Visualization, Virtualization, and 3D Data Analysis in the Historical (Re) Construction of Household, Village, and Regional Landscapes: The Mount Amiata-Maremma Digital Heritage Project

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Abstract

Building on the seminal Mt. Amiata Project, the innovative Emptyscapes Project, and the initial work of Global Digital Heritage (GDH)) in southern Tuscany, a new form of transdisciplinary research is being developed. This project will transform the documentation, interpretation, and dissemination of the region's rich archaeological and historical heritage through interdisciplinary methodologies and the integration of advanced digital tools, including remote sensing, GIS, photogrammetry, and 3D visualization. This paper outlines the project's multi-scalar and diachronic approach to heritage analysis, emphasizing the interaction between digital technologies, historical reconstruction, and local community participation.

CCS Concepts

• *Digital heritage* → *workflow, GIS, 3D visualization, large scale dataset, remote sensing;* • *Landscape archaeology* → *Amiata, Maremma, cultural landscapes, community engagement, archaeology, Tuscany*

1.Introduction and justification

Recent advances in 3D technologies and integrated geospatial methods have significantly expanded our ability to create visualization and virtualization environments for research, education, public outreach, heritage management, and ultimately, the democratization of heritage.

Two decades of research in southern Tuscany's Mount Amiata and Maremma regions (Figure 1) have generated a robust and detailed foundation for understanding the temporal and spatial histories of a long sequence of local and regional societies. These data directly contribute to investigations of landscape engineering at multiple occupation scales – household, village, and region – and the categorization of heritage landscapes from field, castle, city, and sacred spaces. There is an exhaustive compendium of data available.

The expansive research of the University of Florence focused on Mt Amiata and its environs has documented the tangible Medieval history of this storied landscape. One focus of this work is on household architecture and symbols of household identity, the architecture, sculptures, and artistic embellishments of village and castle, and the integration of these markers of historical identity to form regional social and political infrastructures.

The household and village community identity progressively define themselves in a dialectical relationship with the military and political elites responsible, between the 11th and 14th centuries, for the urban organization of fortified villages and the selection of ecclesiastical sites. Over approximately a millennium, household and community identities emancipate themselves from the spatial language and semantics of the elites. This process results, between the 19th and 20th centuries, in the medieval urban space becoming focal points of private and collective spatiality, which surpass and redefine the priorities of material and social values associated with the village. A substantial database of architectural features, sculptures, artistic features, and other data form the core of a regional project of this magnitude.

Equally significant, the Landscape Archaeology and Remote Sensing laboratory (LAP&T) at the University of Siena maintains

an extensive database on the region's invisible landscape. Using a suite of remote sensing technologies, geospatial databases, and 3D visualization, numerous villages, roads, fortifications, tombs, and other features have been found hidden below the fields and forests of the Maremma.

Figure 1: *Map*

These findings have created an entirely new understanding of the archaeological record, and have transformed our conceptions of Etruscan, Roman, and Medieval use of lowland landscapes. Key to the proposed research is building on the Emptyscapes project, SMart project, and Impero projects, focusing on the so-called "middle-ground": a piece of landscape between Mount Amiata and the Tyrrhenian Sea, aimed at exploring a connective landscape and its transformations from Etruscan times to the Middle Ages [CV19].

The presence in this territory of archaeological sites, such as Rusellae, the fortifications of the coastal regions, and the walled communities of Mt Amiata, among many regional sites and historical landscapes, provide the foundational data to integrate the analyses at multiple temporal and spatial scales. The archaeological dataset is also enriched by the extensive collections available in regional museums, especially in Grosseto and Siena, where material remains from all time periods are preserved.

In its simplest conception, the unifying theme of these two rather disparate research programs is the use of 3D visualization technologies and geospatial databases to organize, synthesize, and analyze the region's heritage. Integrating social-historical data available for the Amiata region with remotely sensed, purely archaeological data from the lowlands through visualization tools is a unique approach. Using the Medieval architecture, art, and symbols of extant communities to interpret the organization of subsurface remains in the lowlands is equally unique. Conversely,

the Amiata region, dominated by walled villages and fortifications, should be reinterpreted from the perspective of dense, non-stone habitations and road networks between communities and regional centers. But the implications are much more substantial. The key theoretical approach to be applied in this study is that throughout the historic times (approximately from the mid-8th millennium BCE), there has been no natural ecosystem and no natural environment of southern Tuscany. Rather, these are engineered ecosystems and landscapes [AAB*11]. The landscapes have been consciously and unconsciously transformed by human engineers who have modified the landscape through roads, villages, markets, fields, ditches, and other features. It has been socially engineered with religious structures, sacred spaces, symbols of belief, sculptures, frescos, tombs, and monuments to spirituality. It has been politically engineered with symbols, art, buildings, and landmarks as constructions of individual and lineage status, power, and self-aggrandizement. These are tangible, physical, and materially significant attributes and the most salient and perhaps spectacular aspect of human socially and economically engineered landscapes is that they can be best visualized, virtualized, analyzed, and presented to the world through integrated 3D technologies.

Global Digital Heritage (GDH) has led the international documentation of tangible cultural heritage worldwide since 2017 (www.globaldigitalheritage.org). GDH specializes in the integration of lidar, photogrammetry, extended reality applications, 3D model-based GIS applications, and the transdisciplinary methodology for developing symmetry in diverse research programs by using extended visualization techniques. Thus, it is uniquely positioned to provide a bridge between these projects, creating an entirely novel integration of methods, technologies, and theoretical perspectives [MLD*19].

