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Mario Parise
Carla Galeazzi, Roberto Bixio, Carlo Germani

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LOST CONSTANTINOPLE: SUBTERRANEAN WATER STRUCTURES - APPLICATION OF SPELEOLOGY TECHNIQUES IN THE ARCHAEOLOGICAL RESEARCH

Çiğdem Özkan Aygün, Ali Hakan Eğilmez
İstanbul Technical University (ITU),Taşkışla Campus, Department of Fine Arts, Istanbul, Turkey

Corresponding author: Çiğdem Özkan Aygün - proceedings_soma2007@yahoo.com, ozkanci@itu.edu.tr

Abstract
This paper is about the archeological survey which was presided by Istanbul Technical University professor Dr. Çiğdem Özkan Aygün, on the water distribution systems of ancient Constantinople. The research covers the cisterns, wells, water distribution channels/galleries and other water structures in the area of today's Hagia Sophia Museum, Topkapı Palace Museum, Istanbul Archaeological Museums and Hippodrome. This area refers to the acropolis of the ancient settlement and the first hill of East Roman city. Apart from some research on the supply system arriving to the city, a comprehensive archaeological research does not exist related to the historic triangle. The main objective of this project is to explain the functioning of the water supply and distribution systems, the connection between them and their connection to the historical upper structure. That is why we preferred to start our survey from the end of the distribution lines. This area kept its importance as the religious and administrative nucleus of the historical city through many eras. Together with a group of archaeologists, architects, civil engineers and art historians from Istanbul Technical University, a group of professionals from ASPEG (Anatolian Speleology Group) participated in the project as well. Freelance photographers and divers have also contributed to the survey. We used underwater and land ROV (Remote Operating Vehicles) for the inaccessible areas. While following the water distribution channels, some unexpected structures have been also found and examined. The most important ones are like a hypogeum under the northern garden of Hagia Sophia. The aforementioned research had been the pioneer for the cooperation of archaeology and speleology in Turkey and had been followed by many other projects done together with speleologists. Information about the publications can be found under www.hagiasophiasubterranean.itu.edu.tr.
Keywords: water supply system, galleries, wells, cisterns, water towers, archaeology, speleology, subterranean cities.

Riassunto
A partire dal 2005 è stata realizzata una indagine archeologica sui sistemi di distribuzione dell'antica Costantinopoli, diretta dal professor Dr. Çiğdem Özkan Aygün per la Istanbul Technical University. I ricercatori fino ad ora hanno scoperto cisterne, pozzi, canali/gallerie di distribuzione e altre strutture idrauliche nell'area dell'odierno Museo di Hagia Sophia, Museo del Topkapi, Musei Archeologici di Istanbul e dell'Ippodromo. In questa zona si trovava l'Acropoli dell'antico insediamento e la prima collina della città orientale romana. Nonostante l'esistenza di ricerche relative al sistema di alimentazione che arriva alla città, non esisteva una dettagliata ricerca archeologica sul triangolo storico. L'obiettivo principale di questo progetto è spiegare il funzionamento del sistema di approvvigionamento idrico e di distribuzione, il collegamento tra queste strutture e la loro connessione alla struttura storica superiore. Questo è il motivo per cui abbiamo preferito iniziare l'indagine dal punto di arrivo delle opere di distribuzione, nell'area che ha mantenuto la sua importanza attraverso tutte le culture che qui si sono succedute, in quanto nucleo religioso e amministrativo della città storica. Oltre ad un gruppo di archeologi, architetti, ingegneri civili e storici dell'arte della Istanbul Technical University, il progetto è stato realizzato insieme ad un gruppo di tecnici della ASPEG (Anatolian Speleology Group). Hanno contribuito allo studio anche fotografi e subacquei. Per l'indagine delle aree inaccessibili abbiamo utilizzato un robot teleguidato terreste e subacqueo. Seguendo i canali di distribuzione dell'acqua sono state ritrovate ed esaminate alcune strutture inaspettate. Le più importanti si trovano sotto ad Hagia Sophia, come ad esempio un ipogeo sotto il giardino nord. Questo progetto è stato innovativo in Turchia per la cooperazione fra archeologia e speleologia ed è stato seguito da molti altri progetti che hanno visto il contributo decisivo degli speleologi. Informazioni sulle pubblicazioni sono disponibili al sito www.hagiasophiasubterranean.itu.edu.tr.
Parole chiave: *sistema di approvvigionamento idrico, gallerie, pozzi, cisterne, torri d'acqua, archeologia, speleologia, città sotterranee.*

Objectives of the Research

The main objective of this research is to detect the unknown parts and explain the functioning of the Byzantine and Ottoman water supply and distribution system under the historical peninsula of ancient Istanbul (Constantinople). Although we know that in the past, the water supply lines were connected like a web, it is currently difficult to detect their connections because of the completely changed over structure of the modern city. Together with the

cisterns, the subterranean remains are the most neglected and destroyed structures of the historical peninsula. The second step of our mission was to find the connection of this substructure to the historical upper structure which is today inexistent or mostly changed.

We chose to start our survey from the last point where the distribution lines arrive, which is named as the 1st Hill of the East Roman city. This is the area which has kept its importance through all cultures as the religious and administrative nucleus of the historical city. The biggest difficulty for our research was to get the necessary permissions to be able to work because the area is covered by museums like Hagia Sophia Museum, Topkapı Palace Museum and Istanbul Archaeological Museums buildings.

