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# PHYSICOCHEMICAL AND CULTURAL STUDY OF COLORING MATERIALS FROM 1st c. AD MAGDALA, LOWER GALILEE

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## ABSTRACT

Archaeological excavations conducted in Magdala in the last decade have recovered a large number of pigments and coloring materials from two main contexts: (1) the first-century synagogue (the oldest one discovered in the region of Lower Galilee), and (2) the market located on the shores of Lake Tiberiades (the Sea of Galilee). The pigments recovered from the synagogue are from the remains of mural paintings preserved there, while the coloring materials recovered from the market are shaped like balls of different sizes. The two main aims of this study are: (1) to conduct the physical-chemical characterization of the remains of the mural painting preserved in the synagogue and the coloring materials found in the market, and (2) to compare the results. To achieve our objectives, we used a multi-technical method based on a combination of optimized physico-chemical analysis techniques for identifying organic and inorganic substances. These comprised microscopic techniques (LM, SEM-EDX), spectroscopic techniques (ATR-FTIR), chromatographic techniques (GC-MS), and others (UV-vis, XRPD). Our results suggest that color in ancient Magdala was used not only for pictorial purposes but also for several others. The components of some of the colored balls discovered in the market, for example, indicate that they had a cosmetic and/or medicinal use, which invites analysis of interesting issues related to customs and everyday life in this first-century Jewish settlement in Lower Galilee.

**KEYWORDS**: Magdala, Lower Galilee, Jewish culture, archaeology, archaeometry, pigments, medicines, cosmetics

## 1. INTRODUCTION

### *1.1 An approach to the ancient settlement of Magdala*

Magdala/*Taricheae* or in its Aramaic form, Migdala, is located on the northwest bank of Lake Kinneret at the foot of the Arbel cliff. Before the foundation of the city of Tiberias by Herod Antipas early in the first century, Magdala was an urban center on the western bank of the Kinneret (Figure 1). During the Roman period, Magdala is mentioned in the historical sources as a Jewish town that played an active role in the Great Revolt of the Jews against the Romans. Josephus records the fortification of Magdala, the conflicts in the town caused by the revolt, and the naval battle off the coast (Josephus, 1966). In the early twentieth century, archaeological excavations conducted in the southern area of the settlement at Magdala revealed that the site was first occupied during the Hellenistic period, that this occupation continued during the Roman and Byzantine periods, and continued until the early Islamic period. The written sources, for their part, describe a village that is economically prosperous thanks to its fishing-related activities. Some of the people who lived in *Taricheae* are believed to have been economically self-sufficient.

All the archaeological evidence uncovered so far – high-quality construction materials, ritual baths, a decorated synagogue (mosaics, mural paintings and Magdala Stone), a local market, the harbor, and other materials – points to this prosperity. Analyses of pottery, coins, oil lamps and glass (Osban, Syon, Terem and Jackson, respectively, personal communication 2019) show that the origin of the settlement at Magdala dates back to the first century BCE and that the settlement remained active between the first and second century CE. The Great Revolt against the Romans in 67 CE led to changes in Magdala's population. This period is considered to have been one of transition, which is reflected in both architectural and spatial modifications. It is highly likely that during this time some inhabitants left Magdala and that new groups arrived but no archaeological evidence uncovered so far suggests the total abandonment of the settlement or the battle that was reported by Flavius Josephus (Josephus, 1966).

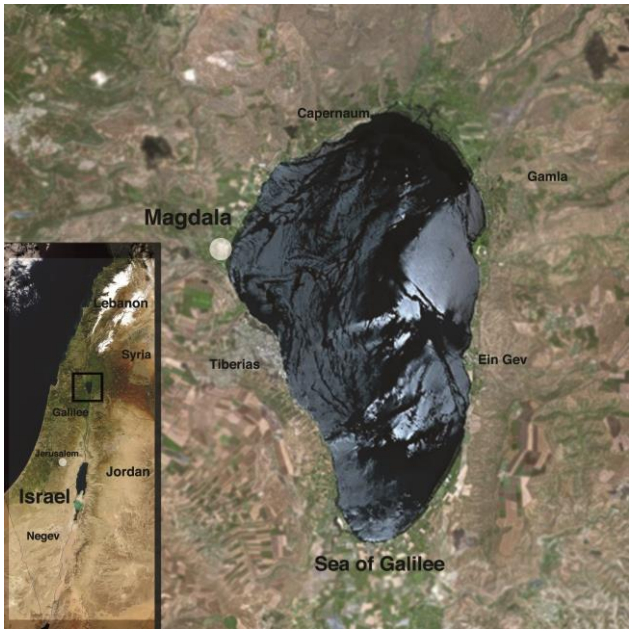



***Figure 1. Map of Magdala indicating the main cities and archaeological sites in the region, e.g. Tiberias, Gamla and Capernaum***

### *1.2 The Synagogue of Magdala*

It is common to read that ancient synagogues were 'religious' institutions. However, recent investigations of synagogues have highlighted their political role at the local official level. According to Runesson (2014: 2), the synagogue was a sort of religious-political town hall. Ryan (2017: 2), on the other hand, reminds us that the synagogue was an important facet of Jewish life, society, religion, culture and identity in Judea and Galilee during the first century. We may assert, therefore, that the synagogue was simultaneously a religious and a political institution. Other scholars recently discussed the origin of the synagogue as an institution. In the 1990s, for example, it was associated with Greco-Roman definitions and described as being similar to a public club and town hall. With currently available archaeological evidence and written sources, there is strong evidence for both definitions. This leads to the conclusion first proposed by Anders Runesson in his dissertation, i.e. there were in fact two types of institutions: semi-public association synagogues and public synagogues.

*Figure 2. Western side of Magdala Synagogue*

*Figure 3. Vestibule of Magdala Synagogue*

With these theoretical precedents in mind, in 2009 on the northwestern side of the Magdala settlement, Dina AvShalom-Gorni and Arfan Najjar, archaeologists from the Israel Antiquities Authority, discovered a synagogue (Figure 2 and Figure 3). Their excavations of the building identified three construction phases: remains dating from the mid-first century BCE indicate that in an early stage the building was probably not used as a synagogue, though it did exercise that function in the two later phases. The final phase of the synagogue was preserved in its entirety and is just like it was when it was abandoned. Analyses reveal that the synagogue consisted of two large rooms—a vestibule and a reading room—and one smaller room. It appears that the entrance to the synagogue, the remains of which were not discovered, was set in the western wall and led from the outside into the vestibule, which was long and narrow. Next to its walls on the inside, a stone-paved corridor was built. This corridor was enclosed within a stone framework. The floor in the middle of the vestibule was made of tamped earth and crushed chalk, and in its center stood a square limestone block for secondary use that may have been used as a base for a chair or table. The floor around the stone consisted of basalt flagstones. The vestibule may also have been a kind of small seminary used for study. A doorway in the eastern wall of the vestibule allowed access to the reading room. This room was surrounded on all sides by a raised corridor, around which a stone bench was built whose construction incorporated architectural elements in secondary use. This corridor was delimited on the inside within a framework that may also have been used as a bench. A mosaic floor was exposed on the eastern side of the corridor (Figure 4). A rosette pattern, flanked on either side by a strip adorned with a meander pattern was found in the centre of the mosaic. This pattern is evenly and precisely severed at both ends, so the construction of the mosaic floor appears to have been interrupted shortly after work on it began.

