An Encrusted Mystery: The Saga Of the Antikythera Mechanism

by W. Leonard Taylor, M.D.

Decoding the Heavens: A 2,000-Year-Old Computer—and the Century-Long Search to Discover Its Secrets
Jo Marchant
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To anyone who has even a tangential interest in the Antikythera mechanism, I highly recommend Jo Marchant's book *Decoding the Heavens*. My interest dates back to 1959, when Derek J. de Solla Price published an article in *Scientific American* entitled "An Ancient Greek Computer." I was amazed that such a complex mechanism of antiquity was not better known. Unfortunately, it still remains obscure.

Through the years, the published papers on the mechanism have increased asymptotically. Jo Marchant has done a great service to the present generation, by condensing and presenting it in an interesting way. I fervently hope this book will finally cause the teaching of history to no longer omit the most significant discovery of antiquity, and allow it to be given the emphasis it deserves.

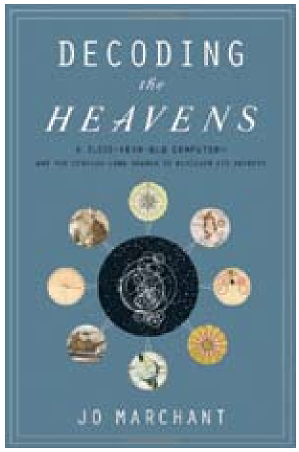
Here, I summarize the story, as told in *Decoding the Heavens* and selected other sources listed in the Bibliography.

The saga of the Antikythera is about an incredibly miraculous chain of events. The ending is still in progress, but it has revolutionized our understanding of the genius of antiquity. This report, for the most part, is not about mechanical detail, but rather about the people who strived to make the incomprehensible comprehensible—and how their lives were forever changed, as they unraveled a creation historians could not believe and still have trouble accepting.

Never before has there been a discovery so long enshrouded in mystery, which, on being unraveled, resulted in such an unparalleled shift in traditional historical thought regarding the genius of deep antiquity. Without this information, the world would have been left with a fateful historical blunder.

How It Began

My interest in this saga began in June 1959, upon reading that article in *Scientific American* entitled, "An Ancient Greek Computer." By contrast to men who literally gave their lives in the study of the mechanism, mine was limited in trying to keep up with the literature, and a trip to Athens to see the instrument in



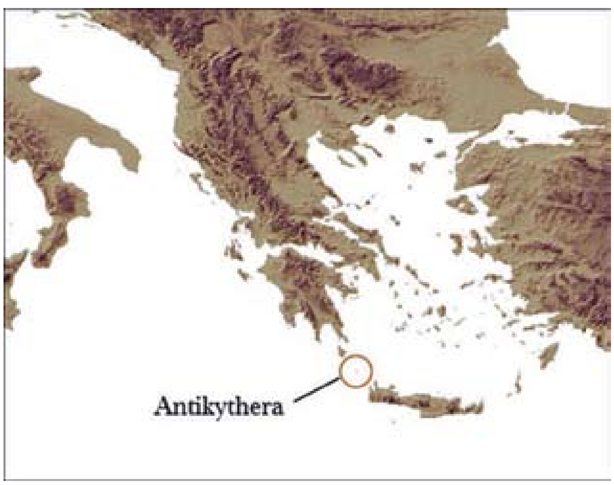
person. Articles were few and far between for about three decades, gradually leading to a trickle of information.

Then, about 15 years ago, it became a torrent. So much so, you would think that everyone in the world knew about the Antikythera mechanism. But even to this day, as monumental as this object is, one finds that most individuals have never heard of it.

A 300-ton ship, laden with magnificent marble and bronze Greek artifacts set sail from Pergamon in about 60 B.C., headed for Rome. This was a period of transition in which the Roman Empire was in ascendancy. The wealthy were decorating their villas with coveted works of Greek art, and this ship was filled with objects to satisfy the demand.

On this journey, the first of a long series of unanticipated events occurred. First, a great storm arose causing the

The harbor at the island of Antikythera, where sponge divers in 1900 found the ancient wreck from ca. 60 B.C., with its load of Greek artifacts, including the torquetum device.



