

HERITAGE 2018

Proceedings of the 6th International Conference
on Heritage and Sustainable Development
10th Anniversary Edition

VOLUME 2

Edited by

Rogério Amoêda

Sérgio Lira

Cristina Pinheiro

Juan M. Santiago Zaragoza

Julio Calvo Serrano

Fabián García Carrillo



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In Memoriam
Professor Gregory Ashworth
(1941-2016)

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*Granada, Spain
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The logo for Green Lines Institute features the text "green lines institute" stacked vertically in a green, sans-serif font. To the right of the text is a graphic element consisting of five vertical bars of varying heights and colors: three green bars and two blue bars.

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Green Lines Institute for Sustainable Development
Av. Alcaides de Faria, 377 S.12
4750-106 Barcelos, Portugal
mail@greenlines-institute.org
<http://www.greenlines-institute.org>

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The detached farmstead towers from 12th Century Sierra de Segura (Jaén, Spain): contributions to the territorial settlement of the al-Andalus period. Results of the R&D&I project #ProyectoSegura

S. Quesada-García & G. Romero-Vergara
School of Architecture, University of Seville, Seville, Spain

ABSTRACT: On the border between the ancient *garb al-Andalus* and *sharq al-Andalus* lies the Segura de la Sierra valley (Jaén, Spain), an area in which the medieval ways from Seville and Granada came together on the way to the east of the Iberian Peninsula. Given its strategic position and fertile orography, during the 11th and 12th centuries, *Sapura* became an important Islamic *cora* (administrative division of al-Andalus). A complex system of towers still remains from this era, built using the rammed earth construction technique. With the aim of delving further into this rich heritage, the research project #ProyectoSegura is being carried out, designed to obtain details that provide more information about the implementation criteria, chronological dating, and construction techniques used by applying a methodology based on the use of new technologies. The description of this work process and the presentation of the main results are the contributions of this communication.

1 INTRODUCTION

In the Segura de la Sierra valley and the surrounding area, located in the northeast of the province of Jaén (Spain), there is a system of fourteen dispersed and sparsely spread out medieval towers, built during the 11th and 12th centuries during the height of the Almohad Empire. A little-known heritage, it is made up of a series of fragile elements using the rammed earth construction technique and which today build and define a landscape that is not only natural but, above all, cultural. Many of these towers have not been modified or undergone any interventions since they were built; therefore, they offer the perfect opportunity to gain more in-depth knowledge about them, as they represent an unaltered record that has reached present day practically intact.

This exceptional series of disperse elements of Muslim architecture had not been systematically and thoroughly studied before 2003, when we began to study these towers with the aim of conducting intervention and conservation projects in order to develop an in-depth understanding of them and to contribute, within the scope of our disciplinary area, towards scientific knowledge within the extensive historiography of medieval Islamic architecture. The work carried out since then has resulted, since 2014, in various competitive research projects, including the Research, Development and Innovation project financed by the Spanish Ministry of Economy and Competitiveness.

Within the framework of this project, various studies and assignments have been carried out using techniques such as material tests, ¹⁴C dating, and stratigraphic and parameterisation

methods, among others. A detailed architectural study of the entire valley's towers has been conducted, along with studying the topography and construction area thereof, using photogrammetric techniques and drone flights, which has enabled detailed 2D drawings to be created along with 3D modelling of the buildings and their surrounding areas. These techniques have enabled the digitalisation, classification and dissemination of this heritage.

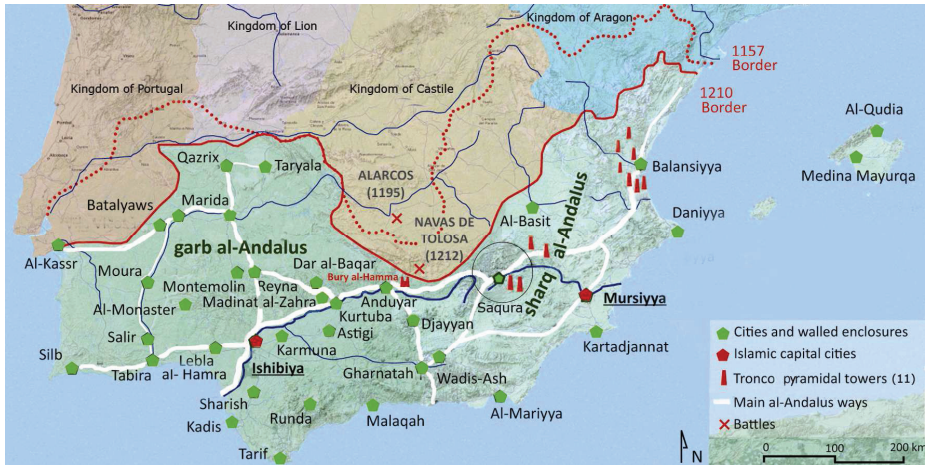


Figure 1. Al-Andalus in the 13th century with an indication of the main roads and cities during that time, among which is the *cora* of Saqura (Segura de la Sierra).

