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Graphic representation of the degree of historical-archaeological evidence: the 3D reconstruction of the "Baker's House"

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Abstract

Over the years, the methodologies used for graphic representation in archaeology have evolved. The substantial change in representation was achieved with the use of computer software. Currently, 3D sketch scanning and photogrammetry are predominating tools used in this field. A new methodology, i.e., the use of the historical-archaeological evidence level scale, has entered this discipline to show the veracity of archaeological studies, as well as that of the vestiges found. The present study is focused on the virtual reconstruction of the 'Baker's House' in the archaeological site of Torreparedones (Córdoba, Spain). The main aim of this study was to show and identify the veracity of the obtained reconstruction, through the use of the historical-archaeological evidence scale and the elaboration of a typological rank. The methodology used shows the evidence level employed by experts in the creation of virtual representations. The dissemination of the proposed historical-archaeological evidence scale entails the graphical identification of the veracity of reconstructions in this type of representations, always complying with the scientific quality criteria established by the Seville Letter.

Keywords: Historical–archaeological evidence scale, Digital 3D reconstruction, Reconstructive units, Baker's House

Introduction

Representation in archaeology began with archaeological drawing, i.e., the graphical recording of heritage [1]. One of the first rules of what would be scientific excavation, proposed by Wheeler [2], includes the analysis of the drawing of stratigraphy as a key element. Authors such as Harris [3] and Carandini [4] expanded the use of plan drawings of excavations (strata mapping), although they only drew the most expressive levels of the sites. Another important milestone in the evolution of archaeology and archaeological drawing was the birth of architectural archaeology. Currently, bi-dimensional (2D) and three-dimensional (3D) drawing allow reconstructing archaeological assets through three-dimensional models using photographs [5].

The representation of archaeological remains is an intrinsic part of the technical process of the discipline [1]. In the 90 s, the representation of three-dimensional models began to be used for the interpretation of archaeological remains, thus giving rise to the term "Virtual Archaeology" [6].

In this context, the representation of heritage in the field of Virtual Archaeology is a cutting-edge trend. There are different forms of representation with a multitude of tools and software available [7, 8]. However, all existing forms of archaeological representation have in common the use as a means for solving problems in the heritage field, and among its applications stand out [9]: graphic document; diffusion; layout; analysis; restoration; documentation.

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The draft published by the Spanish Society of Virtual Archaeology (SEAV) gathers definitions that include four types of representations in archaeological praxes [10]: virtual restoration; virtual anastylosis; virtual reconstructions; and virtual recreation.

Of all the types of representations that have evolved throughout the history of archaeology, this project is focused on a new trend: the representation of the degree of historical-archaeological evidence at the scientific level [11]. While reconstructions bring archaeological remains closer to the public [12], this approach on the scale of evidence would bridge the gap between archaeological research and society, thus helping in the interpretation of virtual reconstructions and increasing their veracity.

Lastly, it is worth highlighting the need for the SEAV to set a series of objectives in the projects carried out in the field of virtual archaeology. Thus, the Seville Letter [13], inspired in the London Letter [14], establishes the principles and criteria to measure the quality levels of projects in this scope [10, 15, 16]. The studies conducted in the field of virtual archaeology must include the scientific approach, choose suitable technology, document the process and obtain an adequate visualisation [14, 17–20].

State of the question: the historical-archaeological evidence scale

The use of colour scale codes in the scope of archaeology began in the 1990s, when these techniques were employed to show the deterioration of monuments [21]. This pioneering scale used gray hues to compare images of different time points through the application of an OR Boolean operator, thereby deducing the differences in the deteriorations of the monuments. However, the idea of using a colour graduation has its origin in the project of virtual reconstruction of the city of Byzantium in the year 1200 [11], where Patrick Clifford, Jan Kostenec and Albercht Berger aimed to support the virtual reconstructions by representing the degree of historical-archaeological evidence.

This scale has ten levels of evidence: (1) the building/object exists in its original form; (2) partially or with modifications; (3) available photographs or plans; (4) archaeological information; (5) detailed graphical evidence; (6) simple graphical evidence; (7) textual and comparative evidence; (8) textual evidence; (9) speculation based on similar structures; and (10) imagination. Each level is associated with a colour, with warmer and cooler hues corresponding to greater and lesser evidence, respectively.

From that point, some authors have used this representation scale to support their reconstructions. Pablo Aparicio and César Figueiredo applied, for the first time, the scale of the Byzantium 1200 project in their studies to verify its effectiveness [22]. The result was the establishment of a fixed colour code (RGB, CMYK and hexadecimal). Each colour of the scale is related to a level of historical-archaeological veracity or evidence: (1) imagination; (2) speculation based on similar structures; (3) basic textual reference; (4) descriptive textual reference; (5) simple basic reference; (6) detailed basic reference; (7) basic archaeological information or simple planimetries; (8) strong archaeological or documentary source; photographs and detailed ground plans; (9) existing (or partially existing) with modifications; and (10) existing according to the original. Moreover, each colour is associated with a number between 1 and 10, from lower to higher level of evidence, with the possibility of including an explanatory infogram, or simply a colour graduation along with the image. This proposition of evidence scale has been used by its authors in heritage buildings [22–26], although it has also been employed by other authors to support their reconstructions [22, 27, 28].

