
Journal of Field Archaeology

ISSN: 0093-4690 (Print) 2042-4582 (Online) Journal homepage: www.tandfonline.com/journals/yjfa20

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**To cite this article:** Michele Abballe, Marco Cavalazzi, Paolo Maranzana, Daniele Bortoluzzi, Enrico Dinelli & Marco Taviani (2025) Approaching Marginal Landscapes in Archaeology: the Case of Ravenna’s Reclaimed Wetlands, Journal of Field Archaeology, 50:8, 680-699, DOI: 10.1080/00934690.2025.2509367

**To link to this article:** https://doi.org/10.1080/00934690.2025.2509367



Published online: 10 Jun 2025.

JOURNAL OF FIELD ARCHAEOLOGY
2025, VOL. 50, NO. 8, 680–699
https://doi.org/10.1080/00934690.2025.2509367

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# Approaching Marginal Landscapes in Archaeology: the Case of Ravenna's Reclaimed Wetlands

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**ABSTRACT**
Among the diverse types of marginal landscapes, reclaimed wetlands present interpretive challenges due to the rapid sedimentation resulting from reclamation activities, which hinders traditional fieldwork methods. In this paper, we therefore adopt a multiscalar approach that integrates historical, geomorphological, sedimentological, geochemical, and paleontological data, along with remote sensing, to investigate the human-environment interactions in the northern and northwestern hinterland of Ravenna. These areas were originally dominated by wetlands, which have been extensively reclaimed from the Middle Ages to the present day. The integration of these datasets enabled us to better contextualize both previous findings and those collected through recent surveys, as well as to carry out a detailed analysis of the landscape transformations, largely driven by reclamation processes and flood events. Finally, we reflect on the unique interpretive challenges posed by reclaimed wetlands, discuss their presumed "marginality," and emphasize the need for a creative research agenda to overcome the specific limitations of these landscapes, as highlighted by ongoing debates in the field.

**ARTICLE HISTORY**
Received 5 October 2024
Revised 24 April 2025
Accepted 28 April 2025

**KEYWORDS**
Landscape archaeology; geoarchaeology; wetland archaeology; marginal landscapes; reclaimed landscapes; wetlands; Ravenna

## Introduction

"Marginal landscapes" are defined by several key factors, including their vulnerability to environmental risks, unsuitability for agriculture, degradation, and limited economic value (Kang et al. 2013; Jumaniyazov et al. 2023). Despite their diverse characteristics, marginal lands have traditionally been perceived in a negative light, frequently classified as less favored areas, within socio-economic systems that prioritize agricultural productivity (Strijker 2005; Messerli et al. 2016). However, in recent years, archaeological and historical investigations have increasingly focused on these regions, with a particular emphasis on lowland valleys and mountainous areas, underscoring their socio-economic relevance in past societies (Mills and Coles 1998; Van de Noort and O'Sullivan 2006; Turner and Young 2007; Klápšte and Sommer 2009; Burri 2014; Vandam 2019). This new wave of research has also demonstrated that the definition of marginal landscapes has varied over time, and their identification was often influenced by cultural and socio-economic factors that changed across time and space, as well as the perspectives of the researchers themselves (Traina 1985; Bailey 1989; Pollard 1997; Attema, Larocca, and de Neef 2019; Orengo 2023).

Indeed, landscapes that we now consider marginal—such as mountainous regions and wetlands—serve as ideal study areas for addressing a wide range of research questions. For example, these environments are highly dynamic and have historically been among the most visibly affected by climate change and extreme events (Price 1995; Castro and Castro 2019). Furthermore, research in these landscapes holds substantial value beyond scientific significance: it directly benefits contemporary society by providing urban and rural communities with the tools and knowledge needed to address challenges such as climate change and biodiversity loss (Davies et al. 2022).

Given their significant geographical diversity, marginal landscapes require region- and period-specific analyses to capture the range of human experiences they hosted. Within this context, reclaimed wetlands present additional interpretive challenges due to the rapid sedimentation caused by reclamation activities, which hinders traditional fieldwork methods. Among marginal landscapes, reclaimed wetlands have traditionally been overlooked in modern scholarship, even more than uplands (Saggioro 2006; Burri 2014; Vanni and Cristoferi 2018). Hence, the paper's focus on reclaimed wetlands serves a dual purpose: 1) to highlight the spatial and temporal fluidity of marginality within this landscape type and 2) to examine the specific methodological challenges of studying reclaimed landscapes, specifically former wetlands that have been drained and are now subjected to intensive agricultural exploitation (de Haas and Schepers 2022). Reclaimed wetlands present several features but are often characterized by substantial clay-rich alluvial deposits and a remarkably rapid rate of vertical accretion (Cavalazzi 2020; Abballe, Cavalazzi, and Fiorotto 2022). These clay landscapes have been largely overlooked in archaeological research, partly because they were seen as less suitable for historical human settlement compared to areas with lighter soils (Mills and Palmer 2007). Additionally, they pose

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significant challenges for archaeological study due to the influence of geopedological factors (Cowley and Dickson 2007; Mills 2007). As a result, a second term has emerged to describe these areas, emphasizing the complexity of their archaeological investigation: difficult soils landscapes (Mills 2007; Boschi 2012). In such cases, the challenges posed by these soils can be overcome only by integrating multiple research methods and improving the visibility of archaeological evidence (De Smedt et al. 2013). At the same time, the interpretation of any settlement pattern that comes to light must be contextualized through stratigraphic data, which are essential for reconstructing the geomorphological development of the area (e.g., Ravesloot and Waters 2004; Leibner 2014; Qin et al. 2023; Gruškovnjak 2024).

Hence, combining diverse datasets requires a new level of theoretical reflection within wetland archaeology, the main discipline focused on studying these landscapes. Since its first attempts at formalization as a distinct discipline in the 1970s and 1980s (Coles 2001), wetland archaeology has tended to orient itself toward functionalism and environmental determinism (Menotti 2012). According to Menotti, this trend was due to the richness of organic finds that characterize waterlogged contexts (2012, 22). This resulted in a predominantly descriptive analysis of the collected datasets, rooted in empiricism and disconnected from theory-related, sociological, and anthropological interpretive frameworks (Noort and O'Sullivan 2007; Johnson 2011; Menotti 2012). Only in recent decades has wetland archaeology embraced a new way of thinking about the landscape, which includes "a major shift from a functionalist to a quite diverse range of social, ideological, and symbolic approaches to understanding past landscapes" (Van de Noort and O'Sullivan 2006, 32). By critically reassessing the concept of wetlands and their historical perception, the discipline has increasingly come to view past elements and phenomena—including environmental factors—as dynamic agents. Within this approach, certain narratives have emerged, addressing topics such as colonialism and internal colonization (McLeester et al. 2022), the ritual use of wetlands (Brown 2003; Larsson 2006), and the archaeology of disasters, whether real or imagined (Gardiner and Hartwell 2006).

However, these approaches have yet to address a key methodological issue: the abundance and fragmentation of datasets in wetland archaeology, especially in reclaimed landscapes. This represents a dual challenge: managing a large dataset while also accounting for the varied nature of historical wetland evidence, which may encompass multiple types of data, including archaeological, geoarchaeological, archaeobotanical, and other sources. This fragmentation highlights the second challenge mentioned earlier: the need to integrate ecofacts and artifacts cohesively, ideally within a coherent theoretical framework that accounts for the diverse phenomena shaping ancient wetlands. Research approaches from historical ecology and landscape ecology have been more responsive to this need. Wetland archaeology, in particular, has seen efforts to develop comprehensive frameworks—both quantitative and qualitative—that holistically address the interaction between historical processes, often within the context of long-term studies (Walsh, Attema, and de Haas 2014; Abballe and Cavalazzi 2022; de Haas and Schepers 2022).

To address the two gaps outlined above—both the historical significance of reclaimed landscapes as marginal lands and the methodological challenge of working with fragmented and diverse datasets from these complex environments—we will present the authors' research conducted over the past two decades in the territory of Ravenna. Situated on the northern Adriatic coast, Ravenna played a pivotal role during Late Antiquity, serving as the capital of the Western Roman Empire in the 5th century A.D. Following this introduction and the presentation of the study area, the paper will continue with three sections: a summary of the multidisciplinary methods adopted and the variety of materials used; a presentation of the integrated research results, focusing on both settlement pattern dynamics and paleoenvironmental reconstructions; and, a final discussion addressing the new local insights, the replicable multi-method approach, and the overall findings within the context of the previously outlined theoretical framework.

## *Ravenna's reclaimed wetlands*

The study area is a broad, low-lying region that surrounds the city of Ravenna to the north and west, extending from the Adriatic Sea to the inland territory of the Bassa Romagna (Figure 1). Like other parts of the Po Valley, this area has experienced significant geomorphological changes until recently, driven by a combination of river sedimentation, subsidence, and human activities. Despite the flat plain, small local variations exist due to fluvial and coastal geomorphological dynamics, primarily river avulsions and coastal progradation, which exposed, and still do nowadays, the area to many environmental risks, especially related to flooding. This factor, along with its distance from nearby cities, especially Ravenna, made the area largely unsuitable for agriculture, contributing to its apparent marginal status. However, intensive land reclamation efforts have led to the near-total disappearance of these original wetlands and have simultaneously flattened and homogenized a landscape that was previously characterized by a constant alternation of drier ridges and wetter lowlands (Stefani 2017). Thus, reconstructing the development of these nearly disappeared wetlands becomes essential for understanding past human-environment relationships in such landscapes. However, this task is methodologically challenging, especially in the absence of historical cartography, which only became abundant starting from the 17th century A.D. (Fabbri 1987). Stratigraphic data have been essential for identifying flooded or flood-prone areas in earlier centuries, as demonstrated by the notable example of the Orizzonte Veggiani (OV) in Lugo (Franceschelli and Marabini 2007; Marabini and Vai 2020; Abballe, Cavalazzi, and Fiorotto 2022). In the area north of Ravenna, since land reclamation is primarily associated with the Cassa di Colmata del Lamone project (A.D. 1839–1962), the wealth of cartographic sources (Nardi 1987) has helped infer the marshes disappeared in the last two centuries, although much research is necessary to gain further insights into their formation and subsequent development.

Such a dynamic landscape, thus, hinders efforts to reconstruct settlement patterns within this region. Even more difficult is the process of contextualizing ancient occupation within its physical environment, which is now substantially different from the ancient one. Therefore, the Bassa Romandiola project of the University of Bologna (2009–ongoing) and the Reclaimed Lands (RecLands) multi-institutional project (2023–ongoing), which provided the main datasets discussed in this paper, aim to holistically reconstruct the

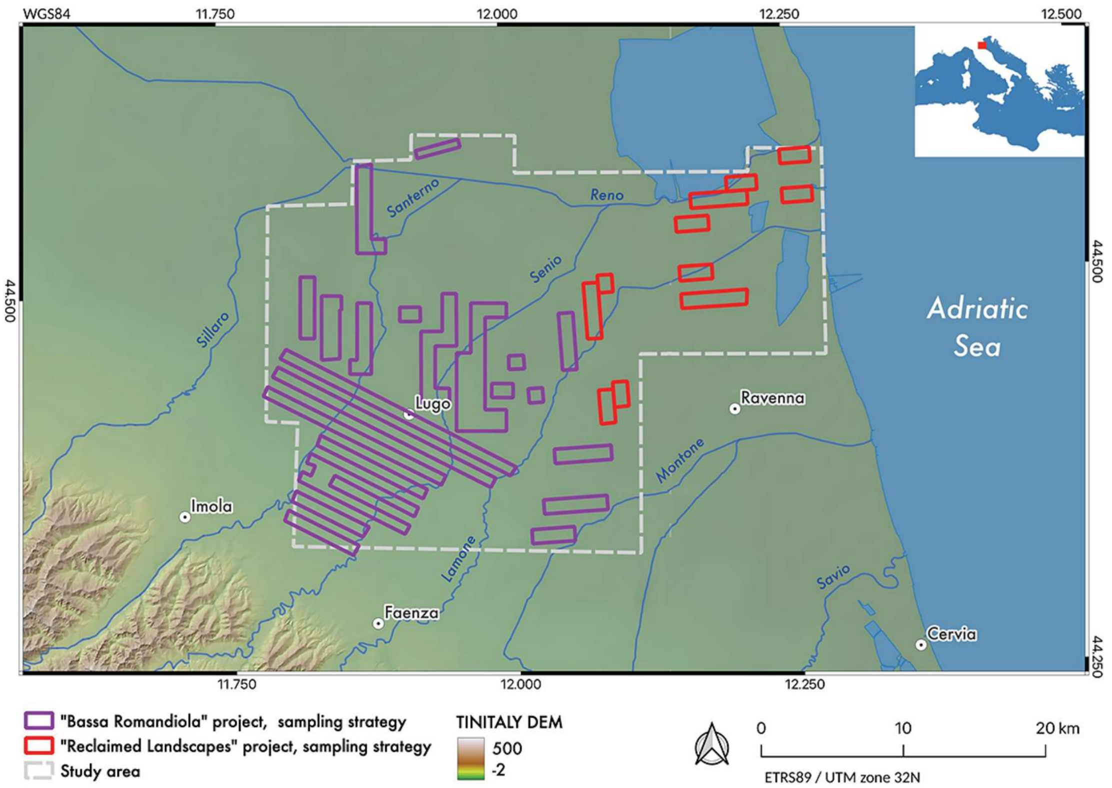


**Figure 1.** Map of the study area showing the sampling strategies of the Bassa Romandiola and RecLands projects (basemap derived from the TINITALY DEM).

natural landscape along with its long-term changes. For this reason, the two projects focus on the formation, development, and disappearance of wetlands due to reclamation—respectively, one in the Bassa Romagna subregion and the other in the area north of Ravenna. By examining the hinterland of Ravenna, we can gain new insights into the socio-environmental dynamics of these often-overlooked clay and reclaimed landscapes. Additionally, this area serves as a testing ground to tackle the challenges of working with fragmented and diverse datasets by integrating various methodologies.

