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SUBMERGED LANDSCAPES AROUND FERRARA (ITALY): UNDERWATER ARCHAEOLOGY BETWEEN QUARRIES AND PALAEOCHANNELS

Giovanna Bucci

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Cover: Gambulaga (FE), Lake Tramonto, submerged landscapes (*G. Bucci*).

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Presentation

The territory of Ferrara has always adapted to the forms of water. The settlement system is inextricably linked to the conditions created by the sea or the waterways; furthermore, in many cases, the flourishing of an area is determined by hydrographic advantages. For these reasons, in the area's settlements and urban centers, the works that regulate water in various ways are among the most demanding in terms of their design, construction, and maintenance. Added to this are man's traces scattered in the waters, even unintentionally, such as wrecks.

The Ferrara region places many challenges in front of archaeology: from the constant attention in detecting traces of such a labile element as water to the study and application of new technologies for investigations in wet and underwater environments. These characteristics reward the multidisciplinary approach and push the scholar to deal not only with archaeological contexts but also, with a broader vision, of the landscape.

The study of quarries represents a field of investigation that often engages the Soprintendenza, to assess the archaeological potential of the dig sites and the surrounding territory since sand excavation constitutes an important economic sector for this area.

Giovanna Bucci's study summarizes all these peculiarities and therefore stands as a milestone in the knowledge of the ancient territory, representing a valid synthesis of known data, new scientific research perspectives, and its important implications for the management and protection of the archaeological heritage.

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Foreword

Relationships between the University of Ferrara and its territory result in various collaboration models and interactions and present a relevant and significant component of the stakeholders' system of the community.

Our departments are linked to the city and local development. They have as their primary objective the production of new knowledge and more recently, they have been increasingly pushed towards applied research and development, aimed at knowledge transfer to industries and to growth and welfare for society.

The case studies presented in this volume represent the profitable scientific, technical, and methodological collaboration between cultural institutions and the mining industry.

Universities, and Superintendencies, Mining Companies engaged in quarry excavation activities with the collaboration of highly qualified freelance geologists, engineers, archaeologists, palaeontologists, and palaeobotanists created a synergy of skills that have given rise to numerous discoveries as well as new models for monitoring the territory including the inland waters sector.

This research highlights a series of research, focused on the underwater sector, that starts from the first paleontological and archaeological findings crossing the Ferrara district from Bondeno, to Portomaggiore and San Giovanni di Ostellato area.

The work is configured not only as a common important scientific investigation but also as a support for teaching in the field of archaeological research methodologies with particular attention to the underwater archeology of inland waters, bringing unprecedented contributions to the reconstruction of the ancient landscapes and waterscapes of our most important river, the Po.

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INTRODUCTION

Research and studies about underwater archeology of the inland waters in the hydrographic district of Ferrara investigate a scientific reality, still little known to the world of archaeology.
The study and monitoring of the artificial basins created during the excavation of quarries for the extraction of sand in the Palaeo-channels of the River Po, an important economic sector at the regional and national level, involve underwater archaeology experts in new challenges.

The constant collaboration, supervision, and scientific direction of the Superintendence - *Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Bologna e le province di Modena, Reggio Emilia e Ferrara* and recently also the *Soprintendenza Nazionale per il patrimonio culturale subacqueo* fostered the process to developing methodological and technical aspects for new guidelines for intervention, protection, surveillance and monitoring of the territory, as required by the actual legislation, with specific reference to preventive archeology and fieldwork[1].

Capitalizing on the results of works carried out in some of the main mining sites of Ferrara district, during the last two decades, five main case studies relating to quarry lakes and former quarry lakes will be here presented, explaining the geo-archaeological context with satellite images, stratigraphic analysis of the drillings, surveys, and remote sensing recent investigation in a prototype site.

The focus of the work is dedicated to the discoveries that came out from the submerged layers, with peculiar attention to riverine archaeology.

The cases studied are Settepolesini di Bondeno, Casaglia, San Giovanni di Ostellato, Sandolo, and Gambulaga.

These mining sites correspond respectively to the following lakes individuated by new toponyms: Lago Quaternario, Lago di Casaglia, Lago Cantoniera Cavallara, Lago Campanella, Lago Tramonto (prototype site of research and remote sensing), which belongs to the system of ex quarry lakes including Lago Alba, and Lago Gattola (to the east side of Lago Tramonto) (Fig.1).

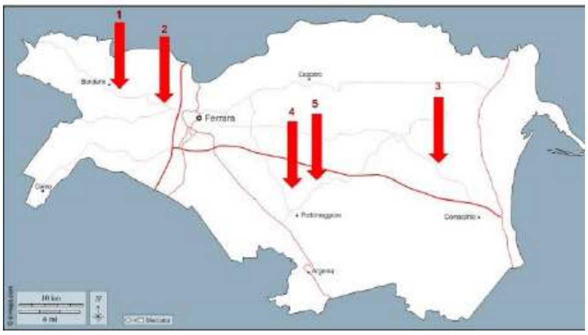

Fig.1 – Province of Ferrara: location of the study cases: 1, Settepolesini, 2 Casaglia, 3 San Giovanni di Ostellato, 4 Sandolo, 5 Gambulaga.

Campanella and Tramonto as well as Alba and Gattola are now oases, meanwhile currently Settepolesini, Casaglia, and San Giovanni di Ostellato are regularly working, thanks to the *Third Infraregional Mining Activities Plan (PIAE) 2009-2028*. As explained in the VAS-VALSAT (*Valutazione Ambientale Strategica - Valutazione strategica ambientale e territorial*, Strategic Environmental Assessment - Strategic environmental and territorial assessment[2]; the priority elements for the planning choices for this third *Infraregional Mining Activities Plan* are the following[3]:

1. Safeguarding environmental values and primarily water resources, through the confirmation of all areas incompatible, in terms of environmental value, with the activity extraction, and updating of the analysis processing to the current *PTCP Piano Territoriale di Coordinamento Provinciale - Provincial Territorial Coordination Plan*; including adaptation of the verification of environmental compatibility, sustainability assessment (environmental and territorial), the mitigation measures to be adopted in the future to identifying zoning; priority choice of extraction centers among the sites already planned or otherwise interested from extractive activities; location of the new hubs, after research and assessments regarding the infrastructure needed for management.
2. Flexibility of the tool to allow Municipalities to make comparisons between choices, as well as improvement variations.
3. Promotion of alternative resources coming from different activities, to reduce the required needs and make the best use of local resources.

[1] About the regulations and guidelines for preventive archeology in Italy: Istituto Centrale per l'Archeologia (ICA): The new Guidelines for preventive archaeology http://www.ic_archeo.beniculturali.it/it/275/archeologia-preventiva.

[2] All the documentation is available on the website: https://pvprovinciafe.lepida.it/sites/drupal_lepida_provferrara/files/01%20VAS%20PIAE%20approvato.pdf (accessed 29/12/2023).

[3] In 2024 a new document will be available.

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4. Containment of activities in the area with identification only of extraction poles and confirmation of the exclusion of areas smaller than 1.000.000 m^3 potentially extractable.
5. Optimal and complete exploitation of the planned poles.
6. Increase the efficiency of the PIAE through the extended copy-planning procedure to most Municipalities and their sectoral implementation tools (PAE) (Fig.2).

This work is divided into three main sections: the first concerns the ambit and the contest of the research, with a focus on methodologies and techniques for preventive and surveillance underwater archaeology addressed to the artificial basins, and the quarry lakes, with peculiar attention to the importance of remote sensing.

The second part includes the presentation of the investigated sites: each case of study is presented through a brief topographical introduction with satellite images and aerial photos showing the topographical areas before the excavations, geo-archaeological considerations reporting the stratigraphy of two sample cores illustrating the sedimentological and archaeological context of the lakes together with photos and drawings elaborated by the author, with a focus on the reprocessing the data coming from one of the main prototype sites for the development of archaeological remote sensing in ex-quarry lakes: Lake Tramonto, Gambulaga.

The third part includes ancient archaeo-environmental reconstructions of the local riverine landscapes, presenting updated data with unpublished records, and illustrating some new hypotheses concerning the ancient landscape when was not submerged.

All the unedited documentation comes from direct and indirect investigations both preliminary to the start of work of mining and during excavation, as well as to the closure of the quarry installations with the conversion of the quarry lakes into naturalistic oases.

The photos were taken by the author of this book.

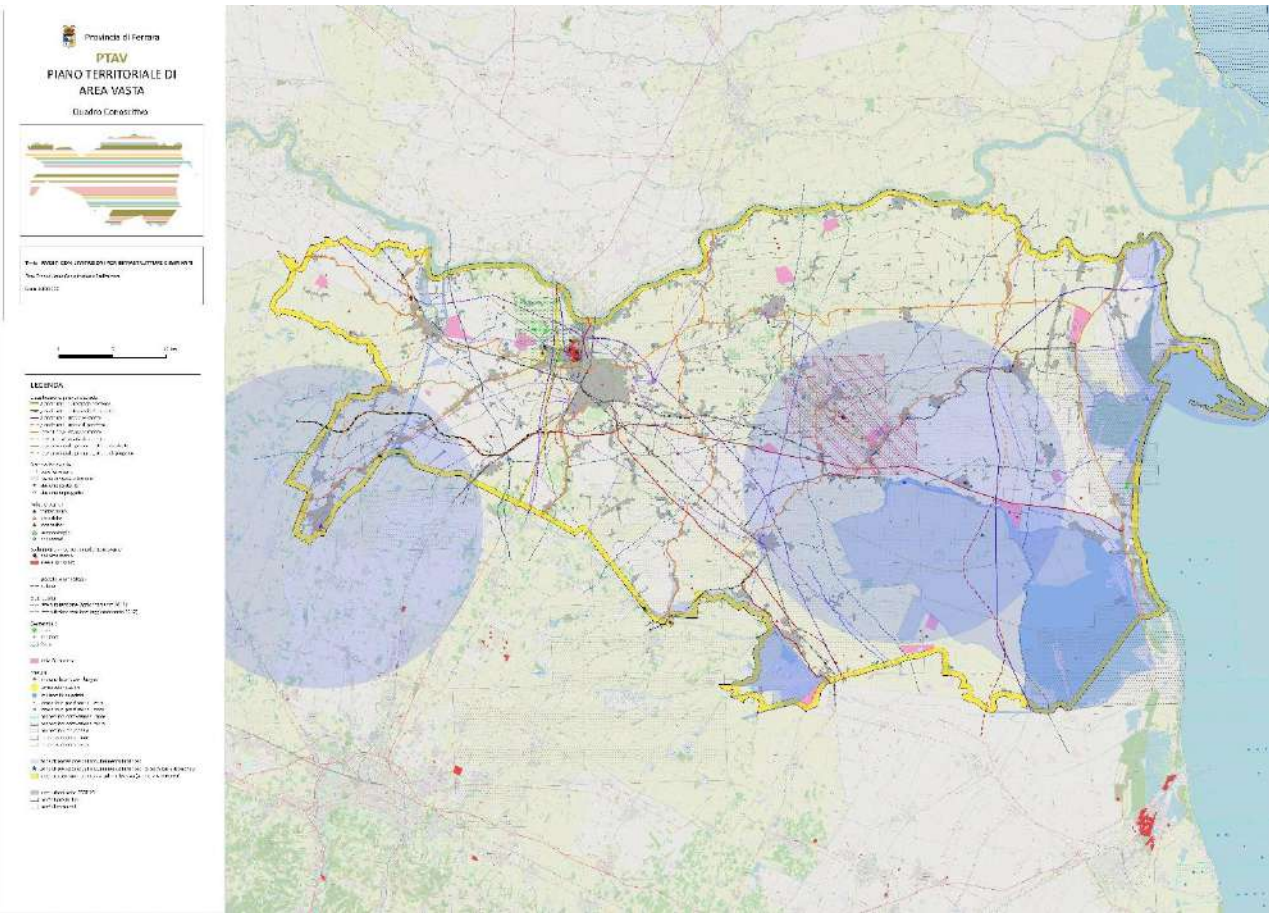

Fig.2. - Map with positioning of the areas with ongoing fine sediment extraction activities (pink area) (*4.1 Tav. Quadro Conoscitivo D: 8. Limitazioni per infrastrutture e impianti* - https://pvprovinciafe.lepida.it/pianificazione-territoriale-e-urbanistica/pianificazione-territoriale/ptav-lavori-corso/la).

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PART I

QUARRY LAKES

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I.1 Underwater archaeology of the artificial basins: methods and techniques

Underwater archaeology of the artificial basins is a sector of studies of underwater archaeology. Here, we will address the issues concerning the artificial basins which are lakes resulting from the excavation of natural layers that have filled, blocked, and covered ancient river courses, with sedimentary deposition resulting from the transport of fine sediments from the rivers themselves (clay, silt, sand) within the Po Valley.

These quarries now are lakes substantially dug into rivers that are no longer active, or rather they are lakes that are formed from the excavation of fine sediments within the palaeochannels of the River Po. These are large lakes, even a few tens of meters deep, dug into ancient river courses whose margins can be found both through satellite and aerial photography analysis, remote sensing, and geological investigations.
As recently underlined by Upadhyay, Kishorea, and Sharmab[4], palaeochannels are remnants of rivers or stream channels that flowed in the past and have been currently filled or buried by younger fluviatile sediments. There are several techniques for detecting these features. In the present study, apart from applying different approaches, the capabilities, and effectiveness to locate and map palaeochannels are compared. Nevertheless, visual field observations for ground-truthing of prospective palaeochannels either exhibiting only subtle alterations in desiccation or vegetation are considered a potent field approach. Added to this are the geological investigations in the field, i.e. core conservation core drilling, and geoelectrical investigations are still milestones of preliminary research.

One of the characteristic elements of the formation of these lakes in palaeochannel is the presence of water for natural reasons connected with the different local groundwater levels and catchment basin of the Ancient River. It follows that after removing the surface stratigraphy the water appears naturally, aligning itself on the highest groundwater level. On average, in the Ferrara area, the water is found at just over one meter deep or even closer to the current walking surface. That's why mining in this context deals with underwater archaeology.

The sand extraction technique is adopted in a lowland environment (open-air with trench excavation) in the presence of water within 1,00 m of the ground level. Dry excavation of the superficial levels, mostly clay and silt, is carried out using a smooth bucket excavator; subsequently, the excavation under the groundwater uses a water-refluent dredger, equipped with mobile disintegrating tip, usually with lamellar toothed blades, with variable diameters from 700 mm – 1300 mm (Fig.I.1.1). The mixture of water and sand with the relative percentage of mixed fine sediments is pumped to a selection and screening system which separates the sand from silt and clay, conveying the water back into the lake, after settling the fine-grained material suspended in a special tank. The works proceed in successive batches and excavations, evaluating both the maximum excavation depth and the progressive modeling of the submerged slopes according to the expected slopes. The excavated sand, cleaned of the clay fraction and screened according to the expected grain sizes, is then put on the market[5] (Fig.I.1.2).

Fig.I.1.1. Example of a sand quarry, Cantoniera Cavallara, San Giovanni di Ostellato with a dredger.

Fig.I.1.2 Example of the sand quarry, Cantoniera Cavallara, San Giovanni di Ostellato: working area and dredge system (Google Earth satellite image accessed (09/11/2023).

[4] About Delineation and mapping of palaeochannels using remote sensing, geophysical, and sedimentological techniques: Upadhyay, Kishore, Sharma 2021; about palaeo-watercourse and geo-archaeology of the inland waters: Bucci 2018.
[5] On the methodologies of sand extraction, see Mantero, Orpelli 2014, pgs.7-8.

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The artificial lakes resulting from the excavation are characterized by artificially cut bank margins, subject to constant rearrangement during dredging; when the construction site is completed, they are remodeled to improve stability and compatibility with the natural environment, favoring the conversion of use from a mining site to naturalistic oasis.

In some cases, the correspondence of the artificial basin margin coincides with the bank of the ancient riverbed, in other cases, it remains even tens of meters away to make the excavation area coincide with the maximum power of the stratigraphy of mineral interest compatible with the concession.

The possible contact with the ancient riverbank margin proves to be a relevant fact in the context of archaeological surveillance. The banks of the Po have been frequented since extremely remote times both as routes for trade, above all, but also as settlement areas thanks to the favorable altitudes compared to Delta Plain[6]. Settlement locations in delta landscapes change through time because of cultural and natural dynamics. Landscape and cultural changes occurred in this area, with river avulsions and changes in flooding frequency coinciding with changing settlement patterns. In the delta plain, the relatively high and dry alluvial ridges of abandoned or active rivers were most favorable for habitation.

From a methodological point of view, on the archaeological side, after a preliminary work of analysis of aerial and satellite photos, historical cartography, ancient literary sources, and bibliography, direct and indirect investigations could be conducted on three fundamental field activities: land surveys near the lakes, geo-archaeological core sampling, remote sensing. Once the lake begins to enlarge and get deeper, underwater surveys with ROV (*remote operating vehicle*) and AUV (*autonomous underwater vehicle*) are very useful; the research accompanied by photos, and videos, may include remote sensing hydrographic surveys with echo-side scan sonar, multibeam, and sub-bottom profiler applying geomatics to archaeology using AUV, towfish or onboard instruments[7].

A tool that has proven to be very useful in this area of work is the hydrographic drone on which it is possible to install the tools mentioned, namely echo side scan sonar, single or multibeam, and sub-bottom profiler (Figs.I.1.3a-b).

Fig.I.1.3a - Example of an autonomous vehicle. Open Swap Shallow Water Autonomous Prospector equipped with echo side scan sonar, single beam, and sub-bottom profiler.

Fig.I.1.3b - Open Swap working in a channel.

[6] About the link between settlement elevation and landscape dynamics Pierik, van Lanen 2019.

[7] For an overview of remote sensing in archaeology: Bucci 2015, 2018b, Campana, Forte, Liuzzi 2010, Mindell 2007, Wiseman, El_Baz 2007.

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Bathymetrical data are useful for geohazard control, modeling, and mapping for the planning and prosecution of the works as well as for predictive archaeology.

It is not possible to dive in the quarry lakes for safety reasons concerning the stability of the bank margins and the possible natural pollution of the water linked to the type of habitat.

The river/lake environment [8] is characterized by poor visibility (clayey suspension) and discontinuous surfaces (canyons, holes, landslides, tree trunks); readable photos can only be close-ups or macros; photogrammetric systems are not suited to this type of surface and visibility; in this case, the video mapping can only be managed at short range, not allowing an overall overview to correlate the findings and due to the morphological discontinuity of the seabed, combined with the soft sediment which enters into suspension, clouding the investigation perspective[9].

We, therefore, equipped ourselves with echo side scan sonar with data reading software, to verify the scan data on the computer.

The steps of the proposed geomatic application involve first the placement of georeferenced points on the edge and bottom of the lake (if possible), a systematic subdivision of the investigation area into swaths/transects with repeatable geometric modules, linked to the geographical coordinates, hydrographic survey, schematization on overlapping levels of morphology and findings, indirect measurement.

Geomatics is a neologism that combines Geography and Computer Science. It includes different detection techniques, processing, and analysis of the metric and physical parameters of the environment, with a leading role of information technology in data processing. Topography (with particular attention to 3D survey), photogrammetry, satellite remote sensing, territorial information systems, and georeferencing

The data fusion phase includes the comparison of side image and down image views with data coming from side scan sonar with an examination of the underwater videos, usually taken by the ROV or, in some cases directly by the divers (Fig.I..1.4 a, b, c).

Considering the different techniques for surveying and analyzing the metric and physical parameters of the environment, the 3D survey and data fusion are correlated to satellite georeferencing into the Google Earth system, positioning the plan with isobaths.

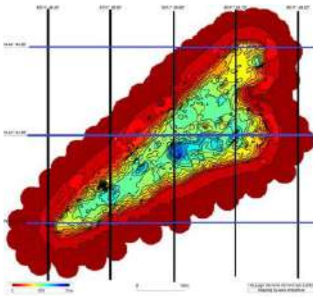

Fig.I.1.4a - Example of a georeferenced map.

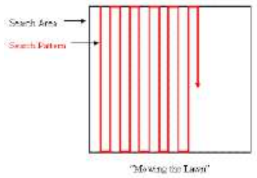

Fig.I.1.4b - Diagram of parallel transects.

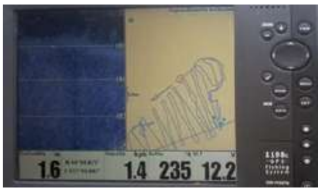

Fig.I.1.4c - Side-scan sonar operating according to the planned swathes: down image and track

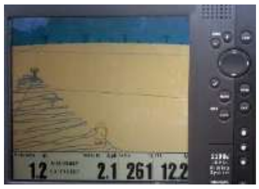

Fig.I.1.4d - instrument operating according to the planned swathes: track

A preliminary step for the studies of the possible realization of quarries in the palaeo-riverbed concerns the preventive archeology phase in the field before the start of any excavation relating to the quarry; it consists not only of the study of the drillings with core conservation, ancient sources, and cartographical studies, bibliographic investigations, archaeological database consulting, and satellite image analysis, but it may also include preliminary trenches or ditches for a precision stratigraphic reading which is necessary for areas of high archaeological potential risk.

This guidelines proposal is aimed at the excavation of fine sediments in the aquifer.

Once the mining excavation has begun, below the outcrop line of the aquifer level, the work is characterized as excavation in an underwater environment.

The preliminary investigations on site, as part of the preventive verification of the archaeological interests, can verify with any geoelectrical investigations the first detectable anomalies in terms of sedimentology and trend of natural and/or artificial structures, whose reference levels may have been related to a careful reading of

[8] The theme of underwater archeology in a river environment is presented in detail in Capulli's works: Capulli 2018, 2020, 2021.

[9] About safe investigations, technique of surveying in quarry lakes and geomatics: Bucci 2010a, 201b, 2018.

