A geophysical survey in the center of Rome

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A geophysical survey was performed recently in the center of Rome to verify the presence of archaeological structures inside an ancient villa. A museum (to house a large private collection of Greek and Roman statues) with underground parking was proposed for an abandoned area of the park surrounding the villa.

Two geophysical techniques were used: the frequency domain electromagnetic method (FDEM) and the magnetic method (gradient technique).

The area of investigation was square with a side of 2 m. More than 1500 measurements were recorded.

FDEM. An EM31 terrain conductivity meter was used. Four measurements were recorded at each station: in-phase and quadrature components, both in horizontal and vertical configuration.

The first interpretation of the data concerned in-phase values, in order to locate obviously metallic objects. The resulting contour map (Figure 1) shows the effect of a metallic greenhouse (G) that produces a bipolar anomaly between -25 and +30 parts per 1000 (ppt). A positive anomaly (about 30 ppt) is due to the metallic fence (F) along the northeastern side of the park. Other anomalous points are small metallic objects (M). The area has a background value of about -5 ppt, indicating the absence of other metallic objects.

Figure 2 shows the contour map of the quadrature component of conductivity in the horizontal configuration; therefore a depth of exploration below 3 m can be expected. This shows greater variability than the in-phase values, because the EM component is more influenced by the electrical properties of the ground. The mean value of con-

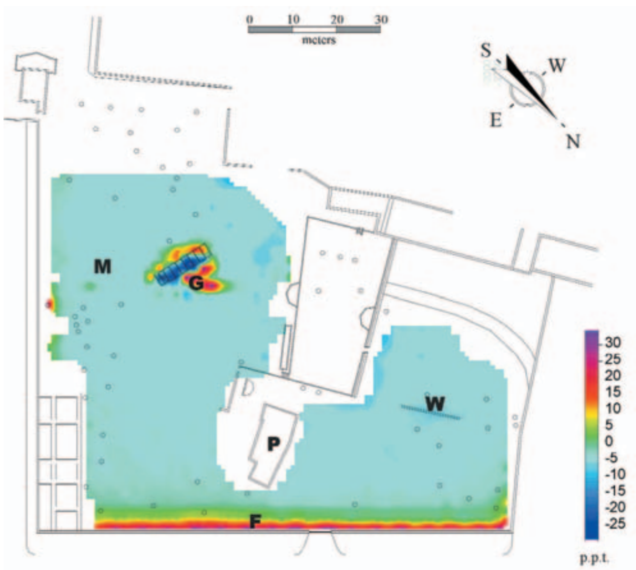

Figure 1. Contour map of conductivity (in-phase component).

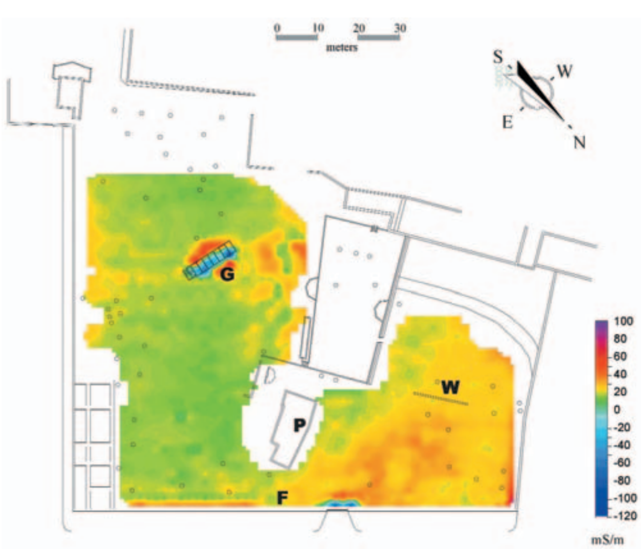

Figure 2. Contour map of conductivity (quadrature component, horizontal configuration).

