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The application of geophysical prospection to understand ancient Greek rural island landscapes: Magnetometry survey at Palaiopyrgos, Paros (Cyclades)

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ABSTRACT

Geophysical prospection in Greece has predominantly been applied at ancient urban sites on the mainland and Crete. It is rarely used on Cycladic islands and even less so in rural contexts, despite their centrality to the eastern Mediterranean region and the ability of geophysical techniques to efficiently cover extensive rural spaces and identify archaeological traces of agriculture and landscape exploitation. This study applies magnetometry for the first time on Paros, around the so-called Hellenistic Palaiopyrgos tower, with the aim of detecting the presence of buried ancillary structures and archaeological indications of agricultural activity. Several sub-surface features were identified and are compared to those at similar tower sites in the Cyclades and Greece. We highlight challenges to this approach and possible pathways forward specific to the investigation of rural landscapes. The data captured in this study will also play a central role in the protection of the Palaiopyrgos archaeological site, highlighting a methodological approach to be deployed in other areas that are experiencing rising pressure due to tourism and rapidly expanding development.

1. Introduction

Geophysical prospection has now seen several decades of use at archaeological sites across mainland Greece and Crete. Since early surveys in the 1990s (e.g. Theocaris et al., 1996), attempts have been made to detect and map subsurface archaeological features using various techniques, predominantly magnetometry (or gradiometry), Ground-Penetrating Radar (GPR), and electrical resistivity. As technology improves, certain geophysical methods are able to document landscapes and features at increasingly high resolution and with greater speed. Research in Greece has concentrated around sites in the Peloponnese (Zananiri et al., 2010; Lolos and Gourley, 2011; Papadopoulos et al., 2015; Sarris et al., 2015; Sarris et al., 2020), Boeotia (Konecny et al., 2012; Bintliff et al., 2013), Thessaly (Kalaycı and Sarris, 2016; Donati, 2020; Vaïopoulou, 2023), Macedonia (Provost and Boyd, 2002; Vargemezis et al., 2013; Tsokas et al., 2023), and several locations on Crete (Driessen and Sarris, 2020; Sarris et al., 2023). While the precise methods used in the present study may therefore not be novel per se, the combination of the landscape to which they are applied (rural areas on the island of Paros) and our research focus (investigating agricultural features and areas surrounding Hellenistic towers) demonstrate an innovative and original approach. The importance of this becomes apparent when one considers the impact of increasing human pressures acting on such landscapes (below).

Geophysical prospection across Greece has been dominated by its application in ancient urban contexts (e.g. towns and cities). While the potential to reveal the buried remains of entire articulated cities can capture public interest (e.g. Falerii Novi in Italy: Verdonck et al., 2020; Andrews et al., 2023; or in Greece: Donati et al., 2017), these techniques are equally adept at mapping rural contexts due to their ability to cover large areas increasingly efficiently at high resolution. Furthermore, while archaeological surface surveys on Aegean islands have vastly

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increased our knowledge of diachronic rural settlement patterns (e.g. Renfrew and Wagstaff, 1982; Cherry et al., 1991; Mendoni, 1994; Bevan, 2002; Bevan et al., 2013; Knodell et al., 2022; Renfrew et al., 2022; Knodell et al., forthcoming; Levine et al., forthcoming), we know comparatively less about subsurface rural remains including residual traces of how people interacted with and exploited the landscape. Recent work elsewhere in the Mediterranean and Europe highlights the potential of non-invasive prospection to map the remains of more ephemeral ancient agricultural activities common to rural contexts (e.g. Campana and Francovich, 2007; Smekalova et al., 2016; Dodd and Van Limbergen, 2024, 2025; Pomar, forthcoming). This can include the detection of various negative features, such as trenches, cuts and pits for the cultivation of crops, planting of trees and management of water.

While the Cycladic archipelago has been archaeologically investigated for several centuries, geophysical prospection is rarely undertaken, either alone or complementary to other approaches. Only a handful of geophysical surveys have been published (e.g. Zagora, Andros: Beaumont et al., 2012; Therasia: Sarris et al., 2021; Santorini: Trinks et al., 2017). This lacuna is particularly noticeable in publications that sketch the state of the field in Greece and the Aegean (cf. Donati and Sarris, 2016, map 4). To our knowledge, it has never been utilised on the island of Paros, the subject of this study (Fig. 1). A core objective of this project, therefore, was to apply and test the efficacy of geophysical techniques in the Cyclades, in particular on the geology of Paros, which is quite different to the volcanic geology of Therasia or Santorini. Paros is composed of four lithostratigraphic units, with the region under study here dominated by the Marmara, Quaternary and Marathi deposits (Kolaiti and Mourtzas, 2020). Such testing is essential in order to understand the impact of local environmental and contextual factors that can influence geophysical data capture, including geomorphology, soil noise, external or natural sources of noise, later surface occupation, and anthropogenic interventions (Driessen and Sarris, 2020; Schmidt et al., 2020).

Another objective was to test the efficacy of this survey approach in the context of cultural heritage documentation, preservation and protection. Paros, and the Cyclades more broadly, are experiencing rapidly rising tourism and development of the built landscape, which is threatening cultural heritage sites and their surrounding countryside (Tsilimigkas et al., 2022). It is imperative to document archaeological landscapes in an efficient and targeted manner, generating data that can be used by government authorities to inform site protection and preservation. Geophysical prospection forms an excellent tool to do so, by recording archaeological features in advance of development, even ahead of rescue excavations, which form a more costly and invasive measure with often similar aims. The methods within this case study thus bear promise to be implemented more widely across Paros and other Cycladic islands. We aimed to generate proof-of-concept in the fields surrounding the Palaiopyrgos tower in northern Paros (Fig. 2), where building development is already threatening to encroach on the tower's archaeological zone.

Although this article focusses on geophysical methods and results, several other approaches were undertaken in tandem with the geophysics survey, including fieldwalking to document and collect material culture on the ground surface, and digital documentation of standing remains, features and excavation test trenches (Fig. 3). An additional objective included the integration of this multi-proxy dataset to improve understanding of diachronic occupation and longue durée activity at Palaiopyrgos. While some of these results are discussed briefly below, they will be in reported more extensively in a future publication.

1.1. The Hellenistic tower at Palaiopyrgos, Paros

Paros is situated near the centre of the Cycladic archipelago at a hinge point in ancient Aegean trade networks and is known to have

