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# PALEOENVIRONMENTAL RECONSTRUCTION OF THE PREHISTORIC PILE-DWELLING SETTLEMENT OF STAGNO (LIVORNO, ITALY) BASED ON MOLLUSCAN ASSEMBLAGES

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ABSTRACT: Aim of this study is to improve the knowledge about the palaeoenvironment of a prehistoric pile-dwelling settlement that was discovered near Stagno (Collesalvetti, Livorno) in 1993. Calibrated radiocarbon dates on materials from the wooden poles of the pile-dwellings have dated the site to an interval of time from the Late Bronze Age to the Early Iron Age (cal 1116-1091 ±15 yr BC). The palaeoenvironment of the area has been reconstructed studying the molluscan assemblages found in the fossiliferous levels recovered during the archaeological excavations. The palaeogeography of the zone around the site was also reconstructed using data from previews stratigraphic studies performed on the nearby areas. The molluscs occurring in the archeological site are represented by 9 taxa: 6 taxa belonging to bivalves and 3 to gastropods. The associations correspond to fossil communities that are characteristic of lagoon muddy-clayey bottoms. We hypothesise that all the data considered allow a palaeogeographic reconstruction of the area providing different environments represented by alternating land and submerged areas. This reconstruction can be also useful to shed light on the causes of the abandonment of the pile-dwelling site.

Keywords: Molluscs; Tuscany; Late Bronze Age-Early Iron Age; Palaeoenvironment; Palaeogeography

## 1. INTRODUCTION

In 1993, remains of a pile-dwelling settlement were found at Stagno (Collesalvetti), near Livorno, in Tuscany (Zanini, 1997; Fig. 1). Following Gambogi et al. (1995) and Giachi et al. (2010), the ceramic and metal materials found in association with wooden structures, date the archaeological site of Stagno back to the Late Bronze Age-Early Iron Age transition. More precisely, Zanini & Martinelli (2005) radiometrically dated some samples from wooden poles to an age between cal 1116 ±5 and cal 1091 ±15 yr BC. Excavations and archaeobotanical studies assess that these human settlements based their livelihoods essentially on the gathering of wild fruits and nuts, and the cultivation of cereals and pulse (Giachi et al., 2010). Analyses of plant remains show the presence of temporary freshwater pools and of a lowland forest in the surroundings (Mariotti Lippi & Mori Secci, 2007). This archaeological site, which is presumed to have been built in a lagoon environment (Zanini, 1997), is an important find that has provided, and can provide, meaningful data about the central Italy pile-dwelling settlements of the Late Bronze -Early Iron Age. In fact, up to now very few pile-dwelling sites have been investigated in central Italy. Actually, pile-dwelling settlements of the Bronze Age are only present in Trentino (see: Perini, 1984), Lombardia (see: De Marinis et al., 2005; Valsecchi et al., 2006), Emilia-Romagna (Bertolani Marchetti et al., 1988; Rottoli, 1997; Cremaschi et al., 2006; Mercuri et al., 2006), near Rome (Gran Carro di Bolsena: Fundurulic et al., 2022) and near Napoli (Longone-Poggiomarino: Livadie et al., 2010). About the end of some of these pile-dwelling settlements, cultural and climatic factors (or induced by climatic factors) have been argued (e.g., Jennings, 2014; Hitchcock & Maeir, 2016). Our research, providing a detailed palaeogeographic reconstruction of the area around the pile-dwellings found near Stagno, gives us a view of the ancient landscape and its evolution that could shed light on the causes of the abandonment of the Stagno site, which have not been clarified in previous studies (Giachi et al., 2010 cum biblio).

## 2. STUDY AREA

From a geological point of view, the study area is located within the Viareggio Basin (Mariani & Prato, 1988; Pascucci, 2005). This basin of tectonic origin is located in the inner part of the Northern Apennine; it originated during the late Miocene after an extensional tectonic phase linked to the Apennines orogeny (Carmignani et al., 2001). According to classic geodynamic models, this basin and the others nearby are bounded by north-west-south-east-trending normal faults and east-west-aligned transform faults (Mariani & Prato, 1988; Pascucci, 2005). Since the late Miocene,

