# Preliminary geophysical investigation in the archaeological site of Bocca delle Menate (Comacchio, FE)

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**Abstract**. The Bocca delle Menate archaeological site is located in Comacchio town (FE) and provides important evidence of the Roman presence in the Po Delta (Italy). The excavations realized sixty years ago have confirmed the presence of an extensive Roman villa and some part of it was highlighted. With the aim to identify the villa plan and the old highlighted archaeological remains, an archaeological preliminary survey and a geomagnetic geophysical campaign were carried out in October 2020. Although geophysical methods are now considered the best tools for archaeological detections, our results show that they are also excellent tools for the preservation, protection and monitoring of the excavated archaeological heritage.

## 1. INTRODUCTION

The application of geophysical methodologies in the archaeological field represents an essential phase for the detection of the archaeological buried structures, during the preliminary phases of the archaeological activities.

These methodologies are also crucial for those archaeological sites, which were excavated decades ago but for which it was not possible to develop conservation projects. In these cases, after the detection and excavation analysis of archaeological structures, the findings were mapped and re-buried. Indeed, it was necessary to bury the ancient structures again, with the aim to protect and preserve them. Among the various methods, the most effective for archaeological purposes are the Geomagnetometric measurements (MAG) and the Ground Penetrating Radar (GPR), able to investigate at different resolution the buried structures in the first meters of the subsoil [1]. These abilities are important also when it is necessary to locate buried structures previously detected during previous archaeological excavation, which passed decades beneath the earth. During this period, their condition, in term of preservation and conservation, could not be checked. In this perspective, the indirect geophysical methods could be excellent monitoring tools.

MAG offers a great tool for the analyses of the archaeological sites, thanks to the possibility to investigate large surfaces, saving times and costs [2-3]. The MAG highlights well the anomalies due to buried structures, but to define the detailed geometry and the depth of them, the best is to adopt different geophysical techniques. The GPR is one of the best geophysical methods to apply for archaeological aims and it permits to obtain 3D image of buried structures. The GPR prospection can investigate large site, but this is possible using special instruments with multi-antenna system, which are actually expansive and time consuming for elaboration process. Therefore, our approach was to start our research with a large MAG survey, to depict the main buried remains and to define the location of the archaeological structures previously excavated in the archaeological site in Bocca delle Menate, which is located in Emilia Romagna region, close the Comacchio (FE) town (fig.1).


a) b)

*Fig. 1: Localization of the archaeological site of Bocca delle Menate (top), and its position with respect to the Comacchio town (b).*

## 2. Geological setting

The roman site Bocca delle Menate is located in the area of the Po Delta, that has always been characterized as a lagoon landscape, covered by a rich and varied vegetation and furrowed by numerous waterways that, over the millennia, have undergone continuous changes and evolutions. From a geological point of view, the investigated area presents the elements typical of the environments of the Padana-Apennine Trench transition, which represents the continuity between the Apennine chain and the Alpine chain. The area is characterized by a large quaternary sedimentation basin of transition between continental and marine environment. The actual geological setting is coming from the events post-glaciation period, when the last phase of progressive migration of the coastline from W to E, until it reached its current position. The stratigraphy of the Comacchio area shows the presence of clayey soils in the central area, where are located depressions and paleorivers. The territory was part of a vast area only partially emerged and crossed by rivers coming from the Alps and the Apennines. In the course of centuries, the area was characterized of alternating phases of emersions and flooding of the territory. Therefore, the lithology present on the surface and in the subsoil shows the alternation and interdigitation of purely continental lithologies (paleorivers, dune cordons) with marine lithologies (sands, silts, clays), testifying to its complex evolutionary history. The lithology of the dune cordons is predominantly sandy on the contrary the paleorivers are affected by a clay lithology.

## 3. Archaeological context

In Roman times, and especially between the first century BC and the third century AD, the connections between cities and smaller towns and the navigation within the Delta area were guaranteed both by the presence of natural waterways (river and lagoon routes) and by the creation of artificial canals, the fossae, in particular the fossa Augusta, an engineering operation commissioned by Augustus to connect Ravenna to the Po Delta. An important role for the connections was also played by the overland routes, as the via Popillia, opened in 132 BC to connect Bologna to Rimini, of which a second section was then built from Rimini to Altino-Aquileia, passing through Ravenna and Adria (128 BC). Terrestrial and aquatic ways were also fundamental commercial routes which linked the Mediterranean to the Cisalpine area: on their sites, many settlements have been developed, which were devoted to the exploitation of the local resources and to the clay production, especially to the manufacture of clay construction products (bricks, tiles etc.)