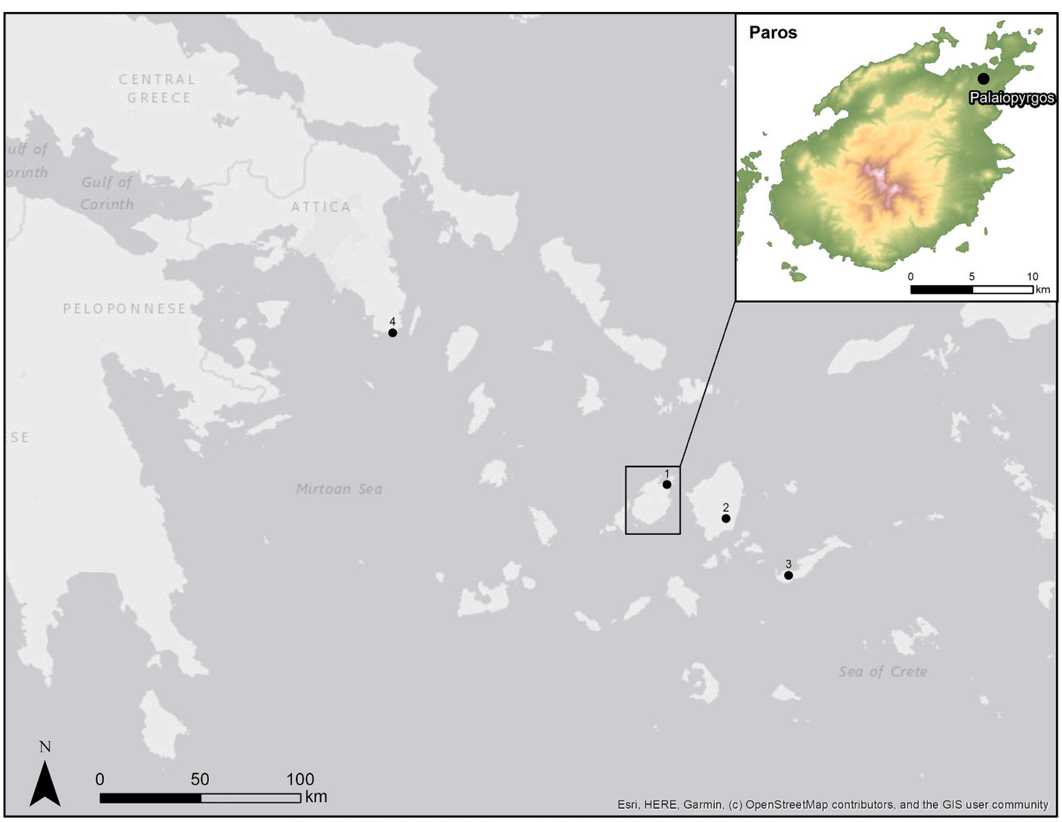

Fig. 1. Map of the Aegean showing the location of Paros and main tower sites mentioned in the text: 1. Palaiopyrgos, Paros; 2. Cheimarrou, Naxos; 3. Agia Triada, Amorgos; 4. Princess Tower, Sounion (map by C. Whittaker).

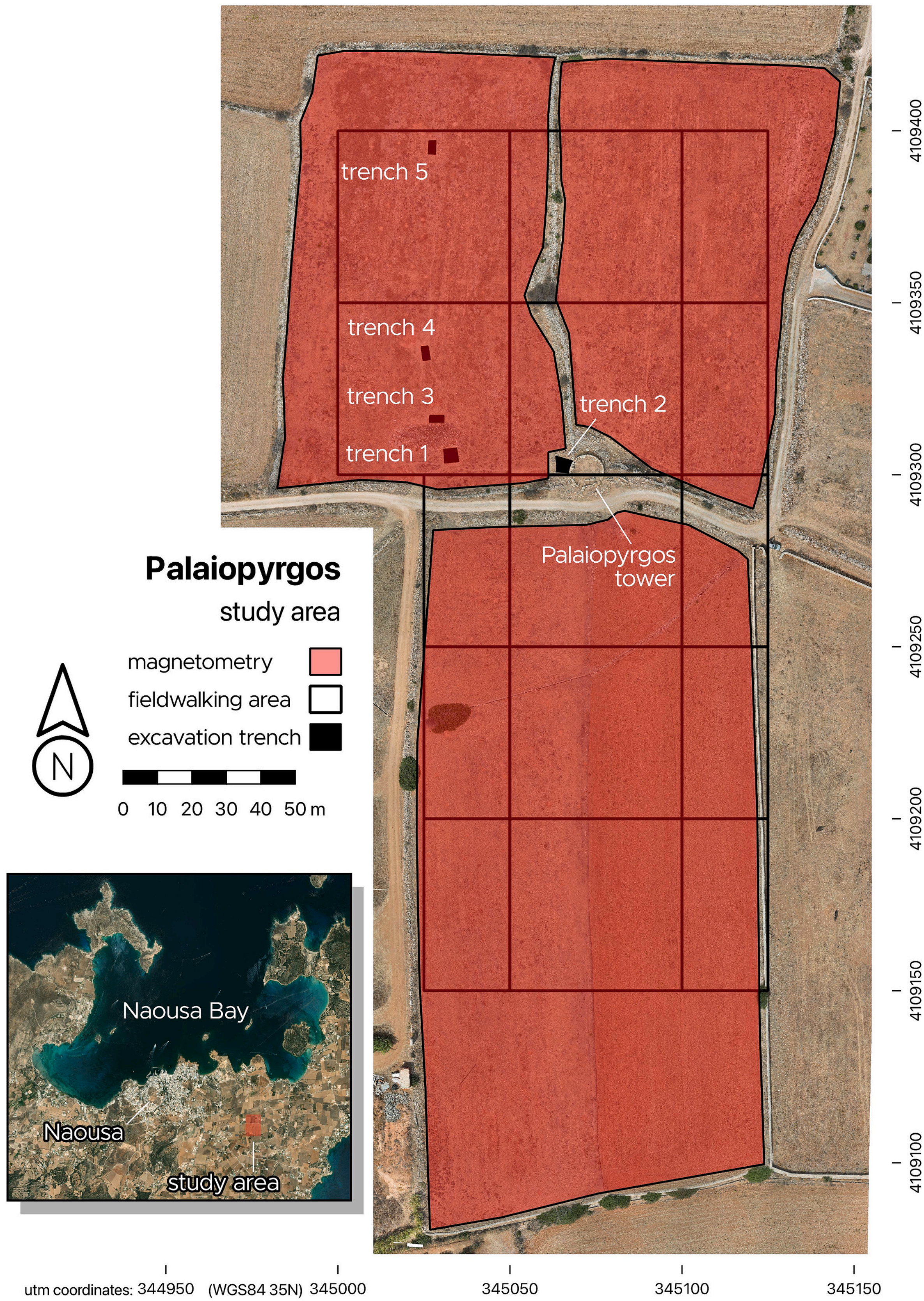

Fig. 2. Overview of the study area, including the four fields surveyed using magnetometry and fieldwalking around the Palaiopyrgos tower. Fieldwalking grids and test trench excavation locations are also indicated (figure by E. Levine).

Fig. 3. Aerial orthophotographs of the study area and features, showing positions and details of the tower and five test trenches excavated prior to the geophysical survey. The small stretch of wall referred to in the main text can be seen abutting the exterior of the tower in trench 2 (figure by E. Levine).

produced and exported substantial agricultural produce in antiquity (Dodd, 2021, 2022b, 2022c, 2025). The circular Palaiopyrgos tower sits 800 m inland from Naousa Bay in northern Paros (Figs. 1, 4–5) and is relatively unstudied, save architectural assessment and brief notes on surface material (Haselberger, 1978; Roussos, 2017). Its construction has traditionally been dated to the Hellenistic period, from the late fourth to third centuries BCE, based on surface ceramics, its arched doorways and the five standing courses of double-walled limestone ashlar masonry (Figs. 4–5) (Haselberger, 1978). We now suggest this might be refined to the Late Classical era based on the discovery of an additional external wall and earlier ceramic material in trench 2 (below).

Surrounding material culture indicates a lengthy occupation history, beginning in the Archaic period and continuing through the Roman, late antique and Byzantine eras. Gridded fieldwalking completed alongside the geophysical survey (Fig. 2) identified local *pithos* sherds with a 'kalamoti' decoration from the early seventh century BCE, along with limited quantities of Classical and Hellenistic ceramic material. Much more concentrated and extensive quantities of Roman and Late Roman pottery were identified, decreasing in density further away from the tower, including abundant fragments of *amphorae*. Some *amphora* sherds show similarities in form and fabric to locally produced types from the sixth to seventh century CE kilns excavated at Lageri on Naousa Bay (see Diamanti 2016). Several press counterweights have also been identified nearby, suggesting notable local production of wine or olive oil in antiquity, perhaps coeval with and connected to this ceramic industry, which enabled the storage and maritime export of these products (Dodd, 2020, 2021, 2022b).