Research Members and Methodology

The survey was spread on a vast area inaccessible to the public. Archaeologists, architects, civil engineers and art historians from Istanbul Technical University, together with a group of about 20 professionals from ASPEG (Anatolian Speleology Group), photographers and divers have contributed to the survey. Because of the high architectural vulnerability factor, we had to implement nondestructive methods.

The conduits, wells or cisterns which were still full of water, had to be entered through scuba techniques and even a hookah system. (Hookah is the diving system which uses surface-supplied air for divers in narrow spaces and shallow depths, so a diver doesn't wear a tank on his back). We used underwater and land ROV (Remote Operating Vehicles) in order to reach the inaccessible areas and to detect the dangerous objects in some parts of the research area. The ROV were produced specially for the survey by our research member Engin Aygün who also filmed the underwater documentary.

Contributions to the Public Archaeology

Although most of the subterranean cisterns and related conduits have already been destroyed, there is a vast number of structures still to be discovered. The inhabitants of the city are the real owners of the remains and should have been the ones to preserve, instead of destructing them. Also we need the public awareness and collaboration to get reports for the remains unknown to us.

To receive the public support and to share the results of our findings, we have been shooting documentaries and showing them on television channels like İZtv documentary channel (*https://www.youtube.com/watch?v=qDm29b05src*) and TRT (Turkish Radio and Television). We have also organized conferences open to public to raise the awareness on the subject. As a result, we gladly observed that the interest towards the subterranean city had been increased dramatically.

Our survey also generated a positive collaboration between archaeology and speleology. Other projects have been conducted especially about the water supply lines in different archaeological areas with the help of speleologists since then.

The Water Structures under the First Hill of ancient Constantinople/İstanbul

Galleries and Cisterns

It is well known that the water scarcity had been a great challenge for the city of Istanbul. The historical peninsula did not have enough fresh water sources but it was chosen as a settlement area because of its strategic importance. The most ancient water structures in the area were the wells and small cisterns. The first Roman supply line to channel water to the city was built by Emperor Hadrian (117-138). Emperor Valens (364-378) supplied water for the city from Thracia, and constructed the Valens Aqueduct to pass the supply line over. Byzantines added many closed and open cisterns which are generally related with the supply lines but also can function autonomously. The cisterns were critical for a medieval city where the supply lines arriving from outside of the city walls could be difficult to maintain under the frequent sieges.

The supply lines basically come from two different altitudes. The Thracian waters consist of the high level sources, whereas the Belgrade Forest waters being closer to the city represent the low level sources (35 m a.s.l.).

The Ottomans maintained the Byzantine supply lines and added new sources; the line known as Kırkçeşme higly correlates with the Byzantine line arriving from Belgrade Forest. The supply lines under the First Hill is basically the Byzantine galleries. Those galleries are generally above the level of the main rock and the dimensions change from 40 to 90 cm in width and 40 to 180 cm in height (Aygün Özkan, 2011; Aygün Özkan, 2007; Aygün Özkan, 2007 b; Aygün Özkan, 2006a; Aygün Özkan, 2006b).

Wells

Unlike the cisterns, the wells are fed by the subterranean water sources. Before the construction of big cisterns like the Basilica cistern, L-shaped cistern in the southern courtyard of Hagia Eirene or Euxippos cistern in the west of Hippodrome (dated to V-VI centuries), the acropolis area was fed through the wells and small cisterns. First Hill area of the east Roman city which consists also the acropolis of the ancient city, is the center for the religious and administrative structures from pagan, Christian and Islamic era and contains the most ancient wells in the city.

Water Towers

Water arriving to the city from far away sources through the supply lines is taken into a distribution reservoir (*castellum*) and from there it is delivered to the quarters of the city. The water towers have the function of leveling the pressure of the water to be distributed so we see those water towers in İstanbul approximately every 10 m of difference in altitude. Some also have a special chest utilised for the discharge measurement.

Discharge Measurement System

Water discharge had been measured by the help of a a spillway which was constructed over a wide and long

