n EGYPT

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t Alexandria – a Greek city in Egypt, by the Ptolemaic dynasty until the of Cleopatra – today lies hidden h the sprawling modern city. There place, however, where the remains of bled metropolis are still accessible: the sea.

ologist Franck Goddio and his team 10 years exploring the seabed around dria's harbour. Their object was to he ancient port, the semi-mythical Magnus, as well as the coastline and te some of the buildings tantalisingly ed in ancient texts.

12,000 hours of diving, sifting gh 23 centuries of history, Franck o, André Bernand and the IEASM piece together this compelling nt of the largest underwater archae-l site ever explored.

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SUNKEN EGYPT ALEXANDRIA

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ALEXANDRIA

PERIPLUS

The ports

This city facing the open sea was a great centre of commerce. Known as Rome's granary, it relied upon the export of cereals and the import of materials which were in short supply locally, most notably wood. Many ships were built here too, the shipyards occupying the whole of the westernmost area of the Portus Magnus. Alexandria was the city of ports – commercial ports, royal ports, private ports, ports for the use of galleys and for the passage of goods and people.

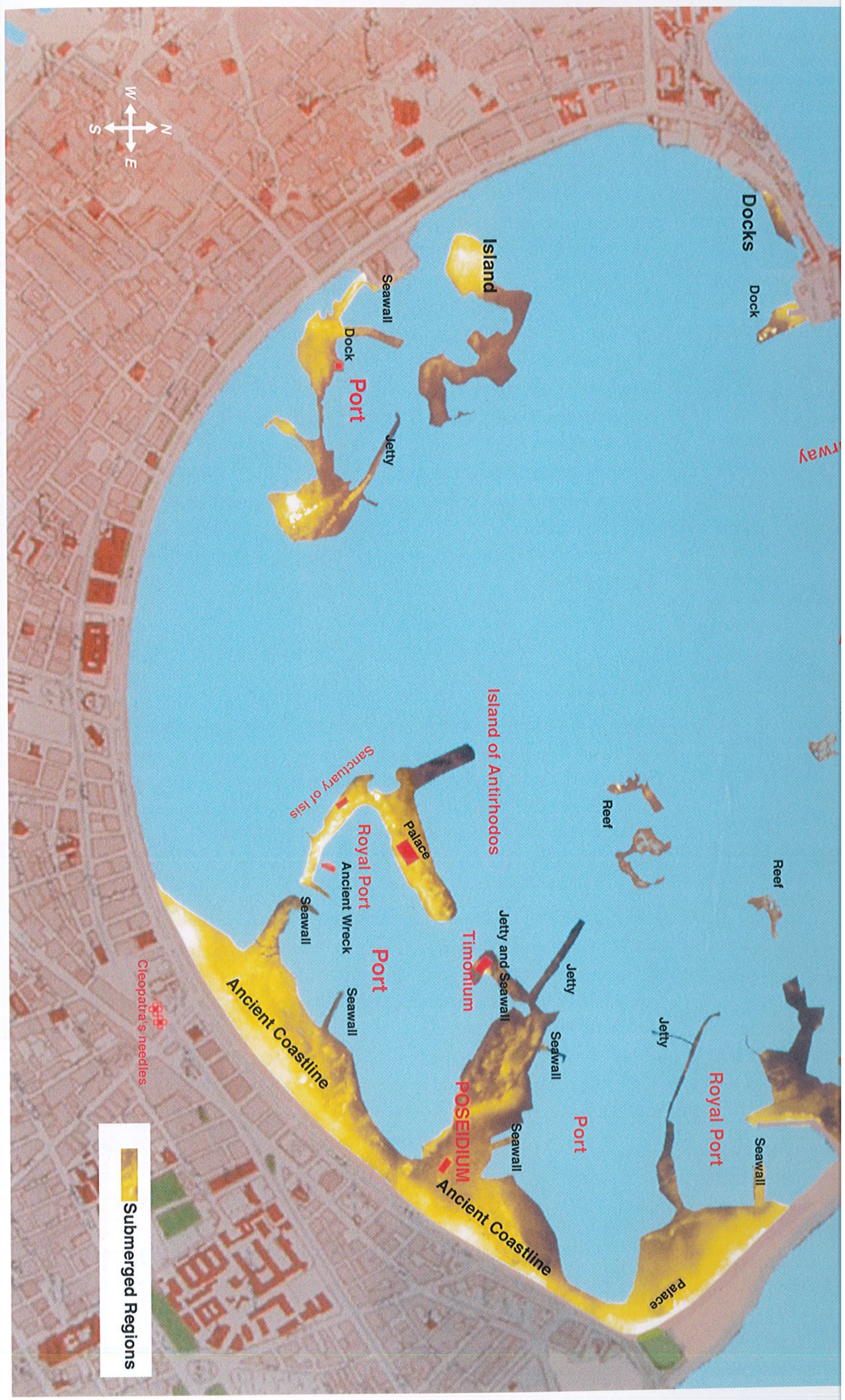
Although we generally use the singular to describe a city as a seaport, where Alexandria is concerned we are obliged to speak in the plural, since this particular city boasted a number of harbours or ports, all of them quite different from one another.

Word games

Alexandria's eastern harbour was called the Great Harbour – Megas Limin in Greek or Portus Magnus in Latin. Its western harbour was situated on the other side of the mole known as the Heptastadion and was styled Eunostos, the 'port of safe return', although in fact it was difficult to access due to the presence of shoals and barrier reefs and the prevailing winds blowing from the north-west. This use of antiphrasis is common in Greek: the Black Sea, which was extremely perilous, having relatively few safe anchorage sites and hostile inhabitants populating its shores, was nevertheless called the Euxine, or 'hospitable', sea.

The name Antirhodos can be interpreted in two different ways. According to Jean Yoyotte and Pascal Charvet in their commentary to *Voyage en Égypte de Strabon*, "As a result of its name, the little island of Antirhodos would have represented a challenge to a stubbornly independent city-state (before it became an ally of Rome), whose merchants, engineers and intellectuals rivalled those of the Alexandrian monarchy." Antirhodos can also be understood quite simply as 'the Rhodes opposite', since Alexandria was in the southern Mediterranean, while Rhodes was in the north.

In the western harbour there was an artificial basin which was given the name Kibotos (the 'coffer') on account of its enclosed position at the foot of Rhakotis Hill. Within the eastern part of the Portus Magnus, the underwater excavations carried out by Franck Goddio and his team (and described in his book *Alexandria: the submerged royal quarters*) have revealed the existence of three interior ports, as indicated by the overall plan on p. 149. His recent excavations in the western part of the Portus Magnus have also revealed a large additional port with several docks, situated just opposite the Heptastadion, the huge causeway which connected the coast to the island of Pharos. It appears that the latter served as a transit area between the eastern and western harbours (cf. *The* navalia, p. 156). This configuration was completed by a series of substantial moles constructed along the length of the island of Pharos.



Map of the Portus Magnus incorporating the submerged regions of the ancient city dating back to Roman

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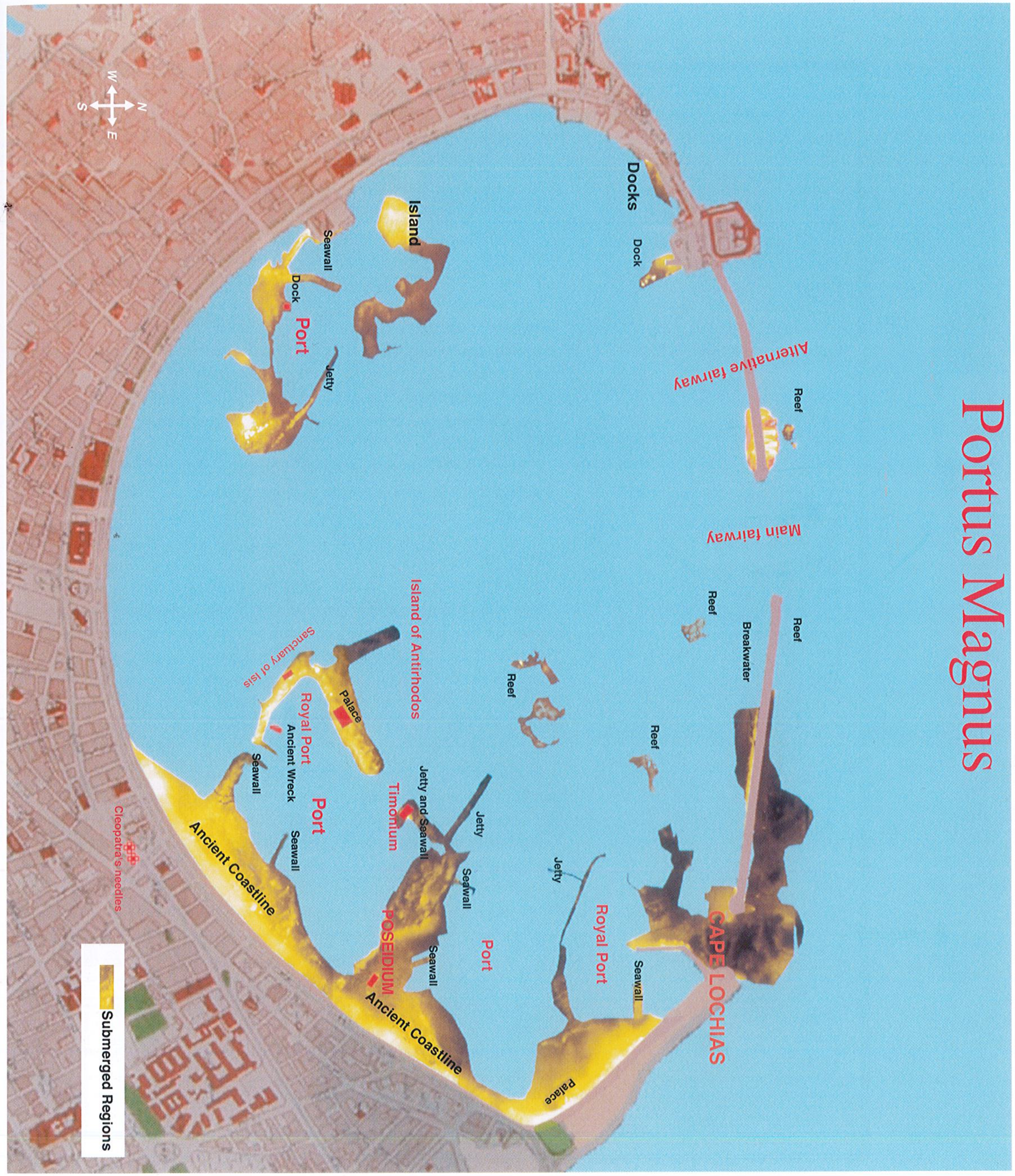


Map of the Portus Magnus incorporating the submerged regions of the ancient city dating back to Roman times.

