Medieval Lighthouses
Part 13 - Evolution of Structure

by Dr Ken Trethewey

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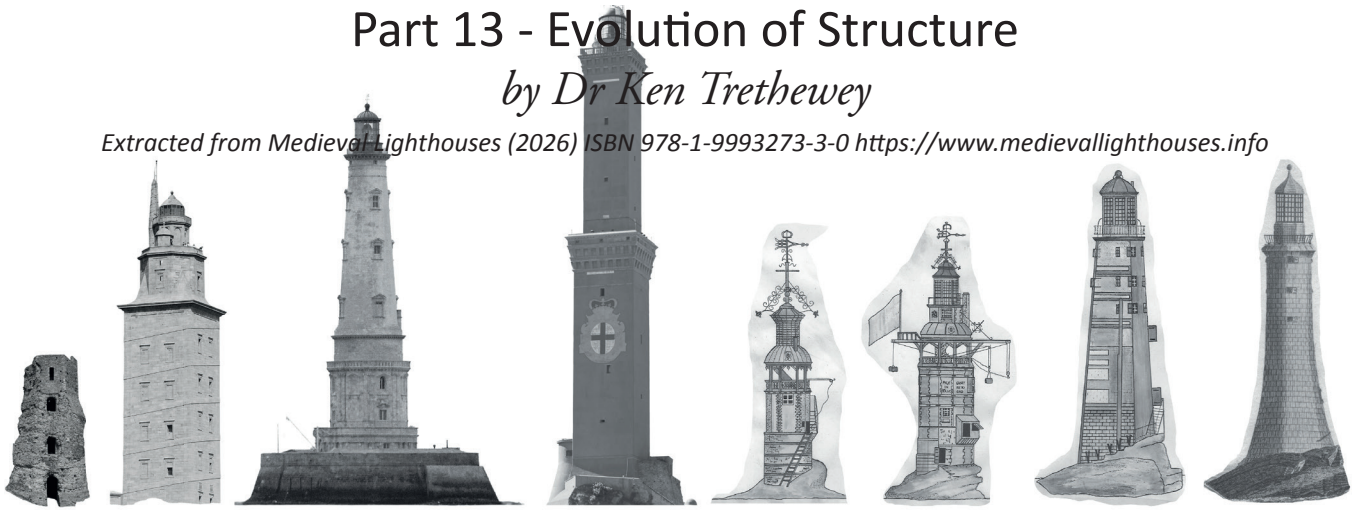


Most people have a firm mental image of the shape and general appearance of a lighthouse. The reason is that lighthouses were adopted into the essence of western culture as far more than just a navigational aid. They became a symbol of life itself, their light offering hope in the darkness of the world.

We have seen during the course of these two volumes how lighthouses adopted many forms on their way towards reaching that final iconic shape. In my opinion, the round, stone tower of Smeaton's Eddystone lighthouse - above right - is that icon. Built in 1756-9, it never failed in its task and is in perfect condition on Plymouth Hoe today, a preserved monument to centuries of human endeavour and loss. I have already presented its detailed history elsewhere.[1] Furthermore, it is the starting point for Volume 3 so I shall not repeat my words here.

However, in this book we have followed the course of thirteen centuries of possible lighthouse building and have arrived at the point where, to coin a phrase, *everything changed*. In this chapter I shall summarize how the world arrived at this point.

Objectives

The objectives of this chapter are:

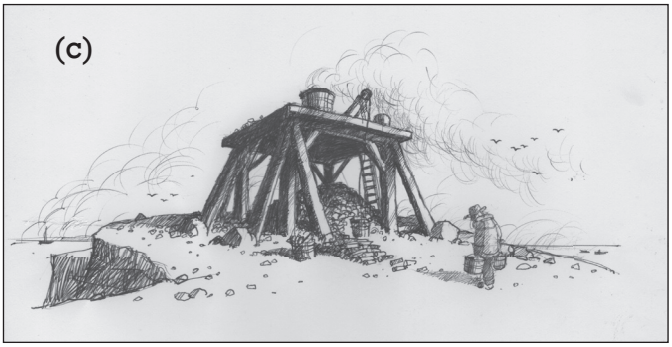
1. To summarize the changes in design of the structures of lighted aids to navigation during the period of study.

2. To compare and contrast the elements of the design philosophy that caused the evolution of lighthouses into the shape recognized by western Society.

In this, my final chapter it is perhaps time to come clean. Even with the scope of thirteen centuries, this might have been a very thin volume, for it is now clear that over this immense period of time - for lighthouses - *nothing much happened!*

On several occasions I have admitted that the only thing standing between a safe voyage and a close inspection of Davy Jones' Locker was a fire on a beach. However, it is my view that I would be doing a great disservice to my subject by not considering the wider picture. In some respects, it is something of an enigma as to how one of the world's greatest structures (the Pharos) could have been followed by nothing for so long. Of course, my reasoning is that the restrictions posed by the poor control of fire limited what was possible, however much mariners might have wished otherwise. So my book has really been an extended review of the use of fire, interspersed with discussions about the success or otherwise of navigation through the ages.

But I repeat that it would have been an omission and a bare mistake to jump straight from Romans to Romantics, for there has certainly been a story to tell that bridges the years to what we are more familiar with today. Many readers will have little knowledge of the efforts made by members of the Christian communities to save souls at sea. You may also never have realised the beauty of some of the structures that did arise at various points in history, for the magnificence of the Torre d'Hercules, the Cordouan King of Lighthouses and the extraordinary Lanterna of Genoa are still not household names. So as a final flourish, I shall set the scene for the explosion of technology, many of the main developments taking place in lighthouses!



What Could Be Simpler?

