Honor Frost

Ancient harbours and anchorages in the eastern Mediterranean

I.7

PROTO-HARBOURS

A harbour is designed primarily to ensure that a given area and depth of water will remain calm in all weathers. Proto-harbours (i.e., pre-Roman harbours) maintained calm water by methods that are a mystery to us. They antedated dredgers. Technical innovations (e.g., hydraulic concrete) which later allowed men to impose the familiar pattern of breakwaters and docks on any strategically convenient part of a coast, regardless of its natural shelter, were still unknown. On the Levant coast the most interesting sites are pre-Roman. It might come as a surprise to a layman, to whom the names of Tyre and Sidon, for instance, are household words, to hear that the nature of their ancient harbourworks is still barely understood.

An alternative to the known forms of harbour design is hard to imagine, and the disjointed remains of one would be harder still to interpret. Add to this the obvious difficulties of excavating under water, and it can be seen why, in academic circles, the very existence of proto-harbours is questioned. From coastal sites, archaeologists have unearthed overwhelming evidence of the importance of Bronze Age sea trade, but their excavations never proceeded to the logical conclusion of excavating the remains of a harbour under the sea.

The situation has changed. Archaeologists can now use divers, or dive themselves. Even so, there has been little enthusiasm for co-ordinated harbour excavations. There are several reasons for this. First, archaeologists have not taken to the water, and their confidence in sportsmen-divers is limited. Second, divers have not the same enthusiasm for harbour work that they have for excavating ancient wrecks; they point out that marine installations would probably be under several metres of silt, so that heavy machinery would be needed to uncover them. Third, and perhaps most important, archaeologists are put off by the difficulty of dating those rare harbour installations which have survived above water-level. Architectural datings are not feasible, and the marine context precludes stratigraphy. Finally, even the identification of these installations is difficult, because a harbour is a complex of mechanically interdependent parts, and to understand one of them it is necessary to have knowledge of the whole; consequently, an over-all plan is needed, to make detailed study profitable. This reverses the standard procedure of excavation on land, but, as will be seen, the problem is not insoluble.

So little evidence of proto-harbours has been collected that many people still believe that, during the Bronze Age, harbours were superfluous. They claim that all primitive ships could be beached, and if not drawn up in front of towns, they traded from offshore anchorages. Both hypotheses can be dismissed as a result of recent archaeological findings. Ugaritic texts describe ships that would have been too big to beach.

These texts are confirmed by discoveries (both at Ugarit itself and in the sea) of Bronze Age stone-anchors weighing half a ton. Such anchors would sink beachable boats; they imply craft at least 20 m long, weighing 200 tons (according to the standard ratio of anchor weights for wooden ships). The second hypothesis, that anchorages were a substitute for harbours, would be easier to accept if it were applied exclusively to the northern Mediterranean (where steep, rocky coasts in any case provide natural harbours). In the east, ancient offshore anchorages have been identified, but there is no evidence that they were substitutes for harbours; on the contrary, as will be seen, their use seems to have been purely navigational.

Against this background we can consider the existing evidence for proto-harbours, and the techniques needed for surveying and dating marine architecture.

FIRST HARBOUR PLANS

The engineer Gaston Jondet was the first to survey an ancient harbour, some thirty years before the invention of aqualung diving. The installations he recorded off the island of Pharos may have been the earliest traces of harbour construction at Alexandria. But were they extant when Homer described: 'an island in the surging sea, which they call Pharos, lying off Egypt. It has a harbour with good anchorage, and hence they put out to sea after drawing water'? Were the 5 km of partly rock-cut constructions Phoenician, Hellenistic, or even Roman? Knowledge of the harbour built by Alexander suggested to Jondet that the ruins he surveyed were earlier, but he could not prove this. Consequently, his admirable piece of recording lies dormant on the shelves of specialist libraries, waiting for some marine archaeologist to produce comparative material.

Karl Lehmann-Hartleben's comprehensive *Die Antiken Hafenanlagen des Mittelmeers* (1923) need not be discussed here, since it is based mainly on texts. It is, of course, a valuable work of reference.

Ernest Renan's direct observations on the Levant coast make rewarding reading, but he did not produce harbour plans.

The most important surveys, both for methods and results, were carried out by the Rev. André Poidebard, S.J., the real pioneer of underwater research. He too worked before the invention of the aqualung. He introduces into his major studies a wide background knowledge of comparative port sites along the Levant coast.

Between 1934 and 1936 Poidebard surveyed Tyre, with the help of French naval and military personnel and local sponge divers (see Fig. 52).

In 1946, when a scheme had been mooted to improve the modern harbour at Sidon, he was called upon to record the ancient remains which would come to light as the work proceeded. Though the aqualung had just been invented, he had no aqualung divers at his disposal, but could use dredgers and other equipment usually beyond the means of an archaeological budget.

Poidebard was already a pioneer of aerial photography. He applied this knowledge to harbour problems, and also adapted a camera to make the first underwater archaeological photographs. From his intimate knowledge of the coast, he was able to deduce the probable local alternative to the later, known forms of harbour construction. This is perhaps his most important contribution to the subject. He also realized that, whereas any trench on a land site will produce some information, trenching in the sea, even when feasible, will be disappointing as a first step. He devised methods for making comprehensive plans of submerged constructions. Proto-harbours, however, can spread over several kilometres (the reasons for this will be discussed later). The remains have to be found before they can be surveyed; Poidebard discovered the criteria for identification.

However, his findings were doubted by archaeologists who themselves had no way of checking. My own observations as a diver contradict some of his findings, but these discrepancies detract neither from his pre-eminent status as a pioneer, nor from the principles he enunciated.

THE DESIGN OF PROTO-HARBOURS

Poidebard suggested that, on the exposed, flat Levant coast, the earliest harbour works would not have been built, but cut out of (a) rocky outcrops (b) the offshore reefs that run parallel with the land or (c) islands. A rock mass would be flattened on its sheltered landward side to make a quay, leaving a wall of rock on the weather side. Whenever the height of this protective wall was insufficient, it would be augmented by courses of stone—usually the stone produced in the process of levelling the quays would suffice. Tanks, sluices, warehouses, mooring bitts and other installations would also, whenever possible, be rock-cut.

This pattern of rock-cutting is still visible all along the coastline. In parts easily accessible from the land, the pattern is often obliterated by later quarrying, but on offshore reefs and islands (as at Arwad or the small island off Sidon) portions of sea walls, or their rock-cut foundations, remain intact, and indeed still to some extent fulfil their original function.

The installations being rock-cut, their size depends on the size of reefs which may be as long as 5 km. Only after man had learned how to build walls under water did it become possible to construct compact harbours. This accounts for the enormous size of the remains which Jondet surveyed at Pharos and which Poidebard surveyed at Tyre.

A SYSTEM OF HARBOURS AND ANCHORAGES

Poidebard's theory is applicable, in a general way, to all proto-harbours, major or minor, along the Levant coast. He does not, however, explain the basis of a system of harbours sufficient to ensure the known volume of pre-Roman trade. Major harbours, appropriately spaced, would have been essential, in the same way, for example, that Marseilles and Genoa are essential to the trade of the Ligurian coast. Given that installations had to be rock-cut, only islands large enough to be habitable could be adapted as major harbours (Fig. 51). In fact, three such islands do exist between Turkey and Africa: Arwad (or Arados), Tyre and Pharos. Tyre and Pharos are now peninsulas, having been artificially joined to the mainland in antiquity but not Arwad—some 3 km out to sea—the only site where the ancient harbour works have survived intact.

On these three major harbours depended the trade of the minor ones such as Byblos. Without Tyre, for instance, it would be difficult to imagine a regular trade, between Byblos and Egypt, in such a bulky cargo as cedar wood. Ships large enough to carry, or tow, cedar logs must have lain at anchor off Byblos, since the small harbour could never have accommodated them. Loading by lighter was common along this coast within living memory.

Even modern engine-driven ships must have some major harbours. Ports without harbour facilities, like Byblos are, in one sense, mere anchorages. In ancient times, however, there appear to have been other forms of anchorages, now obsolete. First, as their rock-cuttings suggest, some reefs were used as a kind of outer, auxiliary harbour where ships could anchor and discharge their cargoes, later transferred by small craft to the nearest town. This was clearly so in the case of the small, uninhabited reef-island off Sidon; probably also at Machroud, at the southernmost extremity of the Arwad reef, some 3 km from the main island (see: *Arwad*, p. 101). The reef ends opposite one of Arwad's colonial towns on the mainland, and probably served during the Bronze Age as the anchorage-harbour for this colonial port, built on the sandy shore opposite it. Poidebard suggests that the southern 'Egyptian Harbour' at Tyre was similarly situated on a reef some distance south of the town's harbours. Because of wave erosion and other factors, this reef is now submerged and, as will be seen, evidence about structures on it is doubtful.

