Using georeferenced historical maps in support of archaeological research and urban planning

Giacomo Piazzini[1,*], Gabriele Bitelli[2], Giorgia Gatta[2]

[1] Ministry of Culture, Superintendency of Archaeology, Fine Arts and Landscape for the Provinces of Ancona and Pesaro-Urbino, Italy
[2] University of Bologna, Department of Civil, Chemical, Environmental and Materials Engineering (DICAM), Italy
* Corresponding author: giacomo.piazzini@cultura.gov.it

ABSTRACT

Historical cartography constitutes a rich source of information on ancient landscapes. When managed in digital form and accurately georeferenced, it becomes an invaluable tool for investigating the history and evolution of urban contexts. Within an archaeological framework, the multidisciplinary integration of georeferenced historical cartography and archaeological data in a Historical Geographic Information System (HGIS) offers significant advantages. One of the key strengths of historical cartography lies in its capacity to contextualise, within past environments, the archaeological evidence brought to light through investigations, thereby supporting archaeologists in identifying and interpreting elements of the ancient city. The present study aims to exemplify this application of historical maps, focusing on two recently investigated archaeological sites in Ancona, Italy. This city is characterised by a rich archaeological heritage, much of which remains buried and unexplored, resulting in a high likelihood of encountering archaeological assets during public or private works. The proposed methodology, applicable to a wide range of cases, proves to be valuable not only for enhancing archaeological knowledge of urban areas but also for supporting urban planning, urban regeneration, and risk management. Historical Geographic Information Systems, enriched with archaeological data, constitute essential tools for guiding urban development and selecting optimal locations for new structures and infrastructure.

KEYWORDS

archaeology; historical maps; geomatics; HGIS; urban planning

Received: 15 January 2026
Accepted: 17 May 2026
Published online: 29 May 2026

Piazzini, G., Bitelli, G., Gatta, G. (2026): Using georeferenced historical maps in support of archaeological research and urban planning, e23361980.2026.10
https://doi.org/10.14712/23361980.2026.10

1. Introduction

With ongoing urban growth and increasing land exploitation, comprehensive knowledge and monitoring of historical monuments, archaeological areas, and cultural heritage in general are fundamental requirements for cities. In this context, Geomatics plays an important role in detecting and monitoring heritage assets and remains, thereby facilitating more responsible urban development (Agapiou et al. 2015; Pappu et al. 2010; Roychowdhury et al. 2011).

To manage a territory effectively and plan its development, a thorough understanding of its history is essential. Among the various sources of historical knowledge, historical maps – now managed digitally through geomatic methods – are particularly valuable and effective where available. Cartographic heritage has a fundamental and universally recognised value, as it preserves historical and geographical data and often possesses artistic qualities. For these reasons, it must be preserved and made accessible, increasingly through digital means. The digital management and regeneration of ancient cartography represent valuable opportunities offered by Geomatics, which provides techniques not only to safeguard these precious documents from deterioration but also to enable innovative metric applications of the historical and geographical data they contain – applications that would not be possible using analogue media alone (Balletti 2000; Boutoura and Livieratos 2006; Bitelli et al. 2014; Livieratos 2006). Once digitised and appropriately processed, cartographic heritage becomes more accessible and usable, not only to experts (researchers, archivists, historians, archaeologists, technicians), but also to citizens, tourists, map enthusiasts, and the general public.

The metric regeneration of historical cartography is based on georeferencing, i.e., the process of assigning geographic coordinates to the digital image of an ancient document, usually within a modern reference system. A georeferenced digital map, therefore, possesses metric content and can be measured and directly compared with modern maps in a standard reference system. In this process, it must be considered that any map has a certain degree of error. This is especially true for historical cartography, which was produced using surveying methods and representation tools that were far less precise than those available today. Therefore, understanding the metric properties and assigning a reliability level to each map are essential for determining how accurately it represents a given area. An ancient map is invariably less precise than a modern one at the same scale, primarily due to errors arising from historical surveying techniques and instruments, the absence of rigorous geodetic-cartographic reference systems, and deformations of the map support material (Edney and Pedley 2019).

A particularly illustrative case is that of city maps, which began to appear in the sixteenth century. Initially, these were perspective representations with an oblique, non-zenithal viewpoint. From the eighteenth century onwards, higher viewpoints were gradually adopted, eventually becoming coincident with the zenith. By the mid-eighteenth century, zenithal maps had become the most common representations of cities and, due to their scientific and objective nature, the only accepted form in the nineteenth century. Eighteenth-century city maps are the first to provide reliable planimetric representations of urban areas and are fundamental sources for understanding the urban context of that period.

A valid and essential tool for reconstructing the history of cities and studying their evolution is the Geographic Information System (GIS) environment. Within a Historical GIS (HGIS), cartographic data from different historical periods, georeferenced within a common cartographic reference system, can be collected, managed, compared, and integrated with other data types (e.g., images, databases, texts), to perform change detection analyses or investigate specific topics across space and time. In recent years, numerous HGIS projects and studies have been developed, demonstrating the great potential of these tools for managing Cartographic Heritage (Balletti et al. 2020; Bitelli et al. 2019; Bitelli et al. 2016; Brovelli et al. 2016; Frazzica et al. 2015; Gatta et al. 2017; Gatta and Bitelli 2017; Gregory and Healey 2007; Larson 2003; Lundberg and Peterson 2005; Nobajas 2014; Schlichting 2008; Timár 2008; Wilson 2001). However, it is important to emphasise that only accurate georeferencing – often a challenging task, especially for very old maps – allows the extraction of quantitative data useful for further analyses, for example in urban archaeology or in support of future urban development.

1.1 Historical cartography and urban archaeology

The multidisciplinary integration of historical cartography and archaeological data offers significant benefits for historical and archaeological research. Historical cartography contains potentially unique data – otherwise lost or altered – regarding toponyms, natural features, buildings, and boundaries. Numerous studies have already highlighted the important contribution of historical maps to landscape archaeology (Green et al. 2019; Petrie et al. 2019; Cugno 2015; Dall'Aglio et al. 2002; Cambi and Terrenato 1994; Cataldo et al. 2005; Sperti et al. 2020).

However, the use of historical cartography in support of archaeological research does not always receive the attention it merits. This limited consideration is likely due to the dating of cartographic documents, which generally do not predate the sixteenth century. As a result, these sources are often associated with post-medieval archaeology, a field that still struggles to be regarded as equal to those related to other chronological periods. Evidence of this perspective, at least in Italy, is found in the frequent exclusion

of post-medieval data from archaeological maps (Milanese 2014; Augenti 2014).

In the specific case of urban archaeology, the object of study – the city – is often difficult to interpret. Human activities within a confined space have left overlapping traces, resulting in a highly complex stratification. It is precisely this difficulty in interpreting urban archaeological data that underscores the potential value of historical maps and the necessity of integrating them into research.

In addition to their relevance for the study of medieval and modern cities, historical maps can also aid in identifying elements of earlier urban phases, such as those from the Roman period. This is achievable by locating and describing features that have since disappeared but were still visible when the maps were produced, including natural elements and ancient structures.