## Materials and Methods

### *Archival methods*

The historical and archaeological knowledge of this territory is grounded in a comprehensive collection of previous data (Franceschelli and Marabini 2007; Augenti, Ficara, and Ravaioli 2012; Abballe et al. 2022; Cavalazzi 2022), to which we have added a systematic analysis of both published written sources and archival archaeological records. The former includes one of the largest archival repertoires at the national level, particularly rich for the last centuries of the Early Middle Ages (9th–11th centuries A.D.), consisting primarily of lease contracts that provide valuable information about the cultivated fields of that time, which can often be geographically located through toponymic evidence (Fiorotto 2018). However, this category of sources shares a common limitation: the absence of topographical references to human settlements—such as villages, castles, or farms—whose mentions are far more common in contracts from the other parts of the Italian peninsula (Pasquali 1998). It is possible that the survival of cadastral records from earlier traditions made it unnecessary for Medieval notaries to include these details in transactions. Therefore, the integration of material evidence is essential for reconstructing the evolution of this territory during the Late Antique and medieval periods.

The second category of archival records consists of hundreds of reports from rescue and preventive archaeology preserved in the archives of the Superintendency of Bologna (SABAP-BO) and Ravenna (SABAP-RA), which have significantly enriched our knowledge with more recently collected data (Abballe, Cavalazzi, and Fiorotto 2022). Additionally, in the last decade, numerous aerial and satellite images have been digitized and made freely available online (Abballe and Cavalazzi 2023, 6, fig. 2). Their systematic analysis has improved our understanding of river network changes, allowed the mapping of traces of flood events and reclamation canals, and shed light on the morphology of numerous archaeological sites (Abballe and Cavalazzi 2021, 2023; Abballe 2023).

### *Field methods*

While previous data and information from written sources provide a solid foundation, the most significant new archaeological evidence comes from systematic artifact surveys conducted by the ongoing Bassa Romandiola and RecLands projects (see Figure 1). They employ a consistent methodology that includes systematic and intensive survey techniques, along with a sampling strategy designed to balance resources—time and costs—with the research objectives. More specifically, this involves the application of a systematic disproportional stratified strategy, where different landscape strata are investigated in varying proportions to ensure a comprehensive understanding of the area (Cavalazzi 2020). In other words, every cadastral parcel with a minimal level of surface visibility—referred to as a "Topographical

Unit"—was systematically surveyed by archaeologists walking in parallel lines spaced 10 m apart, a distance that defines the "Intensity" of the survey. The Topographical Unit was treated as the fundamental unit in which any archaeological find, as well as traces of human and natural activities on the ground, were recorded. During the artifact survey, the position of every single find was recorded using a GPS receiver, following an approach of siteless surveys. In cases where artifact concentrations exceeded the background scatter within the Topographical Unit, these areas were interpreted as archaeological "sites." Here, the intensity of the survey increased, with the distance between archaeologists reduced to 1 m. Every archaeological find was collected, except for architectural materials like bricks or roof tiles. This dual approach, combining site-based and siteless survey methods, enabled the mapping of the continuum of artifact distribution while still preserving the interpretative category of "site," which remains valuable for further archaeological analysis and public policies, including the development of tools for cultural heritage protection, such as archaeological maps (Cavalazzi, Abballe, and Ferrari 2022).

Since 2018, a systematic approach has also been adopted for the collection of geoarchaeological data from the subsurface, primarily using hand auger boreholes. These were carried out with an Eijkelkamp set designed for heterogeneous soils, allowing for depths of up to approximately 7 m. Borehole descriptions were conducted in the field, with each borehole's position recorded using a handheld GPS and the total depth of each log measured. Several characteristics were documented for each stratigraphic layer identified, following the guidelines of the CARtografia Geologica (CARG) national geological mapping project. These characteristics included sediment grain size based on finger texturing, sorting, color according to the Munsell Revised Standard Soil Color Chart, boundary characteristics, $CaCO_3$ content expressed on a scale from 0–4, and the presence of organic (e.g., charcoal or shells) or inorganic inclusions (e.g., artifacts or oxides). A final lithostratigraphic interpretation was then inferred for each layer based on field and laboratory data (Abballe 2022). A total of 155 boreholes were cored in the wider hinterland of Ravenna between 2018 and 2020 (Abballe 2021), while specifically in the Cassa di Colmata del Lamone area, we cored 27 additional boreholes between 2023 and 2024.

In addition to the study of legacy aerial and satellite images, continuous satellite monitoring using almost-daily PlanetScope images at a 3 m spatial resolution has been implemented, combined with subsequent drone flights. This approach has proven highly effective for confirming the presence of crop and soil marks of (geo)archaeological interest on the ground within the larger hinterland of Ravenna (Abballe 2023). Within the RecLands project, this combined approach enabled the verification of a fortified site at Marcabò, where photos shot with a DJI Mavic 2 Pro allowed us to document numerous marks associated with this site on both 15 September 2023 and 15 June 2024.

### *Laboratory analyses*

Paleontological information is based upon 15 sediment samples from one mechanical core (PCR02) and four samples from three auger hand boreholes located near an archaeological site, supposedly recognized in the Iron Age *oppidum* (fortified settlement) and later Roman *statio* (a roadside station) of *Butrium* (Bermond Montanari 1966). Macrofossils were hand-picked directly during fieldwork when visible in the core or collected through bulk sediment sampling, whose volume depended upon the thickness of any given fossiliferous layer. Bulk sediment samples were then dried at room temperature and sieved through 1 mm mesh; the residues were oven-dried at 50°C and then examined under a binocular microscope for taxonomic identification.

Published sources (Abballe et al. 2022; Marabini and Vai 2020; Abballe, Cavalazzi, and Fiorotto 2022) provided radiocarbon-based chronological constraints, which were supplemented by AMS-dating of four peat samples at the Radiocarbon Laboratory of KIK/IRPA in Brussels, Belgium, according to their standard procedure (Wojcieszak et al. 2020). The obtained values are reported as $^{14}$C years B.P. and have been calibrated using the software OxCal v4.4 (Bronk Ramsey 2009) and the IntCal20 calibration curve (Reimer et al. 2020).

The assessment of geochemical data for sediment provenance is based upon 71 samples collected from a mechanical core (PCR02) and 19 hand auger boreholes. Combined geochemical and stratigraphic studies have identified various geochemical indices that are effective in tracing sediment provenance and reconstructing paleoenvironmental evolution (Amorosi et al. 2002; Volpi et al. 2024). Building on previous research (Greggio et al. 2018, and references therein), which demonstrated the ability of X-ray fluorescence spectroscopy (XRF) to distinguish between sediments from the Po River (high Cr and Ni), Apennine rivers and streams (low Cr and Ni, high CaO and Sr), and northern Adriatic rivers such as the Brenta and Adige (high MgO and Ba), our study focused on the Cassa di Colmata del Lamone area. Samples were oven-dried at 50°C, powdered, homogenized using an agate mortar, and pressed into powder pellets. These pellets were then analyzed with a Panalytical Axios4000 X-ray fluorescence spectrometer for the following elements: Na, Mg, Al, Si, P, K, Ca, Ti, Mn, Fe, Nb, Zr, Y, Sr, Rb, Ce, Ba, La, Ni, Cr, Co, S, Th, Cu, Zn, Pb, As, V, and Sc. Loss on Ignition (LOI) was gravimetrically determined after overnight heating at 950°C and includes the contribution of volatile substances such as pore water, inorganic carbon, and organic matter (see below, Data Availability). Statistical analyses performed using GCDKit® within the R environment (Janoušek et al. 2016) highlighted the $MgO/Al_2O_3$ and Ni/Vi ratios as valuable indicators for sediment provenance, allowing a further characterization between Romagna rivers (Lamone, Senio, and Santerno) from the eastern Emilia ones (Sillaro and Idice).

## Integrated Results

### *Settlement pattern dynamics*

Reconstructing settlement patterns history in a territory so heavily affected by alluvial sedimentation presents significant challenges, further compounded by a limited surface visibility resulting from current land use/land cover. Indeed, the region is currently intensively cultivated with fruit orchards, which considerably reduces the extent of the areas where artifact surveys can be effectively conducted (Figure 2). Nevertheless, the systematic, multidisciplinary, and

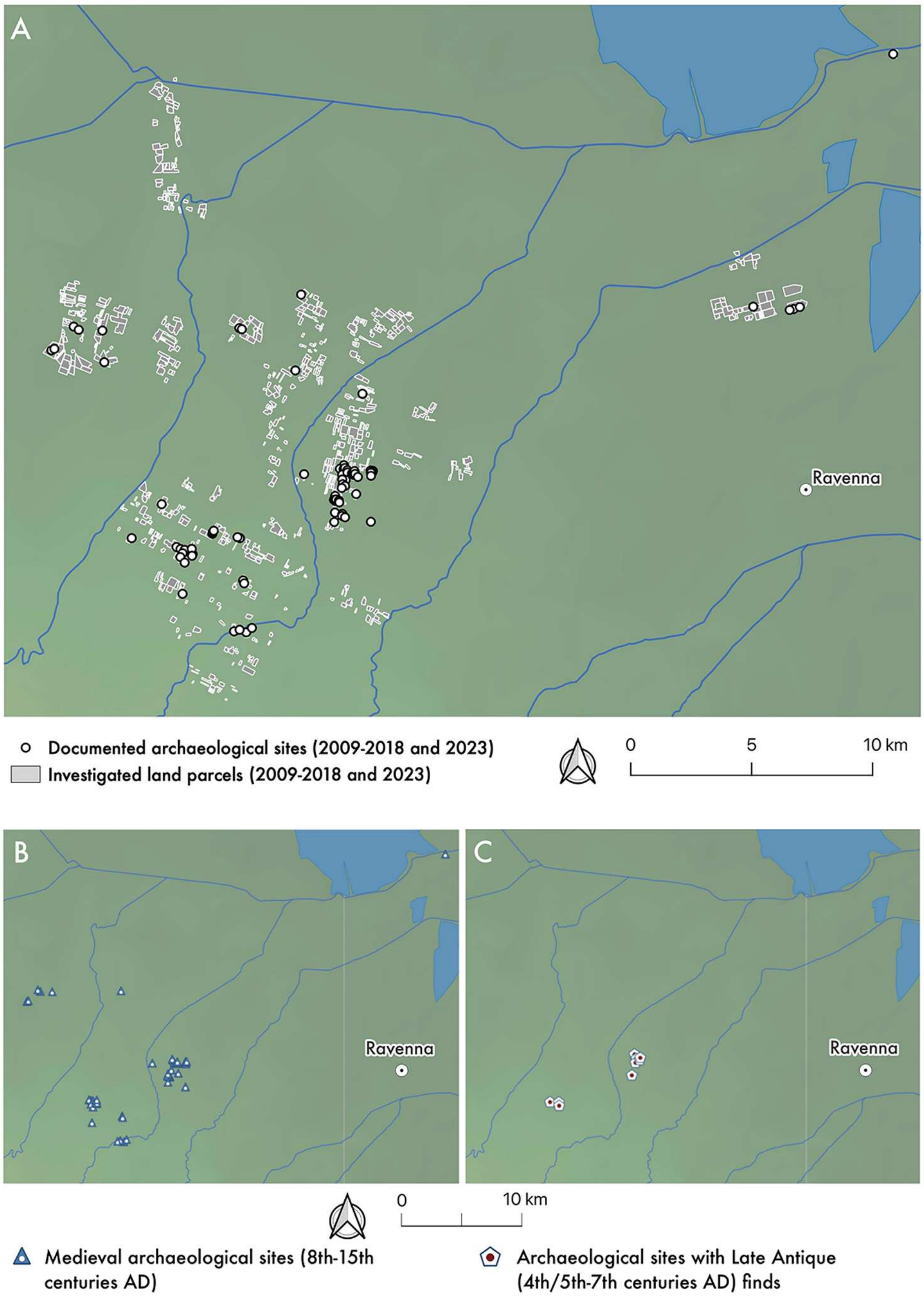


**Figure 2.** A) Surveyed areas and distribution of sites by period: B) Middle Ages and C) Late Antiquity (basemap derived from the TINITALY DEM).