Our knowledge of Cycladic tower sites remains patchy, despite their centrality in the ancient Aegean rural economy and landscape. Past scholarship suggests that they held regionally variable and multifunctional purposes, combining defence, agricultural production, habitation, and imprisonment, and showcase intense exploitation of natural resources and the labour of slaves in agriculture and industry (Marangou, 2005; Morris and Papadopoulos, 2005; Seifried and Parkinson, 2014). Study and interpretation is often centred on tower architecture alone, to the detriment of understanding their integration within surrounding agrarian landscapes. Similar towers on Lefkada and the Greek mainland, however, show that courtyards and functional annex rooms were common (Young, 1956; Nowicka, 1975; Morris, 2001).

In the Cyclades, the existence of annex spaces is best illustrated by the Cheimarrou tower on Naxos (Figs. 1.2 and 6), where four production spaces for the processing of olives, including several presses to create olive oil, were inserted in courtyard rooms during the Late Roman period (Philaniotou, 2003; Dodd, 2022b, 2022c). Towers on Amorgos (Fig. 1.3) also appear to be set within a wider complex, including storage space, cisterns, presses, mills, and domestic pottery (Marangou, 2005). However, we know little about how these surrounding rooms were integrated into layout and use, and clear regional differences exist (Morris and Papadopoulos, 2005). Furthermore, lengthy regular, rectangular cuttings into the bedrock have been identified on Paros and neighbouring Antiparos, interpreted as ancient trenches for the cultivation of grapevines, including several along the coast only 800 m from the Palaiopyrgos tower (Papadopoulou, 2017; Kolaiti and Mourtzas, 2020, 2024). Similar features are known across the Mediterranean, for example in Italy (Dodd, 2022a, 452). Recent work using geological criteria and sea level change from the Archaic through Late Roman periods suggests that the cuttings on Paros were above sea level until ca. 30 BCE, after which they were flooded, and therefore their use within agricultural systems must date between the Archaic and Hellenistic eras (Kolaiti and Mourtzas, 2024). More cuttings were revealed in 2024 due to modern construction activity in fields only 400 m from the Palaiopyrgos tower. It is possible that agricultural field systems such as these were used or controlled by people operating from centralized tower sites and might be expected to continue in its vicinity. We therefore aimed to assess the presence of buried courtyard or ancillary structures along with traces of agricultural activity around the Palaiopyrgos tower, none of which are currently visible on the modern ground surface.

Geophysical prospection provides an ideal approach to efficiently

Fig. 4. The ruins of the Palaiopyrgos tower looking north over two fields surveyed and towards Naousa Bay. The series of excavated test trenches can be seen in the left field, along with the modern dirt road running across the image, which divides the northern and southern survey areas (photo by E. Levine).

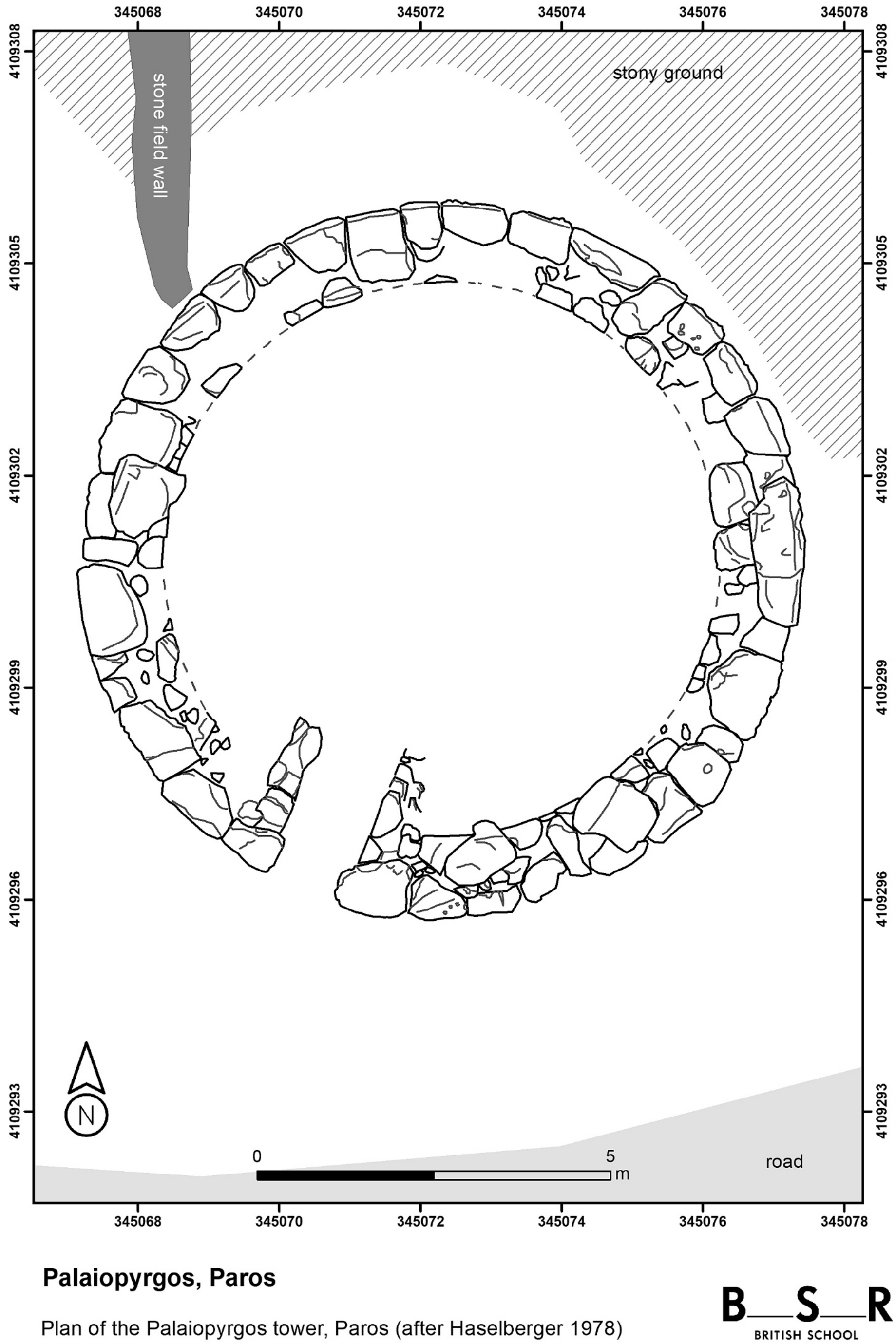

Fig. 5. Plan of the Palaiopyrgos tower, showing entryway and double-walled construction (drawing by C. Whittaker; after Haselberger 1978).

survey accessible areas around towers and map subsurface architectural and agricultural features. The open agricultural fields at Palaiopyrgos provide a suitable location to integrate geophysical survey with systematic fieldwalking and digital documentation to improve understanding of the tower and its surrounding landscape.

