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Original article

ANALYTICAL STUDY OF ARCHAEOLOGICAL POTTERY SARCOPHAGUS, GRECO ROMAN PERIOD, FROM SAQQARA, EGYPT

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Abstract
The current study describes the Archaeological pottery shreds which were found in the excavation made by the Supreme Council of Antiquities (SCA) in Saqqara regions in the western side of the pyramid of Djoser. To perform this study, several analytical instruments were used; including X-ray diffraction (XRD), scanning electron microscopy–energy dispersive spectroscopy (SEM-EDS)., Physical and mineralogical analyses were made by using the thermal behavior (thermo gravimetric analysis (TG) and differential thermal analysis (DTG). The results of these analyses allow the establishment of conclusions about several aspects of their manufacture, It was found out that the discovered shreds comprise a group of the pottery sarcophagus that belong to the Greco Roman period (570-525B.C). It was, also, found that the texture of the pottery was made using a large quantity of medium to coarse plant residues which is one of the most characteristic features of Nile fabrics. The color of the pottery fracture is reddish on the outer part of the wall of the Serco but is black in the middle. The firing temperature was uneven and the hardness of the pottery was medium. The sarcophagus was handmade shaping. All these characteristics belong to the Nile C group. The sarcophagus was fully restored, including cleaning, constructing, completing and coloring.

Keywords: *Pottery, restoration, Saqqara, Greco Roman period, Analytical techniques, Sarcophagus*

1. Introduction
1.1. *Archaeological and historical study*
The necropolis of Saqqara had an extremely long history started around 2650 B.C. [1]. It contains a number of monuments, which confirms the developmental pattern in the history of the tombs, temples, pyramids, and the ancient Egyptian daily life [2]. It is located on the western bank of the Nile about 20 km to the south of Cairo, and 15 km to the north of Giza plateau. The necropolis is a huge area stretching almost 12 km from north to south and about 7 km from the eastern to western desert. The modern name "Saqqara" was probably derived from the name of the mortuary daily sokar. It is used as a royal necropolis of the 1st and 2nd dynasties, where, it contains the temples of god Ptah and tombs of high official and dignitaries as well, such as the tombs of Psamtik, Djen and Hebu. In addition, it contains numerous pyramids such as the famous Step pyramid of Djoser, which is sometimes referred to as the step tomb due to its rectangular base, as well as a number of mastabas. Within the same

context, this necropolis is continually used by some Coptic, who built large and important monasteries as St, Jeremiah which was built in the 5th century AD [3].

1.2. *Documentation*

The sarcophagus of pottery, fig. (1-a) was found in Saqqara. It was discovered in the excavation area, fig. (1-b). The shape of the Sarcophagus is oval for the human bodies, which is characterized as a broad range of the highest in the shoulders and narrow it down at the feet. This form is commonly used over the centuries as characterized by the lack of cover from the top of the total length of the coffin was about 172 cm., and display it in the wider part about 54 cm. The general case of the object was good except for some dusty dirt. Missing part of the base in the form of triangle dimensions are of about 8×15 cm. It had been broken into three parts. Also, it had a gray spot on one site, and a big crack over the base.

