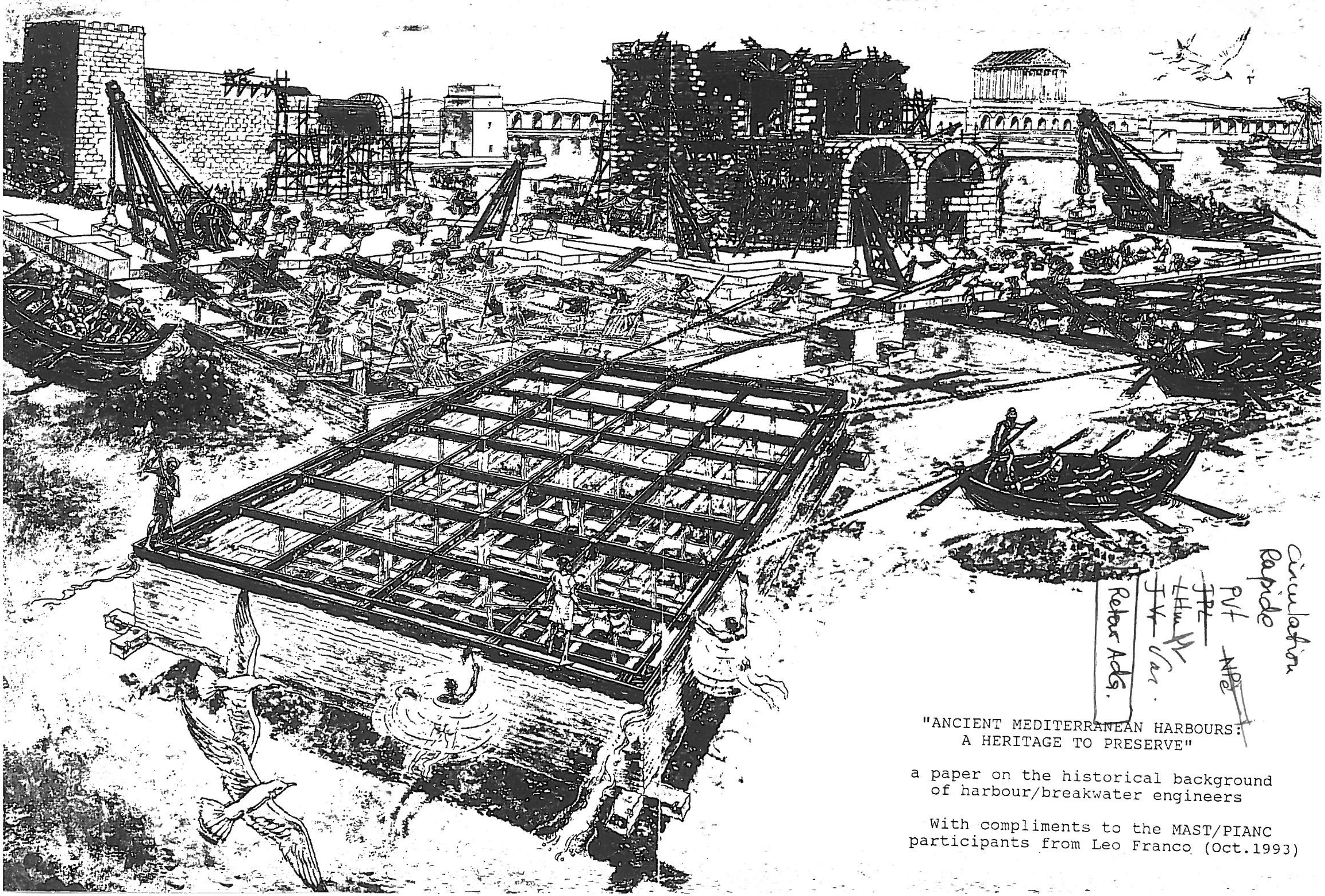

"ANCIENT MEDITERRANEAN HARBOURS:
A HERITAGE TO PRESERVE"

a paper on the historical background of harbour/breakwater engineers

With compliments to the MAST/PIANC participants from Leo Franco (Oct.1993)

circulation Rapide

MED-COAST CONFERENCE, 2-5 Nov.1993, Antalya, Turkey

ANCIENT MEDITERRANEAN HARBOURS : A HERITAGE TO PRESERVE

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Abstract

Management and protection in coastal areas is mostly addressed to the natural environment, but very rarely to cultural and technical resources. This paper represents a plea for driving more attention to some valuable historical features still existing abandoned along the Mediterranean coasts.

Many remains of harbour structures with an age of 2000 years or more are laying partly submerged without any sign of an archaeological site and no protection from the attack of the sea and of the coastal users.

A condensed overview is given of the evolution of ancient harbour engineering, particularly related to the Roman age, describing the most interesting technical aspects, which are derived from the literature and from noticeable remains revealed by the recent development of underwater archaeology and remote sensing technology.

A bilateral cooperation between coastal engineers and archaeologists is needed, as for necessary preliminary surveys before the execution of new coastal works and for the interpretation, defence and valorization of discovered maritime remains.

Brief indications on the techniques for the conservation and restoration of old submarine structures are reported, despite the lack of specific experience.

Recommendations for the musealization of major ancient port sites, with a proposal for the creation of "coastal submarine-archaeological parks", are finally given.

Introduction

It is sad and surprising for a coastal engineer and a restoration architect with a classical education to find out that the study and the conservation of ancient harbours and coastal works have been so much neglected, especially within the Mediterranean countries which almost uniquely retain this valuable heritage from the "classic world".

Remains of quay-walls, breakwaters and other harbour structures (at least in Italy, maybe too rich of ruins to care for them), if not covered by new constructions or re-used for even different destinations, usually lay near the shore without any protection and any explicative sign, progressively destroyed by the aggressive marine environment (now even polluted) and especially by the growing pressure of coastal tourist crowds, fishermen and "predator-scubadivers". Fencing is rarely provided, often only if the ruins of coastal settlements are also present.

Research on ancient harbours was just carried out by archaeologists in the last century, generally without any consultancy from expert port engineers and without following actions to preserve the discovered remains from further deterioration. Their research approach is mainly aimed at the historical investigation, i.e. censing and dating the ruins, identifying the geographical location and giving the reconstruction of the old topographical situation related to the predicted position of the shoreline and of the served town. In fact the analysis of harbour remains is also helpful for assessing long-term sea level changes.

The first systematic excavations of submerged port structures were carried out by G.Jondet at Alexandria in 1912. Later, a powerful surveying technique has been aerial photography (even infrared). Cheap aerial surveys can now be simply performed by using paragliders or similar planes on clear calm days (see example colour slide of Cosa harbour taken by the author from an ultralight). Moreover on-site resistivity analysis with megaohmeters is useful to detect underground silted remains. However, despite the present development of the surveying techniques (eg. tele-survey, underwater inspection), no relevant discoveries have recently been reported.

A sign of lack of interest and organization may be represented by the difficulties encountered in finding the scattered limited specific bibliography. The references given herewith are surely an uncomplete list, but many aspects are not yet known and studied. The field of "harbour archaeology" needs still to be developed. Presently it is just a minor neglected area of "Underwater Archaeology", which is defined as a "nascent discipline", probably due to the high costs and technology involved. In fact, it may be subdivided in three study areas: a) submerged dry sites after climatic changes (eg. cities submerged by earthquakes or bradyseism); b) maritime structures (e.g. harbours and fishing ponds) once already **in** the water ; c) ship wrecks.

The attention of submarine archaeology is especially concentrated on ship wrecks and their often precious cargo. Some 30.000 ship wrecks are laying on the Mediterranean seabed (with a uniform rate of 10 sinks/year even today!).

Our Sea ("mare nostrum") is infact an immense submarine museum, holding signs of several important civilizations, which are still waiting to be revealed. Important artifacts from either ship wrecks or warehouses can also be found in the excavations of ancient harbours, where there are obvious chances to find ship wrecks.

However we believe that also the numerous remains of maritime structures should deserve more attention, especially by coastal managers and harbour engineers. Coastal engineers can have various reasons of interest in these "monuments", such as:
- a better knowledge of the "archaeological risk" of discovering ruins during the construction of a new port,
- the useful lessons which can still be learned from many ancient harbour designs,
- his potential support in planning and defending underwater excavations,
- his contribution for the protection of the degradated structures and their eroding shores from the sea attack.

For example a large beach nourishment project is under way at the Venetian Lidos, which will also defend the 250-year old monumental seawalls called "murazzi" (Franco and Tomasicchio, 1992). Anyway in many developed areas more work is envisaged in the future for the conservation and rehabilitation of old coastal structures than for construction of new ones...

In the development of a new coastal project, the archaeologist could help the engineer in planning and analysing the careful preliminary field surveys which should always be executed to prevent the risk of discovering ruins later during construction .

