



Late Holocene archaeobotanical evolution of the Canale di Imbocco (Roman imperial port of *Portus*, Central Italy)

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ARTICLE INFO

Article history:

Received 3 March 2022

Received in revised form 12 April 2022

Accepted 14 April 2022

Available online 20 April 2022

Keywords:

Plant macroremains

Paleoenvironmental evolution

Fire

Roman imperial port

ABSTRACT

The Roman port of *Portus* was the most important in the Mediterranean during the imperial period (27 BC–476 AD). It was made up of an outer port or Claudius basin and an inner hexagon or Trajan's port, joined by the Canale di Imbocco. The archaeobotanical record obtained in a continuous sediment core taken in this channel is made up of 19 types of plant macroremains, with a predominance of fibers of the seagrass *Posidonia oceanica* L., replaced by fluvial sediments in the upper part of the core. Seeds, fruits and thorns of aquatic species from marine or brackish waters, halophyte species, edible species, freshwater riparian vegetation and remains of charcoal and wood also appear regularly. According to the inferred palaeoenvironmental evolution of this core, *Portus* was an area of fluvial-marine interaction during the Roman Empire, with brackish water conditions interrupted by stormy periods deduced from the record of *P. oceanica*. The archaeobotanical and sedimentary evolution points to a restriction of marine contributions and a final implantation of a fluvial environment. In this evolution, a specific interval with abundant charcoal and caryopses of *Triticum* could correspond to a fire, which was followed by a possible period of greater construction activity linked with large fragments of wood.

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1. Introduction

Archaeobotany has experienced a notable boom during the last quarter of the 20th century and the beginning of the 21st century, with very significant advances in the study of the interrelationship between humans and plants in archeological contexts, as well as the paleoenvironmental implications derived from the botanical record extracted (Greig, 1989; Fuller, 2013; Atkins et al., 2022). In this general scenario, the collection of plant remains in archeological sites includes both botanical macro-remains and micro-remains, the analysis of which addresses a wide variety of problems and even new approaches, such as: i) plant feeding from past periods; ii) craft uses of plants; iii) effects of resource availability on settlement patterns; or iv) the paleoenvironments at the time of sediment deposition (Hather, 1994; Totmaj et al., 2021; Revelles et al., 2022).

One of the most fascinating periods in history was the Roman Imperial Age (27 BC–476 AD). At the beginning of this period (1st century

AD), Emperor Claudius began the construction of *Portus* near the mouth of the Tiber River, about 30 km south of Rome (Fig. 1A). This huge port (> 200 ha), the most important in the Mediterranean during this period, was completed by Emperor Trajan in the early 2nd century AD to supply this city, which then had more than a million inhabitants.

Portus consisted of an outer port or Claudius basin, joined to an inner hexagon or Trajan port by the Canale di Imbocco (Fig. 1B; Keay et al., 2005). This channel was delimited by the Lanterna wharf (Fig. 1C) and a small dock. In the following four centuries, *Portus* was the main imperial port in the Western Mediterranean, with a subsequent decline aggravated by its destruction during the Gothic Wars (6th century AD) and progressive silting, so that port activity was restricted to Trajan's hexagon from the 7th century AD and its definitive abandonment occurred around the 10th century AD (Di Bella et al., 2011; O'Connell et al., 2019).

This short note analyzes the plant macroremains of a continuous sediment core obtained in the Canale di Imbocco. The main objectives are: i) to evaluate the archaeobotanical diversity of this channel during the imperial era; ii) differentiate possible time periods according to the vertical evolution of the determined plant macroremains; and iii) infer past environmental changes based on the observed botanical variations.