Communication between the eastern and western harbours

The Eunostos was not just a sea harbour but also a river port, into which the Mahmoudieh canal flowed. Known in antiquity as the 'guardian spirit', this canal branched off the Canopic arm of the Nile, bringing water from the river to the city and also serving as a route for the conveyance of products from the delta. For Alexandria to be, as Strabo called it, the *Emporion* or marketplace of the ancient world, there needed to be some means of communication between the two harbours to enable the transhipment of cargo. These transhipments were facilitated by the grid layout based on the Hippodamian model and entrusted to the celebrated architect Deinocrates: thanks to Alexandria's straight roads carts could travel by the most direct route and did not have to contend with dangerous bends.

According to Strabo, this layout also favoured the circulation of air through the city, particularly when the summer winds were blowing, from which he concluded: *So summer is a very agreeable season for the Alexandrians*. It was for this same reason that ministers moved their offices and archives from Cairo to Alexandria for the summer season during the reign of King Farouk (1936–52). After spending several summers in Alexandria, however, it is possible to feel less enthusiastic than Strabo, since in July and August these days the only place where one can breathe properly is on the coast road.

Was it the best choice of site on which to construct a capital? This was a question that was debated by the two great philosophers of antiquity, Plato and Aristotle.

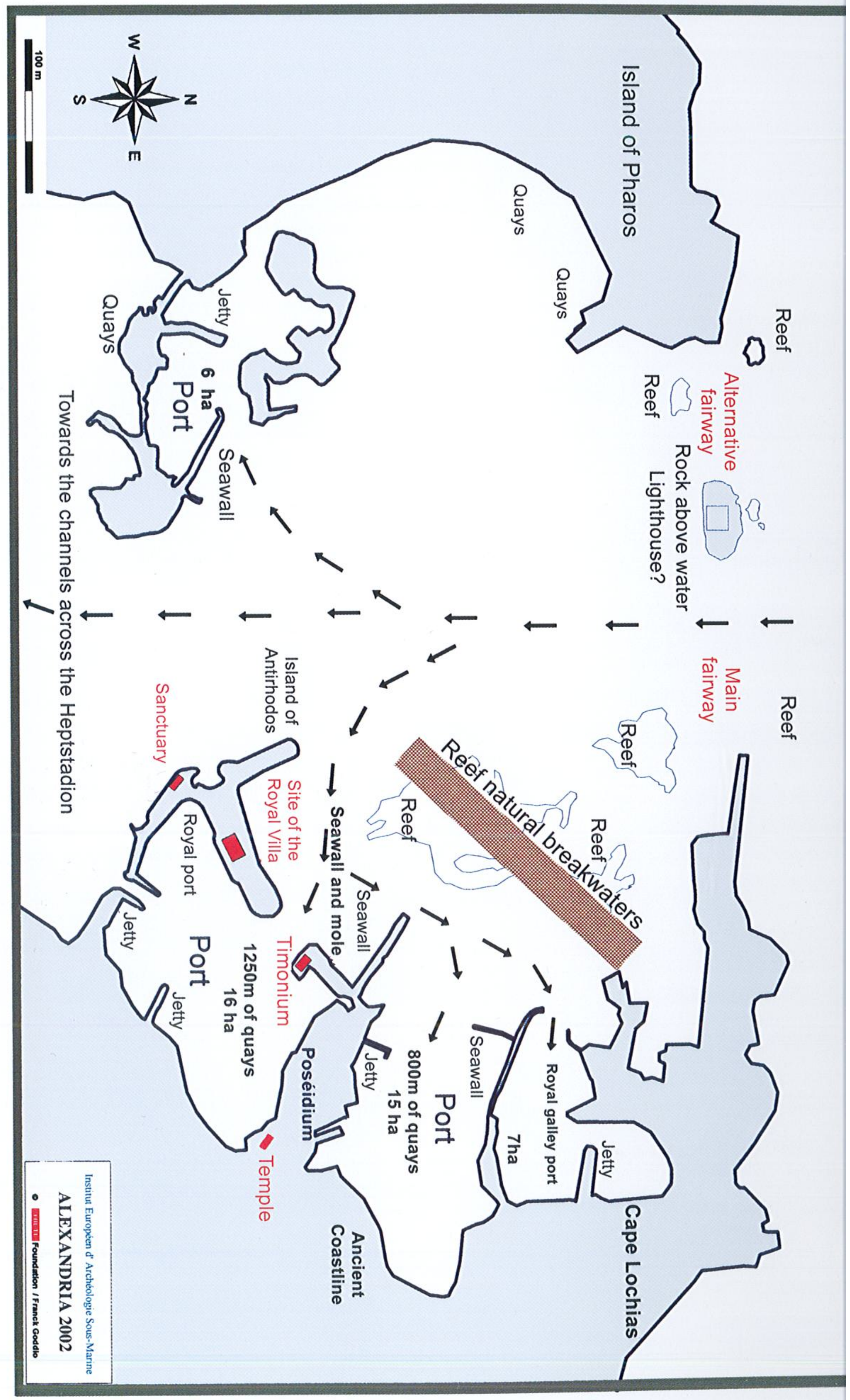
Why fear the sea?

For Plato, building a city on the edge of the sea entailed grave dangers. Firstly, it risked introducing corruption into the city, tainting the values of a population reliant on the hinterland and agriculture by exposing it to international trade. Secondly, it could inflate the population and promote a spirit of anarchy, more especially as merchants and sailors were undesirable additions to the city. Finally, as Plato saw it, the quality of bravery declined in direct proportion to a nation's reliance on ships. He considered that the naval victories won by the Athenians at Salamis and Cape Artemision in 480 BC had turned the Greeks into cowards, whereas the land battles at Marathon (490 BC) and Plataea (479 BC) had created better men united by a greater sense of solidarity.

Taking the opposite view from his master (as was to be expected), Aristotle judged that a nation needed to be able to defend itself both at sea and on land. For the sake of importing and exporting goods, moreover, it had to open itself up to outside trade, and this in turn required the development of its fleet. As for the risk of overpopulation, this could be avoided if sailors were not assimilated into the city and the length of their stay was carefully controlled. If a city was open to the sea, there was no need to enclose it behind high walls. A city needed, on the one hand, to be in communication with every part of its territory; on the other, to be able to offer transport facilities so that products from the soil, wood and construction materials could be brought in.

As Alexander's tutor, Aristotle had expounded these theories to him at length, and Alexander was astute enough to recognise the merits of Aristotle's arguments.

And so the city of Alexandria was born.



Map showing access to the different ports of the Portus Magnus.

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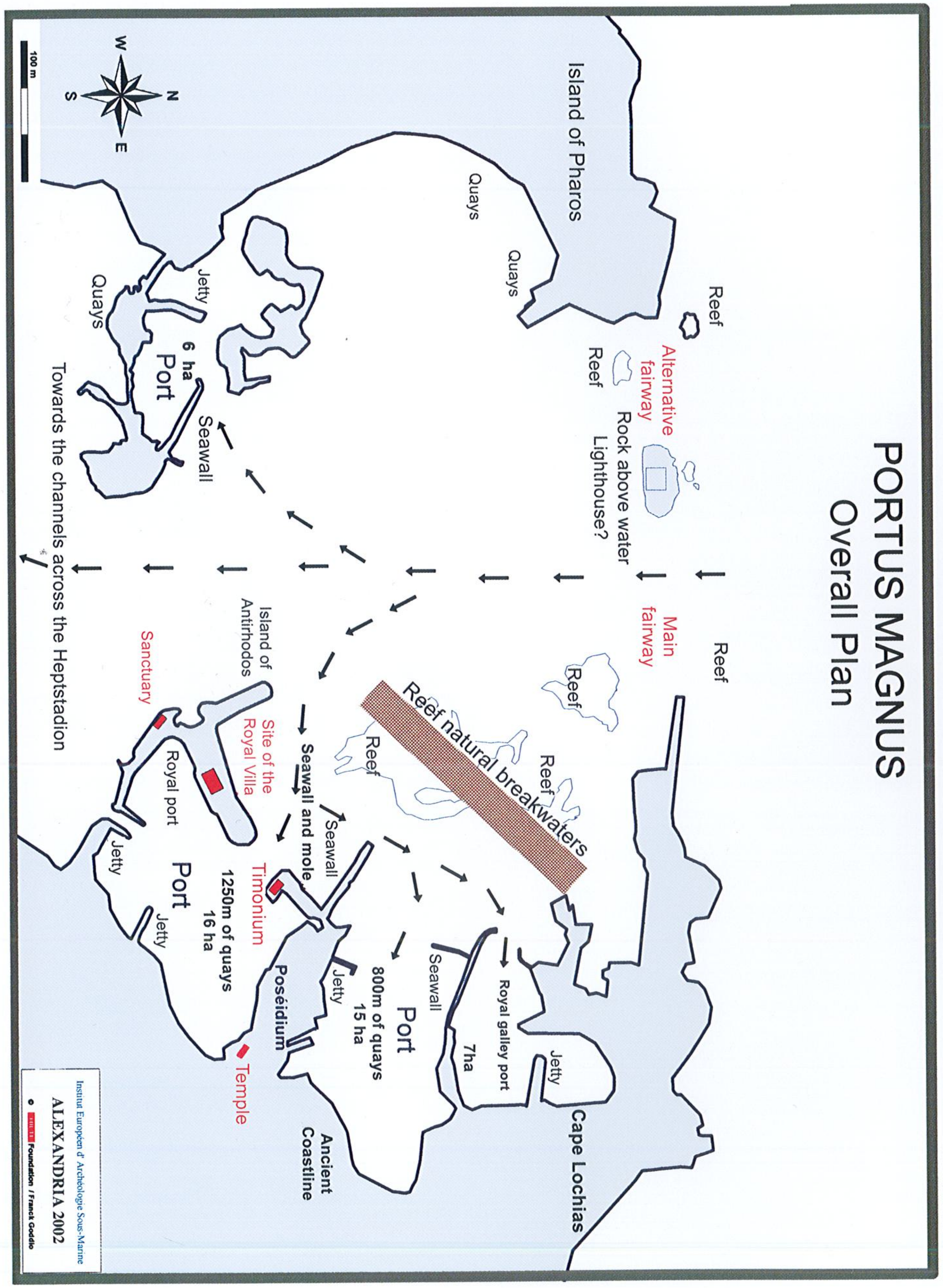

