3D SCANNING FOR THE PRESERVATION OF THE ARCHAEOLOGICAL HERITAGE: THE CASE OF AMRIT (SYRIA) 3D

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ABSTRACT:

The archaeological area of Amrit (350 ha) is located on the Syrian coastal region of Tartus and is known since the 18th century CE, due to its imposing archaeological remains dated to the first millennium BCE and to the Roman period. It was listed in the UNESCO tentative list in 2005.
Since 2022, the University of Firenze (SAGAS) in collaboration with the CNR-ISPC and the DGAM-Syria, conducts a project that aims towards the documentation, restoration, public display, and community involvement of the archaeological site of Amrit, after more than 10 years of conflict and a still ongoing economic and social instability.
Aim of this paper is to present the first results of the 3D survey at the site carried out in September 2022. This survey, conducted by archaeologists, aimed at obtaining a detailed documentation of the monumental structures on the site, to assess their state of preservation as of 2022, and to record the decay process of previous restorations and facilitate the planning for the archaeological park. The rapidity of acquiring data and the precision of this technique is obviously of great advantage in difficult contexts such as is Syria, where power cuts are systematic and there is a need of acquiring as much as data as possible in a limited time. This specific activity aims also at showing that archaeologists can acquire technological skills and gather specific knowledge to obtain the best possible results when dealing with damage assessment of heritage during and after a conflict.

1. INTRODUCTION

The issues related to the conservation and enhancement of archaeological sites represent one of the most discussed topics in the international debate. The protection, restoration and implementation of these sites require the use of a broad interdisciplinary approach implemented by using innovative digital technologies.
Amrit is a cultural and natural heritage site located on the Syrian coastal region of Tartus (Fig. 1). The site is known since the 18^{th} century CE, due to its imposing archaeological remains that were visible on the surface. It has been excavated by a French and later Syrian expedition from the 19^{th} century CE onwards. The area was inhabited since the Neolithic period; however, it is best known as a Phoenician settlement. The best preserved monuments in the area are dated to the Iron Age (1200-600 BCE), and to the Achaemenid and Hellenistic period (600-300 BCE). After its abandonment in the 2nd century BCE, the area fulfilled funerary purposes from the Roman era and until the 3rd century CE. The archaeological area extends over a surface of approximately 350 ha, it is bordered to the north by the outskirts of the city of Tartus and to the south by the river el-Kubbe; it includes the beach to the west, and it extends inlands for approximately 1.8 km.
Since 2022, the University of Firenze (SAGAS) in collaboration with the CNR-ISPC in Milan and the DGAM (General Directorate of Antiquities and Museums in Syria), conducts a project that aims towards the documentation, restoration, and public inclusion at the site of Amrit.
Aim of this paper is not to stress the relevance of 3D scanning techniques in monuments survey or in documenting archaeological heritage. Professionals and software developers have been implementing this technique since the first appearances of laser scan. The goal of this article is rather to show how modern technology in 3D scanner allows young archaeologists, who are usually not equipped with 3D skills, but are frequently active in “difficult” work environments to use these instruments and provide a professional documentation, specific for the research purposes.

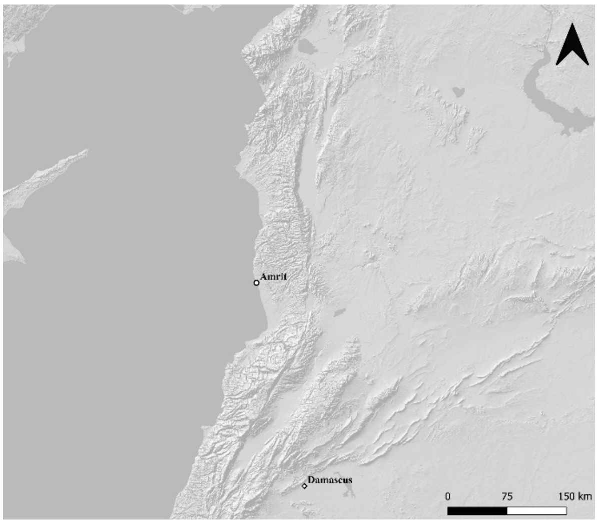

Figure 1. Location of Amrit on the Syrian coast. Base map: Esri shaded relief.

