The Mycenaean drainage works of north Kopais, Greece: a new project incorporating surface surveys, geophysical research and excavation

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Abstract
The attempt to drain the Kopais Lake was one of the most impressive and ambitious technical works of prehistoric times in Greece, inspiring myths and traditions referring to its construction and operation. The impressive remnants of the Mycenaean hydraulic works represent the most important land reclamation effort during prehistoric Greek antiquity, attracting thus the attention of the international scientific community. Nevertheless, in spite of the minor or extended contemporary surveys, the picture of the prehistoric drainage works in Kopais has remained ambiguous. Concerning the function of these works and their precise date within the Bronze Age, the proposed theories were based solely on indications from surface survey; data stemming from archaeological or geophysical research methods have been largely neglected. The new interdisciplinary project focusing on the interpretation of the Mycenaean drainage works of Kopais is conducted. This paper presents the results of the first study season.
Keywords: Drainage systems; Hydraulic works; Kopais; Mycenaean civilization

Introduction
The attempt to drain the Kopais Lake was one of the most impressive and ambitious technical works of prehistoric times in Greece. The size and the importance of this achievement inspired myths and traditions referring to its construction and operation, as well as to its final destruction, which has been attributed to Heracles (Diod. Sic., 4.18.7 "*… but in Boeotia he did just the opposite and damming the stream which flowed near the Minyan city of Orchomenos he turned the country into a lake and caused the ruin of that whole region. But what he did in Thessaly was to confer a benefit upon the Greeks, whereas in Boeotia he was exacting punishment from those who dwelt in Minyan territory, because they had enslaved the Thebans ….*").

Mycenaean Boeotia and the Kopais Lake
Being located on the crossroads connecting the Peloponnese and Attica to the north of Greece (Fig. 1), Boeotia is one of the most important regions of Mycenaean Greece (1600-1100 BC), as borne out by the finds from excavations and its significant place in mythology and ancient traditions. The geographical division of the Boeotian plain into two parts surrounded by mountainous massifs reflects also the political reality of Mycenaean Boeotia: in the northern part, which includes the Kephisos valley and the Kopais basin, Orchomenos was the major center surrounded by a network of smaller

satellite settlements; in the southern part with the extensive fertile plain of Thebes, the plains of Asopos, Tanagra and the coast of the Euboean Gulf, Thebes was dominant, being supported by an analogous regional settlement pattern.

Fig. 1: Map of the Boeotian Kephisos basin and the former Kopais Lake (grey area between Gla and Orchomenos) at the center of mainland Greece.

Fig. 2: Façade of the Mycenaean tholos tomb of Minyas at Orchomenos.

Excavation evidence and historical tradition attest (e.g. Bulle 1907; Iakovidis 1995) that the most important centre in northern Boeotia was Orchomenos, lying in the northwest corner of the Kopais lake/plain. A mainland and primarily a lakeside power, Orchomenos turned its attention mostly towards central Greece aiming for the control of the unique natural resources at hand. Overseas relationships do not seem highly important. The sporadic archaeological investigations in Orchomenos have brought to light only few remains of the Mycenaean settlement. The finds, however, indicate its special flourish. (Schliemann 1881; Papazoglou-Manioudaki 1990) (**Fig. 2**).
In the memory of the ancients, the legendary wealth of Orchomenos was due to the cultivation and exploitation of the drained Kopais Lake (Il. 9.381; Str. 9.2.40.). The power and plenty enjoyed by Orchomenos lasted, according to ancient myth, until Heracles took vengeance on the King of Orchomenos: the famous hero blocked the exit of the Kephisos River towards the sea flooding the Kopais once again (Apollod. 2.4.11, Diod. Sic. 4.18.6).
The enormous installation of Gla (e.g. Iakovidis 1983; 1998) built on a natural island in the east creek of the lake (**Fig. 3**) is located close to Orchomenos. The citadel was constructed in the early thirteenth century BC by Mycenaeans from Orchomenos, along with the works for the drain of Lake Kopais. It is girt by a Cyclopean enceinte pierced with four gateways; remnants of large buildings, clearly palatial, can still be seen. The constructions on the citadel (Cyclopean wall, residences of officials and granaries) were built contemporaneously. This ensemble has been interpreted as part of an ambitious plan for supervising the drainage installations, as well as collecting and storing the production of the plain. Gla was destroyed in the late 13th century BC.**3**

Fig. 3: Aerial photograph of the citadel of Gla.

