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# THE MOSAIC PAVEMENT SUBSTRATES IN THE SOUTHERN ROOMS OF THE EASTERN CHURCH AT KHIRBET ET-TIREH, RAMALLAH (PALESTINE)

## *Los sustratos del pavimento musivo de las habitaciones meridionales en la Iglesia Oriental de Khirbet et-Tireh, Ramala (Palestina)*

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Abstract: The Eastern Church complex at Khirbet et-Tireh comprises five distinct sections: an *atrium*, a *narthex*, a tripartite main hall –nave and two aisles–, three adjoining auxiliary rooms on the north, and finally four more auxiliary rooms along the south side. The floor of the church was originally completely tessellated with polychrome mosaics, forming pavements patterned with figurative and geometric designs on a white background. Structurally, all known floor mosaics of the classical Mediterranean world had two main components: a substrate –all the hidden, preparatory layers– and the *tessellatum* –the *tesserae* and the filling mortar between them–. The most common substrate configuration consists of –from bottom to top– the *statumen*, *rudus*, *nucleus*, and bedding layers. In practice, however, the characteristics of these preparatory layers (substrate) –their number, order, thickness, technique, and material composition– have been found to differ from one period to another, from site to site, from building to building within a site, and even from one room to another within the same structure. In this context, the substrate of the mosaic pavements of the southern rooms of Khirbet et-Tireh church was found to be constructed of five layers, including a thin soil layer existing between the bedding and *nucleus* layers. To our knowledge, this layer has only been documented in Khirbet et-Tireh among the known archaeological sites paved with mosaics.
*Key words*: preparatory layers; conservation and restoration; mosaics; Byzantine-Umayyad churches; archaeometry.

Resumen: El complejo de la Iglesia Oriental en Khirbet et-Tireh comprende cinco partes distintas: un *atrium*, un *narthex*, una sala principal tripartita –nave y dos pasillos–, tres salas auxiliares contiguas al n y finalmente cuatro salas auxiliares más en el s. Originalmente el piso de la iglesia estaba completamente pavimentado con mosaicos polícromos formando solados estampados con diseños figurativos y geométricos sobre un fondo blanco. Estructuralmente, todos los mosaicos conocidos del mundo clásico mediterráneo se componían de dos elementos principales: un sustrato –todas las capas preparatorias ocultas– y el *tessellatum* –las teselas y el mortero de relleno entre ellas–. La configuración de sustrato más común consiste, en orden ascendente, en las capas de *statumen*, *rudus*, *nucleus* y lecho. En la práctica, sin embargo, se ha observado que las características de estas capas preparatorias –su número, orden, grosor, técnica y composición material– difieren de un período a otro, de un sitio a otro, de un edificio a otro dentro de un mismo sitio e incluso de una habitación a otra dentro de la misma estructura. En este contexto se observó que el sustrato de los pavimentos musivos de las habitaciones meridionales de la iglesia Khirbet et-Tireh estaba constituido por cinco capas, incluida una delgada capa de suelo existente entre las del lecho y el núcleo. Según nuestros conocimientos, esa capa únicamente se ha documentado en Khirbet et-Tireh entre los yacimientos arqueológicos conocidos pavimentados con mosaicos.

*Palabras clave*: capas preparatorias; conservación y restauración; mosaicos; iglesias bizantino-omeyas; arqueometría.

## 1. Introduction[1]

Khirbet et-Tireh is located on the western outskirts of Ramallah, approximately 16 km northwest of Jerusalem (Fig. 1). The site was inhabited during the Hellenistic, Roman, Byzantine and Early Islamic periods, and was later used as agricultural land throughout the Ottoman-Turkish period and down to modern times. The entire ancient settlement covered a total area of approximately 30,000 m². Today, the best preserved part of the settlement is an area of some 6,000 m² owned entirely by the Greek Orthodox Patriarchate. The larger site, however, has suffered severe damage due to urban development over the past two centuries and, more recently, from numerous instances of antiquities looting. These activities have already resulted in the irretrievable loss of at least three-fourths of the archaeological remains of the original fortified settlement (Al-Houdalieh, 2014: 188-196; Al-Houdalieh, 2016: 48-50).

[1] We are grateful to Al-Quds University and the Council of American Overseas Research Center for their financial assistance, which allowed us to conduct this most recent conservation season. We are indebted also to the conservation team –Osama Hamdan, Raed Khalil, Ra'fat Khateeb, Hadeel A'ydah, Ahmad Shahada, Bashar Jarara'a, and Mohammad H. Nasser– for their tireless efforts over the course of the season. Thanks are also extended to Najati Fetyani for the final photography of the site, and to all of the first author students who participated in this project. Special appreciation and thanks to Yousef abu Salha –the Univ. of Jordan– for doing the XRD of the two mortar layer samples. We also thank the anonymous reviewers for their constructive comments. Finally, many thanks go to Tom Powers for his constructive proofreading, editing and comments on the draft of this work.

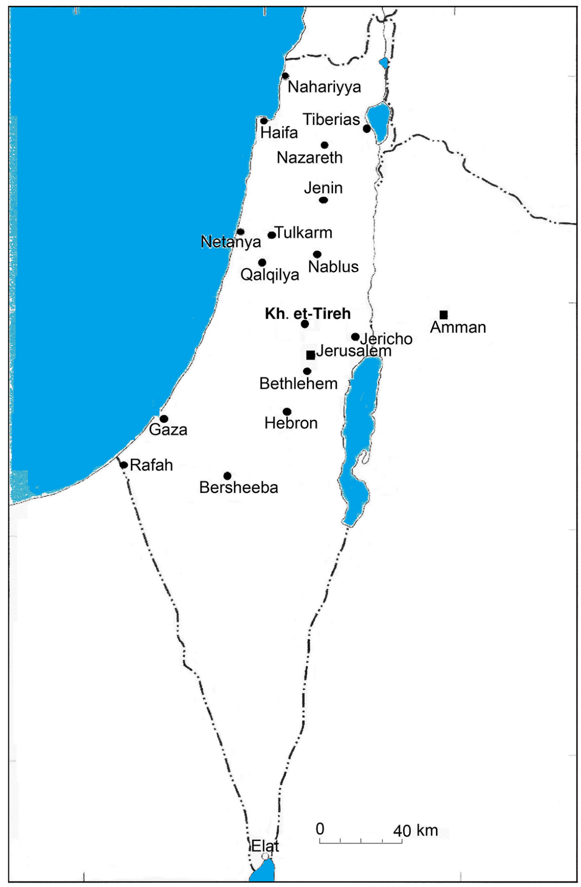


Fig. 1. *A map of historic Palestine locating Khirbet et-Tireh (drawn by I. Iqtait).*

Five seasons of excavation and restoration have thus far been conducted at Khirbet et-Tireh. This work, under the direction of the author on behalf of Al-Quds University, was carried out during the summers of 2013-2015 and 2017-2018, for a total of 36 weeks of work on-site, involving both excavation and restoration. By the end of the fourth


Fig. 2. *Aerial photograph showing the excavated areas at Khirbet et-Tireh, 2018 (photo by N. Fetyani).*

campaign, our teams had excavated a total area of approximately 1,750 m$^2$. Among the significant architectural features uncovered are: a rock-cut, subterranean hiding complex of the Roman period; a Byzantine-Umayyad fortification system; two Byz antine-Umayyad churches –designated 'Eastern' and 'Western' from their relative locations–; several Byzantine-era burial caves and ground graves; a Byzantine-Umayyad subterranean oil press complex; a Byzantine-Umayyad rock-cut cistern with two feeder channels; two pathways or streets leading to the churches; several residential units from the Byzantine to Early Abbasid periods; and numerous Ottoman-period agricultural terraces (Fig. 2) (Al-Houdalieh, 2014, 2015, 2016, 2018)[2].

The Eastern Church complex, the subject of this paper, is located 10 m east of the Western Church and measures internally approximately 28.5 m x 25.5 m. At its core is a basilical hall, but the complex comprises five parts altogether: an *atrium*;

[2] The past fieldwork seasons of this project have been made possible by grants from five different organizations: Al-Quds University, the Greek Orthodox Patriarchate, the Prince Claus Fund (Netherlands), the Palestinian American Research Center, and the Council of American Overseas Research Center (caorc).

