LiDAR, Aerial and satellite remote sensing on Vignale

R. Coluzzi (1), R. Lasaponara (1) , Y. Backe Forsberg (2), R. Holmgren (3), N. Masini (4)

1 CNR- IMAA, C.da S.Loja – 85050 Tito Scalo (PZ), Italy, lasaponara@imaa.cnr.it
2 The Swedish Institute of Classic Studies in Rome, Via Omero 14, I-0019, Rome, Italy, forsberg@isvroma.org
3 ARCDOC, Djurgårdsgatan 38, 582 29 Linköping, Sweden, arcdoc@me.com
4 CNR- IBAM, C.da S. Loja, 85050 Tito Scalo (PZ), Italy, n.masini@ibam.cnr.it

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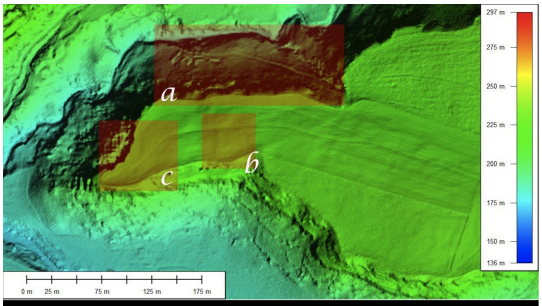
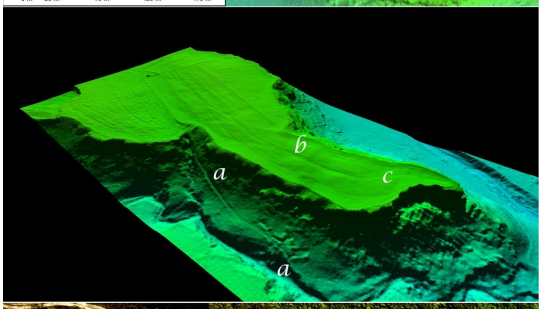
The project

Uncovered habitation remains and the foundations of an Etruscan bridge, excavated since 1960, raised the question of what possibly was to be found on the other side of the crossing of Fosso Pietrisco – an area called Vignale with similar geographic characteristics as the main acropolis of San Giovenale. Could it be another Etruscan village and what about the road – where did it lead?

The Vignale Archaeological Project is working with different survey methods in the ancient areas of San Giovenale in Etruria, Italy. These methods intend to be used as a basis for better understanding of the historical processes that have shaped and influenced the region over a period of 2,500 years. As a natural part of the Swedish research tradition on the Etruscans, our focus has been based on the embroidery of the knowledge already gained around the main site. This is also an important part of our aim of the project - the integration of previously unpublished archaeological results with new methods and findings. Using these new technologies in our aerial surveys, in addition to land surveys, ancient features could be further expanded. This means that we not only gained a good overview of the central area, but also more information about the site's periphery.





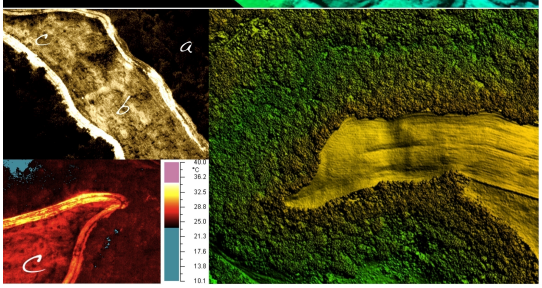


FIGURE 2. ***Upper:*** *LiDAR-image showing the Vignale plateau and the discussed areas a-c. An Etruscan road is clearly visible as a diagonal line in the marked red area a.* ***Central:*** *The Vignale plateau seen from north-west. The road is clearly seen between the markings a, where the lower end marks the area of the bridge.* ***Lower-upper left:*** *Thermo photography of Vignale looking down from the east. Clearly visible is the rectangular construction beneath the surface of area b. Note the cistern in the upper left corner.* ***Lower-lower left:*** *Thermo photography of wells (pozzi) in area c.* ***Lower right:*** *LiDAR-image of Vignale showing the vegetation covering the surrounding ancient infrastructure. Note the central plateau with the "platforms" of area b.*

This material thus involves conventional aerial photography in addition to various remote sensing techniques such as infrared- and thermal photography. The latter technique is a relatively new method of investigation to be used from a low-flying ultra-light aircraft, an asset that our project used during the fieldwork – flown by our own team and conveniently used as a daily tool. An important aspect of this type of field survey is to supplement and develop the already gained knowledge without adding the costs of new extensive excavation ventures.

