THE *AGER TARRACONENSIS* PROJECT (RIGHT SIDE OF RIVER FRANCOLI) (PAT): THE APPLICATION OF GEOPHYSICAL SURVEY TO IDENTIFY RURAL ROMAN SETTLEMENT TYPOLOGIES

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The methodology of the *ager Tarraconensis* project also included geophysical surveys aiming to distinguish different categories of rural settlements. Two geophysical techniques (resistivity and magnetometry) were combined to reveal traces of unearth structures from a selection of sites identified from the field survey. Results of geophysical surveys of these seven sites as well as conclusions obtained from this approach are discussed here.

Keywords: geophysics, rural sites, *ager Tarraconensis.*

The research project "Study of ancient archaeological landscape in the *ager tarraconensis* (right side of the river Francoli) (PAT)" is a multidisciplinary diachronic research of the territory around the capital of the province *Tarraconensis*, the city of Tarraco. An initial project was carried out by Carreté, Keay & Millett (1995) on the left side of the river Francoli providing the basis for further research on the agricultural territory around the *colonia*. The present project attempts to utilize an holistic approach to this ancient landscape studying population, vegetation and climate (i.e. pollens, anthracology and paleobotany), fauna (archaeozoology), geology of soils, and sedimentology (geology of the Quaternary Period). It attempts to envisage the relationships between rural sites in the territory towards the Roman *colonia,* including land distribution (i.e. centuriationes) and coastal changes.

The project methodology involves analysis of the regional archive of archaeological heritage (IPAC), bibliographical material, study of pottery collections, cartography, extensive surveys, field surveys (walked in transects) and geophysical surveys. All the data obtained from these techniques and sources will be combined in a GIS together with results from studies on vegetation, fauna, geology and climate.

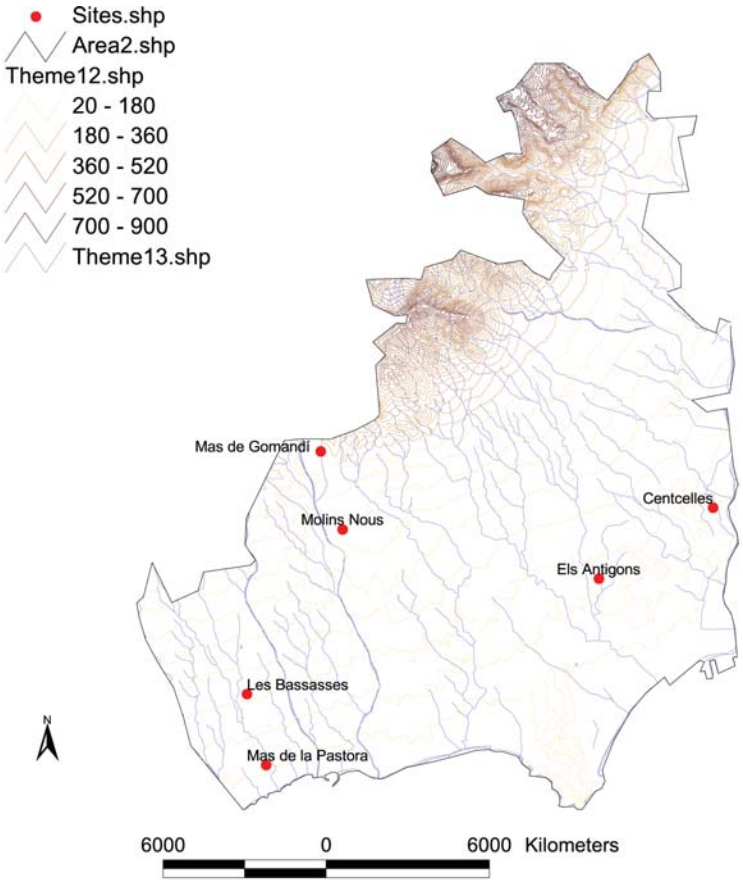
In this multidisciplinary approach, the geophysical surveys enjoyed a key role. This paper is designed to explain the aims and methodology applied to a number of the sites in the *ager tarraconensis* and present interim results from the geophysical surveys. The work was undertaken in collaboration with the archaeological company SOT, the Archaeological Prospection Services of the University of Southampton (APSS) and the British School at Rome (BSR). Intensive magnetic and resistivity surveys were carried out at each site employing Geoscan Research FM36 Fluxgate gradiometer and a Geoscan Research RM15 Resistance Meter. The survey zones were chosen according to the data collected in the field survey (based on the presence of structures or ceramics on the surface), partial excavations and other information. The geophysical surveys were then used to evaluate the site potential as well as to relate superficial archaeological anomalies with buried structures. It was also thought that each geophysical survey could reveal a series of distinctive rural settlement typologies related to specific economic and social functions.

