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Geoarchaeological investigations in the area of the imperial harbours of Rome

Ricerche geo-archeologiche nell'area dei porti imperiali di Roma

Recherches géoarchéologiques dans la zone des ports antiques de Rome

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Résumés

English Italiano Français

This paper shows the results of a geoarchaeological study carried out in the area of the ancient harbours of Rome, built by the Emperors *Claudius* and *Traianus*. Lithostratigraphic, biostratigraphic, chronological (14C) and geophysical surveys have allowed us to define several features of the harbour complex, which is today largely buried under modern sediments. This complex was built near an ancient river mouth, which was already inactive at the time. In particular, the Claudian basin was protected by two curved piers separated by a wide entrance facing the open sea. The basin was approximately 5-7 m in depth and was filled for the most part during the Middle Ages by marine and alluvial sediments.

Il presente lavoro illustra i risultati di uno studio geo-archeologico effettuato nell'area degli antichi porti di Roma, costruiti dagli imperatori Claudius e Traianus. Rilievi litologici, biostratigrafici, cronologici e geofisici hanno permesso di definire la struttura del complesso portuale, che è attualmente sepolto da sedimenti recenti. Questo complesso fu costruito vicino alla foce di un fiume, già all'epoca inattivo. In particolare, il bacino Claudiano era protetto da due moli curvi separati da un'ampia entrata di fronte al mare aperto. Il bacino era profondo circa 5-7 m e fu colmato in larga parte durante il Medioevo da sedimenti marini e alluvionali.

Cet article présente les résultats d'une étude géoarchéologique dans la zone des ports antiques de Rome construits par les empereurs Claude et Trajan. Des analyses lithologiques, biostratigraphiques, géochronologiques et géophysiques ont permis d'identifier les structures du complexe portuaire, qui est de nos jours complètement colmaté de sédiments. Cet ensemble portuaire a été fondé à proximité d'une ancienne embouchure du Tibre. Le bassin de Claude était protégé par deux môles incurvés délimitant une vaste passe donnant sur la mer ouverte. Le bassin présentait une colonne d'eau d'environ 5 à 7 m et a été colmaté en grande partie durant le Moyen Âge par des apports marins et fluviaux.

Entrées d'index

Mots-clés : bathymétrie, delta du Tibre, géoarchéologie, géomorphologie, Ostie, port antique, portus

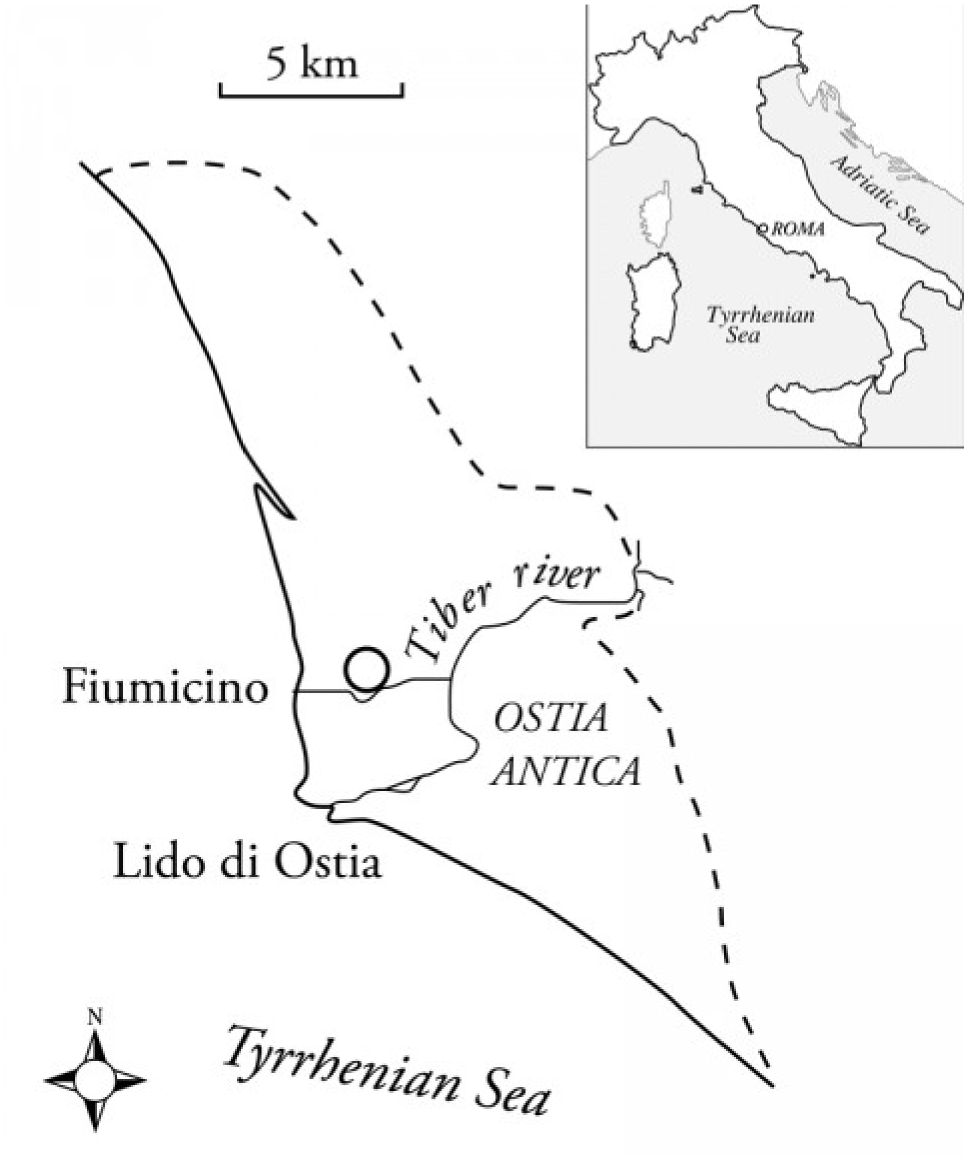
Keywords: ancient harbour, geoarchaeology, geomorphology, Ostia, portus, Tiber delta

Parole chiave: batimetria, delta del Tevere, geoarcheologia, geomorphologia, Ostia, porto antico, portus

Texte intégral

1 The archaeological site of the imperial harbours of Claudius and Trajan is located approximately 4 km north of the main mouth of the River Tiber (fig. 1), in an area which has been subjected to rapid environmental changes during Holocene and Modern Times. Several Latin authors have left accounts of activities carried out at the harbours, even describing part of the structures. Of these, only the Trajan basin can be seen today, while visible remains of the Claudian harbour are very fragmentary since this harbour is mostly buried under delta deposits, and some parts have been destroyed over time. The aim of this work is to supply evidence to support a reconstruction of the Claudian harbour by using geological and archaeological data as well as information deriving from historical sources and recent literature.

