An analytical study of the components and damage appearances of stone muqarnas in some ancient buildings in the city of Cairo

Prof. Mohamed Kamal Khallaf
Professor of Restoration, Dean of the Faculty of Archeology, Faculty of Archeology
mkk00@fayoum.edu.eg
Prof. Mostafa Gouda Temraz
Professor of Geology and Laboratory Manager of sedimentary rocks, Exploration section
gouda250@gmail.com
Researcher. Norhan Abdelgawad Abdel-Wahab
Bachelor's degree in archaeology, restoration department, Faculty of Archeology, Fayoum
norhanabdelgawad10@gmail.com

Abstract:
The goal of this paper is studying the nature of the stone muqarnas and the damage which have been done to the muqarnas understudy with their components being analyzed. The X-ray diffraction (XRD), The X-ray fluorescence (XRF), The infrared rays (IR) Analysis and polarizing light microscope examination have been utilized to study and to identify muqarnas components. The X-ray diffraction (XRD) was applied for samples of stones and mortar used in muqarnas in Islamic archaeological buildings from three different areas, namely; Al-Aqmar Mosque (Fatimid era), mosque Qani bay al-Muhammadi (Mamluk era)and Muhammad Bey Abu al-Dahab Mosque (Ottoman era), where we find that the stone was identified in the three locations consisting of calcite ($CaCO_3$) as a primary compound and quartz (SiO_2) as a secondary compound, as well as a proportion of halite salts (NaCl) as for mortar samples made up of either quartz (SiO_2) and calcite ($CaCO_3$) or gypsum Ca_2O_4 2 (H_2O) ,and a proportion of halite (NaCl) ,as those samples were examined by polarizing light microscope, it became clear that the stones samples in the three buildings are limestone Mikriti which consists of fine-grained calcite. Examination showed presence of remains and traces of fossils, in addition to the spread of white spots that may be halite or gypsum salts. Moreover, samples of pigments and gilding were analyzed by X-ray diffraction (XRD) to identify their mineral composition and analyzed by X-ray fluorescence (XRF) to determine their elemental composition; in conclusion it was obvious that the red is hematite Fe_2 O_3, the green is malachite $Cu_2CO_3(OH)_2$ and the blue is cobalt. The gilding sample, which was revealed through the analysis by X-ray fluorescence, revealed that the sample consists of a simple gold Au percentage of 1.175% in addition to a greater percentage of lead oxide PbO 25.8703 % and zinc oxide ZnO 2.3989 % also an analysis was done by infrared rays (IR) to identify the organic media used, as it appeared to be animal glue.

Keywords:
Muqarnas components , XRD , XRF , FTIR , Polarizing Microscope

الملخص:

تهدف هذه الورقة إلى دراسة طبيعة حجر المقرنصات والأضرار التي لحقت بالمقرنصات التي تمت دراستها وتحليل مكوناتها. حيث تم استخدام حيود الأشعة السينية(XRD) ، وفلورة الأشعة السينية(XRF) ، وتحليل الأشعة تحت الحمراء (IR)وفحص مجهر الضوء المستقطب لدراسة وتحديد مكونات المقرنصات. حيود الأشعة السينية (XRD) لعينات من الحجارة والمونة المستخدمة في المقرنصات في المباني الأثرية الإسلامية من ثلاث مناطق مختلفة، وهي مسجد الأقمر (العصر الفاطمي) ومسجد قانيباي المحمدي (العصر المملوكي) ومحمد بك أبو. مسجد الدهب (العصر العثماني)، حيث نجد أنه تم التعرف على الحجر في المواقع الثلاثة المكونة من الكالسيت ($CaCO_3$) كمركب أساسي والكوارتز (SiO_2) كمركب ثانوي، بالإضافة إلى نسبة أملاح الهاليت (كلوريد الصوديوم) بالنسبة لعينات الملاط المكونة من الكوارتز (SiO) والكالسيت ($CaCO_3$)أو الجبس($Ca_2O_42 (H_2O)$ ، ونسبة الهاليت(NaCl) ، حيث تم فحص هذه العينات بواسطة مجهر ضوئي مستقطب، حيث اتضح أن عينات الأحجار في المباني الثلاثة هي الحجر الجيري ميكريتي (دقيق) الذي يتكون من الكالسيت دقيق الحبيبات. وأظهر الفحص وجود بقايا وآثار أحافير بالإضافة إلى انتشار بقع بيضاء قد تكون من الهاليت أو أملاح الجبس. علاوة على ذلك، تم تحليل عينات من الأصباغ والتذهيب بواسطة حيود الأشعة السينية (XRD) لتحديد تركيبها المعدني وتحليلها بواسطة مضان الأشعة السينية (XRF) لتحديد تركيبها الأولي؛ حيث اتضح أن عينة اللون الأحمر هي الهيماتيتFe_2O_3 ، وعينة اللون الأخضر هي المالاكيت $Cu_2CO_3(OH)_2$ وعينة الأزرق ههيو الكوبالت. أما عينة التذهيب والتي تم الكشف عنها من خلال التحليل بواسطة الأشعة السينية الفلورية، أن العينة تتكون من نسبة بسيطة من الذهب Au بنسبة ١,١٧٥٪ بالإضافة إلى نسبة أعلى من أكسيد الرصاص25.8703 PbO ٪ وأكسيد الزنك ZnO 2.3989٪ وأيضًا تم إجراء تحليل بواسطة الأشعة تحت الحمراء (IR) لتحديد الوسائط العضوية المستخدمة والتي أظهرت أن الوسيط هو غراء حيواني.