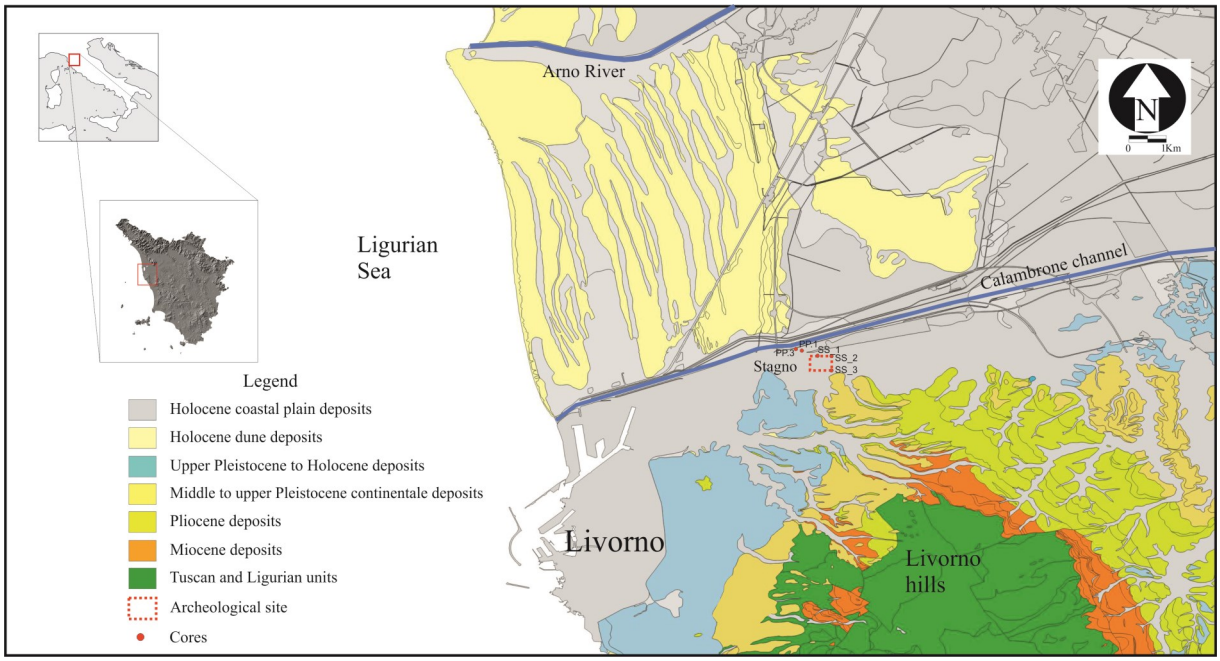


Fig. 1 - Geological map of the study area around the Stagno pile-dwelling site, modified from the Geological Continuum of Tuscany Region (http://www502.regione.toscana.it/geoscopio/cartoteca.html).

the Viareggio Basin was filled by marine, transitional and continental sediments, which show a continuous alternation of transgressive and regressive marine phases, mainly linked to the glacio-eustatic control (Bossio et al., 1993). In addition, recent researches on the subsurface of the Pisa plain, in the southern part of the Viareggio basin, have defined with detail the depositional architecture of the late Quaternary succession (Amorosi et al., 2008; Sarti et al., 2015). According to these researches, during the Last Glacial Maximum, the strong erosive power of the rivers flowing across the basin determined the formation of a palaeovalley system, subsequently filled by sediments linked to the Holocene transgression (Sarti et al., 2015; Rossi et al., 2017). Moreover, continental and transitional environments occurred during the Holocene, as reported in Kaniewski et al. (2018). According to the geological map, the Stagno archaeological site is entirely included in an area where Holocene continental sediments outcrop, while the reliefs located to the south, are characterised by exposed Pliocene marine sediments and late-middle Pleistocene continental deposits (Fig. 1).

## 3. MATERIAL AND METHODS

For the study of the archaeological site, 22 boreholes were realised in the area of the archaeological findings during the 1993 fieldworks, on which Giachi et al. (2010) identified some archaeological units (SU) based on lithology and plant remains. Starting from the stratigraphy of 3 boreholes (SS1, SS2 and SS3, Fig. 2), which were available to us, and from the stratigraphy of the site, we identified eight stratigraphic layers (L1 to L8) on the lithological characteristics and archaeological content of the sediments, and linked them to the stratigraphic units reported in Giachi et al. (2010) (Fig. 3, Tab. 1). The molluscs occurring in the archaeological units SU110, SU160 and SU116, were identified after standard cleaning procedures. The sediments were washed through a 0.84 mm sieve and then dried in oven at 110°C. The identified molluscs are currently deposited at the Museo di Storia Naturale del Mediterraneo of Livorno and at the Soprintendenza Archeologica della Toscana, now Soprintendenza Archeologia, Belle Arti e Paesaggio per le Province di Pisa e Livorno (SABAP) located in Pisa. The molluscs systematic and nomenclature follow Sabelli et al. (1990) and the World Register of Marine Species (WoRMS, 2023).

## 4. RESULTS

### 4.1. Stratigraphy of the archaeological area

A schematic description of the stratigraphy of the cores SS1, SS2 and SS3 is reported in Figure 2.

The 8 stratigraphic lithofacies (layers), to which the archaeological units containing shell remains were linked (Fig. 3, Tab. 1) are briefly described below. From the bottom:

- L8: dark grey silty clay with local peat.
- L7: silty clay with plastic consistency, containing shell remains; centimeter levels of sand occur in places.
- L6: grey silty clay, 0.15 m thick.
- L5: blackish clay 0.15 m thick, with shell remains.
- L4: greenish grey silty clay with sandy levels, 0.40 m thick.
- L3: moderately compacted brown-grey silty clay, 1.30 m thick.
- L2: light brown silty clay about 0.90 m thick, slightly sandy in places.
- L1: heterogeneous sediments, corresponding to a layer of soil about 0.6 m thick.

