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Abstract

Two rural sites on the island of Mallorca (Balearic Islands, Spain) have been investigated with geophysical methods. A previous archaeological field survey provided surface ceramics that allowed for a first classification of the sites as possible Roman rural settlements, possibly villae. The objective of the investigation was to work towards the identification of architectural remains to better understand the nature of the sites. Using the 7-probe fluxgate gradiometer array LEA MAX, magnetic measurements were executed on a large area on each site. GPR measurements were subsequently carried out to examine selected areas of interest in detail by means of the IDS GPR system based on the Fast-Wave module. The investigated areas demonstrated excellent surface conditions with a negligible number of sources of disturbance, permitting a detailed interpretation of the geophysical data. The results helped to reveal the presence of architectural remains beneath the soil at both sites.

Keywords	Roman, villa, geophysics, magnetometry, GPR, Balearics, countryside
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GEOPHYSICAL SURVEY OF TWO RURAL SITES IN MALLORCA (BALEARIC ISLANDS, SPAIN): UNVEILING ROMAN *VILLAE*

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ABSTRACT

Two rural sites on the island of Mallorca (Balearic Islands, Spain) have been investigated with geophysical methods. A previous archaeological field survey provided surface ceramics that allowed for a first classification of the sites as possible Roman rural settlements, possibly *villae*. The objective of the investigation was to work towards the identification of architectural remains to better understand the nature of the sites. Using the 7-probe fluxgate gradiometer array LEA MAX, magnetic measurements were executed on a large area on each site. GPR measurements were subsequently carried out to examine selected areas of interest in detail by means of the IDS GPR system based on the Fast-Wave module. The investigated areas demonstrated excellent surface conditions with a negligible number of sources of disturbance, permitting a detailed interpretation of the geophysical data. The results helped to reveal the presence of architectural remains beneath the soil at both sites.

KEY WORDS: Roman, *villa*, geophysics, magnetometry, GPR, Balearics, countryside

Geophysical survey of two rural sites in Mallorca (Balearic Islands, Spain): unveiling Roman *villae*

1. Introduction

For the last three decades, the growing interest in the human occupation of the countryside across different historical periods has contributed to the development of a large number of archaeological projects in rural settlements throughout the entire Mediterranean region and beyond (see for instance, Barker and Lloyd, 1991; Bintliff and Sbonias, 1999; Alcock and Cherry, 2004).

In the case of the Balearics, and Mallorca in particular, the study of the evolution and transformation of rural landscapes was not developed until recently (Orfila, 1988; Mas and Cau, 2013). The islands were conquered for Rome in 123 BC by *Quintus Caecilius Metellus*. Written sources mention the foundation of two cities *Palma* (Palma de Mallorca) and *Pollentia* (Alcúdia) in Mallorca. Moreover, with the Roman occupation, a progressive organization and exploitation of the countryside can be witnessed through the island. The studies carried out so far have shown that the settlement pattern involved the continuity of pre-Roman Indigenous sites and the creation of only a few Roman *villae* (Orfila, 1988). It is still to be determined when the phenomenon of the implantation of the *villa* system started in the countryside, how pervasive it was, and how these sites interacted with the rest of the indigenous settlements (Mas Florit and Cau, 2013).

The aim of this paper is to investigate the rural Roman countryside of the island of Mallorca, in the Balearics Islands (Spain) (Figure 1), using a geophysical approach on the sites dispersed throughout the landscape. Geophysical prospection has been carried out in the framework of a wider project which adds significantly to research in rural landscapes and island archaeology through an investigation of the transformation of the particular rural landscapes in their island context. The need for new methods and approaches for the study of this insular system derives from a certain degree of dissatisfaction with some of the results obtained in the past, when studies of the territory were conducted with more traditional methods (Mas Florit, 2013). To date, field surveys carried out on different parts of the island have allowed for the documentation of several sites that could be Roman or late antique foundations (e.g. Orfila 1988; Orfila et al.1996, Coll et al., 1984; Coll 1997; Estarellas 1998; Merino and Torres,2000; Cau and Mas Florit, 2013). In some cases, the relatively small dispersion of ceramic materials has led to a classification of the sites as small farms; other larger extensions have been defined as *villae* or even villages. However, archaeological sites have been subject to numerous post-depositional processes which modify the original extent of a site. In order to test these hypotheses and to better define the nature of settlement patterns, geophysical surveys were carried out in two Roman rural sites.

In Mallorca, systematic geophysical surveys were carried out in the Roman city of *Pollentia* (Alcúdia, Mallorca) (Rainieri et al., 2010; Trogu et al., 2011; Ranieri et al., 2016), but never to study the rural landscape. In an initial state, we have selected an area in the eastern part of the island where previous field walking survey resulted in the

location and first dating of several settlements datable to the Roman and late antique periods (Cau and Mas Florit 2013). In this area, the sites of Can Maiol (Felanitx) and Son Joan Jaume (Manacor), which could be considered as *villae* that could have been transformed during the late antique period, were selected in order to apply a combination of a magnetometry and ground-penetrating radar (GPR).

2. Archaeological context

As noted above, evidence of ancient Roman *villae* in the Balearic Islands is very scarce probably due to the fact that many pre-Roman Indigenous sites continued to be inhabited throughout the Roman period. Nevertheless, after the military intervention of 123 B.C., the progressive organization and exploitation of the countryside led to the construction of new Roman rural sites. Some of these sites created *ex novo* have been documented by field surveys in several areas of the island (Orfila 1993; Orfila et al. 1996). In the case of the island of Mallorca, unfortunately, only two sites have been so far partially excavated. The *villa* of Sa Mesquida on the western coast of Mallorca is one of the few examples documented and partially excavated. The remains belong to a structure composed of a series of rooms organised around a courtyard, a pottery kiln for common wares and a cistern that were both used later as a rubbish dump in Late Antiquity (Cau 2003, Mas et al., 2015). The other example partially excavated in the 1980s —and object of one of these geophysical surveys— is the rural site of Can Maiol (Felanitx) located in the plains and near what may have been a road (Figure 1). An interim excavation of the site revealed a single partially paved room with a quadrangular deposit which probably was used to contain some kind of liquid and a hole, near to the eastern wall of the room, that was probably a drainage (Orfila 1993). All these elements suggest that this space was used to carry out productive activities, probably wine production. The site was dated from the first century until at least the end of the 6th or even beginning of the 7th century (Orfila, 1993; Mas Florit 2013). Subsequent archaeological survey of the site revealed a large dispersion of ceramic materials in the surroundings of the excavated area suggesting that Can Maiol was a rural site of a certain importance (Cau and Mas Florit, 2013).

