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Programa de Doctorado en Ingeniería Agraria, Alimentaria, Forestal y del Desarrollo Rural Sostenible

Departamento de Ingeniería Gráfica y Geomática

PUESTA EN VALOR, EVALUACIÓN Y REPRESENTACIÓN GRÁFICA DE LA VERACIDAD DEL DISCURSO ARQUEOLÓGICO EN LAS RECONSTRUCCIONES VIRTUALES. Caso del estudio: La Casa del Panadero del yacimiento de Torreparedones (Córdoba)

ENHANCEMENT, EVALUATION AND GRAPHIC REPRESENTATION OF THE VERACITY OF THE ARCHAEOLOGICAL DISCOURSE IN VIRTUAL RECONSTRUCTIONS. Case study: The Baker's House at the Torreparedones site (Córdoba)

Autora: Irene Cáceres Criado

Directores:

Dra. Paula María Triviño Tarradas

Dr. Diego Francisco García Molina

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TITULO: *Puesta en valor, evaluación y representación gráfica de la veracidad del discurso arqueológico en las reconstrucciones virtuales. Caso del estudio: La Casa del Panadero del yacimiento de Torreparedones (Córdoba)*

AUTOR: *Irene Cáceres Criado*

Campus de Rabanales
Ctra. Nacional IV, Km. 396 A
14071 Córdoba

https://www.uco.es/ucopress/index.php/es/
ucopress@uco.es

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- **Cáceres-Criado, I.**, Triviño-Tarradas, P., Valderrama-Zafra, J. M., & García-Molina, D. F. (2022). Digital preservation and virtual 3D reconstruction of "The Baker's house" in the archaeological site of Torreparedones (Baena, Cordoba-Spain). Digital Applications in Archaeology and Cultural Heritage, e00218.

- **Cáceres-Criado, I.**, García-Molina, D. F., Mesas-Carrascosa, F. J., & Triviño-Tarradas, P. (2022). Graphic representation of the degree of historical-archaeological evidence: the 3D reconstruction of the "Baker's House". Heritage Science, 10(1), 1-14.

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DOCTORANDA/O

Cáceres Criado Irene

TÍTULO DE LA TESIS:

PUESTA EN VALOR, EVALUACIÓN Y REPRESENTACIÓN GRÁFICA DE LA VERACIDAD DEL DEL DISCURSO ARQUEOLÓGICO EN LAS RECONSTRUCCIONES VIRTUALES. Caso del estudio: La Casa del Panadero del yacimiento de Torreparedones (Córdoba)

INFORME RAZONADO DE LAS/LOS DIRECTORAS/ES DE LA TESIS
(se hará mención a la evolución y desarrollo de la tesis, así como a trabajos y publicaciones derivados de la misma)

La presente tesis doctoral se centra en la puesta en valor y representación gráfica y virtual del patrimonio arqueológico del yacimiento de Torreparedones (Baena, Córdoba). Con el desarrollo de esta tesis de investigación, se han identificado los espacios funcionales de la Casa del panadero en el yacimiento, para su puesta en valor y difusión a través de la reconstrucción virtual 3D. Se han implementado las diferentes escalas de evidencia histórico-arqueológicas que existen para comprobar la eficacia de las mismas en este bien patrimonial. Asimismo, se ha creado una nueva escala de evidencia para su implementación siendo esta propuesta factible para ser interpretada por el público en general (no expertos). Y por utlimo, se ha creado una propuesta de escala de resolución asociada al terreno para poder ser ustilizada en las recosntrucciones virtuales.

La tesis tiene un elevado grado de innovación y origialidad habiendo dado lugar a varias publicaciones en revistas de indexadas, entre las que destacan:

1. Co-autor/Co-autores: Irene Cáceres-Criado, Paula Triviño-Tarradas, José Manuel Valderrama-Zafra, Diego Francisco García-Molina
Título del artículo: Digital preservation and virtual 3D reconstruction of "The Baker's house" in the archaeological site of Torreparedones (Baena, Cordoba-Spain)
Título de la revista: Digital Applications in Archaeology and Cultural Heritage
Número de revista: 24 Año: 2022 Páginas: 11 ISSN: 2212-0548
Índice de impacto del año de la publicación, o en su defecto, indicio de calidad: 0.692
Índice relativo que tenga dentro de su categoría: (2022) Q1 SJR (ARCHEOLOGY) Q1 SJR (ANTROPOLOGY)
Fuente: SJR

2. Co-autor/Co-autores: Irene Cáceres Criado, Diego Francisco García Molina, Francisco Javier Mesas Carrascosa and Paula Triviño Tarradas
Título del artículo: Graphic representation of the degree of historical archaeological evidence: the 3D reconstruction of the "Baker's House"
Título de la revista: Heritage Science
Número de revista: 10(33) Año: 2022 Páginas: 14 ISSN: 2050-7445
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Fuente: JCR

3. Co-autor/Co-autores: Irene Cáceres-Criado, Diego Francisco García-Molina, Francisco-Javier Mesas-Carrascosa and Paula Triviño-Tarradas.
Título del artículo: New approach for optimizing the interpretation and representation of the degree of historical archaeological evidence in the virtual Reconstructions
Título de la revista: Virtual Reality
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Fuente: JCR

4. Co-autor/Co-autores: Irene Cáceres-Criado, Paula Triviño-Tarradas, José Manuel Valderrama-Zafra, Diego Francisco García-Molina
Título del artículo: Proposition for the graphic representation, interpretation and evaluation of the degree of terrain resolution in virtual reconstructions
Título de la revista: Journal of Cultural Heritage
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Fuente: JCR

Asimismo, se informa que la doctoranda ha seguido con un destacado aprovechamiento las actividades propuestas por la Comisión Académica del Programa de Doctorado en Ingeniería Agraria, Alimentaria, Forestal y del Desarrollo Rural Sostenible.

Por todo ello, se autoriza la presentación de la tesis doctoral.

Córdoba, a 5 de julio de 2023

Las/los directoras/es

TRIVIÑO TARRADAS PAULA MARIA - 30794106G
Firmado digitalmente por TRIVIÑO TARRADAS PAULA MARIA - 30794106G
Nombre de reconocimiento (DN): c=ES, serialNumber=IDCES-30794106G, givenName=PAULA MARIA, sn=TRIVIÑO TARRADAS, cn=TRIVIÑO TARRADAS PAULA MARIA - 30794106G
Fecha: 2023.07.13 08:29:59 +02'00'

GARCIA MOLINA DIEGO FRANCISCO - 52489214V
Firmado digitalmente por GARCIA MOLINA DIEGO FRANCISCO - 52489214V
Fecha: 2023.07.13 10:44:26 +02'00'

Fdo.:_____
Nombre y Apellidos

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CAPÍTULO 1.

Introducción y objetivos.

Estructura de Tesis

CAPÍTULO 1. Introducción y objetivos. Estructura de la tesis

I-1. INTRODUCCIÓN

Esta Tesis Doctoral se centra en la puesta en valor del patrimonio arqueológico del yacimiento de Torreparedones (Baena, Córdoba), concretamente, en la *domus* romana denominada 'La Casa del Panadero'.

Como introducción a la presente investigación, se cree oportuno hacer un recorrido histórico por el yacimiento mencionado, así como analizar cómo se aborda la puesta en valor del mismo. También, se estudiarán las diferentes técnicas de puesta en valor patrimonial mediante el uso de la Arqueología Virtual.

I-1.1. Localización e historiografía del yacimiento arqueológico de Torreparedones

El yacimiento arqueológico de Torreparedones, también conocido como Castro el Viejo o Torre de las Vírgenes, se localiza en la campiña oriental de la provincia de Córdoba, entre las localidades de Castro del Río y Baena (Fig. I-1), con el río Guadalquivir al norte y el Guadajoz al sur (Morena y Sánchez, 2016).

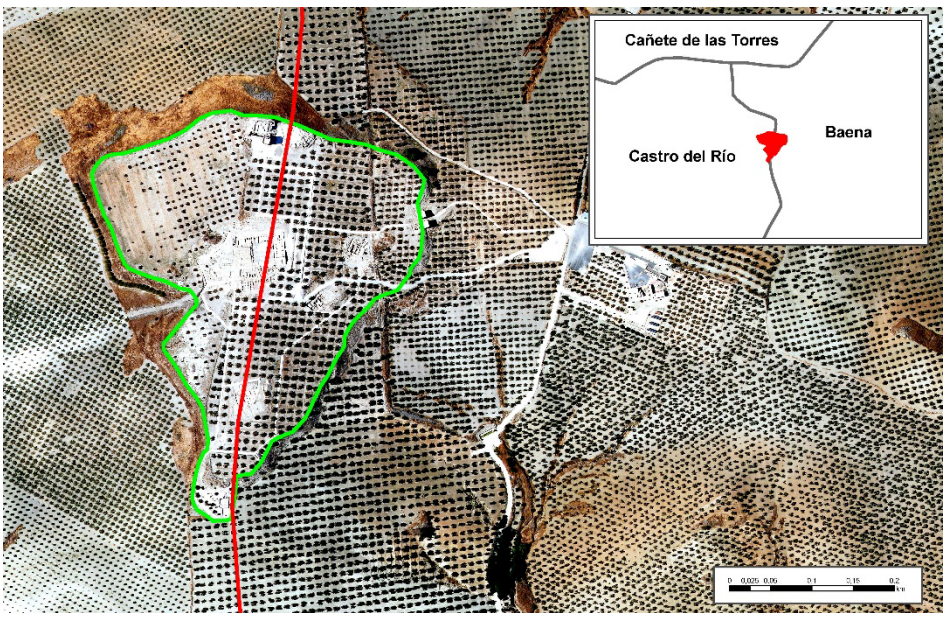

Fig. I-1. Localización del yacimiento arqueológico de Torreparedones. En verde se marca el propio yacimiento, la línea roja indica el límite municipal entre Castro del Río y Baena.

El yacimiento se sitúa en una posición estratégica puesto que se ubica sobre una de las cotas más elevadas de la zona, con altitud de 580 m, y amplia visibilidad hacia los cuatro puntos cardinales (Pericet et al., 2013-14). El espacio que ocupa Torreparedones abarca unas 11 ha de extensión y se encuentra rodeado por una muralla de época iberorromana, con 1.5 km de perímetro (Morena y Sánchez, 2016). Torreparedones se encuentra a unos 60 km al este de Córdoba, tratándose de una región con tierras muy fértiles, siendo la explotación agrícola del territorio uno de los principales recursos económicos de la ciudad durante toda su historia (Morena y Sánchez, 2016).

Los estudios realizados en Torreparedones o "Castro el viejo" apuntan que el lugar estuvo habitado desde el IV milenio a.n.e hasta el siglo XVI, alcanzando sus momentos de máximo esplendor en la época ibérica y la época romana (Morena, 2014). Las excavaciones realizadas en Torreparedones entre 1987 y 1992, por el equipo *Guadajoz Project*, logran definir la primera fase de ocupación del yacimiento. Correspondiente a una fase prehistórica definida como Fase Calcolítica (Martínez-Sánchez et al., 2014), tratándose de una comunidad dedicada a la ganadería y agricultura (Morena y Sánchez, 2016). La lectura estratigráfica de un sondeo realizado en 2012, muestra que este yacimiento presenta para la prehistoria reciente interrupciones en su ocupación (Martínez-Sánchez et al., 2014). Para el tránsito entre el II y el I milenio a.n.e. aparece cultura material correspondiente a la fase conocida como Bronce Final Tartésico (Martínez-Sánchez et al., 2014), volviendo a ser habitado el sitio para los siglos XI-IX a.n.e. (Pericet et al., 2013-14).

Aunque los restos más antiguos daten del IV milenio a.n.e, hay que apuntar que el yacimiento se entendería como una ciudad para la época ibérica y con la llegada de Roma se alcanzaría el rango de colonia, llamándose *Ituci Virtus lulia* (Morena, 2010).

Las excavaciones realizadas entre 1987, 1989 y 1990 sacaron a la luz el pasado Ibérico de Torreparedones (Pericet et al., 2013-14). Fueron durante estas excavaciones cuando se centraron en el *oppidum* ibérico y en el santuario, situado a extramuros y dedicado a la *Dea Caelestis* (Morena y Sánchez, 2016). El *oppidum*, de 10,5 ha. y dotado de una muralla, se constituye como un elemento defensivo y símbolo de poder (Pericet et

al., 2013-14). En cuanto al santuario, se construyó a finales de época íbera e inicios de la dominación romana y, muestra la influencia del culto de los primeros sobre los segundos (Pericet et al., 2013-14).

Con la conquista romana el *oppidum* de Torreparedones empezó a formar parte de la provincia de *Hispania Ulterior* (Melchor, 2011; Pericet et al., 2013-14), y en época augustea estaría dentro de la provincia *Baetica* (Pericet et al., 2013-14; Ventura, 2014a). La ciudad cuenta con un importante conjunto monumental de la época altoimperial, y múltiples edificios administrativos y públicos de distintas fases cronológicas (Morena y Sánchez, 2016).

El foro de Torreparedones es uno de los muchos elementos monumentales conservados de época romana, y se caracteriza por ser el mejor conservado de la Península Ibérica (Morena y Sánchez, 2016). Documentado en las campañas de excavación de 2009-2013, se constituye como una plaza cerrada con la Basílica en uno de sus lados y enfrentada a un Templo (Pericet et al., 2013-14; Ventura, 2014b) (Fig. I-2). En el lado occidental del foro se localiza una *Schola Collegi subaediani* (Pericet et al., 2013-14), en el ángulo norte de este lado occidental se identifica la Curia. En el lado septentrional se encuentra la *Aedicula* y junto a esta, se localiza el *Chalcidicus*. Por último, los intercolumnios centrales estaban presididos por estatuas de los miembros de la familia imperial (Pericet et al., 2013-14; Ventura, 2014b), mientras que, en el lado meridional de la plaza, estaría destinado para estatuas pedestres de los miembros de la aristocracia local (Pericet et al., 2013-14; Morena et al., 2011; Márquez, 2014).

El yacimiento arqueológico de Torreparedones también cuenta con otros edificios públicos típicamente romanos. Las excavaciones de 2009 pusieron al descubierto el *Macellum*, tratándose uno de los pocos *macella* conocidos en Hispania (Pericet et al., 2013-14). Otro elemento fundamental es la Puerta Oriental, construida siguiendo el ritual fundacional romano. Ésta siguió en uso hasta el siglo IV de nuestra era, cuando se documenta su derrumbe (Pericet et al., 2013-14; Moreno et al., 2021).

Fig. I-2. Vista del Foro con la Basílica al fondo (Autor: Antonio J. Criado Algaba).

También se han documentado varios edificios termales en Torreparedones. El balneum, situado al sur del foro, se construyó en época tardorrepublicana. Cuenta con cuatro salas, la correspondiente al *apodyterium*, el *tepidarium*, el *caldarium* y el *frigidarium* (Pericet et al., 2013-14). Otro de los edificios termales, se ubica bajo la Ermita de las Vírgenes de Torreparedones, construido entre la segunda mitad del siglo I de nuestra era y la primera mitad del siglo II de nuestra era. Por sus características morfológicas, autores como Pericet (2013-14), apuntan que puede corresponder al Tipo Anular establecido por Krencher (1929) (Nielsen, 1990; Thébert, 2013). Por último, el edificio termal más emblemático de la ciudad romana de Torreparedones son las Termas Orientales, o también conocidas como Termas de La Salud (Fig. I-3). Cuenta con tres de las salas típicas que poseen estos establecimientos (*tepidarium*, *frigidarium*, *caldarium*), salas de planta rectangular y distribuidas en sentido Este-Oeste. Estas edificaciones debieron construirse durante con emperador Tiberio, en la primera mitad del siglo I de nuestra era, reformándose de forma parcial en época flavio-trajanea, entre los años 60-125 (Morena, 2017).

Fig. I-3. Las Termas Orientales o Termas de La Salud de Torreparedones al amanecer.

En este yacimiento arqueológico existe la presencia de dos necrópolis, ambas a extramuros del recinto urbano (Pericet et al., 2013-14). La primera, conocida como Necrópolis Oriental, se ubica cerca de la puerta de la ciudad. Cuenta con tres fases de ocupación: la primera para época Altoimperial, con tumbas de cámara colectivas con sepulturas de cremación; la segunda, de época Tardorromana con sepulturas de inhumación; y la última, época islámica con tumbas de inhumación (Pericet et al., 2013-14; Morena, 2021). La segunda necrópolis, conocida como necrópolis norte, se caracteriza por contener el famoso mausoleo de los Pompeyos y el monumento funerario de "la Mazmorra" (Pericet et al., 2013-14; Beltrán-Fortes y Morena-López, 2018).

Para época Altomedieval, el asentamiento estuvo habitado, como demuestra la pequeña necrópolis visigoda en la zona de la Basílica, las cerámicas de los siglos X y XI documentadas en el castillo de época islámica, y el enterramiento musulmán documentado en la Necrópolis Oriental (Pericet et al., 2013-14).

En los siglos XIII y XIV el yacimiento de Torreparedones estaría en manos cristianas, jugando un papel estratégico por su proximidad con la frontera del territorio con dominio musulmán. (Pericet et al., 2013-14; Córdoba, 2014). El elemento más distintivo es el castillo, citado en las fuentes como Castro el Viejo, se sitúa en el punto más elevado de la zona, perteneció a Alfonso X quien lo donaría a Fernán Alonso de Lastres (Morena, 2012).

El último vestigio de la vida de Torreparedones es la Ermita de las Vírgenes, que estuvo en uso posiblemente hasta su derrumbe en el siglo XVIII (Pericet et al., 2013-14).

I-1.2. Puesta en valor del patrimonio arqueológico a través de la arqueología virtual

A partir de 1980 tienen lugar las primeras reconstrucciones, el objetivo de éstas era disponer de toda la información de un edificio histórico en un mismo sistema, surgiendo así los modelos tridimensionales (Gómez y Quirosa 2009). Entre 1984 y 1986 se desarrollan los trabajos realizados por Andrew G.N. Walter y Mike Stanley para el IBM UK Scientific Centre (Catedral Vieja de Winchester, Templo de Sulis Minerva en Bath y Abadia de Furness), siendo modelos bastante sencillos y pioneros de esta nueva tecnología aplicada al Patrimonio (Gómez y Quirosa 2009).

El término “Arqueología Virtual” fue introducido por Paul Reilly en 1990 (Reilly 1990), describiéndolo como “el conjunto de técnicas informáticas que permiten la visualización 3D de la representación virtual y realista de los objetos y edificios antiguos, cuyos restos han desaparecido o están en un estado de preservación tan deficiente que hacen imposible su observación o muy difícil su interpretación”. Nació como un método computacional para ayudar a la enseñanza de los principios de excavación arqueológica y análisis a estudiantes, iniciada por los Departamentos de Arqueología de la Universidad de Southampton y la Universidad de York (Rahtz 1988).

En 1990, con la publicación del texto *Towards a virtual Archaeology*, se empezaba a apostar por el uso de estos modelos tridimensionales para la interpretación de los restos arqueológicos (Reilly 1990). Seis años después tuvo lugar otro texto

influyente, "Arqueología, paseos virtuales por las civilizaciones desaparecidas" (Forte 1996), donde tuvieron cabida multitud de reconstrucciones virtuales usadas como sistema de interpretación. Otro proyecto ambicioso nació en 1997, *Rome Reborn 2.0*, y diez años más tarde pasó a llamarse *Rome Reborn 1.0* (Fig. I-4), cuyo objetivo era recrear la antigua ciudad de Roma, así como su desarrollo urbano (Gómez y Quirosa 2009).

Fig. I-4. Reconstrucción de la antigua ciudad de Roma realizada por Rome Reborn 1.0. (Recuperado de https://pruned.blogspot.com/2007/06/rome-stillborn-10.html).

En nuestro país las primeras experiencias del uso de las nuevas tecnologías aplicadas al Patrimonio también fueron pioneras. En la Escuela de Estudios Árabes de Granada del CSIC se llevó a cabo el proyecto de reconstrucción de la Dar al Yund de Madinat al- Zahra' (Córdoba) (Fig. I-5), cuyos estudios se iniciaron en 1990 (Gómez y Quirosa 2009). En esta escuela también tuvo lugar la primera tesis doctoral sobre estas nuevas tecnologías, *La restauración del Patrimonio por la imagen de síntesis*, defendida por José Antonio Fernández Ruiz en 1997, donde se llevaron a cabo los modelos de la antigua Mezquita de Sevilla, la Dar al Yund de Madinat Al Zahra y del Palacio Omeya de Amman (Almagro, 2000).

Fig. I-5. Reconstrucción de la Dar al Yund de Madinat al-Zahra' (Recuperado de https://www.eea.csic.es/laac/divulgacion-laac/reconstruccion-virtual-del-alcazar-y-lamezquita/dar-alyund-casa-militar/).

Asimismo, aparecen más grupos de investigación donde se realizaban reconstrucciones virtuales de diferentes regiones como, por ejemplo, GRIHO de la Universidad de Lleida, o el Grupo de Investigación VideaLab (Grupo de Visualización Avanzada en Arquitectura, Ingeniería Civil y Urbanismo) con la reconstrucción del Coro del Maestro Mateo de la Catedral de Santiago, entre otros (Gómez y Quirosa 2009).

En España, fruto de la reunión del I Congreso Internacional de Arqueología e Informática Gráfica, Patrimonio e innovación ARQUEOLOGICA 2.0 (2009), nació la necesidad por parte de la Sociedad Española de Arqueología Virtual (SEAV) de crear un documento que regulara o estableciera unas recomendaciones en la práctica de la Arqueología Virtual. Tras esto surgió la Carta de Sevilla, inspirada en la Carta de Londres, teniendo como objetivo principal establecer principios y criterios que sirvan para medir los niveles de calidad de los proyectos que se realicen en el campo de la Arqueología Virtual. Estos principios son los siguientes (López-Menchero y Grande 2011):

- Interdisciplinariedad, el uso de nuevas tecnologías para la visualización de patrimonio arqueológico implica un trabajo verdaderamente interdisciplinar.
- Finalidad, previamente ha de dejarse claro el objetivo final que se pretende alcanzar.

- Complementariedad, no debe sustituir a otros métodos o técnicas de gestión en el ámbito del patrimonio arqueológico, debe entenderse como complementaria.
- Autenticidad, siempre debe ser posible la realidad, explicando los niveles de veracidad en los que se sustenta la reconstrucción.
- Rigurosidad histórica, sustentar la reconstrucción en una sólida investigación y documentación histórica y arqueológica.
- Eficiencia, sostenibilidad económica y tecnológica.
- Transparencia científica, contrastable por otros investigadores o científicos.
- Formación y evolución, el cumplimiento de los principios anteriores determinará que el resultado final sea o no "de calidad".

Además, definen varios términos referentes a esta disciplina (López-Menchero y Grande 2011). En primer lugar, restauración virtual, entendida como "*la reordenación, a partir de un modelo virtual, de los restos materiales existentes con objeto de recuperar visualmente lo que existió en algún momento anterior al presente. La restauración virtual comprende por tanto la anastilosis virtual*". El término anastilosis virtual comprende la "*recomposición de las partes existentes pero desmembradas en un modelo virtual*". En cuanto a las reconstrucciones virtuales, las definen como "*el intento de recuperación visual, a partir de un modelo virtual, en un momento determinado de una construcción u objeto fabricado por el ser humano en el pasado a partir de las evidencias físicas existentes sobre dicha construcción u objeto, las inferencias comparativas científicamente razonables y en general todos los estudios llevados a cabo por los arqueólogos y demás expertos vinculados con el patrimonio arqueológico y la ciencia histórica*". Por último, la recreación virtual significa "*el intento de recuperación visual, a partir de un modelo virtual, del pasado en un momento determinado de un sitio arqueológico, incluyendo cultura material (patrimonio mueble e inmueble), entorno, paisaje, usos, y en general significación cultural*".

Cualquiera de los trabajos que componen éstas definiciones, se rigen por los principios mencionados con anterioridad, y los nuevos de (López-Menchero y Grande 2011):

- Generación de criterios fácilmente comprensibles y aplicables por toda la comunidad de expertos, ya sean estos informáticos, arqueólogos, arquitectos, ingenieros, gestores o especialistas en general en la materia.
- Establecer directrices encaminadas a facilitar al público un mayor entendimiento y mejor apreciación de la labor que desarrolla la disciplina arqueológica.
- Establecer principios y criterios que sirvan para medir los niveles de calidad de los proyectos que se realicen en el campo de la arqueología virtual.
- Promover el uso responsable de las nuevas tecnologías aplicadas a la gestión integral del patrimonio arqueológico.
- Contribuir a mejorar los actuales procesos de investigación, conservación y difusión del patrimonio arqueológico mediante el uso de nuevas tecnologías.
- Abrir nuevas puertas a la aplicación de métodos y técnicas digitales de investigación, conservación y difusión arqueológica.
- Concienciar a la comunidad científica internacional de la necesidad imperante de aunar esfuerzos a nivel mundial en el creciente campo de la arqueología virtual.

I-1.3. Arqueología Virtual en el yacimiento arqueológico de Torreparedones

El yacimiento arqueológico de Torreparedones es un enclave de gran interés arqueológico y científico en el país. Los restos hallados hablan por sí solos, muestran la monumentalidad del enclave y, además, la excelente conservación de algunos de ellos, potencia la excepcionalidad del yacimiento. En él, tras el devenir de los años, se han realizado diferentes trabajos de investigación que ponen en valor el mismo. También, se ha trabajado con Arqueología Virtual en algunas zonas del yacimiento, para la representación arquitectónica de los bienes patrimoniales en momentos anteriores al presente.

La puesta en valor del yacimiento arqueológico como producto turístico, además de contar con tareas de excavación, investigación, conservación y restauración, debe de tener en cuenta la Arqueología Virtual. Ésta resulta fundamental para la correcta interpretación de los vestigios arqueológicos y, además, supone una ayuda pedagógica

para la visualización de los restos arqueológicos *in situ* por parte de los usuarios que visiten el enclave. El interés que despierta este yacimiento ha hecho que diferentes autores apuesten por la investigación mediante arqueología virtual de algunos de los restos arqueológicos que se encuentran en el sitio.

El *Macellum* de Torreparedones cuenta con una infografía 3D en su fase III, realizada por Eduardo Guijarro (Morena et al., 2012) (Fig. I-6). Poco se sabe de la ejecución de la misma, puesto que solo se muestran dos imágenes en el artículo de investigación Morena et al., 2012, y la propia infografía insertada en el panel explicativo *in situ* en el yacimiento.

