

Rebuilding the Lost Past

**A virtual reconstruction of destroyed archaeological sites
documented in the 18th and 19th century**



Marco Mion

Master of Arts in Archaeological Practice

Supervisor: Prof. Timmy Gambin

Co-Supervisor: Dr Ing. John Charles Betts

Computer Science advisor: Dr Sandro Spina

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Student's I.D. /Code 0399413L

Student's Name & Surname MARCO MION

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I am hereby submitting my dissertation/thesis for examination by the Board of Examiners.



Signature of Student

MARCO MION

Name of Student (in Caps)

Date 07/07/2022

Submission noted.

Principal Supervisor
(in Caps)

Signature

Date

Abstract

The reconstruction of the past is arguably the main *raison d'être* of archaeology from its conception to the present day. In the past few decades, this task has been facilitated by the introduction of 3D technologies which are capable of conveying archaeological data and interpretations through the use of interactive graphics and imaging. Therefore, when describing what an artefact, a monument or a site looked like in the past, 3D technologies are recognized as an intuitive, efficient and interactive visualization tool. This study makes use of these technologies with the intention of establishing whether a virtual reconstruction of destroyed archaeological sites can be achieved using only available legacy data. The documentation collected for this purpose include textual and drawn sources recorded in the 18th and 19th centuries following the discovery of local archaeological sites. These are: an Early Christian hypogeum (Site A); a Roman warehouse complex (Site B), both located in Marsa; and a Punic building situated in Żurrieq (Site C). While the first two were completely destroyed by the heavy industrial development that characterized the Marsa harbour in the past two centuries, the latter is still partially surviving *in situ*. This research attempted a 3D and VR reconstruction of these sites, in which outcomes were subsequently analysed by assessing their strengths and limitations. This study will rely on Site C as the only partially surviving case study to carry out a comparative analysis between the interpretative 3D model built through the legacy data and the photogrammetry reality-based 3D model of the ruins *in situ*.

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Chapter 1



Introduction

1.1 Introducing the research

Today, computer-based technologies and 3D visualizations represent an essential resource for archaeologists. When introducing the term ‘Virtual Archaeology’, Reilly described 3D modelling as a tool capable of simulating the archaeological formation process.¹ Since the Early 1990s, archaeologists were granted an alternative and dynamic solution to construct and visualize archaeological interpretations.² With the turn of the millennium, the methods for digitally controlling and visualizing 3D contents were enhanced as computational resources and applications continued to improve.³

Since their introduction in archaeology, 3D models have been classified into two categories: reality-based and interpretative models. While the former refers to 3D representations displaying a context as it is at the moment of the data acquisition, the latter represents a hypothetical reconstruction of how a given context (e.g. an artefact, a monument or a site) might have looked like in the past.⁴ The reasons that lead archaeologists and computer scientists to virtually reconstruct an archaeological context are disparate and range from broad outreach purposes to

¹ Reilly 1991: 133.

² Renfrew 1997: 7.

³ Dell’Unto & Landeschi 2022: 22.

⁴ Dell’Unto & Landeschi 2022: 20.

answering specific research questions. However, it can be argued that the touchstone of most interpretative models is the pursuit of a visual display of a specific moment in the history of a monument or site which predates its destruction.

Today, the use of 3D technologies is widespread and allows the reconstruction and documentation of cultural heritage monuments and sites impacted by natural or man-made calamities. Digital scans taken in 2013 of Notre Dame Cathedral in Paris are proving crucial in the ongoing restoration works of its roof and spire, following the 2019 accidental fire.⁵ Moreover, the ‘Backup Ukraine’⁶ initiative is currently encouraging Ukrainian civilians to scan hundreds of cultural heritage artifacts and monuments through a 3D modelling phone app known as Polycam.⁷ This initiative recently resulted in the institution of a digital cultural heritage archive as a reaction to Russia’s military destructive air-raids and the looting of Ukrainian museums.⁸

On a national level, 3D technologies have been employed in the virtual reconstruction of the ruins of the Royal Opera House in Valletta, bombed during WWII, based on photographic legacy data.⁹ Another example is provided by the virtual reconstruction of the Żejtun Roman Villa, based on the *in situ* remains and archaeological documentation collected throughout the several seasons of archaeological fieldwork.¹⁰

In a similar way, this study will employ 3D technologies to virtually reconstruct interpretative models of locally destroyed archaeological sites. Unlike the ones mentioned above which partially survive *in situ* this research chose two sites which have been completely wiped out by past industrial development which occurred in the 18th and 19th centuries. The period of time in which the destruction took place means that any photographic data are unavailable. Therefore, the peculiarity of this research lies in the fact that the interpretative models will be reconstructed by solely relying on written or drawn sources. Such a methodology has not been widely explored in the literature; nor was it carried out on a national level. For this reason,

⁵ Condon 2019.

⁶ Backup Ukraine – Polycam website 2022.

⁷ Tucker 2022.

⁸ Thorpe 2022.

⁹ Scavuzzo 2019.

¹⁰ The Żejtun Roman Villa Website 2022.

this study will firstly explore whether these reconstructions are achievable and assess to what extent they are successful or not. In order to evaluate this reconstruction technique, the inclusion of a partially damaged site was included in this study. By reconstructing an interpretative model alongside its reality-based one, this study will perform a comparative analysis of the same archaeological remains.

The three archaeological sites that this study will attempt to virtually reconstruct are the following:

Site A) An Early Christian Hypogeum discovered in 1874 on the northern side of the Jesuits' Hill¹¹ following a development-led excavation. The site was documented by C.A. Wright who wrote a brief report of its discovery besides surveying the site with a drawn plan and section-elevations. This catacomb was turned into a reservoir and its exact location is today unknown.

Site B) A Roman warehouse complex (*horrea*) discovered in 1768 on the top of the Jesuits' Hill following large public works ordered by the Grandmaster of the time, Pinto da Fonseca. The site was documented by the Count C. A. Barbaro who visited the site at the time and in 1794 published an essay containing a descriptive account and a drawn plan of the site. These remains were totally destroyed by these works and by the following construction of the Marsa Power station in the 1950s.

Site C) The standing remains of a Punic building, today partially surviving *in situ* within the masonry of Early Modern buildings in Żurrieq.¹² This site was visited in 1776 by the French artist and traveller J. P. Houël, who documented his travels in a collection of memoirs. This book contained a brief description and a watercolour containing a survey of the site. In addition, another watercolour illustrating this site can be found exhibited at the Hermitage museum in St Petersburg, Russia.

¹¹ Located in the heavily industrially developed area of Marsa, in the southernmost creek of the Maltese Grand Harbour.

¹² Located in south-east Malta.

1.2 Aims and objectives of this study

- 1) The first aim of this study is to establish whether destroyed cultural heritage sites can be rebuilt using only available legacy data.

The objectives set to achieve this aim are to:

- retrieve and digitise the textual and visual legacy data available for the sites in question;
- follow a specific training on the use of 3D graphics software and establish a suitable technique to build 3D geometries from the digitised legacy data;
- reconstruct the mesh and texture of the 3D models and access these in a Virtual Reality (VR) environment.

- 2) The second aim of this research is to evaluate the effectiveness of these virtual reconstructions built from digitised legacy data by assessing their outcomes and limitations.

The objectives set to achieve this aim are to:

- evaluate the outcomes of the 3D reconstructions;
- identify the determinant factors and difficulties which enabled, or prevented, the reconstruction of the destroyed sites;
- assess the strengths and limitations of the 3D reconstructions;
- compare and analyse the reality-based and interpretative 3D models of the third case study.

1.3 Structure of the dissertation

Following this introductory chapter, the research of this dissertation will be presented in six distinct chapters structured as follows.

Chapter 2 will present the relevant literature reviewed in the course of this study. To introduce this chapter, the relationship between archaeology and computer sciences will be addressed (Section 2.1). Firstly, the history of theoretical and technological developments which brought these two subjects to progressively interact with each other will be presented (Subsection 2.1.1). A result of this increasingly strong interaction led to the establishment of new sub-disciplines, such as that of Digital Archaeology. Subsection 2.1.2 will tackle the different scholarly standpoints over the nature and definition of this field, which is currently being debated. Arguably, one of the most significant contributions of digital technologies to archaeology is that of 3D modelling. Section 2.2 will review the literature concerning the use of 3D technologies in archaeology, by presenting two typologies of archaeological 3D modelling, namely the reality-based (Subsection 2.2.1) and interpretative ones (Subsection 2.2). Literature concerning their definitions, classifications, principles, methods and practical applications with relevant case studies will explain how this technology is reshaping the way archaeological documentation and interpretation is carried out. Ultimately, Section 2.3 will present each the three sites chosen to be virtually reconstructed.

As explained below (Chapter 3), both the methodologies and results could not have been homogeneously presented in two separate chapters, therefore a site-by-site layout approach was preferred. For this reason, the following three chapters (3-5) will individually address the methodologies adopted to respectively virtually reconstruct Site A, B, and C, and the respective obtained results.

Chapter 3 will be structured in three parts, in order to present the methods and results of each stage of the reconstruction workflow, made up of data gathering (Section 3.1), data processing (Section 3.2), and data visualization (Section 3.3). Chapter 4 is structured in a similar way, with the exception of the third stage that did not occur. On the other hand, given the different state of preservation of the last case study, Chapter 5 was structured differently. Firstly, the methods and results of the virtual reconstruction were presented (Section 5.1), followed by the 3D modelling of the *in situ* archaeological remains (Section 5.2), both of which were carried out following the above mentioned workflow. Ultimately, Section 5.3 will present the methods proposed for the comparative analysis and the respective

results obtained through a quantitative (Subsection 5.3.1) and a visual approach (Subsection 5.3.2). As for Site A (Subsection 3.3), the results of the comparative analysis were made accessible in VR and presented in Subsection 5.3.3.

Consequently, the results presented in the former three chapters will be discussed in Chapter 6. This will be done by singularly analyzing each case study's outcomes where in a dedicated section (6.1; 6.2; and 6.3) each virtual reconstruction will be assessed on its strengths and limitations. Subsequently, the three case studies will be discussed together in Section 6.4, where they will be compared and contrasted with each other.

Finally, Chapter 7 will conclude this dissertation by summing up the contents of this research (Section 7.1) and providing five concluding remarks (Section 7.2). In addition (Section 7.3), seven insights will be suggested with the aim of proposing possible future investigations stemming from this study.

Chapter 2



Review of Literature

This chapter will be presenting and assessing the literature relevant to this research in order to contextualise it within a comprehensive theoretical framework. Firstly, an introductory section (2.1) will provide the reader with a brief account on the history and terminology of the archaeological ‘digital approach’ and the current scholarly debate over the nature of this discipline.

Moreover (Section 2.2), the review will focus on the use of 3D modelling amongst archaeological practitioners, presenting applications and methods which are currently reshaping the way archaeological excavation and documentation is done. This will be done by presenting relevant case studies concerning archaeological fieldwork carried out in both development-led and research-led excavations.

After presenting 3D models as tools for on-site data acquisition, the review will focus on the archaeological employment of interpretative 3D models (Section 2.3). Unlike reality-based models, they allow the hypothetical reconstruction of what an archaeological context would have looked like in the past. For this reason, the literature concerning principles and methods of virtual reconstruction will be presented, alongside relevant case studies providing insights on different applications and procedures.

Finally, (Section 2.3) the three archaeological sites chosen to be virtually reconstructed will be described, namely the Early Christian Hypogaeum in Marsa (Site A – Subsection 2.3.1), the Roman Horrea in Marsa (Site B – Subsection 2.3.2),

and the Punic Building in Żurrieq (Site C – Subsection 2.3.3). Each subsection will present the literature concerning the discovery, location, state of preservation, and archaeology of the site in question.

2.1 Archaeology and the digital reality: history and terminologies

2.1.1 Archaeological theory and computing technologies: a shared history

In the second half of the 19th century, Giuseppe Fiorelli, an excavation director and museum curator, designed and commissioned the creation of a scale model of Pompeii. This work was entrusted to Felice Padiglione, who reproduced the urban grid of Pompeii using wood, paper and cork. This model, exhibited at the National Museum of Archaeology in Naples, displays with millimetric precision, a 1:100 replica of the buildings, furnishings and decorations (Fig. 1)¹³ which, over these past two centuries, faced rapid deterioration and partial structural collapse.



Figure 1. Felice Padiglione's model of the urban grid of Pompeii (1861) exhibited at the National Museum of Archaeology (Naples, Italy) (MANN's Website).

¹³ Museo Archeologico Nazionale di Napoli website 2022.

Today, this replica provides a unique possibility to revisit and recover data that is no longer existing on site¹⁴ and has yet been used in studies¹⁵ and research projects.¹⁶

By adopting the practice of model-making employed in other sectors (e.g. building and ship construction sites) pioneer archaeologists had understood the value of a three-dimensional simulation and visualization.¹⁷ Already one century ahead of computer graphics and virtual reality, this model constitutes one of the earliest attempts at 3D documenting cultural heritage, serving both conservation and preservation purposes.

Before approaching the history of the ‘digital’ or ‘virtual’ in archaeology, it is important to keep in mind that it is not new for archaeology to embrace technology.¹⁸ In fact, as stated by Andre Costopoulos “digital archaeology is here (and has been for a while)”.¹⁹ Throughout its recent history, archaeology became progressively dependent on the new technologies and digital solutions offered by computer science, which allowed the management and processing of increasingly larger quantities of archaeological data.²⁰ What can be conceived as the innovative aspect of this relationship is the speed with which, over the recent years the digitalization of archaeology has been developing.²¹

Throughout the history of archaeological theory, innovative computer science technologies allowed new archaeological research questions to be addressed and answered and old ones to be revisited.²² However, not only the progressing computing technologies had a direct impact on archaeology, but, in turn, the development of archaeological theory played a key role in the ways these technologies were employed (Fig. 2). In this regard, the history of the relationship between these technological innovations and developing archaeological theories will be presented below.

¹⁴ Dell’Unto 2015: 56.

¹⁵ See Kockel 2004.

¹⁶ See the Swedish Pompeii Project website.

¹⁷ Dell’Unto 2015: 55.

¹⁸ Gunnarsson 2018: 31.

¹⁹ 2016: 1f.

²⁰ Tanasi 2020: 22.

²¹ Gunnarsson 2018: 31.

²² Zubrow 2005: 13-14.

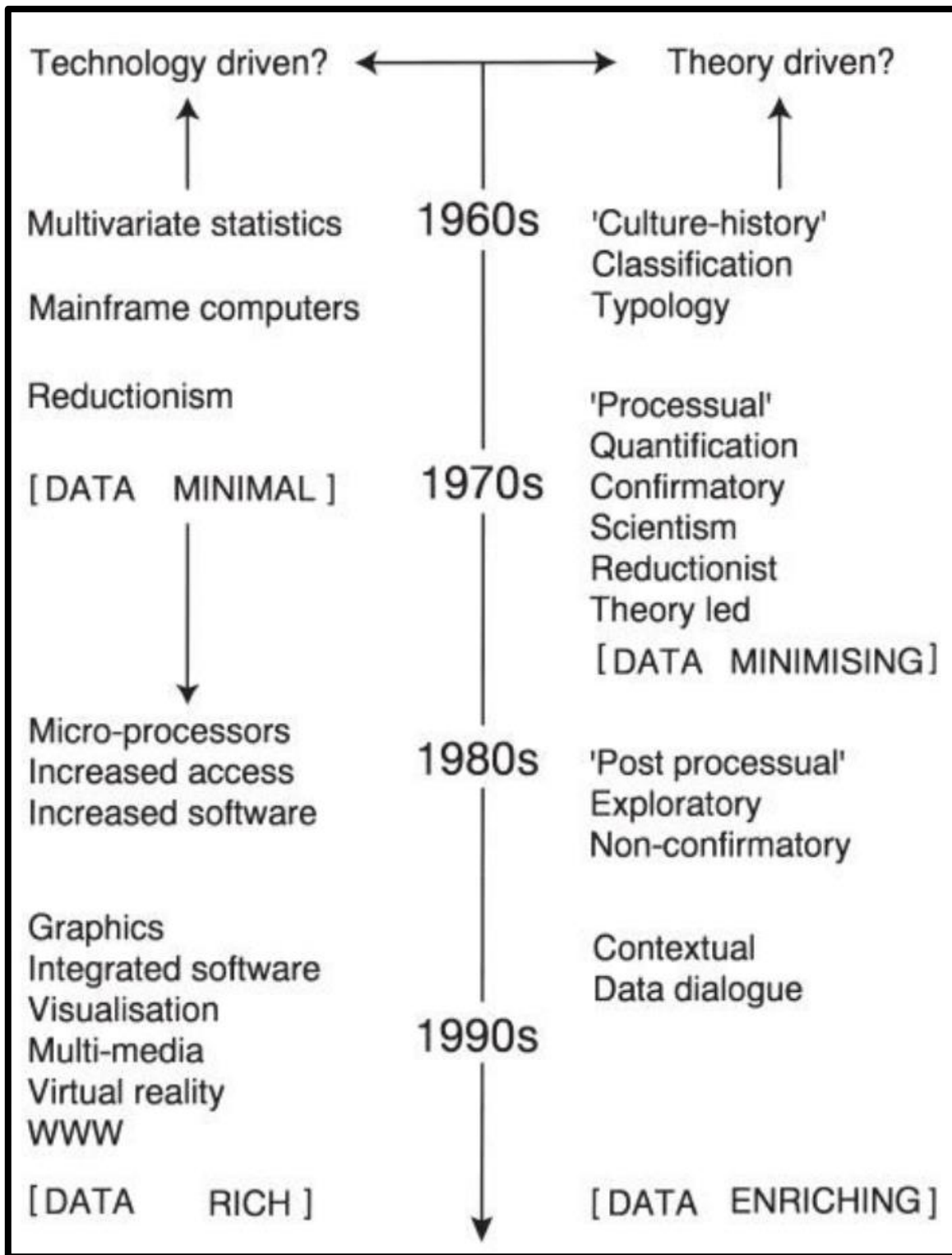


Figure 2. *The development of archaeological computing from the 1960s till the 1990s showing the relationship between technology and theory (Lock 2003: 8).*

Computing technologies and quantitative approaches (1930-1970s)

Since the 1930s, archaeologists have been using calculation machines (the ancestors of present day computers) capable of sorting, counting or tabulating, and providing mere descriptive data (e.g. statistics; figures; tables).²³ In this period, a quantitative approach was chosen towards archaeological data by employing computing technologies which became progressively more elaborate in the following decades.²⁴

However, some scholars suggest that it was not until the 1950s that archaeologists truly began to include these technologies into their workflow.²⁵ Gunnarsson²⁶ points out several significant events that took place in this decade that significantly impacted archaeologists of the time, such as:

- i. quantitative archaeology conferences;
- ii. the publication of the first algorithms of seriation and statistical methods for typometry;
- iii. the application of data retrieval;
- iv. the beginning of data banks in archaeology.

An important step occurred the following decade when geographic information systems (GIS) were developed in the early 1960s. For the first time, these tools allowed quantitative statistical analysis to be combined with geospatial data.²⁷ Throughout the 1960s and 1970s, computers continued to be used mainly for this purpose, although larger sets of archaeological quantitative data could be analyzed now.²⁸ These tools played a crucial role in the development of post-war archaeological theory and practice, which at the time was ‘losing its innocence’²⁹ in the wake of the ‘New Archaeology’. In fact, these technological developments provided significant contributions towards the processualist efforts at making the archaeological discipline more empirical and scientific.³⁰ In North America,

²³ Gunnarsson 2018: 31.

²⁴ Zubrow 2006: 14.

²⁵ Djindjian 2015:1; Moscati 2015:10.

²⁶ 2018: 32.

²⁷ Gunnarsson 2018: 32.

²⁸ Huggett 2015: 88.

²⁹ Clarke 1973: 1.

³⁰ Lock 2003: 9-10.

processualist scholars had employed quantitative methodologies to sustain arguments for objectivity and hypothetico-deductivist theory,³¹ while in Britain the employment of computer-based statistics led to the development of practices based on classification and seriation.³²

The post-processual turn and the digital shift (1980-1990s)

The 1980s saw the emergence of a new set of archaeological principles which directly opposed some of the main beliefs of the processualist school. Theoretical works of scholars such as Hodder,³³ Shanks and Tilley³⁴ directly opposed the Processualists' views on objectivity, arguing that archaeologists could not exclude some elements of their own subjective background (e.g. social-political exposure, gender, age, provenance, etc.) when asked to interpret archaeological data.³⁵

This paradigm shift, which placed the 'individual' at the centre of archaeological attention, significantly impacted the digital development.³⁶ This shift in archaeological theory and practice was considerably assisted by emerging experimental digital tools and concepts, such as:

- i. artificial intelligence (AI);
- ii. advanced GIS;
- iii. visualization;
- iv. agent-based modelling (ABM);
- v. web-based technologies
- vi. virtual reconstructions of archaeological remains.³⁷

One of the first attempts at digitally reconstructing an archaeological site occurred in 1983, when archaeologist Barry Cunliffe was preparing a BBC documentary on Roman Bath.³⁸ Cunliffe provided a University of Bath team of computer scientists and mechanical engineers (headed by John Woodward) with the data to model the

³¹ Binford & Binford 1968.

³² Lock 2003: 9-10.

³³ Hodder 1986.

³⁴ Shanks and Tilley 1987.

³⁵ Tilley 1993.

³⁶ Zubrow 2006: 14f.

³⁷ Gunnarsson 2018: 33.

³⁸ Opgenhaffen 2021: 368.

temple of Sulis Minerva of Roman Bath in 3D.³⁹ Although it was not possible to render an animation, due to the limited computing resources, a sequence of images was generated instead.⁴⁰ Since then, the creation of virtual archaeological spaces became popular throughout the 1990s.⁴¹ This decade saw the advent of early projects⁴² which paved the way for today's use of 3D acquisitions and Virtual Reality (VR)⁴³ reconstructions by contemporary archaeologists.⁴⁴

By 2000, the practice of virtually reconstructing archaeological sites, monuments, and artefacts grew significantly in popularity and accessibility.⁴⁵ This led to the scholarly debate of the main theoretical traits of this emerging field, named by Paul Reilly in 1990 as 'Virtual Archaeology'.⁴⁶ These theoretical traits begun to be summarized in major publications,⁴⁷ with particular focus on distinct matters, such as:

- i. the establishment of standards and methodologies for the use of VR and 3D modelling techniques;⁴⁸
- ii. the historical credibility of the products of VR and 3D;⁴⁹
- iii. the accuracy of these products from an archaeological perspective;⁵⁰
- iv. the need for data transparency.⁵¹

The turn of the century saw the establishment of the VR debate within archaeological researchers. A clear trend showed two major topics of discussion. The first one was a technical debate aimed to improve the quality of the VR product and was carried out only by computer scientists with a background in archaeology. The second one, saw instead cultural heritage professionals who explored and

³⁹ Woodwark 1991: 18.

⁴⁰ Opgenhaffen 2021: 368.

⁴¹ Reilly 1991 ; Hermon 2008: 36.

⁴² Reilly 1989; Reilly & Shennan 1989.

⁴³ An extensive survey of the history of VR is provided by Frischer *et al.* (2002).

⁴⁴ Gunnarsson 2018: 33.

⁴⁵ Hermon 2008: 36.

⁴⁶ Reilly 1991.

⁴⁷ Forte & Siliotti 1997; Barceló *et al.* 2000.

⁴⁸ Hermon 2008: 36.

⁴⁹ Ryan 1996.

⁵⁰ Kanter 2000.

⁵¹ Forte 2000.

discussed new educational and outreach-oriented possibilities that 3D and VR provided to the public. However, Hermon points out how at the time the debate lacked a discussion concerning other two vital matters.⁵² Just a few addressed the methodological and theoretical frameworks of 3D modelling and VR within an archaeological scope⁵³ and how these digital tools enable archaeologists to tackle specific research questions.⁵⁴

2.1.2 Defining Digital Archaeology

Before proceeding further with the principles, methods and applications of this discipline (Sections 2.2 & 2.3), this sub-section will briefly touch upon a rather controversial and contemporary topic of discussion found in the literature. What is the identity of the ‘digital within archaeology’?⁵⁵ Is it a tool, a specialization, a field, a sub-discipline, or a well-structured subject? Throughout its history (Subsection 2.1.1), it has been noted how the relationship between computing technologies and archaeology offered advantages mainly for the benefits of the latter. In the last decade, digital technologies have so rapidly assumed such a predominant role, that it is still hardly debated what this role is, causing confusion among readers, students and scholars. Tanasi identifies the reasons for this widespread confusion and controversy with the ontological challenge and the lack of consistency of this discipline’s definitions, due to the absence of clarity within the terminology. The literature offers several different definitions of Digital Archaeology, which may differ due to the author’s research background or nationality.⁵⁶

Possibly, the main difference can be identified with the already well-known distinct European vs. North American approaches towards archaeology. While the former conceives archaeology as an independent discipline, the same cannot be said for North American academia, which places it within the realm of Anthropology. This divergence can be noticed also in the way Digital Archaeology is perceived in these

⁵² Hermon 2008: 37.

⁵³ Vatanen 2004.

⁵⁴ Dell’Unto & Landeschi 2022: 22; Hermon 2008: 37; Beex & Peterson 2004: 490-493.

⁵⁵ Tanasi 2020: 22.

⁵⁶ Tanasi 2020: 22-23.

two very different environments. In European departments it is treated as a sub-discipline of archaeology and integrated with the study of Archaeological Science, while in the America it plays a peripheral role within the Digital Humanities.

Reviewed literature from American-based authors, such as Costopoulos, oppose the idea of the “Digital” being a thing in archaeology. By stating that archaeologists “are building a digital archaeology by doing archaeology digitally”⁵⁷ he stresses the futile approach of ontologically labelling this discipline and, by echoing Morgan and Eve’s radical statement “we are all digital archaeologists”,⁵⁸ he points out how digital archaeology should be rather conceived as a tool that all archaeologists can embrace. Huggett *et al.*, strongly disagree with Costopoulos’ approach which focuses exclusively on the practical application of these digital tools and rejects the discipline’s intellectual engagement.⁵⁹ In a response to this article, Costopoulos states:

“We have questions. To answer the questions, we have to solve problems. To solve the problems, we have to use tools. I really don’t care where the tools come from [...] For the purposes of solving my research problems, I don’t care where they come from. I don’t care whether someone calls me a digital archaeologist, a simulation technician, or a computational archaeologist. I care whether we all work together on answering some very interesting questions, developing, borrowing, stealing, adapting, repurposing, hacking, some really kick-ass tools”.⁶⁰

Shawn Graham, a public historian, responds to this view, which basically envisages Digital Archaeology as a “mere use of computational tools to answer archaeological questions”.⁶¹ Given his research focus, he conceives digital archaeology as a part of the public archaeology domain as it enables the audience to engage with archaeology in a more straightforward dimension.⁶² This also shows how some definitions might differ based on the researcher’s area of specialization. Some like Walcek, define Digital Archaeology by emphasizing the way the use of computerized, internet-based and portable tools and systems ensure a simplified

⁵⁷ Costopoulos 2016: 1.

⁵⁸ 2012: 523.

⁵⁹ 2018: 50.

⁶⁰ 2018.

⁶¹ Electric Archaeology, 14th March 2017.

⁶² Graham 2017.

documentation, interpretation, and publication of material culture”,⁶³ while others like Zubrow predict how in the future, Computer Science will be even more bound to this discipline, by defining it as the branch of archaeology which employs “future technology to understand past behavior”.⁶⁴ In opposition to a futuristic definition as Zubrow’s, comes that of “Slow Archaeology”, a sceptical approach towards the fast and efficient methodologies and results provided by digital technologies which, according to Caraher, are “de-skilling” archaeological practitioners.⁶⁵

The ontological confusion is then caused by the different labels found within the literature which are sometimes used interchangeably to refer to this discipline. The term ‘Digital Archaeology’ was launched with the 2005 publication of ‘Digital Archaeology: Bridging Method and Theory’,⁶⁶ however, it is also possible to find associated labels such as ‘Virtual Archaeology’ and ‘Cyber Archaeology’. These two terms refer to specific application of computer science solutions to archaeology and should be considered as research focuses in Digital Archaeology.⁶⁷

As has been mentioned earlier, the term ‘Virtual Archaeology’ was coined in the early 1990s,⁶⁸ and has since established itself in the domain of archaeological reconstructions. Virtual Archaeology can be described as the translation of hypothetical archaeological interpretations into digitally gripping visualizations that rely on the so called “wow factor”⁶⁹ of 3D modelling and virtual reality.⁷⁰

The 1990s also saw the emergence of the term ‘Cyber Archaeology’, a less popular one used by a smaller number of scholars such as Jones⁷¹ and was then used by digital archaeologists based in California. One of these academics, Levy defined Cyber Archaeology as being a step forward to Digital Archaeology and Archaeological Science with a higher emphasis on the engineering aspects,⁷² allowing digital archaeologists and computer scientists to develop

⁶³ 2017: 4.

⁶⁴ Zubrow 2005: 23.

⁶⁵ Caraher 2016.

⁶⁶ Daly & Evans 2005.

⁶⁷ Tanasi 2020: 24.

⁶⁸ Reilly 1991.

⁶⁹ Forte and Pietroni 2009.

⁷⁰ Tanasi 2020: 25.

⁷¹ Jones 1997.

⁷² Levy 2013: 28.

cyberinfrastructure for archaeology.⁷³ In short, Cyber Archaeology differs from Virtual Archaeology for being its theoretical and philosophical iteration where the final goal is the simulation of the past, and not the model itself.⁷⁴

A widespread degree of confusion and disagreements over what the identity of Digital Archaeology is, exists throughout the academic community. This emerged by presenting some of the definitions found in the literature given by scholars with different research interests and different academic backgrounds. Some researchers might not be interested in discussing labels or definitions, conceiving the ‘digital within archaeology’ just a means to an end and some are even sceptical about the long-term effects of this digital archaeological practice. However, by reviewing the hefty literature concerning the intrinsic relationship between computer science and archaeology, Digital Archaeology can be understood as a discipline which is still finding its way to establish itself as one. Arguably, rather than being a separate subject, it should be an independent archaeological specialization, just like osteoarchaeology or ceramic studies are.⁷⁵ As suggested by Myers, all archaeologists need to engage with digital technologies – to the same extent basic knowledge over other specializations (i.e. lithics; pottery; bones) is required – however, certain digital skills require a specialized approach.⁷⁶ Archaeology is defined as the study of human past through material remains.⁷⁷ Digital Archaeology allows, to a certain extent, to re-construct some of those past remains and thus to address some un-answered research questions about the past which would otherwise remain answered.⁷⁸

2.2 3D models in archaeology: reshaping interpretations and practices

Since its conception as an academic discipline, the teaching of documentation procedures has always been regarded as a fundamental aspect of the archaeological training.⁷⁹ In 1976, Harris and Ottaway conceived a comprehensive archaeological

⁷³ Levy 2017: 2.

⁷⁴ Forte 2016: 271-272.

⁷⁵ Myers 2011.

⁷⁶ 2011.

⁷⁷ Renfrew & Bahn 2012: 12.

⁷⁸ Tanasi 2020: 35.

⁷⁹ Tassie & Owens 2010; Barker 1982.

excavation and recording system known as ‘single context recording’ which aimed to record each stratigraphic unit (SU) excavated following the rule of superimposition.⁸⁰ This innovative and systematic excavation and documentation system progressively replaced the Wheeler-Canyon’s ‘box-grid’ method and its procedures began to be formally standardized by several academic and cultural heritage institutions.⁸¹ These documentation procedures make use of three different mediums:

- i. the written record (e.g. site notebooks, pro-forma sheets);
- ii. the drawn record (e.g. sketches; scaled drawings);
- iii. the photographic record.⁸²

Throughout time, these conventional recording techniques started to be integrated and enhanced by digital devices (e.g. portable computers, computer-aided design [CAD] software, and digital photography). Subsequently, in the early 1990s, the growth and diversification of computational resources and applications resulted in the development of methods for digitally manipulating and visualizing 3D contents.⁸³ Through the use of interactive graphics and imaging, 3D visualizations displayed these contents in a Cartesian 3D space (defined by x, y, z coordinates), improving the:

- i. extraction of significant data;
- ii. communication of a message;
- iii. clarification of spatial or topological relations;
- iv. illustration of phenomena or processes.⁸⁴

For these reasons, archaeologists started to consider and include 3D technologies as tools capable of enhancing the perception of archaeological data and supporting new forms of interpretation and practice.⁸⁵ When formulating interpretations,

⁸⁰ Harris 2017.

⁸¹ See Tassie and Owens 2010: 177; Museum of London Archaeology Service 1994; Dorrell 1994.

⁸² Tassie & Owens 2010: 176-177.

⁸³ Dell’Unto & Landeschi 2022: 22.

⁸⁴ Kaufman *et al.* 1993.

⁸⁵ Dell’Unto & Landeschi 2022: 22.

archaeologists could now rely on a visual reference which simulated the relationships between spatial phenomena.⁸⁶

However, the high costs of 3D recording and the unavailability of tools and software specifically designed for 3D visualization and analysis did not initially encourage archaeologists to fully employ these technologies.⁸⁷ However, more recently advanced 3D acquisition and visualizations systems have become more widely available and cost-effective triggering an intense phase of experimentation of such tools within the archaeological practice.⁸⁸

As described above (Subsection 2.1.1), the past few decades saw the establishment of 3D modelling techniques within conventional archaeological recording techniques. 3D modelling can be conceived as a process starting from data acquisition of a physical object and ending with a visually interactive virtual 3D model reproduced on a digital device.⁸⁹ By doing so, this technology offers a “summary and simplification of a physical thing, which helps to explain something complicated in one view”.⁹⁰ Furthermore, 3D models are subject to several classifications⁹¹ and can be distinguished on the basis of their different functions, affordances and uses.⁹² The most common 3D models employed in archaeology can be distinguished in three different typologies of representations, known as:

- i. Surface representations;
- ii. Boundary representations;
- iii. Volume representations.⁹³

Gary Lock defines surface representations as 3D models made of points, edges and surfaces⁹⁴ representing the ‘shell’ of the object rather than its internal characteristics.⁹⁵ Although models provide only a partial description of the physical

⁸⁶ Renfrew 1997:7 .

⁸⁷ Gillings and Wheatley 2002: 1.

⁸⁸ Dell’Unto & Landeschi 2022: 30.

⁸⁹ Remondino & El Hakim 2006: 269.

⁹⁰ Nordblad 2012: 245.

⁹¹ Foley *et al.* 1991: 6-8.

⁹² Dell’Unto & Landeschi 2022: 18.

⁹³ Dell’Unto & Landeschi 2022: 18.

⁹⁴ Also known as polygons.

⁹⁵ Lock 2003: 152.

object, they exponentially grew in popularity amongst archaeological practitioners who recognized their potential for on-site data acquisition (Fig. 3). On the other hand, boundary 3D models are often used to create interpretative visualization of damaged artifacts or structures or used to review the stratigraphic relations of excavated deposits (Fig. 4).⁹⁶ For this reason, these models function as ‘solids’ rather than ‘shells’, and are known as boundary representations.⁹⁷ Thanks to their topologically consistent surfaces, the viewer is able to extract data related to their volume and mass.⁹⁸ Finally, volume representations models (e.g. voxel and spatial decomposition) are capable of recording the object’s inner space and are specifically employed to document geological data (Fig. 5).⁹⁹

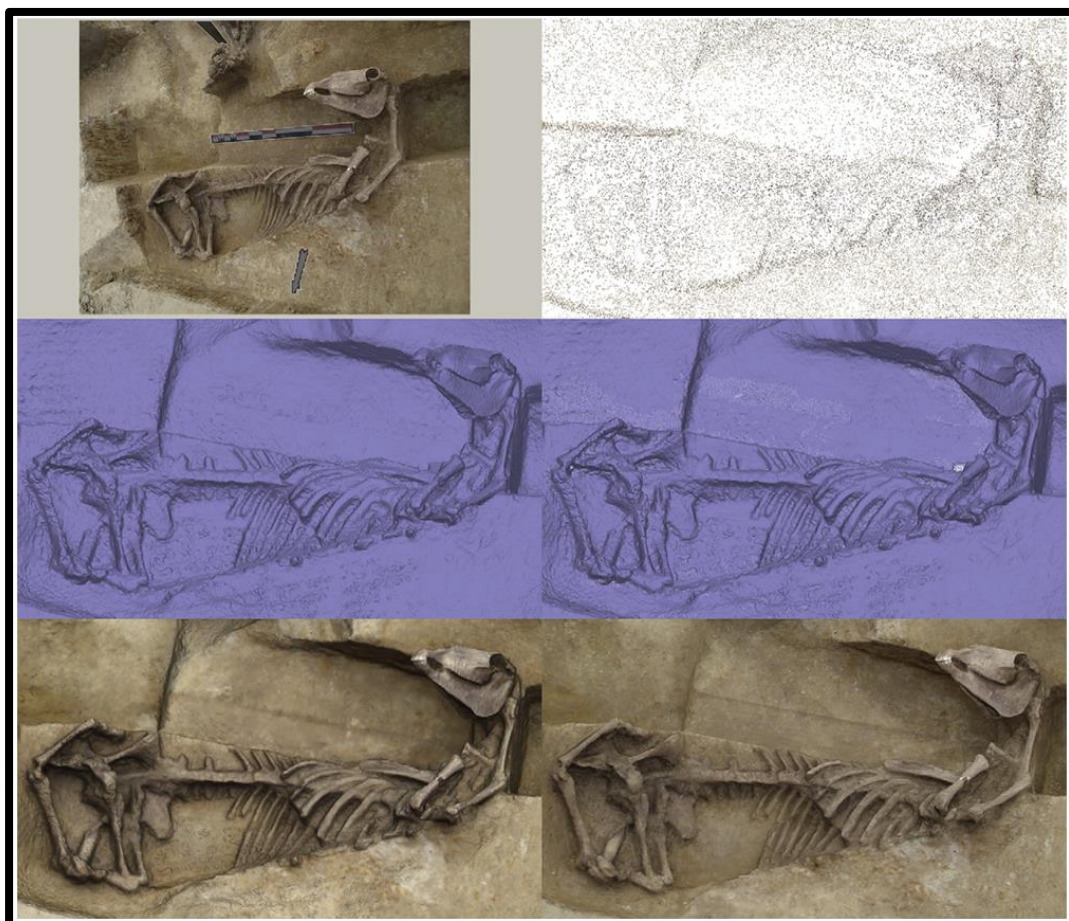


Figure 3. *The different processing phases of a reality-based 3D model (De Reu et al. 2012: 1110).*

⁹⁶ Dell’Unto & Landeschi 2022: 19; Scott *et al.* 2021.

⁹⁷ De Cambray 1993: 342.

⁹⁸ Lock 2003: 152.

⁹⁹ De Cambray 1993: 343.

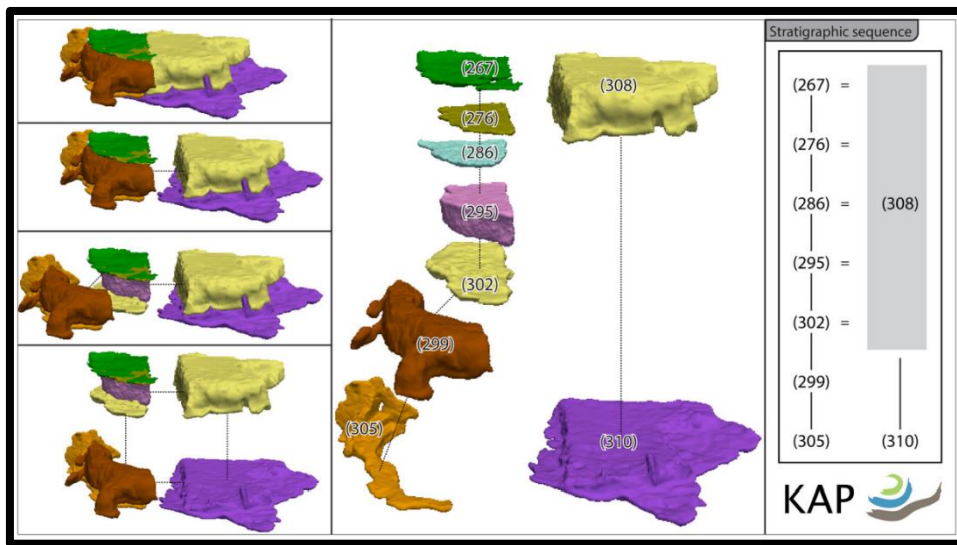


Figure 4. An example of boundary representation models showing a 3D stratigraphic matrix (Scott et al. 2021).

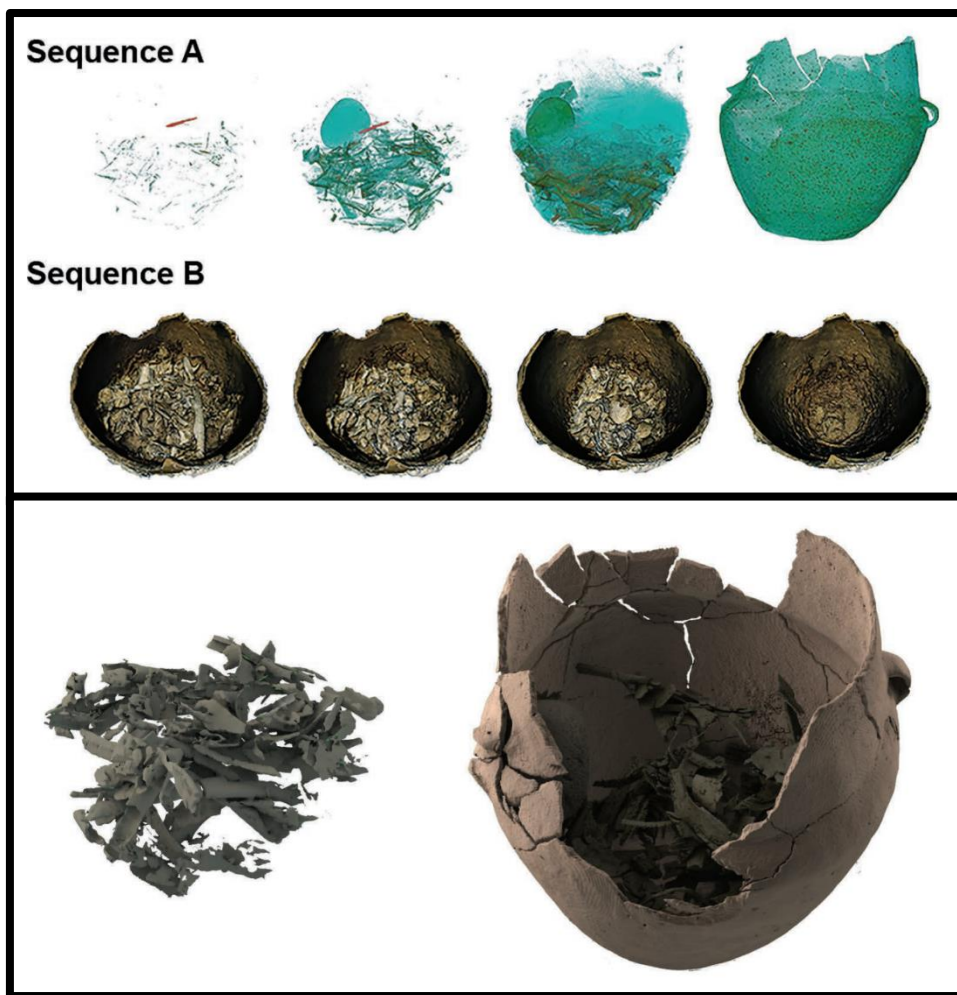


Figure 5. An example of volume representation models (Dell'Unto & Landeschi 2022: 19).

From the different typologies of model representation, a different classification based on the final object of the 3D reconstruction can be distinguished in:

- i. reality-based models;
- ii. interpretative models.

As mentioned above, 3D models can either represent archaeological contexts in their state during the data acquisition (e.g. an artefact, an SU, a site) or display an interpretative representation of these. In archaeology, the former type of 3D models are known as reality-based, whilst the latter as interpretative.¹⁰⁰ Arguably, reality-based models are employed on different types of fieldwork, specifically linked to archaeological documentation practices. On the other hand, the latter are mostly associated with post-excavation and interpretative archaeological observation.

Both reality-based and interpretative 3D models led to the introduction of new archaeological practices and principles, which in turn carried new research questions and difficulties. These will be distinctively presented below by presenting relevant case studies found in the literature.

2.2.1 On-site reality-based 3D models: methods and applications

As mentioned earlier, the adoption of surface 3D modelling to the archaeological practice triggered an intense experimentation phase.¹⁰¹ This led to the establishment of innovative archaeological practices, particularly reshaping standardized conventional recording techniques.

3D acquisition and modelling skills have been widely present within the field archaeologist's tool-kit for some time. Today, archaeologists are able to familiarize with user-friendly (e.g. Agisoft Metashape) and open-source (e.g. Meshroom and MicMac) 3D modelling software. Moreover, case studies in the literature have shown how the documentation of *in situ* archaeological remains employing dense-stereo machines¹⁰² (i.e. digital hand-held cameras) and laser scanners¹⁰³ are proving

¹⁰⁰ Dell'Unto & Landeschi 2022: 18.

¹⁰¹ Dell'Unto & Landeschi 2022: 18.

¹⁰² Callieri *et al.* 2011.

¹⁰³ Jamhawi *et al.* 2016; Lambers 2007; Lerma 2010.

accurate¹⁰⁴ cost-effective¹⁰⁵ and time saving,¹⁰⁶ thanks to increasingly improving software updates.¹⁰⁷

The above-mentioned advantages of on-site digital recording techniques can be a crucial tool for a specific branch of archaeology where time constraints represent a main impediment, namely that of development-led archaeology. Whilst acknowledging the destructive nature of all types of archaeological excavation,¹⁰⁸ the successful recording of archaeological data plays a key role in this sector, since development projects do not always preserve the archaeology *in situ*.¹⁰⁹ It is also worth mentioning how in Rescue Archaeology archaeological recording does not occur under the most favourable conditions. Gunnarsson pinpoints some limiting factors of development-led fieldwork, such as restricted timeframes and budget, limited workforce and equipment, and large developing areas.¹¹⁰

Regarding the latter shortcoming, remote sensing technologies and equipment come to the rescue of contract archaeologists. Today, Unmanned Aerial Vehicles (UAVs), are currently being employed to archaeologically survey large development sites¹¹¹ and in the last decade they became quite commercialized and affordable.¹¹² By piloting UAVs, archaeologists are able to carry out photogrammetry surveys of large archaeological sites. Orthogonal aerial photographs can be easily processed into geographically referenced 3D models from which it is possible to generate Orthophotomosaics¹¹³ and Digital Elevation Models (DEMs)¹¹⁴ (Fig. 6).

Additionally, most photogrammetry software feature measuring tools which allow the calculation of any distance from arbitrary points of the 3D modelled space. Once the object is photogrammetrically surveyed and georeferenced, archaeologists are

¹⁰⁴ Callieri *et al.* 2011: 38.

¹⁰⁵ De Reu *et al.* 2012.

¹⁰⁶ Opitz 2012: 46.

¹⁰⁷ De Reu *et al.* 2012: 1111.

¹⁰⁸ Wheeler 1954: 183; Barker 1982: 13.

¹⁰⁹ Demoule 2012: 612.

¹¹⁰ Gunnarsson 2018: 91.

¹¹¹ Montero Rodrigues 2017; UAV Technology – UAVs in Wessex Archaeology 2022.

¹¹² The Chinese company DJI offers a large selection of different commercial drones with competitive value-for-money ratios. DJI WebStore 2022.

¹¹³ Orthophotomosaics allow to orthogonally map the exposed archaeology on the site.

¹¹⁴ DEMs interactively display the differences in level of the recorded surface.

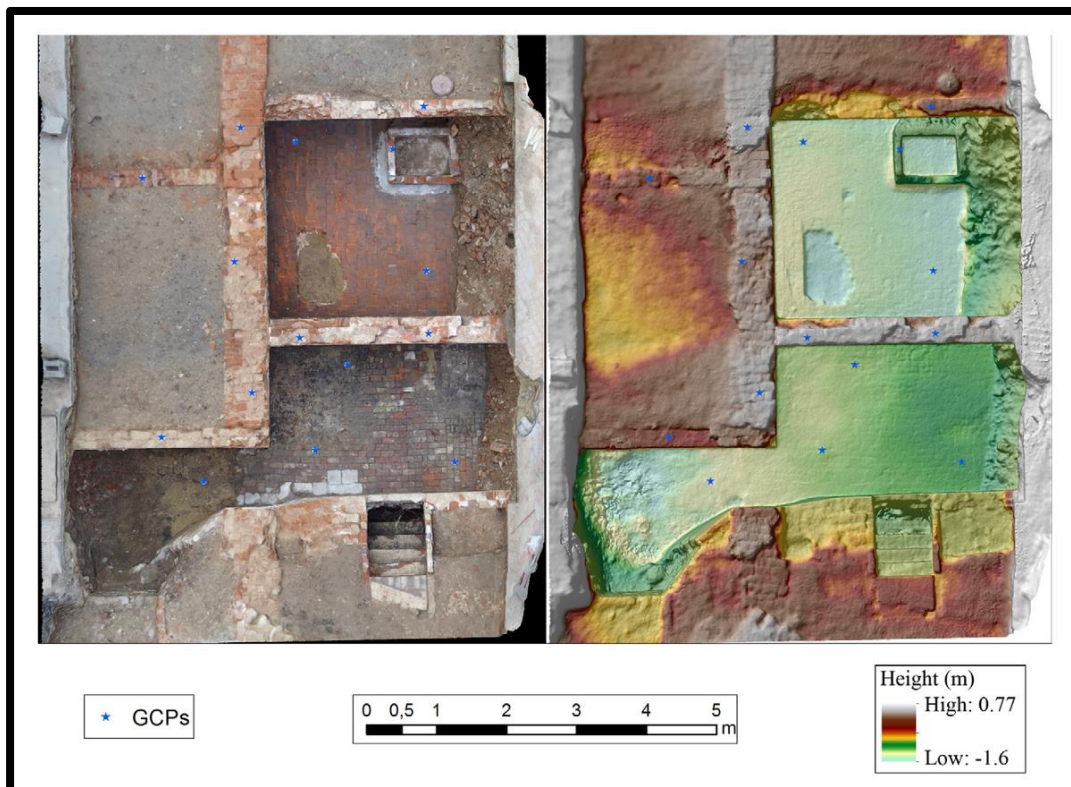


Figure 6. An example of an archaeological Digital Elevation Model (De Reu et al. 2012: 1118).

able to digitally access the site model remotely and obtain accurate spatial measurements at any time, even when the excavation would have progressed further. Moreover, photogrammetry software allows to export 2D images from selected visualizations. These can be then uploaded on CAD software (e.g. AutoCAD) where they can be traced over to produce the digitized versions of the standardized archaeological drawings, such as plans (Fig. 7) and sections/elevations¹¹⁵ (Fig. 8).¹¹⁶ Efficiency, accuracy and high quality representations are arguably the most significant contributions that 3D reality-based modelling offers to the set of conventional archaeological documentation techniques. Some case studies comparing data acquisitions carried out through both conventional (i.e. hand drawings) and digital (i.e. 3D surface model) recording techniques strongly suggest how conventional paper drawings might have been outdated by 3D recording techniques.

¹¹⁵ Photogrammetry software editing tools allow to ‘cut’ across the mesh of these 3D models and project a ‘section view’.

¹¹⁶ Benavides Lopez *et al.* 2016.



Figure 7. Image showing the plan drawing of an orthophotomosaic on a CAD software.
(Image by the author).

