FLUXGATE, OVERHOUSER AND CAESIUM-MAGNETOMETRY FOR ARCHAEOLOGICAL PROSPECTION AT ROSELLE-AIALI (ITALY)

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The place name Aiali is sited on lowland between the medieval town of Grosseto and the Roman town of Roselle in central Italy. The site discussed in this paper was detected from the air during the Aerial Archaeology Research School organized by the University of Siena in 2001 (Campana et al. 2006). Aerial survey allowed us to recognize an area within which the growth of the wheat varied in such a way as to reveal an articulated group of traces that made up the plan of a complex of structures interpreted as a Roman villa, 4 hectares in extent. In the following years Aiali has become the most important test site for the Laboratory of Landscape Archaeology and Remote Sensing at Grosseto. Since 2001 we have collected, processed and interpreted many different kinds of data: Quickbird-2 satellite imagery, historical and recent vertical coverage (from 1954 to 2001), oblique air photographs in various years, seasons and lighting condition; field-walking survey, and in the course of the XV International Summer School in Archaeology at Grosseto several geophysical methods were tested for archaeological prospection at the Roman site at Roselle-Aiali for demonstration to the students. For the purpose of magnetic prospecting a highly automated system consisting of a 4-Foerster-probes (Ferex DLG) on a chart with GPS and a Overhauser magnetometer (GSM-19) were applied in the same grid. At the time of the summer school there was no caesium-magnetometer system available. Therefore the whole area had been remeasured some weeks later with a Scintrex Smartmag SM4G-special in various sensor configurations again in the same grid and under the same surface conditions for comparison (the magnetometer was made available for the test by Schweitzer-GPI company).

Most impressive to everybody was the performance of the Foerster-4-probe system with high resolution differential GPS on a chart. Hard- and software are very well developed and adjusted to the needs of archaeological prospection. But the limits of fluxgate-magnetometry are known and became also evident at the site. In general multi-probe fluxgate magnetometry is the ideal instrument for near surface structures with a high magnetization contrast. At Roselle-Aiali this was the case for the main building of the Roman villa. But the sensitivity of the Foerster probes and the vertical gradient configuration were not suitable for the detection of the deeper structures. However the vertical gradient configuration resulted in a perfect reduction of the very strong noise of the high voltage power line nearby (some squares were measured directly under the power line). The survey system consisted of 4 vertical gradient fluxgate probes with sensor spacing of 65 cm. The lower sensor was guided 25 cm above ground. The FEREX data logger offers a sampling rate of up to 100 Hz for each of the included 4 channels. In the present case 10 Hz had been selected. A measuring range of

10,000 nT is offered, with a sensitivity of 0.1 nT. One interface of the FEREX was used to connect a high resolution DGPS for positioning. The system offers a navigation aid by means a heading indicator on the built in screen, that keeps the user on straight tracks during data sampling (*Fig.1*).