The two mentioned evidence scales differ in the reversal of the evidence levels. For the one that was developed in the Byzantium project, the evidence levels are correlated from the highest evidence level to the lowest. The scale proposed by Aparicio and Figueiredo does not modify the colours; it merely reverses the colours, beginning with the lower levels of historical-archaeological evidence and finishing with the levels of greater evidence.

A new modification of historical-archaeological evidence scale was proposed by other authors [29], who reduced the number of levels to eight. They also modified the spectrum and colour gradation of the evidence levels. The result was a scale with a colour spectrum of dark greens to brown, with eight levels of historical-archaeological evidence: (1) speculation based on the historical, natural and cultural context; (2) speculation based on similar structures in contemporary or recent times; (3) information based on text; (4) information based on archaeological excavations; (5) simple basic representation; (6) detailed basic representation; (7) existing with modifications; (8) existing in its original format.

After the search for heritage assets to which the historical-archaeological evidence scale was applied, the colour scale of the reconstruction of the peristyle of Phase I of the Santiago *Domus* was found (Bracara Augusta, Braga, Portugal) [18]. The application of this scale to a full roman *domus* was not found. Therefore, the reconstruction of the peristyle of the Santiago *Domus* served as the basis for the application of the colour scale of the Baker's House in its entirety.

Research aim

The aim of this study was to integrate the degree of historical-archaeological evidence of an artefact/

architecture/ruin into a computer-based graphic representation (3D virtual model), complying with the scientific quality levels established for this type of research. In addition to the application of the historical-archaeological evidence scale, the percentage value of veracity of the elaborated virtual reconstruction was estimated.

Materials and methods

Implementation of the historical-archaeological evidence scale of Aparicio and Figueiredo, (2017)

Having reviewed the existing propositions of historical-archaeological evidence scales, the one proposed by Aparicio and Figueiredo was selected to be implemented for this research work [22]. The reasons for this selection were: First, and although it is well-known that the scale proposed in the Byzantium project was the pioneer and, therefore, the most antiquated, we consider that the proposal by Aparicio and Figueiredo is its recent version. And secondly, because the scale proposed by Ortiz et al. [29], was not the most suited for such a detailed reconstruction, since colours of each reconstructive unit were not enough appreciated due to its similarity even being the scale of Ortiz et al. [29], the most recent one out of the three. These reasons led us to select the implementation of the historical-archaeological evidence scale proposed by Aparicio and Figueiredo [22] because of its novelty versus Byzantium and because of the colourfulness versus Ortiz et al. [29].

The graphic representation scale of Pablo Aparicio and Cesar Figueiredo [22], is based on a historical-archaeological evidence scale of ten colours, coded with numbers (Table 1). Each colour corresponds to a degree of veracity. The warmer colours show higher degrees of historical-archaeological evidence, whereas the cooler colours indicate lower levels of evidence and lower authenticity.

The application of the historical-archaeological evidence scale began with the search and review of documents and references related to this new trend within virtual archaeology. The next step was to determine which degree of evidence corresponded to each part of the case study, thus identifying a system of reconstructive units (RU) that would help to record, with greater precision, the historical-archaeological characteristics of each element of the Roman house. The RU should be understood as a registration system that includes both the existing archaeological remains and the elements reconstructed in the 3D model. They allow the identification of the components present in the virtual reconstruction. Each RU is associated with a degree of truth, depending on the level of evidence corresponding to the element identified with the reconstructive unit number.

The realization of the present investigation has had four phases of work (Fig. 1): obtaining the 3D virtual reconstruction; application of the historical-archaeological evidence scale; obtaining the percentage values; and its diffusion.

It is worth mentioning that the first phase of the work, 'the elaboration of the 3D virtual reconstruction', was carried out in a previous investigation. [33]. For the evidence scale implementation, the reconstructive units and their correspondent evidence levels of the previous work were established, according to the literature. Blender 2.90 software was utilised for the colour application to the previous reconstruction.

Once the infographic of the 3D virtual reconstruction using the evidence scale proposed by Pablo Aparicio and César Figueiredo was obtained [22], 5 typological ranks were established aiming to identify a certain type of reconstruction (Table 2), Percentage values are

Table 1 Scale depicting historical/archaeological evidence [14]

1	Imagination (Although in context, elements are imagined)	R120 G54 B140 C65 M90 Y0 K0 #78358B
2	Conjecture based on similar structures (Based on comparable element elsewhere)	R0 G79 B159 C100 M70 Y0 K0 #004F9E
3	Basic textual reference (Based on broad textual description)	R0 G139 B206 C85 M30 Y0 K0 #008ACD
4	Descriptive textual reference (Based on detailed textual description regarding dimensions, materials, colours, etc.)	R91 G197 B242 C60 M0 Y0 K0 #5BC5F1
5	Simple graphical reference (Based on simple representation in art)	R108 G190 B153 C60 M0 Y50 K0 #6CBD98
6	Detailed graphical reference (Based on detailed and objective representation in art)	R175 G202 B11 C40 M0 Y100 K0 #AFCA0A
7	Basic archaeological information or simple base plans (Based on broad evidence or plans)	R255 G229 B0 C0 M5 Y100 K0 #FFE500
8	Strong archaeological and documental evidence in photographs and detailed plans (Based on precise measurements documented in photographs and detailed plans)	R245 G160 B87 C0 M45 Y70 K0 #F5A057
9	Still existing (or partially existing) with modifications (Based on structures still existing though altered in a later stage)	R237 G108 B126 C0 M70 Y35 K0 #ED6C7D
10	Still existing in original form (Based on structures which exist to this day in their original shape)	R183 G25 B24 C20 M100 Y100 K10 #B61918