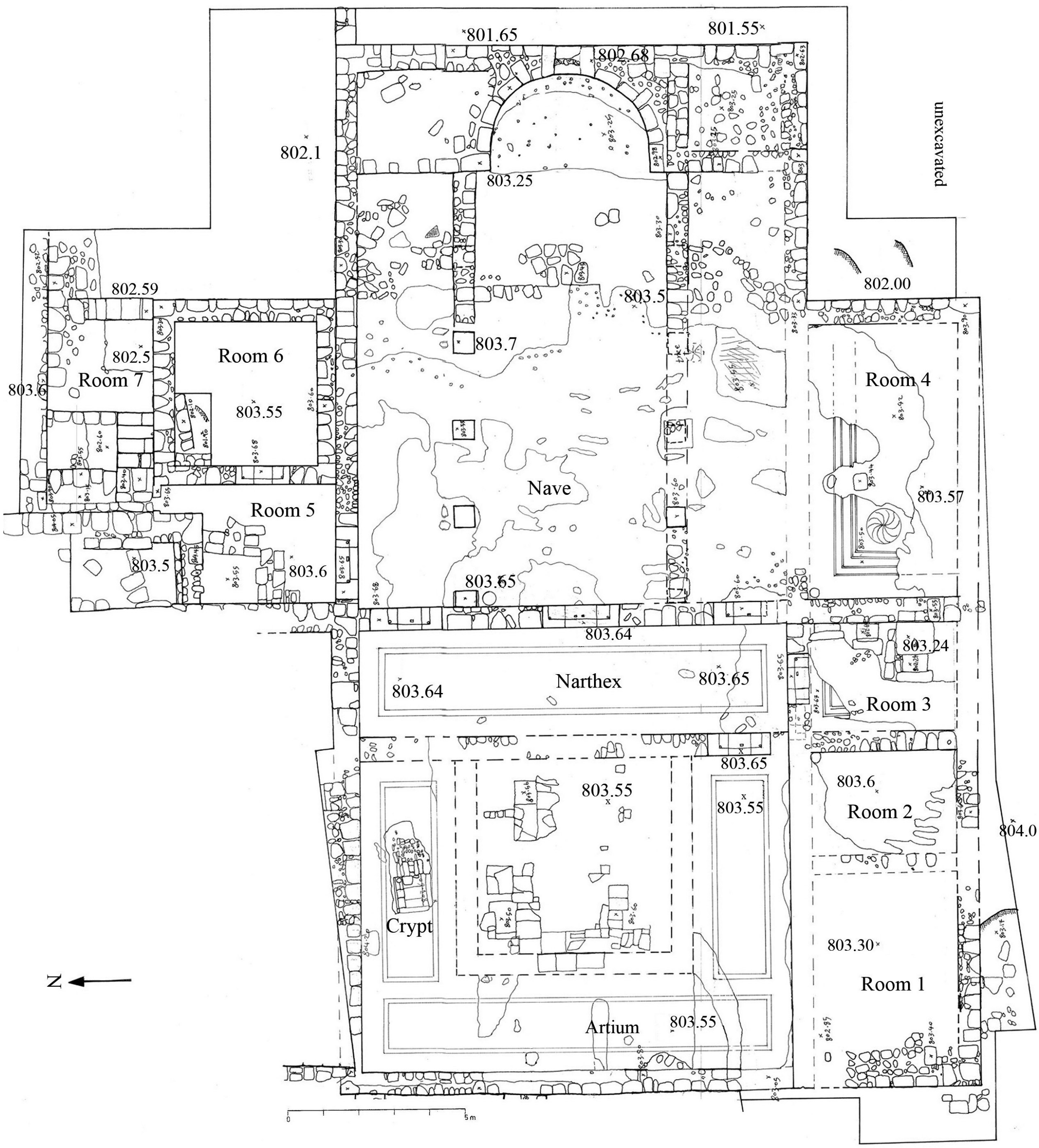


Fig. 3. *Top plan of the Eastern Church of Khirbet et-Tireh (drawn by I. Iqtait).*

a *narthex*; the main hall –*basilica*–, divided by two rows of columns into a nave and aisles; three auxiliary rooms adjoining the basilica on the north; and finally four more auxiliary rooms along the southern side, which are the particular focus of this study. The walls of the church were found mostly dismantled to the original floor level or even below it. The mosaic pavements of the church, consisting mostly of colored patterns, were found partially damaged throughout the complex, and the surviving, intact areas varied as to their physical condition. Several distinct mosaic carpet patterns were revealed, including both figurative and geometric designs rendered in shades of black, gray, pink, orange, red, wine, yellow, green and blue, all on a white background. Notably, in the nave all of the original figurative depictions were altered in antiquity and replaced randomly with larger white cubes, clear evidence of iconoclastic influences. By contrast, the pavements of the two aisles, southern rooms, narthex, and the atrium were unaltered, consisting only of geometric patterns (Al-Houdalieh, 2016; Al-Houdalieh *et al.*, 2017).

The three main aims of this present article are: 1) to present the results of the conservation and restoration work of the southern rooms of the Eastern Church of Khirbet et-Tireh; 2) for comparison, to examine the substrate configuration –number, type, order, and constituent materials of the layers– of known mosaic pavements generally, as documented at various archaeological sites; and 3) to highlight our discovery of a soil layer beneath the bedding layer which is, to our knowledge, unique to Khirbet et-Tireh among the known archaeological sites with mosaics.

## 2. The southern side rooms and their mosaic pavements

The string of four south-side rooms adjoins externally the southern wall of the atrium, the narthex, and part of the southern aisle of the church complex (Fig. 3). The four rooms all have an internal north-south dimension of 4 m, however their east-west measurements vary: Room 1 = 5.2 m; Room 2 = 2.8 m; Room 3 = 3 m; and Room 4 = 7.7 m. The masonry of these rooms consists of large, mostly well-cut and nicely dressed ashlars approximately 0.65 m long, 0.35 m thick, and 0.34 m high on average. One section, the eastern wall of Room 4, which is an exterior wall of the complex, stands as high as 1.5 m, but still at or below floor level. The thickness of the walls is 0.6 m on average, and the southern walls of these rooms (again, exterior walls of the complex) were built with the outer face composed of large, dressed stones and the interior face of medium-sized stones, all bonded with a mortar of compact, brownish soil mixed with a little lime. In Room 3 we encountered three parallel, east-west oriented ground graves, their western ends extending beneath the intact sections of the stone substrate and mosaic pavement. The graves measure 2.2 m x 0.75 m x 1.2 m deep, their walls were built of roughly worked limestone blocks, and all were found covered with large, unshaped limestone slabs.

The former mosaic floor pavement of Room 1, including a stone substrate and part of the underlying earthen leveling deposit, were all found completely destroyed. It is noteworthy, however, that a large number of both white and colored tesserae, and also fist-size stones with lime residue on them –loose remnants of the substrate–, were collected from the area of this room during the 2015 excavation season. Thus, we believe that this room, just like the other architectural units of the church complex, was tessellated.

The mosaic of Room 2, by contrast, is fairly well preserved, except along the southern wall where it was found totally destroyed. This pavement consists first of an outer margin of three rows of white tesserae, ranging between 5 cm and 6 cm in total width and laid parallel to the walls. The rest of this floor pavement is ornamented with three parallel lines of a repeating petal pattern rendered in black and orange on a white background. A bowl-shaped depression 0.27 m in diameter and 0.15 m deep was found in the northeastern corner of the room. This depression is tessellated with white cubes and might have been used to hold a jar or to collect water which drained off the floor during cleaning.

The mosaic pavement of Room 3, on the other hand, is mostly destroyed, except for a section averaging 0.7 m wide along the northern and western walls, but with the stone substrate extending intact over a larger area of the room. This floor pavement is bounded by a band of three rows of white tesserae, just as in Room 2. Proceeding inward, a much wider band 0.45 m in width has tesserae laid at a 45-degree angle relative to the walls; this band features a repeating petal design rendered in black and orange on a white background, with a stylized cross in each corner. Next, the carpet is framed by –counting from the outside–: three rows of white tesserae, two rows of black, two more rows of white, and finally one single row of black. Due to the massive destruction of the inner mosaic carpet of this floor, we could not establish its original ornamentation, except that it contained petals.

