Study and enhancement of the heritage value of a fortified settlement along the Limes Arabicus.

Umm ar-Rasas (Amman, Jordan) between remote sensing and photogrammetry

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ABSTRACT

The Limes Arabicus is an excellent laboratory for experimenting with the huge potential of historical remote sensing data for identifying and mapping fortified centres along this sector of the eastern frontier of the Roman Empire and then the Byzantine Empire. Remote sensing, combined with modern surveying techniques and tools such as photogrammetry and laser scanners, now makes it possible to identify, document and study ancient settlements in the area, as well as to develop site valorisation programmes, including the design of real and virtual routes for better use of archaeological areas. We offer here a preliminary contribution to the site of Umm ar-Rasas (Amman, Jordan), a fortified town on the Via Traiana Nova.

Since the early 1800s, certain explorers have recorded this location, which is marked by the presence of a tetrarchic castrum and a Byzantine settlement to the north. It has been the subject of archaeological study since the second half of the 1980s. The excavations, carried out by the Studium Biblicum Franciscanum of Jerusalem (Piccirillo and Alliata 1994) and the Swiss Max van Berchem Foundation (Bujard 2008), involved a portion of the castrum and, in particular, the settlement north of this fortified site, bringing to light precious mosaic floors that have made Umm ar-Rasas famous. From 2013 to 2019, the Italian National Research Council's Institute of Heritage Science (CNR-ISPC) conducted topographic and 3D surveys of the Saint Stephen, Bishop Sergius, and Saint Paul Churches in the inhabited area north of the castrum, in collaboration with the Jordanian Department of Antiquities (DOA) and co-financed by the Italian Ministry of Foreign Affairs and International Cooperation (MAECI), in order to both document the status of conservation of the mosaic floors and prepare for better tourist access to the area (Gabrielli, Portarena, and Franceschinis 2017). Beginning in 2021, the CNR-ISPC investigations concentrated on the castrum and the region to the north and east of the Byzantine village.

Topographical and architectural surveys were carried out to confirm on the ground the crop marks discovered through the study of historical and modern remote sensing images, as well as to document the fortification's construction phases. An examination of multitemporal remote sensing documents obtained from aerial and satellite platforms preceded the field studies. To begin, historical aerial photographs taken by Sir Marc Aurel Stein in 1939 and space photos acquired by the Corona KH-4B and Hexagon KH-9 satellites throughout the 1960s and 1970s were georeferenced, processed, and interpreted. The analysis of aerial photos taken from 600 to 1200 feet in altitude and space photos with spatial resolutions ranging from 1.8 to 0.60 m allowed for the documentation of preserved structures as well as the identification of archaeological crop, dump, and shadow marks linked to buried ancient features. This research endeavour enabled the design of ground checks for the investigation and reconstruction of the site's ancient topography and historical landscape. Furthermore, the panchromatic and multispectral data from two very high-resolution satellite images, a Pléiades 1B from 2020 (max. spatial resolution 0.5 m) and a Pléiades Neo from 2022 (max. spatial resolution 0.3 m), were processed to identify other marks associated with buried ancient remains and to generate orthorectified images used as base maps during field surveys. Finally, the archaeological elements acquired from multitemporal recording improved the site's archaeological map when combined with comprehensive plans of the castrum and excavated sectors of the inhabited area made during recent topographic surveys or previous studies. The castrum walls were recently topographically surveyed and 3D architecturally surveyed using the following techniques: terrestrial photogrammetry with a Canon 5D Mark II (24 MPixel) and laser scanner survey with two laser scanners, Faro 120 and Faro 330 x. Ad hoc systems were created with the goal of finishing the high-resolution documentation of the masonry; specifically, photogrammetry techniques were applied with multiple pictures to acquire a higher chromatic definition of the surfaces and better photographic detail. Instead, a correct description of the distorted walls was achieved through the capture of 97 laser scanner scans, which showed substantial irregularities. Many relevant and credible facts relating to the building phases and subsequent alterations of the castrum's walls, as well as its state of conservation, have been collected and archived over the course of two years. An initial mapping of the locations of stone material extraction, water reserves, canalization systems, and the organisation of cultivated land around the community was completed. The data are being combined into an archaeological map that will be put into a GIS platform to document the ancient topography of Umm ar-Rasas and will serve as a knowledge foundation for the site's valorization initiatives. With the collapses that hide much of the interior of the castrum, it is impossible to identify a construction phase of the Severian age, which has been hypothesised based on items found in earlier excavations. It is hoped that future missions will be able to complete the aerial laser scanner surveys and conduct geophysical prospecting, allowing for the acquisition of elements on the topography of the area inside the walls of the tetrarch fortification and the highlighting of any pre-existing structures, with the goal of creating a more updated castrum plan.

Keywords: Limes Arabicus, remote sensing analysis, high-resolution satellite images, laser scanner survey, photogrammetry, historical landscape.

Introduction

Umm ar-Rasas, Amman's current governorate, is located about 30 kilometres southeast of Madaba (Fig. 1a). It is an archaeological site best renowned for the beautiful Byzantine mosaics that characterise its churches, which were excavated between the second half of the 1980s and the early 2000s.

The presence of three settlement units characterises the site: the castrum (A), which dates back to the end of the third and beginning of the fourth centuries AD; the Byzantine-Umayyad village, which is directly to the north (B); and the Stylite tower complex, which is about 5 miles to the north (C) (Fig. 1b).