The foundation of a mosaic pavement, made up of small stones, was uncovered elsewhere in the corridor. Two parallel stylobates were built in the reading room and two fragments of basalt columns were discovered *in situ* standing on top of them. A fragment from another basalt column was discovered lying on the floor. A level of small tamped stones, probably the foundation for a mosaic pavement, was uncovered in the middle of the reading room. It is likely that this building had six columns to support the roof. The walls of this room and the columns were covered with colorful mural paintings consisting of dark red, mustard yellow and blue panels set within black and white frames (Figure 5). The roof of the building appears to have been built with wooden beams and mortar and coated on the inside with white plaster. A rectangular stone resting on four feet was exposed to the level of small stones in the room. Five of the stone's sides were decorated in relief (Figure 6). One of the sides contained a relief of a seven-branch menorah (candelabrum) with a triangular base standing on a square structure. The menorah was flanked on either side by amphorae and columns. It appears that the stone represented the Second Temple and was used as a prayer table. In the southwestern corner of the reading room was a small room divided into two by a partition wall. This room was paved with a mosaic and its walls were decorated with a colorful fresco. This room may have been used to store scrolls.


***Figure 4 (to the left): Mosaic floor with a rosette pattern uncovered on the eastern side of the Synagogue corridor. Figure 5 (to the right): Remains of the mural painting conserved at Magdala Synagogue.***

This synagogue appears to be the earliest one discovered so far in Galilee and one of the few from this period found in this region. The seven-branched menorah chiseled into the stone in the synagogue is the earliest menorah from the Second Temple period to have discovered outside Jerusalem; it is also the earliest menorah ever discovered in a religious structure. The excavations revealed that the quarter and the synagogue were probably deserted at the time of the Great Revolt.

The Magdala synagogue can be identified as a public building with more extravagant ornamentation than other early synagogues. However, unlike the Gamla synagogue, its benches are constructed from reused architectural elements from other buildings rather than from well-dressed ashlars. The synagogue would probably have accommodated between 120 and 200 people in the assembly hall (Ryan, 2017: 63-64). The above author also asserts that the decorations of the Magdala synagogue are notable exceptions to the generally austere decorations of Second Temple synagogues. The existence of a mosaic pavement in this synagogue before 70 CE is important because it provides evidence of continuity between Second Temple synagogues and synagogues that postdate the destruction of that temple (Ryan, 2017: 69-71).

### *1.3 The Market of Magdala*

Marketplaces are centers of trade, commerce and social interaction that enable communication between different peoples and cultures. They are forums in which buyers and sellers negotiate with each other to achieve mutually favorable transactions. Marketplaces were not only places in which to exchange activities, since production activities for regional distribution can also be found. It is also worth remembering that sanctuaries in the ancient Near East were prime places for conducting commercial transactions in a foreign country (Aubet, 2001: 277). For this reason, in some places and circumstances, ancient marketplaces were located near places of worship.

During the 2012–2013 archaeological season at Magdala, a market with an area of 542m$^2$ was excavated to the south of the synagogue (Figure 7). The northern part of the market was worked on by the Israel Antiquities Authority, while the southern part was worked on by an archaeological team from Anahuac University, Mexico. The marketplace is flanked by two streets: a narrow one to the north (running east to west) that separates the structure of the market from the structure of the synagogue, and a wider one to the west that continues to the south (running north to south) and connects the market area to the rituals area where the *miqva'ot* (ritual baths) are located. The marketplace comprises 24 rooms and is divided into sections. To the north of the market is a complex made up of two rooms with small rectangular pools covered with plaster, where it is thought that fish-salting activities may have been carried out. However, sufficient archaeological evidence does not yet exist to support this theory. Other possible interpretations for the purpose of these pools is that they were used for ritual immersions, i.e. ritual bathing (*miqva'ot*), for collecting water, or for cleaning the body after certain activities.

The market complex allowed access to the street in front of the synagogue. The complex of rooms facing the western street (str. 8) has open accesses that link directly to the street. In two rooms, stone ovens coated with coarse pottery were identified near the corners. In one of the back rooms, a stepped water installation that may have been used for daily or ritual purity activities was found. Water was filtered through an underground spring, which is how

this type of hydraulic installation (like the *miqva'ot* in the ritual area to the south) was filled.

The archaeological materials found in the market, such as pigments used as raw materials as well as pottery, coins, glass, and metals, date mainly to the complex in the Early Roman and Middle Roman periods.

***Figure 6 (to the left): the Magdala Stone. Note the central iconographic motif of the Menorah, flanked on either side by amphorae and columns. Figure 7 (to the right): aerial view of Magdala Market***

### *1.4 Pigments and coloring materials from ancient Magdala as a case study*

The mural painting remains preserved in the ancient synagogue at Magdala provide the opportunity to study the materials and pictorial techniques employed in this important artistic manifestation of first-century Lower Galilee (Figure 5). Our objectives in addressing the physical-chemical characterization of these traces of color are to: (a) identify the structure and composition of the stucco coatings underlying the pictorial film; (b) ascertain which pigments and coloring matters were used by local painters to decorate the synagogue; and (c) determine the execution techniques. In view of the close relationship between Magdala and Rome in the first century, achieving these objectives would also enable us to associate the materials and techniques employed for mural painting at Magdala Synagogue with those employed for Roman mural painting or, on the other hand, identify the use of different techniques and materials, probably for identity reasons.

In addition, various archaeological campaigns at Magdala Market have uncovered numerous colored balls, whose physicochemical analysis has recently been prioritized. The main objective in studying this evidence was to determine whether these balls were sold on the market in their raw state, i.e. after their excavation from the quarry and/or importation to the ancient settlement, or whether they had already been processed for artistic use before reaching the Market. In the Results and Discussion sections below, we show that analyzing these coloring materials has opened up new lines of research in the *Magdala Project,* since some of them have components and respond to technical recipes that are more typical of the cosmetic and medical fields.

Colors have been used since very ancient times for numerous artistic, cosmetic, hygienic, medical and nutritional purposes and we can therefore achieve a greater and better understanding of ancient cultures and societies by analyzing their materiality. Studying the colors at Magdala will enable us to acquire greater knowledge of what everyday life was like in this first-century Lower Galilee settlement.

## 2. MATERIALS AND METHODS

### *2.1. Materials*

Table 1 shows the series of 16 samples considered in our study of the synagogue wall painting. Non-invasive analysis techniques would have been sufficient for the physicochemical characterization of the pigments. However, our results were mainly acquired using invasive techniques because the large amount of mural paint that was detached from the synagogue in the form of small samples made such analysis viable without affecting the remains of pictorial film preserved *in situ*. It was only for the blue and green colors that there were no fragments or detached samples, so the laboratory analyses of those colors required taking two micro-samples in unexposed areas practically at floor level. Sampling included all tonal variables of the same color in order to detect the different raw materials that were used to prepare the same color or, on the other hand, the different manufacturing processes used.

Table 2 shows the 11 pigment balls analyzed from the market. The majority of these balls naturally re-

leased dust particles, which were stored in individual bags for physicochemical analysis at the Laboratory for the Analysis and Diagnosis of Works of Art and the Science Park of the University of Valencia, Spain, where the entire physicochemical study of the colors at Magdala is being conducted. The transfer of materials to these laboratories was enabled by permissions granted by the Israel Antiquities Authority.

