A DOUBLE-SHEAVED PULLEY BLOCK FROM KENCHREAI

(PLATES 76-78)

ONE of the most unusual small finds from the partially submerged "temple" at Kenchreai, the eastern port of Ancient Corinth, is a large wooden pulley or tackle block (Fig. 1, Pl. 76, 1), complete with wooden pulley wheels, of the fourth or fifth century after Christ. It was discovered in an almost vertical position between the southeast return of the apse and Pile IX of the glass opus sectile panels.[1] This well-preserved ancient mechanical instrument, one of the few of its kind known, represents one of Heron of Alexandria's five mechanical powers of the ancient world: windlass, lever, pulley, wedge, and screw. As such, it adds to our knowledge of Roman technology and also gives us a glimpse into the Hellenistic technology which the Romans inherited and used so profitably.

The block[2] is 0.71 m. in length, 0.19 m. at its widest, and 0.15 m. thick. Basically, it is rectangular with a projection of wood, partially broken, at each end. The top projection is 0.18 m. long and the bottom one is 0.13 m. long. The original shape of either is unknown, for one cannot decide where the wood has been split, and

[1] I would like to thank Professor Robert Scranton of The University of Chicago and Professor Edwin Ramage of Indiana University for permission to study and report on this block, inventoried as KE 1724, MI 453. Further reference to it will be found in the final publication of the site. Preliminary reports of the excavation can be found in *Hesperia*, XXXIII, 1964, pp. 134-145; XXXVI, 1967, pp. 124-186; *Archaeology*, XVIII, 1965, pp. 191-200; XX, 1967, pp. 163-173. The block and its parts were treated by the conservator Charalambos Deilakis by means of continual soaking in polyethylene glycol. The types of wood, unanalyzed at the moment, will appear in the final report. The percentage of shrinking, between discovery and preservation, is slightly under 10%; all measurements given here are post-preservation. I would like to thank Dr. Kenneth Matthews, Professor Rodney Young, Professor George Bass, Professor Lionel Casson, Mr. David O'Connor, Mr. Lanny Bell, Mr. Fred Van Doornick, and Mr. Gerhart Kapitän for bringing to my attention some of the comparative material. Professor Anna Benjamin very kindly consented to let the author illustrate two of the unpublished pulley wheels from the Athenian Agora. Those who kindly suggested ways that the block might have been used, in the light of modern evidence, were Mr. Mendel Peterson and Mr. Howard Chapelle of the Smithsonian Institution, Mr. Donald C. Seamans and Mr. Francis A. d'Entremont of the Boston and Lockport Block Company, and Mr. Clifford Toye of Johnson and Powers, Inc., of Philadelphia. Mrs. Susan Womer Katzev made the drawing in Fig. 1.

[2] Terminology here has been taken from A. Ansted, *A Dictionary of Sea Terms*, Glasgow, 1956. Generally, the pulley block is here referred to simply as "block"; the pulley-wheels as "sheaves," and the central pin as the "axle." For ancient Greek terminology related to the block, see A. K. Orlandos, Τὰ Ὑλικὰ Δομῆς τῶν Ἀρχαίων Ἑλλήνων, Vol. II, Athens, 1958, pp. 104 ff.

apparently there are no similar counterparts on either modern or ancient blocks. The central, " working " section of the block is 0.40 m. long, and is squared on three sides, but it bears indications on the fourth side that some of the wood had been split off in antiquity. The bottom of this central section of the block had been trimmed flat except for the projection on it, whereas the top, for some reason, had been left rounded. In the body of the central block have been cut two vertical slots, from front to back (Fig. 1, 1 and 3), in order to contain two sheaves. A horizontal hole drilled through the opposite sides, from one side to another, provides a central footing for the wooden axle on which the sheaves revolve. For some unknown reason, this axle hole was probably not drilled in the center of the small sides of the original block (Fig. 1, sides

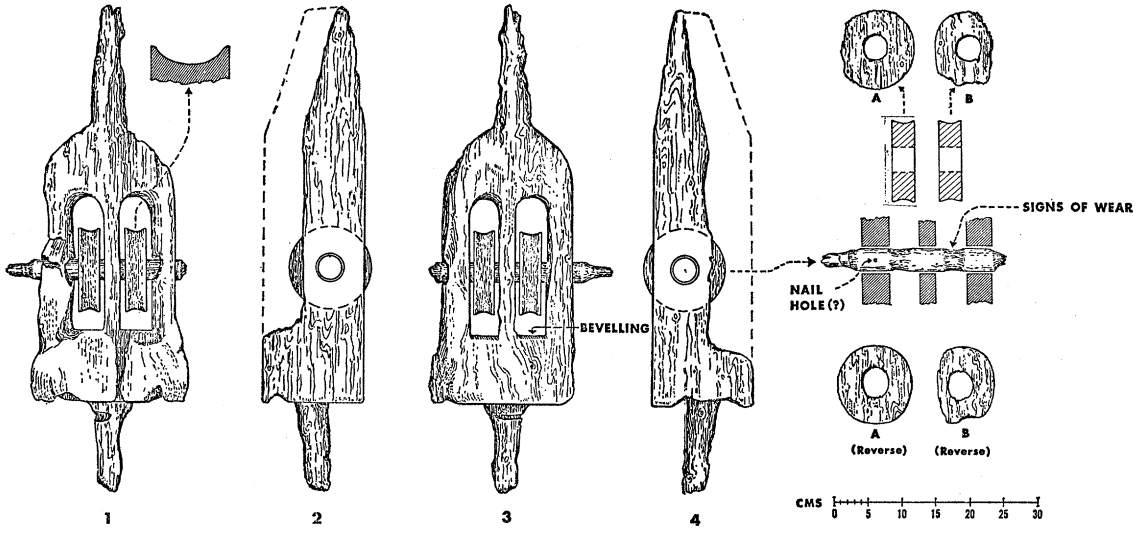

FIG. 1. The Block and its Component Parts
(by Susan Womer Katzev)

2 and 4). A good deal of wear visible on the axle, where the sheaves turned, indicates that the axle (0.27 m. long, 0.032 m. in diameter) was stationary, being held in place either by its tight fit or, perhaps, by nails.

