The Three-dimensional Digital Representation of South Stoa (Portico) and Agonotheteion Mosaic in Ancient Corinth, Greece

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The intention of this interdisciplinary work is the integration of 3D recording techniques to survey and document the archaeological area of the South Stoa monument in Ancient Corinth, one of the most significant archaeological sites in Greece. South Stoa is an impressively large building, which covers an area of more than 4 acres (165 m long and 25 m wide) and consists of: (a) the portico, the northern part – facade with the outer and inner colonnade and (b) the southern part with Hellenistic shops and Roman public buildings. Between the southern buildings, there is the Roman "Agonotheteion", a monument that includes 45 sqm, also known as "Eutychia" (good luck) mosaic. The study group, which was set up and organized by the "American School of Classical Studies in Athens" (ASCSA), carried out an ambitious project (proposal) of the restoration of South Stoa Portico and the conservation of the Agonotheteion mosaic, based on an accurate 3D recording of the area (3D data and photogrammetry – orthoimages - for documentation, conservation, preservation and visualization purposes). The procedure allowed high accuracy measurements of the two monuments, which due to their size, nature and construction were completely different, the correction of the initial published dimensions of the portico, the identification of its initial level, the efficient process of a big quantity of information and the guarantee of the safe detachment of the mosaic.

Key words:
Digital heritage, 3D Modeling, 3D Data Analysis, ancient Corinth.

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INTRODUCTION

Ancient Corinth is one of the most significant archaeological sites in Greece, due to its historical importance as a Panhellenic administrative and commercial center in the late Classical and early Hellenistic times. Among the impressive monuments of the archaeological site are the Apollo temple, the Altar of Paul the Apostle, the Peirene fountain, the Theatre, the South Stoa etc.

South Stoa (Fig. 1) is an impressively large building, which covers an area of more than 4 acres (165 m long and 25 m wide). Its construction is considered crucial for the architectural and urban design of the ancient city of Corinth during its transition from Classical to Hellenistic period. During the Roman era, most of the shops were demolished and were replaced by administrative and other public buildings. One of them is the Roman "Agonotheteion", a monument that includes a 45 sqm mosaic, also known as "Eutychia" (good luck) mosaic.

In 2012, the "American School of Classical Studies in Athens" (ASCSA) carried out an ambitious project of proposing the restoration of the South Stoa Portico (reconstruction of the ground elevations and boundaries, displacement of the archaeological remains etc) and the conservation of the Agonotheteion mosaic for the Hellenic Ministry of Culture. However, the complex process of data acquisition and interpretation of the monument and its surroundings by reports, drawings and photographs is the first and most important step before starting the restoration works [Yilmaz et al. 2007].

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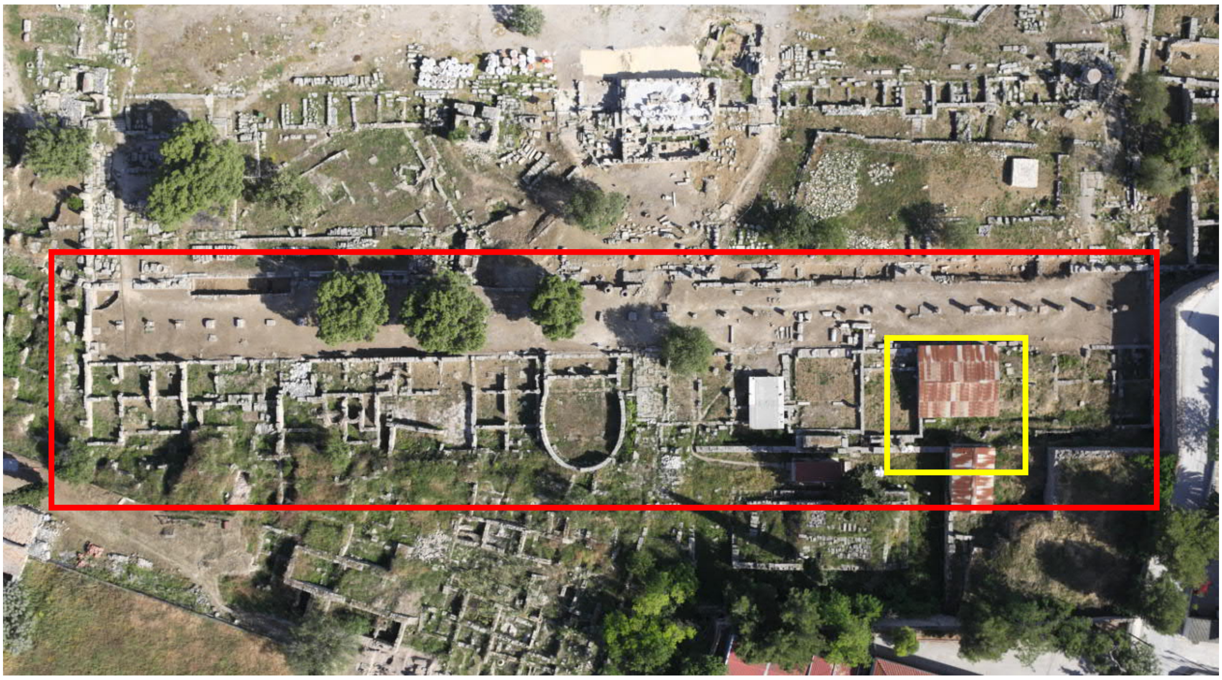