A view of the Antikythera mechanism found in the ancient ship.

overloaded ship to take on water. The ship and all its artifacts began to sink. But instead of going to the bottom, the ship came to rest on a narrow ledge, 130 feet below the surface, on the side of a tiny island, where it lay avoiding detection for more than 2,000 years, while Empires were formed, grew, and crumbled.

Historians pontificated: It was universally agreed that the Greeks could never have made the mysterious object, which was subsequently found on board that ship. Therein lies the crux of this tale. The historians now have been proven wrong, and the genius of the Greek civilization has been firmly established. The impact this has had on understanding the scientific knowledge of the Iron Age is beyond monumental, as author Jo Marchant shows.

During the 2,000 years it lay hidden in the sea, it escaped destruction, along with many other creations of the demonized Greek civilization. So its watery 2,000-year sequestration constitutes another link in the chain of fortunate coincidences.

The discovery was made by a group of very hard working sailors, who made their living harvesting sponges. Their profession resulted in high mortality and morbidity, because of a danger they had no way of understanding. They knew, of course, the agonizing afflictions and frequent death of their fellow divers, but the high demand for sponges made for high incomes of those that survived.

This affliction we now know to be caused by bubbles from nitrogen dissolved in the blood under the pressure of the deep water. The nitrogen in the dissolved state is actually not the main cause of the problem. It is rather due to a phenomenon the modern world observes every day as they open a can of carbonated beverage. There is an instantaneous formation of bubbles.

The bubbles that form as the can is snapped open are caused by the dissolved carbon dioxide gas that was forced into the liquid under pressure during manufacture. In the situation of the sponge divers, it is dissolved nitrogen, the main constituent of the air we breathe, which is forced into the blood stream under the pressure of the deep water. The release of this pressure, like snapping the lid of a pop bottle, happens if the diver surfaces too rapidly, producing bubbles in the blood stream.

The tiny bubbles aggregate, causing blockage of flow of blood through the small blood vessels. These small blood vessels are precisely where oxygen is transferred to the tissues, to keep the tissues alive. The tissues then become necrotic, resulting in agonizing pain and death. This condition is known clinically as the bends.

Sponge-diving had been a constant source of income from before the time of Homer, about 1000 B.C. The divers could descend to 90 feet below the surface. The duration of their dives was limited by their lung capacity, so, of necessity, was of short duration. This prevented the divers from developing the bends. Short-duration dives are not a risk, because it takes time for the nitrogen to go into solution.

This all changed in 1837, when a prolific German inventor by the name of Augustus Siebe invented a diving helmet attached to a watertight suit. Air was pumped down by a compressor. Now the divers could go down to 220 feet and remain there. By about 1865, the suits were brought to Symi, the home of most of the sponge divers.

Fortunes were made. Of course, it was all too good to be true. No one there knew at that time about the bends, although it had been described in the 1840s in miners, and in people working on the footing of bridges. The name "bends" came from the tortured body position, some of which simulated a popular pose known as the Gratian Bend.

Between 1886 and 1920, about 10,000 divers died and 20,000 were paralyzed. One can imagine the adverse impact this had on the families and lives of the sponge divers. Subsequently, most of the helmets and the suits were abandoned throughout the Mediterranean Sea.

The Discovery

A group of sponge divers, returning from Tunisia in the Summer of 1900, risked death by continued use of the helmet. They travelled in small boats, carrying 15 divers who would share one battered helmet. When they reached the passage between Cape Malea and Crete, they encountered a great gale. Captain Kontos, sought shelter off a small island.

Three days later the shrieking wind in the rigging began to abate and calmness returned to the surface. So there they were, next to this small island, in a region noted for its lack of sponges. They were tired, with a boat full of sponges gathered in Tunisia, and eager to go home. Then the last thing one would have expected happened.

Elias Stadiatis, one of the divers, had an unusual thought. We will never know exactly why, but he decided to dive.

This dive forever changed the world! To the amazement of those on deck he surfaced in just 5 minutes in a very agitated state. He was convinced that a ship had recently sunk depositing a heap of naked women. Captain Kontos immediately went down and discovered a 150-foot-long deposit of bronze and marble statues, corroded and encrusted with marine sediment.

Kontos resurfaced, carrying of all things, a bronze arm. The finding of a bronze arm from a statue generated tremendous excitement in Athens and throughout Greece. The bronze arm dated the wreckage to be at least 2,000 years old.

