www.maajournal.com

Mediterranean Archaeology and Archaeometry
Vol. 20, No 3, (2020), pp. 149-158
Open Access. Online & Print.

DOI: 10.5281/zenodo.3960203

ANALYTICAL CHARACTERIZATION OF ANCIENT MOSAIC FLOOR PREPARATORY LAYERS AND TESSERAE FROM THE HIPPOLYTUS HALL IN MADABA, JORDAN: CASE STUDY

Mahmoud Arinat[1*], Adnan Shiyyab[1], Wassef Al Sekhaneh[2]

[1]*School of Archaeology and Tourism, The University of Jordan, Amman, Jordan*
[2]*Faculty of Archaeology and Anthropology, Yarmouk University, Irbid, Jordan*

Received: 09/06/2020
Accepted: 20/08/2020

Corresponding author: Mahmoud Arinat (arinatmahmoud74@gmail.com)

ABSTRACT

This current article is focused on the characterization of the preparatory mortar layers and *tesserae* from the mosaic floor of the Hippolytus Hall at Madaba, located in southwest Jordan.

The chemical analysis of the ancient mosaic mortar and *tesserae* can provide valuable data regarding the ancient materials and technological processes applied for the production of the mosaic floor in the Byzantine period in Jordan. As well as, the conservation of the mosaic requires knowledge concerning the construction techniques, properties of the used materials as well as the deterioration factors. For these purposes, a considerable group of stone *tesserae* of different colors were collected together with two mortar samples from the preparatory layers and analyzed by X-Ray Diffraction (XRD) and Scanning Electronic Microscope attached to energy dispersive X-ray spectrometer (SEM-EDX).

The results showed that the mosaic floor composed of three layers (statumen, nucleus, and supra nucleus). The supra nucleus and nucleus layers mortars are a lime-based mortar and the Calcite ($CaCO_3$) is the main mineral of both samples, which indicates that the mortar used in preparatory layers of the mosaic is localized lime mortar. In addition, the good adhesion between mosaic layers can explain the favourable state of conservation, stability and long-term durability of this mosaic floor

Besides, these results revealed that Calcite is the main mineral of all limestone tesserae samples ($CaCO_3$). The calcite here is a microcrystalline Calcite is known as Micrite.

KEYWORDS: Mosaic, Hippolytus, Tesserae, Lime Mortar, SEM-EDX, XRD, Madaba

1. INTRODUCTION

Mosaic has a long history, starting in Mesopotamia in the 3rd millennium B.C, with the use of polychrome clay cons driven into the muddy wall to form simple geometrical patterns (Avi-Yonah, 1975; Charvát, 2003; Haswell, 1973; Valiulis, 2014). The use of mosaic as a type of floor decoration started during the 2nd millennium B.C, for both aesthetic and functional purposes, there were pebble floors, where different colored stones were used to create patterns (Dunbabin & Dunbabin, 1999; Farneti, 1993; Hetherington, 1967). From the 4th century B.C, the construction of the mosaic floors was developed, widespread and specific requirements and criteria started to be followed, regarding both their materials and application techniques. *Tesserae* comprised of natural pebbles or shaped small pieces of stone of different colors (glass or brick tesserae was also used) representing mythological subjects, animal, vegetal or geometric patterns (Dunbabin & Dunbabin, 1999; Farneti, 1993; Roncuzzi, 2001; Marta, 1991; Pachta & Stefanidou, 2018). The mosaic floors were widespread during the Roman periods and flourished in the Byzantine periods.

The mosaic floors are generally composed of several preparatory layers: *statumen*, *rudus*, *nucleus*, *Supra nucleus,* and *tessellatum* (Carrasco et al., 2008; De Carolis et al., 2015; Wootton, 2012). The thickness and materials of the preparatory layers change according to the physical condition of sites and structures of buildings (Starinieri, 2009). The preparatory layers of floor mosaic play a fundamental role in their structure, enhancing their durability and resistance to environmental factors and external loading (GCI, 2011; Montana et al., 2018 ; Pachta et al., 2018; Pachta & Stefanidou, 2018).