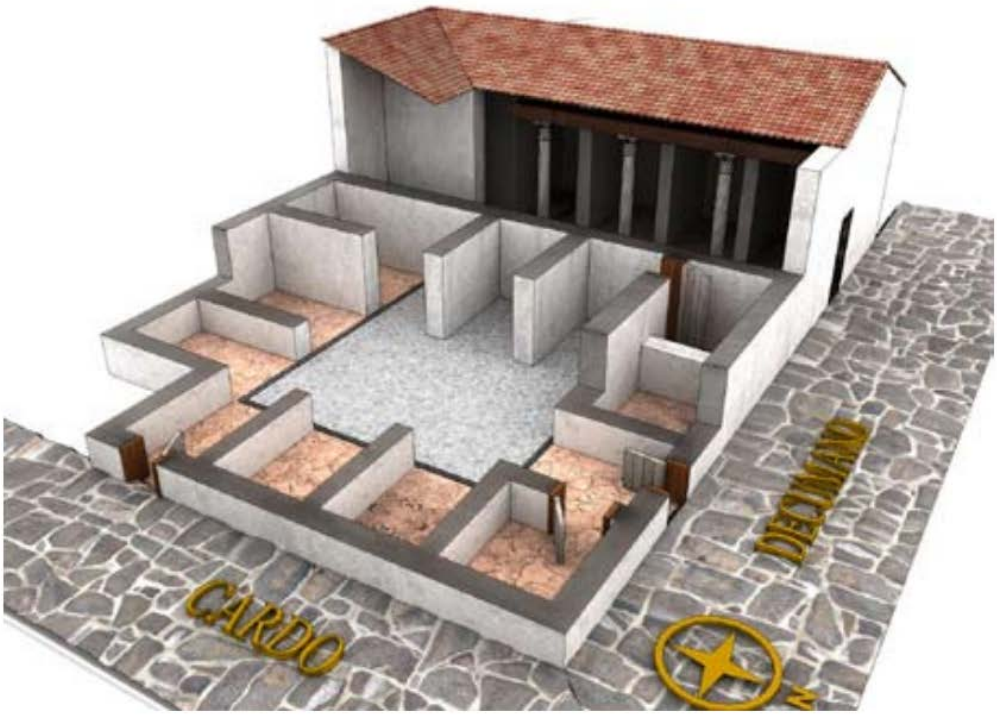

Fig. I-6. Infografía del Macellum del yacimiento arqueológico de Torreparedones, realizada por Eduardo Guijarro (Morena et al., 2012).

Por lo que respecta al Foro, Antonia Merino Aranda (2014) realizó una hipótesis de diseño de la curia y el templo, dado el estado de conservación de los edificios del lado oeste del Foro. Para la obtención de las vistas 3D de los edificios, esta autora realizó el cálculo dimensional teniendo como referencia los textos de Vitrubio, y los aplicó

mediante los softwares Autoad 2010 y SketchUp pro 8. El resultado de este trabajo consiguió la generación de información sobre dimensiones y accesibilidad de dos de los edificios más importantes del foro de Torreparedones (Fig. I- 7).

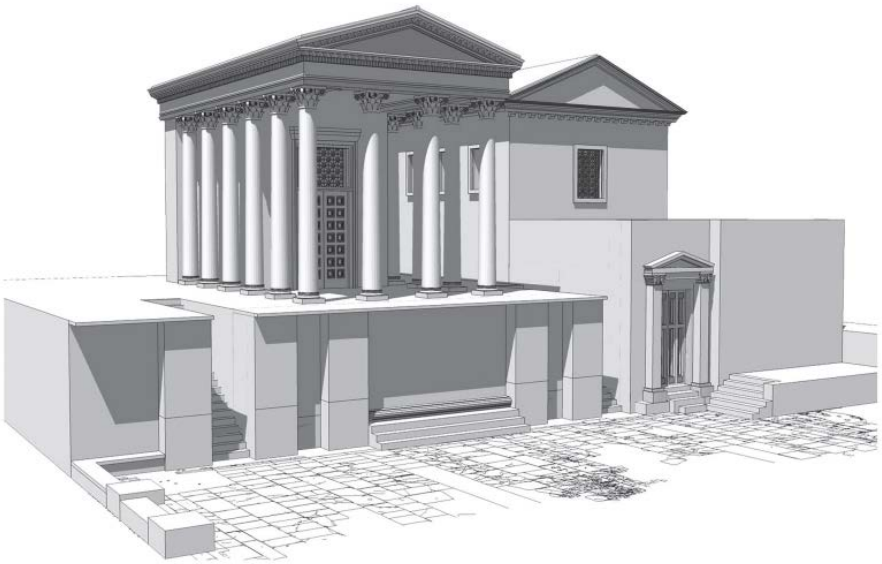

Fig. I-7. Hipótesis reconstructiva del Templo y la Curia del Foto de Torreparedones, realizada por Antonia Merino Aranda (Merino, 2014).

En la Curia, también han implementado Arqueología Virtual otros autores (Pericet et al., 2013-14). La reconstrucción de este edificio se realizó a partir de los datos obtenidos en las excavaciones, utilizando los softwares AutoCad 2012, Sketchup 8, Photoshop CS6 y Google Earth. El resultado fue un modelo que representa en la mayor medida posible la configuración original del edificio (Fig. I-8).

El Castillo Medieval de Torreparedones también cuenta con un trabajo de arqueología virtual. Éste buscaba el análisis geométrico y un escenario virtual interactivo (Porcuna-Bermúdez et al., 2016; Porcuna, 2017). Para ello, este autor utilizó los vestigios arqueológicos existentes y la tipología de otros castillos fronterizos con el Reino Nazarí de Granada. Tras la reconstrucción arquitectónica del Castillo, procedió al modelado 3D, mapeados y texturizados, tanto del terreno circundante y como de los elementos patrimoniales. Por último, aplicó las funciones de un motor gráfico para renderizar en tiempo real los modelados de la fortaleza y los eventos que se suceden en la escena. El

resultado fue la introducción al usuario en un ambiente informático artificial, consistente en mostrar en tiempo real una recreación interactiva en 3D de la hipótesis reconstructiva planteada (Fig. I-9).

Fig. I-8. Reconstrucción virtual de la Curia del yacimiento arqueológico de Torreparedones, llevada a cabo por Ana María Muñoz Rodríguez (Pericet et al., 2013-2014).

Fig. I-9. Reconstrucción virtual interactiva del Castillo Medieval de Torreparedones propuesta por Diego Porcuna Bermúdez (Porcuna-Bermúdez et al., 2016).

El resto de vestigios arqueológicos del yacimiento no cuenta con trabajos de arqueología virtual realizados o publicados. A continuación, se muestra la Tabla I-1 donde se expone cada bien patrimonial, si cuentan con arqueología virtual y de ser así, la referencia de las mismas. Mencionar que, la Casa del Panadero del yacimiento arqueológico de Torreparedones, dispone de la reconstrucción virtual llevada a cabo en la presente Tesis Doctoral, que será explicada en detalle en el Capítulo 2.

Tabla I-1

Identificación de vestigios arqueológicos, Arqueología Virtual y referencias.

Vestigios arqueológicos del yacimiento de Torreparedones	*Arqueología Virtual*	*Referencias*
Puerta Oriental	Publicación científica no conocida.	https://www.youtube.com/watch?v=BtPUDZX860k
Recinto amurallado	No conocida	
Santuario íbero-romano	Se ha llevado a cabo la reconstrucción *in situ* del edificio.	(Morena y Abril, 2013) https://www.youtube.com/watch?v=IsE8nOeK5S4
Foro romano	Reconstrucción virtual llevada a cabo en la Curia y el Templo.	(Merino, 2014; Pericet et al., 2013-14) https://www.youtube.com/watch?v=V1U_QSFXvog
Termas romanas de la Salud	Publicación científica no conocida.	https://www.youtube.com/watch?v=upQZlfP9fCU
Balneum	No conocida	
Macellum	No se conoce el proceso de reconstrucción, solo un par de infografías.	(Morena et al., 2012) https://www.youtube.com/watch?v=Mg-VKrMvZww
Casa del Panadero	Se aborda en la presente tesis.	(Cáceres-Criado et al., 2022).

Red viaria	No conocida	
Castillo de Casto el Viejo	Reconstrucción virtual y escenario interactivo realizado para este bien patrimonial.	(Porcuna-Bermúdez et al., 2016; Porcuna, 2017)
Ermita de las Santas Mozárabes	Publicación científica no conocida.	https://www.youtube.com/watch?v=E8hEJ7t_kOU
Necrópolis Oriental	Publicación científica no conocida.	https://www.youtube.com/watch?v=_Z0RvZsKFvI
Necrópolis Norte	Publicación científica no conocida.	https://www.youtube.com/watch?v=_Z0RvZsKFvI

I-1.4. Estado de la cuestión

La historiografía del yacimiento arqueológico de Torreparedones, así como el recorrido por la arqueología virtual y el uso de ésta en dicho yacimiento, resultan puntos de gran importancia a la hora de abarcar la presente tesis doctoral.

El yacimiento de Torreparedones resulta un enclave de gran interés histórico-arqueológico por su habitabilidad a lo largo de la historia. La importancia del sitio juega un papel fundamental de cara al estudio del yacimiento. Esto significa que la atención puesta en el enclave, mediante las excavaciones arqueológicas y la difusión de los resultados de las mismas, hacen atractivo el lugar para la implementación de arqueología virtual en los bienes patrimoniales presentes en el sitio.

Como se puede observar en la Tabla I-1, la mayor parte del patrimonio arqueológico recuperado en el yacimiento de Torreparedones cuenta con trabajos de Arqueología Virtual, concretamente, reconstrucciones virtuales. Aunque como curiosidad, hay que mencionar que, solo el 50% corresponden a trabajos de investigación indexados en revistas científicas. Esto significa que la mayoría de los trabajos realizados

no cuentan con metodología publicada y accesible para la comunidad científica o para el público en general. Por ello, resulta de gran interés la reconstrucción virtual de la Casa Panadero del yacimiento arqueológico de Torreparedones. La consecución de este objetivo busca el aumento del conocimiento del propio bien y, la creación y publicación/divulgación de una metodología aplicable a todas las reconstrucciones virtuales realizadas en el ámbito de la arqueología virtual.

Con el aumento del uso de las escalas de evidencia histórico-arqueológicas, se apuesta al trabajo con las mismas en la Casa del Panadero de Torreparedones. Hasta la fecha, este método de conocimiento no ha sido aplicado en las reconstrucciones virtuales realizadas en el yacimiento arqueológico objeto de estudio. Además del trabajo a realizar con las escalas de evidencia histórico-arqueológicas existentes, como la implementación y comparativa de las mismas, se busca la creación de una nueva propuesta probada en la reconstrucción virtual de la Casa del Panadero y, aplicable a la reconstrucción virtual de cualquier bien patrimonial independientemente del espacio-tiempo.

La Carta de Londres (London Charter, 2009) y la posterior Carta de Sevilla (López-Menchero y Grande 2011) constituyen documentos donde se establecen principios básicos para regular las prácticas en cuanto a Arqueología Virtual se refiere. Por tanto, son los principios por los que se rigen todos los trabajos realizados en esta tesis doctoral. La puesta en valor del trabajo arqueológico realizado en la reconstrucción virtual 3D de la Casa del Panadero, mediante la nueva propuesta de escala de evidencia histórico-arqueológica, abre paso a una nueva línea de investigación. Como se expone en el Principio 5 "Rigurosidad Histórica" de la Carta de Sevilla: "*El entorno, contexto o paisaje asociado a un resto arqueológico es tan importante como el propio vestigio arqueológico en sí*". Tras el uso de las escalas de evidencia, y teniendo en cuenta el Principio mencionado, se investiga en las metodologías utilizadas para la obtención de modelos digitales del terreno asociados a reconstrucciones virtuales. Esto contribuye a la aplicación de un nuevo método digital de estudio del paisaje, inexistente hasta la fecha. La escala de resolución asociada al terreno en las reconstrucciones virtuales, coopera con la mejora de los actuales procesos de investigación, conservación y difusión del patrimonio arqueológico mediante el uso de nuevas tecnologías.

I-2. OBJETIVOS

Esta tesis busca lograr la puesta en valor de la Escala de Evidencia Histórico-Arqueológica y la Representación del Terreno en las reconstrucciones virtuales, contribuyendo a la mejora del contexto, el paisaje y la evaluación de la veracidad en el discurso arqueológico. Para ello, se pretende alcanzar los siguientes objetivos:

- Identificar los espacios y la funcionalidad de la Casa del Panadero para su puesta en valor y difusión mediante la reconstrucción virtual 3D (O1).
- Implementar las escalas de evidencia histórico-arqueológicas existentes para comprobar la eficacia de las mismas en este bien patrimonial (O2).
- Crear una nueva propuesta de escala de evidencia histórico-arqueológica para su implementación factible en cualquier bien patrimonial, cuyo público objetivo sea el espectador (O3).
- Crear una propuesta de escala de resolución asociada al terreno para utilizarse en las reconstrucciones virtuales (O4).

I-3. ESTRUCTURA DE LA TESIS

La presente tesis se divide en siete capítulos, de los cuales, cuatro comprenden artículos publicados en diferentes revistas indexadas de impacto:

- *Digital Applications in Archaeology and Cultural Heritage* – Capítulo 2
- *Heritage Science* – Capítulo 3
- *Virtual Reality* – Capítulo 4
- *Journal of Cultural Heritage* – Capítulo 5

Capítulo 1: Introducción y objetivos. Estructura de la tesis.

Capítulo 2: Digital preservation and virtual 3D reconstruction of "The Baker's house" in the archaeological site of Torreparedones (Baena, Cordoba-Spain).

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

Capítulo 4: New approach for optimizing the interpretation and representation of the degree of historical-archaeological evidence in the virtual reconstructions.

Capítulo 5: Proposition for the graphic representation, interpretation and evaluation of the degree of terrain resolution in virtual reconstructions.

Capítulo 6: Summary, resumen y conclusiones generales.

Capítulo 7: Aportaciones del doctorando.

Los objetivos que se plantean en la tesis se acometen en los siguientes capítulos:

(O1) en el capítulo 2, publicado en la revista **Digital Applications in Archaeology and Cultural Heritage**: Cáceres-Criado, I., Triviño-Tarradas, P., Valderrama-Zafra, J. M., & García-Molina, D. F. (2022). Digital preservation and virtual 3D reconstruction of "The Baker's house" in the archaeological site of Torreparedones (Baena, Cordoba-Spain). Digital Applications in Archaeology and Cultural Heritage, 24, e00218. https://doi.org/10.1016/j.daach.2022.e00218

(O2) en el capítulo 3, publicado en la revista **Heritage Science**: Cáceres-Criado, I., García-Molina, D. F., Mesas-Carrascosa, F. J., & Triviño-Tarradas, P. (2022). Graphic representation of the degree of historical-archaeological evidence: the 3D reconstruction of the "Baker's House". Heritage Science, 10(1), 1-14. https://doi.org/10.1186/s40494-022-00670-0

(O3) en el capítulo 4, publicado en la revista **Virtual Reality**: Cáceres-Criado, I., García-Molina, D. F., Mesas-Carrascosa, F. J., & Triviño-Tarradas, P. (2022). New approach for optimizing the interpretation and representation of the degree of historical-archaeological evidence in the virtual reconstructions. Virtual Reality, 1-17. https://doi.org/10.1007/s10055-022-00707-6

(O4) en el capítulo 5, publicado en la revista **Journal of Cultural Heritage**: Cáceres-Criado, I., Triviño-Tarradas, P., Valderrama Zafra, J. M., & García-Molina, D. F. Proposition for the Graphic Representation, Interpretation and Evaluation of the Degree of Terrain Resolution in Virtual Reconstructions. Journal of Cultural Heritage, Pendiente de Publicación.

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CAPÍTULO 2.

Digital preservation and virtual 3D reconstruction of "The Baker's house" in the archaeological site of Torreparedones (Baena, Cordoba-Spain)

Artículo:

Cáceres-Criado, I., Triviño-Tarradas, P., Valderrama-Zafra, J. M., & García-Molina, D. F. (2022). Digital preservation and virtual 3D reconstruction of "The Baker's house" in the archaeological site of Torreparedones (Baena, Cordoba-Spain). Digital Applications in Archaeology and Cultural Heritage, 24, e00218.

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CAPÍTULO 2. Digital preservation and virtual 3D reconstruction of "The Baker's house" in the archaeological site of Torreparedones (Baena, Cordoba-Spain)

II-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 (London Charter, 2009).

From the year 1980, the first virtual reconstructions appeared, with the emergence of the three-dimensional (3D) model (Gómez and 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 and 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 (Reilly, 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 and 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 and 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 et al., 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 and Quirosa, 2009; Carreras Monfort, 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 (London Charter, 2009), which establishes the

principles and criteria to measure the quality of projects related to virtual archaeology (López-Menchero and Grande, 2011).

Nowadays, multiple techniques are used in the scope of virtual archaeology (Pavlidis et al., 2007; Gomes et al., 2014; Katz and Tokovinive, 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 and Gibson, 2017).

Over time, virtual reconstructions have advanced, becoming a usual tool in archaeology (Rodríguez-Hidalgo, 2010; Zollh¨ofer 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 and 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; Selmanovíc et al., 2020; Galasso et al., 2021). Thanks to the use of new technologies, archaeology is thriving and growing (Rua and 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 (Albaladejo, 2019; Cerrillo et al., 2019; M´endez, 2020), ceramic material culture (Ruiz and García, 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 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.

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.

II-2. MATERIAL AND METHODS

II-2.1. Materials

II-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, Manuel Moreno Alcaide, Manuel Cobo 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, E-26, E-28, E-31, E-37, E-38. Fig. II-1 shows the numbered spaces of the *domus*, whereas Table II-1 shows the interpretation of the rooms and their surface area.

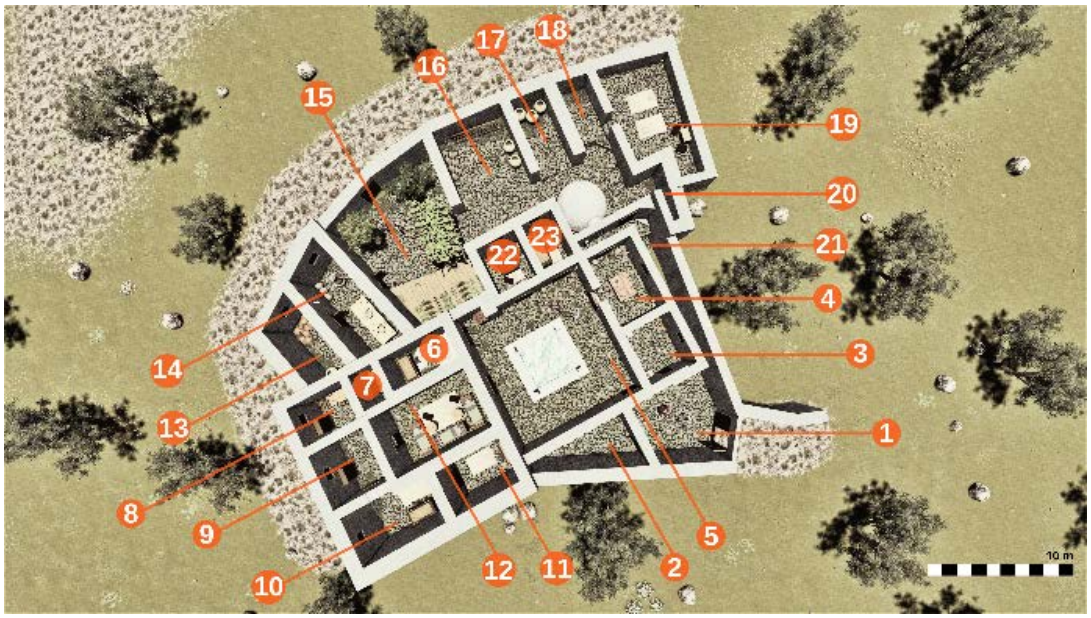


Fig. II-1. Identification of the rooms of the domus.

Table II-1

Identification, interpretation and surface area of the rooms shown in Figure II-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

II-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.

II-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 and Rodney Harrison, 2020).

Once the field work was finished, the desk work was carried out. The field work had two phases: modelling and texturing. The modelling of the building was based on the photogrammetry carried out by Massimo Gasparini after the archaeological work (Research Group HUM-882 "Ancient Cities of Andalusia" of the University of Córdoba). The planar sections were obtained using the 3DReshaper software (Fig. II-2) (García-Molina et al., 2021), which served as the basis for the beginning of the modelling using the SketchUp 2019 software. Once the d*omus* and all the elements present were rebuilt the second and final phase began, the application of textures. The SketchUp 2019 and the LumenRT software's were utilized in order to provide the model with realistic surfaces.

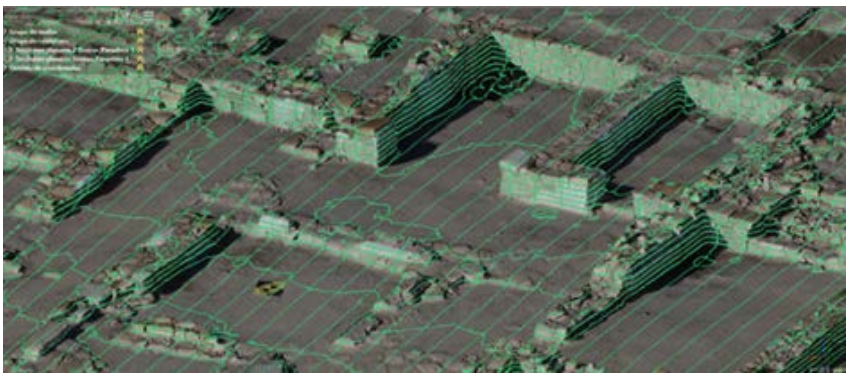


Fig. II-2. Planar sections obtained from the photogrammetry using 3DReshaper (developed by the author).

The explanation and dissemination of the cultural Heritage comes into play after the completion of the reconstruction work, A QR code was generated to make the virtual reconstruction available to all society, in which people can see a video of each part of the *domus* of the Baker's house is explained.

Table II-2 summarizes all the study phases to carry out the virtual reconstruction of such a heritage asset.

Table II-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.

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 and Grande, 2011): interdisciplinarity, purpose, complementarity, authenticity, historical rigour, efficiency, economic and technological sustainability, scientific transparency, education and evolution.

II-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 and Fritsch, 2018; López et al., 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 (Fig. II-3).

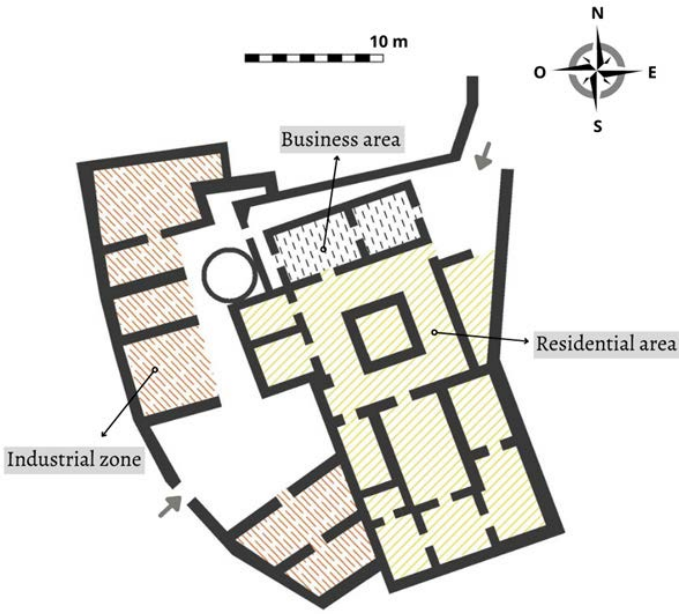
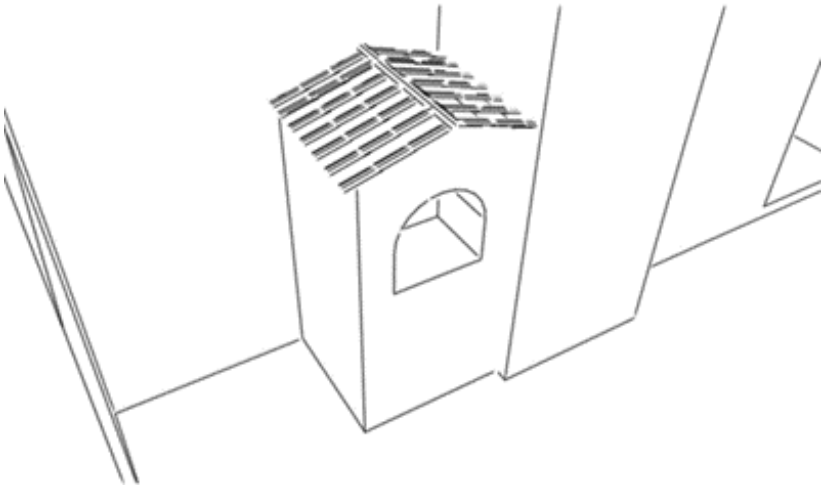


Fig. II-3. Ground plan of the *domus*. Zoning by purpose.

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* (Ruiz, 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 (Fig. II-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 (Ballesteros, 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

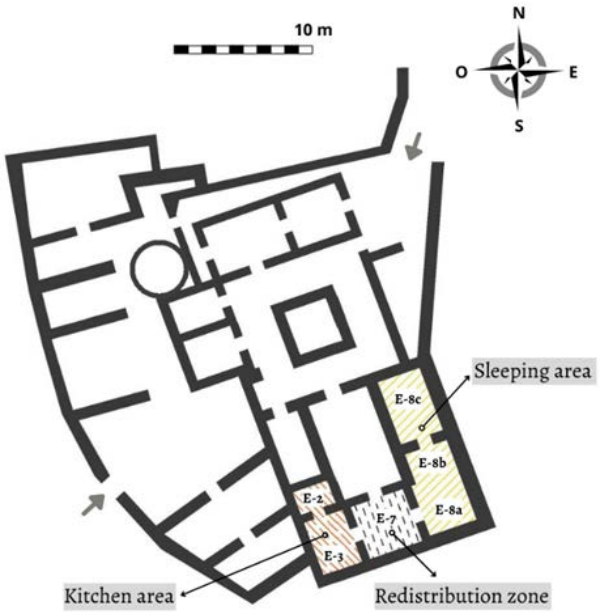
Fig. II-4. a) Recreation of the *lararium* of the Roman *domus* of Torreparedones; b) Detailed view of the *atrium* and the *lararium* in the virtual reconstruction.

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 × 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* (Fig. II-5). Likewise, Balanz´a (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 (Carrascosa, 2019). Therefore, the E-7 space could be a passing zone since it allows access to the pantryand 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

Fig. II-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 (Vegas 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 and 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 (Mezquíriz, 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 × 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 (Fig. II-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 and Sanz, 1787).

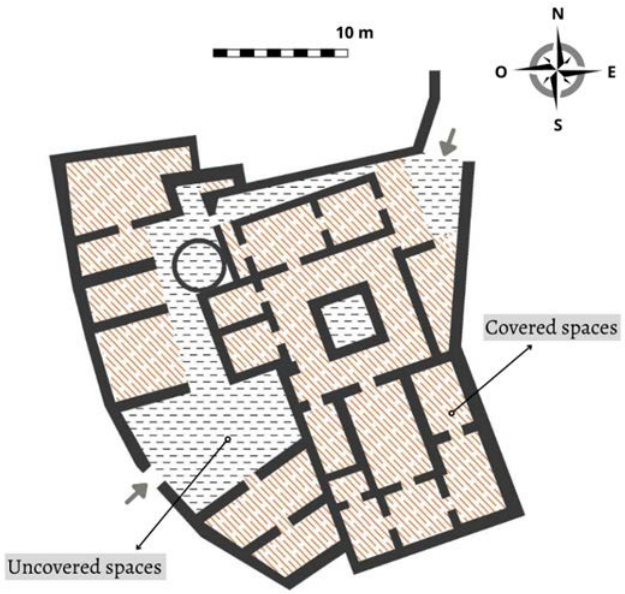
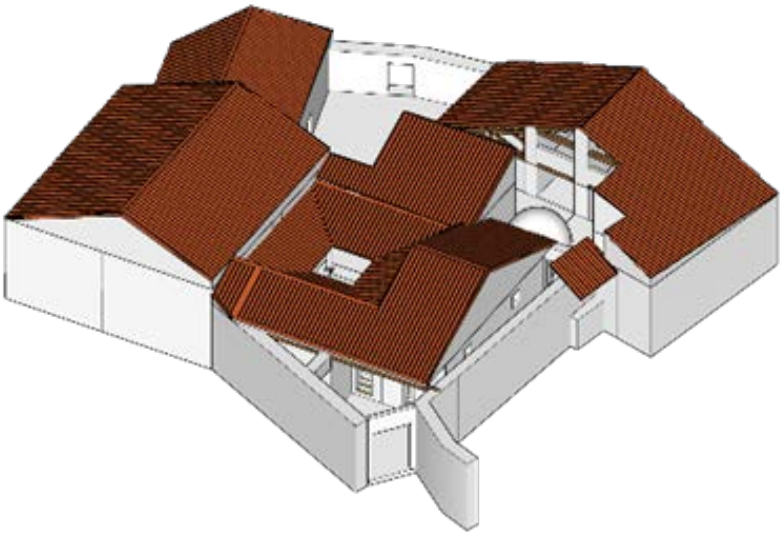


Fig. II-6. Ground plan of the *domus* with the identification of covered spaces and uncovered spaces.