An 1873 newspaper illustration of the Siebe diving invention, which made it possible for sponge divers to descend 200 or more feet.

Within days, a Greek navy transport, bearing Kontos, his divers, and an archaeologist, arrived at the site. It was November 24, 1900. As the artifacts were transported to the National Archaeological museum, crowds came from long distances to see the treasures, corroded as they were. Every day, newspapers carried the unfolding drama, in scintillating detail. It was the largest find of ancient Greek bronzes ever found.

Then problems arose. The divers were having problems finding more artifacts, partly because so many had been taken out, and partly because large boulders obscured the objects. The archaeologist determined that the huge boulders had been dislodged by an earthquake and fallen from the cliffs above the water.

A scheme was devised to pull several of these monstrous boulders over the subterranean ledge into the abyss below, which extended down to 11,600 feet. Fortunately, another archaeologist, Spyridon Staïs, came aboard. He had another idea. Could those boulders be colossal statues so overgrown that the divers could not recognize them. And that is exactly what they were!

For the next 40 years, the experts argued the age of the artifacts, and wound up with a very wide range, spanning the 2nd Century B.C. to the 3rd Century A.D. There was great interest in knowing the date, because taken out with the statues was an encrusted bronze mystery, the likes of which had never before been seen.

The Antikythera Emerges

The object would take more than a century to unravel. It became known as the Antikythera Mechanism because the small island's name, where Captain Kontos had sought shelter, was Antikythera. The name comes from the island's close physical distance to a larger, nearby island by the name of Kythera.

Then came another calamity. Bronze, which is 90 percent copper and 10 percent tin, is relatively safe so long as it remains in seawater. Had it been constructed of iron, it would have soon become an amorphous lump of sludge.

But by a fortunate coincidence of inorganic chemistry, seawater reacts with the copper in the bronze, forming copper chloride. Tin in seawater forms tin oxide. The two compounds form a thin protective film of copper chloride and tin oxide on the surface of the bronze, protecting it from damage. So it would seem that all was well.

However, removing the bronze from the sea results in a series of chemical reactions in which the oxygen from the air, along with moisture, reacts with copper chloride, forming hydrochloric acid. This acid attacks the underlying bronze to form more copper chloride, which again reacts with the oxygen in the air to form more hydrochloric acid. This will go on forever destroying the bronze and whatever object it is made into.

This fate nearly became a reality as this object remained in a crate in the open courtyard of the National Archaeology Museum. It could have remained unnoticed and would have self destructed, except by a chance coincidence of a museum worker eight months later, who picked up the decaying lump and carried it to the museum director, Valorios Staïs.

The outer layers of the artifact had been completely destroyed. The slightest touch caused the powdery material to crumble beyond recognition. Staïs was an ambitious well-trained individual who had studied medicine and archaeology, and became director of the prestigious Archaeological Museum at the age of 30. Since 1889, he had been working on arranging and displaying the artifacts that found their way to Athens.

This object was completely different. He had never seen anything like it. Recognizable gear wheels were present. Author Marchant comments, "The overall effect was eerie and otherworldly, like finding a steam engine on the ancient pitted surface of the Moon."

The cogs and gears had small carefully crafted teeth that required a magnifying glass to count. Staïs was overwhelmed. This mechanism had to be 2,000 years old. But it couldn't be. Nothing like it had ever before been discovered in antiquity. Besides, the Greeks were not supposed to have this degree of sophistication. Clock works didn't show up in Europe for another 1,000 years.

Staïs knew he was in over his head. He made contact with two expert consultants: John Svoronos, director of the National Numismatic Museum of Athens, and one of the most serious archeologists in Greece; and Adolf Wilhelm, a brilliant young Austrian expert in inscriptions, who was in Athens at the time.

Wilhelm determined the device to be dated between the 2nd Century B.C. and the 2nd Century A.D., while Svoronas dated it to the first half of the 3rd Century A.D. Svoronas worked with Pericles Rediadis, a professor of geodesy and hydrography, who provided the first technical account of what he called "this completely strange instrument."

Svoronas noted that the instrument was carried in a wooden box, and decided it was not a piece of cargo, but rather a navigational instrument. He put great weight on a very unusual technical Greek word referring to a graduated scale. This launched speculation that this object was some sort of astrolabe, an instrument dating back into antiquity, which could find the time and position of the Sun and stars. Astrolabes were not used aboard ships to any great extent, as they could not give longitude or latitude.

