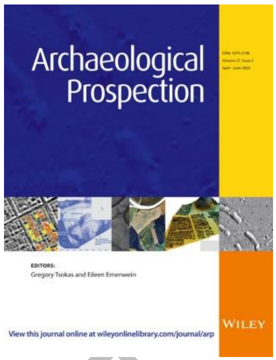
Geophysical survey of the Iberian site (seventh–third centuries bc) of Masies de Sant Miquel (Catalonia, Spain). Interpretative challenges of geophysical data of an Iberian town



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Revista	Archaeological Prospection, 27,2, April/June 2020, p. 181-199		
DOI	https://doi.org/10.1002/arp.1765		
Disponible en línia	01 June 2020	**Data de publicació**	09 February 2020

Per citar aquest document:

Sala R, Ortiz H, Sanmartí J, et al. Geophysical survey of the Iberian site (seventh–third centuries BC) of Masies de Sant Miquel (Catalonia, Spain). Interpretative challenges of geophysical data of an Iberian town. Archaeological Prospection. 2020;1–19. https://doi.org/10.1002/arp.1765

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Funding information

Spanish Ministry of Economy and Competitiveness, Grant/Award Number: HAR2015-67946-C2-1-P and HAR2015-67946-C2-2-P

Abstract

Geophysical surveys based on ground-penetrating radar (GPR) and magnetic methods have recently been carried out at the Iberian site of Masies de Sant Miquel, which is dated to the Iron Age (seventh–third centuries BC). The design and execution of the survey are presented, as well as the interpretation process, which is based on the interaction between the members of the prospection team (SOT Prospection) and the archaeologists from the University of Barcelona (UB) and the Catalan Institute of Classical Archaeology (ICAC), integrating geophysical as well as archaeological data. Although the site had previously been studied during the 1980s and 1990s, excavations have been limited in scope and the settlement remained largely unknown. The new research discussed in this article makes it possible to deduce the general traits of the urban plan and the major architectural features. The results confirm the urban nature of the site, not only due to its size (several densely-occupied hectares), but also the complexity of its architecture and urban planning.

Keywords

geophysical data interpretation, ground-penetrating radar, Iberian culture, Iron Age, urban planning

1 | INTRODUCTION

In this article, we discuss the results of the geophysical surveys carried out at the archaeological site of Masies de Sant Miquel (Banyeres del Penedès, Baix Penedès, Tarragona). This research was undertaken within the framework of the Caracterización de los asentamientos urbanos en la costa de la Iberia septentrional (siglos VI-III a.C.) project with a grant from the Spanish Ministry of Economy and Competitiveness and coordinated by the University of Barcelona (UB) and the Catalan Institute of Classical Archaeology (ICAC).

We present the design and execution of the survey, as well as the joint interpretation process between the members of the prospection team (SOT Prospection) and the archaeologists from the UB and the ICAC, integrating the geophysical and archaeological data.

2 | SURVEY OBJECTIVES

In the past two decades, the geophysical survey methods applied to archaeology have demonstrated their capabilities for the non-destructive delimitation and description of sites. Indeed, improvements in the capabilities, resolution and accuracy of geophysical sensors have come in parallel with a reduction in the cost of measuring systems and, more importantly, the consolidation of a specific scientific corpus around archaeological geophysics, as reflected in the specialized literature (e.g. Aspinall, Gaffney, & Schmidt, 2008; Bevan, 1998; Campana & Piro, 2009; Clark, 1996; Conyers & Goodman, 1997; David, Linford, & Linford, 2008; Gater & Gaffney, 2003; Goodman & Piro, 2013; Sala, Garcia, & Tamba, 2012; Schmidt, 2013; Schmidt et al., 2016; Scollar, Tabbagh, Hesse, & Herzog, 1990). A group of universities and research institutions have led the formation of that corpus and there has also been a remarkable commitment on the part of several private contractors in publishing their research studies (e.g. Benech, 2007; Dalan & Bevan, 2002; De Smedt et al., 2014; Fassbinder, 2010; Gaffney, Gater, Linford, Gaffney, & White, 2000; Linford, 2004; Linford & Canti, 2001; Meyer, Ullrich, & Barlieb, 2007; Neal, 2004; Neubauer & Eder-Hinterleitner, 1997; Neubauer, Eder-Hinterleitner, Seren, & Melichar, 2002; Nishimura & Goodman, 2000; Piro, Mauriello, & Cammarano, 2000; Sala, Principal, Olmos, Tamba, & García, 2013; Schneidhofer et al., 2017; Trinks et al., 2010; Vermeulen, Corsi, & De Dapper, 2012).

Large areas can be covered in a reasonable time and at a reasonable cost, providing decisive information about an urban layout or even covering whole landscapes (e.g. Bossuet et al., 2012; Gaffney et al., 2012; Garcia-Garcia, De Prado, & Principal, 2016). An increasing number of multidisciplinary archaeological research teams have integrated these methods and techniques as an essential part of their investigation strategies over both newly discovered and already known sites. An interesting example of such applications is the synthesis extracted from the geophysical surveys carried out within the framework of the 1st MACIWAG workshop (Garcia-Garcia et al., 2016). In that contribution, the authors presented reports on the diferent geophysical methods [ground-penetrating radar (GPR), magnetics, electromagnetic induction

(EMI) and electrical resistivity] applied to an unexplored area of the Iberian site of Ullastret (Catalonia, Spain) and produced an integrated archaeological interpretation.

As a consequence, the exchange of information between geophysics specialists and archaeological teams has been gaining importance. Archaeological geophysics is a complex discipline that involves the acquisition and analysis of data and their subsequent interpretation to produce archaeological information. The interpretation of a physical variation as a product of a specific archaeological feature entails evident error risks, as a single geophysical anomaly could have multiple explanations. Since the combination of factors such as geology, environmental conditions, etc. and the physical properties of the archaeological remains could produce a wide variety of responses to geophysical sensors, the interpretative process should not be seen as unequivocal (Sala et al., 2012). Data acquisition and processing focus on obtaining scientifically consistent measurements in space, but, in the light of the above, the interpretative phase needs the direct involvement of archaeologists, well acquainted with the characteristics of the settlements of the culture under study. However, we are also aware that basing the interpretation straightforward on previous knowledge of a particular culture can introduce some bias and lead to circular reasoning that tends to obscure new ways of understanding the sites under study. In this article we attempt to provide a suitable response to the challenge of formulating a common interpretation of geophysical data based on the accumulated research into Iberian architecture and urban planning and, in particular, the discussion among specialists in both fields.

The aim of the survey at Masies de Sant Miquel was to describe and delimit the site in an area of c. 15 000 m^2, about half of its presumed size, giving as much information as possible on the building remains and their distribution, depth and conservation. To achieve these goals, a first step was to establish which geophysical method would offer the best cost/information ratio, given the constraints imposed by the geological, environmental and cultural characteristics of the site (Sala, Tamba, & Garcia-Garcia, 2016).

3 | THE SITE AND ITS CONTEXT

Greek textual sources give the name ‘Iberia’ to a region stretching between the present-day province of Murcia, in south-eastern Spain, and western coastal Languedoc in Mediterranean France. This region coincides fairly precisely with the distribution area of the inscriptions in the writing system and still undeciphered language that, precisely because of this spatial coincidence, has been designated as ‘Iberian’; these texts are dated to between the end of the fifth century BC and, residually, the beginning of the early Roman empire. Therefore, we can assume that the Greeks used the ethnonym Iberes to refer to the populations that spoke a common language. The ancient sources attest considerable fragmentation in ethnic and political entities of a much smaller although variable size. We know their names and approximate locations, at least in part, from the Greek and Latin texts, as well as from inscriptions on coins. Extensive surveys and large-scale excavations began in the late 1970s and early 1980s. They have continued until today and have allowed us to recognize various settlement patterns that probably correspond to different polities (Sanmartí, 2009, 2014).

From the second half of the sixth century BC, important changes in material culture indicate the development of the Iberian culture, which reached its climax in the fourth and third centuries BC (Ruiz & Molinos, 1998; Sanmartí, 2014). After the Roman conquest of this area very late in the third century BC, a slow process of acculturation took place, ultimately leading to its dissolution by the second half of the first century BC. Iberian settlement patterns are usually hierarchized. This includes the large sites, some of which are urban in nature, as well as smaller, second-order towns and villages and, at the bottom of the system, farms and isolated houses scattered across the landscape. Large and mid-sized Iberian settlements were mainly located on hilltops or stretching across hillsides, although some are found in flat settings, either on lowlands (Masies de Sant Miquel), islands (Illa d'en Reixac) (Codina, Plana-Mallart & De Prado, in press) or plateaux like Castellet de Banyoles (Sanmartí, Asensio, Miró, & Jornet, 2012).

