Sic. J. Fac. Sci., Menufiya Univ. Vol. XVI (2002) (119 – 134)

Evaluation of kaolin bearing sandstone from Gabal El–Haythyat ,South Sinai, Egypt.

M. H. Aly

Institute of Desert Environment Researches (IDER) , Minufiya University,Sadat City, Minufiya ,Egypt

Abstract

The kaolin- bearing sandstone of Gabal El- Haythyat area belongs to Nagus formation, which has Cambrian-Ordovician age. The kaolin content in the sandstone is about 10% and occurs as discrete laminae and interstitial sand supporting matrix. Simple dry screening was carried out on a $40 \mu m$ sieve to obtain two fractions; namely quartz sand and kaolin above and below $40 \mu m$, respectively. Kaolin fraction was processed for ceramic evaluation. It shows a high content of alumina, (35.75%), as well as a white colour and a degree of whiteness of 84% after firing up 1500°C. The composition and properties of the two fractions indicate their suitability for ceramic, glass, paper and other industries.

Introduction

Clays form the backbone of conventional ceramic industries. Physical characteristics and functional properties of clays paved their way for their application. Kaolinite group of minerals are appropriate for different applications, beside the manufacture of ceramics, e.g. paper, paints, plastic and rubber. Each industry requires specific composition and properties (Highley, 1984). The grade of kaolin applied in ceramic industries is defined according to the chemical composition taking into consideration the contents of alumina, silica, iron and titanium oxides. High alumina content grades of kaolinite raw materials are used to produce alumino-silicate refractories. While beneficiated kaolins are used in the manufacture of luxary porcelain, sanitary ware, dielectric chinaware and fibre glass. This is due that beneficiated kaolin contributes to the homogeneity of composition and properties of the product.

The world production of kaolin is now running at the 16 m.tpa level. Of this figure, about 55% is used for paper industry. While the consumption by the ceramics and refractories sectors does not exceed 25% of the total output. Paints, rubber, plastics and some miscellaneous uses account for the remainder.

In Egypt, the main reserves of kaolin deposits are found in Sinai Peninsula, along Red Sea coast and in Aswan area. These deposits contain many impurities, e.g. iron and titanium bearing minerals and are mainly used for the production of off-white ceramic products.

Ibrahim et al., (1984) and (1993) studied some of the Egyptian kaolin raw materials and they stated that these kaolins are suitable for ceramic and paper industries after beneficiation. Several attempts were directed to the kaolin bearing sandstone in Sinai. Hegab et al., (1992) as well as Abdel Razek (1994) investigated some of these kaolins for ceramic and paper industries.

For this study the kaolin bearing sandstone of Gabal El- Haythyat, Gulf of Aqaba area, south Sinai, Egypt is choosen. Kaolin content is about 10% and is readily separable by dry sieving. The present study aims to concentrate and evaluate the white soft kaolin present in the kaolin bearing sandstone existing in Gabal El – Haythyat, south Sinail, Egypt.

Experimental procedure

A representative sample of kaolin bearing sandstone (50 kg) was processed on a laboratory scale by crushing with a rubber hammer to liberate the fine kaolin from the coarse sand. The sample was then dry screened using a 40 μm sieve. The screening process gave two fractions above and below 40 μm size. These two fractions were weighed to calculate the sand and kaolin recovery. The original sample as well as the - and + 40 μm, fractions were investigated for their chemical and mineralogical composition using X-ray Fluorescence (XRF), X- ray diffraction (XRD), differential thermal analysis (DTA) and differential scanning calorimetry (DSC) methods. Also, the morphology of the separated fractions was identified by scanning electron microscop (SEM).

The kaolin rich fraction (below 40 μm) was shaped by semi-dry pressing into disc samples with 2.50 cm diameter and about 0.4 cm thickness. The pressed samples were dried over night at 110°C and then fired in an electric furnace between 1225°C and 1500°C at a rate of 3°C/min up to vitrification . The physical properties in terms of water absorption, bulk density, apparent porosity, linear firing shrinkage and whiteness were measured according to ASTM standard - C20 - 74.