The second form of obsolete anchorage is found in most parts of the Mediterranean and along the Levant coast. It appears to have been used by ships which were forced to stop in their course. Anchors lost in ancient times locate these sites on offshore shallows and even near dangerous rocks, places which modern shipping would avoid. Ancient ships probably could not sail against the wind so that, when the wind changed, they were forced to drop anchor and wait until it again veered to a favourable direction.

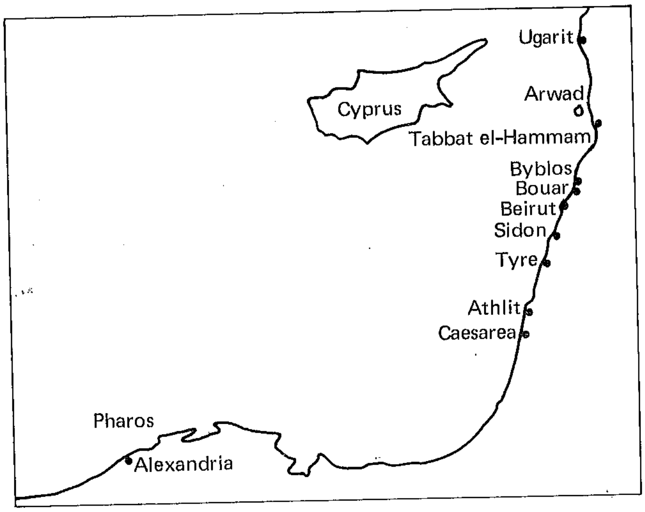

Fig. 51
The Levant coast showing sites mentioned in the text.

A comprehensive survey of anchors lost at such places and around landfalls used by sailing ships, might provide answers to many questions: whether early ships hugged the coast, sailed by night, and so on. Unfortunately, sports-divers are still inclined to snatch things from their context and then—sometimes but not invariably—present their finds, bereft of significance, to a local museum. There is a danger that the anchors that marked these sites will all have disappeared before surveys can be organized. It should also be noted that the standard academic questions about navigation are tendentious. Sailors know that, whether they want to or not, they are very often forced to sail at night. This must always have been so. As for hugging the coast, one has only to observe a modern sailing community (such as the inhabitants of Arwad, who have small caïques and sizeable schooners) to see that their mode of navigation changes according to circumstances. It is too often assumed in academic circles that there was only one type of ship during the Bronze Age, and that its habits were invariable. In interpreting the evidence of marine sites, it should be remembered that cargo ships capable of carrying timber, fast ships of war with oars, fishing boats, and probably a host of other craft existed contemporaneously, all used in slightly different ways.

SURVEYING IN THREE ELEMENTS

Poidebard's survey of Tyre (Fig. 52) was 'carried out from the air, from land and from under water'; on similar sites, all surveys still have to be made in the three elements. Few, however, can hope to draw on military personnel, engineers and equipment as Poidebard did. How then can large areas of submerged remains be recorded? As with wreck excavation, there is no universal solution, because the sites themselves vary in size, in distance from the coast, and in depth below water.

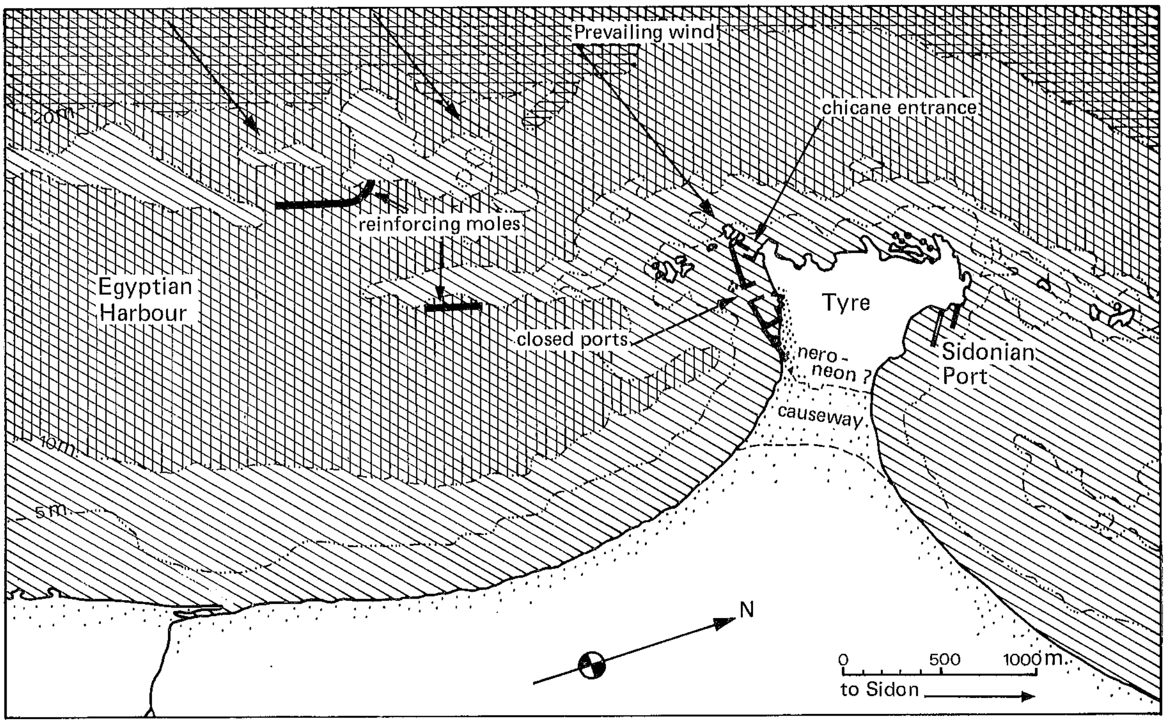

Fig. 52 Tyre's harbours, based on Poidebard's survey (courtesy of Routledge and Kegan Paul, London).

Air

In the early stages, aerial photographs provide essential reference material; later, they may facilitate surveying. Ideally, sites should be recorded photogrammetrically, divers being employed merely for the checking of constructional detail; in fact, the hire of specialized equipment and professional photogrammetricians demands resources on the scale of national budgets or international oil companies rather than of archaeological expeditions.

Existing aerial photographs of coastlines usually show the land rather than the sea; no attempt is made to avoid reflected light on the sea surface and the film used tends to show water as black. They are also taken from too great a height to show individual stones, so their use is limited.

It is best for the archaeologist to take his own aerial photographs, because he alone can know what has to be recorded under the sea and where it is. Pictures obtained with an ordinary camera will not be truly vertical; they will have to be rectified graphically—a laborious process, though no more so than field surveying.

At sea-level

At sea-level, the best instrument for surveying buoyed underwater remains is the sextant, especially if used in conjunction with a prepared circle chart—a method which not only eliminates the need for keeping lists of readings, but allows the surveyor to notice and correct misreadings if and when they occur; the whole can be controlled by one person. If submerged

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remains are very close inshore, however, theodolites, or even alidades, will give more accurate results.

Under water

Below surface, the problem is to fill in details and elevations that do not appear on aerial photographs, or that relate to areas between buoyed points that have been fixed on paper during surface survey. A diver has to take direct measurements in length and depth.