*Table 1. Samples analyzed from Magdala Synagogue*

| Reference | Sample number | Color | Sample typology |
|---|---|---|---|
| 1 | MG-1a | Light yellow | Collapsed wall painting sample |
| 2 | MG-1b | Medium yellow | Collapsed wall painting sample |
| 3 | MG-1c | Dark yellow | Collapsed wall painting sample |
| 4 | MG-1d | Yellow-ochre | Sample from the eastern section |
| 5 | MG-2a | Blue | Sample taken from the mural |
| 6 | MG-3a | White | Collapsed wall painting sample |
| 7 | MG-5a | Black | Collapsed wall painting sample |
| 8 | MG-5b | Grayish black | Collapsed wall painting sample |
| 9 | MG-6a | Light brown | Collapsed wall painting sample |
| 10 | MG-6b | Dark brown | Collapsed wall painting sample |
| 11 | MG-7a | Light red | Collapsed wall painting sample |
| 12 | MG-7b | Medium red | Collapsed wall painting sample |
| 13 | MG-7c | Dark red I | Collapsed wall painting sample |
| 14 | MG-7d | Dark red II | Collapsed wall painting sample |
| 15 | MG-7e | Dark red III | Sample from the eastern section |
| 16 | MG-8a | Green | Sample taken from the mural |

*Table 2. Samples of pigment balls analyzed from Magdala Market*

| Reference | Sample number | Color | Sample typology |
|---|---|---|---|
| 1 | PBmg-1a | Light yellow | Pigment powder particles |
| 2 | PBmg-1b | Medium yellow | Pigment powder particles |
| 3 | PBmg-1c | Dark yellow | Pigment powder particles |
| 4 | PBmg-2 | Blue | Pigment powder particles |
| 5 | PBmg-3a | White | Pigment powder particles |
| 6 | PBmg-3b | Gray white | Pigment powder particles |
| 7 | PBmg-7a | Light red | Pigment powder particles |
| 8 | PBmg-7b | Medium red | Pigment powder particles |
| 9 | PBmg-7c | Dark red I | Pigment powder particles |
| 10 | PBmg-7d | Dark red II | Pigment powder particles |
| 11 | PBmg-8 | Green | Pigment powder particles |

The archaeological mollusks associated with the pigment balls from the same market area were analyzed using optical microscopy (LM) to check their presence in colors such as purple, which could provide information about the sale and use of organic coloring matter in art and everyday life in Magdala.

## 2.2 Methods

***Light optical microscope (LM):*** A Leica E24HD model was used to study the surface of the samples and, for colors from the synagogue's mural painting, the stratigraphy. To obtain the cross sections, the samples were embedded in transparent epoxy resin with catalyst in a 5% solution.

***Visible spectrophotometry (UV-vis):*** A CM-700d portable spectrophotometer was used to obtain the exact measurements of each color and make proposals for subsequent preventive conservation.

***Scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX)*** was used to characterize the inorganic fraction of pigments and plasters. The samples were scientifically examined using a JEOL scanning electron microscope (JSM 6300 model) with a Link-Oxford-Isis microanalysis system operating at a voltage of 10-20 kV between cathode and anode. We used the ZAF method to correct inter-elemental effects in the semi-quantitative analysis.

***X-Ray Powder Diffraction (XRPD)*** was conducted on randomly oriented samples after grinding the powder samples in an agate mortar. A Bruker D8 Advance system operating in θ:θ mode was used as follows: generator setting 40 kV, 40 mA, Cu anode (Cu-Kα = 1.5418 Å), Ni filter, 2θ range 5-80°, step size 0.01°, and scan speed 0.5° $min^{-1}$. Qualitative phase determination was conducted using QualX2.0

software (Altomare et al., 2015) and the correlated COD database (Gražulis et al., 2009). Quantitative Phase Analysis (QPA) was conducted using Quanto software.

***Attenuated total reflection Fourier transform infrared spectroscopy (ATR-FTIR)*** was used to identify organic and inorganic materials. The analysis was performed using Vertex 70 equipment with an FR-DTGS detector coated for temperature stabilization.

***Gas Chromatography-Mass Spectrometry (GC-MS)*** was used to characterize organic substances. Agilent 6890N was used for GC analysis. The chromatograph was coupled to an HP 5973 mass detector. The column used was an HP-5MS (5% phenyl and 95% polydimethylsiloxane). The oven temperature program was 60-220 °C, with temperature increasing at a rate of 1 °C/min and held at 220 °C for 3 min. The injector temperature was 250 °C, the injection volume was 1 µL (95:5), and the inlet pressure was 7.96 psi. The carrier gas was He. The interface temperature was 280 °C. The ionization temperature for the mass detector was 230 °C. To identify possible organic components, we used the GC-MS database (NIST library, version 2002).

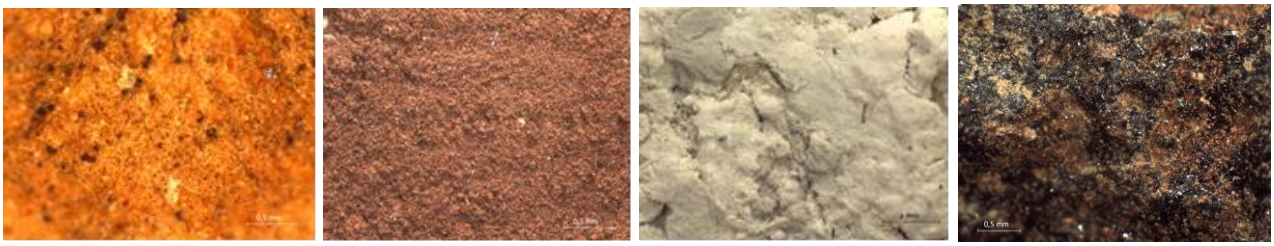
## 3. RESULTS AND DISCUSSION

### *3.1. Pigments and stucco preparations identified in the wall painting of Magdala Synagogue*

Magdala synagogue was painted with a far more sparing or restricted color palette than was used to develop the wall painting of other ancient cultures in contact with Lower Galilee in antiquity, such as Egypt, Greece and, of course, Rome. Lead white [$(PbCO_3)_2 \cdot Pb(OH)_2$], smoke or ivory black, lead red ($Pb_3O_4$), realgar orange ($As_4S_4$), orpiment yellow ($As_2S_3$), lapislazuli [$(Na, Ca)_{7\text{-}8}(Al, Si)_{12}(O, S)_{24}[(SO_4), Cl_2, (OH)_2]$], cinnabar (HgS), azurite blue [$Cu_3(CO_3)_2(OH)_2$] and malachite green [$Cu_2CO_3(OH)_2$] are just some of the lead, arsenic, lazurite and copper pigments that, for mural painting in these other ancient civilizations, were incorporated into the palette of calcium carbonate whites ($CaCO_3$), carbon blacks and Fe-based compounds identified by LM (Figures 8a-d and Figures 9a-d), FTIR (Figures 10 a-d and Figures 11a-d), SEM-EDX and XRPD in the remains of mural paintings preserved at Magdala Synagogue (Table 3).

