we try to minimize the iron content due to the harmful effect of this element on the physical and mechanical properties of superphosphate and phosphoric acid. One of the biggest problems in Abu Tartour phosphate deposits, Western Desert, Egypt is the high iron content within apatite grains. The received data are analyzed statistically to show the distribution of P_2O_5% and Fe_2O_3% at Abu Tartour area. Also, experimental variograms have been constructed for P_2O_5% and Fe_2O_3% of phosphate deposits through the studied area to reflect different variogram models. After fitting the variogram to suitable variogram model, kriged models are established for each variable.

Keywords: Geostatistics; kriging; variogram; Abu Tartour.

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1. INTRODUCTION

The phosphate and phosphate bearing deposits in Egypt are geographically widely distributed in three main localities; the Eastern Desert, Western Desert, and in the Nile Valley [1]. Phosphate ore can be classified according to its grade as follows: poor grade P_2O_5% ranges from 15 to 22%, medium grade P_2O_5% ranges from 22 to 27%, and rich grade P_2O_5% greater than 27% [2]. Geostatistical technique is science concerned with the phenomena that change in space and/or time. It is branch of applied statistics and mathematics that present combination of tools for understanding and modeling of spatial variability [3,4]. Spatial analysis is a statistical method for determining the properties and the relationships of sample points, while taking into account the distance between them. The first law of geography specifically that "*everything is related to everything else, but near things are more related than distant things*" [5]. Constructing of an experimental variogram is the first step in any geostatistical analysis. In this research geostatistical technique is used for modeling the P_2O_5% and Fe_2O_3% in Abu Tartour area, Western Desert, Egypt by using GS^+ (Geostatistics for the Environmental Sciences) software. GS^+ allows for user to readily measure and illustrate spatial relationships in geo-referenced data. Also, it can use to analyse spatial data for autocorrelation and then uses this information to make optimal, statistically rigorous maps of the area sampled. Experimental variogram was constructed for each variable to characterize the spatial variability of the measured P_2O_5% and Fe_2O_3% values depending on the received data. These data are x and y coordinates and P_2O_5% and Fe_2O_3% for each sample location. Spherical and Gaussian variogram models were selected as more suitable fitted to the experimental variograms. Depending on the parameters of the variogram models for each variable, ordinary kriging technique was used to present distribution model of P_2O_5% and Fe_2O_3% which could be used in mine planning and production.

2. LOCATION OF THE STUDIED AREA

Phosphate deposits are distributed in several locations in Egypt along the phosphate belt. The studied area is part of the Western Desert in Egypt and is called Abu Tartour Plateau as shown in Fig. 1. The area of study lies in the central Western Desert of Egypt, bounded by 25^0 15' - 25^0 45' North and 29^0 30' - 30^0 10' East. The area is a semicircular plateau protruding out of the main scarp bounding the Kharga - Dakhla depressions. Its long axis is about 65 km with an Eastern of NE direction while its short axis is about 33 km with a Northern of NW direction. The highest point on the plateau surface attains an elevation of 540 m, while the lowest point at the foot of the scarp is 250 m [6].

3. GEOLOGY OF THE STUDIED AREA

Abu Tartour phosphate deposit is covering an area of about 1200 km^2, which considered as the largest and thickest deposit in Egypt. Abu Tartour plateau makes a part of the main area between Kharga Oasis in the East and Dakhla Oasis in the West. The plateau is divided into the following sectors; Wadi El Battikh sector, El Sebaiya sector, El Zayat sector, Maghrabi and Maghrabi - Liffiya sectors and Ain Amur sector [7]. The general succession records of Formation, age, lithology and thickness from top to bottom as shown in Fig. 2. The Duwi Formation in the studied area is classified into Lower Phosphorite, Middle Shale and Upper Phosphorite members [8]. Duwi Formation consists of three phosphate members, the lower one is economically significant having a thickness ranging from 0.70 m up to 10 m with average 3.5 m and P_2O_5% content ranging from 17 up to 29.9%. The middle member is black shale, and the upper member is noneconomic having a thickness of 3 - 6 m black shale interbedded with 2 thin phosphate beds, having a thickness of 0.5 - 1.5 m and P_2O_5% content less than 15%.The investigated phosphorite samples of the studied area were microscopically showed two principal constituents; phosphatic components (apatite, fish bone fragment and shark teeth) and non-phosphatic components (dolomite, calcite and iron oxides) as cement materials as shown in Fig. 3 [9]. The phosphate grains are generally of angular and elongated in shape and yellowish brown colour. The presence of hematite minerals in phosphorite rocks reflect the oxidation of pyrite mineral due to the geochemical weathering [7].