Fig. 1 - Location of the studied area.



1 - Methods

2 The aim of the geological investigation was to identify buried harbour structures and to define the environmental changes which have occurred over the last millennia. This was achieved by integrating the results of a morphologic analysis, a geophysical survey, and a stratigraphic analysis of the Late Holocene successions. Aerial photographs and a digital elevation model were used to achieve this. Furthermore, lithostratigraphies from 21 cores - broken-down by granulometric, micro-faunistic and 14C dating analyses (tab. 1) - also allowed us to focus on the most significant deposits, as defined in our objectives. Lastly, data from a GPR (Multi-fold Ground Penetrating Radar) survey were also taken into account, with the aim of defining the paleo-environmental evolution and locating buried structures.

Tab 1 - Radiocarbon ages.

Lab identifier	Well	Sample depth (m below the surface)	Conventional 14C age (yr BP± 1σ)	δ13C (‰)	Calibrated age yr BP± 1σ	Material
LTL-461 a	9	3.50	1140±40	-27.1	970-1165	Peaty-sand
LTL-462 a	3	4.40	2935±45	-27.5	3000-3205	Sand with peat

LTL-463 a	12	4.50	1885±50	-24.5	1735-1.880	Sand with vegetal remains
LTL-465 a	12	6.50	2840±35	+ 0.4	2875-2990	Marine mollusc fragment Tellina sp.
LTL-466 a	2D	7.50	3255±35	-24.3	3405-3550	Peaty-sand whit vegetal
LTL-467 a	5	7.75	2165±50	-19.8	2065-2305	Vegetal remains
LTL-468 a	1	11.00	6150±55	- 2.0	7325-7475	Brackish mollusc Cerastoderma glaucum
LTL-469 a	7	11.00	2485±40	- 5.6	2470-2710	Marine gastropoda Bittium reticulatum
LTL-470 a	6	16.50	3920±60	-27.1	4255-4420	Vegetal remains
LTL-471 a	4	17.50	5565±110	- 2.3	6205-6484	Marine mollusc fragments Thracia sp.
LTL-472 a	10	22.20	7485±40	- 4.2	8210-8350	Marine mollusc fragments Tellina sp.
Rome-1718	1	27.00	8490±70	-28.1	9435-9535	Wood fragments

modified from P. Bellotti *et al.*, 2007.

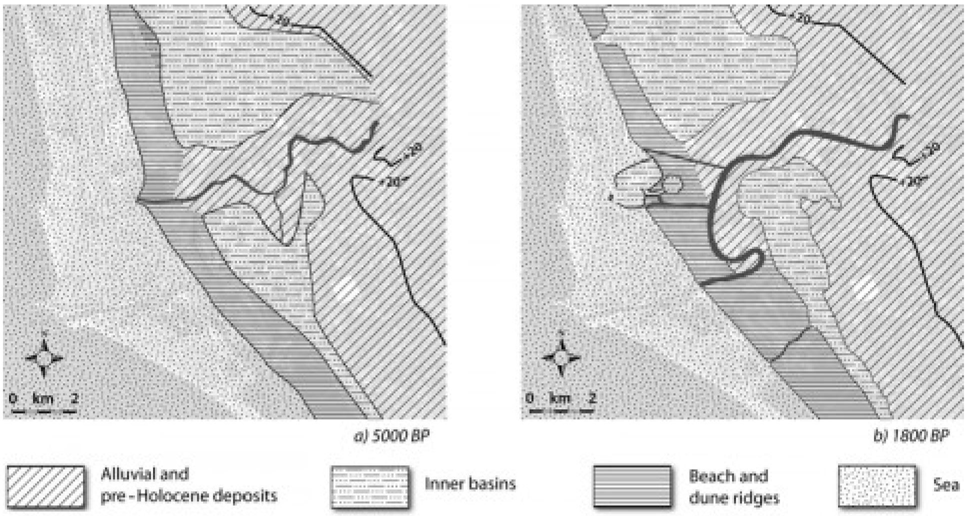
3 The archaeological part of this work has included the creation of an inventory, using aerial photographs and in loco visits, of any Roman archaeological remains visible in the area today. Moreover research was carried out to locate information on the harbours using sources from both Roman and Renaissance literature.

2 - Geological evolution

4 The area of the harbours is located within the Tiber River delta, whose Holocene evolution has been outlined in several studies, mostly based on morphologic and stratigraphic data (Belluomini*et al.*, 1986 ; Bellotti*et al.*, 1994; 1995 ; AmorosiandMilli, 2001 ; Giraudi, 2004 ; Bellotti *et al.*, 2007). All the authors believe that the delta evolution was controlled by: sea-level variations, fluvial sediment supplies, marine processes of sediment redistribution and antecedent topography.

5 At the beginning of the Holocene, the ancient Tiber River valley was flooded by the rising sea, forming a bay in which the mouth of the river was located. Around approximately 5000 years BP, as sea levels became relatively stable, the bay was transformed into two costal lakes, separated by the course of the river and closed off towards the sea by a small coastal barrier (fig. 2a); the river mouth was located where the entry to Fiumicino airport can be seen today (Segre, 1986 ; Giraudi, 2004). Between 3000 and 2600 years BP an avulsion directed the course of the river towards the southern lagoon, moving its mouth approximately 3 km south of where it was previously. The scenario around 1800 years BP is shown in fig. 2b. In this new position repeated episodes of progradation gave rise to the modern beach ridge strand plain. The two lakes later became coastal ponds and were definitively reclaimed in the XIX century.

Fig. 2 - Morphology of the Tiber delta aera.



At the beginning of the present highstand (a) and at the time of the construction of the imperial harbours (b).

3 - The harbours of ancient Rome

3.1 - The Claudian Harbour

6 Although large ships could dock at the fluvial harbour of Ostia and reach Rome, either by sailing or by being dragged upriver by oxen (*Dionysius Halicarnassi*, III, 44), in 42 AD the Emperor Claudius began building works to construct a second harbour for the city slightly further north. Two centuries later historian CassiusDio (*Hist. Rom.* 60, 11, 1 ss) explained that the rationale behind these works was the need to equip Rome with a bigger harbour, one which could better guarantee a continuous supply of foodstuffs to the city.