الكلمات المفتاحية:

مكونات المقرنصات، حيود الأشعة السينية، تفلور الأشعة السينية، الأشعة تحت الحمراء، الميكروسكوب المستقطب

1. Introduction

Islamic Cairo is a part of central Cairo that is noted for its historically important mosques and other Islamic monuments. Egypt can be regarded as a prominent area with respect to the development of muqarnas. From the eleventh century onward, muqarnas can be seen in Egypt in the cornices of minarets, niches of façades and transitional zone of domes. It is an originally Islamic type of wall and ceiling decoration, which is used to make a smooth transition from the rectangular basis of the building to the vaulted ceiling. Muqarnas is the Arabic word for stalactite vault; a captivating structure based on replicating units arranged in tiers, each one supporting another corbel on the top of it. The etymology of muqarnas is not clear and several explanations have been put forward, and it differs from country to another (1). The early purpose of these structures was to create an architectural transition between the circular dome and its square supporting structure. Later, muqarnas was used in different parts of a building, such as in large domes, cupola, niches, on arches, and as a virtual flat decorative frieze (2)(3), and the Europeans named them by the term "stalactites" (4) (5) that means the conical limestone sediments. (6) There are several types of muqarnas, its origin is due to two architectural elements (the corner folds) (7) or spherical triangles, as it had a prominent role in the development of the transition areas(8) .Some historians believe that it entered Egypt through Morocco by the Fatimids (9) or it came from Persia via Armenia(10) by Minister Badr al-Din al-Jamali in the Fatimid era (11),also there are many materials used in the formation /shaping and sculpting of archaeological muqarnas, such as stones, wood and gypsum , limestone is the basic material for forming stone muqarnas [1]. The muqarnas move between two different formations in measurement, composition, and distribution [1]. This appears from what Muslim architects wrote down and compiled, as the writings of Al-Farabi in the 4th century AH [1]. The construction and formation of the muqarnas begins first with the schematic / planning drawing (diagram), they were prepared with clear detailed drawings that helped to visualize the muqarnas [1] whereas the horizontal projection is the controlling factor in the muqarnas design [1]. Secondly, carving the parts of the muqarnas, that were carved according to selected drawing that can reach hundreds or thousands of pieces. The tools used in sculpture are characterized by the diversity of their shapes, sizes and different degrees of hardness [1]. Third, the installation 7 and construction of muqarnas where a mortar is used to install and build the parts of the muqarnas. A good starting point to understand the concept of muqarnas is by understanding their construction methods. Muqarnas are typically constructed in three ways: Corbeled, superimposed and suspended. A corbeled muqarnas is a thick structure that was built from stone or wooden blocks. Muqarnas cells are carved outwards from the middle of the block face, before or after assembling. When creating a superimposed muqarnas, the supporting surface is built first (for example a dome), then muqarnas elements are built up against concave surfaces, leaving no hollow space between the muqarnas and the supporting surface. A suspended muqarnas is an assembly of surface-decorated panels. The panel components are produced on the ground, then combined and fixed to the architectural structure by means of attachment ribs. There is an empty space between the muqarnas shell and the structure. [1] The composition of 8 the muqarnas parts differs from one tier to another, and the cells for each part have the same bases and are parallel. The elements are connected together either in their curved sides directly as they appear in the two elements AB, or they are joined only on the back side of the curved side as in the elements C, D as in fig. no (1).

Forms of Muqarnas elements	
Intermediate element	**Cell**

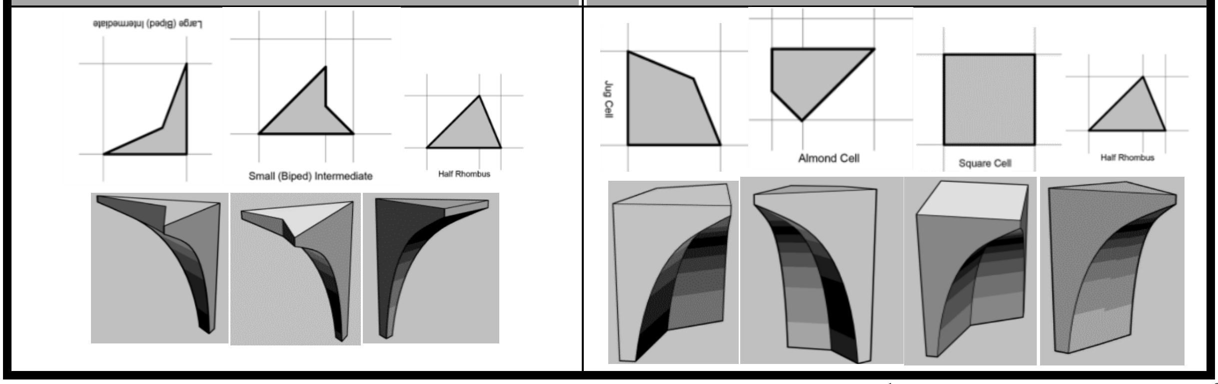
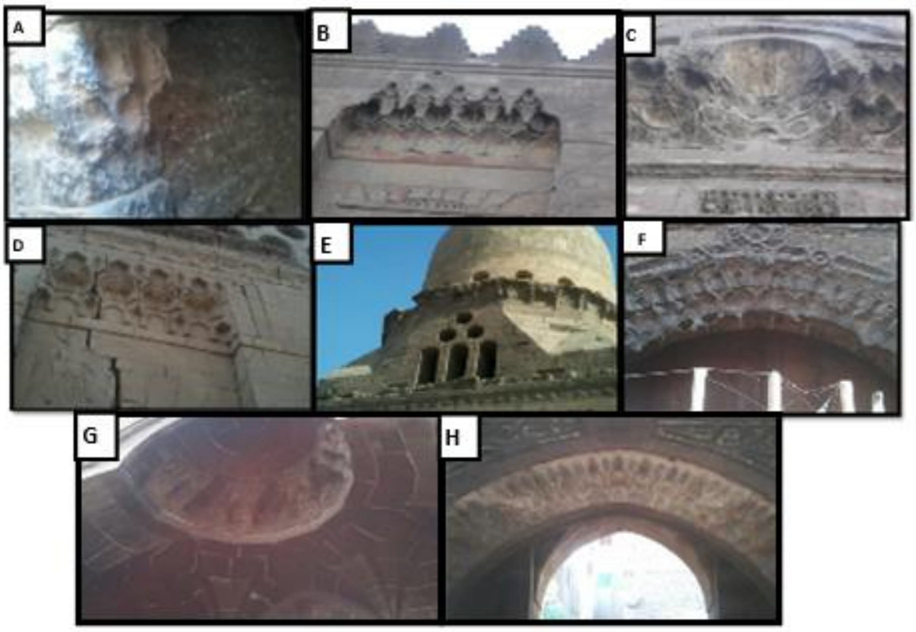