The previous research at Masies de Sant Miquel had been limited to informal field survey, with non-systematic collection of surface materials, and to the excavation of two deep trials in the field that stretches to the north of the surveyed area. The first one was directed by Carrasco, Pallejà, and Revilla (1995), and the second one by X. Cela (Adserias, Cela, & Marí, 2000; Cela, Adserias, & Revilla, 2001). Given the small extent of these digs no coherent plan of any building could be restituted. However, they have allowed to establish the existence of a long occupation period, between the seventh century BCE and the years around 200 BCE.

3.1 | Archaeological context

Masies de Sant Miquel is located some 50 km to the southwest of Barcelona. The name of the site derives from a suburb of Banyeres del Penedès, a small town some 2 km to the northeast in the Baix Penedès region of Tarragona province, whose administrative capital, El Vendrell, is approximately 5.5 km to the southwest. The site is 13 km from the coast as the crow flies (Figure 1).

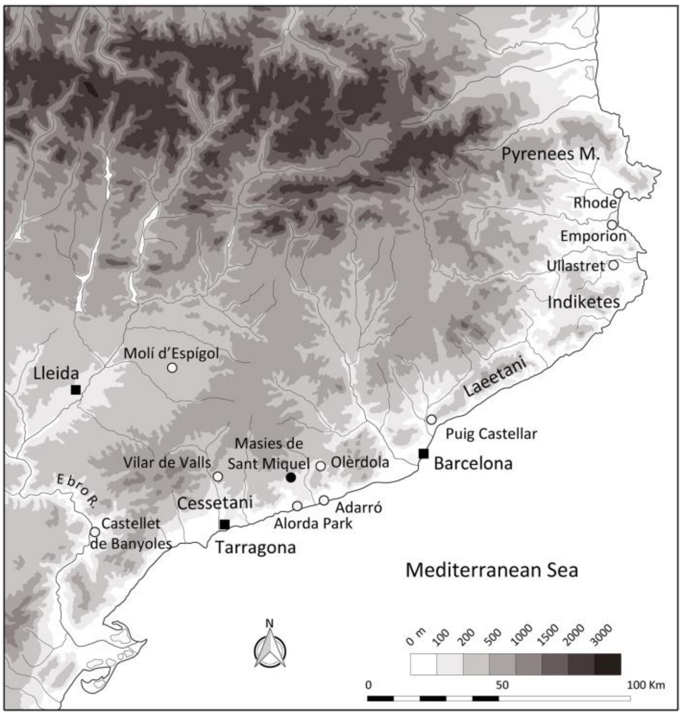

Figure 1. Location of Masies de Sant Miquel and the other sites mentioned in the text

The settlement was built on mainly flat ground. It was partially bordered by a brook, the Riera de Sant Miquel, which has cut deeply into the plain to the east of the settlement, and by a smaller stream to the southwest. In contrast to many other Iberian towns, which were frequently located on hilltops, these small streams are the only, and not very impressive, lines of defence stemming from the natural topography. Since it was easily accessible from the northern and eastern sides, the existence of defensive walls and/or other defensive features (such as ditches) could be expected.

Masies de Sant Miquel was part of an important Iberian polity – perhaps covering an area of some 2800 km^2 – inhabited by an ethnic group the ancient Roman sources called the Cessetani. The region is made up of the plains between the Mediterranean Sea, the Garraf massif and the Catalan coastal mountain range. A remarkably hierarchized settlement system has been documented in this territory. Its capital was on the site of the present-day city of Tarragona, which was known in pre-Roman times as Kese or Tarakon and covered at least 9–10 ha and possibly much more.

Masies de Sant Miquel, with an area of about 4 ha, was a secondorder town, a category to which the settlements of Vilars de Valls, Adarró and Olèrdola also belonged. Hierarchically below these settlements there were smaller ones (some of them, such as Alorda Park, in Calafell, were strongly fortified and probably devoted to the control of smaller areas). At the bottom of the settlement System were the many farms and isolated houses that were scattered across the territory. Similar settlement systems have been documented in the central and northern coastal areas of Catalonia and in Valencia, while in other areas, mostly interior, less centralized, heterarchical forms of organization seemingly prevailed (Sanmartí, 2009, 2014).

3.2 | Geological context

Banyeres del Penedès is geomorphologically located on the Baix Penedès plain, with very small differences in altitude of between 160 m and 100 m above sea level (a.s.l.). Structurally, the pre-coastal mountain range, the coastal mountain range and the Bonastre range border the units of the Penedès basin. In this area of the Penedès, five lithological units can be differentiated:

- Mesozoic: limestone and dolomite.
- Cenozoic: rough clump levels, poorly selected, and calcarenite reefs.
- Cenozoic: marls and lutites that fill neonate depressions.
- Cenozoic: sand and clay, river inputs.
- Lower Cenozoic-Miocene: low-selected red conglomerates cemented by red clay.

The regional structure of the Vallès-Penedès depression is conditioned by two orogenic phases: in the Palaeozoic, Oregano hercynicum, and in the Cenozoic, Alpine. These two compression phases form families of faults and multiple folds. Subsequently there is a distension phase. All these tensions gave rise to a staggered relief, the pre-coastal mountain range, the Penedès depression, the Garraf massif, and the Vilanova plain. Locally, in the area of this study, the emerging sediments are mostly quaternary, gravelly and sandy, with clayey levels that may alternate with conglomerate outcrops (Benzaquen, Núñez, & Martínez, 1973).

3.3 | Survey environment

Most of the area designated for the survey corresponds to cultivated fields, some of which, however, have not been worked in the last 10 years. The main area of the higher plateau is an abandoned almond orchard in which the trees are regularly spaced in lines; the space between these lines was periodically ploughed when the field was farmed. A limited area on the northern side of the plateau was used for conventional farming of different local crops and was consequently more intensively and deeply ploughed each season.

The outer perimeter of the survey consists of lower lands to the south and west of the plateau. These terrain fringes show no evidence of recent cultivation, but there is a deposit of modern debris on the western limit. The local topography is shown in Figure 2, which was created from the ICGC 2 m × 2 m digital elevation model (DEM) based on LiDAR (light detection and ranging) data. The dataset was processed to create a map of topographical variation or a slope map by calculating the standard deviation of the elevation in a window of 3 × 3 cells (6 m). The same data was used later as a visual base for evidence interpretation.

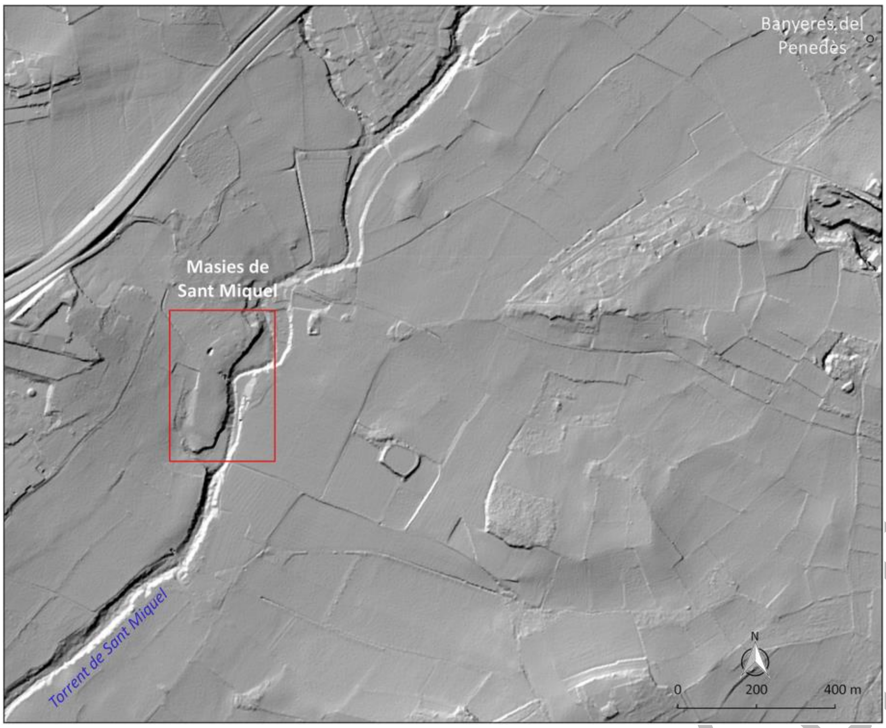

Figure 2. Digital terrain model of the site area

4 | IBERIAN ARCHITECTURE AND ITS PHYSICAL EXPRESSION

The architecture and urban planning of the northern area of the Iberian culture is well known thanks to archaeological research, which has been particularly intense since the 1980s (Sanmartí, 2009, 2014). To a great extent, the urban organization of the settlements was conditioned by the topography. A hilltop settlement often had a circular or oval layout and was delimited by an enclosing rampart that also served as the rear wall of the houses. The latter were radially distributed and shared party walls and were therefore trapezoidal-shaped with an irregular ground plan. In settlements located on plateaux, the houses were arranged in blocks separated by streets according to a relatively regular urban plan. Nevertheless, true orthogonal plans are non-existent and, therefore, the reading direction problem in surveying orthogonal structures of methods such as GPR or magnetics is not usually found at Iberian sites.