For example, the project "Archeologia Urbana a Senigallia", conducted by the University of Bologna, made use of eighteenth-century maps originally produced to plan the diversion of the river that still flows into the city of Senigallia. Once georeferenced, these maps enabled the reconstruction of the river's course before the eighteenth-century modifications. The integration of this information within a GIS environment, together with extensive archaeological data, made it possible to hypothesise the course of the Roman city walls (De Donatis et al. 2012; Lepore et al. 2012).

Georeferencing a zenithal map of a city, particularly in the case of cadastral maps, enables the reconstruction of the historical urban layout with high geometric and dimensional accuracy. At a more detailed level, such georeferenced maps allow the contextualization of finds brought to light by archaeological investigations. The present research aims to demonstrate this latter type of application. By combining historical map processing techniques with archaeological data, this study attempts to facilitate meaningful integration between these sources.

The case study concerns the city of Ancona, Italy, where a rich archaeological heritage lies underground and remains largely unexplored (Piazzini 2017).

2. Materials

2.1 The city of Ancona and its historical cartography

Historiographical tradition dates the founding of Ancona to approximately 2,400 years ago. The port area and the historic city centre have constituted the core of urban life throughout this long period, without interruption (Fig. 1).

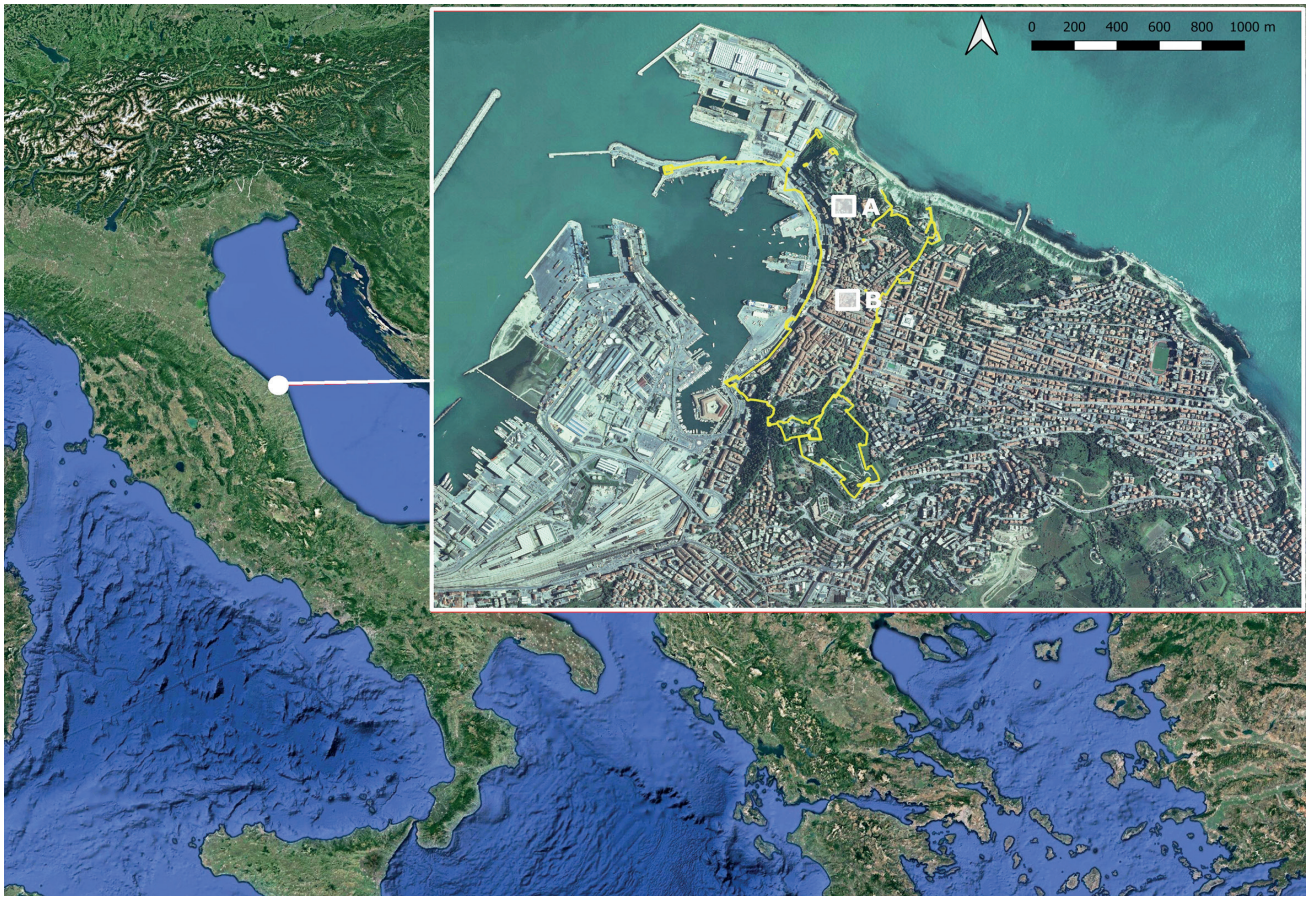

Fig. 1 Location of the city of Ancona (satellite photo from Google Earth) and fortifications – shown in yellow – that surrounded it in the early nineteenth century, with respect to the current city (1:2,000 scale orthophoto kindly provided by the Municipality of Ancona). The white box indicates the location of the two case studies: A (via Ferretti: 43.623464 N, 13.511098 E; Datum WGS 84) and B (via Buoncompagno: 43.619181 N,13.511452 E; Datum WGS 84).

Over the centuries, historical events and the city's evolving dynamics led to the near-total loss of ancient and early medieval archaeological evidence. From the tenth century onwards, a new urban layout gradually emerged. Despite the passage of time, large portions of the medieval city, together with its early modern expansions, remained visible at the beginning of the twentieth century. However, following urban renewal after the unification of Italy, the earthquakes of the twentieth century, and, above all, the bombings of the Second World War, most of the historic city – including the entire Port District – was destroyed. Several historical maps are available to scholars interested in the history of Ancona. In the present study, only maps with a zenithal view are considered.

The two oldest available maps date back to the sixteenth century. One is preserved at the State Archives of Turin; it is anonymous and undated. This map is currently under study, but, based on the buildings depicted, it is possible to propose a preliminary dating to the late 1560s–early 1570s. The second is a map of Ancona contained in the manuscript *Ms. 5463*, dated 1588 and held in the Vatican Apostolic Library in Rome.

No known cartographic documentation from the seventeenth century depicts the city of Ancona in a zenithal view. A similar situation exists for the eighteenth century, with only two known maps. The earliest, dated 1784, bears the signature of the architect Scipione Daretti. The second is the Plan de la Ville et du Port d'Ancone, included in M. de La Lande's Voyage en Italie (Tome Premier), published in 1786. Several graphic features suggest that the latter map derives from the former.

The nineteenth-century cartographic production of Ancona is both quantitatively and qualitatively significant. Two maps are particularly precise and detailed: the map of Ancona from the so-called Gregorian Cadastre (1813) and the *Topographical Map of the City of Ancona*, produced by the Department of Census of the Papal State in 1844. In 1852, the map *Plan der Stadt und Festung Ancona* was drawn up by the occupying Austrian authorities. Shortly afterwards, another map was published in Milan by Francesco Vallardi, likely dating from the 1870s.

The most recent urban developments before the Second World War are clearly visible in the 1937 map, the first to be produced from a photogrammetric aerial survey of the city.