7 The new harbour project was the subject of lengthy debates - especially given that experts at the time were against the idea because of its high costs and construction related issues - so much so that Quintilianus (*Istitutiones* III, 8, 16) cites the case as an example of a public debate in his manual on rhetoric. The work was nevertheless carried out, with excavations taking place both on the beach and seafloor to create a basin for the harbour. Furthermore, to stop it from filling up, drainage from the River Tiber was facilitated with two or three channels, which connected the last meander of the river directly to the sea. In 46 AD, the works were suspended due to a flood, and in 62 AD - right before the harbour was inaugurated (by *Nero* in 64 AD) - a storm sunk at least 200 ships, along with another 100 which, having entered the Tiber, were destroyed by a fire (Tacitus, Annales 15, 18).

8 The Claudian harbour extended over an area of approximately 90 hectares and was a small, vibrant, business centre with buildings used to process and store goods and provide homes for local workers and temporary housing for shopkeepers. Other structures had instead been set aside for mercantile cooperatives, cult rituals and the occasional sacred celebration.

9 A bas-relief from the Torlonia Collection shows the harbour complete with a great lighthouse which, rising out of the seafloor, divides incoming and outgoing ships. Furthermore, the south pier shown in the bas-relief is decorated with sculptures and sophisticated architectural solutions which unfortunately do not allow us to calculate the actual size of harbour structures. What can be gleaned from literary sources is that the lighthouse (also known as the "lighthouse island") was built on a sunken ship which had been previously used by Emperor *Caligula* (I century AD) to transport an obelisk which was installed in the Vatican Circus (Suetonius, *Claud.*, 20, 3,

Plinius,*Historia Naturalis* 16, 40, 201). Suetoniusand Cassius Dio both describe the lighthouse as being built on a small sandy island, while Plinius instead places it on the southern pier.

10 The remains of the harbour, which are still visible today, consist of a cement nucleus, travertine blocks, a portion of the dock, a building for public use, thermal baths and a sizeable cistern, for the north pier. The remains of the southern pier are much more fragmentary and no part of the lighthouse island has been found.

3.2 - The Trajan Harbour

11 The Emperor Traianus designed a second harbour to enlarge the Claudian one, bestowing it with a more internal and protected basin. The project - highly detailed and articulated - was implemented between 100 and 112 AD and the harbour was inaugurated in 112/113 AD, as can be seen on the coin containing the words *portus Traiani*. The inauguration date is, however, purely indicative because an uninterrupted series of works soon followed and continued under the rule of Adrianus, Septimius Severus and Constantinus. The Trajan harbour was connected to the Claudian harbour, which continued to be used as roadstead protection and later inscriptions refer to *uterque portus* (both harbours). The Trajan basin was hexagonal in shape with sides of 357.77 m and a dock complete with mooring points. This in turn was closed off by a wall with five points of access (1.80 m) on each side of the hexagon. Large numbers of warehouses surrounded it, facing a wide, paved road. Trajan's building works are praised both in a comment to a verse by Iuvenalis (*Satires*, XII, 75) and by Plinius (*Panegyric*, 29).

12 Boats entered the harbour through a wide SW-NE channel marked by a lighthouse which was connected to the Claudian harbour. A minor basin (224 x 47 m), so-called Darsena, was located to the south, parallel to the channel. The double harbour complex was connected to Rome by both the via Portuense and the River Tiber, the latter connected to the complex by the Fossa Traiana. According to Keay *et al.* (2005), Darsena and Fossa Traiana were part of the Claudian scheme and in existance at the times of Trajan. Trajan had a large lighthouse built of superimposed blocks, and decorated with marble bas-reliefs, placed at its mouth together with a giant statue of himself. Enormous warehouses were positioned next to the mooring points. The harbour complex also included baths, buildings for the authorities to be employed for representation, and one or more temples containing prized sculptures (Carcopino, 1907; Verduchi, 2002; Zevi, 2004).

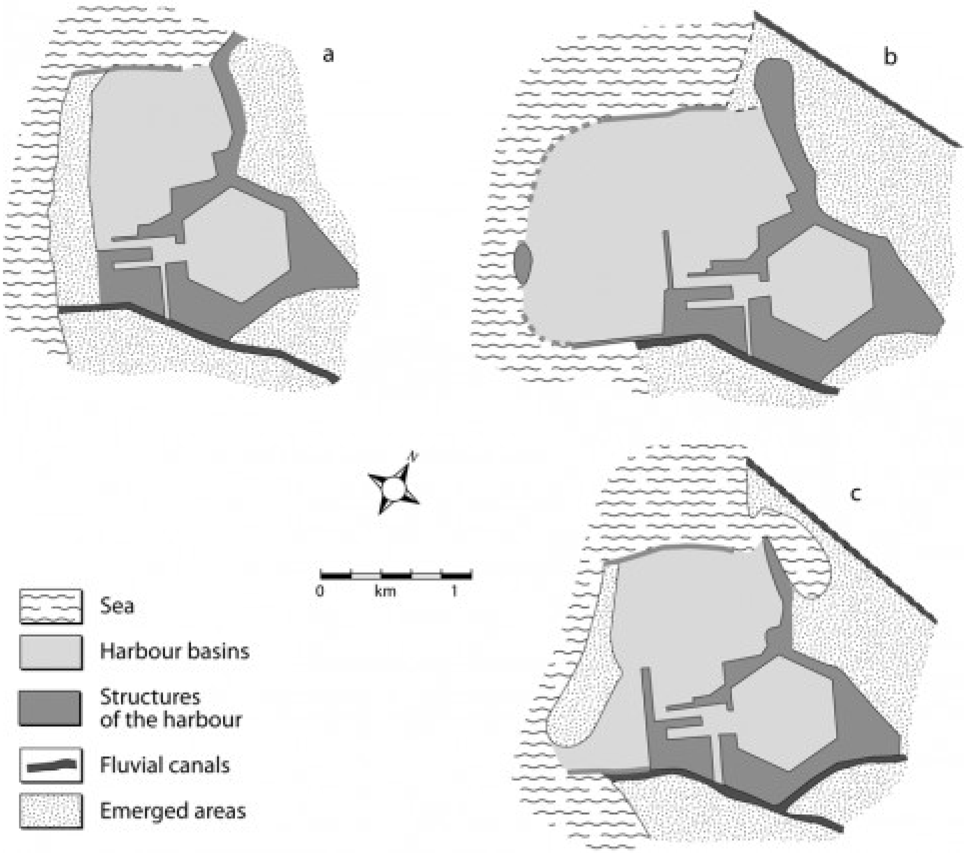
13 With the crisis of the IV century and the transfer of power to Constantinople, mercantile and economic activities at the harbour saw a significant decline. Between the end of the IV century and the beginning of the V century AD, defensive walls were built around the harbour complex to safeguard this important point of access to Rome from Barbarian invasions. The Barbarian incursions of the V century AD devastated the territory and effectively stopped the local population from controlling water drainage in the region. This resulted in a progressive increase of swamplands and in the complete abandonment of the Trajan Basin (MannucciandVerduchi, 1992).