The site of Son Joan Jaume is located in the countryside nearby the current city of Manacor (Figure 1). An archaeological field survey in the 1980's documented a large extension of pottery on surface as well as walls of Roman technique still standing (Merino and Torres, 2000). These findings suggest that the site was a remarkable Roman site. No archaeological excavations have taken place. According to the oral information kindly provided by the family owning the property, a grave was excavated by a priest around 40 years ago that contained an inhumation in supine position. The same priest was nailing a rod of metal in different parts of the field and in some places could be heard beating on slabs for possible graves. Therefore, indication of scattered inhumations or of a necropolis was expected in the results of the geophysical investigation.

3. Methods

The investigation included magnetic measurements executed on a large area on each site, and later, GPR measurements that were carried out to examine selected areas of interest in detail.

3.1. Magnetic Prospection

For the magnetic investigations at the two rural sites an array of seven Förster fluxgate gradiometer probes were used (Figure 2). Mounted on a light and foldable frame, this gradiometer array is a component of the convertible LEA MAX system (Zöllner et al,, 2011)

The Förster FEREX CON650 fluxgate gradiometer probes register the gradient of the vertical component of the Earth's magnetic field with an accuracy of 0.1 nT (Nanotesla). The measured gradient (the difference between two vertically arranged sensors in a gradiometer probe) is insensitive to the typical large fluctuations of the Earth's magnetic field and is determined only by the magnetization near-surface objects and materials (Schmidt, 2009). In general, magnetic gradient measurements register magnetic anomalies of objects and structures in the layer between the surface and a depth of 2 m. The technical details concerning the investigation are specified in Table 1 The greyscale images of the investigated sites are presented in dynamic scales of ±3 nT (Son Joan Jaume) and ±5 nT (Can Maiol), depending on the maximum amplitudes of the local magnetic anomalies at each site.

The data positioning for the magnetic survey was accomplished by means of a differential GPS using two GNSS receivers ─ SMART V1 (NovAtel) ─ with a relative accuracy of 2 cm. The coordinate system in use during magnetic measurements was WGS84/UTM 31North (EPSG: 32631). After data acquisition and processing, the results were re-projected into the project coordinate system ETRS89 /UTM zone 31North (EPSG: 25831) by means of the Cartographic Projections library GDAL.

3.2. Ground-Penetrating Radar (GPR)

The two sites discussed in this paper were surveyed using an IDS GPR system based on the Fast-Wave module. This module collects data simultaneously from five antennas, each of which use a frequency of 600 MHz (Figure 3). The antennas were placed parallel on a survey cart, collecting profiles with 0.2 m of separation, and taking readings every 0.027 m (2.7 cm). The technical parameters concerning the investigation are specified in Table 2

The raw data was processed using the GPR-Slicer software. The processing sequence consisted of three steps: data georeferencing, data filtering and generation of time-slices. The data was positioned by adapting local coordinates to the UTM coordinate system using a transform function based on the real UTM coordinates of at least three local grid points used in our grid. All survey data were collected in local coordinates using orthogonal grids adapted to the local geometry of each survey area. Later on, the data were georeferenced using the same GPS position points as the magnetic prospection.

Once positioned, the raw data were filtered in order to correct phase drifts by applying a filter (*wobble)* that uses an average of 24 to 28 samples. A second filter called *background removal* was used to remove constant EM noises produced by the system.

The time-depth conversion of data was based in a propagation velocity obtained from hiperbolae shape measuring (Conyers and Goodman, 1997), which offered an average value of 0.1m per nanosecond

The last processing step consisted of creating time-slice sequences. This routine involved the integration and re-sampling of the filtered data set in a single 3D data matrix. The final 3D data set was then *sliced* into a sequence of 12 horizontal sections or plan views at increasing depths, representing a depth lapse of 0.34m or 6.4 nanoseconds at 0.1m/ns calculated velocity. The time-slice sequences are generated with at least a 50% depth overlap to avoid the loss of thin features.

Each data set was processed to produce sequences of time-slices, with different thicknesses and overlapping parameters, depending on the data characteristics of each site. The time-slice sequences were represented in greyscales with white corresponding to the minimum and black to the maximum reflection values. The contrast of the time slices was adjusted mostly at 7% (white)-97% (black), but in some cases these values were modified to produce clearer images.

4. Results of the geophysical prospection and their archaeological interpretation

4.1. General considerations

The data shown in the maps mostly succeeded in reflecting the archaeological situation and the surface conditions at the two sites. However, parts of the investigation area could not be covered by magnetic measurements due to the presence of fences, walls, trees and other surface obstacles. In order to present the genuine magnetic data, we abstained from a rough data extrapolation or interpolation to fill the gaps. In this way misinterpretation can be avoided.

After data processing, the geophysical data images were thoroughly examined for anomalies that might indicate archaeological features. Motivation and discussion concerning the results are concisely presented below, as the suggested visualized interpretation can speak mostly for itself. The interpretation presented here is by no means exhaustive, and is instead the outcome of a subjective approach under consideration of the general archaeological context and the environmental conditions. It is rather a cautious proposition serving as a base for further archaeological research.