2. Materials and methods

2.1. Survey area, methods and data capture

The survey area is centred on the tower structure at Palaiopyrgos, extending across its surrounding landscape for approximately 200 m to the south and 125 m to the north, and covering an area of 3 ha (Fig. 2). The tower marks the highest point within the survey area (32 masl), with the elevation gently dropping away through the fields to the north and south. North of the tower, the survey area included two fields, separated roughly equally by a north–south stone wall (Fig. 4), while to the south the two investigated fields were divided in the north by a curving modern concrete drainage channel, as well as a low north–south field boundary. The fields were largely free of obstacles and modern structures, except for the northwestern field where a series of excavation test trenches had been opened prior to the geophysical survey by colleagues in the Ephorate of the Antiquities of the Cyclades (Figs. 2 and 3). These provided useful subsurface structural and stratigraphic information for comparison with the geophysical data, including confirmation of the relatively shallow stratigraphy and overburden across much of the study area. Additionally,

Fig. 6. The enclosed tower complex at Cheimarrou, Naxos, showing the tower, courtyard enclosure and ancillary rooms. The rooms for olive oil production line the interior of the right hand enclosure wall (photo by E. Dodd).

a large accumulation of fieldstones to the west of the tower (between trenches 1 and 3) prevented geophysical survey in this area.

Initially, the survey was planned with two geophysical techniques, magnetometry and GPR, which are the most commonly used for archaeological prospection. By employing an integrated suite of techniques it is possible to maximize the potential to identify archaeological remains, as each technique is responsive to different physical properties. However, the uneven nature of the surface around Palaiopyrgos, including ploughing and a large number of stones, limited the prospection to magnetometry. As the sensors in a magnetometry system have no contact with the ground surface (held at a height of approximately 0.5 m), this technique was suitable to cover the survey area efficiently while maximizing the area of data capture.

The magnetometry survey was carried out using a fluxgate gradiometer Bartington Grad 601 dual sensor system. The instrument is composed of two opposed magnetic sensors that register the small variations of the magnetic field of the soil (Sala et al., 2012). It allows for the identification of anomalies caused by subsurface features whose magnetic values differ from the surrounding context, depending on the consistency and composition of the material (Aspinall et al., 2008). Results can be displayed as a shade plot where different recorded values (indicated in nano-Tesla, nT) correspond to a gradient in greyscale or using a colour palette. Data was collected along parallel traverses at a fixed distance of 0.5 m and at a sample resolution of 0.25 m. Prospection was preceded by a topographical survey in order to set up regular survey grids of 30 by 30 m, the optimal size for the survey area. The GPS survey provided a framework to correctly position the survey area as well as to precisely record the standing tower.

2.2. Data processing

Data was processed using Geoplot 4.0 software and employed despike, de-stagger and zero mean traverse filters (Aspinall et al., 2008). The composite plots were exported as raster files, imported into the project GIS, and georeferenced using GPS control points in order to compare the results with known buildings, namely the tower, and to frame the data in its topographical context. The magnetic anomalies recorded were analysed in the GIS and interpreted with relation to surface features, including the tower structure, excavation test trenches and extant field boundaries.

3. Results

The magnetometry survey recorded a series of anomalies, including features of archaeological interest, several areas of high magnetic readings likely related to modern disturbance, and magnetic spikes generated by metal objects discarded in the fields (Fig. 7).

Towards the northern limit of the survey, both fields are traversed by a substantial east–west linear feature ([1] in Fig. 7) potentially indicating an earlier land division and roughly corresponding with the orientation of the modern dirt road. This interpretation is supported by the different magnetic background values to the north and south of the feature, which fade in strength as they progress west. An indistinct cluster of anomalies was recorded in the northeast corner of the survey area, north of [1]. Elsewhere in the northeast field, an area of strong magnetic recordings [2] may be interpreted as a probable lightning strike which left remanent magnetisation in the soil. The feature is identifiable by the strong signal as well as by the typical shape of alternating positive and negative anomalies (cf. Verdonck, 2013, 45; Jones and Maki, 2005).

In the northwestern field, a positive anomaly [4] was identified in an area between trench 1 and the tower (Figs. 7 and 8). Its topographical position nearby the tower suggests a feature of archaeological interest, however the recorded width of ca. 3.6 m is more compatible with an accumulation of material or a fill rather than a structure. To the east of anomaly [4], a further area of positive magnetic readings was recorded, 15 m to the north of the tower. We hypothesise that these features are archaeological in nature, and enclose the area around the base of the tower (below). A small group of weak regular linear features was recorded at the foot of the rise that leads up to the tower [3]. While buried archaeological features are generally identified in geophysical data by their regular shape and consistent alignment (Aspinall et al., 2008), the weakness of the signal in this instance makes the interpretation uncertain. This might be an area of archaeological interest; equally, however, it could be an artefact in the data.

To the southeast of the tower, at an approximate distance of 35 m, another area of archaeological interest was recorded ([5] in Figs. 7 and 8). A group of anomalies is formed by two high magnetic concentrations together with weak, regular, linear anomalies. Whilst any immediate structural or functional interpretation is unclear, it is worth noting the topographic proximity of these features to the tower as well as their