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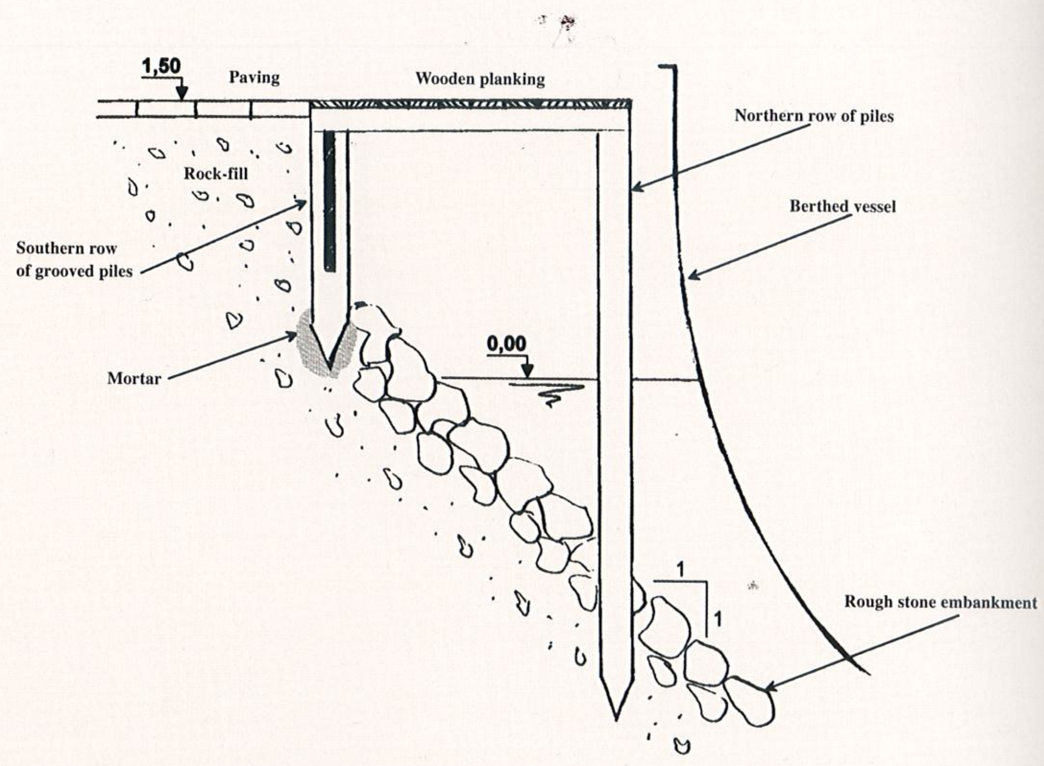
The royal ports from the point of view of a 20th-century engineer

According to the maritime engineer, Arthur de Graauw, of SOGREAH Engineering, based in Grenoble, France, the expert in harbour installations is primarily interested in the following:

- **Overall plan** The configuration of a harbour depends on navigation conditions (winds, waves) and the types of ships using it (sail- or oar-propelled). The size of the vessels determines the degree of acceptable turbulence and the decision whether or not to construct a breakwater to serve as a storm barrier. The length of the quays is determined by the number of vessels using the harbour.
- **Harbour structures** The water depth at the quayside, and consequently the height and structure of the quay, depend on the draught of the vessels using the harbour. The materials locally available (wood, stone, mortar) together with methods of construction influence the structures specific to a particular region and time.



Cross-section diagram of an ancient quay.

Overall plan

Let us start by considering two factors that affect all vessels: wind and waves. We can reasonably assume that wind and wave conditions have not altered, or at least not much, since antiquity. Current statistics demonstrate that the prevailing winds (and waves) off the coast of Alexandria are west to northerly (more than 50% of the time as a yearly average and 70–90% of the time from June to September). A second important directional sector is the north to easterly (20–30% of the time from October to May) – a significant consideration in Alexandria since it was the reason for choosing a double harbour.

The construction of a double harbour was motivated by the presence of two principal wind and wave directions. Where such circumstances exist, as they not uncommonly do, it is an advantage to be able to move ships from one anchorage to another in order to gain optimum protection in all weather and sea conditions. Once the Heptastadion had been built, the island of Pharos became a peninsula which met this criterion perfectly:

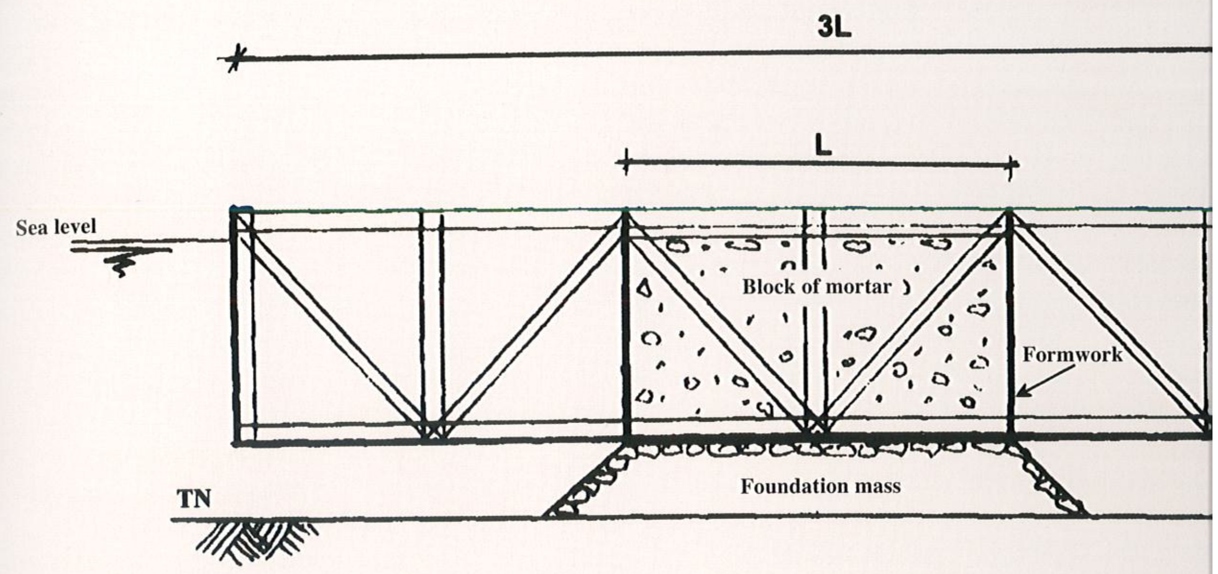
- to the west lay the Eunostos harbour,
- to the east lay the Portus Magnus.

And, thanks to the ingenious construction of channels intersecting the Heptastadion, ships could sail from one harbour to the other without venturing out to sea – although it is worth noting that the western section of the roads at Alexandria must have started gradually silting up following the construction of the Heptastadion for this strip of coastline to curve in the way it does today.

It must have seemed logical to construct the eastern harbour next to the Heptastadion, where it would have been protected by the island of Pharos – at the spot where fishermen shelter today from the predominant west to northerly winds. Whatever its technical merits, such an argument does not appear to have prevailed, since the three ports that have been located are actually on the opposite side of the bay, adjacent to Cape Lochias (modern-day Cape Silsileh), where the royal palaces were situated. This eastern sector of the roads is relatively more exposed to the north-west swell, and it was for this reason that a breakwater was constructed to reinforce the natural barrier provided by the emerging reefs.

In order to gain access to the docks, ships had to negotiate their way round to the south and west of the reefs. This enabled them to enter the roads with the wind behind them before the sails were stowed; they were then rowed towards the north-east and proceeded into one of the three ports.

As regards the types of vessel which used the harbour, it has been possible to identify a few large commercial vessels, but we are in fact better informed about the naval fleets of the time. Not all the ships mentioned passed through the harbour at Alexandria, but they are included for the purposes of comparison.



Floating caisson.

During this time, when the Romans and Carthaginians were confronting one another in their triremes and quinqueremes in the western Mediterranean (at the decisive battle of the First Punic War off the Aegates Islands, 241 BC), the Macedonians and Alexandrians were constructing gigantic galleys. Some of these huge ships were still being built centuries later – Antony ranged a number of them against Octavian's fleet at the Battle of Actium (2 September 31 BC). The most assiduous of these ancient shipbuilders was undoubtedly Ptolemy II, who, at the time of his death in 246 BC, left a fleet of warships that included:

- 2 'thirties' (30 oarsmen a side);
- 1 'twenty';
- 4 'thirteens';
- 2 'twelves';
- 14 'elevens';
- 67 'nines' and 'sevens';
- 22 'sixes' and 'fives' (quinqueremes);
- 4 'threes' (triremes);
- 150 'twos' (biremes).

This makes a total of around 10 large vessels (measuring between 50 x 10m and 70 x 20m), 80 medium-sized vessels (45 x 8.5m) and 175 small vessels (between 20 x 2.5m and 35 x 5 m) – a fleet of some 265 ships.

This is similar to the number of warships we encounter during other periods. Pompey's fleet for his war against the pirates, waged between 67 and 66 BC, consisted of 200 quinqueremes and 30 triremes, and Antony's fleet for the battle of Actium was made up of 220 ships (his largest was a 'ten'). We also know that at other periods the Alexandrian fleet was less extensive. The fleet burned by Caesar at the Battle of Alexandria in 48 BC comprised 50 triremes and quinqueremes, 60 other vessels were beached in the arsenals.

As an exercise in imagining the overall plan of Alexandria's eastern harbour, we calculated how we might house Ptolemy II's entire fleet within the parameters of the three harbours.

The approximate surface area of each harbour is as follows:

- first harbour: 7 hectares;
- second harbour: 5 hectares with approximately 800m of quays;
- third harbour: 16 hectares with approximately 1,250m of quays.

We concluded that the first harbour could easily accommodate the 10 large vessels referred to above. The 80 mid-sized vessels and 25 small vessels could be lined up side by side, stern to quay in the second harbour, and the third harbour (with quay space for up to 250 quinqueremes) could house the remaining 150 small vessels.

By way of comparison, it is perhaps worth mentioning the dimensions of the other great harbours in antiquity.