The general approach to classify the magnetic anomalies is to distinguish them by means of their amplitudes, polarization and shape, respectively. As a consequence, anomalies of unambiguously modern origin were first separated and marked in blue. The second step was to sort the anomalies with an assumed archaeological background. In order to structure them, several classes of magnetic anomalies and corresponding causal physical structures were introduced. The specific anomaly characteristics, the related archaeological structures, and the color scheme as used in the interpretation maps are set out in Table 3 (Meyer, 2013).

With regard to GPR, two interpretation diagrams were created in order to establish an interpretation of the processed slices. The interpretation of features by depths shows the

different linear or extensive anomalies by depth; this is shown on the left in Figure 4. Once the interpretation was proposed, a synthetic diagram was created to describe, group, and name the significant anomalies, in order to offer a simplified interpretation diagram.

4.2. The site of Can Maiol

The magnetic measurements were executed on an area of 2 ha, enclosing the smaller GPR investigation area. The results of the magnetic investigation are displayed in Figure 5 (greyscale values of ±5 nT). The interpretation follows in Figure 6.

Immediately noticeable in the magnetic image is the imprint of a building visualized by negative linear anomalies with dimensions of at least 10 x15 m. Another set of weaker negative linear anomalies is recognizable to the northeast, presumably displaying an elongation of the building, suggesting less preserved features. The remains in the subsoil are situated in the immediate vicinity of the wine deposit found in earlier excavations. The linear negative anomalies, interpreted as walls and depicted in dark yellow are associated with strong circular positive anomalies that are likely pits, and linear positive anomalies indicating ditches. These observations may point to rural production activity in this specific area. Furthermore, to the east of the detected building structures, a negative, partly circular anomaly of unclear origin is discernible, possibly indicating a reuse or refill. More obscure is the situation in the eastern part of the investigated area. There, a series of positive linear anomalies interpreted as ditches and depicted in brown color form the imprint of a large rectangular structure. Remains of walls, however, were not detected here and the magnetic data interpretation of this area remains difficult, especially considering the modern plough tracks which have been implanted in the same northeast-southwest orientation. There are hints of an area of strong positive and negative anomalies in the southwest. Although the situation here seems very unclear, the magnetic data indicate an accumulation of rubble, possibly of archaeological origin, as well as a modern waste deposit or the outcrop of a bedrock body of higher magnetization.

The GPR survey at Can Maiol covered 3.932 m² in the western part of the area investigated by magnetic measurements. The specific area for the survey was chosen to offer additional information on located building remains and on an apparently highly disturbed area on the western edge of the grid. The results of the GPR survey are presented in Figure 7. The interpretation of the GPR data is given in Figure 8 and Figure 9.

The GPR data maps of this area show a good correspondence with the magnetic results, clearly describing three areas: zone A, B and C. Zone A includes the anomaly groups 1, 2 and 3. They consist of linear, mid-amplitude anomalies at shallow depths (0 to 0.4 m). Although they show similar orientations to the building features described in zone B, their shallowness and intensity could indicate that they are related to recent agricultural works.

Zone B includes a group of linear anomalies with high reflection amplitudes coming from building remains in the shallow ground. The time-slice sequence shows the shallower features in these areas at 0.25 to 0.35 m depth, displaying the main ground-plan of the building (groups 8, 9, 11 and 19) of nearly 150 m². Secondary groups of anomalies (groups 10, 12, 6, 7) originate in external building remains placed to the SE and NW of the main building.

The third zone corresponds to an area of high contrast magnetic anomalies, interpreted preliminarily as a shallow bedrock area, but possibly indicating some kind of deposit. The GPR results seem to confirm this interpretation, as they show an area of nearly 1200 m² of highly reflective anomalies. As it is shown in the depth interpretation diagram, the bigger anomaly groups 14, 15, 20 do not demonstrate geometrical patterns. But the anomaly groups 22 and 17, closer to the building groups of zone B include some linear anomalies that could be related to refilled depressions in the bedrock. As seen in the time-slice sequence, the anomaly group 22 consists of a 12 m long, highly reflective anomaly running parallel to a low amplitude secondary anomaly to its south. This secondary anomaly possibly points to an excavation in the bedrock. The anomaly group 17 shows groups of small linear features and isolated anomalies near the surface (0 to 0.5 m) probably related to building remains.

In conclusion, the results of GPR survey show a main building group in zone B with adjacent remains surrounding it to the north and west. The limit between the main building area and the deposits or bedrock outcrop at zone C is not clear, as some of the anomaly groups in this area (groups 22 and 17) show ambiguous morphologies indicating either geological structures or areas of ancient production and agricultural activity.

4.3. The site of Son Joan Jaume

The magnetic measurements (1.9 ha) were executed in the lower part, to the southeastern side of the presumed settlement center. The settlement center could not be prospected due to the presence of a large wooded area which is protected by the authorities for its environmental importance. Some modern disturbances such as fences and scrap metal, as well as surface obstacles including bushes and roads interfere with the data or cause gaps in the data set. Nevertheless, to a great extent, the results of the geophysical work permit an unambiguous interpretation. The results of the magnetic investigation are displayed in Figure 10 (greyscale values of ±3 nT). The interpretation can be found in Figure 11.

To the north of the modern dirt road, there are clear traces of building remains. Long linear negative anomalies reflect the walls (depicted in yellow) of a rectangular building with a length of about 20 m. There seems to be a prolongation of the building in the direction of the upper part of the site, where remaining above-ground structures are documented. The remains of the rectangular building visible in the magnetic data have a subdivision in rectangular rooms similar to the above-ground structures in the upper part. Also, positive anomalies of irregular shape indicate fillings or refills (indicated in brown) inside the building, and smaller strong positive circular anomalies disclose the distribution of pits (depicted in orange) inside and outside the building, extending to the north. Both anomaly groups, in association with the building structures, may point to ancient agricultural or other activity on the site. South of the modern dirt road, a necropolis is very clearly discernible. Negative linear anomalies indicating stones (depicted in yellow) occur in the data in close connection to semi-circular strong positive anomalies (depicted in brown). The fillings have an average extent of 2 m, clearly indicating inhumation burials. Possibly, the burial area continues to the north-northwest.