It is then believed that the coordination of different specialists, such as archaeologists, geographers, architects and coastal engineers, would be very important and useful to interpret, defend and valorize the discovered remains and to enrich the skills of each expert learning the different approaches and views of the others.

This paper aims to underline the importance of this cultural-technical heritage and the need to protect it and make it accessible to the public in attractive "maritime archaeological parks". A short overview of the interesting aspects of ancient harbour engineering, particularly along the Italian coasts, is then given in the following section.

Evolution and remains of ancient Mediterranean harbours

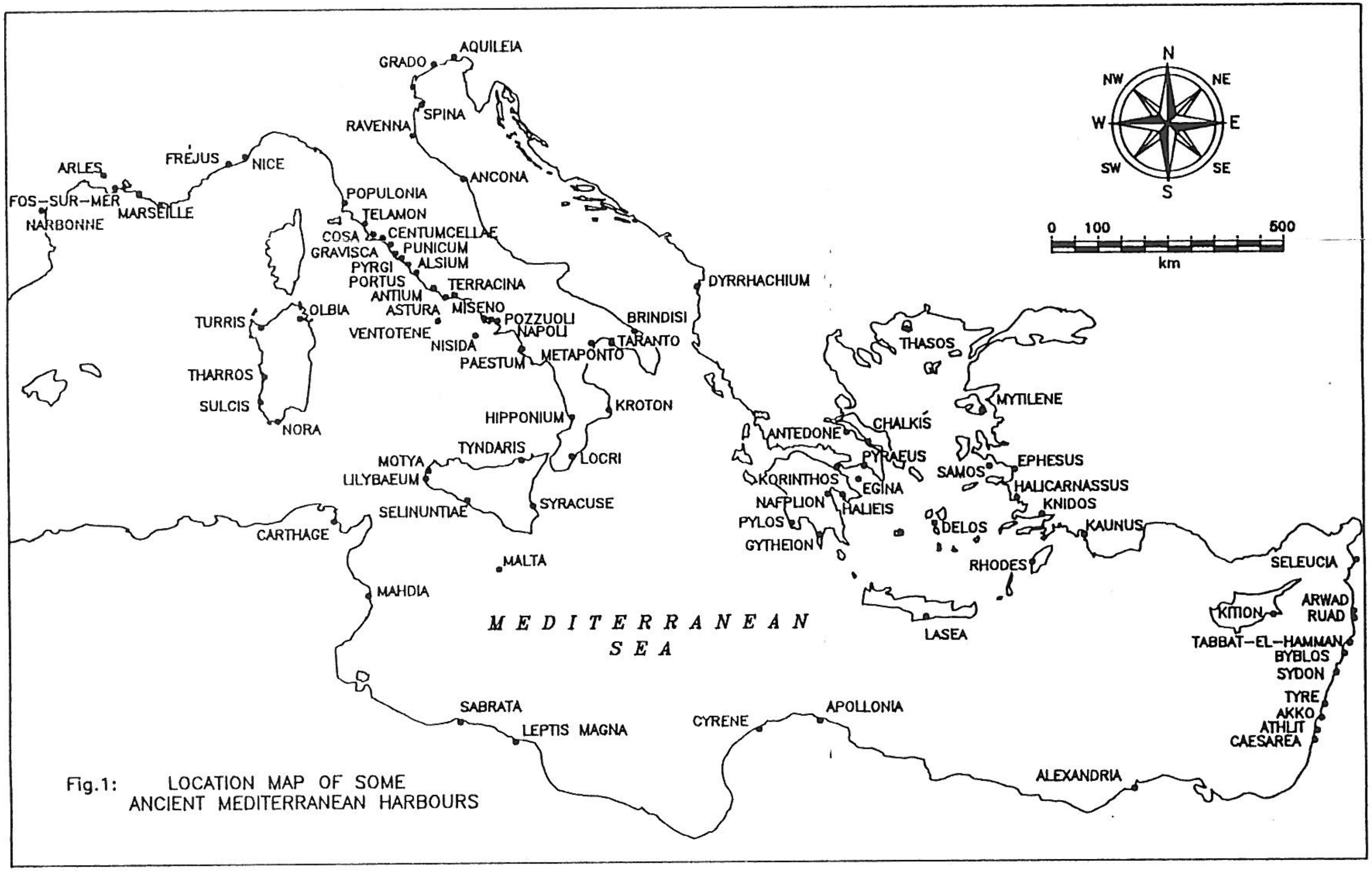
The development of harbour engineering in the ancient classic times is related to the different dominations and cultures which followed in the Mediterranean basin: first Egyptians and Phoenicians, then the Greeks, the Etruscans and the Romans. In fact after the Roman age only a minor evolution occurred until Napoleon times !

Unfortunately very few written sources of information are existing on the ancient methods for port design and construction. The main reference still remains Vitruvio (30 B.C.), shortly describing the techniques of Roman engineers.

A general map of the main ancient harbour sites in the Mediterranean Sea, with apparent remains, is shown in fig.1. The map should actually be completed (particularly for the southwestern areas) after a detailed census toward a useful specific atlas.

Little is known on pre-Roman harbours (also called "proto-harbours"). A comprehensive review was given by Lehmann-Hartleben (1923). Proto-harbours were mainly used for refuge and freshwater supply for the many fragile wooden vessels cruising in the Mediterranean Sea only during the good season.

The design of the early phoenician harbours (VII-IV century B.C.) was mainly dictated by nautical constraints, such as providing easy access even in hard weather: two or more entrances were sometimes provided to ease navigation under variable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GRADO
SPINA
RAVENNA
FRÉJUS
NICE
ARLES
FOS-SUR-MER
NARBONNE
MARSEILLE
ANCONA
POPULONIA
TELAMON
COSA
CENTUMCELLAE
GRAVISCA
PUNICUM
PYRGI
ALSIUM
PORTUS
TERRACINA
ANTIUM
ASTURA
MISENO
POZZUOLI
NAPOLI
VENTOTENE
NISIDA
PAESTUM
METAPONTO
BRINDISI
TARANTO
DYRRHACHIUM
TURRIS
OLBIA
THARROS
SULCIS
NORA
HIPPONIUM
KROTON
TYNDARIS
MOTYA
LILYBAEUM
LOCRI
SELINUNTIAE
SYRACUSE
CARTHAGE
MALTA
MAHDIA
MEDITERRANEAN SEA
SABRATA
LEPTIS MAGNA
CYRENE
APOLLONIA
ALEXANDRIA
THASOS
MYTILENE
CHALKIS
ANTEDONE
PYRAEUS
EGINA
KORINTHOS
NAFPLION
HALIEIS
PYLOS
GYTHEION
SAMOS
EPHESUS
HALICARNASSUS
KNIDOS
DELOS
KAUNUS
RHODES
LASEA
SELEUCIA
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Fig.1: LOCATION MAP OF SOME ANCIENT MEDITERRANEAN HARBOURS

winds and to favour water flow in the relatively tideless Mediterranean Sea, in order to keep silt in suspension and avoid harbour siltation. This classic de-silting method was frequently used also later: the examples of Syracuse, Halicarnassus (Bodrum) and Mytilene are listed by Lehmann-Hartleben (1923). River flow (sometimes diverted in settling-tanks) was also used to prevent siltation (Marseille). Even ramps were constructed to allow the wave crests to sweep over and collect sand-free water in a tank at an higher elevation for periodical release into the harbour (Sidon). This system is now proposed for flushing marinas with the name of "wave pump".

Early harbours were "natural", typically located in favourable geographical conditions, such as sheltered bays near capes or peninsulas, along rivers, inside lagoons or deep coves, often close to high coastal mountains easily visible from the sea in the distance. Harbours were generally spaced at 40-50 km intervals to allow safe day by day tranfer to the vessels sailing at a speed of 5 knots (700 "stadia" per day). Simple anchorages were also frequent for temporary stopovers or for mooring of smaller boats. Thus numerous ruins of ancient ports can be encountered in the Mediterranean!

A typical feature of phoenician port layouts was the so-called "cothon", an internal basin, sometimes dredged inland, used for their own fleet (leaving the outer harbour for foreign ships) and often just for repair works.

Beautiful examples are represented by Motya (Sicily) and Carthage (Tunisia). The harbour of Carthage, recently studied under a UNESCO safeguard program, shows two large basins excavated inland, a rectangular one probably devoted to commercial traffic and the inner anular refuge basin with the circular Admiralty island used as shipyard for up to 200 war-ships (fig.2). Other phoenician-punicum harbour ruins in Italy are visible at Nora and Tharros (Sardinia) and Lylibeum (Sicily).