2. Historical context

To understand the political and economic importance of the Mount Amiata region, a few key aspects must be considered. First, Mount Amiata is a former volcano, relatively high in elevation and located near the Tyrrhenian Sea. Humid air masses from the sea frequently bring rain and snow, and the volcanic substrate filters this precipitation into a dense network of stable and abundant springs. These springs are concentrated in a band between 600 and 900 meters above sea level, known as the *line of springs* [Nuc99]. It is along this line that the densest clusters of medieval settlement developed, particularly after the *incastellamento* — the process of castle-building that took place between the 11th and early 13th centuries [AK89].

From a different perspective, we can consider the system of road connections between Rome and northern Europe. Although Mount Amiata is not intersected by the main Roman or Lombard road systems (which ran to its east and west), it was nonetheless crossed by important secondary routes. In the Middle Ages, these were used by travellers, merchants, and military forces, including during imperial coronation journeys. As the major roads increasingly came under the control of city authorities such as Siena, pro-imperial factions were often excluded from access. Particularly in

the late 13th and early 14th centuries, alternative routes through the Maremma and Mount Amiata were often exploited by imperial supporters. Numerous documented examples attest to this strategic function.

Mount Amiata's political significance likely resulted from the intersection of two major factors: its abundant natural springs, which supported productive industries such as milling, ironwork, and timber processing, and its role as a node in regional mobility networks.

This significance was strongly tied to the powerful princely family of southern Tuscany, the Aldobrandeschi. Originating as Carolingian counts or imperial functionaries in the 9th century, they gradually consolidated a princely domain in southern Tuscany from the 11th century onward. By the 12th century, the Aldobrandeschi had absorbed key lordships such as that of the Abbey of San Salvatore al Monte Amiata, as well as a number of minor dynastic lordships. A remarkable list of their most important vassals appears in a charter issued by Emperor Frederick II in the 1220s [Col98; Col02].

One major consequence of Mount Amiata's centrality within the Aldobrandeschi domain was the significant impact it had on local settlement strategies. Chris Wickham, in his seminal 1989 study on the topic, argued that by the second half of the 13th century, virtually all inhabitants of the region lived within the walls of a castle — that is, in fortified villages centered on a fortress and a lordly residence [Wic89; Wic10]. Many of today's historic town centers in the Mount Amiata region still preserve the urban fabric and buildings of this *incastellamento* phase.

Mount Amiata delineates the eastern boundary of the greater Maremma. Conversely, the western boundary is formed by the Tyrrhenian coast, which, in contrast to the Amiata landscape, is predominantly characterized by the presence of ancient cities such as Rusellae, Vetulonia, Populonia, and Cosa.

In particular, Rusellae was an important Etruscan and subsequently Roman city, which survived until the Middle Ages before finally being abandoned, more or less, in the 12th century AD [NP11]. Starting from the Orientalizing Period, in around the mid-7th century BC, there appear to have been city walls, a transformation in the topographic layout of the city and a generalised phase of public and private building activity. The process was continued and reinforced during the Archaic period, with a general growth of the city and the progressive development in the surrounding landscape of a pattern of dispersed settlements which were probably related to agricultural production. There also grew up a network of roads and other communication routes, no doubt including the waterway of the Ombrone river to gain ready access to inland Etruria.

In 294 BC the Etruscan city was conquered by the Romans and from the end of 3rd century to the middle of the 1st century BC there ensued a long process of further building activity within the city walls. In the Rusellae area, as in the rest of Etruria, later centuries saw a major restructuring of the landscape, introducing Roman villa settlement and productive systems aimed at improving agricultural productivity [Vac08]. In the 1st century BC Rusellae was designated as a Roman Colony and from the 1st century AD begun another phase of building activity, both within

the city and in the surrounding landscape: forum, amphitheatre, temple, domus, further Roman villas in the countryside and perhaps a pattern of centuriation. Starting from the 4th century AD there is clear evidence of further transformations within the city, which is beginning a phase of progressive decline. This is reflected in the decrease of new public building foundations and the conversion of some pre-existing buildings to new functions, such as the case of the *Domus dei Mosaici* transformed into a metallurgical workshop [Seb11; Cel22]. A similar fate also happened to the so-called Hadrianic Baths, abandoned during the 4th century AD, and successively reused for the construction of a church at the end of the 6th century AD [Cel22]. In the countryside, the pattern that developed during the late Republican and early Imperial phases fell into crisis during the Antoninian Age in the middle and later part of the 3rd century AD. From the 4th up to the mid-6th century a slight recovery is visible in the revival of a number of Roman villas, both close to Rusellae and in the more distant hinterland, at Aiali, Sterpeto and Casette di Mota for instance [Vac08]. However, Rusellae maintained its role as an administrative centre with a complex urban topography.