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the stratigraphy deduced from core sampling, core conservation, and any exploratory trenches, therefore, a first phase on the field that we could define as terrestrial has been completed. The archaeologist who dealt with the archaeological control of the phase relating to the first superficial levels removed with an excavator, now finds himself faced with water, an artificial basin in a natural context.

The peculiarity of these quarry lakes is in fact that they are artificial basins in a fully natural context, in this case, a river context in the plains. As we have seen, the incipit of the excavations born from a first geometric model that allows a useful reach for the excavators at work; little by little the excavation tends to reach deeper depths: from an excavation made bulldozer and excavators, we move on an underwater excavation using a hydro-refluent dredger.

Without prejudice to the fact that any preliminary trenches were made with heights compatible with the water table and with safety margins connected to the specificity of the rest angles of the sediments, we will be faced with new stratigraphy which only geological cores have given us account accurately. However, since these are a punctual intervention while being able to offer data of great importance regarding the sequences of the layers as well as the presence of paleosoils or anthropic traces, they remain a tool that provides a relative indication. That is, if soils and anthropic traces had already been identified from the core samples, it is likely that even during the excavation we can find traces of this type with evidence that may prove of possible archaeological interest in an extended area. It is understood that if we also excavate directly at the bottom of the river, we cannot exclude isolated discoveries attributable to sinkings we are excavating a river, i.e. nautical vessels and objects thrown into the river or fallen into the water may be found. Precisely for this reason, as part of the lake bathymetric checks sessions, carried out periodically to best organize the planning of the excavation it is important to complete a session of remote sensing investigations, not using a simple echo sounder, but rather an eco-side scan sonar, a multi-beam, a sub-bottom profiler: in this situation, the specific technical knowledge of underwater archeology comes into play.

Below is a sequence of images illustrating the work in progress since the individuation of the quarry area of San Giovani di Ostellato, Cavallara quarry (Fig.I.1.5) and the morphological development of two quarry basins (Casaglia and Cavallara), enlarged during the different phases of excavation, after individuating the soil markers characteristic of the palaeochannels (Figs.I.1.6-7).

Fig.I.1.5 - Example of workflow sequences in San Giovanni di Ostellato, Cantoniera Cavallara. On the left, a satellite image of the quarry area before the start of the work (image 2016 Digital Globe) with clear soil markers of the main riverbed meander; excavation of an exploratory trench for detailed stratigraphic analysis; positioning of the first dredge in the water.

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An important datum connected to the hypothetical archaeological risk at the margins of ancient rivers is linked to the altimetry of the sites, of the bank area, characterized by the highest altitudes of the territory naturally linked to fluvial deposition and to the regulation of the rivers since ancient times (see over significant examples).

We can evict from the table of other provincial metrics (Fig.I.1.8) and from the measurements that can be carried out through Google Earth The elevations reach ranges between three and eight meters in height compared to the ground level. Some significant examples in the palaeo-hydrographic context of Ferrara province of the quarry lakes are reported in sequence (altimetric visualization of the landscape - Fig.I.1.9 a, b, c, d, e, f, g)..

a

b

Fig.I.1.6 - Casaglia, 2021 Google Earth satellite: the beginning of mining activity and quarry expansion (accessed 11/12/2023).

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a

b

c

Fig.I.1.7. San Giovanni di Ostellato, Cantoniera Cavallara. Google Earth satellite images: the evolution of Lake Cava during sediment extraction in the years 2014, a, 2018, b, 2022, c (accessed 11/12/2023).

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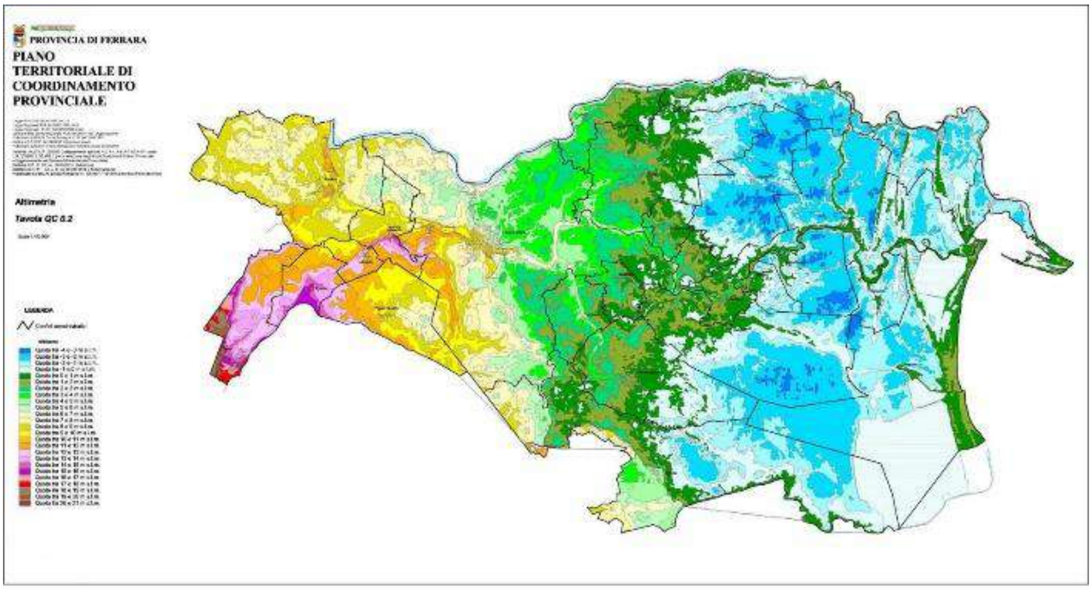

Fig.I.1.8 - Altimetric table of the province of Ferrara (https://geoportale.regione.emilia-romagna.it/catalogo/dati-cartografici/altimetria).

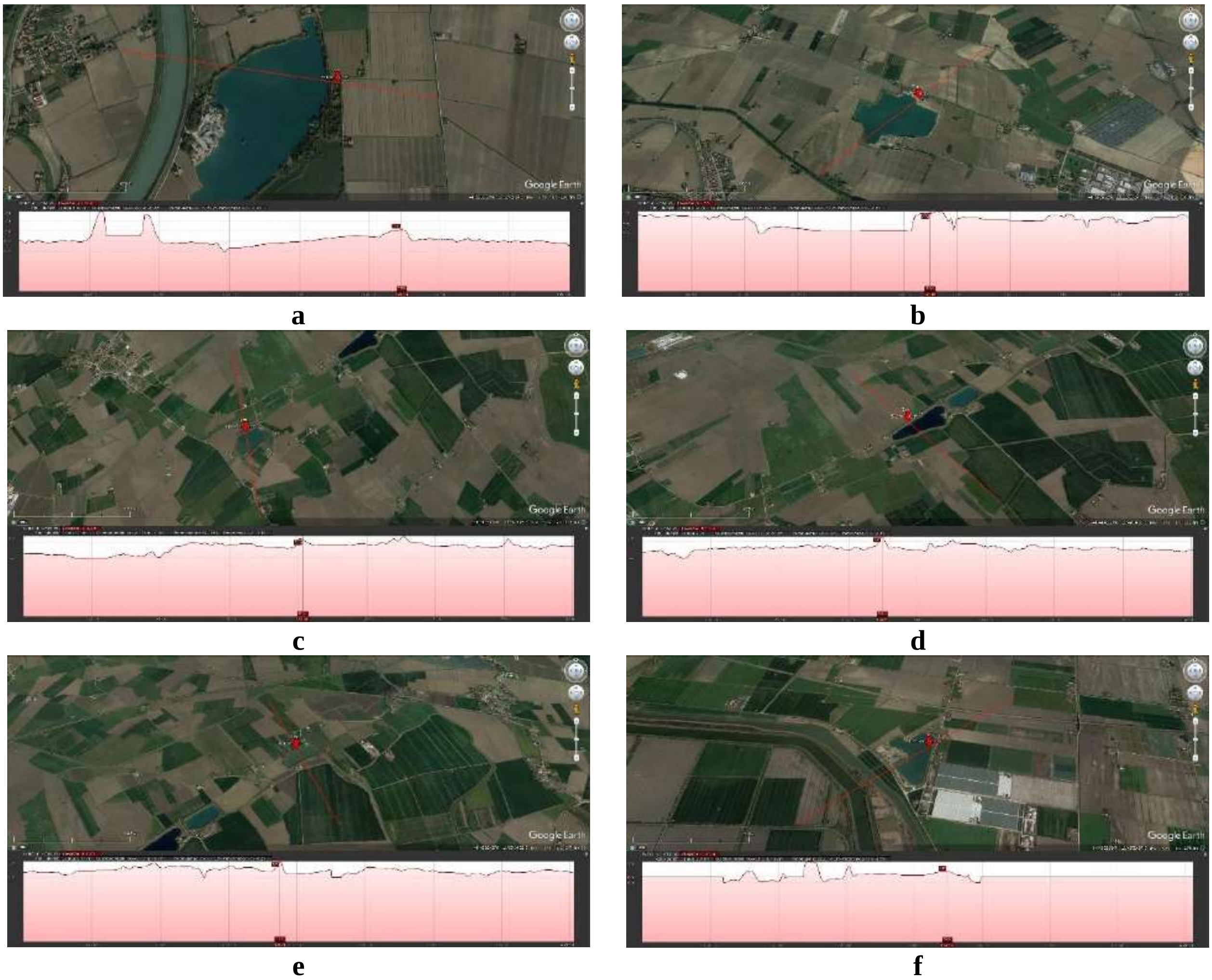

Fig.I.1.9 - Google Earth altimetric profiles across six quarry lakes in Ferrara district: a) Quaternario, b) Casaglia, c) Campanella, d) Tramonto, e) Gattola, f) Cavallara (accessed 11/12/2023).

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I.2 The geo-archaeological context of the research: quarries and palaeochannels around Ferrara

The studies of artificial basins for sand extraction intersect with various types of expertise: geology, with particular attention to sedimentology due to the large stratigraphy found, hydrobiologists and limnology for the characteristics of the waters, and riverine archaeology. The archive investigations, especially in the cartographic field, were useful support for the historical and archaeological investigations of the surrounding area. Ancient cartography associated with the examination of aerial and satellite photos gave the possibility of interpreting the trend of the river axes with the territory, highlighting the close relationship between settlements and attendance on land and in the waterway systems.

The preventive archaeology activities, as mentioned, begin before any excavation or expansion activity of the poles.

The selection of the chosen case studies, as examples of good practice in programming and monitoring all the activities, as mentioned, are the quarry of Settepolesioni – Bondeno, with the lake so-called Lago Quaternario, the Casaglia pole, Lago di Lago di Casaglia, the Cavallara quarry in San Giovanni di Ostellato, the Lago Tramonto in Gambulaga in relation with the coeval ex quarries now Lago Alba, Lago Campanella, and Lago Gattola.

Examining the sites from West to East, palaeochannels of the western mining poles can be traced back to the River Poazzo going into the Cassana meander, a digression of the Po di Spina, reaching the area of Voghenza, Gambulaga, then going to the coastal areas, across Ostellato. The waterways were active in the Etruscan, Roman, and Medieval Phases.

The ancient hydrographic context of the Ferrara Delta is characterized by the presence of waterway axes that develop through meanders and straight sectors. The latter is the result of the regulation of the riverbeds, certainly frequented since the Etruscan phase. The "large" Po branched off in an East – Southeast direction, separating into Po di Volano – *Olana*, Po di Spina – *Eridanus*, and, subsequently, to the South, into Po di Primaro (Fig.I.2.1).

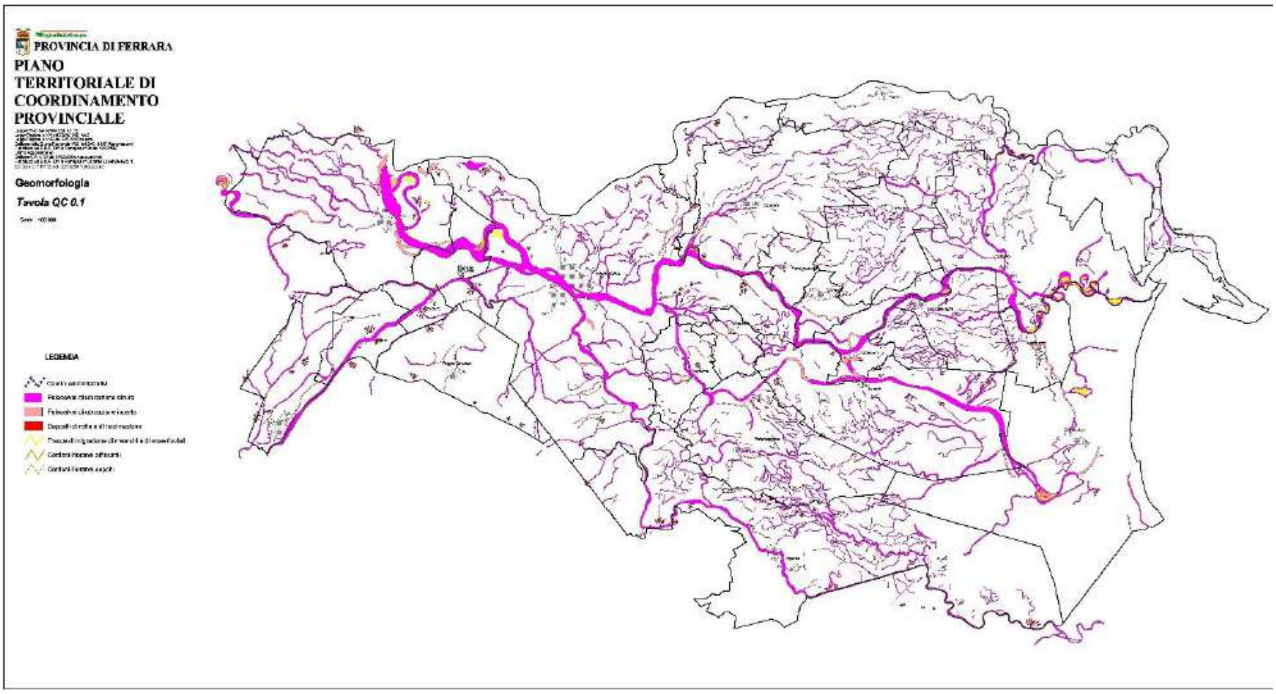

Fig.I.2.1 - Magenta: palaeochannels of certain location; pink: palaeochannels of uncertain location; red: overflow and flooding deposits; yellow: traces of migration of meanderings and river meanders; green: emerging coastal dunes; dashed green: buried coastal dunes (PTCP, Table Qc 0.1 - https://pvprovinciafe.lepida.it/pianificazione-territoriale-e-urbanistica/pianificazione-territoriale).

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The so-called Po di Spina, known from literary sources, crosses the centers of Voghiera – Voghenza in the Roman and medieval phase, a *vicus*, of Gambulaga, the wooded areas of Rovereto (formerly *Roburetum*), the territory of Ostellato to reach Comacchio, the *Castrum Cumiacli*, near the Church of Santa Maria in Padovetere[10], recently subject of archaeological investigations by the Superintendence in collaboration with the Municipality of Comacchio; such research has also highlighted a sector of the northern bank margin of the river branch, revealing a stitched wooden hull and some monoxyle pirogues[11].

In correspondence with the central sector of the paleochannel of the Po di Spina, *Eridanus*, the river divides in the direction of the Reno, parallel to the Sandolo, to deviate towards a small hamlet of the municipality of Portomaggiore, Gambulaga [12], an area characterized by fine sediment extraction centers active in the 1990s, now abandoned and converted into naturalistic oases. Lago Tramonto is an artificial basin in the aquifer and develops within a paleo-river bed with a meander oriented towards the North-East and a northern bank margin characterized by a high parafluvial rise (+2 m - 5.00 m above sea level). The stratigraphic context is characterized by alternations of clays, silts, and sands; the waters are green and mainly opaque due to the fine sediment suspended together with the algae. The historic river is recognizable in aerial and satellite photos.

The first research in the field of mineral exploitation of Ferrara quarries paleochannels was geological and has been underway since 1979 around Settepolesini di Bondeno.

Until a few years ago, the archeology of the inland waters of the Ferrara area had not been the subject of systematic studies and underwater surveys with direct and indirect geophysical surveys, but since 2009, the educational-scientific project *Underwater Archaeology of the Inland Waters*[13], coordinated by who is writing, examined the sector of study dedicated to the artificial basins in the paleo riverbed of the Po.

The evolution of preventive archeology[14] has made it possible to develop a new approach for the protection of underwater heritage also thanks to the technological innovation of tools for the indirect documentation of submerged sites. The combination of direct investigations and remote sensing has allowed us to increase the archaeological work and create new guidelines necessary to organize the excavation, protection, and conservation of the submerged heritage.

These waters are now characterized by shallow water with an average depth of around 10.00 -20.00 m (with a maximum depth of 30.00 m in Settepolesini); the thermocline is attested at depths between -3.00 and 5.00 m (the surface is affected by solar heating) to reach rather cold levels at the lake bottom of around 6 - 10°C. A dense algal composition often develops in warm surface aquifer levels, with a great growth of *Myriophyllum* (Fig.I.2.2).

Fig.I.2.2. Gambulaga, Lake Tramonto: *Myriophillum* forest.

[10] A specific study about ancient literary sourced: Calzolari 2004. Overview of the connection between ancient rivers and local archaeology: Fabbri 1987, Patitucci Uggeri 2002b, Corti 2007, Rucco 2020. An updated work is published by Badiali, Berti, Stefani 2022. About the geological studies: Bondesan, Masè 1984; Calabrese, Centineo, Cibin 2009; Luetti, Veronese, Brunaldi 2005; Stefani 2006 and 2020. About Voghenza: Berti 1984, 1987, 1989; Cornelio Cassai 1984.

[11] About the boat and the recent excavations: Ceserano 2014, Cesarano, Corti 2017, Beltrame, Costa 2023 and http://www.archeobologna.beniculturali.it/fe_comacchio/imbarcazioni_2014. htm.

[12] See Bondesan, Masè 1984; Bondesan 1990, 2005; Calabrese, Centineo & Cibin 2009; Luetti, Veronese & Brunaldi 2005; Stefani 2006, 2020.

[13] The project has been a collaboration between Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Bologna e le province di Modena – Settore Archeologia, Reggio Emilia e Ferrara, the Federation ITA F07 CMAS Diving Center Italia - Confédération Mondiale des Activités Subaquatiques, Comune di Portomaggiore Assessorato alla Cultura, Agriturismo ai Due Laghi del Verginese (Bucci 2020a and bibliography).

[14] Recently the ICA - *Istituto Centrale per l'archeologia* uploaded the new guidelines for preventive archaeology http://www.ic_archeo. beniculturali.it/it/275/archeologia-preventiva.

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PART II

CASE STUDIES

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II.1 Settepolesini

The quarry of Settepolesini in Bondeno is one of the major fine sediments mining centers in the Ferrara area: it borders to the north with the Strada Comunale Bondeno – Settepolesini, to the south with the Burana Canal, to the east with the Canale Cittadino, and the west with the Cavo Napoleonico. This is a large lot already studied by the University of Ferrara. The mining activity is currently regulated by the third P.I.A.E. of the Province of Ferrara. (Figg.II.1.1-2).

Fig.II.1.1 – Settepolesini di Bondeno. The area before the excavation (RER flight orthophoto, 1976-1978 - https://mappe.regione.emilia-romagna.it – accessed 09/11/2023).

Fig.II.1.2 - Settepolesini di Bondeno. Google Earth satellite image of October 2021 (accessed 11/12/2023).

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Excavation began in the 1980s and the first paleontological finds were recovered in 1989[15]. Actually, the lake is called Lago Quaternario (Fig.II.1.3).

Fig.II.1.2 - Settepolesini quarry lake, so-called Lago Quaternario (Cave SEI website, accessed 2016).

From a geological point of view, the quarry lake is located within the ancient course of the Po, in an area of strong depression and mud shoaling of the subsidence Pliocene - Quaternary Padano basin. As regards the depositional history of the strata, it is estimated that locally the sands found up to a depth of -15.00 m are of fluvial origin, deposited by the Po, while those located at greater depths are of glacial origin dating back to the Wurmian. The stratigraphy was documented by geologists up to a depth of -60.00 m from ground level and highlighted the presence of five main horizons composed as follows: clayey silts and silty clays between 0.00 and -2.00 m from the ground level, sands, and silty sands between -2.00 and -37.50 m, silty clays and clayey silts between m -37.50 and -40.00, sands between -40.00 and -55.00, silty clays from -55.00 (V.A.S. 2016: 4-5).

The finds recovered document a broad chronological excursus that goes from 50.000 to 12.000 years ago for paleontological data (Mammoth - *Mammuthus primigenius*, Woolly rhinoceros *Coelodonta antiquitatis*, Steppe bison *Bison priscus*, Megaceros *Megaloceros giganteus*, Elk *Alces alces*, Red deer *Cervus elaphus*, Roe deer *Capreolus capreolus*, Wild boar *Sus scrofa*, Horse *Equus ferus*, Wolf *Canis lupus*, Brown bear *Ursus arctos*, Beaver *Castor fiber*) (Figg.II.1.3-4), reaching the beginning of Late Antiquity as evidenced by human bone fragments of the 4th century AD.

An relevant datum is also represented by the presence of the remains of a boat found near the Farnia Fund southeast of the lake and therefore on the right bank of the palaeo-riverbed. More precisely, it is the bow of a flat-bottomed boat[16] found during the digging of a well at a depth of 7 m; the find dates to the 4th - 8th century. A.D., therefore, is probably in phase with the human remains found during the excavations and the anthropogenic area northern to the lake[17]. All the materials recovered from the dredge were studied and cataloged by the University of Ferrara[18].
Here we present the stratigraphy elaboration of two representative drilling showing the geo-archaeological context[19], with 2 autonomous progressive numerical lists.