Lastly, knowledge has been transferred with the creation of a patent applied to the restoration of free-standing rammed earth buildings, as is the case with these towers. The information and results obtained to date are contributing to the creation of a historical, typological and functional characterisation of these medieval elements, which enables them to be interpreted and compared with one another and with other similar cases on the Iberian Peninsula, allowing their origin to be confirmed and the theories set out at the beginning of the research to be proven.

These tasks are being carried out by researchers from the TEP-965 research group from University of Seville with occasional collaborators from other Spanish and international research groups, all of whom are coordinated by Prof. Santiago Quesada-García, the lead researcher for the project.

Among the various articles and communications through which this research has been disseminated, mention should be made of the article published four years ago in REHAB 2014 entitled: "Rehabilitation Proposal of some of the Islamic Towers in the Segura de la Sierra Valley (Spain). Significance and cultural values of this built heritage and their territory". The article focused on presenting an in-depth individual description of these towers, analysing them from a constructive, morphological and functional point of view. The communication presented the first photogrammetric surveys and proposals for the restoration of the rammed earth constructions, called *tapia* in Spanish. It also set out some restoration theories that intended to explain the criteria for constructing the towers in the territory.

This communication is a continuation of previous publications; it explains new findings and results, as well as the method used to obtain these. It also, for the first time, compares the Sierra de Segura towers with other disperse Muslim architectural elements built in the territory of al-

Andalus during the 12th century, with the aim of identifying common patterns and finding criteria for constructing these sparsely spread out elements in the territory that do not form part of urban centres. To do so, it illustrates how the tower system defines the region, connecting ways, waterways, farmed areas, topographies, etc., as well as how these elements have the capacity to organise regions, anthropise spaces and become essential elements of the landscape that we admire today. These territorial relationships in this type of sparsely spread out, medieval Islamic architecture are seldom studied in our discipline, and yet research is providing information of significant documentary value in this regard, which will serve as a new reference for knowledge of these detached and dispersed buildings constructed during the 11th and 12th centuries on the Iberian Peninsula (Fig. 1).

The description of the work process, the methodology and the main results obtained to date are the contributions of this communication to the REHAB2018 international congress, to be held in June 2018 in Granada.

2 BACKGROUND

Given the extensive nature of this research, it is worth including the main milestones achieved over the last fifteen years regarding these towers in Sierra de Segura, to ensure the relevant documentary evidence is recorded:

- 2003 Photogrammetric survey and restitution of the tower of El Cardete (Benatae), North and South Watchtowers of Santa Catalina (Orcera), the Tower of Góntar and the Tower of Water (Segura de la Sierra).
- 2006 Drafting of the restoration and consolidation project for the North and South Watchtowers of Santa Catalina (Orcera). Laboratory tests on the physical, chemical and mechanical characteristics of materials.
- 2007 Drafting of the restoration and consolidation project for the Tower of Góntar and Tower of Water (Segura de la Sierra). Laboratory tests on the physical, chemical and mechanical characteristics of materials.
- 2010 Execution and management of the project for the consolidation of the Tower of Góntar
- 2013 Pre-competitive research project “The construction of a landscape: rammed earth architecture in High Andalusia during the 13th century. Study and analysis of the Andalusian tower system in the Segura de la Sierra valley”, University of Malaga.
- 2014 Update of the execution projects for the North and South Towers of Santa Catalina (Orcera) and for the Torre del Agua project (Segura de la Sierra).
- 2015 Research, Development and Innovation Project, “The Islamic medieval tower system in Segura de la Sierra: establishment, construction techniques and restoration of rammed-earth constructions” (*#ProyectoSegura*).

In other words, an initial consolidation project was drawn up, still to be executed, for the North and South Watchtowers of Santa Catalina (2005). Subsequently, two intervention projects were carried out for the Tower of Water and the Tower of Góntar (2007). Of all these projects, only the one referring to the remains of walls and the Tower of Góntar was carried out in 2009.

The towers in the Segura de la Sierra valley are subjected to various pressures, which sometimes compromise their survival or leave them open to interventions without guarantees or without prior research projects being conducted to gain greater knowledge of them and to establish the best techniques to be applied, based on specialist knowledge.

Furthermore, this historical heritage forms an unbreakable part of the identity and the sustainable use of a cultural landscape defined within the framework of a natural protected area such as the Cazorla, Sierra de Segura y las Villas Natural Park, making it essential to carry out comprehensive research, as outlined below (Fig. 2).