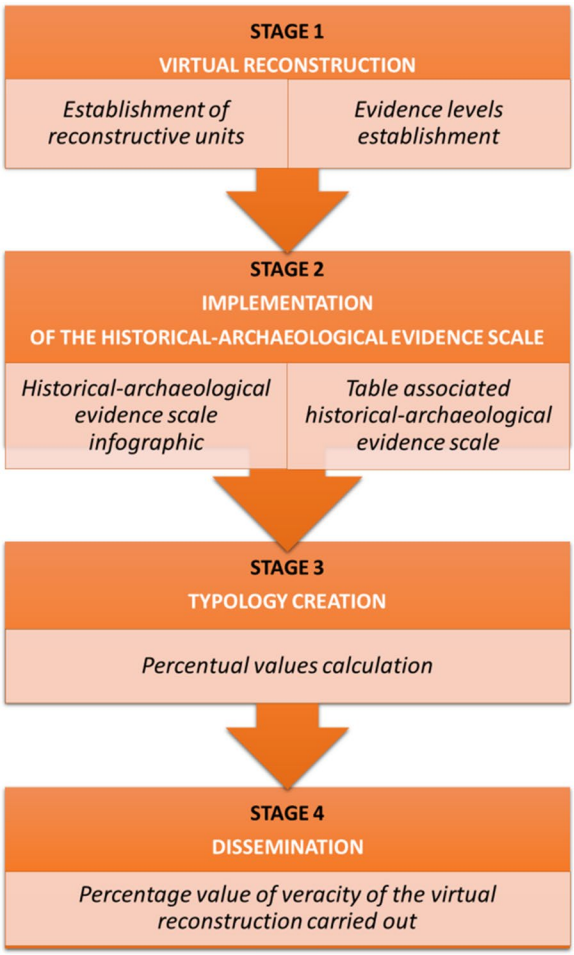

Fig. 1 Methodology working phases

obtained by dividing the total sum area of each rank by the total area of the *domus*.

These results favour dissemination of the research work, for the enhancement not only of the heritage assets but also the veracity grade of the 3D virtual reconstruction model of the Baker's House.

Case study and background

The 'Baker's House' is located in the archaeological site of Torreparedones, between the northern limits of the municipalities of Castro del Río and Baena, in the Cordoban countryside (Fig. 2).

This building is characterised by the presence of the floor of a Roman bread oven and the foundation of what may have been a Roman rotary mill [29, 31]. The recovered archaeological vestiges refer to three construction phases: late Roman Republic, early Roman Empire and medieval-modern age.

The Baker's House plays a key role in the old city of Torreparedones. The recovery and interpretation of this space lead to speak about the commercialisation of bakery products increase, thus, to have a better understanding of the lifestyle of the people who lived there. In addition to the heritage value of this particular house, the heritage value of the entire archaeological site of Torreparedones must be added. All this encompasses the importance of carrying out a virtual 3D reconstruction, which helps viewers to understand the spaces of the Baker's House. The application of the historical-archaeological evidence scale to the 3D model contributes to the knowledge of the levels of evidence of each element that has been reconstructed. The spectators could be able to know which is the historical-archaeological evidence grade of each part.

The virtual documentation of the heritage using digital technologies is fundamental for the preservation and protection of heritage assets, and such technologies offer new techniques for the dissemination of the world heritage [32]. The implementation of the historical-archaeological evidence scale started on the basis of the 3D virtual reconstruction of the Baker's House carried out previously [33]. The 3D model was elaborated thanks to the photogrammetry works carried out after the excavation. The virtual reconstruction was based on the existing and preserved vestiges, as well as on other referenced investigations of contemporary houses, in which certain spaces could be identified as similar to those of the

Table 2 Percentage values, evidence levels, ranks and types of virtual reconstruction

Historical- Archaeological evidence level	Rank	Typological classification of virtual reconstruction	Typology area ranked vs the total area of the *domus* (%)
1–2	5	Based on similar elements of the historical and natural context	52
3–4	4	Based on textual references	6
5–6	3	Based on graphic references	3
7–8	2	Based on archaeological data	13
9–10	1	Based on actual existing structures from the past	26