Most of the information we have about how ancient mosaic floor foundations were prepared comes from the ancient treaties of Vitruvius (1st century B.C) in his De Architectura, who described in detail the techniques used for the preparation of mosaic pavements. According to Vitruvius, the process of manufacturing the mosaic floor foundation started with a thick foundation layer of large stones, known as '*Statumen*', laid without mortar on the ground that is rammed and leveled (Vitruvius, 1960). The second foundation layer, spread over the *statumen* is the '*Rudus*', made of coarse mortar, composed of mixed gravel with lime in 3:1 proportion. The thickness of this layer is at least 12 cm. this layer is rammed using wooden stamps. The third foundation layer, called ` *nucleus*`, made of powdered pottery and lime in a 3:1 proportion. The thickness of this layer was about 15 cm. The purpose of this layer was to ensure the drainage of surface waters. The last layer called the Bedding layer (*Supra nucleus*). It is applied to the *nucleus* and *tesserae* inserted in it before the lime dries. This layer laid out a section at a time so that it remains soft during the whole inserting process, where the outlines of the drawing (*sinopia*) were marked on the surface of the bedding layer to guide the mosaicist when inserting the *tesserae* (Larionov & Frolov, 2019; Palomar et al., 2011; Ruiz-Lopez, 2013; Vitruvius, 1960).

According to Starinieri, not all ancient mosaic pavements contain all the layers exactly as described in the ancient treatise of Vitruvius or others, such as Pliny and Alberti. The thickness and the nature of their constituent materials vary among sites or even within the same building among pavements. Therefore, the investigation that takes account of the whole structure of the pavement is of primary importance (Alberti, 1955; Pliny, 1971; Starinieri, 2009).

Several studies performed on the stratigraphy and characteristics of ancient floor mosaic layers confirmed the importance of the good compaction of the layers, which reduce the pores and voids of each layer and then enhance their mechanical and properties. This resulted in enhancing the durability of the mosaic floor layers. Furthermore, these studies point out that the characterization of the preparatory layers is crucial to the understanding of a mosaic`s conservation problems (Pachta et al., 2018; Pachta & Stefanidou, 2018). In Jordan, the study of the mosaic preparatory mortar layers is still limited. Hammarneh and Abu Jaber (2017) conducted a study of mosaic mortar layers composition from the churches of St. Cosmas and Damiannus and Bishop Genesius (6th century A.D.) in Gerasa.

This current study is attempt to fill this missing gap and improve our knowledge on ancient Byzantine mosaic materials and techniques by means of chemical and mineralogical investigation on mortar layers and colored *tesserae* composing the mosaic floor of the Hippolytus Hall in Madaba, Jordan.

2. HALL AND DESCRIPTION

The Hippolytus hall is located in the city of Madaba, 30 km southwest of the Jordanian capital, Amman, and it lies in the center of the city of Madaba, along the Roman road that crosses the city from east to west. It was built in the first half of the 6th century A.D. The mosaic of Hippolytus hall is unique among Jordan`s mosaics. It depicts the ancient myth of Phaedra and Hippolytus, inspired by the Euripidean tragedy of Phaedra and Hippolytus. (Piccirillo, Bikai, & Dailey, 1993; Schick, 1995) (Fig. 1).

Figure 1. General view of the Virgin church and the Hippolytus Hall with new shelter

Archaeological investigations conducted between 1972 and 1991 by Michele Piccirillo, revealed that the church of the Virgin Mary (the end of the 6th century A.D.) was built above the Hippolytus Hall and was built over a Roman temple. Both the roman temple and the Hippolytus hall are on the south side of a paved courtyard. The western part of the mosaic floor was discovered by the house owner Sulayman Sunna in 1905, which was found 1.3 meters below the mosaic of the virgin church. The larger part of the mosaic was discovered in 1982 by Michele Piccirillo (Piccirillo, 1982, 1995) (Fig. 2).

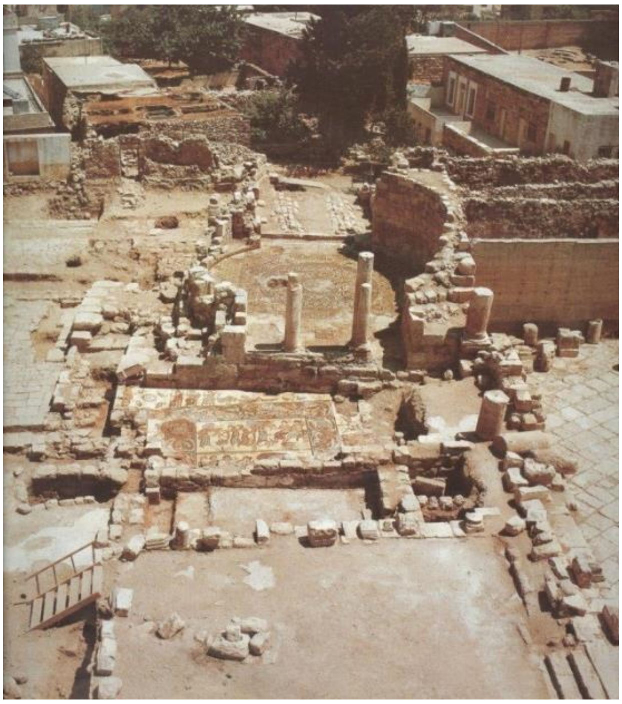

Figure 2. General view of the Virgin church and the Hippolytus Hall after excavation

The hall is irregular dimensions, measuring approximately 7.3 m W x 9.5m L. It was originally covered by four north-south arches and was entered from the mansion`s courtyard by a door on the north side of the northeast corner. Birds facing a flower decorated the inter-columnar spaces between the side pillars of the arches (Fig. 3).

