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# Egyptian Aluminum containing ores and prospects For their use in the production of Aluminum

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**Abstract**— Kaolin plays a very significant role in the industrial aspects of life and new ones are still being discovered. It has been considered as an economic gateway for a lot of industrial applications, it is a unique industrial mineral and very widely utilized in industry and its usage is influenced by its functional properties and its purity. However, the Egyptian kaolin is hard and massive; it is also low grade so that it needs processing to be suitable for different industries. Beneficiation enhances kaolin applications; hence, it becomes imperative to study comparative means of upgrading kaolin, for the process integration and optimization. Egypt has large reserves of kaolin in many localities. These kaolin's can satisfy the local demand for filler, paper, ceramic and aluminum industries more times in comparison to the current demands. It is shown that there is a limited number of studies devoted to the possibility of processing alumina production from Egyptian kaolin ores. This raises the need for further research to involve this type of raw material in the production of aluminum and by-products. On the territory of Egypt there are also deposits of nepheline syenite, industrial processing technologies are well known and allow obtaining alumina and various building materials (Portland cement, ceramics and glass). Previous studies have shown that the quality of nepheline concentrate can be significantly improved during the magnetic separation of nepheline-syenite ore.

**Index Terms**- Egypt, Aluminum ores, Kaolin, Nepheline syenite, Alumina production.



## 1 Introduction

Aluminium is the third most abundant element in nature comprising approximately eight percent of the earth's crust. Today more aluminium is produced each year than all other non-ferrous metals combined. Aluminum is light, strong, conductive, durable, flexible and easy to recycle. Among a wide diversity of applications from art and crafts to high technology, the three main fields in which aluminum is used are transportation, packaging and building and electrical and machine tools [1].

Kaolin is used in a multiplicity of industries because of its unique physical and chemical properties because it is chemically inert over a relatively wide pH range, is white, and has good covering or hiding power when used as a pigment or as an extender in coated films and filling applications like paper, plastic, rubber, PVC coating on wire and cables, and ceramics. Shape, particle size, color, softness, and non-abrasiveness are physical properties that are especially important [2, 3].

The main characteristic, which determines the utility of the clay for various applications, is its purity [4]. The oldest known use of kaolin is as a ceramic raw material. Presently, kaolin also finds application as a coating and filler pigment for paper, as a filler for paint, rubber, insecticide, plastics, fiberglass, fertilizers, food additive, formulation of medicine, cosmetics, etc. One of the highest value additions is achieved when the product kaolin meets the specifications of paint and paper coating grades where the critical properties are high brightness, low color values and small particle size [5]. The optical properties (brightness, Lab color, whiteness and yellowness) are improved only when the coloring impurities are removed. Purification of kaolin clay by conventional methods of beneficiation (such as attrition scrubbing, classification, and magnetic separation) can succeed in removing the majority of coarse particles of free silica and feldspars However, these methods of physical separation cannot remove such fine and ultrafine particles of associated coloring impurities (iron oxide and titanium oxide particularly those present as anatase particle) and in turn they reduce their brightness and quality. At the same time application of leaching technique to treat these fine and ultrafine coloring impurities is tedious and costly [6].

This study aims at studying the aluminum ores in Egypt its occurrence, reserves, geology, mineralogy, the last studies done on their upgrading, their industrials applications and uses and the problems that face the aluminum industry in Egypt and some suggestions to solve these problems.

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## 2 KAOLIN

### 2.1 Occurrence of kaolin deposits in Egypt

One of the numerous aluminous raw materials distributed on a large scale in Egypt is the kaolinitic clays. The Egyptian kaolin is present in three main areas namely, Sinai, Red Sea coast, and Aswan (Kalabsha) as shown in Fig.1. Sinai Manganese is the main producer of kaolin from the Nubia Succession of Sinai at Mussaba Salama, El- Tih, Farsh El-Ghozlan and other localities with total reserves of about 100 million tons of a grade ranging from 26% to 35% $Al_2O_3$. The GYMCO (The Egyptian Co. for Quarries Gypsum and Marble), is the producer of kaolin from the Kalabsha region. Wadi Kalabsha kaolinite lies at distance of about 105km south west of Aswan as interbeds within the so called Nubian sand stone of the upper Cretaceous age. Kalabsha kaolinite is of great economic potential, the total geological reserves amount to 17 million tons. This kaolinite is hard, massive compact and white to earthy gray. The kaolin deposit is divided into two main types depending on textural properties. These are, from top to bottom:- (A) Kaolin enclosed within the upper sandstone member [1-The non-pisolitic (plastic) kaolin 2-The pisolitic kaolin with coarse or granular quartz grains], (B) The Wadi Kalabsha kaolin deposit 1-The pisolitic kaolin, 2-The nodular concretionary kaolin. The two types of Kalabsha kaolin are represented by well-developed and more persistent kaolin beds forming the main bulk of the deposit in this area. The ore with an average $Al_2O_3$ of 32-35% has been utilized for production of alum by the aluminum sulphate Co. of Egypt [8, 9, 10, 11].

