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Digital Maps for the Study of Medieval Landscapes

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Abstract. During the last five years the LIAAM (Laboratory of Computer Science Applied to Medieval Archaeology) of the Siena University has worked heavily on developing and testing a wide range of digital cartography related to archaeological data. In this paper we will discuss our approach to the management of a complex cartographical data set, focusing particularly on what kind of data archaeologists need and on how to relate these maps to possible research applications and management alternatives. Another important point is represented by the requirement of data exchange with local and regional administrations; this process has to be bi-directional (archaeologists acquire basic maps and return maps of archaeological risk) in order to really let our discipline be part of landscape administration processes. The GIS platform of the Archaeological Map of the Siena Province represents a valid model for both of the main points explained above; it has produced good results in fact of historical knowledge improvement.

Keywords. Digital Maps, Archaeological Heritage, Production of Topography, Georeferencing Methodology

1 Introduction

This paper, focused on Tuscany, illustrates the criteria adopted in building a digital cartography set suitable for archaeological data management; discussed scales range from the regional context to excavation area detail level. In particular, the projects we manage are:

- Atlas of Tuscan Fortified Hilltop Sites;
- Atlas of Tuscan Published Sites;
- Atlas of Tuscan Crop Marks;
- Archaeological map of the Siena Province;

Choosing the right supports means considering which representation formats and scales are more appropriate to the researcher's aims in all the different phases of a project. In particular, there is a need for tools satisfying requirements in terms of topography (georeferenced storing of data) and analytical-modelling elaborations (data processing in order to identify diachronical settlement patterns).

Besides the scientific usage, site plotting and localisation of areas with archaeological evidence are also destined to geographical information systems of public administrations and local governments. This allows archaeologists to have more influence on complex dynamics such as territorial planning and historical-archaeological heritage valorisation processes.

Availability of differentiated cartographical supports enables articulated physical and archaeological data treatment. In fact, recent progresses of spatial analysis modules and statistical calculus tools guarantee a fairly advanced elaboration level even to non-specialized users.

Regarding the software we adopted for landscape data management, ESRI's ArcGis environment has been, almost forcefully, our choice; it represents the standard application suite used by public administrations, our major digital maps suppliers (in four years we have acquired more than 50 Gb of numerical cartography).

2 Data exchange with Public Administrations

As we have already seen, numerical management of archaeological information allows its use within public administrations GIS's. This fact stimulates collaboration forms between archaeologists and institutions; both parts pursue an enhancement of their cartographical-informative supports. Levering on this kind of motivations, we have been able to settle agreements aiming at an exchange of numerical cartography. In particular, against our data regarding landscape surveys or published material, we get the necessary base-maps to store and elaborate identified sites. In this way the public administrations acquire material produced by specialized research, ready for integration with the already available digital maps; on the other hand, archaeologists are able to have updated and reliable digital maps at their disposal. In other words, the set of maps we gain is being sent back to administrators after an elaboration phase which improves thematic data to be used in decision-making process regarding landscape planning and valorisation of historical-archaeological heritage.

This kind of agreement has been promoted at a provincial level (Administration of the Province of Siena) and at a regional scale (Region Tuscany); through them we have obtained detailed coverage on many of the territories under investigation.

3 Cartographical supports for archaeological data recording

In site georeferencing we use both raster and vector support. Besides the traditional basic raster-tiff maps (IGM, Military

Geographic Institute - 1:25.000; CTR, Regional Technical Cartography (*fig. 1.1*) - 1:10.000, 1:5.000. 1:2000) we use ortorectified aerial photographs at a 1:10.000 scale and ground resolution of 1 m (*fig. 1.2*).

