The following article puts the Antikythera mechanism in context and may help to understand how the ancient Greeks came to make such a complex device.

Rob S. Rice
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The Antikythera Mechanism:

Physical and Intellectual Salvage from the 1st Century B.C.

At some time around 80 B.C. a heavily laden merchant ship sank to the bottom of the sea off the Southern coast of Greece. After two millennia, materials from that vessels cargo have combined with the work of several scholars to allow wider speculation on the subject of seafaring in Greek and Roman antiquity. The objective of this treatment of the chain of events involved is to provide a useful survey of early and modern underwater archaeology and the mechanics of artifact preservation and interpretation as well as to offer conclusions drawn from the data presented here concerning ancient celestial navigation and the island of Rhodes. The united efforts of a wealthy Roman, a frightened Greek sponge diver, an English physicist, and an American naval historian have combined to allow some further inquiry into civilian and military seafaring in the first century before Christ.

Sailing further south past the island of Antikythera off the southernmost coast of Greece offers an alternative to, as a very ancient proverb says, "rounding Malea and forgetting home." Whether he sought to avoid the pirates or the storms clustered around the infamous cape, the skipper of what apparently was a good-sized Roman merchant vessel of around 300 tons made a wrong decision. His ship crashed into and sank off the island's coastal cliffs, and what was probably a wealthy Roman buyer eventually learned that his treasure ship's cargo had gone down in nearly two hundred feet of very cold, current-swept water.[1]

"Treasure ship" is a legitimate label. The corbita had held everything from original bronze life-size statues, to marble reproductions of older works, jewelry, wine, other bronzes, and at least one immensely-complicated scientific instrument. It was the statues that frightened a Greek sponge diver named Elias Stadiatos nearly out of his wits in 1900, when his captain winched him back over the side, removed his helmet and breathing hose, and found him babbling about a "heap of dead naked women."[2]

Rumors from around that time show a resulting pattern of events all too familiar to the modern underwater archaeologist. The local divers had found the ship first. The villagers of Simi, near the site, speak of many small bronze statues sold in Alexandria soon after the wreck was found, and when later archaeologists surveyed her, the vessel was missing all her heavy lead anchor stocks. The ship was big enough to have had five anchors, in water too deep to have used any of them, and divers needed lead weights to find their sponges and rare black coral, just as they needed money to support their families.[3]

Still, Captain Kondos of the sponge vessel in 1901 told the Greek government of Stadiatos's discovery, and agreed to hire his ship and divers for the salvage. He pushed his equipment and his men to the limit, but he recovered one of the most amazing troves ever winched from the bottom of the sea. Statues, jewelry, transport jars, utensils, and tableware of all kinds came to the surface. "Huge boulders" obscuring the cargo and hauled up to the salvaging vessel with difficulty turned out to be statues covered with marine growth, their marble eaten away by the chemical action of centuries of sea-water and animals. The divers suffered from all the hazards of their trade, one fatally. When the winter storms came up, the divers and the Greek government were ready to quit. The bronze statues went into galleries, the jewelry into display cases, and a great deal of material went into museum storage, waiting for careful analysis to determine the significance of, among other things, clumps of marine growth and corrosion surrounding what looked like some kind of gearing. What wood was brought up resembled wet cardboard in more ways than one as it dried out and shriveled away.[4]

It would be unfair to call this proto-excavation "unscientific," for there were trained archaeologists from the Greek antiquities service waiting to process the material once Kondos's divers had brought it to the surface. A modern excavation would, for all that, hopefully progress a great deal differently, using techniques pioneered by Peter Throckmorton and George Bass over the course of research beginning in 1959.

Archaeologists themselves would descend to investigate the wreck. The hoses and helmets that had hampered the sponge divers of 1901 would be replaced by self-contained apparatus designed to bleed off the carbon dioxide that had exhausted and dazed the original divers. Modern compressors would be filling air tanks and pumping air down to the wreck level, and that air rising up again inside a tube would lift silt and small items up to the surface for sifting and removal. Inside plastic bags rising bubbles would lift statues and jars. A decompression chamber would stand ready in the event of nitrogen narcosis, with atmospheric pressure within carefully regulated to let the nitrogen built up by the compressed air breathed underwater leave the diver's arteries slowly enough to avoid damage. A grid over the wreck made of plastic plumbing pipe would direct drawings and photography for stratigraphic records of the objects discovered. Drawings and recorded measurements would possibly be combined with stereoscopic photography, the whole allowing graphic reconstruction of the original ship and its cargo.[5] There might be a diving bell with a telephone to talk to the surface, or a midget submarine to help with the photography. An underwater metal detector would be useful, and an "air probe" to jet into the sea bottom with compressed air to prod for things under the mud. Computers would store information topside, and potentially underwater as well, since one of the things that suffers with exposure to water is a diver's short-term memory.