The GPR survey at the Son Joan Jaume site covered 2.536 m² in the center of the magnetic investigation area. In this particular area, a group of magnetic anomalies shows the outline

of a major building complex. The GPR survey area is located on a gentle slope descending to the SE. The results of the GPR survey can be found in Figure 12. The interpretation is displayed in Figure 13 and Figure 14.

The GPR results brought a sequence of time-slices with a noisy appearance, probably caused by pebbles and gravel in the soil composition. According to the images shown in the sequence, two zones have been traced and interpreted. A first zone, called A, includes the remains of a building of rectangular shape of 15 x10 m, that shows a possible secondary construction towards the East (anomaly group 10). The internal division of the building is expressed in two anomaly groups (6 and 18). The ground plan of this building is progressively defined by depth, from 0.3 to 0.9 m, probably due to its position on the slope, leaving the eastern side of the building in lower relative depths. A linear reflective feature that crosses the building group was detected from 0.4 m depth. The characteristics of this anomaly lacking relation to other detected elements and the orientation in parallel to the actual field limits suggest that is a relatively recent features related to agricultural activities.

A second zone (B) is defined in the northwest of the survey area. Although the time-slice sequence shows a spread of highly reflective anomalies (group 15) with a poor geometrical definition, some linear features indicate walls or foundations that maintain the same orientation as that of group A. Groups 5, 17, 20 and 19 seem to display a second building body, but the blurred images obtained for this area suggest a poor state of preservation and a high amount of debris under the surface layers. The anomaly group 4 to the northern limit of the area indicates an extension of the building group to the Northeast. Two mid-amplitude anomalies at the northeastern corner of the survey area may be related to further, isolated building remains.

The GPR data show therefore clear building structures in zone A matching the interpretation of the magnetic data. The connection of zone A and zone B is less clear, but the orientation of the anomalies for both zones is similar, suggesting a structural and temporal relation between them.

5. Discussion

Several archaeological projects have applied geophysical methods on numerous sites in the Mediterranean (Hay et al. 2006), often associated with Roman settlements demonstrating that these methods can help to understand the built environment of the region (e.g. Strutt, 2008; Meyer et al., 2012; *Sala* et al., 2013; Ariño et al., 2015; Poyuelo Anchuela et al., 2016). In the case presented here, with a combination of magnetometry and GPR surveys, it is clear that the results indicate the presence of architectural remains on both of the rural sites where the geophysical survey has been undertaken. Although it is not possible to determine the specific function of these features without excavation, the anomalies present forms consistent with Roman buildings.

For Can Maiol the results from both the magnetic and the GPR data reveal evidence for the remains of a rectangular building with dimensions of at least 10 x 15 m. A possible prolongation of the building to the northeast is also recognized, although the remains seem less preserved. Negative anomalies interpreted as pits and ditches suggest some kind

of rural production activity of the site, an observation that is substantiated by the former excavation of a wine deposit. To the southwest, a large area of ambiguous morphologies might indicate an area of deposit, possibly of ancient origin or bedrock outcrop. The outcomes of the geophysical research seem to confirm the existence of a building that could be Roman *villa* or a farmstead

At the known Roman rural site of Son Joan Jaume, the results of the geophysical work allow an unequivocal interpretation. In both the magnetic and the GPR data, clear traces of building remains are visible. Long linear negative anomalies depict a rectangular building with a length of at least 20 m and a subdivision in rectangular rooms, resembling the above-ground structures found in the upper part. In the center of the site, there seems to be a prolongation of the building. Circular and irregularly-shaped anomalies indicate the distribution of pits and ditches, assigned to agricultural or other functional activity on the site. Further, to the southwest, a large necropolis is recognized. Fillings with an extent of about 2 m, randomly distributed, indicate inhumation burials. On the basis of the oral information and the date provided by the magnetometry it seems that the necropolis can be dated to Late Antiquity. As there seems to be a continuation to the north, further research is highly recommended in order to better understand the site of Son Joan Jaume.

Even though the geophysical survey has helped to define the type of structures that lie beneath the surface of these rural Roman archaeological sites, only archaeological excavations will permit answers to many questions that remain as of yet unsolved: when were these rural sites founded? Did these Roman sites suffer any type of transformation over time? How long did these buildings survive?

The broader context of the sites does offer some clues. The sherds collected during the field survey on the site of Can Maiol indicate that the site was probably founded in the Augustan period. As regards the transformations that the villas underwent over time any of the anomalies detected by the geophysical surveys can suggest if there were any type of transformation over time in these sites. However, the necropolis detected by magnetrometry on the site of Son Joan Jaume could be dated to Late Antiquity based on the oral information given by the owner of the property. In the western Mediterranean during Late Antiquity the construction of burials in different parts of the *villa* is well attested (Chavarría, 2007)

The anomalies detected seems to relate both sites to Roman agricultural practices. However, the typology of the sites is still difficult to determine. The anomalies in Can Maiol seem to correspond to a rectangular building and its possible prolongation to the northwest. With the data obtain it is however difficult to know whether this is part of a larger establishment or not. It could be a *pars rustica* of a *villa rustica.* If that was the case, other buildings linked to this settlement should be found nearby. However, Can Maiol could be only a small farmstead. In the case of Son Joan Jaume, the structures documented through geophysical prospection seem to be linked to the remains of another building still visible in a bushy area to the north were the presumed settlement center was located. In this case, there are different buildings that were part of the same rural Roman site but only archaeological excavations will nourish our understanding of their function.