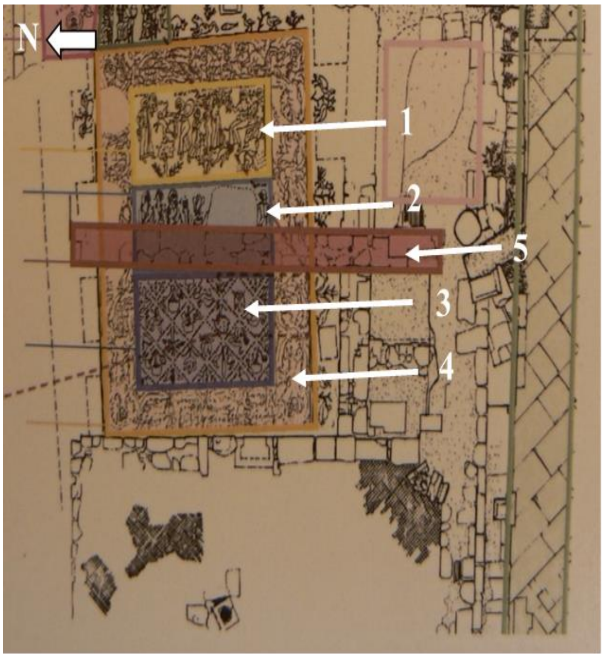

Figure 3. The map of the Hippolytus Hall: 1= East panel shows Aphrodite seated on a throne; 2= Central panel shows of the major characters of the story of Phaedra and Hippolytus; 3= West panel decorated with a grid of flowers, plants and aquatic birds; 4= Wide border of acanthus scrolls framing the central field of the mosaic; 5= Added wall partially damaging the central panel (Piccirillo, 1995)

The main carpet of the mosaic is enclosed by a border of acanthus scrolls decorated with hunting and pastoral scenes against a dark background. The four scrolls on the corners are decorated with personifications of the seasons: Spring and Autumn are on the west side, while Summer and Winter are to the east. All four are represented as Tyche in half bust, and each wears a turreted crown.

The central field of the mosaic is sub-divided into three rectangular panels. The west panel of the carpet, a section which was discovered in 1905, is decorated with a grid of flowers and plants which alternate with aquatic birds. Two seagulls with extended wings glide over the water (Piccirillo, 1984). The central panel was partially destroyed when the hall was divided into two rooms in antiquity, but it shows some of the major characters of the story of Phaedra and Hippolytus. Captions reveal the names of the characters in the scene which shows handmaidens assisting Phaedra. Meanwhile, a wet nurse turns toward Hippolytus who is accompanied by his ministers and servant holding his mount. In the third panel, Aphrodite sites a throne next to Adonis who holds a lance. A Grace presents to her a Cupid whom she threatens with a sandal. A second Cupid supports Aphrodite barefoot, while a third watches and a fourth has his head in a basket from which flowers fall, the basket and flowers allude to a poem in which a honeycomb with bees flying away is used to symbolize both the sweetness and sting of love. A second Grace grasps the foot of yet another Cupid who attempts to take refuge among the branches of a tree, and a third Grace chases the sixth Cupid. To show that this scene takes place in the open countryside, the artist added a barefooted peasant girl carrying a basket with fruit on her shoulder and a partridge in her right hand. Again, all the characters are identified by captions (Piccirillo, 1995; Piccirillo et al., 1993).

An irregular area of the pavement near the entrance is decorated with a medallion in which a pair of sandals is framed by four birds. Along the eastern wall, there are personifications of three cities together with two sea monsters who challenge each other, as well as flowers and birds. The cities are Rome. Gregoria and Madaba. They are each depicted as Tyche seated on a throne and each holds a small cross on a long staff in her right hand. Gregoria and Madaba wear turreted crowns on their heads, while Rome wears a helmet of a style that is common in the official iconography of the era (Piccirillo et al., 1993) (Fig. 4).