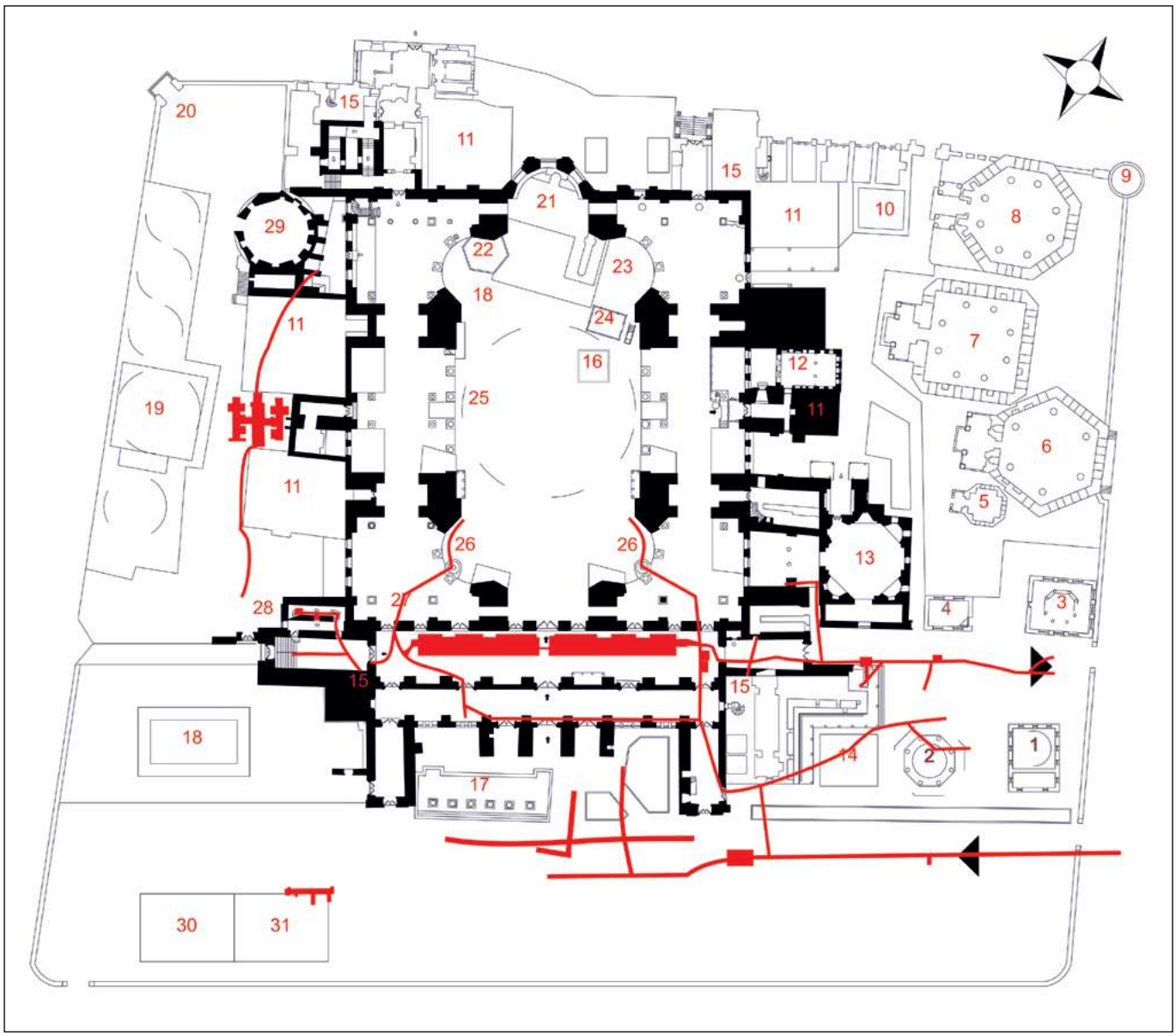

Fig. 1: findings of the project related to the subterrains of Hagia Sophia (redrawn from drawing of Murat Eğrikavuk by Kaçar, M., Bir, A. for Aygün, Ç.Ö.).
Fig. 1: i risultati del progetto sui sotterranei di Hagia Sophia (rielaborazione del disegno di Murat Eğrikavuk a cura di Kaçar, M., Bir, A. for Aygün, Ç.Ö.).

rectangular stone chest. They had also the functions of precipitation and regulating the distribution of water to the fountains and to the houses of the high ranked people according to their need. We have information on how they have functioned, and of the measurement techniques applied in Ottoman time which were based on the same principles probably also during the Byzantine era.

The Findings of Our Survey

Hagia Sophia Subterranean (Fig. 1)

The findings related to the subterranean of Hagia Sophia including 1 km of galleries, pipelines (Fig. 2), subterranean rooms, wells, *spolia* especially from the second phase of Hagia Sophia (V century), hypogeum and the substructure under the narthex (Fig. 3) have been found through this research (Aygün Özkan, 2011). As those findings have been already published, we will not go into details for every subtopic but we will give information about the hypogeum in the N garden which is the less known and neglected structure in the Hagia Sophia complex. Hypogeum and the substructure under the Inner Narthex are the structures which had not been built as water structures but converted in a later time and connected to the supply line system. Those were the most enigmatic structures between the findings under Hagia Sophia.

One of the most interesting findings of our research has been two wells still full of water under the nave just below the pavement slabs. Our dives into those wells one full with 10 m and the other with 6,5 m of water have been like a voyage to the pagan times of the structure through a water tunnel. The one S of the NW pier of the dome had been mentioned before (Antoniades, 1907; Emerson and Van Nice, 1943) but the others were found or researched for the first time. In total, 8 wells have been found at Hagia Sophia and its courtyards.

Fig. 2: the gallery with terracotta and iron pipelines (photo Metin Albükrek).
Fig. 2: la galleria con tubazioni in terracotta e ferro (foto Metin Albükrek).

There were various *spolia* generally belonging to the Theodosius' Hagia Sophia. The Justinian's Hagia Sophia was known to be a rush job and we have observed in the subterranean channels that even very fine material belonging to previous building has been used as an ordinary stone to build those channels.
As the area of Hagia Sophia had several historical layers from the pagan and Christian eras (IV, V and VI centuries) it had a complicated system of water supply/drainage lines and galleries. The supply lines reached 3 different layers on top of each other under the W garden. The supply line which was in connection to the main supply line of the city was also passing under the W garden and continued towards Hagia Eirene, and later towards the Harem section of the Topkapı Palace. Especially the gallery which is connected with the Horologion and being used as a store room for the museum today, was high and large enough to be a passage between the church and probably the Great Palace and Hippodrome.
Some of our findings proved and some of them denied the legends created especially by the travelers who have visited this marvelous building in the history. For instance, there was no trace belonging to the legendary cistern (De Clavijo, 1406; Grelot, 1680; Moreno, 1789; Van der Vin, 1980) but it is probable that we have found the well so called the sacred Samaritan well (Antoniades, 1907; Lethaby & Swainson, 1894; Bonfiglioli, 1974). The well is accessible from outside of the building and stands at the point, SE of the church.