Each of the two sheaves (Fig. 1, A and B), warped and partially destroyed, has a diameter of *ca.* 0.12 m., a thickness of 0.033 m., with the central hole for the round axle 0.038 m. in diameter. The concave channels on the edges of the sheaves (" gorges "), where the rope would slide, are at their maximum depth 0.007 m. On the sides of the sheaves and elsewhere on the interior of the block are traces of a thin layer of hard, caked material which may well prove upon analysis to be the remains of grease originally used to lubricate the sheaves.

The tops of the slots into which the sheaves fit differ from the bottoms. Above, the cuttings are rounded, while below they are cut flat with a slightly bevelled edge

along the side preserved (Fig. 1, 3). Moreover, the gap between the perimeters of the sheaves and the tops of the slots, 0.05 m., is greater than the 0.03 m. gaps below. These differences are important, I think, for they allow us to decide, on the basis of modern block construction, which end of the block was " up " when it was in use.[3] The greater gap would allow the rope to pass over the sheaves—no rope would pass through the lower gaps—and the bevelling along the bottom edges of the slots reduced friction as the rope passed up alongside the block. Before we can discuss its exact function, however, it would be helpful to consider analogous ancient blocks and their components.

Ancient wooden blocks are rarely found today, even though these, as well as other construction materials, must have been plentiful during the Roman era, especially in contractors' sheds near areas where building construction took place, or in harbors, such as Kenchreai, where special sheds may have been built to house tackle used for handling cargo,[4] raising and lowering sails and anchors, etc. The general absence of such items now may, naturally, be explained by the fact that wood is preserved only in rare instances in areas that undergo rapid changes in temperature and humidity throughout the year. For the same reason iron blocks, though attested by inscriptions, seem to have disappeared.[5]

Fortunately, there are some examples of wooden sheaves and blocks that have been preserved, either through submersion in water or by being continually dry. Two sheaves from Egypt (Pl. 77, a, b) probably date from the time of the Romans, since as far as we know the Egyptians did not use blocks. (Indeed, the earliest known example of a sheave in use may well be that shown on an Assyrian relief dating from the reign of Ashur-nasir-pal II, 883-859 B.C.[6]) The larger of the two sheaves from Egypt [7] is of almost the same diameter as those of Kenchreai (0.095 m. versus

[3] " Up " here is a relative term, for the block might have been at the lower part of a block-and-tackle rig. Then the " up " here would be " down."

[4] The use of machines for the handling of cargo is discussed in J. Rougé, *Recherches sur l'organization du commerce maritime en Mediterranée sous l'empire romaine,* Paris, 1966, pp. 160-166.

[5] *I.G.*, II², 1672, lines 205, 239; and see *infra*, note 10.

[6] J. Laessoe, " Reflections on Modern and Ancient Oriental Water Works," *J.C.S.*, VII, 1953, p. 6, fig. 1. For further references see also R. D. Barnett, " North Syrian and Related Harness Decoration," *Festschrift für A. Moortgat*, Berlin, 1964, p. 24. Dr. Barnett has kindly informed me that an actual example, contemporary with the relief, has been found by Mallowan at Nimrud, no. 132162. This single wheel, only half of which is preserved, is 0.135 m. in diameter, and 0.055 m. thick.

[7] W. M. Petrie, *Tools and Weapons*, London, 1917, p. 60, pl. LXXV, pp. 143-144; now in the Petrie Collection in University College, London, by whose courtesy they are reproduced here (Pl. 77, a, b). One might note here that the larger sheave is cut with the grain and from a fairly soft wood; the smaller, however, is cut against the grain and from a much harder wood. For reference to the absence of blocks in pre-Roman Egypt, see S. Clarke and R. Engelbach, *Ancient Egyptian Masonry,* Oxford, 1930, pp. 44, 85, 87, 96. Another Roman wooden sheave, *ca.* 0.11 m. diameter, 0.021 m. in thickness, and 0.023 m. diameter of central hole, has been found in a ship-

0.12 m.), but its relative thinness suggests that a much lighter rope would have been used in the former and that the load would have been correspondingly less. Three other, heavier, wooden sheaves (Pl. 77, c, d), of the first to third centuries after Christ,

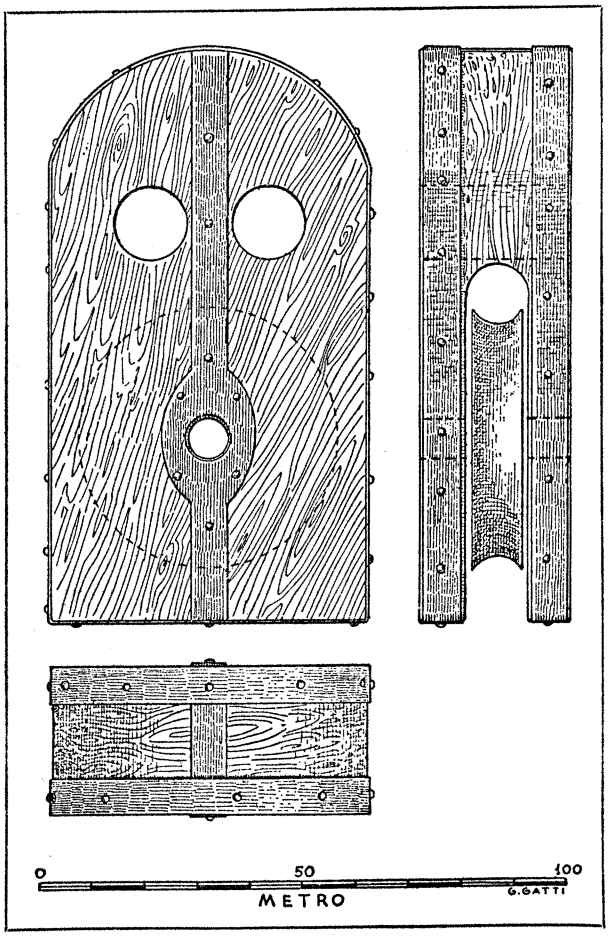

FIG. 2. Single-sheaved Block for Nemi Ships

have been found in the Athenian Agora.[8] Their diameters (0.13 m., 0.16 m., and 0.19 m., respectively) and thicknesses (0.035 m., 0.058 m., and 0.075 m., respectively) are all greater than those of the Kenchreai block. The one major difference between the two lots, however, is that in the examples from the Agora the central holes are

