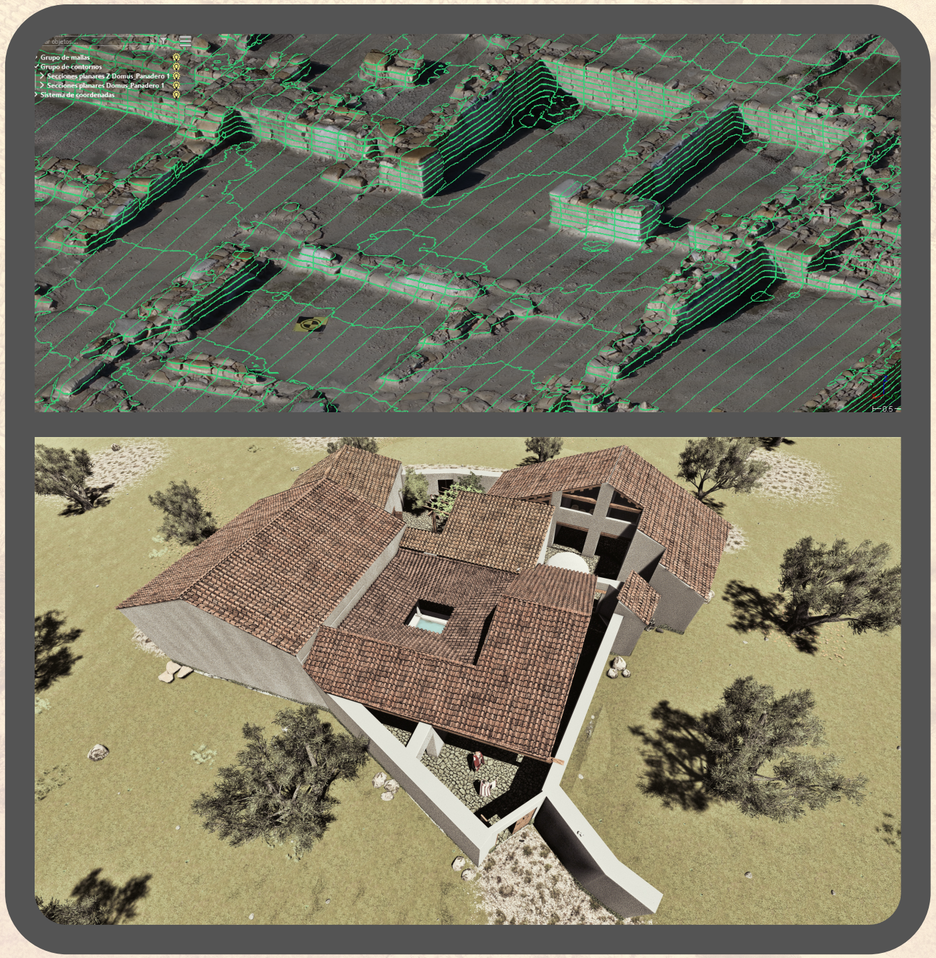
Highlights:

- The virtual reconstruction meets the quality criteria required in the field of Archaeology and promotes the Sustainable Development Goals.
- Geometric documentation from photogrammetry was used for the virtual reconstruction.
- QR codes utilization reports significant advances for Cultural Heritage visualization.

Graphical Abstract

3D MODEL OF THE BAKER'S HOUSE IN THE ARCAHEOLOGICAL SITE TORREPAREDONES

QR CODE



CONSERVATION

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DISSEMINATION

ARCHEOLOGICAL HERITAGE IN ANDALUSIAM

CONTRIBUTION TO THE SDG-11.4

Title Page (with Author Details)

DIGITAL PRESERVATION AND VIRTUAL 3D RECONSTRUCTION OF "THE BAKER'S HOUSE" IN THE ARCHAEOLOGICAL SITE OF TORREPAREDONES (BAENA, CORDOBA-SPAIN)

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DIGITAL PRESERVATION AND VIRTUAL 3D RECONSTRUCTION OF "THE BAKER'S HOUSE" IN THE ARCHAEOLOGICAL SITE OF TORREPAREDONES (BAENA, CORDOBA-SPAIN)

Abstract:

Torreparedones archaeological site is in the heart of the Cordoba countryside. The documentation of the domus "The Bakers's house" took place, being a key heritage asset for understanding its spaces.

The domus, is named after the conservation of the floor from a Roman bread oven. Also, the preservation of the base of a Roman rotating mill, implies the elaboration of bakery products in this house. Due to the lack of archaeological remains, it is necessary to carry out a thorough literature review, working on the interpretation of each area. Thanks to the bibliography of contemporary domus, the interpretation of the residential area spaces is achieved, as well as the interpretation of architectural and decorative issues.

The main research objective was to obtain solid documentation to perform the 3D model of the Baker's domus and its display by decoding QR code, that facilitates the conservation of existing Andalusian Archaeological heritage.

Keywords: 3D virtual reconstruction, virtual archaeology, code QR, archaeological site, *domus*.

1. Introduction

Archaeological studies do not only consist in excavating the remains of the past, as they also involve the documentation and investigation of archaeological vestiges and the development of virtual recreations and reconstructions (Galeazzi, 2018).

According to art. 1.2., Law 16/1985, of June 25th, on Spanish Historical Heritage: "The Spanish Historical Heritage is composed of the buildings and furniture objects of artistic, historical, paleontological, archaeological, ethnographic, scientific or technical interest, as well as the documentary and bibliographic heritage, archaeological sites and zones, and natural spaces, gardens and parks with artistic, historical or anthropological value". In addition to the laws in force, the protection and preservation the Heritage is gathered in the following documents: the Athens Charter for the Restoration of Historical Monuments (Athens Charter, 1931), the Hague Conference (UNESCO, 1954), the Venice Charter (Venice Charter, 1964), the Convention concerning the Protection of World Cultural and Natural Heritage (UNESCO, 1972), the Convention for the Protection of the Architectural Heritage of Europe (Granada Convention) (C. Europeo, 1985), the International Charter for the Protection and Management of the Archaeological Heritage (ICOMOS, 1990), the Charter on the Preservation of Digital Heritage (UNESCO, 2003) and the London Charter for the Computer-based Visualisation of Cultural Heritage (Denard, 2009).

From the year 1980, the first virtual reconstructions appeared, with the emergence of the three-dimensional (3D) model (Gómez & Quirosa, 2009). Between 1984 and 1986, outstanding works for IBM UK Scientific Centre were carried out, reconstructing simple and pioneer models using these new technologies applied to heritage (Gómez & Quirosa, 2009).

According to Reilly (1990), the term "virtual archaeology" is defined as "the set of computer techniques that enable the 3D visualisation of the virtual and realistic representation of ancient buildings and objects, whose remains have disappeared or are in such a poor conservation state that it is impossible to observe them or very difficult to interpret them". Thus, Virtual archaeology was conceived as a computer method to assist the teaching of the principles of archaeological excavation and analysis for students (Rahtz, 1988).

From the 1990s, archaeological remains began to be interpreted through 3D models (Really, 1990; Forte, 1996). One of the most ambitious projects of virtual archaeology, i.e., Rome Reborn 2.0, started in 1997, and 10 years later it was renamed as Rome Reborn 1.0; the aim of that project was to recreate the ancient city of Rome and its urban development (Gómez & Quirosa, 2009).

Spain was in the forefront of using digital technology applied to heritage. The School of Arabic Studies of Granada (CSIC) conducted a reconstruction project for the Dar al Yund in Madinat al- Zahra (Cordoba), whose studies began in 1990 (Gómez & Quirosa, 2009). This school held the first doctoral thesis to implement these technologies in 1997, with the restoration of heritage by image synthesis, which included infographic digital models of the Old Mosque of Seville, the Dar al Yund in Madinat al- Zahra and Umayyad Palace in Amman (Almagro & Jiménez, 2000). Other research groups have performed virtual reconstructions of different regions, such as GRIHO of the University of Lleida, and the VideaLab Research Group, who reconstructed the Maestro Mateo Choir at Santiago's Cathedral (Gómez & Quirosa, 2009; Carreras, 2006).

In Spain, the first International Congress on Archaeology, Computer Graphics, Cultural Heritage and Innovation (ARQUEOLOGICA 2.0) (2009) gave rise to the need for the Spanish Society of Virtual Archaeology (SEAV) to identify the objectives for the projects conducted in this field. This led to the creation of the Seville Charter (SEAV, 2011), inspired by the London Charter (Denard, 2009), which establishes the principles and criteria to measure

the quality of projects related to virtual archaeology (López-Menchero & Grande, 2011).