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 Fig. II-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

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

All the doors 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. Agudo (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) (Díaz 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 (Fig. II-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, wherethe pavement preserved in this space was reconstructed.

Fig. II-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* (Fig. II-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 Balanza 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).

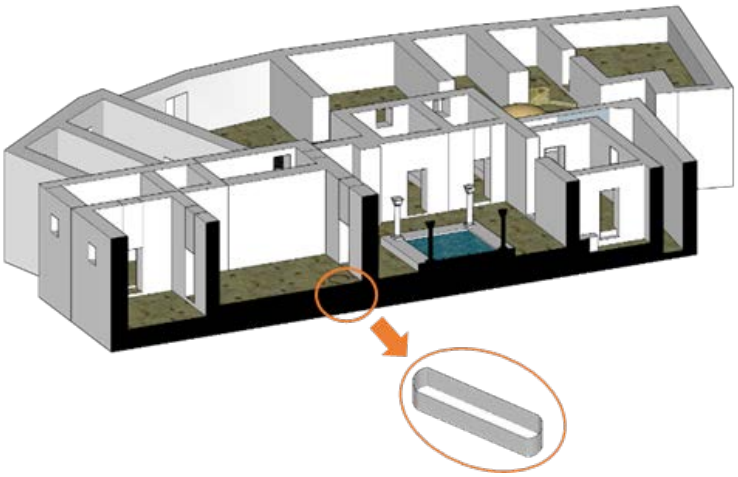


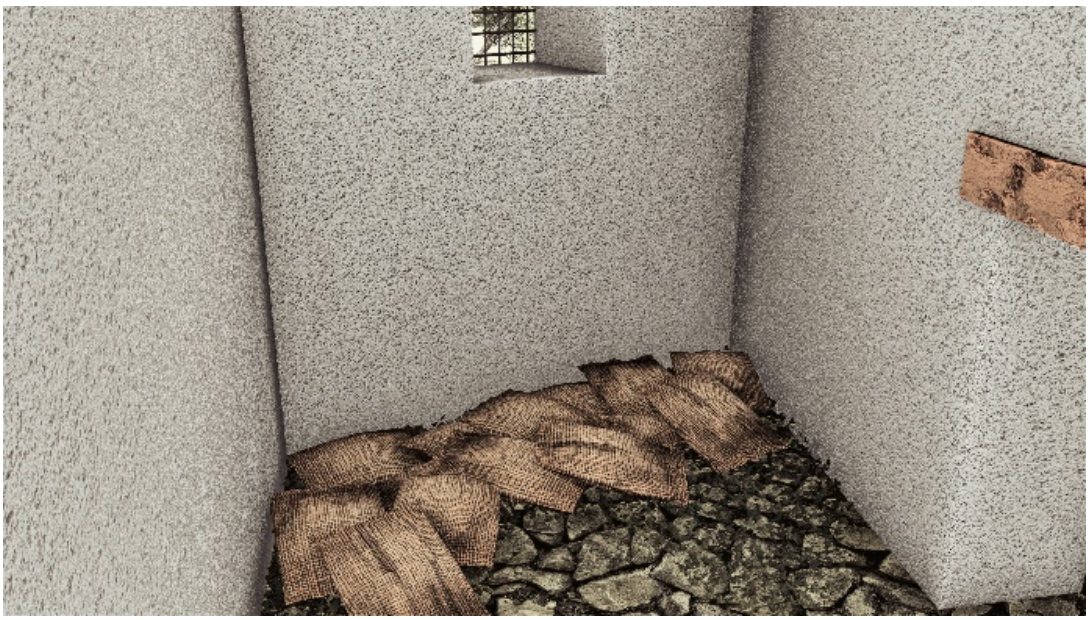
Fig. II-9. Horizontal and vertical section of the 3D model with the location of the water tank.

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 (Fig. II-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 (Ortiz, 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.

a



b

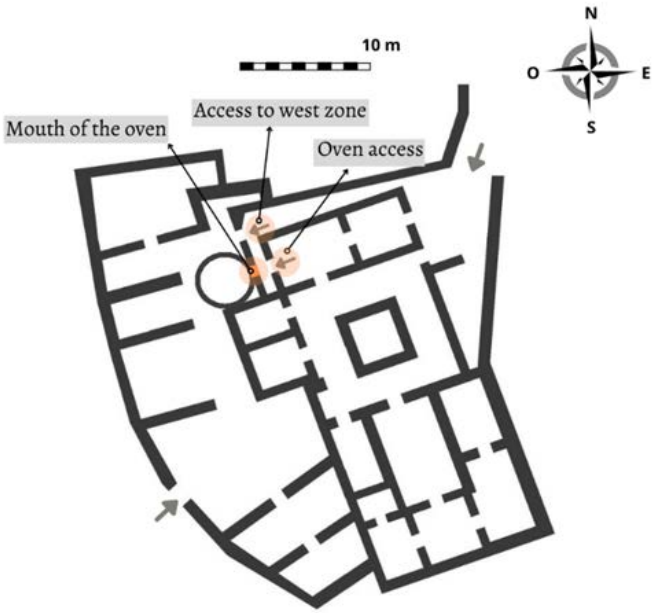
c

d

Fig. II-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 (Fig. II-11).

a



b

Fig. II-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 (Becerril, 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. (Becerril, 2007) (Fig. II-12).

a

b

c

Fig. II-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 (Fig. II-13), which allows visualising the virtual 3D reconstruction of the *domus*.

Fig. II-23. QR code

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).

II-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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CAPÍTULO 3.

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

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

III-1. 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.

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. Tus, 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].

III-1.1. 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]. Tis 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 Cliford, 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. Tis 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.

III-1.2. Research aim

Te 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.

III-2. MATERIAL AND METHODS

III-2.1. 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 III-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.

Table III-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

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. III-1): obtaining the 3D virtual reconstruction; application of the historical-archaeological evidence scale; obtaining the percentage values; and its diffusion.

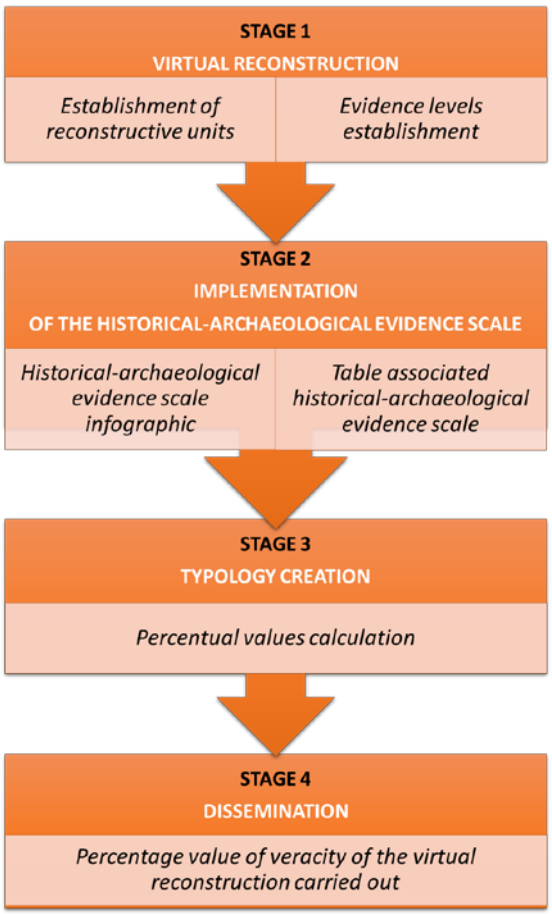

Fig. III-1. Methodology working phases.

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 III-2), Percentage values are obtained by dividing the total sum area of each rank by the total area of the *domus*.

Table III-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%

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.

III-2.2. 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. III-2).

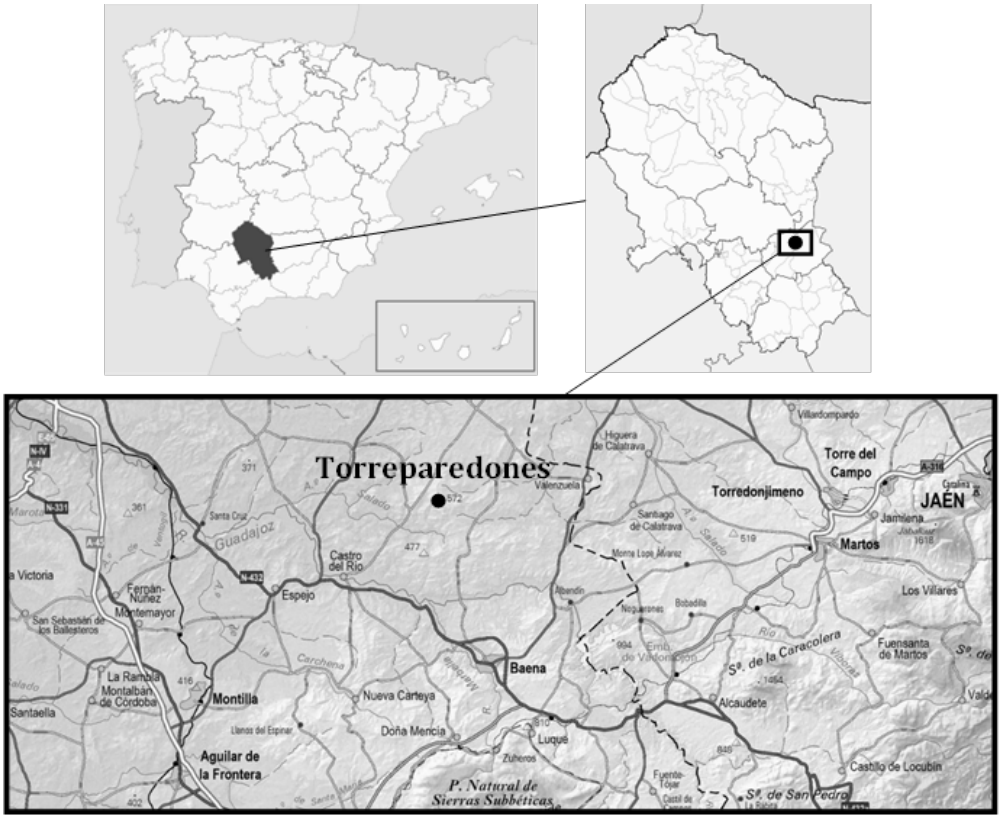

Fig. III-2. Location of the Torreparedones archaeological site.

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 Baker's House. (Fig. III-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 software's were used: 3DReshaper, SketchUp and LumenRT.

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

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 (interdisciplinary, 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. III-4).

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

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.

III-3. 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.

The historical-archaeological evidence scale that resulted from the *domus* of Torreparedones has 31 RUs (Fig. III-5). Different RUs were used for different elements, even though they are identified with the same colour. Table III-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.

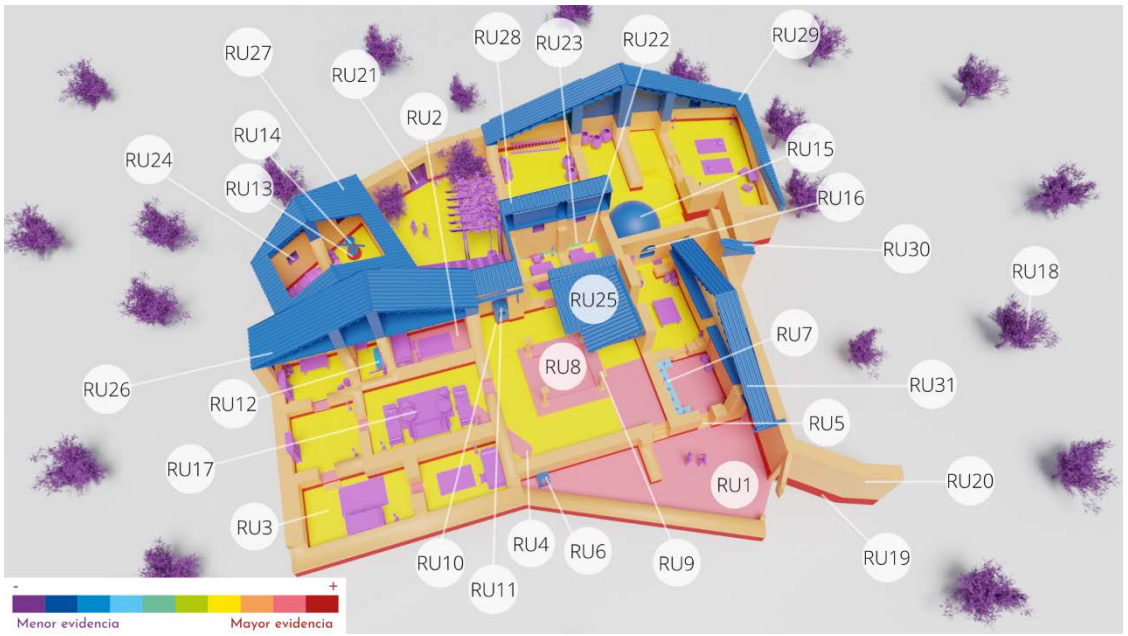

Fig. III-5. Infographic obtained from the 3D model of the 'Baker's House' for the historical-archaeological evidence scale implementation.

Table III-3

Identification of the RUs and evidence levels associated with Figure III-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.

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'.

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. III-6). The rest of the *domus* does not present any type of paving, and, for the virtual recreation, the first technique mentioned was chosen. Tus, 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.

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

The Baker's House has "*a bagnarola*" water tank (RU4), 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]. Tis structure is fully preserved, although it should have a paved cover system given its location. Tis 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]. Tis 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 (RU13), which appears to correspond to the base of a rotatory mill [30]. Tis structure is preserved according to its original form (Fig. III-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 upside down one over the other, grinding the grain with the friction between them [45, 46].

Fig. III-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).

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 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]. Tis 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 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 (RU24) (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 *tablinum* (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 III-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 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.

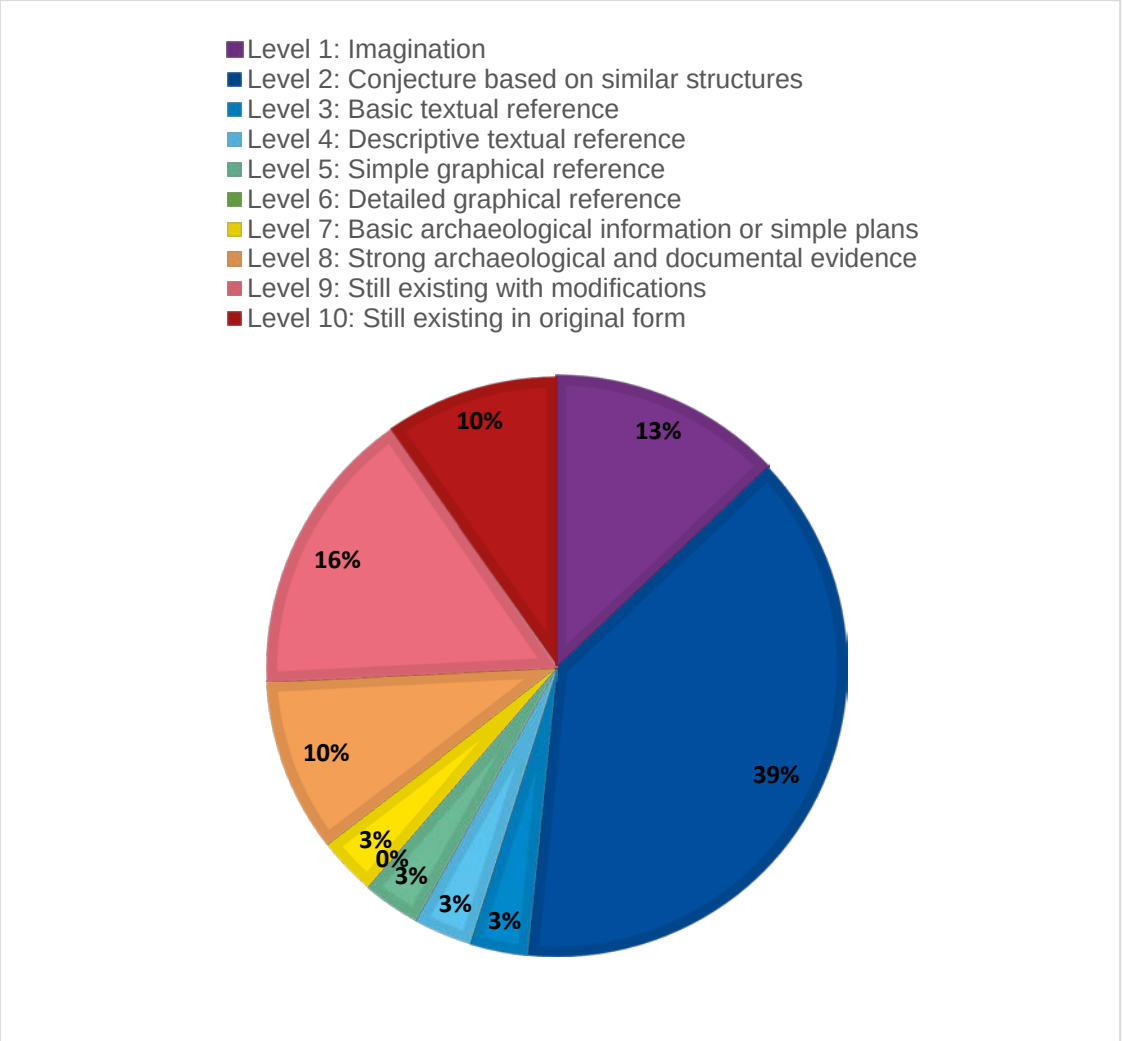

Fig. III-8. Percentage values obtained from the implementation of the historical-archaeological evidence scale of the domus of the Baker's House'.

III-4. 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 proposes, 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. Tis 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). Tis 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 refect 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.

III-5. CONCLUSIONS

The representation of archaeological remains exists practically since the origin of archaeology. Tis 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.

Tis 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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CAPÍTULO 4.

New approach for optimizing the interpretation and representation of the degree of historical-archaeological evidence in the virtual reconstructions

Artículo:

Cáceres-Criado, I., García-Molina, D. F., Mesas-Carrascosa, F. J., & Triviño-Tarradas, P. (2022). New approach for optimizing the interpretation and representation of the degree of historical-archaeological evidence in the virtual reconstructions. Virtual Reality, 1-17. https://doi.org/10.1007/s10055-022-00707-6

CAPÍTULO 4. New approach for optimizing the interpretation and representation of the degree of historical-archaeological evidence in the virtual reconstructions

IV-1. INTRODUCTION

In the archaeological scope, virtual reconstruction plays a fundamental role as a research tool (Machete et al. 2021; Moskvin et al. 2021; Rebec et al. 2022). Regarding the interpretation of heritage, the historical-archaeological evidence scale designates the representation of the degree of veracity of virtual reconstructions through the use of colours.

To date, three historical-archaeological evidence scales have been used in the scientific literature: (1) the pioneering proposition, i.e., the historical-archaeological evidence scale developed in the Byzantium 1200 project (http:// www. byzantium1 200. com/); (2) the proposition of Aparicio and Figueiredo (Aparicio and Figueiredo 2017); and (3) the more recent proposition used for the reconstruction of the Mosque-Cathedral and river landscape of Córdoba (Spain) (Ortiz et al. 2018).

The first two propositions of historical-archaeological evidence scale are distinguished by the fact that their evidence levels (10 levels in total for both) are inverted with respect to each other. For the proposition developed in the Byzantium project, the evidence levels are ordered from greater to lower veracity (http:// www. byzan tium1 200. com/), whereas the scale proposed by Aparicio and Figueiredo is ordered from lower to greater levels of historical-archaeological evidence (Aparicio and Figueiredo 2017; Aparicio 2016; Aparicio et al. 2021). Although the levels were inverted, their colours were not modified, and thus they have a very similar colour range of warm and cool colours. However, the third proposition uses a colour range from dark greens to browns, with eight levels of historical-archaeological evidence (Ortiz et al. 2018).

Table IV-1 shows the bibliometric study conducted on the implementation of the historical-archaeological evidence scales throughout history. Each of the existing propositions of representation scales uses specific colours. Behavioural scientists have

reported that colour affects the reactions of the human organism, produces certain physiological reactions, creates emotional states and draws attention (Sierra et al. 2000).

Table IV-2

Bibliometric study on the implementation of the existing historical-archaeological evidence scales.

Reference	*Applied scale*	*Item*	*Levels*	*Chromatic gradation*
http://www.byzantium1200.com/ (Byzantium 1200)	Byzantium 1200 project	Byzantium city around 1200	10	From warm to cool colours (greater evidence-lower evidence)
Aparicio 2016	Aparicio & Figueiredo	The crenellated tower of San García, Algeciras (Spain) (17^{th}-18^{th} century). Virtual recovery of a military structure using technology	10	From cool to warm colours (lower evidence-greater evidence)
Aparicio and Figueiredo 2017	Aparicio & Figueiredo	The historical-archaeological evidence degree of virtual reconstructions: toward a graphic representation scale	10	From cool to warm colours (lower evidence-greater evidence)
De Mota and Valle 2018	Aparicio & Figueiredo	Archaeology of the military orders in Castilla-La Mancha and the virtual reconstruction of its heritage	10	From cool to warm colours (lower evidence-greater evidence)
Ortiz et al. 2018	COR_16	Proposal for the improvement and modification of the scale of evidence for the virtual reconstruction of cultural heritage: A first approach to the Mosque-Cathedral and the river landscape of Córdoba (Spain)	8	Colour range from greens to browns
Rodríguez-Hernández et al. 2021	Aparicio & Figueiredo	Virtual 3D reconstruction of the "Fortified tower" of the Ulaca Oppidum (Solosancho, Ávila, Spain): much more than an image	10	From cool to warm colours (lower evidence-greater evidence)
Aparicio et al. 2021	Aparicio & Figueiredo	Virtual 3D reconstruction of Gauzón Castle (Castrillón, Principado de Asturias, Spain)	10	From cool to warm colours (lower evidence-greater evidence)

Cáceres-Criado et al. 2022	Aparicio & Figueiredo	Graphic representation of the degree of historical-archaeological evidence: the 3D reconstruction of the "Baker's House"	10	From cool to warm colours (lower evidence-greater evidence)

Most experts agree that it is ideal to reflect the degree of historical-archaeological evidence in the virtual representation of a heritage asset, for the sake of clarity and authenticity. The graphic representation of the degree of historical archaeological veracity, with a new proposition of evidence scale, considers the objectives set in projects conducted in the scope of virtual archaeology (López-Menchero and Grande 2011; SEAV 2011; http:// www. londo nchar ter. org/).

IV-1.1. Literature review

Previous studies have carried out the virtual reconstruction of the Baker's House, at the archaeological site of Torreparedones (Baena, Córdoba, Spain) (Cáceres-Criado et al. 2022a, b). This heritage asset, as is indicated by its name, is characterised by the presence of the base of a Roman bread oven, as well as the foundation of what could have been a rotatory mill (Morena et al. 2016, 2019). It has three constructive phases: late Republican Roman phase; late Imperial Roman phase; and Modern-Medieval phase. The virtual reconstruction is focused on the second phase (late Imperial Roman phase).

For the correct dissemination of the scientific work performed in this Roman house, the historical-archaeological evidence scale was considered a key element. The debate was about which of the propositions of historical-archaeological evidence scales would be the most suitable for the graphic representation of the archaeological remains found. The existing propositions were compared by implementing them in a specific area of the Baker's House (Cáceres- Criado et al. 2022). Pending to be published in lectures Notes in Mechanical Engineering). Based on the amount of reconstructive units presented by the virtual reconstruction, the results of such study showed that the best option was the proposition of Pablo Aparicio and César Figueiredo (Cáceres-Criado et al. 2022a, b).

At this point, a question emerged, which motivated the present study. The scientific character of the evidence scale raises doubts about its objective: Is the evidence scale designed only for experts in the field of archaeology or is it aimed at the viewers of the archaeological sites?

The creation of a new proposition of evidence scale is considered appropriate to attain a visual representation scale that can be easily employed and understood by any type of viewer. To this end, it is fundamental to reduce the evidence levels and the modification of their colours. Moreover, previous studies provide data that support the creation of the new proposition.

Furthermore, one step further would be to understand evidence scaling as a technique for evaluating virtual reality systems. The virtual reconstruction of a heritage asset together with the infographic of the scale of evidence helps with the visual interpretation of the veracity of the work carried out. This topic could be included in the so-called Museums of the twenty-first century, where users would learn about the heritage asset and the 3D reconstruction work, for example, with virtual reality screens (Puig et al. 2020; Baradaran-Rahimi et al. 2022; Scavarelli et al. 2021; Hammady et al. 2021).

IV-2. RESEARCH AIM

The present study aims to disseminate archaeological work through the use of a new proposition of historical-archaeological evidence scale. This proposition is supported by a quantitative and qualitative analysis made for the 'Baker's House' at the archaeological site of Torreparedones.

The main objective of this study was to generate a proposition of historical-archaeological evidence scale for the virtual reconstructions as a universal, understandable and applicable criterion for both experts and viewers in general. The aim is to provide the public with greater understanding of both the archaeological heritage and the scientific work conducted in the heritage assets.

IV-3. METHODOLOGY

The present work was conducted in three methodological phases (Fig. IV-1): comparison of the existing historical-archaeological evidence scales; creation of the new historical-archaeological evidence scale; and implementation of the new proposition of historical-archaeological evidence scale.

