THE INVESTIGATION OF ROMAN URBANISM IN ITALY THROUGH ARCHAEOLOGICAL GEOPHYSICAL PROSPECTION

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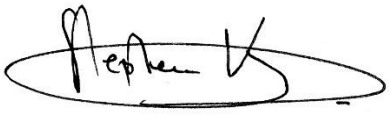
Critical Appraisal

Submitted in partial fulfilment of the requirements

for the degree of PhD by Publication

December 2024

I, Stephen John Kay, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.



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19/12/2024

Abstract

The research presented in this portfolio - in the form of nine of my nominated publications from over the past 10 years and an accompanying critical appraisal - presents a long-term programme of study I have undertaken into forms of Roman urbanism. The selected articles also show the development of a methodological approach that demonstrates my significant contributions to understanding Roman towns and their networks. My research draws principally on non-invasive techniques, in particular archaeological geophysical prospection, as these methods permit a detailed and non-invasive form of assessment of the sub-surface archaeological record. As demonstrated by the nominated publications, a range of different site types were investigated, including both major and minor settlements, principally in central Italy but also at other major sites throughout the peninsula and Sicily. This aimed to identify the different influences that drove the development of a settlement as well as the role it performed within a territory. The appraisal draws upon the candidate's publications on a range of other settlement forms, including *vici*, villas and rural sanctuaries, thereby placing this research programme in a wider context and generating a greater understanding of the various elements that contributed to the process of urbanism.

Through the selected publications and drawing upon a large body of archaeological research undertaken by the candidate over several decades, the appraisal also discusses the development of a research methodology designed to support the non-intrusive investigation of the ancient built environment within contemporary contexts. Combining different geophysical techniques with other investigative approaches, such as environmental coring and 3D building survey, can lead to a greater understanding of deep and complex stratigraphy. The nominated publications and appraisal demonstrate how this can be supported by detailed archival research and the inclusion of legacy data into a multilayered workflow.

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Nominated publications

#1. Kay, S. 2013a. Geophysical survey of the city of Gabii, Italy. In P. Johnson and M. Millett (eds.) *Archaeological survey and the city*. University of Cambridge Museum of Classical Archaeology Monograph no.2, Oxbow, Oxford: 283-302.

#2. **Kay, S.**, Hay, S. and Smith, C.J. 2023. From sanctuary to settlement. Mapping the development of Lucus Feroniae through geophysical prospection. In A. Launaro (ed.) *Roman urbanism in Italy: recent discoveries and new directions*. Oxbow, Oxford: 121-137.

#3. **Kay, S.**, Pomar, E. and Morelli, G. 2023. Rome Transformed: a multiple method geophysical approach for the urban investigations of the East Caelian. In I. Haynes, T. Ravasi, **S. Kay**, S. Piro and P. Liverani (eds.) *Non-Intrusive methodologies for large area urban research*. Archaeopress, Oxford: 56-51.

#4. **Kay, S.**, Pocobelli, G. F. and Pomar, E. 2023. Indagini aerotopografiche e prospezioni geofisiche per la conoscenza dell'area urbana di Vulci. In G. Ceraudo, G. Scardozzi, V. Ferrari (eds.) *Archeologia Aerea XVII*. Claudio Grenzi Editore, Foggia: 45-58.

#5. **Kay, S.**, Pomar, E. and Hay, S. 2020. Spina revisited: the 2008 geophysical prospection in the light of the excavation results. *Groma: Documenting Archaeology 5*. Archaeopress, Oxford: 1-16.

#6. Haynes, I., Liverani, P., Ravasi, T. and **Kay, S.** 2023. The changing face of the eastern Caelian in the 1st -2nd centuries AD: work by the Rome Transformed Project. In A. Launaro (ed.) *Roman urbanism in Italy: recent discoveries and new directions*. Oxbow, Oxford: 22-43.

#7. **Kay, S.**, Trümper, M., Heinzelmann, M. and Pomar, E. 2020b. Geophysical survey at Morgantina. *Archäologischer Anzeiger* 2020/1: 68-91.

#8. Trümper, M., **Kay, S.**, Pomar, E., Fino, A., Lappi, T. and Santospagnuolo, P. 2022. New research at the gymnasium of Agrigento. *Archäologischer Anzeiger* 2022/1: 130-167.

#9. **Kay, S.**, Pomar, E., Castignani, V. and Cooper, D. 2023. High resolution spatial documentation of Renaissance church interiors through multiple non-invasive survey technique, *Groma: Documenting Archaeology* 8, Archaeopress, Oxford: 101-109.

Introduction

The selection of geophysical surveys and accompanying publications presented in this critical appraisal illustrate the significant contribution that my published work has made to our understanding of different settlement forms and more broadly to the study of Roman urbanism. It focusses on central Italy but includes comparative examples across the peninsula and its islands to support and contextualise the discussion. The principal approach developed over a sustained period of research has been the systematic application of multiple forms of geophysical prospection with the aim of better defining the factors behind settlement forms and what can be learnt about urban development processes. This includes diverse manifestations of urbanism, from large towns through to minor settlements and administrative centres, as well as other focal points for populations, such as *vici*, villas and sanctuaries. Alongside this, a methodology has been developed to support the study, that has carefully combined multiple non-invasive techniques, therefore allowing a deeper, multilayered approach to identifying and investigating some of the influences that affected the structure of a settlement.

The research activity has therefore involved the systematic exploration of a selection of key sites that are discussed in the nominated publications. I led extensive surveys at the site of Gabii (**#1**),[1] where a quasi-orthogonal grid was discovered, which opened questions regarding the potential Hellenistic origins of the town's layout and encouraged comparative surveys at the major settlements of Morgantina (**#7)** and Agrigento (**#8**) in Sicily. The survey at Gabii also revealed the influence of topography on settlement form, as the layout was made to fit the physical geography of the site. A novel component of my body of work was to focus on earlier centres, including Lucus Feroniae (**#2)** and Vulci (**#4**), in order to assess the effect that preexisting settlements may have had on later (Roman) urban development. All this in turn draws on comparative work I have undertaken at other centres such as Spina (**#5**). Many of my earlier publications, cited here in the references, demonstrate the progressive and coherent development of my geophysical methodology where new contexts were examined that presented different challenges, as well as the diverse settlement typologies I have investigated.[2] Building upon this examination of a broad range of sites, as well as the experience that was gained, has led to the application of geophysical prospection to study sites that are now buried

[1] Publications nominated for the PhD by Publication are highlighted in bold, with a number cross-referencing to the list on p. 6.

[2] The selected publications for the PhD by Publication are drawn solely from my research over the past 10 years, as defined by the terms of the degree programme. However, my research on this topic predates this period and therefore earlier publications are also cited throughout the critical appraisal narrative and bibliography.

beneath in modern built environments, illustrated through current research undertaken in Rome (**#3** and **#6**). Finally, methodological developments have been made in the integration of geophysical data with non-invasive technologies, such as laser scanning, illustrated by work within ecclesiastical buildings (**#9**) to further the ability to access complex deposits.

The arrangement of this appraisal demonstrates the structured methodological process that has been followed by my research, beginning with its initial aims and the wider context of research into Roman urbanism through geophysical prospection. Drawing upon the results of these initial surveys, my research has involved a broad study of forms of urbanism and settlement, the key findings of which are presented through my chosen publications. These studies in turn provided the foundations for new investigations at many of these sites, illustrating the impact of my research. The appraisal concludes by showing how the experience and results of these surveys have created the platform for a rigorous methodological approach to the analysis of complex urban settings.

Context of the research

The application of geophysical prospection in Mediterranean landscape archaeology emerged after its adoption as a survey method in Northern European archaeology in the late 20th century. Initial applications in Italy were within programmes led by research foundations such as the Fondazione Lerici which conducted surveys at the Etruscan centres of Cerveteri, Tarquinia and Vulci. The Consiglio Nazionale delle Ricerche was also an earlier practitioner in the application of Ground-Penetrating Radar (GPR) in archaeological contexts, including at Veii, however many of these investigations either focused upon a major site or an individual monument. Several small surveys were undertaken by foreign research projects, for example by the Biferno Valley Survey (Barker 1995) and subsequent San Vincenzo Survey (Bowes, Francis and Hodges 2006), but these invariably covered a discreet area and were used to target specific features.

The aim of my preliminary research undertaken in Italy, through the Cecina Valley Project, was to test the effectiveness of geophysics (in particular magnetometry) as a tool to support the classification of sites from fieldwalking data (Kay 2003). Up to that point, sites were traditionally identified using aerial photography and fieldwalking, however this approach is limited by visibility, through factors such as weather, crop growth and surface coverage (i.e. ploughed or fallow fields, grassland, etc). By including geophysical prospection in the

workflow, surveys could be undertaken that allowed an understanding of the sub-surface, beyond the concentrations of surface material. Sites identified through fieldwalking were targeted with magnetometry and given the rapidity of the technique, numerous identified concentrations of material could be investigated. The approach was successful in providing a complimentary methodology, collecting a different dataset to fieldwalking, and was particularly effective where surface material revealed little about the potential character of a site, such as non-elite settlements. The classification of sites through fieldwalking remains complex due to the many variables, in particular how types of surface material may be used to identify a settlement type.[3] Through the addition of geophysical prospection, alongside aerial photography and fieldwalking, a further interpretive method is offered to better understand the character of a site. More recently, the increasing integration of UAV systems (incorporating cameras with multispectral and thermal imaging) allows sites to be re-visited multiple times, further helping to mitigate issues of visibility.[4] The Roman Peasant Project (Bowes 2020), which focused on an area in southern Tuscany close to the Cecina Valley, followed a similar methodology to my early research, whereby eight sites that had been identified through prior field walking were subject to geophysical prospection.[5] The project, which also focused on lower status settlements, has been able to extend this methodology by also undertaking excavation with the aim of collecting more precise information about the lives and diet of the rural poor.

The application of geophysical prospection as an aid to site identification and classification provided the foundation from which I further developed my research. Through my involvement in the Roman Towns Project (RTP),[6] part of the British School at Rome's Tiber Valley Project (TVP), I was able to gain experience in the implementation of largescale geophysical prospection, subsequently developed in my own research projects. This in turn led to innovations in my research methodology, including the integration of multiple techniques through which to investigate more complex urban sites.

The largescale geophysical surveys at Falerii Novi and Otricoli conducted by the RTP led to a reconsideration of the methodological approach to the study of towns and determination

[3] See for instance the site classification for the Tiber Valley Project (Witcher 2020, 42, Table 2.7).
[4] For example, the Tappino Area Archaeological Project (Stek 2018).
[5] I re-surveyed the site of Marzuolo on behalf of the subsequent Marzuolo Archaeological Project.
[6] As BSR staff member under the umbrella of the TVP, I participated in the RTP and undertook data collection at the sites of Falerii Novi (1998) and Portus (1999 – 2003). Over the same period, as part of the TVP, I also surveyed at the site of Forum Novum (1999).

of their role in the landscape. The data raised questions about their formation as well as earlier settlement dynamics, and illustrated their close relationship with topography. Prior to this, approaches to the study of Roman towns had drawn heavily on the two best known excavated towns, Pompeii and Ostia Antica, as well as Rome itself, due to their exceptional preservation (Keay et al. 2004). Focus was given to the excavation of major public monuments, such as theatres, baths and *fora*, however it became clear that this left a gap in our knowledge regarding many aspects of a town, including internal organisation, economy and culture. Through the application of geophysical prospection, it was illustrated that studies could be undertaken of entire, unexcavated towns, permitting a more rigorous investigation of these highly complex environments.

Geophysical prospection at Falerii Novi led by the RTP was fundamental in illustrating how this approach can provide new information about the internal organisation of a town at a site-wide scale (Keay et al. 2000). The magnetometry survey investigated the full extent of the 31ha intramural space and recorded in unprecedented detail the orthogonal grid plan of an entire town in central Italy (Fig. 1). Ancient sources suggest that the city was founded as a new settlement in 241 BC, with the Byzantine chronicler Zonaras (8.18) adding much later that forced migration of the defeated inhabitants of Falerii Veteres was designed to place them in a less defensible location. Whilst there remains considerable debate around the initial layout of the city and the date of the construction of the city walls,[7] the survey showed dense occupation within the city, with the addition in the Augustan period of further public buildings, such as a theatre and amphitheatre.

The magnetometry survey (1997 – 1998) was conducted at the highest sampling resolution viable at the time, with a sample interval of 0.5m and data collected in parallel traverses at a spacing of 1m.[8] Whilst by current standards this is considered a coarse resolution, the exceptional results paved the way for future research at the site and helped establish geophysical prospection as an essential tool in the investigation of Roman towns. More recently, our understanding of the city was refined through a subsequent GPR survey that allowed the clear identification of public monuments as well as private housing (Verdonck et al. 2020; Millett et al. 2024). These surveys have provided the platform for the Falerii Novi Project, which I co-direct, where our new excavations are able to target individual buildings to explore key questions regarding the role and functioning of the city within the wider territory

[7] See Millett (2007) and Wallace-Hadrill (2013) for further discussion.
[8] The survey used Geoscan FM 36 fluxgate gradiometers.

(Andrews et al. 2023). Whereas previously fieldwork and research on Roman towns focussed on the principal public buildings and spaces, such as the forum, temples and theatre, the project has instead focused on aspects of commerce and daily life through the excavation of structures including a macellum, *tabernae* and a domus (Andrews et al. 2024).