Results and discussion

The kaolin bearing sandstone of Gabal EL- Haythyat area Fig. (1) belongs to Nagus formation, Cambrian- Ordovician age, (Issawi, 1982). Kaolin in the sandstone occurs as discrete laminae and interstitial sand supporting matrix. This kaolin is believed to be the result of the decomposition of feldspar minerals of the neighbouring igneous and metamorphic terrain.

X-ray diffraction patterns of the original kaolin - bearing sandstone as well as the fractions above and below 40 μm are shown in Figure (2). Quartz, kaolinite and feldspar minerals are the main constituents. Quartz is concentrated in the coarse fraction (above 40 μm), while the kaolinite in the fraction less than 40 μm . The type of feldspar is belonging to plagioclase (albite). The average chemical composition of the kaolin – bearing sandstone sample and its fractions is presented in Table (1). The silica content reaches ≈ 95% in the original sample, which reflects the high content of quartz as well as the low content of alumina (3.52%) with other constituents amounting 0.5%. This indicates the high purity of kaolin – bearing sandstone sample and its high content of quartz sand and low kaolin content. This is confirmed by the weight percentage of the fraction separated on 40 μm sive (92.0%) and the – 40 μm fraction (8.0%) as illustrated in Table (1). The fraction below 40 μm shows relatively higher contents of Al_2O_3 (35.75%), TiO_2 (0.23%) and Fe_2O_3 (0.66%) as well as lower SiO_2 (49.93%) and CaO (0.06%) as compared with the corresponding of the + 40 μm fraction. The latter fraction contains 98.90% SiO_2 and 0.58% Al_2O_3 with minor amounts of Fe_2O_3 (0.024%), TiO_2 (0.06%) and CaO (0.14%). The high contents of Al_2O_3 (35.75%) and loss on ignition (13.53%) of the - 40 μm fraction reflect its high content of kaolinite mineral (Al_2O_3. 2 SiO_2 . $2H_2O$). Figure (3a,b) shows the predominance of different forms and shapes of kaolinite particles characterized by pseudomorphs of feldspar minerals after kaolinization. On the other hand, the + 40 μm fraction is composed mainly of quartz sand (SiO_2) as indicated from its very high content of SiO_2 (98.90%) and rather low Al_2O_3 (0.58%) and loss on ignition (0.60%). Figure (4) exhibits different shapes and sizes of angular quartz grains in the + 40 μm fraction.

The basic conditions for evaluation of first quality washed kaolins for ceramic industry are white colour after firing up to 1400°C and a maximum admissible content of total iron Fe_2O_3 (0.90% to 1.1%) and TiO_2 (0.30% to 0.50%). The sum of Fe_2O_3 and TiO_2 should not exceed 1.1% (konta, 1979) or 1.2% for second- rank quality kaolins and a maximum content of alumina 36% (and 34% for the second quality kaolins). In fraction below 40 μm, the level of the total colouring oxides, (Fe_2O_3 and TiO_2) amounts ,0.89%, which is lesser than that of high grade kaolins. Moreover, the content of Al_2O_3 (35.75%) lies in the group B according to Seger's classification (Schicht, 1967).

The silica in the form of quartz is concentrated in the fraction above 40 μm. Therefore, this fraction can be used as a glass-sand raw material and can be directed to the manufacture of glazes, frit and ceramic bodies. Also, this fraction with its low alumina content (0.58%) can be used in the production of refractory superduty silica brick.

The differential thermal analysis and differential scanning calorimetry curves are shown in Figures (5 and 6) . The DTA curve, of the original sample, shows a very weak endothermic trough at about 575°C, endothermic peak at about 780°C and exothermic peak at about 980°C. The first endothermic trough at 575°C is due to the low- high polymorph quartz transformation. The endothermic peak at 780°C is probably due to the presence of trace amount of calcite ($CaCO_3$) mineral. The exothermic peak at 980°C is related to with SiO_2-rich spinel crystallization (Grim , 1962).