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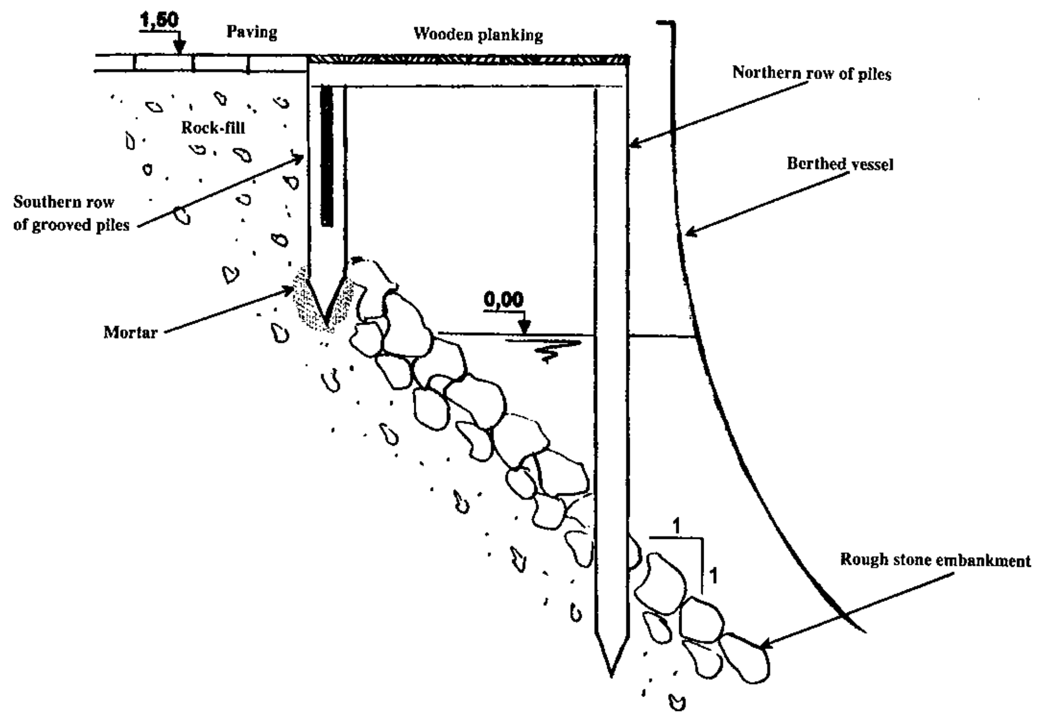

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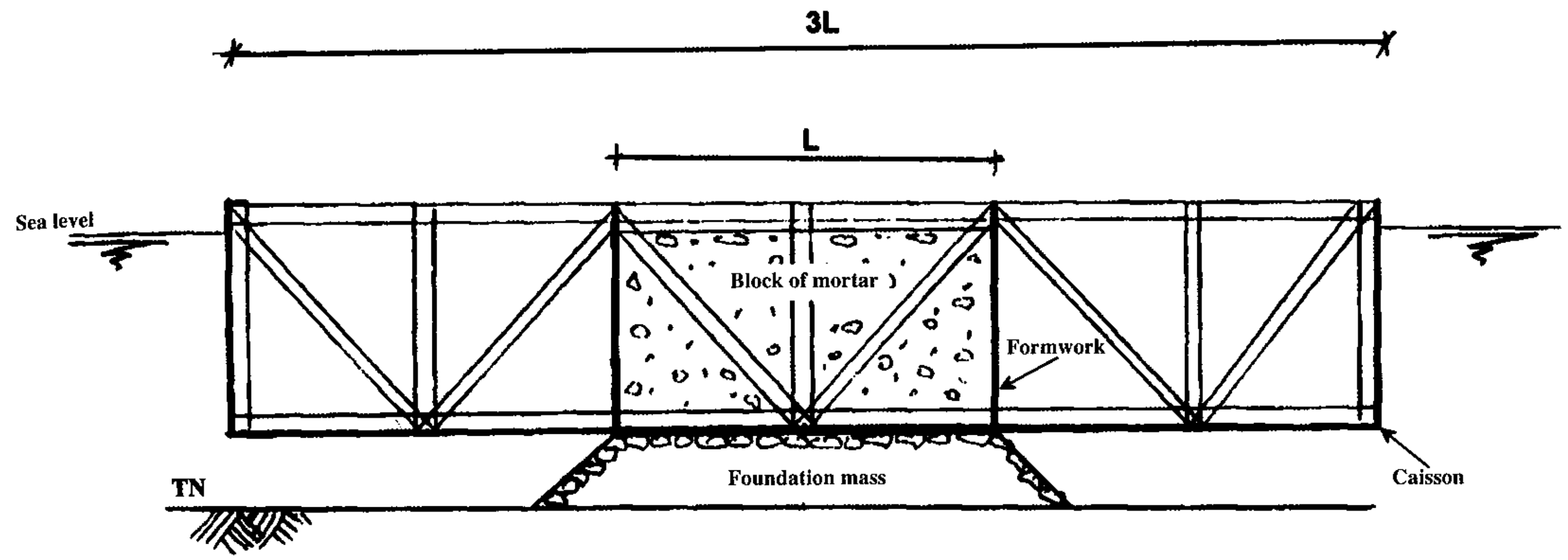

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By way of comparison, it is perhaps worth mentioning the dimensions of the other great harbours in antiquity.

- Piraeus at Athens
  - Cantharus (commercial): 1,000 x 500m (50 hectares), 100 boatsheds;
  - Zea (military): circular with a diameter of 300m (7 hectares), 196 boatsheds;
  - Munychia: 82 boatsheds (approx. 5 hectares).
- Carthage
  - Commercial harbour: 500 x 300m (15 hectares) in addition to the Lake of Tunis;
  - Cothon (military): circular with a diameter of 330m and a central island (7 hectares of water), 220 boatsheds.
- Rome
  - Portus: Porto Claudio (approx. 60 to 80 hectares) and Porto Trajano (33 hectares);
  - Misenum (military): base of Octavian's imperial fleet for the battle of Actium;
  - Puteoli (commercial): situated alongside Misenum in the Bay of Naples.

We can see from this that the Portus Magnus was of average size in relation to the other large harbours of the time.

Harbour structures

It is an irony of civilisation that the naval harbours of antiquity resembled the marinas of our own times in terms of their overall dimensions and the size of the ships using them (a luxury yacht measures between 15 and 70m or more). The ancient galleys had a shallower draught, however, in the order of 1 to 1.5m, although the largest ships must have had a draught that could reach 4m.

The two main types of harbour structures were breakwaters, which provided a barrier against the waves, and quays.

The breakwaters could be either sloping embankments of rough stone or vertical structures made of blocks. What remains of Alexandria's ancient breakwaters out to sea has not (as yet) been explored since the ancient structures are probably located beneath their modern counterparts.

The internal breakwaters which protected each of the three harbours consisted of a sloping embankment on the outer face and, in the majority of cases, a quay constructed from blocks of mortar on the structure's inner face.

The various structures can be classified as follows depending on which materials were used:

- wooden – wooden platforms supported by piles of stone pillars;
- without mortar – blocks of hewn stone, possibly with an infill between two facings;
- with mortar, without pozzolana (a porous volcanic ash used in making hydraulic cements) – massive blocks formed by pouring mortar into a wooden formwork in dry conditions;
- with mortar, with pozzolana – massive blocks formed by pouring mortar into a formwork underwater.

The technique using blocks of hewn stone is the oldest of these. For structures of a certain width, two separate facings were constructed using stone blocks and the cavity between them was filled with ungraded quarry materials. The surface this provided was then covered with paving. It was important that the blocks weighed no more than a tonne apiece so that they could be readily manoeuvred using the lifting devices available at the time. The blocks found at Tyr in the southern harbour weigh around 500kg, although, to provide greater resilience, blocks weighing 10 tonnes or more were used in places exposed to the waves.

The mortar was made of slaked lime, sand and water. Since this mixture could only harden in the open air, and not underwater, the following mechanism was devised for use in marine construction work. A wooden formwork was installed in the water, at the site chosen for the construction of the quay, and filled with sand to just above the water level. The mortar was then poured on to this bed of sand and allowed to dry in the open air. In order to place the mortar in position on the sea-bed, the sand simply had to be emptied from the formwork by opening the doors let into its sides.

The introduction of pozzolana by the Romans in *circa* 30 BC revolutionised hydraulic construction work. This silico-aluminous material of volcanic origin combines with lime in the presence of water and enables mortar prepared in this way to harden underwater. The use of pozzolana rendered obsolete the process described in the previous paragraph, since the mortar could now be poured directly into the formwork installed on the sea-bed. The Alexandrians had not yet acquired this expertise, however, at the time when the eastern harbour was constructed.

The large quay blocks discovered in Alexandria's third harbour (typically 5–8m wide, 10–15m long and 1–3m high) do not contain pozzolana and the dating of the wood indicates a period when pozzolana did not yet exist in Egypt (c. 250 BC). The presence of wood beneath the block indicates that the formwork almost certainly formed part of a floating caisson (a technique also used at Caesarea under Herod and still in use today).

We may suppose that after being floated above the quay under construction, the caisson was weighted so that it sank down to the sea-bed, where a foundation surface had been prepared. The caisson had to be sufficiently buoyant, and also watertight, to enable the mortar to dry in the open air. It functioned as a kind of barge capable of supporting the block of mortar, for which purpose it had to be about two and a half to three times wider than the block of mortar (which had a density of approximately 2.5 kg/m^3), since the draught of the caisson with its block would then be approximately equal to the height of the block to be set in place.

This explains the presence of planks and pieces of timber beneath the block, as well as that of vertical and obliquely angled timbers held fast in the mortar, which were used to make the caisson structurally rigid while it was being floated and lowered to the bottom. It also explains the absence of any vertical wooden walls, since these must have been removed after the block of mortar had been lowered to the bottom.

The double row of piles discovered at the eastern extremity of the island of Antirhodos is older (c. 400 BC) than the large blocks mentioned above. The presence of mortar at the lower end of the piles of the southern row indicates that these rows of piles must have been constructed in dry conditions, in other words that they were submerged after they were constructed.

We may postulate, therefore, that this double row of piles is the remnant of an ancient wooden quay. The piles of the southern row have grooves into which planks were slotted to form a timber shuttering capable of holding a fill of quarry waste. The northern row had no such grooves, but could have supported wooden planking and have been sunk into the sea-bed to a depth of about 1m.

Oceanographic conditions in Alexandria

Winds

The following statistics (expressed in terms of percentage of time per directional sector) were provided by Alexandria's meteorological office for the period 1973–1992.

The first four lines of the table show the frequency of the wind in the four 90° sectors. The last two lines give the figures for the two 180° sectors: the N (E) S sector, or 'east wind' as we can call it, and the S (W) N sector, or 'west wind'. The last column gives the annual average. The following trends can be observed:

- on an annual average, the wind blows 2/3 of the time from the west and 1/3 of the time from the east;
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- the summer winds (between June and September) blow from the NW sector for most of the time; only in October, then during the winter through May, do the winds blow from the east 35–40% of the time.