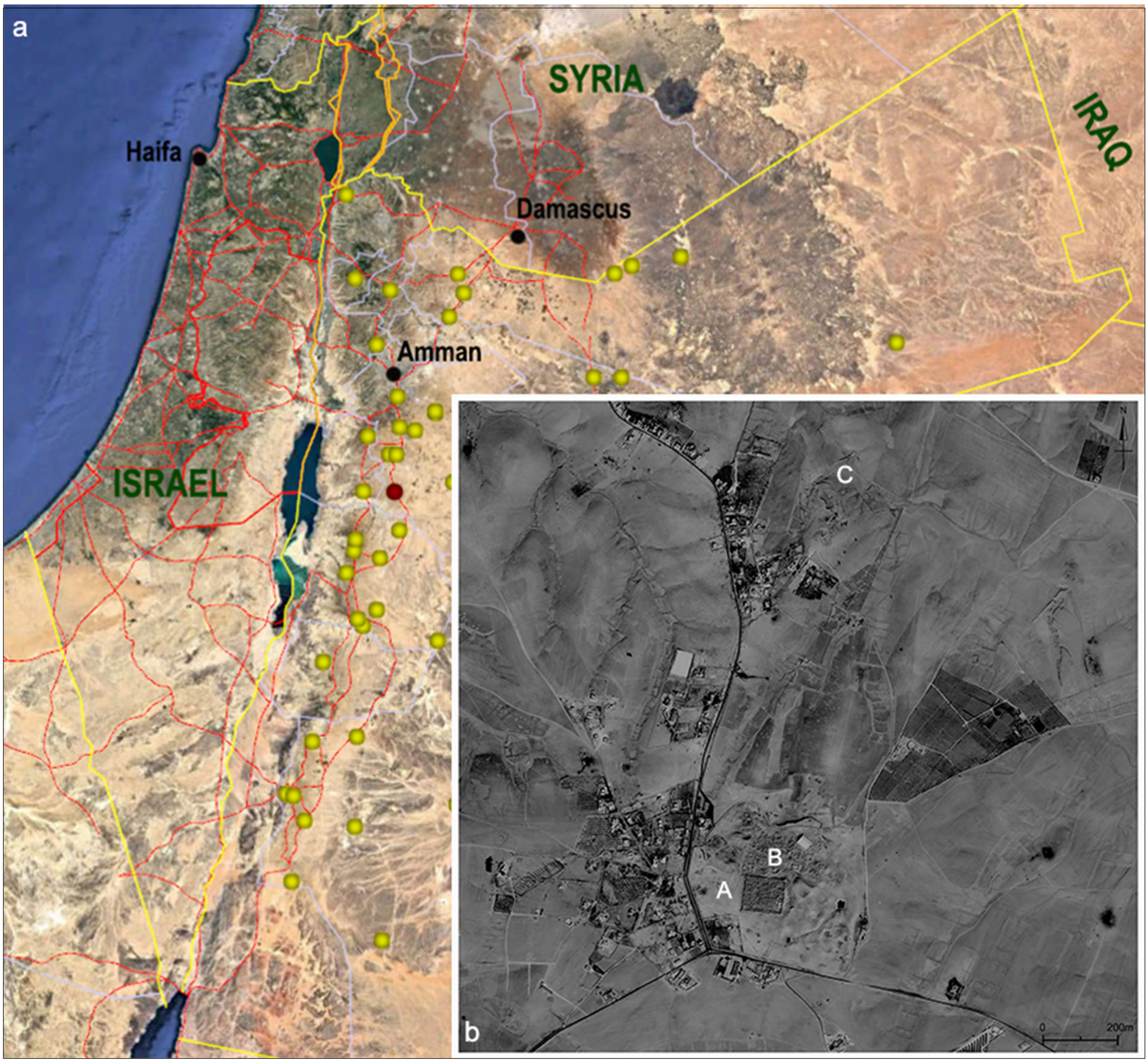

Figure 1 - a) Site location. **b)** Framing of the archaeological area: castrum (A); Byzantine-Umayyad village (B); Stylite tower complex (C).

State of art

Umm ar-Rasas in Arabic means “mother of lead”. The toponomy probably refers to the size and colour of the stones that distinguish the castrum. It was the destination of all explorations since 1800 (Burchardt 1822; Irby and Mangles 1823; Buckingham 1825; Robinson 1837; Seetzen 1854, Palmer 1871; Tristram 1874; Layard 1887; Vailhé 1896; Germer-Durand 1897; Clermont-Ganneau 1898; Lagrange 1898; Wilson 1899; Brünnow and Domaszewski 1905; Musil 1907; Glueck 1934; Savignac 1936; Saller and Bagatti 1949). In 1986, two inscriptions discovered on two mosaic floors, in the Lion Church and St. Stephen's Church, permitted the site to be linked to the biblical and historical KASTRON MEFA. Mefaat was the city of the Ruben tribe (Gs. 13, 18; 21, 37; 1Cr. 6, 64; Ger. 48, 21), the φρούριον mentioned in the Onomasticon of Eusebius (Onomasticon 128, 21) and the Roman camp of Equites Promoti Indigenae mentioned in the Notitia Dignitatum (NotitiaDignitatum, p. 81, n. 19).

In 1939, the site was explored from the air by Sir Marc Aurel Stein. Between 1986 and 2006, the Studium Biblicum Franciscanum of Jerusalem excavated the churches of the Byzantine village immediately north of the castrum (Abela and Acconci 1997; Abela and Pappalardo 1998; 2002; 2004; Piccirillo 1986; 1987; 1988; 1989; 1991; 1992; 1995; 1996; 1997; 1999; 2001; 2002; 2003; 2006; Piccirillo and Alliata 1994; Piccirillo and Attiyat 1986; Piccirillo, Abela and Pappalardo 2005; 2007). Finally, the Swiss Max van Berchem Foundation (1988-2000) studied a tiny portion of the castrum. The gates, particularly the east gate, as well as the south-east portion of the walls, comprising the twin churches, were explored (Bujard 1992; Bujard 2008; Bujard and Joguin 1995; Bujard and Haldimann 1988). In 2004, Umm ar-Rasas was designated a UNESCO World Heritage Site (Abu Dayyeh 2002).

Kastrum Project

In 2013, Roberto Gabrielli began a project aimed at documenting, enhancing, and musealizing the archaeological area of Umm ar-Rasas. Seven successful missions incorporating the churches of the Saint Stephen complex and the Stylite Tower were carried out between 2013 and 2019 (Cozzolino et al. 2019; Gabrielli et al. 2016; Malinverni et al. 2019). Various topographic reliefs were undertaken throughout those years, as well as 3D surveys on structures and mosaic floors utilising GPS, photogrammetry, and laser scanners. Several tests have been carried out over the years in order to establish a method that would allow for the comprehensive documentation of the mosaic flooring in high resolution utilising photogrammetry techniques with a significant number of pictures and approximately thirty scans for the church (Gabrielli et al. 2017).

Since 2021, the already multidisciplinary study team has expanded even more, and research on the castrum and its surrounds has resumed, utilising remote sensing analyses and surveys (architectural, archaeological, photogrammetric, and laser scanners).

Methods and tools

This section presents the methods and tools used during the last two years of remote sensing and fieldwork at Umm ar-Ras. The research has focused on the study of Umm ar-Rasas (castrum and settlement) and its surroundings, using mostly unpublished historical and recent remote sensing data. Research has also focused on ground, architectural, photogrammetric and laser scanning surveys. In particular, photogrammetric and laser scanning surveys were carried out on the walls of the castrum, and all features were verified on the ground using remote sensing analysis.

Remote sensing analysis

Starting with remote sensing analysis, the main research tools have been: historical aerial photographs taken by Sir Marc Aurel Stein in 1939 during a flight over Umm ar-Rasas; satellite panoramic camera photographs taken by Corona KH-4B, but especially the recently declassified Hexagon KH-9, which have been important in contextualising the site; and finally, recent high and very high resolution satellite images, which have allowed us to record the current state of preservation of the traces and also to discover new ones.