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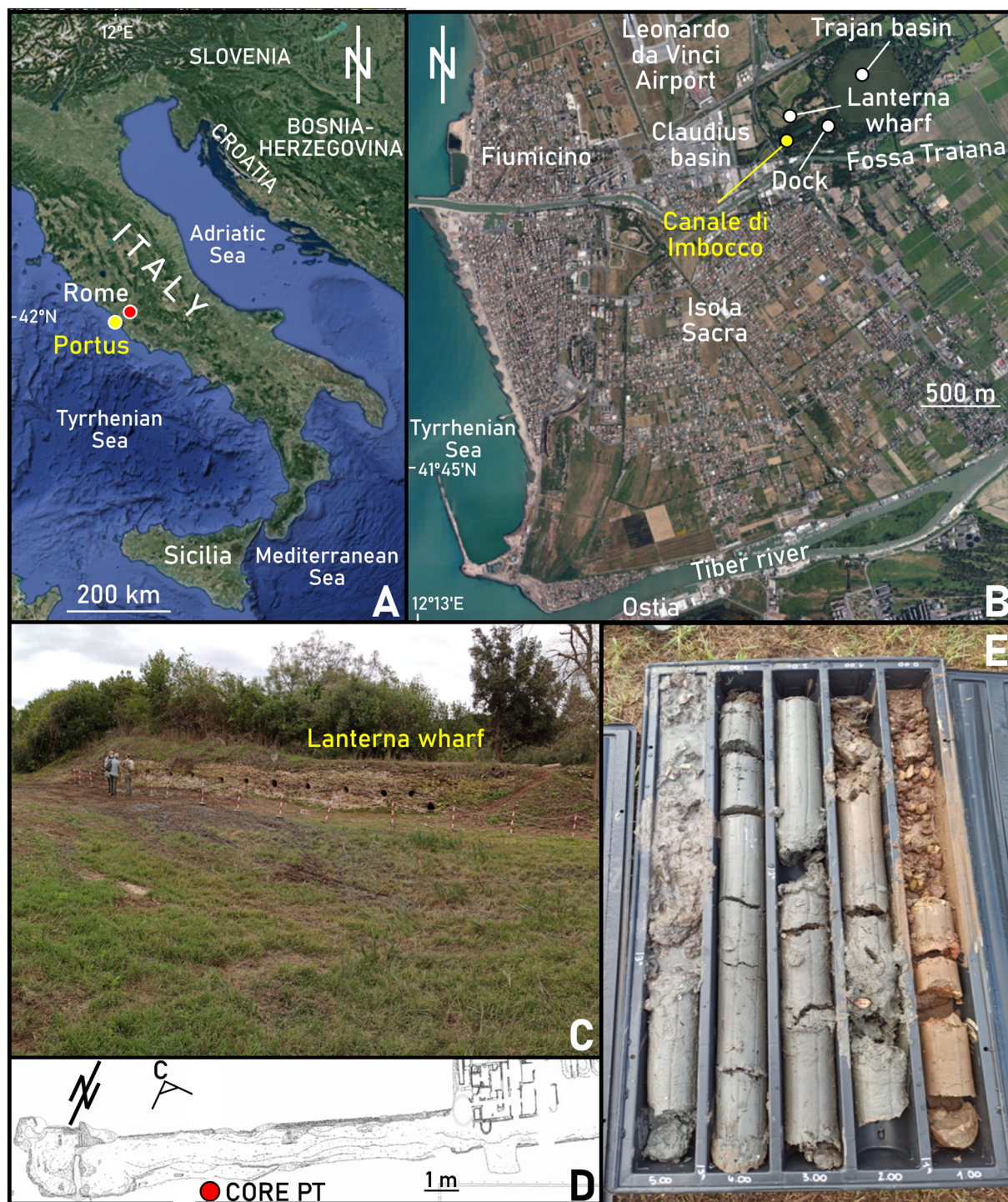


Fig. 1. A) Location of the imperial port of *Portus* (courtesy: Google Earth). B) Structure of the imperial port of *Portus* and its surroundings, with indication of its main components. C) Photograph of the Lanterna wharf, originally located on the Canale di Imbocco between the Claudio basin and Trajan's hexagon; E) Overhead map of the Lanterna wharf, with the location of core PT. F) Photograph of core PT, with the situation of the samples studied.

2. Material and methods

Core PT (Fig. 1D–E: 5 m depth; 41°46'24"N; 12°15'11"E) was extracted by the company Geocompany using usual rotation techniques in the Canale di Imbocco in *Portus*, in the vicinity of the Lanterna wharf. In an initial phase, a visual differentiation of the sedimentary facies was carried out, taking into account the lithology, the color, the limits between the different sedimentary units, the macrofaunistic content and the visible plant remains, among other differentiating elements.

In a second phase, sixteen representative samples of the appreciated facies were selected (Fig. 1E). Twenty grams of each sample were separated for the archaeobotanical study of their macroremains, which were levigated through a 125 μ m mesh diameter sieve.

