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What’s beyond the Etruscan bridge?

Analysis and dating of the Vignale plateau

San Giovenale. Results of excavations conducted by the Swedish Institute of Classical Studies at Rome and the Soprintendenza alle Antichità dell’Etruria Meridionale
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Back cover: Bridge (illustration by R. Holmgren).
Dust jacket: The enigmatic Stone Platform excavated on Vignale in 1959, looking north-west (photograph by C.W. Welin, courtesy of SIR). See p. 183, *Fig. 155*.

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ABSTRACT
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The Etruscan site of San Giovenale has been excavated periodically since 1956. From the beginning the main focus has been the question of settlement remains. However, a fundamental area within the site had still not undergone the inquiry necessary for a complete understanding of the site as a whole. The Vignale plateau, connected to the main site by an Etruscan bridge, was surveyed and partly excavated in 1959–1960, but not published. The Vignale Archaeological Project (VAP) began new investigations in 2006 that aimed to answer the question of "What's beyond the Etruscan bridge?" This publication focuses on the initial investigations of 1959–1960, augmented by new ground- and aerial remote sensing surveys.

The current volume is divided in six chapters. Through an introduction, and geological/topographic and historical/archaeological settings (*Chapters 1–3*), the reader achieves a general understanding of Vignale within a larger framework. The main archaeological studies of various features on the plateau, their function and dating are covered in *Chapter 4*, where Vignale from the Final Bronze Age to medieval times is approached with an emphasis on the Etruscan periods. The study of the latter investigates the connection to Vignale's sister plateau (the Acropolis area), and the plateaus' connection to the surrounding landscape. An intrinsic aspect of Vignale is the association with wine over time. *Chapter 5* therefore elaborates on wild and domesticated vines with emphasis on production, ritual, and material remains, concluding with a summary and synthesis in *Chapter 6*. Two extensive appendices follow, one detailing the material remains and data connected to the southern Bridge Complex, and the other a treatise on the Etruscan awareness of their local mineral salt, alunite.

Keywords: San Giovenale, Vignale, Etruscan, viniculture, viticulture, cisterns, infrastructure, necropolis, remote sensing, LiDAR, aerial, bridge, ram's head, settlement, photography, defence structures, platform, quarry, wine press, alun, alunite

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Chapter 3. Archaeological studies on Vignale

Early archaeological studies and recent surveys

Since the first studies in the Etruscan territory, numerous field surveys and excavations have successively increased our knowledge.[69] San Giovenale has been considered in a number of articles, such as in publications of tombs, architectural remains, and finds from various study areas of interest.[70] The importance of San Giovenale cannot be underestimated since it was one of the first major sites in Italy to focus on excavating settlements rather than graves.

From the 19th to the 21st centuries San Giovenale has been explored on various occasions by Italian and Swedish archaeologists along with their students. Such ventures started in 1876 when Odoardo Rispoli, an Italian archaeologist from Tarquinia, unearthed hundreds of tombs at Casale Vignale. Subsequently, in 1876–1877, the archaeologist Giosafat Bazzichelli published the first note on Rispoli's excavation of the tombs.[71] Gian Francesco Gamurrini and his Italian colleague Adolfo Cozza made the first land survey of San Giovenale in 1881–1897.[72] However, it took a few decades before the survey was published as 'San Giovenale' and 'Necropoli di San Giovenale', in *Carta archeologica d'Italia* (1881–1897).[73] Half a century later, between 1956 and 1965, surveys and excavations were undertaken by the "flying squad" and scholars from the Swedish Institute of Classical Studies in Rome.[74] The results of the investigations were to be published in Acta Instituti Romani Regni Sueciae, Series in 4° (ActaRom-4°).[75] In 1962 an excellent book of more general appeal was published on the excavation results at San Giovenale, and on the Etruscans in general—*Etruscan culture. Land and people*.[76] Subsequently, several articles and books treating San Giovenale and its environs have been published.[77]

The Soprintendenza alle Antichità dell'Etruria Meridionale, in collaboration with Gruppo Archeologico Romano (G.A.R. settore Etruria interna), continued to explore and document many of the looted tombs at San Giovenale and reported them in the periodicals *La Toretta* and *Studi Etruschi*.[78]

Pamela Hemphill conducted land surveys in 1981–1989 in the Civitella Cesi area, which included San Giovenale and its surroundings. The results were published in the *Forma Italiae* series and a book was also published in the San Giovenale series of the Swedish Institute of Classical Studies in Rome.[79] Recently, Fredrik Tobin-Dodd has furthermore conducted targeted land surveys and, in collaboration with Matthew

[69] Dennis 1883. See, for example, Wetter 1962; Potter 1979. On field survey as a method, see Attema *et al*. 2010, 15–16.

