Navigational aspects of calling to the Great Harbour of Alexandria

Alexander Belov

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Belov A.A.
Center for Egyptological Studies of the Russian Academy of Sciences
ploion@yandex.ru

Μητέρι χαίρειν

1. Introduction.

Today the East port of Alexandria with its total surface of 600 hectares accommodates just a flotilla of fishing vessels of modest size and several dozens of yachts. All the intense maritime traffic has long gone to the West port that disposes of necessary handling infrastructures. However archaeological realities follow just the opposite scenario. Studies of the basin of the ancient port of Eunostos encounter serious difficulties[1] while the remains of the structures of the Great Harbour (*Megas limen*, *Magnus portus*) are well preserved and continue to bring precious information on the functioning of this famous port and on its role in the development of the city. Current paper proposes some ideas concerning the navigation within this port in Greco-Roman times.

European Institute of Underwater Archaeology (IEASM) has been applying up-to-date techniques of underwater archaeological research in the East Port of Alexandria since 1992.[2] These techniques that included bathymetric, side-scan sonar and magnetometric surveys allowed plotting with high accuracy the submerged port structures of the Great Harbour of Alexandria. Discovered structures consist of well founded breakwaters and peers of various orientation and length that divide the harbour into several basins. During the last years the general image of the submerged structures has been precised even more, especially in the western part of the harbour (Figure 1). Judging on the bench marks on the reefs and taking into consideration the basic principles for this type of installations it has been possible to establish at least 7.5 metres sea level rise since Antiquity.[3] However this figure can change from one region of the port to another.

[1] Intense silting of this port in modern times is described in Volney, 1807: 4-8. Recent underwater reconnaissance in the interior of the West port showed that the bottom is covered with the thick layer of black oil. See Belova, S. Ivanov, 2003: 4. This problem is coupled with intense shipping on the surface that does not permit regular studies.
[2] Goddio, 2011.
[3] Goddio, J. Yoyotte, 2008. Contribution of eustatic sea level rise in the region of Alexandria is estimated to be in range from 1.0 to 1.5 metres while that due to land subsidence, which is the major factor of the flooding, makes from 5 to 6 metres over the last 2.000 years. See Franco, 1996.

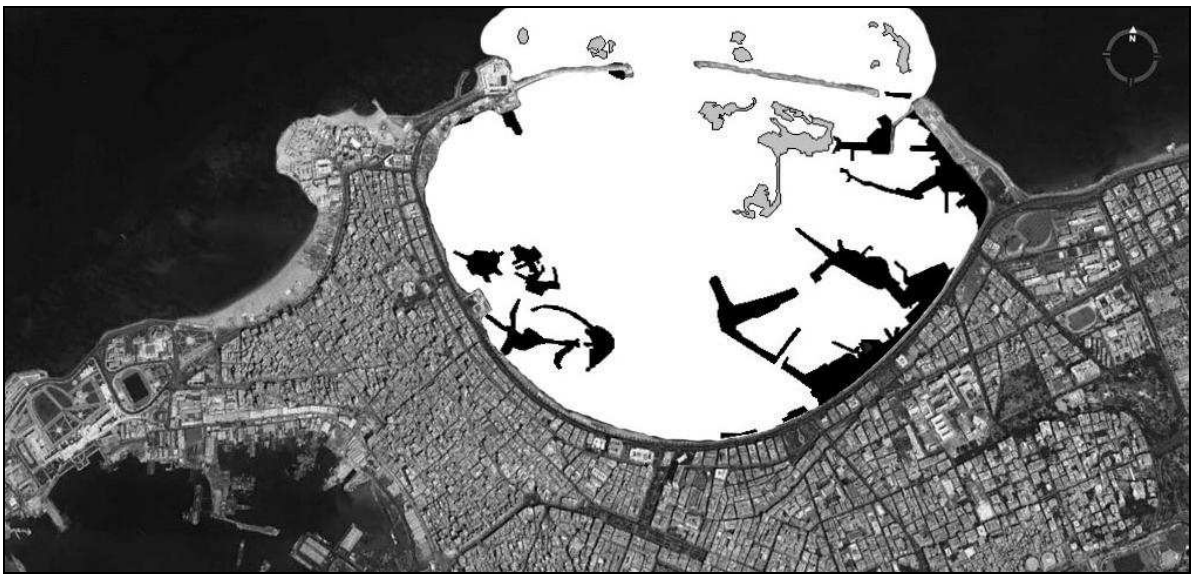

Figure 1. Submerged remains of the ancient Great Harbour of Alexandria inside modern Eastern Port of the city. Port structures that were situated above the sea level in Antiquity are shown in black while those below it (including natural reefs) are grey-colored. After Goddio, D. Fabre, 2008.

Strabo stayed in Alexandria in the twenties of the 1st century BC and he begins the description of Alexandria with the ports of the city and especially praises the sophisticated design of the Great Harbour.[4] Indeed, ancient builders took advantage of the coastline that offered the best conditions for creating a port on the Mediterranean coast of Egypt. An opportunity to construct a double port, less dependent of the direction of the wind, also followed traditional preferences of the ancients.[5]

Considering the main ports of Alexandria known from the classical sources one can notice the advantageous position of the Great Harbour. It was situated in the central and the richest part of the city, in direct proximity to the imperial residences and major public buildings.[6] This was not the case of the western port of Eunostos (*Εὐνόστος λιμήν*, meaning "*Harbour of Good return*") with the adjoining port of Kibotos (*Κιβωτός*, "*Box*"). According to Strabo, the city soon came to end farther west from Eunostos, where an extensive Necropolis began.[7] The port on Lake Mareotis (*λιμὴν λιμναῖος*) had trading value *par excellence*[8] in spite of the fact that sometimes a navy could have been accommodated there.[9]

Literary sources describe military conflicts that took place in the Great port. Here Caesar has burnt 50 quadriremes and quinqueremes as well as other 22 vessels during the Alexandrian war of 48-47 BC.[10] Further development of this war included numerous naval encounters. Later the

[4] Strabo, *Geography*, XVII, I.6.
[5] Robert, 1960.
[6] Strabo, *Geography*, XVII, I.6-9.
[7] *Ibid.*, 10.
[8] *Ibid.*, 7.
[9] Philo, *In Flaccum*, 92.
[10] Caesar, *The Civil Wars*, III, 111-112.

fleet of Octavian entered the Great Harbour in 30 BC after his glorious victory at cape Actium.[11] The shipyards around the Great Harbour in Strabo's description obviously surpassed in size those of the port of Kibotos.[12] It is logical to assume, that one of the most powerful fleets of Hellenistic time, created by Ptolemy II Philadelphus (285-246 BC),[13] has been accommodated in the Great Harbour. At the same time this port was of primary trade significance that reached its peak in Roman Imperial Period.[14] Thus, the Great Harbour of Alexandria had a paramount trade, military and political value both for the city and for the country as a whole.

The primary analysis of the port installations of *Megas limen* as per new archaeological evidence has been done in the monograph that has been published in 1998.[15] The organization of the discovered port structures has been explained from the point of view of modern marine engineering taking into account technical possibilities of the time. The arrangement of the outer breakwaters, the moles that separate three major harbours within the port's inner structure as well as supplementary moles and peers proved to follow a well-conceived strategy that made optimal use of the site's natural features. Certain aspects of navigation within the port have been considered in subsequent publications.[16] However, while the topography of the submerged ancient port is now established, there are still some unresolved questions concerning the operation of the port.

2. Wind.

The definition of prevailing winds is very important for any port as, apart from wind-induced swell, major currents frequently also depend on wind direction.

It is known from textual sources that navigation in the Mediterranean officially passed during the period from 27th of May till 14th of September.[17] Though these limits were not strictly respected[18] it would be no big mistake to consider this period as a time when the absolute majority of the sea voyages have been carried out. Figure 2 shows the percentage of wind in cardinals in summer months according to the data of the meteorological station in Alexandria from 1973 to 1992.[19]

[11] Plutarch, *Lives, Antony*, 76, 1-11.
[12] Strabo, *Geography*, XVII, I.9-10.
[13] Athenaios, *Deinosophistae*, V.203 c.
[14] Rougé, 1966: 38.
[15] Goddio, 1998: 1-52; de Graauw, 1998.
[16] Goddio, J. Yoyotte, 2008; Goddio, D. Fabre, 2010; Goddio, 2011.
[17] Vegetius, *Epitoma rei militaris*, IV, 32.
[18] Arnaud, 2012.
[19] de Graauw, 1998. We should be cautious in applying modern hydro-meteorological data to Antiquity, although, with some reservations, it seems admissible. The fact is that considerable changes in wind circulation in Mediterranean are observed only during last twenty five years, the climate of the seaside areas being much more