A number of issues affected the results of the survey. On the one hand the limestone geology and dry soil conditions meant that the responses to both magnetometry and resistivity presented some technical challenges. On the other hand modern construction developments in the area as industrial and tourist zones also affected the state of preservation of some archaeological sites, and in turn meant that the pattern of archaeological features within the survey results were either constrained or affected by modern deposition of materials.

To date the geophysical surveys have succeeded in complementing the results from the other methodologies employed in the project. It is attempted here to discuss in some detail the results from these initial surveys that include the *villae* of Molins Nous, Centcelles, Els Antígons, and the rural settelments of Les Bassasses, Mas de la Pastora and the ceramic workshop of Mas de Gomandí.

Precedents and present project

The *ager tarraconensis* landscape was a central focus of research in the late 1980s when an Anglo-Catalan team carried out a field survey around the capital of Tarraco. The team selected four-transects parallel to the coastline for field-walking, which took place from 1985 to 1990 (Carreté, Keay & Millett, 1995). Apart from a first archaeological approach to the *Tarraco* hinterland, the project attempted to provide a pattern of distribution of rural population in the countryside over time – from the Iberian to Late Roman period. The results of the project concluded, among several points, that there was some kind of continuity between sites in the Iberian and Republican period, and some shifts from these sites in the Imperial period. Site density in the territory surveyed only reached an average of one site per km^2.



1. Map showing the location of the principal study areas, with the sites surveyed using geophysical methods marked

The present research project on the *ager* of the ancient city of *Tarraco* has been defined as an overall study of the hinterland landscape from 500 BC to AD 700. Due to its focus on a broad period the study was approached by looking at different phases focused on suitable territorial units, in this case our counties – comarcas. The first comarca was Baix Penedès (the ancient Iberian territory of Eastern Cosetania) (Guitart, Palet & Prevosti, 2003). The second sector was centred in the comarca of Baix Camp and Tarragonès, southward of the Francolí river. This was studied under the current project, "The Study of the ancient archaeological landscape *ager tarraconensis* (right side of river Francoli)" (PAT). The study area covers those two comarcas of Baix Camp and Tarragonès, and can be constrained geographically by the river Francolí to the East, Serra de Prades to the North, the Riudecanyes stream to the West and finally, the Mediterranean to the South (Fig. 1). Since our research is focused on the dynamics of landscape, and in spite of the fact that our research team specializes in the study of antiquity, our starting point is the Iberian period.

The Survey Methodology

In terms of methodology, putting together a multidisciplinary approach and use of techniques attempts to offer a more complete view of the *hinterland* of *Tarraco* from the Vth century BC to the VIIth century AD The approach consists of four principal lines of investigation; human population and settlement pattern, territory morphology, paleobiology (palinology and studies of archaeozoology) and geoarchaeology (study and dating of Holocene sedimentology; study of vegetal cover; study of geological maps; paleomagnetism in pottery workshops).

Cartography plays an important role in this approach therefore a GIS (Geographic Information System) is being used for storing and managing the project data. GIS was employed to generate all kind of maps including spatial, temporal and thematic layers related to topography, with ancient roads, plots of land, Tertiary and Quaternary geology and maps of vegetation cover (Prevosti *et alii*, in press).

Studies of settlement pattern were developed in five phases, and the results are recorded in the database of the GIS project:

- An extensive survey of all known sites.
- A second phase that corresponds to intensive surveys planned in two transects. A similar methodology to the work by Carreté *et alii* (1995) was employed with the aim of comparing both surveys as well as the pattern of both studied areas.
- Study of materials preserved in collections and museums.
- Study of the epigraphy of the *ager tarraconensis*.
- Test excavations, geophysical surveys and extended excavations.

For the last phase, the project aims to assign a chronology to the morphological traces in the territory, dating structures that will help to understand rural site typologies, or enhancing knowledge of sites through the production of an architectural map.

Across the whole study area there are a great number of Roman pottery scatters on the surface, either of Republican or Imperial date. Basically, the information available corresponds to large Roman *villae*, as well as the abundant pottery workshops. However, little is known from the excavation of small farms. This is an important gap to be filled in order to have a more complete view of the structures of rural settlement.

It is important to identify the different forms of rural structures (*villae*, farms, *tuguria*, *vici*, different activities and production centres), in other words the site typologies and their hierarchies, which we normally interpret from scatters of finds on surface. In the Baix Camp and the southern sector of the Tarragonès, no complete rural site or villa has been excavated. This situation means a serious lack of information in order to understand how rural sites functioned, their hierarchies and the economic networks in which they were involved. Completing site plans for each settlement is the first important aim. In addition sites that are identified by sherd scatters and structures on surface also need to be assigned to a site typology. Geophysical prospection may be of great help in these cases.