As far as the Eastern Mediterranean is concerned, a typical characteristic of the earliest harbour works was that they were cut out of rock outcrops or reefs or islands. The rock mass was flattened on its sheltered landward side to make a quay, leaving a protective rock wave-wall on the sea side (Poidebard, 1939, Frost, 1972). Well known sites are Arwad, Byblos, Sidon, Tyre.

The Greeks (VI-III B.C.) also took advantage of narrow peninsulae for building safe "multiple harbours". The breakwaters were built with cut rocks regularly placed on rubble mounds. Herodotus reports of a breakwater at Samos in depths up to 35 m ! The block pattern of vertical quaywalls was also different from the later Romans'. Other Greek harbours with existing remains (mainly in Greece and southern Italy) are Pyraeus, Delus, Nafplion, Thasos, Corinth, Apollonia, Kroton and Taranto.

In the same times the western central part of the Italian peninsula was under the Etruscan domination, who also constructed new harbours (often in coastal lagoons), later used and upgraded by the Romans. Some marks exist along the coast north of Rome at Populonia, Telamon, Orbetello, Regisville, Gravisca, Martanum, Punicum (Castrum Novum), Pyrgi, Alsium.

Shore protection works have recently been built at S.Severa (50 km north of Rome) to defend the excavations of the "colonia maritima" of Pyrgi and a superimposed nice medieval castle, deteriorated by the wave activity concentrated at the shallow promontory. The new breakwater partly covers the neglected semi-submerged harbour remains. Recent studies seem to reveal an inland Etruscan

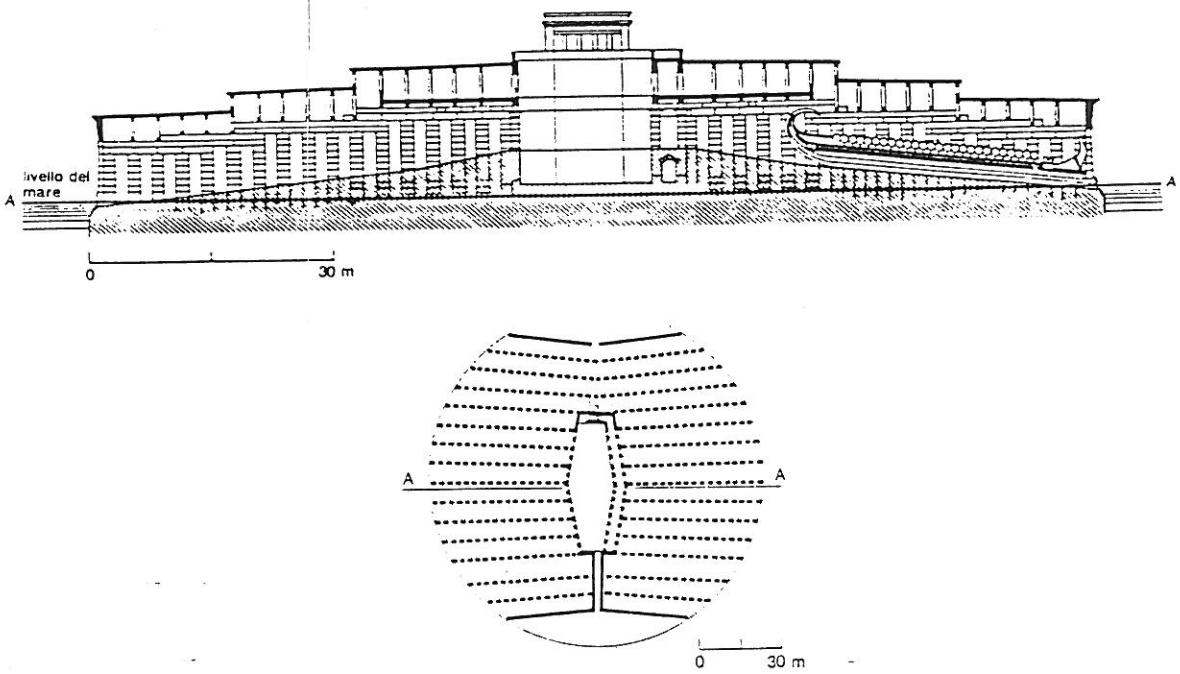


Fig. 2 : Ancient harbour of Carthage: aerial view and reconstruction of the slipways on the Admiralty island at the centre of the circular inland basin (Gianfrotta, 1981)

basin and quaywalls and offshore detached rubble breakwaters at -5 m (Protani and Frau, 1989) (fig.3). Aerial photography shows an interesting access channel dredged across the wide later Roman jetties and an emerging square fishing pond.

In the Eastern Mediterranean, Alexandria (Egypt) is maybe the largest monumental harbour, mainly developed in later Ellenistic times (III-I B.C.), again behind a coastal island (named Pharos after the famous 130 m high lighthouse tower). A 1.5 km long breakwater, with two openings, joined the island to the mainland dividing two basins with an area of 368 hectars and 15 km of quay front !

A peculiar feature of the Greco/Ellenistic harbours is the use of colossal statues to mark the entrance and of a chain gate fixed to the breakwater roundheads in order to control ship entry (Rhodes is a famous application reported by historicians).

The Greek port is still part of the town, whereas in the Roman Empire it becomes an independent infrastructure, with own buildings and warehouses ("horrea").

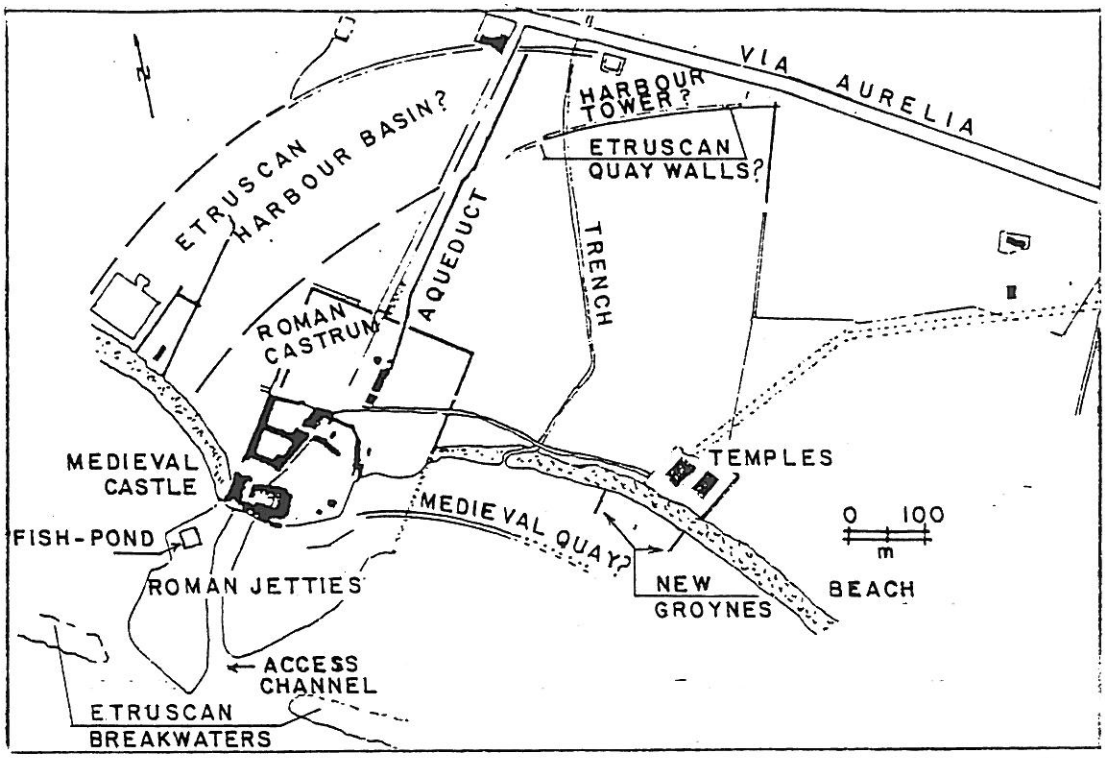
The revolutionary innovation in harbour engineering was really introduced by the Romans, who learned to build walls underwater and therefore managed to construct solid but compact breakwaters to protect fully "external" harbours with free planshape, even curvilinear. They discovered the use of hydraulic cement with pozzolan, which hardens underwater and therefore replaced the Greek rock rubble mound breakwaters with vertical and composite concrete walls ("opus pilarum").

The typical breakwater construction technique consisted in clearing the seabed, pouring a mix of cement, pozzolan and brick pieces within immersed wooden forms ("arcae") supported by driven piles and tie-rods ("catenae") and later casting a concrete emerged superstructure covered by bricks or joined squared rock slabs (fig.4). The figure also shows the characteristic blocks with a hole used for ship mooring. Sometimes, instead of the forms, old ships were sunk filled with concrete, saving time and material: a well known example is the main breakwater of Portus (Rome) built under Claudius (I A.D.) by sinking the large ship which had transported the Vatican obelisk from Egypt. Other breakwater construction techniques codified by Vitruvio are rubble mounds with concrete blocks or rock-filled wooden sheetpiles in soft soils.