Sir Marc Aurel Stein was a Hungarian-born, naturalised English explorer of late 19th and early 20th centuries. In the late 1930s, he conducted significant aerial and ground surveys of the Roman Eastern Frontier between Iraq and Jordan, following the work of Father Antoine Poidebard in Syria (Poidebard 1934). Stein left the Sinjar in the spring of 1938 and completed the mission in May of 1939. On his journey, he used the Kirkut-Haifa oil pipeline and then explored the archaeological sites of the Eastern Roman Limes to the Aqaba Gulf (Stein 1938;1940). In May 1939, Stein flew to Umm ar-Rasas and made four aerial photographs, one vertical and three oblique, at heights of 1200 and 600 feet, respectively (Fig.2).

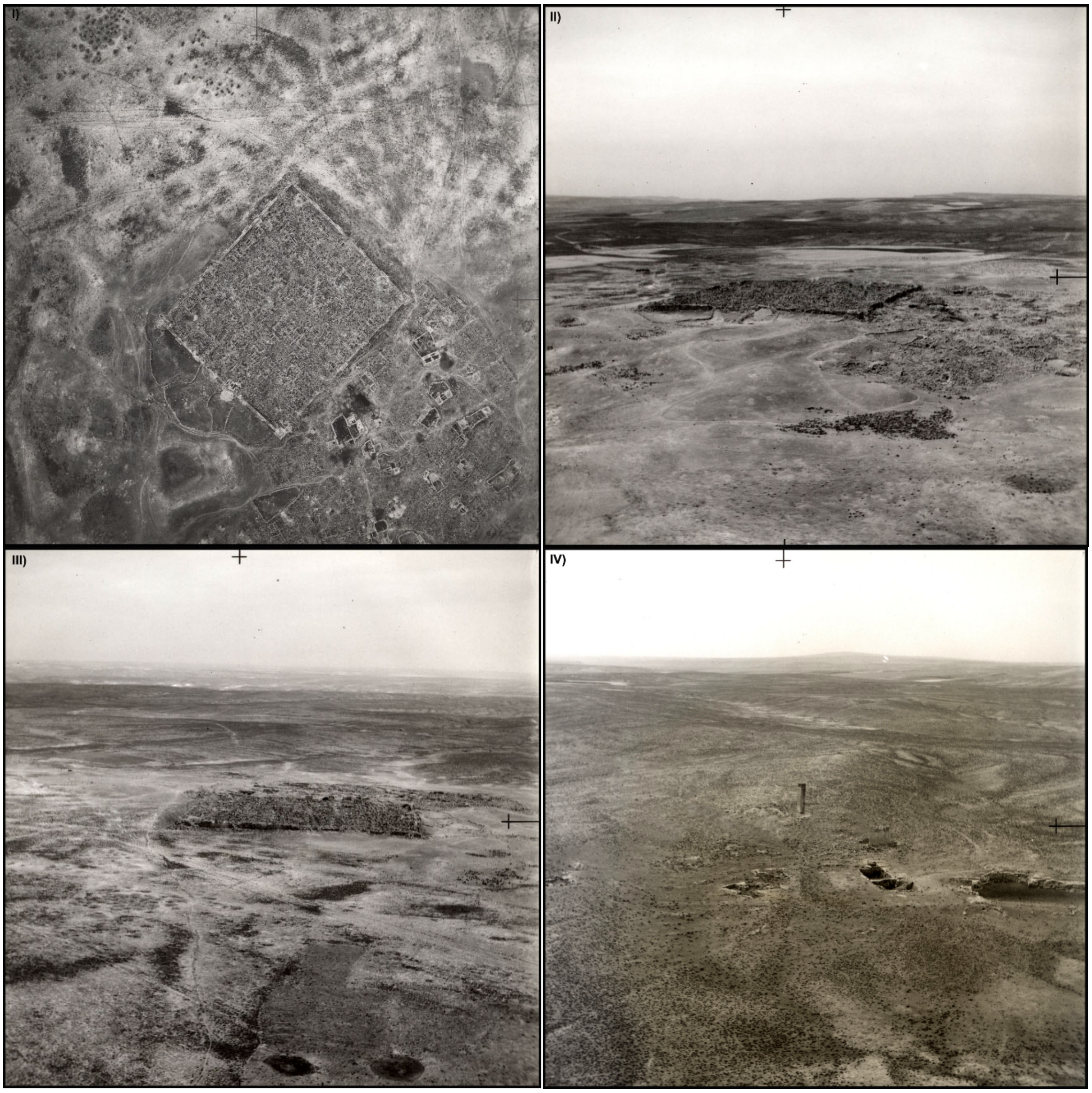

Figure 2 - Umm ar-Rasas May 6th, 1939. The aerial photographs taken by Stein. **I)** a vertical view of the castrum from 1200 feet above ground; **II-III)** oblique views of the castrum and village from the northeast and south, respectively, at a height of 600 feet; **IV)** an oblique view of the Stylite complex from the north, also at a height of 600 feet.

These photographs enable us to recreate the topography and landscape of the archaeological site. These photographs capture a desert landscape marked by the pure presence of ruins. A desert landscape is crossed by roads and wadis but without modern overlays, such as urbanisation or new agricultural uses of the soil.

Historical satellite photographs, in particular a Hexagon KH-9 from 1974, suggest a landscape very similar to that photographed by Stein. Hexagons are well-known panoramic satellite images taken by American spy satellites between 1971 and 1984. Their accuracy on the ground ranges from 1.20 to 0.60 metres.

In addition to the three settlement units (A - the Tetrarchic Castrum, with its water reservoir, in the south; B - the Byzantine-Umayyad settlement, immediately to the north of castrum; C - the stylite complex tower, about two kilometres to the north), the 1974 Hexagon allowed us to better contextualise all of the archaeological evidence. From the north to the south, these comprised quarries and material extraction sites (marked in yellow on the plan); irrigation and hydraulic systems (dams and canals -D), which describe the surrounding zone; and a large dam to the NE (about a kilometre and a half from the castrum -E) (Fig. 3). More specifically, we can make out a series of roadways that lead to, cross, or border the Byzantine hamlet, as well as a network of canals and water storage facilities southeast and east of the castrum. The northernmost component, the stylite tower complex, clearly displays canal-dam systems.