Not an Astrolabe

During the next few years, scholars at various archaeological institutes became involved in trying to understand what this device was. The battle heated up as to whether this was or was not a modification of the Astrolabe. Then, Albert Rehm, an investigator from the University of Munich, discovered a previously hidden Greek word, "Pynchon." Derived from an ancient Egyptian Calendar, Pynchon means month.

Astrolabes had nothing to do with months; therefore, the mechanism had nothing to do with Astrolabe technology, as Marchant discusses.

The work on the object was completely stalled by the First World War. Then, John Theophanidis, an admiral in the Greek Navy, became interested, and found what he thought was a zodiac scale. He became convinced that the Antikythera was a navigational instrument. He spent many years studying and analyzing the inscriptions, and constructing a model of the gear work. His work became so passionate that he sold his real estate in the center of Athens to finance his research. But, unfortunately, he didn't publish, and his years of work lay hidden in piles of papers after his death.

Many other individuals subsequently made contributions, but their story must regrettably be omitted from this review. In the meantime, Albert Rehm, who had found the word "Pynchon," had become a rector at the University of Munich. His increasing recognition came during the rise of Hitler, and he eventually lost his position because of his hostility to Hitler.

After the war, Rehm was reinstated, only to lose his position again in 1946, after a disagreement with the new authorities regarding the importance of classical studies in German education. Despite his academic dissonance, for the rest of his life, Rehm constantly studied and analyzed the geared mechanism. But its mystery eluded him; the keystone paper was never published, and he died in 1949.

During the Second World War, this priceless mechanism was in great peril as the Nazi invasion of Greece put everything in the museum at risk. The museum staff hid objects in caves and in bank vaults, buried them in underground deposits, or hid them under the floors of the museum and covered them with sand. After the war, it took 20 years to get the museum back together. In the confusion, many of the artifacts had been lost. But, by another miracle, the Antikythera mechanism survived.

The previous excitement was gone, however, and the device was largely forgotten, languishing in the bottom of a storeroom box.

More Discoveries

During the 20 years that the museum was reorganizing, important things were happening. Jacques Cousteau and Frederic Dumas visited the underwater ledge with their improved diving equipment, once in 1953 and again in 1976. They found additional objects, but their main contribution was a chance finding of two stacks of coins, one silver and the other bronze. These finds resolved the questions of previous efforts to date the sinking of the ship, and to determine where it had been before it departed on its ill-fated voyage.

Inscriptions on the coins tell who issued them. This information, along with the fact that the coins do not stay in circulation for very long, helps to determine date, better than anything else. The silver coins were from the city of Pergamon and had the initials of a ruler who ruled in Pergamon from 85 to 76 B.C. The bronze coins were from Ephesus, 100 miles south of Pergamon, and were dated from 70 to 60 B.C.

During this period, an American archaeologist, Peter Throckmorton, was working at the museum in Athens, and one of his goals was to get a fragment of wood from the boat tested by radiocarbon dating. He had an impatient personality that did not always follow accepted protocols, and was frustrated that the museum staff refused to let him take away some of the wood from Athens.

However, he managed to spirit away a tiny fragment to the laboratory of Elizabeth Ralph, in America, one of a very few scientists who knew the technique of radiocarbon dating. The radiocarbon dating of the boat gave an age of 260 B.C to 180 B.C. Keeping in mind that the boat was made of wood older than the boat itself, and that the boat had likely been sailing for some time before it sank, there is excellent correlation of the radiocarbon and coin dates.

Of interest is the construction of the boat. It was similar to techniques that had lasted for 3,000 years. In contrast to the modern, less expensive techniques, in which the frames are built before the planking, in this boat, the hull was built first and then the frame. Furthermore, the hull was built with the labor-intensive mortise and tenon construction used in fine furniture, which made for a very strong sturdy ship.

Another captivated individual was Derek J. de Solla Price whose article had caught my attention in 1959. He was born in 1922 in England, and obtained a Ph.D. degree in experimental physics at age 24. He went on to obtain a second Ph.D. degree in the history of science. Then he came to the United States as a consultant to the Smithsonian Institution, and a fellow of the Institute of Advanced Studies in Princeton, spending the remainder of his life at Yale University.