For this purpose, the camera is less useful than it is for recording small objects such as piles of amphorae in ancient wrecks (cf. Sections II.7 and 8). Rock-cuttings and harbour masonry are large in size, but underwater photographs are successful only when taken at close range. Further, harbour remains are usually in shallow water where, even with optimum clarity, the photographer

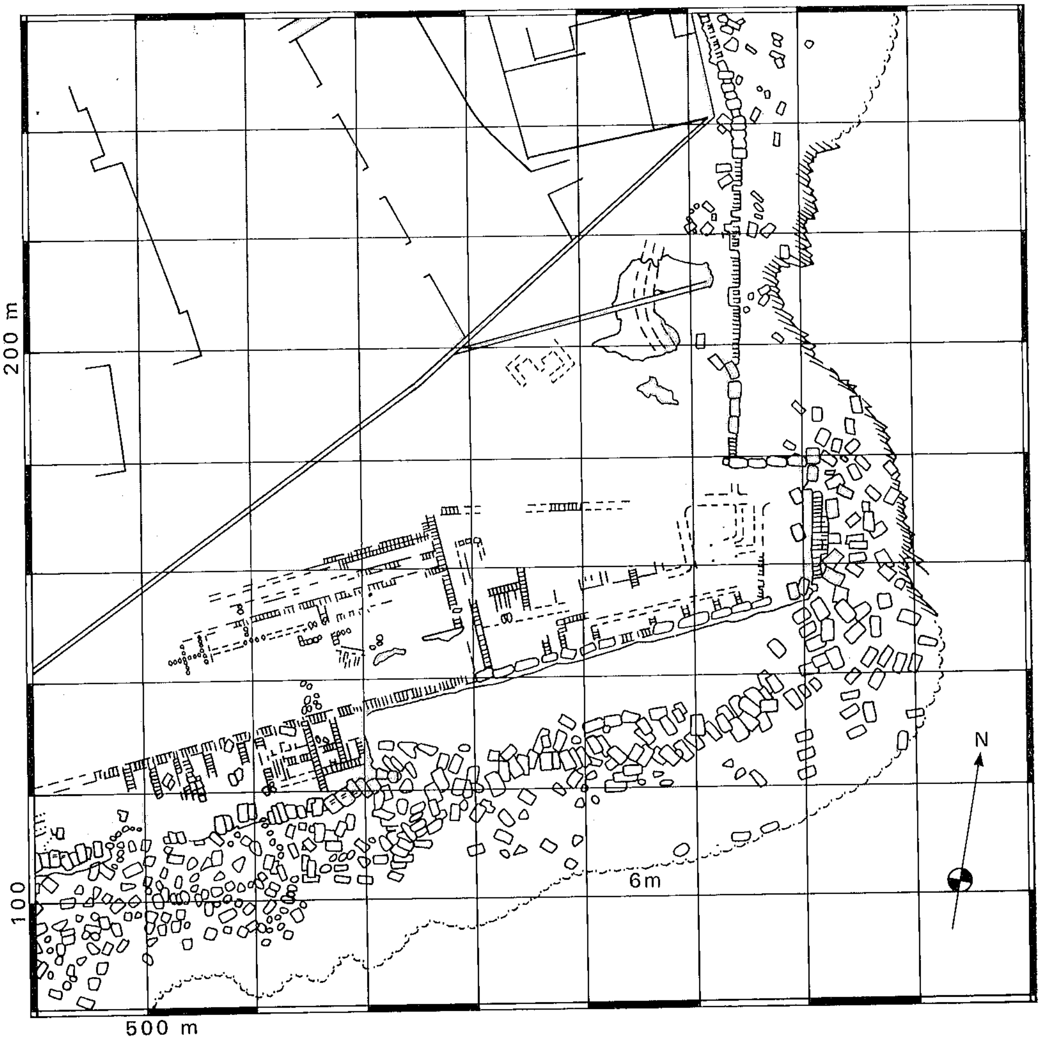


Fig. 53
Detail from the plan of the main island of Arwad showing its south-eastern tip. Dry land indicated by dot-tint. Note that the sea-wall to the south is partly submerged; fissuring (indicated by hatching) accounts for this form of collapse, which could not be attributed to 'enemy action'. Compare gridded aerial photograph, Plate 55.

may not be able to get far enough away from blocks 3 m long, under only 4 m of water. Nevertheless, the camera remains a handy shorthand method of recording.

FIVE SURVEYS

These general observations need illustration. The five resumés of surveys that follow show how local conditions affect technique.

ARWAD. 1963 and 1964. H. Frost, J. O. Lancaster, pilot, J. C. C. Williams, photogrammetrician. (See illustrations 53 to 59.)

Arwad, it will be remembered, is the best

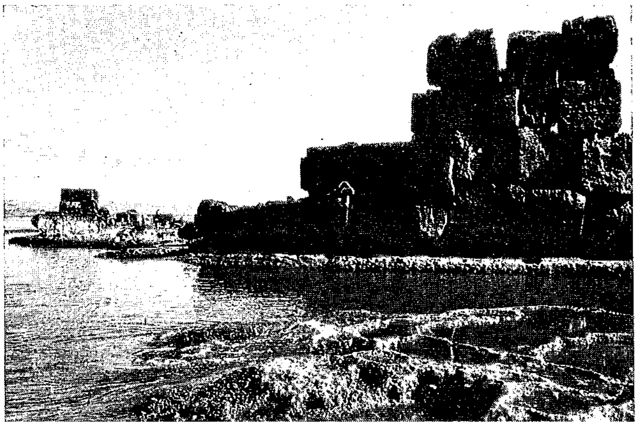
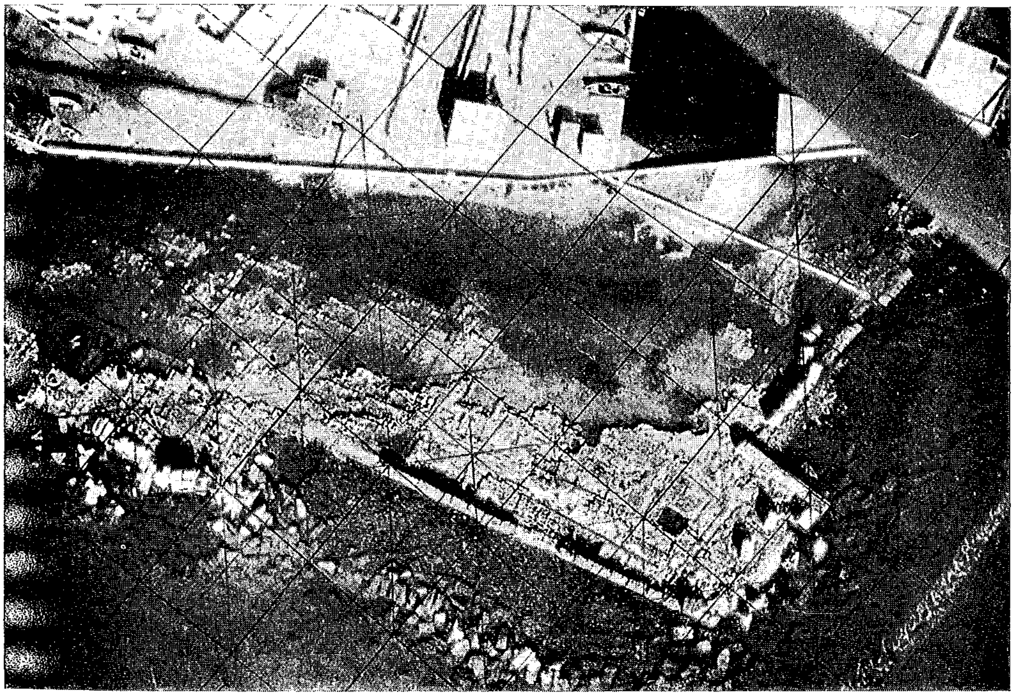


Plate 54
Part of Arwad's sea-wall photographed from the rock off the north-west of the main island. Four courses of blocks show above the sea-level (where they are cut by an erosion *trottoir* edged with *Vermetus*). This wall is founded on at least three courses of small risers, now below sea-level. (Photo: H. Frost.)

Plate 55
The south-eastern tip of Arwad's sea-walls. An aerial photograph taken from a height of 50 m, grid drawn in 20 m squares for plan-making (compare Fig. 53). (Photo: H. Frost.)



preserved of the three major proto-harbours; its name is recorded as early as the sixteenth century B.C. (cf. Frost 1964).

The main island forms an irregular cone or rock, with inhabited dwellings in the centre. A natural double harbour occupies its sheltered, landward side. Along the remainder of its periphery, an esplanade has been cut at sea level (Fig. 53). Beyond the esplanade, at the water's edge, the rock has been left standing as a defence against the sea. In some places, this sea-wall is extended or heightened by colossal blocks (Plate 54). In one section that is preserved, the rock-cut foundations, themselves 2 m high, bear five courses, giving a total height of 9 m. The blocks were quarried from the esplanade itself. Smaller foundation stones of buildings can be traced on the esplanade (Plate 55); they explain the sea-walls—none of the buildings in question could have withstood the storms of a single winter without protection.