multiscale approach being used is helping to shed light on poorly known post-Roman periods (see Figure 2). This is especially true in the Bassa Romagna subregion, extensively explored by the Bassa Romandiola project that completed five systematic survey campaigns between 2009 and 2018 (Cavalazzi et al. 2018; Cavalazzi, Abballe, and Ferrari 2022; Cavalazzi 2023). These surveys systematically covered 78 km$^2$ and identified 78 artifact concentrations dating from the 5th–18th centuries A.D. (see Figure 2). Scattered houses and farms were present in Late Antiquity (5th–7th centuries A.D.) and persisted in the Zagonara area between the 8th and 10th centuries A.D. Meanwhile, a more nucleated settlement pattern emerged in the Bagnacavallo area. By the 13th century A.D., all these rural settlements had nearly disappeared, likely due to a broader reorganization into larger, primarily fortified villages (see below, Data Availability).

At this stage, only preliminary information can be provided regarding the artifact surveys in the Cassa di Colmata del Lamone area, first explored in 2023 (see Figure 1). The absence of surface material in the examined sample has been confirmed, except for some slag of uncertain date at the S. Maria in Palazzolo site, an early Medieval monastery supposedly built on the site of a previous late Roman villa (Bermond Montanari 1983). The absence of surface finds is likely due to the reclamation works that buried the ancient ground level, as will be further discussed in the following section. The only exception so far is the site at Marcabò, where probable fortification elements, such as an embankment and a pentagonal tower, were identified through remotely sensed images (Figure 3). During the first RecLands campaign, the site was surveyed to look for surface finds that could help us with dating and interpreting the fortification. Pottery finds cluster near the tower (see Figure 3A), with a chronology ranging from the 13th/14th–16th/17th centuries A.D., suggesting that the site functioned as a late Medieval and modern fortification (see below, Data Availability). This site appears to be a rarity in the area, as it is one of the few fortified sites identified so far in a landscape otherwise

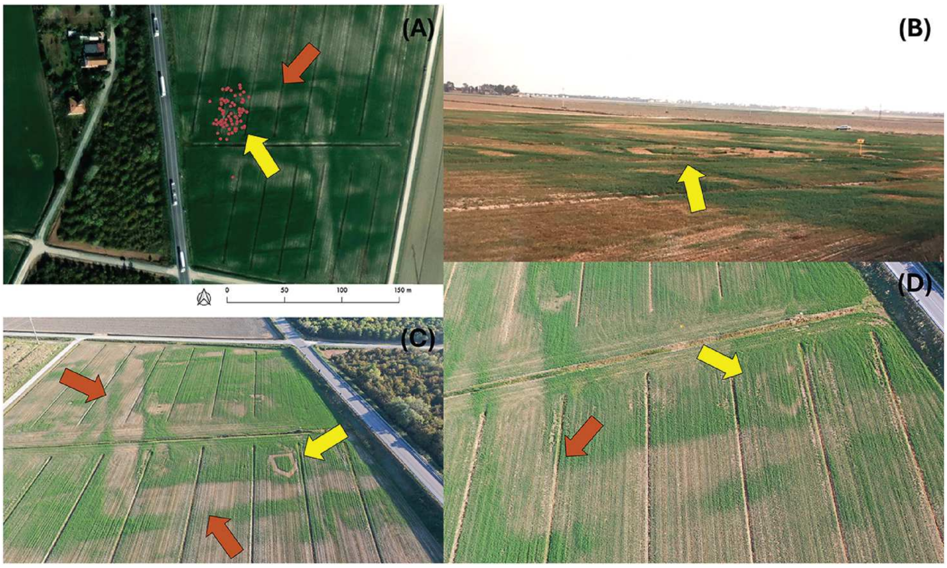


**Figure 3.** Archaeological site in Marcabò, with yellow arrows indicating the pentagonal tower and orange ones the fortification system: A) artifact distribution as collected on 13 October 2023, with WorldView-2 satellite image captured on 28 October 2022 as basemap (Esri basemap, Copyright © Esri); B) archival photo shot in 1987 by Arnaldo Roncuzzi at the site of Marcabò (Biblioteca dell'Università di Beni Culturali di Ravenna, A. Roncuzzi archive); C) drone photo shot on 15 September 2023; and, D) drone photo shot on 15 June 2024.

dominated by religious establishments, such as monasteries and rural churches, along with the village of Sant'Alberto, attested from the 14th century A.D. onward. This is likely due to its strategic location, as it allowed control over the mouth of the ancient Po di Primaro branch, now the Reno River (see Figure 1).

### *Paleogeographical reconstructions*

To study the paleoenvironmental development of the area south of Lugo, an extensive investigation involving manual boreholes was conducted between 2018 and 2020, complemented by the analysis of stratigraphic sections and continuous core drillings, frequently documented in the context of development-led archaeology. To facilitate interpretation, the documented stratigraphies in the area were organized along two orthogonal transects: an east-west cross-section (CS1), passing through the hamlets of Zagonara and Budrio, and a north-south cross-section (CS2), covering the area occupied by the hamlet of Budrio and the town of Lugo itself (Figure 4). By integrating surface data from the geomorphological analysis, remote sensing, and archaeological survey with stratigraphic data, it is possible to shed light on the key geomorphological processes behind the formation of the current landscape in this inland area of the Ravenna territory to better interpret the survey results of the Bassa Romandiola project.

Despite the excellent preservation of what appears to be a Roman centuriation grid, known as *Grande Centuriazione Romagnola*, no Roman sites are visible on the surface, and the few known sites, often found in quarry contexts, lie at depths of up to 5–6 m (Franceschelli and Marabini 2007; Cavalazzi 2021). Therefore, previous studies raised strong doubts as to whether this is truly a Roman centuriation, suggesting instead that it may have been redrawn during the medieval period in imitation of the ancient layout, extending the still-functioning canals towards the lower-lying marshland areas (Franceschelli 2008; Chouquer 2015). The data collected reinforces this hypothesis and allows us to better characterize the spatial and chronological transformation of this portion of the inland plain.

The east-west cross-section (CS1) between the Santerno and Senio Rivers schematically illustrates the main phases of landscape history (Figure 5), often marked by the formation of buried soils. The level associated with the Bronze Age, known as the Geosuolo Formellino (GF), was identified only in the western portion, where it is closer to the surface due to the presence of the former Bagnara fluvial ridge, which runs largely parallel to the modern Santerno River. A significant change occurred between the 8th/9th centuries B.C. and the Roman period, as suggested by the dating of charcoal from a silty clay layer in AUG096, likely formed under partially waterlogged conditions. This layer lies beneath a substantial sandy sedimentation documented in the central portion and interpreted as the formation of the Zagonara fluvial ridge, now mostly buried. This explains the relatively elevated Roman ground level, which has significantly impacted the visibility of archaeological materials on the surface during surveys dating from the 5th/6th centuries A.D. onwards. The absence of Roman material may instead be attributed to subsequent flooding events, which led to the formation of other ridges, progressing from west to east: San Martino, Barbiano, Via Croce Coperta, and Senio, the latter located near the current river. The most significant is undoubtedly the Croce Coperta ridge, which filled a depressed area interpreted as the OV (see above, Ravenna's reclaimed wetlands). Radiocarbon dating confirms that this waterlogged area persisted until the 11th–early 13th century A.D. (Table 1), consistent with the foundation of the Budrio castle in A.D. 1217, as also corroborated by archaeological finds collected in 2018 (Cavalazzi, Abballe, and Ferrari 2022). The interpretation of the stratigraphy in the eastern section with the OV is based not only on its peculiar characteristics, such as the bluish-gray color, the absence of oxidation, and the abundance of organic material typical of redox conditions in waterlogged environments, but also on its stratigraphic correlation with the site where the OV was first identified, near Lugo. Indeed, when analyzing CS2 (Figure 6), we observe how the marshland layers extend

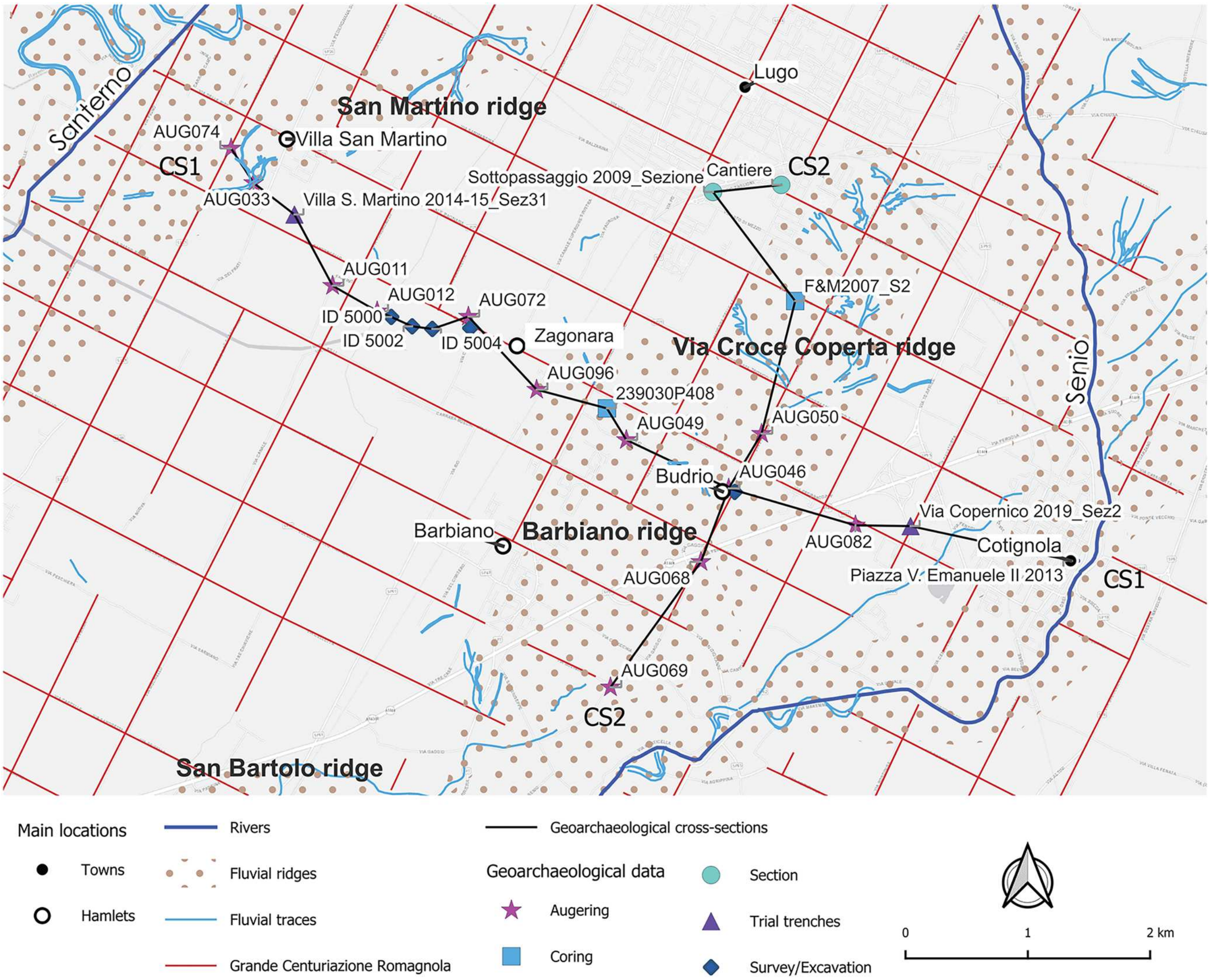


**Figure 4.** Geoarchaeological investigations in the area of Lugo with stratigraphic data, the two cross-sections (CS1 and CS2), fluvial ridges, and remotely sensed marks related to fluvial activities (data from Zenodo online database, available at https://doi.org/10.5281/zenodo.8043357; for more information, see Abballe 2025) and *Grande Centuriazione Romagnola* (Esri basemap, copyright © Esri).