[15] About the palaeontological finds: Sala 2012 – 2019.
[16] Archaeological asset cataloged by the system *Vincoli in rete*, Id. No. 3850614 and *Carta del rischio* Bene Subacqueo ID 925.
[17] As recently evidenced by Stella Patitucci Uggeri various findings from the Roman period are dislocated on the bumps of a completely fossil protohistoric palaeo-riverbed in the Po Valley. We already knew two of them since the 1960s inscriptions, that of the veteran T. Iulius Urbanus, from the Trevisana collection, and that of veteran M. Nevius Marcellus from Ca' di Dio, to which now he joined a fragment of a military diploma awarded to a veteran of Septimius Severus epoch (197-211). It confirms the already known predilection of the Po Delta as a place of retirement for veterans (Patitucci Uggeri 2015). See also Uggeri 2002, nn.87-92 and bibliography. The presence of a Late Roman necropolis at Fondo Cà di Dio is attested by the discovery of the tomb with stele dedicated to *Marco Nevio Marcello* by his sons *Prudens, Velox,* and *Cultor*. It is probably the tomb of a veteran of Spanish origin. This was not isolated: the entire surface appears to be strewn with ceramic materials and tiles. In 1969, after plowing works that led to the emergence of a Roman stele, an excavation was carried out under the direction of R. Benea: at a depth of 0.90 m a tomb was found, made of handle-shaped *sesquipedales* bricks. From the grave goods, reduced to fragments, an amphora with cremated remains and two fragments of fusiform ointment jars were recovered. The slab, in veined white Greek marble has a lower prominence to allow it to be fitted into the base stone, in red Verona marble. The stele is broken and recomposed; it has a tympanum at the top decorated with a Medusa head, flanked by two divergent dolphins. The stele is now preserved in Ferrara, at the National Archaeological Museum. Inv. no. 50029 (https://bbcc.regione.emilia-romagna.it/pater/loadcard.do?id_card=172614).
[18] About the findings: Sala 2002, 2010, 2012, Biancardi 2011, 2013.
[19] The data comes from the Emilia Romagna Geo Data Base online: https://ambiente.regione.emilia-romagna.it/it/geologia/cartografia/webgis-banchedati/prove-geognostiche-e-geotecniche.

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Beta-128160	*Mammuthus primigenius*	33930 +/- 700 By Present (BP)
Ox A-10521	*Mammuthus primigenius*	35800 +/- 500 BP
Ox A-10496	*Mammuthus primigenius*	38550 +/- 550 BP
Beta-128161	*Megaloceros giganteus*	32160 +/- 720 BP
Ox A-10497	*Megaloceros giganteus*	33700 +/- 350 BP
Ox A-10520	*Megaloceros giganteus*	25000 +/- 180 BP
Ox A-10498	*Megaloceros giganteus*	51300 +/- 2000 BP
Ox A-10522	*Coelodonta antiquitatis*	49100 +/- 2300 BP
Beta-128159	*Bison priscus*	13400 +/- 70 BP 2σ Cal.16584-15641 BP
Beta-133862	*Homo sapiens sapiens*	1850 +/- 40 BP 2σ Cal. 1875-1700 BP
Beta-148560	*Homo sapiens sapiens*	1850 +/-40 BP 2σ Cal.1880-1700 BP

Fig.II.1.3 - Sample code, species, age (Table by B. Sala: http://rivista.ibc.regione.emilia-romagna.it/xw-200201/xw-200201-d0001/xw-200201-a0023/#null).

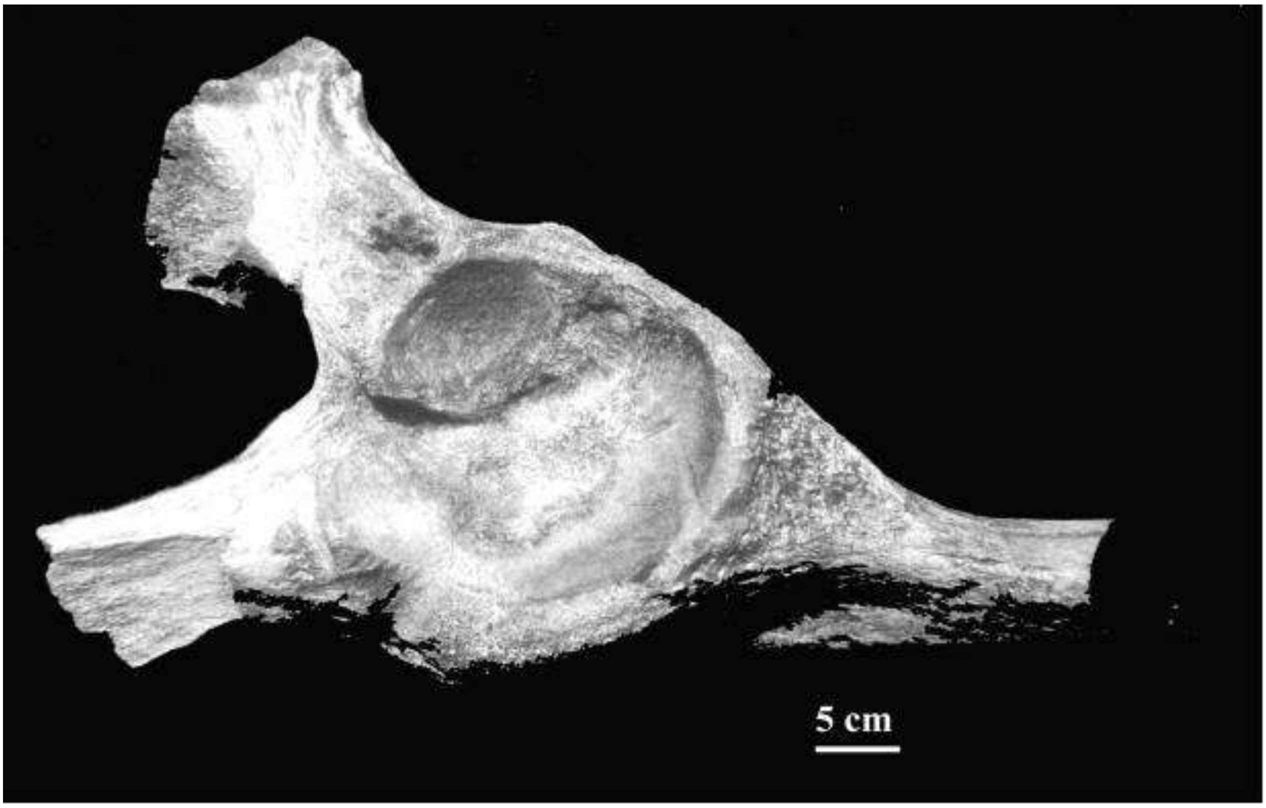

Fig.II.1.4 - *Mammuthus primigenius*: left hemipelvis (Gallini, Sala 2001).

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The detailed observation of the drillings here presented, as well as the sylloge of geological investigations completed on this site, demonstrate the depth of the river (about 15 m) and its activity of collateral sediment transport and flows (Figg. II.1.5-6).

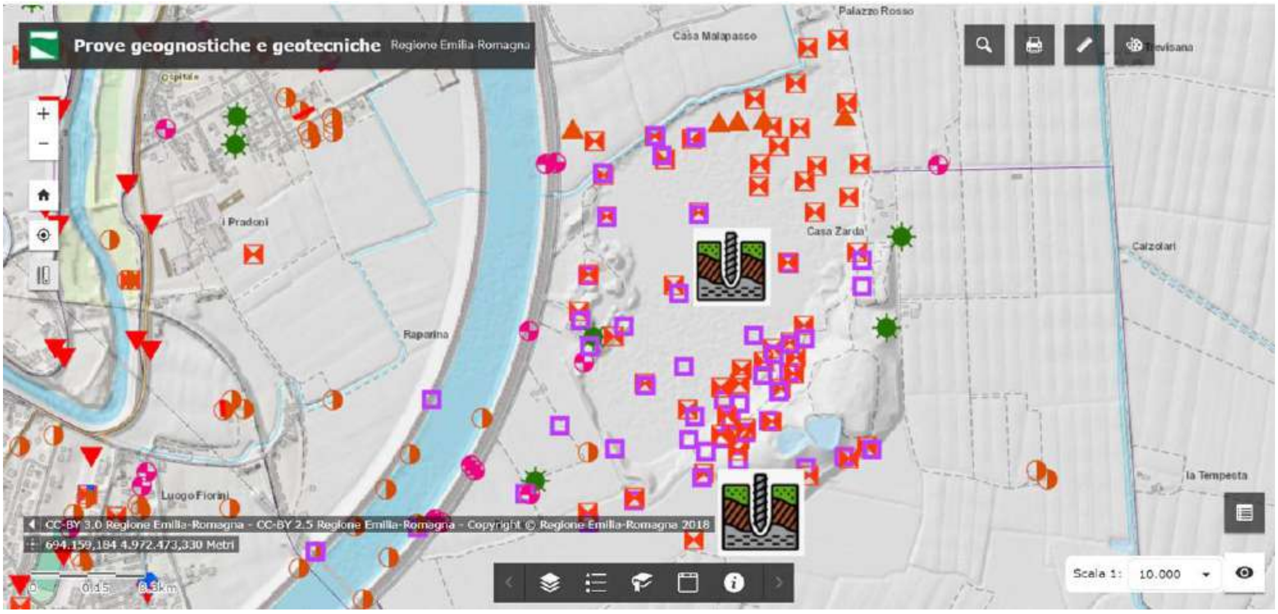

Fig.II.I.5 - Topographic location of the two selected core drillings indicated by icon (map: https://servizimoka.regione.emilia-romagna.it/mokaApp/apps/geg/index.html, accessed on 10/06/2023).

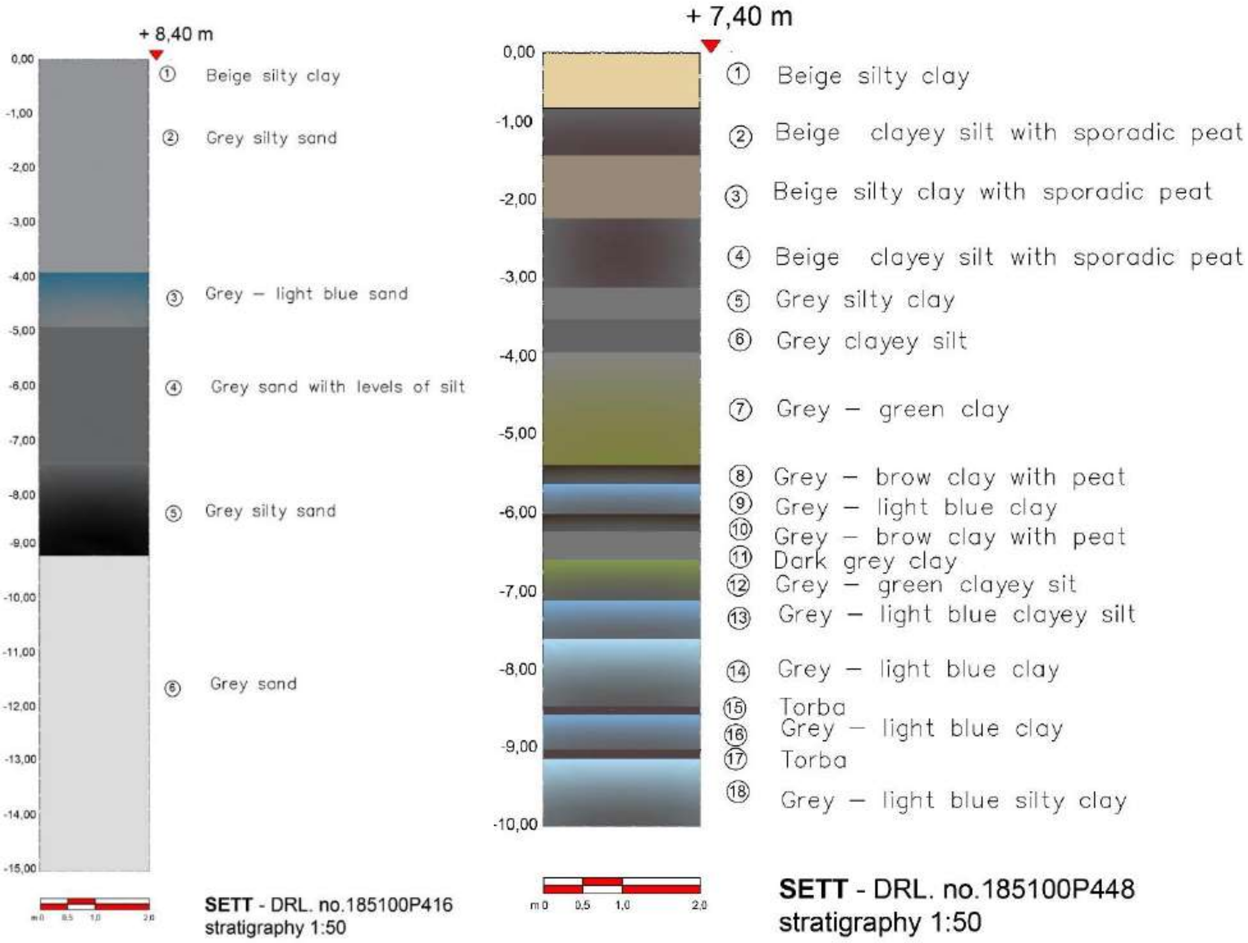

Fig.II.1.6 - Stratigraphy of the two selected drillings, north (to the left) and south (to the right), representing the palaeo-water course and the collateral depositional development.

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II.2 Casaglia

The Casaglia extraction center belongs to the same geomorphological context of Settepolesini; it insists on the palaeochannel of the Po Grande, next to a large meandering hill that winds between Vigarano Pieve and Mizzana to be identified with the oldest route of the Po di Ferrara; the para-fluvial hump of a secondary course, at the western end of the area, with a North-West-Southeast direction, joins the current Po beyond Casaglia Vecchia, coming from Ravalle. The satellite image shows the geomorphological context of the quarry (Fig.II.2.1).

Fig.II.2.1 - Casaglia. The area before the excavation (RER flight orthophoto, 1976-1978 - https://mappe.regione.emilia-romagna.it – accessed 09/11/2023).

Fig.II.2.2 Casaglia, quarry lake in palaeochannel of the River Po, Google Earth satellite image 2021 (accessed 11/09/2023).

The trend of the paleochannel was deduced from the study of aerial and satellite photos together with a series of systematic geological investigations carried out over a wide range also in the adjacent territory: 70 drillings confirmed the presence of sand at variable depths starting from m-3 from the

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campaign plan. As part of the preventive archeology activities, two large investigation trenches were opened using an excavator with a 2.00 m wide smooth bucket, reaching a level compatible with the water table for a length of approximately 50.00 m; the subsequent excavation took place in parallel bands, allowing constant stratigraphic verification. From the sections we see the superficial portion of the area is made up of a layer of brown silty clay (arable land, walking surface), covering an alluvial level of light gray clayey silt, which lies on a layer of beige gray silty clay, lapped by the water table.

The general succession of the superficial sediments can be described as follows: the area is covered by a layer of brown silty clay with turf (surface, US 1) above an alluvial level of light gray beige clayey silt US 2, which covers a layer of gray beige silty clay US 3; below US 3 is the paleochannel sand US4, which is overall homogeneous near the northern bank margin; at the center of the extraction pole the layer is interspersed with micro-layers and lenses of silt.

Fig.II.2.3 - Casaglia, a panorama of the superficial stratigraphy.

Fig.II.2.4 - Casaglia, a panorama of the superficial stratigraphy, detail.

Fig.II.2.5 - Casaglia Quarry Lake with dredge.

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From the geomorphological point of view, the quarry is located entirely in the Cassana meander which constitutes, together with the Poazzo, the vestiges of an ancient course of the Po, presumably active in the Etruscan age. This ancient river has deposited large thicknesses of sand. From the analysis of the summary map of the extractive potential, we deduce that the southernmost part of the pole is located entirely in the outcrop area of the interfluvial and marsh area deposits, made up of silty clays, clays, and clayey silts. These sediments here have a rather modest thickness (1 – 2 m) and therefore constitute a weak cap on the underlying sandy deposit. In the part of the pole that develops between the Canale Cittadino to the north and the Emissary Canal to the south, interfluvial area deposits emerge for approximately a quarter of the area, while the remaining part is made up of meandering plain sands[20]. The analysis of the stratigraphic sections shows that the thickness of the marsh deposits reaches, in a single survey, up to a thickness of approximately 7 m, but remains on average around 2 m. The geotechnical characteristics of the site are characterized mostly by medium or fine-grained sands or silty sands with a degree of density that varies with depth; it means that particular attention must be paid to the stability of the banks, since these are necessarily excavations under the water table, the balance of the banks depends on their geometric profile in static and dynamic conditions (that's why the use of remote sensing check is highly recommended, to prevent any danger for human beings while having excellent results).

Below this layer is the palaeo-bed sand which is almost entirely in the underwater part.

The excavation sector does not reveal any traces of anthropic activity or occupation but is evidence of the river phases between the Bronze Age and the Late Roman Period.

The sedimentological data show in the northern sector of the quarry margins a palaeosoil consisting of a thin layer of gray plastic clay (20-30 cm thick) with roots of slender shrubs (2-5 cm diameter), without traces of habitation (Fig.II.2.6).

The site is characterized by great stratigraphic homogeneity. The general succession describes a depositional sequence that testifies to the natural deviation of the river that flows past the Roman inhabited area of Cassana, where the remains of a rustic villa are found with portions of the brick wall foundations[21].

Fig.II.2.6 – Casaglia. Palaeosoil of thin layer of gray plastic clay with roots of slender shrubs

Some sporadic animal bone fragments were collected during the dredging and they are still in a phase of studies by the University of Ferrara (Fig.II.2.7).

Fig.II.2.7– Casaglia. Animal bone fragment.

Two selected geological drillings confirm the homogeneity of the stratigraphy; below we record the main layers observed before the basin excavation (Figs.II.2.8).

[20] About hydrogeological context: Gargini 2003, pgs. 6-7.

[21] See Visser Travagli 1990, pgs. 83-100 and Patitucci Uggeri 2016, pgs. 55-56: In the Prebenda fund excavations have been carried out since 1977 which have led to two series of rooms emerge, perhaps two wings of the same Roman building complex from the 1st-2nd century AD (20). Faint traces of floor mosaics emerge, which give evidence of the *pars dominica* of the villa, to which we must also refer the base of a trapezoid marble depicting Dionysus leaning against a column with *pardalis*. Neither kiln waste also comes from, which indicates the production of bricks, as well as clear *terra sigillata* and soapstone, which attest to a reduced survival until 6th/7th century. Some Roman capuchin tombs have been investigated nearby.

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Fig.II.2.8 – Casaglia. Topographic location of the two selected core drillings indicated by icon (map: https://servizimoka.regione.emilia-romagna.it/mokaApp/apps/geg/index.html, accessed on 10/06/2023).

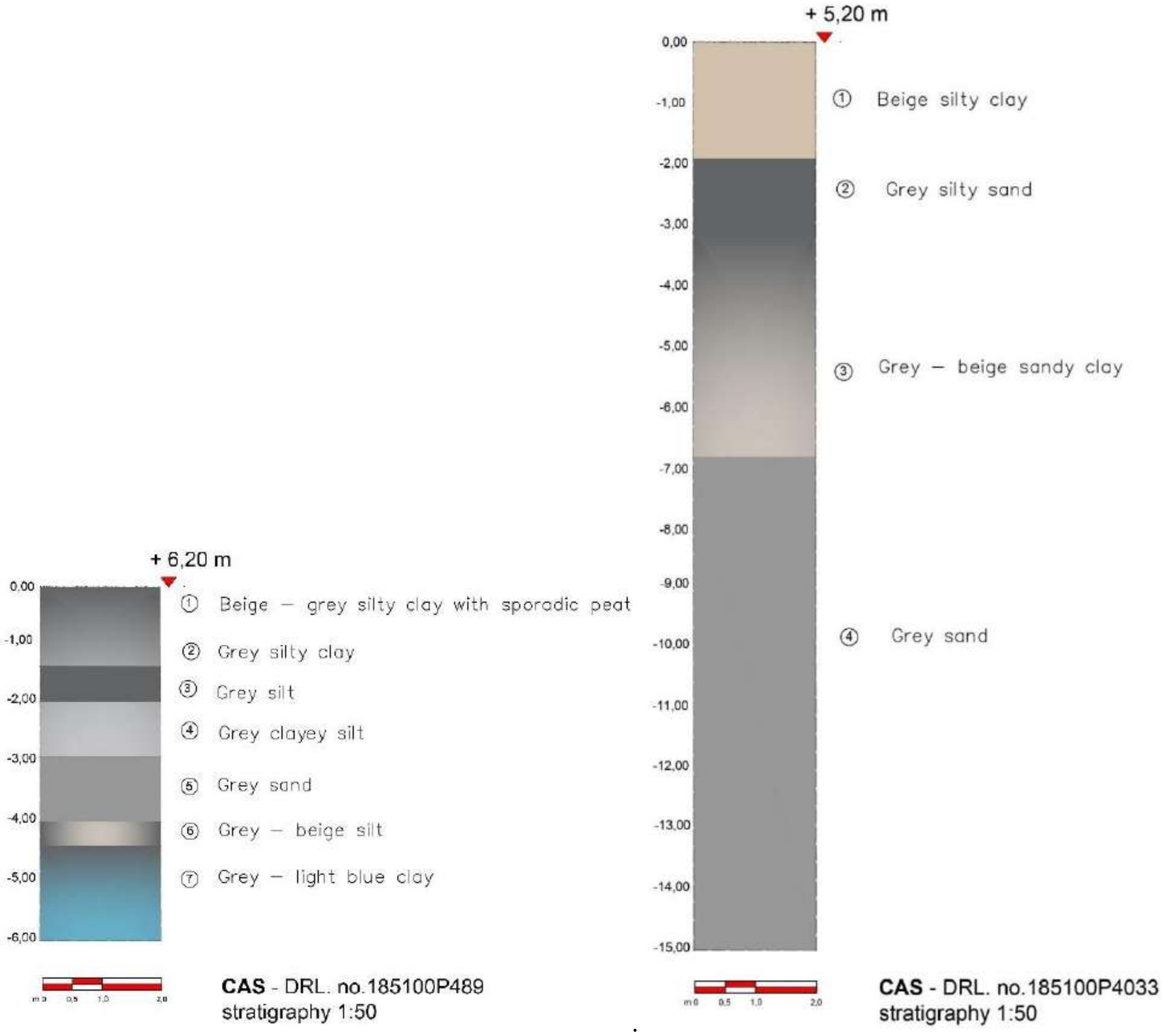

Fig.II.2.9 – Casaglia. Stratigraphy from the selected drillings (north and south).