Winds

month	1	2	3	4	5	6	7	8	9	10	11	12	year
% of time per directional sector													
N to E	19	20	29	30	30	17	5	7	16	30	30	20	21
E to S	15	17	15	15	11	5	2	2	5	12	13	16	11
S to W	35	26	15	9	6	6	5	4	5	10	21	35	15
W to N	31	37	41	46	53	72	88	87	74	48	36	29	53
N (E) S	34	37	44	45	41	22	7	9	21	42	43	36	32
S (W) N	66	63	56	55	59	78	93	91	79	58	57	64	68

These figures demonstrate that sailing from Rome to Alexandria was a great deal easier than sailing in the opposite direction. The journey to Alexandria would have taken between two and three weeks, and the journey to Rome twice that time. Ships did on average two journeys a year, sailing during the summer season (May to September) in order to avoid the storms.

Waves

The following statistics have been obtained from observations carried out in the eastern Mediterranean aboard selected ships during the period 1960–1980.

The first four columns give the frequency of the swell in percentage of time for the sectors indicated. The fifth column gives the percentage of calm seas (and other sectors which do not reach Alexandria). The first line gives the periods of calm. The second line gives the periods of swell of less than 1m (height of the waves from crest to trough) and the third line the periods of swell of more than 1m. The following trends can be observed:

- off the coasts of Egypt and Libya the sea is calm for a little more than half the time;
- waves more than 1m high, which interfere with navigation by sail, occur for 25% of the time;
- waves from the W to N sector (approx. N285 to N5) represent 36% of the time and waves from the N to E sector (approx. N5 to N65) only represent 8% of the time.

Sea levels

The following levels have been recorded by the Egyptian authorities (in relation to the terrestrial datum point, Robert Zero):

LLWL (*lowest low water level*): -0.43m;
CD (chart datum or hydrographic zero): -0.34m;
MLWL (*mean low water level*): -0.05m;
MSL (*mean sea level*): 0.08m;
MHWL (*mean high water level*): 0.21m;
HHWL (*highest high water level*): 0.74m.

These figures show that the lowest water level is 9cm below the Hydro Zero and that mean sea level at Alexandria is 8cm above the Egyptian datum point.

It is worth mentioning that sea levels have changed during the last 2,500 years. Reduced to their simplest terms, scientific calculations show that sea levels have risen during this period by about 1.5m, or approximately 6cm per century. We might

Waves

sector	N285-N325	N325-N5	N5-N35	N35-N65	calms	total
H<0.1m	-	-	-	-	56	56
0.1>H>1m	10	6	2	2	-	20
H>1m	13	7	2	2	-	24
total	23	13	4	4	56	100

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in marine construction work. A wooden formwork was installed in the water, at the site chosen for the construction of the quay, and filled with sand to just above the water level. The mortar was then poured on to this bed of sand and allowed to dry in the open air. In order to place the mortar in position on the sea-bed, the sand simply had to be emptied from the formwork by opening the doors let into its sides.

The introduction of pozzolana by the Romans in *circa* 30 BC revolutionised hydraulic construction work. This silico-aluminous material of volcanic origin combines with lime in the presence of water and enables mortar prepared in this way to harden underwater. The use of pozzolana rendered obsolete the process described in the previous paragraph, since the mortar could now be poured directly into the formwork installed on the sea-bed. The Alexandrians had not yet acquired this expertise, however, at the time when the eastern harbour was constructed.

The large quay blocks discovered in Alexandria's third harbour (typically 5–8m wide, 10–15m long and 1–3m high) do not contain pozzolana and the dating of the wood indicates a period when pozzolana did not yet exist in Egypt (c. 250 BC). The presence of wood beneath the block indicates that the formwork almost certainly formed part of a floating caisson (a technique also used at Caesarea under Herod and still in use today).

We may suppose that after being floated above the quay under construction, the caisson was weighted so that it sank down to the sea-bed, where a foundation surface had been prepared. The caisson had to be sufficiently buoyant, and also watertight, to enable the mortar to dry in the open air. It functioned as a kind of barge capable of supporting the block of mortar, for which purpose it had to be about two and a half to three times wider than the block of mortar (which had a density of approximately 2.5 kg/m³), since the draught of the caisson with its block would then be approximately equal to the height of the block to be set in place.

This explains the presence of planks and pieces of timber beneath the block, as well as that of vertical and obliquely angled timbers held fast in the mortar, which were used to make the caisson structurally rigid while it was being floated and lowered to the bottom. It also explains the absence of any vertical wooden walls, since these must have been removed after the block of mortar had been lowered to the bottom.

The double row of piles discovered at the eastern extremity of the island of Antirhodos is older (c. 400 BC) than the large blocks mentioned above. The presence of mortar at the lower end of the piles of the southern row indicates that these rows of piles must have been constructed in dry conditions, in other words that they were submerged after they were constructed.

We may postulate, therefore, that this double row of piles is the remnant of an ancient wooden quay. The piles of the southern row have grooves into which planks were slotted to form a timber shuttering capable of holding a fill of quarry waste. The northern row had no such grooves, but could have supported wooden planking and have been sunk into the sea-bed to a depth of about 1m.

Oceanographic conditions in Alexandria

Winds

The following statistics (expressed in terms of percentage of time per directional sector) were provided by Alexandria's meteorological office for the period 1973–1992.

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total	23	13	4	4	56	100

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It is worth mentioning that sea levels have changed during the last 2,500 years. Reduced to their simplest terms, scientific calculations show that sea levels have risen during this period by about 1.5m, or approximately 6cm per century. We might add that the present trend indicates far higher increases: approximately 18cm for the last century (1880–1980) and, as currently estimated, 30–110cm for the 21st century.

Oscillations in mean sea levels appear to have occurred in the course of the last two millennia. It is very difficult, moreover, to distinguish eustatic movements (related to the sea) from tectonic movements (related to the earth). The example of Crete is illuminating, since over 2,000 years, the sea level has dropped between 4 and 8m in relation to the land at the western extremity of the island, whereas at its eastern end the sea level has risen between 1 and 4m during the same period.

It is currently accepted that at Alexandria the sea level has risen between 1 and 1.5m and that the land level has dropped between 5 and 6m over the last 2,000 years.

It is also worth noting that tsunamis have been reported on the coasts of the Middle East.

Sedimentology

The sediments found on the beaches and the sea-bed adjoining the roads at Alexandria are made up of sands whose granulometry (D50) ranges between 0.20 and 0.50mm. These sands almost certainly come from ancient deposits of the Nile. The beaches at Alexandria have been experiencing generalised erosion for some decades now and a number of conservation measures (re-sanding of the beaches, creation of rough stone embankments) have been taken with varying degrees of success. The erosion is principally due to the displacement of sand from the beach towards the open sea which occurs during storms.

In addition to this movement of sand out to sea, significant displacement also occurs along the coast, both from east to west and west to east. Experts calculate that these opposing movements are each in the order of 100,000m³ a year, and therefore cancel one another out. It is obvious from this that if an obstacle were constructed at right angles to the coast, 100,000m³ of sand a year would be deposited on either side of the obstacle. This is what must have happened after the construction of the Heptastadion, at least a proportion of these deposits coming to rest against its sides each year.

The *navalia*

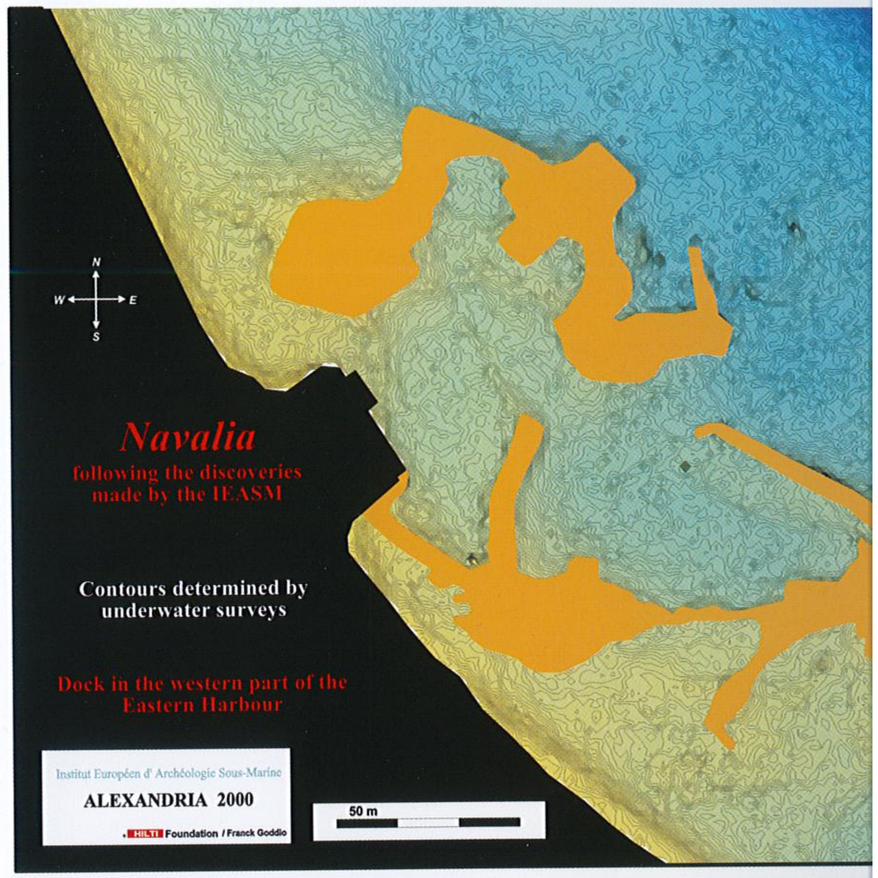
There were powerful reasons why archaeologists should be interested in the eastern half of the Portus Magnus: the ancient coastline was still discernible here beneath the sea, and adjoining it were the royal quarters. The western half of the harbour, less often mentioned in the ancient texts, was excavated at a later date. On the site of the current fishing port, its coastline is largely obscured by the construction of the modern corniche road, so this part of the bay was unlikely to surrender its secrets easily.

The submerged remains of a large quay. Although we fully expected to find architectural remains in the royal quarters, we had no reason to anticipate such impressive structures on the western side of the Portus Magnus.

