

Ancient Lighthouses - Part 5: The Pharos

by Ken Trethewey

Gravesend Cottage, Torpoint, Cornwall, PL11 2LX, UK

Abstract: This paper presents a modern description and analysis of the design, build and functionality of the Pharos of Alexandria. A proposal for the influence of the Pharos on the design of modern lighthouses is given, as well as a comprehensive literature survey.

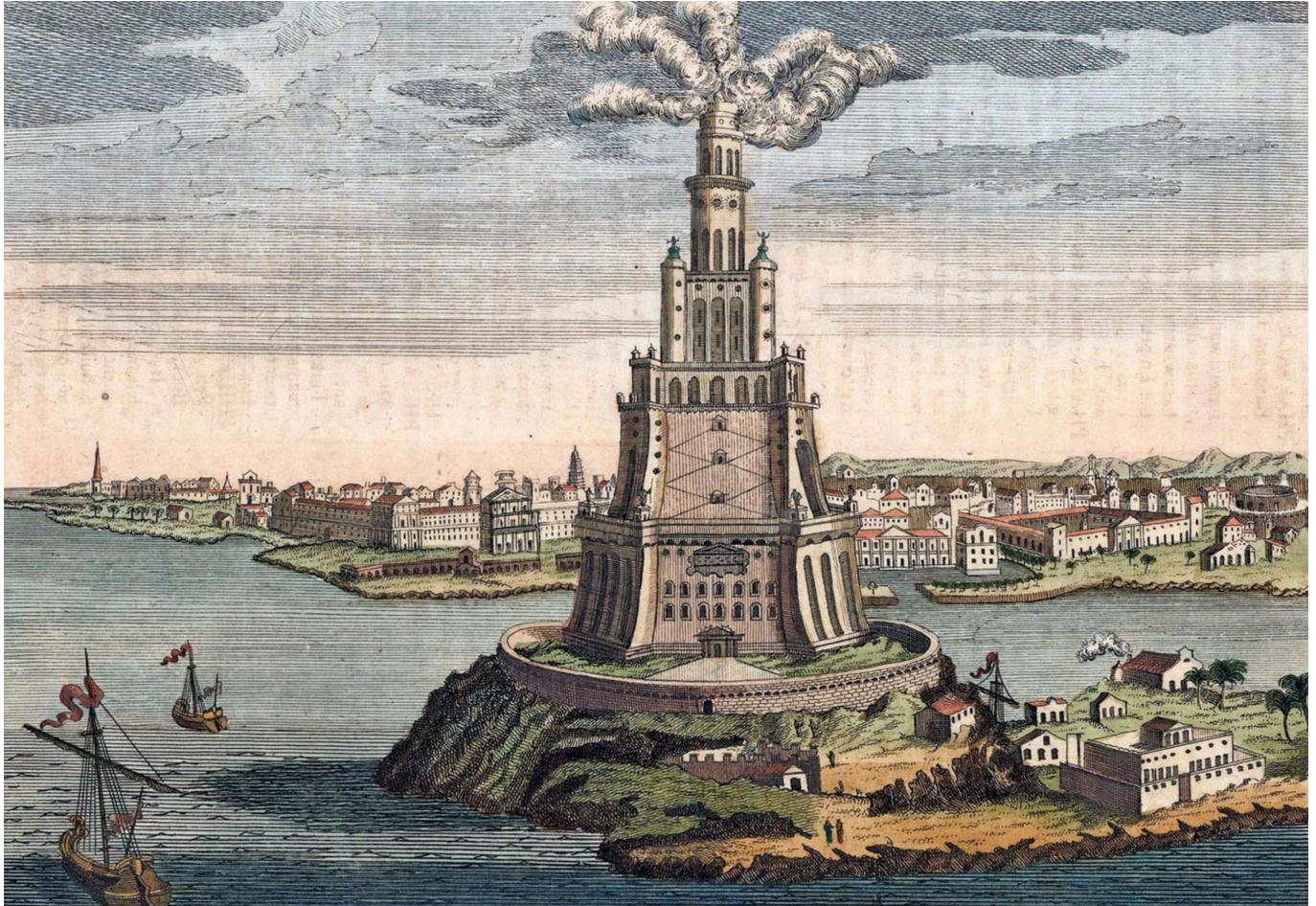


Fig. 5-1: An impression of the Pharos of Alexandria¹¹¹

The Greatest Lighthouse

We frequently find ourselves lost for words when we try to describe things that are without comparison. In this paper, we shall try to describe the indisputably finest structure that has ever been assigned the name 'lighthouse' using words and pictures, and hope that we end in agreement about this ultimate accolade. We shall read about its physical appearance, its design, structure and location. We shall discover the latest information known about its history, and read many remarkable first-hand accounts by visitors to the lighthouse at various stages in its extraordinarily long existence.

Rightly considered to be one of The Seven Wonders of the Ancient World, its construction some

three hundred years before the commencement of the current calendar parallels the greatest of any other engineering achievement.

Perhaps the one aspect of the story that may not achieve its desired effect is just how much the existence of the Pharos of Alexandria influenced people and cultures all over the world and through more than two thousand years of tumultuous history. That would take far more space than is available here.

Objective

The objective of this paper is:

To describe the location, design, construction, function, history and legacy of the Pharos of Alexandria.

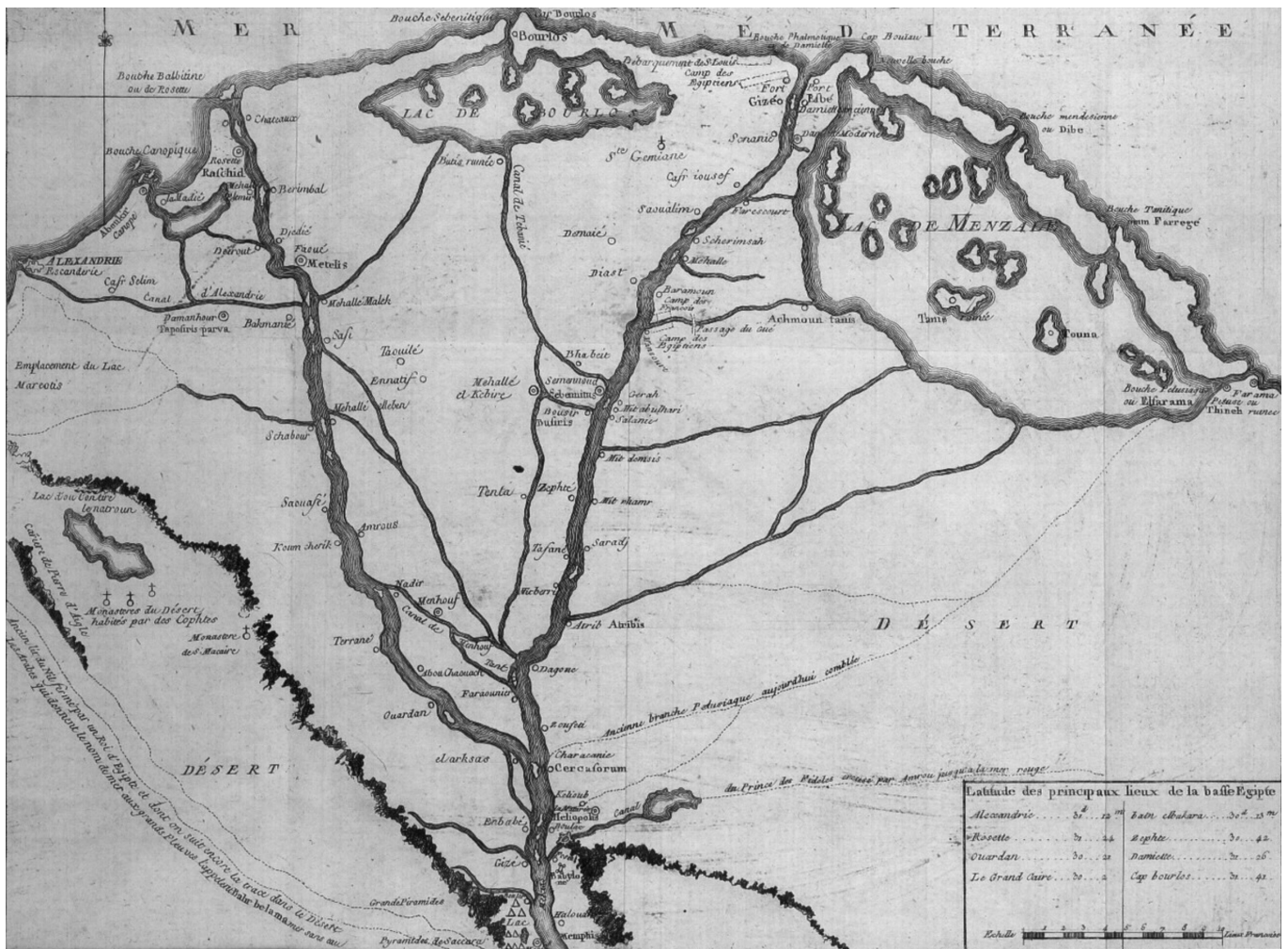


Fig. 5-2: An old map of the extensive region of the Nile Delta, showing the location of Alexandria some 20 km southwest of the Canopic Mouth (Bouche Canopique - top left) of the river.¹¹²

A Great Centre of Civilization is Founded

Alexander the Great was one of the most successful military commanders in history. He acceded to the throne as king of Macedonia when he was twenty, and by the time he was thirty he had built an empire that stretched from Greece to northern India. King Alexander III of Macedonia then added the names King of Egypt, King of Asia and King of Persia to his list of titles. Today we would describe Alexander as Greek by birth, and in creating such an expansive Empire he exposed his new subjects to many aspects of Greek culture. This leads to our description of this period of history to the time when the Romans took Egypt as 'Hellenistic'.¹

When Alexander made his decision to take Egypt into his fold of conquered nations, his touring war machine had just overcome stiff resistance



Fig. 5-3: A bust of Ptolemy I Soter, King of Egypt (reigned 305 to 283), who assumed power after the death of Alexander. He ordered the construction of the Pharos early in his reign. This bust can be viewed in the Louvre, Paris.

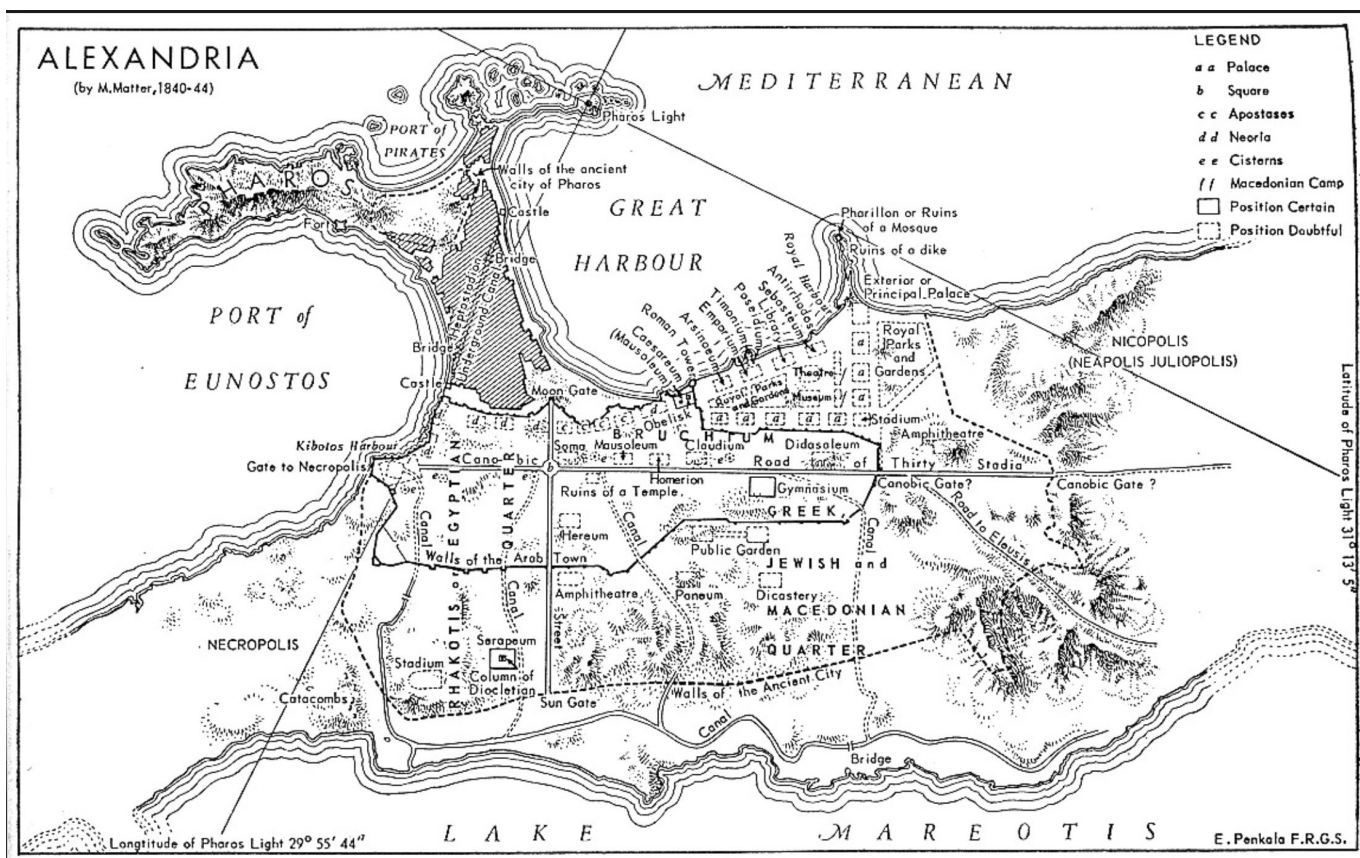


Fig. 5-4: A map of ancient Alexandria showing the location of the lighthouse on the island of Pharos.¹¹³



Fig. 5-5: Alexandria from Space.¹¹⁴ A comparison with Fig. 5-4 is useful.



Fig. 5-6: Phare de l'Egypte, Septième miracle du Monde. (Lighthouse of Egypt, Seventh Wonder of the World) by Georg Balthasar Probst.¹¹⁵



Fig. 5-7: The Pharos of Alexandria, illustrated in 1752 by van Heemsckerck. The images show how frequently an idea by one artist was copied into representations by other artists with no apparent concern for accuracy. Such practices, usually involving exaggerations and engineering impossibilities, have led to many misconceptions - not the least being that Alexandria was mountainous!¹¹⁶

by the people of Tyre. He set sail from Phoenicia and proceeded south along the coast of the Levant taking control of the land as he did so. Most of the towns gave up without a fight, though Gaza proved an exception. Here, as at Tyre, the locals fought bravely, only to lose. The men were killed and the women and children sold into slavery. It was the way he did things.

In late 332 BCE, Alexander brought his fleet into one of the very few sheltered harbours on the southeast Mediterranean - Rhacotis (Racotes or Rhaqote). Then in 331 BCE he founded a new city there and named it Alexandria, Fig. 5-2. His plan was to link Greece with the River Nile and its treasure trove of traded goods. It was just one of many important decisions by this most remarkable leader. He appointed a man called Cleomenes to take charge of his new city and to oversee its development.

Just eight years later in 323 BCE, whilst he was in Babylon, Alexander died at the age of 32. It is uncertain whether the death was by poison or natural causes. However, the event led to a change in the government of a large part of the world, including Egypt, and the creation of one of the finest structures ever built on Earth. Cleomenes' administration in Alexandria came to an end in 323 BCE, a year in which coins were minted showing that a new regime called Soter was in power.

Alexander's death caused fractures in his extensive empire for there was no single man able to take over from him. One of his generals, Seleucus, took over a great part of Asia Minor, and created a long-lasting dynasty of kings who ruled during what is now known as the Seleucid period (312 to 63 BCE). In Egypt, power was assumed by a man named Ptolemy, and, after a period of struggle for domination over his competitors, he finally took the throne in 305 BCE as Ptolemy I Soter (Fig. 5-3) and became first of a new dynasty of Pharaohs. The changes had profound impacts upon Egypt as a whole, but especially on the new city of Alexandria.

Without discarding the legacy of Alexander, or those elements of the Hellenistic culture that had already been absorbed into Egyptian society, Ptolemy decided to take his kingdom forward in a way that embraced the past and expanded it into the future. Perhaps inspired by Alexander's immense ambition, Ptolemy's vision for his coun-

try was grand. He found a new financial, as well as political, freedom and, released from the obligation to send taxes to Byzantium, he embarked upon a spending spree to expand his new city with vigour. One of his plans was to build a great lighthouse. The selected location was a small rocky island just offshore at Alexandria. Figs. 5-4 and 5-5 illustrate its position and the way the island has now become joined to the mainland. The site of the lighthouse is now entirely covered by a 15th c. fortification known as the Citadel of Qaitbay.

The World's First Lighthouse

There have been many representations of the Pharos. Often they have been fanciful or based upon scant or even false reports. Figs. 5-1, 5-6 and 5-7 are typical of how an idea by one artist was copied by others. From time to time, serious researchers have re-evaluated the evidence and produced new images based upon revised data. I have collaborated with the artist, Alfonso Biscas, to present a new image here for the first time (Fig. 5-8). This artist's impression is based upon a review of the available evidence that has not changed significantly for a hundred years and therefore contains little that is new, except for its power to dispel some of the less convincing and erroneous impressions created by other artists. The image shows the Pharos soon after its construction.

As we view these images, we must surely feel surprise that such a structure could have been the first of its kind, yet when we have looked for lighthouses in earlier times, we have found that we are peering into a world where nothing of substance seems to exist. It is as if a new mythology has been created and accepted as being the end of the discussion of where lighthouses came from. It is as if one of the most remarkable, ambitious (and costly) engineering achievements of its time was taken out of a box and placed on the shores of Egypt by some visiting alien. It appears that the name 'Pharos' was first given to the island on which the tower was built, and that there was no specific word for 'lighthouse' in any of the ancient languages – except for the rarely used term 'fire-tower'. I have already discussed these issues at length in Part 1. There is no doubt that the building of the Pharos was a defining moment in history.

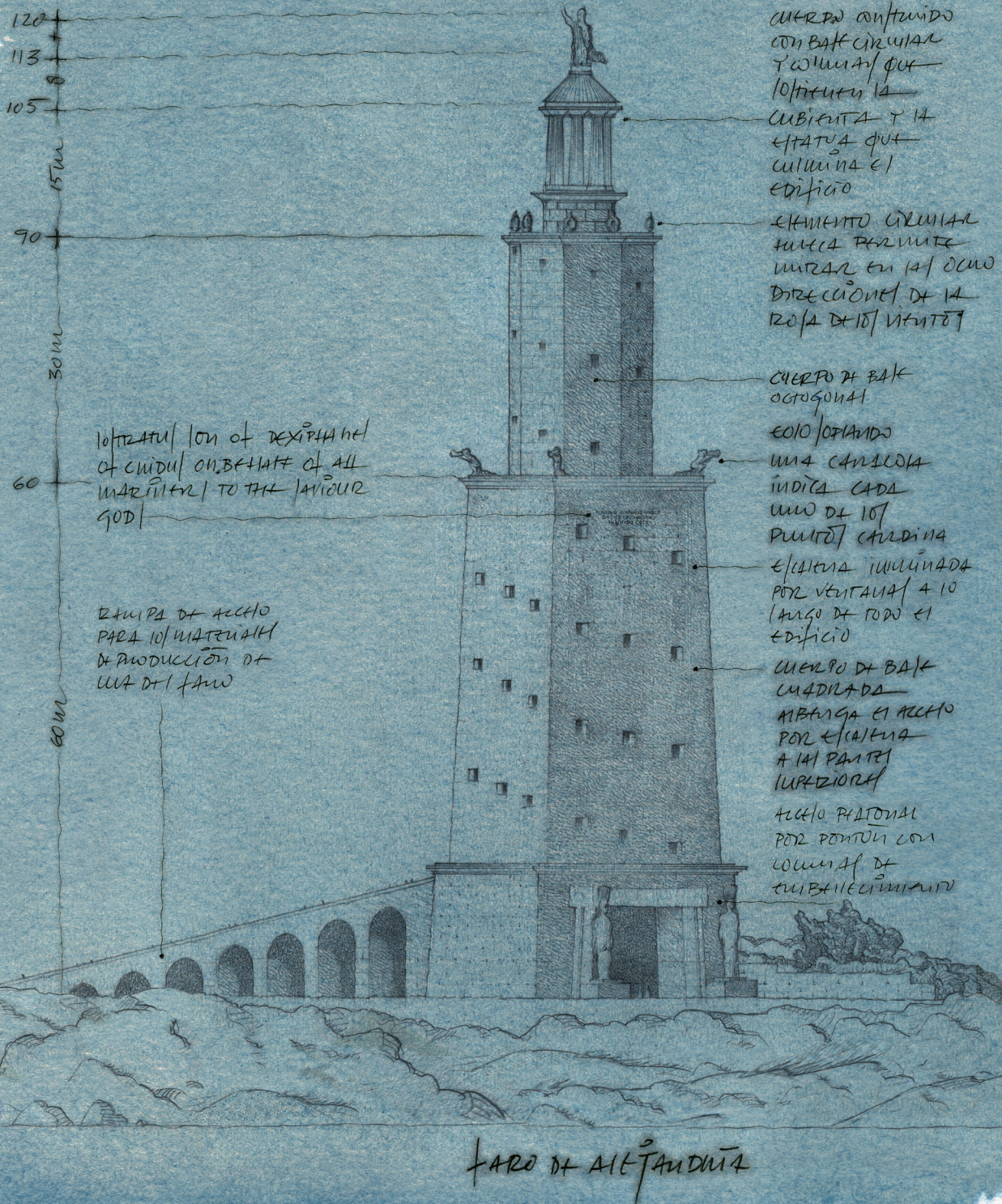


Fig. 5-8: A new impression of the Pharos of Alexandria. The image shows the tower soon after its completion. Numerous modifications were made to it during its existence from 280 BCE to 1303 CE.¹¹⁷

Dates of construction

The date of construction of this magnificent tower will probably never be known accurately, but we may take it to be 280 BCE. This date corresponds to other, better-known historical dates for the conquering of Egypt by Alexander the Great in 331 BCE and the founding of the city of Alexandria. It allows for the assumption of power by Ptolemy I Soter following Alexander's death in 323 BCE and the passing of a reasonable period of time during which the tower was planned and building initiated by Ptolemy. The year 323 BCE corresponds with what historians today call the commencement of the Hellenistic Period of Greek history that lasted until the overthrow of Octavian and Cleopatra in Alexandria in 31 BCE by the Roman Emperor Tiberius.

There are many lighthouses in our early history about which there remain an element of doubt, but there is no question about the existence of the Pharos at Alexandria – one of the Seven Wonders of the Ancient World, built on the island of Pharos just off the coast. Even so, all doubts about the Pharos have not been dispelled. We are still not entirely sure of the years when it was built and we remain uncertain about some aspects of its structure. It may have been in 305 BCE or soon after that Ptolemy commissioned the building of the lighthouse. Its great size would have meant that it took between twelve and twenty years to construct, by which time Ptolemy could have died and been succeeded by his son. Many other major projects initiated by Ptolemy I were overseen to completion by his son, and the lighthouse would have been one of those: it is fairly certain to have been completed by 270 BCE. A tenth century encyclopedia called *Souda* stated that the Egyptians started to build it in 297 BCE and that it was finished in the reign of Ptolemy II in 283 BCE.² Many authors believe it was started around 290 BCE. Zemke³ reports that it took 17 years to build from 300-283 BC, which compares with a report by Eusebius around 300 CE of a completion date of 283-2 BCE.⁴ Stevenson quotes "about 280 BC" for its completion⁵, as does the most widely used present-day source.⁶ I intend to adopt 280 BCE as the date of completion of the lighthouse, whilst accepting that the date may be subject to a small error.

Motivation for the Construction

We are fortunate to have some first-hand contemporary accounts of this great lighthouse. McKenzie, for example, reports the poet Posidippus to have written about the Pharos soon after construction was completed. He gave a good reason for its construction:

*"As a saviour of Greeks, this watchman of Pharos, O Lord Proteus, was erected by Sostratus, son of Dexiphanes, from Cnidus. For in Egypt there are no lookout posts on a mountain, as in the islands, but low lies the breakwater where ships take harbour. Therefore this tower, in a straight and upright line, appears to cleave the sky from countless stadia away, during the day, but throughout the night quickly a sailor on the waves will see a great fire blazing from its summit. And he may even run to the Bull's horn, and not miss Zeus the Saviour, O Proteus, whosoever sails this way."*⁷

Writing sometime between 10 BCE and 20 CE, Strabo, one of the world's first geographers, visited Alexandria and wrote a good description of the city. He also put forward good reasons for building the Pharos:

"Since Alexandria and its neighbourhood constitute the largest and most important part of this subject, I shall begin with them. The sea coast, then, from Pelusium, as one sails towards the west, as far as the Canobic mouth, is about one thousand three hundred stadia – the 'base' of the delta, as I have called it; and thence to the island Pharos, one hundred and fifty stadia more. Pharos is an oblong isle, is very close to the mainland, and forms with it a harbour with two mouths; for the shore of the mainland forms a bay, since it thrusts two promontories into the open sea, and between these is situated the island, which closes the bay, for it lies lengthwise parallel to the shore. Of the extremities of Pharos, the eastern one lies closer to the mainland and to the promontory opposite it (the promontory called Lochias), and this makes the harbour narrow at the mouth; and in addition to the narrowness of the intervening passage there are also rocks, some under the water, and

others projecting out of it, which at all hours roughen the waves that strike them from the open sea. And likewise the extremity of the isle is a rock, which is washed all round by the sea and has upon it a tower that is admirably constructed of white marble with many stories and bears the same name as the island. This was an offering made by Sostratus of Cnidus, a friend of the Kings, for the safety of mariners, as the inscription says; for since the coast was harbourless and low on either side, and also had reefs and shallows, those who were sailing from the open sea thither needed some lofty and conspicuous sign to enable them to direct their course aright to the entrance of the harbour. And the western mouth is also not easy to enter, although it does not require so much caution as the other. And it likewise forms a second harbour, that of Eunostos, as it is called, which lies in front of the closed harbour which was dug by the hand of man. For the harbour which affords the entrance on the side of the above-mentioned tower of Pharos is the Great Harbour, whereas these two live continuous with that harbour in their innermost recess, being separated from it only by the embankment called the Heptastadium. The embankment forms a bridge extending from the mainland to the western portion of the island, and leaves open only two passages into the harbour of Eunostos, which are bridged over. However, this work forms not only a bridge to the island but also an aqueduct, at least when Pharos was inhabited. But in these present times it has been laid waste by the deified Caesar in his war against the Alexandrians since it had sided with the Kings. A few seamen, however, live near the tower. As for the Great Harbour, in addition to its being beautifully enclosed both by the embankment and by nature, it is not only so deep close to the shore that the largest ship can be moored at the steps, but also is cut up into several harbours. Now the earlier kings of the Egyptians, being content with what they had and not wanting foreign imports at all, and being prejudiced against all who sailed the seas, and particularly against the Greeks (for owing to scarcity of land of their own the Greeks were ravagers and coveters of that of others), set a guard over this region and ordered it to keep away

anyone who should approach; and they gave them as a place of abode Rhacotis, as it is called, which is now that part of the city of the Alexandrians which lies above the ship-houses [dockyards], but was at that time a village; and they gave over the parts roundabout the village to herdsmen, who likewise were able to prevent the approach of outsiders. But when Alexander visited the place and saw the advantages of the site, he resolved to fortify the city on the harbour.”⁸

Sometime during the first century BCE, Diadorus of Sicily wrote:

“Now that we have set forth the facts about the three regions which fortify Egypt by land we shall add to them the one yet remaining. The fourth side, which is washed over its whole extent by waters which are practically harbourless, has for a defence before it the Egyptian Sea. The voyage along the coast of this sea is exceedingly long, and any landing is especially difficult; for from Paraetonium (modern day Marsa Matruh) in Libya as far as Iopê in Coele-Syria (modern Jaffa in Israel), a voyage along the coast of some five thousand stades (925 Km), there is not to be found a safe harbour except Pharos. And, apart from these considerations, a sandbank extends along practically the whole length of Egypt, not discernible to any who approach without previous experience of these waters. Consequently, those who think that they have escaped the peril of the sea, and in their ignorance turn with gladness towards the shore, suffer unexpected shipwreck when their vessels suddenly run aground; and now and then mariners who cannot see land in time because the country lies so low are cast ashore before they realize it, some of them on marshy and swampy places and others on a desert region.”⁹

Diadorus was clearly referring to the island of Pharos and the natural harbour provided there. For Alexander, arriving in Egypt with a fleet of ships, it is obvious that this is the place he would have navigated to, and then declared it a natural harbour and place for a new city.

Pliny, who died in 79 AD while attempting to get a close-up view of the eruption of Vesuvius that overwhelmed Pompeii, wrote of the Pharos:

“There is another building, too, that is highly celebrated; the tower that was built by a king of Egypt, on the island of Pharos, at the entrance to the harbour of Alexandria. The cost of its erection was eight hundred talents, they say; and, not to omit the magnanimity that was shown by King Ptolemaeus on this occasion, he gave permission to the architect, Sostratus of Cnidos, to inscribe his name upon the edifice itself. The object of it is, by the light of its fires at night, to give warning to ships, of the neighbouring shoals, and to point out to them the entrance of the harbour. At the present day, there are similar fires lighted up in numerous places, Ostia and Ravenna, for example. The only danger is, that when these fires are thus kept burning without intermission, they may be mistaken for stars, the flames having very much that appearance at a distance. This architect is the first person that built a promenade upon arches; at Cnidos, it is said.”¹⁰

There are some crucial ideas contained in this quotation. First, that the light shows the location of a safe harbour (come here) and also that the seamen will avoid submerged obstacles (don't go there). These are two key roles of lighthouses. It is taken for granted by all who came after that the Pharos was built with the greater objective of impressing all who viewed it that Alexandria was a wonderful city. To do that, the amount of trading in the port needed to be greatly increased, and to do that, an otherwise dangerous part of the coastline needed an aid to navigation that would encourage sailors in their search for a safe harbour. It was as if all this was clearly understood at the time and that it was such common knowledge from centuries of sea travel as to be obvious to all.

Pliny recorded that some mariners found the lighthouse misleading. It is therefore quite clear that Pliny firmly held the idea of the Pharos as primarily a lighthouse. Any possibility of confusion of its light with stars would have been inconsequential once a ship approached to a reasonable distance. However, Pliny was writing some 300 years after the lighthouse had been built and, perhaps influenced by the extensive network of Roman lighthouses that had been built by his time, may have had a different understanding of the reasons for its existence.

The Pharos project was very expensive. The

cost of the project was 800 talents - perhaps one tenth of all the money in the king's treasury.¹¹ (One Egyptian talent is thought to have been equivalent the weight of a man - about 57 kg of gold!) So why would he spend so much on one project? Three reasons are obvious: defence, prestige and navigation. Clearly, he felt fortunate in gaining power after the break-up of Alexander's great empire, and he did not want to lose it. Modern writers are convinced that the lighthouse served as a garrison for a large cohort of defensive troops. From sea level it would have looked like an impregnable fortress, and, built in the Bay of Alexandria, it was a message to foreigners in the loudest possible terms that here was a civilization that was both advanced and mighty. Mess with it at your peril! The Alexandrians could make the message most successful by shouting it from the highest point in the land, so the Pharos needed to be as tall as possible. It could easily have been viewed as a celebration of the wonderful civilization that had been created in Alexandria and, since this was at the entrance to the fabulous hinterland of the Nile, of Egypt too. Thus, it is entirely possible that the Pharos, which later became the model for a universal, built aid to navigation, was originally constructed more as a bright, neon-lit billboard to proclaim the success of the city than specifically to provide directions to passing ships. Clearly, defence and prestige were important reasons for the construction of this magnificent tower, but what of navigation?