2.2 Selected historical maps

Among the aforementioned maps, this study focuses on two documents that have provided the most

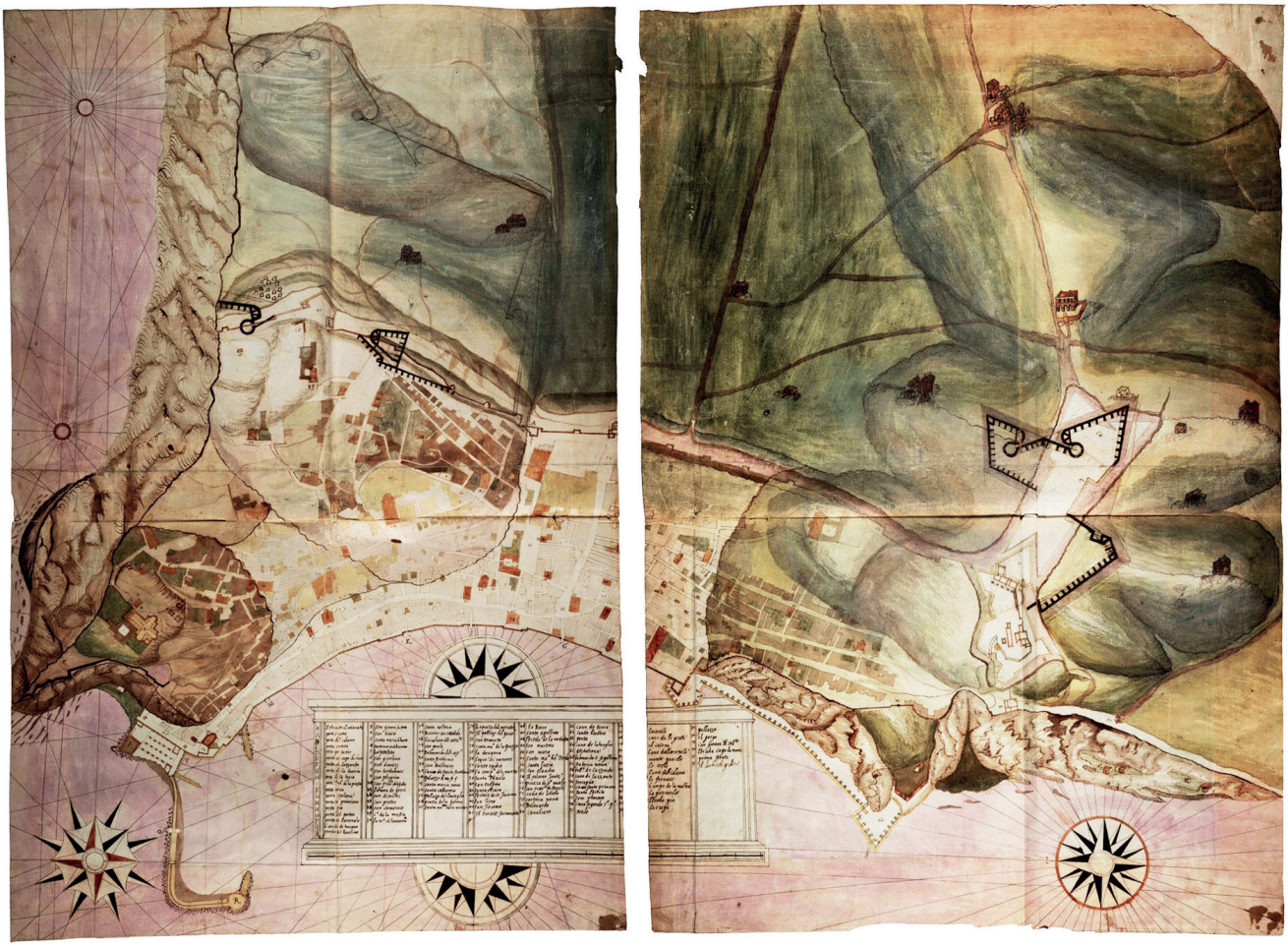

Fig. 2 Ancona: late 16th-century map in two parts.

significant insights for the research: the late sixteenth-century map and the Gregorian Cadastre (1813), selected to ensure an adequate chronological framework.

The first map is an anonymous sixteenth-century cartographic document (Fig. 2), which remains largely unknown in the scientific literature (see Menchetti 2007, fig. 5, p. 72, note 451). It is preserved in the State Archives of Turin (Collection "Architettura militare": Volume V, ff. 9v–10). The archive generally dates the map to the sixteenth century; however, based on an in-depth analysis currently underway, it is possible to estimate that it dates to the late 1560s–early 1570s.

The map measures 75 × 101 cm and was scanned by the State Archives of Turin at a resolution of 200 dpi; it is available at https://archiviodistatotorino.beniculturali.it/dbadd/visua.php?uad=189375.

There is no signature or dedication on the document; the only textual component is the legend, which consists of 96 numerical and 18 alphabetical references to public and religious buildings, as well as to the city's defensive structures. Courtyards, green spaces, and staircases are systematically represented. Despite the remarkable level of detail, the map is characterised by a significant degree of inaccuracy (mean error at check points: 8.6 m), which will be discussed in Section 3.1 (Tab. 1 and Fig. 7).

This is likely a "study" map, that is, a document used by architects to sketch their projects. Indeed, some ink drawings can be identified, representing fortification projects that were never realised. The map is composed of two sheets glued on a common support, unfortunately with the overlapping of one sheet on the other. For this reason, the two sheets were digitally separated. Once two distinct files were obtained, the sheets (Sheet A / Sheet B) were georeferenced independently. In the present case study, integration with archaeological data concerns Sheet A.

The second map, known as the Gregorian Cadastre, is a representation produced by the French administration in 1813, when Ancona was the capital of the Department of the Metauro in the Kingdom of Italy (Fig. 3).

The map measures 206 × 164 cm and was scanned by the State Archives of Rome at a resolution of 200 dpi. It is available at https://imagoarchiviodistatoroma.cultura.gov.it/Gregoriano/mappe.php.

Each cadastral parcel, identified by a number, is represented on the map by its perimeter and described in the cadastral registers by ownership, land use, and area (Fig. 4). The same applies to religious buildings, fortifications, and public spaces, which are indicated by alphabetical letters instead of numbers; urban gardens are systematically depicted

Fig. 3 Ancona: the Gregorian Cadastre, 1813.

in green. The map is drawn at a scale of 1:1,000. The representation includes only the land surface within the city walls at that time, while the description of the entire rural territory is provided on separate maps at a smaller scale.

2.3 Case studies

Two case studies are presented and discussed here as examples, referring to two significant archaeological areas. Both sites are located within the historic centre of Ancona. Investigations at these sites were conducted under the scientific direction of the *Soprintendenza Archeologia, Belle Arti e Paesaggio delle Marche*. The results of these investigations are still largely unpublished. At present, some of the findings from the Roman period have been briefly described in a publication concerning the urban development of Ancona in antiquity (Iacopini 2025a). As for the post-Roman archaeological evidence, only a preliminary excavation report has been published (Piazzini and Ciuccarelli 2022).