As for the building materials, the walls could be completely made of stone, although it was more common to find a Stone plinth with earthen walls, usually mud bricks. Roofs were made from reeds or branches placed over a wooden beam framework and later covered with a layer of mud mixed with straw. We do not have any preserved roofs from this period, only the remains of lumps of mud with the imprint of plant fibres. Houses and other buildings had earthen flooring and only exceptionally were some floors completely or partially paved with stone slabs or covered with adobe. From the beginning of the third century BC, some floors and plasters were made of lime mortar (a mixture of lime and sand, which occasionally included small fragments of crushed pottery). Streets could also be paved with stone slabs, although earth was the most common material (Belarte, 2017).

According to this general description, the geophysical expression of the aforementioned structures can be very diverse since the use of local stone and mud walls or compacted clay floors resulted in a dependence on the local geology when trying to establish the geophysical contrast of archaeological features. For example, Iberian settlements on the Lleida plains, such as Molí d'Espígol, were built using local marlstone in a clayey context. In magnetic terms this results in a low contrast between sediments and wall foundations or a poor depth range in GPR surveys (Sala et al., 2013). Fortunately, anthropogenic activity, as well as several specific archaeological features, such as floors, kilns, ditches or storage pits, tends to enhance the magnetic contrast. Other sites with similar morphological characteristics, such as Ullastret, show a different contrast of physical magnitudes thanks to the lower magnètic contrast of local sandstones, which offers a good representation of stone foundations on magnetic maps. In the same context, GPR data could also be effective in the description of Building remains, but in a limited penetration range due to the clay content of the soils.

Therefore, the dependence on local geology and environmental conditions (roughness of surface, local topography, soil moisture or compaction) makes it difficult to establish a 'correct' method for surveying an Iberian site, if only one had to be chosen. Even considering all the known geological and environmental parameters, there is always uncertainty about the nature of the archaeological remains, their conservation level or their depth.

5 | METHOD TESTING

The specific physical context of Masies de Sant Miquel raised the question about the most effective geophysical survey method. The local limestone was expected to show a magnetic contrast from the soils, bearing in mind that the depth of the few known archaeological remains is about 2 m. However, the high clay content of the soils on the Penedès plains raised doubts as to the effective GPR penetration range.

Primarily two possibilities were considered in order to decidí which method would be applied to carry out the first general survey of the area: magnetics and GPR. On the contrary, electrical resistivity survey was rejected due to its higher cost if we consider the final resolution. An extensive resistivity survey would have required at least twice the fieldwork time (if using RM15-RM85). In addition, the depth penetration of resulting datasets would not have been higher than using GPR. Even expecting optimal results, the final resolution or depth information from two, three, or four electrode measures would produce a less detailed dataset than the GPR survey, since the latter offers a much larger amount of data in the three dimensions. Even using faster systems as Geoscan Research MSP40, the cost/information relation would still be on the side of GPR or magnetics.

An initial comparative test was carried out on an area of 2837 m^2 on 10 May 2018, using a 600 MHz multi-antenna GPR system. This frequency range was selected because our previous (still unpublished) experiences from surveys near Masies de Sant Miquel using GSSI equipment (SIR3000, 270 MHz), and IDS dual frequency antennae (Hi-mod, 200–600 MHz) indicate that the local clayey soils tend to produce a strong attenuation, also in low frequencies. The custom stack of 600 MHz IDS antennae tends to produce more detailed data within the same range. A magnetic gradiometer survey was undertaken in two different parts of the site covering a total area of 4035 m^2. Grid A was placed in the western part of the survey area in order to explore the supposed límit of the settlement in an area of 3200 m^2, while Grid B covered 835 m^2 in the area previously explored using GPR.

5.1 | Systems/adjustments (GPR and MAG)

The magnetic surveys were conducted using the Bartington G-601 dual fluxgate gradiometer system with two pairs of sensors at 1 m spacing. The resolution for the survey was set at 0.5 m × 0.25 m (four readings per metre in line on profiles obtained at 0.5 m spacing). The readings were taken at a resolution of 0.01 nT in a range of +/100 nT. For the GPR survey test an IDS customized system was used. It consisted of a stack of five independent, 600 MHz antennae mounted on an electric motor cart. The vertical range was established in a time window of 60 ns at a resolution of 512 scans. The horizontal resolution was configured at 36 scans per metre and the spacing between profiles was 0.2 m. The data positioning was based on local coordinate grids. The survey results were georeferenced using control data points taken with a global positioning system real-time kinematic (GPS RTK) Leica system.

5.2 | Results (GPR and MAG)

The magnetic dataset was processed using Geoplot 3.0 software. The processing sequence consisted of the application of zero mean line correction in order to remove the line noise caused by the calibration loss of sensors. The resulting maps were interpolated to create a uniform cell-size of 0.25 m × 0.25 m. A gaussian low-pass filter was also applied to generate smoother final images.

The magnetic map obtained from the gradiometer survey shows a disturbed response in all the explored areas where long-range, diffuse anomalies alternating with high-contrast dipoles and other focus anomalies, positive or negative, prevailed (Figure 3). The magnetic map of Grid A shows the interesting anomaly Groups M2, M3, consisting of a fringe of discontinuous negative values (from −3 nT to −5.5 nT), and M1, a parallel area where positive readings are dominant (from 4.5 nT to 8 nT). The interpretation of these anomaly groups is unclear.

The area covered by Grid A corresponds to the western limit of the higher plateau and lower terrains, a suitable location for a wallditch defensive system. The positive anomaly Group M1 could be interpreted as the result of the fill of a possible ditch. In addition, the fringe of positive values matches with the lower elevations in the area, which appears consistent with a buried ditch (Aspinall et al., 2008, 144). However, when examined in detail, the positive anomalies that made up M1 looked too weak and discontinuous to be a massive structure. For these reasons, the interpretation of M1 is considered as inconclusive and without archaeological validation.

