their discovery many other ancient wrecks have yielded precious finds, such as the first-century BC galley loaded with marble pillars discovered in 1907 off the coast of Mahdia, Tunisia, and a Greek ship from around 0 AD found at Cape Artemision with some of the finest ancient bronze statues known, from the classical height of the art in the fifth century BC. Other wrecks have been more scientifically excavated than Antikythera was, and can therefore tell us much more about the way of life on board, such as a Bronze Age ship which sank off Turkey's Cape Gelidonya carrying a cargo of copper ingots from Cyprus. But although many of the treasures from Antikythera have since been matched or even eclipsed, the ship from which they came retains its well-deserved place in history as the first wreck ever to be explored by an archaeological expedition, and the courageous efforts of the sponge divers remain as awe-inspiring today as they were in the 1900s.

That, though, is only the beginning of the Antikythera story. As the salvaged objects from the wreck arrived back in Athens, busy museum staff struggled to cope with the huge influx of artefacts, as they tried to piece together the larger statues and vases. So nobody noticed a formless, corroded lump of bronze and wood lying in one of the courtyard crates. But as the wood dried and shrivelled over the next few months, the secrets inside could contain themselves no longer. The lump cracked open to reveal traces of gearwheels embedded in the newly exposed surfaces, along with some faint inscriptions in ancient Greek.

2

An Impossible Find

To the antiquities brought up from the bottom of the sea at Antikythera belongs a completely strange instrument, whose purpose and use are unknown . . . It is nevertheless very similar to the gear wheel system of a simple modern clock.

— PERICLES REDIADIS

ONE HUNDRED MILLION years ago reptiles ruled a fiery Earth. Dinosaurs terrorised the land, while flippered icthyosaurs and plesiosaurs patrolled the oceans and pterosaurs fought with fast-evolving birds for domination of the skies.

All around them, the planet's crust was punctured by unusually violent volcanic activity. In fact, many believe that climate change caused by the flames eventually contributed to the dinosaurs' destruction, clearing the way for the rise of mammals. The impact of the giant eruptions was just as great beneath the sea. The mid-ocean ridge – an underwater mountain range formed where the Earth's tectonic plates join – was forced open by the strong currents in the hot mantle beneath. Seawater crept down into the cracks and mixed with the molten rock, dissolving minerals from it before being ejected from hot springs that burst up through the ocean floor; the pressure at such depth keeping the water liquid despite temperatures of hundreds of degrees.

The huge scale of this activity enriched the oceans with calcium, which plankton use to build their intricate skeletons of calcium carbonate. As millions of generations of plankton lived and died, more calcium carbonate was deposited in the oceans than ever before, forming the extensive beds of chalk (the White Cliffs of Dover included) from which this period, the Cretaceous, got its name (*creta* is Latin for 'chalk').

The superhot springs also carried dissolved sulphides of iron, copper, zinc and nickel. These precipitated out as dark solids as soon as they hit the cold seawater, forming angry black plumes of undersea smoke, which formed deposits of ore on the seabed wherever they settled. Normally these deposits were recycled back into the mantle beneath – the rock of the deep ocean bed is denser than the continental crust that forms the land and shallow seas of our planet, so when tectonic plates clash and the oceanic crust meets the continental crust, it's the oceanic rock that gets pushed down. On occasion, however, a piece of this ancient seabed peeled away and landed on top of a piece of continental crust, where over time it was forced up into the mountains.

And so a piece of oceanic crust from the ancient sea that separated Europe and Africa in the Cretaceous now forms the picturesque Troodos Mountains of Cyprus. Jump forward

to just 5,000 years ago: the dinosaurs are long gone and people have inherited the gifts of the Earth. The islanders of Cyprus have learned how to smelt copper from the rich stores of blue-black sulphide ore they find in the forested slopes, using it to make tools, jewellery and weapons. Later they will make a fortune selling copper to traders – Phoenician, Greek, then Roman, who will carry ingots of this valuable metal far across the Mediterranean Sea to Greece, Italy, Asia Minor and Egypt.

The mountains of Cyprus are young upstarts, however, compared to the wise old rocks of Cornwall, south-west England. The granite of Cornwall cooled during the Devonian period, around 400 million years ago, when the first fish evolved legs with which to crawl on to the land, and the first ammonites and trilobites colonised the sea. Before the granite completely solidified, hot magma bubbled from below and forced itself up into vertical fissures in the cooler rock. The minerals in the magma crystallised as they cooled, leaving behind lodes of colourfully named and valuable ores, including wolframite, chalcopyrite, sphalerite, galena and especially cassiterite – an oxide of tin.

