DOI 10.13131/UNIPI/2785-0668/N4TG-XZ64

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GEOARCHAEOLOGICAL MAPPING OF MEDIEVAL WETLANDS AND THEIR RECLAMATION IN THE HINTERLAND OF RAVENNA: TWO CASE STUDIES FROM MASSA LOMBARDA (RA) AND VILLAFRANCA DI FORLÌ (FC)

Abstract: Three hand augering campaigns were carried out between 2018 and 2020 in the hinterland of Ravenna to gain new insights into the physical transformations that occurred in the area during the last 3000 years. Understanding these changes is crucial to be able to fully reconstruct past settlements patterns in alluvial landscapes, such as the lowlands around Ravenna. Based on known archaeological and geomorphological data, and historical sources available, six case studies were selected to carry out targeted geoarchaeological research. The paper introduces the main research questions behind these campaigns, the methodology used (hand augering), and the format of data recording for facilitating their future reuse. Finally, two case studies will be used to show the effectiveness of this approach in understanding landscape changes caused by alluvial phenomena, relying not only on archaeological data but also on stratigraphic markers (i.e. palaeosols) buried below the present-day ground. Thanks to this approach, targeted geoarchaeological research can quickly point out the main landscape changes caused by rivers avulsions and flooding processes. In particular, the first geological pieces of evidence will be presented on the existence of medieval wetlands in both areas of Massa Lombarda and Villafranca di Forlì in the Middle Ages, and their subsequent reclamation occurred around the 13th century CE.

Keywords: geoarchaeology, hand augering, wetland archaeology, centuriation, reclamation.

1. Introduction

1.1 Background

Alluvial floodplains are among the most common environments in the world and have always attracted human occupation, which adapted to the various landforms that constitute these complex assemblages, such as channels, levees, backswamps, and crevasse splays (Brown, 1997; Fryirs & Brierley, 2012). The Po Valley represents the largest floodplain in Italy and Southern Europe, with a long history that started in the Pliocene (Amorosi et al., 2017a). Many factors have played a role in shaping this plain, including the Alpine and Apennine rivers, as well as the Adriatic Sea: their combination makes it difficult to reconstruct its evolution (Stefani, 2017). These difficulties also exist when studying historical times, such as the Roman period and/or the Middle Ages, because environmental transformations occurred during and after these periods hinder our understanding of the palaeolandscape evolution. Despite these problems, several studies have successfully been able to reconstruct geomorphological transformations that happened in the Po Valley during the Middle Ages (e.g. Cremaschi &

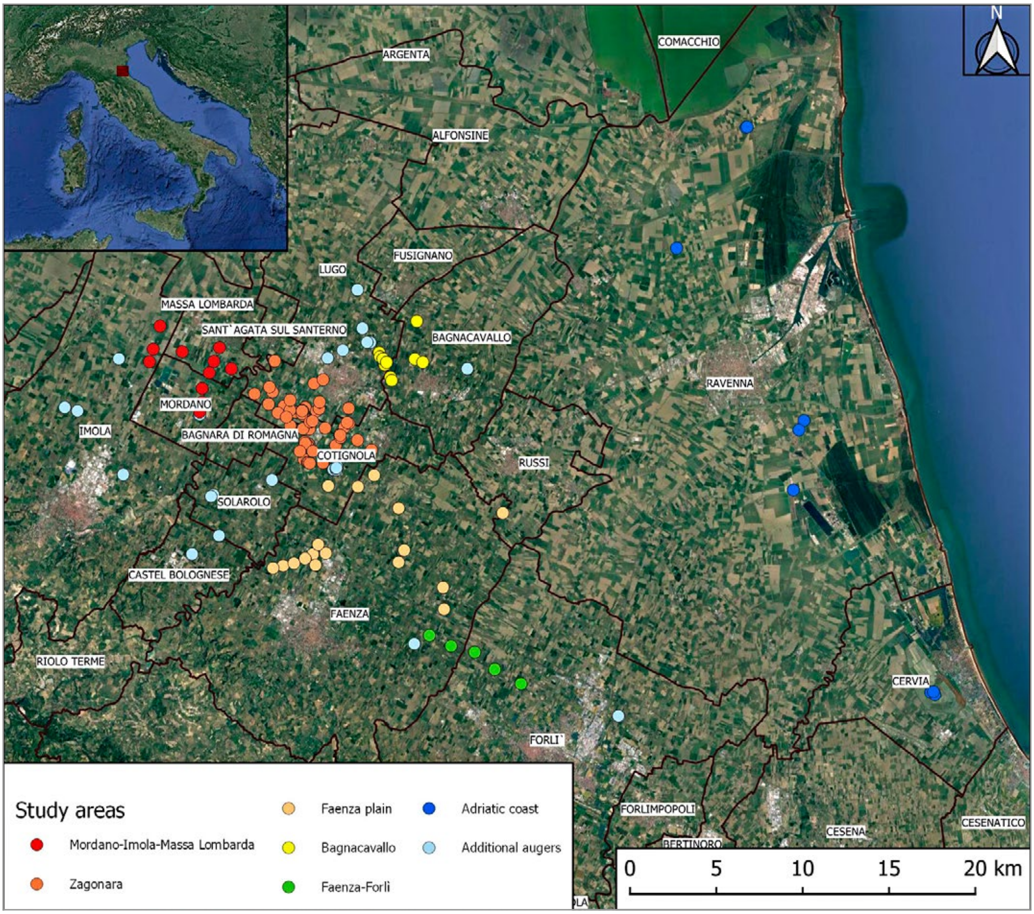

fig. 1. The Ravenna hinterland with the distribution of hand augers carried out between 2018-2020, classified by study areas (Google Satellite as basemap, Dati mappa ©2021 Immagini ©2021 TerraMetrics).

Marchesini, 1978; Marchetti, 2002; Balista & Bonfatti, 2003; Marchetti & Castaldini, 2006; Rucco, 2015; Bianchini et al., 2019; Rucco et al., 2019), although the Romagna plain still remains understudied.

From an archaeological point of view, floodplains are incredibly challenging because of the possible presence of thick layers of alluvial deposits that impede many methods used in landscape archaeology, such as artefact survey, test trenching, remote sensing, and shallow near-surface geophysical methods. Therefore, invasive methods to study buried landscapes, such as coring and direct push sensing, are often necessary for these contexts (e.g. Howard & Macklin, 1999; Carey et al., 2018; Verhegge & Delvoie, 2021). Among these methods, traditional hand augering, initially developed for soil studies, was quickly adopted in archaeological research for dating sites stratigraphically (Stein, 1986), for palaeolandscape mapping (Groenewoudt, 1994; Bats, 2007), and to target geophysical anomalies (de Haas, 2017; Tol et al., 2021). However, hand augering also comes with its drawbacks; it is time-consuming, requires hard work, and it is complicated to reach deeper layers (below 4-5 m), especially through poorly consolidated sediments such as coarse sand (Missiaen et al., 2015). Despite these limitations, hand augering is being applied more and more for landscape reconstructions in the Po Valley due to the economic advantages compared to more costly mechanical coring. A first application occurred around Lugo, in the Ravenna hinterland (Franceschelli & Marabini, 2007), but hand augering was also used in other areas in Emilia-Romagna (Rucco et al., 2019; Rucco, 2020) and in Veneto (Piovan et al., 2012; Fontana et al., 2017; Mozzi et al., 2020; Ronchi et al., 2021).

Based on these positive previous experiences, new targeted geoarchaeological campaigns were promoted between 2018-2020 to understand better the evolution of the Ravenna hinterland (fig. 1), using hand augering as the primary methodology. All the data collected from the 155 augers that were carried out are available in the dataset accompanying this text. However, the main aim of this paper is to discuss the results of targeted hand augering research in two selected study areas: the regular fields system of Massa Lombarda and Villafranca di Forlì. This will be discussed more in detail later, but both areas are characterised by a non-homogeneous distribution of archaeological sites, which could be the result of a lack of research as well as geomorphological biases. However, medieval sources seem to suggest that intense transformations associated with river avulsions could have profoundly changed the landscape, especially between the High (11th-12th centuries CE) and Late Middle Ages (13th-15th centuries CE). To test this hypothesis, hand augering has been chosen as a suitable method to map changes in geological facies, follow palaeosols buried beneath the present-day surface, and more in general to reconstruct the physical evolution of these two parts of the hinterland of Ravenna.