Finally, two radiometric dates were obtained at the Beta Analytic laboratories (Miami, USA), to which the reservoir effect (58 ± 85 years) indicated by Reimer and McCormac (2002) for this sector of the Western Mediterranean during this period was applied.

3. Results

3.1. Sedimentary record

The basal unit of core PT (5–4.75 m) is formed by gray sandy mud with fragments of the bivalve *Polittapes rhomboides* (Pennant), balanids and bryozoan colonies. Between 4.75 m and 1.25 m deep, this core is made up of an alternation of fairly compact bioclastic muds with numerous shells of the bivalves *Polittapes rhomboides* and *Cerastoderma glaucum* (Bruguère) and compact accumulations of fibers and seaballs or 'Neptune balls' of the seagrass *Posidonia oceanica* (L.) Delile with a slimy matrix. In the upper 1.25 m, an increase in grain size and the presence of ceramic and construction material are observed, with a transition from poorly selected muddy sands to fine gravel, ending with 0.4 m of medium and coarse gravel with numerous quartzite stones and ceramic fragments in the upper part of the core, of fluvial and/or anthropic origin.

3.2. Archaeobotanical record and other macroremains

This record is made up of the following groups (Table 1):

(i) Marine aquatic species. They are represented by *P. oceanica*, present as very abundant accumulations of fibers in some horizons (Fig. 2A; 4.65–4.55 m; 4–3.9 m; 1.9–1.5 m) and as "Neptune balls" with 1–2 cm in diameter (Fig. 2B; 4.25–4 m; 3–2.9 m).

(ii) Aquatic species of marine or brackish waters. This core includes seeds of *Zostera noltii* Hornemann (Fig. 2C), mainly between 5 and 4 m depth, as well as isolated seeds of *Najas* sp. (Fig. 2D).

(iii) Terrestrial halophytic and saline soil species. Its remains are very scarce and are concentrated in the upper 2 m of core PT, with two levels: a) 1.9–1.5 m, with a fruit of *Salsola vermiculata* L. (Fig. 2F) and rare seeds of *Suaeda* sp. (Fig. 2G); and b) a calyx of *Frankenia* sp. (Fig. 2H) in the upper 10 cm.

(iv) Edible species. The most abundant macro-remains (33) belong to achenes of *Ficus carica* L. (Fig. 2J), which are distributed between 5 m and 1.5 m depth. They are followed in abundance by the bones and spines of *Rubus* sp. (Fig. 2M–N), very frequent between 1.9–1.5 m, and the caryopses of *Triticum* sp. (Fig. 2K), restricted to 3.5–3.4 m. Isolated seeds of *Cucumis melo* L. (Fig. 2L; 4.25–3.4 m) and *Vitis vinifera* L. (Fig. 2I; 3–1.5 m) have also been found.

(v) Riparian freshwater vegetation. Only seeds of *Hypericum perforatum* L. (Fig. 2O) and two types of achenes of Cyperaceae (A–B; Fig. 2P–Q) between 1.9–1.5 m have been determined.

(vi) Wood. Abundant remains of wood have been observed throughout the core, mostly fragments smaller than 1 cm (Fig. 2S). However, an accumulation of larger fragments between 3.5–2.9 m is observed (Fig. 2R).

(vii) Charcoal. It is frequent between 4.25–4 m and very abundant between 3.5–3.4 m.

(viii) Other macroremains. Oospores of Characeae (Fig. 2E: *Chara* sp.) and fragments of Coleoptera belonging to the families Tenebrionidae (Fig. 2T) and Curculionidae (Fig. 2U) have also been found.

3.3. Dating

The calibration dates of two samples indicate a sediment age consistent with the historical data from *Portus*. The most probable age of the base of core PF (PT-16: 5–4.9 m depth) is placed towards the second half of the 1st century AD, although it extends to the 4th century AD (range: 200 BC–330 AD). The second sample (PT-6: 1.9–1.8 m depth) was deposited between the 1st and 6th centuries AD, with a maximum probability towards the 4th century AD (range: 90 AD–585 AD).

Table 1
Distribution of plant macroremains in core PT. +, +++, very abundant; +, abundant.