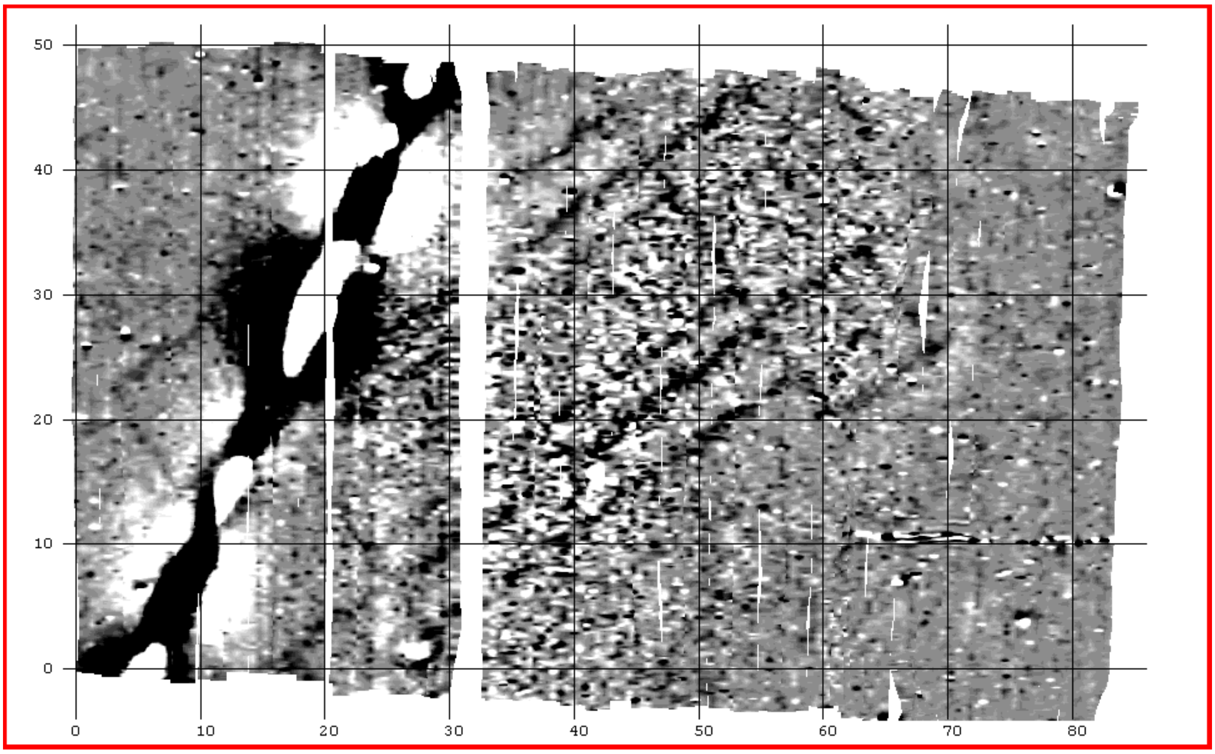

Fig. 1 – Magnetic map of the data collected on the main building of the roman villa using the Foerster-4-probe system

A part of the Roselle-Aiali archaeological area has been surveyed with a GEM System GSM 19 Overhauser magnetometer equipped with an internal low cost gps board, in order to evaluate the performance of the positioning system of this instrument compared to the more accurate acquisition by means of on ground grid definition.
The survey instrument, a single sensor scalar magnetometer, has been configured with a measurement sampling rate of 2 Hz maintaining a distance sensor-ground of about 20 cm; this magnetometer has a sensitivity of 0.01 nT with a maximum measurable spatial gradient of 10,000 nT/m. During the survey the magnetometer internal clock is synchronized with the gps signal in order to precisely attribute a spatial datum to the magnetic field values. The internal gps board is a 12 channel EGNOS enabled system with a resolution of less than 1.5 meters (http://www.gemsys.ca/). During the acquisition the gps coverage has been quite good with not less then 8 satellites and EGNOS correction signal available.
To monitor the magnetic field temporal variations, a second magnetometer has been used in a fixed station nearby the survey area (base station); a GEM System GSM 19 T proton precession magnetometer with a sampling rate of 1 Hz with an internal gps board to synchronize the two magnetometers clocks has been used, assuming that the temporal variations of the base station and of the survey area were the same. After fixing a reference time, the temporal variations measured by the base station unit has been removed from the data acquired by the survey unit, so that the residual magnetic field represents the spatial variations component only.
The global surveyed area is represented in fig.2 with two colored lines groups indicating two different acquisitions days; the “blue lines” group (area1) surveyed area, with main lines

direction of N10°, is 2 hectares wide, the “red lines” one (area2), with mean direction N38°, is 0.4 hectares wide. The first group has been acquired in 4 hours of continuous measurement, the second in 2 hours. The total survey lines length is about 22 km with 43000 measures; the mean line spacing for the first group is 1.25 meters with a spatial density of 1.4 measures/m^2, for the second group the mean line spacing is 1.1 meters for station density of 3 measures/m^2.

In order to map the magnetic anomaly values, a regular data distribution (mesh) of magnetic stations has been realized applying a gridding algorithm to the real measurements; the grid spacing for both areas is 0.5 meters interpolated.

In fig.2 it is reported the resulting magnetic anomaly map displaying the data mesh by means of a grey graded scale. The chosen grey scale linear dynamic range is +/- 15 nT that represents the best interval to visualize the measured magnetic anomalies.

The Overhauser magnetometer seemed to be not very suitable for archaeological prospection independent of the sensor configuration (vertical gradient measurements, variometer = correction by a base station and non-compensated duo-sensor configuration were tried). Measuring speed, inadequate sensitivity and heavy weight of the sensors are the main disadvantages for archaeological prospection.