Documentary evidence shows that from at least 499 AD the bishopric had its seat at Rusellae, remaining in that area until moving to Grosseto in 1138 [NP11]. This shift of the area's main functions does not however appear to have been a unitary and linear process and it would be extremely interesting (in the longer term) to analyse whether any relevant evidence of the process has been left in the landscape between these two central places – changes in the settlement or agricultural patterns, for instance, or transformations in the area's communication systems. Whatever the details, the relationship between Rusellae and Grosseto must have played a significant role within the early Middle Ages, involving first the Lombard and later the Carolingian lordships, the Papacy and a number of prominent aristocratic families, in particular the Aldobrandeschi. Evidence of urban activity in Rusellae is attested until the 10th to 11th centuries AD, mainly in improvements to the fortifications. Up to that time Grosseto, roughly 8 km to the south-west, still served in a 'secondary' role but recent archaeological excavations within the present-day city have demonstrated a progressive development of the settlement area from the 9th to the 11th century, providing conditions for the transfer of the bishopric to Grosseto, as noted above, during the first part of the 12th century. This historical framework, characterized by great vigor and continuous transformation, provides the context for the Emptyscapes project [Cam17; Cam18; Cam19]. As described and discussed in this paper, the cumulative outcomes have prompted a completely new interpretation of the area under examination.

3. Research background

Since the late 1990s, the University of Florence has led research in the Mount Amiata region. Spearheaded by Michele Nucciotti, the work combines traditional archaeological methods with innovative "Light Archaeology" approaches, which prioritize non-invasive techniques, limited excavation, and territorial analysis to reconstruct medieval landscapes and settlement patterns [Bro88;

Bro02; BC12]. These projects focus primarily on the period between the 10th and 14th centuries, examining the role of the powerful Aldobrandeschi family in shaping the territory's development. These studies have revealed how this aristocratic family transformed the rural landscape through castle-building (*incastellamento*), control of water resources, and establishment of economic networks that connected the mountain communities to broader regional systems.

The light archaeology study of the Mount Amiata area began in the 1990s with the objective to explore the potential of archaeology applied to surviving medieval buildings to balance, with the contribution of material sources, that of written records concerning the Middle Ages in the same region.

The latter had already received considerable attention, particularly in the 1970s and 1980s, thanks to the seminal work of Wilhelm Kurze and the publication of the *Codex Diplomaticus Amiatinus* from the Abbey of San Salvatore archive [AK89]. Alongside these developments, architectural studies began to focus primarily on religious buildings linked to the history and possessions of the Abbey of San Salvatore al Monte Amiata.

This work followed the methodologies of architectural history and art history. Key figures included Moretti, as well as local scholars such as Prezzolini, who compiled significant catalogues of medieval buildings that had been part of the Abbey's holdings and whose structures were still extant.

Starting in 2000, originally within the framework of a PhD research on medieval architecture in Mount Amiata, the University of Florence initiated a long-term project that brought archaeological teams to the area for approximately 15 years [Nuc05; Nuc06]. During this period, nearly all standing medieval buildings in the Mount Amiata region were systematically documented. This effort generated a substantial dataset, which has supported the synthesis outlined in the preceding paragraphs and elsewhere.

A significant contribution is Nucciotti's "Atlante dell'Edilizia Medievale" (Atlas of Medieval Buildings), conducted as part of an EU LEADER+ initiative and published in 2009-2010, which documents and analyzes medieval structures throughout the Amiata region and Fiora Valley [Nuc09]. This comprehensive inventory catalogs architectural elements, construction techniques, and building materials used in medieval settlements, providing insights into technological capabilities, resource management, and socio-economic conditions of the period. This project allowed for the documentation of medieval buildings within the municipalities of Monte Amiata and the broader areas of the Fiora and Paglia valleys. His research on Santa Fiora, which he describes as a "rural capital" in medieval southern Tuscany, exemplifies this approach. The detailed analysis of material structures and architectural elements demonstrates how the Aldobrandeschi counts transformed this settlement into an administrative center for their territories from the 11th to the 14th centuries. His work explores the family's fiscal policies, urban planning strategies, and architectural choices as expressions of political power [NV02].

From the perspective of human historical geography, this body of work can be situated within the broader conceptual framework of the "rural world" and studies of rural communities. While such communities are often considered marginal today, they were anything but marginal in the Middle Ages, when much of Europe was governed by rural elites embedded within the countryside.

This pattern is only partially applicable to northern Italy, where from the 10th or 11th century onward, urban centers increasingly emerged as administrative hubs — the so-called *comuni* or municipal authorities. In this context, Mount Amiata presented a particularly compelling case study: a prominent rural political and economic subregion that gradually came under pressure from powerful city-states, especially Siena. This pressure intensified in the second half of the 13th century and culminated in the 14th century, when Siena effectively took control of almost the entire area. The religious dimension of the medieval landscape, as reflected in its monastic foundations, was closely integrated with these developments. His research shows how these religious institutions functioned within the Aldobrandeschi territorial strategy, facilitating economic development and consolidating political control.

More recently, this work has expanded to include "Public Archaeology" initiatives that translate academic research into heritage management tools and public education resources [Bon12; Bon13: BN12; Van11]. The Medieval Landscape Museum in the Arcidosso Castle represents one such outcome, presenting archaeological findings in an accessible format for both tourists and local communities. This compendium of work illuminates the complex interplay between geography, economic resources, political ambition, and religious institutions in the formation of the Amiata region's distinctive medieval landscape.

On the completely opposite end of the archaeological method spectrum, the Landscape Archaeology and Remote Sensing Lab (LAP&T) of the University of Siena specializes in landscape archaeology, focusing on non-invasive methods. LAP&T's groundbreaking Emptyscapes project represents a paradigm shift in how archaeologists' approach Mediterranean landscapes, particularly in the Grosseto region of southern Tuscany.