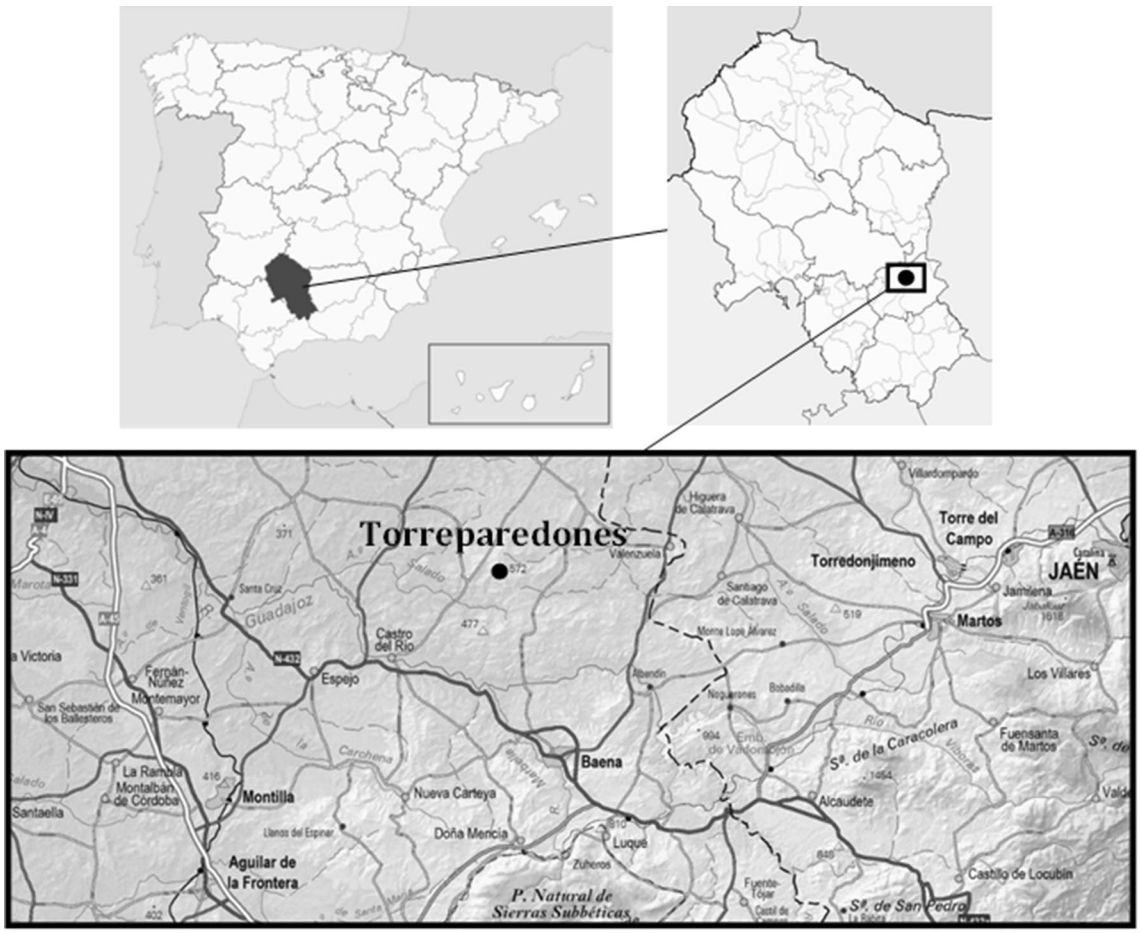

Fig. 2 Location of the Torreparedones archaeological site

Fig. 3 Aerial view of the digital 3D reconstruction of the 'Baker's House' at the archaeological site of Torreparedones [33]

Baker's House. (Fig. 3). As mentioned previously, the *domus* has three construction phases and the virtual 3D reconstruction focuses on the second phase (early Roman Empire phase), in which the bread oven was working. To carry out this previous work, the following softwares were used: 3DReshaper, SketchUp and LumenRT.

This reconstruction [33] meets the scientific quality criteria requested for this type of works, since the principles regulating the Virtual Archaeology practices were taken into account (interdisciplinarity, purpose, complementarity, authenticity, historical rigor, efficiency, scientific transparency and, training and evaluation) [10].

The representation of the degree of historical-archaeological evidence of the 'Baker's House' required the search for documentary scientific references. The documentary search helped to have a better understanding of the spaces and the reconstructed elements in order to maximise the veracity of the *domus*. After the search, we analysed the historical-archaeological evidence scales proposed in other heritage buildings, which guided the application of the scale in our heritage building.

The infograms performed to implement the historical-archaeological evidence scale of the *domus* are based on the information obtained in the digital 3D reconstruction of the 'Baker's House' of Torreparedones [33].

For the application of the colour-coded scale, we used the Blender 2.90 software. Once the model was imported to Blender 2.90, the sections were carried out in the building, to ensure that, when applying the historical-archaeological evidence scale, every part of the *domus* could be observed in a single infogram (Fig. 4).

The classification by RU was performed once the 3D model was sectioned and searched the literature that supports the veracity of the spaces. Each reconstructive element of the domus has one RU. Likewise, one element can have several reconstructive units, e.g. the rotatory mil has two RUs; the one corresponding to the conserved part and the one corresponding to the reconstructed part. Different elements, or different Rus, can have the same colour, i.e. the same evidence level.

According to the results of the implementation of the historical-archaeological evidence scale 5 ranks to classify the typology of the virtual reconstruction were established. Each rank clusters two evidence levels. Percentage values of the virtual reconstruction classified can be determined by count the RUs of the same level of evidence versus the total space.

Results

Previous 3D model of the "Baker's House" was performed by three of the authors of this present research, including an archaeologist. Therefore, the identification of the RUs and the evidence levels was accurately. The credibility of the evidence is evaluated based on what is required for the reconstruction of each element. The archaeological remains that make up the Baker's House could not be recovered as they were, however, we have the archaeological information generated after the excavation, as well as the bibliographic material from the Roman world with which to work through comparative architecture of comparative elements in time and space.