Nowadays, multiple techniques are used in the scope of virtual archaeology (Pavlidis et al., 2007; Gomes et al., 2014; Katz & Tokovinine, 2017; Banfi, 2020), with different computer programmes, both open and commercial, to digitise the cultural heritage and create 3D reconstructions (Staropoli et al., 2019; Taylor & Gibson, 2017).

Over time, virtual reconstructions have advanced, becoming a usual tool in archaeology (Rodríguez, 2010; Zollhöfer et al., 2015; Lercari, 2017; Gisbert, 2019). Moreover, they allow solving specific problems in the scope of heritage. The most popular applications are (Torres et al., 2010):

- Graphic document: a three-dimensional model that shows how a heritage asset was in a specific period.
- Dissemination: to provide knowledge of the heritage to the viewers (Pietroni & Adami, 2014).
- Modelling: the creation of models and replicas using 3D printing technology.
- Analysis: the generation of detailed information and information about the model (Agus et al., 2017).
- Restoration: the computer modelling of missing parts of an object.
- Documentation: the integration of information into the digital model with texts or multimedia links.

The geometric documentation of heritage is fundamental for the conservation and protection of archaeological vestiges that, -due to their outdoor exposure, have suffered the negative action of the meteorological elements (Kioussi et al., 2007; Landeschi et al., 2016; Selmanović et al., 2020; Galasso et al., 2021). Thanks to the use of new technologies, archaeology is thriving and growing (Rua & Alvito, 2011; Dell'Unto et al., 2017).

Nowadays, decoding through QR codes is immersed in cultural heritage, being used in projects such as QVADRARIA (Miramón, 2020), archaeological museums and parks (Baeza, 2019; Cerrillo et al., 2019; Espinoza, 2020), ceramic material culture (Maldonado & Fernández, 2020) and churches (Prampolini et al., 2017), among other applications. However, the application of these codes in cultural heritage stands out especially in the use of the techniques of Virtual and Augmented Reality (Jung et al., 2020), although they have not been used to show virtual 3D reconstructions of archaeological sites. Therefore, the present study is in the cutting edge in enabling the viewers to visualise the digital virtual model of a Roman *domus* through a QR code, improving their interpretation and understanding of said heritage element.

On September 25, 2015, the 2030 Agenda for Sustainable Development was approved by the United Nations General Assembly (UNGA). It consists of 17 objectives (SDGs) for the next 13 years, focused on transforming the world. This article promotes culture, as established in SDG 11, target 11.4, to redouble efforts to protect and safeguard the world's cultural and natural heritage.

1.1. Research aim

The aim of this research was to carry out a virtual reconstruction of the baker's *domus* at the archaeological site of Torreparedones in Baena-Cordoba (Spain), generating a digital three-dimensional model that showed how this heritage asset was in a specific period, creating and providing a QR code for the visualisation of the 3D model of the *domus*, thus facilitating its dissemination. In this context, the 3D reconstruction created is an example of display and advanced development of the applications of novelty techniques to the archaeological field.

2. Material and methods

2.1. Materials

2.1.1. Archaeological background

The site known as Torreparedones is located in the Cordoba countryside (Spain), at the northern border of the municipalities of Castro del Río and Baena.

In the excavation campaign of 2015-2016, under the management of municipal archaeologist José Antonio Morena, and with the collaboration of archaeologists Antonio Moreno and Laura Fernández, the excavation and documentation of the *domus* was conducted (Morena et al., 2016). The recovered archaeological vestiges refer to three construction phases: late Roman Republic, early Roman Empire and medieval-modern age. This project was focused on the second construction phase, with the oven that grants the name to the functioning *domus*.

The nomenclature used to identify the rooms was the one employed in the excavation of 2015-2016. The building is accessed through an entrance at the NE to a redistributing zone E-36, from which three spaces can be accessed: latrines E-13, *domus* E-10 and tavern E-16. In the first, triangular space, the archaeologists documented a drainage channel, which was connected directly to the channeling system that discharged its waters in the street (Morena et al., 2019).

This redistributing zone accesses a second space, i.e., the commercial zone, identified as a bakery based on the presence of a large oven. This zone consists of two spaces: the tavern, where products were sold E-16, and the *pristinum* E-15, a zone that precedes the oven and is interpreted as the working zone. The latter (*pristinum*) is connected to the residential zone, specifically to the *atrium* E-10. To the north of these spaces, a corridor was documented E-35, which connects the lobby with oven, thus it was probably a service corridor.

The *domus* itself, the last space that can be accessed from the redistributing zone, is built around a central *atrium* E-10, composed, in the first phase of four pillars, and an *impluvium* E-10a. To the west of the *atrium*, there is the *tablinum* E-11, whose bay was the largest of the *domus*, and another room interpreted as a *cubiculum* E-12. A characteristic element of Roman houses is the *lararium*, which, in the *domus* of Torreparedones, was documented at the southwestern corner of the *atrium*. In our research, a rectangular structure that may correspond to the basing that held the niche where domestic worship figurines were kept was supposed to be the lalarium. Another typical element of Roman houses is the *triclinium* E-4, E-5, located south of the *atrium*. Around it, the rest of the rooms are distributed, which are related to domestic service and the residential zone.

The western area has a wide-open space that could have been a *hortus* E-9, E-27, E-29. Similarly, a series of rooms

were also documented, which could be identified as a production zone related to the *pristinum* E-22, E-23, E-24, E-25, E26, E-28, E-31, E-37, E-38. Figure 1 shows the numbered spaces of the *domus*, whereas Table 1 shows the interpretation of the rooms and their surface area.

Figure 1: Identification of the rooms of the *domus*.

Table 1: Identification, interpretation and surface area of the rooms shown in Figure 1.

Number	*Nomenclature*	*Interpretation*	*Area (m²)*
1	E-36	Redistributing zone	35.21
2	E-13	Latrine	18.75
3	E-16	Tavern	14.25
4	E-15	*Pristinum*	19.94
5	E-10	*Atrium*	96.35
6	E-1	*Cubiculum*	12.32
7	E-2	*Culina*	4.52
8	E-3	*Cella penuaria*	12.12
9	E-7	Redistributing zone	15.81
10	E-8a/E-8b	*Cubiculum*	21.33
11	E-8c	*Cubiculum*	15.24
12	E-4/E-5	*Triclinium*	31.55
13	E-38	Storage room	16.58
14	E-37	Milling and sieving zone	27.64
15	E-8/E-27/E-29	*Hortus*	58.13
16	E-25	Service and storage zone	30.30
17	E-23	Service and storage zone	14.65
18	E-24/E-46	Service and storage zone	12.70
19	E-22/E-26/E-28/E-31	*Cubiculum*	39.43
20	E-32	Woodshed	1.71
21	E-35	North corridor	18.80
22	E-11	*Tablinum*	11.18
23	E-12	*Cubiculum*	8.79

2.1.2. Equipment and software

The software used to obtain the planar sections extracted from photogrammetry was 3DReshaper, which allowed initiating the first task of the modelling of the *domus*.

The modelling of the building was carried out using SketchUp 2019. Moreover, the SketchUp 2019 gallery was used to add furniture and objects that could have been present in the *domus*. Lastly, the total texturing of the building and its elements was performed with the Bentley LumenRT software. This process is essential for the correct generation of the final images in the creation of virtual reconstructions.

2.2. Methods

The process of virtual reconstruction of the Roman *domus* of Torreparedones began with the documentary research, bibliographic search, visits to the site and interviews conducted in January 2020 with technicians of the site and archaeology experts. Subsequently, the field work, i.e., data collection and photo shooting, was performed.

In the documentation phase, a thorough bibliographic search was performed about other contemporary *domus*, which provided data for the interpretation of spaces and the reconstruction of non-preserved elements in the Roman *domus* of Torreparedones.

The in situ visit to the *domus* helped to understand the current conditions, as it was in totally different conditions with respect to the final moment of the excavation, due to the clogging of some sectors and to the action of the meteorological elements, which have favoured the destruction of the archaeological heritage (DeSilvey & Rodney Harrison, 2020).

Once the field work was finished, the desk work was carried out, obtaining the 3D virtual reconstruction. Table 2 shows the phases of the study.

Table 2: Phases of the study.

Phases	*Work tasks*	*Description*
1	Documentary research	Bibliographic search, visits to the archaeological site and personal interviews.
2	Field work	Visualisation of the heritage asset to reconstruct, collection of data and photo shooting.
3	Desk work	1. Modelling. Once the general characteristics of the *domus* were defined and the planar sections were obtained from the photogrammetry (Figure 2), the virtual reconstruction was initiated from the consensus hypotheses, using 3DReshaper and SketchUp 2019 software.
		2.Texturing.