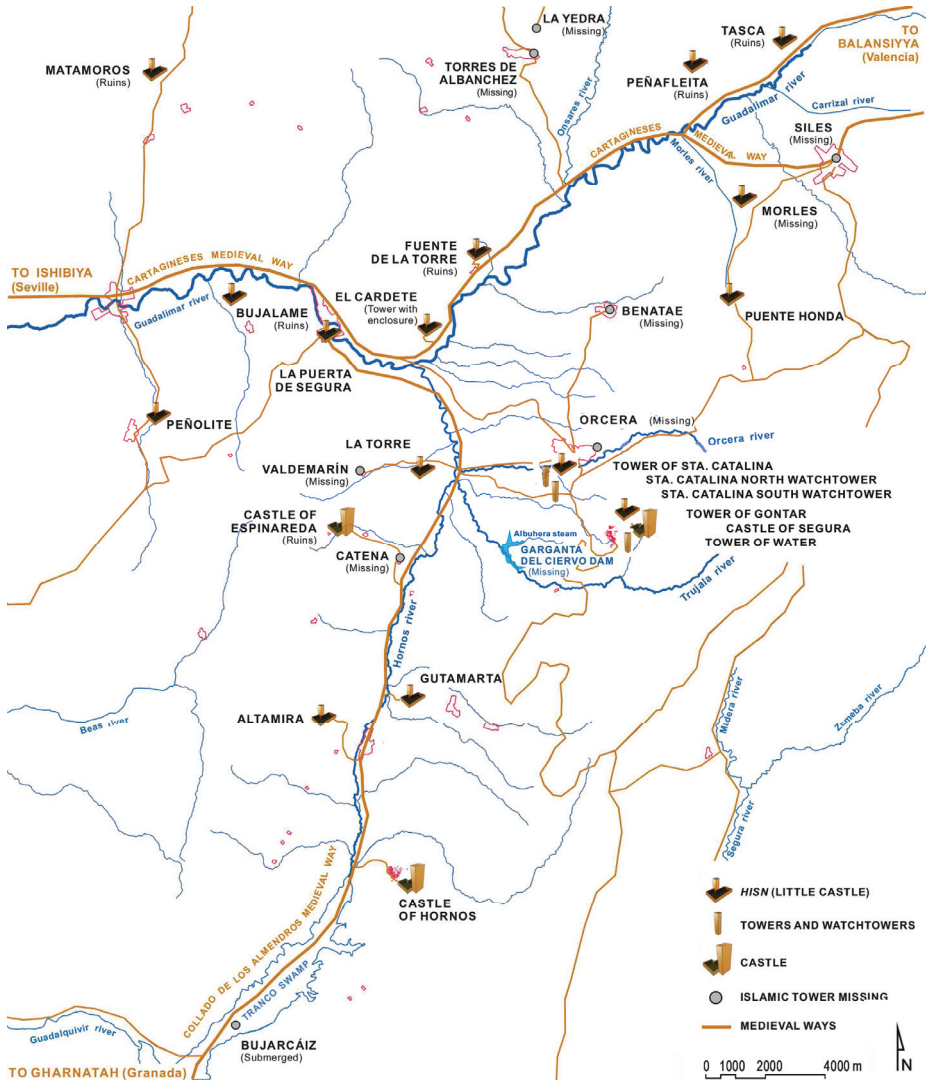


Figure 2. Location of the *husun* (small castles and enclosures with towers), watchtowers and castles in the Segura de la Sierra valley (Jaén) with medieval ways.

3 GOALS

This research, development and innovation project is proposed and developed as part of the Spanish Strategy for Science, Technology and Innovation, within the “Challenge in social changes and innovations v protection and preservation of culture and heritage: artistic-cultural and archaeological heritage as a source for developing new scientific-technical capacities and sustainable exploitation models”, in order to conduct a systematic and thorough study of all the towers in this valley at a documentary, territorial, graphic, constructive or pathological level. The project includes the following general objectives:

1. To study and define the characteristics of the cultural landscape in which this medieval architectural heritage is located, which complements the natural landscape

and defines and builds the territory. To highlight these historical elements as a system that interacts with the topography, roads, waterways, populations, crops, etc., exceeding the perception thereof as isolated and unconnected elements.

2. To disseminate the historical, cultural and landscape heritage of these Islamic elements built in the 11th and 12th centuries in Sierra de Segura among the scientific community and society in general.
3. To create an inventory of these types of constructions that still conserve important emerging structures to manifest their presence in the landscape of ancient al-Andalus, obtaining in-depth knowledge of these towers from various points of view: landscape, territorial, chronological, morphological, typological and constructive.
4. To determine the criteria for the construction of these detached and dispersed architectural elements in al-Andalus, with the aim of discovering their ways of using the territory and to establish commonalities and differences, by applying new technologies to generate documentation, research and conservation of these cultural, landscape and archaeological remains.
5. To study medieval rammed earth construction techniques and compare and establish relationships between the different typologies and morphologies of other towers still preserved in *garb al-Andalus* and *sharq al-Andalus*.
6. To establish a methodology for the study, conservation, restoration and dissemination of these types of buildings with the aim of raising awareness, conserving and protecting both the individual properties and their surrounding areas, fostering interdisciplinary approaches in the study and knowledge of these assets and their territory.

4 METHODOLOGY

The work methodology used in the research project covers various phases basically grouped together into: documentation/research, conservation/restoration and dissemination. These phases are summarised in a series of actions as follows:

4.1 *Compilation, study and analysis of historical and graphic documentation*

- a) Unedited and edited sources.
- b) Archaeological excavations.
- c) Non-metric graphic representations: engravings, drawings, sketches, perspectives.
- d) Metric graphic representations.

