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THE LARGE BUILT WATER CLOCK OF AMPHIARAEION

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ABSTRACT

A very well preserved ancient water clock was discovered during excavations at the Amphiaraeion, in Oropos, Greece. The Amphiaraeion, a famous religious and oracle center of the deified healer Amphiaraus, was active from the pre-classic period until the replacement of the ancient religion by Christianity in the 5th Century A.D.. The foretelling was supposedly done through dreams sent by the god to the believers sleeping in a special gallery. In these dreams the god suggesting to them the therapy for their illness or the solution to their problems. The patients, then threw coins into a spring of the sanctuary. In such a place, the measurement of time was a necessity. Therefore, time was kept with both a conical sundial and a water clock in the form of a fountain. According to archeologists, the large built structure that measured the time for the sanctuary dates from the 4th Century B.C.

KEYWORDS: water clocks, Ancient Greece, Oropos, Attica

INTRODUCTION

Amphiaraus was one of the most important heroes of the Thebaean-Argolic cycle and one of the noblest and respected figures in Greek mythology. He was born in Argus as a descendant of the great foreteller and psychiatrist Melampous (Ovid. XV, 244), from whom he inherited the art of oracles and healing knowledge. According to Pausanias (8, 45, 7), Amphiaraus participated in the hunt of the Calydonian Boar, while according to Apollodorus he also participated in the Argonautic Expedition (Apol.Bibl. I, 9, 16).

Amphiaraus was forced to take part in the military campaign of the "Seven against Thebes" that was started by Polynices against his own brother, Eteocles. Amphiaraus believed this campaign was unfair and, moreover, he had foretold it would cost the lives of all its leaders except Adrastus. In spite of their courage, the Argives were not successful in conquering Thebes and had to retreat hastilly. Amphiaraus, followed by Periclymenus, reached either the banks of Ismenos river or the place of the Amphiaraeion in Oropos, (Strabo IX 399). Periclymenus was ready to strike him from behind, a disgracing act. Then, according to the myth, Zeus threw a thunderbolt and opened a large gap on the surface of the earth, which Amphiaraus fell into along with his chariot and charioteer (Apol.Bibl. III, 6, 8). By doing this, Zeus made Amphiaraus immortal and assigned him to the chthonic deities, i.e. the deities of the underworld, thus defining the character of his worship.

THE OROPOS AMPHIARAEION

The sanctuaries devoted to the worship of Amphiaraus were called "Amphiaraeia". At least twelve of them are known. The "official" Amphiaraeion in Oropos, some thirty miles from Athens, is the most famous of them. It was placed in the southeast of Oropos and was the main sanctuary of that ancient city. The sanctuary was established there in the 5th Century B.C. after a successful oracle was given (the original sanctuary of Amphiaraus in Thebes, known from Herodotus, was in decline). The Oropos Amphiaraeion was an official dream-oracle and holy healing place. The complex also included a stadium, where every four years gymnastic and musical events took place to honor the god (Pausanias I, 34.1). The fame of this oracle was such that it reached Asia: even Croesus sent gifts asking for an oracle (Herodotus I 49 and I 92), as well as Mardonius (Herod. XIII 134).

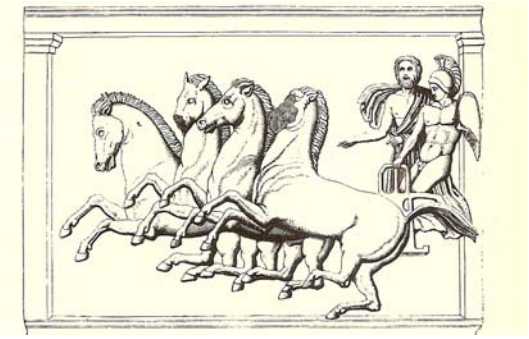

Fig. 1: Amphiaraus on his chariot together with his charioteer (ancient relief from Oropos)

The Amphiaraeion in Oropos is built in a small valley; the locality is known as Mavrodilesi (ancient Psaphis) is near the modern village of Kalamos (2.5 km to the northwest of it), in north Attica. Its distance from the sea is about 2 km. The excavation of the sanctuary started in 1884; it lasted, with intermissions, until 1929 and was directed by professor S. Fintiklis (1820-1894) and, later, by another archaeologist, A. Leonardos (1857-1930).