Groups	Aquatic marine or brackish species				Terrestrial halophyte and saline species		Edible species		Riparian freshwater species					Wood		Charcoal			
	Fibers of <i>Posidonia oceanica</i>	Neptune balls' of <i>Posidonia oceanica</i>	Seeds of <i>Zostera noltii</i> sp.	Seeds of <i>Najas</i> sp.	Seeds of <i>Suaeda</i> sp.	Fruits of <i>Salsola vermiculata</i> sp.	Calyx of <i>Frankenia</i> sp.	Seeds of <i>Vitis vinifera</i>	Achenes of <i>Ficus carica</i>	Caryopses of <i>Triticum</i> sp.	Caryopses of <i>Cucumis melo</i>	Stony endocarps of <i>Rubus</i> sp.	Spines of <i>Rubus</i> sp.	Seeds of <i>Hypericum perforatum</i>	Achenes of Cyperaceae A		Achenes of Cyperaceae B	Wood remains > 1 cm	Wood remains < 1 cm
Samples	Depth (m)																		
PT-1	0-0.1																		
PT-2	0.4-0.5																		
PT-3	0.7-0.8																		
PT-4	1-1.1	+																	
PT-5	1.5-1.6	+++																	+
PT-6	1.8-1.9	+++																	+++
PT-7	1.9-2	+++	1				1												+++
PT-8	2.4-2.5	+																	+++
PT-9	2.9-3	+++			1														+
PT-10	3-3.1																	+++	+
PT-11	3.4-3.5	+																+++	+
PT-12	3.9-4	+++																+++	+
PT-13	4-4.1	+++	2															+++	+
PT-14	4.15-4.25	+++	1															+	+
PT-15	4.55-4.65	+++																+	+
PT-16	4.9-5	+			1													+	+++

