Optimizing Wadi Kalabsha kaolin Ore Grade by GIS for Uses in Egyptian Ceramic and Refractory Industries

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Abstract — The purpose of this work is to evaluate the Wadi Kalabsha Kaolin ore for ceramic and refractory industries. Geographic Information Systems (GIS) technique was used to identify the locations that satisfy the requirements of Egyptian ceramic and Refractory industries and to calculate the volume of ores can be extracted from these locations. An attempt has been done for analyzing of Kalabsha kaolin ore through creating many layers. ArcInfo 9.3 software package was used to achieve this work. The results indicated that the planimetric area of satisfied locations from main elements of Wadi Kalabsha Kaolin ore (SiO_2% and Al_2O_3%) represents 29 % from planimetric area of the study area and the volume of Kaolin ore can be extracted from these locations represents 32% from the total volume of Kaolin ore in Wadi Kalabsha area. These locations need to be treated for upgrading both Fe_2O_3% and TiO_2 %. In another hand, the remaining area of Wadi Kalabsha must be treated to satisfy the requirements of different industries.

Index Terms — Kalabsha Kaolin Ore, Mine Surveying, GIS, Ceramic and Refractory Industries.

1 Introduction

GIS has proven to be an extremely useful tool for a full range of applications in evaluating and development of mineral resources around the world. Beyond map making, GIS can deliver insight and geo-intelligence from data by analyzing spatial patterns and understanding current conditions and past trends. The effectiveness of GIS in providing accurate analysis results and easily disseminating information has allowed GIS to become an extremely useful information analysis, management, and communication instrument that can be used to support a wide range of community development applications [1, 2].

GIS provides tools that will help you integrate a variety of data sources and types, maintain and manage inventories, visualize data and related information using dynamic maps, make decisions about resource management, and perform modelling and analysis [3-5].

In recent years Geographic Information System has been widely used as a powerful tool for analyzing spatial information. A great advantage in using GIS is that all spatial attributes related to a particular location can be saved in the form of digitized map, which can also be searched, modified, and updated. It can also cover the regional area and therefore, regional scale data such as geographic and geologic data of the regional area can be easily analyzed [6]. Therefore, this paper considered that an attempt to evaluate and find the locations that satisfy the requirements of ceramic and refractory industries of Egypt for different ratios of oxides, Kalabsha Kaolin deposit mine based on GIS.

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2 Using GIS in mining industry

Mining industry professionals like to say "if it can't be grown, it's got to be minded." In the GIS industry, it is said "if it can be mined, it's going to required geography." Geography provides the framework to acquire develop, and interpret the complex spatial and tabular datasets used for mining and the earth sciences. Mapping, spatial concepts, and time/space operations technology is absolutely essential to effective mining [7]. GIS technologies create efficiency and productivity opportunities in all aspects of mineral exploration and mining. GIS enables a mineral exploration geologist and mine operator to mine intelligently, efficiently, competitively, safely, and environmentally [8].

Embaby and Ismael [9] made chloride distribution model for Ghorabi iron ore mine area, Egypt by using GIS and geostatistical techniques. GIS was used to create map analysis of chloride concentration and its distribution in Ghorabi mine ore body. The variation of chloride values was investigated considering mine area firstly as one zone and then studying the variation of chloride values by dividing the Ghorabi mine area structurally into four zones to investigate the similarity and dissimilarity through the different zones by using geostatistical analysis. Experimental semivariograms were constructed to characterize the spatial variability of the measured chloride values. Spherical and linear semivariogram models were selected as more suitable fitting to the experimental semivariograms.

Elroi [10] discussed the principles of GIS and expanded its application to the production and post-production phases of a mine. He concentrated on the processing of mine's output, its disposal, and the ultimate closure and reclamation of the mine. He also studied the environmental quality monitoring, volume computations, vegetation characterization, slope-aspect characterization, and visualization. GIS gives careful evaluation of what organization does on a day to day basis and improve the organization's functionality.

Ragbirsingh and Norville [11] presented a Geographic Information System (GIS) analysis of geochemical assessment for trace metals in coastal sediments of the Gulf of Paria. This GIS approach facilitates interpretation of the spatial relationships among key environmental processes. The GIS development involves the integration of spatial and attribute data pertaining to bathymetry, current systems, topography, rivers, land use/land cover and coastal sediments. They used spatial interpolation and retrieval operations to analyze the total trace metal concentrations of aluminum, copper and lead in the sediments and the clay-enriched sediments, to determine whether they are related to sediment type or are affected by the discharge from anthropogenic sources. Spatial distribution modeling of element concentrations are produced to indicate contamination plumes from possible anthropogenic sources such as rivers entering the Gulf of Paria, and to reveal potential hot spots and dispersion patterns. A direct spatial correlation between clay-enriched sediments and high concentrations of aluminum and lead is detected; however regions of high concentrations of copper and lead indicate a relationship to anthropogenic sources.

El Gammal and Salem [12] investigated some significant geomorphic features in the Farafra Oasis area such as natural caves and white desert which display remarkable landscapes of high esthetic value and very important sites for ecotourism. The study aims to produce a GIS ready database for registration of the natural caves with stalactites and stalagmites and a set of printed thematic maps for the above mentioned features with an explanatory notes for the features considered. To achieve these goals remote sensing and GIS techniques have been used, verified by field trip and GPS instrument for correct locations. The used thematic maps are: topographic maps for roads and tracks and main cities, and geologic maps.

3. Description of Kaolin Deposit in Wadi Kalabsha

The Kalabsha area is located approximately105 km south west of the city of Aswan, between latitudes 23° 30 00″ and 23° 28′ 00″ east and long itudes 32° 23′ 30″ and 32° 20′ 32″ north, covering an area about 17 km2 as shown in Figure 1. This area is accessible from Aswan by the Aswan – Abu Simbel asphaltic road. The main kaolin beds crop out in the form of white elliptical patches along the low – lying parts of the area, which are otherwise covered by Wadi wash and wind – blown sands [13].