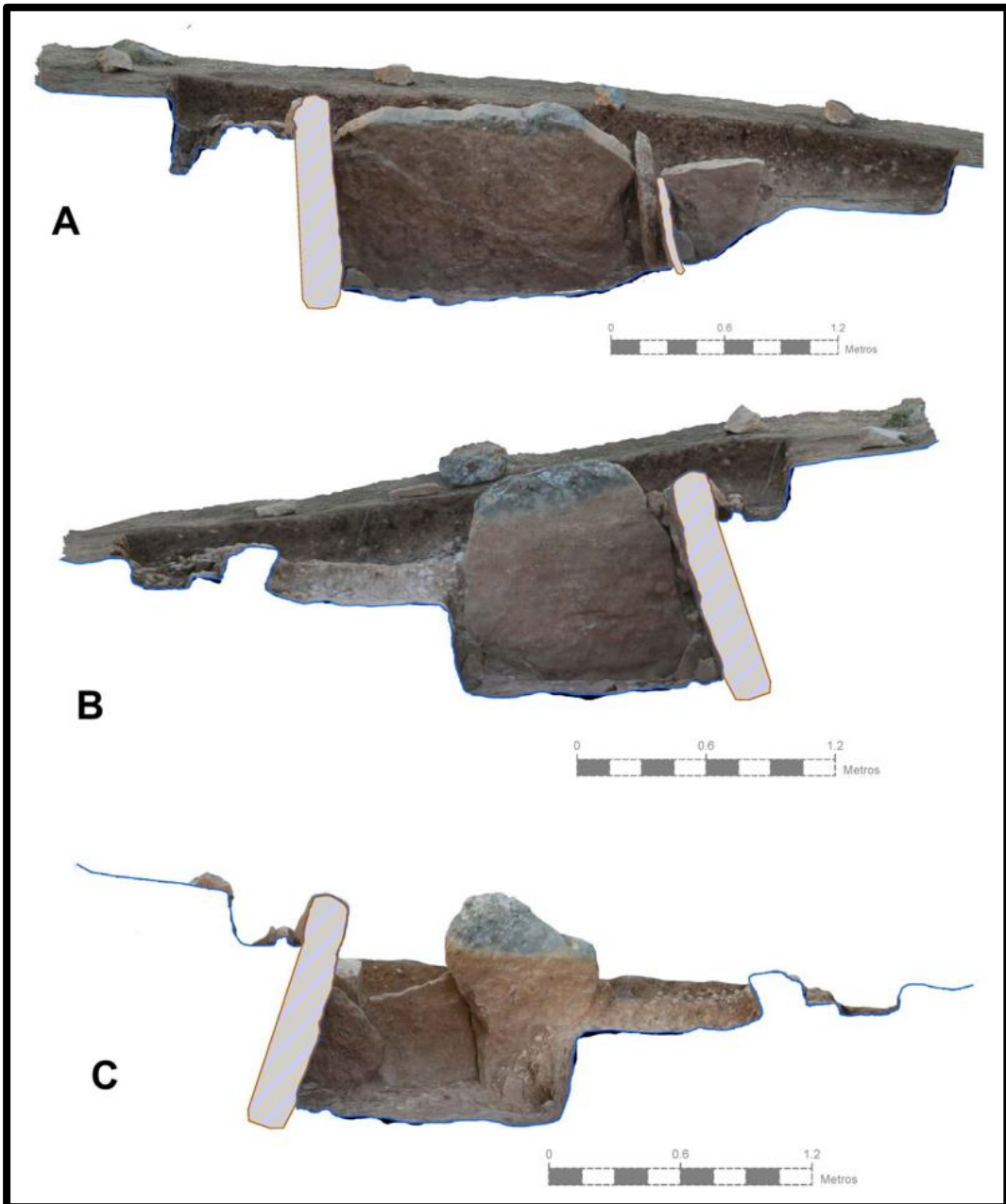


Figure 8. Image showing section-elevations drawn on a CAD software traced over section-elevation orthophotomosaics exported from a photogrammetry model (Benavides Lopez et al. 2016.)

As stated by Benavides Lopez *et al.*, “hand-drawn plans and sections no longer come up to the standards of precision achieved by the new methods in recording the real world more accurately”;¹¹⁷ a view which is supported by De Reu *et al.* who classifies drawings as “two-dimensional documentation, often biased by the interpretation of the archaeologist”.¹¹⁸

As opposed to this standpoint, Dell’Unto underlines the interpretative quality of a hand-drawing and firmly states that 3D models cannot be used to substitute these.¹¹⁹ As a matter of fact, he advocates for the complementarity of these two different sets of data which document different aspects of the same archaeological context and suggests that only when combined together they provide the most exhaustive tool for documenting a site.¹²⁰

2.2.2 Virtual interpretative 3D models: principles, methods and applications

On the other hand, interpretative 3D models aim to display those archaeological contexts missing from *in situ* remains which cannot be documented by reality-based modelling. Interpretative models can be understood as 3D representation displaying the synthesis of the multiple interpretations taking place throughout an archaeological investigation,¹²¹ such as:

- i. preliminary research (e.g. collection of legacy data),
- ii. excavation (e.g. documentation of *in situ* and excavated remains through surface 3D models);
- iii. post-excavation (e.g. compilation of data, building of stratigraphic matrix, and consultation of parallel sources in the archaeological record).

The end result of this process would have to provide the information concerning how the reconstruction was carried out and for what purpose. Only in this way can interpretative models be used in support of archaeological research.¹²²

¹¹⁷ Benavides Lopez *et al.* 2016: 496.

¹¹⁸ De Reu *et al.* 2012: 1120.

¹¹⁹ Dell’Unto 2014: 152.

¹²⁰ Dell’Unto 2014: 152.

¹²¹ Dell’Unto & Landeschi 2022: 18.

¹²² Dell’Unto & Landeschi 2022: 22.

Furthermore, since a virtual reconstruction will always be considered as an approximation of the past, debates concerning its authenticity are being avoided as ‘false dilemmas’.¹²³ Alternatively, when dealing with such models, the transparency with which these processes take place is progressively becoming a key topic of discussion. This can be noticed in the literature, where topics concerning data transparency and reliability are frequently discussed. In the early 2000s, most of these models lacked data transparency, a limit that prevented their spread and inclusion within areas of archaeological research. Following a period of experimentation, different methodologies started being developed to better promote approaches and practices.¹²⁴

Due to a lack of standardization, methodological rigour was required. In 2006, the London Charter developed a set of objectives, principles and definitions concerning computer-based visualizations in the vast cultural heritage realm.¹²⁵ After five years the conditions of applicability of the London Charter specifically to archaeology considerably increased. This resulted in the development of the Seville Principles of Virtual Archaeology,¹²⁶ created to update the previous definitions, principles and objectives.¹²⁷ For the past 15 years, these established guidelines paved the way for the creation of formal methodologies of 3D reconstruction with the aim of enhancing the transparency and reliability of the data.¹²⁸

An example of this kind is the ‘Fuzzy Logic’ approach developed by Niccolucci and Hermon.¹²⁹ By employing a mathematical theory,¹³⁰ this approach provides the user with a numerical index estimating the reliability of an interpretative model. This numerical value would place the virtual reconstruction somewhere between archaeological reality (i.e. what was discovered) and pure modeler’s imagination (i.e. what is believed to be there with no solid proof).¹³¹

¹²³ Demetrescu 2015: 4.

¹²⁴ Dell’Unto & Landeschi 2022: 22.

¹²⁵ London Charter 2006.

¹²⁶ Seville Principles 2011.

¹²⁷ Dell’Unto & Landeschi 2022: 22.

¹²⁸ Dell’Unto & Landeschi 2022: 22.

¹²⁹ Niccolucci & Hermon 2010.

¹³⁰ Zadeh 1965.

¹³¹ Niccolucci & Hermon 2010: 34.

However, since the publication of the London Charter and the Seville Principles, the state of the field of research concerning virtual reconstructions did not change drastically.¹³² In this regard, one of the latest and most significant steps forwards towards the establishment of a formal language of transparent virtual reconstruction was put forward by E. Demetrescu in 2015. This approach, known as the ‘Extended Matrix’ aimed to achieve a method capable of tracking and publishing each step of the virtual reconstruction.¹³³ As suggested by its name, this approach finds its origin in Harris’ stratigraphic theory,¹³⁴ and builds its methodology over the consistent and standardized nature of single-context recording. The term ‘extended’ implies that this method does not only limit to record the superimposed SUs but also includes their hypothetical reconstructions known as Virtual Stratigraphic Units (USV – Fig. 9).¹³⁵ In this way, this extended stratigraphic matrix (Fig. 10) allows the user to record each step of the interpretative reconstruction allowing the model to be fully transparent and verifiable.

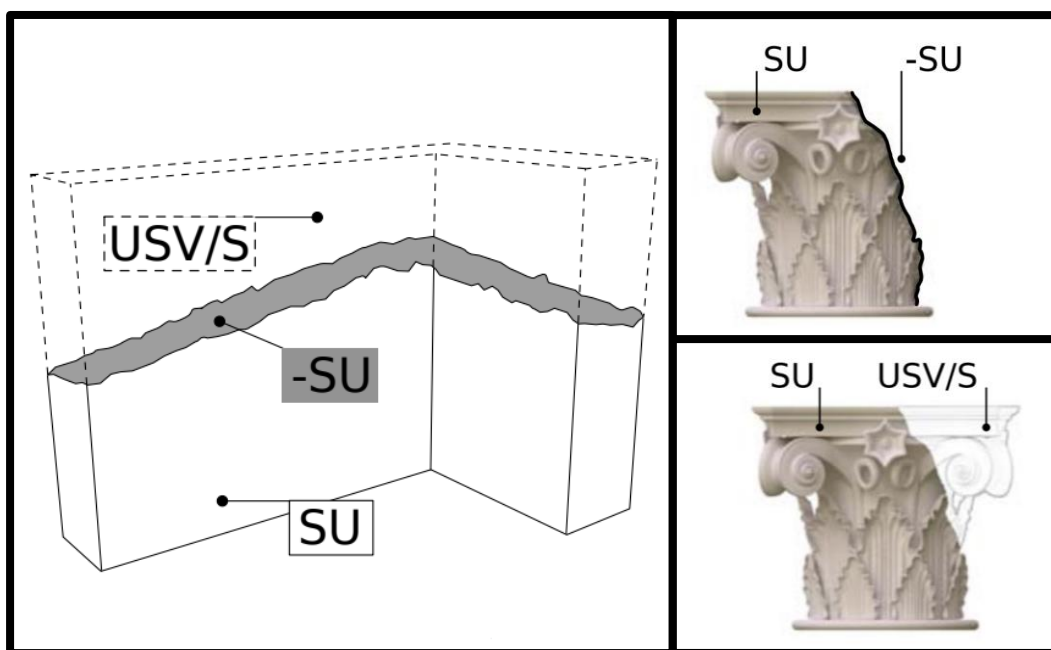


Figure 9. Image showing two examples of a Virtual Stratigraphic Unit (USV) (Demetrescu 2015: 5).

¹³² Demetrescu 2015: 4.

¹³³ Demetrescu 2015: 1.

¹³⁴ Harris 1979.

¹³⁵ Demetrescu: 4.

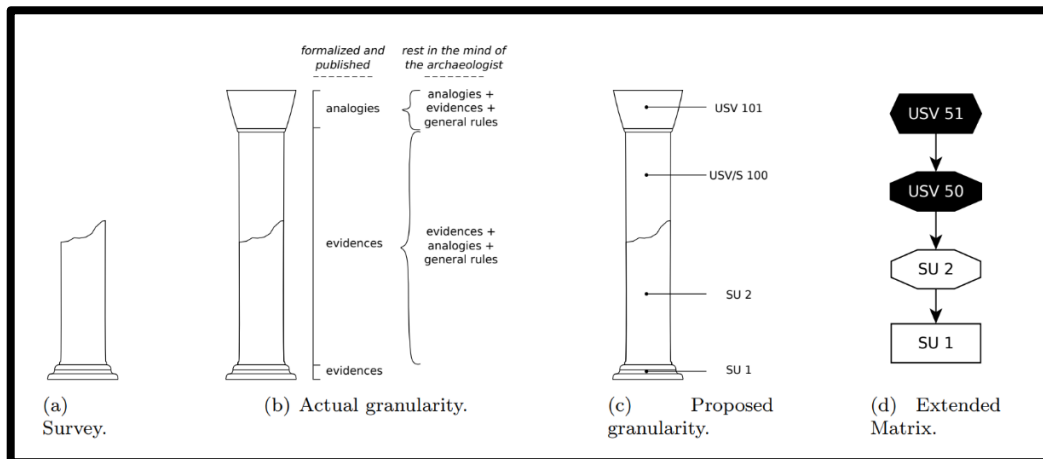


Figure 10. A graphic explanation of the *Extended Matrix principle* (Demetrescu 2015: 4).

Since then, the ‘Extended Matrix’ approach has been tested in several case studies.¹³⁶ A recent one is a joint Italian-Belgian research project, which adopted this methodology to virtually reconstruct the central hall of the Late Roman Villa in Aiano (San Gimignano, Italy). Here, a UAV-based photogrammetry survey was carried out to map the *in situ* remains of the villa.¹³⁷ The reconstructed surface of reality-based model, served as the starting point of this virtual reconstruction. Furthermore, the interpretative reconstruction was based on:

- i. the collapsed and dislocated remains documented throughout the archaeological excavation;
- ii. literary sources reporting theoretical building rules;
- iii. comparisons with similar sites in the archaeological record.¹³⁸

As can be seen in Figure 11 each reconstructed feature was documented through distinct USVs and their extended stratigraphic relationships were established through an extended stratigraphic matrix. This process restored the legibility of the archaeological remains and enhanced the understanding of the site, whilst preserving the intellectual transparency advocated by the London Charter.¹³⁹

¹³⁶ Dell’Unto & Landeschi 2022: 22.

¹³⁷ Ferdani *et al.* 2019: 7-9.

¹³⁸ Ferdani *et al.* 2019: 10-11.

¹³⁹ Ferdani & Petroni 2021: 22.

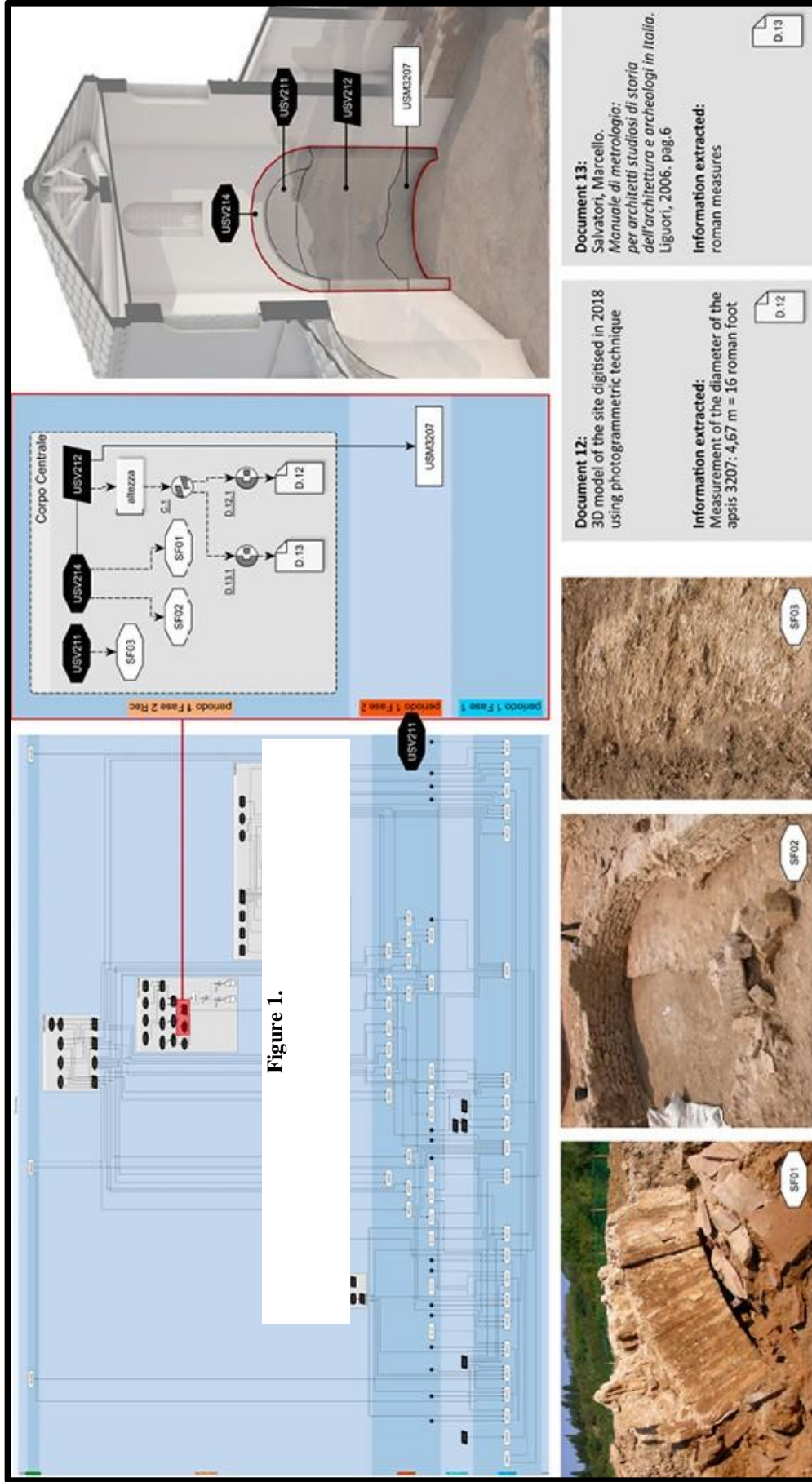


Figure 11. The extended matrix principle applied to the virtual reconstruction of a Late Roman Villa in Aiano, San Gimignano, Italy (Ferdani et al. 2019: 14).

Finally, in order to visually convey the transparency achieved through the extended matrix approach, the researchers decided to develop an alternative texture alongside the realistic one seen in Figure 12. For this reason, each SU and USV were assigned a specific colour-code carrying selected information employed during the reconstruction process (e.g. chronology and sources of reconstruction – Fig. 13). Thus, the viewer is able to engage with a semantic 3D schematic representation and can intuitively verify the interpretative choices of the archaeologists (Fig. 14).¹⁴⁰

On another note, the physical interaction between the public and an archaeological site is currently being challenged by virtual reality (VR) and augmented reality (AR) technologies.¹⁴¹ The potentials of virtual 3D reconstructions and visualizations over the public engagement has long been attested.¹⁴² In the early 2000s, in a phase of profound thrill and investigation of these technologies, most of the publications focused their efforts on computer graphics innovation and public engagement.¹⁴³



Figure 12. *Different views of the virtually reconstructed Late Roman Villa of Aiano (with realistic texture), San Gimignano, Italy (Ferdani et al. 2019: 16).*

¹⁴⁰ Ferdani & Petroni 2021: 22.

¹⁴¹ Grima 2019: 80.

¹⁴² Hermon *et al.* 2005; Williams *et al.* 2019.

¹⁴³ Dell'Unto & Landeschi 2022: 22.

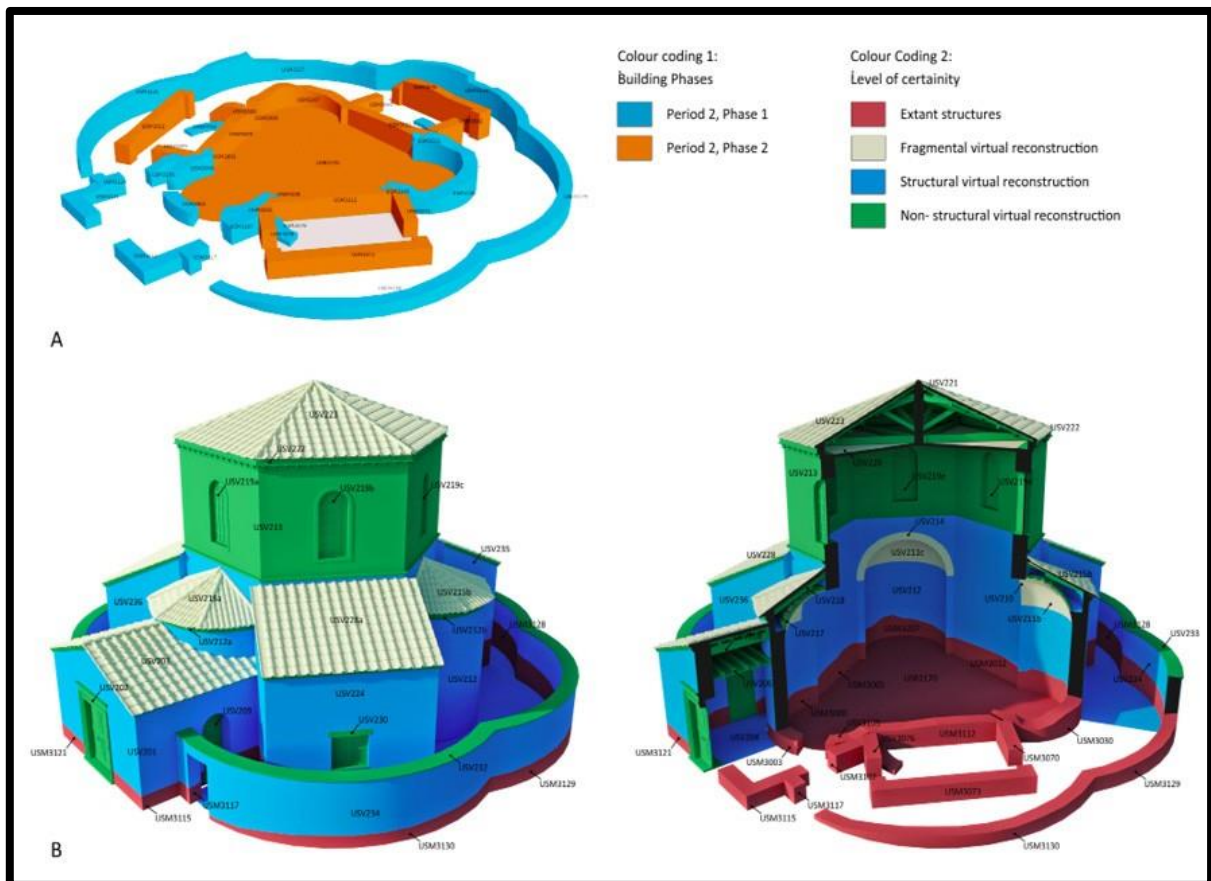


Figure 13. *The semantic 3D schematic representation of the virtually reconstructed Late Roman Villa of Aiano (with colour-coded texture), San Gimignano, Italy (Ferdani et al. 2019: 15).*

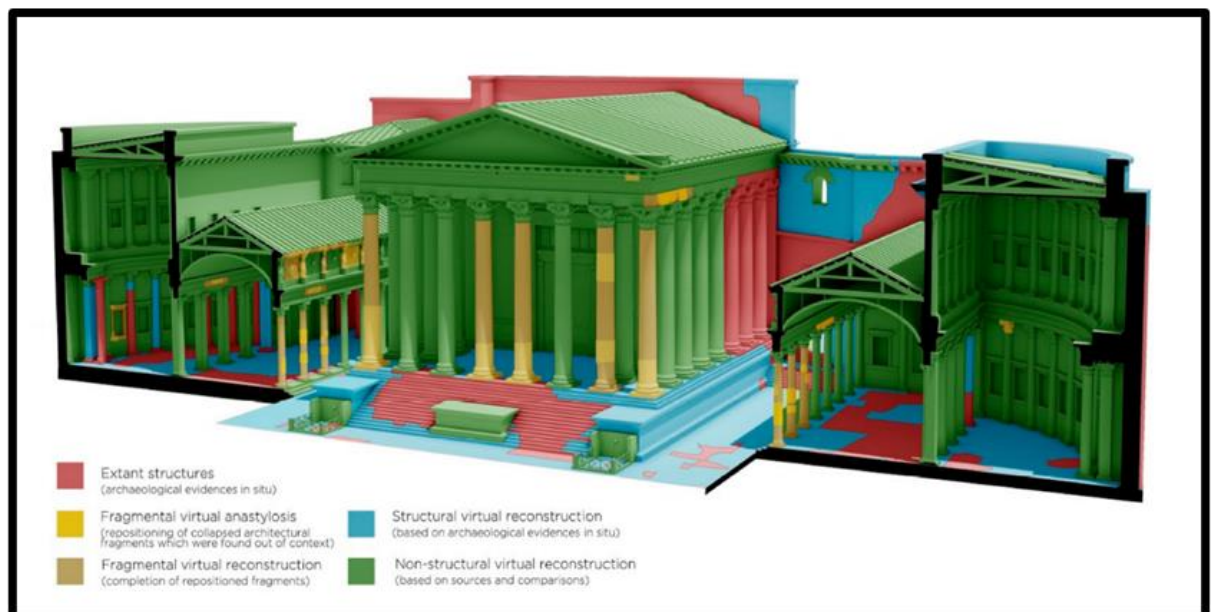


Figure 14. *Another example of transparency of the data through the colour-coding of the layers of virtual reconstruction (Ferdani et al. 2020: 139).*

Possibly due to a lack of standardized methodologies and transparent data, the increasing quantities of 3D data being published at the time was somehow not significantly impacting archaeological theory and methods.¹⁴⁴ The creation of an archaeological 3D model motivated solely by public engagement purposes can arguably be considered as a limited attempt at 3D reconstructing for 3D reconstruction's sake. Today, archaeologists can employ digital technologies to tackle new sets of archaeological research questions, as Frischer and Fillwalk's investigation over spatial relationships between the Ara Pacis and the meridian in the Campus Martius in Rome, investigated through computer simulations.¹⁴⁵

Finally, these technologies can be employed to challenge some past archaeological theories exploring new frontiers of archaeological investigation. An example of this can be found in Tilley's renowned phenomenological approach to the study of landscapes.¹⁴⁶ Today, an approach that thirty years ago was tackled through a philosophical approach is being challenged and re-explored by several scholars such as Mark Gillings and Gary Lock, employing 3D and GIS technologies.¹⁴⁷

2.3 The reconstructed sites: the discovery, location, and archaeology

This section aims to provide the reader with a brief contextual framework for each site that this research attempted to virtually reconstruct. For this purpose, this study chose local archaeological sites that were:

- i. discovered in the past two centuries;
- ii. documented through legacy data;
- iii. damaged or destroyed by past development.

In order to meet these requisites, the sites were to be located in an area both very archaeologically sensitive and also industrialized and overdeveloped. A suitable location for this purpose is that of Marsa, in the south-western end of the Grand Harbour (Fig. 15). Probably due to its favourable geo-morphological conditions, this area has been inhabited since Prehistory.¹⁴⁸

¹⁴⁴ Hermon 2008: 37.

¹⁴⁵ Frischer and Fillwalk 2013.

¹⁴⁶ Tilley 1994.

¹⁴⁷ Gillings 2012; Lock & Pouncett 2017.

¹⁴⁸ A concentration of Neolithic Temples were discovered here (Kordin i-iii) – Trump & Cilia 2008.

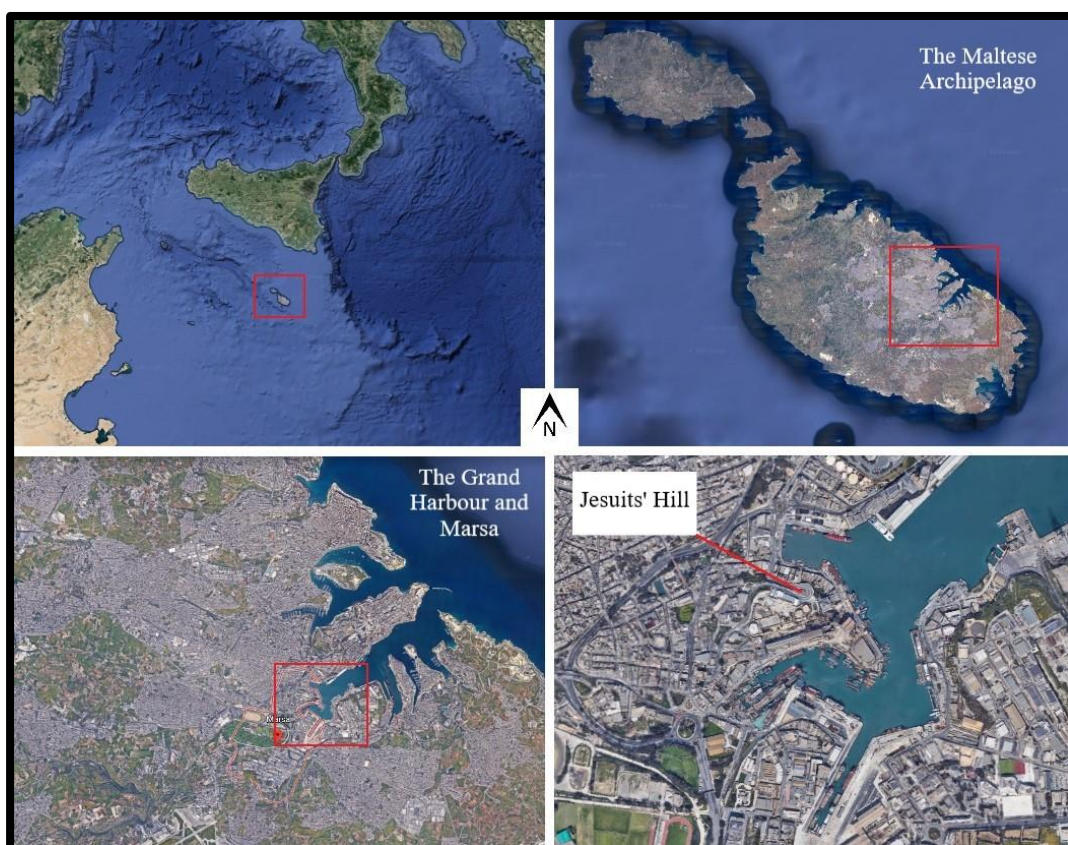


Figure 15. Google Earth Imagery showing the location of the Jesuits' Hill in present day Marsa, Malta (Google Earth 2022).

In Punic-Roman times, it was potentially the location of a port-city of some importance, as suggested by the abundant Classical archaeological remains discovered throughout the past two centuries, such as port facilities, colonnaded structures, *thermae*, and a necropolis.¹⁴⁹ The latter included a number of single rock-cut tombs and small catacombs, located on an elevated strip of land which separated two small inlets. Previously known as ‘Il-Qortin’, this slope has been referred to as ‘Jesuits’ Hill’ since the 17th century, when the *commendatore* and vice chancellor of the Order of St John Gian Francesco Abela (1582-1655) donated part of this land¹⁵⁰ to the Valletta Jesuit College.¹⁵¹

Since the 18th century this very archaeologically sensitive area has been considerably affected by industrialized development (e.g. maritime and naval

¹⁴⁹ Gambin 2005(b); Buhagiar 2014: 135.

¹⁵⁰ Where Abela had built his own residence.

¹⁵¹ Buhagiar 2014: 135.

activities), and with the outbreak of World War II, was subject to heavy aerial bombardments.¹⁵² In the 1950s, the location of the Jesuits' Hill was chosen for the building of a large power-generating plant. The construction of underground bomb-proof control rooms and tunnels resulted in the hollowing-out of a big portion of the hill, ultimately wiping out the archaeology surviving in this area, including the sites discussed below.¹⁵³

2.3.1 Site A – The Early Christian Hypogeum III on Jesuits' Hill, Marsa

Between 1647 and 1969, five distinct hypogea were discovered and investigated on Jesuits' Hill at Marsa. By collecting and summarizing all the scattered knowledge about these burial complexes, Buhagiar provides a comprehensive description of each of them in his essay 'The Jesuits Hill Archaeological Site on the Grand Harbour'.¹⁵⁴ The first site chosen for this study is Buhagiar's 'Hypogeum III', arguably the largest catacomb of the five, which, as the rest of them, had been impacted by the industrial development on the Hill.

The discovery, location and state of preservation of the site: discording sources

The discovery of Hypogeum III was reported by the then Vice-President of the Archaeological Society of Malta, C. A. Wright in the 5th September 1874 issue of The Malta Times and United Service Gazette (MTUSG). In this newspaper article Wright recalls how, accompanied by a friend, he arrived on the site of the discovery "Tuesday last", thus the 1st of September 1874.¹⁵⁵ However, both Cesare Vassallo (the then Librarian and Keeper of Antiquities at the National Library of Malta) and Antonio Annetto Caruana – a prominent pioneer-archaeologist who succeeded Vassallo in the same role at the National Library – provide different dates for this event. The former, who also investigated the site, states that the discovery of this

¹⁵² Two of the three Kordin Neolithic Temples (i-ii) were completely destroyed by WWII air raids – Trump & Cilia 2008.

¹⁵³ Buhagiar 2014:135.

¹⁵⁴ Buhagiar 2014: 135.

¹⁵⁵ Wright 1874: 2.

catacomb took place at the end of May 1874,¹⁵⁶ while the latter refers to August of the same year.¹⁵⁷

Just as the date of its discovery remains unclear, its precise location remains undetermined. According to Wright, the discovery occurred following a development-led excavation of a field owned by Mr Nicola Sacco which was located “on the side of the Jesuits’ Hill”.¹⁵⁸ Although both Vassallo¹⁵⁹ and Caruana¹⁶⁰ narrow down the site’s location to the “northern side” of the hill, this still remains a quite broad one. Unfortunately, after its discovery and speedy documentation in 1874, this site has never been re-located, and even Themistocles Zammit failed to locate this catacomb in 1911.¹⁶¹

The loss of the site resulted in very limited knowledge about its state of preservation. At the moment of Wright’s arrival on site, workmen were in the process of removing the human remains, pottery sherds, and debris and Mr Sacco intended deepening the excavation to convert the catacomb into an extensive reservoir.¹⁶² Nevertheless, the owner was cooperative and halted the works to allow Wright and his companion to take measurements and draw a survey of the underground chambers.¹⁶³ Following this ‘rescue’ documentation, it is not clear if the owner proceeded with the deepening and re-adaptation of this underground burial complex into a reservoir. By referencing Vassallo’s report,¹⁶⁴ Buhagiar states that this catacomb was walled up shortly after Wright’s visit.¹⁶⁵ However Caruana, who writes about this site eight years later, claims that the Hypogeum had been indeed converted into a water reservoir.¹⁶⁶ Most probably, the shaft and doorway of this catacomb – both successfully surveyed in Wright’s plan (Fig. 16) – were walled up, while the circular aperture recorded by Wright on the roof of the burial complex was re-adapted as the reservoir’s opening.

¹⁵⁶ Vassallo 1876: 59.

¹⁵⁷ Caruana 1882: 109.

¹⁵⁸ Wright 1874: 2.

¹⁵⁹ Vassallo 1876: 59.

¹⁶⁰ Caruana 1882: 109.

¹⁶¹ Zammit 1909: 149.

¹⁶² Wright 1874: 2.

¹⁶³ Wright 1874:2.

¹⁶⁴ Vassallo 1876: 59.

¹⁶⁵ Buhagiar 2014: 139.

¹⁶⁶ Caruana 1882: 109.

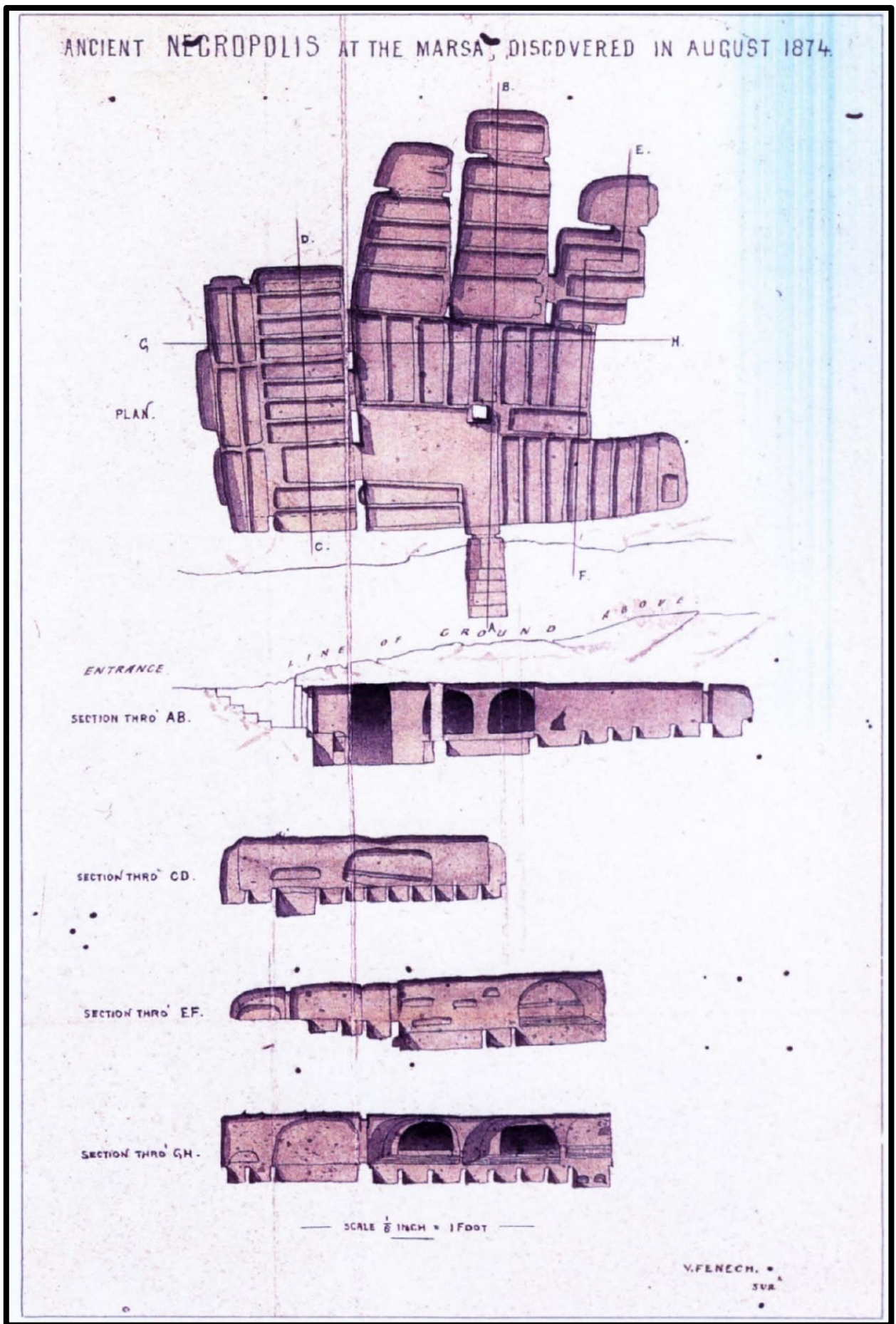


Figure 16. The survey of showing the plan and four section-elevations of the Marsa Hypogeum (Wright 1874).

Today, there are very little chances that this catacomb-reservoir still survives *in situ*. Extensive portions of the bedrock levels of this area were cut to accommodate the abovementioned power station, some residential and industrial buildings and a road, Triq Belt il-Ħażna. This road, which is probably datable to the construction of the power plant, leads to the top of the Jesuits' Hill and extensively cuts through the bedrock. From the bedrock visible in section, a potential truncated burial chamber can be identified (Fig. 17).



Figure 17. Photo showing the burial chamber truncated in section visible from Triq Belt il-Ħażna on Jesuits' Hill in Marsa (Google Earth 2022).

The site

Wright's newspaper report was correlated to a drawn survey (Fig. 16) which was last seen in 1982 at the National Museum of Archaeology in Valletta.¹⁶⁷ This document shows a plan view of the full extent of the hypogeum, and four section/elevations spaced evenly throughout the chambers. One of these (section AB) also records the natural slope of the Jesuits' Hill's bedrock. The drawing is signed V. Fenech (SUR), possibly Wright's companion mentioned above. Although Wright's legacy data represents the only textual and visual documentation sources of this catacomb, Buhagiar reviews it as unclear and challenging to interpret.¹⁶⁸

Access to the burial complex (Fig. 18 – green rectangle) was located on the eastern side,¹⁶⁹ by a narrow flight of six narrow steps, leading to a small arched doorway. The floor of this catacomb is found one meter below the level of doorway and extends over a L-shaped plan. The area is divided in two irregularly-sized chambers. The first one, Chamber A (Fig. 18 – red rectangle), is located right in front of the entrance and is squarish in plan (ca. 5.5m wide and 4.8m long). The second one, Chamber B (Fig. 18 – blue rectangle) is located adjacent to the South of Chamber A and has a rectangular plan (ca. 3.3m wide and 6.2m long). The two chambers are separated by a solid but thin wall pierced by a doorway – which grants access from A to B – and two 'window-like' archways. In both chambers, the "solid roof" is 1.83m high and is supported by a "square pillar" located at the entrance.¹⁷⁰

Wright describes how both these chambers were "pitted with rectangular tombs of various sizes, cut in the rock and lying close to each other"¹⁷¹ – 15 in Chamber A and 17 in Chamber B. Buhagiar understands Wright's description of the graves as "forma or floor tombs" but raises concerns over the reliability of his observations as the clustering of these graves are otherwise unknown in the Maltese archaeological record. Therefore, Buhagiar offers two plausible explanations, by interpreting these graves as mutilated baldacchino-tombs or the so called 'table-

¹⁶⁷ Buhagiar 2014: 139.

¹⁶⁸ 2014: 139.

¹⁶⁹ Given the absence of a north point on the survey, this is the only informative element which allows to understand the orientation of the site.

¹⁷⁰ Wright 1874: 2.

¹⁷¹ 1874: 2.

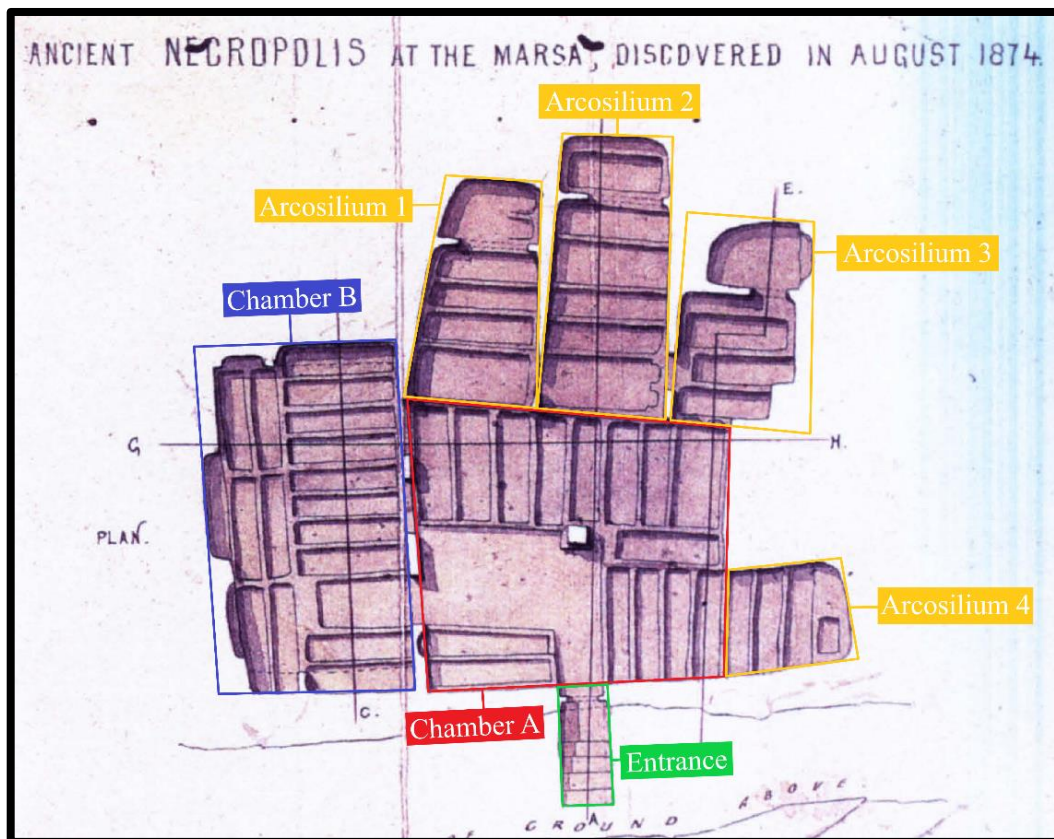


Figure 18. Detail of from Fig. 16 showing the different features of the Hypogeum.

tombs' (rock-cut sarcophagi).¹⁷² In addition, Chamber A also shows four distinct barrel-vaulted *arcosilia* (Fig. 18 – yellow rectangles) – which Buhagiar describes in detail – each containing other floor tombs, including a child-burial (Arcosilium 4). A particular characteristic of these distinct burial spaces is their inaccessibility through dedicated corridors, as instead of what can be observed in other catacombs on the island.¹⁷³ On the contrary, the only way to access these *arcosilia* would be to step over the tombs in Chamber A. This characteristic could suggest that these graves could have been added to this hypogeum at a later stage, once the burial accommodation was limited. This possibility is also proposed by Wright himself, when commenting over three shallow recesses located on the side walls of Chamber B, potential preparatory extensions to the catacomb.¹⁷⁴

¹⁷² Buhagiar 2014: 141.

¹⁷³ E.g. St Aghata and St Paul's catacombs in Rabat.

¹⁷⁴ Wright 1874: 2.

Except for an epigraphic stele¹⁷⁵ discovered in the neighbourhood of Hypogeum III¹⁷⁶ and datable to the Pre-Constantine period,¹⁷⁷ no other material culture was recovered from this site.¹⁷⁸ Wright mentions two “heart-shaped bronze buckles and some earthenware lamps”, one of which was “in the form of a star”.¹⁷⁹ Buhagiar associates the latter with Hayes Type IIA lamp, and the ‘star’ to the Chi-Rho, a symbol found within the Early Christian funerary repertoire, which could suggest a 4th-5th century date.¹⁸⁰

2.3.2 Site B – *The Roman Horrea on the Jesuits’ Hill, Marsa*

The discovery, location and state of preservation of the site

The second site chosen in Marsa consists of structural remains thought to be part of massive Roman warehouses,¹⁸¹ discovered between 1766 and 1768, following a development project aimed to expand and upgrade the Marsa harbour. These public works, ordered by the Grand Master of the Order of St John of the time, Manuel Pinto da Fonseca (1681 – 1773), included the:

- i. dredging and desiccation of part of the marshes to make the Marsa Grande navigable (Fig. 19a);
- ii. building of a water channel to prevent stagnation and improve the healthiness of the waters (Fig. 19b);
- iii. building of a new dock on the northern side of the Jesuits’ Hill (Fig. 19c);
- iv. building a small basin enclosed by a land bridge (Fig. 19d);
- v. construction of a wide rectilinear road (Fig. 19e).¹⁸²

¹⁷⁵ This rectangular stele with a pyramidal top was “set-up by the citizens to the well-deserving Flavius Titus aged 55 years. Buhagiar interprets it as a Roman funerary headstone of a forma or floor-tomb, thus probably related to Hypogeum III (2014: 136).

¹⁷⁶ Discovered beneath 121cm of soil, while excavating Mr Sacco’s property – Wright 1874:2.

¹⁷⁷ As suggested by F. Grossi Dondi – Bellanti 1924.

¹⁷⁸ The stele was donated by Mr Sacco to the cabinet of antiquities of the Valletta National Library and was then transferred to the National Museum of Archaeology in 1956. Buhagiar re-located it in 2012, broken in two pieces and severely upbraided – 2014: 136.

¹⁷⁹ Wright 1874: 2.

¹⁸⁰ Buhagiar 2014: 142.

¹⁸¹ Gambin 2005(b): 50.

¹⁸² Barbaro 1794: 3.

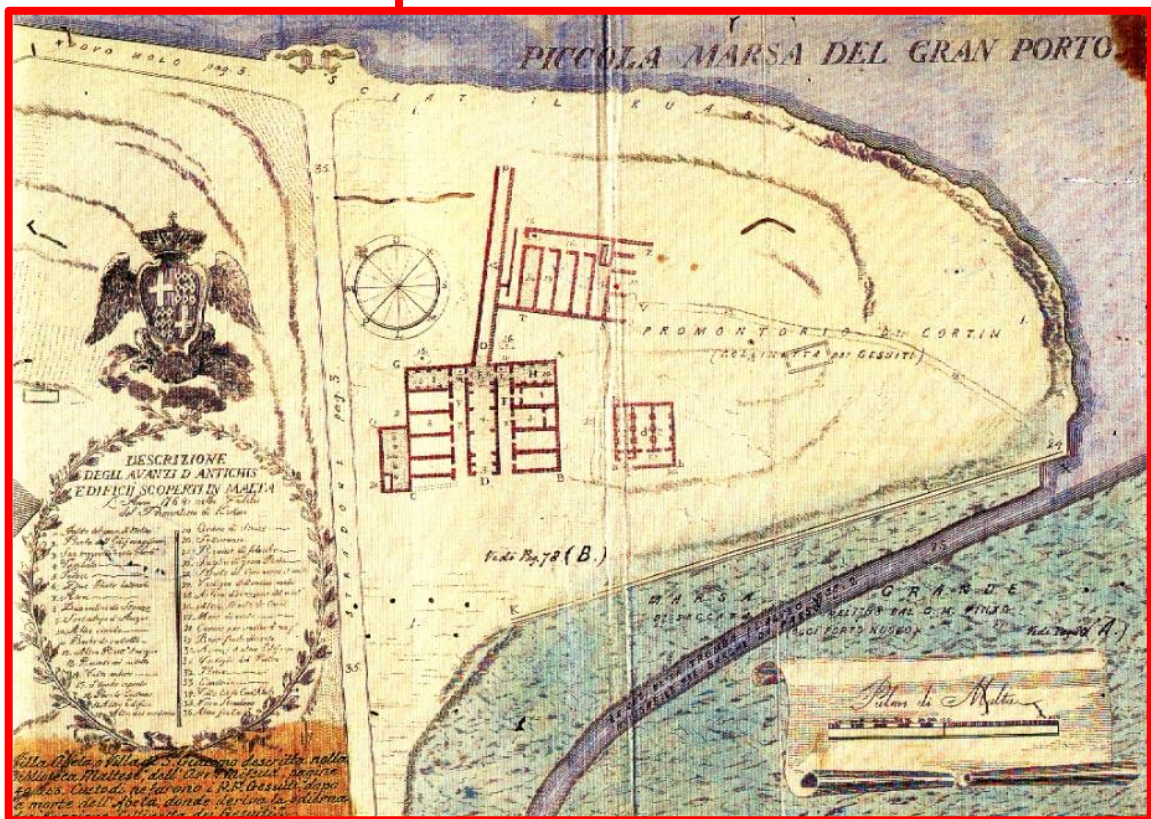
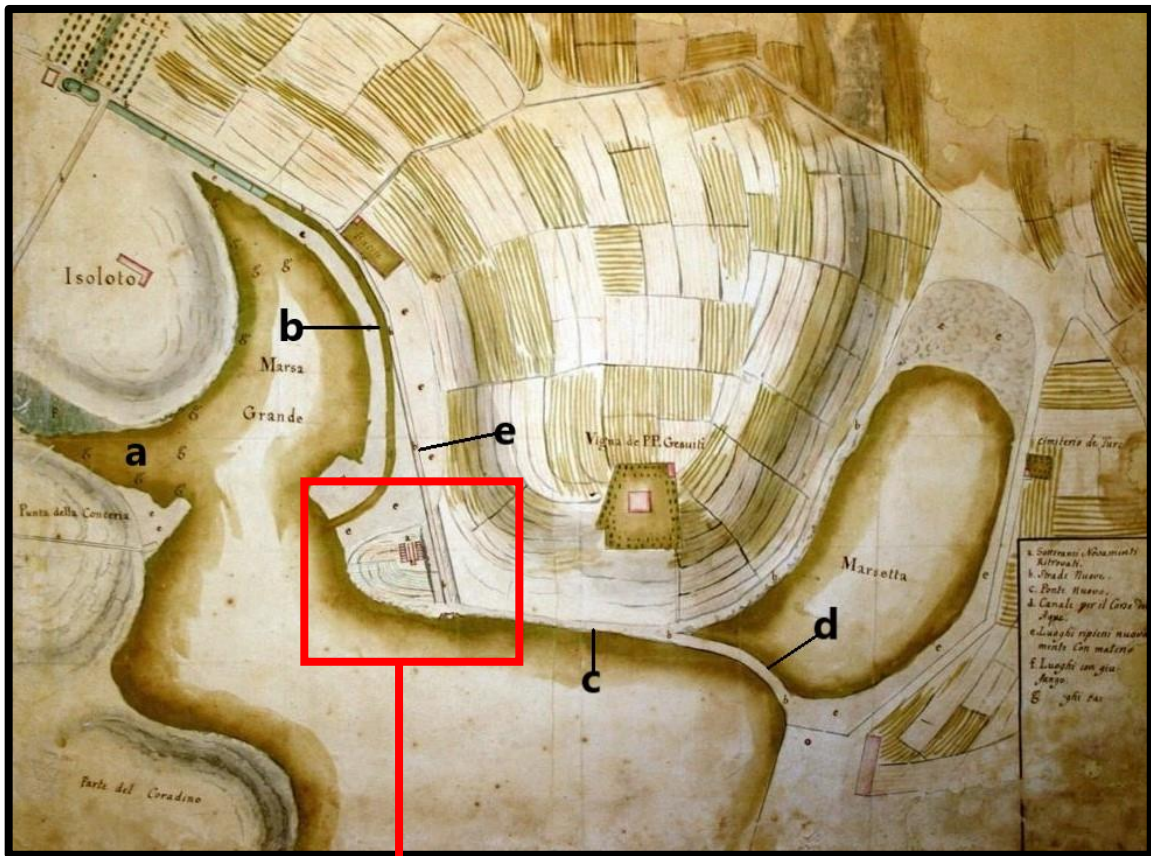


Figure 19. Figure showing scan of a 18th Century survey showing the development project aimed to expand and upgrade the Marsa harbour (figure above – National Library of Malta).

Figure 20. Figure showing a scan of Barbaro's survey of the Horrea. Red rectangle shows the approximate location of these remains from on the survey sheet in Fig. 19 (figure below – Barbaro 1794).

The archaeological remains in question were discovered while cutting of a portion of bedrock located over the eastern promontory of the Jesuits' Hill known as Ta' Ċelġu, where the abovementioned road was planned.¹⁸³ The Maltese marquis Carlo Antonio Barbaro (1720 – 1798), had the occasion to explore the site and took some notes and measurements of the archaeological ruins. Twenty-six years later, the Grand Master of the time, Emmanuel de Rohan-Polduc (1725 – 1797) entrusted Barbaro with the writing of a historical and descriptive account of these ancient structures.¹⁸⁴ From Barbaro's report and survey plan (Fig. 20) the abovementioned road can be seen passing just to the side of the archaeological remains, therefore not directly impacting them. Unfortunately, Barbaro reports how it was decided to extend the flattening of the hill from this road to the coastline, resulting in the obliteration of these ancient standing buildings.¹⁸⁵ In a bitter statement, he recalls:

“Ne' in questo scavo s'ebbe alcun riguardo alla loro conservazione, non senza meraviglia delle persone di buon senso, che in un paese così culto siesi caduto in siffatto errore, atterrando in pochi mesi un monumento, che ad onta del tempo edace si mantenne per tanti secoli, e del quale in qualunque altra parte si sarebbe avuta la maggior cura di conservar la memoria.”¹⁸⁶

Since Barbaro's report, no update over the state of preservation of this site is found in the literature. One aerial photograph shot in 1927 (Fig. 21) shows industrial structures built over the location where Barbaro surveyed the *horrea*.¹⁸⁷ Although it is likely that the building of these structures entailed a certain degree of rock cutting possibly obliterating the remains of the ancient structural foundation cuts, from this aerial picture the flanking road appears to still be in place. By tracing Barbaro's plan and overlaying it over this photograph, it was possible re-establish the *horrea*'s location (Fig. 22).