Figure no. (1) The components of the muqarnas [1] 9

Figure no. (2) Cell intermediate elements[2] 0

The damage mechanism for stone muqarnas in Cairo varies, that is divided according to the nature of the sculpture and its use as a structural element or as a decorative element. According to the nature of sculpture the conditions of formation stone and the chemical composition of the stone that had been used in muqarnas has affected its deterioration [2] , whereas that the tools that had been used in sculpture may cause stresses and pressures on the stone [2] , they had made some fine cracks in stones that are considered one of the reasons in stone muqarnas deterioration. [2] Which makes them more exposed to damage with the help of other factors. The deterioration of muqarnas differs according to the sort of muqarnas that differs in curving method and its installing [2]. According to its use as a decorative element, the muqarnas had been used a lot as decorative purpose in many places in buildings. Muqarnas deterioration is mechanical, chemical or both of them whereas that it shows erosion and the partial loss of its elements, such as pendants and burqas as a result of wind effect. It causes the surface erosion of archaeological buildings. The destructive effect of the wind depends on what it carries from the fragmented materials of sand and dust; it can cut, slash and erode the surfaces (Fig 2 (A) , (C)) [2]. Especially for the decorative elements as muqarnas, its decorative parts, its colors and its gliding layers. The place of muqarnas in the building affects forms and types of deterioration. In addition to the gilding layers may deteriorate as a result of the beats of hummer that they are exposed to during preparation. They also change and oxidize as a result of their reaction with environmental factors as moisture and heat [2]. There is also the peeling and fading of colors and the loss of the coloring layer, which may be due to the effect of air pollution in the city of Cairo, as well as the effect of heat and humidity on the surfaces of the painted muqarnas (Fig 2 (B)) , and there is also the black layer that covers the surface of the muqarnas (Fig 2 (G) , (H)),[2] there are salt spots and salt crusts resulting from the effect of both salts and moisture on the surface of the limestone used in the formation of the muqarnas, as the porous material absorbs water and the dissolved salts in it through the capillary property, so mechanical pressure increase as a result of the growth of salt crystals [2]. Most of the damage that affects archaeological surfaces is due to the repeated process of melting and crystallizing salts [2]. It may crystallize on the outer surface or on the layer of colors or gilding, resulting in pressure and strains [3], that react with colors [3] and lead to their damage, which appears in the form of flakes / peels [3]. According to its use as a structural element, it had been used for structural purpose such as in domes, and muqarnas in those places is exposed to lots of loads. Shakings have an important role in many collapses that occur to archaeological buildings due to heavy transportation which cause damage or even the full collapse of the building or the loss of some architectural elements [3] or may cause some cracks or the falling of some parts of muqarnas, and all factors react and cause deterioration for muqarnas.

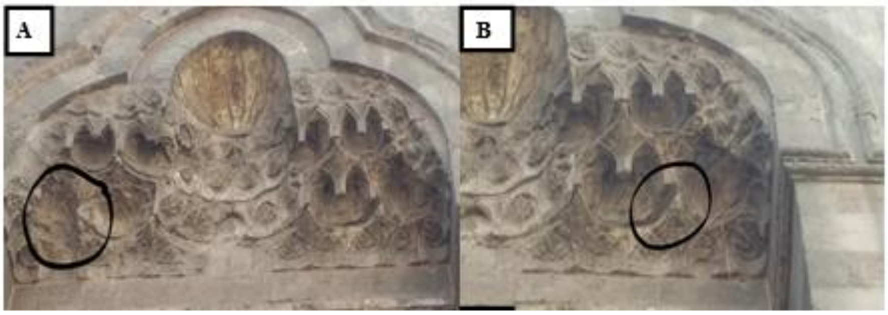
This paper aims to make an analytical study of the various deterioration phases to stone muqarnas and the characteristics of the stones used in their formation and the materials for their decoration of pigments and layers of gilding and etc. As well, writing the most important recommendations for the processes of treatment, restoration and maintenance of muqarnas**.**



Picture No. (1) shows the damage that catch up with stone muqarnas and the damage caused by the effect of wind by erosion of the muqarnas at the entrance to Ibrahim Agha Mustaf Zan's tomb (b) shows the damage to the layer of colors from fading and loss in the colors that adorn the muqarnas at the entrance to the Dome and Singer Al – Jawli , (c) shows the damage caused by the effect of the wind by erosion and loss of muqarnas at the muqarnas of Qani bay Al-Muhammadi, (d) and (e) shows the damage caused by earthquakes and heating in the form of cracks with stalactites from seven girls dome , (f) shows the damage caused by birds and insects from the accumulation of spider nets in one of the entrances, The collection of Muhammad Bey Abu al-Dahab, (g) and (H), the damage resulting from the influence of air pollution and humidity, which appears in the form of the dark black layer covering the surface of the muqarnas in the wekalat (a big market for imported cheap and good material of clothes and other goods) of Qayitbay and the Quarter of Qaytbay .

2. Materials and methods

The samples of muqarnas components (stones and mortar) were taken from three archaeological buildings, as in the fig (2) .