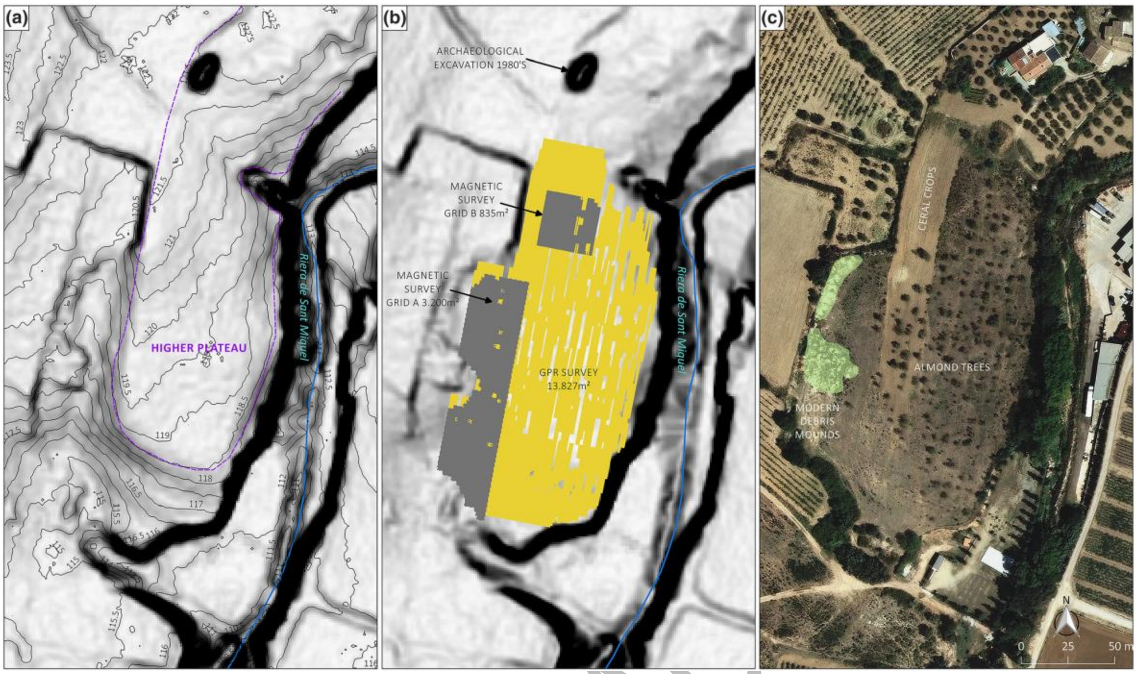

Figure 3. Site topography. (a) The digital terrain model of the site also using 0.5 m elevation contours. (b) Areas covered by magnetic survey

In a similar way, the anomaly Groups M2 and M3 could be interpreted as the remains of a possible wall, but again the discontinuous negative response and variable magnetic values could also be interpreted as a deposit of building materials fallen from structures placed on the higher plateau.

As a consequence, the magnetic survey of Grid A offered interesting information by pointing to the possible remains of a defensive system, but the morphology and the values for the anomaly Groups M1, M2 and M3 were not consistent enough to consider that interpretation as more than a hypothesis subject to future validation.

The results obtained in Grid B showed unconnected and diffuse anomalies, such as M6, a linear feature interpreted as a possible trench related to previous archaeological trials, or to a focal anomaly of negative values interpreted as a possible void (probably a storage pit). More intense dipole anomalies were also detected. M7 consisted of two dipole anomalies showing positive anomalies of 10 nT to the south and negative halos of 3.5 nT to the north. These anomalies are interpreted as a result of possible thermally altered materials from kilns or domestic hearths (Aspinall et al., 2008).

The GPR dataset produced in the test of 10 May covers 2837 m^2. Preliminary processing based on the filtering of frequency and continuous noises (bandpass filtering, background removal) was used to build a sequence of 18 time slice sequences from 0 to 33 ns in low resolution (0.2 m per pixel). The resulting plots show a good contrast and a reasonable penetration, despite the roughness of the terrain, which had recently been ploughed.

As is shown in Figure 4, the time slices reveal the geometry of multiple high reflection, linear features interpreted as walls. They make up what appears to be the partial layout of an urban settlement. The sharpness and coherence of some of the time slices and the depth penetration after the first processing were decisive for deciding which method would be more reliable for exploring the remaining area. Obviously, a multi-method survey strategy would have been desirable, since a magnetic dataset would have complemented the morphological accuracy of GPR with relevant qualitative information. As we shall see later, proof of this is the decisive role played by the magnètic dataset from Grid A in the interpretation of the western limit of the settlement's defensive perimeter.

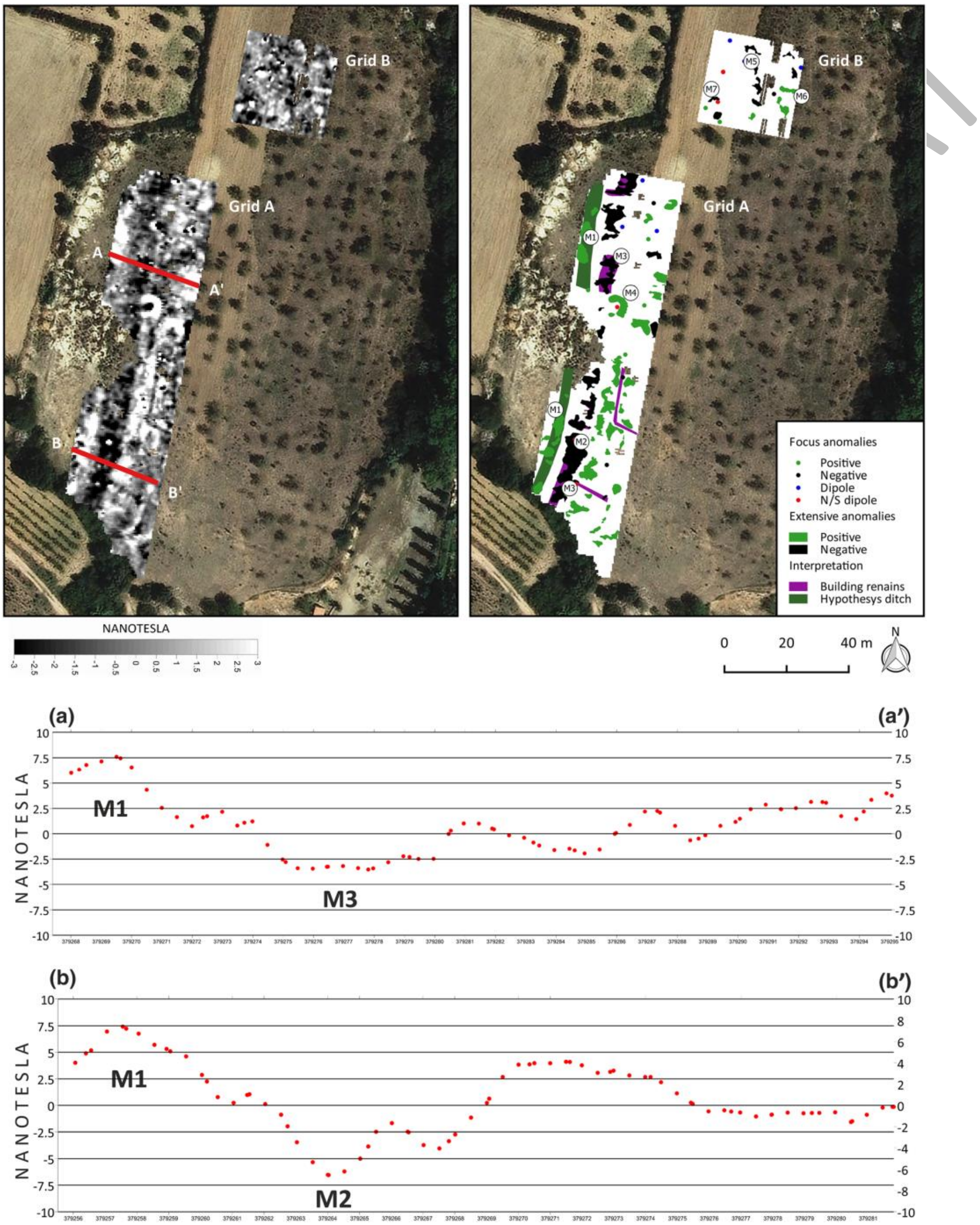

Figure 4. Method testing. Magnetic survey maps and interpretation diagram (top). Bottom, two cross-sections of the magnetic data over anomaly Groups M1, M2 and M3

6 | COMPLETING THE GPR SURVEY

The GPR survey covering the remaining area used the same settings for the GPR system. The weather remained stable during the two subsequent survey days.

The surface of the area to be explored was not uniform, resulting in different contact surfaces for the GPR antennae. The higher plateau, a recently ploughed field of almond trees, had a rough surface and obstacles that slowed data collection. The southern and western perimeter had almost no vegetation, but a spread of rocks and pebbles on the surface forced the slowing of the data acquisition, as it caused problems in the ground contact of the GPR antennae.

The complete GPR dataset covered 13 827 m^2, showing a better quality on the higher plateau occupied by the almond orchard. The dataset has some positioning errors caused by the ground contact problems with the GPR system survey wheel.

6.1 | Data processing

The data processing was carried out entirely on GPR-SLICE software. Several alternative processes were tested, but the application of bandpass-gaining and background removal proved to be the best basis for subsequent time slice creation. Figure 5 shows the average spectra of the five channels of the system raw data (a), and after the application of band-pass and gain routine (b) using a high-pass of 356 MHz and a low-pass of 858 MHz. The resulting data spectra show low frequency constant noises which were reduced by using a background removal filter 150 sample length (d). The subtraction of (b) and (c) allows us to appreciate the effect of background removal.