A reef, of which the main island forms part, runs southward from it, parallel with the land, for some 3 km (Fig. 56). Now mostly submerged, it is marked on the surface by four islets, all bearing traces of rock cutting. Some cuttings on the southernmost islet of Machroud are now under water; its rock-cut walls, like those of Arwad, were heightened by colossal blocks (Fig. 57, Plate 58).

The ruins of some of Arwad's colonial towns on the mainland are situated opposite this reef. One, at a place now called Tabbat el-Hammam, is directly opposite the island of Machroud, which may have served as its earliest anchorage-harbour. Later, Machroud was submerged and, by the ninth century B.C., a harbour had been built at Tabbat el-Hammam (the implications are discussed below) (Fig. 59).

After the whole Arwad area had been prospected, over 300 photographs were taken by the writer from a Piper aeroplane. Two Calypsophot cameras were used, one containing monochrome and the other colour film (colour has certain advantages in photographing underwater subjects from the air).

These photographs were turned into plans by a method devised by the surveyor, J. C. C. Williams (see Section II.8). The aerial coverage was supplemented by an even greater number of photographs taken from the surface and from under water. The ground controls used were: a cadastral map of the modern houses, the marine chart of the reef and coast, and measurements obtained by the writer. When these proved insufficient, scale was deduced from any object of known size, such as a boat, or even the tracks of a lorry on the sand. J. C. C. Williams devised a standard grid system, transferable from one photograph to the next; from this, the writer, working from field notes, and supplementing the aerial photographs with detailed photographs of the same subjects taken on land, drew up the plans. Photography thus transferred a great deal of the surveying from the field to the drawing table. On this large area, conventional ground methods would have meant several seasons in the field with a team of surveyors.

In 1965, the Arwad survey, though incomplete (various archaeological questions and topographical verifications still outstanding) had to be discontinued. Even so, it has yielded certain conclusions and raised some interesting questions; these are discussed below in the section on dating.

SIDON. The island outer harbour at Sidon. 1965 and 1966. H. Frost and J. Chaumeny. Area surveyed: 800 m. (See Figs. 60, 61 and Plates 62*a*, *b*.)

In collaboration with the surveyor Jean Lauffray, Poidebard surveyed the island off Sidon without divers (Fig. 60). They found no submerged structures off this boomerang-shaped rock, 2 km from the town's main harbour. On the island, they found: a rock-cut quay facing land along the southern portion of the island (1), a wall of rock backing it (2), a rock-cut chamber behind this wall (3), which was connected to the quay by a passage; some quarries to the north of the island (4), a jetty (5) running from the southern tip of the island towards land, and constructed of large blocks topped by a late form of concrete, probably Roman. There are some curious details, including a series of rock-cut mooring bitts at the water's edge along the northern half of the island, and the emplacement for a winch on the islet 50 m south of the main island. They are so placed that they could not now be of much use to ships.

In 1965, history repeated itself. Improvements to Sidon's harbour involving the island were mooted. I was asked by the Lebanese Antiquities Service to make sure that no underwater remains risked destruction. To my surprise, I found the foundations of another jetty (Plate 62*a*) almost identical with the first, and parallel to it, some 160 m to the north; about 12,000 cubic metres of masonry along the landward rock-base joining the island to the islet (Plate 62*b*); and a series of piles of rubble running along the northern sector of the island in front of the mooring bitts (Fig. 61). This rubble very largely consisted of broken plaques of quartzite revetment. There were also some intact plaques among the masonry between the islands. Between the natural spur of rock that on land encloses the town's harbour and the islands, there was a mysterious line of sparsely scattered, small masonry.

These submerged remains were, on average, in about 5 m of water, and only 3-4 m from the island. They had therefore to be plotted by two surveyors with theodolites, stationed on the island. Currents made it impossible to hold a levelling staff at the vertical from a boat; a sausage-shaped, inflatable buoy 1.5 m long (invented by the well-known diver, Georges Barnier) was used instead. One metre of buoy protruded above water; to its other end a measuring tape was attached which was held by the diver on the bottom. The surveyors followed the pointed tip of the buoy through their lenses. They received their signals from a swimmer, stationed beside the buoy, whose other duties were to see that the buoy was at the vertical, and to transmit signals to the diver by pulling on the tape. The diver's duties were to choose and then identify underwater stations by notes and photographs, and to record their depths by reference to the tape.

In this way, 107 stations were recorded at an average rate of three minutes per fix.

Photographs were used, as well as direct measurements, to fill in details of masonry. A 30 m measuring tape, for instance, was pegged to the sand along the base of the tumbled masonry which was then photographed progressively. A compass, mounted for legibility on a white plastic board, was placed in each photo and always orientated

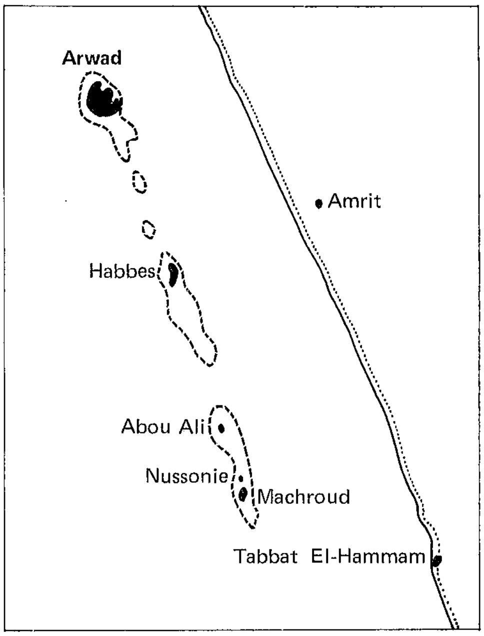


Fig. 56
Sketch map of the Arwad reef.

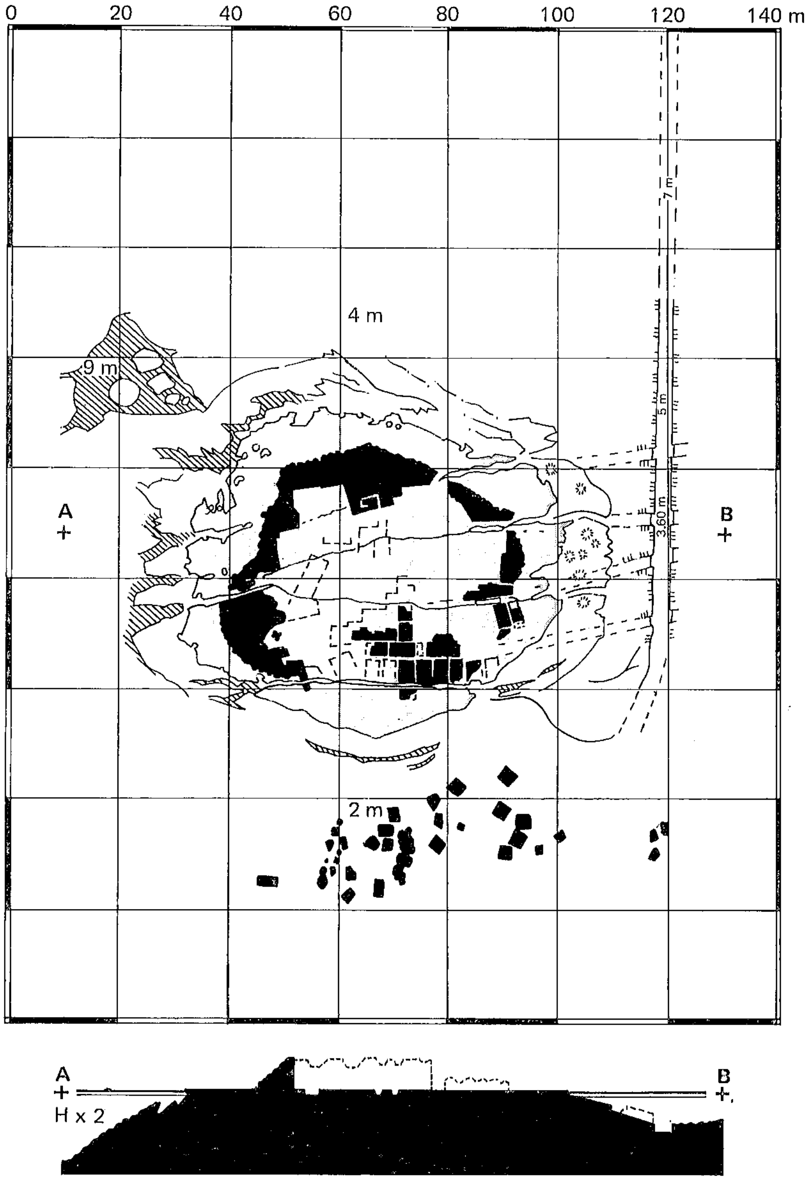


Fig. 57
The southernmost reef-island of Machroud (see Plate 58). Note how erosion *trottoirs*, both above and below sea-level, have cut through the architecture, which is now partly above and partly below sea-level. Fissures are indicated by hatching, dry land by dot-tint, and submerged *marmites* by dotted line.