As mentioned above, in 1953, the Jesuits' Hill was the chosen location for the construction of national power plant. Eventually, the Marsa Power Station was

¹⁸³ Bonanno 2005: 238; Barbaro 1794: 3.

¹⁸⁴ Barbaro 1794: XVII.

¹⁸⁵ Barbaro 1794: 47-48.

¹⁸⁶ Translated as: “During these works, no care was given to the conservation of these (remains), unsurprisingly for the people of good common sense, that in such a cultured country such a mistake happened, wiping out a monument that survived so many centuries, and that in any other place, more care would have been given to preserve its memory.” – Barbaro 1794: 47-48.

¹⁸⁷ National Collection of Aerial Photography (NCAP) website.



Figure 21. *Aerial photograph shot over the Jesuits' Hill in 1927 (National Collection of Aerial Photography Website).*

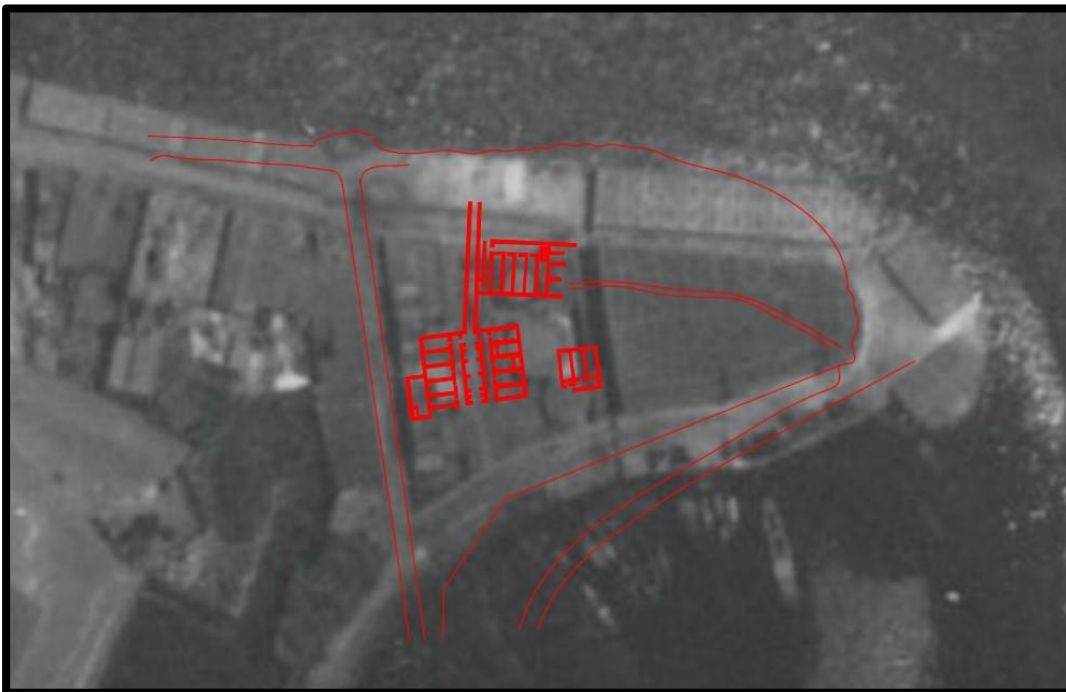


Figure 22. *Overlay of Barbaro's plan (traced on CAD) over Fig. 21 (screenshot by the author).*

switched off in 2014 and after four years it was totally dismantled (Fig. 23).¹⁸⁸ Today, open-access satellite imagery, shows a large portion of exposed bedrock (Fig. 24). The same overlaying exercise shows how the location of the *horrea* has now been cleared by modern construction (Fig. 25). Although with low chances of success, an archaeological survey of the exposed bedrock could possibly identify some undocumented foundation cuts related to the archaeological structures.

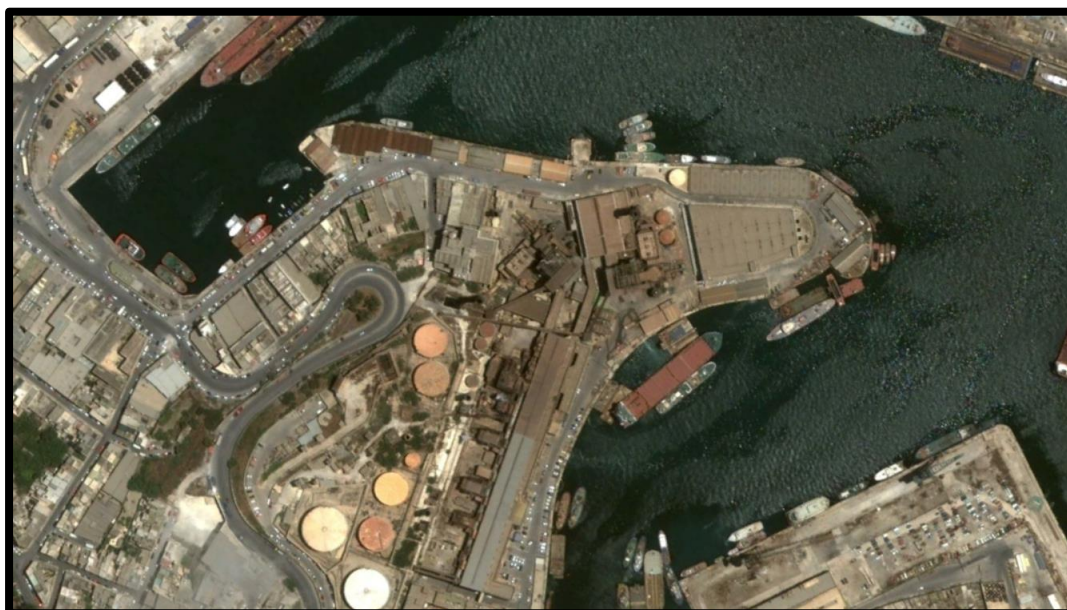


Figure 23. Screenshot from Google Earth showing the state of the Marsa Power Station when it was switched off in 2014 (Google Earth 2014).

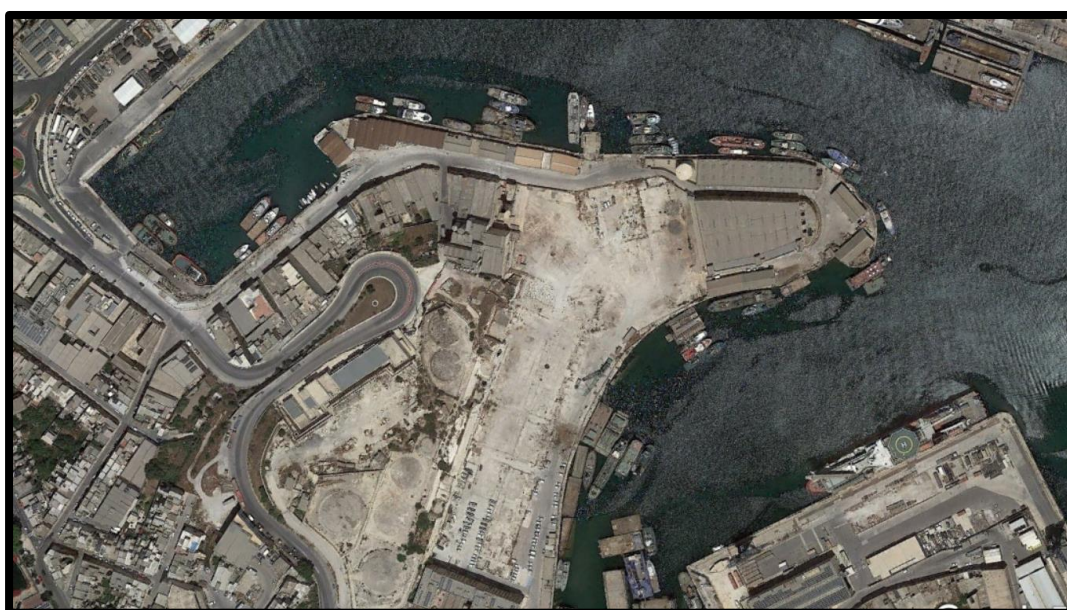


Figure 24. Screenshot from Google Earth showing the current state of the demolished Marsa Power Station (Google Earth 2021).

¹⁸⁸ EneMalta website 2018.



Figure 25. *The same overlay exercise of Fig. 22 was carried out over the 2022 Google Earth screenshot of Fig. 24 to estimate the location of the destroyed Horrea (screenshot by the author).*

The site

Although Barbaro admits his own limited knowledge over the studies of antiquities,¹⁸⁹ he was capable of presenting a detailed and consistent written description and a drawn survey of these archaeological structures (Fig. 26). His publication ‘Degli Avanzi d’Acluni Antichissimi Edifizi Scoperti in Malta l’Anno 1768’ constitutes the only surviving first-hand documentation of this site.¹⁹⁰ The site is described and discussed in the sections II and III of his work, concerning the standing structures and corresponding underground features respectively.

The standing archaeology consisted of buildings constructed mainly using “*grosse pietre*” which were 180-240cm long and 50cm large and wide. These likely Roman ashlar blocks were found connected to each other with mortar and placed into a foundation cut in bedrock.¹⁹¹ The walls of these structures survived in relatively good conditions to an average height of approximately 210cm. Barbaro surveyed the extents of these, recognizing three distinct structures:

- i. the “main building”;
- ii. the “second building”;
- iii. and the “third building”.

The first one (Fig. 26 – n.2), described as the largest of the three, was spread over an oblong quadrilateral area of 24.7m in length (Fig. 26 – A-B) and 34.3m in width (Fig. 26 – A-C). The main doorway (Fig. 26 – D) granted access to an arched vestibule which led to a rectangular porch (Fig. E). On the opposite side of this porch stood two doorways (Fig. 26 – M and L) from where it was possible to access two symmetrical foyers (Fig. 26 – F) which extended behind the walls of the main arched corridor. From these two *atrii* it was possible to access five equally-sized arched rooms (Fig. 26 – H), which Barbaro interprets as storage places. Close to the porch (E), stood the remains of an ancient vault built with rustic masonry and pozzolana (Fig. 26 – O) which functioned as an exit to a road. This was cut into the bedrock and flanked on both sides by ashlar blocks. This passage extended down

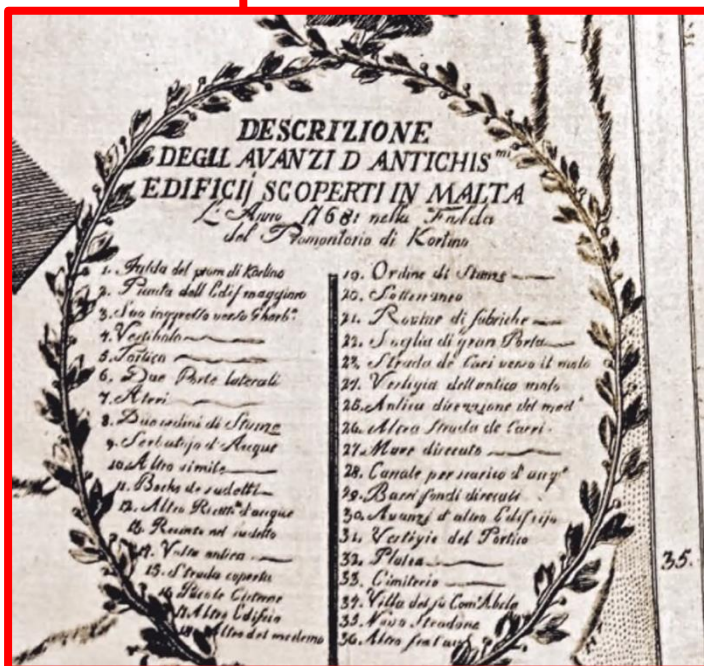
¹⁸⁹ Barbaro 1794: XVII.

¹⁹⁰ Gambin 2005(a): 121-122.

¹⁹¹ Barbaro 1794: 3.



Figure 26. Photo from C. A. Barbaro's essay showing his survey of the Horrea on the Jesuit's Hill. (Barbaro 1794: Tav. 1).



the natural slope of the hill, ending at close proximity to the north-eastern coastline (Fig. 26 – P).¹⁹²

The remains of the second building were located on the right hand side of this sloping road (Fig. 26 – n.17). Its architectural outline resembles the “main building” and suggested it was probably another warehouse. However, Barbaro’s report shows a number of structural differences to the former. Although, this building appears smaller in size,¹⁹³ the storerooms are preceded by a rectangular atrium and are slightly longer than the ones in the first warehouse. The distinctive feature of this building is a large doorsill slab, located in a room at the east of this warehouse (Fig. 26 – V) which was meant for the passage of carriages.¹⁹⁴ Barbaro makes this assumption after discovering set of cart ruts running from just outside the doorsill (V) down to the southern tip of the promontory (Fig. 26 – X). According to Barbaro and Abela¹⁹⁵ this point (X) coincides with the location of the ancient quay, composed by large ashlar blocks, which extended north-west towards the “main” *horreum*.¹⁹⁶ Therefore, these ruts could have allowed the loading and unloading of cargo from the dock to the storerooms.

Ultimately, the third and smallest building consisted of a substructure divided in three equal rooms and was aligned to the south-east side of the largest warehouse (Fig. 26 – n.30). One of these underground rooms (Fig. 26 – c) was found filled with several intact amphorae which did not show any sign of usage, along with several fragments of pottery and glass unguentaria. Given these finds, Barbaro assigns a funerary meaning to the underground rooms of this building.¹⁹⁷ Today, these finds, which were drawn in detail by Barbaro (Fig. 27), are identified with the Byzantine transport amphorae ‘Spatheion’ and ‘Keay XXV’ (Fig. 28).¹⁹⁸ Beyond providing information over the dating and maritime connectivity, these amphorae indicate how this building might have also served as a storage facility, probably

¹⁹² Barbaro 1794: 4-5.

¹⁹³ Some of the walls of this building suggest it might have extended further – Barbaro 1794: 5.

¹⁹⁴ Barbaro 1794: 5.

¹⁹⁵ Abela 1647: 16.

¹⁹⁶ Barbaro 1794: 5.

¹⁹⁷ 1794: 6.

¹⁹⁸ Gambin 2005(a): 135; Bruno & Cutajar 2013: 21-22.

reutilizing a previous rock-cut funerary chamber.¹⁹⁹

In 'Section III' Barbaro describes four distinct water reservoirs, all equipped with well-heads. The largest one was located adjacent to the north-western wall of largest *horreum* (Fig. 26 – n.21) and resembled a cistern discovered at the Roman Villa of Ta' Kaccatura in both style and size.²⁰⁰ The others were found beneath the storerooms (Fig. 26 – nos. 9-10; 20) and scattered around the site (Fig. 26 – n.16).



Figure 27. Photo from Barbaro's essay showing the amphorae drawn by Barbaro (Barbaro 1794: Tav IV).

¹⁹⁹ Barbaro 1794: 9; Gambin 2005(a): 122.

²⁰⁰ See Bonanno 2005: 107.



Figure 28. Photos showing a 'Spatheion' (left) dredged from the seabed of the Grand Harbour and a 'Keay XXV' (right) from the Xlendi wreck on display at the Gozo Archaeology Museum (Gambin 2005: 135 – Fig. 4.34).

2.3.3 Site C – The Punic Building in Żurrieq

As will be explained below (Chapter 5), this study entailed the virtual reconstruction of a site documented by legacy data which, unlike the former two, was not totally obliterated in the past. Following these requisites, the third site was identified in the village of Żurrieq, located in south-west Malta, and surviving incorporated within Early Modern town houses (Figs. 29-30).

The site consists of a wall-alignment made of ashlar blocks (Fig. 31) and a square plan structure topped with a characteristic ‘Egyptianizing’ cornice (Fig. 32-33). While the former is visible from a narrow street located behind the Parish Church of St Catherine (Triq il-Karmnu) the latter is located in the back garden of the *domus curialis*, accessible by appointment from the same street.

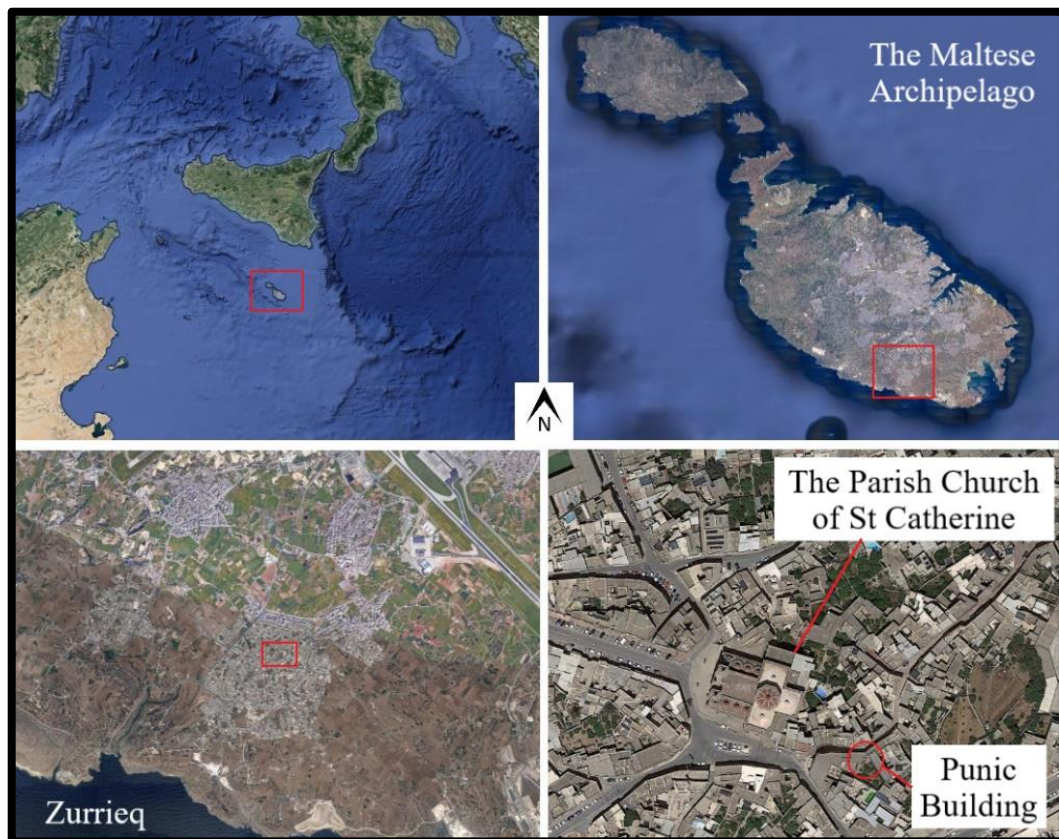


Figure 29. Google Earth Imagery showing the location of the Punic Building in the town of Żurrieq in South West Malta. (Google Earth 2022).

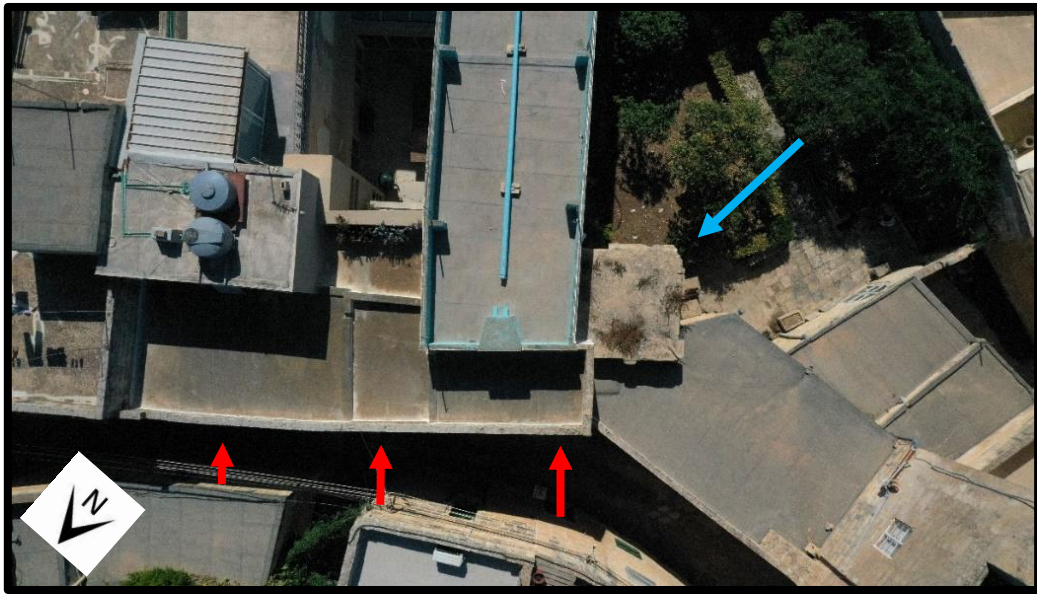


Figure 30. UAV aerial photograph showing the location of the tower-like structure in the garden of the Parish office (blue arrow) and that of the ashlar wall in Triq Karmnu (red arrows) (photo by the author).



Figure 31. Photo showing the ashlar masonry wall in Triq Karmnu (Wikimedia).



Figure 32. UAV aerial photograph showing the tower-like structure located in the garden of the Parish office (photo by the author).



Figure 33. Photo showing the profile of the Egyptianizing cornice topping the tower (photo by the author).

The earliest mention of this building occurred in 1680 by Bishop Jeronimo de Molina and was visited by the French painter and *Grand Tour* traveller Jean-Pierre Houël in 1776.²⁰¹ A written description and two illustrations were included in Houël's '*Voyage Pittoresque de Sicile, Malte et Lipari*', published in 1787. Already by that time, these remains were incorporated within the Early Modern buildings of the chaplain's house. Houël took measurements of the structures and drew a basic survey of the plan of the site along with a detailed section of the distinctive cornice. This plan is included in a watercolour of the house, which he depicted omitting the modern masonry (Fig. 34).²⁰² The modern clerical buildings were also omitted in another illustration of this site, today exhibited at the State Hermitage Museum in Saint Petersburg, in which he depicts the building from a different observation point (Fig. 35).²⁰³ Houël interprets them as the remains of a Greek domestic building,²⁰⁴ a view also shared by A. A. Caruana who inspected the site in 1882. Although Caruana reports the disappearance of the cornice documented by Houël, he otherwise found the site in "complete preservation".²⁰⁵

A few years later, in 1885, this site featured in a Phoenician art-historical publication by Perrot and Chipiez, who praised Houel's observation and artistic skills, but corrected the Greek interpretation in favour of a Phoenician origin. Following this, the site was also visited by Mayr in 1909²⁰⁶ and Ashby in 1915,²⁰⁷ both confirming its Phoenician origins from an archaeological perspective. The first fieldwork investigations occurred in 1938 and 1964, both carried out by the National Museum of Archaeology, which aimed to provide a secure date for these structures. Although some Punic-Roman ceramics were collected from these digs, both excavations were not successful at providing stratigraphic layers.²⁰⁸ However, these excavations provided valuable archaeological documentation, such as a section-elevation of the tower-like structure's façade, which included the foundation blocks and the bedrock exposed by these archaeological interventions.

²⁰¹ Vella 2016: 7; Wettinger 1985: 144–45.

²⁰² Houël 1787: Pl. CCLIX.

²⁰³ Hermitage Online Catalogue 2022.

²⁰⁴ Houël 1787: 97.

²⁰⁵ Caruana 1882: 94.

²⁰⁶ Mayr 1909: 89-90.

²⁰⁷ Ashby 1915: 49.

²⁰⁸ Gouder 1991: 17.

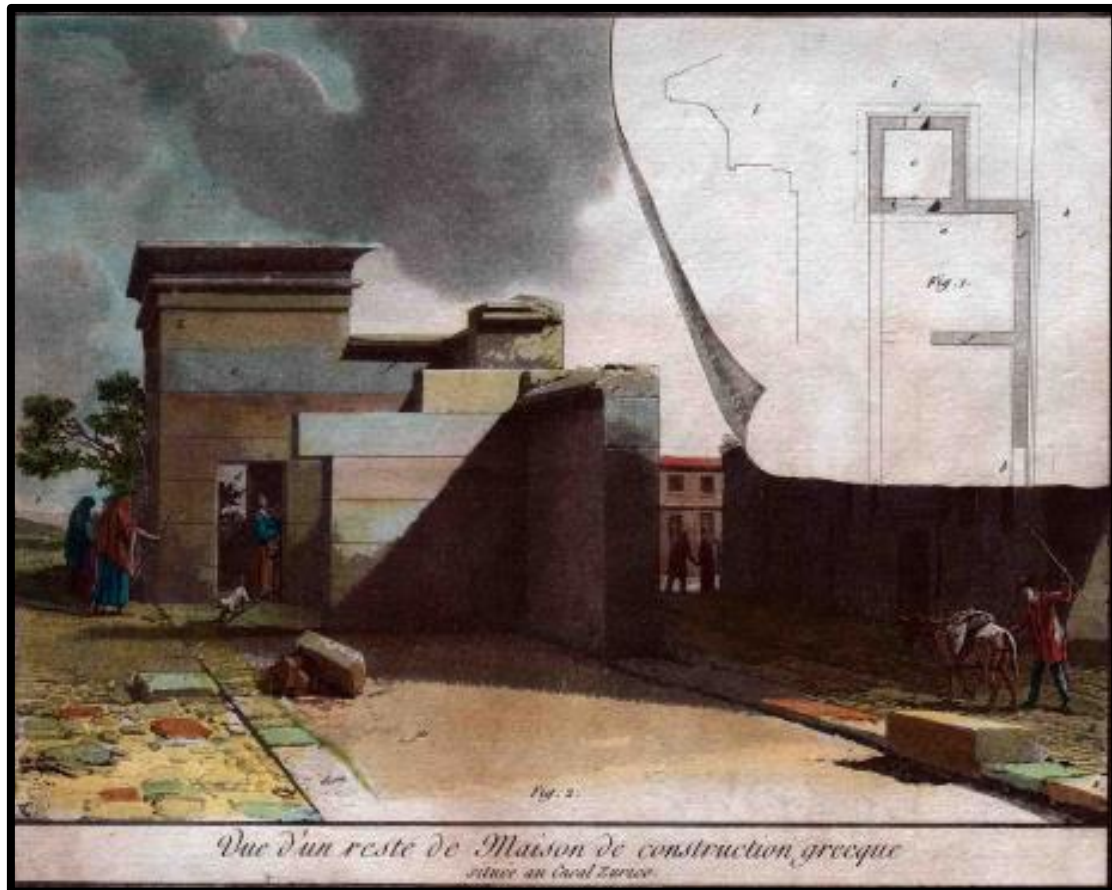


Figure 34. Jean Houël's watercolour depicting the Punic Building in Żurrieq from a front perspective (Houël 1787: Pl. CCLIX).



Figure 35. Jean Houël's watercolour depicting the Punic Building in Żurrieq from a rear perspective (Hermitage Website).

This drawing can be found in a later publication by Bonanno and Vella (Fig. 36).²⁰⁹ As seen by these drawings, the distinctive architectural features of this structure, such as the ashlar blocks and the Egyptian gorge cornice, strongly suggest a Punic date. Gouder points out how distinctive Punic architectural traits were heavily influenced by the Egyptian legacy and these were quite characteristic in temple or funerary architecture.²¹⁰ In fact, identical types of Egyptianizing cornices can be found in 5th C. BC North African sites of Carthaginian culture, such as Zaroura (Fig. 37 – a), Aïn Berghla (Fig. 37 – b) and Bir Mecherga (Fig. 37 – c) in present day Tunisia.²¹¹ A slightly different rendition of this cornice was found locally at the Sanctuary of Astarte at Tas-Silġ, in south-west Malta.²¹²

This reinforces the hypothesis that would see these structures being part of a monumental temple complex, as opposed to this building being a rural dwelling. These speculations are linked to the Temple of Melqart mentioned by Ptolemy,²¹³ however, there is no strong evidence to support this interpretation. Since 1998, these Punic structures are scheduled as ‘Grade A’ by the Maltese Planning Authority²¹⁴ and are accessible through appointment at the Chaplain’s office.²¹⁵

²⁰⁹ 2000: 17.

²¹⁰ Gouder 1991:17.

²¹¹ Francisi 2002: 243.

²¹² Cardona 2013: 21.

²¹³ Bonanno 1982: 197.

²¹⁴ Malta Government Gazette – 17th April 1998.

²¹⁵ Archdiocese of Malta Website 2022.

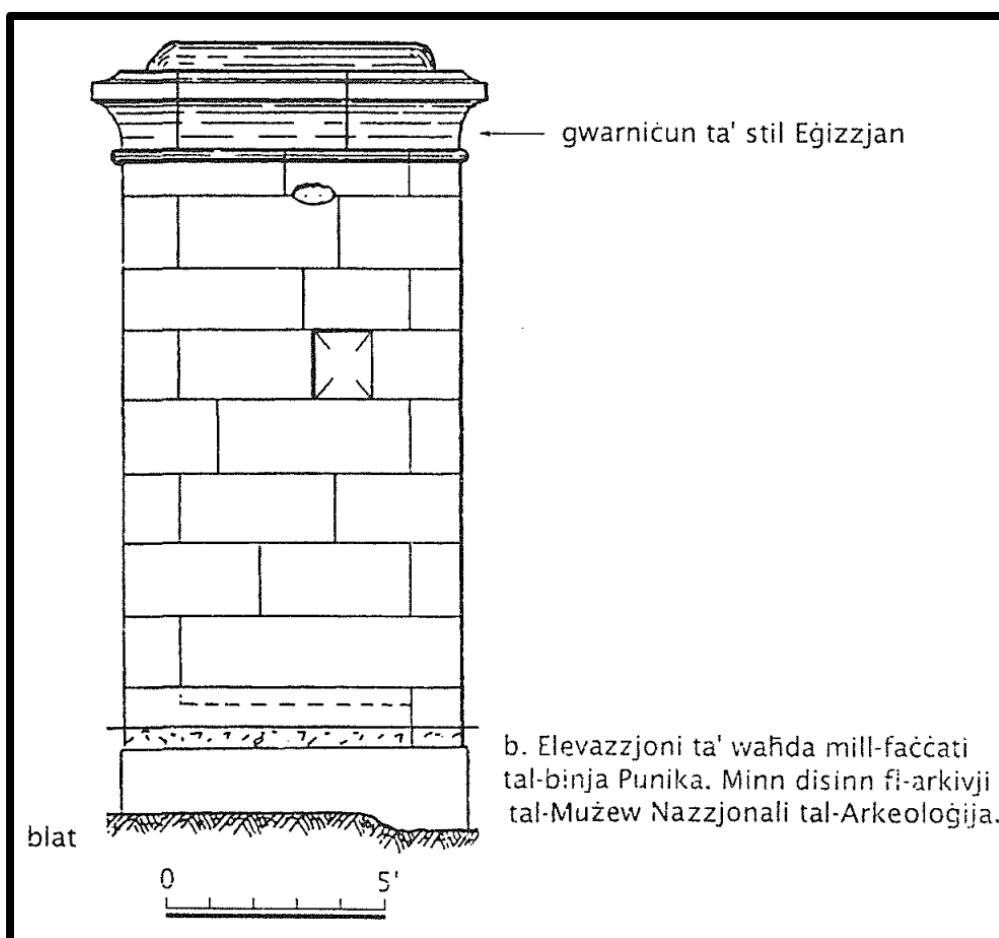


Figure 36. The section elevation drawn following the 1964 archaeological excavation (Bonanno & Vella 2000: 17).

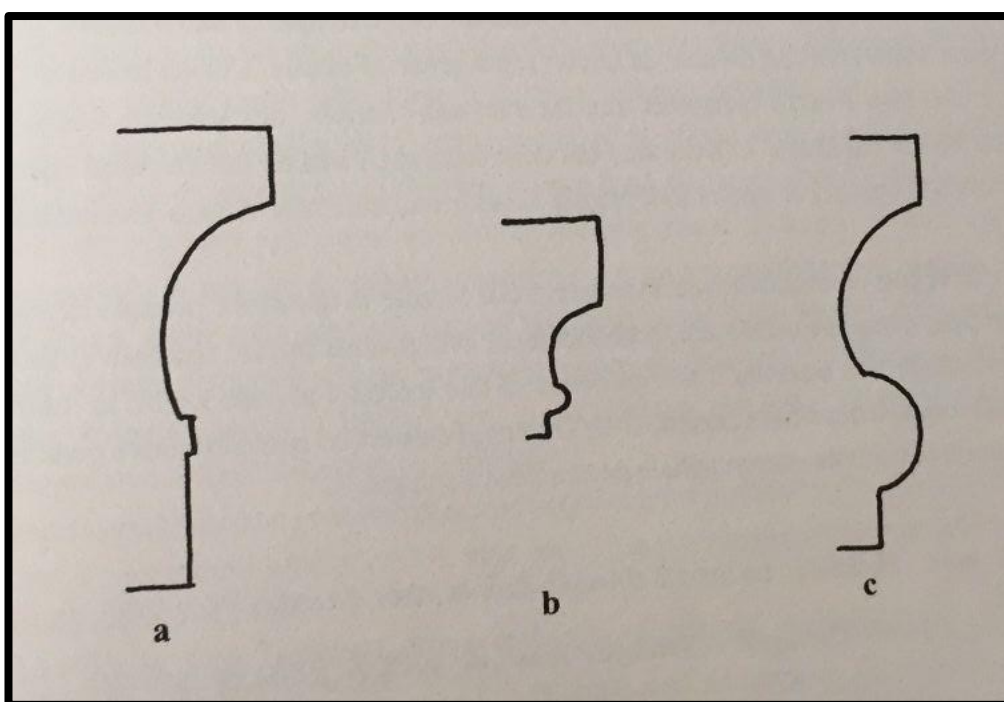


Figure 37. Photo showing the types of Egyptianizing cornices found in 5th Cen. BC North African sites of Carthaginian culture, such as Zaroura (a), Ain Berghla (b) and Bir Mecherga (c) in present-day Tunisia (Francisi 2002: 243).

Chapter 3



Methodology and Results

Site A

The review of the literature presented a historical, geographical and archaeological framework for each of the archaeological sites that were chosen for virtual reconstruction (Section 2.3). With these frameworks in mind, this and the following chapters (3-5) will present each one of the virtually reconstructed sites. In this regard, two considerations were made:

- i. **A site-by-site layout approach was preferred to presenting all of the methodologies and results of this study in two separate dedicated chapters.** This decision was made due to the heterogenous nature of the group of case studies, which required different methodologies and, as a result, generated diverse results.
- ii. **The methodologies adopted for each site's reconstruction will be presented in conjunction with the obtained results.** As mentioned in the introduction (Chapter 1), at the beginning of this research the author lacked advanced computer science knowledge and underwent basic training. Therefore, the virtually reconstructed models were a result of an ongoing investigation. For this reason, since certain methods were adopted specifically to tackle unsuccessful outcomes, this choice (premise ii) was made to coherently present these.

Therefore, this chapter will present the virtual reconstruction of the first case study: the Early Christian hypogeum discovered on the northern side of the Jesuit's Hill in Marsa in 1874. This will be done by presenting the methods adopted to virtually reconstruct this site and the results obtained throughout the stages of data gathering (Section 3.1), data processing (Section 3.2), and data visualization (Section 3.3).

3.1 Gathering the data: retrieving and digitising Wright's documentation

Given the first aim of this study (Section 1.2), the first stage of the workflow consisted in the collection of legacy data (i.e. textual, drawn, photographic documentation) available for the site in question. The method adopted for this exercise occurred mainly through researching and reviewing the literature of this site. Therefore, this exercise was undertaken whilst reviewing the literature presented above (Subsection 2.3.1). Nonetheless, this process entailed the retrieval of two primary sources and several secondary sources.

Although no photographs were recovered, the primary legacy data was accessed in the form of both written and drawn documentation and were both employed by this study after being digitised. As mentioned previously (Subsection 2.3.1), these sources consisted of an archaeological report and survey of the site, both produced by C. A. Wright in 1874. The former was published as a newspaper article in the 5th September 1874 issue of the MTUSG, which is today stored at the archival records of the National Library of Malta in Valletta (Fig. 38). Unfortunately, the drawn survey mentioned in this report was not found together with this document and it is not clear where this drawing is currently kept. Although Buhagiar locates it at the National Museum of Archaeology in Valletta,²¹⁶ a digital scan of this drawing had been already carried out and was included in Gambin's doctoral thesis (Fig. 16).²¹⁷ Given the good quality of this scanned drawing, it was decided not to retrieve the original survey, also not to further impact on its state of conservation.

As it will be shown below (Subsection 3.1.2), the visual reconstruction process of this site was almost entirely based on Wright's plan and section elevation drawings. However, this pioneer archaeological drawing is lacking two important surveying

²¹⁶ Buhagiar 2014: 139.

²¹⁷ See Gambin 2005(a) Fig. 4.2.

BIRTHS. On Aug. 29, at Beech View Villas, Anstley, the wife of Michael...

MARRIAGES. On Aug. 19, at All Saints, South Hamstead, by Dr. Rev. John...

DEATHS. On Aug. 19, at Sanderstead, MAY AGERS, infant daughter of Alexander Allen...

THE MALTA TIMES Saturday, 5th September, 1874.

We are daily, you verily, hourly reminded, sometimes in screaming accents, and on other occasions in whispering tones, that the people of this island are growing under the weight of the taxation imposed upon them.

Our space is much too limited to admit of dipping deeply into the question of the island revenues. We will, on the present occasion, content ourselves by noticing the nature of a few of the taxes imposed by other Governments; and will draw comparison between them and the dues imposed by the Malta Government.

We will now turn to another phase of the subject, bearing on the question of revenue, and which is of the most vital importance to the industrial classes of the island.

The Chief Secretary to Government informed us, from his place in Council that all works of real utility must for ever remain on paper, if our revenues are not increased. It was the wish of the Government to expend in 1875 the sum of £25,500 on new works and repairs, and which are urgently demanded; but it has been considered expedient to cut the figures down to £19,850.

THE BRITISH EMBASSY AT CONSTANTINOPLE.—Sir Henry Elliot, says the Levant Herald, entertained at dinner on Tuesday, (18th Aug.) at her Majesty's Embassy at Thessalonica, a large party composed of official and other members of the English colony, amongst whom were Admiral Hobart, Pasha and the Hon. Mrs. Herbert, Sir Philip and Lady Francis, Sir George and Lady Thomas, Mr. Foster, C.B., Captain and Mrs. Burnell, and others.—On Thursday evening, his Excellency entertained at dinner General Ignatieff, the Russian ambassador, Kiamil Pasha, the Turkish ambassador, at St. Petersburg, now on leave in Constantinople, and a few other members of the diplomatic body.

DISCOVERY OF AN ANCIENT NECROPOLIS AT THE MARSA.—During the course of excavation for building purposes on the side of the Jesuit's Hill, near the Marsa, on the property of Signor Sacco, the workmen lately came upon an ancient rock-cut cemetery, just below the surface of the ground.

The general shape of the excavation is of an irregular pentagonal form, divided into two unequal sized chambers; the smaller on the left being separated from the larger by a solid wall of rock, pierced by a doorway and two archways. Entrance is gained on the east side, by a narrow flight of some half dozen steps, leading through a low archway cut in the rock.

To the left, in close proximity to this old necropolis, an isolated rock-tomb was discovered, which was at first believed to have access to it, but, although probably of the same age, is quite distinct.

At a little distance to the right are two curious sepulchral excavations, containing rock-tombs, now used as store rooms by a boat-builder. In one of them is an inscription almost entirely effaced, only enough remaining to show that it is in Latin characters.

The proprietor of the ground, Signor Nicola Sacco, has presented to the Public Library an Epitaph which he found about four feet under the surface, a little higher up the hill. It is carried on a slab of Malta stone, of a sub-pyramidal form, 2 feet 7 inches high, with a base of 14 inches.

Respecting this relic we have received the following note from Dr. Cesaro Vassallo, the learned Librarian and Archaeologist:— "It is interesting as belonging to the fifth or sixth century, and is remarkable for the beautiful simplicity of the inscription, which is as follows:—

D. M. FLIVSTITUS VIXITANNOS LVGIVENBE NEMERENTI FICERVNT.

Which may be read—

Dom Martino Flivstus Vixit annos LV Cives Nemerenti Fecervnt.

"Over the inscription is carved the figure of a ship, one of the symbols which the Chris-

tians used on sepulchral monuments in Rome as late as the fifth century, and still later in the provinces. The name of Flivstus was not unknown to those early Christians; and the Martyrology mentions Flavianus Clement, and the Consul, who suffered martyrdom under Domitian."

We only hope that the laudable example set by Signor Sacco, in presenting this Epitaph to the above-named public institution, will be followed by others; for the monumental history of these Islands, as displayed in the Museum of the Public Library, would then be rendered more complete, by the addition of many valuable records at present entirely lost to archeology.—C. A. WATSON, Vice-President of the Archaeological Society of Malta.

THE SLAVE TRADE ON EGYPTIAN TERRITORY.—The Times correspondent at Alexandria writes:—Of the Khedive's sincerity in desiring the suppression of the trade there is no doubt, but this is not easy to compass. Before Sir S. Baker's expedition, the slave trade had been tacitly permitted in the Soudan, and that expedition was the first great attempt made to put an end to it. This could not be effected without annexing and bringing under Egyptian control the vast regions of the interior. But, though everything was done by the Government to insure success, the expedition proved a failure, and I have heard that from first to last it cost about £150,000—i.e. the lives of some 1,200 men. Sir S. Baker cannot fairly be blamed for the issue. The natural obstacles were too great to be overcome and it was an attempt to effect in a year or two what will require a long series of years. As regards the Arab, Abu Saoud, whom the Khedive, at Colonel Gordon's request, has allowed to accompany the expedition, it is but fair to conclude that he was not so guilty as appeared, for otherwise, honorable men like Chirif Pasha and Nubar Pasha would not have acquitted him. The man, no doubt, had been a slave-owner, the ivory trade is hardly possible otherwise, neither slaves or improved natives, paid for in cattle, which, as the natives are unwilling to sell them, are taken by force. It is this vicious circle which the Egyptian Government has resolved to break through, by prohibiting all private ivory trading. But it should be borne in mind that until Sir S. Baker's expedition the slave trade was permitted, and Abu Saoud strenuously proclaimed his innocence of most of the charges laid against him. The Egyptian Government, knowing the man's great experience and knowledge of the country, though he could not be put to a worse use than hanging, but even now he goes under threat of death if caught playing any tricks. I had a long conversation with him in Cairo just before his departure. His knowledge of the Chiefs and people bordering the great Lakes, of the Nile, and of the great Nile, is very extensive, and he gave most interesting details of that country. He is a young and handsome man, of polished manners, and extremely intelligent, not at all like the truculent character he is supposed to be. All this, of course, goes for nothing, but the Khedive has sent him with Colonel Gordon as a present likely to be of much service towards effecting the desired end—that is, the suppression of the slave trade in the Soudan, and which his Highness has undoubtedly at heart, but which neither he nor any other human power can effect as if by magic and without great perseverance and energy."

THE MALTESE POLITEAMA.

The Company Martini and Co. have already reached their forty-second representation, so that, with a few extra performances, they may hope to close their engagement with the subscribers at the end of the present month. Have the proceeds of their labours proved equal to their wants? We have no hesitation in replying with a negative? To their expectations? We hardly think so. The company, it is true, is very numerous, and their expenses are very great, much greater than they ought to be, in any instance particularly. Who can have suggested to Sig. Martini the proposer's idea of paying twenty per cent, or one fifth of the proceeds of each evening, to the constructor of the Theatre? We will have paid him double that in the value of his wood, and that, at the close of the two months, will again become the constructor's property with very little deterioration. The other expenses are also, in some cases, rather onerous, but not so ridiculously heavy as the one above-mentioned. We hope that before the close of his engagement, Sig. Martini will meet still greater encouragement. We should like to hear of the theatre's being frequently well attended as it was on Wednesday last, when for the benefit of Signa. Emma Foscarini, every box was full, and every place in the pit occupied. The entertainment was very good, and the youthful artist did great credit to the characters she undertook in the Italian comedy, and the Maltese farce. She was incessantly applauded, particularly in the latter, of which an impossible repetition was requested. The Italian farce in which she had no part, was also much admired, and at its conclusion all the artists engaged in it were called out to receive a well-deserved applause. Signa. Emma Foscarini, for whom we predict, and to whom we heartily wish, success in the career she has so well begun, has requested us to return her sincere and heart-felt thanks to the generous public for their liberality and indulgence to her on the evening aforesaid.

MALTA.—Travelling Notes, by HENRY BRUNETT, M. D.—Malta is a calcareous rocky island, which rises a few hundred feet only above the sea, and is situated in latitude 42° 15' N. It is 55 miles from the nearest point of Sicily, 179 from the nearest coast line of Africa, 44 miles in circumference, 37 miles in greatest length north to south, 9 miles in greatest width east to west. A slight rocky elevation or ridge, from north to south, separates the island into two unequal portions, the eastern being the more extensive and the more populous. The surface is undulating and uneven, although the general character of the island is that of a plain, everywhere rising more than 600 feet above the sea.

In the town of Valletta, overlooking the magnificent harbour, there is but little vegetation; still there are some squares planted, and a small straggling garden on the ramparts. Moreover, wild plants grow here and there in nooks and corners. The vegetation appeared to me identical in the same as in the warmer parts of the Mediterranean, at Athens or Sardinia, at Corfu, Tunis, or Smyrna, and the stage of growth the same as in these and other similar regions at this epoch of the spring (the second week in May). My explorations commenced on the 10th.

In the rampart garden I found *Althaea* coming into leaf, *Schinus Mollis* in flower, *Oleander* in bud, large *Malva* in flower, *Eucalyptus japonica* in flower, *Pomegranate* in leaf, *Carouba* trees, *Sida arborea*, *Spartanum africanum*, *Buddleia madagascariensis* in flower; *Rosa*, *hybrid*, *Banksia*, *multiflora*, in flower; *Juncus*, *atrobis*, *Nesturtium*, *Stoeck*, *Petunia*, *Verbena*, *Marrigold*, *Pelargonium*, *Larkspur*, in flower, *Virginia* *Stock*, *Hollyhock*, first flower opening; *Fig* in full leaf, fruit swelling; *Opuntia* and *Aloe*. Nearly all these had been flowering in my garden at Mentone ever since February or March.

In the garden of the Governor's town palace surrounded on all sides by buildings, a more planted courtyard in the interior of the town were many of these plants and flowers. In addition I noticed a magnificent *Aranea* *eximia* at least 50 feet high, and then only 7 feet in height. The walls were covered with *Leucosiphia* in full bloom, a beautiful sight. The vigorous and luxuriant of this plant showed that the calcareous soil and climate of Malta suit it thoroughly. There was also *Jasminum revolutum*, *Bigonia capensis* in flower, *Oranges* just set, *Logan's* ripening, *Cassarea* flourishing, *Cereus grandiflorus* the same.

The following day I took a leisurely drive to Gitta Vecchia, the former capital, 6 miles from Valletta, nearly in the centre of the island, on one of the highest points of the central ridge. On a subsequent occasion I drove right through the island to St. Paul's Bay, at the south-western extremity, carefully examining the aspect of the country and the vegetation all the way. When not seen from a distance, as for instance from a church steeple at Gitta Vecchia, the island of Malta looks barren, and there, no doubt, it has been described as a barren rock. The most cursory inspection, however, shows that this is a gross error, and that the accounts of soil having been transported from the continent are totally devoid of foundation. The error, no doubt, originates in the fact that the entire island is divided into fields of a few acres each, as in England; and that these fields are bounded by stone walls 4 or 5 feet high, and that scarcely any trees higher than the walls are to be seen; higher trees exist, but they are hidden in gardens surrounded by walls 15, 20, or 25 feet high. Thus an observer may pass through the country, and under the very walls of these gardens, without seeing a shrub or a tree there cultivated. It is the winds that course over the low sea-girt island from every point of the compass, that necessitate this extraordinary amount of shelter. No trees, except the pyramidal *Cypress*, and even that wind-proof *Conifer* scarcely appears to be able to resist their influence, and to grow without the protection of walls or surrounding buildings.

If, as we pass along the road, we look over the stone walls, we at once perceive that every enclosure contains soil cultivated with extreme care, and producing crops abundant, although meagre and low in habit. I observed principally bearded *Wheat* and *Barley* turning colour, *Potatoes*, *Vetches*, *Clover*, and *Beans*. The value of manure is clearly appreciated; for many fields had been ploughed and were covered with heaps of manure about to be dug in. I was told that the second summer crop is Cotton, which is extensively planted. In all these fields there was not a weed to be seen, they were clear as a gentleman's garden in England just after it has been trimmed.

It is said that more than two-thirds of the island is under cultivation, the rest being rock, where it rises to the surface in rugged elevations, but that the area of cultivated land is gradually being extended. I noticed in several places the process of formation of new fields, and found that it is very much the same as what I am doing among my Grimaldi rocks at Mentone. Calcareous rocks are always full of fissures, cracks, crevices, in which, in the Mediterranean, *Thyme*, *Rosemary*, and other plants grow. In the course of centuries grasses grow, forming earth, which collects in the size of the crack quantity according to the size of the crack.

* The height of Nadur, in Malta, is nearly eight hundred feet above sea-level.—*Exp. Malta Times*.

Figure 38. A scanned copy of the 5th September 1874 issue of the Malta Times and United Services Gazette reporting the discovery of the ancient necropolis in Marsa (Malta National Library 2022).

features, a scale bar and a North point. Although at the bottom of this document the author states that one-sixth of an inch on the draughting paper equals one foot of the site, the value of this scaling data can only be employed when dealing with the original document itself. In these regards, the written report played a key role by providing in-text measurements and an indication of the easterly oriented access.

In a similar way, the secondary sources²¹⁸ that followed Wright's primary legacy data provided valuable information about the context of its discovery, archaeology and state of preservation, along with a critical understanding of the site and reliability of Wright's documentation. Although these did not play a direct role in the virtual reconstruction itself, they still improved the understanding of the site which this research is re-building.

3.2 Processing the data: from a 2D drawing to a 3D model

The second stage of the workflow consisted of the building of a 3D mesh of the site. A mesh can be understood as the structural backbone of a 3D model, which is composed by polygons, and basic geometric components, made of faces, edges and vertices.²¹⁹ In photogrammetry- and laser-scanning-based modelling, these are generated through a 3D-acquisition of data present in the physical world. Unlike in these techniques, the challenge of this study was to manually build the vertices, edges, and faces of each polygon from scratch using Wright's survey as the only guiding source.

For this purpose, the software selected for this type of data processing was Blender®. The reason for this choice lies in the software's widely-known advantages, such as being a free and open-source 3D computer graphics software that offers an efficient, wide and versatile toolset used for a wide range of applications (e.g. from 3D modelling applications to motion and visual graphics used in video-gaming and animated cinematography).²²⁰ Its accessibility and user-friendliness allowed the establishment of a massive online community which resulted in a large number of available learning resources. This was possibly the

²¹⁸ See Vassallo 1876; Caruana 1882; Becker 1913; Buhagiar 2014.

²¹⁹ Lewis 2022.

²²⁰ Blender Website 2022.

determining factor behind the choice of this software, since the author had no knowledge in 3D computer graphics and had to undergo a tutorial-led training. This was provided by Dr Sandro Spina, a senior lecturer from the Department of Computer Science at the University of Malta and took place between April and May 2021.²²¹ As part of the training, this strategy was first tested on the Punic structure case study (Site C), as shown below (Subsection 5.1.2).

Following the successful training and the building of Site C, this provisional methodology was established and was adopted for the reconstruction of the Site A. As occurred for Site C (Section 5.1), the jpg scan of the drawing was imported in Blender, placed in the software's X-Y plane and scaled accordingly. Subsequently, a filled planar mesh was added over the full extent of Wright's plan and positioned it at the same Z-axis value, in order to overlay the drawing (Fig. 39). By selecting Blender's 'Toggle X-Ray' function, the mesh was displayed with increased transparency, allowing to visualize the drawing through it (Fig. 40).

This function proved to be crucial for this reconstruction technique, as it allowed to subdivide the planar mesh according to the geometries and spaces seen on the drawing.

