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Mineralogical Study and Restoration of the Lid of an Alabaster Sarcophagus in the Step Pyramid, Saqqara, Egypt

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[Abstract]

The pyramid of king Djoser in Saqqara is one of the oldest stone building in history. There are five levels of corridors under the pyramid. There are two alabaster sarcophaguses in the fifth level. It is thought that they are for two daughters of king Djoser, although they were found empty. The lid of one of these sarcophaguses were found broken into nine pieces. Mineralogical investigations by both X-Ray diffraction and polarizing microscope were required to help identifying the components of the alabaster lid. The obtained results revealed that mineralogical study should have been carried out to achieve the restoration processes.

The restoration process was carried out. The broken pieces of the lid were collected and glued, the lid was put in its place and the sarcophagus was closed. A drill, stainless steel bars and an epoxy called Araldite AW 106 were used in the restoration process. The restoration process was completed successfully.

1 Introduction

The Pyramid of king Djoser is called the Pyramid of Saqqara or the Step Pyramid. It was built in Saqqara necropolis northwest of Memphis. It was built during the 27th century BC in the time of the third dynasty. It was built by Imhotep who was known as the first architect in ancient Egypt. The pyramid was built in the period between 2667 and 2648 BC (Madkour and Khallaf 2012), the height of the pyramid being about 62 meters (204 feet). The pyramid consists of six steps, the base of the pyramid is about 109 m by 125 m (358 feet by 410 feet), the pyramid being built of limestone. It is thought that the pyramid is the oldest stone structure in history. The pyramid contains two entrances; one is an entrance from the northern side, which is the main entrance to the pyramid, and the other is a southern entrance that was cut in the late period of ancient Egyptian history (the 26th dynasty). On entering from the northern entrance, there are five levels cut underneath the pyramid, each level contains several corridors; the

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length of these corridors is about 6 to 7 km underneath the upper structure of the pyramid. There is a burial shaft with a depth about 28 meters. In the base of the shaft, there is a special kind of sarcophagus consisting of 32 blocks of granite. There are two sarcophagi made of alabaster in the fifth level (Fig. 2). Those two sarcophagi are said to be mostly for the daughters of king Djoser. Both sarcophagi were found empty.

The aim of this paper is to identify the mineralogical composition of the alabaster sarcophaguses and to choose the best technique and products to restore the broken lid. It is important to put back the broken lid after restoration in its original place.



Fig. 1 Panorama view of the Pyramid of king Djoser



Fig. 2 Corridor that contains the alabaster sarcophagus in the fifth level of the Step Pyramid

2 Materials and Methods

2.1 Materials

In this study, XRD analysis was used with X-ray model X'Pert ProPhillips MPD PW 3050/60 X-ray diffractometer to investigate the components of the alabaster. Polarizing microscope was used with Olympus BX50, Japan. X-ray diffraction was to carry out petrographic study to give more information about the components of the alabaster. Two main products were used in the restoration work; Stainless steel bars and Araldite were used to join the broken pieces

2.1.1 Alabaster

Historically, alabaster was used by ancients in Near Eastern cultures for luxury goods (Testa and Lilyquist, 2006). In Egypt, particularly alabaster is well-known as it has some criteria such as its compactness and resistance to weathering factors around the world. Rocks with similar appearance are also called "Egyptian Alabaster."

Geologically, alabaster is calcite alabaster which is almost entirely made of mm to cm size calcite crystals with a color ranged from white to brown passing through creamy based on impurities contents. The geological origin of alabaster is formed mostly by precipitation of calcium carbonate in caves, in karstic cavities, or in stalactites and stalagmites. It can be found wherever there is limestone or marble outcrop (Bruno 2002; Çolak–Lazzarini 2002).

It was used in the manufacture for the pots in which sacrifices were made for gods and for the pots in which oils and perfumes were preserved.

2.1.2 Alabaster Sarcophagus

The sarcophagus is made of alabaster. It is located in one of the corridors in the fifth level of the Step Pyramid. This sarcophagus is one of two sarcophagi which are thought to have been belonged to king Djoser's daughters. The dimensions of this sarcophagus are 200 cm long, 100 cm wide, and 100 cm high. The dimensions of the sarcophagus lid are 200 cm long, 100 cm wide. The thickness of the lid varies; the outer edges are about 20 cm thick, while the lid body is about 10 cm thick.