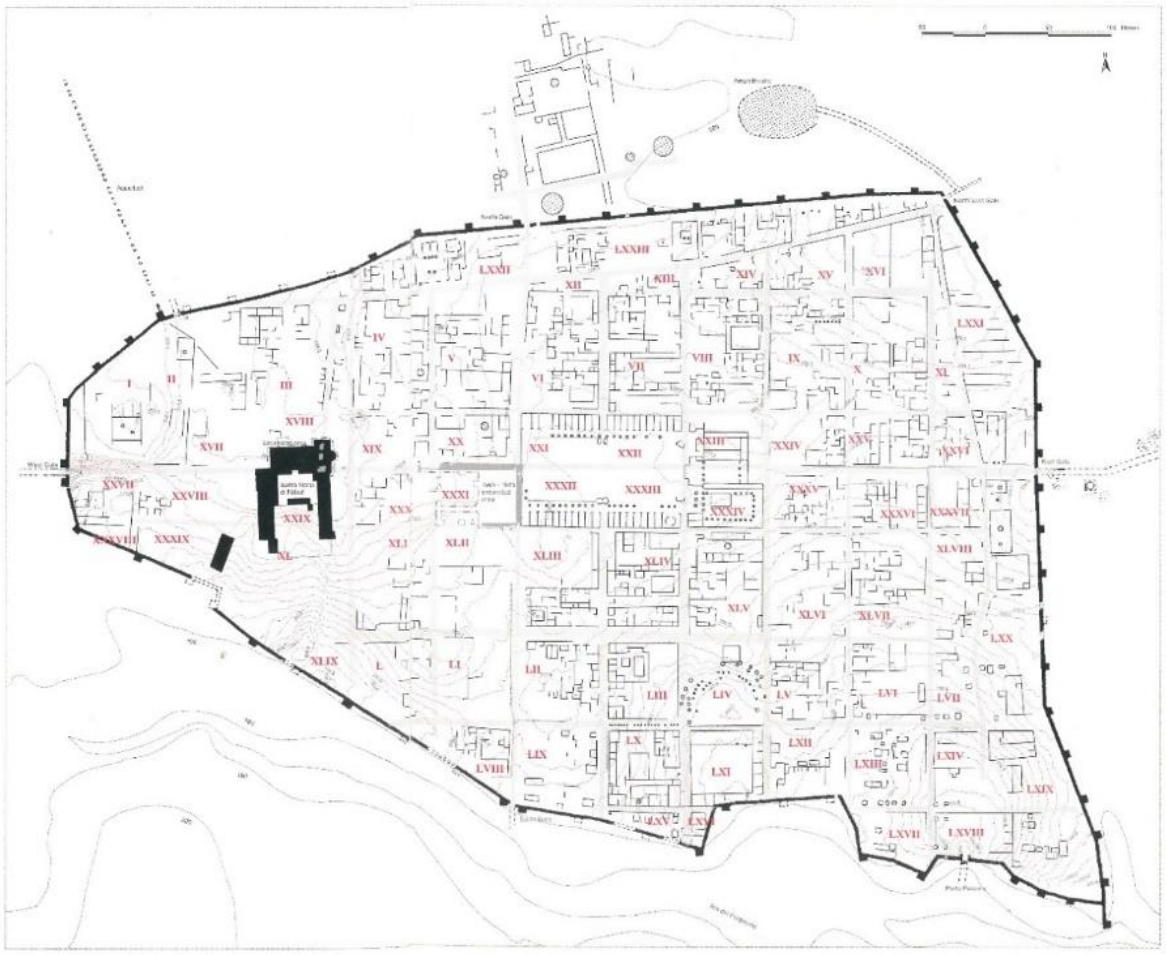

Figure 1. Interpretation of the magnetometry survey at Falerii Novi showing the recorded plan of the city (after Keay et al. 2000: fig. 7).

As the excavations have progressed, various strengths and limitations of geophysical prospection have been brought into focus. The extensive plan of the city revealed by geophysical prospection is in part a result of the long occupation, shown by our excavations to continue without interruption though until at least the 7th century AD. The GPR survey has been found to principally record structures built from *opus caementicium* or brick, which the excavations have shown belong to the late antique phases, whereas the structures of the Republican city were mostly built from tuff blocks in *opus quadratum*. Whilst magnetometry was more sensitive to the latter construction material, the GPR struggled to differentiate between architectural tuff blocks and the background geology and soil (largely composed of a

similar Tufo Rosso a Scorie Nere). However, it remains clear, principally through the roads and drainage systems, that the plan of the city has its origins in the first phase of occupation. Ongoing research at Falerii Novi is therefore exemplifying that the approach of applying geophysical prospection to better our understanding of ancient urban life is highly effective, constructing a more diverse pool of evidence with less reliance on the examples of Pompeii, Ostia and Rome, which themselves cannot be considered typical nor illustrative of urbanism in central Italy. For this reason, as presented below, I have aimed through my research to embed the surveys conducted by the RTP within a wider optic of comparative studies in order to improve understanding of urban development in ancient Italy.

The geophysical survey undertaken at Otricoli, 50km to the north of Rome on the left bank of the river Tiber, was encouraged by the preceding work at Falerii Novi (Hay et al. 2013). However the survey also served to illustrate the flexibility of geophysical prospection as a tool for the study of Roman settlements. The topography of the Republican town, laid out alongside the river and below the earlier Umbrian settlement on the hilltop above, appeared to encourage a much more diffused settlement layout with little recognisable urban plan. Despite being equipped with significant public monuments by the mid-1st century AD, such as an amphitheatre and theatre, then later in the 2nd century AD a monumental bath complex, the prospection was unable to identify clear urban articulation. Much of this was due to the undulating topography and close underlying bedrock, where major buildings such as the amphitheatre were cut into the tuff. By the imperial period, the town was focussed on the Porto dell'Olio towards the north due to its principal role as a port supporting the trade of goods towards Rome. The town was also established alongside the Via Flaminia which further emphasised its importance as a crucial supply node on an important route into Umbria. The magnetometer survey, which covered much of the estimated 14ha of the town also recorded few traces of private architecture, perhaps an indication that much of the population was dispersed in the surrounding countryside. Whilst its location on the river Tiber and importance to commerce were perhaps the main factors that influenced the form of the settlement, Otricoli may have also performed a role in the local administration of the territory. This form of settlement type, a focal point for the local population for administration, religion, festivities and trade, has also been recorded elsewhere in the lower Sabina and Apennines and has therefore been more widely investigated as part of my research.

The surveys at Falerii Novi and Otricoli illustrate the high level of understanding that can be achieved through the investigation of sites through geophysical prospection. Several

themes emerged from those surveys that form the core of this critical appraisal, and which bring together the publications listed in my portfolio. The surveys demonstrated the possibility of studying the internal organisation of sites, a theme which is principally explored in my publications of Gabii (**#1**) and Lucus Feroniae (**#2**). Falerii Novi and Otricoli were also seemingly founded at new locations in the Republican period. I wished to explore through geophysics the influence that earlier phases of settlement may have had on the later urban plan, which is demonstrated through my research at Vulci (**#4**) and Lucus Feroniae (**#2**). One particular aspect of internal organisation and early urban development, gridded plans, is explored through my publications on Morgantina (**#7**) and Agrigento (**#8**), where an orthogonal model was adopted for these Hellenistic cities. These surveys were also able to explore issues surrounding the density of occupation within city limits, as increasing geophysics and excavations have shown that some parts of towns were seemingly uninhabited.

The geophysical prospection conducted at Falerii Novi and Otricoli was also undertaken in ideal survey conditions, where the sites had been abandoned with no substantial later settlement, leaving structures undisturbed at a shallow depth beneath the ploughsoil. An ongoing thread in my research has been the broadening of my methodological approach through the application of complementary techniques, both geophysical and geospatial (**#9**), as well as applying techniques in less suitable conditions to assess their response, exemplified in the case of Spina (**#5**). This effort has culminated in bringing together these techniques and methodological approaches to undertake research in modern urban environments. Sites where there has been a continuous occupation until the present day have generally been less examined due to the complexities of survey in a modern environment. However, as illustrated through my research as part of the Rome Transformed project (**#3** and **#6**), through the implementation of a robust and tested methodology, significant results and understanding can be achieved in the study of Roman urbanism.

Major settlements

The geophysical prospection I conducted at Gabii, a major Latin town 20km east of Rome, was undertaken within the framework of the Gabii Project (**Kay 2013a, #1**). The results of the survey have made a significant contribution to our understanding of the planning of towns in Central Italy in the early Republican period. Whilst other contemporary sites (perhaps with the exception of Norba) have an irregular urban layout, Gabii appears to have a planned, quasi-

orthogonal layout, which has recently been dated by the project through excavation to the end of the 5th century BC (Mogetta and Johnson 2024).

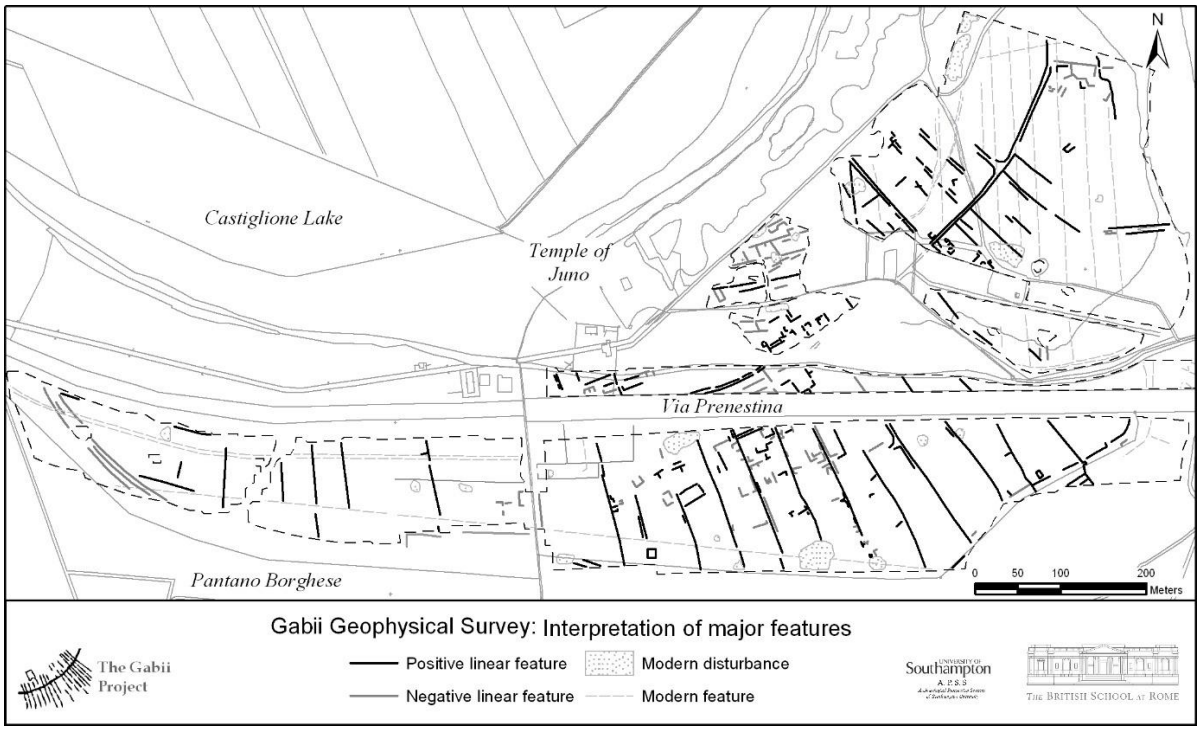

Figure 2. Schematic interpretation of the magnetometry survey at Gabii showing the recorded plan of the city (after Kay 2013: fig. 13.7, **#1**).

Geophysical results also emphasised the critical role of topography in shaping the planning of Gabii's built landscape. The site lies on the southern edge of the volcanic crater of Lake Castiglione, which was drained towards the end of the 19th century. Furthermore, the geology of the site also had a strong influence on its appearance, as it lay on a peperino tufa known as '*lapis Gabinus*'. This stone was quarried throughout the Roman period as it was considered fireproof and has been identified in the architecture of the Forum of Augustus. Therefore, the location of the site on the edge of the crater, as well as later intensive quarrying had a profound effect on the urban layout of the city.

The geophysical survey encompassed a majority of the 70ha within the walled city and recorded for the first time a series of regular parallel roads radiating out from a central trunk road that followed the topography around the edge of the crater (Fig. 2). Few minor interconnecting roads were recorded in the data, subsequently confirmed by excavation, with the major roads stretching away from the crater towards the south. This had the effect of creating open spaces within the city, suggesting that, whilst enclosed by the city wall, not all areas were populated even in later periods. This is a phenomenon that has also been observed

in geophysical data at other sites, such as Falerii Novi (Keay et al. 2000). Elsewhere, at Lucus Feroniae (**Kay et al. 2023, #2**) and Interamna Lirenas (Launaro and Millett 2023), the same pattern of open spaces has been observed in the data, where, in the absence of a city wall, the determining factor of the extent of the site appears to be local topography.

My publication of this early form of orthogonal layout at Gabii is an exception in this central area of Italy (others, such as the quasi-orthogonal layout at Aquinum, date to the Triumvirate, and Falerii Novi probably to the mid-3rd century BC) and appears to possess greater resemblance to Hellenistic sites in Southern Italy. Therefore, in order to establish a comparative dataset to use against Gabii and to better understand the nature of early urban development in Italy, I conducted geophysical prospection at Morgantina (**Kay et al. 2020b, #7**) and Agrigento (**Kay in Trümper et al. 2022, #8**) in Sicily.

The geophysical prospection at Morgantina provided an opportunity to assess the orthogonal grid plan of the city, established in the 5th century BC. Magnetometry was used to investigate much of the Classical and Hellenistic city which stretched east-west along the length of the Serra Orlando Ridge. The city was divided by two wide east-west avenues (*plateia*) and approximately 30 narrower north-south streets (*stenopoi*) and is estimated to have occupied an area of approximately 78ha. Along with mapping the grid plan, my survey also sought to understand if the city was ever densely inhabited, a recurring theme that had arisen from work at Falerii Novi and Gabii. Whilst this seemed to be suggested by the excavated quarters (around the *agora*) the more peripheral areas of the city remained unexcavated; therefore, perhaps similar to the central Italian towns, these may have remained undeveloped. Furthermore, I sought to examine influencing factors for the implementation of the grid plan at Morgantina. Unlike the gentle slope of Gabii or the relatively flat plateau on which Falerii Novi was built, Morgantina stretched over 1km across a series of steep ridges. Therefore, the grid plan had to account for the more extreme topographic nature of the site. A final aim of the survey was to assess the presence of aspects relating to the functional organisation of the city, such as public buildings or the identification of production areas. The results of this study encouraged my subsequent investigations at both Agrigento and Lucus Feroniae.