Some of these stratigraphic layers contained the

archaeological units with shells identified by Giachi et al. (2010). Unit SU110, which consists of grey clay with decaying wooden elements and shell remains, corresponds to the L7 stratigraphic layer. This unit contains very frequent *Cerastoderma edule, Cerastoderma glaucum, Loripes orbiculatus* and *Peringia ulvae,* frequent *Macomangulus tenuis* and *Bittium reticulatum,* rare *Glycymeris nummaria*, *Mytilaster minimus* and *Rissoa membranacea*. Unit SU160 corresponds to the L5 stratigraphic layer and unit SU116 corresponds to the L3. Both these units consist of grey clay with molluscs. SU160 contains very frequent *Cerastoderma edule, Cerastoderma glaucum, Loripes orbiculatus* and *Peringia ulvae,* frequent *Macomangulus tenuis,* rare *Glycymeris nummaria, Mytilaster minimus*, *Bittium reticulatum* and *Rissoa membranacea*. SU116 contains very frequent *Cerastoderma edule, Cerastoderma glaucum, Loripes orbiculatus,* frequent *Peringia ulvae,* rare *Mytilaster minimus* and *Bittium reticulatum*.

### 4.2. Remarks on the molluscs found in the archaeological site

The molluscs recovered from the archaeological units (SU110, SU160 and SU116; Tab. 1; Fig. 3) of the Stagno archaeological site are represented by 6 species of bivalves (*Glycymeris nummaria*, *Mytilaster minimus*, *Loripes orbiculatus*, *Cerastoderma edule*, *Cerastoderma glaucum*, *Macomangulus tenuis*) and 3 species of gastropods (*Rissoa membranacea*, *Peringia ulvae*, *Bittium reticulatum*). Preservation of fossils is generally good, the protoconch of gastropods has a sculpture nearly always intact, and some specimens of the bivalves *Cerastoderma glaucum* and *Loripes orbiculatus* have articulated valves. In addition, the species *Cerastoderma glaucum*, *Loripes orbiculatus* and *Peringia ulvae* occur with different stages of growth. The good preservation of great part of shells and the occurrence of articulated valves with different stages of growth, prove that the mollusc with these features were autochthonous. Pictures of selected species are represented in Figure 4, while Table 2 shows the distribution of molluscs within each archaeological unit

### 4.3. Class Bivalves

1) *Glycymeris nummaria* (Linneus, 1758) can be found in infralittoral areas, at depths that range between 2 and 40 m in muddy sands and well-sorted fine sands (Peres & Picard, 1964; Martins et al., 2014; Crnčević et al., 2013). This species is also reported in low salinity littoral environments, near river mouths (Vatova, 1949). The species rarely occurs, and some specimens found in SU160 show evidence of manufacturing and exploitation traces. It is possible that the *Glycymeris nummaria* valve with an irregular hole in the umbo area, shown in Figure 4, could be a shell ornament as those found in other archaeological sites of the Bronze Age (Poggiani, 2017).

2) *Mytilaster minimus* (Poli, 1795) is a euryhaline and eurythermic species typical of lagoonal systems that lives on soft bottom (i.e., Nicolaidou et al., 2006). This species was found in all samples, but in low abundance (Tab. 2).

3) *Loripes orbiculatus* (Poli, 1795). Ragaini & Mari-

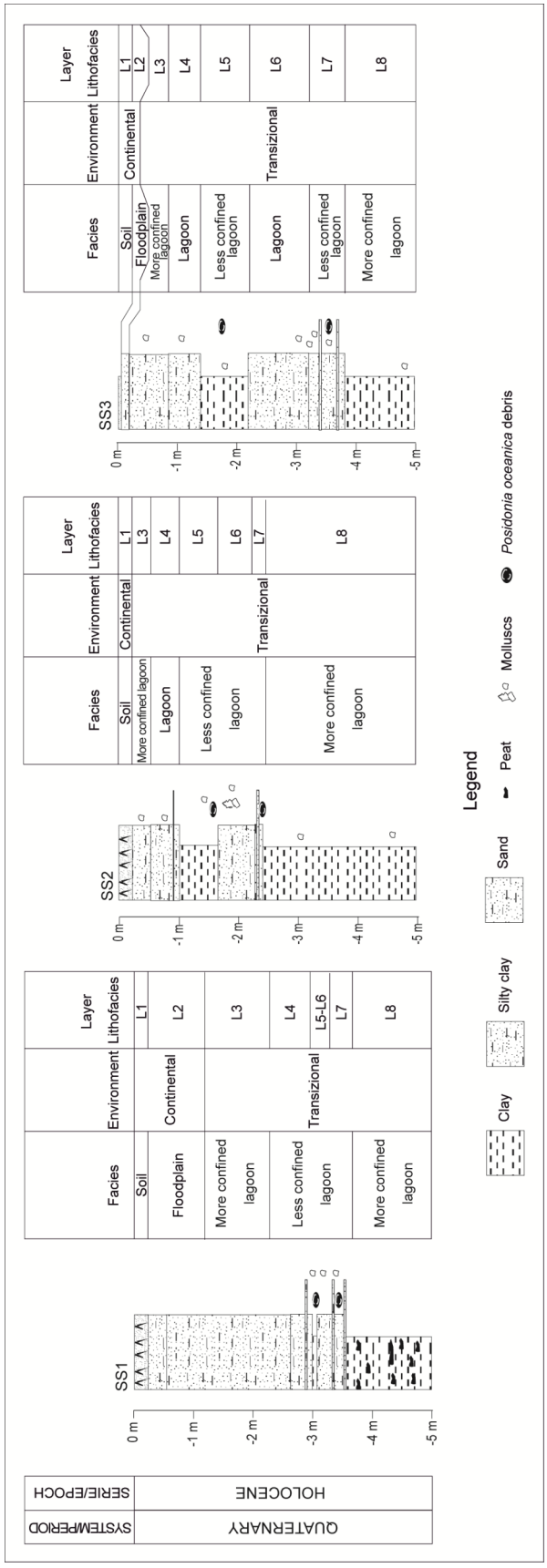


Fig. 2 - Stratigraphic columns of the cores from the archaeological area.