Funding, as well as the physical difficulties of such intricate underwater activity can act to limit such exploitation of first-hand ancient material. The additional hazard of post-recovery destruction of recovered material is not always countered by techniques of modern artifact conservation. Shifting during the descent of the original ship's hull to bottom had already inflicted extensive damage on her cargo before the first diver approached the wreckage. The ubiquitous Mediterranean teredo worm employed the intervening centuries to destroy the integrity of the hull and larger wooden artifacts, while marine bacteria left only the hollow cell walls of the remaining timber. Marine shellfish devoured the limestone of the statues, while the sea's own electrolytic bath wrought havoc on all metallic artifacts unprotected by bottom mud. Unauthorized "pot-hunting" before the official excavation undoubtedly also further damaged the available material left behind.[6]

The bronze gearing retrieved from the Antikythera wreck, with its own chemical and animal accretions, broke into several pieces soon after its return to the surface. The ship's wooden planks and what appears to have been a case for the mechanism shriveled soon after retrieval. The marble statues were eaten away and disfigured wherever they had been exposed to the sea. As usual in terrestrial archaeological sites around the Mediterranean, ceramic material in some form survived, except for the damage inflicted by the heavier cargo and defacement by marine growths. The chemical composition of the glassware retrieved in 1901 was fortunate. Phoenician beads George Bass recovered off Cape Gelidonya exploded into dust once they began to dry.[7]

Modern conservators would place everything but the pottery into a tank of fresh water until preliminary analysis was possible. Marine conservators are a rare combination of archaeologists and chemists, employed on occasion, and on occasion, in vain. The wood can be preserved, as was the Swedish 17th-century galleon Vasa, in polyethylene glycol, which fills the empty cell walls with a waxy material over a great deal of time. Metal artifacts receive their own immersion in chemical solutions with the goal of stabilizing each piece and hopefully removing accumulated corrosion, an expensive and not always successful procedure. Cleaning off what lived and died on all materials submerged for any length of time can be difficult as well, particularly when the person so doing is uncertain of what lies under the accreted material and how much cleaning the object can withstand before disintegrating or losing desirable features.[8]

In the case of the Antikythera fragments, the four large pieces and a box of much smaller fragments were momentarily overshadowed by the staggering other results of the first directed retrieval of archaeological evidence from the sea. The original excavators had their hands full reassembling the bronze statues, sorting and identifying coins, and cataloguing all the items for museum storage at Athens. Eventually, other scholars found time to consider the fragments of original artifact. The initial belief was that the bronze object was an astrolabe--a type of navigational instrument first attested in 625 A.D. Correctly, one Konstantin Rados in the earliest debate insisted that what was visible on the lump's surface was too complicated for such a device, intricate as in fact were some medieval examples. At the same time other scholars argued that the Greek artisans who had fabricated the wreck's statues could not have built even an astrolabe.[9]

In 1951, a British physicist and historian of science named Derek De Solla Price went to the Athens Museum for his own analysis of the fragments taken from the Antikythera wreck. Price himself was familiar with construction of medieval astrolabes, and the complexity of the device and the astronomical inscriptions visible on the surface led him to eight years of informed study. In 1959 Price published his own conclusion that the fragments represented some form of intricate clockwork.[10] The idea was sufficiently unthinkable to the experts of the time for one professor to claim in responding that someone in the Middle Ages had dropped a machine of that era into the sea coincidentally over the same current-swept spot off Antikythera's rocky coast.[11]

Price remained undiscouraged and maintained his conclusions. In 1971 the Oak Ridge national laboratory published an article on the use of high-energy gamma radiation to examine the interiors of metallic objects. Price soon secured the assistance of the Greek Atomic Energy Commission in shooting gamma rays into the clumps of corroded bronze. He was able to produce photographic plates that not only allowed him to reconstruct the device but to ascertain its date of construction.[12]