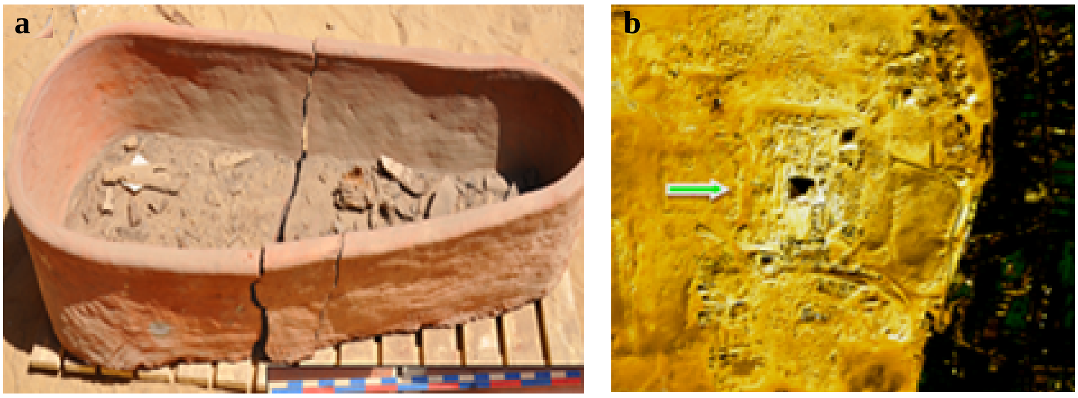

Figure (1) Shows **a**. The Sarcophagus of pottery in the excavation site, **b**. the map of the excavation the area in Saqqara

1.3. *The uses of pottery*

Through Egyptian Polish excavations in Saqqara, a cemetery dated back to the Roman era was found to the Western side of Djoser pyramid. In addition they found some buried mummies, where, some of them wrapped mat and the others had put in the coffins of pottery such as our case study.

2. Materials and Methods

2.1. *Visual examination*

The samples were examined using naked eye as well as magnifying glass (x-10) to identify the type of the components of the Sarcophagus. Furthermore, they help in discovering the structures, the roughness, porous fabric, and gaps in the samples.

2.2. *X–ray powder diffraction (XRD)*

Preliminary analysis by X–ray powder diffraction (XRD) allows the identification of major crystalline phases in the pottery body. XRD was performed with an *X' Pert PRO analytical diffract meter equipped with conventional X-ray tube (Cu-Kα) radiation (k=1.5406 Å) with power condition 45Kv and 40 MA.* The XRD patterns were measured in the range of 4 to 70° (2θ) with the step size of 0.02° and 30s counting per step at room temperature (25 °C). It was used to study the mineralogical composition of the pottery.

2.3 Scanning electron microscopy and micro chemical (EDX-SEM)

The SEM-EDX was used to determine micro textural and micro chemical features of the sarcophagus body. The investigations were done using *SEM-EDX were performed with JEOL 5410 scanning electron microscope* *equipped with an Oxford EDX Microanalysis system and conditions (25KV, 0.28 NA, ~1 µm beam diameter, 60 scounting time).*

2.3. *Thermal analysis*

It is a very important method used for materials characterization and control of the different reaction process of sand. The thermal analyses were performed on a *TGA/SDTA 851 Mettler Toledo equipment*, in a temperature range 35–1200 ºC (10 ºC min^{-1}) in an air stream with a heating rate of 5 ºC min-1, using alumina crucible.

3. Results

Visual examination; It had broken into three parts. Also, it had a big crack over the base, fig.(2) that shows the shapes drawn and the condition of deterioration of the sarcophagus. **XRD** results are listed in tab. (1) and fig. (3-a), that show the XRD pattern of black pottery and fig. (3-b) that shows the XRD pattern of red pottery. **EDX-SEM**; resulted data are listed in tab. (2) and fig. (4-a, b, c) that show SEM of black pottery and fig. (4-d, e, f) that show SEM of red pottery. **TGA** results of the analyzed sample of the black part are shown in fig. (5-a), where fig. (5-b) shows TGA results of the red part of the sample.