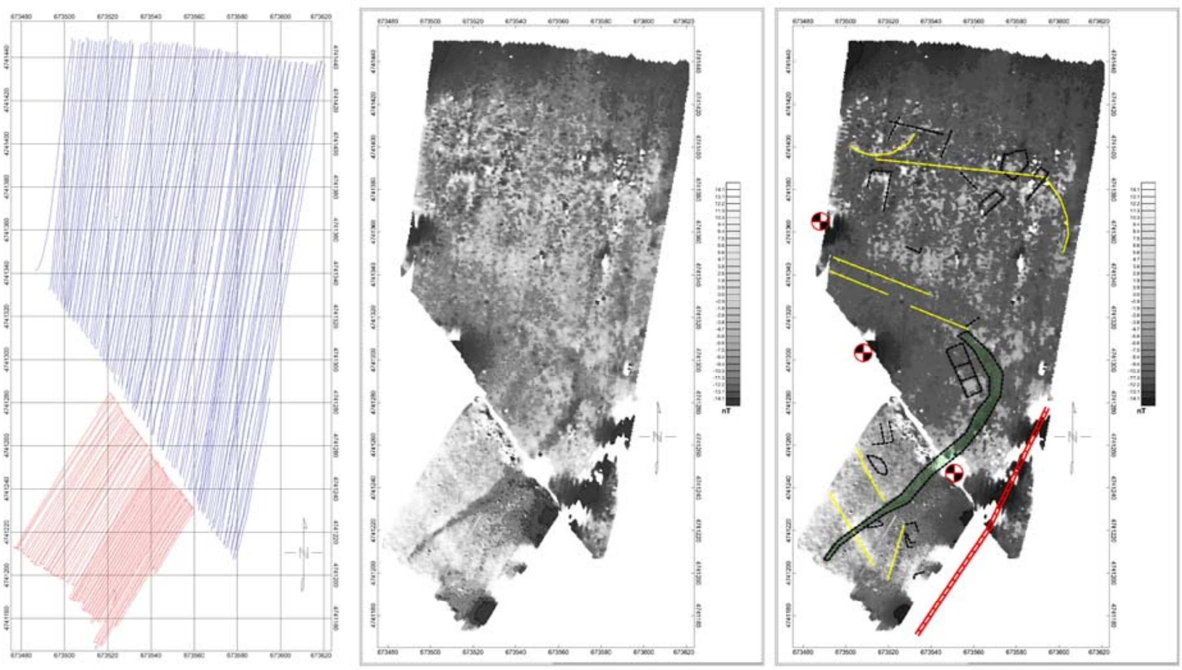

Fig. 2 – From the left side: surveyed profile lines at Roselle-Aiali archaeological area.(UTM 32N, WGS 84); magnetic anomaly map of Roselle-Aiali archaeological area; interpretation of magnetic data

power line tower; pipe; possible subsurface archaeological structures;
linear anomalies; negative magnetization contrast area (paleochannel? Road?)

The caesium-magnetometry with Smartmag SM4G-special was applied for the whole field in the duo-sensor configuration on a chart with half automated positioning by the rotation of the wheel for non compensated total field measurements. Spacing of the lines was set to 0.5 m and sampling rate to 0.1 Hz (10 measurements per second, corresponding to 10 – 15 cm sample spacing). Later in data processing and visualization of the magnetograms the raster was interpolated to 0.25 x 0.25 cm. For the reduction of the high frequency noise a bandpass filter in the magnetometer processor was set to 5 Hz.