The first site is currently laid out as an open-air archaeological area, visible from outside a fence, and is situated along Via Ferretti, directly opposite the Archaeological Museum of the Marche Region. Archaeological investigations were conducted here between 2002 and 2004, when the area served as a car park. Immediately beneath the parking surface, the excavation revealed the pavement and several walls of a post-medieval building destroyed during the Second World War bombings (Fig. 5). After removing part of the pavement, the investigation proceeded into the underlying stratigraphic layers. These revealed remains of early medieval buildings, part of a late antique cemetery, sections of a colonnade, and a Roman-period road. The site is situated in an area of Ancona where many scholars have proposed the location of the Roman city's forum. For this reason, the discovery of the colonnade has led to the identification of the site as the "Roman forum of Ancona", a designation now widely used. The post-medieval building occupied the entire excavation area and extended beyond its limits. Numerous structural elements are associated with this building, including internal and perimeter walls, an entrance threshold, pillars, floors, drainage channels, a well, and a staircase leading to an underground cellar.

The second archaeological site is located in Via Buoncompagno. The remains discovered there are housed in the basement of the new wing of the Museum of the City of Ancona, owned by the municipality, and are visible through glass windows along the public street. The site was identified in 2001, during redevelopment works for the museum's expansion. Two main excavation campaigns were carried out in 2001

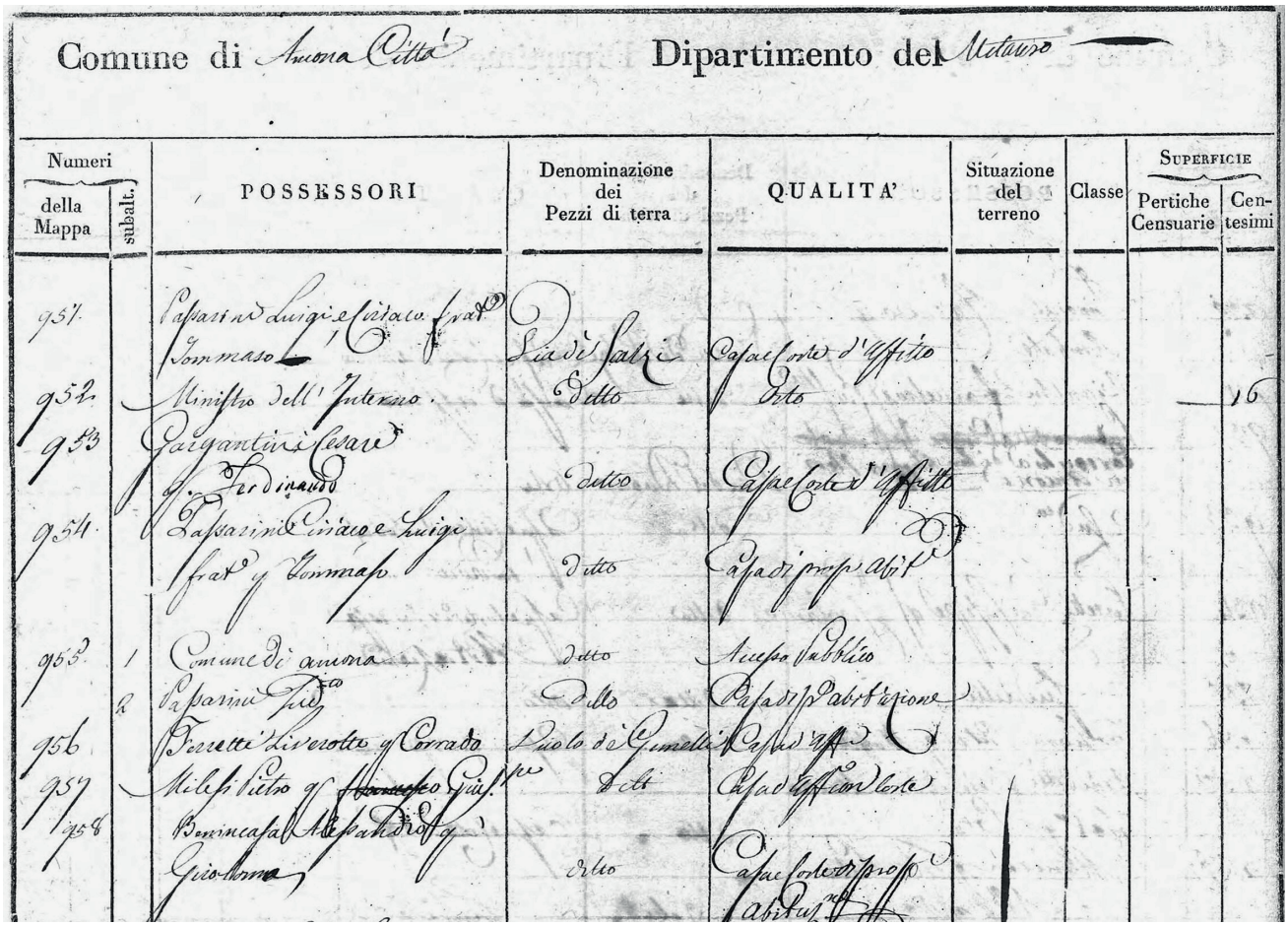

Fig. 4 An example of cadastral register, concerning the parcels of the site of Via Ferretti (Fig. 9).

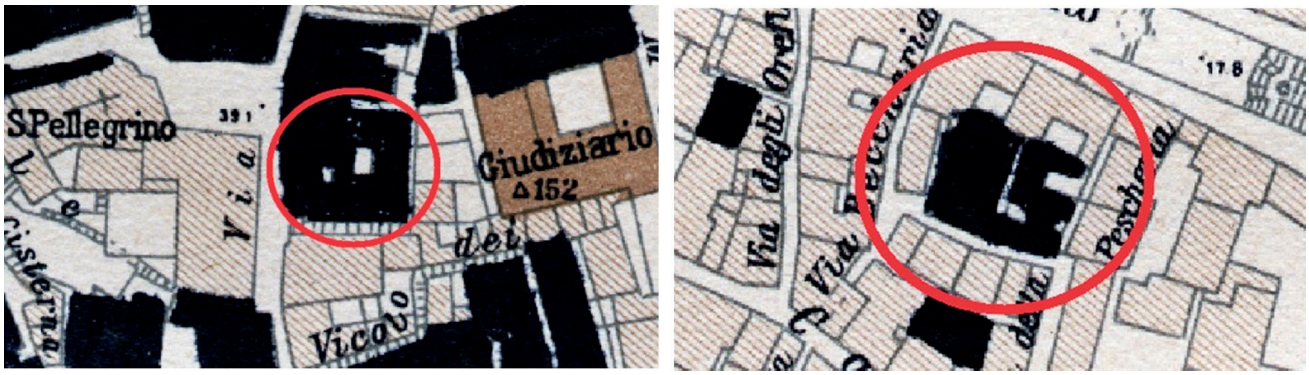

Fig. 5 Two details from the aerial-photogrammetric map of 1937, indicating (in black) the buildings struck by the bombings in 1943/44; the archaeological areas discussed in the text are highlighted by circles.

and 2009. The investigations revealed a stratigraphic sequence more than six metres deep, spanning from the Roman Republican period to the Modern Age. As for the earliest phase, only fragments of isolated walls were identified, whose function is difficult to determine. The phase, on the other hand, is better preserved and dates back to the Augustan Period. The walls of a *domus* were found, together with fragments of a mosaic floor. The early medieval layers are poorly preserved due to extensive later disturbances. For the late medieval and Modern Age phases, the excavations revealed a residential area of the city. For this phase, a building complex comprising at least seven rooms was identified. Outside the complex, the excavation uncovered a road, as well as the entrance threshold of another building. The structure remained in use over the centuries, undergoing minor modifications and renovations, until it was destroyed during the Second World War bombings (Fig. 5). A particularly noteworthy discovery is evidence of a fire that affected the entire area during the late medieval or early modern phase. This is indicated by a widespread layer of charcoal and ash (Fig. 6).