3.3 - Hypotheses on the Structure of the Claudian Harbour

14 Paintings and reconstructions of the double harbour complex, based on the archaeological remains which were still visible before the last phase of delta progradation (XVI-XIX centuries), were already being painted during the

Renaissance. However, it was only in the XX century that the first hypotheses on the layout of the harbour itself were put forth, after archaeological digs had been carried out and aerial photographs had been examined. Three different hypotheses were essentially put forward following the work carried out by G. Lugliand G. Filibek (1935). The first hypothesis (Scrinari, 1960, 1986 ; Testaguzza, 1970), has a coastal spit bordering the Claudian basin and a pier positioned in the north, with a point of access next to the coast (fig. 3a). Hypothesis 2 (Castagnoli, 1963; Giuliani, 1992), refuted the existence of the spit, believing instead that the harbour was closed off by two piers grounded on the coast and had a westward facing point of entry (fig. 3b). Hypothesis 3 (Giraudi*et al.*, 2006) claimed instead that the coastal spit was, in fact, part of a delta cusp dating back to a pre-imperial age, and that the harbour had one point of access facing west and one (probably secondary) to the north (fig. 3c).

Fig. 3



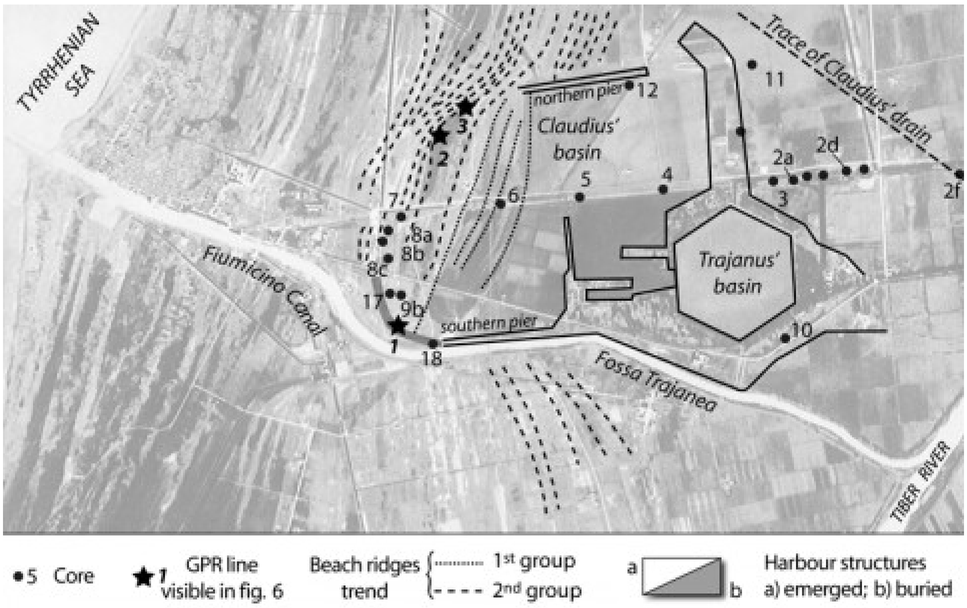
Reconstructions of the Roman harbours following three different hypotheses.

4 - Geological data

4.1 - Morphology

15 Aerial photographs and topographic data (DEM) highlight that the area of the harbour complex is relatively flat and depressed compared to the surrounding region. However, topographic irregularities are present both inside and outside this area, and they are due to two beach ridge systems (fig. 4).

Fig. 4



Stratigraphic organization of the deposits in the Roman harbour areas.

16 The first system, within the Claudian basin, shows straight ridges in the outer basin (core zones 7 and 8) and slightly arched ridges in the internal part (core 6). The second system, outside the basin, appears to be brusquely deflected by the north pier, proof that the latter probably stretched further out toward the sea than what may be evinced from its remains today. Furthermore, this deflection straightens out as it travels south, as if to "embrace" the outer harbour pier, which is not currently visible.

17 All the aforementioned features suggest: a) the basin of Claudius was filled by sediment in relatively high-energy conditions, since the formation of beach ridges (first system) requires wave action; b) the filling occurred in a basin which was at first semi-protected (arched beach ridges) and later more open to the sea (straight beach ridges); c) because the beach ridges are typically aligned to the right of wave direction, the filling of the basin was controlled by a western wave access; d) this access could correspond to the original entrance of the harbour or to the total or partial destruction of the western pier; e) the position of the second beach ridge system seems to provide an outline of the original perimeter of the harbour, which is much closer to the Castagnoli/Giuliani hypothesis (the second one) than to the other two (fig. 3).

4.2 - Core Stratigraphy

18 The oldest deposits, found in the easternmost zone, consist of mud and sand containing gastropods (*Hydrobidae* and *Neritina* sp.), fragments of small bivalves, ostracodes, and rare forms of *Ammonia parkinsoniana* and *Ammonia tepida*. These deposits can be traced back to a bay environment with local barrier-lagoon systems, dated between 9500 and 7300 BP (fig. 4), and refer to the last marine transgression (Transgressive Systems Tract: TST).

19 Above the flooding surface (MFS), modern deposits (highstand systems tract: HST) are differentiated on the basis of stratigraphic depth and distance from the present coastline (fig. 4). Those from the inner (cores 1-3, 10 and 11) and outer (cores 7-9b) zones are usually organised in a coarsening-up sequence.