[70] For a general bibliography of San Giovenale, see Bellerba & Alroth 2013, 155–159.

[71] Bazzichelli 1876–1877, 151–154. See, for example, Bellerba & Alroth 2013, 155. The *c.* 200 tombs were placed in the Porzarago necropolis in *San Giovenale* I:5, 9, n. 2, but according to Gamurrini *et al.* 1972, 146 fig. 100, and Ricciardi 1983, these were found in the north-east part of the Casale Vignale necropolis: see also Tobin-Dodd 2015, 207. Cf. also del Chiaro 1959, 264–274. In the late 1960s R.E. Linington, a foundation staff member of the C.M. Lerici Foundation conducted a geophysical examination (*magnetometro a protoni*) in the Porzarago necropolis in order to locate further Iron Age pozzetti tombs, but could find no evidence of any, Linington 1967.

[72] Gamurrini *et al*. 1972.

[73] Gamurrini *et al*. 1972, 146–151.

[74] Hanell 1962, 304–306, figs. 279–280.

[75] Bellerba & Alroth 2013.

[76] Boëthius *et al.* 1962.

[77] See a revised bibliography, Bellerba & Alroth 2013.

[78] *San Giovenale* I:5; I:6; I:8; Fuglesang 1997–1998. For the tombs recently excavated by Gruppo Archeologico Romano (G.A.R. settore Etruria interna), on the Casale Vignale plateau and the Castellina Camerata necropoleis, see Ricciardi 1983; 1986a; 1992. During the 1980–1990s the soprintendenza in Rome continued excavating several tombs in the Casale Vignale and Castellina Camerata necropoleis: cf. Ricciardi 1984; 1987a: see information on tumuli and cube tombs (*tombe di dado*) reported by Colonna 1973, 537, during the construction of the large pozzolana quarry along the Blera–Civitella Cesi road near the Fosso del Pietrisco tombs, see *San Giovenale* I:8.

[79] Hemphill 2000, 22.

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Fig. 18. The excavations of the northern abutment of the Etruscan Bridge Complex in 1962, looking north (photograph by S. Hallgren, courtesy of SIR).

Berry and Sophie Hay, undertaken a geophysical survey on the Acropolis and the surrounding plateaus. This has resulted in hundreds of newly documented Etruscan tombs, as well as new discoveries and other archaeological remains.[80]

Investigations at the Pietrisco bridge and the Vignale plateau

Investigations carried out on both sides of the Pietrisco brook began almost 60 years ago (1959–1963), undertaken by the Swedish Institute of Classical Studies in Rome and in close collaboration with the Soprintendenza alle Antichità dell'Etruria Meridionale, with Carl Eric Östenberg, Ingrid Pohl, and Stig Forsberg as excavators.[81]

Amidst dense vegetation, scholars from the Swedish Institute of Classical Studies in Rome discovered remains of walls on the northern side of the Pietrisco brook in 1959 (*Fig. 18*).[82] The site was easily reached from the Dogana (Via Ceretana), the important economic route that runs through the settlement. A smaller path branched south to the Fosso del Pietrisco, where a trial trench on the northern side of the brook was first opened and examined by Östenberg in 1959, subsequently investigated by Pohl in 1960, and then widened by Forsberg in 1961. Several trenches were later opened on the south side of the brook when the excavators realized that the remains that initially were interpreted as part of a defence system were in fact the remains of a monumental bridge abutment.[83] The excavations continued on both sides of the brook until 1963.[84]

In 1983 the results of the excavations were discussed at a symposium at the Swedish Institute of Classical Studies in Rome, and were published the following year in *San Giovenale. Materiali e problemi*.[85] In 2005, the Bridge Complex was further elaborated on in a Ph.D. thesis, *Crossing the bridge*—

[80] Tobin-Dodd 2014; 2015; Berry & Hay 2015.