Jump forward again and, as with Cyprus, traders from all over the Mediterranean come to Cornwall to purchase the smelted tin. They collect it at the tiny rocky island that will one day be called St Michael's Mount and carry it back to France, where they load it on to horses and travel overland for 30 days until they reach the mouth of the Rhone, where ships will continue the journey to the sea.

Although copper was at first widely used for weapons and utensils, it was quite soft and easily dented. A copper axe would not keep its edge for very long and a copper shield would soon wear down against sharpened stones. Then, probably in several different places at several different times, someone realised that adding a small proportion of tin to the copper, around 10 per cent, made it stronger and harder. It also lowered the melting point of the new metal, giving smiths more time to cast it as it cooled. Knowledge of this new alloy – bronze – spread around the world, ushering in the Bronze Age, which in the Mediterranean began around 2500 BC.

Advanced metalworking techniques were developed and complex networks of trade, supported largely by the markets in copper and tin, stretched from Africa and Asia Minor to the north of Europe. The glint of bronze was everywhere and the people of the Mediterranean were richer than ever before.

It didn't last. Somewhere around 1200 BC everything collapsed. Why this happened is one of the most controversial questions in ancient history – theories put forward include economic decline, climate change, earthquakes and invasion – it may even have been a combination of all of these. Whatever the cause, trade stopped, kingdoms fell apart, skills such as navigation, metalworking and literacy were lost and the region was plunged into a dark age from which very few records survive. Without the trade networks to unite copper and tin, bronze was hard to get hold of, so

iron – though not as strong or beautiful as its rosier cousin – became the metal of choice for weapons and other implements.

By Homer's time, around the eighth century BC, Greek civilisation was pulling itself out of the darkness, with the rediscovery of old skills and the rise of city states such as Athens and Sparta. By this time craftsmen had worked out how to add carbon to iron to make steel, which is much harder than wrought iron. But bronze was still prized – objects made of it were never discarded, but melted down and used again and again over generations. A dagger that lost its point might become beads or a bangle, then be sold and recycled into a cooking pot or a bedstead suitable for a royal household, then reincarnated as a chariot wheel or a statue, a knife, an axe or a spearhead.

At some point, however, a piece of worn out bronze was melted down and recycled not into any of these items, but into the delicate gear work of a complicated scientific mechanism. And because of a quirk of fate – a ship in the wrong place at the wrong time – this particular mechanism was never melted down. Instead, it sank 60 metres to the sea bed off Antikythera and lay there until Captain Kontos and his divers retrieved it at the turn of the twentieth century.

Bronze fares a lot better than many other metals when languishing for long periods under the sea. Seawater is a soup of charged ions – mainly hydrogen and oxygen from the water and sodium and chloride from the salt, but there are others floating around too, such as sulphate and carbonate.

These ions do their best to attack any material they come into contact with. Iron, for example, oxidises completely in contact with sea water, losing its original form and eventually taking on the consistency of chocolate.

Copper, on the other hand, is relatively unreactive. The ions in the seawater strip electrons from any exposed copper atoms, forming positively-charged copper ions that each react with a negatively charged chloride ion to form copper chloride. Similarly, tin reacts with oxygen ions to form tin oxide. Certain marine bacteria do their bit too; their idea of a satisfying meal is to combine sulphate ions in the sea water with metal ions to form tin and copper sulphide, releasing chemical energy in the process. But the damage is limited. These new compounds form a thin layer on the surface of any bronze object that is left in the sea, which protects it from further corrosion.

That's why the bronze statues brought up from the Antikythera wreck were quite well preserved – once they were cleaned, the original form of the ancient figures was revealed. But the chemicals formed by the corrosion of bronze can turn nasty. Copper chloride is a stable compound in water, but not in air. When objects that have been corroded in this way are removed from the sea, the copper chloride reacts with oxygen and moisture in the air to form hydrochloric acid. The acid attacks the uncorroded metal beneath to form more copper chloride, which again reacts with air to form more acid, and the cycle continues. If the reaction isn't stopped, the object slowly and inexorably self-destructs.

For many months before it was discovered the mysterious Antikythera mechanism sat in a crate in the open courtyard of the National Archaeological Museum in Athens, unnoticed, untreated and literally eating itself away. By the time an unnamed museum worker noticed the significance of the decaying, fractured lump and brought it to the attention of the museum director Valerios Staïs, the outer layers of bronze had been completely destroyed.