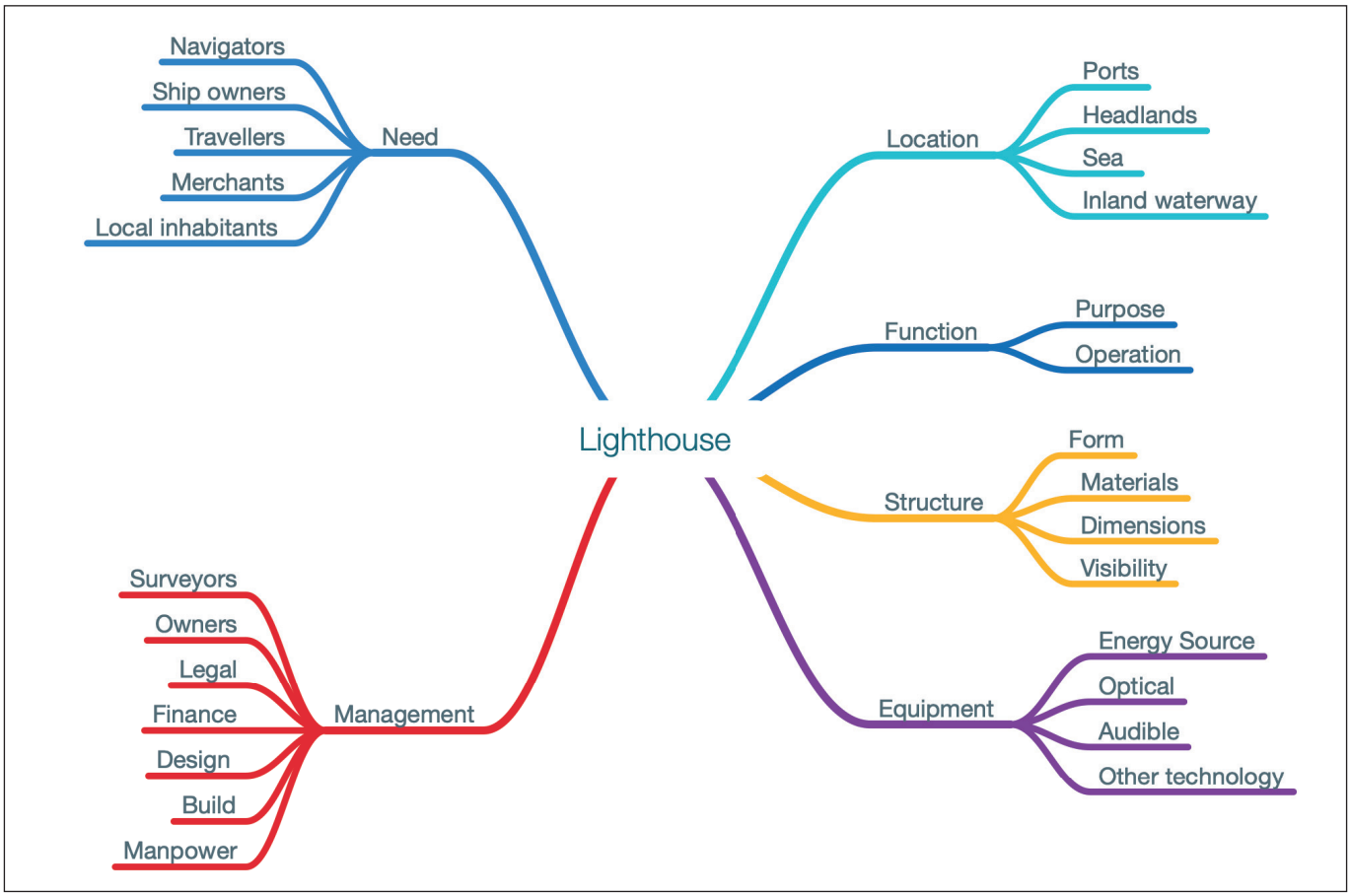
The difficulties of confirming the presence of early lights set up for navigation rather than signalling have been made clear now, notably in my discussion of the conundrum at Dover (p79). In the situation where a light on a pier is considered to be as common as a stable or a brew house, why would it be considered necessary to record the activities associated with something like the structure in image (a) above? This could easily have been the guiding beacon for ships entering ports like Dover all over the world, and it would probably have escaped the notice of anyone except those in special cases such as chart makers and compilers of Rutters (p36) or the pilots themselves. Even so, we might have expected some note to be made somewhere over 1300 years of marine activity.

The kind of light illustrated in (a) is perhaps most likely to be found on a quayside or on the end of a pier than at a great height on a promontory. Its characteristic is essentially to be seen from a reasonably short distance. It does not need to be high off the ground where it would cause difficulty to keep alight. On the other hand it needs to be high enough not to be obscured by abandoned fishing gear.

However, when the distances are greater - the ship is far out to sea or remote from the port - a more substantial installation might be expected such as shown in (b), (c) or even (d). The significant design factor is the height above sea level because it determines the distance at which the light can be seen. High on a cliff top its only need is to be seen above the tree-line. Furthermore, to assist in maximizing the visibility, a greater mass of fuel needs to be burnt and this introduces the requirements to have larger storage facilities and greater human power to keep it alight. We at once understand the differences between having harbour lights versus headland (waypoint) lights. The second possibility implies a greater chance of there being a designated structure that would appear in the historical record.

In an earlier chapter I discussed cultural changes that took place in different parts of the world and speculated on the likelihood that navigation lights might be shown. I pointed out that with simple fires as the only practical option there were significant difficulties in identifying such locations, especially when the showing of a fire might be for the purposes of signalling. The ambiguity in the English language and the use of the word beacon does not help in distinguishing a deliberate act of showing a light for navigation purposes.

Accepting therefore the large degree of uncertainty during this extensive period of time, we must move on and start to consider how the decisions were made about the various design elements of what we are more confident today about calling lighthouses.



