Underwater survey of Apollonia

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More recently, in 1958–9, a Cambridge expedition led by Mr. Nicholas Flemming studied and planned the Greek harbour at Apollonia, in North Africa.[10] We are indebted to him for the following preliminary note:

'The purpose of the 1958 expedition was to survey accurately the partially submerged city of Apollonia on the coast of Cyrenaica, and to discover the cause and date of its inundation. It is at present submerged to an average depth of 2·50 m. In the year before our visit, Captain D. Forrow, R.E., had made a rough survey. During our four-week stay, most of the city was planned, but, because of bad weather during the last few days, we were unable to extend the survey to the eastern limits of the site, and to plan in detail the *piscina loculata*.

'In ten days during September 1959, we surveyed the eastern part of the city, checked the position of the sea-walls, established the existence of two harbours, defined the true entrance to the harbours, discovered the foundations of a lighthouse, planned the *piscina loculata*, discovered a ruin-covered island to the west of Apollonia, made a rough survey of Phycus, and established the probable cause of subsidence.

'Behind Apollonia, the Gebel Akhdar is 1·5 kms. from the shore. From the foot of the hills a plain slopes gently to the sea, and continues with no break of slope to 3 kms. out and a depth of 76 m. From this point the slope increases rapidly.

'At the present waterline are two lines of Pleistocene sand dunes which have been calcified. The inner line of dunes forms the present shore, while the outer line forms a chain of islands and promontories some 360 m. from the shore. Between the two there are many basins, which made excellent natural harbours. At Apollonia the part of the city which is still on land is on the inner line of dunes; the two harbours and their surrounding buildings are in the basin, with a few buildings on the islands.

'Apart from some imported marble columns, all the building-stone for the city was quarried from the calcified dune ridges.

'The Gebel Akhdar as a whole is a very stable structure, and there is no evidence for major tectonic movements. Dr. Hey levelled a 6-m. beach from Derna to Benghazi, and has shown clearly that there has been no large movement over this stretch. However, Mr. P. Howard, a petroleum geologist of the Esso Oil Company, who has just completed an intensive survey of the area, informed us that there were several minor faults near Apollonia which could easily account for the subsidence. From this we conclude that there is no evidence for eustatic change of sea-level, and that the subsidence was probably due to local faulting.

'The submerged area of the city, lying between the islands and the shore and measuring about 0·4 kms. from north to south, and 1·2 kms. from east to west, varies in depth from zero to 5 m., though the eastern harbour is 8 m. deep in places.

'The surf breaks up, scatters, and buries all the foundations in the beach area, and sweeps bare the rocky areas, so that the land site is divided from the submerged areas by a band, varying in width from 10 m. to 50 m., in which nothing survives. A cross-section from the land through the beach to the sea would show all archaeological strata from early hellenistic to Byzantine on land, only a few blocks scattered at random on the beach, and the earliest foundations in the sea.

'On the assumption that two or more scraps of foundation, though individually unintelligible, may seem clearly related as soon as they are plotted, we surveyed all visible foundations in the area. Many of these scraps are still incomplete, but they are left on the map in case the shifting sands should uncover related material at a later date.

'For obvious reasons, most of the submerged city sites in the Mediterranean are very close to the shore, and thus it is usually possible to do a large part of the survey from a base-line on the mainland.

'At Apollonia we marked a base-line of 900 m. from the Main Gate at the west to the Theatre in the east, which was marked with a stake at every 50 m. From this we worked with a plane table and telescopic alidade, and fixed three points on the Western Island. Since these three were to be used as base-points for the seaward part of the site, we checked their location by fixing back from them to the original base-line on shore.

'While the base-line was being set up, parties of swimmers with plastic drawing-boards were making sketches of the foundations of the city, working from west to east. For the first stage of the survey, an area was chosen which was fairly well known, and on the rough sketch each key-point was numbered. The leader of a team of four swimmers was given one copy of this diagram, and the man at the alidade took the other. The leader of the team was then responsible for positioning the swimmers in order over points 1, 2, 3, and 4, where they held ranging poles on which a sight was taken. On a signal from the man at the alidade, the team leader moved the swimmers to the next points and positioned them in the same order on positions 5–8. Since it was possible to recognize the swimmers through the alidade, the surveyor could always be sure which point the swimmer represented.

