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Christos Maris, Styliani Minetou, Ioannis P. Staikopoulos, Stefania Chlouveraki

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Revisiting the Mosaic of the Masks on Delos: A Comprehensive Condition Survey

Christos Maris, *Department of Conservation of Antiquities and Art Works*, School of Applied Arts & Culture, University of West Attica, Greece, *Department of Conservation of Antiquities & Works of Art*, Ephorate of Antiquities of Cyclades, Greece
marischristos@gmail.com

Styliani Minetou, *Department of Conservation of Antiquities and Art Works*, School of Applied Arts & Culture, University of West Attica, Greece
stminetou@gmail.com

Ioannis P. Staikopoulos, *Department of Conservation of Antiquities & Works of Art*, Ephorate of Antiquities of Cyclades, Greece
istaikopoulos@culture.gr

Stefania Chlouveraki, *Department of Conservation of Antiquities and Art Works*, School of Applied Arts & Culture, University of West Attica, Greece
schouve@uniwa.gr

Abstract. A condition survey was conducted on the 'Mosaic of the Masks' located in the homonymous Hellenistic house on Delos to reassess its condition twenty years after its conservation. This mosaic adorns the central symposium room and comprises a central geometric carpet with a 3D cube pattern, along with figurative bands featuring theatrical masks and floral motifs. Extensive and drastic conservation treatment was applied to the central carpet, involving its detachment in sections and reinstallation on a new, purpose-built setting bed, while the peripheral sections were preserved in situ. The particularly poor state of preservation necessitated thorough research into the weathering processes and the factors affecting its condition. Investigation into the archival records, the original constituents, conservation materials, and past conservation interventions were conducted to better understand the deterioration processes. Photogrammetric methods were employed in the study and documentation of surface geometry, while the cohesion of the substrate was examined through acoustic tapping. Environmental monitoring throughout a full year provided insights into the weathering factors at play. SEM-EDS and XRD analyses enabled the characterization of constituent materials, manufacturing techniques, and weathering products, offering clues about the deterioration processes.

Keywords: Hellenistic mosaics, Delos, condition survey, documentation, photogrammetry, SEM-EDS, XRD.

1 Introduction

The "Mosaic of the Masks" adorns the floor of the central room of the homonymous house at the World Heritage Site of Delos in the Cyclades, Greece, and exhibits a diverse range of materials and techniques. The 'House of Masks' was excavated in the 1930 [1] and dates to the late 2nd - early 1st century BC [2]. It stands out as one of the most luxurious buildings at the site, with figurative mosaics of the highest quality in all its rooms. Restoration of the building was undertaken in the 1950s, which involved reconstruction of the walls to their estimated initial height and the addition of a reinforced concrete slab roofing. The mosaic floor underwent extensive conservation treatment in the late 1970s which involved the detachment of the central, geometric panel in sections, their remounting in custom-made supports, and reinstallation on a new foundation. The rest of the mosaic was preserved in situ.

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2 The mosaic of masks: materials and techniques.

The mosaic under study measures 9.12 x 7.09 meters and features a central geometric pattern composed of '3D cubes,' a recurring motif in Hellenistic mosaics. This design is characterized by the arrangement of cubes to create a three-dimensional effect. The central pattern is bordered by a decorative band of waves, with two lateral bands on the east and west, each showcasing five theatrical masks, interwind with floral motifs. The outer band is plain, giving the illusion of a big carpet on the floor (Fig.1).

Fig. 1. Orthophoto of the mosaic of the Masks, 9.12 x 7.09 meters (by C. Maris)

A variety of materials and fabrication techniques are employed. The sides of the cubes are set in *opus segmentatum*, characterized by the random setting of irregular red and black tesserae with wide and irregular interstices (Fig. 2). In contrast, the top of the cubes is set in *opus tessellatum,* characterized by a well-organized *andamento*, using white tesserae of approx. 1 cm side arranged in concentric lozenges [3]. Additionally, lead strips [4,5] are used to define the sides of the rhombuses that form the three-dimensional cubes and the outlines of the waves. *Opus vermiculatum* is used in the masks, and *opus tessellatum* in their background, the floral motifs, and the rest of the decorative bands. Glass tesserae are used in a few details of the masks while the rest of the mosaic is made of stone tesserae.

Fig. 2. Detail of the 3D cube pattern of the central mosaic carpet (left) and the masks (right) (photo and drawing by S. Minetou).