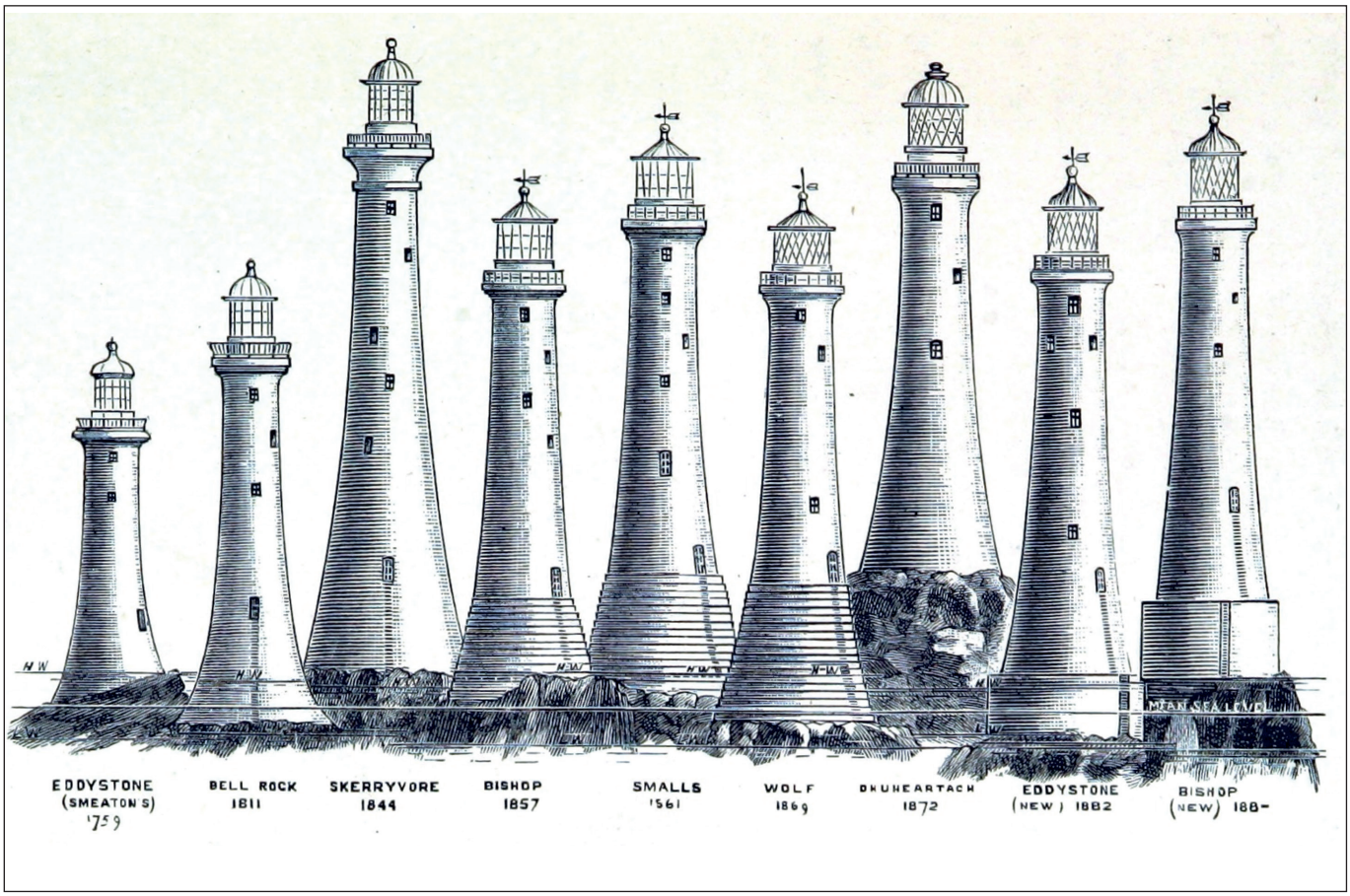
Above: A topic taxonomy showing the design factors that need consideration when a new lighthouse is proposed.

Lighthouse Design In The Middle Period

The diagram above lists the topics that need to be considered by the builder when a new lighthouse is proposed. As with any 'business' proposal, the resources required to complete the project (not least of which is money) are the over-riding factor and these make certain final decisions inevitable. We shall probably never know just how the resources were found to construct the outrageously extravagant Alexandrian Pharos.

We do not know how the costs of the many Roman lighthouses were decided; we must presume they were at the discretion of those with absolute power. Perhaps the Emperor decided to appropriate the finance for a structure such as the stone Pharos at Dover entirely on the basis of his perceived need. Military requirements tend to over-ride all else so that was probably in play here. However, in a world in which the cogs of action are greased by money (as was true for all of the history recorded here) affordability is almost always the deciding factor.

Many of the factors overlap each other. For example, the purpose is a strong factor, for a simple harbour light may not need to be seen from as great a distance as a waypoint light for passing ships. The observation distance is dependent upon the height of the light, so if a large distance is required then a high - clifftop - location should be chosen rather than one at sea level. If a clifftop location is not available then the tower must be tall and probably solid rather than an open framework structure. Across much of the southern North Sea, there are very few high points and so we find many high towers today. A really tall tower cannot be made of wood so stone is preferable. Leading lights need two aligned lights to create a line for navigators to steer. Front lights were often minor, almost insignificant structures in comparison to the rear light and from a distance may not have been visible, but front lights often need to be moved when channels change and so they need to be movable, which tends to exclude



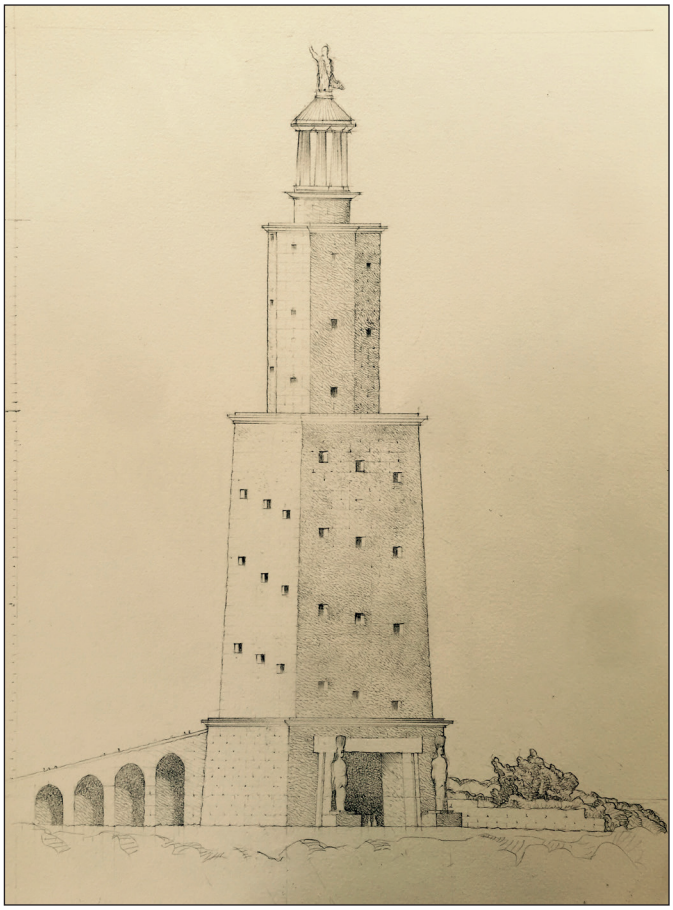
Above: Major British lighthouses built after the Smeaton Eddystone (far left) generally adopted the proven model of its engineer. This technology was then exported around the world during the Imperial Age.