The technical decision as to which output formats the survey results should have is extremely important for translating them into archaeological information. Although current processing software allows highly detailed scan-by-scan three-dimensional (3D) views of datasets to be produced, the specific information to be analysed and interpreted needs to be systematized. One solution is to establish a short sequence of time slices that summarizes the depth range available in a few horizontal cuts. After several tests, the sequence was established at 18 time slices representative of 3.28 nanoseconds or a depth-lapse of 0.16 m at an average v = 0.1 m/ns. The propagation velocity was estimated by measuring hyperbolae shapes in radargram profiles (Conyers & Goodman, 1997). The 18-cut sequence covers 33 ns (270 scans) at a depth overlapping nearly 50% covering an approximate depth range of between 0 m and 1.65 m below the surface.

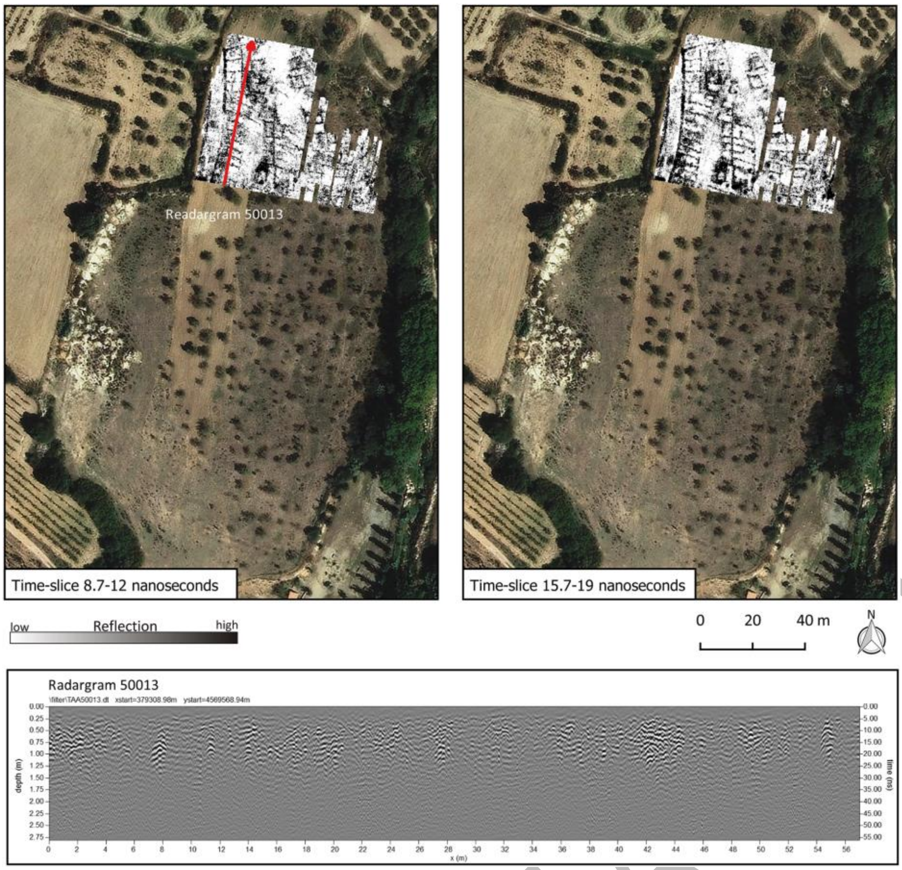

Figure 5. Method testing. Two time slices created from the first ground-penetrating (GPR) data (top) and a radargram crossing a group of building fractures (bottom)

6.2 | Creating data visualizations. Vector anomaly maps

Given the range and complexity of the GPR survey results, a condensed expression of the detected elements was considered desirable in view of the interpretation phase. The creation of vectorized anomaly maps of the time slice sequence allows an agile format for understanding data changes with depth and drawing simplified interpretation diagrams. The interpretation was produced in the frame of a geographic information system (GIS) environment, which also helped to analyse data in a wider context (topography, aerial image and magnetic data).

A sequence of vector anomaly maps corresponding to each time slice was created using a specific function of the GPR-SLICE software called depth-threshold, which allows new maps to be extracted from time slices containing only anomalies above a given threshold value (Goodman & Piro, 2013; Schmidt & Tsetskhladze, 2013). The raw data processing necessary to generate time slice visualizations could substantially change the original data statistics in many aspects. Factors such as the frequency spectrum of the antennae, as well as the processing applied to the specific output formats or even soil conditions, can produce very different plot histograms. As a consequence, the threshold values for generating the vector anomaly maps must be established by evaluating the visual information resulting from the vectorizing process, rather than using a standard value. Higher threshold values reproduce only the strongest reflective anomalies, while lower ones add complexity to the resulting maps. In our specific case, a threshold of 70% reflection values for each time slice (except for the first three of the sequence, where a value of 85% was used) generated the depth-maps. Since threshold values are relative to each time slice, the response of the first three, corresponding to the shallower soil layers, offered blurred images due to the anomalies produced by ploughing. As a consequence, their relevance in the archaeological interpretation is minor.

The next step was to convert the resulting plots to vectorial format in QGIS and to merge them into a single polygon.shp file. The file is displayed by assigning a colour scale to the increasing depth of features (Figures 6 and 7). The anomaly vector maps constitute an intermediate format in the interpretation process. That kind of representation cannot be considered as entirely objective information, as it is built from establishing higher or lower thresholds over the original time slice sequence, although it is a very consistent basis for further interpretation work.

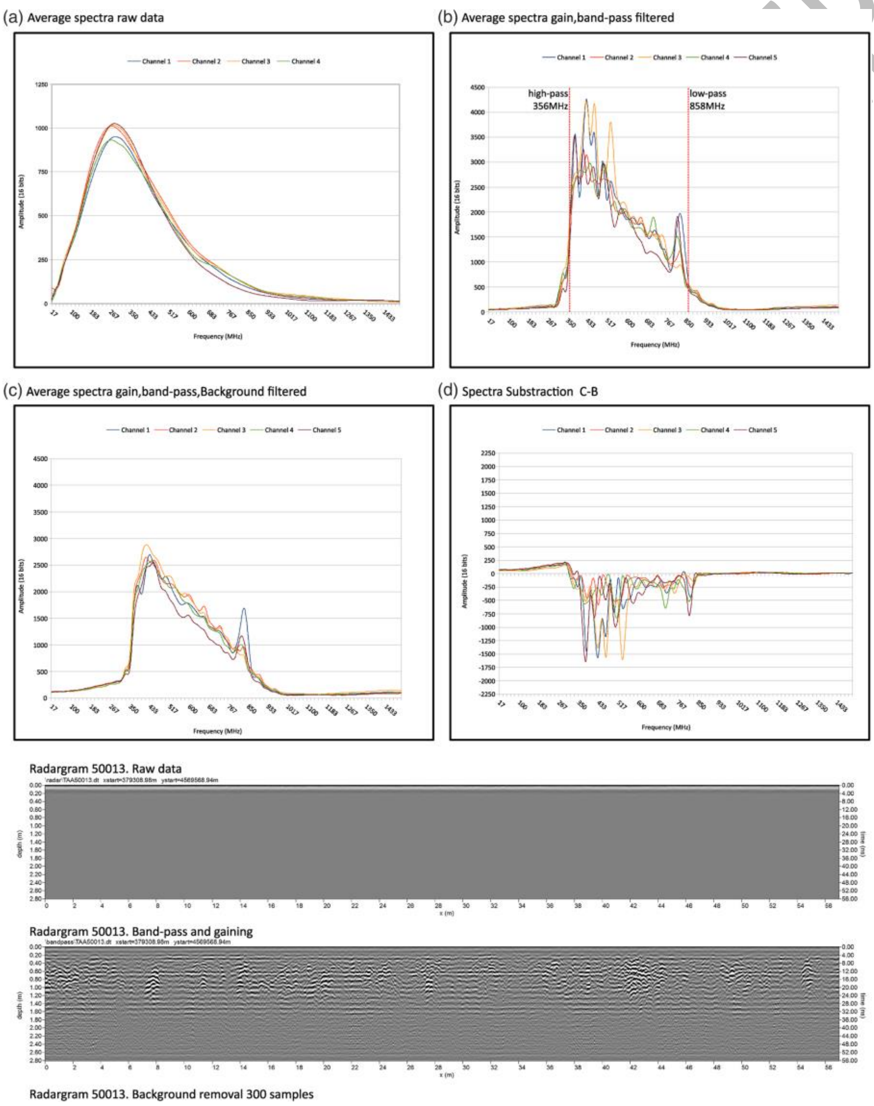

Figure 6. GPR data processing. (a–d) The changes in the frequency and spectra from the five-channel, 600 MHz raw data after processin steps. Bottom, radargrams showing the same processing results

7 | GEOPHYSICAL RESULTS

The time slice sequence obtained from the survey provides fairly detailed information on the features between the surface and the penetration limit, at a depth of around 1.6 m (Figure 7).