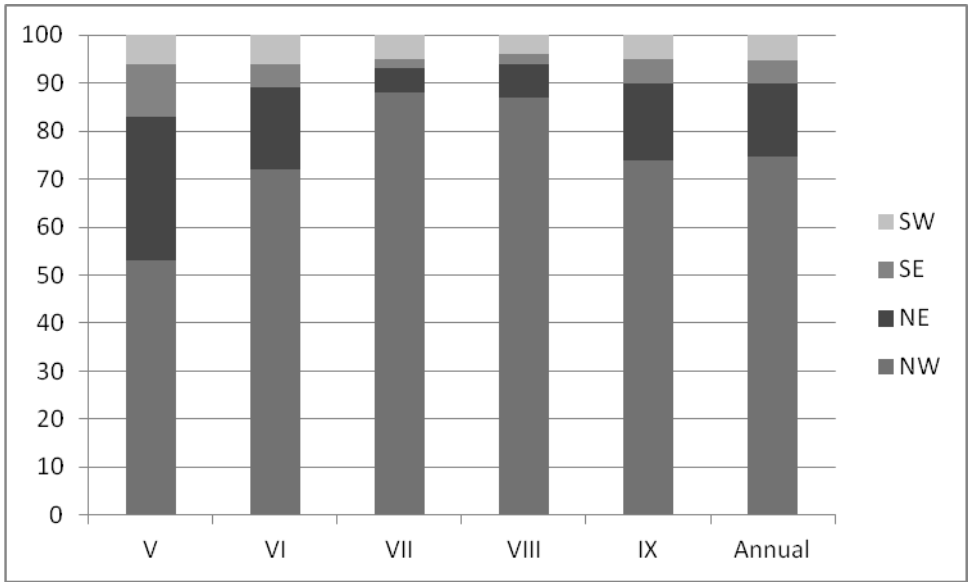

Figure 2. Monthly percentage of wind in cardinals during the period from May to September in the region of Alexandria averaged for 20 years (1973-1992).

As follows from the chart above the northwest wind dominates throughout all the period of the "open sea". These are so-called Etesian winds (*ετέσιαι* - "annual", "periodic") which arise in summer between the high pressure area over the Balkans and the area of low pressure over Asia Minor.[20] Around Alexandria the northwest wind blows during 75 % of time in summer and thus it is this direction that is most significant for the port (Figure 3). We can see that the basins of *Megas Limen* were indeed constructed under the lee of the Pharos Island and submerged reefs that are situated to the NW from the port. Apart from the artificial piers that protected the port from the wind of this dominating direction, there is also a group of quite numerous piers designed to shield the port from the North-East in complete correspondence with the second prevailing wind direction.

stable than the continental one. As far as Alexandria concerned the direction of major winds in this region known from ancient sources corresponds well with contemporary data.

[20] Diodorus, *Historical Library*, XVII, 52.2; Strabo, Geography, XVII.7.

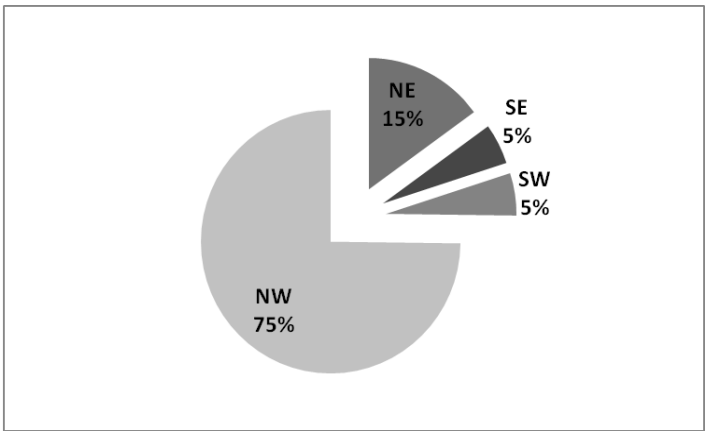

Figure 3. Average percentage of wind in cardinals during the period from May to September in the region of Alexandria during 20 years (1973-1992).

Today weak east currents with the speed of 0.1 - 0.7 knots prevail in the considered area.[21] At the same time the construction of Heptastadium that has connected the island of Pharos to the mainland, should have changed seriously the character of circulation within the port. According to modelling approach this effect was rather favourable for the Great harbour slowing down the silting rate.[22]

3. Position of the Pharos Lighthouse

Egyptian coast being so low, the right course for Alexandria had to be signalled from a long distance. From the other hand, numerous reefs complicated the approaches to the port and obstructed the channel itself. According to Strabo some of the reefs were on the surface while the others were submerged and, thus, were even more dangerous for navigation.[23] Thereby the position of the Pharos Lighthouse is of primary importance and this question has been repeatedly raised in literature.[24] Several different locations have been proposed for the Lighthouse: the site of the medieval fort Qait Bey (end of 15th century AD), the site of the submerged reef called "*Diamond Rock*" located East-North-East from Qait Bey and, finally, the site on the submerged islets close to the modern main entrance to the harbour (Figure 4).

[21] Goddio, 1998: 6.
[22] Millet, J.-P. Goiran, 2007.
[23] Stabo, *Geography*, XVII, I.6.
[24] Jondet, 1912: 14; Jondet, 1916: 47-50 ; Bernand, 1966: 31-32, 110; Frost, 1975 ; Bernand, 1995: 48-51; Grimal, J.-Y. Empereur, 1997: 693-713 ; Empereur, 1998a: 64-87 ; Empereur, 1998b ; Goddio, 1998: 12; Empereur, 1999: 25-29.

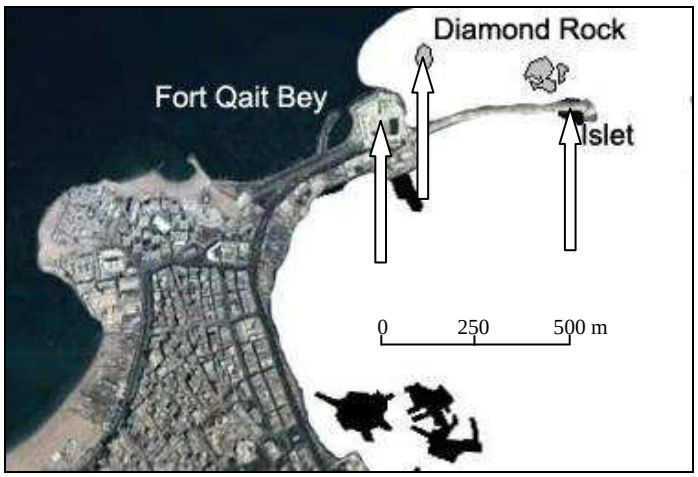

Figure 4. Location of the Lighthouse as per the different hypotheses.

After the charting of the ancient remains of the Great Harbour has been accomplished, it was possible to reconsider the information of ancient authors on the relative position of the harbour's entry, the Lighthouse and some other topographical features of the city.[25]

Although there is no lack of descriptions of the Great Harbour,[26] the most precise one undoubtedly belongs to Strabo. According to him the site of the Lighthouse was located on the rock at the extremity of the Pharos Island and this rock has been surrounded by water.[27] Description of Achilles Tatius (2nd century AD), who was born in Alexandria, contains such expressions as "*structure… in the middle of the sea"* and *"building… suspended above the surface* [of the waters]".[28] Moreover, in this evidence the extremity of the island of Pharos and the position of the Lighthouse are not mixed together.[29]

In Islamic period *Pharos* has been visited by many travellers.[30] One of them, who have seen the Lighthouse in AD 985, tells us that it was connected to the land by narrow road firmly built on the rocks. More information is to be found in a very interesting evidence of Aboul Haggag Youssef Ibn Mohammed el-Balawi el-Andaloussi who has visited the Lighthouse in 1166 and left the detailed description of this event.[31] At the time of his visit the Lighthouse has been already repaired many times but it was still functioning. According to Aboul Haggag the Lighthouse has been located on a small island connected to the mainland by a dyke.[32] The dyke

[25] Goddio, I. Darwish, 1998: 15-16.
[26] Bernand, 1998.
[27] Strabo, *Geography*, XVII, I.6: ἔστι δὲ καὶ αὐτὸ τὸ τῆς νησῖδος ἄκρον πέτρα περίκλυστος.
[28] Achilles Tatius, *Leucippe and Clitophon*, V, 6. trans. S.Gaselee. The Loeb Classical Library, 1969.
[29] *Ibid.*: "*…After this* [sightseeing of the Lighthouse] *he took us to his house, which was on the shore at the extremity of the island*".
[30] Palacios, 1933.
[31] Tousson 1936, 49-53. The reliability of Aboul Haggag report was much critisized and it is true that the dimensions suggested by him for separate levels of the Lighthouse are inaccurate (Empereur, 1998b: 82). At the same time his general description of the site might better reflect the reality.
[32] Obviously it is not the Island of Pharos the auther describes as even at modern sea level its length would exceed 3600 meters. Moreover, by 12th century the Island of Pharos must have already been transformed into the peninsula

was only 1.60 meter above the sea level and it was inundated in case of bad weather.[33] Finally there is a crucial evidence of the chronicler of sultan Qaitbey who mentioned that in June 1477 the ruler arrived in Alexandria and ordered to build a fort on the foundations of Pharos that had been completely destroyed a century before.