1.2 The geoarchaeological setting of the hinterland of Ravenna

The alluvial plain around Ravenna can be considered part of the Po Valley, although human interventions during the Modern period moved the course of this river further away from the city. Previously, Ravenna and its hinterland gravitated around the river most southern branch, known as *Po di Primaro*, until the 18th century CE, when the river Reno was artificially connected to the old dying channel (Bianchini et al., 2014). As part of the main Italian floodplain, the lowlands around Ravenna have experienced intense geomorphological transformations, caused mainly by a combination of river sedimentation, subsidence, and at least 6000 years of coast progradation (Amorosi, 2002). Another common phenomenon was backswamps (*valli*) and lagoon development due to water stagnation in depressed areas bordered by fluvial and/or beach ridges. However, these wetlands were almost entirely reclaimed in the last few centuries (Gambi, 1949, pp. 111-155), but a systematic mapping of their extensions in pre-modern times has never been carried out.

In addition, floods and river avulsions, both natural and human-induced, the latter attested at least since the Middle Ages (Abballe, 2021, pp. 43-44; Gambi, 1949, pp. 29-98), continued to change the landscape until recently, often causing the burying of previous archaeological sites. These These burial phenomena occurred in the whole Po plain, although they reached a peak in the study area as shown by the post-depositional sedimentation cover of respectively 10 m at a Roman villa in Russi (Mansuelli, 1962) and 14 m at the Neolithic village of Fornace Gattelli, north of Lugo (Staffè & Degasperi, 2019). Thus, our archaeological knowledge is generally deeply biased, with sites clustered in the medium valley (more than 20 m a.s.l.) or on top of fluvial/beach ridges, which were naturally protected from later alluvial events (see also Cavalazzi, 2021a).

The necessity for geoarchaeological methods to overcome these limitations was understood already in the early 2000s when hand augering and (limited) continuous coring were promoted in the area around Lugo (Franceschelli & Marabini, 2007). This work has been essential in confirming that some Holocene palaeosurfaces, surfacing at the Apennine foothills, also extended in lower parts of the valley, below the more recent alluvial deposits. This represents a crucial factor since, given the finite amount of archaeological data available, well-dated palaeosols are essential to correlate stratigraphic records to the chronological evolution of the plain, as successfully shown in Bologna (Bruno et al., 2013) or Minerbio and Budrio, Bologna (Rucco, 2020).

Specifically for the study area, two important markers are known (tab. 1): the palaeosol of San Martino (or PSM), related to the Neolithic occupation of the area (Marabini et al., 1987; Marabini & Vai, 2020, p. 41)[1], and the Formellino geosol (or GF), correlated to the Bronze Age period (Franceschelli & Marabini, 2007, pp. 104-107). In addition, a partially developed horizon

[1] It can be associated to the YD paleosol recognized also in the Ferrara plain (Amorosi et al., 2017b).

Palaeosol	CaCO3	Colour	Inclusions
San Martino palaeosol (PSM)	0	Very dark brown/black	Fe-Mn nodules, oxides
Formellino geosol (GF)	0/1	Dark (reddish) brown	Fe-Mn nodules, oxides
Roman palaeosol (PR)	1/3	Dark brown	Fragments of brick/rotten ceramics, oxides

tab. 1. Main stratigraphic markers recognizable in Ravenna hinterland and mentioned in the text.

can often be associated with the Roman period (or PR), due to the common presence of fragments of brick/rotten ceramic. Instead, it is mainly impossible to recognise palaeosols datable to the Middle Ages since they often correspond to the current plough soils. Therefore, it is difficult to understand if pedological processes did not have enough time to produce traces visible to the naked eye or if eventual feeble traces were destroyed by modern machinery.

A few years after this novel geoarchaeological research (Franceschelli & Marabini, 2007), the north-western part of Ravenna hinterland became the focus of several artefact surveys campaigns promoted by the Bassa Romandiola Project (University of Bologna) that mapped many archaeological sites dating between Late Antiquity and the Modern Age (Cavalazzi, 2012; Cavalazzi et al., 2015, 2018). Specifically, dozens of early and high medieval rural sites were discovered, previously rarely documented, many of which located around Zagonara castle. Since 2017 the Bassa Romandiola project has been promoting archaeological excavations on this fortified settlement (Fiorotto et al., 2020). More recently, new survey projects have been started in the Romagna plain by the University of Bologna, in the municipalities of Cervia (Augenti et al., 2020) and Faenza[2], which are further increasing our archaeological knowledge for the Ravenna hinterland. However, since all the results achieved by these projects can be potentially biased by geomorphological transformations (Attema, 2017), the geoarchaeological investigations aimed to assess their impact on our understanding of the historical settlements patterns.

However, the geoarchaeological research focused also on areas not yet investigated by these survey projects, also to pre-assess the chances to find archaeological sites whether artefact survey will be carried out in the future. In particular, the focus was on the border between the towns of Mordano, Imola and Massa Lombarda, and the one between Faenza and Forlì (fig. 1), since both show uneven distribution of archaeological sites that could be due to both lack of research and geomorphological biases.

1.3 Study areas

Specifically, in the first area (fig. 2), the southern half shows good general preservation of the Roman centuriation, almost continuously from the *via Aemilia* up to Mordano, with Roman and pre-Roman sites well distributed within it. However, artefact surveys carried in the 1990s, and early 2000s focused only on the most southern part of the Mordano municipal area, successfully mapping many archaeological sites. On the contrary, the only data in the northern part of the centuriated landscape come from the clay quarries of Via Ringhiera (fig. 3), where also a Bronze Age village was discovered at a depth of 120 cm below the present-day surface (CRA-CI, no. 131). This could indicate that later alluvial events have covered archaeological sites and, at the same time, hindered the survival of the centuriated system, but there is still a lack of evidence for this. This contrasts with both the northern municipal area of Imola and the whole territory of Massa Lombarda, where there is a void of archaeological data, especially older than the Middle Ages, with the only sites discovered in the Massa Lombarda clay quarry (fig. 3): a Roman farm and Bronze Age artefacts respectively at a depth of 410 and 620 cm from the present-day surface (Veggiani, 1963). However, the situation seems to be more

[2] https://sites.google.com/view/faentival-/home (last accessed on 15/10/2021).

