WATER SUPPLY TUNNELS OF ISTANBUL KÜÇÜKÇEKMECE LAKE BASIN (BATHONEA)

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Abstract
In summer 2012, archaeological fieldwork at an ancient site on the western shore of the Küçükçekmece Lake, 22 km west of Istanbul, unearthed the entryways to two water supply tunnels. The survey of the tunnels has been carried out by a team of speleologists from ASPEG (Anatolian Speleological Society) that joined the research project during the 2012 and 2013 field seasons. The research team discovered and mapped galleries for a total length of 313 m, along with five chimneys with heights varying between 4.5 and 7.7 m. These structures could be identified as two representatives of the so-called qanat system that is constructed to extract underground water and transfer it to the desired location. This system incorporates several well-like vertical shafts connected by gently sloping tunnels and are employed in ancient and modern times in arid regions, particularly in parts of western and central Asia. Surprisingly, both structures are still serving the purpose, for which they were built in antiquity. A stamped brick discovered in one of the tunnels could be dated to the fifth or sixth centuries A.D. based on epigraphic examination. This evidence infers the date for the construction of at least a part of the structure. Both tunnels predominantly consist of narrow galleries, which turn into very tight squeezes at certain points. These narrow sections, along with the cold water always present in tunnels, rendered exploration somewhat difficult. Furthermore, the bottom of one of the tunnels is covered by flowstone, which raised the floor level and created extremely irregular formations and pools, necessitating cumbersome crawling through the entire tunnel.
Keywords: Bathonea, Küçükçekmece Lake Basin, qanat, water supply tunnels.

Riassunto
Nell'estate del 2012 il campo archeologico di un antico sito sulla sponda occidentale del lago Küçükçekmece, situato 22 km a ovest di Istanbul, ha portato alla luce gli ingressi di due gallerie di approvvigionamento idrico. Le indagini delle gallerie sono state effettuate da un team di speleologi dell'ASPEG (Anatolian Speleological Society) che hanno aderito al progetto di ricerca sul campo nelle stagioni 2012 e 2013. Il team di ricerca ha scoperto e cartografato le gallerie per una lunghezza totale di 313 m, insieme a cinque camini con altezze variabili tra 4,5 e 7,7 m. Tali strutture potrebbero essere due tipici esempi del cosiddetto sistema di qanat, costruito per estrarre l'acqua sotterranea e condurla alla destinazione desiderata. Questo sistema incorpora diversi pozzi verticali collegati da gallerie in leggera pendenza ed è impiegato in tempi antichi e moderni in regioni aride, in particolare in alcune parti dell'Asia occidentale e centrale. Sorprendentemente, entrambe le strutture studiate servono ancora allo scopo per il quale furono costruite nell'antichità. Un laterizio bollato, scoperto in uno dei tunnel, potrebbe essere datato al V o VI secolo d.C. sulla base di una analisi epigrafica. Da questa evidenza di deduce la data di realizzazione di almeno una parte della struttura. Entrambi i condotti sono composti prevalentemente da strette gallerie che si trasformano in alcuni punti in angusti passaggi. Questi, insieme con l'acqua fredda sempre presente in galleria, hanno reso l'esplorazione alquanto difficile. Inoltre il fondo di uno dei tunnel è coperto da concrezioni che hanno sollevato il livello del piano di calpestio creando formazioni estremamente irregolari e piscine, che richiedono di avanzare strisciando nell'intero tunnel.
Parole chiave: *Bathonea, bacino lacustre di Küçükçekmece, qanat, tunnel di approvvigionamento idrico.*

Introduction

The archaeological importance of the area around the Küçükçekmece Lake, 22 km west of Istanbul, has been known since the discovery of prehistoric habitation at Yarımburgaz Cave in the middle of the nineteenth century. Modern excavations at this cave between 1963 and 1990 unearthed evidence for occupation in Paleolithic, Neolithic, Chalcolithic and Byzantine periods (ÖZBAŞARAN, 1995). More recent archaeological fieldwork in the basin of the lake was initiated in 2007 as part of the Istanbul Prehistoric Research Project, under the directorship of Assoc. Prof. ŞENGÜL

Fig. 1: archeological research area (source Google Earth).
Fig. 1: area di ricerca archeologica (da Google Heart).