The first explicit reference to the existence and operation of the Oropos Amphiaraeion is found in Aristophanes' comedy *Amphiaraos*. The person acting as a di-

rector bore the title of the priest. The people in charge of the sanctuary and the leaders of the ancient city of Oropos (12 stadia or about 2.2 km away) named the years after them. This was not a unique occurrence: e.g. in Argus, according to Thucydides (II 2), time in years were measured beginning from the day of the inauguration of the new priestess of Hera (the term was lifelong).

The Oropos Amphiaraeion was mainly a healing center, as evidenced by the lists of the believers' "argyromata": Everyone admitted into the sanctuary had to pay an amount of money ("argyroma"); he or she was then given a ticket made of lead, 55 mm long, 15 mm wide and 2 mm thick, which had the figures of Amphiaraos and Hygeia in relief on it, as well as the words ΙΕΡΟΝ ΑΜΦΙΑΡΑΟΥ ΥΓΕΙΑ ("Holy Health of Ampiaraus"). The patient was also required to abstain from wine for three days and from food for one day. This cleansing by fasting, and also by bathing in the water of the sanctuary's spring, was required for the people that came for healing as well as those that came for an oracle. The believers then sacrificed a ram, on whose skin skin they were instructed to sleep in the main gallery ("enkoemesis"). Amphiaraus would appear to them in their dreams and inform them how to be cured from the disease or gave them oracle (Paus. I, 34, 5).

The main buildings identified in the ruins of Oropos Amphiaraeion are a Doric temple (29 m × 13 m), a long gallery made from porous stone (most probably the gallery where the enkoemesis was taking place) and a theater. Many other buildings are to be seen in ruins there: a minor temple and a stadium for hosting the gymnastic and music events (known as "Amphiaraeia") are among them.

The large temple of Amphiaraus (4th Century B.C.) had in front of it a large altar; to the SE of the altar was the sacred spring of Amphiaraus, from which according to the myth the hero reappeared out of the earth as a god. The believers had to throw into this spring a golden or silver coin after they were cured. To the east of the altar there was a fountain and the men's baths (4 rooms). To the north we can see several scripted pedestals of statues of the Roman period, as well as many steles with inscriptions. The women's baths were to the NE corner of the sanctuary, next to the gallery, and were dated to the 4th Century B.C..

There is also a large complex built for the believers on the right bank of the creek. Its most significant buildings are a hostel with 11 rooms, an agora and a hydraulic clock or water-clock-like fountain: a large built device measuring the time for the sanctuary, which dates, according to Leonardos (1918), to the 4th Century B.C. The dating is based largely on construction methods and materials.

During the excavations, a well-preserved conical sundial was discovered – even the gnomon was recovered, a rare occurrence – but unfortunately the sanctuary's Museum where it is kept has been closed for years.

All the above buildings testify to the intense activity around the oracle and healing center of Amphiaraus. Its end came with the replacement of the ancient religion by Christianity in the 5th Century A.D. Today, the sanctuary with its restorations and ruins is one of the best archaeological sites in all Attica.

THE BUILT WATER CLOCK OF THE SANCTUARY AND ITS USE

The invention of the water clock is attributed by ancient tradition to Hermes Trismegistus, who was allegedly a time-

keeper and father of all sciences.The Greek word for the water clock, *clepsydra*, is a composite word: it means "thief of the water"; it was used to measure time mostly during the night or on cloudy days, when sundials could not be used. The water clock was known to Egyptians since the 18th Dynasty (Pogo, 1936; Cotterell et al., 1986), while Babylonians knew it at least since the 12th Century B.C. (Neugebauer, 1947).

In India a similar device, jala-yantra, is mentioned around 300 B.C. (Fleet, 1915). The ancient Chinese are also known to have used water clocks; however, the oldest reference to it in China is in the book *Lou - Shui - chuan - Houn - t'ien - i- chi*, which means *Method of rotating a sphere with ring by the water dripping from a water clock*, a much later work since it was written by Chang Heng in 90 A.D. (Needham et al., 1986).

J. H. Breasted (1934) writes that the most ancient water clock is named after the Egyptian pharaoh Amenhotep III and thus it can be dated from *circa* 1400 B.C.. Yet, the oldest Egyptian water clock for which there is written information belongs to the 16th Century B.C. (around 1550), and was constructed for the Egyptian priest and astronomer Amenemhet, who probably was the true inventor of such devices. Amenemhet left his autobiography carved on the walls of his death chamber in Luxor. He wrote there that the winter night was 14 hours long, while the summer night was equal to 12 hours. The passing of the hours was indicated by statuettes of deities – probably floating on water – that appeared at the proper moments as the water level flowed from the main to the lower tank.