Fig. 4 Aerial view with sections of the digital 3D reconstruction (developed by author)

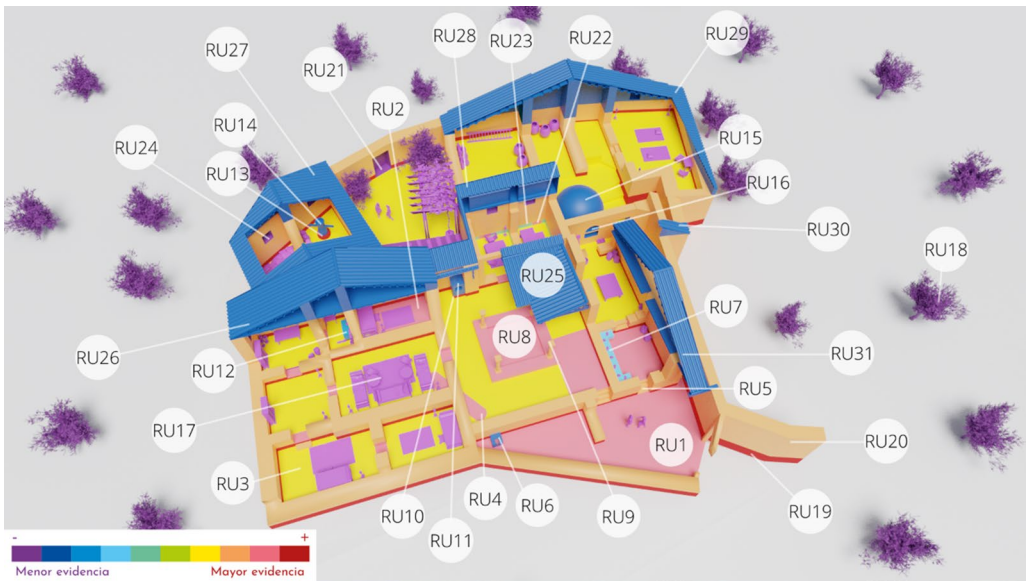

Fig. 5 Infographic obtained from the 3D model of the 'Baker's House' for the historical-archaeological evidence scale implementation

The historical-archaeological evidence scale that resulted from the *domus* of Torreparedones has 31 RUs (Fig. 5). Different RUs were used for different elements, even though they are identified with the same colour. Table 3 shows the different RUs with the historical-archaeological evidence levels of the 'Baker's House', as well as a description of the element or structure.

In the archaeological excavation, pavements based on large stone slates were documented in the hall (fauces), latrine, *tabernae* and *atrium*. This type of construction technique consisted in extending a bed of *opus incertum* and irregular flagstone paving, being parallel to the technique used in the paving of the streets of the city of Torreparedones [36]. The pavement of the mentioned areas corresponds to RU-1, with an evidence level 9, i.e., 'it exists or partially exists with modifications', as it is altered. Another type of pavement present in the building is a pavement of *opus signinum* (RU-2), located in a room identified as *cubiculum* [30]. As in the previous case, it presents an evidence level 9, due to its food state of preservation (Fig. 6). The rest of the *domus* does not present any type of paving, and, for the virtual recreation, the first technique mentioned was chosen. Thus, all the paving of the *domus*, except the two preserved types, correspond to RU-3, which presents an evidence level 7, as it is inferred that the building would have the same pavement in all areas.

The Baker's House has "*a bagnarola*" water tank (RU-4), which is located in the residential area, across a wall that separates the *atrium* from the *triclinium*, thus it can be inferred that it was built in a previous time (Late Roman Republic). It would be supplied with rainwater gathered in the roofs, as it is located in one of the corners of the *atrium* [31], which is a system that has been documented in other buildings, such as the *Domus* of Salvius [38]. This structure is fully preserved, although it should have a paved cover system given its location. This cover has not been documented in the excavation, associating it with an evidence level 9.

RU-5 corresponds to the stairs proposed in the accesses to some rooms to bridge the different levels of the rooms. These were not documented in the archaeological excavation, although the differences in the level of each space suggest strong evidence for them, which is why it was assigned an evidence level 8.

The latrine was represented in the 3D model based on the presence of a limestone slab that stands out in size among the rest of the evidence found in the pavement. According to Morena et al. [31], the difference in size could indicate the location of the latrine hole. Therefore, this RU-6 presents an evidence level 2, since comparative architecture was used for its virtual representation.

The room dedicated to the sale of bakery products (tabernae) preserves a garret composed of 20 cm-high limestone slates built in the southern half of the room [31]. It could be a structure designed to place the products for sale. This structure (RU-7) is associated with an evidence level 4, since it was reconstructed based on a detailed description of it.

The reconstructed *impluvium* of the *domus* (RU-8) gathered the rainwater and discharged it into the street through a canalisation system connected to a larger

canalisation system [30]. It has an evidence level 9, since the structure is preserved, although it has been altered. The columns of the *impluvium* (RU-9) correspond to a first construction phase of the *atrium* [30]. Only their skewback has been documented, thus they have an evidence level 8, i.e., 'strong archaeological evidence'.

In the 'Baker's House', a square structure was identified, which would correspond to the base of the recess that would hold the domestic worship figurines [31]. This base of the *lararium* (RU-10) has the maximum evidence level (10), since it exists according to the original. The *lararium* that may have existed (RU-11), based on its chronology and location, seems to correspond to an *aediculae* variant, i.e., pseudoaedicular [39, 40]. The virtual reconstruction achieved in the *lararium* of the 'Arucci North House' [41] helps in the interpretation of this type of lararia, serving as a basis for the representation of the *lararium* of Torreparedones. Therefore, it presents an evidence level 2, since, again, comparative architecture was used for its virtual reconstruction.

In the room identified as the kitchen, a masonry structure was documented, which is centred and attached in its northern facing [31]. In this context, this structure has been represented as the space for cooking (RU-12). An evidence level 3 was assigned to it, since the only information that was obtained for its reconstruction was a poorly-detailed documentary description.