The Geophysical Surveys: their geological context, and the strategies and techniques

Geophysical surveys were undertaken in collaboration with the archaeological company SOT, the Archaeological Prospection Services at the University of Southampton (APSS) and the British School at Rome (BSR). Survey zones were chosen according to the data collected in the field survey (from the presence of structures or ceramics on the surface), partial excavations or other information from IPAC (the Archaeological Service Archive). Therefore, geophysical surveys were used to evaluate the site potential as well as to relate superficial archaeological clues with unearthed structures.

It was attempted from geophysical survey to identify different architectural typologies of rural structures such as *villae*, farms, huts or pottery workshops and relate them to sherd scatters collected on the surface. The geophysical survey results may also facilitate the targeting of features at some potential sites for future excavation.

The area of *ager tarraconensis* is located in the middle of the Reus-Valls depression, created during the movement of the Alps as a final phase of the formation of the Iberian mountain range (Gallart, 1985). This depression was filled in the Neogen with materials that belong to diverse geological periods from the Aquitanian to the Tortonian superior. Most of the geological substrata have been modelled by three important factors: the river Francoli to the east, the Prades mountains range to the west and the Mediterranean Sea to the south. Horizontal levels of the terraces of the river Francoli are optimal for human occupation, while the mountainous foothills of the Prades range are more problematic. Coastal settlement may have appeared as soon as the coastline and marshes were suitable for agricultural exploitation. Some of the areas studied by Álvarez & Daza (2007) reveal the presence of limestone pebbles and clays in the Prades foothills near Constantí (*p.e.* Mas del Serapi). River terraces near Riudoms include a sedimentary matrix with sandstones and clays.

An initial geophysical survey at Molins Nous (Riudoms) was carried out by the archaeological company SOT in June 2006. The site was special in the sense that there were remains of a Roman villa with an olive-oil press facility, which was excavated earlier (Romero, 1978a; Id., 1978b). Numerous scatters of pottery sherds on the nearby fields suggested that there were more architectural structures unearthed. The main field to the south of the excavated area was opened with no obstacles present that might have constrained the fieldwork. However, the two areas to the North and West of the site contained olive-groves that made the operation of the geophysical survey quite complicated. The survey results were also affected by buried metal objects from a watering system in the area as well as the remains of modern burying, which were removed or detected where possible.

It was decided to undertake a magnetometer survey of the whole area employing a Geoscan Research FM256 fluxgate gradiometer for a rapid survey of the whole area. This was complemented by a small GPR survey of the area close to the excavation in order to trace the line of the walls running from the excavation. Nevertheless, the irregular soil surface made this site not really suitable for GPR since antenna produced reverberations because it does have complete contact with the soil.

The first results of the magnetometry were not clear enough (SOT, 2006). It was realized that background noise due to limestone substrata interfere with the magnetic signal generating a complex image (Fig. 3). Only results from the western part of the survey area suggested any archaeological remains. There is a large rectangular structure that may correspond to a chalk or pottery kiln. Around the excavated area, a series of anomalies turned up but without any clear shape so they are quite difficult to be interpreted.

The first lesson learned from this initial experience was that the importance of the limestone background affected any other magnetometry in the *ager tarraconensis* area, something that was realised when resistivity was also employed.

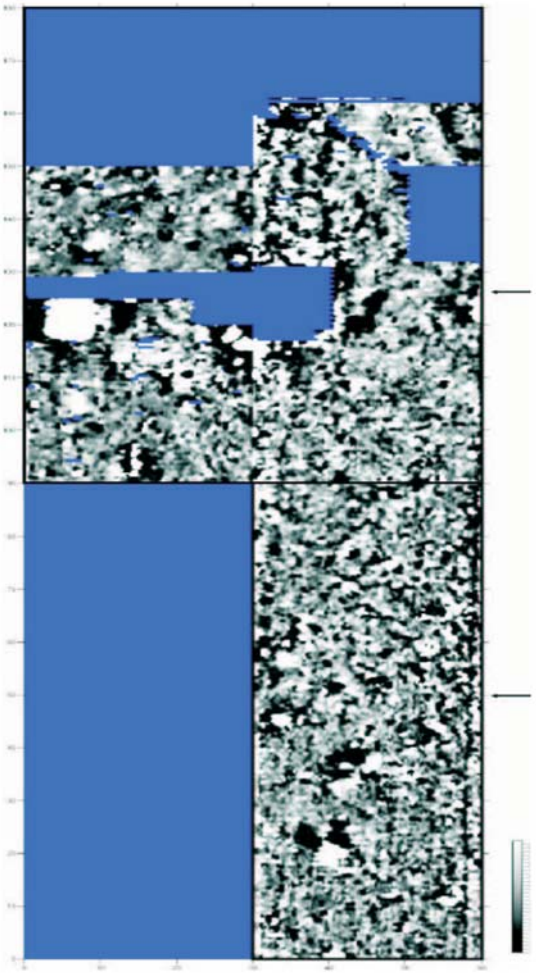
In 2007 an agreement was signed between the ICAC and the Archaeological Prospection Services of Southampton (APSS) and the British School of Rome (BSR) to undertake a series of geophysical surveys in different sites of the a*ger tarraconensis*. The aim was to survey as many of the sites as possible in a two-week campaign. Furthermore, sites were selected beforehand according to their geological and archaeological conditions in order to obtain optimum results. Sophie Hay (APSS) visited the prospective sites in May. Of the ten possible sites four were discarded on the basis that their size or the nature of the modern cultivation meant that they were not suited to geophysical survey. These discarded sites were situated in the middle of vineyards, olive-groves, close to metal fences or with dense vegetation that hindered movement of the operators. Such environmental conditions affected the potential results of the geophysical surveys. Thus it was decided not to include them in the first selection.