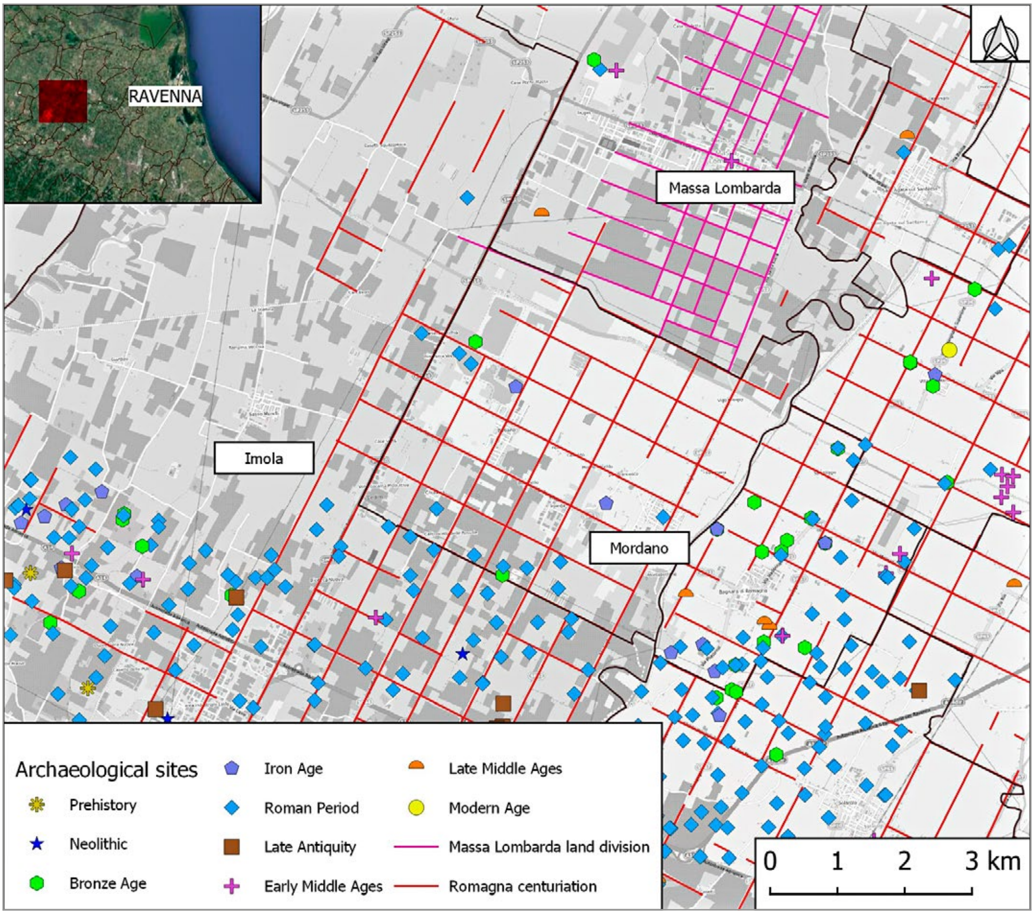

fig. 2. Study area of Massa Lombarda regular fields system, with known archaeological sites and relationship with Romagna centuriation (basemap by © OpenStreetMap contributors).

complex than previously thought, after the recent discovery of the medieval fortified site of Cavassona (Abballe & Cavalazzi, 2021).

The main geomorphological features of this study area, mostly mapped by previous studies, are represented by (fig. 3): the actual course of the river Santerno to the east, interested by the artificial cut-off of meanders after the Renaissance; a fluvial ridge of Chiusura to the west, related to an earlier course of the river Santerno, whose formation should be dated at least at the Bronze Age (Abballe & Cavalazzi, 2021; Marabini & Vai, 2020); another ridge to the north related to the medieval course of the river Santerno, when it used to flow towards San Patrizio e Conselice (Franceschelli & Marabini, 2007, p. 33, no. 14); the palaeochannel of Via Felice, within Massa Lombarda's regular fields system, which has been mapped during this study mostly thanks to Esri Satellite images, likely departing from the medieval course of the Santerno and associated with several secondary crevasse splays. The recognition of these geomorphological elements is crucial to understand location choices and to assess our archaeological knowledge. This is the case of the almost-outcropping Bronze Age site of Via Ringhiera (fig. 3), located nearby a ridge of the Santerno river, originally raised above the surrounding floodplain. In the same way, it would be fundamental to map landforms buried below the present-day ground by later alluvial deposits.

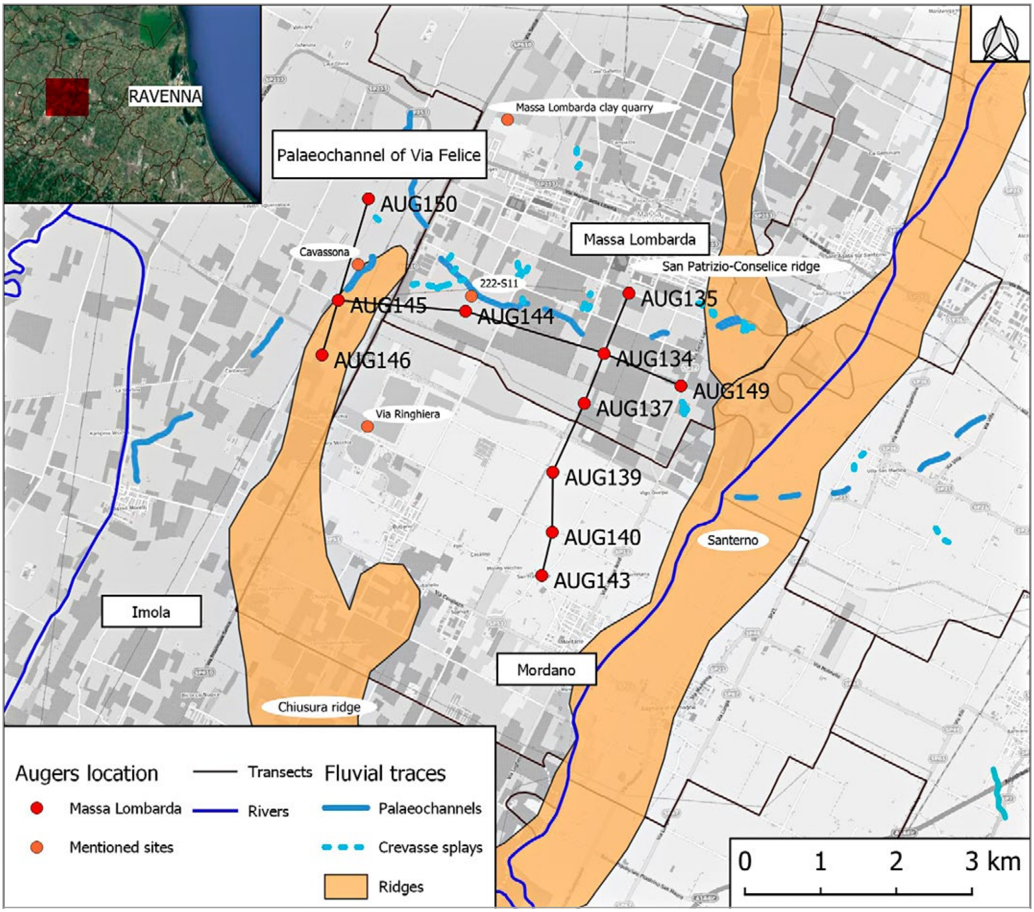

fig. 3. Study area of Massa Lombarda regular fields system, with main geomorphological features, archaeological sites mentioned and geoarchaeological transects (basemap by © OpenStreetMap contributors).

The last aspect that needs to be pointed out regarding this study area is the regular fields system surrounding the town of Massa Lombarda (fig. 2). This land division has been associated with a colonisation effort promoted by Lombard families around the middle of the 13th century (Lazzari, 2005; Chouquer, 2015, p. 84). The uniqueness of this medieval system within the Po Valley has been already expressed by previous studies (more recently by Chouquer, 2015, pp. 248-250), but neither geological nor archaeological research have ever been carried out, also to assess whether reclamation efforts were associated with this colonisation process and their possible effect on the settlement patterns.

The second study area extends at the border between the towns of Faenza and Forlì (fig. 4), delimited by the Cosina and Montone rivers (fig. 5). For the eastern part of Faenza, some archaeological sites were already known (Franceschelli & Marabini, 2007), but this number has sharply increased thanks to artefact surveys promoted by the Faventia Project in 2019-2020, which mainly focused on the area between Basiago, Corleto and the Via Emilia[3]. These investigations made it possible to map 16 previously unknown archaeological sites, with a chronology between the Bronze Age and the Late Middle Ages. On the contrary, the city of

[3] The reports of these campaigns have been submitted for inclusion in the Geoportale Nazionale per l'Archeologia (GNA).