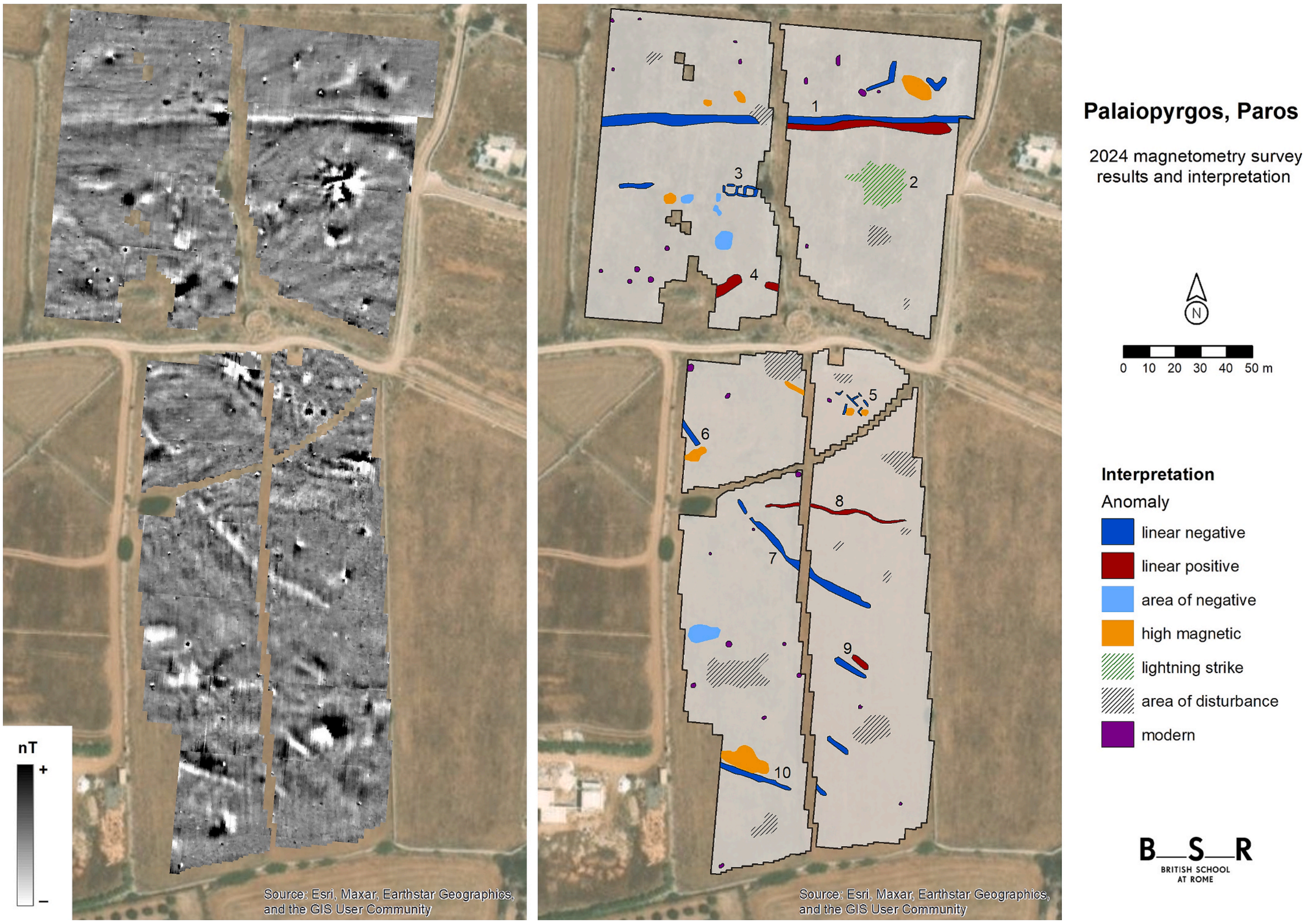

Fig. 7. Magnetometry data (left) and interpretation (right) with main anomalies and features referenced in the text indicated from [1] to [10] (figure by E. Pomar).

correspondence with high artifact densities recorded by fieldwalking and surface survey in this area, especially the substantial quantities of *amphora* sherds mentioned above. It might be possible to advance interpretations for these features upon comparison to the nature and position of ancillary spaces at other tower sites (below).

A series of linear anomalies recorded across the south of the survey area each display a continuous geometry (including [6], [7], [9] and [10] in Fig. 7), however their irregular distribution limits a more precise interpretation. These negative features may be caused by non-magnetic rock (e.g. limestone) or cut features (such as a soil-filled ditch); however, their irregular form could equally indicate a natural origin. The weak positive/negative linear anomaly [8] that traverses the southern field in an east–west direction also has an irregular form, the shape of which indicates a potential naturally formed drainage fissure in the field.

4. Discussion

This study demonstrates the potential afforded by magnetometry as a method to efficiently and effectively investigate ancient Greek rural landscapes, including those of islands like Paros and the wider Cyclades. It is important to emphasize this in light of the fact that geophysical prospection is rarely used on Cycladic islands. The methods applied at Palaiopyrgos contextualized a standing archaeological structure within its historic landscape, allowing for the identification of possible aspects of rural exploitation and *longue durée* occupation. Most of the possible structural and agricultural activity is situated in close proximity to the tower (ca. 35–40 m), taking advantage of the rise in the topography and gradually thinning further away from the tower. This pattern is consistent with evidence from other tower sites in Greece, including Cheimarrou (Naxos), Agia Triada (Amorgos) and Poros (Lefkada) (Young, 1956, 139; Morris, 2001, 296; Marangou, 2005).

While a series of features were located by the magnetometry survey, modern disturbance, including the road alongside the tower, drainage channels and modern rubbish impacted the quality of data capture. This underscores the challenging nature of undertaking geophysical prospection in rural landscapes that experienced both lengthy reuse and occupation in antiquity as well as the impact of post-ancient farming and modern development. Nonetheless, results display several linear features likely related to anthropic shaping of the landscape around the tower, along with a group of anomalies at [5] whose promising archaeological or structural characteristics warrant further investigation (Fig. 8). It remains to determine the precise nature and chronology of these features, though it is notable that they cluster in spaces where, based on comparanda elsewhere, we might expect to find ancillary structures and activity related to the ancient occupation of the tower.

One of our primary objectives was to assess the potential existence of structural and agricultural features in proximity to the tower. Comparison with other tower sites shows that circuit walls often enclosed ancillary buildings to form a courtyard complex that clusters around the tower proper (cf. Young, 1956, fig. 7). There does not appear to be a consistent pattern in terms of dimensions and shape of the enclosure, however a possible parallel with Palaiopyrgos is provided by the complex at Cheimarrou on the neighbouring island of Naxos (Fig. 6). This tower, whose dimensions are comparable to Palaiopyrgos, has a courtyard (34 x 34 m) enclosing at least seven ancillary rooms (Young, 1956, 139; Haselberger, 1972; Philaniotou, 2003; Dodd, 2022b, 163).