The western area has a room in which a circular base of slightly over 1 m in diameter was documented (RU-13), which appears to correspond to the base of a rotatory mill [30]. This structure is preserved according to its original form (Fig. 7), thus the maximum evidence level was assigned to it (10). The rotatory mill (RU-14) reconstructed for this base was carried out by comparative architecture, thus an evidence level 2 was assigned to it. It is believed that it consisted of two hollow cones placed

Table 3 Identification of the RUs and evidence levels associated with Fig. 5

RU	Evidence level	Name	Description
1	9	Pavement made of large stone slates	This building technique consisted in extending a bed of *opus* incertum and irregular flagstone paving, being a parallel technique to the one used in the paving of the streets of the city of Torreparedones.
2	9	Pavement of *opus signinum*	Pavement of *opus* signinum in the room identified as *cubiculum*.
3	7	Non-preserved pavement	Pavements of the *domus* that are not preserved.
4	9	"*A bagnarola*" water tank	Supplied with rainwater gathered in the roofs, given its location in one of the corners of the *atrium*.
5	8	Stairs	Stairs proposed for bridging the different levels of the rooms.
6	2	Latrine	The presence of a limestone slate that stands out in size in all the pavement could be an indication of the location of the latrine hole.
7	4	Structure designed for the sale of bakery products	Garret made of large 20cm-high slates, located in the southern half of the space.
8	9	*Impluvium*	Square pond that gathers rainwater and discharges to the street through a canalisation system connected to a larger canalisation system.
9	8	*Impluvium columns*	First building phase of the *atrium*.
10	10	Base of the *lararium*	Square structure that could correspond to the base of the recess that held the figurines for domestic worship.
11	2	*Lararium*	Due to its chronology and location, it seems to correspond to a variant of the aediculae type, pseudoaedicular, characterised for being made of walls or a solid block, with an inner recess-like cavity, where domestic worship figurines would be placed, crowned by a gable.
12	3	Kitchen structure	Masonry structure
13	10	Circular base associated with the rotatory mill	Circular base of slightly over 1 m in diameter that seems to correspond to the base of a rotatory mill.
14	2	Roman rotatory mill	Formed by two hollow cones placed upside down, one over the other, with the grain remaining between the two cones and being milled by the friction between the two cones.

Table 3 (continued)

15	2	Oven vault	In Augusta Emerita, an oven was recovered, which presented an access similar to the one in the *domus* of Torreparedones, consisting of a small passable entrance up to the very mouth of the oven, embedded in a square structure. Similarly, the floor of the oven preserved in Torreparedones is typologically identical to that of the bread oven of the 'Birds' House' and that of the *domus* of the Planetarium (Itálica, Seville, Spain).
16	2	Oven mouth	It has a diameter of 4 m and it would have been covered by a vault, being embedded, at least in the upper part by a wall, with side openings for putting in and taking out the products to be baked and the fire wood.
17	1	Roman furniture	Roman furniture associated with each space.
18	1	Vegetation	Contemporary vegetation in time and space.
19	10	Skewback of the walls of the *domus*	The walls were built with rammed earth and *opus incertum* for the plinths, resorting to irregular bonds of limestone, which is the natural local rock, applying plaster as the final layer.
20	8	Elevation of the walls of the *domus*	Since the total height of the walls of the *domus* is not preserved, the work of Vitrubius was selected. It is important to take into account that the ratio relationships established by Vitrubius are approximate.
21	1	Access to the western area	Without archaeological evidence, it was decided to create an open door to the *hortus*, since there must have been an access in the production area to introduce the elements for their use.
22	9	Preserved parietal decoration	Ornamental technique in which a mortar coating is repeatedly hit with a mold containing the embossed decoration. Then, the coating is covered with pure lime or mortar.
23	5	Parietal decoration	This type of decoration has also been found in other Roman sites. The archaeological work conducted in Beatas Street (Cartagena, Spain) recovered panels decorated with embossed motifs.
24	1	Windows	In the Villa de las Musas (Arellano, Navarra, Spain), a window grill was discovered. The preservation of this type of elements helps in their 3D reconstruction, as well as in the calculation of the size of the hollows.
25	2	*Atrium* cover	*Compluvium* / *impluvium* system
26	2	Cover of the southern rooms	Large gabled cover that discharges the rainwater into the *atrium* and into the street located south of the *domus*.
27	2	Cover of the storage and milling area	Spaces E-37 and E-38 consist of a hip roof that discharges rainwater into three areas: the northern area (*hortus*), the street located south of the *domus* and the street located west of the *domus*.
28	2	Cover of the *tablinum* and *cubiculum*	The *tablinum* (E-11) and the *cubiculum* located in the northern area (E-12) consist of a shed roof that also discharges into the *atrium*, since, otherwise, the rainwater would go to the open corridor of the western area of the *domus*, where there are no canalisations or storage structures.
29	2	Cover of the service area	The other cover is the one that covers spaces E-22, E-23, E-24, E-26, E-28, E-31 and E-46, with a gable roof, which discharges the rainwater into the *hortus* and into the northern area of the *domus*.
30	2	Cover of the woodshed	Shed roof proposed for the closing of space E-32, identified as woodshed.
31	2	Cover of the commercial area, redistribution area and latrine	Spaces E-15 and E-16 are composed of a gable roof, discharging, on the one hand, into the western area of the *domus*, and, on the other hand, into the eastern area. The closing of spaces E-36 and E-13 consists of a shed roof that would be the continuation of the previous cover, discharging the rainwater into the 'porch'.

upside down one over the other, grinding the grain with the friction between them [45, 46].