[81] Forsberg 1984.

[82] The *Squadra volante* (the "flying squad") consisted of E. Wetter, A. Boëthius, E. Welin, C.E. Östenberg, J. Asplund, and King Gustav VI Adolf. See Wetter 1962, fig. 189. See also Wetter 1960, 177, fig. 146, with Östenberg, G. Filipetto, and a few co-workers; Östenberg 1976, 38–40.

[83] Hanell 1962, 281, 304–305; *San Giovenale* I:1; I:7; I:9.

[84] See *Appendix 1*.

[85] Forsberg 1984, 73–80, pls. 5–6.

Fig. 19. Left: the southern bridge abutment showing the walls flanking the two road directions on the Vignale slope, east and west respectively. The left road going east and uphill leads to the plateau through Via Vignale Nord. Right: Via Vignale Nord with its Etruscan paving exposed near the bridge, looking north-west (photograph by S. Forsberg, courtesy of SIR).

Image only available in print edition.

Fig. 20. Two aerial views of the two main plateaus in San Giovenale, taken in 1961. On the Vignale summit, visible to the right, the long excavation trenches of 1959–1960 are clearly visible (© ICCD-Aerofototeca Nazionale, fondo Aeronautica Militare, volo 23 giugno 1961 fotogrammi 412, 411).

An interpretation of the archaeological remains in the Etruscan bridge complex at San Giovenale, Etruria by Backe Forsberg. However, stepping back to the late 1950s, the southern side of the Bridge Complex came to problematize yet another question which regarded an ancient route that forked to the west and east respectively. The eastern connection, which seemed to lead up to the Vignale summit, encouraged additional archaeological studies on the plateau (*Fig. 19*). In 1959, the first test trenches were made on Vignale and thorough excavations followed that same and the following year.[86]

[86] The Vignale hill was partly surveyed by Gian Francesco Gamurrini in 1879–1882, but no results were presented: see Gamurrini *et al.* 1972, fig. 100. Östenberg and del Chiaro investigated the Vignale hill in 1959, and Brown in 1960 (CEÖ notebooks I–II 1959; MdC notebook 1959; FB notebook 1960), see also Gierow 1986, n. 2; Hanell 1962, 304. Plans,

Investigations on the western part of the Vignale summit were conducted in 1959–1960, when cisterns and wells filled with pottery, as well as architectural terracottas and house remains, were uncovered—seemingly an Etruscan habitation (*Fig. 20*). The wall foundations could be dated to the Early and Late Archaic periods and the pottery material dated from the Proto-Villanovan to the Hellenistic periods.[87]

In 1989 Hemphill ended her seventh and final survey, the series of which had started in the early 1980s. She reported the results in an article published in 1993 as well as in her book published in 2000, *Archaeological investigations in southern Etruria. The Civitella Cesi Survey*.[88] She documented over 200 Roman sites (villas, farms, and houses) in the surroundings of San Giovenale, including the Vignale plateau, and concluded that there was a seemingly peaceful Roman infiltration in the area.[89] She also discovered and documented a new Etruscan chamber tomb, dated to the 6th century BC, *c*. 1.5 km from the Valle Vesca cemetery that was excavated and published by Pär Göran Gierow.[90] Her survey also recorded some Etruscan pottery and tiles associated with the "San Giovenale suburb of Vignale",[91] as well as Roman coarse ware pottery and tiles spanning from the 3rd to the 1st centuries BC up to the 2nd century AD. This material was connected to the central and northern parts of the plateau, not far from Via Vignale Nord which connected the Bridge Complex with the Vignale summit.[92]

In 1999 the present authors conducted an architectural study and trial soundings on the northern Bridge Complex abutment. The primary objective of the study, conducted together with the Swedish Institute of Classical Studies in Rome and the Soprintendenza alle Antichità dell'Etruria Meridionale, was to reinvestigate the foundations of House 1 and 2 together with the connecting street making part of the bridge abutment.[93] The examination of the various features was also helpful in order to recreate architectural plans as well as reconstruction drawings of the ancient setting. The results were eventually published by Backe Forsberg,[94] where parts of the graphic records made by Richard Holmgren are also presented in this book. The trial soundings performed were primarily concerned the lower strata of the houses where a great variety of pottery types were contained in the fills. These pottery-rich deposits appear to have created a foundation for the houses and also distinguished different phases of building activity. Apart from the more scientific endeavour, the work in 1999 also tinged the authors with nostalgia, because they had the privilege to be guests of one of the last herdsmen to still live in the empty tombs of south-western Casale Vignale.