The + 40 μm fraction shows similar DTA Curves as the original Sample. On the other hand, the -40 μm fraction which is rich in kaolinite shows a broad and intense endothermic reaction between 450 and 700oC with an intense exothermic peak at about 980oC. Both of these peaks are characteristic for the dehydroxylation of kaolinite mineral followed by the recrystallization of some alumino-silicate with spinel structure (Grim,1962).

The presence of quartz sand is confirmed from the DSC curve shown in Figure (6). The intense endothermic peak detected at 575oC is relevant of low-high quartz polymorphic transformation. The intensity of this peaks is increased in the order - 40 μ m fraction < original sample <+40 μ m fraction.

The fraction less than 40 μ m was choosen to carry out the tests needed for ceramic industries. Table (2) shows the results of physical properties of samples fired between 1225°C and 1500°C.As expected, as the firing temperature increased the water absorption and apparent porosity decrease with the increase of bulk density and firing shrinkage. These properties are taken as indication for the degree of vitrification. During firing below 1000°C, the fired samples loose their adsorbed and lattice water . At about 1000°C, the decomposed meta-kaolinite components, (alumina and silica) react together and a silica-rich spinel is formed, followed by the crystallization of mullite up to 1400°C, Grim (1962). Figure (7) exhibits the XRD patterns of the samples fired at 1400°C as processed from the - 40 μ m fraction. It is noticed that the detected crystalline phases are mullile, quartz and cristobalite. Silica is released and crystallizes as cristobalite. The formation of mullite and cristobalite is usually controlled by the vitrification range, which is the temperature interval between the early point for liquid phase formation and the development of enough liquid to vitrify the fired samples without deformation.

From the obtained data of Table (2), it is noticed that the fired samples start to vitrify at about 1300°C and the end of its vitrification range occurs at ≥ 1500°C. At 1300°C and 1500°C, the values of water absorption and bulk density are ranging between 10.09 and 2.23% as well as 2.12 and 2.38 g/cm3, respectively. Moreover, the complete vitrification can be expected to occur after firing above 1500°C. This Fraction contains high content of kaolinite and low content of fluxing oxides. Also, the whiteness of the samples fired at 1400°C with the colour observed by the naked eye are listed in Table (2). The fired samples show a white colour with a whiteness of 84%.

Conclusions :

Simple dry screening method can be easily used to produce high grades of kaolin (8%)as well as 92% quartz sand fractions. The kaolin is of white colour when fired at 1400°C and can be used for luxury porocelain, sanitary ware, dielectric chinaware and fibre glass production. While the sand can be used as a glass-sand raw material and can be directed to the manufacture of glaze and frit and for ceramic bodies.

Reference

Abdel Razek, M.M., (1994): Geology and processing trials on kaolin-bearing sandstone from Gulf of Aqaba and Abu Zeneima areas, Southern Sinai, Egypt.; Proceedings of the first Int. Symp. On Ind. Application of Clays.

Grim, R.E. (1962): Applied Clay Mineralogy, McGraw Hill Book Co. Inc,. New York – Toronto- London.

Hegab, O.A; Serry, M.A; kora, M.; and Abu Shabana, M. (1992): Suitability of some kaolins from west-central Sinai for use in ceramics and paper industries; Academy of Scientific Research and Technology, a symposium held jointly with Geol. Surv. And Mining Authority, Cairo, Egypt.

Highley, D.E.(1984): Mineral Dossier No.26: china clay. London , HMSO.

Ibrahim, D.M.; Sallam, E.H et al., (1993) ; Up-grading of Egyptian kaolin to meet specifications for paper and ceramic industries ; Joint research project between National Research Center and Academy of Scientific Research and Technology, Cairo, Egypt.

Ibrahim, D.M.; Serry. M.A et al., (1984): Chareaterization of south Sinai kaolin deposits; Joint research project between National Research Centre and Sinai Manganese Company.

Issawi, B; and Jux, u. (1982): Contribution to the stratigraphy of the paleozoic rocks in Egypt, Geol., Surv. Egypt, Vol., 64.

Konta, J. (1979): Deposits of ceramic raw materials (1 st part); Ceramic Monographs-

Handbook of Ceramics, Monograph 1.1.3 Verlag Schmid Gmb H, Freiburg i-Brg.