The Kalabsha area is covered by Nubian Sandstone beds which fall into three members, lower and upper sandstone. Members which enclose an intermediate member made up of kaolin. This Wadi Kalabsha Kaolin member forms a continuous and map-able marker horizon and probably extends beyond the limits of the area described. It is distinctive by virtue of its lighter colour. This well-marked kaolin member is made up of two beds, each representing a textural variety. In addition to these two main kaolin beds, the upper sandstone member includes several thin kaolin beds that have been classified into two other textural varieties. The upper and the lower sandstone members, as well as kaolin member, form relatively small exposures and patchy outcrops in a vast plain covered with blown sands. The dominant dip is towards the south east at angels not exceeding 15°. A pronounced fault runs in the north eastern sector of the area, where as some other faults are indicated by displacement of relevant beds. The Wadi Kalabsha Kaolin is inter bedded within the Nubian Sandstones and like other similar occurrences, it could be considered as an elastic deposit which was formed by the transportation of an intensely weathered parent aluminous rock and its deposition in a closed aqueous body. The deposit is mainly of the normal gradational type with channel deposition recorded at occasional parts of the area [14].

The Wadi Kalabsha Kaolin is of great economic potential total reserves of kaolin are 9,421,430 tons pisolitic type, 6,638,620 tons of concretional kaolin and 464,270 tons of the plastic non-pisolitic type [15].

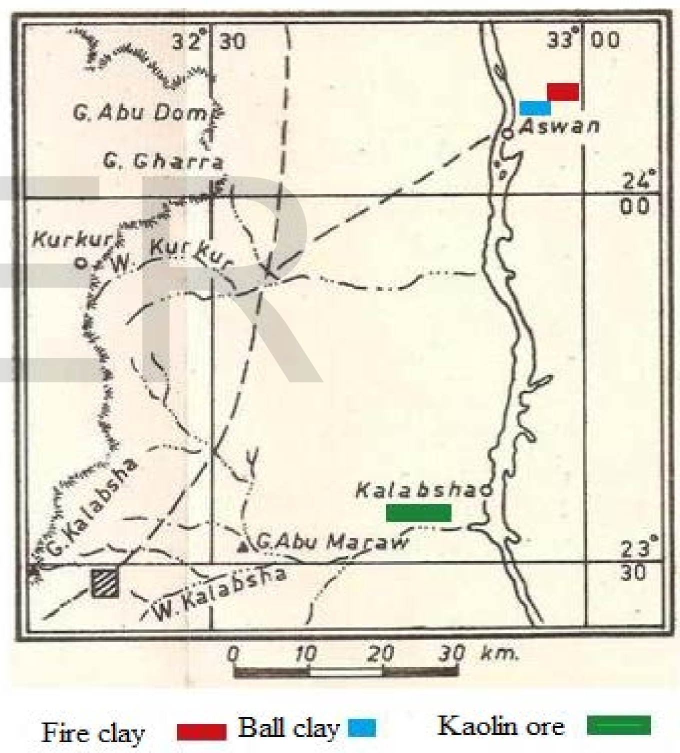

Fig.1. Location map of studied area (Wadi Kalabsha) [14].

4. Data Source

The data used in this work are obtained from El-Nasr mining company. This data include that hard copy form of the site surveying map of the study area. This map has geographic coordinates of bore holes locations, blocks of ore reserves, ore thickness and complete chemical analysis for Kaolin samples which taken from bore holes.

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5. Requirements of Ceramic and Refractory Industries from Wadi Kalabsha Kaolin Deposits

The required specifications of kaolin deposits for ceramic and refractory industries are given in Table 1.

TABLE 1
SPECIFICATION OF KAOLIN DEPOSITS FOR CERAMIC AND REFRACTORY INDUSTRIES [16].

Element	Percentage (%)
Al_2O_3	30-35
SiO_2	47-50
Fe_2O_3	1-1.5
TiO_2	1-2

6. The Locations that satisfy the Requirements of Ceramic and Refractory Industries from Kaolin Deposits

The process of finding the locations that represent the different concentrations of ore elements is important process in mining industry, which helps in the exploitation of the ore by using the optimum method. The following procedures have been used to find the locations that satisfy the requirements of ceramic and refractory industries from Wadi Kalabsha area, and to calculate the volume of Kaolin ore that can be extracted from these locations:

1. Scan the site surveying map to convert it from hard copy form to digital raster form. Then convert the coordinates of this map from geographic to ETM (Egyptian Transverse Mercator).

2. Import the digital raster map into AutoCAD map 2014 software and orient it in the correct position using ETM coordinates. Then digitize all features (bore holes locations) from oriented raster map. Then export these features to shape files format to be relevant to be used within the GIS ArcInfo 9.3 software.

3. Insert the exported shape file from AutoCAD map software to ArcInfo 9.3 software and add all analysis associated with Kaolin Deposits from site surveying map to attributes of this shape file.

4. Creating interpolated Triangulation Irregular Network (TIN) for Wadi Kalabsha Kaolin ore elements, which are consistent with the requirements of ceramic and refractory industries by using 3D Analyst menu.

5. Convert the interpolated TIN for each element of Kaolin ore elements to raster. Then convert this raster to grid of points.

6. The shape file of all converted points is created by join the grids of points of Kaolin ore elements based on spatial location.

7. Using GIS query to find the locations that satisfy the requirements of ceramic and refractory industries from Wadi Kalabsha Kaolin ore elements.