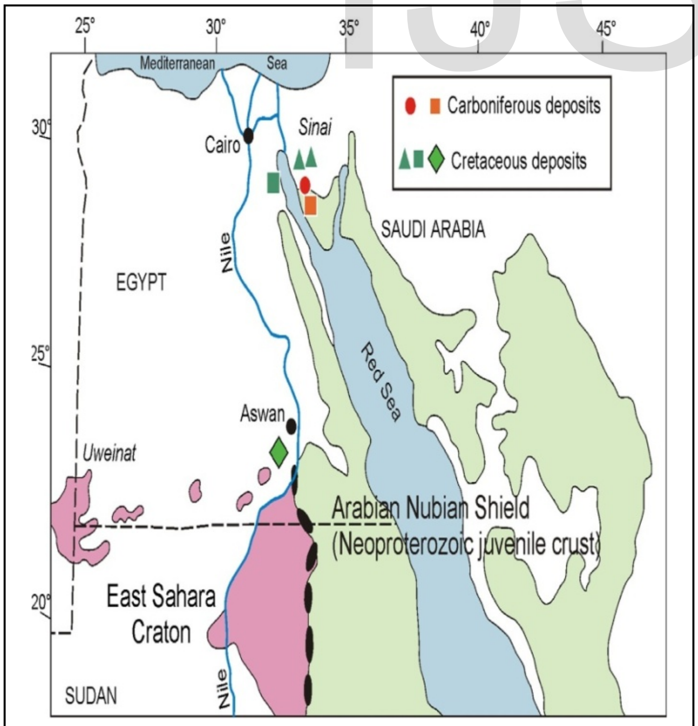


Fig. 1. Location of the Carboniferous and lower Cretaceous sed mentary kaolin deposits in Egypt in relation to the crystalline rocks of the East Sahara Craton (ESC) and Arabian Nubian Shield (ANS) [7].

### 2.2 General geology of kaolin deposits in Egypt

The Sedimentary kaolin deposits of Egypt are Cretaceous or Carboniferous deposits. The lower Cretaceous deposits occur in the Sinai, Red Sea and Aswan regions, while the Carboniferous deposits are present only in Sinai area. Based on the possible proveniences of these deposits, they can be classified into two groups. The first group, which might be derived from the Arabian Nubian shield (ANS) crystalline rock, includes the Carboniferous and lower Cretaceous deposits in Sinai area as well as the lower Cretaceous deposit in the Red Sea area. The second group, which might be derived from the East Sahara Craton (ESC) crystalline rocks, includes the lower Cretaceous deposit in Aswan area [12, 13, 14].

The Carboniferous sedimentary kaolin deposits in north and east of the Abu Zenima area, west central Sinai, occur in the Khaboba and Hasbar areas between latitudes $29^{0}03'0''$ and $29^{0}13'30''$N and longitudes $33^{0}10'00''$ and $33^{0}16'33''$E and belong to the Abu Thora Formation. Kaolin deposits in these two areas occur as moderately hard, gray to dark gray, massive or rarely fine laminated kaolin. They exist in the form of lenses that may attain a maximum thickness of about 2.5m. Southeast of the Abu Zenima area, the Carboniferous kaolin deposits cover the floor of wadis Abu Natash, El Shellal, and Mukattab. The kaolin deposit of Abu Natash area looks different in lithology compared to those of the Kaboba and Hasbar areas. It occurs as whitish gray to earthy gray, massive, moderately hard beds that range in thickness from few centimeters up to 7m and are bounded by sandstones as shown in Fig. 2 [15].

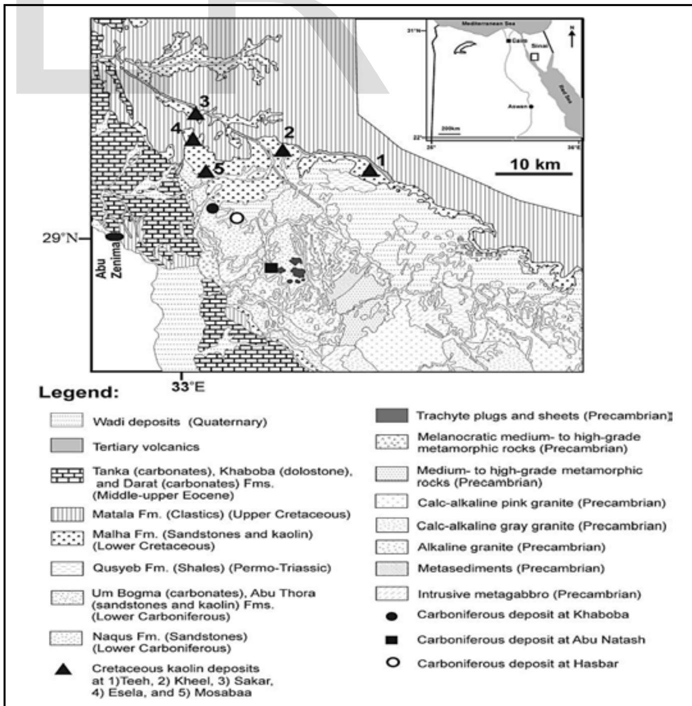


Fig. 2. Geological map of the Sinai Peninsula showing the locations of the Carboniferous and Cretaceous sedimentary kaolin deposits as well as the Precambrian igneous and metamorphic basement rocks. The map was adapted from a geological map of Egypt published by the Geological Survey of Egypt [16].