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II.3 San Giovanni di Ostellato

Following the path of the Po towards the East we reach the Volano - Po di Spina bifurcation, with a big meander curving into the south, very well visible from satellite and aerial view. Traces of interfluvial palaeosoils are found at the Cantoniera Cavallara in San Giovanni di Ostellato – Ostellato (FE), north of the Navigable Canal, between Strada Valmana and Strada Provinciale 1 (Fig.II.3.1). The analysis of aerial and satellite photography highlights the presence of a paleochannel with meander and concavity migration facing southwest. The area characterized by the riverine geomorphological trace is located throughout the pole and is particularly evident in the southern sector (Figs.II.3.2-3)

Fig.II.3.1 Area before the excavation (RER flight orthophoto, 1976-1978 - https://mappe.regione.emilia-romagna.it – accessed 09/11/2023)

Fig.II.3.2 San Giovanni di Ostellato, cantoniera Cavallara, Google Earth satellite image April 2022 (accessed 11/12/2023)

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Fig.II.3.3 - San Giovanni di Ostellato before the quarry excavation (Quick Bird Flight 2002)

The surface survey was carried out with a route that followed the agricultural layout *in situ*, a system of rectangular fields separated by straight drains parallel to one each other. Throughout the northern area of the extraction hub, silty clays with tiny fragments of bivalves are attested, mainly *Cerastoderma glaucum* and small gastropods such as *Cyclope neretea*, typical of the local stratigraphy, evidence of ancient marine ingressions. By examining the records of the 13 geological surveys carried out, 5 cumulative sections were obtained. The stratigraphy presents 6 main units that are almost continuous in a linear sequence with a horizontal position in a simple coverage ratio: arable level, clay–silty clay on the surface, silt–clayey silt, fine sand, and sand. Small pea traces have been documented at -4.00 and –27.00 m belonging respectively to marshy levels and a probable very ancient palaeosoil. The current groundwater level emerges at approximately -1.00 m from the walking layer, therefore the excavation takes place in a submerged environment.

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From the *Regia Archaeological Landscape Map* and the Archaeological Map of the Province of Ferrara on an IGM basis preserved at the National Archaeological Museum of Ferrara, the surrounding territory records archaeological finds of different chronologies. The 2 main areas relating to San Giovanni di Ostellato n.38012 (PAR 1990: 242) and n.38023 (PAR 1990: 250) - pre-Roman and Roman) settlements (6th century. B.C. to the 2nd century AD), underline the continuity of anthropogenic scattered presence. The archaeological features are located on an alignment that tends to follow the course of the ancient river, especially in its straight sections. The paleochannel had been identified by S. Patitucci Uggeri (2002, followed by Calzolari 2004, and Muggia 2004) as a stretch of the Padovetere active until the 7th century AD. During the activity of sand extraction until today, as part of archaeological surveillance on the sediment taken from the water, no objects of material culture have been found to date, while to the east-southeast, very recent preventive excavations underway are documenting the remains of furnaces.

Fig.II.3.4 Core drilling with palaeosoils levels without anthropic traces

Fig.II.3.5 Topographic location of the two selected core drillings indicated by an icon (map: https://servizimoka.regione.emilia-romagna.it/mokaApp/apps/geg/index.html, accessed on 10/06/2023).

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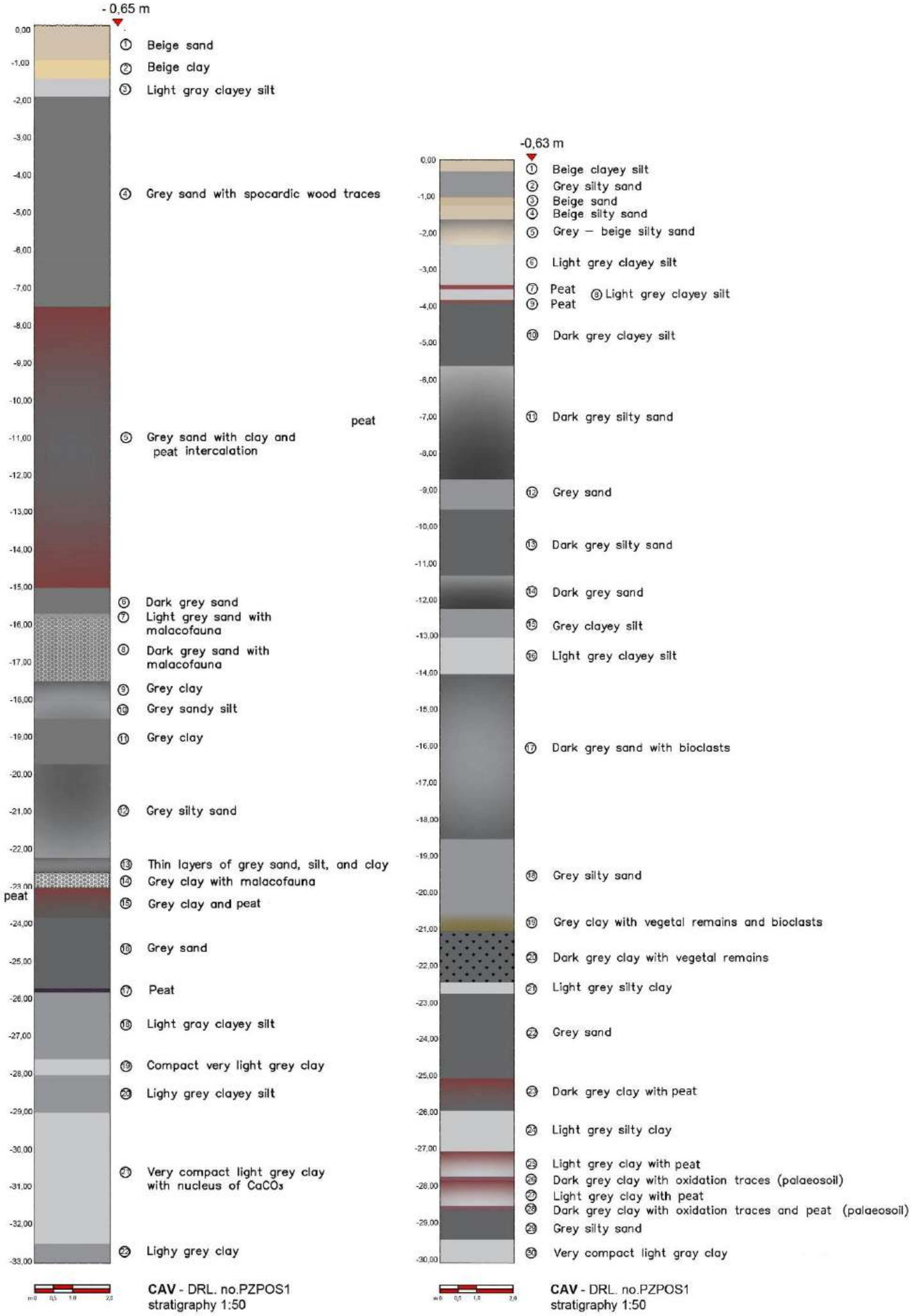

Fig.II.3.6. Stratigraphy of the selected deep drillings.

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II.4. Sandolo

North of Portomaggiore, between Voghenza and San Vito di Ostellato, there are 4 former quarry lakes aligned along an important paleo-river that was regulated between Roman and Medieval times: from West to East, we find the following lakes: Campanella, Tramonto, Alba, Gattola. As mentioned, the southern branch of the Po is divided in the direction of the Reno, parallel to the
Sandolo, to deviate towards a small hamlet of the Municipality of Portomaggiore: the area is characterized by abandoned mining poles converted into a naturalistic oasis, in the ambit of the local project Environmental requalification in ecological corridors, started in 2017 (https://www.unionevalliedelizie.fe.it/).
Campanella Lake is an artificial basin, born from quarry excavation in the palaeo-watercourse of the River Po; it is a few Km West of Lake Tramonto, located at the elbow of the meander of the ancient Po, between Via Veginese to the North, Via Campanella, to the East and Southeast, and Via Sandolo Gambualga to the West (Figs..II.4.1-2 -3-4).

Fig.II.4.1 Sandolo, area before the excavation (RER flight orthophoto, 1976-1978 - https://servizimoka.regione.emilia-romagna.it/mokaApp/apps/CORERH5/index.html – accessed 09/11/2023).

Fig.II.4.2 Sandolo, Lake Campanella. (Google Earth Satellite Image April 2022 – accessed 09/11/2023).

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Fig.II.4.3 - Sandolo, Lake Campanella, east -west panorma.

Fig.II.4.4 - Sandolo, Lake Campanella.
The northern sector corresponds to the elbow of the meander of the ancient river

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Relevant studies for the Campanella lake were carried out by the University of Bologna in 1995, by L. Forlani and G. Nanni[22] investigating the Sandolo wood fossil forest, cataloging 1519 wooden finds, including trunks, 2 artifacts, 3 roots, 7 cork samples, and 8 branches. There were parts of trees, shrubs, lianas, deciduous broadleaf and conifer. Between the three main units identified by the palaeobotanists, the third sampling conserves elements dating back to the Roman Period or the early Middle Ages. The sampling identifies *Populus*, *Ulmus*, *Salix*, *Quercus*, *Alnus glutinosa*, *Juglans regia*, *Juniperus communis*, *Prunus,* and many other species (Figs.II.4.5-6)

Fig.II.4.5 - Campanella Lake accumulation of timbers near the excavation (elaboration from Nanni 2002).

Fig.II.4.6 - Work in progress: the outcrop of wood in the water table (elaboration from Nanni 2002).

The C14 analyses dates to a chronological span between the fourth and sixth century AD.
As evidenced Nanni who studied the site at the time of the beginning of the excavation and by Cremonini[23] who had the opportunity to visit the site during the work in progress, in between the large quantity of wood extracted from the quarry works, the presence of squared beams with a section of considerable size among the various specimens of tree trunks attested with may exemplars. The number of specimens was concentrated within the sands of a large channel on the right of the *Eridanus*. The absolute dating carried out is therefore extremely limited in number compared to the total number of specimens available: they however suggest the first half of the 4th century AD. as the approximate age of the trunks of the arboreal association which must have represented the riparian vegetal landscape both in situ and floating in the Eridano riverbed. Given their dimensions, the beams could represent elements of the dock or riverbank protection works. A comparison can be made with the context of the LakeTramonto site (Figs.II.4.7-8).

Fig.II.4.7 – RER flight orthophoto, 1976-1978: traces of the palaeochannel with flooding north-west of Lake Campanella (https://servizimoka.regione.emilia-romagna.it/mokaApp/apps/CORERH5/index.html accessed 09/11/2023).

Fig.II.4.8 - RER flight orthophoto, 1976-1978: traces of paleochannel with sandy overflows in the section between Lake Campanella and Lake Tramonto (https://servizimoka.regione.emilia-romagna.it/mokaApp/apps/CORERH5/index.html accessed 09/11/2023).

As it is possible to deduce from the stratigraphy reported below obtained from boreholes corresponding to the central area of the palaeochannel of the Padovetere, alternating layers of silty clay and clayey silt, sand and vegetal traces are found starting from 2 meters from the walking surface and reaching over 10 meters deep, thus

[22] About botanical research: Nanni 2002; about the data interpretation and the archaeological context Bucci 2020a.

[23] Nanni 2002, p. 248, Cremonini 2021, p.79.

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outlining the depth of the river and the great flow rate (Figs.II.4.9-10).
The presence of construction elements evidenced by beams leads to hypothesize a possible dock or a structured bank margin traced by our research in Sunset Lake a few hundred meters northeast of Lake Campanella.

The accumulation attested right in the elbow of the meander can be traced back to the deposits of the river current and must also be related to flooding and breaches of the riverbanks in Roman and Late Roman times.

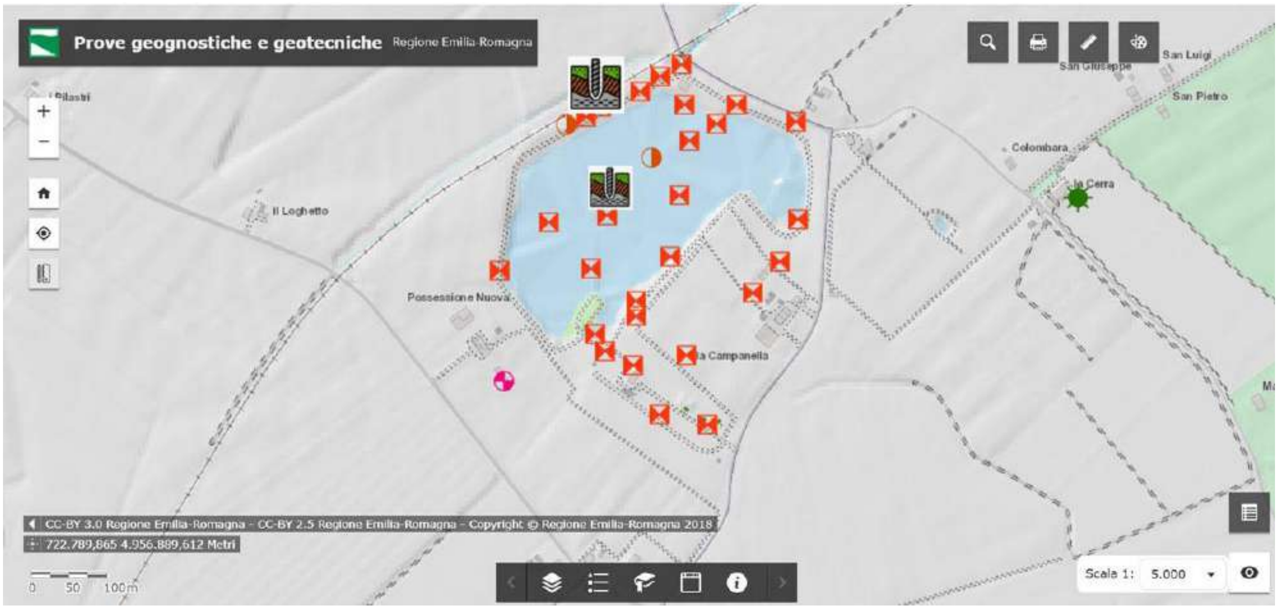

Fig.II.4.9 - Sandolo . Topographic location of the two selected core drillings indicated by icon (map: https://servizimoka.regione.emilia-romagna.it/mokaApp/apps/geg/index.html, accessed on 10/06/2023).

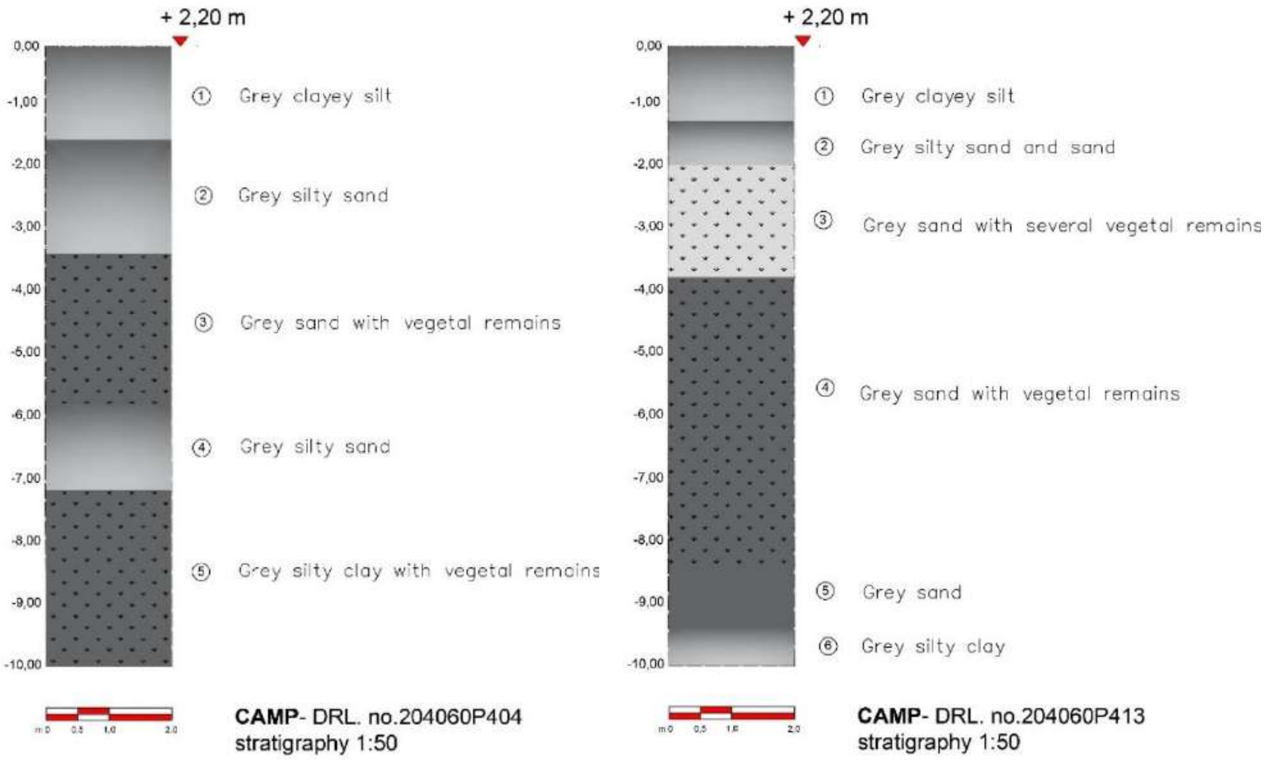

Fig.II.4.10 - Sandolo . Stratigraphy of the selected drillings (north and south).

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II.5 Gambulaga

The Tramonto Lake is between Via Verginese, Via Bargellesi, and the Verginese Canal. It belongs to the mentioned group of quarries located on the palaeochannel of the *Eridanus*. The lake develops within a paleochannel with a meander oriented towards the northeast, with a northern bank margin characterized by a high para-fluvial rise (+5.00 m above sea level). Traces of the ancient riverbed are partially detectable from the old satellite images (Fig.II.4.1)

Fig.II.5.1 – Gambualaga. Area before the excavation (RER flight orthophoto, 1976-1978 - https://servizimoka.regione.emilia-romagna.it/mokaApp/apps/CORERH5/index.html – accessed 09/11/2023).

Fig.II.5.2 Gambulaga, Lago Tramonto and Lago Alba (Google Earth Satellite Image April 2022 – accessed 09/11/2023)

As highlighted by Stefani, in the recent updates on the geological context of the Gambulaga territory, the area is part of the Po delta plain, in which exclusively fluvial sediments of rather recent Holocene age emerge. The very recent age is due both to the strong contribution of sediments, both from the Po Valley and the Apennines, and to the strong subsidence of this external portion of the

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Apennine foredeep, which is tectonically and seismically active. The plain discussed here developed on the external folds of the buried Apennines, so the anticline areas are characterized by lower subsidence rates than the syncline areas.

Fig.II.5.3 – Gambualga, Lake Tramonto, east west panorama.

The basin is located above a structural high, which locally reduces the rate of subsidence, favoring the presence on the surface of Roman and pre-Roman sediments, which are buried in nearby areas[24].
The sector of archaeological interest, highlighted by the sub-dial excavations of the *Fadieni* necropolis, immediately north of Lake Tramonto, suggested to perform underwater investigations through the educational-scientific project *ASAI Archeologia Subacquea delle Acque Interne - Underwater archeology of inland waters: investigations in Lago Tramonto in Gambulaga* (FE), active from 2009 to 2019[25].
We analyzed local geological drillings and penetrometric tests performed in 1990, preliminary to the quarry excavation. Perforation No. 204060 P4242 Comune di Portomaggiore Dato R/7 SONGEO, after 3 m of silt alternated to gray sand, shows a level of grey medium sand with wood at a depth of 6.8–7.7 m (from the ground level). The presence of wood gives a useful comparison to our database, coming from direct investigations. This data, compared with the lake-bottom measures, coincides with our main, detected archaeological, underwater findings. The falda level at the time of the 1990 drillings and penetrometric analysis was found to be 2.5 m, which means the archaeological level was at a depth of 5.5 m. As visible from the satellite photo, the palaeo-watercourse is partially obliterated, exactly in coincidence with the archaeological site.

Two specific drillings investigate in detail two different depositional situations. To the South side, we have the river with its “clean” sediments, and to the North side, there are traces of ancient human settlements, confirming all our preceding research. Drill No. 1/2017 reached 5 m depth and presented the following stratigraphy (expressed in meters): from 0 to 0.60 there was beige silt, 0.60−1.25 sandy silt (beige and orange), 1.25−1.55 grey silty sand, 1.55−1.80 grey coarse sand, 1.80−2.20 grey sand, 2.20−3.10 beige lightly silty sand, and from

[24] Stefani 2020.
[25] About geological map of the area: Calabrese, Centineo, Cibin 2009, Stefani 2020; on the Fadieni necropolis: Berti 2006 and 2020; Bucci 2010a, 2010b, 2015, 2018, 2020.

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3.10−5.00 there was grey coarse sand (Figs. II.5.4-5).