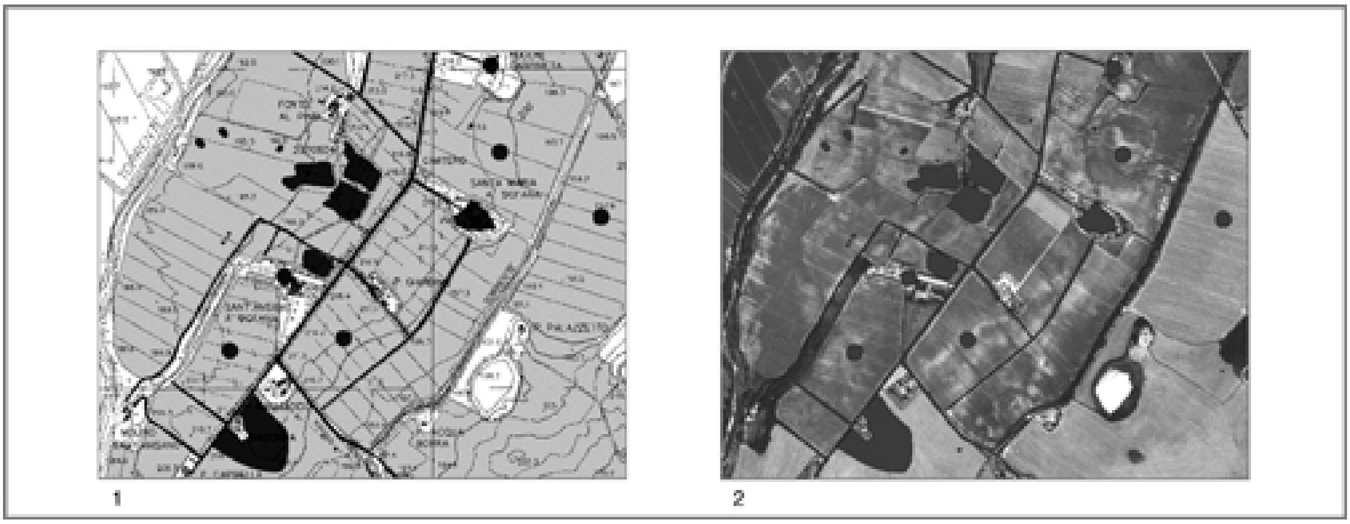

Fig. 1. *Examples of raster supports for sites and surveyed fields georeferencing. (1) Polygonal georeference of sites (in black) and surveyed fields (in grey) on a CTR 1:5.000 raster map. (2) Polygonal georeference of sites (in black) on ortorectified image (1:10.000, 1 m ground resolution).*

These ensure real reproduction of landscape, without the filters of cartographical symbology; also, traditional raster maps are not usually as up to date as ortorectified imagery, which are updated every 5-6 years and always reach more detailed resolutions. In fact, ortorectified aerial photographs end up being more useful in the process of site identification. Moreover, georeferencing of aerial photographs (flights done by our Department twice a year, and other official sources), allows detailed insight of interesting areas like those subject to crop-marks identification (*fig. 2*).

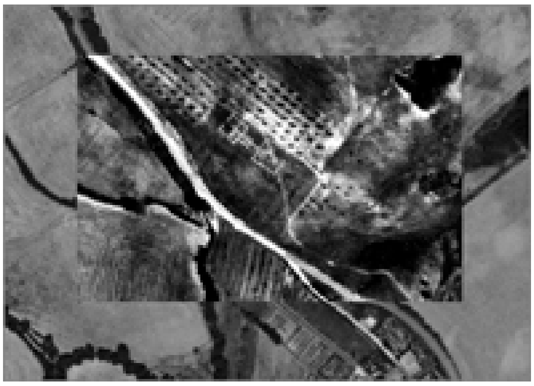

Fig. 2. *Georeferenced oblique aerial photograph overlaid on a ortorectified image (1:10.000, 1 m ground resolution).*

Regarding vector formats we use again the CTR set, which codifies geographical elements on the basis of data typology, associated with place name indications or other data pertaining to the particular kind of represented geographical features. Obviously we use higher scales (1:2.000 and 1:1.000) for researches focusing on urban centres (*fig. 3*), while on the landscape medium-high scales (1:5.000 and 1:10.000) can be considered sufficient.

Using these supports, alone or in different combinations, allows us to take advantage of cross-referenced information and decide on the basis of every single evidence which tool suites better the particular georeferencing process.

Besides acquisition of numerical cartography we use Internet tools and resources, especially providers of location-centric applications available for Italian[1] and European[2] territories.