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The clay fractions of the Carboniferous deposits at the Khaboba and Hasbar areas are composed of kaolinite, anatase, illite and traces of chlorite and were sourced from a mixture of low grade, granitic and alkaline rocks. On the other hand, the clay fraction of the Carboniferous deposit at Abu Natash deposit is composed of kaolinite and anatase and was derived from mafic rocks [13].

The lower Cretaceous sedimentary kaolin deposits in west central Sinai belong to the Malha Formation and occur mainly in the north and north-east of Abu Zenima covering an area of 200km$^2$ between latitudes $29^0 03' 0''$ and $29^0 13' 30''$ north and longitudes $33^0 10' 00''$ and $33^0 16' 33''$ east where the Mosaba, Esela, Hanash and Teeh deposits are located [12]. Kaolin deposit in the Mosaba area occurs in the form of lenticular beds in three kaolin horizons (20 cm to 2m thick) that are separated by sandstones, while at the Esela area, kaolin deposit attains approximately 7m thick of intercalations of black, gray, yellowish, brownish, massive, and moderately hard kaolin. In the Teeh Plateau, kaolin deposit occurs as separated beds range in thickness (10cm to 1.5 m) that are intercalated, underlain and overlain by yellowish to reddish sandstones. The clay fractions of the lower Cretaceous deposits in Sinai are composed of kaolinite and anatase and were derived from a mixture of medium to high grade metamorphic, granitic and/or alkaline rocks [13].

The Red Sea deposit is located approximately 85 km south of Suez at Abu Darag area and belongs to the lower Cretaceous Nubia Sandstone Formation outcropping on the slopes of the Gallala Plateau on both sides of Wadi Araba. The kaolin deposit occurs as separated beds range in thickness (10cm to 2m) that are intercalated, underlain and overlain by yellowish to reddish sandstones. The clay fraction of this deposit is composed of kaolinite and anatase and was derived from a mixture of medium to high grade metamorphic, granitic and/or alkaline rocks [14].

The Aswan kaolin deposits are located approximately 105km south-west of Aswan City at Wadi Kalabsha area and bounded by latitudes $23^0\ 30' 00''$ and $23^0 28' 00''$ east and longitudes $32^0 23' 30''$ and $32^0 20' 23''$ north covering an area about 7km$^2$. When distinguish the three lithological units at Wadi Kalabsha Area with a total thickness of nearly 28m. The Lower and the Upper Sand Members enclose the Wadi Kalabsha Kaolin Member. The Wadi Kalabsha Kaolin Member contains two kaolin beds varying in thickness (10cm to more than 9m); laterally tabular cross-bedded sandstone beds are intercalated. The lower kaolin bed (nodular kaolin) fills up the irregular topography of the underlying sandstone unit and consists of rounded to subrounded nodular kaolinitic fragments embedded in a kaolinitic matrix. The upper bed is mainly composed of pisolitic flint kaolin [10].

### 2.3 Mineralogy of Egyptian kaolin

Microscopic analysis of Egyptian kaolin's indicates that they contain fragments, white to yellowish brown in color, characterized by the presence of plastic and colloidal pisolites ore. The colloidal pisolites forming nodules or concreation of different shapes, colors and sizes. Such colloidal pisolites are cemented with microcrystalline kaolinite and amorphous material. Variable amounts of quartz grains, especially in Red Sea kaolin's, are encountered inside the pisolites as well as in the ground mass. Carbonaceous material and sometimes gypsum fragments are encountered. Accessory minerals include subangular to subrounded zircon, rutile and anatase grains. Tourmaline is rarely detected. Different degrees of ferrugination are observed in most samples. The presence of $TiO_2$ minerals is confirmed, with varying degrees, in most samples of different localities [9,17].

### 2.4 Mineral processing of the Egyptian kaolin

Sophisticated beneficiation flow sheets are well established, particularly in UK, USA and to reach the required specification for good quality kaolin concentrates. However, the Egyptian kaolin is not subjected to any beneficiation process and the Egyptian companies apply selective mining in some localities, followed by crushing and size reduction only. Such low quality kaolin is used mainly in refractory and pottery production because its quality does not satisfy the requirements for paper industries. On the other hand, extensive studies on upgrading of Egyptian kaolin from different localities have been conducted both on bench and pilot plant scale. These studies showed that the Egyptian kaolin is hard and massive and it needs aggressive attrition scrubbing, after primary crushing, to disintegrate the matrix and separate the coarse gangue minerals. Therefore, the suggested pilot plant flowsheet is based on using the (Denver) attrition scrubber as a blunger at the head of the flowsheet. The degritted kaolin ore is screened, the oversize evaluated for tile manufacture and the undersize is pumped to a spiral classifier. Separation of intermediate size quartz and feldspar occurs in this step and the classifier underflow product, is either dumped or recycled to the attrition scrubber depending on its quality. Microscopic and XRD analyses of this underflow fraction show that gypsum fragments in the +0.25 mm fraction whereas angular to subangular quartz grains are abundant in the size fraction over 0.16 mm. Angular to subangular rutile grains are identified in the size fraction +0.074 mm. The classifier overflow product is then delivered to the 3$''$ hydrocyclone for further classification. X-ray diffraction analysis of both hydrocyclone products confirms the accumulation of quartz on the underflow cut and the enrichment of kaolin in the overflow product. The hydrocyclone overflow and underflow product is beneficiated by applying high gradient magnetic separation to minimize its coloring ingredients (mainly oxides of iron and titanium), to meet the specifications of ceramics and paper industry. The final concentrates obtained from these pilot plant operations were evaluated in the production lines of some Egyptian ceramic and paper companies. The results indicated that such kaolin concentrates are suitable for the ceramic industry and as filler in paper making. However, the still high $TiO_2$ content of Sinai and Red Sea kaolin hindered their application in fine ceramics and in paper coating [18, 19].

