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MAGNETOMETER PROSPECTION AT SAN BASILIO DI ARIANO NEL POLESINE, 2020-2024

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1. Environmental and archaeological setting

Under favourable conditions, geophysical methods provide archaeologists with unique tools to investigate the spatial characteristics of ancient sites and landscapes. At the Archaic and Roman site of San Basilio di Ariano nel Polesine, the conditions for geophysical prospection are extraordinary, as we discovered during a series of magnetometer surveys between 2020 and 2024. In this contribution, we explain the approach and method applied at San Basilio and review why it worked so well at our site. Moreover, we discuss how geophysical data enhance our understanding of the site in conjunction with the ongoing excavations and geoarchaeological work in the Po delta.

The archaeological site of San Basilio is located just north of a curve in the Po di Goro, a southern branch of the Po river that today constitutes the border between the Italian regions of Veneto and Emilia Romagna (fig. 1). At our site, the river cuts through a fossil dune ridge which formed during the

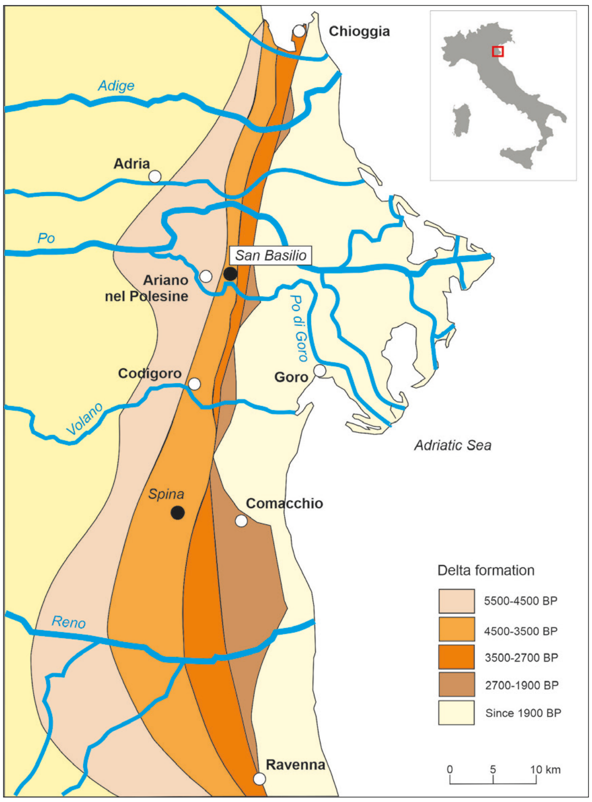

Figure 1. Schematic overview of the Po delta with the formation phases of ancient dune ridges and delta lobes until the Roman period (after Stefani and Vicenzi 2005, fig. 13). Present-day towns are indicated with white dots, archaeological sites discussed in the text with black dots.

earlier phases of Bronze Age, between ca. 4500-3500 BP (Stefani and Vicenzi 2005, fig. 13). During Archaic and Roman times, the Adriatic coastline would have been right behind the dune ridge, where new delta lobes formed during the first millennium BCE. At present, high dikes reinforce the banks of the Po di Goro about 350 m south of the archaeological area (fig. 2). In the past, river branches may have been much closer to the site, as is suggested by palaeochannels visible in aerial photos.

The site was first occupied in the 6th and 5th centuries BCE, a phase associated with Etruscan expansion in the Adriatic (Iadicicco *et alii* 2022). San Basilio was at the crossroads of inland and maritime exchange networks, as is evidenced by artefacts of Etruscan, Venetian, and Greek origin (De Min 2001). In the first century BCE, an area to the south of the Archaic site was settled, best known from a large villa complex located partly in the orchard of the present-day Agriturismo Forzello (locations in fig. 2). This was later extended with a large storage building (a *horreum*, 2nd-3rd century CE). From the 4th century CE, a paleochristian community settled at San Basilio, as is seen in graves found directly west of the *horreum*. All phases are likely to have left traces beyond the known sites, and it is our current task to map the spatial organization and character of these consecutive occupations.