Vignale Archaeological Project (VAP) from 2006 onwards

After nearly 50 years of archaeological fieldwork at San Giovenale, the research then continued with four distinct field and aerial surveys of Vignale, conducted under the name of Vignale Archaeological Project (VAP). An important aspect of this study was to determine the actual boundary of the settlement itself. The aim of the VAP project was not to provide an all-embracing answer to the extent and function of the settlement remains on Vignale—such a venture could only be answered through the removal of soil through excavation, or by future probing techniques. VAP rather tried to build a platform for future research, by studying the available material remains and presenting those as both direct and indirect indicators of what could be expected on and around the plateau, an important part of the site we today call San Giovenale.

Thus, in the years 2006–2010, the project focused on a landscape-archaeological survey of the sporadically studied high plateau of Vignale with its surrounding infrastructure. Three weeks of fieldwork during February and March of 2006 initiated the project.[95] The objective of this assessment field study was to re-evaluate the soundings made in the late 1950s; this approach was inspired by the questions raised between the present authors during the 1999 fieldwork. The survey conducted in the early spring occasionally encountered heavy rains, which equally limited and delivered rewarding results. The muddy slopes and strong currents in the river Vesca hampered the workflow, but the harsh environment also made clear the need for and benefits of aerial perspectives. The rains also advantageously washed the topsoil on the plateau, exposing datable pottery and revealing the perimeters of scattered settlement remains. Detailed field documentation with plan and section drawings was achieved, embracing the chamber tombs in the Southwestern necropolis, wine presses (*pestarole*), visible wall structures on the southern slopes, ramps, the

sections, and photographs by the architect J. Asplund and the excavators, and stored at SIR, have also been consulted.

87 Hanell 1962, 304. See also MdC notebook 1959; CEÖ notebooks II and IV 1959; FB notebook 1960.

88 Hemphill 1993; 2000, 44, sites 55 and 57.

89 Hemphill 2000, 44. See also Hemphill 1993.

90 *San Giovenale* I:8; Hemphill 2000, 44, figs. 40–41, sites 55, 57, 69; *Carta d'Italia, foglio* no. 143 (Civitella Cesi).

91 Hemphill 2000, 44, site 57.

92 Hemphill 1993, figs. 3, 5–6; 2000, sites 55, 61, figs. 203–206. Material dated to the 6th century AD has been collected at various places in the survey area.

93 Backe Forsberg 2005, 53–56, figs. 36, 38–44a.

94 Backe Forsberg 2005, figs. 96–97.

95 The field survey staff of 2006 consisted of the present authors together with Prof. Ingela M.B. Wiman.

distribution of small bridge abutments along the river Vesca and the Pietrisco brook, roads and passageways, as well as detailed studies of scattered stray finds (*Figs. 11, 21*).

The field survey as a whole was instrumental for the overall understanding of both Vignale and the outskirts of the San Giovenale settlement. The thorough documentation was particularly important in establishing areas of interest for the upcoming and proposed aerial surveys—where the visible features and traces of crop-marks became important guides. The field survey also comprised visits to local farmers on Vignale, where fruitful discussions enriched the understanding of rumours regarding concealed structures, features, and other finds on their respective properties.

Fig. 21. Survey and documentation during the field season of 2006. Documentation of Vignale's defensive structures, here Wall A. Left R. Holmgren, right I.M.B. Wiman (photograph by Y. Backe Forsberg).