For this reason, some trials were performed to refine these concentrates by reducing their $TiO_2$ contents using the different techniques of flotation such as froth flotation, carrier flotation and column flotation on the El-Tih kaolin. The tests were performed using sodium silicate as a depressant and oleic acid as a collector. The froth flotation process produced a concentrate (≈ 84.7 wt. %) of 0.68% $TiO_2$ with a whiteness of 78. while the carrier flotation technique using limestone as a carrier, gave a concentrate (≈ 76.1 wt. %) of 0.61% $TiO_2$ and whiteness of 90 [18, 21, 22, 23]. However, the column flotation process gave the best concentrate (≈ 84.5 wt.%) of only 0.38% $TiO_2$ and degree of whiteness of 91.5 as shown in Table (1) [19, 24].

The selective flocculation of the Red Sea kaolin pre-concentrate for minimizing its $TiO_2$ content was, successfully conducted. Cleaner concentrates of about (78.3-80.3 wt.%) of the feed and assaying only 0.52% $TiO_2$ were obtained, that satisfy the requirements of the local paper coating industry and fine ceramic production [25].

Several sintering and acid-extraction processes have been investigated for the production of alumina from kaolin and other clays. The extraction of alumina from Egyptian kaolin by hydrochloric acid leaching was described in several papers. The calcination temperature was the most important parameter affecting the extraction process followed by reaction temperature [26, 27].

Egyptian kaolinite was successfully modified using sedimentation, chemical bleaching, calcination, and dealumination methods for application in paper coating. The original and modified kaolinites were applied in paper coating mixtures. The results showed that the $Fe_2O_3$ and $TiO_2$ in Egyptian kaolinite were reduced chemically via sodium dithionite from 0.41%to 0.25% and 2.20% to 2.00%, respectively. Calcination at 900$^0$C, followed by acid activation and bleaching, showed a further decrease in $Fe_2O_3$ and $TiO_2$ impurities to 0.012 and 1.45 (wt. %) respectively. The results revealed that all characteristics reflection of kaolinite disappeared upon calcination. Calcination and dealumination of kaolinite did not improve coated paper roughness, while air permeance and optical properties significantly increased in comparison with commercial kaolinite. In addition, a significant improvement was observed in coated paper mechanical properties including burst, tensile strength, stretch, and tensile energy absorption with respect to original and commercial kaolinite. In contrast, the kaolinite fraction <2 μm highly improved paper gloss, print density, and print gloss, more than calcined kaolinite and its modified pigments. In conclusion dealumination of calcined kaolinite did not show any further change in all coated paper properties compared to the calcined ones [28]. The mechanical activation of kaolinite facilitates its acid dissolution, whereas the mechano-chemical behavior is more frequently observed when grinding is carried out in equipment that utilizes impact and friction forces among particles (vibrator, oscillating mills, etc. The energy delivered by the mill causes increasing damage to the crystal structure by formation of smaller grains giving an increasing number of grain boundaries and increasing crystalline defects due to deformation. This type of treatment producing important changes in Physico-chemical properties of solid, lead to structural alteration by loss of regularity crystalline network [29, 30, 31, 32].

The Influences of Vibrating Grinding and Calcination on the Physico-chemical Properties of the Egyptian Kaolinite have been studied. The results indicated that is the Surface area increases from 18m²/g of the original sample to reach maximum value of 42m²/g at120min. The reactivity of kaolinite was increased as grinding time and calcination temperature increase. These may be attributed to the disassociation of kaolinite structure. The extraction of alumina after 30 min. leaching time is about 97.52% for ground kaolinite at 240 min. and 85.4% for 180min grinding time. While the maximum recovery of alumina from calcinated kaolinite was 93.47% at temperature 550$^0$C [33].

The amenability of beneficiation of an Egyptian kaolin ore of El-Teih locality, Sinai, to be suitable for different industrial applications has been studied. Attrition scrubbing and classification followed by magnetic separation are applied to remove the associated impurities. Attrition scrubbing and classification are used to separate the coarse silica and feldspars. Wet high intensity magnetic separation was applied to remove colored contaminants such as iron oxide and titanium oxide. The results indicated that substantial decrease in iron oxide (1.69% to 0.75%) and $TiO_2$ (3.1% to 0.71%) contents as well as improving iso-brightness (63.76% to 75.21%) and whiteness (79.85% to 86.72%) of the product could be achieved [34].