'In this way it was possible to fix thirty-five points in two hours. Since the whole survey was conducted from the same base-line, there was no cumulative error.

'The details of buildings were filled in by direct measurement with a metre rule, or with a wire mounted on a reel strapped to the diver's chest. Here follows a detailed account of the salient features of the site (Fig. 68).

'The wall to the West Reef (G1 to D3) was both sea- and city-wall. Eighty metres northwards along its total existing length of 140 m. is a small rectangular fort similar to those south-east of the Acropolis. The wall itself peters out in sand and rough water about 75 m. from the reef.

'The West Reef (B4) itself comprises a series of small islands and submerged rocks left by regular quarrying. Many of these residual masses have carefully cut parallel sides, the outer faces of which form a natural sea-wall.

'In the gap between West Reef and the Western Island (B5 to A8) there is a natural ridge running from the west reef to the Western Island, with a raised area of quarrying on its outer edge. This rock at A5 comes within ·5 m. of the surface, whereas most of the ridge is under more than 3 m. of water. There is a series of large blocks (*c.* 2 m. by 6 m. by 6 m.) and quantities of rubble overlying the ridge and at the foot of the slope towards the inner harbour.

'On the Western Island (A9 to B9) there are ten parallel slipways of elaborate construction and in a fine state of preservation (Fig. 69). These were formed by quarrying, and are divided by walls of unquarried stone, now 2 m. high at the top and trailing off towards the bottom end. They are cut in steps to allow a superstructure of squared blocks. The tops of these walls may have been carried up, as at Sunion, to support wooden roofs. Polybius, in his description of the destruction of Carthage in 146 B.C., states that the slipways in the harbour there had storage chambers above them for the ships' gear, and that there was a column at the foot of each dividing wall, so that the frontage looked like a portico. There are in fact four columns (4 m. by 1 m.) lying on the slipways, but whether they were part of the structure or have fallen from the land or from a ship it is