northward, reaching the outskirts of the town, specifically near the railway station (Cantiere site). Chronologically, there is also a strong correlation with a previous radiocarbon date of material recovered from a 2009 railway underpass construction site, recalibrated here. This entire depressed area was leveled by predominantly sandy sediments linked to the Via Croce Coperta ridge and the numerous crevasse splays mapped through remote sensing. While these data allow us to contextualize the absence of pre-13th century A.D. archaeological materials on the surface, they also confirm that what we observe cannot be interpreted as an uninterruptedly preserved Roman centurial system. This leads us to suggest that significant (re)layout work on the water management system was likely undertaken during the same period in which the new settlement of Budrio (A.D. 1217) and the refounding of Lugo (A.D. 1218) took place, as both are seamlessly integrated into the centurial grid. Interestingly, the contemporary chronicler Tolosano reports that Faenza, in addition to creating new fortified centers, including Budrio, also engaged in managing excess water through the excavation of large and deep canals (Abballe, Cavalazzi, and Fiorotto 2022, and references therein).

In the area north of Ravenna, a total of 27 manual boreholes were carried out between 2023 and 2024, organized along two transects (Figure 7). The southern transect (CS3) included 19 boreholes and a continuous mechanical core conducted in 2020 (PCR02), which traverses the archaeological sites of Butrium and S. Maria in Palazzolo. The northern transect (CS4), consisting of seven boreholes, runs parallel to the Lamone River, just north of the hamlet of S. Romualdo, near the site of S. Pietro in Armentario. Geochemical analyses focused on sediments from this area (see below, Data Availability), with particular emphasis on determining when the influence of the Po River intensified, likely coinciding with the activation of its southern branch, known as the Primaro. While the exact timing of its activation is uncertain, it is well established that this branch remained active from the High Middle Ages until its deactivation in the mid-18th century A.D., when the Reno River was diverted in its paleochannel. Specifically, the MgO/$Al_2O_3$ and Ni/Vi ratios allowed a further qualitative characterization between Romagna rivers (Lamone, Senio, and Santerno) from the eastern Emilia ones (Sillaro and Idice), in addition to those relatable to the Po (Figure 8). Previous studies on subsurface sediments in the area suggested a provenance dominated by Apennine sources (Amorosi and Sammartino 2007), although a few different signals were also identified (Buscaroli, Zannoni, and Dinelli 2021).

The east-west cross-section (CS3) between the site of Butrium and S. Maria in Palazzolo (Figure 9) documents the main phases of landscape development typical of a barrier-lagoon system responding to the marine regression in roughly the last 5000 years (Campo, Amorosi, and Vaiani 2017; Stefani 2017). The stratigraphy is relatively homogeneous, with marine sediments encountered at a depth between 6.2 and 8 m by the deeper mechanical core (PCR02). This is the only sample that documents a Po-related signature and contains a macrofossil assemblage with elements sourced from sandy upper shoreface habitats (Table 2), such as *Chamelea gallina* (Linnaeus 1758), *Donax semistriatus* (Poli 1795), associated with *Bittium reticulatum* (Da Costa 1778), and abundant *Lentidium mediterraneum* (Costa 1830), indicating a riverine-influenced coastal marine setting (Pérès and Picard 1964; Taviani 1980). The shallowest samples from this phase also contain brackish shells, such as *Cerastoderma glaucum* (Bruguière 1789) and *Ventrosia ventrosa* (Montagu 1803), between 6.2 and 6.6 m, signaling the transition to a fully brackish lagoonal environment. This latter deposition environment, characterized by alternating fine and coarser sediments, with a significant amount of organic material, is associated with typical brackish-lagoonal elements such as *Abra segmentum* (Récluz 1843), *C. glaucum*, *V. ventrosa*, and *Theodoxus* sp. Sediment signatures vary significantly west of Via S. Alberto, likely due to reworking by tidal processes. This road was built exploiting a preexisting geomorphological landform, since very coarse sandy sediments identified in borehole BH003 allowed us to locate the partially known Etruscan-Roman beach ridge, archaeologically dated to this rough chronological span. Instead, both samples east of the same alignment show a clear Po source, potential evidence that the activation of the Po di Primaro branch may have caused the coastal progradation of the late Roman period. Lagoon sediments have been identified not only in the continuous core but also in nearly all manual boreholes, with only a few exceptions. Besides the beach ridge sediments of BH003, three other boreholes (BH020-21-22) were drilled in alignment with well-recognizable soil and crop marks, periodically visible in aerial and satellite images, to confirm the presence of the dunes. This later beach ridge is supposedly dated to the Late Antique–early Medieval period (Preti 2002), although no absolute dates exist, as for more recent systems where OSL dating was used to assess their formation chronology (Scarelli et al. 2016). Typical coarse sandy sediments were indeed almost outcropping in BH020 and BH021, while in BH022, they were buried under 1.7 meters of fine sediments, likely indicating an ancient interdunal swale now filled with subsequent alluvial deposits. The alternation between exposed dunes, likely further leveled by human activities, and depressed areas filled with finer sediments supports the initial interpretation of the observed differences in vegetation growth or soil color as pertaining

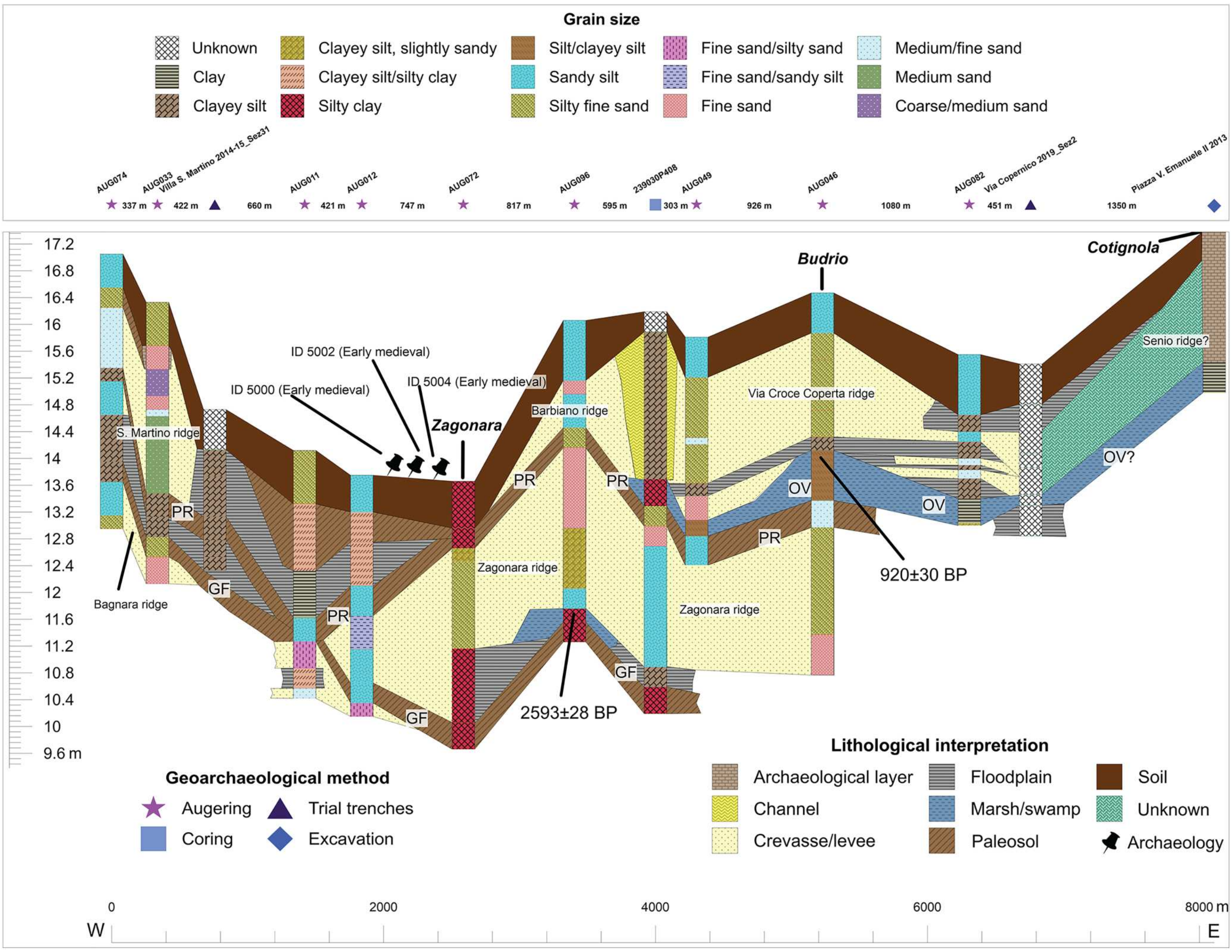


**Figure 5.** East-west stratigraphic cross-section (CS1) across the plain between Santerno and Senio rivers (PR = Roman paleosol; GF = Geosuolo Formellino; and, OV = Orizzonte Veggiani) (modified from Abballe, Cavalazzi, and Fiorotto 2022, 129, fig. 10).

**Table 1.** Radiocarbon dates from the Bassa Romandiola project, carried out by the Centro di Datazione e Diagnostica–CEDAD of the Università del Salento (LTL), Beta Analytics (Beta), and the Royal Institute for Cultural Heritage of Bruxelles (RICH). Dates have been calibrated with OxCal 4.4. (Bronk Ramsey 2009) using the IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (Reimer et al. 2020).

| Sample | Depth (m) | Material | Lab code | Date B.P. | Date CAL (95.4% probability) |
|---|---|---|---|---|---|
| Lugo 1 | 3 | Wood | LTL-4425A | 894 ± 35 | A.D. 1041–1109 (31.7%), A.D. 1114–1222 (63.8%) |
| Budrio18-AUG46-S1 | 2.35–2.5 | Seed (*Vitis vinifera* L.) | Beta-531205 | 920 ± 30 | A.D. 1035–1180 (88.8%), A.D. 1188–1210 (6.6%) |
| Barbiano20-AUG96-S1 | 4.3–4.5 | Charcoal | RICH-29410 | 2593 ± 28 | 812–759 B.C. (95.0%), 678–674 B.C. (0.5%) |

to a beach ridge system. Sandy deposits identified in BH027 as being heavily oxidized due to the presence of groundwater suggest the possible presence of another negative feature, likely a swale, which would confirm that the dune system extended in this direction very close to the site of Palazzolo, as visible in remotely sensed images. Another exception is in borehole BH002, where the absence of clearly lagoonal sediments and brackish shells led us to date the base of the thick peat deposits, yielding a very recent date spanning across the last four centuries (Table 3). This anomaly in quite regular stratigraphic sequence led us to suggest that we may have again identified a non-depositional erosive feature, most likely a channel, which only recently filled up, although we cannot establish whether its origin is natural or its exact chronology. The final exception is borehole BH011, located in the protected area of Butrium, where the auger head could not penetrate beyond a layer of hard terracotta at the bottom of an 80 cm archaeological deposit to reach the deeper subsoil.