4.2 *On-site data acquisition and sample extraction*

- On-site data acquisition. A thorough data acquisition system is carried out on-site by means of photos, videos, sketches and au naturel drawings. Subsequently, topographic measurements are taken with the Leica total station together with laser distance measurers. Stereoscopic photographs are taken using 22-megapixel cameras with an optical zoom of 14, 20 and 28mm.
 - Recording topographic points using differential GPS and via total station. The ground point cloud is completed with another obtained using a drone, which incorporates a compact 16-megapixel camera with a fixed zoom at 28mm. Traditional techniques are combined with the use of advanced technology such as 3D scanning of the territory.
 - For the photogrammetric restitution, a computer with ASRix software licences is used for photographic rectification, VSD and PoivilliersF for stereoscopic restitution, Orthoware to adjust blocks of photos and Photoscan for photogrammetric scanning.
 - Recognition and archaeological research into the surrounding area of the towers, completed with the review of files located in the Regional Ministry of Culture of the Regional Government of Andalusia regarding surveys conducted in the surrounding areas of these towers in recent years.

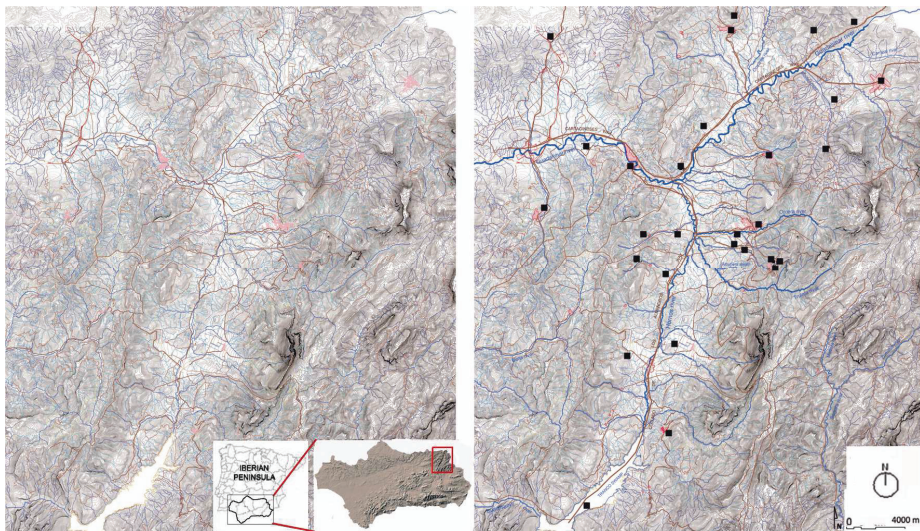


Figure 3. Analysis of the territorial, orographic and topographic scope of the Segura de la Sierra valley. The new planimetry is generated at 1:30,000 scale, and the locations of physical elements and of the existing and missing Islamic remains are determined.

- Material sample extraction with the aim of carrying out physical and chemical tests, which has enabled the resistance and composition of limes, aggregates and particle sizes to be established. Collection of wood samples from points, beams, struts and yokes for analysis by means of dendrochronological and radiocarbon analysis in the National Accelerator Centre (CNA) at University of Seville.

4.3 Analysis of the territorial, orographic and topographic scope

- Analysis of cartographies and territory of the spatial area in which the Sierra de Segura towers are located. This involves an inventory of maps and existing aerial photographs of the area, analysis of historical maps and, above all, macro-spatial readings of the valley's territory, its orography, water network and infrastructure system, in order to learn more about the occupation, defence and exploitation thereof (Fig. 3).
 - Various areas with similar orographic characteristics and architectural elements were selected in the territory of al-Andalus in order to compare these and identify similar and/or different elements in the way in which they are constructed. Three different areas have been individualised as follows: the old way between Seville and Badajoz, the Segura valley and the Sierra Calderona in the area of Valencia.
- Generation of new surveys of the Segura de la Sierra valley. The most updated digital mapping was used (flights and surveys from the Institute of Cartography of Andalusia and the National Geographic Institute). Based on these, vector-based planimetric maps and cartographies were created with computer-assisted design programs and image processing, generating a planimetric map at a scale of 1:50,000 and 1:30,000 (Figs. 4-5).
- Based on the point cloud obtained of the terrain with the drone, the three-dimensional orography of the area in which the towers are located is obtained and, based on the break lines, the isometric lines at a scale of 1:10/1:20 with contour lines every 20cm.
- Creation of digital terrain models (DTMs) that enable a better orographic representation of the areas in which the existing military structures are located; the graphic representation of the territory is always shown in 3D because this enables a more in-depth analysis of data than when conducted in two dimension.