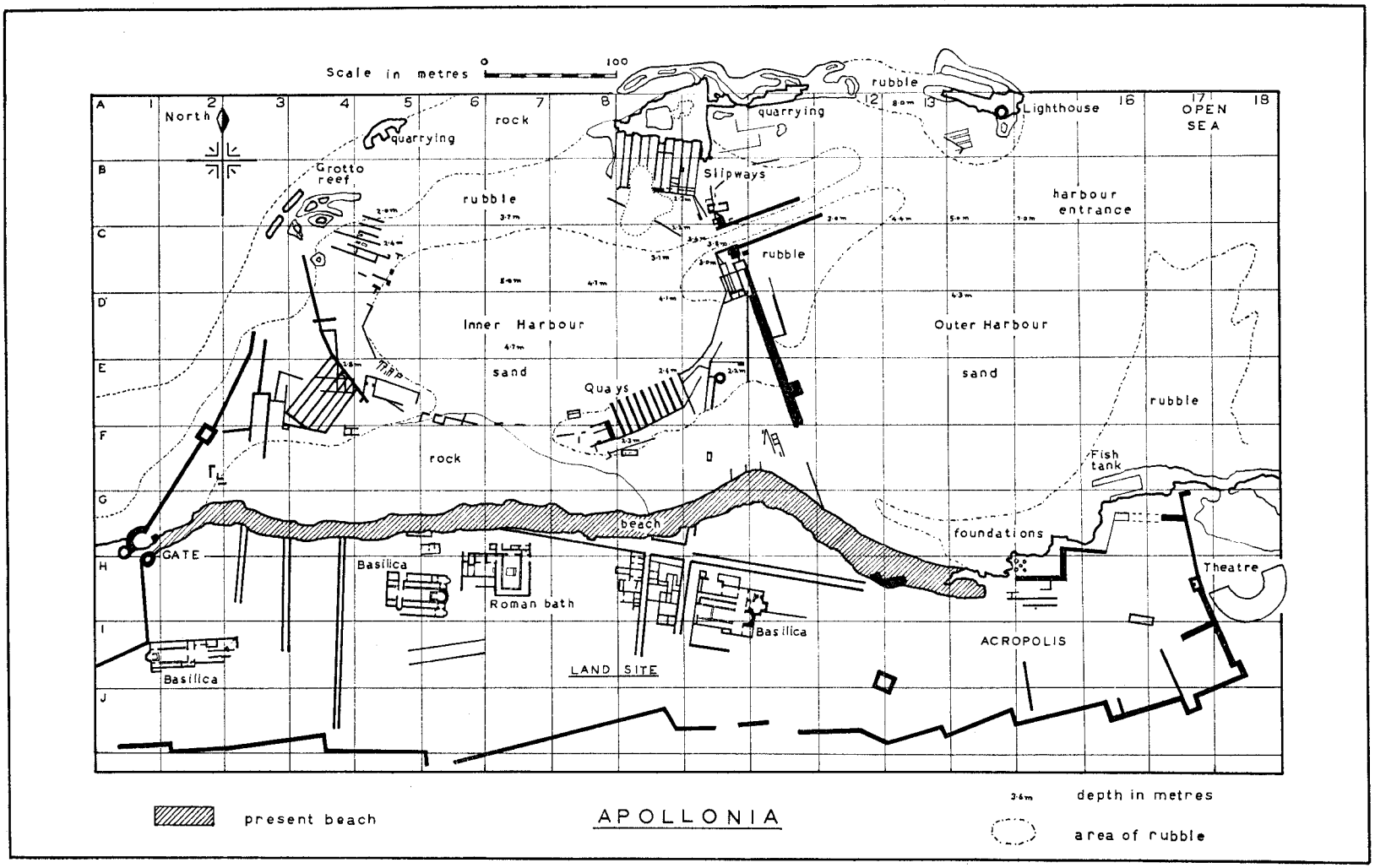

FIG. 68. Plan of Apollonia Harbour (N. C. Flemming)

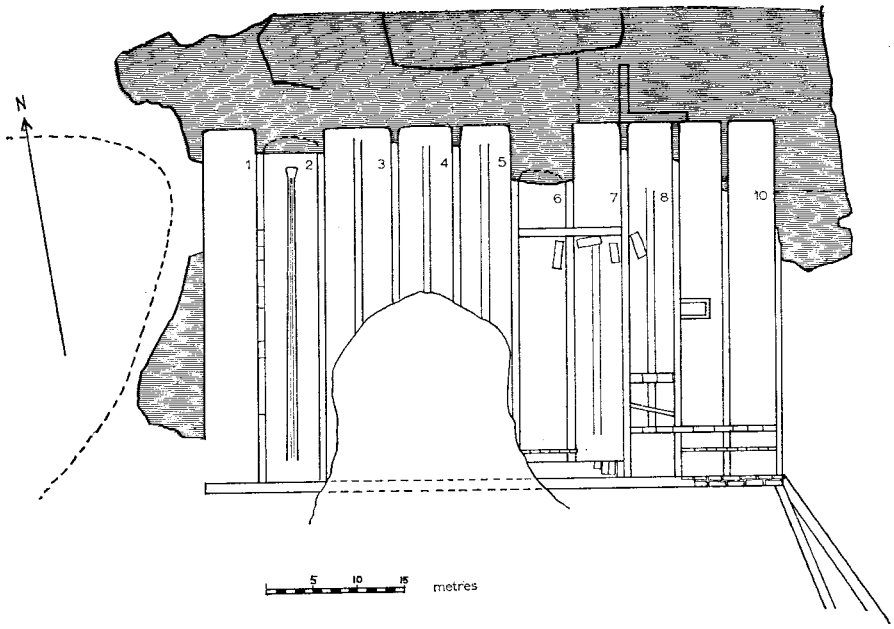

FIG. 69. Plan of Apollonia slipways (N. C. Flemming)

impossible to say. Three of the slipways are half covered by rubble, and there are later foundations over most of them.