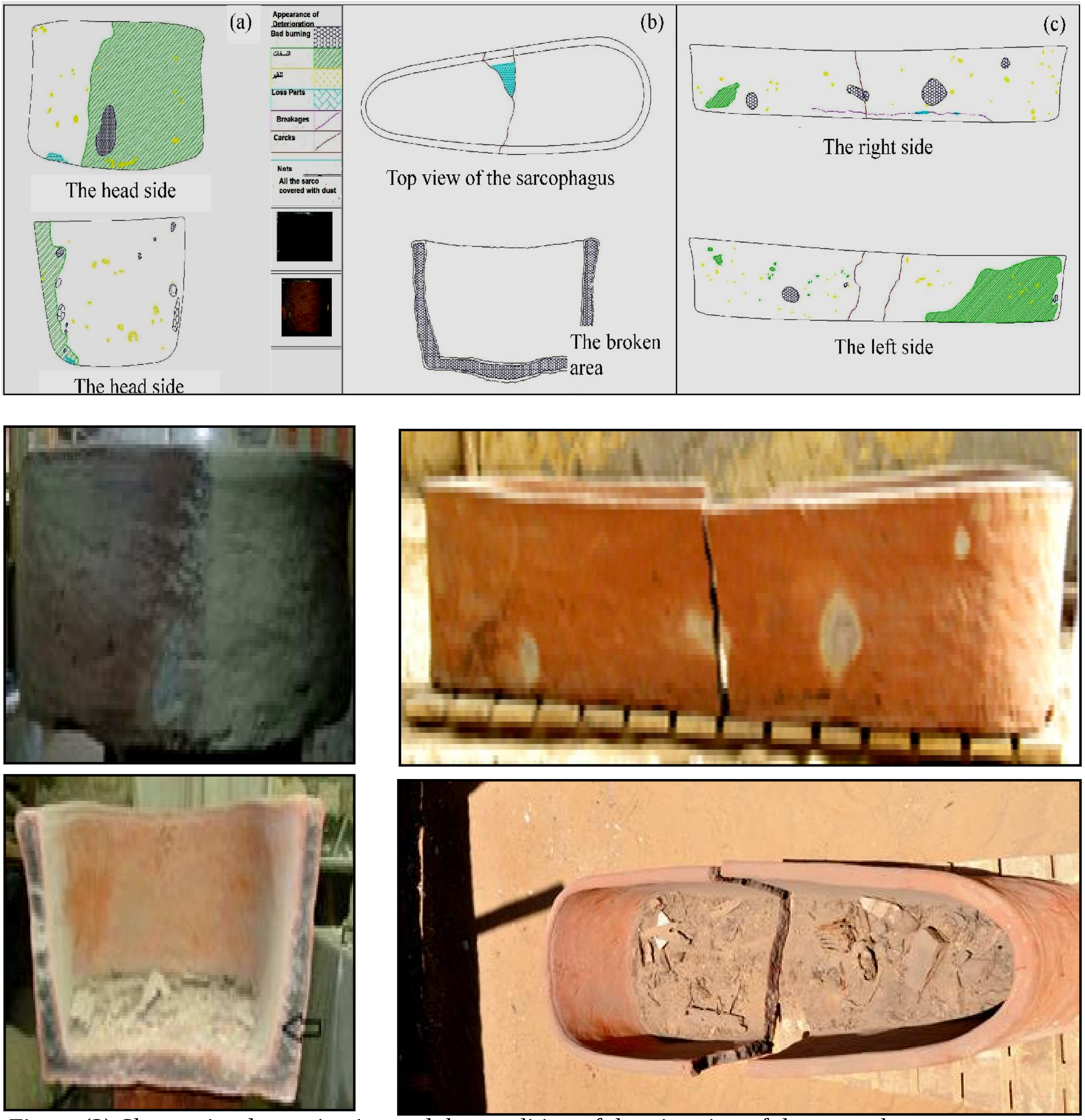

Figure (2) Shows visual examination and the condition of deterioration of the sarcophagus.

Table (1) Shows X-Ray diffraction pattern of the black and red part of the pottery.