The marine regression process culminated with the end of sea-influenced brackish lagoonal environments, located west and east of the Etruscan-Roman beach barrier, which roughly corresponds to the modern street Via S. Alberto. The transition to a closed wetland environment is marked by the formation of a thick peat layer to the west of the barrier, while it is less pronounced to the east. The shell assemblage (see Table 2) from sample PCR02 S1 4.75–4.8 includes species such as *Bithynia tentaculata* (Linnaeus 1758), *Theodoxus* sp., *Acroloxus lacustris* (Linnaeus 1758), and *Gyraulus* sp., likely pointing to a shallow and low-energy freshwater habitat, plus the semiamphibious *Succinea* sp., as well as shells *Hydrobiidae* sp., possibly reworked from underlying brackish assemblages. Sediment signatures vary considerably, with most samples traceable to the Apennine rivers, both from Emilia and Romagna, while the few samples associated with the Po are located on both sides of Via Sant'Alberto. The three radiocarbon dates from the base of the peat layers (see Table 3, Figure 10) suggest two

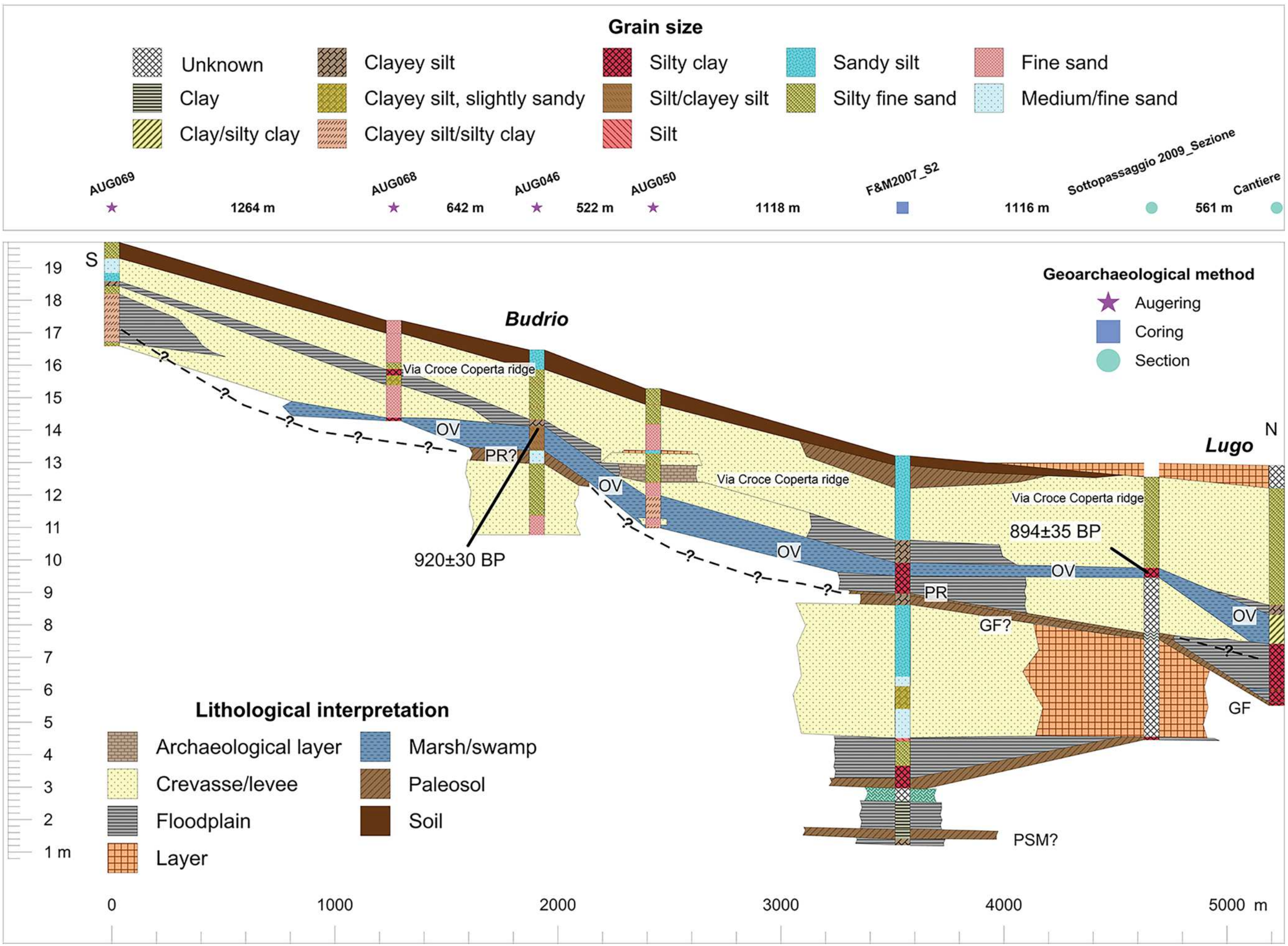


**Figure 6.** North-south stratigraphic cross-section (CS2) between Budrio and Lugo (PR = Roman paleosol; GF = Geosuolo Formellino; OV = Orizzonte Veggiani; and, PSM = Paleosuolo San Martino, a paleosol associated with the Neolithic occupation of the area; the dashed lines indicate uncertainty in the stratigraphic correlations) (modified from Abballe, Cavalazzi, and Fiorotto 2022, 132, fig. 13).

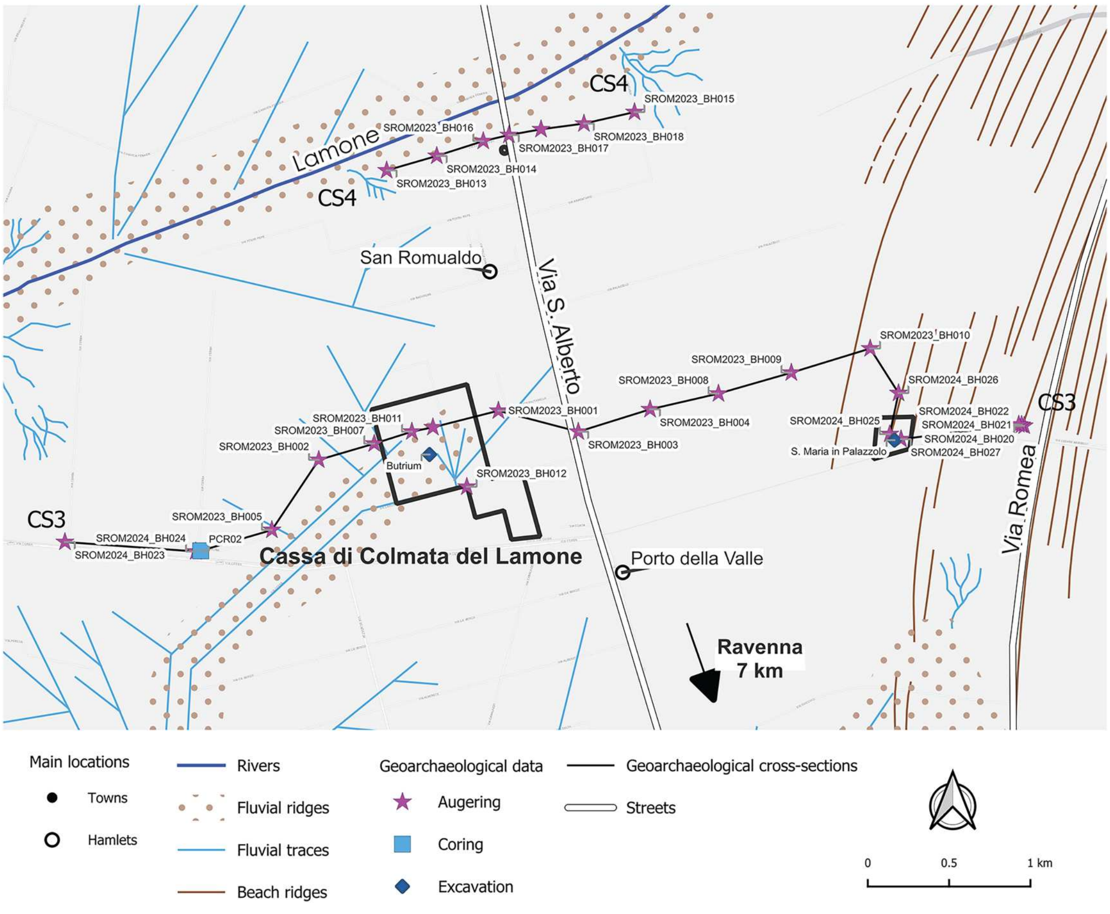


**Figure 7.** Geoarchaeological investigations in the area of S. Romualdo with stratigraphic data, the two cross-sections (CS3 and CS4), known archaeological sites, fluvial ridges, fluvial evidence related to the Cassa di Colmata del Lamone project, and remotely sensed traces of beach ridges (data from regional geodatabase available at https://servizigis.regione.emilia-romagna.it/wms/geologia50k?service=WMS&version=1.3.0&request=GetCapabilities; Esri basemap, copyright © Esri).

distinct phases in transitioning from a brackish to a freshwater environment. The first phase, between the late 2nd century and early 4th century A.D., appears to be confined to the innermost part of the analyzed area. A second phase occurred between the mid-7th and the third quarter of the 8th century A.D., as evidenced by samples from boreholes BH001 and BH004. This suggests that the closure of the lagoon took place synchronously both to the east and west of the Etruscan-Roman barrier, likely due to a significant increase in sedimentation and/or the advance of the coastline. Although these initial few radiocarbon dates cannot entirely resolve whether these two distinct phases of marine progradation occurred, certain stratigraphic elements seem to support this possibility. The area where the site of Butrium is located appears to act as a divide between a more inland zone, where lagoonal sediments lie at a lower elevation (at

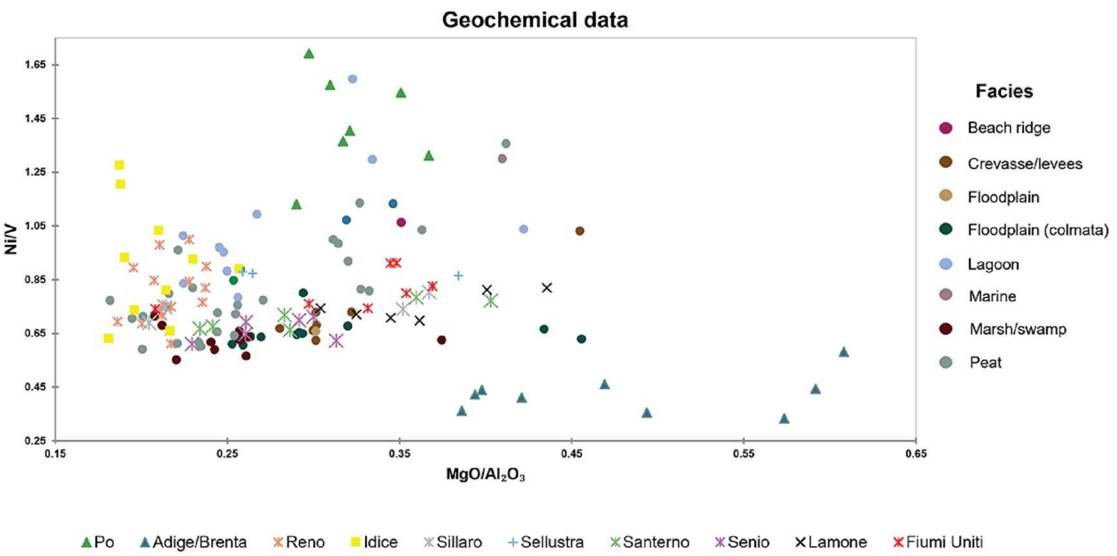


**Figure 8.** Ni/V versus $MgO/Al_2O_3$ concentrations of all bulk samples classified by facies association, with average composition of Po River, Apennine rivers, and northern Adriatic rivers such as the Brenta and Adige based on literature data (Dinelli and Lucchini 1999; Amorosi et al. 2002).