The quality of the Egyptian kaolin was improved using magnetic separation in a two scale, the first one is a laboratory scale and the second one is a semi pilot scale. Results showed that the whiteness of kaolin was improved through the application of wet high intensity magnetic separation technique, as in a laboratory scale, about 48% by weight of a non magnetic fraction of kaolin with 0.7% $TiO_2$ and 0.55% $Fe_2O_3$ was obtained. The $TiO_2$% was decreased (3.56 % to 0.7%) with about 87% removal. This leads to increasing the whiteness of kaolin from 86% of the original kaolin to 91% in non-magnetic kaolin. While in a Semi pilot plant two products were obtained. The first is a non magnetic fraction which represents about 74% by weight with 0.56% $TiO_2$ and 0.49% $Fe_2O_3$. The second is a middling fraction represents about 10% by weight with 0.76% $TiO_2$ and 0.49% $Fe_2O_3$ [2].

TABLE 1

REFINING OF KAOLIN BY DIFFERENT FLOTATION TECHNIQUES [20].

| | Flotation process | | |
|---|---|---|---|
| | Froth | Carrier | Column |
| Wt.% Recovery | 84.75 | 76.06 | 84.50 |
| % $Al_2O_3$ | 37.22 | 37.22 | 37.40 |
| % $SiO_2$ | 46.95 | 46.68 | 46.84 |
| % $TiO_2$ | 0.68 | 0.61 | 0.38 |
| % $Fe_2O_3$ | 0.56 | 0.51 | 0.49 |
| % LOI | 13.17 | 13.68 | 13.55 |
| % Whiteness | 78 | 90 | 91.5 |
| References | Abdel-Khalek et al., 1996, 1998. | | Hassan A. 1997. |

### 2.5 The industrial application of the Egyptian kaolin

The prepared aluminum chloride from the kaolinitic clay may be used as a coagulant to remove the turbidity; however, it has problems due to its high correstivity that may lead to problems in usage and storage [35].

These Egyptian Kaolins can satisfy the local demand for filler, paper and ceramic industries 10 times for at least 50 years, in comparison to the current demand after its Beneficiation. Beneficiation of the Egyptian kaolin from different localities indicated their technical viability for ceramic production and as paper filler.

The Egyptian industry uses kaolin mainly in the following sectors: Tiles and ceramics, Cement, Alumino-silicate and alum, Sanitary and porcelain, Paper. The annual production of Egyptian kaolin used in ceramic products in 2016 was 441,020 tonnes. In the same year, the annual production of kaolin for paper, white cement and alum industries was found to be 128,000, 300,000 and 150,000 tonnes, respectively. In ceramics and paper production, the imported Kaolins represent about 26.83% of the kaolin consumption in these industries. This does not mean that the local kaolin, which supplies the industry with about 73.17% of its needs, satisfy the required specifications for ceramics and paper production. This is because the produced ceramics or paper is of low quality, due to the application of Egyptian kaolin without previous beneficiation to remove its associated gangue minerals. This also results in producing a large quantity of waste materials of ceramics and paper because they are out of specification. This clearly shows the vital role of upgrading the Egyptian kaolin to meet the specification of ceramics and paper industries to increase its economical value, reducing the quantity of waste or refused products and improving the economy of production of such products [9].

It is clear that United Kingdom is the main exporting country about 72.9%. of high grade kaolin to Egypt. This is followed by Turkey 10.86% and Japan 9.94%. The other countries exported about 6.3% of high grade kaolin to Egypt. This again indicates the importance of upgrading the Egyptian kaolin to meet the required specification of fine ceramics and paper coating. [36].

## 3. Nepheline Syenite

### 3.1 The properties and the uses of Nepheline syenite

Nepheline syenite is a light-colored alkaline igneous rock formed mainly of alkali feldspar and Nepheline in appreciable amounts. It is similar in appearance to coarse-grained granite but characterized by absence of quartz. Nepheline syenite is an indispensible raw material in glass and ceramic industries. The low fusion point of Nepheline syenite lowers the melting temperature of the mix, promoting faster melting, higher productivity, and fuel savings. In ceramics industry, the low fusibility temperature and high fluxing capacity of Nepheline allow it to act as vitrifying agent by contributing an early glassy phase that binds other constituents of the mix. This permits lower flux content in the ceramic body, increases alumina content in the mix, lowers the firing temperature, and shortens firing schedules. Furthermore, Nepheline syenite finds uses in the manufacture of paints and pigments as filler in paints, papers, rubbers, and plastics. It is also used in the manufacture of alumina, alkali carbonates, and Portland cement. Nepheline syenite, which contains no free silica (quartz),is used for the production of fillers and extenders in the area of plastics and paints, particularly when it is finely ground. Environmentally, it is less hazardous in handling and processing than other competing fillers and extenders [37].

### 3.2 The world production of Nepheline syenite

The major world commercial reserves of Nepheline syenite ores are located mainly in the former USSR, Norway, Canada, Turkey, and Brazil [37, 38]. The main producing countries of marketable Nepheline syenite are Russia, Canada and Norway, where their total production in 2016 reached 4.40 million tons. Most of the Russian Nepheline syenite production is consumed locally for the production of alumina [38].