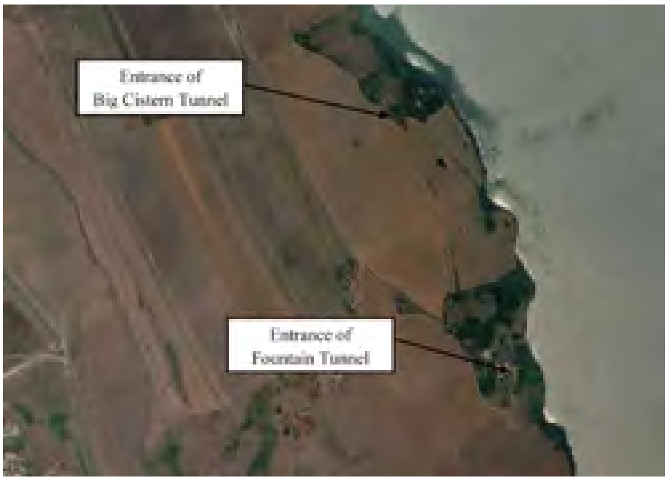

Fig. 2: location of discovered tunnels (source Google Earth).
Fig. 2: localizzazione delle gallerie riscoperte (da Google Earth).

AYDINGÜN of Kocaeli University. The project has been carried out by an international team of researchers in conjunction with the Turkish Ministry of Culture and Tourism. The major undertaking of the project is the excavations conducted since 2009 at an ancient settlement in the Avcılar district on the western shore of the lake (Fig. 1). Based on epigraphic evidence, this site carries the potential to be Bathonea of late antiquity. Since Küçükçekmece Lake was connected to the Sea of Marmara, the settlements around the lake occupied desirable position for maritime activities. Hence, current archaeological evidence indicates that the site had been extensively involved in maritime trade from the seventh century B.C. until its complete abandonment in the eleventh century A.D., following the destructions caused by two consecutive earthquakes. The most notable finds at the site predominantly belong to the Late Roman and Byzantine periods, and include two harbors, a lighthouse, marble-paved roads, a large open cistern, and several monumental structures, the most exciting of which is a palace-monastery complex of basilica plan (AYDINGÜN, 2013).

Besides these discoveries, excavations exposed the entryways to two narrow tunnels in summer 2012 that still contain fresh water. The tunnels were identified as parts of water supply systems, due to their association with other water-related structures. The first tunnel was named as "Fountain Tunnel" (previously named as Apsidal Building Tunnel) and supplies water to an ancient fountain. The second tunnel, on the other hand, feeds the large open cistern and was named as "Big Cistern Tunnel" due to this association (Fig. 2). These discoveries first caused great excitement, which later turned into disappointment when the first researcher to enter one of the tunnels could not negotiate the narrow passage only ten meters after the entrance. A team of speleologists from ASPEG (Anatolian Speleological Society) was invited to the site so as to investigate the tunnels and explore the means of water supply for the settlement. Having negotiated the extremely tight sections near the entrances in both tunnels, the speleologists made exciting discoveries. Both tunnels were explored, mapped, photographed and filmed during the 2012 and 2013 field seasons.

General Characteristics of the Tunnels

The tunnels were found to have a total length of 313 meters and incorporate five well-like chimneys of rectangular plan. These chimneys have heights varying between 4.5 and 7.7 meters and were closed at their top by means of rectangular stone slabs. The small niches on the walls of the chimneys apparently facilitated climbing down and up to access the tunnels. These water supply structures are typical representatives of the "qanat system" that is characterized by a series of well-like vertical shafts connected by gently sloping tunnels (Fig. 3). These systems are used to extract water from an underground aquifer and ultimately transfer it to the surface by gravity (HILL, 1996; WILSON, 2008). Most surprisingly, both structures are still serving the purpose, for which they were built in antiquity. By analogy with more recent examples, the chimneys must have facilitated the removal of excavated earth when the tunnels were first being dug. Consequently, when the system is in use, these chimneys also enabled access into the tunnels for maintenance purpose.