The Location

Strabo made a good effort to describe the local landscape for Alexandria, the most important seaport for Egypt, then and now. First, he described the Nile and its Delta:

“The Nile flows from the Ethiopian boundaries towards the north in a straight line to the district called Delta, and then, being ‘split at the head’, as Plato says, the Nile makes this place as it were the vertex of the triangle, the sides of the triangle being formed by the streams that split in either direction and extend to the sea, the one on the right to the sea at Pelusium and the other on the left to the sea at Canopus and the neighbouring Heracleium as it is called, - and the base by the coastline between Pelusium and the Heracleium. An island, therefore, has been

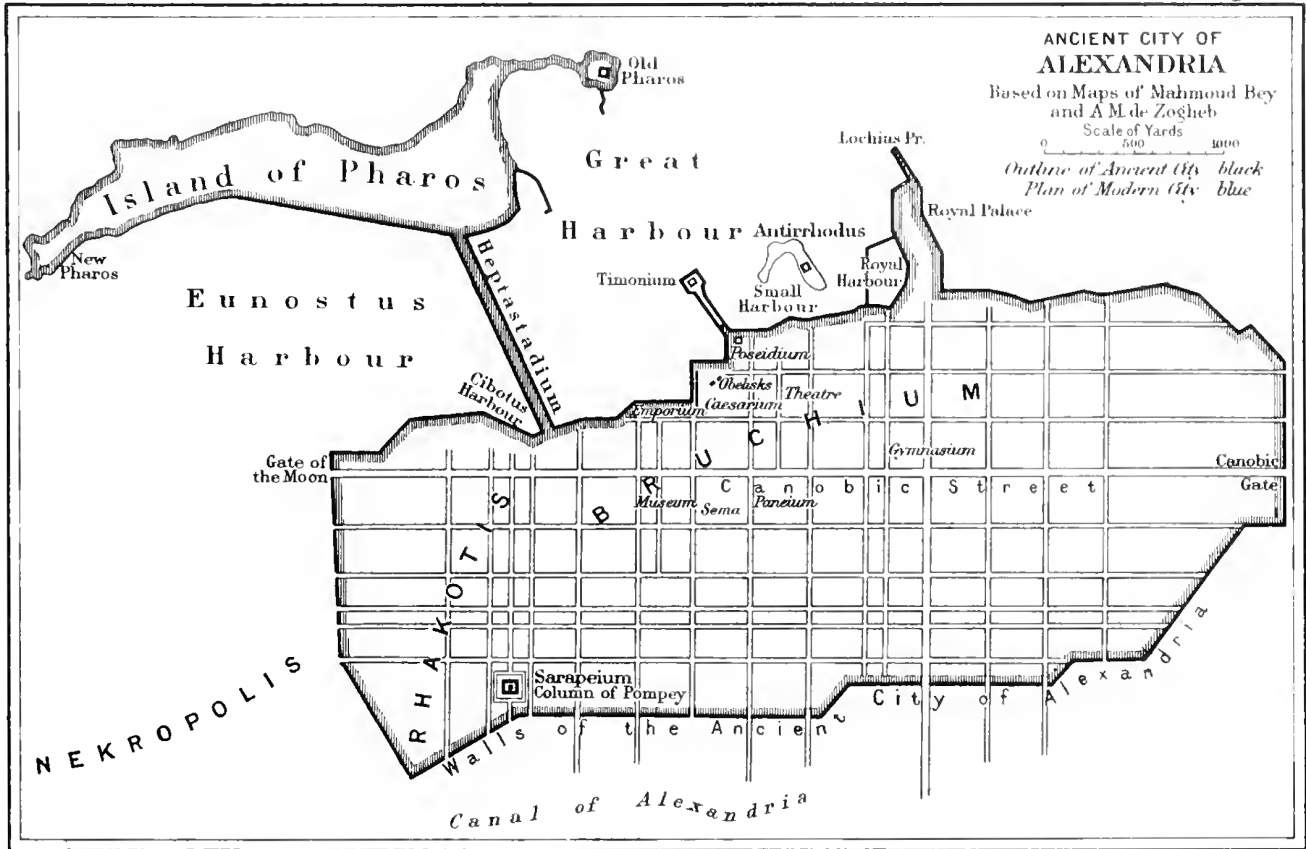


Figure 5-9: A map of the Ancient City of Alexandria, redrawn and based upon ancient maps by Mahmoud Bey and A. M. de Zogheb. Of particular note is the location of the small islet to the east of the main island on which the Pharos was built. For easier access it was soon bridged by a structure called the Heptastadion (Greek) or Heptastadium (Roman).¹¹⁸

formed by the sea and the two streams of the river; and it is called Delta on account of the similarity of its shape; and the district at the vertex has been given the same name because it is the beginning of the above-mentioned figure; and the village there is also called Delta. Now there are two mouths of the Nile, of which one is called Pelusiatic and the other Canobic or Heracleiote; but between these there are five other outlets, those at least that are worth mentioning, and several that are smaller; for, beginning with the first parts of the Delta, many branches of the river have been split off throughout the whole island and have formed many streams and islands, so that the whole Delta has become navigable – canals on canals having been cut, which are navigated with such ease that some people even use earthenware ferry boats.”¹²

Remarkably, Herodotus, writing some four hundred years earlier, went to great trouble to

describe in almost scientific detail, not just the distances involved, but also the characteristics of the area. It was he who gave memorable descriptions of the impact that the Nile had on the geography of the Nile Delta and surrounding lands. It was clear to him that the shape of the coastline and thus the available land was in a constant state of flux as the Nile changed its pattern of alluvial deposits over centuries. He wrote:

“I am convinced that the Delta is alluvial land and has only recently appeared above the water.”¹³

Homer created confusion about the distance of the island from the shore by referring to a “day’s sailing”:

“There is an island called Pharos in the rolling seas off the mouth of the Nile, the day’s sailing for a ship with a roaring wind astern. In this island is a sheltered cove where sailors put in to draw their water from a well and afterwards launch their trim ships

into the deep sea. It was here that the gods kept me for 20 days; and all that time there was never a sign of the offshore breezes that speed ships out and into the open sea.”¹⁴

We know now that the island was about 1 km off the coast. The reason for this supposed mistake was simple. Homer had no word for the Nile, so he used his word Aigyptos in two ways: when in the feminine, he meant the land of Egypt, whereas when he mentioned it in the masculine, he was referring to the river of Egypt. The whole day of sailing was necessary to reach the Canopic mouth of the Nile that, of course, was the gateway to Egypt.¹⁵

The site chosen for the building of the Pharos was at the eastern tip of the island, which soon afterwards, of necessity, became linked to the mainland by a causeway called the Heptastadium. This resulted in a kind of ‘T’-shape with an eastern and a western harbour that still exist today. Homer’s advertisement of Pharos Island as a safe harbour had been successful and there was already a settlement there when Alexander arrived. He recognized it as a place of natural defence and decided that the most useful harbour should also become a defended site. This probably meant that the function of defence was already implicit in any design that might be created.

Strabo went on to describe the harbour zone in some detail:

“In the Great Harbour at the entrance, on the right hand, are the island and the tower Pharos, and on the other hand are the reefs [also known as Hog’s Back Rocks or the Choirades; the rock known as the Bull’s horn was also nearby] and also the promontory Lochias, with a royal palace upon it; and on sailing into the harbour one comes, on the left, to the inner royal palaces, which are continuous with those on Lochias and have groves and numerous lodges painted in various colours. Below these lies the harbour that was dug by the hand of man and is hidden from view, the private property of the kings, as also Antirrhodos, an isle lying off the artificial harbour, which has both a royal palace and a small harbour. They so called it as being a rival of Rhodes. Above the artificial harbour lies the theatre then the Poseidium — an elbow, as it were, projecting from the Emporium, as it is

called, and containing a temple of Poseidon. To this elbow of land Antony added a mole projecting still farther, into the middle of a harbour, and on the extremity of it built a royal lodge which he called Timonium. This was his last act, when, forsaken by his friends, he sailed away to Alexandria after his misfortune at Actium, having chosen to live the life of a Timon the rest of his days, which he intended to spend in solitude from all those friends. Then one comes to the Caesarium and the Emporium and the warehouses and after these to the ship-houses [dockyards], which extend as far as the Heptastadium. So much for the Great Harbour and its surroundings.”¹⁶

Writing around 90 CE, about the siege of Gamla which took place around 66/7 CE, Josephus also described how difficult it was to get to Egypt and of entering the port of Alexandria:

“So upon the exhortations of Mucianus, and the other commanders, that he would accept of the Empire; and upon that of the rest of the army, who cried out, that they were willing to be led against all his opposers, he was in the first place intent upon gaining the dominion over Alexandria; as knowing that Egypt was of the greatest consequence in order to obtain the intire government: because of its supplying of corn [to Rome]. Which corn, if he could be master of, he hoped to dethrone Vitellius; supposing he should aim to keep the Empire by force: (for he would not be able to support himself, if the multitude at Rome should once be in want of food:) and because he was desirous to join the two legions that were at Alexandria to the other legions that were with him. He also considered with himself, that he should then have that country for a defence to himself against the uncertainty of fortune. For Egypt is hard to be entered by land; and hath no good havens by sea. It hath on the west the dry deserts of Libya; and on the south Siene, that divides it from Ethiopia; as well as the cataracts of Nile, that cannot be sailed over: and on the east the Red Sea, extended as far as Coptus; and it is fortified on the north by the land that reaches to Syria; together with that called the Egyptian Sea; having no havens in it for ships. And thus is Egypt walled about on every side. Its length, between Pelusium and Siene,

is two thousand furlongs. And the passage by sea from Plinthine to Pelusium is three thousand six hundred furlongs. Its river Nile is navigable as far as the city called Elephantine: the forenamed cataracts hindring ships from going any farther. The haven also of Alexandria is not entred by the mariners without difficulty, even in times of peace. For the passage inward is narrow, and full of rocks, that lie under the water; which oblige the mariners to turn from a straight direction. Its left side is blocked up by works made by mens hands on both sides. On its right side lies the island called Pharos, which is situate just before the entrance, and supports a very great tower, that affords the sight of a fire to such as sail within three hundred furlongs¹⁷ of it; that ships may cast anchor a great way off in the night time, by reason of the difficulty of sailing nearer. About this island are built very great peers, the handywork of men. Against which, when the sea dashes itself, and its waves are broken against those boundaries, the navigation becomes very troublesome, and the entrance through so narrow a passage is rendred dangerous. Yet is the haven it self, when you are got into it, a very safe one; and of thirty furlongs in largeness. Into which is brought what the country wants in order to its happiness; as also what abundance the country affords, more than it wants it self, is hence distributed into all the habitable earth.”¹⁸

A Greek trading colony was founded further inland at Naukratis in the 7th century BCE. According to Herodotus, it was:

“... the only trading post in Egypt, and anyone who brought a ship into any of the other mouths of the Nile was bound to state an oath that he did so of necessity and then proceed to the Canopic mouth; should contrary winds prevent him from doing so, he had to carry his freight to Naucratis in barges all round the Delta, which shows the exclusive privilege the port enjoyed.”¹⁹

From Fig. 5-9, it appears that the actual site on which the Pharos was constructed was once a small island in its own right.²⁰ It would have been an important first step to bridge the gap of a few hundred metres with landfill from Pharos, thus extending the island to the east.

In the second century CE, an Alexandrian resident called Achilles Tattius described the Pharos as:

“... the most remarkable and extraordinary structure upon which it rested; it was like a mountain, almost reaching the clouds, in the middle of the sea. Below the building flowed the waters; it seemed to be as if it were suspended above their surface, while at the top of this mountain rose a second sun to be a guide for ships.”²¹

Later in its lifetime, the two ports of Alexandria were delineated as eastern (Christian ships) and western (Muslim ships).

The Architect

It is generally accepted that Ptolemy commissioned an architect called Sostratus of Cnidus to design the Pharos.²² This is because the only writer to explicitly name someone as directly responsible was Strabo, himself the writer closest to the date of the event. The stories associated with Sostratus are almost uncontested. (Vorderstrasse says that Islamic authors frequently named Alexander as the ‘builder’ of the Pharos.²³)

Another architect of great lighthouses, Alan Stevenson, in his own treatise wrote:

“It is recorded by Strabo, that the architect Sostratus, the son of Dexiphanes, having first secretly cut his own name on the solid walls of the building, covered the words with plaster, and, in obedience to Ptolemy’s command, made the following inscription on the plaster—” King Ptolemy to the gods, the saviours, for the benefit of sailors.” What truth there may be in this account of the fraud of Sostratus there is now no means of determining ; and the story is only now interesting, in so far as it shows the object of the royal founder and the use of the tower.”²⁴

The story may have originated from Lucian of Samosata who wrote:

Recollect how the Cnidian architect acted, who built the famous light-house on Pharos, one of the greatest and most splendid works in the world, to give a signal from its top to the mariners by night, how to avoid the dangerous cliffs of Paraetonium. When he had finished that lofty edifice, he carved his own name on a stone of the building; but the

name of the then reigning king he inscribed only in the plaster with which the stone was coated: well knowing that this inscription would in a little while drop off with the mortar, and then everyone would read the words: "Sostratus, the son of Dexiphanes of Cnidos, to the gods-preservers, in behalf of mariners." - This Sostratus therefore looked beyond the short space of his own life, into the present; and all future ages, as long as the light-house of Pharos, the monument of his skill shall last. Thus ought history to be wrote, rather with veracity for future hopes, than with adulation, for the gratification of those who are yet alive.²⁵

In his substantial description of the Pharos, Fraser remains closest to providing the most precise analysis of this detail. He discusses difficulties due to assigning Sostratus as the architect. He prefers to think of Sostratus as a benefactor to the project, providing significant financial back-up as a loyal courtier.²⁶ Having carefully studied the original Greek sources, he attributes the role of architect for Sostratus as a mistranslation by Pliny into Latin and confusion between words meaning 'dedicant' and 'architect'. According to Fraser, Pliny chose the word 'architect' when he should have written 'dedicant'. Fraser writes that Sostratus was identified as the designer of other engineering projects, but decides that he was misidentified, confused with another person of the same name who was an envoy of Ptolemy Philadelphus around 270 BCE. According to Fraser, the architect is unknown. He is certain, however, that the Pharos was:

"... one of the earliest Alexandrian buildings of which we know. It was also probably the earliest architecturally developed lighthouse, and was the direct or indirect model of many others throughout the Greco-Roman world."²⁷

This is a most important conclusion in view of material discussed in these papers.

The popular story of Sostratus that was alluded to by Stevenson but has no solid foundation in fact was inevitably relayed by others. Thus the Victorian writer Hardy thus:

The architect's name was Sostratus, and he, desiring to be perpetually remembered in connection with the lighthouse, cut deeply into one of the stones these words: 'Sostratus of Guidos (Cnidos), son of Dixiphanus, to the Gods protecting those upon the sea.' Then

- being assured that Ptolemy would permit no name save his own to be remembered in connection with the work - he coated over the inscription with a layer of cement, and placed thereon one wholly laudatory of Ptolemy and associating his name alone with the erection of the pillar. Time went by; monarch and architect had been gathered to their fathers, and at last the cement began to crack, and then drop away; bit by bit it vanished together with the writing upon it, and the letters on the true face of the stone beneath stood out clear and readable - then the world knew to whose skill was due this blessing to sailors and travellers!"²⁸

The Structure

During the latter part of the 20th century, new archaeological remains were discovered in the shallow waters of the bay adjacent to the site of the Pharos. It was in 1737 that the idea of remains of the lighthouse was first put forward by Robert Pococke. It was a team supported by UNESCO under Honor Frost, that made some major finds, and later, in 1994, it became clear that there was much research to be initiated underwater. These events prompted Empereur, one of the leading participants, to report the findings to a wide audience and to take the opportunity to publish a new history of the Pharos.²⁹ The finds provided important evidence of its existence and some new clues about its structure, but no confirmation of the details of the design, particularly the internal structure, which are still a matter for debate.

From the summary of evidence collected by many previous academics, we can be quite sure about some details. The main body of the tower consisted of three parts of diminishing cross-section. The bottom third was a most substantial square tower. The central section was octagonal in shape, whilst the top was short and cylindrical with an open lantern area. On the pinnacle of the tower was a 5 m tall statue of Zeus or Neptune (Poseidon).

I believe the octagonal shape was chosen because of a direct correlation with the mariner's ancient compass rose (although, of course, he had no compass at the time). Awareness of the wind direction was essential to ancient mariners.

Lucian also attested to the skills and knowledge



Fig. 5-10: An 18th century drawing of the Tower of the Winds in Athens showing the proposed bronze weather vane.¹²⁰



Fig. 5-11: It is generally agreed that the Pharos was topped with a statue of Zeus Soter. Descriptions of it are consistent with it being rotatable in the wind, a theory proposed by Lowe.^{121 122}



Fig. 5-12: A sketch of a typical Triton blowing a conch shell. These sculptures were used to represent each of eight winds at the corners of the octagonal section of the Pharos where they were inspirational in the design of the Tower of the Winds.¹¹⁹

displayed by the architect, agreed generally today as Sostratus, who had made engineering successes elsewhere.³⁰ Lucian took detailed measurements and described a building of three storeys, the bottom being square in section, the middle octagonal and the top circular, and total height being 133 m. Many representations have been made that should be quite representative of the original.³¹

The first modern, in-depth study of the Pharos was made by the German, Hermann Thiersch, in 1909. Thiersch had built upon the work of Alfred J. Butler, who published detailed information taken from studies of the Pharos during the centuries when it was under the control of the Arabs.^{32 33}

A number of different variations took place during the course of the 1600 years of the tower's existence. For the initial design, a reasonably flat building site was prepared that was about 110 m square and about 7 m above the sea on a small islet about 150 m off the eastern tip of the main island of Pharos. The building site was bridged to the main island with infill.

The lower section of the main body of the tower was 30 m square and 72 m high; the middle section octagonal, 17 m across and 35 m high; the top section cylindrical, 9 m diameter and 15 m high, surmounted with a statue of 9 m height. Unfortunately, measurements are approximate because of differences in units of measurement, and having been misreported in various sources over



Fig. 5-13: A detail of one of eight decorative features around the top of the Tower of the Winds shown in Fig. 5-10, shows the north wind known as Boreas blowing a conch shell. (This is a tropical marine mollusc with a robust spiral shell which may bear long projections and have a flared lip.) We see this as further evidence that the Tower of the Winds was influenced by ideas exhibited on the Pharos.¹²³

time. Units in question are the ancient ell, cubit, palm, or span. Both the ell and cubit were defined as the length of a man's arm from the elbow to the tip of the middle finger, but that length could vary. Thiersch, for example, states that an ell is 0.54 meters or approximately 21 inches. More commonly, it is defined as 0.46 meters or 18 inches.

It is commonly believed that the base of the tower was later surrounded to the 110 m square limit by a fortified, possibly colonnaded stone structure of two or (in parts) three stories, designed to help resist the wave action that, from time to time, caused damage to the base of the lighthouse. (Fig. 5-14.) This structure was capable of providing additional accommodation to troops garrisoned on the island. The first occasion of damage by enemy military action was probably during the attacks by the Romans, first under Julius Caesar in 48-47 BCE and later Octavian who fought with Queen Cleopatra around 30 BCE. Damage to the Pharos was repaired soon afterwards and may have resulted in this additional fortification.

The use of rectangular and circular geometries is quite understandable, but the use of the octagon is puzzling. The most obvious answer is its relationship to the compass rose. Without necessarily having words to identify them, early hominins made an association of east and west with the sun some time near the start of human consciousness. It was followed quite naturally with the recognition of north and south. This led to four main points of direction that lasted across all cultures

for many thousands of years. As navigation methods developed, it seemed natural to identify winds that were slightly off the four main cardinals, so increasing the directions either side of the four led to a rose of twelve directions, all associated with winds that were of fundamental importance to mariners. However, many mariners also concluded that it was sufficient to define directions that were midway between the four, and so an eight-point rose was also created.³⁴ Men working at the level of the lantern of the Pharos would have been instantly aware of the direction of the wind (as well as, perhaps, the direction of the smoke from the fire) by looking down at the compass rose displayed by the octagon beneath their feet. One of the finest reminders of this is the *Torre Dels Vents* (Tower of the Winds) in Athens, a perfect example of how the ancients divided the compass into eight directions, as shown in Fig. 5-10 and also in Fig. 2-16. I am sure that this is the reason why the octagonal shape was used for the central section of the Pharos.³⁵

In 2016, after this work was begun, Lowe published a paper that has added a new level of interest to the installation of the statue of Zeus Soter.³² He has presented a detailed study of monumental weather vanes and evidence of clear relationships between the Pharos and the Tower of the Winds in Athens that has already been mentioned (Fig. 2-16).

Early work has already clarified the history of the Athens structure, identifying it as a combina-



Fig. 5-14: An impression of the Pharos of Alexandria depicting the lighthouse surrounded by a 110 m square accommodation building, possibly constructed during the Roman period and used as a military barracks. It offered increased protection of the lighthouse from wave damage. The image offers the addition of a mirror mounted on the cylindrical section just below the lantern level.¹²⁴

tion of wind-vane, sundials and water-clock.^{36 40} It was built at least as early as 37 BCE and possibly in the second century BCE.³² Far from being a simple - though ornate - monument, it was in fact a complex design of horologion (a timepiece) that was intimately associated with seasons and weather. As a clepsydra - an ancient time-measuring device worked by a flow of water - it combined with sundials that could add extra information as to season, and on the highest point, a movable device could indicate wind direction. On each of the eight sides of the supporting tower were representations of the eight winds of the compass. Fig. 5-13 is a representation of sculptures used to represent winds on the Pharos and is similar to the image Boreas carved into the Tower of the Winds for the north wind.

Vitruvius wrote a detailed account of the Tower of the Winds, which he said had been largely built by Andronicus of Cyrrhus. In particular he described a weather vane for the first time.

“On top of the tower he set a conical shaped piece of marble and on this a bronze Triton with a rod outstretched in its right hand. It was so contrived as to go round with the wind, always stopping to face the breeze and holding its rod as a pointer directly over the representation of the wind that was blowing.”³⁷

For a writer with the reputation of Vitruvius to describe such a device on the Tower of the Winds lends much credibility to the idea that weather vanes had been devised, along with their methods of installation and that these ideas had emanated from the most technically advanced city in the world - Alexandria. The possibility that such a device had first been tried out on the Pharos cannot be ignored. Lowe believes that the Pharos was indeed the inspiration for the Tower of the Winds and that the complexity of the latter was conceived and executed thanks to cutting edge science and engineering practices developed in Alexandria.

Regrettably, knowledge of the mechanistic aspects were lost due to damage and theft over centuries. This left the Tower shrouded in mystery as to its true purposes until it was re-evaluated from the 18th c. onwards. The re-invention of its designs suggested a bronze weather vane that moved with the wind, as shown in Fig. 5-10 and Fig. 5-11. This would unquestionably be the first of its kind if it did not immediately raise the possibility that the statue of Zeus Soter atop the Pharos had been designed in a similar fashion.

Part of the design of a weather vane is an asymmetrically weighted object that catches the wind and turns to point in the same direction from which the wind blows. Many observers were keen to point out that the statue of Zeus held aloft a tool, said by some to be a thunderbolt or a royal sceptre. Lowe, however, considers it more likely to be a sceptre-like rudder that symbolized the protection of ships.

Thiersch had already written in some detail about the possibility of the Zeus statue on top of the Pharos being used as a weather vane and had discounted the possibility, but it is not hard to see how he might have been too pessimistic. In a more positive sense, he also described water-clock systems in the Pharos that were similar to those in the Tower of the Winds, and was clear about just how wonderful the Pharos had been for its inclusion of devices based on the latest engineering science. More information can be found in the Appendix at the end of this paper.

The Materials

We thank Strabo for telling us that the Pharos was built of “white stone” (leukos lithos).³⁸ The bright colour of the surface led to a description by Posidippus in a well-known epigram already given above, that the tower had a very high visibility in the daytime too.

McKenzie makes the best summary of the materials used.³⁹ In 1154, al-Idrisi had reported that the lighthouse was built of ‘excellent stones of a type known as caddzan (kadhhdhan).’ Butler⁴⁰ calls it Tiburtine, which seems to have been an old name for the more usual Travertine, a common light-coloured calciferous stone much used in Rome. This is a hard type of limestone - almost marble - with a high degree of durability. The sites where the stone was excavated are not known, but it is not an

uncommon material.

In addition, red granite was used for items such as lintels, door frames, and also for decorative elements. The method of building appears to have involved very large blocks of stone held together by lead clamps, examples of which have been found on the seabed in the harbour.

The Inscriptions

It is said that Ptolemy instructed Sostratus to ensure that the name of Ptolemy was in a position of prominence. Thus, the people of succeeding generations could marvel at the vision and power of this great king. In this apocryphal tale, Sostratus decided that his own contribution should not go unrecognized. It was Lucian who, around 150 CE who promoted the story:

“Do you know the story of the great Cnidian architect? He was the builder of that incomparable work, whether for size or beauty, the Pharos tower. Its light was to warn ships far out at sea, and save them from running on the Paraetonia, a spot so fatal to all who get among its reefs that escape is said to be hopeless. When the building was done, he inscribed on the actual masonry his own name, but covered this up with plaster, on which he then added the name of the reigning king. He knew that, as happened later, letters and plaster would fall off together, and reveal the words:

**SOSTRATUS SON OF DEXIPHANES OF CNIDUS
ON BEHALF OF ALL MARINERS
TO THE SAVIOUR GODS**

He looked not, it appears, to that time, nor to the space of his own little life, but to this time, and to all time, as long as his tower shall stand and his art abide.”⁴¹

Lucian, however, was not a historian and may have exaggerated the story.

Strabo, a man more inclined with fact than journalism, paraphrases the dedicatory inscription thus:

“Sostratus the Cnidian, friend of the sovereigns, dedicated this, for the sake of the safety of those who sail the seas, as the inscription says ...”³³



Fig. 5-15: In the Chapel of Zen (or Zeno) in the baptistry of the Basilica of Saint Mark in Venice, a mosaic dated around 1200 CE depicts the arrival of St. Mark in Alexandria, bringing the word of the Gospel.¹²⁵

Dedications

It could be argued that when little is understood about the science of the natural world, it becomes important to rationalize - indeed, to influence, the world around you by invoking relationships with supernatural beings. This was as true for the Greeks, as for any other culture. As the Greek culture developed, a large number of gods were realized, each with its own identity, related to human history wherever possible, and with a place in a hierarchy of the spiritual world. Links to these gods were formalized so that in a given situation it was clear which god was relevant.

The Greeks had twelve principle deities, at the top of which seniority list came Zeus. Hades and Poseidon were his brothers, the former presided over the Underworld, whilst the latter was Lord of the Sea. Without a sacred text, it was to Homer's two texts - the *Odyssey* and the *Iliad*, that Greeks looked for religious inspiration. There were many ways in which Greeks were motivated to smooth the path of daily life, not least of which was a sanctuary. An essay published on the New York Metropolitan Museum of Art website explains:

"The Greeks worshipped in sanctuaries located, according to the nature of the particular deity, either within the city or in the countryside. A sanctuary was a well-defined sacred space set apart usually by an enclosure wall. This

*sacred precinct, also known as a temenos, contained the temple with a monumental cult image of the deity, an outdoor altar, statues and votive offerings to the gods, and often features of landscape such as sacred trees or springs. Many temples benefited from their natural surroundings, which helped to express the character of the divinities. For instance, the temple at Sounion dedicated to Poseidon, god of the sea, commands a spectacular view of the water on three sides."*⁴²

It was therefore entirely appropriate to dedicate the Pharos to relevant gods, in particular, those which could oversee safety at sea. For the Pharos, there was already a reference to the location in Homer, who had written in his tale of Menelaus:

*"This island is the haunt of that immortal seer, Proteus of Egypt, the Old Man of the Sea, who owes allegiance to Poseidon and knows the depth of all the seas."*⁴³

In the poem by Posidippus quoted earlier, he expressed an invocation to Proteus, the island's patron. Besides making reference to the safety that mariners would feel on approaching Alexandria and seeing the tall lighthouse from an extreme distance, he wrote that a sailor "might run to the very Bull's Horn" - a rock at the entrance to the channel of the Great Harbour, whilst guided by the statue of Zeus himself on the pinnacle of the tower.^{44 45}

According to Fraser, the use of the phrase ‘Saviour gods’ can be interpreted in two ways: first, as a reference to Ptolemy Soter and his wife Berenice; second to Castor and Pollux who were invoked by sacrifice to assist those travelling by sea. Fraser is unwilling to make any conclusions.^{37 46}

The Statues

Great statues of Ptolemy and his queen stood in front of the Pharos on the side facing the port entrance. Floors on the inside of the inclined plane or staircase would have permitted many inner rooms or corridors for accommodation of troops or others, whilst an inner well could have run from the ground to the lantern level, allowing other items to be hoisted to the top more easily. The outer ramp leading to the main entrance door, is said to have had sixteen arches.

The Greek poet, Posidippus de Pella, a contemporary of the new lighthouse, wrote a romantic verse that included elements of the structure of the Pharos and made it clear that the statue on the top was of Zeus. We can be confident of this, at least for the earliest period of the existence of the Pharos. It may well have been changed later, especially after damage by earthquake.

Both Poseidon and Helios are other gods reported to have adorned the cupola of the Pharos in later centuries. Isis and Poseidon, the two main deities for ships and mariners, are said to have each had a temple close to the foot of the Pharos, and their presence somewhere on the lighthouse itself is very likely at some time during the tower’s long lifespan.

Empereur believes it was Zeus that topped out the Pharos, at least until the city fell under the power of the Romans, for it was Zeus who was closely associated with the Ptolemaic dynasty and who featured on many coins of the period.⁴⁷ (A selection of coins depicting the Pharos is given in Fig. 5-24.)

Originally, it was Amun who was the worshipped deity, but over time the god assumed greater importance until he was promoted to King of Gods. He then transformed into Zeus-Ammon, known to the Greeks simply as Zeus.

Change probably occurred once more when Roman Emperor Theodosius brought Christianity to Alexandria and banned the old pagan gods in 391 CE.

Empereur supposes that a statue representing some element of Christianity, perhaps Christ himself, might have followed. Alexandria was a common port of call during the spread of Christianity, as illustrated in Fig. 5-15.

The Heptastadion

As activities in the port of Alexandria increased, there arose a link between the island of Pharos and the shore. It was called the Heptastadion, which means that it was seven stadiums in length, and since 1 stadium (stadion or stade) is considered to be between 150 and 200 m, then it was about 1 to 1.4 km long. Strabo’s description was that:

“... the embankment forms a bridge extending from the mainland to the western portion of the island, and leaves open only two passages into the harbour of Eunostos, which are bridged over.”⁴⁸

The presence of a land bridge from the mainland to the island led to the formation of two harbours, to the east and west, with the island of Pharos as the cross bar to a ‘T’-shaped spit of land.

Fraser says that there were two arches in the Heptastadion, allowing ships to cross from the less important Eunostos harbour in the west to the Great Harbour harbour in the east. There was also a water supply provided to the island, but this was destroyed during the battles with the forces of Julius Caesar in 48-47 BCE.

Its creation was probably deliberate at first, so as to facilitate the movement of stores and materials onto the island. Having constructed an artificial barrier to the natural flows of water it probably then silted up, allowing further development.

Jones notes in his translation of Strabo that the Heptastadium:

“... has been so much enlarged by alluvial deposits and debris from the old city that it is now, generally speaking, a mile wide, and forms a large part of the site of the city today.”⁴¹

Indeed, aerial views of the city today, Fig. 5-5, will find no evidence that the land between the two harbours was ever a small causeway.

Fraser makes some interesting points about the Heptastadion:

“It formed the main inhabited area of the

city until the nineteenth century, at a time when the chief residential quarters of today, round the ancient Great Harbour, were largely sand-hills. It is therefore not surprising that no trace of the Heptastadion has been discovered. Its construction is evidently presupposed by the story of the Translators of the Greek Bible, as recorded by pseudo-Aristeas (in itself the earliest surviving reference), according to whom Demetrius of Phaleron led the Translators across the mole to their quarters on the island. It is likely that it was one of the first engineering operations, carried out either by Cleomenes or Ptolemy Soter. Quite apart from its importance as linking the city with Pharos, its construction was also an essential part of the development of the harbours, for it broke the force of the prevailing current and provided the eastern harbours with much-needed protection.”⁴⁹

We read from Fraser’s comments that accommodation was available on the island, yet there seem to have been intermittent periods when it was uninhabited. Ancient accounts describe an aqueduct that fell into disrepair when the island was uninhabited. The ideas appear to be contradictory, for it would be most surprising if, during the existence of such a massive structure, it did not house a large number of people.

We can be fairly certain that there were, from time to time, large garrisons of troops on the island, so perhaps it was to supply these men that the aqueduct was built, rather than those who merely looked after the functions of the lighthouse. Nevertheless, we can be confident that with such a vast interior and so many rooms, the Pharos would also have been much lived in. The details of the water supply to the island will probably remain unknown. Greeks used the word *diolkos* for a paved track that was used to move heavy loads. It was most famously used for the name of the narrow isthmus of land that bridged northern and southern Greece at Corinth. Boats could be dragged across the *diolkos*, thereby making a passage between the Aegean and the Ionian Seas and greatly shortening their voyages. In a smaller way, the *diolkos* at Alexandria allowed boats to pass between the two harbours, but it could also be used just as a slipway. Today, its precise location remains unclear.⁵⁰

Demise

The basic structure of the Pharos lasted from 280 BCE until 1303 or 1375 - around 1600 years, but suffered many severe events during that time, Fig. 5-16. The last traces of the lighthouse disappeared when the site was built upon in 1480.