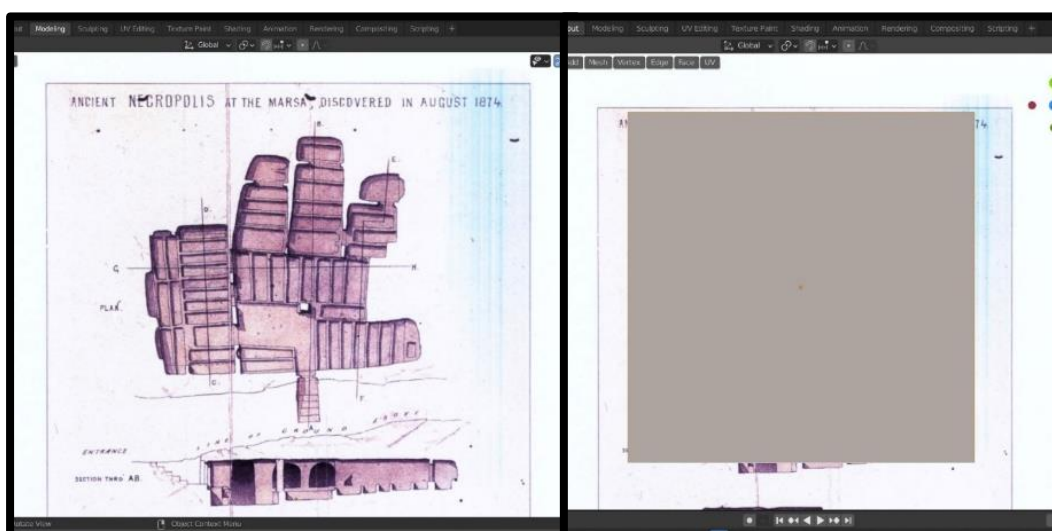


Figure 39. Screenshots showing the import of Wright's scanned survey in Blender and the overlay of a planar mesh (photo by the author).

²²¹ By adhering to Covid-19 restriction protocols.

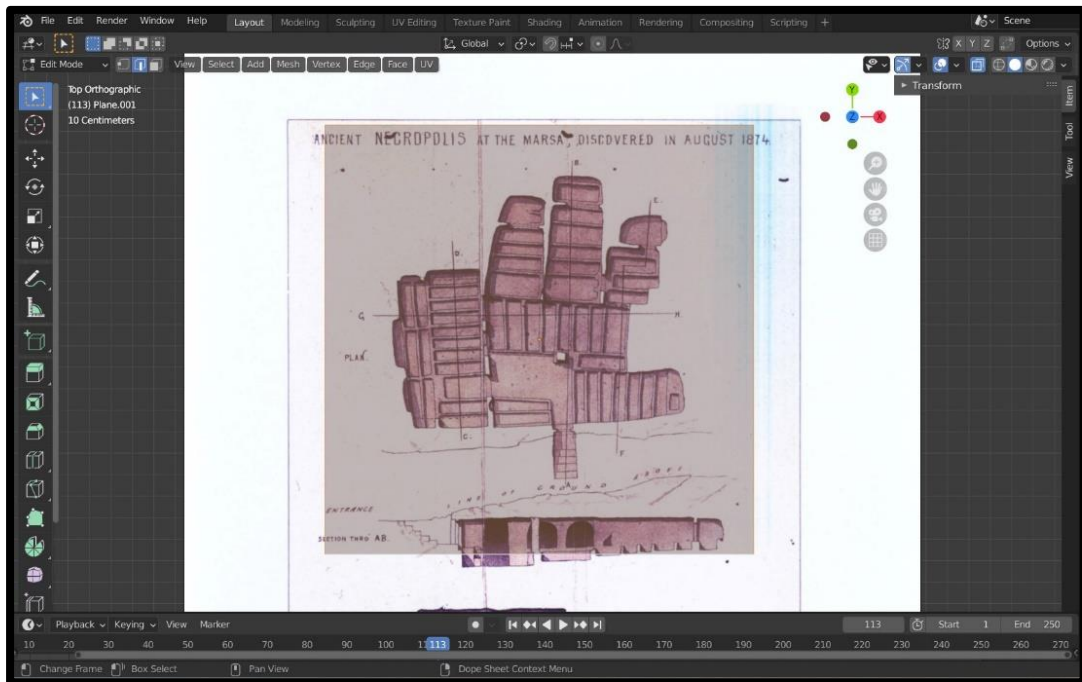


Figure 40. Screenshot from Blender showing the 'Toggle X-Ray' function in action (photo by the author).

Unfortunately, at this stage the above-mentioned provisional methodology adopted for Site C failed in delivering successful results and was deemed not suitable for this case study. The cause of this lies in the differing natures of these two sites. The strategy adopted in Site A (Subsection 5.1.2) appeared successful for orthogonal geometries (e.g. rectilinear walls), however when dealing with the irregular shapes of the rock-cut underground environment of a catacomb this was not equally effective. By consulting numerous online Blender-support groups, a solution to this shortcoming was discovered and a new strategy was adopted.

A new way forwards was found in Blender's 'Knife' tool, which allows to freely subdivide the planar mesh into distinct geometries, by selecting arbitrary vertices which followed the irregular perimeter of feature documented by Wright (Fig. 41). Once this perimeter of vertices and edges was defined (Fig. 42), the data concerning the depth of this cut had to be reconstructed. For this purpose, the strategy consisted of importing the same survey, in order to reconstruct the sides and bottom edges of the features by employing the corresponding section drawing.

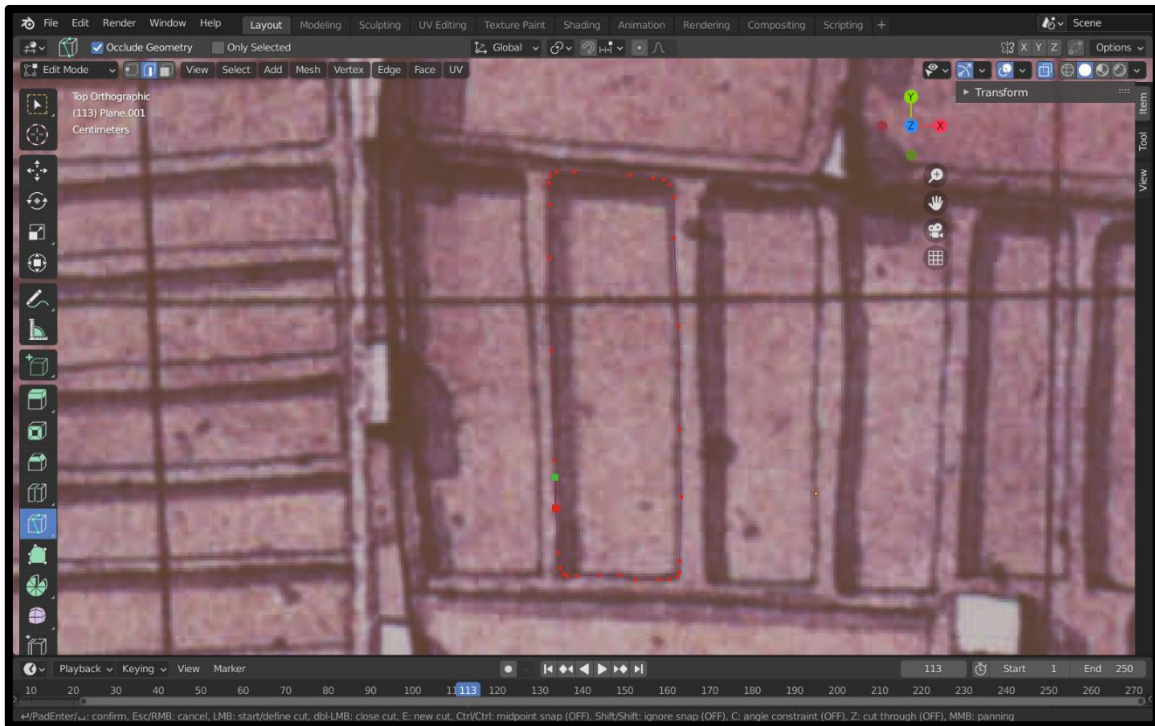


Figure 41. Screenshot from Blender showing the 'Knife Tool' function in action (photo by the author).

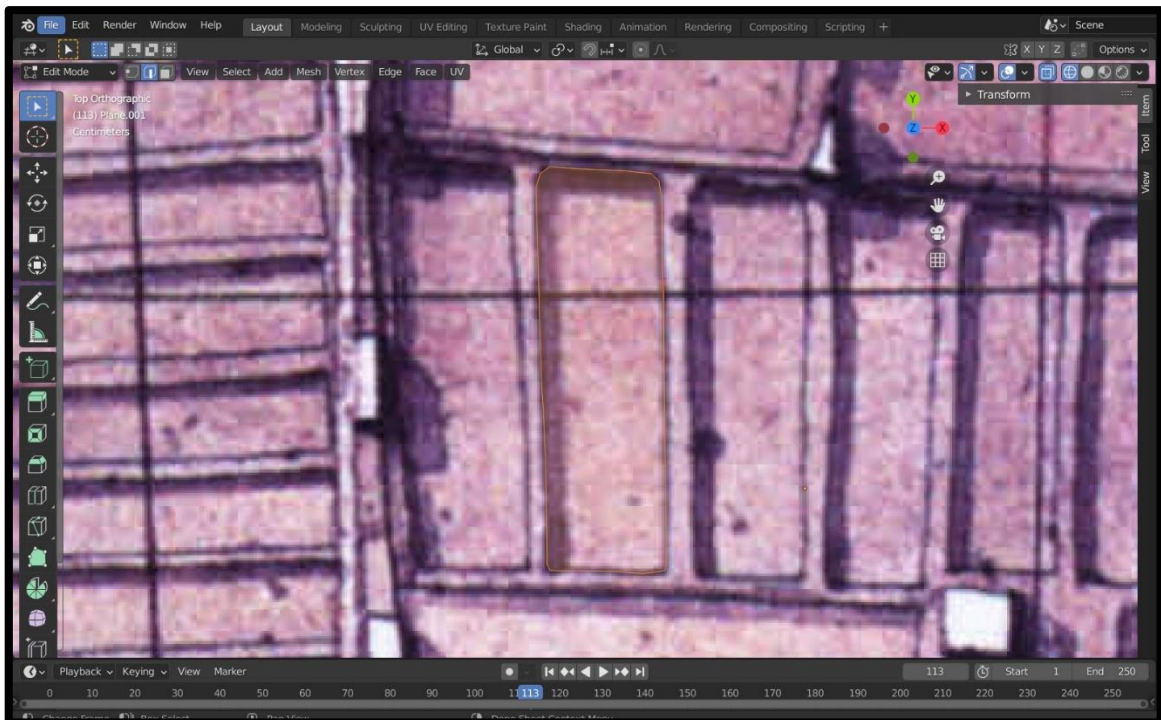


Figure 42. Screenshot from Blender showing the perimeter of vertices defined around the feature (photo by the author).

Therefore, following the uploading of the same jpg file, it was scaled equally to the previous but was instead placed in the Z-X axis plane, rotated to match Wright's location of the section in the plan (Fig. 43), and was positioned to match the survey in the X-Y plane (Fig. 44). After changing the viewpoint to the Z-Y axis and selecting the 'Extrude Region' tool, the edges of the perimeter were extruded along the Z-axis following the profile drawn by Wright in the section (Fig. 45).

The screenshots included below (Fig. 46-48) present the step-by-step results of this process, showing the reconstruction of one sarcophagus in Chamber A. By intersecting all four section-elevations, each tomb was reconstructed, and these were eventually connected to each other by joining the neighbouring vertices, edges and faces using the 'Fill' tool. The end result of this process can be seen in Figures 49 and 50 where the final mesh of all the 'bottom' features (i.e. steps, floors, and tombs) of this catacomb are reconstructed. The same technique was adopted to reconstruct the wall features (i.e. *loculi*; *arcosilia*; lamp-holes – Fig. 51), the standing geometries (i.e. walls; arches; barrel vaults – Fig. 52) and the final results can be seen below (Fig. 53).

Finally, the roof was reconstructed by employing the sections AB and GH of Wright's survey and joining together the walls of the chambers, the window-arches, and the barrel-vaulted *arcosilia*. Additionally, in section-elevation AB, Wright surveys a portion of the bedrock lying above the catacomb.

Although this appears to be a sketched topographic approximation of the Jesuits' Hill's bedrock slope, as opposed to a survey, it was still decided to reconstruct it. Once the outline of this section was built, it was arbitrarily extruded along the X-axis in order to enclose the catacomb (Fig. 54). This choice was purely motivated by a visually aesthetic intention which aimed to provide a reasonable spatial context to the reconstructed catacomb. By visually surrounding and hiding the underground environment with the reconstructed terrestrial topography of the Jesuits' Hill, the viewer is encouraged to interact with the stepped shaft and doorway (Fig. 55) which once granted access to the underground chambers. This choice enhanced the visual interactivity of the reconstructed archaeological site.

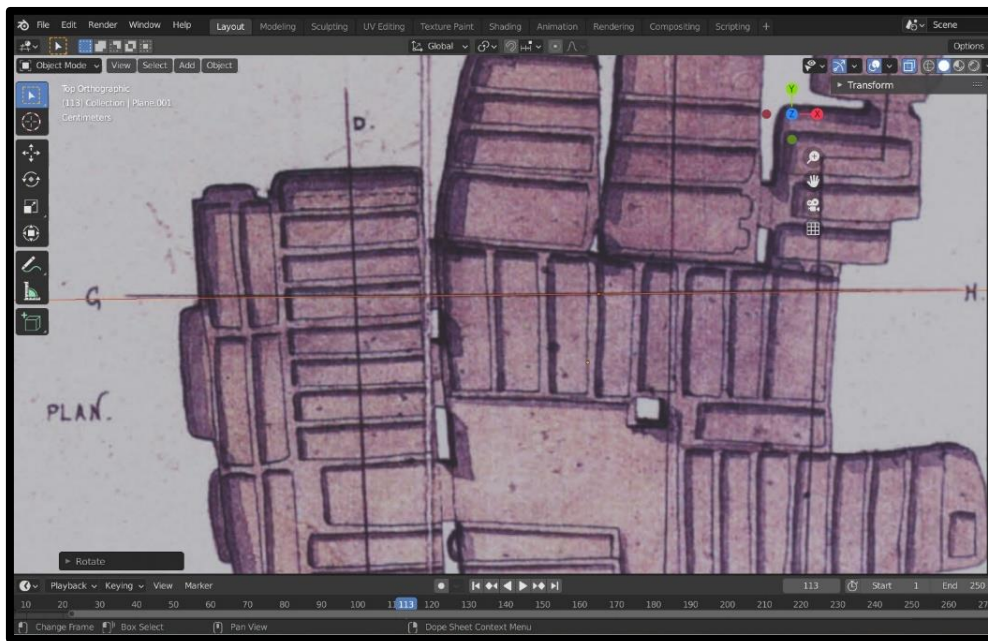


Figure 43. Screenshot from Blender showing the rotation of the vertical survey file to match the position of the section on the plan (photo by the author).

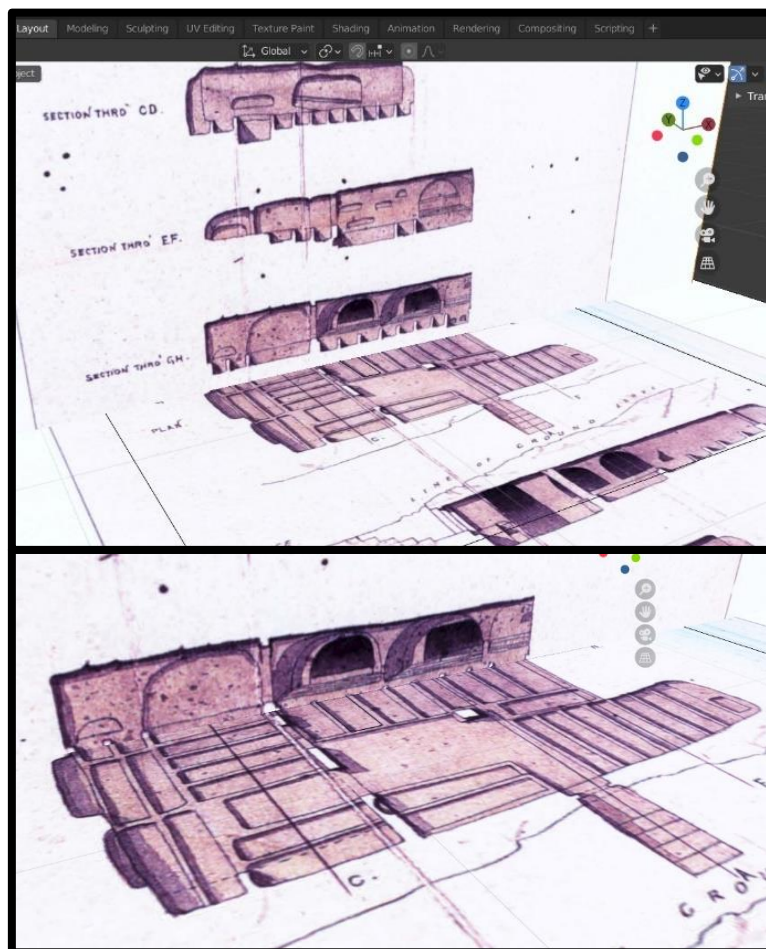


Figure 44. Screenshots from Blender showing the two surveys matching the section elevation to the plan (photo by the author).

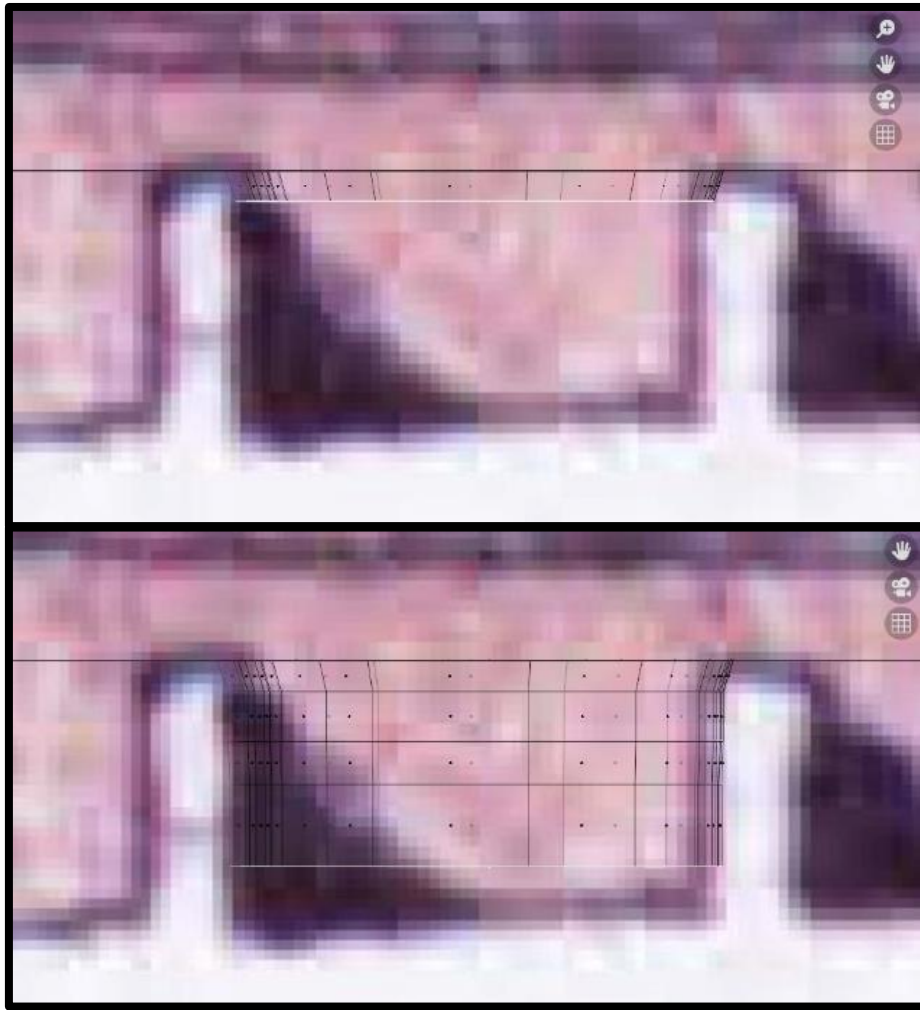


Figure 45. Screenshots from Blender showing the extrusion of the perimeter along the profile of the survey (photo by the author).

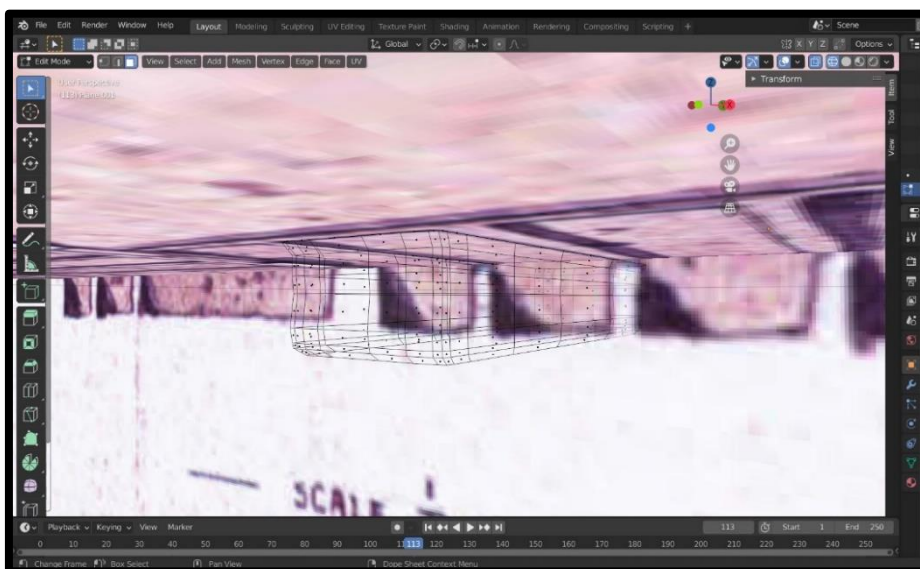


Figure 46. Screenshot from Blender showing the reconstructed mesh of the sarcophagus (photo by the author).

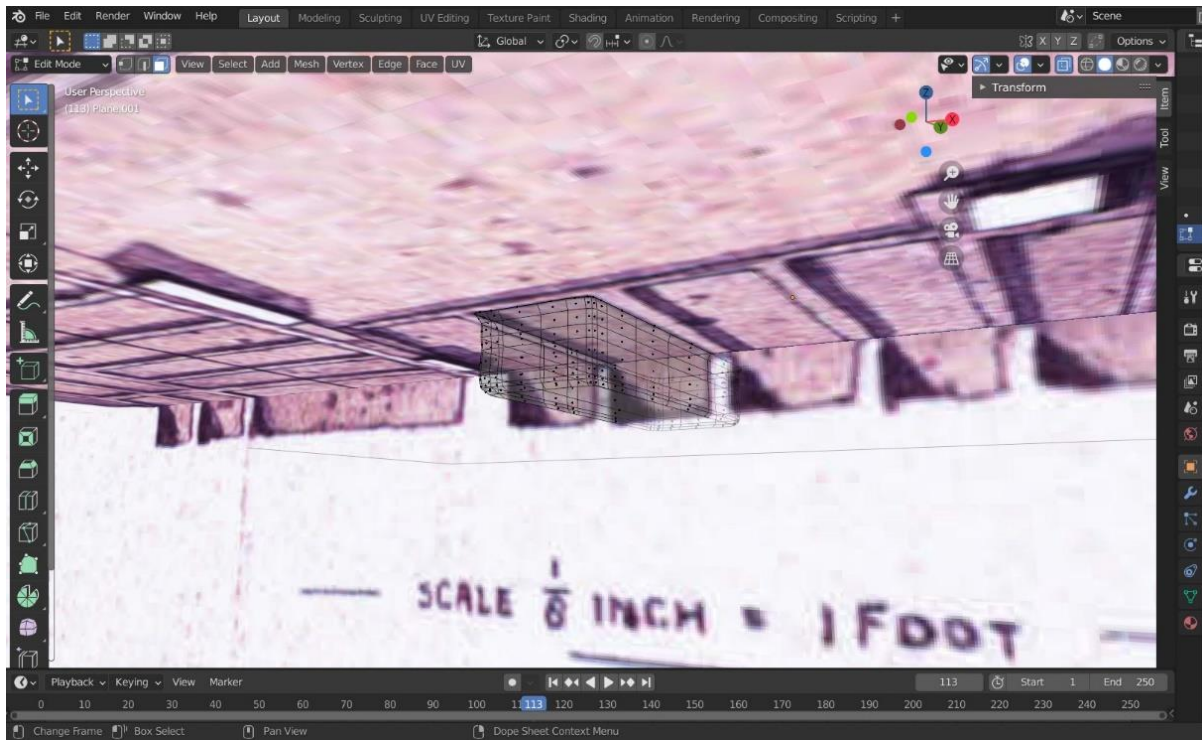


Figure 47. Screenshot from Blender showing the reconstructed mesh of the sarcophagus (photo by the author).

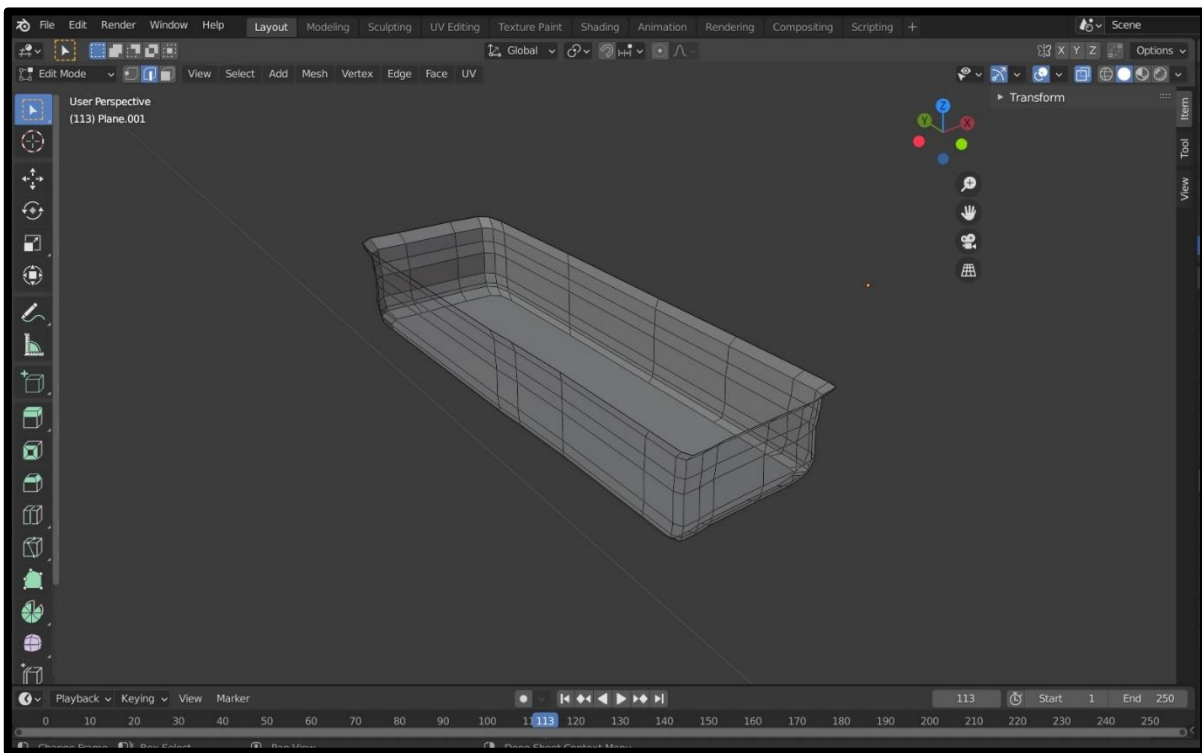


Figure 48. Screenshot from Blender showing the reconstructed mesh of the sarcophagus (photo by the author).

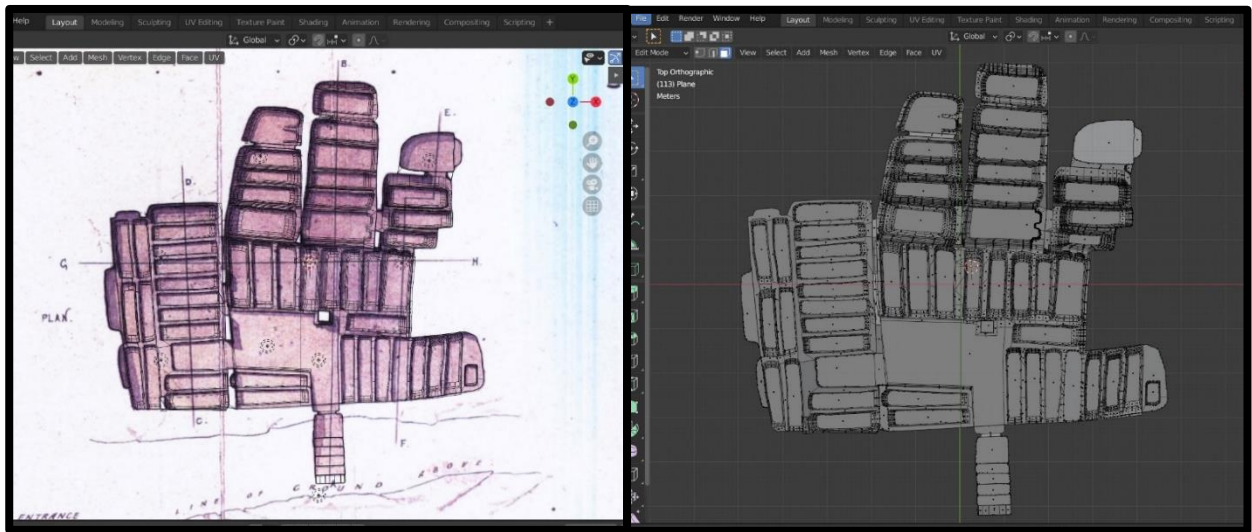


Figure 49. Screenshots from Blender showing the reconstructed sarcophagi and floors of the hypogeum (photo by the author).

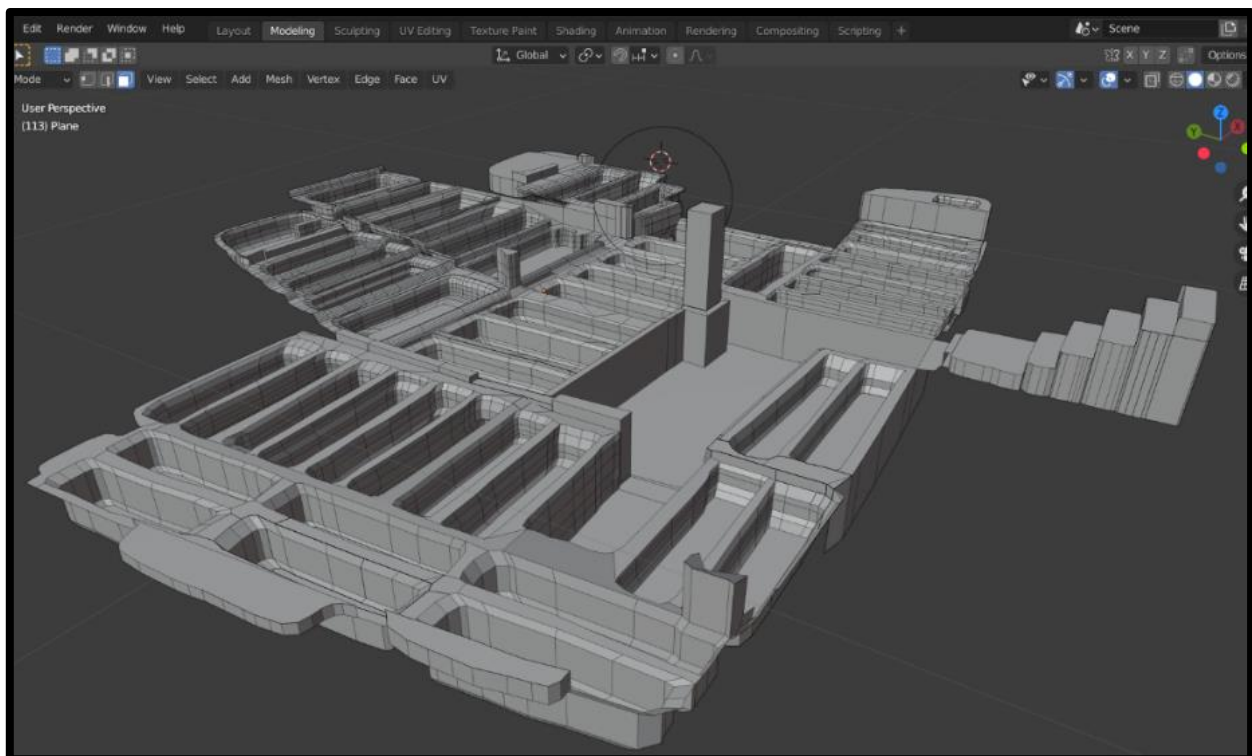


Figure 50. Screenshot from Blender showing the reconstructed sarcophagi and floors of the hypogeum (photo by the author).

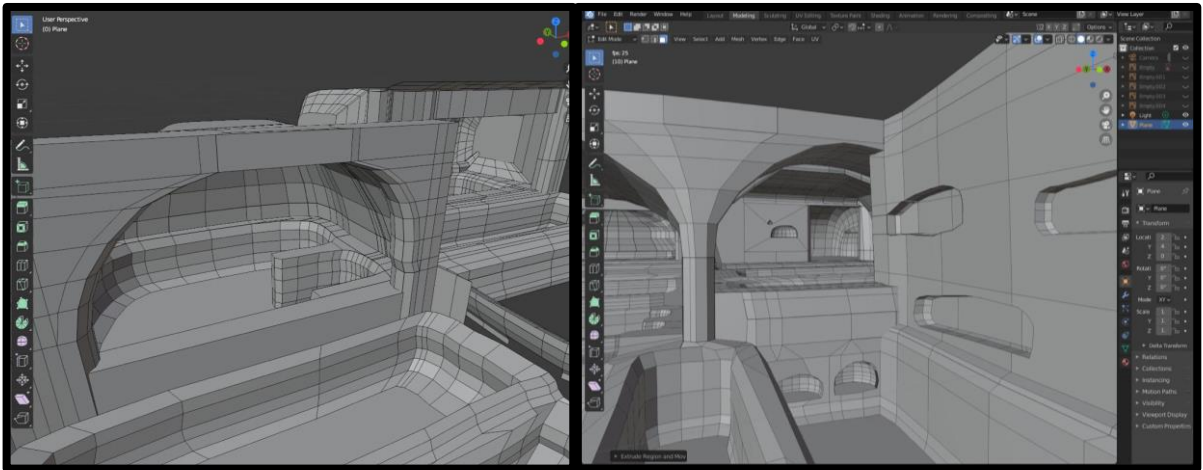


Figure 51. Screenshots from Blender showing the reconstructed wall features (i.e. loculi; arcosilia; lamp-holes) (photo by the author).

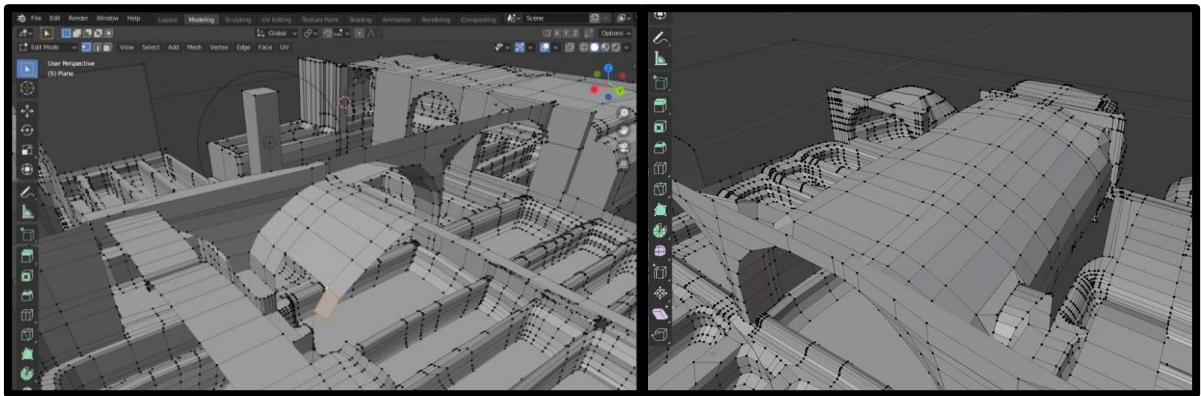


Figure 52. Screenshots from Blender showing the reconstructed standing geometries (i.e. walls; arches; barrel vaults) (photo by the author).

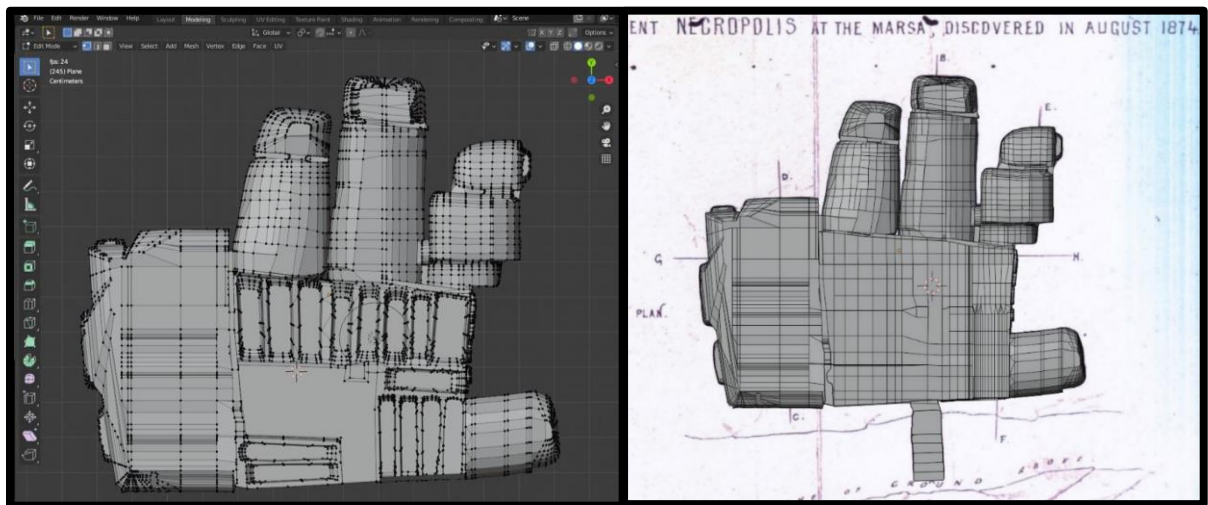


Figure 53. Screenshots from Blender showing the reconstructed roof and final result of the mesh reconstruction (photo by the author).

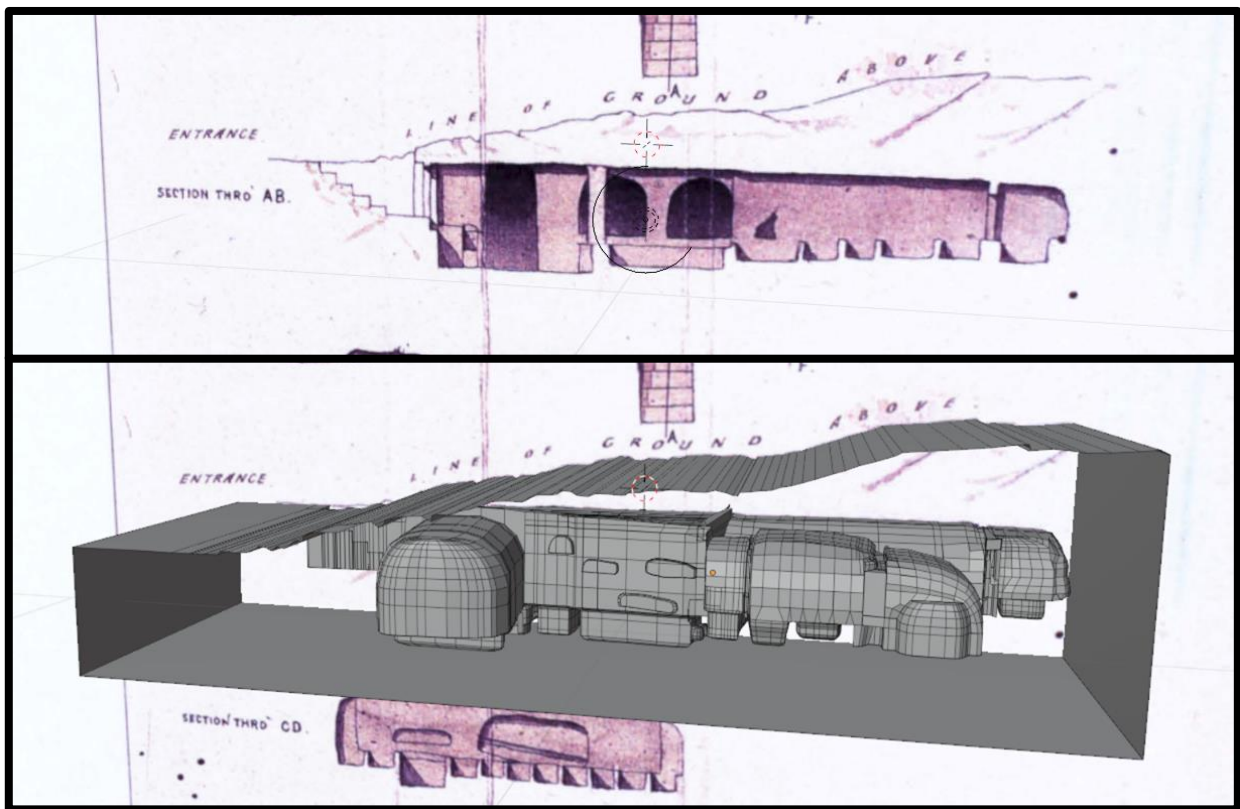


Figure 54. Screenshots from Blender showing the section AB with the sketched profile of the bedrock (above) which was reconstructed (below) to simulate the terrestrial topography of the Jesuits' Hill (photo by the author).

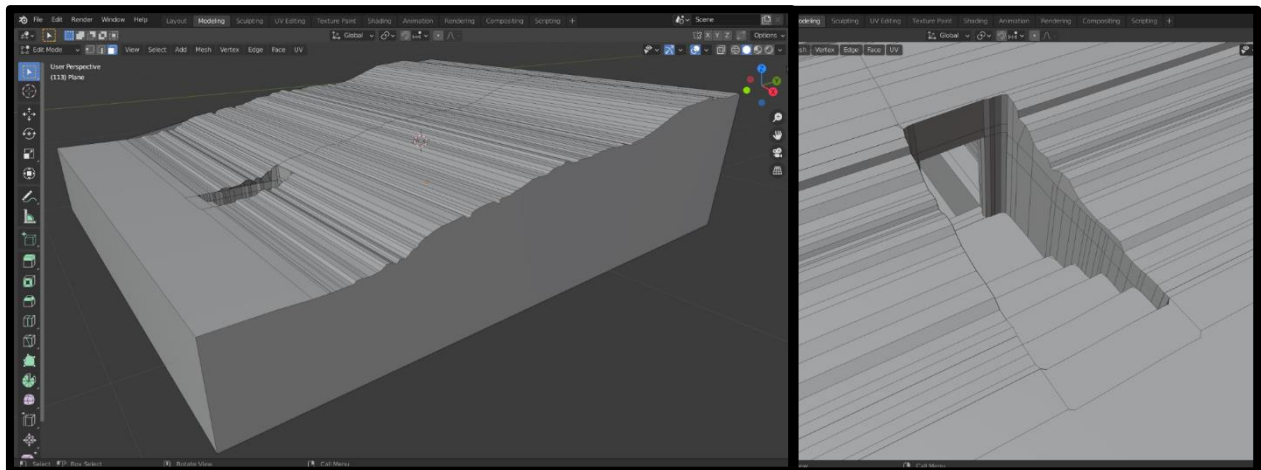


Figure 55. Screenshots from Blender showing the reconstructed shaft, steps and doorway of the hypogeum (photo by the author).

3.3 Data visualization: from a 3D to a VR engagement

Having mentioned the importance of the viewer's visual interaction and engagement, the third and last stage of this workflow consisted in the creation of a suitable medium to present the reconstructed 3D model of site in question to the public/audience. The most suitable medium identified to tackle this task was that of Virtual Reality, a computer-based simulation which allows the viewers to be fully immersed in the environment of the reconstructed model.²²²

In order to do so, the 3D mesh was exported and uploaded to a different software, Unity®, a free and open source game engine that was chosen for similar reasons to those for the choice of Blender and for which training could be provided. The employment of this game engine improved the raw 3D mesh to a fully-immersive VR experience. This was accomplished through a number of different VR features which will be presented individually below.

3.3.1 Texture

First and foremost, texture had to be applied to the polygons of the site's 3D mesh, a task that can be carried out either on Blender or on Unity. In order to apply texture to a 3D model, each polygon has to be unwrapped and placed onto a 2D plane, on which a given texture is overlaid. These textures can either be selected to represent specific uniform colours, or distinct material patterns, representing surface characteristics and appearances. For this site, it was decided to texturize the site with a material characteristic of the geological nature of the site, namely the Globigerina Limestone formation.²²³ Initially, it was decided to exploit one of the many portions of exposed bedrock visible today on the Jesuits' Hill (e.g. Fig. 56), by capturing photographs of these and including them as a texture material.

Unfortunately, this strategy did not work out as expected since these texture images need to be seamless. This is an important requirement, since it allows the textures to perfectly match when repeated along the polygons of the 3D mesh and therefore, a suitable seamless texture had to be obtained from an open-source catalogue.²²⁴

²²² Bardi 2019.

²²³ Geological Map of the Maltese Islands 2022.

²²⁴ Downloaded from Texture Library 2022.

Between several options of limestone textures, the one selected to feature in this reconstructed Early Christian hypogeum can be seen below (Fig. 57) and was chosen because of its characteristic toolmarks which strongly resemble those found in other burials sites of this kind in Malta (e.g. Ta' Bistra – Fig. 58).



Figure 56. Photo showing the texture of the *Globigerina* Limestone, the geological layer present in Marsa. (Google Earth 2022).



Figure 57. The limestone texture with distinctive toolmarks chosen to texturize the reconstructed mesh of the hypogeum (Texture Library 2022).



Figure 58. Photo showing the distinctive toolmarks visible in the Ta' Bistra catacombs in Mosta, Malta (Google images).

3.3.2 Lighting

In order to better represent the environment of the virtual scene, 3D graphic software and game engines allow users to create, adjust, and position different sources of lighting within the model. While virtually diffused lighting allows to mimic the natural sunlight and resulting shadows, other light sources are crucial to better illuminate and present scenes of the texturized mesh.

The creation of simulated sunlight located opposite to the reconstructed portion of the Jesuits' Hill was not sufficient to properly illuminate the underground chambers, due to the underground nature of this site. Therefore, simulating the practice in catacomb sites accessible to the public in Malta (e.g. St Paul Catacombs in Rabat), spotlights were uniformly positioned in each chamber and *arcosilium*. In

order to avoid dazzling sources of illumination, it was decided to ‘bake’ the lighting within the inner walls of the 3D mesh, in order to enhance the rendering of the texture and ensuring a diffused illumination throughout the site.

Nevertheless, in order to preserve a faithful representation of a site of this kind a certain degree of darkness was maintained which allowed to experience the site as probably Wright discovered it in 1874. However, to allow the VR viewer to explore the darker chambers, a source of mobile lighting simulating the lighting of an electric torch was enabled. This can be activated by the user by pressing on a side button on the left controller and it follows the movement of its hand enhancing the physical engagement and interactivity.

5.3.3 Accessing the model

Once the visual-aesthetic components (i.e. texture and the lighting) of the VR model were completed, efforts were focused on allowing virtual accessibility to the reconstructed site. This stage entailed the most elaborate computational tasks of this study, such as computer programming (also known as coding), which were executed on Unity by Dr Spina. The sequence of processing included:

- i. the creation of a ‘character’ serving as a virtual viewer within the model, whose field of view corresponds to that of the observer in the physical world;
- ii. the coding of commands which allow the character/observer to move in space through the implementation of a locomotion system.

The ‘Unity scene file’ of the virtually reconstructed hypogeum can either be accessed from a computer or from an appropriate VR Headset. In the first case, the user would view the VR model through a computer display while navigating freely using keyboard and mouse commands. The VR headset chosen was the ‘Oculus Quest 1 (Fig. 59) a popular head-mounted device which provides the wearer with a full-immersive engagement with the VR model.²²⁵

²²⁵ Kuchera 2015.



Figure 59. *The VR Headset chosen for this study: the Oculus Quest 1. (Oculus Website 2022).*

Following the uploading of the Unity scene file to the Oculus device, the viewer is able to access and experience the VR simulation of the Marsa catacomb. Thanks to its ‘head-tracking’ technology, the field of vision changes as the human body moves and the head turns, allowing the viewer to simulate a human interaction with the underground spaces projected in the VR headset. Although this feature guarantees the user to freely move in all spaces of the reconstructed catacomb, it was decided to integrate this physical navigation with a virtual one. Taking into consideration that this device allows to access the site from the comfort of an indoor location, a programmed set of commands would support the viewer’s navigation, in case the spaces in the physical world are restricted.

In addition to these commands, it was decided to include an additional virtual locomotion technique known as teleportation. This allows the character to be virtually transported to a preselected area of the model when accessing a designed virtual portal. These portals, represented as floating transparent spheres, were set equidistantly in selected locations of the catacomb. Through a coded script, Dr Spina associated a specific command to these spherical teleports, which, if selected, would allow the character to be re-located in the same position of the spheres. While wearing the VR headset, these portals can be selected by virtually pointing at them (Fig. 60) a virtually simulated red-laser beam using the right-hand controller (Fig. 61). Once hit by the laser, the sphere turns white (Fig. 62) and, after pulling the right-hand controller trigger, the character is teleported.



Figure 60. Screenshot from the VR model showing how to select the teleporting spheres with the right hand controller (photo by the author).



Figure 61. Screenshot from the VR model showing the simulated red-laser beam in the act of hitting the teleport sphere. (photo by the author).



Figure 62. Screenshot from the VR model showing the simulated white-laser beam when hitting the teleport sphere (photo by the author).

This choice was implemented to tackle two shortcomings noticed when the VR headset was tested on volunteers, such as feeling disoriented inside the virtually reconstructed catacomb and experiencing VR sickness. As a matter of fact, teleportation is known to facilitate the logistics of VR navigation and reduce the possibilities of VR sickness,²²⁶ allowing users to navigate from a stationary location (e.g. sitting down).

3.3.4 Functional decorations

A few functional and decorative elements were added to the final VR model. Keeping in mind that the catacomb was correctly scaled on Blender and that Unity portrays the VR model in a scale of 1:1, it was decided to include some elements that would provide the viewer with a visual sense of scale. Instead of opting for an archaeological scale bar, a VR model of a human scale was preferred. Therefore, a contemporary female figure – representative of a tourist intent on visiting the reconstructed archaeological site – was imported from an open-source catalogue built-in Unity. The visual impact of this figure on the viewer was achieved by placing this character standing on the floor of Chamber A (Fig. 63). Given the height of this human scale (175cm), it can be observed how its head almost touches the roof of the chamber, conveying a sense of spatial constriction, which characterizes this small-scaled catacomb.

Additionally, a few VR models of articulated skeletons (downloaded from the same catalogue) were also imported in the reconstructed site; scaled to fit (between 155cm and 165cm); and placed in a couple of sarcophagi (Fig. 64). This choice was motivated by purely decorative purposes as, at the time of discovery, Wright was unable to recover any human remains “as all fell to atoms on being touched”.²²⁷

3.3.5 Accessing of the data

Finally, in order for the readers to access the reconstructed catacombs and engage with the VR experience of the site, an Oculus Headset will be made available with this dissertation. In addition, a number of screenshots and video-recordings taken

²²⁶ Prithul *et al.* 2021: 1.

²²⁷ Wright 1874: 2.

from the VR visualization will be included in a folder downloadable from the Google Drive link found below.²²⁸ In this folder, the Blender and Unity files will also be uploaded although can only be accessed after installing these software.



Figure 63. Screenshot from the VR model showing the 175cm tall virtual human scale model. (photo by the author).

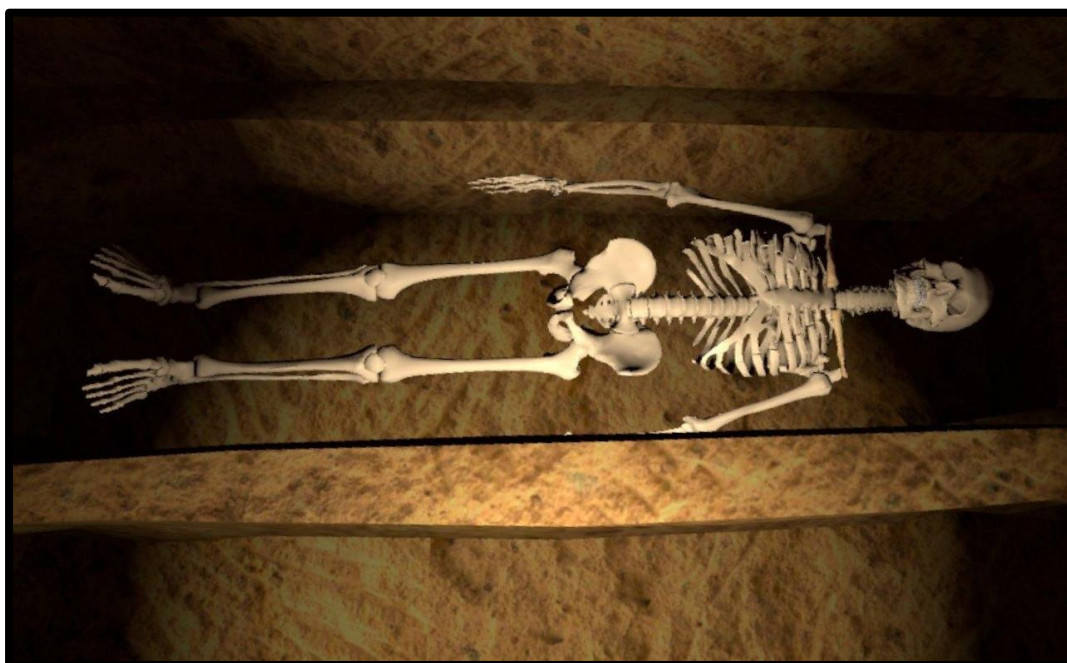


Figure 64. Screenshot from the VR model showing the simulated skeleton located in one of the sarcophagi (photo by the author).

