ARCHAEOLOGIA MARITIMA MEDITERRANEA

An International Journal on Underwater Archaeology

*

«Archaeologia Maritima Mediterranea» is a Peer-Reviewed Journal

ARCHAEOLOGIA MARITIMA MEDITERRANEA

An International Journal on Underwater Archaeology

6 · 2009

PISA · ROMA
FABRIZIO SERRA EDITORE
MMIX

Amministrazione e abbonamenti
Fabrizio Serra editore
Casella postale n. 1, Succursale n. 8 · i 56123 Pisa
Tel. +39 050 542332 · Fax +39 050 574888

Abbonamenti (2009):
Italia: Euro 165,00 (privati) · Euro 395,00 (enti, brossura con edizione *Online*)
Euro 695,00 (enti, rilegato con edizione *Online*)
Abroad: Euro 225,00 (*Individuals*) · Euro 445,00 (*Institutions, paperback with Online Edition*)
Euro 845,00 (*Institutions, hardback with Online Edition*)

I pagamenti possono essere effettuati tramite versamento su c.c.p. n. 17154550
o tramite carta di credito (*American Express, Eurocard, Mastercard, Visa*)

*

Autorizzazione del Tribunale di Pisa n. 21 del 15 settembre 2004
Direttore responsabile: Fabrizio Serra

*

Si invitato gli autori ad attenersi, nel predisporre i materiali da consegnare alla redazione e alla casa editrice, alle norme specificate nel volume Fabrizio Serra, *Regole editoriali, tipografiche & redazionali*, Pisa · Roma, Serra, 2009²
(Euro 34,00, ordini a: iepi@iepi.it). Il capitolo Norme redazionali, estratto dalle Regole, cit., è consultabile Online alla pagina «Pubblicare con noi» di www.libraweb.net.

www.libraweb.net

Stampato in Italia · Printed in Italy

issn 1724-6091
issn elettronico 1825-3881

SOMMARIO

THE ANCIENT PORTS OF ROME: NEW INSIGHTS FROM ENGINEERS

Alberto Noli* · Leopoldo Franco**

Foreword

The paper gives an overview of the development of the ports of Rome in the antiquity with an engineering perspective. The importance of navigation and consequently of seaports was very large in ancient times and especially in the Imperial Age when commercial maritime traffic was complex and busy, and essential for the supply of food to the large population of Rome.

Surprisingly, there is still poor and uncertain information about the large harbour complex of *Portus*, the most famous Roman port. This review aims to update available knowledge and provide the analysis of hydraulic engineers in order to support the work of archaeologists, who often forget to take advantage of the contribution of researchers and technical experts from other disciplines, sometimes genuinely interested to historical facts and works of the past. Their logic-based good reasoning may usefully complement the reconstructions which cannot only be based on often partial historical reports and remains.

Indeed there have been a lot of publications by archaeologists on this subject and we apologize for not giving complete references, as well as for our different writing style, but we hope that this short review including some innovative thoughts will provide useful insights and stimulus for the discussion and for the final definition and valorization of this unique heritage.

Roman harbours in the Republican Age

The town of Rome is located along the river Tiber at some 35 km "water distance" from the Mediterranean sea. The river is characterized by destructive floods but also relatively high discharges in the summer period, which allowed the transit of vessels with a draft up to 2 m at the mouth. The safety against inundation and of navigation was managed by the *"curatores alvei et riparum Tiberis"*, the ancient important Water Authority. Navigation along the Tiber could be carried out as far as some 100 km inland.

No news exist about a Roman seaport terminal until the 4th century BC. The port of Ostia, so named for its position at the river mouth (*ostium*) was operational since about 330 BC and the river-bed path was then different from today's (Fig. 1): the ample final meander called *fluminis flexus* by Ovidius was cut through by the catastrophic big flood

* Former professor of Maritime Constructions at the University of Rome "La Sapienza"; via Montezebio 40, 00195 Rome.

** Professor of Coastal Engineering at the University of Rome 3, Department of Civil Engineering, v. V. Volterra 62, 00146 Rome, leopoldo.franco@uniroma3.it.

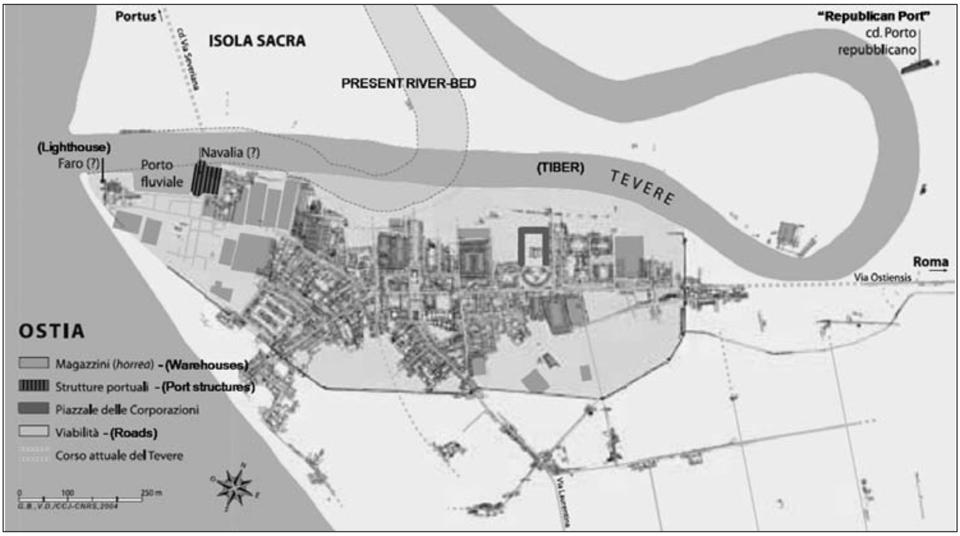

Fig. 1. The plan of the ancient harbour of Ostia (from Lazio's ancient ports, ANSER project, 2006).

of 1567 AD. The left banks along this meander were used as refuge harbour for the general cargo ships (*onerariae*) up to 25 t displacement (net loading capacity of 3000 wheat *modii* [1 *modius* = 8.7 litres]). The goods were then transferred onto the river barges (*naves caudicariae*) which were towed by oxes or slaves from the river banks (preferably the right one) upstream to the *Portus Tiberinus* in a 2-3-day trip. Actually there was not a single downtown river port but various berthing points distributed along the Tiber banks and specialized in handling different goods: one of the most important berth was first located on the left arm of the Tiberina island, then relocated on the right bank (today Ripa Grande) and then again on the left side (near Testaccio).

The *onerariae* ships used to make transhipment operations on smaller vessels offshore Ostia to allow the consequent river navigation. Off-loading of goods from ships anchored in the open sea was difficult and dangerous; thus the port system in the 2nd century was extended as far as Pozzuoli *(Puteoli)* where significant transhipment was taking place in a sheltered bay (up to 300,000 t/year of wheat from Egypt).

A location map of the main ancient harbours along the Tyrrhenian coast near Rome is shown in Fig. 2, together with the offshore wave climate (polar frequency diagram) at Ostia, as obtained from the transposition of new accurate 15-year buoy records off Ponza island: it is noted that the prevailing waves come from the WSW sector (*libeccio-ponente*), while a secondary directional sector is S (*scirocco-mezzogiorno)*. There are no reasons to believe that the wave climate of 2000 years ago was different from today's. Local tides are very small (<0.5 m).