Schicht,R (1967): Die Lagerstätten der keramischen Rohstoffe. Handbuch der keramik, Gruppe IA2. frebirg i. Brg.

Table (1) Chemical composition of kaolin bearing sandstone (original sample) as well as above and below 40 μm fraction samples.

Size	Quantity %	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	Na_2O	K_2O	L.O.I
Original sample	100	94.75	3.52	0.05	0.18	0.22	0.01	0.01	1.50
Above 40 μm fraction	92	98.90	0.58	0.02	0.06	0.14	0.01	0.01	0.80
Below 40 μm fraction	8	49.93	35.75	0.23	0.66	0.06	0.01	0.01	13.35

Table (2) Physical properties of the -40 μm fraction sample after firing up to 1500°C

Temp. °C	Physical properties				Whiteness (%)	Colour
	Water absorption (%)	Bulk density (g/cm3)	Apparent porosity (%)	Linear firing shrinkage(%)		
1225	12.22	2.03	25.19	4.15	84	white
1300	10.09	2.12	21.36	4.91		
1400	8.61	2.19	18.83	5.60		
1500	2.23	2.38	5.30	7.92		

Fig(1) Panorama View of Gabal El-Haythyat area, South Sinai, Egypt.

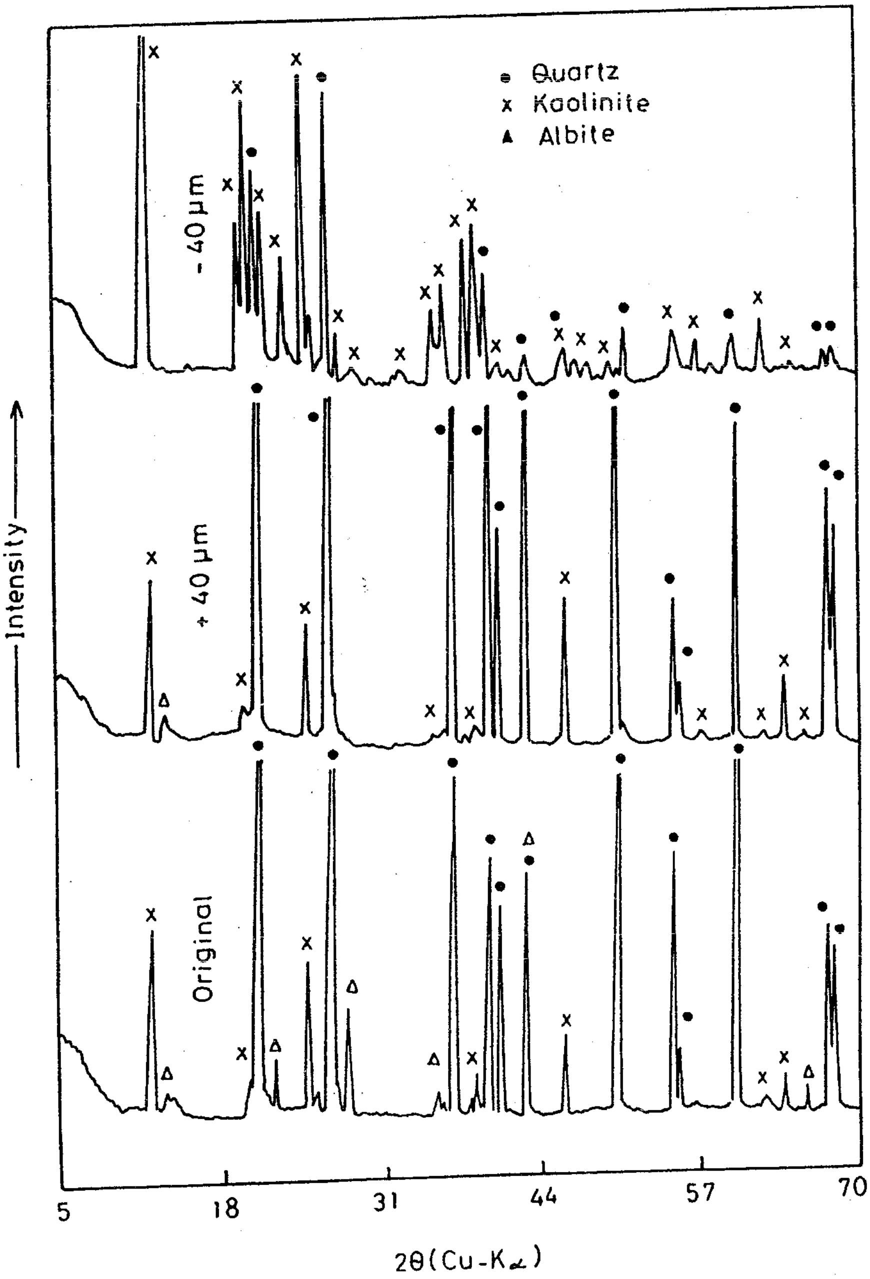

Fig.(2) XRD patterns of the original kaolin-bearing sandsotne sample as well as its two fractions above and below 40 μ m.

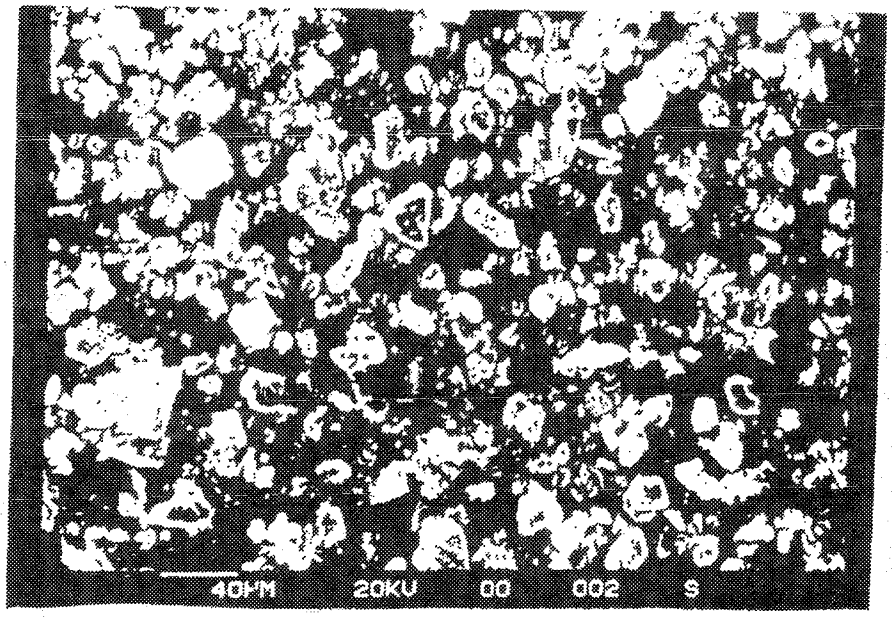

Fig.(3a) The SEM micrograph of the –40 μ m Fraction. (X:250)