20 The lower portion of the HST, between MFS and -10/12 m from land surface, includes: below, poorly sorted muddy-silt with thin sand levels containing plant remains and mollusc fragments; and above, moderately sorted fine sand with occasional peaty and gravely layers. Micro-fauna - significantly more abundant in the cores from the central and western zones - is marked by large numbers of *Ammonia parkinsoniana* and *Ammonia tepida*, and to a lesser extent of: *Aubignyna perlucida*,

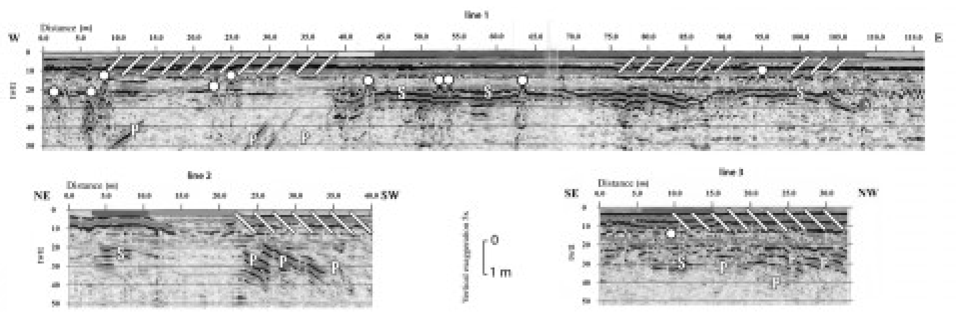
Asterigerinata mamilla, *Adelosina mediterranensis*, *Bolivina puntata*, *Bulimina elongata*, *Bulimina marginata*, *Elphidium decipiens*, *Elphidium incertum*, *Elphidium granosum*, *Triloculina schreiberiana*, *Valvulineria bradyana*. The lower HST can be interpreted as deposits formed in a bay influenced by a river, passing transitionally westwards to an infralittoral environment with freshwater influence (fig. 4).

21 The upper portion of the HST (above -10/12 m), in the western zone (cores 1-3, 10 and 11) consists of silt-grey sands including rare bivalves (lower sequence) as well as peaty layers, plant remains and ancient Roman brick (upper sequence). Micro-fauna is almost completely absent. In the central zone (cores 4-5-6) two distinct stratigraphic intervals are found. The lower is 5-7 m thick and includes poorly sorted silty-sand and sandy-silt sediments, containing bivalve remains (primarily *Cerstoderma glaucum* and *Tellina* sp.) and wood fragments. Micro-fauna - scarce in core 4 - becomes richer towards core 6 where it is marked by the presence of *Ammonia parkinsoniana* and *Ammonia tepida* (less frequent than in the previous association) and includes *Rosalina bradyi*, *Lobatula lobatula*, *Milionella grata*, *Milionella elongata*, *Milionella dilatata*, *Quinqueloculina subpolygona*, *Quinqueloculina levigata*, *Quinqueloculina seminulum*. The upper stratigraphic interval is instead made up of sandy-mud and fine to coarse sand, with local concentrations of small clams and fine polygenic rounded gravel. Micro-fauna - absent in core 4 and scarce in core 5 - is richer and present almost from the land surface in core 6, with *Ammonia parkinsoniana*, *Ammonia beccarii*, *Triloculina marioni*, *Triloculina plicata*. Stratigraphy in the western zone (cores 7-9b) reveals the ubiquitous presence of fine to medium sands containing local bivalve fragments as well as fragments of Roman amphorae and brick. Micro-fauna is only present below -5 m with a similar association as the one found in core 6, but including *Ammonia inflata*.

22 Upper HST deposits of the eastern zone are linked to a river-swamp environment. Transition towards the sea of this environment is located in the central zone, whose western margin is heavily influenced by marine waters (fig. 4). Specifically, deposits from the upper stratigraphic interval can be for the most part traced back to Claudian basin sedimentation, which occurred during the harbour's period of activity and its successive filling. Stratigraphy in the western zone instead attests to an infralittoral environment developing into a submerged and emerged beach.

23 Ground Penetrating Radar survey - This was carried out in zones where we assumed the entrances to the Claudian harbour were located. Specifically, the survey in the eastern margin of the north pier (entrance according to hypothesis 1 and 3) did not reveal the presence of buried structures or beach ridge foresets. The zone of the western point of access (hypotheses 2 and 3) instead showed beach ridge foresets and sub-horizontal surfaces with high reflectivity which may be attributed to harbour structures. Part of the buried southern pier (fig. 5, line 1) - whose remains were also found in core 17 - were detected, while highly reflective surfaces situated further north (fig. 5 lines 2 and 3) appear sporadically and are difficult to interpret.

Fig. 5 - GPR records



Symbols “C” and “S” indicate reflectors possibly linked to buried remains of the Claudian harbour, whereas symbol “P” refers to beach ridge foresets (left and right oblique bars highlight only the extension of the foreset-field). Dots denote the modern drain, gas and sewer pipes