2.1.3 Stainless Steel

It is a kind of steel in the form of an alloy consisting of several different types of metals. These metals become harder when they are mixed, and more durable if they are separated. Stainless steel can be used for many purposes (Zheng et al. 2022).

It was used in the restoration work through the process of assembling the broken pieces. Stainless steel bars should be spiral because it is more suitable in restoration work than smooth stainless steel. One of the advantages of stainless steel is that it is resistant to corrosion, and it does not rust neither interact with the raw materials around.

2.1.4 Araldite AW 106

It is a multi-purpose epoxy resin. It is suitable for bonding a variety of materials, because it is suitable for using at a temperature degrees from 20 to 180 Celsius. As a stiffener, it is characterized by a transparent yellow color, while the resin is distinguished by a white color. It is also characterized by hardness, chemical resistance, and good

resistance to moisture. The rate is resin AW 106*1 (1 kg) and hardener have 953 U*1 (0.8 kg) (Technical Beacons 2022)



Fig. 3. Product used as glue, epoxy AW 106.

3. Restoration work

The restoration work was carried out by assembling the broken parts of the sarcophagus lid that was made of alabaster as it is illustrated in Fig.4. Perforation work was done using a drill in one of the sides of the first broken piece, and after the perforation was completed, a piece of cotton containing a color was used to put in the hole and the two pieces are assembled together to mark the place of drilling in the second piece. Then, the second piece was drilled, after that, both pieces were assembled together using stainless bars and epoxy resin, Araldite AW 106. Nine different shapes in different sizes were assembled all together and reshaped for the lid of the sarcophagus. After assembling the pieces, the mechanical cleaning was done using different soft brushes.

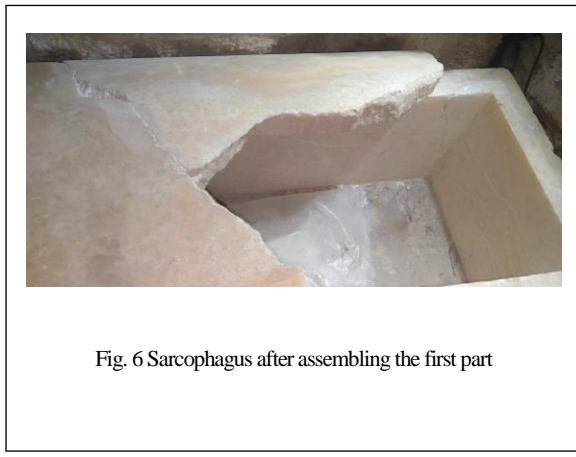
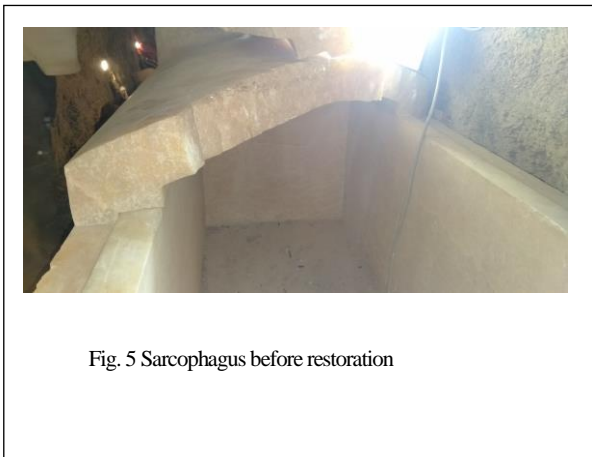
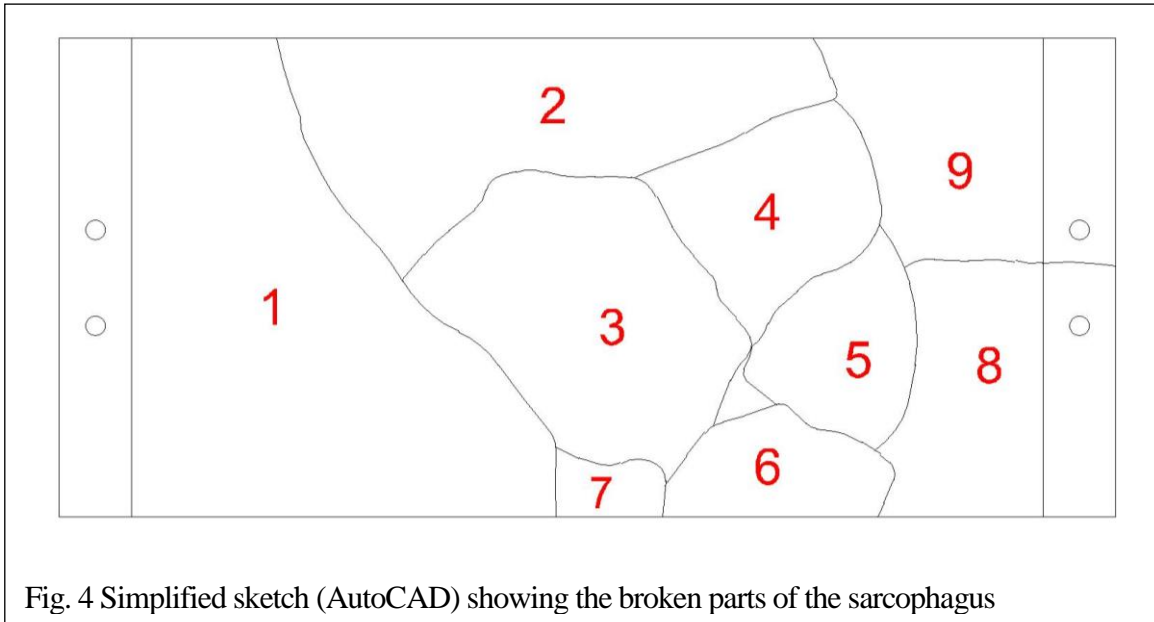