Even the forerunners of modern cellular floating caissons were used to build the 60 m wide breakwaters of Caesarea harbour by Herod the Great's engineers in 20 B.C.(Hohfelder, 1987). Double-walled wood forms constructed nearshore were towed into position over a foundation of boulders on a sandy bottom and waterproof mortar packed between the double walls to sink the form. Concrete was infilled by lowering baskets and a rubble toe protection provided. The excavation project at Caesarea also revealed a subsidiary parallel breakwater to reduce wave impacts onto the main walls.

One of the earliest Roman harbours was built at Cosa (Ansedonia) in the formerly Etruscan region of southern Tuscany (II B.C.). It is worth to mention some of its interesting engineering features, mostly visible today, despite the lack of protection and signs in this beautiful coastal site. Excavations have been carried out at Cosa by the American Academy in Rome since 1948 (Brown,1980) and an interesting study was reported by Lewis (1973).

The harbour represents a transition between the natural anchorages of the early Etruscans and the elaborate artificial harbours of the later Romans (fig.5). It was composed by a lagoon and an outer basin (3 hectars) sheltered by the limestone



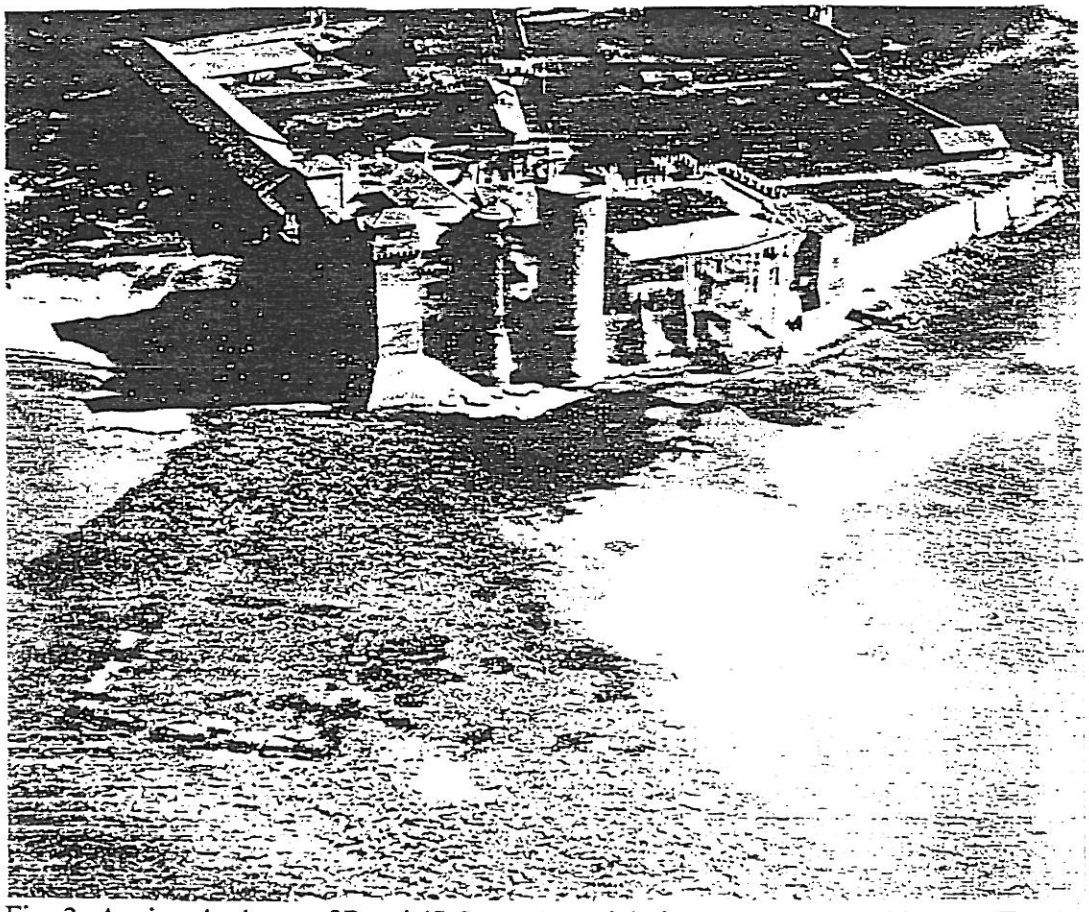


Fig. 3: Ancient harbour of Pyrgi (S.Severa): aerial view and proposed layout (Frau)

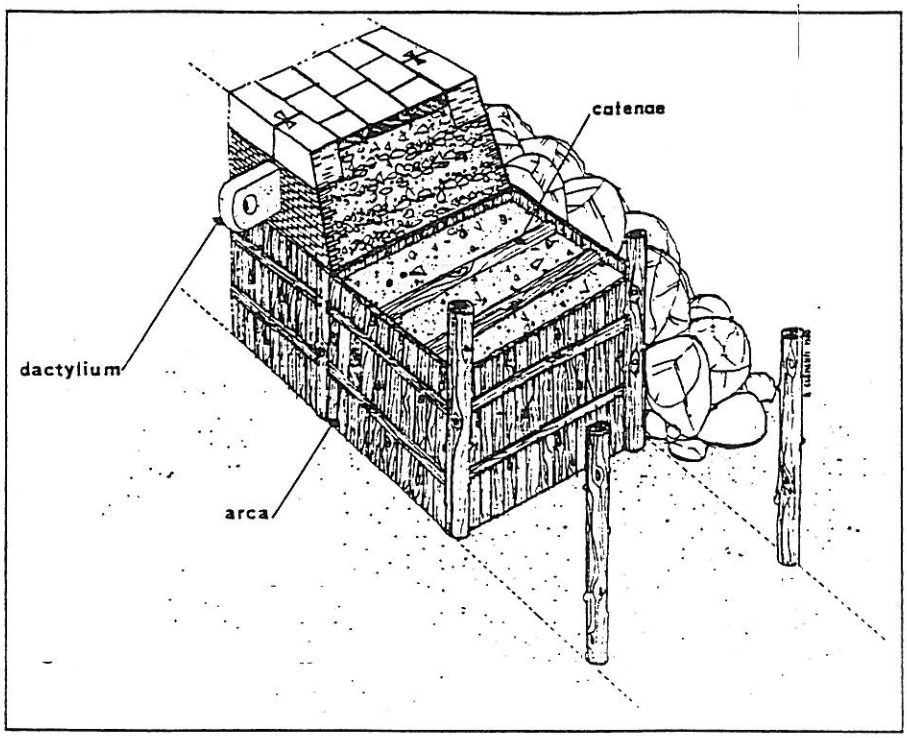


Fig.4: Reconstruction of the Roman breakwater construction system (Clementi, 1980)

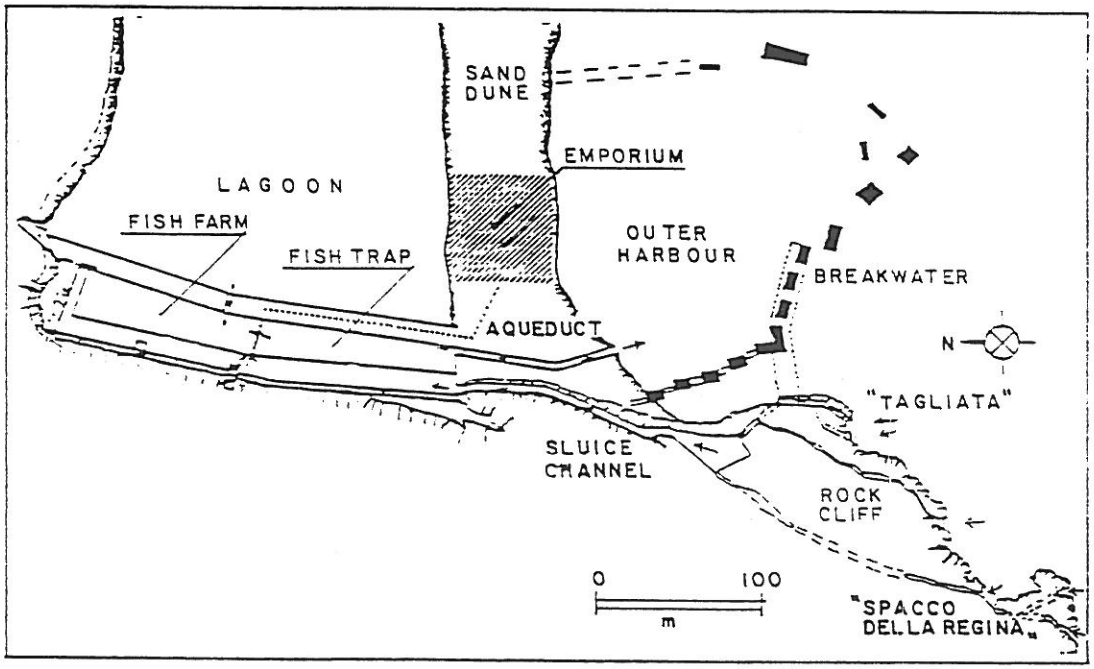


Fig.5: Reconstruction of the Etruscan and Roman harbor layout at Cosa (Brown, 1980)