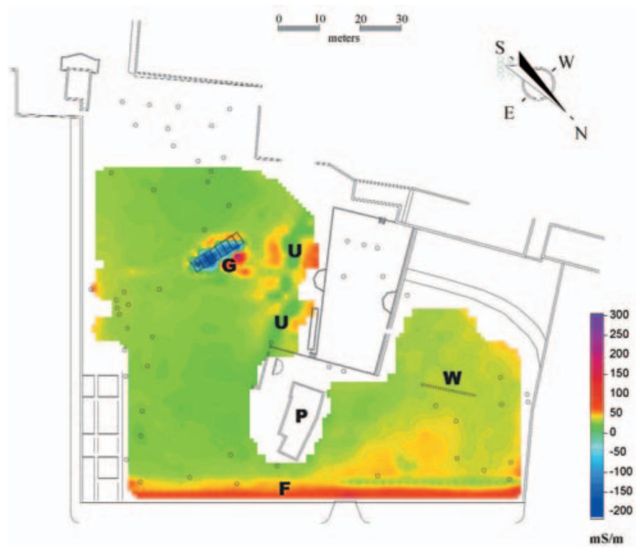

Figure 3. Contour map of conductivity (quadrature component, vertical configuration).

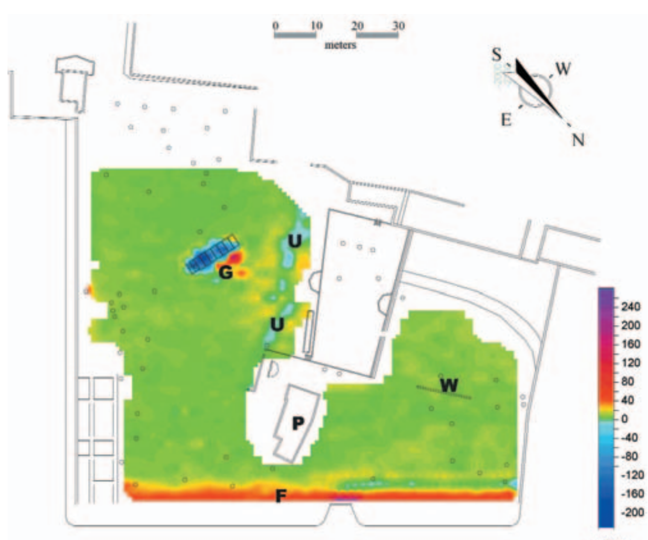

Figure 4. Contour map of conductivity (differential values).

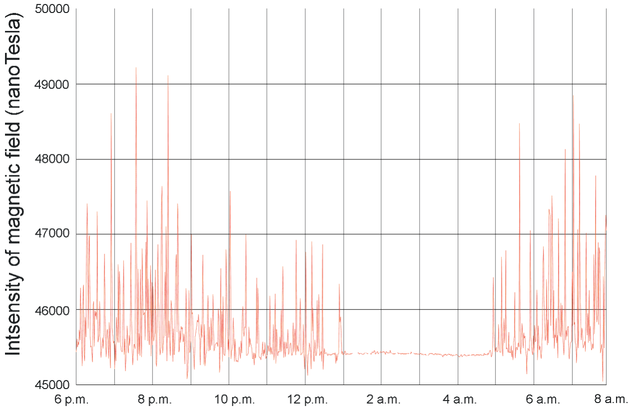

Figure 5. Time variations of magnetic field.

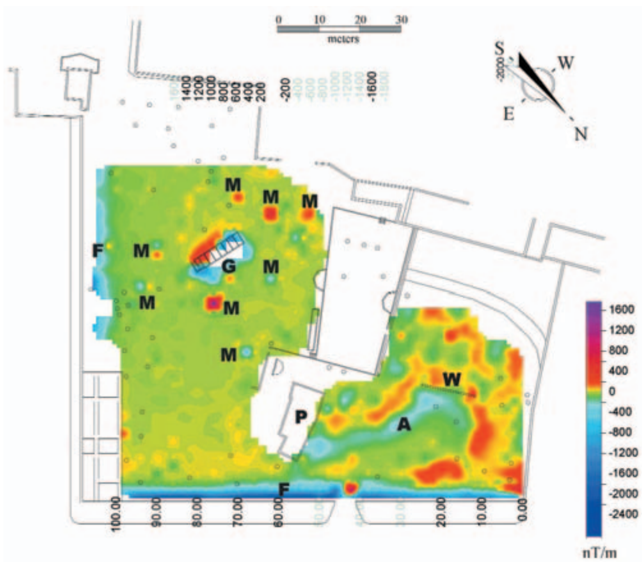

Figure 6. Contour map of vertical magnetic gradient.