The port system of Claudius and Trajan (Portus)

Since the times of Julius Caesar (1st century BC) there was a need to replace the commercial port of *Puteoli* with a harbour closer to Rome, in order to enhance control and reduce risks of cargo losses along the route. Moreover the neighbouring main

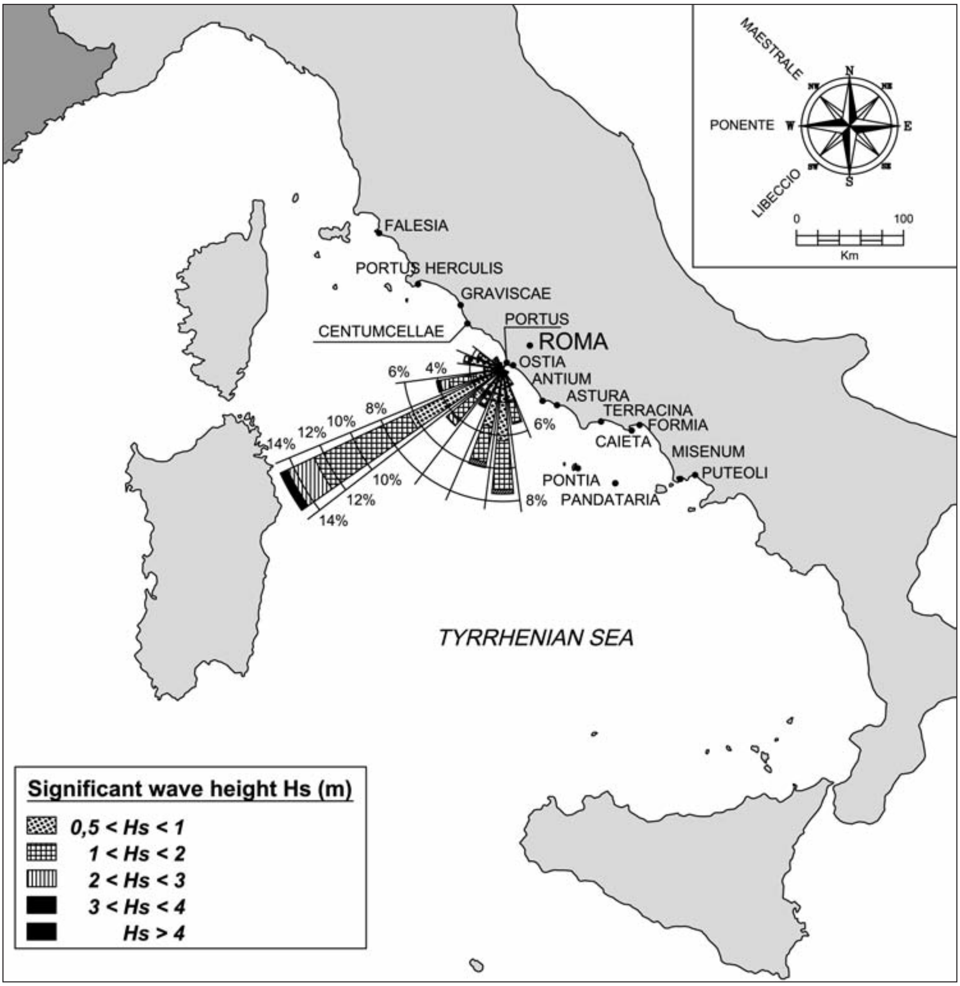

Fig. 2. Geographical map with location of main ancient harbours near Rome and representation of the directional wave climate offshore Ostia after transposition of Ponza buoy records 1989-2005.

military harbour of *Misenum*, well operational since the time of Augustus and after the construction of Portus, was also later complemented by an additional military base at *Centumcellae* to provide defense at sea from either south and north of Rome.

Caesar conceived two important civil engineering works to solve the hydraulic and maritime problems of Rome: firstly a Tiber flood overflow canal bypassing the town from around Ponte Milvio downstream to about Ripa Grande, secondly a large canal between Rome and Terracina with the additional function of a partial safer inland navigation from *Puteoli*. These projects were long discussed but were abandoned.

Later on the emperor Claudius (ruling Rome in 41-54 AD) constructed a number of important hydraulic works, such as the Claudius aqueduct and the Fucino outlet chan-

Fig. 3. Example of river delta in tideless seas with lateral spits and bays to be used for port development (the Rhone mouth from Google Earth).

nel, and also the well known new artificial external seaport on the sandy coast at 3 km northward distance from the Tiber mouth, a position strongly opposed the experts. The new basin was created at a coastal lagoon, which can typically form at river deltas in tideless seas (see for instance the present mouth of the Rhone river in Fig. 3).

According to Suetonius, "Claudius built the port by creating two arms (left and right) and a central breakwater at the deepwater entrance. To provide a solid foundation a ship was sunk which had transported a big obelisk from Egypt and a very high tower was raised similar to the Alexandria lighthouse to guide ship manoeuvres with nocturnal fires" (Fig. 4).

According to historians, this ship of Caligula, the largest one of those times, had transported a ballast of some 650 t of lentils. The engineer O. Testaguzza (1970), based on this information and on ship traces found on the "left" mole near Mount Arena, believed that the ship had a length of 100 m, width of 20.3 m and draft of 6.5 m. However these dimensions appear to be overestimated, since even today a wooden ship of such size would create building problems; the largest ancient commercial ship, as reported by Lucianus, was "only" 55 m long and 13.5 m wide and the Caligula's ship was probably of similar size.[1]

[1] Indeed the question of the maximum length of cargo ships is still a matter of debate. Clearly, from the points of view of naval architecture and port engineering, the ships of more than 50 m LOA needed deep draughts, which were not acceptable in most antique ports and were very difficult to manufacture. Literary reports of ancient giant ships should thus be considered with care. Even in recent times wooden ships were rarely exceeding 50 m, such as those hauled in Venice Arsenal or the famous *Cutty Sark* which was built in 1809 in wood and iron with a length of 65 m and 6.4 m draught, while the famous fully wooden *Wasa* was 70 m long and 4.8 m deep and sank in her initial voyage in 1628 after capsizing; the main limit is attributed to the lack of engineering design support. It is then reasonable to believe that the few ancient ships of over 55 m length were not designed for commercial traffic but for other purposes (such as the Nemi lake "party"-ships).

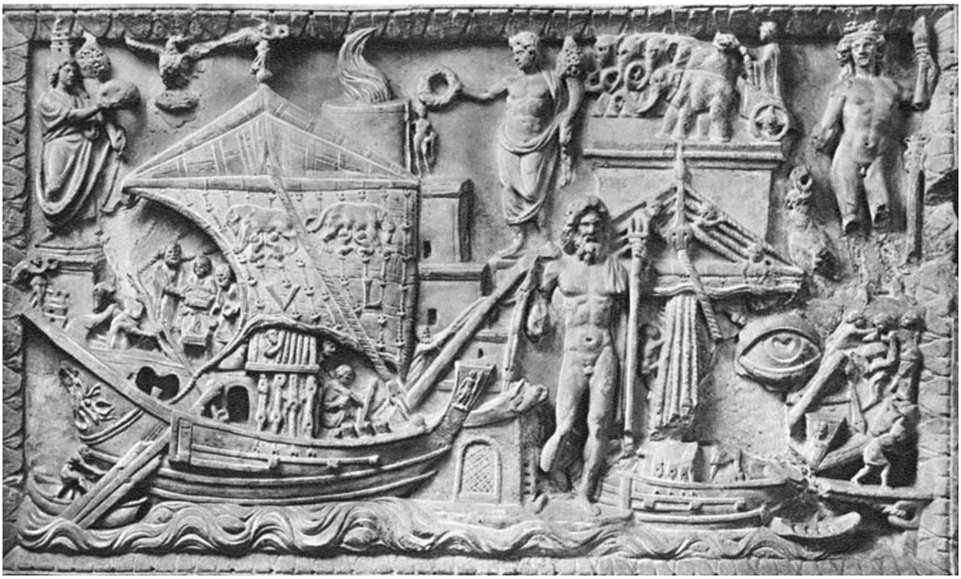

Fig. 4. Marble representation of Claudius port and lighthouse (from Lugli and Filibeck 1935).

The port was mostly obtained by excavation of large volumes of sand. No data are available about the actual port water depths, but it is reasonable to assume a value of -4/-4.5 m below mean sea level (MSL) to allow berthing of the largest ships of the time. Recently a few authors (Giraudi et al. 2007) have found depths of about 8 m MSL in the harbour basin, but it is likely to be a local feature related to ancient river bed positions, since expensive over-dredging would have not been justified.