2. CULTURAL HERITAGE IN CONFLICT AREAS

Field activities related to immovable archaeological heritage are directly and strongly connected to the territory where the cultural heritage is located, to the cultural policies of the country where it is located, to international politics and to the local communities that interact with the monument/monuments. Archaeologists, who have been active in the past with public archaeology, restoration and research projects focused on the cultural heritage of countries that have experienced political instability, military conflict, and natural disasters, face issues that are not strictly related to the scientific discipline, but with needs related to the contingency of a specific situation. If the goal of every archaeologist is not only to investigate the material remains of past cultures from a scientific point of view and to contribute to understanding past societies, but also to actively participate to its preservation and in raising public awareness, archaeology in conflict areas faces specific challenges connected with international politics, disruption in social life, economic crisis, instrumentalization of cultural heritage for political purposes. Syria, as many other countries, has experienced a more than a 10 years-long civil war, and it is still living an ongoing economic crisis, and internal confrontations that brought to looting, destruction, and neglect of its cultural heritage. Until 2010, Syria was one of the most archaeologically investigated countries in Western Asia (Pucci 2020), more than hundred international research projects based their field research in this country, actively contributing with public archaeology projects and restoration activities. When the war broke out (2011), archaeological field research obviously stopped and the international community, including those Syrians who escaped the country, helplessly witnessed the partial destruction of the heritage as a side effect of the war (bombing of cities as Aleppo), as a target of violence (Palmyra), as a consequence of the economic crisis (looting). Syrian archaeologists and cultural heritage experts in the country, both belonging to the DGAM and to local community groups, have been continuously working to prevent and protect their heritage despite sometimes very dangerous circumstances. International operators began to intervene in protection of the cultural heritage already in 2016 with the United Nations Development Programme and since then, few operators are working in this country with the main aim to draft damage assessments, document the destructions and contribute to safeguarding this heritage.

3. THE ARCHAEOLOGICAL AREA

The site of Amrit has been known since the 18th century CE, due to its imposing archaeological remains that were visible on the surface. It has been excavated by a French and later Syrian expedition from the 19th century CE onwards. The site was first identified and excavated by Ernest Renan in 1860 (Renan 1864-74). He mapped the major monuments that were already visible at the site.