Shrivelled fragments of wood clung to the bronze pieces, suggesting that the object had once been housed in a wooden box about the size and shape of a squat dictionary. Perhaps as the water evaporated out of the wood, the force of shrinking had literally pulled the contents apart. Perhaps a museum employee, eager to see what was inside, had hit the lump with a hammer. Either way, it was now in four crumbling bits.

An ugly layer of limestone – mostly calcium carbonate deposited as sea creatures feeding on the wreck died – covered much of the outer surfaces. But where the lump had cracked open patches of colour revealed the army of reactions devouring the bronze. The whitish green and bright blue-green of different forms of copper chloride dominated, but snaking through the green Staïs saw streaks of brownish-red copper oxide, the brown-black and whitish grey of various forms of tin oxide, and even the yellow and blue-black of tin and copper sulphide. Although a small core of metal remained in the centre, the surface of the fragments was made up of a powdery material that fell away at his touch.

Staïs was enjoying an impressive career. He was originally from the rugged island of Kythera, just north of Antikythera. Like his Uncle Spyridon, the Education Minister who first received news of the Antikythera shipwreck from Captain Kontos, Valerios had travelled to mainland Greece as an ambitious young man. He studied medicine, then archaeology, and he became director of the prestigious National Archaeological Museum of Athens aged only 30, just in time for the completion of the museum's first permanent home in 1889. Since then the new buildings had been filled with ancient Greek statues, tools, weapons, pots, jewellery, and not least the fabulous finds from Antikythera, which, over the past few months – incredible, chaotic, wonderful months – had gained international fame for him and his museum. But with all the precious artefacts that had come through the museum's doors, Staïs had never seen anything like this.

It was clockwork. Ancient clockwork. The largest piece of the strange object was about as wide as a page in a book, and almost as tall. One corner might once have been square, but the other sides were rough and eroded. Limestone formed an uneven layer over much of the front, although through it the outline of long-buried yet modern-looking gearwheels could still be made out. The overall effect was eerie and otherworldly, like finding a steam engine on the ancient, pitted surface of the Moon.

The clearest structure was a large wheel, almost as wide as the fragment itself, with a square hole in the centre where

an axle might once have sat. Triangles had been cut out of the middle of the wheel, so that four unequally broad spokes formed the shape of a cross. Around the edge were about 200 tiny jagged teeth, carefully cut into triangles by some ancient hand and so small that they could only be counted with the help of a magnifying glass. A second, smaller, toothed wheel on the same side looked as if it might have engaged with the first, and there were hints, harder to make out, of other much smaller wheels or circles.

On the other side of this largest fragment, several more cogwheels were visible, with yet more little teeth – freshly revealed where the object had broken open and stunningly sharp and precise. Two medium-sized wheels lay one on top of the other, the upper one slightly offset from the lower, and several much smaller wheels were also visible, as well as a square peg. A thin, flat sheet of bronze appeared to be stuck over the bottom right-hand corner and it carried the remains of a Greek inscription. Strings of capital letters in a miniature, precise hand were so worn as to be practically unreadable, but they tantalisingly filled line after line without a single gap, as if the message had been too urgent to afford any pause between words.

A second slightly smaller fragment also had a flat sheet stuck on to one face, engraved with another inscription. On the back of it had been cut a series of concentric circles, which looked as though they might have served as guides for a rotating pointer. Rocky deposits completely covered the front of the third fragment, but on the back of it was part of an illegible inscription, as well as a raised ring that intersected with another raised, curved edge. An inscribed letter 'T' was just discernible inside the ring, and something that looked like a movable pointer projected from the centre. The surface of the fourth fragment was completely eroded, but from the size and shape it looked as though it might contain a lonely cog.

The number of gearwheels and the precision with which they were cut, along with the presence of various scales, pointers and inscriptions, perhaps instructions, immediately suggested to Staïs that this was a mechanical device for making accurate measurements or calculations.

But it couldn't be. The pieces crumbling in his hands had to be 2,000 years old and nothing like that had ever been found from antiquity. The ancient Greeks (or anyone else around at the time) weren't supposed to have had complex scientific instruments, or even, according to many scholars, any proper science at all. And clockwork wasn't supposed to have been invented until the appearance of, well, clocks, in Medieval Europe more than a thousand years later.

It's hard to overestimate the uniqueness of the find. Before the Antikythera mechanism, not one single gearwheel had ever been found from antiquity, nor indeed any example of an accurate pointer or scale. Apart from the Antikythera mechanism, they still haven't.