Of course, water clocks are mentioned in ancient Greece, too. The Greeks used *clepsydrae* since the age of Thales (636-546 B.C.); they were known to Empedocles, Anaxagoras, Aristophanes (450/444-385 B.C.) and Aristotle (*Athenaion Politeia*, or *The Athenian constitution*, 67, 2). Plato had constructed a most precise water clock for the night, known as the "Plato's night clock" (H. Diels, *Antike Technik*, Berlin 1914, pp. 199-200).

In summary, the water clock is one of the most ancient instruments for the measurement of time. Its function was based on the steady and continuous flow of water between two vessels, or, in the case of the large built clepsydra of the Amphiaraeion, on the continuous flow (emptying) of a large rectangular structure, a large water tank.

It is possible that this clepsydra was an original model of water clocks that preceded similar instruments of Ctesibius and the other astronomers of Alexandria, since its construction is placed in the 4th Century B.C.. As already mentioned, it was constructed very close to the right bank of the creek. The whole clepsydra's building (tank, corridor and stairs), is made of carved porous stone of the region, isodomically built (i.e. with stones of equal size).

The architect of our team, M. Katsiotis, observed that the inner surface of the tank is covered with thin waterproof mortar; the dimensions of the rectangular tank are: 0.85 m (upper length) × 0.85 m (upper width) × 1.95 m (depth) ± 0.02 m. It gets wider in its upper part (verge) by 7 cm, with wedge-like cutting of the uppermost row of stones. The diameter of the opening through which the tank emptied is 2.6 mm; it can be reached by descending nine steps on its west side. The danger of silt or dirt clogging the outlet is apparently the explanation for the setting of this opening about 20 cm above the floor.

Fig. 4: The Oropos Amphiaraeion *clepsydra* (water clock)

The whole building lies lower than ground level. The rectangular tank has a narrow staircase in its exterior and a corridor (most probably a "service area"). The water from the tank was running at a very low draining rate from a faucet at its bottom. As the level of its water dropped, an index inside the tank also lowered and a time inscription could be read.

Fig. 5: The clepsydra from the SW

The tank was filled probably through a pipe. When the tank was full, a a slave in charge of the clepsydra, the *"eph' hydor"*, descended the nine exterior steps to the base of the tank and regulated the outflow rate; he was given orders by the priests for starting or stopping the water flow of the clepsydra. The simplest mode of operation would be to fill the tank at night or at the beginning of every day and starting the water flow early in the morning; the level of the water would fall slowly until the evening. For the permanent closing of the hole they used a conical wooden plug.

Fig. 6: The interior of the tank

By examining this large water clock *in situ* we observed that on the bottom of the tank there is an oval cavity about 38 cm in diameter by 16 cm deep, with an opening in the center, now sealed. When the *eph' hydor* slave removed the tap from the outer hole, the water would flow through the opening and was directed through another pipe to the adjacent creek. The Oropos clock shows no sign of renovation or remodeling; there is but a single outlet pipe. It is very similar, as Armstrong and McK. Camp (1977) point out, to the water clock in the Athenian Agora. The same basic elements of the plan are common to both: square central tank, surrounding walls, stairway, and service area; the differences in dimensions are slight. However, the Oropos device is remarkably well preserved, much better than its Athenian counterpart. In view of these similarities, the proximity of Athens to Oropos, and the fact that these two are the only devices of this design yet discovered, it does not seem unreasonable to suppose that they were the work of a single person.

The proper functioning of the clepsydra was based on the steady flow of the water, which was regulated at the drain

hole. Perhaps there were indications on the mortar of the water level, which would indicate the time; however, we did not discern any trace of them. So, we believe that most probably there was a float on the water in the tank: an index on the float would then show the water level by pointing at a calibrated vertical tablet. As was usual in antiquity, the float probably had a statuette on it, and either its hand or a stick held by the statuette pointed at the tablet. Indeed, such a tablet, made of marble and measuring 0.77 m × 1.25 m, which bears special line inscriptions, was discovered and is kept in the yard of the Amphiaraeion museum. The archaeologists consider it an integral part of the clepsydra, since there is a basewith a notch, which would be the natural position of the tablet. Depending on the water level in the tank, the float would show one of the lines on the tablet that would correspond to the hours of day and night.

These horizontal lines on the tablet are carved in equal distances on its surface; on its upper part there are also some vertical lines for an unknown purpose. The equal distances of the horizontal lines are also curious, because it is known that generally in antiquity hours had different durations, depending on whether it was winter or summer: Almost all ancient people shared the notion that in any season, there were 12 hours (of varying length) between sunrise and sunset. A summer day hour was longer than a winter day hour. Greeks followed the same system. Therefore, it would be expected that the spaces between the lines indicated by the float on the marble tablet should be different from one month to the next and, moreover, the index should run through the 12 hours of day and night at the proper rate.