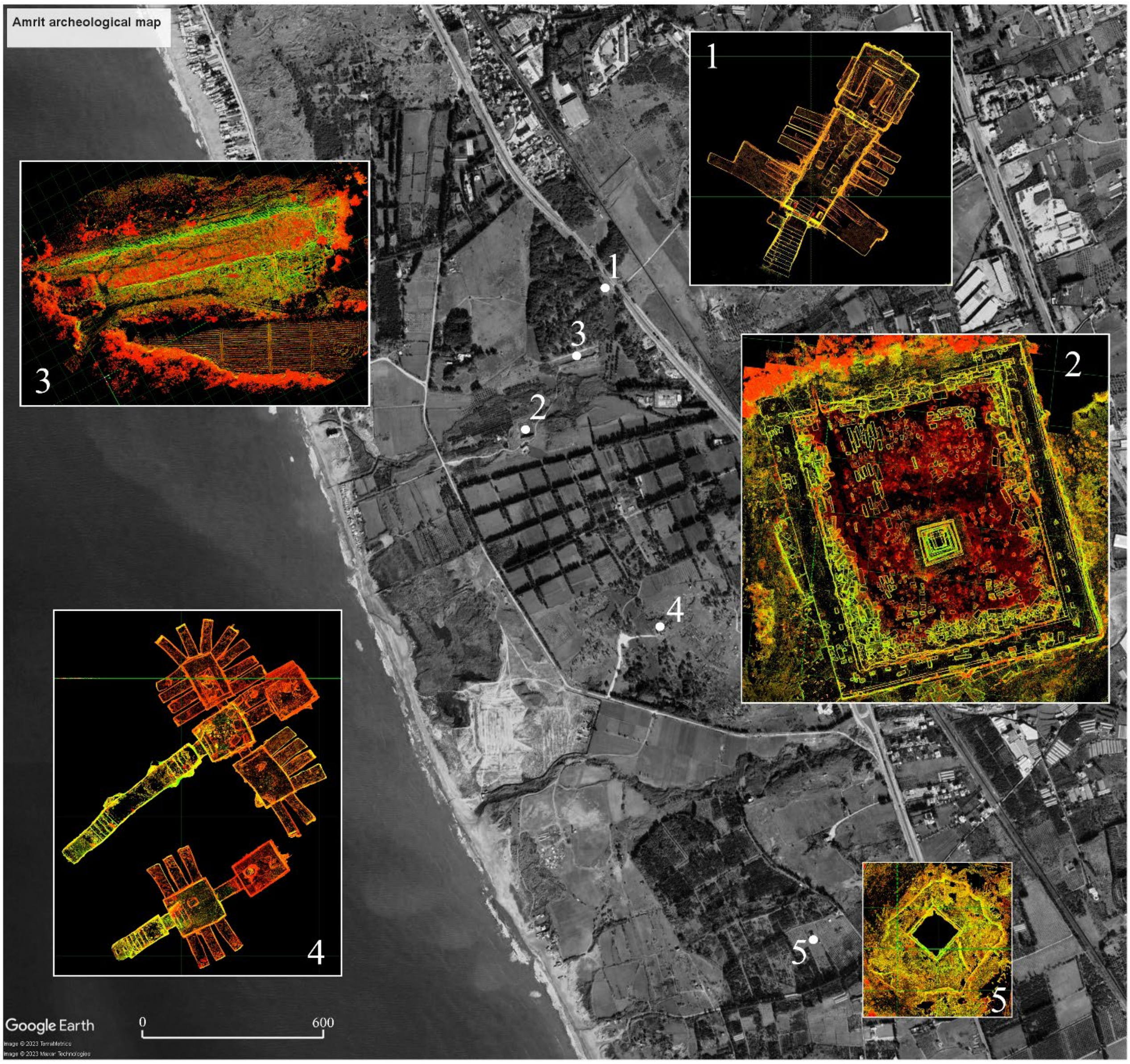

Figure 2. Amrit archaeological area with location of main monuments that have been scanned in 2021. Base map: google earth.

In 1926, Dunand excavated the area of the so called Ma'abed, the sanctuary (Dunand and Saliby 1955; 1956; 1961; 1985) and, since 1954, excavations led by the DGAM of Syria focused on the residential area, located on the main mound, and in other areas that were identified both through archaeological research, and as a consequence of the urban and touristic development of the area (Maqdissi and Benech 2009; Maqdissi 2014; Mustafa and Lozoya 2016; Youssef 2018). During the 1960s and later 90s, several preservation and restoration works were mainly carried out on the sanctuary to transform the archaeological area into a natural and archaeological park (Saliby 1971). During the recent war, the area was not interested by fighting, however, several military camps have been installed in the archaeological area and the infrastructures (fences, ticket office) were dismantled. Furthermore, any control on the archaeological area was lost, subjecting it to neglect and lack of maintenance.

Currently, the archaeological area extends over approximately 350 ha and it is a public park with a well preserved natural heritage due to the governmental restrictions to exploit this area for urban purposes. Two rivers cross this area flowing from east to the west, the Nahr el Amrit to the north (just north of n. 2 in Fig. 2) and the Nahr el Kubbe, to the south. Several monuments are well visible at the site dispersed in this vast area (Fig. 2): a Roman monumental tomb carved into the bedrock (n. 1 in Fig. 2), the Phoenician sanctuary (Ma'abed) built around a natural spring (n. 2 in Fig. 2), and the Hellenistic stadium (n. 3 in Fig. 2) are all located in the valley of the Amrit river. The monumental hypogeum tombs dated to the Achaemenid period, so-called Meghazil, (n. 4 in Fig. 2) and the stone chamber tombs probably dated to the Achaemenid period (n. 5 in Fig. 2) were identified to the south of the site. All these monuments, except for the Roman tomb (n. 1), were already visible in the 19th century CE, when Dunand began archaeological excavations. Research conducted over the following hundred and fifty years have revealed their relevance.

