The Etruscan Town on the Bisenzio
Geophysical Research and Applications

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Abstract. The need to identify the boundaries of the Archaic Etruscan center recently discovered in Gonfienti, an area bordering the territories of Prato and Campi Bisenzio (province of Florence), has initially suggested using a type of geophysical prospection (GPR method) in an area of approximately 27 hectares. Analyses of the radargrams and the subsequent checking of anomalies by stratigraphic sampling enabled us to recognize an additional sector of the settlement in correspondence to a strip of ca. 5 hectares, and also to identify naturally occurring layers of gravel, caused by the deposits of the Bisenzio River. Aided by an optical scanner we developed a three-dimensional model of an antefix bearing a feminine head recovered from the collapsed roof of an important residential complex located in the southwestern part of the settlement. The relief of this antefix represents the first application within the scope of a wider project that will lead to the hypothetical reconstruction of the "Cittá degli Etruschi sul Bisenzio".

1. Introduction

A number of researches have been carried out throughout 2004 within the framework of the "Cittá degli Etruschi sul Bisenzio" project (in collaboration with Regione Toscana, the provinces of Prato and Florence, the Municipalities of Prato and Campi Bisenzio and also with the Archaeological Superintendence of Tuscany) in order to establish the boundaries of the new Archaic Etruscan center of Gonfienti, whose discovery constitutes one of the most significant acquisitions of recent years in the field of Etruscology.
Stratigraphic sample analyses carried out from the late 1990s to 2004 in an area of the Prato territory previously destined to accommodate the structures of the Freight Terminal of Central Tuscany, enabled us to activate the legal process of protection on ca. 12 hectares of territory. The streets and residential complexes discovered within this protected area suggest the existence of a settlement that is coherent as far as urban settlement, architectonic characteristics and chronology (VI–V century AD) are concerned, and which will be the object of further studies.
This new center, located in that part of the Fiesole countryside we nowadays call Prato and realized according to regular urban forms since at least the second half of the VI century AD, appears in every aspect to resemble Marzabotto and to be strongly projected along the transapennine axis, going from the fluvial valley of the Bisenzio towards the corresponding Apennininic Val di Setta, which allows to reach Bologna and the northern territories. In particular, the excavation of a residential building of notable size has uncovered, besides the material – of local and imported production – typically found in a domestic environment, the layer resulting from the collapse of the roof and including tiles, and also three exquisitely-made, late-Archaic antefixes with heads of maenads surrounded by shell-shaped nimbi with radial pod-shaped grooving (Bocci and Poggesi 2000; Millemaci and Poggesi 2004; Poggesi et al forthcoming).

2. Area Involved in Research

The territory in question has an extension of ca. 27 hectares and is situated between the Municipalities of Prato and Campi Bisenzio. It has always been utilized for agricultural purposes (with the exception of the lands on which Villa Niccolini stands) and is characterized by those features that are typical of its function, such as canals, dimples, enclosures, holes for implanting trees, furrows, elements which have somehow shaped the soil and which are bound to interfere with any underlying archaeological remains.

3. Geophysical Prospection

Because of the vastness of the territory interested in the potential expansion of the Etruscan city, it was necessary to choose a type of instrumental geophysical prospection that was capable of identifying the areas characterized by the underground presence of structures or materials not pertaining to the natural layers of sedimentation succession. Because of the types of material and of the structures that were to be located, the georadar technique was chosen and different antennae were set out at frequencies that varied according to the characteristics of the terrain (operations carried out by Georisorse Italia, Sinalunga, province of Siena).
Each sector was tested using Ground Penetrating Radar (GPR) methodology, where the antennae frequency was configured to allow the acquisition of any anomaly present at a depth of up to 3 m. As there was a total absence of information regarding the possible presence of underlying archaeological finds, the type of acquisition technique used is called continuous profiling, with intersecting scansions along equidistant lines. The spacing between lines (10 m) was set according to the typology of possible structures present. In order to guarantee the exact location of the scansion lines, therefore of any possible underlying anomaly, the profiles

were appropriately signaled by the presence of georeferenced markers.

