The Management of Archaeological Information at the Site of Vascos (Navalmoralejo, Toledo): Approach, Data Integration and Representation in an Intra- and Intersite Model

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The necessary collection and management of the wide range of data from the archaeological site of "Madina Vascos" in its different excavation campaigns since 1975, has required the design of a system for the integration of all geographic, geological, archaeological and historical information available. These data have later served as an analytical tool both intra- and intersite. Furthermore, we believe it is essential to conduct a detailed analysis of the most important architectonic elements-the defensive system-, for which we consider having three-dimensional documentation at our disposal necessary. Moreover, the importance of this archaeological site suggests the use of new technologies for the necessary dissemination of the information. In this paper we present the project for the management, analysis and visualization of this old Al-Andalus city, by means of the development of a Web-based Geographic Information System, the three-dimensional reconstruction of the Kasbah with a laser scanner, and the development of a website to allow the use of Internet as a platform for the search and diffusion of Archaeological Heritage.

Keywords: Web-GIS, Intra- and Intersite analysis, Lasser Scanner, "Mādina Vascos"

1. Introduction

In this paper we present the tools on which we have worked to design a system that brings together all the available information, archaeological, geographical, architectural, historical... Through a configuration that will permit its development and application for its potential use not only in the study of historic landscapes, but also as a working tool that provides information about the state of all the archaeological excavation processes, the state of conservation and the restoration work carried out on the buildings, the potential management of tourist routes, and likewise many other potential uses created by the practical application of these information management tools.

To make this idea possible, an interdisciplinary collaboration was absolutely necessary. The relationship between the team of the University of Santiago de Compostela (USC), supervised by María J. Iniesto Alba, and the team of the ancient al-Andalus city, Ciudad de

Vascos, supervised by Dr. Ricardo Izquierdo Benito, has finally allowed the project presented here to take shape. The site is located in the province of Toledo (Spain), in the municipality of Navalmoralejo, about 5 km from the town centre. It is enclosed by defensive structures that protects a total of 8 hectares, in addition to the suburbs, cemeteries and tanneries outside the city that form a settlement of 35 hectares.

2. The archaeological perspectives

The excavation projects that have been carried out without interruption since 1975, and which have continued to 2012 in different excavation campaigns funded by the Junta de Comunidades de Castilla-La Mancha (JCCM), have revealed an important percentage of the structure of the known Islamic settlement. Summarizing these interventions, we note that under the supervision of Dr. Izquierdo Benito, three neighbourhoods around three entrances to the Medina have been uncovered

within the walls, along with their complex street layout (IZQUIERDO BENITO, 1979,1994), an urban structure round a hypothetical old era (threshing floor), and a large neighbourhood at the foot of the citadel, which in turn has been the site of many digs so that we can now see it fully excavated (IZQUIERDO BENITO and DE JUAN, 2004). Meanwhile, outside the walls, the excavations on the site of Los Baños de la Mora -the Hammam-can be highlighted, as well as the tanneries (IZQUIERDO BENITO, 1996), some graves in each *maqbara* and, in recent years, different entrances to the city which have led to a deeper understanding of the defensive layout of Medina Vascos (a summary of the interventions can be located in IZQUIERDO BENITO, 2005).

As you can imagine, the vast amount of information generated by the archaeological record, as well as all the data that existed before the excavation projects, made unfeasible a comprehensive study of all the data from the dig. Due to this fact, it will be proposed the development of a GIS that would allow the management, analysis and development of information. The team envisioned that this system could bring different benefits to the study of the site, as shown in the intrasite applications already developed, either through the Italian experience in Poggibonsi or in Castelo di Miranduolo (FRANCOVICH *et al.*, 2000; NARDINI, 2000; FRONZA *et al.*, 2003) or through the English experience (CONOLLY and LAKE, 2006) with some applications in Spain (BERMUDEZ, 2001; QUESADA *et al.*, 1995). As a result, it could integrate intersite applications, which have until now been the most used in archaeology, to quote a few examples: GAFFNEY and STANČIĆ, 1991; GAFFNEY *et al.*, 1996; SALZOTTI, F. NARDINI, A. *et al.*, 2005; ZAMORA, 2006, or some specific conferences on this topic in Spain (BAENA *et al*, 1997; GRAU, 2006). In addition, it could benefit possible future developments, like the implementation of 3D topographical surveys, or surface data obtained by geophysical techniques, that would permit the analysis and interrelation of such disintegrated information.