### 3.3 The presence of Nepheline syenite in Egypt

The occurrence of Nepheline syenite in Egypt is restricted to the intrusion of the phanerozoic postorogenic alkaline ring complexes scattered in the southern sector of the Eastern Desert along the Red Sea hills, in five main localities as shown in Fig.3. These ring complexes form a circular igneous structures formed after magma solidification. The rocks in theses complexes are of the alkaline silica-free type rocks. These localities are limited by longitudes $34^{0}36'$ E and latitudes $22^{0}25'$ N [39, 40]. The largest reserves of these localities are at Abu Khruq area, where the probable reserve estimate is about 65 million tons [41]. The geographic coordinates of Abu Khruq area is at the intersection of longitude $34^{0}08'18''$N and latitude $24^{0}38'55''$E. Gebel Abu Khruq ring complex is formed of incomplete outer ring structure surrounding incomplete conical or stock-like intrusions forming the inner ring as shown in Fig.4.

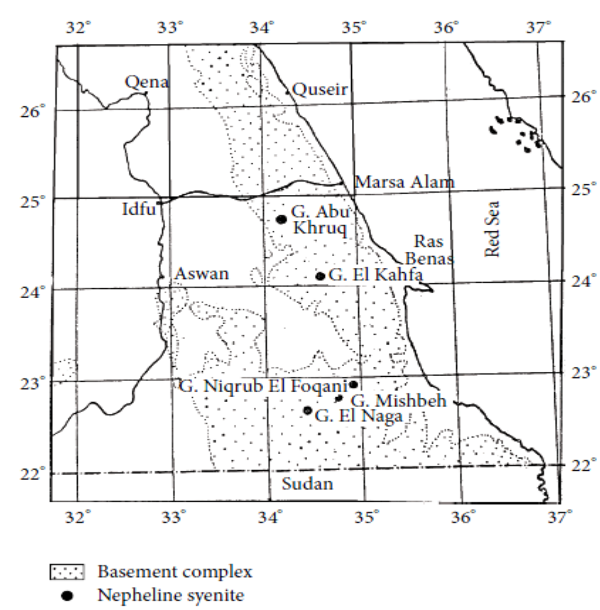


Fig. 3. Key map of Nepheline Syenite locations [42].

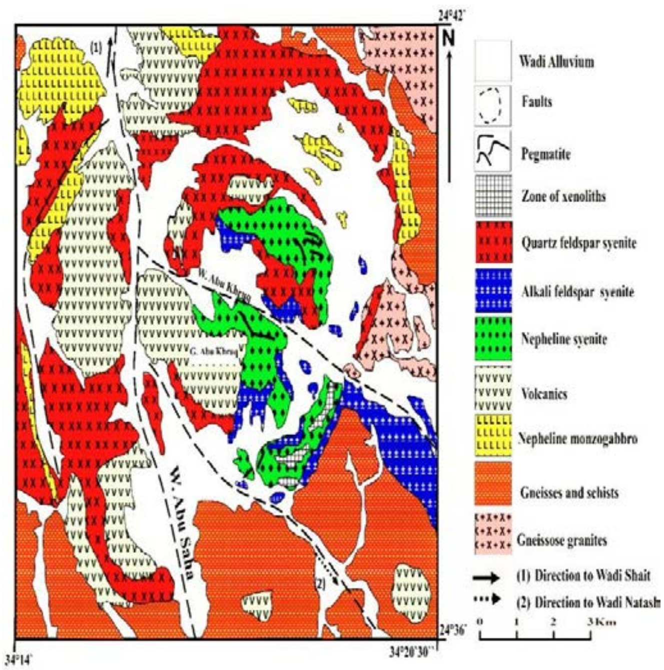


Fig. 4. Geological map of Abu Khruq Ring complex area (modified after El Afandy and Abdalla (2002)) [43].

The outer ring is occupied by alkali syenites which are essentially of orthoclase pethite, albite, aegorite-augite, aegirine, ferrorichterie, and biotite. Theinner ring consistsmainly of Nepheline syenites which are characterized by gray color. Close to the main shear zones, the gray color changes to pinkish gray and red colors where the mineralization became ferroginated and stained by red colored iron-bearing (hydrothermal) solutions. Geologically, it has been shown that these ring complexes are tied to form a chain running along the zone of Great African faults which run in the Eastern zone of Africa [44].

### 3.4 Mineral processing of the Egyptian Nepheline syenite

Thorough investigations of Nepheline syenite in Egypt were conducted from 1966 to 1969 by the Egyptian Geological Survey with the cooperation of Soviet geologists and aluminum experts [40]. The main Nepheline syenite deposit investigated was in the Jabal Abu Khuruq massif about 140 km northeast of the Aswan Dam. This massif is an oval complex consisting of an incomplete ring of alkalic syenite intrusive bodies surrounding a group of conical or stock like intrusive bodies of Nepheline syenite. The part of the massif on which most of the field work was done contains 26 million metric tons of Nepheline syenite in which the average content of the main components is 55.69% $SiO_2$, 21.08% $Al_2O_3$, 4.92% $Fe_2O_3$, 9.63% $Na_2O$, and 5.08% $K_2O$ [39]. Another part of the massif that was less thoroughly investigated was estimated to contain an additional 40 million-50 million metric tons of rock of similar composition. A large sample of the Nepheline syenite was studied in U.S.S.R by the All Union Institute of Aluminum and Magnesium (VAMI) in Leningrad. The VAMI metallurgical tests and similar tests by the Egyptian Geological Survey showed that alumina can be recovered from the Jabal Abu Khuruq Nepheline syenite when it is mixed with Egyptian limestone. The VAMI process yields valuable byproducts. An annual production of 100,000 metric tons of alumina would yield the following byproducts: 1.5 million-1.6 million metric tons of Portland cement, 75,000 metric tons of soda, and 30,000-35,000 metric tons of potash [40]. The investigation also showed the presence of at least nine other igneous ring complexes between the Nile River and the Red Sea. At least four of these complexes contain Nepheline syenite [45].