The ancient coastline could be traced from Cape Lochias as far as the section of coast that faces the island of Antirhodos. We continued our survey of the bay by proceeding westwards from this point. Our first surprise came at the midpoint of the corniche – which yielded absolutely nothing. The current shoreline was actually underwater in Ptolemaic times and because it is now so extensively built up it is impossible to form an impression of the original coastline (although it was probably set very much further back). There were no remains to be found here, therefore. Further along, however, in the south-west of the bay, we came across some huge submerged forms. After producing relief maps of the seabed and examining the loose sediment in order to determine the contours of any solid structures, we decided to proceed from a visible point and demarcate the submerged mass by working our way along its edge. Little by little, as our team of divers drew off the sediment, the outlines of a vast harbour structure emerged, fitted out with numerous quays. We drew up a new map, showing the current contours of the structure, from which we were able to reconstruct the ancient contours as we may suppose them to have been prior to the occurrence of subsidence, rock falls and natural accretions due to the deposition of sediments by marine currents.

The structure facing the Heptastadion resembled a peninsula connected to the island of Pharos and extended at several points by long quays and breakwaters expertly constructed from blocks of limestone. It was protected by a natural island situated to the north and partly paved, and itself formed a bulwark for the Heptastadion, sheltering it from the full onslaught of the sea. The harbour quays are paved in limestone, and ancient mortar foundations, paving stones, limestone construction blocks and fragments of red granite columns attest the presence of a small monument situated on the central mole.

Much further north, near the fort of Qait-Bey, an impressive harbour installation composed of a number of docks has been discovered. The collapsed platforms tell us something about the construction technique (see the chapter on Antirhodos) using piles set in a buttress of loose rocks, sheeting piles, enormous mortar blocks and areas of paving. The size of the quays and the remains of walls suggest that large buildings may once have stood on this site. The whole configuration dates from the Roman period, when Alexandria's harbour structures appear to have undergone a general programme of alterations: the piles of the



Map of the Portus Magnus with the western navalia shown in red.

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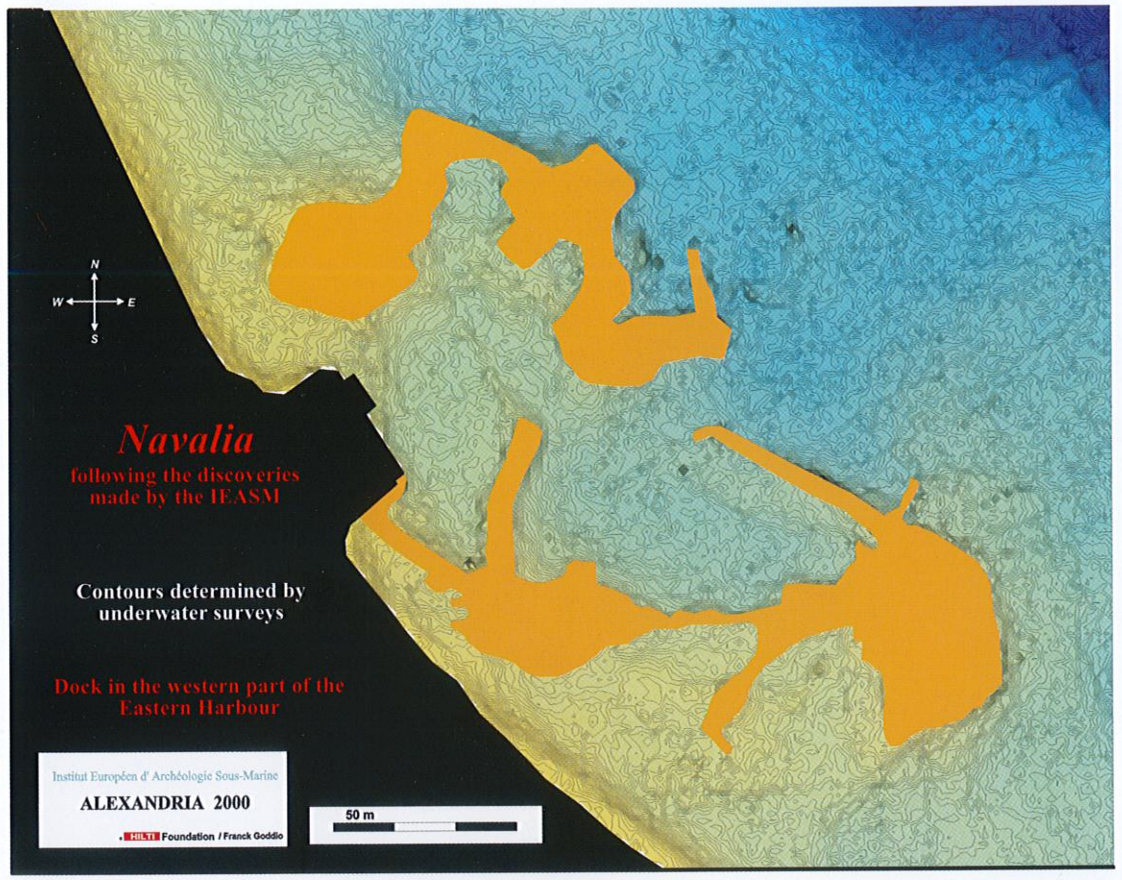

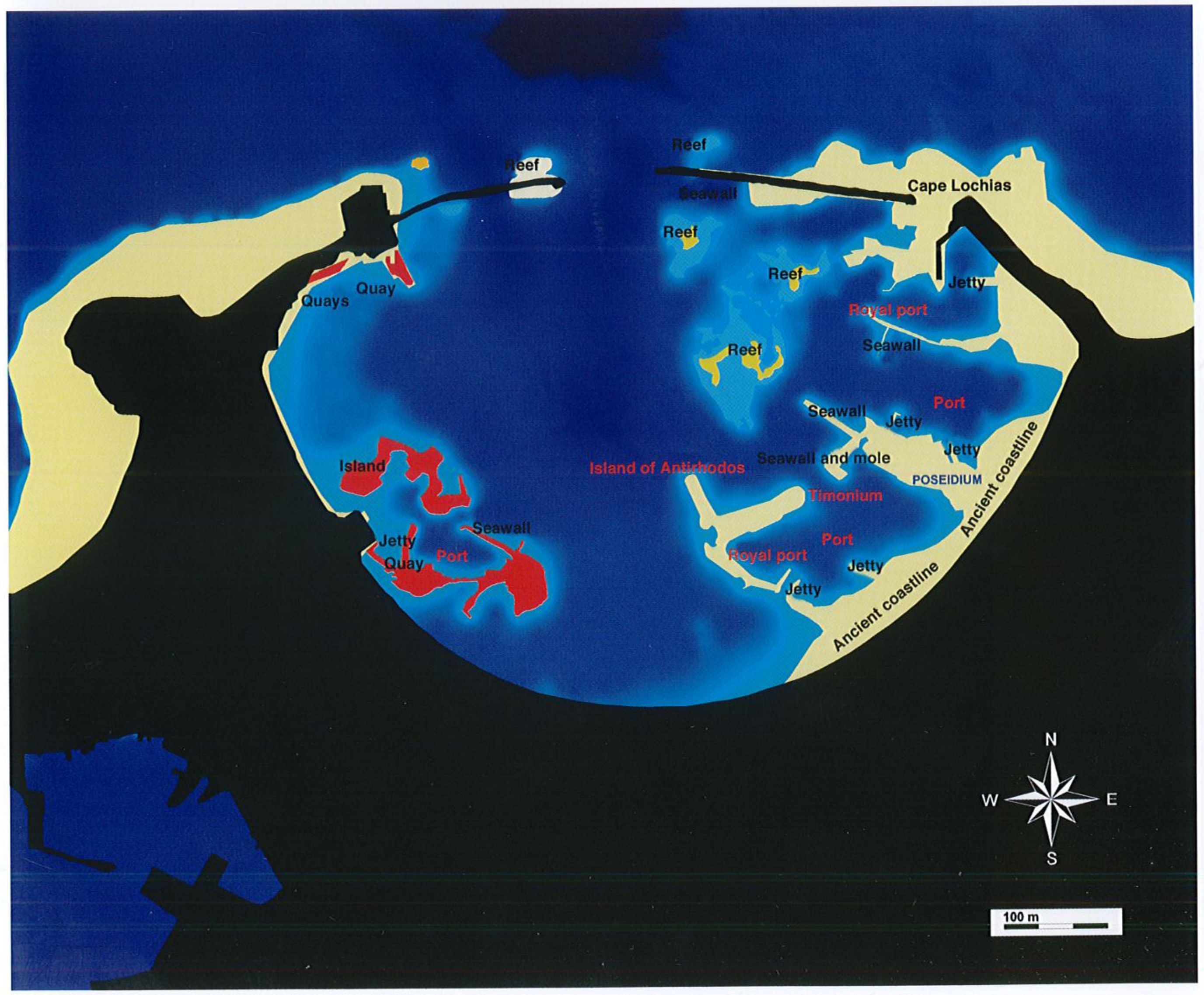

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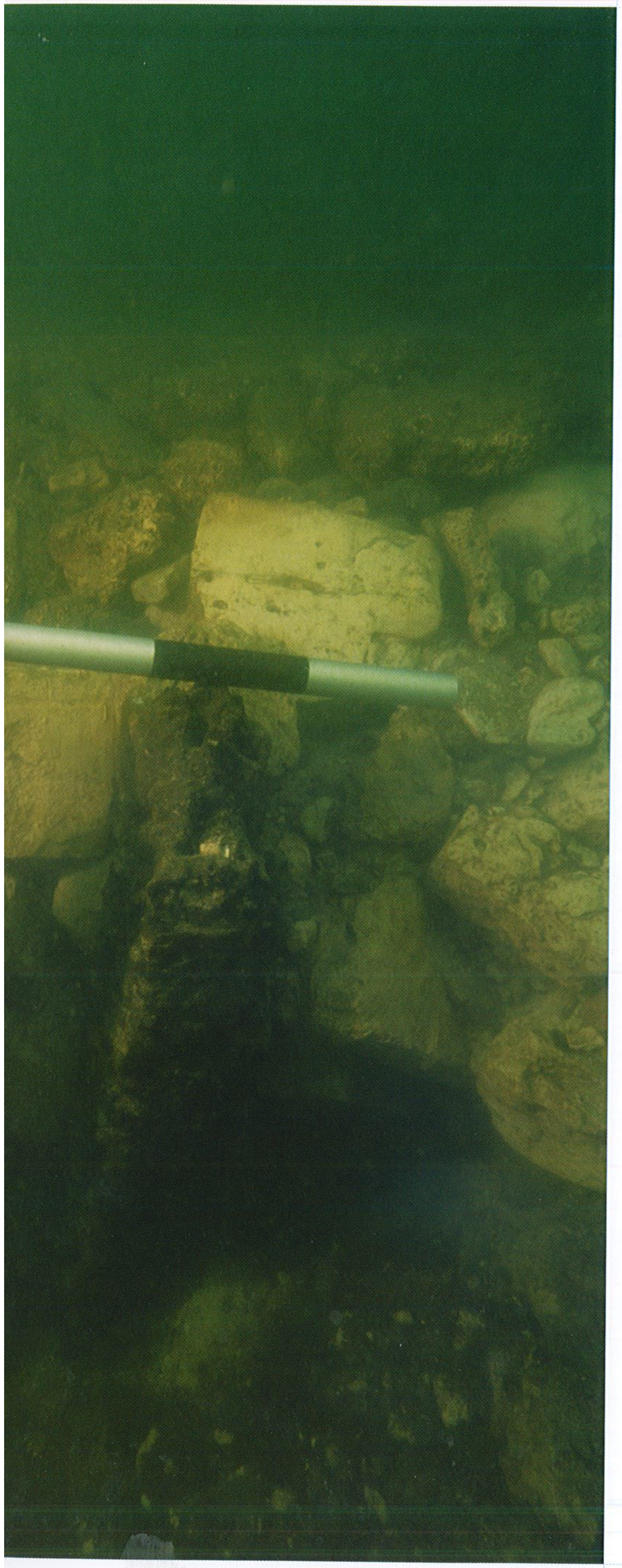