3. **MATERIALS AND METHOD**

3.1 Analyzed samples

Two representative samples of the preparatory layers including *supra nucleus* and *nucleus* were collected together with 9 stone *tesserae* of different colors (White, Black, yellow, red, Pink, Orange, light gray, light brown, dark gray) and subjected to different analytical and examination methods. A detailed visual examination of the whole mosaic is carried out *in situ*. This assisted us to understand the stratigraphy of the mosaic preparatory layers, the general characteristics of each layer (thickness and color), the mortars cohesion, the layers mutual adhesion as well as the color range of the *tesserae*. Photographs of the tesserae samples are shown in figure 5, where a schematic description of the collected samples is given in Table 1 and 2. The samples have been collected utilizing a hammer, chisel, and scalpel and stored in sealed plastic bags for transfer to the laboratory.

Figure 4. General view of the mosaic of the Hippolytus Hall showing three panels: 1= Aphrodite seated on a throne; 2= the major characters of the story of Phaedra and Hippolytus; 3= decorated with a grid of flowers, plants and aquatic birds) framed by a wide border of acanthus scrolls.

Table 1. The description of the stone tesserae samples

Sample Code	Material	Thickness	Color
HT1	Stone Tesserae	1.7 cm	White
HT2	Stone Tesserae	1.8 cm	Black
HT3	Stone Tesserae	1.6 cm	Yellow
HT4	Stone Tesserae	1.4 cm	Red
HT5	Stone Tesserae	1.4 cm	Pink
HT6	Stone Tesserae	1,4 cm	Orange
HT7	Stone Tesserae	1.6 cm	Light Gray
HT8	Stone Tesserae	1.5 cm	Light Brown
HT9	Stone Tesserae	1.6 cm	Dark Gray

Table 2. The description of the mortar layers' samples

Sample Code	Layer	Thickness
HM1	Bedding layer (supra nucleus)	1cm
HM2	Nucleus	4.5cm

Figure 5. The stone tesserae selected for experimental study

3.2 Methods

The tesserae and mortar samples powder were analyzed using XRD instrument (Shimadzu XRD-7000) equipped with Cu Kα radiation source and at a setting of 40 kV accelerating voltage and 30 mA current, the scanning range of 2θ was from 3 to 80 degree and the scanning speed was 1°/min. All experiments are done under the same conditions, to determine their mineralogical composition. Furthermore, SEM-EDS Bruker microanalysis was performed to diagnose the microstructure and morphological texture of the selected samples as well as to determine the micro elemental composition, operates at 2.5-10 kV voltage, and current of 3.66 µA filament, 7.35×10-4 Pascal vacuum, and 16-18 mm working distance.

4. RESULTS AND DISCUSION

4.1 *Preparatory mortar layers*

According to the in situ investigation, the mosaic preparatory layers of the Hippolytus Hall was built on natural leveled ground and made of three layers. The adhesion between the mortar layers is very good. The mosaic preparatory layers consisted of Statumen, Nucleus and Supra nucleus. The rudus layer in this mosaic did not exist. The statumen is made of large stones without mortar. The nucleus layer is of 4.5 cm thickness, made of white mortar. The Supra nucleus layer is comprised of very thin white mortar of 1cm thickness (Fig. 6 A and B).