Results from the survey at Morgantina were examined alongside the schematic grid plan that had previously been proposed (Fig. 3) based upon excavations conducted at various points in the city (Kay et al. 2020b, fig. 1, **#7**). The geophysical prospection confirmed that the plan was rigidly imposed, with few deviations from the regular pattern of north-south *stenopoi*

at a distance of 38.64m. Despite a number of steep ridges and a small hill on the southern edge, there were few variations in the regular pattern. Less clear in the magnetic data were the narrow dividing streets (*ambitus*), however excavation has shown that the subdivision of lots was regularly exceeded with minimal space between buildings. Finally, it remains unclear from the survey whether there were undeveloped areas within the city, however all those investigated so far recorded traces of housing and habitation. The overall impression therefore is that the orthogonal plan of the 5th century BC was rigidly imposed, regardless of topographical factors, with the *agora* forming the focal point of the city.

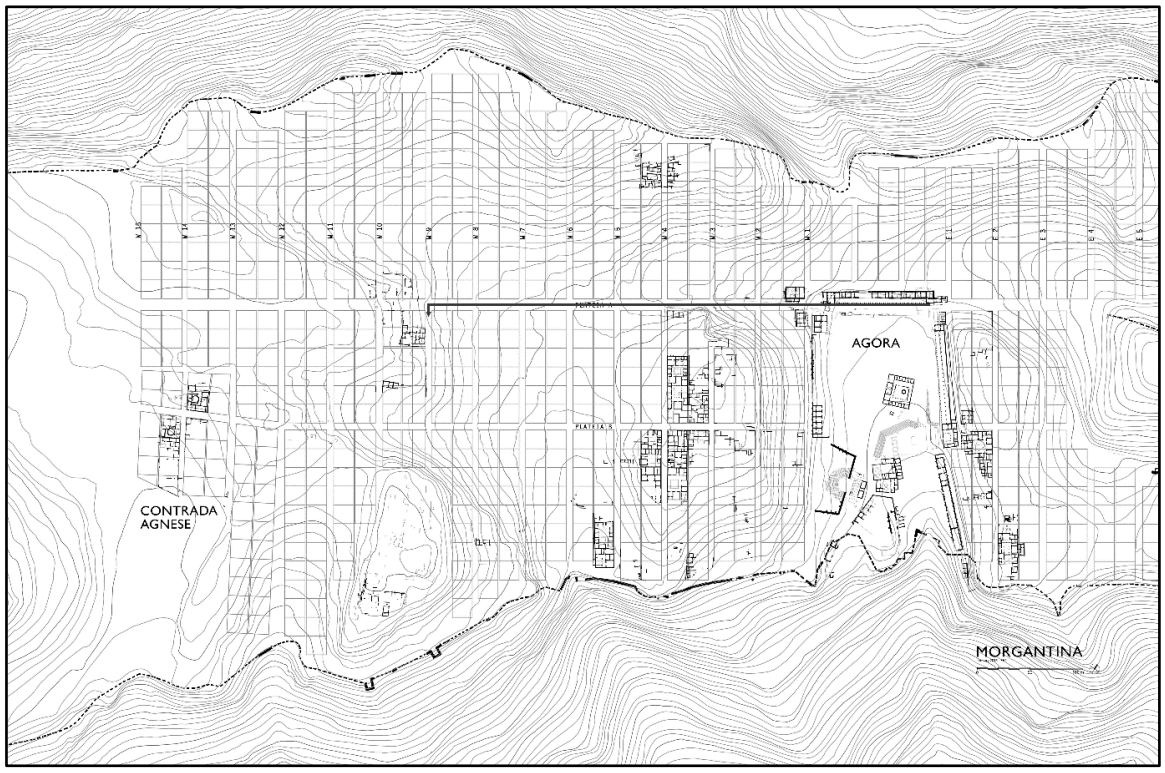

Figure 3. Plan of the central sector of Morgantina (after Kay et al. 2020: fig. 2, #**7**).

In order to further examine the layout of gridded cities, survey was undertaken at Agrigento, another large Hellenistic city. Founded in the early 6th century BC, the orthogonal grid plan of Agrigento has also been dated to the early 5th century BC. The geophysical prospection I undertook focused on the western area of the city and the position of the gymnasium within its overall plan. Despite being placed between two *stenopoi*, it appears otherwise isolated in published plans (Trümper et al. 2022, 132, Fig. 1, **#8**), and therefore the survey aimed to place the complex within its broader urban context. A further aspect of the survey was to attempt to locate the gymnasium's *palaestra*, an essential feature of the complex.

The results of this survey confirmed a general impression that has been gained from recent fieldwalking at the site: the gridded city, estimated as covering 450ha between the sanctuaries on the southern ridge and the acropolis to the north, was never densely inhabited (**Kay in Trümper et al. 2022, #8**). The gymnasium, which was probably of the 2nd century BC, was however built over an earlier *stenopoi*. Therefore, whilst a gridded system had been implemented, it was probable that the individual plots were never fully developed. A further impact of the geophysical survey was that it successfully located the *palaestra*, which has subsequently been confirmed by excavation targeting the GPR anomalies (Trümper et al. 2023). This discovery is of remarkable importance to our understanding of these structures, key public buildings within the city, as few gymnasia with *palaestra* (and none with a racetrack) have been identified in the western Mediterranean. Therefore, as well as making a significant contribution to our understanding of early planned cities in Italy, my work also had a significant impact across other areas of research.

The surveys at Gabii, Morgantina and Agrigento have made a substantial contribution to our understanding of early urbanism, and in particular the adoption of a gridded plan. Through an examination of the sites at a macrolevel wider patterns emerge, such as their relationship with the topography and the positioning of major throughfares and public architecture. Alongside this, the high level of data resolution also permits detailed study at a microlevel, such as the investigation of individual building complexes, as in the case of Agrigento. This study of the influencing factors on the layout of a town was explored through my geophysical prospection at the site of Lucus Feroniae in the Tiber Valley (**Kay, Hay and Smith 2023, #2**). One of the few larger early imperial settlements in the Tiber Valley (alongside Falerii Novi and Veii), Lucus Feroniae had been hypothesised as diverging from the canonical model of Augustan colonies in Italy due to an existing sanctuary of Feronia (Witcher 2020). However, despite excavations following its discovery in 1953, prior research prioritised the sanctuary and outlying villas. No previous study had attempted to examine the extent and form of the overall settlement.

Extensive geophysical prospection, conducted with both magnetometry and GPR, revealed a town much smaller than the 25ha previously hypothesised (Keay 2010). The survey showed that, rather than forming around the road junction of the Via Capenate and Via Tiberina, the town instead extended to the south of the sanctuary alongside the Via Tiberina (Fig. 4). To the north, the magnetometry revealed agricultural traces, perhaps a sacred woodland associated

with the sanctuary, which continued to be respected beyond the 2nd century BC when the city experienced a substantial transformation funded by Cnaeus Egnatius.

Figure 4. Combined schematic interpretation of the magnetometry and GPR surveys at Lucus Feroniae showing the recorded plan of the city (after Kay, Hay and Smith 2023: fig. 8.3, **#2**).

The amphitheatre of the Trajanic – Hadrianic period and a Late Antique bath complex are testimony of the investment in public urban infrastructure, and are located close to the forum, demonstrating both the size of the city and how space around the centre remained relatively open. The GPR survey to the south, facing the Via Tiberina, potentially recorded a few private dwellings with open areas to the rear of the properties. Lucus Feroniae was never

enclosed by a wall circuit and the provision of space, perhaps for agricultural practice close to the centre, is similar to patterns noted in the geophysics both at Gabii as well as Falerii Novi.

Late Republican Lucus Feroniae therefore seems to correspond to a settlement type that has been increasingly recorded within the Tiber Valley and Central Italy. The town appears to have taken on the role of administrative centre with public buildings grouped around the forum serving the needs of a more dispersed population in the immediate hinterland. It also acted as a religious centre for festivities as well as markets, with little private architecture. While the size of the settlement around the early sanctuary remains unclear, it is apparent that the later settlement incorporated the sanctuary into the town, in a manner that continued to respect the place of worship. My survey at Lucus Feroniae has therefore demonstrated that, far from conforming to an imposed canonical Roman or Hellenistic model, these poli-focal centres were lived spaces that adapted to the social, cultural, political, and economic requirements of the population.

In concluding this discussion of my research on major settlements, a comparison can be made with the methodological approach that has been followed to investigate the town of Interamna Lirenas in southern Lazio, founded in 312 BC (Launaro and Millett 2023). In a similar manner to Falerii Novi, Otricoli and Lucus Ferioniae, extensive surveys were undertaken with both magnetometry and GPR. The survey revealed in detail the plan of the city on a northwest-southeast axis with regular side roads leading off from a central throughfare, the Via Latina, in a manner not dissimilar to Gabii. It is suggested that the town grew in wealth in the early imperial period as a central marketplace for the region, documented also by epigraphic evidence, as well as being on a major route of transhumance, similar to patterns seen at Amiternum (Heinzelmann, Jordan and Murer 2010) and Iuvanum (Kay, Bispham and Pomar, forthcoming). Differing from the approach that has been taken by our continuation of work at Falerii Novi, at Interamna Lirenas the excavations, guided by the geophysics, have focussed on major monuments in the town, including the theatre and basilica. This method of focusing on well documented building types, whilst illustrating its monumentality, perhaps overlooks some questions regarding the internal organisation of the town and its relationship with the surrounding landscape. These limitations are mitigated however, through the high-resolution geophysical surveys that have been able to place these monuments within the broader townscape.

My research into larger settlements has also extended into their suburbs. The geophysical surveys undertaken have mapped the full internal layout of towns, drawing attention away from the main public monuments within a town. Yet the majority of productive activities are usually on the edge of the city, as well as some public buildings such as amphitheatres, which were built in more liminal areas for practical reasons as well as for motives of social and civic control. The type of structures recorded in these areas of the city (for example pottery workshops and forges) are generally ideal for mapping through geophysical prospection due to the use of kilns and hearths that are strong, distinctive anomalies in magnetometry due to their high magnetic fields. My research in the suburban area of Pompeii, outside the Porta Nola gate, aimed at documenting the necropolis as well as the activities that took place outside the city gate (Kay et al. 2020a). Similarly to the Porta Sarno and Porta Nocera, the space to conduct these investigations was limited due to the encroachment of the modern city and its infrastructure. However, the geophysical prospection and subsequent targeted excavations revealed a peripheral area that underwent significant change shortly after AD 62, with structures such as the funerary garden attached to the tomb of *Aesquilla Polla* being used for the disposal of building rubble. Geophysical prospection was fundamental to mapping the area outside the gate, and illustrates considerable potential for this technique to broaden our understanding of crucial zones that lie between city and countryside. Already the geophysical survey I have conducted at Gabii (**#1**) as well as those at Interamna Lirenas and Falerii Novi have revealed open spaces on the edge of the city and this remains a central theme in my ongoing research.

Minor settlements

In mapping the various forms of Roman urbanism, I also investigated a series of minor settlements with geophysical prospection. One of the first sites surveyed was Forum Novum, as part of the Tiber Valley Project, where I participated in the survey and excavation (1999-2004). On the left bank of the river Tiber in the lower Sabina, the foundation of the settlement has been dated to the late Republican period which was marked by the construction of a forum and temples (Gaffney, Patterson and Roberts 2004). The town was enlarged in the early imperial period with a basilica and amphitheatre, however the extensive geophysics recorded only infrastructure associated with public buildings, with the exception of a villa and funerary precinct a short distance to the north. The small size of the settlement (c. 4ha) and lack of

private buildings testify to the administrative role that the town appears to have performed, serving a scattered rural population. The location of Forum Novum on a transhumance route is also of importance. It has been hypothesised that, close to the basilica, was a *forum pecuarium* (dated to the Augustan period) financed by a wealthy patron of the town, P. Fainius Plebius (Coarelli 2005). That a livestock market should take such a prominent position alongside temples and the basilica is significant, demonstrating the key role of the settlement.

In order to explore this form of minor settlement and its relationship with its territory, my research extended beyond the Tiber Valley to examine several sites in the lower Apennines. As a comparison to my work, I was able to draw upon earlier non-invasive work undertaken at the site of Amiternum, where similar results to those noted at Forum Novum in the late Republican period were recorded (Heinzelmann, Jordan and Murer 2010). Amiternum was equipped with a sizable amphitheatre as well as a theatre, probably thanks to the beneficence of an upper class, who found wealth through trade in livestock along the transhumance route of the Aterno valley. The magnetometry revealed few private dwellings, and those identified centred around the theatre. Other buildings opened on to the Via Caecilia in a similar fashion to those recorded at Lucus Feroniae. It was concluded that the town most likely also performed an administrative role, in particular a market for livestock, as well as a place for festivals for the local population.

Building from the results at Amiternum, I undertook a survey at Iuvanum (Abruzzo), where a similar settlement pattern was recorded (Kay, Bispham and Pomar, forthcoming). The town appears to have been founded in the 3rd century BC and by the time of the Social War was a *municipium*. Excavations have revealed a paved forum, enclosed by a portico with a basilica at the northern end, that lies at the foot of an acropolis upon which was a small sanctuary, dated to the 2nd century BC. Cut into the hillside on its eastern flank is a theatre of a similar date. The magnetometry survey encompassed the area around the forum and the surrounding suburbs, revealing a settlement that was centred along the principal throughfare, the Via Orientalis (Fig. 5). The structures recorded by the geophysics appear to be a series of *tabernae*, with a probable *domus* a short distance to the east, but little other private architecture. Again, in this upland area, the transhumance of livestock undoubtedly played an important part in the role of the city with Iuvanum acting as a central marketplace. The geophysics that I have conducted at Iuvanum and Lucus Feroniae (**#2**), when coupled with research at other sites such as Forum Novum and Amiternum, has developed a new understanding of this settlement type, opening up new avenues of potential research for future work to build upon. This growing body of

evidence, driven by extensive geophysical surveys which allow an understanding of the towns and their suburbs, have shown the crucial role that these towns performed in the management of the territory. These small centres took an urban form, with monumental characteristic public architecture, yet were designed to fulfil a specific role in the territory rather than become the central place of settlement.