6. Conclusions

The geophysical investigation, consisting of magnetic and GPR measurements, provides satisfactory results that contribute to the overall understanding of each of the rural sites under study. The investigated areas demonstrated excellent surface conditions with a negligible amount of sources of disturbance, permitting a detailed interpretation of the data. In the perspective of the stated survey objective, it can generally be said that the application of geophysical methods to investigate the occupation of the countryside in Mallorca is feasible. This study is the first geophysical survey that has been applied on the Roman rural landscape of Mallorca and we hope that the demonstrated effectiveness of geophysical prospection in this setting will spur more investigations of this kind on the island. The combined use of magnetic measurements and GPR survey has served to cover large areas first with the array of seven Förster fluxgate gradiometers and to subsequently undertake GPR prospection only in selected areas, allowing us to save effort and resources. The ability to conduct research using geophysical methods without disturbing ongoing agricultural activities provides obvious benefits both to archaeologists and farmers by allowing archaeological investigations to take place in areas that might otherwise be off-limits and by allowing agricultural production to unfold with minimal disturbance from researchers.

Overall, the results obtained help to clarify some of the forms and terms of rural occupation of the territory of eastern Mallorca and to answer one of the main research questions: what lies beneath the sherds? This is only a first step in pinpointing sites of interest for possible future excavations and to define the real area of protection for each of the rural sites where geophysical surveys are carried out. The work will continue in this direction, by completing the geophysical survey of the sites investigated here and by increasing the number of sites in the eastern part of Mallorca and extending the application of these methods to sites across the island.

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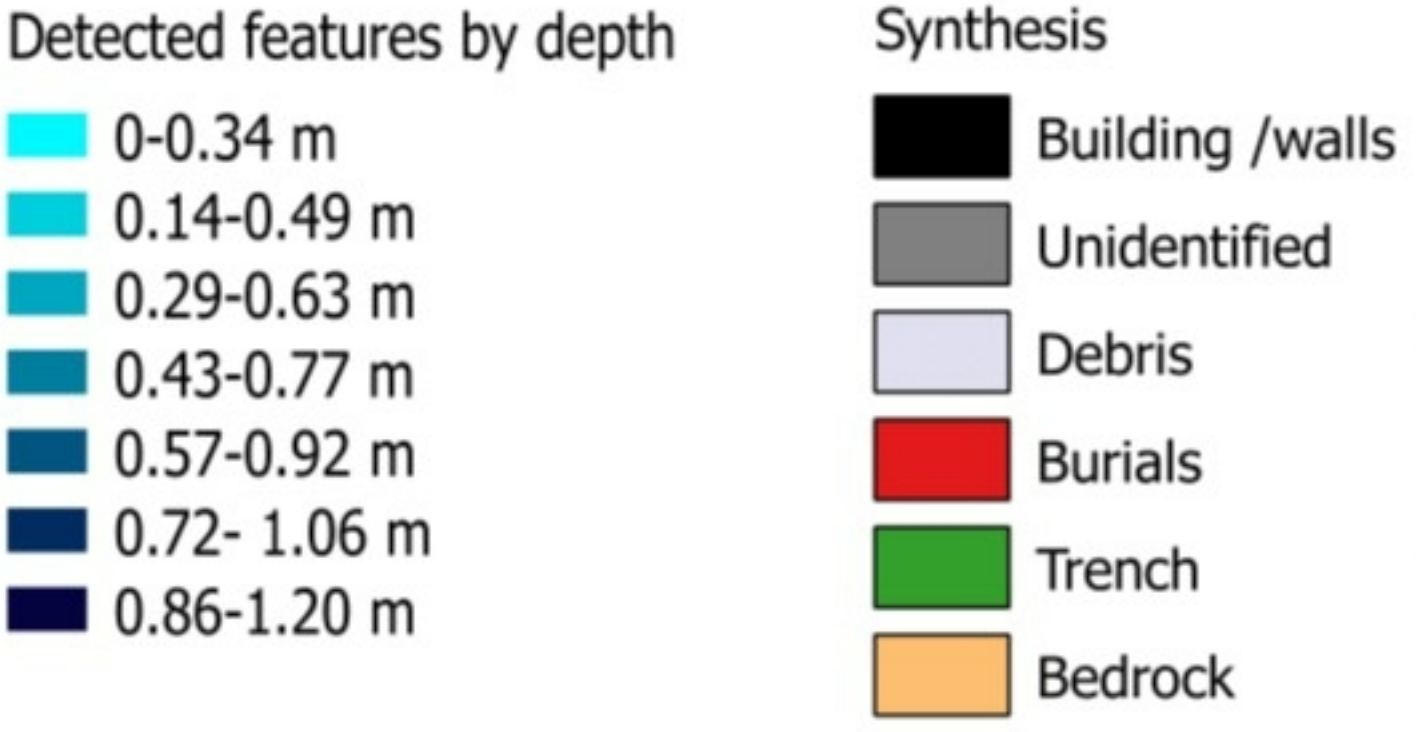
Balearic islands
MALLORCA
2
1
N
0
10
20
30
40
Km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0.14-0.49 m
0.29-0.63 m
0.43-0.77 m
0.57-0.92 m
0.72- 1.06 m
0.86-1.20 m
Synthesis
Building /walls
Unidentified
Debris
Burials
Trench
Bedrock

510825 510900 510975

4368900 4368825 4368750

510825 510900 510975

Magnetic prospection

Vertical gradient ΔZ of the Earth's magnetic field [nT]

- 5 nT ΔZ + 5 nT

Resolution: 0.5 m x 0.05 m
Grid resolution: 0.1 m x 0.1 m
Sensors: 7 x Fluxgate Förster Gradiometer 4.032 CON650
Equipment: LEA MAX system, LEA D2 (digitiser)
Positioning: GPS L1/L2 in WGS84 / UTM 31N (EPSG: 32631)

0 10 20 30 40 50 m

Coordinate system: ETRS89 /UTM zone 31North (EPSG: 25831)
Base map: Plan Nacional de Ortofotografía Aérea (EPSG: 25831)