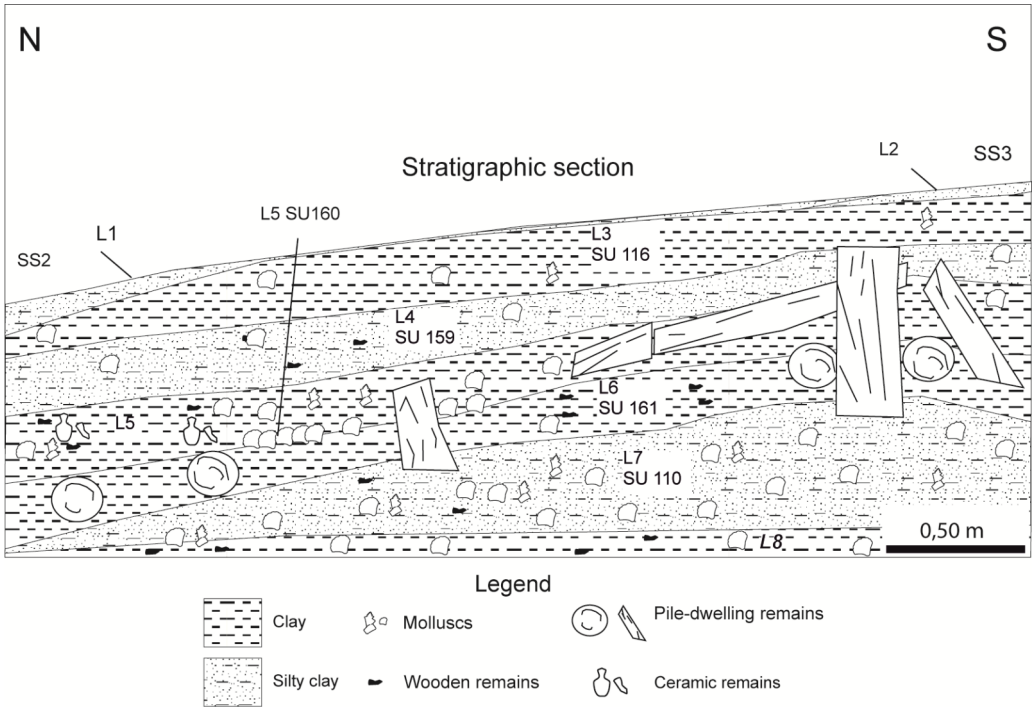


Fig. 3 - Composite stratigraphy of the Stagno pile-dwelling site (from the Area C of Giachi et al., 2010), with stratigraphic layers (L) and archaeological units (SU *sensu* Giachi et al., 2010).

| Stratigraphic Layers | | Archaeological Units (Giachi et al., 2010) | | | Archaeological Phases | Paleoenvironment |
|---|---|---|---|---|---|---|
| Layer | Description | Unit | Depth (m) | Description | | |
| L1 | Soil | | 0 – 0,6 | | | Alluvial plain |
| L2 | Light grey silty clay | | 0,6 – 1,3 | | | Alluvial plain |
| L3 | Grey silty clay with slighty hard consistency | **SU116** | 1,3 – 2,6 | Grey clay with shells | Post abandonment phase | Less confined lagoon |
| L4 | Greenish grey- silty clay with sand levels | SU159 | 2,65 – 3,0 | Greenish grey clayey layer with sandy lenticular bodies | Settlement phase | Lagoon |
| L5 | Blackish clay with shells remains *(Cerastoderma* spp.), fish remains and *Posidonia oceanica* debris | **SU160** | 3 – 3,15 | Grey clay with small wood fragments and shells | Settlement phase | Less confined lagoon |
| L6 | Grey silty clay | SU161 | 3,15 – 3,3 | Grey clay with small wood fragments | Settlement phase | Lagoon |
| L7 | Very plastic silty clay, partially sandy, with abundant shells remains *(Cerastoderma* spp.), fish remains and *Posidonia oceanica* | **SU110** | 3,3 – 3,5 | Grey clay with abundant shells | Pre-settlement phase | Less confined lagoon |
| L8 | Grey clay with peat | | >3,5 | | Pre-settlement phase | More confined lagoon |

Tab. 1 - Sequence of the stratigraphic layers and the main archaeological units recognised in the Stagno pile-dwelling site. In bold the archaeological units sampled.