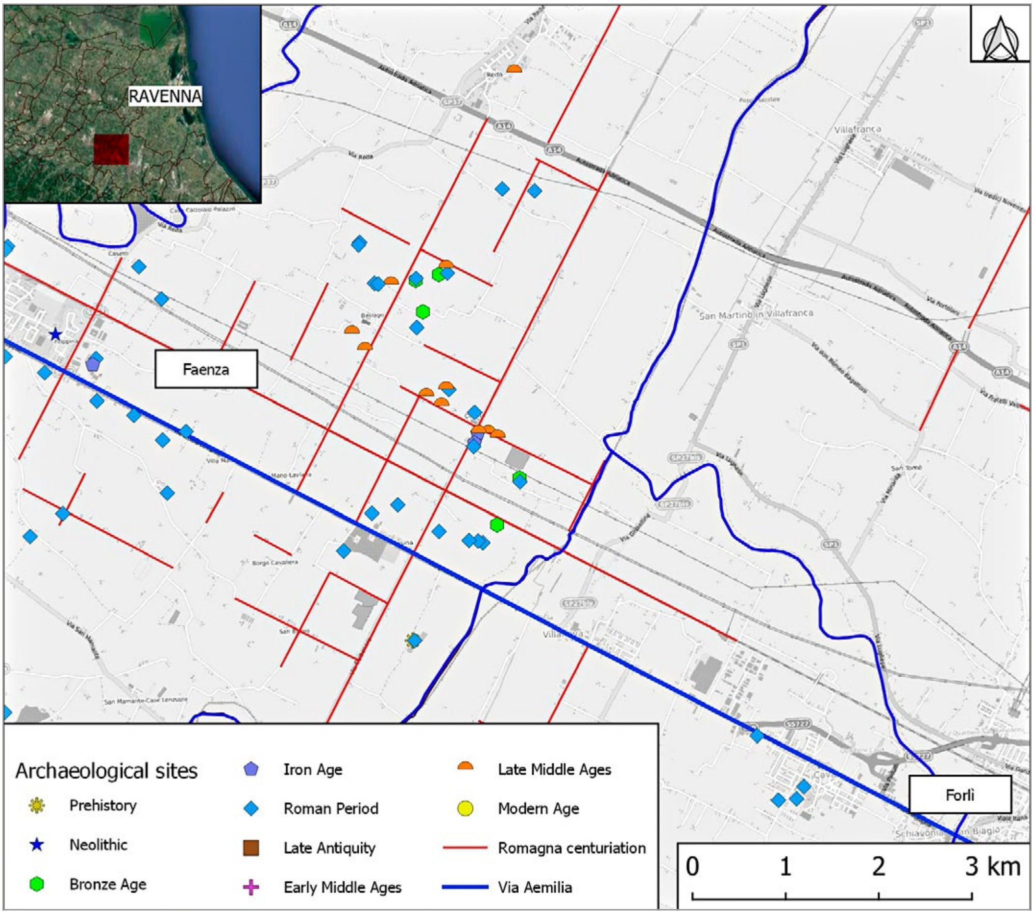

fig. 4. Study area of Villafranca di Forlì, with known archaeological sites and relationship with Romagna centuriation (basemap by © OpenStreetMap contributors).

Forlì has never been systematically investigated, so it is not surprising that the local archaeological map does not report many sites[4]. Moreover, especially in the western part towards the border with Faenza, very limited urban and industrial expansions occurred in the last decades, further limiting the chances to record archaeological remains.

From a geomorphological point of view, the main element of the area is the fluvial ridge built up by the Montone river, characterised by a SE-NW direction at first, then turning SW-NE after joining the smaller Cosina river (fig. 5). A previous course of the river Montone, likely during the Roman and early medieval times, generated the Canal Ravaldino ridge to the east (Abballe, 2021), while a medieval course of the Lamone river created the Reda-S. Anna ridge to the west (Franceschelli & Marabini, 2007, p. 32, no. 11). The analysis of the aerial and satellite images highlighted many other minor fluvial traces, mostly connected to the Cosina and Montone rivers (fig. 5).

Essential for understanding the recent history of the latter river is a medieval chronicle, which testifies the artificial avulsion of this watercourse in 1217 CE, promoted by the citizens of

[4] The still unpublished *Carta delle potenzialità archeologiche del Comune di Forlì* was created in 2016 by Tecne SRL thanks to funding from the city of Forlì, under the supervision of Soprintendenza Archeologia dell'Emilia-Romagna, now Soprintendenza Archeologia, Belle Arti e Paesaggio per le province di Ravenna, Forlì-Cesena e Rimini.

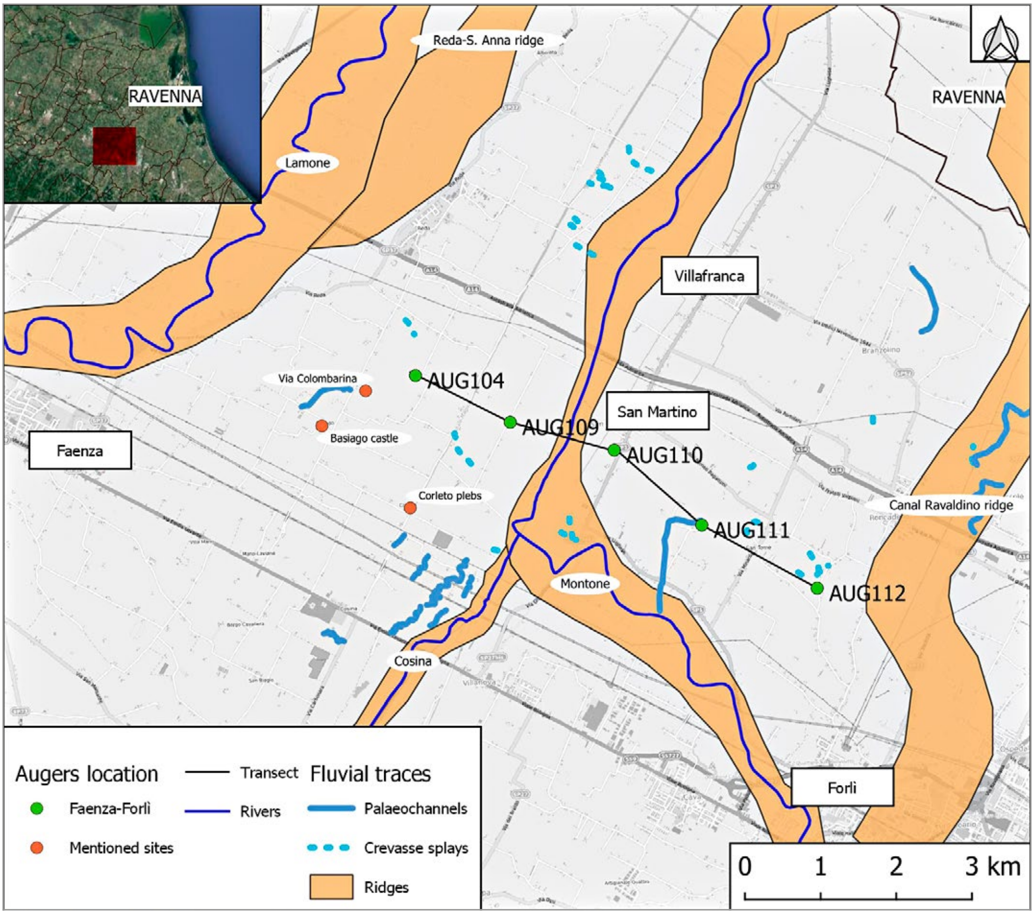

fig. 5. Study area of Villafranca di Forlì, with main geomorphological features, archaeological sites mentioned and geoarchaeological transect (basemap by © OpenStreetMap contributors).

Forlì (Tolosano, 1936, p. 131; Abballe, 2021). Relying on this new course of the river, a *fluviaires* (= fluvial) fields system was likely laid out in the Late Middle Ages by the settlers of Villafranca and San Martino hamlets (Chouquer, 2015, pp. 268-271). This system is made of narrow plots extending away from Via Lughese, the main road of the area, called *Viam Novam* (= new street) in the Middle Ages (Brusi, 2000, p. 106).

2. Materials and methods

The data discussed in the paper are part of a larger dataset of hand augers carried out between 2018-2020, primarily focused around Zagonara and its immediate surroundings at first, to characterise the site itself and its setting (Abballe, 2020). These investigations were later enlarged to the nearby area of Cotignola, simultaneously to the 5th survey campaign of the Bassa Romandiola Project (Abballe & Cavalazzi, forthcoming) and other areas of the Romagna plain connected to the recently-started projects run by the University of Bologna.

During these three campaigns, an Eijkelkamp auger set for heterogeneous soils was used in the field, mainly employing an Edelman auger of different sizes and the auger for stony soils. The latter was handy when facing particularly hard layers, such as compacted sand or dry clay,

Chronology	Range	Chronology	Range
Contemporary Age	19th-21th CE	Pre-Roman	
Modern Age	16th-18th CE	**Iron Age**	9th-3rd BCE
Post-medieval		Post-Bronze Age	
Late Middle Ages	11th-15th CE	**Bronze Age**	2300-10th BCE
Medieval		Pre-Bronze Age	
Early Middle Ages	7th-10th CE	**Neolithic**	5400-2300 BCE
Post-Roman		Pre-Neolithic	
Late Antiquity	4th-6th CE	**Mesolithic**	6500-5400 BCE
Roman Period	2th BCE-3rd CE	Palaeolithic	

tab. 2. The chronological classification used with both main periods (with ranges in centuries) and intermediate stages.

and for collecting less disturbed soil or sediment samples, for instance, for pollen analysis.