The landscape setting of the Etruscan and Roman parts of San Basilio is still poorly understood. The Archaic inhabitants settled on a slightly elevated dune ridge which prevented them from wet feet, but it is unclear to what extent they managed the surrounding coastal wetlands, for instance with canal systems. Nor do we know how large the site was. These questions also apply to the Roman site, which is located south of the Etruscan zone. Previous excavations in the 1980s and 1990s revealed a large building for the storage of agricultural produce, which suggests that San Basilio was well-connected in regional infrastructure. However, the presence of a road network and/or a river harbour has so far not been confirmed. As these topics are difficult to answer with targeted excavations, we applied geophysical surveys to investigate the spatial organization of the two occupation areas and their setting in the wider delta landscape. In the following, we will first elaborate on what geophysical prospection entails in archaeological research, and then move on to the methods and aims of our surveys at San Basilio.

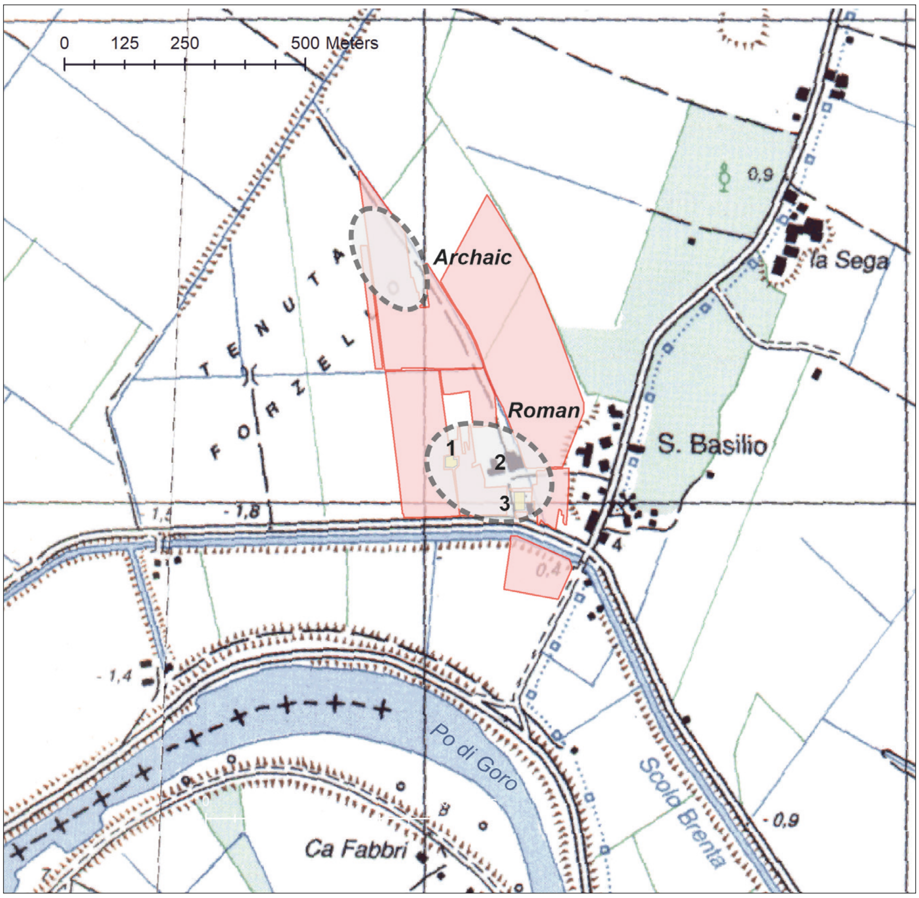

Figure 2. San Basilio di Ariano nel Polesine. The Archaic and Roman occupation zones are indicated with a dashed line. The magnetometry areas surveyed between 2020-2024 are indicated in pink. 1: the Roman villa complex; 2: Agriturismo Forzello; 3: the storage building / *horreum*. Background: IGM 1:25.000 topographic map (source: ESRI online resources).