3. Objectives

The project for the management, analysis and visualization of this old al-Andalus city has been conceived to be both dynamic and timeless. At this early stage it can be divided into two subprojects with two clearly differentiated objectives, but with the intention of combining them in the future. On the one hand, the development of a Web-based Geographic Information System, and on the other hand, the three-dimensional reconstruction of one of its most important defensive elements, the Kasbah or citadel. Finally, the design of a website to link both subprojects, allowing the use of the Internet as a platform for the search and dissemination of Archaeological Heritage.

4. Material and Methods

In the initial stage of the development of the project all the documentation resulting from successive digs since 1975: reports, graphs, sketches, photographs... and a topographical survey made in 1996 was made available. Even so, a number of topographical surveys using different instruments were necessary in order to create the GIS. The instruments used included a total station, a digital camera and two GPS Leica 530 receivers, as well as a photogrammetric flight, which consisted of 32 aerial photographs to obtain cartography to scale 1/500, that covers a total area of 340 hectares of the walled city and its surroundings.

A Digital Elevation Model (DEM) was made from the restitution of the photogrammetric flight to obtain an orthophotograph, which was used as a base map. The later photo-interpretation allowed the division, organization and spatial distribution of the urban framework of the medina Vascos (dwellings, streets, rooms, walls, etc.), thus leading to the digitization of the topographic, geographic and architectonic elements and the archaeological remains of the city.

The software used in the photogrammetric restitution process was DIGI3D, available at the University of Santiago de Compostela (USC). The process of orthophoto generation was done with a specific module called Ortobatch.

The photogrammetric restitution required a stage of fieldwork measurement corresponding with the topographical survey of the check and control points. The coordinates of 63 points, measured with GPS techniques by the method known as RTK (Real Time Kinematic), were needed. This work involved placing a reference station at the highest point of the site, on top of the wall.

Furthermore, to give absolute coordinates to the data, the topographical survey had to be linked to the geodetic network. This task involves the observation of three vertices REGENTE (National Geodetic Network by Space Techniques) also employing GPS techniques but, in this case, by the method of static positioning.

Finally, the topographic field work ended with the measurement of the scanning bases in the citadel and the survey of those elements not visible in the aerial photos, again using the RTK method.

4.1. The GIS

A database management system, i.e., a geodatabase, has been designed to organize all the existing information about the dig. This data model, which is implemented in ArcGIS 9.2, the system used by ESRI GIS software, allows the integration of geographical elements associated with their alphanumeric attributes.

The design and structure of the database can begin once the data from the above mentioned operations has been

obtained. Initially, the implementation of a GIS requires an excellent database design to ensure that the information is readily available and retrievable when doing both a simple mapping output and an advanced spatial analysis.

Before designing the database, it is necessary to define the archaeological entities that form the urban framework of this Medina in order to define the conceptual model of data in relation to this scheme. In ascending order: Zones, Sectors, Excavations, Dwellings, Rooms and Findings (Fig. 1).
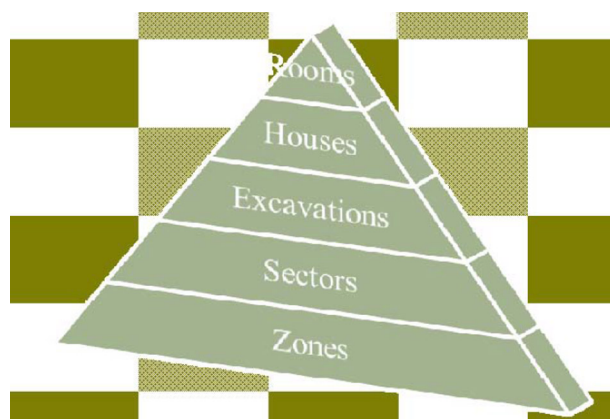