ductivity is about 15 mS/m (green), the maximum points are >30 mS/m (red), and the minimum points are negative (blue). The latter correspond to metallic objects (we again find the effect of the greenhouse and of metallic debris). Positive values show the presence of the *pozzolane*—fine sandy volcanic rocks that represent the natural bedrock. Anthropic overburden, when it is formed by coarse material (e.g., tuff debris, bricks), is less conductive than bedrock because of the presence of voids. Therefore the areas with low conductivity, on the south, can be interpreted as zones with greater thickness of anthropic overburden. On the north, high conductivity can show an uplift of tuffs.

Greater depths can be explored (about 6 m) by a vertical configuration. Figure 3 confirms the anomalies previously detected, but it shows more clearly the effect of an excavation to locate an underground pipe (U).

By contouring the differential values (i.e., the value recorded by vertical configuration minus the one recorded by horizontal configuration), a general increase of conductivity with depth can be verified (Figure 4). In fact, when in vertical configuration, the instrument records a greater volume of tuffs, which are more conductive than the overburden. The only negative areas are the greenhouse, along the fence, and along the pipe.

Magnetic method. For archaeological purposes, a gradiometer technique is preferable in order to minimize the

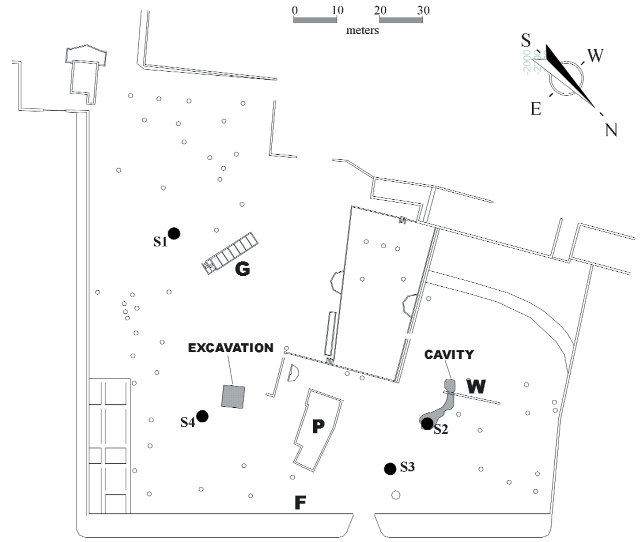

Figure 7. Map of direct investigations.

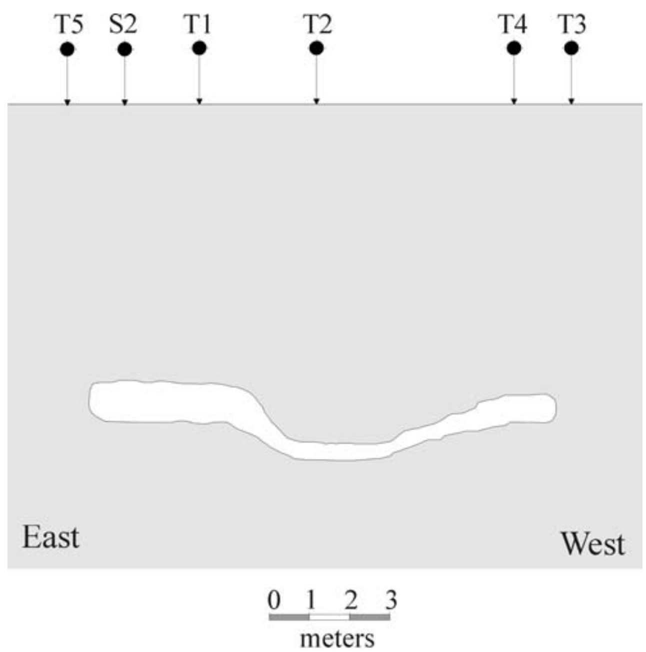

Figure 8. Cross-section of the cavity.

effect of background noise and of other objects. A cesium gradiometer, with the lower sensor at 0.3 m above ground and the upper sensor at 1.8 m, was used.