wreck in Provence; F. Benoit, "Nouvelles épaves de Provence," *Gallia*, XX, 1962, pp. 168-169, fig. 46. Through the central hole has been restored a curiously shaped pin (metal?), unexplained in the report.

[8] Agora Inv. W1, W21, W27; they will be published by Anna Benjamin in the volume of *The Athenian Agora* on miscellaneous finds.

square, which suggests that the sheaves fitted closely upon a wooden or metal axle which turned along with them rather than turning about a stationary axle. This in turn indicates that they were probably part of the apparatus used for drawing water out of the wells in which they were found, rather than being within a lifting machine, such as a block.[9] The circular marks visible on the side of one sheave (Pl. 77, d) probably indicate abrasion during such use.

One huge wooden block reinforced with iron bands (Fig. 2), of the first century after Christ, has been found in one of the large vessels possibly constructed by Caligula on Lake Nemi.[10] The huge block is 1.08 m. long, 0.60 m. wide, and 0.28 m. thick. The diameter of the sheave (quite possibly metal, although this is not specified in the publication) is approximately 0.50 m. According to Ucelli, the rope passing through the block was used either as a tow line or for maneuvering the mooring hawser. One or more ropes passing through the attachments visible in the head of the block would have secured it to some solid support. In this case, the block would probably have been used not to reduce the amount of purchase necessary to lift a heavy object, but simply to change the direction of force in order for the crew to tighten the hawser.[11]

A very interesting wooden block (Fig. 3), resembling in some ways the one from Kenchreai, was found in the " County Hall Ship " in London.[12] It dates slightly later than A.D. 293. As preserved, it is small, about 0.16 m. long, 0.045 m. wide, and 0.045 m. thick. Both sheaves are missing, and there are no indications of metal parts.

[9] Evidence for such simple devices is plentiful. (For an early example, see *supra*, note 6). Aside from inscriptional evidence (*infra*, note 17, and W. Kendrick Pritchett, " The Attic Stelai," *Hesperia*, XXV, 1956, no. 26, pp. 304-305) there are various well-side scenes on vases (D. A. Amyx, *A.J.A.*, XLIX, 1945, pp. 504-515, note 24, with references to Tischbein, *Hamilton Collection*, I, pl. 58, and *ARV*, 705, 15; Leroux, *Madrid*, pl. 29, 1). Sockets for metal or wooden frames built over stone well heads are fairly common. One of the most elaborate well installations can be found in the " House of the Trident " at Delos; *Délos*, VIII, 1, Paris, 1922, pp. 139-152. Here the wheel was hidden within an architrave block placed directly over the well opening. These examples can be compared with one of the sixth century after Christ; O. M. Dalton, *Byzantine Arts and Archaeology*, Oxford, 1911, p. 205.

[10] G. Ucelli, *Le Navi di Nemi*, 2nd ed., Rome, 1950, p. 181, fig. 197. As regards metal sheaves, two pairs of bronze sheaves (diam. 0.145 m. and 0.13 m., respectively) have been found underwater by Gerhart Kapitän near Syracuse in a Roman shipwreck dating to the early third century after Christ. These sheaves are quite modern in appearance, with a central hub, joined to the outer wheel by means of four wide flat spokes. According to the discoverer, pieces of wood found in association with the sheaves indicate that they could have been used in at least one block.

[11] Theoretically, the block could have been used in conjunction with a compound pulley block, for example, somewhere in the rigging of the huge ship.

[12] P. Marsden, " The County Hall Ship," *Transactions of the London and Middlesex Archaeological Society*, XXI, part 2, 1965, pp. 109-116, fig. 3, no. 2; and *Ship of the Roman Period Discovered on the Site of the New County Hall*, London City Council, 1910, p. 13. Figure 3 courtesy of the London Museum and Mr. Peter Marsden.

In this case the block has a lateral cut along its side, most probably serving to hold a tightened rope (strop) which reinforced the wood, thus preventing it from splitting. Its relatively small size suggests that it aided the crew of the ship in raising a sail or tightening a line, rather than performing such strenuous duty as lifting cargo into or out of a ship. The two round holes bored in either end would have served for attachment of ropes, as in the block from Nemi. In the " County Hall " block, how-

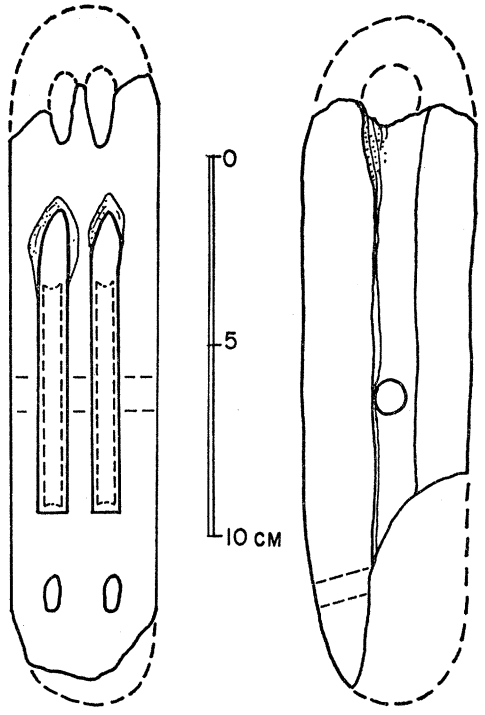

FIG. 3. Double-sheaved Block from the Thames

ever, the holes are on both ends rather than only on one, thus giving the block a greater variety of uses either on deck or in the rigging.