Red Sample		Black Sample	
Mineral	***Chemical Formula***	***Mineral***	***Chemical Formula***
Quartz	SiO_2	Quartz	SiO_2
Hematite	Fe_2O_3	Magnetite	Fe_3O_4
Albite	Na $AlSi_3O_{10}$	Albite	Na $AlSi_3O_{10}$
Ilite	$KAl_2Si\ _3AlO_{10}$	Halite	Na Cl
		Gypsum	Ca $SO_4.2H_2O$

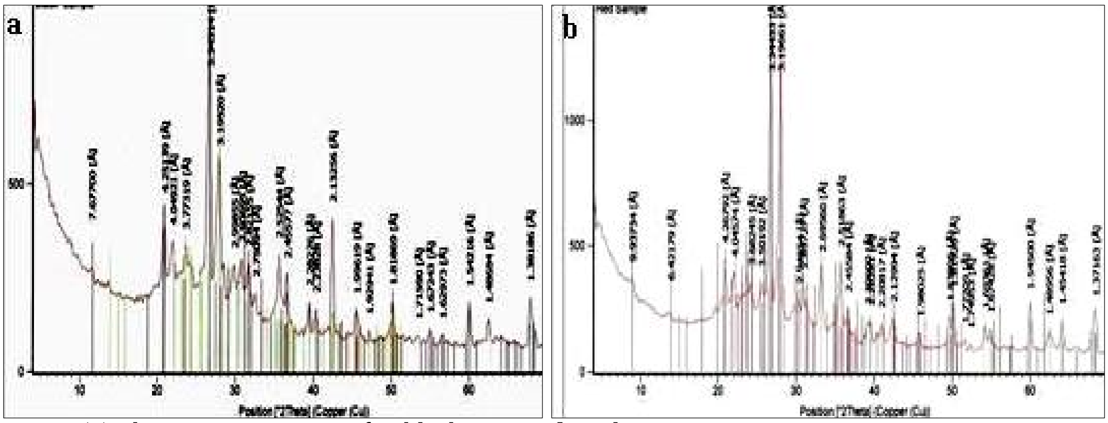

Figure (3) Shows XRD patterns of **a**. black pottery, **b**. red pottery

Table (2) shows EDX pattern of the black and red part of the pottery.

Elemental	***Al***	***Si***	***P***	***S***	***Cl***	***K***	***Ca***	***Ti***	***Fe***	***Cu***	***Zn***
Black part	7.09	40.71	5.33	0.04	3.77	2.16	7.92	1.62	30.00	0.38	0.98
Red part	7.58	40.25	5.78	0.50	1.48	4.12	7.58	1.71	28.43	0.54	1.01