8. The area of satisfied locations and the volume of Kaolin ore can be extracted from these locations are calculated, by extracted these locations from the interpolated TIN of Kaolin ore thickness and using area and volume from 3D Analyst menu.

6.1. Requirements of Ceramic and Refractory Industries from Al_2O_3 %

The required percentage of Al_2O_3 % for ceramic and refractory industries ranges from 30% to 35 %. A query is made to find good locations for producing this percentage and the result of the query explains that there are many satisfied locations from Al_2O_3 % as shown in Fig. 2.

6.2. Requirements of Ceramic and Refractory Industries from SiO_2%

The required percentage of SiO_2% for ceramic and refractory industries ranges from 47% to 50 %. A query is made to find good locations for producing this percentage and the result of the query explains that there are many satisfied locations from SiO_2% as shown in Fig. 3.

6.3. Requirements of Ceramic and Refractory Industries from Fe_2O_3%

The required percentage of Fe_2O_3% for ceramic and refractory industries ranges from 1% to 1.5 %. A query is made to find good locations for producing this percentage and the result of the query explains that there are many satisfied locations from Fe_2O_3% as shown in Fig. 4.

6.4. Requirements of Ceramic and Refractory Industries from TiO_2%

The required percentage of TiO_2% for ceramic and refractory industries ranges from 1% to 2 %. A query is made to find good locations for producing this percentage and the result of the query explains that there are a few satisfied locations from TiO_2% as shown in Fig. 5.

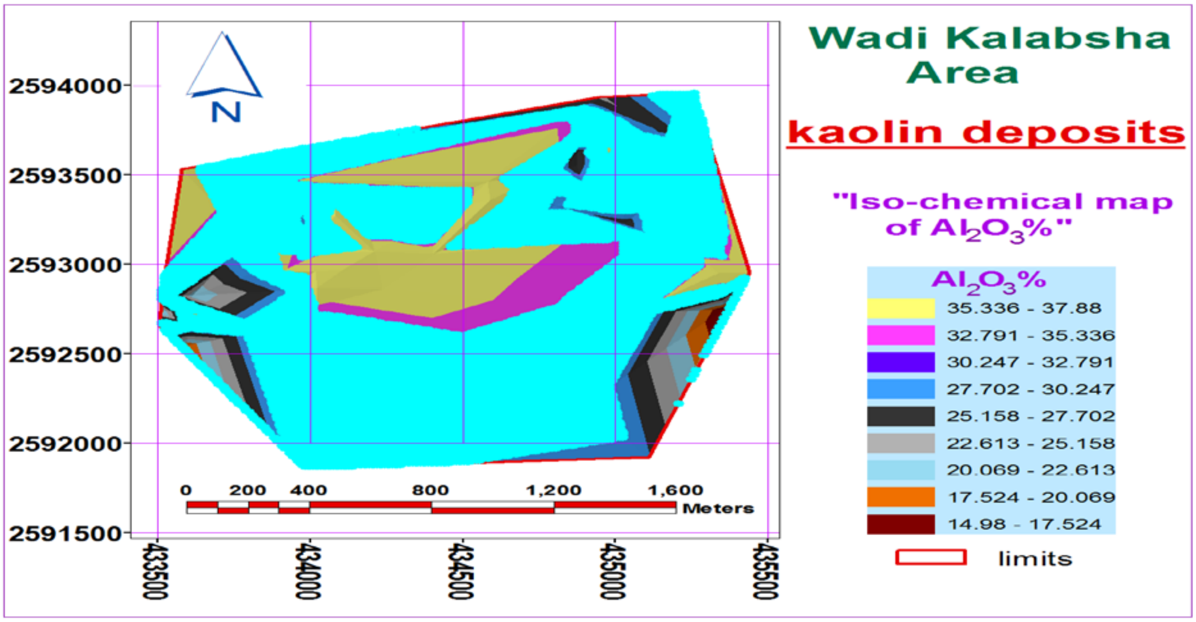

Fig.2. The locations that satisfy the requirements of ceramic and refractory industries from Al_2O_3 %
(Note that these locations are colored with tourmaline green).