A pair of small wooden blocks, approximately 0.10 m. long, each with a single sheave, comes from a Coptic monastery in Egypt.[13] Although these unique blocks, used between the fifth and eighth centuries after Christ, may post-date the example from Kenchreai, they are nevertheless instructive. One of them (Pl. 77, e, left)

[13] Illustrated but without commentary or measurements (nor are both faces of the two blocks shown) in J. E. Quibell, *The Monastery of Apa Jeremias*, Cairo, 1912, pl. LIV. The sizes given are approximations made by comparison with the surrounding objects on the lower part of the same plate.

preserves part of the original rope, secured through a hole bored in the lower part of the block. Perhaps the block was held from below by means of this rope. It is more likely, however, that the hole served as an attachment (or "becket") found on modern blocks and used for securing one end of the rope, the other end being held from below after passing around the sheaves. (The holes drilled in the "County Hall" and Nemi blocks could well have served the same purpose.) Also worthy of notice are the round, dowel-like projections at the end of each block, each with fairly deep grooves cut around it. Could these projections, apparently broken, be similar in function to those on our block from Kenchreai, or were they left there by the maker as reinforcements in order to prevent the block's splitting down the middle?

A number of Roman reliefs [14] (Pl. 78, a, b, e) of stone or terracotta, and one wall painting [15] illustrate the use of the block in building construction; others [16] (Pl. 78, c, d) show the block used for adjusting stays in ships' rigging, for holding buffers to protect the ships while up against the quay, or unloading cargo, and quite possibly for lifting anchors. Some of these reliefs have been discussed in studies of ancient technology, usually in connection with the types of lifting machines involved.[17]

Of these reliefs, the most instructive and finest is on the Monument of the

[14](1) Plate 78, a: details of relief from the Haterii Monument *ca.* A.D. 100, Lateran Museum, Rome.

(2) Plate 78, b: detail of Via Cassia terracotta relief from Rome, Terme Museum, Rome. Photo by courtesy of Superintendent of Antiquities, Rome.

(3) Plate 78, e: detail of relief from Terracina, first or second century after Christ, Terme Museum, Rome; Walter Goss, *Arch. Anz.*, LIII, 1938, cols. 149-150. Photo courtesy of German Archaeological Institute, Rome.

(4) Terracotta relief from Practica del Mare; R. Lanciani, *Mon. Ant.*, XIII, 1903, p. 169, fig. 8.

(5) Relief from Syracuse, first century after Christ, Orlandos, *op. cit.*, p. 114, fig. 49 and (perhaps the same relief but published earlier) the Capua relief, B. Gille, *A History of Technology*, II, ed. by E. Singer, Oxford, 1956, p. 637, fig. 578.

[15] Orlandos, *op. cit.*, p. 112, fig. 47 (from Pompeii, in Helbig, *Wandgemälde von Pompeii*, no. 1266.)

[16](1) Plate 78, d: detail of relief on triumphal arch at Orange, republished in R. Amy etal, "L'Arc d'Orange," *Gallia*, Supplement XV, pl. 25 (from which our photo). A portion of this same drawing is reproduced in Daremberg and Saglio, *Dictionnaire*, I, p. 267. The latter illustration is misleading, however, for it gives the impression that there is only one (not two) blocks involved.

(2) Plate 78, c: detail of the famous Torlonia Relief. The total relief, of which this is a detail of the right-hand ship, can be found with a description and bibliography in R. Meiggs, *Roman Ostia*, Oxford, 1960, pls. XX, XXI, a.

[17] For recent studies of the ancient literary sources and the invention of such lifting machines as well as general views of some reliefs shown on Plate 78 see A. Orlandos, *op. cit.*, pp. 101-116, 369-371 (with list of Greek inscriptions referring to the *troxalias*); A. G. Drachman, *The Mechanical Technology*, London, 1963, pp. 15, 53, 55, 67, 86, 97, 109, 143, 173, 203; R. Martin, *Manuel d'Architecture grècque*, I, Paris, 1965, pp. 202 ff.; G. Lugli, *La Technica Edilizia Romana*, Rome, 1957, pp. 222-231, pls. XXX, XXXI; and A. G. Drachman, "A Note on Ancient Cranes," *A History of Technology*, II, ed. by E. Singer, pp. 658-662. In none of these, surprisingly, is there a description of actual blocks found. See also, J. Rougé, *op. cit.*, 161, note 3.

Haterii in Rome, of *ca.* A.D. 100 (Pl. 78, a). Here an enormous crane is being used for lifting building materials. Men walking and climbing within a circular "squirrel cage" at the bottom of the crane's mast provide the power for lifting the architectural members. At the top of the mast are a series of blocks, with double sheaves, bound to the mast by triple thickness of rope. Each of the blocks has a hole for attachment bored through it, and along the sides two pin- or dowel-heads are visible. Each of these pins probably functions as the axle upon which one sheave turns. Three rope thicknesses proceed down to a lower level (not shown in the relief) where one might expect to find a single-sheaved block with a becket or other attachment (such as one of the holes visible in the blocks above) for securing the block to some stationary object. From each of the upper blocks shown there hangs the loose end of the rope that passes down the length of the mast to be secured somewhere below, where it could be alternately pulled or loosened in order to adjust the position of the mast. To the right of the mast, just below the topmost stay, can be seen suspended the massive block that would be used to do the actual lifting. This block probably has four sheaves. There are three pins (one partly destroyed) visible on the side of the block. The upper two probably hold two sheaves each, while the lower one appears to function as a reinforcement for the lower part of the block and, at the same time, as a becket.