²²⁸ Google Drive link available at: <https://drive.google.com/drive/folders/1iVhD-TTJDff74eSWiXhWgxpuzJQn-8z?usp=sharing>

Chapter 4



Methodology and Results Site B

Chapter 4 presents the virtual reconstruction of the second case study: the Roman *Horrea* discovered on the top of the Jesuit's Hill between 1766 and 1768. This will be done by presenting the methods adopted to virtually reconstruct this site and the obtained results, occurred through two main stages:

- i. Data gathering (Section 4.1);
- ii. Data processing (Section 4.2);

4.1 Gathering the data: retrieving and digitising Barbaro's documentation

As explained in Section 3.1, the collection of available legacy data was key to the first stage of this methodology and part of this exercise begun when reviewing the literature (Subsection 2.3.2). As for Site A, the reconstruction of this site was entirely based on the primary source of one author, namely C.A. Barbaro. Since the *Horrea* were discovered before photography, the legacy data consists of written and drawn sources.

Barbaro's written report on the discovery of ancient remains in Marsa was published and printed by the Grand Master's press in 1794. The first task of the data gathering entailed the retrieval of a copy of this document. Since the author of this report wrote in 18th century Italian, the second task focused on the translation of the chapters relevant to this study. The translation was carried out by the author and

concerned ‘*Sezione II*’ and ‘*Sezione III*’, where the standing structures and the underground features are presented respectively. Barbaro’s written account included architectural and archaeological data crucial for the site’s virtual reconstruction, such as:

- i. measurements: to confirm (or amend) those portrayed in Barbaro’s survey and provide additional data when building the 3D mesh;
- ii. construction and building materials (CBM): to render the surface textures of the 3D mesh;
- iii. spatial relationships: to grasp the interactions between the structures of the site, and how the latter relates to the morphology of the landscape;
- iv. functional interpretations: to enhance the understanding of the site’s structures when 3D modelling. This allows to rebuild features basing the reconstruction on examples found in similar sites documented in the archaeological record.

The units of the collected in-text measurements had to be translated. Each structure documented by Barbaro was measured in ‘*palmi*’, a unit of length, which at the time in Malta was equivalent to 0.26 m.²²⁹ Therefore, by multiplying each value in *palmi* by 0.26, all of Barbaro’s measurements were converted to the metric system.

The gathered drawn legacy data consists of a 18th century printed survey which was probably based on a hand-drawn sketch which Barbaro drew when he first visited the site in 1768.²³⁰ Unfortunately, this drawn plan of the ruins was not available from the acquired copy of Barbaro’s *dissertazione*. However, a .jpeg scan of this survey was provided by Prof. Gambin, who had accessed it and employed it in his doctoral thesis.²³¹

²²⁹ Palaiseau 1816: 160.

²³⁰ Barbaro 1794: 3.

²³¹ 2005 – Figure 4.24.

As seen above (Fig. 26), this survey shows:

- i. a plan of the archaeological ruins;
- ii. a North point to orient the survey;
- iii. a 200 *palmi* scale bar (equivalent to 52m).

4.2 Processing the data: 3D modelling Barbaro's legacy data

As in the case of Site C (Subsection 2.4.3), the composition and architectural layout of the structures described by Barbaro are characterised by orthogonal alignments of limestone ashlar blocks. For this reason it was decided to tackle the 3D reconstruction of the *horrea* adopting the strategy provided by Dr Spina's above-mentioned tutorials. As shown below (Section 5.1), when dealing with orthogonal architectural layouts Spina's methodology, which consists of subdividing and extruding a plane mesh, proved effective. On the other hand, when it came to 3D render and texturize construction building materials (CBM), this method presented some limitations. For this reason, in addition to the method described, an additional approach was specifically designed in order to tackle this shortcoming. As for Site A (Section 3.2) and Site C (Section 5.1.2), these two complementary 3D reconstruction techniques were carried out using Blender and are presented below.

4.2.1 Method 1: reconstructing by CBM unit

When assigning a texture to the polygons of a 3D mesh, the objective is to visually reconstruct the surface appearance that would have once characterised the structure in question. Most frequently, these textures are taken from a 2D set of data which are then projected onto the polygons of the mesh. Therefore, in order to convey to the viewer an enhanced visualization of the monument's physicality, the method consisted in reconstructing a single structural unit of the CBM, from which a structure could have been built.

The first stage of this data processing entailed the 3D reconstruction of this CBM unit, namely a Roman limestone ashlar block which Barbaro describes as being 0.5 m wide, 0.5 m high and between 1.8 m and 2.4 m long.²³² This was accomplished

²³² Barbaro 1794: 3

following three relatively straightforward steps on Blender (Fig. 65). Firstly, a cubical-shaped mesh was generated and scaled accordingly. Since Barbaro provided a length range, the ashlar blocks were scaled with three different lengths (i.e. 1.8 m; 2.1 m; and 2.4 m). Secondly, to avoid visually artificial sharp edges, the ‘Bevel’ tool was employed to smoothen the sides of these blocks. Thirdly, a yellowish limestone texture was downloaded from an open source catalogue and was used to individually texture an ashlar block.

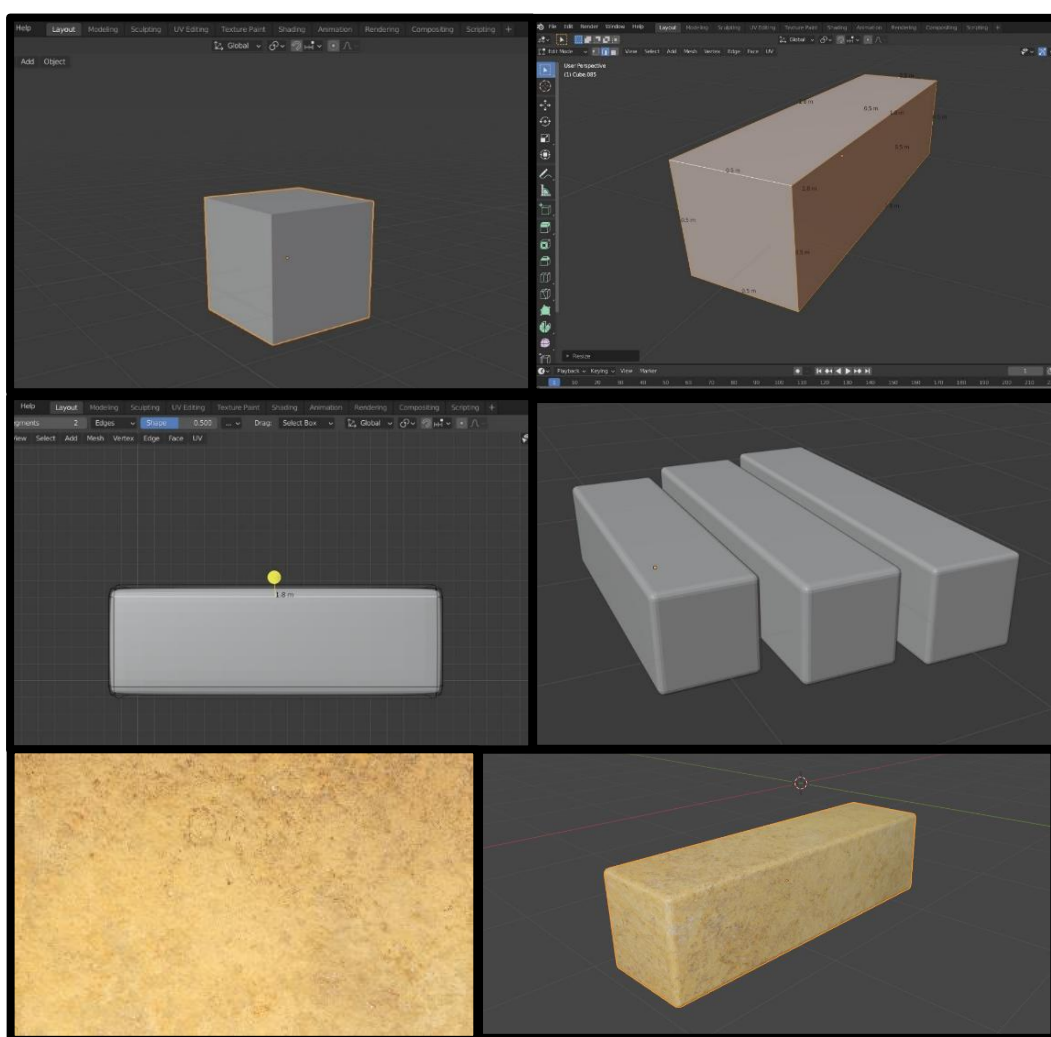


Figure 65. Screenshots from Blender showing the steps of 3D reconstruction of one of the ashlar blocks described by Barbaro (photo by the author).

Once the individual CBM unit was virtually reconstructed, the second stage of this process entailed the replication of this ashlar block using Blender's 'duplicate' function (Fig. 66). In this way, it was possible to create a wall unit and subsequently an orthogonal structure (Fig. 67). By uploading and scaling Barbaro's survey on Blender's X-Y plane, it was possible to replicate the ashlar blocks following the perimeter of the surveyed structures and reconstruct one room of the *horreum* (Figs. 68-70). Since Barbaro describes the ruins being between 1.8 m and 2.4 m, high, the 3D reconstruction was concluded after the fourth course of ashlar blocks was reconstructed. A 3D model showing the results of this exercise can be accessed on Sketchfab by clicking on a link in the footnotes.²³³

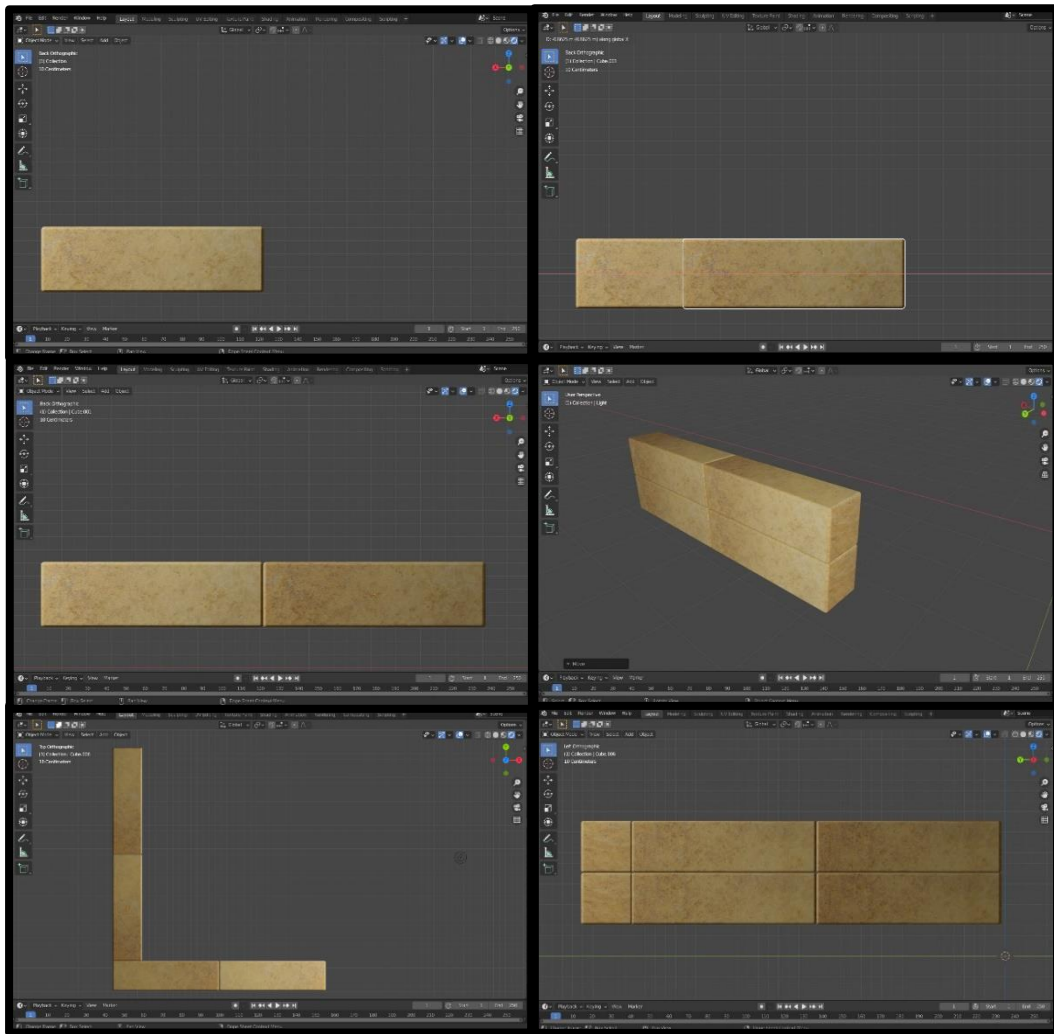


Figure 66. Screenshots from Blender showing the steps of 3D reconstruction of an ashlar wall (photo by the author).

²³³ This 3D model is available at: <https://skfb.ly/o6UzW>.

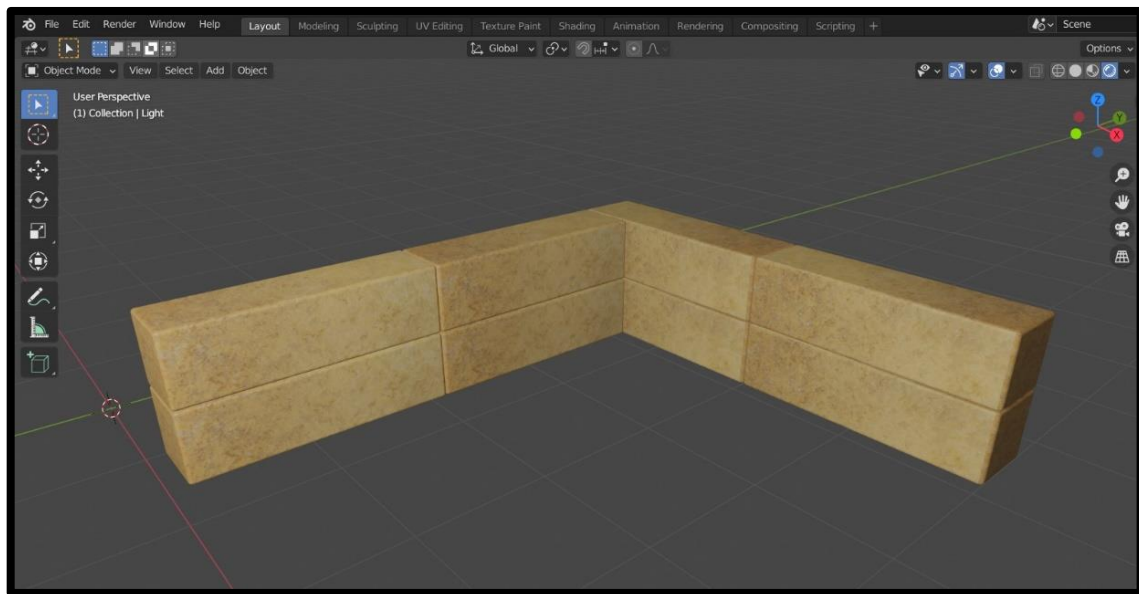


Figure 67. Screenshot from Blender showing the reconstruction of an orthogonal structure (photo by the author).

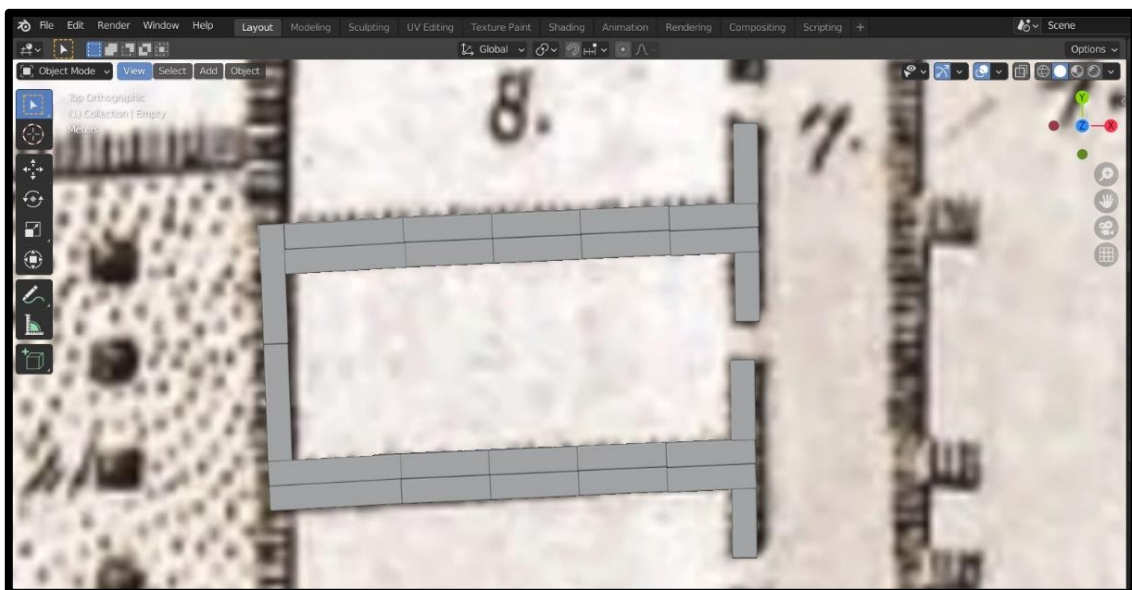


Figure 68. Screenshot from Blender showing a reconstructed room of a Horreum from a plan view (photo by the author).

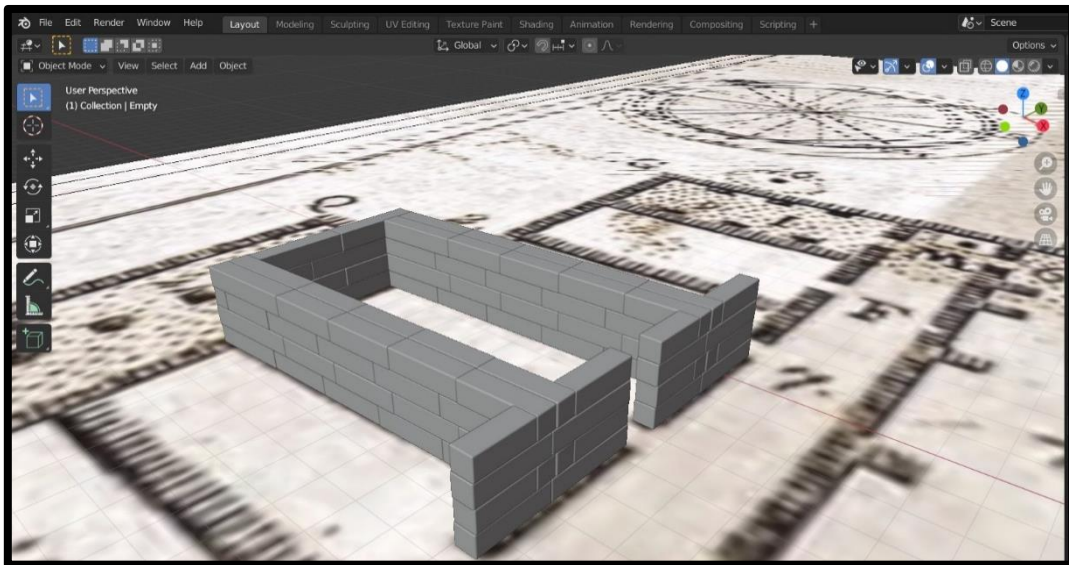


Figure 69. Screenshot from Blender showing a reconstructed room of a Horreum from a perspective view (photo by the author).

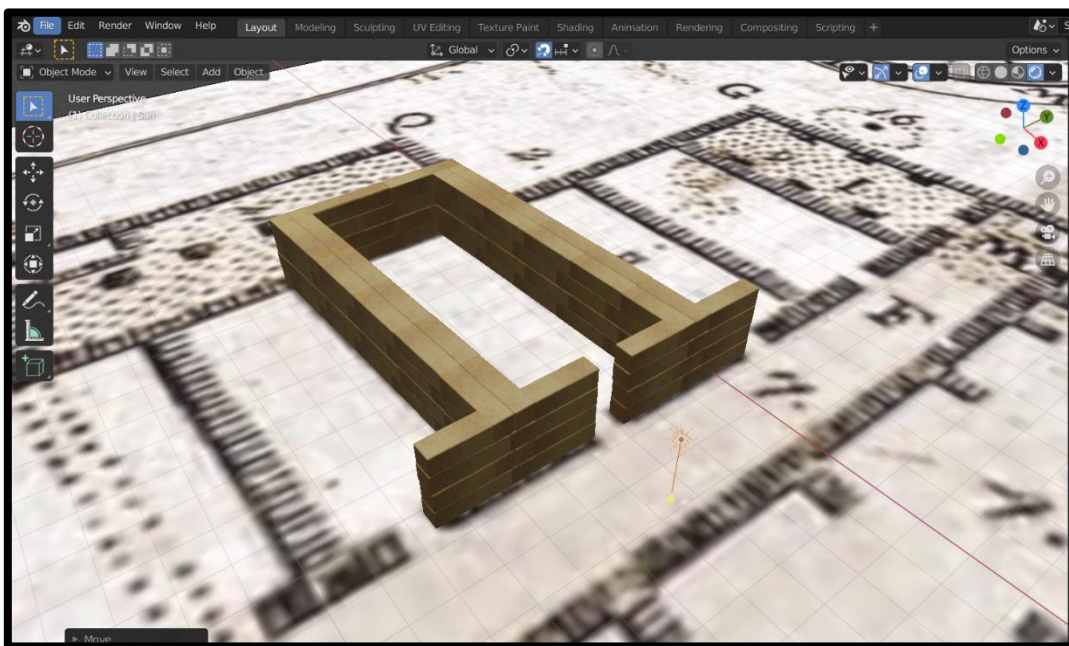


Figure 70. Screenshot from Blender showing a reconstructed room of a Horreum from a perspective texturized view (photo by the author).

4.2.2 Method 2: reconstructing by planar mesh subdivision

Alternatively, the 3D mesh of the *horreum* structures were reconstructed employing the strategy suggested by Dr Spina. The .jpeg file portraying the scanned survey of the *horrea* was imported on a new Blender file, placed in the software's X-Y plane and scaled using the scale bar found at the bottom-right corner of the drawing. Since this 3D reconstruction strategy is entirely based on the drawn documentation, it was worth verifying the accuracy of Barbaro's survey. This exercise entailed a comparison of measurements calculated from the scaled plan over those specifically mentioned in the text, which Barbaro personally measured on site. Therefore, a sample of ten distances were selected from Barbaro's text, converted to the metric system, and measured in the scaled survey using Blender's 'Edge Length' function (Fig. 71). Therefore, it was possible to calculate the errors and accuracies of these ten sampled distances by employing the formulas below:

$$e = x_{(t)} - x_{(d)}$$

$$\delta = \frac{e}{x_{(t)}} \cdot 100\%$$

$$a = 100\% - \delta$$

Firstly, the error (e), understood as the difference between the in-text measurement $x_{(t)}$ and the respective survey measurement $x_{(d)}$, was calculated by simply subtracting the two corresponding values.²³⁴ However, to understand the weight of these discrepancies, it was crucial to relate each error to the total value of $x_{(t)}$.²³⁵ For this reason, the percent error (δ) was calculated relating the error to the respective in-text value. Consequently, the accuracy (a) was gathered by subtracting δ to a total 100%. The results are presented below in Table 1.

Although this exercise included just a limited number of samples, it provided a broad, yet clear, insight on the reliability of drawn legacy data, which is the central source on which this 3D reconstruction strategy is based. The collected and processed measurements provided very diverse results, from some almost matching

²³⁴ In order to avoid negative values, only the magnitude was considered.

²³⁵ Assuming that the measurements of the drawing are based on the ones in the text.

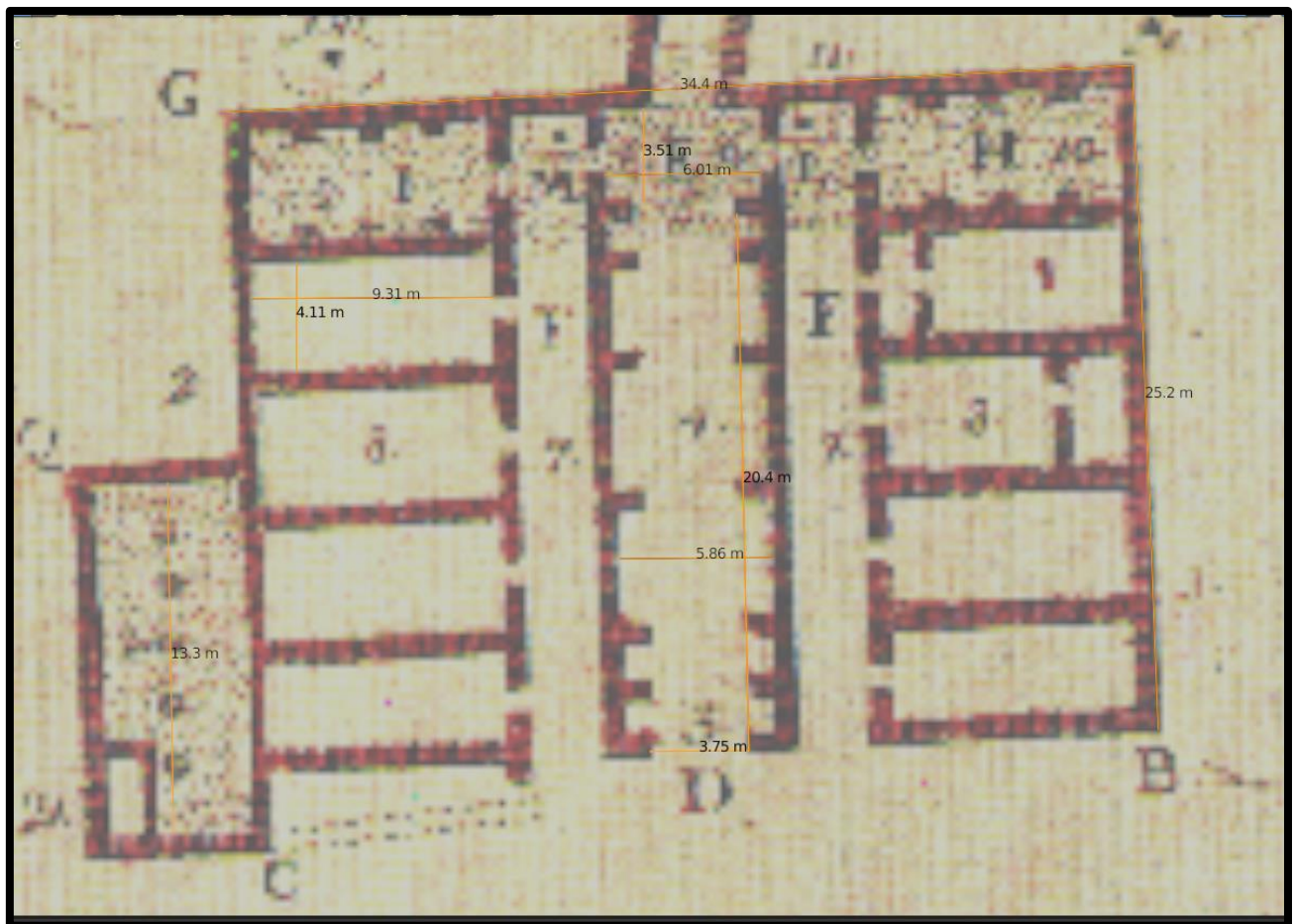


Figure 71. Screenshot from Blender showing the sample measurements selected and measured with the 'Edge Length' function on Blender (photo by the author).

Distance description	Measurement in Palmi	Conversion to Meters	Measurement on Survey	Error (m)	Error (%)	Accuracy (%)
Length <i>Horreum</i> A-B	95	24.7 m	25.2 m	0.50 m	2.02%	97.98%
Width <i>Horreum</i> A-G	132	34.3 m	34.4 m	0.01 m	0.03%	99.97%
Width Doorway D	12	3.12 m	3.76 m	0.64 m	20.5%	79.5%
Length Vestibule D-E	80	20.8 m	20.4 m	0.40 m	1.92%	98.08%
Width Vestibule	20	5.20 m	5.86 m	0.66 m	12.7%	87.3%
Length Porch E	10	2.60 m	3.51 m	0.91 m	35.0%	65.0%
Width Porch E	20	5.20 m	6.01 m	0.81 m	15.6%	84.4%
Length Room	36	9.36 m	9.31 m	0.05 m	0.53%	99.47%
Width Room	15	3.90 m	4.11 m	0.21 m	5.38%	94.62%
Length Cistern Q-C	50	13.0 m	13.3 m	0.03 m	0.23%	99.77%

Highest Value	0.91 m	35.00%	99.97%
Lowest Value	0.01 m	0.03%	65.0%
Median Value	0.45 m	3.70%	96.3%
Mean Value	0.42 m	9.39%	90.61%

Table 1. Table showing the results of the comparative analysis of Barbaro's the measurements.

(e.g. the width of the horreum A-G), to some consistent differences (e.g. the length of the porch E). However, the mean value calculated out of these ten samples shows that the expected average discrepancy is of 0.42 m which, given the great extension of these structures, provides a reassuring 90.61% of accuracy.

With this result in mind, the bottom edges of the 3D mesh of the largest *horreum* were reconstructed relying entirely on the measurements provided by the drawing. Again, in this case, a planar mesh was added, overlaid on Barbaro's survey, and made transparent using Blender's 'Toggle X-Ray' function (Fig. 72). This was subdivided using the 'Knife' tool. In order to reconstruct the walls of the *horreum* the reconstructed footprint of the structure (Fig. 73) had to be extruded in the Z-plane, perpendicular to the ground. Given the lack of drawn section-elevations and exact height measurements, it was decided to extrude the walls of the *horreum* by an arbitrary height of 2.1 m, the average value of the 1.8-2.4 m range provided by Barbaro (Fig. 74).²³⁶

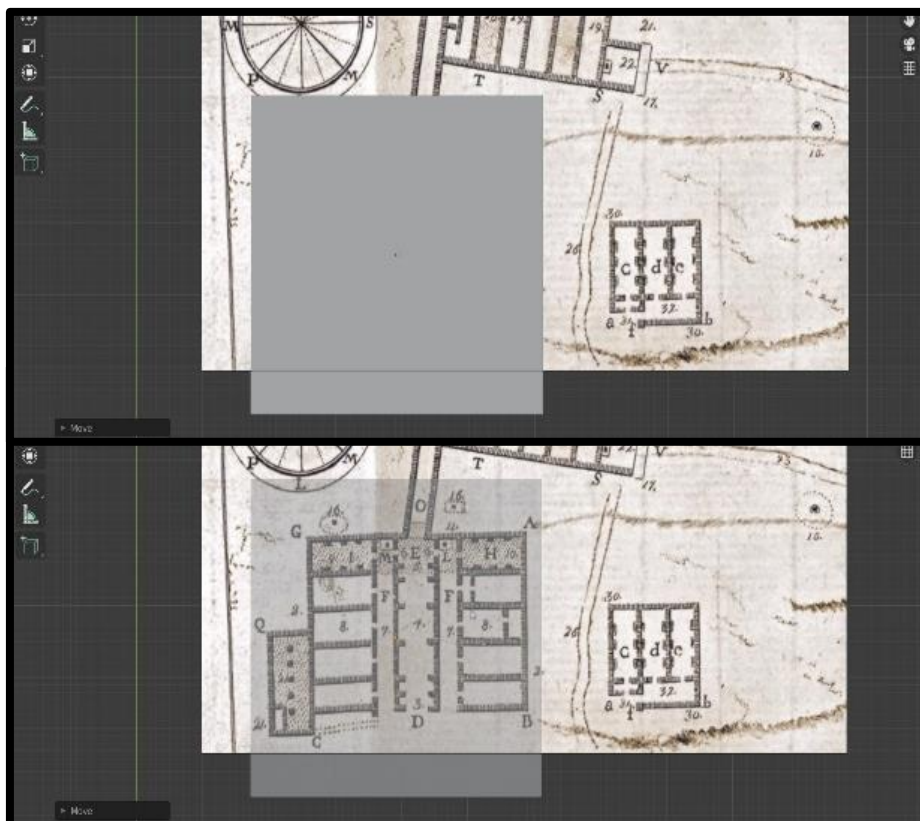


Figure 72. Screenshots from Blender showing the overlaying of the planar mesh made transparent with the toggle-view function (photo by the author).

²³⁶ 1794: 3.

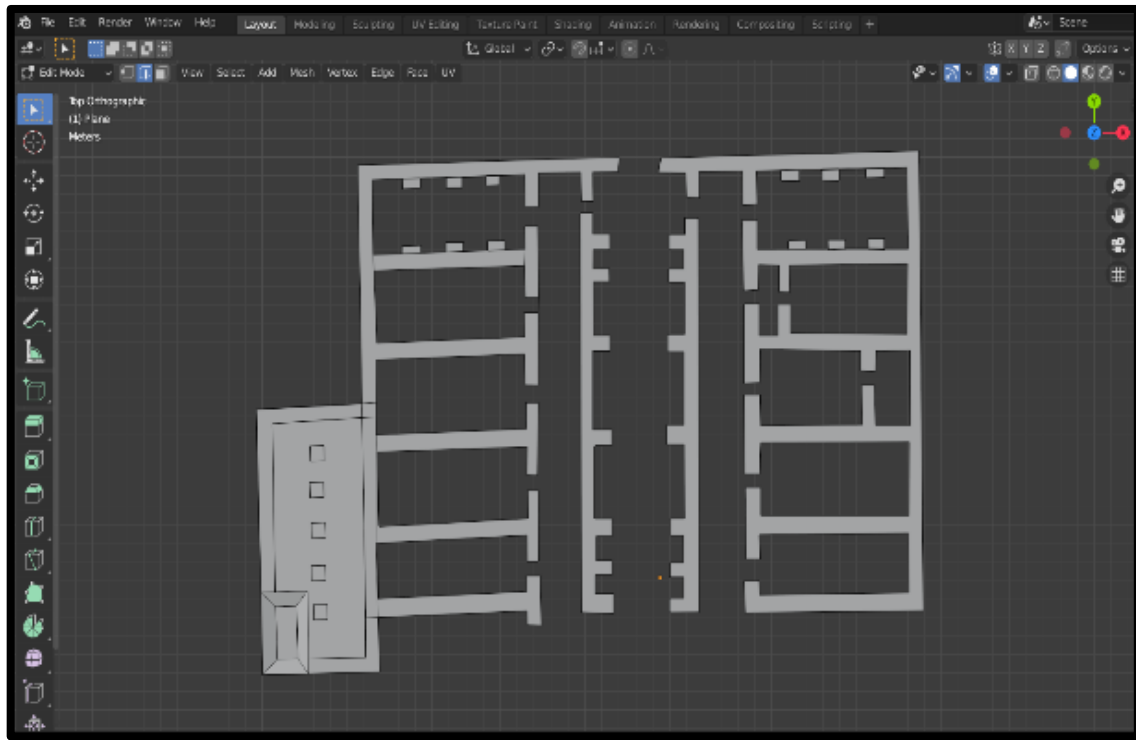


Figure 73. Screenshot from Blender showing the plan view of the reconstructed mesh of the largest horreum (photo by the author).

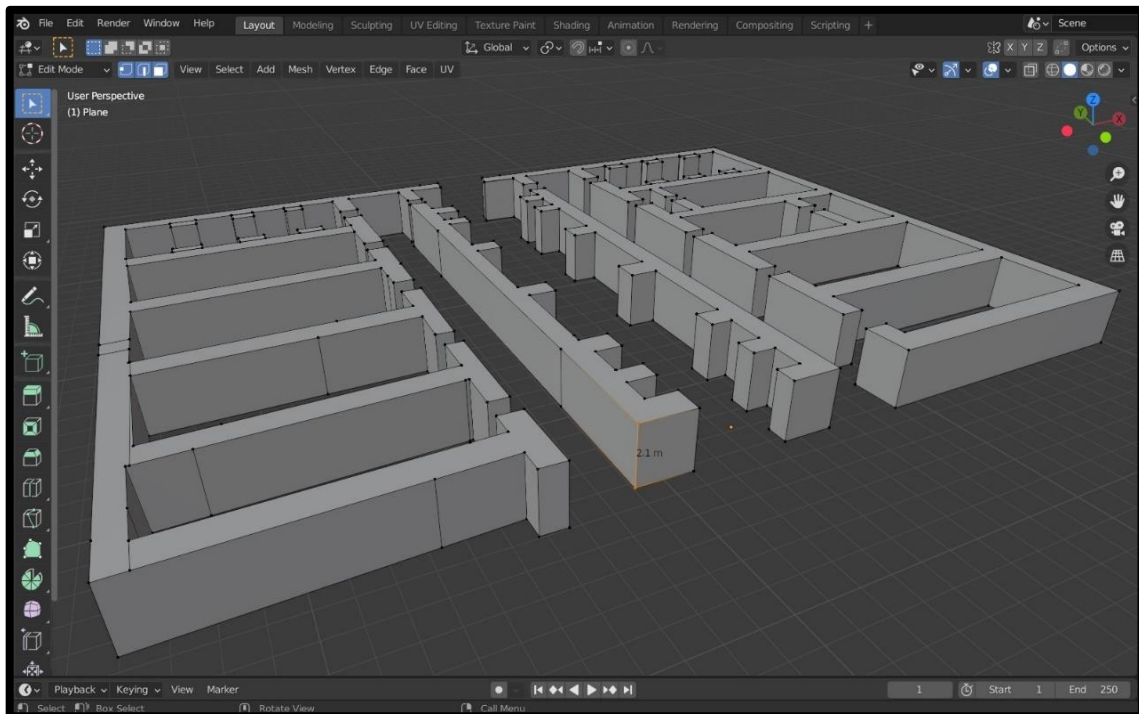


Figure 74. Screenshot from Blender showing the perspective view of the reconstructed largest horreum mesh after extruding the plan in the z-axis orientation by 2.1 m (photo by the author).

4.2.3 The limitations of Site's B legacy data: incomplete 3D reconstructions

Following these stages, a set of problems did not allow this study to proceed further with the 3D reconstruction of this site. These shortcomings, which affected both strategies, originated from the legacy data and are addressed below.

Arguably, the most evident limitation of Barbaro's legacy data is to be identified with the absence of section-elevation drawings. As in the case of Site A, these drawings would have been imported on Blender's Z-X plane and located over their respective positions in the plan, allowing the reconstruction of the walls and ceilings of the site. Given this gap in the drawn record, the missing data was therefore sought after within the written descriptions of the site. As a result of this exercise, two other shortcomings were identified within Barbaro's legacy data, the lack of important measurements and the inconsistency of some of Barbaro's own descriptions and interpretations.

The first method adopted to fill these data gaps was to identify any in-text references to the heights of the standing structures and depths of the underground features of Site B. If Barbaro can be considered quite rigorous in describing the lengths and widths of these structures, unfortunately the same cannot be said for their heights and depths. The only two instances where Barbaro mentions these values, they appear vague and possibly inaccurate. The former refers to the aforementioned broad range elevation of the walls of the largest *horreum*, while the latter to the height of an archway (See Fig. 26 – O) which he describes being “*alta palmi 27 incirca*”²³⁷ corresponding to an excessive 7 m tall feature. Although this height is not beyond the construction capabilities of the time (e.g. *Horrea Epagathiana* in Ostia Antica), it is unlikely that such a standing building survived.

This rather confusing description is not an isolated case of unclarity within Barbaro's descriptions. Although the aim of the reconstruction of this case study is not to rebuild the site as it was in antiquity, but rather as it was when discovered in the 18th century, it is however difficult to establish from the text which walls were found standing, in which conditions, and if any roofing was found *in situ*. This task was made challenging by some of Barbaro's ambiguous statements, specifically,

²³⁷ Barbaro 1794: 4.

when discussing architectural features on site. In some instances it is questionable whether Barbaro is documenting features he encountered or rather interpreting how they would have looked like in antiquity. It is possible that, when providing the 1.8-2.4 m elevation range, Barbaro was generally referring to all the exposed ruins on site. However the lack of depth measurements for any of the recorded rock-cut cisterns clearly shows that some features were not thoroughly investigated or accessed in the first place. Furthermore, it is important not to forget that this work was published almost 30 years after Barbaro's site inspection, and it cannot be excluded that some of the data collected on site went missing or got reassessed.

One final problematic involves the lack of morphological data of the landscape. The *horrea* surveyed by Barbaro spreads over an approximately 3000m² area which from the top of a hill slopes eastward towards the sea. Unlike Wright did in Site A, Barbaro neither included any section drawings nor roughly sketched the slope of the bedrock, which would have permitted an understanding of the differences in the level of the structures of the site. In addition, these data are no longer available today due to the heavy development of the area over the past two centuries, resulting in heavy rock-cutting which transformed the morphology of Jesuits' Hill. Due to the lack of the geological and morphological data, buildings like the second *horreum* – accessible from a downhill road – and the third building – described as a 'substructure'²³⁸ built against the natural slope of the bedrock – could not have been virtually reconstructed.

For these abovementioned reasons, the reconstruction was not completed. Assuming that the bedrock below the largest *horreum* was fairly flat, the 3D reconstruction of the largest of the three buildings was interrupted at the stage shown in Fig. 70 (for Method 1) and in Fig. 73 (for Method 2). Although these results are not as complete as those of Site A, the mere extrusion of the foundations or the ashlar-by-ashlar reconstruction of a room of the largest *horreum* at least grants the viewer an enhanced visual engagement with this building.

Furthermore, even such a limited 3D reconstruction could still be employed to tackle small-scale research questions. A possible exploratory exercise could

²³⁸ Barbaro 1794: 6.

consider visualization of the storage of transport amphorae inside one of the reconstructed rooms of this warehouse, in order to investigate storing capacities and techniques. For this reason, two 3D models of 1st-2nd Cen. AD Roman amphorae, namely the Dressel II and Dressel XX, were downloaded from an open source catalogue (Fig. 75).²³⁹ These were imported into the ‘Method 1’ Blender file, duplicated, and placed accordingly inside the reconstructed rooms of *horreum* (Fig. 76) with the aim of fitting as many amphorae standing on the ground (Figs. 77-78). However, since these amphorae have significantly different dimensions than the Byzantine ones illustrated by Barbaro (Figs. 27-28),²⁴⁰ it is important to clarify that this exercise was carried out as a mere visual experiment which can be accessed by clicking on the link attached in the footnotes.²⁴¹



Figure 75. *The amphorae 3D models download from the open source catalogue (Free3D 2022).*

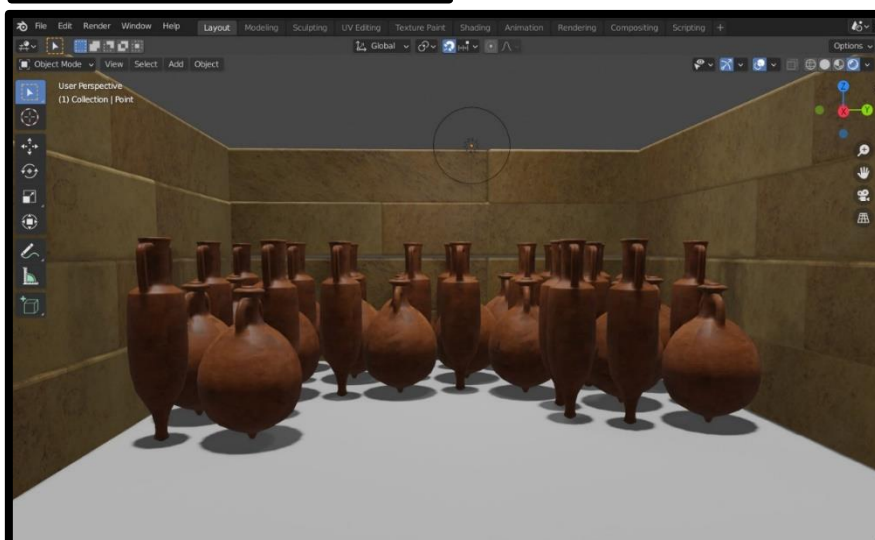


Figure 76. *Screenshot from Blender showing the positioning of amphorae in a room of the Horreum (photo by the author).*

²³⁹ Downloaded from: <https://free3d.com/3d-model/roman-amphora-pack-3836.html>

²⁴⁰ The ‘Spatheion’ and ‘Keay III’ typologies. See Bruno and Cutajar 2013: 21-22.

²⁴¹ This 3D model is available at: <https://skfb.ly/ovEvn> .

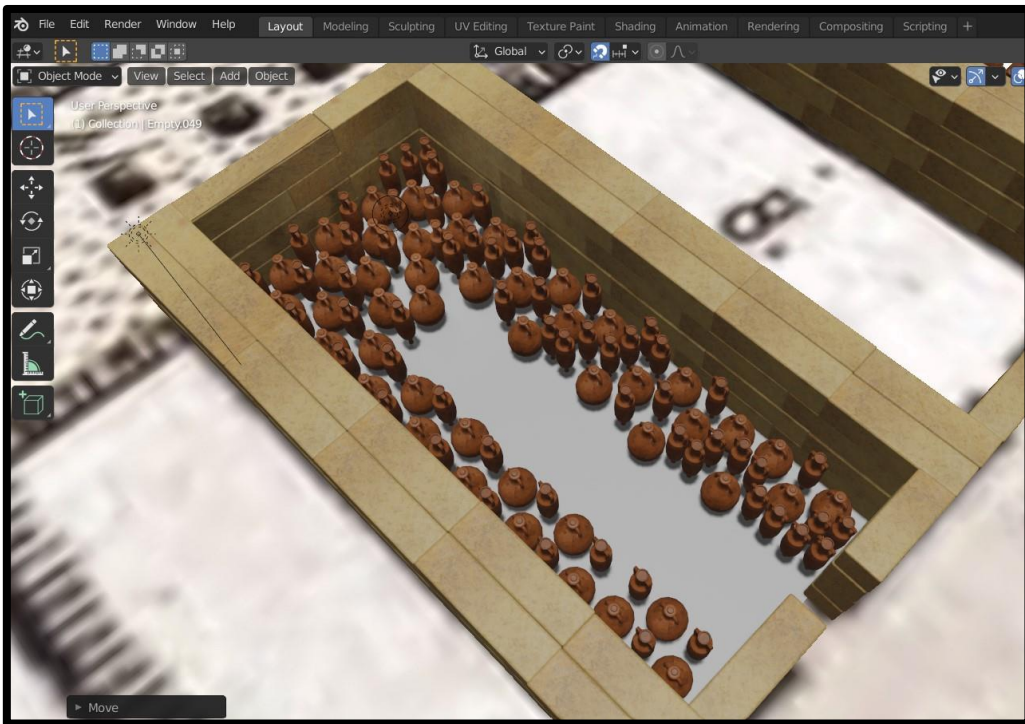


Figure 77. Screenshot from Blender showing the positioning of amphorae in a room of the Horreum from an aerial view (photo by the author).

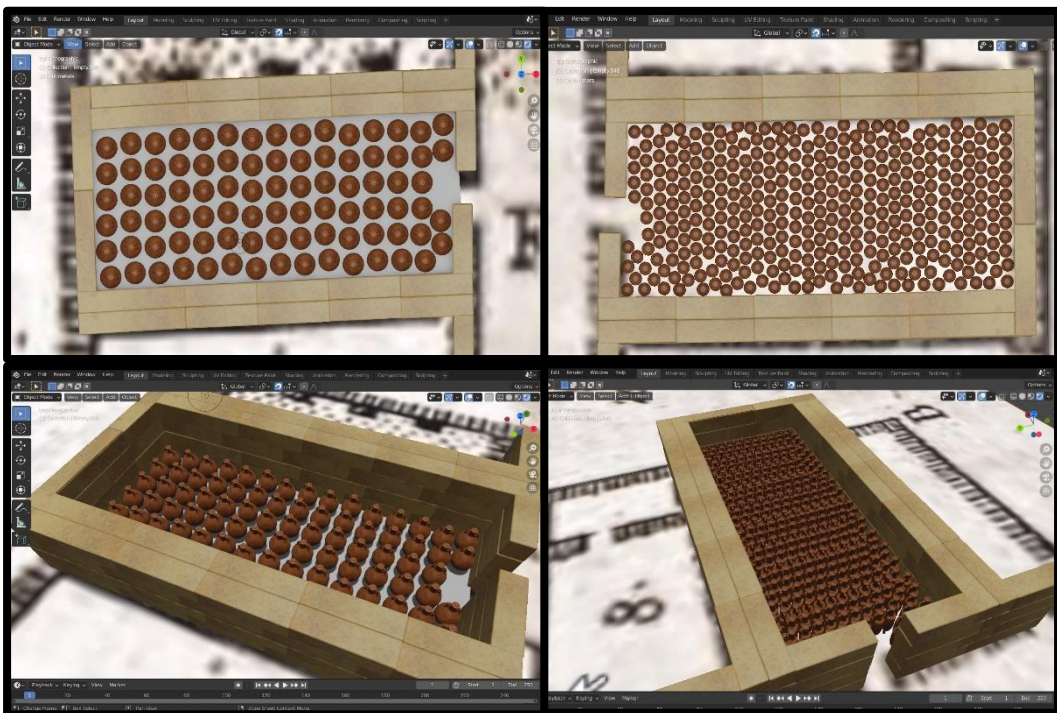


Figure 78. Screenshots from Blender showing the rooms of the reconstructed horrea stacked with amphorae (photo by the author).

Chapter 5



Methodology and Results Site C

The virtual reconstruction of the third and final case study of this research is presented below. As opposed to the former two (Chapters 3-4), the Punic building in Żurrieq is the only site which partially survives today. This factor enables this case study to compare of the virtual reconstruction built using legacy-data with the archaeological remains surviving *in situ*. Therefore, Chapter 5 will describe the methodologies adopted to reconstruct these two 3D models and the obtained results. The model reconstructed from the existing legacy data will be presented first (Section 5.1), and will be followed by the 3D model built from the surviving remains (Section 5.2). The methods and results for both these models will be presented through the main stages of their workflow, namely the:

- i. Data gathering (Subsections 5.1.1 and 5.2.1);
- ii. Data processing (Subsections 5.1.2 and 5.2.2);
- iii. Data visualization (Subsections 5.1.3 and 5.2.3).

Finally, these result will be assessed by a comparative analysis, which methods and outcomes will be presented in Section 5.3. This exercise will be carried out through a quantitative (Subsection 5.3.1) and a visual approach (Subsection 5.3.2) and will be ultimately be made accessible in VR.

5.1 The virtual reconstruction of the Punic Building as depicted by Jean Houël

5.1.1 Data Gathering: collecting the documentation

As for the former two sites (Sections 3.1 and 4.1), the first stage of this reconstruction consisted in the collection of the data required for the 3D and VR reconstruction of this site. By reviewing the literature of this site (Subsection 2.3.3) it was noted that the French painter had documented these ruins in 1776, while visiting Malta on a *Grand Tour*. The legacy data gathered from Houël consists of a brief written account and two watercolour paintings. Although these two illustrations were executed practically at the same time and portray the ruins in a similar state of preservation, these are quite different from each other.

The first drawing (Fig. 34 above) was published in Houël's 1787 publication '*Voyage Pittoresque de Sicile, Malte et Lipari*' and is based on an earlier preparatory *bozzetto* (Fig. 79). Here, Houël's drawing illustrates the written description of the site and for this reason it is cross-referenced within the text. The artistic rendition of this painting recalls that of a Renaissance, or rather Neoclassical, study of perspective and proportions, with the aim of portraying and illustrating the architectural features of this site. The artist achieves these aims by selecting a point of view which permits the viewer to fully appreciate the extent of the Punic structures. Moreover, by including human figures and depicting the surrounding 18th century urban context of Żurrieq, the scale and proportions of this site are well rendered. Beyond the artist representation of the site, Houël includes a technical drawing in the top-right corner of the paper sheet, providing a plan of the remains and a section drawing of the profile of the cornice topping the walls of the inner rooms (Fig. 80).

On the other hand, in the second painting (Fig. 35), today exhibited at the Hermitage Museum of Saint Petersburg (Russia), the artist adopts a different artistic style and point of view, located behind the structures. Though this watercolour still conveys a good sense of perspective and scale of the ruins, the stylistic rendition significantly shifts to a more romantic depiction. Here, the urban setting of Żurrieq is replaced by a rural one, almost predating those 19th century romantic landscape.