3. Methods

3.1 Georeferencing of historical maps

Georeferencing and the analysis of map deformations are based on the identification, in both historical and modern maps, of homologous points (Ground Control Points, GCPs) corresponding to features (primarily buildings, in the case of urban maps) that have remained unchanged over time and whose coordinates are known in the current cartographic reference

Fig. 6 Archaeological site of Via Buoncompagno: the layers of ash, coal, and rubble in the northern area, later used as a courtyard (photo SA AN 261480).

system. On the basis of these points – selected in large numbers and distributed as evenly as possible across the image – it is possible to calculate the parameters of the geometric transformation between the image coordinates of the historical map (in digital format) and the cartographic coordinates of the modern map. Using these parameters, during the resampling phase, cartographic coordinates are assigned to each pixel of the historical map.

The inevitable residuals observed for the GCPs are related both to the metric quality of the historical map and to the georeferencing process itself; therefore, they can be used as an indicator of map deformation. The spatial variation of these deformations can also be visualised directly on the map image using specialised software, based on the computation of local geometric transformations (Jenny and Hurni 2011).

In the present study, within a GIS environment, the two analysed maps were georeferenced in a modern reference system (UTM-ED50) using approximately one hundred Ground Control Points (GCPs), distributed as evenly as possible across the image. To facilitate the identification of GCPs between historical and modern maps (in this case, the digital Technical Map of the Municipality of Ancona), the georeferencing process was first performed on the more recent map (1813), using maps of intermediate age (from 1937 to 1844), then on maps of the eighteenth century, and finally on the late sixteenth-century map, using the same points whenever possible.

The selected points corresponded to building corners, which were verified to have remained unchanged over time. In addition to the GCPs, approximately twenty Check Points (CPs) were used for each map in order to obtain a more reliable estimation of the georeferencing residuals, as these points are not involved in the calculation of the transformation parameters. Table 1 presents the results of the residual analysis for both GCPs and CPs, obtained using second-order polynomial transformations.

Tab. 1 Statistical analysis on the georeferencing residuals using a 2nd order polynomial transformation.

	late 16th c. (Sheet A)		1813	
	GCPs	CPs	GCPs	CPs
Number of points	151	23	101	23
Mean error [m]	9.9	8.6	1.8	1.9
Standard deviation [m]	5.1	5.3	1.2	1.5
Root Mean Square error [m]	11.1	10.0	2.1	2.4

In Figure 7, the results of the map deformation analysis (based on the same GCPs used for georeferencing) are presented as obtained using the MapAnalyst software (Jenny and Hurni 2011). As expected, the variation in the scale factor is more limited in the nineteenth-century map, ranging from 1,040 to 1,070 (average 1,057) for the 1813 map, and from 1,850 to 2,200 (average 2,050) for the late sixteenth-century map.

3.2 Georeferencing and structuring of archaeological data

The graphical documentation produced during the archaeological campaigns conducted at the two sites was first digitized through scanning. As it had not been georeferenced at the time of the survey, it was necessary to perform this process using a set of clearly identifiable points recognised in the modern

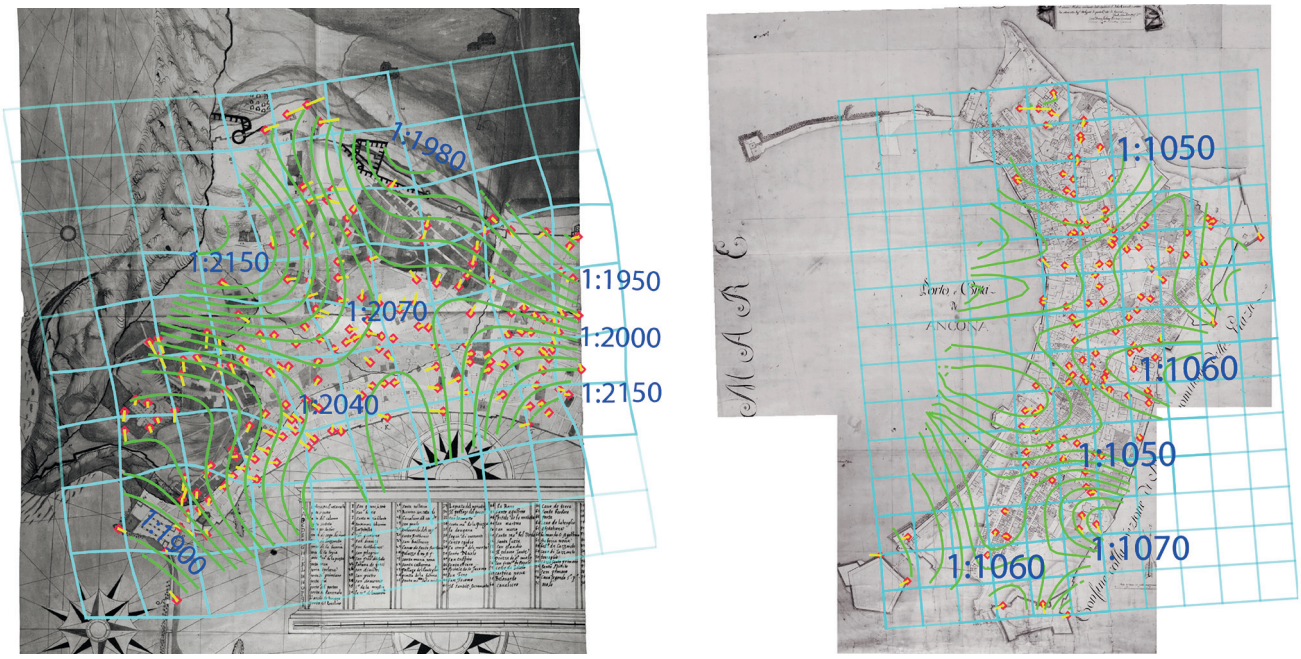

Fig. 7 Results from the analysis of deformations on the late sixteenth-century map (a) and the 1813 map (b): the cartographic grid with mesh = 100 m (exaggeration factor = 2 for the 1813 map) in light blue, the GCPs in red, the residual vectors in yellow (exaggeration factor = 2 for the late 16th century map and 5 for the 1813 map), the scale isolines in green (some values in blue).

cartography. For this purpose, certain cornerstones of the urban fabric surrounding the excavation areas were used. By matching these points with their homologous counterparts in the modern cartography, previously loaded into the GIS project, the plans were georeferenced using polynomial transformations.

This process enabled the subsequent vectorisation of the individual structures of interest. This phase required a careful analysis of the archaeological data and made it possible to organise the structures into different layers according to their chronological phases. Only structures dating to the late medieval or modern periods are likely to be identified in the historical maps.