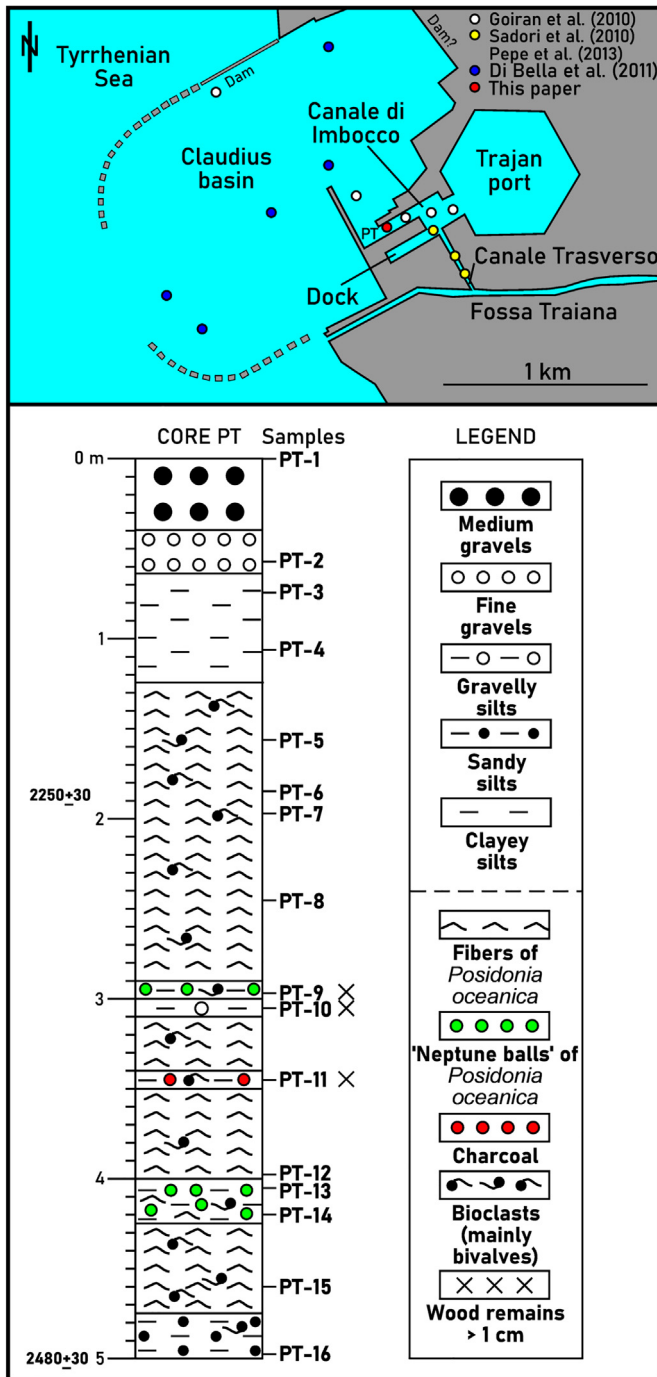


Fig. 2. A) Fibers of *Posidonia oceanica* L.; B) 'Neptune balls' of *P. oceanica* L.; C) Seeds of *Zostera noltii* Hornem.; D) Seeds of *Najas* sp.; E) Oospore of *Chara* sp.; F) Fruit of *Salsola vermiculata* L.; G) Seed fragment of *Suaeda* sp.; H) Calyx of *Frankenia* sp.; I) Seed of *Vitis vinifera* L.; J) Achenes of *Ficus carica* L.; K) Caryopses of *Triticum* sp.; L) Seed of *Cucumis melo* L.; M) Bone fragments of *Rubus* sp.; N) Spines of *Rubus* sp.; O) Seeds of *Hypericum perforatum* L.; P) Achene of family Cyperaceae (type A); Q) Achene of family Cyperaceae (type B); R) Wood fragments greater than 1 cm; S) Wood fragments smaller than 1 cm; T) Coleoptera: fragment of Tenebrionidae; U) Coleoptera: fragment of Curculionidae.

4. Discussion

4.1. The importance of *Posidonia oceanica*

The most distinctive archaeobotanical character of the Canale di Imbocco filling is the presence of massive accumulations of *P. oceanica*, both in fibers and in Neptune balls. This endemic Mediterranean

seagrass currently forms meadows on a soft substrate at depths between 0.5 and 40 m (Roig, 2001) and this paper testifies to its presence in this sea for about 1800–2000 years. Other analyzes carried out on cores obtained in the vicinity of Portus advance this appearance to at least 3300–3000 years BP (1300–1000 BC) on the western coast of the Italian peninsula (Millet et al., 2014).

The massive and continuous contributions of fibers and Neptune balls of *P. oceanica* to this sedimentary filling, together with the sediments transported by the Tiber River and the deposit of fine materials in this area of low hydrodynamic gradient, would have caused serious clogging problems in this channel. According to the dates obtained, the sedimentation rate between the base of core PF core and a depth of 1.8–1.9 m would be very high and would be around 1.17 cm/year (~3.1 m in ~265 years), very similar to that found in other nearby cores (1 cm/year; Goiran et al., 2010). Consequently, the Canale di Imbocco should be dredged with certain periodicity to maintain its average depth during the imperial era (7–8 m; Goiran et al., 2010). Dredging of other channels near core PT has been confirmed in the 4th century AD (Pepe et al., 2013), within the range of the radiometric dates obtained in this paper, so both these dates and the inferred sedimentation rate must be treated with some caution and the latter could be even somewhat higher.

In core PT, the disappearance of *P. oceanica* is confirmed in two different scenarios (Table 1): i) temporary absence (3.2–3 m), coinciding with an increase in grain size, attributed by Pepe et al. (2013) to intense periods of regular discharge of the Tiber River; and ii) a definitive disappearance (1–0 m), which coincides with the presence of coarse sediments of fluvial and/or anthropic origin that denote the definitive clogging of Portus (Fig. 1E).

Another interesting aspect is the punctual presence of levels (4.25–4 m; 3–2.9 m) where the "Neptune balls" are very abundant and hardly any fibers of *P. oceanica* are found. These pellets come from the release of the cellulose fibers that constitute the leaves of this phanerogam after its death in autumn, with a mechanical erosion that leads to the formation of these subspherical structures and their final transport to land during periods of storm (Sánchez-Vidal et al., 2021). If the previously obtained sedimentation rate is applied, the approximate age of the base of the lower concentration of Neptune balls (4.25 m) would be estimated between 136 BC and 394 AD, if the dating obtained in the base of core PT is taken as a reference (Table 2: 200 BC–330 AD). In this interval of radiometric ages, Portus suffered a period of strong storms in 62 AD, which caused the loss of about 200 ships and would force its expansion with the Trajan hexagon (Keay et al., 2005), so this Neptune balls-storm interrelationship is plausible. However, new research and more precise age models applied to new sediment cores are needed to confirm this correlation.