Strabo says that the Lighthouse was built at the extremity of the Pharos Island but there is no contradiction with the evidence of medieval travellers because in geographical sense the dyke would "unify" the site of the Lighthouse with the Island of Pharos.[34] The dyke in question can be observed on many marine charts and maps of the city dating from 17th to 20th centuries (

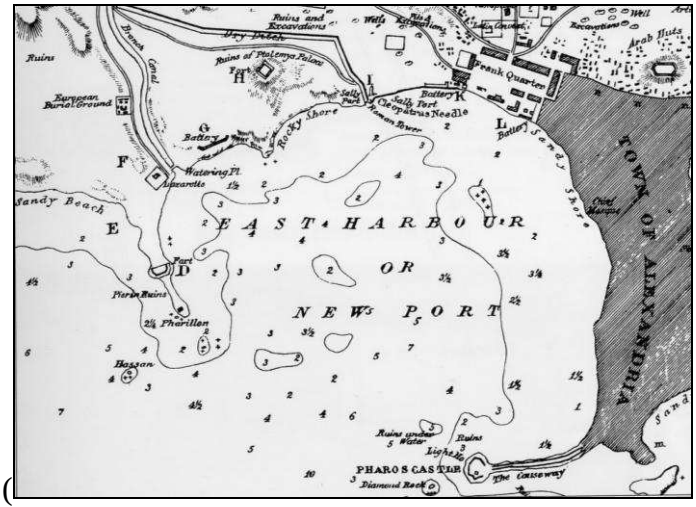

Figure 5).

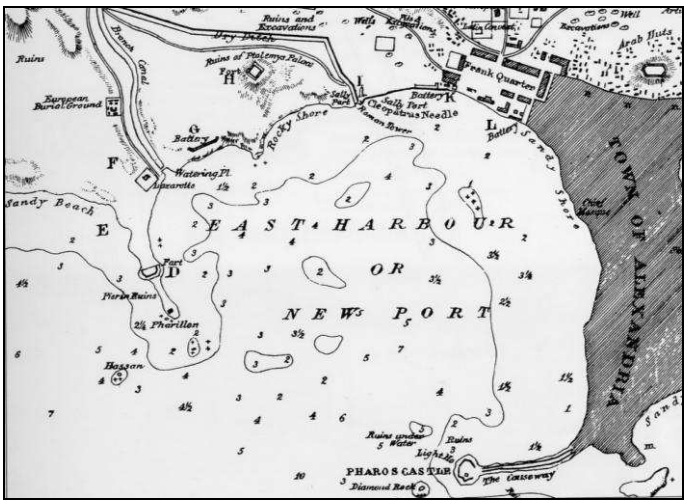

Figure 5. Fragment of a map of Alexandria and of East Harbour by E.Napier (1841). Note the "*Causeway*" leading from the mainland to the "*Pharos castle*" (bottom right corner).

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following the sedimentation of the two harbours. See Hesse, 1998: 27. Mosque of Abd el-Kader el–Gilani has been built on the coast projection in 953. In 10th century it was possible to walk along the 20-meter wide beach that formed at the west side of Heptastadium. The lands from the two sides of Heptastadium were assymetric. See Hesse, 2002: 234.

[33] We must bear in mind that by 12th century AD considerable sea transgression must have already occurred and this also must be the reason why the platform of Pharos was partially underwater. Arab traveller who visited the Lighthouse in 1227 tells that it was accessible only by sea (see Palacios, 1933). The Lighthouse was completely destructed by an earthquake on August 8, 1303.

[34] Arguments in favour of a probable location of the Lighthouse on a small island can be found in Fraser, 1972:18, note 98.

During the underwater research of the *Centre des Etudes Alexandrines* more than 3500 blocks occupying 2.25 hectares of the sea bottom to the North-East of the fort Qait-Bey have been discovered.[35] Some of the blocs of red Aswan granite exceeding 11 meters in length probably formed the monumental doorway in Doric style. Two colossi, attributed to Ptolemy II and Arsinoe II, are of outmost importance for the localization of the Lighthouse.

As we can see the arguments in favour of the site of Qait-Bey are very convincing. At the same time it is necessary to take into consideration the observations of another nature. During the underwater survey of the Great Harbour numerous lines of wave erosion have been discovered on many submerged reefs. The depth of these lines varies within 6.5 – 7.0 meters.[36] A theoretical elevation of about 7 m would considerably change the appearance of the zone around Qait Bey. A line of reefs to the North-West of the modern coast of Anfoushi would transform into the steep coast while the water area of the bay of Anfoushi becomes *terra firma* of the island of Pharos. A bathymetric chart or even a space photograph can serve as a good illustration for this (Figure 6). Accordingly the fort of Qait Bey would no longer be situated on the extremity of the island but rather far from the shoreline. Observations and measurements made by G. Jondet proved that the plateau of Qait-Bey continued 200 m in northeast direction from the wall of the fort and the upper surface of the plateau was only 70 cm under water.[37] It has already been noted that the ancient peninsula of Lochias on the East of the harbour extended much further West than today[38] and the rock Pharillion charted in the *Description d'Egypte* could not mark ancient peninsula's end. The same conclusion must necessarily apply to the Fort Qait Bey that is located just on the other side of the harbour. It should be noted as well that the Lighthouse positioned at the site of Qait Bey would have given dangerous bearing across the reefs.[39]

[35] Empereur, 1999: 27.
[36] Goddio, I. Darwish, 1998: 12.
[37] Jondet, 1916: 48.
[38] Saint-Genis, 1818: 52-54.
[39] *Ibid.*

Figure 6. Space view of a fragment of the Alexandrian coast with a part of the East port, the Anfoushi region and the Fort Qait-Bey. © Digital Globe 2009

In the light of the above arguments we would propose the location of the Lighthouse some 200 meters to the North-East from the Fort of Qait-Bey that would correspond to the extremity of the Pharos Island in Antiquity (Figure 7).

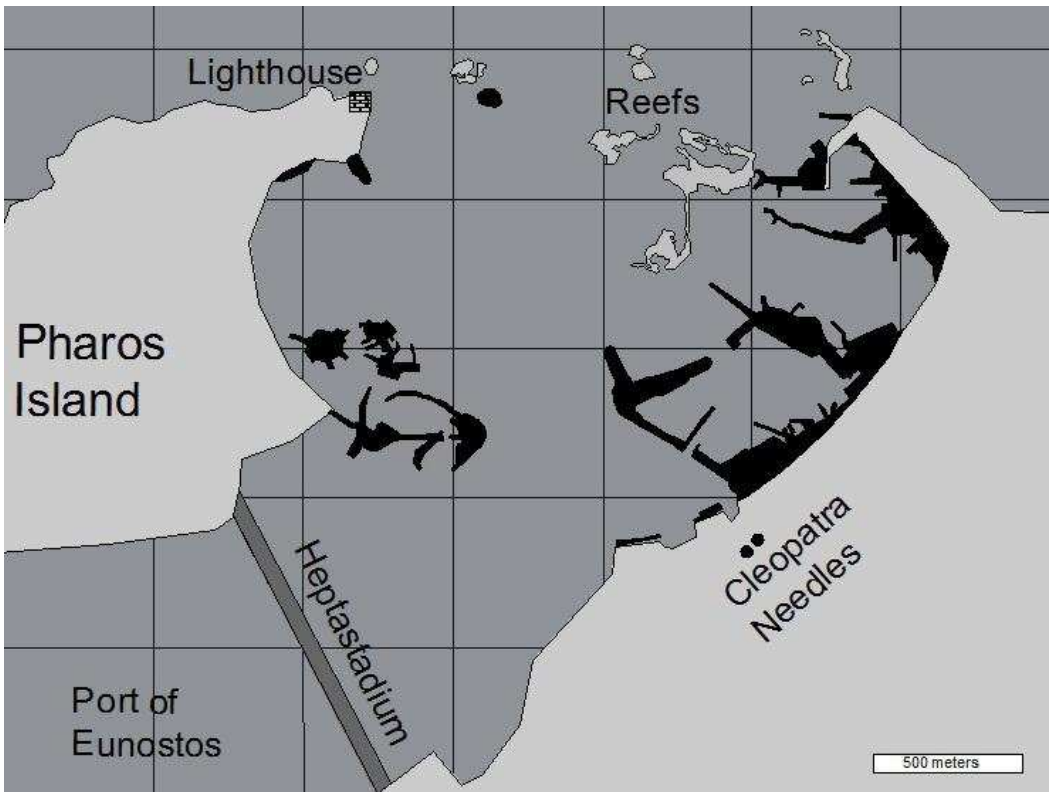

Figure 7. Reconstruction of the ancient topography of the Great Harbour including the submerged reefs and port structures discovered. After Goddio, D. Fabre, 2008.[40]

[40] Except for the position of the Lighthouse which, according to the referenced work, is to be located on the central islet.