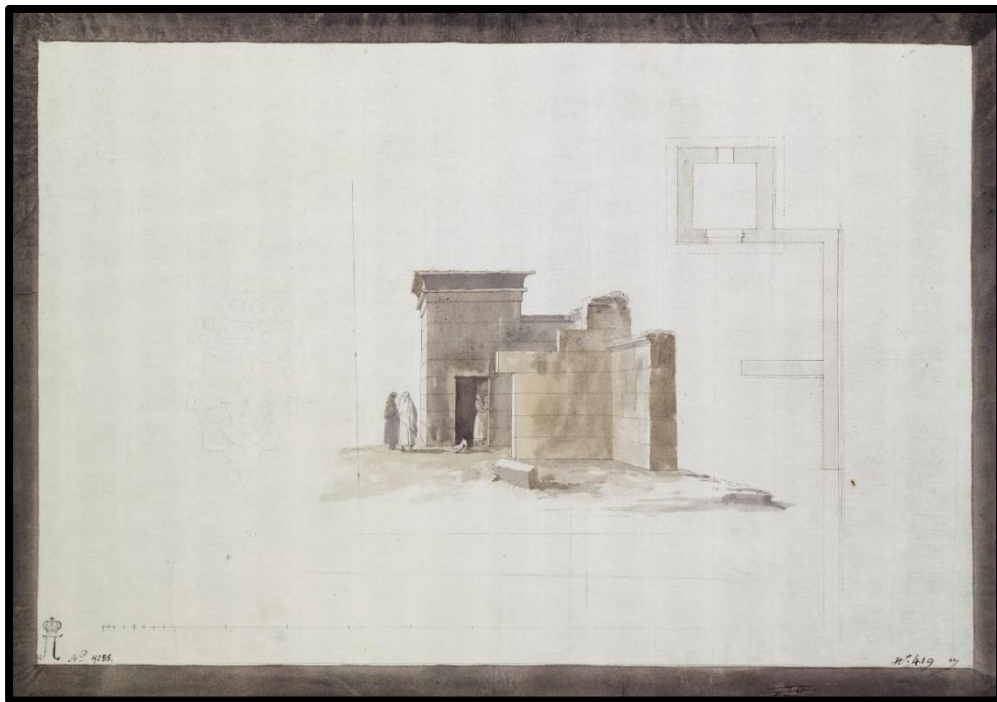


Figure 79. *The preparatory bozzetto of Houël's watercolour (Hermitage website 2022).*

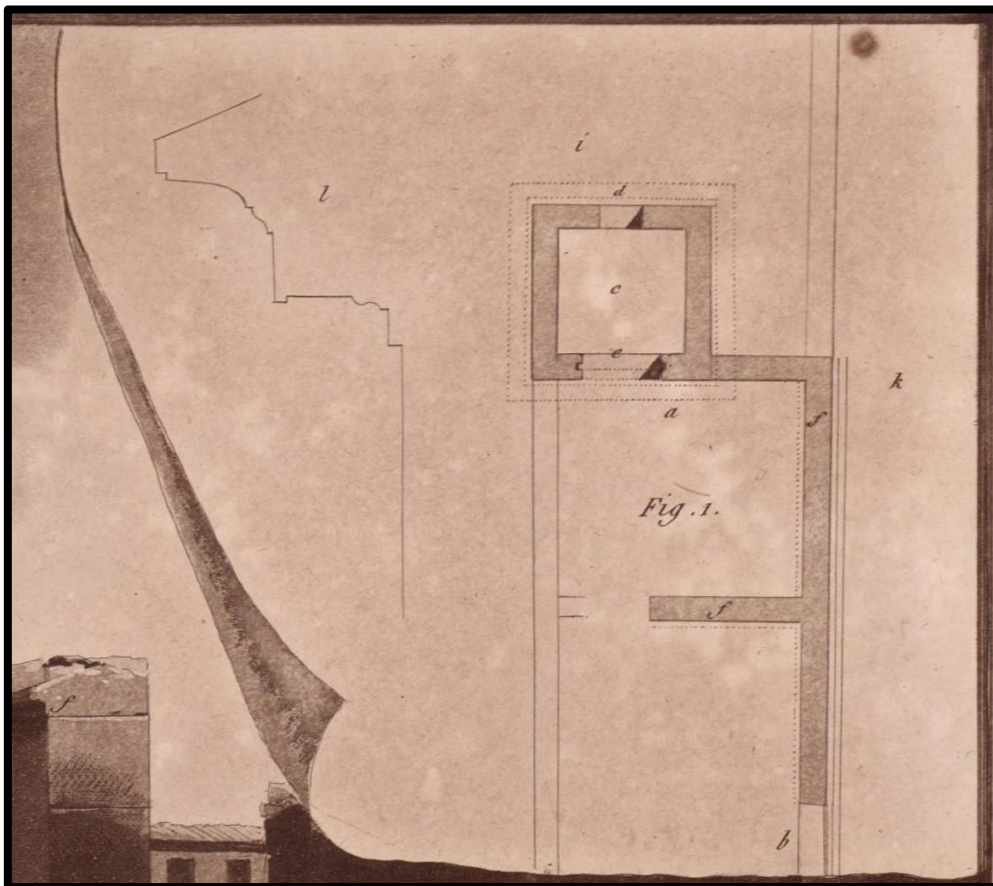


Figure 80. *Detail of the plan of Houël's survey (Hermitage website 2022).*

paintings that included ancient ruins in naturalist environments.²⁴² For the reasons mentioned above, this virtual reconstruction was based directly on the first watercolour, which appeared closer to an archaeological survey of the site.

Furthermore, the written account not only allows the reader to put the drawing into context, but it also provides important data for the virtual reconstruction itself. In order to gather the data available in this 18th century French report, this text was translated with the help of Ms. Emma Richard Trémeau, from the Department of Classics and Archaeology at the University of Malta. This exercise provided a couple of measurements which were crucial to scaling this survey, since the drawing's only indication of scale had to be assumed by the height of the 18th-century Maltese women included in the illustration. These measurements recorded the width of the square plan 'tower' and its height, respectively 9 feet wide and 17 feet tall. In pre-revolutionary France, this unit of length measured approximately 0.3248 m,²⁴³ making the tower 2.92 m wide and 5.52 m high.

Moreover, two other important details were extracted from Houël's statements in the text. The first concerns the artist's personal decision of not including in this drawing the modern masonry of the chaplain's house, which explains that by that times the archaeological remains were already built-over. The second regards the description of the drawn profile of the cornice, which he assigns to that topping the inner walls structures and not the tower's Egyptianizing cornice, as initially assumed. Probably due to its location at five meters above the ground, Houël was unable to survey the latter feature. To cover this gap in the legacy data, it was decided to include in the data gathering the section-elevation drawn during the 20th century archaeological investigations.

5.1.2 Data processing: 3D modelling Houël's legacy data

Having gathered all the relevant data, these were processed to obtain a 3D model of the Punic structures. As mentioned in Section 3.2, this was the first

²⁴² Such as 'Modern Rome – Campo Vaccino' by J. M. W. Turner and 'Salisbury Cathedral from the Bishop's Grounds' by J. Constable.

²⁴³ Boudriot & Berti 1993: 10.

reconstruction carried out by this study and therefore the one on which the training provided by Dr Spina was based. The proposed strategy was adopted in the Spring of 2021 and entailed the building of a 3D mesh by plane subdivision.

Firstly, Houël's survey file was uploaded on Blender in the X-Y plane (Fig. 81) and scaled using as reference the 2.92 m wide edge of the tower-like structure. Subsequently, a planar mesh was located at the coincidental Z-location of the survey and through the 'Toggle X-Ray' function, it was possible to see through the overlaid drawing (Fig. 82). At this stage the planar mesh was cut across selected locations employing Blender's 'Loop Cut' tool, which allows to equally subdivide a mesh and respectively generate independent areas within the mesh. These cuts were positioned along the orthogonal edges of the structures shown in plan. As a result of this exercise, the planar mesh was subdivided in areas corresponding to the walls of the Punic building, which could have now been reconstructed by extruding them along their top Z-axis orientation (Fig. 83).

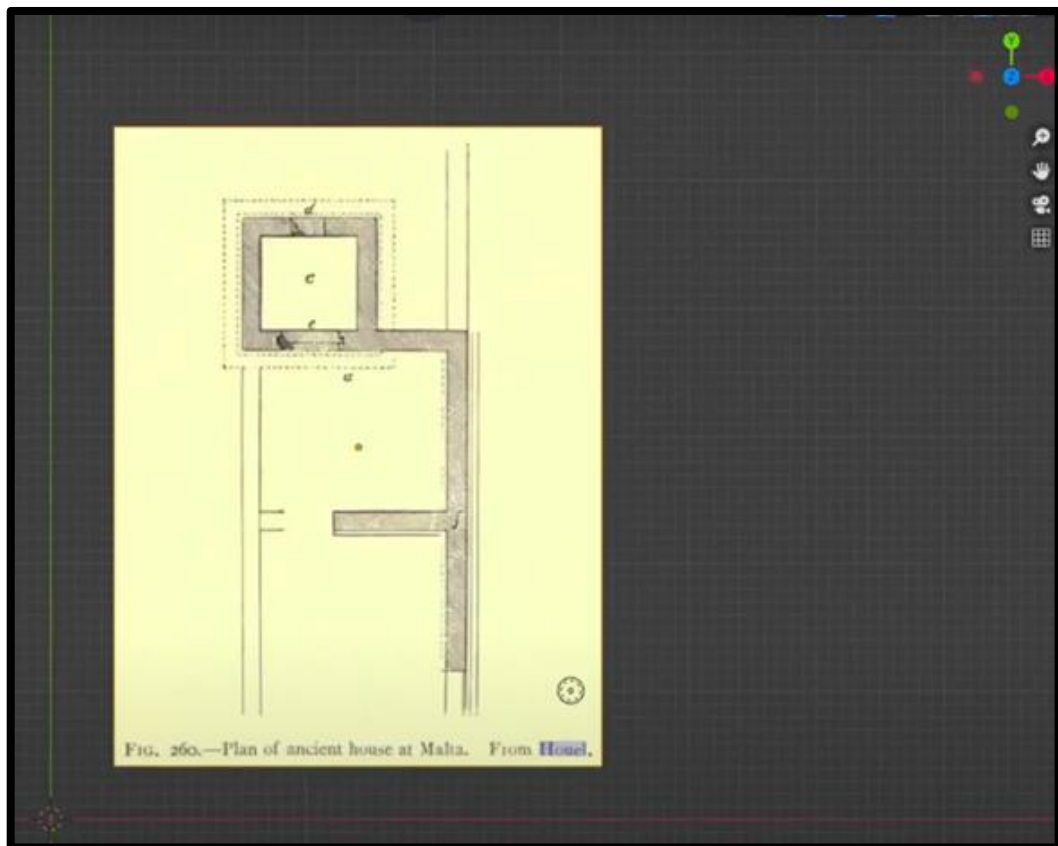


Figure 81. Screenshot from Blender showing Houël's survey uploaded in the X-Y plane (photo by the author).

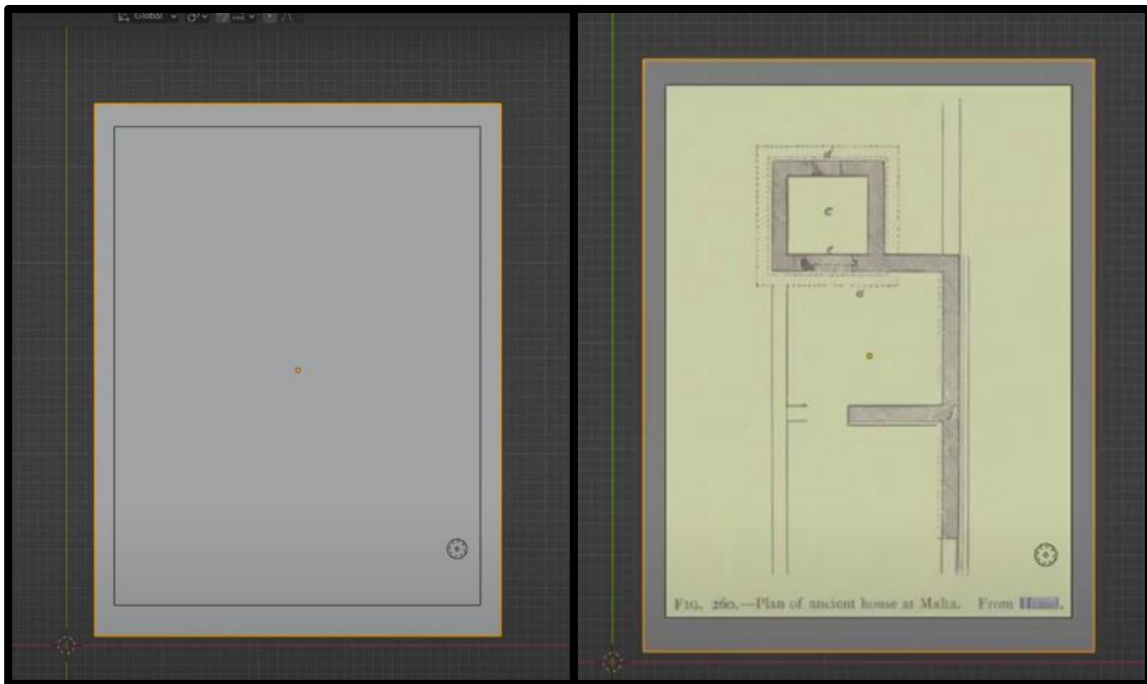


Figure 82. Screenshots from Blender showing Houël's survey overlaid by the planar mesh (left) made transparent by the 'Toggle View' function (right) (photo by the author).

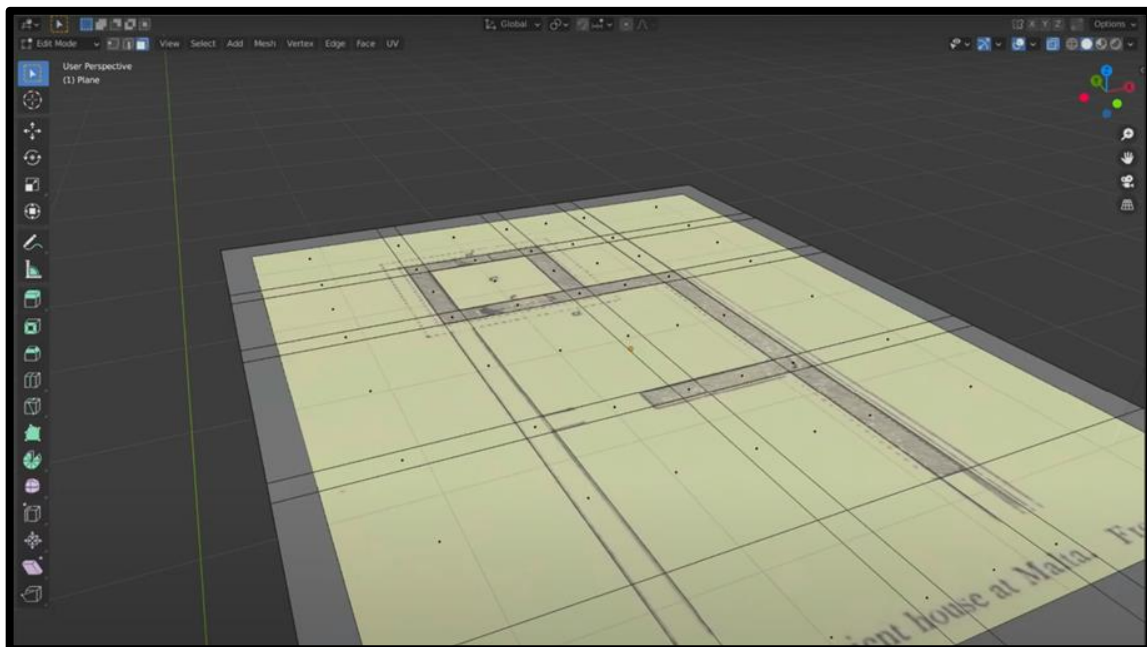


Figure 83. Screenshot from Blender showing the planar mesh being subdivided following the orthogonal structures surveyed by Houël (photo by the author).

At this stage, the elevation data had to be uploaded to know up to which height these structures had to be extruded. Therefore, in order to reconstruct the walls and top edges of the tower-like structure, the 20th-century section-elevation was imported in Blender's Z-X axis plane and it was scaled to fit Houël's measurements (Fig. 84). The edge of the tower depicted in the section-elevation was accurately located in its corresponding location on plan. After selecting Blender's orthogonal view aligned to the Y-axis point of view, the four subdivided areas corresponding to the walls were selected and extruded until the beginning of the Egyptian cornice (Fig. 85-86). At this point, the mesh of the tower was subdivided once more in order to reconstruct the back window and front door access, paying attention to reconstruct the door hinges' grooves as recorded by Houël (Figs. 87-88).

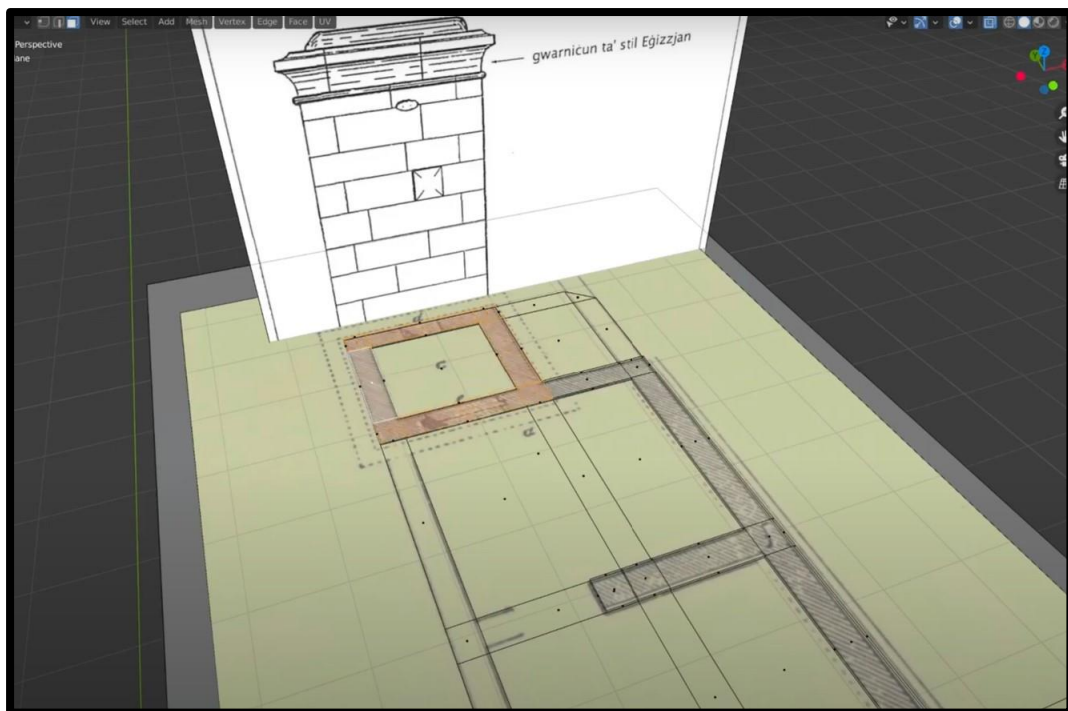


Figure 84. Screenshot from Blender showing the positioning of the 20th-century section elevation matching Houël's survey (photo by the author).

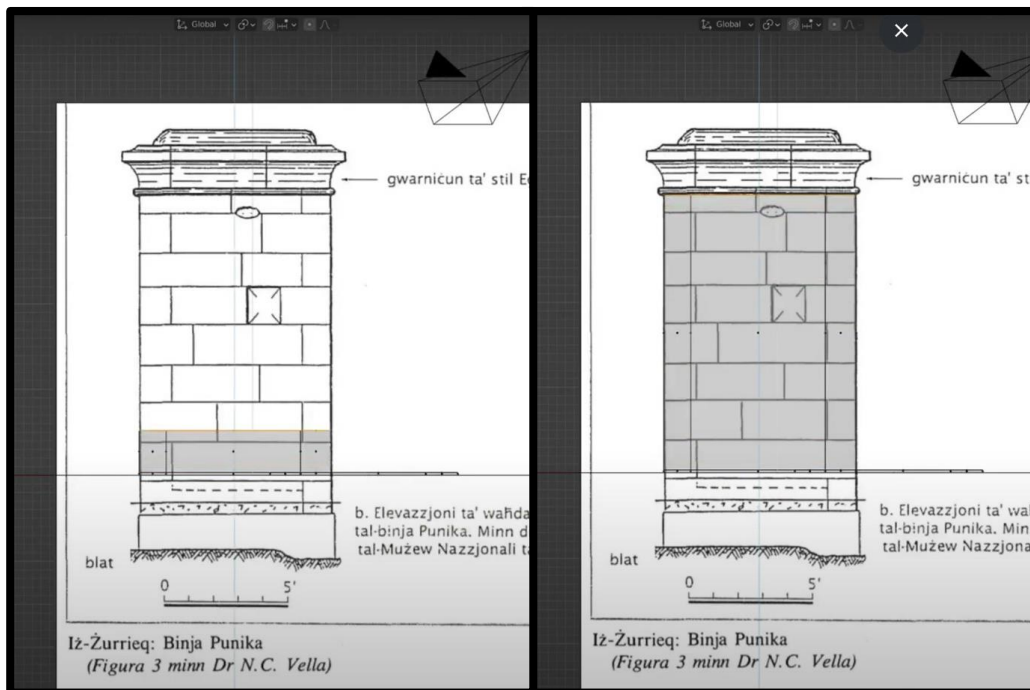


Figure 85. Screenshots from Blender showing from an orthogonal view the extrusion of the tower along the z-axis orientation to reconstruct the tower until the cornice (photo by the author).

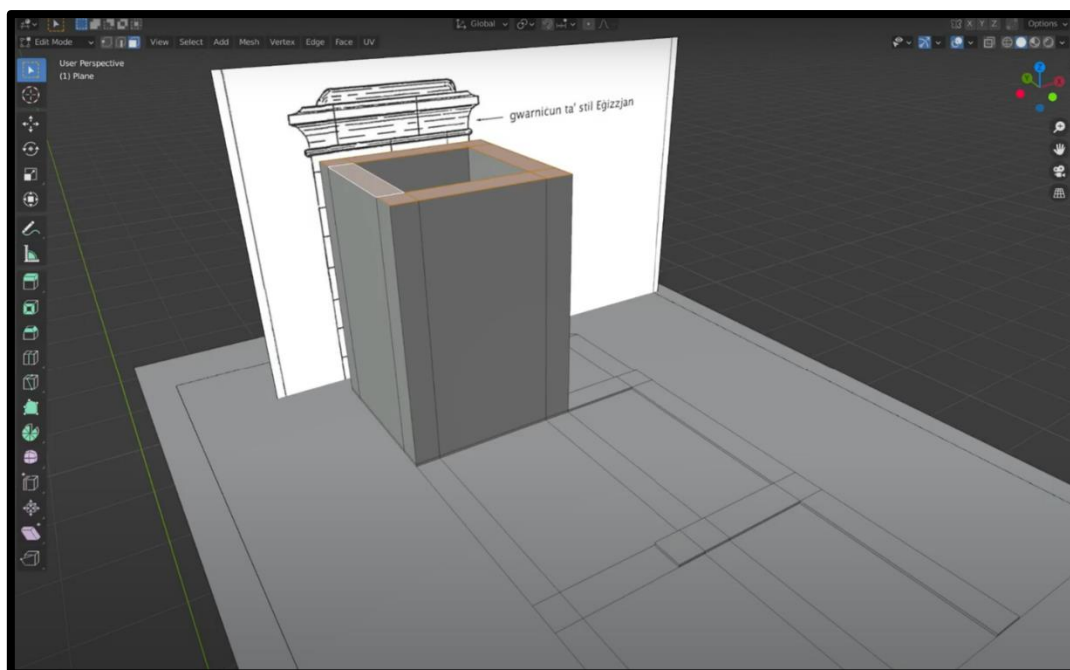


Figure 86. Screenshot from Blender showing from a perspective view Houël's survey uploaded in the X-Y plane (photo by the author).

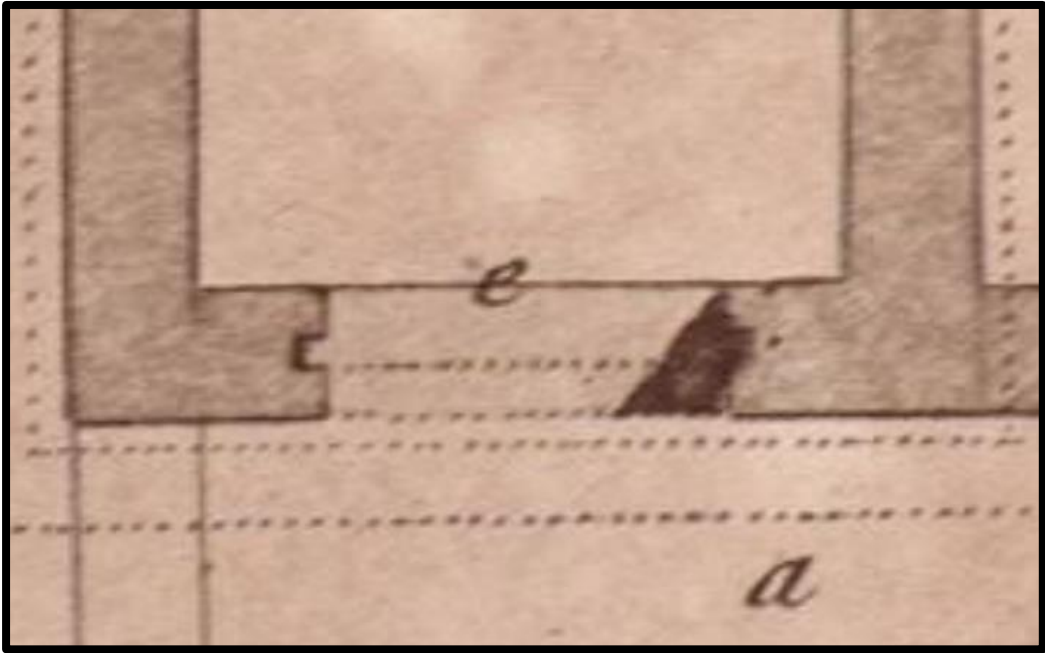


Figure 87. *Detail of Houël's survey showing the documented door hinges (photo by the author).*

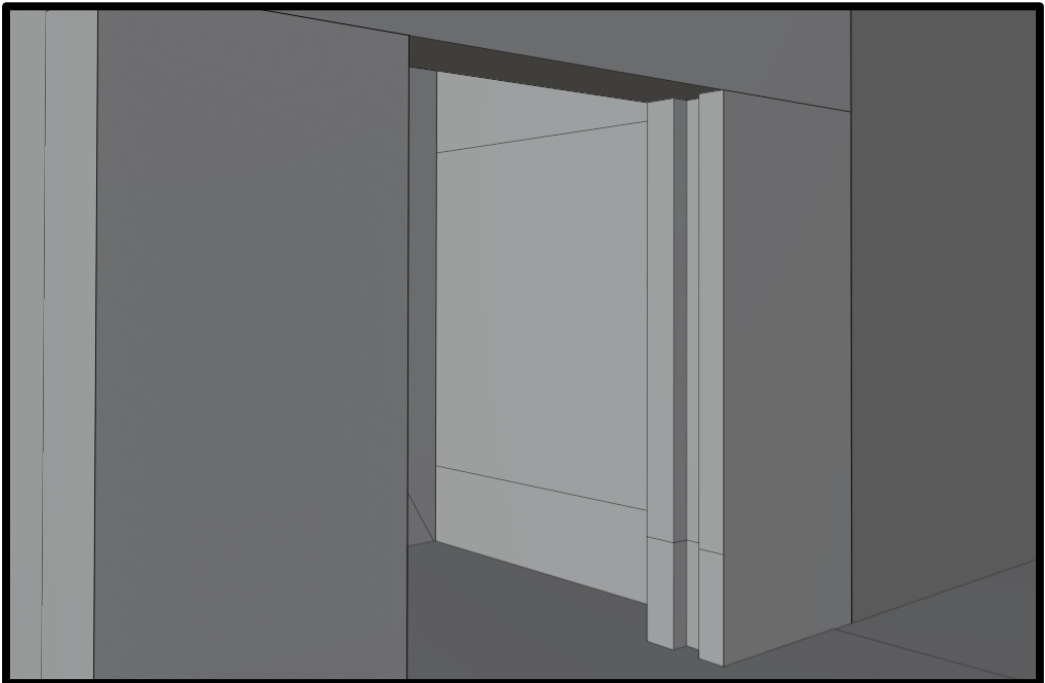


Figure 88. *Screenshot from Blender showing the detailedly reconstructed door hinges (photo by the author).*

The 3D reconstruction process continued with the Egyptianizing cornice, which was built following its curved edges as seen in the section-elevation from the orthogonal Y-axis point of view. The method adopted to build this feature consisted in selecting the four edges of the walls and alternating two Blender functions: the extrusion in the top Z-axis orientation (Fig. 89 – left) and the scaling following the outer X- and Y-axis orientations (Fig. 89 – right). With this method, the reconstruction of the most detailed curved surfaces was achieved (Fig. 90). The same strategy was adopted to reconstruct the cornice from Houël’s section drawing (Figs. 91-92), which was built separately to be later added to the walls.

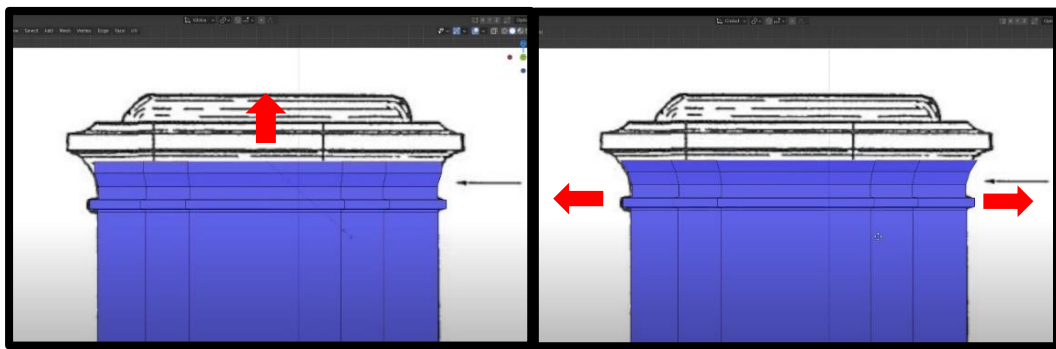


Figure 89. Screenshots from Blender showing the reconstruction by extrusion and scaling of curved profiles such as the Egyptianizing cornice topping the tower (photo by the author).

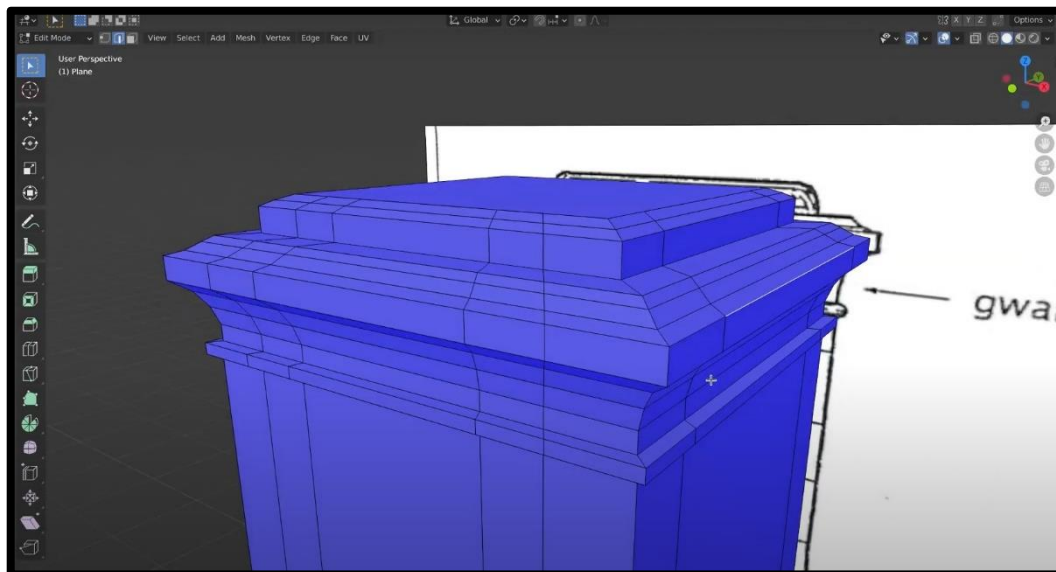


Figure 90. Screenshot from Blender showing the final reconstruction of the mesh of the Egyptianizing cornice topping the tower (photo by the author).

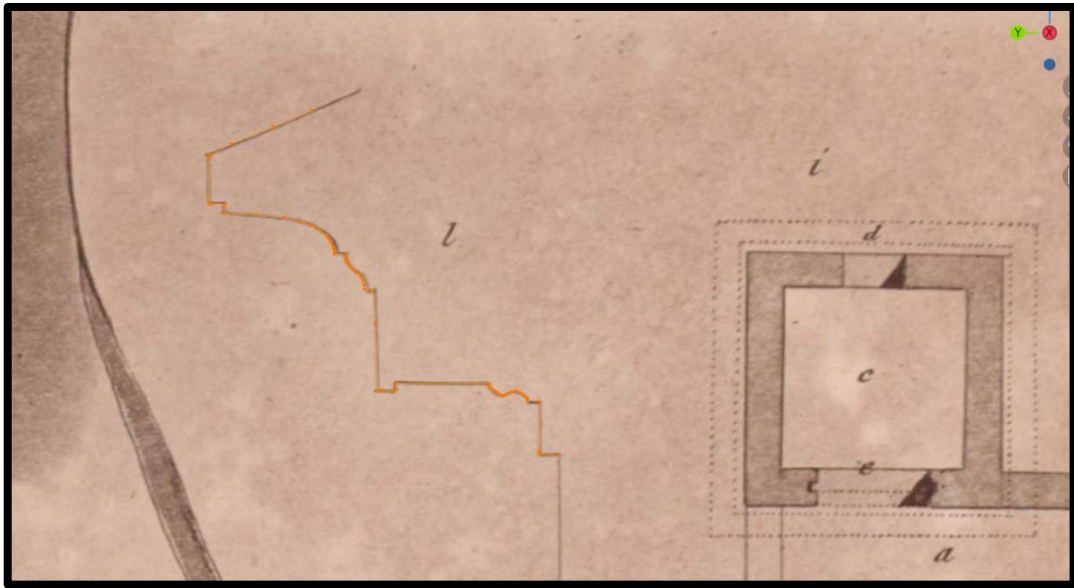


Figure 91. Screenshot from Blender showing the reconstruction of the other type of cornice topping the wall of the building, following Houël's section drawing (photo by the author).

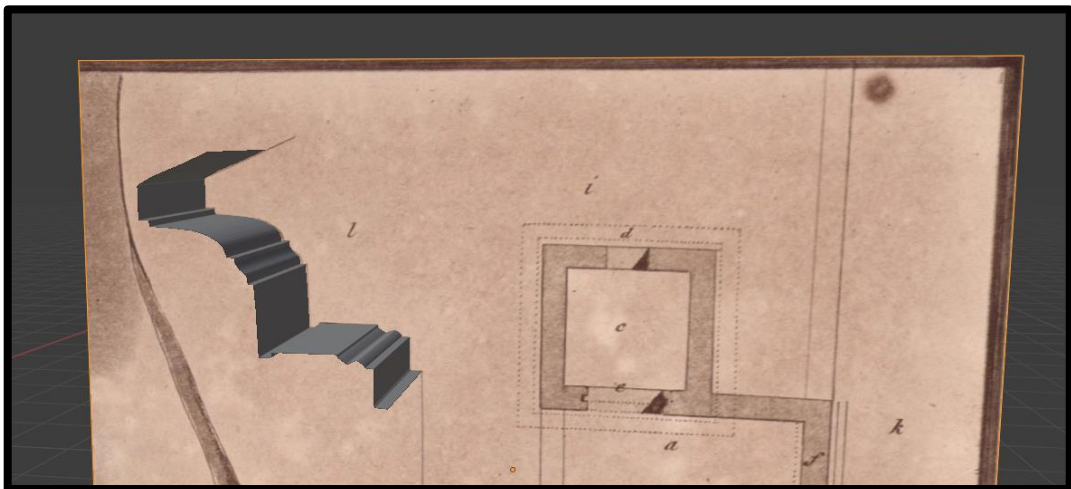


Figure 92. Screenshot from Blender showing the final reconstruction of the other type of cornice topping the wall of the building, following Houël's section drawing (photo by the author).

Concerning these walls, it is important to mention that their elevation was not covered by any of the gathered data and therefore had to be interpreted from the artistic work of Houël. Initially, it was thought that the height of the walls could have been indirectly calculated by observing the courses of masonry which Houël carefully depicts. Since he describes these ashlar blocks as being similar in size²⁴⁴

²⁴⁴ Houël 1787: 98.

and provides the total height of the tower, it was possible to calculate what the average height of an ashlar block would have been like. This was accomplished by dividing the total height of the masonry of the tower (4.23m – Fig. 93) by the number of courses of ashlar blocks (7). With this method it was calculated that each ashlar measured an average of 0.60m in height.

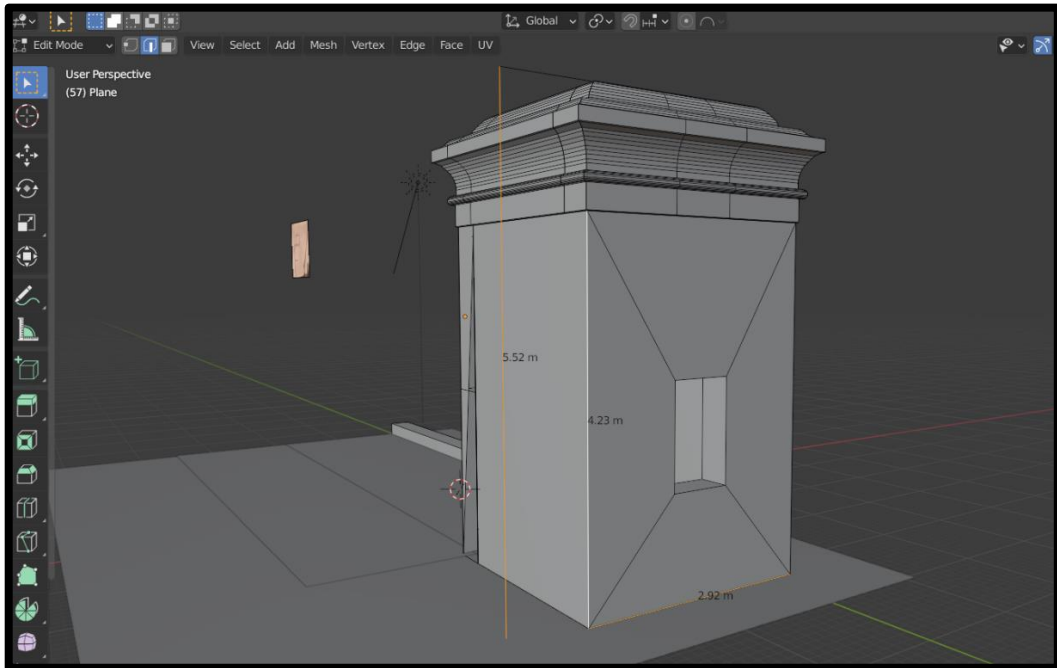


Figure 93. Screenshot from Blender showing the heights of Houël's tower calculated with the 'Edge Length' function (photo by the author).

Unfortunately, this strategy did not work due to a fallacy in Houël's drawing. As can be observed in Fig. 94, although the tallest wall is made of seven courses of ashlar blocks, it appears connected to the tower's sixth course. This could either be caused by Houël's use of an artistic license when rendering the perspective of the structures, or might suggest that larger blocks were used to construct the tower.

However, an alternative strategy was established. Given the correlation between the wall's seventh block and the tower's sixth, the height of the tallest wall was calculated by subtracting the height of the tower's ashlar blocks (4.23m) against the average height of one block used in the tower (0.60m). Therefore, the tallest wall was extruded till a total height of 3.63m, while the smaller wall, made of five blocks was approximately 2.59m high. Finally, as shown in the watercolour, the cornice was positioned on top of these walls and extruded accordingly.

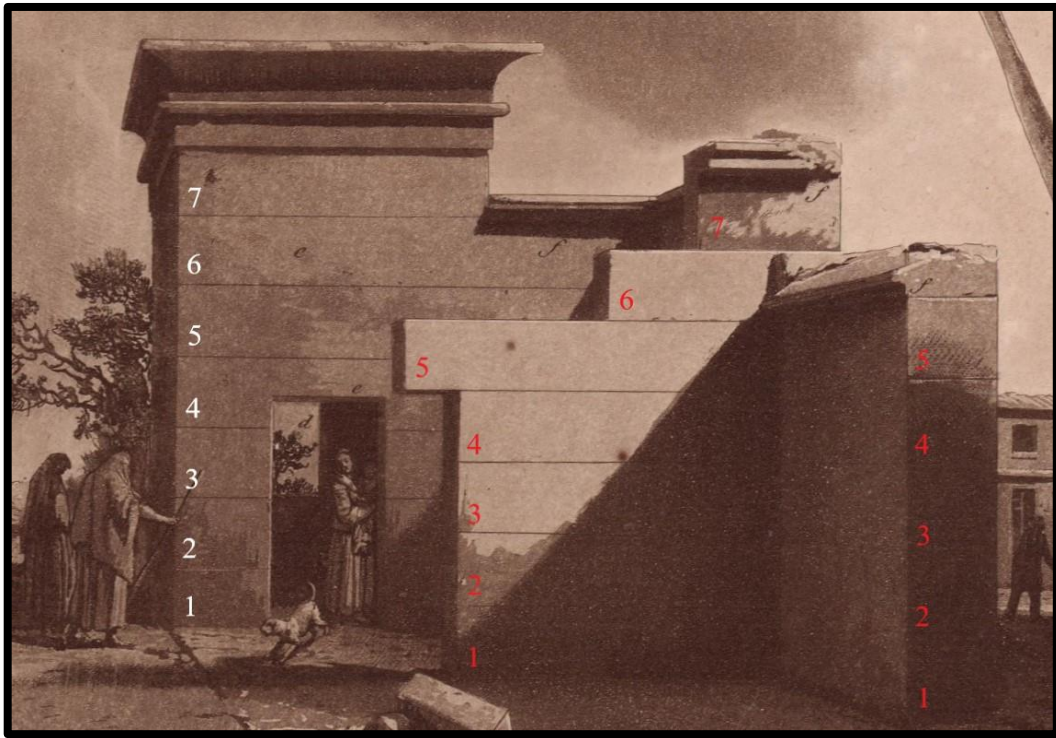


Figure 94. Edited print of Houël's watercolour showing the number of ashlar block courses in from the wall and the tower (photo by the author).

5.1.3 Data visualization: improving and accessing the 3D reconstruction

The final stage of this reconstruction consisted of those tasks which allow the viewer to visually engage with the virtual reconstruction of the site just as Houël experienced it. This entailed providing texture to the model, adjusting the lighting and making the model accessible. Since the final result of this case study aims to achieve a comparison with its reality-based model counterpart, this model was not yet exported on a VR platform. For this reason, the final tasks of this virtual reconstruction were carried out on Blender.

Given the encountered CBM texture complications mentioned in Site B (Subsection 4.2.1) it was not possible to provide the Punic building with a texture that would illustrate each ashlar block. For this reason, the building was assigned the same open-source limestone texture used for site B (Fig. 65). For the floorings, a cobbled pavement was chosen for the side roads, while a dark brown soil texture was selected for the inner floor below the structures. Additionally, a 3D model of a tree was downloaded from an open-source catalogue²⁴⁵ and positioned behind the tower,

²⁴⁵ Free3D catalogue – Available at: <https://free3d.com/3d-model/tree-74556.html> - Last accessed: 23/06/2022.

as seen in the Houël's watercolour. Moreover, natural sunlight was chosen to illuminate the Punic building. Once Blender's 'Viewport Shading' was activated, the simulated sunlight was placed in a specific location in the model and oriented accordingly to recreate the shades visible on the walls of the watercolour (Fig. 95). In this way, the remains of the Punic building as documented by Jean Houël, were virtually reconstructed and made accessible on Sketchfab, by clicking on the link attached in the footnotes.²⁴⁶



Figure 95. Screenshot from Blender showing a plan view (above) and a perspective view (below) of the final texturized interpretative 3D model of the Punic Building, as reconstructed from Houël's first watercolour (photo by the author).

²⁴⁶ This 3D model is available at: <https://skfb.ly/ovE9t> .

5.1.4 The hypothetical Punic Building: a process of virtual anastylosis

After rebuilding the Punic features as seen in Houël's watercolour, this study investigated the possibility of hypothetically reconstructing how the site could have looked like in Classical times. In order not to venture on speculative interpretations, this reconstruction was based on a process of virtual anastylosis, reconstructing those missing structures indirectly suggested by the ruins themselves. By correlating the watercolour with the survey (Figs. 96-97), it is possible to notice some of these missing structures, such as:

- i. Two walls: one being the extension of 'f', and one opposite it, both suggested by Houël's documentation of foundation stones ('b') found *in situ* (Fig. 96 – red arrows – Fig. 97 red area);
- ii. One doorway: aligned to the doorway of the tower, suggested by Houël's documentation of a protruding lintel (Fig. 96 – blue arrow) and a foundation pilaster from the wall above (Fig. 97 – blue arrow);
- iii. A vestibule: located between the two doorways, reconstructed following the abovementioned wall and the extrusion of the fifth, sixth and seventh course of ashlar blocks over the doorway to connect the two parallel walls.

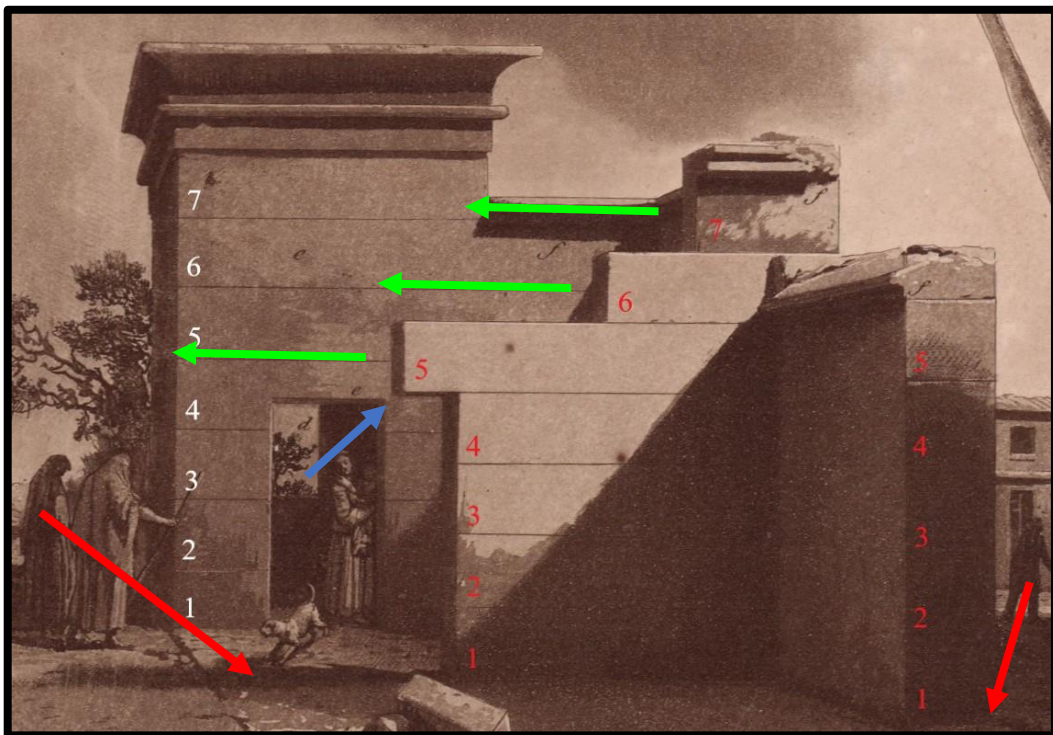


Figure 96. Edited print of watercolour showing the hypothetically missing structures noticed when cross referencing the watercolour to the survey (photo by the author).

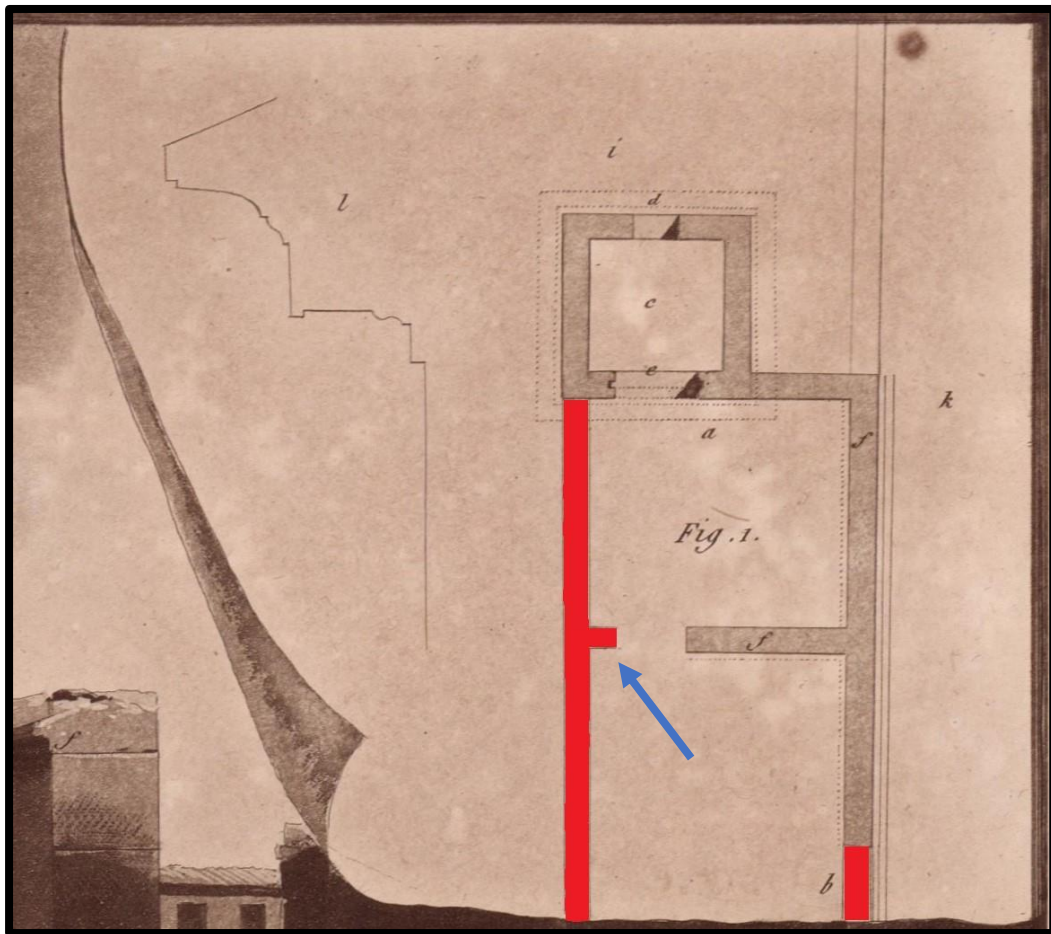


Figure 97. Edited print of the survey showing the hypothetically missing wall and foundation pilaster (photo by the author).

All these reconstructed walls were decorated with the same cornice recorded by Houël, located on top of each top course of ashlar blocks, oriented mirroring the existing ones. The final hypothetical reconstruction was added as a separate Blender layer to the previous 3D model, therefore preserving the same texture and lighting (Fig. 98). As the previous one, a model of this hypothetical reconstruction of the Punic Building was exported as an .obj file and made accessible on Sketchfab, by clicking on the link attached in the footnotes.²⁴⁷

²⁴⁷ This 3D model is available at: <https://skfb.ly/ovE8p> .



Figure 98. Screenshots from Blender showing a frontal view (above) and a perspective aerial view (below) of the final texturized hypothetical 3D model of the Punic Building, following the interpretation of Houël's first watercolour (photo by the author).

5.2 The reality-based model of Site C: 3D modelling the *in situ* remains

Unlike the archaeological remains of Site A and Site B, the Punic structures documented by Jean Houël still partially survive *in situ* close to the parish church of St Catherine in Żurrieq. Today, these archaeological remains can be found incorporated within the Early Modern masonry of domestic houses located in Triq il-Karmnu. Specifically, the ashlar wall documented by Houël can be observed in section from the narrow street while the tower-like structure can be accessed from the garden of the Parish Office (8, Triq il-Karmnu). Therefore, the site was accessed to document the remains.

5.2.1 Data gathering: collecting the photogrammetry data

In order to 3D document the *in situ* remains of Site C, it was decided to carry out a photogrammetry survey of the visible Punic structures. The data gathering of this exercise consisted in the collection of overlapping imagery of the elevation of ashlar blocks and of the tower. In order to reach the structural remains located at the highest levels of the site, the use of a handheld camera was integrated with an Unmanned Aerial Vehicle (UAV). The former piece of equipment was a *Canon EOS 2000D*, with which a total of 409 photographs were taken. These were shot at different angles and orientations from:

- the street: to capture the full elevation of the masonry (Fig. 99);
- the garden: to record the bottom and middle portions of the tower (Fig. 100);
- the roof: to shoot closeups of the cornice (Fig. 100).