4.2. The palaeoenvironmental reconstruction of the Canale di Imbocco

Archaeobotany also provides tools for the paleoenvironmental reconstruction of this great port and the surrounding areas (Fig. 3). In its lower part (5–4.25 m), the seeds of *Zostera noltii* and *Najas* sp. appear together. *Z. noltii* is a common phanerogam on intertidal or subtidal muddy or sandy bottoms of estuaries, marshes and shallow marine areas of the Mediterranean and European Atlantic coasts (Valle et al., 2010). It is a euryhaline species, which supports salinities between 8‰ and 35‰ (Pérez Llorens, 2004). This distribution, together with the massive accumulation of *P. oceanica*, would be indicative of a brackish environment with important marine contributions towards the Canale di Imbocco some 2000–1800 years ago. This strong initial marine component deduced at the base of core PF is also revealed by the presence of the bivalve *Polittapes rhomboides*, a species that is found from the intertidal zone to 183 m depth, in very diverse seabeds (Yamuzza-Clavijo et al., 2010). (See Fig. 4).

This brackish scenario is also reflected in the following 2.25 m of core PF (4–2 m) by the conjunction of the bivalve *Cerastoderma glaucum* and

Table 2
Radiometric dating of core PT.

Sample	Depth (m)	Material	Laboratory number	Uncalibrated C ¹⁴ age (BP)	Error	Calibrated C ¹⁴ age (BC/AD)
PT-6	1.8–1.9	<i>Cerastoderma glaucum</i>	Beta-602823	2250	30	200 AD–540 AD
PT-16	4.9–5	<i>Polititapes rhomboides</i>	Beta-602826	2480	30	90 BC–250 AD