4. Results and discussion

By superimposing the layers of the vectorised archaeological structures onto the two historical maps, it was possible to identify, in the latter, the late medieval and modern buildings uncovered during the excavations.

At both archaeological sites (Figs. 8–11), the overlap with the Gregorian Cadastre allows for the almost exact identification of several walls documented during the excavations. This enabled the distinction of perimeter walls, internal partitions, and boundary walls separating adjacent buildings among the structures identified.

Moreover, an important result for the interpretation of the excavation data was achieved: the reconstruction of the continuation of walls beyond the limits of the investigated areas. In the case of Via Buoncompagno, in particular, it is now possible to define the extent of the buildings identified through excavation beneath the current roadway and to assess the risk of encountering their remains during future works (e.g., the installation of underground utilities).

A further result is the possibility of assigning functional classifications and ownership information to modern buildings, based on the records attached to the cadastral documentation.

At both archaeological sites, the overlap between the two maps allows the recognition of the same buildings, which appear to have persisted over the centuries while undergoing specific modifications.

One example is the internal courtyard of the building identified in the Via Ferretti excavations. This courtyard presents a markedly different layout in the two maps. It can be inferred that its function as an internal courtyard remained unchanged, but that building modifications took place between the late sixteenth century and 1813.

Fig. 8 Archaeological site of Via Ferretti (for the localisation within Ancona, see figure 1, box A): detail of the superimposition of the late and post medieval findings on the current satellite view (left) and on the current digital Municipal Map 1:2,000 (right).

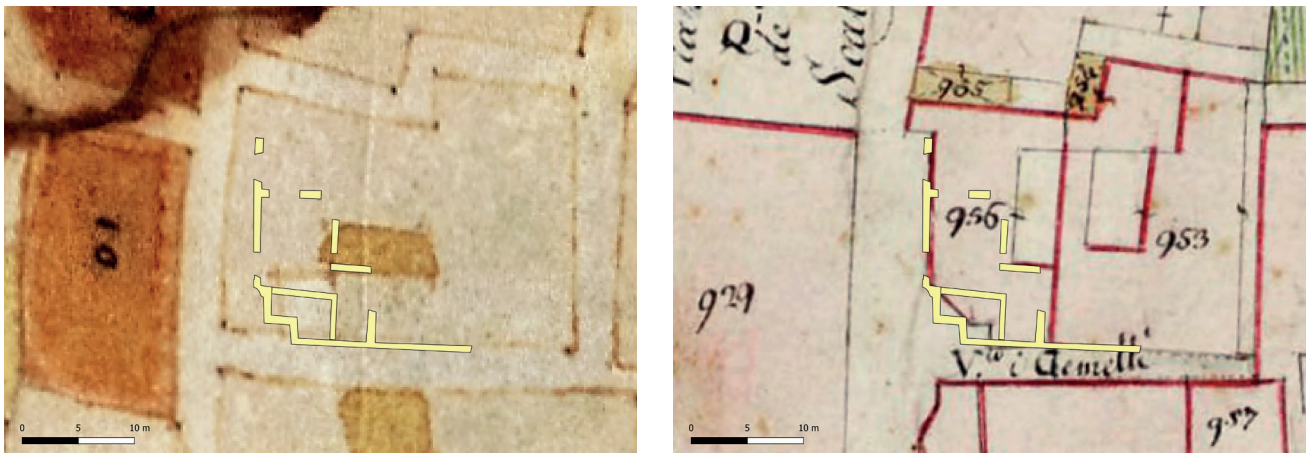

Fig. 9 Archaeological site of Via Ferretti: detail of the superimposition of the late and post-medieval findings on the late 16th century map (left) and on the map of 1813 (right).

Fig. 10 Archaeological area of Via Buoncompagno (for the localisation within Ancona, see figure 1, box B): detail of the superimposition of the late and post-medieval findings on the current satellite view (left) and on the current digital Municipal Map 1:2,000 (right).

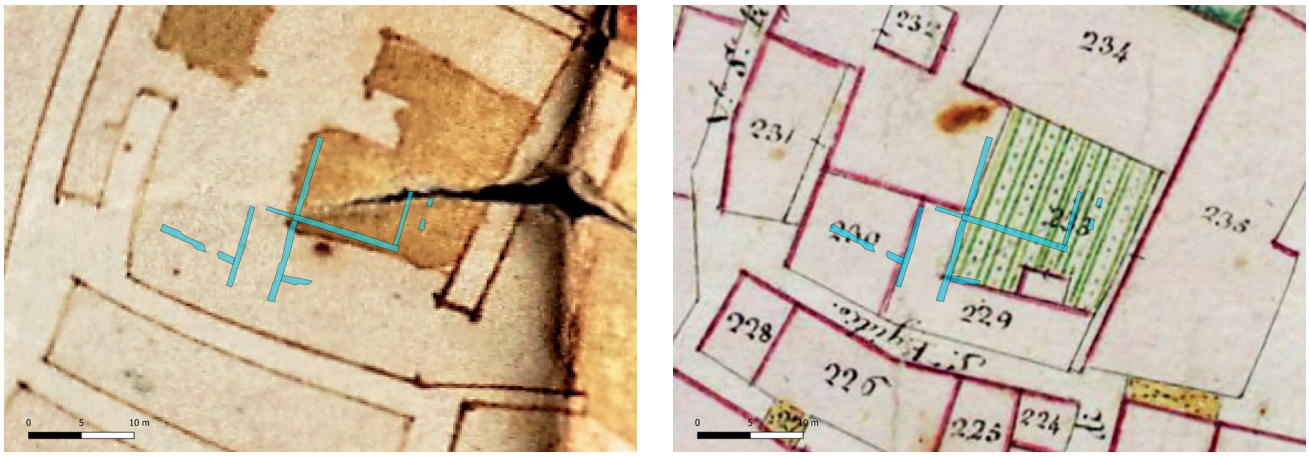

Fig. 11 Archaeological area of Via Buoncompagno: detail of the superimposition of the late and post medieval findings on the late sixteenth century map (left) and on the map of 1813 (right).

Another difference between the two maps concerning the Via Ferretti site relates to the configuration of the main façade. Written sources provide evidence of a renovation that likely set back the façade during the second half of the eighteenth century (Giochi and Mordenti 2005).

Concerning the Via Buoncompagno excavation, the superimposition of the two maps onto the archaeological plan reveals a discrepancy in the position of the southern boundary of the courtyard. This boundary corresponds to two different archaeological structures in the two maps. The southward shift may be attributed either to georeferencing residual errors associated with the sixteenth-century map or, alternatively, to the demolition of part of the building and the consequent expansion of the courtyard over the approximately two and a half centuries separating the two maps.

At the same site, the archaeological excavation revealed evidence of a major fire that affected the entire area. One of the damaged buildings, unlike the others, does not appear to have been subsequently restored. The debris was not removed, and the space was transformed into a courtyard. In this case, historical cartography proves useful for dating the fire. Indeed, this event must predate the creation of the late sixteenth-century map, as the courtyard is already clearly represented in it. The map therefore provides a *terminus ante quem* for the fire, most likely around 1567. The destruction identified during the excavation may thus be related to one of the most catastrophic events in the history of Ancona: the fire of 1348 (Pavia and Sori 1990).