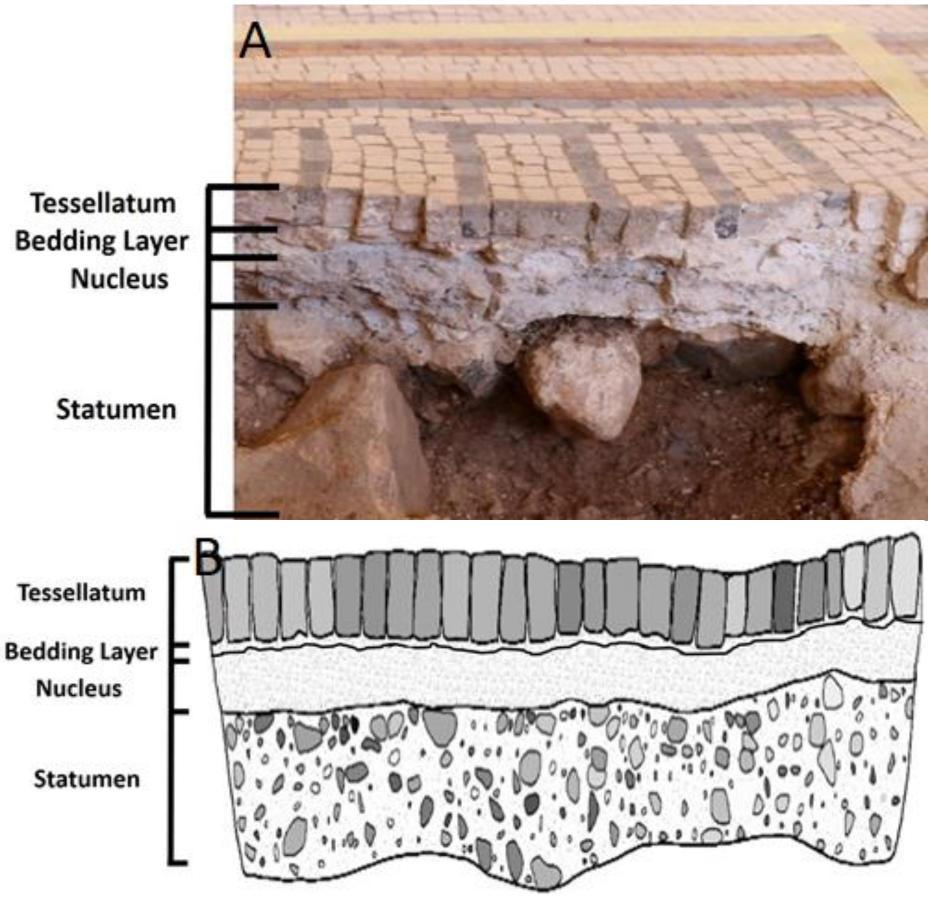

Figure 6. A) Detailed stratigraphy of the Hippolytus Hall mosaic; B) The schematic diagram of the mosaic stratigraphy of the Hippolytus Hall mosaic

The mortar results of X-ray diffraction analysis showed that the Supra nucleus layer mortar sample reveals only the presence of $CaCO_3$, and the Nucleus mortar sample contains calcite as the major mineral, whereas Carlinite (TI2S), Graphite (C) and Natroniobite ($NaNbO_3$) are present as a minor or trace minerals (Table 3). However, Quartz sand (SiO_2) is detected in both samples in EDX microanalysis which suggests that these mortars are corresponding to local calcareous remains or deposits in Jordan.

Table 3. The chemical composition of the resulting minerals using XRD of the preparatory layer structure.

Sample Code	Layer	Minerals	Formula	Card No.
HM1	Bedding layer (supra nucleus)	Calcite	$CaCO_3$	00-005-0586
HM2	Nucleus	Calcite	$CaCO_3$ major	00-005-0586
		Carlinite	Tl2 S trace	00-029-1344
		Graphite	C trace	00-012-0212
		Natroniobite	$NaNbO_3$ trace	00-026-1380

The SEM analysis of the bedding layer mortar shows that the particles are irregularly shaped and varied in sizes. Whereas other aspects of fractured surface and highly fissured nature of coarse surfaces were observed (Fig. 8a). Furthermore, SEM examination was carried out on cross-sections of the same samples to examine the structural morphology of the inner core of every block of mortar. SEM images (Fig. 8b) have shown how the inner body relatively differs from the outer surfaces illustrated in figure 8a.

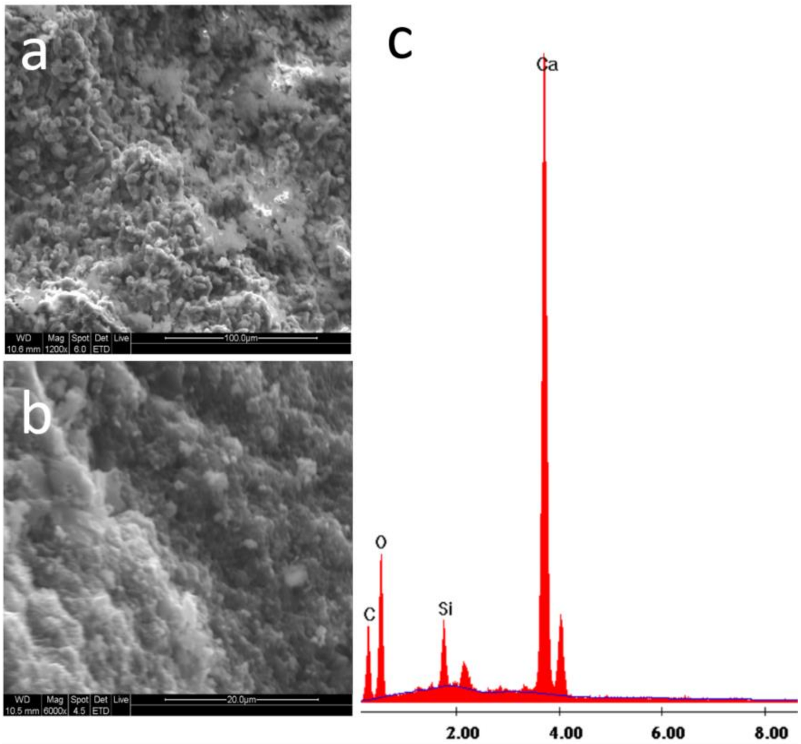

Figure 8. A) shows the SEM image of the bedding layer; B) SEM image of bedding layer; C) shows the Energy-dispersive X-ray results of mortar of nucleus layer from Hippolytus Hall.