The amenability of beneficiation nepheline syenite from Gabal El-Kahfa locality of the Eastern Desert in Egypt, for different industrial applications was studied .The dry high intensity magnetic separation o f the ground samples using cross-belt separator at feed size -0.125+0.045mm gave nepheline concentrate having 0.58% $Fe_2O_3$. Using the induced roll magnetic separator, a concentrate having 0.61% $Fe_2O_3$ was obtained with the same size fraction -0.125 + 0.045 mm feed. Using the wet high gradient magnetic separator at a pulp density of 10% solid, it was possible to obtain cleaner nepheline syenite concentrates from finely ground feed, i.e. 100% less than 0.045mm. Product having 0.32% $Fe_2O_3$ was obtained with an alumina content of about 24%. When separation was conducted at a diluted pulp density (5% solid instead of 10%) in presence of sodium silicate as a dispersing agent, a nepheline concentrate assaying 0.2% $Fe_2O_3$ and 23.76% $Al_2O_3$ was obtained from a feed having 5.3% $Fe_2O_3$ and 17.1% $Al_2O_3$ at alumina recovery of 68.9%. The reverse flotation process for minimizing the iron bearing contaminants, a concentrate was obtained with El-Kahfa nepheline sample reaching 0.4% $Fe_2O_3$ and 23.5% $Al_2O_3$ from a feed having 5.3% $Fe_2O_3$ and 17.1% $Al_2O_3$. Combined magnetic separation and flotation of the finely ground samples yielded cleaner concentrates having 0.21% $Fe_2O_3$ and 23.63 % $Al_2O_3$ at recoveries of 81%. This means that combined magnetic separation - flotation technique improved the alumina recovery almost the same grade as the high gradient magnetic separation. Microscopic studies of the nepheline syenite concentrates show a brownish tinge of iron-bearing minerals which can be a surface coating which were not separated by mechanical attrition or disseminated fine grains in a matrix of syenite. This might explain the difficulty of obtaining high quality products that satisfy the international specifications for glass and ceramics production. However, these concentrates can be used in the local ceramics industry [46].

The amenability of dry beneficiation of two nepheline syenite samples from Gabel Abu-Khrug and Gabel El-Khafa localities in the Eastern Desert of Egypt to overcome typical problem of no water resources, as well as to reduce the operating cost of the beneficiation process was studied. Applying the dry high intensity magnetic separation of the ground samples using cross belt separator gave nepheline concentrates having1.3% and 0.58% $Fe_2O_3$ for Abu-Khrug and El-Kahfa samples, respectively. Using induced roll magnetic separator, as a free fall technique, showed better separation with doubling the feeding rate (24 kg/h) and at nearly the same magnetic field strength, concentrates having 0.72% and 0.61% $Fe_2O_3$ were obtained respectively. Application of rare earth permanent magnetic separator, resulted concentrates with a substantial decrease in the iron content, reaching 0.24% and 0.28% for Abu-Khrug and El-Kahfa samples, respectively. These concentrates satisfy the international specifications for amber glass and fiberglass production as well as local ceramics industries [47].

The beneficiation of the Nepheline syenite ore at Gabal Abu-Khruq ring complex in the Eastern Desert of Egypt to produce a high quality concentrate having high alumina content and the lowest possible iron content to be used in ceramics and glass raw material meals, as a flux and as a source of alumina was studied. By a combination of magnetic separation and reverse anionic flotation, a nepheline syenite concentrate assaying 0.2% $Fe_2O_3$ and 23.9% $Al_2O_3$ was obtained. Furthermore, the radioactive elements (uranium, thorium, and radon) decreased to some extent with decreasing the iron content of the products. The nepheline syenite concentrate for high quality glass and ceramics contained lowest concentrations of these hazardous elements than the feed was obtained [42].

## 4. ALUMINIUM INDUSTRY IN EGYPT

### 4.1The present and future of Aluminium industry in Egypt

In 1972 a scheme was initiated on the banks of the river Nile which was to culminate in the completion of one of the most exciting developments to rise from the desert in centuries. The aluminium industry started in Egypt, when the first company for the aluminium production was built that called Egyptalum. Egyptalum is largest Egyptian company for the production of aluminum in Egypt. Its main factory is known as aluminum compound. It has the largest aluminum plant in the Arab world.

After the construction of the High Dam, electrical energy was available. Therefore, thinking of building an aluminum factory was very essential in which aluminum extraction needs Alumina and high electrical energy for the electrolysis process.