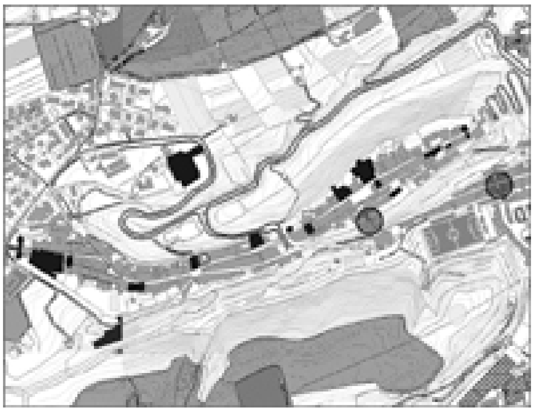

Fig. 3. *Polygonal georeference of sites (in black) within a historical town centre (Colle Val d'Elsa, Siena) on a CTR 1:2000 vector map.*

These tools present a rich collection of place-names and can be a valid support in lack of adequate cartographical support; they render themselves especially useful for the national and international scaled projects we are conducting, when there is no direct knowledge of the landscapes under research or detailed digital maps are missing.

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[1] For the Italian territory a fairly valid tool, especially regarding the place name database, is represented by Virgilio Mappe (http://mappe.virgilio.it/mappe/index.html).

[2] In a European context we usually consult two different interactive free services: Maporama (http://www.maporama.com/) and Map 24 (http://www.map24.com/).

For remote sensing applications we use multi-spectral satellite imagery, in particular ICONOS, with 4 meters ground resolution, integrated with vertical and oblique aerial photographs; a complete overview of our Department's activities in this field is discussed by the paper of Stefano Campana in this volume.

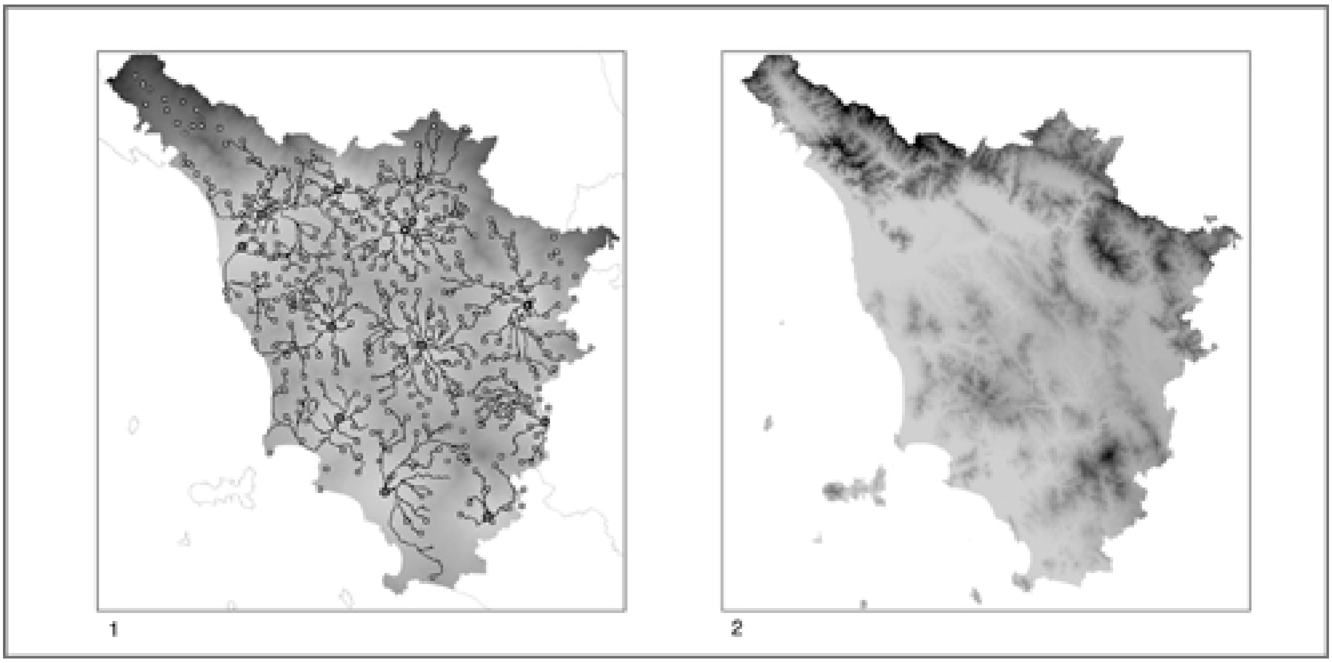


Fig. 4. Examples of grid usage. (1) Tuscan historical road network hypothesis (14th century) derived by overlaying of plebs (white points) on a grid-based cost surface analysis applied to cities (grey points). (2) DTM of Tuscany.