		Application of textures to the virtual model with SketchUp 2019 and LumenRT.
4	Restoration of the heritage	Explanation and dissemination of the archaeological heritage. Visualisation of the virtual 3D reconstruction through QR codes.

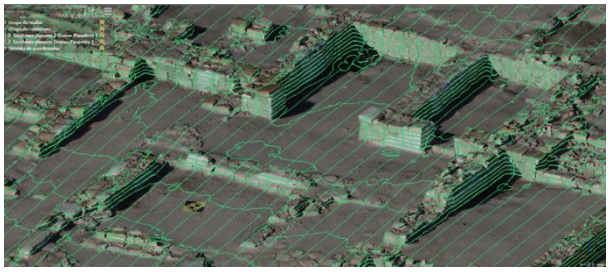


Figure 2: Planar sections obtained from the photogrammetry using 3DReshaper (developed by author).

The methodology used for the reconstruction of "The Baker's Roman House" of Torreparedones meets the quality criteria requested in the field of Virtual Archaeology, based on the principles of the Seville Charter (López-Menchero & Grande, 2011): interdisciplinarity, purpose, complementarity, authenticity, historical rigour, efficiency, economic and technological sustainability, scientific transparency, education and evolution.

3. Results and discussion

One of the main results of the documentary research is related to the information provided by the report of the excavation (Morena et al., 2019). Similarly, the personal interviews conducted with the expert technicians of the archaeological excavation contributed to the interpretation of spaces. The documentary information used was materialised in the planimetry, specifically: general situation plane, the plane of the sectors excavated in the campaign of 2015-2016, the plane of the final floor of the southern sector, and two aerial pictures of the excavated *domus*.

Photogrammetry is an essential method for documenting the cultural heritage (Yastikli, 2007; Guidi et al., 2014; Balsa-Barreiro & Fritsch, 2018; Alshawabkeh et al., 2020). Thus, another result of the documentary research was the photogrammetry of the building performed after the excavation.

All the documentary material backed the decisions made for the realisation of the 3D model. The accurate 3D reconstruction of the *domus* contemplates the identification of all its spaces and their purpose, differentiating them by zones. Three zones can be distinguished in the *domus*: the commercial zone, the residential zone and the industrial zone (Figure 3).

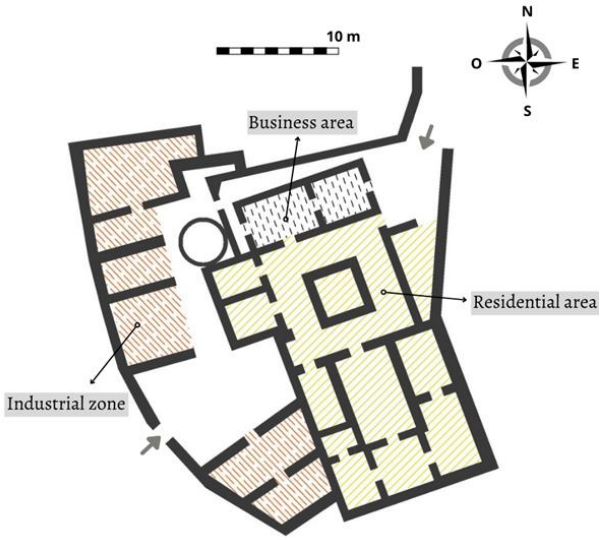
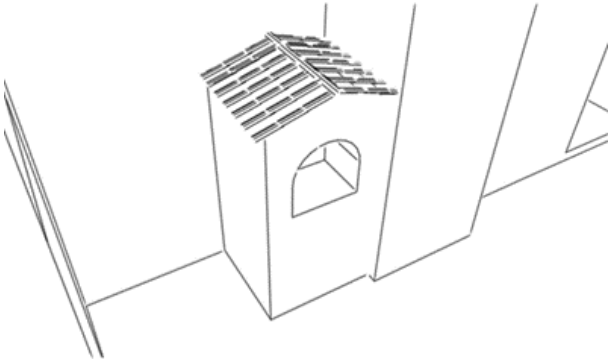


Figure 3: Ground plan of the *domus*. Zoning by purpose.

The residential is accessed through a door in the redistributing zone E-36, which is connected to the *atrium* E-10. The *tablinum* E-11 and the *cubiculum* E-12 are two accesses from the *atrium*. The *tablinum* corresponds to a reception hall of the pater familiae, and the *cubiculum* corresponds to a possible bedroom. South of the *atrium*, two doors were documented: one of the leads to a room E-1 that, based on the preserved pavement, could be a cubicle or the bedroom of the pater familiae (Morena et al., 2016), and the other door leads to the *triclinium* E-4 and E-5, which is the distributor to the rest of accesses of the residential zone of the *domus*. The access to the latrines E-13 is assumed to be south of the redistributing zone E-36 for two reasons. Firstly, it is presumed to be located in a marginal zone of the *domus*. Secondly, there is a channeling system that comes from the *atrium* E-10 and continues to the outside of the *domus* through the redistributing zone E-36. The presence of a limestone tile, which stands out in size from the rest of the pavement, could indicate the location of the latrine hole (Morena et al., 2019).

There is a wide typological variety of Roman lararia: pictorial, niches, pictorial with niches, *aediculae*, *sacraria*, altars and *sacella* (Pérez, 2007-2008). In this study, the basing of the *lararium* documented in the southwestern corner of the *atrium* preserves 30 cm of elevation and a size of around 80x90 cm. The base of the *atrium*, according to its chronology and location, seems to correspond to an aediculae type, pseudoedicle variant (Figure 4). These are characterised by solid walls or blocks, with a niche-shaped inner cavity, where domestic worship figurines would be placed, crowned by a pediment (González, 2003). The virtual reconstruction of the *lararium* of Arucci's North House has helped to understand Roman lararia, specifically the one in Torreparedones (Corrales et al., 2016).

a



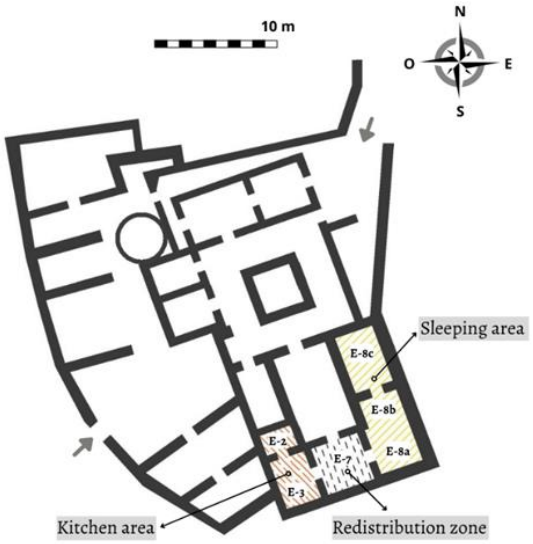
b

Figure 4: a) Recreation of the *lararium* of the Roman *domus* of Torreparedones; b) Detailed view of the *atrium* and the *lararium* in the virtual reconstruction.

There are four rooms around the *triclinium* that have not been identified due to the lack of archaeological vestiges. The first of these rooms is the E-3 space, south of the *cella penuaria* E-2. Based on its size (1.5 x 2.5 m), and its proximity to the *culina*, this room is presumed to be related to the *cella penuaria* and to the storage of food and cookware. A distributor space E-7 provides access to both rooms.

In the baker's *domus*, there were similarities with the works of authors like Corrales et al. (2018), in the North House of the archaeological site of Arucci (Aroche – Huelva). Different rooms were identified, such as the *cella penuaria* (pantry) and the *culina*, in which the latter was only accessed through the pantry, as in the case of the baker's *domus* (Figure 5). Likewise, Balanzá (2011) studied the *Domus* dels Peixos (Saguntum), where this closed distributing space is connected to the kitchen. The difficulty of the access could be aimed at isolating smells and noise, as well as hiding this service from guests (Peñalver, 2019). Therefore, the E-7 space could be a passing zone since it allows access to the pantry and to the E-8a and E-8b spaces. The lack of evidence of cubicles in a transit zone suggests that this could be a service zone of the residential part of the *domus*. These spaces E-8a, E-8b and E-8c could be resting zones, such as bedrooms. Although it is difficult to accurately identify these zones, the existing literature indicates that Roman *domus* had rooms for guests (Dukelsky, 1993).

a



b

Figure 5: a) Location of the kitchen: ground plan zoning of the *domus*; b) Detailed north view of the zone interpreted as pantry and *culina* at the back in the virtual reconstruction.