The Phoenician sanctuary (Ma'abed), built around the end of the 5th century BCE, is considered the landmark of the site. It lies *ca.* 1.2 km from the coast, consists of a large porch, a water basin and a central *naos* (Fig. 3). It is the best-preserved Phoenician sanctuary in the whole Mediterranean. To the north of the sanctuary flows the river Amrit, to the east two natural springs pour water into the internal basin surrounding the central *naos* (Dunand and Saliby 1985).

Figure 3. Ma'abed with central *naos* (3D mesh 2022).

The two monumental tombs (Meghazil or "the Spindles") from the Achaemenid period (6th -5th cent. BCE) have underground chambers with a monumental landmark above them (Fig. 4). The monument above tomb B has a pyramidal top, while the one above tomb A is a circular top flanked by four lions carved on the stones. In both tombs, steps lead into underground funerary chambers cut into the rock (Renan 1864-74; Youssef 2018).

Figure 4. 2022, the Meghazil tombs.

The stadium, carved into the natural rock, is horse-shaped on its eastern side and it has several rows of seats (Fig. 5). The western end of the structure and the field are covered by vegetation, the stone steps on the eastern part are slightly eroded. The structure dates prevalently to the Hellenistic period, but it has been reused also in later phases (Renan 1864-74: pl 7; Youssef 2018).

Figure 5. 2022, the Stadium.

The Roman hypogeum (Fig. 6) was discovered during construction works of the neighbouring road by the DGAM. Although partially looted in the past, it still contains three marble coffins dated to the 3rd century CE, while materials and statues found inside were brought to Tartus (Maqdissi 2014: fig. 7; Mustafa and Loyoza 2016).

The stone chamber tomb (Fig. 7) located to the south, probably dated to the Achaemenid period, is a squared structure completely above ground level that includes two grave chambers, the one above the other. The external area of this monument has been recently investigated by the DGAM.

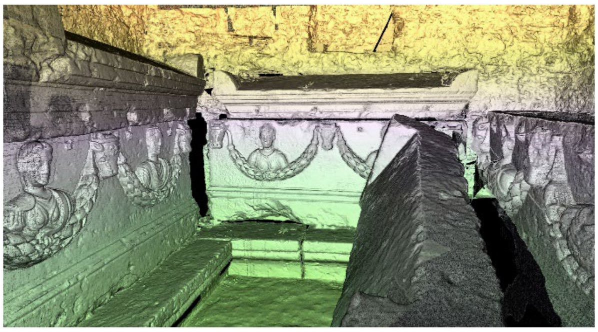

Figure 6. Point cloud of the internal chamber of the Roman hypogeum.

Figure 7. The Achaemenid chamber tomb.

4. THE FIELDWORK

The fieldwork lasted for seven days. The scanning of each monument required one workday, except for the Ma'abed that needed four days to first clean the structure, followed by three days of scanning, due to the size and complexity of the structure.

Name of the monument	Number of workdays	Number of setups
Achaemenid Meghazil	1	30
Roman hypogeum	1	17
Hellenistic Stadium	1	24
Phoenician sanctuary (Ma'abed)	4	59
Chamber tomb (Achaemenid)	1	5

Table 1. Number of works and setups carried out in seven workdays.