Hypogeum under the Northern - 'Vezir's Courtyard of Hagia Sophia

There is a totally neglected hypogeum under the N courtyard which is also known as the Vezir's Courtyard. Although it is one of the most interesting structures under the courtyards of Hagia Sophia, it is full of rubbish and sewage today. This structure is located between the NW and NE buttresses. Hagia Sophia had to be supported by outer buttresses which were built at different times all along its history, including the Ottoman era. We have entered into the hypogeum through a hole in front of the NE buttress.
The structure is made of three chambers. The subterranean marble doorjambs of the portal still exist. The main chamber is 1.4 m wide and 7.61 m long, high 2.3 m. All chambers have barrel vault.
The cubicula located N and S of the main chamber contain *arcosolia* and 10 *kline* (a couch upon which reclined the body of the deceased) which still exist (Fig. 4). The S chamber is destructed with the northwest buttress from its western end which could contain two more *kline* at that side.
The *kline* chambers are broken up by a wall of greenstone at their W extremity.
The main chamber is connected with two water conduits from its W and E ends, and the whole structure is covered with hydraulic cement transforming it to a cistern. M. Kouppas describes hydraulic cement made of *"coarse lime (titanos) slaked by water into powder, sifted and laid in layers with cotton shreds. This was thoroughly mixed, and then olive oil was poured in and the whole gradually brought to a homogeneous mass"* (Lethaby and Swainson, 1894).
The W conduit is all brick and today carries sewage into the hypogeum. The E conduit comes from the direction of the *skeuophylakion* (treasury), and can be connected to the channel inside the niche in its interior. The pipe continues to N towards the big L-shaped cistern in the S courtyard of Hagia Eirene. Recalling Socrates' statement that Hagia Sophia and Hagia Irene were *'enclosed by a single wall and served by the same clergy'*, it is possible that the L-shaped cistern was used by both the buildings. Fresh water still runs coming from the direction of *skeuophylakion*.
The vaults of both the S and N chambers have been broken at the center and earthenware pipes are visible at those points. The pipes are 18 cm in diameter, covered with glaze from inside. Also, a piece of white marble slab can be seen from the broken points to allow the passage of the pipes. Those pipes seem to be used for pouring water in (likely, drinkable water) rather than carrying water out. The piece of white marble slab is in accordance with the records from previous explorations in the N courtyard. As the marble is irregularly broken to let the earthenware pipe pass through, we may

Fig. 3: the substructure under the inner narthex (photo Çiğdem Özkan Aygün).
Fig. 3: la sottostruttura sotto il nartece interno (foto Çiğdem Özkan Aygün).

think that it belongs to the marble revetment of an upper structure dating back to the original hypogeum building. The later usage of hypogeum as a cistern can be related to a probably Justinianic structure (Great Baptistery?), in the same context with the brick and greenstone pier visible W of the NW outer buttress.
This funerary structure is unique for its depth, size and plan when compared with the very few examples found in and around Constantinople. It is obvious that it belongs to a date prior than Justinianic Hagia Sophia (4th or beginning of 5th century). Being all covered with hydraulic mortar including the vaults, there must had been a structure related with it after its transformation in a cistern.

Hippodrome

The water supply line following the W side of Hippodrome, the cistern beneath Sphendone, the 16th century Ottoman fountain related with the supply line, a stone chest belonging to the water discharge measurement system, and the terra cotta and iron pipelines have been researched and documented through our research at the Hippodrome of Constantinople.
We have found out that the Byzantine supply line was also used in the Ottoman time . The Ottoman inscription over the fountain built SW of Hippodrome show that it has been an important distribution point in 16th-17th centuries with water flow of 9lt/min and being raised to 18 lt/min.
Hippodrome lies in NE-SW direction, and its SW apsidal termination is called Sphendone. This part of the Hippodrome was built over the 1st Hill of Constantinople which is descending towards the Marmara Sea. The level difference is tolerated with a 12 m-high structure under the Sphendone. The inner buttresses of this structure creates 25 rooms covered with barrel vaults. Some of them are utilized

Fig. 4 the arcosolium in the cubiculum of Hypogeum under the northern courtyard of Hagia Sophia (photo Engin Aygün).
Fig. 4: l'arcosolio nel cubicolo ipogeo sotto il cortile nord di Hagia Sophia (foto Engin Aygün).

Fig. 5: inner buttresses of Sphendone (photo Metin Albukrek).
Fig. 5: contrafforti interni di Sphendone (foto Metin Albükrek).

as arcosolium-type tombs. Although the construction material is brick (31x5 cm) and mortar, the walls are covered with hydraulic cement.
Those rooms are surrounded with a 4,5 m-wide corridor. Inner buttresses were also added in the corridor, probably after the 551AD earthquake (Fig. 5).