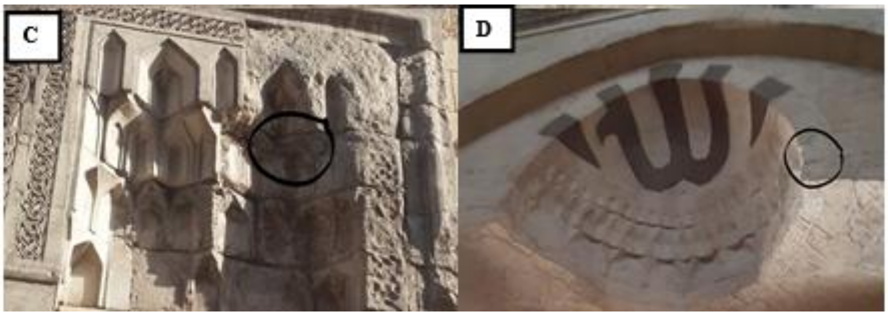


Fig (2). (A) the place of stone and samples from the entrance muqarnas of Qanibay al-Muhammadi mosque (Mamluk era), (B) the place of mortar samples from the entrance muqarnas of Qanibay al-Muhammadi mosque, (C) the place of stone sample from the decorative muqarnas in the AL-Aqmar mosque interface (Fatimid era) , (D) the place of stone the place of stone samples from the muqarnas that decorated Spherical triangles at the bottom of dome of Muhammad Bey Abu al-Dahab Mosque (Ottoman era) .

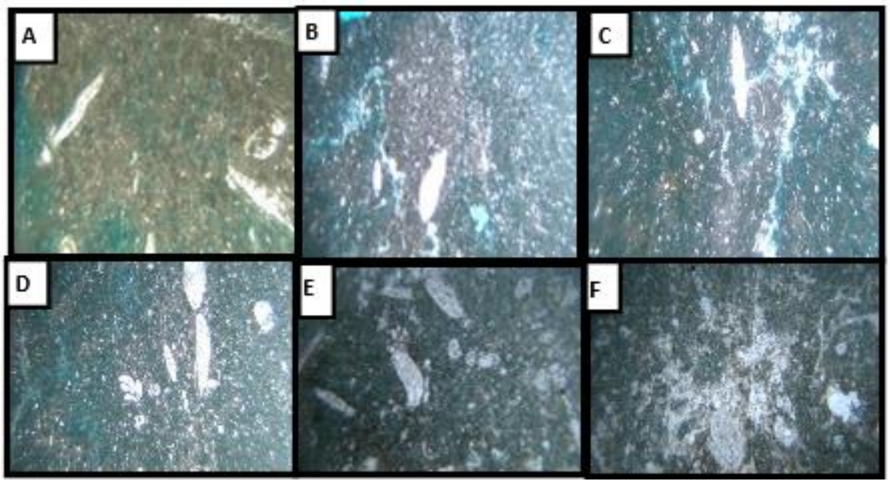
2.1 Examination using a polarizing microscope

Polarizing Microscope is another type of compound microscope. Which can enhance the contrast and image quality on a specimen where other techniques such as phase contrast or dark field are not as effective. Two polarizing filters are used called the 'polarizer' and 'analyzer' filters. The polarizer is placed in the path of the light source, and the analyzer in the optical pathway. Polarizing compound microscopes are used to examine chemicals in the pharmaceutical industry, petrologists and geologists use polarizing microscopes to examine minerals and thin slices of rocks.

Thin sections were prepared for study under an Olympus BH-2 polarizing optical microscope to identify the different minerals and altered phases of the construction materials. Olympus BH-2 Polarizing microscope includes 4x, 10x, 20x, and 40x objectives and comes with a trinocular head. 4 Position revolving nosepiece -BH-PRE, Centerable circular stage, with stage plate, centering wrenches and stop screw - BH2-SRP, Abbe 1.25 NA Condenser, Intermediate Polarizing Attachment - BH2-PA, with Analyzer and Quarter (147.3nm) wave plate - AH-TP147 Analyzer, Coaxial coarse and fine focus, Variable 12V 100W Halogen Lamp House - Kohler Illumination.

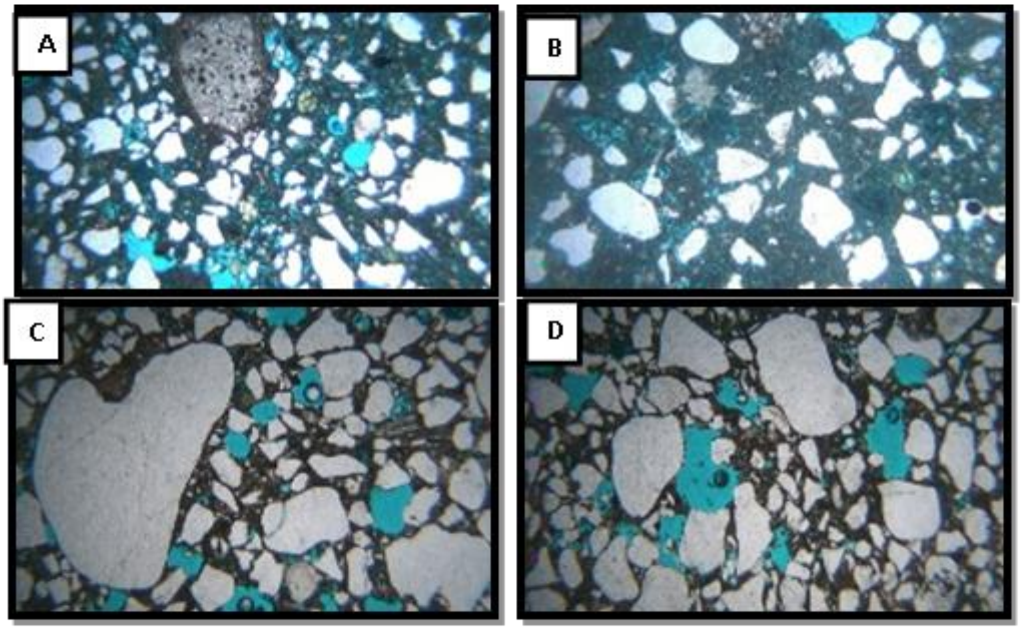
Analysis and inspection of building materials