2. Geophysics and geophysical prospection

Geophysics is the study of the physical aspects of the Earth and its immediate environment using quantitative methods. These methods can be either 'active', meaning that they selectively alter a physical aspect of the Earth and measure the effects of such short-term changes (e.g., ground penetrating radar and electrical resistivity), or 'passive', meaning that they measure physical properties of the Earth without altering them (e.g., magnetometry). They can be applied at a planetary scale (monitoring of tectonics and volcanic activity), large exploratory scale (detection of natural resources such as oil and gas), but also to small-scale cultural heritage (identification of archaeological remains, monitoring of buildings). In recent decades, applied geophysics has become a standard component of archaeological prospecting, using techniques and equipment suitable for the detection of relatively small-scale, near-surface targets.

Compared to traditional archaeological methods such as excavations, geophysical methods have distinct advantages: they are non-destructive and can produce high-resolution information about the presence of objects below the ground in a relatively short time. Furthermore, recent technological developments allow to survey extensive areas using large (motorized) arrays, as well as a high positioning accuracy using GNSS (Global Navigation Satellite System) antennas attached to the equipment. At the same time, geophysical data are not without problems: they do not provide chronological detail and their interpretation requires both cultural and geoscientific knowledge. Moreover, the detectability of archaeological remains in a given context depends on a specific geophysical contrast between the anthropogenic object and its natural environment. Such contrasts may be picked up by a specific geophysical technique, but not by another. Therefore, the success of geophysical prospection depends on a wide variety of factors including soils and geology, burial depth, materials and dimensions of the archaeological remains, post-depositional processes and modern disturbances, but also the chosen method and survey strategy. In the following, we discuss these aspects of detectability for the different archaeological and natural features present at San Basilio.

3. Method and aims of the geophysical survey at San Basilio

At San Basilio, we chose magnetometry using magnetic gradiometry as our main survey method. We used two similar gradiometer arrays mounted with multiple sensors on mobile carts, which we towed/pushed on foot across the fields in parallel lines (fig. 3). Gradiometer sensors have two coils, one close to the surface and one further away, each of which picks up different magnetic densities. The recorded value is the difference between the two coils, which expresses the vertical difference in the vertical component of Earth's magnetic field. In our case, we directly positioned the data through a GNSS antenna attached to the cart, resulting in georeferenced datasets with an accuracy of ca. 2 cm. After processing, the data are visualized

Figure 3. Magnetometer survey in July 2023, using a LEA Mini system with four SENSYS FM650 probes and a Leica GS15 GNSS antenna mounted on the cart. In the background the dike of the Po di Goro is visible (photo W. de Neef).

in 2D maps of local variations in the Earth magnetic field. These may be caused by a variety of natural and anthropogenic impacts, which we discuss below. Depending on the depth, dimensions, and material properties of subsurface objects, as well as their magnetic contrast with the natural surroundings, we are generally able to detect archaeological remains to depths of ca. 1.5 – 2 meters.

Our choice for magnetometry was informed by the nature of the archaeological remains uncovered by previous excavations, most notably the large storage building (*horreum*) which now composes the most visible remains of the site (location marked in fig. 2). It has thick walls and pillar foundations built in bricks, buried within 2 meters of the present-day surface. Burnt materials like tiles, bricks or furnaces have distinct magnetic properties altered by exposure to high temperatures (so-called 'thermoremanent magnetization') that usually produce a strong contrast with surrounding natural soils. Since San Basilio is situated in the Po delta, where no natural rock is available for construction, we expected other possible buildings here to be also built in bricks.