The outer part of the floor (approx.1 m wide), is paved with a course *opus segmentatum* consisting of marble fragments in the order of 5-6 cm. The remains of a surface coating consisting of a fine red plaster colored with iron oxides are preserved on the periphery of the opus segmentatum, indicating that the entire area of the outer band is covered in colored plaster. Moreover, evidence indicating the '*giornata'* (the portion of the work produced in a day) is apparent in this outer band [6,7]. A monochrome (white) *opus tesselatum* section is found in front of the entrance steps, alluding to an entrance carpet. The color pallete consists of pink, brown, green, orange, blue, white, grey, and black. Information about the mosaic's stratigraphy is retrieved from the archival records indicating the following layers from the bottom up: *statumen*, charcoal layer, *rudus*, *nucleus*, setting layer (or *supra nucleus*), and the tessellatum.

3 Condition Survey 2021-2023: objectives and methodology

The condition survey undertaken on site aimed at the documentation and the assessment of the current state of preservation of the mosaic, the identification of the prevailing weathering factors, the evaluation of previous treatments, and finally, the development of a methodological approach towards its conservation and protection. The investigation began with archival research followed by field surveys and laboratory analyses. The field survey included macroscopic observation, photogrammetric documentation, acoustic tapping, the detection of metal reinforcement, environmental monitoring, and measurements of surface and substrate moisture content. Finally, the color pallete was defined using the Munsell Rock Color Chart. Sampling and laboratory analyses focused on the study of surface depositions and the characterization, the original and restoration mortars, and the surface coating that is preserved on the opus segmentatum.

3.1 Archival research

The conservation interventions undertaken between 1978 and 1994 were retrieved through archival research conducted at the Archaeological Ephorate of Cyclades [1]. After the detachment of the central carpet mosaic in the 70s, the project was abandoned, and 16 years later, the sections were remounted in new mortar reinforced with aluminum frames and galvanized mesh (chicken wire). A new foundation was constructed on-site for the reinstallation of the mosaic sections. This foundation comprised of a layer of loose stone gobbles, two iron bars set diagonally above the gobbles, and a final layer of cement mortar. To mitigate the risk of rising dumps, a polyethylene sheet was laid on the ground before the new foundation was set [1,8], thus isolating the reinstalled mosaic section from direct contact with the ground. This approach prevented the infiltration of moisture and condensation water and encouraged salt crystallization cycles to occur primarily within the layers of the new foundation and the re-laid mosaic sections especially at their interface. The alignment of the mosaic sections was challenging due to the loss of legibility of the initial records. As a result, their joins appear disruptive.

3.2 Macroscopic observation

The entire mosaic was covered by loose deposits originating from the disintegration of the wall plasters, and the masonry, concrete, and iron fragments collapsed from the roof, as well as biological depositions. Acoustic tapping indicated the loss of cohesion between the mosaic surface and the substrate across the entire floor, in particular on the previously detached area. Extensive disintegration of the interstitial mortar was observed at the *opus segmentatum* of the outer band, especially in the northern and western parts of the floor, leading to loss of adhesion and often to detachment of tesserae. Cracks, bulges, and rises were concentrated in re-laid areas. Salt efflorescence covered the northern side, which kept reoccurring shortly after their removal. The green tesserae are extensively eroded, often partially or completely pulverized. The ceramic tesserae on the north and west sides show cracking, exfoliation, erosion as well as biological and microbiological colonization (Fig. 3).

Rainwater seepage from the north side of the roof and walls favors salt migration and biological colonization on both the masonry and the mosaic floor. Soluble salts and iron corrosion products originating from the restoration materials are leached and transported to the mosaic floor. Severe corrosion of the metal bars is observed at the northern part of the roof, causing the detachment of small fragments of the concrete slab and rendering the mosaic inaccessible to visitors. The incorporation of incompatible intervention materials into the new substrate further contributes to the continuous degradation of the mosaic. In addition, the action of insect swarms, which create colonies inside the masonry, intensifies the degradation of the wall plasters, resulting in their gradual collapse on the mosaic surface. It is evident that the severe condition of the mosaics is largely owing to the detrimental effects of the past restoration practices. When comparing the detached portion of the mosaic with the part that remained in situ, it becomes evident that the detachment has led to enhanced deterioration. In addition to the severe deterioration of the mosaic substrate and surface, the misalignment of the re-laid sections compromises the aesthetic values of the mosaic floor, also affecting the broader architectural context.