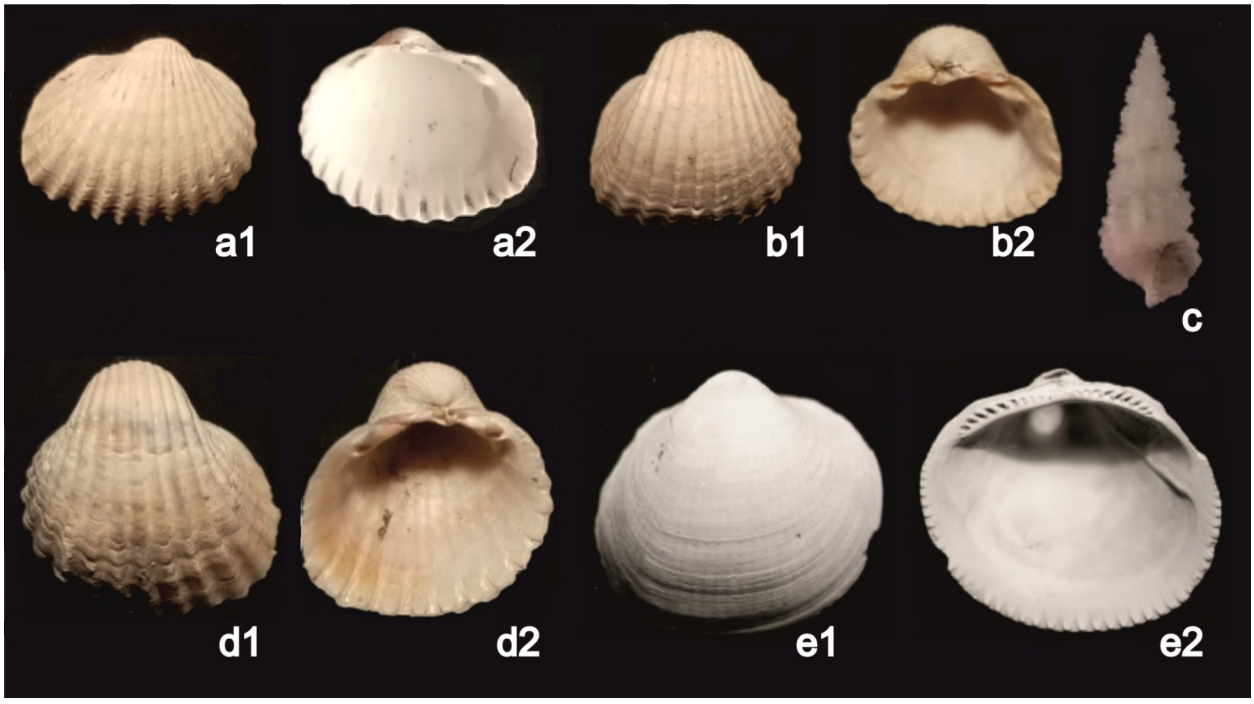


Fig. 4 - Photographs of selected species of molluscs from the archaeological units SU116-SU160-SU110. a) *Cerastoderma edule* (Linnaeus, 1758), length 6 mm, repository code n. 827, external view; 1a, internal view. b) *Cerastoderma glaucum* (Linnaeus, 1758), length 17 mm, repository code n. 827, external view; 1b, internal view. c) *Bittium reticulatum* (da Costa, 1778), height 4 mm, repository code n. 826. d) *Cerastoderma glaucum* (Bruguière, 1789), length 20 mm, repository code n. 828, external view; 1d, internal view. e) *Glycymeris nummaria* (Linnaeus, 1758), length 45 mm, repository code n. 830, external view; 1e, internal view.

ani (1992) include this species in the biocenosis of muddy sands, especially in zones influenced by fresh water. This species is reported in the Mediterranean and Atlantic intertidal grassland ecosystems, including the Bay of Arcachon, where water salinity ranges between 25 and 35 ppt (Mosbahi et al., 2017). All samples contain very frequent specimens of this species (Tab. 2).

4) *Cerastoderma edule* (Linneus, 1758). It is one of the more common bivalve species, which is used as food source. This extremely polymorphous species is euryhaline and eurythermic and lives in the sandy or sandy-muddy bottoms (Dabouineau & Ponsero, 2009; El Asri et al., 2022). It was resulted to be very frequent in the analysed samples (Tab. 2).

5) *Cerastoderma glaucum* (Bruguière, 1789). This species is reported to thrive in microtidal lagoons, shallow creeks, ponds, and salt marshes, or more rarely on lower shores in estuaries (Sromek et al., 2019). Also this species resulted to be very frequent (Tab. 2).