4 Cartographical supports for data treatment

Besides storing basic cartography, we proceeded towards the creation of a complete set of thematic geographical data. Particular attention has been paid to geological, hydrographical, morphological and land-cover aspects, useful during the preliminary phases of survey projects (identification of research sample areas) as well as in calibrating results of landscape research, justifying redistribution and projection of data on the features of present habitat. This operation can pass through the creation of archaeological probability maps, which are obtained by cross-referencing the above-mentioned thematic data; they can be verified, during the last phase of work, by studying the disposition of sites on the elaborated grids.

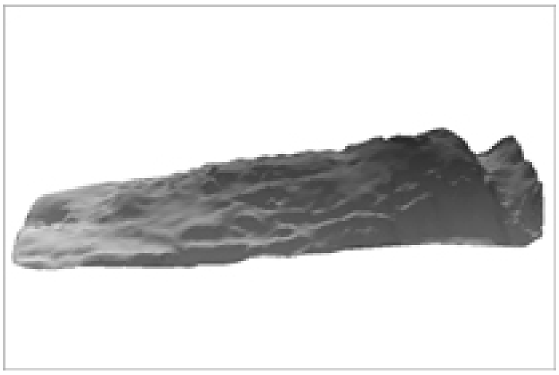
We use raster-grid formats in spatial analysis for overlays of different data levels (physical and morphological elements with historical-archaeological information) and in data processing, or in analysis of site distribution tendencies (*fig. 4.1*). Secondary uses are represented by simple morphological GIS visualization features, empirically perceivable from a DTM (*fig. 4.2*), and by derivation of the *z* (height) coordinate of each cell.

5 Three-dimensional cartographical support

Regarding the third dimension in a GIS environment, we need to point out a few notes on real efficiency in analysis and calculus features, as well as on 3D representation. It happens often to hear inopportune talk about three-dimensional GIS: our position is perfectly aligned with the definition expressed by Kvamme's team when, at CAA 2001, they talked about 2.5D GIS[3].

In fact, all major GIS software houses have released 3D modules (our personal experience is based on ESRI's ArcView 3D Analyst and on 3D module for GeoConcept), capable only of three-dimensional landscape visualization (*fig. 5*); it is not possible, today, to develop features suitable for analytical treatment of spatial-volumetric data.

Impossibility of applying real analysis on 3D topology forces us to partially postpone an in-depth discussion on 3D GIS topics since no satisfactory hardware and software choices are available. Today we can only take note of a few pioneering and courageous experiences in this field, like the one of Dominique Powlesland, who has codified his own GIS architecture, capable of managing and processing archaeological data in the third dimension[4].



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[3] Limp, Kvamme, Nigro et alii 2002.

[4] Powlesland 2001.

Fig. 5. DTM representing the hill on which the castle of Miranduolo (Chiusdino, Siena) is located (1 cm ground resolution). On the right part of the image, two ditches delimiting the upper part of the castle are clearly perceivable.

6 The production of new cartographical support

It sometimes happens to have archaeological projects on areas for which no detailed numerical cartography is available (1:1.000 or 1:2000), especially in the case of excavation projects; in these cases, being able to self-produce suitable tools becomes of major importance. The use of total station technology allows us not only to create topographical layers, but it also represents a good occasion to obtain important altimetric-morphological data in order to read the landscape. The map sequence you see in *fig. 6* regards the excavation of the castle of Miranduolo in Chiusdino, located between Siena and the tyrrhenian coast, in an area of heavy mining resources exploitation during the medieval period. Besides the mapping of more than 2.000 height points in an area something bigger than 0,5 hectares (*fig. 6.1*) and of all non-excavated structures traceable on the hill (*fig. 6.2*), we have produced a DTM through spline interpolation at a 1 cm ground resolution (*fig. 6.3*) from which we have derived isohypses (*fig. 6.4*), sun exposure and slope maps (*fig. 6.5*). In a predictive phase, useful indications can come especially from the combination of alignments regarding archaeological features identifiable on the surface ground with the evidence of morphological anomalies (slope maps). Integrating such data with those derived from surveys and from remote sensing analysis (both aerial photographs and satellite imagery) can conduct to hypothesis about topography of the site and distribution of non-localised structures.