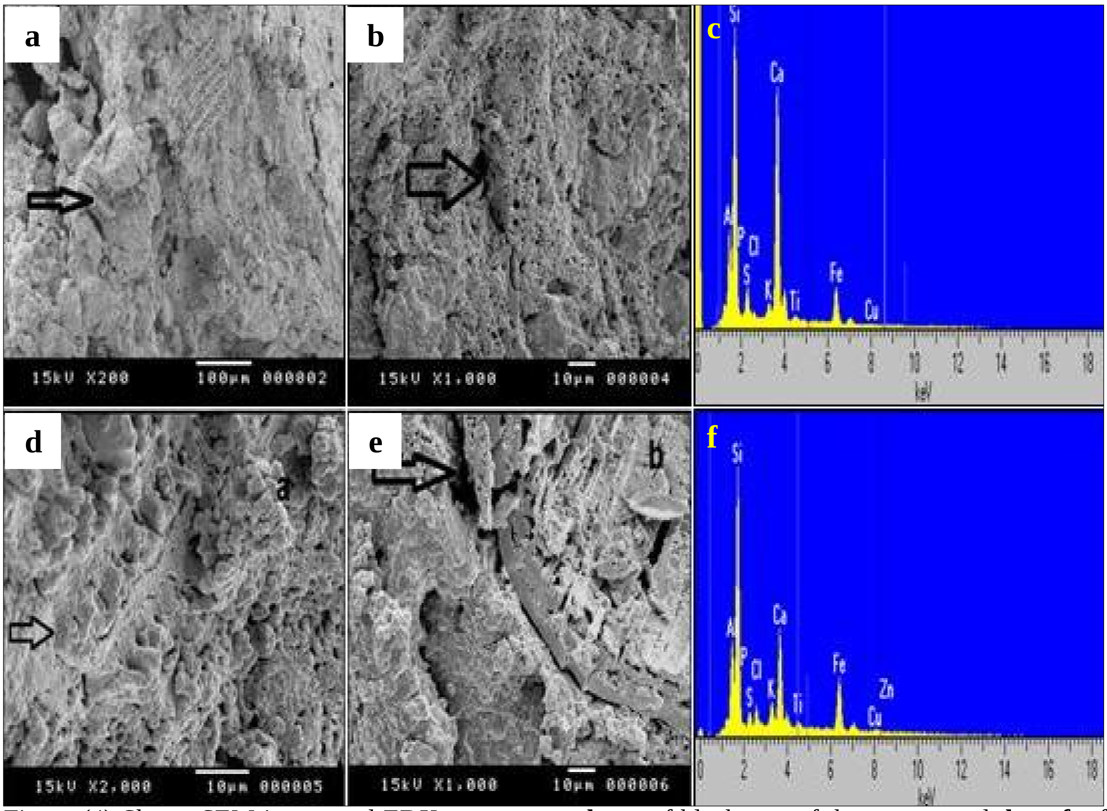

Figure (4) Shows SEM image and EDX spectrum **a**., **b**., **c**. of black part of the pottery and **d**., **e**. **f**. of the red part of the pottery

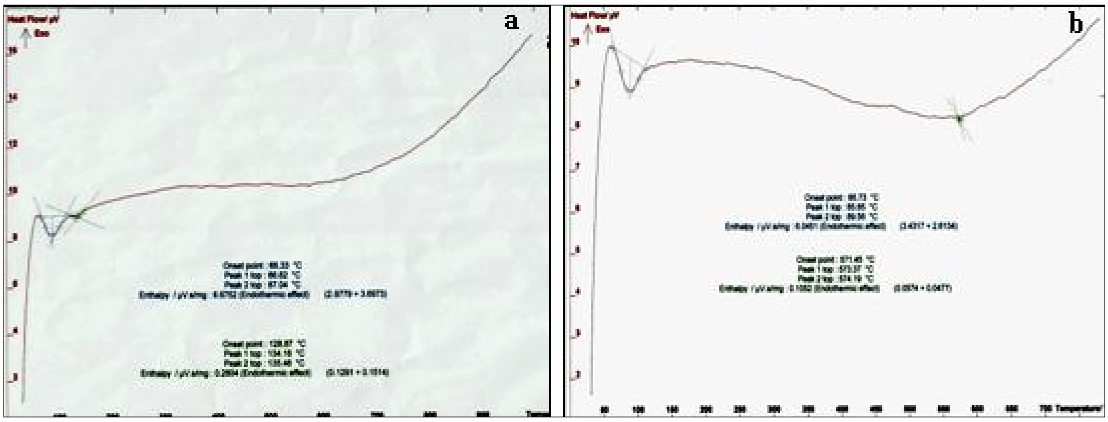

Figure (5) Shows TGA results for the analyzed sample **a**. of black part, **b**. of red part.

4. Treatment and Conservation Methods for the Selected Object.

4.1. *Cleaning processes*

Mechanical cleaning, on one hand, was done using some types of brushes and scalpels to remove sticks and loose dust from the pottery sarcophagus. Then, the loosed remains were completely pushed using air currents to get rid of fine dust. On the other hand, chemical cleaning processes were done using distilled water and a mixture of water, ethyl alcohol and purified by a 1:1 has given good results in the cleaning and removal of dust [4].

4.2. *Assembling the separate parts*

The three separated parts of sarcophagus were compiled using chopsticks fiberglass with appropriate diameter. The length of chopsticks fiberglass is (8 mm), and they were chosen depending on the thickness of the sarcophagus wall which is bigger (2 mm). The chopsticks fiberglass were replaced in the holes at regular intervals calculated according to the weight of the sarcophagus [5] using mixture of Paraloid B 72 dissolved in acetone 15 % with a paste of Micoroballon.