The main hydrosystem components of Lake Kopais

Greece contains several closed (endorheic) basins and plateaus, usually surrounded by mountains of karstic limestone and drained by natural sinkholes. The Boeotian Kephisos basin, on the Eastern Central Greece, north of Athens, is the largest one, covering an area of about 2000 km^2 (**Figs. 1, 4**).

Fig. 4: Topographic overview of the Kopais Basin in Boeotia with the location of the main river courses.

The Boeotian Kephisos River, flowing from northwest to southeast, is discharged at the south-eastern edge of the local basin. Having no outlet to the sea, the concentrating waters of the river formed the Lake Kopais. This body of water either evaporated or drained through several sinkholes in the eastern part of the basin. The basin represents a structural polje of intra-mountainous tectono-karstic depression in a limestone region (Tsodoulos et al. 2008). The polje is well known as a geoarchive for high-resolution palaeoclimatological proxies spanning the period since the mid Pleistocene (Tzedakis 1999; Griffiths et al. 2002). During the winter, the minimal evaporation coupled by the limited discharge capacity of the sinkholes led to the increase of depth, area and storage of the shallow Lake Kopais. On the contrary, the lake decreased in summer, occasionally in a quite spectacular manner.

The Kopais basin hydrosystem also includes Melas River, which is supplied by the homonymous springs of mount Akontion and is discharging in karstic sinkholes of the northeastern fringe of Kopais basin. Spring altitude varied between 97.70 m and 101.50 m, whereas discharge varied from 2.80 m^3/s to 5.30 m^3/s (88.0 – 166.6 x 10^6 m^3/year) (Xanthopoulos et al. 1990). The local hydrosystem also comprises Erkyna, Pontza and several other small streams, flowing mainly from the south of the basin, as well as a

variety of springs. The mean total annual discharge of the springs of the Boeotian Kephisos is currently about 300 x 10^6 m^3/year, but it used to be higher at the beginning of the 20th century (about 380 x 10^6 m^3/year). The altitude of the lake's bottom was 84 m a.s.l. and it did not exceed 92 m a.s.l. in its greater part. The water level of the lake was determined by the elevation of the sinkholes, usually not exceeding 97 m a.s.l. The lake covered an area ranging from 150 km^2 to 250 km^2 (Constantinidis 1984). During the floods of 1852 and 1864, water level exceeded 97 m, resulting in the flooding of about 20 km^2 of the neighboring Levadeia basin, whereas the year 1856 drought led to the complete draining of the lake.
Prior to the construction of the 19th century drainage infrastructures, the Boeotian Kephisos emerged from the mountain valley onto Kopais river basin at Pyrgos, NE of Skripou – Petromagoula, joining the Melas river bed. The combined flow was slowly accumulated towards the great sinkholes of Kephalari, south of Topolia village. The Mycenaean drainage works were exactly based on this natural mechanism. Hence, the Mycenaean inhabitants of Orchomenos, in their efforts to secure arable land, must have realized that their main purpose should be to convey the combined discharge of Boeotian Kephisos and Melas away from the Kopais basin, towards the sinkholes to the northeast.

Subsequent attempts to drain Kopais: historical notes
Among several subsequent attempts to drain Kopais, an unfinished tunnel in the northeast part of the basin close to the sinkholes stands out: the so-called Kephalari pass has been dated to the Mycenaean period (Knauss 1991). However, there is a strong possibility that the tunnel was constructed much later, during the Hellenistic age. In such a case, it could be considered as part of the drainage works that Alexander the Great has assigned to Krates, his chief engineer who originated from the nearby Chalkis (Stephani Byzantii, Ethnica, 2. 591). During Roman times, at least two attempts to drain Kopais are documented: first by Epameinondas Epameinondou, a prosperous local from the ancient Akraiphia (Oliver 1971), and then by the Emperor Hadrian (Boatwright 2000).
At the end of the 19th century, initially a French and then an English company (Karavasili 2000, Grypari 2000, Karavasili et al. 1996) constructed the extended drainage network of canals, drains and levees, as well as the Karditsa diversion tunnel, which drained the lake by diverting the water into the adjacent lake Hylike. This was the first major hydraulic project in the Modern Greek state. As part of this project, the part of the Boeotian Kephisos downstream of the site Veli was realigned through an artificial channel (known as Grand Canal, Canal in the March or Emissary Canal). The cartographical and topographical surveys conducted by the French and English engineers of the companies that undertook the works to dry up the Lake have brought ground in the study of the Kopais' basin history (for the previous research in Kopais see Curtius 1892, Kambanis 1892, Kambanis 1893, Kenney 1935; Kahrstedt 1937; Wallace 1979). The impressive remnants of the Mycenaean hydraulic works that were discovered represent the most important land reclamation effort of prehistoric Greek antiquity, reasonably attracting the attention of the international scientific community. Nevertheless, in spite of the minor or extended surveys that followed (e.g. Lauffer 1938/1939; 1939;