Claudius also built two canals (*fossae*) in order to provide a link between the port basin and the river and even to reduce inundation levels in Rome. However this latter aim is known to be not effective for modern hydraulic experts, unless the canals diversion would start upstream of the town of Rome. In fact the old Julius Caesar's idea to use the Pontine swamps as flooding areas could have been more effective, even if recent poor experiences with such solution (e.g. Arno, Ombrone) show that the maintenance of the canals is critical to ensure their efficiency during extreme floods.

The selected location of the new port of Claudius was opposed by the expert engineers, who were following Vitruvius' recommendations, due to the siltation problem caused by the sediment supply of the Tiber. Even then the delta was advancing into the sea: a shoreline accretion of about 650 m at Fiumara Grande is estimated to have occurred between 330 BC (Ostia *castrum* construction) and 110 AD (new lighthouse at entrance in a position later occupied by the Boacciana Tower). Then the shoreline continued to advance until 1950 by about further 4 km, before erosion processes begun (Fig. 5) (see also Bersani and Moretti 2008).

The rate of coastal accretion was particularly high in the period between 1570 and 1850 due to increased rainfall, extensive forest cuts and agricultural developments. The local eusthatic sea level rise of about 1.5 m in the last 2000 years has only marginally contrasted this process of shore advance.

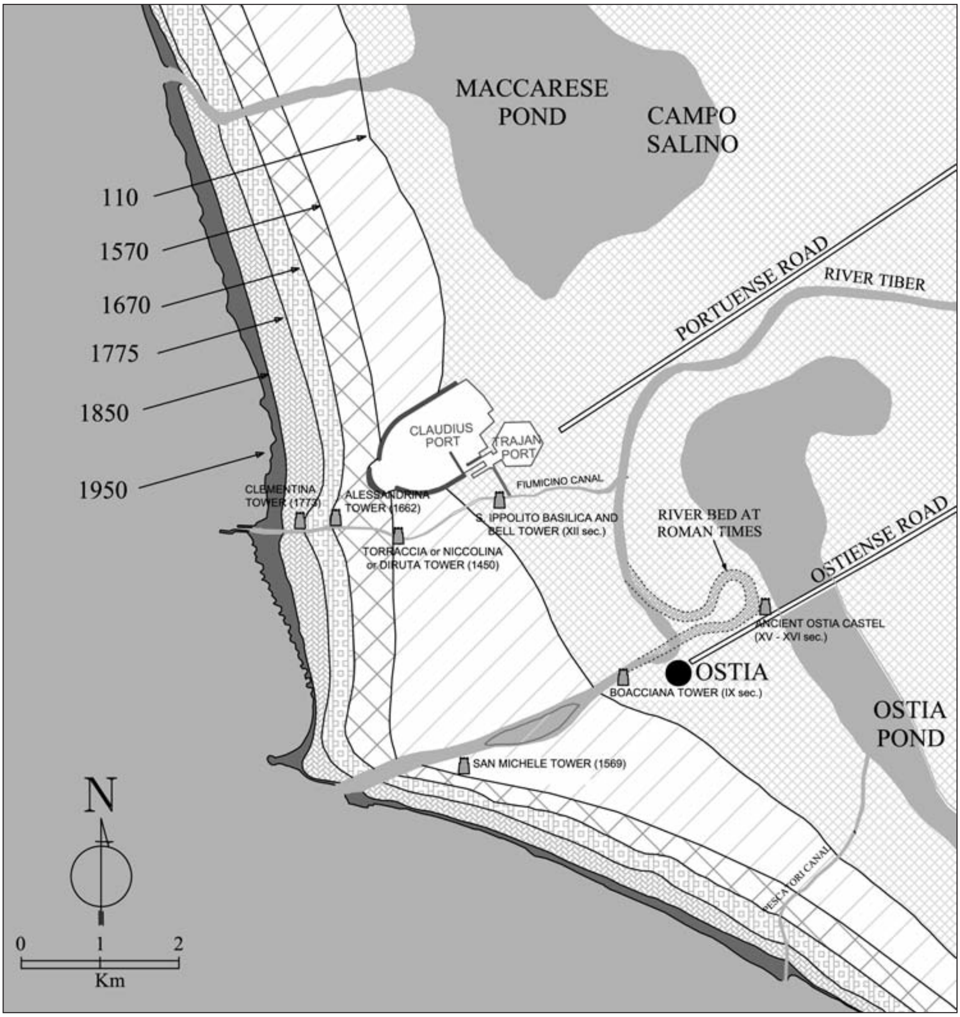

Fig. 5. Historical shoreline variations at the river Tiber mouth
(partly from Bersani and Moretti 2008).

However, despite the Senate opposition and the very large construction cost (even for present times!), Claudius decided to go ahead. In fact the berthing basin had a surface of more than 150 Ha: assuming that some 100 Ha were excavated on dry land for an average depth of 4 m, it comes out a total dredging volume of 4 million cubic meters of sand.

The importance of this exceptional engineering work was admired by Juvenal and also recorded in the famous Torlonia marble inscription (see Lugli and Filibeck, 1935). In particular reports and mosaics highlight the value of the entrance lighthouse which had as a reference the famous one of Alexandria in Egypt: it is noticeable that the port of Alexandria, the largest in antiquity, was protecting a surface of nearly 400 Ha, in-

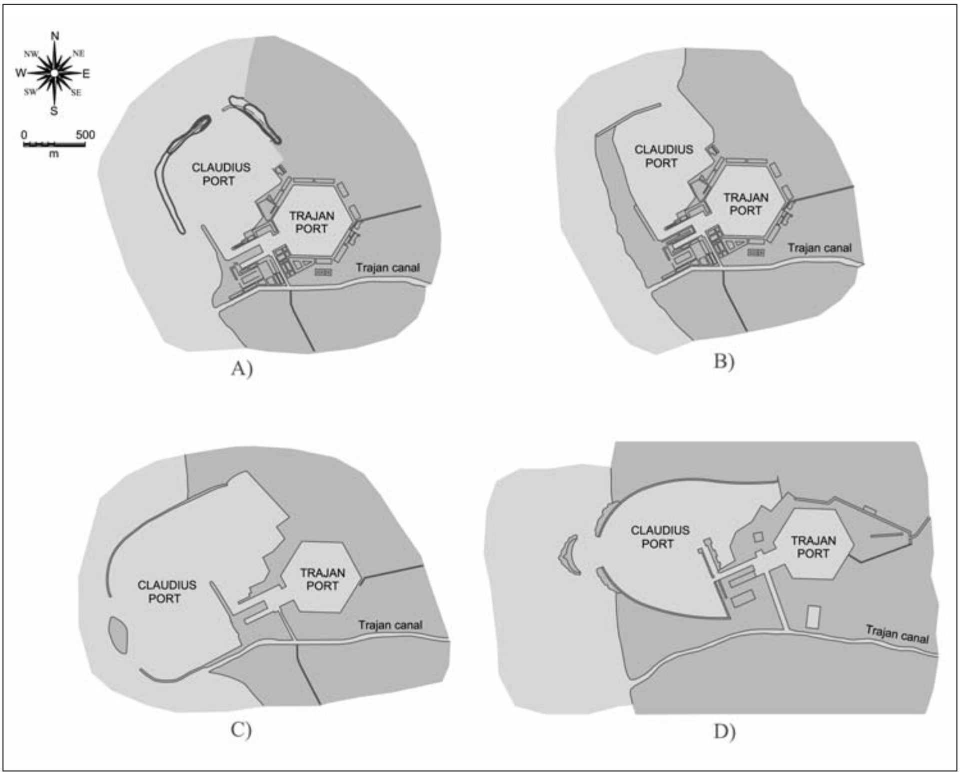

FIG. 6. Reconstruction of the ports of Claudius and Trajan according to:
A) Lugli and Filibeck 1935, B) Testaguzza 1970, C) Giuliani 1992, D) Peruzzi 1550-1573.

cluding coastal lagoons and inland channels similar to those at *Portus* (even if a natural island named *Pharos* provided more favourable geographical conditions).

The port construction started in 42 AD and ended in 64 AD under emperor Nero.