With respect to the architectural elements, the walls were built with rammed earth and *opus incertum* for the plinths, with irregular limestone rigs, which is the natural local rock, applying plaster as the final layer. As in the reconstruction works of the Roma Villa of El Saucedo (García et al., 2017), and since the total height of the walls of the *domus* is not preserved, we considered what was described by Vitrubio (Ortiz y Sanz, 1787): "The longitude of the *triclinium*s will be double their latitude. The general height of rooms and oblong rooms will be calculated by adding the longitude and the latitude, giving the height half of the sum; however, since they are square, the height will be 150% of the width". According to these formulas, the height of the *domus* was over 7 m and, considering the difference in level among the rooms, the heights of the covers were unified, except for the inner roofs. As was shown by Coarelli (1989) in an example about the proportion of the *atrium* of Scauro, the report provided by Vitrubio is slightly different in length, and the proportion is approximate, although it is enough to roughly reconstruct this space. Another important factor regarding the height of the walls is the possible open bays that communicated the *domus* with the outside, whose purpose was to illuminate and ventilate the house. It is impossible to know the location of these bays since the

total height of the walls of this building is not preserved. In this context, it is worth mentioning that the ancient construction criteria were related to those of natural lighting (Monteoliva et al., 2020), and that the ground floor of Roman houses was characterised for facing the inside of the building, presenting few and small windows in the upper areas (Dukelsky, 1993). In the Villa of Las Musas (Arellano - Navarra) a window grill was found (Mezquírriz, 2004). The preservation of this type of elements helps in their 3D reconstruction, as well as in the calculation of the size of the bays. The recovered grill of one of the windows facing west, which consisted of wrought iron plates, was 88 x 83 cm in size.

The outer parameters of the northern and western parts of the *domus* are dividing walls, since other attached *domus* would be located in both areas, which made it impossible to place windows. To solve the lack of natural light in the rooms attached to the dividing walls, and illuminate the largest possible number of rooms, we decided to recreate windows in three rooms E-1, E-11 and E-12. In the commercial zone, two windows were reconstructed: one in the north wall of the E-15 room, and another one in the E-16 room since the northern corridor was not covered. The outer south wall is presumed to have had three windows, corresponding to three spaces E-8a/b, E-7 and E-3. The rest of the rooms attached to the west wall also have open windows, corresponding to E-37, E-38 and E-22-26-28-31.

To reconstruct the covers, we distinguished between covered and uncovered spaces (Figure 6). All the spaces of the *domus* are covered, except the zone identified as a possible *hortus* E-9, E-27 and E-29, as well as the corridor that goes along the northwest zone and which connects the *hortus* with E-35. The ground plan of half of the entrance zone to the *domus* E-36 indicates that it would be opened as a porch. The recreated covers consist of a wooden and ceramic structure (tegulae and imbrex). The construction of the wooden bent begins with the assembling of the trusses, where the rafters would be held perpendicular to them. On the rafters, a plank would be placed, which would hold the strips for the ceramic elements (Ortiz y Sanz, 1787).

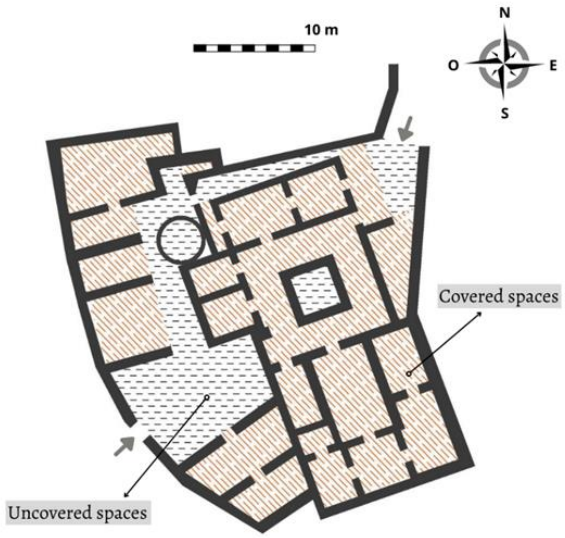
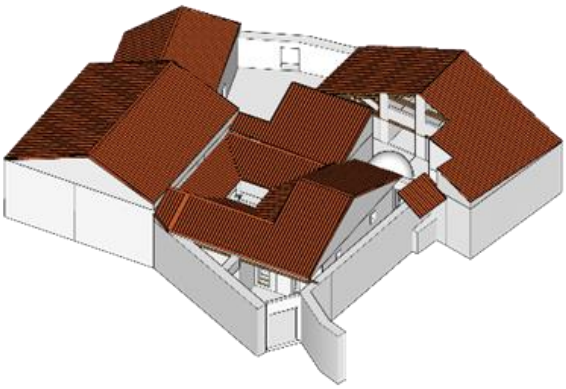


Figure 6: Ground plan of the *domus* with the identification of covered spaces and uncovered spaces.

Due to the uniqueness of the ground plan, the covers were laid considering the best effectiveness in the evacuation of rainwater, thus preventing its discharge inside the *domus*, where there is no possibility of gathering and channeling it. The *atrium* played a fundamental role, with the *compluvium*/*impluvium* system E-10a, which has been documented in other *domus* (Corrales et al., 2018; Bergamasco et al., 2018), as in the Pompey *Domus*, where the central pond (*impluvium*) has a channeling system that discharges the water in the street. Some of the covers around the *atrium* discharged in it, consisting of a hip roof. Spaces E-15 and E-16 had a double pitch roof, which discharged westward and eastward *domus*. The closing of spaces E-36 and E-13 consisted of a single pitch roof, which would be the continuation of the previous cover, discharging to the mentioned “porch”. The *tablinum* E-11 and the *cubiculum* located in the north E-12 were covered with a roof that also discharged to the *atrium*, since, otherwise, the waters would be discharged in the open corridor of the western zone of the *domus*, where there are no channels or storage structures. For the rest of the southern rooms, a large double pitch roof was created, discharging the waters in the *atrium* and in the street located south of the *domus*. In the western zone of the *domus* there are two roofs. A hip roof covers spaces E-37 and E-38, discharging the water in three zones: northward (*hortus*), to the southern street and to the western street. Another double pitch roof discharges both to the *hortus* and to the northern zone of the *domus*, covering spaces E-22, E-23, E-24, E-26, E- 28, E-31 and E-46. As is shown in Figure 7, in order to accurately place the roofs and their correct discharge of rainwater in the virtual reconstruction, we considered the differences in level among them, taking into account that the higher roofs discharge on the lower roofs.

a



b

Figure 7: a) Perspective of the recreated roofs of the *domus*: image taken from SketchUp; b) Image renderised with LumenRT.

All the doors of the *domus* are documented, except the bay, which opens the western zone (industrial zone) to the street (Morena et al., 2019). Despite the lack of archaeological evidence, an open door to the *hortus* was created, since there had to be an access to introduce the goods required for production, such as the rotary mill, the grain to produce flour, timber for the oven, etc. Uribe (2004) states that the spaces remained open or closed depending on their purpose. The main door of the house, which opens to the redistributing space, has two preserved column bases, each doorframe with iron hinges and collapsed plasters, which reflects the monumentality of the access in the baker's *domus* (Morena et al., 2016). The ianuae (gateways) used to be displaced to the inside to the house. They were tall wooden doors, with locking systems such as keys and bolts. However, the service doors did not use to have any hint of monumentality, being bays of different sizes with alternative purposes (Fernández, 2003).

Regarding decoration, only parietal plasters are preserved in the *tablinum* and the adjacent *cubiculum* (Morena et al., 2016), which are mould decorated, forming geometric motifs. This ornamental technique consists in a mortar coating, to which a mould is repeatedly applied with the relief decoration, and it is finished by covering it with pure lime or mortar. This type of decoration has been documented in other Roman sites, such as the one excavated in Beatas Street (Cartagena, Spain) (Fernández et al., 2005), where panels decorated with relief motifs were recovered. Two of these ornamental motifs are geometrical, with interesting bands forming diamonds with oblong contours and linked together by their tips. These are similar to those recovered in the *domus* of Torreparedones, which also form diamonds, although their size is unknown, due to their deficient state of preservation.

During the excavation, no ornamental data were found in the rest of the rooms of the *domus*, thus adding such details to the reconstruction would lead to inaccuracies. Therefore, we decided to create neutral textures, with the aim of avoiding the reconstruction of elements that have not been archaeologically documented (Jones et al., 2018). This method has been used in other reconstructions, such as in the case of the North House of the archaeological site of Arucci (Aroche - Huelva) (Corrales et al., 2018), and the convivial space of the Roman Villa of 'El Saucedo' (Talavera la Nueva - Toledo).