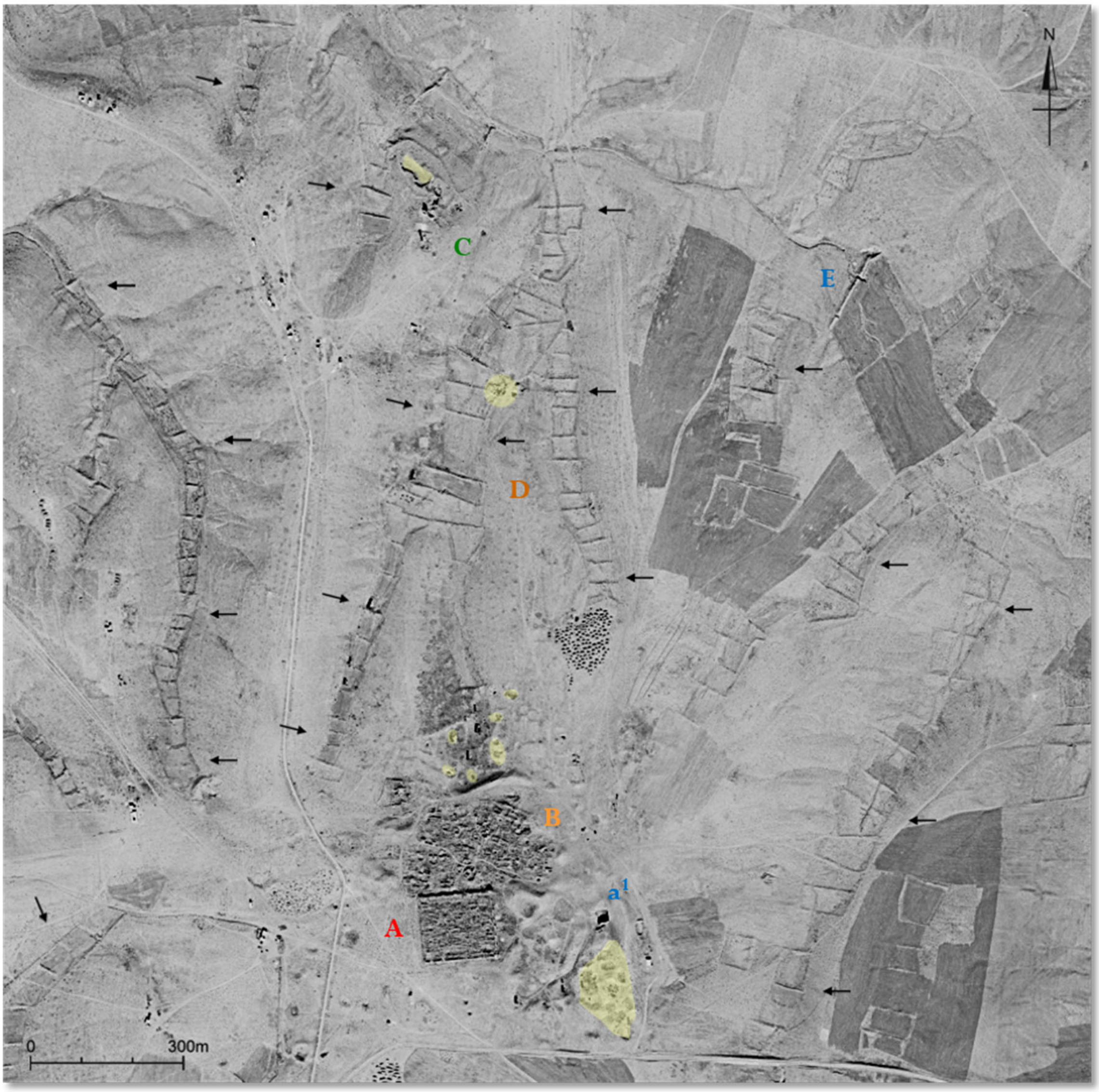

Figure 3 - Umm ar-Rasas. Hexagon KH9 images 1974/12/01, ground resolution: 1.20-0.60 m. Featured: **A** Roman castrum; **a1** hydraulic reserve; **B** Byzantine and Umayyade settlement**; C** Stylite tower complex; **D** System of irrigated plots (channels and dams); **E** the dam. Quarries and material extraction points are highlighted in yellow, whilst arrows indicate hydraulic channelling systems.

We can assess the conservation state of the traces of the fossilised agricultural ecosystem seen on the Hexagon by comparing them to a recent and high-resolution satellite image, Pleiades 1-A from 2020 (Fig. 4). Additionally, archaeological features from published maps were georeferenced and vectorized using the 2020 Pleiades-1A. Furthermore, it was essential for validating, georeferencing, and vectorizing any data obtained through on-site remote sensing analysis.

In order to make archaeological and paleoenvironmental traces and remains more legible, the Pleiades-1A satellite image was lastly processed utilising data fusion and different enhancing techniques.

The image processing of optical satellite data, carried out using specific software in order to facilitate the identification and examination of archaeological marks and anomalies, represents one of the possibilities offered by the remote sensing application for archaeology.