During the 1600 years of its existence it was rebuilt and modified many times. Holy Roman Emperor Anastasius I (491-518 CE) carried out repairs to the base of the tower after storm damage in 491. Alexandria came under Muslim rule in 641 CE and the lantern level was changed into a mosque around 835 CE by Ahmed Ibn Touloun who governed Egypt and Syria from 868 to 884 CE.⁵¹

In 796 CE the lantern collapsed during an earthquake. Then in 951 CE, an earthquake shook Egypt, destroying many houses. The lighthouse was cracked but apparently did not suffer major damage. However, an earthquake further damaged it in 956 CE, causing severe damage at the level of the lantern. It is said that the ground shook violently for thirty minutes. The lantern was once again re-built, this time to incorporate a mosque as well as an open brazier, to show a light by night and smoke by day. In 1262 CE, a great earthquake caused severe damage across much of Egypt and the lighthouse was once again badly damaged, barely surviving the accompanying tsunami. It is not known exactly how much of the tower collapsed. Presumably, it was enough to prevent it functioning as a lighthouse. The finale of this great story began in 1303 CE when another violent earthquake caused irrevocable damage to the lighthouse. A record by a visitor recorded:

“In the year 1303, August 8, there was a great earthquake in Alexandria that brought down the lighthouse and the third well of the city.”

It is understood that there was also a tsunami to make matters worse. Repairs were attempted, but limited in extent.

In 1349, an Arab cartographer from Montpellier, Ibn Battuta, visited Alexandria. According to his account:

“When I arrived at the lighthouse, I found that the state of dilapidation was such that it was not possible to enter by the entrance door.”⁵²

By 1375, the lighthouse was effectively in ruins after yet another earthquake. Then, in 1477-8 a Turkish Sultan called Qait (Kait) Bey (today, Qait-



Fig. 5-16: Three impressions of damage to the Pharos caused by earthquakes in 796, 951 and 1303 CE, as well as by severe waves and even a tsunami (left).¹²⁶ With varying degrees of success, repairs were attempted on each occasion, causing changes to the form and size of the tower. By 1375, virtually all of the structure had been destroyed. The last traces of the lighthouse were removed in 1480 when the site was used for a fort called Qaitbay. For a complete time line of the Pharos see Table 5-3.

bay) used the great base as the foundation for the construction of a fort known after him. The fort stands there today, and many stone blocks of the Pharos are an integral part of the fabric of the fort. Visitors can content themselves by inspecting the square base of the fort whereupon they should find that its measurements closely match the original base of the Pharos.



Recovery

In the second half of the twentieth century, it was at last realized that there were large quantities of the original lighthouse resting on the seabed adjacent to the site of the Pharos.

Honor Frost (1917-2010) was born in Cyprus and brought up in London. In 1968 UNESCO appointed her into the lead role in the first underwater dives on the Alexandrian seabed and became a leading exponent of the now blooming subject of underwater archaeology. She dived the site and confirmed the existence of ruins representing part of the Pharos as well as the remains of submerged buildings representing the lost palace of Alexander and the Ptolemies, and published a preliminary report with drawings which revealed the site's importance.⁵³

From 1994 onwards, a new major project has been undertaken by a joint Egyptian-French team under the leadership of Jean-Yves Empereur at the Centre for Alexandrine Studies. They found the site to be extensive. Because of its significance, a part of their report is reproduced here.

“Over an area of 2.5 hectares, 2,500 pieces of stonework of archaeological interest were scattered about: columns of all sizes, in their hundreds, column bases and capitals, sphinxes, statues, and some immense blocks of granite which, given where they lie, certainly came from the famous lighthouse.

“Hundreds of columns, mostly in pink granite from Aswan, but some of marble, range from the small modules of the small columns of Proconnesis up to the huge granite column shafts which reach 2.40 m in diameter; that is, the width of Pompey's Column. This column was erected in honour of Diocletian and is one of the few monuments of [ancient] Alexandria still standing. This monolith is made of pink Aswan granite; it is 29.7 m high with a diameter between 2.7 m at its base and 2.4 m at its peak. The capitals belonging to these columns are of composite-Alexandria style, with floral volutes, sometimes in white marble or black granite. There were also several large bases of Ionic form in white marble. Alongside these architectural elements of Greek style, there were some pieces from pharaonic monuments, notably six papyriform columns, of which one bears Ramses II's insignia. There

were four obelisks; three were consecrated by Sethi I and the other is from a much later period, belonging no doubt to one of the Ptolemies. The first three thus date from the XIX dynasty, near the end of the 14th century BCE, and the latter, from the early 3rd century BCE.

“Several sculptures belong to the pharaonic era; there were 28 sphinxes, bearing the insignia of the Pharaohs Sesostris III (XII dynasty), Sethi I, Ramses II (XIX dynasty) and Psammetic II (XXVI dynasty). Their dates therefore range from the Middle Kingdom up to the last dynasties, or the mid-19th century BCE to the early-6th century BCE.

“The presence of some pharaonic elements cannot fail to surprise us. Fortunately, two Egyptologists from IFAO, Jean-Pierre Corteggiani and Georges Soukiassian, were team members; underwater, they deciphered the hieroglyphics that most of the monuments bear. Several facts must be pointed out immediately: each sphinx is different from every other, so we must exclude the possibility that they formed part of an approach to a monument. All the inscriptions describe scenes of offerings to the divinities of Heliopolis, as do the inscriptions on the obelisks found at the underwater site.

“In the Hellenistic era, the venerable sanctuary of Rê was no more than ruins; Strabo described them as being abandoned. The sanctuary was burned down and thereafter became a veritable quarry. Strabo tells us, ‘Among the obelisks, two that had not been totally destroyed were transported to Rome’. This was about 25 BCE, and this exploitation of the Heliopolis site [as a quarry] had begun during the reign of the Ptolemies.

“Obviously, the transportation posed hardly any problems, crossing the Canopic Branch of the Nile then the canal that arrived at Alexandria between Lake Mariout and the southern part of the city wall. Given the good state of conservation of some of these monuments, we must suppose that they served to decorate the city, as did certain discoveries at the terrestrial archaeological sites. Cleopatra's Needles, the two obelisks that had been placed in front of the Caesarium



Fig. 5-17: Artist's impression of a fire cresset inside the lantern of the Pharos.¹²⁷

in 13 BCE, also came from Heliopolis. It is not the place, in this paper, to draw up a list of the pharaonic monuments of Alexandria that we know from the ancient authors or archaeological discovery; we need simply note that the excavations at Qait Bey contribute a new group belonging to this ensemble. Some of the monuments had apparently been transported whole from Heliopolis, as one of the obelisks of Sethi I shows: in one part of the excavation, we found three fragments and two larger parts of the base. It seems unlikely that they would all have arrived at the one place by coincidence."⁵⁴

The Light from the Pharos

One topic about which we know least is the way the light was created and projected out to sea. There are very few instances where the uses and operation of the lighthouse (or, indeed, *any* ancient lighthouse) are discussed. Further detailed discussion of the internal structure will appear be-

low, and I shall discuss the lighting methods again in Part 8. We can make conclusions about some aspects, bearing in mind the state of technology of the time, but the details are unlikely to be clarified further. We must also bear in mind that, over the many centuries the lighthouse existed, there were many changes to both its structure and use, and it is extremely difficult to correlate the structures and various uses with anything other than very approximate years. Nevertheless, let us combine what we do know with the logic of the science available.

A lantern graced the summit, Fig. 5-17. (Even then, the lighthouse had not reached its zenith for a statue of Zeus is believed to have featured on top of the building and that the total height of the Pharos was exceeded only by the Great Pyramid of Cheops.⁵⁵) Whether the lantern was glazed or open to the weather is not known, but it is likely that it was not glazed at any point in history since no references to it have been found so far. Without further comment or support, and referring to lighthouses generally, Stevenson baldly states:



Fig. 5-18: Fuel for the lighthouse fire being carried up the tower. ¹²⁸

“Records of ancient beacons and lighthouses are confined to the mention of their sites and general observations as to their construction. The more important bore fires of wood or torches burning in the open air or perhaps under a roof for protection from rain and wind. The lesser lights may have burned candles or oil lamps in a lantern glazed with sheets of horn or skin, or thinned oyster-shells. Glass panes were used after the 1st century A.D.” ⁵⁶

Stevenson’s reference to “glass panes” can only be applicable to structures elsewhere. However, in this study I have found no references to glass panes used in the lighthouses that have been studied. In the 16th and 17th centuries, lighthouses lit by fire faced real difficulties in this regard because soot coated the inside of the panes of glass and there were problems in dealing with huge amounts of smoke. All this greatly reduced visibility at sea. The sheer scale of the operation in the Pharos would mean that great quantities of smoke would be produced and so the idea of glazing is not sensible. Thus, it is most likely that the lantern, whilst

covered with a roof, was nevertheless open to the atmosphere. (Smoke is, of course, equally valuable as a signal during daylight hours.)

Fraser, an expert on the architecture of Alexandria, stated that:

“... we may rest satisfied that the Pharos was polygonal in shape, and built of three stages, tapering towards the top, and that near the summit there burnt a fire which shone far out to sea.” ^{57 58}

It is possible that light was produced by the burning of other fuels. Oil lamps were available and could certainly have been used at some point. It has been suggested that naphtha could have been used, for a “miraculously flammable liquid” had been reportedly produced in certain places such as Basra and Baku, although perhaps not on a commercial basis until the fifth or sixth century CE. These matters are discussed extensively by Duggan.⁵⁹ Perhaps we might conclude that the inclusion of a wide ramp for easy access up the inside of the tower was to facilitate transport of the voluminous fuel materials to the top of the

lighthouse. This would imply the use of wood for the first light, Fig. 5-18. Open fires are well known to consume large amounts of fuel and this would necessitate the implementation of an effective logistics operation on a big scale. The use of horse-drawn carts or simply pack-horses up the internal ramp is likely in view of the design of the tower. Other organic fuels could have superseded wood at a later date, reducing the need for such a heavy demand for fuel.

We should conclude that the fire was large and generated much light, for later descriptions of the marvels of the tower include reference to the great light generated from the building. Josephus recorded that the light from the Pharos was visible for 300 stadia - translated into 300 furlongs or 35 miles.¹⁸ This is consistent with current knowledge. Calculations show that the distance to the horizon of a viewer at a height of 120 m above sea level is 40 km.⁶⁰ Therefore, we must discount accounts that claimed the light could be seen from 300 miles. Certainly the Earth's curvature would preclude direct observation from such a distance, and it is true that with a sufficiently bright light the glare can be seen from beyond the horizon. However, such a great distance must be much too far.⁶¹ In a cloudless sky, it would have been possible to see smoke from distances greater than 40 km and perhaps this might have given support to mariners heading in the direction of Alexandria.

An outstanding feature of the Pharos was its great height. For ships that were dependent for their navigation on the identification of natural landmarks, it was surely a good idea to make it visible to ships at sea over a far greater distance than the surrounding low land would allow. Ships would find the port of Alexandria easily by day and night and it was good for business to have as many ships as possible visit the port.

The Mirror

A most intriguing feature of the Pharos is the possibility of a mirror or group of mirrors being used in the lighthouse. There are numerous reports of a 'mirror' amongst the descriptions of the Pharos by Muslim writers. Butler devotes space to a discussion of the mirror:

"The lowest, or ground story, was square on plan; the next was octagonal ; the third circular; and the topmost was an

*open lantern containing fireplaces for the beacons and a wonderful mirror."*⁶²

Referring to Arab sources from the ninth and tenth centuries, Butler writes:

*"But even more marvellous stories are told about the mirror, which all the Arab writers agree in regarding, quite apart from the lighthouse on which it stood, as one of the wonders of the world. In the ancient Egyptian city of Rakoti there is said to have been a dome on pillars of brass, all gilded, and above this dome rose a lighthouse, on which was a mirror of composite metal, five spans [1.14 m] in diameter."*⁶³

We note the use of the word 'composite' in this translation for some reports say that the mirror was made of 'Chinese Iron', whilst we can be sure that it would have had a highly polished reflecting surface of a different metal. Another writer alleges that the mirror was made of "finely wrought glass ..." (Zajaj mudabbar is the term used by al-Makrizi).

The mirror had two functions, according to the ancient sources: first it was a telescope used to observe approaching ships, and secondly it was used as a burning-glass to destroy the ships of an enemy.

Speaking of the people of Rhacotis, Murtadi wrote:

*"They made in the midst of that city a little turret on pillars of copper gilt, and set upon it a mirror consisting of diverse materials, in length and breadth five spans, the turret 100 cubits high ... It was used as a burning-glass against the enemy. The Pharos also had not been made but for a mirror that was upon it."*⁶⁴

As usual, such a new invention was soon exaggerated by those who had not seen it. For example, `Abdallah, son of `Amr, is quoted as saying:

One of the wonders of the world is the mirror hanging in the manarah at Alexandria, which shows what is passing at Constantinople.

(We note his use of the word 'manarah' as an Arabic term for 'lighthouse'.) Al-Masudi describes it as:

"... a large mirror of transparent stone, in which ships could be seen coming from Rum [Rome] at too great a distance for the eye to detect them."

These writers are excited about the idea of a de-

vice that could see things from afar. To those who had never seen a telescope, the idea that it could allow things to be seen beyond the horizon was perfectly understandable.

According to Butler, Al-Suyuti wrote that:

"...the mirror was seven cubits [3.15 m] wide; that it showed all ships coming from Europe; and that it was used as a burning-glass. 'They turned the mirror towards the westering sun, and the rays being reflected burned up the enemy's ships.' All say that it showed vessels at sea far beyond the range of common vision: a man sitting under the mirror could see all the way to Constantinople."

"What was the purpose of this mirror? Was it a mere reflector to flash the sun-rays by day and the beacon-light by night? and was it an ordinary mirror, or had it a complex refracting surface, so that it might really serve as a burning-glass under the intense heat of the sun in Egypt? These are questions for men of science: but it is at least curious that, as early as the tenth century of our era, the Arab writers in their account of this mirror should anticipate the use of the telescope. It is also curious that different writers should describe the mirror as made of some transparent material — 'finely wrought glass' and 'transparent stone': for these terms suggest a lens rather than a mirror. Is it conceivable that the great Alexandrian school of mathematics and mechanics discovered and constructed the lens, and that their discovery was lost and forgotten in the destruction of the Pharos?"

"That the Pharos was used as a signal-station as well as lighthouse is certain: but it is not quite clear whether the fire was kept up day and night. Al-Idrisi speaks of a fire by night and 'a cloud of smoke by day': but another account represents the lighthouse keepers as living in the building and ready always to light the beacon by night."⁶⁵

Arculf (c. 670 CE) speaking of this 'very high tower' wrote:

"Men are employed there by whom torches and other masses of wood, which have been collected, are set on fire to serve as a guide to the land, showing the narrow entrance to the straits ... Round the island also,

beams of immense size have been regularly laid down to prevent the foundations from yielding to the constant collision of the sea."

"Unfortunately no evidence of the original practice is obtainable: for the Pharos suffered serious injury within a century of the conquest. The story is that in the caliphate of Al Walîd ibn `Abd al Malik, i.e. early eighth century, the Romans were so annoyed at the advantage which the Pharos gave to the Muslims as a watch-tower against sea-raids and surprises, that they resolved to destroy it by stratagem. Accordingly one of the courtiers of the Emperor went with rich presents to the Caliph, and feigning to have incurred the Emperor's mortal enmity, professed his desire to become a Muslim. He was believed and welcomed to Islâm, and to the friendship of Al Walîd, whose imagination he fired with stories of buried treasure in Syria. This was duly discovered; and the Caliph, becoming greedy of wealth, listened eagerly to the report of the wily Roman, that a vast store of gold and jewels, which had belonged to the ancient kings of Egypt, was buried in vaults and chambers beneath the Pharos. So the Caliph sent troops to conduct the search, and they pulled down half of the lighthouse tower, removing the mirror, before the plot was suspected."⁶⁶

So what conclusions can be made from these observations?

The physics of optics is well understood today and is better placed in a book about lighthouse engineering. This will form a later volume in this series. There is still much uncertainty regarding the design of the optical installation, unhelped by crude illustrations like Fig. 5-19. In his still unsurpassed work, Thiersch presented some possibilities and showed that the ideas at the roots of the stories are both sensible and realistic.⁶⁷

It is inevitable that descriptions by observers of such advanced science would not have possessed the vocabulary or the understanding to make accurate reports. The materials quoted are all suitable for manufacture of the reflecting mirror: polished metal surfaces such as copper, silver and gold are known to work best and various kinds of metal mirrors have been used around the world since very early times.⁶⁸ The use of glass is rather less obvious in mirrors, but could have been used

in lenses.

Received wisdom says that the technology of the telescope did not develop until the 17th century in Europe thanks to people such as Galileo, but it was Ibn al-Haytham (aka Alhazen) (965-1040), an Arab mathematician, astronomer and physicist, who is credited as having laid down the path to the modern subject of optics. However, the Greek mathematician Euclid who was active in Alexandria during the reign of Ptolemy I, discovered much of the geometry regarding the principles of optics of plane and concave surfaces. It is therefore entirely possible for engineers in Alexandria to have created a telescope using reflecting concave surfaces. We can be clear, however, that such technology only works to the visible horizon.

As to the use of a mirror for setting fire to ships at a distance, this is rather more fanciful. The subject has raised much controversy in the past. Archimedes (287-212 BCE) is credited with the invention whereby he actually used a device consisting of one or many mirrors, plane or concave. With this weapon, it is said, he could focus the sun's rays sufficiently to set a ship on fire over a distance of a bowshot - perhaps 200 m.

The principle of whether it can be done is certain - yes, it can. The problem is one of scale: could the device be built large enough to work over such a distance? The biggest issue is that the sun's energy focused for destructive purposes works best over short distances and when the targets are stationary. Neither condition applies to ships.

We are all familiar with the modern satellite TV antenna and its concave design. TV signals are received as parallel waves at a great distance provided they are pointed directly at the source - a transmitting satellite. The signals are reflected from the parabolic surface to a small point called 'the focus' where an amplifier magnifies the TV signal into an electric current that feeds down the cable to the TV.

Where the sun is used as the source, the heat would be focused at the same small point close to the reflector. To move the focus to greater distances, the parabolic shape must be flattened and calculations show that to focus all the heat from the reflected sun's rays onto a small point on a ship, it would render the mirror almost (but not quite) flat.

The balance of probabilities is that ships were



Fig. 5-19: Depiction of the Pharos in a mosaic found at Qasr el-Lebia, Cyrenaica. McKenzie suggests that "Helios is depicted ... beside the mirror."¹²⁹ However, she makes no further comment about her interpretation.

not actually set on fire, but that, after a small demonstration of the kind that schoolchildren achieve on sunny days with magnifying lenses and dry leaves, the *threat* of doing the same to a ship at great distance was enough to raise rumours and real fears in all who heard of it. Amongst ancient god-fearing peoples, the sudden appearance of a very bright light onto ship crews would have been sufficient to cause alarm.⁶⁹

It is hard to conceive of a single arrangement that could have performed both functions. When used as a weapon, therefore, a concave mirror must focus the sun at a point where the ship is positioned, a distance that must surely be more than 100 m. This demands a mirror with a very long focal length and means that it has only a small amount of curvature. The optical requirements for a telescope are entirely different. Some of Thiersch's ideas on the subject can be found in the Appendix at the end of this Paper.



Fig. 5-20: Facsimile of part of the diary made ca. 1106 CE by Abu Hamid al-Gharnati, showing the Pharos of Alexandria.^{130 131}



Fig. 5-21: An illustration to an Arabian tale showing a representation of the Pharos made ca. 1390-1450.¹³²



Fig. 5-22: A 12th century Persian illustration from the Mojmal al-tawarik wa'l-qesas.¹³³

Descriptions from Arabic Literature

The most comprehensive study of the Pharos and its records in history has, without doubt, been carried out by Thiersch.⁷⁰ His collation of the many references to the Arab literature is remarkable, even though it was built upon a great deal of earlier work by Max van Berkem.⁷¹ Sadly, this is still only available in German.

Any thoughts of Muslim control over the Pharos raise immediate questions about the similarity between lighthouses and minarets. Figs. 5-20, 5-21 and 5-22 give examples of images of the Pharos made by Arab authors. The Pharos (Arabic, *manar* or *manara*) is mentioned or described in many of the Arabic geographical works; al-Qazwini even gives a diagram of it in *Athar al-Bilad*.⁷² The Egyptian encyclopaedist al-Qalqashandi (1355-1418) describes the Pharos from the work of the eleventh-century writer al-Quda'i, and says that the famous mirror on its summit was broken by a stratagem on the part of the Christians ...⁷³

In Arabic, the word 'manara' means 'an object that gives light'. The origins of the minaret have been well discussed in a thesis by Louise.⁷⁴ Both Butler and Thiersch were in agreement that the minaret had indeed been inspired by the Pharos of Alexandria, although the view of Thiersch was that it was limited to Egypt alone. We need not debate the issue further here, other than by noting the clear relationship.

Of more concern is the construction of a mosque at the top of the lighthouse. It has been suggested that, following earthquake damage during the centuries of Muslim management, the tower was rebuilt to include a mosque. The two functions of lighthouse lantern and religious sanctuary might seem incompatible, and we shall never know for certain whether the two functions were executed individually or both at the same time, or whether one dominated the other. Perhaps the structure was a mosque by day and a lighthouse lantern (fuelled by oil rather than wood) by night? It is both curious and frustrating that the Arabic accounts make little comment on this aspect of the use of the Pharos.

Nevertheless, these accounts have proved to be priceless in improving our knowledge of the Pharos and so the final part of this paper will study them in more detail. The Arabic records are especially

important for deciding upon the dimensions of the lighthouse. However, the variety and uncertainty of the ancient units of measurement gives no clear definition of the true measurements in modern units. Table 5-1 draws together the best data available at this time.

Some of the original Arabic sources have been made available on the Internet in different translations. In the century that has now passed since Thiersch's publication, there have been many additions and clarifications that have remained scattered throughout the literature. There have been many contradictions and misinterpretations too, some of which I try to clear up here. For example, problems have occurred with the identification of Arab authors because of their complex name structures and the transliteration from Arabic symbols into the English alphabet; spellings vary greatly. For extra clarity, the reader is invited to examine the table of authors, Table 5-2, and the Timeline in Table 5-3.

Al-Yaqubi (d. 897)

An Arab official from Baghdad called al-Yaqubi wrote in 870 that the tower was 175 cubits from base to the lantern level. If we take the cubit as approximately equal to the length of a forearm. It was typically about 18 inches or 44 cm, though there was a long cubit of about 21 inches or 52 cm, which makes Yaqubi's height 77 m or 91 m depending upon which measure was used. Both of these measures do not correspond to those from other sources. In 796 CE we know there was an earthquake and the Pharos suffered great damage, so we might surmise that he was describing the much reduced Pharos.

Al-Masudi (896-956)

Al-Masudi tells us that, during Christian times, it was customary on Maundy Thursday for families to take food to the foot of the lighthouse and to enjoy a meal and spend the day there. He also told how fishermen had found precious stones in the waters around the Pharos. His explanation was that when Alexander the Great died, his mother took all his jewel-covered drinking vessels and broke them into many pieces that she then threw into the sea. He said there was another story that Alexander himself had deposited the jewels in the

sea so that there would always be people there looking for them.⁷⁵

Al-Gharnati (1080-1170)

Abu Hamid al-Gharnati was born ca 1080 in Granada in al-Andalusi and died in 1170 in Damascus. He was an Arab traveler, geographer and writer of numerous reports on Eastern and Central Europe. Al-Gharnati made a drawing of the Pharos when he visited it around 1106 CE (Fig. 5-20). At first sight, the image seems to bear no relation to the structure we might have expected to see. Bearing in mind that he was clearly not an artist, there are some important points to note. First is that the structure has been reduced to just the first stage with a lantern (or mosque?) on top. Second is that the ramp leading to the elevated door is still present.⁹¹ Al-Gharnati's description is significant for its statement of the three-tier geometry, for the presence of the ramp, and for the description of the mirror, which will be discussed below:

*"The first tier is a square built on a platform. The second is octagonal and the third is round. All are built of hewn stone. On the top was a mirror of Chinese iron of seven cubits wide (364 cm) used to watch the movement of ships on the other side of the Mediterranean. If the ships were those of enemies, then watchmen in the Lighthouse waited until they came close to Alexandria, and when the sun started to set, they moved the mirror to face the sun and directed it onto the enemy ships to burn them in the sea. In the lower part of the Lighthouse is a gate about 20 cubits above the ground level; one climbs to it through an archway ramp of hewn stone."*⁷⁶

Al-Idrissi (1100-1165)

Al-Idrissi (Edresi), a geographer and traveler born in Ceuta, Morocco, visited Alexandria in 1154. He wrote:

"We saw the famous lighthouse which is unrivalled in the world with regard to the structure and solidity; because, regardless of what it is actually excellent stones of the species called caddzân, the foundations of these stones are sealed against each other with molten lead, and the joints are so adherent that the whole is indissoluble,

although the waves of the sea on the north side are continually hitting the building. The distance that separates the lighthouse and the city is, by sea, about a mile, and by land about three miles. Its height is about 300 [coudées] of the measure called [rachachi], each equivalent to 3 [empans], which therefore makes 100 [brasses] in height, giving about 96 to the cupola and 4 for the height of the cupola. From the ground to the middle gallery is exactly 70 [brasses]; and from this gallery to the top of the lighthouse, 26. One climbs there by a wide staircase, built in the interior, as are ordinarily those we practice in the towers of mosques. The first staircase ends towards the middle of the lighthouse, and there the building became, for its four sides closer. In the interior and under the stairs were built rooms. From the middle of the gallery, the lighthouse rises to the top, narrowing more and more, not however so narrow that a man cannot pass another. In the same gallery, one goes up again to reach the top by a staircase with dimensions narrower than that of the lower stairs. In all its parts the lighthouse has windows designed to procure daylight to people who climb, and so that they can properly place their feet.

*"This building is especially remarkable because of its height and its great mass; it is very useful for it is lit by night and day with fire, to give a signal to navigators during the whole of their voyaging season; seamen recognize this fire and navigate accordingly, for it is visible from 100 miles away. During the night it is visible by its brilliant glare; during the day it is recognizable by its smoke."*⁷⁷

There is some doubt here, for it may have been that an inclined plane wound around the inside walls at least to the top of the first stage to enable carts to be pushed up with loads of wood for the fire.

It is possible that the windows were not arranged horizontally but at an angle to the horizontal so that they ran parallel to the internal incline. This is clearly indicated in some of the representations made by Jean-Claude Golvin.⁷⁸ It should be said that such a design is highly unusual, but possible in view of the uniqueness of the edifice. More likely would have been windows arranged

parallel to the ground, but with a wide staircase on the inside walls.

Al-Balawi (1132-1207)

A very detailed account of a visit to the Pharos is often quoted in the literature. It had not been available to Thiersch, but it contained a great amount of detail that had yet been published.

It was only in the 20th century that the document reached a wider audience. It was thanks to the Egyptian Prince Omar Toussoun, a scholar and philanthropist, who published a report of the paper in an archaeological journal that made historians finally take notice.⁷⁹ The author of the work was named by Toussoun as Aboul Haggag Youssef Ibn Mohamed el Balawi el Andaloussi. Some writers have called him al-Andaloussi. As others have done, I shall use the name al-Balawi throughout this work.

It seems that the first translation was made into Spanish by Palacios.^{80 81} A translation into French by Toussoun was published in 1936⁸². The first English translation appears to have been by Clayton⁸³ in 1988, whilst ten years later, Empereur⁸⁴ translated Clayton's version back into French! Unfortunately, there are some clear errors that have been repeated. These must derive from either the first translation, or were made by the author himself. Unfortunately, the original Arabic manuscript is not available.

Al-Balawi visited the Pharos in 1166 and wrote the most detailed account of the lighthouse so far found. He also made many measurements that have helped us to gain a more complete understanding of the structure. The title of the work was Alif Ba, equivalent to the first two letters of the alphabet, so perhaps it is unsurprising that the paper remained unnoticed for so long.

Al-Balawi's report is priceless and represents the most detailed and compelling description that exists today, and it is therefore worth quoting in full.

"The Pharos rises at the end of the island. The building is square, about 8.5 m on each side.⁸⁵ The sea surrounds the Pharos except on the east and south sides. This platform measures, along its sides, from the tip up to the foot of the Pharos walls, 6.5 m, and rises above the level of the sea to an equal height. However, on the sea side, it is larger because

of the construction and it is steeply inclined like the side of a mountain. As the height of the platform increases towards the walls of the Pharos, its width narrows until it arrives at the measurements mentioned above. On this side it is strongly built, the stones being well shaped and laid and long, with a rougher finish than elsewhere on the building. This part of the building that I have just described is recent because on this side the ancient work needed to be replaced. On the seaward wall, that is the south side, there is an ancient inscription which I cannot read. It is not a proper inscription because the forms of the letters are carried out in hard black stone. The combination of the sea and the air has worn away the background stone and the letters stand out in relief because of their hardness. The A measures a little over 54 cm. The top of the M stands out like a huge hole in a copper boiler. The other letters are generally of the same size. The doorway to the Pharos is high up. A ramp about 183 m long used to lead up to it. This ramp rests on a series of curved arches; my companion got beneath one of the arches and stretched out his arms but he was not able to reach the sides. There are 16 of these arches, each gradually getting higher until the doorway is reached, the last one being especially high. We penetrated about 73 m beyond the doorway. Here we found a closed door on our left which led we knew not where. About 110 m further on we found an open door. This we entered and found ourselves in a room, followed by another, and others just the same, for a total of 18 rooms along the corridor, all communicating with one another. Then we realised that the island of Pharos was uninhabited. Walking on for another 110 m we counted another 14 rooms to right and left. In a further 44 m we found 17 rooms. Eventually after another 100 m we reached the first stage. There was no stairway but a ramp that gradually ascended around the cylindrical core of this huge building. On our right was a wall that was not particularly thick and on our left the body of the building whose rooms we have explored down below we entered the corridor 1.6 m wide overhung with finished stones that formed a ceiling; two of my companions were not able to pass in it. When we arrived at the top of the first stage

we measured its height from the ground with a piece of string from which we hung a stone – it was 57.73 m; the parapet being about 1.83 m high. In the middle of the platform of this first stage the building continued upwards, but now in the shape of an octagon with each face 18.30 m long and 3.45 m from the parapet. The wall was between 1.5 to 2 m thick; the figure which I had written down in my original notes is not very clear, but close by where I had recorded the length of the string I had written details in ink, which had not smudged. This is most strange, but I am sure it was 2 m. This stage was taller than its base line. Entering we found a staircase which we counted as having 18 steps and arrived at the middle of the upper floor. We measured again with the string and found that it was 27.45 m above the first stage. In the centre of this platform on top of the second stage, the building continued upwards in cylindrical form with a diameter of 75.20 m. From the foot of the wall to the parapet was 2.19 m. We entered again and climbed 31 steps to arrive at the third stage. The height of the third stage was measured with the string as 7.32 m. On the platform of the third stage there is a mosque built with four doors and a cupola. It is 5.49 m high and 36.60 m* in diameter. The parapet is 46 cm high and only 1.51 m separates it from the mosque wall. In summary the structure that we had explored had 67 rooms, except for the first which we found closed and which, it was said, lead underground to the sea. The height of the Pharos, following these dimensions, is 96.99 m and, from its base to the edge of the sea, it is 9.15 m; the portion that is visible below the sea level is about 1.83 m.”*

Unfortunately, there are some clear errors in the dimensions provided above - marked with (*), errors that may have occurred in the original translation from Arabic that included non-metric units. The descriptions cited, in both French and English versions, say that the diameter of the cylindrical section was 75.2 metres, and in the penultimate paragraph it is recorded that the mosque is 36.60 m in diameter. These dimensions are clearly ridiculous.⁹⁰

Table 5-1 contains a summary of all dimensions of the Pharos that were found in this study.