Predominantly, the tunnels have the form of narrow galleries, with the width dropping to 0.25-0.30 m at certain points. It is very unlikely that the gallery was originally that narrow, which would have seriously restricted movement inside the system. It seems more plausible that the walls were originally farther apart,

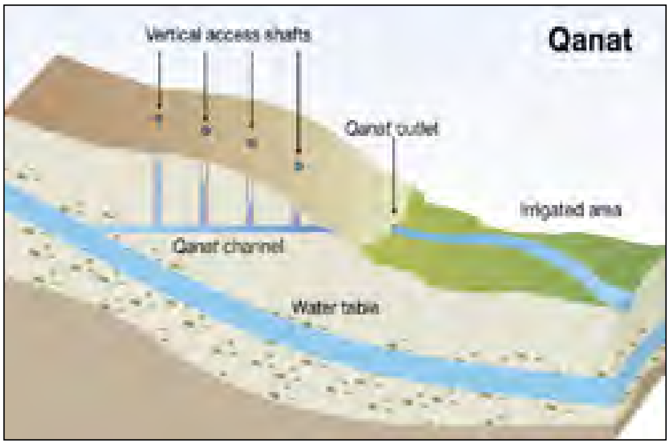

Fig. 3: the qanat system (source PRAVETTONI, 2010).
Fig. 3: il sistema di qanat (da PRAVETTONI, 2010).