6) *Macomangulus tenuis* (da Costa, 1778). This species is found in fine sands from middle shore to shallow sublittoral zone (Picard, 1965). It was found both in fragments and as rare unbroken specimens in the US110 and US 116 (Tab. 2).

| Taxa | US 110 | US 160 | US 116 |
|---|---|---|---|
| Bivalves | | | |
| *Glycymeris nummaria* (Linneus, 1758) | R | R | - |
| *Mytilaster minimus* (Poli, 1795) | R | R | R |
| *Loripes orbiculatus* Poli, 1795 | VF | VF | VF |
| *Cerastoderma edule* (Linné, 1789) | VF | VF | VF |
| *Cerastoderma glaucum* (Poiret, 1789) | VF | VF | VF |
| *Macomangulus tenuis* Da Costa, 1778 | F | F | - |
| Gastropods | | | |
| *Rissoa membranacea* (Philippi, 1836) | R | R | - |
| *Peringia ulvae* (Pennant, 1777) | VF | VF | F |
| *Bittium reticulatum* (Da Costa, 1778) | F | R | R |

Tab. 2 - Distribution of the molluscs found in the archaeological units of the Stagno pile-dwelling site. Classes of abundance: R (Rare = number of specimens between 1 and 10), F (Frequent = number of specimens between 11 and 50), VF (Very Frequent = number of specimens > 50).

**4.4. Class Gastropods**

1) *Rissoa membranacea* (Adams, 1800). Like many species of *Rissoa* it has a lagoon habitat and among them it has a higher degree of eurihalinity (Mars, 1950). In the analysed samples the species is rare (Tab. 2).

2) *Peringia ulvae* (Pennant, 1777). This species usually lives on muddy sand bottoms, in transitional low salinity environments such as eustuaries, lagoons and marshes. Samples from Stagno site contain frequent forms of the species (Tab. 2).

*3) Bittium reticulatum* (da Costa, 1778). This species is commonly recorded on sandy muddy bottoms in lagoons and coastal shallow waters (Fersi et al., 2023

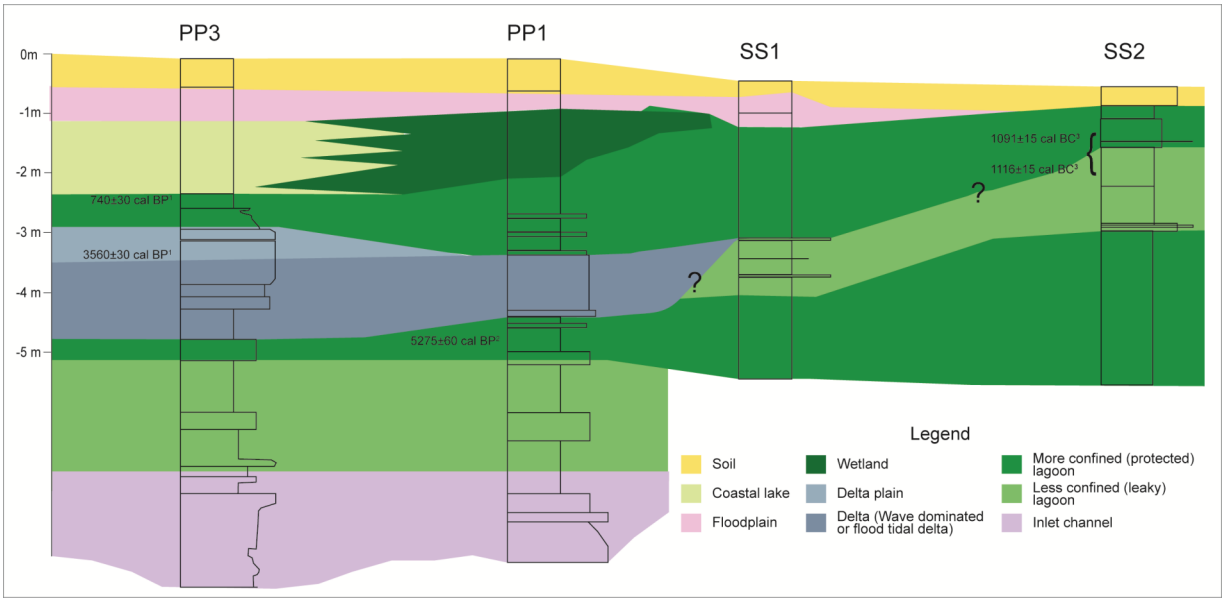


Fig. 5 - Tentatively correlation of the depositional facies recognized in the cores PP3 (modified from Kaniewski et al. 2018), PP1 (modified from Mazzini et al., 2017), and in the cores SS1 and SS3. Radiometric data from 1 Kaniewski et al. (2018), 2 Mazzini et al., (2017), 3 Zanini & Martinelli (2005).

cum bibliography) of the Mediterranean Sea. In our samples, it ranges from frequent to rare (Tab. 2).

## 5. DISCUSSION

The palaeontological analysis shows that, with the exception of *Glycymeris nummaria, Mytilaster minimus* and *Macomangulus tenuis*, all the taxa found in the sampled archaeological units belong to the lagoon euryhaline and eurythermal biocenosis, both as exclusive opportunistic (*C. edule, C. glaucum*, *P. ulvae*), either as preferential (*R. membranacea*, *B. reticulatum*) or as accompanying species (*Loripes orbiculatus)*. The occurrence of autochthonous species related to the biocenosis of the infra-coastal environment in SU110 and SU160 suggests the existence of a connection between the lagoon and the nearby open sea, also supported by the presence of fish remains and *Posidonia oceanica* debris in layers L7 and L5 (Tab. 1). The large number of fragments of *M. tenuis*, found in the SU110 and SU160 units, probably due to exceptional high-energy events (sea coastal storms) would support the argument that during the pre-settlement and settlement phases (Tab. 1) the pile-dwelling site was not far from the sea. On the other hand, the total absence of the marine species *Macomangulus tenuis* and *Glycymeris nummaria* in the more recent SU116 seems to indicate that the lagoon was increasingly protected from the sea (more confined lagoon), so that it was not affected by the sea coastal high-energy events. Therefore, molluscs and stratigraphic analyses indicate that lagoon conditions with a minor degree of isolation from the sea (less confined lagoon) remained unchanged in the Stagno site from the pre-settlement phase (corresponding to SU110) to the settlement phase (corresponding to SU160). Furthermore, lagoon conditions with a greater degree of isolation from the sea (more confined lagoon) is evident for the post-abandonment phase (SU116, Tab. 1).