Fig. 7 During drilling in the first part



Fig. 8 During the punching process in the second part



Fig. 9 During the drilling in third part



Fig. 10 Lid after joining some pieces



Fig. 11 Lid after joining some pieces



Fig. 12 Lid after joining all pieces



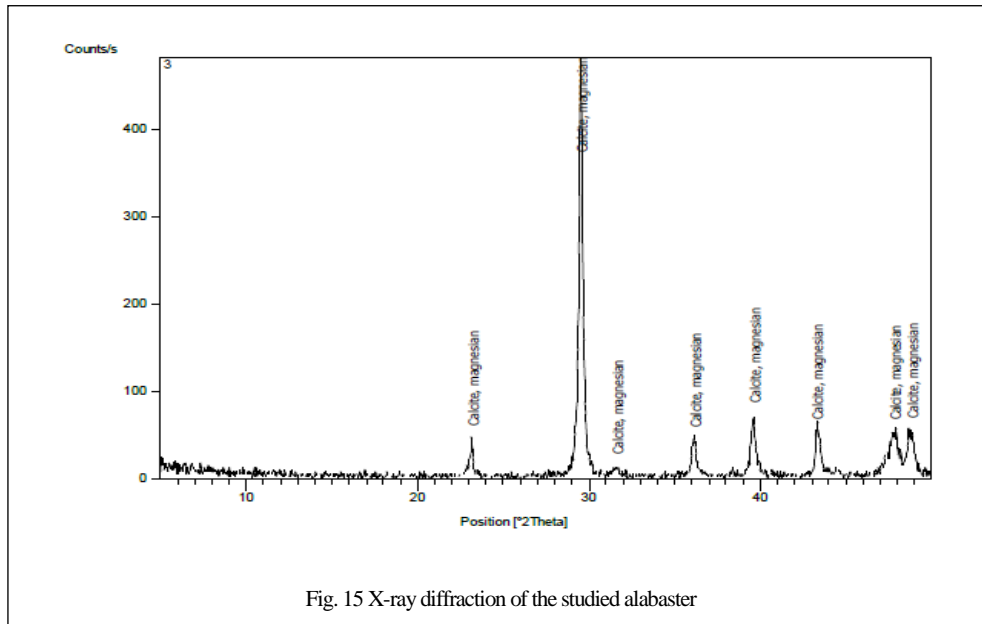
Fig. 13 Sarcophagus from the south after restoration