Ibn Jubayr (1145-1217)

Abu 'l-Husayn Muhammad ibn Ahmad ibn Jubayr (otherwise just ibn Jubayr) was a Muslim traveller who set out from Granada in 1183 and arrived in Alexandria in April of that year. It was the first part of what turned out to be an extensive journey and he wrote a detailed journal of his travels. Thankfully, this is available to us today.⁸⁶

Ibn Jubayr wrote the following description of the Pharos:

“One of the greatest wonders that we saw in this city was the lighthouse which Great and Glorious God had erected by the hands of those who were forced to such labour as ‘a sign to those who take warning from examining the fate of others’ [Koran, XV, 75] and as a guide to voyagers, for without it they could not find the true course to Alexandria. It can be seen for more than seventy miles, and is of great antiquity. It is most strongly built in all directions and competes with the skies in height. Description of it falls short, the eyes fail to comprehend it, and words are inadequate, so vast is the spectacle.

“We measured one of its four sides and found it to be more than fifty arms’ lengths. It is said that in height it is more than one hundred and fifty kamah [one kamah equals a man’s height].⁸⁷ Its interior is an awe-inspiring sight in its amplitude, with stairways and entrances and numerous apartments, so that he who penetrates and wanders through its passages may be lost. In short, words fail to give a conception of it. My God not let it cease to be an affirmation of Islam and (for that creed) preserve it. At its summit is a mosque having the qualities of blessedness, for men are blessed for praying therein. On Thursday 5th of Dhu 'l-Hijjah, we went up to this blessed mosque and prayed in it. We saw such marvels of construction as cannot faithfully be described.⁸⁸

We note particularly the two measurements he gives. First, the height of 150 kamah (about 275 m) is almost certainly far too tall. Second, the width of the square side of the tower at 50 arms (about 34 m) seems too small, even allowing for his observation that it was greater than 50.⁸⁹

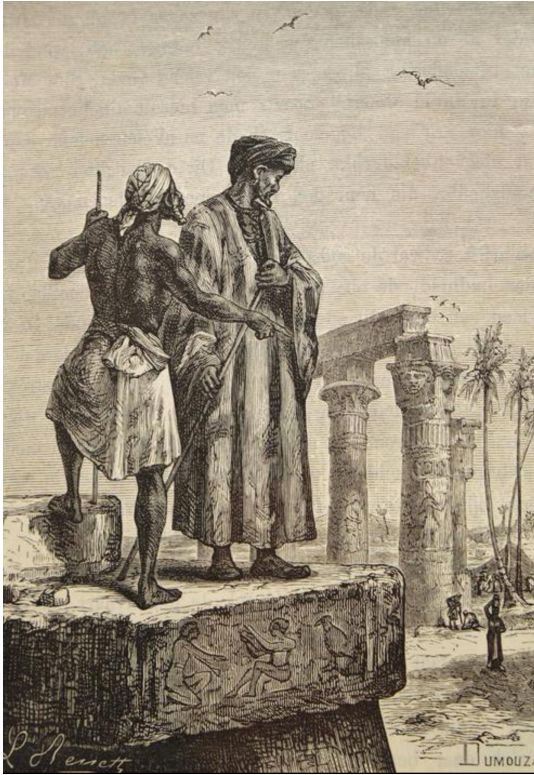


Fig. 5-23: The great Moroccan traveller, Ibn Battuta, (centre) visiting Alexandria and the Pharos in 1326.¹³⁴

Ibn Battuta (1304-1369)

The Moroccan traveler Ibn Battuta is one of the greatest travellers of pre-modern times, Fig. 5-23. He departed from Tangier at the age of 21 to make the holy pilgrimage to Mecca and made a series of extraordinary journeys that spanned nearly three decades. He travelled to India and China, as well as the Volga River valley and south to Tanzania. The full story of his travels has become available only in the 20th century and is a unique account on Islamic and medieval history. Several translations are now available that have slightly different details.

[1326] "I went to see the lighthouse on this journey and found one of its faces in ruins. One would describe it as a square building soaring into the air. Its door is high above the level of the ground, and opposite its door and at the same height is another building; wooden planks are laid from one to the other, and on these one crosses to the doorway. When they are removed there is no means to approach it. Inside the door there is a place for the guardian of the door to sit in, and within the lighthouse itself there are many chambers. The breadth of the passage in its interior is nine spans; and the breadth of the wall ten

spans; the breadth of the lighthouse on each of its four faces is 140 spans. It is situated on a high mound and lies at a distance of one farsakh (three miles) from the city on a long tongue of land, encompassed on three sides by the sea up to the point where the sea is immediately up to the city wall, so that the lighthouse cannot be reached by land except from the city. On this peninsula connected with the lighthouse is the cemetery of Alexandria. I visited the lighthouse again on my return to the Maghrib in the year 750 (1349), and found that it had fallen into so ruinous a condition that it was impossible to enter it or to climb up to the doorway. Al-Malik al-Nasir (God's mercy on him) had started to build a similar lighthouse alongside it, which he was prevented by death from completing."⁹⁰

A second translation reads slightly differently.

[1326] "I went to see the lighthouse on this occasion and found one of its faces in ruins. It is a very high square building, and its door is above the level of the earth. Opposite the door, and of the same height, is a building from which there is a plank bridge to the door; if this is removed there is no means of entrance. Inside the door is a place for the lighthouse-keeper, and within the lighthouse there are many chambers. The breadth of the passage inside is nine spans and that of the wall ten spans; each of the four sides of the lighthouse is 140 spans in breadth. It is situated on a high mound and lies three miles from the city on a long tongue of land which juts out into the sea from close by the city wall, so that the lighthouse cannot be reached by land except from the city. On my return to the West in the year 750 [1349] I visited the lighthouse again, and found that it had fallen into so ruinous a condition that it was not possible to enter it or climb up to the door."⁹¹

Other Writers

The historian Procopius of Gaza said that the base of the monument was repaired by Emperor Anastasius I (491-518 CE).⁹²

Bishop Arculf (ca. 670 CE)

One of the most interesting stories is that of Bishop Arculf who visited Alexandria during a long tour of the newly Muslim middle-east.

“When one has escaped the narrows and mouths of the port, a stretch of sea is spread out before one, far and wide, like the form of the rest of the body. On the right side of the port there is a small island, on which is a very high tower, which the Greeks and the Latins have in common called, from its use, Pharos because it is seen by voyagers at a great distance, in order that, before they approach the port, they may, specially during the night, recognise the proximity of land by the light of the flames, that they may not be deceived by the darkness and fall upon rocks or fail to recognise the boundaries of the entrance. Men are accordingly employed there by whom torches and other masses of wood which have been collected are set on fire to serve as a guide to the land, showing the narrow entrance of the straits, the bosom of the waves, and the windings of the entrance, lest the slender keel should graze the rocks and in the very entrance strike upon the rocks that are hidden by the waves. Accordingly a ship ought to be somewhat deflected from the straight course, to prevent its running into danger from striking on hidden stones. For the approach in the port is narrower on the right side, but the port is wider on the left. Round the island also, beams of immense size have been regularly laid down, to prevent the foundations of the island from yielding to the constant collision of the rising sea, and being loosened by the injury. So that the middle channel, among rugged rocks and broken masses of earth, is beyond doubt always unquiet, and it is dangerous for ships to enter through the roughness of the passage. The port extends in size over thirty furlongs, and it is quite safe even in the greatest storms, as the above mentioned straits and the obstacle of the island repel the waves of the sea, the

bosom of the port being so defended by them as to be removed from the reach of tempests and at peace from breakers by which the entrance is made rough. Nor are the safety and the size of the port undeservedly so great, since there must be borne into it whatever is needful for the use of the whole city.”⁹³

Zhao Rugua (ca. 1225 CE)

We have covered the accounts written by classical authors, mostly during the period before the Pharos fell under Muslim control. After that, there were many visits by travellers, not only from the Islamic world, but also from the Hebrew and Persian communities. The travellers recorded details of their visits, which eventually reached distant regions, especially China. In 2012, Vorderstrasse wrote a study of these descriptions that draws together many strands from these rare sources.⁹⁴ One book, entitled *Zhu-fan Zhi* (Records of Foreign Peoples), written by Zhao Rugua includes a detailed section about the Pharos.

Vorderstrasse expresses surprise that the story of the Pharos did not seem to have a great impact on Chinese appreciation of foreign lands. Only from the time of the Tang and Song dynasties of the 13th century did China have sufficient contact with the west to make an impact on the Chinese view of Egypt and Africa. Until this point all descriptions and names of foreign places were extremely vague. Writing his book in 1225 CE, Zhao was holding the post of Inspector of the Department of Foreign Sea Trade at the harbour of Quanzhou, and ideally qualified to describe Egypt and Alexandria.

“The country of O-kon-to (Alexandria) belongs to Wu-ssi-li (Egypt). According to tradition, in olden times a stranger, Tsuko-ni by name (Alexander the Great), built on the shore of the sea a great tower under which the earth was dug out and two rooms were made, well connected and very well secreted. In one was grain, in the other were arms. The tower was 200 chang high. Four horses abreast could ascend to two thirds of its height. In the centre of the building was a great well connecting with the big river.

“To protect it from surprise by troops of other lands, the whole country guarded this tower

that warded off the foes. In the upper and lower parts of it 20,000 men could readily be stationed to guard, or to sally forth to fight. On the summit there was a wondrous great mirror; if warships of other countries made a sudden attack, the mirror detected them beforehand, and the troops were ready in time for duty.

“In recent years there came to O-konto a foreigner, who asked to be given work in the guardhouse of the tower; he was employed to sprinkle and sweep. For years no one entertained any suspicion of him, when suddenly one day he found an opportunity to steal the mirror and threw it into the sea, after which he made off.”⁹⁵

Vorderstrasse maintains that it is most likely that Zhao wrote down a story he heard from a Chinese merchant in Quanzhou who had returned from Alexandria.

The Legacy

The most obvious legacy of the existence of the Pharos is its name, which became synonymous for all lighthouses. In a most influential work of the early 7th c. Isidore of Seville wrote:

A pharos is a very high tower which the Greeks and Romans, because by its flames it is visible at great distances to mariners, call after Pharos which Ptolemy erected at Alexandria at the cost of 800 talents. Its aim is to give fire-signals to the nightly course of ships, to mark shallows and harbour entrances, so that the ships surprised by the dark do not run into cliffs. Hence one calls buildings erected in harbours to illuminate the approaches pharus.⁹⁶

The three-part design, once established for the Pharos, was copied extensively in many subsequent designs of lighthouse around the Mediterranean coastline.

Romer⁵¹ identified a smaller version of the Pharos that still exists today about 30 miles west of Alexandria at Taposiris Magna (Abusir, Abousir). This is a particularly important find because it corresponds exactly with the currently accepted shape of the Pharos, i.e. a square lower tower section, an octagonal middle section and a cylindrical upper section. The small tower is but 15 m tall, but it contains a stone staircase within its walls and was almost certainly used as a fire tower at some

point in its long history. In a way, it acts to confirm the shape of the original, even though it was probably after the Pharos. This is because the proportions of the different geometries can be used to calculate the likely strengths of the original, as well as the stresses necessary to make it collapse. The existence of the small lighthouse has confirmed the possible dimensions of the large one. In contrast, a careful study of the structure concluded that the structure was definitely not a lighthouse.⁹⁷ A noted expert on Alexandria described it as:

“... a large funerary monument in the form of a lighthouse or beacon, which appears to reproduce closely the form of the Pharos ...”⁹⁸

Some features of the design exhibit a high level of engineering competence for the times. For example, the presence of many windows is said to have been to reduce the resistance of the tower to strong winds. The use of timber to secure sections of wall was thought to be helpful to the tower's resistance to earthquake. Besides a great ramp on the exterior that led up to the tower's entrance and enabled wheeled transport to bring provisions inside, there was reported to be a ramp inside also. No other lighthouse has ever been built as tall as the Pharos. In recent times the closest competitors are Lanterna in Genoa, Italy, which is 57 m and Ile Vierge in Finisterre, France, which is 82 m. With the light of the Alexandrian lighthouse set at 110 m above sea level, this meant that in good weather conditions, the light could be seen at a distance of 45-48 km, depending upon the height of the observer. This is close to the observation by Josephus in the 1st century AD that it could be seen from a distance of 300 stadia - equivalent to 54 km using today's conversion estimates.⁹⁹

Because of its fame and longevity, the Pharos of Alexandria became the model for many lighthouses thereafter. Over many centuries, it has been written about more than any other lighthouse and, for obvious reasons, a great deal of inconsistency has developed as to its actual design. There are many illustrations, which vary enormously in their portrayal of the structure. For example, the thirteenth-century mosaic in the Zen Chapel of St Mark's, Venice, purports to show the Pharos of Alexandria as a backdrop to an episode in the life of St Mark, but probably does not accurately represent the real structure.

We must conclude that such a grand and mas-

sive undertaking would not have been the first of its kind. The Emperor Ptolemy of Egypt initiated the project with enthusiasm and it is hard to imagine him committing so many resources to a project whose concept was so new. The idea of a lighthouse was surely formulated well before this and it is certain that there were already some, possibly many, lighthouses already in existence by 300 BCE. The concept of a source of light that would guide ships safely into harbour was surely proven and hence highly desirable.

These days, the role of the Pharos as a lighthouse has become the predominant one to the exclusion of other purposes. Naish makes a strong argument that the Pharos was built as much for defence and prestige as for navigation. Such a great building that could house contingents of soldiers, as well as giving them elevation to launch projectiles towards enemies from great distances was a powerful asset against potential enemies. Then there was the deterrence that such a massive construction offered. Clearly, such a permanently manned fortress would be visible by night as well as by day, so the Pharos need not have been solely designed for navigational reasons. Nevertheless, all three purposes were served: prestige, defence AND navigation.¹⁰⁰ Indeed, this composite purpose seems to have been applied to almost all of the lighthouses of the Roman era, if not those that came before.

For hundreds of years, many dedicated scholars have scoured the available literature looking for definite indications of the existence of any lighthouse that may have acted as the inspiration for the Pharos. None has so far been found. We should remember at this point that the Romans were prolific lighthouse builders. However, all evidence of Roman lighthouses post-dates the Pharos; indeed, the Pharos must surely have inspired the Romans to copy it. Images of lighthouses crudely corresponding to the Pharos appeared on many coins of the period, but all of them date from years after the construction of the Pharos. The same applies to iconography in general, a complete discussion of which there is no space for here. Possible avenues for research are immediately obvious. Surely the answer must lie in a deeper study of ancient civilizations prior to the Hellenic Period.

No certain proof has yet been produced that any lighthouse actually did exist before the build-

ing of the Pharos. There are reports about the existence of a number of structures that could have been lighthouses. Hague, for example, states that an ancient tower led into the western arm of the Nile.¹⁰¹ Without firm evidence to the contrary, the consensus amongst pharologists, including the author, is that, accepting that there may have been forerunners, lighthouse history formally begins with the Pharos. This does not prevent us from considering the likelihood of other earlier light-structures.

The Eunuch and the Mirror

Many of the stories associated with the Pharos have been often repeated, and the legacy of the literature is rich, even if the fantasy and the fiction have blurred the truth. One of the most important stories involves a eunuch, a fabulous treasure and a wonderful scientific invention. Let's begin by examining some ancient texts.

The reigning king (Caliph) in Alexandria was Walid I (675-715) son of Abdul al-Melik, son of Marwan I, of the Omayyad dynasty. Writing in 951, Al-Masudi appears to be the original source of a much-repeated tall story.¹⁰² First, he discusses the person who commissioned the lighthouse:

“According to the report of most historians from Egypt and Alexandria, the lighthouse of Alexandria was built by Alexander, son of Philip of Macedonia, in the circumstances reported above concerning the foundation of that city. According to other authors, it was the old queen Dalukah (Deloukeh) who built it and made an observation post to watch the movements of offensive troops.¹⁰³ Others attribute its origin to the tenth Pharaoh, of which it has been spoken previously. Finally, other writers assert that it is to the founder of Rome that Alexandria, the lighthouse and the pyramids owe their existence; in this hypothesis, the name of Alexandria would come only from the celebrity of Alexander whose arms subjugated most of the world.”

We should not dismiss too easily the idea that, even before the Pharos, there was an observation tower protecting Rhacoutis, or perhaps the mouth of the Nile. Now al-Masudi introduces a most curious idea of the lighthouse being built on unusual foundations. He also describes statues that were more than just decorative installations.

“In support of this opinion, several facts are cited. Alexander, it is said, did not need to make this lighthouse an observation post, since he feared no attack by sea, and that no foreign sovereign would have dared to invade his States and march on its capital. It is added that the real author of the lighthouse builds it on a huge glass pedestal of crayfish, which rested on the bottom of the sea, at the end of this tongue of land which is detached from the mainland (island of Pharos). He crowned the top of the edifice with statues of bronze and other metal. One of these statues had the indicator of the right hand constantly turned towards the point where the sun was; if he was in the middle of his race, his finger indicated his position; if it disappeared from the horizon, the hand of the statue was lowered, and thus described the revolution of the star. Another statue lined his hand towards the sea, as soon as the enemy was at a distance from a navigation night. When he arrived within sight of the light, a sound coming in and heard two or three miles away from the statue, the inhabitants, thus warned of the approach of the enemy, watched the movements. A third statue indicated all the hours of the day and the night by an irresistible sound, which varied with each hour.

Now let us move on to the details of al-Masudi's strange tale.

“In the reign of al-Walid, son of Abd al-Melik, son of Merwan, the king of Byzantium sent on a secret mission one of his favourite eunuchs. This service, endowed with cautious prudence and astuteness, arrived safely, thanks to skilful manoeuvres, as far as the Moslem frontier, he and his followers. Conducted in the presence of al-Walid, he informed him that he was one of the courtiers of the Greek king, and that this king, in a moment of anger and on ill-founded suspicions, having wished to put him to death, he had left the courtyard. This stranger manifested the desire to become a Muslim and made his profession of faith in the hands of al-Walid. Little by little he seized the good graces of this prince, and revealed to him the existence of treasures hidden in Damascus and in other places of Syria, according to precise indications furnished by certain books which he had brought. When

the sight of these treasures and jewels had redoubled the curiosity and covetousness of al-Walid, the eunuch told him one day: ‘Prince of the believers, there are here even treasures, precious stones and other objects of value hidden by ancient kings.’ And, at the insistence of al-Walid, he added, ‘It is under the lighthouse of Alexandria that the treasures of the earth are buried, and know that when Alexander seized property and precious stones, had belonged to him in Cheddad, they of Ad, or to other Arab kings in Egypt and Syria, he had cellars and subterranean chambers built, surmounted by vaults and arcades. It was there that he deposited all his treasures, ingots, valuable coins and semi-precious stones. Above these underground chambers he built the lighthouse, which was not less than a thousand cubits high¹⁰⁴, and placed at the top, a mirror and a post of watchmen. As soon as the enemy showed themselves, they shouted to warn the neighbouring posts and, with the help of signals, awakened those farthest away. In this way the inhabitants were warned, they ran to the defence of the city and thwarted the attempts of the enemy.’

“Accordingly, al-Walid sent this eunuch with soldiers and loyal courtiers; they demolished the lighthouse to half its height, and destroyed the mirror. This event of destruction angered the inhabitants of Alexandria and the other cities, because they understood that it was a ruse and a treacherous manoeuvre of which they would be the victims. Seeing that these rumours spread and that they would not delay to arrive until al-Walid, the eunuch, whose goal was attained, escaped during the night and departed on a ship which people, posted by him, had made ready to leave. Thus was accomplished his stratagem, and since then the lighthouse remained half ruined, until the present year 332 (944 CE) of the Hejira.¹⁰⁵

A second, possibly more detailed account is provided by Bouriant in his French translation that reads, in English, as follows:

“As to the lighthouse of Alexandria, says al-Masa’oudi, most of those of the Egyptians and Alexandrians who take care of the history of their country, claim that it was built by Alexander, son of Philip, the Macedonian;

according to others, it would be Queen Dalukah who would have raised it to watch the enemies who threatened Egypt. There are, however, some who suppose it to be the work of the sixth pharaoh of Egypt; others admit that the founder of Rome was also the founder of Alexandria and the builder of the lighthouse and the Pyramids of Egypt. I am inclined, as for myself, to attribute Alexandria to Alexander, for he is universally famous for his conquests of almost all the countries of the earth, and, thanks to him, the city of Alexandria has become famous. Yet all the writers we are talking about have told many stories about Alexandria to prove the veracity of their statements. But no enemy threatened Alexander on the sea, and he feared no king who could come to attack him in his own country or beat him in his Empire. It is he, however, who established this lighthouse as watchman. He, whoever he was, built it, placed it on a pedestal of glass, to which he gave the shape of a crab; it was situated in the open sea, at the end of the cape, which is advancing in the waters. At the top were placed statues of copper and other materials, including a statue that showed the sun's right forefinger at any place in the sky; if the sun rose in the firmament, the finger of the statue was stretched out on its side, and, if it were lowered towards the horizon, the hand of the statue also lowered, following it in its course. Another statue kept his hand extended towards the sea; if any enemy advanced on this side, even during the night, if he threatened the city or disembarked and approached sufficiently to see his own wishes, this statue uttered a frightful cry which was heard two or three miles away; and thus the inhabitants of the city knew that the enemy threatened them, and could see them themselves; a third statue uttered, each time an hour of the day or night had passed, a cry different from that which it had uttered at the end of the preceding hour, and this cry was pleasant to hear.

“Under the reign of al-Walid bin Abd al-Melek bin Merwan, a king of the country from Rome sent one of his particular servants endowed with wisdom and cunning. He surrendered himself full of confidence to a certain town on the frontier and, armed with sumptuous

presents and accompanied by an escort, he reached al-Walid and told him that he was one of the King's special friends, but that he had wanted to kill him in a moment of irritation; like the attempt of which he had been the object had no reason to be, he was very affected and wanted to become a Muslim. He converted himself to Islam in the hands of al-Walid and gained his affection by revealing to him the existence of buried treasures, which he brought out of earth for him in Damascus and other cities of Syria, thanks to some books he owned and where was the description of these treasures. Once master of these treasures and jewels, al-Walid became greedy and his desire only increased. His servant told him one day, ‘O Emir of the Believers, there are riches, jewels and treasures buried by kings.’ al-Walid asked him for details. ‘Under the lighthouse of Alexandria,’ answered the servant, ‘are the treasures of the kings of the earth, because Alexander brought together the riches and jewels of Sheddad bin ‘Ad and kings of Egypt, and for them he built a subterranean vault and a vault with cupolas, cellars, and corridors, and deposited these treasures, gold, silver, and precious stones; and above, he built this lighthouse. The height is a thousand cubits, and one mirror overcomes it, around which criers are seated; and as soon as they see some enemy, thanks to the glow projected by this mirror, they warn by cries those who are in their neighbourhood and draw signals that can be seen by those who are further away. So the inhabitants are warned, the country is on its guard and the enemies find the road barred.’

“al-Walid sent his servant with an army and trusted people and his friends. The upper half of the lighthouse was demolished and the mirror disabled. The inhabitants, seeing this, rebelled, understanding that here there was some artifice and some cunning. At this news, the servant, knowing that he had lied to al-Walid and his ploy having succeeded, fled during the night on a boat which he had prepared on purpose. The protective virtue of the lighthouse was destroyed and this monument remained in this state until now, that is to say until the year 332 (944).

“The base of the lighthouse of Alexandria is covered by the river, and one draws fragments of all kinds of precious stones of which one makes kittens of rings. It is said that these fragments come from the drinking utensils that Alexander had made himself and which, after his death, were broken by his mother and thrown by her in that place. Others assert that Alexander himself had collected all these stones and thrown them into the sea around the lighthouse by bushel to protect the surroundings of the lighthouse against the rapacity of the people, because the proper of jewels is to be sought. It is said that this lighthouse had been provided with a summit only because the kings of the country of Rome, after the death of Alexander, were to wage war against the kings of Egypt and Alexandria, and that, for this reason, the king who reigned at Alexandria installed this mirror, which enabled him to see any enemy coming from the sea; it was thus possible to meet anyone who wished to enter the city; unless he was recognized as one of the inhabitants, which could not be known at first because of the number of houses, squares and streets which constituted the city. When the Maugebins, in the time of the Caliphate of Moqtader, came with the army of the master of the West (al-Mo’ezz li bin Allah), they all went on horseback to the lighthouse, went astray in the city and fell into a path leading to a well that descended to the glass crab. There were cracks communicating with the sea; the horses fell, a great number disappeared, and no one heard of it. They were, as it were, told, on a pedestal where their chest had broken.

“ In the lighthouse there was an oratory where Egyptian and other volunteers were garrisoned. In 777 (1375) the top of the lighthouse was overthrown by an earthquake. The lighthouse was, it is said, built of interlocking stone held together by means of lead, all resting on a glass arch placed on the back of the crab. This lighthouse consisted of three hundred superimposed rooms, and the pack animals went up with their burdens to all the rooms of the interior of the lighthouse; each of these rooms had a window overlooking the sea. On the eastern side of the lighthouse was an inscription that was

translated into Arabic, here it is: “The one who builds this belvedere¹⁰⁶ is Qaribah, daughter of Marinous la Greque, to observe the stars.

“Ibn Ouacif Shah, after recalling the story of Misraim ben Beisar bin Ham bin Nouh, adds: They built on the city, among others Racoutis; the place of the future Alexandria, and they placed in the middle a cupola resting on pillars of gilded copper; the cupola was equal, and golden. Above the cupola was erected a tower surmounted by a shaft of various substances, the diameter of which was five emfans. The height of the cupola was a hundred cubits. If any of the peoples of the neighbourhood wanted to attack and destroy them, or advanced towards the sea, the rays of this mirror were directed at the arrivals and burned. The mirror preserved this virtue until it was overthrown and destroyed by the sea. Alexander, it is said, only rebuilt a lighthouse similar to the first, on which he also placed a mirror, where the enemies from the country of Rome. But some king of Rome managed, by trickery, to put an end to the protective virtue of this mirror which was made of glass prepared with art.

“El Masa’oudi (Al-Masudi) in his book of the Warning and the Illustrious Men, tells that when the vizier of El Moutawaqqel Obeid Allah bin Yahia bin Khafan was moved by Moustai’in to Barkat in the year 248 (862 CE) he returned to Alexandria, where he saw the top of the lighthouse lit by the rays of the sun while the sun was already set, and remained convinced that he was not to break the fast until the sun was gone for all the regions of the Earth. He sent one of his people up to the top of the lighthouse, carrying a stone with him, and ordered him to look attentively at the place where the sun was setting and to throw the stone at the moment when the star would disappear. The man executed the order, and the stone reached the ground while the last evening prayer was over. The vizier therefore fixed the moment of breaking his fast after the last evening prayer. And later, when he had to fast, he acted as he had done in Alexandria; and, having returned to his country, the memory of what he had seen came back to him, and he fasted till after the last evening

prayer; he had made a law of it, and the two times were equivalent. It shows how far the science of law was and how much little fixed on the course of the sun from East to West.

*“Aristotle, in his *Metaphysical*, reports that, on the side of the east of summer, is a mountain very high and quotes among other particularities concerning her, the fact that, for her, the sun only sets at three o’clock in the night and rises three hours before day. The lighthouse of Alexandria is one of those learned and marvellous constructions that rose the Ptolemaic Greek dynasty after the death of the King Alexander, son of Philip, while on land and sea, war with the kings of Rome. These kings built the lighthouse, placing top a huge mirror, made of all kinds of selected stones, to watch the ships of the sea that would have approached the shore, ahead thus their landing. They saw all this in the mirror and the awakening was given to the inhabitants before the arrival of the enemies. The height of the lighthouse is currently about 230 cubits, but formerly it was reaching nearly 400 cubits; the height has diminished considerably, the weather, the earthquakes and the rains having partly broken it; for it rains abundantly at Alexandria; it is not like Fustat¹⁰⁷ where, because of the more considerable altitude, it rarely rains. The construction of the lighthouse was made according to three different types: almost half, or at least more the third is square and white stones; this construction occupies nearly 110 cubits; at this square part succeeds an octagonal part consistent in stone and gypsum on a height of 60 and a few cubits, all in the surroundings are inhabited dwellings; finally, the summit is circular.*

“Ahmed bin Touloun partly repaired it, and placed at the top a cupola, where it was necessary to ascend the lighthouse; but the interior was smooth, built with art and without degrees. On the north side, was an inscription Greek in lead characters encrusted in stone; each letter was one cubit high and one span wide. The area occupied by the monument was about 100 cubits, but the waters of the sea, having foundations, had the angle collapsed facing the sea to the west. Abu’l

Geich Khamaraouyah bin Ahmed bin Touloun repaired it. Today, between the lighthouse and the city of Alexandria, there is a distance of about a mile; the lighthouse is built at the end of the tongue of land whose sea bathes them two sides, at the entrance of the present port of Alexandria and not in the old port; the latter, indeed, is in the ancient city and the ships do not enter more, because it is too far from inhabited neighbourhoods. The port is the where the ships of the sea come to approach.

“The Alexandrians tell, according to their ancestors, that between the lighthouse and the sea, it was formerly about the same distance as today between the city and the lighthouse, but that the water of the sea had in a short time invaded this space, which has only increased since then. It is reported that in the month of Ramadan of 341 (953 CE) ‘the top of the lighthouse was destroyed by a height of about 30 cubits by the earthquake that was felt at the same time in Egypt, in several localities of Syria and in the Maghreb; it is at least what the tradition tells us. While we were at Fustat Misr, an enormous earthquake took place; terrible; scary; which lasted nearly half an hour it was happening around noon time. Thursday lentils we met at the lighthouse. Everybody left his house that day and went to the lighthouse, taking his meal, which included an inevitable dish of lentils. The lighthouse doors were open; everyone entered it, who to invoke God, who to pray, who to entertain. We stayed there until noon, then we retired; and from that day the sea was carefully watched for the unexpected arrival of enemies. It is said that once the lighthouse was very far from the sea, but in the time of Constantine, son of Constantine, the sea approached and submerged many points and quantities of churches in the city of Alexandria; since then, the marine invasion has continued and the sea covers one parcel of land after another.

“An author claims to have measured the lighthouse and claims that its height was 233 cubits, consisting of three distinct parts: the first part, of form square, measured 121 and a half cubits; the second part, of octagonal form, measured 81 cubits and a half, and the third,

circular in shape, measured 31 cubits and a half.

“In his travel report, Ibn Jubayr (ibn Gabir) says that the lighthouse of Alexandria is seen from a distance of more than 70 miles; he claims to have measured one of its four sides in 578 (1182) and declares that it was nearly 50 cubits. The height of the lighthouse was more than 150 men and at its summit was an oratory where people prayed for heavenly blessing.

“According to Ibn el Hakem, it has been claimed that the one that built the lighthouse was Queen Cleopatra, the same who dug the channel that she succeeded, by her ingenuity to bring to Alexandria. This canal started from the village of Kassa, in front of El Karioun; she dug it until it entered the city and went the ceiling. Ahmed Ibn Touloun, while he was governor of Alexandria, top of the lighthouse a dome of wood that was later removed by the winds. In the time of Zahir Baibars,¹⁰⁸ one of the angles of the construction faltered and fell; Baibars had restored what had been destroyed, in 673 (1275 CE), and he reinstalled at the same time the location of the dome in mosque; this mosque was destroyed in turn in the 702 (1303 CE) earthquake; during the course the year 703 (1304 CE) it was again rebuilt under the direction of Emir Baibars II; since then it has remained undamaged until our time.”¹⁰⁹

There are many items contained in these accounts that tease us into thought. It was al-Balawi who wrote (1166 CE) about what he and his colleague found just inside the door of the lighthouse: “Here we found a closed door on our left which led we knew not where.” Rumours persisted of a long passageway that led deep under the foundations of the lighthouse where valuables might have been kept safe.

Here, too we find references to devices that are certainly decorative, but which function as audible timekeepers and weather vanes. A different translation reads:

“A third statue uttered, each time an hour of the day or night had passed, a cry different from that which it had uttered at the end of the preceding hour, and this cry was pleasant to hear.”¹¹⁰

British people think at once of London’s won-

derful clock, Big Ben!

Then there is the nugget that tells us of the mirror. We may speculate about its true capabilities, and whether Archimedes had really invented the earliest death ray. We have no reason to deny the idea’s validity, and certainly there was good reason for an enemy spy to infiltrate the court in order to destroy what was seen as a deadly weapon being used against them. We shall never know if al-Walid was truly foolish enough to part-demolish his beautiful lighthouse in search of treasure, but the tale could easily come about from the great damage inflicted on the tower by earthquakes.

Conclusions

1. The Pharos of Alexandria was one of the world’s finest ancient engineering achievements that was in use for the great part of 1600 years.

2. It survived for many centuries, despite occasional severe damage, in several differing forms and dimensions. It was inevitable that, in time, earthquakes would have a terminal effect on such a tall structure, built without a modern understanding of shock and vibration resistance.

3. There is good reason to support the existence in the 8th or 9th century of a reflecting telescope used to monitor distant shipping.