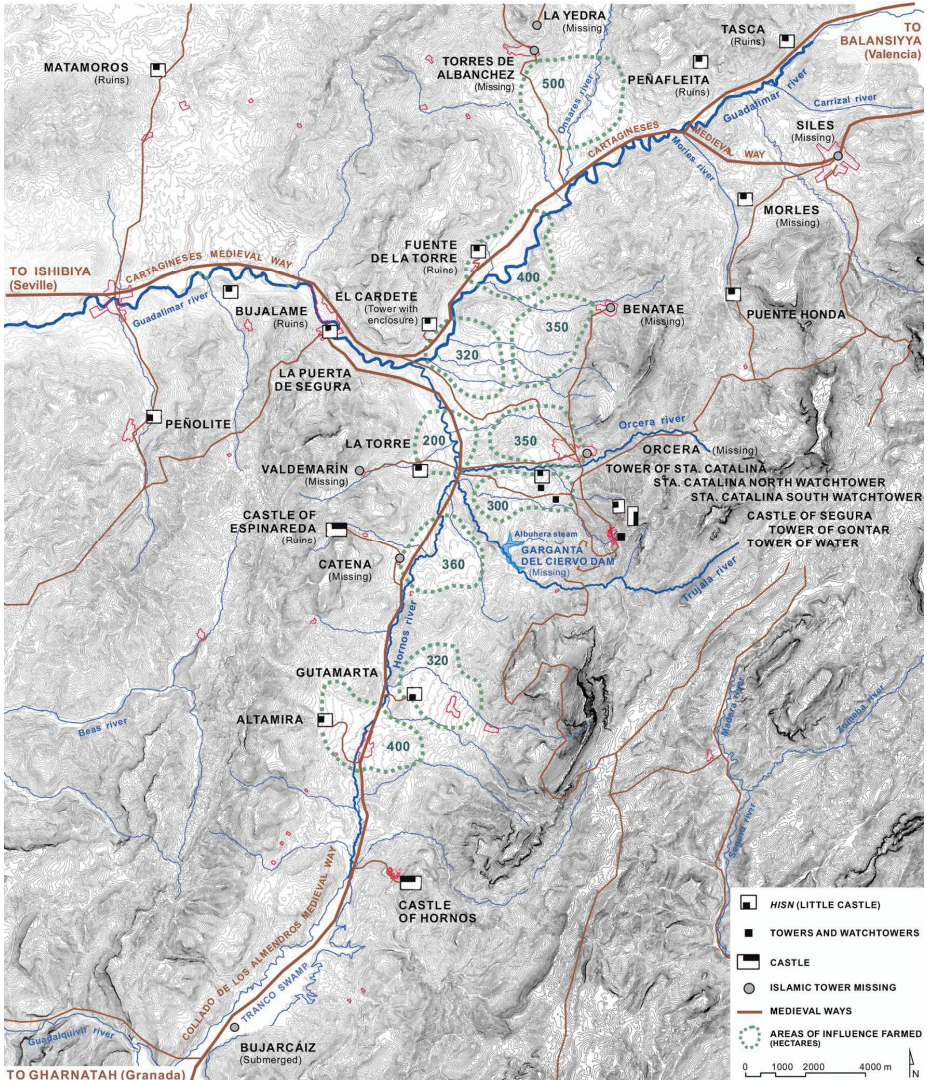


Figure 4. An analysis of the territorial implantation of the castles, towers with enclosure (existing and missing) and watchtowers on the Segura de la Sierra valley, as well as their relation to the medieval ways, rivers, topography and cultivable areas.

— Based on this, topographic surveys of each of the tower sites are carried out, at a scale of 1:500 and, very occasionally, at 1:200, with the aim of drawing or precisely interpreting their layout and perimeters and identifying possible continuities or existing roads hidden by development processes, olive plantations, water basins, river channels, roads, quarries, erosions and other anthropic and natural alterations, since the territory contains marks made by previous occupations and is made up of successive stratifications of the same area. This cartographic base enables the construction of the towers to be studied more precisely, as well as the relationship of these with other fortifications, productive structures, historical roads, infrastructure works and water routes (Fig. 6).

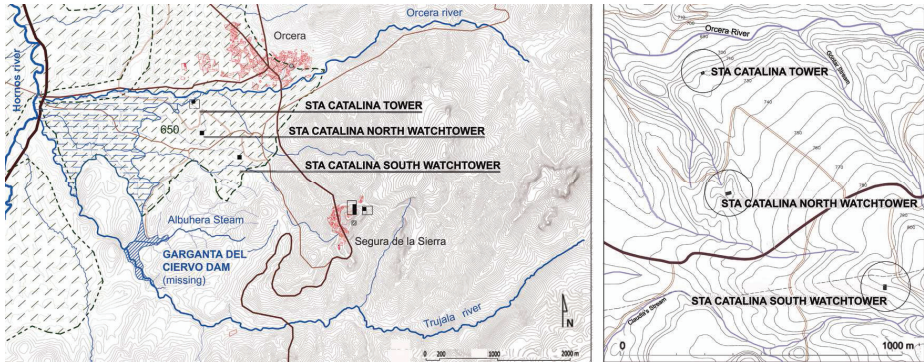


Figure 5. Sta. Catalina Plains with the implantation of the towers and the delimitation of arable and irrigable areas by the Almohad dam Garganta del Ciervo (Salvatierra & Gómez, 2016) located in the area where the Albuhera stream now flows (the meaning of the toponymic means: artificial water deposit)