The only element preserved in the bread oven that gives the *domus* its name is its floor, and two RUs are associated with it: the vault of the oven (RU-15) and the mouth of the oven (RU-16). The virtual reconstruction of both parts was carried out by comparative architecture, which is why an evidence level 2 was assigned to it. It is 4 m in diameter and would have been covered by a vault, being embedded, at least in the front part by a wall, with side openings that would allow putting in and taking out the bakery products and the firewood [31]. In the site of Augusta Emerita, an oven similar to that of the *domus* of Torreparedones was recovered, with a small passable entrance to the very mouth of the oven, being embedded in a square structure [48]. Similarly, the floor of the oven preserved in Torreparedones is typologically identical to the bread oven of the 'Birds' House' and to the oven of the *domus* of the Planetarium (Itálica, Seville, Spain) [49].

One of the RUs that have le less evidence grade (1) corresponds to elements that have been reconstructed based

Fig. 6 *Opus signinum* of RU-20 (Source: Massimo Gasparini, Research Group HUM-882 "Ancient Cities of Andalusia" of the University of Córdoba)

on the historical context, such as the Roman furniture associated with each space (RU-17). Likewise, the crops and trees of the *domus* (RU-18), both inside and outside of the building [43, 44], were also assigned the minimum evidence level.

RUs 19 and 20 are identified with the walls that compose the building. RU-19 is related to the skewback of the walls, that is, the archaeological remains of these that are preserved. Therefore, the corresponding evidence level is maximal (level 10), as it exists according to the original. On the other hand, RU-20 corresponds to the elevation of the walls that make up the *domus*, with an evidence level 8, indicating 'strong archaeological or documentary evidence'. Since the total height of the walls is not preserved, the work of Vetrubio was considered [34], which offers approximate ratio relationships; this technique has also been used in the Roman Villa of 'El Saucedo' [35].

Other RU with an evidence level 1 is the access to the western area from the street (RU-21); even without archaeological evidence, the digital reconstruction included and justified the creation of a door that allowed introducing the foods into the production area.

With respect to the parietal decoration preserved (RU-22), the ornamental technique consists in a mortar coating that is repeatedly hit with a mold containing the embossed motif, and then it is covered with pure lime or mortar [30]. This technique, which is well documented [31], is only preserved in some areas of the room identified as the *tablinum* and the *cubiculum* located next to it. Since only some areas are preserved, and in an altered manner, an evidence level 9 was assigned to it. This type of decoration has also been found in other Roman sites; for instance, the excavation conducted in Beatas Street (Cartagena, Spain) recovered panels decorated with embossed motifs [47]. The digital reconstruction of the parietal decoration of the two rooms of the building of Torreparedones was

Fig. 7 Circular base that may correspond to the rotatory mill (Source: Massimo Gasparini, Research Group HUM-882 "Ancient Cities of Andalusia" of the University of Córdoba)

carried out in its four walls (RU-23), considering the representations of Beatas Street in Cartagena, assigning it an evidence level 5.

A window grill found in the Villa de las Musas was considered to establish the size of the windows proposed in the virtual reconstruction of the house (RU-24) (Arellano, Navarra) [42]. The preservation of this type of elements helps in their 3D reconstruction, as well as in the calculation of the size of the hollows. The creation of the windows was carried out through comparative architecture, although, due to the absence of traces of such windows in the building, the minimum evidence level was assigned to it.

Regarding the covers, these have seven RUs, all of them with an evidence level 2, since none of them are preserved; their representation is based on comparative architecture [33, 34, 37]. The cover that corresponds to the *atrium* (RU-25) was proposed to be a hipped roof, since a rectangular pond was documented at the centre of the *atrium*, as well as the skewback of four columns in it [30]. Therefore, this would be a *compluvium*/*impluvium* system. Secondly, the cover of the rooms in the southern area (RU-26) was proposed to be a gable roof, with the rainwater being discharged into the *atrium* and into the street located south of the *domus*. Thirdly, the covered area of storage and milling (RU-27) are composed of a hip roof that discharges the rainwater into three areas: northern area (*hortus*), the street located south of the *domus* and the street located west of the *domus*. The next cover corresponds to the *tablinum* and to the *cubiculum* located next to the *tablium* (RU-28); this cover is a shed roof that discharges into the *atrium*. The covers of the service area would be RU-29, composed of a gable rood that discharges into the *hortus* and into the northern area of the building, and another shed roof that discharges into the western street. The cover that corresponds to the woodshed (RU-30) is a shed roof that discharges into the northern area of the *domus*. Lastly, RU-31 corresponds to the cover of the commercial area and to the redistribution area and latrine. The cover of the commercial area is represented as a gable roof, discharging, on the one hand, into the western area of the *domus*, and, on the other hand, into the eastern area. The closure of the redistribution area and the latrine consists of a shed roof that would be the continuation of the previous cover, discharging the rainwater into the 'porch'.