There are also other types of archaeological remains that can be detected using the effect of burnt materials, such as kilns or structures destroyed by fire, due to the thermoremanent magnetization of burnt matters such as burnt bdaub or clay. The latter was of direct relevance for the prospection of Archaic San Basilio: here we did not expect buildings built in bricks, but rather in perishable organic materials, similar to the buildings at the contemporary site of Spina, further south in the Adriatic delta (Zamboni 2017, 55; Kay *et alii* 2020). During the first occupation phase of Spina (6th century BCE), houses were built with wood, reeds, and unfired clays. Such materials typically do not produce a significant magnetic contrast unless they are burnt. Therefore, the tragic event of a house destroyed by fire may be a lucky circumstance for the archaeological prospector, centuries later. At San Basilio, we indeed think this was the case, as we will see below.

However, the aims of our survey were not limited to the mere identification of buildings. A specific goal was to establish the presence of a road system alongside which Roman San Basilio formed. The course of an ancient coastal road, following the fossil dune ridges, is more or less secure, although the houses and street of the present-day hamlet prevent us from confirming its precise location. More difficult is the course of the *Via Annia*, which presumably branched off towards the northwest, at or near San Basilio. The *Via Annia* was built in 131 or in 153 BCE and connected *Atria* (today Adria) with *Patavium* (Padova) and *Aquileia*. If it indeed branched off at San Basilio, this would underline the strategic importance of the site and explain the presence of the large storage building known from the legacy excavations. Roman roads are, in theory, favourable to geophysical detection because of their construction with gravel beds, ditches, and stone slabs of igneous or metamorphic origin, which are likely to cause a strong magnetic contrast. Unpaved roads, which manifest as compacted clayey layers in the archaeological record, often demonstrate increased magnetization. This is caused by the incorporation of settlement material such as organic matter, ceramic fragments, and ashes.

Apart from buildings and roads, magnetometry is also highly suitable for the detection of other types of archaeological features. Iron artefacts constitute an obvious category. Metal objects can be identified with a magnetometer if they produce a magnetic contrast, such as iron (ferromagnetism). However, many metals are not magnetic, including bronze and gold. Because the variations in the Earth's magnetic field may be caused by a variety of material and soil processes, including burning, bacterial activity, and chemical alterations, magnetometers can detect a very broad range of archaeological traces, including pits, ditches, canals, fireplaces, kilns, and graves - of course always depending on the geophysical contrast with the surrounding soil. In the context of San Basilio, this broad applicability is especially useful since we are dealing with different archaeological phases and a wetland environment. In this landscape, we expect organic materials to cause magnetic contrasts due to the formation of biogenic magnetite in organic deposits in anaerobic environments.

At a broader scale, the wetland environment unites the research topics of occupation, architecture, and infrastructure during the Archaic and Roman phases. During both phases, the inhabitants of San Basilio settled on the higher and drier parts of the coastal zone, but surely with direct access to (navigable) waterways that would have been an important part of delta infrastructure. Mapping the palaeochannels and other geomorphological aspects of the ancient delta, using their various magnetic responses, thus provides a spatial layer of information that helps us to understand the location choice and layout of the archaeological evidence. In addition, these data also help us to assess and monitor the site's preservation.

4. Results

Between 2020 and 2024, we covered an area of more than 20 hectares around the Agriturismo Forzello (fig. 4). The sediments of the Po delta generally have a low magnetization, so that archaeological traces and geomorphological features stand out clearly, even those consisting of weakly magnetized materials. Here, we give a concise overview of our results so far, according to the types of archaeological remains we expected to be able to find (as discussed above).