The Emptyscapes initiative, launched as a Marie Curie project with support from the University of Cambridge, addresses what Campana identifies as a fundamental challenge in Italian landscape archaeology: the existence of "empty spaces" and "empty phases" in the archaeological record. Traditional archaeological survey methods, primarily relying on field walking and artifact collection, have often failed to detect significant evidence of human activity in certain areas and time periods, creating a fragmented understanding of historical landscapes.

The project's innovative approach focuses on a sample transect of 3000 hectares in the valley between the ancient Etruscan-Roman city of Rusellae and the medieval town of Grosseto [CMR*25]. This area was strategically chosen to investigate key historical questions about the urbanization of Etruscan cities, the Romanization of the landscape, and the transition from Late Antiquity to the Middle Ages - periods that had previously appeared as "empty" in traditional archaeological records.

Emptyscapes' methodological innovation lies in its integration of multiple remote sensing technologies with traditional archaeological approaches. LAP&T has conducted extensive geophysical surveys, collecting approximately 1,100 hectares of

data (1,050 hectares of magnetometry, 30 hectares of resistivity measurements, and 20 hectares by GPR). This large-scale geophysical prospection is complemented by aerial photography, LiDAR scanning, and targeted field walking to create a comprehensive picture of the archaeological landscape.

The results have been transformative for understanding the historical development of the Grosseto region. In areas previously considered "empty," LAP&T has discovered extensive evidence of human activity, including previously unknown road networks, field systems, burial landscapes, and fortified settlements. Particularly significant has been the identification of several medieval settlements with ditched enclosures that traditional survey methods had failed to detect. These findings have challenged existing models of *incastellamento* and settlement patterns during the critical transition from Late Antiquity to the medieval period [FG00; Cam17; Cam18; Cam22].

One of the project's most important discoveries was a substantial Roman complex spanning approximately 4 hectares near what appears to be a major road connecting to Rusellae. The settlement shows occupation from the late Republic through the Middle Ages, demonstrating continuity of previously unrecognized habitation. Similarly, the identification of field systems and agricultural infrastructure has provided new insights into the economic organization of the countryside surrounding ancient Rusellae.

LAP&T's work extends beyond the Emptyscapes project, encompassing significant research throughout the Grosseto and Siena provinces, along the Ombrone and Orcia valleys. His earlier investigations in around the western and northern side of the Amiata revealed important archaeological evidence from prehistory to the Middle Ages, substantially enhancing the understanding of the region. Additionally, his research on Grosseto's development has shed light on the city's emergence following the decline of Rusellae in the early 12th century, when the bishopric was transferred to the growing medieval town.

In 2019, GDH began working in the Mt Amiata region to document tangible heritage, including artifacts, sculptures, castles, and heritage landscapes. Building on Maschner's work using 3D digital heritage to democratize access to museum collections and heritage monuments [Mas13; MSH13], this project found immediate symmetry with Nucciotti's Amiata Project and LAP&T's Emptyscapes Project.

This three-year initiative will focus on the digital documentation of historical and archaeological heritage in Mt Amiata and Grosseto regions. The project integrates themes from Etruscan, Roman, and Medieval archaeology, historical topography, landscape analysis, and digital heritage studies. It explores the connections between road networks, marketplaces, domestic spaces, and religious sites. It does so in the context of a physical approach to things, places, and landscapes that emphasize visualization in transformative ways.

Art, architecture, villages, and landscapes are approached as both functional and symbolic built environments. Decorative motifs, religious iconography, and construction techniques are read as visual languages that reflect social hierarchies, economies, religious beliefs, and local identities. Special attention is given to production centers and ancient roads, which are understood not merely as logistic infrastructures but as relational spaces used to promote cultural exchange, mobility, ideas, and the movement of tangible heritage: artifacts, sculptures, symbols.

4. The methodology in practice

4.1. The Mount Amiata Region

The application of Light Archaeology and Building Archaeology within a broader Historical Archaeology framework has enabled the reconstruction of numerous historical narratives about medieval Mount Amiata. As originally intended, these narratives integrate and balance the historical reconstructions based solely on written records and art-historical analyses available in the 1990s.
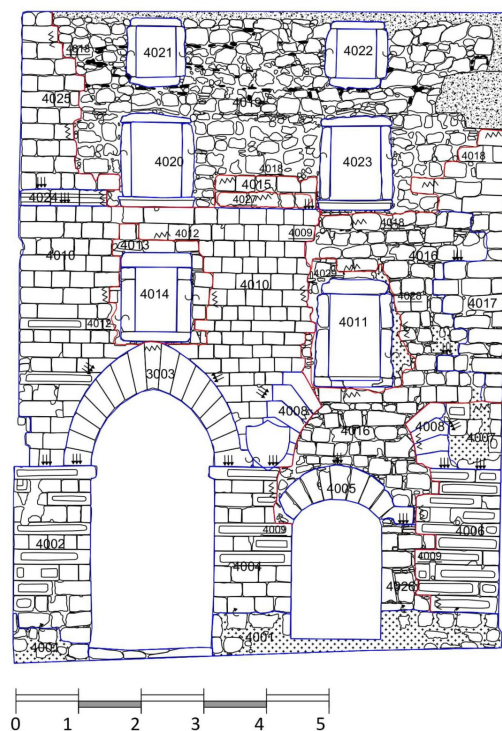

Figure 2: *Stratigraphic analysis of a medieval house in Abbadia San Salvatore (SI) (University of Florence archive – Diletta Bigiotti). Note the presence of two equal-sized arches in the building's earliest phase (late 13th century). The right arch was later reduced to a smaller doorway in the 14th century. Following post-medieval collapses, the building was restored and equipped with a new system of windows and internal subdivisions.*