Figure 1: *Graph with the hierarchical structure of the excavation. A pyramidal model is used to establish the relationships between the cartographic elements, thereby obtaining a hierarchical structure.*

Respect to the graphic component of the database, and taking into account the above mentioned distribution, raster and vector models will be used indistinctly. A distinction will be made between geographic data, i.e. information associated with structural (buildings, land distribution, etc.) or natural elements (hydrography, vegetation, etc.), and the archaeological aspects that are defined within the city, due to their nature and their importance, as these are the features to highlight in this environment.

Moreover, all the alphanumeric information available is scanned for its conversion to digital and its integration into the GIS. The aim is to classify all the information by means of reports of each archaeological element or entity referred to with a definition of its location, and both a graphic and literal description of the depicted
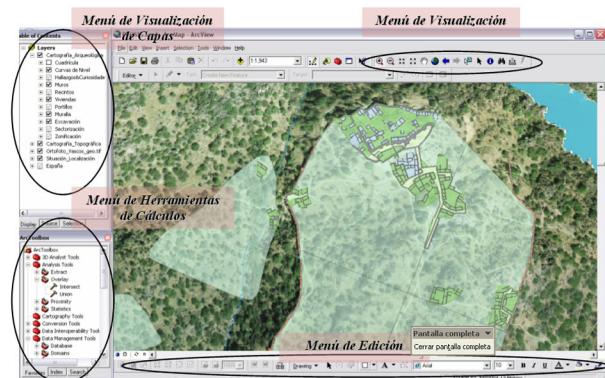
element. As a result, 206 reports of the various elements of the city were created.

With the georeferenced graphic information and the alphanumeric information in digital, the next step is to establish a system to link each graphic entity with its thematic attributes. With this intention the GIS which defines the database is created, consisting on tables and fields for each group of elements and the relationship between them.

Using the module called ArcMap, tables for each type of element are created from the graphic information, which form the geographic database. On each table all the elements with geographic information (coordinates, perimeter, area, etc.), are stored as records, thus defining a geographic database. Then, each element is associated with its alphanumeric information and its report.

Also, a number of fields are added to the database as additional information (year of excavation, site status, etc.), which are included in the category of alphanumeric information gathered from the reports of the previous phase. Finally, a hyperlink is added to the report which specifies this information and it is complemented by a description of each element, photograph, drawing, etc.

Under the ArcGIS platform, we managed with the ArcToolbox to produce a series of spatial and quantitative analyses of the Ciudad de Vascos. Intersite analyses have been obtained, like visual analysis, optimal routes or site catchment analysis, and intrasite analyses, like studies of human occupation, estimation of streets, housing and population... or archaeological data studies (release of material, furniture, orientation, saturation index of buildings…).

Apart from the use of GIS for the management and consultation of the different layers of information, some graphical outputs that provide solely visual information of the city and its surroundings were created with specific modules of ArcGIS. These are 3D representations obtained from a virtual reconstruction. To introduce the site easily to any user, a 3D visualization in VRLM format, together with the presentation of the excavation through a flight simulation, can be created. In this way, through reconstructions of the ancient structure, we can get to
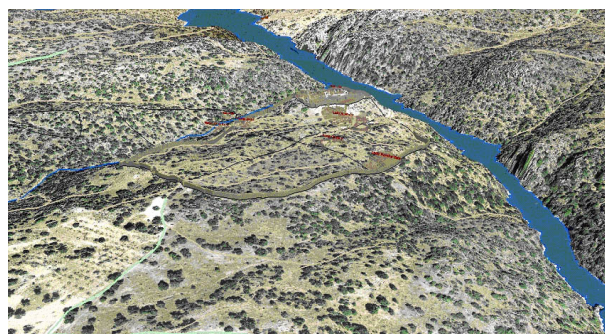

Figure 2: *Screenshot in which we can observe the user interface of the GIS.*

Figure 3: *Screenshot of the Three-dimensional reconstruction of Ciudad de Vascos. Oblique view from the south.*

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know the city quickly and relate the different data existing now and in the past.