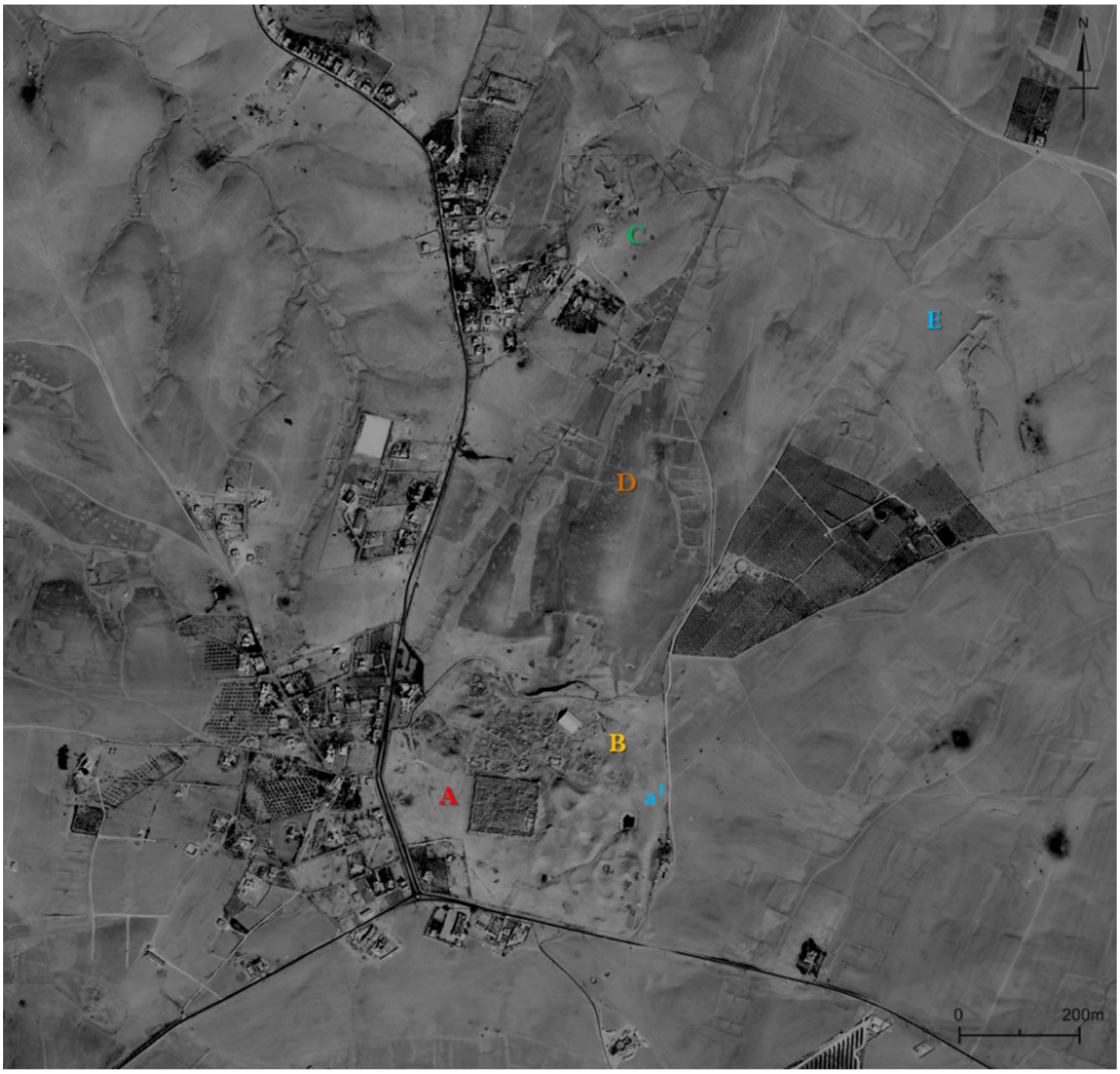

Figure 4 - Umm ar-Rasas. The Pléiades 1A satellite's image acquired on October 30, 2020, ground resolution 0.50m. Featured: **A** Roman castrum; **a**^{1} hydraulic reserve; **B** Byzantine and Umayyade settlement; **C** Stylite tower complex; **D** System of irrigated plots (channels and dams); **E** the dam. The hydraulic channelling systems remain visible, albeit less prominent than depicted in the Hexagon image.

A satellite image is a matrix of numerous pixels, and the value of each is related to the solar energy reflected by the corresponding portion of the earth's surface. This energy is divided into various bands of the electromagnetic spectrum: a small portion of this radiation, divided into the blue, green, and red bands, gives an image similar to that of an aerial photo; another portion, wider and particularly important, especially for archaeological studies, is occupied by the Red Edge (720nm) and Near Infrared (840nm) channels, which allow the investigation of elements and phenomena of the earth's surface otherwise not visible to the human eye. These two bands are very important for archaeological applications because they are particularly sensitive to stress factors in vegetation growth, which, as is known, is one of the main mediating elements of the archaeological features (crop marks). The presence of positive buried ancient structures (wall structures, floors, ruins) affects the vegetation growth, while the negative archaeological structures or even paleo-elements of the ancient landscape (ditches, canals, excavated trenches, but also depressions and paleo-riverbeds) favour full vegetation growth thanks to ideal conditions in the humus soil layer that is very drained of humidity.

Over the years, numerous methodologies and techniques have been developed to improve these images, i.e., processing classes that operate on the particular radiometric, spectral, and geometric properties of satellite data (Lasaponara, Masini 2012). These elaborations are necessary to increase the readability of the images and to better discriminate small differences in tone and colour, which, as is well known, are useful indicators in the identification of marks related to buried or semi-surfaced ancient structures.

Therefore, the availability of two very high-resolution satellite images that capture the Umm er-Rasas area - the first image acquired on October 30, 2020, by the Pléiades 1A satellite and the other acquired on November 11, 2022 by the Pléiades Neo-4 satellite - has allowed us to test the potential of remote sensing applications through specific data processing chains for the investigation of the ancient topography of the site and its territory. Compared to its predecessors Pléiades constellation, which provides four multispectral bands (Blue, Green, Red and Near Infrared) (Pléiades satellites provide images with a resolution of 0.5 m in panchromatic mode and a resolution of 2 m in multispectral mode, https://earth.esa.int/eogateway/catalog/pleiades-esa-archive), Pléiades Neo images have a better spatial resolution and have two additional bands, the Deep Blue and the Red Edge, thus adding important information on the earth's surface characteristics (Pléiades Neo satellites provide images with a resolution of 0.3 m in panchromatic mode and a resolution of 1.2 m in multispectral mode, https://earth.esa.int/eogateway/missions/pleiades-neo).

Pléiades Neo data products are characterised by two images: the RGB image, with Red, Green and Blue channels, and NED image, with and Near-infrared, Red Edge and Deep Blue channels. As anticipated, Red Edge is very important for archaeological applications because it is used for analysis of vegetation status through detailed photosynthesis characterization. Thanks to the ready availability of the images in Standard Ortho mode (the product is a georeferenced image in Earth geometry and is corrected from acquisition and terrain off-nadir effects), the pre-processing operations, which involve the geometric and radiometric correction of the image, have been skipped.

For the two images of Umm er-Rasas, the most performing processing chains were then applied for the identification of the archaeological traces and are already widely used in consolidated remote sensing studies applied to archaeology: the RGB Colour Composite, the Datafusion and the Principal Component Analysis. The software used was ENVI 4.7. A necessary and preparatory first step to the subsequent image processing phases was a qualitative examination based on the visual inspection of each band.