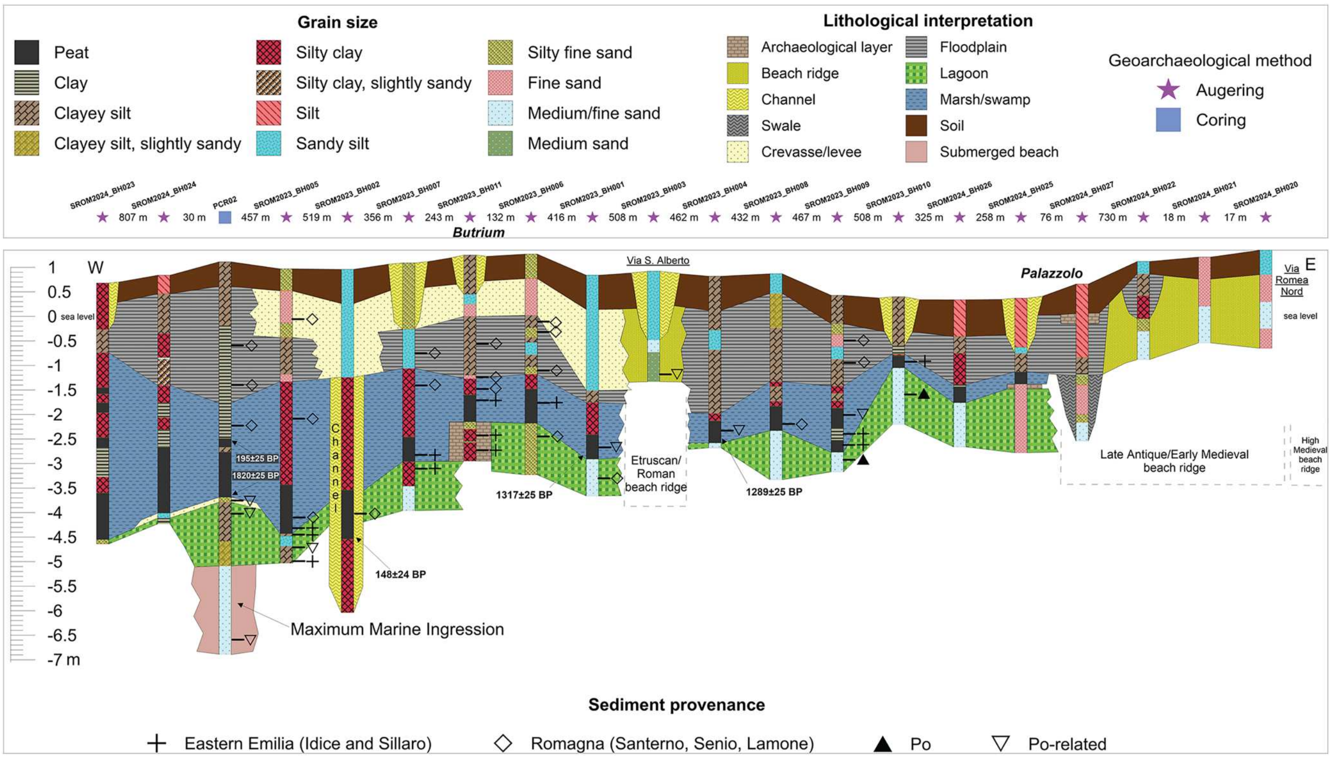


**Figure 9.** East-west stratigraphic cross-section (CS3) south of the hamlet of San Romualdo, across the site of Butrium and S. Maria in Palazzolo, with radiocarbon data and provenance classification based on geochemical signature.

least 3 m below present sea level) and the marsh deposits, often with peat-rich layers, are thicker (up to 4 m in total), and the eastward area, where the lagoonal sediments are generally found at shallower depths (maximum at 3 m below present sea level) and the marsh deposits are typically thinner (maximum around 1.5 m). Another notable difference between the two portions of the territory, apparently separated by the site of Butrium, is the presence of a thin, slightly sandy layer in boreholes PCR02 and BH024. This layer separates the lagoonal deposits from the peat-rich marsh accumulation and may be indicative of a fluvial flood event that affected the area in the late Roman period, which, according to sediment provenance, appears to be attributable to a branch of the Po River. This event could have contributed to the earlier closure of this portion of the lagoon compared to the more seaward area, possibly in association with a first phase of coastal progradation.

The upper deposits across the whole area, up to the current ground level, are likely related to the land reclamation activities of the Cassa di Colmata del Lamone project (A.D. 1839–1962), as also suggested by the age of the peat layer in PCR02, indicating its attribution up to the 20th century A.D. It is highly probable that the sediments associated with the reclamation also encompass those classified as marsh/swamp in their uppermost layers, when sedimentation was still occurring in a waterlogged and thus oxygen-poor environment, hence its gray-blueish color. Such conditions are consistent with an early stage of the colmata process, namely the reclamation method used in the area, which involved the progressive accumulation of sediments within an existing water body, ultimately leading to its gradual transformation into the present-day terrestrial environment. The more superficial deposits exhibit typical characteristics of sedimentation in a drier continental setting, as seemingly testified by land snails, like a fragment of *Zonitidae* sp. in BH001 at a depth of 0.95 m. Within these fine sediments of the floodplain phase, there are often centimeter-thick sandy layers, possibly indicating phases of enhanced sediment transport within the reclamation channels. All of these sediments have geochemical signals coherent with a provenance from the Romagna rivers. It should also be noted that the sediments in the area between Butrium and Via S. Alberto tend to be more sandy, due to the proximity to the diverted Lamone River, which acted as the major drainage channel of the Cassa di Colmata project, while the channel identified in BH002 could be one of the secondary drainage channels (see Figure 7).

The stratigraphic sequences from the last cross-section (CS4) north of the hamlet of S. Romualdo (Figure 11) closely resemble those identified farther south, displaying the characteristic phases of lagoonal environments, a subsequent transition to an inland marsh phase with peat accumulation, and finally, the substantial deposits associated with land reclamation. Near the surface, a sandy layer is distinguishable, which may be linked to the final stage of reclamation when the Lamone River was redirected to its current course, leading to the deposition of coarser sediments. Despite the lack of dating evidence and archaeological data, all samples associated with the colmata process show Romagna river provenance, suggesting that the chronologies of the main environmental transition phases may align with those documented in CS3. Unfortunately, we were not able to locate the Etruscan-Roman beach ridge, which is expected to extend northward but does not correspond to Via S. Alberto in this area.

## Discussion

### *Settling in marginal landscapes*

The evidence presented in this paper calls for a major reconsideration of how the former wetlands and adjacent

**Table 2.** Shells identified in the fossil assemblages from the RecLands project, grouped by environmental contexts.

| Environment | | | Marine | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Core | Sample | Depth | *Bittium reticulatum* | *Chamelea gallina* | *Donax semistriatus* | *Elphidium crispum* | *Glycymeris insubricus* | *Lentidium mediterraneum* | *Lymnaeidae* sp. | *Mangelia attenuata* | *Nassarius nitidus* | *Pusillina* sp. | *Scrobicularia plana* | *Spisula subtruncata* |
| PCR2 | S1 | 4.75–4.8 | | | | | | | | | | | | |
| | S3 | 5–5.2 | | | | | | | | | | | | |
| | S4 | 5.2–5.35 | | | | | | | | | | | | |
| | S5 | 5.35–5.6 | | | | | | | | | | | | |
| | S6 | 5.6–5.8 | | | | | | | | | | | | |
| | S8 | 6–6.2 | | | | | | | | | | | ✓ | |
| | S9 | 6.2–6.4 | | ✓ | | | | ✓ | | | ✓ | | ✓ | |
| | S10 | 6.4–6.6 | ✓ | ✓ | ✓ | | | ✓ | | | ✓ | ✓ | ✓ | |
| | S11 | 6.6–6.8 | ✓ | ✓ | | | | ✓ | | | ✓ | | | |
| | S12 | 6.8–7 | ✓ | | ✓ | | | ✓ | ✓ | ✓ | | | | |
| | S13 | 7–7.2 | ✓ | ✓ | ✓ | | | ✓ | | | | | | |
| | S14 | 7.2–7.4 | | ✓ | ✓ | | ✓ | ✓ | | | | | | |
| | S15 | 7.4–7.6 | ✓ | ✓ | ✓ | ✓ | | ✓ | | | | | | |
| | S16 | 7.6–7.8 | | ✓ | ✓ | | | ✓ | | | | | | |
| | S17 | 7.8–8 | | ✓ | ✓ | | | ✓ | | | | | | ✓ |
| BH001 | S1 | 1.35 | | | | | | | | | | | | |
| | S5 | 3.75–4.5 | | | | | | | | | | | | |
| BH002 | S3 | 6.5–7 | | | | | | | | | | | | |
| BH004 | S3 | 3.4–3.5 | | ✓ | ✓ | ✓ | | ✓ | | | | | | |

| Environment | | | Marine/brackish | | Brackish | Brackish/Fresh | | Fresh | | | | Land | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Core | Sample | Depth | *Abra segmentum* | *Cerastoderma glaucum* | *Ventrosia ventrosa* | *Hydrobiidae* sp. | *Theodoxus* sp. | *Acroloxus lacustris* | *Bithynia tentaculata* | *Gyraulus* sp. | *Succinea* sp. | *Hygromiidae* sp. | *Zonitidae* sp. |
| PCR2 | S1 | 4.75–4.8 | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | |
| | S3 | 5–5.2 | ✓ | ✓ | ✓ | | ✓ | | | | | | |
| | S4 | 5.2–5.35 | ✓ | ✓ | ✓ | | ✓ | | | | | | |
| | S5 | 5.35–5.6 | | ✓ | ✓ | | ✓ | | | | | | |
| | S6 | 5.6–5.8 | | ✓ | | | | | ✓ | | | | |
| | S8 | 6–6.2 | | | ✓ | | | | | | | | |
| | S9 | 6.2–6.4 | | | ✓ | | | | | | | | |
| | S10 | 6.4–6.6 | | | ✓ | | | | | | | | |
| | S11 | 6.6–6.8 | | ✓ | | | | | | | | | |
| | S12 | 6.8–7 | | ✓ | ✓ | | | | | | | | |
| | S13 | 7–7.2 | | | ✓ | | | | | | | | |
| | S14 | 7.2–7.4 | | | ✓ | | | | | | | | |
| | S15 | 7.4–7.6 | | | | | | | | | | | |
| | S16 | 7.6–7.8 | | | | | | | | | | | |
| | S17 | 7.8–8 | | | ✓ | | | | | | | | |
| BH001 | S1 | 1.35 | | | | | | | | | | | ✓ |
| | S5 | 3.75–4.5 | | ✓ | ✓ | | | | | | | ✓ | |
| BH002 | S3 | 6.5–7 | | ✓ | ✓ | | | | | | | | |
| BH004 | S3 | 3.4–3.5 | | | ✓ | | | | | | | ✓ | |

**Table 3.** Radiocarbon dates from the RecLands project, carried out by the Royal Institute for Cultural Heritage of Bruxelles (RICH). Dates have been calibrated with OxCal 4.4. (Bronk Ramsey 2009) using the IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (Reimer et al. 2020).

| Sample | Depth (m) | Material | Lab code | Date B.P. | Date CAL (95.4% probability) |
|---|---|---|---|---|---|
| ViaCarlina20-PCR2-S3 | 4.78–4.8 | Peat | RICH-29707 | 1820 ± 25 | A.D. 130–144 (2.5%), A.D. 155–256 (73.7%) A.D. 284–325 (19.2%) |
| SROM2023_BH1_S3 | 3.75 | Peat | RICH-34347 | 1317 ± 25 | A.D. 655–708 (50.8%), A.D. 727–774 (44.6%) |
| SROM2023_BH4_S2 | 3.4 | Peat | RICH-34348 | 1289 ± 25 | A.D. 665–774 (95.4%) |
| PCR2_S2 | 3.6 | Peat | RICH-34346 | 195 ± 25 | A.D. 1650–1690 (23.8%), A.D. 1727–1809 (57.0%), A.D. 1921– … (14.7%) |
| SROM2023_BH2_S1 | 4.5 | Peat | RICH-34349 | 148 ± 24 | A.D. 1668–1710 (15.7%), A.D. 1718–1782 (26.0%), A.D. 1796–1821 (9.9%), A.D. 1831–1893 (24.3%), A.D. 1905– … (19.6%) |

cultivated areas of the Ravenna hinterland have been traditionally interpreted. These landscapes have often been overlooked by researchers, viewed as peripheral to major ancient cities, marginal to local socio-ecological systems, and difficult to study due to challenging geopedological conditions (Pasquali 1995b). However, archaeological research conducted in Bassa Romagna reveals an unexpectedly dense network of settlements, steadily increasing from Late Antiquity onward. These patterns—both dispersed and nucleated—differ significantly from those suggested by historians who first analyzed early and high Medieval sources (6th–11th centuries A.D.; see Andreolli and Montanari 1983). A re-evaluation of these sources, combined with the new archaeological data (Mancassola 2008; Abballe and Cavalazzi 2022), demonstrates that this area was far from marginal. On the contrary, it was socially and economically connected to the more prominent cities nearby, challenging earlier interpretations of these wetlands as peripheral spaces.