4. THE AVAILABLE DATA

The available data for the present study is based on sampling information derived from the location as shown in Fig. 4. The data used in this studied area were obtained from Phosphate Misr Company. These data include technical report about mining works and site surveying map for the studied area.

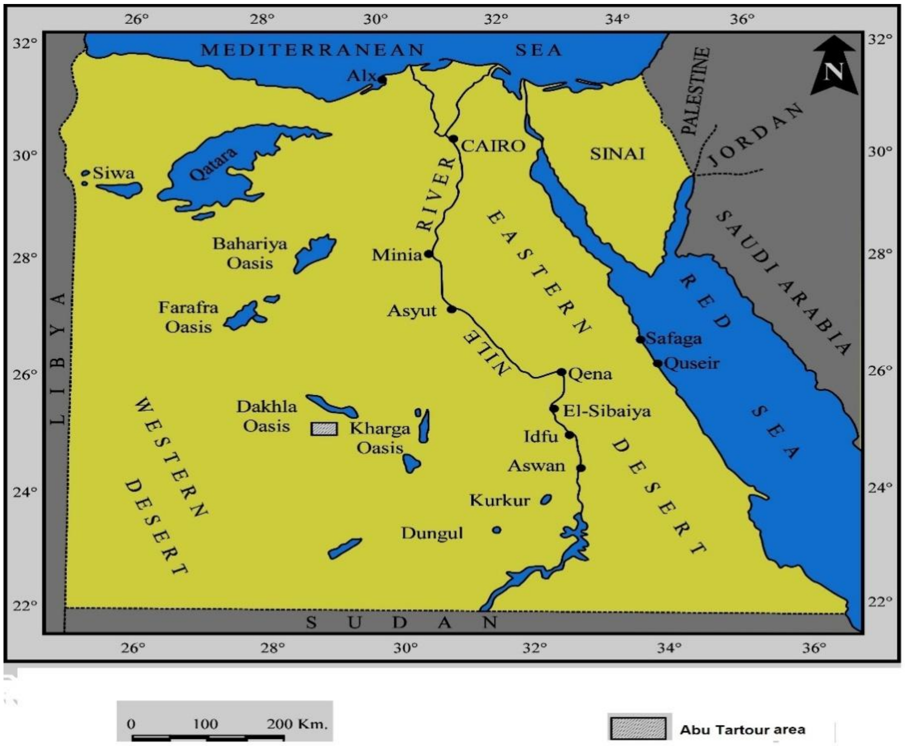


Fig. 1. Location map of the studied area

5. STATISTICAL ANALYSIS

The statistical analyses have been performed on two variables P_2O_5% and Fe_2O_3% which gives the distribution of P_2O_5% and Fe_2O_3% and the standard parameters of statistics. Table 1 gives the summary statistics of the data sets for two variables of the studied area. Fig. 5 shows the histograms of P_2O_5% and Fe_2O_3% that constructed for studied area while Fig. 6 shows the posting distribution maps of them along the studied area. The results show that the distribution tends to be normal distribution with negatively skewed of the P_2O_5% while the distribution is positively skewed of the Fe_2O_3% content. Also, coefficient of variation value of Fe_2O_3% is higher than P_2O_5% in the studied area which shows a significant change of the Fe_2O_3% content within the orebody.