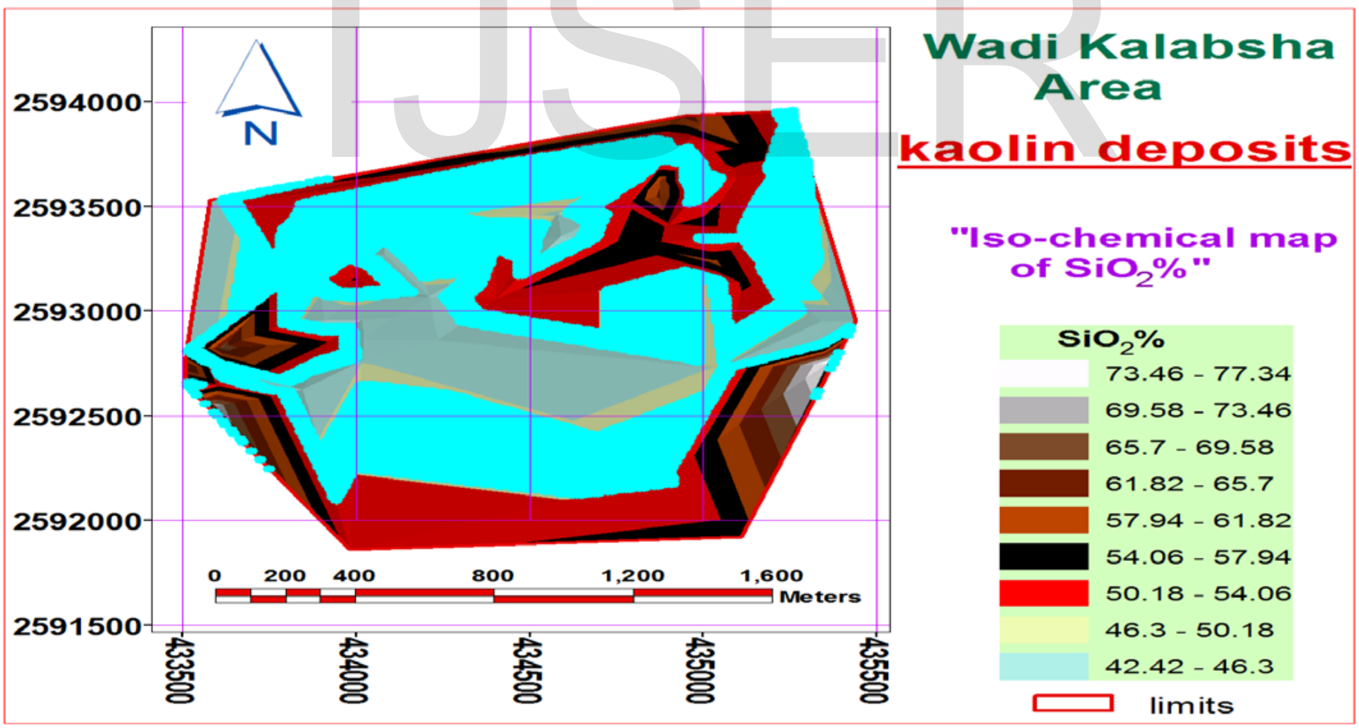

Fig.3. The locations that satisfy the requirements of ceramic and refractory industries from SiO2%
(Note that these locations are colored with tourmaline green).

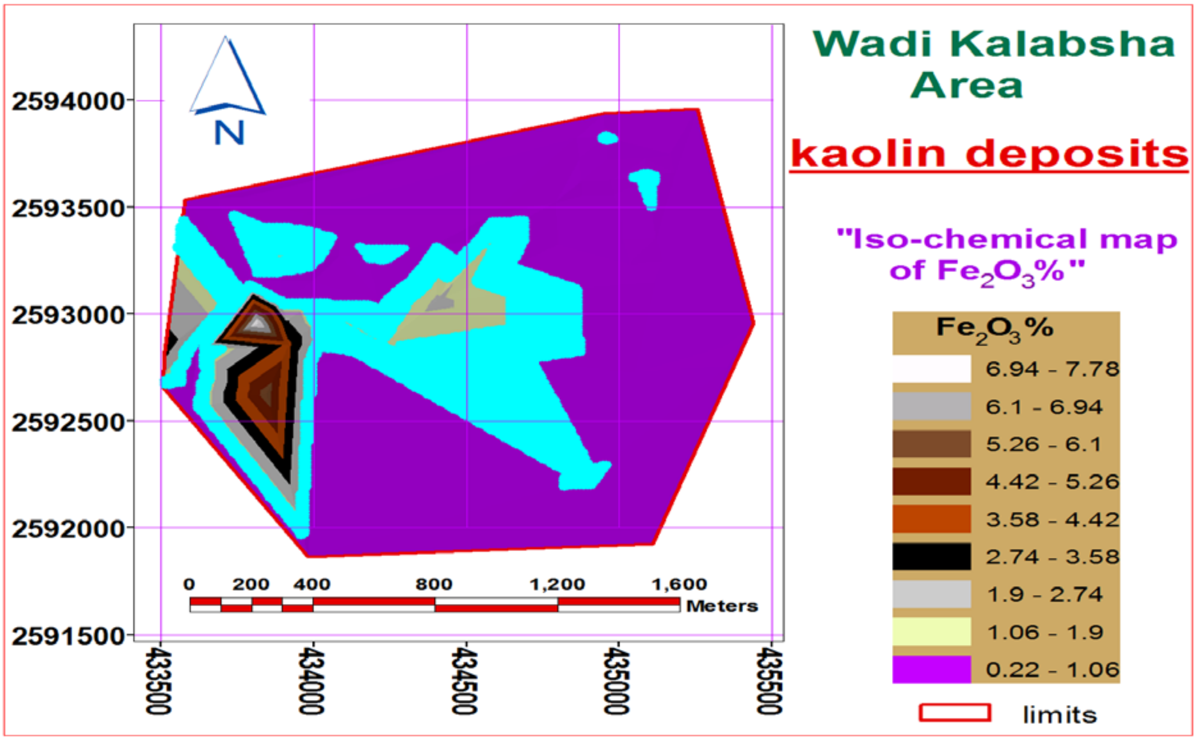

Fig.4. The locations that satisfy the requirements of ceramic and refractory industries from Fe_2O_3%
(Note that these locations are colored with tourmaline green).