A similar consideration can be proposed for the northern Ravenna coast, although only tentatively, as the data collected in this area on the development of settlement patterns are still preliminary. This region has traditionally been considered an example of *Desertum*, namely a sparsely inhabited space controlled by monastic institutions and used primarily as a place of prayer and solitary retreat (Pasquali 1995a). However, a more thorough and attentive analysis of written sources (11th–14th centuries A.D.) indicates seasonal or non-permanent exploitation of coastal resources, including hunting, timber gathering, fishing, and salt production (Bortoluzzi and Cavalazzi 2022). Furthermore, these areas hosted major routes, including the Roman Via Popilia and the later Medieval Via Romea, along with secondary roads that traversed wetlands along deactivated river ridges and several natural and artificial waterways connecting coastal and inland harbors. These opportunities for movement both within the region and to neighboring areas emphasize the importance of this landscape as a transit zone (Van de Noort and O'Sullivan 2006), challenging once again the idea that such spaces were socially or economically marginal in spite of the environmental constraints.

However, our research shows that the concept of marginality can still be meaningfully applied to these aspects,

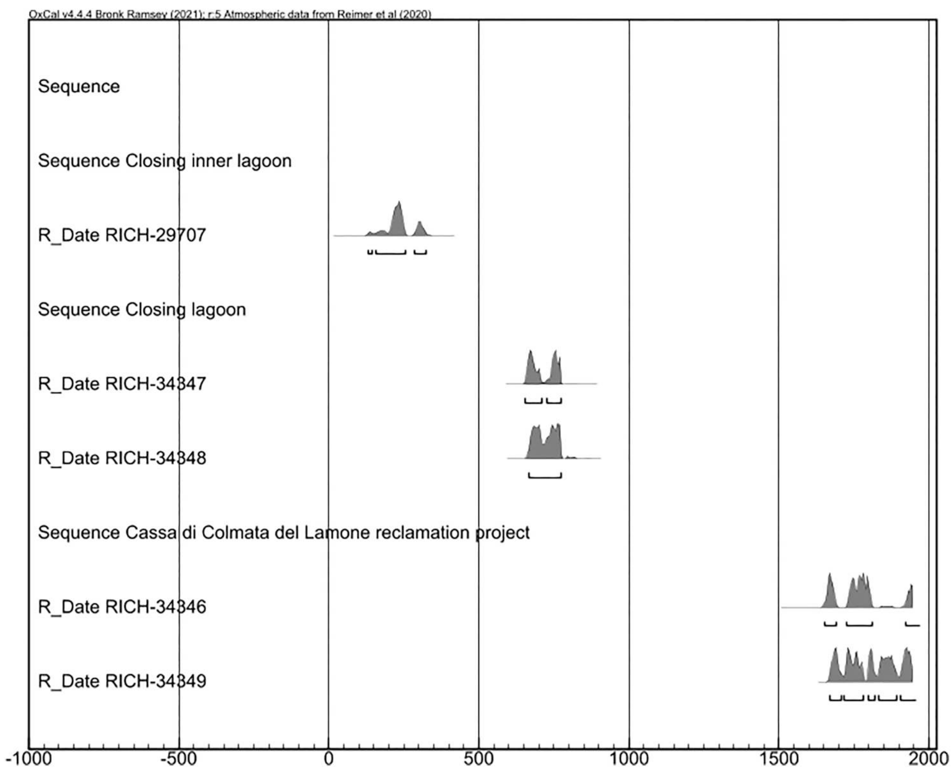


**Figure 10.** Probability distributions of radiocarbon dates from the Cassa di Colmata del Lamone area, divided by three main sequences of landscape evolution.

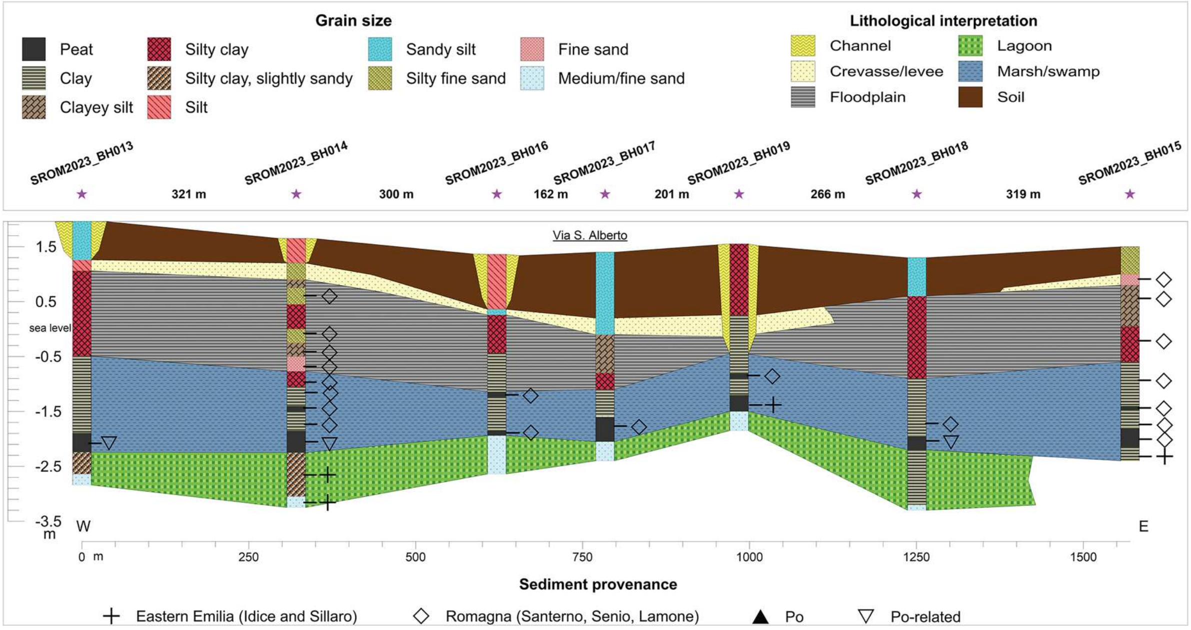


**Figure 11.** East-west stratigraphic cross-section (CS4) north of the hamlet of San Romualdo, with provenance classification based on geochemical signature.

though only in relation to the exposure of past settlements to risks and their vulnerability. Indeed, the analyzed historical socio-ecological systems were exposed to extreme events and characterized by a fragile equilibrium. These features determined the "marginality" of this landscape, even in some contemporary senses of the term (see above, Introduction), while also making it one of the most valuable contexts for investigating social and environmental systemic transformations, such as climate change or political crises.

## *Investigating marginal landscapes*

Marginal landscapes, such as those surrounding Ravenna, present significant methodological challenges due to the rapid sedimentation caused by reclamation activities, which, as previously mentioned, hinder traditional fieldwork methods. This issue remains evident, as both survey projects have mapped large areas devoid of outcropping archaeological sites. However, without the systematic transect-based survey approach successfully employed in Bassa Romagna and replicated north of Ravenna, we would not have identified dozens of sites entirely overlooked in historical records and elusive from an archaeological perspective. It is through the combination of methodologies, integrating both surface (e.g., remote sensing) and stratigraphic data, that we have been able to contextualize settlement patterns by gaining a better understanding of the paleoenvironmental changes in the area south of Lugo. Here, weakly developed paleosols can be laterally correlated with the aid of unevenly distributed archaeological data and targeted absolute dating, allowing us to assess whether the absence of surface archaeological finds is the result of past geomorphological transformations. Specifically, this multidisciplinary approach helped us understand why it was possible to identify new archaeological sites in certain areas of the studied landscape corresponding to former fluvial ridges, which are sometimes still slightly elevated above the surrounding terrain. Even when no longer raised, their traces can still be recognized on the ground through channels and crevasse splays detectable via remote sensing, as well as in the subsoil, predominantly characterized by sandy sediments. However, in areas with significant sedimentation (up to a meter or more), surface investigations may indeed be pointless, necessitating alternative methods to detect buried sites. This approach has also proved helpful in neighboring regions like Forlì and Massa Lombarda, similarly characterized by intense sedimentation phases, whether caused by natural flood processes or human-led reclamation attempts (Abballe 2022), allowing us to both contextualize the absence of legacy archaeological data and gain a better understanding of the local landscape evolution.

Based on such fruitful experiences, within the newly launched RecLands project, the simultaneous implementation of survey and stratigraphic mapping allowed us to interpret site presence/absence in real-time across vast portions of the landscape. This combined approach optimizes resources while avoiding data loss due to potential research biases arising from limited previous knowledge. In terms of geomorphological evolution, after a progressive regression of marine environments, the transition from lagoonal environments to a marine-brackish system more influenced by freshwater occurred in two main phases between the end of the Roman period and Late Antiquity. Finally, only human intervention led to the complete emergence of this naturally depressed area, still partly below sea level, which would otherwise have remained waterlogged for much longer. Based on this improved understanding of local environmental changes, we will not only be able to resolve uncertainties surrounding the major known sites but also better assess their exact location and position within the broader landscape, clarify their actual depth—often unclear due to the limited documentation preserved from earlier investigations—and refine their chronology of occupation, also drawing on new absolute dating. In addition, we could also identify high-potential areas for the discovery of new ones, as was the case with the fortified site at Marcabò. Positioned on the ridge of the ancient Po di Primaro River course, this site was not significantly affected by later sedimentation, making it an exceptional example of an outcropping site within an otherwise vastly reclaimed landscape.

### *Understanding marginal landscapes*

Although ecologically marginal (Kang et al. 2013), the former wetlands located around the city of Ravenna clearly played a key role in the history of this region and supported intense socio-economic activities. Previous research on marginal landscapes suggests that areas with limited resources and susceptibility to degradation, such as the case study presented in this paper, often foster more efficient strategies for the survival and growth of local socio-ecological systems (Vandam 2019). In the Ravenna hinterlands, this translated into a strong connection to the main urban center, which frequently influenced the nature of activities in these peripheral areas. For instance, enhanced connectivity with the center was a key factor in this region, which was linked to both Ravenna and the rest of Italy through roads and waterways, making strategic use of the complex geomorphology. Additionally, the analysis of the settlement pattern reveals a dynamic exploitation of the agricultural landscape over time, offering new insights into the complex strategies adopted by local and urban communities in the area.

In more general terms, we believe that the fragmented datasets typical of reclaimed wetlands are best interpreted within synthetic frameworks that allow movement beyond the inherent fragmentation of the evidence, a common issue in such landscapes. This approach is particularly relevant to the case discussed in this paper, where comprehensive data collection—e.g., pollen and animal bones—is limited by geopedological factors, and, consequently, the use of quantity-based explanatory models, such as agent-based models (Daems 2024), is hindered.

Hence, qualitative approaches should be favored, as they equally weigh the impact of each individual factor or historical actor, both natural and human, in shaping the interactions within ancient socio-ecological systems, as documented through archaeological research. Among the most promising approaches is the Panarchy framework, which offers a multiscalar perspective on Resilience Theory (Gunderson and Holling 2002). This framework enables the construction of a narrative based on adaptive cycles (exploitation, conservation, release, and reorganization), which shows how communities responded to pressure at different scales; this includes external forces, such as environmental change, and/or internal factors, such as social or political decisions. When applied to the inland of Ravenna, it proved particularly effective in characterizing the dynamics of the complex relationship between urban and rural systems within a rapidly evolving alluvial landscape (Abballe and Cavalazzi 2022). For example (Table 4), the increase in rural occupation in Late Antiquity could be seen as a period of reorganization (α) dictated by renewed public and private interest in the region, which led to both investment in infrastructure and intensification in agricultural production. This process, as defined in the Panarchy framework, describes a "Remember" connection, where higher, broader, and slower socio-ecological structures retain memory and, thus, stabilize the dynamics of the system, including those of the lower-level cycles (Figure 12). This transformation followed a phase of release (Ω), triggered by environmental instability noted in our record during the 2nd/3rd centuries A.D., combined with the broader crisis affecting the Roman Empire from the late 2nd century A.D. onward—for example, depopulation, spread of infectious diseases, and mounting military threats from the north and east (for an overview, see Erdkamp 2019).