6. VARIOGRAM MODELING

The first step in geostatistical estimation procedure is constructing the variogram. It is the most important step because the model chosen will be used throughout the process of kriging and will influence all results and conclusions [8]. Depending on the available data for each variable, isotropic variogram, without considering the direction, have been constructed and fitted to a suitable model as shown in Fig. 7. The variogram parameters for P_2O_5% and Fe_2O_3% in the studied area were summarized in Table 2.

Table 1. Summary statistics of P_2O_5% and Fe_2O_3% in the studied area

Statistical parameters	P_2O_5 %	Fe_2O_3 %
Mean	25.53	4.10
Variance	2.46	2.74
Standard deviation	1.57	1.65
Coefficient of variation	0.07	0.4
Skewness	-0.55	0.44
Kurtosis	2.35	2.66

As shown from the variogram models in Fig. 7 and geostatistical parameters in Table 2, it is clear that P_2O_5% is characterized by the presence of nugget effect and this is expected as the result of the presence of iron oxides intercalated within microstructure of the deposits, which in turn took a higher value of the nugget effect and has a high value of both sill and range of influence.

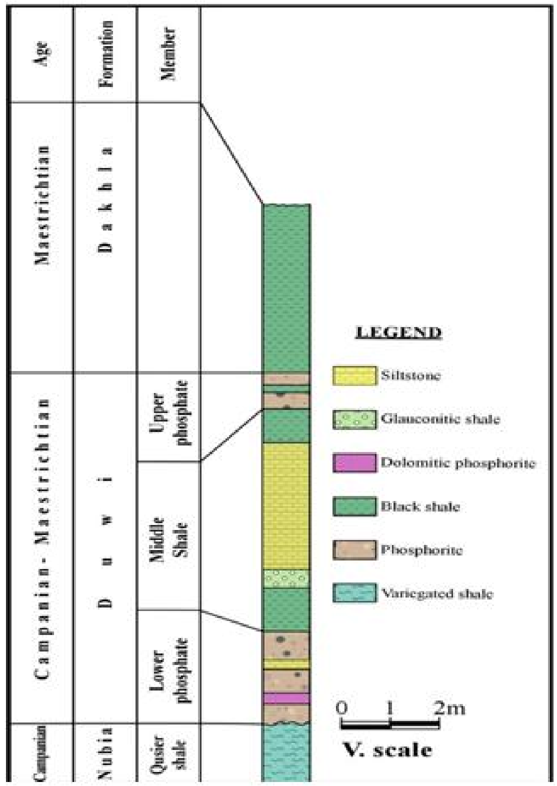
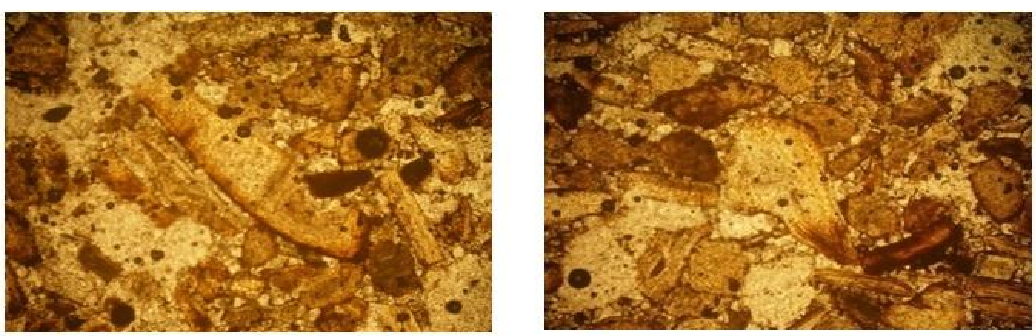


Fig. 2. Lithostratigraphic succession in the studied area



(1) (2)

Fig. 3. Showing apatite grains, (1) elongated and (2) angular surrounded with bone fragment embedded in carbonate and iron oxides cement