In Room 4 the mosaic pavement is quite well preserved in its northwestern corner, however over the rest of the room it was completely destroyed, sometimes along with the substrate. The remains of this pavement include an outer margin like that documented in Room 3, but then an ornate frame of saw-tooth designs flanking a classic braid. Inside this, the carpet is laid in rich geometric patterns rendered in black, grey, orange and yellow on a white background. The surviving portion of this central panel features an impressive whorl set inside an octagon, formed in turn by the edges of eight squares each filled with a different geometric design. Although most of the central panel was destroyed, the remaining clues show it was rectangular in shape, measuring 6.6 m east-west and 2.9 m north-south, and suggest additional complex geometric patterns (Fig. 4). A bowl-shaped depression of the same size and characteristics as that in Room 2 was found in the northwest corner of this floor pavement.

The pavements of the southern rooms –3, 4 and 5–, of the porticoes of the atrium, and of the narthex all consist of medium-size stone cubes, 1.5 cm by 1.5 cm and 2.1 cm thick on average, at a density of 35 cubes per 100 square centimeters. The tesserae of the main hall, however, are smaller than those of the above-mentioned areas of the same church, averaging 150 cubes per 100 square centimeters. The tesserae of the northern Room 5 are of intermediate size compared to all the other sections, laid at a density of 50 cubes per 100 square centimeters. The cutting and setting techniques of the tesserae of all pavements are of high quality, with good cubical shaping and well-polished upper surfaces (Al-Houdalieh, 2016; Al-Houdalieh *et al.*, 2017).

Fig. 4. *The mosaic and repair of the floor pavement of Room 4 (photo by N. Fetyani).*

## 3. Conservation of the mosaics of the Eastern Church

Already in 2015 we conserved, restored and consolidated the mosaics of the atrium, the narthex, the main hall (nave and aisles), as well as Room 5, one of the northern auxiliary rooms. In 2018 we consolidated, conserved and restored the mosaic pavements, stone substrates and walls of the southern side rooms. The conservation work of the 2018 season took place over a period of six weeks –six days a week, eleven hours per day–, carried out by a working team of 11 persons: the director of the project, one architect, three archaeology students from Al-Quds University, two unskilled workers, and as many as four conservators at any given time. Our work proceeded generally through the following successive stages –we do not present here the details of each stage or individual intervention–:

1) Cleaning the top surfaces of the mosaic pavements –both intact tessellation and exposed substrate–, first using dry brushes only then with the application of a minimal amount of water and using brushes, scalpels, dental tools, and


Fig. 5. *Condition assessment and intervention map (prepared by R. Khalil).*

blades; afterward the wet surfaces were dried using sponges and cloths.

2) Documenting the physical condition of the mosaic pavements through visual inspection and textual recording; preparing a series of thematic charts detailing the physical condition of the surveyed pavements, especially noting all visible problems (Fig. 5); compiling a written description of the problems relating to these floors; and finally, formulating a detailed action plan for intervention.

3) Performing intervention actions on the mosaic pavements, which can be summarized as follows: a) edge repair and filling of lacunae using two different types of mortar applications: a lower layer composed of Calce Romana lime (46%), washed sand (24%), quartz powder (15%) and gravels (15%), and an upper layer of the Calce Romana lime (50%), washed sand (25%), and quartz powder (25%) only, with no gravel; b) re-setting the detached tesserae from the floors of the three rooms using a mortar composed of a lime-based mix, similar to that detailed above for the upper repair layer; c) filling the cracks in the mosaic pavements using a fluid mortar, again, similar to the upper repair layer mix; d) treating the tree roots found growing through the mosaic pavements, by cutting both of their visible ends and then injecting them with Preventol; e) lifting and re-laying the mosaic floor of Room 3 completely; f) reconstructing large sections of the destroyed stone substrates of Rooms 2-4, using fist-size stones having the same characteristics as those of the intact sections of stone pavement (Figs. 4 and 5); g) stabilization of all walls of Rooms 2-4 by applying two lime-based mortar layers –again, similar to the preparations detailed above– into the interstices of the exposed top and side surfaces of these walls.

4) Recovering the mosaic pavements with a permeable, plastic-mesh geotextile material, topped by a layer of sieved soil 0.2 m to 0.25 m thick.

The intervention actions carried out to the mosaic pavements of all structural components of the Eastern Church –especially the careful cleaning along the degraded edges of the mosaic surfaces and the lacunae, lifting and relaying two large sections of the pavements in the atrium and in Room 3, plus digging three trial trenches in Rooms 2, 4 and 6– have all enabled us to examine the preparatory layers of the mosaic pavements of the this church, and to identify the similarities and differences between them.

## 4. The foundation layers of the mosaic pavements of the southern rooms

According to the Getty Conservation Institute (2003: 3), the substrate layers of mosaic pavements can generally be classified into four types (from bottom to top): 1) *statumen*, considered the first preparatory layer, it consists of stones of different shapes and sizes laid directly atop natural earthen deposits, without mortar; 2) *rudus*, it consists of lime mortar mixed with large aggregates and covers the *statumen*; 3) *nucleus*, it is composed of lime mortar mixed with fine aggregates, spread over the *rudus* in a thinner layer; and 4) bedding, a lime-rich mortar layer, thinly applied over the *nucleus*; the tesserae are set into it before the lime starts to harden.

The ancient writers Vitruvius and Pliny both described the construction techniques and the foundation layers of the contemporary mosaic pavements of the Early Roman period. According to them, the construction of mosaic pavements began by digging the bare soil to a depth of two feet, next the newly created floor level was carefully compacted, and then three foundation layers were spread on top of it. The *statumen* was laid down, followed by a ten-inch-thick *rudus* layer, which in turn was topped with the five-inch-thick *nucleus*. The *nucleus* was carefully leveled to create a flat and even floor surface, into which the mosaic cubes were directly inserted.

At Khirbet et-Tireh, however, the preparatory layers of the mosaic pavements of the church's southern rooms differ somewhat from both of the standard schemes described above. We actually identified five distinct layers, as follows (Fig. 6):

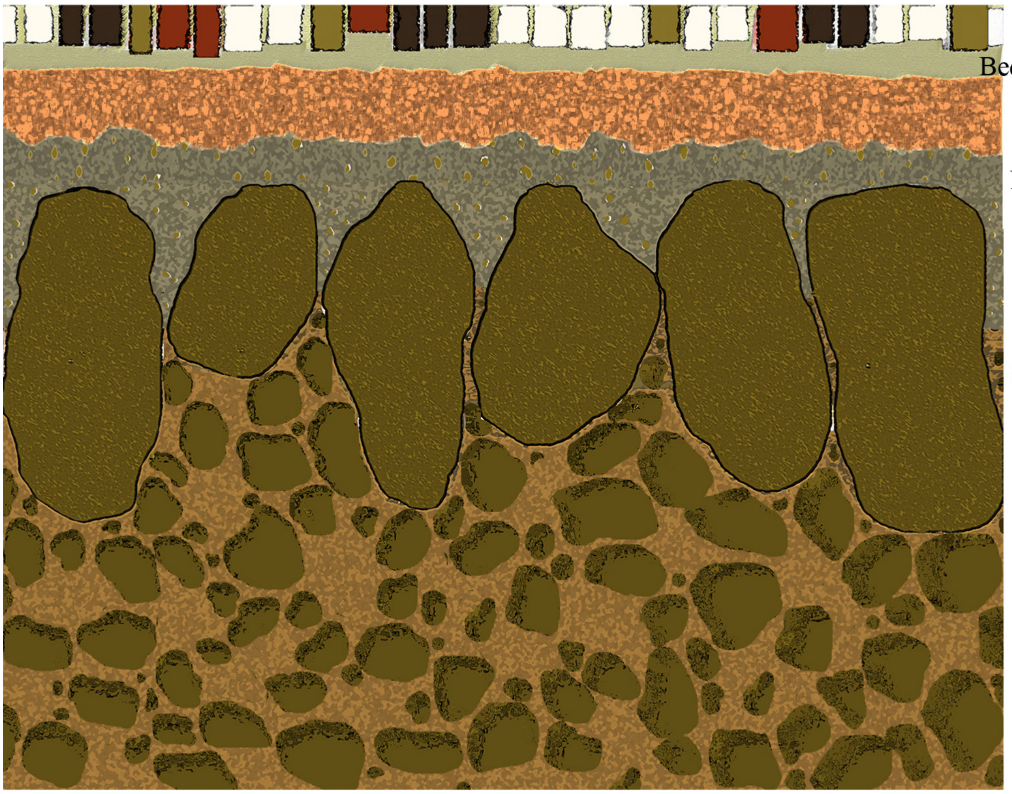


Fig. 6. *The foundation layers of the mosaic pavements of the southern rooms (prepared by R. Khalil).*