THE *PORTUS* PORT LAYOUT QUESTION

The exact planshape (layout) of Claudius port is still a matter of debate. Available literary reports (Suetonius, Juvenal, Dio Cassius, Cassiodorus, Pliny the younger) and coin representations are rather simplified and not all in agreement. Still today the archaeologists are searching for a final evidence. One of the main doubts is related to the entrance type and position: it could be the traditional double opening with central island breakwater with lighthouse (named *insula* by Pliny), or a single opening to the north (against the moderate wave sector), or two quite distant opposite openings to allow different options under variable winds, given the ancient use of sails as ship propulsion (see FIG. 6).

According to Lugli and Filibeck (1935) there were two artificial breakwaters following the existing hills of Monte Giulio (right) and Monte Arena (left) (see FIG. 6A) and the left one was bending to the south to overlap a smaller southern arm fixing a

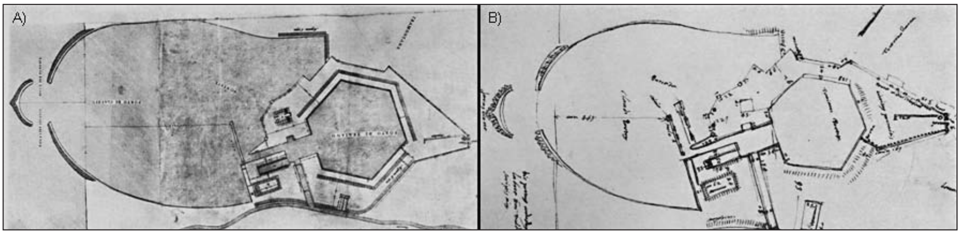

Fig. 7. Original drawings of Portus by A. Labacco 1567 (a) and S. Peruzzi (between 1550 and 1573) (b).

secondary southern entrance: such layout seems not realistic and no archaeological evidence is yet found.

A more recent reconstruction by Testaguzza (1970), based on findings during the construction of Fiumicino airport, is shown in Fig. 6B with the main west breakwater partly formed by a natural sand spit, a main entrance to the north (quite unlikely near the coast) and a possible secondary entrance through one of Claudius' *fossae.*

A recent reconstruction by Giuliani (1992), as reported in the anser project and in Keay et al. 2005 (Fig. 8.6), and following a similar scheme proposed by Castagnoli (1980) based on an aerophotographic mosaic of early 1900, shows a quite different port planshape: a large basin is enclosed by two converging arms and by a central offshore island-breakwater supporting the entrance lighthouse in a position shifted to the South as compared to the previous schemes (Fig. 6C): such configuration proposed by Giuliani would also justify the need of the additional internal straight mole (oriented about N-S) to shelter the later Trajan basin from wave penetration.

Finally Fig. 6D shows the port complex represented by S. Peruzzi who visited the still visible remains of the ancient lighthouse between 1550 and 1573. Claudius basin is given a longer and narrower planshape with the port entrance located further seaward and the arc-shaped central island placed offshore of the entrance gap between the two converging breakwaters and not aligned to their roundheads.

Fig. 7 shows the comparison between the original drawings produced in the same period by S. Peruzzi and by A. Labacco (1567) which are exhibited in the Uffizi museum. They both provide some distances given in *canne* (one *canna* is about 2 m). The only differences between the two schemes are a more seaward position of the port entrance according to Labacco, slightly wider openings and the presence of a double internal mole in Peruzzi's drawing: the second parallel mole is however not indicated in another perspective view by Peruzzi himself.

It is quite surprising that, assuming these latter schemes as the most likely ones, no evident traces of such important offshore breakwaters (now onshore) have been yet found by the archaeologists.

Such harbour layout type with a double central entrance is quite likely also because of many similar examples in that same period. For example, Fig. 8 shows the layouts of *Centumcellae*, *Antium*, *Astura* and *Terracina*: only at Terracina the shorter island breakwater (not facing the main wave sector) is located in the middle of the entrance gap and not seaward of it, possibly due to the designer reference to Alexandria's port layout. It is noted that the Antium port layout is as reported by anser (2006), even if other recent studies (Felici, 2002) are proposing a slightly different planshape.

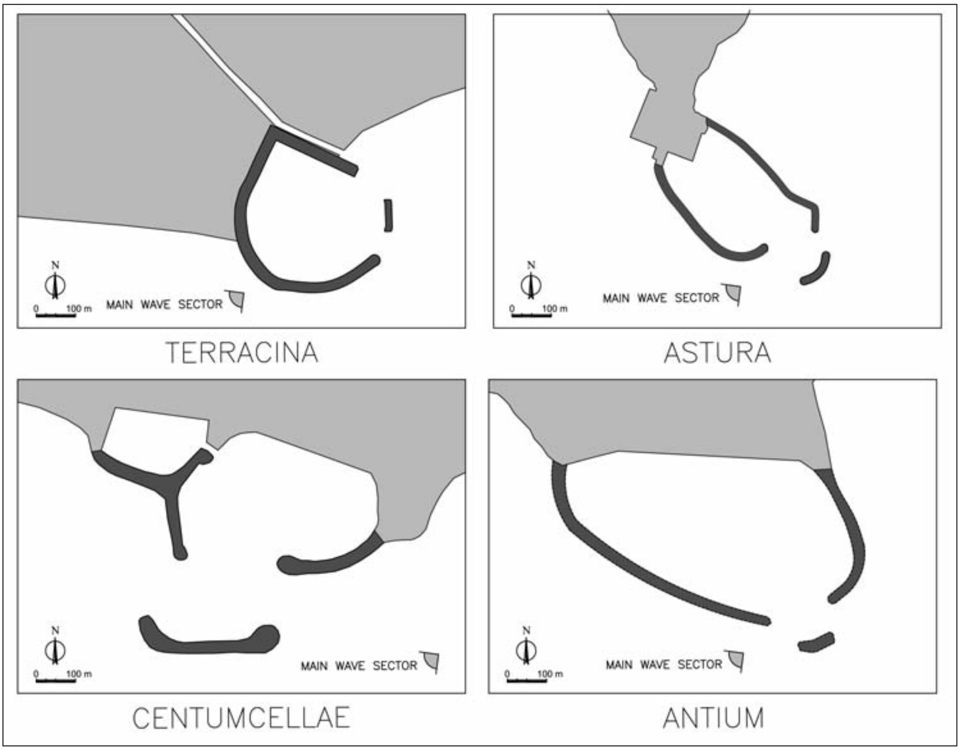

FIG. 8. Roman harbour layouts with double breakwaters and central island.

From the port engineering point of view the offshore island position, as proposed by Peruzzi, is more logical and realistic than the aligned one assumed by Giuliani, since it provides a better reduction of wave penetration, even if ship entrance manoeuvres may become more difficult (still relatively straight ship routes were allowed).

A recent satellite photograph of the old large eastern port of Alexandria (FIG. 9) clearly shows how significant wave penetration can occur with the parallel double gap scheme (note that the main wave sector at Alexandria is NW, as also shown by the boats position).

However, even with the longer seaward island breakwater the wave penetration is not negligible, as it will be demonstrated in the following. In fact this could explain the sinking of some 200 moored ships during a severe storm in 62 AD as reported by Tacitus. Some authors (Caputo and Faita, 2000) attribute the event to a tsunami generated by an earthquake which damaged Pompeii well before the famous Vesuvius eruption (79 AD), but there is no documental evidence of it.

In fact both the large Roman ports of *Portus* and *Centumcellae* (today Civitavecchia) include a wide "outer harbour" *(avamporto)* and a protected internal mooring basin: the first part seems to be given more attention by the Roman engineers. In both cases however the outer harbour is not fully protected against wave penetration, as demonstrated by some simulations carried out with an advanced numerical model able to represent the combined effects of wave diffraction and reflection (FIG. 10-11). The

Fig. 9. Satellite view of Alexandria eastern (old) harbour (from Google Earth).

chromatic plots show the wave height distribution in adimensional terms (i.e. assuming a wave height of 1 m outside the port) for three typical main wave directions and a wave period of 7-8 s. The best port agitation conditions seem to occur under the most frequent perpendicular wave attack from the West-Southwest. It is noted that in both ports very calm conditions only occur in the internal basins (Trajan basin at *Portus* and *darsena romana* at *Centumcellae*). It is also believed that the internal perimeter along the eastern side of Claudius basin was probably left as a wave absorbing beach, in a similar way as at Ventotene.