Egyptalum Aluminium plant situated at Nag Hammady, some 100 kilometers north from Luxor to represent a commitment to investment in the future which reflects the philosophy of Egypt itself. Several factors were taken into consideration in the selection of Nag Hammady as the site of the Egypt Aluminium complex. One was its proximity to the High Dam and to the Nag Hammady electrical substation 326km. from Aswan . Another was its easy access to the port of Safaga, 210 km to allow the importing of raw materials and exporting products . And third important factor was the availability of skilled and semi-skilled labor in the area. In addition to the foregoing, there was a social consideration : an attempt to raise the standard of living of this part of upper Egypt Hence the choice of the location of Nag Hammady in 1972, and the construction of the first two potlines which took place in October 1975 and reached 5 potlines in July 1983. And new prebacked potline no. 6 started at October 1997.

That the company imports about one million tons of raw materials (alumina) annually , from abroad at the current dollar price, and thus the production cost increases according to international prices. Alumina imported entirely from Australia since the establishment of the plant because it is not available locally. In addition to about 20,000 tons of green coal per year are also imported. The company exports 60% of its production abroad to provide the dollar to purchase production raw materials, which reach about 400 million dollars annually. The Egyptian market consumes 140,000 MT and the rest of the production is exported to Europe, especially the countries of Italy, France, England and the Netherlands, North Africa, Tunisia, Morocco and Algeria, as well as to Arab countries such as Jordan, Syria and Lebanon in addition to Turkey.

The annual production of Primary Aluminum by Aluminium Co. of Egypt (Egyptalum) was more than 132,000 tons per year. This Capacity in 2010 reached 266,000 MT. In 2017 the capacity increased to be 320,000 MT with current intensity 210 KA/hr as shown in Fig. 5.


Fig. 5. Egyptalum annual production in 2017.

### 4.2 The problems that face Aluminum industry in Egypt

1- The increasing in the price of electricity in Egypt.
2- For increasing the amount of production, there must be new resources for electrical energy.
3- The increasing price of imported raw materials.
4- The increased demined for large amount of aluminium because of the new industries that depend on aluminium.
5- The increased number of population that at the same time need more increased in the produced aluminum.

### 4.3 Some suggested solutions for these problems

1- The using of the local ores and raw materials like kaolin and nepheline syenite after their upgrading by suitable methods.

2- Construction new stations for electrical energy to solve this problems.

3- The applications of modern technologies to compete on the world level.

## CONCLUSION

1- Kaolin in Egypt is localities in 3 main areas, namely Sinai, Red Sea coast, and Aswan Kalabsha with a low grade ranging from 26% to 35% $Al_2O_3$ , accessory minerals, and varying degree of ferrugination and $TiO_2$ are observed in different localities.
2- The applications of the Egyptian kaolins is influenced by its functional properties and its purity.
3- The large and important applications of Kaolins, clearly shows the vital role of upgrading the Egyptian kaolin to meet the specification of ceramics and paper industries to increase its economical value, reducing the quantity of waste or refused products and improving the economy of production of such products.
4- The upgrading of Egyptian kaolin from different localities showed that the Egyptian kaolin is hard and massive and it needs aggressive attrition scrubbing, after primary crushing, to disintegrate the matrix and separate the coarse gangue minerals.
5- The obtained kaolin concentrates are suitable for the ceramic industry and as filler in paper making. However, the still high $TiO_2$ content of Sinai and Red Sea kaolin hindered their application in fine ceramics and in paper coating.
6- When refining the kaolin concentrates by reducing their $TiO_2$ contents using the different techniques of flotation such as froth flotation, carrier flotation and column flotation. The column flotation process gave the best concentrate.
7- Cleaner concentrates of kaolin and assaying only 0.52% $TiO_2$ can be obtained by selective flocculation of the Red Sea kaolin pre-concentrate for minimizing its $TiO_2$ content, that satisfy the requirements of the local paper coating industry and fine ceramic production.
8- The whiteness of the Egyptian kaolin can be improved through the application of wet high intensity magnetic separation technique to decrees the percentage of $Fe_2O_3$ and $TiO_2$.
9- Calcination at $900^0$C, followed by acid activation and bleaching, showed a further decrease in $Fe_2O_3$ and $TiO_2$ impurities.
10- The extraction of aluminum from the Egyptian kaolinite can be improved by vibrating grinding and calcination. The reactivity of kaolinite was increased as grinding time and calcination temperature increase. These may be attributed to the disassociation of kaolinite structure.
11- The large reserves of Egyptian kaolinite can be used as source for extracting alumina for aluminium production instead of bauxite that is rarely found in Egypt.
12- The important prosperities of nepheline syenite makes it find itself in many vital industrial applications. Nepheline syenite is an indispensible raw material in glass and ceramic industries. Nepheline syenite finds uses in the manufacture of paints and pigments as filler in paints, papers, rubbers, and plastics. It is also used in the manufacture of alumina, alkali carbonates, and Portland cement.
13- The Egyptian nepheline syenite concentrates beneficiated by magnetic separation satisfy the international specifications for amber glass and fiberglass production as well as local ceramics industries.
14- By a combination of magnetic separation and reverse anionic flotation high quality nepheline syenite concentrate for glass and ceramics contained lowest concentrations of hazardous radioactive elements (uranium, thorium and radon) elements than the feed can be obtained.

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