A map showing the exact location of the points interested by the presence of variations (anomalies) in the sequence of natural sediments was produced through the analysis of the radargrams produced and graphically rendered in scale of 1:2000. A subsequent detailed analysis of the different anomalies enabled us to eliminate those due to the modern hydraulics of the terrain and to vertical discontinuity attributed to recent events.

The remaining anomalies, potentially deriving from the expansion of the Etruscan city, needed to be verified by stratigraphic sampling that would determine their exact attribution to strata or structures of archaeological interest, to the presence of strata characterized by pebbles (palaeobeds or high energy alluvional deposits) or to disturbences or levels of a different nature. During the verification process, favoring those anomalies placed in strategic areas (according to what the archaeological data in our possession and the objective analysis of the geomorphic aspects of the territory suggested) was deemed necessary in order to optimize the available financial resources.

4. Analysis of the Anomalies

About 60 verification samples of the anomalies were taken using mechanical means and trenches of up to 3 m in depth. Each sample was photographically documented and graphically positioned, even when the anomalies were clearly

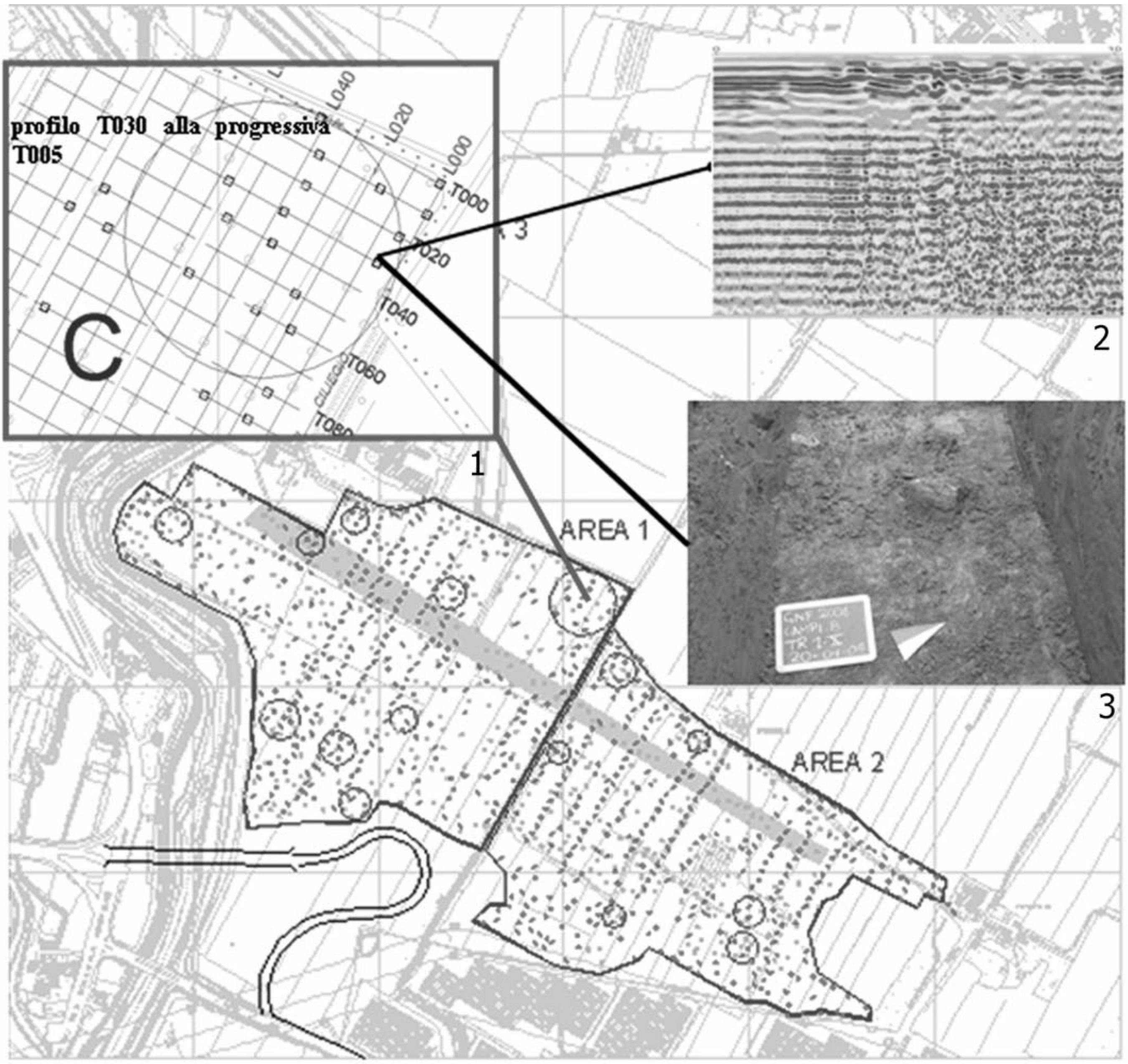

Fig. 1. Area interested by geophysical research showing anomalies located with GPR technique. In blocks 1, 2 and 3 are depicted respectively: a detail of the anomalies; the sonogram indicating the anomaly along the profile T030 to the progressive L005; and the corresponding archaeological deposit.

due to non-archaeological reality, according to the principle that – in archaeology – negative data are also precious for elaborating a relevant picture of the ancient history of the territory in question.

When the samples gave back positive results, highlighting structures and materials that refer to the archaic Etruscan horizon, therefore connecting to the Gonfienti settlement, or that witness the frequentation of the site in Roman era, further in-depth analyses were carried out. The method used was that of stratigraphic excavation in order to obtain as much information as possible and to recover material useful not only for determining the exact chronology, but also to clearly define the ancient function of the site.

The verification of the samples has also given interesting results regarding the highlighting of the strata of natural gravel, which bears witness to the deposits of the river Bisenzio. It has therefore been useful to define any possible variations of the river bed itself, particularly in correspondence to its principal bends.

5. The Archaeological Picture