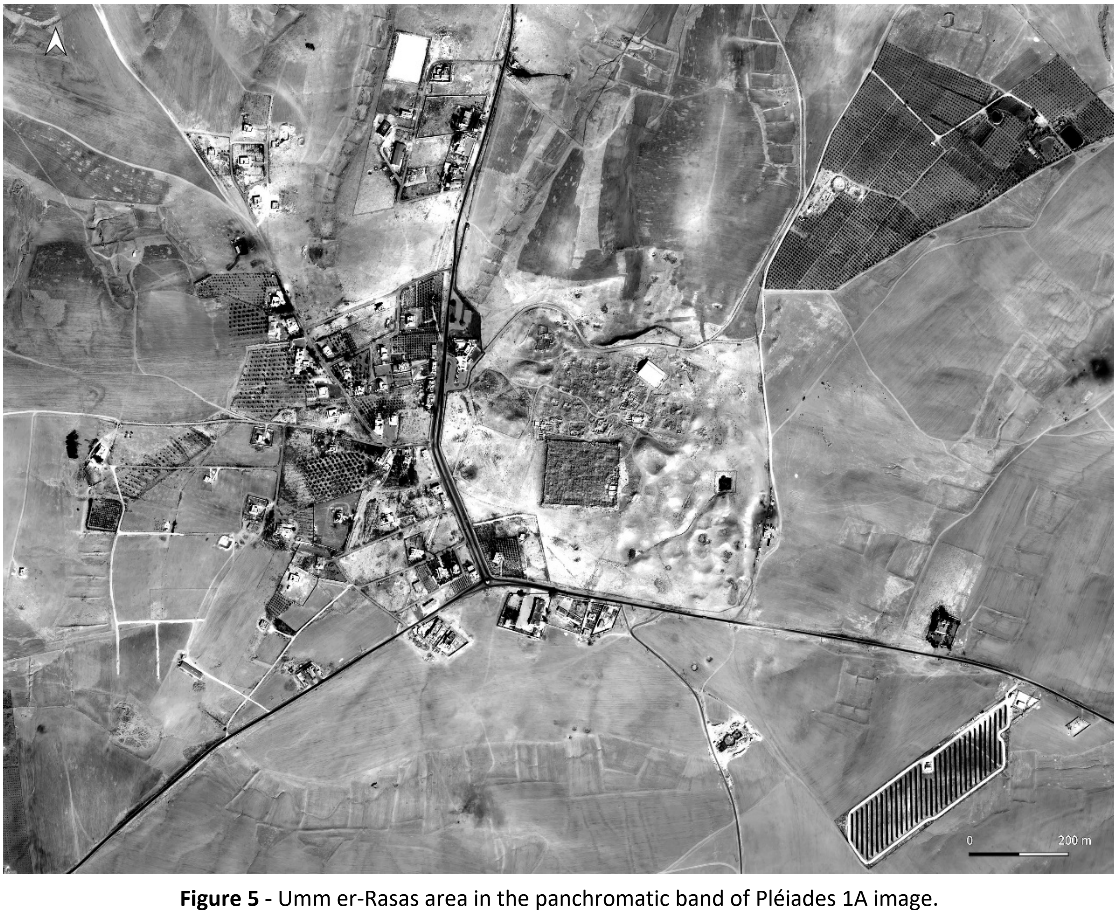

Figure 5 - Umm er-Rasas area in the panchromatic band of Pléiades 1A image.

This phase was necessary to verify the visibility of the different types of traces and their immediate surroundings and to evaluate which bands guarantee more effective discrimination of their spectral or radiometric separability. The evaluation showed that, to the detriment of the spectral information, the panchromatic band proved to be very useful in the identification of the micro-reliefs produced by buried or semi-buried ancient structures because its very high spatial resolution allows the detailed visualisation of the micro-reliefs (Fig. 5). On the other hand, the spectral bands, in particular the near infrared, the red edge, and the red, allow us to investigate characteristics of the soil surface, such as the surroundings of buried elements that appear more vegetated or humid. Once the properties of each band have been examined in depth, the effective processing chain has begun.

Among the most basic processing techniques, there is undoubtedly the RGB Colour Composite, which allows viewing the image with a different order of band overlapping, useful for perceiving some information better than others. So, the image is displayed with an appearance similar to what the human eye perceives in the "true colour combinations", while in other combinations, called "false colour combinations", the near infrared or red edge band, invisible to the human eye, appears in place of the red and green bands.

In the case of the Umm er-Rasas site, the simple composition of bands with false colours facilitated, making it more immediate, the preliminary visual analysis of the more humid and vegetated surfaces, normally difficult to identify in these geographical contexts characterised by very arid conditions but potentially indicative of disappearing elements of the ancient landscape. This result is particularly clear in the false-colour composition of the Pléiades 1A image, acquired in October, a period when the soil is not excessively dry. The infrared band (visible in red) and the red band (visible in green) show a consistent network of small wadis exploited through reclamation and regimentation works to obtain cultivable areas (Fig. 6A). While other interesting features are more evident in the false colour composition of the Pleiades Neo image, the small vegetated and rounded depressions that are highlighted within the remains of the buried village could correspond to disused cisterns (Fig. 6B).

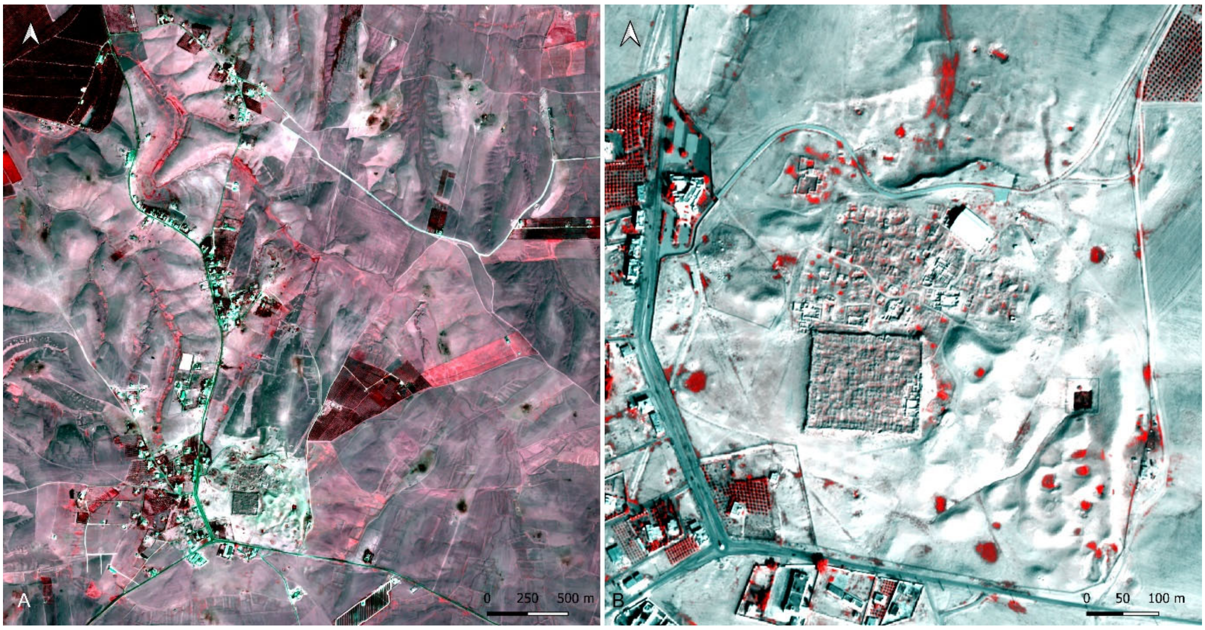

Figure 6 - Umm er-Rasas. RGB Colour Composite in false colour of the Pléiades 1A image showing the general view of the Umm er-Rasas area, and of the Pléiades Neo-04 image showing a detailed area of the late antique castrum and the Umayyad village.