To conclude this section it must be necessary mentioned a port of which *epoch* is being analyzed. Obviously one cannot consider the Great Harbour as a complex of permanent installations but rather as a mobile system that constantly changed in time depending on natural, economic and political factors. For the moment it is not easy even to date the appearance of the first port installations. According to the wood remains discovered on the Island of Antirhodos the first port facilities had appeared in Pre-Ptolemaic time.[41] In a course of time new breakwaters and peers appeared while some others became dilapidated. Some parts of the Harbour were subject to silting and special efforts must have been undertaken to counteract this process.[42] However this paper proposes just some general ideas on the navigation within the Great Harbour and so we consider a well-organized harbour that included all major port structures according to the current research.

In fact we possess all major parameters to analyze an ancient ship's maneuvers calling to the Great Harbour, namely: a dominating wind direction, navigation signs (lighthouse), natural hazards (reefs) and the topography of the port itself.

4. Anchorage of the ships on the roads of the Great Harbour.

Most likely the proper roads of the Great Harbour began under the shelter of the Island of Pharos. The French engineer Gaston Jondet who was studying the remains of the port of Eunostos at the beginning of the 20th century has stated this point of view as follows:[43]

«*Before the construction of Heptastadium, which has connected the Pharos island with the littoral, western and eastern ports were freely communicated and formed the roads of Alexandria that were completely protected by a line of reefs and the area of considerable depths which lies in parallel to the coastline to the southwest from Pharos till cape Agami and to the northeast till cape Silsileh at average distance of about 2500 meters*».[44]

The anchorage seaward from Pharos was risky, and it seems possible to assume, that whenever possible it has been avoided. The coast was alee and abounded with reefs[45], to the same the population of the island was reputed as "pirates" that according to Caesar did not shun plundering any ships that touched the coast here.[46] However Flavius Josephus (37-95 AD) tells

[41] Goddio, J. Yoyotte, 2008: 273; Goddio, D. Fabre, 2010: 65. There is an evidence of occupation of the site of Rhakotis already in the Old Kingdom. See Véron, J.-P. Goiran, 2006.
[42] For example, the slipway for the ships (*diolkos*) is attested only after 1 AD probably due to silting of the two passages in the Heptastadium. See Fraser, 1961.
[43] Jondet, 1916 : 6-7.
[44] Construction of Heptastadium in fact changed nothing in this sense except that now each port possessed its proper roads.
[45] Strabo, *Geography*, XVII, I.6; Flavius Josephus, *The Jewish War*, 612.
[46] Caesar, *The Civil Wars*, III, 112.

that the light of the Lighthouse warned the seamen to put anchor at some distance and wait till the end of the night before daring to enter the port.[47] There existed other circumstances that could prevent the skipper entering the basin of the Great Harbour immediately. Among them are unfavourable weather conditions, [48] the channel closed by chains[49] or even the reasons of secrecy.[50] However it seems that in majority of cases pilots tried to proceed under the protection of the Pharos Island as soon as possible and actually this space was considered as proper roads of the port. The remains of several shipwrecks which have been discovered by the *Centre des Etudes Alexandrines* to the north from fort Qait-Bey testify to the dangers that were ready in stock for seamen who lingered to enter the port.[51]

5. Ships entry to the harbour's basin

Strabo (20-26 BC) and Flavius Josephus (37-95 AD) witness that for the arriving ship the Island of Pharos with the Lighthouse was on the right hand, that is to the West[52], while the submerged reefs and cape Lochias were on the other hand, that is to the East. It should be remembered that in Antiquity the peninsula of Lochias provided a natural protection for the Harbour from the North-East and it was much more prominent and wider than today.[53] The ancient breakwater of cape Lochias probably did not exist at the time of Strabo as he speaks of natural barrier only; however, the breakwater is mentioned by Flavius Josephus.[54] The narrowness of the entrance to the Great Harbour is witnessed by Caesar, Strabo and Flavius Josephus. All these authors speak only of one entry channel leading to the Great Harbour.[55] According to Pliny the Elder (23-79 AD) there were three basic passages to the port of Alexandria - *Steganus, Posideum, Taurus.*[56] However it is necessary to notice, that we do not know whether Pliny meant the passes to the Great Harbour only or to both major ports of Alexandria divided by Heptastadium.[57] Nevertheless, it seems that there were at least two major channels leading to the Great Harbour (Figure 8).

[47] Flavius Josephus, *The Jewish War*, IV, 613.
[48] Caesar's auxiliary fleet misguided by the East wind was anchored near the cape of Agami (ancient cape *Chersonesus*) and the author of the "Alexandrian War" wrote that «*the coast is very convenient for anchorage*». Caesar, *The Civil Wars*, IX.
[49] Lucan, *Pharsalia*, X, 53-60.
[50] Philo, *In Flaccum*, 27-28, 109-111. Secret landings of Agrippa and centurion Bassus in the port of Alexandria.
[51] Empereur, 1999: 29; Empereur, 2002: 325-334.
[52] Strabo, *Geography*, XVII, I.9; Flavius Josephus, *The Jewish War*, IV, 612.
[53] Modern topographic data (Goddio, 2011) proves the ideas expressed in Saint-Genis, 1818: 52-54 and Fraser, 1972: 23.
[54] see Fraser, 1972, note 141.
[55] Caesar, *The Alexandrian War*, III, 112; Strabo, *Geography*, XVII, I.6, 9; Flavius Josephus, *The Jewish War*, IV, 612-615.
[56] Pliny, *Natural History*, V, XXXIV, 128.
[57] This idea has been proposed by Saint-Genis, 1818: II, XXVI, 31-32 and critisized in Fraser, 1972: note 136. Fraser emphasizes that Pliny in his narrative speaks about the Lighthouse that in any case was of no use for entering

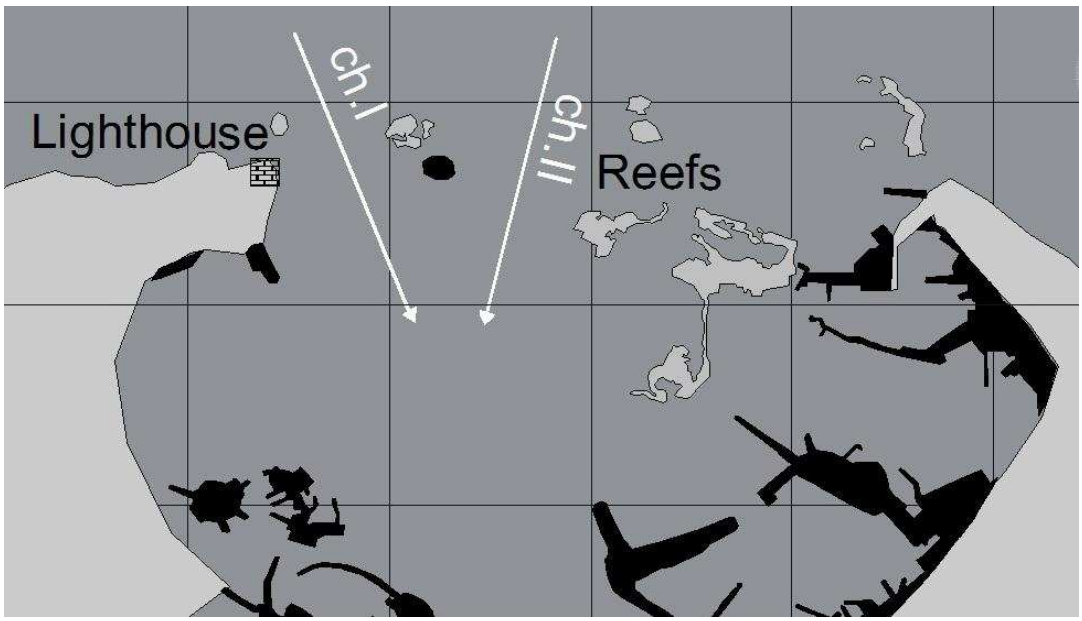

Figure 8. Hypothetic position of the channels leading to the Great Harbour in Antiquity.

The first one was situated between the Lighthouse and the central islet where the remains of some constructions have been discovered by G.Jondet.[58] It seems appropriate to recollect here the meaning of the Greek word *στεγανός* that has been used in Latin by Pliny for the name of one of the passes. It means "closed", "tightly closed" and even "impenetrable". The same sense of complicated access sounds in another name of the pass - "*scopulus"* (*lat.* "rock") – a name, that most often had been applied for the reefs.[59] An access to the Harbour was not easy and Flavius Josephus (37-95 AD) describes the entry channel as follows:

"The port of Alexandria is difficult for ships to approach even in peace-time, the entrance being narrow and diverted by submerged rocks which preclude direct passage".[60]

Indeed, bathymetric chart shows many submerged reefs in a passage between the Pharos Island and the central islet, the width of the channel itself would not exceed 170 meters. It would be difficult enough to pass the channel without changing the course of the ship. Flavius Josephus continues his description of the entry channel:

"Round this island immense walls have been reared by human hands; and the sea dashing against these and breaking around the piers opposite renders this passage rough and ingress through the strait perilous. The harbour inside is, however, is perfectly safe and is thirty furlongs in length".[61]

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the western harbour. This argument does not seem to be decisive as Pliny's description is very general and is not based on personal observation.