'On the second slip from the west the central runner had a slot for the keel of a ship. While the slot grew shallower, but not wider, towards the bottom of the slip, the runner itself grows flatter and broader. This would facilitate the aligning of the keel in the initial stages of hauling a ship up the slip. There are five cross-sections of this on Fig. 70.

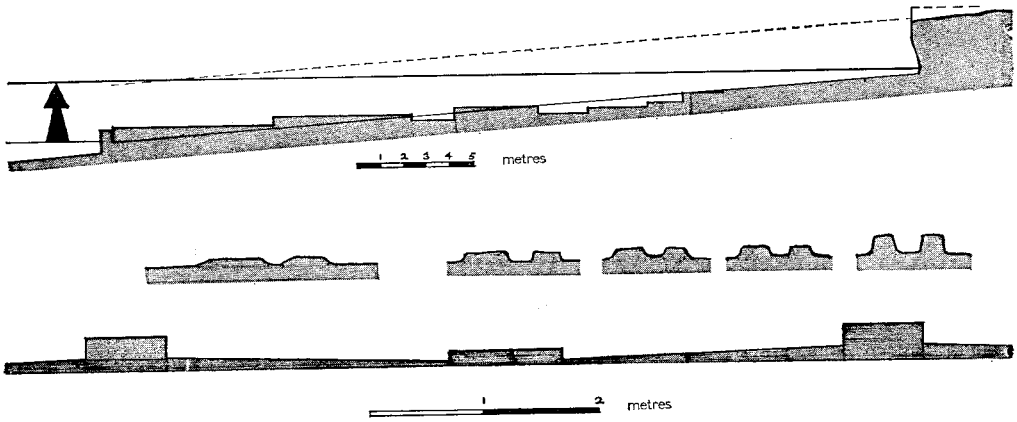

FIG. 70. Sections across slipways (N. C. Flemming)

'From west to east, the third, fourth, fifth, seventh, and eighth slipways have flat central runners with no slots. The first, sixth, ninth, and tenth have neither slot nor runner.

'The West Island slipways at Apollonia may be compared with those at Sunion.[11] Although the slipways at Sunion are considerably later than those on the West Island at Apollonia, their construction is worth comparing, since both were built for light vessels. The slips at Sunion were more highly developed, but the differences were dictated more by the direction in which they faced, and the consequent lack of shelter, than by their later date.

'The prevailing wind is approximately north-north-west in each case, and, while the ships at Sunion face north-east by east on to the open sea, those at Apollonia face south-south-east and into a sheltered harbour. This accounts for the great difference in gradient, those at Sunion being at 15° 50′, compared with 4° at Apollonia. The steepest slope at Sunion would prevent waves carrying up the slip in an onshore wind.

'That a general rule can be made of this is confirmed by the gradient of 6° at Piraeus, which is also a sheltered harbour facing south-south-east.

'While the gentle slope at Apollonia would have enabled ships to be man-handled, this would not have been so at Sunion. (The bronze ratchet-wheel found there in 1900 by Stais, then thought to have been part of some cargo-lifting derrick, may have been part of a winch for hauling up ships.)

'The Eastern Island (A14) is quarried on all its faces, and at the south-east corner an overhanging buttress of rock has been left, which supports the edge of a circular foundation 15 m. in diameter. Some blocks, cut on the round, are still in position in recesses specially shaped for them. This is probably the site of a fortified tower or lighthouse.

'There are three simple slipways in the shallow water near the Eastern Island which are merely platforms of sloping rock. A later wall 20 m. long crosses the foot of two of these slips diagonally.

'From the inner harbour a channel (C10 to B11) leads out between two block buildings, and it is defined for 65 m. by well-preserved walls 14 m. apart. The channel is now partly silted up, and we could not establish the original depth; but the present depth graduates from 4 m. by the inner harbour to 6 m. at the outer end.