N

510825 510900 510975

4368900 4368900

4368825 4368825

4368750 4368750

510825 510900 510975

Interpretation of the magnetic data

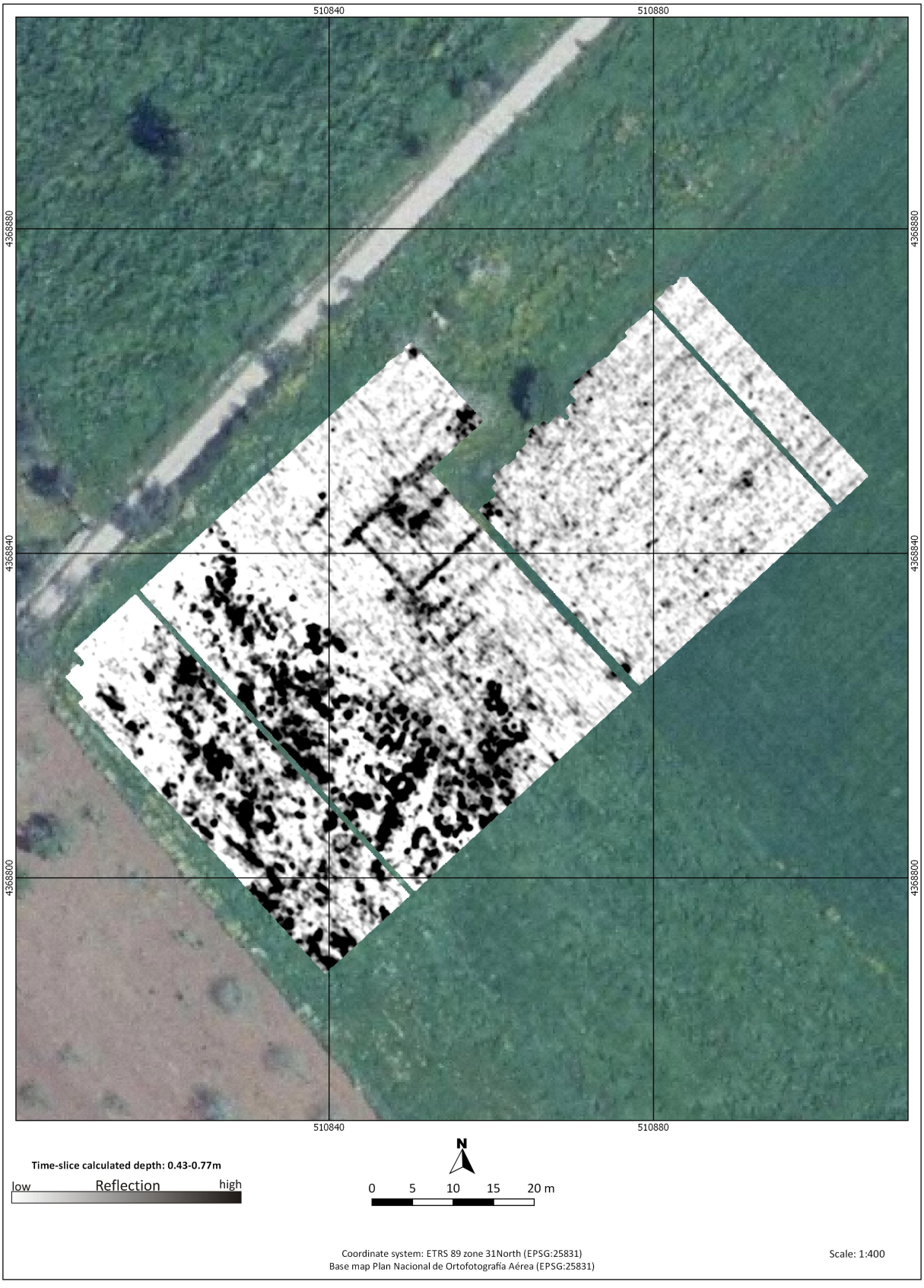
- Wall
- Ditch / filling
- Pit
- Unclear feature of archaeological origin
- Modern feature
- Geology

0 10 20 30 40 50 m

N

Coordinate system: ETRS89 /UTM zone 31North (EPSG: 25831)

Base map: Plan Nacional de Ortofotografía Aérea (EPSG: 25831)