The Cistern under Sphendone of Hippodrome

The structure under Sphendone is quite complex, with its W end 6 m higher than the E end. The lower E part is transformed into a 12 m-high cistern (Fig. 6), fed with a pipeline connected to the main supply line passing underneath the *Mese* (the main street of Constantinople). This cistern was one of the biggest in the city with its neighbor Philoxenos Cistern and Basilica Cistern, and was supplying water for the Great Byzantine Palace. It must be the cistern Psykhra Kinsterna which was mentioned in *Patria* (trans. Berger, 2013).

The Water Supply Line and The Water Distribution Chest under Sphendone

We have found a water distribution chest at the beginning of the supply line under Sphendone (Fig. 7). The water distribution was regulated towards three different directions from the supply line (Özkan Aygün et al., 2014). The gallery at its entrance is 70 cm high, and then it reaches 160 cm in height. The material of the wall is rubble, mortar and brick.
There are two types of pipelines passing in the gallery that provide insights for the water capacity and production era. The oldest pipelines are in terracotta. We have also found evidence of a siphon probably related with the supply line coming from the Philoxenos cistern.
It seems that there are terracotta pipes from Byzantine and 16th century Ottoman phases; then, there exists the iron pipe which runs parallel to the more ancient terracotta pipe. The iron pipe probably belongs to the phase of the restoration of the pipelines during the era of Mahmut I (18th century). The same iron

Fig. 6: the Cistern under Sphendone of Hippodrome (photo Metin Albükrek).
Fig. 6: la cisterna sotto Sphendone nell'Ippodromo (foto Metin Albükrek).

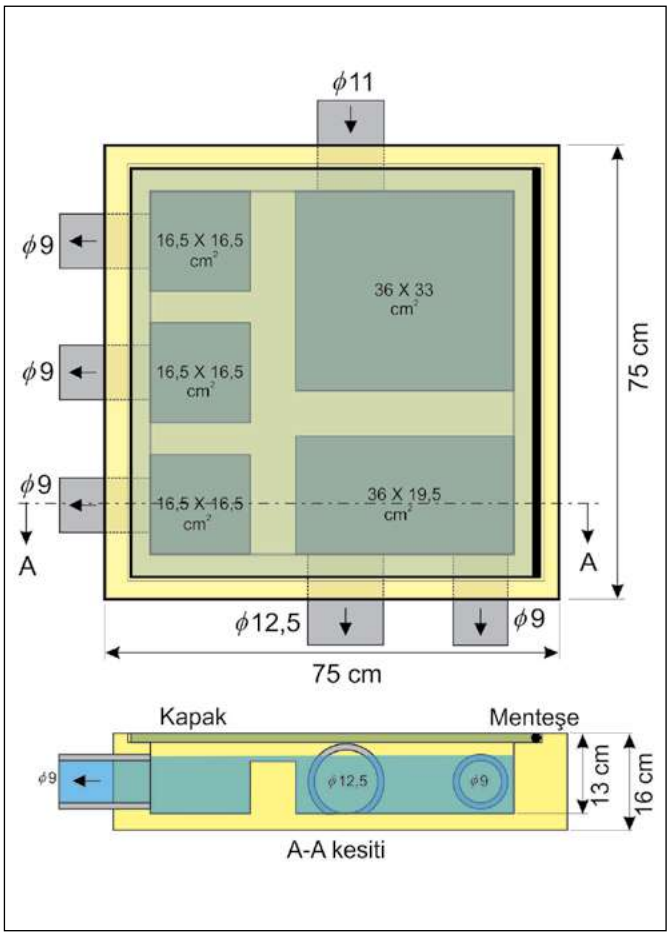

Fig. 7: drawing of the Marble Chest belonging to the water discharge system under Sphendone (by Çiğdem Özkan Aygün, Atilla Bir and Mustafa Kaçan).
Fig. 7: disegno della struttura marmorea appartenente al sistema di scarico delle acque sotto Sphendone (elaborazione Çiğdem Aygün, Atilla Bir e Mustafa Kaçan).

Fig. 8: L shaped cistern under the South Courtyard of Hagia Eirene (photo A. E. Keskin).
Fig. 8: cisterna ad "L" sotto il cortile sud di Hagia Eirene (foto A.E. Keskin).

pipelines have been found in the galleries under Hagia Sophia when Mahmut I ordered also building of a new *Şadırvan* (fountain) for Hagia Sophia.
The existence of a fountain related with the outer wall of the Sphendone gives us a *terminus ante quem* for the water chest and the gallery. From the legend of the fountain we know that it was built in the 16th century by the reign of Sultan Suleiman the Magnificent.

Water Structures in the area of Topkapı Palace
The waters arriving to the Topkapı Palace area come from two different sources at different heights. There exists 3 Ottoman maps showing the supply line so called *Beylik Supply Line* which arrives to the Palace from approximate heights of 62 m a.sl., from the province of Thracia (Maps of 1584, 1607 and 1748) but there is no map showing the arrival of the *Kırkçeşme Supply Line* from the Belgrade Forest (N forests of Istanbul) to the Topkapı Palace.
Although those were the supply lines used during the Ottoman era, they were mostly restorated from Byzantine water supply lines. The line coming from the Belgrade Forest maintains water structures with an altitute of 30-35 m like Hagia Sophia and Basilica Cistern. Our research has maintained the evidances for the distribution of water from Kırkçeşme line in the Topkapı Palace area. It was also found out the two huge interconnected wells known as *Dolap Ocağı* (Wells with pump wheel), fed by the Kırkçeşme line. Water distribution to the *Harem* was also unknown. The distribution and drainage channels beneath Harem area have been found out through our research.