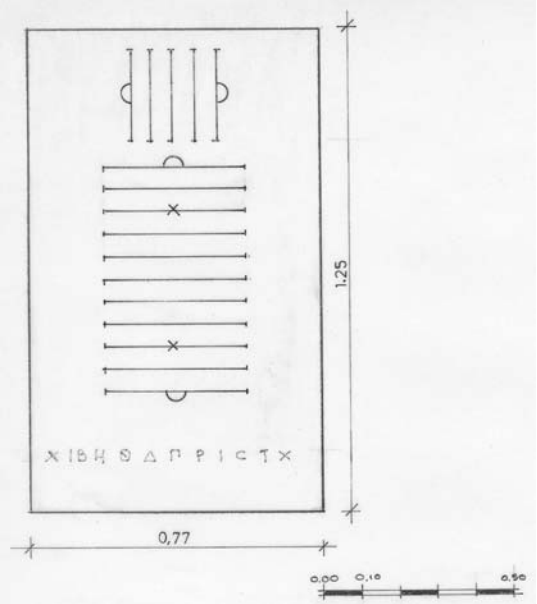

Fig. 2a: The marble tablet (dimensions 0.77 m × 1.25 m) bearing special calibration, which is kept in the yard of the Amphiaraeion museum (drawing)

This problem could be solved with the use of more than one tablets – and they probably exist, although in fragments. Otherwise, they could measure the hours in a different way: For example, the scale of the marble tablet could be altered by adding or removing parts depending on the hour duration. It is also pssible that the marble tablet found is not related to the clepsydra. However, Sir Thomas L. Heath mentions (1921, p. 71) that archaeologist Alex. P. Raghavis discovered in 1846 on the island of Salamis the famous "Salaminian Table", which bears units of measurements of liquids (*Revue archéologique*, iii. 1846) and resembles the marble tablet of the Oropos Amphiaraeion. The Salaminian Table (now in the Epigraphical Museum of Athens) is made of stone, measures 0.75 m × 1.5 m and bears horizontal lines and similar number symbols (known as "symbols of Herodianos").

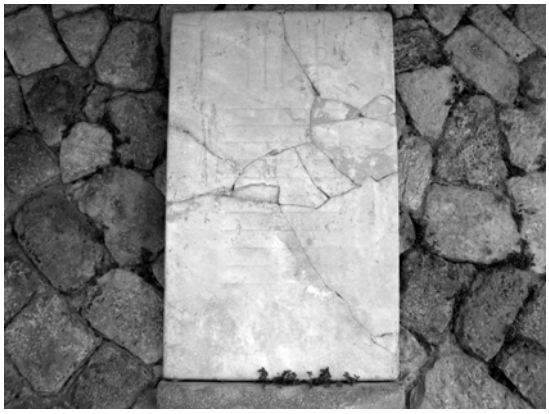

Fig. 2b: Photograph of the marble tablet of the Amphiaraeion

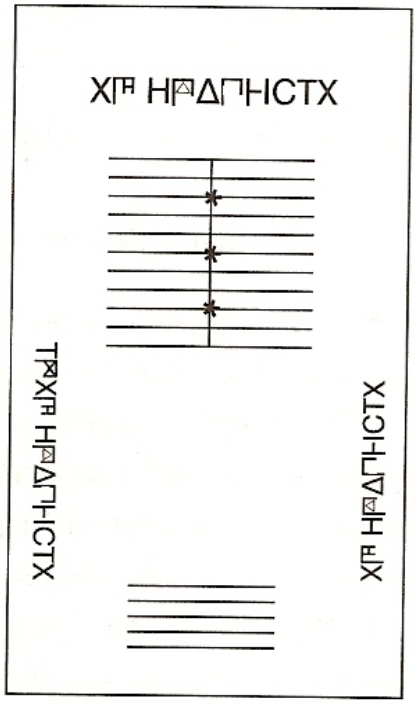

Fig. 3: The "Salaminian Table", a stone plate measuring 0.75m × 1.5m, now in the Epigraphical Museum of Athens (drawing)

It is possible that another method for showing elapsed time was used: perhaps a cylinder calibrated with the old Egyptian system of variable seasonal hours that could be rotated slowly in some way every day. The hour lines on this drum would be closer to each other as the winter approached. It should be noted that all the above in a more complex form is described by Vitruvius for the instrument of Ctesibius of Alexandria (Vitruvius, *De architectura*, 9.8.5-7).