Plate 58
The islet of Machroud at the southernmost extremity of the Arwad reef (see Figs. 56 and 57). (Photo: H. Frost.)

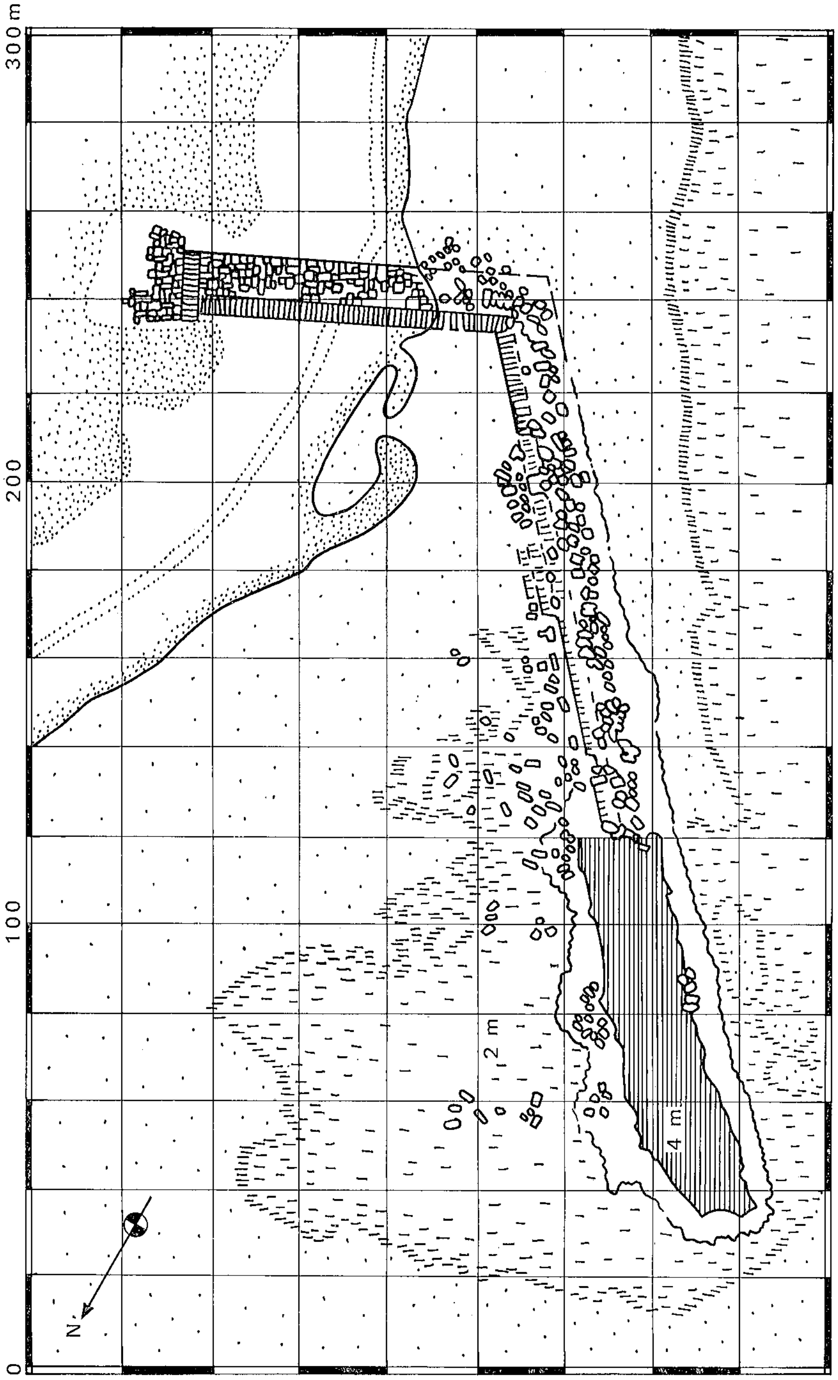


Fig. 59
Tabbat el-Hammam, a sketch plan made from aerial photographs, to which the landward end of the jetty (based on R. J. Brailwood's 1940 survey) has been added.

to the north. Thus, changes in direction of the line of rubble, as well as the distances between individual blocks, were immediately visible on each photograph.

Existing surface plans of the area were checked and corrected. The survey will be continued, so that further detail can be added and the survey of the area between the islands and the mainland completed. With this in mind, plans were drawn up with five different scales, the working scale for detail being 1 : 200.

It can already be deduced from this survey that the islet and island were once joined, that the installations between them were protected from the swell by an elbow-shaped breakwater to the south, that the rock-cut sea-walls on the island had probably been raised by courses of masonry as at Arwad (Plate 63*b*), that quays had extended between the two jetties and beyond, in front of the mooring bitts to the north. Finally, and most surprisingly, it was found that the installations had been faced with quartzite. The dating is discussed below.

Tyre. Minor surveys by the writer between 1956 and 1966. I am deeply grateful to its excavator, the Emir Maurice Chéhab, Director-General of Antiquities in Lebanon, for his permission to visit it and for the facilities he granted me.

The observations I made at Tyre over a period of ten years are here mentioned for two reasons. First, the site is of great archaeological and historical importance. Second, because the site has shown that technical requirements are involved in harbour research that do not occur on land. My observations contradict some of Poidebard's findings, but they are not put forward in any way as a criticism of his astonishing achievement.

He never claimed that his survey of Tyre was complete; and, indeed, listed various outstanding questions. He interpreted his survey as follows. Two 'closed' harbours adjoined the peninsula town—one to the north, and a smaller, less sheltered harbour to the south where a built mole supplemented rock-cutting. The original island of