*Table 3. Pigments identified in the wall painting at Magdala Synagogue*

| Reference | Sample number | Color | Pigments identified | Origin |
|---|---|---|---|---|
| 1 | MG-1a | Light yellow | Yellow ochre | Local |
| 2 | MG-1b | Medium yellow | Yellow ochre | Local |
| 3 | MG-1c | Dark yellow | Yellow ochre | Local |
| 4 | MG-1d | Yellow-ochre | Yellow ochre | Local |
| 5 | MG-2a | Blue | Egyptian Blue | Local or imported? |
| 6 | MG-3a | White | Calcium carbonate | Local |
| 7 | MG-5a | Black | Carbon Black | Local |
| 8 | MG-5b | Grayish black | Carbon Black | Local |
| 9 | MG-6a | Light brown | Red earth | Local |
| 10 | MG-6b | Dark brown | Red earth | Local |
| 11 | MG-7a | Light red | Red earth | Local |
| 12 | MG-7b | Medium red | Red earth | Local |
| 13 | MG-7c | Dark red I | Red earth | Local |
| 14 | MG-7d | Dark red II | Red earth | Local |
| 15 | MG-7e | Dark red III | Red earth | Local |
| 16 | MG-8a | Green | Malachite | Local |



*Figures 8a-d: LM photographs of the surface of yellow (Figure 8a: MG-1b), brown (Figure 8b: MG-6a), white (Figure 8c: MG-3a) and black (Figure 8d: MG-5a) pigments preserved on the wall*

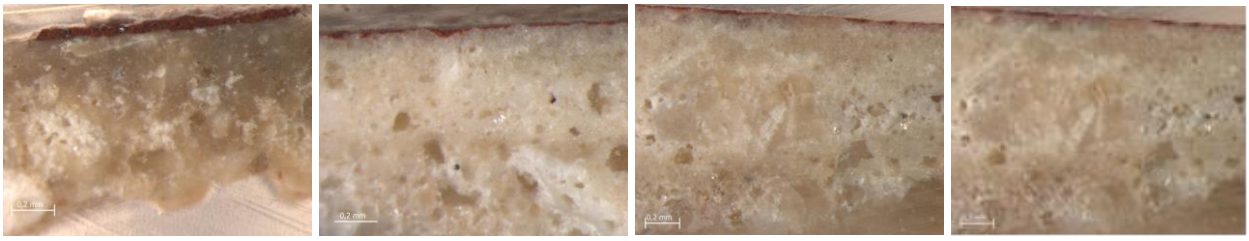


*Figure 9a: MG-7d* *Figure 9b: MG-7c* *Figure9c: MG-7b* *Figure 9d: MG-7a*

***Figures 9a-d: LM stratigraphic images of four tonal varieties of red preserved in the wall painting at Magdala Synagogue***

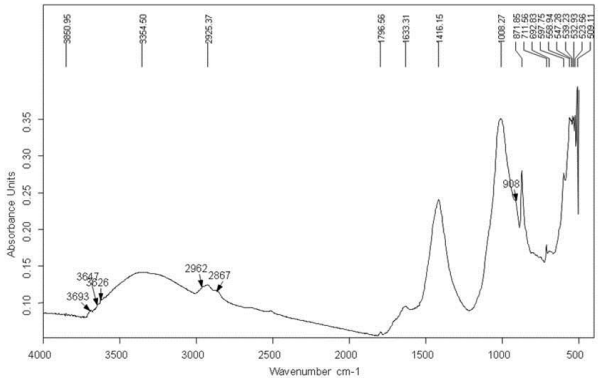



*Figure 10a: MG-1a*

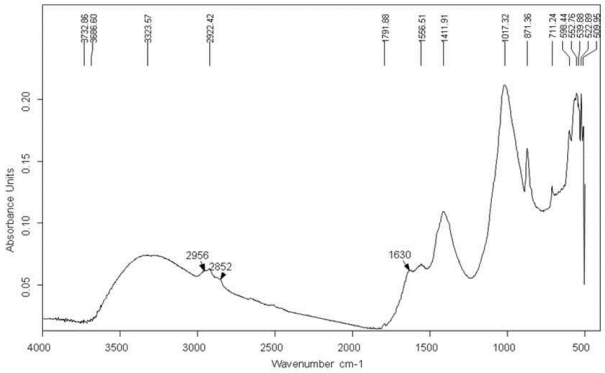



*Figure 10b: MG-1b*

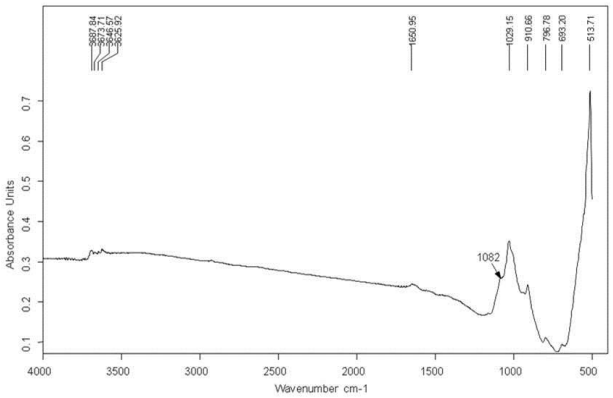



*Figure 10c: MG-1c*

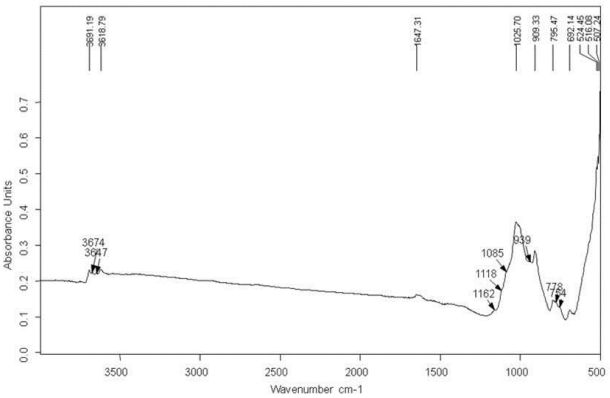



*Figure10d: MG-1d*

***Table 4: Results by FTIR of the four tonal varieties of yellow preserved on the wall painting at Magdala Synagogue***

| | Wavenumber cm-1 | | | |
|---|---|---|---|---|
| **SAMPLE** | **CALCITE** | **HALLOYSITE/ KAOLINITE** | **QUARTZ** | **IRON OXIDES** |
| MG-1a | 1416, 871, 711 | 3693, 3647, 3636, 1633, 1008, 908 | | 532 |
| MG-Ib | 1411, 871, 711 | 3703, 3626, 1655, 1088, 600 | | 539 |
| MG-1c | | 3687, 3673, 3646, 3625, 1650, 1029, 910, 693 | 1082, 796 | 513 |
| MG-1d | | 3691, 3674, 3647, 3618, 1647, 1118, 1025, 939, 909, 795 | 1162, 1085, 795, 778, 692, 516 | 524 |