promontory and by breakwaters (now submerged) made with 2 t rock blocks directly quarried from the adjacent cliff, piled on the seabed and later cemented with natural sand concretion, hydraulic cement and addition of broken pottery to increase the bond. The rocks are now worn to an oval shape and reduced in size due to sand abrasion and animal borings over 2000 years. A few tufa-and-mortar eroded piers (docks?) are still standing out of the water and some detached breakwater extensions are visible underwater near the 50 m wide entrance: their staggered arrangement was probably intended to provide the usual scouring de-silting currents. Existing spectacular features are the gigantic natural sluiceways formed by two nearly parallel cuttings along the adjacent rocky cliff, the natural crevasse Spacco della Regina (260 m long, 30 m deep and 1 to 6 m wide, after suitable wall scarping and bed clearing) and the artificial Tagliata (70 m long and 4 to 5 m wide, partly tunneled), which link the deep sea with the inner harbour and lagoon. Vertical rockcut slots are clearly visible on opposite sides of the channel which were surely used for sliding boards as sluice-gates to control the water flow (probably also the fish flow to and from the lagoon) according to wind conditions and tidal cycle. Photos 1 to 4 by the authors show the present remains.

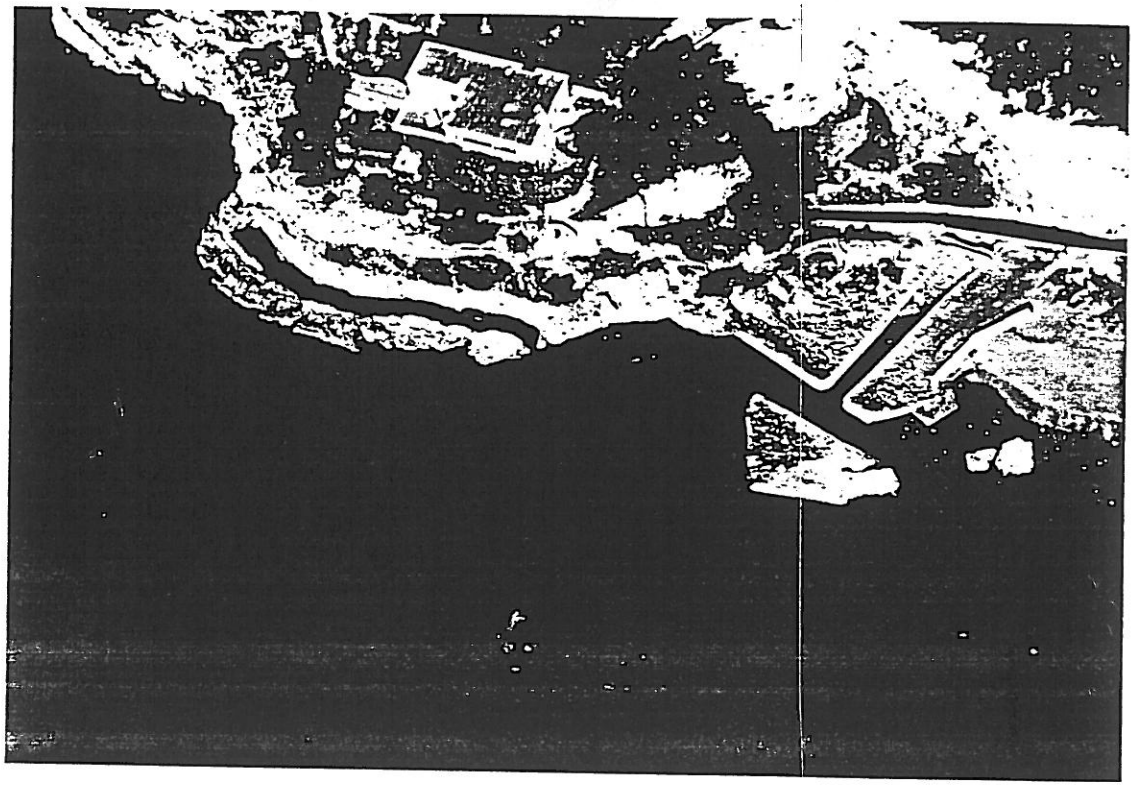
The first harbours of the golden imperial times (after the I century B.C.) are Forum Julii (Frejus), Miseno and Puteoli (Pozzuoli). The latter one was then restored in 139 a.C.and is famous for its arched breakwater (372 m long and 16 m wide, fig.6) now incorporated in the modern structure (!).

The technical reasons for "perforated-vertical" breakwaters (still favoured by De Fazio in 1832 !) may be: control water circulation and toe scour against siltation; reduce wave reflection which affects coastal navigation; save material; reduce loads on the seabed; and even follow the construction techniques and aesthetical views of the Roman aqueducts. The arcades could have been equipped with sliding gates for partial closure during storms. These openings across breakwaters are found in many other Roman harbours, despite their uneffectiveness due to sedimentation in sheltered areas and unacceptable wave disturbance in the basin (at Astura they appear partially closed at a later stage). Small underwater passages are used today to favour harbour flushing, especially in marinas (Franco and Marconi, 1993).

At the ancient naval base of Miseno various remains of harbour deposits and tanks are visible. Other marks of well known Roman harbours are found at Nisida, Terracina, Antium (Anzio), Portus (Roma), Ancona, Centumcellae (Civitavecchia), Astura, Caesarea (Israel), all with monolithic concrete breakwaters. Inland harbours along the Adriatic coasts and rivers were built at Ravenna, Grado, Aquileia.

The largest and best preserved harbour complex is the imperial port of Rome: the maritime town at the Tiber mouth was infact named Portus (Testaguzza,1970). It is now 4 km from the sea, mainly buried under Rome-Fiumicino airport (the outer port of Claudius) and partly within a private estate (the inner hexagonal port later built by Traianus) (fig.7). Despite its importance for the supply to the empire capital the port always suffered from river siltation, but this is also the reason for its conservation in modern times. Unfortunately the remains of Claudius'port structures are hidden among the airport hangars and offices and the beautiful water-filled basin of Traianus (area of 33 hectars and depth of 5 m) is not accessible to the public.

The near port of Antium was developed by the emperor Nero and the ruins of



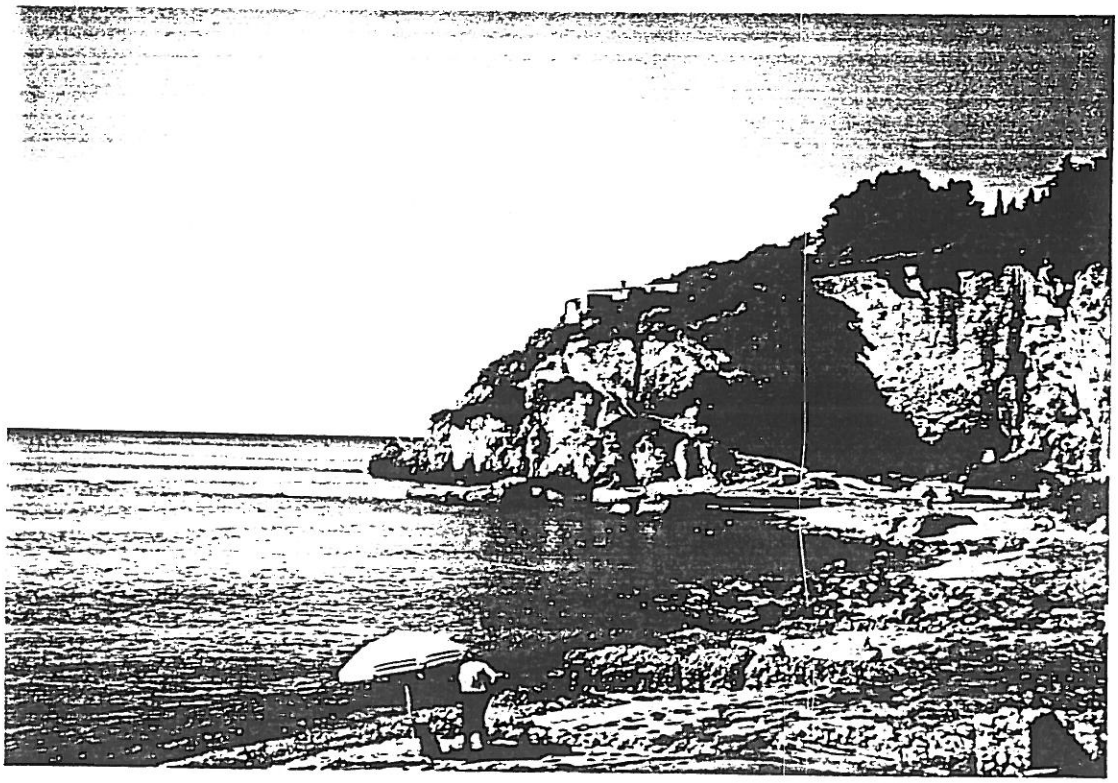


Photo 1-2: Views of the ruins of Cosa harbour from the sky and from the beach (1993)