4.2. The architectonic 3D documentation

Another interesting application to be found in this information, because it is inherent to the existence of the site, is the documentation of architectural remains in 3D. It is not only necessary to be able to understand the different phases within the archaeological site, through the archeologia della architettura (e.g. FRANCOVICH and PARENTI, 1988), but also to have a detailed map of the conservation of these structures, that were ultimately those that made possible the intrinsic nature of the settlement. We have therefore carried out the development of surveys of different parts of the defensive structure, the city's main symbol, be it for protection or for promotional purposes. In this way the three-dimensional documentation of one of the areas of great relevance, the Al-Qasbah, the citadel, has been made and the same process is underway for two other main gates into the city.

Figure 4: *Photograph taken in the area of the citadel of the laser scanner Trimble GX Advanced and Trimble-brand targets used to orientate the work..*

Data capture was done with the Trimble GX Advanced laser scanner, creating a mesh from a point cloud separated by 2cm or less. Furthermore, some photographs were taken with the camera: Cannon 450D, to improve the quality of the images used, as the camera of the scanner did not provide the desired quality for this work. The scanning methodology was the "Longest Range Scan Mode", similar to that used in surveying, i.e. working on the level and directed at objects. In this case a series of Trimble-brand targets were used. On the other hand, the photos were taken using the methodology of close range photogrammetry.

After the data processing and debugging with Real Works 6.3, Trimble's specific software for processing scanner and photographic data, the three dimensional mesh and a series of results was generated for the detailed study and visualization of the Citadel of Vascos.

4.3. The diffusion of data

In this process of development of management forms for the archaeological site, the necessary dissemination of information that this vast amount of data requires has always been present. This need has been considered from three different perspectives. Three recipients of the data have been identified: a broad audience that, having visited the site or not, could be interested in general aspects of the site and the society that lived there; a specific audience in the field of archaeology, that requires detailed knowledge and bibliographic links; and, finally, the technical staff and external collaborators working on different digs.

In order to allow for such a wide range of users of information, we believed that the key element for the dissemination work, independent of conferences and scientific and popular journals, should be based on internet.

To this end, a website with Macromedia Dreamweaver CS4 is first designed, where specific web pages relating to the digs, findings, publications and activities of the team members can be found and, obviously, a webpage (visualizer) which gives access to the GIS, and another (virtual city) where you can find the results of the 3D topographical survey of the citadel.

ArcIMS (of ArcGIS) is the module used for the definition and creation of the Web-GIS, as it enables the creation of a web service on a computer that acts as a server, and a web site on which to store all the information to be published. The steps to follow consist of three distinct parts: the Map Service, for the definition of the layers to represent the "web service", setting symbols and scales of representation; the Web Service, from which the administrator can manage and run each application to view, search, consult, etc. that the user makes; and the Web Site to establish a link between the map service and the web service, building a website which gives access to users. The final process is to make a series of modifications in the interface of the visualizer to give it a personal configuration.

5. Results

As a result of the GIS project, a cartographic series has been designed to inform users of the most important aspects of the dig. Both topographic and thematic maps were created, such as the map of slopes, the hypsometric map or those resulting from different inter and intrasite analysis.

Regard to the intersite analyses, the calculation of the best routes of access to the city must be highlighted.

We set up the study based on three fundamental questions: the identification of possible ancient roads, the closest areas of the site catchment analysis, and whether both spaces could be dominated from the walls.