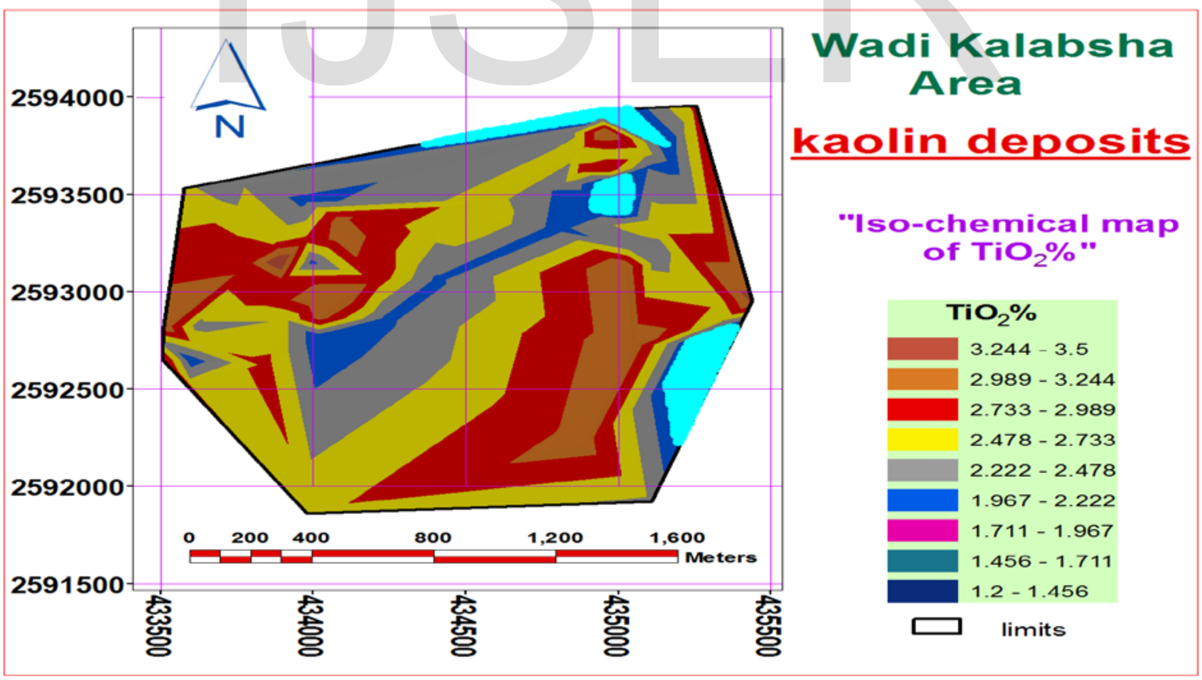

Fig.5. The locations that satisfy the requirements of ceramic and refractory industries from TiO_2%
(Note that these locations are colored with tourmaline green).

6.5. Requirements of Ceramic and Refractory Industries from Main Elements of Kaolin Deposits

The required percentages for ceramic and refractory industries from main elements of Wadi Kalabsha Kaolin ore are the percentage of Al_2O_3 ranges from 30 % to 35 % and the percentage of SiO_2 ranges from 47% to 50 %. A query is made to find good locations for producing these percentages and the result of the query explains that there are many satisfied locations from main elements of Wadi Kalabsha Kaolin ore as shown in Fig. 6.

7. Area and Volume Calculations

The results of calculating the area and volume for the interpolated TIN of Wadi Kalabsha Kaolin ore thickness as shown in Fig. 7, indicate that the planimetric area of the study area is approximately 3,178,338 m^2 and the total volume of the Kaolin ore deposits that can be extracted from Wadi Kalabsha area is approximately 6,702,171 m^3.

The planimetric area of satisfied locations from Al_2O_3 % is approximately 1,914,879 m^2 and represent approximately 60% from planimetric area of the study area. The volume of Kaolin ore can be extracted from these locations is approximately 4,192,687 m^3 and represent approximately 63% from the total volume of Kaolin ore in Wadi Kalabsha area. Fig. 8 shows the Area and volume calculations for satisfied locations from Al_2O_3 %.