A- Examination of limestone by polarizing microscope



Picture No. (3) (A) a stone sample from Al-Aqmar Mosque showing that it is a fine-grained Micritic Limestone rich in fossils and algae, showing the presence of protrusions, holes and minute cracks; under a polarizing microscope; Normal light PPL 40X magnification. (B) and (C) A stone sample from Qanibay Al-Muhammad Mosque showing that it is a fine-grained Micritic Limestone rich in fossils and algae, showing the presence of protrusions, holes and minute cracks; under a polarizing microscope; Normal light PPL 25X magnification, (D) a fine-grained Micritic limestone rich in foraminifera fossils; Stone Specimen from Qanibay Muhammadi Mosque Under PPL Normal Light Polarized Microscope 40X Magnification, (E) and (F) a stone sample from the Muhammad Bey Abu al-Dahab mosque, showing a microsparitic limestone rich in fine fossils: It shows some white spots that form a film of halite salts, under a polarized microscope, normal light, PPL, 25X magnification.

b- Examination of mortar samples by polarizing microscope:



Picture No. (4) (a) and (b) a sample of mortar from the Qanibay al- Muhammadi Mosque; under the normal polarized microscope PPL magnification 25X and (c) a mortar sample of Muhammad Bey Abu Al-Dahab Mosque under the normal polarized microscope PPL magnification 40X, and (d) the mortar sample from Muhammad Bey Abu Al-Dahab Mosque of high porosity sandstone (blue color) showing large size quartz grains z in a fine-grained calcite bed, showing heterogeneity and random scattering of grains; under normal polarized microscope PPL 25X magnification.

2.2 Analysis by XRD

X-ray powder diffraction methods have been more and more extensively used, in the last twenty years, in the characterization of different crystalline and non-crystalline materials of archaeological, historical, artistic interest Analysis of building materials by X-ray diffraction. The X-ray diffraction (XRD) method was used on all samples from the muqarnas and to identify the phase composition and the mineralogy of the powdered samples. X-ray diffraction, fine powders of the samples were analyzed with a diffractometer (Philips, PW 9901, CoKα 40 kV, 30 mA, λ: 1.5405 Å, 4–60° 2θ).

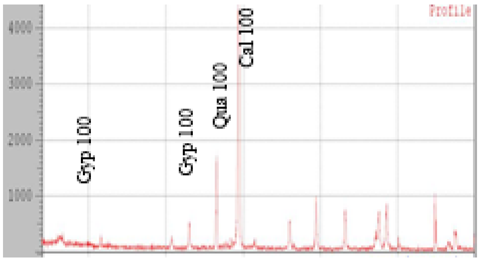


Figure (3) shows the analysis by X-ray diffraction of a stone sample from Al-Aqmar Mosque

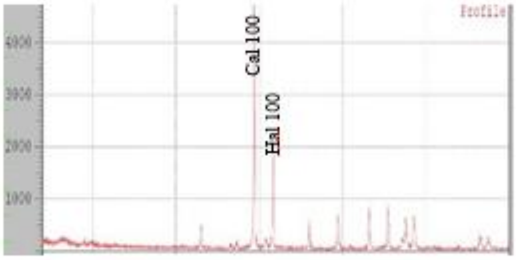


Figure No. (4) shows the analysis by X-ray diffraction of a stone sample from Qanibay Muhammadi Mosque

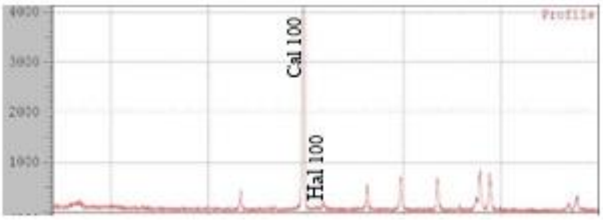


Figure (5) shows the analysis by X-ray diffraction of a stone sample from the Muhammad Bey Abu al-Dhahab Mosque

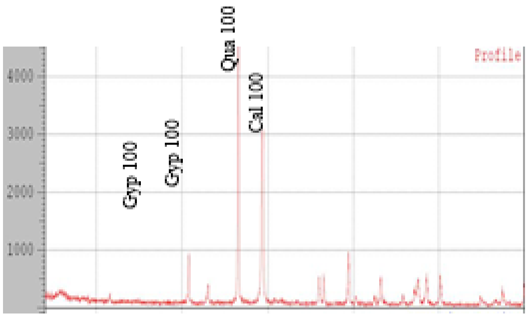


Figure No. (6) shows the analysis by X-ray diffraction of a mortar sample from the Qanibay Muhammadi Mosque

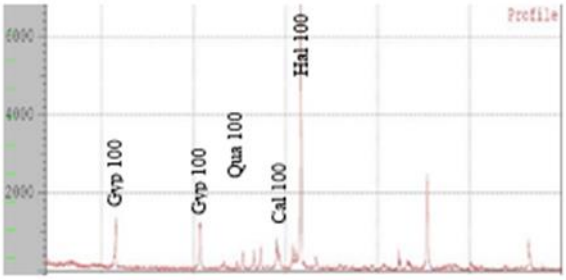
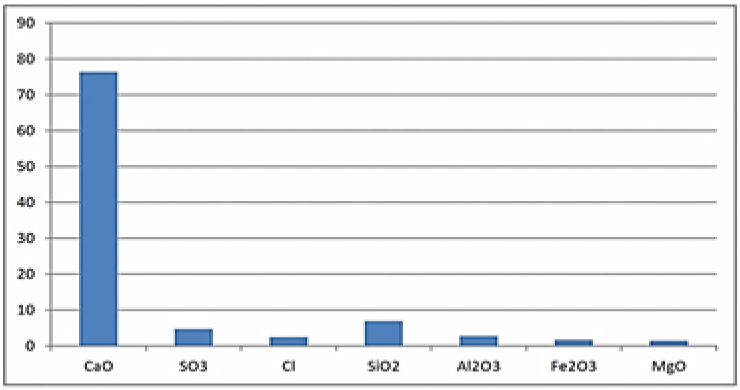