1) The filling layer: this first –lowest– level, which we are calling a foundation layer of the pavement, is fill material intentionally laid down during the building process and consists of compacted, yellowish-brown soil mixed with a large number of small-size stones. This layer was revealed by two soundings of 0.4 m x 0.6 m excavated in the southwest corner of Room 2 and in the southeastern corner of Room 4; it was also observed in the course of cleaning the disturbed earth accumulations along the eastern section of Room 3 down to the stone slabs covering the three above-mentioned graves. We found that the thickness of this filling layer is 1 m in Room 2, 0.12 m in Room 3, and 1.6 m in Room 4, on average; the thickness varied according to the elevation of the underlying bedrock surface, which slopes generally downward toward the east –and due to the three slab-covered graves in Room 3–. This filling layer resembles the one revealed in a previous campaign – in 2015–, in a trial trench 2 m long x 1 m wide x 1.7 m deep along the northern wall of the northern Room 6.

2) The stone pavement –*statumen*–: it consists of fist-sized stones, ranging between 7 cm and 14 cm thick, carefully laid close together on top of the leveled filling layer but leaving spaces between their irregular edges. Their bottom surfaces are slightly embedded into the filling layer, probably indicating that they were tamped down using a pounding tool[3].

3) The *nucleus*: consisting of lime mixed with stone aggregates of different sizes ranging between 2-5 mm, along with some ash and tiny particles of charcoal, it ranges in thickness between 1.5 cm and 2 cm above the tops of the stones of the *statumen*, plus it fills all the spaces between the stones of the underlying pavement.

[3] Here it is worth noting that we did not discover an identifiable *rudus* layer in any of these rooms.

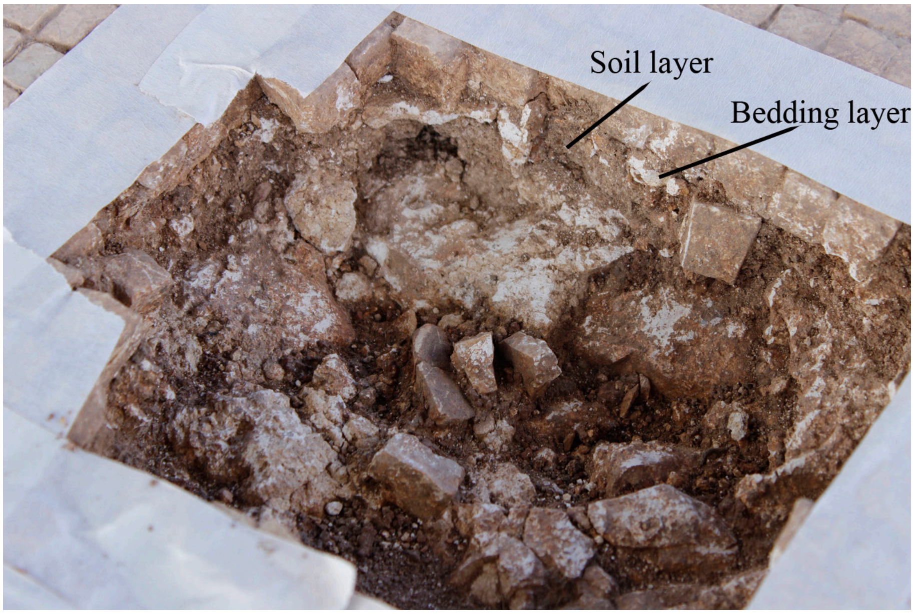


Fig. 7. *The soil layer in between the bedding layer and nucleus in Room 2.*

4) Soil layer: in the course of cleaning the earthen deposits within the lacunae and along the degraded edges of the mosaic pavement in Room 4, we clearly noticed the existence of this soil layer lying between the *nucleus* and the bedding layer. At the time, our work team engaged in in-depth discussion trying to clarify and interpret the existence of this layer, exploring all possible scenarios. Especially, we considered whether or not this layer should indeed be considered as one of the original foundation layers of the mosaic pavement. During these several days of brainstorming among our conservation team in search of a logical explanation for this layer, part of the team undertook a similar exploration in another room, Room 2. Cleaning the earthen deposits from the lacunae and along the broken edges of the floor, they discovered the same sequence: a thin soil layer between the *nucleus* and the overlying bedding layer –with embedded *tessellatum*–. Also in Room 2, we decided to dig a test probe –10 x 10 cm– down through a totally intact section of the mosaic floor –an area without lacunae or cracks–, and the results of this work revealed the same soil layer seen elsewhere, extending beneath the intact section of this floor (Fig. 7). Furthermore, when we lifted the mosaic floor of Room 3, we again found a soil layer of the same characteristics, composition and thickness as those found in Rooms 4 and 2 (Figs. 8-9). So, we can conclude that the soil layers found in Rooms 4, 3 and 2 between the *nucleus* and bedding layers are an original part of the foundation layers of these mosaic

Fig. 8. *Remains of the bedding and soil layer after lifting a mosaic section in Room 3.*

pavements. The thickness of this 'extra' layer ranges between 1 cm and 3 cm, depending on the regularity of the surface of the underlying *nucleus* layer (Fig. 9). For further details on its composition, please see the following section.

5) The bedding layer: in order to study and analyze the uppermost mortar layer of the mosaic floors of the Eastern Church, we took two samples: the first sample from Room 3, and the second from the nave. The thickness of the bedding layer in room 3 ranges between 0.5 cm and 1 cm, while the thickness of the bedding layer in the nave is greater, varying from 2 cm and 3 cm. For detailed information on the composition of the two samples, please see the following section.

## 5. Archaeometric study

Three samples made the subject of this archaeometric study. Two of them are mosaic bedding (plaster); the other one comes from an earth layer located just below the bedding plaster in Room # 3. Fig. 10 below shows these three samples, respectively. In sample # 3, fragments include the bedding plaster still attached to a mosaic cube.

### 5.1. Samples preparation

Mosaic samples 1 and 2 were subjected to same preparation procedure. An area of one mosaic cube with the attached plaster was cut using a mini diamond saw. Sample 2 has chipped into two fragments –a and b– and both were prepared in the same way. No special preparation was needed for the fill soil –Sample 3–. Meanwhile, other portions of samples 1 and 2 were sent to the University of Jordan for analysis with X-ray powder diffraction –XRD–.

For microscopic examination, Samples 1, 2a and 2b had to be embedded in epoxy, ground, and

Fig. 9. *The soil layer in between the bedding layer and nucleus in Room 3.*


Fig. 10. *Samples studied: (a) Sample # 1 consisting of several fragments of the mosaic from Room # 3 of the Eastern Church taken in 2018; (b) sample # 2 consisting of a mosaic fragment taken from the nave of nave of the Easter Church in 2017; (c) sample #3, taken from an earth layer found just below the bedding layer in Room # 3 of the Eastern Church.*