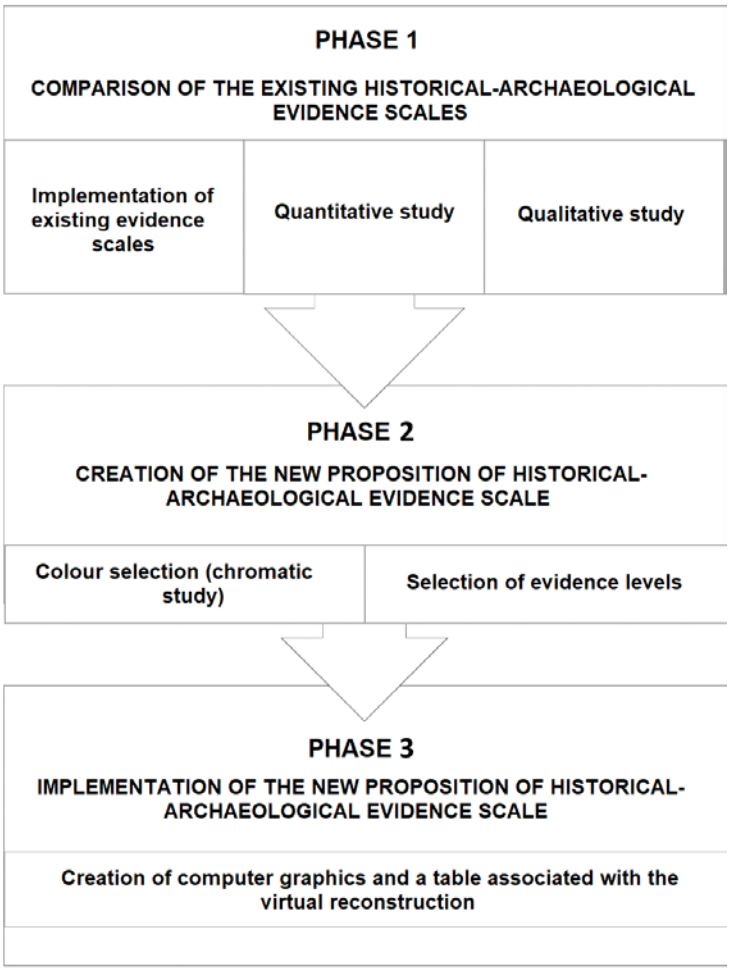


Fig. IV-1. Methodological phases.

Regarding the first phase of the study, it is important to take into account that the creation of a new proposition of historical-archaeological evidence scale is based on the existing historical-archaeological evidence scales. After knowing these, they are compared with each other in order to establish common criteria and differences. As was previously mentioned, the building in question already has a virtual 3D reconstruction (Cáceres-Criado et al. 2022a, b), in which the evidence scale proposed by Pablo Aparicio

and César Figueiredo (Cáceres-Criado et al. 2022a, b) was implemented (Fig. IV-2). The comparison of the existing evidence scales required the attainment of computer graphics of the heritage asset from each of the propositions. To this end, the rest of the scales were implemented in the Baker's House at the archaeological site of Torreparedones (Figs. IV-3 and IV-4).

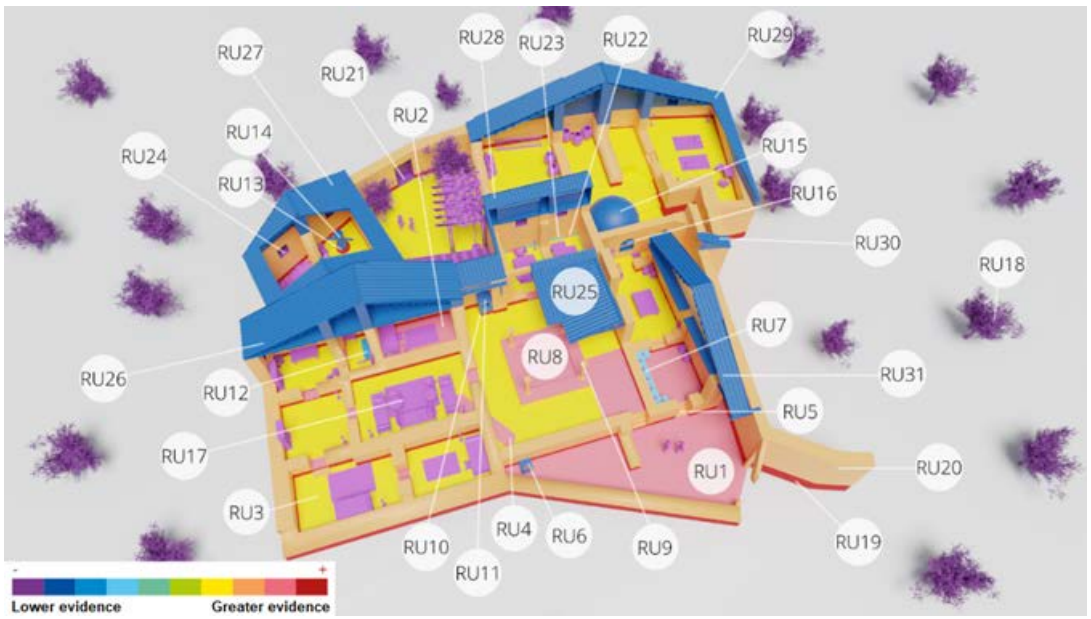


Fig.IV- 2. Application of the evidence scale proposed by P. Aparicio and C. Figueiredo in the Baker´s House virtual reconstruction.

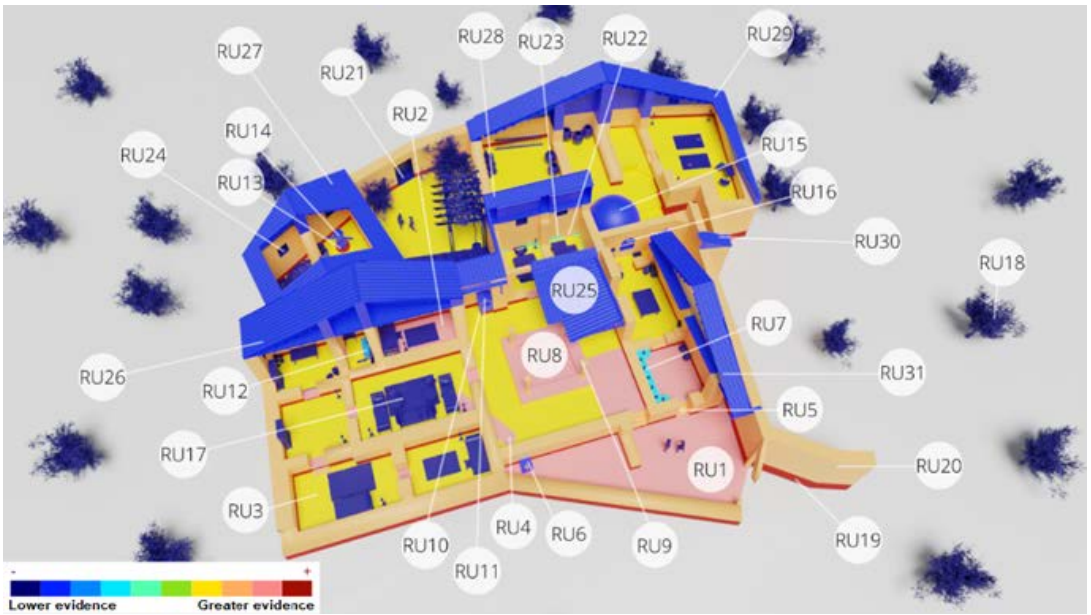


Fig. IV-3. Application of the evidence scale proposed in the Byzantium 1200 project in the Baker´s House virtual reconstruction.

Fig. IV-4. Application of the evidence scale proposed by Ortiz et al. in the Baker's House virtual reconstruction.

In the first phase of this study, and based on the existing propositions of historical-archaeological evidence scales, a quantitative study was performed as a result of the Topical Seminar 'Scientific Representation in Archaeology through the Use of Digital Technologies': Implementation of evidence scales in the Mosque-Cathedral of Córdoba and in Gauzón Castle', which was held on March 4th 2022 at the University of Córdoba. This totally anonymous study was carried out on-line and face-to-face, depending on the modality chosen by each attendee. The questionnaire consisted of 18 closed questions (In Table IV-7 "Appendix"), which were answered after receiving the information presented by Pablo Aparicio and Rafael Ortiz.

The answers obtained in the questionnaire were statistically analysed, which is why information about gender, age and education was gathered. The mean of these answers was calculated and an analysis of variance (ANOVA) was performed to compare the variances between the means of the 'gender', 'age' and 'education' categories in each of the questions proposed in the questionnaire.

Moreover, before the Topical Seminar, a meeting was held with professionals of this professional category (archaeologists) with the aim of solving doubts about the propositions of historical-archaeological evidence scales. After explaining the propositions, since many of the attendees did not know about their existence, questions were asked to Pablo Aparicio and Rafael Ortiz in an interview at the mentioned seminar (In Table IV-8 "Appendix").

The aim of the second phase of the study was to assign colours and evidence levels for the new proposition, which required a thorough search for bibliographic material related to the symbology of the colour associated with people. From this bibliographic search regarding colour assignment for the new scale proposition, it was observed that colours with greater wave length (e.g., red and orange) cause a greater physiological activation than green (Díez et al. 2000; Wilson 1966). This is frequently described as a stimulating, energetic and vital colour. On its part, yellow is less exciting than red (Schaie and Heiss 1988), being associated with vitality, mirth and fun (Sharpe 1974). In regard to the colour green, its excitation potential is more limited (Schaie and Heiss 1988), being associated with safety, comfort, calmness, quietness, youth and freshness. The coolest colour of the chromatic wheel is blue, and the preference for it is thought to indicate good control over emotions and behaviours (Díez et al. 2000).

A recent study conducted in Spain about the emotional connection with colour shows the concepts associated with each colour (Bazán 2018; Corbin 2017), including the following:

- Blue: tranquility, calmness, peace, serenity, stillness, relaxation, quietness, harmony and well-being.
- Green: mirth and life, tranquility, serenity, relaxation, quietness, calmness, peace and hope.
- Red: strength, passion, mirth, life, energy, love, heat, intensity, vitality, optimism, beauty, emotion, power, fire, dynamism, self-esteem, action, revolution and struggle, effort and excitement.

- Purple: serenity, tranquility, peace, relaxation, calmness, mirth and happiness, balance, harmony, wellbeing, women, femininity, freedom, beauty, profoundness, transformation and spirituality.
- Yellow: mirth, fun, light, luminosity, life, liveliness, energy, positivity, good vibes, heat, warmth, tranquility, peace, optimism and happiness.
- Orange: mirth, optimism, fun, energy, strength, vitality, life, liveliness, spark, creativity, warmth, heat, showy, intensity, cheerfulness and sympathy.

In addition to the meaning of the colours, several studies show that the preferences for them change throughout life (Dittmar 2001; Mohebbi 2014; Terwogt and Hoeksma 1995). This could be attributed to the alterations in the discrimination of colours and also to the decrease in the functions of the mechanisms present in sight with ageing (Dittmar 2001). The change in colour preferences in older people could be attributed to the alterations in the discrimination of colours and in visual images, the yellowing of the lens and the decrease in the function of the blue cone mechanism with ageing.

After selecting the colours and evidence levels for the new proposition, the last phase of the study was conducted. These colours and evidence levels were implemented in the virtual 3D reconstruction of the Baker's House, obtaining computer graphics of the virtual model and a table associated with such graphics presenting information of the evidence levels that correspond to each reconstructive unit.

IV-4. RESULTS AND DISCUSSION

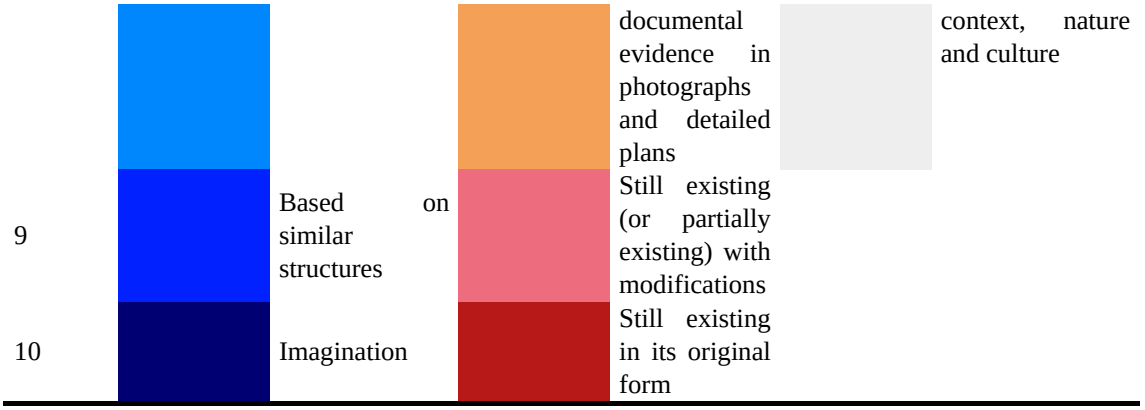
The representation of the degree of historical-archaeological evidence of the 'Baker's House' through a new scale proposition required the comparison of the existing evidence scales. Their implementation in the Baker's House provided results of their use in this heritage asset (Table IV-2). On the one hand, the scale proposed in the Byzantium 1200 project (http:// www. byzamtium1 200. com/) is closer to the proposition of Aparicio and Figueiredo (2017) than to that of Ortiz et al. (2018). It could be said that the second proposition is more recent than the first proposition and, thus, it is an improved version of it. Their colour range is quite similar and, in both scales, warm colours represent greater

historical-archaeological evidence, whereas cool colours represent lower evidence. Both scales are very visual, and each of the evidence levels is easily identified. Regarding the third proposition (Ortiz et al. 2018), it is visually very different from the other two propositions. The colour range is different, and the reduction of the evidence levels is observed in the computer graphics, showing less colours. Visually, the evidence levels are not so easily distinguishable, due to the similarity between their colours, unlike in the other two propositions.

Table IV-2

Identification of the evidence levels, colours and definition of the propositions of historical-archaeological evidence scales.

Level of evidence	*Colour Byzantium 1200*	*Definition Byzantium 1200*	*Colour Aparicio and Figueiredo (2017)*	*Definition Aparicio and Figueiredo (2017)*	*Colour Ortiz et al. (2018)*	*Definition Ortiz et al. (2018)*
1		Exists in its original form		Imagination		Still existing in its original form
2		Partially or with modifications		Conjecture based on similar structures		Still existing with modifications
3		Photographs or plans available		Basic textual reference		Detailed graphical evidence
4		Archaeological information		Descriptive textual reference		Slight graphical evidence
5		Detailed graphical evidence		Simple graphical reference		Archaeological hypothesis
6		Simple graphical evidence		Detailed graphical reference		Textual evidence
7		Textual and comparative evidence		Basic archaeological information or simple base plans		Based on similar structures
8		Textual evidence		Strong archaeological and		Based on historical



Regarding the colours used in the pioneer scale (http://www. byzantium1 200. com/) and in the proposition of Aparicio and Figueiredo (2017), several observations emerged. Firstly, the colours selected are not pure, that is, their value and intensity are altered as they are mixed with achromatic colours (white and black). These colours identified as pastel colours stand out less, despite corresponding to warmer colours. For instance, by mixing orange with white, this colour loses purity and thus yellow stands out over orange, in spite of the fact that the latter is warmer. Likewise, the use of pink in the historical-archaeological evidence scale would alter the colour range, since pink results from modifying the intensity of the colour red. Lastly, regarding the proposition of Aparicio and Figueiredo (2017), the colour purple does not allow the proposed evidence scale to go from cool to warm colours, since purple is not a cool colour. Purple results from mixing the primary colours blue and red, which would imply inverting the chromatic circle, obtaining a scale of warm to cool colours.

Moreover, from the proposition of Ortiz et al. (2018), it is worth mentioning that the colour palette used is too large and difficult to understand for the users who are not familiarised with colour theory. By modifying the attributes of the colours, the proposition of evidence scale is little intuitive, since it uses atypical colours that result from the mixture of primary and secondary colours. To sum up, it is a much personalised palette and, thus, it is poorly universal.

The evidence levels also show differences between the propositions. Firstly, the evidence levels of the pioneer proposition (http:// www. byzantium1 200. com/) and the proposition of Aparicio and Figueiredo (2017) are quite similar. The difference lies in the fact that the Byzantium project orders the levels from higher to lower veracity, whereas the second proposition orders them from lower to higher evidence level. Although the levels are ordered in the opposite manner, the colours associated with them are the same for both propositions, with the warmer colours corresponding to greater evidence and the cooler colours corresponding to lower evidence. Regarding the evidence levels proposed by Ortiz et al. (2018), there are significant differences with respect to the previous propositions. In this case, the authors reduced the levels from 10 to 8, ordering them from greater to lower historical-archaeological evidence. Moreover, another difference lies in the veracity levels aimed at the archaeological hypotheses. Ortiz et al. (2018) associate them with lower veracity compared to the graphic evidence, whereas the two previous propositions associate the archaeological hypotheses with greater veracity compared to the graphic evidence.

As was previously mentioned, and as a result of the Topical Seminar held in the University of Córdoba, a live interview was carried out with Pablo Aparicio and Rafael Ortiz. Different aspects are worth highlighting from such interview. Firstly, Aparicio and Ortiz consider each other's propositions to be correct, and they answered most of the questions with similar answers. They both thought about the same type of audience when they created their propositions of evidence scales, i.e., both experts of the discipline and the general public. This is different from the selection of colours, since, although both of them considered all types of audience, the interpretation of the colours from all viewers is different for each proposition. While the colours used by Pablo Aparicio are focused on the use of the chromatic wheel, Ortiz et al. (2018) use a more difficult palette in terms of colour theory. Furthermore, according to Pablo Aparicio, the works that implement their proposition of evidence scale and its corresponding colours show its validity not carry out independent studies in the Mosque-Cathedral, thus they could only validate the evidence levels and the corresponding colours of their proposition in said heritage asset.

Although each author has implemented the scale in a larger or smaller number of scopes, they both agree that their scales are being used with increasing frequency to support virtual reconstructions, and they also know that they are being used in other countries. Lastly, it is worth highlighting that they both agree that this research field should be taught in subjects at universities, and they are doing everything they can to disseminate it, both in their workplace and through teaching.

Additionally, as a result of said Topical Seminar, the questionnaire was administered and completed, with the participation of 30 people. To obtain the results of this questionnaire, the mean of each of the questions (except for the first three: gender, age and education) was statistically analysed. Moreover, the variance of the means of the 'gender', 'age' and 'education' categories with each of the questions was also explored. Next, Table 3 shows the results of the analyses.

For the correct interpretation of the results of the means, it is important to take into account that not all questions have the same number of response options. Question 1, 2 and 3 are not focused on the historical-archaeological evidence scale, as they were used to characterise the respondents.

Focusing on the most interesting results for the creation of a new proposition of historical-archaeological evidence scale, it is important to highlight that, regardless of gender, age and education, the mean value in question 4 was 1.367. This indicates that over half of the respondents (maximum mean value: 2) had heard about the evidence scale for the first time. In question 5, half of the respondents agree that this is due to the fact that virtual reconstructions are not usually accompanied by an evidence scale (mean value: 2.07). For questions 6 and 7 (maximum mean value: 4), the respondents answered that they knew between 1–5 and 5–10 virtual reconstructions, and that, among these, between 0 and 1–5 were accompanied by a historical-archaeological evidence scale. Regarding question 8 (maximum mean value: 3), the respondents stated that the information presented in the evidence scale reached the general public (mean value: 2.27).

The rest of the questions (9–18) belong to the Likert scale on the level of agreement or disagreement (maximum mean value: 5). As can be observed in Table IV-3, except for question 18, none of them exceeded the mean value of 2. This indicates that, from question 9 to 17, the respondents 'strongly agreed', with some of the questions being close to 'agree'. However, question 18 obtained a mean value of 2.59, being close to 'neither agree nor disagree' regarding the opinion about the colours used in the proposition of Ortiz et al. (2018).

Table IV-3

Statistical results obtained from the questionnaire.

Question	*Mean*	*ANOVA ('Gender' variable)*	*ANOVA ('Age' variable)*	*ANOVA ('Education' variable)*
4	1.37	Pr(>F): 0.271	Pr(>F): 0.74	Pr(>F): 0.0746
5	2.07	Pr(>F): 0.546	Pr(>F): 0.866	Pr(>F): 0.71
6	2.50	Pr(>F): 0.184	Pr(>F): 0.69	Pr(>F): 0.0885
7	1.90	Pr(>F): 0.491	Pr(>F): 0.848	Pr(>F): 0.0757
8	2.27	Pr(>F): 0.64	Pr(>F): 0.118	Pr(>F): 0.854
9	1.73	Pr(>F): 0.101	Pr(>F): 0.236	Pr(>F): 0.298
10	1.90	Pr(>F): 0.00375	Pr(>F): 0.213	Pr(>F): 0.0568
11	1.23	Pr(>F): 0.489	Pr(>F):0.147	Pr(>F): 0.706
12	1.20	Pr(>F): 0.253	Pr(>F): 0.708	Pr(>F): 0.0233
13	1.43	Pr(>F): 0.607	Pr(>F): 0.0361	Pr(>F): 0.705
14	1.20	Pr(>F): 0.346	Pr(>F): 0.119	Pr(>F): 0.959
15	1.83	Pr(>F): 0.345	Pr(>F): 0.466	Pr(>F): 0.00863
16	1.86	Pr(>F): 0.626	Pr(>F): 0.312	Pr(>F): 0.208
17	1.80	Pr(>F): 0.279	Pr(>F): 0.596	Pr(>F): 0.726
18	2.59	Pr(>F):0.412	Pr(>F): 0.0086	Pr(>F): 0.00539

After the analysis of variance (ANOVA) carried out for the 'gender', 'age' and 'education' categories with each of the questions, the following results were obtained:

- With respect to the 'gender' category, for all questions, except question 10, the p value was over 0.05, exceeding the 5% significance level, which shows that gender did noT influence the responses at 95% confidence level. In question 10,

the p value was below 0.05, which indicates that gender did influence the responses given to this question, and thus the null hypothesis was accepted.

- For the 'age' category, for all questions, except for questions 13 and 18, the p value was over 0.05, exceeding the 5% significance level, and thus age did not influence the responses at 95% confidence level. Regarding questions 13 and 18, the *p* value was below 0.05, thus age did influence the responses given in these questions, and the null hypothesis was thereby accepted.
- In the 'education' category, except for questions 12 and 18, the p value was over the 5% significance level, showing that education did not influence the responses at 95% confidence level. For questions 12 and 18, the *p* value was not over 0.05, indicating that the null hypothesis was accepted, since education did influence the responses given in these questions.

Based on the fact that this project pursues a proposition focused on the common viewer, without losing its scientific character, we firstly evaluated the historical-archaeological evidence levels to be shown. The aim was to obtain a very visual scale, without excessive information, that can be understood by any person regardless of their age or education.

Since virtual reconstructions are created to show how a heritage asset was in a specific time (López-Menchero and Grande 2011), we believe that, visually, the archaeological remains that require highlighting the least are those that are preserved, as, due to the fact that they can be personally observed, their intensity should not be highlighted in the evidence scale implemented in the virtual reconstruction. Therefore, this would imply ordering the evidence levels from lower to greater historical-archaeological veracity, with the former being associated with a greater visual colour intensity.

Furthermore, it is important to consider that not all visitors of archaeological sites are experts of the discipline, and thus, the greater the number and information of evidence levels, the greater the difficulty to interpret them. To solve this, it was decided to reduce the historical-archaeological evidence levels, in order to omit information of these which

not all users know how to interpret. Based on the existing propositions of evidence scales, six historical-archaeological veracity levels are proposed:

1. Elements of the historical and natural context. Elements close to the historical and natural context.
2. Representation through compared architecture. Structure or object represented by compared architecture or similar contemporary elements.
3. Archaeological hypotheses. Information based on the result of the archaeological excavations.
4. Textual references. Textual description of elements.
5. Graphic references. References of elements in drawings, prints or paintings.
6. Preserved archaeological remains. Structure or object preserved in the present.

As was previously mentioned, the intensity of the colours is fundamental in the present proposition. Some studies show that one of the attributes of colour is value (Edwards 2004; De Grandis 1985). By transforming the chromatic scale to achromatism, the value scale can be observed (Fig. IV-5), which shows the darker and brighter colours of the chromatic wheel. In other words, the intensity of each colour can be observed.

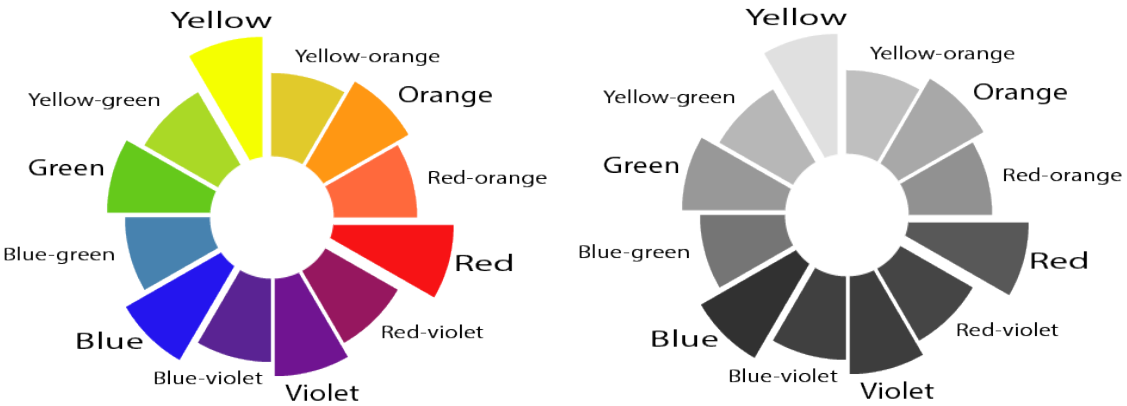


Fig. IV-5. Transformation of the chromatic wheel to achromatism.

As was previously mentioned, the discrimination of colours can be affected by age (Dittmar 2001; Mohebbi 2014; Terwogt and Hoeksma 1995; therefore, it is important to use colours that can be distinguished from each other by their intensity. The new

proposition of historical-archaeological evidence scale aims to denote the levels of lower veracity with darker and more intense colours, while associating the greater veracity levels with clearer and less intense colours.

To this end, it was fundamental to transform the chromatic wheel to achromatism, thus observing the intensity of the colours. Moreover, the 3D model was essential to apply the different groups of colours and verify how they worked in it. After several colour tests performed in the 3D model, it was decided to select a scale composed of warm colours, from greater to lower intensity (Table IV-4). Analog colours were used to create a warm colour scale. The discrimination of the primary colour blue and the secondary colour green is due to the pursuit for a gradation without leaps in the chromatic wheel, thus creating a visually harmonious scale.

Table IV-4

Evidence levels and their associated colours of the new proposition of historical-archaeological evidence scale.

Level of evidence for virtual reconstructions	*Definition*	*Colour*	*RGB*	*HEX*
1	Elements of the historical and natural context		128 0 52	800034
2	Representation through comparative architecture		243 33 47	F3212F
3	Archaeological hypotheses		241 78 37	F14E25
4	Textual references		249 153 33	F99921
5	Graphic references		239 206 4	EFCE04
6	Preserved archaeological remains		255 234 15	FFF30F

In order to accurately evaluate the intensity (brightness or darkness of the colours used), the scale of greys associated with the colours used was created. Additionally, this scale was used to calibrate the degrees of value of the selected colours (Edwards 2004). As can be observed in Table IV-5, the scale of greys corresponding to the selected colours

shows different intensities among them, with the levels of lower historical-archaeological evidence being more intense than those of greater veracity.

Table IV-5

Scale of greys of the veracity levels of the new proposition of historical-archaeological evidence scale.