The recorded soil and/or sediment data include: a unique identifier using the prefix AUG (= auger) and a progressive number; location information including town, province, street/site, coordinates, expressed in ETRS89/UTM zone 32N (EPSG:25832)[5], and elevation[6]; date; depth information including depth interval (in cm), depth to top, depth to base, and total depth (in m); grain size classification based on finger texturing[7]; colour recorded using Munsell Soil Color Chart (ed. 2009); mixture classified as homogeneous (Ho), heterogeneous (He) or very heterogeneous (He+); unit transition as gradual (G), sudden (S) or object(O)[8]; inclusions with a list of all organic, mineral and anthropogenic finds recorded; response to hydrochloric acid test (HCl), classified between 0-4, with a high number indicating a large amount of calcium carbonate (CaCO3) still present in the sample since the local soils are naturally rich of this compound, while a value between 0-2 testifies the occurrence of pedological processes that have reduced the carbonate amount due to degradation of organic matter (Amorosi et al., 2002; Amorosi & Pignone, 2009, pp. 34-35)[9].

Based on all soil and sediment properties recorded in the field, but especially grain size, colour, inclusions, and CaCO3 value, a lithological interpretation has been proposed between natural (e.g., crevasse/levee, marsh/swamp, floodplain, palaeosol, etc.) or anthropogenic facies (e.g., archaeological layer), simplifying a specific local classification proposed by Amorosi et al (2017b, p. 107, fig. 2)[10].

Afterwards, a chronology classification has been proposed as shown in tab. 2. This includes both main historical periods (highlighted in bold) and intermediate ones, with only the firsts having chronological intervals. The use of intermediate chronological phases is twofold: it is

[5] The recording in the field was carried out using a handheld GPS Garmin 64s in WGS84, later transformed into GIS software.

[6] This value has been extrapolated by a local DEM at 10 m resolution, produced by the author interpolating the elevation points of the Emilia-Romagna region, retrieved from https://geoportale.regione.emilia-romagna.it/download (last accessed on 15/10/2021).

[7] Following the guidelines developed for the CARG project, available at http://www.isprambiente.gov.it/it/progetti/suolo-e-territorio-1/progetto-carg-cartografia-geologica-e-geotematica/linee-guida (last accessed on 15/10/2021).

[8] The term object indicates when the auger has been stopped due to the presence of modern objects/archaeological artefacts.

[9] This field measure was carried out following the guidelines developed for the CARG project, available at http://www.isprambiente.gov.it/it/progetti/suolo-e-territorio-1/progetto-carg-cartografia-geologica-e-geotematica/linee-guida (last accessed on 15/10/2021).

[10] See also the dataset metadata.

Value	Chronology type	Methods used
5	Absolute dating	C14, OSL, etc.
4	Archaeological chronology (certain/well-dated)	Chronology from archaeological excavation
3	Archaeological chronology (uncertain/poorly-dated)	Other archaeological chronology (e.g. artefact survey)
2	Stratigraphic correlation (certain)	Recognition of palaeosols/dated layers
1	Stratigraphic correlation (uncertain)	Possible correlation with known palaeosols/dated layer
0	Unknown	Not enough data to propose a date

tab. 3. Explanation of the reliability values given to the chronological classification.

not always possible to know precisely the chronology of a unit formation (e.g. alluvial deposits covering the Roman palaeosol can be medieval or modern, so the "post-Roman" class is used); more than one lithological unit can mark the passage from a chronological period to the following, thus while these intermediate periods can be repeated several times, the main phases are used only once. This uniqueness will come in handy in a future interpolation of these geoarchaeological data with archaeological ones for palaeotopographical mapping, as done for the area around Zagonara, in Lugo (Abballe, 2020).

In tab. 3 an explanation of methods used for chronological dating is presented, that heavily rely on correlation to locally known stratigraphic markers (see tab. 1) and archaeological data. In the second case, a specific database has been created integrating published data, partially previously collected (Cavalazzi, same issue), with the most recent (supra)municipal archaeological maps available (CPA-RA; CPA-UBR; CPA-URF; CRA-CI). In tab. 3 also a reliability value is shown, expressing the confidence on the dates proposed with a score between 0-5.

Additional information regards whether samples were collected, namely when archaeological finds or organic matter (e.g., seeds, wood, peat) were visible. Bulk samples usually come from a single auger content (usually around 10 cm of sediments = S), but sometimes also from full layers (= L). This was done to speed up the fieldwork but also to avoid time-consuming floating and sieving of soil samples devoid of any archaeological or natural additional elements[11]. Furthermore, since the 2020 campaign, several dozens of pollen samples have also been collected.

More specifically, the strategy chosen to investigate the two targeted areas of Massa Lombarda and Villafranca consists of several hand augers organised into two S-N and one E-W transects and a W-E one, respectively.

3. Geoarchaeological results

3.1 Massa Lombarda's regular fields system

Of the three lithological transects schematically representing the evolution of the plain south of Massa Lombarda (fig. 3), the first to be discussed is the eastern S-N one (fig. 6). In this area, two different palaeosols have been recognised: the more superficial one can be related to the Roman period, also for the presence of fragments of bricks (< 1 cm), while the deeper one should correspond to one of the two pre-historical palaeosurfaces known in the

[11] Some of these samples have been floated, sieved and preliminarily studied by Celeste Fiorotto, within her doctoral research at the University of Verona/Ghent University. Based on this still ongoing work, the field "inclusions" was updated integrating any new finds, such as pottery sherds or seeds.

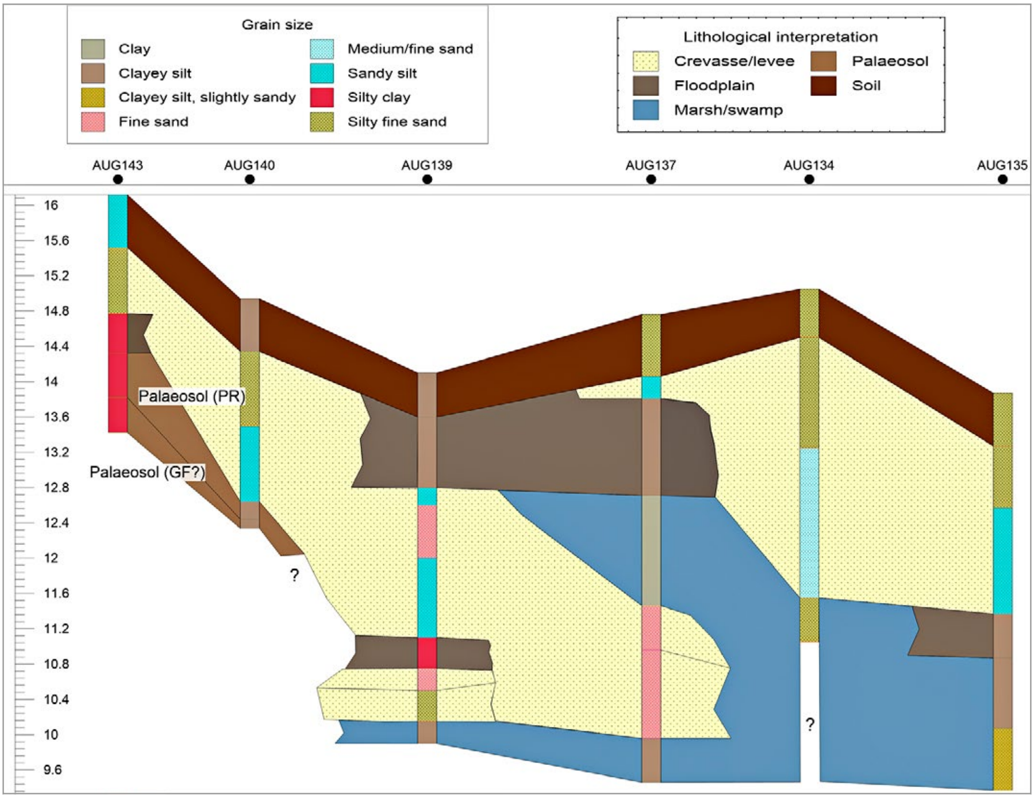

fig. 6. Eastern S-N transect of hand augers of study area of Massa Lombarda regular fields system, with grain size and lithological interpretation.

area (see tab. 1). Hypothetically, the latter is more likely to be interpreted as GF, since the oldest archaeological site of the area dates to the Bronze Age (see above). Both palaeosols have been recorded in the two southernmost augers (AUG140 and AUG143), while further north, they have not been identified, maybe simply because buried deeper than reachable by hand augering.