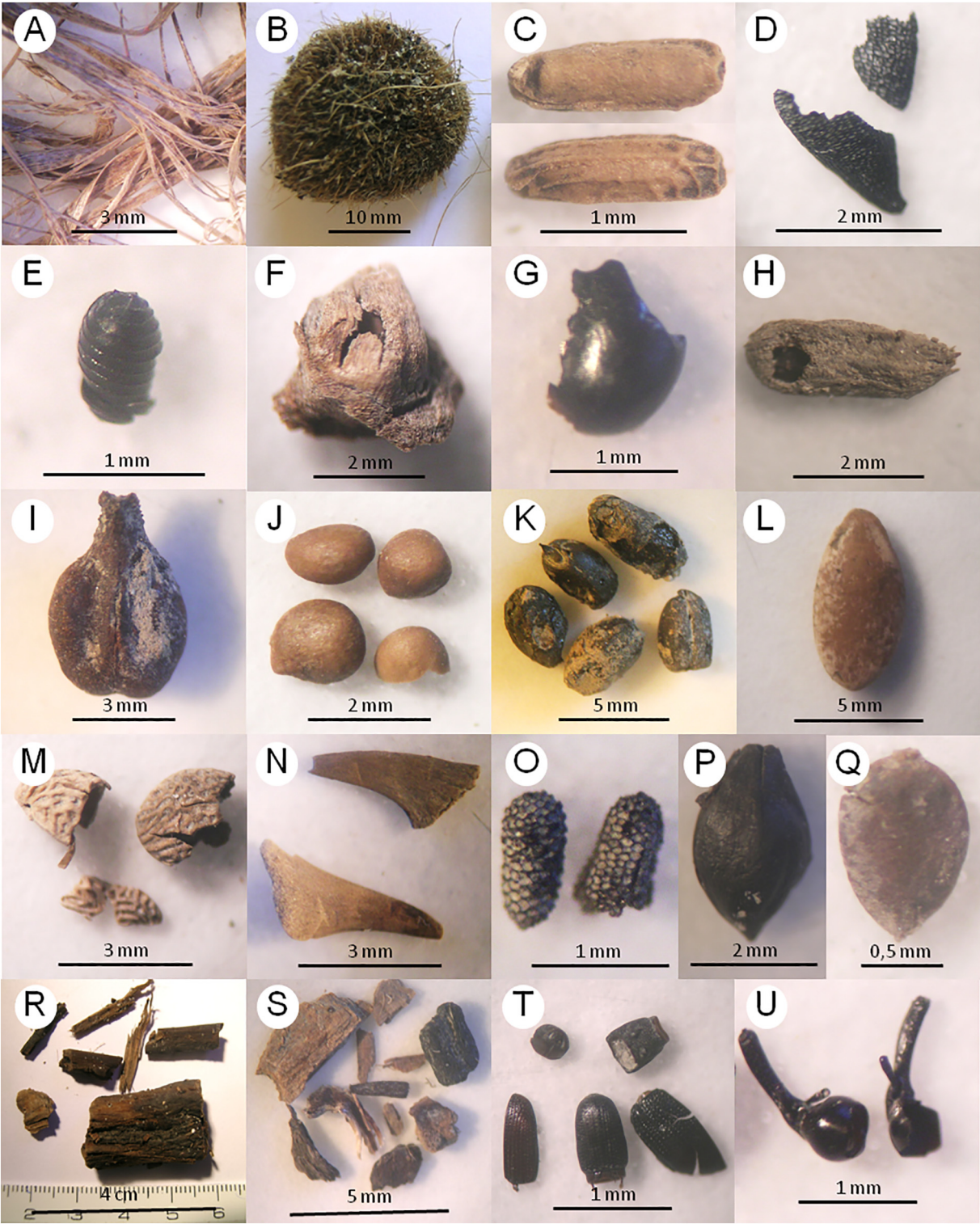


Fig. 3. Palaeoenvironmental reconstruction of core PT.

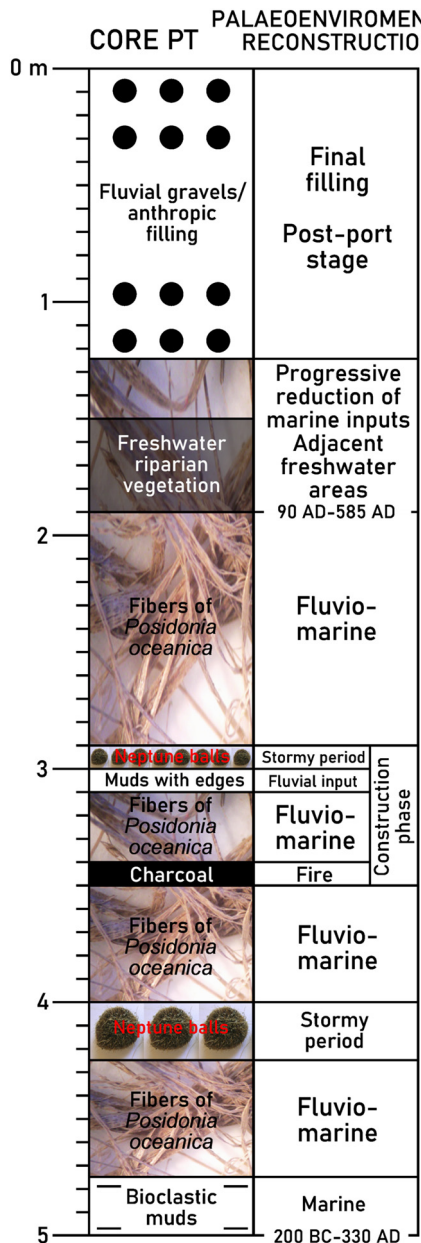


Fig. 4.. Paleoenvironmental reconstruction of core PT.

the accumulation of fibers of *P. oceanica*. This bivalve, commonly called the green cockle, is common in coastal environments (lagoons, estuaries, etc.) with significant environmental stress, as it tolerates a wide range of salinities (5–38.5 ‰) and temperatures (0–25 °C) (Boyden and Russel, 1972).

In this interval, high concentrations of charcoal are observed between 3.5–3.4 m depth. In other cores from the Italian coast, these high densities have been related to local fires (Sadori and Giardini, 2007). In other cores of *Portus*, these concentrations have been associated with its destruction during the Gothic Wars (537 AD; Pepe et al., 2013). Evidence in favor of this hypothesis is its coincidence at this level with the only caryopses of wheat (*Triticum* sp.) observed in this core, which could correspond to the destruction of the warehouses or horrea of *Portus*, where large quantities of cereals were imported and stored (Keay et al., 2005; Keay and Paroli, 2011). Despite this, archaeobotanical remains of wheat do not usually appear in other cores of *Portus* (Pepe et al., 2013; Sadori et al., 2015). From this level, the size of the wood fragments increases notably (> 1 cm) up to a

depth of 2.9 m, which could correspond to a construction phase on the margins of the channel after the possible aforementioned fire.