Each setup was performed with the scanner Leica 360 RTC set on the highest density cloud that gives an accuracy of 1.9 mm to 10 m for each recorded point. In order to have the most complete documentation for each setup, the camera option was selected, and a 360-degree photo was done in each setup. With these settings, each scan needed five-seven minutes to be carried out. A different work was performed on each day on the field, and for each work different numbers of setups have been recorded, depending on the monument shape/size (Table 1). Each work was pre-registered and pre-aligned with the Leica app Cyclone Field 360, using a tablet to visualise in real time each setup and bundle, to correct alignments, to delete, and to repeat setups. Thanks to the VIS technology, it was possible to work without targets. This made the survey faster and more flexible. The team could survey each monument, even the underground spaces, without changing procedure or preparing the area beforehand.

The Leica 360 RTC showed a fast and flexible workflow that was crucial in Syria where the power cuts are systematic, and the work time is limited. The scanner battery life lasted for eight hours (average workday), and the batteries were able to charge completely during the night even with only a few hours of electricity at disposal.

5. DATA PROCESSING AND CREATION OF 3D MODELS

5.1 From point cloud to 3D model

During this phase, the laser scans recorded on the field have been aligned using the program Cyclone Register 360, thus obtaining a single point cloud totalling of approximately 2 billions points and with an error between 1 and 8mm (Fig. 8). The point cloud was visually aligned in order to obtain a better overlapping percentage between the point clouds created by the different setups (Figs. 9-10).

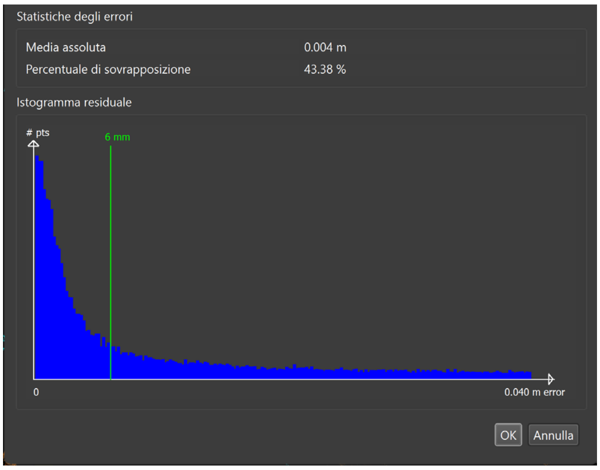

Figure 8. Alignment curve error.

Once the metric accuracy of the photogrammetric point cloud was verified, it was converted into a mesh with an associated texture generated by the photogrammetric software. The point cloud was imported in Cyclone 3DR and cleaned to facilitate the creation of a high-resolution mesh used to draft the 3D models of all the monuments (Fig. 11).

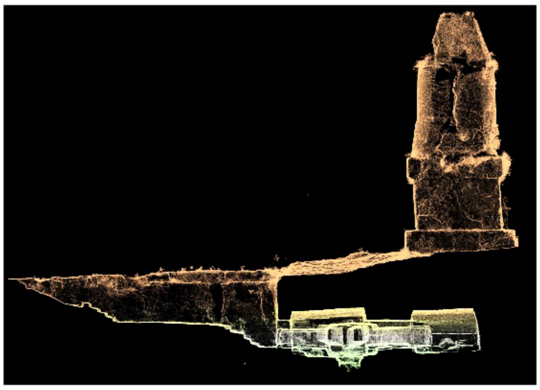

Figure 9. Meghazil B, shaded point cloud, long section.

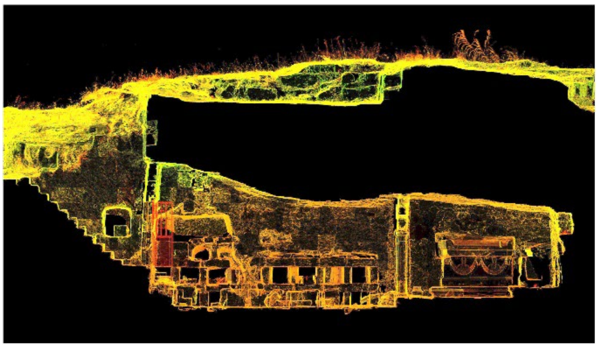

Figure 10. Roman hypogeum, shaded point cloud, long section.