The Antikythera mechanism was an arrangement of calibrated differential gears inscribed and configured to produce solar and lunar positions in synchronization with the calendar year. By rotating a shaft protruding from its now-disintegrated wooden case, its owner could read on its front and back dials the progressions of the lunar and synodic months over four-year cycles. He could predict the movement of heavenly bodies regardless of his local government's erratic calendar.[13] From the accumulated inscriptions and the position of the gears and year-ring, Price deduced that the device was linked closely to Geminus of Rhodes, and had been built on that island off the southern coast of Asia Minor circa 87 B.C. Besides the inscriptions' near-identity to Geminus's surviving book, the presence of distinctive Rhodian amphorae among other items from the wreck supported Price's deduction and date once Virginia Grace had re-examined the pottery recovered in 1901.[14]

Price's straightforward and viable analysis came despite a host of ideas the device's discovery should have dispelled. He was too concerned with what was before his eyes to realize that prevailing beliefs among historians of the period would lead others to slight or ignore what physics and archaeology had combined to discover. Price correctly noted that Rhodes was a center for astronomical thought. He mentioned Poseidonius, Cicero's friend and teacher, who built a much more complicated astronomical computer than the one recovered.[15] He was unaware of the widespread belief that continues to maintain that Rhodes in the first century B.C. was little more than a fading ghost of past glory, crippled economically by the competition of the Roman free port of Delos after 166 B.C.

It is neither facile nor uninstructive to remark that the Antikythera mechanism dropped and sank--twice. The second submersion came after Price's publication of Gears from the Greeks in 1975. Since that time little attention has been paid to our most exciting relic of advanced ancient technology. It was in the course of research into the navy of Rhodes that the mechanism first came to this author's attention, and it was that research and knowledge of extant flaws in earlier scholarship that allows this assessment of the significance of the device and Price's reconstruction.

Scholars before and after Price ignored and continue to ignore the length of Rhodes' enduring reputation among the ancients themselves as a center for intricate military and naval technology.[16] Rhodes had resisted the largest and most advanced weapons systems produced by the Macedonian warlord-inventor Demetrius. In 305 "the Besieger" sent a siege tower nine stories tall, pushed by two thousand men against the Rhodians' walls. Rhodes was a center for the construction and use of antiquity's heaviest and most intricate catapults. The historian Diodorus of Sicily would record how Demetrius's helepolis, or city-taker, had to retreat from one of the most intense artillery barrages of antiquity, burning from several direct hits with incendiary bolts.[17] The tradition of advanced technology on Rhodes continues to appear for centuries in the surviving historical records of the Hellenistic Age. Mithridates V of Pontus fared no better than the Macedonian attacker in his own onslaught of 88 B.C., in which he encountered what F.E. Winter considers to be one of the most formidable protected catapult batteries in antiquity.[18] Polybius, Strabo, and Aristides in later years attest to the legendary speed and surpassing deadliness of the ships and weapons built behind the wall of Rhodes neorion.[19] The pirates of the Mediterranean feared and fled before the war fleet of a single small island, and the last of the Greek democracies successfully warded off even Roman domination until 43 B.C.[20] Years afterward, the finest ships in the Mediterranean world could still be found in her shipyards.

In the light of the ancient literary evidence and the physical existence of the Antikythera mechanism, it is necessary for scholars of the period to discard the idea that Rhodes and her economy were ruined by the Roman actions concerning Delos. An impoverished, decaying backwater could not have provided impetus for such a mechanism, much less supported the minds that conceived it. Among other advances, the apparatus found among Rhodian coins and amphora contained a differential gearing system more complex to design than to build, and its presence among original bronzes, gold jewelry, and marble statues clearly attests to the buyer's recognition of its value.[21] The Roman Cicero reports that the general Marcellus prized an orrery, or analog planetarium, of Archimedes' more than any other booty from captured Syracuse.[22] The Rhodians could apparently build similar devices for export to such wealthy Roman buyers--including, possibly, Cicero, who knew Rhodes well and was governor of a neighboring province shortly before the ship was lost.[23] Further research into the island's history reveals additional nourishment for the speculation the Antikythera mechanism's existence prompts and should have prompted about Rhodes, ancient technology, and our study of the past in general. On Rhodes, Philo of Byzantium encountered and described the polybolos, a "machine gun" catapult that could fire again and again without a need to reload.[24] Philo left a detailed description of the gears that powered its chain drive and that placed bolt after bolt into its firing slot. Philo and scholars since have believed that the polybolos was useless because the Rhodians had convinced him that it was close range only and couldn't traverse from side to side.[25] The perspective of a naval historian can provide a kind of warfare where a fixed weapon at close range could be useful--in an era when ships routinely rammed each other. Anyone could have wondered why the Rhodians built and refined something so complicated if they had no idea of using it. Again, they conceived and built the Antikythera device, and someone else had thought enough of it to send it overseas.