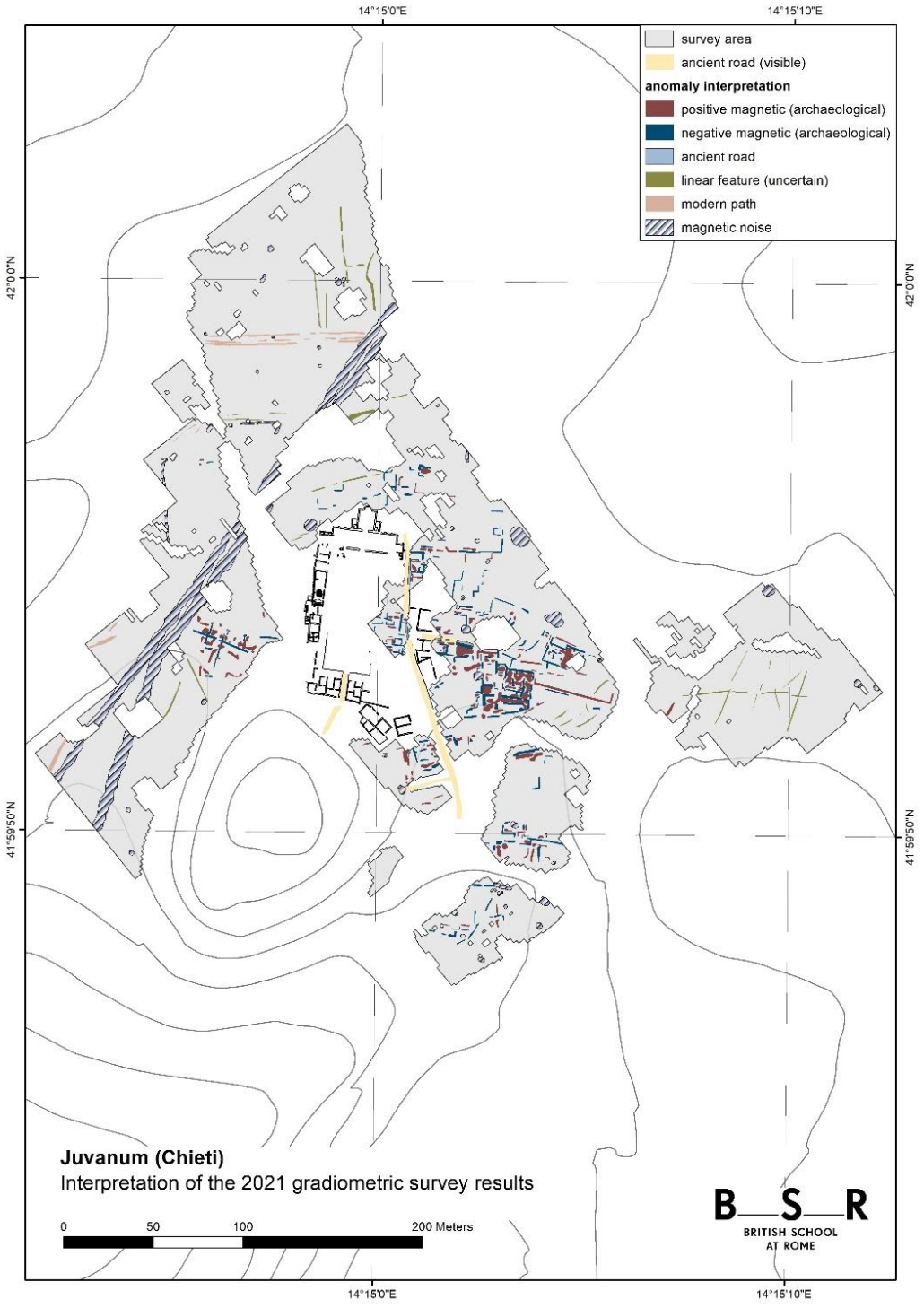

Figure 5. Interpretation of the magnetometry survey at Iuvanum showing the recorded plan of the city.

Etruscan settlements

The surveys described above illustrate the variation in size, form and function of towns, in particular how they adapted both to the needs of the local population as well as the specific topography of the site. However, it is clear that other factors also influenced the development of different forms of urbanism. The initial largescale geophysical surveys undertaken as part of the Tiber Valley Project focused upon substantial Roman settlements (Falerii Novi, Otricoli), and subsequently other minor centres and road stations (e.g. Capena (Keay, Millett and Strutt 2006) and Baccanae (Johnson, Keay and Millett 2004)). Whilst these surveys provided a preliminary understanding of how the Roman urban plan adapted to various pressures and influences (e.g. topography), the possible impact of an earlier settlement on the configuration of later cities or towns remained unclear. It is acknowledged that the ability to understand or interpret the phasing of a site from geophysical data remains complex, in particular with magnetometry which provides a palimpsest dataset where potential differences in depth are unclear. Whilst this is improved through the application of GPR and Electrical Resistivity Tomography (ERT), the complex stratigraphy of sites with lengthy or continued occupation renders the identification of different phases difficult. However, the trajectory of my research has been to investigate these earlier phases so as to begin to build an understanding of their influence upon a site's later layout. To approach this question, I investigated two major Etruscan centres in central Italy that were extensively occupied in the Roman period, Vulci and Tarquinia.[9]

It was useful in commencing this work to assess research already undertaken at Veii, where a long-term programme of non-invasive survey had explored 170ha of the site (Campana 2019). Building upon a detailed study of historical aerial photographs, their magnetometry survey pursued a similar aim of establishing whether the technique could assist in better understanding the urban layout of the site. The survey recorded two principal arterial routes, crossing the site in the main cardinal directions and which follow its topography. These roads were augmented by a series of smaller internal streets that connected the main throughfares. When magnetometry results were analysed alongside the fieldwalking data,[10] it was found that the areas with dense occupation in the magnetic data corresponded to areas with little Roman

[9] I have also conducted geophysical prospection at the Etruscan sites of Acquarossa (2017), Crustumerium (2015) and San Giovanale (2015) within the broader research strategy of the British School at Rome. Survey was also conducted at the site of Montetosto (Kay in Belelli Marchesini et al. 2019) in support of the research of Sapienza University of Rome.

[10] The fieldwalking data draws upon the Tiber Valley Project restudy of Veii (Cascino, Di Giuseppe and Patterson 2012).

material. The conclusion, therefore, was that these dense areas of habitation belonged to the main archaic phase, the period of greatest development of the city. Furthermore, it was noted that the main Roman buildings (theatre, forum, baths) did not appear to conform to a regular pattern, but instead fit into the preceding Etruscan road system. The results from this survey at Veii offer a window into understanding the urban settlement pattern of an Etruscan city, although arguably Veii was an exception rather than a rule due to its political importance and vicinity to Rome. Furthermore, following its defeat in 396 BC, the Roman occupation of the city was rather limited and never to the extent of the Archaic city. In summarising the results of the survey at Veii, where the importance of the pre-existing road network was established by the geophysical survey, it is relevant in the context of this appraisal to note that a parallel for this interpretation is drawn from my earlier published survey at Gabii (Campana 2019, 31), thereby further demonstrating the impact and legacy of my research.

The survey at Veii showed how largescale geophysical prospection at a site with long term occupation could be successful in mapping elements related to earlier phases of a city. Similarly to Veii, the Etruscan city of Vulci was occupied in the Roman period, although this appeared to be a much denser habitation, as indicated by prior small-scale geophysical survey.[11] The geophysical prospection I undertook at Vulci, as part of the Understanding Urban Identities project (UUI), concentrated on the eastern section of the plateau above a preserved length of the city wall, dated towards the end of the 4th century BC (Kay in Sabatini et al. 2021). A transect was identified for the geophysical prospection that began in the centre, stretching to a more peripheral area that was potentially less disturbed by this later occupation, but which still lay within the city walls. The approach also allowed for an assessment of any potential decrease in construction leading away from the centre.

A preliminary survey was undertaken with both magnetometry and GPR in order to test the responsiveness of each technique, as a previous study in the lower area of Ponte Rotto had recorded differing results for each of the two techniques (Lockyear, Riva and Shlasko 2018). An area of approximately 0.6ha was surveyed with both instruments, with a better response recorded in the GPR dataset (Fig. 6, bottom). The magnetometry was heavily disturbed by the underlying geology, which masked many of the weaker magnetic features.[12] In contrast, the GPR recorded strong responses to the buried features, and provided a richer understanding of

[11] For example, the preliminary work of the Vulci 3000 project (McCusker and Forte 2017).
[12] Subsequent to my survey a full magnetometry survey was undertaken where the effects of the geological background are also apparent (Pasieka et al. 2023).

the study area. The methodological practice of combining techniques, applied in several of the surveys previously discussed (Lucus Feroniae, **#2** and Agrigento, **#8**), has the advantage of providing comparative datasets, as each draws on different physical properties of the subsurface. Theoretically, magnetometry is less suitable for the mapping of structures built of stone (such as limestone) due to the lack of a magnetic field. However, my extensive experience has shown these structures may regularly be recorded, appearing as negative readings against a stronger magnetic background value. Therefore, whilst such a dual approach may have other limiting factors (e.g. cost, time), in cases where a multi-methodological approach can be undertaken, a much greater understanding is often achieved of the subsurface.[13]

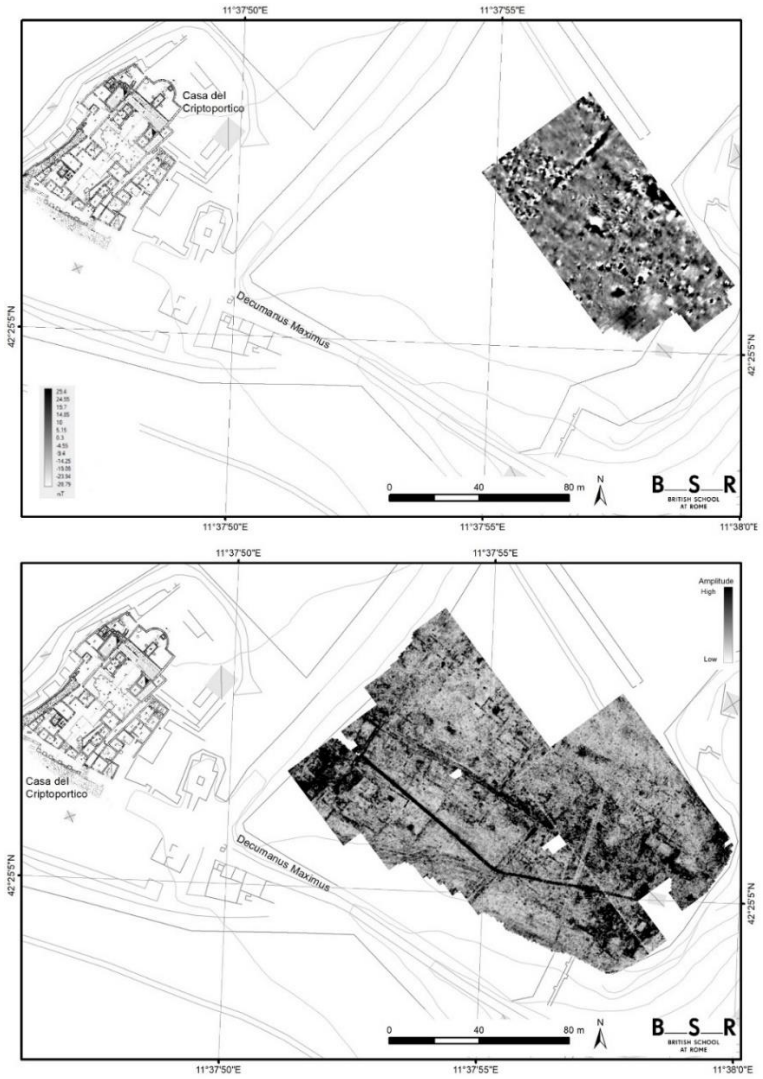

Figure 6. Results of the magnetometry survey (top) and a composite of the GPR depth slices (bottom) at Vulci (after Kay, Pocobelli and Pomar 2023: fig. 12, **#4**).

[13] The advantages of a multiple geophysical approach which has characterised much of my research is discussed in further detail below.

The results of the complete GPR survey, covering approximately 2ha, indicated a dense occupation to the northeast of the intersection of the *decumanus* and *cardo maximus*, which, given their orientation and layout, would seem to date to the Roman phase (Kay et al. 2021a). Similarly, the GPR data provided a clearer indication of a quasi-orthogonal grid, as had been hypothesised through the interpretation of historical aerial photographs, along with a less dense area of settlement towards the eastern edge of the plateau (**Kay, Pocobelli and Pomar 2023, #4**). The subsequent seasons of excavation conducted by the UUI project, based upon the geophysics data, concentrated on a small complex of structures, confirming the earlier dating of the area and recording a non-monumental Etruscan ritual space. It is apparent that this area was respected and incorporated into the town plan, revealing how allowances were made for preexisting urban architecture. The contribution of the geophysics at Vulci demonstrates its ability to assist in our understanding of the later reorganisation of urban space.

I conducted a further geophysical survey at Tarquinia, 20km to the south of Vulci, which provided additional opportunities to examine the urban layout of a major Etruscan centre and the influence that this may have had on the later city. Tarquinia was previously the subject of an extensive magnetometer survey by the Fondazione Lerici which began in the 1960s and over a 20-year period covered an area of more than 60ha. However, the lack of associated topographical recording rendered the correct geographical positioning of the datasets complex. Therefore, a different methodological approach was taken in order to maximise the potential of this legacy data. Three sample areas, each measuring 60m by 90m, were selected at the eastern, central and western points of the plateau. The areas were surveyed using the same technique (magnetometry) as the Fondazione Lerici surveys, and the recorded magnetic anomalies were matched between the datasets, therefore allowing the correct positioning of the overall legacy dataset (Kay in Bagnasco Gianni et al. 2018). This approach was highly successful, and, along with a LiDAR survey and detailed topographical modelling, allowed the dataset to be re-examined, revealing how the layout and roads of the city were adapted to the topographical contours of the plateau. Therefore, through a multi-methodological approach, combining new survey data with legacy data as well as precise topographical recording, further information could be extracted from the dataset.

Like Tarquinia, geophysical prospection undertaken at the Etruscan site of Spina also presented a different methodological challenge. Rather than an orthogonal grid organised by roads, the town was instead laid out with a system of narrow waterways and built upon a series of artificial islands. The town fell into decline and was abandoned by the 3rd century BC,

therefore it offered an opportunity to assess its composition without the imposition of a later Roman settlement to obscure the archaeological record, as was the case at Veii and Vulci (**#4**). Furthermore, it provided the opportunity to test the effectiveness of magnetometry on a different form of construction technique, as the surveys discussed above used the method to investigate sites constructed from stone or fired materials.