Ancient texts reveal slightly more, although with written descriptions it's harder to tell how the objects being described actually worked, or whether they were ever made. Also you

often have to rely on texts in which the writer is describing something long after the event, or texts that have been copied and recopied many times and therefore could have been corrupted. But there are a few scattered mentions of gearing. The earliest may be a treatise on mechanics dating from around 330 BC, dubiously attributed to the revered philosopher Aristotle. It discusses circles that roll in contact, pushing each other round in opposite directions. The author might be talking about gears, but there's no mention of cogs or teeth, so it's hard to know for sure.

The first Greeks we know of to use working gears were the two most famous inventors of the third century BC: Ctesibius and Archimedes. Ctesibius, the son of a barber, became the greatest engineer of the time that we know about – after the legendary Archimedes – and he worked in Alexandria – in fact, he was probably the first director of the famous museum there. None of Ctesibius' writings survive, but we hear a lot about him from later authors, such as the Roman architect Vitruvius, writing a couple of hundred years later. Vitruvius said that Ctesibius built a water clock in which a float that rose with the water level moved an hour pointer by means of a 'rack-and-pinion' gear. This is a set-up in which a single gearwheel engages with a flat, toothed rack, and it's used to convert linear motion into rotational motion or vice versa.

Archimedes lived in the rich city state of Syracuse on the island of Sicily, although during his youth he almost certainly worked in Alexandria with Ctesibius. Among many other things he is credited with the invention of the wonderfully named 'endless screw' – in which a threaded screw is used to engage a toothed wheel with a much larger gear ratio. One full turn of the screw only turns the wheel through one tooth's worth of rotation – meaning that a lot of gentle winding turns the wheel only a small distance, but with a much stronger force than that originally applied by the winder. According to the ancient historian Plutarch, such a device allowed Archimedes to impress Syracuse's king by single-handedly dragging a ship over the ground, 'as smoothly and evenly as if she had been in the sea'.

Another, slightly more complicated device described by Vitruvius was a distance-meter or odometer, based on the principle that chariot wheels with a diameter of about four feet would turn 400 times in one Roman mile. For each revolution a pin on the wheel's axle engaged a 400-tooth cogwheel, moving it around the equivalent of one tooth, so that the cogwheel made one complete turn for every mile. This wheel engaged another gear with holes along its circumference that held pebbles, so that as the gear turned the pebbles dropped one by one into a box. Counting the pebbles therefore gave the distance travelled, in miles.

Perhaps Roman chariot drivers charged by the mile. We don't know for sure that the devices were ever built, but the general idea seems sound enough and they may have been around much earlier than Vitruvius' time. Alexander the Great was accompanied on his campaign in Asia in the fourth century BC by 'bematists', who had what must have

been one of the most boring jobs in the ancient world – counting their steps to measure distances. Their accuracy even over journeys of hundreds of miles (they were often less than 1 per cent out) has led to suggestions that they must have had mechanical odometers to help them.

The height of invention in ancient Greek gears was supposedly reached by the instrument-maker Hero, another follower of Ctesibius and a lecturer at the Alexandria museum some time later in the first century AD. Hero wrote about the principle that Archimedes had started to develop of using gearwheels of different sizes to change the strength of an applied force.

In particular, he talked about a weight-lifting machine called a *baroulkos*. He drew a picture of it, showing how a series of gearwheels of increasing size would allow a relatively small force to lift a heavy weight. There's no evidence that it was anything but an armchair invention – indeed many scholars have argued that the teeth wouldn't have been strong enough for the device to work in practice – but the description alone proves that the principle of intermeshing gearwheels was understood. Another device described in detail by Hero was an elaborate *dioptra* or sighting instrument, which used an endless screw and cogged semicircle to allow it to be aligned accurately.

So we know that the Greeks used toothed gearwheels in simple mechanical devices from around 300 BC onwards. But most of these devices involved just one or two wheels that engaged with a screw or rack and they didn't need to be particularly precise, they just needed to apply force or lift a weight. Even so, Hero has been seen as an aberration in the history of technology: a genius who did not represent his age but described mad, impossible devices far beyond the comprehension of his peers. One eminent publication on the subject from the 1950s describes Hero's *dioptra* as 'unique, without past and without future: a fine but premature invention whose complexity exceeded the technical resources of its time'.