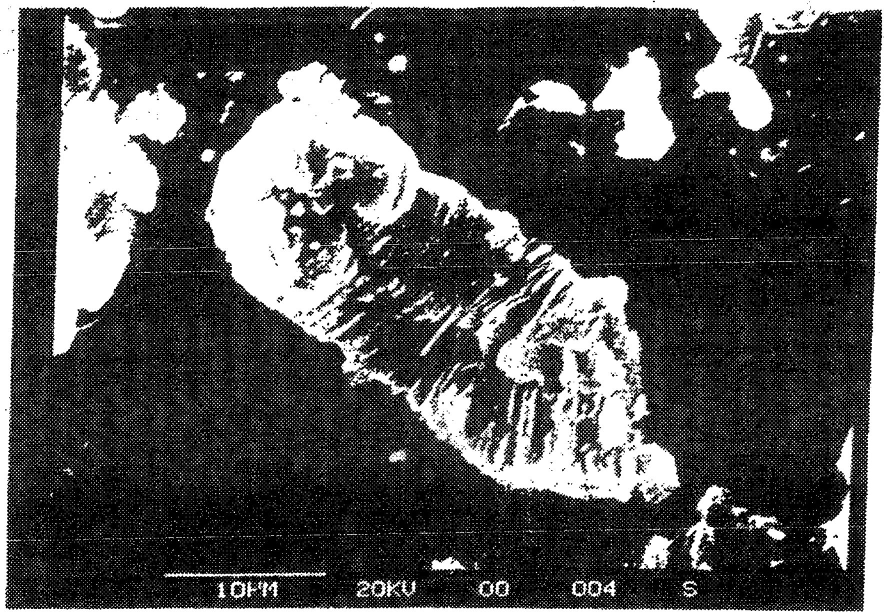

Fig.(3b) The SEM micrograph of a pseudomorph feldspar grains detected in the - 40 μ m fraction. (X:2000).

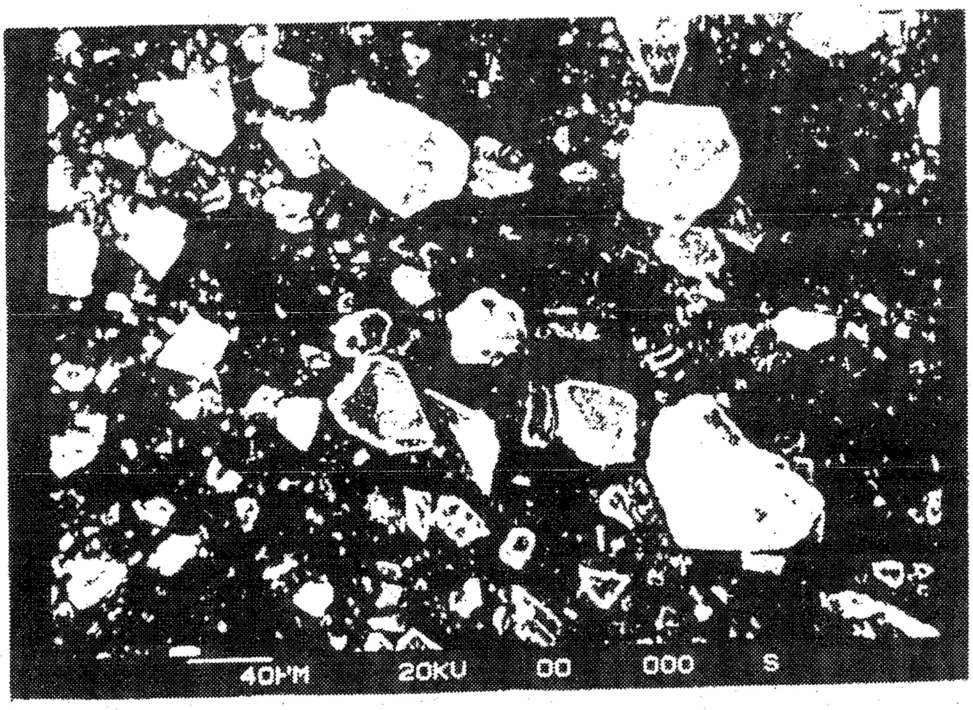

Fig.(4) SEM micrograph of quartz grains in the +40 µm fraction. (X:250)