Indeed, the use of a water clock as an horological instrument had some basic problems to be solved. First, its operation was controlled by a human and not automatically. And second, the water flow was not steady, but it depended on the level of the water inside the main tank. In order to achieve a constant rate of flow, independent of the water level, the main tank was usually wider at its upper part. This is perhaps the reason that the Amphiaraeion water clock main tank was built wider in its upper part (verge) by 7 to 12 cm, by cutting the uppermost rows of stones: At the preserved top, the tank measures 0.85 m square, whereas at a point approximately 0.75 m below the top it has decreased to 0.75 m, from which point to the bottom the walls are almost vertical. In any case, the ancients did not manage to eradicate this source of error in time measurement. The relation between the water flow rate through a narrow hole at the bottom of a vessel and the water level in that vessel was studied by Archimedes and the Alexandrine engineers Ctesibius, Philon and Hero(n). They introduced simple mechanisms, i.e. hydraulic siphons, to control the level (and therefore the flow rate) .

The siphon, and more specifically the axial siphon, functions as a hydraulic switch, by controlling the level (h) of the water in a vessel so that it cannot exceed a maximum value (h_o), equal to the height of the siphon. With a small but steady supply (g_o), the level of the water in the vessel slowly increases up to the point it reaches the height h_o of the siphon; at that moment, the water flows suddenly and rapidly through the siphon and the vessel

empties with a flow g >> g_o. The siphon is by itself a first simple closed system of control for the water level in a tank. However, the invention of new closed systems of automated control resulted from the need for a self-controlled smooth operation of the hydraulic clocks. The great Alexandrine engineers excelled in this field. First among them was Ctesibius (*circa* 308-246 B.C.). His work is described in detail by the Roman architect Vitruvius (1st Century B.C., *De architectura*, 98.2).

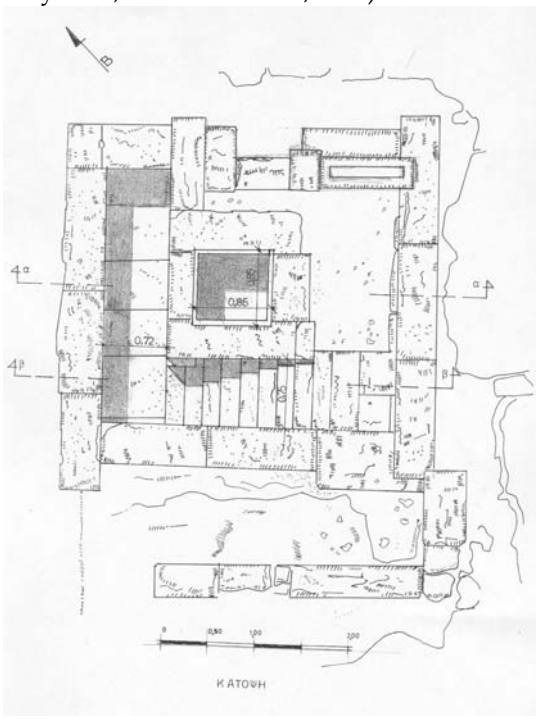

Fig. 7: Schematic representation of the clepsydra

The main difficulty was, as we saw, the division of the day and the night into 12 unequal hours. The hours of day and night were equal only at the equinoxes and their difference continuously varied according to the season of the year. So the scale of the hours should also be variable. The astronomers-engineers of antiquity tried to overcome this difficulty in the following way: the hour scale was placed in the lower vessel, where the water was collected after passing through the narrow hole. This lower vessel assumed a cylindrical shape. A float inside it could then measure the water level in the respective hours. In this way the water clocks were replaced by the hydraulic mechanical clocks and humanity passed into a different era concerning time measurement.

CONCLUSIONS

The large built *clepsydra* (water clock) of the Oropos Amphiaraeion is one of the best preserved ancient water clocks in Attica; we know that a smaller but similar clock was situated in the interior of the octangular "Tower of the Winds" (or "Horologion of Andronicus the Kyrrhestos / Kyrrhestes", circa 50 B.C.), in the Roman Forum of Athens, which in addition bears eight vertical sundials on its exterior walls. The size of the Oropos clock stresses both the great significance of the sanctuary and the special importance of time measurement for that particular kind of healing center. The fact that the water for the operation of the device was the same with the "sacred water" of the sanctuary's spring that was used for the cleansing of patients arguably indicates an underlying belief to the sacred nature of time and time measurement itself.

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