Concerning the pavements, the same is observed in the wall decoration, as pavements of large stone slabs in the lobby (fauces) and in the *atrium* were documented in the archaeological excavation. This building technique consisted in laying a bed of *opus incertum* and an irregular paving, with the latter being the one used in the paving of the streets of the city of Torreparedones (Moreno, 2015). The room identified as *cubiculum*, possible room of the pater familiae (E-1), has a pavement of *opus signinum*, and no pavement was found in the rest the *domus*' rooms (Figure 8). Therefore, the paving of the *domus* was reconstructed based on the preserved elements. With the aim of avoiding historical error, stone slabs were used for all the spaces of the *domus*, except room E-1, where the pavement preserved in this space was reconstructed.

Figure 8: View of the pavement of the *cubiculum* or possible room of the pater familiae in the virtual reconstruction.

Another relevant element in the *domus* is the water tank, which is located in the residential zone of the *domus* (Figure 9). It is situated transversal to the wall that separates the *atrium* from the *triclinium*, which suggests that it was built in an early phase (Late Roman Republic), as other walls found in the house. Authors such as Madrid et al. (2005) have found storage and water supply systems in other Roman *domus* such as the one of Salvius, and they are similar to the ones documented in Torreparedones. In the present study, we found vestiges of a bagnarola water tank in one of the corners of the *atrium*, supplied with rainwater gathered by the roof system (Morena et al., 2019).

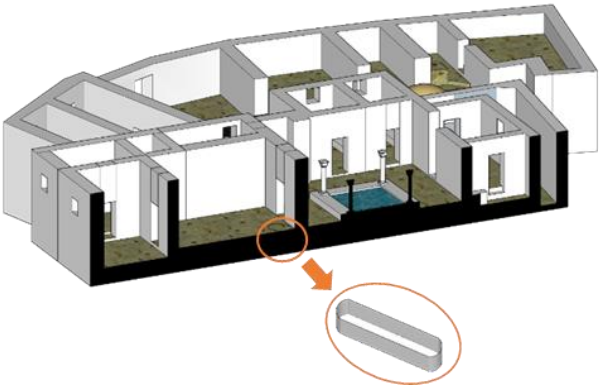


Figure 9: Horizontal and vertical section of the 3D model with the location of the water tank.

The western zone of the *domus* has been interpreted as a production zone dedicated to the manufacture of bakery products. Its rooms would be used for the purpose of this type of service (Figure 10):

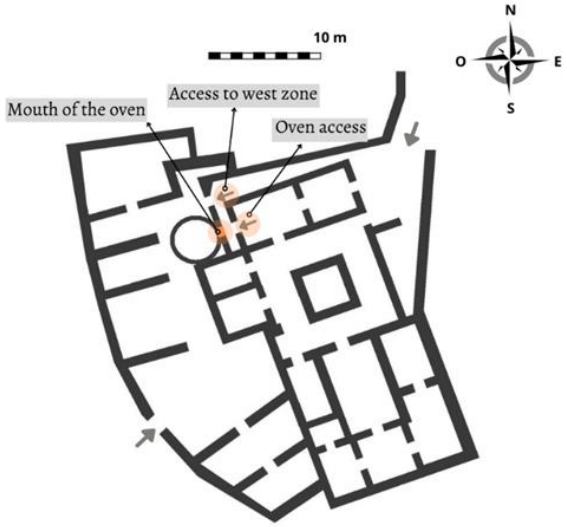
- 1st room for the storage of grain, possibly located in the southwest E-38. It is unknown how grain was stored (sacks, ceramic vessels, wooden archons, etc.), but there had to be a method. In this room, apart from storage, the first task would take place, i.e., preparing the grain for milling and sieving.
- 2nd room for milling. The room adjacent to the previous one E-37 has a circular basing, slightly over 1 m in diameter, which seems to correspond to the base of a rotary mill. This type of mills, existing in pre-Roman times, have been documented in Italy and North Africa in zones dedicated to milling or baking (Flores, 1993). On the other hand, the ones found in Pompey consist of two inverted shallow cones placed one on top of the other, where the grain is milled by friction between the two pieces (Morales, 2008).

- The sieving process is identified in reliefs like the one found in the “Baker’s Tomb” (M. Vergilius Eurysaces, 1st century B.C.), as well as the tools used for such purpose, present in reliefs like that of P. Nonius Zethus. The sieve would be held on a wooden table and, once the task was done, the product would be classified in trays (Bustamante et al., 2014).
- 3rd room for kneading. According to M. Bustamante et al. (2014), there would be a first kneading process carried out in large stone troughs, probably moved by animals. Due to the lack of evidence indicating the existence of horses in the *domus*, it has been interpreted that space E-25 would be a working space for the first kneading, that is, the mixing of ingredients to obtain a uniform and flexible dough. After this first kneading, the next task would be manual kneading on working tables, providing the final shape of the product, which could have been carried out in the *pristinum*.
- 4th room for baking. This is the last process of a bakery. The oven that grants the name to the *domus* plays an important role within this process. It is embedded in a wall at the front, with holes through which the bakery products and timber would be introduced. It is about 4 m in diameter and is covered with a dome.

Figure 10: Phases for the production and sale of bakery products in the *domus* of Torreparedones: a) Grain storage; b) Milling; c) Kneading; d) Baking.

From the *pristinum*, there was direct access to the mouth of the oven and, in the northern zone, there would be a corridor in which a door would connect to the western zone of the *domus*, with the woodshed being located to the right (Figure 11).

a



b

Figure 11: a) Detailed views of the oven mouth; b) Perspective of the virtual reconstruction of the oven mouth from the northern corridor of the *domus*.

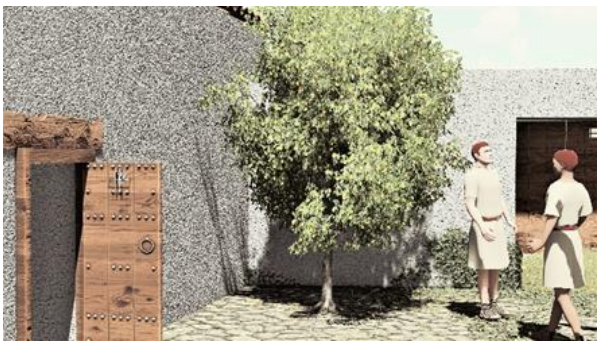
The previously mentioned study about planning in Roman Hispania shows similarities with architectural distribution (Bustamante et al., 2014). An oven was excavated in Augusta Emerita, whose access is identical to that of the oven of the *domus* of Torreparedones, i.e., a small accessible entrance to the mouth of the oven and embedded in a quadrangular structure (Bustamante et al., 2014). Likewise, the ground plan of the oven preserved in Torreparedones is typologically identical to that of the bread ovens of the "Bird House" and the Planetary *Domus* (Italica - Seville) (Luzón, 1975). The oven is associated with the room that precedes it, i.e., the *pristinum*, which is accessed from the *atrium* and communicated with the tavern E-16, where the bakery products would be sold in the commercial zone.

Due the lack of more archaeological vestiges that could correspond to or help to interpret other rooms of the *domus*, it is difficult to identify their purpose in the reconstruction. However, based on logistic criteria, it was deduced that, since the western zone was dedicated to production, spaces E-23 and E-24 could have been used as rooms to store tools, whereas spaces E-22, E-26, E-28 and E-31 are identified as a single resting room for the service and production staff of the house.

In Rome, the traditional garden and orchard was called *hortus*, which was exclusively limited to the family home before the 5th century B.C. (Fariello, 2018). From the Republic age (509 B.C.-44 A.D.) and due to Hellenistic influence, the meaning, properties and uses of the *hortus* expand. Thus, it could be large or small in urban, suburban, military, funerary, commercial and self-consumption areas. Roman houses had a small space for growing vegetables and holding different animal species, in addition to other purposes, such as leisure and fun (Muñoz-Delgado de Mata, 2016).

The ceramic and numismatic materials recovered from the Baker's *domus* indicate that this building was active during the 1st century A.D (High Roman Empire) (Morena et al., 2016). In this sense, there is a production zone in the western zone of this *domus* related to the *pristinum*, and an open room next to the latter, which, based on its characteristics and the archaeological intervention of 2015- 2016 (Morena et al., 2016) could be a primitive garden or possible *hortus* (E-9, E-27 and E-29). Moreover, the lack of evidence of Hellenistic elements suggests that this space could have been merely dedicated to self-consumption. To justify such hypothesis, and after a thorough study of Roman self-consumption (Villegas, 2007), it has been documented that their diet included a wide variety of products, such as vegetables, which could have been grown in the *hortus* of the house. This space could have also been used to grow fruit trees, such as fig trees, vines, pomegranates, apricot trees, plum trees, etc. (Villegas, 2007) (Figure 12).

a



b

c

Figure 12: a) Perspective of the *hortus*: view of the southwestern zone of the *hortus*; b) View of the *hortus* from the northwestern corner; c) Corridor of access to the rooms.