A particularly clear example of this approach is the identification of building intensification episodes as reflections of demographic and economic growth — for instance, as seen in the evolution of domestic structures (Figure 2), or in the expansion of Aldobrandeschi residences with the addition of spaces for

permanent professional staff, such as the late 13th-century vertical extensions observed in the Aldobrandeschi palace in Arcidosso (Figure 3) [DeF05; Nuc00; Nuc10].
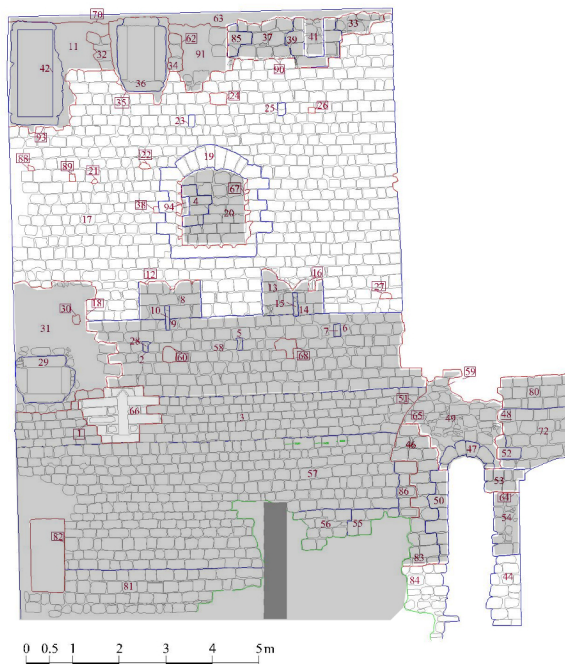

Figure 3: *Stratigraphic analysis of the Aldobrandeschi palace at the Rocca of Arcidosso. Highlighted is the elevation of the new palace in the second half of the 13th century, coinciding with increased residential stability of the comital court and the organization of a palatine bureaucracy around the count.*

In both cases, this information was provided or refined through archaeological analysis of standing architecture.

The same methodology used to study medieval urbanization processes will be further applied in this project to deepen our understanding of the long-term spatial and social dynamics that shaped village life in Mount Amiata [Nuc01]. Within the broader integrated research initiative conducted by Global Digital Heritage and the Universities of Florence and Siena, the villages of Mount Amiata are being investigated as material expressions of civic voice — as arenas where dialogue and competition between institutions and citizens were materially enacted.

In this perspective, archaeology is not simply a means of documenting a particular period (e.g., the Middle Ages), but a tool for understanding the broader processes of material transformation. These transformations are interpreted as heritage values in their own right, independent of whether they follow trajectories of growth or decline, and in line with a "deep cities" approach [JBR*24; Nuc24].

The current GDH *Amiata 3D Collection* (Figure 4), developed in collaboration with the University of Florence, offers a concise yet rich preview of the research directions to be pursued over the next three years. The material culture and social histories of rural communities in Mount Amiata are already visible in the selected case studies. These range from institutionalized sacred spaces (such as churches, chapels, and abbeys) to personal devotional contexts (including Christian symbols on domestic buildings, inscriptions, decorative elements, and ex-voto tabernacles) (Figure 4).
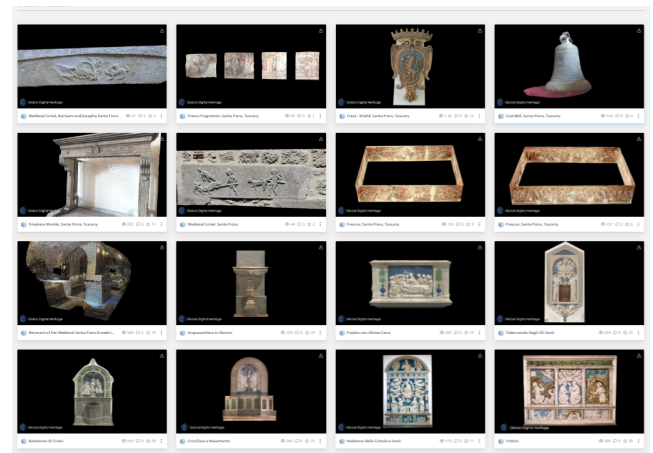

Figure 4: *A Sample of the Amiata 3D Collection on Sketchfab.*

Heterodox elements further enrich the sacred landscape — sometimes not perceived as such — such as Latin inscriptions dedicated to Jupiter reused in medieval buildings, or scenes from the life of the Buddha incorporated into Christian narratives and reproduced in the well-known medieval bas-relief in Santa Fiora (http://sketchfab.com/GlobalDigitalHeritage/collections/santa-fiora-grosseto-tuscany-34ec6341714449a3bce193ff1a76def0). In other cases, heterodoxy is explicitly manifested, as in the 19th-century shrine of David Lazzaretti on Monte Labbro.

The GDH collection also includes specimens relating to the material expressions of state elites such as 3D scans of fortresses (Figure 5), coats of arms displayed in public buildings: http://sketchfab.com/GlobalDigitalHeritage/collections/arcidosso-grosseto-tuscany-3c45ad4be2a34d7db66a06a21e22a9df), and collective institutions representing medieval communities (such as the 16th-century bronze municipal bell of Santa Fiora).

These two spheres often intersect significantly. Additional data provides insight into the spatial organization of crafts and labor, as evidenced by professional signage on arches and lintels of ancient workshops.