'On either side of the channel are block buildings (C10), their construction being so massive that they remain sound to within inches of the surface. These, and the sea-wall leading to them, proved on comparison of block sizes to be a continuation of the late hellenistic structures on land. There are parallels for such a channel with block buildings at Fréjus and Piraeus, and it has been suggested that in both cases they were built to take a defensive boom. The block buildings at Piraeus also link up with the city defences.

'The central sea-wall (H13 to F11 to C10) is of particularly solid construction, and when the current moves the sand in the right direction it can be traced right on to the beach. In E11 there is a platform or wharf of large blocks linked by dovetailed dowels of lead.

'This wall, which separates the two harbours, may have been constructed to act as fortification and defence against the sea before the building of the Eastern Mole. In any case, its enormous width would serve as wharf space when the Eastern Mole was built to enclose the outer harbour, and the walls in D11 and the debris of blocks and pottery testify to the fact that there was plenty of activity on the eastern side of the wall.

'The rectangular building in E11 is 7 m. by 12 m., excluding the thickness of the sea-wall. The dovetailed dowels are of lead and are 30 cm. by 8·5 cm. wide. The most common form of dowel is I-shaped, and is not earlier than the fifth century B.C., whereas the dovetailed shape occurs in the sixth century B.C., and also very much later. Most Greek examples are iron-centred, the lead filling being sometimes melted in and sometimes cold-packed. Crude forms were used in Egypt, archaic wooden dowels being followed by pure lead.

'It was impossible to say for certain whether those at Apollonia had had iron centres. The centres were in fact missing, though the gaps were large enough to have taken iron, and the lead came away in chunks, as though it had been cold-packed.

'The Eastern Mole (F17 to C17) is represented by a broad strip of rubble and blocks stretching out almost 200 m. into the sea from the foot of the Acropolis Hill, on a bottom which is otherwise white sand. At the end nearest the Eastern Island there is an accumulation of large blocks measuring about 1 m. by 2 m. by 4 m. and amongst the general mass of local sandstone there are many blocks of white marble. The rubble lies in 8 m. of water, and from it the sea-bed slopes up in a basin shape towards the Eastern Island, the Central Wall, and the mainland. The gap between the rubble and the Eastern Island is also 8 m. deep.

'In the bed-rock at the foot of the Acropolis Hill there is a fish-tank (F16), which is now completely submerged.

'The ends of these buildings (E9) are open to the inner harbour, and, as they are of exceptional breadth and solidity, they may have been used as quays for small merchant vessels. The top courses of the westernmost quays are complete, which suggests that this is the original top, and at a depth of 2 m.

'The "Shipsheds" (C5) are also hewn from the solid rock, and although at first we thought that they were slipways, they have no central runner or slot, and the rock-cut floor is horizontal. The tops of the dividing walls, however, slope down towards the harbour at about 4°. The fourth bay from the north has a series of notches, 15 cm. cube, at distances of 1 m. apart along the top of the inside edges of its sloping walls. There are also two boat-shaped hollows, each about

10 m. long, cut in the floor of the third and fourth bays, for which no explanation can be found.

'The remaining foundations (E4) comprise six parallel walls, with traces of two more on the south-east side. They are closed at the ends by contemporary walls. These walls, and the absence of gradient, show that, although they have been associated with the water's edge in the early hellenistic period, they were not slipways. (Mr. Goodchild suggests that they could have been the foundations of a warehouse. There would have been difficulty in finding timbers to roof a wide gap; close, parallel walls would have been the most economical way to cover a large area.)

'Above the "warehouse" grid lie the well-preserved foundations of a house (or office) of Roman or later date (E4). There is an apsidal end to the centre room, three courses of stone remaining at this end, while elsewhere only one course remains.