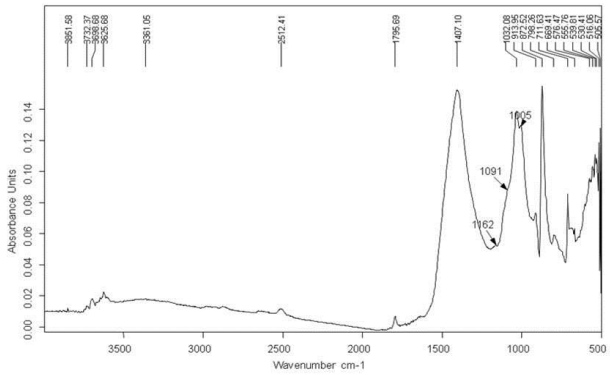



*Figure 11a: MG-7a*

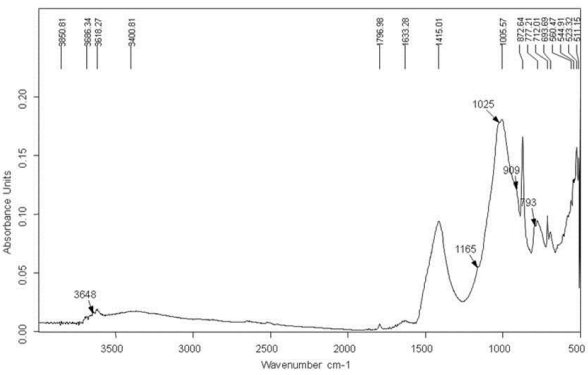



*Figure 11b: MG-7b*

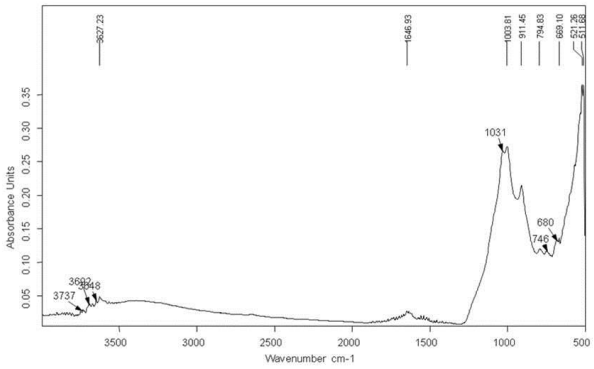



*Figure 11c: MG-7c*

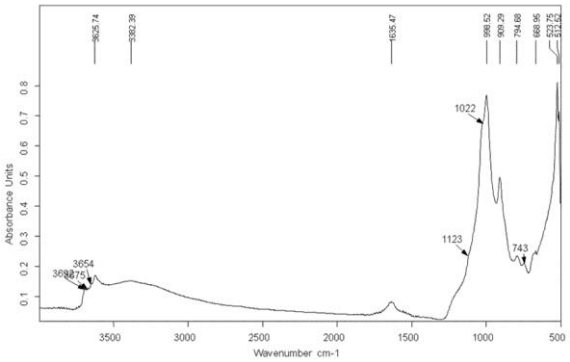



*Figure11d: MG-7d*

***Table 5: Results by FTIR of four tonal varieties of red preserved on the wall painting at Magdala Synagogue***

| | Wavenumber cm-1 | | | |
|---|---|---|---|---|
| **SAMPLE** | **CALCITE** | **HALLOYSITE/ KAOLINITE** | **QUARTZ** | **IRON OXIDES** |
| MG-7a | 1407, 872, 711 | 3732, 3698, 3625, 1630, 1162, 1091, 1032, 1005, 913, 798 | 798 | 532 |
| MG-7b | 1415, 872, 712 | 3686, 3648, 3618, 3400, 1633, 1165, 1025, 1005, 909, 793, 777 | 793, 777 | 539 |
| MG-7c | | 3737, 3692, 3648, 3627, 1646, 1031, 1003, 911, 794, 746, 680 | | 513 |
| MG-7d | | 3696, 3675, 3654, 3625, 3382, 1636, 1123, 1022, 998, 909, 794, 743 | | 524 |

The painters who worked on the mural painting at Magdala synagogue also did not use the organic colors of plant or animal origin, including blue indigo (*Indogofera tinctoria L.*), kermes (*Coccus ilicis L; Kermes vermilio Planch.*), and purple (*Purpura haemastoma L.; Hexaples trunculus L.; Bolinus brandaris L.*) that were used for wall paintings in Rome and Roman provinces during the same period. Indeed, the importance attached to these natural dyes for art and everyday life in ancient Mediterranean cultures explains the numerous references to how these species were obtained and used (including for pictorial purposes) in, for example, *Historia Animalium* (Aristotle, fourth century BCE), *Historia Plantarum* (Theophrastus, fourth century BCE) (Katsaros et al. 2009, 2011), *De Arquitectura Libri Dix* (Marcus Vitruvius Pollio, first century BCE), *De Materia Medica Libri Quinque* (Pedanio Dioscorides, first century CE), *De Naturalis Historiae* (Gaius Plinius Secundus, first century CE), *Leiden's Papyrus X* (third century CE) and the *Stockholm Papyrus* or *Papyrus Graecus Holmiensis* (fourth century CE). However, all these organic colors are absent in the mural painting at Magdala. It is highly likely that this was a specific choice that satisfied the requirements of Jewish Law in the first century, which, in the case of a synagogue, no doubt must have conditioned the use of certain materials. It should be noted that the knowledge and use of these organic dyes in Israel had been frequent since ancient times, which suggests that their absence in the synagogue mural painting at Magdala was down to choice. One example of this is the color purple (Kalaitzaki et al., 2017). Many written sources describe the use of this color in the art and everyday life of the Jews of ancient Israel since antiquity: e.g. Josephus (first century CE), Philo (third century CE), Strabo (third century CE) and Septuagint (third century CE). The Bible also makes explicit reference to

its importance in certain fragments. In one of these, King Solomon, who was preparing to build the Temple in Jerusalem, asks King Hiram (also 'Huram') of Tyre to (Chronicles 11 2: 2-6):

*"Now, send me a craftsman to [supervise] work in gold, silver, copper [bronze?], and iron, and in purple, scarlet, and blue, and who knows how to grave [all manner of] engravings, along-side the craftsmen I have with me in Judah and in Jerusalem, who were provided by David my father".*

Archaeological and physicochemical evidence, on the other hand, informs us that the use of this color must date back to at least seventh century BCE (Koren, 1995: 119). Interestingly, archaeological evidence shows that the inhabitants of first-century Magdala were able to purchase organic colors such as purple in the local market (Figure 12). Another dye that was widely used among the Jews of ancient Israel, and which was also on sale in Magdala Market, was the bluish purple named *tekhelet* in biblical and Talmudic Hebrew and 'hyacinthine purple' by the Romans (Wouters, 1992: 17-21; Ziderman, 1990: 98-101; 2004:38-43) (Figure 13). The fact that the written sources describe the use of these dyes by the Jews of ancient Israel and that Magdala market has archaeological evidence that they were actually sold there confirms that their absence from the color palette for the synagogue responded to an intentional choice by the artists as well as (probably) by those who commissioned the painting, who, in turn, were conditioned by Jewish Law. More specifically, we know from written sources that, although some of these coloring materials were hugely important in the rites of the ancient Jews, mixing them with other components was inappropriate since their hybrid nature removed their 'purity', which was a guiding principle in the Jewish religion. A good example of this is *Kermes echinatus*, which in Hebrew is called *shani* (red). This color was used in the Holy Land in the biblical period for both secular (e.g. coloring expensive weavings) and ritual (e.g. purifying lepers (Leviticus, 14:6) purposes and as a component of red cow ash – from the burnt offering of a red heifer – which was also used for purification (Numbers, 19:6) (Cardon, 1990: 191-192; Koren, 1993; Feliks, 1996: 85-102; Amar et al., 2005). Mixing this color with other materials, however, makes it prohibitive.