In summary, the project promotes a reading of the material "vocality" of village life — the tangible dialogues and visible tensions between the state, the communities, and individual actors.

Figure 5: *3D model of the Cassero of Montelaterone, Arcidosso.*

The collaboration between the University of Florence and Global Digital Heritage has yielded a digital collection that encapsulates the essence of Tuscan rural life over a millennium. This collection not only documents but also preserves and reflects on the complex interplay between state institutions and individuals, highlighting the tensions between institutionalized values and the needs of diverse communities. It contributes to giving voice to and preserving the memories of historically and socially marginalized subjects, thus fostering the construction of more inclusive historical narratives on a global scale.

4.2. The Greater Maremma Emptyscapes

In recent years, there has been a revolution in the archaeological methodologies used for the study of the ancient landscape. A wide variety of 'new' remote sensing methods are now increasingly widely deployed for archaeological exploration and mapping. In addition to the improvement in technical capabilities, we have also seen the beginnings of a conceptual change. Archaeology has traditionally been focused upon individual locations – 'sites' – which we have sought to identify and then explore through excavation and the analysis of the finds from them. Although pragmatically understandable, the division of the world into a series of isolated sites is conceptually problematic since human beings do not just exist at particular points in the landscape but rather utilize the whole of their surroundings in a wide variety of different ways. Given that the same was true in the past, and that we increasingly have technologies to explore whole tracts of landscape, archaeology is moving towards changes in approach that seek to explore and understand the reality of total past landscapes.

The Emptyscapes project is part of this new approach to studying landscapes and represents the first of its kind in the Mediterranean area. We mainly focused on the transformation of settlement networks, agricultural landscapes, environmental history, the rural infrastructure, the Christianization of the countryside and the discovery of a new type of so-called 'mound-settlement', previously unknown in Tuscany [Cam08]. In effect this sample area inspired the implementation and development of a new paradigm for the study of landscapes, capable of responding to temporal and spatial gaps as well as to the absence of some important aspects of information, in particular concerning transformations in the related ecosystems (fauna, flora, geomorphology etc.).

The chronological scope of the investigations is broad, open to any archaeological evidence from prehistoric times to the present day. However, in practice we have focused on the period from the beginning of the first millennium BC to the early and later parts of the Middle Ages. The work carried out so far has made it possible to recognize a significant amount of archaeological evidence which would have been entirely unidentifiable if restricted solely to the use of the 'traditional' research methods of field-walking survey, surface collection, artifact studies and documentary research). Effectively, the overall results to date have multiplied the amount of previously known information by a factor of thirty or more. Within the tightly focused sample area between Rusellae and Grosseto systematic investigation using the traditional sources of ancient topography had already identified a considerable amount of information. Overall, there were 80 known archaeological sites of various kinds (Roman villas, farms, cemeteries, furnaces etc.) within the sample area. Integrated methods have so far produced 2746 new archaeological features, considerably expanding not only the quantity but also the variety of finds, in many cases recording features entirely undetected in the past – fences, settlements, burial mounds, tombs, agricultural field systems, buildings, ditches, pits, roads, canals and so on (Figure 6). This is not just a matter of the simple quantity of evidence, but also of improvements in the quality and articulation of the interpretations that can be achieved, providing entirely new understanding of a large variety of phenomena, contexts and phases within entire socio-economic systems [Cam17; Cam18; Cam22; http://www.emptyscapes.org].
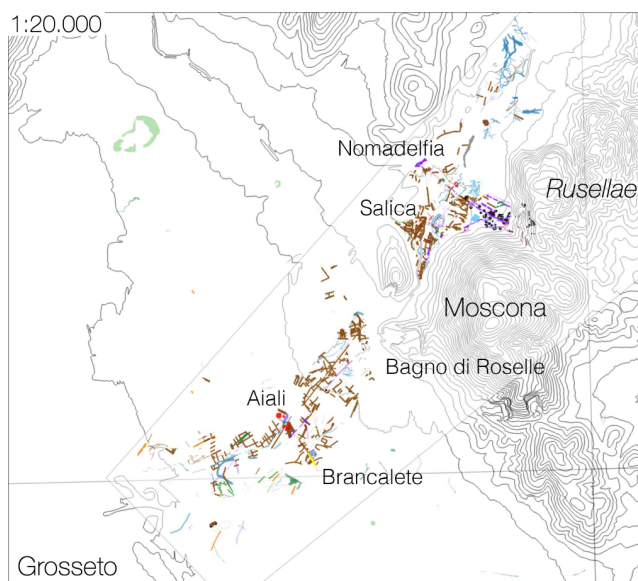
Figure 6: *The territory between Rusellae and Grosseto: general visualization of the evidence (colour lines) identified through the integration of 1100 hectares of extensive geophysical survey, several episodes of exploratory aerial survey by light aircraft, four years of aerial survey by drone, analysis of high-resolution LiDAR data by drone and the detailed examination of high-resolution satellite imagery.*

5. Conclusion

The Mt. Amiata-Maremma Digital Heritage Project represents a significant methodological and theoretical breakthrough in studying historical landscapes. We integrate the Univesrity of Florence's methods of architectural documentation, LAP&T's remote sensing surveys, and Global Digital Heritage's visualization tools, to transcend traditional disciplinary boundaries and create a more comprehensive understanding of southern Tuscany's complex cultural heritage.