Cisterns in the area of Topkapı Palace
There has been recorded 43 cisterns in the area of Topkapı Palace courtyards, Istanbul Archaeology Museum courtyards and *Gülhane Park* (Tezcan, 1989). This is the historical area where the pagan temples of Greek colony Byzantion, Roman Byzantium and churches of Byzantian city of Constantinople rest. Water was the most important need for those religious structures.
As they are forgotten and neglected today, it was very difficult to find their entrances. Even some of the entrances were lost under the modern pavements of the courtyards including the biggest cistern under the courtyards of Topkapı Palace.
In our research of this project we strongly used speleological techniques to have the data from very narrow and dark sides even inside the water by using cave dive techniques.

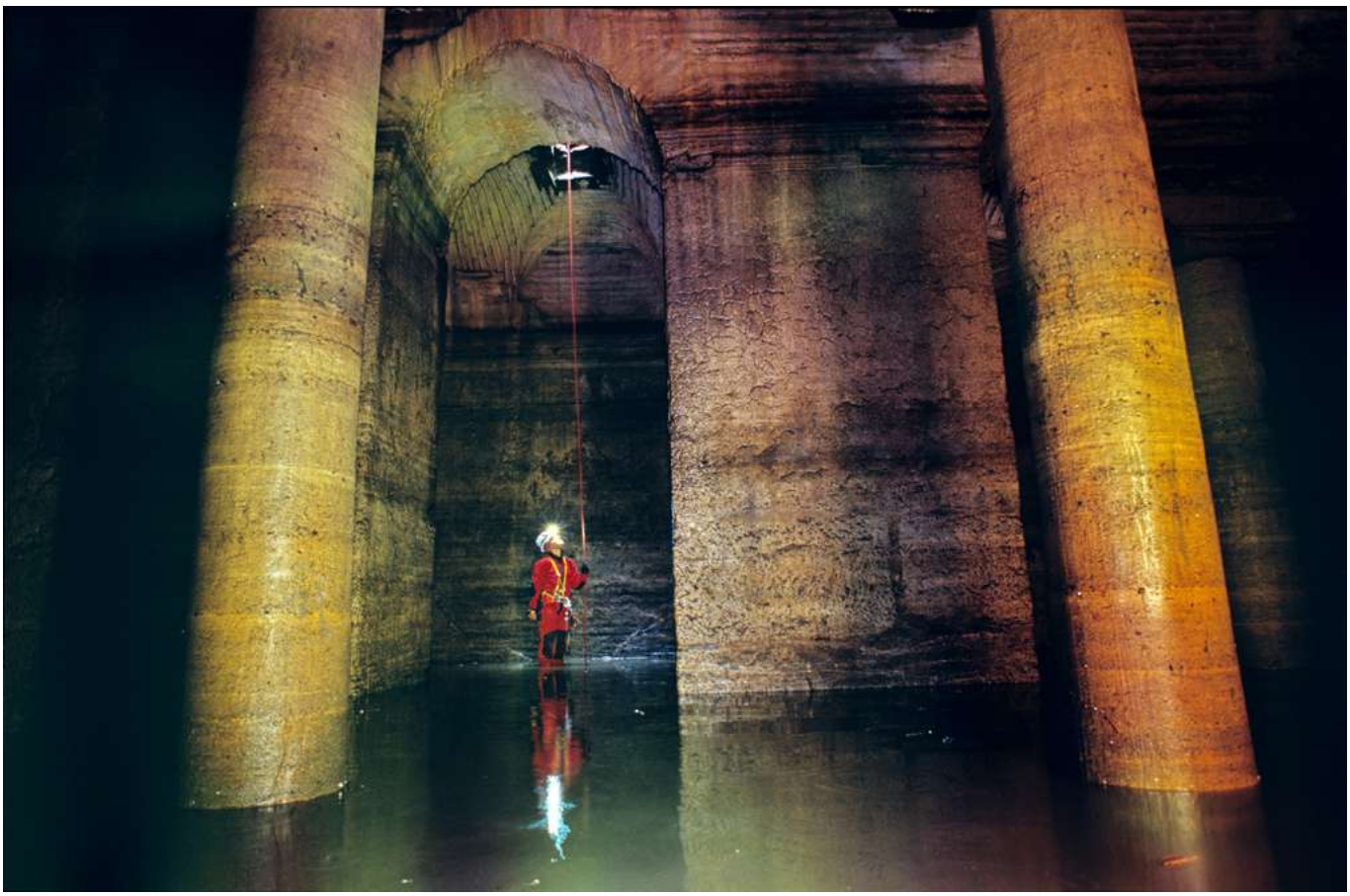

Fig. 9: the Cistern under the Courtyard of Old Chemistery Lab (photo Metin Albükrek).
Fig. 9: cisterna sotto il cortile del vecchio laboratorio di chimica (foto Metin Albükrek).