But compared to the *baroulkos* and *dioptra* – which were supposedly so far ahead of their time – the gearing in the Antikythera mechanism was undoubtedly real, and its complexity was breathtaking. These were precisely cut bronze gearwheels, clearly meant for some mathematical purpose. It was hard to count the gears embedded in the battered fragments, but to Staïs and his colleagues at least 15 wheels were visible on the eroded surfaces alone. They seemed to have interacted to make certain numerical calculations, the answers to which would have been displayed via pointers on a scale.

Rather than anything the ancient Greeks were supposed to have built, the sophistication of this mechanism made it look more like a clock or calculator. But if so it had to be nearly 2,000 years ahead of its time. Mechanical clocks of such a small size required delicate springs and regulators and didn't appear in Europe until the fifteenth century, and the first mechanical calculators – complex contraptions that used metal gearwheels to add, subtract, multiply and divide – weren't devised until some 200 years after that.

Today we're so used to electronic computers and calculators that the idea of a calculation using metal gearwheels might seem bizarre. Imagine, for example, that you have a gearwheel with 20 teeth that engages with a gearwheel with 10 teeth. Each time you turn the first gearwheel through one complete revolution, the second one will turn twice. In other words, your input has been multiplied by two (actually the second wheel turns in the opposite direction to the first, so you could argue that the input has been multiplied by minus two, but you get the picture). This is part of what clocks do – converting the seconds that tick by into the minutes and then the hours of the passing day. The more gearwheels you have, in series or in parallel, the more complex the calculation you can make.

The idea that an ancient clock or calculator might have been found caused excitement and some consternation at the Athens museum. Realising that interpreting it was beyond his expertise, Staïs quickly called in two experts. The first was John Svoronos, director of the National Numismatic Museum in Athens – the keeper of the nation's ancient coins and an expert in reading ancient lettering. Svoronos was one of the most senior archaeologists in the country and hugely knowledgable; unfortunately, he was also prone to coming up with eccentric theories about which few dared to disagree. The second expert was Adolph Wilhelm, a young and brilliant Austrian expert in inscriptions, who was stationed in Athens at the time.

Over the next few days Wilhelm cautiously dated the writing on the mechanism to somewhere between the second century BC and the second century AD. Meanwhile, Svoronos and some of Greece's top scholars exchanged rival and rather pompous articles in the national press, hotly debating what the bizarre instrument might be – their talk of cogs and scales appearing alongside reports of Cuba's newly won independence from the United States and Britain's violent takeover of South Africa. Then the initial excitement died down, as the experts each went away to write up their various theories for scholarly publication.

Svoronos got there first, in a 1903 report written with Pericles Rediadis, a professor of geodesy and hydrography (fields concerned with measuring the Earth and the sea). Rediadis, a senior member of the Archaeological Society of Athens, was also interested in naval history and he was well known for his studies of the site on which the famous Battle of Salamis (480 BC) was fought.

Svoronos pored over the cryptic inscriptions on the Antikythera mechanism with a magnifying glass. He was able to decipher 220 scattered Greek letters, though very few whole words, and he compared their style to those on the ancient coins that he knew so well. He overruled Wilhelm's opinion on the mechanism's age and announced instead that the writing dated from the first half of the third century AD, a turbulent time of civil war when the Roman empire, including Greece, was ruled by a succession of leaders who each briefly seized power before being brutally assassinated.

Meanwhile Rediadis provided a description of the Antikythera fragments – the first technical, if rather vague, account of what he called 'this completely strange instrument'. He noted that the mechanism had been carried in a wooden box, as nautical instruments on ships still were in his own time, and deduced that the object was not part of the Antikythera ship's cargo, but a navigational instrument used by the crew.

From the scraps of lettering deciphered by Svoronos and Wilhelm, Rediadis suggested that the inscriptions were operating instructions, and put great importance on one particular and very unusual Greek word: μοιρογνωμόνιον. This is a technical term referring to a graduated scale. The word was used to describe the zodiac scale in the earliest known account of the astrolabe, written in the sixth century AD. Svoronos and Rediadis concluded that the Antikythera mechanism must therefore be a kind of astrolabe.

Astrolabes were among the cleverest instruments thought to have been around in antiquity, and they were calculators of a sort. They were used for solving problems relating to the time and the position of the Sun and stars in the sky, and they were popular until the seventeenth century or so, when increasingly accurate clocks and astronomical tables began to render them obsolete.