1940; 1985; 1986), the picture of the prehistoric drainage works in Kopais had remained ambiguous. The theories (Knauss et al. 1984) that have been proposed concerning the function and the precise date of the works within the Bronze Age, were based solely on indications from surface survey and not on data stemming from archaeological or geophysical research methods. Furthermore, the representation of the operational scheme of the Mycenaean hydraulic works is admittedly a quite difficult task: these works coexist with (i) several subsequent and possibly incomplete attempts to drain the lake over the centuries (e.g. Oliver 1971; Oliver 1989; Boatwright 2000), plus (ii) the existing 19th and 20th century drainage infrastructures.

The New Kopais project: first fieldwork results

The new interdisciplinary project focusing on the interpretation of the Mycenaean drainage works, is realized by the Hellenic Ministry of Education and Religious Affairs, Culture and Sports in collaboration with the Department of Water Resources and the Environmental Engineering of the National Technical University of Athens (Greece) and the Institute of Geography of the University of Mainz (Germany). The project aspires to answer several queries about the technological background of the inspired technical work in Kopais. Additionally, a series of hydraulic and hydrological analyses attempts to extract the exact operational scheme of the works. The field works, undertaken during the summer of 2011, comprise archaeological surface survey, topographical mapping, geophysical survey, subsurface sampling of soils and three-dimensional terrestrial laser scanning, all combined with exploratory archaeological excavations in selected areas. The results of the first field season provided new evidence on the construction, the course, the size and mainly the dating of the Mycenaean hydraulic works.

This year a total area of 67.5 km^2 was covered, stretching from Orchomenos in the west to the modern village of Kastro in the east, and from the limestone slopes of the basin in the north to the village of Agios Demetrios in the south. Starting from the focal point of the segments of the wall excavated by the first author at the site of Anteras, the Mycenaean levee walls were traced and mapped west, towards Orchomenos, for a length of 2.5 km, and east, in the direction of the village Kastro, for 8.5 km. In addition, the Pyrgos, Stroviki, and Tourlogiannis hills were explored for possible auxiliary installations of the Mycenaean hydraulic works, such as guard posts or small forts. At the same time, smaller drainage works and man-made water storage areas postulated by other scholars (Knauss 1984) were sought in the entire aforementioned region. Four new archaeological sites dating to the Classical, Roman and Post-Byzantine periods were located and mapped with GPS, in the northwestern section of the basin. Their particular geographical position seems especially important, for it is related to the fluctuations of the water levels of the lake during the periods when the water management systems were in operation.

Several initial findings were verified by the preliminary hydrological analysis and the geoarchaeological research. The geo-scientific studies carried out in the Kopais basin by the Institute of Geography of the University of Mainz comprised of vibracoring using an Atlas Copco Cobra mk 1 coring device. The maximum recovery depth reached 7 m below surface with core diameters of 6 and 5 cm. Photo-documentation, description and sampling of the retrieved cores were carried out in the field. Core description included the analyses of grain size, sediment colour, calcium carbonate content and noticeable features such as plant and macrofaunal remains or ceramic fragments.. For the geochemical analyses, X-ray fluorescence measurements (XRF) were carried out during fieldwork using a hand-held XRF analyzer [type Thermo Niton Xl3t 900S, calibration mode SOIL]. Measurements were taken every 5 cm, wherever possible, in order to obtain a detailed vertical distribution pattern for the stratigraphical record. Earth Resistivity Tomography [ERT] measurements were carried out at different locations to detect buried segments of the Mycenaean wall and/or sedimentary structures below present ground surface. ERT transects were orientated perpendicular to the assumed course of the levee according to the survey that had been preceded. The position and elevation of the coring sites and the ERT transects were measured (by means of a TOPCON HiperPro FC-250 DGPS device), and the older stratigraphical excavations, can be set forth.