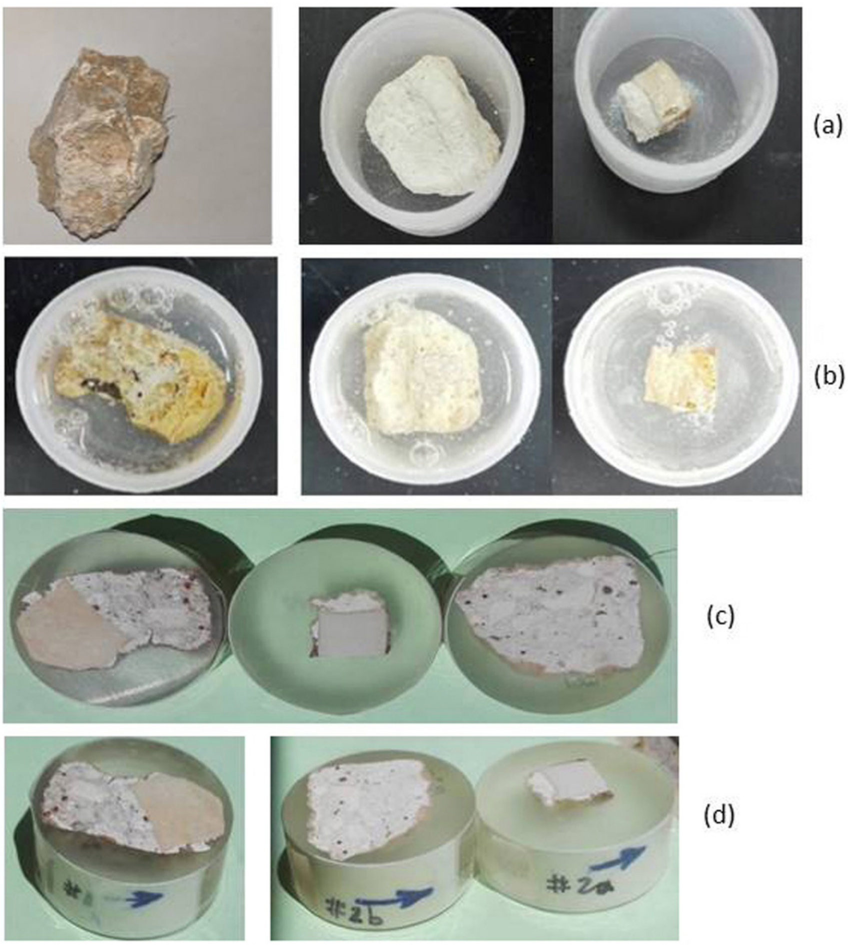


Fig. 11. *Samples preparation for microscopic examination: a) Samples 1, 2a and 2b cut and placed in cups; b) epoxy is poured on samples for consolidation and grinding; c) samples ground and polished; (d) orientation of samples with respect to mosaic surface taken, arrows point to upper surface.*

polished as needed. Samples were placed in plastic cups (Fig. 11a) and epoxy resin was poured until the cups are filled (Fig. 11b). Dry warm air was blown at distance above the cups to expel air bubbles that form during mixing of the epoxy resin with the hardener before pouring it. Once the polymer is dry the discs were removed from cups; the samples will be showing at the lower sides of the discs. The upper side of each disc was first ground to obtain flat and soft surface. This step is needed to make it easy to hold during grinding of the sample side and to allow the disc to sit flat and horizontal on the microscope stage for observation. Grinding of samples was carried out under a stream of water and using sand paper with decreasing grain size of 320, 400, 600, and 1200. Now surface of polished samples is ready for observation with optical microscope (Fig. 11c). Discs are marked with arrows to indicate the surface of the mosaic (Fig. 11d).

### 5.2. Analytical methods

Each sample was analyzed by one or more of the following techniques. Granulometry or measurement of particle size distribution of sample 3 was carried out using stainless steel sieves with varying mesh size from 75 to 2000 microns. The sample was first weighed –134 g– and then sifted for 15 minutes in a sieve set using an automatic shaker. Each size fraction retained in a sieve was recovered and weighed. After noticing that sand particles are still and largely attached to clay, it was decided to proceed to wet sieving of the material. For this purpose, a sample of ~ 100 g was soaked in water for 24 hours before passing it through the same set of sieves. Each sieve was rinsed thoroughly on top of the following one to remove fine clay material that adheres to the sand particles. The dish below the finest fraction –75µ– was allowed to settle and excess water was decanted. The whole set of sieves was placed in oven to dry for several days at 100º C. Material in each sieve and in the lower dish was recovered and weighed after being cooled to room temperature.

Microscopic examination of the embedded samples was carried out under reflected light using an optical microscope with magnification power varying from 40x to 1000x. Digital photographs were obtained and documented with their scales. In particular, attention was given to the type of sand used in preparation of the bedding plaster, its particles size, interface between *tessera* and plaster and occurrence of cracks in the plaster.

| Dry Sample Analysis | | | Wet Sample Analysis | | |
|---|---|---|---|---|---|
| Fraction (µ) | Weight (g) | Fraction Wt. % | Fraction (µ) | Weight (g) | Fraction Wt. (%) |
| < 75 | 16.3 | 12.2 | < 75 | 54.9 | 54.6 |
| 75-150 | 12.1 | 9.0 | 75-150 | 4.6 | 4.6 |
| 150-300 | 17.7 | 13.2 | 150-300 | 5.4 | 5.4 |
| 300-600 | 23.6 | 17.6 | 300-600 | 8.9 | 8.9 |
| 600-1180 | 36.4 | 27.2 | 600-1180 | 12.6 | 12.5 |
| 1180-2000 | 27.9 | 20.8 | 1180-2000 | 14.1 | 14.0 |
| >2000 | 0 | 0.0 | >2000 | 0 | 0.0 |

Fig. 12. *Granulometric dry and wet analyses of dirt fill applied underneath mosaic bedding.*

As mentioned above, the X-ray powder diffraction –xrd– was conducted at the University of Jordan on powders obtained from the bedding plaster and one *tessera* of sample # 2. X-ray scans were done from 2 to 60 degrees using a Cu K$\alpha$ radiation –with wavelength of 1.5418Å–.

### 5.3. Results and discussion of the technical study

#### 5.3.1. Granulometry of fill soil

Data obtained for the fill soil sample screened dry are presented in Fig. 12. The table also shows data obtained for the same sample screened suspended in water. Collected size fractions in both tests are shown in Fig. 13a and b, respectively. These data are presented by the histograms of Figs. 13a and 13b. Histograms show that granulometric analysis of dry fill soil material is misleading in representing the proportion of the fine materials which is mainly composed of clay (Fig. 14a). The fine fraction –<75µ– is underestimated and only makes about 12% of the total mass. Otherwise, the sand fractions are overestimated due to the fact that large amount of clay is still adhering to the sand particles, making grains appear larger than they are and making each size fraction higher. On the other hand, histograms of Fig. 14b provide a realistic measure of the grain size distribution of both the sand and the clay materials. Thus, the clay component amounts now to over 50%, indicating that the two materials –clayey soil and sand– were prepared in a 1:1 ratio. Moreover, the particle size distribution of the sand component is now meaningful. The wt.% of size fractions increases as the particle size increases. There is an artificial cut in particle size at 2000µ. It is worth noting that the sieve with 2000 micron opening did not retain any sand material. This indicates the voluntary elimination of any larger particles. One can claim that a sieve of 2000µ (= 2 mm) size opening –us mesh 10– was employed to screen the sand material before mixing it with equal proportion of clay material.


Fig. 13. *Particle size distribution of the mosaic fill material: a) after screening of dry sample; b) after screening of wet sample.*

### 5.3.2. x-ray powder diffraction –xrd– analysis

xrd patterns obtained for powdered bedding plaster and one tessera show that the material is composed of calcite ($CaCO_3$). The latter phase is the main component of limestone that is being used in making the examined tesserae cube. Calcite could have been used by the Romans, in any of its petrographic forms as sand that is to be added to the slaked lime to make the bedding plaster (Bearat, 1996). It forms also as a carbonation product of the slaked lime. Therefore, the xrd patterns show that the bedding plaster in both samples –1 and 2– was made from slaked lime and calcareous sand. In Fig. 15 xrd data comparing the patterns obtained for all three samples analyzed with the data published for reference calcite[4]. There is a very strong match and there is no other mineral phases detected.

The 10 strongest diffraction lines –peaks– are given for the reference calcite in terms of their 2 theta positions, interplanar distance –d-spacing–, their normalized intensities with respect to the strongest line, and the Miller h k l indices of the diffracting crystallographic planes (Fig. 15). Then the peaks observed in the xrd patterns of our samples are compared to the reference data. One observes the quasi-perfect match. It is worth noting that other mineral phases usually present in the sand, such as quartz and feldspars, are completely absent. In fact, given the

[4] http://rruff.info/Calcite/R050128; accessed 9/14/2019.

sedimentary petrology of the area and lack of water courses justify the use of limestone as source of aggregate and sand in preparing the mortar.