To work this out we took the excavation data in the GIS together with the DEM and the generated slope map, and added the topographic map at a scale of 1:25.000, and defined a buffer of 5 km. around the city, which is estimated to be the distance one person can cover in an hour in normal conditions. With these data we managed to estimate the main lines of communication of the medina with the surrounding environment (which can be seen in broken lines in Figure 5), as well as the most useful zones nearest the city, whose inhabitants would also come to the Medina, in the case of defensive needs or for protection.
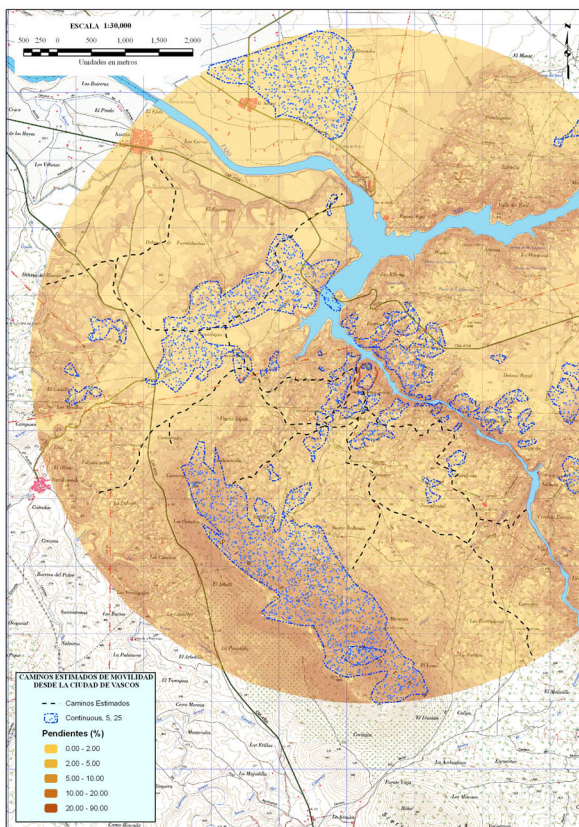

Figure 5: *Map of the intersite analysis: optimal routes of access to the city and their relation to the visual analysis(dot-filled areas) from the high part of the wall of the city.*

We also undertook different visual analyses from the highest points of the wall and, contrasting all these data in the same image, we obtained information that allowed us to determine many interesting aspects. Although we may have had partial knowledge of these aspects, the analysis of the surroundings confirmed them clearly. In this way we can highlight the natural orientation towards an ancient way known as Puente Pinos, that would have been the natural crossroads in the area since prehistoric times (JIMÉNEZ DE GREGORIO, 1954).

Another important aspect is, for example, the point of visual control of the crossing that lays in the area known as Fuentelapio, an area that presents abundant surface material according to oral information, but that was also a point of development for a population in the Middle Ages up until the mid-seventeenth century.

Regarding the intrasite analysis, a surface analysis of the urban framework of the city -streets and housing- has been carried out, taking into account the slopes of the city and the non-habitable areas, thus arriving at an estimate of the excavated areas.

We have also estimated the total number of dwellings and density of population in the city in the 10th century. These values are based on the definition of a "house" model, of approximately 138 m2, and the number of individuals per household (between 4 and 9), giving a number of houses between 434 and 478, depending on the numerical or graphical method used for its definition. Regarding population density, we estimate there were between 2200 and 3200 inhabitants in the city, at the moment of maximum occupancy, the data referring always to the Medina.

Figure 6: *Section of the Map of the estimated urban framework of the Ciudad de Vascos.*

Finally, we have undertaken the analysis of the citadel to determine the number of inhabitants and the habitable areas. The maximum occupancy rate of the mosque, based on the Muslim rite and its system of prayer, is the reference data to determine the population living in the Kasbah. The area of a person in prayer is estimated to be 1.40x0.50 m, giving us an estimated 134 individuals occupying the citadel.
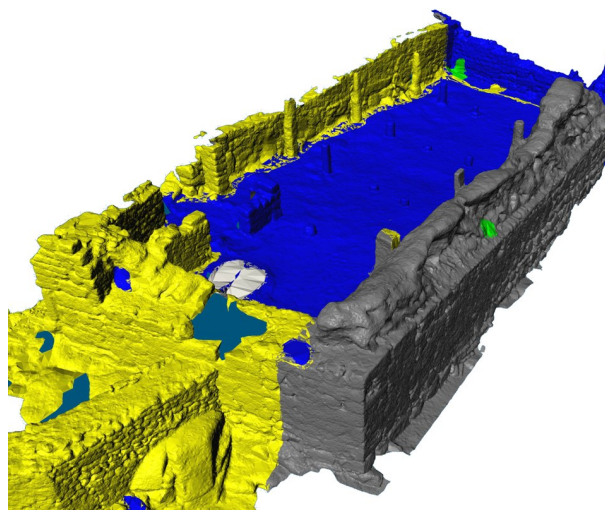