Fig. 1. The South Stoa (red line) and the Agonothteteion (yellow line) in Ancient Corinth, Greece

In order to complete the study of the two monuments, which due to their size, nature and construction were completely different, the project team that consisted of Konstantina Siountri (Architect), Vasilis Soulis (Archaeologist, Architect) and Anastasia Karagiorgou (Survey Engineer) had to thoroughly document the geometry and to fully map the pathology of the objects, either the subject was the 165 m colonnade or a single mosaic *tessera* with absolute precision (measurements, details of the colors and textures etc.).

For that reason, according to similar techniques used at the data management of ancient cultural heritage in Greece [Sapirstein 2015] and Italy [Fiorillo et al. 2013], the methods of topographic site mapping, photogrammetry [Pavlidis et al. 2007] and construction of 3D georeferenced models were used in order to analyze the heritage site and structures

HISTORICAL OUTLINE AND DESCRIPTION OF THE MONUMENT

According to the publication of the monument's excavation [Broneer 1954], the Stoa was constructed by Philip II and is associated with the founding of the Alliance of Greeks, also known as the Alliance of Corinth, and dates to 338 BC. However, according to newer findings [Coulton 1976], the Stoa dates to the early 3rd century BC and hence must be attributed to Demetrius the Polarcetes, who revived the Alliance in 302 BC. The construction phases that followed, throughout the Roman period, from the first imperial years to the destruction of Corinth by Erulus in 267 AD and later by Goths in 395 AD, reflect the long history of the city of Corinth.

The monument consists of: (a) the portico, the northern part – facade with the outer and inner colonnade and (b) the southern part with Hellenistic shops and Roman public buildings. The difficult achievement of the archaeological research and study of the architecture of this large-scale monument is attributed to the ASCSA. The excavators of the monument were a) R.B. Richardson in 1896, Th.W. Heermance in 1904, b) O. Broneer in 1933 (II World War), between 1946 and 1948 and in 1950 and finally c) C.K. Williams [1972; 1973; 1978; 1978a; 1979; Williams and Bookidis 2003]

The study of the monument's architecture and history was published by the excavator O. Broneer in 1954. After two decades, J. J. Coulton studied the historical evolution of the style of the Stoa and its characteristics. His work was published in the mid-1970s.

The South Stoa belongs to the type with a single-story exterior portico (Portico) and a two-story rear section with shops on the ground floor [Broneer 1954]. It has a length of 164.38 m at the facade's stylobate and a width of 25.15 m from the stylobate to the rear wall of the shops, covering an area of more than four acres. It dates to the last decades of the 4th century BC and it was the largest and most carefully designed Stoa that had been built until then. The construction material is the well-known gray-green tufa stone of Corinth, which was used for all public buildings in Corinth during the years before the Roman period.

The South Stoa is characterized by a high-quality detailed construction. The curvature is referring to the architecture of the temples and is not common in galleries. However, in South Stoa we find curvature at the stylobate of the outer colonnade and at the base of the walls. The curvature at the center of the stylobate at the facade's colonnade is estimated at 0.15 m [Broneer 1954], i.e. 0.09 % of the total length, much less than 0.16 % of the curvature of the long sides of the Parthenon [Coulton 1976].

The Portico had a Doric colonnade of 71 columns and an internal Ionic colonnade with 34 columns. The use of the “imposing” Doric rhythm was used due to the large width of the building, resulting to a high roof by the absence of a floor in the Portico, combined with the existence of a floor at the rear of the building. The Doric colonnade had columns with a “lower diameter” (D) of 0.96 m, an “upper diameter” (d) of 0.794 m, a height of 5.70 m (5.94 x D) and a distance between the vertical their axes of 2.34 m (2.44 x D). The columns were tense, but they were not tilted inward, despite the curvature. The corner columns were not thicker than the rest.