Fig. 14 The sarcophagus from the north after restoration

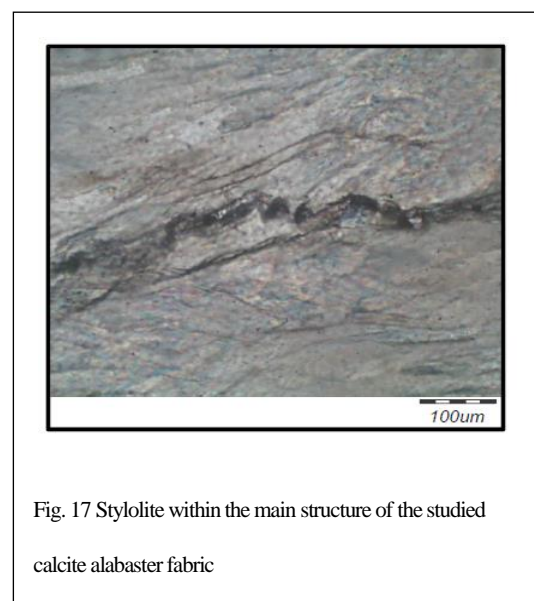
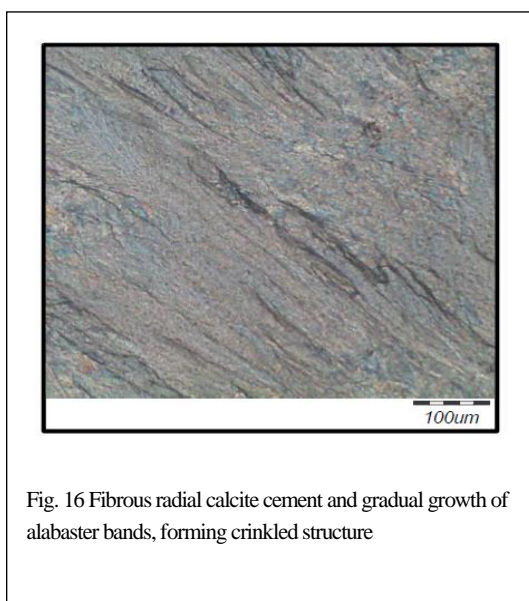
4 Results and Discussion

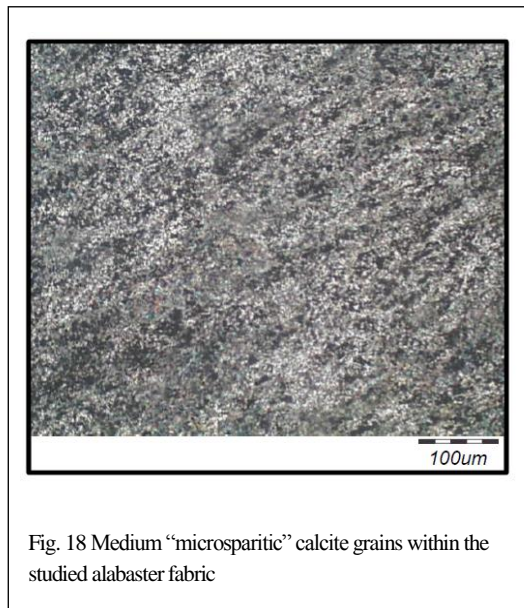
X-ray diffraction was used in the current study to investigate the mineralogical composition of the rock under investigation. It indicated that the selected alabaster representative samples consisted mostly of calcite, particularly calcite magnesium as shown in Fig.15. Based on the obtained previous results, the mineralogical classification of the studied alabaster is calcite alabaster. It should be noticed that there was not any detection for aragonite mineral.



4.1 Petrographic Study

Under the polarizing microscope, two main micro textures were observed in Photomicrographs (Figs 16, 17 and 18). The first one was characterized by its flat, platy and radial fibrous grains, while the second one contains interlocked mosaic grains (fine to medium) similar to dolomite micro texture.





5 Summary and Conclusions

- The sarcophagus is made of alabaster and is located on the fifth level of the Step Pyramid. This sarcophagus is one of two sarcophaguses for the king's daughters.
- It was necessary to study the main mineralogical composition of the broken stones before selecting restoration products and methods.
- The lid of the sarcophagus was found broken into 9 pieces scattered on the floor of the fifth level.
- The lid of the sarcophagus pieces were assembled using stainless steel bars and epoxy AW 106.
- The obtained results of polarizing microscope and XRD determined that the studied alabaster was entirely calcite, particularly calcite magnesium, which helped to choose Araldite as glue in restoration work.

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