The second drill, on the North shore, was 8 m deep and showed the following levels (expressed in meters): from 0−0.50 there was beige silty clay, 0.50−1.35 brown mottled silty clay with vegetal traces, 1.35−2.40 beige orange mottled clayey silt with traces of reeds, 2.40−3.15 beige silt, 3.15−3.65 grey clay (palaeo-soil), 3.65−4.30 grey−light blue silt, 4.30−4.50 grey clay with micro fragments of peats, 4.50−5.10 grey sand, 5.10−5.40 grey clay with a nucleus of $CaCo_3$, 5.40−5.60 violet clay with micro-carbonaceous cores and vegetal traces (palaeo-soil), 5.60−6.10 grey silt with vegetal traces and malacofauna, 6.10−7.40 violet silty clay with micro-carbonaceous cores and vegetal traces (palaeo-soil), and from 7.40−8.00 there was violet silty clay with peats micro levels (Figs. II.5.4-5).

The area was covered by beige silty clay that lay on a brown mottled silty clay with vegetal traces, concerning the last centuries (see Appendix A for a graphic depiction) Stratigraphic Units 1, 2, and 3. A natural alluvial level of beige silt (US 3) covered the first palaeo-soil, connected to a downslope of the riverbank. The natural matrix of grey clay included micro-fragments of bricks belonging to the Roman and Late Roman Periods. There are a couple of typical inland water layers, with gray and light-blue silt, possibly indicating a slow phase of the watercourse from palaeo-soils or beds of inland waterscapes.

The sedimentological characterization performed during 2017 evidenced, in many samples, the presence, of seeds belonging to *flora palustris*, typical of inland waters (see over).

Fig.II.5.4 – Gambulaga. Topographic location of the two selected core drillings indicated by icon (map: https://servizimoka.regione.emilia-romagna.it/mokaApp/apps/geg/index.html, accessed on 10/06/2023).

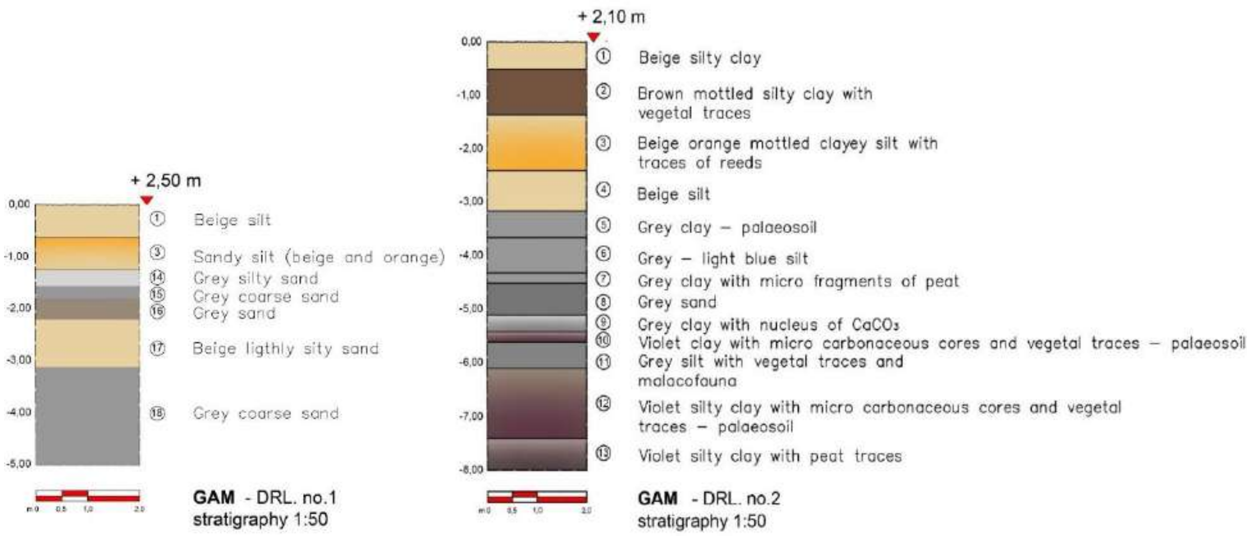

Fig. II.5.5 - Stratigraphy of the drillings

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Thanks to a series of direct underwater surveys we detected the following sequence of anthropic traces: from East to West (not necessarily in phase with each of the elements indicated here, if not in part) a sandy hill was found with two poles driven into the ground and scattered fragments of semi-finished wood (m -3.50 about); to the south of the hill at a greater depth, a beam with four housings (already previously surveyed, length approximately -6.00 m – Fig.II.5.6); two enormous tree trunks, over 10.00 m long, very similar to each other with a bifurcation towards the center of the lake (Fig.II.5.7), lie next to a landslide with clay fragments and animal bones (Figs.II.5.8-9)

Fig. II.5.6 - Wooden beam with slots for joints.

Fig. II.5.7 - Long forked trunk 1.

Fig. II.5.8 - Forked trunk 2 with a landslide on the east side; clayey matrix with worked wood, ceramic fragments, and remains of animal bone (the red arrows indicate traces of binding of the tapered poles).

Fig. II.5.9 - Forked trunk 2 on the west side.

Some fragments of monoxyle pirogues are scattered near the northern shore edge of the lake, probably taken out of context and damaged by the works of the 1990s. Towards the western side, in the lake center, emerging at 7.9 m, a semi-fossil tree trunk rises straight from a non-visible paleosoil. Going up towards the west - north-west end of the lake we detected the presence of foundations perhaps relating to a guard tower[26] (Fig.II.5.10).

Fig. II.5.10 – Possible foundations of the guard tower.

There is a bank margin reinforced with a system of vertical poles. At the bottom of the lake, we can note the presence of fragments of wooden boards, and large pieces of bark probably designed to create a structured bank perhaps with vertical and horizontal elements (now partially collapsed because of the old quarrying activity - which ceased over time ago.

[26] For further information on direct underwater investigations and full data of the project: Bucci 2020a and bibliography.

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In 2013, a bathymetric survey and the cataloging of the 203 finds, deposited at the National Archaeological Museum of Ferrara, have been concluded, demonstrating the anthropogenic frequentation and the activities along the riverbank.

To reach a full understanding of what remains of the northern bank margin of the *Eridanus* in a river stretch of great historical importance, i.e. the sector between Voghenza and Ostellato, a meticulous analysis of shadows and shapes attributable to natural and artificial structures had been completed (see *infra*).

The detection has been completed with an integrated instrument, echo sound scan sonar *Humminbird 1198c SI Combo*, a set on a small aluminum boat with an electric-powered engine, we completed a sequence of 20 parallel swaths, as well as perimeter scanning, beginning from the East side of Lake Tramonto on a total area of m 645.00 × 565. The echo scan records latitude and longitude coordinates for later examination, and depth information for each coordinate value is stored differently for each khz beam from the transducer. The recorded files are stored in two formats, directly, when recorded. The first format is a general allocation file for a Humminbird unit (.DAT files, which recall spatial information connected to depth information). The second format is .SON and this is located in the folder associated with the waypoint that started the original recording track (depth information from each kHz). The instruments detected ancient and modern anomalies. The criteria for anomaly identification were based on the comprehension of peculiar shapes and shadows, identified by watching the *.DAT* files, side and down image files on the computer, displayed by the software *Hum Viewer*. Examining the recorded echo scan track files, we isolated the presence of natural downslopes from the settlement of sediment (after quarry excavation), natural very compact layers of clay, tree trunks belonging to an ancient phase of forestry, wood poles, and beams, and some accumulations of bricks and fragments of pottery. The shapes of the artifacts with sharp edges were evident on the sediment bed, confirming and implementing the archaeology database of the lake.

We georeferenced the discoveries area on a satellite image positioned on Google Earth (Fig.II.5.11)

Fig.II.5.11 - Gambulaga, Lake Tramonto Satellite image: in the yellow rectangle the riverbank area.

Below are 32 "down images" from the two latest scans elaborated with the side-scan sonar data. The records perfectly describe the lakebed and give the main data for a reconstruction of the Roman and Late Roman submerged landscape: a riverine anthropogenic settlement with structural elements, related to the North side of the *Eridanus* – *Padovetere*. The first session is presented with an orange background, and the second with a blue background, both with dedicated progressive numbering preceded by the acronym *SSS* = *side scan sonar*; anomalies location position in Figs.II.5.11**)**.

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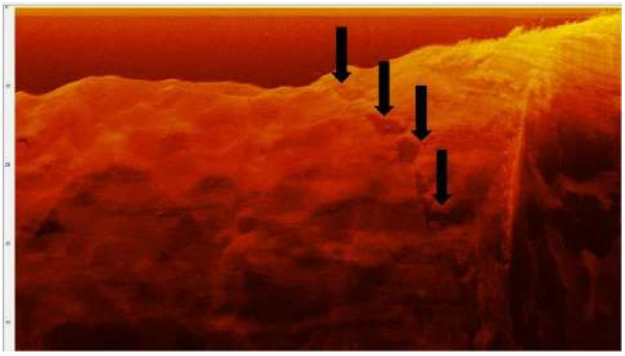
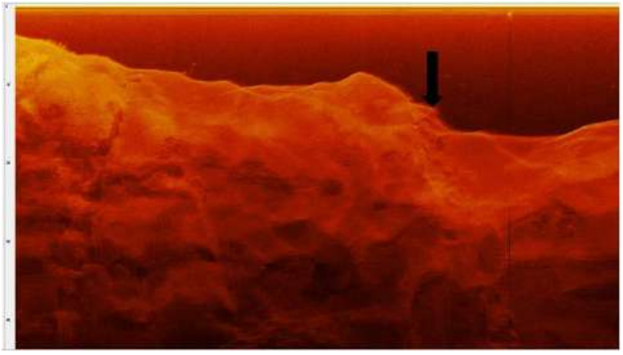
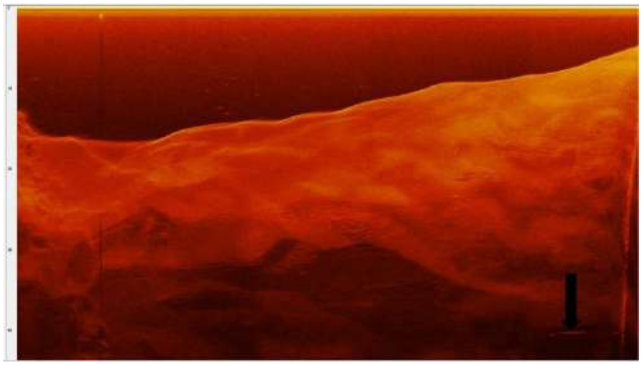


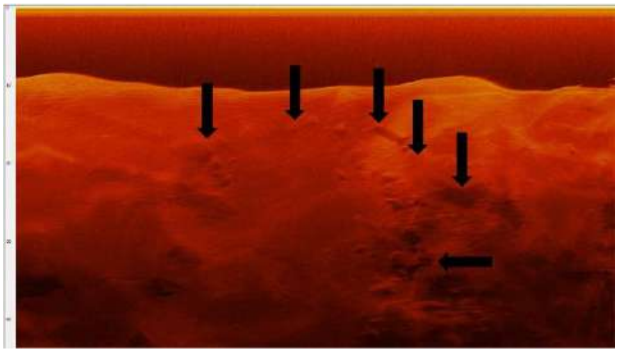
SSS1 - The northern bank margin highlights the overhanging layer of compact clay.



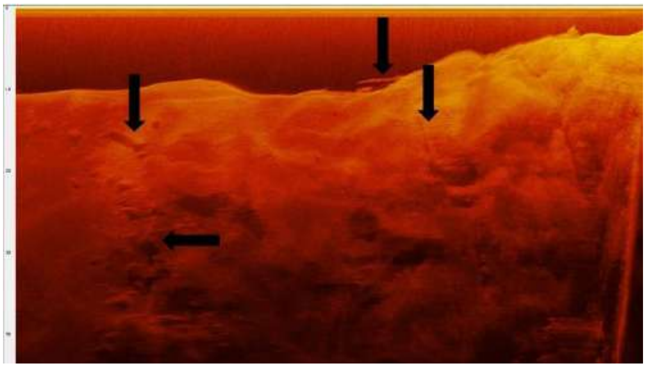
SSS 2 - Trunks outcropping from the clay layer.



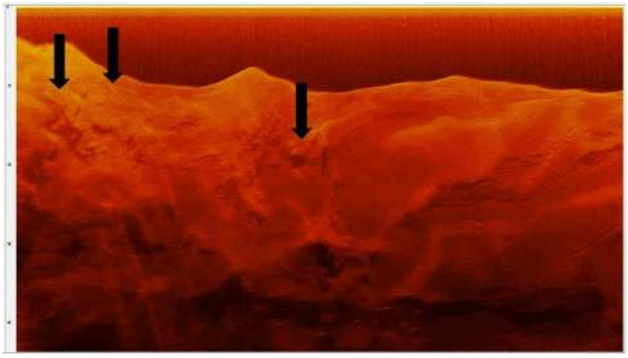
SSS 3 - Horizontal trunk slipped out of place.



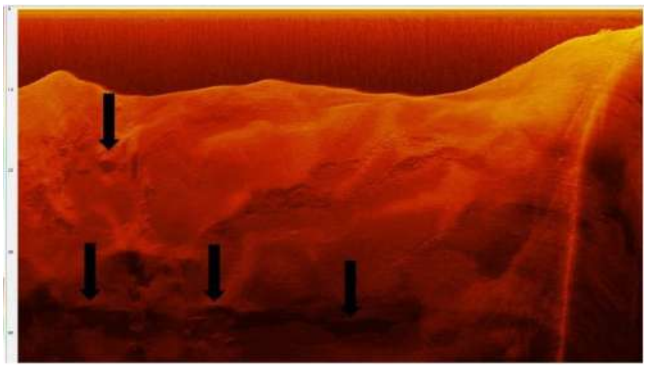
SSS 4- Area excavated with dredge, collapsed bank margin, elements in dispersion.



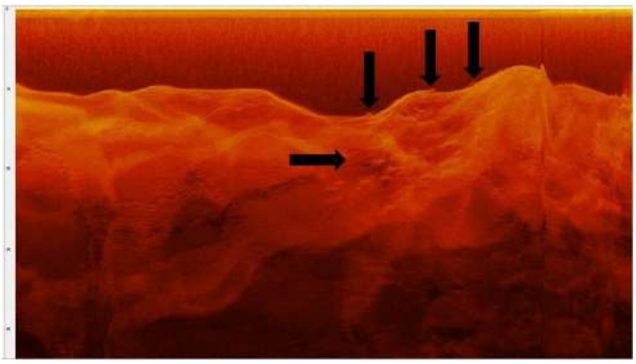
SSS 5 - Trunks protruding from the northern bank edge and landslide.



SSS 6- On the left traces of the destroyed settlement, in the center landslide with dispersing materials.



SSS 7 - At the top, protruding trunks, at the bottom, a compact layer of clay.



SSS 8 - At the top, poles are driven into the ground, in the center layers with remains of anthropic material.

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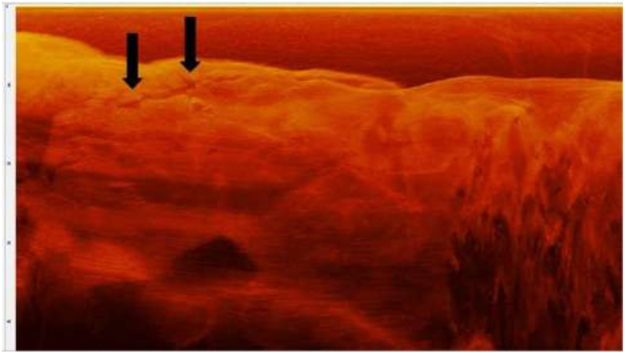
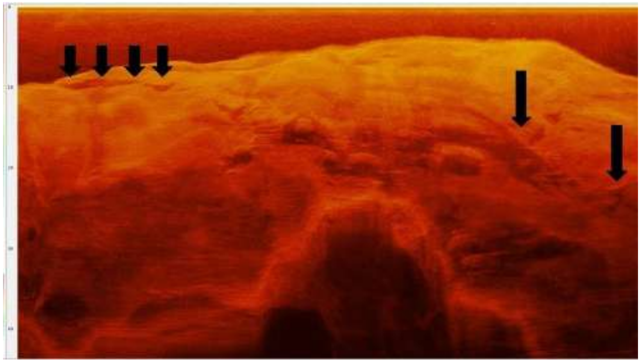
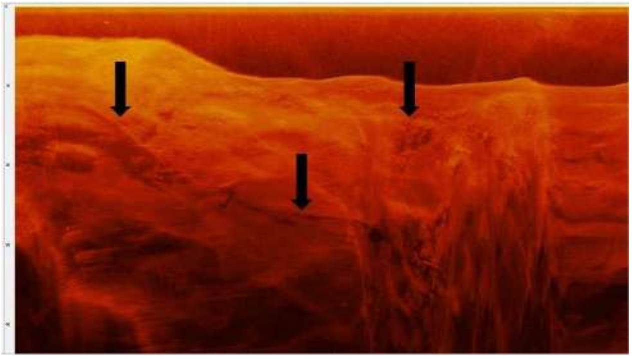


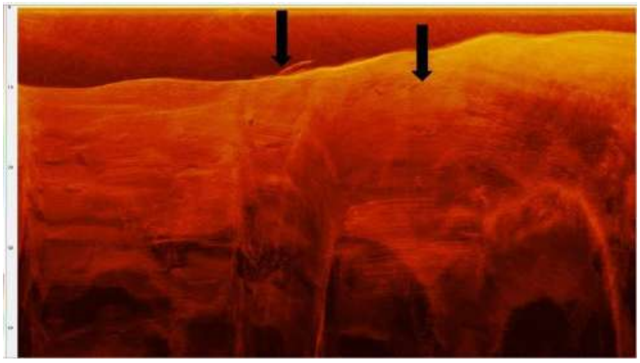
SSS 9 - Structured bank margin, west-east perspective.



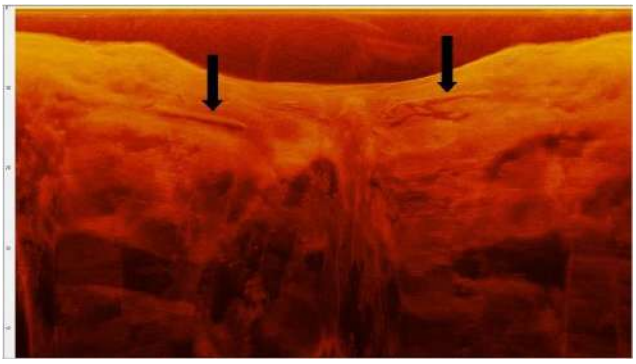
SSS 10 - River quay, east-west perspective.



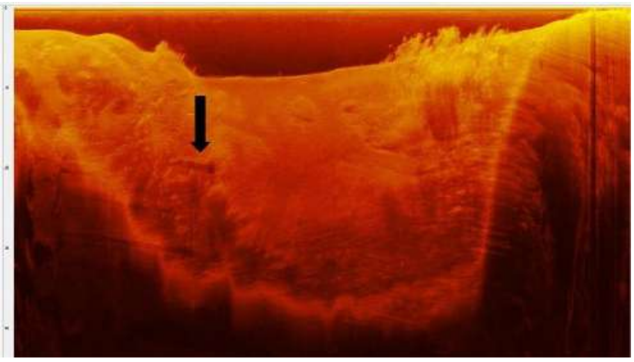
SSS 11- Logs on the left, fixed poles in the center and to the right.



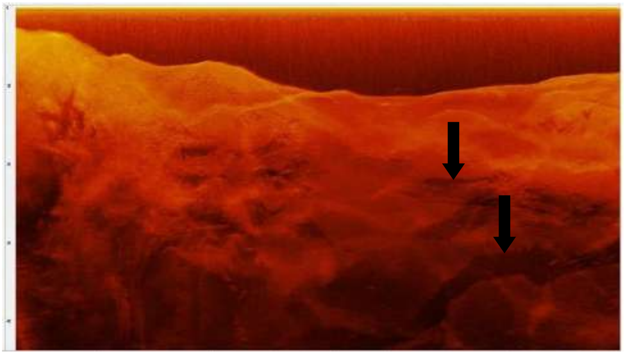
SSS 12 - Emerging trunks and dispersing poles.



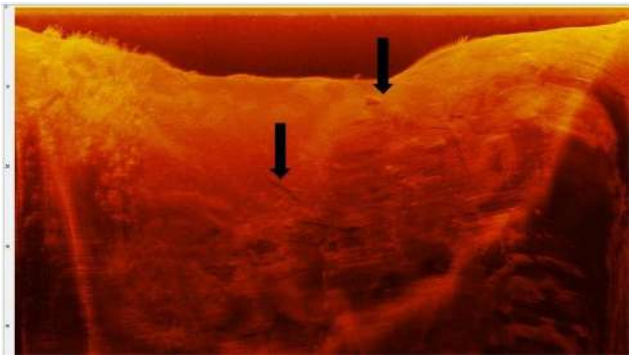
SSS 13 - Two large trunks near the northern bank margin.



SSS 14 - Trunk protruding from the stratigraphy and clay blocks decontextualized.



SSS 15 - Trunks and underexcavated sectors.



SSS 16 - Trunks and wood fragments in dispersion.