Once the virtual reconstruction of the *domus* was finished, the terrain around it was created, i.e., the archaeological site of Torreparedones.

To attain one of the objectives of this study (i.e., the dissemination of the historical heritage), a QR code was created, which allows visualising the virtual 3D reconstruction of the *domus*.

Placing the QR code in explanatory panels would facilitate the interpretation of the site, through a decoding process in a mobile device, which would play a video of the 3D reconstruction of the *domus*. This new digital resource could be used in a pedagogical manner by the visitors of the site, thus favouring the understanding of the *domus* beyond the preserved remains (Kempiak et al., 2017).

4. Conclusions

3D reconstructions of archaeological assets are important for their preservation. The virtual reconstruction created in this study shows very valuable digital information for the future and for the guarantee of having a graphical record of the historical heritage.

Firstly, regarding the study and documentation of the *domus*, the archaeological remains found in "The Baker's House" of Torreparedones were crucial for the understanding of the spaces. The finding of the circular ground plan of the bread oven, as well as the circular basing associated with the Roman rotary mill, were essential for the identification of the purpose of this *domus*.

Despite the difficulty of the interpretation and the few archaeological vestiges found, the rigorous study and documentation of other contemporary Roman *domus* have played a fundamental role in the identification of spaces, their purpose and, of course, their virtual representation.

The creation of the 3D model of the archaeological remains found in the excavation, the non-preserved architectural elements, the associated Roman furniture and the terrain corresponding to the archaeological site, along with the creation of the QR code for visualisation, guarantee the preservation of this archaeological asset, as well as its dissemination, which is one of the most important objectives. Moreover, the virtual model meets the pedagogical goal, as it helps the viewers to understand the *domus*.

The virtual reconstruction of "The Baker's Roman House" of Torreparedones was successful, as rigorous principles and criteria were followed, meeting the quality levels required in the field of Virtual Archaeology.

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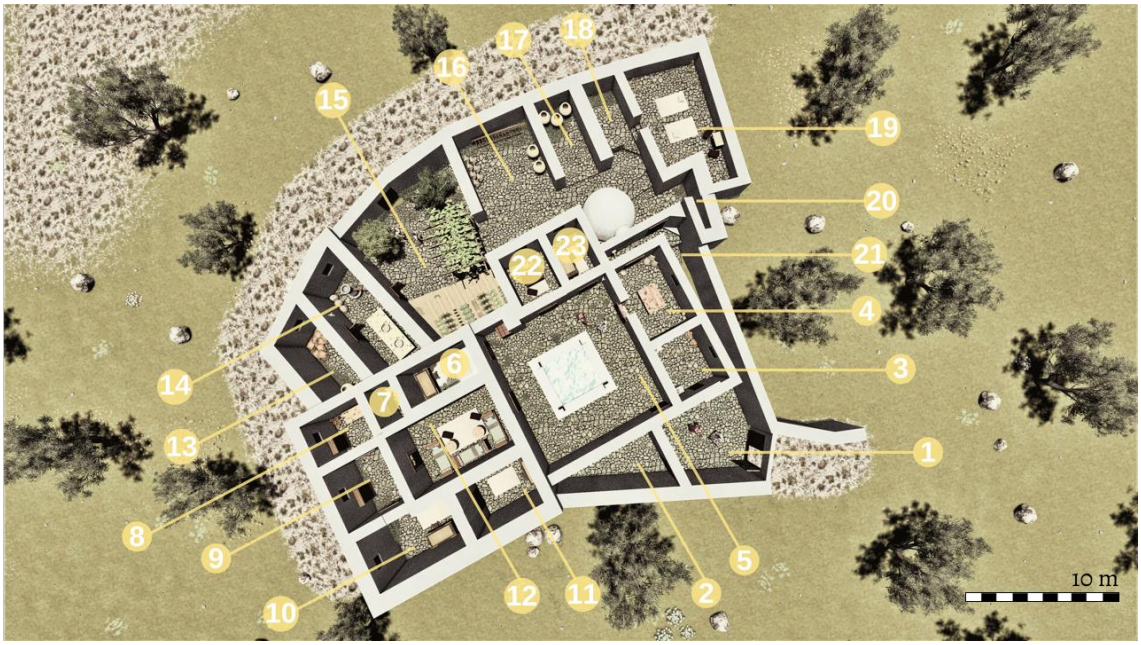

Figure 1. Identification of the rooms of the *domus*.

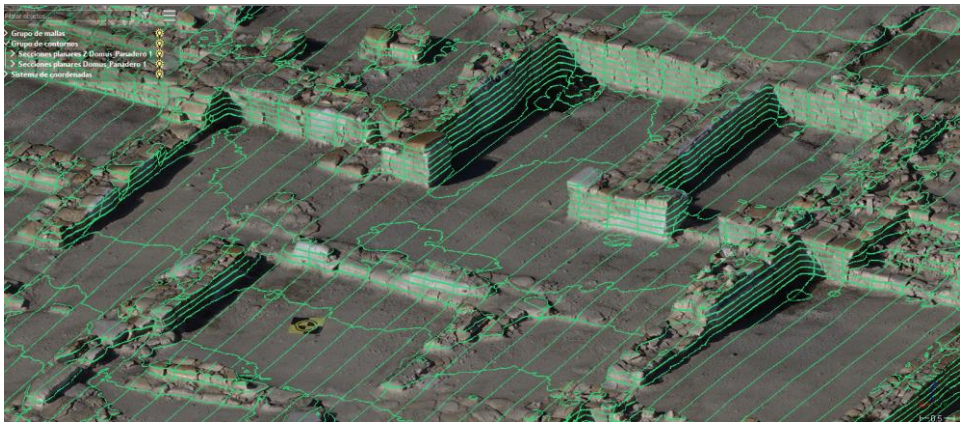

Figure 2. Planar sections obtained from the photogrammetry using 3DReshaper (developed by author).

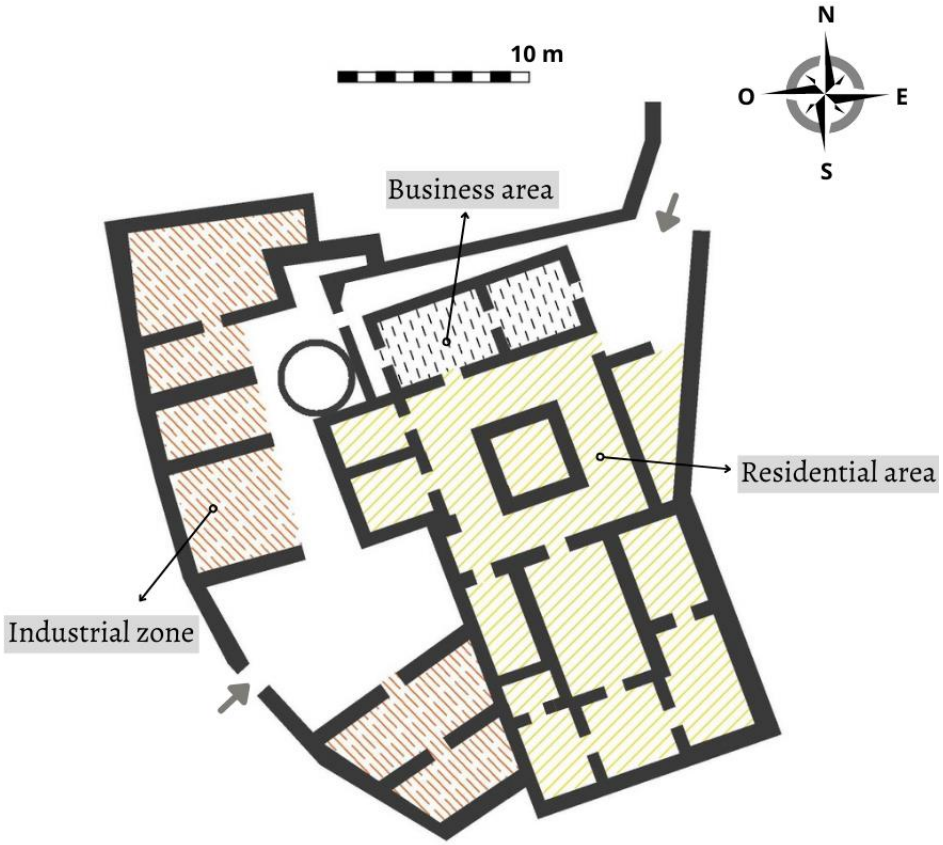

Figure 3. Ground plan of the domus. Zoning by purpose.