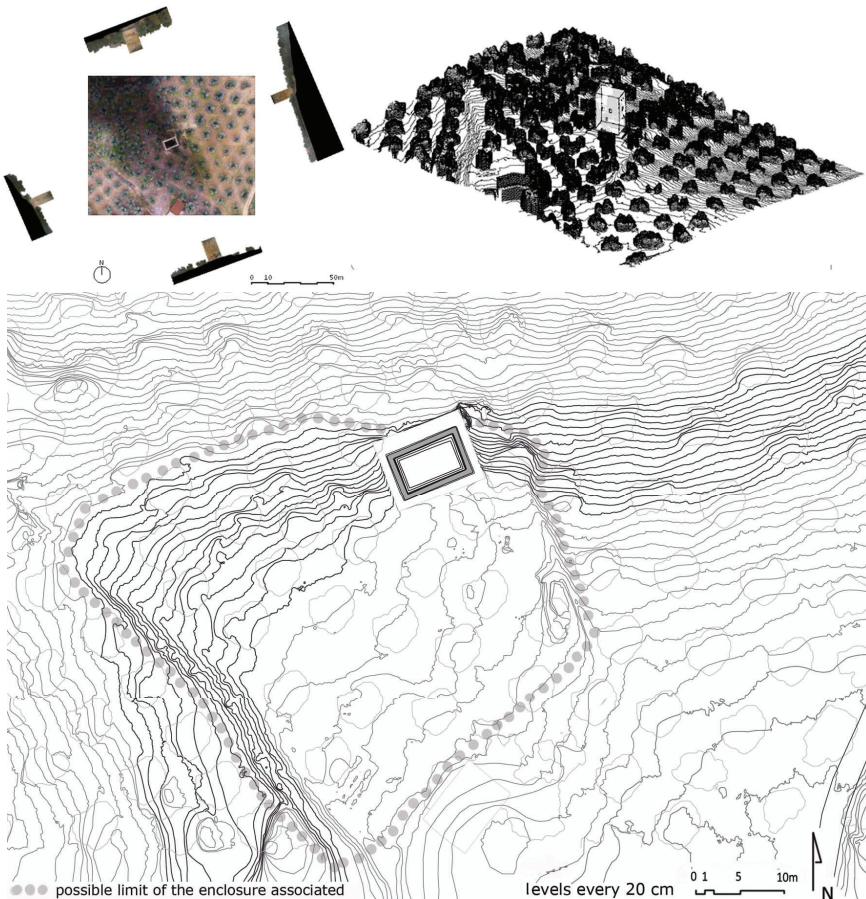


Figure 6. The development of the digital terrain model in 3-D around the Tower of Santa Catalina (Orcera). Taken from the cloud of points obtained with a drone and the subsequent development of isolines with contour levels every 20cm. From here, a topographic survey at a scale of 1:200 is carried out, which allows the location of the possible limits of the enclosure normally associated with each tower.

4.4 Drafting of interpretative, textual and graphic conclusions

- Photogrammetric survey of the elements based on the information obtained with sketches, total station, digital cameras and drones, obtaining all the internal and external elevations of each tower, the planimetry thereof and exact sections. This work has enabled a formal, volumetric and stratigraphic interpretation thereof. These drawings are created with computer-assisted programs, carrying out two-dimensional photogrammetric planimetry with a level of detail equivalent to a scale of 1:50 and defined in varas, boxes or rammed earth sections, and also in metres (Fig. 7).
- Parietal study of the most significant elements by applying the Harris matrix. The stratigraphic reading focused on the study of the different stratigraphic units of each element, analysing the on-site setting of the timber formwork or shuttering, called *tapia* or *tapial* in Spanish, the modulation thereof and the construction technique used. Based on this, the elements of the rammed earth wall construction process could be interpreted and discovered, together with the corbel systems and platforms to enable upper access to the towers.
- Interpretation of the results obtained by means of the 14C analysis, which must always be in addition to the architectural and archaeological analysis of the building. The radiocarbon dating analysis makes sense together with the combined understanding of the stratigraphic sequence of the remains because it is relevant whether the analysed sample was obtained in the original context or from secondary deposits.
- Parameterisation and geo-referencing of all the data, materials and elements obtained in each of the towers via processed databases using GIS applications to enable the integration and analysis thereof and access to the information available in Open Data (Fig. 8).