Moreover, starting from the DTM, we have produced the necessary support in order to create a TIN (*fig. 6.6*) and obtain 3D visualization of the hill on which the castle was founded (*fig. 5*).

On the other hand, the use of GPS has been limited, in our experience, to punctual mapping of surface material concentrations found during landscape surveys; this methodology configures itself as a particularly useful tool in mapping sites at a medium-high detail level; we don't judge it to be suitable for complex cartographical needs, like those pertaining to excavated areas representations.

7 Archaeological data effectiveness

Regarding the management of territorial archaeological data, the punctual reference can be declared ineffective, especially if we consider the needs of cultural heritage management. The use of GIS platforms has made it possible to use surfaces, which represent much more suitable objects when it comes to landscape planning and development. In one of our projects, the Archaeological Map of the Siena Province, we decided to reproduce polygons not only of the superficial archaeological evidence, but also of all agricultural units we have surveyed, in order to keep digital memory of the detail about investigated areas (*fig. 1*). Such a recording system turns out to be extremely useful in a cultural heritage management perspective; at the same time it changes radically the ways of archaeological research and data processing, since our evidence can be effectively measured and therefore considered in its real extension (or, better, in its exact perceivable shape).

We still use punctual objects when we need a symbolic representation of settlement patterns; for example in the production of diachronical and typological maps, or for spatial analysis purposes (*fig. 4.1*).

One last consideration has to be made about identity of archaeological data, and particularly about the characterisation criteria of georeferenced elements. It has been of major importance for our work to assign a visibility code to every surveyed field, while each topographical unit has a reliability code together with a value defining the entity of represented data. We have assigned five reliability grades corresponding to different georeferencing precisions.

Sites which can't be georeferenced. Absence of related place name on our map support or of reliable reference in site records.

Absolutely random positioning

Sites georeferenced with a minimum reliability. Generic positioning on place name but without exact reference to the real localisation, and without persistence of evidence on site.

Generic positioning without precise reference to a place name

Sites georeferenced with medium reliability. Positioning on the basis of a fairly detailed description of site localisation or by weak (and insufficient) persistence of evidence on site, eventually combined with place name persistence.

Justified positioning with a medium precision

Sites georeferenced with good reliability. Positioning on the basis of a complete and detailed description of site localisation, or by clear persistence of evidence and remains, or persistence of place name with citation continuity in written sources.

Exact positioning

Sites georeferenced with optimal reliability. Positioning based on geographic coordinates derived from a GPS or a total station

Instrumental positioning

Moreover we have set up a data representation criteria, based on two different graphical conventions.

Georeferenceable site. Data exactly recognizable in its shape and dimensions, represented as a polygon of its perimeter.

Areal. Symbolic graphical reference (usually a circle with a diameter of 50 m) used in the case of non-defined concentrations (offsite), of non-positionable evidence (for example published sites without a cartographical reference), of sites mentioned by written sources but not traceable in actual landscape.

8 Conclusions

In a bidirectional relationship, cartographical sets and research methodologies influence each other, constraining one or both to adaptations depending on available supports or research finalities.

Our choice in favour of a particularly rich and diversified cartographical support derives from an archaeological data management politics of putting topographical and analytical aims (when both are equally practicable) at the same importance level. In projects on a national and international scale, for which there is no availability of detailed cartography, diachronic and modelling aspects are privileged, while georeferencing is limited to point-shaped (and often generic) positioning. On the other hand, in regional and provincial contexts we also pursued planning and valorisation purposes; evidences have been positioned using high quality and reliability standards, allowing also heritage management institutions (Soprintendenze) and landscape planning institutions (Public Administrations and Local Governments) to take advantage of them.