the use of stone.[2] Of course, builders need to work with the resources available and in locations where there are no trees, stone is the only option. Finally, and of great significance is the type of light to be used. We have identified lights that consisted of a few candles and these could not have been shown without being enclosed in a lantern of some sort. The structure design then needs to be appropriate to support the size of lantern.[3]

We have seen how the use of coal fires was generally in the open air, but that when complaints were received as to their ineffectiveness in bad weather, many attempts to enclose them inside glass lanterns were made. However, we need to remember that throughout all of this period the manufacture of glass was crude and not capable of producing the quality needed for the most efficient transmission of light. The enclosure behind glass was therefore neither easy nor efficient. Even if glass was used, it could be obscured by soot deposits or smoke from the fire, and so many complaints from mariners suggested that they preferred open fires.

And there was the ever-present hazard that any structure having substantial amounts of wood in it was at severe risk of being destroyed by fire.

In the final analysis, we might conclude that there were few optional design choices available to the designer - the shape being one of the few. All three of the main shapes - octagonal, square and circular in section - were used over the course of history. The octagon was the shape of choice for the Pharos of Alexandria and was the inspiration for many structures that came after it, including the Dover Pharos and the Tour d'Ordre in Boulogne. Square section was a common choice, seemingly popular in the military situations of castles, or monasteries or church towers. But it was the circular cross-section of Smeaton's tower that seemed ultimately to become the most common shape of choice.[4] The drawing at the top of the page shows us at once how influential was the design of Smeaton's Eddystone, a form that was reproduced throughout the world of childrens' books. (Only red and white bands are missing!) So, who needs decoration?