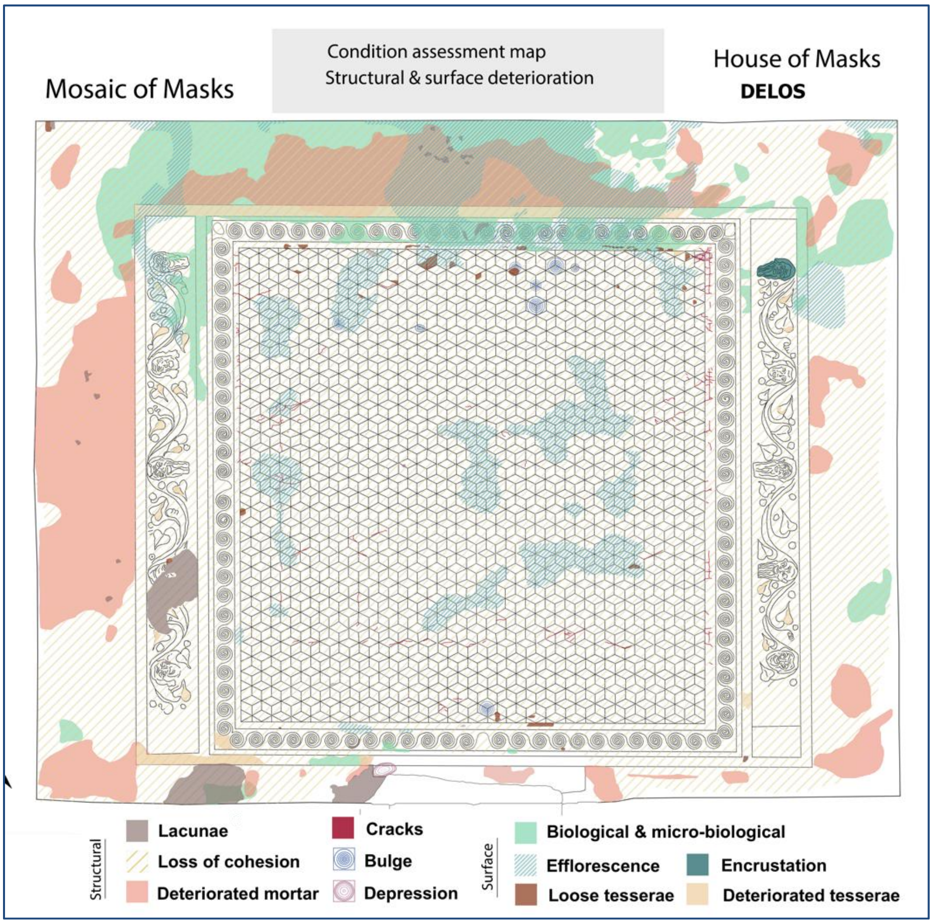

Fig. 3. Condition map, showing the prevailing surface and structural conditions (by S. Minetou).

3.3 Surface and substrate examination

A portable digital microscope was used on-site to examine and document surface weathering features and depositions. However, the limitations of the low depth of field and the high relief of examined surfaces led to unsatisfactory results. The examination of the surface with a portable GMS metal detector confirmed the presence of metallic elements that were used as reinforcement in the mounting system of the detached mosaic sections and allowed us to locate them and correlate them with the loss of cohesion and the bulges occurring on the surface. In addition, moisture distribution maps were drafted based on comparative measurements acquired with a microwave humidity sensor, providing information from the subsurface up to a depth of 30cm. Measurements were taken on 80 points distributed in a 1x1m. Grid over the entire floor. The average of 3 measurements on each spot was plotted to create the moisture distribution map, showing a wide variation of moisture content across the mosaic floor with values ranging from 40 to 99. The obtained data were correlated with the occurrence of salt efflorescence, indicating that salts crystallized on the surface in areas where moisture content values ranged from 62 to 93.

3.4 Photogrammetric documentation

Both handheld digital cameras and drones were utilized to capture images. A first set of 974 images were acquired before cleaning, followed by a set of 857 images after dry cleaning. The first two sets of images were shot from a height of approx. 0,5 m, with a 70% overlap, a rather time-consuming and labor-intensive process. Image processing was similarly challenging due to the large number of images. A third set of 187 images were acquired with a drone from a steady distance of 3 m. The 3D model, the orthophotos, and the digital elevation model (DEM) provided metric information and enabled the study and documentation of surface geometry alterations related to natural deterioration and previous conservation treatments. The orthophotos served as a base for accurately mapping surface and structural conditions, while the point cloud and the DEM provided the basis for monitoring subsequent changes in the geometry of the mosaic, allowing for the assessment of the evolution of decay (Figs 1, 4).