The *crepidoma* of the facade's colonnade consisted of two steps. In front of it, on the ground, there was a stone semi-circular cross-section canal that was connected with 18 square cleaning wells at regular distances. The Doric columns were based in the center of each of the second stone of the stylobate. The stones of the foundations and the stones of the *crepidoma* of the colonnade had a length of 1.17 m, equal to half the distance between the columns. The width of the stones of the foundations was 0.585 m, equal to one quarter of the distance between the columns. On the east and west sides of the building, the foundations, the *crepidoma* and the superstructure of the walls maintain a length of 1.17 m.

Portico was 12.385 m wide [Broneer 1954] from the outer side of the stylobate to the wall of the shops. Inside the Portico interior were the 34 Ionic columns of the inner colonnade, which had a “lower diameter” (D) of 0.66 m, an “upper diameter” (d) of 0.562 m and a “height” (h) of 6.24 m (9.45 x D) [Broneer 1954]. The distance between the vertical axes of the Ionian columns was 4.68 meters, twice of that of the Doric one, that is, an Ionic in each second Doric column of the facade. Because of this arrangement, each Ionic column had an independent foundation and there was no continuous stylobate.

On the ground floor of the back section of the gallery were 33 shops with two rows of rooms. Based on the pottery found in the shops, it is clear that these were functioning as restaurants, with warehouses and food preparation areas. All rooms in the front row except two had one well. The wells were supplied with fresh running water through a longitudinal duct connected to the water transfer system from the fountain of Peirene. The wells served not only for the supply of water but also for the cooling of wine and food. The shops were evenly spaced. The internal dimensions of the stores are in the range of 4.80 x 4.49 m [Broneer 1954]. The last store in the east was about 0.10 m wider than the rest. The floor above the shops was probably an accommodation space. The existence of the upper floor is documented by the great height of the gallery, as is evident from the Doric columns of the facade. If there was no floor, the shops would have a large internal height, unmatched with the dimensions of their floor plan.

For the construction of the South Stoa a central road of the classical city was removed, and buildings were demolished. Also, at its western end, a large tank, with an impressive underground water storehouse system was removed. This tank probably dates to the late classical period and seems to serve many of the buildings that existed in the area before Stoa was erected.

Thus, the building of the South Stoa, by eliminating all the pre-existing elements in a densely populated area of the classical city, was a decisive step in the urban planning of Corinth and became the most important public space and the center of the life of the city in the Roman years [Williams 1981].

In the Roman years, a series of renovations and dramatic reconstructions were carried out, during which the shops in the rear section were demolished and replaced by administrative buildings and other public buildings, except for the last three west shops that were preserved as they were in the initial phase. The process of these modifications, which began in the years of Augustus continued until the end of the 2nd century AD. Until Nero's years, the Agonotheteion, the Fountain, the Southern Basilica and the Bouleuterion had been built.

In 1933 Oscar Broneer during his excavations discovered one of the most important Roman mosaics in Greece dated to the late 2nd and early 3rd century AD, named as "Eutychia" (good luck) mosaic. Around the central panel are 12 smaller squares, four to a side, containing birds, rosettes and other floral designs in colorful *tesserae*. The mosaic's central figural panel (1.30 m x 1.27 m) depicts a nude athlete and a seated, semi-draped goddess who holds a shield inscribed with "Eutychia" (good luck) as well as a vessel from which water streams into a basin, recalling two famous Corinthian trademarks, the Aphrodite of Acrocorinth and the nymph Peirene. The 45 sqm mosaic is interpreted as an allegory of the Isthmian Games and the goddess as Corinth herself. The inscription on the shield, "Eutychia" (good luck), reflects on the fortune of the victor and offers the same to the viewer. The donor of the mosaic is unknown [Robinson 2012]. In 1930's he walls of the Roman Agonotheteion were rebuilt and a roof was placed in order to protect the underneath artifacts.

THE CASE OF THE PORTICO

Since Broneer's excavation and the subsequent arrangements, the trenches of foundations of the external colonnade were left exposed and visible. The existing floor level inside the portico is in most parts uneven, while almost the entire length of the monument diverse from the ancient level. There are problems of understanding the third dimension of the monument since very few elements of the portico are preserved in situ, like parts of the foundation of the internal and external colonnade. Therefore, neither the rhythm nor the size of the columns can be easily understood by visitors (Fig. 2).

Fig. 2. Aerial photos of the Doric External Colonnade (red line) of South Stoa, Corinth

Indicatively, along the external colonnade there are about 10 parts of the stylobate (from 141 in total) and about 23 parts of the steps (from 141), about 50 elements of the layer of euthynteria are visible and some of the underlying layers of the foundation (layers -III, -III, IV).