The high resolution of the photographs allowed the software to build accurate renderings of the chromatic-material information of the wall surfaces.
The primary aim of the data processing was to have a detailed plan of all the monuments, especially the ones presenting underground structures such as the Meghazil and the Roman hypogeum.

Figure 11. Meghazil, 3d mesh.

5.2 From point cloud and 3D model to 2D drawing

Drawings and plans of these monuments were drafted by Renan (1864-74) with hand sketches, sometimes not to scale. The Ma'abed was carefully surveyed and documented by Dunand (Dunand and Saliby 1985: pl. LXI), a plan of the Roman hypogeum was recorded in 2003 and later published (Maqdissi 2014: fig. 7), while sections and plans of the Meghazil, of the Achaemenid stone tomb and of the stadium were never updated after Renan's publication.

The 2022 survey resulted in the implementation of the existing documentation with plans and sections extracted directly from the three-dimensional model and corresponding to the current state of the monuments. The plans and sections have been obtained from the point cloud, previously created in Cyclone Register 360, by using Cyclone Core.
There are two ways of obtaining two-dimensional representations from the point cloud and from the mesh. In the first, the operator identifies section planes, and the software uses automatic interpolation algorithms, which tend to generate somewhat irregular polylines with sharp angles. The second approach, in which the operator develops 2D profiles from appropriate point cloud slices set at different elevations, generates more satisfying results. As the interpretation of studied objects through appropriate graphical information is a critical feature of archaeology, the second method was applied to draw the profiles of the horizontal and vertical sections (Figs. 12-14).
The point cloud created by the laser scanner survey enabled the generation of a more comprehensive model that includes areas that previous systems were unable to access, which in turn allowed the generation of new, more accurate two-dimensional representations, such as the Roman hypogeum section (Fig. 10) and the section of the underground structures of the Meghazil (Fig. 9).

6. OUTCOMES AND CONCLUSION

6.1. Documentation and its application

A detailed bidimensional documentation of all monuments is the most visible outcome of the 3D survey carried out at the site. In seven days-fieldwork and a much longer period for data processing, it was possible to obtain the data that update, complete, and sometimes correct previous surveys. In addition, the datasets are available for further processing and analyses, and comprise an invaluable source of information for any scholar or researcher who aims to investigate these artefacts and architectural features, which may be difficult to access. Overall, the implementation of 3D modelling is a method of safeguarding archaeological heritage and, at times, digital analysis may yield additional discoveries.
Besides the metric information on the monuments that are necessary in any archaeological or architectural analysis, these datasets, and the elaborated images extracted from them, provide crucial information when dealing with restoration, park planning and public archaeology. As an example, in plan Fig. 12, the monument is cut horizontally at the elevation of 2 m (the zero-point elevation was set on the floor of the porch). Below this polyline, the 3D mesh shows all elements belonging to the structure. Confronting this document with the detailed plan drafted in 1950s (Dunand and Saliby 1985: pl. LXI) it is possible to reconstruct which stone boulders have been moved during the 1960s and 70s restoration. This is a crucial information in planning the future archaeological park. This documentation is also necessary to monitor possible decay or damages occurred in the past twenty years on the main monuments. In addition, these

datasets are now an invaluable source of information for future damage assessment. The area of Amrit suffered, as most of the Syrian northern coast, the earthquake that hit Türkiye and Syria in February 2023. The DGAM recorded some damages inside the Roman hypogeum; and the 3D scan conducted in 2022, just few months before the earthquake, will be crucial in drafting a damage assessment and plan future restoration.

6.2. Training and Archaeological Heritage

The activity conducted in Autumn 2022 at Amrit aims to contribute to the debate on the potentials of surveying systems and on how these systems may be developed to fulfil specific research needs. It also mirrors the general change that data recording and processing technology is imposing on the practice of archaeological scientific research. It should be emphasized that these activities, although coordinated by personnel with specific experience and expertise, were carried out by young researchers without extensive training.