In addition to this, a *DJI Mavic 2* drone, mounted with a *Hasselblad L1D-20c* aerial camera, was employed to document wider areas of data and capture pictures from locations otherwise inaccessible to the photographer. A total number of 118 aerial photographs were taken with the UAV, including:

- orthographic pictures: with the camera positioned at a 90 degree inclination (Fig. 101 – birds-eye-view);
- oblique pictures: with the camera oriented at different angles (Fig. 102).



Figure 99. Screenshot from Agisoft Metashape showing the location of the hand-held camera pictures photogrammetrically surveying the wall alignment from Triq Karmnu (photo by the author).



Figure 100. Screenshot from Agisoft Metashape showing the location of the hand-held camera pictures photogrammetrically surveying the tower from the garden of the Parish Office (photo by the author).

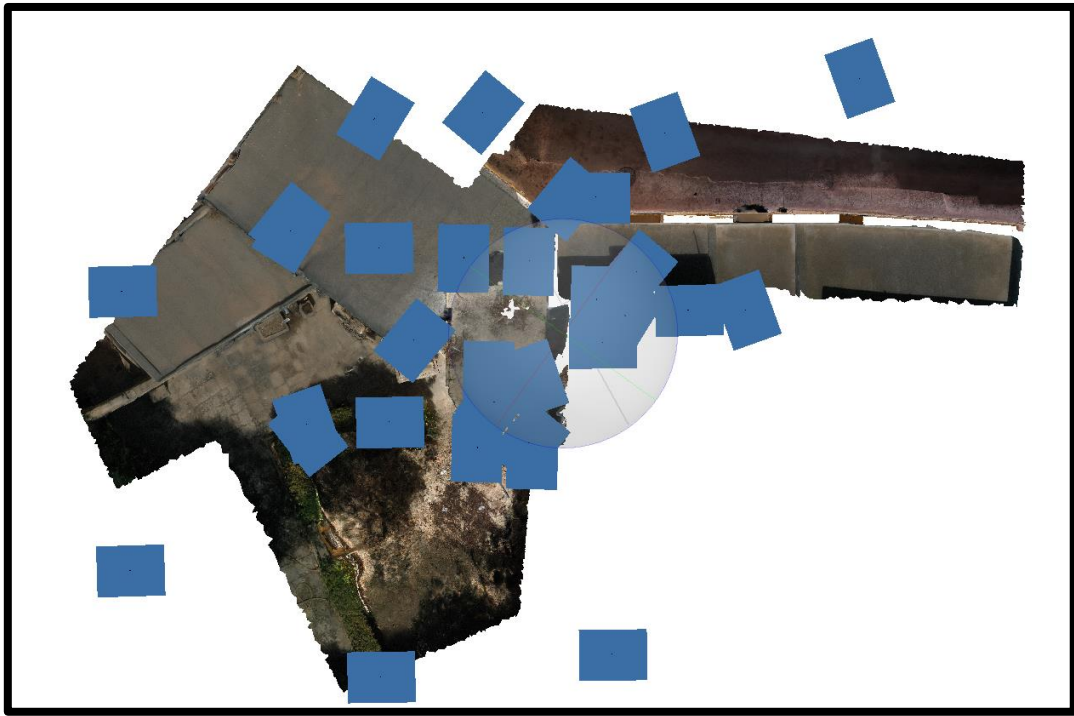


Figure 101. Screenshot from Agisoft Metashape showing the aerial location of the orthogonal UAV pictures photogrammetrically surveying site (photo by the author).

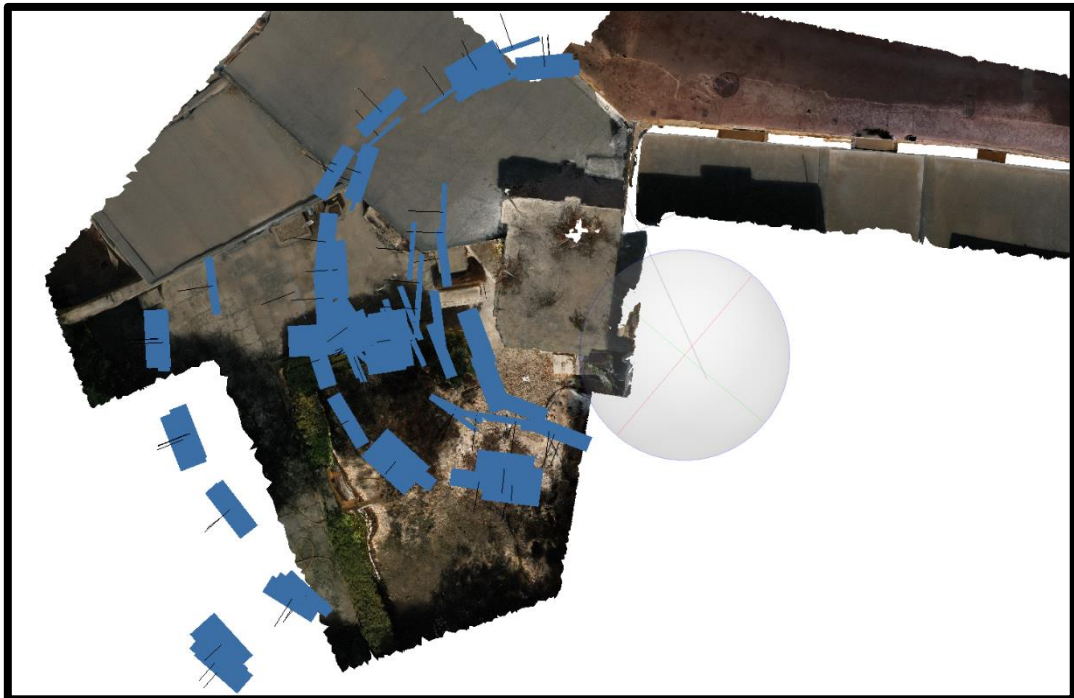


Figure 102. Screenshot from Agisoft Metashape showing the aerial location of the oblique UAV pictures photogrammetrically surveying site (photo by the author).

5.2.2 Data processing: building the 3D model

Following the fieldwork, the photographs were exported from their respective SD cards and stored accordingly in two separate folders, awaiting to be processed. The photogrammetry software employed for this exercise was Agisoft Metashape which, unlike the others adopted by this study, is not open-source. However, Agisoft was chosen due to the author's familiarity with this software and because it was accessible. Moreover, this user-friendly software allows large photogrammetry sets to be built following a relatively straightforward workflow.

Once the two folders were imported into the Metashape file, the 527 photographs were aligned with a high accuracy. This process generated a cloud showing a total of 504,287 points located within the 3D space (Fig. 103), from which a 3D mesh could be built. For this purpose, the mesh was built from the depth maps source, adopting medium quality and face count parameters. This resulted in a quite large 3D model counting 8,250,987 polygon faces (Fig. 104), to which a generic mapping texture was generated (Fig. 105).

Finally, the model was spatially referenced employing the WGS 84 (EPSG::4326) coordinates which the UAV's GPS assigned to each aerial picture. Through Metashape's 'Ruler' tool, it was possible to measure a scale bar included on site, attesting the satisfactory result of the GPS georeferencing. At this point, it was possible to process and export geographical sets of data, such as section-elevations and a DEM (Fig. 106).

5.2.3 Data visualization: editing and exporting the 3D model

Before exporting the data for the next stage of this case study, it was necessary to edit the mesh obtained from the data processing. As a matter of fact, the final result covered a larger area which was not going to be included in the following data analysis (Section 5.3). Before altering this 3D model it was exported and made accessible on Sketchfab by clicking on the link in the footnotes.²⁴⁸

²⁴⁸ This 3D model is available at: <https://skfb.ly/ovKur>



Figure 103. Screenshot from Agisoft Metashape showing the cloud of points of the reality-based 3D model (photo by the author).

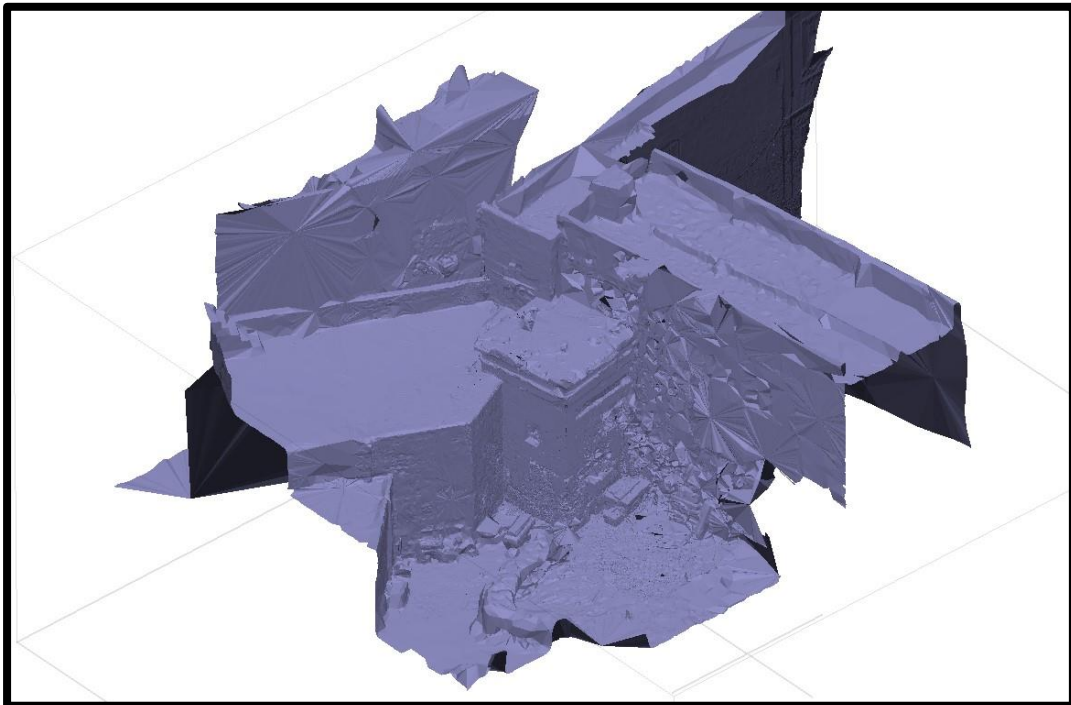


Figure 104. Screenshot from Agisoft Metashape showing the built un-texturized mesh of the reality-based 3D model (photo by the author).



Figure 105. Screenshot from Agisoft Metashape showing the built textured mesh of the reality-based 3D model (photo by the author).

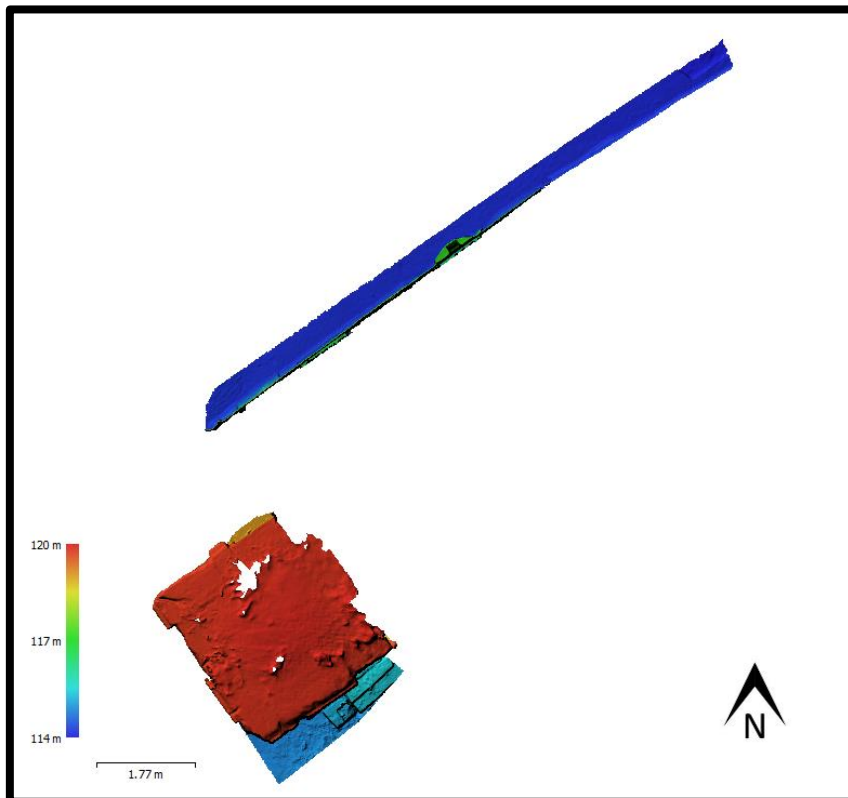


Figure 106. Screenshot from Agisoft Metashape showing the Digital Elevation Model (DEM) of the tower-like structure and the street (photo by the author).

Ultimately, all modern construction units were removed from the 3D model, in order to visualize the Punic remains surviving *in situ*, as seen in Jean Houël’s watercolour. For this reason the surface 3D model was trimmed using the ‘Selection’ tools built-in Metashape and this can be accessed from the Sketchfab link below.²⁴⁹ Fig. 107 shows which masonry was considered modern and therefore removed from the 3D visualization of the wall’s section elevation.

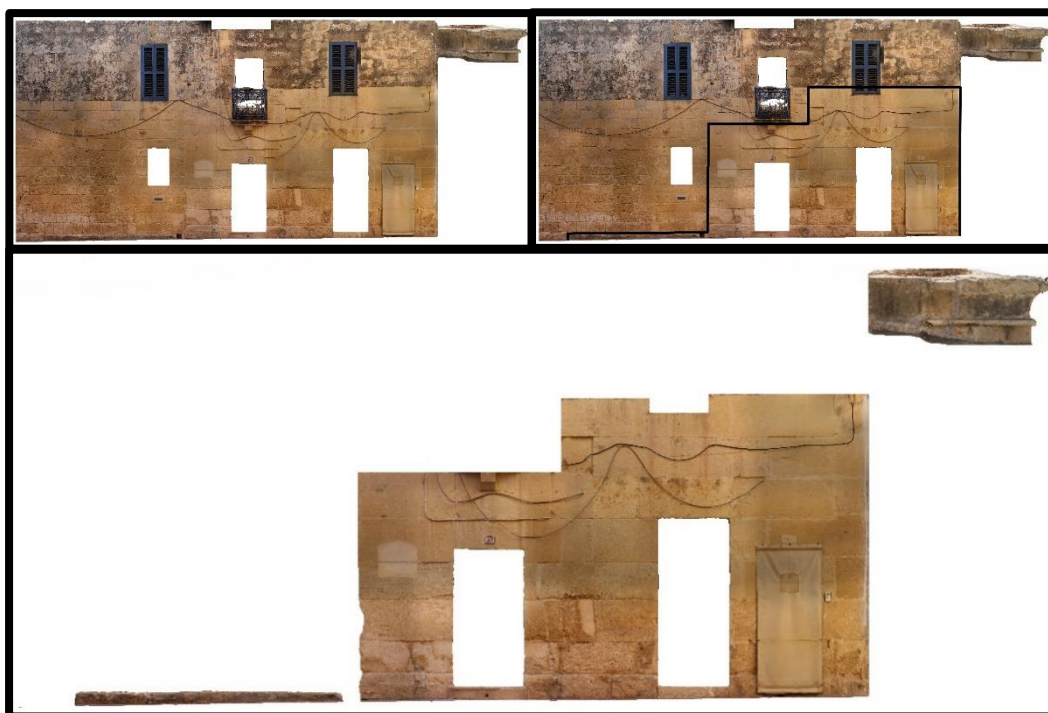


Figure 107. Screenshots from Agisoft Metashape showing the phases of trimming of the modern structures, in order to show the Punic *in situ* remains (photo by the author).

5.3 The comparative analysis of the virtual reconstruction

The *in situ* preservation of these archaeological remains allowed the analysis of the results of this virtual reconstruction against its reality-based counterpart. By doing so, this research is able to assess the methodologies adopted to reconstruct the Punic Building and the results of this will be discussed below (Subsection 6.3.4). This exercise will establish the reliability of the sources employed to reconstruct this site. This assessment was carried out through a comparative analysis of the two 3D models, applying a quantitative and a visual approach.

²⁴⁹ This 3D model is available at: <https://skfb.ly/ovEPv>.

5.3.1 Scale and sizes: verifying Houël's measurements

The quantitative approach aimed to establish the accuracy of the measurements of Jean Houël. The only measurements directly mentioned by Houël in the text referred to the width (2.92 m) and height (5.52 m) of the tower-like structure. By employing these as known dimensions to scale the two drawings imported in Blender, other measurements were indirectly generated when rebuilding the site.

Therefore, the comparative analysis began from these two measurements found in Houël's text. The width of the tower was calculated from Agisoft Metashape, by employing the software's 'Ruler' tool and selecting two edges, which resulted as 2.44 m wide (Fig. 108). On the other hand, the height of the tower was calculated adopting a different method. This consisted in subtracting the Z-coordinate value²⁵⁰ found at the highest point of the tower with that found at the bottom of the seventh²⁵¹ course of ashlar blocks, which resulted as 5.20 m high. Just by comparing these two measurements, it results that the ones of Jean Houël's are bigger than those of the *in situ* structure. Questions over the reliability of Houël's tower arose when scaling it on Blender, which results rectangular instead of square in plan (Fig. 109).



Figure 108. Screenshot from Agisoft Metashape showing the measured length of the tower from the reality-based 3D model using the 'ruler' tool (photo by the author).

²⁵⁰ Coordinate values are visible when selecting an arbitrary point with the 'Ruler' tool.

²⁵¹ This occurred to avoid any possible differences in level caused by past ground disturbances.

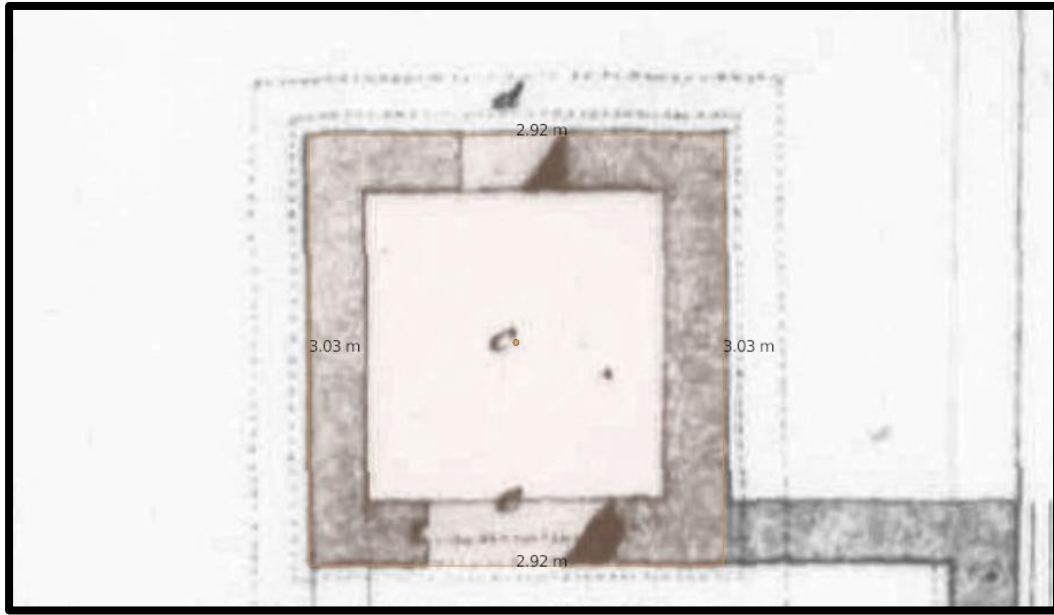


Figure 109. Screenshot from Blender showing the lengths of the tower from the interpretative model using the 'edge length' tool (photo by the author).

Since the drawings employed to virtually reconstruct this site were scaled with two imprecise measurements, it was decided to quantify to which extent this virtual reconstruction differed from the reality-based one. For this task, a total of ten sample measurements were selected from the areas of the building which are visible on both 3D models and where calculated. Figure 110 shows the exact locations of these samples, four of which chosen from the wall and four from the tower. In addition to these, the average height of each ashlar block was calculated from those visible in the wall's elevation and from the tower.

As can be seen in Table 2, the same methodology carried out in the *Horrea* (Subsection 4.2.2) was adopted here. Although here too the assessment was carried out over a limited number of samples, these had shown very dissimilar results which were noted in both the two features. These mixed values varied from considerable errors of almost half a meter, corresponding to a percentage error of almost 20% of its total length, to almost matching results. Finally, it was calculated that the average percent error out of ten sampled values is of about 8.58%. These result might suggest that the legacy data employed to virtually reconstruct Site C is about 91.42% accurate when compared to the real-life archaeological remains.

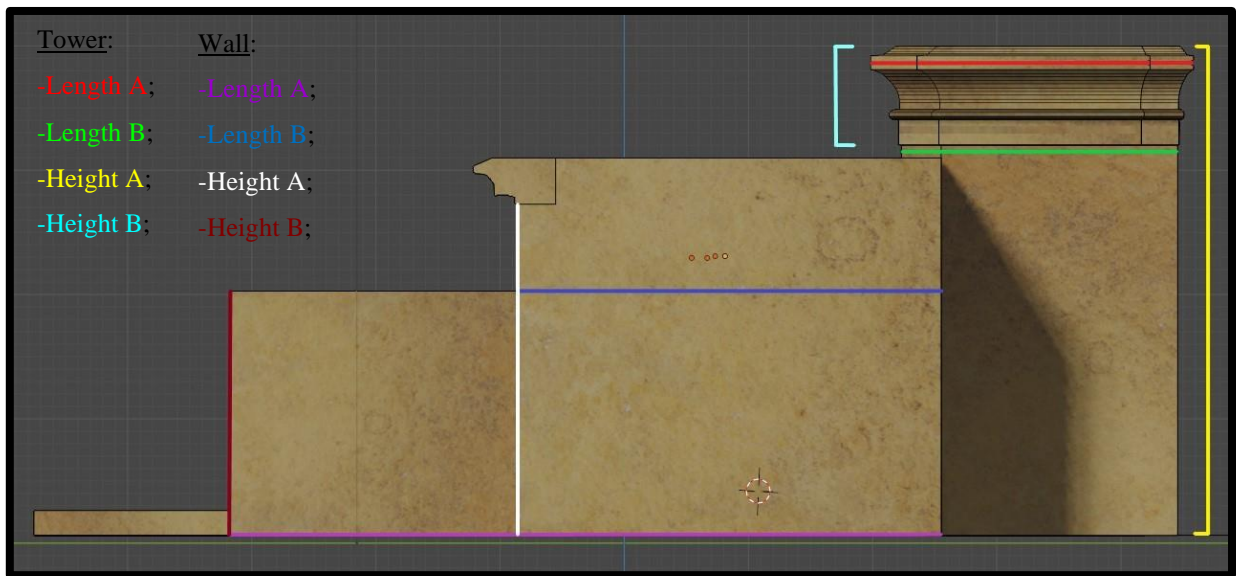


Figure 110. Screenshot from Blender showing the locations of the sampled lengths for the quantitative comparative analysis (photo by the author).

Feature	Distance description	Reality-Based Model (Zurrieq)	Virtually Reconstructed Model (Houël)	Error (m)	Error (%)	Accuracy (%)
Tower	Length A	3.32 m	3.69 m	0.37 m	11.14%	88.86%
	Length B	2.44 m	2.92 m	0.48 m	19.67%	80.33%
	Height A	5.20 m	5.52 m	0.32 m	6.15%	93.85%
	Height B	1.12 m	1.06 m	0.06 m	5.36%	94.64%
	Average Ashar Height	0.58 m	0.60 m	0.02 m	3.45%	96.55%
Wall	Length A	7.30 m	7.72 m	0.42 m	5.75%	94.25%
	Length B	4.31 m	4.61 m	0.30 m	6.96%	93.04%
	Height A	3.98 m	3.63 m	0.35 m	8.79%	91.20%
	Height B	2.87 m	2.59 m	0.28 m	9.76%	90.24%
	Average Ashar Height	0.57 m	0.52 m	0.05 m	8.77%	91.23%

Highest Value	0.48 m	19.67%	96.55%
Lowest Value	0.02 m	3.45%	80.33%
Median Value	0.29 m	6.56%	93.45%
Mean Value	0.27 m	8.58%	91.42%

Table 2. Table showing the results of the quantitative comparative analysis of site C.

5.3.2 The visual comparative analysis: overlapping the two models

The second approach consisted in visually comparing the virtual reconstruction with the reality-based model in one common 3D environment. With these aims in mind, it was important that the former 3D model was equipped with a suitable semantic visualization. As shown in the literature review (Subsection 2.2.2), recent studies have shown how semantic 3D schematic reconstructions would adopt a colour code to enhance their transparency and suggest levels of reliability of the metadata.²⁵²

For the sake of this comparative analysis, it was crucial to distinguish extant structures from the virtual anastylosis. Therefore a similar methodology was adopted and a customized colour-coding was established for this reconstruction. By referring to the reality-based 3D model on Agisoft, a uniform red texture was assigned to the virtually reconstructed remains which are today visible *in situ* (Fig. 111), while the additional remains built from Houël's legacy data were given a blue texture (Fig. 112). Finally, the hypothetical reconstruction based on the anastylosis process were colour-coded with a green texture (Fig. 113). The colour-coded 3D reconstruction can be accessed by clicking on the Sketchfab link found in the footnotes below.²⁵³

Following, these modifications, the visual comparative analysis could take place. Since Blender allows to easily handle, scale and move 3D objects, it was selected as the common virtual environment where to carry out this visual comparative analysis. For this reason, the reality-based model was exported from Agisoft as an fbx file and was imported into Blender. Unfortunately, the export-import process did not preserve its original size, which was eventually re-scaled using the 2.44 m measurement, as shown in Fig. 114. Subsequently, the reality-based model was rotated, aligned, and positioned to overlap the virtual reconstruction,²⁵⁴ and by doing so, it was possible to view and assess how the two models match and differ.

²⁵² Ferdani *et al.* 2019; Ferdani *et al.* 2020; Ferdani & Petroni 2021: 22.

²⁵³ This 3D model is available at: <https://skfb.ly/o7L7B>.

²⁵⁴ Since the comparative analysis concerned just those remains visible in both 3D models and for the sake of a clearer visualization, only the red layer of the virtual reconstruction was selected.

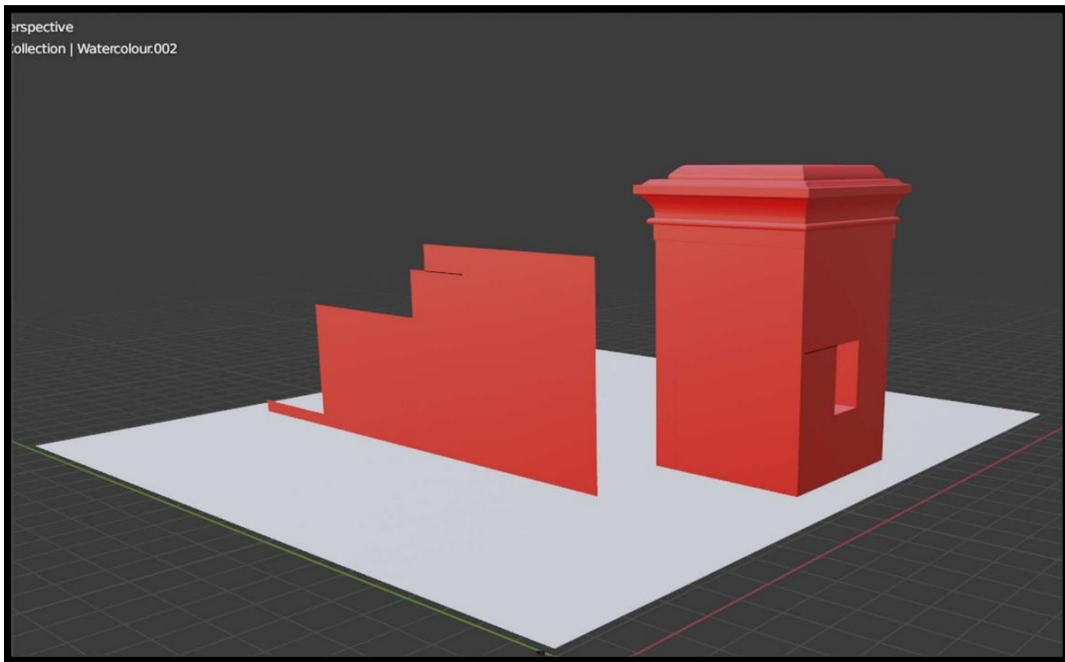


Figure 111. Screenshot from Blender showing the colour-coded red layer which represents the archaeological remains today visible in-situ (photo by the author).

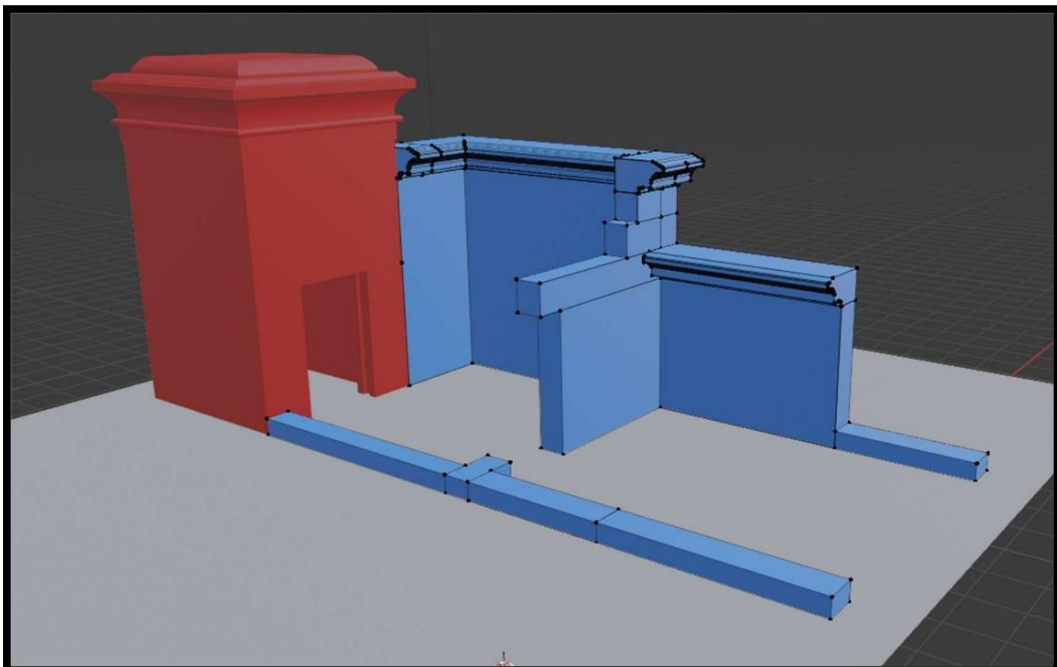


Figure 112. Screenshot from Blender showing the colour-coded blue layer which represents the archaeological remains reconstructed through the available legacy data (photo by the author).

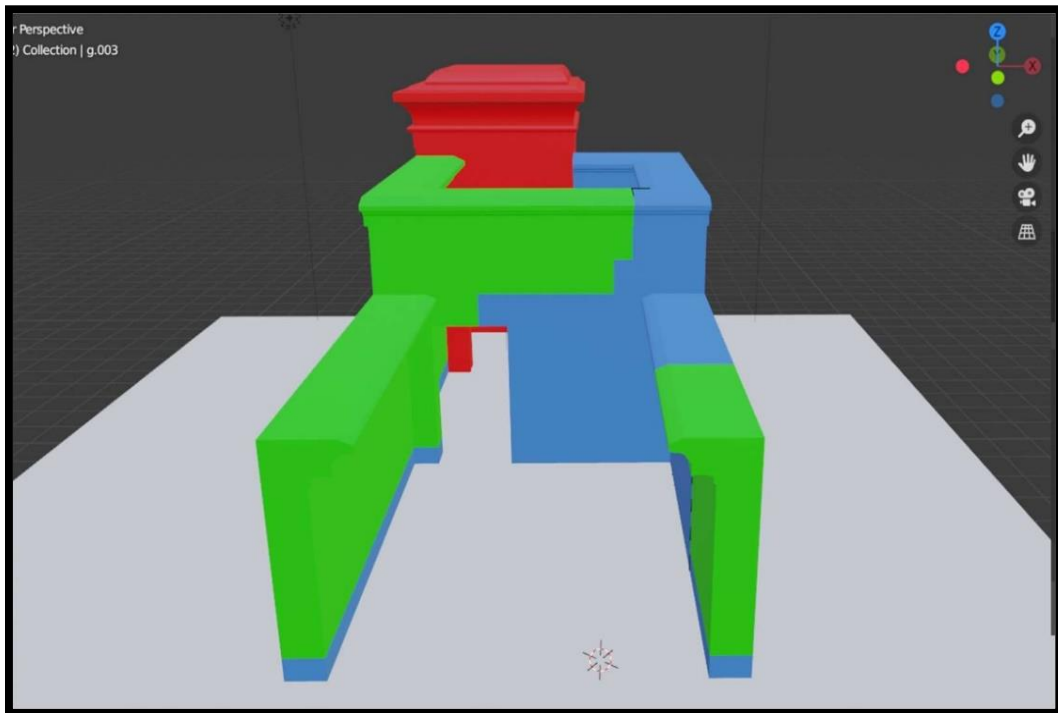


Figure 113. Screenshot from Blender showing the colour-coded green layer which represents the hypothetically reconstructed features (photo by the author).

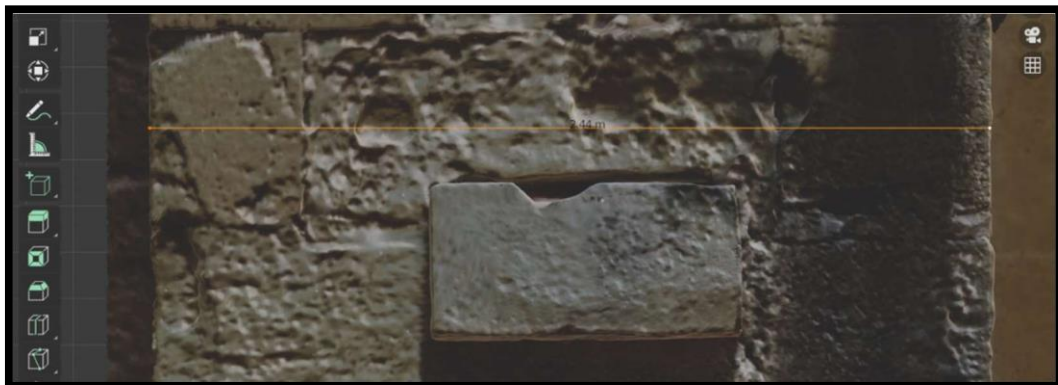


Figure 114. Screenshot from Blender showing the scaling of the reality based model to its 2.44 m length (photo by the author).

If on one hand the numerical values presented above attempted to quantify to what extent the virtual reconstruction matched the *in situ* remains, these figures displayed below (Figs. 115-118) provide the viewer with a visual understanding of these same results. Despite Houël's inaccuracies, it turns out that the virtual reconstruction of the tower (Fig. 115 – red mesh) closely matches the real-life one (Fig. 115 – black mesh), and the same can be said for the location of the wall façade which meshes aligns perfectly (Fig. 116). Regarding the latter feature, the same cannot be said for its location along the Z-axis, which appears built at a much lower level than that of the tower-like structure (Figs. 117-118).

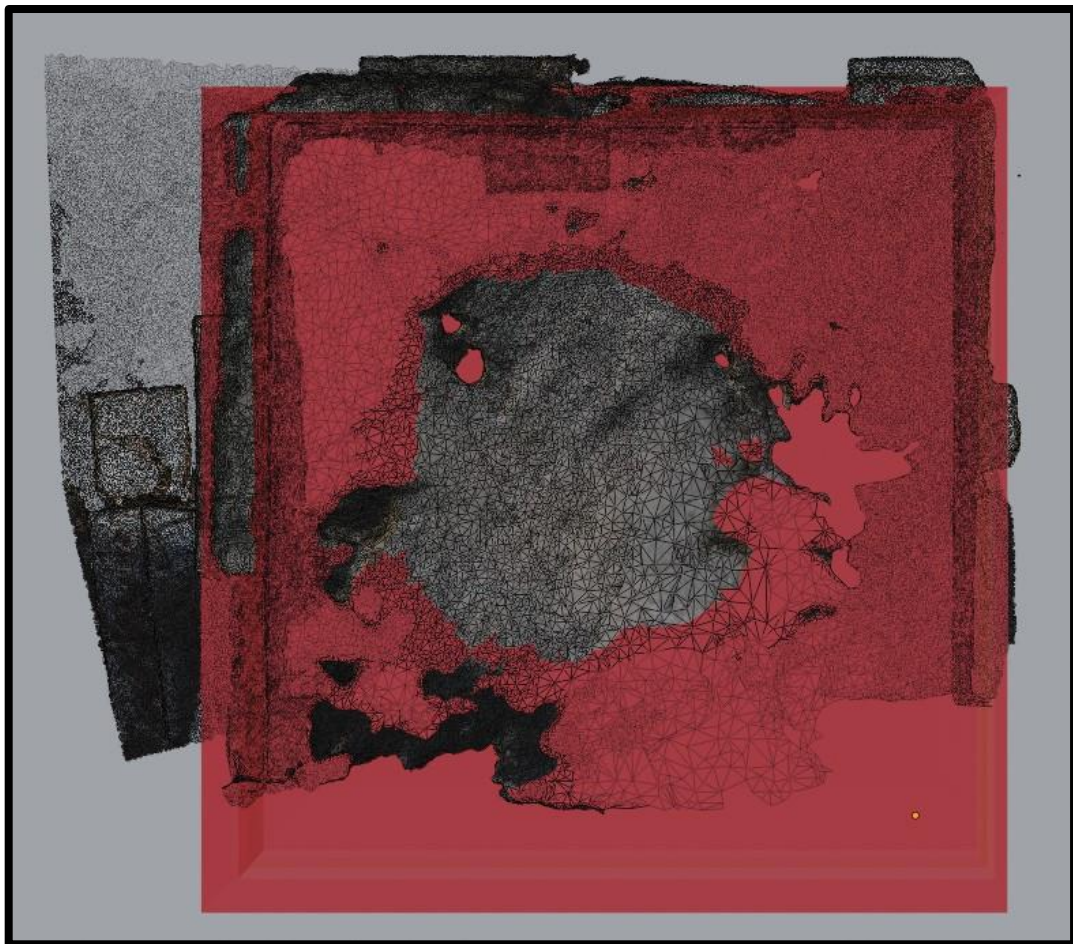


Figure 115. Screenshot from Blender showing the results of the comparative analysis: the tower of the interpretative model (red mesh) closely matches the one of the reality-based model (black mesh) (photo by the author).

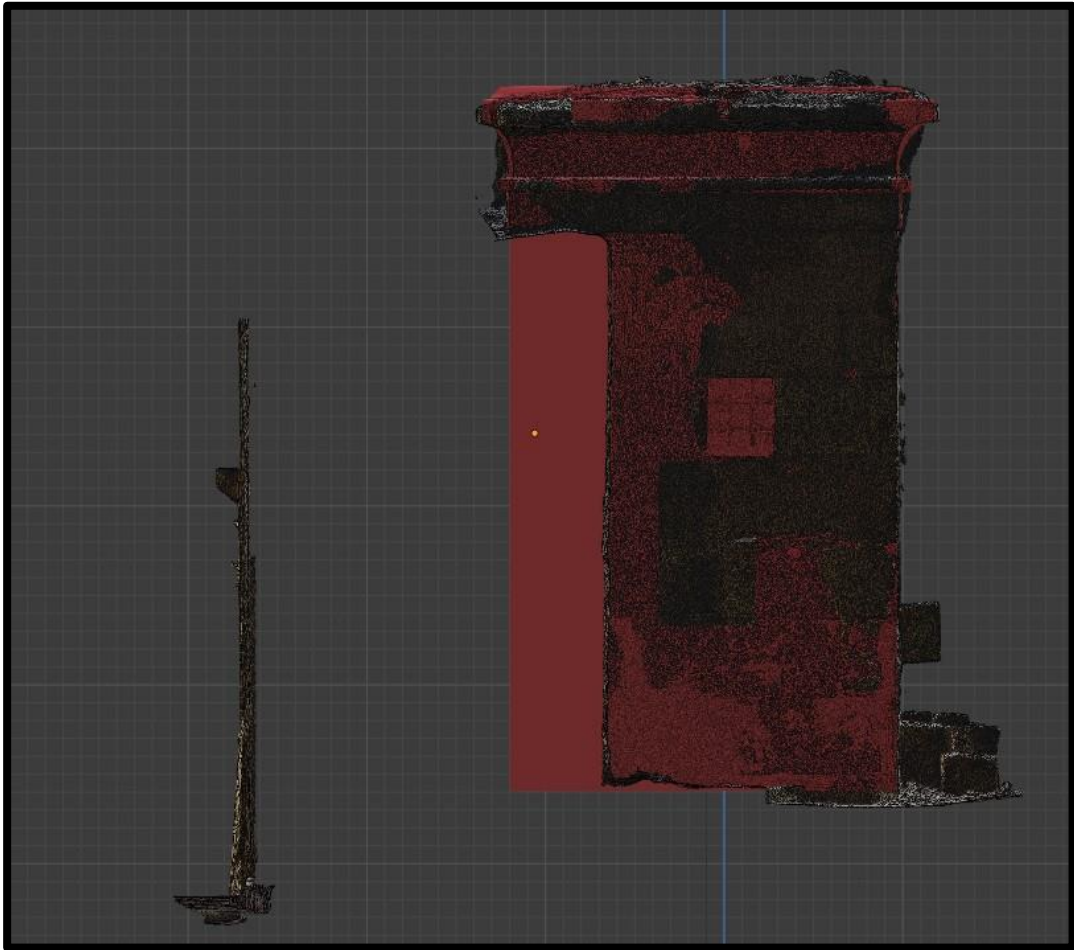


Figure 116. Screenshot from Blender showing the results of the comparative analysis: the tower of the interpretative model (red mesh) closely matches the one of the reality-based model (black mesh) and the same can be said about the two walls (photo by the author).



Figure 117. Screenshot from Blender showing the results of the comparative analysis: different results concern the heights of the two walls where the interpretative model (red mesh) has a wall located at a higher level than the reality-based one (black mesh) (photo by the author).

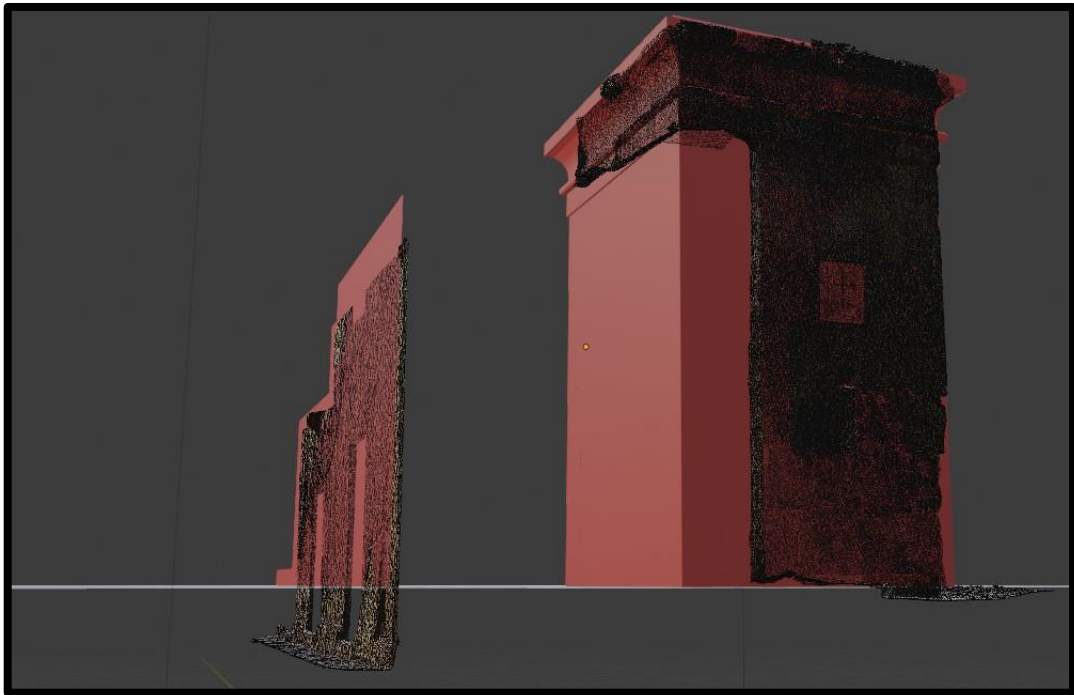


Figure 118. Screenshot from Blender showing how the two towers match quite closely while the walls, despite being on the same easting axis, are on two different levels in height (photo by the author).

5.3.3 Accessing these models: a VR comparative analysis

Finally, the results of this case study were uploaded on Unity and made accessible through the VR headset. As for the Marsa Catacomb (Section 3.3), these tasks were carried out by Dr Spina, who implemented the same methodology adopted in the former VR model (e.g. human scale, lighting; scripting of commands and locomotion systems).

However, in order to still carry out the visual comparative analysis, it was decided to upload all of the models presented above in the same VR environment. With this in mind, a new function was designed, scripted, and activated specifically for Site C. By placing a fixed number of spheres (similar to those used for teleporting) in the viewer's reach (Fig. 119), the viewer is able to interactively switching from one model to another. The spheres which can be selected will respectively switch on:

- the virtually reconstructed model (Fig. 120);
- the colour coded reconstructed model (each colour can be switched – Figs. 121-123);
- the reality-based model (Fig. 124).

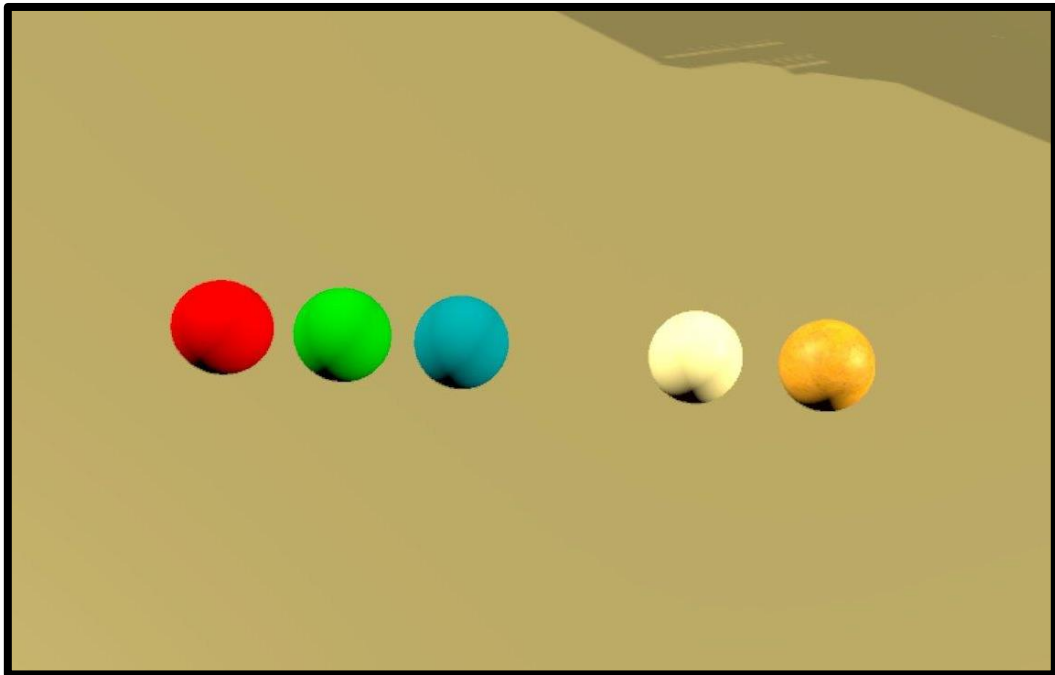


Figure 119. Screenshot from the VR environment showing the spheres which allow the viewer to switch the layers on and off respectively (photo by the author).

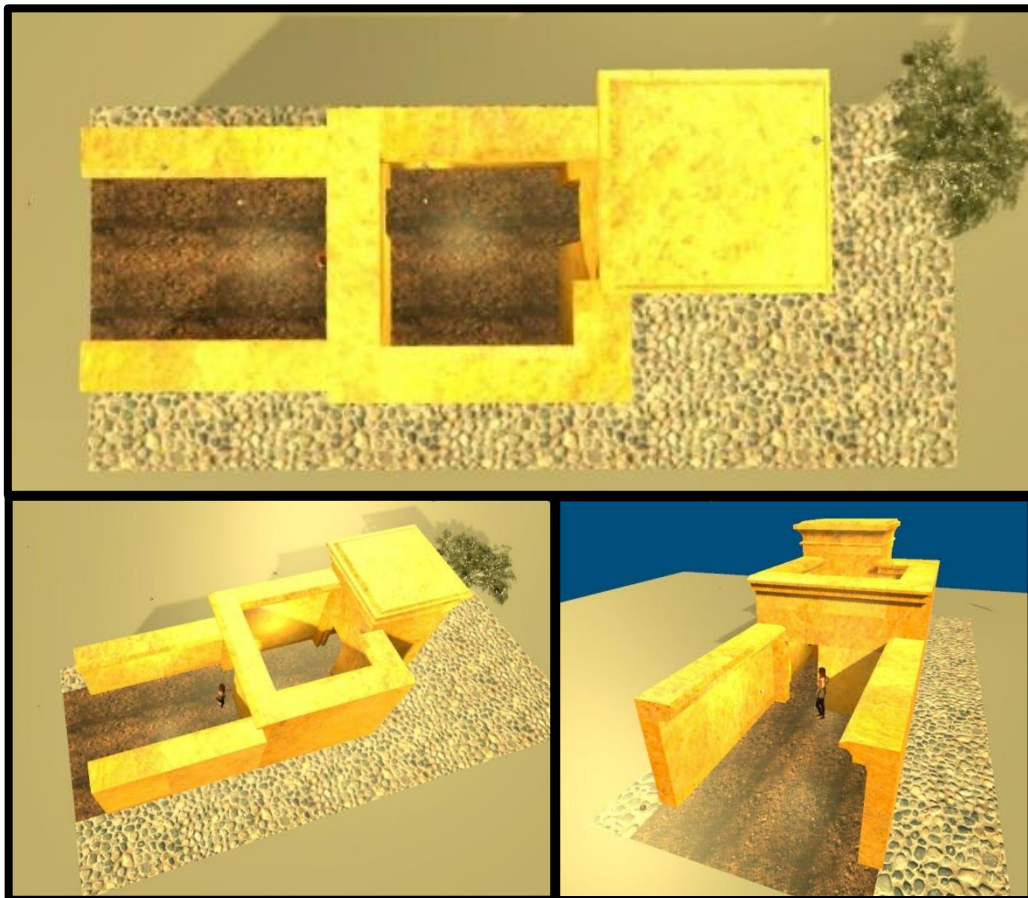


Figure 120. Screenshots from the VR environment showing the hypothetically reconstructed 3D model (photo by the author).

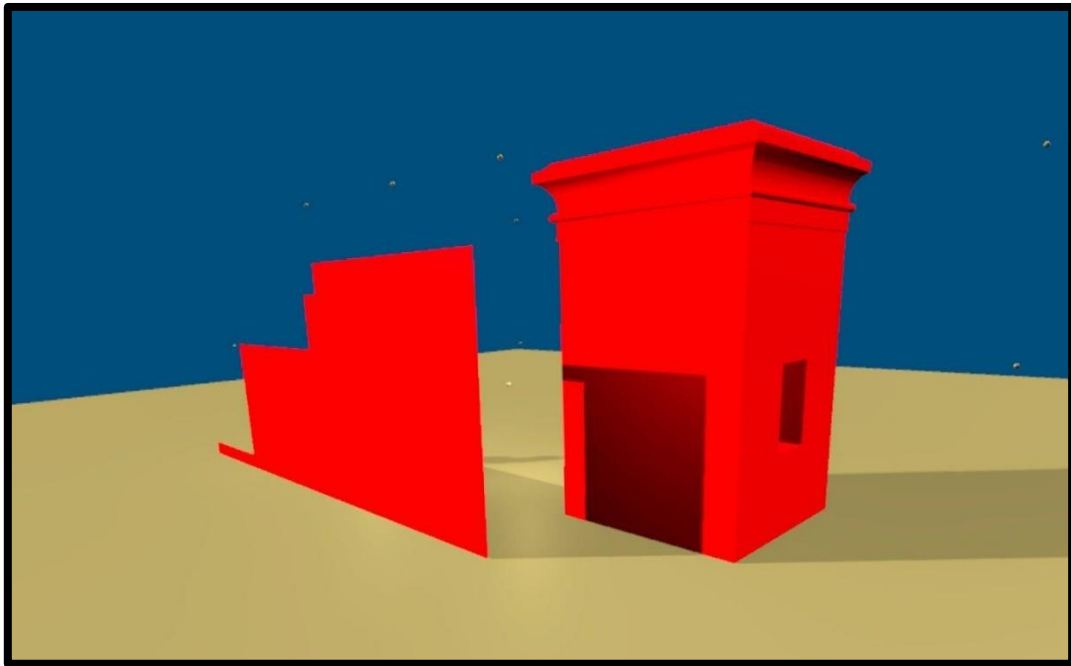


Figure 121. Screenshot from the VR environment showing the red layer of the interpretative model (photo by the author).