Indeed Claudius conceived the port as one whole basin; the introduction of an internal mole to provide a better shelter to part of the basin is not sure at the early stage, but only after Trajan's architects who also used it at *Centumcellae*.

It is believed that the ships would have been waiting in the outer harbour for their turn at the sheltered quays, moving inside in case of storms. Loading and unloading of goods could take place also during "stand-by", but at slower rates by means of small barges called *lenunculi*. The high number of ships at peak times justifies the large dimensions of the port. Even today the outer harbour basin has a crucial importance, even if ship stand-by can take place outside the port itself. The main difference is due to the vessel propulsion system: the use of engines now excludes the use of a double entrance which was useful when sailing under variable winds; a long straight access route is instead preferred today, due to the ship size and limited manoeuvrability. Access speeds need to be relatively high, especially in hard weather, requiring a stopping distance of 3-5 times the ship length and thus a large outer harbour.

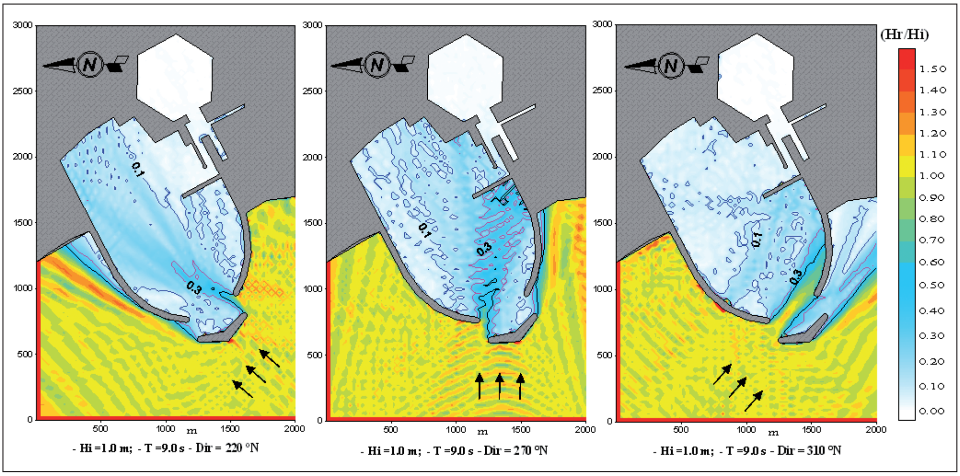

FIG. 10. Wave penetration at *Portus* (according to new proposed port layout) with mathematical model VEGA.

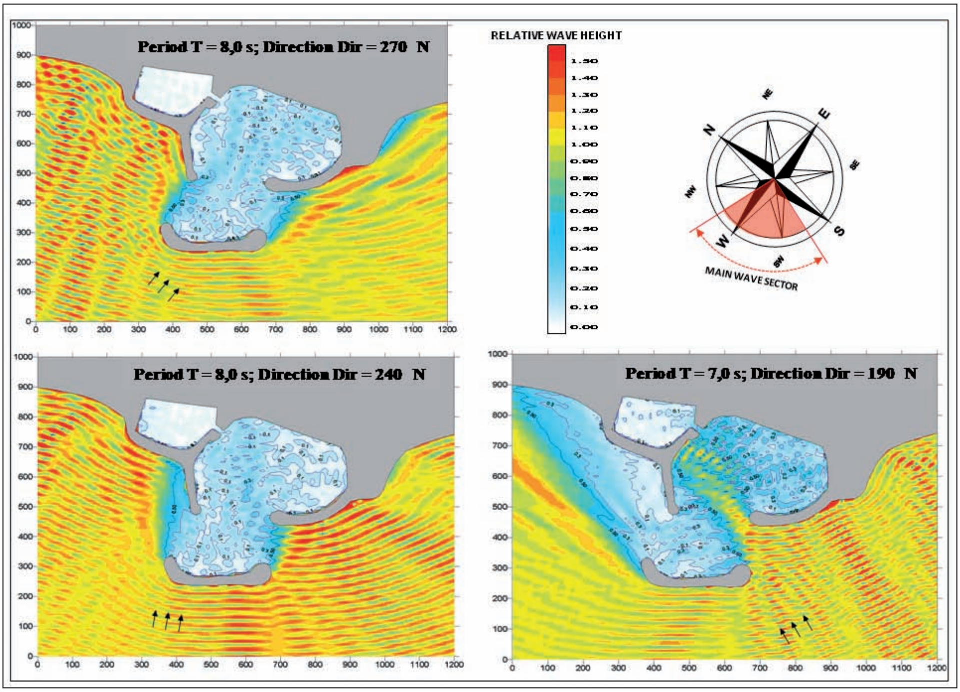

FIG. 11. Wave penetration at *Centumcellae* Port with mathematical model VEGA.

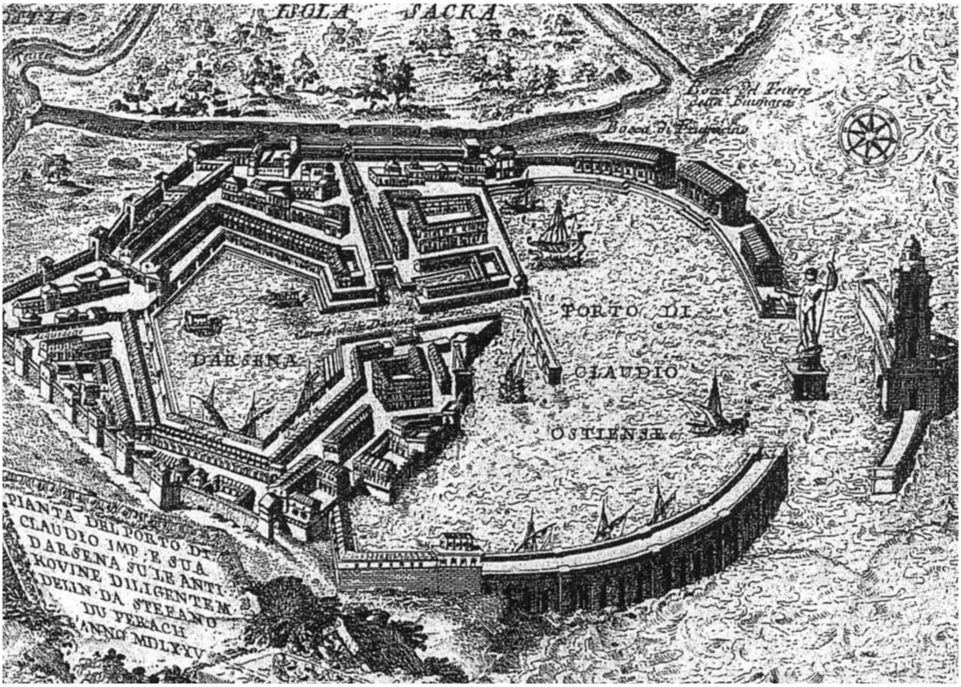

Fig. 12. The most famous representation of *Portus* (J. Blaeu, 1575).

It is hoped that new modern archaeological investigations will finally clear this interesting argument. Indeed Marinucci (2008) announced the finding of the exact island location at a conference organized in march by the British Academy in Rome (not yet published at the time of writing this paper). The actual port entrance position seems to be in good agreement with the one given by Peruzzi, thus justifying the words of Juvenalis: "the harbour arms extended long into the sea leaving Italy far away".

Thus it gains more value and reality the most famous representation of the two ports *(utriusque portus ostiae delineatio)*, often considered as fantastic, due to the Dutch painter J. Blaeu, inspired by a perspective view by S. du Perac (Fig. 12).

As a matter of fact the drawing by Peruzzi was based on a true topographical field survey.

An additional confirmation of the likelihood of Peruzzi and Labacco's reconstructions is given by the nice painting of *Portus* ruins by A. Danti (1582) exhibited at the Geographical Maps Gallery of the Vatican Museum: it shows the position, still in the open sea, of the remains of the final portions of the two converging breakwaters and central island (Fig. 13). As useful reference landmark, the painting shows the location of the tower of Pius V, built by pope Nicolò V in 1450 near the shoreline at that time and thus named Niccolina.