Wooden piles used to reinforce the foundations of structures built along the shores of the island of Pharos. Among the piles of small limestone blocks which they held in place, architectural fragments of ancient monuments were discovered.

northern mole, for example, are identical to those that form the subfoundations of the Poseidium. Was this part of a major renovation programme? And if so why at this time?

The discovery of this site particularly impressed us: everything was bigger and more beautiful than we had imagined from the texts. We were walking underwater on magnificent causeways that were still in excellent condition, endeavouring to imagine what they must have looked like when they were actually in use and stood a good two metres above the water level. By establishing the precise topography of the area we have been able to confirm that this part of the island of Pharos has sunk by 7m since the 2nd century, a fact that gave us our first clue as to the location of the famous lighthouse.

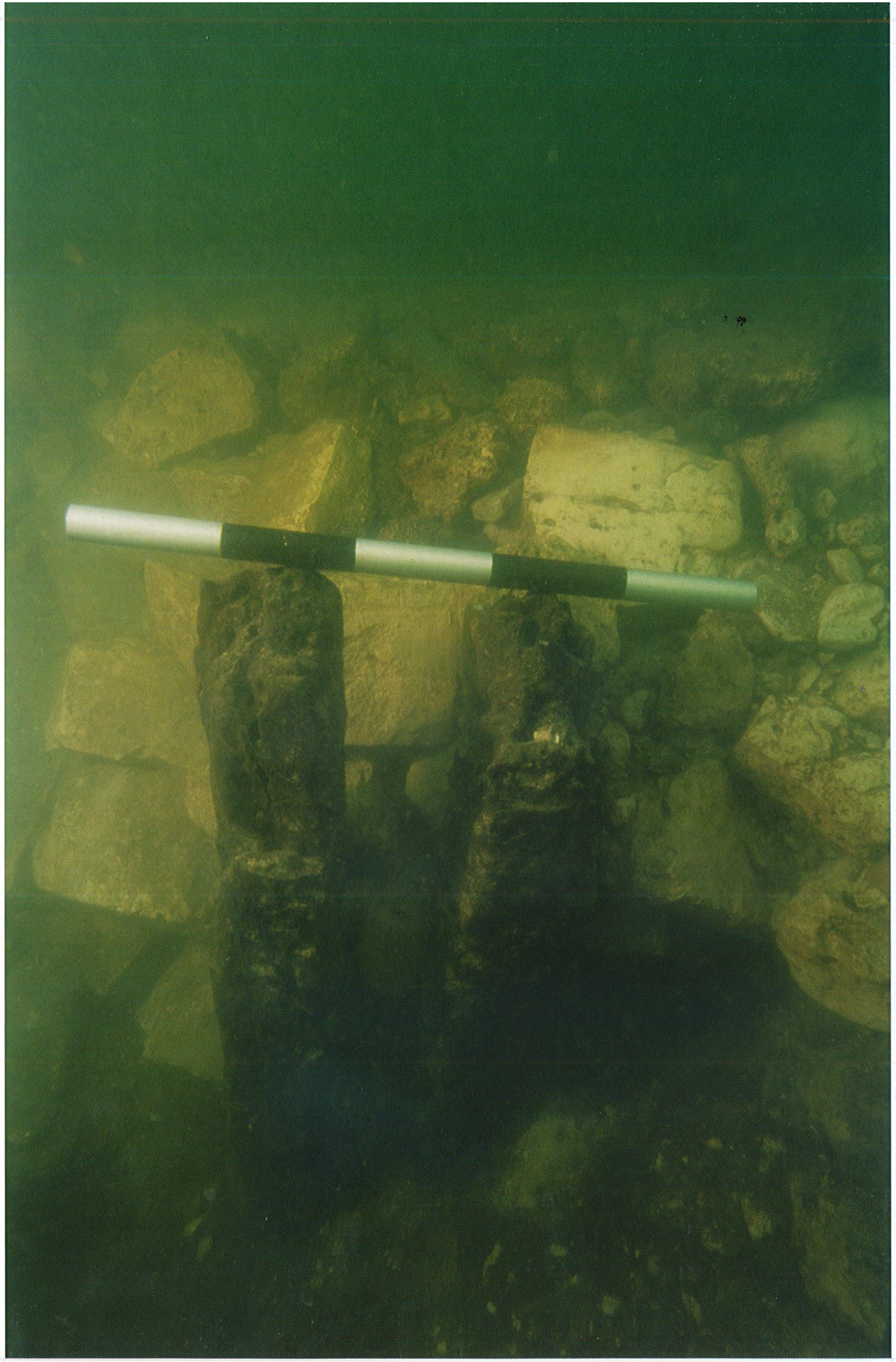
The shipyards

The area that we were studying was the site of the ancient shipyards.

Now there is an island in the surging sea in front of Egypt,
and men call it Pharos,
distant as far as a hollow ship runs in a whole day
when the shrill wind blows fair behind her.
Therein is a harbour with good anchorage,
whence men launch the shapely ships into the sea,
when they have drawn supplies of black water [i.e., water in deep places, where the light cannot reach it].
There for twenty days the gods kept me,
nor ever did the winds that blow over the deep spring up,
which speed men's ships over the broad back of the sea.

So speaks Ulysses, hero of Homer's *Odyssey* (IV, 355, trans. A.T. Murray, Heinemann, 1966): the island of Pharos was clearly one of the many places where he stopped with his crew. Indeed, Pharos is one of the only islands off the coast of Egypt. A thousand years later, Alexander the Great was quick to recognise the geographical advantages of the site with its potential double harbour. The Ptolemies constructed a large mole linking Pharos to the mainland, since which time the area has been extended so much with rock fills and sedimentary deposits that it is easy to forget that Pharos was originally an island.

Opposite and above: paving found on the moles of the navalia and the Pharos docks. The tops of wooden piles can be seen between the paving stones.



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Sheet-pile walls on the site of the Pharos moles.

This whole section of the coast was given over to the shipyards, or *navalia*, where Alexandrian ships were constructed and others overhauled. Alexandria was one of the most important centres for naval construction in Egypt, despite the fact that the country was short of wood, the only varieties to be found there being tamarisk, acanthus and palm, none of them suitable for construction purposes. The pharaohs of the Old and New Kingdoms imported wood from as far afield as Lebanon and Somaliland. The Ptolemies acquired their supplies in Phoenicia, Cyprus or Asia Minor, constructing both their commercial and their naval vessels from long conifer trunks, which had the advantage of combining flexibility with strength. The siege of the city by Caesar, as described by Caesar himself, demonstrates the vigour of Alexandria's shipbuilding industry. *Although the Alexandrians had lost more than a hundred and ten long vessels in the harbour and the shipyards, they were determined to reassemble their fleet*, he tells us. *[...] On every branch of the Nile, patrol boats were stationed for the purpose of collecting tolls. Lying neglected in the palace dockyards were old boats that had not seen service for many a long year; these were repaired, and others were brought back to Alexandria. Porticoes, gymnasia and public buildings were dismantled, and the planks thus obtained fulfilled the function of oars, where these items were missing. Native ingenuity supplied one thing, the city's*

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An excavated area of the navalia.

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resources another. [...] And so, in the space of a few days, against all expectations, twenty-two quadriremes and five quinqueremes were completed, with the addition of a goodly number of smaller, open boats. The shipyards must have been well equipped indeed and the builders enormously skilled to have accomplished so much.

We also know of two other, truly exceptional ships that were built at Alexandria. The first, as described by Athenaeus, whose description is reported by Callixeinus of Rhodes, was 129m long. Built at the behest of Ptolemy IV Philopator, it had 40 banks of oars, two stem-posts armed with seven rams, two stern-posts and four rudders. A special shipyard had to be built for the construction of this one ship, which required as much wood as would have been used to build 50 quinqueremes, and a canal had to be dug on site in order to launch it.

Ptolemy Philopator's royal ship was an even more extravagant affair. Built of rare woods such as thuya, cedar, Milesian cypress and tropical varieties, it was a floating palace, divided into numerous rooms (hence its name: 'Thalamega'), banqueting halls, porticoes and galleries, all decorated with ivory, gilded bronze and costly hangings.

The poets from whom we learn these details have no doubt embellished their subject, but they give us an idea, nevertheless, of the scale of shipbuilding activities at Alexandria: like the city itself, the industry it fostered was gigantic.

A hive of commerce

We may suppose that the harbour sheltered by the island in this western corner of the Portus Magnus was a place of transit for ships bound for the Eunostos and preparing to make their way across the Heptastadion. This long mole, built at the time of the Ptolemies, was intersected by two channels. It was thus possible to reach Alexandria from any of its harbours regardless of the weather, and the city depended on this ease of access: it was to become the 'counting house of the world', in other words a centre for maritime trade with the entire Mediterranean basin. It is probable therefore that these shores we were surveying once housed vast repositories, called 'treasures' in the Greek of the papyri. These public granaries operated in a similar way to banks. Officials known as *sitologos* managed the stocks of corn as if it were money, taking receipt of goods deposited by individuals and making payments to them, in return for which they themselves were remunerated. Alexandria was regarded in a wider sense as Rome's granary, since a large part of Egypt's cereal production was exported by way of Alexandria. The Roman emperors were perfectly aware of this dependence and prohibited their senators from entering Egypt, since confiscating Alexandria's corn would have been tantamount to starving Rome.