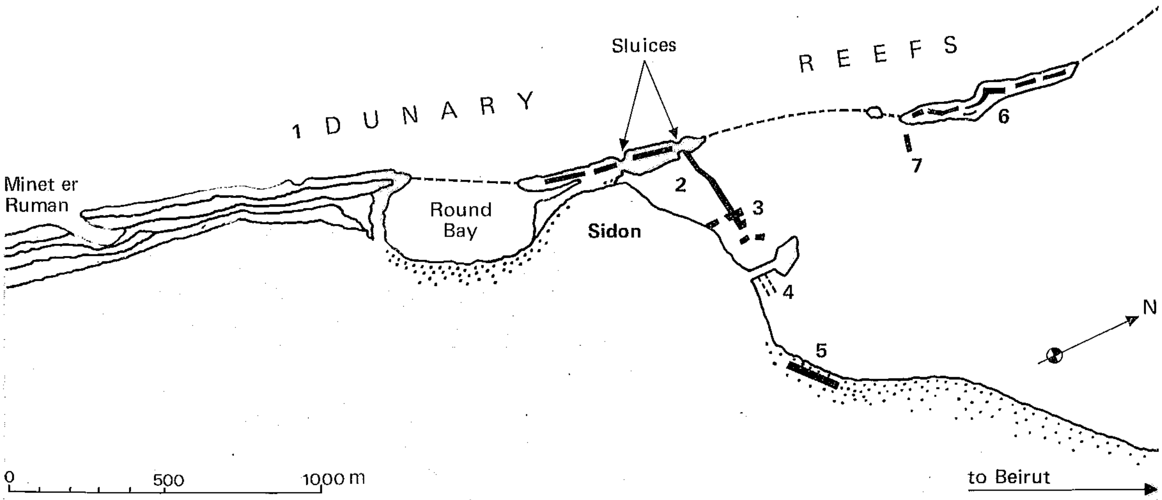
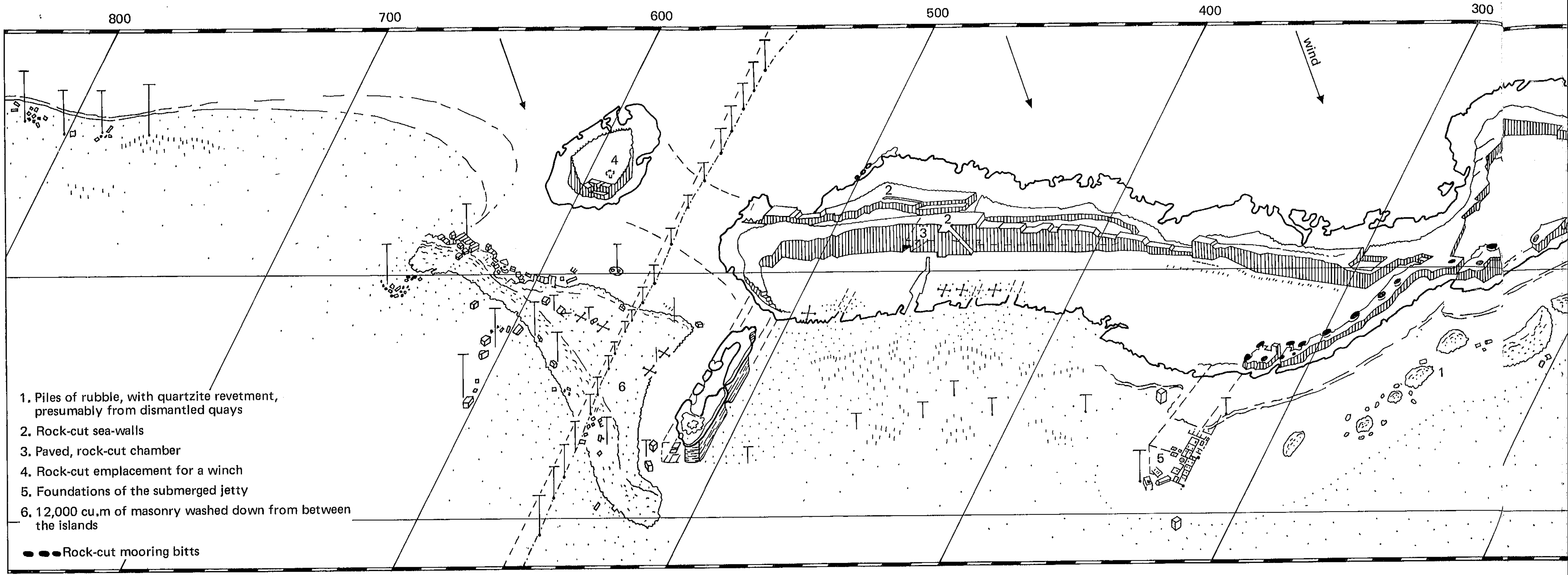
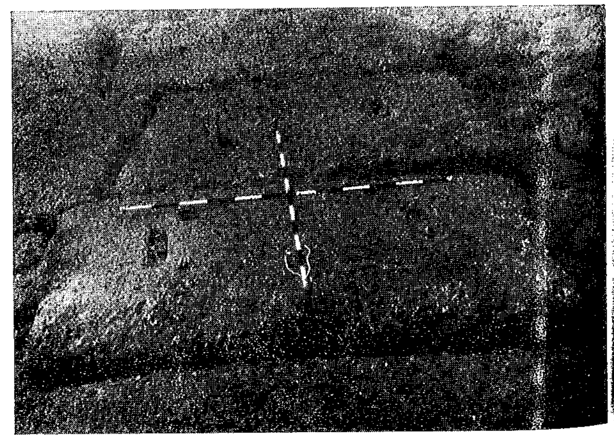


Fig. 60
The inner and island harbours at Sidon, based on Poidebard's survey.


800
700
600
500
400
300
wind
1
2
3
4
5
6
1. Piles of rubble, with quartzite revetment, presumably from dismantled quays
2. Rock-cut sea-walls
3. Paved, rock-cut chamber
4. Rock-cut emplacement for a winch
5. Foundations of the submerged jetty
6. 12,000 cu.m of masonry washed down from between the islands
Rock-cut mooring bitts



62a

62b

Tyre (before Alexander joined it to the mainland by a causeway) was the central portion of a reef that extended north and south from it. Poidebard did not survey the northern section, which is still marked on the surface by rocky islets. At the extremity of the southern section (now under water) he claimed to have found walls of colossal masonry resting on the natural rock. Traditionally, Phoenician ports had 'closed' harbours for their own ships, and outer harbours for foreign ships. Poidebard claimed that the outer 'Egyptian' and 'Sidonian' harbours of Tyre had been on the reef, and that the walls he had found represented the Egyptian harbour (Fig. 52). His claim was not accepted by archaeologists and geologists who knew the coast, though the photographs he published of submerged 'walls' (which he took from the surface) appeared very convincing.

The reef is rapidly disintegrating. The remaining islets on the northern sector are visibly disappearing under the effect of the pounding of the waves. Earth movements may have played their part, but disintegration could also have been accelerated if the surface rocks had once been weakened by rock-cuttings. Joining the island to the mainland would have been a contributory factor, the currents that formerly flowed harmlessly round the island now being unleashed on the reef. This blockage also caused silting, which is particularly heavy in the southern bay.

In 1966, I dived on to the submerged southern reef and found that the 'walls' there were natural formations. Poidebard

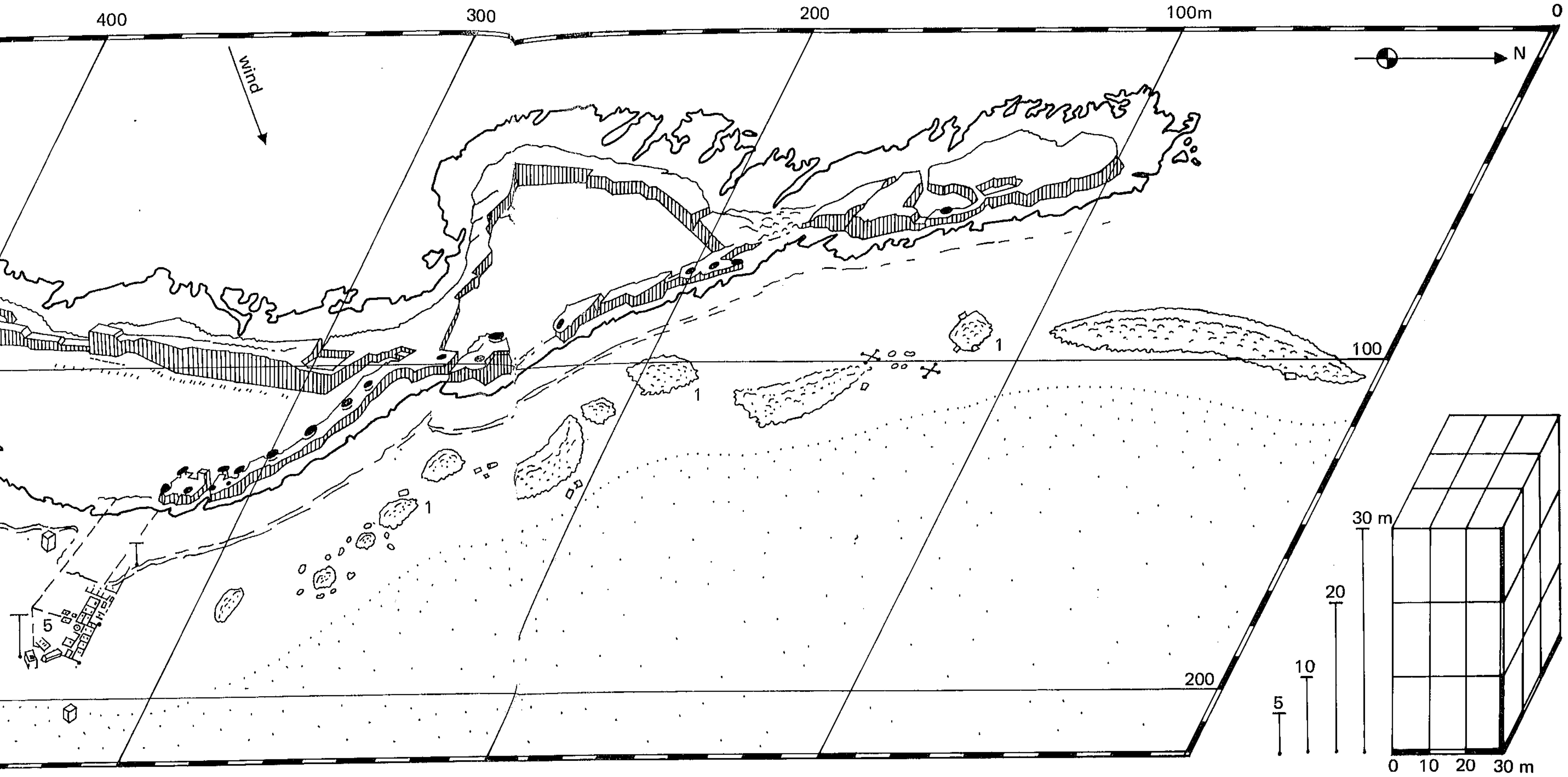
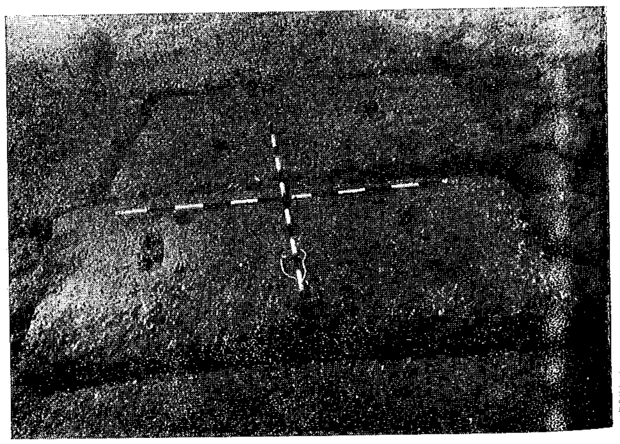