4.3. *Reconstruction material and completion of lost part*

The object under study has lost a part of its base, but the presence of the sarcophagus end and its thickness, in addition to direction of restructuring make the process of reconstruction easier. According to Buys and Oakley [4] and after my experiments, elastic dough was created; it composed of brown pottery powder (Grog 70 %), (brown Phenolic Microballons 30 %) and (paraloid B.72. 20 %) in acetone. This material gives a smooth surface that differs from the original, and it can be manually shaped. Also, it has suitable hardened after dryness with limited shrinkage and it can be re-colored either during or after processing. In addition, it is characterized by a suitable covering index with less mechanical force than the original body. However, it should not affect the archaeological piece chemically. The reconstruction process was done by the free hand similar to the way of the deliberated shaping according to the original part. The process was done after making some experiments to gain an access paste that can give specifications that closely resemble its original pottery form and allow the formation similarly.

4.4. *Coloring*

Some coloring experiments using acrylic reversible colors were made with pieces of the dried dough to define the appropriate one. Water emulsion of red ocher (Red iron oxide "Hematite") as a natural color was used for realizing this target. Finally, some re-cleaning processes were done to eliminate any remains from the sarcophagus surfaces and in its final stage, as shown in fig. (6-a, b, c, d)

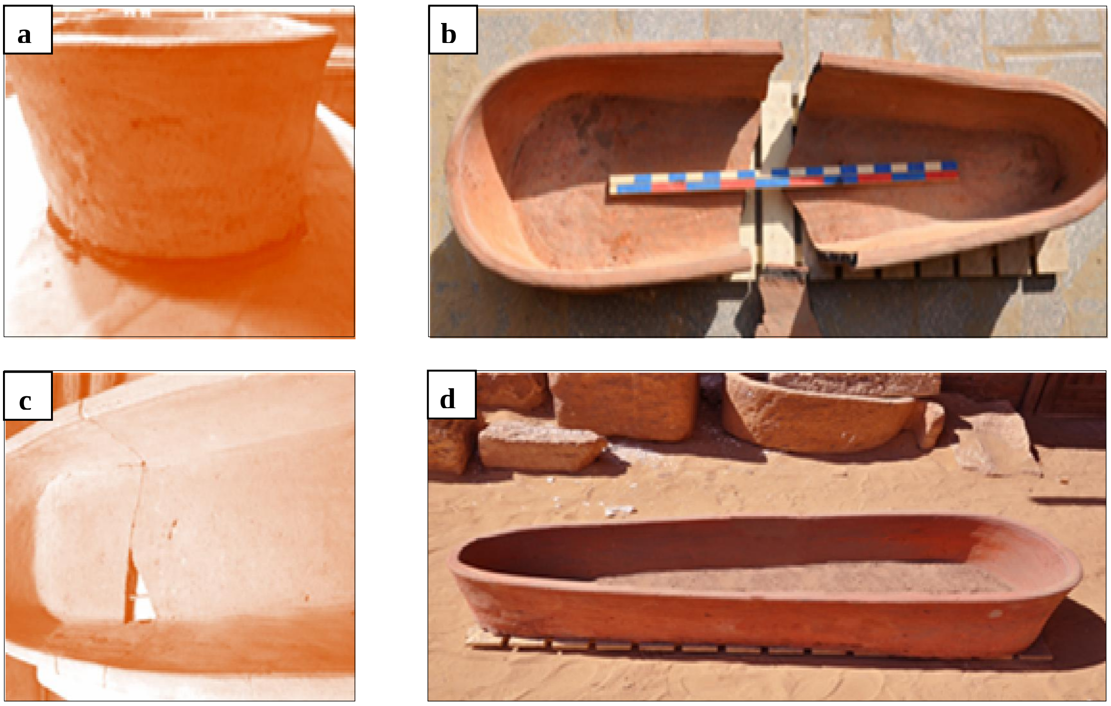

Figure (6) **a**., **b**., **c**. Shows the Sarcophagus of pottery after cleaning, **d**. final stage of the Sarcophagus