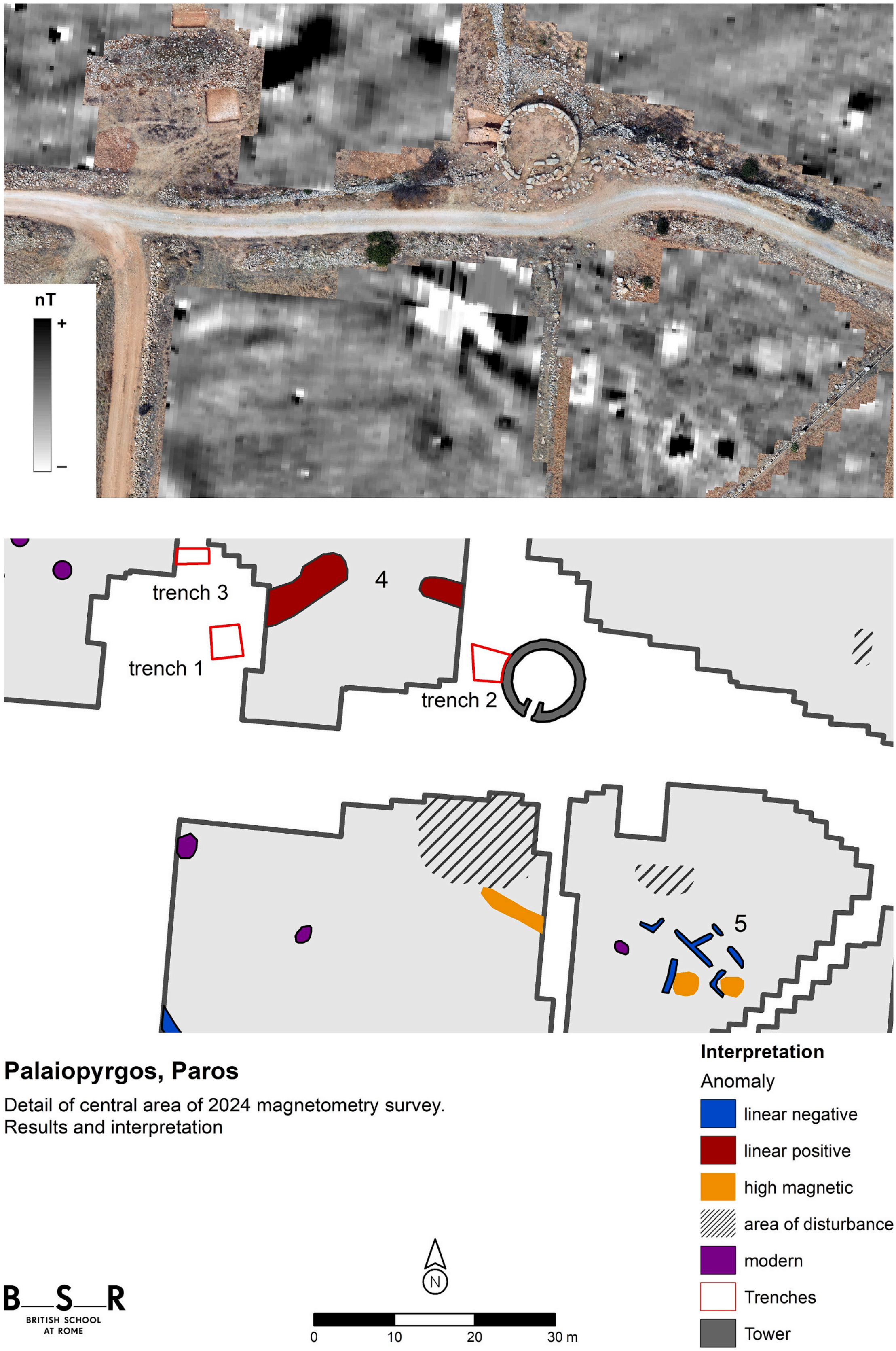

Fig. 8. Close-up of identified anomalies [4] and [5] of archaeological interest situated around the tower, with magnetometry data (above) and interpretation (below). Test trench locations are also indicated along with other anomalies recorded in the survey (figure by S. Kay).

Should a similar situation have existed at Palaiopyrgos, it is possible that some parts of a courtyard of these dimensions would not have been detected by the survey. The presence of collapsed material and accumulations of stones, which limited our ability to access certain areas (shown clearly in the underlying orthophotograph in Fig. 8, top), as well as the modern road, obscured vision of the subsurface in several areas around the tower (up to 15 m to the north, 10 m to the south, 25 m to the east, and almost 10 m to the west). The reality of this limitation was underscored by the excavation of a small test trench (trench 2 in Figs. 2, 3 and 8), which revealed a stretch of wall abutting the exterior western face of the tower and constructed in a similar technique to the tower's interior facing. It is unlikely that this is the only external wall, and entirely possible that additional annex structures exist under these rubble accumulations surrounding and in close proximity to the tower.

The character and distance of anomalies [4] and [5] from the tower align with the placement of other ancillary rooms at the tower sites of Poros and Kleismatia (Lefkada), as well as examples in southern Attica (Young, 1956; Morris, 2001, 330). Their somewhat irregular orientation can be seen at the Princess Tower at Sounion (Fig. 1.4; Young, 1956, 123). The manner in which the potential structures at [5] cluster at the distance where we might expect an enclosure wall recalls similarities to the construction of later rooms for oil production up against the interior of the enclosure wall at Cheimarrou on Naxos (Fig. 6). The dimensions of [5] are similar to those of the short stretch of wall excavated in trench 2, and, although hypothetical, this might suggest that they are similar in nature. Perhaps they represent storage chambers or rooms for production activities, such as those seen at these other tower sites. Cumulatively, this data stresses that the tower likely did not sit in isolation, despite the current invisibility of a courtyard boundary and other structures.

Previous studies of tower complexes highlight their iterative nature, with space developed and repurposed over time to fit the shifting needs of the site in relation to larger networks of production, processing, and exchange. Careful documentation of the Poros tower complex on Lefkada, for example, illustrated frequent renovation, reconstruction, and reinvention of the site over the course of its use, including for agricultural activities (Morris 2001). Glimpses of this can also be seen at Palaiopyrgos. Renovation and occupational reuse are illustrated by contrasting the earliest phases of the tower's original construction, the abutting Late Classical wall excavated in trench 2, and the traces of much later agricultural and production activities. The latter phases are most visible in the substantial quantities of Late Roman ceramic material recovered from fieldwalking along with production equipment recorded previously (Dodd, 2021).

5. Conclusion

The application of magnetometry provided an important and efficient starting point to investigate the surrounding landscape at Palaiopyrgos in a situation where GPR, perhaps better suited to these types of features, could not be applied. While the present study demonstrates the existence of features that bring Palaiopyrgos as an articulated complex closer in form to several of the excavated Cycladic tower sites, it is not yet possible to definitively align its organisation with other Greek towers that are situated within enclosed complexes and do not sit in isolation.

The geophysical data presented here may at first seem limited, especially in contrast to clearer results from the more commonly undertaken surveys of ancient towns and cities in Greece (above). However, one of the objectives of the survey was to assess to what extent this approach can detect signs of rural occupation and agricultural activity. The degree of limitation and success was therefore precisely one of the things we set out to test and forms a key takeaway from this project. While the site of Palaiopyrgos admittedly presented particular challenges in the context of this methodology (e.g. surface obstructions and shallow stratigraphy), we might conclude – perhaps predictably – that it can be difficult to detect clear and obvious signs of rural occupation around these more monumental constructions, despite published instances of success. What we present here is an attempt to show a number of ways that one might work with this limitation and still extract meaningful data and conclusions.

We encourage the reproduction of this methodological approach at similar sites, while highlighting two key considerations for future investigation at Palaiopyrgos and other Cycladic towers: 1) surveys should prioritise and focus on areas in the immediate surroundings of the tower (within ca. 35 m) at high resolution to capture the full extent of courtyard walls, ancillary structures and spaces of focussed activity; and 2) targeted GPR prospection should be employed as much as possible to capture a supplementary form of geophysical signature at higher resolution. It is unfortunate that the ground surface and physical obstructions did not permit the latter at Palaiopyrgos. Where possible, integrating these data sources should aid in more robust identification and interpretation of subsurface features.

Our results also inform and refine future excavation strategies at Palaiopyrgos. The highest priority areas of archaeological interest (e.g. [4] and [5] in Fig. 8) provide feasible, targeted areas for test trenches to be inserted. This would help to clarify the presence of structures along with their function and chronologies of construction, occupation and abandonment. The hypothesized historic field boundary ([1] in Fig. 7) provides another potential target of future research interest, especially if it relates to the organisation of this landscape in antiquity. Of equal importance, however, such results enable more effective placement of test trenches in terms of where they should *not* be positioned. This is illustrated by the outcomes from the series of trenches dug just before the geophysical survey was undertaken (Fig. 3): only trenches 1 and 2 yielded any material, structural or otherwise, that could be used to improve our understanding of the *longue durée* occupation of this area and its tower. By using the magnetometry data as a guide, these trenches could have been positioned directly over likely features of interest thereby making more effective use of limited resources in overstretched local archaeology departments. However, we also acknowledge that, in the current context of rescue excavation driven by accelerating building development pressures (below), the placement of test trenches is not always dictated by research interests, and is just as often used as a scoping tool across a broader area of land to gauge the extent and presence of archaeological material. In this case, too, we believe that the approach demonstrated in this article forms a more suitable and efficient method of capturing data for this purpose.

Dramatically increasing development pressures on Paros and in the wider region further stress the importance of this approach and prompt with some urgency the need for efficient archaeological documentation. Overtourism is leading to rapid construction of short-term rental properties across the island, with the rural landscape around Naousa becoming particularly badly affected. New buildings cluster increasingly closer to the archaeological site of Palaiopyrgos and it is necessary for local authorities to possess detailed and robust empirical data, which they can use to inform site protection strategies and respond to development proposals. The adoption of an integrated methodology, using geophysical and other survey techniques, for the prospection of these landscapes before development offers cost-effective pathways forward for cultural heritage agencies, allowing archaeologists to efficiently record surface and subsurface archaeological features to high degrees of resolution. This data can then be used to guide the placement of test trenches when more clarity is required, or to mitigate the excessive placement of test trenches when geophysical data does not indicate the presence of features, fostering more responsible development of cultural heritage landscapes.