In both augers, the Roman palaeosol was buried by sandy deposits most likely interpretable as crevasse/levee lithological facies. If, on the one hand, the same sandy deposits seem to extend also in AUG139 and AUG137, on the other hand, more silty clayey sediments are present in these last two, interpretable as marsh/swamp layers. This is because of both their grey-bluish colour, likely resulting from deposition in anaerobic conditions (Craft, 2016), and the presence of organic material (i.e. wood and charcoal in AUG139, while only charcoal in AUG137), both phenomena facilitated in water-saturated contexts such as wetlands. In particular, while these sandy deposits constitute most of the recorded stratigraphy in AUG139, they divide into two units the marshy deposits in AUG137. This provides a more articulate relative chronology for the extension of this marshland, which may have originally extended further south, while its size must have shrunk after the deposition of sandy deposits at a depth between 330-480 cm. Towards the north, this marshland seems to continue up to the town of Massa Lombarda (AUG135), also in this case later covered by sandy deposits. Among these, some may still have deposited in water-saturated environments, such as the case of the silty fine sand layer in AUG134 between 350-400 cm, characterised by a bluish-grey colour and the presence of peaty roots. However, it is difficult to say if this layer was deposited by

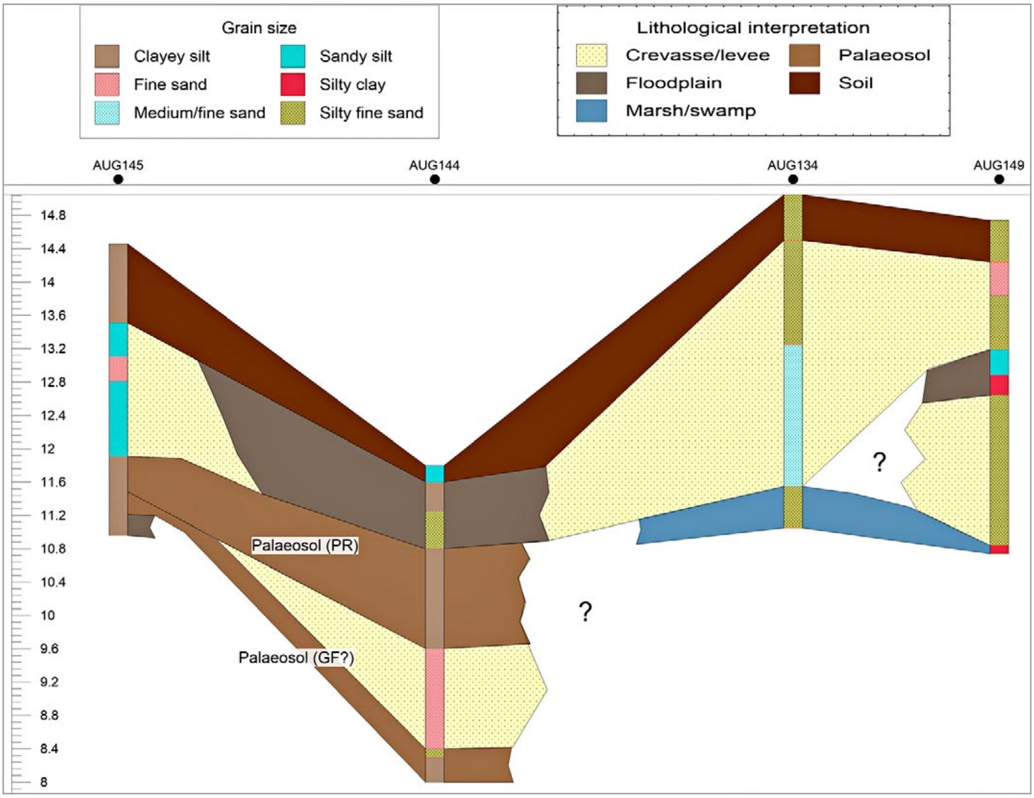

fig. 7. E-W transect of hand augers of study area of Massa Lombarda regular fields system, with grain size and lithological interpretation.

the same flood events that raised the landscape by almost 3 m or by an earlier alluvial event that had a limited impact on this wetland environment.

In the W-E transect (fig. 7), similar marsh/swamp deposits are present also in the easternmost auger (AUG149), which shows two main intense sedimentation phases, most likely to be connected with the nearby course of the river Santerno. Instead, in the two western augers, these marshy layers do not appear, replaced by two palaeosols. A Sigillata sherd found in AUG144 seems to confirm the shallowness of the Roman paleosurface here, which could correspond to the first palaeosol, with the deeper one most likely interpretable as GF. However, a rapid deepening of the Roman topography seems to happen in the area, since in core 222-S11, carried out around 200 m further north by the CARG project[12], where a palaeosol recorded at a depth of around 3 m has been dated to the same period, due to the presence of fragments of brick.

Lastly, considering the western S-N transect (fig. 8), this shows less variability than the others, with the Roman palaeosol directly covering the possible GF in all three profiles. Nevertheless, it is worth underlying at least two aspects on the type of sediments recorded. The first aspect regards the relatively sandy grain size of the palaeosols in AUG146 and AUG150, likely resulting from the proximity of the known Chiusura ridge; while the second one considers the presence of sandy deposits covering the Roman palaeotopography in the two northernmost augers, indicating the proximity to a post-Roman palaeochannel/crevasse splay.

[12] Core 222-S11 is available online at http://geo.regione.emilia-romagna.it/gstatico/documenti/prove_geognostiche/222/222140P519.pdf (last accessed on 15/10/2021).

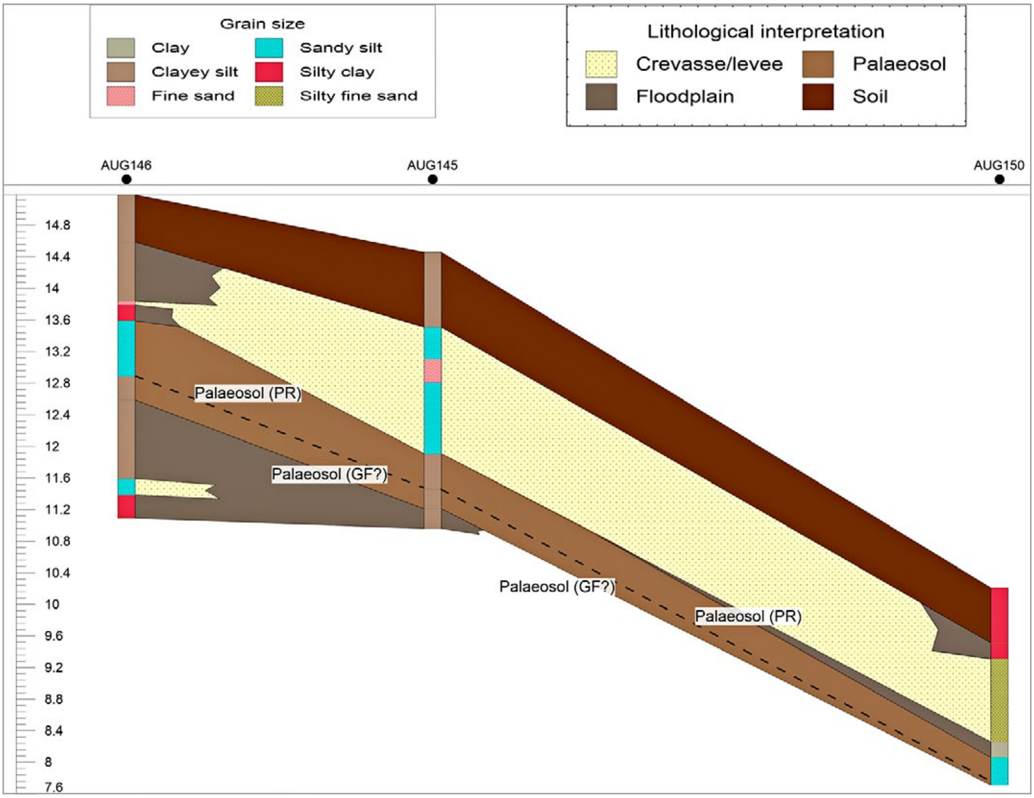

fig. 8. Western S-N transect of hand augers of study area of Massa Lombarda regular fields system, with grain size and lithological interpretation.