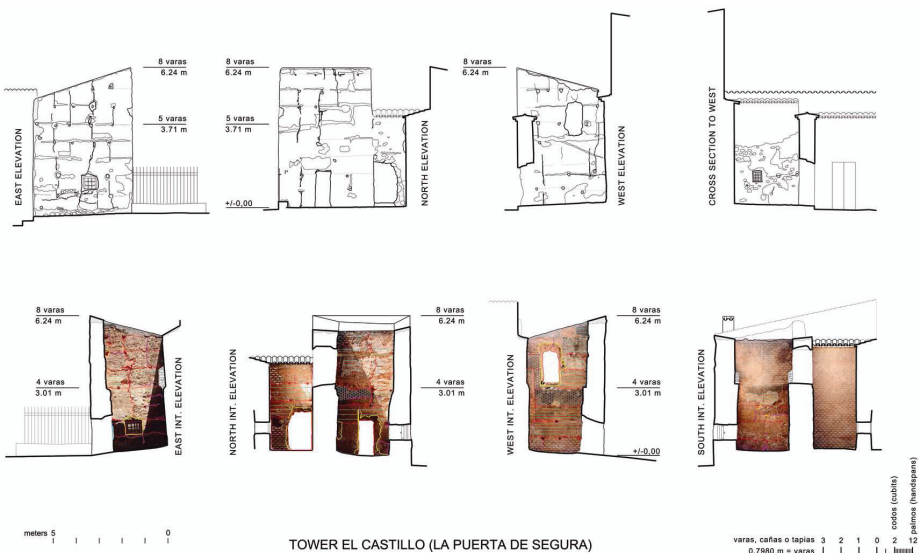


Figure 7. An architectonic survey and façade analysis of the Tower of El Castillo (La Puerta de Segura).

4.5 Transfer of knowledge

The aim of the transfer of results is to find solutions applied to resolving construction and structural problems occurring in these types of narrow and free-standing rammed earth buildings, with breakage problems throughout their height, and with the aim of resolving problems arising as a result of the restoration of and intervention on the rammed earth buildings.

4.6 Dissemination and internationalisation plan

The scientific dissemination of the results of this research is being conducted by organising scientific seminars, exhibitions and by attending national and international scientific conferences such as REHAB, ResTapia, ReUso, etc.

Also with production of 3D drawings, perspectives and models, with the aim of disseminating and communicating these in travelling exhibitions, and creating animations to be disseminated on websites or in interpretation centres, such as those in the Segura de la Sierra castle. Dissemination of this information in the region of Segura, the province of Jaén, Andalusia and other national and international areas, to facilitate access to this knowledge by society in general.

Accordingly, we have proposed the creation of hiking and cycling routes or heritage itineraries that enable this historical architecture to be discovered as part of an integrated, recreational and healthy experience. Dossiers, guides and itineraries will be published to complement existing ones so visitors can locate them easily as another element of the Natural Park. It is also being disseminated online in the institutional repository of Seville University: <https://idus.us.es/>; and via the blog: <https://santiagoquesada.blogspot.com.es/>.

5 MAIN RESULTS AND DISCUSSION

The study, analysis and research of the medieval towers of Sierra de Segura, conducted using the aforementioned methodology, is providing a series of information, some unpublished until now, and in-depth knowledge of this Muslim system of rammed earth architecture. The main results obtained are as follows:

1. Fourteen photogrammetric and topographic surveys of all the towers of which there are remains. These are drawings made by combining traditional techniques with the use of advanced technology such as 3D scanning with aerial means. These drawings have produced comprehensive documentation, partially submitted with the previous REHAB2014 communication and in this one, enabling the correct classification, dissemination and display of this largely unknown heritage.
2. The quality of the rammed earth construction technique on the Sierra de Segura towers is illustrated, among other characteristics, by the presence in some towers (Puerta de Segura and Góntar) of logs embedded in the building, located in places where the section of the wall changes. They are various joined timbers that act as reinforcement. The presence of these timbers as ring beams or tie bars is a new aspect that has also been discovered in these investigations.
3. Another result worth mentioning, obtained in the higher towers, is the slight slope always present on three of their sides (between 2-3°), with the fourth one being completely straight. This aspect illustrates a clear construction intention that must have been planned and taken into account during the execution process.
4. Some of these medieval structures have been chronologically dated by 14C analysis, carried out in the National Accelerator Centre of Seville University, based on samples from the wooden elements. The tests carried out on the North and South Watchtowers of Santa Catalina, El Cardete, Peñolite and La Puerta de Segura, provided an average dating between 1018 and 1155. Another test on the lime crust of the South Santa Catalina tower offered the same range of dates (1026-1154). Therefore, it can be confirmed that these towers date back to before the Christian conquest of the territory, which took place in about 1214. If the oldest dating is taken into account (1026), they may have been built during the Taifa Moorish Kingdom of Saqura. If the later date (1164) is taken into account, it would mean they were built at the height of the Almohad period.