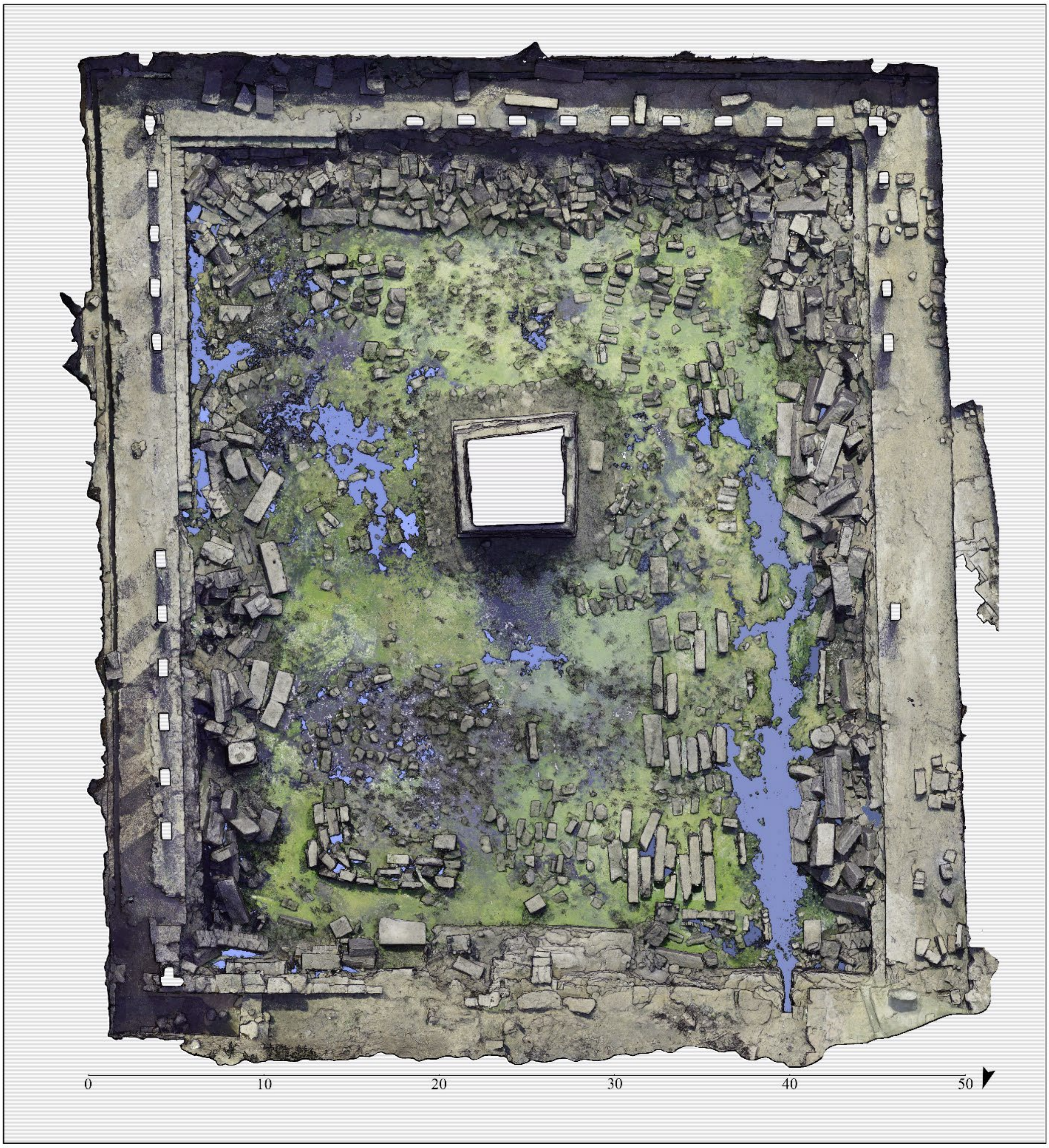

Figure 12. Plan of the Ma’abed based on the point cloud and mesh.