Price took interest in the Antikythera Mechanism in 1951. His great contribution, in addition to understanding this instrument, was to popularize it. Despite his work in other areas of science, the Antikythera mechanism was always on his mind. He spent inordinate amounts of time counting the teeth in the gears and attempting to make sense of their interrelation. Price said: "Nothing like the

Michael Wright, a curator at the London Science Museum, who became fascinated with the Antikythera mechanism, and spent years piecing together the puzzle of how it worked, and what its purpose was. The photo is from his presentation, "The Greek Planetarium: A New Reconstruction of the Antikythera Mechanism," an American Institute of Archaeology Lecture Program, at the Adler Planetarium in Chicago, October 2006.

instrument is preserved elsewhere. On the contrary, for all that we know of science and technology, it could not exist."

Price did not win friends by telling those who had carefully studied a subject all their lives that they were wrong. But he knew that his own conclusions had a high chance of error because of his limited information. When he read a technical report from the Oak Ridge National Laboratory on how gamma rays could be used to study archeological objects without destroying them, he wrote to the lab director, Alvin Weinberg. Weinberg put Price in contact with a radiography lab in Athens.

As so often happens in science, such networking leads to a major discovery. Deep within the encrusted object were even more gear trains than had been expected. Getting the newly discovered gears to make sense in terms of the periods of the Sun and Moon led Price to only one conclusion: He was convinced that he was looking at a differential gear train!

Enter Michael Wright

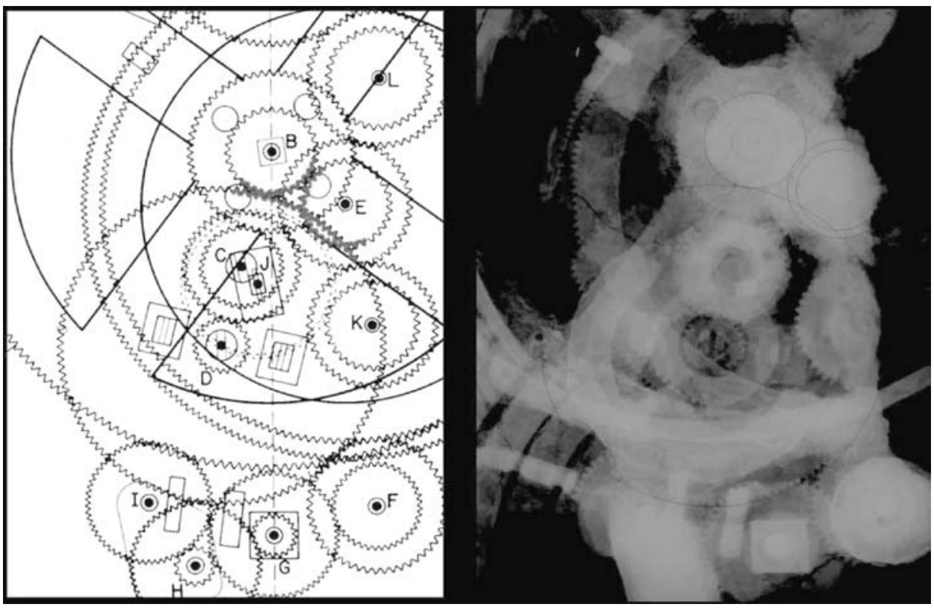
Without Price's enthusiasm and drive, it may have taken decades longer to piece everything together. Price's last paper, "Gears from the Greeks," sparked another life-long obsession with the Antikythera Mechanism. This time, the torch was passed to Michael Wright, a 26-year-old assistant curator at London's Science Museum. Price moved on to computer technology and artificial intelligence, while Wright scrutinized every detail of Price's publications.

Questions arose about the differential gears supposedly used to calculate the phases of the Moon. The emphasis Price had given in his earlier *Scientific American* article to the motion of the planets, was hardly mentioned. In 1983, Wright wanted to discuss things with Price on his next visit to the Science Museum, but unfortunately, just at that time, Price died.

As Wright studied Price's work, more and more details worried him. In particular, he found that Price had discounted and altered many of the tooth counts. Wright had studied carefully the ancient clocks in the Science Museum and understood gear trains well. Price's conclusions didn't make any sense.