Currently it is possible to single out a vast area of ca. 5 hectares used during the Etruscan period, a natural extension of the known portion of the archaic settlement (although it appears to be separate because of a road – via Gonfienti – which happens to constitute the administrative border between the two communes). Both sites are characterized by the presence of strata and foundation structures dry-stone constructed, or of elements deriving from the collapse of said structures, and are reciprocally coherent as far as town planning, chronology and functionality.

Adjacent to the area interested by the presence of Etruscan structures, another strip has been brought to light showing the presence of an ancient anthropic level, with Etruscan- and Roman-era materials. It should be noted that, besides the areas defined by the presence of archaeological findings, areas of particular geomorphological characteristics have been evidenced. One of these, bordering and practically parallel to the new road network (Mezzana-Perfetti Ricasoli) – not far from the area where the recent research carried out along the final stretch of the new road allowed to date a stable human presence in the area back to the Late Bronze Age, with a particular concentration during the Middle, Recent and Final Bronze Age – is characterized by the presence, a few centimeters below the ground level, of a layer of grey plastic clay about 2 m thick; the other areas, marginal to the river, identify the expansion of the river itself.

6. Antefix with Feminine Heads

The documentation of finds of particular importance, such as the antefixes mentioned in the introduction, was undertaken during the survey. In particular we concentrated our attention on the best preserved example.

The complex and articulated morphology of the antefix, its relatively small dimensions (maximum size slightly over 40 cm), the need to exclude any system which would entail direct handling and subsequent damaging of the object, the requirement of obtaining a model rich in details, lead us to use an optic scanner.

In this case, the 3D model was obtained through the acquisition, characterized by a resolution of 0.37 mm, of 50 range maps: 30 were needed to determine a preliminary model and 20 to integrate the missing parts. The various shots of the object were aligned in real-time during acquisition in order to determine during the scan process which areas to integrate in the successive scans.

At this point, after an editing phase aimed at integrating a few small areas that hadn't been perceived by the scanner due to the morphology of the object in question, it was possible to proceed to the subsequent elaboration phases conducted on a complete three-dimensional model devoid of missing areas.

The model, positioned in a Cartesian space, was intersected

Fig. 2. The point-cloud model.