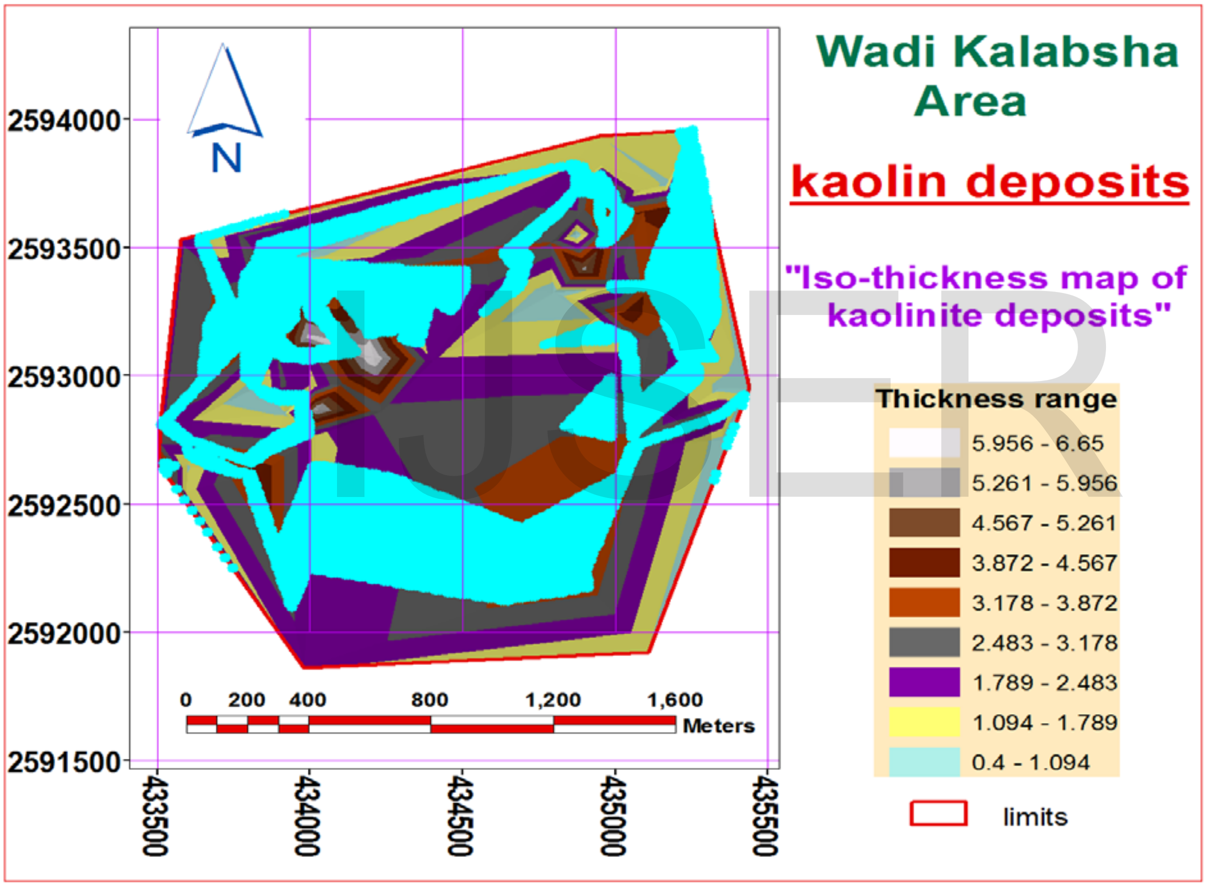

Fig.6. The locations that satisfy the requirements of ceramic and refractory industries from main elements of kaolin deposits (Note that these locations are colored with tourmaline green).

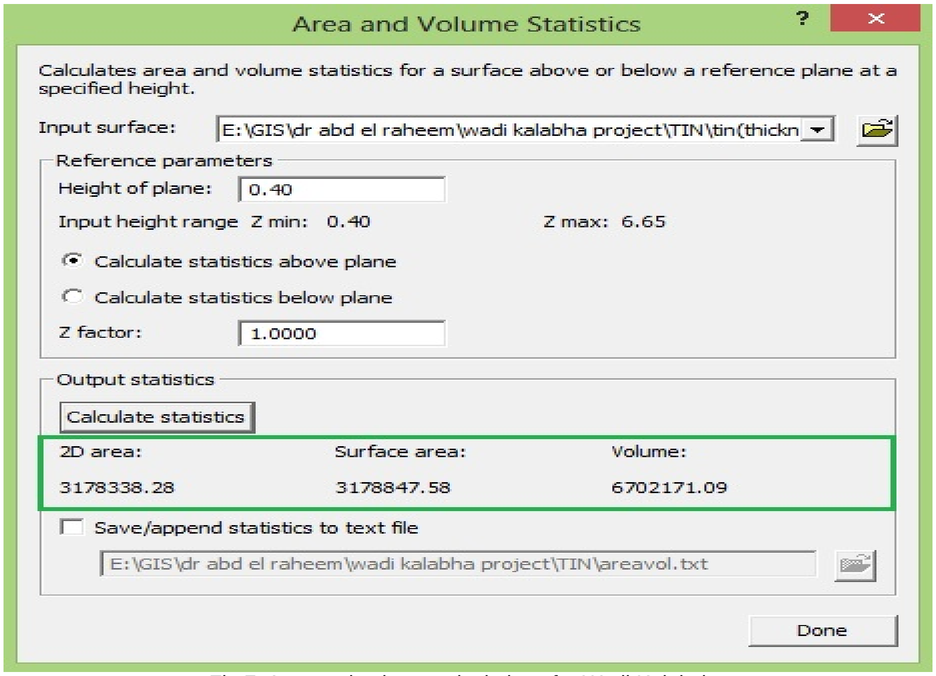

Fig.7. Area and volume calculations for Wadi Kalabsha Kaolin deposits.

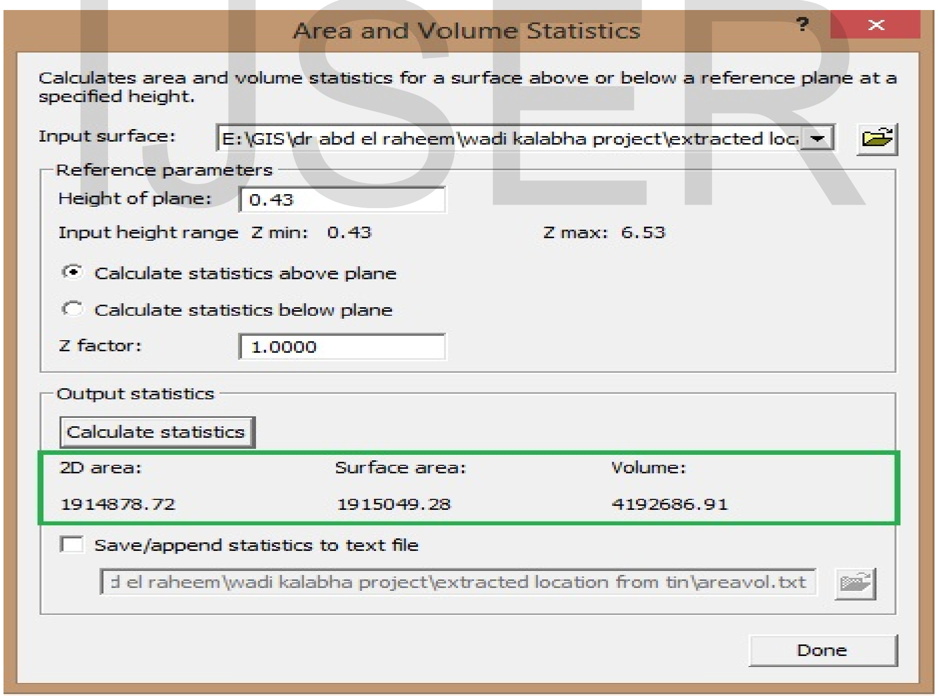

Fig.8. Area and volume calculations for satisfied locations from Al_2O_3 %.

The area and volume statistics for satisfied locations from SiO_2% as shown in Fig. 9 indicate that the planimetric area of satisfied locations from SiO_2% is approximately 1,207,198 m^2 and represent approximately 38% from planimetric area of the study area. The volumes of Kaolin ore can be extracted from these locations are approximately 2,792,872 m^3 and represent approximately 42 % from the total volume of Kaolin ore in Wadi Kalabsha area.