An **initial overview based on the findings of the first field season**

First, at the site of Romeiko, around 2.5 km northeast of Orchomenos, one of the two branches of the lower reaches of Boeotian Kephisos River was diverted from its old bed to a new one, shared with the Melas River; the second branch of the Kephisos continued to flow into the western margin of the Kopais basin. This diversion is likely to have been the work of the Mycenaeans. By diverting part of Boeotian Kephisos and Melas Rivers towards the sinkholes existing along the banks of the basin, the water level and the area of the lake were reduced; consequently, the northern portion of the basin could be turned over to cultivation.

Second, the diversion was accomplished with the aid of a robust levee, carved in a west-east direction, from the area of Orchomenos towards the sinkholes of the north-eastern cove. The levee ran along the northern edge of the lake, in proximity to the limestone slopes of the basin. It was also setting the boundaries of the region flooded by the waters of Boeotian Kephisos and Melas Rivers, before these were being emptied into the sinkholes. In effect, the levee worked as a barrier and water retention dam at possibly the highest rim of the basin, allowing the land on the other side to be dry for agricultural exploitation.

Third, in the portion that was investigated, the levee's course appears to follow, in parts, the modern country road linking Kastro and Orchomenos, as well as a farm road leading towards the village of Pyrgos. The remains of the levee discovered during the modern widening of the country road between Kastro and Orchomenos, as well as the stratigraphy of the excavations taken place in the site of Anteras, confirm the aforementioned course (**Fig. 5**). The terminal point of the levee to the west, near Orchomenos, was not determined during this year's field work. Notably, the aquifer that feeds the Melas springs has a significant storage capacity and extends to a depth of at least 100 m; therefore, the spring discharge is high even in dry periods.

Fig. 5: 3D terrestrial laser scanning of the excavated parts of the levee.

Fourth, the constancy of the water supply of the Melas River in yearly terms made it suitable to be used for irrigation and in domestic settlements, without requiring more complicated artificial reservoirs for floodwater retention. Further investigation is needed in order to certify whether the Mycenaean infrastructures included the construction of polders and artificial reservoirs for floodwater retention and storage.
Fifth, the exterior sides of the levee are consolidated by strong retaining walls, built in the Cyclopean masonry style (**Fig. 6**). These walls improved the resistance of the levee to the pressure of the water and hindered the erosion of the soil. At the same time, they provided a strong retaining infrastructure for the possible construction of a road along the top of the levee, by the creation of an artificial plateau. The exterior face of the retaining wall is sloped at an angle of 78 degrees; the stones of the lower courses protrude markedly from those of the upper courses. The well-built walls are preserved to a height of 2.30 m, having a width of 1.78 m at the top and 2.78 m at the base (**Fig. 7**)

Fig. 6: View from the North of the northern retaining wall of the levee (Doufexis plot).