Conclusions

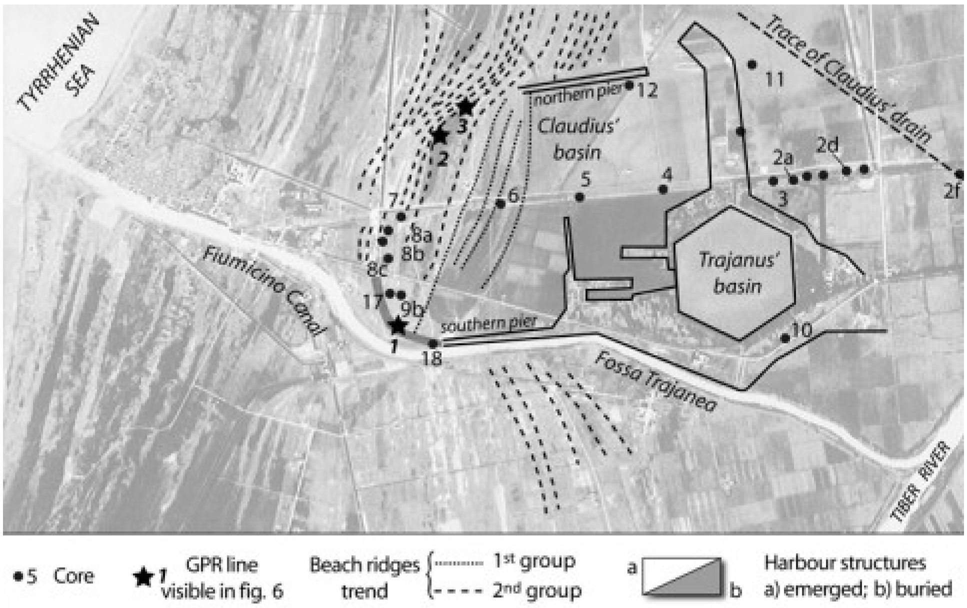
Pre-Roman deposits

24 Keay *et al.,* (2005), indicate that « Portus was constructed on alluvial deposits... ». More exactely, the harbour complex lies in an area which had housed the mouth of the Tiber River up to a thousand years before the construction of this complex, as may be evinced from the: (a) micro-fauna found in the cores which indicates environments with a strong freshwater influence 10-12 m below the land surface; (b) paleo-environmental reconstructions in (Bellotti *et al.*, 2007); (c) beach ridges located near harbours which Giraudi (2004) considers to be part of a delta cusp dating back to between 4000 and 3000 BP; (d) river sequences recognised 8 m below present sea level (Goiran*et al.*, 2007). Giraudi (2004) indicates that the river mouth was abandoned after 2800 BP - as may be seen from the micro-fauna in our study - while Goiran *et al.* (2007) have dated this to 3100 BP.

The perimeter of the Claudian harbour

25 Georadar evidence and archaeological remains from core 17 suggest that the sea-facing part of the southern pier was curved towards the north to provide partial protection for the harbour basin. Furthermore, the deflected alignment of the beach ridges (cited as the second system, fig. 6) reveals the outline of a similarly-curved north pier, originally stretching a great deal further out towards the sea than the portion visible today. Buried remains of this pier can perhaps be seen in the highly-reflecting local surfaces detected by the georadar.

Fig. 6



Orientation of the beach ridges present in the Roman harbour regions, with location of the cores and the GPR lines reported in fig. 6.

26 In contrast, hypotheses 1 and 3 (fig. 3) describe the harbour as closed off on the outside by a coastal spit or delta cusp deposits, which were nevertheless not found in the upper part of core 6, whose micro-fauna is linked to a vegetated infralittoral

environment. Goiran *et al.* (2007) refute the claim that the north pier was built on the deposits described above. More generally, it seems unlikely that a harbour designed for intense traffic would use ephemeral deposits, often associated with shallow seafloor, and perhaps even subject to marine flooding, to provide protection.

Harbour entrances

27 The more western cores (6-9b) are the richest in marine micro-fauna, indicating a western-facing point of access to the harbour. Intense harbour traffic and the difficulty Roman ships had manoeuvring in critical sea-conditions, suggests that the harbour was equipped with a wide entrance. Nevertheless, during the time of the filling of the harbour basin (first beach ridge system), this basin was particularly exposed to wave action, perhaps due to the partial destruction of the north pier following the abandonment of the harbour. Our findings do not allow us to either validate the existence of a lighthouse island nor to establish where it was possibly located.

28 Hypotheses 1 and 3 (fig. 3) provide the harbour with a northern entrance located between the northern pier and the coast. Specifically, Giraudi *et al.* (2006) maintain that the opening was already very shallow in the III century AD and almost completely closed off after the IV century AD, while Goiran *et al.* (2007) found a 2 m thick layer of marine sands in the hypothetical zone of the northern entrance. The cores closest to this alleged point of access (12-4 and 5 *pro parte*) provide no clear evidence of its existence, and in actual fact indicate the presence of a paleo-seafloor with a low level of circulation and a low oxygen content (Di Bella *et al.*, 2007). The georadar survey, like the magnetometer survey in Keay *et al.* (2005), has also found no evidence directly or indirectly connected to this entrance. A northern point of access also appears to be somewhat improbable from an architectural point of view. In fact, it would have meant forcing Roman ships - much less manoeuvrable than modern ones - to approach the harbour using hazardous routes: either following the line of the north pier or obliquely, travelling in shallow waters and with waves lateral to the boats. It also seems unlikely that skilled Roman engineers were unaware of the fact that such an access would have favoured the interment of the harbour due to longshore sediment transported from the north. Therefore, we believe that if such a point of access did exist, it would have been secondary and employed by local traffic only. Recently Tronchère *et al.*, (2008), based on the results of hydraulic models, indicate that “the two openings hypothesis seems to be the best solution from a sediment dynamics and navigation point of view”.

Depth of the Claudian basin

29 We have estimated this to be approximately 5-7 m, taking into account the fact that sediments which may be attributed to harbour deposits (cores 4-5-6) were found -8 m above present sea level, which is about 1 m above the Roman one (Anzidei *et al.*, 2003). Bellotti *et al.* (2006) come to the same conclusion by identifying the Roman paleo-seafloor along a stratigraphic section extending up to the present coastline.

Harbour basin fill

30 Most of the burial took place in the Middle Ages, as can be seen from littoral bar sediments (cores 7, 8, 9) containing peaty lenses dating back to around the X century AD.

The western entrance could have remained active for all of the warm medieval phase, ensuring an influx of marine waters (recorded in cores 6 and 5) with enough energy to form beach ridges (first system). With the recommencement of delta progradation - which completely blocked off the harbour's western point of access - the inner part of the basin turned into a brackish environment, later slowly filled by alluvial sediments.

Closing remarks

31 Hypotheses 1 and 3 (fig. 3) describe a harbour partly protected from the sea by a sandy barrier without a wharf on which to handle goods. This type of harbour would be very unusual in Roman terms, at least with respect to large complexes. Hypothesis 2 (fig. 3) most closely matches our findings and the descriptions and images found in Renaissance literature. Moreover, such a hypothesis seems to best describe the situation in terms of design, given the proven skills of Roman engineers. Further investigations must be carried out in the western zone in order to define the size and shape of the points of access to the harbour and the location of the island-lighthouse.

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Bibliographie

Amorosi A., Milli S., (2001), Late Quaternary depositional architecture of Po and Tevere river deltas (Italy) and worldwide comparison with coeval deltaic succession, *Sedimentary Geology*, 144, p. 357–375.
DOI : 10.1016/S0037-0738(01)00129-4

Anzidei M., Benini A., Lambek K., Antonioli F., Espopsito A., Surace L., (2003), *Siti archeologici costieri di età romana come indicatori delle variazioni del livello del mare: un'appicazione al mare Tirreno (Italia centrale)*, in ANSER, *Evoluciòn paleoambiental de los puertos y fondeaderos antiguos en el Mediterraneo occidental*, I seminario, Alicante 14-15 noviembre 2003, p.115-126.