Level of evidence for virtual reconstructions	*Definition*	*Colour*
1	Elements of the historical and natural context	
2	Representation through comparative architecture	
3	Archaeological hypotheses	
4	Textual references	
5	Graphic references	
6	Preserved archaeological remains	

The 3D model played a fundamental role in the selection of colours, as it was used with different colour values until it was appropriately adjusted. In the scale of greys, it was confirmed that the selected colours were optimal to show the evidence scale from greater to lower intensity. This was also tested in the 3D model to verify that the same effect was obtained (Fig. IV-6). Lastly, the outer terrain of the Baker's House, which is not part of the veracity of the heritage asset, is associated with a neutral colour, which does not stand out among the colours that correspond to the evidence levels.

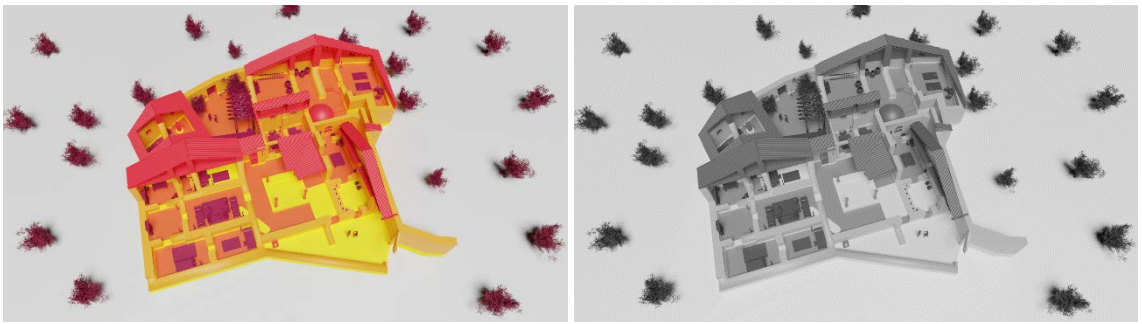


Fig. IV-6. Render with the implementation of the new scale proposition in the Baker´s House in colour and in scale of greys.

Therefore, the new proposition of historical-archaeological evidence scale has six levels of veracity (Table IV-4). The colours of greater intensity show the levels of lower historical- archaeological evidence, whereas the brighter colours (less intense) represent greater veracity. The implementation of the new proposition of evidence scale produced computer graphics with 31 reconstructive units (Fig. IV-7). Next, we present the table associated with the historical-archaeological evidence scale of the 'Baker's House' (Table IV-6). This table identifies the number of the reconstructive unit, the evidence level, a brief description of the element or structure, the chronology and the corresponding bibliography.

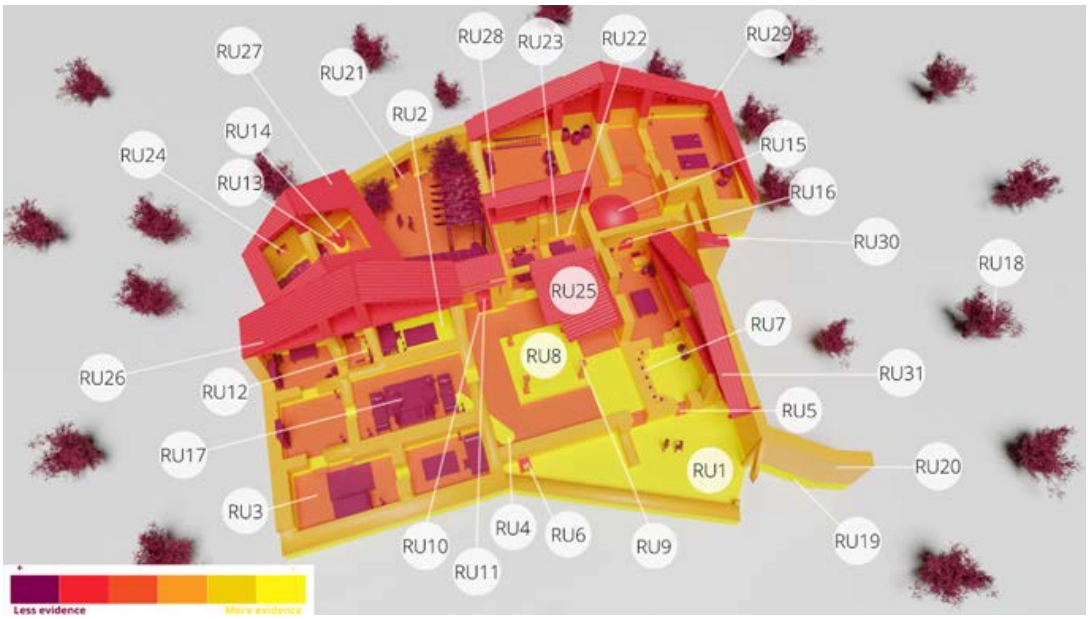


Fig. IV-7 Computer graphics of the new proposition of historical-archaeological scale for the digital reconstruction of the *domus*.

Table IV-6

Identification of the RUs, evidence levels, name, description, chronology and bibliography of the new proposition of historical-archaeological evidence scale of the virtual reconstruction of the Baker´s House of Torreparedones.

RU	*Evidence level*	*Name*	*Description*	*Chronology*	*Bibliography*
1	6	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.	Early Roman Empire	(Moreno 2015)
2	6	Pavement of *opus signinum*	Pavement of *opus* signinum in the room identified as *cubiculum*.	Early Roman Empire	(Morena et al. 2016; Morena et al. 2019)
3	3	Non-preserved pavement	Pavements of the *domus* that are not preserved.		
4	6	"*A bagnarola*" water tank	Supplied with rainwater gathered in the roofs, given its location in one of the corners of the *atrium*.	Late Roman Republic	(Morena et al. 2016; Morena et al. 2019)
5	3	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.		(Morena et al. 2019)
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.		(Morena et al. 2019)
8	6	*Impluvium*	Square pond that gathers rainwater and discharges to the street through a canalisation system connected to a larger canalisation system.	Early Roman Empire	(Morena et al. 2016; Morena et al. 2019)
9	3	*Impluvium columns*	First building phase of the *atrium*.		(Morena et al. 2016; Morena et al. 2019)
10	6	Base of the *lararium*	Square structure that could correspond to the base of the recess that held the figurines for domestic worship.	Early Roman Empire	(Morena et al. 2019)
11	2	*Lararium*	Due to its chronology and location, it seems to correspond to a variant of the		(González 2003;

			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.		Corrales et al. 2016)
12	4	Kitchen structure	Masonry structure		(Morena et al. 2019)
13	6	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.	Early Roman Empire	(Morena et al. 2016; Morena et al. 2019)
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.		(Flores 1993; Morales 2008)
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).	Early Roman Empire	(Bustamante and Salido 2014; Luzón 1975)
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.	Early Roman Empire	(Morena et al. 2019)
17	1	Roman furniture	Roman furniture associated with each space.		
18	1	Vegetation	Contemporary vegetation in time and space.		
19	6	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.	Early Roman Empire	(Morena et al. 2019)

20	4	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.		(Díaz 2014)
21	3	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.		(Cáceres-Criado et al. 2022; Cáceres-Criado et al. 2022)
22	6	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.	Early Roman Empire	(Morena et al. 2016; Morena et al. 2019)
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.		(Fernández et al. 2005)
24	3	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.		(Mezquíriz 2004)
25	2	*Atrium* cover	*Compluvium* / *impluvium* system		(Díaz 2014; Adam 1996)
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*.		(Díaz 2014; Adam 1996)
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*.		(Díaz 2014; Adam 1996)
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		(Díaz 2014; Adam 1996)

			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*.	(Díaz 2014; Adam 1996)
30	2	Cover of the woodshed	Shed roof proposed for the closing of space E-32, identified as woodshed.	(Díaz 2014; Adam 1996)
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'.	(Díaz 2014; Adam 1996)

IV-5. CONCLUSIONS

The application of a colour scale in virtual reconstructions is a valid tool to show the degree of veracity of the work<conducted. Therefore, the existing propositions of each

historical-archaeological evidence scale are considered optimal for such purpose. However, the selection of the evidence levels and colours is key for their easy and unequivocal understanding.

Although no negative results were obtained in the questions about the existing propositions of historical-archaeological evidence scales, the open debate in the Topical Seminar showed aspects that needed to be addressed. Thus, we decided to create a new proposition that encompasses such aspects and which can reach the general public, regardless of their education with respect to the topic.

The achromatic wheel is fundamental to show a scale where the order of the colours is important. The colourless scale in this study was used to adjust the degree of value of each colour and thus obtain a scale of greater to lower visual colour intensity. To increase the understanding of the evidence scale for any type of viewer, regardless of their age or

education, it was decided to reduce the evidence levels. It was observed that the presentation of very detailed information in the evidence levels may lead to mistakes in terms of their visual understanding, since the evidence levels increase, with the consequent increase of visual fatigue in the identification of each colour.

As is shown by the results of the questionnaire, there is still a great percentage of people who do not know the historical-archaeological evidence scale. To solve this issue, it is fundamental to disseminate the scale, highlighting its value in research studies and in the sites of the heritage assets. The historical-archaeological evidence scale for virtual reconstructions is a useful tool to systematise the existing information about the assets, further disseminate them, and finally, assess the virtual reconstruction creation process. In addition to facilitating the correct interpretation of the archaeological work, this scale would help to correctly interpret heritage assets, presenting them in explanatory panels of the archaeological sites, in mockups, museums., etc. Therefore, its use should be encouraged, which is the best way of disseminating it, to pursue the creation of a universal and unique language.

IV-6. APPENDIX

See Tables IV-7 and IV-8.

Table IV-7

Quantitative study presented in the Topical Seminar held in the University of Córdoba

Questions	*Response options*
1. What is your gender?	• Man; • Woman
2. What is your age?	• 20-30 years; • 30-40 years; • Over 40 years
3. What is your academic training?	• Arts and Humanities; • Science;

	• Heatlh Sciences; • Social and Legal Science; • Engineering and Architecture. • Other
4. Is this the first time you heard about the historical-archaeological evidence scale?	• Yes; • No
5. Why do you think you did not know about the historical-archaeological evidence scale?	• Its lack of dissemination; • Virtual reconstructions are not usually accompanied by an evidence scale; • I am not interested in this topic; • Lack of training in the Degree of Archaeology
6. How many virtual reconstructions do you know?	• 0; • 1-5; • 5-10; • Over 10
7. How many of these virtual reconstructions are accompanied by a historical-archaeological evidence scale?	• 0; • 1-5; • 5-10; • Over 10
8. In your opinion, what kind of audience receives the information presented in the historical-archaeological evidence scale?	• Experts in the field; • The general public; • Both
9. In a scale of 1-5, with 1 being Strongly Agree and 5 being Strongly Disagree, do you think that the use of a historical-archaeological evidence scale is a good option to accompany a virtual reconstruction?	• Likert scale*
10. As is proposed by P. Aparicio and C. Figueiredo in one of their studies, the historical-archaeological evidence scale contributes to the creation of a	• Likert scale*

language for all professionals of the field. Do you agree with this?	
11. In a scale of 1-5, with 1 being Strongly Agree and 5 being Strongly Disagree, is the name "historical-archaeological evidence scale" descriptive?	• Likert scale*
12. In a scale of 1-5, with 1 being Strongly Agree and 5 being Strongly Disagree, do you consider that the historical-archaeological evidence scale helps to disseminate and correctly interpret not only the heritage asset but also the archaeological work conducted?	• Likert scale*
13. In a scale of 1-5, with 1 being Strongly Agree and 5 being Strongly Disagree, if it were compulsory to accompany virtual reconstructions with historical-archaeological evidence scales, do you think this would help the general public to understand the archaeological remains?	• Likert scale*
14. In a scale of 1-5, with 1 being Strongly Agree and 5 being Strongly Disagree, do you think it is convenient for the tourist to accompany the information presented in the explanatory panels of archaeological sites with the historical-archaeological evidence scale of the virtual reconstruction?	• Likert scale*
15. In a scale of 1-5, with 1 being Strongly Agree and 5 being Strongly Disagree, what do you think about the evidence levels proposed by P. Aparicio?	• Likert scale*
16. In a scale of 1-5, with 1 being Strongly Agree and 5 being Strongly Disagree, what do you think about the evidence levels proposed by R. Ortiz?	• Likert scale*
17. In a scale of 1-5, with 1 being Strongly Agree and 5 being Strongly Disagree, what do you think about the colours used in the proposition of P. Aparicio?	• Likert scale*
18. In a scale of 1-5, with 1 being Strongly Agree and 5 being Strongly Disagree, what do you think about the colours used in the proposition of R. Ortiz?	• Likert scale*

*Likert scale composed of the following options: Strongly agree; Agree; Neither agree nor disagree; Disagree; Strongly disagree

Table IV-8

Qualitative study conducted to Pablo Aparicio and Rafael Ortiz.

	Questions	*Response Pablo Aparicio*	*Response Rafael Ortiz*
1.	Everyone agrees that the evidence scale, in addition to its scientific value, has an educational and informational purpose, but what is the target audience? Experts in the discipline, common viewers or both?	"Exactly, both. I think it is very important that the scale does not lose its educational character and that looking at the caption with the warmer or cooler gradation along with the image of the virtual reconstruction should be enough for anyone to understand which areas have a greater or lower level of evidence. Subsequently, we could expand them with further information for the study".	"From my point of view, I think that the evidence scale is useful for all audiences, and it grants transparency to the virtual reconstructions, for both technicians and the general public. In our case, when we started working with the scale, we saw that it had to be reduced, and the change of colour was due to the work we began, where we made several propositions and talked to all the technicians involved".
2.	What did you consider for the selection of colours?	"In this sense, since we based our work on the proposition developed in the Byzantium 1200 project, considering the need for standardising the scale, we believed it would be most interesting to keep using colours similar to those used in the Byzantium project, basically because we understood that they worked very well. We made small changes in the colours, that is, we adjusted the colours in a way that they could be distinguished. However, as was previously commented, purple may be a bit confusing, and it should be recalculated a little".	"Solving the problem related to the work we were doing and also in the colours that were used in geographic information systems. We attempted to create a scale of colours that solved the problems regarding the consideration of warm colours – cool colours that existed in the previous propositions".
3.	Do you think that your proposition is the most appropriate one for any virtual reconstruction regardless of the number of reconstructive units	"It should be. The aim is to make this proposition useful for any kind of virtual reconstruction. I was able to apply it to all virtual reconstructions that I have carried out to date. There was not one virtual reconstruction in which I said 'it's impossible here'. However, in some cases, it is necessary to reduce a little, such as the number of reconstructive units; otherwise, it can be difficult. In	"Unlike Pablo Aparicio, we always work in the same scope, so I cannot really answer that question. Since we always work on the same thing, the Mosque-Cathedral, we cannot export this information to other virtual reconstructions".

		other cases, it is necessary to merge reconstructive units into a single unit. The case of Elephantine City is paradigmatic; it was possible to apply it to the entire city, and I believe that it allows the viewer to clearly see the evidence level of each area. We must also be aware that the evidence scale must be flexible and that its use depends on the excavation team or scientific team. It is important to understand that this is a tool that shows the evidence level and that we must apply it in each case as clearly as possible".	
4.	As has been previously mentioned, many of the archaeologists who attended this seminar did not know the historical-archaeological evidence scale. What do you think this is due to?	"I get emails from Italy, UK, etc., and I see that its use in virtual reconstructions is increasing. Moreover, I teach in the MSc of Virtual Heritage and in the education platform of Koré, and there we aim to disseminate the use of the evidence scale, also through seminars like this. It is important to use it in our workplace to increase its dissemination, as well as to modify it if necessary, although it would be good to modify it in a consensuated manner in order to achieve its standardisation".	"As Pablo Aparicio says, the use of the historical-archaeological evidence scale is increasing, in Spain and in other countries, such as Portugal, Italy, etc., so a greater number of people will surely know it soon".
5.	One of the attending archaeologists proposed the following: "The main disadvantage is the scarce training given to archaeology students. Greater dissemination and analysis of this system would considerably help in this matter". Do you think that it would be possible,	"Education is essential for the application of knowledge. I think it would be very good to explain this tool in universities, since, as has been explained, it can be applied not only to virtual reconstructions, but also to traditional historical drawings, and it allows providing a scientific section. To date, when virtual reconstructions were performed, if you were very lucky you could find an article that explained how it had been done, but their veracity was never addressed. Therefore, I think it is a very	"Yes, but it is important to highlight that there are still archaeologists who do not understand digital technologies, so universities should start changing some things to highlight the relevance of this scope, which is widespread".

from research, to show the relevance of the evidence scale, even teaching it as part of a subject in the university?	important tool that came here to stay".

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CAPÍTULO 5.

Proposition for the graphic representation, interpretation and evaluation of the degree of terrain resolution in virtual reconstructions

Artículo:

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CAPÍTULO 5. Proposition for the graphic representation, interpretation and evaluation of the degree of terrain resolution in virtual reconstructions

V-1. INTRODUCTION

Archaeology involves the construction of a historical discourse based on past societies. In other words, this discipline analyses history through Material Culture, that is, the material remains that are preserved [1]. In addition to understanding the social and cultural meaning of these materials, it is fundamental to situate them in space and time. Therefore, this science requires multidisciplinary work with cartography, topography, Geographic Information Systems (GIS), Global Positioning System (GPS), georeferencing and Digital Terrain Models (DTM).

The Seville Principles, in the third section of Principle 5 "Historical rigour" [2], state that: "The surroundings, context or landscape associated with an archaeological remain is as important as the remain itself. Anthracological, paleobotanical, paleozoological and physical paleoanthropological studies must be used as reference for the development of rigorous virtual recreations of the landscape and context. Lifeless cities, lone buildings or dead landscapes cannot be systematically shown, as these represent false history."

Similarly, the Seville Principles gather in their definitions the visual recovery of heritage alongside elements such as the surrounding and the landscape in virtual recreations [2]. A large number of 3D representations consist of material culture, surroundings and landscape, and the authors themselves classify their works as virtual reconstructions. Therefore, it can be deduced that it is very difficult to differentiate virtual reconstructions from virtual recreations.

Not all virtual reconstructions of a heritage asset incorporate the surroundings, context or landscape [3, 4, 5]. Although the most recent studies incorporate them, they do not explain the method they used to obtain these elements [6, 7, 8, 9, 10], and only some of them describe the way in which they acquired them [11; 12].

A scientific traceability tool used in some virtual reconstructions is the historical-archaeological evidence scale. It consists in the implementation of colours in the virtual reconstruction to show its veracity. All the propositions of historical-archaeological evidence scale consist of a colour scale in which the different evidence levels determine the veracity of the reconstructed archaeological remains [13, 14, 15, 16]. None of the existing scales consider the terrain or surroundings. Aparicio and Figueiredo [14] established that, since the terrain did not have a corresponding evidence level, it would be appropriate to apply a colour different from those used for the evidence levels.

V-1.1. Research aim

The aim of the present study was to develop a proposition of resolution scale to graphically represent, interpret and evaluate the terrain associated with virtual reconstructions, addressing the need to provide virtual reconstructions with elements of the surroundings, landscape and context in line with the topography, as this information shows real evidence that has persisted for centuries. The proposition was developed in the terrain associated with Carcabuey Castle (Cordoba, Spain), where its suitability was verified. Subsequently, the proposition was implemented in the virtual reconstruction of the Baker's House at the archaeological site of Torreparedones (Spain) [17], and in the reconstruction of the historic district of Priego de Cordoba (Spain) [18].

V-2. METHODOLOGY

To attain the main objective of this study (the development of a proposition of terrain resolution scale in virtual reconstruction), a thorough literature review was carried out in the scope of Digital Terrain Model (DTM) creation. This literature review allowed identifying the existing methodologies for the creation of DTM. Likewise, we searched for the evaluation of point density and horizontal and vertical precision of each methodology. These data are gathered in Table V-1: source; description; point density; horizontal precision; vertical precision.

Table V-1

Compilation of existing methodologies for the creation of DTM.

Source	*Methodology description*	*Point density*	*Horizontal precision*	*Vertical precision*
Google	Google Earth		>3metres	>2metres
SIG	MDT200	200 metres	0.3 metres	0.4 metres
SIG	MDT25	25 metres	0.3 metres	0.4 metres
SIG	MDT05	5 metres	0.3 metres	0.4 metres
SIG	MDT02	2 metres	0.3 metres	0.2 metres
Independent production	Unmanned aerial vehicle flights	Defined by user	On demand depending on the scale (>10cms)	On demand depending on the scale (>10cms)
Independent production	Land-based laser scanning – Airborne laser scanning	Defined by user	On demand depending on the scale (>10cms)	On demand depending on the scale (>10cms)
Independent production	Topographic survey	On demand depend in on the area and scale	On demand depending on the scale (>10cms)	On demand depending on the scale (>10cms)

The first technique identified for the creation of DTM is the use of Google Earth [19, 20]. Through a GIS application, such as Blender GIS, it is possible to upload global mapping through Google Earth, selecting the image of the area of interest; thus, the relief is obtained, creating the 3D view of the area [12].

In Spain, the Spanish Institute of Geography (IGN) plays a fundamental role as a source of geographic data. This institution is considered a Geographic DataBase (GDB), where the data are organised for the realisation of analyses and the management of territory through GIS software. This GDB includes DTM, which are considered as the set of layers that represent different characteristics of the Earth's surface derived from a Digital Elevation Model (DEM). In the Download Centre of the IGN there are four DTM, which depend on the point density marked in the data capture:

- Digital Terrain Model - DTM02: digital terrain model 1st Coverage (2015-present) with 2m mesh pitch.

- Digital Terrain Model - DTM05: digital terrain model 1st Coverage (2015-present) with 5m mesh pitch.
- Digital Terrain Model - DTM25: digital terrain model 1st Coverage (2015-present) with 25m mesh pitch.
- Digital Terrain Model - DTM200: digital terrain model 1st Coverage (2015-present) with 200m mesh pitch.

The mesh pitch of each model indicates its precision. The smaller the mesh, the greater the DTM precision and reliability. Therefore, DTM02 presents greater precision and reliability than DTM05, and so on. The QGIS software can be used to manipulate the DTM and to obtain the 3D terrain file.

A DTM can be created using three different techniques. The first technique is the use of unmanned aerial vehicles (UAV) [21]. In this case, it is important to consider the target GSD (Ground Sample Distance), which directly depends on the quality criteria of the CCD (Charge-Coupled Device), the pixel size of the camera, orientation, and flight height, among other aspects [22]. Prior planning of the flight is essential, and this should include the planning of the overlapping, flight direction, flight speed, and the distribution of points and control marks for the correct georeferencing of the terrain [23, 24, 25]. Once the field work is carried out, the georeferenced images are obtained, which, after being processed with a suitable software, such as Agisoft Metashape, provide the 3D model of the terrain [22, 26, 27].

The second technique for the generation of DEM and DTM is land-based or airborne laser scanning [28, 29, 30, 31, 32, 33]. The information gathered by the laser consists of a set of points, represented by XYZ coordinates of the scanned surface with respect to the reference system of the scanner [34]. The result is a set of points called “point cloud”, which must be georeferenced for the subsequent generation of the three-dimensional model [34, 35], in photogrammetry programs such as Agisoft Metashape. This georeferencing is achieved by establishing certain control points (homogeneously distributed over the area both planimetrically and altimetrically), to which precise global coordinates are assigned through topographic methods. Point density in this method is

defined by the user; depending on the extension of the surface to be scanned, the amount of points to be obtained by the scanner are established [18].

Lastly, the third technique is topographic elevation, which consists in a series of activities aimed at gathering information for the graphic representation of the terrain [36]. The traditional topographic elevation process is conducted through a total station or GPS, which are instruments of reliable measurement for topography [22]. With these measurement instruments placed, leveled, and geolocalised in a precise manner, a global positioning system is obtained. Then, the elevation points that are described by the topography of the area are radiated. Subsequently, back in the office, the obtained data are downloaded and exported to the software, AutoCAD 3D for example, to obtain the shape of the terrain and the DEM [22]. Point density in this technique would be on demand, that is, at the user's choice depending on the area and scale.

It is worth mentioning that there are two sources that were not considered in the current methodologies for obtaining DTMs: historical cartography and aerial photography. Obtaining a DTM from historical cartography involves manual digital modelling or sculpting, as the cartography would be used as a reference for manual modelling. Therefore, the level of accuracy would depend on the person doing the work. For aerial photography, the IGN has aerial photographs or orthophotographs of the entire national territory, as well as their corresponding DTM. Thus, this information could be downloaded directly without the need to personally take the aerial photograph, thereby reducing the workload for obtaining the DTM.

Once the existing methodologies were documented for the creation of a DTM, the following step was to develop the proposition of a terrain-associated resolution scale. To this end, we designed a terrain-associated resolution scale that allows identifying the veracity of the terrain. The terrain resolution scale is implicit to the historical-archaeological evidence scale; therefore, the need to implement one of them would also imply the implementation of the other. Consequently, virtual representation studies must explain how the terrain associated with the virtual reconstruction was obtained.

V-3. RESULTS AND DISCUSSION

V-3.1. Creation of the proposition of a terrain-associated resolution scale

The first step in the creation of the new proposition was to select the classification criterion for the degree of veracity of the DTM. The DTM obtained through our own and external data sources are reliable, although, depending on their precision, they could be classified from greater to lower veracity or vice versa. With a good planning of support points, we could obtain the greatest precision, as long as the distribution and quantity requirements are met. The classification by precision depends both on the scale and on the instrumentation. Precision depends on the scale, since, based on the proximity to the reconstructed 3D model, greater or lower tolerance will be required. The lower the scale, the greater the proximity to the points that make up the 3D model and, therefore, the greater the precision. The greater the scale, the lower the proximity to the points that make up the 3D model and, therefore, the lower the precision. The Andalusian Institute of Historical Heritage has technical recommendations for the geometric documentation of heritage entities[1]. Such document gathers the acceptable precision tolerance according to the working scale. Moreover, the maximum pixel size as a function of the scale is recommended; for instance, for a 1:1 scale, the pixel size must be equal to or under 0.05mm. Regarding instrumentation, it is usually quite precise, as there are good instruments in the market. However, such instruments are not expected to improve, that is, they are not likely to be more precise in the future. Thus, it is not considered viable to establish a classification methodology as a function of precision.

Taking precision into account, we decided to classify the models as a function of the data sources used for each methodology. The best data are those of lower precision, that is, those obtained through Google (Google Earth). The next data in the classification are those obtained from the SIG; in this case, we decided to group the four data available

[1]Technical recommendations for the geometric documentation of heritage entities provided by the Andalusian Institute of Historical Heritage (Culture Department) (v1.0 23/11/2011) https://www.iaph.es/export/sites/default/galerias/patrimonio-cultural/documentos/gestion-informacion/recomendaciones_tecnicas_documentacipm_geometrica.pdf

(MDT02; MDT05; MDT25; MDT200) into the same resolution level. When extrapolating this proposition to the international scope, the data of the SIG would be replaced with those provided by the country in which the study is conducted. Lastly, the data obtained appear as user's production, from manual to mechanical, whose precision is established by the scale and instruments used: topographic elevation; land-based or airborne laser scanning; drone flights.

Although the mentioned data are all reliable, it is necessary to think of another possibility, such as the terrain being created by the user. This implies that, through a digital modeling software, the terrain would be sculpted manually, which entails the addition of a new resolution level associated.