More recently, the Triangular Landscape model has also been developed to visually weigh and measure the evolving influence of biological, geo-physical, and cultural processes within similar wetland (and later reclaimed) landscapes; this allowed for a more clear interpretation of landscape transformation both geographically and diachronically (Schepers et al. 2021; de Haas and Schepers 2022; a similar approach in Blouin 2014; Perego and Scopacasa 2018). Applying this framework to our study area (see Table 4), during the same two time slices—the Late Imperial period (2nd/3rd–4th centuries A.D.) and Late Antiquity (5th–7th centuries A.D.)—some interesting considerations emerge. During the Late Imperial period, much of the northern and northwestern hinterland of Ravenna experienced intense sedimentation from flooding events, which coincided with a widespread abandonment of rural settlements. During Late Antiquity, land reclamation and agricultural development were documented in several parts of this plain, accompanied by the emergence of new scattered rural settlements, suggesting a new strategy of land use, although its precise nature remains difficult to reconstruct at present. This change may also have been accompanied by a process of vegetation succession at the local level—for instance, in uncultivated areas and in lagoonal zones that gradually transformed into marshes—although we currently lack paleobotanical data to confirm these processes. From the perspective of the Triangular Landscape model (see Figure 12), the Late Imperial period reveals an almost equal impact of biological, physical-geographical, and cultural processes, which led to a radical transformation of the local landscape. This balance shifts in Late Antiquity, when, in our opinion, biological and cultural factors prevail, leading to some significant transformations.

While both the Panarchy framework and the Triangular Landscape model offer valuable insights, each presents certain limitations. Resilience Theory primarily emphasizes systemic processes over individual actors and tends to overlook spatial and temporal variability. Conversely, the Triangular Landscape model is more temporally anchored, focusing on specific periods without fully capturing the long-term dynamics. Hence, these methodologies should not necessarily be seen as mutually exclusive, but their complementary use could create a more comprehensive framework for understanding landscape change. For example, in our case, the Panarchy framework provides a long-term, process-driven narrative of resilience and adaptation, while the Triangular Landscape model was effective in focusing on specific periods and geographies, measuring how the interaction of biological, geographical, and cultural factors shaped those particular moments in time. By employing both methodologies in tandem, we could construct a more holistic understanding of the complex interplay between societal, environmental, and cultural processes over time. This approach would allow us to link datasets and interpretations more effectively and account for both the broad, dynamic processes at play and the unique local factors that shaped particular historical moments. This discussion, therefore, represents a starting point for future studies, highlighting the potential for combining these frameworks to overcome existing interpretive limitations.

**Table 4.** Resilience adaptive cycles and geo-physical, biological, and cultural processes in the evolution of Ravenna's reclaimed wetlands from the Late Imperial period (2nd/3rd–4th centuries A.D.) to Late Antiquity (5th–7th centuries A.D.).

| Time slice | Physical geography | Geo-physical processes | Biological processes | Cultural processes | Phase in the adaptive cycles |
|---|---|---|---|---|---|
| 2nd/3rd–4th centuries A.D. | Floodplain with increased hydrogeological instability | Soil subsidence; fluvial sedimentation; flooding; coastal progradation; disruption of canal network and possible failure of the drainage infrastructure | Peat formation | Widespread abandonment of scattered settlements | Phase of release (Ω), which is signaled by the disruption of the local settlement pattern and land use strategies |
| 5th–7th centuries A.D. | Partially reclaimed floodplain characterized by wetlands and incipient reclamation activities | Soil subsidence; fluvial sedimentation; significant coastal progradation | Biodiversity reduction; vegetation succession; peat formation; vegetation colonization on newly formed coastal lands | Reclamation processes; creation of new scattered settlements; possible restoration of drainage systems | Phase of reorganization (α) showed by settlement reorganization, as well as renewed investments in local infrastructure |

## Conclusion

An increasing number of studies in recent decades have challenged the supposed marginality of uplands and wetlands in the past. The data we brought to light from the northern and northwestern hinterland of Ravenna—former wetlands now almost entirely reclaimed—likewise call into question longstanding views of these areas as peripheral or underutilized over the last two millennia. For instance, our findings offer new insights into broader regional dynamics, including strong socio-economic connections to nearby urban centers, such as Ravenna, and beyond. Despite their assumed marginality, the former wetlands around Ravenna sustained socio-ecological systems shaped by the interweaving of biological, physical-geographical, and cultural processes. However, we concluded that one aspect of the contemporary meaning of "marginal" applies to the reclaimed landscapes examined—namely, their exposure to environmental risks, which makes them more vulnerable and less suitable for agricultural uses. By applying both the Panarchy framework and the Triangular Landscape model, this study sheds light on the transformations that affected the Ravenna plain between the end of the Roman period and the Early Middle Ages. Each framework offers distinct strengths: Panarchy emphasizes long-term dynamics, while the Triangular model effectively synthesizes the interactions of key processes within specific spatial and temporal contexts. Their combined application enables a more comprehensive reconstruction and understanding of historical socio-ecological systems, even within the geomorphologically complex setting of the Ravenna plain. However, the complexity of the area under investigation continues to pose significant challenges for both data collection and the development of tailored interpretative frameworks. Nonetheless, we believe that the multidisciplinary research agenda established thus far offers a

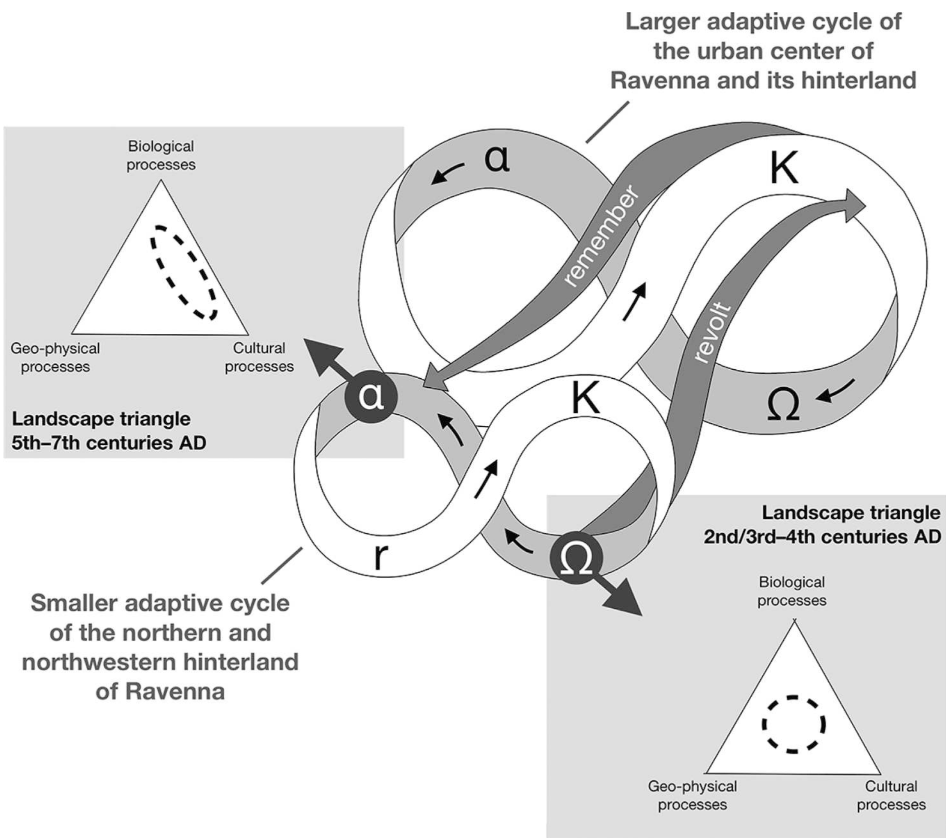


**Figure 12.** Resilience adaptive cycles with panarchical connections and the Triangular Landscape Model applied to the evolution of Ravenna's reclaimed wetlands from the Late Imperial period, omega phase (2nd/3rd–4th centuries A.D.), to Late Antiquity, alpha phase (5th–7th centuries A.D.). Modified from Gunderson and Holling (2002, fig. 3-10) and Schepers and colleagues (2021, fig. 1).

solid foundation for future research to address this significant knowledge gap.

## Disclosure Statement

The authors report there are no competing interests to declare.

## Acknowledgements

M. A., M. C., and P. M. are the first authors of this paper. M. A. contributed to the following sections: Ravenna's reclaimed wetlands, Archival methods, Field methods, Laboratory analyses, Paleogeographical reconstructions, Investigating marginal landscapes, Conclusion. He created Figures 3–11 and Tables 1–3. M. C. contributed to the following sections: Introduction, Archival methods, Field methods, Settlement pattern dynamics, Settling in marginal landscapes, Understanding marginal landscapes, Conclusion. He created Figures 1–2 and 12, as well as Table 4. P. M. contributed to the following sections: Understanding marginal landscapes, Conclusion. D. B. contributed to the following section: Archival methods. E. D. contributed to the following sections: Field methods, Settling in marginal landscapes. He created Figures 8, 9, and 11. M. T. contributed to the following sections: Field methods, and Settling in marginal landscapes. He created Table 2.

The Bassa Romandiola project received funding by Fondazione Flaminia of Ravenna, Fondazione Cassa di Risparmio e Banca del Monte di Lugo, Comune di Lugo, Comune di Conselice, Comune di Fusignano, Centro di Studi sulla Romandiola Nord Occidentale, and Comune di Cotignola. The Reclaimed Lands project received funding from the Fondazione Cassa di Risparmio di Ravenna. This project was preceded by research on the Pinewood of Ravenna in Dante Alighieri's time (Ra.Pi.Da.-Ravenna, Pinewood, and Dante project, 2019–2021), funded by the Fondazione del Monte di Ravenna e Bologna. M. A. carried out geoarchaeological research, studying remotely sensed images, drone flights, and paleoenvironmental reconstructions. His research in Bassa Romagna was supported by a Doctoral Scholarship from the Bijzonder Onderzoeksfonds UGent (BOF) under Grant number BOF.FJD.2017.0002.01 and two Grants for a long stay abroad by the Research Foundation Flanders—Flanders (FWO) under Grant numbers V421419N and V430720N while completing his Ph.D. in archaeology at Ghent University and the University of Verona. Research for this article was also funded by the European Union, as part of a research fellowship which is supported by ERC grant SSE1 K, GA 101044437, DOI 10.3030/101044437. Views and opinions expressed are, however, those of the author only and do not necessarily reflect those of the European Union or the European Research Council Executive Agency. Neither the European Union nor the granting authority can be held responsible for them. M. C. conducted archaeological research, focusing on the analysis of archaeological finds, site distribution, chronology, and the study of written sources. His research in the Bassa Romagna and Ravenna areas was supported by three postdoctoral fellowships at the University of Bologna (2018–2021) and received funding from the European Union's Horizon 2020 research and innovation program under the Marie Skłodowska-Curie grant agreement No. 101029015 (project BiGAr). P. M. conducted some of the geoarchaeological research in the Butrium and Palazzolo area within the Ra.Pi.Da. project. His work was funded by a Start-Up Grant from Bilimsel Araştırma Projeleri, Boğaziçi University (Grant number 20B09SUP3). D. B. studied the written sources, without receiving additional funding. E. D. performed the geochemical analyses and interpreted the results, without receiving additional funding. M. T. carried out the paleontological research and interpreted the results; this is Ismar-CNR, Bologna, scientific contribution no. 2101. Finally, we are grateful to the anonymous reviewers of *JFA* for their useful comments on our paper.

## Data Availability

Archaeological data are available on Zenodo: https://doi.org/10.5281/zenodo.15230544 and https://doi.org/10.5281/zenodo.15224772. Geoarchaeological and geochemical data are available on Zenodo at https://doi.org/10.5281/zenodo.14884347.

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