7. KRIGED MODELING

Ordinary kriging is used to interpolate the unknown locations by creating map analysis that showing the distribution of P_2O_5% and Fe_2O_3% in the studied area as shown in Fig. 8 and Fig. 9. This map is classified into classes, each class represent specific percentage from P_2O_5% and Fe_2O_3%, which helps in showing the distribution of two variables in different locations in the studied area. From the two model, it could be noticed that, the areas of high P_2O_5% are accompanied by medium and low Fe_2O_3% except some small areas, where high Fe_2O_3% are found. Also, the Southern Eastern part of the studied areas include both of low P_2O_5% and Fe_2O_3%. This result reflects the complex effect of Fe_2O_3% on the distribution of P_2O_5% within the deposit. Hence, the mining engineer should consider this effect during the production stage.

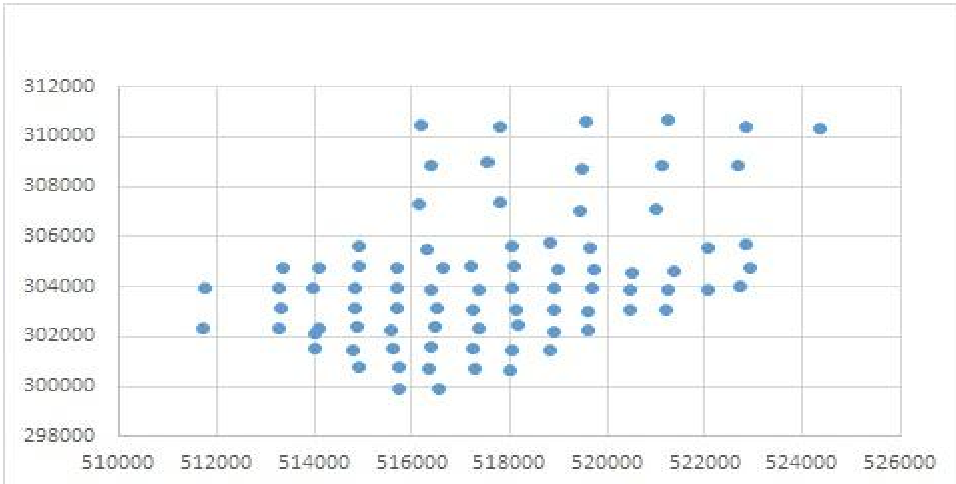


Fig. 4. Scatter Plot of Bore Holes at the studied area

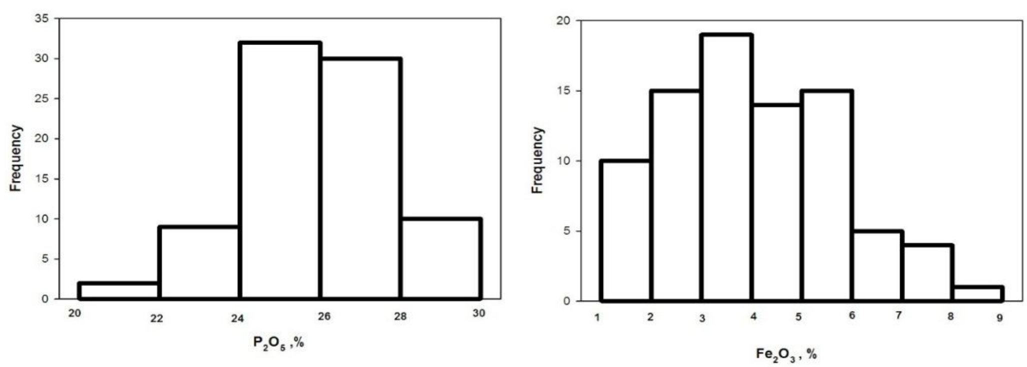


Fig. 5. Histograms of P_2O_5% and Fe_2O_3% at the studied area

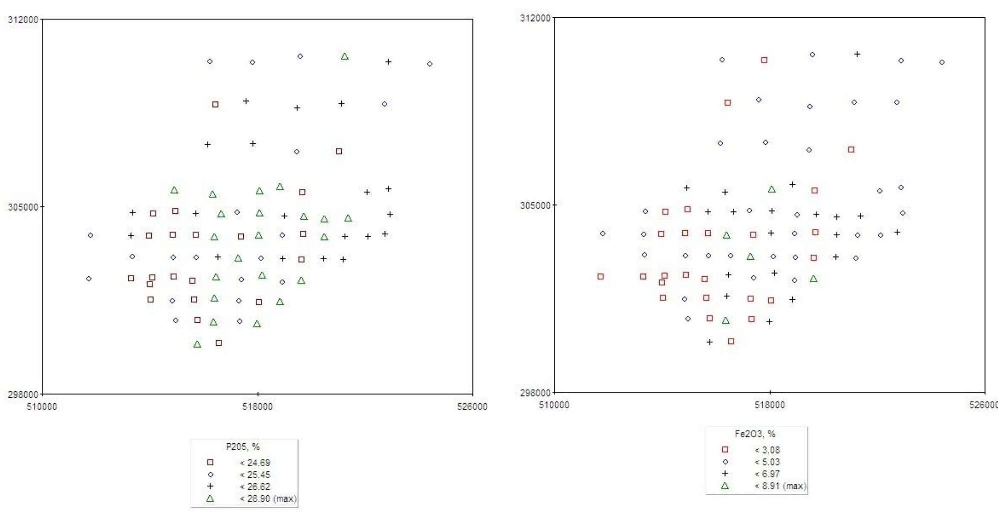


Fig. 6. Posting distribution maps of P_2O_5% and Fe_2O_3% at the studied area

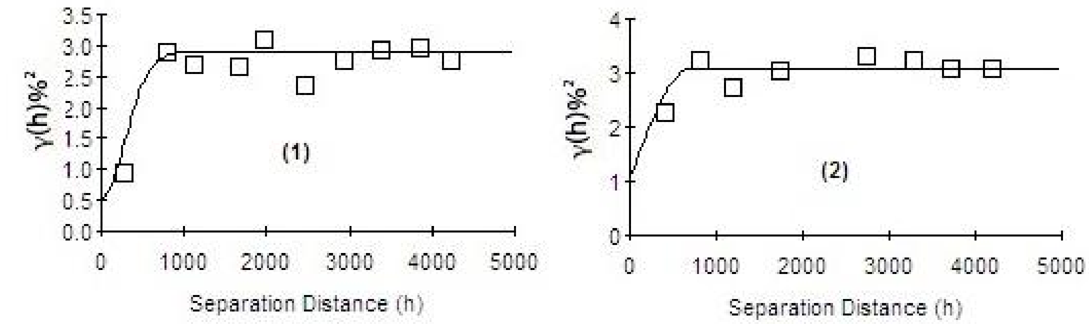


Fig. 7. Variogram models for P_2O_5% and Fe_2O_3% in the studied area where, (1) P_2O_5% and (2) Fe_2O_3%