This transdisciplinary integration addresses a fundamental challenge in archaeology: the artificial separation of visible and buried heritage, mountain and lowland zones, and different temporal periods. The project reveals the interconnected nature of historically engineered landscapes by removing these false dichotomies. Integrating the "visible" Medieval heritage of Mt. Amiata with the "hidden" landscapes of the Maremma allows us to understand regional development as a coherent, though complex, historical process.

Using a multiscalar approach—examining households, villages, and regional networks simultaneously—provides unique insights into how communities negotiated their relationships with political and religious authorities. The dialectical process between household identity and elite power structures, documented in the architectural record of Mt. Amiata, can now be contextualized within the broader spatial organization revealed through geophysical survey. This approach enables us to reinterpret both the densely occupied lowland landscapes and the fortified mountain communities as parts of a single integrated regional system.

The methodological innovation of combining 3D documentation with advanced remote sensing and traditional archaeological techniques creates a robust analytical framework that transforms our interpretive capabilities. Rather than viewing the landscape as a collection of isolated sites, this approach reveals the "archaeological and historical continuum" that connects different temporal phases and geographical zones. The project demonstrates that seemingly "empty" landscapes are rich information repositories accessible through appropriate technological approaches.

From a theoretical perspective, conceptualizing Tuscan landscapes as economically, socially, and politically engineered environments provides a robust framework for understanding long-term landscape transformation. When we visualize these engineered landscapes through integrated 3D technologies, we make tangible the complex interplay of economic structures, social hierarchies, and political ambitions that shaped the region's development from the Etruscans through the Medieval period and beyond.

Beyond its academic significance, the Mt. Amiata-Maremma Digital Heritage Project also offers opportunities for community engagement and heritage management. We find that through visualization, we democratize access to cultural heritage and foster community involvement in heritage preservation. The digital tools developed through this research create new opportunities for public education, tourism development, and sustainable management of archaeological resources.

As this initiative progresses, it promises to redefine our understanding of southern Tuscany's historical development while establishing methodological standards for integrated landscape archaeology elsewhere. By bridging the gap between traditional archaeological practice and cutting-edge digital technologies, the Mt. Amiata-Maremma Digital Heritage Project represents the future of archaeological heritage research—one that is simultaneously more comprehensive in scope, more rigorous in methods, and more accessible in outcomes.

References

[AAB*11] ALBERTI, M., ASBJORNSEN H., BAKER L. A., BROZOVIC N., DRINKWATER L. E., DRZYZGA S. A., JANTZ C. A., FRAGOSO J., HOLLAND D. S., KOHLER T. A., LIU J., MCCONNELL W. J., MASCHNER H. D. G., MILLINGTON J. D. A., MONTICINO M., PODESTA G., GILMORE PONTIUS JR., R., REDMAN C. L., J. REO, N., SAILOR D., URQUHART G.: Research on Coupled Human and Natural Systems (CHANS): Approach, Challenges, and Strategies. *Bulletin of the Ecological Society of America*, Vol.

92, No. 2, (2011), 218–28. DOI: 10.1890/0012-9623-92.2.218.

[AK89] ASCHERI, M. e KURZE, W.: *L'Amiata nel Medioevo*, Roma, 1989.

[Bon12] BONACCHI, C.: *Archaeology and Digital Communication. Towards strategies of Public Engagement*, London, 2012, 1 – 16.

[Bon13] BONACCHI, C.: The development of Public Archaeology in Italy: a review of recent efforts. *Public Archaeology*, Vol. 12 (3), 2013, 211 – 216.

[BN12] BONACCHI, C., NUCCIOTTI, M.: Archeologia "pubblica". La grande occasione. *Archeologia Viva,* 155, Settembre – Ottobre 2012, 80 – 81.

[Bro88] BROGIOLO, G.P.: *Archeologia dell'edilizia storica: documenti e metodi*, Como, 1988.

[Bro02] BROGIOLO, G.P. Ricerca archeologica. Lo studio degli elevati. *Il mondo dell'Archeologia*, 2002.

[BC12] BROGIOLO, G.P., CAGNANA, A.: *Archeologia dell'architettura, metodi e interpretazioni*, Firenze, 2012.

[Cam17] CAMPANA, S.: Emptyscapes: filling an 'empty' Mediterranean landscape at Rusellae, Italy. *Antiquity*, 91 (359), 2017, 1223–1240. DOI: 10.15184/aqy.2017.139

[Cam18] CAMPANA, S.: EMPTYSCAPES. Towards Filling Gaps in Mediterranean Landscape Archaeology. *Humans and environmental sustainability*, 2018, 8–15.

[Cam19] CAMPANA, S.: 'Emptyscapes' and medieval landscapes. *Mediterranean Landscapes*, Post Antiquity, 2019, 64–83.

[CV19] CAMPANA, S., VACCARO E.: Archeologia della Media e Bassa Valle dell'Ombrone: i progetti Santa Marta ed Emptyscapes. *Bollettino Archeologia Online*, X, 2019 3-4.

[Cel22] CELUZZA M.: Roselle. *Una terra di mezzo. I Longobardi e la nascita della Toscana*, Grosseto, 2022, 259-273.