[58] Jondet, 1916: 50.

[59] Botti, 1897: 58.

[60] Flavius Josephus, *The Jewish War*, IV, 612. Trans. H.S.T.J. Thackeray, The Loeb Classical Library, 1957; "crooked run" - *καμπτόμενος δρόμον.*

[61] *Ibid*., Trans. H.S.T.J. Thackeray, The Loeb Classical Library, 1957.

This narrative perfectly reflects the situation of the narrow channel situated in the direction of dominating wind and swell. Refraction of the waves causes the appearance of irregular swell ("broken water", "chopped waves") that is potentially dangerous for navigation. On the other hand, the surface current must have helped the ship to pass the channel. It would have been convenient to enter the Harbour by Channel I with the following wind or on a broad reach on starboard tack. Under good weather conditions the ship could continue sailing till the central part of the harbour. In case of a strong gale or unfavourable wind the skipper could considerably reduce sail by means of brails.[62] While running downwind it was possible to take in the sail completely and to continue the course by windage of the hull only. Vessels with the two masts could have left the sail only on the front one – artemon. This would reduce the speed of the ship while assuring good manoeuvrability.

Channel II between the central islet and the reefs to the East was slightly wider than the first one. It coincides with the modern entrance to the Eastern Port and corresponds to a pronounced depression in underwater relief.[63] At the same time this channel was less advantageous in case of dominating wind direction. While the Channel II was quite easy to pass on broad reach, it was less easy on beam reach because the space was limited and the reefs so close alee.[64]

The descriptions of the voyages that have reached us in peripli that start to appear in 4th century BC are usually restricted to the enumeration of the great land marks and distances and do not go into detail of peculiarities of entry into the specific ports. In any case these documents were not destined to be used by the people of the sea.[65] However it is no doubt that the knowledge of the coast and of the specific features of each port was at the base of the mastership of an ancient mariner.[66] When calling to complicated ports like Alexandria skippers must have regularly used *alignments* that permitted choosing the right bearing. There were a lot of remarkable and high buildings in Alexandria that could have served as the reference points. Thus the height of two obelisks surnamed "*The Needles of Cleopatra*", erected in 13 BC at the entrance of the Caesareum, amounted to 21 meters.[67] This temple was situated in the central part of the harbour close to the shore. A line from the entrance of the harbour till one of the obelisks

[62] Casson, 1995 : 270.
[63] Goddio, I. Darwish, 1998.
[64] It seems appropriate to cite here the following fragment by Philo (13-50 AD):
«*For many a time and to many has it happened that they have crossed wide spaces of navigable waters and passed a long voyage in safety escorted by favourable breezes, and then in the harbour itself have suddenly been shipwrecked just when they were on the point to cast anchor*». Philo, *De Somniis*, II, 143, trans. F.H. Colson, The Loeb Classical Library, 1958.
[65] Arnaud, 2012.
[66] Arnaud, 2012.
[67] For the position of the obelisks see Goddio, I. Darwish, 1998: 10; Empereur, 1998a: 112-118; Arnaud, 2002: 177-190.

would cross the central part of the Island of Antirhodos with a royal palace on it[68] (Figure 9). To the same the cult of Octavian Augustus has been especially venerated in Caesareum by the seamen and therefore such alignment would have concealed additional symbolic significance.[69]

There is no doubt that there have existed a certain number of other alignments. For example the temple of Serapis was situated on a hill approximately one kilometer from the shore. The obelisques installed in front of this temple[70] should have been visible from the sea even before the installation of Diocletian's column in 298 AD. In modern times the latter appears on a number of marine charts, for example on the chart of the New Port compiled in 1738 by the captain of the Danish Navy F.L.Norden.[71] Together with the old tower situated closer to the coast this column forms an alignment that marks the reef at the entrance to the port.

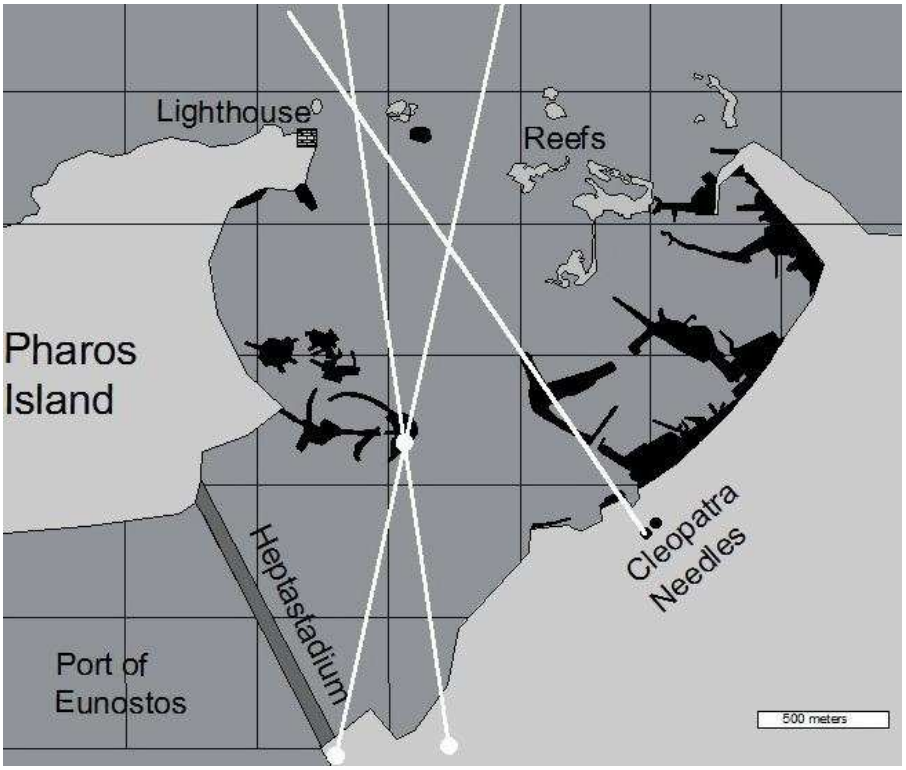

Figure 9. Possible alignments marking the entrance to the Great Harbour.

Interesting information concerning the port's entry can be found in the epigram of Poseidippos of Pella (3rd century BC) devoted to Ptolemy I Soter that contains the following fragment:

« And the sailor might run to the very Bull's Horn, yet he would not miss, in sailing hither, O Proteus, his target, Zeus Soter ».[72]

[68] Strabo, *Geography*, XVII, I.9 - the palace on the Antirodos Island.
[69] Philo, *De Legatione ad Gaium*, 151.
[70] Pseudo-Callisthen, *Romance of Alexander the Great*, 33.
[71] See Goddio, I. Darwish, 1998: 19, Fig.4.
[72] Trans. by P.M.Fraser 1972, 18.

P.M.Fraser believed that the Bull's Horn (*Ταύρου κέρας*) is a noted rock at the entrance of the Great Harbour since Pliny mentions the channel called *Taurus*.[73] However the results of recent topographical surveys allow suggesting another hypothesis.[74] Let us take a look on a small islet just in the center of the ancient water area of the Harbour (see Fig.10, number 4). This islet, now submerged, is remarkable for the curved breakwater of an impressive length. It is difficult to deny that the islet with the breakwater resembles a profile of a horned bull's head. At the same time the breakwater is situated right opposite the hypothetic channels leading to the harbour. In fact this mole was constructed to protect the small port to the south from the swell of the open sea. A landmark installed on the breakwater or on the islet itself should have been well visible from the sea. The primary task of the Lighthouse was to show the entrance to Alexandria at a great distance but, because of its dimensions, *Pharos* was not efficient for entering the harbour. It seems more probable that another reference point could have been erected or chosen somewhere further along the coast, for example at the base of the Heptastadium as shown on Figure 9.

6. The Harbours of Magnus Portus

Before we continue the discussion of navigation within the ancient port it is necessary to give a short description of its basins (Figure 10).