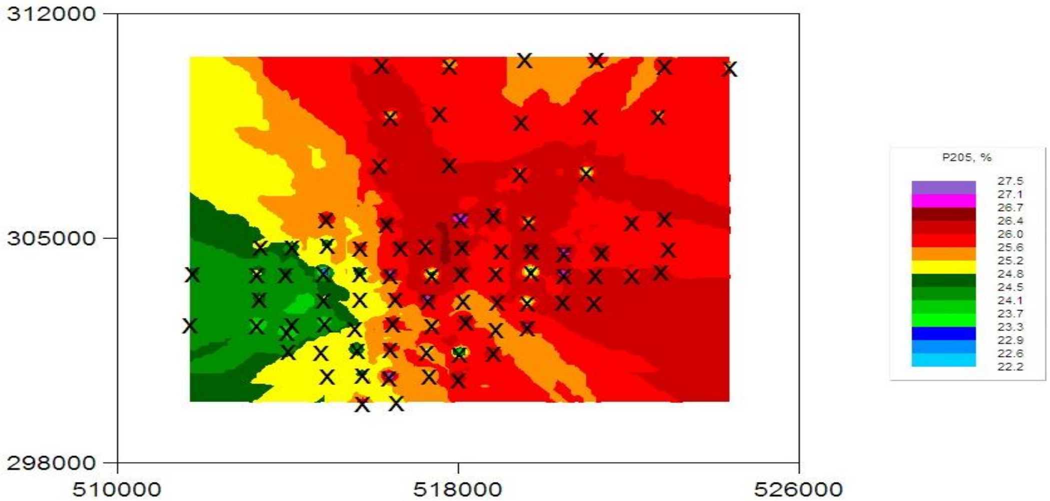


Fig. 8. Kriging model showing P_2O_5% distribution for the studied area

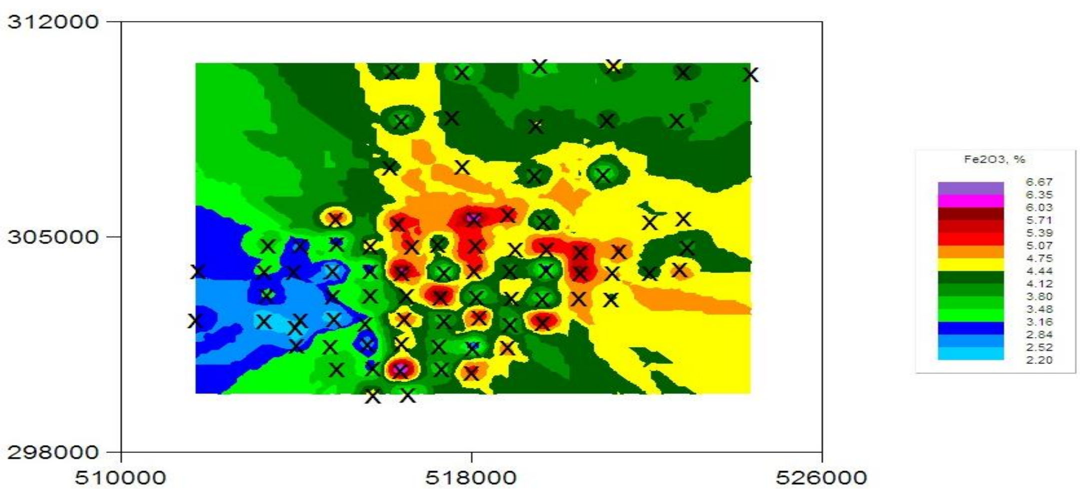


Fig. 9. Kriging model showing Fe_2O_3% distribution for the studied area

Table 2. Variograms parameters of P_2O_5% and Fe_2O_3 in the studied area

Variogram parameters	P_2O_5 %	Fe_2O_3 %
Type	Gaussian	Spherical
Direction	Global	Global
Range, m	703	708
Nugget effect (C_0), $\%^2$	0.54	1.06
Sill (C), $\%^2$	2.89	3.1
Screen Effect Ratio C_0/C	0.19	0.34

8. CONCLUSION

The conclusions drawn from the present study can be summarized as follows:

1. The Statistical analysis of the available data provided the average value for P_2O_5% has been estimated to be 25.53% ranges from about 20.35 – 28.9% while the average value for Fe_2O_3% has been estimated to be 4.1% which is considered high value.
2. The histogram for the grade of P_2O_5% is characterized by negative skewness and the histogram for the grade of Fe_2O_3% characterized by positive skewness in a reversed manner. However, they can all be approximated by normal distribution.
3. Applying geostatistical techniques revealed the behavior of mineralization within the deposit as reflected by the variograms, where nugget effect recorded higher value for Fe_2O_3% than for P_2O_5% to represent the disseminated nature within the deposit.
4. Kriged models illustrated the relationship between P_2O_5% distributions and Fe_2O_3% distributions within the deposit where it can be useful when planning the mine for production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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