Figure 7: *Screenshot of the three-dimensional reconstruction of the remains of the citadel on the al-Andalus city of Vascos, corresponding to the mosque area.*

Figure 8: *Ortophoto of the south front of the Qasbah.*

If we compare the data obtained from the mādina and the Qasb, we can draw some interesting conclusions, namely, that 6% of the population dominated the rest, these being the inhabitants of the citadel. These results are very similar to the data stipulated of the individuals that dominated Andalusian society since their arrival in the Peninsula.

To go more deeply into the intrasite analysis, we must refer readers to the specific short paper in this conference. And it is necessary to underline the great variability of analysis depending on the data included in the database.

Regarded to the architectonic 3D documentation and the data from the topographical survey with the laser scanner, we obtained the 3D textured model of the Kasbah (Fig. 7) and we generated a series of 16 orthophotos (in format .tiff) of the citadel wall (Fig. 8), with an actual pixel size of 2mm, on which measurements can be made with great precision and which allows us to speed up studies of stratigraphic units (Fig. 9).
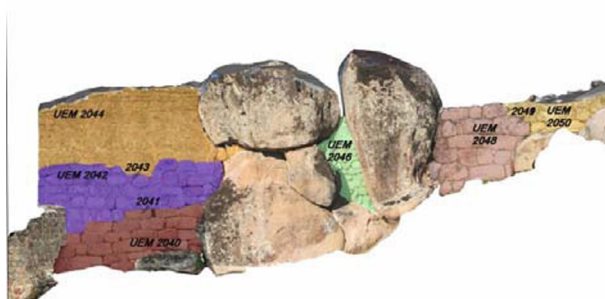

Figure 9: *Stratigraphic units drawn in an orthophoto.*
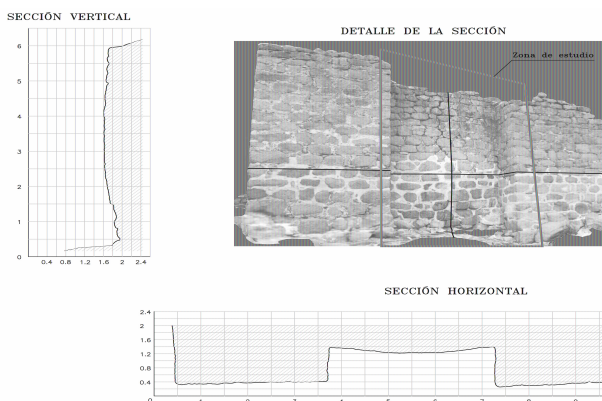

Figure 10: *Sections of zone 1 on which a study of distortions has been made. In these sections the wall can be seen to present curvatures with regard to a theoretical vertical plane.*

Also, we created a virtual model with real texture and generated a "bird's eye view" video across the virtual model. The mesh of the city wall, obtained by laser scanner, is supported on a digital terrain model generated by the photogrammetric flight.

This information and the detailed study of the excavation data will be used at a future date to attempt a three dimensional reconstruction of how we envisage the whole structure of this Fortress.

Finally, with a more informative than scientific approach, so as to be more user-friendly, all the information obtained has been included on the excavation Web site (www.ciudaddevascos.com). This Web will also be useful in creating a means of communication between technical staff in the field and the scientists responsible for management so that any type of data can be sent without delay.