While waiting for the publication of the new archaeological findings, we attempt an updated reconstruction of the port based on the available information (Fig. 14). The two proposed schemes only slightly differ for the position of the island breakwater, which in the first case (A) follows Peruzzi's survey and in the second one (B)

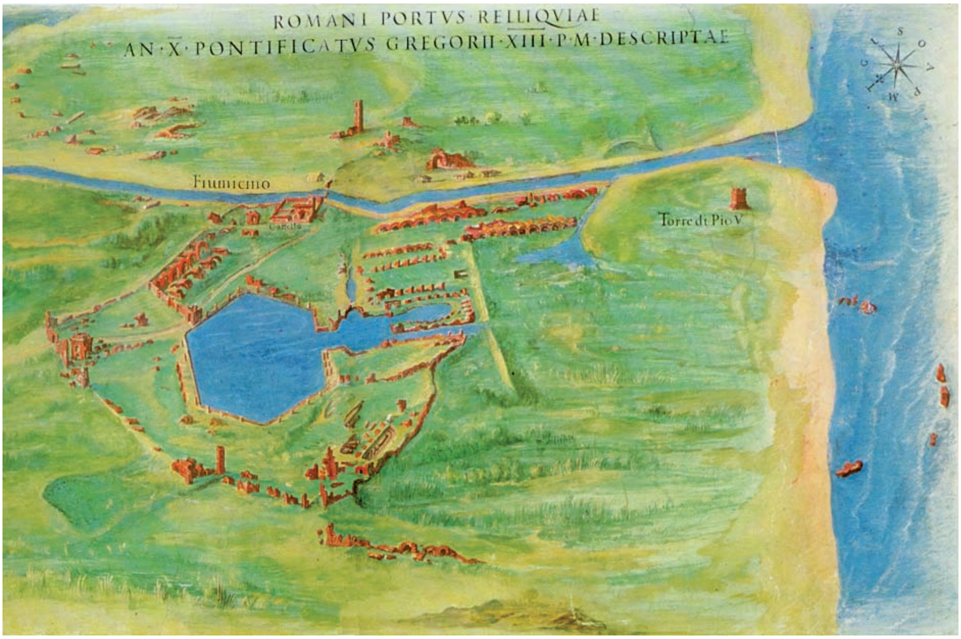

Fig. 13. Painting with the ruins of *Portus* (A. Danti 1582).

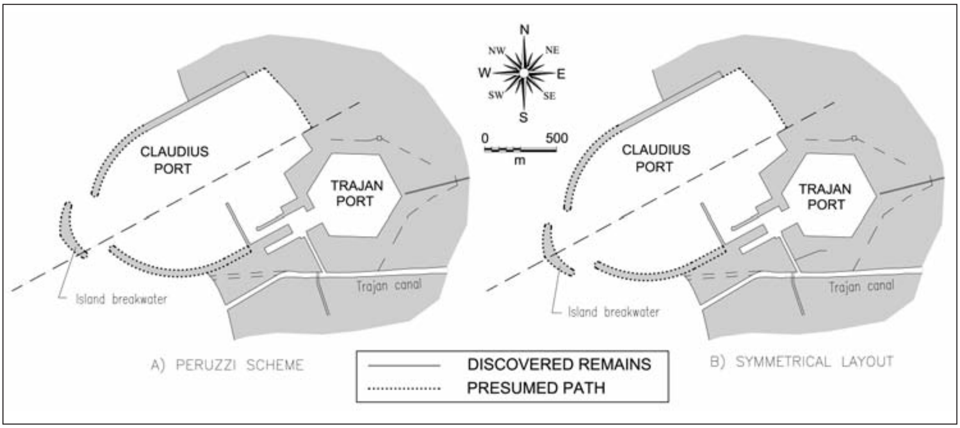

Fig. 14. Reconstruction of *Portus* according to Peruzzi (A) and as proposed by the authors (B).

assumes a more complete symmetry of the two converging moles with regard to the central axis which is exactly oriented along the main WSW wave direction. Indeed there was no reason to give a non-symmetric shape to the port layout, since symmetry was one of the main architectural features in antiquity.

According to this hypothesis the island breakwater location would have been at a distance of about 800 m from the shore in a water depth of 7-8 m, assuming an average seabed slope of 1% similar to the present foreshore slope.

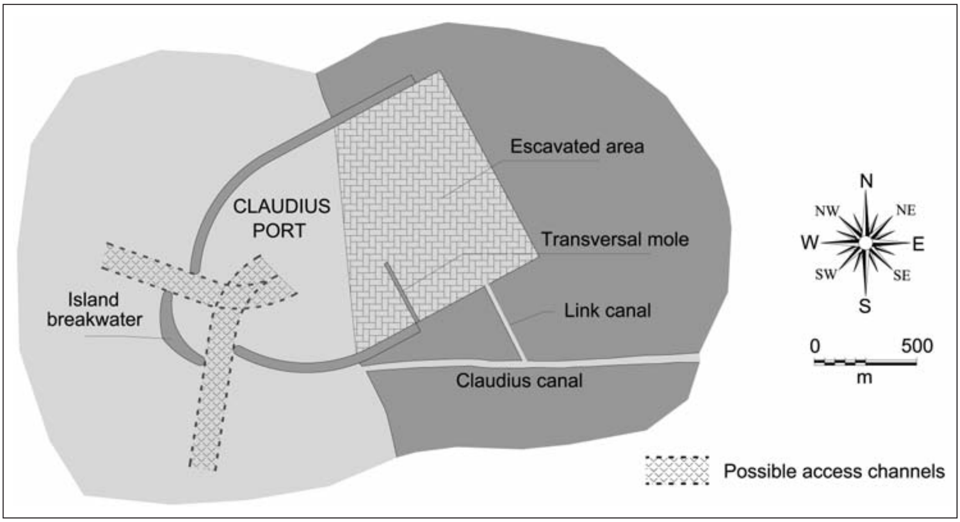

Fig. 15. Schematic reconstruction of the port of Claudius.

Fig. 15 shows a possible reconstruction of Claudius port only, assuming that the transversal internal mole was already existing (indeed just near the remains of Claudius arcade) to provide a full shelter to a part of the port basin.

It is well known that the port was later extended inland by emperor Trajan between 100 and 112 AD according to Juvenalis and Pliny the younger. Trajan, who also promoted the construction of the ports of *Centumcellae*, Ancona and Terracina, excavated a new hexagonal basin, thus transforming Claudius basin in an "outer harbour" (*avamporto*). The basin now has a surface of about 32 Ha (each of the six sides being nearly 350 m long) with some variations occourred in modern times for its use for irrigation, by raising the edge level with slopes. The aesthetically appealing exact geometry of the new port basin makes us believe that the architect was *Apollodorus of Damascus*, then a favourite of the emperor, who also designed the nice layout of *Centumcellae* port. This latter port layout became the ideal port model in the Renaissance Age.

Trajan also improved the southern artificial canal by Claudius, by widening it and armouring the banks: this canal is still operational today at Fiumicino.

No doubts exist about the well preserved "port of Trajan", which was surrounded by a majestic set of port buildings and warehouses (*horrea*): these ones were useful to preserve large quantities of goods with excellent conditions of aeration and safety against fires and robbery, since shipping trade was not allowed in winter.

In conclusion we believe that also the port of Claudius should have been designed following the majestic regular architectonic concepts which have been used later by Trajan. The symmetry of the double breakwater layout is justified by the absence of particular local geographical constraints; only the exactly located Claudius'canal on the southern side would have influenced the alignment of the south breakwater, which was reasonably made straight and parallel to the north one; probably the canal mouth was kept outside the port basin to avoid siltation.

The proposed port layout shown in FIG. 14B and 15 with a detached seaward island breakwater and two quite symmetric long moles is indeed the most reliable from many aspects, such as iconographic evidence, archaeological remains, engineering and architectural concepts and common sense.