5. Discussion

This study is an analytical study of the pottery sarcophagus dated to (570-525 B.C) in Saqqara region, which is considered an important city in the Egyptian history. XRD analysis of the pottery bodies suggests the presence of three sources of silicate minerals as Quartz (SiO_2), Albite (Na $AlSi_3O_{10}$) and Ilite ($KAl_2Si_3AlO_{10}$) in both two samples [6,7]. This high content of silica indicates that the used clay has a high proportion of silica that owes to either fillers or the composition of minerals. In addition, it could be attributed to the adding of quartz with clay as additive for its improvement [8]. Moreover, a proportion of red iron oxide Hematite (Fe_2O_3) was found, it works as a strong aid during melting process. It, also, gives the red color to the pottery body where the final color of pottery depends on the chemical state of iron [9]. In our case, it was completely oxidized in the case of hematite in the red part of pottery, but in the black part Magnetite was found causing the black color. The presence of Gypsum Ca SO_4. $2H_2O$ in the black part as a secondary mineral could be explained due to some variables; the 1^{st} is the reaction process after the burning, the 2^{nd} is the effects during burial time and the 3^{rd} is the effect of moisten soil and crystallization cycle [10]. Halite is salt mostly presence in the Egyptian soil. It is considered one of the most aggressive salts that affect archaeological objects, particularly with continuous alternative cycles of wetting and drying [11]. From these revealed results, we conclude that all the pottery was made of Nile clay containing quartz. Through using the SEM, it could be noted that the investigated samples are characterized by the presence of internal structuring composition and defined fabric. In addition to the homogeneity with the appearance of some gaps, plant debris and, the shape of grains in terms of coherence and fragmentation. All these characteristics are the advantage of the pottery of the Nile C type [12]. The thermal effects were observed in the temperature range from 25 to 1000 °C. They were comparable to those previously obtained in similar Roman materials. The mud turning from the first fragile hydrous form to the solid form is not affected by water. Where the oven temperature is between (500-600 °C) it turns the Kaolinite (hydrous aluminum silicate) into amorphous glass-like material at these grades of temperature and does not return again to the case of crystallization except at a high degree of 1000 °C according to the following equation.

$$\underset{\text{crystalline}}{\underset{Al_4Si_4O_{10}(OH)_8}{\text{Kaolinite}}} \xrightarrow{560\ °C} \underset{\text{amorphous}}{\text{Meta Kaolinite}} \xrightarrow{1000\text{-}1100\ °C} \underset{\text{crystalline}}{\underset{3Al_2O_3.\ 2SiO_2}{\text{Mullite Kaolinite}}}$$

Finally, it could be said that the appropriate temperature to burn the ancient Egyptian pottery, ranges from 550-700 °C [13]. In addition, it could be claimed that the properties of the clay differ from one type to another according to the difference in chemical composition. Also, water significantly affects the characteristics of the clay used [14] (Nicholson, 1985) which greatly affects the degree of firing.

6. Conclusion

The mineralogical and morphological analyses and their analytical data allowed not only the characterization of the pottery sarcophagus, but also the formulation of some hypotheses regarding their specific manufacturing techniques. Technology and manufacture, materials used of the Sarcophagus located in Saqqara region could be summarized as follows: the pottery analyzed is found to be a domestic pottery Sarcophagus that was used for poor (public) person. It was, also, found that the texture of the pottery was made using Nile C fabric which is characterized with a large quantity of medium to coarse plant residues and high porosity which is suitable for manufacturing these types of sarcophagus. The addition of some materials such as sand and pottery fragments is used to improve the sarcophagus properties. These materials are known as temper or filler. The quartz present in the ceramics could have double origin, it could have been added as a temper or it could have been formed during the annealing from the decomposition of the clay silicates.

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