Taking in account settlement typology, the archaeological remains allow us to suppose that starting from the late republican age, the Po deltaic area was occupied by a scattered type of settlement: small centers on the river bumps and the vici - such as vicus Habentia (Voghenza) and vicus Varianus (Vigarano Mainarda). Close to them, some villae, such as villa of Bocca delle Menate, are located, consisting of a residential part and a productive part formed by buildings functional to the works of exploitation of the territory.

These villas, located along the most important routes of communication, were linked to land of vast dimensions, the latifundia or saltus, initially belonging to members of the Roman ruling class, then merged, through confiscation or sale, in the imperial patrimony [4].

The great works of land reclamation that have affected the Valleys of Comacchio since the 1920s have highlighted not only the remains of the famous Graeco-Etruscan settlement of Spina, but also what remained of these villas. The building complex Bocca delle Menate, located in Valle Lepri, was highlighted between 1958 and 1959 during the construction of the Valle Lepri drainage pump channel for the Mezzano Valley swamp drainage operations. The villa was highlighted by Nereo Alfieri in 1959 on the left bank of the Padovetere on an area of about 1000mq (fig. 2). The complex included the pars dominica and the productive one. These old excavations allowed to know the presence of a plant of a refined living spaces and of rooms destined to productive activities. On the contrary, even if a planimetry was made [5], the excavated structures were not defined on a georeferenced map. Moreover, to identify the highlighted structure plan of the site, and consequently give detailed information about their conservation, a geophysical work approach was required and magnetometric analyses are realized in the site with a collaboration between University of Ferrara and the Institute of Methodologies for Environmental Analysis (IMAA) of the Italian National Research Council (CNR).

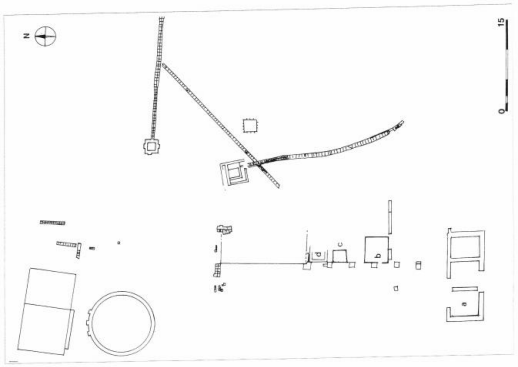

*Fig. 2: Plan of the archaeological remains in Bocca delle Menate archaeological site after the excavations in 1959 [5]*

## 4. Magnetometric application

The MAG is a geophysical methodology able to detect archaeological remains by analysing the variations of the earth magnetic field due to the different magnetic susceptibilities of construction materials and the magnetic characteristics of the shallow subsoil. By means of MAG, it is possible to investigate large subsurface areas in a relatively short time and identify the most significant archaeological anomalies [6].

MAG acquisitions were carried out in October 2020 and was used the Overhauser GSM-19 (GEM System) in gradiometric configuration, with two magnetic probes set in a vertical direction at a mutual distance of about 1 m. Such a configuration allowed the automatic removal of the diurnal variations of the natural magnetic field. The two magnetic sensors are oriented after the necessary consideration about the survey direction and site location. Data are acquired along parallel profiles 1 m apart with a sampling rate of 5 Hz, obtaining a mean spatial resolution of 1.0 m × 0.125 m. All the data were collected with GPS coordinates. A surface of about 1500 mq was investigated according to the acquisition scheme showed in fig.3. This scheme was studied in according with the archaeologists to identify the plan of the previous archaeological excavation, and for this reason, the maps are acquired immediately on the area identified by aerial photo image. Therefore, the area was divided in six part each one 2500mq with a dimension around 50m x 50m (fig. 3).

Further, all the acquisitions are supported by a topographical survey allowing a centimeter accuracy for the geophysical acquisition. Indeed, all the magnetometric acquisitions have been preceded by the tracking of regular polygons within which the measurements are carried out.