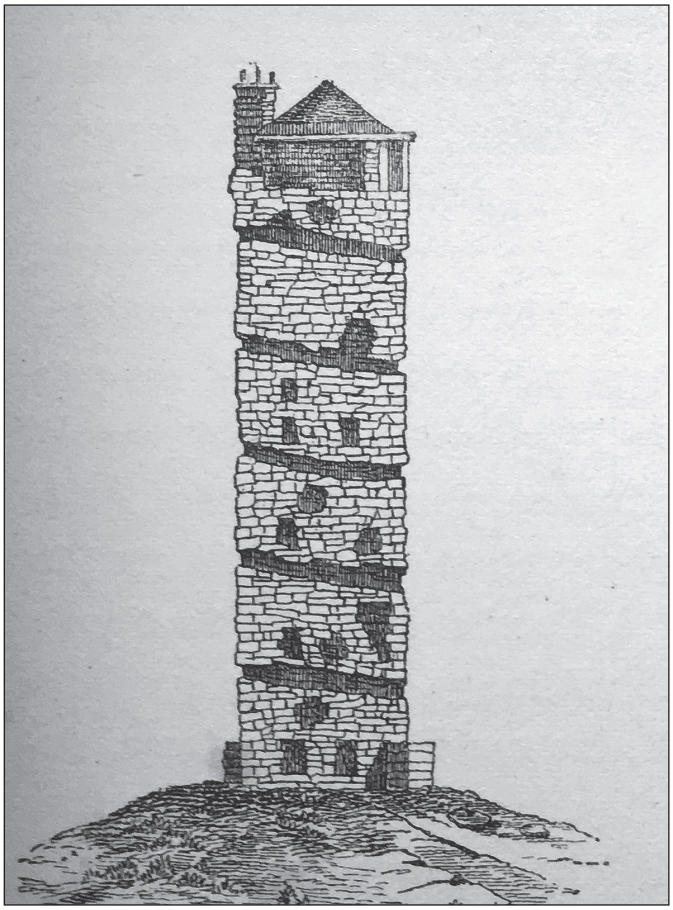


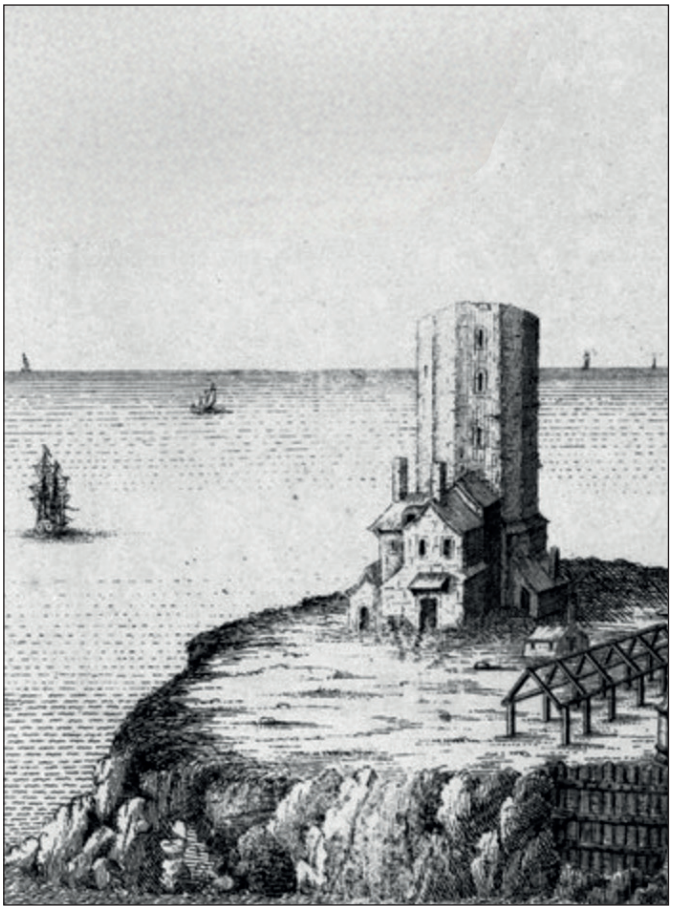
The Pharos of Alexandria

Probably the most famous lighthouse in the World is the Pharos of Alexandria.[5] This structure was extravagant in the extreme and few structures have ever come close to it. Commissioned in the third century BCE, it was the tallest ever built, and so its mass could only have been supported within an immense stone structure. Its sectional design embraces several different geometries and at the top was a lantern structure inside which a wood fire was kept alight by a small army of men who were in constant transit with the fuel to keep it alive - indeed, it was large enough inside to house a substantial body of soldiers to protect it. Although built in what is now Egypt, it was very much an idea formed within the Greek culture, but this grand lighthouse fits perfectly into the category of megastructures for which Egypt is famed. It was suitably ornamented with sculptures that gave reference to the gods to whom the locals paid homage. Such a structure was bound to survive the ravage of centuries, but sadly it did ultimately succumb to earthquakes and was gone in the early 15th century, replaced by the fort that exists on the site today. Thus it was not just an ancient lighthouse but a medieval one too.

Portus Dubris - Dover

The Roman gateway to the British Islands was first at Dover where sometime during the first or second centuries, two phari were built either side of the harbour. The structure closest to the viewer is the western tower, today almost entirely gone, whilst the remains of the distant tower can be found in the grounds of Dover Castle. The Romans had only recently completed a similar tower on the French side of the Channel at Boulogne called the Tour d'Ordre, also now completely destroyed. The similarities to the Alexandrian Pharos are fairly obvious, with their geometrical cross-sections and stepped sections reaching skyward to the top level where there were fires burning. Whether the fires were protected from the elements by an enclosure of some kind is not known. There is strong confidence that the Alexandrian lighthouse had such protection and the Romans typically copied from successfully engineered structures in many other situations so it is possible that there were built lanterns on top, not just open braziers. We also do not know if the lights were shown constantly throughout the night, every night. It is possible that they were shown only when approaching ships were observed.