The essence of an astrolabe, however, was something that the new technologies could never replace. The name means 'star catcher' and it is apt: holding the engraved, metal circle of an astrolabe you have the whole of the heavens in the palm of your hand. From Aristotle's time onwards, it was accepted (with just a few dissenters) that the Earth lay motionless at the centre of the universe, with the Sun circling around it and a sphere of fixed stars rotating behind that. An astrolabe is a flat disc in which one circular plate rotates over another to represent in two dimensions the spinning heavens as seen from Earth. The Sun, stars, horizon and even the very sky itself are represented by intricate patterns on its face. The inscriptions look complex and alien to us today, but they are the result of centuries of astronomical observations, and they elegantly encode our place in the visible universe.

The circular instrument's base – called a *mater* (or 'mother') in Latin – had a central pin over which a flat metal plate fitted snugly, like a disc on a record player. Engraved on it was a bewildering yet beautiful set of intersecting curves, lines and circles. This was a map of the sky, imagined as a sphere and projected on to the flat disc with the North Pole in the middle – just as a map of the Earth represents the spherical surface of the planet on a flat piece of paper. Although the sky looks like a featureless expanse, you can actually draw lines that mark very specific locations on it. The plate was engraved with a straight vertical diameter to show north and south, for example, and a horizontal diameter to show east and west. A series of curves and circles depicted the celestial equator (the Earth's equator as extended straight up into the sky), the Tropics of Cancer and Capricorn, and the horizon, as well as marking various altitudes above

the horizon and degrees from north. The position of these lines is dependent on how far north or south of the equator you are, so most astrolabes came with a series of interchangeable plates, each engraved for a specific latitude.

Placed on top of this fixed sky map was a rotatable plate called a *rete*. This disc had key star constellations marked on it, as well as a circle to represent the path that the Sun follows through the sky. The whole sky rotates as the Earth turns, of course, but the Sun (because we're going around it) appears to us to move slightly faster than the stars through the sky, gaining on them by a few degrees each day. The path the Sun traces with respect to the stars over the course of a year is called the ecliptic, because the only time you can see directly where the Sun is in relation to the background stars is during an eclipse. In ancient times, the 360-degree circle of the ecliptic was divided into twelve 30-degree sections of longitude, which correspond to the twelve signs of the zodiac. These were marked around the circumference of the astrolabe – this was the scale referred to in the sixth-century text, and in the inscription on the Antikythera mechanism.

On the *rete*, the spaces between the constellations were cut out so you could still see the sky map beneath (hence its name, which means 'net' or 'web'). The precise positions of the stars were represented by pointers, often in the dramatic form of flames or daggers, so that as the skeletal *rete* was rotated over the sky map, it showed the movement of the stars through the sky. Then on top of the *rete* was attached a rotatable straight bar, called a rule, which represented the Sun. The Sun's precise position on the sky map was given by the point at which the rule crossed the circle of the ecliptic. First the rule was set with respect to the ecliptic to show a particular day of the year, then it was rotated along with the *rete* to simulate the Sun's movement through the heavens on that day. Extra hour lines engraved on the fixed *mater* beneath allowed an astronomer to use the rule to read off the time at which the Sun or any marked star would hit a particular altitude.

Astrolabes were generally used for astronomical predictions and observations (there were sights on the back for measuring the altitude of stars or the Sun). They weren't especially helpful for navigation. Quite apart from the fact that the heavy metal disc would swing about clumsily in the wind if you tried to use it on deck, there were other, simpler devices for measuring the Sun's noon altitude, which was all you needed to determine the latitude of a ship at sea. And astrolabes did not measure longitude – how far east or west you were. There wasn't a way to do that until the eighteenth century, when the legendary British clockmaker John Harrison perfected clock mechanisms robust and accurate enough to be taken to sea to keep a record of the time at the ship's home port, and therefore show the time difference between that and the hour at the ship's present location, as indicated by the stars.

Although the first known description of an astrolabe comes from the sixth century and no actual instruments

survive from before the ninth century, they were almost certainly around much earlier. The Greek astronomer Ptolemy described the maths necessary to make an astrolabe in the second century AD and reported lots of astronomical observations that were probably made using one. There's a colourful (if unlikely) story that Ptolemy invented the instrument when he was riding on a donkey, wisely pondering his celestial globe. He dropped the globe and the donkey stepped on it, squashing it flat, and giving him the idea. There are hints in other manuscripts, however, that the astrolabe may have been invented by Hipparchus, an astronomer who lived and worked on Rhodes in the second century BC, and from whom Ptolemy took much of the astronomy that he wrote about.