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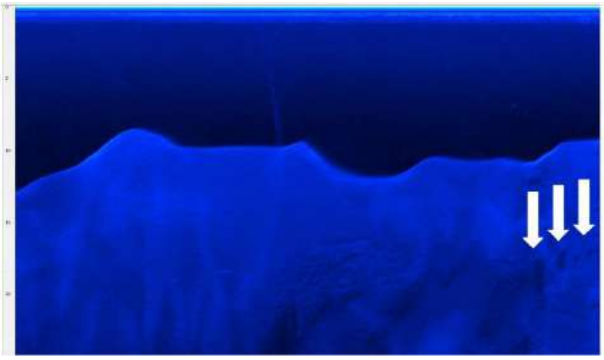
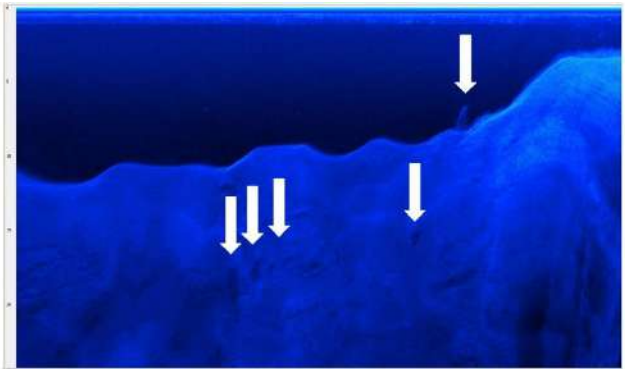
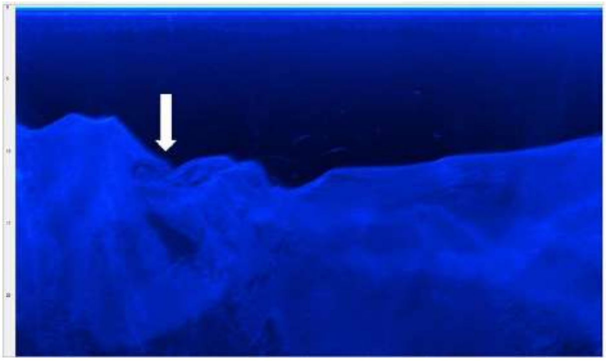


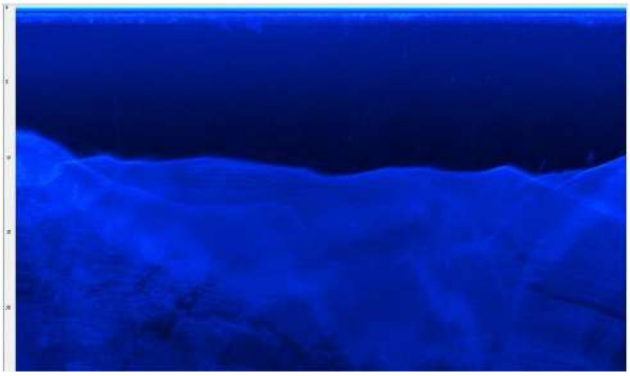
SSS 17 - Poles jutting out in correspondence with the layers relating to the river bank.



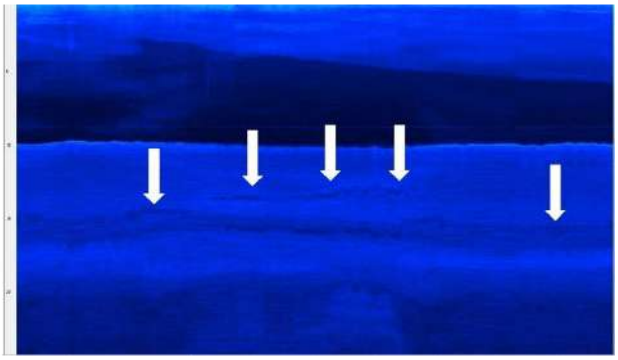
SSS 18 - Poles jutting out in correspondence with the layers relating to the river bank.



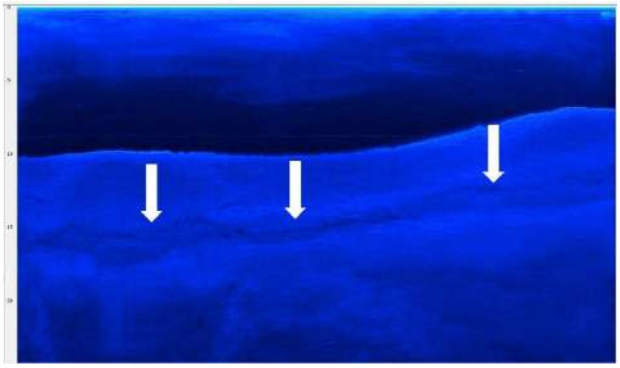
SSS 19 - Detachment of the bank margins with landslide.



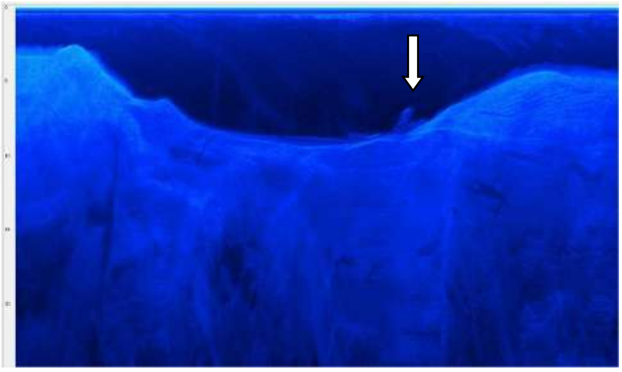
SSS 20 - Canyon and clay bank.



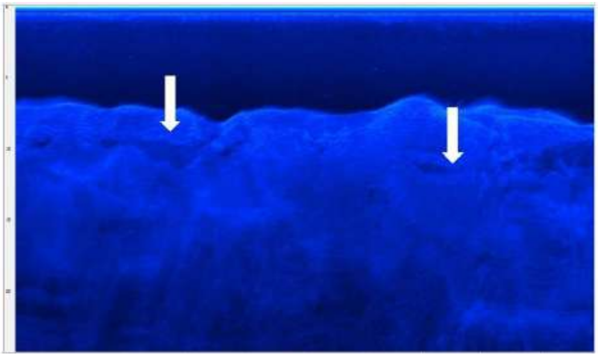
SSS 21 - Panorama of the bank margin with an east-west trend: the clayey layers are highlighted.



SSS 22 - Structured bank margin.



SSS 23 - Trunk or possible tree emerging from the lake bottom.



SSS 24 - Two sectors of the bank and pegs.

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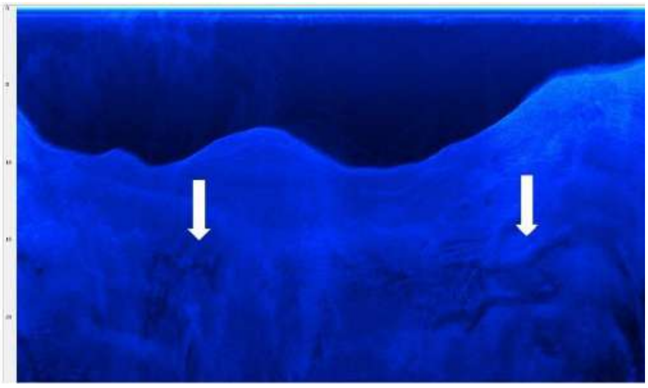
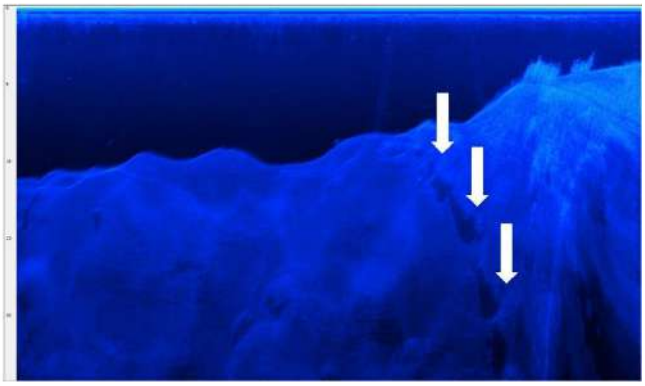
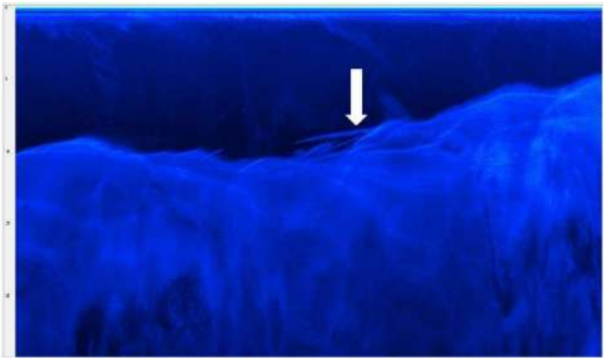


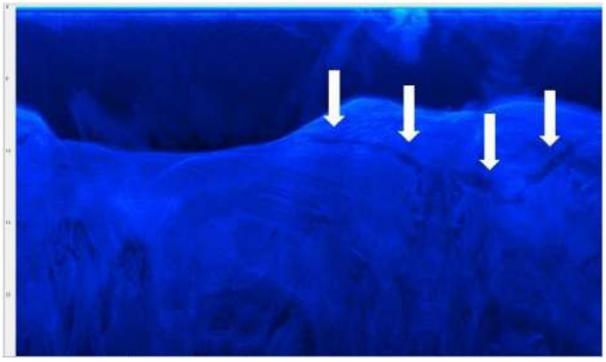
SSS 25 - On the left remains of poles, on the right landslide of the remains of the parafluvial settlement.



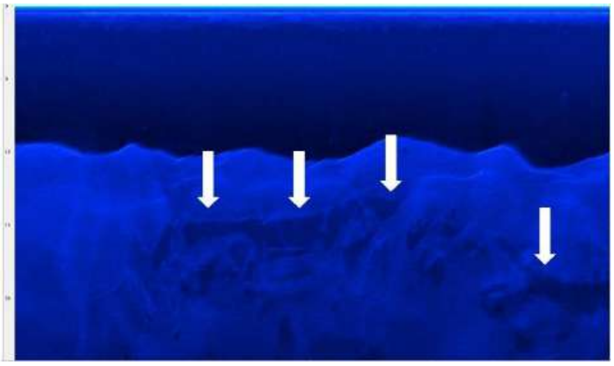
SSS 26 - Structured bank margin, sector attributable to the quay with piles, east-west perspective.



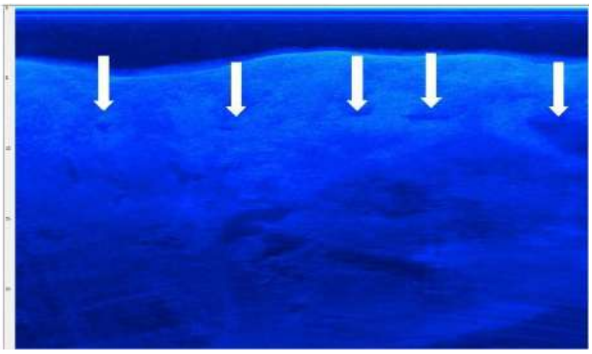
SSS 27 - Overhanging trunks near the dock.



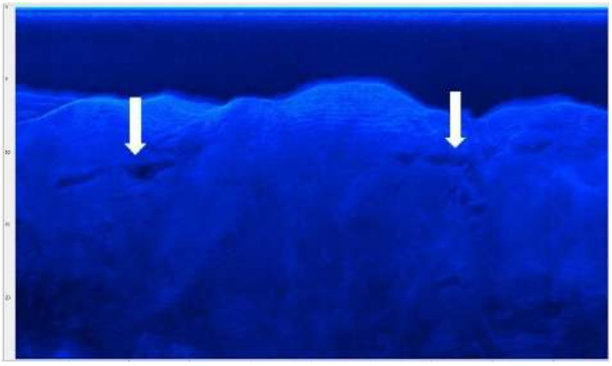
SSS 28 - Area with structured dock and landslide.



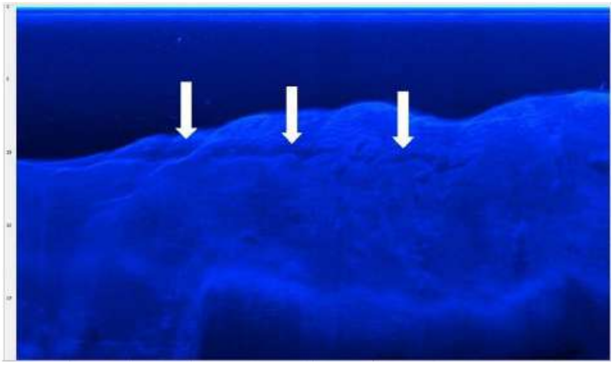
SSS 29 - Bank margin structured with poles and wooden elements collapsed out of place.



SSS 30 - Traces of the antropogenic bank margin and a trunk below.



SSS 31 - Large tree trunk, clayey bank margin, and collapse of the margin itself with landslide and dispersing materials.



SSS 32 - Structured bank margin.

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With on-site surveys, we checked the new diagnostic evidence collected, concentrated in the northwest area. The northern bank of the ancient river was made of compact clay, with quite vertical excavated margin and micro-depositional levels of clay and silt, visible on .DAT files as a long dark rectilinear shadow running West-East (Fig.II.5.12).

Post-processing analysis of the echo side scan sonar data allowed us to take measurements of the big trunks laying on the silty clay, close to the northern river bank: they were almost 10 m long. We also detected traces of the quarry excavations, better understood with immersion on-site.

There was a big flow, that has already been studied by geologists, at the southeastern side of the lake, which likely modified the local landscape at the time of the destructive flow. Our research suggests a catastrophe of the Late Quaternary, happened at the beginning of the Early Middle Ages. The chronology is documented by more than 200 finds (pottery, bricks, tiles, and some glass fragments – see in bibliography Bucci 2020 and Rossetti).

At the current state of the studies, it is possible to hypothesize how a catastrophic event of a hydrogeological nature, i.e. a violent flood, connected with an exceptional flood of the branch of the Po, caused the demolition of structures near the northern bank of the river, covering everything. The large, forked trunks and most of the downed piles are iso-oriented, sub-parallel in the direction of the possible flood current; they are oriented in a similar way to the Fadieni stelae which were not knocked down voluntarily (see Berti 2006), but rather by natural events, attributable to Late Antiquity (see Berti 2006, Bucci 2020a, Stefani 2020).

The presence of archaeological material in dispersion and secondary layering was determined not only by the quarry excavations but, above all, by a much older natural event. The remote cause of the destruction of the northern shore margin of Lake Tramonto is perhaps to be found in the diluvium mentioned by Paolo Diacono in *Historia Langobardorum* III.23: *Eo tempore fuit aquae diluvium in finibus Venetiarum et Liguriae seu ceteris regionibus Italiae, quale post Noe tempore creditur non fuisse.*

For a better understanding of the site, georeferenced 3D bathymetry, 3D plan views, and 3D sections were obtained from the remote sensing investigations (Fig.II.5.13)

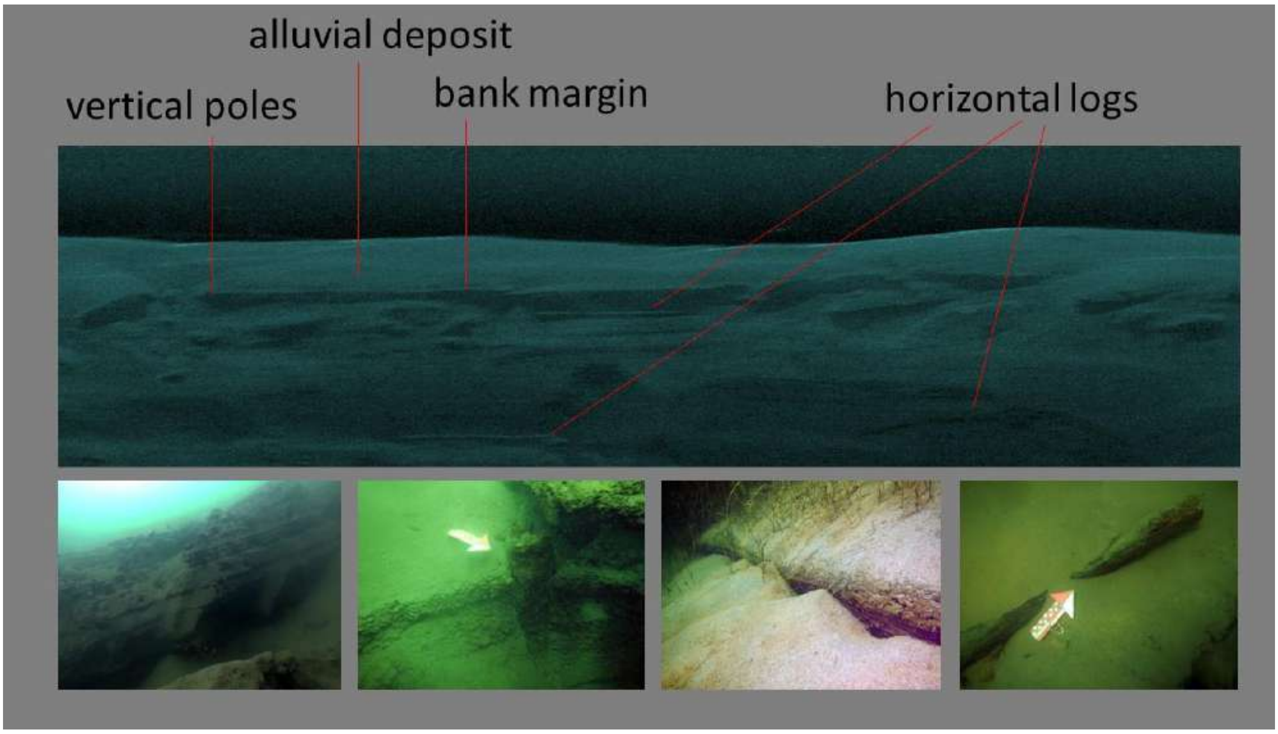

Fig.II.5.12 - Down image visualization of the river bank with the main elements recorded, below some photographic details; from left to right: margins bank under excavated, pole in site, horizontal log, collapsed pole.

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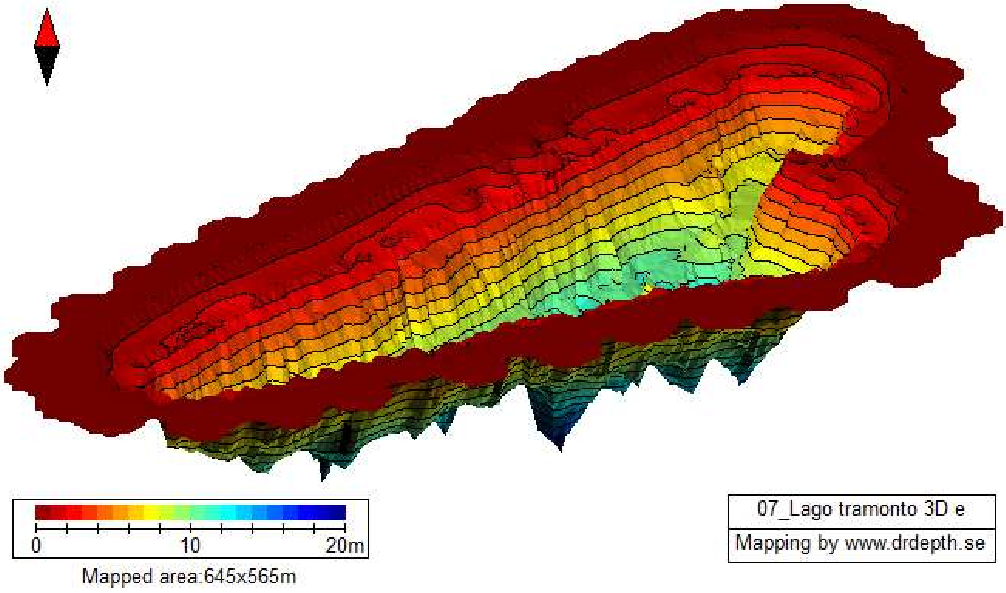
a



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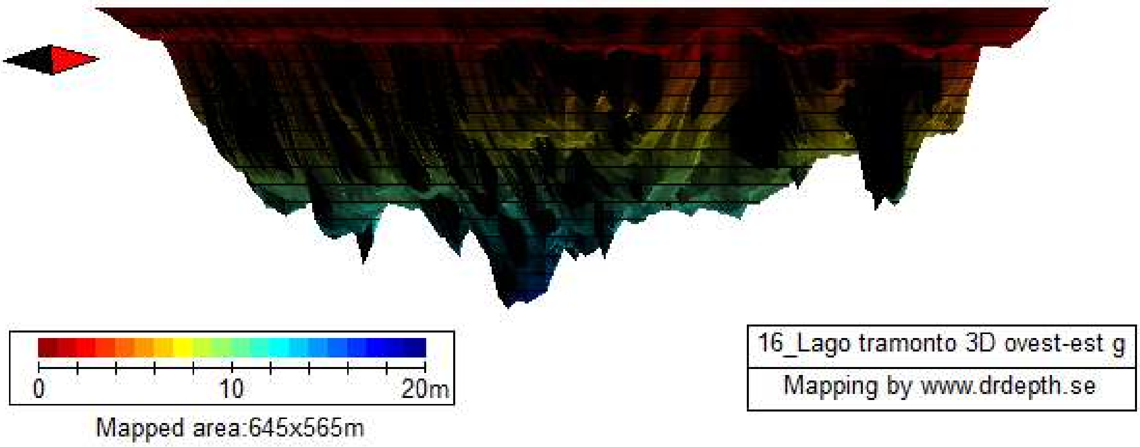

c

Fig.II.5.13 - **a** Gambulaga, Lake Tramonto. Georeferenced bathymetrical map; **b**, 3D bathymetry; **c**, 3D section West-East.

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PART III

LANDSCAPE BEFORE SUBMERSION
HYPOTHESIS OF ENVIRONMENTAL RECONSTRUCTION

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III.1 Riverine scapes.

Rivers are central components of the terrestrial realm, and historically many human settlements have been located along rivers. As reported by Martin R. Gibling[27], river systems include the channels themselves, the riparian zone, floodplains, and terraces, adjoining uplands dissected by lower-order channels, rivers, and deltas. Anthropogenic activities are often considered discrete elements: the use of fire, domestication of plants and animals, soil development, cropland expansion, the establishment of settlements, and irrigation. However, they are all affected by, and contribute to, the dynamics of nearby rivers; it is important to consider them in a holistic environmental and geomorphological context. Fluvial scientists have drawn largely on sedimentological evidence to assess anthropogenic influence on rivers, related to developments in agriculture.