3.2 Villafranca di Forlì

Analysing the interpreted transect (fig. 9) that crosses the border between the towns of Faenza and Forlì (fig. 5), the first auger worth focusing on is AUG104 that revealed complex stratigraphy, in which it seems possible to recognise all the three local palaeosurfaces. Starting from the top, the likely Roman palaeosol gave back fragments of brick, oxides, carbonate concretions (140-170 cm), while below the possible Bronze Age GF contained some not identifiable rotten ceramics (230-265 cm). Finally, a very dark layer with a lot of concotto and a lithic artefact (possible arrowhead) may correspond to the Neolithic PSM (270-300 cm), likely reworked by human activities in contemporary or later phases (fig. 10.1-2). Here, the sediments of the two most recent palaeosols are also quite sandy, indicating that they developed nearby a watercourse, likely the one identified next to the site of Via Colombarina (fig. 5).

Towards the east, two palaeosols have been recognised in AUG109: while the one above (390-415 cm) could be related to the Roman period due to the presence of fragments of bricks (< 2 cm), it is safer to correlate the second one between 415-470 cm to the Bronze Age GF. Moreover, just above the likely Roman palaeosol (fig. 10.3), a layer characterised by grey-bluish sediments with much organic matter (347-390 cm) seems to indicate that a marsh/swamp context developed in the area after the Roman period. Layers with generic organic matter, charcoal, and fragments of shell and similar grey-bluish colour and have also been identified on the other side of the Montone river, in AUG110-111-112 (fig. 10.4), where they were documented to a depth of up to 640, 490 and 520 cm respectively. In all three cases, it was not possible to reach the end of this layer, and the possible palaeosols below it, due to the limitations of the hand augering methodology. In all augers, these marshy deposits were

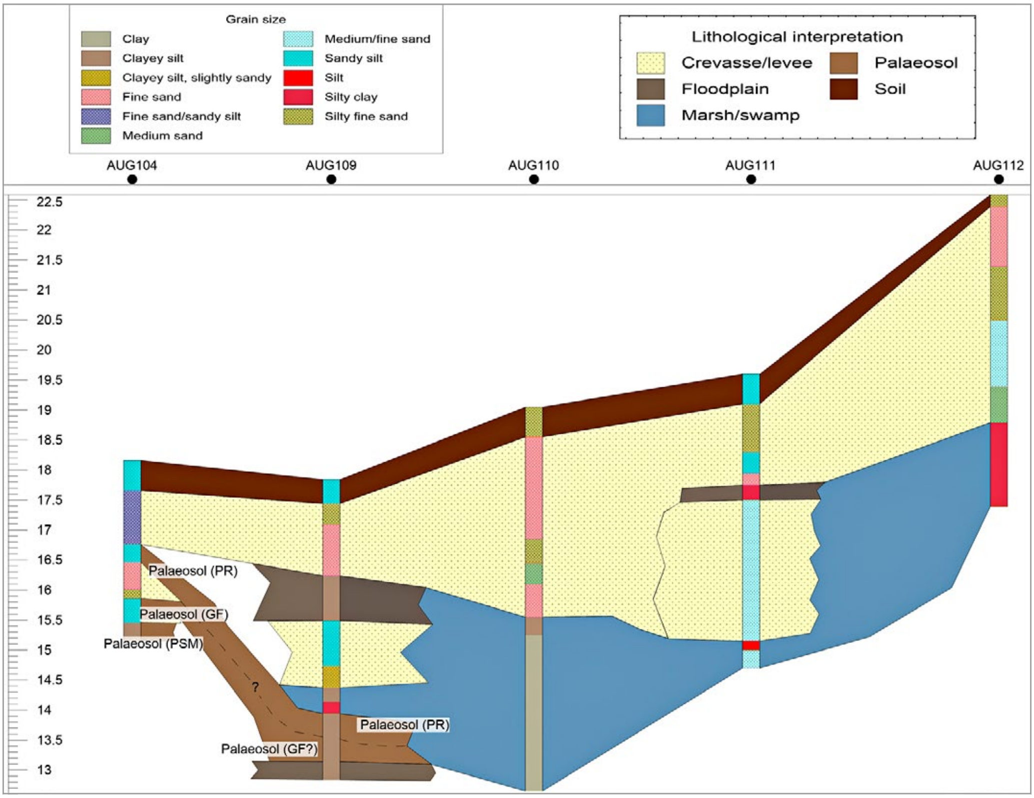

fig. 9. Transect of hand augers at the border between Faenza and Forlì, with grain size and lithological interpretation.

fig. 10. Selection of photos from study area Villafranca di Forlì: 1-2. archaeological layer containing a lithic artefact (top left) and concotto (bottom left) from AUG104; 3. soil sample with likely fragment of "Roman" brick from AUG109 (bottom right); 4 marshland sediments with organic material from AUG110 (top right).

then covered but more sandy ones, to be interpreted as crevasse/levee depositional facies. As in AUG134, despite being characterised by medium/fine sandy sediments, the layer in AUG111 between 460-490 cm has been interpreted as part of the marshy/swampy context, due to its dark greenish-grey colour, possibly result of deposition of the sediments in a still (partially) water-saturated environment.

4. Discussion

4.1 Massa Lombarda's regular fields system

After having presented the results of the hand augering carried out around Mordano, Imola and Massa Lombarda, we can use these data to answer the research questions that were presented above. Firstly, despite the apparent good preservation of the Roman centuriation in the northern half of Mordano municipal territory (fig. 2), it is clear that the Roman palaeotopography has been buried by later alluvial events (up to 230 cm in AUG140). At the moment, it is difficult to tell when and how these sediments were deposited, but considering the apparent absence of palaeochannels north of Mordano, to relate these deposits to the nearby Santerno river is the most plausible explanation. More interesting is the possibility to include this case study within the broader academic discussion about the process of preservation of the Roman *centuriatio*, very active around the Po Valley. So far, two main models have been proposed for the recovery of this type of system: the so-called *risalita verticale* (= vertical growth), where channels and streets that compose the centuriation system are restored after short crises, associated with little sedimentation, following elements that were only partially buried (i.e. trees, see Bottazzi, 1993, pp. 184); the so-called *risalita laterale* (= lateral growth), where the elements of the land division are redrawn prolonging those still preserved in the nearby areas (Franceschelli, 2008, p. 100; Chouquer, 2015, p. 126, fig. 20). The latter model is considered to be prevalent in areas where the Roman topography has been buried by several metres of alluvial deposits, and especially if associated with wetland formation: this is the case of the post-Roman marshland that developed in the Lugo plain (Franceschelli, 2015, p. 188; Abballe & Cavalazzi, forthcoming). According to these hypotheses and the stratigraphy documented in AUG139, where the southernmost marshy deposits have been documented, we could hypothesise that a process of *risalita laterale* occurred in this area. Namely, channels and streets were redrawn after the Roman period starting from the southern part of Mordano municipal territory, where surfacing Roman sites suggest the resilience of the land division system. However, due to the total absence of archaeological data, it is not possible yet to propose a chronology for the reestablishment of this regular fields system.

Interesting is also the relationship between the Roman centuriation and the newly established fields system of Massa Lombarda, that despite having different orientation and plot measures, seems to connect to the pre-existing system just 400 m to the east of AUG144. The shallowness of the Roman palaeosol in the area may suggest the authenticity of this part of the Roman centuriation, thus representing one of its well-preserved northernmost sections. Refining the chronology for these land division works may be crucial to understand why a different orientation was used for the Massa Lombarda system.