CRediT authorship contribution statement

Emlyn Dodd: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Stephen Kay:** Writing –

review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Evan Levine:** Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Elena Pomar:** Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Investigation, Formal analysis, Data curation. **Christopher Whittaker:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation. **Demetrios Athanasoulis:** Writing – review & editing, Resources, Project administration. **Apostolos Papadimitriou:** Writing – review & editing, Resources, Project administration, Investigation.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Emlyn Dodd reports financial support was provided by The British Academy. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

References

Andrews, M., Bernard, S., Dodd, E., Fochetti, B., Kay, S., Liverani, P., Millett, M., Vermeulen, F., 2023. The Falerii Novi Project. Papers Br. School Rome 91, 9–34. https://doi.org/10.1017/S0068246223000053.

Aspinall, A., Gaffney, C., Schmidt, A., 2008. Magnetometry for archaeologists. AltaMira Press.

Beaumont, L.A., et al., 2012. New investigations at Zagora (Andros): the Zagora archaeological project 2012. MeditArch 25, 43–66.

Bevan, A., 2002. The rural landscape of Neopalatial Kythera: a GIS perspective. J. Mediterr. Archaeol. 15 (2), 217–256.

Bevan, A., Conolly, J., 2013. Mediterranean Islands, Fragile Communities and Persistent Landscapes: Antikythera in long-term Perspective. Cambridge University Press, Cambridge.

Bintliff, J., et al., 2013. The Leiden-Ljubljana ancient cities of Boeotia project, 2010–2012 seasons. Pharos 29 (2), 1–34.

Campana, S., Francovich, R., 2007. Understanding archaeological landscapes: steps towards an improved integration of survey methods in the reconstruction of subsurface sites in South Tuscany. In: Wiseman, J., El-Baz, F. (Eds.), Remote Sensing in Archaeology. Springer, Boston, pp. 239–261.

Cherry, J.F., Davis, J.L., Mantzourani, E., 1991. Landscape archaeology as long-term history: Northern Keos in the Cycladic Islands from earliest settlement until modern times. Los Angeles, Cotsen Institute of Archaeology.

Diamanti, C., 2016. The late Roman amphora workshops of Paros island in the Aegean Sea. ReiCretActa 44, 691–1667.

Dodd, E., 2020. Roman and Late Antique Wine Production in the Eastern Mediterranean: A Comparative Archaeological Study at Antiochia ad Cragum (Turkey) and Delos (Greece). Archaeopress, Oxford. https://doi.org/10.2307/j.ctvwh8c1m.

Dodd, E., 2021. Wine and olive oil across the ancient Cyclades: a preliminary report and new thoughts on the development of Greek and Roman press technology. Medite. Archaeol. 32/33 (2019/2020), 123–138. https://doi.org/10.1086/719697.

Dodd, E., 2022a. The archaeology of wine production in Roman and pre-Roman Italy. Am. J. Archaeol. 126 (3), 443–480. https://doi.org/10.1086/719697.

Dodd, E., 2022b. Wine, oil, and knowledge networks across the Graeco-Roman Cyclades: new data from Paros and Naxos in 2021. Mediterranean Archaeol. 34 (35), 155–167.

Dodd, E., 2022c. Wine, oil, and knowledge networks across the Graeco-Roman Cyclades (Greece). Papers British School Rome 90, 352–1335. https://doi.org/10.1017/S0068246222000095.

Dodd, E., 2025. The Roman Cyclades: wine production and press technology. In: Van Limbergen, D., Dodd, E., Busana, M.S. (Eds.), Vine-growing and Winemaking in the Roman World: New Data and Original Perspectives. Peeters, Leuven, pp. 385–400.

Dodd, E., Van Limbergen, D. (Eds.), 2024. Methods in Ancient Wine Archaeology: Scientific Approaches in Roman Contexts. Bloomsbury, London.

Dodd, E., Van Limbergen, D., 2025. Advancement and innovation in ancient wine research. Curr. Opin. Food Sci. 64, 101330. https://doi.org/10.1016/j.cofs.2025.101330.

Donati, J.C., Sarris, A., 2016. Geophysical survey in Greece: recent developments, discoveries and future prospects. Archaeol. Rep. 62 (2015–2016), 63–76. https://doi.org/10.1017/S0570608416000065.

Donati, J.C., et al., 2017. A regional approach to ancient urban studies in Greece through multi-settlement geophysical survey. J. Field Archaeol. 42 (5), 450–467. https://doi.org/10.1080/00934690.2017.1365565.

Donati, J.C., et al., 2020. New insights into the urban plans of Demetrias and Pherai from integrated geophysics and satellite remote sensing. In: Mazarakis-Ainian, A., Batziou-Eustathiou, A. (Eds.), Proceedings of the 5th Archaeological Meeting of Thessaly and Central Greece, 2012–2014. University of Thessaly, Volos, pp. 243–253.

Driessen, J., Sarris, A., 2020. Archaeology and geophysics in tandem on Crete. J. Field Archaeol. 45 (8), 571–587. https://doi.org/10.1080/00934690.2020.1826749.

Haselberger, L., 1972. Der pyrgos Chimarru auf Naxos. Archälogischer Anzeiger 431–447.

Haselberger, L., 1978. Der Paläopyrgos von Naussa auf Paros. Archäologischer Anzeiger, pp. 345–375.

Jones, G., Maki, D.L., 2005. Lightning-induced magnetic anomalies on archaeological sites. Archaeol. Prospect. 12, 191–197.

Kalaycı, T., Sarris, A., 2016. Multi-sensor geomagnetic prospection: a case study from Neolithic Thessaly, Greece. Remote Sensi. 8 (966), 1–14. https://doi.org/10.3390/rs8110966.

Knodell, A.R., et al., forthcoming. A regional survey of the uninhabited islands of the western Cyclades: the Small Cycladic Islands Project 2021-2022. Hesperia.

Knodell, A.R., et al., 2022. An island archaeology of uninhabited landscapes: offshore islets near Paros, Greece (the Small Cycladic Islands Project). J. Island Coastal Archaeol. 17 (4), 475–511.

Kolaiti, E., Mourtzas, N., 2020. New insights on the relative sea level changes during the Late Holocene along the coast of Paros island and the northern Cyclades (Greece). Ann. Geophys. 63 (6), OC669.

Kolaiti, E., Mourtzas, N., 2024. In: Οι Αρχαίες Λαξευτές Τάφροι Αμπελοκαλλιέργειας Της Πάρου, Αντιπάρου, Και Των Γύρω Νησίδων (κυκλάδες). Megaron the Athens Concert Hall, Athens, pp. 1–45.

Konecny, A.L., Boyd, M.J., Marchese, R.T., Aravantinos, V., 2012. The urban scheme of Plataiai in Boiotia: report on the geophysical survey, 2005–2009. Hesperia 81, 93–140.

Levine, E.I., et al., forthcoming. An island through time: surface survey and selective occupation on Strongylo (Antiparos). In: Angliker, E., de Angelo Laky, L. (Eds.), Small Island Resilience and Vulnerability, Society and Ecology in Island and Coastal Archaeology. University Press of Florida.

Lolos, Y., Gourley, B., 2011. The town planning of Hellenistic Sikyon. Archäologischer Anzeiger 1, 87–140. https://doi.org/10.34780/4o9h-o7dx.

Marangou, L., 2005. Αμοργός ιι. Athens, Athens Archaeological Society, Οι αρχαίοι πύργοι.