In general terms, the interpretation criteria were based on the identification of linear, reflective anomalies due to reflections caused by limestone walls in clayey stratigraphic contexts. Obviously, this is a simplification, as the time slice maps reproduce a number of more complex features, such as extensive increases in reflectivity, interpreted as debris layers or floors, and even low reflection areas that could reflect homogeneous fillings or clayey deposits.

Figure 7. Selection of six time slices at increasing depths

The areas corresponding to the higher plateau, occupied by cultivated fields, have an initial lapse of 0.3 to 0.4 m, that is completely altered by agricultural work; they present a spread of variable amplitude anomalies that are interpreted as the result of debris and soil compaction differences produced by the aforementioned work. From depths of around 0.4 m the plots indicate the first groups of linear, high-reflection anomalies, interpreted as the shallowest building remains. Interestingly, the time slices corresponding to these layers show blurred areas, covering features that become progressively sharper with depth. This is consistent with a sequence of superficial layers made up of agricultural humus and debris, followed by archaeological stratigraphy (at a depth of around 0.6–1.0 m). Despite the good definition of numerous building features, it is hard to discern possible building phases. The discontinuity of some linear features could be attributed to poor preservation or the consequences of successive building phases that would have cut across previous walls. Therefore, the discrimination of features corresponding to different chronologies seems unfeasible without the support of archaeological excavations.

The anomaly vector map shows concentrations of linear anomalies corresponding to groups of buildings separated by elongated narrow spaces, which were interpreted as streets (Figure 8). The urban grid appeared to be based around three main streets running from north to south and by some narrower alleys running from east to west, with an apparently less regular distribution. There appear to be two types of blocks of buildings. The first consists of irregular, quadrilateral groups of rooms of variable sizes delimited by streets. A second type consists of a single line of rooms along the westernmost, and possibly easternmost streets, although the latter has been almost completely washed away by the Torrent de Sant Miquel. On the western side of the surveyed area, two different features (Group A, Groups 21–23) were identified as possible parts of a defensive system matching the limits of the higher plateau. Given the lack of a wider survey context, we have doubts about the precise nature of such features, as recent research has proven that Iberian defensive systems could be quite complex (Codina & De Prado, 2018; Sala et al., 2013). Group A was defined in the north-western area of the survey by a fringe of low reflectance delimited by two linear, parallel anomalies identified as walls. At first sight, this low reflectance fringe looks like a street, but when observed in more detail, it appears to be wider (6 m) than the roads detected at the site (between 2 and 5 m). Remarkably, it has almost no connections with the houses located immediately to the east (Group 26). All these elements suggest a possible connection with a defensive feature such as a kind of corridor related to a main entrance of the settlement. However, the field immediately to the west of that feature was not explored, making this interpretation hypothetical due to the lack of a wider context.

Figure 8. Initial interpretative diagrams. From a vector anomaly map (left), a first linear feature recognition was traced, including an interpretation of possible streets or lanes (centre). The interpretation diagram on the right includes debris areas and unsolved features, as well as the interpretation of magnetic data collected on the western side of the survey area

Anomaly Groups 21–23 are also defined in the west of the surveyed area as a 60 m long discontinuous reflective fringe located on the western limit of the higher plateau. Unfortunately, the area corresponding to that feature was only partially covered due to the presence of bushes and other ground obstacles. Despite the discontinuous trajectory and major changes in the reflection values, we can recognize a certain linear geometry, possibly connecting with the western limit of Group A.

The southern edge of the surveyed area corresponds to a transition space between the higher plateau and a lower area. The survey revealed a number of features, although they do not show a clear structure. Anomaly Groups 6, 7, 17, 18 and 20 are interpreted as singular buildings, with thicker walls than those detected inside the urban grid in the north. Since these features are located on the southern edge of the higher plateau, it seems logical to link the thicker walls with defensive functions. However, in a fringe of terrain about 2 m below the higher plateau, new linear features to the south of these groups were clearly detected (anomaly Groups 8, 14, 15 and 16). Although the time slice sequence exhibits weaker reflection values for those features, their morphology and response are consistent with their interpretation as buried building remains. Again, as in the western area of the survey, this suggests a defensive perimeter adapted to the higher plateau, and possibly another in the lower areas that surround the core of the settlement.

8 | DISCUSSION AND CONCLUSIONS

The decision as to which methodology to use in the geophysical survey of Masies de Sant Miquel was conditioned by the need to obtain a good cost/information ratio. The initial tests showed that the 600 MHz IDS GPR system was better at detecting archaeological structures. The choice of GPR as the method to cover the entire area was based both on scientific reasons and the availability of resources. Although the fluxgate gradiometer data showed a poor definition of building remains in the first tests, a magnetic map of the entire survey area was expected to help by adding a new layer of information to the detailed GPR results. Indeed, the limited use of this second method in the southwestern part of the surveyed area has provided some interesting results, which, as will be shown later, probably provide a better understanding of the structure and temporal evolution of the settlement's defensive system.

The GPR survey results and the interpretation maps produced a description of the building remains in the explored area, although the plots and diagrams indicate that the information retrieved is much more conclusive on the higher plateau than in the lower areas to the south and west. The combination of the fieldwork, data processing and interpretation phases allowed the creation of a block of information that will play a decisive role in future investigations of the site. However, the geophysical data also left some unasked questions that could be answered by combining future excavations and a reinterpretation of the data collected in these surveys.

As said, geophysical surveys do not provide results that are directly translatable into archaeological plans. In fact, plans generated using this method may depict features that do not correspond to actual archaeological structures; conversely, they may fail to show structures that are there but were not detected for a variety of reasons (in our case, the surface conditions, i.e. a plantation of trees, areas that have recently been covered with rubble or are inaccessible due to dense bush vegetation). Finally, actual features may be shown on the geophysical plans with varying intensities, which do not necessarily correspond to their effective entity. In short, geophysical plans need to be interpreted, a task that must be undertaken by geophysicists and archaeologists working together. In this respect, a given anomaly could be disregarded by a geophysicist because it is weaker than those surrounding it or because it matches the survey direction and could therefore be due to poor ground contact by one of the antennae. Conversely, an archaeologist interpreting the same data from a structural point of view could take the same anomaly into account as an archaeological feature.

In light of the earlier-mentioned, the scientific exploitation of the data from the geophysical survey at Masies de Sant Miquel has been grounded on an interpretation of the plans, following a process of systematic analysis and debugging by both archaeologists and geophysicists, in which only the features considered to be truly coherent with the structure of the Iberian town are represented. In other words, these plans are simplified, interpreted and hypothetical versions of the set of anomalies objectively identified by the survey. A certain priority has therefore been given to the archaeologists' view, based on their knowledge of Iberian urban planning and architecture, although the geophysicists understanding has always been taken into account. Needless to say, the accuracy of these hypotheses can only be verified by excavations, which are expected to begin very soon.

To prepare these plans, it was decided to use vector-drawing software to represent manually the supposed archaeological features. A second question was which of the plans generated by the geophysicists was (or were) to be used. The obvious answer was that it would be necessary to use all the plans of different depths separately to analyse the possible evolution of the settlement over time, even though we are well aware that a difference in depth does not necessarily mean a different dating. On the contrary, it was estimated that the cumulative plans on which every feature is represented, regardless of its depth, can be misleading for the purposes of planimetric interpretation, although they can be useful for showing the structure of some deep features, especially those that have been dug out. However, the results observed in the depth plans between 0.65 m and 1.30 m basically match each other and allow us to propose a plan for the Iberian town as shown in Figure 9. In the paragraphs that follow, we discuss in more detail our interpretation, pointing out above all the challenges that remain and can only be resolved through excavation.