Fig. 3. Broneer's designs of publication in 1954 (© [Broneer 1954])

From the early beginning of the project, it was obvious that apart from the historical and architectural research of the findings and the archives, the project team had to carry out an integrated survey of the monument in order to extract quantitative data that document the location, size and dimensions of monument's components. The collection and processing of images through aerial and terrestrial photogrammetry could enable the construction of 3D georeferenced models and the management of the huge amount of data from the office environment, reducing the number of visits in the field.

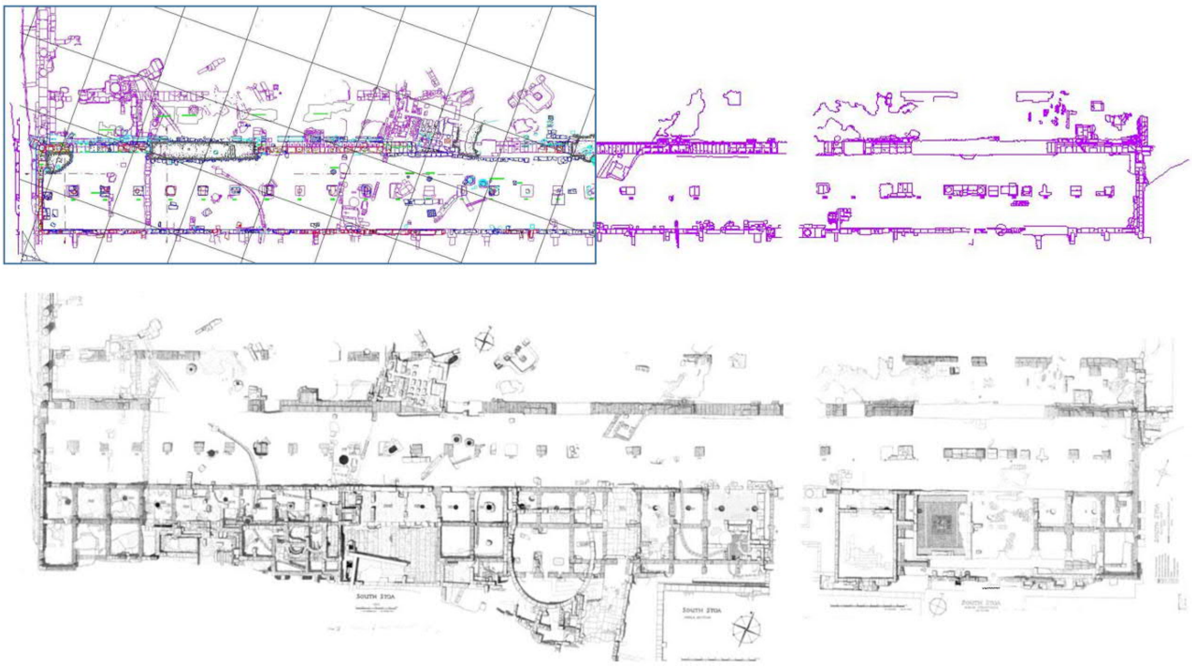

Fig. 4. The united plan of Broneer's designs with geolocation and the new plan with the track of changes

The challenges were multiple and demanded customized auxiliary equipment (customized focal length, calibration, depth of field of the camera). For each type of cultural object (with different scale as well as the different structure), the requirements in the process of photogrammetry and imaging techniques differed in order to achieve better and accurate results [Moysiadis and Perakis 2011].

As far as it concerns the aerial photogrammetry, in 2012 the use of UAS (Unmanned Aerial Systems – Drones) was not widespread. Therefore, the combination of a large helium balloon with a calibrated wide-angle lens camera was chosen in order to obtain a large number of overlapped photographs, at different levels, based on a reference coordinate system that allowed the extraction of accurate 3D data and produced accurate and visually detailed geometric information.