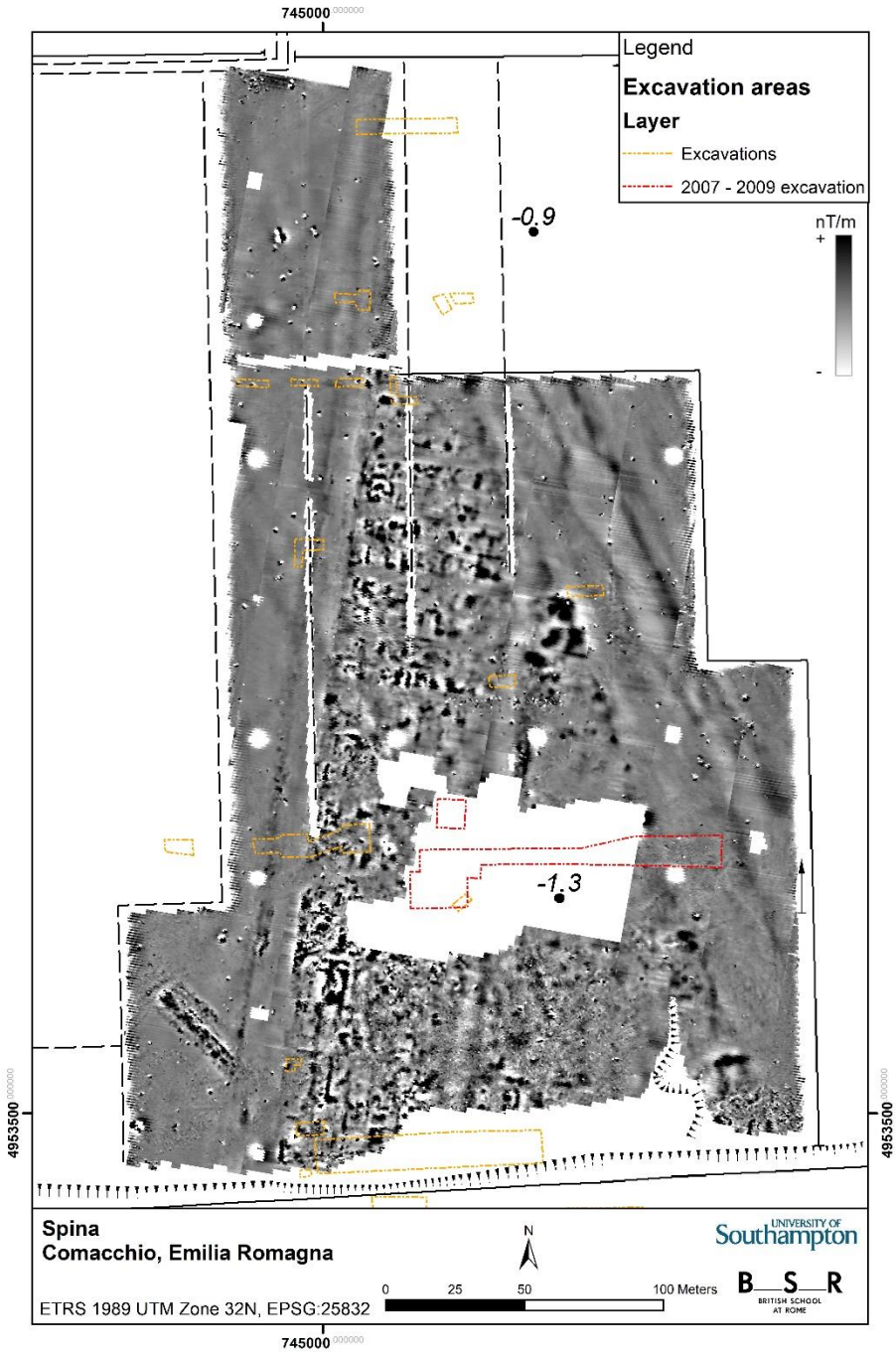

Figure 7. Results of the magnetometry survey of the central area at Spina revealing the regular settlement layout (after Kay, Pomar and Hay 2020: fig. 6, **#5**).

The survey at Spina, which covered an area of over 10ha, recorded the full extent of the site and revealed how the artificial islands of the town were divided by one main channel with smaller channels defining individual '*insulae*' (**Kay, Pomar and Hay 2020, # 5**). The channels were recorded as a network of negative features, whilst the positive values indicated areas of habitation on the regular islands (Fig. 7). Excavation has subsequently revealed that whilst the channels were created with two rows of vertical wooden posts and horizontal planks, behind this space were inserted sizable fragments of ceramic vases and amphorae, fired material that may have helped the magnetometry define the edges of the waterways. The houses of the second phase, dated to the 4th century BC, have been shown through subsequent excavation to have used terracotta tiles laid horizontally and vertically as a form of humidity barrier for the overlying wooden construction beams. The roofs were made of reeds and hay, the floor of unfired pressed clay and sand, and the threshold of stones and cobbles. It seems likely that the positive readings of the geophysical survey were these wall foundations as well as small hearths. Therefore, whilst not seemingly a site suitable for magnetometry, the survey was successful in mapping this unusual form of urban construction.

The site of Spina was a unique challenge for a magnetometer survey of an urban centre as the results were dependent on factors other than the primary construction technique. However, data revealed its similarities with other Etruscan sites in Etruria Padana such as Marzabotto and Forcello, in terms of the presence of a regular urban grid. Interestingly, the geophysics from Spina do not appear to have recorded areas of public space, in contrast to, for example, Marzabotto where the main temple neatly fitted into the orthogonal plan.

Also of significance in this discussion of urban form is Spina's role as a commercial hub at the mouth of the river Po. The quality and quantities of Greek amphorae discovered during excavations led to the interpretation that Spina functioned as a city in its own right, not as the auxiliary port of a larger inland city (e.g. at Pyrgi and Caere, or Regisvilla and Vulci). Indeed, the fact that Spina was one of the few Etruscan cities to have a treasury at the sanctuary of Apollo at Delphi indicates the close connection the city had with the Hellenic world. The orthogonally organised layout of the city, albeit using water channels rather than roads, perhaps also emphasises this close relationship. The publication of the survey at Spina can be placed in a group together with those of Gabii (**#1**), Morgantina (**#7**) and Agrigento (**#8**) where I also investigated this regular form of settlement pattern.

Other settlement forms

The appraisal so far has demonstrated how my publications have contributed through geophysics to the understanding of large and small urban centres, as well as those with a preceding Etruscan settlement. However, in understanding the wider influence of Roman urbanism it is useful to also look at the other forms of settlement that could replace or supplement urban centres. The following section presents geophysical surveys that have been conducted at a range of smaller settlements, including *vici*, villas and sanctuaries. The aim was to survey a cross-section of settlement types that has not only assisted in understanding the individual sites but also their role within the wider territory and therefore their relationship with the main urban centres. Building upon the results that have been achieved by my geophysical prospection, several of the sites have since been the focus of broader investigations involving other forms of field survey and excavation.

Vici

The survey I undertook at Iuvanum, as well as those at Forum Novum and Amiternum, helped to demonstrate the role, particularly from the late Republican period, that small administrative (minor) centres performed, especially in more remote parts of the countryside. Alongside this settlement form should also be considered the role of the rural *vicus*. The term may perhaps best be understood as equating to a village, or a group of houses, which may also have had an official administrative role. Therefore, in order to investigate this settlement form, I have recently commenced research using largescale geophysical survey at the site of Furfo in the hinterland of Peltuinum.[14] Its location has been identified through a toponym, noted in CIL IX, 3513 (*the Lex Aedis Furfensis*) and in the name of the Church of Santa Maria di Farfona. Limited previous research at the site consisted of fieldwalking as well as an unpublished excavation. The rural *vicus* of Furfo appeared to have an administrative role and is recorded as having its own magistrates (the *aediles* of the *Lex Aedis Furfensis*), emphasising the importance of this settlement type within the territory. My survey utilised extensive magnetometry, accompanied by both fieldwalking and LiDAR survey, which revealed a dispersed settlement organisation with small nuclei of structures extending over an area of approximately 12ha (Kay in Cifarelli et al. 2024a). The combined results suggest that the settlement was occupied throughout the Roman period and preliminary results from the fieldwalking and a first season of excavation also indicate an earlier Vestini occupation (Kay in Cifarelli et al. 2024b). It is

[14] A preliminary season of geophysics was conducted by the author at Peltuinum in 2012, the results of which appear to indicate a regular orthogonal grid (presented at the 10th International Conference on Archaeological Prospection, Vienna, 2013).

therefore interesting in light of the discussion above that this form of settlement did not develop into an organised planned settlement but appears to have maintained a more dispersed form.

A definition of the term *vicus* is provided by Festus (502, 508 L.) writing in the 4th century AD: 'Vicus can be intended in three ways: firstly to define those types of buildings to which those who did not own villas returned after working in the fields, such as the Marsi and the Peligni…'. [15] This would indicate an alternative form of settlement to the minor centres discussed above or villas (discussed below). An example of the type of settlement described here by Festus may come from the *vicus* of *Falacrinae* at the 80th mile on the Via Salaria, where I conducted geophysical prospection, the results of which subsequently formed the framework for a targeted excavation programme (Coarelli, Kay and Patterson 2008). Recorded by Suetonius as the birthplace of Vespasian, little information, beyond the sporadic find of a small statue base, gave any indication of the location of the settlement. An extensive magnetometry survey was undertaken targeting areas indicated by earlier fieldwalking (Kay 2009). In the area of Pontone di Vezzano (Cittareale), the survey recorded a small cluster of features, which subsequent excavation revealed as a series of modest buildings with storage areas. The unsystematic layout and simple construction style, together with an unrecognisable urban plan, would therefore seem to fit the interpretation of a rural *vicus*. Whilst differing in extent to Furfo, an unstructured layout seems to characterise this form of settlement, of which few have been recorded or excavated. My geophysical prospection has therefore made a significant contribution to our understanding of this little understood settlement form.

The results of the surveys conducted at Furfo and *Falacrinae* displayed some similarities in terms of revealing an unstructured layout and encouraged the enlargement and strengthening of this comparative dataset. Therefore, an investigation was conducted at another site in the Sabina, 30km to the south towards Rome. Terme di Cotilia differed from the previously examined sites due to the monumental scale of the excavated structures, which have variously been interpreted as a bath complex, a villa belonging to the Emperor Vespasian, a sanctuary to Vacuna, or potentially a *vicus* in the hinterland of *Reate*, alongside the Via Salaria.

The site is dominated by a central pool (*natatio*) measuring 60m by 20m and is laid out over several terraces, at the base of which passed the Via Salaria. Structures surrounding the *natatio* on three sides were excavated over a number of years and have been dated to the end

[15] Festus 502, 508 L. Translation: W. M. Lindsay (1913) *Festus De Verborum Significatu cum Pauli Epitome (Bibliotheca Scriptorum Graecorum et Romanorum Teubneriana).* Leipzig, Teuber.

of the 2nd to early 1st century BC. The geophysical survey I undertook applied both magnetometry and GPR, and aimed to better contextualise the excavated structures by placing them in their wider topographical context (Kay et al. 2021b). [16] The surveys revealed for the first time a dense area of occupation along the northern edge of the Via Salaria, which itself was traced east-west in front of the complex (Fig. 8). The results indicated that the settlement spread further to the west, perhaps joining with other standing structures that had previously recorded by Persichetti at the end of the 19th century (Persichetti 1893).

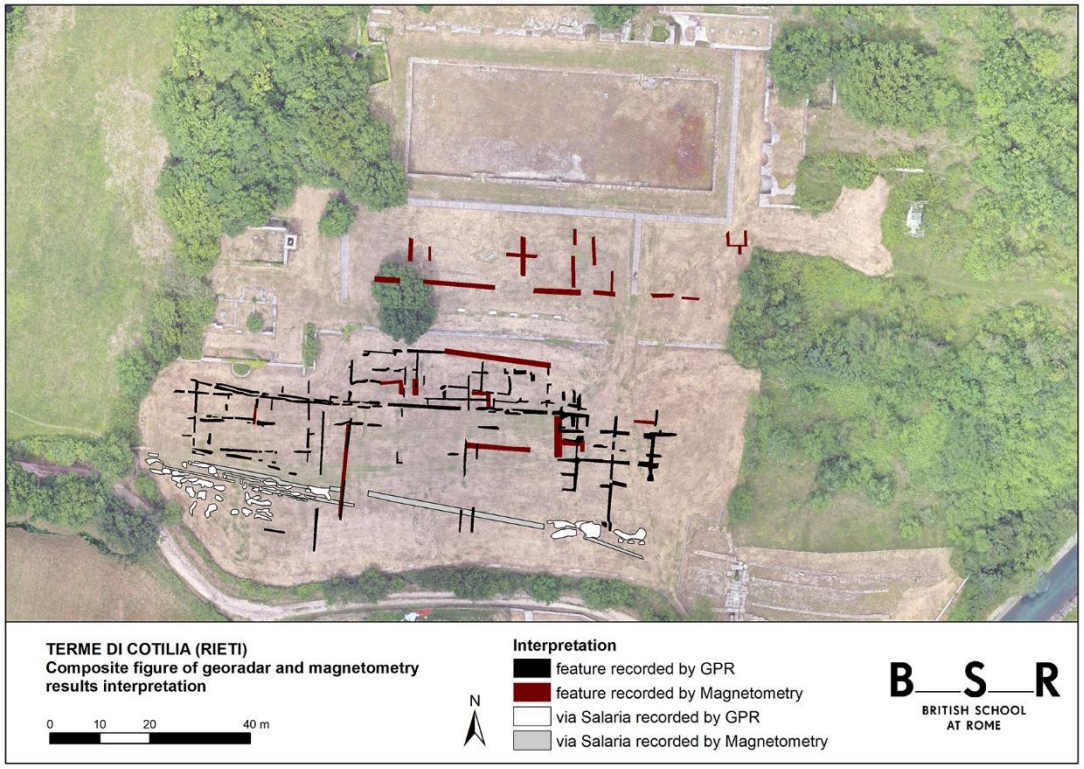

Figure 8. Interpretation of the magnetometry and GPR survey at Terme di Cotilia (after Kay et al. 2021: fig. 2).