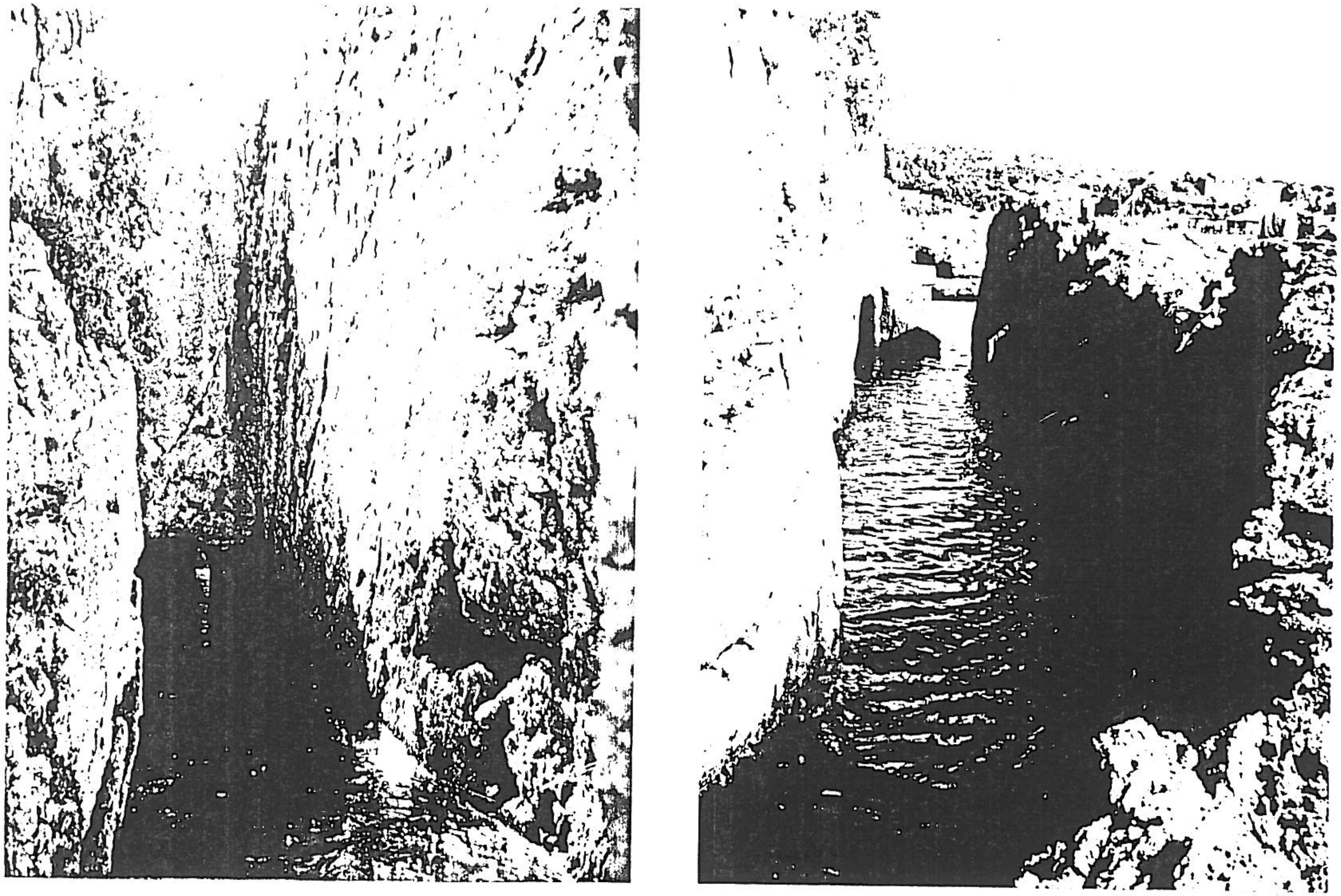


Photo 3-4: The ancient artificial rockcut channel "Tagliata" at Cosa (Ansedonia)(1993)

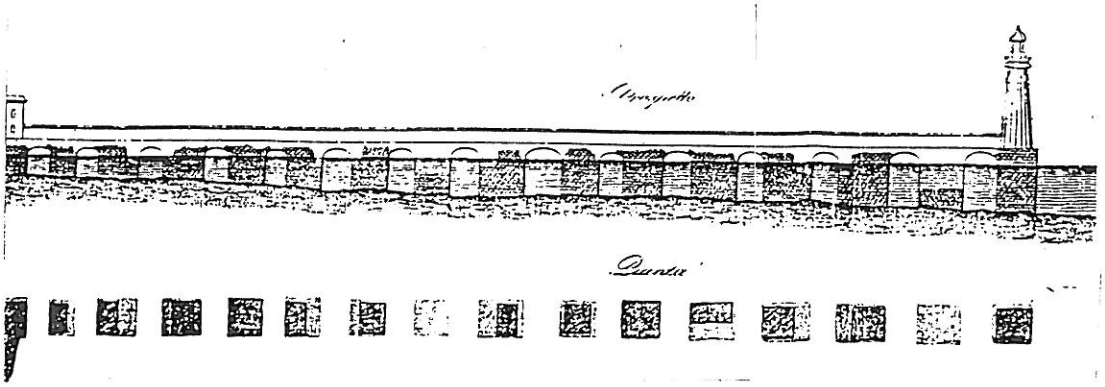


Fig.6: Longitudinal section and plan of Pozzuoli arched breakwater (De Fazio, 1832)

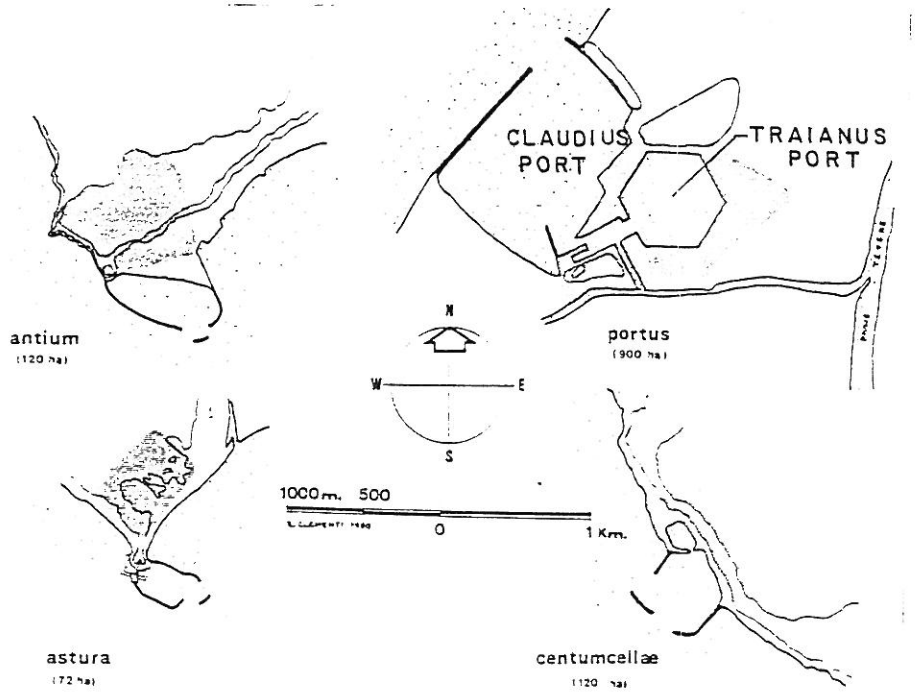


Fig. 7: Layouts of famous Roman harbours near Rome (Clementi, 1980)

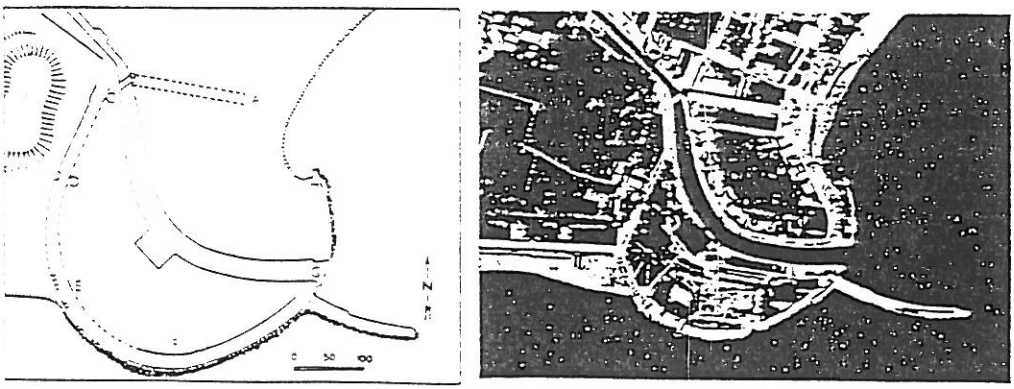


Fig.8: Plan and aerial view of the Roman port of Terracina (Schmiedt, 1970)

the 850 m long main breakwater are still visible underwater beside the modern harbour.