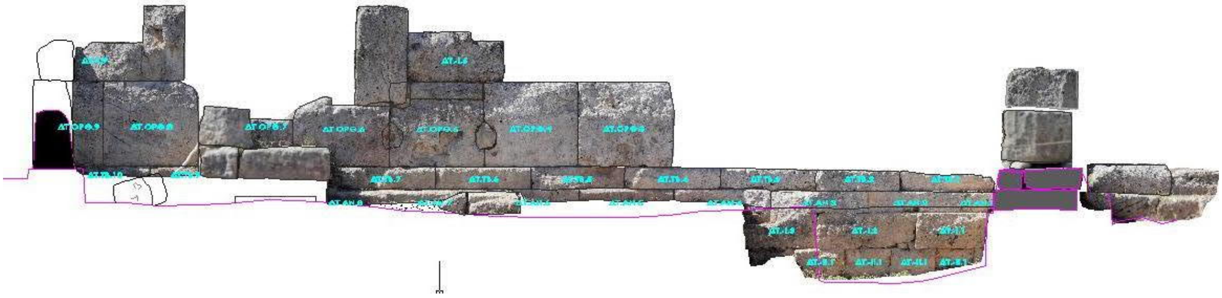

Fig. 5. Section in the western part of the South Stoa Portico

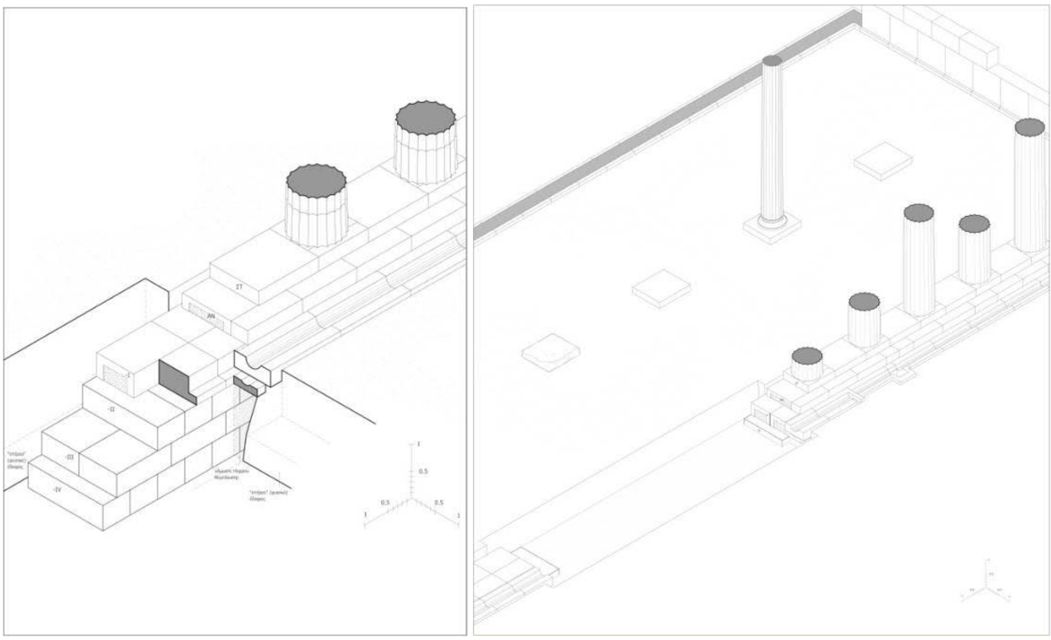

Fig. 6. The partial restoration of the foundation and the crepidoma of the external colonnade and the proposal for the internal remaining columns

One of the main tasks of the team was to succeed to insert Broneer's designs (Fig. 3), from the excavator's publication in 1954, into the system and through geolocation to give them exact X,Y coordinates. In that way it was possible for the first time to unite the different sheets of drawings in one single accurate plan. This allowed the project team to proceed in mapping (apart from the existing pathology of the monument) the changes (displacements, further excavations etc.) that have taken place from 1954 until today (Fig. 4).

The survey of the remaining parts of the foundation from layers -III, -III, IV allowed the team to confirm Culton's study about the curvature 0.09 % of the total length (it is estimated at 0.15 m in the center of the stylobate of the facade colonnade). However, as far as it concerns the distance between the vertical axes of two columns (interaxial width <*μεταξόνιο*), although the theory of Broneer was proven quite accurate, the project led to corrections regarding the areas of the monument's corners.

Regarding the South Stoa Portico, some of the project goals that were achieved can be described as follows:

(1) The restoration of the foundation and the *crepidoma* of the external colonnade in order to regain the form of the original construction (Figs. 5 and 6)

(2) The formation of the space between the external colonnade and the wall with the facades of the shops and public buildings in a way that restores the unity of the interior of the stoa

(3) The partial elevation of the external and internal colonnades using the best-preserved elements

(4) Enhancement of the monument.

THE CASE OF AGONOTHETEION

The detachment and conservation of ancient mosaics is considered a quite demanding procedure requiring high expertise and technical knowledge [Županek et al. 2016]. The scope of the study was the geometric documentation of the mosaic floor (horizontal and altitude) and the accurate digital preservation of the geolocation of each *tessera*. One of the major problems of pathology of the mosaic was the retreat of the subsoil, probably because of the existence of a wide network of pipelines, wells and galleries in the wider area. The unevenness of the surface of the structure led some areas being submerged and others being on the rise. In addition, there were intense problems of partial detachment of the *tesserae*, moisture phenomena, severe problems of biological actions that made the three-dimensional mapping necessary not only for the reinstallation of the tesserae in its original place, but also for the complete documentation of the existing multicriteria condition (Fig. 7).