4. The possibility that a reflecting device suitable for inflicting fear and damage upon an enemy cannot be denied.

4. Other novel mechanical devices such as weather vanes, water-powered pumps and clocks, and astronomical observation tools may have been installed as a result of developments in science and engineering in Alexandrian schools.

5. The impact of its long existence upon the psyche of civilized thinking has been immense and immeasurable. The entire world has benefited from its construction.



Fig. 5-24: Coins depicting the Pharos of Alexandria, except where indicated. Rulers on the obverse are listed, with either dates of their rule or specific dates of minting a coin. All images reproduced courtesy of Mark Staal, www.ancientcoinage.org. Copyrights for specific images are indicated.

- C1 - Top left: Domitian 81-96 CE
 C2 - Top centre: Trajan 98-117 CE [Busso Peus]
 C3 - Top right: Hadrian 117-138 CE [CNG/Triton XV]
 C4 - Middle left: Hadrian 117-138 CE
 C5 - Middle centre: Hadrian 117-138 CE [Pavlou Coins]
 C6 - Middle right: Hadrian 117-138 CE
 C7 - Bottom left: Hadrian 136-7 CE [Edward Waddell]
 C8 - Bottom centre: Hadrian 117-138 CE
 C9 - Bottom right: Sabina 117-138 CE

Appearance on Coins

The appearance of the Pharos is best attested by the Roman coins of Alexandria, on which it appears intermittently from the tenth year of Domitian (91 CE), as shown in C1 above.³⁷

Such images would further publicize the monument, which was already widely talked about. The commonality of its truncated structure consolidated mental images as a logo for a lighthouse for centuries to come, whether they were representative or not.

Romans were especially impressed with the idea that was adopted throughout their culture. Perhaps the most famous Roman lighthouse was at Ostia (C18). This is discussed in detail later.

Several common features are depicted. Firstly, the entrance door, raised above ground level is



Fig. 5-24 (contd.):

C10 - Top left: Antoninus Pius 138-161 CE

C11 - Top centre: Antoninus Pius 138-161 CE

C12 - Top right: Marcus Aurelius 148-149 CE [www.cgb.fr]

C13 - Middle left: Marcus Aurelius 161-180 CE

C14 - Middle centre: Faustina II 161-180 CE

C15 - Middle right: Faustina II 175 CE

C16 - Bottom left: Commodus 177-192 CE [CNG]

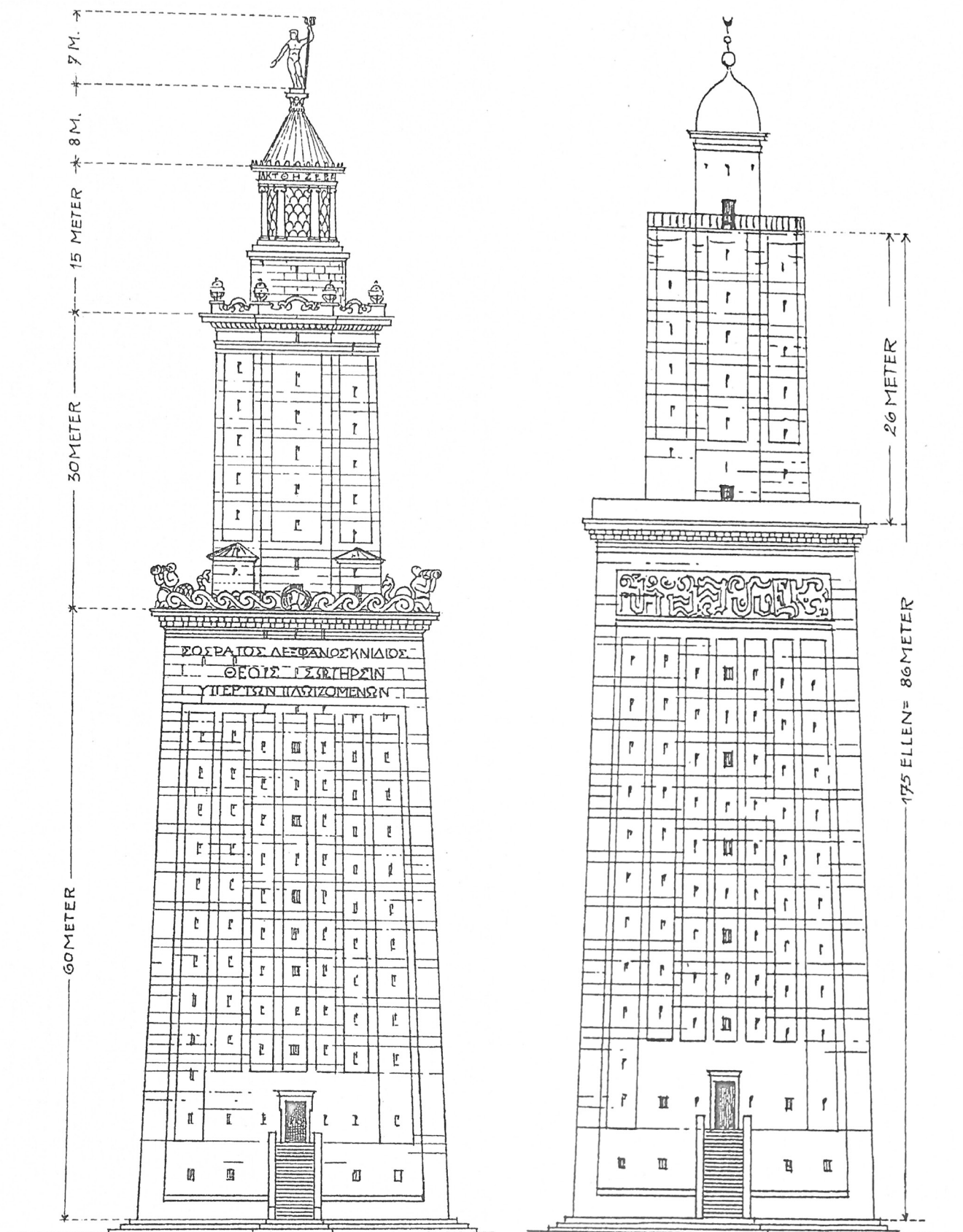
C17 - Bottom centre: Commodus 177-192 CE [CNG]

C18 - Bottom right: Nero 54-68 CE [CNG] This depicts the Roman port of Ostia for which the lighthouse is in the centre top of the image.

shown in C2, C6, C7, C9, C10-15. Almost all show the statue of Poseidon on the uppermost point. This must surely indicate that the light was emitted from a point below the statue. Likewise, almost all show the presence of the wind sculptures on the points of the upper level.

Fig. 5-25: The four images on these two pages represent the Pharos at different stages of its life. They are only approximately to scale. All have been derived from measurements made and reported by ancient Arab authors. **Far left** is the design presented by Thiersch. It is of a time in the early phase

of its existence. We note the three sections, the slightly tapered square bottom section 1; windows to each room progressing upwards in parallel with the internal ramp, the various ornamentations at each level; the Greek inscription; the octagonal section 2 with vertical sides; the cylindrical lantern



section 3 with pillars supporting the conical cupola (glazing shown is most doubtful); the statue of Zeus / Neptune on the summit; total height 120m. **Centre-left** is a drawing based upon data given by Al-Yacoubi in 891 CE. After coming under Muslim control in 641 and severe earthquake damage in

796, the lighthouse was rebuilt with a mosque in place of the lost lantern section 3. The height of section 1 is given as 86 m instead of 60 m, but this must be doubtful. Most likely is that sections 1 and 2 were of the same height. The new section 3 was reportedly wooden and without the 7 m; therefore perhaps shorter overall at about 115 m. It seems that during this period the Pharos did not function as a lighthouse. The wooden mosque was blown off in strong wind. **Centre-right**, the image depicts the description of Al-Masudi from 951 CE. This design returns section 1 to its original dimensions with 60 m height of section 1 and 30 m height of section 2. Now a fully functional stone lantern gallery is included. **Far right** is a truncated version of the Pharos, as described by Yakut in 1229 CE, during the final period of its existence. Yakut describes a square, buttressed building with a shortened second storey, topped by a small cupola.

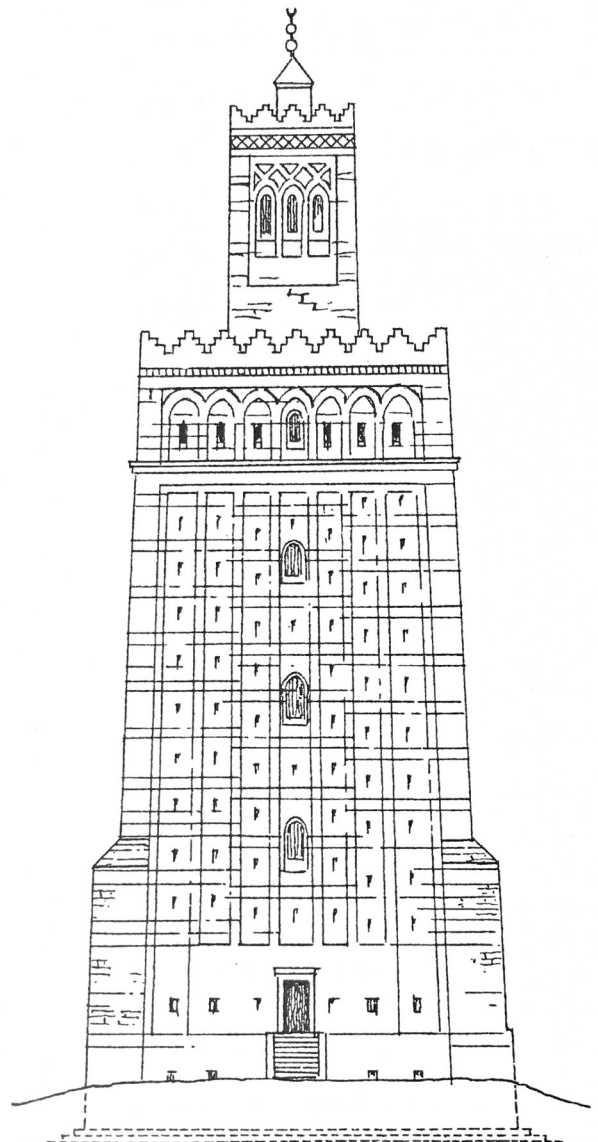
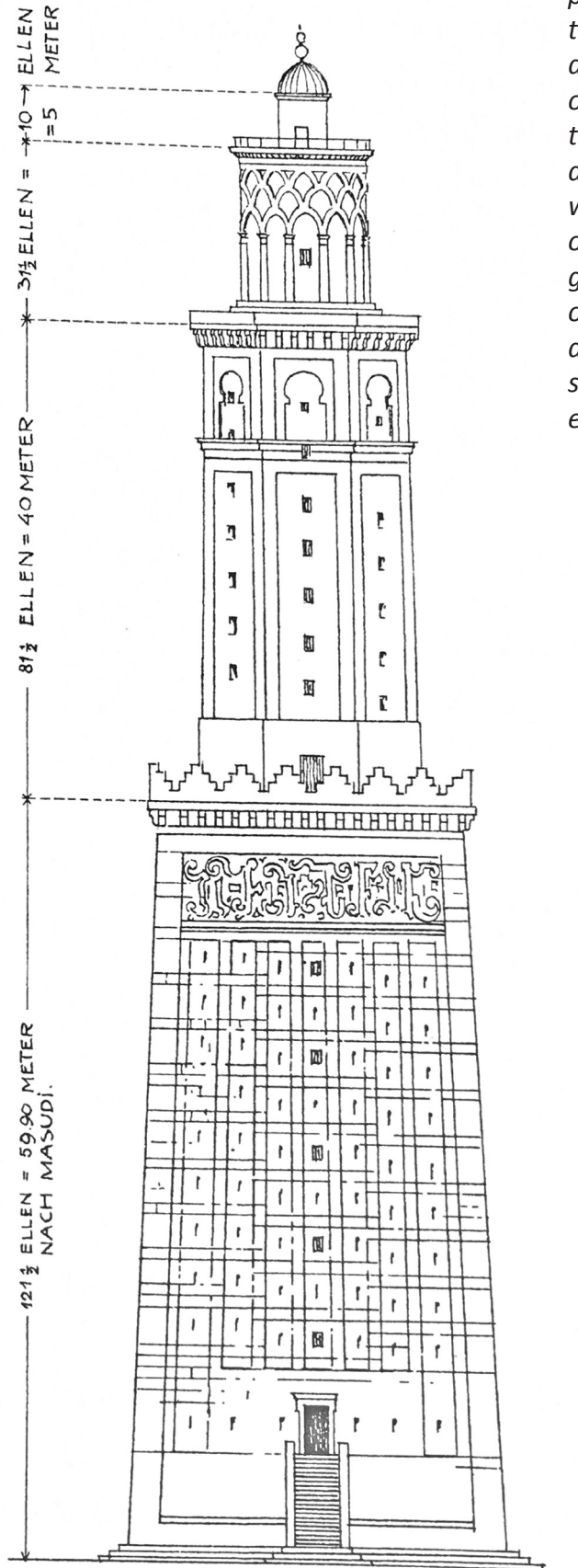


Table 5-1: A compilation of reported measurements of the Pharos obtained from sources indicated. Ancient units have been converted with factors from reputable sources, mostly Behrens-Abouseif (2006). Some data (shaded red) are incorrect; the repetition of the mistake by Clayton shows that he used Toussoun's data. Either Toussoun translated it incorrectly or the Arab author noted it wrongly. There are differences in some dimensions due to the changes in structure over the period of existence of the Pharos.

Cited measurements	dimension	size	unit	metres	Ref.
Causeway	length	600	dhira	300.00	BA1
		600	pics	324.00	T
Causeway	width	20	dhira	10.00	BA1
		20	pics	10.80	T
Causeway - above sea level	height	3	dhira	1.50	BA1
		3	pics	1.62	T
Ramp with vaulted arches	length	100	ba	68.00	BA1
Number of vaulted arches in ramp		16			BA1
		16			T
		16			C
Entrance ramp	length			183.00	C
		100	brasses	183.00	T
Door at ramp end: height above ground level	height	20	dhira	10.00	BA7
Lighthouse surrounded by a platform	width	12	dhira	6.00	BA1
Base above sea level	height			6.50	C
Square base	height			8.50	C
Square base, platform, edge to foot of Pharos	length			6.50	C
		12	pics	6.48	T
Square base; side of square	length	45	brasses	82.35	T
Stage 0 (Ground) Level to include Rectangular Section 1					
Rectangular section base at ground level	length	45	ba	30.60	BA1
		140	shibr	30.8	BA4
Rectangular section above ground level	height	31	qama	77.50	BA1
				57.73	C
		50	ba (arm)	34	BA2
		110	dhira	55	BA5
Rectangular section	width			8.50	C
		45	brasses	82.35	T
Rectangular section base at level 1	length			26.3	BA
Monumental inscription on the southern wall of the rectangular shaft	height	1	dhira	0.50	BA1
Dimension of letters used in inscription (letters A and M)	height			0.54	C
		1	pics	0.54	T
Rectangular section parapet	height	1	qama	2.50	BA1
				1.83	C
Rectangular section parapet (actually given as 7 shibr 9 ashkil)	width	7	shibr	1.54	BA1
Rectangular section to parapet from octagonal section	length	15	shibr	3.30	BA1
Inner ramp of the rectangular shaft allows two horsemen to pass	width	7	shibr	1.54	BA1
		9	shibr	1.98	BA4
Total length of inner ramp	length	239	ba	162.52	BA1
Distance to first (closed) door on the left from the entrance	length			73.00	C
		40	brasses	73.20	T
Distance from the first (closed) door to the second (open) door	length			110.00	C
		60	brasses	109.80	T

Four storeys to the top of the rectangular section					
Storey 1 not counted					
Storey 2 - rooms		18			BA1
		18			C
		18			T
travel to...	length			110.00	C
		60	brasses	109.80	T
Storey 3 - rooms		14			BA1
		14			C
		14	rooms		T
travel to...	length			44.00	C
		24	brasses	43.92	T
Storey 4 - rooms		17			BA1
		17			C
		17	rooms		T
travel to...	length			100.00	C
		55	brasses	100.65	T
Stage 1 Level to include Octagonal Section 2					
Octagonal section (taller than its base line according to Clayton)	height	15	qama	37.50	BA1
Octagonal section side	height			27.45	C
		60	dhira	30	BA5
		15	kama	27.45	T
Octagonal section side	length			18.30	C
		10	brasses	18.30	T
Octagonal section side	length	10	ba	6.80	BA1
Octagonal section side to side	length	24.1	ba	16.39	BA1
Octagonal section shaft distance to parapet	length	15	shibr	7.50	BA1
				3.45	C
		15	empans	3.45	T
Octagonal section parapet	width	2	shibr	0.44	BA1
Octagonal section wall thickness	width			2.00	C
		9	empans	2.07	T
Walk inside octagonal section	length	15	brasses	27.54	T
Octagonal section - no of steps		18			C
		18			T
Inner ramp is a corridor according to Clayton - wall on both sides.	width			1.60	C
		7	empans	1.61	T
Stage 2 Level - to include Cylindrical Section 3					
Cylindrical section distance to parapet	length			2.19	C
		9	empans	2.19	T
Cylindrical section height	height			7.32	C
		4	kama	7.32	T
Cylindrical section circumference	length	40	ba	27.20	BA1
Cylindrical section diameter	length	12.7	ba	8.64	BA1
				75.20	C
		40	brasses	73.20	T
Cylindrical section including Oratory	height	7	qama	17.50	BA1
Steps to the top of cylindrical section... to Stage 3		31			C
		31			T

Stage 3 Level - to include Oratory					
Oratory - open on four sides - circumference	length	20	ba	13.60	BA1
Oratory diameter	length	6.4	ba	4.35	BA1
				36.60	C
		20	brasses	36.60	T
Oratory height	height	3	qama	7.50	BA1
				5.49	C
		3	kama	5.49	T
Distance from Oratory to parapet	length			1.51	C
		5	empans	1.15	T
Parapet	height			0.46	C
		2	empans	0.46	T
Zeus Soter statue	height			5.00	C
Totals					
Section 1 - rectangular	height			77.50	BA1
				57.73	C
		121	dhira	60.5	BA3
		31	kama	56.73	T
		320	dhira	160.00	BA6
		210	dhira rashashi	113.00	BA8
Section 2 - octagonal	height			27.50	C
		81.5	dhira	40.75	BA3
		80	dhira	40.00	BA6
Section 3 - cylindrical	height			7.50	C
		31.5	dhira	15.75	BA3
Mosque height	height	10	dhira	5	BA3
Section 3 plus mosque height	height	50	dhira	25.00	BA6
Tower height to dome - two rectangular sections: lower = 70, upper = 26	height	96	kamah	175.68	BA8
Height of dome	height	4	kamah	7.32	BA8
Total height of three sections above ground level	height	53	qama	132.50	BA1
				96.99	C
		233	dhira	116.5	BA3
		53.00	kama	96.99	T
		150	kamah	274.5	BA2
		230.00	dhira	115	BA5
		450	dhira	225	BA6
		100	kamah	183.00	BA8
		300	dhira rashashi	162.00	BA8
Total height of Pharos above sea level	height	58	qama	145.00	BA1
Stage 0 above sea level	height			9.15	C
Pharos base to sea	length			9.15	C
		5	kama	9.15	T
Visible below sea level	height			1.83	C
		1	kama	1.83	T
Total number of rooms		67			C
		67			T
Total length of inner ramp	length	239	ba	162.52	BA1

Facing page: Fig. 2 and Fig. 3 - Alexandrian medal; Fig. 4 - The lighthouse of Alexandria shown on the Peutinger Table; Fig. 5 - An ancient lamp with an image of a lighthouse. [Allard (1898), p10.]

Two sources of dimensional data were the works of Clayton and Empeur. Clayton's data was published first; his work was a reproduction of measurements cited by Abu al-Haggag Yusuf Ibn Muhammad al-Balawi al-Andalouisi, aka al-Balawi or al-Andalouisi and published by Toussoun. Empeur's data were taken from Clayton's work and so are not reproduced again here. Clayton himself converted the data into modern units. The original translation from the Arabic report of al-Balawi seems to derive from French text published by Toussoun (1936). Palacios (1933) published a Spanish translation of the same original report, translated from Toussoun's French, it appears. Most recently, a publication by Behrens-Abouseif (2006) draws together data published by a number of Arab authors. Behrens also gives conversion factors for the data, identified as (BA) in the table below (not to be confused with the ancient unit of ba).

Table 5-1 Reference codes:

BA = Behrens-Abouseif; BA1 = al-Balawi; BA2 = ibn Jubayr; BA3 = al-Baghdadi; BA4 = ibn Batuta; BA5 = al-Mas'udi; BA6 = al-Bakri; BA7 = al-Gharnati; BA8 = al-Idrisi; C = Clayton; T = Toussoun

Table 5-1 Conversion factors:

number	unit	metre
1	dhira	0.5 (BA)
1	shibr	0.22 (BA)
1	qama	2.5 (BA)
1	ba	0.68 (BA)
1	ashkil	n/k
1	cubit	0.46
1	pic	0.54
1	empans	0.23
1	kamah	1.83
1	brasse	1.83
1	arm	0.68
1	dhira rashashi	0.54 (BA)

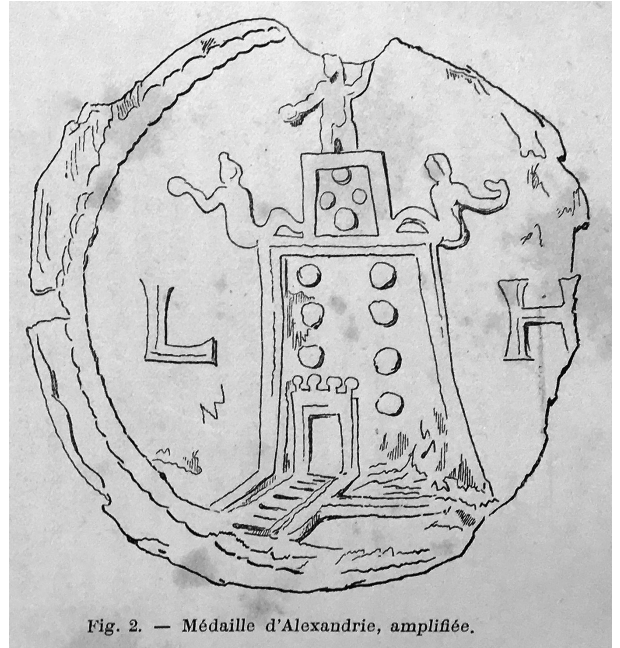


Fig. 2. — Médaille d'Alexandrie, amplifiée.

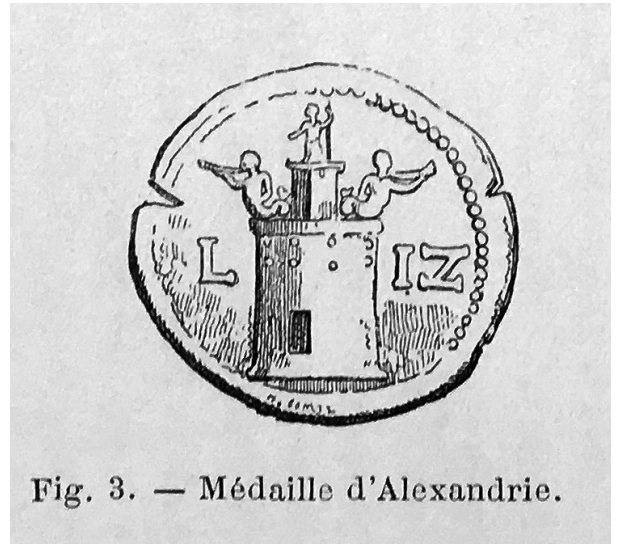


Fig. 3. — Médaille d'Alexandrie.

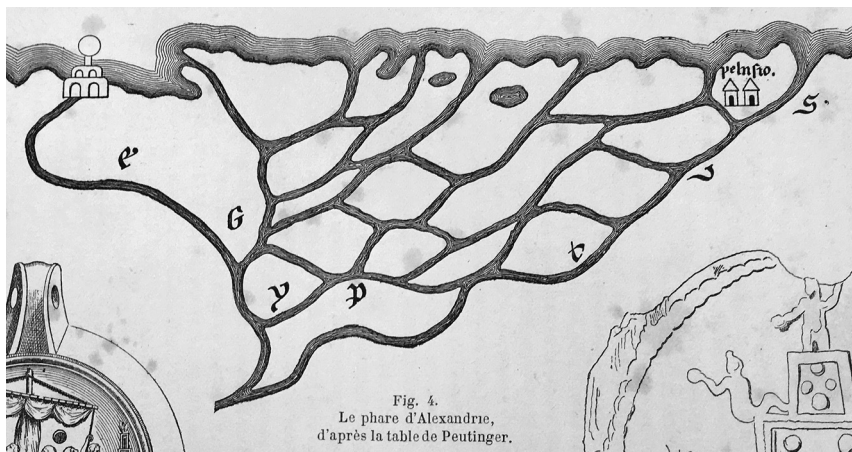


Fig. 4.
Le phare d'Alexandrie,
d'après la table de Peutinger.

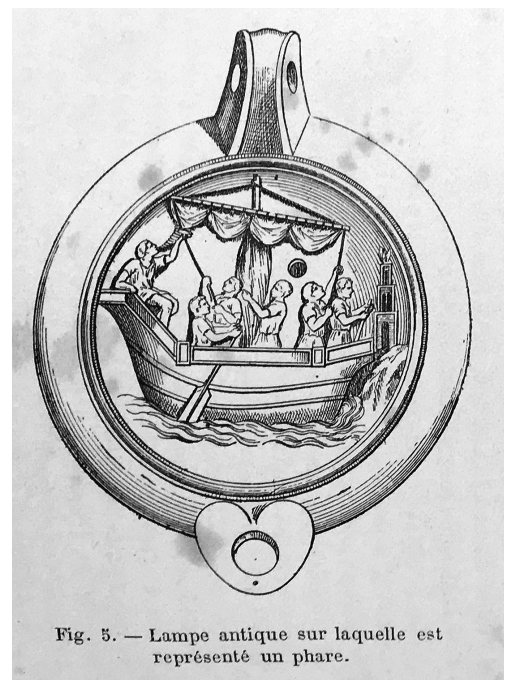


Fig. 5. — Lampe antique sur laquelle est représenté un phare.

Table 5-2: This table draws together details of the main reporters of the history of the Pharos during the time when it was under Muslim control. Names are English versions of the Arabic, with most common variations as well as the long familial names. Dates are years CE and are approximate. The main work in which the writer recorded details and stories of the Pharos is quoted, and its approximate date of publication. Almost all were written in Arabic and the details have been obtained by intensive research and translation by a small army of scholars. Some are available in the public domain; others are now lost.

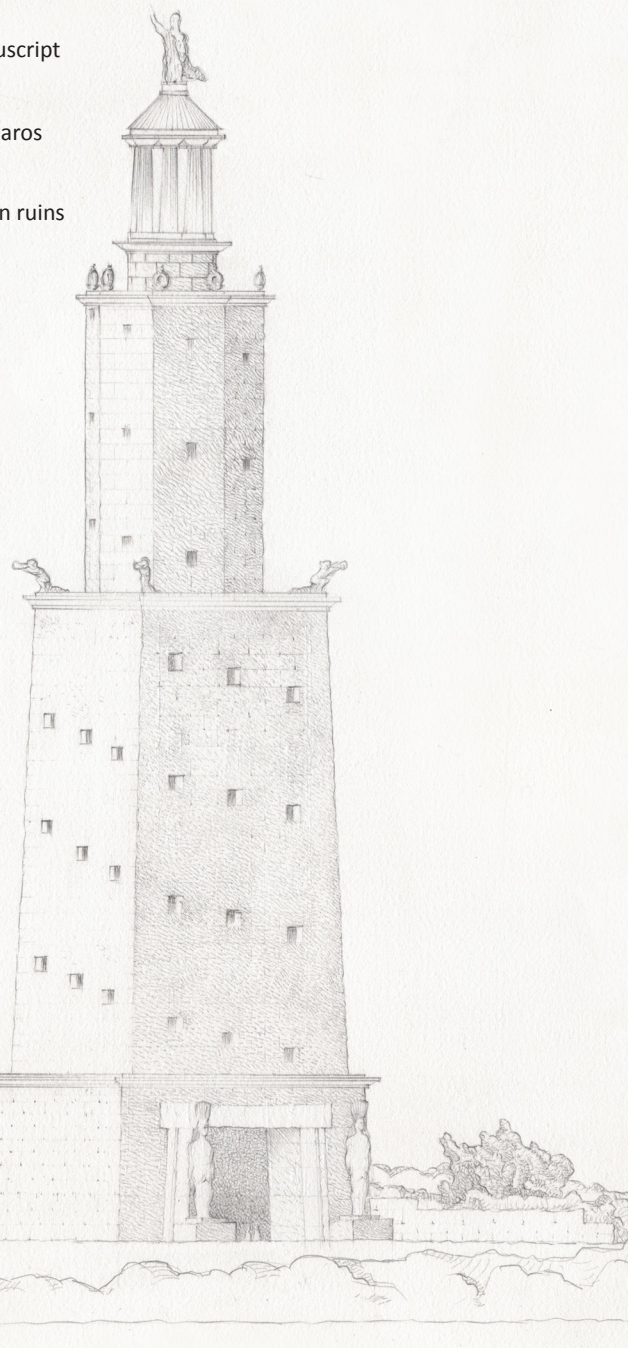
Name	Born	Died	Bio-Note	Work	Publ.
Ibn Khordadbeh: Abu'l Qasim Ubaydallah Ibn Abdallah Ibn Khordadbeh or Ibn Khurdadhbih; Ibn Khurradadhbih	820	912	A Persian geographer who wrote the earliest surviving Arabic book of administrative geography	Book of Roads and Kingdoms (Kitab al Masalik w'al Mamalik)	846
al-Yaqoubi: Ahmad Ibn Abu Yaqub Ibn Jafar Ibn Wahb Ibn Wadih al-Yaqubi	820	897	An Arab historian and geographer from Baghdad; became an Egyptian official	Book of Countries (Kitab al-buldan)	891
Ibn al-Faqih: Ibn al-Faqih al-Hamadani	869	951	A Persian historian and geographer	Book of Countries (Mukhtasar Kitab al-buldan)	903
Ibn Rustah: Ahmad Ibn Rustah	900	980	A Persian explorer and geographer from Isfahan	Book of Precious Records	950
al-Masudi: Abu al-Hasan Ali Ibn al-Husayn Ibn Ali al-Mas'udi or al-Macudi; el-Masa'oudi	896	956	An Arab historian and geographer; b. Baghdad, d. Cairo; wrote history of world	(1) Meadows of Gold (Muruj al-dhahab) (2) Mines of Gems (al-Tanbih wa'l Ishraf)	951
al-Istachri: Abu Ishaq Ibrahim Ibn Muhammad al-Istachri		951	A Persian-Islamic geographer and cartographer in Baghdad	Book of Ways and Provinces (Kitab al-Masalik wa-i-mamalik)	951
Ibn Hawqal: Muhammad Abu 'l-Qasim Ibn Hawqal		978	Arab Muslim writer and geographer	The Face of the Earth (Surat al-'Ard)	977
al-Muqaddasi: Muhammad Ibn Ahmad Shams al-Din al-Maqdisi or al-Maqdisi.	945	991	An Arab geographer, born in Jerusalem	The Best Divisions for Knowledge of the Regions	985
Khusraw: Abu Mo'in Hamid ad-Din Nasir Ibn Khusraw al-Qubadiani or Nasir-i Khusraw Qubadiyani; or Khusrow or Khosrow; Sayyidna Nasir Khusraw	1004	1088	A Persian poet, philosopher, traveller and writer; Lived in Alexandria for about three years in the late 1040s	Book of Travels (Safarnama)	1049
al-Quada'i: Abu Abdallah Muhammad Ibn Salamah Ibn Ja'far al-Quada'i- al-Safi'l or Muhammad Ibn Salama al-Quada'i		1062	An Egyptian historian	A Treasury of Virtues	1062
al-Bakri: Abu 'Ubayd al-Bakri		1094	An Arab geographer, theologian and poet	al-Masalik wa'-mamalik	1068
al-Gharnati: Abu Hamid al-Gharnati	1080	1170	An Arab geographer and traveller; born Granada, died Damascus.	Tuhfat al-Albab	1117
al-Idrisi: Abu Abdallah Muhammad al-Idrisi al-Qurtubi al-Hassani al-Sabti Ibn Abdelziz al-Sharif al-Idrisi or Muhammad al-Sarif al-Idrisi or al-Edresi	1100	1165	An Arab Muslim geographer, cartographer and Egyptologist; born in Ceuta (H493); lived in Palermo Sicily; drew a world map called Tabula Rogeriana	Kitab nuzhat al-mushtaq fi ikhtiraq al-afaq	1165
al-Balawi: Abu al-Haggag Yusuf Ibn Muhammad al-Balawi al-Andalusi or Yusuf Ibn al-Shaykh al-Balawi or al-Andalusi.	1132	1207	An Arab traveller and writer, born in Malaga; made a trip to Mecca and recorded the Pharos in great detail	Book of A and B (Kitab Alif Ba)	1166
Tudela: Benjamin of Tudela	1130	1173	A medieval Jewish traveller	(1) The Travels of Benjamin (Masa'ot Binyamin) (2) Book of Travels (Sefer ha-Masa'ot)	1173
Ibn Jubayr: Abu 'l-Husayn Muhammad Ibn Ahmad Ibn Jubayr or Ibn Gubair or Ibn Dschubair or Ibn Jobair or Ibn Gabir	1145	1217	An Arab geographer, poet and traveller from al-Andalus. Writer of a travelogue. Secretary to the ruler of Muslim Spain in Granada. Died in Alexandria	The Travels of Ibn Jubayr	1182