***Figure 12 (on the left): exterior shell of one of the snails (purple variety) discovered at Magdala Market; Figure 13 (on the right): mollusk responsible for the variety of blue known in Jewish culture as tekhelet.***

This may also explain the composition of the underlying strata of the pictorial film of the Magdala synagogue mural. Surprisingly, the stratigraphy of these levels of preparation and their composition are different from those of characteristic Roman wall painting such as *arriccio*, *intonaco* and *intonaquino* (Bratitsi et. al., 2019; Gutman et al., 2016; Kholod et al., 2016). For the mural painting at Magdala synagogue, two types of rendering were used: a thick and irregular mortar (*arriccio*) on which rested a thin and regular plaster (*intonaco*) (Figure 14). Moreover, neither of these two strata contains the *puzzolana* or clays that are characteristic of the preparatory levels of Roman wall painting. Only one compound is identified in the mortar and plaster at Magdala synagogue: high purity calcium carbonate ($CaCO_3$) (Figure 15). This material afforded much luminosity in the pictorial film of the mural painting, favored the use of the *frescco* technique (according to the results of GC-MS), and helped to partially conserve the painting since lime powder was widely known for its anti-bacterial and microbial properties in antiquity. The absence of any organic binder in the color samples analyzed indicates that, as we have mentioned, the technique used to execute the mural was *frescco*, which was widely used in first-century Rome and Roman provinces. The color palette identified in the mural at Magdala synagogue, which was mostly based on iron pigments, is fully compatible with the lime carbonation process, which explains the strength and good color preservation over time. Only the green malachite and Egyptian blue (Nicholson

and Shaw, 2000: 109; Colinart et al., 1996: 29-45; Bianchetti et al., 2000: 179-188; Mazzochin, 2004: 129-133) offer some indication of a certain sophistication in a pictorial decoration that, unlike Egyptian, Greek or Roman decorations (Bearat, 1997: 11-34), is characterized by simple and austere materiality in both the underlying levels and the pictorial film. This, of course, affords an identity to this artistic manifestation and distinguishes it from the socio-cultural perspective.

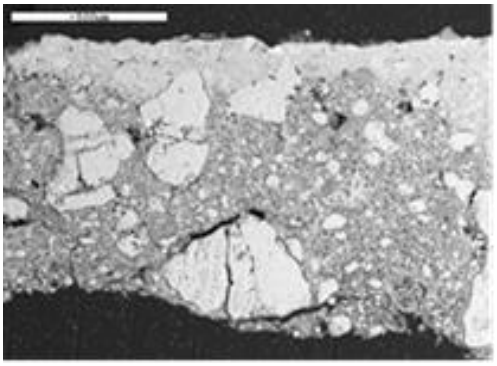


*Figure 14: SEM image from samples 3a*

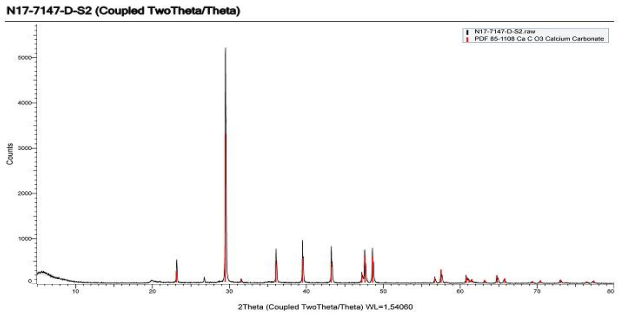



*Figure 15: XRPD spectrum of the $CaCO_3$ used in the mortar*

### *3.2. The colored balls found at Magdala Market: are they pigments, cosmetics or medicines?*

In Magdala, colored balls are frequently found in several areas of the settlement, e.g. (a) the market, (b) the ritual baths, (c) the residential area and (d) the port. So far we have analyzed the balls from the market to identify their composition and compare it with those of the colors used for the synagogue mural. Our starting hypothesis was that the colored balls discovered in the market would show the pigment in two states: (a) as a raw material, and (b) as a manufactured product for artistic use. Magdala market did offer these coloring materials in both states. However, the compositions of some of the pigments identified are more specific to the fields of cosmetics or medicine than to painting or art. One example involves the red and yellow earths (PBmg-1a, PBmg-1b, PBmg-1c, PBmg-7a, PBmg-7c). All the red earths sold at Magdala Market may have been used as pigments, cosmetics or drugs. In the second century CE, Galen already referred to the medicinal properties of this coloring matter (Photos-Jones and Hall, 2011:17):

*[…] it will be necessary to distinguish medicinal earth from that used in agriculture. There could be no greater mistake than to give this latter name to that which we use in medicine, although the fatty part even of agricultural soil is useful in the treatment of all parts needing desiccative treatment.*

*Table 4. The pigments balls identified from Magdala Market*

| Ref. | Sample | Color | Pigments identified | Uses | Origin |
|---|---|---|---|---|---|
| 1 | PBmg-1a | Light yellow | Yellow ochre | Pigment/cosmetic/drug | Local |
| 2 | PBmg-1b | Medium yellow | Yellow ochre | Pigment/cosmetic/drug | Local |
| 3 | PBmg-1c | Dark yellow | Jarosite $KFe_3(SO_4)_2(OH)_6$ | Cosmetic/pigment/drug | Imported? |
| 4 | PBmg-2 | Blue | Azurite $Cu_3(CO_3)_2(OH)_2$ | Pigment | Imported |
| 5 | PBmg-3a | White | Clay; a laminar-type clay | Pottery/ hygienic-medicinal purposes | Imported? |
| 6 | PBmg-3b | Gray white | Clay; a laminar-type clay | Pottery/ hygienic-medicinal purposes | Imported? |
| 7 | PBmg-7a | Light red | Red earth | Pigment/cosmetic/drug | Local |
| 8 | PBmg-7b | Medium red | Cinnabar (HgS) | Pigment/cosmetic/drug | Imported |
| 9 | PBmg-7c | Dark red I | Red earth | Pigment/cosmetic/drug – Lemnian Earth | Imported |
| 10 | PBmg-7d | Dark red II | Haematite $Fe_2O_3$ | Pigment/cosmetic/drug | Imported? |
| 11 | PBmg-8 | Green | Malachite $Cu_2CO_3(OH)_2$ | Pigment/cosmetic/drug | Imported |

One of the earths, identified in the PBmg-7c sample at Magdala Market, is Lemnian Earth (Figure 16a-b), which consists of siliceous mineral material (Figure 17) and whose use as a pigment is described by, for example, Vitruvius (Photos-Jones and Hall, 2011:30):

*[…] the red variety too, is extracted in great abundance from many places but the best comes only from a few of*

*them, like Sinope in Pontus, Egypt and the Balearic Islands of Hispania, also Lemnos.*

In fact, as is described by Pliny and Galen in their respective treatises, each year the priestesses at the Temple of Artemis/Diana prepared this red earth at the goddess's sanctuary on the Island of Lemnos (Photos-Jones and Hall, 2014:185):

*The priestess collects this, to the accompaniment of some local ceremony, no animals being sacrificed, but wheat and barley being given back to the land in exchange. She then takes it to the city, mixes it with water so as to make moist mud, shakes this violently and then allows it to stand. Thereafter she removes first the superficial water, and next the greasy part of the earth below this, leaving only the stony and sandy part of the bottom, which is useless. She now dries the greasy, mud until it reaches the consistency of soft wax. Of this she takes small portions and imprints upon them the seal of Artemis namely the goat, then again she dries these in the shade till they are absolutely free from moisture.*