With regards to the geophysical survey strategy, the APSS and BSR decided that due to the limestone geology of the region, and the potential for poor response from magnetometry over such deposits where the nature of the archaeology does not provide sufficient contrast, that an integrated method of both magnetometry and resistivity should be applied. The representation of archaeological remains in the results of

a

b

2. Geophysical survey methods used: a) magnetometry being carried out at Els Antígons using a Geoscan Research FM36 fluxgate gradiometer, b) resistivity survey being conducted at Centcelles using a Geoscan Research RM15 Resistance Meter



3. Magnetometer survey results from Molins Nous

magnetometry over such deposits can be poor but works well with fired remains such as kilns and furnaces. Therefore resistivity was used also as a more reliable techniuque for locating masonry walls and structures. As a result the team undertook at each site an intensive magnetic and resistivity survey employing Geoscan fluxgate gradiometer (FM36) and Geoscan Resistance Meter (RM15) equipment (Fig. 2).

Once the results were downloaded onto a computer, they were processed and analysed with the Geoplot 3.0 software following a standard procedure. Resistivity data were despiked to remove any single high anomalies across each composite. The grids within each composite were then edge-matched to remove any differences in the background of the data. High and low pass filters were then used to filter out low and high frequency readings respectively. Finally the data were interpolated in both the X and Y directions. The magnetometer data were manipulated to remove any distorting iron 'spikes' from the survey results. A zero mean traverse function was then applied to remove the effect of drift caused by changes in the Earth's magnetic field. A low pass filter was then used to filter out any high frequency anomalies. The data were also interpolated along the north-south axis of each composite, providing a 0,5 m resolution to complement the 0,5 m resolution along the axis of the traverses.

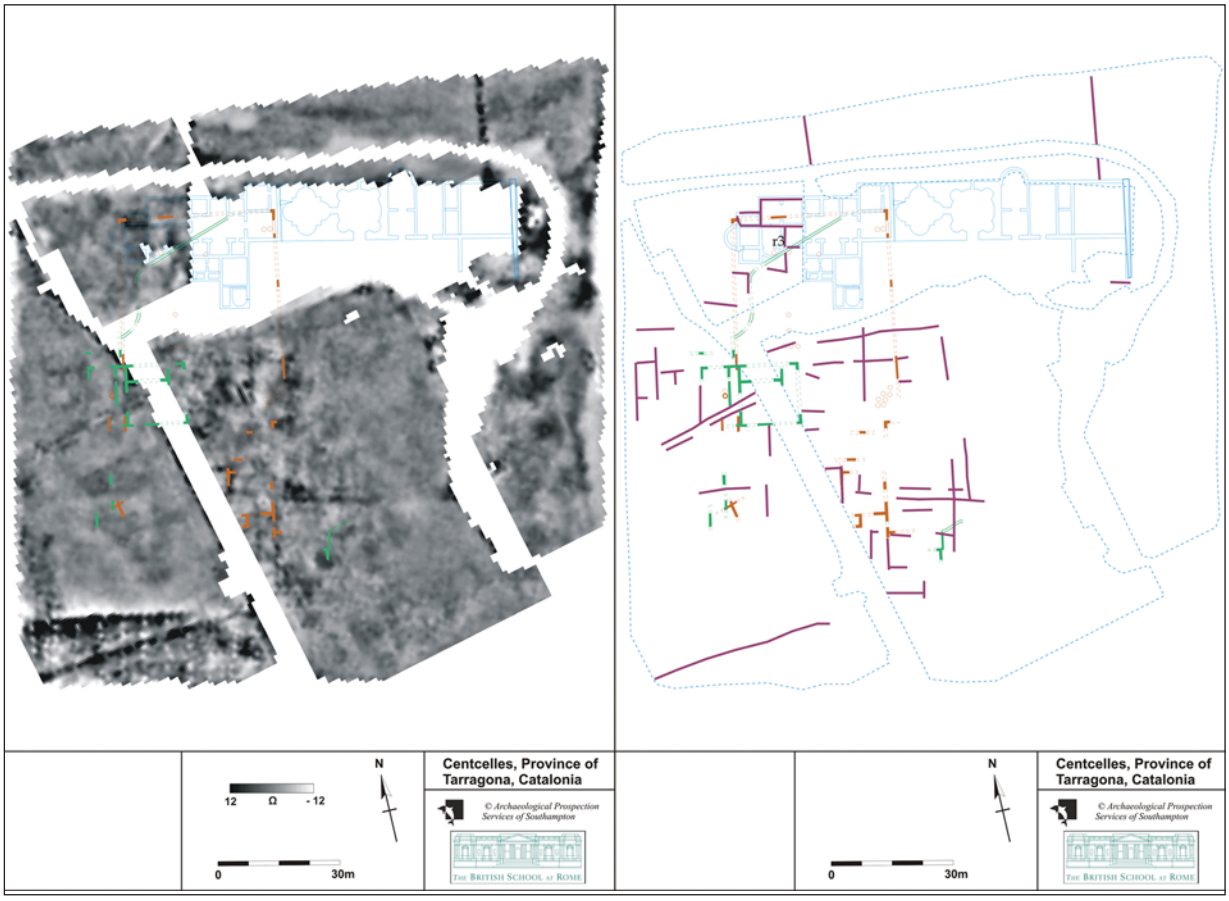
Interpretation of the geophysics surveys