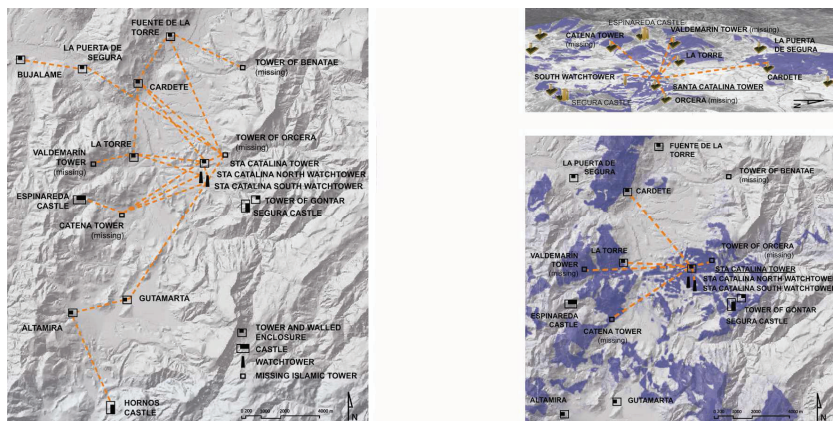


Figure 8. Left: A study of the visual basins and the intervisibility between the different towers of the valley. Right: The visual basins are from the Tower of Santa Catalina (Orcera).

5. Another contribution of this research is the discovery in the Góntar and Cardete towers of lime coatings with shapes and drawings simulating false ashlars. This aspect would confirm the chronological detail outlined in the preceding section, given that this particular technique is attributed to that African Berber dynasty. Therefore, these Sierra de Segura towers can be related to similar examples built by the Almohads in al-Andalus, bearing in mind that the age of the original tree in the analysed sample would have to be added to those dates.
6. The stratigraphic reading of the walls has enabled the manner in which some of these towers were accessed to be established. In the case of the North Watchtower of Santa Catalina, the access was 7.18m high, and it was 6.85m high on the South Watchtower. These significant heights made it impossible to reach with a single step (wooden or ropes) given the weight and the difficulties involved in handling it. We were able to determine through the location of alcoves and wall drains, planned during the execution, that the access system was via different external platforms, which, like a scaffolding, enabled a logical and rational access.
7. We should point out, given the importance and implication of the restoration of these types of rammed earth constructions, the result obtained in the transfer of knowledge from this research which has led to a national invention patent granted by the Spanish Patent and Trademark Office, consisting of a “Flexible Anchor for Attaching an Elastic Tie to an Earthen Wall” ES 2329207B1. The patent is related to the restoration of heritage and consolidation interventions in rammed earth architecture.

6 CONCLUSIONS

These Muslim architectural elements, located in the Segura de la Sierra valley, are situated in an area in which the two medieval ways from Seville and Granada meet, joining to head towards the east of the Iberian Peninsula. They are towers built using the rammed earth construction technique. As a result of the stratigraphic analyses carried out, comparisons with similar examples of al-Andalus, the presence of shapes simulating false ashlars on the lime coatings and the results of the ¹⁴C dating, it can be definitely concluded that these are Muslim towers, built between the 11th and 12th centuries.

One of the main contributions of this work has been to discover the construction criteria for these Islamic constructions in the territory, dispersed and detached constructions that, nevertheless, form part of a complex system of infrastructures made up of ways, livestock trails, rivers, water dams, farming land, etc. and in which these enclosures with towers constitute the main hubs. This aspect has been verified by determining that the different locations of the

towers triangulate the territory, eliminating dead angles and blind spots, creating an intricate network of visual connections. However, the most significant aspect is that these towers are closely related to the surrounding land area, with a gentle topography and, therefore, are easily accessible and irrigable, which justifies the location. This situation can be clearly appreciated in Altamira, Gutamarta, Catena, La Torre, Sta. Catalina, Orcera, El Cardete, Fuente de la Torre, Benatae and Torres de Albanchez. All of them are elements that control equivalent areas comprising between 350 and 500 ha. This enables us to conclude that these towers were associated with farmsteads and buildings related to productive activities in this valley, some of which are still present today in the form of small hamlets, groups of country houses or farmhouses still in use today (Altamira, La Torre), and others are now urban centres (La Puerta, Orcera, Benatae).

As a provisional conclusion, we could say that this research into the tower system in the territory of Sierra de Segura has enabled and is managing to extract a large amount of information from the new details now emerging. The insight offered by this knowledge will enable aspects such as the territorial establishment of these free-standing Islamic architectural elements to be covered and addressed from a new perspective. Likewise, the increasing depth of understanding regarding their construction systems enables new contrasted methodological patterns to be established for interventions on rammed earth buildings. The interest and scope of the findings obtained justify their dissemination in this communication.

ACKNOWLEDGEMENTS

This work has been possible thanks to the research carried out within the framework of the State Programme for Research, Development and Innovation Aimed at Society's Challenges, as part of the 2013-2016 State Plan for Scientific and Technical Research, with the project entitled "The Islamic medieval tower system in Segura de la Sierra: establishment, construction techniques and restoration of rammed-earth constructions". The precursor to this project was the pre-competitive research project from University of Malaga called: "The construction of a landscape: rammed-earth architecture in High Andalusia during the 13th century. Study and analysis of the Andalusi tower system in the Segura de la Sierra valley", proposed and directed by the same researcher.

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