Fig.III.1.1 - Schematic diagram of anthropogenic influences on river systems (Gibling 2018).

Humans have interacted with rivers over the past millennia in enormously varied ways, culturally and climatically influenced. To make a realistic evaluation of anthropogenic effects, it is necessary to consider information from many disciplines: archaeology, anthropology, genetics, ancient history, geomorphology, palaeo-climatology, and material science. Each discipline has its approach to age assessment. The palaeochannels are archives of data to disclose[28]. In our case, we have waterscapes that were landscapes. The scientific recorded data show a diachronic panorama from the *Middle Würm* to the Late Antique. From the Lake of Settepolesini, we deduct mainly the most ancient phase, documented thanks to archaeozoological studies; fauna finds also come from Casaglia quarry. From the basin of Sandolo we detected a great vision of fossil wood, with some fragments of wood artifacts related to Roman and Late Roman structures, attested by several witnesses in the Tramonto Lake, the basin excavated quite close and partially over the ancient anthropogenic riverbank.

III.2 Palaeontological framework.

Relevant studies have been carried out by scientists of the University of Ferrara, who dealt mainly with the oldest phases of the Quaternario Lake, with peculiar reference to paleontological aspects. The studies were conducted on the analysis of the bones remains found during the excavation of the quarry. Chronological attribution of the finds was achieved by radiocarbon, dating them at the *Middle Würm (ca. 35.000 – 33.000 years ago), Late Glacial (ca. 13.000 years ago),* and *Roman Age.* The studies of Sala and Gallini, reconstruct at least three different chronological contexts.

In the first period, *Middle Würm*, we find mammoth, Irish elk, together with woolly rhinoceros, and steppe bison, denoting the environmental context defined as "mammoth steppe", documented for the first time in Italy. It was a cold steppe that extended from the Atlantic coast of Europe as far as Alaska, across Beringia. The lowering of the sea level during the glacial period had brought to light the Upper Adriatic, forming an extensive plain, and favoring faunal exchanges between the Italian peninsula and eastern Europe. Animals of varying dimensions arrived via this route and spread throughout the Po Valley: the mentioned big animals were together with smaller species such as the whistling hare (*Ochotona pusilla*), wild sicista (*Sicista betulina*) and root vole (*Microtus oeconomus*)[29] (Fig.III.2.1).

[27] Gibling 2018. Many human activities from antiquity focused on rivers, channels, and floodplains.

[28] About Fluvial deposits as an archive of early human activity: Chauhan *et Alii* 2017.

[29] The full data Sala, Gallini 2001, Sala 2002, 2013, 2019. Comparisons in Bona, Baioni, Cilli 2023.

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Fig. III..1 - Reconstructive drawing of the Last Glacial (arid steppe, 13.000 years ago) fauna found in the excavations of Settepolesini (IBC Regione Emilia Romagna).

In the second detected period, *Late Glacial,* we find witnesses of the steppe (an example is bison (*Bison priscus*). Based on data on the deposits of the nearby Apennine and the upper Veneto-Lombardy plain, it is possible to hypothesize the faunal association of large mammals including elk (*Alces alces*), horse (*Equus ferus*), Irish elk (*Megaloceros giganteus*), red deer (*Cervus elaphus*), and beaver (*Castor fiber*), present in the deposit but not dated. We deduct the existence of a prevalent steppe setting with riparian wooded areas. The temperature must have had higher average values than the preceding period, though it is likely that the marked drought heavily conditioned biodiversity.

The third period is characterized by sub-fossil material ascribed to the Roman Age. It is represented by red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), wild boar (*Sus scrofa*), domestic animals, and human remains. The type of fauna, alongside the documentation available in the literature, allows us to suppose a temperate climate environment that favored the spread of forest settings.

Sala and Gallini underline probable various neo-tectonic liftings, caused by the structural high, known as the Ferrarese Ridge, which crossed the area of Settepolesini, led to repeated deviations of the main watercourses, creating extinct branches or reduction of current. The fresh appearance of all the fossils that remain unearthed, together with the finding of whole bones without any anthropic alterations or signs of animal gnawing, permit a taphonomy hypothesis to be advanced: i.e. carcasses of drowned animals were carried downstream until they reached a shallow point, where they sank to the riverbed, and decomposed, and covered by sediment, already skeletons (Fig. III.2.2).

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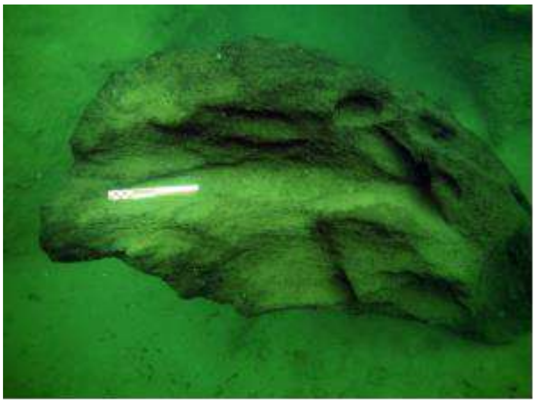
Fig. III.2.2 Reconstructive drawing of the Last Glacial (Mammut Taiga Steppe, 50-25.000 years ago) fauna found in the excavations of Settepolesini (IBC Regione Emilia Romagna).

A possible connection between palaeontological layers attested in our case studies could be between Quaternario Lake and Casaglia Lake, but also in the Cavallara site where at a depth between 20 and 30 m from the surface, we recorded a natural layer with peats containing leaves (Fig.III.2.3), attributable to the same phases attested in Settepolesini, as well as the big trunk of a tall tree emerging vertically on the bottom of the Tramonto Lake, at 12,5 m depth (Fig.III.2.4a-b).

Fig. III.2.3 – Cavallara Lake. Paleosoil attested at -27 m from the campaign plan.

a



b

Fig. III.2.4a-b – Tramonto Lake, semi-fossil trunk emerging from the bottom of the lake.

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Concerning the Roman and Late Roman phases, the context reveals several findings attested around the area of the lakes.
The Roman and Late Antique panorama in the para-fluvial area of this territory, developed according to the criteria of the so-called scattered settlement. Between Settepolesini and Casaglia up to Cassana, Portomaggiore, and San Giovanni di Ostellato traces of inhabited areas are testified by anthropogenic layers, remains of villas, tombs, and necropolis (also with stele).

III.3 Palaeobotanical framework.

As regards the archaeobotanical sector, as mentioned before, (see II.4) in the Campanella Lake a wood fossil forest was attested, conserving elements dating back to the Roman period or the early Middle Ages. The sampling carried out identifies P*opulus* (Poplar – *Salicaceae* Family), *Ulmus* (Elm – *Ulmaceae* family), *Salix* (Willow – *Salicaceae* Family), *Quercus* (Oak – *Fagaceae* Family), *Alnus glutinosa* (Alder – *Betulaceae* Family), *Juglans regia* (Walnut – Juglandaceae Family), *Juniperus communis* (Juniper – *Cupressaceae* Family), *Prunus* (Cherry Laurel – *Rosaceae* Family). These data are in cross-reference with those recorded in Tramonto Lake.

The para-fluvial settlements, recently discovered, have been studied with complex research structured according to different disciplines.

The Tramonto Lake documents a reinforced riverbank where houses probably faced a pond immediately north of the river. Considering the geomorphological data illustrated for the sites of Gambulaga, petrographic, and palaeobotanical analyses of some Lago Tramonto samples were carried out. It is important to underline that during the microscopic analyses of geological samples, data regarding the flora, attested at Sunset Lake was also found. Organic samples found went through isotopic and archaeobotanical investigations.
Palaeobotanical and palaeocarpological data attested the following plants: *Apium*, *Nimphea*, *Spaganium*, *Tipha* (Fig. III.3.1).
From the analysis of the botanical remains found in samples S2/C13, S2/C14, and S2/C15, through a stereoscopic microscope, two types of plants attributable to the group of aquatic macrophytes, Hydrophytes and Helophytes, were identified.

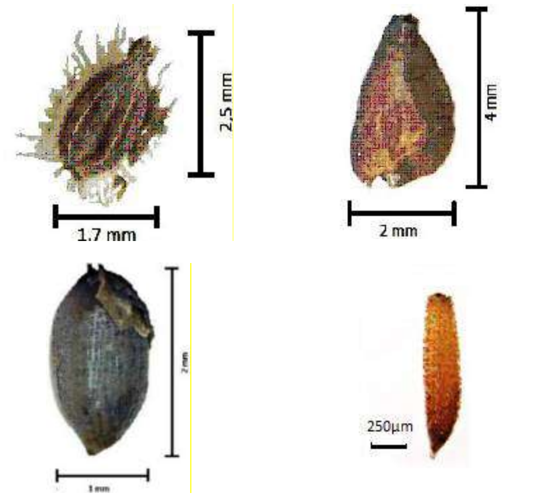

Fig. III.3.1 Stereoscopic microscope images: *Apium*, *Nimphea*, *Spaganium*, *Typha* (Facchini 2020).

Aquatic, or hydrophytes, are those macrophytes that can develop in purely aquatic environments, on soils or substrates that are periodically submerged by water or that present high humidity. They are therefore characterized by particular anatomical and physiological adaptations that allow them to survive in such environments.

Three types of hydrophytes are attested: emerging: floating, rooted in the substrate, or free-floating, submerged.
Emerging hydrophytes are plants rooted in a substrate saturated with water (with piezometric levels even 50 cm below the surface) or completely submerged (even with water coverage greater than 150 cm). These are perennial species with a long system of rhizomes and roots spread across the substrate. They are originally terrestrial plants that have developed good survival skills in aquatic environments and, like plants in terrestrial habitats, synthesize atmospheric carbon and nutrients taken up through their root system into organic compounds.
They live in our basins of variable heights between 25 and 350 cm and are characterized by floating leaves. They live mainly in sheltered areas of stagnant or slow-moving bodies of water. One of the most common types of floating hydrophytes is *Nymphaea alba*. Even floating hydrophytes, like emerging hydrophytes, synthesize carbon by taking it from the atmosphere, while nutrients are assimilated through the root system with which they are equipped. The roots also provide the medium for filtration, absorption of suspended solids, and bacterial growth.
Submerged hydrophytes live in water basins of variable heights up to 10/11 meters and are completely submerged. Unlike plants in terrestrial habitats and like microalgae, submerged

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hydrophytes synthesize carbon and nutrients by taking them directly from the water column. The typical habitats for the development of these species are stagnant fresh, or brackish waters. A typical distribution of hydrophytes in the transition zones between terrestrial and aquatic habitats includes the presence of submerged hydrophytes in deeper waters and emerging hydrophytes in shallower waters. The presence of rooted hydrophytes with floating leaves concerns medium-deep waters, while that of freely floating hydrophytes is independent of the depth of the support. In our lakes, there are also Helophytes, semi-aquatic plants. They live along the banks of humid and marshy environments and have a full vegetative and reproductive system meanwhile the roots and the lower part of the vegetative structure are submerged. Some species among the Helophytes survive with the base of the stem always submerged, while others, more "terrestrial", can also live dry, as long as the roots are always in soil soaked in water. From the studies of F. Facchini (Facchini 2020a-b), we evict that the samples from the S2 drilling pertain to an inter-distributary environment, located beyond the riverbank. Samples C13, C14, and C15, found at greater depths, can be traced back to a marsh environment, as demonstrated by the high percentage of organic matter found and the seeds found in the samples themselves (*Nymphaea Alba, Apium Indundatum cf., Typha cf . and Sparganium cf. erectum*). The high percentage of organic matter present is further confirmed by isotopic investigations (C/N and δ13C ratios). This is one of the demonstrations showing that the identified marshy environment was subsequently covered by levels attributable to an alluvial deposit, as emerges from the trend of the melt curves obtained through textural and granulometric analyses. In the samples, S2/C9 and S2/C10 (also belonging to core 2) fragments of bricks with dimensions in the order of a millimeter were found

The analysis led to deduct that, immediately north of the bank margin containing the quay, there was a pond, an important element of the ancient landscape to be linked to the anthropic activities of fish farming, aquaculture, and cultivation of aquatic plants, maybe domestication of plants.

If the palaeobotanical investigations carried out on the samples coming from the Tramonto Lake area have highlighted the presence of river and marsh aquatic plants, tohe paleobotanical studies at Lake Campanella have recorded the presence of numerous tree species that therefore characterize the surrounding landscape or rather the landscape that emerged in the Roman and Late Roman phase.

The forest, from Roman Time to the Middle Ages, was developed *circum ripa Padi et litora Maris Hadriatici* (close to the banks of the River Po and the coast of the Adriatic Sea), as mentioned by Vitruvius (*De Architectura*, II, 9, 14) and Cassiodorus (*Variae*, V, 17, 5). Big arboreal finds were discovered in the Lake of Casaglia, at Lago Campanella, and in Lago Tramonto. Several trees are documented emerging on a now submerged walking surface (Fig.III.3.2).

Fig.III.3.2 – Like Tramonto. Sbmeged natural layer with tree and anthropogenic layers.

The long oak trunks, which are notable for length and diameter, are attributable as habitat to the local or nearby forest, and from an archaeological point of view to the raw material to build pirogues. Seven trunks of trees have been documented in Lake Tramonto at an average depth of between 5.0 and 10.5 m. Trunk no.1 measures 13.7 m; trunk no.2, 8.3 m; trunk no.3, 10.0 m; trunk no.4, 7.9 m, trunk no.5, 16.5 m; trunk no.6, 5.7 m; trunk no.7, 8.0 m. They are all dislocated along the North bank of the river. Some of them could be in a primary position, and others have been transported by the stream of the flow, chronologically ascendable to the sixth century AD. The big trees were used also to build means of transport. As mentioned, remains of pirogues are attested in Lake Tramonto: underwater, we found two bow or stern fragments, some starboards of monoxyle boats, and some partially excavated trunks, suggesting the hypothesis of a small pirogues production area (Fig.III.3.3).

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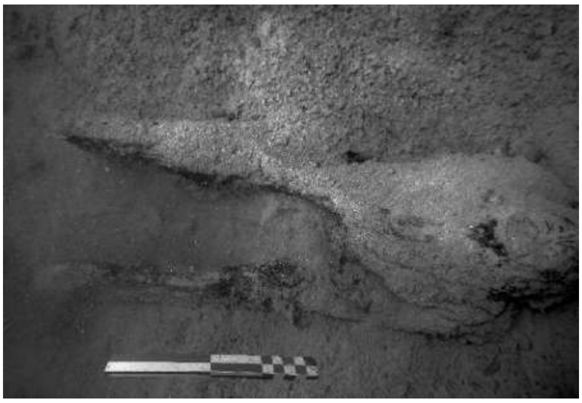

Fig.III.3.3 – Tarmonto Lake, pirogue fragment.

The trunks number 1 and number 5 are compatible with lengths and diameters of the pirogues discovered in the Ferrara area (more than 23 exemplars are already known: Valle Isola, Valle Rillo, Valle Ponti, Valle Pega (all in Comacchio area), Pomposa (Codigoro), Codigoro, Valle Volta (Massafiscaglia), Valle delle Gallare (Ostellato), Iolanda di Savoia. These boats are characterized by a common shape, similar measures, and the same kind of wood; they can be traced back to the Late Antiquity and the Middle Ages[30] (Figs.III.3.4-5).

Fig.III.3.4 - Ferrara, Museo Archeologic Nazionale, Middle Ages Pirogues.

Fig.III.3.5Comacchio, Museo delta Antico, Middle Ages Pirogue.

The recent archaeological excavation in Comacchio (2014), always on the palaeo-watercoruse of the *Eridanus,* brought some news in the panorama of wood used for nautical means. The preliminary archaeobotanical analysis performed by Marchesini, palaeobotanist, on the planks of the sewn boat and pieces of the monoxyl pirogue found close to the local bank, detected Farnia wood (Quercus robur) and Elm (Ulmus), respectively, the first to build the monoxyle pirogue, the second to build the boat. Considering the diffusion area of the plants from which the wood was obtained, it could be assumed that the riverboat of Comacchio 2014 field[31], was built in the Po area, northern to Santa Maria in Padovetere (exact location of the excavations). Elm tree wood was also found in Voghiera[32].

To have an overview of the plants, below is a conspectus of the main botanical species attested on the riverbanks of the *Eridanu*s from Protohistory to Late Antique; the images are extracted from the book of W. Müller, *Prof. Dr. Thomé's Flora von Deutschland, Österreich und der Schweiz in Wort und Bild*. Gera-Untermhaus: Verlag von Fr. Eugen Köhler, 1886.

[30] About the pirogues inf Ferrara district: Berti 1983, 1987, Marchesi 1995. For a detailed description of the pirogues found in Tramonto Lake: Bucci 2020.

[31] Ceserano 2014, 2017; Marchesini 2014; Beltrame Costa 2023.

[32] About xilologic analyses of Voghenza: Forlani, Bandini Mazzanti 1984.

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Populus - Poplar – *Salicaceae.*

***Ulmus* -** Elm – *Ulmaceae.*

Salix - Willow – *Salicacee.*

Quercus Oak – *Fagaceae.*

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Alnus glutinosa **-** Alder – *Betulaceae.*

Juglans regia **-** Walnut tree – *Juglandaceae.*

Juniperus communis Juniper – *Cupressaceae.*

Prunus cerasus **-** Cherry tree – *Rosacee.*

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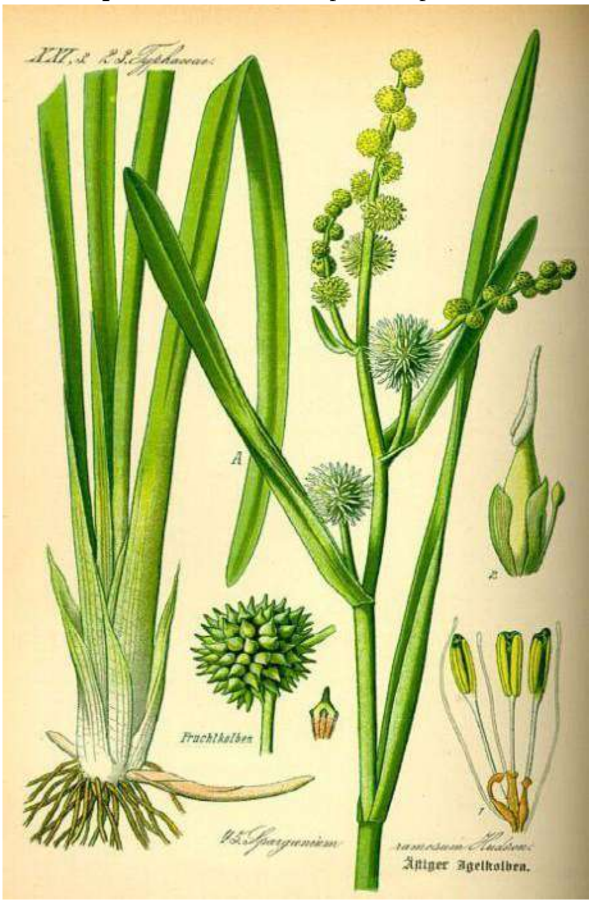
Nymphaea alba Water lily – Nymphaeaceae.

***Apium inondatum* -** Apium -Apiaceae.

Typha latifolia Cattail plant – *Typha.*



Sparganium erectum Major Knife – Typhaceae.

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III. 4 Geo - archaeological contexts

The Lake Qauternario (II.1), Casaglia (II.2), Cavallara (II.3) and Campanella (II.4) offered paleontological and archaeological data with particular reference to the scattered settlements, relating the sporadic findings to the Big River.

Due to mining choices, positioning of the excavations, and methods of archaeological control, the bank margins were intercepted with certainty in Tramonto Lake, the basin from which we obtained important data regarding not only the attendance of the parafluvial sites but also, above all, concerning their management between Roman Age and Late Antique.

The artificial basin that has returned the greatest number of strictly archaeological data linked to the evolution of the territory related to riverine scapes is Gambulaga.

The study of Tramonto Lake has brought an extraordinary contribution regarding the methodologies and construction techniques of management and reinforcement of the banks and quays. Several wooden finds and related buildig elements allow us to formulate some reconstruction hypotheses of the riverine structures. Despite their precarious state, heavily compromised by excavations, landslides, and natural causes linked to large floods, thanks to deep critical analysis and comparisons with other settlements excavated in Europe (and found quite intact), we managed to get an overview of the *Eridanus* banks with a focus on wooden construction methods and techniques in the Eastern Pianura Padana.

The scanning with the eco-side scan sonar combined with the underwater surveys made it possible to recognize the position of each piece and, georefencing them, we deducted the complex artificial construction. Beams, poles and posts, pegs, and trunks were used with skillful engineering capacities. Two structures have been documented for the regulation of the river: a wooden palisade with elements fixed in the clay without digging a preliminary hole (Fig.III.4.1) and a system for counterfeiting the bank margin created with beams and joints (Figs. III.4.2-7).