The geophysical surveys were conducted by APSS and the BSR under the direction of Kristian Strutt in October 2007 for a period of two weeks (Strutt & Fry, 2007, p. 4). Bearing in mind the limestone geology of the area, and the nature of archaeological deposits at each site, both magnetometry and resi-

stivity were employed at all of the sites. It was believed that resistivity would provide the most efficient mode for assessing the shape and nature of archaeological remains of the surveyed area (Gaffney & Gater, 2003), in particular buried walls and masonry, ditches, banks and paved areas. Magnetometry was also applied to locate the remains of brick and tile structures, and also to detect the remains of fired areas and structures, particularly kilns and furnaces associated with Roman rural settlements.

a. Centcelles (Constantí)

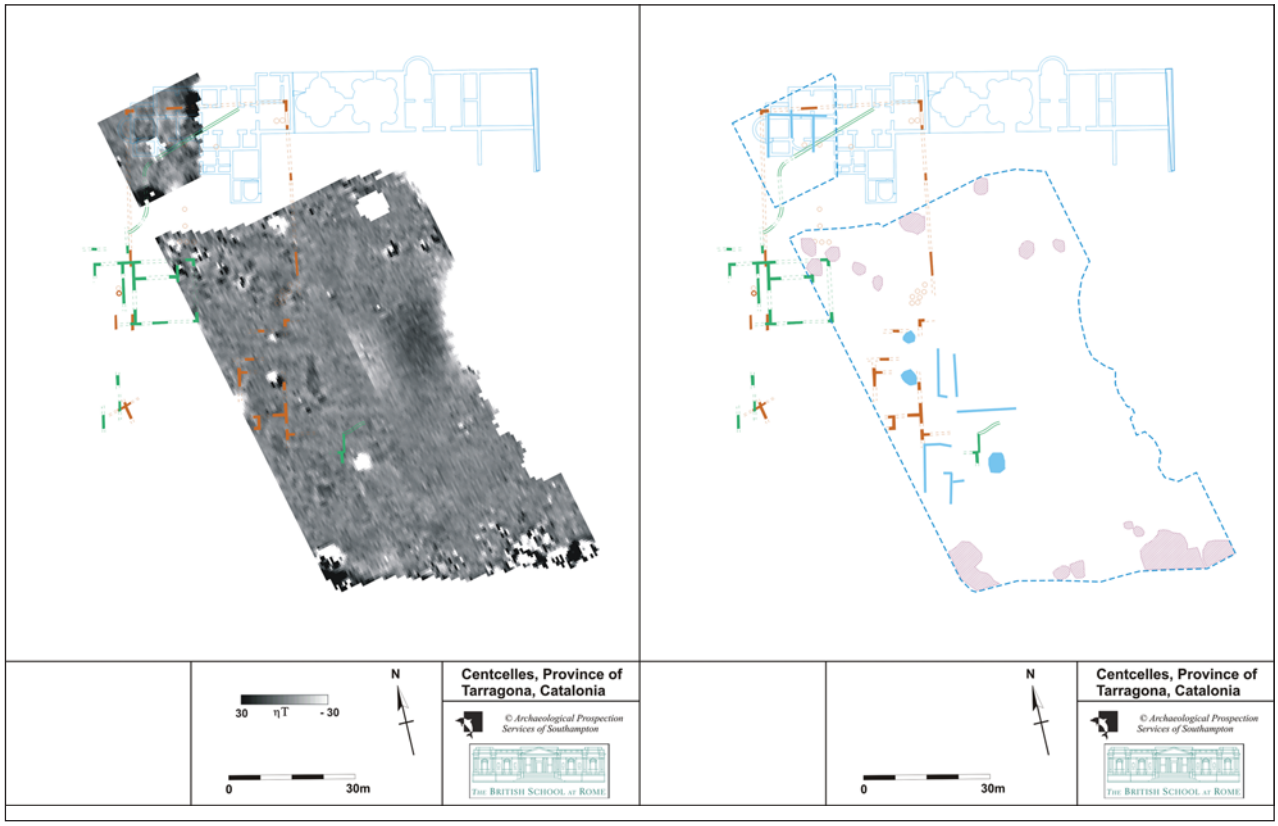
Approximately 2 hectares of resistivity survey was conducted at Centcelles, complemented by 1 hectare of magnetometry, in the area immediately to the south of the extant remains of the villa. Results of the resistivity (Fig. 4) indicate the extensive nature of the buried structural remains, some of which were already located in excavations by the Deutsches Archäologisches Institut (DAI) (Hauschild, 1965; Id., 2002; Hauschild & Arbeiter, 1993;). Several linear features were also visible close to the area of the 1960s excavations giving a more complete idea of the plan of the villa in this area.