Buildings

In the Archaic part of the site, we expected difficulties in identifying structures made of organic materials and unfired clay – unless they were (intentionally or accidentally) destroyed by fire. Indeed, it is difficult to establish a consistent pattern of buildings such as seen in the magnetometer surveys of Spina (Izzet 2010; Kay *et alii* 2020). However, there are (semi-)rectangular features with strong dipole magnetic gradient values that indicate thermoremanent magnetization due to fire. These occur in different parts of

Figure 4. Overview of the results of the magnetic gradiometry surveys. Dynamic range +/-5nT.

the site and have different orientations and dimensions. The largest one measures ca. 4 x 14 m and is oriented SW-NE [feature 1 in fig. 5]. A similar structure further north measures ca. 4 x 12 m and is oriented NW-SE [2]. Both are surrounded by linear structures with positive (black) magnetic amplitudes, which we tentatively interpret as the borders of raised platforms to prevent the buildings from flooding, similar as seen in Spina.

In the Roman part of the site, magnetometry has proven to be very useful in the detection of a range of buildings. The most conspicuous is the isolated square building in the west of ca. 24 x 24 m, surrounded by the foundations of a portico [feature 6 in fig. 6]. It shows very strong magnetic nomalies with dipole characteristics, which suggests that strongly magnetized building materials were used, and that it is buried close to the surface. Indeed, during the survey we saw trachyte blocks in the field ditch cutting through the building, indicating that this non-local, highly magnetic rock was transported to San Basilio for construction. Additional measurements with a magnetic susceptibility meter indeed showed high magnetic susceptibility

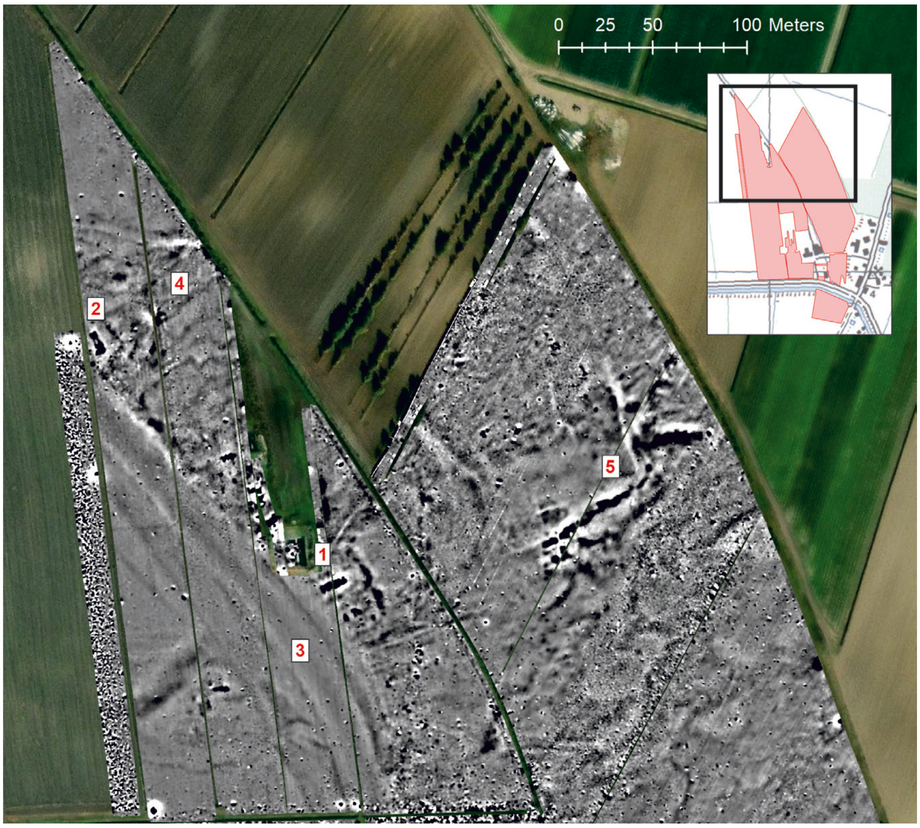

Figure 5. Detail of the northern part of the survey area. Features discussed in the text are labelled with red numbers. Dynamic range +/-5nT.

readings of the trachyte blocks. Trachyte is an extrusive igneous rock that occurs in the Colli Euganei, some 80 km away, and would have been transported to San Basilio by either land or water.