VAP field and aerial surveys of 2007, 2009, and 2010

In 1961 Bertil Hallert made a photogrammetric survey based on aerial photographs taken in 1959–1961 by the Italian agency Stato Maggiore Aeronautica Militare to produce a topographic map of the San Giovenale area. The map was at the scale 1:1,000 with contour intervals of 1 m or more.[96] Vertical aerial photographs of satisfactory geometrical and photographic quality were taken from a flying altitude of 750 m above the ground and the scale of the photographs was 1:5,000.[97] The topographic model can today be seen in the entrance hall of the Museo Nazionale Etrusco Rocca Albornoz in Viterbo, as well as in *San Giovenale* I:2–3, 8–11, figs. 3–4.

The aim of our modern aerial and remote sensing venture was to complement the already gained results from the ground surveys and the earlier aerial surveys in 1960s (*Fig. 22*). This provided the project with a better site overview and the possibility to investigate new techniques for locating obscured structures, hidden both underground and under dense vegetation. The focus of the aerial surveys performed periodically in 2007, 2009, and 2010 focused on the Vignale plateau and its immediate surroundings—but also San Giovenale as a whole in order to visualize Vignale as an integral part within the settlement. Roads, isolated structures, and nearby necropoleis could now be studied from yet another perspective. Various results have been achieved when combining high-resolution satellite data, and these have been earlier presented in separate articles.[98] This volume will only focus on the methods used that provided the most effective outcomes—results that could be corroborated with archaeological data from the ground surveys that took place concurrently during 2007 and 2009. The aerial data consisted of digital models deriving from the LiDAR survey made in 2010 and the remote sensing activities of 2007 and 2009. During these first two years a multisensory aerial prospection was utilized—that is, traditional aerial photography as well as thermal (IRT) and near-infrared (NIR) methods.[99]

Apart from the LiDAR survey, the remote sensing activities executed over Vignale utilized a DTA Combo small ultralight aircraft. It was remodelled for archaeological purposes and generously sponsored by team member Hannu Kuisma, and operated by the team's pilots Robin Fjellström and Richard Holmgren. The modest size of the machine and its cost-effective operation, as well as the ability to land and to take off next to the study site, made this kind of venture a very effective contribution to the overall success of the survey. The aircraft became a useful tool within the daily work of the archaeologists and it allowed data to be verified and recreated almost immediately. It is important to note that during our time of remote sensing, the development of low-cost and easily operated drones such as the ones utilized today was still in its infancy. Furthermore, equipment used for thermal photography was at the time too weighty for drones or remote-controlled aircraft technology. Using an aircraft with two surveyors was also part of an assessment study by ARCDOC, Archeological Documentation,[100] to evaluate surveying techniques over

[96] *San Giovenale* I:2–3.

[97] *San Giovenale* I:1, map 2; I:2–3, 3, 8–9, fig. 3. A 3D map of San Giovenale is also presented by Scardozzi 2003, 261, 265, fig. 476.

[98] Backe Forsberg *et al.* 2008a; 2008b; Coluzzi *et al.* 2011; Lasaponara *et al.* 2012; Scardozzi 2003; Backe Forsberg & Holmgren 2017, 12–15.

[99] Backe Forsberg *et al.* 2008b; Coluzzi *et al.* 2011. See also Verhoeven 2012, 138.

[100] ARCDOC, Archaeological Documentation, was started in 1992 by Richard Holmgren, as an international consulting company to carry out

Fig. 22. Vignale Archaeological Project: Robin Fjellström, pilot upper left, Richard Holmgren, pilot/archaeologist lower left, Yvonne Backe Forsberg, archaeologist lower left, Hannu Kuisma, sponsor/photographer lower right, & an aerial view of Civitella Cesi, upper rigt (photographs by VAP).

large areas, where the archaeologists themselves were required to land and perform direct ground inspections. Such a methodology can only be performed using a conventional plane.

For the best viewing results, the entire housing of the aircraft was removed, giving clear views all around and allowing for vertical photography. All flying equipment was brought to Italy from Mora in Sweden by car using a trailer (*Fig. 23*). The project initially used a small airstrip close to the city of Blera and eventually used a hangar and a conventional airfield near the town of Vejano for the daily operations.[101] Vejano is a three-minute flight from Vignale, where all the remote-sensing activities were carried out from altitudes of between 50 and 400 m (*Fig. 24*). The higher altitude was a limit imposed due to the airline traffic from Rome's international airport at Fiumicino.