Bellotti P., Chiocci F.L., Milli S., Tortora P., Valeri P., (1994), Sequence stratigraphy and depositional setting of the Tiber delta: Integration of high resolution seismics, well logs and archaeological data, *Journal of Sedimentary Research*, B64-3, p. 416-432.

Bellotti P., Milli S., Tortora P., Valeri P., (1995), Physical stratigraphy and sedimentology of the late Pleistocene-Holocene Tiber Delta depositional sequence, *Sedimentology*, 42, p. 617-634.
DOI : 10.1111/j.1365-3091.1995.tb00396.x

Bellotti P., Di Bella L., Tortora P., Valeri P., (2006), *Studio per l'identificazione del paleo-fondale di età romana nel sottosuolo dell'area del futuro porto di Fiumicino.* Rapporto scientifico del contratto di ricerca tra il Dipartimento di Scienze della Terra (Univ. di Roma "La Sapienza") e L'Autorità dei Porti del Lazio, 66 p.

Bellotti P., Calderoni G., Carboni M G., Di Bella L., Tortora P., Valeri P., Zernitskaya V., (2007), Late Quaternary landscape evolution of the Tiber River delta plain (Central Italy): new evidence from pollen data, biostratigraphy and 14C dating, *Zeitschrift für Geomorphologie*, 51(4), p.505-534.
DOI : 10.1127/0372-8854/2007/0051-0505

Belluomini G., Iuzzolini P., Manfra L., Mortari R., Zalaffi M., (1986), Evoluzione recente del Delta del Tevere, *Geologica Romana*, 25, p. 213-234.

Carcopino J., (1907), Il porto Claudio Ostiense, *Notizie Scavi*, p. 734-740.

Castagnoli F., (1963), Astura, *Studi Romani*, 11, p. 637-644.

Di Bella L., Bergamin L., Frezza V., Bellotti P., Carboni M.G., (2007), *Paleoenvironments in the Roman Claudius Harbour at the Tiber River Mouth (Central Italy). Evidences from benthic foraminifera*, EGU 2007, Vienna.

Giraudi C., (2004), Evoluzione tardo-olocenica del delta del Tevere, *Il Quaternario*, 17, p.

477-492.

Giraudi C., Paroli L., Ricci G., Tata C., (2006), Portus (Fiumicino – Roma) Il colmamento sedimentario dei bacini del Porto di Claudio e Traiano nell'ambito dell'evoluzione ambientale tardo-antica e medievale del delta del Tevere, *Archeologia Medievale*, 33, p. 49-60.

Giuliani C.F., (1992), Note sulla topografia di Portus, In V. Mannucci (ed.)*, Il Parco Archeologico-Naturalistico del Porto di Traiano. Metodo e progetto*, Roma, p. 29-44.

Goiran J.-P.*et al.*, (2007), *Recent geo-archeological findings of Portus, the ancient Harbour of Rome, People/environment relationships from Mesolithic to Middle Ages: recent Geo-Archaeological findings in Southern Italy*, International Congress, Salerno 4th-7th September 2007, p.30-31.

Lugli G., Filibeck G., (1935), *Il porto di Roma Imperiale e l'Agro Portuense*, Roma, Istituto Italiano d'Arti Grafiche.

Keay S., Millett M., Paroli L., Strutt K., (2005), *Portus: an archaeological survey of the Port of Imperial Rome*. Archeaological Monographs of the British School at Rome, p. 360.
DOI : 10.1002/9781444338386.wbeah16111

Mannucci V., Verduchi P., (1992), « Il Porto imperiale di Roma: le vicende storiche », in V. Mannucci, *Il Parco Archeologico Naturalistico del Porto di Traiano. Metodo e progetto*. Roma, p. 55-60.

Scrinari V., (1960), Strutture portuali relativa al "porto di Claudio" messo in luce durante i lavori dell'Aeroporto Intercontinentale di Fiumicino (Roma), *Rassegna dei Lavori Pubblici*, 3, p. 173-190.

Scrinari V. S. M., (1986), Indagine al porto di Claudio, *Archeologia Laziale*, 8, p. 181-188.

Segre A.G., (1986), Considerazioni sul Tevere e sull'Aniene nel Quaternario, *Archeologia Laziale*, 8, p. 9-17.

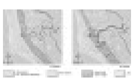
Verduchi P., (2002), Quindicesimo itinerario. Un'area archeologica complessa. Il Porto di Roma, in *ROMArcheologica, guida alle antichità della città eterna*, Roma De Rosa, 64 p.

Testaguzza O., (1970), *Portus. Illustrazione dei porti di Claudio e Traiano e della città di Porto a Fiumicino*, Roma, Julia editrice, 249 p.

Tronchère H., Millet B., Botto G., Goiran J.P., (2008), *Water currents modelisation in the ancient Harbour of Rome*, poster *XVII AIAC Archeological Congress, Roma*, 22th-26th September 2008.

Zevi F., (2004), Inquadramento storico relativo ai porti di Roma, in Anser, *Strutture dei porti e degli approdi antichi.*, II seminario, Roma-Ostia Antica 16-17 aprile 2004, p. 211-219.

Table des illustrations

	**Titre**	Fig. 1 - Location of the studied area.
	URL	http://journals.openedition.org/mediterranee/docannexe/image/3131/img-1.png
	Fichier	image/png, 66k
	**Titre**	Fig. 2 - Morphology of the Tiber delta aera.
	Légende	At the beginning of the present highstand (a) and at the time of the construction of the imperial harbours (b).
	URL	http://journals.openedition.org/mediterranee/docannexe/image/3131/img-2.png
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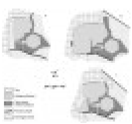	**Titre**	Fig. 3
	Légende	Reconstructions of the Roman harbours following three different hypotheses.
	URL	http://journals.openedition.org/mediterranee/docannexe/image/3131/img-3.png
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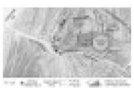
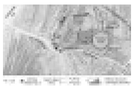
	**Titre**	Fig. 4
	Légende	Stratigraphic organization of the deposits in the Roman harbour areas.
	URL	http://journals.openedition.org/mediterranee/docannexe/image/3131/img-4.png

	Fichier	image/png, 265k
	**Titre**	Fig. 5 - GPR records
	Légende	Symbols “C” and “S” indicate reflectors possibly linked to buried remains of the Claudian harbour, whereas symbol “P” refers to beach ridge foresets (left and right oblique bars highlight only the extension of the foreset-field). Dots denote the modern drain, gas and sewer pipes
	URL	http://journals.openedition.org/mediterranee/docannexe/image/3131/img-5.png
	Fichier	image/png, 324k
	**Titre**	Fig. 6
	Légende	Orientation of the beach ridges present in the Roman harbour regions, with location of the cores and the GPR lines reported in fig. 6.
	URL	http://journals.openedition.org/mediterranee/docannexe/image/3131/img-6.png
	Fichier	image/png, 265k