A base station was inside the area of investigation to record the time variations of magnetic field. Before starting the survey a test was executed to verify the background noise. Figure 5 shows the time variations recorded by the base station between 6 PM and 8 AM. The strong disturbance due to the tram-line is evident (variations over 1000 nT). Variations were 20-30 nT only between 1 and 5 AM, a more desirable range considering the kind of survey. Thus, it was necessary to collect field data during the night. Background noise was still relatively high (in archaeological surveys anomalies of a few nT are sought), but the gradient technique solved this problem. In fact, the instrument's cycle rate (less than 1 s) minimized the disturbance due to quick time variations.

As shown in Figure 6, the effect of the greenhouse and the metallic fence is clear. The isolated anomalies, usually small metallic objects, are easily detected on the ground or in the shallowest part of the soil.

The area of investigation can be separated into two zones: the south, where negative values prevail, and the north, where the vertical gradient is more often positive. Because the gradient is the difference between the values of the upper and the lower sensor, positive values show an increase of magnetic susceptibility with depth; this can be explained by the approach of the *pozzolane* which is highly magnetic (both induced and remanent magnetization). On the other hand, negative values show a lack of magnetic rocks, i.e., the presence of thick anthropic overburden. This interpretation agrees with conductivity data.

A wide negative anomaly can be observed between -200 and -300 nT/m (A) that links an isolated wall (W) with the pigsty (P). It can be interpreted as a linear cavity embedded in *pozzolane* or as a channel filled by debris.

Our conclusions are:

1) Most anomalies are due to isolated small objects, which have slight archaeological interest.
2) The southern part of the area is characterized by greater thickness of anthropic overburden; in the north, the "pozzolane" is shallower.
3) In the south, an anomaly (A) corresponds to a cavity or a channel filled by debris, and this is the only anomaly which must be verified by excavation and drillings.

Results of direction investigations. Figure 7 shows four holes (S) and an excavation which were dug in the area. The excavation confirmed the presence of anthropic overburden of about 4 m; bottles and other materials from the beginning of this century revealed very recent age. Stone foundations, which were connected with the pigsty, were found at the base of the excavation. They did not produce any geophysical anomaly.

Two drillings in the south confirmed the great thickness of the anthropic overburden (6-7.5 m); on the contrary, two drillings in the north part showed the absence of the overburden. This confirms the interpretation of the geophysical data: High values of conductivity and vertical magnetic gradient show the approach of the *pozzolane.* Low values show anthropic overburden with great thickness.

The drilling centered on anomaly A detected a void cavity, 7.3-8.8 m below the ground. Further drillings and TV monitoring made it possible to determine the geometry of this structure. Figure 7 shows a plan view, and Figure 8 shows a cross-section of the cavity. The first map, when compared with gradient data, shows very good agreement between anomaly A and the buried structure. In the cross-section, S2 indicates a drilling, and T indicates further drillings for TV monitoring. The cavity has a depth of 7-9 m, a low height (0.4-1.5 m), and a length of about 14 m. It rests on the volcanic rock, with the top and the bed made by natural soil. The absence of bricks and masonry excludes the possibility that it was hydraulic pipe. The Soprintendenza Archeologica of Rome is going to evaluate the importance and the meaning of this buried structure.

Only magnetic data were able to detect this cavity because it was out of the depth of investigation of the EM instrument. The resolution of so small a structure, if compared to its depth, can be considered a good result, particularly when the difficult environmental conditions are kept in mind. LE

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