The aerial method of linking previously excavated sites with covered, or from the ground undetectable structures, made it possible to put several decades of detailed studies in a wider and more meaningful context. This kind of survey method furthermore revealed excellent views for studying the geological processes that reshaped and affected the cultural landscape over the centuries.

The remote sensing apparatus used from the aircraft, sometimes fundamental for the feature descriptions in this volume, comprised conventional aerial photography, infrared thermographic (IRT), and near-infrared (NIR). The NIR photography was used to cover the NIR spectral channel which had a potential to further enhance vegetation marks for hints of irregularities below ground. The thermal imaging camera, on the other hand, generated images of warmer and colder areas

archaeological excavations and cultural heritage conservation, conveyed through written and graphic documentation.

[101] Scuola di volo in Blera, and Aviosuperficie Alituscia, Scuola di volo in Vejano.

Fig. 23. Robin Fjellström seen by the trailer in Austria. Flying equipment was brought to Italy from Mora in Sweden by car (photograph by R. Holmgren).

Fig. 24. The ultralight aircraft used for remote sensing by conventional photography, NIR, and IRT, here seen near the castle of the di Vico family in San Giovenale, looking east (photograph by VAP).

of structures hidden beneath ground. All cameras used a digital interface and the NIR and conventional landscape photography covered images in both colour and greyscale (*Fig. 25*).

Camera provision and digital processing of the IRT images was made possible through our co-operation with Dr Nicola Masini (CNR/IBAM) and Dr Rosa Lasaponara (CNR/IMAA), National Research Council of Italy (CNR), Potenza. The acquisition of the LiDAR data was carried out by the Geocart srl by helicopter, with the processing and interpretation conducted by Masini and Lasaponara. Various articles on this co-operation have been presented elsewhere which contain more in-depth technical data, as well as details of complementary satellite remote sensing over Vignale.[102]

CONVENTIONAL PHOTOGRAPHY

Landscape aerial photographs were shot from the aircraft with a digital Nikon DSLR camera in order to provide informative overviews of focused study areas of San Giovenale. These photographs were also essential for detecting variations in vegetation cover and soil types generated by underlying structures, such as soil, shadow, and crop-marks, visible to the naked eye. Certain crop-marks were already visible from the ground, such as concentrations of certain flora at wet spots. The combination of infrared thermography (IRT) and conventional photography could, for example, be used to locate hidden wells or cisterns.[103]

INFRARED THERMOGRAPHY (IRT)

In spring 2009, VAP made its second survey with the aircraft and extended the research methods by including infrared thermography, which had already been briefly tried out in spring 2007. The thermal imaging camera, an AVIO TVS 600 microbolometer was provided by the above-mentioned collaborators in Potenza. The rather bulky and weighty camera had not been used for aerial remote sensing activities earlier, but thanks to the determination of the team from CNR/IBAM and CNR/IMAA, it was utilized handheld from the aircraft and, as will be shown, delivered some noteworthy results. When using infrared thermography, variations in surface tem-

[102] The project has generated both scientific and popular articles, e.g., Backe Forsberg *et al.* 2008b; Lasaponara *et al.* 2012; Backe Forsberg & Holmgren 2017, 12–15.

[103] See *Chapter 4* 'Water installations (WI)' and Lasaponara *et al.* 2012; Coluzzi *et al.* 2011; Backe Forsberg *et al.* 2008b; Masini *et al.* 2018; Verhoeven 2012; Musson 2005, 35–39, 41–43, figs. 2.7–9; Shell 2005; Musson & Campana 2005, 173–183.