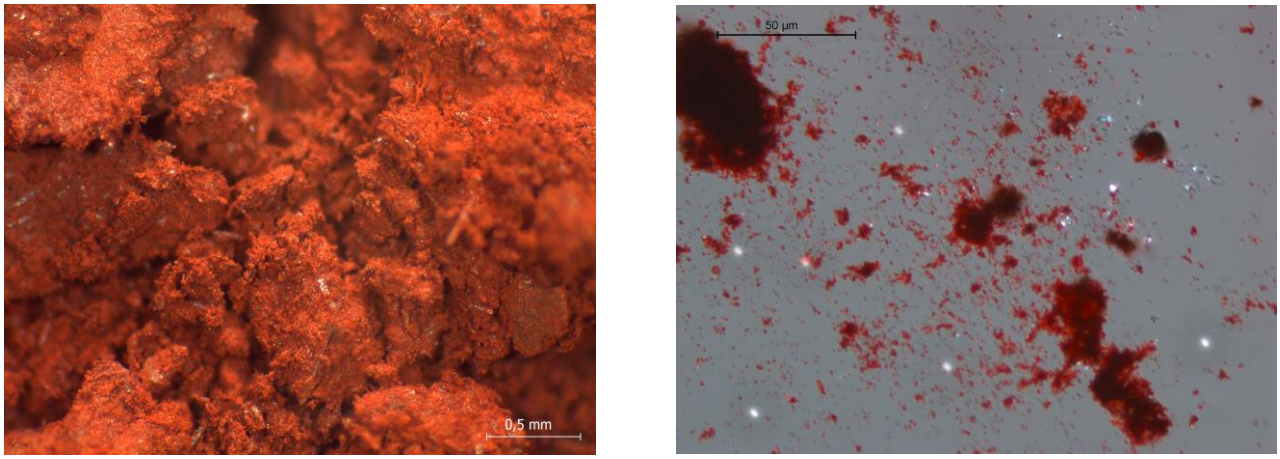



***Figure 16a-b: (a) Optical surface microcopy (LM) and (b) LM with transmitted light from PBmg-7c sample***

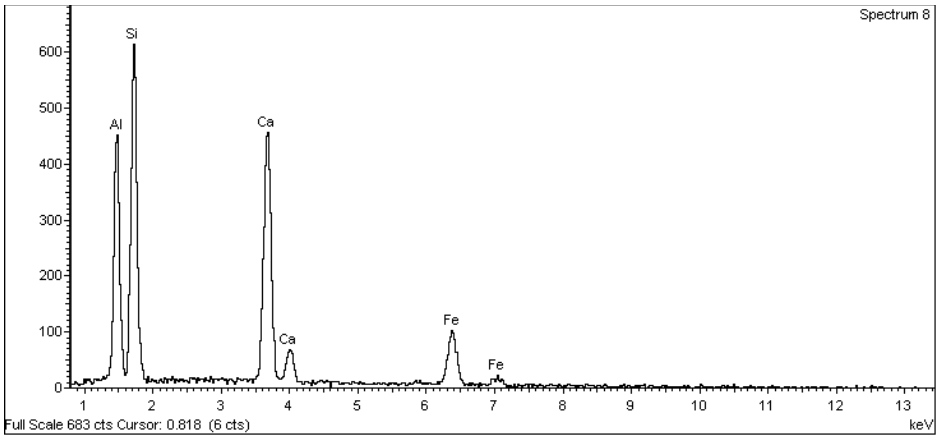



***Figure 17. EDX spectrum of the Lemnian Earth. This material can have colorations between white-gray and red. The evidence found at Magdala Market is of the reddish variety, which explains the high iron content identified in the sample***

According to the same historians, the priest at Hephaistos also used Lemnian Earth to treat certain diseases. Pliny (*Naturalis Historia*) and Galen (*De Simplicium Medicamentorum Temperamentis ac Facultatibus*), as well as Theophrastus (*On Stones*) and Discorides (*De Materia Medica*), refer to the significant use of this red pigment in three contexts: painting, rituals, and medicine. The pigment was used medicinally to treat, for example, epilepsy, which was known as the 'sacred disease' after the term was coined in the *Corpus Hippocraticum* due to the association, established in ancient Greece, between this disease, the moon, and the goddess Diana (Lanata, 1967). Many written sources from around the first century therefore describe the medicinal, pictorial and ritual properties of Lemnian Earth, the clay silicate of the kaolin type with a high ferric component identified in the above sample from Magdala (Figure 17). The use of this material by the inhabitants of Magdala in the first century CE may therefore have had three purposes rather than just the artistic.

The presence of Lemnian Earth at Magdala Market suggests that the inhabitants of this ancient settlement in the first century probably used this mate-

rial more for medicinal purposes than for artistic ones. In fact, it was for this purpose that Lemnian Earth was manufactured, marketed and used until the 19th century, as is demonstrated by its sale in the Modern and Contemporary periods in various European *spezierie* and pharmacies (Vázquez de Ágredos et al., 2018). It is important to note that this earth was not of local origin. In other words, Lemnian Earth must have arrived in Magdala through its port and from a fair distance, e.g. the Aegean Islands, including the Island of Lemnos, where its formation has been recorded since very ancient times. The geological setting and history of Lemnos indicate potential for sulphur-bearing hydrothermal mineralization and therefore acid sulphate alteration related to volcanism, which, in turn, can produce both red (iron oxide) and yellow/white (clay-kaolin) materials (Photos-Jones and Hall, 2011: 51). Since Lemnian Earth must have arrived in Magdala from Aegean islands such us Lemnos, we believe that the same medium-distance trading route was used to import into Magdala other red and yellow earths identified, such as jarosite (PBmg-1c), which was hugely important for Egyptian and ancient Middle Eastern cosmetics, as well as in Greece and Rome. This same occurs with the white colors found at Magdala Market (PBmg-3a, PBmg-3b). Both of these are clay silicates of limited formation in dry and arid environments such as Lower Galilee but are abundant in several geological contexts in the Aegean Islands. In fact, the composition based on kaolin, aluminum and silica, in the form of quartz minerals, that was identified in sample PBmg-3a responds to other pigments/drugs that were traditionally used in the ancient Mediterranean, e.g. Melos white, from the island of the same name located southwest of the Cyclades Islands (Photos-Jones and Hall, 2011: 78).

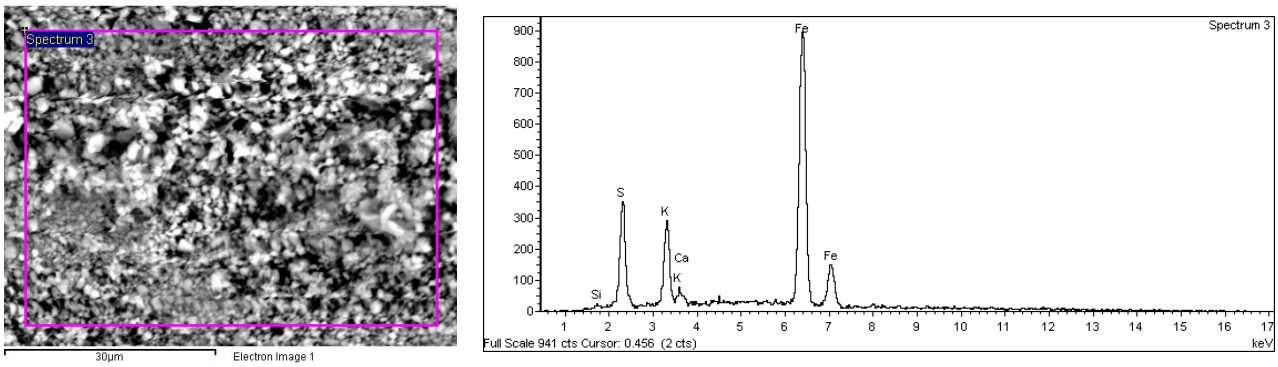



*Figure 18a-b. SEM image (18a) and EDX (18b) spectrum of sample PBmg-1c. Our results identified this coloring material as jarosite $KFe_3(SO_4)_2(OH)_6$*