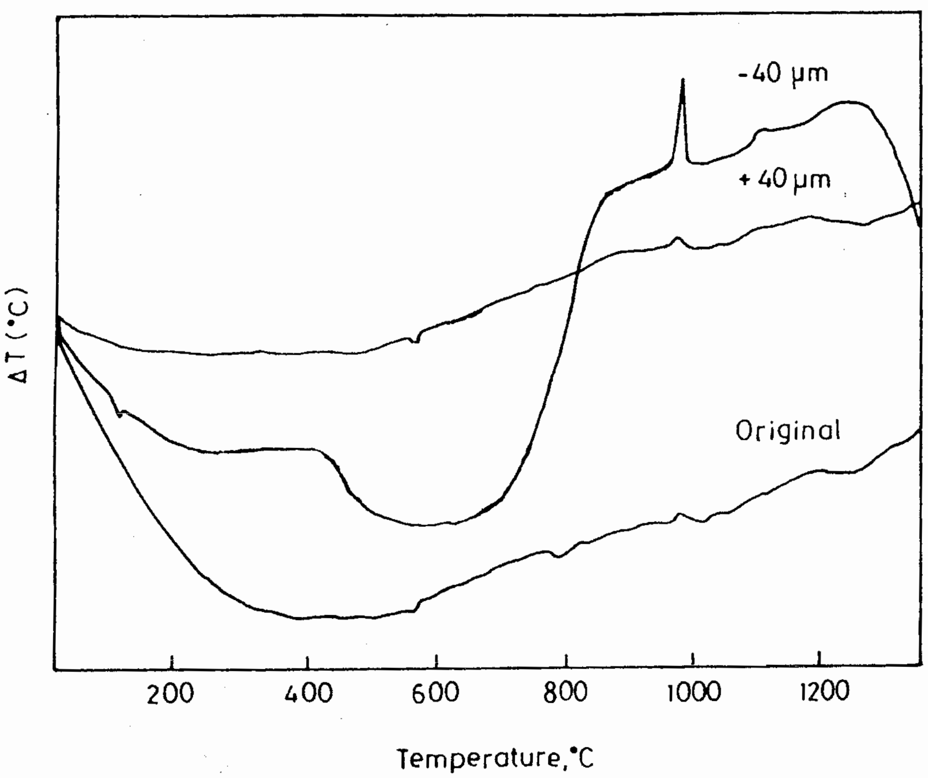

Fig.(5) DTA curves of the original kaolin-bearing sandsotne sample as well as its fractions above and below 40 μ m.