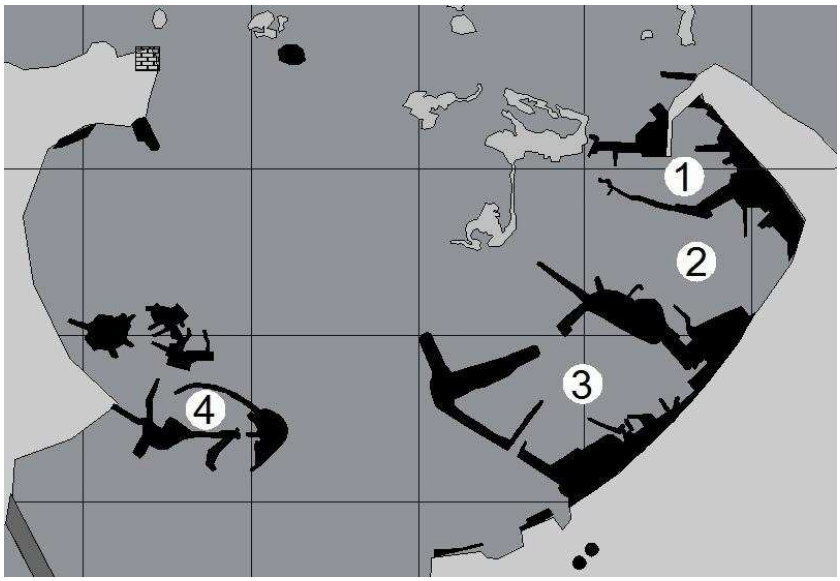

Figure 10. Major basins of the Great Harbour.

[73] Fraser, 1972: 18.
[74] Goddio, J. Yoyotte, 2008.

The "dug into the rock" [75] Royal Port of the Galleys (harbour ①) was located to the West from the Cape Lochias.[76] The water area of this harbour does not exceed 5 hectares. The entrance to the harbour was very narrow and, thus, easy to close with chains.

Harbour number two further to the south had an area of about 15 ha. It seems that the reefs to the North-West protected both of these harbours from the swell. An access to the harbour ② had been restricted too by means of a breakwater of considerable length anchored on the peninsula and stretched in the direction of the reefs nearby. Remains of the masonry have been discovered on the central reef on the other side of the channel. Probably the narrow passage between the reef and the breakwater was closed by chain. This harbour has been identified as a military port[77].

Further South-West along the coast a third harbour follows. It had a considerable area of 16 hectares and was closed on one side by the peninsula of the Poseidium and on the other side by the Island of Antirhodos. A mole protrudes from the Poseidium towards the eastern tip of Antirhodos. A secondary inner port was situated under the lee of the Antirhodos Island. Its southern part was separated by a long and narrow dyke. According to Strabo that was a small royal port.[78] A secondary passage between this dyke and the mole protruding from the ancient coast had a double function. From one hand, it provided an alternative exit in case of strong North or North-Western winds, and, from the other, it supported water circulation in the port preventing a silting-up of the latter.[79] The reefs situated to the North broke the swell coming from the open sea and the mole at the North-West tip of the Antirhodos Island protected the port from the reflected waves formed in the West part of the Great Harbour. Numerous piers of this central port were most probably used for the trade ships.

An intricate system of peers and dykes that has been discovered in the west part of the *Megas Limen* can correspond to the region of small trading ports and shipyards.[80]

7. Navigation within the port's basin

Now we can consider the most probable maneuvers for the ancient ship navigating within the Great Harbour.

7.1 Manoeuvres of calling to the harbours of Megas limen.

The most rapid and logical course for getting access to the harbours of Megas limen must

[75] Strabo, *Geography*, XVII, I.9.
[76] Goddio, J. Yoyotte, 2008.
[77] Goddio, J. Yoyotte, 2008.
[78] Strabo, *Geography*, XVII, I.9.
[79] Goddio, J. Yoyotte, 2008.
[80] Strabo, *Geography*, XVII, I.9. See Goddio, D. Fabre, 2010.

have been the direct trajectory towards the passage between the central reef and the island of Antirhodos (Figure 11, A1). The distance from the central point of the channel I to the entrance of the third, second and first harbor makes respectively 1300, 1600 and 1900 meters. However, in case of strong wind direct access to these harbours becomes risky. In this case it would be preferable to put the helm starboard after passing the channel and to resume the course under the protection of the Pharos Island (Figure 11, A2). Here the strength of the wind and swell was less and the ship could continue sailing the SE course towards the narrow 20-meter passage between the island of Antirhodos and the shore.

In both cases the crew had enough time to take in sail on the approaches to the third harbour.[81] A square-rigged vessel of the time could furl the sail rather quickly by means of brails that ran to the deck and thus just few crew members could complete this operation.[82]

Another probable tack can be suggested towards the newly discovered port structures in the west part of the Harbour (Figure 11, A3). Some remains in the North-West of the Eastern Port probably correspond to the quays that belong to the submerged coast of the Island of Pharos. Complicated structures in the south part of the Island include several well-protected ports of modest size.

Finally it's worth considering another important itinerary towards the passages that have existed in Heptastadium[83] (Figure 11, A4). It is well known that the entrance to the western port of Eunostos was possible via narrow channels among the reefs that were not easy to pass.[84] In Roman time there were shallows in the port's basin.[85] Under certain conditions like bad visibility or high swell it might have been safer to enter the inner roads of the Great Harbour first and to pass to the port of Eunostos through the passages in the Heptastadium. In any case the goods that were destined for shipping to the inner parts of the country must have been constantly channeled from Portus Magnus to the Port of Eunostos that has been connected to the Lake Mareotis and the Nile.

Because of its low speed and stability the *sea breeze* can be very efficient for entering the harbour.[86] The direction of the sea breeze generally corresponds in Alexandria to that of dominating wind direction from the North-West.[87] Regular character of Alexandrian breeze has

[81] Calms are quite frequent in the Mediterranean in summer. Therefore all vessels, even the larger cargo ships destined for long-range voyages, were equipped with oars. Rowing was also indispensable while calling to tricky ports like that of Alexandria. See Casson, 1995: 65, 157.
[82] Casson, 1995: 68.
[83] Strabo, *Geography*, XVII, I.6.
[84] Strabo, *Geography*, XVII, I.6, Jondet, 1916: 8-9.
[85] Caesar, *The Alexandrian War*, XIV.
[86] Breeze is the wind that arises on regular basis in all coastal areas due to the difference in day heating and night cooling of the neighbouring surfaces of sea and land. The *sea breeze* blows in the afternoon and blows from sea to land. The *coastal breeze*, on the contrary, blows at night from land towards the sea.
[87] In fact the Etesian wind is the same breeze in its origin but just taken on a much larger scale.

been noted by Gaston Jondet who understood perfectly the importance of this factor for port's design.[88]

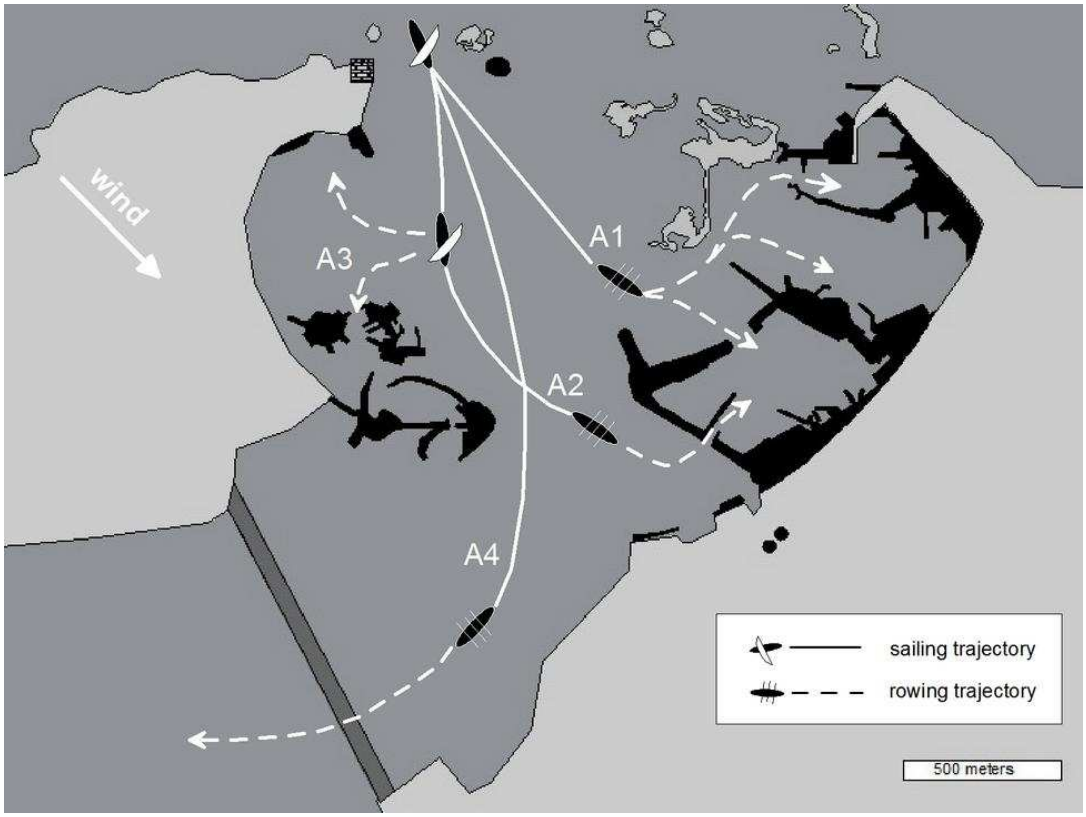

Figure 11. Hypothetic courses of preference for the ships calling to the harbours of *Megas limen* and to the port of *Eunostos*.