Fig. 61
The island harbour at Sidon (projection from the survey made by Frost and Chaumeny in 1966).


62*a*

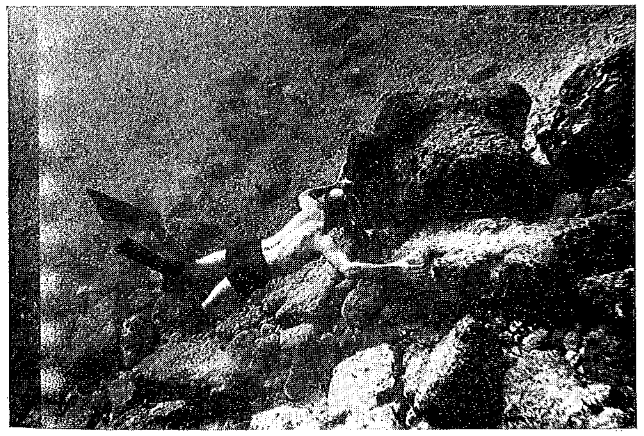

62*b*

Plate 62*a*
Detail of the foundation course of the submerged northern jetty of the island-harbour off Sidon (see Fig. 61). The graduated cross, in decimetres, can be used for photogrammetric plan-making, as described by J. C. C. Williams in Section II.8. (Photo: H. Frost.)

Plate 62*b*
A column base and other distinctive masonry from Sidon's offshore harbour (behind the island and the islet, see Fig. 61). (Photo: H. Frost.)

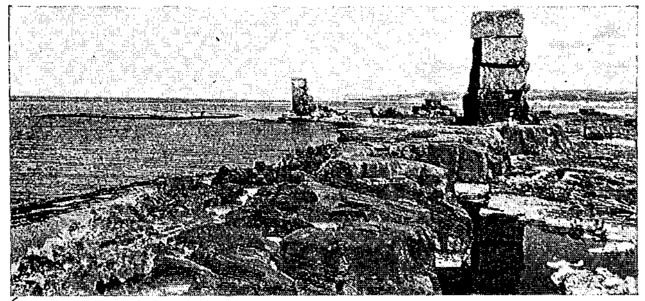

63*a*

Plate 63*a*
Rock-cut foundations of Arwad's sea-walls. In the middle distance they are surmounted by five courses of masonry. The four-course section of wall shown in elevation in Plate 54 can be seen in the background. (Photo: H. Frost.)

Plate 63*b*
The foundations of a similar protective sea-wall at Sidon Island, looking south (see Fig. 61). All the blocks that must have heightened this wall have been removed. (Photo: H. Frost.)


63*b*

himself had seen them from the surface only; otherwise, he had to rely on the reports of his divers. They had told him that, in elevation, the 'walls' had more than one course and that the joints between the blocks alternated, conclusively proving that they had been laid by human hands. During my dives, I could not find a second course on either 'wall'; both rested on bedrock, sparsely covered with sand (deep sand being found further down, at the base of the reef) (Plate 64*a*, *b*). The maximum height of the 'walls' was less than Poidebard had stated. Finally, as I followed these admittedly curious formations, the shapes of the stones became less and less regular, showing that the wall-like appearance that occurs in two places was fortuitous.

These observations do not invalidate Poidebard's view that the reef might once have served as an outer harbour or anchorage. They do mean that other techniques, such as trenching, or examining the sub-bottom with electronic devices would have to be used to find whether or not there were man-made remains in the vicinity. The same applies to the northern reef. Poidebard did not survey it, but he quotes the reports of local divers that whenever fishermen throw a charge of dynamite, it uncovers 'columns made of pink stone' and other masonry. I did not see any building materials on my visit to the reef, but I did find pottery near its top and lost anchors at its base, sufficient to justify further, equipped, search.

The validity of the small 'closed southern harbour' theory is also dubious. Its entrances are so exposed that it would not have been very useful to sailing ships (as distinct from boats with oars). In size, it is just large enough to accommodate small boats. In 1964, I noted an alignment of broken columns along its mole and, with the help of the excavation surveyor, incorporated them in Poidebard's survey, so that his harbour plan was co-ordinated with the plan of the recent land excavations.

The result, very briefly, was that a large Roman structure on land (some 6 m above the present sea level) fell within the line of walls whose submerged extensions Poidebard had described as docks. Either the Roman structure had been built on top of some, by then, silted docks, or it had been built on top of some earlier town that had subsequently become submerged. A bed of clay within the 'southern harbour' seems to confirm the latter hypothesis, because when a section is cut in the clay—this is not possible on a sandy part of the bottom—closely packed stratified pottery is revealed.

Plate 64*a*
The regular blocks, 3 m long, which Poidebard mistook for construction reinforcing the 'Egyptian Harbour' south of Tyre. (Photo: H. Frost.)

This density of sherds would be extremely improbable on a harbour bottom, but it is identical with the trench-sections on land.

Technically, the question as to whether or not the submerged structures were docks could be settled by taking a line of core-samples across the area. If, as Poidebard suggested, it was the harbour predating Alexander the Great, the cores ought to show first, the natural sea bed, then sediment and possibly artefacts corresponding to the bottom of an enclosed harbour, then a change in weight of the particles of sediment (the building of the causeway would have diminished the force of the currents so that heavier particles would have been dropped), and so on.

CAESAREA. 1960. The Link marine expedition to Israel.

Caesarea harbour was built by Herod the Great and dedicated in the year 10 B.C. It differs from the harbours hitherto discussed because, techniques of building having improved, it was imposed artificially on a relatively unsheltered part of the coast. Josephus describes its harbour-mouth with three colossi, pillars, and a wealth of other detail.

The Edward Link expedition ship, the *Sea Diver*, was equipped with electronic devices, pumps and dredges. Besides charting the breakwater encircling the harbour, the most important results were obtained from actual excavations. The original bottom of the harbour was of clay and stones. The remains of Roman masonry were now under several metres of silt. It was estimated that 5 m of sand had accumulated under the 5 m of water at the harbour mouth. All the findings indicated considerable local submergence since the harbour was built (possibly the result of the earthquake that took place in A.D. 130).

ATHLIT. 1965 to 1966. Elisha Linder and the Underwater Exploration Society.

The site of Athlit was occupied from the eighteenth century B.C. until 1291, when the Mamelukes took the Crusader castle there. The pottery excavated on land shows imports at all periods, but most numerous during the Phoenician and Persian periods.