Figure (7) shows the analysis by X-ray diffraction of a mortar sample from Muhammad Bey Abu al-Dhahab Mosque

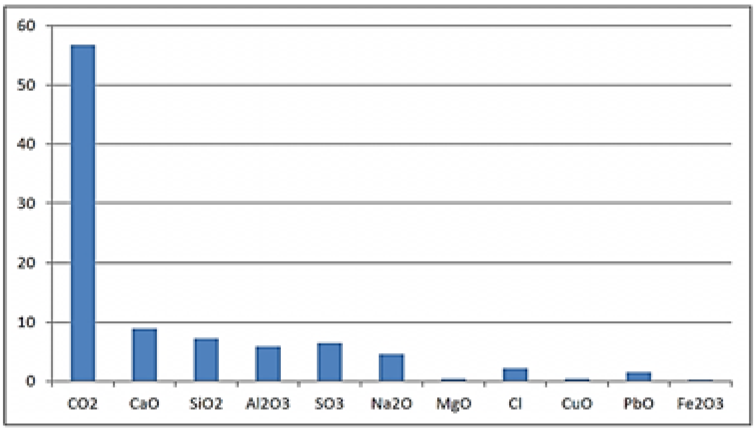
Analysis by X-ray fluorescence XRF

The X-ray fluorescence technique was used to identify the chemical composition of the samples and the elements for each sample of construction materials of muqarnas. The Rigaku was used for analysis, the Rigaku Supermini 200 offers superior fundamental parameters and empirical software capabilities in a high-resolution instrument with a compact footprint. As a high-power bench top sequential wavelength dispersive X-ray fluorescence (WDXRF) spectrometer, for elemental analysis of oxygen (O) through uranium (U) in almost any material. Analyzing complex matrix materials with a wide range of light and heavy elements, from trace to high concentration levels, is this instrument's core competency. With its high-powered (200 W) X-ray tube. Analyzing low concentration levels of light elements (F, Na, Mg, Ca, Si, Al, and P) is easy. X-ray tube (50 kV, 200 W Pd-anode), Primary beam filter (Zr is standard; Al optional, Crystals (3-position changer), Sample sizeable to accommodate 51.5 mm diameter samples, Optional (12 sample positions (up to 44mm diameter samples)), Power: 100 – 120V (50/60 Hz) 15A or 200 – 240V (50/60 Hz) 10A



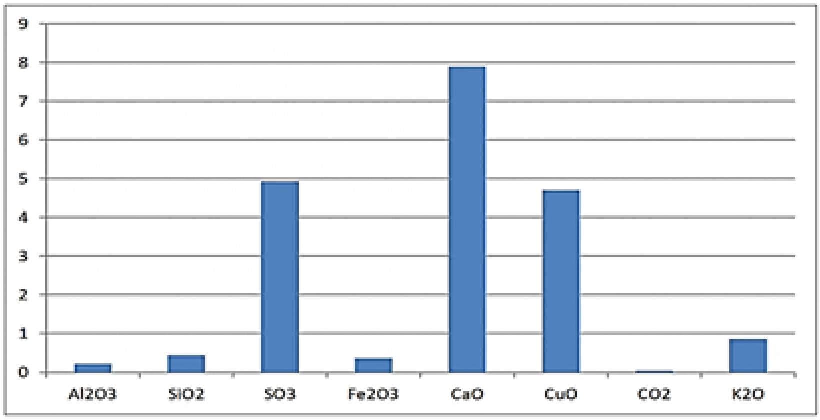
العنصر	النسبة
CaO	76.3277
SO_3	4.682
Cl	2.4139
SiO_2	6.839
Al_2O_3	2.6647
Fe_2O_3	1.6238
MgO	1.3376

Figure (8) shows the components of the red color sample



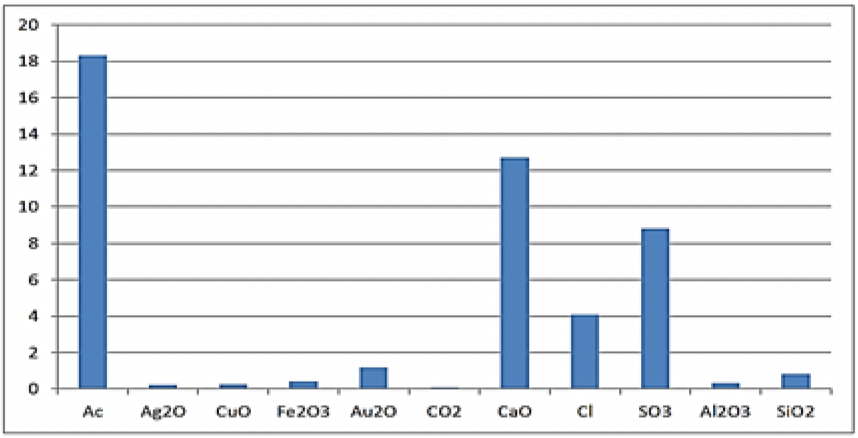
النسبة	العنصر
CO_2	56.7513
CaO	8.9049
SiO_2	7.2363
Al_2O_3	5.8625
SO_3	6.4228
Na_2O	4.5625
MgO	0.3858
Cl	2.1561
CuO	0.3897
PbO	1.519
Fe_2O_3	0.249

Figure (9) shows the components of the blue color sample



العنصر	النسبة
Al_2O_3	0.2197
SiO_2	0.4349
SO_3	4.9394
Fe_2O_3	0.3592
CaO	7.9005
CuO	4.7042
CO_2	0.0003
K_2O	0.8508