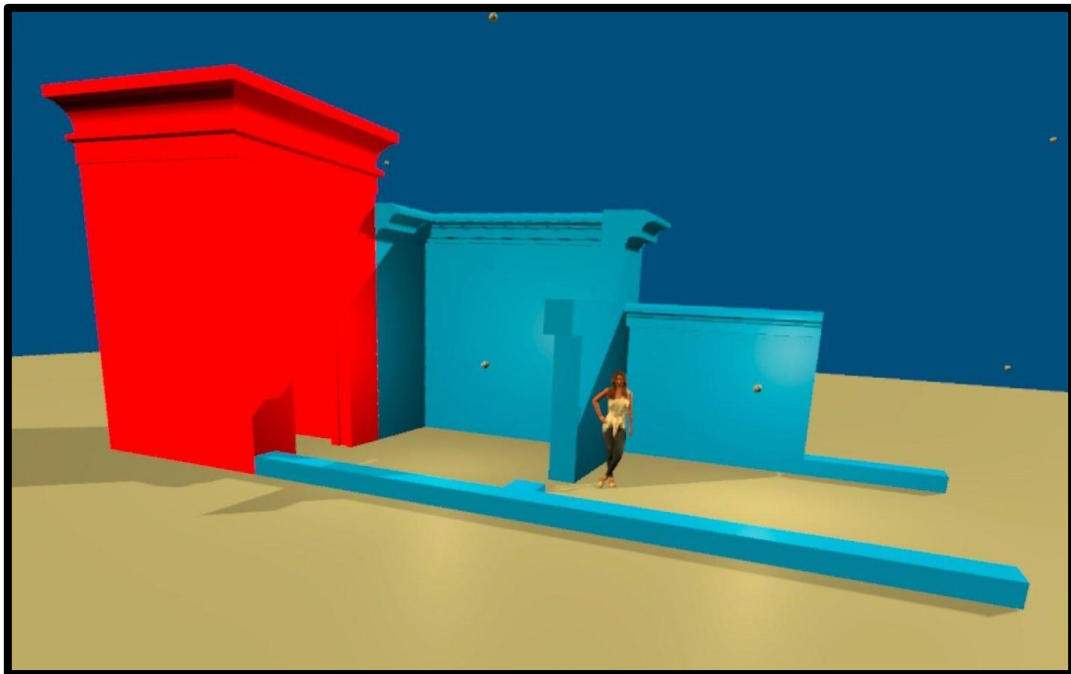


Figure 122. Screenshot from the VR environment showing the blue layer of the interpretative 3D model (photo by the author).

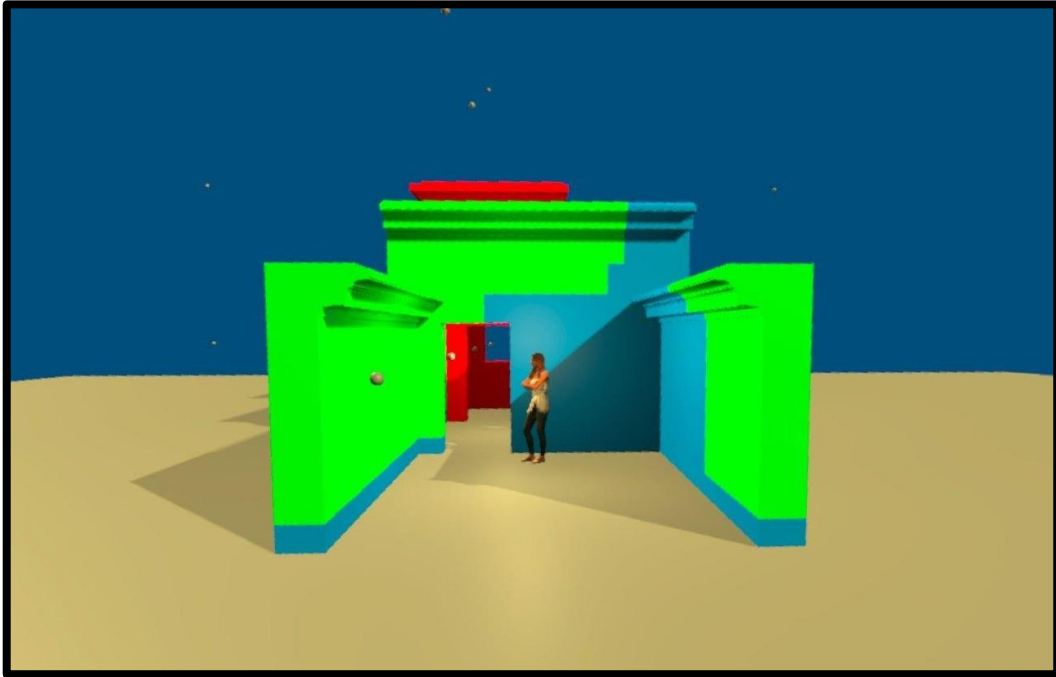


Figure 123. Screenshot from the VR environment showing the green layer of the interpretative 3D model (photo by the author).



Figure 124. Screenshot from the VR environment showing the reality-based 3D model (photo by the author).

By switching from one model to another, the viewer can carry out an interactive visual comparative analysis by switching on the reality-based model and the virtually reconstructed models as seen in the screenshots below (Figs. 125-126).

In addition, the two watercolours painted by Jean Houël will also be included in the VR environment, located from the artist's point of view (Figs. 127-128). As for Site A, this VR model will be installed in the Oculus VR headset which will be provided with this dissertation. However, a set of screenshots and video-recordings of the VR experience will be taken from the author and included in a folder downloadable from the Google Drive link found below in the footnotes.²⁵⁵ In this folder, the Blender and Unity files will also be uploaded although these software would require to be downloaded beforehand.

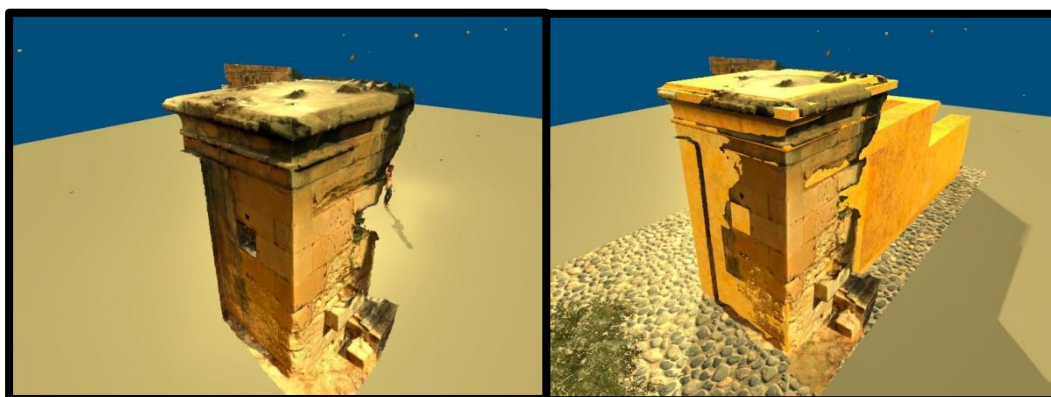


Figure 125. Screenshots from the VR environment showing the visual comparative analysis on the interpretative 3D model over the reality-based one (photo by the author).

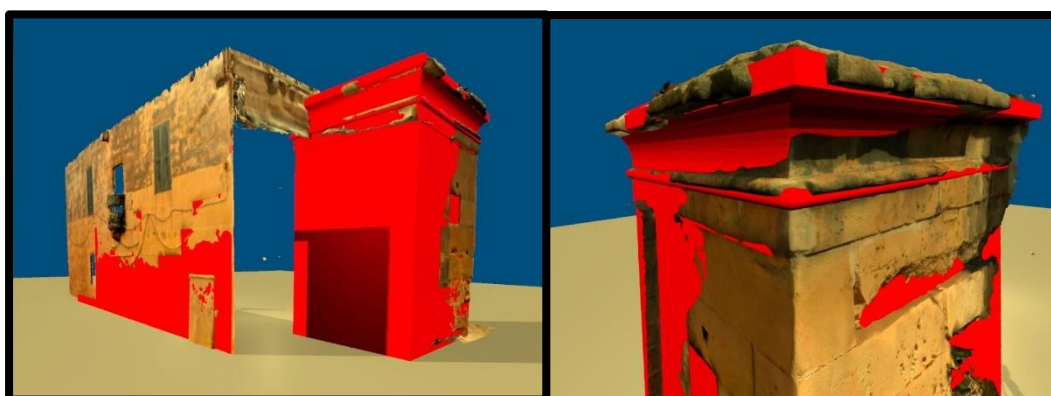


Figure 126. Screenshots from the VR environment showing the visual comparative analysis on red layer of the interpretative 3D model over the reality-based one (photo by the author).

²⁵⁵ Google Drive link available at: <https://drive.google.com/drive/folders/1iVhD-TTJDff74eSWiXhWgxpuzJQn-8z?usp=sharing>

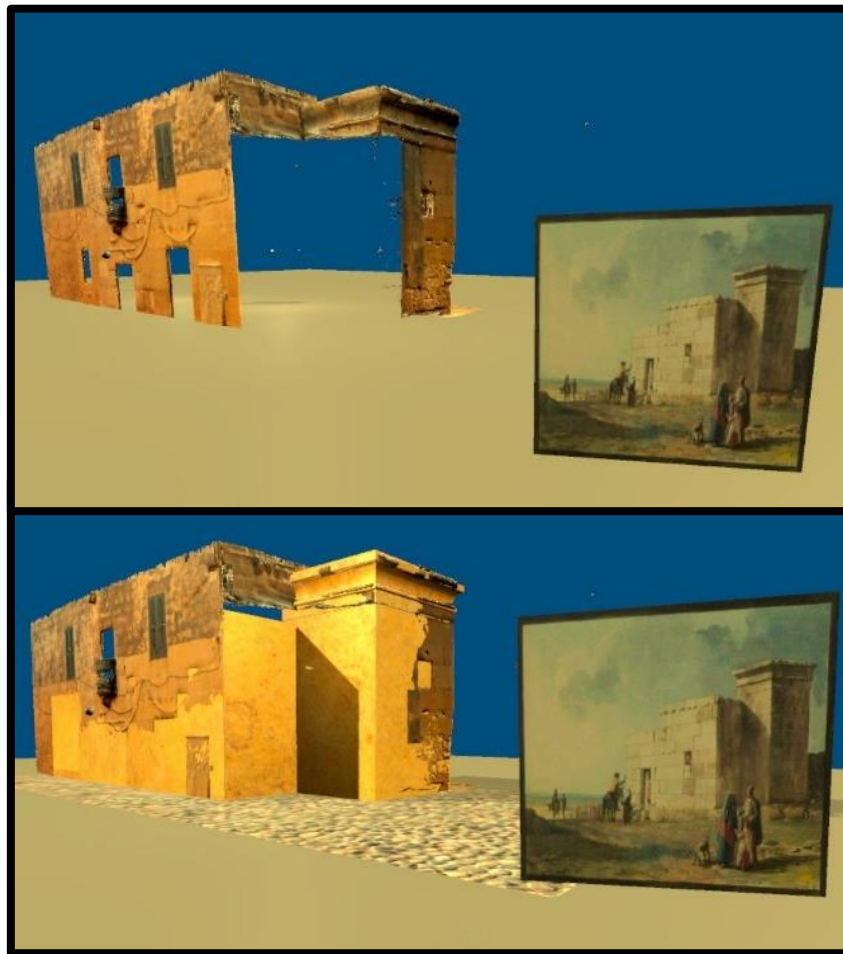


Figure 127. Screenshots from the VR environment showing the visual comparative analysis from the point of view of the second watercolour (photo by the author).

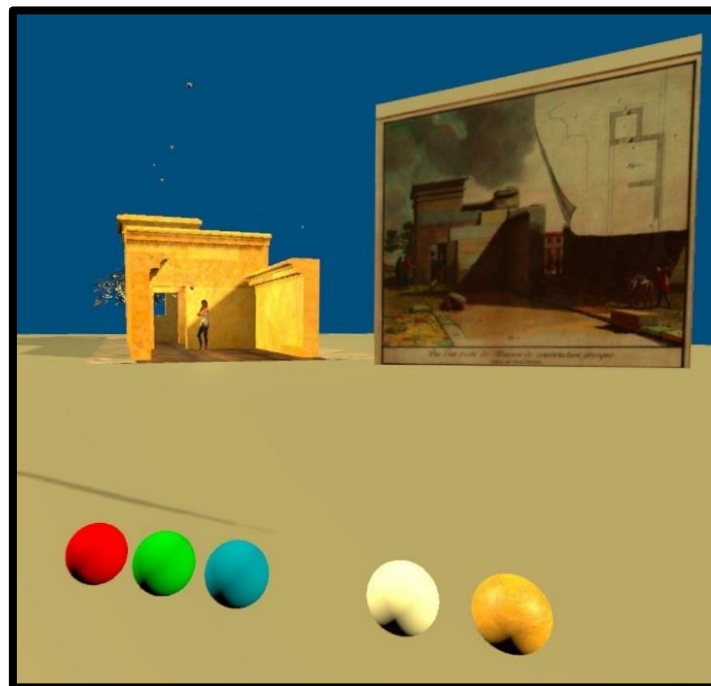


Figure 128. Screenshot from the VR environment showing the interpretative 3D model from the point of view of the first watercolour (photo by the author).

Chapter 6



Discussion

The results presented above (Chapters 3-5) will be discussed by answering the research aims of this study (Chapter 1) and showing how they relate with the literature reviewed in Chapter 2. This will be done by carrying out a site-by-site analysis where the outcomes of this study's investigation will be assessed.

In order to do so, each analysis (Sections 6.1-6.3) will discuss whether a virtual reconstruction built solely employing legacy data could be achieved (Aim 1 – Section 1.2). In order to address the second aim of this research (Section 1.2) the results of each virtual reconstruction will be assessed by:

- i. summarizing the outcomes;
- ii. identifying the determining factors which enabled, or prevented, the achievement of Aim 1;
- iii. assessing the strengths and shortcomings of the final reconstruction;
- iv. discussing relevant additional considerations.

The results of the comparative analysis carried out in the third case study (Aim 2 – Section 1.2) will be discussed in Subsection 6.3.4.

Finally, in Section 6.2. the three analysed case studies will be discussed jointly. These will be compared and contrasted amongst each other on different aspects as their documentation and their outcomes. Finally it will be discussed if legacy data can be regarded as a valid means to reconstruct lost archaeological sites.

6.1. The analysis of Site A: a successful reconstruction of an Early Christian Hypogeum

As shown in Subsection 2.3.1, the first case study of this research attempted to virtually reconstruct an Early Christian catacomb discovered in 1874 on the northern slope of the Jesuits' Hill in Marsa and shortly later destroyed by construction works. The legacy data surviving from that time consisted of a brief archaeological report and archaeological drawing featuring one detailed plan and four section-elevations executed by C.A. Wright.

6.1.1 The outcomes of the exercise

The methodologies and results presented in Chapter 3 have shown that by digitising and uploading Wright's drawn survey on Blender, it was possible to achieve a full reconstruction of this underground site. In addition, given the successful results of this reconstruction, the interpretative 3D model of this site was uploaded to a VR platform which allowed the site to be virtually accessible.

6.1.2 Assessing the reconstruction process: determining factors and difficulties

The reasons for such a successful reconstruction are to be identified with two crucial factors which characterised this case study, such as: the comprehensiveness of the gathered legacy data and the nature of this archaeological site. Regarding the former, the primary documentation recorded by Wright represented an exhaustive set of archaeological data, especially when considering the drawn survey. In fact, thanks to his detailed plan, every single length and width of all the features on site could have been reconstructed. Similarly, the four sections included in the survey allowed to reconstruct most of the heights of the chambers and the depths of the *sarcophagi*, including a portion of the Jesuits' Hill.

However, some missing areas of this site were left without section-elevation data (e.g. *Arcosilium* 1 and 4). These gaps in the data represented the main difficulty of this reconstruction and were challenged by the second determinant factor. This can be identified with the typology of the site in question which belongs to a common repertoire within the Maltese archaeological record. Therefore, these minor gaps in

Wright's data were overcome employing data found within the site itself,²⁵⁶ its broad location,²⁵⁷ and in other local examples.²⁵⁸

6.1.3 Assessing the final result: strengths and limitations

Arguably, the most evident strength of this case study can be identified with the completeness with which the reconstruction of this lost archaeological site was achieved. As mentioned earlier, this was only possible thanks to a fairly complete set of archaeological legacy data and by the nature of the site itself. In fact, it can be argued that the topology of this closed underground feature, permitted a higher immersive visualization.

In this regards, the VR visualization can be considered as another strength of this case study. As confirmed by the literature,²⁵⁹ VR headsets allow fully immersive visualization capable of virtually simulating a physical site visit. However, beyond the visual engagement, some decisions were taken to enhance the viewer's interactivity with the virtual site. This was achieved by leaving some chambers of the catacomb unilluminated, requiring the viewer to activate the virtual electric torch (Section 3.3). In this way, to visualize the archaeological remains left in the dark, the viewer would have to leave a passive-observer role.

Beyond aesthetic assessments, no major shortcomings were assessed with this reconstruction. Improvements can be carried out over some 3D graphic renderings (e.g. sharpness of structural edges and the texture) however, for the purpose of this research these are acceptable.

6.1.4 Reliability and transparency of the virtual reconstruction

As mentioned in the literature (Subsection 2.2.2) an interpretative 3D model is capable of simultaneously displaying all those subjective interpretations occurring

²⁵⁶ E.g. the depths of the sarcophagi of Arcosilium 1 and 4 were reconstructed on the basis of the average depth recorded in the section-elevations.

²⁵⁷ E.g. the colour of the texture was assumed by the physical characteristics of the geology of the land.

²⁵⁸ By comparing this site with others found outside ancient Melitae (e.g. St Paul's Catacombs; St Agatha's Catacombs, Abbatija Tad-Dejr, etc.).

²⁵⁹ Grima 2019: 80.

during an archaeological investigation.²⁶⁰ In a similar way, it can be argued that the 3D reconstructed hypogeum is representing a synthesis of how Wright experienced and interpreted the site in the 19th century and how the author engaged and re-elaborated his legacy data almost 150 years later. For this reason, it is crucial not to separate the descriptive representation of site from the archaeological' interpretative process which are being displayed virtually at once.

Furthermore, the literature (Subsection 2.2.2) provides different strategies to make these archaeological interpretative choices visible and verifiable, enhancing the reliability and transparency of the data.²⁶¹ Given the aims of this exercise and the reconstruction process being almost entirely based on Wright's documentation, the data transparency was limited to the description of the methodology (Chapter 3).

However, as far as this study tried to faithfully represent the features as recorded in 1874, there were instances where the consultation of secondary sources and first-hand interpretations were required. As mentioned earlier, the well-known typology of the site in question provided the author with an empirical understanding of the features being virtually reconstructed. Although it can be argued that this factor came in handy, this should be acknowledged as a subjective influence over the interpretative exercise of the reconstruction. Therefore, in support of reliable and transparent archaeological research based on this 3D reconstruction, these considerations would need to be factored in.

6.1.5 Shifting visualizations and changing interpretations

In the previous subsection it was stated how Early Christian catacombs represent a well-known archaeological feature within the repertoire of Maltese cultural heritage. Although this helped the reconstruction of archaeological gaps in the legacy data, one could question whether this interpretative 3D model adds any new knowledge to the established archaeological record. Albeit acknowledging that this query does not fall within the above-stated research aims, it represents a valid point of discussion which echoes the emphasis shown in the literature over the use of 3D

²⁶⁰ Niccolucci & Hermon 2010: 34; Dell'Unto & Landeschi 2022: 18.

²⁶¹ Demetrescu 2015; Ferdani *et al.* 2019; Ferdani & Petroni 2021: 22.

technologies beyond the mere use for public engagement purposes.²⁶²

Specifically for this case study, it can be stated that the archaeological interpretation did not substantially change following the 3D reconstruction. However, it can be argued that this exercise enabled to validate some of the theories put forward by Wright himself. By referring to the construction phases of the catacomb, Wright suggests how the *arcosilia* where later additions to the chambers. He justifies this statement by referring to the illogical layout of the sarcophagi and a large niche that was tentatively dug in the southern façade of Chamber B, interpreted a unfinished *arcosilia*.

Thanks to the unique possibility of shifting the visualization from a 2D archaeological drawing to a VR experience of the site on a scale of 1:1 it was possible to experience the narrow spaces which characterise this site. This possibly suggest how these catacombs were designed to host a smaller amount of tombs (probably those of Chamber A and B) and was at one point enlarged into four different *arcosilia*. Thanks to the locomotion system activated on the VR model it is possible to simulate the path it would take to carry a buried individual in the furthest sarcophagus. The assumed path would entail stepping over other tombs, confirming Wright's statement over the illogical disposition of these burials.

Finally, when discussing the Wright's legacy data, Mario Buhagiar²⁶³, states how this is "not very clear and its interpretation creates difficulties"²⁶⁴ and concludes by doubting the reliability of his observations.²⁶⁵ For this reason, the 3D reconstruction of a site with interpretational complexities could prove beneficial in providing visual clarity, therefore facilitating its further investigation and understanding.

6.2 The analysis of Site B: incomplete legacy data, incomplete reconstruction

The second case study of this research attempted to virtually reconstruct a Roman warehouse complex discovered in 1768 on the top of the Jesuits' Hill in Marsa as a result of a development project (Subsection 2.3.2). Before the latter obliterated the

²⁶² Hermon 2008: 37; Dell'Unto & Landeschi 2022: 22.

²⁶³ Arguably the leading figure of Maltese Early Christian art history and archaeology.

²⁶⁴ Buhagiar 2014: 139.

²⁶⁵ Buhagiar 2014: 141.

archaeological remains, the site was visited by C.A. Barbaro who documented the site through a written descriptive account and a plan drawing of the standing remains.

6.2.1 The outcomes of the exercise

The results of this virtual reconstruction (Section 4.2), show that legacy documentation gathered by Barbaro in the 18th century did not allow this study to fully reconstruct the Marsa *Horrea*. On the other hand, only a partial reconstruction of the remains of the largest *horreum* was achieved and could not be reconstructed any further.

6.2.2 Assessing the reconstruction process: determinant factors and difficulties

The determinant factors of this unsuccessful 3D reconstruction can be identified with the gathered legacy data itself. Since the shortcomings of Barbaro's documentation were discovered during the data processing, these presented in detail as the results of this reconstruction (Subsection 4.2.3).

The main difficulty identified during the reconstruction of the *horrea* was the major data gap caused by the lack of section-elevation drawings in Barbaro's documentation. Unfortunately, this difficulty could not be overcome as the values concerning the heights and depths of these features were also missing from those stored within the textual description of the site.

Additionally, the latter document also represented a problematic due to Barbaro's style of writing. In order to discuss this factor, Barbaro's legacy data must be understood within their historical context, at a time where the archaeological discipline was still at its initial stages. By describing the remains of the site with an antiquarian archaeological approach, Barbaro lacked methodical and scientific rigour, which resulted in some unclear and contradictory descriptions. In particular, it was difficult to distinguish when his descriptive statements were based on physical evidence or on personal interpretations of the ancient architecture.

Finally, the reconstruction of these features was also made challenging by the lack of geomorphological data. Since the warehouse complex was built on a hill,

Barbaro describes the second and smaller buildings as being constructed on the slope of the hill. Today, this landscape has drastically changed due to the heavily industrialised development which occurred throughout the past two centuries. Therefore, even in the case of a successful reconstruction, this gap in the geomorphological data (i.e. missing bedrock levels) would not have allowed this study to locate these buildings within their geospatial relationship.

6.2.3 Assessing the final result: strengths and limitations

As will be discussed below (Section 6.4), legacy data cannot always represent a good means to virtually reconstruct lost archaeological remains. For this reason, it can be argued that the several shortcomings experienced during this exercise represented in turn its main strength. Albeit unsuccessful, the reconstruction of the *horrea* provides a unique case study showing the limits of the methodology adopted by this research, where virtual reconstructions of destroyed sites were attempted using solely legacy data (Aim 1 – Section 1.2). This also shows how success outcomes of the methodology being proposed in this research strictly depends on the completeness of the legacy data itself.

Moreover, this exercise was capable of evaluating the reliability of Barbaro's drawn document, on which the reconstruction process is based. Since the measurements reported within the text were collected by Barbaro himself during the 1768 site visit, these were cross-referenced to those indirectly measured from the survey plan which was drawn at a later stage. The comparative analysis of these measurements (Subsection 4.2.2) shows that the 3D model reconstructed from Barbaro's plan will carry with an average difference of $\pm 0.42\text{cm}$. Although this length corresponds to almost the height of an ashlar block, when considering the vastness of this structural complex, this value should be understood as a low difference corresponding to approximately 9.39%.

Finally, this case study was also successful at designing a different 3D graphic reconstruction strategy. The ashlar-by-ashlar approach presented in Section 4.2.1 aimed to specifically reconstruct the particular construction building materials employed in these structures to convey the virtual physicality of the masonry. Just by reconstructing the extents of one room of this building, this exercised provides

the viewer with an enhanced visualization of these spaces in 3D. Beyond the clear visually engaging value of this interpretative model, this exercise shows that even with a fragmentary legacy data, a partial reconstruction can be employed to support further archaeological investigation. The brief experiment investigating stacking techniques and capacities of transport amphorae in the rooms of this reconstructed warehouse serves as an example over the possibility to include specific research questions in such an uncompleted virtual reconstruction.

6.3 The analysis of Site C: assessing the reliability of Jean Houël's watercolours

The third and last case study aimed to virtually reconstruct a Punic building today partially surviving within Early Modern buildings in the town of Żurrieq, Malta. The virtual reconstruction of these structures was based on the legacy data of Jean Houël, consisting of a brief report and two watercolours, executed after he visited the site in 1776.

6.3.1 The outcomes of the exercise

This exercise provided three successful results (Sections 5.1-5.3), namely:

- i. an interpretative 3D model reconstructed from Jean Houël's legacy data;
- ii. a reality-based surface 3D model of the Punic remains surviving *in situ*;
- iii. a comparative analysis of the interpretative and reality based models.

The following subsections will be assessing the results of the interpretative 3D reconstruction while the results of the comparative analysis will be discussed in the last Subsection (6.3.4).

6.3.2 Assessing the reconstruction process: determinant factors and difficulties

The availability of legacy data rich in visual documentation played a key role during the interpretative 3D reconstruction process. Together with a survey plan of the

Punic archaeological remains, Jean Houël artistically recorded this site in two very different watercolours. For the reasons explained above (Subsection 5.1.1), the documentation uploaded to the 3D graphic software was the watercolour displaying the survey (Fig. 43), which featured in Houël's book briefly describing the site.

The first difficulty encountered here was the lack of a scale reference to this drawing. This shortcoming was overcome by cross-referencing the drawing with the written account, which provided two measurements.

The second difficulty encountered with Houël's legacy data was caused by the lack of a section-elevation for the tower-like structure and the wall alignment. As explained above (Subsection 5.1.2), the data gap concerning the tower was fixed by an archaeological section-elevation drawn in the second half of the 20th Century; while the lack of elevation data for the wall was calculated from the geometrical perspective used by Houël himself.

6.3.3 Assessing the final result: widening the archaeological knowledge of the site

In order to reconstruct this site, Houël's own interpretations displayed in his drawings were archaeologically analysed and reproduced in an interpretative 3D model. Therefore it can be said that the final result of this exercise consisted of a 21st century archaeological-interpretative 3D display of an 18th-century artistic interpretative 2D documentation of ancient Punic structures. This statement recalls the discussion carried out in Subsection 6.1.5, where it was questioned whether the reflexive process of an interpretative 3D reconstruction based on legacy data would add any new information to the archaeological record.

In this regard, it is possible to state that the virtual reconstruction based on Houël's legacy data contributed significantly to widen the archaeological knowledge of the site. Arguably, this represents the main strength of this interpretative virtual reconstruction. Following the 3D reconstruction of the site as seen in the 18th century drawings, this study attempted to carry out one further interpretative reconstruction based on the ruins of a wall and the traces of foundation blocks depicted by Houël. By employing digital archaeology tools and methods, this study

was able to provide archaeological knowledge to this site, by providing hypothetical observations suggesting how this could have looked in a time before Houël's visit.

This was done by conveying a certain degree of data transparency and reliability over the hypothesised interpretations. In fact, the methods adopted for this exercise followed those formal languages established after the publication of the London Charter²⁶⁶ and Seville Principles.²⁶⁷ This reconstruction was based on the 'extended matrix'²⁶⁸ approach which, for the purposes of this research was adopted only in its theoretical form.²⁶⁹ However, to transparently display the layers of this reconstruction the semantic colour-coding approach presented in the literature²⁷⁰ was chosen, distinguishing the remains visible *in situ*; those reconstructed through the legacy data; and those hypothetically reconstructed (Fig. 129).

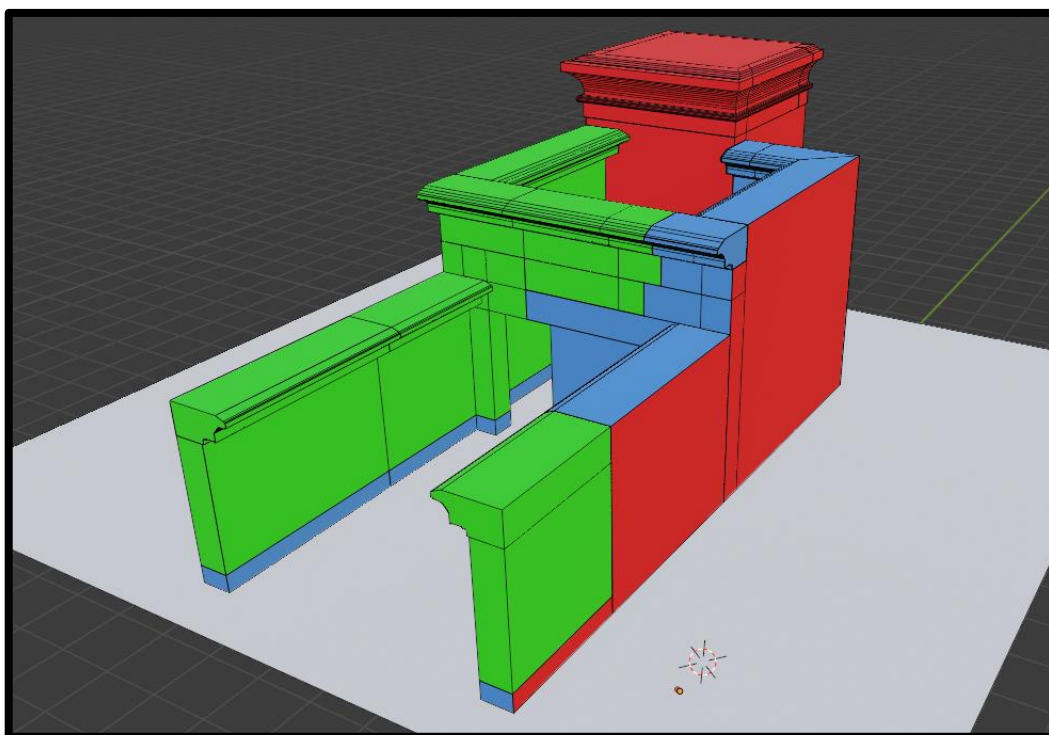


Figure 129. Screenshot from Blender showing the 3D hypothetical reconstruction of the Punic tower. The colour-coding allows the viewer to recognize the surviving *in-situ* remains (marked in red), the structures reconstructed from Houël's watercolours (marked in blue), and the ones hypothetically reconstructed by this study (marked in green) (photo by the author).

²⁶⁶ 2006.

²⁶⁷ 2011.

²⁶⁸ Demetrescu 2015

²⁶⁹ No access was gained to the SUs of the 1964 excavation, reconstructed features were not assigned a USV and therefore the extended stratigraphic matrix was not created.

²⁷⁰ Ferdani *et al.* 2019; Ferdani *et al.* 2020; Ferdani & Petroni 2021: 22.

6.3.4 Interpretative vs reality-based models: a comparative analysis

By including a site which is both documented through legacy data and still partially surviving in situ, this study was able to assess the reliability of the legacy data used to reconstruct this interpretative model. Today, the archaeological remains of this Punic building are visible from a narrow street (i.e. an ashlar-wall alignment built over foundation blocks) and from a back garden of the Parish Office in Żurrieq, and were successfully 3D modelled through a photogrammetric survey (Section 5.2). Consequently, a comparative analysis of the archaeological remains visible in the surface reality-based model and those of the interpretative 3D model (the red layer) was carried out through a quantitative and a visual approach.

In a similar way to that adopted to evaluate Site B's measurements, a sample of measurements were selected from the interpretative model and were compared to the respective ones found in the reality based model. This exercise showed that the size and scale of the virtually reconstructed model had an average error of ± 0.27 m. Considering the total lengths of the chosen samples, this value represents only a 8.58% difference, suggesting that the interpretative model built from Jean Houël fairly matches the physical structures.

However, the second visual approach did not fully reflect these results. Surprisingly, by uploading the two models on a same 3D graphic software and matching them on a common point, this exercise showed three different results. Firstly, all the sides of the two towers, and the eastern axis of the two walls (Figs. 115-116) were found almost perfectly matching. On the other hand, a slight positional difference was noticed on the northern axis of the two walls while their heights were considerably inconsistent (Figs. 117-118).

The reason for this considerable difference was identified with the reality-based model, where it was noticed that the tower was built at a higher level than the wall, most probably due to different levels of the bedrock. However, from the watercolour employed for this reconstruction, this difference was not documented by Houël, who depicts the floor and the street as relatively flat surfaces. However, by closely examining Houël's second watercolour, this geomorphological feature is instead depicted. Unfortunately, when deciding on what watercolour to rely on,

this study chose the first one (Subsection 5.1.1). Although the second watercolour was regarded as more fictional²⁷¹ when compared to the former, it showcases a surprisingly accurate depiction of the archaeological remains. In a time without photography, the artist depicted this structure with such a high degree of detail that if compared with the reality-based model, it is still possible to detect each of the depicted ashlar blocks (Fig. 130). The significance of this exercise reveals the dualistic nature of legacy data. If on one hand Jean Houël's drawings²⁷² can be safely regarded as a reliable; on the other they contain inconsistencies that, if not cross referenced and verified, could mislead the archaeological interpretation.

Finally, by reconstructing the chronology of these structures, these 3D technologies play a crucial role in the narration of the building's biography and of the events and individuals who shaped its form and function throughout time. One element of artistic licence of which Houël is transparent about concerns the removal of the modern houses to better represent the archaeological remains. However, by cross referencing the reality-based model it is possible to track the structural alterations from the Punic ashlar wall. In this way, it can be noted how already by 1776 a doorway existed and since then another two were built disrupting the Punic architecture (Fig. 131). These alterations can be visualized through the VR experience of the monument's comparative analysis. If compared to the one developed for the catacombs which has a more public-engaging appeal, this one might appear less realistic and immersive. On the other hand, this VR model serves an analytically engaging visualisation tool to interpret and investigate the different phases of construction and re-construction of the site.

6.4 Comparing and contrasting the case studies: assessing legacy data as a means of reconstructing lost sites

The previous sections (6.1-6.3) provide an individual analysis for each case study. This was done by assessing the outcomes, strengths and limitations of each virtual reconstruction and discussing these in relation to the aims of this research (Section 1.2) and the reviewed literature. Therefore, the discussion will now bring the three

²⁷¹ Due to the Romantic rendition of rural landscape.

²⁷² For this specific case study.

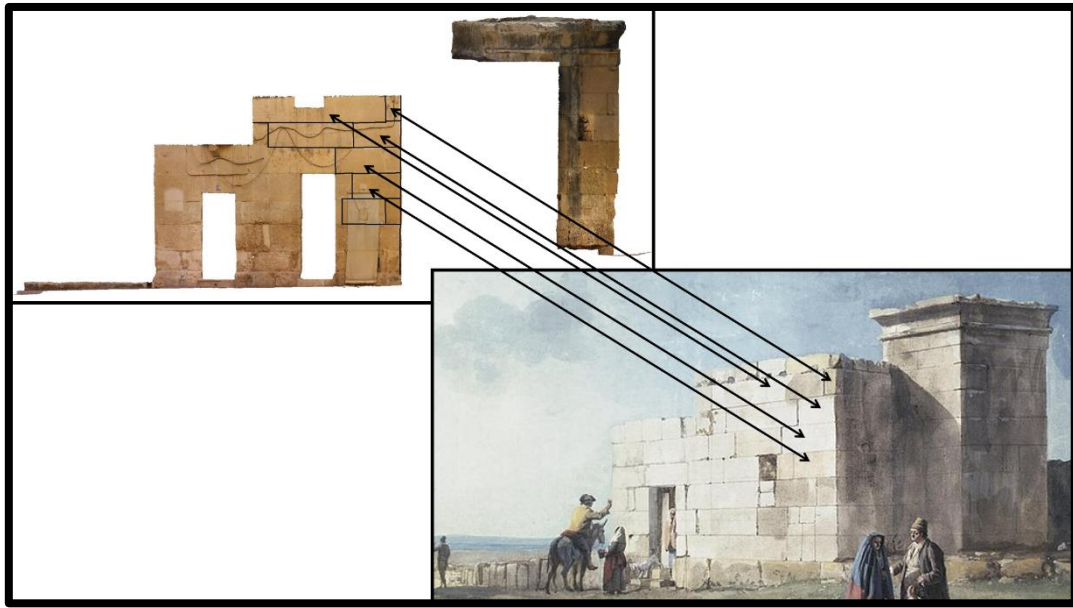


Figure 130. *By comparing the second watercolour with the reality based model it was possible to notice how each of the ashlar block match (photo by the author).*



Figure 131. *Photo showing the schematic representation of the modern remains tracking the structural interventions (photo by the author).*

case studies together to compare and contrast them on different aspects of this research. The final aim of this section is to assess whether legacy data can be regarded as a valid means to reconstruct lost archaeological sites.

6.4.1 Comparing the three sets of legacy data

Firstly, it is important to state that the sites chosen for this research were not selected arbitrarily. On the contrary, for the benefits of this research's investigation, sites with a diversified set of documentation were examined. As seen in Table 3, the two destroyed archaeological sites chosen to be reconstructed were both documented by written and drawn sources. Regarding the first medium, the *Horrea* were recorded by an 18th century dissertation, while the discovery of the catacombs featured on a local 19th century newspaper article instead. On the other hand, the latter site shows a richer set of drawings, including a detailed plan and four section elevations;²⁷³ while the former was only visually documented through a plan survey of the remains located on the Ta' Ċelju promontory. As opposed to the former two, the third case study was characterized by archaeological remains surviving *in situ*. Beyond a brief written account, the Punic building was documented through a diversified set of visual data. These included two watercolours of different artistry, one technical drawing of the plan of the structure, and one section drawing of the decorative cornice topping the walls. Although it lacked important elevations of its most distinctive features,²⁷⁴ the legacy data of the third case study represented the most comprehensive set of documentation of the three. On the other hand, Barbaro's documentation turned out to be the least complete of the three, a factor that as will be discussed below directly impacted the outcomes of this case study.

Site	Drawn record			Written report	State of preservation
	Plan	Section-elevation	Illustration		
Catacomb	✓	✓✓	✗	✓	Destroyed
<i>Horrea</i>	✓	✗✗	✗	✓	Destroyed
Punic Building	✓	✓✗	✓	✓	Partially <i>in situ</i>

Table 3. Table showing the comparison of the legacy data available for the sites of this study.

²⁷³ Including a section of the bedrock hill-slope.

²⁷⁴ The tower-like structure and its walls.

6.4.2 Comparing the three outcomes and determinant factors

In order to discuss the results concerning the first aim of this research, the outcomes of each case study will be discussed by comparing and contrasting the factors that made their 3D reconstructions either successful or unsuccessful. As can be observed in Table 4, this study achieved two successful reconstructions, one of which was totally obliterated in the 19th century (catacomb) and one is still partially surviving today (Punic building).

Site	Successful 3D reconstruction	Determinant factors
Catacomb	✓	Comprehensive archaeological survey Nature of the site
<i>Horrea</i>	✗	Fragmentary written report Limited drawn record
Punic Building	✓	Diversity of legacy data Partially surviving <i>in situ</i>

Table 4. Table showing the comparison of the outcomes and determinant factors of this study.

Both case studies owe their positive outcomes to factors linked to the characteristics of their own legacy data. In the first case, the Early Christian hypogeum benefitted from an archaeological survey which documented almost the entirety of its underground spaces. In addition, as discussed above (Section 6.1), both the topology and typology of this archaeological site played a crucial role in filling data gaps and to ensure an immersive visualisation engagement when accessed in virtual reality. Similarly, the reconstruction of the third site was facilitated by the rich visual documentation and by the surviving archaeological remains.

As opposed to these two sites, the reconstruction of the Roman *horrea* was not fully achieved. Also in this case, the determinant factor of this result lies in the legacy documentation gathered for this site, which although restricted in quantity (Subsection 6.4.1), turned out to be also fragmentary and limited.

By comparing these results it was noticed how the factors directly involved with the final outcome of this exercise were related to a specific type of documentation,

namely the drawn data. This very close relationship between 3D models and drawings is understood by the fact that these two mediums both convey data through a visual technique and as such can be considered complementary.²⁷⁵ Therefore, it can be stated that technical drawings are arguably the most significant type of documentation of the ones gathered by this research. Furthermore, it can be argued that also artistic representations such as paintings, watercolours and illustrations can successfully contribute in adding knowledge over lost archaeological remains.

6.4.3 Legacy data as a means to reconstruct lost sites

After having assessed and discussed the legacy data employed to achieve the aims of this study and its outcomes, the final topic of discussion queries whether such legacy data can be considered as a valid means to reconstruct lost sites.

In order to answer this question it is important to clarify what are the research questions involved with reconstructing such 3D models. If the aim is to faithfully visualize lost archaeological remains at a specific period in time prior to their destruction, it is difficult to provide an absolute affirmative or negative answer. This study has shown that successful results can be achieved, however it also presented the limits of legacy data. Three case studies presented throughout this research show that the outcomes are dependent on the multiple variables²⁷⁶ at play (e.g. the nature of site, the quantity and quality of the legacy data, the geomorphological condition of the landscape, etc.).

However, the answer changes when the focus of the exercise shifts from the pursuit of an authentic and accurate 3D reconstruction to a reflexive investigation of the past archaeological interpretations contained in the legacy data. In the reviewed literature (Subsection 2.2.2) this topic is challenged by Clark and Demetrescu. The scholars consider the debate over authenticity of reconstructions a “false dilemma”,²⁷⁷ as the authenticity of a lost monument or site vanishes the moment it

²⁷⁵ Dell’Unto 2014: 152.

²⁷⁶ Such as those included by the nature of site, the quantity and quality of the legacy data, the geomorphological condition of the landscape, etc.

²⁷⁷ Demetrescu 2015: 4.

is destroyed.²⁷⁸ For this reason, when building an interpretative model which is, by definition, built from hypothetical archaeological interpretations, it is contradictory to strive for authenticity.²⁷⁹ Furthermore, since the drawn legacy data has earlier been discussed as the most effective means to virtually reconstruct a lost site (Subsection 6.4.2), it becomes even more clear that through legacy data-based reconstructions accuracy and authenticity are relative. This is because archaeological drawings²⁸⁰ are known to display subjective interpretation of the recorder in charge.²⁸¹

By placing this study within the reviewed literature, the analysis and discussion of these results allowed to understand research from a new perspective. Initially this research was approached with a technical methodology focused on the 3D graphic tasks applied to the reconstruction of lost archaeological sites. However, as the exercise progressed the understanding of this research progressively shifted towards a more reflexive approach. This shift in perspective consisted in understanding the undergoing reconstruction process not as attempting to rebuild the sites as they existed in the past but as they were perceived by an individual who experienced and interpreted them before their destruction. In turn, by retrieving and processing legacy data, this study carried out another level of archaeological investigation which re-assessed and re-interpreted the site.

Under this new light, the answer to the former question would be affirmative. Arguably, even the uncompleted *horrea* would not be considered as an unsuccessful result, since the exercise still provided valuable archaeological considerations. Finally, this approach contributed to the widening of the archaeological knowledge concerning the third case study. From the 3D model based on Jean Houël's interaction and interpretation of the site, this study was able to theorize a more complete 3D reconstruction of the Punic building. By following up some structural hints suggested by the artist himself, the hypothesis consisted in the reconstruction of a square plan room which can be interpreted as a vestibule leading to the tower-like structure (Figs. 98 and 129).

²⁷⁸ Clark 2010: 71.

²⁷⁹ Dell'Unto & Landeschi 2022: 18.

²⁸⁰ Let alone artistic representations.

²⁸¹ Dell'Unto 2014: 152.

Chapter 7



Conclusion

7.1 Summary

This research sought to establish whether destroyed archaeological sites could be virtually reconstructed using exclusively available legacy data. This was accomplished employing 18th and 19th-century legacy documentation of local archaeological sites destroyed in the past.

The first site to be chosen was an Early Christian Hypogeum (Site A). This was discovered in 1874 on the northern side of the Jesuits' Hill in Marsa, documented by C. A. Wright, and destroyed shortly after. By employing Wright's brief report and archaeological drawings, this study was able to successfully reconstruct the underground chambers of this site using an open-source 3D graphic software. Moreover, this model was imported to a game engine where a VR model of this site was built. Through an immersive VR experience, this exercise allows viewers to virtually engage with an archaeological site destroyed almost 150 years ago.

The second site to be selected was a Roman warehouse complex (Site B). This was discovered in 1768 on the top of the Jesuits' Hill in Marsa and was destroyed by an industrial development project shortly after. These archaeological remains were documented by C. A. Barbaro through an essay and a survey of the plan of the site. Unfortunately, this set of legacy data was deemed fragmentary and not sufficient to achieve a successful virtual reconstruction of these Roman *horrea*.

Moreover, in order to evaluate the effectiveness of these virtual reconstructions, this research included a site documented in the 18th century which instead was not totally destroyed in past. The site in question consists of a Punic building which today can be found incorporated between Early Modern townhouses in Żurrieq (Site C). This study was successful at virtually reconstructing this archaeological site by employing legacy documentation by the French traveller and artist Jean Houël, who documented this site in 1776 through a brief report and two watercolours of these standing remains. By 3D-recording the remains surviving *in situ*, this study was then able to carry out a comparison analysis between the reconstruction based on Houël's legacy data and the reality-based 3D model of these Punic remains. This allowed to assess both outcomes and limitations of this exercise.

7.2 Concluding Remarks

Five concluding statements can be made.

1. **3D technologies are improving archaeological practices and are helping to answer past and new archaeological research questions.** Following thirty years of debates, experiments, methods and innovations, 3D technologies are today regarded as widely available essential resources for the practice of the archaeological discipline. Beyond facilitating and improving the quality of the archaeological record, these have also widened archaeological researches by answering new specific questions which could not have been answered otherwise and reassessing past archaeological theories and practices.
2. **This study shows the potentials and the limitations of employing legacy data as a means of virtually reconstructing destroyed archaeological sites.** By selecting three sites documented by different sets of legacy data, this study achieved diversified results. Although successful reconstructions were obtained it was also understood that sets of legacy data lacking visual documentation (survey plans, section elevations, artwork, etc) might result insufficient to carry out successful reconstructions.

- 3. Due to the variables at play, the virtual reconstruction technique adopted by this study cannot be generalised to one unique methodology.** The general categories of these variables can be identified with the nature of the site, the quantity and quality of the legacy data and the changes in the landscape of the site. However, this research showed how in specific cases where archaeological remains are partially preserved *in situ*, a comparative analysis can be carried out to broadly assess the reliability and accuracy of the collected legacy data.

- 4. An archaeological virtual reconstruction can never be authentic but they can (and should) be transparent and reliable.** Although recognising the value of a thorough and a methodical reconstruction techniques, it can be argued that discussions concerning authenticity over the reconstruction are substantially flawed. Destroyed cultural heritage features are arguably lost the moment of their destruction and even the most faithful interpretative 3D model attempting to reconstruct it remains, by definition, an hypothesis. However, in order to support new forms of archaeological interpretations, the interpretative reconstruction process should be conveyed in a transparent and verifiable way.

- 5. The virtual reconstructions of study show the sites as they were experienced and interpreted by the individual who documented them.** Drawings can be understood as a component of archaeological documentation displaying a visual synthesis of interpretations gathered on site. For this reason, it is important to underline how this study is not presenting these reconstructed sites as they were exactly before being destroyed. In fact, by retrieving and basing the reconstruction method on legacy data, this study analysed, re-interpreted and re-produced the experience and interpretations which took place in the subjective understanding of the recorder. By acknowledging this aspect, it was possible to understand the archaeological interpretations portrayed in the documentation and, building from these, the site could have been reinterpreted.

7.3 Recommendations for further research

Finally, this research has provided seven insights which can be considered valid for future research. These are listed hereunder.

1. The last effort at relocating the Hypogeum in Marsa (Site A) occurred in 1911 by Temi Zammit, who did not succeed at this task. Today, given this study's successful reconstruction and the available digital technologies a further attempt can be made in this direction. Firstly, given the virtually reconstructed bedrock slope of this catacomb, the possibilities of reconstructing the ancient bedrock levels should be explored. In this regards, remote sensing techniques (e.g. LIDAR) and 3D geographical information systems (GIS) could help mapping the geomorphological changes.
2. Furthermore an attempt should be carried out at recording and mapping any evidence of truncated cultural heritage features visible in section from the exposed portions of bedrock of the area. Also, a 3D survey of the truncated burial chamber noticed in section on the northern slope of the Jesuits' Hill, should be carried out, in order to asses any possible links to the *arcosilia* of the catacomb reconstructed by this study.
3. The 150th anniversary since the discovery, documentation, and destruction of the Marsa catacombs will occur in 2024. In light of this occasion, different outreach and engagement methods should be put forward and assessed in order to provide the local public with access to the reconstructed archaeological site.
4. Although only partially reconstructed, the *Horrea* reconstructed by Barbaro could serve as a starting point for a wider study attempting to 3D reconstruct these Roman . However, given the limitations of the legacy data taken on their own, other sources of interpretations should be consulted. A further archaeological reconstruction should explore other examples of warehouses found within the Roman maritime ancient world (e.g. *Horrea* at Ostia Antica, Myra, Leptis Magna, etc.). Moreover, if the ancient landscape is reconstructed (recommendation n. 2) the virtually reconstructed *horrea* could answer a

research question aimed to investigate the maritime inter-visibility between incoming Roman ships and this massive structure linked to the ancient Roman port in Marsa.

5. Moreover, the comparative analysis carried out between the interpretative and the reality-based model of the Punic Building in Żurrieq attested the impressive accuracy with which Jean Houël's watercolours recorded the remains in the 18th century. Given his wide repertoire of watercolours depicting archaeological features, further research should aim to assess whether other destroyed archaeological features reconstructed from these artworks is possible. Moreover, these 3D reconstruction should aim to widen the archaeological interpretation of the site. By adopting an object biographical approach, 3D reconstructions built from artistic visual sources can contribute to the narration of how an archaeological monument or site changed its meaning and function throughout time.
6. A case study focused to introduce the formal languages established to carry out an archaeologically transparent and reliable virtual reconstruction could be introduced in a local research-led excavation. This would set a precedent for the local practice of a standardized Digital Archaeological practices, adhering to the methods developed by the London Charter and the Seville principles.
7. Given the successful outcomes achieved when introducing legacy data as a means to reconstructing archaeological sites, further research should investigate the potentials and limitations of another type of legacy source, namely photography. The 3D graphics software employed by this research allows to calibrate photographic parameters in order to reconstruct 3D geometries from photographs. In this regard, black and white photographs dating to past archaeological excavations can be used (e.g. 1930s excavations of the Tarxien Temples). By cross-referencing 3D generated data with field-notebooks, this exercise could allow the reassessment of past archaeological interpretations which took place during excavations. As a result, this exercise could potentially shed light on new archaeological understandings of these sites.

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Appendix I

Sketchfab links to 3D models.

SITE A:

- Interpretative 3D model of the Early Christian Hypogeum (without walls and roof). Available at: <https://skfb.ly/opqSB>
- Interpretative 3D model of the Early Christian Hypogeum (with arches and roof). Available at: <https://skfb.ly/opqSH>
- Interpretative 3D model of the Early Christian Hypogeum (final – with bedrock). Available at: <https://skfb.ly/opqQs>

SITE B:

- Interpretative 3D model of the *Horreum* walls built ashlar-by-ashlar containing Roman amphorae. Available at: <https://skfb.ly/ovVr7>

SITE C:

- Reality-based 3D model of the Punic Building in Żurrieq. Available at: <https://skfb.ly/ovKur>
- Trimmed reality-based 3D model showing exclusively the *in situ remains* of the Punic Building in Żurrieq. Available at: <https://skfb.ly/ovKur>
- Interpretative 3D model of the Punic Building as depicted by Jean Houël. Available at: <https://skfb.ly/ovE9t>
- Hypothetical 3D reconstruction of the Punic Building (realistic texture). Available at: <https://skfb.ly/ovE9t>
- Hypothetical 3D reconstruction of the Punic Building (colour-coded). Available at: <https://skfb.ly/o7L7B>

Appendix II

Contents of Google Drive folder:

- Instruction on how to use the Oculus Quest 1 to access the VR models
- VR screen recordings

Link available at: <https://drive.google.com/drive/folders/1iVhD-TTJDff74eSWiXhWgxpuzJQn-8z?usp=sharing> .