The triple use of the yellow and red colors sold at Magdala Market can also be identified in the two white pigment balls also uncovered from there. In agreement with the results obtained from FTIR and SEM-EDX, for example, sample PBmg-3b is a laminar-type white clay (Figures 19a-b). This kind of clay contains a higher proportion of water (Besoain, 1985:415), which confers two further properties that have accounted for its use in ancient and modern cosmetics since the early Mesopotamian period (Rytwo, 2008:16): luminosity and moisture (Whitney, 1990). Clays such us kaolin and illite also confer hygienic/medicinal properties thanks to their ability to absorb impurities from the skin (Vázquez de Ágredos et al., 2018) and remove dead cells, toxins and impurities, thus normalizing skin texture (thanks to their peeling and purifying effects). For these reasons, laminate clay silicates have been used since ancient times in pelotherapy, i.e. the use of natural clay mud baths applied to the skin for their purifying and medicinal effects. This, and the fact that white balls (still under study) were found close to the ritual baths at Magdala makes us consider whether the hygienic and medicinal use of these white laminar-type clays was common among Jews in the first century CE. For the answer to this question, further research must be conducted. It is also interesting that the clay-type white pigment balls discovered at Magdala Market contained a large proportion of potassium sulfate, a salt that has been widely used in medicine since ancient times in cultures such as those of Egypt and the ancient Near East. Egyptian medical papyri, for example, contain many prescriptions that include salts. The Greeks and Romans also attributed various properties to sea and rock salts, asserting, for example, that they were:

expectorant (when inhaled in the form of water vapor), emetic (when mixed with vinegar), digestive (when diluted in cow's milk), disinfectant (when combined with honey, e.g. for ulcers), and dermatological (in salt water) – as recorded in Hippocratic and Galenic medicine (Cavallo and Vázquez de Ágredos, in press). The composition of these white colors, which was very different from that of the white calcium carbonate identified in the synagogue mural, suggests that their use by the inhabitants of Magdala was not artistic but medicinal. In other words, the composition of the white balls found at Magdala market makes them a complex formulation for hygienic/medicinal or cosmetic purposes. This conclusion can also be extended to some of the red and yellow earths identified, such as Lemnian Earth and jarosite, which are more used for medicinal/hygienic and cosmetic purposes than for artistic ones, as is evidenced, for example, by their absence from the wall painting at Magdala synagogue.

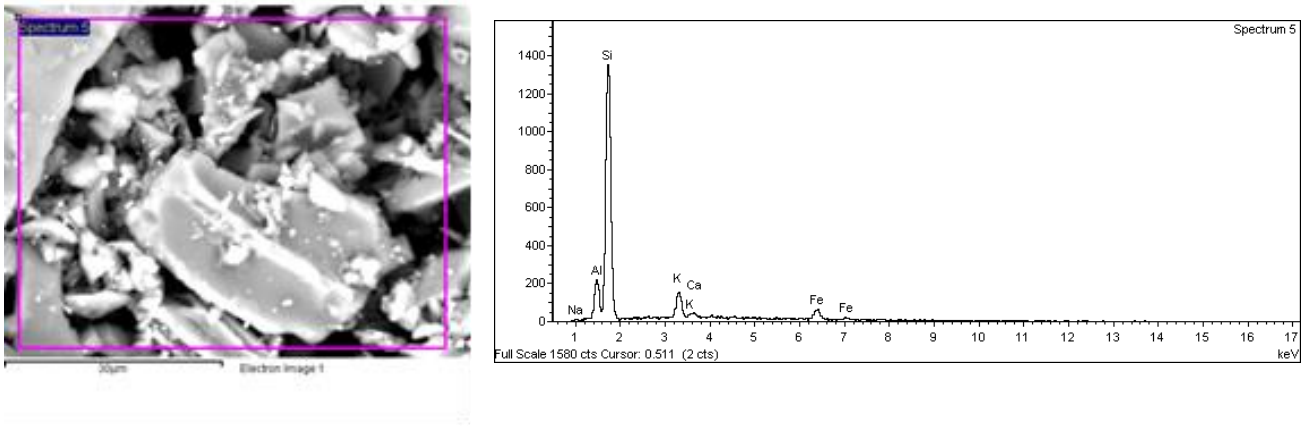



***Figure 19a-b. SEM image (19a) and EDX (19b) spectrum of sample PBmg-3b, from a laminar clay silicate such as kaolin or illite***

Finally, cinnabar, azurite and malachite are pigments, cosmetics and drugs (especially malachite and cinnabar) that were imported into Magdala via mid-to-long distance trade. It is highly likely that these coloring materials arrived from Rome, which, in turn, obtained them from provinces such as Spain (cinnabar) and Cyprus (basic copper carbonates such as azurite and malachite). The presence of malachite at Magdala Market and Egyptian blue in the wall painting of Magdala Synagogue (whose formula includes malachite in combination with silica, calcite and natron) suggests that Egyptian blue may have been prepared in Magdala by local painters who knew the recipe and manufacturing procedure for this artificial pigment. This hypothesis, which we will continue to explore, also suggests that either some artists at Magdala were of foreign origin or that all were locals who were able to travel and establish contact with workshops and schools from other cultures to acquire knowledge with which they could expand their application of new techniques and materials (such as Egyptian blue) in their artwork.

## 4. CONCLUSIONS

The physicochemical study of the pigments and coloring materials analyzed so far at Magdala shows that, although the materials and techniques used in the wall painting at the Synagogue are similar to those that were used in Rome and Roman provinces, they have elements that give this artistic manifestation an identity of its own in its region and culture of origin. The purity of the calcareous coatings underlying the pictorial film and the austerity of the pigments used (except in the case of Egyptian blue) are some of the results found in this regard. Analyses of the colored balls found at Magdala Market, on the other hand, show that (a) the range of coloring materials is more diverse than those identified in the wall painting of the Synagogue, and (b) many of these materials have a close relationship with the fields of medicine, hygiene and cosmetics. Also, some of these pigments and coloring materials were not local but were imported through mid- and long-distance trade. This is the case, for example, of Lemnian Earth and some white clay silicates, which came from the Aegean Islands, as well as cinnabar, azurite and malachite, which may have arrived in Magdala from Rome, which, in turn, would have previously acquired them from provinces such as Spain and Cyprus.

Finally, the greater manufacturing complexity of these copper- and mercury-based coloring materials suggests that highly specialized artists were operating in Magdala. In fact, the Egyptian blue identified

in the Synagogue wall painting may have been prepared on the shores of the Sea of Galilee by the same local artists, using the malachite, calcite, silica and natron they were able to obtain from the region. This high level of color specialization in Magdala has also been detected in arts such as mosaic or glass. In this sense, the well-dated and secure contexts of the varied glass found at Magdala reveal a significant use of glass vessels during the Early Roman period (first century CE), with a slight predominance of cast vessels alongside the increasing use of blown ones. This makes a significant contribution to our understanding of glass production and commerce in the Early Roman period. The varied colors and reoccurring vessel types seen in this assemblage, and the evidence of glass production, suggest that a local workshop operated at the site. In the next excavation season, we expect to uncover more discoveries that will enable us to confirm or refute this assumption.

We hypothesize that there may have been a relationship between the types of pigment discovered at Magdala market, which may have been used to develop medicinal treatments, with the miniature glass bottles that may have served as medicine containers.

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