It is useful to reflect here upon the role water had at the site of Terme di Cotilia and its function. Access to water was fundamental to all sites, whether through aqueducts, cisterns, rivers, wells or springs. It performed a critical role in the formation of an urban settlement and in the daily life of the inhabitants. In investigating Roman urbanism, whilst attention can be drawn to other major monuments such as walls and places of worship, the supply of water was a key part of the success of any urban centre. Geophysical prospection has performed a crucial role in helping to understand aspects relating to water supply, through the mapping of

[16] I first presented the results of the survey at the 2021 Near Surface Geophysics Group (NSGG) conference *Recent Advances in archaeological geophysics*, 'Vespasian's baths? Geophysical prospection at the site of Terme di Cotilia, Lazio (Italy)' and subsequently published in the International Society for Archaeological Prospection (ISAP) Newsletter 61, 1-4.

aqueducts, cisterns and water channels. In the work summarised in this critical appraisal, the supply of water has always been a central consideration, in the belief that it will lead to a better comprehension of the different forms of urbanism.

In the case of Terme di Cotilia, the properties of the '*aquae cutiliae'* were noted by Strabo (*Geography* 3, V) who describes them as being both good for drinking and suitable for the treatment of illnesses. Indeed, Suetonius (*De vita Caesarum*, Vespasian, 24) writes that it was the nearby waters of Lake Cutilia that led to the death of Vespasian. The area continued to be frequented throughout antiquity (appearing in the Tabula Peutingeriana) and by the 12th century a church, Santa Maria in Cesonis, had been built at the site, not dissimilar to the situation at Furfo and the construction of Church of Santa Maria di Farfona. Indeed, both sites were located on major transport arteries through the countryside: Cotilia along the Via Salaria and Furfo on the Via Claudia Nova. Whilst it remains unclear whether the site of Terme di Cotilia can also be considered a *vicus*, it illustrates that even within this classification of this form of urbanism there remain various possible permutations.

The geophysical surveys at these *vici* have provided a unique contribution to the understanding of this form of settlement as very few (and previously none in the Sabina prior to my research) have ever been surveyed or investigated. The contribution has therefore provided considerable insight into this underrepresented settlement typology, crucial to the functioning of the Roman landscape. The approach that has been followed by my research has therefore, where possible, built upon the results of the geophysical prospection to develop and to pursue a more detailed research programme, often undertaking targeted excavation of specific contexts to provide better evidence about activities and the role of the site in the wider urban landscape. In the following discussion, examples are presented from the villa sites of Matrice, San Lorenzo and the sanctuary of Monte Rinaldo where it is possible to compare the results of the geophysics with subsequent excavations.

Villas

As a projection of the town in the countryside, villas performed a key function in the ecosystem of the territory, both in terms of agriculture as well as local administration (*villa publica*) and they had a considerable impact on commerce through consumption, production and trade. Villas were therefore an important part in the overall pattern of the Roman influence, often becoming central places within the countryside. In this short section are presented the results of geophysical prospection at two sites where I have worked, which demonstrate the

importance of the positioning of villas in the territory, the impact that they had on production and how they were crucial nodes within the landscape, acting to join urban centres. The examination of this settlement form illustrates the robust approach that has been taken in this research, which has incorporated all forms of settlement that have implications for our understanding of Roman urbanism.

The rural villa at the site of Matrice (Campobasso, Molise) was chosen for investigation as previous research had indicated the central role it had fulfilled within an otherwise remote territory. The villa lay a few kilometres to the south of the *municipium* of Fagifulae and appeared to have its origins as a small farmstead in the late Samnite period (Lloyd 1991). In the early 1st century AD, it underwent significant restructuring, in particular with the construction of a series of production spaces with three partially buried dolia. The purpose of the new study was to apply geophysical prospection to explore beyond the excavated areas, to understand the full extent of the complex. Furthermore, through targeted excavation, the aim was to further investigate questions of consumption and production, as these would have had an impact upon the pattern of settlement in the valley.

The geophysical prospection required a combination of both magnetometry and GPR, as in this instance part of the site lay under a modern road, therefore requiring survey with GPR. The joint surveys recorded a previously unknown extension of the villa beyond a modern road that divides the site. In order to verify the interpretation of the geophysics an excavation was undertaken, as the survey had recorded the potential location of a large cistern, a key aspect to the functioning of the villa, as discussed above (Kay, Roberts and Rathbone 2019). Measuring 8.42m by 4.22m the *cocciopesto*-lined cistern appears to have been the main source of water supply to the villa, and its excavation revealed a site that was flourishing by the 2nd century AD, as identified through a considerable quantity of imported fineware. This pattern continued until the 5th century AD. However, the combined excavations and geophysics did not reveal a clear partitioning between *pars urbana* and *rustica*, rather they suggested that the villa gradually evolved around a central courtyard. The production spaces, which were the focus of a second season of excavation in 2022, indicate the role that the villa may have played within the territory, also emphasised by its position on a key route of transhumance on the western edge of the Biferno valley (Kay, Rathbone and Roberts 2023).

I employed a similar methodology of extensive geophysical prospection and targeted excavation to investigate the rural villa site of San Lorenzo in the Sabina.[17] Similar to the villa at Matrice, the site lies in a remote inland area, 820m above sea level, although a short distance from the Via Salaria. The villa's presence was first recorded by Persichetti in the late 19th century (Persichetti 1896), and encompasses an area of 4500m^2, the central part of which was later reused for the foundations of the Church of San Lorenzo, first documented in the 10th century AD.

The site was surveyed with magnetometry which was extended beyond the concentration of material that was recorded by a preceding fieldwalking survey (Kay 2012). At its northern limit, the geophysics recorded the *pars urbana* which my subsequent excavation showed was comprised of a double portico, several rooms with mosaic floors and a triclinium decorated in *opus sectile*, next to which was a small caldarium. To the south lay the *pars rustica,* less evident in the geophysics due to a predominant use of local stone, where excavations recorded simpler pavement decorations in *opus spicatum* and *opus signinum* with rooms that faced on to a small courtyard. The excavations revealed that the complex was founded in the late Republican period and was further expanded in the Augustan period with the addition of a range of rooms to the north. Whilst little evidence was recorded from the 3rd century AD, perhaps associated with the general decline in this period (Patterson 2009), the site was reoccupied in late antiquity and seemingly became a centre of production. Along with several decanting basins, the excavation recorded hearths, regularly aligned pits for the placement of dolia, millstones as well as fragments and wasters from a kiln, including a mould for an imitation catacomb lamp dated to the 5th century AD (Kay 2011).

Within the context of this appraisal, the examination of this site with geophysics was fundamental as few surface traces remained visible. Its identification has brought to light a substantial villa, founded in the late 1st century BC with a significant expansion in the following century. Its position in the upper Velino valley is of considerable importance, as few other large villas have been located in the area, with the closest identified, Villa di Tito, 25km to the south. Set back 500m from the Via Salaria, it is clear that the villa was a focal point both along the consular road and within the regional settlement. In its later phases it also became a centre of production, as evidenced by the kiln wasters, as well as having a substantial agricultural facility.

[17] Regular articles were published in the proceedings of the annual *Lazio e Sabina* conference series between 2011-2014: Kay 2011, Kay 2102, Kay, 2013b and Kay and James 2014.

The discovery and investigation of this site contributes substantially to our knowledge of the regional settlement pattern and how this fed into the urban network.

Overall it can be seen that the sites of Matrice and San Lorenzo were focal points for the local economy, both through the import of goods such as pottery fineware and marble, as well as supporting and managing local production. The research undertaken, through geophysical prospection and excavation, has provided evidence for the organisation of these remote areas and the role that villas performed in creating a network with the urban hubs, generating a better understand the overall settlement pattern in central Italy.

Rural sanctuaries

The investigations of the rural sanctuary at Monte Rinaldo (Marche) provided the opportunity to examine a further settlement type through geophysics within a landscape which typically became dominated by towns following Roman conquest. The settlement pattern of the region has been shown to be heavily influenced by the geography, dominated by long valleys beginning in the Apennines and leading down to the Adriatic coast. Each valley has been found to have at least two cities, one in the middle and then a port town at the mouth of the river, such as Firmum and Castellum Firmanorum in the Tenna valley or Asculum and Castrum Truentinum in the Tronto Valley (Giorgi, Demma and Kay 2020). However, despite a long history of research, no town has been identified in the Aso valley, leading to the interpretation that the sanctuary at Monte Rinaldo played a central role, not just as a religious meeting place but also administratively and economically. I therefore began a programme of geophysical prospection in the surrounding area of the temple, which had been excavated and partly reconstructed in the 1960s.

The sanctuary at Monte Rinaldo was frequented from around the time of Rome's conquest of Picenum in 268 BC. The first monumental Tuscanic style temple, built on a podium was renovated around the end of the 2nd century BC with a 3-sided portico and a small sacellum. However, by the Augustan period the sanctuary had been abandoned. The architectural terracotta and foundations of the western wing of the portico were repurposed in the construction of a small farmstead (Giorgi and Kay 2020).

The geophysical survey, conducted with a caesium magnetometer, a fluxgate gradiometer and GPR revealed few traces of structures in the immediate vicinity of the temple, in part due to the deep deposition of the structures as the site lies on the side of La Cuma hill. However, a short distance to the south, a complex of buildings was recorded that were

subsequently revealed to be associated with agricultural production (Fig. 9). Excavation targeting the strong positive anomalies brought to light a workshop, centred around a courtyard where the base of a furnace was found, together with iron slag and numerous tools, including hatches, knives and blades. Also recorded were a small shallow tank lined with *cocciopesto* and a well, the head of which was formed from the carefully cut rim of a dolium (Giorgi, Kay and Pizzimenti 2022).

Figure 9. Results of the magnetometer survey at Monte Rinaldo recording the site of a rural workshop (after Giorgi and Kay 2020: fig. 2).

The date of the foundation of the sanctuary recorded by the excavation is of importance, as it suggests a need for a form of self-representation, as well as establishing a means of control over the territory. The sanctuary was the central node within a territory where there was no preexisting town. However, only a century after the reconstruction of the sanctuary it was no

longer required, abandoned then to be reused as a farm and workshop. It was therefore important within the wider consideration of Roman urbanism that this form of settlement was also analysed. The leading role of geophysical prospection in this research was of central importance as through an examination of the surrounding territory, indicators such as the workshop were discovered. Furthermore, within the broader context of my research on Roman urbanism, through the application of geophysical prospection it was possible to investigate a settlement form that performed a critical function in the landscape, which in the case of Monte Rinaldo substituted the role of a town.

The aim of this discussion of smaller settlement forms, covering a selection of my published geophysical surveys of *vici*, villas and sanctuaries, has been to demonstrate both the methodology and wide-ranging scope of my research, as well as the critical role that different settlement types performed in processes of urbanism. Towns were reliant upon a regional network for production and trade to support the urban population, whilst the demand supported the more rural population, that also required aspects of urban infrastructure. By using geophysics to assess various settlement forms, a better understanding has been achieved of some of these drivers.

Methodological approaches to complex settlements

The appraisal to this point has focused on my publications that have contributed to the study of urban centres and other associated settlement types, principally in central Italy, along with contributions to our understanding of their formation, topography and role within the phenomenon of Roman urbanism. The majority of these examples have been surveys conducted at rural greenfield sites, where the use of a single technique (principally magnetometry or GPR) was sufficient to establish a detailed overview. However, sites where there has been continuous occupation into the contemporary period demand a different methodological approach. Modern towns and cities often have a deep and extensive vertical stratigraphy, therefore requiring a multifaceted approach, drawing upon multiple geophysical and geospatial techniques as well as other non-invasive methods.

Methodological developments

The development of an approach involving multiple techniques, which was adopted in some of the surveys described previously, had drawn upon my experience from the long-term investigations of the Portus Project at the port of Imperial Rome. One of the principal objectives of the project was to develop an integrated approach to largescale archaeological excavation

and geophysics, which, by drawing rapidly on a site-wide data management system, could help better inform the results of the geophysical survey.[18] In essence, the project sought to more closely align all digital data, leveraging the strengths of each method to help better interpret both the geophysical prospection and the excavations.

The Portus Project initially applied a similar methodological approach as the other towns investigated by the RTP, beginning with a magnetometry survey of the imperial harbours and their hinterland, covering 220ha (Keay et al. 2005).[19] This innovative approach to port studies revealed for the first time a highly complex port closely entwined with its hinterland, where a network of roads, canals and aqueducts was recorded. As with the later surveys I conducted at Gabii and Lucus Feroniae, the practice of extending the geophysical prospection beyond the known centre of the settlement allowed a greater understanding of both the layout and the suburbs of the port.

As the Portus Project moved into its second phase and concentrated on the excavation of structures between the two imperial harbours, the project required a more detailed understanding of the size and depth of buried structures. Therefore, the study area, which included the eastern edge of the Imperial Palace and the first of a series of bays of a *navalia*, was investigated with three types of geophysics: resistivity, GPR and ERT. [20] This multi-instrumental approach required precise geospatial recording to allow direct comparison of the datasets, a new approach which was subsequently published in *Archaeological Prospection* (Kay in Keay et al. 2009). The process of combining these techniques was not only beneficial in understanding the types of features that were recorded by each technique, but also allowed a refinement of instrumental settings and survey resolution, which in itself proved helpful in subsequent investigations in modern urban environments.

The practice of applying multiple techniques to better understand the sub-surface became a standard methodological approach in my research and was implemented where possible for many of the surveys discussed in this appraisal.[21] Variations in geology, soils,

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[18] From 2008 I led the topographical recording of the Portus Project, summarised in Kay, S. (Forthcoming) Chapter 6: 'The topographic and building survey', in S. Keay (ed.) *Uncovering the harbour buildings. Excavations at Portus 2007-2012. The surveys, excavations and architectural reconstructions of the "Imperial Palace", shipsheds and navalia and adjacent buildings*, Cambridge University Press.

[19] I participated in the first field survey in 1998 and subsequently directed the survey of the Claudian harbour (see Chapter 5: 'The survey results'. Simon Keay, Martin Millett and Kristian Strutt (incorporating work by Letizia Ceccarelli Paul Johnson, **Stephen Kay**, Julia Robinson and Timothy Sly) in Keay et al. 2005.