Between 1.9–1.5 m depth, the joint presence of seeds of halophytic terrestrial species and saline soils together with seeds and achenes of freshwater riparian vegetation is confirmed. This would be indicative of a progressive clogging of the Canale di Imbocco and a transition towards a confined lagoon environment, probably surrounded by brackish marshes, freshwater flooded areas and possibly some dune ridges, as can be deduced from the seeds of *Sueda* sp. and *H. perforatum* and the fruits of *S. vermiculata* that have been extracted in this interval (Mateus, 1992; German and Pino, 2018).

Plant macroremains are almost absent in the uppermost 1.5 m of core PF, coinciding with a notable increase in grain size (especially gravel) that denotes the implantation of a fluvial environment or a final anthropic fill. The calyx of *Frankenia* sp. obtained in the last 10 cm of the PT control could come from *Frankenia laevis* L. or *Frankenia pulverulenta* L., species of non-flooded sandy or silty soils, outside the influence of the tides (Olson et al., 2003). It would testify the definitive implantation of terrestrial palaeoenvironments and the definitive silting of the Canale di Imbocco.

4.3. The edible species of *Portus*

The archaeobotanical record of edible species is relatively limited in core PT, as well as in other cores obtained at *Portus* and other Roman ports from the same historical period. However, it is interesting to note the extraction in almost all of them of pits and/or seeds of *V. vinifera* (vine), *F. carica* (fig tree), *C. melo* (cantaloupe) and *Rubus* sp. (blackberry) (Pepe et al., 2013; Sadori et al., 2015). These macroremains can come from nearby trees or crops, or from transport by sewage or surface runoff, since they are adapted to be consumed by animals or humans and to be excreted without being affected. In archaeobotanical analyzes carried out in the buildings located on the northwest side of Trajan's hexagon, numerous macroremains of *Triticum* spp. were extracted, as well as fruits of vines, fig trees and blackberries, which attests to the presence of these species in warehouses and other constructions close to core PT (O'Connell et al., 2019).

5. Conclusions

The archaeobotanical record of the Canale di Imbocco, located in the Roman imperial port of *Portus*, has made it possible to infer its environmental evolution during the first centuries of our era. In a first phase, this channel was dominated by marine dynamics and progressively evolved into a fluvio-tidal zone, where fibers and Neptune balls of the seagrass *P. oceanica* were mixed with bivalves from brackish environments. During this second fluvio-tidal phase, the levels of Neptune balls have been assimilated to stormy periods, while the absence of this phanerogam would imply an increase in fluvial contributions. The presence of a level with accumulation of charcoal and wheat seeds has been associated with a fire, which would be followed by a construction interval characterized by a larger size of the wood remain. In a third phase, a transition towards more restricted environments is observed, with riparian freshwater vegetation adjacent to the channel. Finally, this channel was definitively filled by fluvial and/or anthropic sediments. During all these phases, seeds and fruits of edible species (cantaloupe, vine, blackberry, fig) have been detected, also present in the archaeobotanical record of constructions located near the Canale di Imbocco.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This paper was jointly supported by the following projects: a) project DGYCIT CTM2006-06722/MAR; b) DGYCIT project CGL2006-01412; c) “From the Atlantic to the Mediterranean (DEATLANTIR): Research in the infrastructures of Portus-Ostia Antica: the Lanterna wharf” (Programme of Archeology Projects Abroad, Ministry of Culture and Sports); d) From the Atlantic to the Tyrrhenian. Hispanic ports and their commercial relations with Ostia Antica (DEATLANTIR II - HAR2017-89154-P - (National R&D Plan)); and e) FEDER project 2014-2020 UHU-1260298. Other funds come from the research groups HUM-132, RNM-238 and RNM-293 (P.A.I.D.I). It is a contribution to the Center for Research in Historical, Cultural and Natural Heritage of the University of Huelva. The archaeobotanical record is deposited in the Laboratory of Paleontology and Applied Ecology of the University of Huelva.

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