Price had argued that a particular dial exhibited a 4-year cycle, but Wright noted that the mechanism had 7 gears and a dial of 7 concentric rings. Why, Wright wondered, did someone go to all the trouble? Price had a lot of insights, but Wright could see that he had barely scratched the surface. As Wright dreamed of going to Athens, he studied ancient astronomy and brushed up on his Greek.

Then, an energetic astrophysicist from the University of Sydney, Allan G. Bromley, came into Wright's life. His expertise was interstellar gas, which required high-power computing, and so he studied the history of computation. In the course of this work, he became aware of Charles Babbage, who had worked with the famous astronomer John Herschel in the early 1800s.



An X-ray image of the Antikythera gears with one of Wright's gear diagrams.

Through Herschel, Babbage saw the tremendous need for precise astronomical tables. So Babbage, then a 29-year-old mathematician, began a project to do just that. He filled numerous notebooks with notes and drawings of his ideas, and the British government paid a fortune to Babbage to produce this machine.

Although none of these machines was completed, the London Science Museum held the largest collection of Babbage's work, and Bromley would spend his Summer vacations there in London. By the mid-1980s, he understood enough of Babbage's notes to start construction, but he had questions about how the parts would have to be made and assembled.

Wright's handsome working model of the Antikythera mechanism.

Wright, a highly intelligent curator and a master craftsman, knowing clocks inside and out, was assigned to work with Bromley on assembling one of Babbage's calculating machines. With Wright's insights, a most ambitious scientific reconstruction began, costing a quarter of a million British pounds. By November 1991, their computer turned out its first calculation, one month before the bicentennial celebration of Babbage's death. During Bromley's many visits to the London Museum of Science he and Wright became friends, and Wright introduced the Antikythera Mechanism to Bromley.

At the same time, Wright talked of his dream to go to Athens and study the mechanism firsthand. Price's paper was discussed and Wright indicated the areas where Price had gone wrong. Immediately, like many before him, Bromley became totally captivated. His mind began to form a new plan of action. He would be the first man to solve its mystery.

Bromley returned to Sydney and put together a working alternative sequencing of the gears. Wright, by contrast, was even more rapidly losing faith in Price's reconstructions. Just before Christmas 1989, Bromley suddenly burst into Wright's office announcing he had just returned from Athens where he had obtained permission to work on the Antikythera mechanism!

This was more than Wright could bear. How could this man from Australia, his friend and confidant, steal his ideas? There was a written code of Greek antiquities that no researcher could begin work on an artifact until the person already working on it had finished. But then the nature of Wright's character and dedication broke though, overrode his depression. He went to Bromley and asked if he could go to Athens—as his assistant.

Bromley agreed, and for the next 30 days they photographed and measured everything in detail. It became clear that Price was wrong in many important details, and his model had to be discarded. Additionally, a new fragment was discovered, not known to Price. Standard X-rays were taken of every fragment. But for unexplained reasons, the images were fogged and discolored. The team ran out of time and left disappointed.

Later in England, Bromley gave a lecture to the Antiquarian Horology Society, and referred to the project as if it were entirely his. Despite this belittling of Wright, Bromley's lecture had a positive outcome. In the audience was a retired physician who had a real interest in Price's work and had attempted a reconstruction, Dr. Alan Partridge.

Partridge suggested they use a technique called linear tomography that he had used to locate bullets and shrapnel. With it, the X-rays could be reconstructed to see deeply into the interior of a human at sequential levels. Wright then studied tomography and built an improved linear tomograph suitable for metal. It worked beautifully, resulting in separating the layers to less than a tenth of a millimeter.

The next year, Bromley and Wright were back in Athens with Wright's tomography machine. Their first task was to find out why the X-ray images were fogged. The culprit was an incredibly careless technician using extremely old chemicals. Wright took over the darkroom work while Bromley took the photographs. They repeated this routine every Winter, and after three years, they had taken and processed 700 exposures. Wright knew that the films would provide the answer.

But then Bromley dropped a bombshell: He was taking the tomographic X-rays back to Sydney, leaving in February 1994. After five years of hard work, Wright was horrified and totally depressed. The years went by, and correspondence from Bromley had trickled to a stop, when an unexpected letter came from Bromley's wife. "If you want to see him, you have to come soon." After an invitation arrived from Bromley himself, Wright left for Australia in November 2000, with great misgivings.