[20] See Keay et al. 2012 for a full discussion.

[21] The decision of applying multiple techniques in the investigation of a site was also governed by external factors, such as time constraints and funding.

moisture and construction material differently effect the capacity of the instrument to map the sub-surface, therefore through a combined approach a fuller understanding may be obtained. However, to fully maximise the potential of geophysics in contemporary urban centres, as well as within internal spaces, techniques needed to be more closely integrated with geospatial technology, such as high-precision mapping with GPS and total stations, as well as photogrammetry and laser scanning.

Geophysics and laser scanning

The study of two Renaissance churches in central Italy, Sant'Agostino (San Gimignano, Tuscany) and San Domenico (Città di Castello, Umbria), which I undertook as part of a joint project reassessing church interiors encouraged the development and refinement of an approach integrating geophysics and laser scanning. The aim of the research was to use GPR to determine the location of rood screens – architectural structures typical of churches of the 12th and 13th centuries that divided the liturgical space and determined the visibility of artworks. These screens were removed during the Counter Reformation and are therefore poorly documented. Furthermore, the study aimed to better understand the original positioning of artworks as these would have been closely integrated with their architectural and liturgical settings, as well as investigate the potential traces of removed altars and the location of tombs (Cooper, Kay and Pomar 2023). As well as forming part of the process of development of the overall methodology with which to approach the archaeological prospection of towns in modern urban settings, through this project I helped to address key questions regarding the study of Renaissance churches. Their interiors have been radically transformed over the centuries and conventional scholarship has focused upon building analysis and archival documentation to achieve a reconstruction for a specific period. Therefore, the current state of scholarship remains dependent on a small corpus of artistic representations and a few excavations leaving many questions unanswered. In essence, art historical research in this area which is driven by archival studies has reached an impasse. The approach that was taken with this research offered a new way of approaching such questions and has made a considerable contribution to this field of study.

Whilst the application of GPR in ecclesiastical buildings has previously been undertaken, the novelty of this research was its integration in a 3D environment with georeferenced laser scan data from building survey, with all data stored and analysed in point-cloud format (Fig. 10). The GPR survey provided information concerning the sub-surface and laser scanning allowed the creation of a virtual 3D framework and structure for placing the

features in their precise topographical, visual and structural context. The detail captured by the laser scan therefore provided additional elements for the interpretation of the geophysical anomalies in relation to the standing structures.

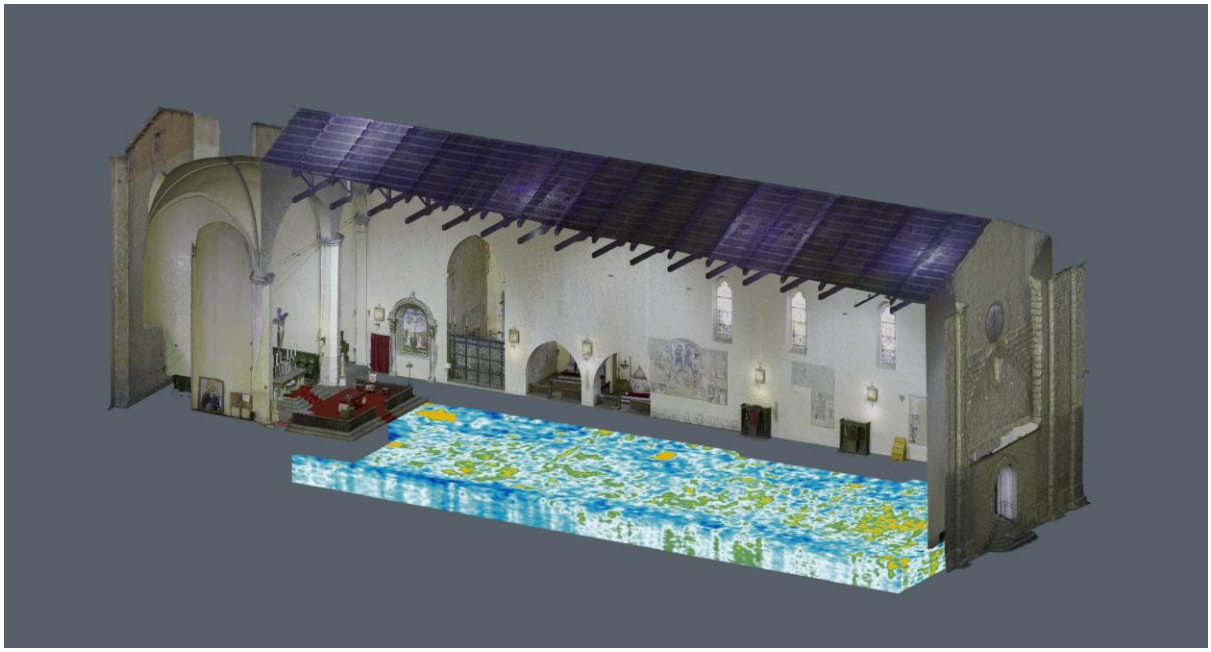

Figure 10. Digital representation in point cloud format of the church of San Domenico (Città di Castello) with the GPR dataset (after Kay et al. 2023: fig. 1, **#9**).

The combined geospatial-geophysical investigation of these two Renaissance churches was highly successful. New elements were identified through close study of the architecture together with the high amplitude features recorded by the GPR. The GPR recorded screen footings which could only be understood though their position with architectural features recorded in the laser scan data. Similarly, previously unknown tombs were located, which, besides their discovery, was also significant as these were often placed in association with altars, some of which had been removed. The 3D nature of GPR data is often underutilised, especially by the generation of horizontal 2D time-slices, however when combined with a digital 3D model they can be more fully exploited, with less reliance on vertical radargrams or differently cut horizontal time-slices (**Kay et al. 2023, #9**). The increased precision offered by aligning the data more closely with the topographical information in a 3D environment allowed for a more robust methodology, fundamental to understanding the complex stratigraphy found in an urban environment.

This methodological approach was further tested through fieldwork at Piazza Sant'Anastasia in Rome, where target features in deeply stratified deposits sit in a complex

modern urban environment (Pomar et al. 2023). The survey aimed to establish the continuation of a Roman building, dated between the 1st and 4th centuries AD, upon which the Basilica of Sant'Anastasia was built at the southwest corner of the Palatine. Using a combination of GPR antennas (200MHz and 400Mhz) to record at the highest resolution at differing depths as well as laser scanning we documented the façade of the basilica and built a digital surface model of the piazza to topographically correct the data. The successful documentation of a range of rooms, continuing from under the basilica to the east, demonstrated the effectiveness of this multilayered approach that I subsequently applied to my research as part of the Rome Transformed Project (below).

Geophysics and environmental coring

Another method by which to approach the investigation of settlement in modern urban environments has been the use of ERT in close combination with environmental coring. The collection of resistance data, similarly to GPR, allows the analysis of deeply stratified contexts through the recording of vertical profiles, with increased depth achieved through an expanding array. The technique is particularly useful for targeting high resistance features, such as walls, as well as lower resistance features such as filled channels or quarries. Through subsequent targeting with environmental coring, the interfaces recorded by the ERT, as well as the high and low resistance features can be more rigorously examined.

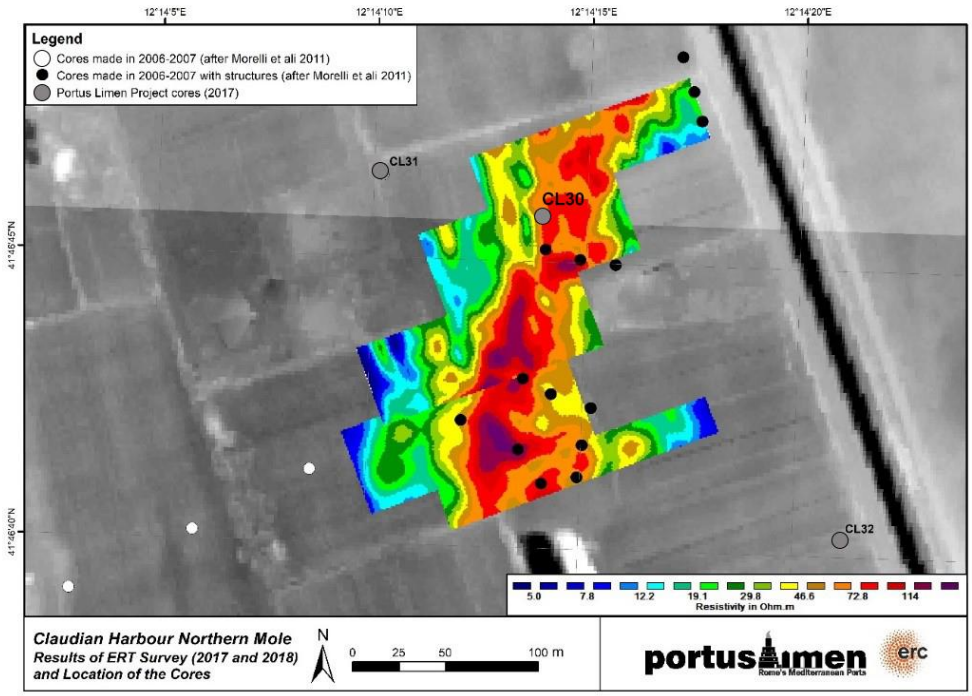

Figure 11. Results of the ERT survey and the location of the 3 new cores (CL 30, 31, 32) at Portus (after Kay et al. 2019: fig. 3).

An example of an initial evaluation of this methodology in my research can be drawn from investigations at Portus, where deep sedimentation caused by coastal progradation led to the burial of much of the Claudian harbour, which now lies 2.5km inland. Whilst the basin of the imperial port had been explored with magnetometry (Keay et al. 2005), and the excavation areas with multiple techniques, there remained uncertainty regarding the extent and location of the Claudian moles (Keay and Kay 2018). The estimated depth of the features excluded the use of magnetometry, whilst a preliminary survey with a 200MHz GPR antenna was unsatisfactory due to high signal attenuation caused by the shallow water table. Therefore, an area of c. 2.5ha was investigated with ERT, with 64 probes used at 2m intervals to allow a sufficient vertical sounding profile. The ERT recorded a high resistivity anomaly of c. 100-110Ωm, which traversed the survey area at a continuous depth between 5m and 15m below ground level. The significant dimensions as well as the orientation and depth suggest that the feature indicated the position of the northern Claudian mole, but in order to confirm the interpretation, three cores were drilled, one to the north of the anomaly potentially outside the harbour (Fig. 11, CL31), one directly above (Fig. 11, CL30) and one to the east (Fig. 11, CL32), estimated as inside the harbour (Kay et al. 2019). The core drilled on the anomaly (CL 30) showed that the high resistivity value was created by a constructed layer of pozzolana, basalt and tuff, the origin of which was subsequently analysed, revealing that the majority of materials have a close spectra resemblance with Tufo Lionato and Pozzolane rosse. Through investigating the raw construction materials, the study provided insights into the sources of materials and building strategies during the construction of the imperial harbour of Rome (Kay in Chapkanski et al. 2021). The combined ERT and coring of the Claudian harbour provided a precise understanding of the location, construction and functioning of the mole. The core located inside the harbour (as identified through the distinctive harbour sedimentation) provided useful information concerning the marine environment inside the port and how the mole affected the movement of water. Likewise, the information from the ERT survey proved for the first time that the mole was built on a continuous foundation, with a width of approximately 50m which may then have supported an upper structure.

The methodology applied for this survey at Portus, high resolution ERT with targeted environmental coring, was effective in this deep sedimentary estuarine environment. I have therefore taken a similar approach for my continued research at Spina, located at the mouth of the river Po. Following the magnetometry survey (**#5**), I have undertaken an ERT survey, targeting some of the channels recorded by the magnetometry to assess their depth and

formation. As at Portus, the location of each ERT probe was spatially recorded by GPS to both locate the measurements and to provide a precise height above sea level. Following a study of the results of the vertical profiles, 11 deep sedimentary cores have been drilled and are now in the process of being studied.[22]

This short section describing how geophysical prospection has been closely aligned with geoarchaeological coring illustrates how I have accumulated a body of experience and field tested a method that I aimed to transfer into modern urban environments. As highlighted at the beginning of the appraisal, prior studies in investigating Roman urbanism through geophysical prospection have often focused upon easily accessible greenfield sites. My approach has aimed to establish a methodology, combining geophysics and other non-invasive techniques, to progress our ability to study urbanism in complex-built environments.

Geophysics in modern urban environments

The preceding sections demonstrate how I have generated a considerable body of research that has allowed me to develop a protocol for the application of geophysical prospection in a modern urban environment. My overall aim was to undertake geophysical prospection in close combination with other techniques to maximise our understanding of complex, often still inhabited, urban environments. Whilst previous research I completed at Segni (Lazio) had also shown the effectiveness of GPR in a modern urban environment, the results were tested through excavation rather than other non-invasive technologies (Kay in Cifarelli et al. 2013). However, in many circumstances it is not feasible to conduct excavations, and therefore it was important to build a technical non-invasive approach that would still generate a robust dataset.

Research conducted as part of the ERC-funded Rome Transformed Project (2019-2025)[23] provided the opportunity to incorporate geophysical prospection with an array of other methodologies to investigate highly complex stratigraphy in the heart of Rome. The geophysical programme which I have directed represents one of the largest such studies undertaken in a modern city.[24] The project aims to develop an understanding of Rome and its place in cultural change across the Mediterranean world by mapping political, military and religious changes across the Eastern Caelian hill from the 1st to 8th centuries AD, encompassing

[22] The study, part of the Etruscans on the Sea project (University of Bologna), is now being prepared for publication.
[23] https://cordis.europa.eu/project/id/835271
[24] In partnership with the Consiglio Nazionale delle Ricerche and Geostudi Astier s.r.l.

a densely occupied area of 13.7km^2 lying between the Basilica of San Giovanni in Laterano and the Basilica of Santa Croce, at the site of the Sessorian Palace (**Kay in Haynes et al. 2023, #6**). It achieves this through the integration of different platforms of data capture including structural analysis (combining building survey, laser scanning, photogrammetry, UAV Structure-from-Motion and topographical survey), geophysical prospection, archival/bibliographic research and environmental coring.