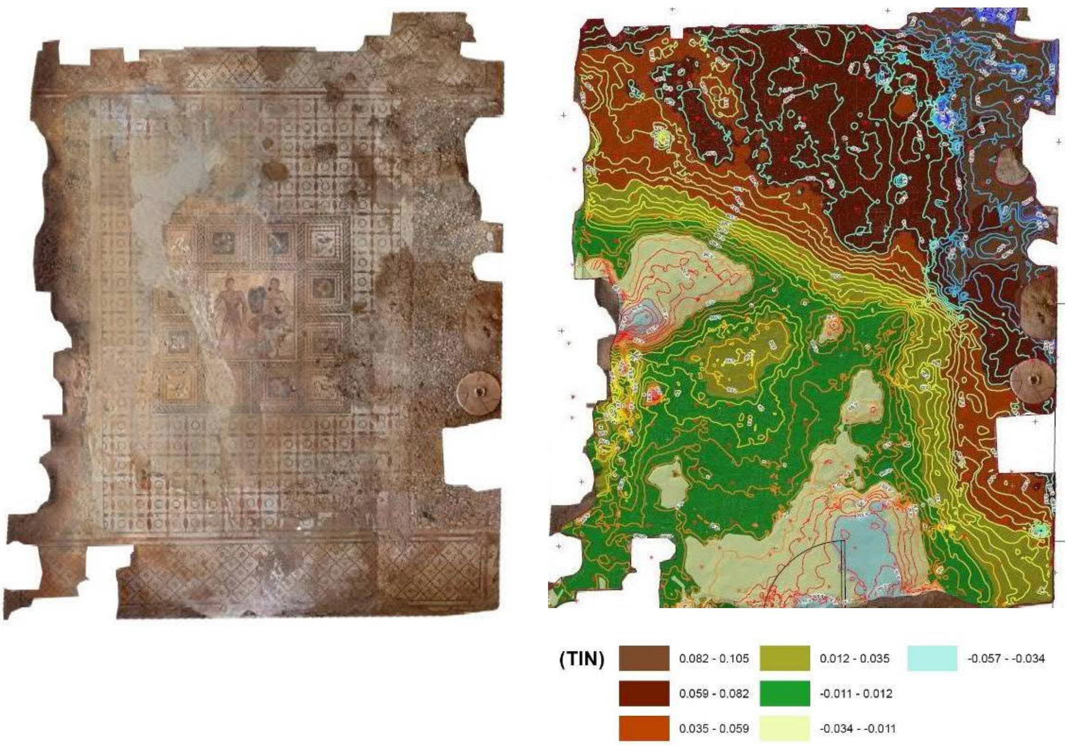

Fig. 7 The digital mapping of mosaic of Agonotheteion with multilevel information

The produced image was used as a background for the recording of the pathology and the mapping of its damage. After the evaluation and analysis of its situation, the team collaborated with the Conservator of ASCSA in Ancient Corinth, Nicol Anastassatou, in order to produce all the necessary designs of pathology and its conservation. The project was approved in 2013 by the "Central Archaeological Committee" (CAS) of the Hellenic Ministry of Culture.

The geometric documentation of the mosaic included the following substations:

(1) Field Works technical photography. The photographs were taken with a full format "digital single lens reflex" (DSLR) camera. A calibrated wide-angle lens was used so that the interior orientation elements were known. In addition, in order to keep similar lighting conditions throughout the procedure, technical lighting was used. The shots were made in such a way that they could be used in the photogrammetric procedure that followed. The overlap between the shots was of the order of 65 % cross-strip and 30 % cross-block and was obtained with special camera equipment in order to minimize the speeds ω, φ, κ. It is noted that the photographic equipment was customized for the needs of the photogrammetry and did not exist in this form on the market. Some of its parts (such as the vertical system) were entirely made by the group of photographers.

(2) Topographic measurements – measurement of photo-stable labels. Given the fact that the mosaic was extensively damaged, the team paid special attention so as not to aggravate its condition. On the other hand, these damages should not affect the accuracy of the measurements (local fields of surface). Additionally, custom targets for the labeling (before the photography) were used as well as custom lights of almost zero weight in order to avoid local loads.

(3) Photogrammetric processing that involved the process of recovery of the exterior orientation of the shots, creating a DSM (Digital Surface Model) and the production of deliverable geometric documentation with accuracy 0.5 mm, including the mapping of digital (.pdf) and analogue map-raft with multilevel information. ortho mosaic, altitude curves, elevators, hillshade surface mapping (Fig. 8), surface classification based on features such as gradients, wear etc.