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- Pannuzi, Simona. (2018) *Ricerche su Ostia e il suo territorio*. DOI: 10.4000/books.efr.3753
- Marriner, Nick. Morhange, Christophe. Flaux, Clément. Carayon, Nicolas. (2017) *Encyclopedia of Earth Sciences Series Encyclopedia of Geoarchaeology*. DOI: 10.1007/978-1-4020-4409-0_119
- Marriner, Nick. Morhange, Christophe. Flaux, Clément. Carayon, Nicolas. Kaniewski, David. (2023) *Encyclopedia of Earth Sciences Series Encyclopedia of Geoarchaeology*. DOI: 10.1007/978-3-030-44600-0_119-1
- Milli, Salvatore. D'Ambrogi, Chiara. Bellotti, Piero. Calderoni, Gilberto. Carboni, Maria Gabriella. Celant, Alessandra. Di Bella, Letizia. Di Rita, Federico. Frezza, Virgilio. Magri, Donatella. Pichezzi, Rita Maria. Ricci, Valeria. (2013) The transition from wave-dominated estuary to wave-dominated delta: The Late Quaternary stratigraphic architecture of Tiber River deltaic succession (Italy). *Sedimentary Geology*, 284-285. DOI: 10.1016/j.sedgeo.2012.12.003
- Salomon, Ferréol. Strutt, Kristian. Mladenović, Dragana. Goiran, Jean-Philippe. Keay, Simon. (2023) Management of fluvio-coastal dynamics in the Tiber delta during the Roman period: using an integrated waterways system to cope with environmental challenges at Ostia and Portus. *Water History*, 15. DOI: 10.1007/s12685-023-00324-3

- Bellotti, P.. Calderoni, G.. Di Rita, F.. D'Orefice, M.. D'Amico, C.. Esu, D.. Magri, D.. Martinez, M. Preite. Tortora, P.. Valeri, P.. (2011) The Tiber river delta plain (central Italy): Coastal evolution and implications for the ancient Ostia Roman settlement. *The Holocene*, 21. DOI: 10.1177/0959683611400464

- Di Bella, Letizia. Bellotti, Piero. Frezza, Virgilio. Bergamin, Luisa. Carboni, Maria Gabriella. (2011) Benthic foraminiferal assemblages of the imperial harbor of Claudius (Rome): Further paleoenvironmental and geoarcheological evidences. *The Holocene*, 21. DOI: 10.1177/0959683611405239

- Salomon, Ferréol. Keay, Simon. Carayon, Nicolas. Goiran, Jean-Philippe. (2017) Un « modèle âge-profondeur paléoenvironnemental » pour interpréter les séquences sédimentaires en milieu portuaire (Portus, Italie). *Quaternaire*. DOI: 10.4000/quaternaire.8011

- Salomon, Ferréol. Goiran, Jean-Philippe. Noirot, Brice. Pleuger, Elisa. Bukowiecki, Evelyne. Mazzini, Ilaria. Carbonel, Pierre. Gadhoum, Ahmed. Arnaud, Pascal. Keay, Simon. Zampini, Sabrina. Kay, Stephen. Raddi, Michele. Ghelli, Alessandra. Pellegrino, Angelo. Morelli, Cinzia. Germoni, Paola. (2018) Geoarchaeology of the Roman port-city of Ostia: Fluvio-coastal mobility, urban development and resilience. *Earth-Science Reviews*, 177. DOI: 10.1016/j.earscirev.2017.10.003

- Giraudi, C. (2012) The Holocene record of environmental changes in the 'Stagno di Maccarese' marsh (Tiber river delta, central Italy). *The Holocene*, 22. DOI: 10.1177/0959683612455543

- Delile, H.. Mazzini, I.. Blichert-Toft, J.. Goiran, J.P.. Arnaud-Godet, F.. Salomon, F.. Albarède, F.. (2014) Geochemical investigation of a sediment core from the Trajan basin at Portus, the harbor of ancient Rome. *Quaternary Science Reviews*, 87. DOI: 10.1016/j.quascirev.2014.01.002

- Salomon, Ferréol. Delile, Hugo. Goiran, Jean-Philippe. Bravard, Jean-Paul. Keay, Simon. (2012) The Canale di Comunicazione Traverso in Portus: the Roman sea harbour under river influence (Tiber delta, Italy). *Géomorphologie : relief, processus, environnement*, 18. DOI: 10.4000/geomorphologie.9754

- Milli, Salvatore. Mancini, Marco. Moscatelli, Massimiliano. Stigliano, Francesco. Marini, Mattia. Cavinato, Gian Paolo. (2016) From river to shelf, anatomy of a high-frequency depositional sequence: The Late Pleistocene to Holocene Tiber depositional sequence. *Sedimentology*, 63. DOI: 10.1111/sed.12277

- Salomon, Ferreol. Keay, Simon. Carayon, Nicolas. Goiran, Jean-Philippe. (2016) The Development and Characteristics of Ancient Harbours—Applying the PADM Chart to the Case Studies of Ostia and Portus. *PLOS ONE*, 11. DOI: 10.1371/journal.pone.0162587

- Mazzini, I.. Faranda, C.. Giardini, M.. Giraudi, C.. Sadori, L.. (2011) Late Holocene palaeoenvironmental evolution of the Roman harbour of Portus, Italy. *Journal of Paleolimnology*, 46. DOI: 10.1007/s10933-011-9536-7

- Salomon, Ferréol. Goiran, Jean-Philippe. Bravard, Jean-Paul. Arnaud, Pascal. Djerbi, Hatem. Kay, Stephen. Keay, Simon. (2014) A harbour–canal at Portus: a geoarchaeological approach to the Canale Romano: Tiber delta, Italy. *Water*

History, 6. DOI: 10.1007/s12685-014-0099-1

- Bozzano, Francesca. Esposito, Carlo. Mazzanti, Paolo. Patti, Mauro. Scancella, Stefano. (2018) Imaging Multi-Age Construction Settlement Behaviour by Advanced SAR Interferometry. *Remote Sensing*, 10. DOI: 10.3390/rs10071137

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