Other image processing techniques, useful for obtaining the maximum information in qualitative and quantitative terms, were therefore employed. The datafusion technique of the panchromatic and multispectral data of the Pléiades Neo-04 of 2022, exploiting the high spatial resolution of the panchromatic image (0.30 m) and the high spectral resolution of the multispectral image (6 bands), was performed to obtain an optimal result. This operation, carried out using the "Gram-Schmidt" method of the ENVI routine, produced a “pansharpened image”, a new image where the spectral resolution of the colour bands has been adapted to the resolution of the panchromatic data (Lasaponara, Masini and Scardozzi 2007, pp. 213-217).

The result obtained was a good qualitative image for the discrimination of spatial details and a good quantitative image for the discrimination of a series of crop marks and dump marks highlighted, as mentioned before, by the responses in the infrared band, the red edge, and red (Fig. 7).

Figure 7 - Pansharpened product of the datafusion tecnique by panchromatic and multispectral data of Pléiades Neo-04 image.

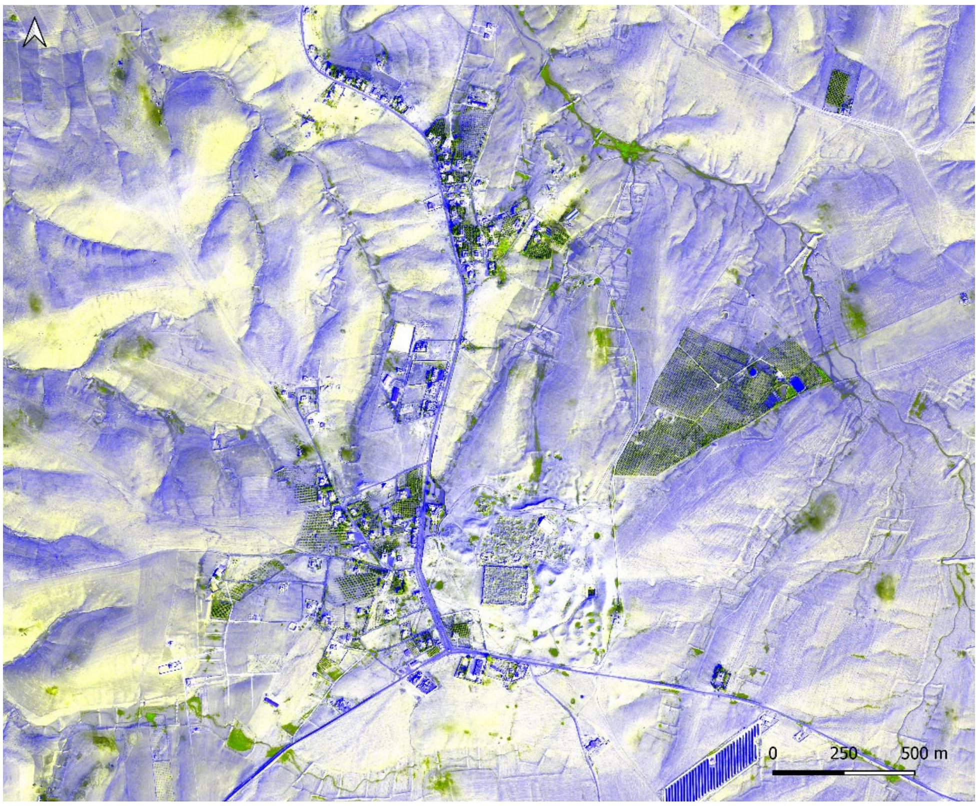

Figure 8 - RGB colour composite in false colour of the Pléiades Neo-04 multispectral image processed by PCA tecnique. R: PC1 band of RGB data; G: PC1 band of the NED data; B: PC2 band the NED data.

The choice to apply Principal Component Analysis technique (PCA) using the pansharpened bands and to minimise the redundancy in information in some areas seemed quite effective (Lasaponara, Masini, Scardozzi 2010, pp. 486-490). Among the six new bands obtained, the best were the first (PC1) and second (PC2) bands of the RGB image and of the NED image (Fig. 8).

At this point, some operations were tested to combine the products obtained from the individual enhancement techniques into a new false colour composition; this operation does not improve the analysis of the anomalies much, but overall it offers a more immediate perception of some feature traces.

Finally, since the outputs of the various processing products were exported in geotiff format, their loading into a GIS platform was sufficient to implement the information layers of the project. After a further visual examination and interpretation of the images on the basis of other contextual information, the traces and anomalies identified were vectorized.

Results

From the air to the ground

The remote sensing analysis was then followed by the verification of all the proof discovered from above. All quarries, irrigation systems, and water canalization have been mapped in detail. Forty reservoirs, dozens of quarries, and dozens of canal systems have been mapped in total. In addition, hypogean settings probably going back to the Bronze Age, such as those found in Amman's Citadel, have been identified. One thing to note about the water reservoirs: we recognised their primary role as a quarry in at least five or six of them.

Finally, a fantastic result was obtained with the discovery of a dam to the north-east of Umm ar-Rasas. It was made possible by Hexagon analysis and a later check survey on the ground. The dam has not been photographed by Stein and has never been studied before. The Jordanian Department of Antiquities itself didn't know about the existence of this dam. From the ground, we were able to determine that the dam's construction period for building materials, dimensions, and block fabrication can most likely be considered contemporaneous with the castrum or of the same period as the castrum.

Laser scanner and photogrammetric surveys

They were then carried out during the Kastrum Project 2021 and 2022 missions: preliminary architectural and stratigraphic analysis; study and documentation (photographic and graphic) of architectural components; photogrammetric surveys and processing of the walls (tests); laser scanner surveys and processing; archeological-architectural surveys inside the walls.

For the research and documentation of the castrum walls, a special form has been developed.

Despite significant obstacles, photogrammetric acquisition of the castrum's exterior walls began in 2021. Difficulties brought on by the following factors: a large castrum (159 x 138 m approx.); numerous collapses; and (of course) the Mission's short duration.

Even so, a first photogrammetric test of the walls' full external circuit has been completed (Fig. 9).