These indications allow us to hypothesise that the causes of the abandonment of the site was not closely linked to climatic or environmental changes, but maybe to cultural changes. Probably, local conflicts and/or invasions could have induced inhabitants to refuge in larger settlements, far from the sea. Actually, at the transition between the Late Bronze Age and the Early Iron Age, eastern but also western Mediterranean coastal regions were impacted by the attacks of the so-called Sea Peoples (e.g., Kaniewski et al., 2011; Hitchcock & Maeir, 2016). During this period, cities and states from Greece through Mesopotamia to Egypt declined or collapsed in consequence of variable causes and literature provides evidence in support of the drought hypothesis as a triggering factor behind the Late Bronze Age collapse (e.g., Kaniewski et al., 2010 cum bibliography). The Sea Peoples invasion could probably have led to the disruption of the flourishing communities that inhabited the Tuscan coast during the Bronze Age (Grifoni Cremonesi, 2006). As a consequence, or either alternatively, the cultural changes occurring in the final stages of the Late Bronze Age and beginning of the Iron Age, led humans to break with traditions and change type of settlements, which corresponded better to new needs (Jennings, 2014).

Our new data, and both the previous stratigraphic studies of boreholes and the findings from archaeological sites located near the Stagno site, allow a better knowledge of the palaeogeography of a wide area, in the period between the Late Bronze Age and the Early Iron Age. We can compare the stratigraphy of the archaeological site with the stratigraphy performed by Kaniewski et al. (2018), on a core drilled at Santo Stefano ai Lupi (PP3, north of the Stagno pile dwelling, Fig. 1). The PP3 stratigraphy (Fig. 5) suggests the presence