Svoronos and Rediadis's discovery of the zodiac scale certainly suggested that the Antikythera mechanism had something to do with astronomy. But it wasn't like any other astrolabe that was known at the time. For a start, astrolabes weren't square and they didn't come in wooden boxes. More fundamentally, although astrolabes had scales and pointers, they didn't have any need for gearwheels.

Like everyone else who saw the mechanism, Professor Rediadis was astonished at the sophistication of its gearing, and despite Svoronos's relatively late dating of it to the third century AD, he struggled to believe that this wasn't a much more recent instrument. To Rediadis, the gearing of the Antikythera mechanism looked just like the workings of a modern clock. If it wasn't for Svoronos's assurances that the instrument dated from centuries before the invention of the springs, regulators and escapements necessary for the continuous motion of a clockwork clock, he said, he 'would be bent to seize the history of nautical stopwatches from [John] Harrison'.

But when it came to identifying the mechanism, Rediadis was undaunted by its lack of similarity to known astrolabes. He thought that, as in a conventional astrolabe, the ancient instrument would have used a sighting line in combination with a degree scale to measure the height of stars or the Sun in the sky. But rather than using engraved maps and scales to read off the time of the day, say, or the longitude of the Sun, he speculated that the Antikythera device was a completely new type of astrolabe that calculated these values mechanically using trains of gearwheels and showed the result by means of the pointers. Although he called it an astrolabe (a description that would 'stick like a barnacle', as one historian put it, for the next half-century), he was really describing a sort of clock-like mechanism that instead of running automatically after being wound, was rotated by hand and set according to the movements of the stars.

From the sparse clues offered by the Antikythera fragments it was an inspired and quite beautiful guess. Unfortunately, neither Rediadis nor Svoronos addressed the question of why anyone would bother to build such a complicated mechanism to do what an ordinary astrolabe could have done perfectly well.

In 1905 another naval historian called Konstantin Rados,

who, like Rediadis, was an expert on the Battle of Salamis, published a paper arguing that the Antikythera mechanism was far too complex to have been an astrolabe. He, too, likened the gearwork to that of a clock and even thought he could see the remains of a metal spring in one of the fragments. Might this, after all, have been a mechanical clock capable of being wound? Rados could not believe that such a sophisticated device could have existed on the same ship as the ancient Greek statues recovered from Antikythera. He suggested that it must have dated from a second, much later shipwreck, and had found itself among the older remains by chance.

Two years later a young German called Albert Rehm entered the fray. He would go on to become one of the world's greatest experts on ancient inscriptions. But at this point he had just accepted a post at the University of Munich and was still making his name. Scornful of the lack of technical detail in Rediadis' description, and of the poor quality of his photographs, he went to Athens to examine the fragments himself, after which he sided with Rados and concluded that although it was certainly ancient, the mechanism could not possibly have been any kind of astrolabe.

By this time the fragments were being carefully, though controversially, cleaned. The treatment was revealing new markings and was necessary to prevent further corrosion of the bronze, but at the same time it destroyed some of the outer details. As a result of the cleaning, however, Rehm was able to read on the front dial of the third fragment a previously hidden and crucial word: *Pachon* (ΠΑΧΩΝ). Pachon is the Greek form of a month name in the ancient Egyptian calendar. There would be no use for the names of months on an astrolabe, Rehm argued, nor on any kind of navigational instrument.

He suggested that the fragments might be the remains of a planetarium. As a handle was turned, the differently sized gearwheels might have converted the motion into the appropriate speeds for each of the planets known at the time – Mercury, Venus, Mars, Jupiter and Saturn – showing their approximate paths as seen from Earth throughout the days, weeks and months of the year.

A ruffled Rediadis got his own back in 1910. In a new paper he argued that even if the mechanism wasn't an astrolabe, then a planetarium was a much less reasonable assumption – the gearwork was much too weak and flat for such a spherical device. He repeated his somewhat dubious argument that because the object was found on a ship and it had been housed in a wooden case, it must have been one of the ship's instruments.

After this, work on the mechanism stalled, despite the continued bickering of some of the world's most eminent science historians. The only major new research on the fragments around this time was done by John Theophanidis, a rear admiral in the Greek navy, who became interested in the mechanism in the 1920s when he was researching an article for a nautical encyclopaedia about the voyages of St Paul, who sailed back and forth across the Mediterranean

preaching Christianity in the first century AD, before being shipwrecked on Malta while the Romans were taking him as a prisoner to Rome.