The proof the mechanism offers of Rhodes' enduring technological expertise poses a question the device also helps to answer: What could have led to the construction of such an expensive and intricate device? Certainly the mechanical expertise that built the polybolos indicates the physical ability to build the mechanism. But what inspired the intricate theories and substantial body of astronomical knowledge that lay behind the mechanism? Rhodes even in its supposed "glory days" was chiefly famous for the abilities of its seafarers--and therein lies the answer. Very little indeed, is known about ancient celestial navigation, besides indisputable proof that it did, in fact, occur.[26] It is worth noting, however, that the man who invented trigonometry and first scientifically catalogued the stars' positions was Hipparchus of Rhodes; that in more than one ancient system of latitude and longitude the meridians crossed at Rhodes, and that a man Strabo rated second only to Aristotle--Poseidonius--found support for his travels and devices on the same island where Geminus did his writings, and inspired or built the Antikythera mechanism.[27]

There is a evidence for a clear tradition of scientific research on Rhodes, just as there is an anecdote preserved in by the Roman architectural authority Vitruvius concerning two engineers' competition for a city stipend.[28] Geminus's surviving book shows him making a determined effort to bring the transmitted data of the Babylonian astronomers to the attention of his Greek readers in the first century B.C. In the preceding century Hipparchus had laid the groundwork for Geminus's efforts to "popularize" Babylonian astronomy by working their surviving eclipse data into his own astronomical writings. Modern scholars of scientific history have yet to pay Hipparchus his due honor for his failure to construct a planetary system of his own even as he catalogued the observable stars. Although he had used observed parallax to make an extremely close estimate of the moon's distance from the earth, Hipparchus had the scientific honesty to state that there was insufficient data in his time to understand the true arrangement of the solar system.[29] The refusal of others to admit that hobbled scientific thought until well after Galileo's death. Geminus's contemporary Poseidonius did much more than build complicated astronomical devices of his own. One of the journeys celebrated and preserved by his friend and pupil Cicero took him beyond Gibraltar to the Bay of Biscay, where he was the first to note the connection between the tides and the moon phases Hipparchus had measured. He also possessed the novel theory that all the world's oceans formed a single body of water.[30]

Hipparchus, Geminus, Poseidonius--we must still search out details of what may well have been an analogue to our own and Britain's naval observatory, in competition and parallel with the state-funded research at Alexandria's museum. The Rhodians' immunity to the pirates of the Mediterranean continued long after their supposed post-Delian decline. The island could not feed itself, but the grain ships continued to arrive--possibly steering by starlight through the deep sea while the frustrated pirates hugged the coast. The Rhodian navy displayed in a long and distinguished operational history an almost uncanny ability to function and maintain unit cohesion at night. In 198 B.C. a Roman fleet eluded a Syrian squadron sent to intercept it by what seems to have been a difficult nocturnal cruise--shortly before two of its Rhodian escorts openly made a night voyage to locate an arriving Roman praetor.[31] In 88 B.C., directly before Price's date for the device's construction, the Rhodian admiral Damagoras set the world an unforgettable example of Rhodian courage and naval expertise. After eluding a Pontic blockade of the city's harbor, Damagoras led a force four times the size of his own on a day-long chase, pausing only before sunset to turn and sink two of the larger enemy vessels and disable two more. With the rest of the enemy fleet alert and positioned to intercept his return, Damagoras kept his command integrated and functional for an entire night on the high seas, and returned safely to blockaded Rhodes in the morning.[32]

The discovery of the Antikythera mechanism has much to offer besides tantalizing hints concerning state-funded research and technological expertise on Rhodes. The very existence of such a complicated gear train should also prompt fundamental change in the way the ancient sources are read. We have found the tracks for the emperor Nero's revolving ceiling, and the Tower of the Winds still stands in Athens, its clock faces empty, but its functioning success materially and textually preserved.[33] When Cicero, Ovid,[34] Plutarch and others speak of "celestial spheres" going back to the time of Archimedes, and describe their use, the Antikythera device's very existence should prompt us to something besides unthinking skepticism. Perhaps we should take a look at the