Another significant result of these campaigns is having documented the subsoil below the Massa Lombarda regular fields system, guided for the first time by geoarchaeological questions. In particular, we now have clear evidence that the area was partially covered by marshes, whose reclamation has been likely followed by a land division project. Despite not having stratigraphic records attesting a post-Roman chronology for this marshland, helpful information to propose a date for this feature come from the Massa Lombarda clay quarry (fig. 3). At that site, the Roman palaeosol identified at 410 cm from the present-day surface was covered by 2 m of grey clay with many shells and a lot of charcoal, which were interpreted as marshy deposits. These were covered by a 10-cm layer dated generally to the Middle Ages

(Veggiani, 1963): although located a few km far from the study area, these data may offer a first chronological constrain for the development of this wetland.

Furthermore, the analysis of aerial and satellite images offered the opportunity to partially map the palaeochannel likely responsible for the "reclamation" of this wetland, called Via Felice, from a nearby street. This feature seems to depart from the so-called San Patrizio-Conselice ridge, giving us additional chronological constraints. Indeed, the Santerno must have abandoned this course between 1228-1264 CE, when the river activated a more eastern course towards San Lorenzo hamlet, similarly to the actual course (Veggiani, 1990, pp. 90-91). This represents a *terminus ante quem* for the activation of the Via Felice palaeochannel, which is compatible with the chronology suggested by the written sources for the reclamation of the area, which likely occurred after 1251 CE (see above).

Finally, the data here presented can be used to frame the medieval site of Cavassona in a more broad environmental context (fig. 3). First, we have to consider the occupation span of this settlement seems to date to the 11th-12th centuries, according to a preliminary study of artefacts recovered in September 2020, although several finds also suggest earlier phases of frequentation[13]. Secondly, the location of the site on a fluvial ridge, with the relative palaeochannel likely flowing next to the site, points out to a place originally raised above the surrounding plain (Abballe & Cavalazzi, 2021). In case absolute dating will confirm that the marshland was indeed reclaimed only in the first half of the 13th century, this site would have represented an offshoot settlement, lying not far from more "hostile" marshy environments.

4.2 Villafranca di Forlì

The easiest stratigraphy to contextualise is AUG104, which has been recorded around 600 m northeast of the Bronze Age site of Via Colombarina (Righini Cantelli, 1980, pp. 57-58). Next to this settlement, a palaeochannel has also been mapped (fig. 5), which may be responsible for the sedimentation that occurred in this area during and after the Bronze Age period. In fact, above the PSM, sandy sediments are prevalent in all layers, suggesting the presence of a watercourse nearby, which must have changed path only "recently".

Regarding the other profiles, the main feature is represented by the marshy layers that extended on both sides of the Montone river, before its artificial avulsion. Contrarily to Massa Lombarda, for this case study, we are confident that this wetland covered the Roman palaeosol, as attested in AUG109. This represents a very good chronological foothold, that even in the absence of absolute dating, offers the possibility to question a previous reconstruction of the study area. Indeed, several scholars had interpreted the Via Lughese as part of the Roman centuriation connected to the city of *Forum Livi* (Forlì), more recently Pier Luigi Dall'Aglio (2009, pp. 292-293). A few years later, Gérard Chouquer questioned this hypothesis (Chouquer, 2015, p. 268), having found several orientations for different chunks of this street that diverged from the primary orientation recognised north-east of Forlì (Bottazzi, 1993). Based on these pieces of evidence, the author suggested that Via Lughese must have been part of the *fluviaires* system connected to the Montone river. The formation of a wetland in the post-Roman period argues in favour of this second hypothesis, considering that at least 640 cm of alluvial sediments may cover the Roman palaeosol in AUG110, just next to Via Lughese. Moreover, the combination of these geoarchaeological data with the attestation of the artificial avulsion of the Montone in 1217 CE becomes solid proof of the critical reclamation process that occurred here in the 13th century. Although the shortage of historical sources, this reclamation must be connected with the establishment of the settlements of *Sancti Martini in Villafrancha* and *Sancte Marie in Villafrancha*, corresponding to the present-day hamlets of San Martino and Villafranca[14]. According to their historical names, we can include these settlements within the broader phenomena of *ville franche* (= free towns) foundation that interested all of Italy between the

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[13] The report of this survey campaign has been submitted for inclusion in the Geoportale Nazionale per l'Archeologia (GNA).

[14] The first mention of both settlments dates to 1312 CE (Brusi, 2000, p. 404).

12th-13th centuries (Comba et al., 2002). Thanks to the recent archaeological investigations promoted by the University of Bologna in the Ravenna hinterland, this phenomenon of new settlements foundation is known more and more also in the Romagna plain (Cavalazzi, 2021b). In the particular case of these two "free" settlements, fiscal privileges and recently-reclaimed land plots may have come together with the burden to take care of the Montone riverbanks. Indeed, we are sure that this obligation was requested in 1359 CE (Rinaldi, 1913, p. 338), but this may have occurred also before (Gambi, 1949, p. 34).

5. Conclusion

The results obtained in the two case studies discussed in the paper aim to show how targeted hand augering allowed to gain new insights on crucial landscape transformations that occurred in the Ravenna hinterland in the last 3000 years. This was possible thanks to the combination of new geoarchaeological data with pre-existing archaeological and geomorphological knowledge, supported by a systematic study of all aerial and satellite images freely available online. Thus, it was often possible to hypothesise which alluvial process/transformation caused the sedimentation recorded in the stratigraphy, greatly expanding the understanding of these phenomena. Moreover, many of the conclusions drawn here heavily relied on the foothold offered by some previously identified stratigraphic markers, which allowed me to propose a solid relative chronological framework for most of the alluvial events, although absolute dating will undoubtedly further refine it. Despite this limit, the approach can be applied in many other areas of the Po Valley, especially considering that alluvial transformations have often been less intense than in the Romagna plain.

From a historical point of view, the results allow us to understand much better the reclamation processes that occurred in the Ravenna hinterland in the Middle Ages, which were only conceivable on the basis of the written sources. In addition, since these "hostile" swampy or marshy environments were rarely mentioned in the documents, usually as *silva* or *forestum* (= woodland; see Cavalazzi, 2017), it is fundamental to start documenting their material traces, to map them, and to collect pollen samples and macrobotanical remains to characterise them further.

However, due to the lack of absolute dating and the limits of the methodology used, in terms of maximum depth that can be reached through hand augering, several questions remain open about the two marshlands discovered in Massa Lombarda and Forlì. This is true for their formation and their development, while it seems safe to believe that they were reclaimed around the 12th/13th centuries, as also happened around Lugo, in a widespread effort to expand political control and agricultural production (Abballe & Cavalazzi, forthcoming). Indeed, due to the lack of archaeological data, it cannot be excluded a priori that they existed already in the Roman period or before, clearly smaller in size, as an expansion in medieval times has been documented in both cases. In fact, there are already a few pieces of evidence proving that the whole Romagna plain was not completely reclaimed during the Roman period, especially in the northernmost parts (for Conselice, see Preti, 1999; for Lugo, see Franceschelli & Marabini, 2007, pp. 104-106) and along the coast (for Ravenna, see Amorosi, 2002). Continuous coring and absolute dating will be necessary to understand these formation processes better.

Nevertheless, it is worth underlining the "Villafranca wetland" exceptionality, specifically for its proximity to the Apennines. The few shreds of evidence available so far attested wetlands essentially in the lower valley (i.e. Lugo, Conselice), but in this case, the Roman *Via Aemilia* is less than 4 km away. Thus, although the Apennine foothills are generally geomorphologically stable, a combination of various factors, likely including local water resurgence (*fontanili*), must have caused water stagnation in the area for a prolonged period that led to the formation of a large wetland.

More in general, a better comprehension of the alluvial transformations that occurred in the Ravenna hinterland are essential to fully understand the settlement patterns emerging from the archaeological research promoted in the areas and to overcome the current interpretative problems that we are usually facing in alluvial contexts (for the local area, see Cavalazzi, 2021a). A further step will be to model local palaeoDEMs combining all (geo) archaeological data available because we could gain further insights from the analysis of buried topographical surfaces (for a local example and extra references on the subject, see Abballe, 2020), including mapping buried fluvial/beach ridges or identifying depressed areas, more prone to water stagnation. Especially about the latter, there is still much to discover about these former wetlands, from their formation to their disappearance, from their land cover to their land use, and thus more in general on the human-environmental relationships in these hostile landscapes, that characterised much of the Po Valley and many other alluvial plains in Italy and Europe.

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