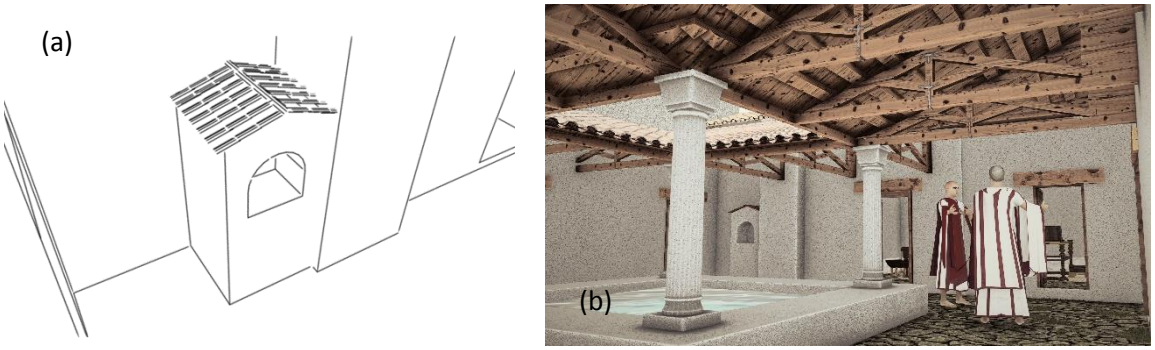

Figure 4. Recreation of the *lararium* of the Roman *domus* of Torreparedones (a) and detailed view of the *atrium* and the lararium in the virtual reconstruction (b).

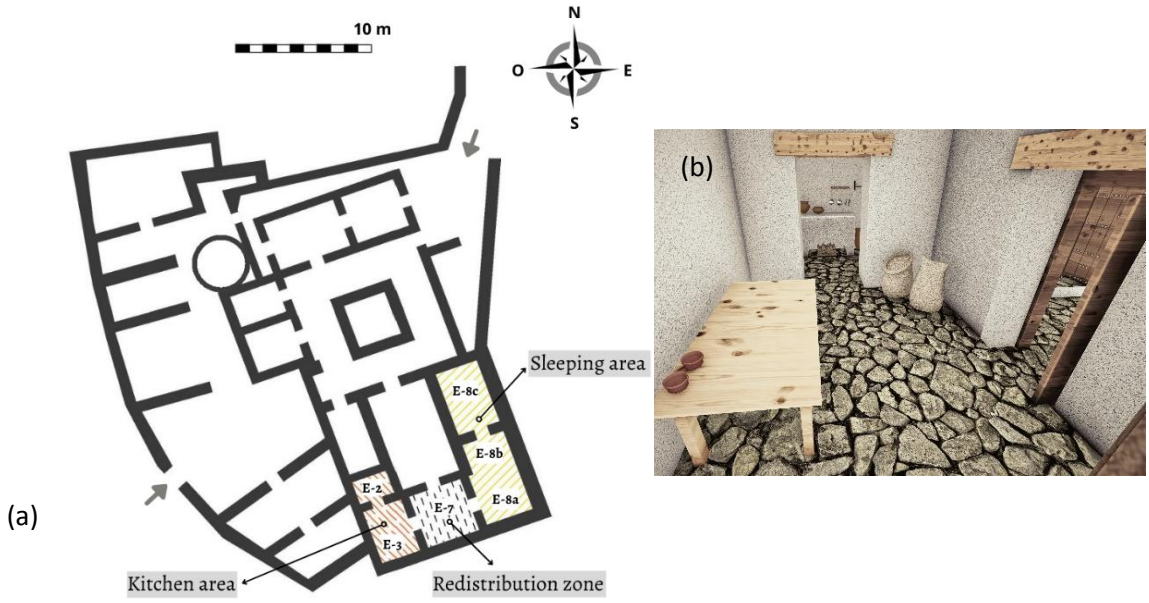

Figure 5. Location of the kitchen: ground plan zoning of the *domus* (a); detailed north view of the zone interpreted as pantry and *culina* at the back in the virtual reconstruction (b).

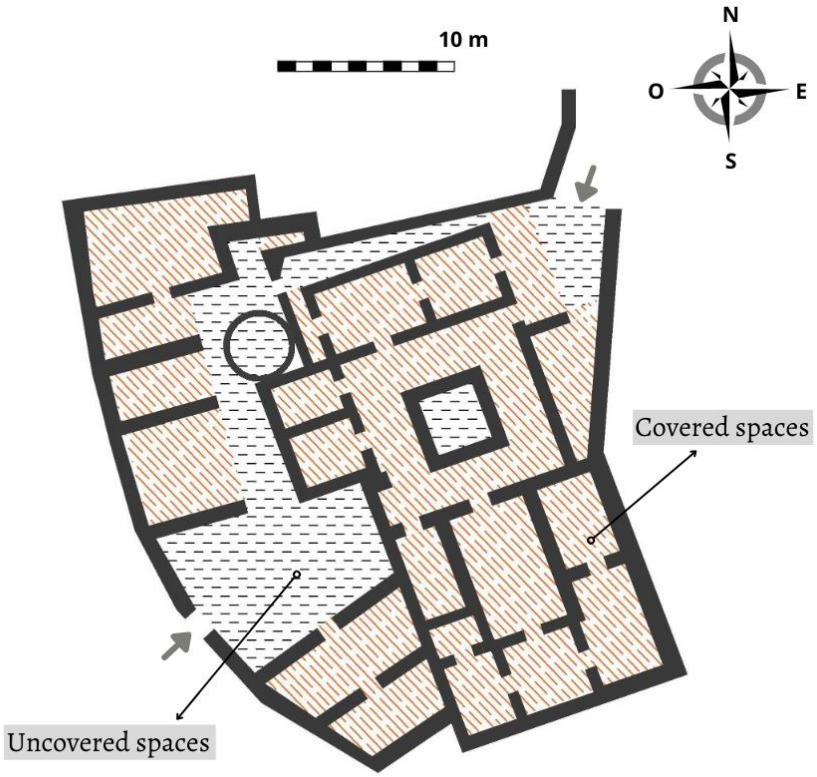

Figure 6. Ground plan of the *domus* with the identification of covered spaces and uncovered spaces.

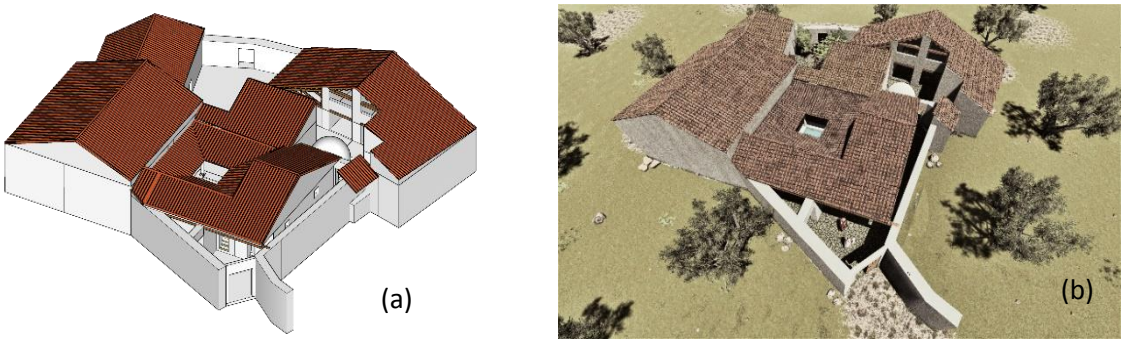

Figure 7. Perspective of the recreated roofs of the *domus*: image taken from SketchUp (a); image renderised with LumenRT (b).

Figure 8. View of the pavement of the *cubiculum* or possible room of the *pater familiae* in the virtual reconstruction.

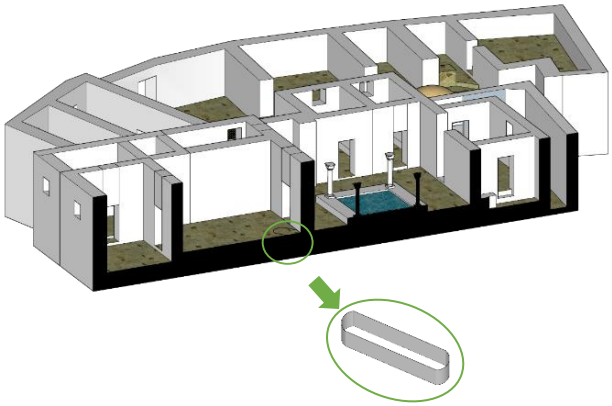

Figure 9. Horizontal and vertical section of the 3D model with the location of the water tank.