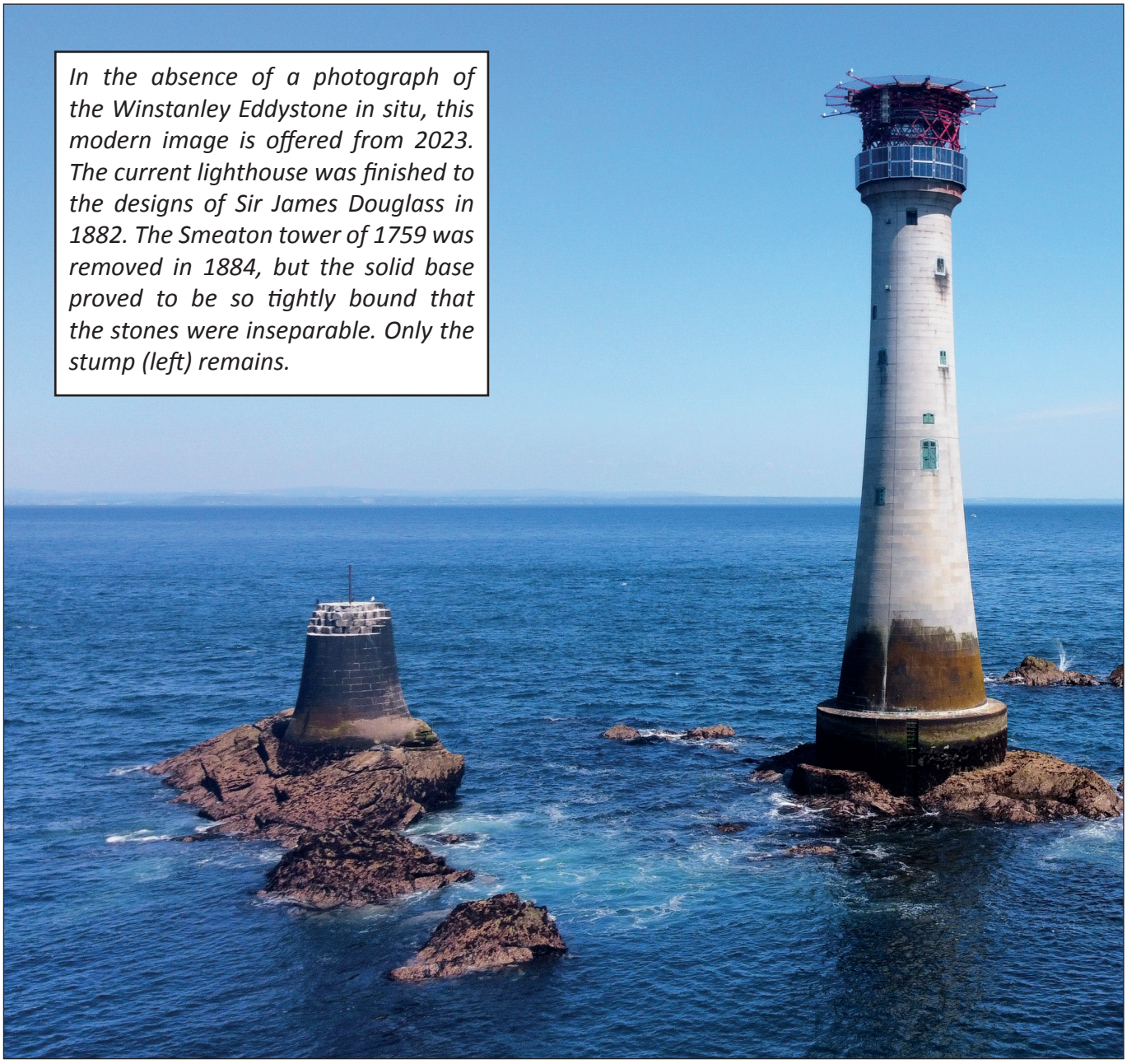


The Torre d'Hercules

This Roman lighthouse has a spiraling line of brickwork on the original Roman core and relates to the internal spiral ramp that winds its way up through the tower. It's a visible hint on the outside of the internal structure. The ramp spirals upwards between the tower's double walls. The outer masonry had to accommodate the rising path of this ramp, leading to slight offsets in the courses of stonework, which now appear as a diagonal or helical line. Windows were placed along the spiral ramp, primarily functional, not decorative, positioned to allow natural light into the internal spiral ramp. Since the ramp wrapped around a central solid core and had thick exterior walls, openings were essential to reduce darkness. This prevented the interior from becoming damp and structural integrity was retained with narrow windows to avoid weakening the tower. Roman engineers were careful to balance light and ventilation with the need for durability in a coastal environment. Typically narrow slits or small rectangular openings were often slightly angled or deep-set due to the wall thickness. Their positions on the facade often corresponds with the line of the spiral ramp.

Cordouan

The lighthouse is located off the coast of France near the mouth of the Gironde estuary. The first tower was constructed in 1360–1362, commissioned by the English "Black Prince", then also Prince of Wales. However, the site had been used long before by hermits. It was a tower with a fire beacon to help ships navigate into the Gironde estuary, especially toward Bordeaux. A simple octagonal, stone tower it had a coal or wood fire burning on top and was maintained by monks or hermits. This light was not very high, so its visibility was limited, but it was a major improvement nevertheless because of the Cordouan shoals with shifting sandbanks and strong Atlantic currents. Even a rudimentary beacon tower provided essential guidance. The old medieval beacon was demolished in the late 1500s to make way for the current Cordouan Lighthouse, a Renaissance masterpiece built by Louis de Foix. The new structure was taller, more ornate, and built with marble and carved stone, featuring living quarters, a chapel, and increasingly advanced lighting technologies over time. The Cordouan site is considered the oldest lighthouse site still in use in France.



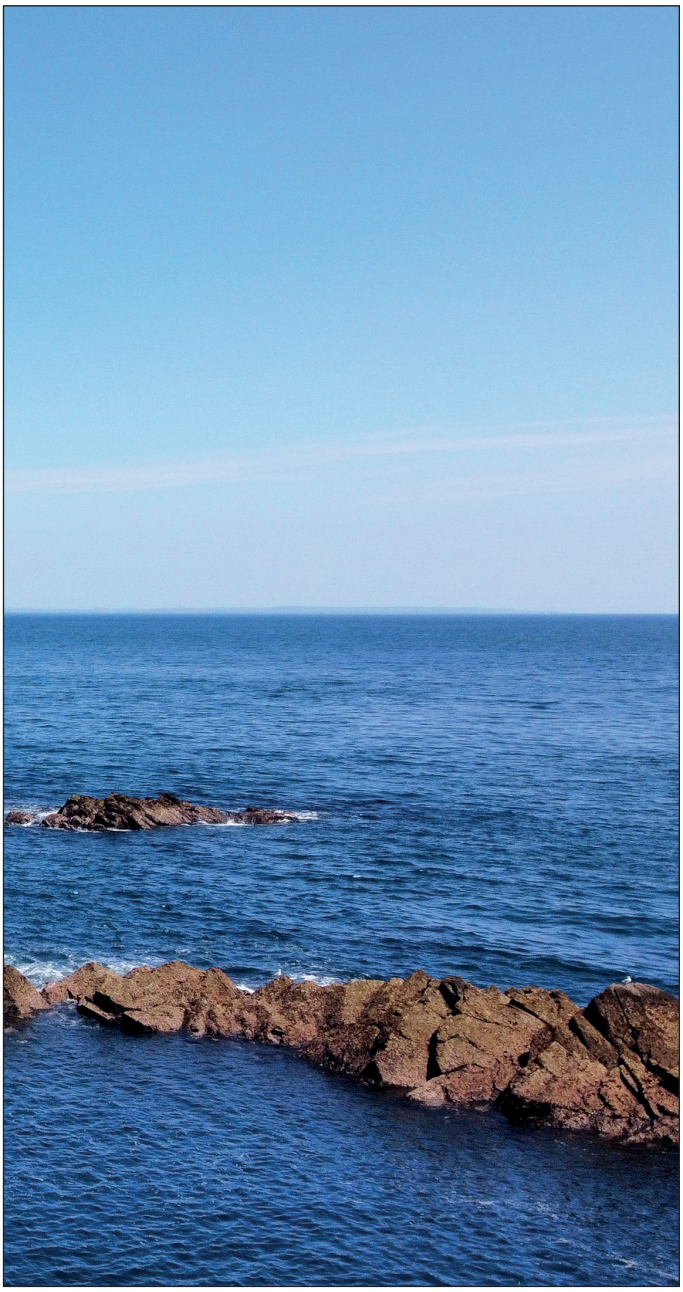
In the absence of a photograph of the Winstanley Eddystone in situ, this modern image is offered from 2023. The current lighthouse was finished to the designs of Sir James Douglass in 1882. The Smeaton tower of 1759 was removed in 1884, but the solid base proved to be so tightly bound that the stones were inseparable. Only the stump (left) remains.

The Eddystone Seed

Having now studied pharology for sixty years, I am convinced that the history of the 'modern' lighthouse begins on the jagged, red, granite rocks of the Eddystone Reef. As I noted previously, this is not the place to revisit that detailed story, or to explain the reasons why. That will be left to the opening part of Volume 3. I was born in Plymouth and have lived in the shadow of the wonderful Smeaton Tower for most of my life. It could be argued that I am therefore inevitably biased. I would counter that it has given me a head start in my studies and that accusations of bias are short-sighted. The entire story of the love affair between the two of us is available elsewhere.[6]

With this confession now duly offered, my conscience is clear to continue to discuss the contributions made at the Eddystone that constitute the transition between the two periods of my study - from Medieval to Modern - and why I consider it to be so important.

