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production and preparation. Emmer glume bases are the most abundant form of chaff, but the commonest cereal is barley. The preponderance of barley and emmer chaff suggests that the composition of the deposit is not just a cross section of everything that was being consumed on the site but indicative of the way that materials were consumed. Free-threshing wheat Triticum durum/aestivum was also identified in smaller quantities. One example of bitter vetch was recorded, as well as grape pips, fig seeds, and hazelnut.

The two Bronze Age structures at the San Giovanni site, of transitional date between the Early Bronze – Middle Bronze Ages, are an important discovery for the southern Abruzzo where few Bronze Age sites have been identified.

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CIVITA DI TARQUINIA (COMUNE DI TARQUINIA, PROVINCIA DI VITERBO, REGIONE LAZIO)

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The Università degli Studi di Milano began its research on the Civita di Tarquinia in 1982 under the direction of Maria Bonghi Jovino. In 1997 an assessment of past aerial photographs, geophysical prospection and a survey of the fortifications was undertaken (Bonghi Jovino, 1997; Harari, 1997; Cavagnaro Vanoni, 1997). Subsequently the investigations of the Tarquinia Project (directed since 2004 by Giovanna Bagnasco Gianni) have continued this research and focused on the excavation of a monumental complex and on the sanctuary of the Ara della Regina (*Tarchna*, 1997, 1999, 2001, 2012) as well as studying the chronological phases of the necropolis (Marzullo, 2016, 2017) and the topography of the ancient city (Marzullo, 2018). In partnership with the Politecnico di Milano (Bagnasco Gianni, 2014, Marzullo, 2018) work has begun on a systematic study of the fortifications aimed at the reconstruction of the city enclosed within the walls (Marzullo, Piazzi, 2017; Bagnasco Gianni, Garzulino & Marzullo, 2017). The research has involved the collection of all available cartography, aerial photos and LiDAR data, as well as other information obtained from historical documentation and thematic representations (from the Renaissance through to the present) to fully understand the area of the Civita. One of the most significant outcomes of a collaboration with the Soprintendenza Archeologia, Belle Arti e Paesaggio per l'area metropolitana di Roma, la provincia di Viterbo e l'Etruria meridionale has been the creation of a Geographical Information System (GIS) of the Civita with 220 site entries including several which were poorly known. Building upon the creation of this dataset, it was possible to begin to assess the geophysical surveys conducted by the Fondazione Lerici from the 1960s to the 1980s. The data had numerous difficulties for its useful application, the foremost of which was its correct topographical positioning, as well as the problems of interpreting this legacy data.

In 1964 the chance discovery of painted architectural terracottas near the Ara della Regina sanctuary suggested that an early temple may have been located in the vicinity. After several trial trenches had been unable to locate any structures, the former Soprintendente Mario Moretti requested a geophysical survey of the area following its successful application in the area of

the necropolis. The reports in the archive of Fondazione Lerici show that a trial survey was undertaken in the autumn of 1964, during which only a small area was investigated. The successful results of the survey encouraged the wider inspection of the area and in 1965 Fondazione Lerici explored a further 4 hectares, with the aim of recording both elements of the city plan and investigating the existence of a temple. Several linear anomalies indicated the existence of a regular plan and subsequently 13 annual seasons were undertaken through until 1981 which covered a large part of the plateau. Alongside the excavations a number of cores were made in 1985 in order to clarify the geophysical survey results. In total the survey investigated approximately 60 hectares (Fig. 1a), 600,000 measurements of the intensity of the earth's magnetic field were taken and 135 individual cores were made to confirm the buried structures. However, despite several attempts to process the magnetometry data with simple mathematical filters and for the data to be represented digitally, the overall plan had to be created with hand-drawn symbols and remained unchanged for a long time.

In the 1990s a research initiative between the Fondazione Lerici and the Institute of Mining in St Petersburg reanalysed the data. The 600,000 magnetometry measurements of the surveys were pre-processed in order to obtain quickly and efficiently a different kind of data representation and a revised dataset where modern noise was removed. However, the reanalysis did not produce an overall synthesis of the data as it focused exclusively on limited areas, including the 'monumental complex' and the Ara della Regina sanctuary as well as highlighting some anomalies possibly related to a road network (Cavagnaro Vanoni, 1997; Cucarzi, Gabrielli & Rosa, 2001; Cavagnaro Vanoni, 1989).

The difficulty in the interpretation of this dataset is due to several factors including the long occupation of the city, its level of conservation and the effects of modern agricultural practice (including metal fences and ploughing). The natural stone of Tarquinia also has variable characteristics which appear to influence the results of magnetometry. However, through a comparison of the cores and the magnetic anomalies it has been possible to demonstrate the usefulness and reliability of some of the data. Above all, during the initial phases of the work at the end of the 1970s, but also afterwards during the shorter seasons of work by the Fondazione Lerici, the data collection and post-processing had problems which affected the overall interpretation. This meant that some results were removed from the final published survey even if they contained valuable information (Fig. 1, a–c). The positioning issues of the survey can be summarized as follows:

1. The Fondazione Lerici surveys were set according to magnetic North.
2. Each square of the grid drawn on the map corresponds to a predetermined linear length without factoring for the changing topography of the terrain. Therefore, the grids do not match any corresponding features on the cartography and furthermore, to produce the large-scale diagrams, the data were reduced and merged, producing further distortions.