L Shaped Cistern under the S Courtyard of Hagia Eirene

The L shaped cistern is dated back to the VI century (Fig. 8). It has 48 columns, and is the second biggest cistern underneath the courtyards of Topkapı Palace. It is located under the S Courtyard of Hagia Eirene (*Ecclesia Antiqua*) which was built even before the first Hagia Sophia (*Megale Ecclesia*). Those two structures were so close to each other, they were sharing the same *peribolos* and the same clergy. It can be inferred that the L-shaped cistern was serving both Hagia Sophia and Hagia Eirene. We examined that the supply line is going towards the Basilica Cistern, so the L-shaped cistern and the Basilica Cistern also must be connected via supply lines. It has 3 meters of water in it and is full of rubbish today.

The Cistern under the Courtyard of Old Chemistry Lab belonging to Istanbul Archaeology Museums

Another cistern was found by using vertical cave techniques. The entrance is closed so we penetrated from the narrow entrance of the drainage water (used as a sewer). The base was 8 meters below and was full of poisonous water including cyanide and mud.
We inferred that the cistern must be the under-structure of a IX-X century Greek Cross planned church, inexistent today. It has four, 22 x 13 meter corridors. The columns are surmounted by ionic impost capitals (Fig. 9).

The Cistern under "Gözdeler Taşlığı" Section of Harem

This cistern, dated to IV-V centuries, has barrel vault. The capitals are half-finished corinthian type. We can understand from the water mark that it was full of water up to the top of the capitals (Fig. 10).

The Cistern under the III. Courtyard of Topkapı Palace

The cistern under the III Courtyard of Topkapı Palace is by 33 x 25 meters, with reused ionic capitals with simple cross in relief (Fig. 11). Today, it is full of municipal water, and is being used as a water reservoir. It was interesting to see the huge sized inscription of "Allah" on the wall. It was covered with Ottoman hydraulic mortar as a sign that it was used as a cistern also in the Ottoman era.

Dolap Ocağı – Wells with Pump Wheel

Two, gigantic connected wells are located in the I. Courtyard of the Topkapı Palace. They are also connected to the Kırkçeşme supply line which is 18 meters below (Fig. 12). The pump wheel which took the water up was run by oxen. The so-called "Küçük-Small Dolap-Small Wheel" well has a diameter of 5,2 m, and depth of 26 m (8 m of water when we dived), and is connected with a gallery to the "Büyük Dolap-Big Wheel" well which has a diameter of 6,5 m and depth of 22 m (Fig. 13).

Fig. 10: the Cistern under "Gözdeler Taşlığı" Section of Harem (photo Ali Ethem Keskin).
Fig. 10: cisterna sotto al "Gözdeler Taşlığı" nell'Harem del Topkapi (foto Ali Ethem Keskin).

Fig. 11: the Cistern under the third Courtyard of Topkapı Palace (photo Ali Ethem Keskin).
Fig. 11: cisterna sotto il terzo cortile del Palazzo del Topkapi (foto Ali Ethem Keskin).

Although this system was built in the Byzantine era, it was lost by the time when Ottomans conquered the city. It had been rediscovered by Architect Sinan in the 16th century and totally renovated as an Ottoman architectural structure (Cecen, 1996). According to the notes of Architect Sinan dated 1715, 247.5 lt/min of water was delivered to these wells through the supply line.
We have also detected that the supply line is descending towards Marmara Sea, pointing to the Byzantine Mangana quarter which housed an imperial palace, arsenal and several churches.

Non-Destructive/Non-Invasive Methods Used for the Survey

Surveys with non-destructive/non invasive methods are helpful for economy of time and money especially before the excavations in a vast area or for underwater explorations. Non invasive methods are also needed for preservation in situ. They are sometimes vital for the sites where the excavation permissions are almost impossible to get, or for the sites to be rescued in a limited time.
As our survey area was very problematic for permissions, we had to use a combination of different methods for our survey in the limited time given.

Underwater ROV (Remote Operated Vehicle)

It was designed and produced by Engin Aygün for the deep wells, cisterns, galleries dark and full of water, and used for pioneer inspection for dangerous materials and where there is no possibility for man penetration (Fig. 14).
It is neutrally buoyant and can move in every direction. It can reach the depth of 150 m and carries a 2x400 lumen led lamp and a nickel–metal hydride battery. It can be commanded from surface and is able to take photographs and do audio-visual recording.

Subterranean ROV

The subterranean ROV has been designed and produced by Engin Aygün solely for our survey. It can move on rough and muddy ground in every direction and can be maneuvered with a monitor on its commander. It has rubber tracks and a water-proof compartment for camera. Controlled with a 30 m cable, it has a 2x400 lumen led lamp.

The Current Situation and Dangers Against Archaeological Remainings

The galleries under Hagia Sophia are not used only for the passing of pipes for water supply but also function as a drainage. The blocked and damaged galleries cause moisture problems, with consequent falling dawn of the mosaics.
The hypogeum (converted to a cistern) under the N garden of Hagia Sophia and some galleries are full of sewage. The subterranean structures and galleries got damaged because of the new upper structures.
The denial of the existence of these galleries makes these areas available for illegal actions.