4. Centcelles: resistivity results and interpretation

Results of the resistivity were complemented with the magnetometer survey (Fig. 5), which were less conclusive than the resistivity results. Negative rectilinear anomalies documented the location of earlier excavations, while large dipolar maculae indicate a disturbed area in the crossroad of two modern tracks.

The interpretation of these geophysical anomalies deserves a more thorough study together with the reports of the early excavations of the DAI. Apart from the evident coincidences with structures of the IIIrd century villa, there are also potential walls that may identify earlier constructions. According to the German researchers, most structures of the roman villa were built in the second half of the IInd century in a place which was previously occupied by agricultural structures.



5. Centcelles: magnetometry results and interpretation

b. Els Antígons (Reus)

The survey at Els Antígons was not particularly successful in locating any of the remains of this villa. There was a rescue excavation in the 70s carried out by Massó & Capdevilla (1976-1977), which recognised an industrial area with the presence of a series of amphora workshops as well as a residential part with a nympheum with a group of Dionysian and Cybeles sculptures dating to the II-IIIrd c. AD (Capdevila & Massó, 1976-1977).

Results obtained from the resistivity (Fig. 6) reveal a number of features associated with modern disturbances. For instance, there is a large anomaly measuring 20 x 30 metres that probably corresponds to rubble infillings for the construction of the nearby industrial unit. Besides, there are a few high resistance anomalies that may identify villa structures, but they do not provide a clear shape. There is also a line of high resistance continuing to the west that identifies a modern pipeline.

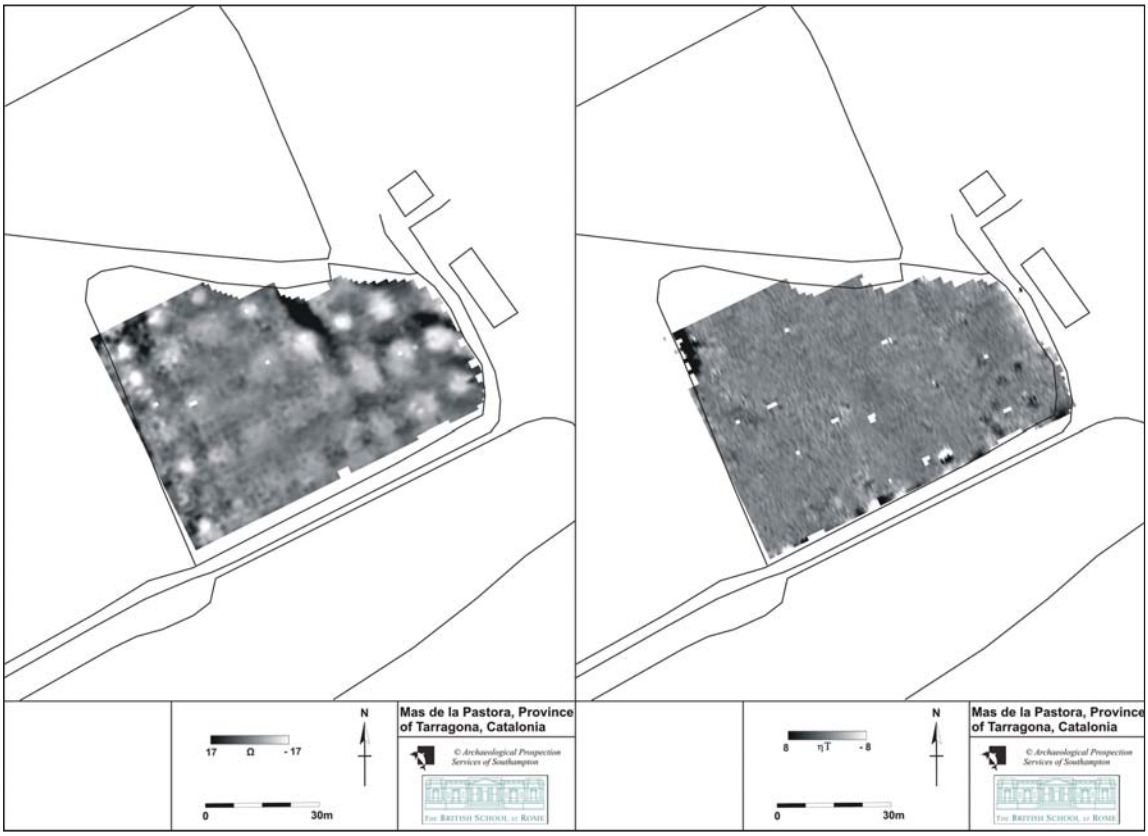
Magnetometry results also confirm the presence of modern disturbance, clearly evident with regards to the pipeline parallel to the modern track and dipolar anomalies representing ferrous material. It is believed that under the modern rubble remained well-preserved archaeological layers. Therefore, if the disturbing layers of rubble could be removed a new geophysical survey with more potential results could be undertaken.