To correctly reposition the survey, the data needs to be stretched to the topography of the site. However, due to the length of time that has passed since the surveys, the only reliable fixed points are a few monuments on the site and the output data itself of the earlier surveys. Given the importance of this dataset, which could shed new light on the urban layout of the city, and through the graphical support provided by the GIS archaeological map based on the LiDAR coverage, it was decided to apply a new method in order to enhance the legacy data.

In collaboration with the British School at Rome, three sample blocks each of 60 m by 90 m were chosen as reference areas to locate the earlier work. The areas were subject to new gradiometry surveys which were subsequently overlaid with the previous *Fondazione Lerici* outputs. The new surveys were placed according to a

Fig. 1a. Area covered by geophysical prospecting as published at the end of the investigation in 1997.

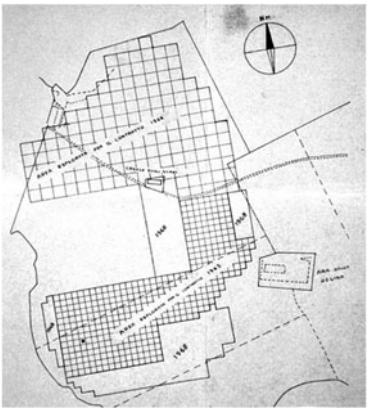

Fig. 1b. Areas investigated in 1964–8 west of the Ara della Regina and not included in subsequent editions of the work.

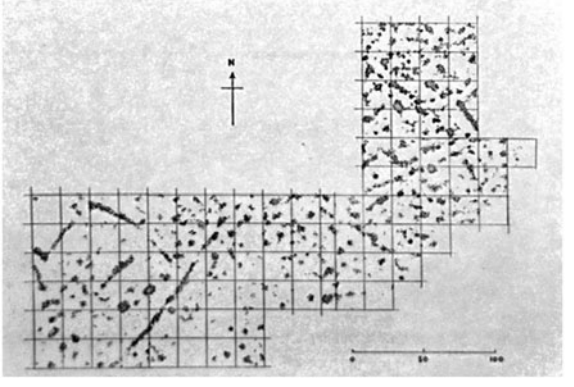

Fig. 1c. Results of the 1964–5 campaigns not included in subsequent editions of the work.

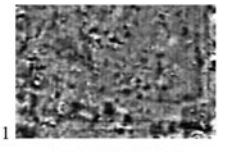

Fig. 1d. Positioning of the sample areas and the *Fondazione Lerici* grid on the LiDAR data. The routes of the ancient roads are highlighted following recent work by *Università degli Studi di Milano* (Marzullo, 2018). On the right are the results of the three areas investigated in 2017.

number of criteria including areas with little modern interference, areas where anomalies were clearly distinguishable on the *Fondazione Lerici* outputs and areas that overlapped with previously unexplored areas, therefore increasing the overall coverage of the site.

The first sample area chosen was situated to the west on the plateau (Fig. 1, d1). The new data has allowed for the earlier work to be more securely located through the comparison of several linear anomalies in each dataset. Moreover, several rectangular anomalies were also recorded that may be associated with regularly arranged buildings, several blocks of which can be partially distinguished on the surface.

The second area chosen lay to the south-west of the Ara della Regina where the earlier campaigns of 1964 had begun (Fig. 1, d2). Similarly to the other areas, the positioning of the survey was complicated by the steep terrain below the monument. However, the new survey identified high magnetic linear anomalies that matched precisely with the results of 1965–66. This has allowed for the earlier data to be anchored in this area and for other features in the earlier outputs to be rectified (Fig. 1, c). The new data also highlights with greater clarity the form of a rectangular building in the centre of the survey area, which may be associated with the sacred structure with decorated terracottas which has yet to be identified and from where the research began in 1964.

The third area surveyed lay immediately south of the Ara della Regina (Fig. 1, d3). The new study identified a series of quadrangular structures arranged along the north–south road previously identified by the *Fondazione Lerici* on the eastern side of the test area. Where the magnetometry survey was extended for the first time the results indicated the likely presence of a road leading towards the temple, as well as other structures in the southwest portion of the grid.

In conclusion the new geophysical surveys, together with the GIS and archaeological evidence described above, combined with the precision and versatility of the LiDAR data, have combined to fulfil the potential of the earlier geophysical survey. It was possible to compare signs clearly associated with buried archaeological remains to the results of magnetometry and subsequently verify this data by querying the LiDAR point cloud and obtaining their position. This method has overcome the issue created by the disappearance of the topographic references used by the earlier work and the errors that occurred in rescaling the data by the earlier survey. The ability to precisely anchor the geophysical prospection has allowed for an initial interpretation to be made of the urban plan of the Civita di Tarquinia and for the planning of future research.

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