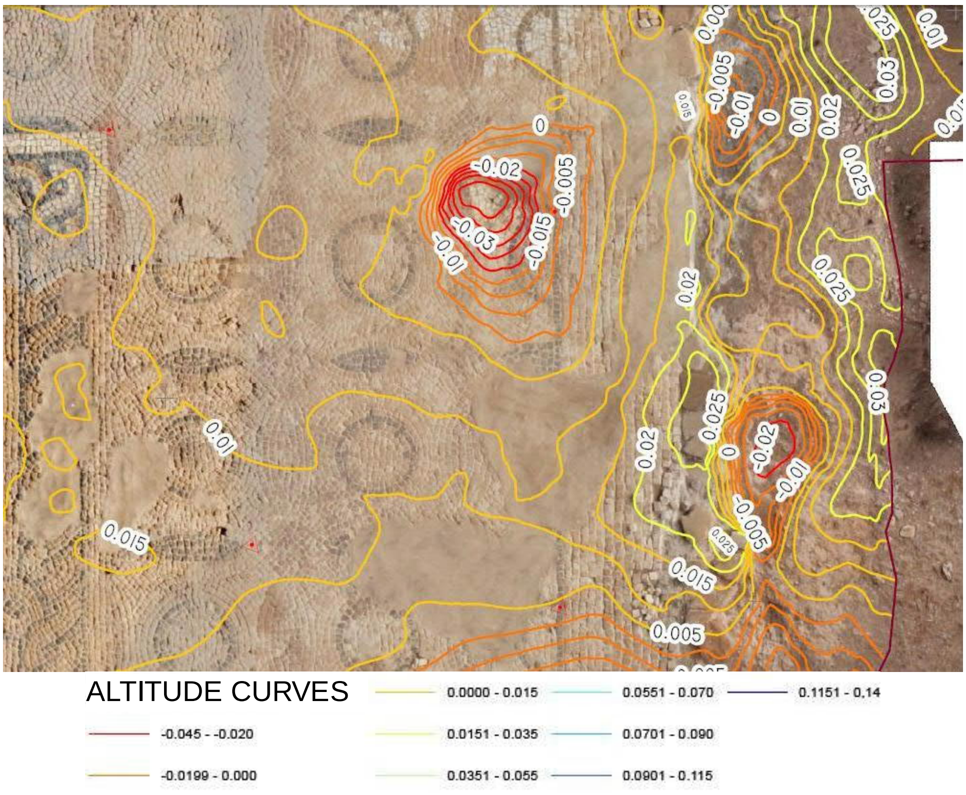

Fig. 8 The ortho mosaic with altitude curves, elevators, hill shade surface mapping

The form of the deliverables of the geometric documentation of the mosaic provided the conservator of ASCSA all the necessary data of recording the pathology. Under the conservator’s instructions, the project team designed different types of pathology (Fig. 9) like surface deterioration of *tesserae*, biological damage factors, past interventions, areas with disturbed *tesserae*, internal void etc. As far as it concerns the mosaic, today the detachment has already been completed, bedding layers and underlying strata are excavated and its conservation, including cleaning and remounting on a new support, is in progress.