c. Mas de la Pastora

The survey of Mas de la Pastora covered an area of 0,6 hectares and also provided disappointing results (Fig. 7). In this case, the surveyed area was in an olive grove so the olive roots and the infilling where the trees had been planted generated disturbances mainly in the resistivity. A series of regular low resistance maculae following parallel lines identified those olive trees in the resistivity survey.

Only the magnetometry survey presented some anomalies on the north-west corner of the survey area that may identify potential archaeological features continuing in the next field. It is difficult to interpret such features, although they do resemble pits following a circular pattern.

6. Els Antígons: resistivity (left) and magnetometry (right) results



7. Mas de la Pastora: resistivity (left) and magnetometry (right) results

d. Mas de Gomandí (Riudoms)

This is another site where geophysical results were not as good as expected (Fig. 8) despite the fact that the survival of great number of pottery sherds on surface. In fact, the site is identified as a possible amphora workshop due to the high number of amphora sherds recorded, some of which fired rubble and by a kiln cut by the railway construction. Nevertheless, the site was disrupted when a nearby railway was built in the midle of the XIXth century. Therefore, archaeological deposits may have been removed at this stage. The geophysical results appear to confirm that material had been redeposited to the north of the line of the railway.

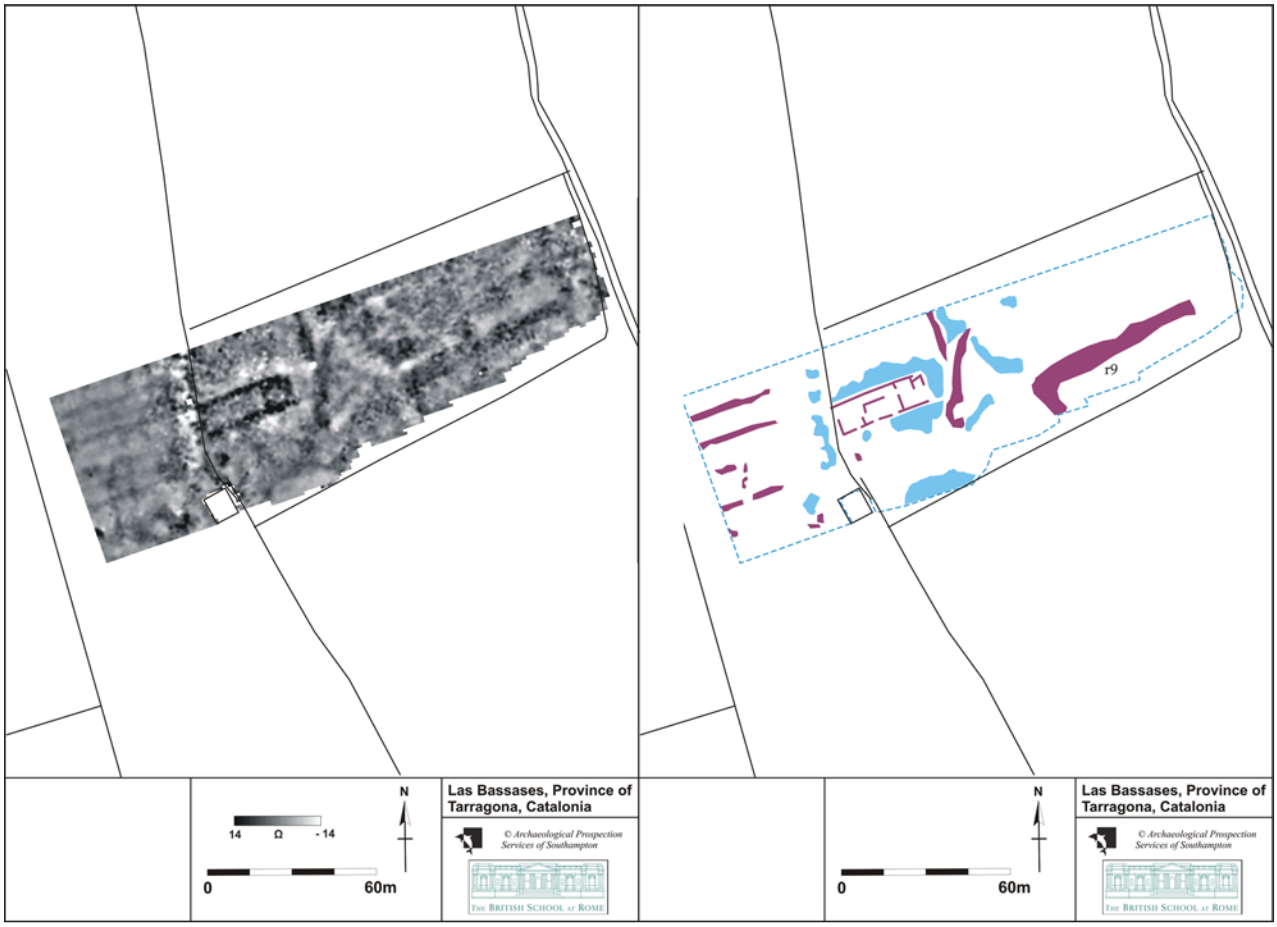
Resistivity survey suggested little evidence of archaeological structures. Some high resistance lines cutting across the terrace towards the railway (SE) and other parallels lines seem to be related to the railway construction. High resistance lines in the upper terrace (N) identify lines of carob trees. The same anomalies are also recorded in the magnetometry results. In this case, lines of carob trees (N) and cutting lines in the SE are less evident than in the resistivity survey. There is also some disturbance of ferrous material on surface that probably comes from the railway construction.