[CMR*25] CIRIGLIANO, G. P., MAZZACCA, G., REMONDINO, F., LIVERANI, P., CANTORO, G., MASCHNER, H., & CAMPANA, S.: Drone-Based High-Resolution LiDAR for Undercanopy Archaeology in Mediterranean Environment: Rusellae Case Study (Italy). *Archaeological Prospection*, 2025. DOI: 10.1002/arp.1980

[Col98] COLLAVINI, S.: *Honorabilis domus et spetiosissimus comitatus'. Gli Aldobrandeschi da 'conti' a 'principi territoriali' (secoli IX-XIII)*, Pisa, 1998.

[Col02] COLLAVINI, S.: I conti Aldobrandeschi nel contesto storico generale e locale. In Ascheri, M., Niccolai, L. *Gli Aldobrandeschi. La grande famiglia feudale della Maremma toscana*, 2002, 21–36.

[DeF05] DE FALCO, M.: *Edilizia civile nell'Amiata medievale: il caso di Arcidosso*. Tesi di laurea in Archeologia Medievale, Università di Firenze, 2005.

[JBR*24] JJONES, S., BONACCHI, C., ROBSON, E., BROCCOLI, E., HISCOCK, A., BIONDI, A., NUCCIOTTI, M., GUTTORMSEN, T. S., FOUSEKI, K., & DÍAZ-ANDREU, M.: Assessing the dynamic social values of the 'deep city': An integrated methodology combining online and offline approaches. *Progress in Planning*, 187, 2024. DOI: 10.1016/j.progress.2024.100852

[Mas13] MASCHNER, H. D. G.: Democracy in 3D. *Museum*, 2013, 26–31.

[MSH13] MASCHNER, H. D. G., SCHOU, C. D., HOLMES, J.: Virtualization and the democratization of science: 3D technologies revolutionize museum research and access. *Digital Heritage International Congress*, 2013, 265–271.

[MLD*19] MASCHNER, H., LÓPEZ-MENCHERO, V. M., DU VERNAY, J., et al.: La digitalización tridimensional del patrimonio cultural como medida preventiva. *Patrimonio cultural y catástrofes,* 2019, 379–384.

[NP11] NICOSIA F., POGGESI G.: *Roselle. Guida al parco archeologico*. Grosseto, 2011.

[Nuc99] NUCCIOTTI, M.: *Santa Fiora nel basso Medioevo (ss. XII-XIV). Gestione del potere e dinamiche urbanistiche in un castello amiatino: una lettura archeologica.* Tesi di laurea in Archeologia Medievale, Università di Firenze, 1999.

[Nuc00] NUCCIOTTI, M.: Le murature medievali di Santa Fiora (Monte Amiata-Toscana): mensiocronologia delle murature in pietra, un caso di studio. *Archeologia dell'Architettura*, V, 2000, 65–85.

[Nuc01] NUCCIOTTI, M.: Storia e archeologia di un'economia "dell'acqua" in area montana. *Tracce*, Fiesole, 2001, 19–46.

[Nuc05] NUCCIOTTI, M.,: *Le pietre del potere. Per una storia 'archeologica' dei quadri politico – istituzionali dell'Amiata occidentale nel medioevo.* Tesi di dottorato in Archeologia medievale, Università dell'Aquila, 2005.

[Nuc06] NUCCIOTTI, M.: L'Amiata nel Medioevo (secoli VIII-XIV). Modi, tempi e luoghi della formazione di un paesaggio storico, in Ciuffoletti (a.c.), Il Parco minerario dell'Amiata. Il territorio e la sua storia, Arcidosso (GR), 2006, 161-199. *Reti Medievali* [http://www.retimedievali.it]

[Nuc09] NUCCIOTTI, M.: Atlante dell'edilizia medievale, Inventario. Arcidosso (GR), 2009, *Reti Medievali* [http://www.retimedievali.it]

[Nuc10] NUCCIOTTI, M.: Paesaggi dell'Impero nella Toscana del X secolo. Il Palatium di Arcidosso: senso storico di un tipo edilizio europeo. *Archeologia Medievale* XXXVII, 2010, 513-527.

[Nuc24] NUCCIOTTI, M.: Archeologia pubblica e archeologia leggera a Firenze: Mappare le trasformazioni urbane della 'Città Profonda'. *Archeologia in Toscana. Ricerca, tutela, gestione, valorizzazione*, Vol. 6. Arbor Sapientiae. 2024, 18–26.

[NV02] NUCCIOTTI, M., VANNINI, G.: Santa Fiora: strutture materiali di una capitale rurale nella Toscana meridionale del Medioevo, in Ascheri Niccolai *Gli Aldobrandeschi: la grande famiglia feudale della Maremma toscana* 2002, 111–149.

[Seb11] SEBASTIANI A.: Nota su due strutture produttive nell'Ager Rusellanus: la bottega di un mastro vetraio a Spolverino (Alberese-GR) e l'officina metallurgica a Rusellae (Grosseto). *Fasti Online*, FOLDER 2011-221.

[Van11] VANNINI, G.: *Archeologia Pubblica in Toscana: un progetto e una proposta*, Firenze, 2011.

[Vac08] VACCARO E.: An Overview of Rural Settlement in Four River Basins in the Province of Grosseto on the coast of Tuscany (200 B.C.-A.D. 600). *Journal of Roma Archaeology*, 21, 2008, 225-247.

[Wic89] WICKHAM, C.: Paesaggi sepolti: insediamento e incastellamento sull'Amiata, 750–1250. *L'Amiata nel Medioevo*, 1989, 101–137.

[Wic10] WICKHAM, C.: Archeologia e mondi rurali: quadri di insediamento e sviluppo economico. *Archeologia Medievale*, XXXVII, 2010, 277-281.