I feel it is disadvantageous to apply the adjective 'modern' to the structures that were to follow in the 18th century, especially as the 21st century has seen a marked reduction in the practical value of lighthouses due to satellite technology. Many of the marvellous structures once considered as modern are now discontinued, and some even destroyed entirely. In that sense, the 'modern' period is now over and, now that we are firmly in the digital age, it makes more sense to speak of the period from



1700 to 2000 as the Industrial Age. It will come as a surprise to many readers that it was in lighthouses that a number of the great steps forward in technology took place, but that story will also be reserved for volume 3.

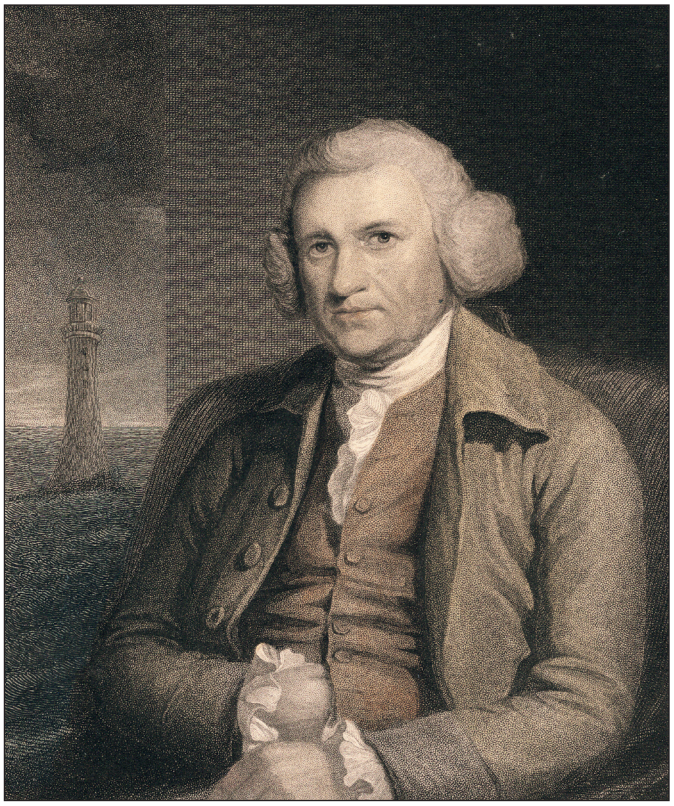
The Eddystone reef first comes into view in 1698, a year that partly determined the end point of this book. The monumental efforts made under the stewardship of a remarkable man called Henry Winstanley - and that would ultimately cost him his life - probably formed an event of tiny significance at the time for anyone living beyond the boundaries of Plymouth.

Contrary to popular wisdom that he had lost ships on the Eddystone rocks and was therefore motivated to stop it happening again, it is now considered that Winstanley was not a ship owner but that he accepted the challenge of building what would be the first lighthouse ever built on a wave-swept rock at sea because of his eccentric nature and his love of invention to solve practical problems.[7] His life on the outer fringes of the Royal Circle meant that he could meet men of influence and that it was his meeting with a Plymouth man passionate about the dangers of the Eddystone that persuaded Winstanley to accept this great challenge. The eccentricity for which he was then (and still is) well known is immediately apparent in his first structure, successfully completed at the end of 1698 with the help of sixty candles. His excessive use of ornamentation, as well as the inclusion of elements we might consider today as wildly unnecessary, was met with admiration for there was no established pattern or formula for the building of such a structure in these times. We could easily argue that Winstanley began with a blank sheet of paper upon which he was free to exercise his fulsome imagination.

And when, during the first season of exposure to the wild winter storms of the English Channel, he realized that his design was less resilient than he would like, he undertook a complete rebuild that not only significantly increased the size, mass and strength of the structure, but included even more strange devices, contraptions and embellishments than before. The result was a success, until that final night in 1703 when his proud creation was exposed to "... the greatest storm there ever was." Tragically, the lighthouse was a total loss and coincidentally he was present to observe the terrifying forces of nature firsthand; Winstanley and his light keepers were victims of the seas they had dared to resist.

Here we find the essence of the romance of lighthouses and their keepers, stories that confound us with their drama, but in this chapter my object is simply to point out that **this was a world first.** As far as we know, this was the first serious attempt to build a lighthouse in the style in which we think of them today - a tall structure on a rock being pounded by the waves. And it was successful, as far as the technology of the time allowed.

During the short years of its existence, Winstanley's Eddystone left its mark, recognized for the remarkable achievement it was intended to be so that, once it was no more, the stakeholders knew the importance of replacing it.



Above: John Smeaton FRS (1724-92), widely regarded as the fore-runner of the profession of civil engineering.