*Fig. 3: The investigated area with MAG (in yellow the areas analyzed). Six square areas were carried out 50m x 50m with the GSM-19 overhauser magnetometer*

The preliminary elaboration phase of the acquired data consisted to use GemLink software to remove the outliers imputable to the operator walking. Then, the data are elaborated with the TerraSurveyor software [7]. In detail, the geomagnetic raw data have been filtered to increase the signal/noise ratio providing: a clip process, to remove extreme datapoint value; a de-spike filter, to remove spikes caused by small surface iron anomalies; de-stagger filter, to compensate for data collection errors caused by the operator started recording each traverse too soon or too late; destripe process, to equalize underlying differences between grids and to reduce the linear features. Finally, the processed data are visualized in a regular grid using a Kriging interpolator with a linear variogram (Surfer software), to highlight the main magnetic anomalies.

## 5. Results

The preliminary results unequivocally show interesting anomalies distributed on the investigated area. The measured geomagnetic anomalies ranged between 40nT/m and -40nT/m (fig. 4). The magnetic map highlighted three main group of anomalies. One group is located on the western part of map where three long parallel magnetic anomalies are well defined. The magnetic lines follow the direction W-E and the inter-distance is around 20m. Each ones have different length from 80m to 50m. A second group is located on the east where is possible to define some regular shapes of them. The last group is located on the eastern part of the first group, in the middle of the magnetic map.

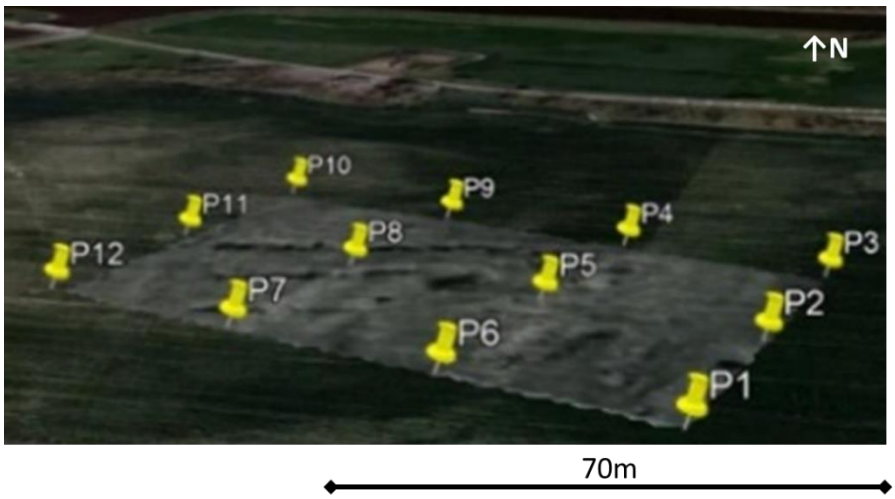


*Fig. 4. Gradiometric maps disposed on a Google Earth image. The acquired area were divided in six squares. Some magnetic anomalies are well identified (comments and interpretation in the text)*

The magnetic anomalies are not well defined by a regular shape, but the magnetic intensity highlights the presence of archaeological buried remains. Anyway, the magnetic map shows a series of anomalies that could be associated with buried objects of archaeological type, but the geometries of the traces highlighted by previous excavations described in figure 2 are not clearly identified. The reasons could be different, for example the structures identified do not have the conditions to be identified by the method used for an absence of materials capable of producing changes in the local magnetic field, or the area investigated does not completely cover the area of previous excavation.

## 6. Conclusions

Results obtained with the use of magnetometric measurements in the archaeological site of Bocca delle Menate (Comacchio, Ferrara, Italy) show the great potentialities of the geophysical methodology adopted for the reconstruction of buried structures. Anyway, no magnetic anomalies are well defined to compare with the geometries of structures excavated in the past. Therefore, there are two possible considerations: the first one is about the possibility that the detected archaeological structures during the old excavation were removed; the second one should correlate on the possibility that the structures were remodelled due to anthropic actions correlated with the farming activities.

Further, a great number of magnetic anomalies, often distributed regularly in the site, testifies the still presence of more buried structures, highlighting the importance of the villa in Bocca delle Menate for the knowledge of the settlement dynamics during the Roman age in the Comacchio territory. Future geophysical activities, based on the integration of ground penetrating radar measurements and electromagnetic analyses will give new impetus for the archaeological research providing fundamental information about the shape and distribution of the buried structures placed in the urban plan admirably detected by the first magnetometric analyses.

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