Theophanidis published his findings in 1934. As the limestone was scraped away, a large ring had been revealed on the front face of the main fragment of the mechanism, with a graded scale around its circumference. Could this be the zodiac scale referred to in the accompanying inscription? Theophanidis also confirmed that the big cross-shaped gearwheel engaged the rotation of several smaller gearwheels and he described a crank at the side that seemed to have driven the main wheel – wound by hand, Theophanidis suggested, or perhaps even driven by a water clock.

He also noted that the letters were so precise they must have been engraved not by a labourer but by a highly trained craftsman. Like all of the experts studying the device who came from a naval background Theophanidis became convinced that the mechanism was a navigational instrument. The inscriptions were instructions or rules, he concluded, which the ship's captain would have had copied for his personal use.

Theophanidis thought, like Rehm, that the device was for calculating the precise positions of the Sun, Moon and planets, with the ratios between the gear teeth producing their appropriate speeds of movement. But he couldn't quite give up on the astrolabe idea. In some of the engraved numbers he saw ratios reminiscent of the lines and circles of an astrolabe, and suggested that the inscriptions were instructions for tracing these markings with a ruler and compass, so that they could be used in conjunction with the instrument to solve various astronomical and nautical problems. He also speculated that by setting various pointers on the device according to the shadow cast by a nail placed in the middle of the concentric circles, it could calculate, by means of the gearing, the precise orientation of the ship.

Theophanidis became quite obsessed by the Antikythera mechanism and ended up spending many years working on his photographs of the fragments and building a model of the gearwork – to the extent that he had to sell several buildings that his family owned in the centre of Athens in order to finance his studies. But he did not publish on it again. Most of his extensive work lay unrecognised, hidden after his death within dusty piles of papers at his family home.

In the meantime, Albert Rehm's career went from strength to strength and in 1930 he was appointed rector of the University of Munich, making him one of the most influential academics in the country. But around him, everything was changing. The Nazi party had been growing in power since the mid-1920s, aided by a severe economic depression. Rehm was horrified to see the Nazi movement gaining ground among his students and did everything he could to dissuade them, without much success. After Hitler gained power in 1933, many of Rehm's Jewish colleagues had no choice but to flee the country. Rehm himself continued to protest vocally, earning the increasing displeasure of the regime, until he was forced to retire in 1936.

Nine years later, when the Second World War was over, Rehm was appointed rector once more in recognition of his resistance to the Nazis. But it didn't last long. He was just as outspoken against the new authorities for not recognising the importance of classical studies in German education, and he was removed from the position again in 1946.

Such stubbornness ran through everything that Rehm worked on and, like Theophanidis, he was unable ever to give up thinking about the ancient gears of the Antikythera mechanism. After his first paper on it he studied the fragments on and off for the rest of his life, intending to solve the workings of the device beyond doubt so that he could silence his critics with one triumphant, definitive publication. But despite his achievements in other fields, the secrets of the mechanism eluded him and the final paper never came. He died from a heart attack after attending a faculty meeting against his doctor's orders in 1949.

While Rehm had been fighting the Nazi regime, Hitler's shadow had reached Athens too. In April 1941 German forces advanced on the city and as the king and the government fled for Crete (except for Prime Minister Alexandros Koryzis, who shot himself in despair), the National Archaeological Museum was closed down. The precious exhibits were taken from their cases and buried in boxes – some in caves in the hills around Athens, some in the underground vaults of the Bank of Greece, and the rest under the floors of the museum itself, where they were hurriedly covered with sand. There the artefacts waited out the long, dark years of occupation, hidden from the looting army. Unfortunately there was no similar way to safeguard the city's food. The German soldiers, who had neglected to bring their own supplies, seized all they could from Athens's warehouses. By the time the buried exhibits saw daylight again, tens of thousands of Athenians had starved to death above them.

Once the occupation was over Greece remained crippled by civil war for several years, but the museum opened again under a new director, Christos Karouzos, and between 1945 and 1964 those artefacts that had not disappeared in the confusion were gradually retrieved and put back on display. The Antikythera mechanism survived it all, but by this time the excitement surrounding it was largely forgotten. With so much disagreement over its date and identity the science historians had moved on, while to the art experts and archaeologists now working at the museum the shabby-looking fragments could not possibly compare in importance to the beautiful vases and sculptures that filled the building's halls.

So the mysterious pieces were not put on display alongside the rest of the Antikythera haul. Once more they sat unnoticed at the bottom of a storeroom crate.