al-Baghdadi: Abd al-Latif al-Baghdadi	1162	1231	A physician, historian, Egyptologist and traveller; wrote one of the earliest works on Egypt; d. Baghdad	Account of Egypt	1195
al-Harawi: Ali Ibn Abi Bakr al-Harawi or Abu al-Hasan; Ali of Herat		1215	A Persian traveller from Herat, Afghanistan; born in Mosul, died in Aleppo	Book of Indications (Kitab al-ishara ila ma`rifat al-ziyara)	1214
Zhao Rugua	1170	1228	A Chinese official in the Song dynasty	Wrote a book about the world known to China in the 12th and 13th centuries.	1225
Yakut: Yakut Ibn-Abdullah al-Rumi al-Hamawi or Yaku al-Hamawi; Yaqut	1179	1229	An Arab biographer and geographer of Greek origin, born in Constantinople. Yakut was a slave to his master, al-Hamawi	Dictionary of Countries (Kitab Mu`jam al-Buldan)	1228
al-Athir: Abu al-Hassan Ali Ibn Muhammad ash-Shaybani or Ali `Izz al-Din Ibn al-Athir al-Jaziri	1160	1233	An Arab historian and biographer; died in Mosul	The Complete History (al-Kamil fi al-Tarikh)	1233
al-Qazwini: Abu Yahya Zakariya' Ibn Muhammad al-Qazwini or Zakarya Qazvini	1203	1283	A Persian physician, astronomer, geographer and proto-science fiction writer; born in Qazvin, Iran	Monuments of the lands and historical traditions about their peoples (Atar al-Belad wa akbar al-ebad)	1283
al-Abdari: Abu Abdallah Muhammad Ibn Muhammad Ibn Ali Ibn Ahmed Ibn Hajj al-Abdari al-Hihi		1300	A Moroccan travel writer	The Moroccan Journey (al-Rihlah al-Magribiyah)	1289
Ibn Idhari: Abu al-Abbas Ahmad Ibn Muhammad Ibn Idari al-Marrakushi			An Arab author, born and lived in Marrakech	History of the Maghreb and Iberia (al-Bayan al-Mughrib)	1312
al-Dimashqi: Shams al-Din al-Ansari al-Dimashqi	1256	1327	An Arab geographer, born in Damascus, completing his work in 1300.	Wrote extensively about SE Asia; also of the Pharos (Nukhat al-dahr)	1327
Ibn al-Wardi: Abu Hafs Zayn al-Din `Umar Ibn al-Muzaffar Ibn al-Wardi	1291	1349	An Arab historian and geographer	The Pearl of Wonders and the Uniqueness of Strange Things (Kharidat al-Aja`ib wa faridat al-gharaib)	1349
Ibn Battuta: Shams al-Din Abu Abdallah Muhammad Ibn Abdallah Ibn Muhammad Ibn Ibrahim Ibn Battutah al-Lawati al-Tanji	1304	1369	An Arab traveller and geographer and writer. Visited the Pharos in 1326 and 1349	A Gift to Those Who Contemplate the Wonders of Cities and the Marvels of Travelling (The Travels) (Tuhfat an-Nuzzar fi Ghara`ib al-Amsar wa `Aja`ib al-Asfar)	1369
Ibn Khaldun: Abu Zayd Abd` ar-Rahman Ibn Muhammad Ibn Khaldun al-Hadrami	1332	1406	An Arab historian born in Tunis; died in Cairo	Prolegomena (A Critical Introduction) (Muqaddimah)	1377
Ibn Duqmaq: Sarim al-Din Ibrahim Ibn Muhammad al-Hanafi Ibn Duqmaq		1407	An Arab author; teacher to Maqrizi	History of the Islamic Empire (Nuzhat al-Anam fi tarikh al-Islam)	1407
al-Qalqashandi: Shihab al-Din abu `I-Abbas Ahmad ben Ali ben Ahmad Adb Allah al-Qalqashandi or Abou L'Abbas Kalkashandi	1355	1418	An Arab Egyptian scholar and writer in Cairo	Dawn for the Blind (Subh al-a`sha) in 14 volumes	1412
al-Maqrizi: Taqi al-Din Abu al-Abbas Ahmad Ibn Ali Ibn Abd al-Qadir Ibn Muhammad al-Maqrizi or al-Makrizi	1364	1442	An Arab Egyptian historian	Topographic Description and History of Egypt (Mawaiz wa al`itibar bi dhikr al-khitat wa al-`athar)	1442
al-Suyuti: Abu al-Fadl Abd al-Rahman Ibn Abi Bakr Ibn Muhammad Jalal al-Din al-Khudayri al-Suyuti or Jalal al-Din al-Suyuti	1445	1505	An Egyptian scholar and teacher	History of the Caliphs (Tarikh al-Khulafa) and many others e.g. Husn al-Muhadara	1505
Ibn Iyas: Muhammad Ibn Iyas or Ijas	1448	1524	An Egyptian historian, he witnessed the Ottoman invasion of Egypt	History of Egypt in 6 volumes	1522

Table 5-3: Timeline for Pharos. Negative dates BCE; positive dates CE. 'Name' is the individual related to the event. Names in parentheses are modern authors who report the event. Elnashai reports earthquakes known from seismological data. Roman numerals indicate increasing earthquake magnitudes.

Year	Name	Event
-297	anon	Pharos build begins; ends in 283/2 BCE
-250	Posidippus of Pella	Wrote a poem about the Pharos and said that the top statue was Zeus
-30	Cleopatra	Pharos suffers damage during the Alexandrian War under Cleopatra
-26	Strabo	Lived in Alexandria from -30 to -27; Describes the Pharos as built of white marble (leucos lithos) with many storeys
79	Pliny the Elder	Records the cost of the Pharos as 800 talents
90	Josephus	Titus Flavius Josephus, aka Yosef ben Matityahu; Described Alexandria harbour in 66/7 CE; Said the tower was visibility from 300 stadia; visibility of 300 miles wrongly attributed to others
91	Domitian	The first coins depicting the Pharos are minted
150	Lucian of Samosata	Provides the story of Sostratus and the disappearing inscription
150	Achilles Tattius	A resident of Alexandria, he mentions the Pharos in his writing
283	Eusebius of Caesarea	In his work, Chronicle, he records that the Pharos was completed in the 124th Olympiad; report dated around 300 CE
491	Anastasius I - Emperor	The base of the structure was repaired after damage caused by the sea
641	anon	Muslim army under Amr takes control of Alexandria, defeating Byzantine Greeks
670	Arculf	The Frankish Bishop visits the Pharos; reports that Large wooden beams are regularly laid down on the weather side to resist the effects of waves
680	John of Nikiu	aka Johannes von Nikiu; Egyptian Coptic Bishop; wrote Chronicle with much history of Alexandria, but nothing of the Pharos
705	al-Masudi	Caliph al-Walid (r. 705-15) is fooled by a eunuch from Byzantium; destroys the top half of the Pharos
750	(Elnashai)	Alexandria comes under Muslim control; Pharos known to be functioning normally
796	(Elnashai)	Earthquake (VIII) damages Pharos; uppermost section (lantern) collapsed
835	Ahmad ibn Tulun	Ruler of Egypt 868-884; Placed a mosque on the top of the Pharos with a crescent on top of that
846	Ibn Khordadbeh	Describes a mosque built on top of the Pharos
870	Yacoubi	An Arab official from Baghdad called Yacoubi wrote that the tower was 175 cubits from base to the lantern level
891	Yacoubi	Wrote a description of the Pharos with wooden cupola; suggests watchtower not lighthouse; mentions sending fire signals to ships
903	Ibn al-Faqih	Relates the story of the crab and glass foundations of the Pharos
944	al-Masudi	Related the tale of the Eunuch and the Treasure in Meadows of Gold
951	al-Istachri	Describes the pharos
951	(Elnashai)	Earthquake (VIII-IX) damages Pharos
951	al-Masudi	In Meadows of Gold, he reported the destruction of the Pharos and Alexandria in earthquakes; b. Baghdad d. Cairo 956; describes slow destruction
955	al-Maqrizi	Earthquake damages Pharos; about 30 cubits in height lost; this has been denied by al-Ghendy (2003)
956	al-Masudi	Wrote Kitab al-Tanbih wa l'ishraf. Gives a more detailed description of the structure
956	(Elnashai)	Earthquake (VIII-IX) reported to have cause major damage to the lantern, but denied by others
977	Ibn Hawqal	Reports that lead was used to strengthen the masonry
985	al-Muqaddasi	Visited the Pharos; describes the interior with rooms and wide enough for a horseman to climb it, and the approach by a causeway
1013	al-Hakim	Caliph of Alexandria (r. 996-1021) began a rebuilding programme in the city; he may have renewed the upper levels of the Pharos
1049	Nasir-i Khusraw	Wrote that the Pharos was in good condition and suggested to the caliph that a new mirror be installed
1068	al-Bakri	Published a report of the Pharos
1106	al-Gharnati	Lived in Egypt for 4 years; made drawing of the Pharos
1115	al-Idrisi	Visit report; a fire burned day and night to guide ships
1117	al-Gharnati	Descriptions of the mirror and its uses

1154	al-Idrisi	Reports that the lighthouse was built of excellent stones of a type called caddzan (kadhghan)
1166	al-Balawi	Made a famous visit; made detailed measurements; report not published until 1870; gained attention 1930
1173	Tudela	Reported the Pharos on his travel diaries; especial mention of the mirror
1182	Ibn Jubayr	There were gigantic stairs and passages, also so many chambers that one could become lost in them; reportedly seen Pharos from 50 coudees
1195	al-Baghdadi	Published his account of Egypt
1202	al-Baghdadi	Date given for al-Baghdadi's report
1215	al-Harawi	Wrote that the lighthouse was not a marvel and had the appearance more of a watchtower
1225	Zhao Rugua	Report of the Pharos published in China; Zhao himself did not visit the lighthouse
1228	Yakut	Described the lighthouse in simple terms as two rectangular sections one on top of the other, with a small platform with a dome that resembled a watchtower
1229	Yakut	Yakut records a visit to Alexandria made just before his death the same year
1233	al-Athir	reported the earthquake of 955
1262	(Elnashai)	Earthquake (IX, SW) damages Pharos. (SW = Sea Wave)
1303	(Elnashai)	Earthquake (IX, SW) severe damage to Pharos; repairs attempted
1303	(Casson)	The date of final destruction given in a manuscript in the monastery at Montpelier
1312	Ibn Idhari	Reports the earthquake that affected the Pharos
1323	(Clayton)	Damage to Pharos; not reported by Elnashai
1326	Ibn Battuta	Visited Alexandria; found 1st tier of pharos in ruins
1341	(Elnashai)	Earthquake (VIII-IX) in Alexandria
1349	Ibn Battuta	Visited Alexandria for the second time; found the Pharos in ruins; Sultan al-Nasir Muhammad had planned to build a new lighthouse next to the old one but died in 1341 before starting
1375	Maqrisi	Earthquake finally destroys the last remains
1375	(Elnashai)	Earthquake (VIII) in Alexandria. Near complete collapse; Ambraseys gives date as 1373
1436	Khalil Zahiri	Reported that the tower was destroyed
1480	(Elnashai)	Completion of Qait Bey
1522	Ibn Iyas	Recorded that the fort was built on the site of the lighthouse
1582	(Thiersch)	Turkish script written in Paris
1737	(Pococke)	Remains found in waters adjacent; first reported by Robert Pococke 1737
1968	(Honor Frost)	A team supported by UNESCO makes the first survey of submerged artifacts
1994	(Empereur)	Underwater research begins again



Notes

- 1 Wikipedia, Hellenistic Period: 20171015.
- 2 Empereur (1998), p14.
- 3 Zemke (1992).
- 4 Eusebius quoted in McKenzie, p41. In his translation of Eusebius' Chronicle, Jerome gives the date of completion of the Pharos in the first year of the 124th Olympiad (284 BCE). This would be 283 BCE in the Armenian translation where the Olympiads differ by one year. [http://penelope.uchicago.edu/~grout/encyclopaedia_romana/greece/paganism/pharos.html]
- 5 Stevenson (1959), p8.
- 6 Wikipedia, Lighthouse of Alexandria 20160618.
- 7 Posidippus: Quoted in McKenzie, p41. The complete details of the source are given in McKenzie's ref 48, p383.
- 8 Strabo: Geographica 17, 1, 6.
- 9 Diodorus Siculus, Library of History, Loeb Classical Library edition, 1, 31, 4-5 (1933).
- 10 Pliny the Elder: The Natural History 36, 18; Trans. John Bostock, H.T. Riley; Taylor and Francis, Red Lion Court, Fleet Street, London (1855). Quoted in McKenzie, ref. 58, p383.
- 11 McKenzie, (2007), p42
- 12 Strabo: Geographica 17, 1, 4.
- 13 Herodotus: The Histories 2, 15.
- 14 Homer: Odyssey 4, 356-360. The following reference explains why Homer described the island of Pharos as a day's sail from Alexandria. https://kb.osu.edu/dspace/bitstream/handle/1811/47007/Gurd_Book4CD.pdf?sequence=1.
- 15 Harris (2004).
- 16 Strabo: Geographica 17, 1, 9.
- 17 The citation of 300 furlongs is a result of the translation from the unit used in the original source into the contemporary unit of the translator (Whiston - see the reference to Josephus). Thus 300 furlongs equates to 37.5 miles. This is a perfectly reasonable distance for the visibility of a bright light shown from 120 m above sea level.
- 18 Josephus: Whiston (1737).
- 19 Herodotus: The Histories 2, 179.
- 20 McKenzie (2007), p36.
- 21 The Adventures of Leucippe and Clitophon, V.6; [http://penelope.uchicago.edu/~grout/encyclopaedia_romana/greece/paganism/pharos.html]
- 22 Cnidus is the home of Sostratus, generally accepted as the architect of the Pharos. Knidos or Cnidus (modern-day Tekir in Turkey) is an ancient Greek city in Asia Minor, once part of the country of Caria. It is situated at the extremity of the long peninsula that forms the southern side of the Sinus Ceramicus or Gulf of Kos (Cos).]
- 23 Vorderstrasse (2012).
- 24 Stevenson (1857).
- 25 Lucian: Tooke (1820).
- 26 Fraser (1972), p20.
- 27 Fraser (1972), p19-20.
- 28 Hardy (1895), p18-21.
- 29 Empereur (1998).
- 30 Lucian: Tooke (1820).
- 31 Empereur (1998), p24-31.
- 32 Thiersch (1909).
- 33 Butler (1880).
- 34 Taylor (1956), pp3-20.
- 35 I have recently become aware that my conclusion is shared by another academic, Lowe (2016)
- 36 Noble (1968).
- 37 Vitruvius: De Architectura 1, 6, 4.
- 38 Strabo: Geographica 17, 1, 6.
- 39 McKenzie (2007), p42; also McKenzie's reference 68 on page 384.
- 40 Butler (1902), p391.
- 41 Lucian: Fowler (1905).
- 42 Hemingway (2003).
- 43 Homer: Odyssey 4, 384-6.
- 44 Fraser (1972), p18.
- 45 Fraser (1972), ref 107.
- 46 Fraser (1972), ref 105.
- 47 Empereur (1998), p33.
- 48 Footnote to Strabo: Geographica 17, 1, 6.
- 49 Fraser (1972), p21.
- 50 Empereur (1998), p35.
- 51 Thiersch (1909), p47.
- 52 Empereur, Jean-Yves: Underwater archaeological investigations of the ancient Pharos, Centre d'Études Alexandrines, Alexandria. At: <http://www.unesco.org/csi/pub/source/alex6.htm> 20160801.

- 53 Anon (1975).
- 54 Empereur (1998).
- 55 Naish (1985).
- 56 Stevenson (1959), p30.
- 57 Fraser (1972), p18
- 58 Fraser (1972), ref 101
- 59 Duggan (2014), pp416-7
- 60 See the section entitled How Lighthouses Work at www.pharology.eu. The calculation is only approximate because there is refraction of light through layers of air that bends the light and makes it visible over slightly greater distances.
- 61 The science of light visibility is not relevant in this volume; it will be covered comprehensively in a later volume.
- 62 Butler (1902), pp389-397.
- 63 A span is regarded as equivalent to 9 inches and the same as half a cubit. Thus five spans equate to about 45 ins, i.e. 1.14 m.
- 64 Al-Murtadi: Davies (1693).
- 65 Butler (1902). His reference to the lighthouse keepers has not been found.
- 66 Arculf: Stewart (1896).
- 67 Thiersch (1909), pp89-93.
- 68 Wikipedia: Mirrors, Telescopes, Speculum metal, 20180228. The earliest manufactured mirrors were pieces of polished stone such as obsidian, a naturally occurring volcanic glass. Obsidian mirrors from Anatolia have been dated to around 6000 BCE; polished copper (Mesopotamia) from 4000 BCE and Egypt 3000 BCE. Polished stone mirrors from Central and South America date from around 2000 BCE; China had bronze mirrors from around 2000 BCE. Mirrors made of other alloys such as copper and tin speculum metal date from around 0 CE in China and India.
- 69 http://www.unmuseum.org/burning_mirror.htm
- 70 Thiersch (1909).
- 71 van Berkem (1900).
- 72 Al-Qazwini (1283).
- 73 https://archive.org/stream/workss2v110hakl/workss2v110hakl_djvu.txt
- 74 De oorsprong van de minaret. (The origin of the minaret), Tim Louisse (2011). Free, downloadable file available by Google search. In Dutch.
- 75 Al-Masudi: Lunde (2007), p46.
- 76 Abu Ḥamid al-Gharnāṭī: Tuḥfat al-Albab, p99-100; quoted in Okasha el-Daly: Egyptology: The missing Millennium: Ancient Egypt in Medieval Arabic Writings (2008), p53. ISBN 9781598742800. Also Hamarneh, S: The Ancient Monuments of Alexandria According to Accounts by Medieval Arab Authors (IV-XV century). Folia Orientalia 13 (1971) pp77-110; refers to Al-Gharnati's visit p86, 87. A French translation with notes is given in Ducène (2006).
- 77 Al-Edrisi: Dozy (1866), p166 (e-book p202). This reference is clearly a translation from Arabic into French. Both are given here, along with extensive notes. The units of measurement are inconsistent. Measurements are quoted in square parentheses and in French having presumably been converted from Arab equivalents. The writer is known in English as Abu Abdullah Muhammad al-Idrisi al-Qurtubi al-Hasani as-Sabti, or simply Al-Idrisi. [Wiki: Muhammad al-Idrisi, 20171109] In French, his name is spelled Edrisi.
- 78 Empereur (1998), pp28-9.
- 79 Toussoun (1936) pp49-53. Asín Palacios, "Descripción," translated the French text into Spanish.
- 80 Palacios (1933).
- 81 Behrens-Abouseif (2006).
- 82 Toussoun (1936). The author says that the search for this article was made as a result of a report by Don Miguel de Asin: Ibn Al-Sayj, the Duke of Alba, Proceedings of the British Academy, 19 (1933) 277-292.
- 83 Clayton (1988), pp153-5
- 84 Empereur (1998), pp86-7
- 85 This is in error. The original paper by Toussoun gives 45 fathoms (82.35 m). Clayton's error is repeated by Empereur.
- 86 Broadhurst (1952).
- 87 The kama or qama is clearly a somewhat vague unit of measurement. It is perhaps best taken as 1.83 m although it has been quoted as 2.5 m.
- 88 Broadhurst (1952), pp32-3.
- 89 This value is given as 50 ba in Thiersch's work. (Thiersch (1909) p434. In his own footnote (4), Thiersch equates this with a dhira which seems to be about 0.5 m, but is given elsewhere as 0.68 m. The dhira or dira is traditionally taken as two Arabic feet where one Arabic foot is 0.32 m. The dhira has also been equated to a cubit. [Wikipedia: Ancient Arabic units of measurement, 20180209].
- 90 Mackintosh-Smith (2002), p7. The traveller is best referred to as ibn Battutah. His full name is given as: Shams al-Din Abu Abdallah Muhammad ibn Abdallah

ibn Muhammad ibn Ibrahim ibn Battutah al-Lawati al-Tanji. Mackintosh-Smith spells the name Battutah; Thiersch spells it 'Batuta'.

91 *The Travels Of Ibn Battuta 1325-1354, Vol. 1 Second Series No. CX (1956)*, The Hakluyt Society. Translated with revisions and notes from the Arabic text edited by C. Defremery and B. R. Sanguinetti; by H.A.R. Gibb Vol. I Cambridge; at The University Press 1958; The Syndics Of The Cambridge University Press. <http://archive.org/details/workss2v110hakl>

92 Elnashai (2006), p144.

93 MacPherson (1895).

94 Vorderstrasse (2012).

95 Rugua: Hirth (1911).

96 The quotation of Isidore (600-625 CE) is given on p185 of Forbes (1964). The Chapter entitled "Some Applications of Lights and Lamps" discusses the Pharos and other ancient lights.

Isidore Hispalensis: *Episcopi Etymologiarum Sive Originum*, Book XX, Ch. X, §10

Farum turris est maxima, quam Graeci ac Latini in commune ex ipsius rei usu farum appellarunt eo quod flammarum indicio longe videatur a navigantibus, sicut supra (15,2,37) praediximus, qualem Ptolomeus iuxta Alexandriam construxisse octingentis talentis traditur. Vsus eius est nocturno navium cursu ignes ostendere ad pronuntianda vada portusque introitus, ne decepti tenebri navigantes in scopulos incidant: nam Alexandria fallacibus vadis insidiosos accessus habet. Hinc igitur in portibus machinas ad praelucendi ministerium fabricatas pharos dicunt.

The final sentence reads, literally: Here (Hinc) therefore (ignatur) devices (machinas) built (fabricatas) in ports (in portibus) for leading lights (praelucendi) are called (dicunt) lighthouses (pharos).

[<http://www.thelatinlibrary.com/isidore/20.shtml>]

A similar sentence is also attributed to Gaius Julius Solinus, XXXIII (Aethiopia) in the early 3rd. c.

97 El-Fakharani (1974), p272.

98 Fraser (1972), p18.

99 McKenzie, (2007), p42.

100 Naish (1985), p16.

101 Hague (1975), p1.

102 Full references can be found in Cobb (2012) pp471-2. Also see Reference 59 on p472. The story is similarly covered by al-Maqrizi: Translated from Arabic into French by Bouriant (1895-1900), Chapter IX: Du Phare d'Alexandrie, p444-50.

103 Harris (2016). Harris relates a tale when an army of Pharaoh was defeated and lost in the Red Sea. Women and slaves who survived were fearful of attack from Syria. A woman called Dalukah was crowned Queen, whereupon she surrounded her lands with a great wall. Men were found to keep guard and they were assisted by many fearsome statues placed at frequent intervals around the outside of the wall. She also made statues of soldiers on horseback. If an enemy army came close, she would utter magic spells to make these stone soldiers disappear into the ground, taking their mortal counterparts with them. She reigned for thirty years.

104 This figure leads to 457 m in height which is generally considered incorrect.

105 Al-Masudi: Barbier (1863). Translated into English using Google Translator.

106 Belvedere: a summer house or open-sided gallery, typically at rooftop level, commanding a fine view.

107 Fustat and Fustat-Misr, was the first capital of Egypt under Muslim rule. It was built by the Muslim general 'Amr ibn al-'As immediately after the Muslim conquest of Egypt in AD 641, and featured the Mosque of Amr, the first mosque built in Egypt and in all of Africa.

108 Baibars or Baybars: al-Malik al-Zāhir Rukn al-Dīn Baybars al-Bunduqdārī (1223–1277) was of Turkic Kipchak origin. He was nicknamed Abu al-Futuh and Abu l-Futuh (Father of Conquest) referring to his victories and was the fourth Sultan of Egypt in the Mamluk Bahri dynasty. He was one of the commanders of the Egyptian forces that inflicted a defeat on the Seventh Crusade of King Louis IX of France.

109 Bouriant (1895).

110 al-Maqrizi: Translated from Arabic into French by Urbain Bouriant as: *Description topographique et historique de l'Égypte*, Paris (1895-1900) Chapter IX: Du Phare d'Alexandrie, p444-50; translated into English by Google.)

111 An impression of the Pharos of Alexandria.

112 Tome 1. Carte dépl. p.278: Carte de la Basse-Egypte. Cartographer not known. Source: [gallica.bnf.fr / Bibliothèque nationale de France](http://gallica.bnf.fr/Bibliothèque_nationale_de_France).

113 M. Matter (1840-44).

114 photo-iss007e10960; courtesy of NASA.

115 Georg Balthasar Probst: [gallica.bnf.fr / Bibliothèque nationale de France](http://gallica.bnf.fr/Bibliothèque_nationale_de_France).

116 The Pharos of Alexandria, illustrated in 1572 by van Heemskerck. The Pharos of Alexandria (1572), Maarten van Heemskerck [Public domain], via Wikimedia Commons <https://commons.wikimedia.org/wiki/File%3A->

Pharos_of_Alexandria.jpg

117 Image ©2016 Alfonso Biescas

118 There are many variants of this map, which must be considered to be in the public domain. Annotation on this version is Stanford, London (1907).

119 Image ©2016 Alfonso Biescas

120 Stuart and Revett (1762), Plate III.

121 Image ©2016 Alfonso Biescas, see Fig. 5-8.

122 Lowe (2016).

123 Stuart and Revett (1762), Plate XII.

124 Image by Emad Victor Shenouda. Reproduced under the terms of the Wikimedia Creative Commons License (2007).

125 Clayton, p156; uncredited photo.

126 Images ©2018 Mark Lewis.

127 Image ©2018 Mark Lewis.

128 Image ©2018 Mark Lewis.

129 McKenzie (2007) p42.

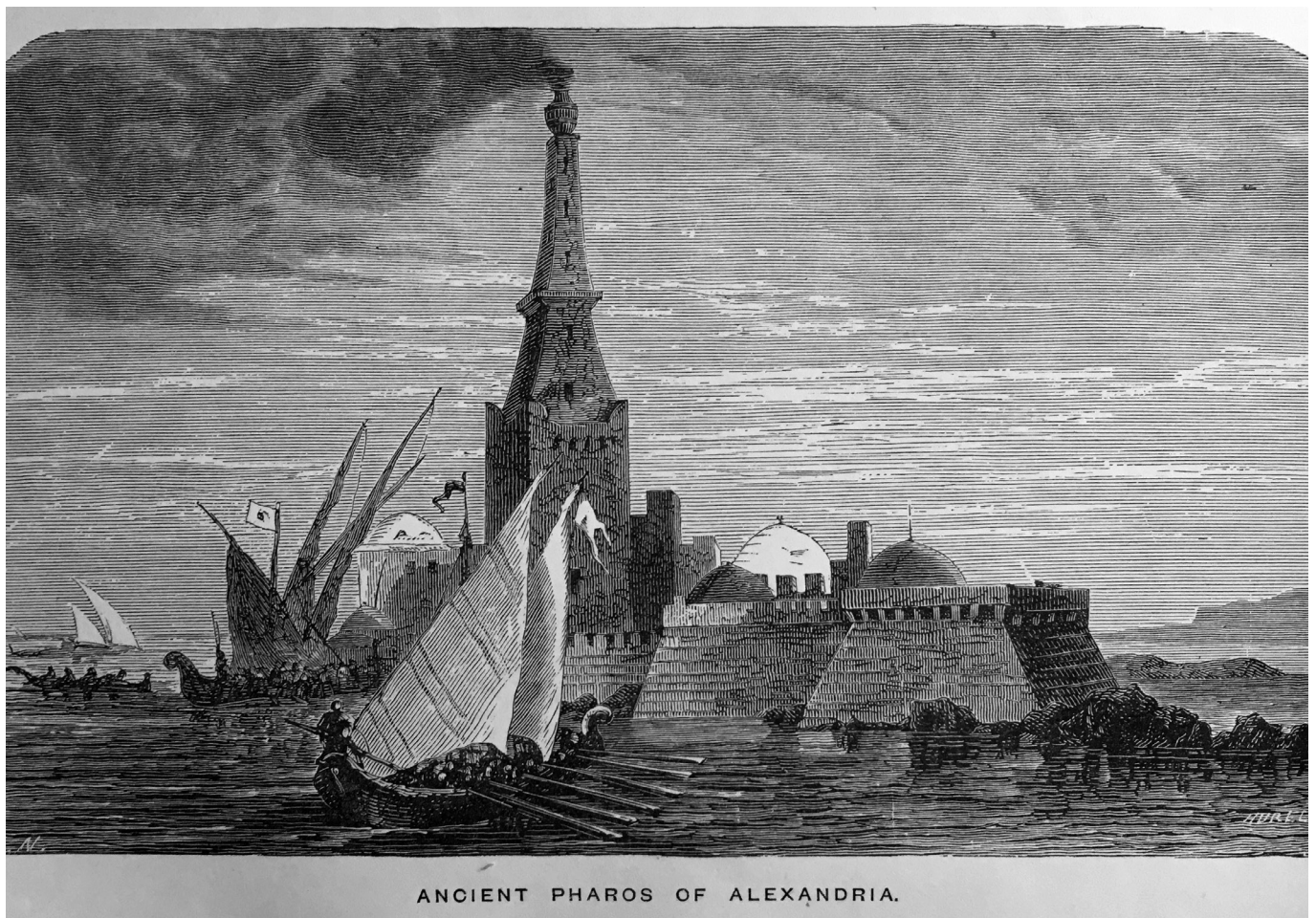
130 Abu_Hamid_al-Gharnati: Al-mu'rib 'an ba'd 'adjâ'ib al-Maghrib (Clear Exposition of Some Wonders of the West). Translated in Ducène, Jean-Claude: De Grenade À Bagdad: La relation de voyage d' Abû Hâmid al-Ghar-nâtî (1080-1168)(2006), 210pp. ISBN 9782296005594. <http://www.muslimheritage.com/article/light-house-of-alexandria>; <https://de.wikipedia.org/wiki/>

131 Petry (2008), p167.

132 Representation of the lighthouse of Alexandria made ca. 1390-1450. Taken from a page from a manuscript known as Kitab al-bulhan or "Book of Wonders" held at the Bodelian Library. MS. Bodl. Or. 133.

133 Artist uncertain: a 12th century Persian illustration from the Mojmal al-tawarik wa'l-qesas

134 Benett (1878).



ANCIENT PHAROS OF ALEXANDRIA.

Image: The Ancient Pharos of Alexandria. [W. H. D. Adams (1871); author's collection.]

Appendix to Paper 5

The following is an extract from the work of Thiersch (1909), translated from the original German by the author with the assistance of Google Translator. It has been included because it has direct relevance to the contents of this Paper and is the only English material of its kind that I have found. Thiersch's book (in German) is available in paper format and is now in the public domain because of its age. Where appropriate I have added comments in square brackets. However, parts of the translation unfortunately remain somewhat obscure.

Thiersch's unsurpassed study provides a great deal of reporting and analysis, especially of a number of innovations that were used in the Pharos. For example, it is not generally appreciated that complex astronomical observations could have been made in the 8th or 9th c. CE, especially the use of mirrors, lenses and prisms to form a telescope, centuries before the invention of William Herschel in 1774. We must remember that Alexandria was one of the foremost centres of learning in the world at this time and so the expertise to include these instruments and engineering improvements was locally available. The crucial importance of the Sun to Egyptian culture is well understood, and Thiersch goes into detail as to how giant sundials might have come about at the Pharos. Lastly, he describes the kind of utilities that might have been installed to provide water and drainage to the tower, and how various mechanical pumps and pipes, well-known to the Romans (thanks to the great engineer, Vitruvius) could have provided water-powered clocks and other devices.