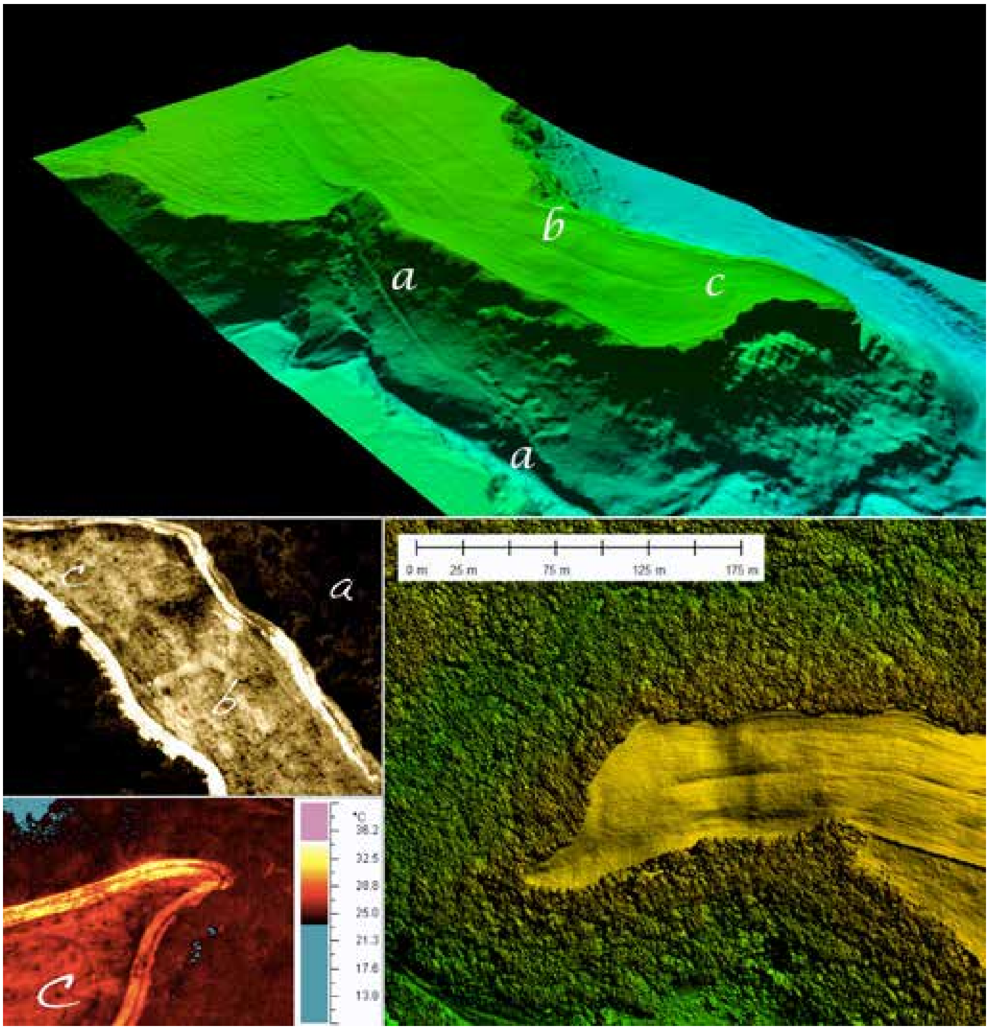

Fig. 25. Upper image: LiDAR image of the Vignale plateau showing (a) the Etruscan road connecting the bridge with the upper plateau. Lower right image: vertical LiDAR image of Vignale showing the dense vegetation cover before being digitally removed. Central left image: infrared thermography (IRT) of Vignale from east. Clearly visible are bright patches of wall structures in areas (b) and (c) not visible from the surface. Lower left image: infrared thermography (IRT) of hidden wells and/or cisterns shown as dark dots on Vignale's westernmost point (c) (illustration and photograph by VAP, N. Masini [CNR/IBAM], R. Lasaponara [CNR/IMAA]. The acquisition of LiDAR data was carried out by Geocart srl; the processing and interpretation were conducted by N. Masini and R. Lasaponara).

perature have the potential to pinpoint underlying structures. The system identifies warmer or colder regions where image postprocessing generates a relative colour scheme on a thermal map depending on the radiation wavelength, temperature, and the characteristic of soil properties. For example, any hidden cistern/well would reveal itself as a blue or darker spot because of its colder interior in relation to its warm-coloured surrounding.[104] If conditions were optimal the same relationship between warm and cold could be detected among various features buried in the soil—for example, where soil types are relatively moist and/or deep. The best photographic results were delivered in the late afternoons. After an entire day of sunlight the ground had begun to cool down, but shallow depths above structures such as walls or any other dense material were still warm enough to provide a relative reading. Thus the variations in temperature of various buried structures are seen in a measurable value depending on the emissivity of the source. The method was fairly imprecise due to, for its time, the rather low resolution of the digital image where geometrical patterns embracing larger areas became more useful.[105]

NEAR-INFRARED (NIR)

Infrared photography (near-infrared, about 1200 *nm*) permits sites with superficial structures to be traced through variations in moisture and temperatures in the covering soil. This in turn affects plant conditions due to differing chlororphyll contents, which is preferably registered with colour photography.[106] NIR photography was utilized by using an ordinary DSLR camera

[104] Lasaponara *et al.* 2012, 34, fig. 8.