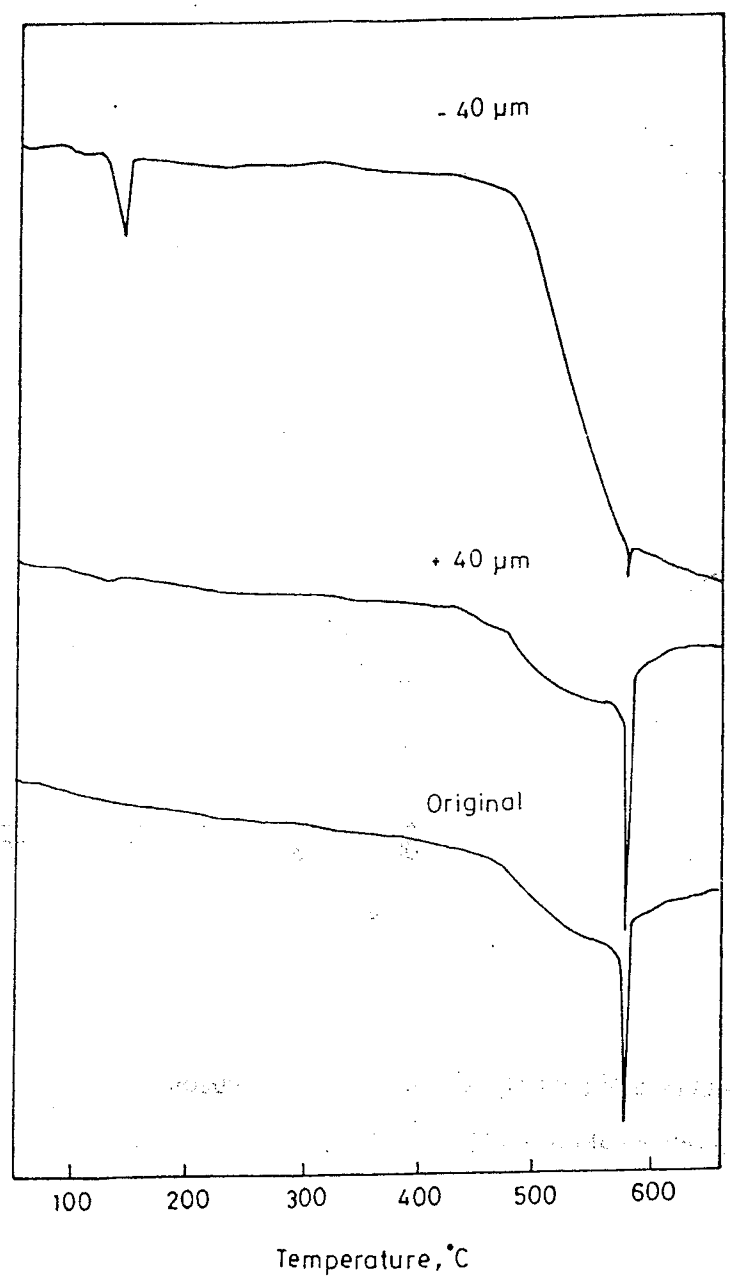

Fig.(6) DSC curves of the original Kaolin-bearing sandsotne sample as well as its fractions above and below 40 μ m.

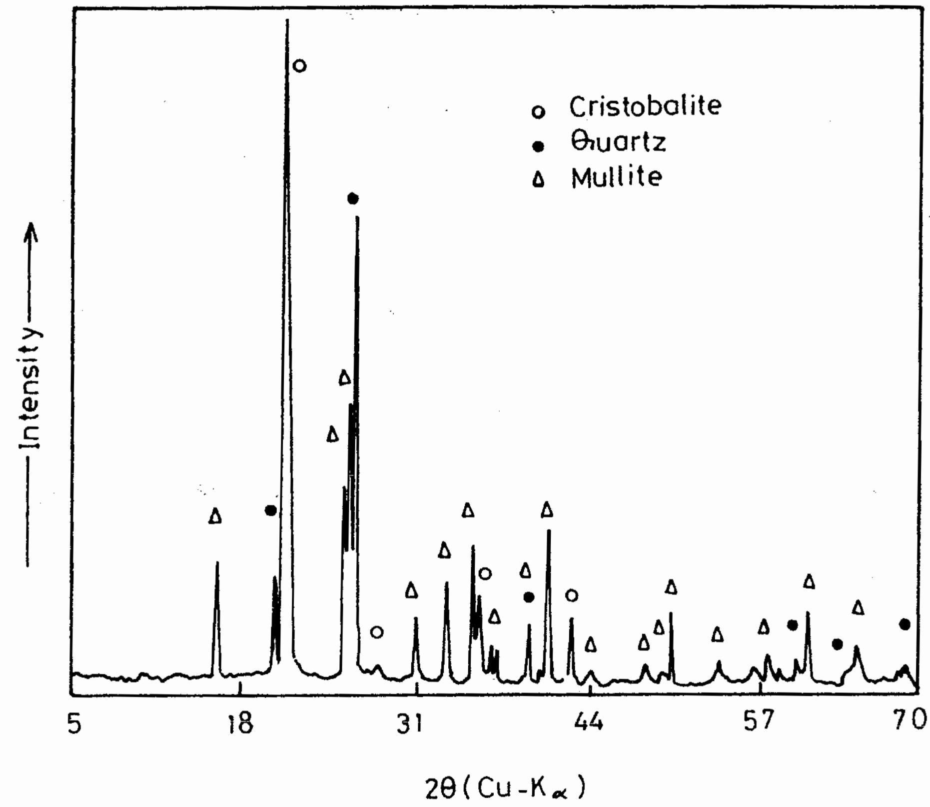

Fig.(7) XRD patterns of the -40 µm fraction after firing at 1400 °C.

تقييم الحجر الرملى الحاوى على الكاولين

جبل الحيثيات – جنوب سيناء

أستخدم فى هذه الدراسة الحجر الرملى الحاوى على الكاولين بمنطقة الحيثيات – جنوب سيناء وتم تركيز وفصل الكاولين من الرمل باستخدام طريقة النخل وتم الحصول على ركازين الاول اكبر من ٤٠ ميكرون والثانى اقل من ٤٠ ميكرون وتم دراسة وتقييم الركازين وقد اظهرت الدراسة ان الركاز الاقل من ٤٠ ميكرون هو كاولين عالى النقاوة وذو درجة بياض عالية ويمكن استخدامه فى صناعة السيراميك والحراريات والورق. اما الركاز الاكبر من ٤٠ ميكرون هو عبارة عن رمال الزجاج ويمكن استخدامها فى صناعة الزجاج والجليز والفرتا..