To sum up, the proposition of terrain-associated resolution scale for virtual reconstructions would have six classification levels:

- Topographic elevation
- Land-based laser scanning – Airborne laser scanning
- Drone flights
- SIG – Digital Terrain Model (MDT02; MDT05; MDT25; MDT200)
- Google
- Digital manual sculpting

Using the terrain-associated resolution scale implies selecting, for the terrain proposition, colours that are different from all those implemented in the historical-archaeological propositions. The selection of colours for the terrain-associated proposition is difficult, due to the chromatic variety among the historical-archaeological propositions. For instance, a chromatic variety of blue colours would work in the last two propositions [15, 16], but not in [13] and [37]. On the other hand, a variety of brown colours would work for all the propositions, except for [15], and so on.

The above mentioned indicates that any chromatic spectrum selected for the terrain resolution scale will have colours similar to those of some of the existing propositions of historical-archaeological evidence scales. Therefore, this study advocates

for the implementation of defined colours used for the representation of terrains by contour lines. The subjective connotations of colours also play an important role in this sense, due to the meanings that are associated by society to the colours in a conventional and generalised manner [38, 39, 40; 41].

Verifying the effectiveness of the resolution levels proposed, as well as the colours selected, required their implementation in a DTM. To date, all works have been conducted in the Baker's House at the archaeological site of Torreparedones. However, the points that make up the DTM of this site do not show great differences in terms of mesh, thus they do not have a marked relief. Consequently, another terrain was selected, in which research is currently being carried out. This terrain corresponds to Carcabuey Castle (Cordoba), and it has greater topographic characteristics.

The DTM obtained for Carcabuey Castle was generated through the implementation of four methodologies (Fig. V-1): unmanned aerial vehicle (UAV); Digital Terrain Model – DTM05; Digital Terrain Model – DTM25; Google Earth. These methodologies were selected for the precision obtained from each of them. In this case, the aim was to achieve greater precision in the natural rock on which the castle is located; therefore, the delimited terrain was obtained through unmanned aerial vehicle flight. For the terrains that make up the rest of the surroundings, the further away they are from the castle, the lower the precision they require; thus, less precise methodologies were implemented.

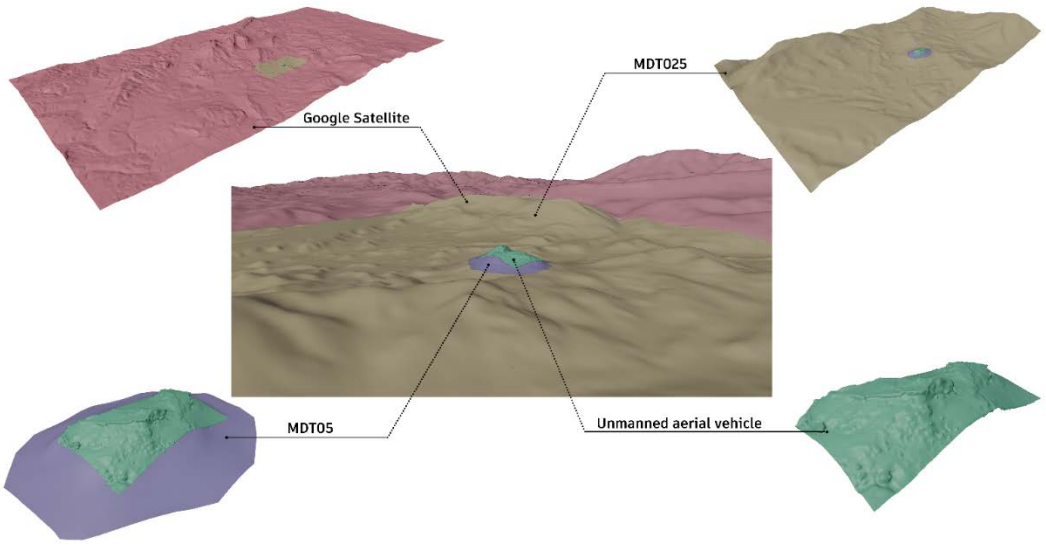

Fig. V-1 Differentiation by colours of the methodologies used to obtain the terrain: Green: UAV; Violet: MDT05; Yellow: MDT25; Pink: Google Earth).

In a previous study based on the creation of a new proposition of historical-archaeological evidence scale [16], it was important to convert the chromatic scale to achromatism for the selection of colours of different intensities. Achromatism consists in modifying the attribute "colour value" [42, 43], transforming the chromatic scale into an achromatic scale, where a scale of values is obtained, in which the intensity of each colour can be observed.

As was previously mentioned, the colours selected for the new proposition of terrain-associated scale were based on a sienna spectrum. For its adjustment, achromatism was considered, which allowed adapting the intensity of each colour. Before establishing as optimal the colours selected for the proposition, they were implemented in the DTM of Carcabuey Castle (Table V-2).

Table V-2

Scale of greys of the veracity levels of the proposition of terrain-associated scale.

Level of resolution	*Definition*	*Colour*
1	Digital manual sculpting	
2	Google	
3	SIG –Digital Terrain Model (DTM02; DTM05; DTM25; DTM200)	
4	Drone flights	

5	Land-based laser scanning; Airborne laser scanning	
6	Topographic elevation	

After verifying the dissimilarity of the values that make up the achromatic scale, we obtained a scale of colours with different intensities among them. This scale consists of six veracity levels associated with the existing methodologies for the generation of a DTM as a function of precision, ordered from lower to greater precision (Table V-3; Fig. V-2).

Table V-3

Resolution scale proposed for the terrain associated with virtual reconstructions.

Level of resolution	*Definition*	*Colour*	*RGB*	*HEX*
1	Digital manual sculpting		53 36 13	35240D
2	Google		93 63 25	5D3F19
3	SIG –Digital Terrain Model (DTM02; DTM05; DTM25; DTM200)		124 87 37	7C5725
4	Drone flights		150 115 69	967345
5	Land-based laser scanning; Airborne laser scanning		169 144 112	A99070
6	Topographic elevation		233 218 177	E9DAB1

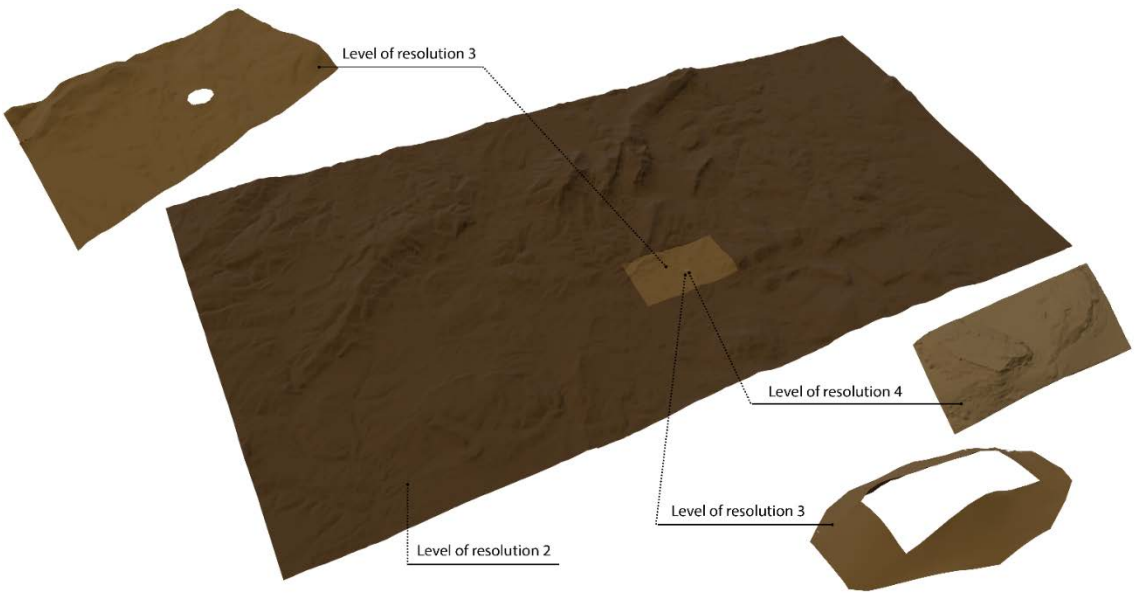

Fig. V-2 Implementation of the terrain-associated resolution scale in Carcabuey Castle.

Once the resolution levels and the colours associated with them were established, a more complex aspect was addressed: the reconstructive units. These are understood as a record system that allows for a better identification of each of the elements of the reconstruction [14]. A reconstructive unit is constituted by a reconstructed element, for example, walls, windows, floors, etc. Likewise, an element can have several reconstructive units, as it can be composed of one part reconstructed based on what is preserved and another part reconstructed from comparative architecture [44]. Furthermore, each reconstructive unit is associated with an evidence level and, therefore, with a colour. This entails that different reconstructive units can have the same evidence level, which means that their reconstruction was conducted under the same criterion (comparative architecture, archaeological hypothesis, etc.), although referring to different elements [44].

The record system with reconstructive units was designed to be used in the historical-archaeological evidence scale [14]. This system could contain the terrain if this were identified with such scale; however, as this is not the case, it was necessary to establish a new system for the terrain. Since the terrain-associated resolution scale was created based on the methodology used to obtain it, for its similarity with the proposition, it was decided to identify the terrain resolution levels with methodological units (MU). These would have the same theoretical basis as reconstructive units, but they would identify the units that correspond to the terrain-associated resolution scale.

In the case of the terrain of Carcabuey Castle, since it contains four methodologies for its generation, there would be four MUs (Fig. V-3). The first MU (MU1) would correspond to resolution level 4 (UAV), followed by the MUs of the DTM of SIG, DTM05 and DTM25. Although both DTM05 (MU2) and DTM25 (MU3) correspond to the same resolution level (3), they are different MUs, since the data used for the generation of each terrain are different. Finally, the last MU (MU4) corresponds to resolution level 2, since it was obtained using data from Google Earth.

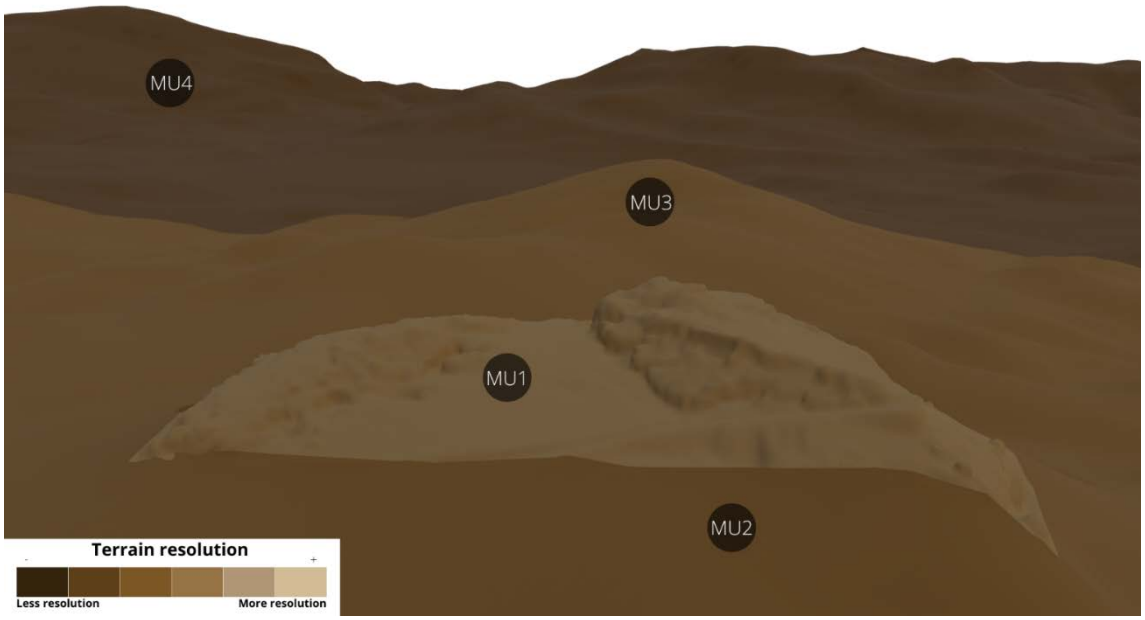

Fig. V-3 Final infogram of the terrain-associated resolution scale of Carcabuey Castle.

V-3.2. Implementation of the new proposition in a virtual reconstruction

V-3.2.1. The Baker's House (Torreparedones, Baena, Spain)

The Baker's House is located in the archaeological site of Torreparedones (Baena, Cordoba, Spain) [44]. It is a Roman domus with occupation from the Late Republican, Early Imperial and Medieval-Modern Ages [17]. After performing the virtual reconstruction of the building and analysing the existing propositions of evidence scales [45, 46], a new proposition of historical-archaeological evidence scale was conducted by Cáceres-Criado [16]. As in the previous propositions, the most recent proposition does not consider the terrain in the historical-archaeological evidence scale. In other words, to date, the virtual reconstructions generated with an associated historical-archaeological evidence scale do not take the terrain into account.

At this point, we implemented the terrain-associated resolution scale for the virtual reconstruction of the Baker's House. To this end, it is important to consider the methodology that was previously used to create the terrain associated with the domus of Torreparedones. In this case, we used data from the Spanish Institute of Geography,

specifically, the Digital Terrain Model of 1st Coverage with 5m mesh pitch (DTM05) [12]. Therefore, this terrain is associated with resolution level 3.

The MUs of the terrain were represented in a similar way as in the case of the reconstructive units, except for the inversion of colours, in order to better differentiate them. The final result would be the generation of an infogram that shows two captions: 1) the one corresponding to the historical-archaeological evidence scale; and 2) the one corresponding to the terrain-associated resolution scale (Fig. V-4). Moreover, this infogram must also show the reconstructive units associated with each reconstructed element of the heritage asset, as well as the MUs associated with the terrain.

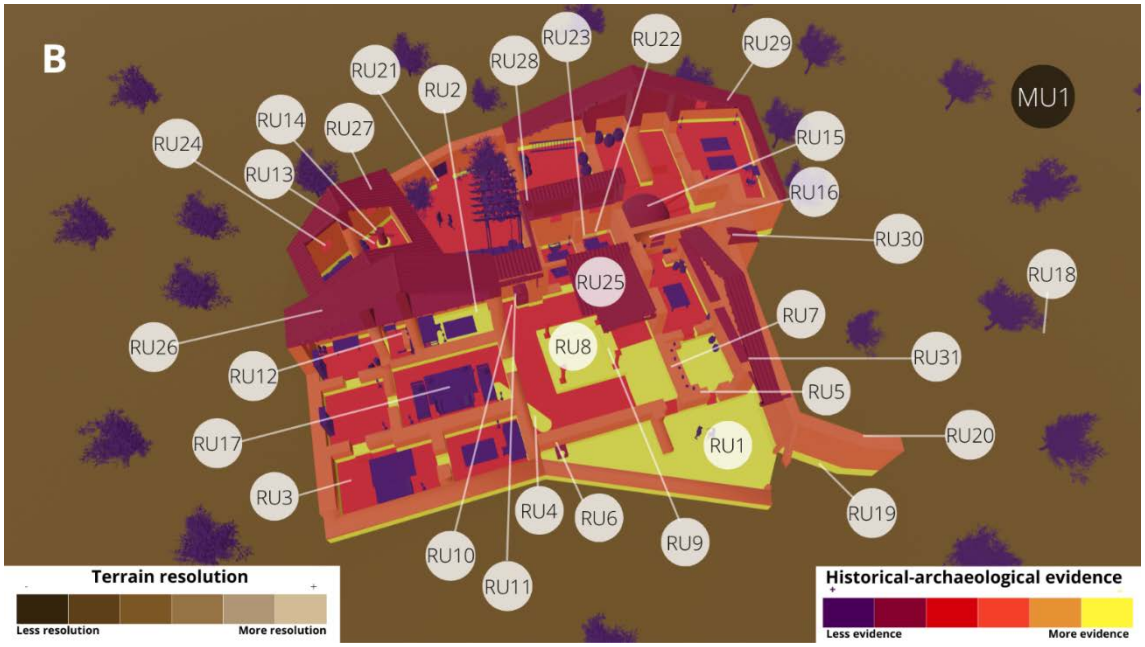

Fig. V-4 Final infogram of the Baker's House: A. Terrain-associated resolution scale; B. Terrain-associated resolution scale and historical-archaeological evidence scale.

All the information gathered in the image would be linked to an explanatory table, which would provide detailed information, focusing on aspects such as [16]: the number of reconstructive units/methodological units; evidence/resolution level; name; description; chronology; bibliographic references. Including the MUs in the explanatory table guarantees necessary information in the long term. For instance, the MU1 of the Baker's House shows the year of the DTM used. This information could be renewed in the future after updating the data of the SIG. Moreover, if the DTM is modified with more recent data, this could lead to new studies on the terrain and potential variations in time.

The terrain obtained for the Baker's House does not have great elevation differences in its topography. Therefore, in the final infogram of the implementation of the scales (Fig. 4), a flat terrain with no relief is observed. Next, we present another example of the terrain obtained for a virtual 3D reconstruction, a terrain obtained with different methodologies that has greater topographic elevations.

V-3.2.2. Historic district of Priego de Cordoba

The virtual 3D reconstruction of the walled enclosure and the town of Priego de Córdoba, at the time of its greatest splendour (15th century), was previously carried out by Diego F. García Molina as part of his doctoral thesis [18]. In the search to implement the resolution scale of the terrain associated with a virtual reconstruction, this site was chosen based on the methodological possibilities for its creation, as well as for showing greater differences in topographic levels compared to the previously mentioned terrain.

A fundamental characteristic of this site is its natural ditch, also known as the walkway ditch. It is set as a natural wall that, along with man-made walls and towers, enclosed and defended the neighbourhood of the town in the Middle Ages [47].

For the creation of the terrain associated with the historic district of Priego de Cordoba, five methodologies were used (Fig. V-5). Firstly, the neighbourhood of the town was reconstructed by digital manual sculpting, using orthophotographs. Over this model, the ditch was placed, which was obtained through two methodologies. One of these methodologies was land-based laser scanning, which allowed generating the natural rock that makes up said ditch; the other methodology, i.e., traditional topographic elevation, was used to obtain the model that would join the natural rock of the ditch with the medieval walkway. The surroundings of the historic district were created with data from the SIG, specifically DTM02. Lastly, for the terrain that corresponds to the horizon, we used data from Google Earth.

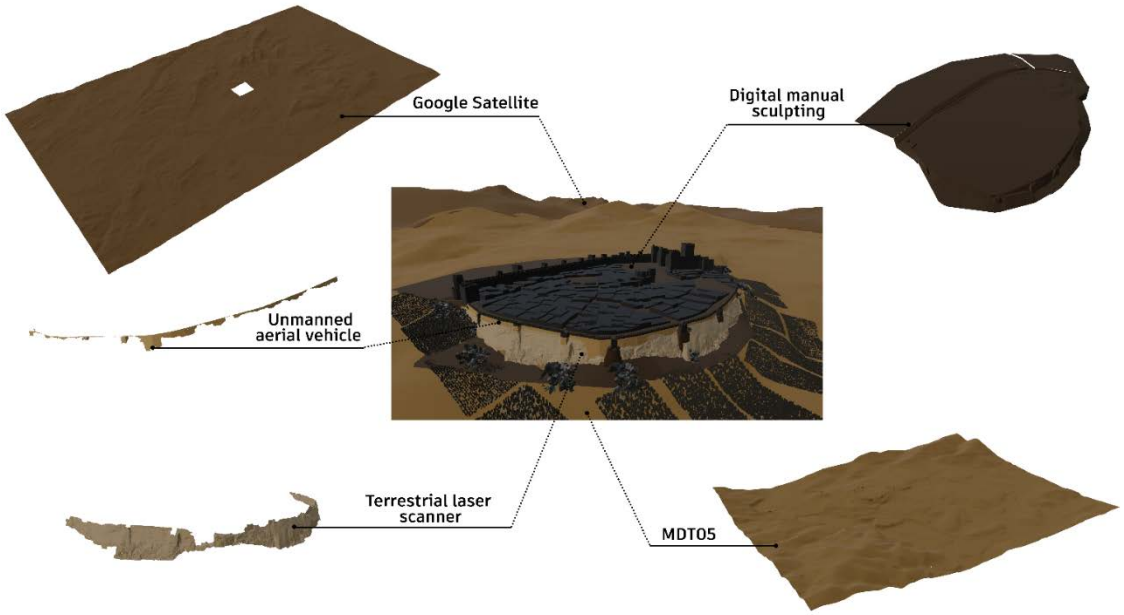

Fig. V-5 Identification of the methodologies used to obtain the terrain associated with the historic district of Priego de Cordoba.

The five methodologies implemented to create the terrain are associated with five terrain resolution levels: 1) Neighbourhood of the town: resolution level 1; 2) horizon terrain: resolution level 2; 3) detail terrain: resolution level 3; 4) natural ditch: resolution level 5; 5) ditch-walkway joint: resolution level 4. Regarding the record of the methodologies used to create the terrain, five methodological units were established, one per level of veracity: MU1 (resolution level 2); MU2 (resolution level 3); MU3 (resolution level 1); MU4 (resolution level 5); and MU5 (resolution level 4). As a final result, we obtained an infogram that shows the terrain-associated resolution level (MU) and the historical-archaeological evidence scale of the reconstructed heritage asset (Fig. V-6).

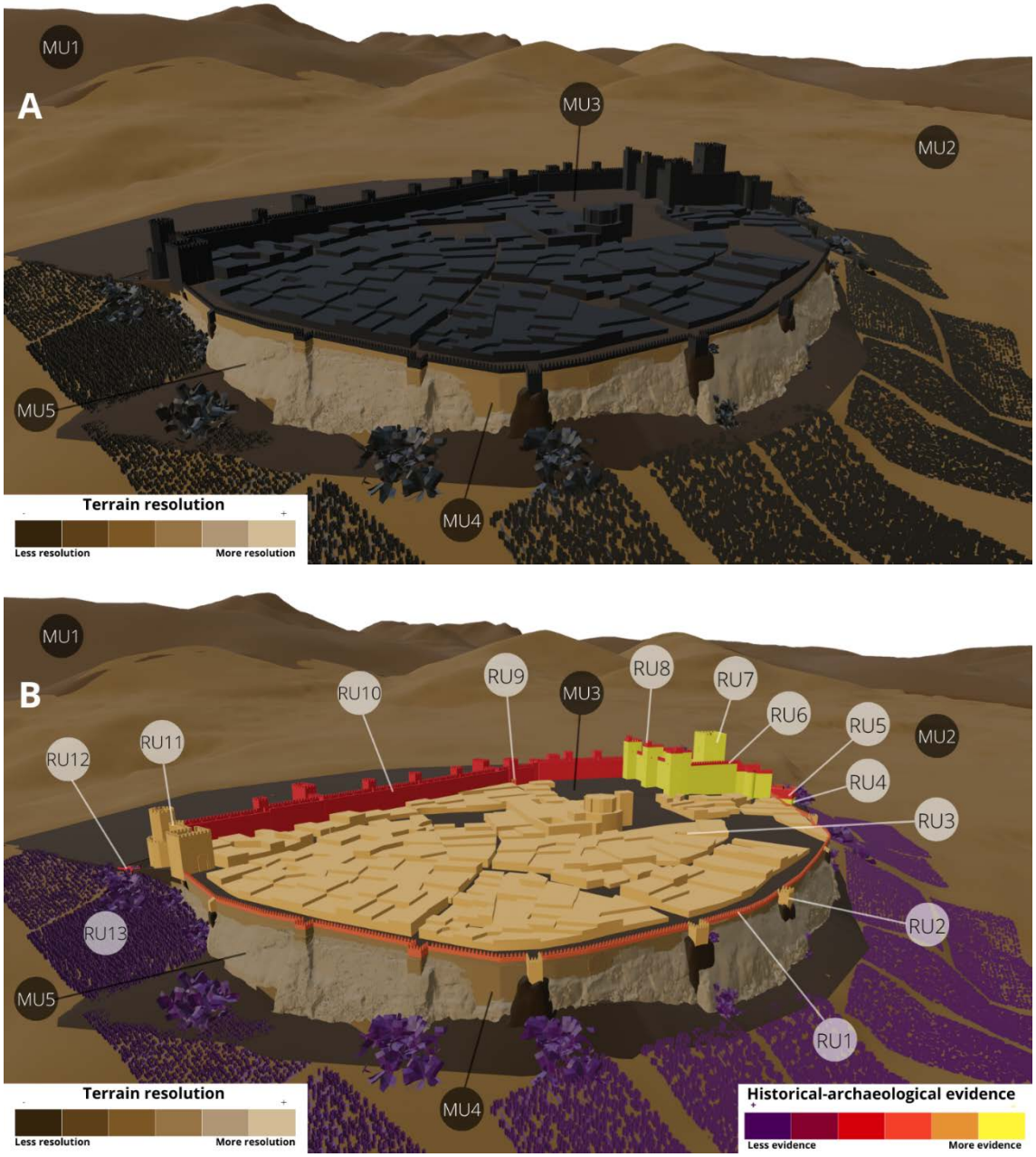

Fig. V-6 Final infogram of the virtual reconstruction of the walled enclosure and the town of Priego de Córdoba: A) terrain-associated resolution scale; B) terrain-associated resolution scale and historic-archaeological evidence scale.

The altimetric differences in the historic district of Priego de Cordoba make up an optimal infogram to visualise the relief of the terrain.

V-4. CONCLUSIONS

The implementation of propositions of historical-archaeological evidence scales in virtual reconstructions help to interpret and disseminate the heritage. The implementation of the terrain resolution scale alongside the historical-archaeological evidence scale can be used to represent the quality levels of virtual reconstructions, and it contributes to the dissemination of the archaeological heritage. Furthermore, it paves the road for the application of a digital research methodology in this field, and, with its use, it is intended to encourage the expert community in the construction of a common language. The creation of a proposition of terrain-associated resolution scale adds precision and greater veracity to the reconstruction of the physical surroundings.

The reconstructive units and methodological units imply the study and construction of the historical discourse shown in a single graphic image. The final infogram obtained, in which both scales are implemented, along with the explanatory table associated, highlight the virtual archaeological work conducted, for both the heritage asset and its surroundings.

The terrain-associated resolution scale proposed and described in this study poses the first creation of a criterion that can be understood and applied by the expert community. Furthermore, it helps the observers to understand and visualise the landscape represented in virtual reconstructions. To sum up, the terrain-associated resolution scale meets the principles established in the Seville Principles.

Through this research work, it was possible to represent the terrain associated with the virtual reconstructions of heritage assets based on a graphic scale. This fact can be transferred to other scientific disciplines, such as topography and engineering, among others. Any expert of another scientific discipline who obtains Digital Terrain Models in their research may implement the terrain resolution scale to show their veracity, that is, the methodology used for the generation of the Digital Terrain Models.

V-5. AUTHOR CONTRIBUTIONS

D-FG-M and IC-C contributed to the conceptualization; ICC, PT-T and J-MV-Z were involved in the methodology; PTT and D-FG-M contributed to the validation; IC-C, D-FG-M, PT-T and J-MV-Z were involved in the investigation; D-FGM contributed to the resources; IC-C contributed to the data curation; IC-C and PT-T contributed to the writing—original draft preparation; IC-C, PT-T and D-FG-M were involved in the writing—review and editing; IC-C and PT-T contributed to the supervision. All authors have read and agreed to the published version of the manuscript.

V-6. AVAILABILITY OF DATA AND MATERIALS

The data and material can be provided upon request from Paula Triviño-Tarradas (ig2trtap@uco.es).

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CAPÍTULO 6.