8. Mas de Gomandi: resistivity (left) and magnetometry (right) results

e. Les Bassasses (Cambrils)

This site provided numerous sherds from the surface of a cultivated field, with a possible kiln being located in the field immediately to the west, although no architectural remains were visible on the surface. On the contrary, the geophysical survey registered quite remarkable results that identified a building more than 40 metres long and 12 metres wide. In addition a possible ceramic kiln was identified from the results of the magnetometry.

The resistivity survey results (Fig. 9) give a clear layout for the building, in which a series of rooms may be detected. There are also high resistance parallel anomalies running east to west showing the lines



9. Les Bassasses: resistivity results and interpretation

of olive trees to the west. Further to the east there is a broad line of low resistance that may represent a bank or area of rubble.

Magnetometry showed fewer features than resistivity (Fig. 10). The main building detected in the resistivity appears only as a few spurious rectilinear anomalies. The combination of results from both techniques, however, reveals clearly all of the structural elements from the site. This includes a significant dipolar anomaly in the SE corner identify a possible ceramic kiln, also confirmed by pottery and kiln debris found in the nearby.

Preliminary Conclusions

Our experience of using geophysics (resistivity and magnetometry) to identify typologies of rural settlements in the *ager tarraconensis* project (PAT) has provided a mixture of results. On the one hand, two sites (Centcelles and Les Bassasses) generated excellent results which helped us to identify more structures than expected and assess the potential of the archaeological remains unearthed.

The other three sites produced less clear results due to alterations of the area in modern times, because of agriculture and railway construction. According to the geophysical survey results, no architectural remains can be expected from sites though it also provides useful information about the presence or absence of material. There is always a risk in using geophysics in such small sites because there are less possibilities of finding anomalies than on large surveys such as Roman towns like *Portus* (Keay *et alii*, 2005). The constraints placed on such surveys within the small land divisions and abrupt changes in topography and ground elevation are a limiting factor that is, to a certain extent, countered by the inte-

10. Les Bassasses: magnetometry results and interpretation

gration of survey techniques to provide as much comparative data from a particular area as possible (Millett *et alii*, 2000, section 6.3; Strutt, Gutierrez & Reyes, forthcoming). The strategy of combining two geophysical methods – resistivity and magnetometry – in the *ager tarraconensis* has been rewarding at most of the sites, since they either complement one another by providing evidence of different archaeological remains or confirm the same general nature and extent of buried materials.

It is apparent from the results here and from surveys elsewhere in Catalonia that the limestone background geology means that resistivity is best suited to obtain contrast between soils and archaeological remains, in particular the walls and structural elements from the Iberian and Roman periods. The overall success of the methodology means that we plan to continue surveying other rural sites in the a*ger tarraconensis* in order to increase the volume of data to define suitable rural typologies. So far our data from surveys and excavations is not enough for this purpose. On the basis of the survey results from the 2007 geophysical surveys, we also intend to conduct a targeted excavation at Les Bassasses, allowing a comparison of the excavation results with the geophysical survey results, and allowing a ground truthing of the geophysical results to be carried out.

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