'On the seaward side of both the Western and Eastern Islands the quarrying was so conducted that a deep basin was left, separated from the sea by a wall of solid rock several metres thick. The top of this wall is now within centimetres of the surface, and would have projected about 2 m. from the water in classical times. Newbiggin reports that there is a similar construction on the exposed western side of the Phoenician island colony of Arvad. He suggests that the lagoon was excavated as a wave-trap, so that in rough weather the waves would break over the wall and plunge into the lagoon, and would not inundate the island. In spite of the change of level, the lagoon still serves this purpose admirably. The depth of the lagoon is now 3 m.

'Karl Lehmann-Hartleben[3] has made a general survey of classical harbour plans and methods of construction throughout the Mediterranean, but inevitably, since he could not see underwater, his plans are very rough. Nevertheless, the basic properties of a harbour system, one basin or several, man-made or natural, are usually clear on simple investigation, and his work demonstrates the way in which the Phoenicians, Greeks, and Romans adapted a wide variety of sites to their needs.

'There are three common patterns. The first is a partly enclosed bay with sea-walls, built to protect it from the open sea. Misenum is an example of this. The second is a headland or offshore island which provides several rather exposed harbours, each of which has to be protected by the joining of islands, reefs, and the mainland with a series of sea-walls. Apollonia conforms to this pattern. The third is represented by artificially excavated harbours, as at Carthage.

'At Apollonia the site is very exposed to the dominant north-west winds, and before shelter could be obtained for any number of ships artificial walls must have been built. From the literature, it is known that the Greeks built sea-walls in up to 8–10 m. of water, and at Syracuse we have seen the remains of a sea-wall in

10 m. of water. Thus, taking into consideration the large quantity of rubble between the West Reef and the Western Island, it is certain that a mole was built across this gap. Since the principal slipways are on the Western Island, and since it is unlikely that the material for the repair and construction of ships was ferried thither in small boats, it is probable that the sea-wall was very broad and was topped by a roadway.

'In 1958 we did not discover the rubble at the extreme east of the site, and, ignorant of the possibility of a second harbour, we supposed that the entrance to the inner harbour was between the two islands. In spite of the depth at this point, 8 m., it is now suggested that this gap was also closed by a sea-wall. The great quantity of rubble between the islands, the presence of quarries and low-lying foundations on the islands facing towards the supposed channel where they would have been exposed to the open sea, and the difficulty of entering harbour by a narrow channel with a right-angle bend in it, all suggest this.

'The rubble at the extreme east of the site testifies to the existence of the East Mole, a fact borne out by the buildings and wharves which face into the second basin so formed, and which would otherwise be facing the open sea.

'The construction of moles falls into two types: first, the solid mole formed by tipping rubble into the sea, and second that of *Opus pilarum*, formed of blocks of stone or concrete joined by arches.

'The *Opus pilarum* seems to have been developed in order to allow currents of water through the harbour, and thus prevent silting. At Apollonia there is relatively little sand, and the solid type of mole was used in all parts of the site.

'In 1820 a chart was made of the area, which shows the shoreline at Apollonia some 150 m. north of its present position. The retreat of 150 m. in 140 years is consistent with the destruction which occurred in the winter of 1958–9, but if this rate of damage has been constant since the time when the city was last occupied in the sixth century A.D., it is surprising that there is anything left at all. This may be explained by supposing that the sea-walls lasted for some time after the initial submergence of the city, and that it was only after they had been breached that the lesser buildings were exposed to the full force of the winter storms.

'The fish-tanks at Apollonia are examples of an interesting type. Most of the early fish-tanks, or *piscinae*, seem to have been constructed on lake-sides (especially in north Italy) and river-sides (especially the Nile), and must therefore have been for fresh-water fish.

'In the fifth century B.C. the Agrigentinians had built a piscina 7 stadaes (1,295 m.) long and 20 coudées (9 m. 24 cm.) deep. They led the waters of nearby rivers through it, and trapped and assembled vast numbers of fish.