7.2 Leaving the port

The tides being negligible in the Mediterranean, there were no danger of "*missing one's tide"*. Therefore, it was the wind that acquired great importance when leaving the Great Harbour. A ship could rely exclusively on rowing, of course, but that was possible only in case of relatively weak winds of northern direction or the winds from the shore (coastal breeze). As for a sufficiently fresh wind (approximately more than 5 points on Beaufort scale) of the dominating direction from the North-West, it hardly left any chance of leaving the port by rowing.

Coastal breeze was the most advantageous wind for the ship leaving the harbour. Besides favourable direction that is perpendicular to the shore, it is very stable and not too strong. At the same time the influence of the coastal breeze can sometimes extend up to 20 km from the coast. To make a good use of the coastal breeze while leaving the Great Harbour, the ship should have rowed first till the open water area in the central part of the port and, having put sail, to move right ahead towards the channel using the Lighthouse as a reference point (Figure 12, B1-B5).

[88] Jondet, 1916: 12.

Putting sail before passing the channel seems to be righteous in all these cases except when sailing from the port near the South-Eastern extremity of the Pharos (B3). Probably in this case it was more safe and easy to put sail after passing the channel.

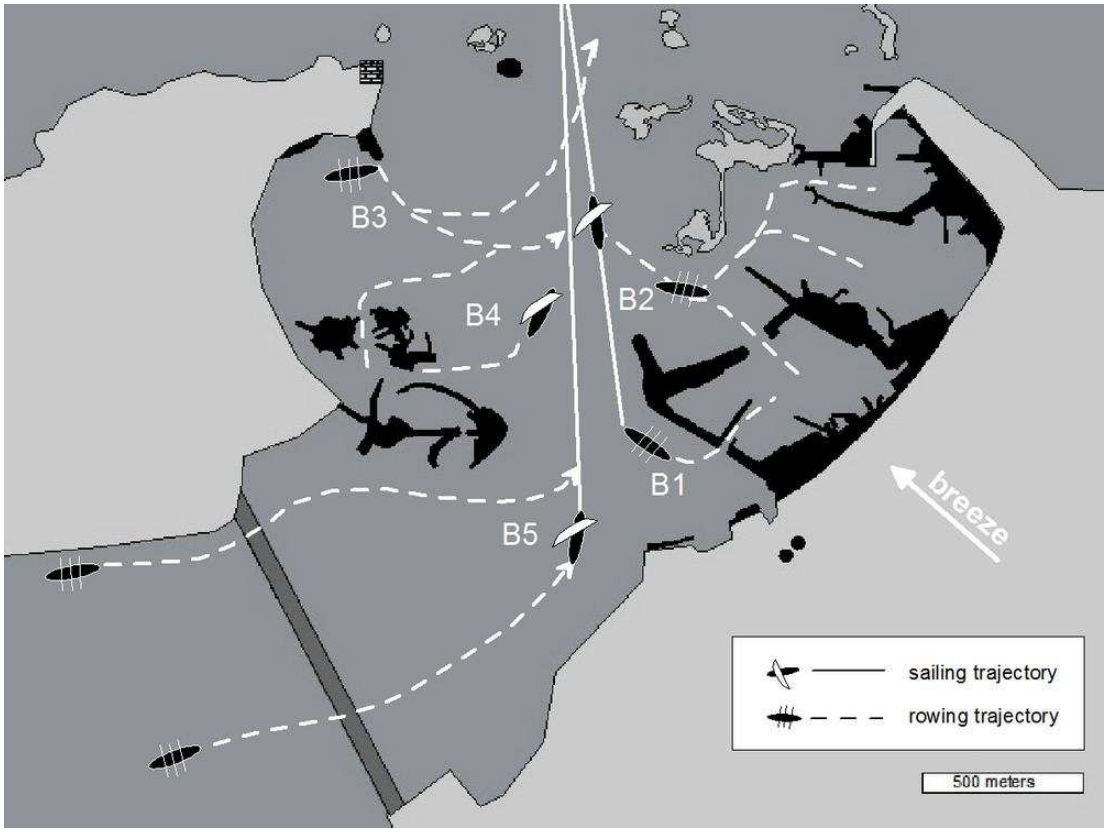

Figure 12. Possible courses of ships leaving the Great Harbour with the coastal breeze.

It was a more difficult business to leave the harbour under sail with the usual North-West wind blowing and finally impossible if this wind was fresh enough. Caesar has experienced himself that Etesian winds can prevent ships from leaving Alexandria.[89] The question whether the ships of the classical period were able to beat against the wind or not has been repeatedly raised in literature.[90] Written sources indicate without any ambiguity that this kind of sailing was well known to the ancients. Of course, the angle of windward sailing was not high, surely less than 60° to the wind,[91] so it was used when it appeared to be more efficient than rowing, chiefly during long separate tacks.[92] However, windward sailing in the limited space of the harbour seems improbable. The ship that has approached alee the island of Pharos near Heptastadium would have been theoretically able to leave the harbour by Channel II while sailing on a beam reach on port tack (Figure 13, B6). At the same time it is necessary to remember that actually the

[89] Caesar, *The Civil Wars*, III, 107.
[90] Tilley, 1994; Casson, 1995: 273, 464; Roberts, 1995; Wachsmann, 1998: 253; Whitewright, P. Starkey, 2007; Palmer, 2009; Whitewright, 2011.
[91] Roberts, 1995. A figure of 70-80 degrees to the true wind seems more convincing: Arnaud, 2012.
[92] Roberts 1995.

ship had to be directed closer to a wind because of considerable drift of an ancient vessel. Moreover, in case of an error and an uncontrollable fall off the maneuver could finish by catastrophe on leeward reefs. At the same time moderate weather conditions would render this maneuver quite admissible.

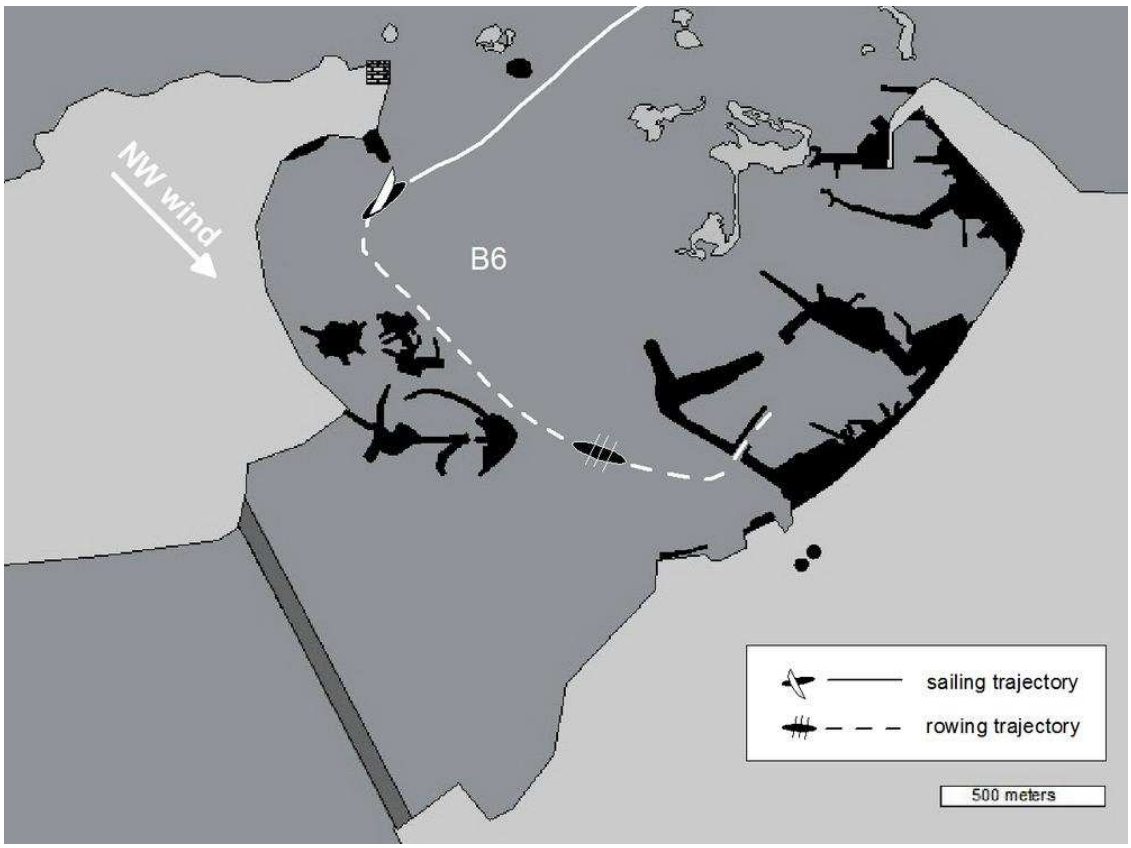

Figure 13. Possible track of leaving the harbour under sail in case of moderate NW wind.