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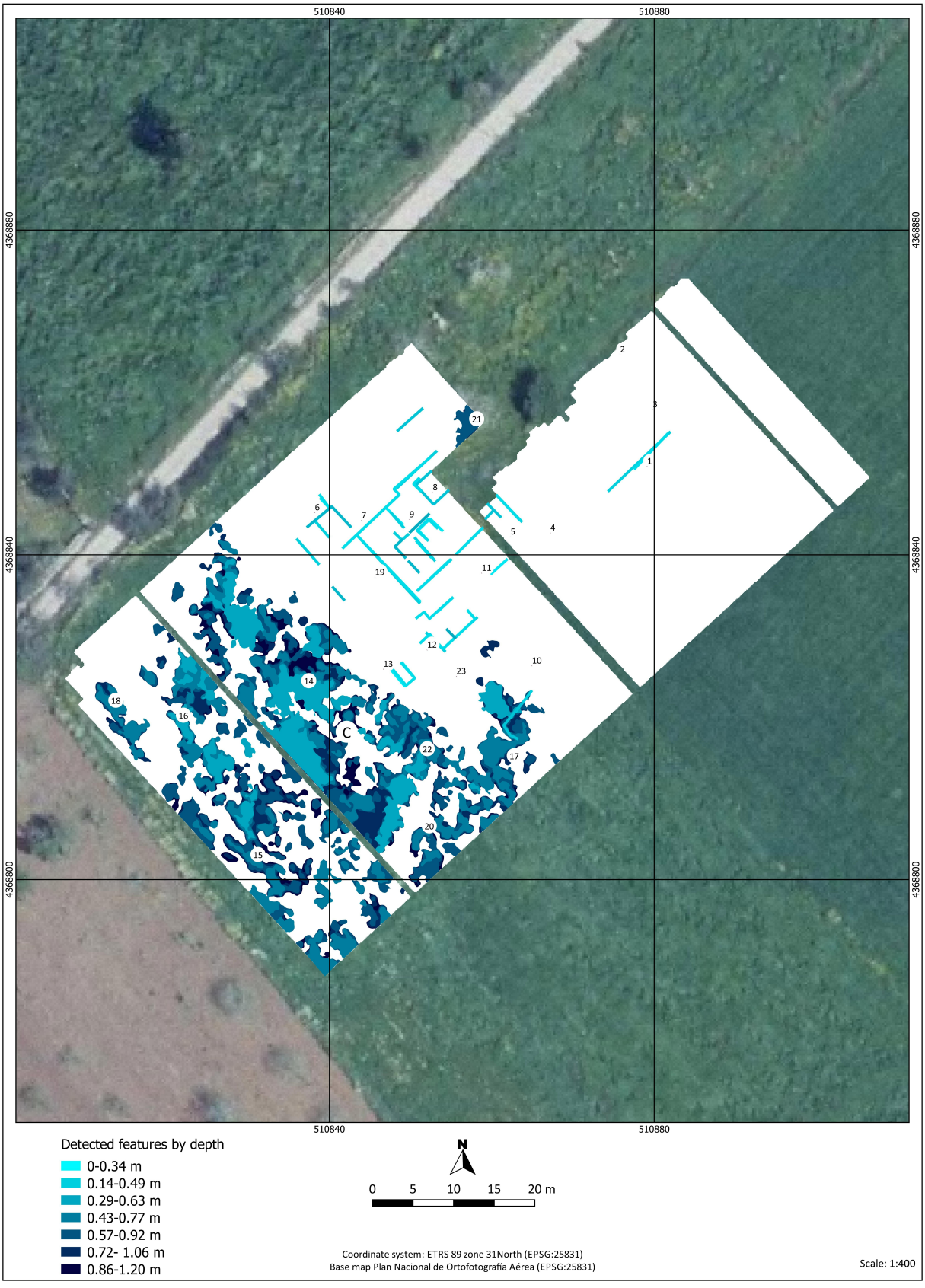
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4368840
4368800
Detected features by depth
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0.14-0.49 m
0.29-0.63 m
0.43-0.77 m
0.57-0.92 m
0.72- 1.06 m
0.86-1.20 m
N
0 5 10 15 20 m
Coordinate system: ETRS 89 zone 31North (EPSG:25831)
Base map Plan Nacional de Ortofotografía Aérea (EPSG:25831)
Scale: 1:400


510840
510880
4368880
4368840
4368800
C
Synthesis
Building /walls
Unidentified
Debris
Bedrock
N
0 5 10 15 20 m
Coordinate system: ETRS 89 zone 31North (EPSG:25831)
Base map Plan Nacional de Ortofotografía Aérea (EPSG:25831)
Scale: 1:400

514200 514275 514350

4375200 4375125 4375050

514200 514275 514350

Magnetic prospection

Vertical gradient ΔZ of the Earth's magnetic field [nT]

- 3 nT ΔZ + 3 nT

Resolution: 0.5 m x 0.05 m
Grid resolution: 0.1 m x 0.1 m
Sensors: 7 x Fluxgate Förster Gradiometer 4.032 CON650
Equipment: LEA MAX system, LEA D2 (digitiser)
Positioning: GPS L1/L2 in WGS84 / UTM 31N (EPSG: 32631)

0 10 20 30 40 50 m

Coordinate system: ETRS89 /UTM zone 31North (EPSG: 25831)
Base map: Plan Nacional de Ortofotografía Aérea (EPSG: 25831)

N

514200 514275 514350

4375200 4375125 4375050

Interpretation of the magnetic data

- Wall
- Ditch / filling
- Pit
- Unclear feature of archaeological origin
- Modern feature
- Lightning strike