To fully understand this change, we may consider the following assumption: after a constant evolution in technological systems and applied methodologies developed over the past 30 years, archaeologists can consider themselves fully autonomous not only when dealing with the analysis and understanding of the archaeological and architectural evidence, but also with the governance of the technologies called upon to illustrate and describe these realities. Although very often young archaeologists gain specific skills because of personal talent, extracurricular educational opportunities, or personal technological curiosity, this project shows that university students and researchers can be trained directly on the field or at the university using datasets based on ongoing research projects. Unlike not so many years ago, when the presence of an expert (surveyor, architect, engineer, computer scientist, self-taught, etc.) was necessary to use surveying and documentation equipment (theodolites and tacheometers first, total stations later, stereoscopy), modern survey instruments compensate, both in hardware and software, the lack in trigonometric and topographic knowledge of archaeologists. Moreover, operators working in archaeological field research, in the safeguard and protection of the archaeological heritage, and in public archaeology are required to gain skills related to new technologies and digital data. Computer management systems, production and processing of digital photographic archives, and 3D documentation are all fields of application in which technological knowledge is indispensable. On all this the university structure has much to say (in terms of methodological definition) and much to do (in terms of professional training). A close and osmotic relationship between universities and industry would be desirable in the field of humanities (Alvaro *et al.* 2016), since it would broaden the operational horizons of the technical equipment, with mutual benefit in terms of diffusion (and thus commercial) and target (with systems dedicated to cultural heritage).

The experience at the site of Amrit confirmed the benefits of the digital survey by fast acquiring the point clouds on site and processing the data "at home". This operational speed, which can be crucial in difficult contexts, the high accuracy of the systems employed, and the user-friendly software associated to the equipment were crucial element in the project design. During the processing phase, which is far more demanding than field work, the advantages of laser scanner technology become evident; the datasets are three-dimensional archives composed of Cartesian vertices and mosaic digital images. These remain available over time for whatever processing is required for research, preservation, dissemination. This flexibility (a homogeneous digital archive for each product), makes the experience of processing a cognitive process, able to suggest new approaches or insights. The archaeologist, who has carried out the documentation, and gained experience and direct observation of the object of research, will develop its potential in study and processing.

Figure 13. Ma'abed, Section E-W from 3d mesh.

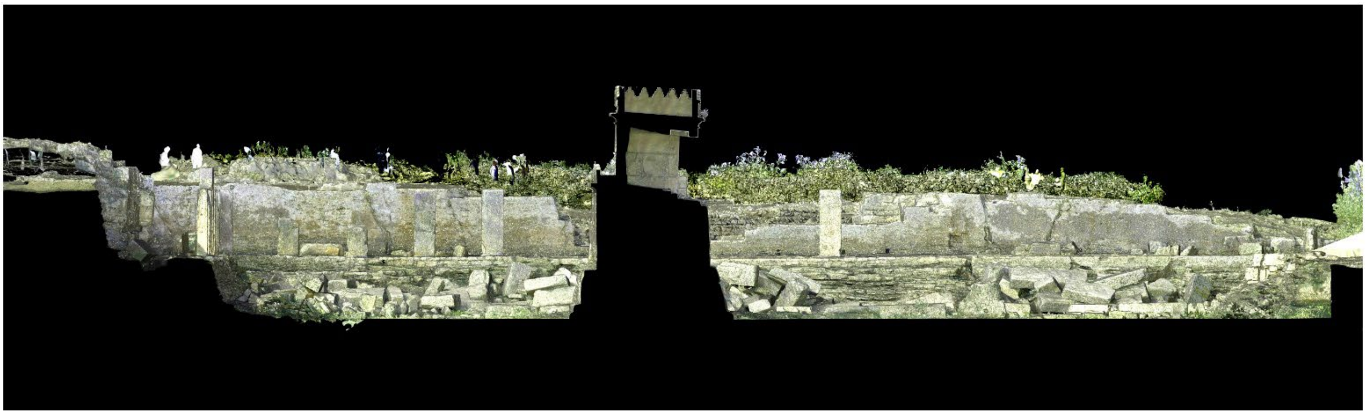

Figure 14. Ma'abed, Section S-N from 3d mesh.

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