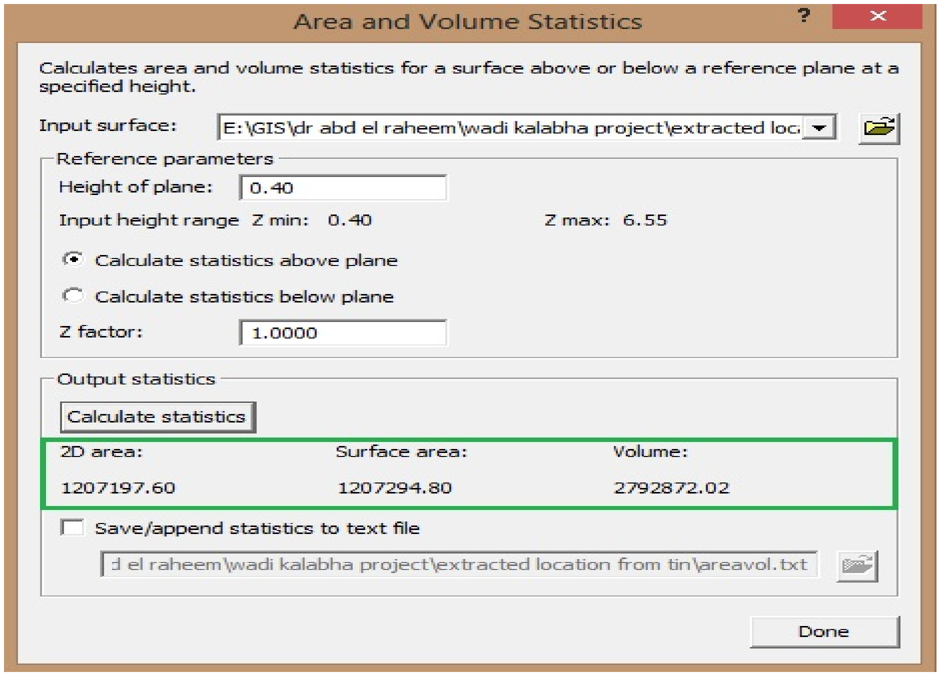

Fig.9. Area and volume calculations for satisfied locations from SiO_2%.

The planimetric area of satisfied locations from Fe_2O_3% is approximately 564,156 m^2 and represent approximately 18% from planimetric area of the study area. The volume of Kaolin ore can be extracted from these locations is approximately 1,007,508 m^3 and represent approximately 15 % from the total volume of Kaolin ore in Wadi Kalabsha area. Fig. 10 shows the Area and volume calculations for satisfied locations from Fe_2O_3%.

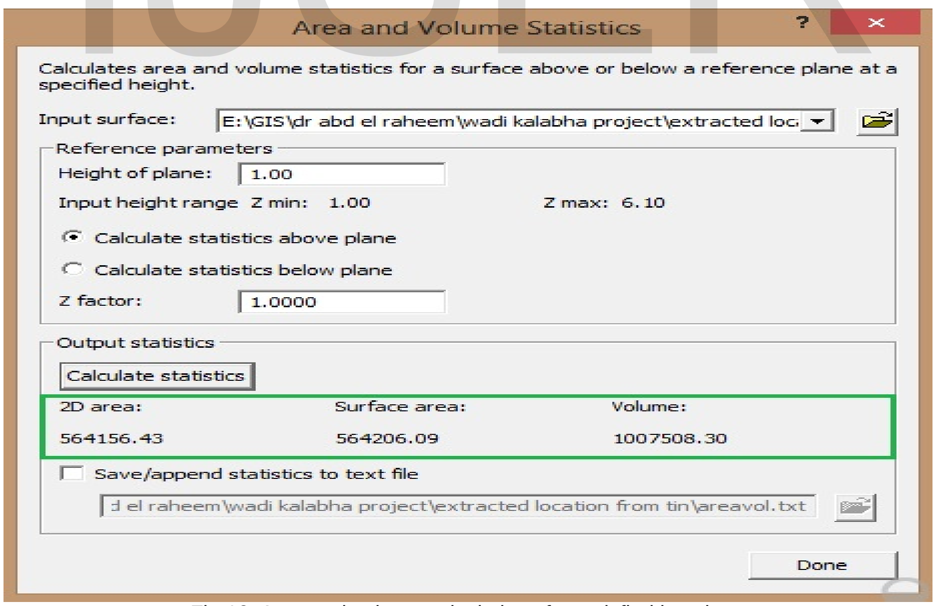

Fig.10. Area and volume calculations for satisfied locations from Fe_2O_3%.

The planimetric area of satisfied locations from TiO_2% is approximately 98,913 m^2 and represent approximately 3% from planimetric area of the study area. The volume of Kaolin ore can be extracted from these locations is approximately 108,503 m^3 and represent approximately 2 % from the total volume of Kaolin ore in Wadi Kalabsha area. Fig. 11 shows the Area and volume calculations for satisfied locations from TiO_2%.