Summary, resumen y conclusiones generales

CAPÍTULO 6. Summary, resumen y conclusiones generales

VI-1. SUMMARY

Archaeology is the science that studies the knowledge of past societies through the material remains that come down to us from them. Since the beginnings of the discipline, methods have been used for the documentation and representation of archaeological remains, so that all the information corresponding to the heritage assets is recorded.

Opening a window into the past from the present is synonymous with the term Virtual Archaeology. According to the Seville Principles, the aim of virtual archaeology is the research and development of ways of applying computer-aided visualisation to the integrated management of archaeological heritage. Although virtual archaeology is a branch of archaeology, it involves two different methods of work, since the former is composed of non-invasive digital methods, while the latter involves destructive studies as the site itself is destroyed during excavation.

Virtual archaeology, in addition to being a tool that aids research, preservation, interpretation and presentation of heritage projects by means of computer-assisted visualisation, is a pedagogical aid for the viewers of heritage sites. This means that it provides users with a better understanding of the archaeological remains in situ. The creation of an archaeological document that represents these remains at a time prior to the present, as in the case of the Casa del Panadero de Torreparedones, helps the interpretation of the knowledge of the past.

For a correct dissemination of the archaeological heritage, it is necessary to consider to whom the final product studied reaches. The present thesis is interested in the dissemination of archaeological heritage and, therefore, thinks of the spectators in each of the investigations that have been carried out. For this reason, without losing the scientific nature of the work carried out, it is committed to the understanding of ordinary users, tourists and all those interested in archaeological heritage.

Today, all scientific disciplines rely on digital technologies for the production of their work. Digital technologies have advanced exponentially over the last 20 years, transforming science and societies. Digital technologies are a valuable resource in everyday life, as demonstrated during the health crisis.

In the field of heritage, digital technologies are also at the forefront, and are constantly being researched to advance the implementation of archaeological assets. The current situation of these technologies can be observed in more and more museums and archaeological sites, where they are used to help in the correct interpretation and dissemination of heritage. In the field of teaching, they are also supported by digital-virtual resources for students to learn about history and heritage. The use of these tools has advantages in teaching, such as increased motivation and interest on the part of students.

As mentioned above, the work carried out for this Doctoral Thesis is committed to the dissemination of archaeological heritage, specifically, the Casa del Panadero at the Torreparedones archaeological site. Therefore, taking as a starting point the archaeological remains preserved in situ and the results of the excavation of this property, the first objective was the 3D virtual reconstruction of this Roman house.

The virtual reconstruction of the Casa del Panadero involved the use of abundant information, corresponding to the excavation itself and bibliography of other Roman domus contemporary in time and space, for the identification and interpretation of spaces. After a better understanding of the dwelling, based on a photogrammetry carried out after the end of the excavation work, the reconstruction of the spaces began. The result was the dissemination of the 3D virtual reconstruction of the Casa del Panadero de Torreparedones by means of a QR code inserted in the article, which leads to a video on YouTube with an explanation of the house based on what was interpreted for the reconstruction of the heritage property.

Once the reconstruction of the Casa del Panadero had been disseminated, it was decided to disseminate the digital archaeological work that had been carried out on the

property. To do this, we opted for the use of the scale of historico-archaeological evidence. Firstly, the scale proposed by Aparicio and Figueiredo was implemented. With the current seminar entitled "Scientific representation in archaeology through the use of digital technologies: Implementation of the scales of evidence in the Mosque-Cathedral of Cordoba and the Castle of Gauzón", where two authors of different scales of historico-archaeological evidence were invited, conclusions were obtained that led to a new work. This work consisted of a comparison of the existing scales of evidence and the creation of a new proposal, the latter being supported by qualitative and quantitative studies.

The new proposal for the existing scale of historical-archaeological evidence is intended to be understood by the whole of society, regardless of age or background. To this end, the levels of evidence were reduced and achromatism was used for the choice of the chromatic range. The result was a scale of historical-archaeological evidence composed of six levels of veracity and with a chromatic range of warm colours.

With the work carried out for the virtual reconstruction of the house, taking into account the terrain of the house, and the work carried out with the scales of evidence, it was decided to make the most of the resolution of the Digital Terrain Models in archaeological work. This led to the creation of a non-existent proposal, the resolution scale associated with the terrain in the virtual reconstructions. Therefore, the last result presented in this Thesis is a colour scale composed of the existing methodologies for obtaining DTMs, where more intense colour levels denote lower resolution, while less intense colours denote higher resolution.

VI-2. RESUMEN

La arqueología es la ciencia que estudia el conocimiento de las sociedades del pasado a través de los restos materiales que nos llegan de ellas. Desde los inicios de la disciplina, se han utilizado métodos para la documentación y representación de los vestigios arqueológicos, de modo que quedara registrada toda la información correspondiente a los bienes patrimoniales.

Abrir una ventana al pasado desde el presente, es sinónimo del término Arqueología Virtual. Según los Principios de Sevilla, la arqueología virtual tiene por objeto la investigación y el desarrollo de formas de aplicación de la visualización asistida por ordenador a la gestión integral del patrimonio arqueológico. Aunque la arqueología virtual es una rama de la arqueología, suponen dos métodos distintos de trabajo, puesto que la primera se compone de métodos digitales no invasivos, mientras que la segunda, implica estudios destructivos ya que el propio yacimiento se destruye con su excavación.

La arqueología virtual, además de ser una herramienta que ayuda a la investigación, preservación, interpretación y presentación de proyectos patrimoniales mediante visualización asistida por ordenador, supone un instrumento de ayuda pedagógica a los espectadores de los sitios patrimoniales. Esto quiere decir que da pie a un mayor conocimiento de los restos arqueológicos *in situ* por parte de los usuarios. La elaboración de un documento arqueológico que represente dichos restos en momentos anteriores al presente, como es el caso de la Casa del Panadero de Torreparedones, ayuda a la interpretación del conocimiento del pasado.

Para una correcta difusión del patrimonio arqueológico hay que considerar a quiénes les llega el producto final estudiado. La presente tesis tiene interés en la difusión del patrimonio arqueológico y, por ende, piensa en los espectadores en cada una de las investigaciones que se han realizado. Por ello, sin perder el carácter científico de los trabajos realizados, se apuesta por el entendimiento de los usuarios de a pie, de turistas y todas las personas interesadas en el patrimonio arqueológico.

En la actualidad, todas las disciplinas científicas se apoyan de tecnologías digitales para la producción de sus trabajos. Éstas han avanzado exponencialmente en los últimos 20 años, transformando las ciencias y las sociedades. Las tecnologías digitales son un recurso valioso en el día a día, y quedó demostrado en plena crisis sanitaria.

En el ámbito patrimonial, las tecnologías digitales también son punteras, y siguen en constante investigación para el avance en la implementación de bienes arqueológicos. La situación actual de ellas se puede observar cada vez en más museos y yacimientos

arqueológicos, donde las usan para la ayuda de una correcta interpretación y difusión del patrimonio. En el ámbito docente, también se apoyan de recursos digitales-virtuales para el aprendizaje de la Historia y del Patrimonio por parte del alumnado. El uso de dichas herramientas supone ventajas en la enseñanza, como el aumento de la motivación y el interés por parte de los estudiantes.

Como se ha mencionado, el trabajo realizado para esta Tesis Doctoral apuesta por la difusión del patrimonio arqueológico, concretamente, de la Casa del Panadero del yacimiento arqueológico de Torreparedones. Por ello, teniendo como punto de partida los restos arqueológicos conservados *in situ* y los resultados de la excavación de dicho bien, el primer objetivo era la reconstrucción virtual 3D de esta vivienda romana.

La reconstrucción virtual de la Casa del Panadero supuso el manejo de abundante información, correspondiente a la propia excavación y a bibliografía de otras *domus* romanas contemporáneas en tiempo y espacio, para la identificación e interpretación de espacios. Tras el mayor entendimiento de la vivienda, teniendo de base una fotogrametría realiza tras la finalización de los trabajos de excavación, se empezó con la reconstrucción de los espacios. El resultado fue la difusión de la reconstrucción virtual 3D de la Casa del Panadero de Torreparedones mediante un código QR inserto en el artículo, que deriva a un video en YouTube con la explicación de la vivienda en base a lo interpretado para la reconstrucción del bien patrimonial.

Una vez realizada la difusión de la reconstrucción de la Casa del Panadero, se pensó en la difusión del trabajo arqueológico digital que se había realizado en el bien. Para ello, se apostó por el uso de la escala de evidencia historico-arqueológica. En primer lugar, se llevó a cabo la implementación de la escala propuesta por Aparicio y Figueiredo. Con la realización del seminario de actualidad llamado “Representación científica en la arqueología mediante el uso de tecnologías digitales: Implementación de las escalas de evidencia en la Mezquita-Catedral de Córdoba y en el Castillo de Gauzón”, donde se invitó a dos autores de diferentes escalas de evidencia historico-arqueológica, se obtuvieron conclusiones que desembocaron en un nuevo trabajo. Éste se compuso de la

comparativa de las escalas de evidencia existentes y la creación de una nueva propuesta, estando esta última apoyada por estudios cualitativos y cuantitativos.

La nueva propuesta de escala de evidencia histórico-arqueológica existente pretende el entendimiento de la misma por parte de toda la sociedad, independiente de su edad o formación. Para ello, se redujeron los niveles de evidencia y utilizó el acromatismo para la elección de la gama cromática. El resultado fue una escala de evidencia histórico-arqueológica compuesta por seis niveles de veracidad y con una gama cromática de colores cálidos.

Con el trabajo llevado a cabo para la reconstrucción virtual de la vivienda, teniendo en cuenta el terreno de la misma, y el trabajo realizado con las escalas de evidencia, se apostó por la puesta en valor de la resolución de los Modelos Digitales del Terreno en los trabajos arqueológicos. Esto dio lugar a la creación de una propuesta inexistente, la escala de resolución asociada al terreno en las reconstrucciones virtuales. Por tanto, el último resultado que presenta esta Tesis, es una escala de color compuesta por las metodologías existentes para la obtención de MDT, donde los niveles de color más intenso denotan menor resolución, mientras que los colores menos intensos denotan mayor resolución.

VI-3. CONCLUSIONES GENERALES

Las conclusiones de este trabajo, como indica la propia definición del término, es la consecuencia fruto de los estudios realizados. Para la obtención de estas, se requiere hacer mención a los objetivos planteados en cada uno de los trabajos ejecutados. Así como los objetivos generales de la presente tesis doctoral.

A lo largo de nuestras investigaciones hemos tenido como objetivo fundamental demostrar el potencial de la arqueología virtual en la Casa del Panadero del yacimiento arqueológico de Torreparedones. Es decir, hemos propuesto y defendido en esta tesis doctoral la reconstrucción virtual 3D, la implementación de las propuestas existentes de escalas de evidencia histórico-arqueológicas, la creación de una propuesta nueva de escala

de evidencia histórico-arqueológica y la creación de una escala de resolución aplicada al terreno o entorno donde se ubican las reconstrucciones virtuales.

Cabe mencionar que, la nueva versión de la Arqueología con las tecnologías digitales como herramienta principal, hace que los arqueólogos se formen en estos instrumentos. Desde el inicio de la disciplina siempre estuvo presente la representación de los vestigios arqueológicos, llevado a cabo por aquellos arqueólogos eruditos con papel milimetrado y lápiz siempre a mano. En la actualidad, cada vez más arqueólogos son capaces de manejar herramientas digitales para completar sus trabajos de arqueología, desde simples dibujos digitalizados de excavaciones a potentes recreaciones virtuales.

Por tanto, a partir de los resultados obtenidos, concluimos que, a pesar de la importancia de la formación de equipos multidisciplinares en arqueología, desde las Universidades se forman a profesionales que cuentan con las destrezas para trabajar por si solos con herramientas digitales. Teniendo esto en cuenta, sintetizamos a continuación las conclusiones principales.

En primer lugar, la reconstrucción virtual 3D de la Casa del Panadero (O1) ha resultado exitosa. Este trabajo supone el conocimiento de la vivienda en cuanto a su interpretación y al funcionamiento industrial-comercial de la misma, avanzando en el entendimiento de la vida de las personas que vivieron en el pasado en el yacimiento arqueológico de Torreparedones. La difusión de la producción 3D realizada ayuda al entendimiento de los restos arqueológicos *in situ*, con la explicación de ellos contenida en un Código QR que deriva a un video en YouTube. Entre otros aspectos, se piensa que, además de la difusión de la reconstrucción por parte del propio yacimiento arqueológico, esta podría ser utilizada en el ámbito docente, tanto para la explicación de la vivienda en época romana, como para conocer los espacios que comprenden la producción de productos panaderos en dicha época.

Otro de los objetivos a realizar en la investigación de la Casa del Panadero de Torreparedones era representar gráficamente el grado de evidencia histórico-arqueológica de la reconstrucción virtual previamente efectuada (O2). La implementación de la escala de veracidad propuesta por otros autores dio lugar visualización a través de una escala de

color, no solo de la reconstrucción virtual, sino también del trabajo arqueológico realizado en la ejecución de dicha producción. Esto se debe a que las escalas de evidencia histórico-arqueológicas expresan la veracidad de cada elemento presente en la reconstrucción, dando lugar a información sobre la producción de cada uno de ellos.

A pesar de la validez de las escalas de evidencia histórico-arqueológicas existentes, se propuso también como objetivo de esta tesis, crear una propuesta nueva en la que primara la comprensión de la misma por parte del público en general (O3). Trabajar con colores implica el trabajo con la teoría del color, por tanto, el comportamiento del color identificado mediante la rueda acromática, hizo que la elección de colores no fuera arbitraria, sino que se pensara en cómo afectan los mismos al ojo humano, qué reduce la fatiga visual, y cuál implica mejor comprensión visual. La nueva propuesta de escala de evidencia histórico-arqueológica facilita al público un mayor entendimiento del patrimonio arqueológico y del trabajo científico realizado en los bienes patrimoniales, pensada como criterio universal, comprensible y aplicable tanto por expertos como por espectadores en general.

Por último, y hasta la fecha, solo se había trabajado con reconstrucciones virtuales de los propios restos arqueológicos. En este contexto, y aludiendo al último objetivo específico de esta tesis, se apostó por abordar la necesidad de dotar a dichas reconstrucciones virtuales de elementos del entorno, paisaje o contextos coherentes con la topografía (O4). El objetivo fue definir/elaborar una escala de resolución para representar gráficamente, interpretar y evaluar el terreno asociado a las reconstrucciones virtuales, suponiendo un dato de evidencia real y mantenido durante siglos. Esta propuesta, que consigue la representación del terreno asociado a las reconstrucciones virtuales con una escala de color, aunque nace pensada para su implementación en arqueología virtual, es transferible a cualquier otra disciplina científica donde trabajen con Modelos Digitales del Terreno.

En definitiva, se puede decir que las investigaciones realizadas han concluido de manera exitosa. La investigación realizada en cada uno de los artículos presentados pone en valor y garantiza el cumplimiento de los principios de autenticidad y transparencia

científica considerados para las producciones de la Casa del Panadero, del yacimiento arqueológico de Torreparedones.

A partir de los resultados obtenidos en esta tesis doctoral, las posibles perspectivas futuras se orientan en dos direcciones principalmente. En primer lugar, avanzar en el testeo y la posible evolución tanto de la nueva propuesta de escala de evidencia histórico-arqueológica, como de la escala de resolución asociada al terreno. Para ello se prevé la implementación de ambas herramientas en otros bienes patrimoniales para observar cómo actúan tras su uso en diferentes restos arqueológicos. Por otro lado, se quiere trabajar en la obtención de metodologías precisas para la creación de reconstrucciones virtuales, de modo que el trabajo con ellas pueda ser accesible a más profesionales sin necesidad de una gran formación previa.

CAPÍTULO 7.

Aportaciones del doctorando.

Otras publicaciones

CAPÍTULO 7. Aportaciones del doctorando. Contrubuciones a Congresos Internacionales.

VII-1. DIGITAL REPRESENTATION OF THE TERRAIN ASSOCIATED WITH AN ARCHAEOLOGICAL SITE: CASE STUDY OF THE 'BAKER'S HOUSE' IN TORREPAREDONES

Artículo:

Triviño-Tarradas, P., Molina, D. F. G., Fernández, R. H., & Criado, I. C. (2022). Digital Representation of the Terrain Associated with an Archaeological Site: Case Study of the 'Baker's House'in Torreparedones. In Advances in Design Engineering II: Proceedings of the XXX International Congress INGEGRAF, 24-25 June, 2021, Valencia, Spain 30 (pp. 3-10). Springer International Publishing.

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VII-1.1. Introduction

Geographic Information Systems (GIS) are sets of related data with georeferenced information, that is, they are basic elements for the management of everything that presents a usable geographic component [1].

In every discipline, 70% of the information used is georeferenced [1]. In archaeology, this percentage is greater, as it is very important to place each element in space, in order to know the exact position of each heritage asset. These systems, in the archaeological scope, are key for the management of datasets that, combined in a single pack of information at a large scale, act as analytical systems [2]. In addition to the archaeological analysis, the combination of different tools and techniques allows documenting the heritage for subsequent valuation, and even solving complex research problems [3].

VII-.1.2. Objectives

The aim of this study was to compare the precision of two sources of terrain description data in order to integrate them into the visual representation of the archaeological site of Torreparedones (Cordoba, Spain), where the "Baker's House" is located. Both methodologies were described and we selected the one that required less investment time based on the quality of the work obtained. Then, qualitative results with a 360 panoramic picture taken at the study site were compared to determine the degree of accuracy of both methodologies.

VII-1.3. Materials and Software

The geographic framework of a project is fundamental for data extraction, and it is not always obtained from a single, coherent and quality source [4]. This project had a single administration unit (Baena, Spain), which provided information from central and administrative organisations.

To create the terrain of this heritage asset and, for the first study case, the data were extracted from the Spanish Geographic Information Centre (CNIG) [5], specifically, the 1st coverage digital model of the terrain with a 5-m mesh step (DTM05). Regarding the second study case, the source used for data extraction was Google Satellite, which allows visualising maps of the entire planet based on satellite images [6].

It is worth mentioning the different qualities of the data to be used. On the one hand, digital terrain elevation data from the Shuttle Radar Topography Mission (SRTM) has a mean square error of around 10 m worldwide, at best, and even worse on steep terrain [6]. It also has a poor ground sampling distance (GSD) of 90 m. On the other hand, the vertical accuracies of the LIDAR DTM data can be less than one meter, and with a GSD of 5 m [5]. It is also necessary to mention the updating of said data. While the PNOA LIDAR data is relatively up-to-date, the SRTM data was taken in February 2000. The differences between the two data are notable, and it might be impractical to make a comparison between them. From the point of view of virtual archaeology, it is comparable for the visual integration of a virtual archaeological environment.

Two open-code programmes were used in this study: 1) QGIS 2.3.15, and 2) Blender 2.90.0. The former is a GIS, whereas the latter is a programme designed for the modelling, animation and creation of three-dimensional graphics.

VII-1.4. Methodology

VII-1.4.1. Creation of the Terrain Using LIDAR Data in GGIS

Firstly, to create the terrain, it is fundamental to be sure about the geographic framework of interest for the study. In our case, the geographic framework is the countryside of Cordoba, specifically, the archaeological site of Torreparedones, at the northern end of the municipalities of Castro del Río and Baena [7, 8].

The data were obtained from the Download Centre of CNIG, "Digital Models of Elevations", which allows searching by list and selecting the province of municipality of interest. The Digital Terrain Model (DTM) downloaded for this study was of 1st coverage, with a 5-m mesh step. It has two raster layers: one for the relief at the national level and the other one for elevations.

To obtain a DTM in QGIS using LIDAR data, the raster layers were entered. The study area was located at the archaeological site of Torreparedones. To export the 3D DTM files, we used the QGIS2threejs tool. This complement can be downloaded from Google by typing its name [9]; once downloaded, it has to be loaded in QGIS. This complement allows visualising the DTM.

The resolution was improved by changing the properties of the relief layer, increasing the geometry resampling level to 6 and the resolution of the material to 400% (5500 × 3456 px). This improvement allowed the DTM to be saved and used for the desired purpose. The model can be saved through two options: as an image (.png) or as a gITF file (.gltf, .glb); the latter is the most commonly used to import this model to other software.

The last step of this methodology consists in removing the rear walls and the base of the three-dimensional model, with the aim of reducing the size of the file. To this end, the Blender 2.90.0 software was used, importing the model obtained in QGIS. Each side of

the terrain obtained in QGIS is an independent model. Therefore, it was only necessary to select and delete the unwanted sides.

The result was a 3Dmodel with good resolution (Fig. VII-1), which, after being imported to other software, such as Blender, can be further manipulated to optimise the resolution in areas of interest; additionally, the model can also be optimised by modifying the terrain manually.

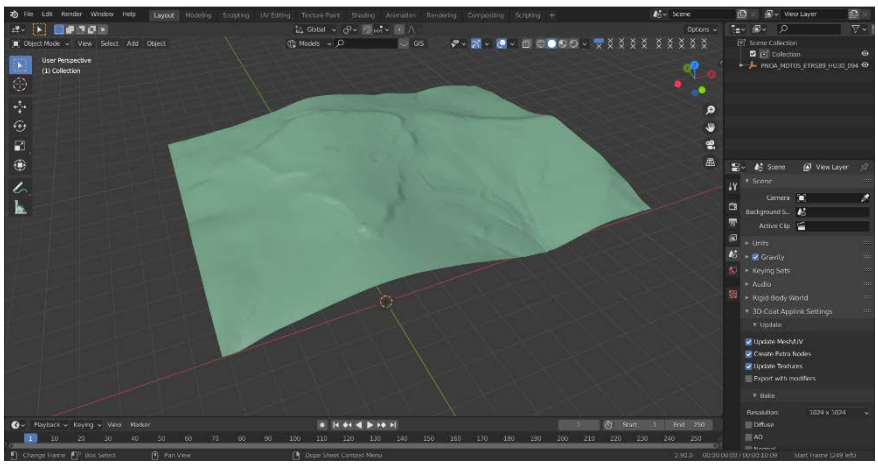

Fig. VII-1. Result of the digital terrain model of the obtained terrain (Developed by authors).

Furthermore, textures can also be incorporated into the model. Uniform textures can be applied to the entire terrain or specific areas. Lastly, other models can be added to this 3D model, to make the terrain more realistic. In this case, the *domus* of this archaeological site, and even vegetation, can be added to the environment.

VII-1.4.2. Creating the Terrain with Blender GIS

The second tool used in this study, i.e., Blender GIS, allowed adding maps of real locations of the entire world directly from this software. Although the detail of these maps is not very high, they can provide a good basis for the elevation of the terrain.

The first step for the creation of a terrain using Blender GIS was to install Add-ons 3D View: BlenderGis [10]. With the installation of this necessary complement, a work tab called “GIS” appears in the screen, where the terrain is developed (“Web

geodata" – "Basemap"). To create the terrain of the archaeological site of Torreparedones with Blender GIS, we used Google as a source and Google Satellite as a layer. Once we had the desired view for the 3D map, we obtained the view in an image without relief. This was achieved through "Get SRTM", which, from the data of Open Street Maps, created the 3D area of the current view. To improve the visualisation of the relief, with better resolution, the model was subdivided, obtaining a mesh with smaller polygons.

To increase the horizon, the same steps must be followed, adding a new layer of Google GIS and selecting a broader view of the environment. The overlapping of the two objects can be prevented by adding a cube whose dimensions allow for a slight overlapping at the edges. Then, this cube can be subtracted from the new horizon terrain (Fig. VII-2). Thus, greater detail was achieved for the archaeological site of Torreparedones, where the *domus* was later placed, obtaining smaller polygons, while the horizon had lower detail and a broader view.

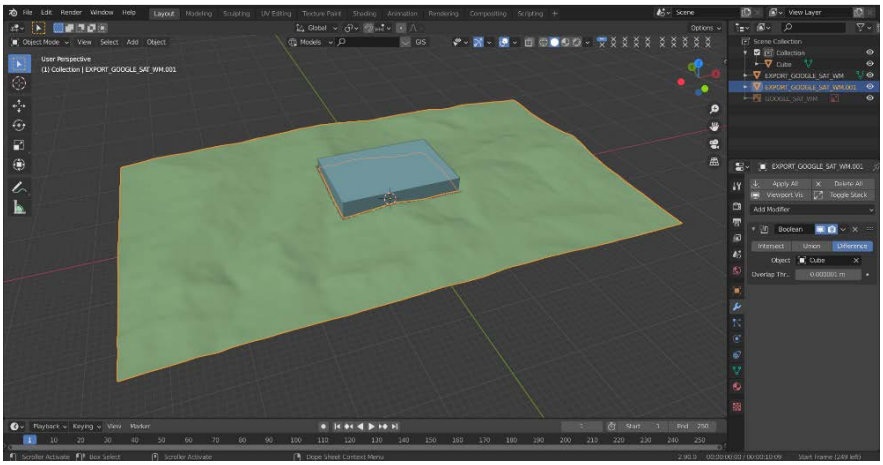

Fig. VII-2. Difference of the cube applied to the horizon using the "Boolean" modifier (Developed by authors).

As in the first methodology, these models can be further manipulated to attain new results in them, or even add new models to them.

VII-1.5. Results and Discussion

The main results of this study were achieved from the data obtained from the download centre of CNIG [5] and Google Satellite [6]. Likewise, the use of the described programmes was of great help for the realisation of this work.

The digital representation of the terrain was successful with both methodologies. However, at this point, we must determine which methodology best suits the desired results. It is fundamental to know the resolution of the model; i.e., the greater the detail, the greater the quality of the representation. Therefore, the qualitative comparison of the two methodologies suggests associating greater detail to the creation of the terrain using LIDAR data in QGIS. The data extracted for the creation of the terrain are key for such resolution, thus the data from CNIG can be considered to be more precise than those from Google Satellite. As was previously mentioned, Blender GIS does not stand out for its detail level.

Another important factor to take into account is the time invested in each methodology. The programmes used are not intuitive, thus handling them for the first time can be tedious. For the creation of the terrain, QGIS requires fewer steps than Blender; i.e., the latter requires more time. Therefore, QGIS generates greater resolution in less time.

Lastly, the two methodologies were compared with a 360 panoramic picture taken in situ. It is worth mentioning that the 360 panoramic picture was divided into four sections (the cardinal points), as the landscape of the archaeological site of Torreparedones was too small due to the large size of the image. Four sub-images (north, south, east and west) of each methodology were obtained, with the same camera parameters used in the in situ panoramic picture. This accurately shows the common points of the landscape in both methodologies and the four cardinal points with respect to the 360 panoramic picture.

To calculate the approximation percentage of the points marked in the images obtained from the programmes with respect to the 360 panoramic picture (Table VII-1), we used the scale presented in Fig. VII-3. Supposing the 117 squares of each image to be

100% of the approximation, each square would be 0.85%. We subtracted half of a square (0.42%) from each point, since, although the points of the data from LIDAR and Google Satellite are in the same square with respect to the 360 panoramic picture, they are not in the exact position. The level of similarity for both methodologies is shown between brackets.

Table VII-1.

Points and their locations associated with Fig. VII-3.