Figure (10) shows the elements that make up the green color sample



العنصر	النسبه
Ac	18.3151
Ag_2O	0.1965
CuO	0.2534
Fe_2O_3	0.4099
Au_2O	1.1725
CO_2	0.0003
CaO	12.696
Cl	4.0888
SO_3	8.813
Al_2O_3	0.3073
SiO_2	0.8116

Figure No. (11) shows the components of the gilding color sample

Analysis of colored materials and gilding layer by XRD:

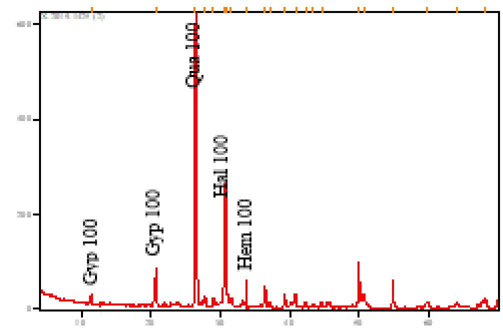


Figure (12) shows the analysis of the blue color by X-ray diffraction

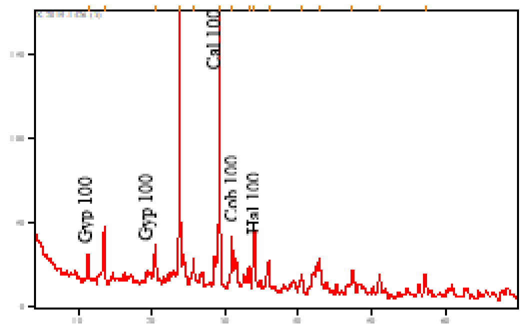


Figure (13) shows the analysis of the blue color by X-ray diffraction

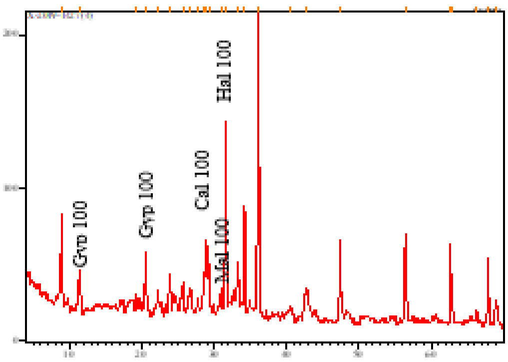


Figure (14) shows the analysis of the green color by X-ray diffraction

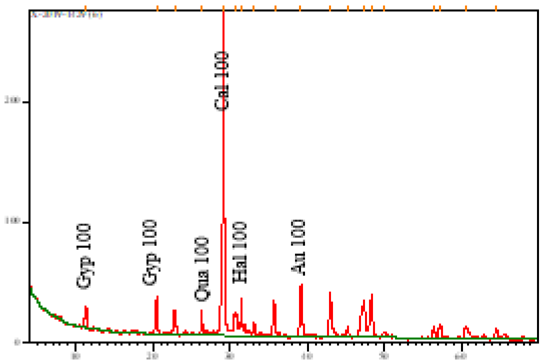


Figure (15) shows the analysis of the gilding layer by XRD

5 Analysis of the chromatic medium by infrared

FTIR provides information on both the organic and inorganic components. Jasco FTIR 430 Fourier Transform Infrared Spectrometer (Jasco FTIR 430. Japan) were analyzed in potassium bromide (KBr) pellets for Fourier-transform infrared absorption (4000–400 cm1; mid-IR spectral range), resolution of 4 cm−1 and scan speed is 2 mm/s.

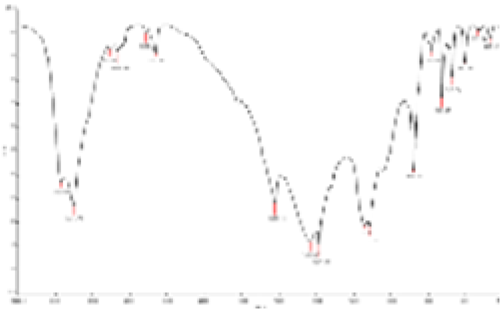


figure (16) shows the analysis of the red color by infrared rays

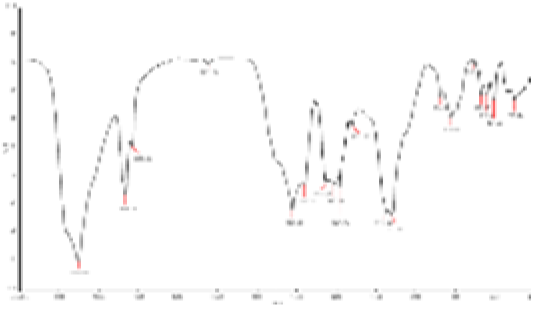


Figure (17) shows the analysis of the blue color by infrared rays

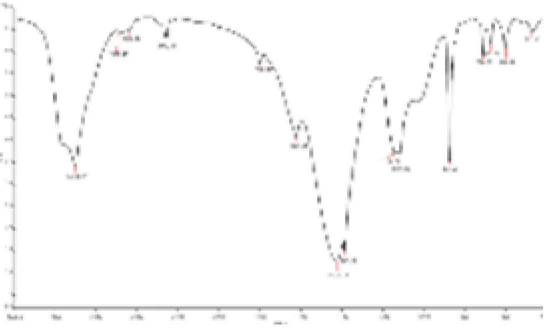


figure (18) shows an analysis of a gilding sample by infrared rays Figure

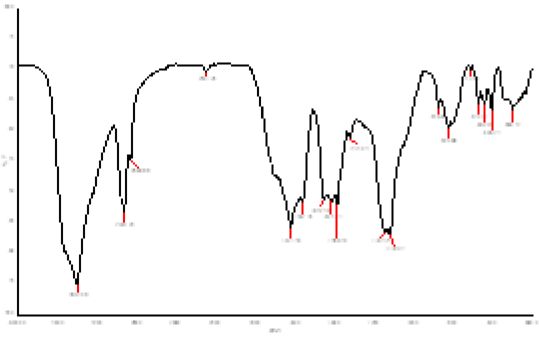


figure (19) shows the analysis of the green color by infrared rays

Results:

Limestone samples from the three buildings were examined by Polarizing Microscope (PM) and, it was found that: Samples consist mainly of fine-grained calcite besides presence of iron oxides, quartz minerals, which are naturally present as a binder for sedimentary rocks or as an impurity; and fossils include Foraminifera fossils these components increase the ratio of stone decay, in addition to traces found related to algae. There is high ratio of halite, gypsum salts, or deposition of calcite on the surface, also there are protrusions, holes and tiny or small cracks - in the sample, as it is obvious from the penetration of the blue dye into it as for the mortar samples, the examination showed that they consist of quartz, calcite and gypsum. It also shows presence of fine cracks in the mortar samples. This may be due to the loss of mortar to moisture, and this may be due to environmental damage factors such as heat, in addition to the presence of iron oxide. From analyzing by X-ray diffraction, we find that the samples of stones from the three buildings of different ages is mainly composed of calcite ($CaCO_3$) and quartz (SiO_2) as a secondary compound as a binder, and halite salts (NaCl) as an impurity was found. As for the mortar samples, they are composed of either quartz (SiO_2) and calcite ($CaCO_3$) or gypsum ($CaSO_4$ 2 (H_2O)) and halite (NaCl), which in one of the two samples forms the highest proportion. Through the analysis by X-ray diffraction of the pigments samples, it showed that the red pigment is Hematite Fe_2 O_3, the green one is malachite – Cu_2CO_3 $(OH)_2$, and the blue is cobalt. Through the analysis of samples by X-ray diffraction, a high proportion of halite salts appeared, especially in the green and blue samples and the gilding sample, which indicates the damage that happened to the samples, which formed white spots and were observed through visual examination. The prepared layer, which consist of gypsum and calcite, which appeared in the analysis of samples, was also identified, as it was noted through the analysis of the samples by X-ray fluorescence some / presence halite in all samples which enhances visual examination and there is calcium and carbon that are the two components of calcite which may be due to the composition of the stone or as a preparation layer under the color in addition to the aluminum and silicates that form quartz, which may be a component of the preparation layer or present as an impurity within the - colored materials. Through the analysis by X-ray fluorescence showed that Fe_2O_3 (1.6238) with the results of the analysis by XRD that red pigment is hematite , presence of CuO (4.7042) and CO_2 (0.0003), which confirmed the results of the analysis by XRD that the green pigment is malachite, specialized that the sample consists of a simple Au gold percentage of 1.175% in addition to a greater percentage of lead - oxide PbO 25.8703 % and zinc oxide ZnO 2.3989 % in addition to traces from other elements, FTIR analysis suggested the binding media was identified as animal glue by a comparison with controlled sample, which means that there were signs of painted layer applied on the stone muqarnas

disscusion of the results:

It was found through the analysis by X-ray diffraction of samples of stones, mortar and XRD pigments samples, the presence of halite salts NaCl, and the porous material absorbs water and dissolves salts in it through the capillary property, where the mechanical stresses increase as a result of the growth of salt crystals [3] such as limestone, which[4] is exposed to the appearance of air spaces / blisters ([3]). The presence of halite[5] (NaCl) may be due to either its presence as an impurity or its presence in the soil and groundwater and thus its rise to the building and the muqarnas through the capillary property [3], Also the Examinations[6] and analysis showed presence of iron oxides, which caused damage to the stones containing iron, even if they were found among the impurities or as a component of colors, “which causes rust” [3]. This explains 7
the cracks that were observed during the examination using the polarizing microscope, which causes pressure to the internal stone structure and therefore the impurities which present in the stones affect its damage. Iron oxides are an important factor in the deterioration, as their magnetic properties can make them attractive sites for calcium carbonate deposition in weathering areas such as cracks [3]. As it appeared during[8] the analysis by X-ray diffraction, gypsum mineral in the stone sample from the Qanibayi Mohammadi Mosque (the Mamluk era) and it maybe existed within the components of the stone or as a result of the transformation of calcium carbonate into calcium sulfate due to environmental factors such as air pollution. In the past 30 years, archaeological buildings have been exposed to increasing of the proportion of sulfur dioxide [3] that caused chemical decomposition[8], we find that the limestone that includes gypsum in its composition increases its porosity as a result of the transformation of gypsum into anhydrite [4]. The animal glue appeared[9] at the values 3200 - 3400 cm -1 N-H, 2800 - 3100 cm -1 C-H, 1600 - 1660 cm -1 C=O, 1500 - 1565 cm -1 C-N-H and 1300 - 1480 cm -1 C-H. [4]

Conclusion:

- Before carrying out any of the restoration operations, the necessary studies, examinations and analyses must be conducted to identify the components and characteristics of the antiquity and

the problems it faces to determine the mechanism through which the restoration, treatment and maintenance of the antiquity will be carried out.
- Attention should be paid to study each of the architectural elements separately and its construction techniques to find out the mechanism that helps us to identify the damage it has suffered and the maintenance it needs.
- Attention should always be given to conduct many researches and comparative studies between the reinforcement materials and striving to obtain the best materials and the best results, and work must be done on the continuous development of the strengthening processes.
- Before using any cleaning material, first we must be carried out tests to identify its effect on the stone monuments and the possibility of its use.
- It is better during restoration and treatment the colored or gilded architectural elements to stay away from chemicals because of their dangerous effects on that surface.
- It is always recommended to follow up on the latest studies, research and modern techniques in restoration and discuss them to complete the scientific research process.

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