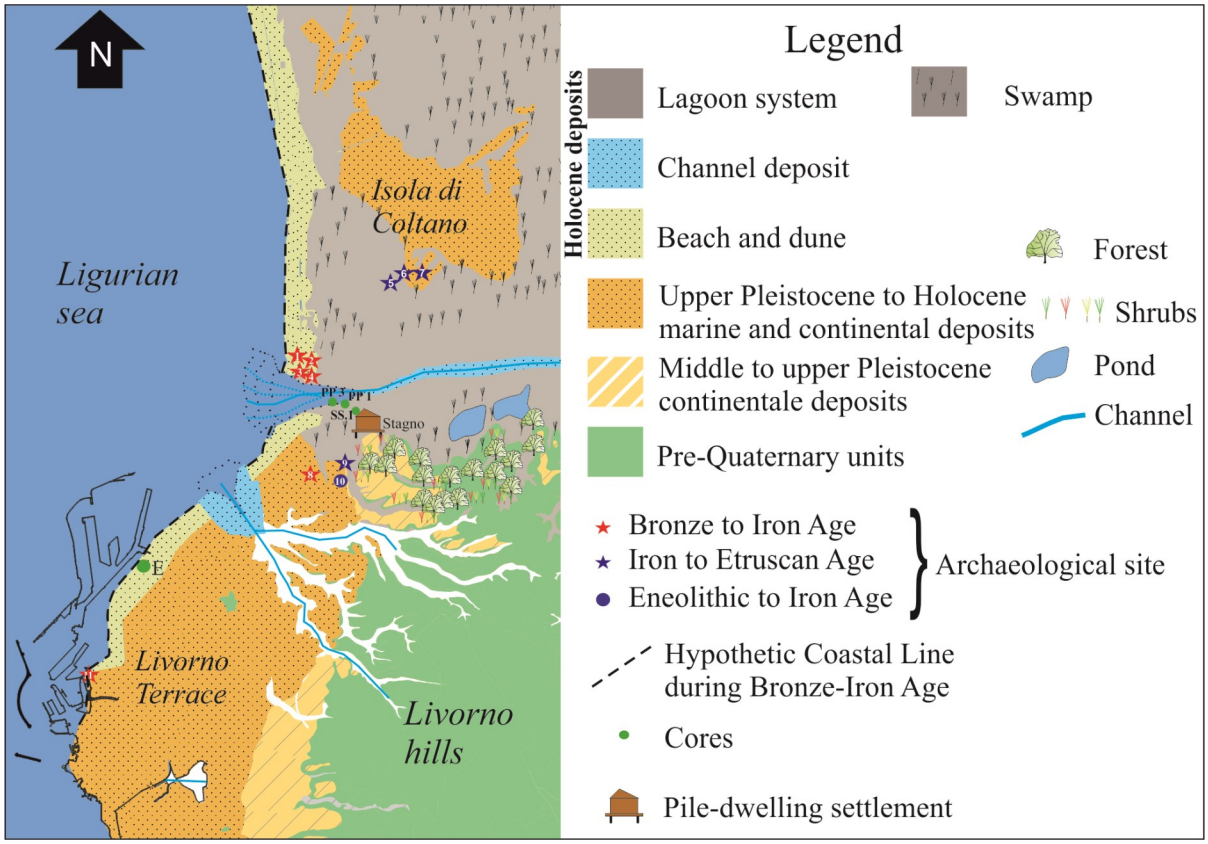


Fig. 6 - Palaeogeographic reconstruction of the area around the Stagno pile-dwelling site, during the Late Bronze Age-Early Iron Age (modified by Dall'Antonia & Mazzanti, 2001 and Mariotti Lippi & Mori Secci, 2007). Archaeological sites: 1-4) Poggio al Lupo (Panicucci & Bagnoli, 1986); 5-7) Isola di Coltano (Pasquinucci & Menchelli, 1997; Boschian et al., 2006); 8) Casone (Sammartino, personal communication); 9) Lago Filippo (Sammartino, 1986); 10) Casa Paretaio (Sammartino, 1997); 11) Fortezza Vecchia (Gambogi & Materrazzi, 1997); Core E (Dall'Antonia et al., 2004), Core PP3 (Kaniewski et al., 2018), Core PP1 (Mazzini et al., 2017).

of a delta plain system characterized by a high input of freshwater since 1950 ±45 BC. In particular, the same authors identify a phase of marine influence linked to a decreasing river flow at 1250 ±40 - 850 ±40 yr BC. In addition, the stratigraphy performed by Mazzini et al. (2016) on the core PP1 (Fig. 5) located between PP3 and the archaeological site (Fig.1) records a delta depositional facies younger than 5275 ±60cal yr BP, probably comparable with that found in PP3. Delta depositional facies is not present in the cores SS1 to SS3 (Fig. 5), so confining the delta system to the north (Fig. 6).

North-west of the Stagno pile-dwelling area, not far from Poggio al Lupo (sites 1-4, Fig. 6), four sites have been identified with concentrations of coarse-grained ceramic materials, with smooth and notched cords, which refer to the Bronze to Iron Age (Panicucci & Bagnoli, 1986) and allow us to confine the lagoon mouth of Stagno. Northwards the lagoon was constrained by the Isola di Coltano relieves as testified by the occurrence of remains of a village of the Iron to Etruscan Age (1600-1200 BC; Pasquinucci & Menchelli, 1997; Boschian et al., 2006; sites 5-7, Fig. 6) that indicates emerged land. South of the Stagno pile dwelling, ceramic materials related to the archaic Etruscan interval of time were recently found at Casone (site 8, Fig. 6; Sammartino, personal communication). The presence of a large emerged beach area, which stretched from the harbour area to the mouth of the lagoon, can be assumed through the evidence of human settlements, referable to the Eneolithic Age-Early Iron Age interval of time, found at Lago Filippo (site 9, Fig. 6; Sammartino, 1986) and Casa Paretaio (site 10, Fig. 6; Sammartino, 1997). Furthermore, southwards a large area of beach was present, as testified by the Etruscan artefacts found at Fortezza Vecchia (site 11, Fig. 6; Gambogi & Materrazzi, 1997). Finally, the presence of a large system of beaches and dunes west of the lagoon, seems to be also supported by the study of a core drilled in the Livorno Harbour (E, Fig. 6) that records beach deposits, up to 4530 ±60 yr BP, in the area of Livorno (Dall'Antonia et al., 2004). As consequence, the lagoon area of Stagno was constrained to the south by continental deposits and to the north by a delta system.

## 6. CONCLUSIONS

This contribution, through a palaeontological and stratigraphic approach, improves the knowledge of the environment where the prehistoric Stagno archaeological site was built. The analysis of the molluscs found in the stratigraphic layers SU110, SU160 and SU116, allowed us to confirm that the pile-dwelling settlement was

built in a lagoon environment close to the Livorno hills. Furthermore, the site was located in a strategic area, in a relatively closed lagoon near the sea, so that the marine resources could be guaranteed. Because of its palaeoenvironmental characteristics, the Stagno site is a singular example of a Late Bronze Age-Early Iron Age lagoon pile-dwelling settlement in Italy. In addition, we were able to reconstruct the palaeogeography of the area between the Livorno Harbour and Isola di Coltano during the Late Bronze Age-Early Iron Age transition. Uncertainties are still about the precise location of terrestrial and submerged areas; this gap of knowledge can only be filled by studies aimed at the reconstruction of the shoreline of the northern area of Livorno based on radiometric datings, and geomorphological, sedimentological and stratigraphic studies. Finally, the palaeontological and stratigraphic study seems to suggest that the abandonment of the pile-dwelling settlement was not strictly due to major environmental or climatic changes, but probably to historical and cultural reasons or a combining both, however associated to a general worsening of the economic and territorial organization of the societies of that time.

**ACKNOWLEDGMENTS**

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