It was nearly 10 years since they had begun their work together and six years since he had seen Bromley. His on again/off again friend was dying of Hodgkin's lymphoma, but even then Bromley tenaciously refused to release the films. Mercifully, Bromley's wife intervened, allowing Wright to bring the majority of the films back to England. Bromley died in September 2002.

Back in England, Wright was working nights and weekends publishing significant discoveries. By now, Wright's son was at Oxford University where he had the equipment to scan the radiographs at high resolution. At the end of 2003, things were really starting to move. Wright discovered what is known as a pin and slot component in the mechanism, which predated by 1,500 years anything like it in

Europe.

Then, another Antikythera-obsessed scientist came on the scene, an English mathematician and filmmaker, Tony Freeth. With the urging of Mike Edmonds, chief of astronomy at Cardiff University, Freeth was trying to get access to the fragments, but according to protocol, this was not possible while Wright's work was ongoing. Freeth had read Price's publications, and, like Wright, saw that the details didn't add up.

Mathematician and filmmaker Tony Freeth, who also took up the challenge of solving the Antikythera mystery. He raised the funds to provide the new technology of micro X-ray imaging to scan the Antikythera fragments, providing images with resolution down to a few thousandths of a millimeter.

Soon Freeth was beyond obsessed; not only was he going to make a film about it, but also, like Bromley, he was determined to be the man to solve the mystery. As he researched the project he became aware of Wright's publications, and mistakenly considered the technique too crude to be useful. But this led him into discovering the usefulness of micro X-ray imaging, and Roger Hadland's X-Tec Company that made micro X-ray equipment.

Freeth also read about the incredible technique developed at Hewlett-Packard by Tom Malzbender, which made it possible to read unreadable ancient clay tablets from the 4th Millennium B.C. Malzbender was working in computer graphics in Southern California. So, Freeth had two state-of-the-art companies to work on the Antikythera mechanism—but he had no money, and no permission to study the mechanism!

Freeth intensively lobbied the science community, and amassed a team of scientists, including Greece's most eminent astronomer and astrophysicist at the University of Athens, and the director of the Center for History and Paleontology. By 2005, the team had persuaded the soon-to-be-founder of Unilever to fund the project.

To gain access to the mechanism, the astrophysicist ceaselessly lobbied the Greek Ministry of Culture, and through his persistence, in June, the Ministry finally permitted Freeth to have access to the fragments for the month of September. This brought the high drama of the Antikythera mechanism to a head. It was 2006, and Wright, after a lifetime of work, was very close to solving the mystery.

Meanwhile, Freeth had to convince Roger Hadland at the X-Tec Company to make a suitable X-ray machine for investigating the fragments. This would have to be two times more powerful than anything in the world, and ordinarily would take two to three years to build. Hadland accepted the challenge. He shut down the other work of his company and put all his research and development staff on the new project.

Freeth was in a state of panic as September approached. Would Hadland be able to produce the equipment necessary to do the job? Freeth's anxiety was increasing as Wright's papers systematically were taking the wraps off the great archeological secret, and Freeth worried that there wouldn't be anything else to discover by the time they could bring all his team's expertise together.

Then in the process of improving the museum catalogs, another three large fragments and many small fragments of the mechanism were found, for a total of 82! If these fragments had been available to Wright, he probably would have by that time, solved the mystery. It was now September 2006, and the X-ray machine lay in pieces all over Hadland's research floor in England. Malzbender was already in Athens, and in seven days he had taken 4,000 photographs.

Hadland's team was working night and day, with only one week left. But the meters on his machine were registering only one tenth the voltage needed. When he yanked a cable from the generator, there was a terrific explosion. Fortunately, no one was hurt. The near-lethal explosion told Hadland that the generator was working just fine, and the fault must be in the recording instruments.

In what seems to be a miracle, within two days the apparatus was fixed and packaged for shipment—all 12 tons of it. After truck transport across Europe, the 20-meter long rig made it to Athens, where it required a police escort to clear the narrow streets of traffic. With the aid of three forklifts, all the equipment was finally packed into the research room. In one hour, Hadland collected 3,000 images, and then scanned all the fragments.