[105] Backe Forsberg *et al*. 2008b, 225–228.

[106] Verhoeven 2012.

modified for this specific purpose. The hot mirror filter in front of the sensor, blocking the infrared part of the spectrum, was removed and replaced with an infrared filter. Since this filter is behind the mirror, the camera could be used in a ordinary fashion—handheld, with normal shutter speeds and with conventional composition through the viewfinder. This also allowed for faster exposures which was an advantage in a sometimes unsteady aircraft. The images were taken in tandem with the conventional aerial colour and black-and-white photographs. Since the NIR photography enhances changes in the chlorophyll reflectance, it was expected that anomalies would be detected in the low vegetation which could reveal cultural patterns. However, the method used from the aircraft proved to be less useful for large-scale anomalies, but beneficial for identifying wells and cisterns due to their higher concentration of moisture affecting the green cover. Mostly, the NIR images taken over Vignale were used as an intermediate analysing tool when comparing conventional aerial photography and thermal images, for example, when identifying wells.[107] Since aerial colour and monochromatic photography does not reveal any hidden features, but thermal photography does, the NIR images could often help us to find a match between the visible landscape and the often abstract low-resolution thermal imagery.

LIGHT DETECTION AND RANGING (LiDAR)

The final method utilized as remote sensing technique was a LiDAR survey, carried out by Geocart srl in September 2010, over an area of around 6 km^2 using a full-waveform scanner. Aerial LiDAR is an active remote sensing technique that provides direct range measurements between a laser scanner and earth's topography, mapped into 3D point clouds. The method of using LiDAR within archaeology was at the time a relatively new research method and the first results were published in 2012.[108] The principal idea of implementing a LiDAR survey over Vignale was to find a solution to overcoming the dense vegetation. Not only did this vegetation obstruct work during land-based surveys, but it also prevented aerial investigations in many important areas surrounding the open plateau (*Fig. 25*, upper and lower right images).[109] LiDAR allowed us to see the ground surface terrain in order to later collect detailed information of the study area on the ground. As expected, the integration of the various data sets enabled the identification of a number of unknown features of cultural interest, which were also verified and confirmed by conventional archaeological field surveys.

SPATIAL DATA (GPS)

The spatial data gathered over and around Vignale was achieved by using a handheld (standard point positioning) Garmin GPS 60. All measurements provided acceptable precision for the task and were taken on at least two different occasions during 2009—this in order to adjust for possible atmospheric distortions. The spatial accuracy of the pinpointed features was within 3–5 m on the slopes and 2–4 m on flat open terrain, such as on the plateau itself. All GPS measurements presented in the feature descriptions are established with one central reading only. Long features, such as walls, usually have two readings with one at each end. The overall aim was to position the described elements as accurately as possible, where sub-metre or exact measurement readings could be obtained in future ventures when exposed from the obscuring soil and/or vegetation. One should regard VAP's surveys of 2006–2011 as a broad analysis encompassing all features of interest, includingthe data acquired from before 1965. To verify and acquire additional detailed information, the preferable next step of field documentation would be that of geophysical surveys in selected areas of interest. Thus, in terms of the Vignale plateau the most appropriate way to proceed after the already implemented (1) field and aerial remote sensing surveys, would be that of (2) ground-based physical sensing techniques, later verified by (3) trial soundings and excavation.

107 Lasaponara *et al.* 2012, 33.

108 VAP presented a poster, *LiDAR, aerial and satellite remote sensing on Vignale*, in a Remote Sensing Conference in Vienna, April 2011, see Coluzzi *et al.* 2011, as well as in peer-reviewed extended articles, Lasaponara *et al.* 2012; Shell 2005, 285–293.

109 After Lasaponara *et al.* 2012, figs. 6a–c.