Portus after Trajan

The following emperors, especially Septimius Severus, continued to maintain and improve the port structures, particularly on land. Under Constantine the town of *Portus* obtained the full municipal autonomy (*Civitas Flavia Constantiniana Portuensis*). Walls were then built to protect *Portus* from the attacks of pirates and barbarians. In the 4th century the port begun to silt up significantly, despite periodical excavations of the seabed sand (also used as ship ballast).

In 408-410 AD Alaricus occupied *Portus*, even if new works were later built, such as the Placidian Porticus. A new sack was made in 455 AD by Gensericus, king of Vandals. Even after the fall of the western Empire in 476 AD Theoderic spent some port restoration efforts.

The invasions of *Portus* and Rome showed the intrinsic weakness of the capital city which was too much dependent on its port and river for the supply of food. The reduced efficiency of the complex Roman transportation system is in fact considered by historians as one of the main causes of the decline of the empire (Ward-Perkins, 2005).

Therefore the selection of Byzantium (Costantinople) as new capital of the Eastern Empire was also dictated by the need of a port-city which was more difficult to be conquered. Even the western capital was transferred to Ravenna, where the port of Classis was well protected by ponds and swamps.

During the Gothic wars (535-553 AD) *Portus* was alternatively ruled by the Byzantine generals Belisarius and Narsetes and by the Gothic kings Vitige and Totila. Afterwards *Portus* was abandoned and the original harbour entrances were silted up. Therefore at this stage a new entrance and access channel were probably excavated at the north side, as represented by Testaguzza (FIG. 16). This hypothesis of a successive opening of a northern entrance is also supported by the finding of breakwater armour rocks buried under the seabed of this entrance.

It is important to highlight the validity of the port scheme of Claudius and Trajan, which was operational with continuity for about five centuries, three of them (60 to 337 AD) in good conditions and two more without any maintenance. Thus the port design cannot be considered as a failure due to the delicate location near an advancing river mouth. Indeed it showed an exceptional lifetime, also considering that the modern designs of harbours and most civil engineering structures are conceived with a useful lifetime of just 50-100 years. It is felt that the port life could have lasted even longer if the splendour of the Roman empire would have continued as well as the careful maintenance by the port managers.

The Roman heritage in harbour engineering

The above considerations can well justify the importance given by archaeologists and scholars to the system of Roman ports, by far the largest and most innovative in an-

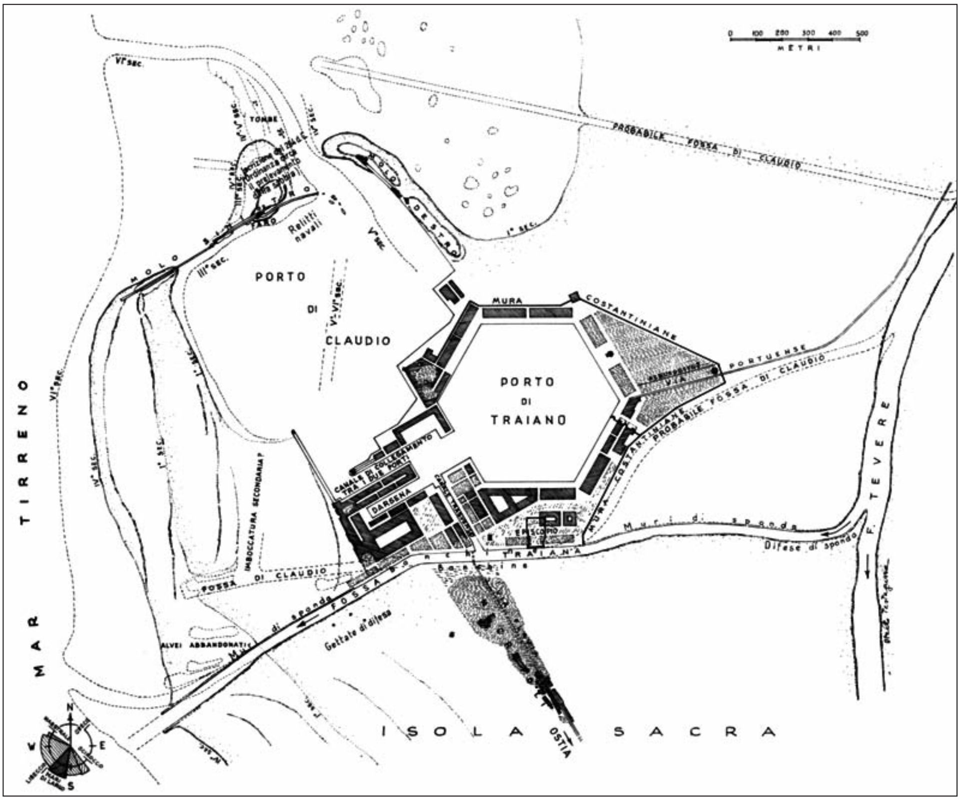

FIG. 16. Reconstruction of *Portus* in the 4th century (from Testaguzza 1970).

tiquity. Reference is also made to Franco (1996) for a general review of the ancient harbour engineering heritage.

Unfortunately the *Portus* archaeological site is not easily accessible to tourists, partly because the remains occupy a quite large area, partly because some areas are still undiscovered or covered by new structures, such as Fiumicino airport and its access roads and railway. Today only few people visit *Portus* necropolis and the Museum of Roman Ships in the airport area, also due to schedule limitations, as well as the remains of Trajan port and its nice hexagonal basin (only after agreement with the Consortium *Oasi di Porto*).

We agree with those who wish to restore the ancient situation, by carefully filling with seawater the Claudius basin and lowering the level of Trajan's lake, which was raised by the prince Torlonia by means of a dyke with concrete revetment for water storage and irrigation purposes. Of course the question of the water levels in the port basin and in the near river and sea needs to be discussed taking into account the modern sea-level rise with no ambition to reproduce exactly the ancient conditions. This idea is anyway expensive and with various technical problems to be solved, such as the underground road link Rome-Fiumicino, the interference with the airport run-

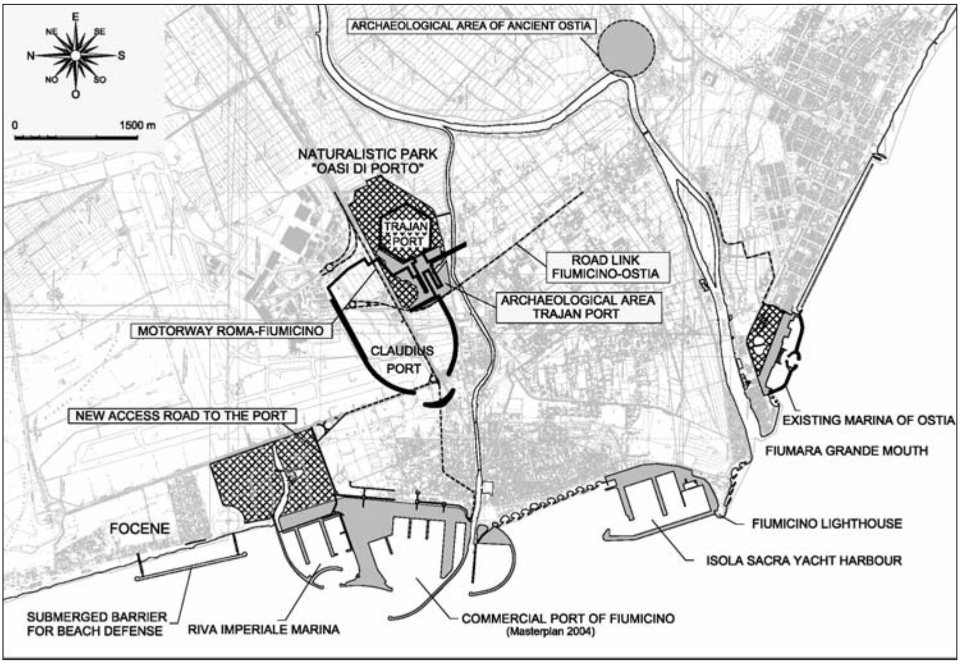

FIG. 17. Possible future port system around the Tiber mouths.

away n. 1, the oil deposits and the Coccia di Morto road between Fiumicino and Focene (FIG. 17).