The SEM analysis of the bedding layer and nucleus show and reveal that the particles were heterogeneously shaped and less-vitrified with a lot of incisions (Fig. 9a). Besides, there is a slight evident structural and compositional continuity between the surface and the bulk. Whereas the SEM images show clear crystalline phases of calcite ($CaCO_3$) in both samples (Figs. 8a and b). However, obvious dissimilarities in color and texture were observed during examining all the sample sections.

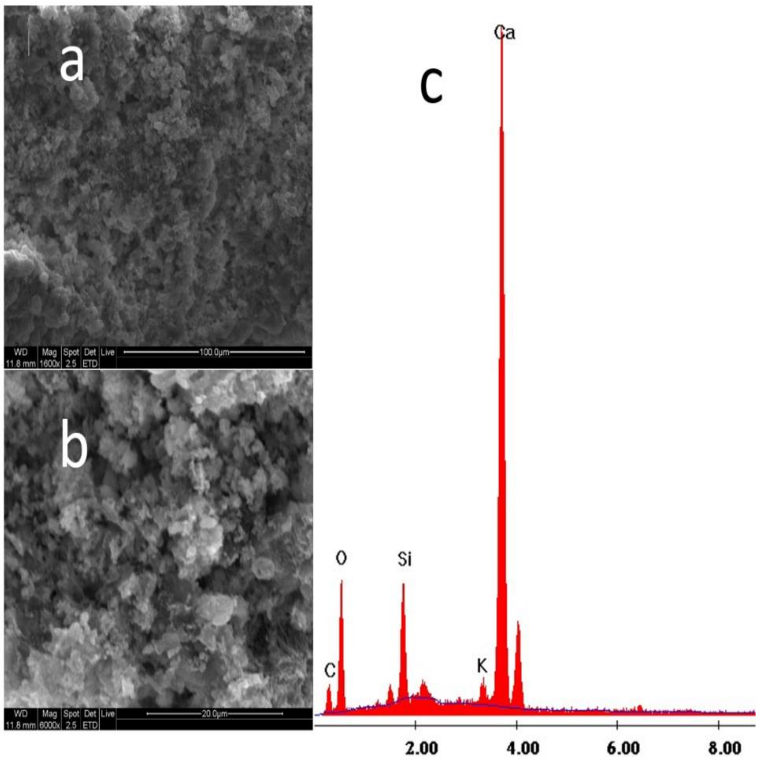

Figure 9. A) SEM image of the nucleus layer; B) SEM image of bedding layer showing crystalline phases; C) shows the Energy-dispersive X-ray results of mortar of nucleus layer from Hippolytus Hall

The SEM images showed slight fragility of mortar constitution or structure; this is maybe due to the attack of some deterioration factors in the site that affecting the bonding or cement materials and causing decomposition of mortar structure.

However, EDX microanalysis revealed the low percent of Quartz (SiO_2) and Graphite (C) where a high content of calcium carbonate (Calcite ($CaCO_3$) is detected which indicates that the mortar can be classified as lime or calcareous local mortar in the site.

The results of the XRD and SEM-EDX indicate that all mortar layers were based on lime (Fig. 10). The low intense peaks of quartz are a clear indication that quartz was not intentionally used as a filling material. This is might be since quartz was an impurity present in the raw limestone used in the production of lime. Besides, SEM analysis revealed that the aggregates in both mortar layers' samples were absent, no inclusions indicating the use of aggregates were found. The absence of the aggregate could be proof of the use of pure lime to produce mortar layers. This is probably connected to the use of calcite as a filler for the economic advantage of less energy and time expenditure for lime production (Hamarneh & Abu-Jaber, 2017).