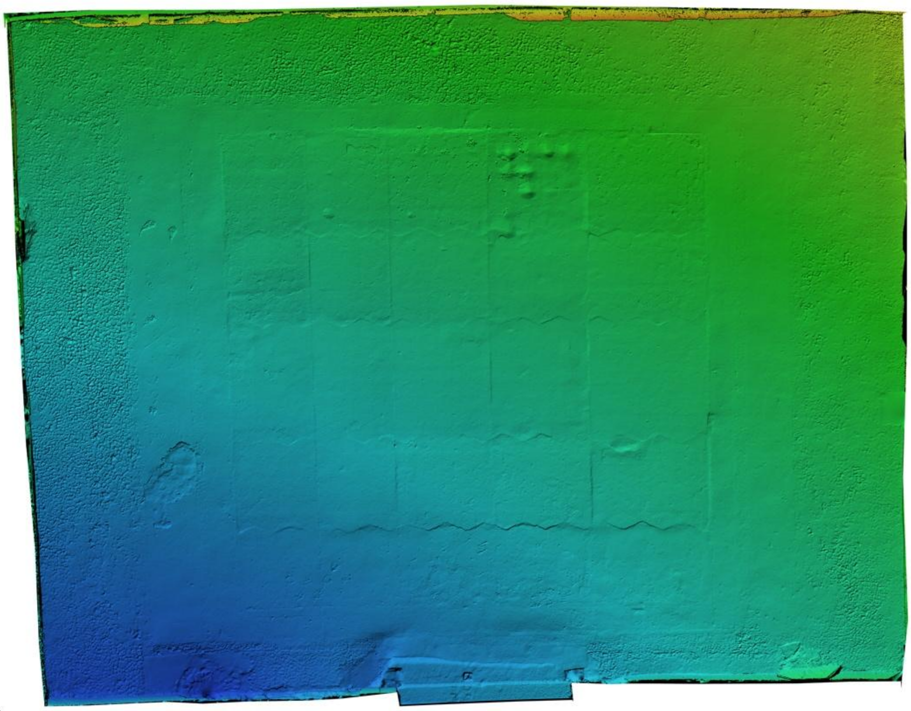

Fig. 4. Digital Elevation Model (DEM) of the mosaic floor generated using Agisoft Metashape v1.7.3. The blue tones indicate the lower areas of the floor, sloping towards the water drain exit (by S.Chlouveraki).

3.5 Environmental monitoring

Temperature (T) and relative humidity (RH%) values were recorded via a Tiny-tag data logger placed inside the room for a period of 10 months and 2 weeks, from November 1st, 2018, to September 15th, 2019. The data acquired reveals consistently high relative humidity levels, with average values reaching

76,6% during the winter months and 65,3% during the summer months. Due to the lack of outdoor monitoring equipment on Delos (the nearest weather station is on the nearby island of Mykonos), it was not possible to evaluate the effectiveness of the shelter in terms of mitigating the impact of the environmental parameters. However, the research by Prokos [9] offers environmental data for different areas of the archaeological site, including the prevailing humidity and temperature inside the room where the mosaic under study is situated. The findings of this study suggest that marine aerosols are the primary source of salt affecting the architectural remains of Delos, both in sheltered and outdoor environments.

3.6 Sampling and laboratory analyses

Sampling was concentrated on the heavily deteriorated areas and the surface deterioration/corrosion products, targeting fragments that had already detached. All samples were initially examined and documented with an optical stereoscope Olympus SZ61 using the Infinity Analyse & Capture software. Cross sections of the original mortars, which included the surface red layer and the main body of the setting mortar, as well as samples from the lower layers of the mosaic bedding stratigraphy and the lead strips (used to outline the geometric motifs), were prepared for study under the SEM-EDS. Additionally, samples were taken from surface salt efflorescence of two different morphological types and one of a biological deposition with a leafy structure.