5. Conclusions

The present study aimed to evaluate the contribution of historical cartography, once properly georeferenced, to the interpretation of archaeological evidence in an urban context.

The georeferencing of historical maps, when carried out accurately, enables their precise superimposition with both modern and archaeological cartography, allowing for rapid and effective comparison of spatial data. Working within an HGIS environment is particularly advantageous for this type of analysis, as it facilitates the visualisation of the spatial distribution of features represented in historical maps, as well as the detection and measurement of changes over time.

In the case of a city such as Ancona, characterised by a high density of pre-existing structures and a complex stratigraphic sequence, this approach proves particularly valuable. Through comparison with historical maps, it has been possible to assign precise qualitative and chronological attributes – previously unknown – to the archaeological structures analysed in this study.

The reconstruction of the spatial distribution of past urban features offers both cultural and practical benefits. From a research perspective, it contributes to a better understanding of the city's historical development and enhances the interpretation of archaeological data. From an urban planning perspective, the proposed method is highly effective for preservation and valorisation purposes. The ability to anticipate what may be uncovered during new interventions supports more informed planning decisions, improving both the protection of archaeological remains and their integration into urban regeneration processes.

The work presented here represents the initial stage of a broader research process aimed at developing a multifunctional tool. Further development in this direction would represent a significant advancement for cities such as Ancona, where the interpretation of archaeological data is hindered by their complexity and by the limited number of dedicated studies. It is worth noting that, in recent years, the methodology and HGIS project described here have already demonstrated their practical usefulness in Ancona, having been applied in the preparation of archaeological risk reports for various urban renewal projects (including squares, stairways, streets, buildings, and courtyards).

A recent project by the Soprintendenza Archeologia, Belle Arti e Paesaggio delle Marche and the University of Bologna enabled the mapping of all archaeological evidence currently known in the city of Ancona (Iacopini 2025b). This led to the creation and publication of the web-GIS "Archaeological Map of Ancona" (https://archeoancona.cultura.gov.it/). The data generated by this project have already been used for interpretative analyses of the pre-Roman and Roman city (Iacopini 2025a). However, the study of the city's subsequent evolution during the medieval and post-medieval periods, in light of these new data, remains to be completed. In this context, the use of georeferenced historical maps, following the methodology proposed here, appears both essential and highly promising.

Acknowledgements

This article is based on research conducted within the School of Specialization in Archaeological Heritage at the University of Bologna, and in particular on G. Piazzini's specialisation thesis in Surveying and Cartography, entitled "Digging into Maps: Digital Processing of Historical Maps for the Urban Archaeology of Ancona", supervised by the co-authors.

The authors would like to thank the Soprintendenza Archeologia, Belle Arti e Paesaggio delle Marche for providing access to unpublished data from the archaeological excavations cited in the text, and the State Archives of Rome and Turin for granting access to high-resolution digital copies of the historical maps used in this research.

References

Agapiou, A., Dimitrios, D. A., Vasiliki, L., Apostolos, S., Branka, C., Kyriacos, T., Diofantos, G. H. (2015): Impact of urban sprawl to cultural heritage monuments: The case study of Paphos area in Cyprus. Journal of Cultural Heritage 16(5), 671–680, https://doi.org/10.1016/j.culher.2014.12.006.

Augenti, A. (2014): Archeologia della città medievale. In Gelichi, S. (Ed.), Quarant'anni di Archeologia Medievale in Italia. La rivista, i temi, la teoria e i metodi; All'Insegna del Giglio: Firenze, Italy, pp. 173–182.

Balletti, C. (2000): Analytical and Quantitative Methods for the Analysis of the Geometrical Content of Historical Cartography. International Archives of Photogrammetry and Remote Sensing XXXIII(B5), 30–37. Available online: https://www.isprs.org/proceedings/xxxiii/congress/part5/30_XXXIII-part5.pdf (accessed on 20 September 2025).

Balletti, C., Galeazzo, L., Gottardi, C., Massaro, M., Vernier, P. (2020): From historical maps to digital technologies: the visualisation of the Venetian Ghetto's history. e-Perimetron 15(3), 155–167. Available online: http://www.e-perimetron.org/Vol_15_3/Balletti_et_al.pdf (accessed on 20 September 2025).

Bitelli, G., Bartolini, F., Gatta, G. (2016): HGIS and Archive Researches: A Tool for the Study of the Ancient Mill Channel of Cesena (Italy). The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XLI-B5, 183–189, https://doi.org/10.5194/isprs-archives-XLI-B5-183-2016.

Bitelli, G., Cremonini, S., Gatta, G. (2014): Cartographic Heritage: Toward unconventional methods for quantitative analysis of pre-geodetic maps. Journal of Cultural Heritage 15(2), 183–195, https://doi.org/10.1016/j.culher.2013.04.003.

Bitelli, G., Gatta, G., Guccini, A. M., Zaffagnini, A. (2019): GIS and Geomatics for archive documentation of an architectural project: The case of the big Arc of entrance to the Vittorio Emanuele II Gallery of Milan, by Giuseppe Mengoni (1877). Journal of Cultural Heritage (38), 204–212, https://doi.org/10.1016/j.culher.2019.01.002.

Boutoura, C., Livieratos, E. (2006): Some fundamentals for the study of the geometry of early maps by comparative methods. e-Perimetron 1(1), 60–70. Available online: http://www.e-perimetron.org/Vol_1_1/Boutoura_Livieratos/1_1_Boutoura_Livieratos.pdf (accessed on 20 September 2025).

Brovelli, M. A., Kilsedar, C. E., Minghini, M., Oxoli, D. (2016): GIS-based analysis of a peculiar effect of urbanization: the case of the buried watercourses of Como (Italy).