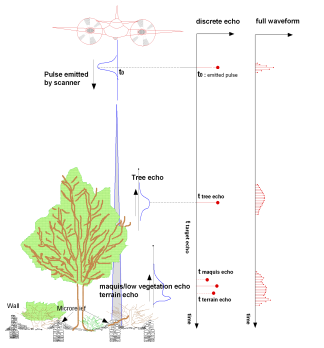


FIGURE 1 *– Conventional and full-waveform Airborne Laser Scanning*

A hidden landscape comes to life

Various remote sensing techniques were used in order to complement each other. These were however based on several seasons of previously made land surveys made by the team in the area of interest.
Conventional digital photography from the plane was used in order to easier detect ancient installations from the air. Satellite imagery at very high and medium resolution (QuickBird and Aster images, respectively) allowed us to analyze the landscape and to identify potential sites of archaeological interest, by exploiting the synoptic view and the multispectral resolution of such data. The satellite data are also the georeferenced maps for locating and studying, by means of methods of spatial analysis, archaeological findings, sites and anomalies identified by using the rich aerial and satellite data set.
Near infrared (NIR) photos were also taken parallel to these photos to further enhance variations in the chlorophyll of the green areas covering the site. In this way we could detect shallow underlying structures. The latter was not so effective in itself, but helped us in being an intermediate tool when identifying structures on photographs with another technique – that of the thermo camera. The results based on these remote sensing techniques were further clarified by performing a second series of ground inspections to verify the provided data. The latter included dating of pottery recovered on the sites and more detailed visual inspections.
The current and last step of our approach involved a LiDAR-survey, provided by Full-wave form scanner, which has been carried out in order : to overcome the limits of optical imagery, such as over all, the dense vegetation which covers a large area of the Vignale plateau. Moreover, the very high spatial resolution of DTMs derived from LiDAR survey allowed us to observe and analyze microrelief, thus discriminating those microrelief related to geomorphological factors from those of possible cultural interest.

Archaeological results combining conventional-, NIR-, thermo photography and LiDAR scanning

The recent five years of studying the Vignale plateau and its surroundings, have greatly broaden our knowledge of the area beyond the bridge. Today, ample evidence suggests that we are dealing with a sister acropolis adjacent the already studied main site of San Giovenale. Not only do we see the presence of a settlement around the middle of the first millennium BC, but also a continuation into the Roman period, indicating scattered habitation remains among intensively used locales of cultivation. These installations can furthermore be studied in relation to the development of infrastructure, such as ramps, roads, walls and necropoleis.

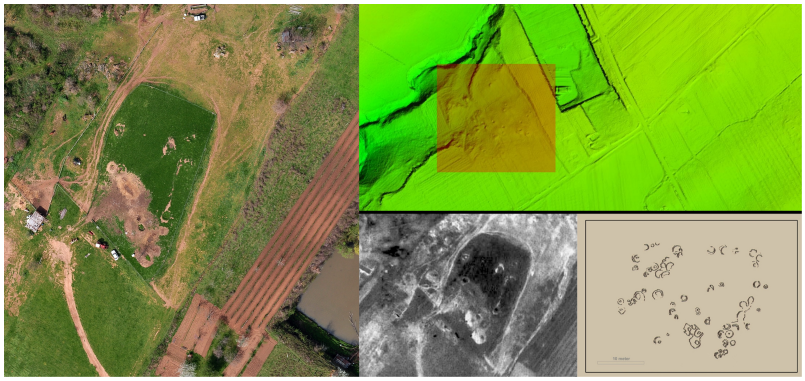


FIGURE 3. ***Left:*** *Aerial photograph of the necropolis of Fosso Pietrisco. Only a few robbed tombs are visible as circular spots below the central green area.* ***Upper right:*** *LiDAR-image of Fosso Pietrisco marked in red. Around a dozen tombs are clearly visible in the uneven soil covering further tomb structures.* ***Lower left:*** *Thermo photography of the same necropolis showing many uncovered and visibly undetectable tombs.* ***Lower right:*** *Drawing showing an interpretation of the separate tomb structures revealed through thermo photography and LiDAR-image.*

Thermo photography in combination to the LiDAR-survey can show us the relation between the infrastructure and the areas of habitation. A rough outline of these entities can for example be seen in fig. 2, where the vegetation on the northern slopes of Vignale covered a direct link between the two sites of habitations in San Giovenale. The letter *a* marks an intricate passage of roads and ramps that directly connects the Etruscan bridge to the plateau of Vignale. The road is best detected through the use of LiDAR when, on the contrary, thermal images have been vital to detect remains on the actual plateau. The road connects to the plateau through a ramp just inside a feature that resembles a larger wall crossing the plateau. On the western side of this protective installation, two major areas of habitation can be discerned – area *b* and *c*. Ground inspections in area *c* show evidence of large amounts of pottery and scattered remains of tufa blocks – originally constituting building materials. The thermal images helps us completing the evidence of habitation through a vast amount of wells, distributed over the entire western point of the plateau. The remains suggest an area of habitation through at least three centuries starting from the sixth century BC.

Area *b* indicates a similar dating, but trial soundings and thermo photography reveals a dense cluster of building material shaping a larger rectangle of about 40x30 meters. This is also evident from the LiDAR images that imply some kind of levelled plateau beneath this construction. A small and rectangular "cold spot" is evident surrounded by the rectangular space and is confirmed through excavation as a cistern. Adjacent trial soundings have revealed cultivation trenches, cut into the tufa bedrock. These type of trenches strongly suggest a dating around the late forth century BC, hence belonging to a period of Roman villas leaving their testimonies in the Vignale area. The current working hypothesis therefore advocates a monumental building on this spot even though it is impossible to give a precise function and dating at this stage.
Several burial grounds around Vignale are of interest because it allows further knowledge of the presence of the settlements on the site. An area with a few single graves that were excavated already in the 1960s, has changed vastly through the use of remote sensing techniques. The necropolis of Fosso Pietrisco (fig. 3), discovered during excavations in the 60's, contained three so-called pozzi-graves from *c*. 700 BC. Through the aerial survey we can now see that this burial site is much larger than expected. Thermal images show the presence of at least 60 individual graves beyond the ones already excavated. Aspects on these kinds of findings provide clues to the general picture of the area's early history, infrastructure and demographics.

Reference

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Map of San Giovenale and its surroundings. Courtesy of Soprintendenza per i Beni Archeologici dell'Etruria Meridionale

Integrated archaeophysical approach: LiDAR, Infrared, satellite imagery,

VIGNALE PROJECT: Etruscan civilization, settlement, road, necropoleis