Goods upon which the economy not only of Egypt but also of a large part of the Mediterranean depended were conveyed, therefore, via Alexandria. The Alexandrian miracle is that such an activity could have flourished on a site so geographically ill adapted to it.

Large pink granite column base forming part of a protective barrier built of blocks and architectural elements taken from demolished monuments. Shoreline of the navalia.

resources another. [...] And so, in the space of a few days, against all expectations, twenty-two quadriremes and five quinqueremes were completed, with the addition of a goodly number of smaller, open boats. The shipyards must have been well equipped indeed and the builders enormously skilled to have accomplished so much.

We also know of two other, truly exceptional ships that were built at Alexandria. The first, as described by Athenaeus, whose description is reported by Callixeinus of Rhodes, was 129m long. Built at the behest of Ptolemy IV Philopator, it had 40 banks of oars, two stem-posts armed with seven rams, two stern-posts and four rudders. A special shipyard had to be built for the construction of this one ship, which required as much wood as would have been used to build 50 quinqueremes, and a canal had to be dug on site in order to launch it.

Ptolemy Philopator's royal ship was an even more extravagant affair. Built of rare woods such as thuya, cedar, Milesian cypress and tropical varieties, it was a floating palace, divided into numerous rooms (hence its name: 'Thalamega'), banqueting halls, porticoes and galleries, all decorated with ivory, gilded bronze and costly hangings.

The poets from whom we learn these details have no doubt embellished their subject, but they give us an idea, nevertheless, of the scale of shipbuilding activities at Alexandria: like the city itself, the industry it fostered was gigantic.

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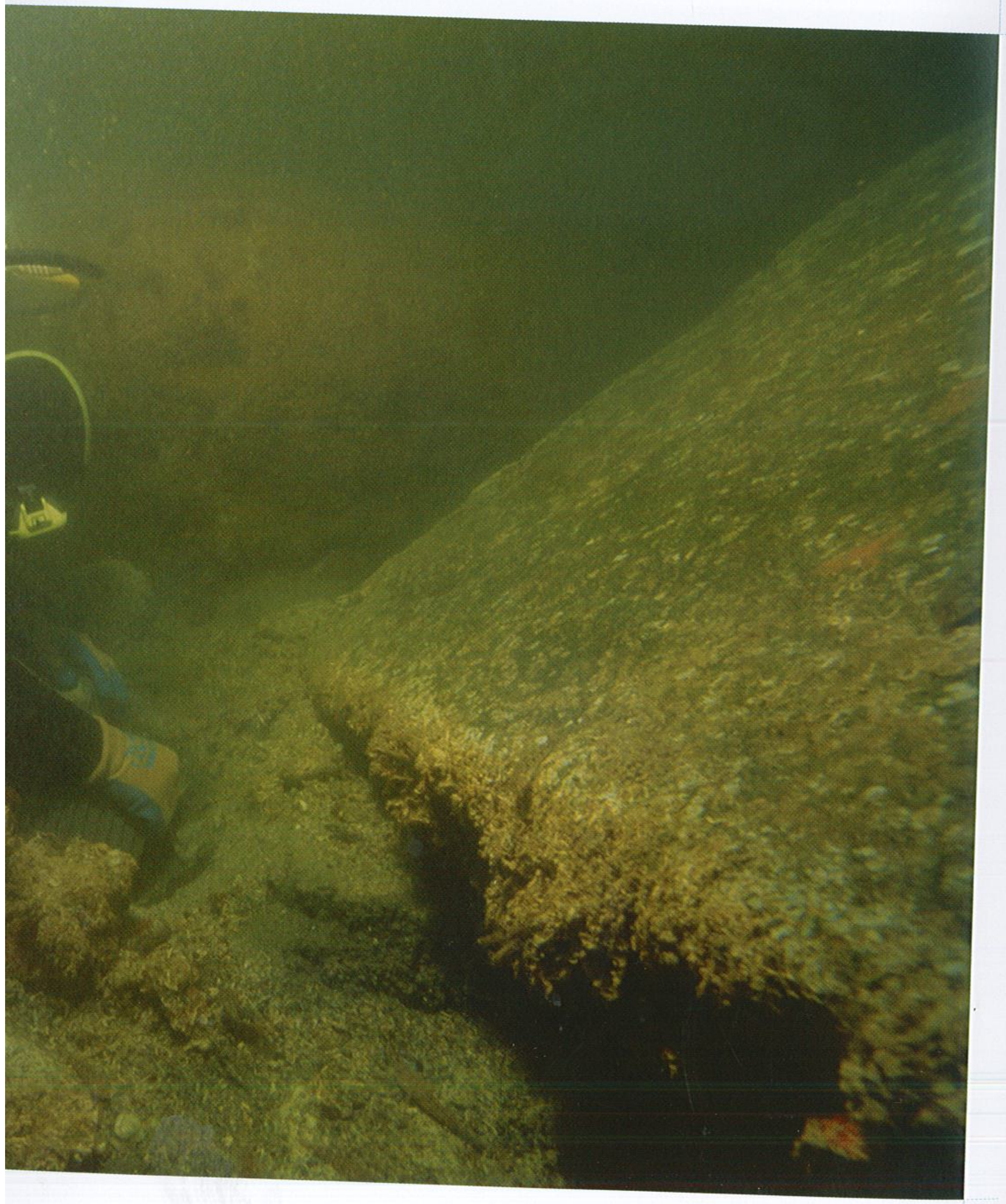
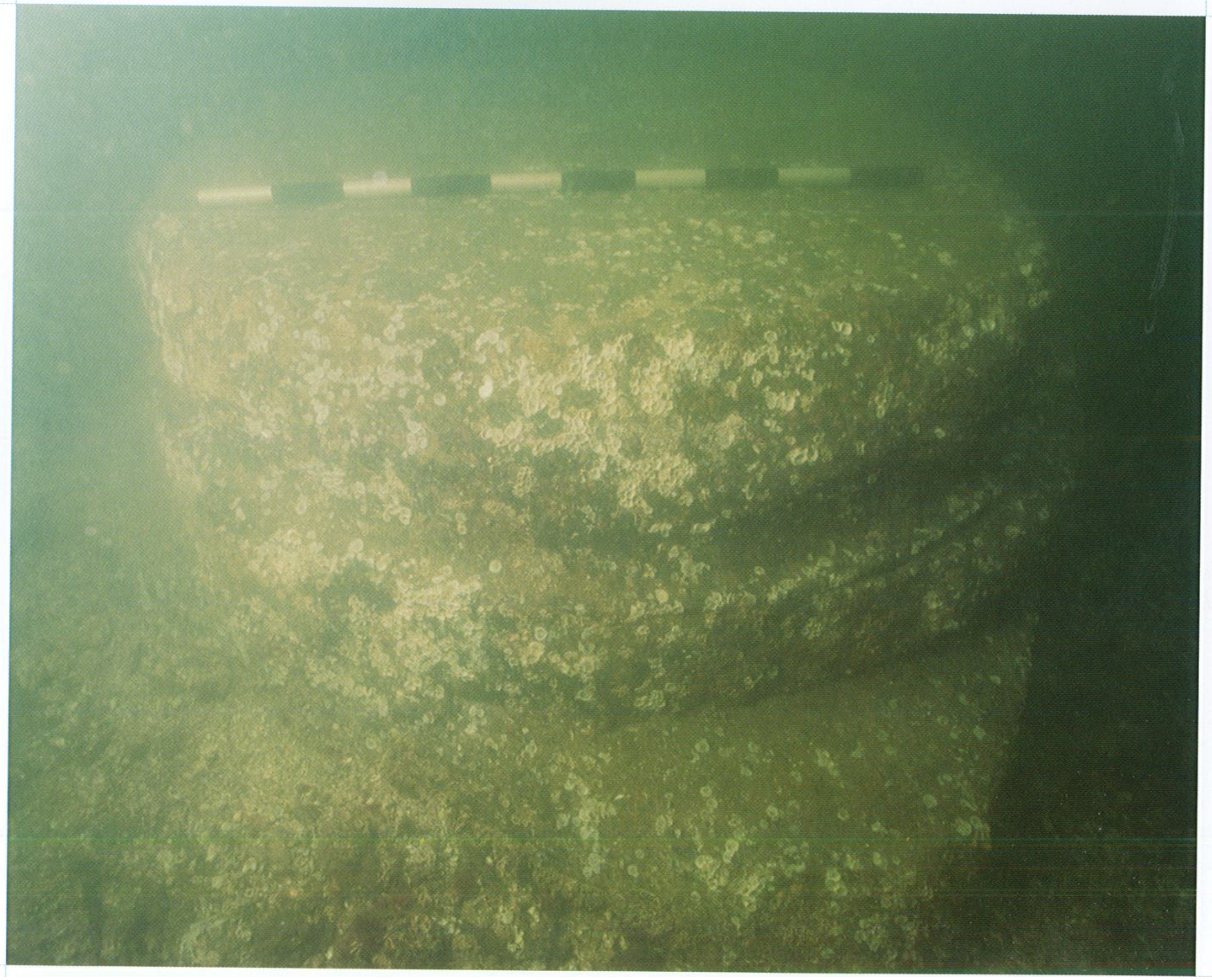


A hive of commerce

We may suppose that the harbour sheltered by the island in this western corner of the Portus Magnus was a place of transit for ships bound for the Eunostos and preparing to make their way across the Heptastadion. This long mole, built at the time of the Ptolemies, was intersected by two channels. It was thus possible to reach Alexandria from any of its harbours regardless of the weather, and the city depended on this ease of access: it was to become the 'counting house of the world', in other words a centre for maritime trade with the entire Mediterranean basin. It is probable therefore that these shores we were surveying once housed vast repositories, called 'treasures' in the Greek of the papyri. These public granaries operated in a similar way to banks. Officials known as *sitologos* managed the stocks of corn as if it were money, taking receipt of goods deposited by individuals and making payments to them, in return for which they themselves were remunerated. Alexandria was regarded in a wider sense as Rome's granary, since a large part of Egypt's cereal production was exported by way of Alexandria. The Roman emperors were perfectly aware of this dependence and prohibited their senators from entering Egypt, since confiscating Alexandria's corn would have been tantamount to starving Rome.

Goods upon which the economy not only of Egypt but also of a large part of the Mediterranean depended were conveyed, therefore, via Alexandria. The Alexandrian miracle is that such an activity could have flourished on a site so geographically ill adapted to it.



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