Points	*On-site panoramic*	*LIDAR data*	*Google Satellite data*
1	N2-A4	N2-A4 (99.58%)	N1-A5 (97.88%)
2	N1-A7	N1-A7 (99.58%)	N1-A8 (98.73%)
3	N2-A12	N2-A13 (98.73%)	N2-A11 (98.73%)
4	E3-B2	E3-B2 (99.58%)	E3-B2 (99.58%)
5	E2-B6	E2-B6 (99.58%)	E3-B6 (98.73%)
6	E5-B8	E5-B8 (99.58%)	E4-B9 (97.88%)
7	S3-C3	S3-C4 (98.73%)	S3-C2 (98.73%)
8	S4-C4	S4-C4 (99.58%)	S3-C4 (98.73%)
9	S3-C9	S3-C9 (99.58%)	S3-C10 (98.73%)
10	O9-D4	O8-D4 (98.73%)	O8-D4 (98.73%)
11	O2-D8	O2-D7 (98.73%)	O3-D8 (98.73%)
12	O2-D13	O2-D13 (99.58%)	O2-E13 (99.58%)
		99.29%	98.73%

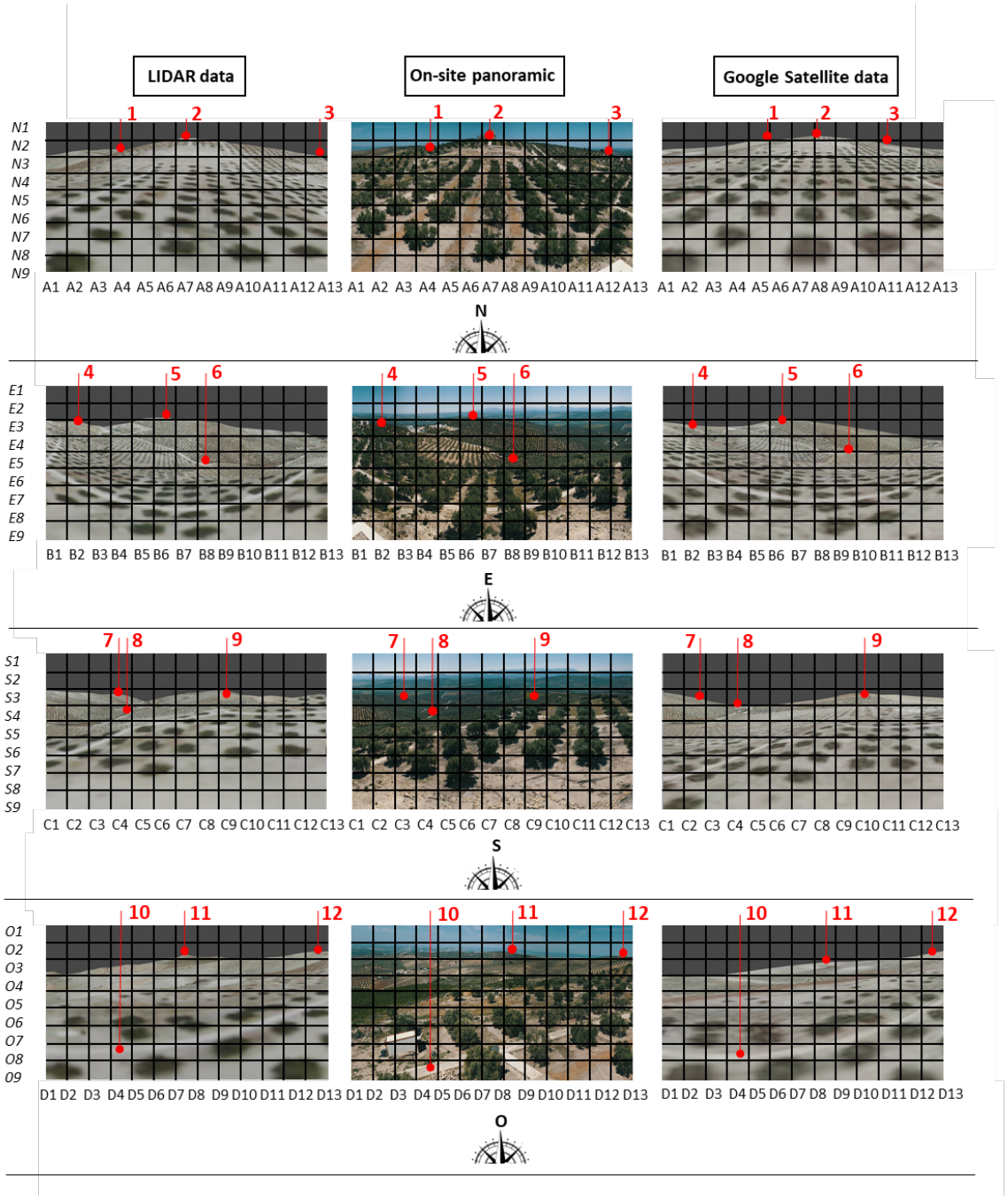

Fig. VII-3. Comparison of LIDAR data and Google Satellite data with the 360 panoramic picture.

Thus, we can assert that the recreation of the terrain is more accurate using LIDAR data with respect to Google Satellite data, since the points marked in the first methodology are 99.29% similar to those of the 360 panoramic picture, whereas the points in the second methodology showed 98.73% similarity (Table VII-1).

VII-1.6. Conclusions

Geographic Information Systems are indispensable in archaeological research. Virtual reconstructions guarantee the graphic recording and conservation of heritage, thereby playing an important role in the recreation of the landscape of heritage assets.

The data used to carry out the recreations of the terrain using the two methodologies were determinant. The LIDAR data showed greater detail and accuracy in the similarity of common points. Despite the fact that the methodology performed with Google Satellite produced lower detail and resolution, it provided a good basis for the elevation of the terrain, although the latter required manual modifications to obtain better results in some areas.

It can be concluded that the results of the present study were successful, since the two proposed methodologies were adequately compared. The recreation with QGIS using LIDAR data was more favourable, since, in addition to the above mentioned, it requires less time to produce a 3D terrain.

VII-1.7. References

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VII-2. TECHNIQUES FOR THE REPRESENTATION OF THE APPLICATION OF HISTORICAL-ARCHAEOLOGICAL EVIDENCE SCALES IN HERITAGE ASSETS

Traducción del artículo:

Cáceres-Criado, I., García-Molina, D. F., Hidalgo-Fernández, R. E., & Triviño-Tarradas, P. (2022, September). Techniques for the Representation of the Application of Historical-Archaeological Evidence Scales in Heritage Assets. In *Advances on Mechanics, Design Engineering and Manufacturing IV: Proceedings of the International Joint Conference on Mechanics, Design Engineering & Advanced Manufacturing, JCM 2022, June 1-3, 2022, Ischia, Italy* (pp. 1610-1619). Cham: Springer International Publishing.

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VII-2.1. Introduction

Representation techniques in archaeology exist since the beginning of this discipline. These have advanced and gained global interest in cultural needs. To cover what society demands in terms of heritage, there is a fundamental tool: its dissemination [1]. Archaeology does not only consist in recovering heritage assets of past societies, but

also in building a historical discourse based on them. This requires archaeological research, which currently relies on digital technologies for the interpretation of archaeological remains. Moreover, these technologies play a key role in the conservation, preservation and dissemination of cultural assets [2].

The dissemination of heritage and archaeological research can be included in education, which is achieved with the representation of heritage using digital technologies. This study is focused on the comparison of three propositions of existing historical-archaeological evidence scales, which show the veracity of the virtual reconstructions. A historical-archaeological evidence scale is a colour scale associated with a 3D virtual reconstruction. The aim was to indicate the levels of evidence that make up such reconstructions, in order to allow the observer to identify which parts have greater or lesser historical-archaeological evidence. The use of the historical-archaeological evidence scale dates to around 2014, since then only six scientific research papers have been published in this field.

VII-2.2. Objectives

The aim of the present research was to represent the degree of historical-archaeological evidence of a heritage asset, through the use of the existing three propositions of evidence scale. These scales were compared to obtain accurate results of their application, identifying the suitability of each proposition.

VII-2.3. Materials and Software

The extraction of data from the existing historical-archaeological scales is fundamental for their comparison. In the literature about this type of graphical representation, it was observed that not all propositions have been used to support virtual reconstructions. Moreover, the two propositions used in scientific research appear in a different number of studies.

Project Byzantium 1200 was developed to recreate the city of Bizantium for the year 1200 [3]. Patrick Clifford, Jan Kostenec and Albercht Berger, with the use of a colour graduation, aimed to complement and support the virtual reconstructions with the

representation of the degree of historical-archaeological evidence. The scale proposed by these authors has ten levels of evidence, each of them associated with one colour, with warmer and colder hues indicating greater and lesser evidence, respectively (Table VII-2).

Table VII-2.

Historical-archaeological evidence scale of Project Byzantium 1200 [3].

Level of evidence	*Colour*	*Definition*
1		Exist in its original form
2		Partially or with modifications
3		Photographs or plans available
4		Archaeological information
5		Detailed graphical evidence
6		Simple graphical evidence
7		Textual and comparative evidence
8		Textual evidence
9		Based on similar structures
10		Imagination

This proposition has been used by other authors. P. Aparicio and C. Figueiredo applied it for the first time to verify its effectiveness [4]. As a result, they established a fixed colour code, which relates the historical-archaeological evidence to a level of veracity. Colours are associated with a number (from 1 to 10), corresponding to the lower to higher level of evidence (Table VII-3).

Table VII-3.

Historical-archaeological evidence scale proposed by P. Aparicio and C. Figueiredo [4].

Level of evidence	*Colour*	*Definition*
1		Imagination
2		Conjecture based on similar structures
3		Basic textual reference
4		Descriptive textual reference
5		Simple graphical reference
6		Detailed graphical reference
7		Basic archaeological information or simple base plans
8		Strong archaeological and documental evidence in photographs and detailed plans
9		Still existing (or partially existing) with modifications
10		Still existing in original form

The last proposition, which is more revolutionary, was developed by R. Ortiz, E. León and R. E. Hidalgo [5]. Unlike the previous propositions, it has eight different levels of historical-archaeological evidence and, in addition, it modifies the colour range and gradation of the evidence levels. They obtained a scale with a colour range of dark greens to browns for eight levels of historical-archaeological evidence (Table VII-4).

Table VII-4.

Historical-archaeological evidence scale proposed by R. Ortiz, E. León and R. E. Hidalgo [5].

Level of evidence	Colour	Definition
1		Still existing in original form
2		Still existing with modifications
3		Detailed graphical evidence

4		Slight graphical evidence
5		Archaeological hypothesis
6		Textual evidence
7		Based on similar structures
8		Based on historical context, nature and culture

After obtaining the information of the existing options of historical-archaeological evidence scales, we selected the heritage assets on which they would be applied for their comparison.

In this case, we selected the area of a heritage asset: the *cella penuaria* (pantry) and *culina* (kitchen) of a Roman *domus*. A virtual reconstruction of these spaces, as well as of the entire building, had been previously performed.

Computer programmes 3DReshaper, SketchUp and LumenRTwere used to carry out the previous virtual reconstruction. However, to implement the evidence scale, Blender 2.90 was used; therefore, the 3D model had to be imported to this software in order to conduct this study.

VII-2.4. Methodology

The archaeological site of Torreparedones is located in the countryside of Cordoba, on the northern border of the towns of Castro del Río and Baena. The studies carried out in this place indicate that it was inhabited from the 4th millennium BC to the 16th century. In the 2015–2016 excavation campaign, the excavation and documentation of the *domus* under study took place [6]. The recovered archaeological remains have three construction phases: the late republican Roman phase, the high imperial Roman phase and the medieval-modern phase. The 3Dvirtual reconstruction carried out in this heritage asset focuses on the second construction phase, with the bread oven in operation [7].

Prior to the implementation of the evidence scales, the reconstructive units of the previous reconstruction were selected, as well as the evidence levels that correspond to

each reconstructive unit (Fig. VII-4). The latter help to record more accurately the historical-archaeological characteristics of the elements that are present in virtual reconstructions. Each reconstructive unit (RU) is associated with a degree of veracity, depending on the level of evidence corresponding to the element identified with the reconstructive unit number.

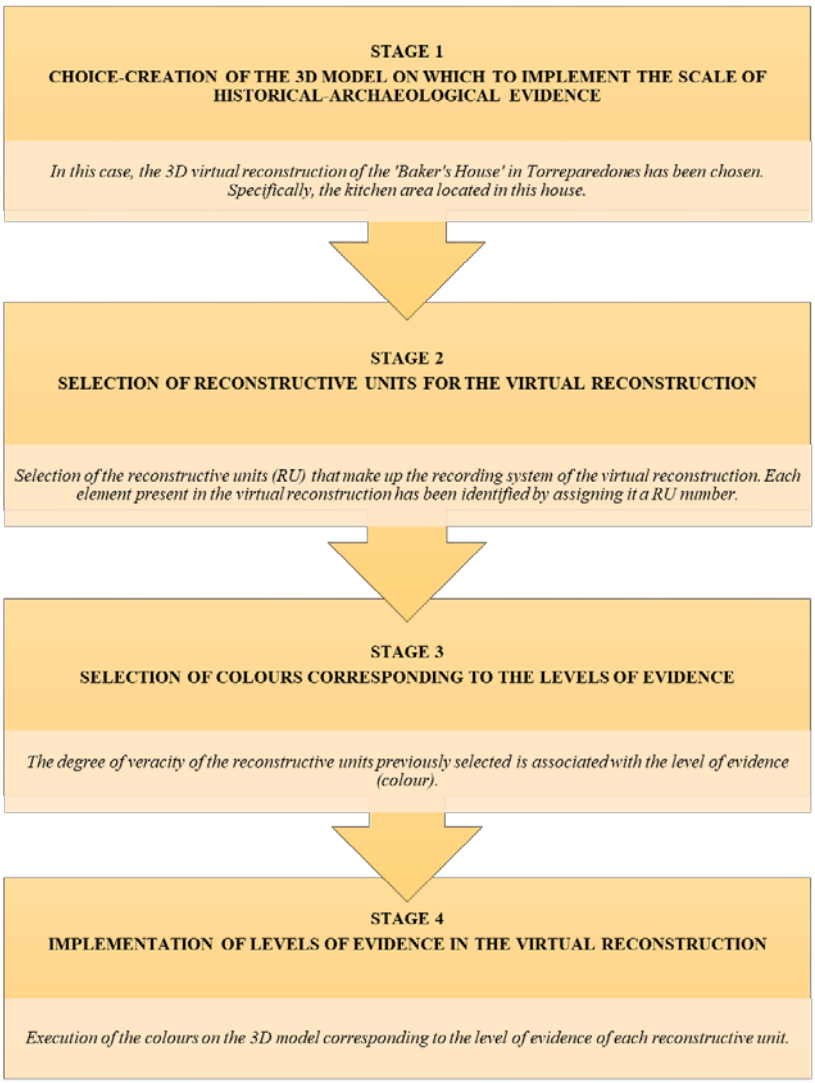

Fig. VII-4. Implementation phases of the historical-archaeological evidence scale in the kitchen area in the Baker's house in Torreparedones.

The area selected for the implementation of the historical-archaeological evidence scales has 6 reconstructive units, corresponding to:

- Pavement
- Base of the walls
- Elevation of the walls
- Bay of access to the *culina*
- Preserved remains of a masonry structure
- Elevation of the masonry structure
- Roman furniture associated with these spaces

The evidence levels associated with each reconstructive unitwere established according to the elements used for their virtual reconstruction. For the pavement, the level of evidence is associated with the archaeological information and hypotheses. The pavements of these rooms were not preserved, although it is possible to estimate how they would be, based on remains documented in other areas of the building.

The walls that make up the spaces have two levels of evidence: the one for the foundations and the one for the elevation. Regarding the foundations, that is, the base of the walls, since they were preserved, the greatest degree of veracity or evidence is assigned to them. To analyse the reconstruction of their elevation, the study is based on the work of Vitrubio, that is, on the proportions, since the height is not preserved in its entirety.

In its northern side, the space identified as the possible cella penuaria presents an access to the culina, which is 0.97 m wide. Since the bay does not preserve its height, it was assigned a “partially existing” level of evidence. In the culina, the remains of a masonry structure were documented; therefore, the preserved remains are attributed the greatest level of evidence. For the reconstruction of such structure, we used the textual references of the archaeological excavation report, which corresponded to the evidence level of the structure elevation.

Lastly, for better understanding the spaces, Roman furniture associated with them was added. Such elements, simply added for pedagogical reasons, have the lowest level of evidence.

After applying the colours that corresponded to each of the evidence scale propositions in the kitchen of the Roman building, three infographics of the 3D model were obtained: Project Byzantium 1200 (Fig. VII-5), P. Aparicio and C. Figueiredo (Fig. VII-6) and R. Ortiz, E. León and R. E. Hidalgo (Fig. VII-7).

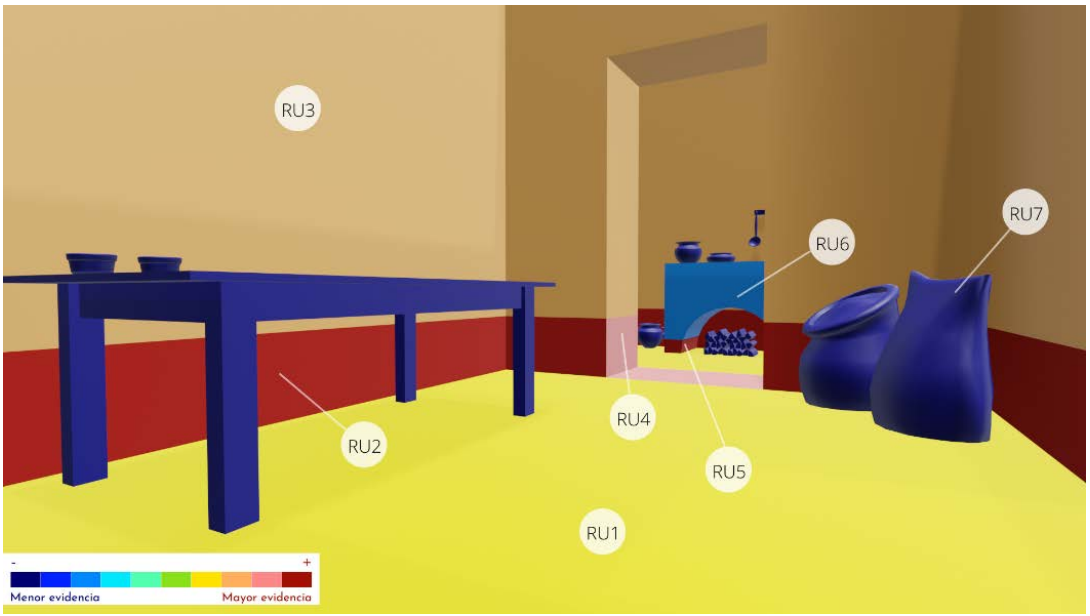

Fig. VII-5. Application of the historical-archaeological evidence scale proposed in Project Byzantium 1200.

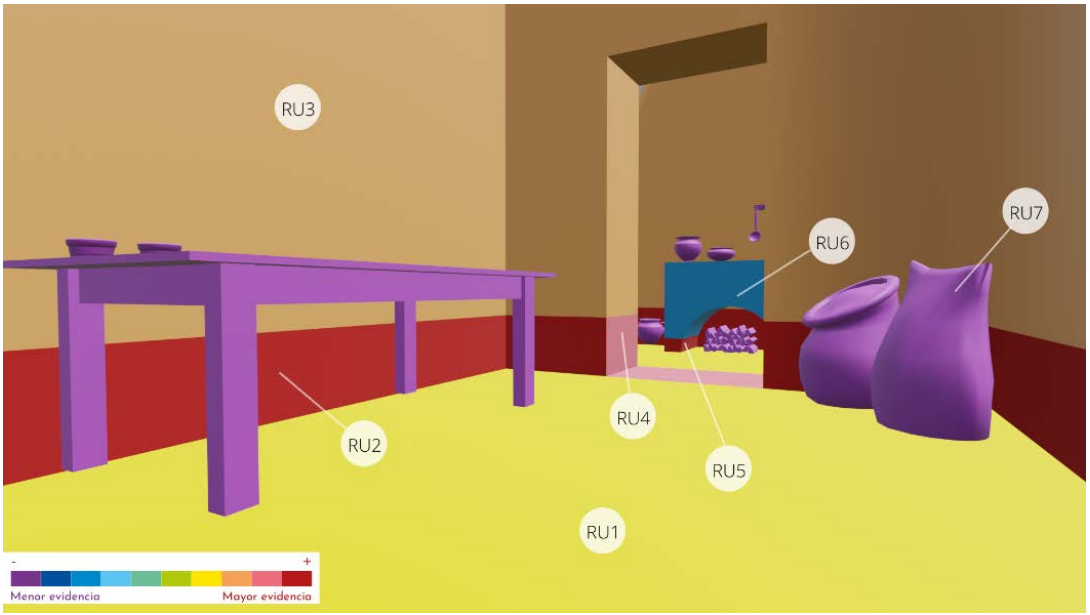

Fig. VII-6. Application of the historical-archaeological evidence scale proposed by P. Aparicio and C. Figueiredo.

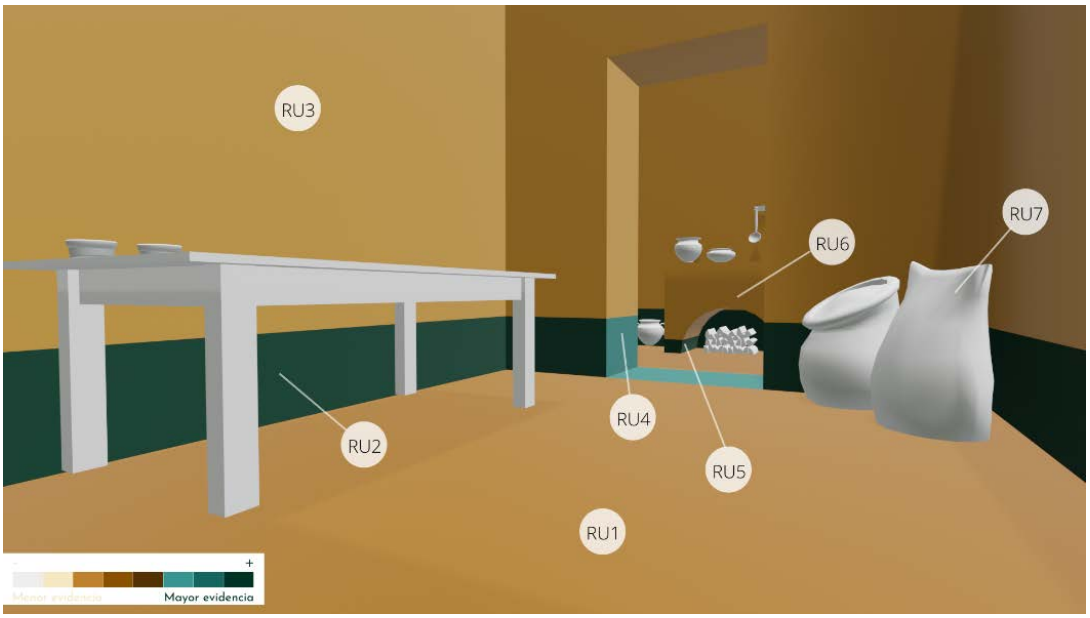

Fig. VII-7. Application of the historical-archaeological evidence scale proposed by R. Ortiz, E. León and R. E. Hidalgo.

VII-2.5. Results

As was previously mentioned, for the implementation of the historical-archaeological evidence scales, a thorough documentation process was conducted to obtain the ideal materials to perform the virtual representation. From that search, we obtained results regarding the amount of scientific studies found. The proposition of Project Byzantium has not been used in any scientific study. The proposition of P. Aparicio and C. Figueiredo appeared in six studies, four of which were conducted by the mentioned authors to support virtual reconstructions [4, 8, 9, 11], and, in the fifth and sixth studies, different authors used the proposition to support the representation of the degree of evidence of a heritage asset [10, 12]. The proposition of P. Aparicio and C. Figueiredo was first used in the year 2016 [8], and was last applied in the year 2021 [9]. Lastly, it is worth highlighting that there is only one scientific paper about the most recent evidence scale, which presented the scale to the scientific community [5].

The application of the existing evidence scales in the area of the kitchen of the Roman building led to the creation of a table that shows the reconstructive unit number, the levels of evidence of each proposition, and the name of the reconstructed elements (Table VII-5).

Table VII-5.

Identification of the reconstructive units and the evidence levels of the three scale propositions.

RU Nº	Evidence level Project Byzantium proposition	Evidence level P. Aparicio and C. Figueiredo proposition	Evidence level R. Ortiz, E. León and R. E. Hidalgo proposition	Name
1	4	7	5	Pavement
2	1	10	1	Base of the walls
3	3	8	6	Elevation of the walls
4	2	9	2	Access bay

5	1	10	1	Base of the masonry structure
6	8	3	6	Elevation of the masonry structure
7	10	1	8	Roman furniture

Table VII-5 shows two significant aspects: the colour and number of the evidence levels. Firstly, regarding colour, it is observed that the first and second propositions have quite similar colours and the same colour range, but different hues, whereas the third proposition has a totally different colour range. Secondly, the evidence levels of the first and third propositions are numbered from greater to lesser veracity, with level 1 corresponding to the existing elements, whereas the last level (level 10 for the first proposition and level 8 for the third proposition) refers to elements or structures based on the historical, cultural and natural context. However, in the second proposition, the evidence levels are numbered from lesser to greater veracity, with level 1 corresponding to elements based on the historical, cultural and natural context, whereas level 10 refers to the existing elements.

After the application of the evidence scales, considering the obtained infographics (Fig. VII-5, VII-6 and VII-7), it is worth mentioning that there are no differences between the first and second propositions, except for the level identified as elements or structures based on the historical, cultural and natural context. The colours of both propositions are clearly differentiated from each other. In the third proposition, evidence levels 5 and 6 are not differentiated, since they have very similar colours.

Finally, it is worth mentioning that the existing proposals for scales of historical-archaeological evidence comply with the theoretical framework of the Seville Charter and the principles of interdisciplinarity, purpose, complementarity, authenticity, historical rigor, efficiency, scientific transparency, and training and evaluation [13].

VII-2.6. Conclusions

The number of elements in the virtual reconstruction is proportional to the number of reconstructive units. The graphic representation of the historical-archaeological evidence scales must differ visually, in order to easily identify and interpret their differences in terms of veracity.

Therefore, the present study considers the proposition of P. Aparicio and C. Figueiredo as the most suitable, for several reasons. Firstly, this proposition is a more recent and improved version of the scale proposed for Project Byzantium 1200. Likewise, the colours are valid for the understanding and differentiation of the reconstructed elements. Moreover, of all the existing scales, this is the most frequently used to support virtual reconstructions. In the third proposition, there are two evidence levels that cannot be clearly differentiated. It is believed that this is not valid for this type of representations and that there would be more undifferentiated levels if the evidence scale were applied to the building in its entirety.

An advance in this field, that is, the graphic representation of the veracity of the degree of historical-archaeological evidence, could be the discrimination by colours that the general user employs in his/her everyday life, interpreting the colours according to a daily routine symbology: red, yellow and green are associated with danger, precaution and guarantee, respectively. The establishment of these three main colours would pose the creation of a unique language that would be easy to understand for the general public. Observers would very easily identify the evidence levels that correspond to all the reconstructive units reflected in the virtual reconstructions.

The use of the historical-archaeological evidence scale is a great opportunity to add value to archaeological research. With it, users can observe the representation of the heritage assets in a specific period before to the current one and identify the degree of veracity of each of the parts of the virtual reconstruction.

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