By the second century B.C. the Romans had done the same in the lakes of Ombria and Toscana, Risti, Bracciano, Bolsena, and Vico. But by the time of Cicero they seem to have lost interest in fresh-water fish, and only constructed

piscinae salsae, or salt-water tanks. From *c.* 90 B.C. onwards, private *piscinarii*, as Cicero called those of the gourmets, became a veritable passion. Vedius Pollio, a friend of Augustus whose *piscinarii* may be seen in the water off Marechiano, near Naples, threw condemned slaves to his moray eels, while Antonia, the wife of Drusus, had rings put in the gills of a favourate moray. By the end of the first century A.D. most *piscinarii* were communally owned.

'Varro compares a *piscina loculata* to a paint-box, with each kind of fish confined to its own compartment. Columella, however, makes two distinctions: Firstly, there is the use of a natural cove, with the rocks trimmed to a convenient shape and the entrance blocked with a grill. For this type, 2 m. is the minimum depth. Secondly, there is the artificially cut basin, lined with *opus signum*; but in this case the walls must be 3 m. high, with 1 m. of them above the surface of the water, and the bottom must be covered with rocks and weed.

'In both systems it is essential to keep a constant flow of clean water through the tank to prevent stagnation. Therefore canals (*rivi*) are placed not only at the open end, but also along the sides, and are controlled by sluice-gates of stone or bronze pierced with holes (*cancelli*). Aurigemma[12] found two examples of *piscinae loculatae* at Formiae in 1935 which were constructed on a rhomboid pattern, as opposed to the rectangular pattern at Apollonia. Leatham found a stone sluice-gate in Crete in 1956.[8]

'The discoveries at Apollonia provide some evidence of a change of water-level. The Romans did not use slipways, so we assume those on the Western Island to have been Greek.

'The slipways must have projected into a sufficient depth of water at their lower end to have taken the keels of the largest vessels, and, although we cannot say exactly what these would have drawn, the table below sets out the reasonable limits:

Depth at foot, m.	*Dry length of slipway, m.*
1·5	18
1·0	25
0·8	28
0·5	32

'While a depth of 1·5 m. would take vessels too long for the length of the slipway remaining out of the water, 50 cm. would only take such small vessels that the slipway need not have been made so long. This is based on the assumption that, since the slips are 6 m. wide, the ships must have been about 4 m. wide, but no assumptions have been made about the construction of the ships, other than nautical common sense.

'Since the present depth at the foot of the slips is 2·8 m. it follows that the sea-

level in the Greek period must have been relatively 2 m. lower than the present—that is, the land has sunk 2 m. since then.

'From the plan of the fish-tank, it appears that the shelf which is marked as being 2·5 m. below the water must originally have been meant as a terrace to walk on, since there are steps leading down from it. The fact that the bottom of the tank appears to be at only 3 m. is because of the debris lying in it. Thus it would seem that the southern part of the site has sunk slightly more than the northern.

'When comparing the depths of other foundations with a proposed change of from 2 m. to 2·5 m., it should be borne in mind that in the Mediterranean, where there are no tides, it is common practice to build quays, roads, etc., only a few centimetres above the water-level, provided that the water is sheltered from the open sea.

'It is tempting to correlate the subsidence of Apollonia with the earthquake which devastated Cyrene in A.D. 365, but for this there is no real evidence, and the subsidence may well have been very gradual.

'We found that the quarries of the Western Island at Apollonia, the tanks on the New Island, and many of the chambers at Phycus often contained what appeared to be concrete. At Apollonia it was over 2 m. thick and had potsherds and building blocks embedded in it. It almost filled the largest tank on the New Island, and there were in it many building stones set at all angles. At Phycus several of the tanks were half full, and the passage into which the rock-cut steps led was filled to within 1 m. of the roof.

'In all cases the material was as hard as the local sandstone, and it had the appearance of having been tipped into the cavities like concrete from a lorry, but we soon realized that this was a natural formation created by the action of the sun on a mixture of sand and sea water; it was a variety of "beach rock", an opinion confirmed by Mr. Howard, the Esso geologist. Beach rock is fairly common, though the process of its actual formation is not understood, and it is interesting to note that a thickness of over 2 m. can be laid down in less than 1,500 years.'