Figure 9. (a–f) Time slice sequence interpretation diagrams from 1.46–1.30 to 0.65–0.49 m depth; (e) also indicates the location of the possible excavation trench and (f) shows the areas with possible modifications in the urban planning

The geophysical survey provided a total of nine plans corresponding to the time slices obtained at depths of between 0.16 and 1.46 m. The deepest (1.30–1.46 m) shows a large number of structures; except for a few minor modifications and additions, they are all found in the others up to 0.49 to 0.65 m depth plan. This indicates that the urban structure did not undergo important changes (or any at all) during the period in which this sedimentation was formed, except perhaps in its very last moments, when, as we shall see later, some major modifications took place that may be observed in the 0.49 to 0.65 m depth slice. This could indicate that the period corresponding to the formation of this 1.5-m-thick sedimentation did not last very long, which is consistent with what we know from a number of Iberian sites. It is possible, however, that there are earlier remains in the prospected area, given that excavations in the field immediately to the north have yielded evidence of Iberian buildings up to a depth of 2 m (Cela et al., 2001).

The urban structure is already well-defined in the 1.14 to 1.30 m time slice. This plan shows a densely occupied settlement bordered to the west and south (the northern and eastern sides could not be explored) by several walls that are thicker than those attested in the area they enclose; this strongly suggests a defensive nature. Following the interpretation diagram of Figure 10, peripheral habitation blocks are attached to one of these thick walls (1); sections of a second similar wall, apparently parallel to Wall 1, are seen to the west (2) and, although less clearly, to the south (2?). The inner wall apparently had three towers located on the western side (5), the southwestern corner (6) and near the south-eastern corner (7). In addition, the magnetic survey suggests the existence of a ditch in the western part of the site (3); this runs parallel to the wall, but extends southwards for at least 30 m beyond the southern wall that delimits the site. Moreover, the magnetic survey also indicates the probable presence of another thick wall (4) between the possible ditch and the aforementioned outer wall (2). Like the ditch, it also extends southwards beyond the town limits suggested by the two parallel walls (1 and 2). In fact, this could be the scarp wall of the ditch.

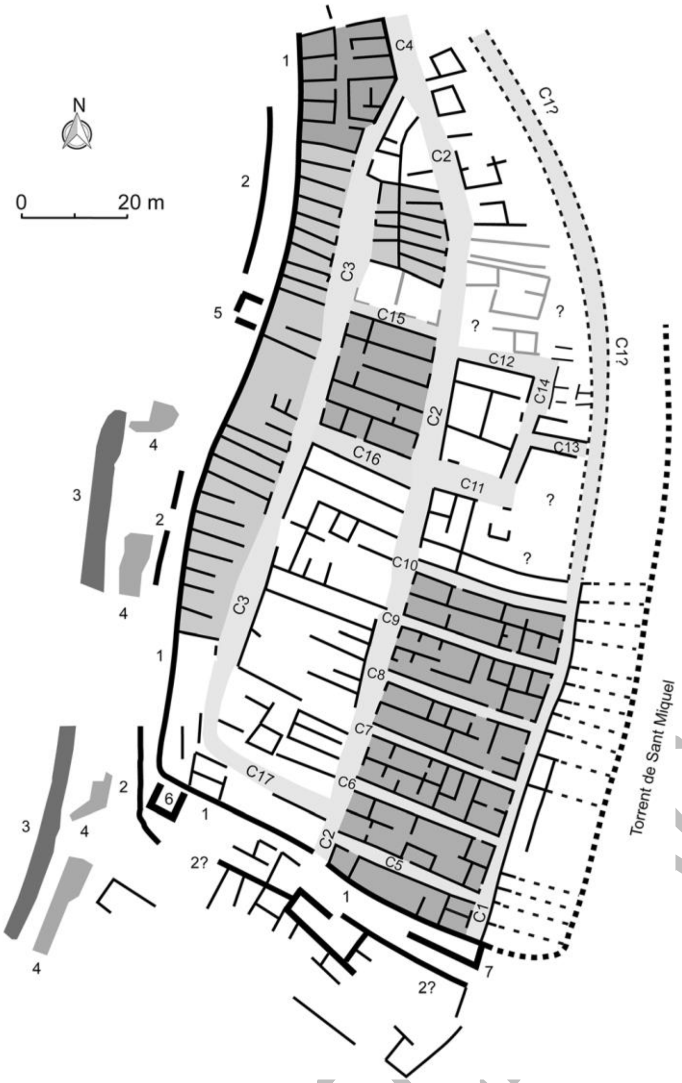

Figure 10. Interpretation of the Masies de Sant Miquel urban layout and defensive system

Thus, the existence of a defensive system of remarkable structural complexity can be deduced. This may be explained either by the topography of the site, which, as previously stated, barely has any natural obstacles that could help defend the settlement, or by the presence of built structures erected in different phases, which may have functioned simultaneously during the final phase, at least to some extent. We will return to these issues later when discussing the existence of extramural buildings in the southern part of the settlement. For the time being we will just say that these observations alone provide reasonable evidence for the hypothesis that the town of Masies de Sant Miquel occupied an important position within the regional settlement pattern, which has already been described earlier. It is a reasonable assumption that the eastern side of the site was also protected by a defensive wall, of which, however, nothing remains, due to the erosive action of the Torrent de Sant Miquel.

The internal layout of the settlement is based mainly on three streets running approximately from north to south (C1, C2, and C3), that delimit four large habitation areas of unequal width, one of which, the easternmost one, has almost completely disappeared due to the changing course of the Torrent de Sant Miquel. To these streets we have to add another, much shorter one running from north to south in the north-eastern part of the site (C4). A series of six east to west streets (C5–C10) are also clearly distinguishable to the southeast, between Streets C1 and C2, that delimit six rectangular habitation blocks. To the north, two more streets (C11 and C12) connect C2 to the short C14 street, which in turn is probably linked to C1 by an east to west lane (C13). In the westernmost area, adjoining the defensive wall, there is only one more or less clearly distinguishable short street (C4), perhaps leading to a narrow gate. In the central area, between Streets C2 and C3, a narrow path (C15) is clearly distinguished. Further to the south, at least two more streets (C16 and C17) connecting C2 and C3 can be observed. This leaves a very large built space (65 m long) between C16 and C17, which is an unusual and not easily interpretable feature.

The streets we have described look 'clean' (i.e. without any apparent features located in the circulation space) on the geophysical plans corresponding to depths between 1.30 and 0.65 m. This is not the case, however, of the 0.49 to 0.65 m depth plan, on which some transverse features are observed that would have prevented circulation in several streets. These features appear in C2, C18, the northern part of C3 and, less clearly, in C16. Moreover, a longitudinal feature is recurrently seen from the 0.98–1.14 m to 0.33–0.49 m depth plans in the southern part of C2. This is probably a trial excavation trench. Considering that most of these features are only seen on the 0.49 to 0.65 cm depth plan, as well as the fact that Street C2 leads to what appears to be a gate in the southern defensive wall, we understand that these features, if they really do correspond to contemporary archaeological structures, must belong to a very late phase, perhaps indicating a partial privatization of the public space.

While the general layout of the ancient site can be reconstructed without major difficulty, the internal structure of the habitation blocks is often quite obscure, which makes it extremely difficult to discern the plans of distinct houses. The westernmost habitation block is occupied by simple rectangular buildings arranged in a row with the fortification wall constituting the rear wall, which is a typical arrangement in Iberian architecture. It is not possible to say if each of these corresponds to a unicellular dwelling, either domestic or of another kind. Such simple houses are indeed present at many Iberian sites, but we cannot rule out the possibility that some of these rectangular spaces communicated laterally to form larger structural units, perhaps composed of two or even three spaces of this type. Such dwellings have been attested, for example, at Castellet de Banyoles (Sanmartí et al., 2012, 55–56) and Puig Castellar in Santa Coloma de Gramenet (Ferrer & Rigo, 2003). Having said that, the geophysical results suggest a lack of large, more complex houses in this area, except in the northernmost part, where a more complex building with rectangular rooms opening onto an elongated central space accessible from Street C3 can be made out. An arrangement similar to the one we have just described may have existed in the easternmost habitation block. However, given the extremely poor preservation of this area, this can never be more than a reasonable assumption based mainly on frequently attested layouts of Iberian sites.