Figure 9 – Kastrum Project 2022 **a)** Print screen processing of all wall reliefs completed; **b)** Detail of the west wall, print screen processing in progress

As a result, a first laser scanner acquisition campaign was run during the 2022 expedition, allowing accurate documentation of the masonry and the castrum's state of conservation. Two pieces of equipment, the FARO Focus 3D S120 (which can scan objects up to 120 metres away and measure at speeds of up to 976,000 points per second, with an optimal distance of 50 to 60 metres) and the FARO Focus X 330 HDR (can scan objects up to 330 metres away and measure at speeds of up to 976,000 points per second, with an optimal distance between 208 and 290 metres), were used to conduct the laser scanner surveys. Two instruments were employed to expedite the measurements due to the limited amount of time available. One point every three millimetres at a distance of ten metres was the resolution that the two laser scanners had been calibrated to.

The two laser scanners were positioned less than 50 metres from the castrum walls and 10 metres apart from one another (they were spaced this way to provide sufficient scan overlap). This shows that the two instruments performed at their highest level.

The scans were processed using Reconstructor 4.4, a software created by a Brescia University spinoff.

Before being registered automatically, the scans were manually pre-registered. This procedure has never had more than 2mm of average inaccuracy.

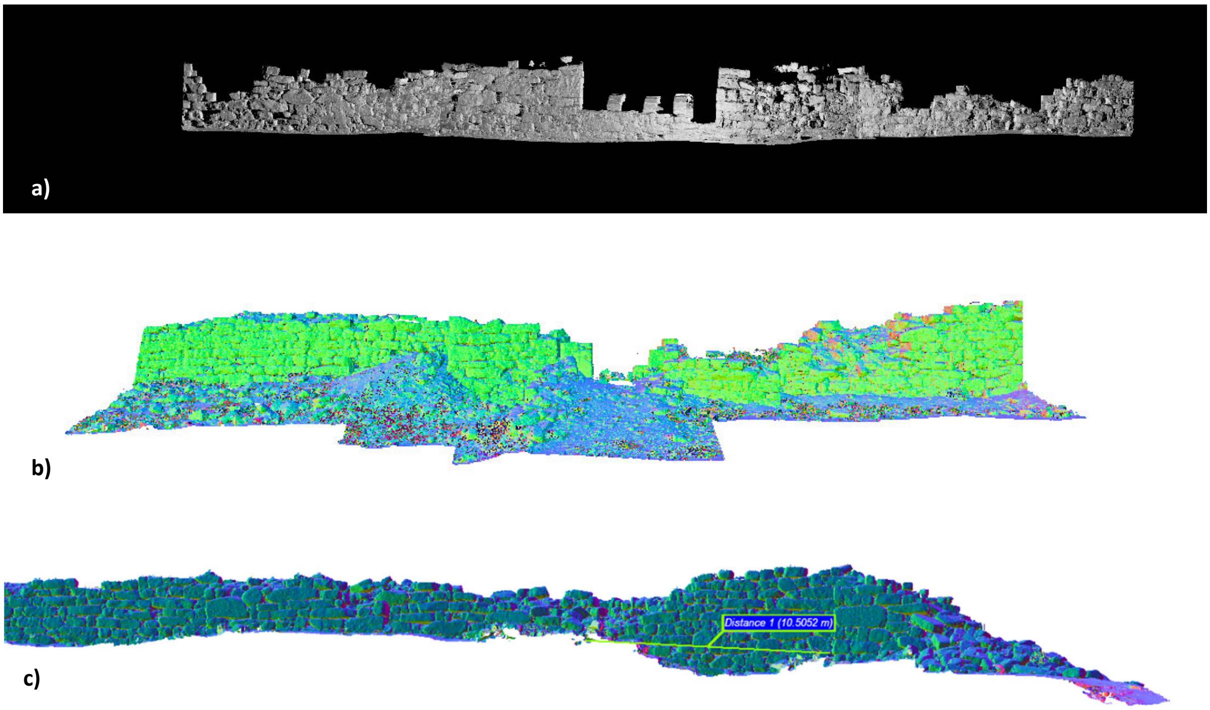

Figure 10 – a) Results of the data processing phase: Ortho-image of East Gate; **b)** Noth Gate. Data processing phase. Colour mapping: inclinantion**; c)** a section of West wall. Colour mapping: inclinantion.

However, this is a comprehensive survey that enables us to create a 3D model that can be remotely measured and analysed (Fig. 10).

Discussion and upcoming perspectives

In summary, the material, construction, stratigraphic, and structural degradation characteristics of the masonry were identified. We also finished the photogrammetric and laser scanner surveys of the exterior walls in order to accurately record the structures, create a 3D model that can be remotely measured and analysed, plan future research and preservation efforts, and improve accessibility.

About the systematic analysis of (unpublished) remote sensing data, both historical and recent, in terms of a large-scale question: the remote sensing analysis allowed the identification of new archaeological sites (hypogeum environments/graves of the Bronze Age emptied and used as dwelling/shelter in Umayyad times until recent times, dams and the dam, etc.); the remote sensing analysis allowed the identification and study of the historical landscape (specifically on water channels, dams, quarries, reservoirs, and systems of irrigated plots) and the connection with the Byzantine-Umayyad settlement. In terms of a smaller-scale question (about the castrum), the analysis of remote sensing data (particularly historical data) combined with a preliminary survey on the ground enabled the identification of ancient wall remains (Fig. 11).

Figure 11 – Umm ar-Rasas. Highlighting the site where remains of ancient walls have been found, either from the earlier and smaller fortress of Umm ar-Rasas (Severan period) or from the same period as the castrum wall (Tetrarchic period).

These walls could be associated with the castrum or with a previous and smaller fortification (Severian ages?). In this regard, a fragmentary Latin inscription indicating a Roman presence in 306 and 307, as well as many pottery shards from the 2nd-3rd centuries AD, have been found (Scarpati 1991; Lewin 2001; Bujard 2008, p. 22, 35). After all, there are several references in the bibliography to Severan fortresses that were later incorporated into much larger Tetrarchic fortifications (Arce 2010; 2015).

In closing, Umm ar-Rasas has recently been used as an experimental lab for interdisciplinary searches. Research aimed at understanding and maximising a site with a lot of potential. There's still a lot to do.

Regarding the prospects for the future, aerial photogrammetric and laser scanner surveys will be used to finish the surveys (we would have preferred to present the results here, but it was not possible due to issues with permits from the Jordanian Department of Antiquities) and in order to improve the map of the military camp during the Tetrarchic period. We plan to use electrical resistivity tomography to investigate the area inside the castrum walls in order to find and confirm structures that were present at the time the castrum was built as well as to find and confirm the presence of earlier structures (previous fortification).

We intend to define the extent of the Byzantine and Umayyad settlement in the north, confirm the existence of walls surrounding the Byzantine settlement, and investigate the hydraulic systems of the settlement using geophysical surveys, processing, and archaeological interpretation of new remote sensing data.

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