The types of blocks here resemble in some ways the "County Hall Ship" example (Fig. 3). For instance, the ship's double-sheaved block could be lashed to an object to be moved, and the holes in the ends might very well serve as beckets. In contrast, the Kenchreai example lacks either a bored becket or a pin, and does not apparently have provision for being lashed securely to another object, unless the projections, now partly destroyed, could have performed these functions. If they did so, however, the Kenchreai block might well have been hung from a mast such as that shown in the Haterii relief, although the more modest site of Kenchreai would require a much simpler version of the stay-and-mast crane. Perhaps more in accord with the limited scale of building construction at Kenchreai are examples from two other reliefs, from the Via Cassia and from Terracina (note 14, nos. 2, 3, Pl. 78, b, e) which demonstrate how in ancient times (as now) limestone blocks were lifted by means of pulley-blocks suspended from tripods or bipods composed of heavy posts joined at the top. Sometimes they were supported from the sides by rope stays, and held together by wooden (or metal) crosspieces. Just below the block (or, as the case may be, from a lower block) would be suspended heavy metal tongs for lifting the wall blocks. In some cases we can imagine that the tongs would be replaced by ropes, chains, or other means of attachment such as lewises.

In the two examples representing the rigging of ships (note 16, Pl. 78, c, d) there appears a somewhat novel rigging of the blocks. In the first example, from the Triumphal Arch at Orange (Pl. 78, d), are shown two blocks with ropes (partially preserved) connecting them. They are hung from and partly wrapped around what

may be the *artemon* mast of a ship, since the remainder of the objects in the relief (prows of ships, anchors, a trident, etc.) are probably booty from naval victories. To the left of the two blocks is a coil or rope, the ends of which pass through the blocks. To judge from the arrangement of the blocks, however, it appears that the two ropes lead first from the coil around the topmost two sheaves of the left-hand block, then to two sheaves in the bottom block, back around the two bottom sheaves of the first block, and then finally back at the top of the second block where, to ensure the proper functioning as a block-and-tackle rig, they are tied to beckets (not seen). In effect, then, we have a " double " simple block-and-tackle rig. This explanation would make more understandable the otherwise confusing scene in Plate 78, c (a detail from the

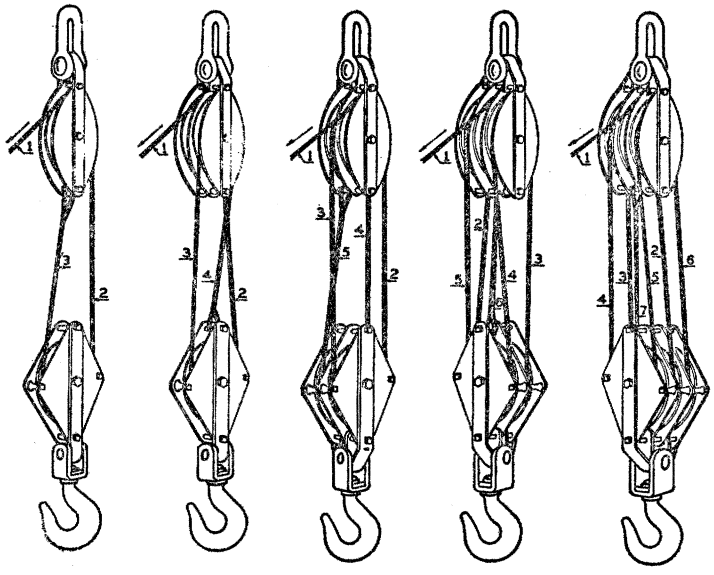

FIG. 4. Ways in which Metal Blocks can be rigged today
(Courtesy Boston and Lockport Block Company)

famous Torlonia relief) in which a man, part way up the *artemon* mast of a frigate, is hauling in or letting out a buffer (?) by means of two ropes attached to a block and tackle seen suspended from the mast. Though sufficient detail is lacking here, we may well have the same type of rigging as that described above, which introduces another unusual possibility of how the block from Kenchreai might have been rigged.[18]

[18] Two other possibilities should be mentioned. Mr. Francis A. d'Entremont, Chief Engineer of the Boston and Lockport Block Company, after a detailed study of drawings of the block suggested that the bottom projection may well have fitted vertically into a hole cut out at the top end of a mast. " This spindle located the block and kept it from shifting once the downward thrust loads of the shrouds and stays was applied. The other ends of the stays and shrouds were no doubt made fast to a belaying pin or some other object which made it possible for them to take up whatever slack was necessary . . . The large point on what we will call the top of the block could have

From the preceding analysis it should be clear that when a block with a single sheave (like that from Nemi or the sheaves from the Agora) functions alone, it tends only to transfer the direction of force from one point to another. A block with a becket, used in tandem with another block, will reduce proportionately the force necessary to lift a heavy object. Naturally, a rig having at least one double-sheave arrangement (as in the Torlonia and Haterii reliefs, Pl. 78, c, a) will require less straining on the part of the workmen than would a pair of single-sheaved blocks (such as the Coptic examples, Pl. 77, e). Thus for any particular job, the types of blocks as well as the ways in which they were rigged might differ (Fig. 4). The varieties of work accomplished differed, too. Blocks were used in ancient times, for instance, for setting a patient's limb, dragging war-tortoises into position, lifting curtains of theaters or traps in an amphitheater, setting columns in place, restoring leaning walls to their former positions, splitting wood, quarrying marble, etc. Even to begin to determine the exact function of our block from Kenchreai, therefore, we must look again at the block itself and also inspect more closely certain aspects of the context in which it was found.