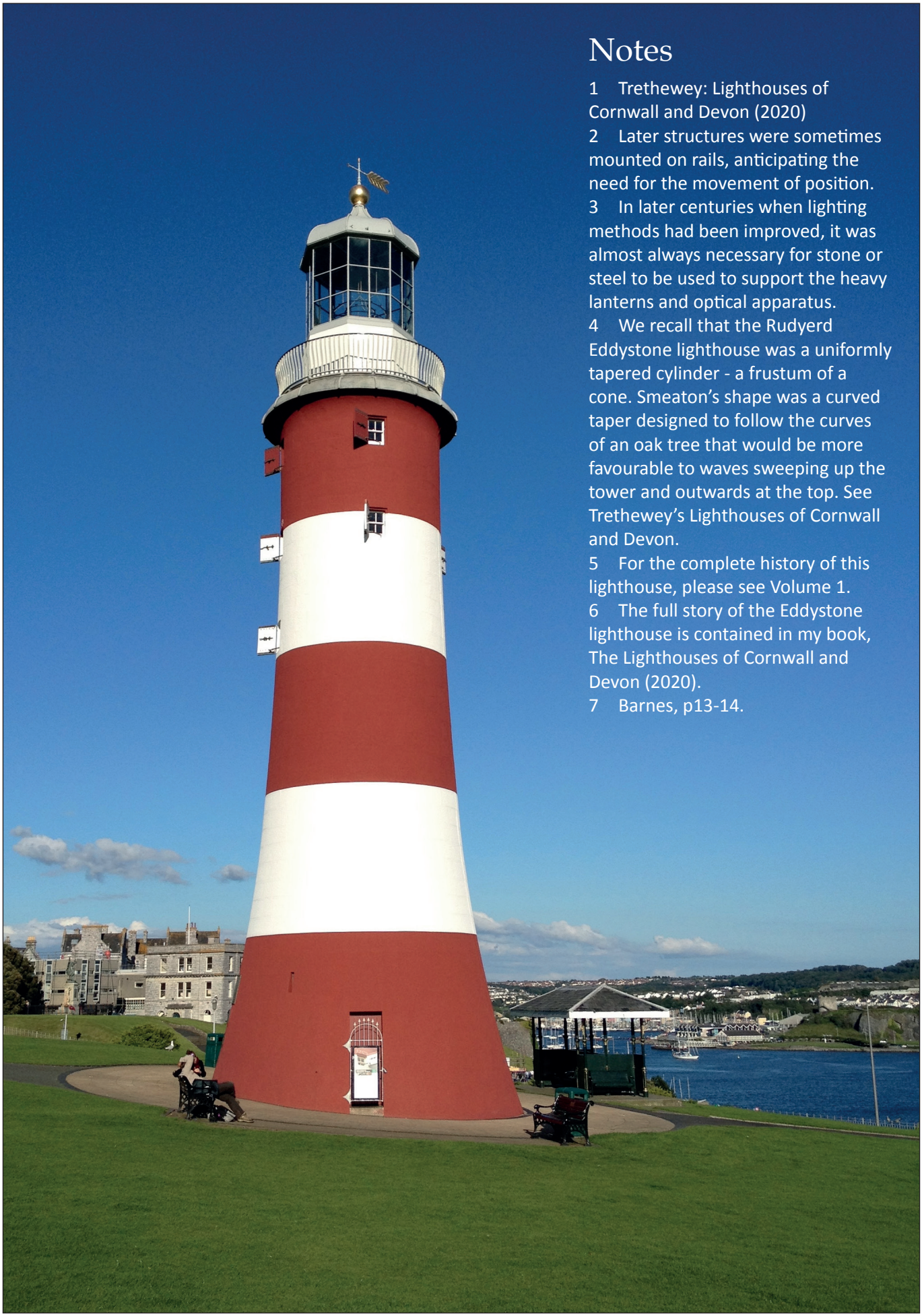
A Rapid Increase Of Momentum

Compared to the many centuries of inertia, things took a sudden turn for the better at the Eddystone once Henry Winstanley had proved the impossible. The innovative ideas bequeathed by the unfortunate fellow were quickly re-evaluated by a new engineer called John Rudyerd. His logic prevailed over his desire for artistic flair and he decided that, for a structure to resist the sea, it was surely better to adopt methods that had already been well proven at sea - those used in ship building. His new Eddystone lighthouse of 1708 was designed as if it were a ship standing on end. The logic was impeccable and his tower survived perfectly well until 1755 with just the same kind of regular maintenance given to frigates and sloops. Its Achilles Heel was the same as had befallen so many medieval structures before it, for wood is always susceptible to fire, and when a stray spark somehow escaped from the burning light mechanism its fate was sealed. By good fortune, the keepers were saved but the loss of the lighthouse was deeply felt, not just in the local communities, but far beyond.

It is most fortunate that there was no 18th century *Linked-In* because John Smeaton, a Yorkshire-man with a CV as an instrument-maker would never have got the job. So important was his achievement at the Eddystone that his record lives on worldwide as the *Father of Civil Engineering*. It is hard to imagine a time when doctors were alchemists and scientists were philosophers, but these were days without professions. There were no text-book methods for building lighthouses - only the shared experiences of what had gone before. So unsurprisingly, Smeaton's first actions on being given the job of rebuilding this now famous structure was to deeply consider where Rudyerd and Winstanley before him had gone wrong. The solution he devised is, in my opinion, the icon for a great proportion of the structures that succeeded it, greatly assisted by the fame and success achieved by Robert Stevenson and his engineering dynasty in Scotland that started with the Bell Rock lighthouse of 1815 and which drew much inspiration from Smeaton and his methods. So, notwithstanding the plethora of innovations across the full spectrum of engineering, it was the simple recognition by Smeaton that firmly bonded stones formed into an optimum curvature was the most successful way to resist the power of the ocean.

Readers of a more pedantic nature might criticize my inclusion of Smeaton's Tower as marking the transition between Medieval and Modern since it falls outside my 1700 endpoint. I hope you will allow me a measure of 'artistic licence' however for, whilst I have made it clear that Winstanley's structures were a resounding marker in pharology, his eccentric design features demand that we progress into the middle of the 18th century when we actually find the lighthouse blueprint created by John Smeaton. There we have it.

Right: The magnificent Smeaton Tower stands proudly on Plymouth Hoe, the site to which it was removed from the Eddystone, 14 miles distant, in 1884. So tightly bound were the stones of the original base that they were inseparable and left on the reef. Thus a new lowest section was formed to retain the beautiful shape so carefully created by Smeaton. It is the author's opinion that this structure is the template for a great proportion of the lighthouse designs that followed, and that it rightly takes its place as the signpost for the commencement of the Industrial Age of lighthouses.



Notes

1 Trethewey: Lighthouses of Cornwall and Devon (2020)

2 Later structures were sometimes mounted on rails, anticipating the need for the movement of position.

3 In later centuries when lighting methods had been improved, it was almost always necessary for stone or steel to be used to support the heavy lanterns and optical apparatus.

4 We recall that the Rudyerd Eddystone lighthouse was a uniformly tapered cylinder - a frustum of a cone. Smeaton's shape was a curved taper designed to follow the curves of an oak tree that would be more favourable to waves sweeping up the tower and outwards at the top. See Trethewey's Lighthouses of Cornwall and Devon.

5 For the complete history of this lighthouse, please see Volume 1.

6 The full story of the Eddystone lighthouse is contained in my book, The Lighthouses of Cornwall and Devon (2020).

7 Barnes, p13-14.