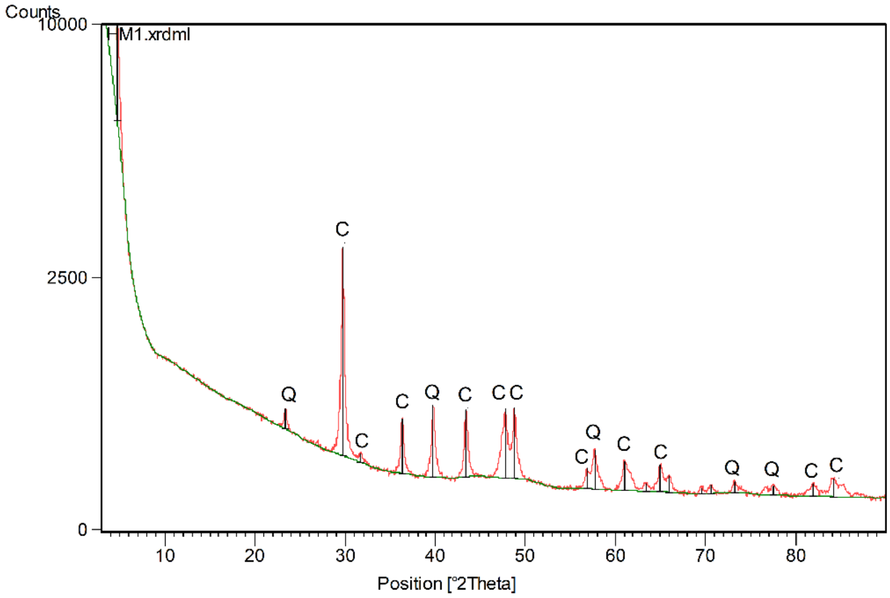

Figure 10. XRD pattern of the Nucleus Mortar sample

4.2 *Tesserae*

The results of XRD analysis of the nine stone tesserae (Table 4) indicate that except samples HT3, HT4, and HT5 (Yellow, Red, and Pink), calcite is the main composed mineral of all limestone samples ($CaCO_3$, Calcium Carbonate) and traces of Quartz (SiO_2). However, Calcite here is the microcrystalline Calcite which is known minerallogically as Micrite. It also observed that samples HT3, HT4, and HT5 contain the Dolomite which is the other face of Calcite ($CaCO_3$) is a major component together with Calcite. It was previously stated that these stones were locally used in Jordan since ancient periods to construct a stone mosaic. The *tesserae* used for the mosaic production probably derive from an area nearby the archaeological site.

Table 4. Chemical composition of minerals tested by XRD of stone tesserae

Sample Code	Color	Minerals	Formula	Card No.
HT1	White	Calcite	$CaCO_3$	00-005-0586
HT2	Black	Calcite	$CaCO_3$	00-005-0586
HT3	Yellow	Dolomite	$CaCO_3$	00-034-0517
HT4	Red	Dolomite	$CaCO_3$	00-036-0426
HT5	Pink	Dolomite	$CaCO_3$	00-036-0426
HT6	Orange	Calcite	$CaCO_3$	00-005-0586
HT7	Light Gray	Calcite	$CaCO_3$	00-005-0586
HT8	Light Brown	Calcite	$CaCO_3$	00-005-0586
HT9	Dark Gray	Calcite	$CaCO_3$	00-005-0586

5. CONCLUSION

Overall, this study investigated the characterization of the preparatory layers and *tesserae* of the mosaic floor of the Hippolytus Hall at Madaba city in Jordan. The result of this study contributes to widening our knowledge of the ancient materials and technological processes applied for the production of the mosaic floor in the Byzantine period. Besides, the conservation of the mosaic requires knowledge concerning the construction techniques, properties of the used materials as well as the deterioration factors. For this reason, this archaeometric study is of fundamental importance for the future conservation project of the mosaic.

Based on the field observation and the archaeometric study results of the preparatory layers and *tesserae* of the mosaic floor of the Hippolytus Hall. It can be noted that the mosaic floor of the Hippolytus Hall composed of three layers (*statumen*, *nucleus,* and bedding layer). The *rudus* layer in this mosaic floor did not exist. The absence of the *rudus* layer is probably connected to the economic advantage of less energy and time expenditure for mosaic production.

It was also observed that the mortar in both samples is a lime-based mortar and Calcite ($CaCO_3$) is the main mineral of both samples. This indicates that the mortar used in preparatory layers of the mosaic is localized lime mortar. Regarding the preparatory layers, the good adhesion between mosaic layers played an important role to ensure the stability of the preparatory layers and guaranteed the longevity of these mosaic floors, preserved until now. In addition, as already stated by Vitruvius (1st century B.C) in his De Architectura, the function of the first layer of the pavement is to give stability to the pavement and favors the flow of infiltrated waters. This description concord with that of the first layer of the mosaic floor of Hippolytus Hall, Madaba, made of stones laid on natural leveled ground, without any mortar.

As well as, these results revealed that the stone tesserae are mainly limestone and the main mineral of all limestone tesserae samples is Calcite ($CaCO_3$, Calcium Carbonate) and the Calcite her is the microcrystalline Calcite which is known in mineralogy Micrite. These observations lead to the conclusion that the information obtained in this paper will be useful in the elaboration of compatible repair mortars as well as is of primary importance for the future mosaic conservation project.

ACKNOWLEGMENTS

The authors would herby like to acknowledge the Deanship of Academic Research (DAR) of the University of Jordan for funding this research. The gratitude is also extended to the archaeologists in the Department of Antiquities of Jordan (DOA) for their support as well as to the supervisors of XRD and SEM laboratories in the Water, Environment and Arid Regions Center in the Al al-Bayt University.