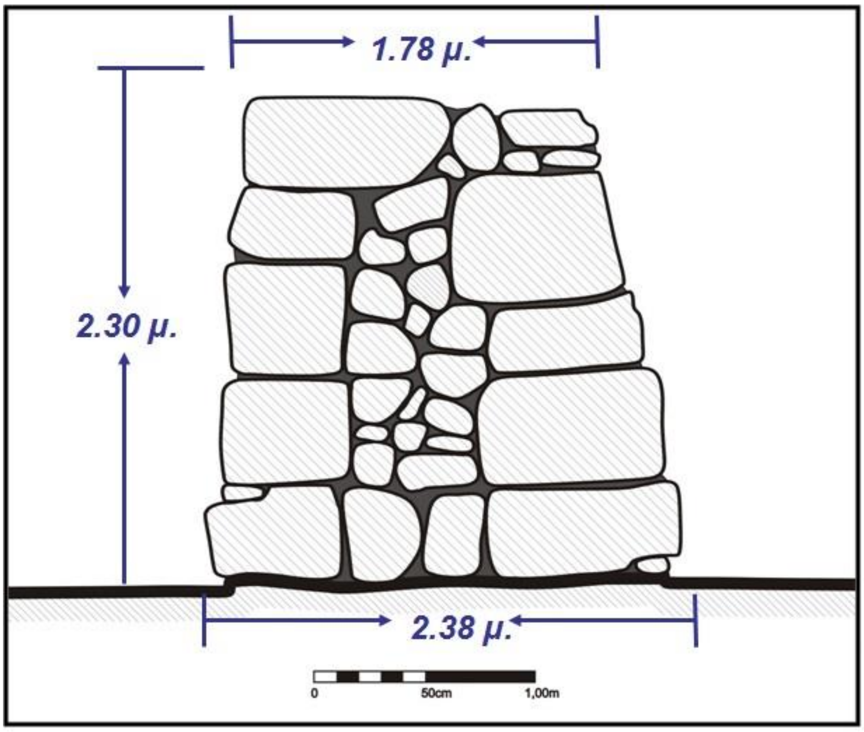

Fig. 7. Section of the northern retaining wall of the levee.

Given the quantity of stones found in the destruction layers, an original height of over 3 m can be postulated. The walls were created using large boulders placed in roughly regular courses, with smaller stone chips used as filling. Initially, a foundation trench was dug consisting of a shallow ditch. This was somewhat wider than the retaining wall and it was filled with small stones set into a thick layer of clay. Above this waterproof insulating infrastructure, the stones of the first courses were laid, supplemented by a clay filling in between the joints. The rest of the retaining wall was constructed on top of this course. Unlike the exterior face of the wall, the interior facade was erected vertically, without any particular aesthetic attention; it was filled with uncut boulders protruding and receding at random, and a thick mass of small to medium stones and clay.

Sixth, the core of the retaining wall makes extensive use of yellowish clay originating from lake deposits, which is characterized by plasticity and waterproof qualities. A thick and compact layer of this clay, measuring a total of 2 m thick, reaches down to the foundation trench of the retaining wall; the layer was completely devoid of any ceramic material (**Fig. 8**). In a certain case, at the lowest level of this layer of clay, a large stone was found, having fallen from a higher course of the retaining wall. Around it, a small quantity of stone chips indicates that the boulders were roughly hewn on the spot.

Fig. 8: Stratigraphy of the core of the levee**.**

Seventh, the retaining walls did not have the same dimensions everywhere. These were often dictated by the geomorphology of the area and proximity to the limestone slopes and the sink holes. The total width of the wall at the site of Anteras, including the two Cyclopean segments which marked its northern and southern long sides, measures 30 m.
Eighth, the second retaining wall, on the side facing the dry valley, is often omitted. In these cases, the width of the wall is much smaller.
Ninth, a *terminus ante quem* for the chronological determination of the construction of the retaining wall is provided by the cemetery found at Stroviki. The site is located at a level lower than that of the foundation trench, and dates to the MH period (Aravantinos et al. 2006). In addition, the investigation of undisturbed layers of fill have provided ceramics which clearly place the period of construction and use of the corresponding portions of retaining wall in the LH IIIB period (the middle of the 13th century BC). It is thus confirmed that they belong to the same chronological horizon as that of the citadel at Gla.

Questions posed and future research
Up to now, fieldwork has equally posed new and answered already set questions. Several of them relate to the effectiveness and any possible failures of the technical works, the chronological sequence of the construction of the various sections and the joints between these sections.
It should be stressed that a technological work of such a scale required extensive excavations and removal of huge quantities of earth, not to mention the quarrying, transport, processing and lifting of such large boulders for the building of the retaining walls. The fact that the stones for the construction of the retaining walls seem to have

been hewn in place requires organized teams of personnel with clear and distinct responsibilities; at the same time, it presupposes the existence of a steady flow of supplies. All of the above support the case that there must have been a particularly strong and centralized authority in the region. Should we consider Orchomenos as that central power mobilizing human resources, means and materials for the design, the construction and the logistics of such a prestigious work? Or are we facing a case of cooperation between certain powers of the time, including the other powerful administrative centre in the region, Thebes? For the time being, the former hypothesis seems more possible.

Future fieldwork will focus on (1) further locating the western starting as well as the eastern terminal point of the levee, along with any secondary works, (2) identifying specific construction details of the levee, (3) excavating more selected sites in order to confirm the chronological framework, and (4) clarifying the exact operational hydraulic pattern of the works.

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