Traianus (100 a.C.) also built the ports of Terracina and Civitavecchia (fig.7,8). The former one was excavated at a river mouth and the mooring quays and columns are well visible along the nice circular perimeter. The harbour of Centumcellae was built just to serve his villa and remained unchanged for over 1000 years. The inner Roman Basin, still in use today, was dredged in the rock (200,000 m^3), which was used for the construction of unusual rubble mound breakwaters (now partly visible under the modern port structures).

The Roman habit of creating a harbour just near an important villa can also be seen at Astura point, where Cicero had stayed. All the breakwaters are well visible underwater together with some ship wrecks, columns, fishing ponds and the whole villa (fig.9). This small port is preserved due to difficult access and military constraints.

Well preserved monumental structures are also existing at the harbour of Leptis Magna (Lybia), with a basin of 400 m diameter excavated inland under the later emperor S.Severo near a river mouth, which was diverted to avoid siltation.

As far as the harbour layout is concerned, the modern concept of the outer harbour with spending beach can be seen in the Roman port of Ventotene island ("Pandataria"). This beautiful harbour excavated in the tufa-rock, including the typical warehouses is still in use in its original form!

However, the characteristic planshape of the Roman harbours had two converging arms and a short island breakwater to reduce wave penetration through the gap and provide a double entrance for manouvrable vessels (and often supporting a large fire-lighthouse). Classic examples are Antium, Astura and Centumcellae (see fig. 7).

The latter one was then assumed by Leonardo as the ideal city-port. It is even suggested that the perfect round planshape of the famous columnates in S.Peter's square in Rome was derived by Michelangel from the converging arms of Centumcellae harbour and consequent Renaissance port models!

Protection and restoration of ancient maritime structures

It is quite surprising to find out that almost nothing exists in the specialized literature regarding the conservation of old civil structures placed in the water. No information was found of any restoration project ever carried out on submerged ancient harbour walls, maybe due to the variety and complexity of the new field of monument preservation. Moreover, in the water the delicate specialist's operations have even to be executed in difficult conditions.

Even on land material degradation, which is due to various physical, chemical and biological causes, is mostly activated by the water. In coastal waters the old structures are subjected to additional deterioration processes (taking also account of an estimated 1 m rise of the sea level from classic times), such as: high hydrodynamic stresses, abrasion of suspended mobile sediments, aggression of salt-water, fouling and corrosion due to marine organisms (even stone and marble are consumed by seawater micro-organisms) and finally the uncontrolled impact of present beach tourist crowds...

The only advantage for a ruin of resting deeply underwater is the possibility to be preserved from all the historical modifications. In many cases the ruins are also

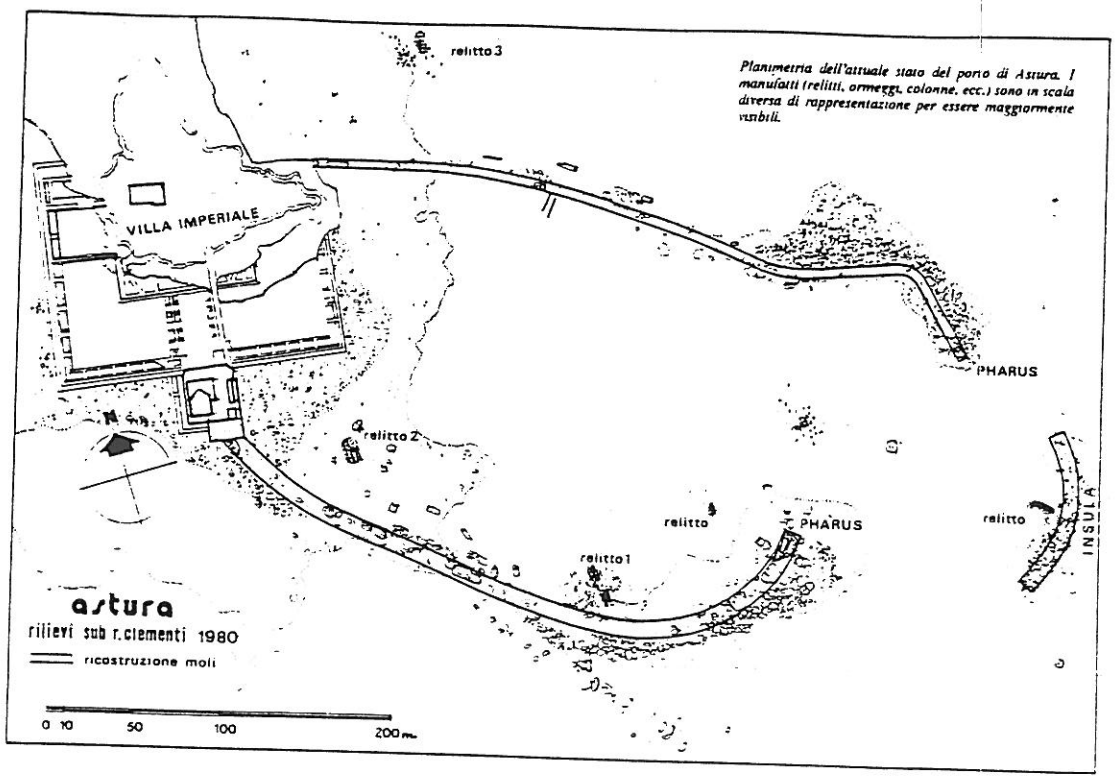


Fig.9: Present remains of Astura harbour and imperial villa (Clementi, 1980)

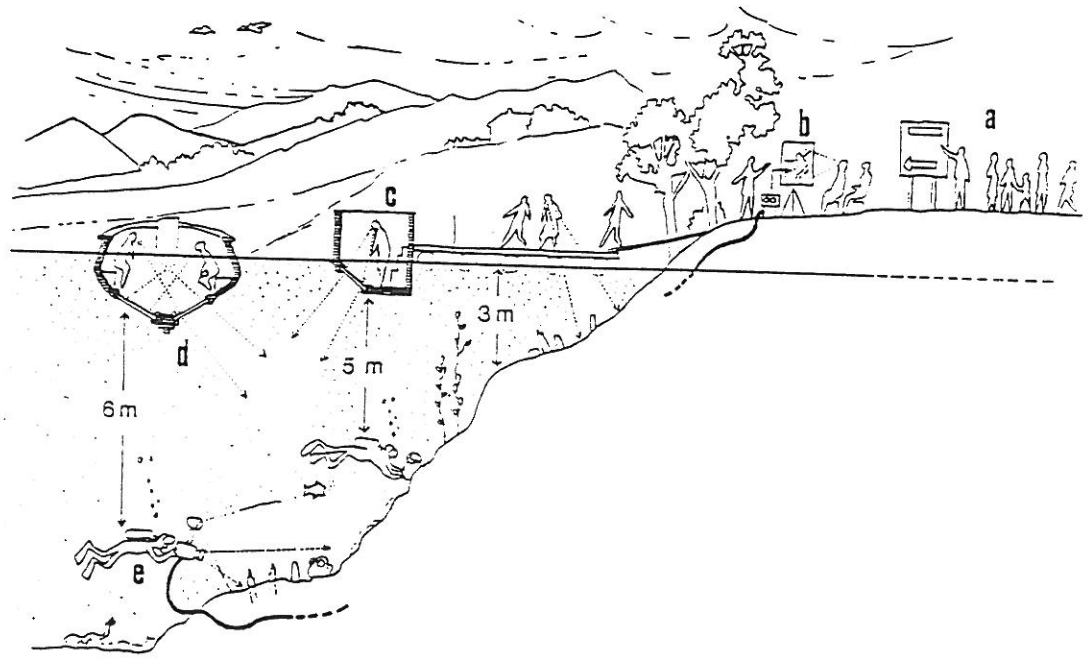


Fig.10: Proposal of "open air/water" musealization for Mezzano lake (Mitchell, 1988)

"protected" by a sand cover, and occasionally revealed by "beneficial" sea erosion. In that case, careful sediment suction from the seabed is first needed to uncover the walls.