We also saw trachyte blocks in the ditch at the north of the Roman site. The magnetometer survey here revealed a rectangular building with at least one clearly recognizable room of ca. 11 x 12 m [7]. Other parts of this building are damaged by ploughing, as is indicated by the dense cluster of small positive and dipole magnetic anomalies. We think that trachyte may also have been used in the construction of this building, apart from the many tiles and fragmented bricks we saw on the field surface during the survey.

The magnetogram also showed the extent of the villa currently excavated by the University of Padova at the centre of the site. Here, too, the building is impacted by ploughing, as can be deduced from the dense cluster of small anomalies. Still, we can discern rectangular spaces to the south [8] and west [9] of the excavation area. Moreover, the very clear demarcation of the villa zone, possibly by a ditch (the linear feature with positive magnetic amplitudes curving around the villa zone in the west and south) is conspicuous [10], even if it is partly impacted by the strong magnetic disturbance of an electricity pole [11]. The garden area directly south of the Agriturismo Forzella [12] is difficult to interpret, as it is strongly disturbed by iron poles and objects hanging in the trees.

The eastern part of the Roman site holds a special discovery: here we detected the extension of the storage building [13] excavated in the 1990s. This building now appears to be part of a large structure centred on a courtyard opening to the south [14]. Considering the excavated part, the total structure measures more than 80 m from E-W. The N-S dimensions are difficult to establish, as the building is cut by the tarmac road and covered by an orchard, but must be at least 75 m. The building has several rooms of which we see the division walls, but also an inner portico with pillar foundations. A room at the center (24 x 13 m) has two parallel rows of five semi-rectangular pillar foundations each [15]. These resemble the pillar foundations seen in the excavation of the storage building; therefore, we think they are also made in bricks. The magnetic values of this large building are generally positive and weaker than those of the isolated rectangular building in the west. This suggests that trachyte was not used in its construction, or that it was buried at larger depth.