0 10 20 30 40 50 m

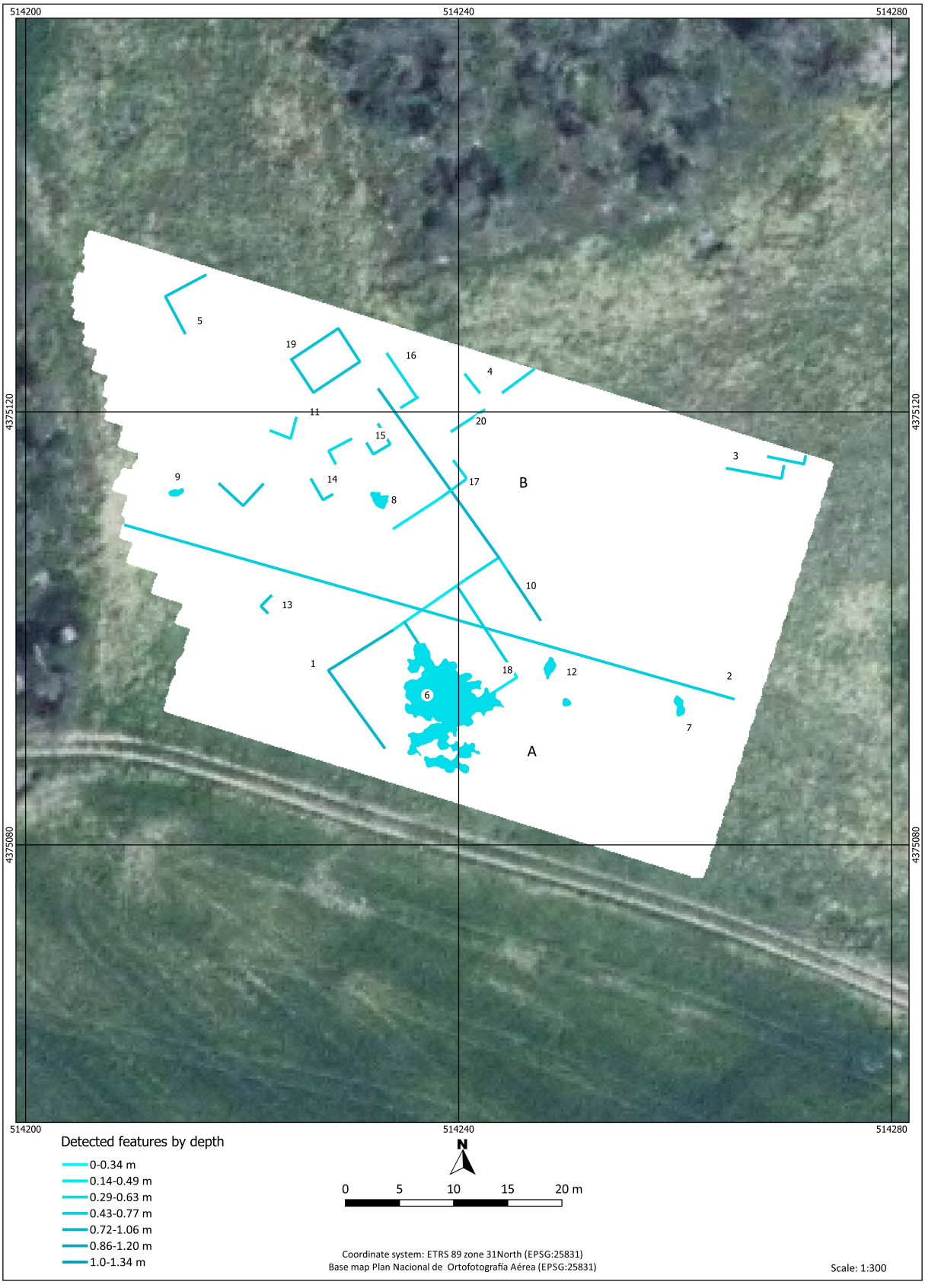
N

Coordinate system: ETRS89 /UTM zone 31North (EPSG: 25831)

Base map: Plan Nacional de Ortofotografía Aérea (EPSG: 25831)

Coordinate system: ETRS 89 zone 31North (EPSG:25831)
Base map Plan Nacional de Ortofotografía Aérea (EPSG:25831)

Scale: 1:300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514240
514280
4375120
4375080
5
19
16
4
11
20
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9
14
17
B
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13
1
18
12
2
6
7
A
Detected features by depth
0-0.34 m
0.14-0.49 m
0.29-0.63 m
0.43-0.77 m
0.72-1.06 m
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N
0
5
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15
20 m
Coordinate system: ETRS 89 zone 31North (EPSG:25831)
Base map Plan Nacional de Ortofotografía Aérea (EPSG:25831)
Scale: 1:300


514200
514240
514280
4375120
4375080
A
B
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18
19
20
N
0 5 10 15 20 m
Synthesis
Building /walls
Unidentified
Debris
Coordinate system: ETRS 89 zone 31North (EPSG:25831)
Base map Plan Nacional de Ortofotografía Aérea (EPSG:25831)
Scale: 1:300

Method	Magnetic prospection
System	LEA MAX (Eastern Atlas)
Sensors	7 Förster Fluxgate Gradiometer FEREX CON650
Data logger	LEA D2 with 10 channels (Eastern Atlas)
Measurement category	Vertical gradient in nT
Configuration	7 sensors, mounted on cart Vertical sensor separation: 0.65 m
Resolution	0.5 m profile distance max. 0.1 m point distance
Topographic measurement	2x SMART V1 GNSS receiver (with embedded NovAtel OEM6 technology)
Data positioning	Relative error: 0.02 m
Processing and filters	Eastern Atlas decoding program including offset and drift correction
Data format	ASCII, GeoTiff
Image resolution	0.1 m x 0.1 m

Table 1: Technical parameters of the magnetic prospection

Method	GPR prospection
System	IDS Fast-wave custom 5-antenna system
Sensors	IDS 5X600MHz
Data logger	Panasonic CF-18
Measurement category	Amplitudes (SI)
Configuration	5 antennas separated 0.20 m 600 MHz 60 ns 512 samples per trace
Resolution	0.20 m between profiles; 0.027 m between traces
Data positioning	Integrated encoder and local coordinates with subsequent georeferencing.
Topographic measurement	3 points of the local system were measured using a DGPS (EPSG 25831)
Processing and filters	Drift correction (based on 24-28 average samples), background, time slicing
Data format	ASCII, GeoTiff, .grd
Image resolution	0.1 m x 0.1 m

Table 2: Technical parameters of the GPR prospection

Colour	Magnetic anomaly type	Amplitudes	Type of magnetisation	Related structures
	Distinct linear negative anomalies of moderate amplitudes	-1... -10 nT	Induced, diamagnetism	Walls, foundations, stone settings made of marès
	Distinct circular and oval positive anomalies	+5... +25 nT	Predominantly remanent	Fillings of pits and post holes, burial chambers, fillings may contain pottery fragments, metal objects and burned material, scattered construction debris enriched with burnt daub and pottery fragments
	Linear but partly irregularly shaped zones of positive anomalies	±5... ±25 nT	Induced and remanent	Organically enriched fillings of ditches and fillings of construction debris enriched with burnt daub and pottery fragments
	Positive and dipole anomalies of large extension and irregular shape	-50... +100 nT	Induced and remanent	Outcrops of bedrock and fillings of water courses
	Strong dipole anomalies of irregular shape	>±50 nT	Thermoremanent	Thermoremanent magnetisation of bedrock and soil by lightning strokes (Jones and Maki, 2005)
	Linear patterns of weak dipole anomalies	±3... ±5 nT	Unclear	Magnetic anomalies of uncertain origin, possibly archaeologically relevant
	Clearly defined dipole anomalies	>±50 nT	Induced	Modern disturbances caused by iron poles, scrap metal and other ferromagnetic sources

Table 3: Colour scheme of magnetic data interpretation

Highlights

- Magnetometry and Ground Penetrating Radar were applied to two rural Roman sites
- The results show anomalies in both sites explored revealing the existence of structures
- The site of Can Maiol seems to correspond to a Roman villa or farm
- At the site of Son Joan Jaume, apart from different structures, a necropolis was detected