As was mentioned at the outset, the block was found in association with a series of nine stacks of opus sectile panels.[19] Each of these stacks is composed of six or more double layers of mosaic, each layer being backed by a coating of plaster and then by tile fragments. In every case so far examined, around each double layer are preserved sections of wooden " packing cases " held together by iron nails and wooden pegs. These cases were apparently brought into the building and were first laid up against the wall, then one against the other. Since a single case might weigh about 200 pounds when dry, it could have been carried in by three men and put in place among the crate groups. It is possible, however, that an entire group of crates, properly secured, might have been gently lowered into the building from the outside.[20]

been used to accommodate the eyesplices on the ends of the shrouds or the fore and back stays." This theory might help explain the nature of what might be a crudely represented block pictured in the Torlonia Relief (note 16, no. 2) towards the top of the mast of the ship on the right. The " block " here may also be the hooped attachment on the top of the mast, through which halyards passed in Greek and Roman ships. See C. Torr, *Ancient Ships* (reprinted Chicago, 1964), p. 93, note 200; for illustrations see E. Pfuhl, *Malerei und Zeichnung der Greichen,* III, Munich, 1923, fig. 479. A second theory, also ascribing the use of the block to the rigging of ships, suggested by Mr. Mendel Peterson and Mr. Howard Chapelle, is that " the block probably fitted into a frame such as the railing of a ship to act as a fair-lead for lines coming from the rigging . . . The two points at either end fitted into holes, allowing the block to turn if necessary." This is also a definite possibility, although I know of no ancient reliefs on which this may be pictured.

[19] It is possible that when the temple area was engulfed by water the block may have floated about in the room until it reached its findspot near Pile IX. All indications are, however, that it was somewhere within the room, if not at the findspot itself, when the catastrophe took place. Another possibility being considered is whether the block might be a later intrusion, dumped in with the fill used to support a later floor found at a higher level.

[20] This implies either that the walls of the building were not complete at the time of the catastrophe or that the walls, when complete, only went up to a certain level above the mosaic floor.

In an adjoining room to the south were found various other indications of work in progress. Upon the rough clay floor were materials for making tesserae mosaics, chips of reddish stone used to reinforce the mortar used in the building and elsewhere

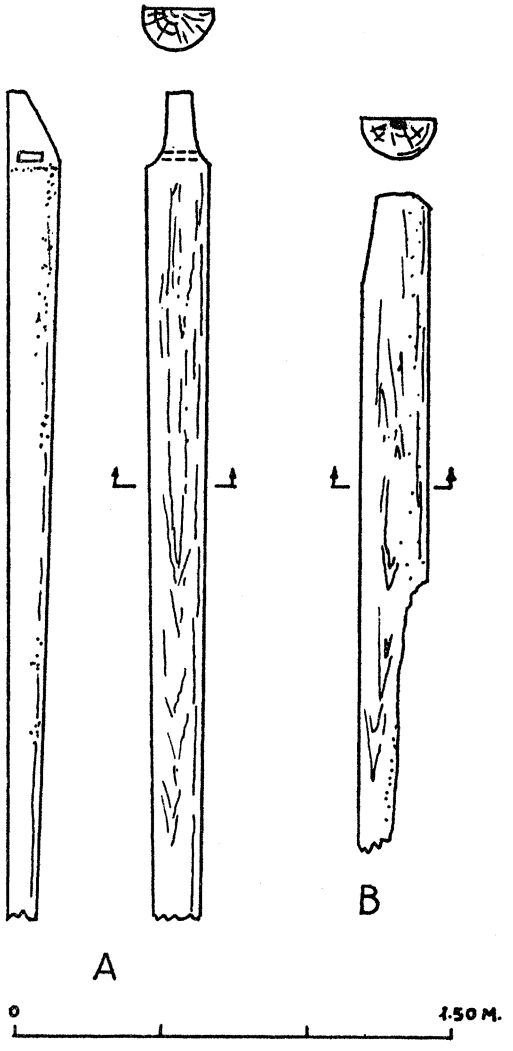

FIG. 5. Logs.

in the area, partially worked fragments of marble revetment, and grinding stones. Overlying those was a variety of wooden boards, poles, and two heavy logs.

But here there is nothing for our block to lift. The two logs mentioned (Fig. 5), however, might have been used as aids in the lifting process, even though they were

Both are possibilities being considered. One might ask, however, whether these fragile, certainly costly, panels would have been stored in the open, especially in a building which was in the process of construction.

not found in the same room as the block. Both timbers are broken at one end, so we do not know their original length. As preserved, log A is 2.80 m. long, log B is 2.30 m. long. Each was left with its bark on, except for one side which had been adzed or planed down. The preserved end of B has a small diagonal section cut from its end. Log A has about one-third of its thick end cut off on each side for a length of *ca.* 0.27 m., and through the remaining tongue of wood a slot *ca.* 0.05 m. wide and 0.10 m. high was cut. How these logs may have been used will probably remain unknown. One consideration, however, is that they were part of a bipod supported from the sides by stays. The block under consideration may have been hung from the apex of the bipod. With this possibility in mind, a small scale model was constructed by the author. The end of Log B was cut with a notch that fitted over the tongue of Log A. A rope was passed through the slot in Log A, and the apex was bound. Below was hung a single-sheaved and a double-sheaved block. This and a number of other combinations worked satisfactorily.[21] Vitruvius describes a similar procedure quite clearly: [22]

> First we shall treat of those machines which are of necessity made ready when temples and public buildings are to be constructed. Two timbers are provided, strong enough for the weight of the load. They are fastened together at the upper end by a bolt, then spread apart at the bottom, and so set up, being kept upright by ropes attached at the upper ends and fixed at intervals all round. At the top is fastened a block, which some call a "rechamus." In the block two sheaves are enclosed, turning on axles.[23] The traction rope is carried over the sheave at the top, then let fall and passed round a sheave in the block below. Then it is brought back to a sheave at the bottom of the upper block, and so it goes down to the lower block, where it is fastened through a hole in that block. The other end of the rope is brought back and down between the legs of the machine . . . This kind of machinery, revolving with three sheaves, is called a trispast.