The pictures were spectacular, with resolution down to a few thousandths of a millimeter. Freeth's team had increased the number of legible characters to approximately 3,000. It is estimated there were originally 15,000. They found that operating instructions were written directly on the instrument!

Freeth's major contribution came in realizing that the apparatus had the capability of predicting eclipses. And six months later, he realized that also built into its gears, with the pin and slot, was the measurement of a nine-year lunar cycle, tracking its elliptical orbit around the Earth. Wright had predicted it, and Freeth had proved it.

Freeth set up a conference in Athens to announce his findings on Nov. 29, 2006, and he invited Wright to speak. Wright had completed his working model of the Antikythera mechanism, to present at the conference. More than 500 people were in attendance, and they gave Freeth a standing ovation.

Wright then gave a half-hour presentation: "…I have conducted [my research] on my own time and my own cost in the face of professional and personal difficulties: intrigue, betrayal, bullying, injury and illness, loss of years of my data, the long illness and death of my collaborator, and more…." Then Wright paused, and said, "Even so, I am still here."

Wright challenged Freeth on several points, which although contested at the time, were later found to be true. At dinner that night, Wright, Freeth, Hadland, Malzbender and others were sitting at the same table. The encrusted mystery had finally given up "most" of its secrets, and history was rewritten.

I use the word "most," because there is at least one more consideration. This is related to a proposal by *21st Century Science & Technology* Associate Editor Rick Sanders that the device had the potential to determine longitude aboard ship. I

Fragments of the Antikythera mechanism on display at the National Archaeological Museum of Athens. A short film of the mechanism can be found here and here. A virtual reconstruction of the mechanism by Wright and Mogi Vincentini can be found here.

have been in personal contact with Sanders regarding this proposal because of my interest in celestial navigation. He has studied how the ancients used the Moon in the determination of longitude.

The story, as told in *21st Century* magazine, is that around 232 B.C., Captain Rata and Navigator Maui set out from Egypt to circumnavigate the Earth. Maui's expedition was under the guidance of Eratosthenes, who had, by other means, determined the Earth to be a sphere with a circumference of 24,500 miles. Maui had with him an ancient navigational instrument that he called a Tanawa, later called a Torquetum, and he would have used tables brought from Alexandria drawn up by Eratosthenes.

If a known star is in a given position on the celestial sphere (measured by azimuth and right ascension), a table can be drawn up at a given location for each night, showing how distant the Moon appears to be from the star. And from this, a longitude can be determined. We know that Maui and Rata travelled as far as Irian Jaya, in Western New Guinea. Here, there is a cave, on the walls of which are drawings, left by Maui, of his Tanawa. Also on the walls was written out a proof of Eratosthenes' experiment to measure the Earth's circumference.

Farther east, in Chile, more evidence of Maui's trip is reported. Discoveries were made on Pitcairn Island, with evidence that they were there to observe an eclipse predicted by Eratosthenes.

The Antikythera mechanism, as we know, was constructed with the motion of the Moon integrated in amazing detail, including its elliptical orbit and oscillations. From the work of Wright and Freeth, we know the instrument was capable of depicting the positions of the stars, the planets, the Sun, and the Moon, and in predicting the eclipses of the Sun and Moon, as well as giving the dates of the Olympic games. But why, as Sanders asks, was so much attention given to the intricate detail of the Moon's celestial mechanics. What would justify the creation of a "Mount Palomar" instrument, to be carried on a ship?

Was it there as cargo, or more importantly, was it an aid to navigation? From a navigational standpoint it has two significant capabilities: one is to predict eclipses and the other to forecast lunar distances among the stars and planets, both of which are critical for determination of longitude. As noted earlier, one must have tables as a point of reference to reduce the sights. The advantage of a geared mechanism is that it provides a portable almanac, which would make tables unnecessary.

In modern times, we know that in 1802, Nathaniel Bowditch published a comprehensible method by which the Moon could be used to determine longitude. This revolutionized the spice trade and provided a great economic advantage for the newly formed United States.

It wasn't until accurate, affordable mechanical clocks capable of maritime use were introduced in 1850, that the Moon was no longer used for longitude determination. Sanders's work with the Torquetum, using the Moon in the determination of longitude, should refocus discussion on longitude as the real reason for the Antikythera mechanism.

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