device and believe a little more of what we have been told. Wooden ships have been set on fire with sunlight,[35] and John Morrison's efforts to reconstruct the trireme demonstrate that the full complexities of ancient ship construction continue to elude us. When all the implications of Price's discovery are understood and acted upon, it will then be possible to say that we have begun to understand the Antikythera technology.
Cicero mused:
"Suppose a traveller carried into Scythia or Britain the orrery recently constructed by our friend Poseidonius, which at each revolution reproduces the same motions of the sun, the moon, and the five planets that take place in the heavens every day and night, would any single native doubt that this orrery was the work of a rational being?"[36]
With the evidence before our faces, do we continue to believe that Rhodes declined, the ancients were technologically inept, and that our sources can be easily discarded? Or do we accept the existence of ancient advanced technology, study its implications, and look for deeper meaning in what we have difficulty understanding? Much has been learned about ancient technology and ancient seafaring. With the right set of mind and purpose, it is clearly possible to learn a great deal more.

1. Peter Throckmorton, "The Road to Gelidonya," in The Sea Remembers: Shipwrecks and Archaeology from Homer's Greece to the Rediscovery of the Titanic, ed. Peter Throckmorton (New York: Smithmark Publishers, 1987), p. 20.
2. Throckmorton, pp. 14-16.
3. Throckmorton, p. 16.
4. Throckmorton, 16-18.
5. v. Throckmorton, p. 29 illus.
6. Throckmorton, p. 16; Victoria Jenssen, "Archaeology and Conservation," in The Sea Remembers: Shipwrecks and Archaeology from Homer's Greece to the Rediscovery of the Titanic, ed. Peter Throckmorton (New York: Smithmark Publishers, 1987), pp. 102-104.
7. Jenssen, p. 102.
8. Jenssen, pp. 102-105.
9. Throckmorton, p. 18; Derek J. de Solla Price, Gears from the Greeks : the Antikythera Mechanism: a Calendar Computer from ca. 80 B.C. (New York: Science History Publications, 1975), p. 10.
10. Derek J. de Solla Price, "An Ancient Greek Computer," Scientific American Vol. 200 No. 6 (June, 1959): 60-67, with some detailed reconstructions of the device's original appearance.
11. Price, Gears, p. 10.
12. Price, Gears, pp. 10-13, Throckmorton, pp. 18-20.
13. The Oxford Classical Dictionary, second edition, (OCD2) entry s.v.

"Calendar" only begins to describe pre-Julian chronological chaos between the competing regional states.
14. Price, Gears, pp. 8-9.
15. Price, Gears, pp. 56-9; Cic. Nat de. 2.34-35.
16. Dio Chrys. 31.104.
17. D.S. 20.96.3-97.3.
18. App. B.C. 4.66-7, Winter, p. 199-201.
19. Plb. 5.88.5, Str. 14.2.5 (653), Aristid. 25.4.
20. Str. 14.2.5 (653), Plb. 21.7.1-4.
21. Price, Gears, pp. 60-61.
22. Cic. De re pub, 1.14.21.
23. Cic. ad Att. 5.12.1, Brut. 1; Plu. Cic. 36.
24. Philo. Bel. 73. For reconstructions of the device, cf. Vernard Foley and Werner Soedel, "Ancient Catapults," Scientific American 241 (April, 1979): 155-6; J. G. Landels, Engineering in the Ancient World (Berkeley: University of California Press, 1978), pp. 123-7.
25. V. P. M. Ptolemaic Alexandria, 3 vols. (Oxford, Clarendon Press, 1972), 2.431.
26. Homer, Od. 5.233-40, Libanus, Progymnasmata, Sententiae 1.13.
27. Dicaearchus Fr. 33, Strabo Str. 2.1.1 (67), 5.7 (114), 2.5.19 (122-3), 2.5.39 (134).
28. Vitr. 10.46-48.
29. Pappus, Comm. in Alm. 4.11.66 f., ed. Rome, Almagest, 9.2, OCD2 s.v.
30. Str. 16.2.10.
31. Liv. 36.43.8; 37.14.3. App. Syr. 22, Johannes Hendrik Thiel, Studies on the History of Roman Sea-power in Republican Times (Amsterdam: Noord-hollandsche uitgevers mij., 1946), p. 301.
32. App. Mith. 25; FGrH 434 F 22.13-15.
33. V. Joseph Noble and Derek Di Solla Price, "The Water Clock in the Tower of the Winds," American Journal of Archaeology 72 (1968): 744-755.
34. Ov. Fast. 6.263-283.
35. C.A. Kinkaid, Successors of Alexander the Great (Chicago: Ares Publishing Company, 1980) p. 143.
36. Cic. De Nat. Deo. 2.34-5 (87-88), Rackham's translation.