So far the attention of underwater archaeologists and restorers has been almost totally addressed to the conservation of artifacts (terracotta amphorae, pottery, bronze statues,etc.) or wooden hulls from ship wrecks (Leigh,1973). Artifacts are heavily washed with freshwater to avoid salt cristallization, before the restoration process in the dry. Ships' wood is often saturated with a special syntetic wax (PEG) which expels the water. Only for woodwork attempts have been made to restore them underwater.

For the classic building materials the traditional sequence of dry restoring operations could be considered in analogy: cleaning, glueing,consolidation, protection.

In general, cleaning is aimed at eliminating external damaging products (deposits, microflora, fouling) by using nebulized or pressurized freshwater or dry mechanical sand-blasting. Stucco-work and glueing can then be applied to repair small surface crackings or material losses,typically with cement mortar (hydraulic mortar if in water). Consolidation is an in-depth structural strenghtening which results in a porosity reduction: organic or inorganic composites may be used, the latter ones are more rigid and fragile but with greater affinity with the original stone or concrete. Usually the difference between the new and the old degradated material is made clear. Finally the protection is aimed at slowing down degradation processes, either by modifying the external agents , or by applying suitable coating with chemical waterproof products. The first option may be used for example by drying up the area and the old structures or by reducing wave attack with new sea defences, such as submerged breakwaters. Active conservation techniques make use of prestressed reinforced concrete, but this is not recommended in the marine environment due to the vulnerability to corrosion.

Proposal for musealization

The final goal is to spread out to the public these scientific and historical achievements and let the visitors combine the usual beach activities with a rewarding "cultural bath". A minimal option should be to sign the coastal archaeological sites by means of simple illustrated panels with historical-technical descriptions (which are often unfortunately missing also during the execution of new coastal works...!).

However many coastal sites with ancient harbour remains (or other civil structures built by the sea) could satisfy the requirements for an "open-air/water" musealization, which are: a) concentration of points of interest in a relatively small area; b) combination of historical events and monumental remains; c) beautiful natural attractions and surroundings.

Good examples for a potential application in the vicinity of Rome are Astura, Pyrgi (S.Severa), Cosa (Ansedonia). These neglected coastal archaeological sites appear very suitable for a successful creation of an "ancient harbour park", including modern facilities for underwater visualization and didactical exhibitions onshore, possibly within the adjacent Roman villa (Astura) or the medieval castle (S.Severa) or the ruins of Cosa village (Ansedonia). In this latter site a spectacular observation path could be created underground along the rockcut channels leading the visitors to the open sea and also upon the cliff overlooking the harbour remains near/on the beach.

A much larger and impressive "inland" park could be created around the preserved port of Traianus near Fiumicino airport.

In general, one possible option for musealization in shallow-water conditions might be to dry up the whole harbour area, including the breakwaters, by means of permanent dykes and pumping system, thus allowing an easier protection and access.

Another attractive solution (particularly feasible around ship wrecks) is to provide submarine footpaths within glass tunnels in a confined sea area. The water would need to be filtered and cooled to avoid marine growth and improve visibility. Fixed underwater observatoriums are largely used for acquariums.

In deep waters a cheap solution for an archaeological visit is the use of semisubmerged mobile systems, such as the French Acquascope. Cheaper glass-bottom boats or fixed floating batiscopes may be used in clean shallow waters.

A closed-circuit television could also enable to display more remote underwater remains and show excavations under way. The onshore exhibition can easily include other explicative panels, shows and displays of objects excavated from the seabed.

A good solution would be a combination of the above systems, as shown in the sketch of fig. 10, proposed for the musealization of the submerged remains of a prehistoric settlement found in the Mezzano lake (Mitchell, 1988).

The exhibition might include harbour structures and facilities, buildings, ships and artifacts, even with an artificial rigorous reconstruction, to display technical and social features of the important ancient maritime trade. The high costs would be easily recovered with admission fees. It may be worth observing that such costly operations are sometimes afforded with different purposes: the site of Astura was temporarily renovated to reconstruct the port of Alexandria for the movie "Cleopatra" !

Conclusions

Wet coastal site archaeological resources are under-represented, if not totally unknown in many Mediterranean regions, despite the fact that they do exist and represent a highly valuable cultural heritage.

The protection and management of submerged cultural resources is yet to be developed, but there is a great potential for furthering human understanding and scientific knowledge. In particular, the remains of impressive works of ancient harbour engineering need to be discovered, studied, protected and exhibited.

The fundamental tasks for the fruitful management of these coastal historical resources are: improved detection skills (remote sensing techniques); preventive site investigations where new works are planned; coastal protection; control of public access; conservation and consolidation; "on-the-water" musealization.

The creation of coastal "maritime-archaeological parks" or museums would certainly qualify the touristic offer of many Mediterranean areas, also improving the cultural asset and reducing unemployment.

The need for collaboration between archaeologists and scientists from other disciplines, particularly coastal engineers and "restoration" architects, is recognized.

Legislation is also required to provide the substantial funds that are needed for the recovery and preservation of ancient harbour remains, especially if underwater.

Acknowledgements

The help of A.Lentini in providing useful bibliographic sources is gratefully recognized. The advice of E.Mitchell and F.Pallarés is also acknowledged. Thanks to C.Fontemaggi too for carrying the author on his ultralight plane to take interesting aerial photographs of coastal submerged harbour remains.

References

- Brown F.E.(1980). Cosa, the making of a Roman town. Michigan University Press
- Clementi R.(1981). Il porto romano di Astura. L'Universo n.6, I.G.M., Firenze
- De Fazio G. (1832). Intorno al miglior sistema di costruzione dei porti, Napoli
- Franco L., Marconi R. (1993). Marina design and construction. Marina Developments. Computational Mechanics Publications, Southampton, pp.143-213
- Franco L., Tomasicchio G.(1992). Hydraulic and mathematical modelling of historical and modern seawalls for the defense of Venice lagoon. Proc.23rd ICCE Conference on Coastal Engineering, Venice, pp. 1879-1893
- Frost H.(1972). Ancient harbours and anchorages in the Eastern Mediterranean. UNESCO Congress "Underwater archaeology: a nascent discipline", Paris, pp.95-114
- Gianfrotta P., Pomey P.(1981). Archeologia subacquea. Ed.A.Mondadori, Milano
- Hohlfelder R.L.(1987).Caesarea Maritima. National Geographic, vol.171, n.2
- Lehmann-Hartleben K.(1923). Die Antiken Hafenanlagen des Mittelmeers. Klio, Beiheft XIV, Leipzig
- Leigh D. (1973). Reasons for preservation and methods of conservation. Marine Archaeology, Colston Papers 23, London, pp.203-218
- Lentini A. (1993). Porti Antichi. DIIAR, Politecnico di Milano
- Lewis J.D. (1973). Cosa: an early Roman harbour. Marine Archaeology, Colston Papers 23, London pp.233-261.
- Ministero per i Beni Culturali e Ambientali (1990). Archeologia subacquea: bilanci e prospettive. Notiziario V. 30-31, Roma, pp.18-30.
- Mitchell E. (1988). Il lago di Mezzano: un esperimento di collaborazione tra Enti di tutela ed Enti locali per la salvaguardia e la valorizzazione di un sito archeologico sommerso. Primo seminario di studi su "I siti archeologici: un problema di musealizzazione all'aperto", Roma, pp.112-117
- Poidebard A. (1939). Un grand port disparu, Tyr. Paris
- Protani V., Frau B.(1989). Pyrgi e il castello di S.Severa. GAR, Comune S.Marinella
- Scrinari V. (1965). Il porto di Claudio ed osservazioni sulla tecnica del conglomerato cementizio presso i Romani. L'Industria Italiana del Cemento n.7.
- Schmiedt G. (1970). Atlante aerofotografico delle sedi umane in Italia. Le sedi antiche scomparse. Istituto Geografico Militare, Firenze
- Schmiedt G. (1975). Antichi porti d'Italia. L'Universo 45/2,46/2,47/1. Istituto Geografico Militare, Firenze
- Testaguzza O.(1970). Portus- I porti di Claudio e Traiano e le città di Porto e Fiumicino, Roma.
- Vitruvio M.P. (30 B.C.). De Architectura, vol II, ch VI; vol V, ch XII (in Latin).