#### 5.3.3. Microscopic examination

One learns several things from the microscopic examination. The polished samples mentioned above and shown in Figs. 11c and 11d were examined using an optical microscope in reflected light mode. Digital images were collected for each sample at different magnification power and for different zones of the section. Selected micrographs are presented in Figs. 16-18. In Fig. 17a and b low magnification images show, for samples 1 and 2b, respectively, areas covering parts of the tesserae and the adjacent bedding plaster layer. Both tesserae are made of a homogenous yellowish limestone. The lower sides of the tesserae are not rigorously flat, which could be done in purpose to improve the mechanical strength of the mosaic to avoid the exfoliation of the tesserae from the bedding plaster. The adjacent plaster layer does look different between the two samples. Sample 2b, coming from a finer mosaic, has a fine and homogenous plaster, which conforms with known recipe described by Vitruvius (*De Arch.*, VII, 1). Sample 1, on the contrary, has higher proportion of sand mixed with the slaked lime and larger grain size. Figs. 17 and 18 show more details of the bedding plaster in sample 1: some red particles of iron oxide-rich material, derived most probably from brick powder (Figs. 17a-c), are sporadically present especially in areas close from the edges of the plaster layer. Also are present larger grains of rock –limestone– as well as some large granules of slaked lime (Figs. 17c and d). The fact that Sample 1 has chipped easily leaving a 4-5mm plaster layer attached to the *tessera*, may indicate two successive layers of plaster, also recommended by Vitruvius.

In conclusion, we can say that this archaeometric study indicates that fine Byzantine mosaic work was realized with the standard Roman procedure. The fill layer was prepared with a mix of equal proportions of clayey soil and calcareous sand that had already been processed and screened. The bedding plaster layer was prepared with slaked lime and a local calcareous aggregate that was ground finely. The tesserae were applied on a final thin layer of plaster made of slaked lime and a very fine calcareous sand.

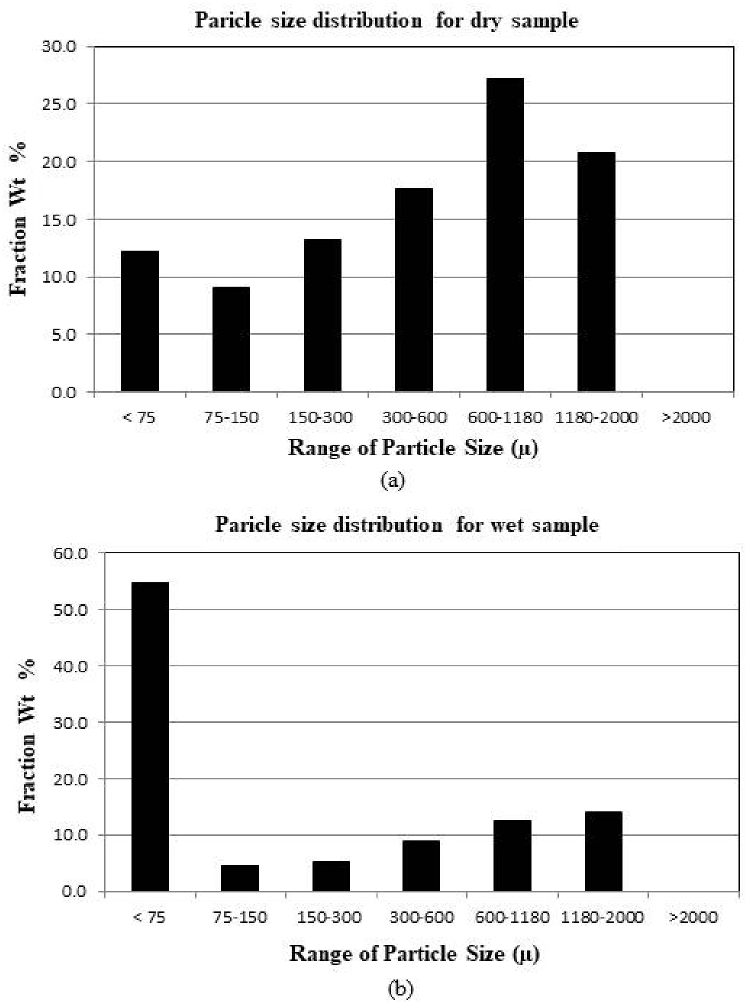


FIG. 14. *Different size faction of the fill soil material after sieving. (a) dry-sieved; (b) sieved as water suspension.*

| Reference Calcite Pattern | | | | Sample 1 Plaster Matrix | | Sample 2 Plaster Matrix | | Sample 2 Mosaic tesserae | |
|---|---|---|---|---|---|---|---|---|---|
| 2 Theta (degree) | d-spacing (Å) | Relative intensity | Plane h k l | 2 Theta | Relative intensity | 2 Theta | Relative intensity | 2 Theta | Relative intensity |
| 23.07 | 3.8556 | 8.9 | 0 1 2 | 23.25 | 10.81 | 23.2 | 9.19 | 23.2 | 9.73 |
| 29.42 | 3.0364 | 100 | 1 0 4 | 29.5 | 100 | 29.4 | 100 | 29.2 | 100 |
| 31.45 | 2.8448 | 2.43 | 0 0 6 | 31.7 | 2.70 | 31.4 | 2.70 | 31.6 | 2.16 |
| 36.00 | 2.4951 | 13.70 | 1 1 0 | 36.3 | 12.97 | 36 | 12.43 | 36.2 | 13.51 |
| 39.43 | 2.2850 | 20.15 | 1 1 3 | 39.7 | 17.30 | 39.4 | 17.30 | 39.5 | 18.38 |
| 43.19 | 2.0947 | 14.25 | 2 0 2 | 43.25 | 15.68 | 43.2 | 14.05 | 43.2 | 15.14 |
| 47.14 | 1.9277 | 6.16 | 0 2 4 | 47.5 | 5.95 | 47.2 | 5.95 | 47.25 | 6.49 |
| 47.53 | 1.9132 | 19.68 | 0 1 8 | 47.7 | 17.84 | 47.7 | 17.84 | 47.7 | 16.22 |
| 48.53 | 1.8758 | 20.02 | 1 1 6 | 48.7 | 18.38 | 48.7 | 18.38 | 48.7 | 16.76 |
| 57.44 | 1.6043 | 9.18 | 1 2 2 | 57.6 | 7.57 | 57.6 | 6.49 | 57.5 | 8.11 |

Fig. 15. *XRD data for the bedding plaster samples and a mosaic* tessera *compared to data (strongest 10 diffraction lines) for reference calcite.*