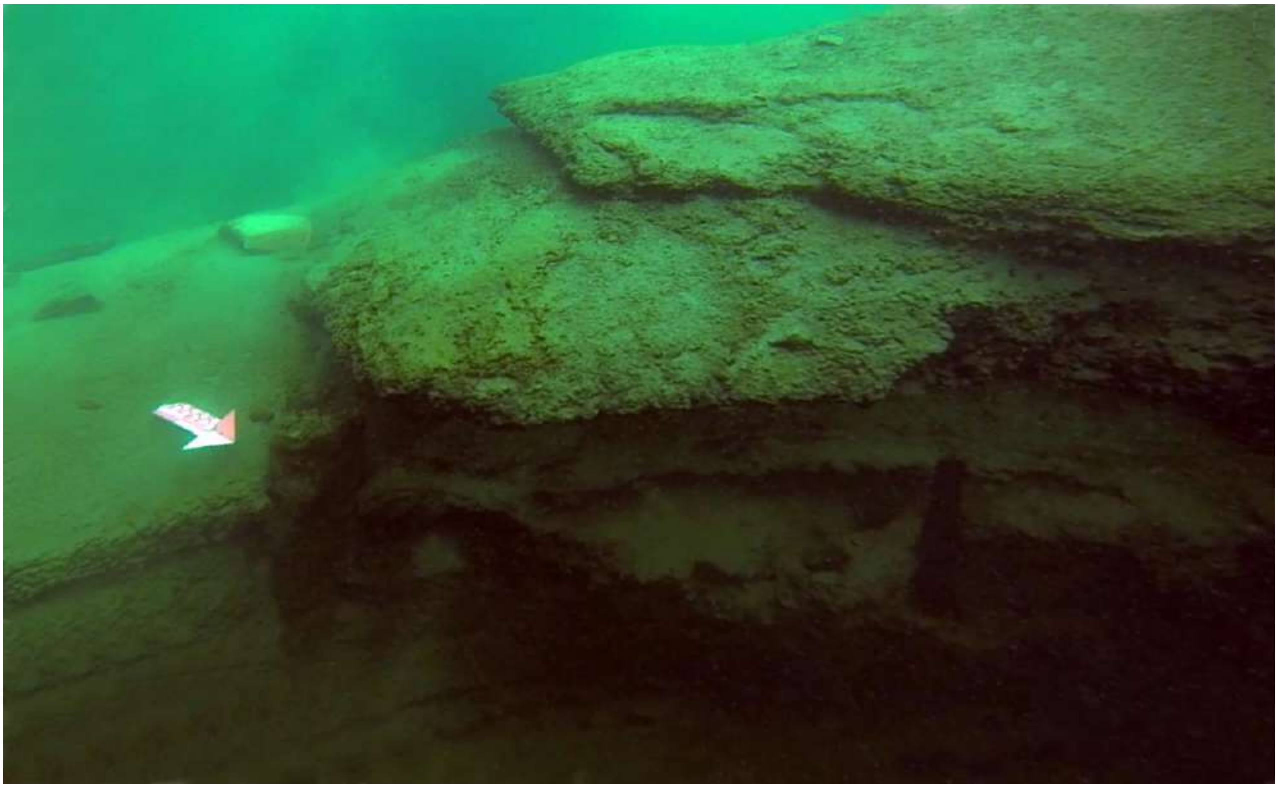

Fig. III.4.1 – Tramonto Lake, palisade. Details of the piles driven into the clayey bank margin.

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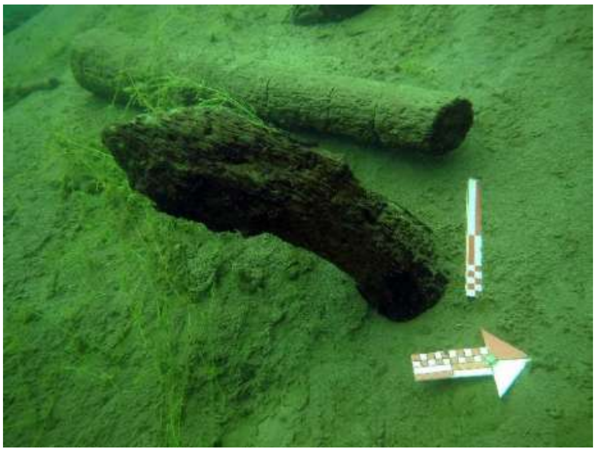
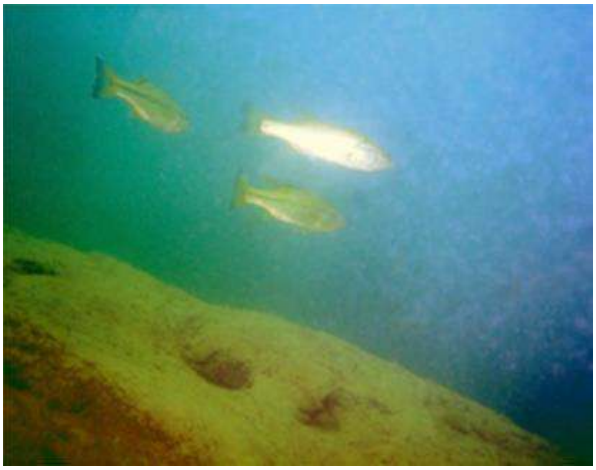
Fig.III.4.2 - Tramonto Lake: collapsed beams, poles, and posts.



a

b

c



d

Fig.III.4.3 – **a**, pile *in situ* and tapered pole with traces of binding; **b**, pile *in situ* with jamming; **c,** rectangular section beam with holes; d, square section beam with holes.

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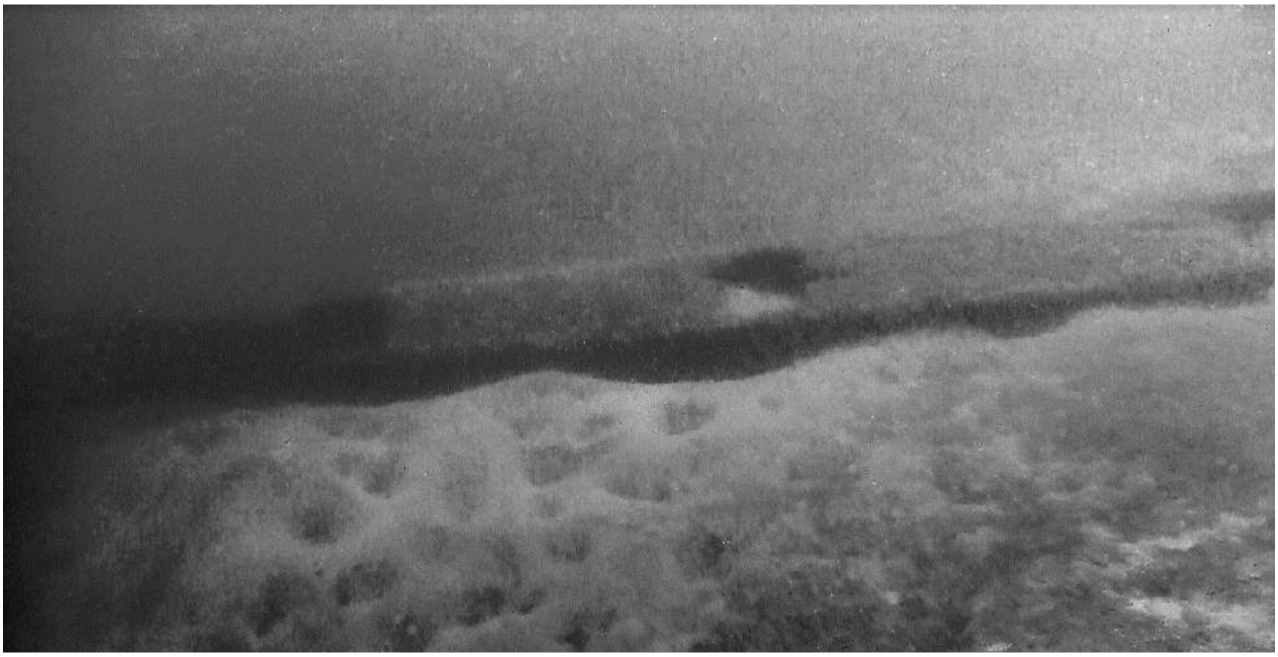
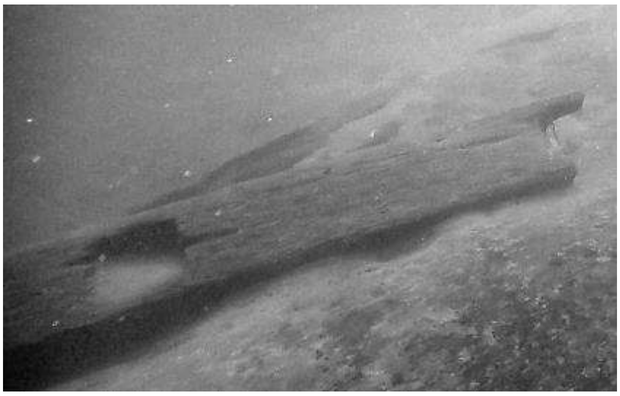
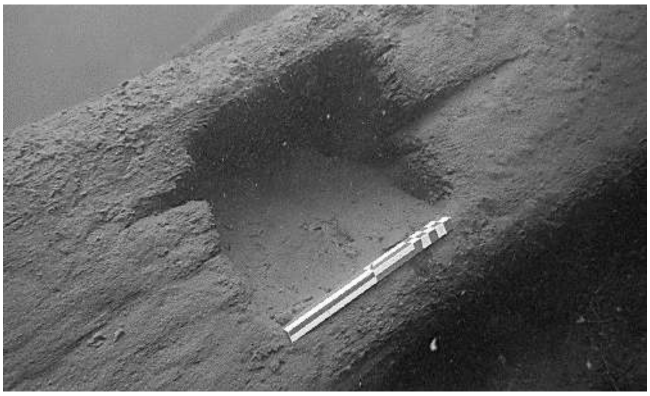


a



b



c

Fig. III.4.4 – Tramonto Lake: **a**, beam with slots for interlocking; **b**, northern extremity; **c**, detail of a slot.

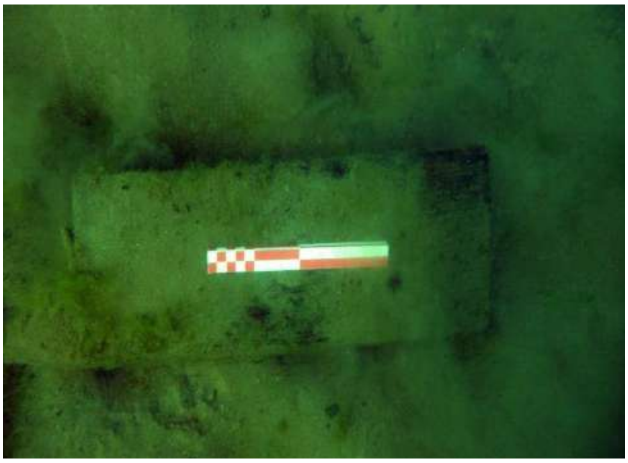


Fig.III.4.5 Tramonto Lake: small plank, f trunk cut lengthwise

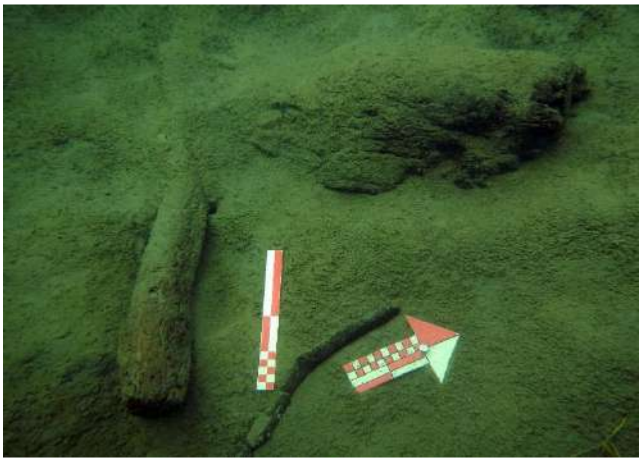


Fig.III.4.6 Tramonto Lake: remains of wooden structure

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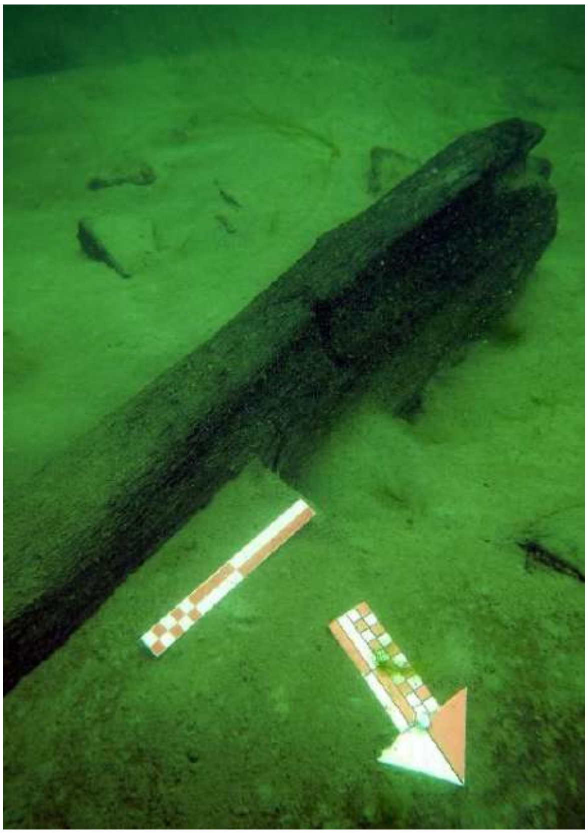

Fig.III.4.7 - Tramonto Lake: trunk cut lengthwise for longitudinal housing.

An interesting study made by Allinne regarding the relationship between archeology and river risk in the Roman Age delineates three types of systems: works on river courses (diversions, channelization), riverbed and bank management (bed dredging, channel straightening, bank stabilization), and the implementation of defenses against the effects of flooding (dykes, raised house floors, construction of dwellings on foundation stakes, drains, and underfloor spaces)[33].

The sum of these data collected between Sandalo and Gambulaga, allows us to verify some construction comparisons. An important study on reinforced bank edges and docks built with wooden foundations was conducted by Felici [34] who explains how in river and lagoon areas, wood is used as an absolute material for bridges and walkways, or as a foundation piling for stone quays; otherwise, as a timber consolidation of the banks or to create widening caissons, with filling without binders, in which the firmness of the building is permanently entrusted to the carpentry. In the excursus of studies presented by Felici the cases of the palisades of the River Brenta and the port of San Rossore have some common elements to the structures of Gambulaga.

The case of the palaeochannel of the River Brenta in Padova (Largo Europa) was studied by Tuzzato, Balista, and Serafini [35] . In the archaeological excavation, conducted in 1991 a Roman palisade with structured bank, reinforcement, and containment work was found (Figs.III.4.8 – III.4.9); it is chronologically coeval to the Gambulaga settlement.

Similar structures are published by Camilli, concerning the Pisa – San Rossore port in a secondary arm of the River Arno[36]. Those port facilities are built with a heterogeneous palisade. The heterogeneity of the diameters of the palisade fixed in the clay layers is a characteristic that the river banks of the central and northern Peninsula have in common. Also, the area of San Rossore was closely connected with the hydrogeological events and destructive floods which led to the swamping of the Port, the burial as well as the abandonment of the structures (Fig.III.4.10).

In the ambit of Late Antique contexts, the port of Villaggio San Francesco near Comacchio documents important rows of poles and wooden piers relating to the endo-lagoonal landings in the Delta area[37]. The 1996 excavation identified containment structures of the type definable as *waterfront*, the most precise comparison of which is provided by similar structures found in the Venetian lagoon. Calaon underlines that since they are essentially wooden containment structures, with one side directly in contact with the water, their construction involves the soil used as fill, on which a wooden walking surface is generally placed above. In particular, some structures in Villaggio San Francesco were built with an external row of poles, very close together, consolidated by a wicker trellis. The possible presence of reeds in the construction systems documented in Gambulaga can be seen in the discovery of tapered equal parts with traces of binding. They are also part of the so-called bank armor systems, documented until the Middle Ages. Several comparisons are detectable in France and

[33] Allinne 2007. Alline mention also the case of Padova (pgs.73-74). The excavation is published by Tuzzato 1991, and Balista, Serafini 1993. About river dynamics and settlement conditions Corrò *et Alii* 2020.
[34] Felici 2022 presents several study cases with a great excursus about methodologies and techniques of construction of banks and quay.
[35] About the excavation: Tuzzato 1991. The report of the excavations is followed by a geo-archaeological interpretation of Balista who explains the palaeo-hydrographical records connected with the ancient river.
[36] The chronology remains uncertain. About San Rossore excavation: Camilli 2004 and bibliography.
[37] Calaon 2007.

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in England: we can see the structure on site, well preserved and made with the same elements found in Tramonto Lake: that is, a bank reinforced with a system of equal beams and planks with interlocking elements attested in the London waterfront (Fig.III.4.11).

River dock construction techniques are confirmed as an element of technical continuity throughout Northern Europe.

Fig.III.4.8 - Padova, Largo Europa, 1991 archaeological excavation: Roman palisade (Tuzzato 1993).

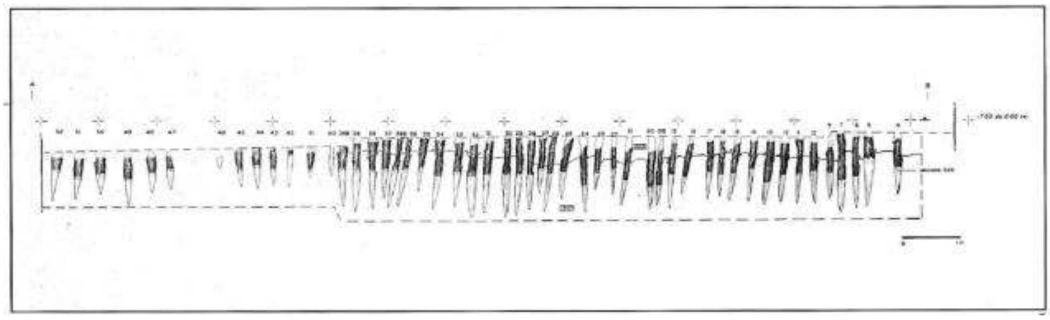

Fig.III.4.9 - Padova, Largo Europa, 1991 archaeological excavation: prospect of the palisade (Tuzzato 1993).

Fig.III.4.10 - Pisa San Rossore (Camilli 2004),.

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Fig.III.4.11 - London's Waterfront (Schofield, Blackmore, Pearce 2018).

Schofield, Blackmore, and Pearce's studies allow us to understand the correct position and the joints of the elements found scattered on the bottom of Traomnto Lake, contributing to a possible reconstruction of the river section.

At the current state of the studies, it seems that the remains of wood buildings found in the lake mainly belong to infrastructures linked to defense and the arrangement of the river banks. However, the presence of bricks, especially tiles, and bricks, together with objects belonging to material culture, denotes the presence of a settlement near the river[38].

According to the indications provided by the archaeological finds, the bank margin was reinforced and used until Late Antiquity, correlating the life of the river with the scattered settlement, of *pagi* and *vici*, characterized by constructions made mainly of local poor materials, i.e. foundations with bricks and tiles, including reused ones, and elevation made of wood and clay with roofs built with rushes and light twigs (Fig.III.4.12)[39].

[38] An interesting comparison in the ambit of the Po – Venetian Plain, concerning riverbed and banks with an examination of Roman infrastructures and interventions see Page 2022. About the local finds: Bucci 2020b, c, d; Rambaldi 2020, Rossetti 2020.

[39] Methodologies and construction techniques during the Roman Age in the Pianura Padana: Ortalli 1995. For the later phase: Rucco 2015 and bibliography; Saggioro 2006. About Roman woodworking: Ulrich 2007.

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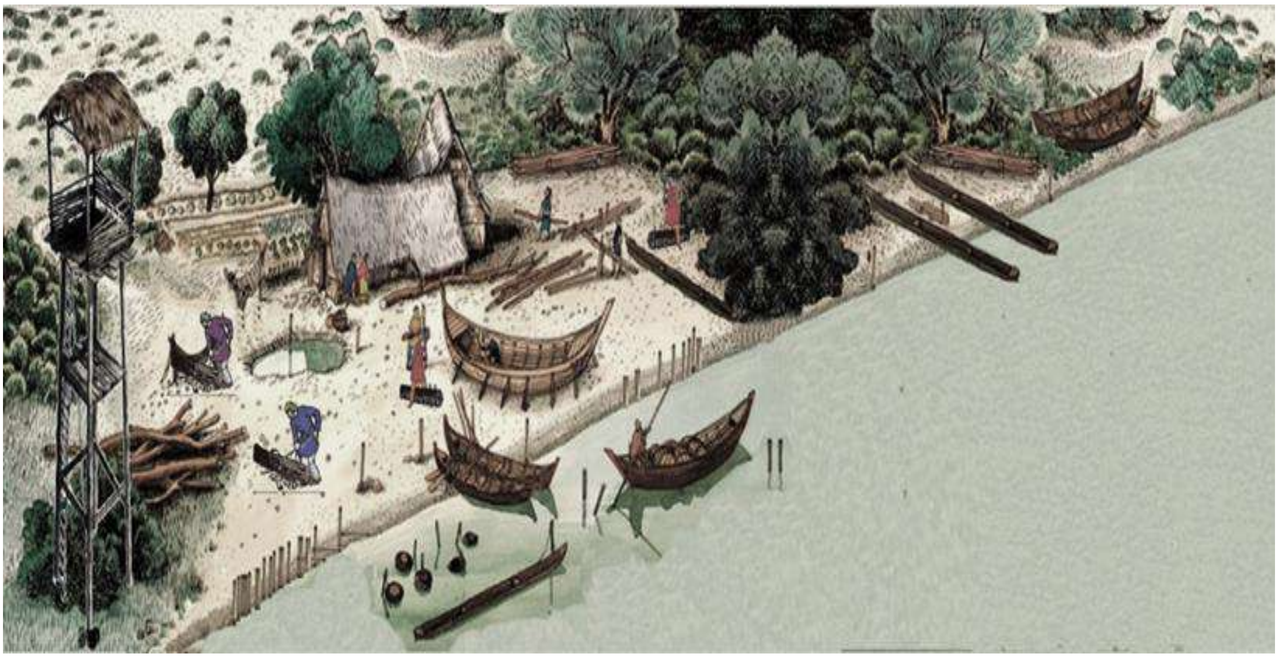

Fig.III.4.12 - Reconstruction of the Late Roman phase of the northside of Tramonto Lake, actually submerged.

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