All of these theories, well supported by Thiersch's research, give an even more remarkable picture of this fabulous engineering marvel.

“Internal Facilities [p89-90]

“A lighthouse, which served not only as a fortification, but was also intended for nautical observations, so was like our Hamburg Seewarte [chronometer] today, had to be provided with all facilities, which requires the permanent attendance of numerous people, with water supply and sewerage. To be sure, the great mechanical inventions that distinguished Alexandria at that time were practically exploited here, and justified their reputation as a miracle of the world.

“There were pumping machines like the unit designed by Ctesibios (Vitruvius, X, 7) necessary to lift the water led on the Heptastadion not only into that reservoir beside the east side of the tower, but also to push it up the tower, at least to the first platform where it serves as drinking water and to the operation of water clocks, and pneumatic mechanisms. See the description of the water-operated tools at Vitruvius X, 8 that had to be used to rinse the drains.

“In the plan of the building spaces were allocated for various machines and water tanks and suitable places for mounting various pipes. For the latter, possibilities are offered by the angles between octagon and square, as indicated in the plans on Plate V, and the extensions of the first platform. At the foot of the octagon there may have been four semicircular extensions, such as that at the wind tower in Athens, into which the observers could recline at night or in the event of stormy weather, while others may have served as water containers or as drains.”

“Further guesses [p90-93]

“The Poseidon figure on the top [of the Pharos] gives the impression of a wind vane at first glance. A closer consideration, however, makes it unfit for this purpose. No side of the figure offers the wind a much larger attack surface than the other, if one thinks of the statue divided according to its axis of rotation. This can not be otherwise with a human form, which is in a state of the rest and neither the outstretched arm nor the fluttering robe offers the wind a one-sided attack. Poseidon appeared to be swiveling, pointing his outstretched right [arm] like a clock-hand to the day-time marked on the cone-base. The bowl in [his] hand was necessary for clarity. Imagine a clockwork mechanism, like Vitruvius described [IX, 8], driven by water movements, and as shown in Fig. 71. The axis of the figure continued in an asbestos [sic] tube through the hearth into the octagon down to a water tank and was controlled by a small opening in a higher-level vessel, and as the lower vessel filled and the float ascended, the pole lifted itself and turned at the same time, if it was threaded through a nut. The very significant weight of the rod or turntable was balanced by large counterweights across rollers. These weights had to surpass the weight of the axis of rotation by as much as was necessary, and

the friction of the screw and the guides of the rod did not have to rise, if only from the lower one. A similar work was probably to be found in the side tower described on p89, which perhaps represented the phases of the moon or the movement of the sun in the zodiac, that is, it could have been a monthly clock.

“As a sundial in a large scale, as a real lunch clock finally seems to have served the great staircase on the south side of the tunnel. Like the entrances to the great pyramids being parallel to the Earth’s axis, i.e. after the Pole Star had been moved, the entrance stairway of the Pharos probably rose in that direction and with its railing edges threw very concise shadows over the southern wall of the tower, which was parallel to the equator. [The concave sundial, the ‘skapha’, was first invented several decades after the construction of the Pharos by the astronomer Aristarchus.] Similarly, one also read off the hours on the vertical wall surfaces of the wind tower in Athens. This sundial was not the only one, but probably one of the most important reasons for the exact astronomical orientation of the wonderful building. For Alexandria, the Pole elevation is 31° and a few minutes. The reconstruction in supplement 1 indicates the design of this gnomon. [Gnomon: the projecting piece on a sundial that shows the time by the position of its shadow.]

“One could argue that the side towers threw their shadows over the stairs and made their effect as a sun-pointer illusory. This case could occur in winter, when the rising or setting sun would cast the shadow of the side door over the banisters. However, the sunrise in Alexandria does not exceed 28° in the winter from east to southeast. Further, the side towers did not occur either, so they deviate slightly behind the Pharos diagonal for this reason.

“To justify this argument, the following can be said: an excellent analogy to our case, and actual, if unconscious, descendants of the outer Pharos ramp as the sun’s pointer are the giant wall quadrants of the Islamic East and India. The most impressive construction of this kind is still the Samraj of the observatory Jayasimha’s yu at Jaipur in central India. Although this observatory dates back only to the beginning of the 18th century (it was completed in 1734), and its related facilities in Delhi, they are not much older (1710), but

they represent the Stone Age of astronomy; they are the last, and at the same time the most accomplished, representatives of ancient, primitive, telescope-free astronomy. Hindu astrology was based on the experience of the Greeks conveyed to them by the Arabs. Thus, the double-sided wall quadrant, the Dakshino Bhatti Yantra in Jaipur, has its forerunner in the ridge of the wall quadrant (180 feet high) Ulugh Beg in Samarkand [an observatory in Samarkand, Uzbekistan, considered by scholars to have been one of the finest observatories in the Islamic world] (built 1420) and this again in the probably analogous installations at Meragha (1258), Rakka (9th century), Baghdad and Damascus (8th century). To this end, Ulugh Beg’s college in Samarkand was intended to be an imitation of the Alexandrian Museum (see Mädler, *Geschichte der Himmelskunde* I, p. 104).

“Bergholz has recently written extensively about the Laghu Samrat Yantra [the world’s largest sundial] in Jaipur in the magazine *Das Weltall*, Volume 7, Issue 16. In addition to the giant structure (good view p257, geometric side view p307 plan p316) there is a smaller one and then twelve very small specimens (for observing the zodiac). This kind of sundials is a giant gnomon, built in stone, i.e. a walled triangle, then resting on the longer cathedra [foundation?], whose hypotenuse is directed towards the pole, that is, it has a slope whose angle ($26^\circ 56'$) corresponds to the northern latitude of the location. The wall body below - highest end 27.4 m, length 45 m - is dissolved in arched holes. On both sides of this gnomon is extremely complex in a complex curve, built with the greatest accuracy ever, a massive quadrant, on the hollow arch of the shadow lines were read, which gave true solar time.

“The similarity to the angle of the Pharos, which of course can only have served as a giant shadow, not used for its angle of elevation, is striking. The wall surfaces of the rising tower take the place of the complicated quadrant of the curve. In this outward sense, they were also forerunners of Tycho de Brahe’s Quadrant [astronomical instrument], who had come to this invention completely new and independent of the Arabs (see Newcomb-Engelmann, p106). The angle of inclination of the Pharos *treppen* [stairway? ramp?] should have been $31^\circ 13'$ - the northern latitude of Alexandria. Then, and nothing seems to stand in the way, it would

have performed like a gnomon. Then suddenly the high position of the tower door would be understandable, just at the upper end of the outside staircase. Even in the substructure, the outside staircase seems to have resembled those Indian and Samarkand gnomons - the vertical triangular area would have been broken through arched openings. See above, p51 (Sujuti).

“Finally, the fabulous-sounding stories of the mirror, which showed the images of ships as soon as they appeared on the distant horizon, may well be correct. Tiny openings in the walls of the lantern substructure had to throw inverted images of the sea on the opposite wall of the otherwise dark interior (*camera obscura*). If mirrors were hung inclined here at 45°, they could throw down the images of the distant objects and project them onto the floor of the room at the level of the lower platform, where at the same time they seemed to be greatly enlarged (compare Figures 71 and 72). More probably the following happened - the telescopic apparatus perhaps consisted of several mirrors. The main mirror, of which there is always talk, was evidently a large concave mirror, mounted in the dark interior of the central shaft, so that the images of ships appearing on the horizon are seen in great magnification. Be it that smaller mirrors, placed at the corners of the octagonal window, caught the rays of light and phenomena on the sea in the interior of the cylindrical projectile, whether through simple gaps in the cylindrical wall of the uppermost floor: hanging up here, a mirror pointing downwards could transmit the rays vertically downwards, where they had to produce an enlargement of the image seen from the concave mirror placed horizontally at the level of the first terrace. In this case, the dark, closed central shaft of the octagonal bullet actually served as a giant telescope: it would have been an ancient forerunner of Herschel’s great telescope, consisting of a mighty tube with a large metallic concave mirror at the lower end, magnifying more than a thousandfold, the big telescope built similar to a design by Lord Russell, with 17 m length and 1.8 m focal length. These instruments have been surpassed in optical power by others, but they proved to be difficult to operate. That’s why they got away from them and now they use refractors with glass lenses. Here at the Pharos the tube was vertical and did not need to be moved to be turned. This was a

great advantage: the telescope itself was immovable, and at its base it included the metal concave mirror, which in this case would indeed have been applicable to the observation of the stars, as well as events at sea.

“What if a significant achievement of ancient astronomy had really been lost here? In any case, the message of Jaqut, [Yakut] cf. pp. 45 and 61, agrees perfectly with this idea of the mirror apparatus: he described the place where the mirror had once been: a wall over 100 cubits above the ground, i.e. at the first terrace height, and not from the highest point of the tower! Not all of the upper mirror apparatus, and among them the firing-mirror must have been lost, had been lost here, but through the various Arabian renovations of the upper part of the tower, the original inner downwards communication [shaft] had been completely destroyed and abolished.

“The concave mirror combines the light rays emanating from a distant object near its focal point into a reversed image. This image is real and is visible only when it is captured by a matte disk (much like the plate of a photographic apparatus), or when the eye is near the focal point and within the indicated beam. For clarification, see Fig. 74.

G denotes the size of the object

E its distance from the center of the concave mirror surface

f the focal length

so for the image size b, the equation applies

$$B : f = G : E$$

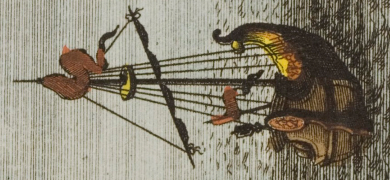
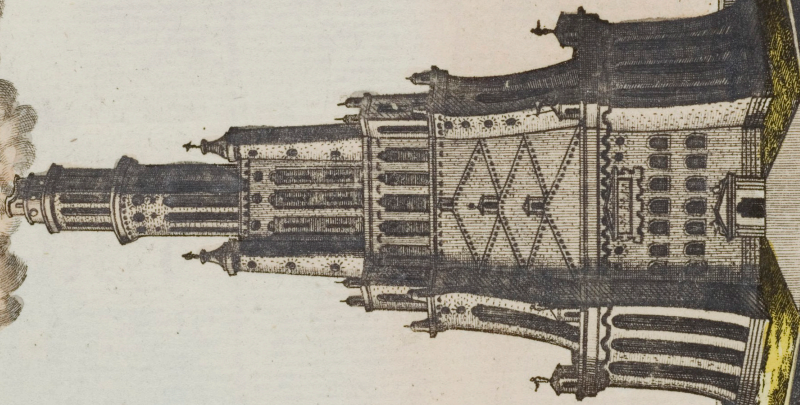
$$b = f \times G / E$$

If, for example, a ship with a 5 m high mast appears at a distance of 5 km at the sea horizon, the picture size will be

$$b = 30 \times 5 / 5000 = 0.03 \text{ m}$$

In other words, the magnification of the picture seen with the naked eye is 30 times.

Since the doctrine of the lawfulness of the reflection of crooked surfaces was well known to antiquity, the internal probability of our assumption stands in the way. If here an application of these catoptric experiences of honor was made in the manner we suspect or a similar one, the upper part of the interior, which was completely dark, only has a sensible and, indeed, exceedingly sensible purpose.”



Bibliography

Conventions used

1. References are given in the usual format: Smith (2002), p123. Multiple citations having the same author and year are given the suffix a, b, c etc.
2. A reference given as Smith (online) has no date if it is continuously updated. Specific information downloaded from the Internet is given a date of download.
3. Entries in the Bibliography are considered relevant to the content of this book, but are not necessarily to be found in the references.
4. Entries are in alphabetical order of the first author's last name. Unnamed authors are assigned the usual 'Anon'.

Bibliography

- Abu Hamid Al-Gharnati: *Tuhfat Al-Albab*, p99-100. In: Okasha el-Daly: *Egyptology: The Missing Millennium: Ancient Egypt in Medieval Arabic Writings*. (2008). ISBN 9781598742800.
- Abulafia, David (ed): *The Mediterranean in History*, Thames and Hudson (2003). ISBN: 9780500251201.
- Adams, William Henry Davenport: *Lighthouses and Lightships*, T. Nelson & Sons, London, (1871).
- Akurgal, Ekrem: *Ancient Civilizations and Ruins of Turkey*. Haset Kitabevi, Istanbul (1985), 6th edition.
- Allard, Emile: *Les Phares. Histoire, construction, éclairage*, Paris (1889).
- Al-Edrisi; R. Dozy; M. J. de Goeje; E. J. Leyde (trans): *Description de L'Afrique et de L'Espagne. Troisième climat, quatrième section*. Brill (1866).
- Al-Gharnati, Abu Hamid; Jean-Charles Ducène (trans.): *De Grenade à Baghdad - La Relation de Voyage d'Abu Hamid al-Gharnati (1080-1161)*. L'Harmattan, Paris (2006). ISBN: 9782296005594.
- Allen, Jim; O'Connell, James F.: *Getting from Sunda to Sahul*, pp31-46. In: Clark (2008).
- Alley, R.B.: *GISP2 Ice Core Temperature and Accumulation Data*. IGBP PAGES / World Data Center for Paleoclimatology Data Contribution Series #2004-013. NOAA/NGDC Paleoclimatology Program, Boulder CO, USA (2004).
- Al-Masudi (translated by Lunde and Stone, (2007), p46.
- Al-Masudi: *Les Prairies D'Or*. Translated in French by C. Barbier de Meynard et Pavet de Courteille. Volume 2, Paris, (1863) p433.
- Al-Murtadi: *The Egyptian History*. Vattier, Pierre (French): 1623-1667, Davies, John (English): 1625-1693. London, (1672), 8 vols.
- Al-Qazwini, Zakariya Ibn Muhammad: *Br. Mus., Or. MS 3623, fol. 41b*. <http://www.iranicaonline.org/articles/atar-al-belad-geographical-work>
- Ambraseys, Nicholas N.; Melville, C. P.; Adams, R. D.: *The Seismicity of Egypt, Arabia and the Red Sea - A Historical Review*, Cambridge University Press (1994). ISBN: 9780521391207.
- Ambraseys, Nicholas: *Earthquakes in the Mediterranean and Middle East - A Multidisciplinary Study*, Cambridge University Press (2009), 968pp. ISBN: 9780521872928.
- Anderson, Atholl; James H. Barrett; Katherine V. Boyle (eds.): *The Global Origins and Development of Seafaring*. McDonald Institute Monographs, McDonald Institute for Archaeological Research, Cambridge UK (2010). <http://www.mcdonald.cam.ac.uk/publications/publication-images/table%20of%20contents/global-seafaring-toc>
- Anon: *A Brief History and Description of Nea Paphos*. Antiquities Department, Republic of Cyprus (1978).
- Anon: *Brief History and Pre-History of Libya*. www.temehu.com
- Anon: *The Adventures of Leucippe and Clitophon, V.6* (online). http://penelope.uchicago.edu/~grout/encyclopaedia_romana/greece/paganism/pharos.html
- Anon: *The Pharos Site, Alexandria*, *Egypt International Journal of Nautical Archaeology*, March (1975) 4(1), pp126-130.
- Arculf; Stewart, Aubrey (trans.): *Burchard of Mount Sion. Palestine Pilgrims Text Society, Vol. iii*. (1896). <https://archive.org/details/libraryofpalesti12pale>
- Arnold, John H.: *History: A Very Short Introduction*. Oxford University Press (2000), p17. ISBN 019285352X.
- Arunachalam, B.: *Navigation Environment of Ancient and Mediaeval Ports of Tamilaham*, KW Publishers, New Delhi, India (2008). ISBN: 9788187966784.
- Aubet, Maria Eugenia: *The Phoenicians and the West - Politics, Colonies and Trade*. Cambridge University Press (1996). ISBN: 9780521795432. Also 2nd edition (2001). ISBN: 9780521795432.
- Aubet: *Spain* (1988) p228. In: Moscati (1988).

- Aucler, M. Paul. In: Sladen (1906).
- Bailey, Geoff: Earliest Coastal Settlement, Marine Paleoeconomies and Human Dispersal - the Africa-Arabia Connection (2010). In: Anderson (2010).
- Barthelemy, P.: History of Boulogne-sur-Mer, from Julius Caesar to the year 1825; embellished with plans by M. Barthelemy. Griset, Paris (1825).
- Bartocchini, Renato: Il Porto Romano di Leptis Magna, In *Bollettino del Centro Studi sull' Architettura*, Supplemento 13, Roma (1958).
- Bartoloni, Piero: L'Antico Porto di Nora. In: *Antiqua* 13 (1979), pp57-61.
- Bartoloni, Piero: Ships and Navigation (1988), pp72-7. In: Moscati (1988).
- Beaver, Patrick: A History of Lighthouses, Peter Davies Ltd (1971).
- Beckby, H. (ed.); Higgins, R. (trans.): *Anthologia Graeca*. Munich (1957) 4, 171.
- Bedon, R.: Les Phares Antiques. In: *Archeologia. Prehistoire et Archaeologie*, Paris (1988b), pp54-66.
- Bedon, R.; R. Chevallier, P. Pinon: *Architecture et Urbanisme en Gaule Romaine*, Paris (1988a).
- Behrens-Abouseif, Doris: The Islamic History of the Lighthouse of Alexandria. In: *Muqarnas*, Vol. 23 (2006), pp1-14. <http://www.jstor.org/stable/25482435>
- Benett, Léon. In: Verne, Jules: *Les Grands voyages et les grands voyageurs. Découverte de la Terre*. Paris: J. Hetzel (1878). <http://www.artfinder.com/work/ibn-battuta-in-egypt-hippolyte-leon-benett/>
- Bernard, E.: *Alexandrie la Grande*, Paris (1956).
- Blackman, David: Roman Shiphsheds; *Memoirs of the American Academy in Rome, Supplementary Volumes*, Vol. 6, *The Maritime World of Ancient Rome* (2008), pp. 23-36; University of Michigan Press for the American Academy in Rome. <http://www.jstor.org/stable/40379295>
- Bloom, Jonathan; M. Cresswell: The Origins of the Minaret, *Muqarnas* 8 (1991) p56. <http://archnet.org/system/publications/contents/4179/original/DPC0329.pdf?1384781505>
- Boin, Douglas: *Ostia in Late Antiquity*. Cambridge University Press (2016). ISBN: 978-1316601532.
- Boivin, Nicole; Roger Blench; Dorian Q Fuller: *Archaeological, Linguistic and Historical Sources on Ancient Seafaring* (2009). In: *Petraglia* (2009) Chapter 18, p260.
- Bond, G. et al.: A Pervasive Millennial-Scale Cycle in North Atlantic Holocene and Glacial Climates. *Science* 278, No 5431 (1997), pp1257-1266.
- Boston Public Library: *Ships and the Sea - A Catalog of an Exhibition of Books and Manuscripts*, Boston Public Library, Boston, MA (1966).
- Bouras, Catherine: On the Urbanism of Roman Harbours- The Evolution of Space Organization in Harbours of the Aegean Sea. In: *Ladstätter* (2014), pp669-682. <http://www.ancientportsantiques.com/wp-content/uploads/Documents/PLACES/GreeceIslands/Rhodes&Kos-Bouras2014.pdf>
- Bouriant, Urbain: *Description topographique et historique de l'Egypte*. Paris (1895-1900), Chapter IX: Du Phare d'Alexandrie, pp444-50.
- Brandon, C. J.: Roman Formwork Used for Underwater Concrete Construction. In *Oleson* (2014) Chapter 8, pp189-235.
- Brandon, C. J.; R. L. Hohlfelder; J. P. Oleson: The Concrete Construction of the Roman Harbours of Baiae and Portus Iulius: The ROMACONS 2006 Field Season; submitted to *International Journal of Nautical Archaeology* 20 April
- Breeze, David J.: *The Northern Frontiers of Roman Britain*. Batsford Academic and Educational Ltd., London (1982) 188pp. ISBN: 0713403454.
- Broadhurst, Roland (trans.): *The Travels of Ibn Jubayr*. Goodword Books, India (2001). ISBN: 9788187570554. First published: London (1952).
- Brogan, Olwen: *Roman Gaul*, G Bell & Sons Ltd, London (1953), 250pp.
- Bromwich, James Stephen: *The Roman Remains of Northern and Eastern France*, Routledge (2013) p51-2. ISBN-13: 9780415143585.
- Bronson, R.G., G Uggeri: *Isola del Giglio, Isola di Giannutri, Monte Argentario, Laguna di Ortebello - Notizia Preliminare dei Rinvenimenti del 1968*. In: *Studi Etruschi*, 38, II,(1970), pp201-14.
- Broodbank, Cyprian: *The Making of the Middle Sea*. Thames and Hudson (2015). ISBN: 9780500292082.
- Buceti, Giuseppe: *Gialo. I Misteri Del Peloro*, Messina, EDAS (2012), 176pp. ISBN: 9788878203747.
- Burgess, Jonathan S: *Tumuli of Achilles*, Center for Hellenic Studies, Harvard University. <https://chs.harvard.edu/CHS/article/display/1312>
- Butler, Alfred J.: *The Arab Conquest of Egypt and the Last Thirty Years of the Roman Dominion*. Clarendon Press, Oxford (1902). <https://archive.org/details/arab-conquestofeg029678mbp>. Retrieved 20170330.
- Butler, Alfred. J.: *The Ancient Pharos at Alexandria*. The Athenaeum, November 20 (1880), p681.
- Casson, Lionel: *The Ancient Mariners - Seafarers and*

- Sea Fighters of the Mediterranean in Ancient Times. Princeton University Press, 2nd edition (1991). ISBN: 9780691014777.
- Casson, Lionel: *Travel in the Ancient World*, The Johns Hopkins University Press (1994). ISBN: 9780801848083.
- Cintas P.: Fouilles Punique a Tipasa. *Revue Africaine*, 92 (1949), pp1-68.
- Clark, Geoffrey; Foss Leach; Sue O'Connor (eds.): *Islands of Inquiry (Terra Australis 29) Colonisation, seafaring and the archaeology of maritime landscapes*. ANU Press (2008). ISBN: 9781921313899. <http://press.anu.edu.au?p=26551>
- Clayton, Peter A.: *The Pharos At Alexandria* (1988b), pp138-57. In: Clayton (1988).
- Clayton, Peter A.; Price M. (eds.), *The Seven Wonders of the Ancient World*. Routledge, London (1988a). ISBN: 0415002796.
- Cobb, Paul (ed): *The Lineaments of Islam: Studies in Honor of Fred McGraw Donner*, Leiden: Brill, (2012), 488pp. ISBN: 9789004218857.
- Constable, Anthony R.; William Facey (eds): *The Principles of Arab Navigation*. Arabian Publishing (2013), 146pp. ISBN: 9780957106017.
- Cook, J. M.: *The Greeks in Ionia and the East*. Thames and Hudson, London (1962), 268pp.
- Cook, J. M.: *The Troad - An Archaeological and Topographical Study*. The Clarendon Press, Oxford (1973), 444pp.
- Cooper-Marsdin, Arthur Cooper: *The History of the Islands of the Lerins - The Monastery, Saints and Theologians of S. Honorat*. Cambridge University Press (1661). Republished (1913), (2013). ISBN: 9781107615465.
- Cornide de Folgueira, José: *Investigacion Sobre Origen, Progresos y Fabrica de la Torre llamada de Hércules Situada a la Entrada del Puerto de la Coruña*. Madrid (1792).
- D'Ascenzo, Annalisa: *Civitavecchia Penuriava D'acqua Dolce da Bere da Molto Tempo Già Persa...* ASITA2014. <http://atti.asita.it/ASITA2014/Pdf/044.pdf>
- Dallas, M. F.; Yorke R. A.: *Underwater Surveys of North Africa, Jugoslavia and Italy*, Underwater Association Report (1968).
- Daux, A.: *Origines et l'emplacement des emporia Phéniciens*. Paris, Imprimerie Impériale, (1869) p302.
- De Asin, Don Miguel: *Ibn Al-Sayj, the Duke of Alba*, *Proceedings of the British Academy*, 19 (1933), pp277-292.
- De Graauw, Arthur: *Ancient Ports and Harbours*. Volume I: *The Catalogue*, 5th edition (March 2016). Volume II: *Citations of Ancient Authors*. Volume III: *Ancient Port Structures*. Volume IV: *Stories of Ancient Sailors*. www.ancientportsantiques.com.
- De La Blanchere, R.: *Terracina, Saggio di Storia Locale, Terracina* (1983); Reprinted from *Terracine, Essai D'Histoire Locale*, Paris (1884). https://archive.org/details/terrachineessaidh34labl_0
- De Montfaucon, Dom Bernard: *L'Antiquité Expliquée et Représentée en Figures*, vols. 1-15, Paris (1719-1724).
- De Rose Evans, Jane (ed): *A Companion to the Archaeology of the Roman Republic*, Wiley-Blackwell (2013), 746pp. ISBN: 9781405199667.
- De Rossi, G.M.: *Ventotene e Santo Stefano*, Roma (1993).
- Della Croce, I.: *Nistoria Antica e Moderna Sacra e Profana Della Citta di Trieste, Venetia* (1698).
- Denny, Mark: *The Science of Navigation, From Dead Reckoning to GPS*; The Johns Hopkins University Press, Baltimore (2012), 262pp. ISBN: 9781421405124.
- Di Vita, A.: *Sabratha*. In: *Libya, the Lost Cities of the Roman Empire*, Cologne (1999), pp146-175.
- Diels, H.: *Antike Technik*, Osnabrück (1965).
- Dionysius Byzantius; G³ngerich [1927] (trans.): *Per Bosporum navigatio*. (1958), pp92-94.
- Donaldson, G.H.: *Signalling Communications and the Roman Imperial Army*. *Britannia*, Vol. 19 (1988), pp349-356, Society for the Promotion of Roman Studies, DOI: 10.2307/526204. <http://www.jstor.org/stable/526204>
- Dorigo, W.: *Venezie Sepolte Nella Terra Del Piave, Due-mila Anni Fra Il Dolce E Il Salso*, Rome (1994).
- Dubois, Charles: *Pouzzoles Antique (Histoire et Topographie)*. Paris, A. Fontemoing (1907).
- Ducène, Jean-Charles (trans.): *De Grenade À Bagdad: La relation de voyage d'Abû Hâmîd al-Ghar-nâtî (1080-1168)*, *L'Harmattan* (2006), 210pp. ISBN 9782296005594. <http://www.muslimheritage.com/article/lighthouse-of-alexandria>
- Duggan, T.M.P.; Aykan Akpaya: *On the Missing Navigational Markers, Beacon Towers; Pharos Of Antiquity, And Notice Of Two Extant Small Marker Beacon Towers of Roman Late 1st c. BC - Early 1st c. AD Anemorium*. Akdeniz.Edu.Tr; Cedrus
- Dunn, Ross E.: *The Adventures of Ibn Battuta - A Muslim Traveller of the 14th. Century*. University of California Press, Los Angeles (1986). ISBN: 0520243854.
- El-Fakharani, Fawzi: *The Lighthouse of Abousir in Egypt*. *Harvard Studies in Classical Philology*, Department of Classics, Harvard University Press, Vol. 78 (1974),

pp257-272.

Elnashai, A.S.; L. Di Sarno; M.D. Carter: *New Light on an Ancient Illumination - The Pharos of Alexandria*. *International Journal of Nonlinear Sciences and Numerical Simulation*, Freund Publishing House Ltd, 7:2 (2006), pp137-48. <https://scribium.com/sebastien-polet/a/laspect-du-phare-dalexandrie-dapres-les-sources-medi-evaies>

Empereur, Jean-Yves: *Le Phare d' Alexandrie, La Merveille Retrouvée*, Découvertes Gallimard (1998) 112pp. (In French). ISBN: 9782070303793.

Engels, Donald W.: *Roman Corinth: An Alternative Model for the Classical City*. University of Chicago Press (1990), 264pp.

Esposito, E.; E. Filici, P.A. Gianfrotta, E. Scognamiglio: *Il Porto di Kyme*. In: *Archaeologia Subacquea, Studi, Ricerche, Documenti*, III, Roma (2002), pp1-37.

Euzennat Maurice: *Ancient Marseille in the Light of Recent Excavations*. *American Journal of Archaeology*, Vol. 84, No. 2, Apr (1980), pp133-140; DOI: 10.2307/504261. <http://www.jstor.org/stable/504261>

Fantar, Muhammad: *North Africa* (1988), pp166-185. In Moscati (1988).

Fatta Francesca: *Luci del Mediterraneo. I fari di Calabria e Sicilia*. Disegni, rilievi e carte storiche. Rubbettino (2002), 198pp. ISBN: 9788849803501.

Feissel, D.: *Gouverneurs et Edifices Dans Epigrammes de Smyrne au Bas Empire*. REG, 111 (1998), pp125-44.

Ferentinos, George; Maria Gkioni; Maria Geraga; George Papatheodorou: *Early Seafaring Activity in the Southern Ionian Islands, Mediterranean Sea*. *Journal of Archaeological Science* 39(7), July (2012), pp2167-2176.

Fernandez Ochoa, C.; A. Morillo: *Roman Lighthouses on the Atlantic Coast*, BAR International Series 2162 (2010). https://www.academia.edu/9887581/_2010_Roman_lighthouses_on_the_Atlantic_coast. Retrieved 20180312.

Ferreol Salomon; Simon Keay; Nicolas Carayon; Jean-Philippe Goiran: *The Development and Characteristics of Ancient Harbours* Applying the PADM Chart to the Case Studies of Ostia and Portus, September 15 (2016). <https://doi.org/10.1371/journal.pone.0162587>

Fichou, Jean-Christophe; Noel Le Hénaff; Xavier Mével: *Phares - Histoire Du Balisage Et De Léclairage des Cotes de France* (1999), Editions Le Chasse-Marée / Armen, Abri Du Marin, 29177, Douarnenez Cedex, 452pp. ISBN: 2903708924.

Finocchi, S.: *La Laguna e L'Antico Porta di Nora*; In: *Rivista di Studi Fenici* 27 (1999), pp167-92.

Fischer, Steven Roger: *A History of Writing*. Reaktion Books (2001). ISBN: 9781861891679.

Fisher, M. B.; M. R. Griffin: *Pliny's Letters*, Cambridge University Press (1973), 74pp.

Florus, Lucius Annaeus; E. S. Forster (trans): *The Epitome of Roman History* (1929).

Forbes, Robert James: *Studies in Ancient Technology*, Vol. 4., E. J. Brill (1964) 311pp.

Forster, E. M.: *Pharos and Pharillon*, London (1923).

Foucher, L; *Hadrumetum*, Paris (1964).

Fox, Robin Lane: *The Classical World - An Epic History of Greece and Rome*. Penguin Books (2006).

Fraser, P. M.: *Ptolemaic Alexandria*, The Clarendon Press, Oxford, Volumes 1-3 (1972).

Garbini, Giovanni: *The Question of the Alphabet* (1988), pp86-103. In: Moscati (1988).

Gardiner R.: *Earliest Ships - The Evolution of Boats and Ships*. Conway Maritime Press Ltd (1996). ISBN: 9780851776408.

Gébara, Chérine; Christophe Morhange: *Fréjus (Forum Julii); Le Port Antique; The Ancient Harbour*. Portsmouth, R.I., *Journal of Roman Archaeology* (2010), 152pp. (2010)

Giardina, Baldassarre; *Navigare Necesses Est - Lighthouses from Antiquity to the Middle Ages; History, Architecture, Iconography and Archaeological Remains*. BAR International Series 2096; BAR Publishing; Oxford (2010) 348pp. ISBN:

Giorgetti, G.: *Geografia Storica Ariminense*. In: *Analisi Di Rimini Antic, Storia Ed Archeologica per un Museo*, Rimini (1980).

Goiran, J-P.; Salomon, F.; TronchPre, H.; Carbonel, P.; Djerbi, H.; Ognard, C.: *Caractéristiques du Bassin Portuaire de Claude - Nouvelles Données pour la Localisation des Ouvertures*, pp31-45. In: Keay (2011)

Goren-Inbar, Naama; Nira Alperson, Mordechai E. Kislev; Orit Simchoni; Yoel Melamed; Adi Ben-Nun; Ella Werker: *Evidence of Hominin Control of Fire at Gesher Benot Ya'aqov, Israel*. *Science*, 30 Apr (2004) Vol. 304, Issue 5671,

Grant Michael (ed): *The Birth of Western Civilization*, Thames and Hudson (1964).

Graves, Robert: *The Greek Myths - The Complete and Definitive Edition*, Penguin Books (1992), reissued (2011). First published (1955) by Pelican Books, London.

Grimal, Pierre; G. Michael Woloch (trans): *Roman Cities*. University of Wisconsin Press (1983).