Figure 8 shows a graphic with the percentage values of the different evidence levels for this 3D model. Evidence levels more used are 1 (Imagination) and 2 (Conjecture based on similar structures). Both correspond to the percentage value of 52%, therefore this virtual

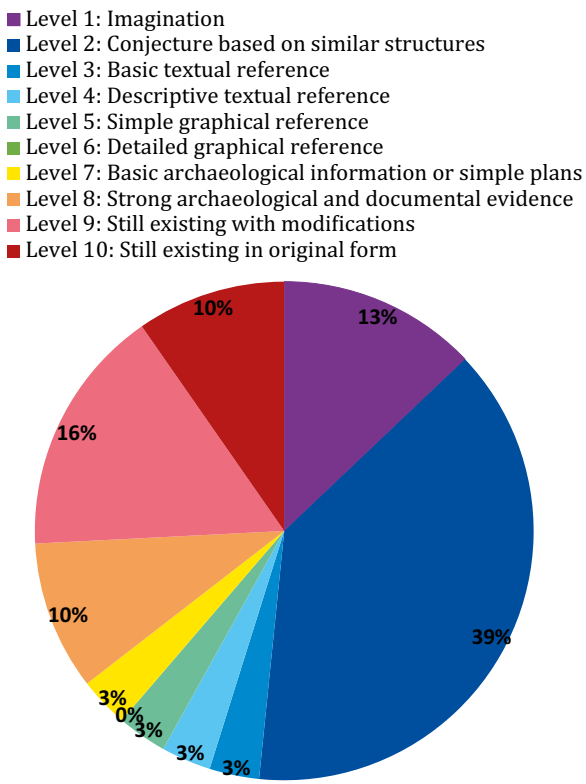

Fig. 8 Percentage values obtained from the implementation of the historical-archaeological evidence scale of the *domus* of the Baker's House'

reconstruction could be identified of rank 5: based on similar elements of the historical and natural context. This classification is not related to the suitability of virtual reconstruction, but rather reflects which levels of evidence have been more used. In this case, rank 5 indicates that more than a half of the 3D virtual model has been built through comparative architecture and elements based on the historical and natural context, all supported by bibliographic data and archaeological information to avoid historical fakes.

Discussion

Having done a searched about the scientific works where the scale of historical-archaeology was applied, we highlight several statements. On the one hand, there were not any scientific work in which the historical-archaeological scale proposed by Byzantium project [11] was used. Four research works were found that implement the evidence scale proposed by Pablo Aparicio and César Figueiredo [22] to support their virtual reconstructions. The most recent evidence scale propose, the one of Ortiz et al. [29], only counts with its own contribution to put into value and explain it. On the second hand, it is important to

mention that there is only one work research in all the literature review, the virtual reconstruction of the Gauzón Castle [24], which have a table such as Table 3 containing the different RUs with the colour linked to the historical-archaeological evidence scale and the explanations.

A comparison of virtual reconstructions typologies was made according to the scale of evidence. The virtual reconstruction of the Gauzón Castle [24] was utilised, since it counts with the associated table like our research. This 3D model has 26 RUs coloured according to the Pablo Aparicio and César Figueiredo work [18], whereas our research has 31 RUs. The following percentages were observed according to the typological rank proposed in this research: 38,46% (rank 5); 0% (rank 4 and 3); 30,77% (rank 1 and 2). This indicates that the reconstruction of the Baker's House collects more RUs (31) and more levels of evidence (9), compared to the reconstruction of the Castle of Gauzón where (26) RUs and 5 levels of evidence are obtained.

Regarding the typology of the reconstruction of Gauzón Castle, the highest percentage value is established within rank 5 (around 40%). Therefore, likewise for the virtual reconstruction of the Baker's House, its 3D model has been made through comparative architecture and elements based on the historical and natural context.

The lifestyle of the people has changed, impacting the sites of archaeological heritage [50, 51]. Currently, digital technologies are important in the communication between the heritage and the public [52–54]. Therefore, the historical-archaeological evidence scale tested in the 'Baker's House' of Torreparedones allows people to reflect on the structures of the past, observing the preserved remains in situ, the virtual 3D reconstruction performed and the degree of veracity of such reconstruction.

Conclusions

The representation of archaeological remains exists practically since the origin of archaeology. This study complements the most classical types of representation, computer-assisted visualisation and material archaeology, transforming the archaeological work into a scientifically verifiable infogram that is intangible for society.

As mentioned before, there are many tools and software in the field of digital technologies applied to heritage. This work research has focused on the representation of the degree of veracity of a virtual reconstruction, the software used for this purpose being essential. In this case, Blender was crucial for the application of the colours corresponding to the levels of evidence of the reconstructive units.

The historical-archaeological evidence scale implementation in the virtual reconstruction of the Baker's House in the archaeological site of Torreparedones plays a fundamental role in the dissemination of the heritage assets. Not only of the conserved remains but also of the performed research of the heritage asset. The 3D model helps society understand the existing visible remains and how the past developed. In addition, the historical-archaeological evidence scale clarifies its evidence level of each reconstructed element and its veracity grade.

A criterion is established by the creation of ranks, where the identification of the typology of virtual reconstructions is collected based on the scale of evidence. Therefore, the use of the typology rank helps facilitates the having a better understanding of the type of virtual reconstruction accordingly to the documentation used to build it.

This study grants value to and guarantees compliance with the principles of authenticity and scientific transparency considered for the digital 3D reconstruction of the 'Baker's House' in the archaeological site of Torreparedones.

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IC-C, PT-T, and D-FG-M conceived the research; IC-C, analyzed the data; IC-C, PT-T, and F-J M-C writing and review. All authors read and approved the final manuscript.

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Declarations

Competing interests
The authors declare that they no competing interests.

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