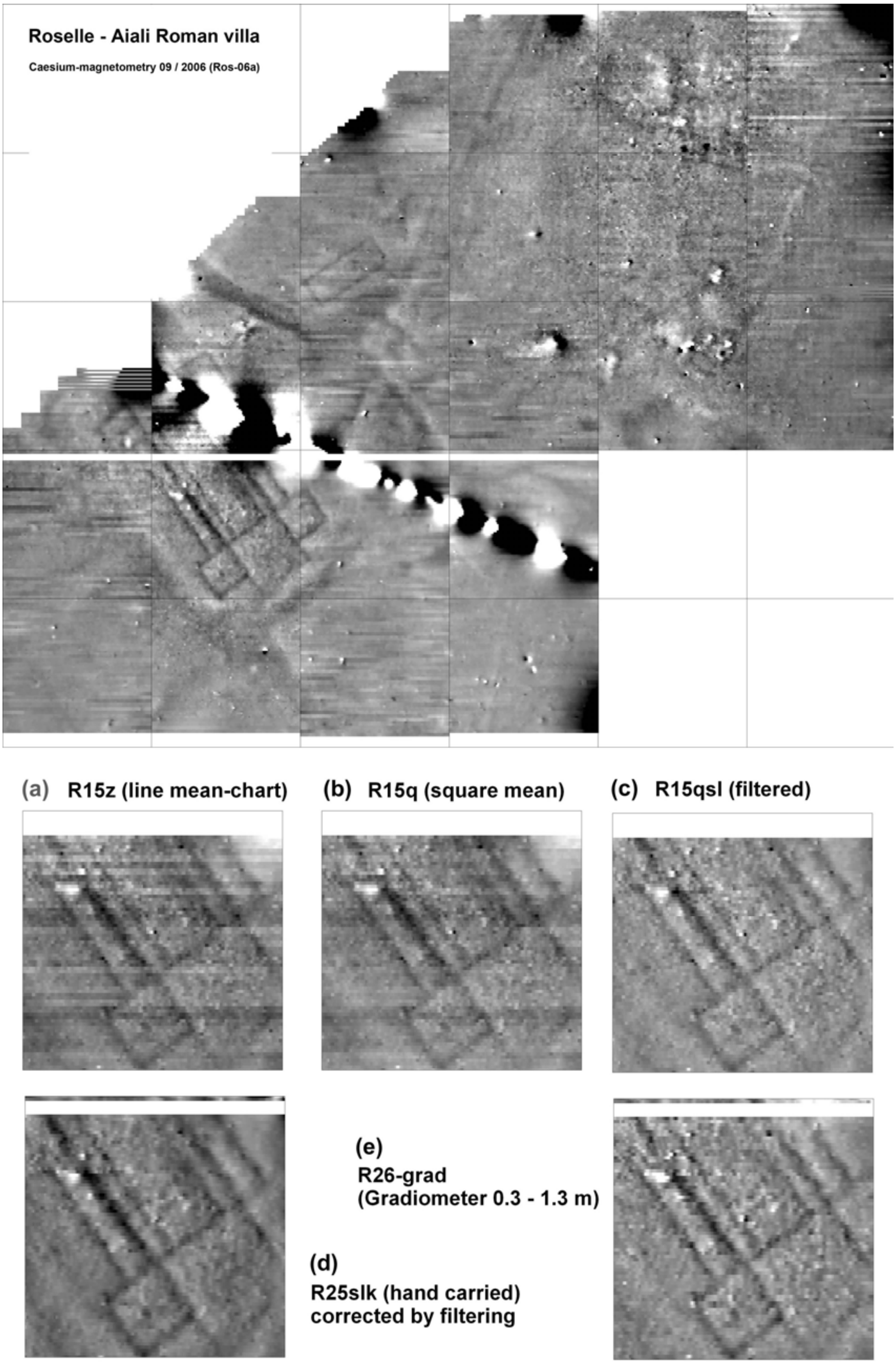

Fig. 3 – Roselle-Aiali. Caesium-magnetometry with Scintrex Smartmag SM4G-special with duo-sensor configuration on a chart. Sensitivity 30 pT at 10 Hz cycle. Raster 0.10 x 0.5 m (interpol. 0.25 x 0.25 m), dynamics +- 25 nT, 40m-grid.

Roselle-Aiali. Caesium-magnetometry of a part of the main building with various sensor configurations. (a) measurement on a chart, reduction of the time dependent anomalies by the reduction on the line mean value, (b) same by square mean value, (c) reduction of the long wavelength *anomalies on the square mean value, (d) measurement with the hand carried frame and (e) gradiometer measurement with 0.3 m and 1.3 m above ground.*

Resampling and the reduction of the diurnal geomagnetic variations by line-mean and square mean value were processed by RESAM2. Further data processing and visualization of the magnetograms were achieved by Geoplot 3, Archaeo-Surveyor, Surfer 8 and Photoshop. In the raw data the long wave length noise of the high voltage power line is strongly visible. But this could be cancelled by desloping filters in Archaeo-Surveyor. Unfortunately the main building of the Roman villa had been cut by a modern pipe line with steel flanges, which gave very strong magnetic disturbances, which could only partly removed by filtering techniques (fig. 3).

Part of the main building had been remeasured by Smartmag caesium-magnetometer with different methods for comparison. Fig. 3a, b, c shows the measurement on the chart with long wave length reduction by line mean (a), square mean (b) and complete reduction by deslope filtering on the line (c). Fig. 3d gives the example of the measurement with a hand carried frame with the distance triggering on the line only every 5 m by switching. The high frequency noise is minor, which is due to a more quite movement of the sensor compared with the rather bouncy push-pulling method of the chart over a field with lots of stones at the surface. Fig. 3e shows the result of a hand carried vertical gradient measurement over 1 m with the lower sensor at 0.3 m and the upper sensor at 1.3 m above ground. Despite of the optimal reduction of the long wave length anomalies of the power line we loose by the gradiometer setup of the sensors the information of the deep structures under the surface and in speed the factor of 2. Considering the essential importance of the 3 “**S”** in archaeological prospection – **S**peed, **S**pacial resolution and **S**ensitivity – one should forget gradiometer- or variometer measurements and not waste the second sensor for minor quality of the magnetogram of an archaeological site.

References

Becker H. 1995. From Nanotesla to Picotesla - a new window for magnetic prospecting in archaeology. Archaeological Prospection, 2, 217-228.

Becker H. 1999. Duo and quadro-sensor configuration for high speed/high resolution magnetic prospecting with caesium magnetometer. *Archaeological Prospection*. Proceedings of the 3rd International Conference on Archaeological Prospection. Fassbinder JWE, Irlinger E (eds). Munich.

Campana S., Piro S., Felici C., Ghisleni 2006. *From Space to Place: the Aiali project (Tuscany-Italy)*, in Campana S., Forte M. (eds.), *From Space To Place*.

Tabbagh J. 2003. Total Field Magnetic Prospection: Are Vertical Gradiometer Measurements Preferable to Single Sensor Survey? *Archaeological Prospection* **11**: 75-82.