The web page design is focused on the tree diagram presented in Figure 11. Its structure has a hierarchy in which information related to the archaeological site, to the current excavation areas, and to the most representative finds can be found.
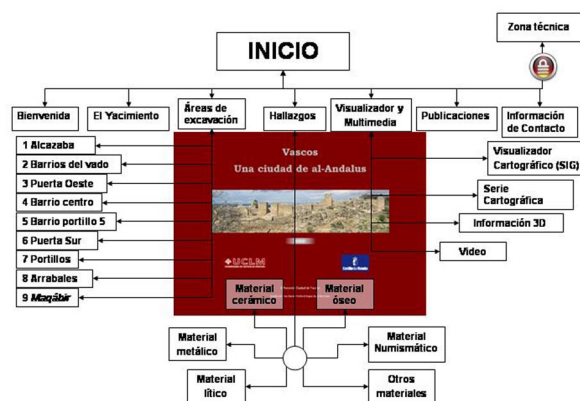

Figure 11: *Tree diagram of the structure of the website of the archaeological site of Ciudad de Vascos.*

In addition, one of the aims of the project is the publication of the GIS, the three-dimensional reconstructions and other multimedia information about the site in internet. For this purpose, the "Visualizer and Multimedia" zone has been created, which gives access to the GIS, the three-dimensional information and the results of the 3D topographical survey of the citadel, and finally to different videos centred around the archaeological site.

A specific area has been created for downloading previously published scientific and popular articles about the archaeological site, copies of which can be obtained in .pdf format. Lastly, contact details for the site are given in the areas open to the general public.

Finally, an area called the "Technical Zone" is set up, which aims to hold the contents of the recent excavation reports and templates for data submission for museums. This place is designed to become the area of data

communications between the various partners and researchers associated with the project, where they can exchange information. For this reason, and because this information is for review among team members, the dissemination of these data will be limited.

This website is currently in its final completion stage and during 2010 we hope to make it operational through the websites of the University of Castilla-la Mancha and the University of Santiago de Compostela.

Conclusions

The geodatabase link in the GIS allows the creation of a sole element of management of the essential information for consultation and information about the archaeological al-Andalus site of Ciudad de Vascos. The development of this system has required the implication of the entire Vascos team and, with its commitment to maintaining a continual process of revision and updating, will be a management model for future excavations, providing up-to-date results of the ongoing work.

This project creates the bases of an Archaeological Information System within the framework of al-Andalus cultural heritage. We have managed to weave together in a single structure and format a whole collection of disparate information about the excavation, gathered in different campaigns, and creating different criteria of scale, aspect, map symbols, etc. In this way, not only have thematic map results been obtained satisfactorily, but also the creation of a good data base with an organizational structure of sets of logical information, related to each other, that will provide information and knowledge to develop different types of analyses and studies.

In addition, one of the advantages of this GIS is that, because of the simplicity of the "geodatabase", it can be updated with the data collected in new campaigns as and when the archaeological investigation advances.

The success and continuity of the project depends on the commitment of the investigating team using a common methodology and terminology, so that doubts regarding the information contained in the data do not exist.

We have noticed that, thanks to the cooperation and the management of the data, we can get results as thought-provoking as those observed in the analysis of the terrain using the GIS, which shows how the connection of apparently disjointed data leads to the formation of a picture that lends sense to our interpretation of the past. We are talking about the connections of visibility, optimal paths and historical data on the ground.

Apart from this small analytical sample, we can see that the tools used to build the citadel in 3D allow us to speed up studies of stratigraphic units and put them automatically in relation to surrounding structures, as well as to develop specific conservation studies of the wall.

Future activities will follow with the implementation of data of structural elevation and 3D elements. We envision this system to be the future of these applications, since we should not forget an important part of documentation, which is that provided by the third dimension, an inherent element in the historical geography of this archaeological site, and, as our Italian colleagues are demonstrating, we believe that the implication of 3D applications in the GIS is possible. (PERIPIMENO, 2006).

However, it is fundamental that all this information should be disseminated to a varied public through the media provided by these new technologies. For this reason, we believe that combining both information and technology through the Internet could be an important system for communication and development that would allow for new challenges between the different teams that work in the field of research of al-Andalus cities.

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