There are still some unanswered questions about the block. The first is, if this is indeed part of a block-and-tackle rig, was there a mate with which it would have worked in tandem? The absence of the necessary second block can probably be explained only by assuming that it was not preserved (perhaps it was at a higher level in the fill), that it was being used elsewhere at the time of the destruction of the building, or that the block found was simply stored temporarily in the room.

The second question concerns the projections on each end of the block. How were they used? As we have seen they might have had provision for attachments in the forms of holes or hooks. One explanation for their use in the room (contrast with note 18) is that the block was intended to be laid upon the rafters of the ceiling

[21] In this reconstruction, logs A and B were made 4 m. long; the adzed sides and the bevelled end of B, however, remain unexplained.

[22] Vitruvius, *De Architectura*, X, 2, 1 and 3 (translated by Morris Hickey Morgan, New York, 1960).

[23] There are a number of points worth noting. First, Vitruvius is describing the type of construction he recommends. He uses a bolt, therefore, rather than a rope to bind his timbers. Also, he describes an upper block with two sheaves, one above the other, unlike the one from Kenchreai. The function of the model, however, is basically the same.

or roof, and that the projections would be bound to the rafters while work was in progress. But would not the projections have broken under the strain? Another suggestion is that they were to fit into sockets (such as the slot in log A), and be bound into place. Indeed the entire pulley block may have fitted into a wooden or metal frame or " cradle," from which it could be removed, when necessary. It is also worth considering whether the lower, flattened edge of the block rested on a horizontal board or bar attached to the legs of the tripod or bipod mentioned, p. 396, Plate 78, e. The projection would then fit through a hole in the board. The other, rounded end of the block (obviously the top) would then fit quite well into the sloping head of the tripod, where it would be lashed.

The exact function of the block, as well as the means of its incorporation into a machine for lifting, remains unknown. Its large size and the fact that it is double-sheaved, however, suggest that it was used to shift very heavy weights.[24] That it had anything to do with the near-by docks of the port is unlikely, since it was found within the " temple." We may assume, therefore, that it was brought there for a specific purpose, quite possibly for the building or repairing of the " temple " walls.

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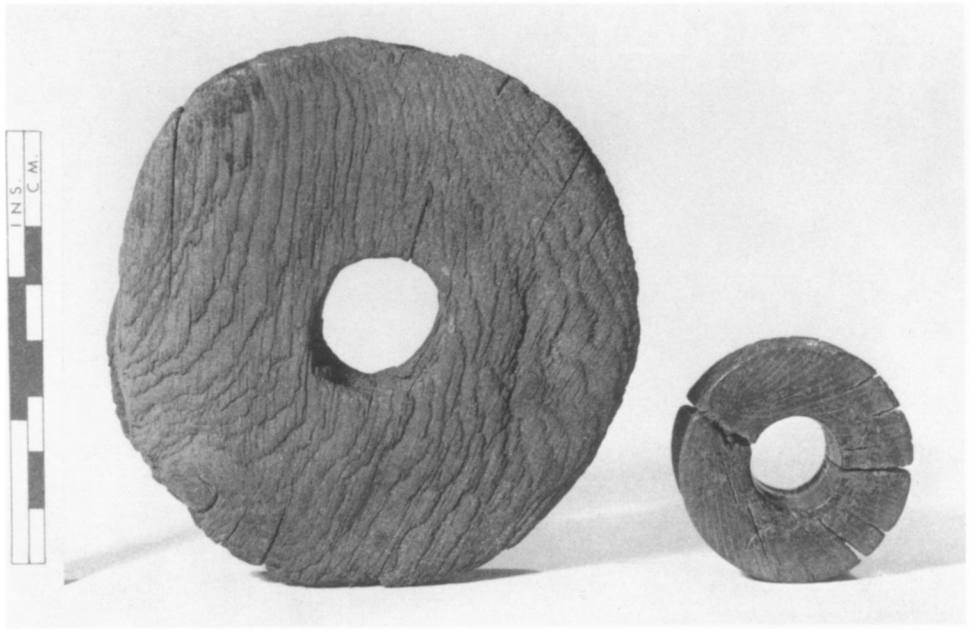
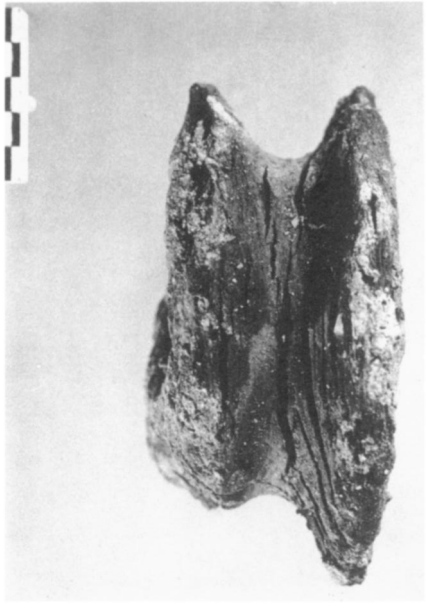
[24] The approximate size of the rope used in the sheaves would have been 0.031 m. Modern Manila rope of the same size, probably superior to ancient rope in a number of respects, has a tensile strength of 13,500 pounds per foot, 2,700 pounds working load. A conservative estimate of the safe working load (SWL) of this size ancient rope is 1,200 pounds. Since at least three lengths of rope would have been holding up the weight lifted, a normal load for such a block, therefore, would have been in excess of a ton. The wooden axle itself could probably have supported 2,000-2,400 pounds at each sheave.