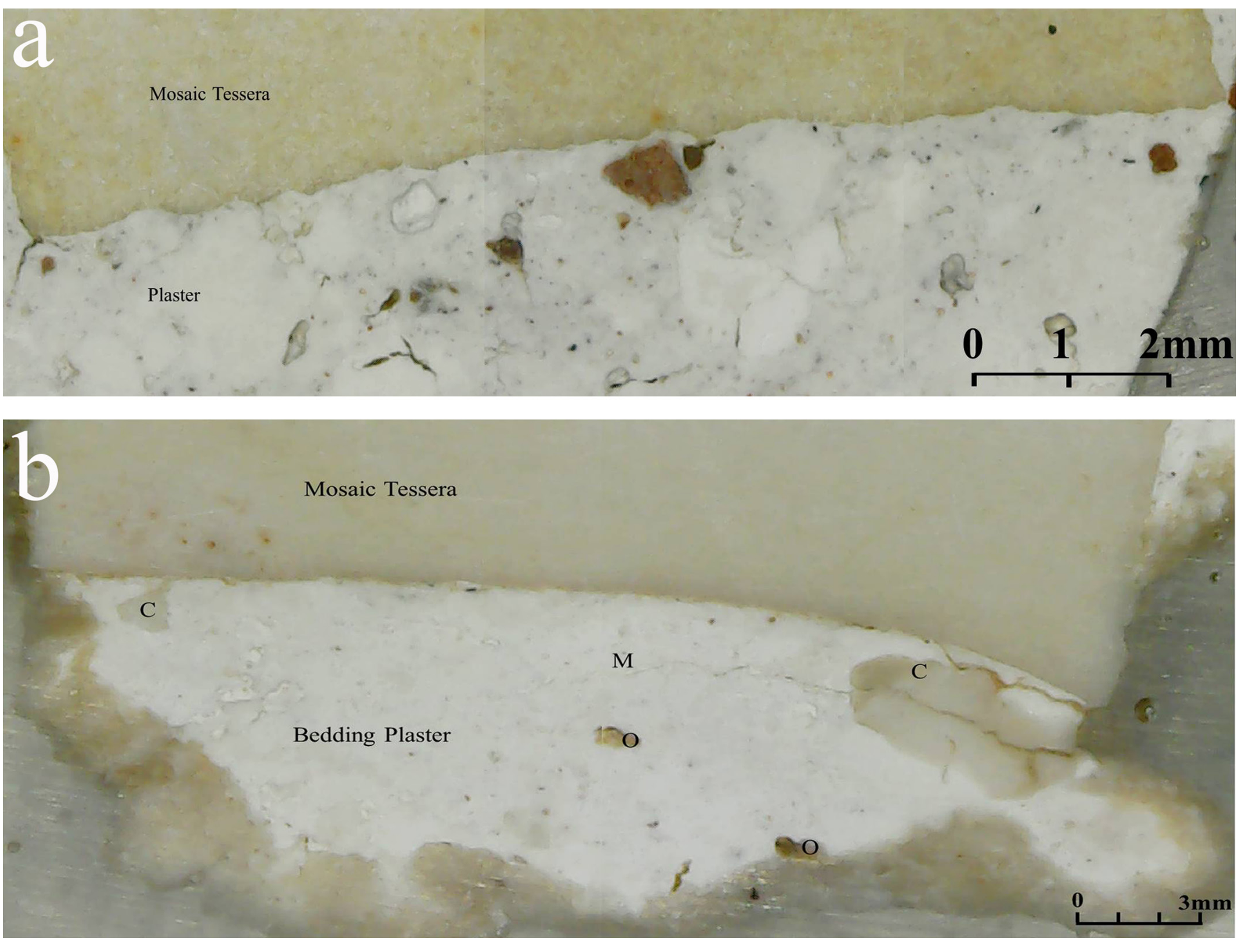


Fig. 16. *Photomicrographs of polished sections of Samples 1 and 2b showing both tessera and bedding plaster layer:* M *= matrix;* C *= calcite;* O *= iron oxide-rich grain.*

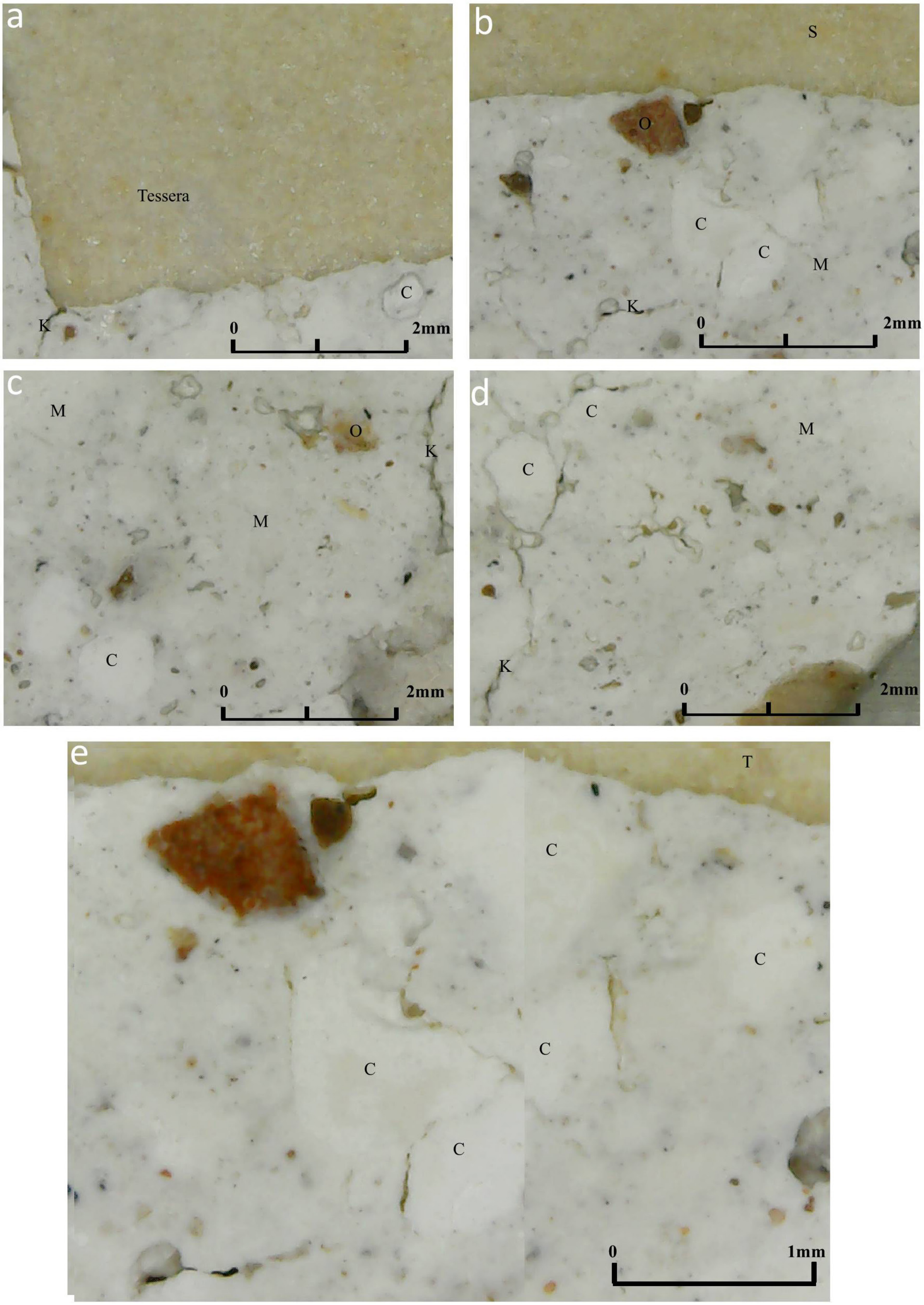


Fig. 17. *Photomicrographs of polished section of Sample 1 showing more details of the texture:* M *= matrix;* C *= calcite;* O *= iron oxide-rich grain;* K *= crack;* S *= mosaic stone.*