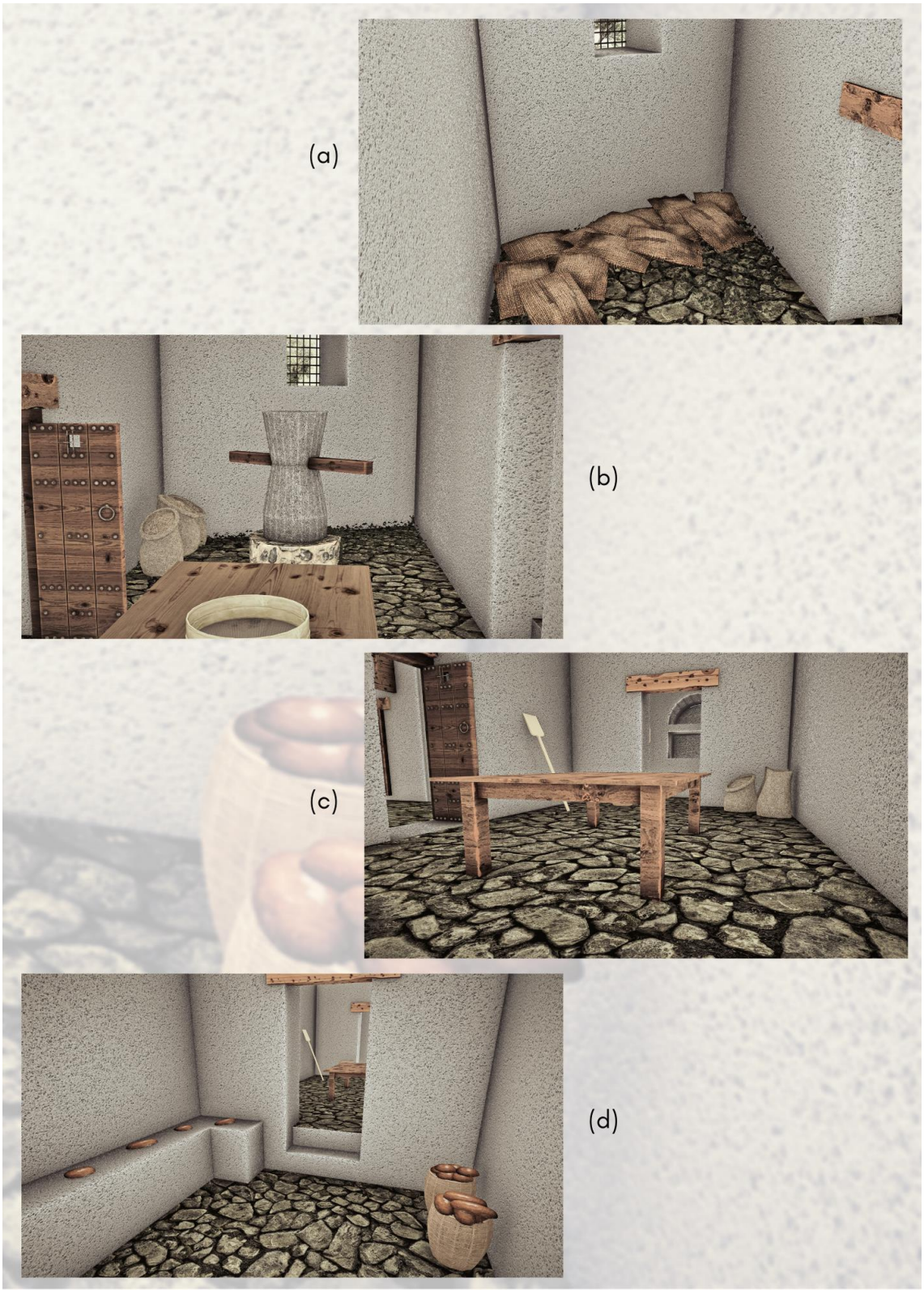

Figure 10. Phases for the production and sale of bakery products in the *domus* of Torreparedones: grain storage (a); milling (b); kneading (c) and baking (d).

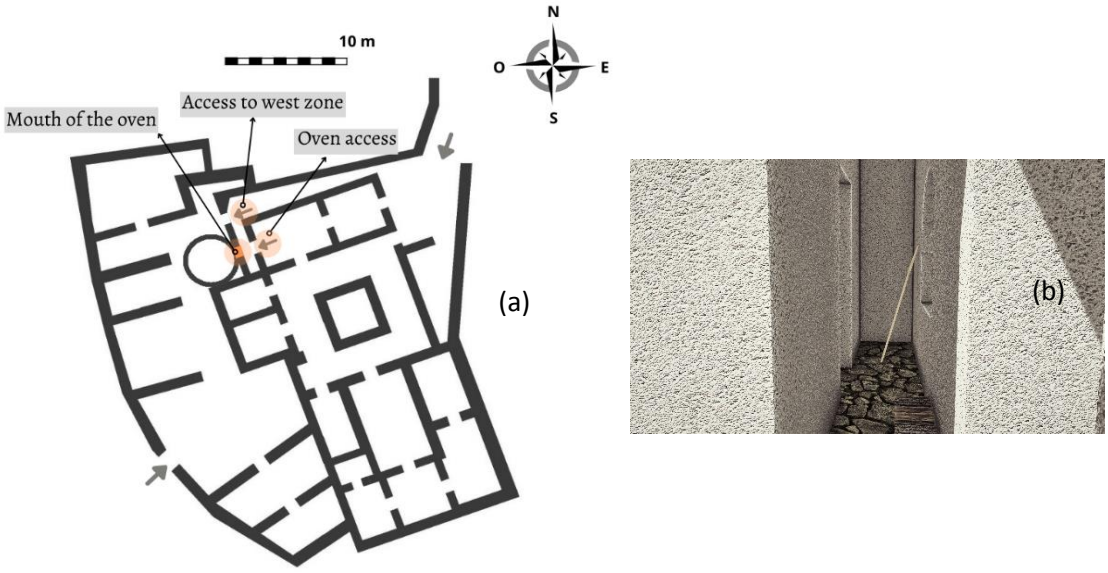

Figure 11. Detailed views of the oven mouth (a), perspective of the virtual reconstruction of the oven mouth from the northern corridor of the *domus* (b).

Figure 12. Perspective of the *hortus*: view of the southwestern zone of the *hortus* (a), view of the *hortus* from the northwestern corner (b), and corridor of access to the rooms (c).

Table 1. Identification, interpretation and surface area of the rooms shown in Figure 1.

Number	*Nomenclature*	*Interpretation*	*Area (m²)*
1	E-36	Redistributing zone	35.21
2	E-13	Latrine	18.75
3	E-16	Tavern	14.25
4	E-15	*Pristinum*	19.94
5	E-10	*Atrium*	96.35
6	E-1	*Cubiculum*	12.32
7	E-2	*Culina*	4.52
8	E-3	*Cella penuaria*	12.12
9	E-7	Redistributing zone	15.81
10	E-8a/E-8b	*Cubiculum*	21.33
11	E-8c	*Cubiculum*	15.24
12	E-4/E-5	*Triclinium*	31.55
13	E-38	Storage room	16.58
14	E-37	Milling and sieving zone	27.64
15	E-8/E-27/E-29	*Hortus*	58.13
16	E-25	Service and storage zone	30.30
17	E-23	Service and storage zone	14.65
18	E-24/E-46	Service and storage zone	12.70
19	E-22/E-26/E-28/E-31	*Cubiculum*	39.43
20	E-32	Woodshed	1.71
21	E-35	North corridor	18.80
22	E-11	*Tablinum*	11.18
23	E-12	*Cubiculum*	8.79

Table 2. Phases of the study.

Phase	*Work tasks*	*Description*
1	Documentary research	Bibliographic search, visits to the archaeological site and personal interviews.
2	Field work	Visualisation of the heritage asset to reconstruct, collection of data and photo shooting.
3	Desk work	1. Modelling. Once the general characteristics of the *domus* were defined and the planar sections were obtained from the photogrammetry (Figure 2), the virtual reconstruction was initiated from the consensus hypotheses, using 3DReshaper and SketchUp 2019 software. 2.Texturing. Application of textures to the virtual model with SketchUp 2019 and LumenRT.
4	Restoration of the heritage	Explanation and dissemination of the archaeological heritage. Visualisation of the virtual 3D reconstruction through QR codes.

Declarations of interest: none

Certificate of accuracy (EN)

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