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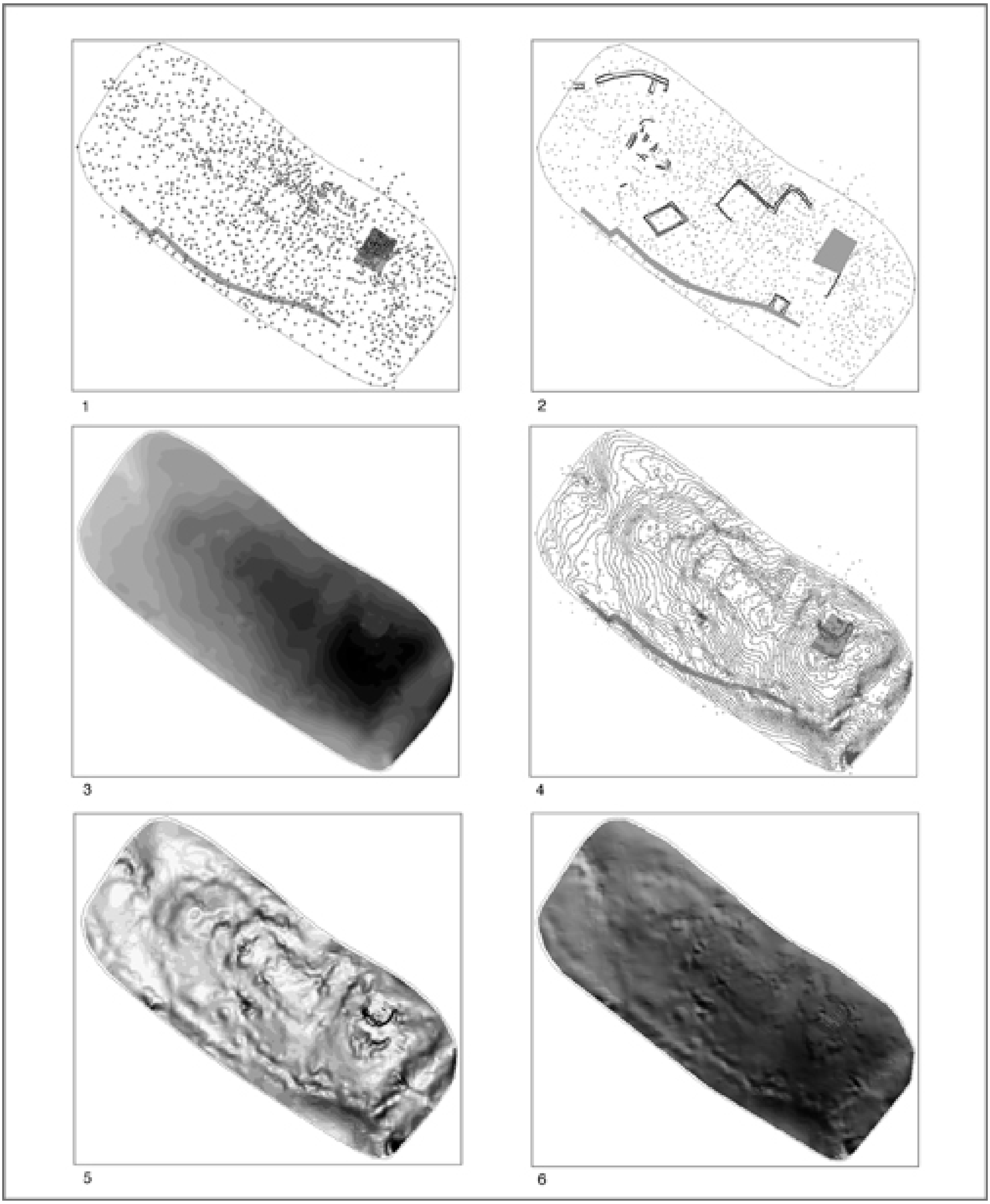

Fig. 6. *3D topographical survey of the hill of the Miranduolo castle, obtained through application of total station technology and ArcView Spatial Analysis extension. (1) Point acquisition through total station and excavation area delimitation. (2) Total station survey of non-excavated emerging evidences. (3) 1 cm ground resolution DTM of the hill obtained through spline interpolation on surveyed points. (4) Contour map obtained from DTM using ArcView Spatial Analysis extension. (5) Slope map obtained from DTM using ArcView Spatial Analysis extension. (6) TIN obtained from DTM using ArcView Spatial Analysis extension.*