Mendoni, L.G., 1994. The organisation of the countryside in Kea. In: Doukellis, P.N., Mendoni, L.G. (Eds.), Structures Rurales et Sociétés Antiques. Université de Franche-Comté, Besançon, pp. 147–162.

Morris, S., 2001. The towers of ancient Leukas: results of a topographic survey, 1991–1992. Hesperia 70, 285–347.

Morris, S., Papadopoulos, J., 2005. Greek towers and slaves: an archaeology of exploitation. Am. J. Archaeol. 109, 155–225.

Nowicka, M., 1975. Les maisons à tour dans le monde grec. Wroclaw, Wydawn.

Papadopoulos, N., et al., 2015. 'Geophysical mapping of a classical Greek road network: a case study from the city of Elis Peloponnese. Archaeologia Polona 53, 489–492.

Papadopoulou, Z., 2017. Πρόσφατες αρχαιολογικές έρευνες στην Αντίπαρο. In: Triantafyllidis, P. (Ed.), Το Αρχαιολογικό Έργο στα Νησιά του Αιγαίου. Διεθνές Επιστημονικό Συνέδριο, Ρόδος 27.11–1.12.2013, vol. B. Mytilene, pp. 355–369.

Philaniotou, O., 2003. Συγκρότημα ελαιοτριβείων στον πύργο χειμάρρου στην νάξο. In: Polymerou-Kamilaki, A. (Ed.), Η Ελιά Και Το Λάδι Στον Χώρο Και Τον Χρόνο: Πρακτικά Συμποσίου, Πρέβεζα, 24–26 Νοεμβρίου 2000. Greek Folklore Research Centre, Athens.

Pomar, E., forthcoming. Tracce agricole attraverso la lente della geofisica. In: Proceedings to the conference Landscape 5: una sintesi di elementi diacronici. Giustapposizione e contaminazioni nelle ricerche interdisciplinari sul paesaggio antico. (Padova 23-24 May 2024). Archaeopress.

Provost, S., Boyd, M., 2002. Application de la prospection géophysique à la topographie urbaine, IL Philippes, Les Quartiers Ouest. Bulletin De Correspondance Hellénique 126, 431–488.

Renfrew, C., Wagstaff, J.M., 1982. An Island Polity: the Archaeology of Exploitation in Melos. Cambridge University Press, Cambridge.

Renfrew, C., et al., 2022. The sanctuary at Keros in the Aegean Early Bronze Age: from centre of congregation to centre of power. J. Greek Archaeol. 7, 1–36.

Roussos, K., 2017. Reconstructing the settled landscape of the Cyclades: the islands of Paros and Naxos during the late Antique and Early byzantine centuries. Amsterdam University Press, Amsterdam.

Sala, R., Garcia, E., Tamba, R., 2012. Archaeological geophysics: from basics to new prospectives. In: Ollich-Castanyer, I. (Ed.), Archaeology: new approaches in theory and techniques. InTech, pp. 133–166.

Sarris, A., Manataki, M., Cuenca-Garcia, C., Donati, J.C., Kalayci, T., Papadopoulos, N., 2015. Revealing the urban features of the ancient Greek city of Mantineia through the employment of ground penetrating radar. In: 8th International Workshop on Advanced Ground Penetrating Radar (IWAGPR), Florance, Italy, 7-10 Jul 2015, pp. 1–14. https://doi.org/10.1109/IWAGPR.2015.7292689.

Sarris, A., et al., 2020. Geophysical explorations of the classical coastal settlement of Lechaion, Peloponnese (Greece). In: Dabas, M., Campana, S., Sarris, A. (Eds.), Mapping the past: from Sampling Sites and Landscapes to Exploring the 'archaeological Continuum'. Archaeopress, Oxford, pp. 43–52.

Sarris, A., Kalayci, T., Papadopoulos, N., 2021. Revealing the hidden cultural landscape of the volcanic island of Therasia through geophysical techniques. In: Sbonias, K., Tzachili, I. (Eds.), Therasia III: archaeological research and landscape history of an island community. University Press of Florida, Athens, pp. 104–123.

Sarris, A., Hatzigiannakis, K., Panagiotopoulos, D., 2023. The Contribution of Geophysical and Spectral Imaging Techniques in the Archaeological Investigations of Minoan Koumasa. In: Advances in on- and Offshore Archaeological Prospection. Kiel University Publishing, Kiel, pp. 237–241.

Schmidt, A., Dabas, M., Sarris, A., 2020. Dreaming of perfect data: characterizing noise in archaeo-geophysical measurements. Geosciences 10, 382. https://doi.org/10.3390/geosciences10100382.

Seifried, R.M., Parkinson, W.A., 2014. The ancient towers of the Paximadi peninsula, southern Euboia. Hesperia 83 (2), 277–313.

Smekalova, T., Bevan, B.W., Chudin, A.V., Garipov, A.S., 2016. The discovery of an ancient Greek vineyard. Archaeol. Prospect. 23, 15–26.

Theocaris, P.S., Liritzis, I., Lagios, E., Sampson, A., 1996. Geophysical prospection, archaeological excavation, and dating in two Hellenic pyramids. Surv. Geophys. 17, 593–618.

Trinks, I., et al., 2017. Documenting Bronze Age Akrotiri on Thera using laser scanning, image-based modelling and geophysical prospection. In: 3D Virtual Reconstruction and Visualization of Complex Architectures, 1–3 March 2017. Nafplio, Greece, pp. 631–668.

Tsilimigkas, G., Gourgiotis, A., Derdemezi, E.-T., 2022. Spatial planning incompetence to discourage urban sprawl on Greek islands: evidence from Paros, Greece. J. Coastal Conserv. 26.11. https://doi.org/10.1007/s11852-022-00859-2.

Tsokas, G.N., et al., 2023. Innovative and conventional geophysical investigations at the Hamza Bey (Alcazar) monument in Thessaloniki, Greece. In: Anagnostou, G., Benardos, A., Marinos, V.P. (Eds.), Expanding Underground – Konwledge and Passion to Make a Positive Impact on the World. CRC Press, London, pp. 377–384.

Vaïopoulou, M., et al., 2023. The Palamas Archaeological Project: a preliminary report of the 2022 fieldwork conducted by the ongoing Greek-Swedish archaeological field programme in Palamas, region of Karditsa Thessaly. Opuscula 16, 61–85. https://doi.org/10.30549/opathrom-16-03.

Vargemezis, G., et al., 2013. Ground penetrating radar and electrical resistivity tomography for locating buried building foundations: a case study in the city centre of Thessaloniki Greece. Bull. Geol. Soc. Greece 47, 1355–1365. https://doi.org/10.12681/bgsg.10946.

Verdonck, L., 2013. Fluxgate gradiometer and GPR survey to locate and characterize the perimeter, early Imperial centre and street network of the Roman Town Mariana (Corsica). In: Johnson, P., Millett, M. (Eds.), Archaeological Survey and the City. Oxbow, Oxford, pp. 241–260.

Verdonck, L., Launaro, A., Vermeulen, F., Millett, M., 2020. Ground-penetrating radar survey at Falerii Novi: a new approach to the study of Roman cities. Antiquity 94, 705–723. https://doi.org/10.15184/aqy.2020.82.

Young, J., 1956. Studies in south Attica: country estates at Sounion. Hesperia 25, 122–146.

Zananiri, I., Hademenos, V., Piteros, C., 2010. Geophysical investigations near the ancient agora at the city of Argos Greece. J. Geophys. Eng. 7, 174–182. https://doi.org/10.1088/1742-2132/7/2/S03.