Fig. 3. Surface consisting of a polygonal mesh (single triangular faces that generate the three-dimensional object).

by a series of planes at intervals of 5 mm, placed at times parallel to the (x, y) plane, to the (y, z) plane and to the (x, z) plane. Thus were brought to the bi-dimensional level three series of intersection surfaces between plane and object which documented the dimensional variation of the section of the object along the three axes. We then proceeded to project the surface of the object onto six planes of axes, respectively *x*, *-x*, *y*, *-y*, *z*, *-z* and over every prospect thus obtained was superimposed a square grid (5 mm x 5 mm).

At the same time as the above described process, a map of the three-dimensional model was developed that allowed us to go from a model made of points to a surface faithfully representing the real object.

The complex and articulated job of mapping the model was executed by individuating a series of two-dimensional patterns extracted from the photographic campaign, carried out in parallel to the scansion procedures of the surface.

The photographic patterns were elaborated systematically with editing procedures, level regulation and chromatic calibration. These were applied to the forms of the digital model, using solid-modeling software with advanced photo-realistic rendering, in order to obtain a virtual representation of the state of the object.

Descriptive computer models of a three-dimensional space were created permitting the visualization from any angle of the object represented.

The antefix thus appeared visible in static form (panoramic views, sections, graphic views), and in dynamic form (animation and documentation sequences).

The model, enriched by this new and abundant documentation, will be able to represent reality even more closely and will furthermore allow to be employed as a basis that is no longer simply informative and reconstructive, but that will also constitute a plausible instrument for studying and analyzing the real object.

The finality of the documentation is to make available virtual models of the building and decorative elements recovered among the structures found on site in order to be able to, in accordance with the Scientific Direction, undertake at a later stage their hypothetical assembly. The model of the antefix should be considered as a first step in the framework of a broader project finalized in hypothetically reconstructing of the archeological site of Prato-Gonfienti.

7. From the Virtual Reconstruction to the Physical Model

The virtual reconstruction could be followed by a real reconstruction in 1:1 or reduced scale of the most significant finds. The availability of the 3D models allows producing models of the objects by means of two principal applications.

The most common application consist of a CAD-CAM procedure that permits the simulation of a virtual cut that subsequently leads to a real physical cut of the elements that constitute the object.

The design files, in .dwg format, are subjected to a ‘nesting’ procedure for the cutting material, chosen before the creation of a file suitable to the three-axis cutting machine. Next the single elements are reassembled to recompose the reproduced object in its entirety and true-to-life form. This application allows realizing elementary and non-complex plane elements.

Instead the second application allows the realization of complex models, such as antefixes, by using an anthropomorphic robotic arm. The procedure consists in extracting the predefined model from a solid parallelepiped made of a chosen material (wood, polystyrene, stone or other) by means of a robotic arm on whose extremity an electric drill has been mounted, that is an electric motor that is able to support and power the rotation of a cutting utensil.

Fig. 4. Application of a generic pattern to the three-dimensional surface.

Fig. 5. Application of a pattern obtained through the photographic campaign.

Starting from a three-dimensional CAD representation and by using the CAM (Computer-aided Manufacturing) software tool, a virtual parallelepiped containing the object is constructed. The cutting sequences are then planned and little by little bring to light its content from the initial solid, producing a mathematically proportioned and in scale model of the original object.

Acknowledgements

Paragraphs 1.1–1.5 have been authored by G. Poggesi and P. Pallecchi, paragraphs 2.1–2.2 by Machetti.

References

Bocci, E. and Poggesi, G., 2000. Prato-Gonfienti: La ricerca archeologica nell'area dell'interporto. In *Archeologia 2000. Un progetto per la Provincia di Prato, Atti della Giornata di Studio, Carmignano 29 Aprile 1999*. Montespertoli: 58–71.

Millemaci, G. and Poggesi, G., 2004. Ceramica attica dall'abitato etrusco di Gonfienti (scavi 1996–2001). In Bentz, M. e Reusser, C. (eds), *Attische Vasen in etruskischen Kontextfunde aus Hausern und Heilig-tumern*. Munchen. 45–52.

Poggesi, G., Donati, L., Bocci, E., Millemaci, G., Pagnini, L., Pallecchi, P., in press. Prato-Gonfienti: un nuovo centro etrusco sulla via per Marzabotto. In *Culti, forma urbana e artigianato a Marzabotto. Nuove prospettive di ricerca. Atti del Convegno, Bologna 3–4 Giugno 2003*. Bologna.