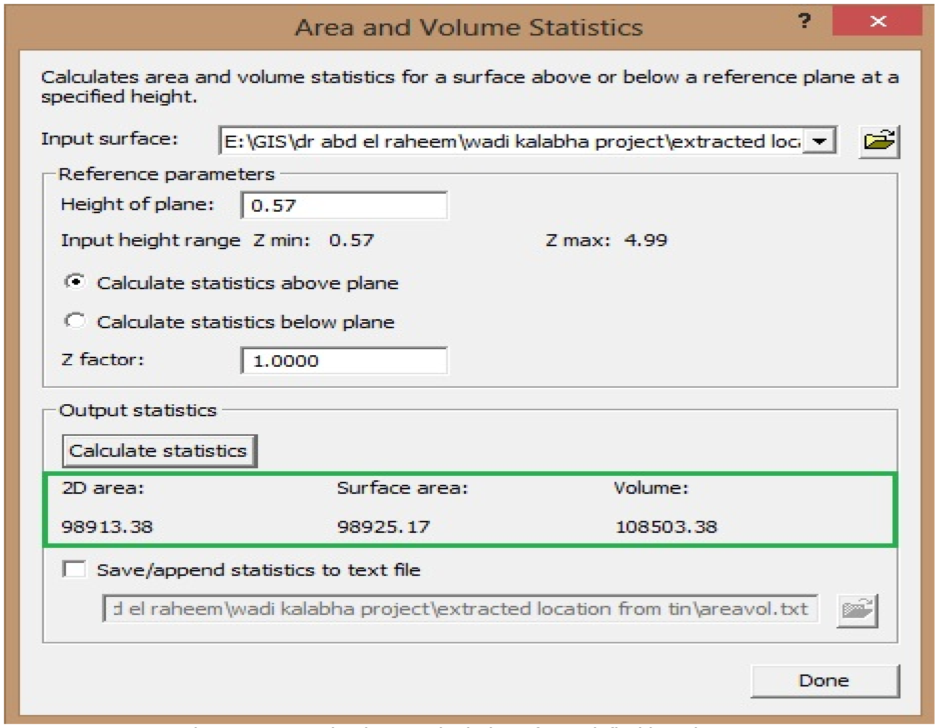

Fig.11. Area and volume calculations for satisfied locations from TiO_2%.

The area and volume calculations for satisfied locations from main elements of Wadi Kalabsha Kaolin ore as shown in Fig.12 indicate that the planimetric area of satisfied locations from main elements of Wadi Kalabsha Kaolin ore is approximately 925,000 m^2 and represent approximately 29 % from planimetric area of the study area. The volume of Kaolin ore can be extracted from these locations is approximately 2,132,620 m^3 and represent approximately 32% from the total volume of Kaolin ore in Wadi Kalabsha area.

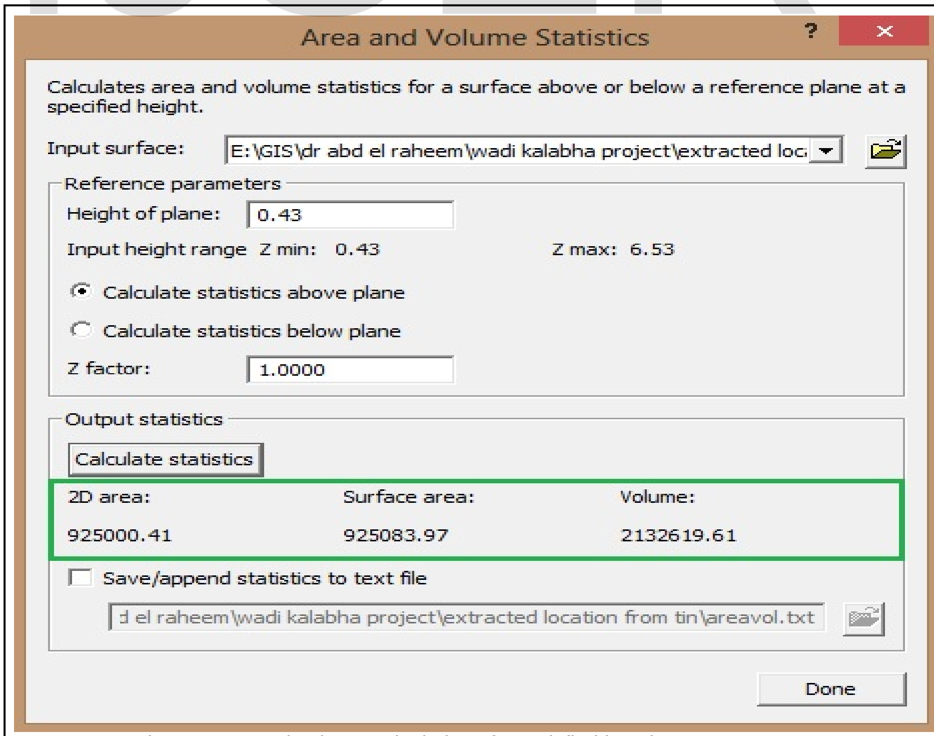

Fig.12. Area and volume calculations for satisfied locations from main elements of Wadi Kalabsha Kaolin ore.

The above mentioned results and analysis for the locations that satisfy the requirements of ceramic and refractory industries from Wadi Kalabsha Kaolin deposits indicate, that the planimetric area of satisfied locations from main elements of Wadi Kalabsha Kaolin ore (SiO_2% and Al_2O_3%) represents 29 % from planimetric area of the study area and the volume of Kaolin ore can be extracted from these locations represents 32% from the total volume of Kaolin ore in Wadi Kalabsha area. These locations need to be treated for upgrading both Fe_2O_3% and TiO_2 %. In another hand, the remaining area of Wadi Kalabsha must be treated to satisfy the requirements of different industries. Therefore the Kaolin deposits of Wadi Kalabsha area cannot transport directly to ceramic and refractory industries without treatment for upgrading.

8. Conclusions

1. The planimetric area of satisfied locations from main elements of Wadi Kalabsha Kaolin ore represents 29 % from planimetric area of the study area and the volume of Kaolin ore can be extracted from these locations represents 32% from the total reserve of Kaolin ore in Wadi Kalabsha area. These locations need to be treated for upgrading both Fe_2O_3% and TiO_2 %.

2. GIS processing for Wadi Kalabsha Kaolin ore area proved that the Kaolin ore cannot transport directly to ceramic and refractory industries without treatment for upgrading.

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