The habitation block between C2 and C3 is even more difficult to interpret. To the north of C15 there is a large, roughly triangularshaped space structured by a long wall. On both sides of this wall there are long rectangular buildings, similar to those adjoining the western wall we described in the previous paragraph, and at least two large spaces in its southern part. These buildings could correspond to small dwellings, although other functions, such as storage, cannot be ruled. To the south of C15, in most of the space between C2 and C3, there are elongated rectangular units, which are particularly visible in the 0.81–0.98 m and 0.98–1.14 m time slices. They are of variable width, although mainly about 4 m, and their length varies from 17 m in the north to 20 m in the south, with an average area of some 70 m^2. Some of these spaces appear to be grouped into larger sets consisting of two or even three units. These would be dwellings of a considerable size, structurally similar to those attested during the fourth century BC at the Alorda Park site, located just 9 km away as the crow flies. The described structure is still recognizable in the depth plans nearest the surface (0.65–0.81 and 0.49–0.65 m), although the built spaces look more compartmentalized and, as already mentioned, part of the streets seems to have been occupied. This could reflect some changes in the domestic architecture of this area, perhaps considerable in some cases, although the plans deriving from the geophysical prospecting do not clearly show recognizable types of houses usual in the third century BC (Belarte, 2008). We know, for example, that the large Iberian houses of the fourth and third centuries BC were often preceded by a large open space or arranged around a courtyard. The presence of such courtyards or open areas would be the most valuable indication for recognizing such large domestic units, but in this case they cannot be clearly identified from the geophysical plans.

The situation is not much clearer in the habitation blocks in the southeastern part of the site. Here, the presence of large courtyards, either in a central position or preceding the entrance to the built area, does not seem likely, given the elongated proportions of the blocks and their dimensions (230 m^2). This spatial arrangement suggests that each block was occupied by two houses of some 110 m^2 each, which is consistent with the more or less systematic presence of the walls that seem to divide them according to the transversal axis. However, it is also plausible that each block had been designed and functioned as a single large house. In any case, we have not been able to define a typical plan characteristic of the houses in this sector, perhaps because of restructuring.

In spite of the many uncertainties we have just mentioned, some interesting observations can be made about the general arrangement of the domestic units. The first aspect that deserves some comment is the diversity of shapes and sizes of the blocks of buildings. As already indicated, the elongated rectangular blocks in the southeastern part occupy 230 m^2, but those located between Streets C2 and C3 are seemingly much larger. The block between Streets C15 and C16 is nearly 400 m^2 and the one that follows it immediately to the south, between Streets C16 and C17, as much as 1300 m^2. These figures are normal for some of the large mansions seen in important Iberian settlements such as Ullastret. However, Ullastret is a very large (some 18 ha) first order site, the capital city of the Indiketes' polity (in present-day northern Catalonia), while Masies de Sant Miquel is a secondary town within the settlement pattern of the Cessetanian polity, which had its capital in Tarragona (ancient Kesse). The presence of the elite may be assumed at both sites, although it is a reasonable assumption that the most important social groups of the Cessetanian polity resided in Tarragona and not in Masies de Sant Miquel. Consequently, we could suggest that the area between Streets C2 and C3 was occupied by several houses of perhaps a few hundred square metres. These figures are closer to those attested at other sites of similar size, particularly Castellet de Banyoles (Tivissa), a town with an area of some 4.5 ha (Sanmartí et al., 2012, 43), a size similar to that of Masies de Sant Miquel.

Another large house may have been located in the block bordered by Streets C11, C2, C12 and C14. It would have occupied some 230 m^2, like the elongated blocks of the southeastern area. To the north and east of this house, the data are sparse and confusing on every depth plan and do not allow any hypothesis to be put forward. This may be due to the poor preservation of the building remains in that area, although we have no further data to sustain that hypothesis.

Given all the above, we believe it is possible to propose an interpretative hypothesis based on what we know today about Iberian town planning and architecture and how they reflected social organization (Figure 10). To our minds, Street C2 separates two areas respectively occupied by two large, internally hierarchized social groups. The higher-ranking family groups would have occupied the houses located in the central part, between Streets C1 and C3, while the subordinate groups would have lived in the much simpler houses adjoining the western – and probably the eastern – wall. A similar arrangement has been documented in Castellet de Banyoles, although in that case the large houses appear to adjoin the wall and the simpler buildings are found in the inner area. In spite of a different spatial organization, the same diversity in dwelling size is attested at Ullastret, more specifically in the Illa d'en Reixac area (Martin Ortega & Plana Mallart, 2012, 184; Codina, Plana-Mallart and De Prado, in press). It is possible that the two groups at Masies de Sant Miquel were organized hierarchically and, in that case, the large mansions to the west of Street 2, if they actually existed, would indicate that this was the highest-ranking social group.

Another issue that presents interpretation problems is the defensive system. The existence of an outer wall running at a distance from the inner one that ranges from 3.5 to 6 m on the western side and up to 9 m on the southern side is not a normal feature in Iberian defensive architecture. However, double walls of this type are attested in other chronological and cultural contexts and therefore we cannot rule out that the two walls we document at Masies de Sant Miquel were in use simultaneously as a structural unit. One serious objection, however, is the presence of towers attached to the inner wall, since these could not have been used with the outer wall. A logical inference would be that the towers were built at a later stage, after the outer wall had been dismantled (a similar evolution has been documented, for example, in the Alorda Park settlement) (Asensio, Morer, Pou, Sanmartí, & Santacana, 2005). This is consistent with the fact that extensive sections of the latter do not appear in any of the geophysical survey depth plans. However, some parts of it may have been preserved in the defensive system. It is possible, for example, that to the north of Tower 5 both walls formed a corridor that gave access to a gate located further north. A similar arrangement could have existed near the south-western corner, between the outer wall and Tower 7.

The final interpretation challenge is raised by the existence of architectural features located outside the southern wall, whose structure remains unclear. One possible explanation is that this is a periurban occupation area, like others that have been recognized in recent decades around several Iberian towns (Martin Ortega, Plana Mallart, Codina, & Gay, 2008; Plana-Mallart & Martin, 2012). However, these extramural quarters are generally some distance from the defensive walls – within a radius of 300 to 500 m at Ullastret (Plana-Mallart & Martin, 2012, 144). These constructions could be related to the extension southwards of the possible ditch documented by the magnetic survey. In our view, the most likely explanation is that they were built when the old outer wall was dismantled and the towers were added to the inner wall. This would have considerably extended the walled town area towards the south and would have strengthened the defensive system with a ditch that was probably linked, at some point to the southeast, with the Torrent de Sant Miquel stream. A large part of the town would thus have been surrounded by this obstacle. As we have already said, this was by no means a superfluous measure, since the settlement is located in a very vulnerable position, in the middle of the Penedès plain, with no defensive advantages deriving from the topography (except for the Torrent de Sant Miquel). There is no evidence for dating the different parts that make up this defensive system, but we tend to think that the great restructuring we have described must have occurred well into the third century BC, probably in relation to the Second Punic War or perhaps somewhat earlier, as a result of the formation of the Barcas' Carthaginian empire on part of the Iberian Peninsula. These are the kind of events that would have justified such a major investment.

The interpretation difficulties we have highlighted clearly indicate the challenges that can arise from the use of geophysical prospecting in pluristratified sites, but also show its considerable usefulness in various ways. Firstly, for the formulation of interpretative hypotheses regarding the structure of settlements and even the organization of the society that founded and developed them. In this respect, the image offered by the geophysical prospection may be blurred in different aspects, but it seems to confirm the general organization of the Iberian towns into neighbourhoods composed of groups of houses of different sizes and structures, each of which would have corresponded to a specific gentilitian group and its sections (Tivissa, Illa d'en Reixac).

The role of the geophysical prospection is also very relevant to the planning of the subsequent stages of the research. In the case under study, the evolution of the defensive system, the precise delimitation of the habitation blocks between Streets C2 and C3, and the study of the internal structure of several blocks in the area between Streets C1 and C2 –which should provide information not currently available on the size and structure of the houses – are the key research elements for the immediate future. These questions can only be resolved through archaeological excavation. However, the planning and execution of this new stage of research will benefit enormously from the results obtained by the geophysical prospection.

ACKNOWLEDGEMENTS

This article was written as part of the research funded by the Spanish Ministry of Economy and Competitiveness (HAR2015-67946-C2-1-P and HAR2015-67946-C2-2-P projects).

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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