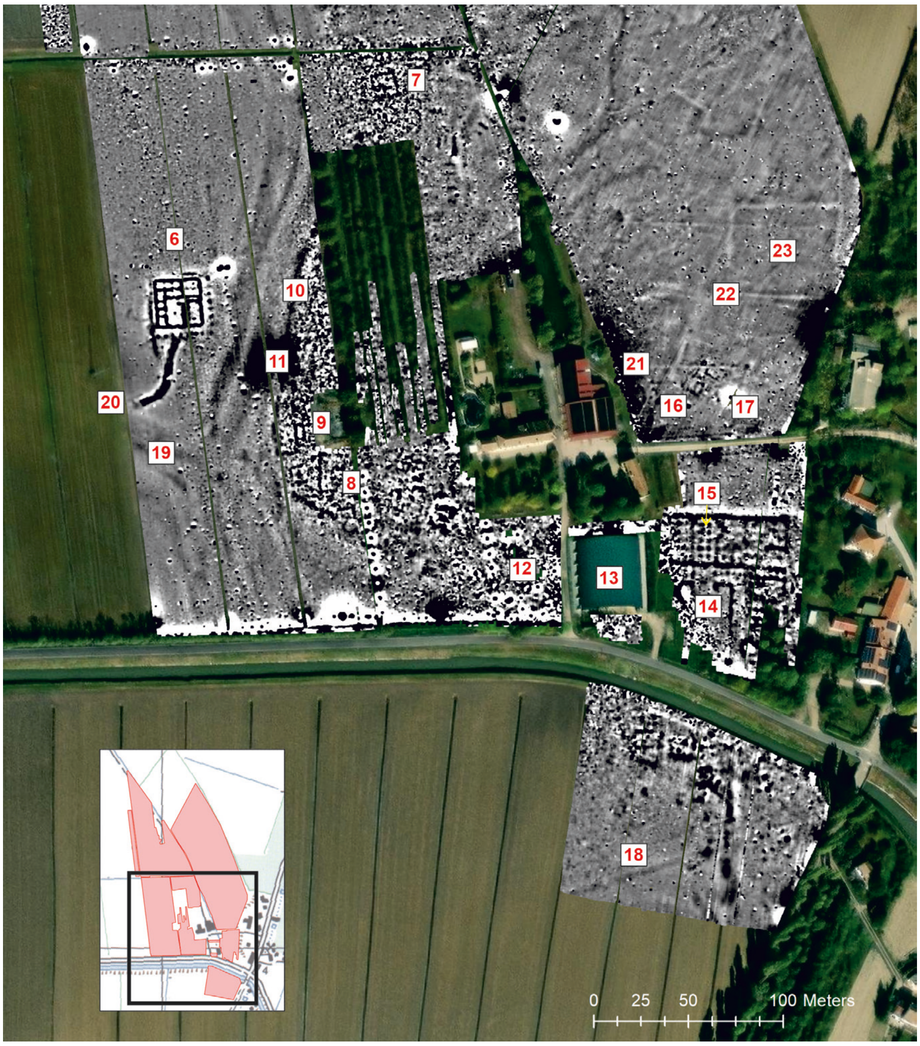

Figure 6. Detail of the southern part of the survey area. Features discussed in the text are labelled with red numbers. Dynamic range +/-5nT.

North of the large courtyard building are further traces of a rectangular building [16], partly disturbed by an electricity pole [17]. This consists of a cluster of rooms and has a different orientation than the other structures at Roman San Basilio. At this point, we do not know whether this building belongs to the Roman occupation phase, or that its different orientation is an indication for another phase. In any case, the magnetometer data show that all buildings at San Basilio are oriented slightly different.

Roads and infrastructure

One of the main aims for the geophysical work was to establish the presence of a Roman road. So far, the results are rather ambiguous. We do not have indications for a Roman road built with trachyte slabs or other igneous rocks typically used, which would have produced elevated magnetic values. However, roads in the wetland environment of San Basilio may have been constructed differently. A raised causeway is a possibility, consisting of a reinforced embankment with ditches on either side. Such an interpretation has been proposed for the large curvilinear feature cutting the Etruscan settlement [feature 3 in figure 5]. However, its widely irregular western border rather suggest that this is a hydrological feature (paleochannel or canal) and not a piece of Roman engineering. A series of manual corings perpendicular to the feature indeed confirm that this was a channel filled with clayey and loamy clay deposits (Garatti *et alii* 2021). C14 dates from one core date the filling of the channel between the Roman imperial age and the late Antiquity.

A more likely candidate for a road is the weak, SW-NE running linear feature in the southernmost survey area [18 in figure 6]. It is also visible as a dry zone on aerial photos. It runs south of a series of rectangular structures directly bordering on the present-day canal, and intersects a N-S oriented linear feature which we tentatively interpret as a waterway. The continuation of both linear features should be investigated further to understand how they are placed in the wider landscape.

Further indications of infrastructure are present in the Etruscan part of the site. Especially in the northernmost peak of the survey area, a series of linear features may pertain to a regular street (or canal) system inside the settled zone [4 in figure 5]. They are aligned with the building mentioned before.

Other traces

The impacts of hydrological processes in the delta wetlands are clearly visible in the magnetometer data. The curving paleochannel [19] in the SW seems to cut part of the site. If this river branch indeed belongs to a post-Roman phase, it may have destroyed part of the archaeological area. An indication for this is provided by the abrupt end of the curvilinear feature attached to the south of the isolated western building [20]. Its positive magnetic intensity suggest that this is a ditch or canal filled with organic materials. The previously mentioned large curvilinear feature cutting the Archaic site [3] is another example of intrusive waterways impacting on traces from earlier periods. In the NE, a cluster of linear magnetic features with relatively strong positive anomalies seems related to the Archaic site [5]. It may be part of the site's delimitation to the E, or a set of canals employed in the water management of this side of the fossil dune ridge.