- Guzzo, Maria: Painting, pp448-455. In: Moscati (1988)
- Hague, Douglas B; Rosemary Christie: Lighthouses, Their Architecture, History and Archaeology. Gomer Press (1975). ISBN: 850883245.
- Hamarneh, S: The Ancient Monuments of Alexandria According to Accounts by Medieval Arab Authors (IV-XV century). *Folia Orientalia* 13 (1971), pp77-110
- Hancock, Graham; Santha Faiia: Heaven's Mirror - Quest for the Lost Civilization. Michael Joseph and Channel 4 (1998). ISBN: 0718143329.
- Hapgood, Charles H.: Maps Of The Ancient Sea Kings - Evidence Of Advanced Civilization In The Ice Age. Adventures Unlimited (1996). ISBN: 9780932813428.
- Harari, Yuval Noah: Sapiens, A Brief History of Humankind. Vintage (2011). ISBN: 9780099590088.
- Hardy, W. J.: Lighthouses - Their History and Romance. The Religious Tract Society (1895).
- Harris, Eleanor: Ancient Egyptian Magic, Weiser Books, (2016), 240pp. ISBN: 9781578635917.
- Harris, Jonathan: A Statue for America - The First 100 Years of the Statue of Liberty. New York City. Four Winds Press (1985). ISBN 9780027427301.
- Harris, W. V.; Giovanni Ruffini: Ancient Alexandria between Egypt and Greece. Brill, Leiden, Netherlands (2004), 318pp.
- Heeren, Arnold Hermann Ludwig: Historical Researches Into the Politics, Intercourse, and Trade of the Principal Nations of Antiquity, Henry Bohn (1854).
- Heilbrunn: Timeline of Art History. New York: The Metropolitan Museum of Art, 2000. http://www.metmuseum.org/toah/hd/grlg/hd_grlg.htm
- Hemingway, Colette; Sean Hemingway: Greek Gods and Religious Practices (2003). In: Heilbrunn (2000). http://www.metmuseum.org/toah/hd/grlg/hd_grlg.htm
- Herm, Gerhard (trans. from German by Caroline Hillier): The Phoenicians. First Futura Publications, London (1975).
- Herodotus; Aubrey de Sélincourt (1954): The Histories. Revised by John Marincola (1996), Penguin edition (2003).
- Heyerdahl, Thor; P. Crampton (trans): The Ra Expeditions, Penguin (1972). ISBN: 9780140034622.
- Higgins, Reynold: The Colossus of Rhodes. In: Clayton (1988), pp124-37. ISBN: 0415002796.
- Hill, Donald: A History of Engineering in Classical and Medieval Times. Routledge (1996). ISBN: 0415152917.
- Hodges, Henry: Technology in the Ancient World. Michael O'Mara Books, London (1996). ISBN: 9781854796042.
- Hohlfelder, Robert L.; Christopher Brandon: Narrative of the ROMACONS Fieldwork. Ch. 4, pp73-81. In Oleson (2014).
- Hohlfelder, Robert L.; Christopher Brandon; John P. Oleson: Constructing the Harbour of Caesarea on the Sea - New Evidence from the ROMACONS Field Campaign of October 2005. <https://web.uvic.ca/~jpoleson/ROMACONS/Caesarea2005.htm>
- Holmes, George C. V.: Ancient and Modern Ships. Createspace (2015).
- Homer; Butler, Samuel (trans): Iliad.
- Homer; Murray, A. T. (trans): Iliad. Loeb Classical Library Volumes, Cambridge, MA, Harvard University Press; London, William Heinemann, Ltd (1924).
- Homer; Murray, A. T. (trans): Odyssey. Loeb Classical Library Volumes, Cambridge, MA, Harvard University Press; London, William Heinemann Ltd (1919).
- Homer; Pope, Alexander (trans): Iliad (1796); notes by Gilbert Wakefield.
- Homer; Rieu, E. V. (trans): Iliad (1950); notes by Peter Jones, Penguin Classics (2003).
- Homer; Rieu, E. V. (trans): Odyssey (1946). Penguin Classics (2003).
- Hourani, George F.; Arab Seafaring - In the Indian Ocean In Ancient and Early Medieval Times. Princeton University Press (1951, reprinted 1995), 190pp. ISBN: 0691000328.
- Hughes, A. J.: The Book of the Sextant with Ancient and Modern Instruments of Navigation. Brown, Son & Ferguson, Glasgow (1949).
- Hutter, Siegfried: Der Romische Leuchtturm von La Coruna, Verlag Philipp Von Zabern, Mainz am Rhein (1973). (In German).
- Hutton, Edward: Ravenna - A Study (1913).
- Huxley, George: The History which Inspired Homer (1964). In: Grant (1964).
- Irby, Georgia L. (ed): A Companion to Science, Technology, and Medicine in Ancient Greece and Rome, Volume 1 (2016a). ISBN: 9781118372678.
- Irby, Georgia L.: Navigation and the Art of Sailing (Chapter 51) (2016b). In: Irby (2016a).
- Irwin, G.: The Prehistoric Exploration and Colonization of the Pacific. Cambridge University Press (1992). Online publication date: January (2010). ISBN: 9780511518225. <https://doi.org/10.1017/CBO9780511518225>

- Işık, Fahri; Merih Çobanoğlu (trans.): *Patara - The History and Ruins of The Capital City of Lycian League*. Orkun & Ozan Medya Yayinlari, Antalya (2000), 173pp. ISBN 9789757094043.
- Iskan-Isik, H.; W. Eck; H. Engelmann: *Der Leuchtturm von Patara und Sex. Marcius Priscus als Statthalter der Provinz Lycia von Nero bis Vespasian*. *Zeitschrift für Papyrologie und Epigraphik*, 164 (2008), pp91-121.
- James Stephen Bromwich: *The Roman Remains of Northern and Eastern France*, Routledge (2013) pp51-2. ISBN: 9780415143585.
- Josephus; William Whiston (trans.): *The Jewish War*. Book IV Chapter 10.5, Cambridge (1737). <http://penelope.uchicago.edu/josephus/index.html>
- K Muckelroy: *Archaeology Under Water - An Atlas of the World's Submerged Sites*, London, (1981).
- Karageorghis, Vasos: *Cyprus* (1988), pp152-165. In Moscati (1988).
- Kassab, Maroun (online). www.phoenicia.org/originphoenicians.html
- Keay, S. J. (ed): *Rome, Portus and the Mediterranean*. *Archaeological Monographs of the British School at Rome*, The British School at Rome, London (2012), 38pp. ISBN 9780904152654. <http://www.bsr.ac.uk/site2014/wp-content/uploads/Rome-Portus-and-the-Mediterranean-Chapter-2.pdf>
- Keay, S. J.: *Roman Spain*, London (1988).
- Keay, S. J.; Millett, M.; Paroli, L.; Strutt, K: *Portus - An Archaeological Survey of the Port of Imperial Rome*. *Archaeological Monographs of the British School at Rome*, 15. London: The British School at Rome (2005).
- Keay, S. J.; Paroli, L.: *Portus and its Hinterland*. *Archaeological Monographs of the British School at Rome*, The British School at Rome, London (2011), 18pp.
- Kozelj, T.; Wurch-Kozelj, M.: *Phares de Thasos*. *Bulletin de Correspondance Hellenique*, CXIII (1989) 1:161-181, Ecole Francaise d'Athènes. (In French). http://www.persee.fr/doc/bch_0007-4217_1989_num_113_1_4716
- Krause, Clemens: *Villa Jovis*. *Die Residenz des Tiberius auf Capri*, Verlag Philipp von Zabern, Mainz am Rhein (2003), (In German). ISBN: 9783805330916.
- Krischen, F., *Die Grieschische Stadt*, Berlin (1938).
- Ladstätter, S.; Pirson, F.; Schmidts, T.: *Harbors and Harbor Cities in the Eastern Mediterranean*. *BYZAS* 19 (2014).
- Lagan, Jack: *Barefoot Navigator*. *Navigating with the Skills of the Ancients*. A & C Black (2006). ISBN: 9780713674293.
- Lakin, David; Fiona Seeley; Joanna Bird; Kevin Rielly; Charlotte Ainsley: *The Roman Tower at Shadwell, London - A Reappraisal*. *Museum of London Archaeology Service, English Heritage, Archaeology Studies Series 8*, (2002) 72pp.
- Lamboglia, N.: *I Monumenti Medioevali Della Liguria del Ponente*, Torino (1970)
- Lamboglia, N.: *Liguria Romana*. Alassio (1939).
- Landels, J. G.: *Engineering in the Ancient World*. Chatto and Windus, London(1978), 224pp. ISBN: 0701122218.
- Laronde, André: *Apollonia de Cyrénaïque*. *Archéologie et Histoire, Journal des savants*, no 1 (1996), pp3-49.
- Lehmann-Hartleben, K; *Die Antiken Hafenanlagen des Mittelmeeres*. In *Klio*: 14 Aalen (1963) pp178-180.
- Lewis, David: *The Voyaging Stars*. *Secrets of the Pacific Island Navigators*. Collins, Sydney (1978).
- Lewis, David: *We, the Navigators - The Ancient Art of Landfinding in the Pacific*. University of Hawai'i Press, United States (1994). ISBN: 9780824815820.
- Lianos, Nikolas A.: *The Ancient Port of Marea-Philoxenite at Lake Mareotis in Alexandria*. *The Alexandria International Conference on Maritime and Underwater Archaeology* (2016). https://www.researchgate.net/publication/322235868_The_ancient_port_of_Marea-Philoxenite_at_Lake_Mareotis_in_Alexandria
- Lindsay, William S. (1816-1877): *History of Merchant Shipping and Ancient Commerce*. ReInk Books (2015).
- Lipinsky, Edward: *Itineraria Phoenicia (Orientalia Lovaniensia Analecta)*; Peeters Publishers (2005). ISBN: 9789042913448.
- Litchfield West, Martin: *Greek Epic Fragments from the Seventh to the Fifth Centuries BC*. Harvard University Press, 2003 - *Literary Criticism* - 316pp.
- Liversidge, Joan: *Everyday Life in the Roman Empire*. B. T. Batsford Ltd (London), G. P. Putnam's & Sons (New York) (1976). ISBN: 071343239X.
- Long, Neville: *Lights of East Anglia*, Lavenham Press (1983) p2.
- Lowe, Dunstan: *Twisting in the Wind - Monumental Weathervanes in Classical Antiquity*. *Cambridge Classical Journal*, 62, (2016), pp147-169. ISSN 17502705.
- Lucian; H. W. Fowler; F. G. Fowler (trans.): *The Works of Lucian of Samosata*. The Clarendon Press Oxford, 1905, pp135-6.
- Lucian; William Tooke (trans.): *Lucian of Samosata*. Vol 2, London (1820). <http://www.sacred-texts.com/cla/luc/wl2/index.htm>
- Mackintosh-Smith, Tim (ed): *The Travels of Ibn Battut-*

- ah. Picador (2002) 325pp. ISBN 9780330418799.
- MacPherson, James Rose: *The Pilgrimage of Arculfus in the Holy Land About the Year A.D. 670*, Palestine Pilgrims Text Society, London, (1895). <https://archive.org/details/libraryofpalesti03paleuoft>
- Mahmoud-Bey, *Memoire sur L'Atlantique Alexandrie*. Copenhagen (1872). <https://archive.org/stream/mmoiresurlantiq00falagoog#page/n5/mode/2up>
- Maiuri, Amedeo: *La Specola Misenate*. In: *Itinerario Flegreo*, Bibliopolis, Napoli (1983), pp177-194. ISBN: 9788870880847.
- Malkin, Irad: *A Small Greek World*. Oxford University Press (2011) 284pp. ISBN: 9780199315727.
- Manfredini, C.: *Il Libro Dei Fari Italiani*. Mursia editore, Via Tadino 29, Milano, Italy, (1985), pp 196.
- Mansel, A.M.: *Die Ruinen von Side*, Berlin (1963).
- Marimpietri, K.: *Fra le dune della Cirenaica/ Archeo* (2008), XXIV 4 (278), pp12-13.
- Maryon, H.: *The Colossus of Rhodes*. *The Journal of Hellenic Studies*, 76 (1956), pp68-86. doi:10.2307/629554.
- Matter, M.: (1840-44).
- McCann, A.M.; Bourgeois, J.; Gazda, E.K.; Oleson, J.P; Will, E.L.: *The Roman Port and Fishery of Cosa - A Centre of Ancient Trade*, Princeton University Press (1987).
- McCormick, W. H.: *The Modern Book of Lighthouses, Lightships and Life-Boats*. A&C Black, London (1936), 142pp.
- McCrinkle, John Watson: *The Commerce and Navigation of the Erythraean Sea*. Forgotten Books, United States (2015). ISBN: 9781330880883.
- McKenzie, Judith: *The Architecture of Alexandria and Egypt 300 BCE - AD 700*. Yale University Press, New Haven and London (2007) 460pp. ISBN: 9780300170948.
- McMahon, Donald J.: *A Seafarers Decoding of the Irish Symbols - The Oldest Testament - 3200 BCE to 2500 BCE*. Createspace, United States (2014), 9781497395206.
- Medas, Stefano: *De Rebus Nauticis: L'Arte Della Navigazione nel Mondo Antico*. Rome: L'Erma di Bretschneider (2004), 234pp. ISBN: 8882652785.
- Meiggs, Russell: *Roman Ostia*, Clarendon Press, Oxford, UK (1997), p279.
- Merriam, Augustus Chapman: *Telegraphing Among the Ancients*. *Papers of the Archaeological Institute of America, Classical Series*, 3, 1 (1890), 32pp.
- Mikelson, Jon: *An Overview - Greek Sanctuaries and Worship*. AGRC01 (2004), 31pp. http://www.blackwell-publishing.com/content/BPL_Images/Content_store/Sample_chapter/0631232222/Mikalsen_sample%20chapter_ancient%20greek%20religion.pdf
- Milne, Gustav: *The Port of Roman London*. B. A. Batsford Ltd., London (1985), 160pp. ISBN: 0713443642.
- Mingazzini, P.; F. Pfister: *Forma Italiae: Regio I - Latium et Campania, Volumen Secundum, Surrentum*, Firenze (1946).
- Mirley, Margaret: *Closing the Helix - The Journey and Experiences of Pytheas, the Greek Merchant Adventurer Who Explored the Northern Seas*. Troubador Publishing, UK (2007). ISBN: 9781906221133.
- Moreno, Alfonso: *Hieron - The Ancient Sanctuary at the Mouth of the Black Sea*. *Hesperia*, 77 (2008), pp655-709. Quotation on p697.
- Morkot, Robert: *The Penguin Historical Atlas of Ancient Greece*. Penguin Books (1996). ISBN: 0140513353.
- Morton, Jamie: *The Role Of The Physical Environment In Ancient Greek Seafaring*. Brill (2001), 363pp. ISBN: 9789004351073.
- Moscato, Sabatino (ed): *Phoenicians*. Bompiani, Palazzo Grassi, Venezia (1988a).
- Moscato, Sabatino: *The Carthaginian Empire* (1988b), pp54-61. In: Moscati (1988a).
- Moscato, Sabatino; Alastair Hamilton (trans): *The World of the Phoenicians*, Weidenfield and Nicholson (1968), Also Sphere Books (1973). ISBN: 0351174044.
- Moscato: *Sardinia*. (1973b), pp257-282. In Moscati (1973a).
- Most, Glenn W.; Schreyer, Alice (Eds.): *Homer In Print: A Catalogue Of The Bibliotheca Homerica Langiana At The University Of Chicago Library*, University of Chicago (2013) 352pp. ISBN: 9780943056418. <https://www.lib.uchicago.edu/e/webexhibits/homerinprint/BHL.html>
- Mothersole, Jessie: *The Saxon Shore*. The Bodley Head (1924).
- Muckelroy, K.: *Archaeology Under Water - An Atlas of the World's Submerged Sites*, London, (1981).
- Naish, John M: *Seamarks - Their History and Development*. Stanford Maritime Limited, 12-14 Long Acre, London WC2E 9LP, (1985), 192pp. ISBN: 0540073091.
- Newhouse, Daniel (Capt.): *The Whole Art of Navigation in Five Books* (1685).
- Noble, Joseph V.; Derek J. de Solla Price: *The Water Clock in the Tower of the Winds*, *American Journal of Archaeology*, Vol. 72, No. 4. Oct (1968), pp. 345-355.
- O'Connell, James; Jim Allen; Kristen Hawkes: *Pleistocene Sahul and the Origins of Seafaring Ch5* (2010),

pp 57-68. <https://www.researchgate.net/publication/251888687>

Oates, Whitney J.: The Population of Rome. *Classical Philology*, Vol. 29, No. 2 Apr (1934), pp101-116.

Obregon, Mauricio: *Beyond the Edge of the Sea*. Modern Library Paperback Edition (2002). ISBN: 9780679783442.

Oleson, J. P. and M. D. Jackson: *The Technology of Roman Maritime Concrete* (2014b), pp1-10.

Oleson, John P., C. J. Brandon, M. D. Jackson, R. L. Hohlfelder: *Building for Eternity: The History and Technology of Roman Concrete Engineering in the Sea*, Oxbow Books, United Kingdom (2014). ISBN: 9781782974208

Oleson, John P., M. D. Jackson and G. Vola: Appendix 3: Catalogue and Descriptions of Concretes Drilled from Harbour Structures by ROMACONS, (2014a), pp260-263. In: Oleson (2014).

Ordonez Agulla, Salvador: El Faro de Gades y Las Fuentes Medievales. In: *II Congreso Peninsular de Historia Antiga, Actas Coimbra* (1993), pp247-277.

Ormerod, Henry A.: *Piracy in the Ancient World*. Johns Hopkins University Press, United States (1996). ISBN: 9780801855054.

Paget, R. F.; From Baiae to Misenum. *Vergilius, The Vergilian Society*, No 17 (1971), p22-38. <http://www.jstor.org/stable/41591669>

Paglia, Alessandro: *La Lanterna - Trieste Sono Io*, Trieste, Assicurazioni Generali, (1997) p116.

Palacios, Miguel Asin: Una Descripción nueva del faro Alejandria, *al-Andalous* 1 (1933), pp241-92. Reproduced in *Obras Escogidas*, II-II, 389-460.

Pasquinucci, Marinella; G. Rossetti: Porto Pisano - The Harbour Infrastructure at Pisa and Porto Pisano from Ancient Times to the Middle Ages. (1988), pp137-55. In Raban (1988)

Pasquinucci, Marinella; Simonetta Menchelli: The Landscape and Economy of the Territories of Pisae and Volaterrae (Coastal North Etruria). *The Journal of Roman Studies*, 69, November (1979).

Patai, Raphael: *The Children Of Noah - Jewish Seafaring In Ancient Times*. Princeton University Press (1998), ISBN: 9780691015804.

Pausanius; Peter Levi (trans.): *Guide to Greece - Vol. 1*, Penguin Books (1971), 586pp. ISBN: 9780140442250.

Peman, Cesar: *Las Fuentes Literarias de la Antigüedad y Fundación de Cadiz*, Madrid (1954).

Petraglia, M. D.; Rose, J. I. (eds.): *The Evolution of Human Populations in Arabia - Vertebrate Paleobiology*

and *Paleoanthropology*. Springer Science and Business Media B. V. (2009)

Petry, Carl: *The Cambridge History of Egypt, Volume 1 & Volume 2*. Cambridge University Press (2008).

Phillips-Birt, Douglas: *A History of Seamanship*. Allen & Unwin (1971). ISBN: 9780046230098.

Philp, Brian: *The Excavation of the Roman Forts of the Classis Britannica at Dover 1970-1977*. Kent Archaeological Rescue Unit, CIB Headquarters, Dover Castle, Kent (1981).

Pliny the Elder; John Bostock, H.T. Riley (trans): *Natural History*. Taylor and Francis, Red Lion Court, Fleet Street, London (1855).

Pliny the Elder; John Healy (trans.): *Natural History - A Selection*; Penguin Classics (1991).

Poochigian, Aaron: *Phaenomena*. Johns Hopkins University Press (2010). ISBN: 9780801894664.

Raban, A. (ed.): *Archaeology of Coastal Changes. Proceedings of the First International Symposium: Cities on the Sea, Past and Present*; Oxford, B.A.R. (1988).

Raban, Avner; Kenneth G. Holum: *Caesarea Maritima - A Retrospective After Two Millennia*. (*Documenta et Monumenta Orientis Antiqui*), Brill, Netherlands (1996). ISBN: 9789004103788.

Rapisarda, Massimo; M. Ranieri: *A Phoenician Lighthouse at Capo Gallo Palermo*. *Mediterranean Archaeology and Archaeometry*, Vol. 16, No 4 (2016), pp225-231.

Reich, David: *Who We Are And How We Got Here*, Oxford University Press (2018), 335pp. ISBN: 9780198821250

Renard, Leon: *Les Phares*, Editions L'Ancre de Marine, St. Malo (1990).

Ricci, R.: *Bergeggi - Un Isola Davanti ad Un Isola*, Torino (1998).

Rigsby, K. J: *Asyilia - Territorial Inviolability in the Hellenistic World*. University of California Press, Berkeley (1996).

Robinson, Damian; Goddio, Franck (eds): *Thonis-Heracleion in Context*, Oxford Centre for Maritime Archaeology, University of Oxford (2015). ISBN: 9781905905331. <http://www.franckgoddio.org/projects/sunken-civilizations/heracleion.html>

Rowlett, Russ: *The Lighthouse Directory* (online). <https://www.unc.edu/~rowlett/lighthouse>

Rugua, Zhao; Hirth, Friedrich, W.W. Rockhill (trans.): *Zhu fan zhi* (1225), (1911). <http://ebook.lib.hku.hk/CADAL/B31403797>

- Rutherford, Adam: *A Brief History of Everyone Who Ever Lived*. Weidenfeld and Nicolson (2016), 420pp. ISBN: 9781780229072.
- Sachs, Abraham: *A Classification of the Babylonian Astronomical Tablets of the Seleucid Period*. *Journal of Cuneiform Studies*, Vol. 2, No. 4 (1948), pp271-290.
- Scarre, Chris (ed.): *Antiquity, A Review of World Archaeology*, Vol. 90, 350, April (2016).
- Schoff, Wilfred Harvey: *The Periplus of the Erythraean Sea - Travel and Trade in the Indian Ocean by a Merchant of the First Century*. London, Bombay & Calcutta (1912).
- Sharp, Andrew: *Ancient Voyagers in the Pacific*. Penguin (1957).
- Silius Italicus; J. D. Duff (trans): *Punica*. William Heinemann Ltd, London (1959).
- Sladen, Douglas Brooke Wheelton: *Carthage and Tunis, The Old and New Gates of the Orient*. Hutchinson, London (1906).
- Smith, James: *The Voyage and Shipwreck of St. Paul - With Dissertations on the Life and Writings of St. Luke, and the Ships and Navigation of the Ancients*. Forgotten Books, United States (2016). ISBN: 9781332037926.
- Somner, William: *A Treatise of the Roman Ports and Forts in Kent*. James Brome, Oxford (1693). <http://name.umd.umich.edu/A60898.0001.001>
- Spence, Simon: *The Image of Jason in Early Greek Myth*. Lulu.com, (2011), pp292. ISBN: 9781446115817.
- Stevenson, Alan: *On the Theory and Construction of Lighthouses* (1857).
- Stevenson, David A.: *The World's Lighthouses Before 1820*. Oxford University Press (1959).
- Stewart, Charles: *Magic Circles - An Approach to Greek Ritual*. *Journal of the Anthropological Society of Oxford* 25:1 (1994), p91-101.
- Strabo; Jones, Horace L. (trans.): *The Geography of Strabo*. William Heinemann, London & New York (1917). Books 1 to 17 in 8 Volumes with index in Volume 8.
- Strong, Anthony: *The Phoenicians in History and Legend*. 1st Books Library (2002). ISBN: 140336690X.
- Stuart, James; Nicholas Revett: *The Antiquities of Athens*. London (1762).
- Suetonius Tranquillus, C.; Alexander Thomson (ed): *The Twelve Caesars*. Penguin Classics (2007)
- Sutton-Jones, Kenneth: *Pharos - The Lighthouse Yesterday, Today and Tomorrow*. Michael Russell Publishing Ltd, Salisbury UK (1985).
- Talbot, Frederick A.: *Lightships and Lighthouses*. William Heinemann, London (1913), 325pp.
- Taylor, E.G.R.: *The Haven-Finding Art; A History of Navigation from Odysseus to Captain Cook*. Hollis & Carter, London (1956).
- The New English Bible, Cambridge University Press (1970), Acts 27:20.
- Thiersch, Hermann: *Pharos, Antike, Islam Und Occident*. B. G. Teubner, Leipzig und Berlin (1909). Reprinted under license. ISBN: 9781248365946.
- Thomas, Stephen D.: *The Last Navigator - A Young Man, an Ancient Mariner, the Secrets of the Sea*. Booksurge Publishing, United States (2009). ISBN: 9781439233498.
- Thompson, D.J.: *Ptolemaios and The Lighthouse - Greek Culture in the Memphite Serapeum*. *Proceedings of the Cambridge Philological Society* 33 (1987), p105-21.
- Thouvenot, Raymond: *Essai sur la Province de Bétique*, Paris (1940).
- Torrin, Ken: *Maritime History Part 1 - Ancient Times Age of Navigation; Medieval Times; and More*. Webster's Digital Services (2016). ISBN: 9781276188869.
- Toussoun, Prince Omar: *Description du Phare d'Alexandrie d'après un auteur arabe du XIe siècle*. *Bulletin de la Société Royale d'Archéologie d'Alexandrie* 30 (1936) 49-53.
- Trethewey, K. R.: *What is a Lighthouse? A Modern Definition*. *World Lighthouse Society Quarterly Magazine*, 1st. Quarter (2013), Volume 11, Issue 1, 5-14.
- Tripati, Sila: *Maritime Archaeology- Historical Descriptions of the Seafarings of the Kalingas*. Kaveri Books, New Delhi (2000). ISBN: 9788174790385.
- Tuck, Steven L.: *Ports*, Chapter 21. In: *A Companion to the Archaeology of the Roman Republic*, Jane DeRose Evans (ed) Wiley-Blackwell (2013), 746pp. ISBN: 9781405199667.
- Tusa, Vincenzo: *Sicily* (1988) p186-205; In *Moscatti* (1988).
- Uggeri, Giovanni: *Baro Zavelea near Comacchio, Aemilia Ferrara* (1973); *Torre Romana*: In *Fasti Archaeologica, XXX-XXXI*, pp821-822.
- Usai, D.; S. Salvatori: *The Oldest Representation of a Nile Boat*. *Antiquity* Vol 81 issue 314 December (2007).
- van Berkem, Dennis: *Sanctuaires a Hercules-Melqart, Syria*, 44 (1967).
- van Berkem, Max: *Materieux pour un Corpus Inscriptio-num Arabicarum (Egypte)*. Paris (1900), pp473-89.
- van de Noort, Robert: *North Sea Archaeologies - A Maritime Biography, 10,000 BC - AD 1500*. Oxford University

- Press (2011), pp282. ISBN: 9780199657087.
- Vann, Robert L.: The Drusion - A Candidate for Herod's Lighthouse at Caesarea Maritima. *International Journal of Nautical Archaeology*, Vol. 20 No.2 (1991), pp123-139.
- Villa, Paola; Wil Roebroeks: Proceedings of the National Academy of Sciences, 14 March (2011). <http://www.colorado.edu/today/2011/03/14/neanderthals-were-nifty-controlling-fire-according-cu-boulder-researcher>
- Vincent, William: *The Commerce and Navigation of the Ancients in the Indian Ocean* (1807). British Library, Historical Print Editions (2011). ISBN: 9781241411022; Also Nabu Press (2014), USA. ISBN: 9781294892038.
- Vincent, William: *The Periplus of the Erythraean Sea (1739-1815)*. Pre-1801 Imprint Collection (Library of Congress) DLC, Thomas Leiper Kane Collection (Library of Congress, Hebraic Section) DLC, ReInk Books (2015).
- Vitruvius; Morris Hicky Morgan (trans.): *The Ten Books on Architecture*. Harvard University Press Cambridge Mass. USA / Oxford University Press, Oxford, UK (1914).
- Vorderstrasse, Tasha: *Descriptions of the Pharos of Alexandria in Islamic and Chinese Sources: Collective Memory and Textual Transmission* (2012), pp457-81. In: Cobb (2012).
- Wachsmann, Shelley: *Seagoing Ships and Seamanship in the Bronze Age Levant*. Texas A&M University Press (2009). ISBN: 9781603440806.
- Wallace, Paul W.: *The Tomb of Themistocles in the Peiraeus*. *Hesperia*, Oct. - Dec. (1972), The American School of Classical Studies at Athens, pp. 451-462. <http://www.ascsa.edu.gr/pdf/uploads/hesperia/147386.pdf>
- Wheeler, R. E. M.: *The Roman Lighthouses at Dover*. *Archaeological Journal* Vol. 86 (1929) 1., pp29-46. <https://doi.org/10.5284/1018054>; www.archaeologydataservice.ac.uk
- White, Tim D.; Asfaw, B.; DeGusta, D.; Gilbert, H.; Richards, G. D.; Suwa, G.; Howell, F. C.: *Pleistocene Homo sapiens from Middle Awash, Ethiopia*. *Nature*, 423 (6491) (2003), pp742-747.
- Whitney, Marie: *A Look At The History Of Sailing Including Ancient Maritime History, History Of Navigation, Maritime History Of The United States, Plus Historic Ship Types...* Webster's Digital Services (2016). ISBN: Wikipedia: Australia (continent) 20160727
- Wikipedia: Beta Ursae Minoris 20160831
- Wikipedia: Black Sea 20171012
- Wikipedia: Black Sea Deluge Hypothesis 20171012
- Wikipedia: Brittenberg 20180110
- Wikipedia: Bronze Age Collapse 20171010
- Wikipedia: Carthage (2016)
- Wikipedia: Compass 20170828
- Wikipedia: Cushite (2016)
- Wikipedia: Denisova 20160727
- Wikipedia: Dido (2016)
- Wikipedia: Hellenistic Period 20171015
- Wikipedia: History of the Cyclades 20171010
- Wikipedia: Homo 20160723
- Wikipedia: Inland Sea (Geology) 20180110
- Wikipedia: Land of Punt 20160728
- Wikipedia: Lighthouse of Alexandria 20160618
- Wikipedia: Milos 20170828
- Wikipedia: Mirrors, Telescopes, Speculum metal 20180228
- Wikipedia: Neanderthal 20160727
- Wikipedia: Nuraghe (2017)
- Wikipedia: Odyssey, 20160822
- Wikipedia: Panormus (2017)
- Wikipedia: Periplus of the Erythraean Sea 20180129
- Wikipedia: Phoenicia (2016)
- Wikipedia: Pleistocene (2017)
- Wikipedia: Pythea, 20180129
- Wikipedia: Reed boats 20160723
- Wikipedia: Sardinia (2017)
- Wikipedia: Venerius the Hermit 20170417
- Wilde, W. R.: *On the Pharos of Coruña*. Proceedings of the Royal Irish Academy (1836-1869), Vol. 2 (1840 - 1844), pp. 583-594, Published by: Royal Irish Academy, pp12. <http://www.jstor.org/stable/20520203>
- Wilford, John Noble: *Geologists Link Black Sea Deluge To Farming's Rise*. *The New York Times* (17 December 1996). Retrieved 17 June 2013.
- Witney, Dudley: *The Lighthouse*. Arch Cape Press (1989) 256pp. ISBN: 0517669536.
- Wood, Michael: *In Search of The Trojan War*. BBC Books (2005). ISBN: 0563522658. Also ISBN: 0520215990.
- Woodburn Hyde, Walter: *Ancient Greek Mariners with Maps*, Oxford University Press (1947).
- Woodman, R.; Jane Wilson: *The Lighthouses of Trinity House*, Thomas Reed Publications (2002). ISBN:

190405000X.

Wright, George R.H.: *Ancient Building in Cyprus*. Brill, Netherlands (1992). ISBN: 9789004095472.

Wroth, L.C.: *The Way of a Ship - An Essay on the Literature of Navigation Science*. Martino Publishing, Mansfield Centre (2001). Reprint of 1937. ISBN: 9781578983254.

Yorke, Robert A.; David P. Davidson: *The Harbour at Ptolemais - Hellenistic City of the Libyan Pentapolis*. *The International Journal of Nautical Archaeology* (2017). <https://doi.org/10.1111/1095-9270.12212>.

Zemke, Friedrich-Karl: *Leuchttürme Der Welt*. (Volume 1), Koehler (1992). ISBN: 3782205375.