Applied Geomatics 8, 91–105, https://doi.org/10.1007/s12518-016-0169-4.
Cambi, F., Terrenato, N. (1994): Introduzione all'archeologia dei paesaggi; Nuova Italia Scientifica: Roma, Italy, 313 p.
Cataldo, R., De Donno, A., De Nunzio, G., Leucci, G., Nuzzo, L., Siviero, S. (2005): Integrated methods for analysis of deterioration of cultural heritage the Crypt of Cattedrale di Otranto. Journal of Cultural Heritage 6(1), 29–38, https://doi.org/10.1016/j.culher.2004.05.004.
Cugno, S. A. (2015): Landscape archaeology and historical cartography: A contribution to the study of ancient and medieval settlement in Canicattini Bagni (Syracuse). In Benedetto, B., Farrugia, C., Romiti, B., Sipos, A. (Eds.), Cartography and Cadastral Maps. Visions from the Past, for a Vision of Our Future; Edizioni della Normale: Pisa, Italy, pp. 111–120.
Dall'Aglio, P. L., Di Cocco, I., Marchetti, G. (2002): La cartografia storica per la ricostruzione del paesaggio antico: Alcuni casi dell'Italia Padana. In Proceedings of the VI Conferenza Nazionale ASITA; Perugia, Italy, pp. 55–60.
De Donatis, M., Lepore, G., Susini, S., Silani, M., Boschi, F., Savelli, D. (2012): Sistemi informativi geografici e modellazione tridimensionale per la geo-archeologia a Senigallia: Nuove scoperte e nuove ipotesi. Rendiconti Online della Società Geologica Italiana 19, 16–19.
Edney, M. H., Sponberg Pedley, M. (2019): The History of Cartography. Volume 4: Cartography in the European Enlightenment; University of Chicago Press: Chicago and London, https://doi.org/10.7208/chicago/9780226339221.001.0001.
Frazzica, V., Galletti, F., Orciani, M. (2015): Gregoriano Cadastre: The Creation of a WebGIS from Historical Cartography through the Techniques of Classification of Satellite Images. e-Perimetron 10(2), 60–72. Available online: https://www.e-perimetron.org/Vol_10_2/Frazzica%20et%20al.pdf (accessed on 20 September 2025).
Gatta, G., Bitelli G. (2017): A historical GIS for the comparison of past and present views: Bologna, yesterday and today. e-Perimetron 12(3), 102–108. Available online: https://www.e-perimetron.org/Vol_12_3/Gatta_Bitelli.pdf (accessed on 2 November 2025).
Gatta, G., Arioti, E., Bitelli, G. (2017): Geomatics science applied to cartographic heritage and archive sources: A new way to explore the XIX century Gregorian Cadastre of Bologna (Italy), an ante-litteram 3D GIS. Journal of Cultural Heritage 23, 68–76, https://doi.org/10.1016/j.culher.2016.06.009.
Giochi, F. M., Mordenti, A. (2005): Civiltà anconitana. Vita quotidiana ad Ancona tra XVI e XVIII secolo: Palazzi, feste, modi di vestire, di arredare e di mangiare di una città adriatica; Il Lavoro Editoriale: Ancona, Italy, pp. 61–66.
Green, A. S., Orengo, H. A., Alam, A., Garcia-Molsosa, A., Green, L. M., Conesa, F., Ranjan, A., Singh, R. N., Petrie, C. A. (2019): Re-Discovering Ancient Landscapes: Archaeological Survey of Mound Features from Historical Maps in Northwest India and Implications for Investigating the Large-Scale Distribution of Cultural Heritage Sites in South Asia. Remote Sensing 11(18): 2089, https://doi.org/10.3390/rs11182089.
Gregory, I. N., Healey, R. G. (2007): Historical GIS: structuring, mapping and analysing geographies of the past. Progress in Human Geography 31(5), 638–653, https://doi.org/10.1177/0309132507081495.
Iacopini, E. (2025a): L'urbanistica di Ancona; Edizioni Quasar: Roma, Italy, 228 p., https://doi.org/10.48235/1219.
Iacopini, E. (2025b): The Archaeological Map of Ancona: new IT tools. Groma: Documenting Archaeology 9(1), 142–150, https://doi.org/10.32028/Groma-Issue-9-2024-3247.
Jenny, B., Hurni, L. (2011): Studying cartographic heritage: Analysis and visualization of geometric distortions. Computers & Graphics 35(2), 402–411, https://doi.org/10.1016/j.cag.2011.01.005.
Larson, R. R. (2003): Placing cultural events and documents in space and time. In Duckham, M., Goodchild, M. F., Worboys, M. (Eds.), Foundations of Geographic Information Science; Taylor & Francis: London, UK, pp. 223–239, https://doi.org/10.1201/9780203009543.ch12.
Lepore, G., Ciuccarelli, M. R., Assenti, G., Belfiori, F., Boschi, F., Carra, M. L., Casci Ceccacci, T., De Donatis, M., Maini, E., Ravaioli, E., Savelli, D., Silani, M., Visani, F. (2012): Progetto "Archeologia Urbana a Senigallia" I: le ricerche di Via Cavallotti. FOLD&R 248, 1–19.
Livieratos, E. (2006): On the Study of the Geometric Properties of Historical Cartographic Representations. Cartographica 41(2), 165–175, https://doi.org/10.3138/RM86-3872-8942-61P4.
Lundberg, C., Peterson, L. (2005): Land use history of central Luleå: a case study in the use of historical maps together with modern geographic municipal information. Applied GIS 1(3), 25.1–25.30, https://doi.org/10.2104/ag050025.
Menchetti, F. (2007): Note sui progetti di Francesco Paciotto per le fortificazioni e i lazzaretti di Ancona. In Viglino, M., Bruno, A. (Eds.), Gli ingegneri militari attivi nelle terre dei Savoia e nel Piemonte orientale (XVI–XVIII secolo); EDIFIR: Firenze, Italy, pp. 65–80.
Milanese, M. (2014): Dall'archeologia postclassica all'archeologia postmedievale. Temi e problemi, vecchie e nuove tendenze. In Gelichi, S. (Ed.), Quarant'anni di Archeologia Medievale in Italia. La rivista, i temi, la teoria e i metodi; All'Insegna del Giglio: Firenze, Italy, pp. 41–49.
Nobajas, A. (2014): Historical cartography as a tool to study urban change: the case of Garriga i Roca's quarterons. Treballs de la Societat Catalana de Geografia 77, 205–220.
Pavia, R., Sori, E. (1990): Le città nella storia d'Italia: Ancona; Laterza: Roma, Italy.
Pappu, S., Akhilesh, K., Ravindranath, S., Raj, U. (2010): Applications of satellite remote sensing for research and heritage management in Indian prehistory. Journal of Archaeological Science 37(9), 2316–2331, https://doi.org/10.1016/j.jas.2010.04.005.
Petrie, C. A., Orengo, H. A., Green, A. S., Walker, J. R., Garcia, A., Conesa, F., Knox, J. R., Singh, R. N. (2019): Mapping archaeology while mapping an empire: using historical maps to reconstruct ancient settlement landscapes in modern India and Pakistan. Geosciences 9(1), 11, https://doi.org/10.3390/geosciences9010011.

Piazzini, G. (2017): Digging into Maps: Digital Processing of Historical Maps for the Urban Archaeology of Ancona. Unpublished thesis, University of Bologna, School of Specialization in Archaeological Heritage, Bologna, Italy.

Piazzini, G., Ciuccarelli, M. R. (2022): Ancona. Archeologia urbana: i rinvenimenti postmedievali in Via Buoncompagno. Archeologia Postmedievale. Società, Ambiente, Produzione 26, 300–302.

Roychowdhury, K., Taubenböck, H., Jones, S. (2011): Delineating urban, suburban and rural areas using Landsat and DMSP-OLS night-time images. In Joint Urban Remote Sensing Event (JURSE 2011); Munich, Germany, pp. 33–36, https://doi.org/10.1109/JURSE.2011.5764712.

Schlichting, K. (2008): Historical GIS: new ways of doing history. Historical Methods 41(4), 191–196, https://doi.org/10.3200/HMTS.41.4.191-196.

Sperti, L., Cipriano, S., Paveggio, A., Delpozzo, E. (2020): Altinum: discovering a hidden municipium through GIS, historical research and new excavations. e-Perimetron 15(3), 114–129.

Timár, G., Székely, B., Molnár, G., Ferencz, C., Kern, A., Galambos, C., Gercsák, G., Zentai, L. (2008): Combination of historical maps and satellite images of the Banat region: re-appearance of an old wetland area. Global and Planetary Change 62(1–2), 29–38, https://doi.org/10.1016/j.gloplacha.2007.11.002.

Wilson, A. (2001): Sydney Timemap: Integrating Historical Resources Using Gis. Journal of the Association for History and Computing 13(1), 45–68, https://doi.org/10.3366/hac.2001.13.1.45.