The Kenchreai Pulley Block

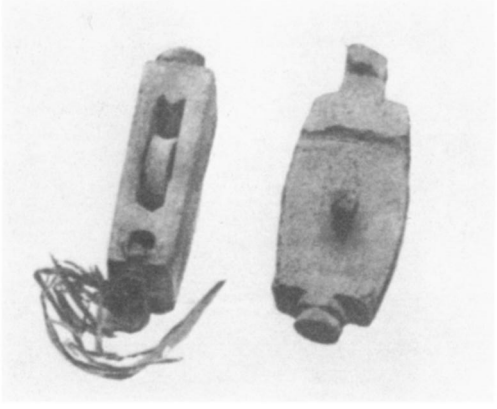


a. and b. Two Roman Sheaves from Egypt

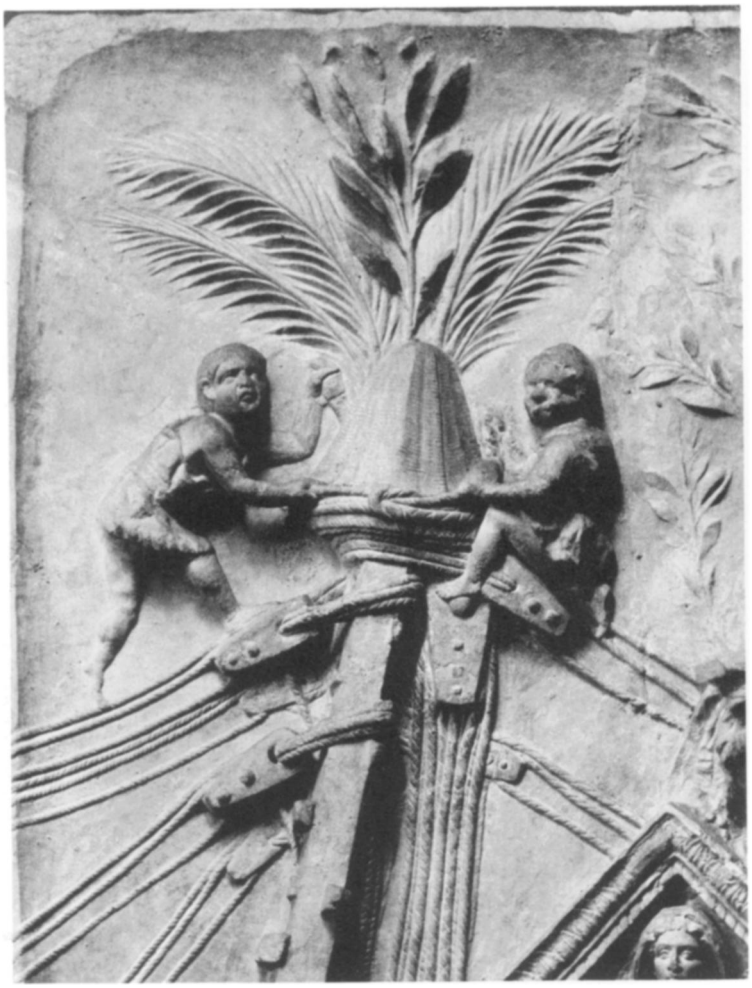


c. Side View of Sheave W 12 from the Athenian Agora

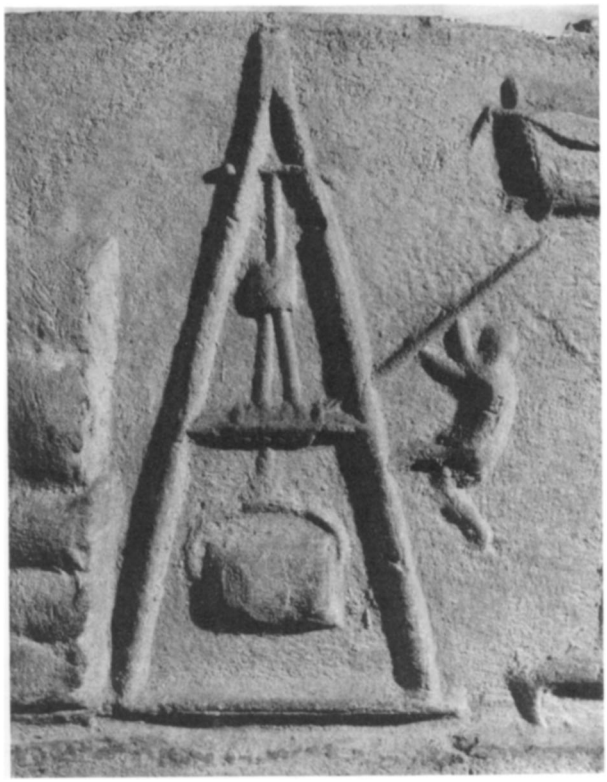
d. Sheave W 27 from the Athenian Agora



e. Two Single-sheaved Coptic Blocks from Egypt

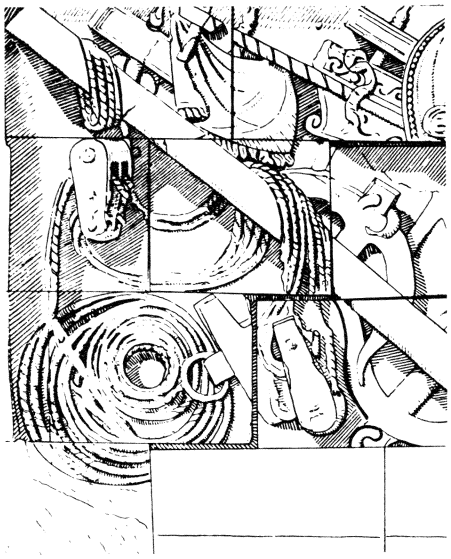


a. Top of the Roman Crane on the Haterii Relief



b. Detail of a Terracotta Relief from Via Cassia, Rome

c. Detail of Torlonia Relief



d. Detail of Spoils from Naval Battle on Triumphal Arch at Orange

e. Detail of Relief from Terracina