The site consists of a rocky promontory, flanked by bays to the north and south. In the northern bay, two islets at the tip of the promontory have been incorporated into a harbour construction scheme, the protection they afford being extended, to the north, by a mole built of colossal riders. A similar construction reaches out from the shore, leaving a gap which constitutes a

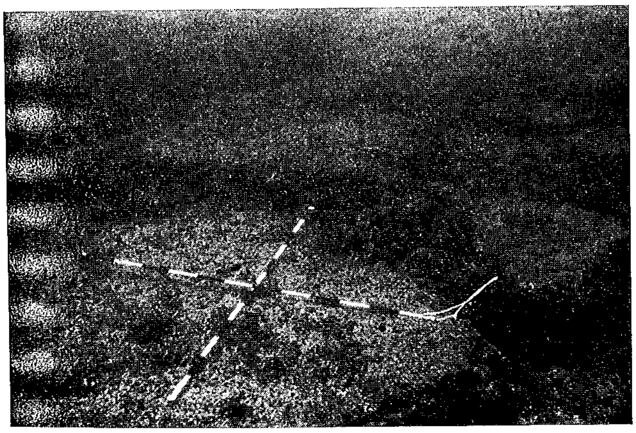


Plate 64*b*
Some thirty metres to the south of the blocks shown in Plate 64*a* the regularity disappears. The rock is seen to have been deposited in shallow layers (the cross is graduated in decimetres). At no point are there 'blocks with alternating joints'. (Photo: H. Frost.)

harbour mouth. In the only, short report available at the time of writing, there is no mention of rock-cutting on the islands.

Linder dates the moles as Phoenician or Persian. He notes that there has been no great variation in sea-level at Athlit comparable with those caused by submergence at Caesarea (only 30 km to the south).

TOWARDS A METHOD OF DATING

The surprising variations in submergence between harbours only a few kilometres apart have a bearing on dating. Examples of these variations: at Caesarea, built at the beginning of our era, about 5 m submergence; at Athlit, 30 km to the south, none; at Tyre (to judge from the trenches on land and from the reefs), considerable submergence; at the island off Sidon, 40 km north of Tyre, experts find little sign of oscillation; at Arwad, several courses of masonry are now under water; at Machroud, at the southern extremity of the same reef, rock-cuttings are submerged to at least 6 m. Similar variations are observable at other unsurveyed sites, all along the coast.

The case of Machroud, at the southern tip of the Arwad reef, is important because archaeological and geological findings for once coincide. The jetty at Tabbat el-Hammam, on the mainland opposite, is partly on land; Robert J. Braidwood was therefore able to date it to the ninth century B.C. on the basis of his excavation in the adjoining *tell*. He sounded two related *tells* further inland, and found unbroken occupation levels from Chalcolithic to Byzantine, but on the coastal *tell* the Bronze Age levels were missing. On the island of Machroud opposite, the geologist René Wetzel considers that the sea retreated after the deposition of the reef to below its present level, but that by the end of the Iron Age it returned to a height 3-4 m above its present level. We can deduce that the constructions on Machroud must have been Bronze Age and that they were useless at the beginning of the Iron Age. The Iron Age seems to have been the period when man learned to build walls under water. so the submerged anchorage-harbour at Machroud was replaced by the ninth-century jetty at Tabbat el-Hammam.

Unfortunately, dating by geology is not as simple as this would seem to indicate. There is considerable argument as to whether changes in sea-level are localized and tectonic (the relationship of strata that are thought to have been separated from each other by geological phenomena), or general and eustatic (the oscillation of seas, by which certain geologists explain the displacement of beaches). To a lay observer of coastal sites, it would appear that both must have a bearing.

Geological time scales are wide. It should be possible to build up evidence for the shorter, and more recent changes in sea-level in collaboration with geographers, sedimentologists, marine biologists, botanists, and other experts. From biological evidence, for instance, Fevret and Sanlaville have obtained carbon-14 datings from dead molluscs. These *Vermetidae* lived at sea-level along the edges of erosion *trottoirs*. So far only *trottoirs* raised above sea-level have been dated (see Section II.4, by P. Sanlaville), but in time it may be possible to find and date submerged *trottoirs*, and also to tell the age of *trottoirs* at the present sea-level.

Erosion *trottoirs* cut across ancient architecture on nearly all marine sites. Archaeologically, they can be used to deduce not only the date but the function of certain remains. For example: the rock-cut fish tank at Bouar, in Lebanon, used to be referred to as a 'sanctuary', or a 'lustral chamber', until it was noted that a raised *trottoir* ran along its outer, seaward side about 80 cm above the present sea-level. At this earlier sea-level, water would have circulated within the chamber through a system of holes on its seaward side. From this observation, it became clear that not only was the chamber a fish tank, but that it was a known form of fish tank. It so happened that Fevret's and Sanlaville's carbon-14 datings were carried out on *Vermetus* taken from this raised *trottoir* in the Bouar region. Their datings show that the fish tank could not have been built after late Roman times.

The vagueness of this dating may shock stratigraphers, but the divergence of opinion on proto-harbours is so wide that any method of dating should be investigated and welcomed. The Arwad installations, for instance, have been described as Phoenician, presumably on the basis of Renan's definition that, when architecture was found on the Phoenician coast and nowhere else, it was Phoenician. They could be very much earlier if we accept Poidebard's definition of rock-cut proto-harbours. A contrary view, recently expressed, was that Arwad's walls were built by the Crusaders and destroyed by the Mamelukes. My own survey disproves this by showing how the defences collapsed into the sea as the result of earthquake rather than enemy attack; it also shows Persian and Hellenistic repairs on older structures. Arwad may well be Bronze Age, like Machroud on the same reef.

Dateable masonry is rare, but it sometimes occurs as, for instance, at Sidon. When it does, it throws light on hitherto undated marine structures in the same context, and a comparative scale can be devised. For example, the cut and mortising of much of the submerged masonry at Sidon island is identical with masonry found in the current excavation of the nearby temple of Eshmoun on the mainland. The plaques of quartzite revetment along the length of the island find a parallel at only one site on land: the fortress at Byblos from the Persian period which coincides, historically, with Sidon's greatest prosperity, when the Sidonian fleet served Xerxes in the Greek wars. Further research at Sidon may confirm this.

Datings can be deduced from the way indications of sea-levels cut across architecture. Consequently, the aim of marine archaeologists should be to recognize all possible indications of ancient sea-levels. These are not always easy to see at close quarters; their pattern is far more clearly shown on aerial photographs. On the Arwad photographs, for instance, round holes can be seen on submerged ledges of rock surrounding the island and islets. They echo the *marmites* or solution basins that form at sea level on the present *trottoirs*, and probably represent a submerged version of the same phenomenon.

On coastal harbours, marine botany may contribute another means of dating comparable to *Vermetus*. On the bottoms of some known sites of ancient harbours such as Motya or Ognina in Sicily, le Brusc in France, or (to some extent) Tyre, there is a growth of *Poseidonia*. This plant roots and re-roots itself in layers until it almost reaches the surface of the sea. Its growth rate, or a carbon-14 dating of dead rhizomes from its lowest layers might well give some

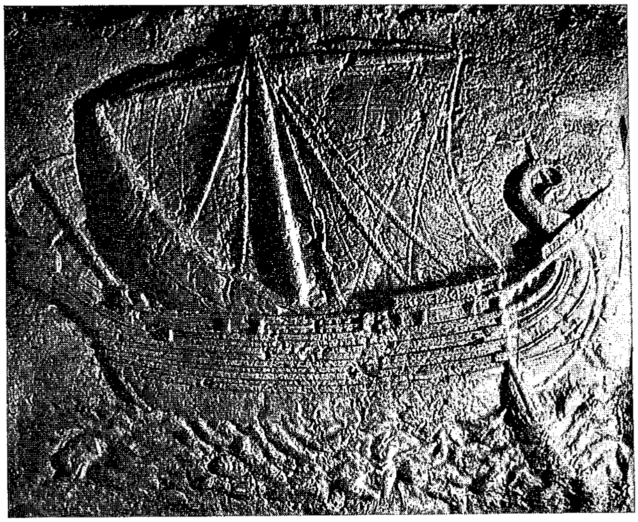


Plate 65
Ship of Roman type; bas-relief from a sarcophagus in Beirut Archaeological Museum. (Photo: Roger Viollet.)

indication as to when the harbour fell into disuse. As already suggested in connexion with Tyre, the analysis of sediments from core samples would also help with dating. These and many other possible methods of dating can be developed only by collaboration between archaeologists and scientists from other disciplines. At present it is in the archaeologist's interest to take the initiative in formulating the questions.

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