The application of geophysical prospection in this environment presents numerous challenges, ranging from instrumental to logistical and topographical. The choice of techniques is limited to GPR and ERT due to the significant electromagnetic disturbance in a city, thereby precluding the use of magnetometry. Whilst not unique to a modern urban environment, the vertical depth of archaeological features creates further challenges. Due to continuous occupation, as well as the intentional raising of ground levels and burying of structures, a complex, interlocking stratigraphy is created that poses difficulty for geophysical data interpretation. Other challenges include modern utilities (often unmapped), differing road surfaces (e.g. asphalt, San Pietrini) as well as street furniture (such as tramlines) and accessibility to conduct a survey. In planning the research, the focus was therefore on open areas within the city, including public parks, private gardens and playgrounds as well as the full road network which comprised around 3.5ha (**Kay, Pomar and Morelli 2023, # 3**).

The geophysical methodology developed employed a full range of GPR antennas (from 70 to 800 MHz) and setups (single, multichannel and multi frequency) which were applied on a case-by-case basis with the overall aim of inspecting different depths at the optimal resolution. Areas were often also resurveyed with different antennas to obtain the maximum resolution at varying depths. Alongside intensive GPR coverage, ERT was also used over 1.7ha to provide a comparative dataset (Fig 12). This methodological approach has since helped to inform other GPR archaeological surveys of modern urban centres. The recent work of the Roman York Project[25] as well as the Sotto Siena Project (Campana et al. 2023), have also deployed a range of antenna and have shown the complexities of data collection on asphalt roads, where, in seemingly ideal conditions, minimum depth penetration is achieved by the GPR antennas. It was therefore essential to the approach taken by the Rome Transformed project that the GPR surveys were complemented by other forms of non-invasive investigation.

[25] Presented at 15th Roman Archaeology Conference / 32nd Theoretical Roman Archaeology Conference, University College London from 11-14 April 2024. RAC/TRAC Session 16: New Perspectives on Roman York, 'Seeing through Medieval York to the city beneath' (John Creighton).

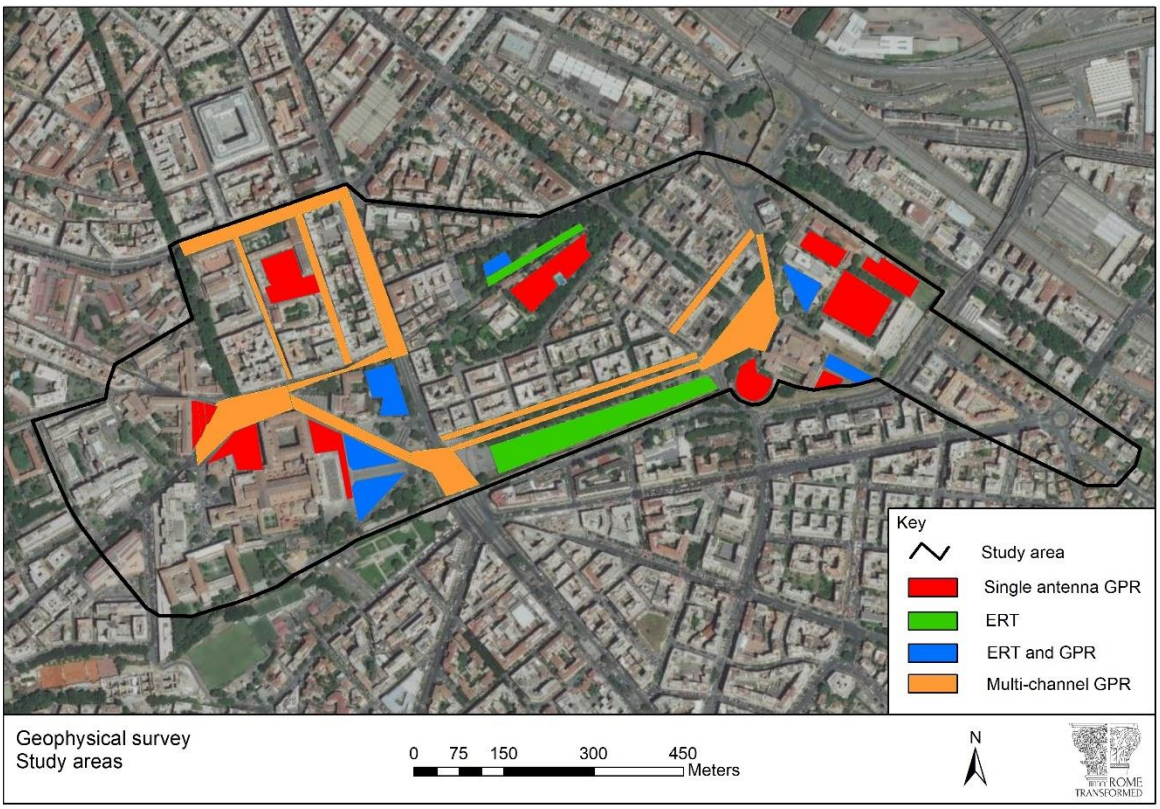

Figure 12. The geophysical survey areas of the Rome Transformed project divided by prospection method.

A central part of the methodological approach was therefore an extensive archival investigation of the research area (Carboni and D'Ignazio 2023). Whilst Rome is perhaps unusually rich in this respect due to its continuous occupation and history of scholarly research, this combination of approaches, together with the digital recording of standing monuments (as discussed above) has provided a framework in which to undertake the geophysical prospection. Furthermore, the prospection was able to draw upon a vast digital registry of excavations in Rome.[26] Through the use of a digital platform (GIS), different datasets can be layered, from historical plans and cartography through to modern mapping of utilities, which are crucial for the interpretation of the geophysical datasets. Subsequent to the prospection, precisely positioned environmental cores were then drilled in areas where the core data could provide comparative information, allowing a greater understanding of the non-invasive survey datasets. The geophysical prospection that has been undertaken as part of the Rome Transformed project has made a considerable contribution to our understanding of the urban development of the eastern Caelian in Rome. Discoveries include parts of the residence of the bishops of Rome, the *patriarchium*, destroyed by the 14th century AD, that were recorded by GPR and ERT with

[26] Collated within the ARCHEOSITAR project (www.archeositarproject.it).

additional data from 2 cores to the east of the Basilica di San Giovanni. Around the Basilica di Santa Croce, structures belonging to the Sessorian palace were discovered at depth, together with a potential tower of the Aurelian wall, recorded with a 200MHz antenna 2.8m below an astroturf football pitch[27].

Ongoing impact of selected publications

The publications selected for this critical appraisal were chosen to illustrate the breadth of my studies in Roman urbanism through geophysical prospection and the thorough methodological approach. Alongside various discoveries and increased understanding across all sites investigated, my research has inspired and enabled further work, in part from the mapping of sites, but also through the new themes that it has explored. Some examples are outlined below:

- Geophysical prospection at Gabii (**#1**) has formed the framework for a project which has for the last decade used the findings to continue to explore the city. The early quasi-orthogonal plan that emerged from the geophysics data, dated to the 5th century BC, has implications for our understanding of urban development in central Italy.
- At the site of Lucus Feroniae (**#2**), the discovery through geophysical prospection of a sacred woodland surrounding the sanctuary is of considerable archaeological and historical importance, as well as the mapping of an elongated settlement form, that has led to a reassessment of the role of this town.
- My research at Vulci (**#4**) showed how, with a carefully structured multi-methodological approach, earlier urban layers and be identified amongst later construction. The geophysical results, complemented by a detailed comparison with aerial photography, have allowed for precise targeting of structures through excavation, revealing new information about the early phases of the city.
- Geophysical prospection at Spina (**#5**), where a city grid formed by water channels was discovered, has inspired a new research programme at the site. Building upon the results of the magnetometry survey, new excavations are underway, supported by other types of geophysics (resistivity and ERT) and deep environmental coring that have drawn upon my research at Portus.

[27] The results of the survey are currently in preparation for publication in **Kay, S.** and Azzari, M. 'The transformation of the landscape of the Eastern Caelian Hill, Rome. The geophysical and topographical studies of the Rome Transformed Project', in I. Haynes and P. Liverani (eds.): *New studies in the Archaeology and Topography of Rome*, British School at Rome Archaeology Monographs (Series editor **Kay, S.**), Archaeopress, Oxford.

- The two geophysical surveys in Sicily at Morgantina (**#7**) and Agrigento (**#8**), whilst making major discoveries within the cities, such as the *palaestra* at Agrigento, have formed the basis of subsequent excavation programmes, helping to better understand their urban histories. The orthogonal grids previously hypothesised were shown by the geophysics to have been rigidly imposed, regardless of the suitability of the topography.
- The methodological approach of integrating point clouds generated from laser scanning with those of high amplitude GPR anomalies has illustrated how the 3D properties of the data can be captured to better the interpretation of sub-surface features. The study of the two Renaissance churches (**#9**) using this methodology has made a significant contribution to our understanding of their earlier history, pushing the boundaries of art historical research.
- Research that is now being undertaken in Rome, involving one of the largest geophysical surveys undertaken in a modern metropolis, draws upon the experience and methodology that I developed over a lengthy period. The many different surveys and the increased merging of geophysics with geospatial techniques (see above, **#9**), 3D visualisation and coring has allowed a framework to be established whereby geophysics can be applied in a modern urban environment (**#3**) and has formed the conceptual basis for similar research in other modern cities. The results of the project (**#6**) show how this close combination of geophysical prospection with other forms of non-invasive investigation can generate multilayered datasets of complex environments allowing for more refined understanding and interpretation.

Conclusion

Geophysical prospection has had a profound impact on the study of Roman urbanism. It has allowed the systematic, non-invasive investigation of ancient towns as well as their surrounding landscapes in unprecedented detail, and my research forms a core part of this trajectory in Italy. As illustrated by my publications, I have consciously sought to address the full range of different forms of urbanism to establish a deeper understanding of the factors that influenced the evolution of these settlements. Through the study of entire towns, a much better understanding has been gained of both their form and role within a territory. This is highlighted by my investigation of Lucus Feroniae (**#2**) where the geophysics revealed a smaller settlement than estimated, and through the mapping of the plan of the town, how the settlement performed

a different role, acting as a focal point in the territory. Furthermore, geophysical results revealed how earlier phases, principally the sanctuary, had a lasting impact on the development of the city as potentially sacred areas were respected in the towns later phases.

A further factor influencing the urban plan of towns that has been drawn out by my research is the principal role of local topography. Whilst my research in Sicily (**#7, #8**) demonstrated the potential rigidity of early town planning with limited adaptation for topographic changes, research at other sites, such as Gabii (**#1**), revealed how they were specifically adapted to the local topography. At the site of Spina (**#5**), magnetometry showed how solutions were found to adapt to local conditions, where water channels replaced the usual system of a regular road network. Individual variations in the layout and role of small towns are also now being recognised in the archaeological record through the more complete examination of these sites. At Iuvanum, the survey aimed to establish whether the excavated areas represented the centre of a town, presumably surrounded by a larger urban layout. However, the geophysics instead suggests that, similarly to Amiternum and Forum Novum, Iuvanum characterises as an administrative settlement with little private architecture. Survey of its suburbs revealed how the few structures present are all concentrated around the forum, theatre, temple and basilica.

The research that I have undertaken on *vici* in central Italy has opened a new area of research into this little studied settlement form; one crucial in the Roman management of the territory and its population, serving as a focal point for a rural population and important agents in territory control. The first geophysical surveys conducted in the Sabina of this settlement form will help in developing our understanding of these peripheral settlements.

A key driver of my research has been the creation of a multitiered methodological approach, led by geophysical prospection, which can better inform our knowledge of urbanism, in particular in modern environments (**#6**). The application of multiple techniques allows for a fuller understanding of the subsoil, which is vital if in support of targeted excavation. By integrating geospatial techniques (**#3**), in particular merging GPR and laser scanning point cloud data, I have sought to demonstrate how the 3D attributes of this data encourage a better analysis, through combining standing structures with subsoil features. The research conducted at a series of Renaissance churches to investigate art historical questions further demonstrates the cross-applicability of the methodology to other disciplines (**#9**). This layered approach, when combined with the collection of legacy data (trialled through my work at Tarquinia),

archival information, and deep coring permits a robust approach allowing an understanding of contexts that are both deeply stratified as well as complex to investigate. My selected publications evidence the development of a methodological approach leveraging the strengths of geophysical prospection alongside other techniques and, when set in the context of my broader research trajectory and publication record, as well as relevant scholarship in this field, highlights my significant contributions to understanding Roman towns and their networks.

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Portfolio of nominated publications submitted in partial fulfilment of the requirements for the degree of PhD by Publication.

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December 2024

1. Kay, S. 2013. Geophysical Survey of the City of Gabii, Italy, in P. Johnson and M. Millett (eds.) *Archaeological Survey and the City*, University of Cambridge Museum of Classical Archaeology Monograph no.2, Oxbow Books, Oxford: 283-302.

2. Kay, S., Hay, S. and Smith, C.J. 2023. From sanctuary to settlement. Mapping the development of Lucus Feroniae through geophysical prospection, in A. Launaro (ed.) *Roman Urbanism in Italy: recent discoveries and new directions*, Oxbow Books, Oxford: 121-137. DOI: https://doi.org/10.2307/jj.9941113.11

3. Kay, S., Pomar, E. and Morelli, G. 2023. Rome Transformed: a multiple method geophysical approach for the urban investigations of the East Caelian, in I. Haynes, T. Ravasi, **S. Kay**, S. Piro and P. Liverani (eds.) *Non-Intrusive methodologies for large area urban research*, Archaeopress, Oxford: 56-51. DOI: https://doi.org/10.32028/9781803274461

4. Kay, S., Pocobelli, G. F. and Pomar, E. 2023. Indagini aerotopografiche e prospezioni geofisiche per la conoscenza dell'area urbana di Vulci, in G. Ceraudo, G. Scardozzi, V. Ferrari (eds.) *Archeologia Aerea XVII*, Claudio Grenzi Editore, Foggia: 45-58.

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9. Kay, S., Pomar, E., Castignani, V. and Cooper, D. 2023. High resolution spatial documentation of Renaissance church interiors through multiple non-invasive survey technique, *Groma: Documenting Archaeology* 8, Archaeopress, Oxford: 101-109.