Scanning electronic microscopy (SEM-EDS)
The study of the samples was carried out on a JEOL JSM6510LV Scanning Electron Microscope (SEM), accompanied by an Oxford Instruments x-act type X-ray Energy Dispersive Spectrometer (EDS/EDX) with the use of INCA program. The intensity and radius of the analyzer were maintained at BEC 20kV, with Spot Size 34-35ss and 40ss. The distance of the sample to the analyzer was kept steady at WD 15 ±1. The samples were not carbon-coated. Between 6 and 12 point-analyses were obtained from each sample depending on the complexity of its composition.

X-Ray Diffraction (XRD)
The X-ray diffraction method was used to investigate the crystal structure of the salts present on the surface of the mosaic and identify the mineral composition of the aggregates used in the original mortar. The study of the samples was carried out using the Inxitu - BTX 262 model with a cobalt tube, and the analysis time of each sample was 75 minutes.

4 Results

The analyses provided insights into the manufacturing technology of the Hellenistic mosaics of Delos and the information required for proposing the optimal conservation methodology and materials for future interventions. The examination of the red mortar that is preserved in the interstices of the *opus segmentatum* showed that it comprises a thin layer (404 - 613μm thick) of lime mortar, with fine aggregates of pure quartz and ceramic powder, which is responsible for its color. The mortar beneath the red layer consists of lime mortar with crushed ceramic, with maximum particle size in the range of 2,95 mm, and natural aluminosilicate aggregates with a chemical profile of Si 27%, K 10%, Al 8.46%, and Na 1%. The grain size ranges from ~1.37mm to ~2.48mm. The aggregates exhibit a greyish hue and a rounded shape. In addition, the use of lead strips was affirmed with a composition of Pb 41.09 wt%.
Two different types of intervention mortars were sampled from lacunae and were examined by SEM-EDS, which show a composition that corresponds to lime mortars. Similarly, the crystal phases of the intervention mortars identified by XRD do not appear to contain cement compounds. The silicate and calcite aggregates used show great variety in colour, structure, grain size, and composition and, in some cases, are found rich in Ti (av. 14.72wt%). Grain size varies from 305μm-2.483mm, with the majority in the order of 550-750μm. The analysis of salt efflorescences shows the presence of Na combined with high percentages of S. Specifically, the average weight of the two samples examined shows percentages of Na 24.93%, S 19.15%, Ca 1.35%, and Al 0.6%. A low Cl of 0.45 wt% was identified only in one analysis. The main crystal phase identified in XRD analyses showed primarily Thernadite (Na_2SO_4) with crystal phases of Gypsum, Calcite, Coesite, Quartz, and Halite. The salt contents examined in the current survey point out that salt efflorescences primarily originate from the leaching of sulphates form the restoration materials surrounding the mosaic, with minimum amounts of halite. The biological organisms

could not be identified at this stage of research, but they were extensively documented through electron microscope images for future research purposes.

5 Conclusions

The condition survey of the *'Mosaic of the Masks'* on Delos, conducted twenty years after conservation, has provided valuable insights into its current state of preservation and the factors affecting its deterioration. The investigations conducted so far have led to the conclusion that the deterioration of the mosaic is primarily attributed to the drastic interventions of the past, along with the absence of systematic maintenance for both the mosaic floor and the modern concrete roof forming its current architectural context. When comparing the detached portion of the mosaic with the part that remained in situ, it becomes evident that the detachment process has led to enhanced deterioration. These observations underscore the intricate interplay between natural and anthropogenic factors shaping the mosaic's evolution of decay. Photogrammetry, environmental monitoring, SEM-EDS, and XRD analyses have enriched our understanding of the deterioration processes as well as the materials and manufacturing techniques.
Moving forward, it is imperative to implement targeted mitigation strategies to safeguard the *'Mosaic of the Masks*' against further deterioration. This may include new conservation treatments targeted to the detached area after further research and pilot on-site applications.
It's evident that immediate action is necessary to address these issues. Proper maintenance is essential to prevent further damage and ensure the safety of both workers and visitors. This may involve repairing the roof, improving drainage systems to prevent water seepage, and implementing measures to control moisture and biological growth. Additionally, steps should be taken to make the mosaic accessible to visitors once again, as it's an important part of the building's heritage.
Furthermore, the lessons learned from the conservation and preservation efforts of the *'Mosaic of the Masks*' serve as a valuable case study for similar cultural heritage sites worldwide. By sharing our experiences and best practices, we can collectively strive to ensure the long-term preservation of our shared cultural heritage for future generations to appreciate and enjoy.

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