8. Mooring of the ships in the Great Harbour.

Let us compare the dimensions of the three major harbours of *Megas limen* with some of the largest Mediterranean ports of Antiquity (Figure 14).[93]

Port	Dimensions (м)	Water area (ha)	Wharfage length (m)
Pireus-*Kantaros*	1000x500	50	
Carthage	500x300	15	
Portus		234	c.13,890
Caesarea Maritima		20	
Lepsis Magna		10.2	1,200

Alexandria (total)		**>226**	**12,380**
Harbour 1 (Royal)	350x200	7	
Harbour 2	600x300	15	
Harbour 3 (Antirhodos)	550x400	16	

[93] de Graauw, 1998 ; Schörle, 2011.

Figure 14. Dimensions of the selected ancient ports.

It has been already noted above that the Great Harbour must have been the most logical choice for the disposition of the Navy in Greco-Roman times. As we can see that the water areas of the three harbours of *Megas limen*, as well as the length of their piers, were quite sufficient for the mooring of the large fleet of both trade and military vessels. However we can offer several conclusions concerning the most probable site for a constant disposition of the Navy.

Some part of the Navy, probably elite military units and king's personal fleet of luxury boats could have been accommodated in the Royal harbour (Figure 10, port N1). However its modest size and extremely narrow entry passage do not satisfy the requirements for a constant military port. Comparing the two other harbours we must conclude that the second harbour (N2) has an advantage of a single entry channel that was well under control. This conclusion is proved by the existence of an important breakwater at the north-western tip of the peninsula. It seems that one of the objectives that were assigned to this 180 meter long construction was to constrict the entry channel. To the same, two walls and a small dyke have been discovered on the central reef on the other side of the channel.[94] Probably these remains correspond to the structure responsible for closing the entry with a chain.

At the same time the third harbour could have been also used from time to time for the disposition of the Navy. This conclusion can be illustrated by the events of the Alexandrian War of 48-47 BC. According to Caesar, immediately after his arrival to the city he was accommodated in the part of the royal palace that has been joined by the theater that "*was attached to the house which took the place of a citadel, and had approaches to the port and to the other docks*".[95] In this defensive position Caesar had been forced to burn his own fleet consisting of 50 large ships (quadriremes and quinqueremes) and 22 smaller ships.[96] A part of vessels that he has burnt was beached. Caesar has been surrounded and he did not dispose of many soldiers and thus we can conclude that both the port and the shipyards were not far away from Caesar's position.[97] At the same time the location of the theatre is attested by Strabo. He says that before the island of Antirhodos there is an artificial harbour and the theatre is over it. [98]

[94] Goddio, I. Darwish, 1998: 14.
[95] Caesar, *The Civil Wars*, III, 112, trans. A.G.Peskett, The Loeb Classical Library, 1996.
[96] *Ibid*, III, 111.
[97] *Ibid.*
[98] Strabo, *Geography*, XVII, I.9. Next he describes the position of the *Posidium* and *Timonium*. The submerged island of Antirhodos and the peninsula with the platform of Timonium have been discovered during the topographic surveys and their position corresponds well with the description of Strabo: Goddio, I. Darwish, 1998.

Therefore we can suppose that the theatre, that is more than once mentioned in the sources, has been situated in the vicinity of the third harbour and possibly it is in this latter that the Caesar's fleet has been moored and beached.

Here we encounter another question connected with the storage of military ships during the peace time and in winter. It is well known that lead sheathing has been used in Antiquity as protection against shipworms and also for enhancing the water-tightness of the hull of merchant ships.[99] Thus, merchant ships could rest in the water during the whole period of navigation.[100] However this is not true for military galleys devoid of lead sheathing because of its weight and subsequent loss of speed.[101] The normal life period for a sea-going ship according to the sources was around 20-26 years and this was chiefly achieved by regular beaching of the ships (*ἀνέλκειν*) and by keeping them in the shipsheds (*νεώσοικοι*) in winter.[102] Shipworm (*Teredo navalis*) can decrease the life span of the ship many times. Apart from this, ship's weight could increase by at least 15% as a result of constant stay in the water.[103] Ancient naval commanders tried by all means to avoid this.[104] Therefore we can assume the necessity of an existence in Alexandria of the shipsheds that usually were incorporated in a standard naval base (*τὰ νεώρια*, *navalia*).[105]

In his description of Alexandria Strabo uses the word *τὰ νεώρια* twice.[106] First he mentions shipyards in his description of the monuments near the third harbour. After that, while moving from East to West, he describes the temple of Caesar, then the emporium with the warehouses (*ἀποστάσεις*), and, finally, *τὰ νεώρια* extending till Heptastadium. According to him, there were shipyards in the port of Kibotos as well, that is on the western side of Heptastadium. This is proved by the events of the Alexandrian War as the adversaries of Caesar prepared their fleet in the inner part of the port of Eunostos.[107] We have rather precise idea of the position of the Caesareum thanks to the "*Needles of Cleopatra*" and thus it is possible to estimate the distance used by the emporium, the warehouses and the shipyards approximately at 1.300 meters. To cite Strabo's words, the shipyards were "*extending till Heptastadium*"; therefore they were long enough and occupied the major part of this space. It seems quite probable that the main shipsheds for winter storage of the ships might have been situated somewhere here.

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[99] Today this fact, well testified by the sources, is also confirmed by archaeological finds. See Steffy, 1998.
[100] However merchant ships were also sometimes hauled out inside the port. See Blackman, 1995.
[101] Steinmayer, J. Macintosh Turfa, 1996.
[102] Morrison, 1996: 355-356.
[103] Tests carried out by the American Navy proved that the wood infested by the shipworm is destroyed within the period of 2-7 years. See Steinmayer, J. Macintosh Turfa, 1996.
[104] Herodotus, *Histories*, 7.59.3 ; Xenophon, *Hellenica*, 1.5.10; Thucydides, *Historiae*, 7.12.3, 7.60-72; Polybius, *Historiae*, 1.51.7, 1.51.9.
[105] Casson, 1995 : 363-365.
[106] Strabo, *Geography*, XVII, I.9-10.
[107] Ceasar, *The Alexandrian War*, XIII.

The shipsheds are best known from the Athenian port of Zea (Pireus).[108]They were constructed to house the triremes and looked like stone slips partially cut in bedrock and partially constructed of the blocks of the same local stone.[109] The slip for a ship was around 37 meters long and 3 meters wide, not counting its underwater part. The roof was supported by the columns that also served to hold the ship's hull on the slip.[110]

According to Herodotus, the Greeks that were settled near the town of Bubastis in the Delta by the pharaoh of the 26th Dynasty Psamtik I (664 - 610 BC) had the slips (*ὁλκός*) for their ships (*Histories*, 2.154). Later Necho II (610-595 BC) built slips for his war galleys on the coast of the Red Sea (*Histories*, 2.159).

So-called "places for drying" (*ψύκτραι*) has been discovered near Syracuse on Cyprus and on some islands in the Aegean.[111] They are represented by the rows of parallel grooves in the bedrock 40-50 meters long, 80-90 cm wide and 40-50 cm deep situated on shallow places, hidden from the waves. Obviously this is a more simple type of ships' storage but its application in Alexandria seems less probable as it does not correspond to the carefulness of the Ptolemies in creation of their Navy. Alexandria stands on the Pleistocene sandstone bedrock and the construction of the shipsheds of this type should not have presented any particular difficulties.

Unfortunately till now no archaeological evidence has been found to prove the existence of the shipsheds of one or another type in Alexandria. Although possible traces of the shipsheds must have been destroyed during the construction of the modern embankment, we can still hope to uncover some remains of the facilities of this kind in the submerged part of the city in the western part of the Eastern Port.

9. Conclusions

More than ten years of archaeological surveys of the Great Harbour of Alexandria have completely changed the conception of the ancient topography of the port area of the city. The remains of ancient port structures show the high level of port's organization and well correspond to the descriptions of ancient authors. This new archaeological data permits to consider general aspects of navigation within the Great Harbour. The most probable courses of the ships calling to the Great Harbour and leaving it under sail or oars have been considered while taking into account ancient sources, hydro-meteorological factors and the performance of

[108] The evidence for the shipsheds is exhaustive and includes the remains from Rome, Carthage, Syracuse, Crete, Rhodes, Kos, Dor, Apollonia, Thurii, Oeniadae, Sunium and other harbour cities. See Blackman, 1982; Blackman, 1987; Blackman, 1995; Blackman, 2003.
[109] Casson, 1995: 363-365.
[110] Coates, 2002.
[111] Auffray, 2002.

the rigging of the time. An important role of the alignments for the navigation within the harbour is underlined and some possible reference points are proposed. In the absence of archaeological proofs some thoughts are developed on the probable disposition of the Navy and on the location of the shipsheds for the winter storage in greco-roman times.

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