The easternmost part of the research area holds several linear features with weak negative magnetic gradient values [21, 22]. These have the same general orientation as the buildings of Roman San Basilio, but there appear to be different phases: one E-W running line [21] cuts the building with the divergent orientation mentioned earlier. The negative magnetic values indicate that these features are made of diamagnetic materials (i.e., materials that repel an external magnetic field) such as limestone, or ditches filled with sandy material free of organic fractions perhaps used to demarcate field borders or perhaps large basins. The clearest demarcated area measures ca. 48 x 57 m [23]. The lines are not entirely regular and may belong to the Roman occupation phase, since they have the same orientation. In any case, they are completely different from the actual field borders and thus clearly pertain to a previous occupation phase of San Basilio.

5. Conclusion and outlook

In this brief discussion of the goals, method, and results of the magnetometer surveys at San Basilio, we showed how we have been able to identify different types of ancient human activity. These include previously unknown buildings and shed new light on the character and spatial organization of the archaeological zones. Magnetometry has proven to be very successful in detecting a wide range of archaeological materials, ranging from highly magnetic trachyte blocks and bricks to weaker traces such as organic fills and earthworks used for raised platforms. At the same time, we have shown that the interpretation of such data is not easy: it requires a detailed assessment of single magnetic anomalies in relation to their wider anthropogenic and natural context. For now, many questions remain open. Only the interdisciplinary exchange between prospectors, excavators, material experts, and soil scientists will advance our understanding of how the inhabitants of Archaic and Roman

San Basilio shaped their direct surroundings, and conversely how centuries of alluvial landscape formation processes have affected the archaeological site. In the future, we hope to continue the geophysical surveys in order to establish the extent of the occupation in the different phases.

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References

De Min M. 2001, *San Basilio*, *Bibliografia topografica della colonizzazione greca in Italia e nelle Isole Tirreniche* 17 (1), pp. 239-243.

Garatti G., Giunto A., Iadicicco G. 2022, *Indagini multiscalari del sito di San Basilio di Ariano nel Polesine (RO)*, in *Le lenti del Passato. Approcci multiscalari all'Archeologia*, edited by L. Filoni, G. Garatti, A. Giunto, G. Iadicicco, N. Ruberti, F. Spagiari, Roma, pp. 77-88.

Iadicicco G., Vicenzutto D., Paltineri S. 2022, *Cluster analysis, classificazione numerica e remote sensing. Metodi di analisi integrati applicati alla survey presso San Basilio di Ariano nel Polesine (RO)*, in Archeologia e Calcolatori, 33, pp. 53-76.

Izzet V. 2010, *New approaches to Etruscan cities: the case of Spina*, in *Etruskischitalische und römisch-republikanische Häuser*, edited by M. Bentz and C. Reusser, Wiesbaden, pp. 117-121.

Kay S., Pomar E., Hay S. 2020, *Spina Revisited: the 2008 geophysical prospection in the light of the excavation results*, in *GROMA Documenting Archaeology*, 5, pp. 1-16.

Stefani M., Vincenzi S. 2005, *The interplay of eustasy, climate and human activity in the late Quaternary depositional evolution and sedimentary architecture of the Po Delta system*, in *Marine Geology*, 222, pp. 19-48.

Zamboni L. 2017, *Case di legno e d'argilla. Urbanistica, tecniche edilizie e vita quotidiana a Spina tra VI e IV sec. a.C.*, in *Spina. Neue Perspektiven der archäologischen Erforschung. Tagung an der Universität Zürich vom 4.–5. Mai 2012. Zürcher Archäologische Forschungen 4*, edited by C. Reusser, Rahden/Westfalen, pp. 51-59.