FIG. 17 also describes a possible general new plan of the roman coastal area, which might include four different ports after about 1500 years without any port at all.

It is really impressive to observe that the dimensions of the ancient Port of Claudius were even greater than those of the new port masterplan of Fiumicino, which is designed for ships up to 300 m long!

Anyway such unique immense archaeological complex, representing a too long neglected "eighth wonder" of ancient work of engineering, deserves more attention and valorization, also taking advantage of its strategic position near the busy international airport of Rome-Fiumicino (which now partly overlaps the ancient transport infrastructure). As a first step it is recommended to create updated poster maps (at least in Italian and English) to describe the most reliable reconstruction of the Portus complex with a summarized description.

We believe that the harbour engineering heritage by the Romans has still a great technical value. The double breakwater layout with exposed central gap (but without the island-breakwater) is still today a favourite port design solution for both navigability and siltation aspects. Again the concept of inland excavation is being followed in modern designs (e.g. Gioia Tauro, Sibari, Cagliari ports): the Romans used this concept even in rocky foreshores, such as at *Centumcellae* and at *Pandataria* (Ventotene).

Further modern technical innovations are due to the Romans: for example the use of pozolanic hydraulic cement for underwater structures and the use of caissons or

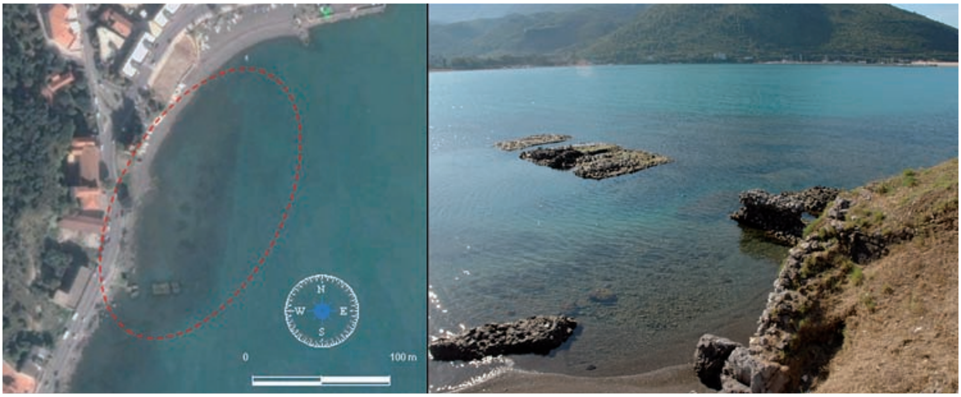

Fig. 18. Satellite views and photograph of the semi-submerged remains of a Roman caisson breakwater in the gulf of Sapri.

old ship hulls to be sunk in-situ by sand or concrete filling. Remains of caisson "lost forms" are found in the Claudius port breakwaters even away from the offshore island made by sinking the Caligula's ship. Fig. 18 shows the semi-submerged remains of a Roman harbour breakwater made with typical prismatic caissons at the seaside villa of Cammerelle (Sapri).

Also the use of pozolanic concrete is still widespread in modern maritime engineering due to its impermeability and durability, with new specific laboratory investigations being performed on this exceptional construction material.

In addition to the technical heritage, further considerations arise from the Roman port engineering experience. When vital needs demanded new large port infrastructures, the Roman emperors decided and completed the work construction within few years, even against the opinion of the experts and of the Senate in the case of Claudius, showing a remarkable courage aimed at the public interest. Today, in a much more rapidly changing world, similar important requirements of infrastructural development or protection works (eg. MOSE in Venice, TAV, solid waste plants, etc.) are not followed by rapid construction due to long political discussions and oppositions. The example of the old decision-maker emperors might not be forgotten in order to ensure the necessary development of modern Rome and Italy.

Bibliography

ANSER - Regione Lazio 2006, *Anciennes routes maritimes méditerranéennes*, Lazio's Ancient Ports.

Bersani P., Moretti D. 2008, *Historical evolution of the coastline near the Tiber river's mouth* (in Italian), «L'Acqua» n. 5, pp. 77-88.

Castagnoli F. 1980, *Port installations in Rome* (in Italian) Roman Seaborn Commerce, «Mem.Aca.Rome», 36, 35 ss.

Caputo M., Faita G. 2000, *First catalogue of Italian tsunamis* (in Italian). Accademia Nazionale dei Lincei.

Franco L. 1996, *Ancient Mediterranean Harbours: a heritage to preserve*, «Ocean & Coastal Management», vol. 30, n. 2-3, pp. 115-151.

Felici E. 2002, *Epigraphic and topographic discoveries on the construction of the Neronian port of Antium* (in Italian), «Archeologia Subacquea» III.

Giraudi C., Tata C., Paroli L. 2007, *Cores and geological studies at Portus: the Tiber delta at the times of Ostia Tiberina till the construction of the ports of Claudius and Trajan* (in Italian), The Journal of Fasti Online.

Giuliani C. F. 1992, *Notes on Portus topography*, in V. Mannucci (ed.), *Il Parco Archeologico Naturalistico del Porto di Traiano: metodo e progetto*, pp. 29-43, Roma, Soprintendenza Archeologica di Ostia, Gangemi.

Keay S., Millett M., Paroli L., Strutt K. 2005, *Portus*, Archeological Monographs of the British School at Rome n. 15.

Janni P. 1996, *The sea of the ancient people* (in Italian), Dedalo.

Lallemand F. 2007, *The log of Maarkos Sestios* (in Italian), Magenes.

Lugli G., Filibeck G. 1935, *The port of Imperial Rome and Agro Portuense* (in Italian), Officine dell'Istituto Italiano d'Arti Grafiche, Bergamo.

Marinucci A. 2008, *The lighthouse-island in the port of Claudius* (in Italian), presented at the Workshop at the British School in Rome "Recent research at Portus and in its hinterland", organized by S. Keay and L.Paroli, march 2008.

Noli A., Franco L. 2007, *The planning of ports and maritime works* (in Italian), «L'ACQUA» n. 1.

Regione Lazio - Assessorato opere e reti di servizi e mobilità - Università "Sapienza" di Roma 1999, *Update of the masterplan of Lazio's ports* (in Italian).

Testaguzza O. 1970, *Portus*, Julia, Roma.

Vitruvius M. L. 27 BC, *De Architectura* (in Latin), vol. II, 6, vol. V, 13, Roma (in English in Morgan M.H. 1914, Cambridge, or in Loeb Classical Library 1983, London).

Ward-Perkins B. 2005, *The fall of Rome and the end of civilization*, Oxford University Press.

Sommario

La memoria fornisce, con la prospettiva dell'ingegnere idraulico-marittimo, una rivisitazione della portualità nella Roma antica ed in particolare del grandioso complesso imperiale di Portus e della sua più verosimile configurazione planimetrica. Sorprendentemente ancora oggi la geometria del cosiddetto porto di Claudio non risulta definita con certezza, nonostante la disponibilità di varie pur contrastanti ricostruzioni, in attesa dei risultati di nuove prospezioni archeologiche.

Viene ripercorsa l'evoluzione storica della portualità ostiense e tiberina sottolineandone l'importanza per l'impero e l'eccezionalità dell'opera d'ingegneria marittima, con significativi contributi alle tecniche moderne. Si discute specificatamente sul classico schema portuale romano "a moli convergenti con isola-antemurale" impiegato anche a *Centumcellae* ed in altri porti minori mostrandone la funzionalità ed i limiti, anche con simulazioni della penetrazione ondosa con modello matematico. È sollecitata la cooperazione multidisciplinare degli studiosi e la valorizzazione archeologico-turistica del complesso portuale di *Portus*.

COMPOSTO IN CARATTERE DANTE MONOTYPE DALLA
FABRIZIO SERRA EDITORE, PISA · ROMA.
STAMPATO E RILEGATO NELLA
TIPOGRAFIA DI AGNANO, AGNANO PISANO (PISA).

★

Luglio 2009

(CZ 2 · FG 21)