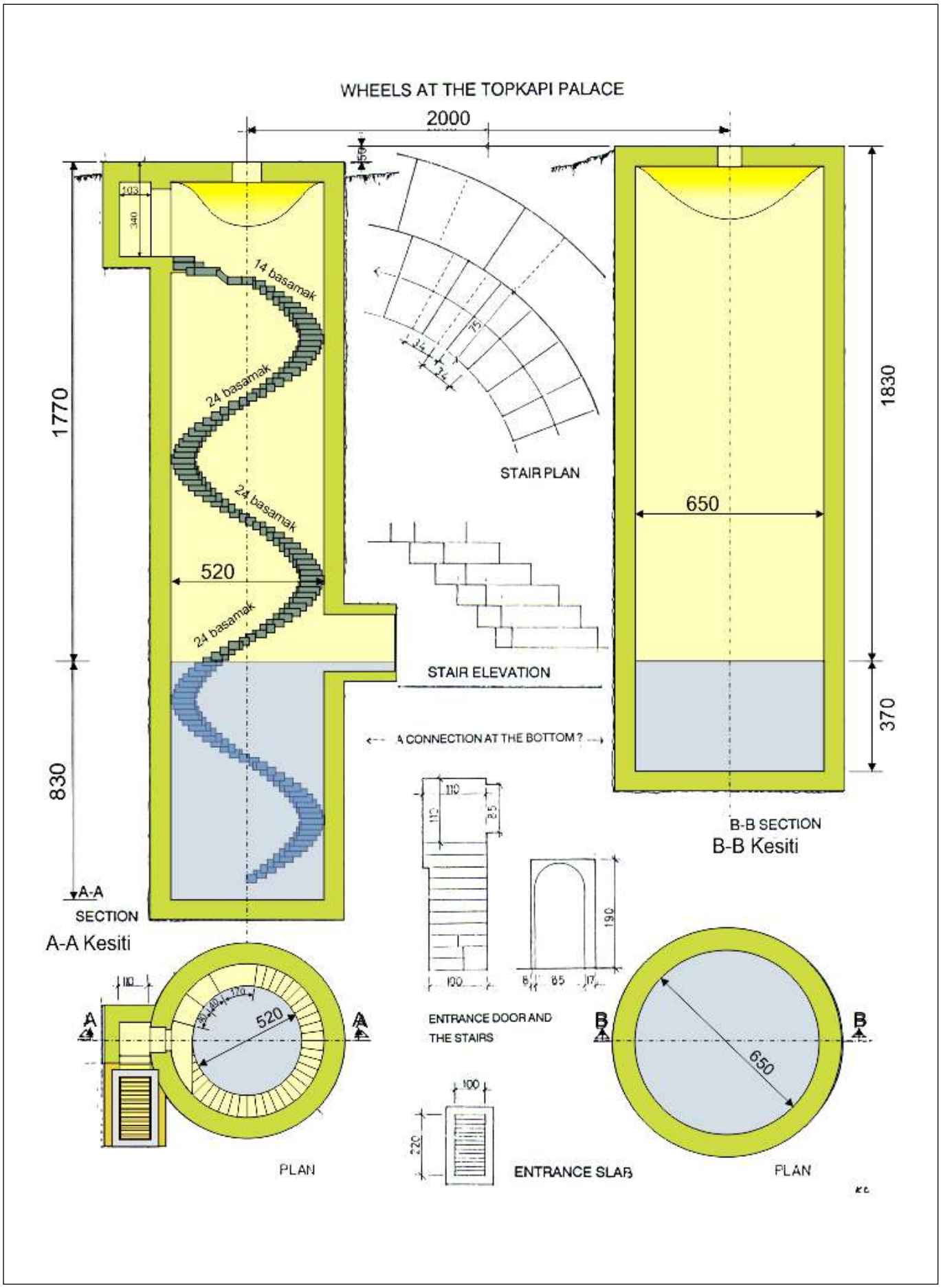

Fig. 12: wells with Pump Wheel (drawing Atilla Bir and Mustafa Kaçan).
Fig. 12: pozzi con ruota della pompa (elaborazione grafica Atilla Bir e Mustafa Kaçan).

Fig. 13: the terracotta pipeline in the channel connecting the wells (photo A.E. Keskin).
Fig. 13: conduttura in terracotta nel canale di collegamento dei pozzi (foto A.E. Keskin).

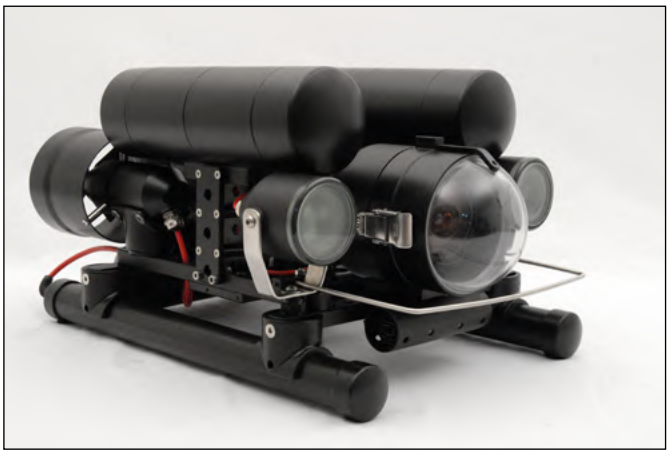

Fig. 14: underwater ROV produced for our survey (photo Engin Aygün).
Fig. 14: il ROV subacqueo utilizzato per il nostro sondaggio (foto Engin Aygün).

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