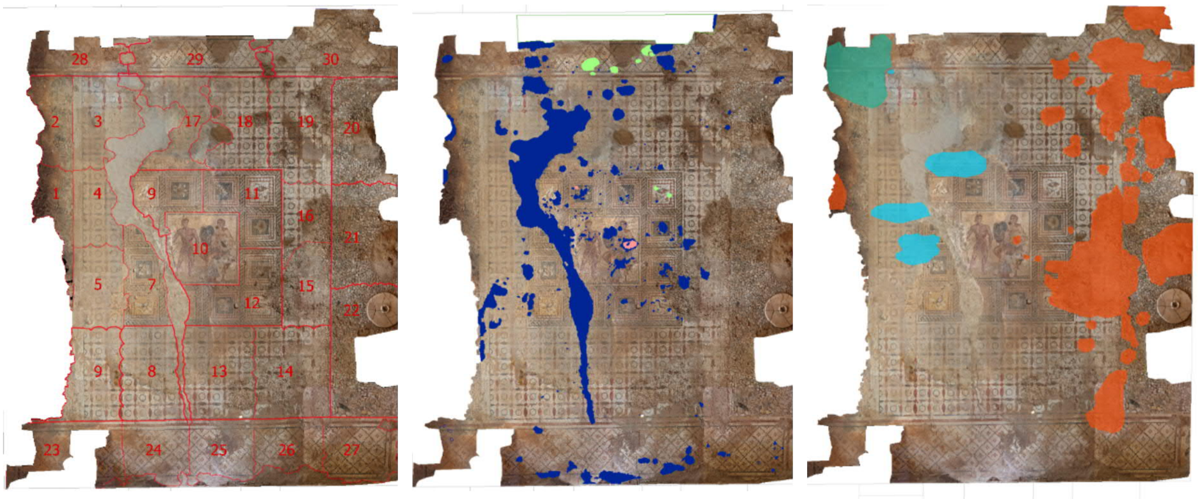

Fig. 9. The geometric documentation of the mosaic pathology

CONCLUSIONS

In this paper, the implemented 3D representation projects of South Stoa (Portico and Agonothteteion) in Ancient Corinth succeeded to deliver accurately structured data dealing with issues of monitoring geometry and pathology of the monument (e.g. correction of the initial published dimensions of the portico, the identification of its initial level). Photogrammetry and topography analysis were employed and integrated, in order to obtain 3D results that were used to produce orthoimages, maps and sections of the site. This procedure led to the digitization the georeference and the quality monitoring of the historical surveying and drawings of O. Broneer [1954] and therefore to comparisons. This technic made possible a) the track of changes in the morphology of the area and the position of the elements of the monument during the last six decades, b) the recognition of their original elevations, c) the partial restoration of the internal and external colonnade and d) the enhancement of the monument.

Apart from the big scale interventions, the project of mosaic allowed a detailed documentation of its whole structure that led in 2013 the Services in Competence (Ephorate of Antiquities in Corinth, Directorate of Anastylosis of Ancient Monuments, Directorate of Conservation of Antiquities and the Central Archaeological Council of the Hellenic Ministry of Culture) decide on its full detachment, removal to the laboratories and conservation with the vision of reinstalling it in its original place. Furthermore, the produced material can be used for informative and educational purposes and applications.

REFERENCES

O. Broneer. 1954. Corinth I.IV: *“The South Stoa and its Roman Successors”*, Princeton – New Jersey.

J.J. Coulton. 1976. *The architectural development of the greek stoa*, Oxford, 1976.

F. Fiorillo, B.-J. Fernández-Palacios, F. Remondino, and S. Barb. 2013. *“3d Surveying and modelling of the Archaeological Area of Paestum, Italy”*, Virtual Archaeology Review, [S.l.], v. 4, n. 8, p. 55-60.

A. Moysiadis and K. Perakis. 2011. "*The potential of conventional surveying, photogrammetry and laser scanning in monuments of cultural heritage documentation*", Proceedings of the 3rd International CEMEPE & SECOTOX Conference Skiathos, June 19-24, pp. 12911296

G. Pavlidis, A. Koutsoudis, F. Arnaoutoglou, V. Tsioukas, and C. Chamzas. 2007. *"Methods for 3D digitization of cultural heritage"*, Journal of Cultural Heritage, vol. 8, no. 1, pp. 93-98.

B. Robinson. 2012. “*Corinth: A Mosaic of Allegory, Athletics, and City Identity*” (AJA, Vol. 116, Jan 2012, p 105-132).

P. Sapirstein. 2015. “Photogrammetry as a tool for architectural analysis: The Digital Architecture Project at Olympia”, Proceedings of the 1st Conference on Computer Applications and Quantitative Methods in Archaeology, Greek Chapter. Rethymno, Crete.

C.K. Williams. 1972. *“Corinth, 1971: Forum Area”*, Hesperia 41, ps 143-184.

C.K. Williams. 1973. *“Corinth, 1972: The Forum Area”*, Hesperia 42, ps 1-44.

C.K. Williams. 1978. *“Corinth 1977, Forum Southwest”*, Hesperia 47, ps 1-39.

C.K. Williams. 1979. *“Corinth, 1978: Forum Southwest”*, Hesperia 48, ps 105-144.

C.K. Williams. 1978a. *“Corinth excavations, 1979”*, Hesperia 49, ps 107-134.

C.K. Williams. 1981. *“Corinth: Excavations of 1980”*, Hesperia 50 (1981), ps 1-44.

C.K. Williams and N. Bookidis. 2003. *Corinth XX: The Centenary 1896 – 1996*, Princeton.

H.M. Yilmaz, M. Yakar, and S.A. Gulec. 2007. *Dulgerler O. N, "Importance of digital close-range photogrammetry in documentation of cultural heritage"*, Journal of Cultural Heritage, vol. 8, no. 4, pp. 428-433.

B. Županek, M. Lesar Kikelj, K. Žagar, and S. Kramar. 2016. *“A new lightweight support for the restoration and presentation of a large Roman mosaic”*, Journal of Cultural Heritage, Volume 19, p. 477-485.

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