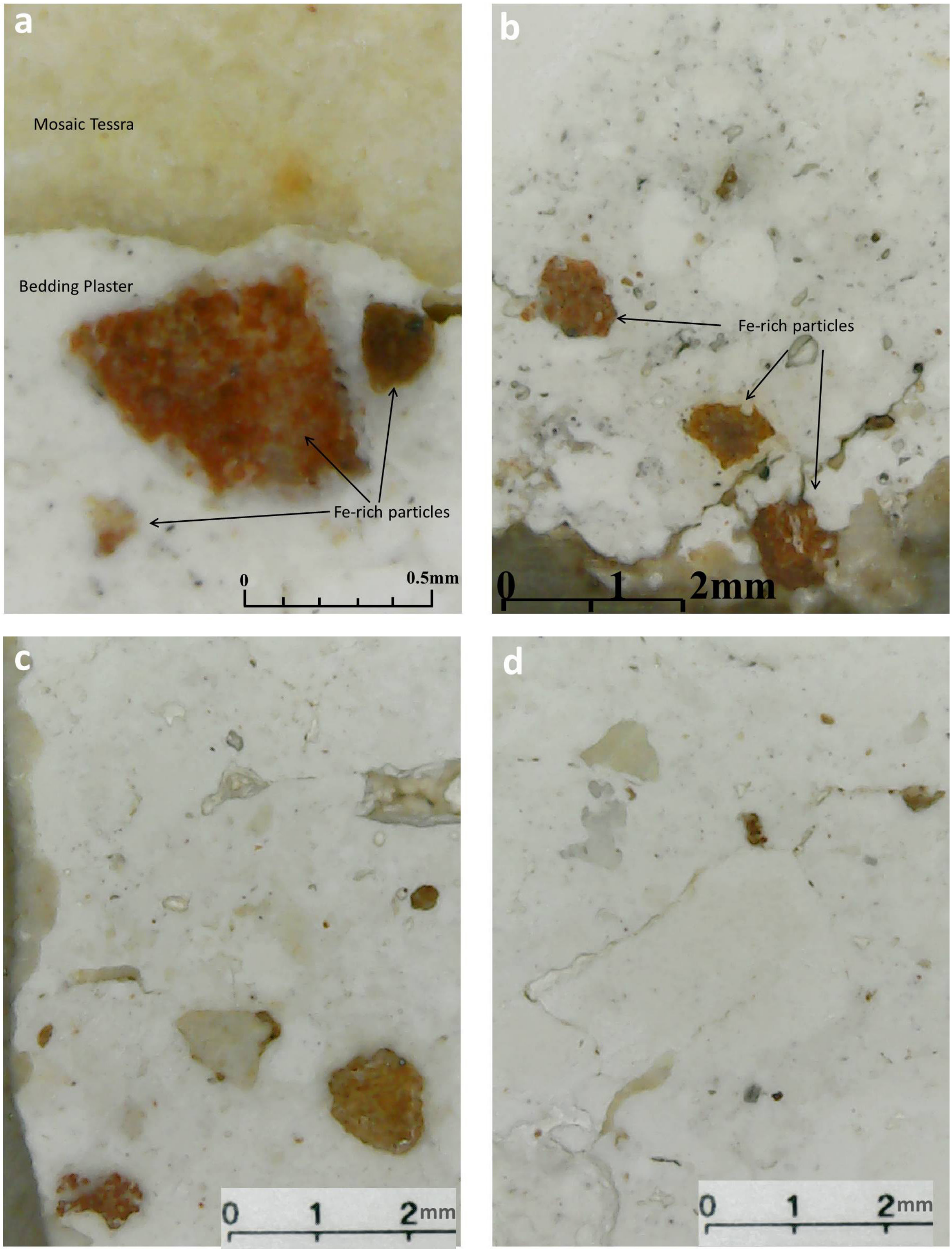


Fig. 18. *Photomicrographs of polished section of Sample 1 taken at higher magnification and showing areas with iron oxide-rich grains.*

## 6. Comparisons


Fig. 19. *The foundation layers of the mosaic pavements of the main hall of the Eastern Church at Khirbet et-Tireh (prepared by R. Khalil).*

Actually, considerable modern study has been devoted to the differences observed in mosaic substrate construction. Starinieri[5] and Starinieri *et al*. (2008), for example, stated that the total number of mosaic preparatory layers, as well as their thickness and constituent materials, are all variable, depending upon the physical conditions and features of each ancient site and also the structure and function of the buildings. Wootton (2012: 213) emphasized the fact that the mosaic substrate layers are often found to be of better quality and more thinly laid the closer they are to the top surface. Merrony[6] argued that the quality of the mosaic preparatory layers reflect the socio-economic status of the owners of the tessellated buildings. In order to identify the similarities and differences between the mosaic foundation layers of the southern rooms of the Eastern Church of Khirbet et-Tireh and those found elsewhere, both at Khirbet et-Tireh itself and at several other sites, we offer first the following comparative cases:

[5] Starinieri, V. (2009): *Study of Materials and Technology of Ancient Floor Mosaics' Substrate*. Unpublished Ph.D. Dissertation presented in 2009 in the Alma Mater Studiorum-Univ. di Bologna.

[6] Merrony, M. W. (2001): *Socio-Economic Aspects of the Byzantine Mosaic Pavements of Phoenicia and Northern Palestine*, vol. 1, p. 141. Unpublished Ph.D. Dissertation presented in 2001, in the Univ. of Oxford.

At Khirbet et-Tireh, the substrate of the main hall of the same Eastern Church was constructed of six distinct layers (Fig. 19): 1) A filling layer ranging from 1 m thickness over the western part of the church to 1.7 m in the eastern part, varying with the elevation of the underlying bedrock surface which, again, slopes generally downward toward the east; 2) a stone pavement –a lower *statumen*– 0.2 m to 0.3 m thick; 3) a leveling layer of additional earthen fill 10 cm to 15 cm thick; 4) another stone pavement –an upper *statumen*– 7 cm to 12 cm thick; 5) a *nucleus* layer 1.5 cm to 2 cm thick; and finally 6) the bedding mortar layer 2-3 cm thick –as stated above, along with additional analysis–.

Several other sites are also useful for comparison. At Paphos, Cyprus, in the House of Orpheus, the mosaic preparatory foundation consists of six layers: two *statumen* layers –without an intervening soil layer–, the *rudus*, a mortar layer, the *nucleus*, and the bedding layer (Getty Conservation Institute, 1991). In the basilica of Agios Lot in Jordan, the preparatory foundation also consists of six layers, but composed differently: *statumen*, sand layer, rubble, *rudus*, *nucleus*, and bedding mortar (Chlouveraki and Politis, 2003). In the bathhouse of Caesarea, the substrates consist of six identifiable layers: *rudus* –two layers–, *nucleus* –three layers–, and a bedding layer. Also at Caesarea, in Room 006, the mosaic foundation has five distinct layers: *statumen*, *rudus* –two layers–, *nucleus*, and bedding (Merrony, 2001: 141-145). Five additional Mediterranean sites conform exactly to the standard four layers –*statumen*, *rudus*, *nucleus*, and bedding– of the above-mentioned Getty classification: the Episcopal Palace at Aphrodisia, Turkey[7]; Caesarea (Merrony, 2001: 143); Tel Dor (Wootton, 2012: 213); the Augusteum of Dion, Greece; and the Villa Romana Delle Muracche in Tortoreto, Italy (Starinieri, 2009: 36 and 64). Finally, mosaics of Ravenna and the Santa Eufemias Cathedral (Grado, Italy) consist of only three layers: *rudus*, *nucleus*, and bedding (Karayazili, 2013: 11).

Based on the above comparative cases of mosaic foundation layers, we conclude the following: 1) the southern rooms of the Eastern Church of Khirbet et-Tireh represent the only published site distinguished by the existence of a thin soil layer between the *nucleus* and bedding layers in its substrates. 2) The *rudus* layer is completely absent from the southern rooms of Khirbet et-Tireh, whereas it appears among most preparatory layers of the other sites mentioned above. And 3) while the *statumen* of the southern rooms of Khirbet et-Tireh –especially Rooms 2 and 4– is constructed directly atop a thick layer of earthen fill, the *statumen* layer –fist-sized stones– in the main hall of the same church was constructed indirectly over a solid foundation of relatively large stones.

## 7. Conclusions

The mosaics and substrates of the southern rooms, as we found them, varied in physical condition, ranging from good, through severe damage, to complete destruction. Based on the scant overlying earthen deposits –only 0.2 m to 0.4 m thick– which we excavated from the surface of the southern rooms of the Eastern Church at Khirbet et-Tireh in 2015, and also the plow marks clearly visible in the *nucleus* layer of Room 4 (Fig. 20), we believe that the mosaics in this area of the church were dramatically damaged through agricultural activity, probably over a long period of time. The mosaics of these rooms are distinguished not only

Fig. 20. *Plow marks and deep cracks on the surface of the nucleus layer in Room 4.*

[7] Karayazili, Z.: *Material characteristics and deteriorated problems of Roman mosaics in Antandros Ancient City*, p. 11. Unpublished MA Thesis presented in 2013 in the Izmir University of Technology, Turkey.

by the total absence of the *rudus* layer, but also the existence of a thin soil layer between the *nucleus* and bedding layers –a unique sequence, as far as we can tell–. After much discussion, our conservation team has concluded that this unusual configuration may represent a constructional aberration, attributable to one of three possible causes: a lack of sufficient quantities of mortar; shortcuts taken by otherwise skilled workers; or some as-yet unknown special use for these particular rooms.

The study of the mosaic foundation layers of the southern rooms of the Eastern Church at Khirbet et-Tireh emphasizes the fact that the number, thickness, construction technique, and the constituent materials of ancient mosaic substrates can all vary from one archaeological site to another, from one building to another within the same site, or even between different rooms in the same building. These differences can be attributed to the particular physical conditions and features of each ancient site; the structure and function of the buildings; the socio-economic status of the owners of the tessellated buildings; a lack of sufficient quantities of lime-based mortar, based on the required total thickness of the substrates; or perhaps to shortcuts or innovations introduced by the ancient workers themselves.

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