REFERENCES

Alberti, L.B. (1965) In: Rykwert, J., Tiranti, A. (Eds.), *Ten Books on Architecture*, (J. Leoni (translation), London).

Avi Yonah, M. (1975) *Ancient Mosaic*, Cassell's Introduction Archaeology Series, Cassell, London.

Carrasco, J.M., Fernández Ugalde, A., García Dils, S., Gómez Rodríguez, Á., Lancha, Janine Oliveira, C. and Teruel, V. (2008) *A rota do mosaico romano: o sul da hispânia (Andaluzia e Algarve)*: Universidade do Algarve. Departamento de História, Arqueologia e Património.

Charvát, Petr. (2003) *Mesopotamia before history*: Routledge.

Dunbabin, Katherine (1999) *Mosaics of the Greek and Roman World*, Cambridge University Press, New York.

Farneti, M. (1993) *Technical-Historical Glossary of Mosaic Art*. Longo Edotore, Ravena, Italy.

GCI (2011) *Technician Training for the Maintenance of in Situ Mosaics*, J. Paul Getty Trust, Los Angeles.

Hamarneh, C., Abu-Jaber, N. (2017) Mosaic pavement mortar production in Gerasa in the Byzantine period. *Archaeol. Res. Asia* 9, 22–33.

Haswell, J. (1973) *The Thames and Hudson Manual of Mosaics*, Thames and Hudson, London.

Hetherington, P.B. (1967) *Mosaics, the Colour Library of Art*, Pull Hamlyn, DruryHouse, London.

Larionov, Andrey I, & Frolov, Alexandr P. (2019) Some Observations on the Mosaic Pavements in Lod, Huqoq and Wadi Hamam. *The Actual Problems of History and Theory of Art*, 9, 90-97.

Marta, R. (1991) *Tecnica Construttiva Romana*, Edizioni Kapp- Rome, Italia.

Montana, G., Randazzo, L., Vassallo, S and Udine, F. (2018) The Mosaic of the Frigidarium of "Villa Bonanno" in Palermo: Mineralogical and Petrographic Analysis for in Situ Conservation and Restoration Interventiona, In: *Mediterranean Archaeology and Archaeometry*, Vol. 18, No 5, pp. 95-107.

Pachta, V., Stefanidou, M. and Marinou, M. (2018) Development and testing of repair mortars for floor mosaic substrates, *Journal of Building Engineering* 20 (2018) 501–509.

Pachta, V. and Stefanidou, M. (2018) Technology of multilayer mortars applied in ancient floor mosaic substrates, *J. Archaeol. Sci. Rep.* 20 (2018) 683–691.
Palomar, T., García-Heras, M., Saiz-Jiménez, C., Márquez, C., & Villegas, M.A. (2011) Pathologies and analytical study of mosaic materials from Carmona and Italica. *Materiales de Construcción*, 61(304), 629-636.
Piccirillo, M. (1984) The Umayad Churches of Jordan, *Annual of the Department of Antiquities of Jordan*, 28: 333-341
Piccirillo, M. (1982) La Chiesa Della Vergine A Madaba, *Liber Annuus*, 32: 373-408, Studium Biblicum Franciscanum, Jerusalem.
Piccirillo, M. (1993) *Chiese e Mosaici di Madaba*, Studium Biblicum Franciscanum, Jerusalem.
Piccirillo, M. (1995) *The Mosaic of Jordan*, editors: Bikai, P.M. and Daily, T.A., ACOR, Amman.
Pliny (1971) *Natural History*, Book XXXVI. W, Heinemann Ltd., London.
Roncuzzi, I., (1992) *Il Mosaico, Materiali e Techniche delle Origine ad Oggi*, Longo Editore, Ravenna.
Ruiz-Lopez, Andrea Erica. (2013) *Hellenistic or Roman? A Case Study of a Mosaic in Tel Dor, Israel, in its Regional Context*.
Schick, R. (1995) *The Christian Community of Palestine from Byzantine to Islamic Rule: A Historical and Archaeological Study*, the Darwin Press, New Jersey.
Starinieri, V. (2009) *Study of materials and technology of ancient floor mosaics' substrate*. PhD Thesis, Doctoral dissertation, Alma Mater Studiorum Università di Bologna, Bologna, Italy.
Valiulis, Algirdas Vaclovas (2014) *A history of materials and technologies development*: VGTU leidykla „Technika".
Vitruvius (1960) *The Ten Books of Architecture*, Translated by Morgan M.H. Dover Publications Inc., New York.