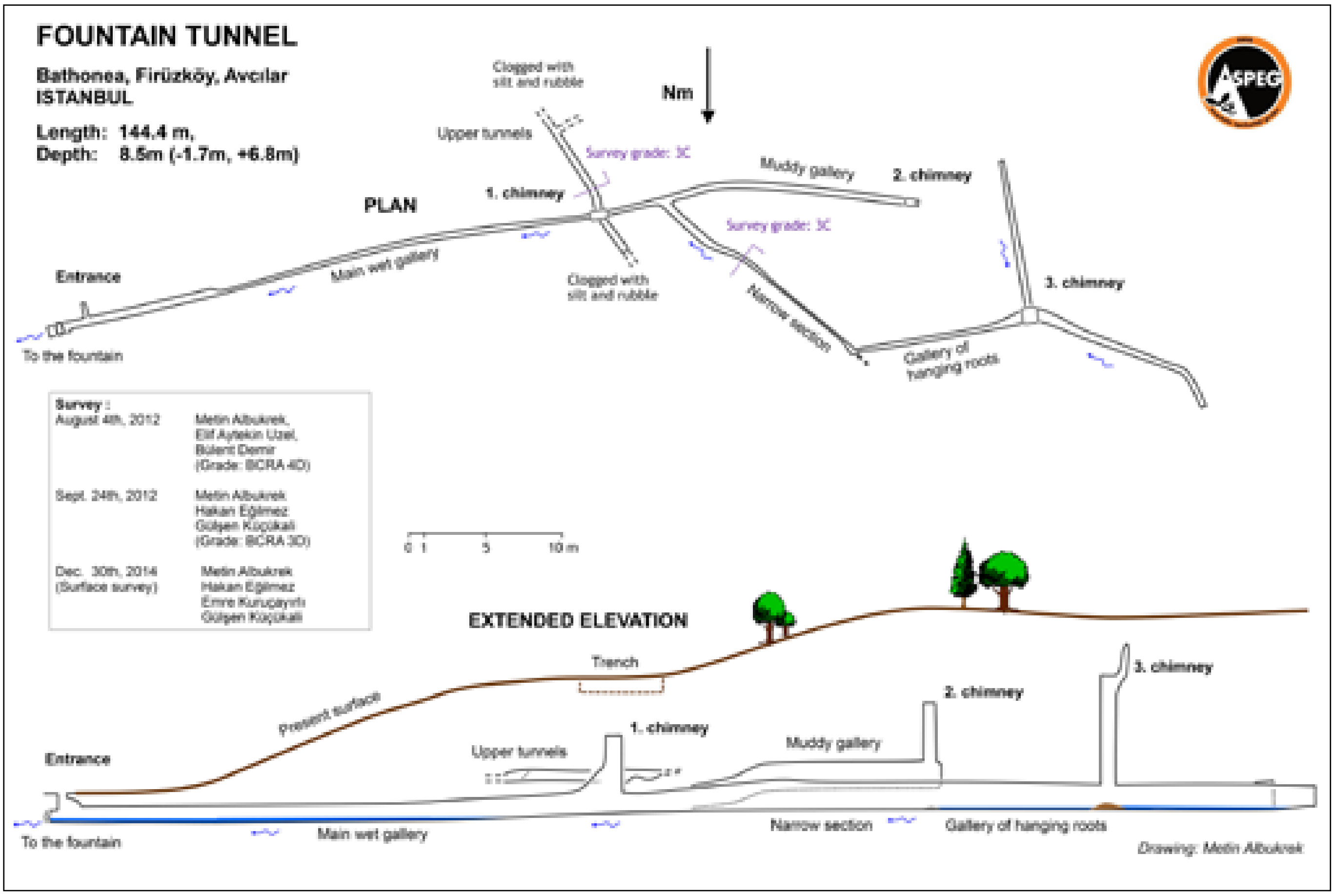

Fig. 4: plan of the Fountain Tunnel.
Fig. 4: planimetria del cunicolo di alimentazione della fontana.

but later got closer as a result of earthquakes and rains, which soften the soil and increase the pressure exerted on the walls from the outside. Such phenomena must have eventually pushed the walls at their weak points. In both tunnels the average slope was measured as ca. 1%, enabling a slow and steady flow of water, as desired in qanat systems. Water temperature was 14^0 C in both tunnels and observed to remain stable throughout the year.

Description of the Tunnels

Fountain Tunnel

The entrance to this tunnel was exposed in summer 2012 when the excavation team lifted a stone slab on the floor of the "Apsidal Building", a building from the sixth century A.D. or earlier (AYDINGÜN, 2013). It became immediately evident that the tunnel was supplying water to the fountain, situated 28 m to the W of the tunnel entrance. Right at the entrance, it was observed that the water was disappearing through an unmortared stone wall, which probably is serving as a coarse filter (Figs. 4 and 5). As the exploration progressed, the initial tunnel of a single gallery turned into a system of multiple interconnected branches with a total length of 145 m (Fig. 4). The system also incorporates three chimneys of 4.5, 5, and 7.7 m height. A common feature for all galleries is that the side walls were constructed by means of roughly shaped stones with dimensions between 0.2 and 0.4 m.
The sector, which contains water in its entire length stretches for about 57 m from the entrance, was named as "Main Wet Gallery". The gallery differs from the others as its ceiling was formed by rows of flat, rectangular slabs rather than vaulting (Fig. 5). The height of the gallery is generally between 1 and 1.5 m, but rises to 2.5 m along a short passage. This gallery also incorporates the first chimney, from which two upper tunnels extend at a height of 1.75 m above the floor. Both tunnels were found to be clogged by silt

Fig. 5: entrance of the Fountain Tunnel (photo Elif Aytekin Uzel).
Fig. 5: ingresso al cunicolo della fontana (foto Elif Aytekin Uzel).

Fig. 6: ceiling of the Muddy Gallery (photo Elif Aytekin Uzel).
Fig. 6: volta della galleria fangosa (foto Elif Aytekin Uzel).

and rubble. The barrel vaulted branch that adjoins the main gallery 4 m after the first chimney was named as "Muddy Gallery" after the accumulated silt covering its floor. It is also because of this accumulation that the floor of the gallery lies 1 to 1.3 m higher than that of the "Main Wet Gallery" (Fig. 6). The gallery is 17 m long and ends with the second chimney.
The final sector of the tunnel system is occupied by the "Gallery of Hanging Roots", such named due to the abundance of plant roots hanging from its walls.

Fig. 7: third chimney in the Fountain Tunnel (photo Ali Hakan Eğilmez).
Fig. 7: terzo pozzo del cunicolo della Fontana (foto Ali Hakan Eğilmez).

Fig. 8: end of the right-hand branch of the "Gallery of hanging roots" (photo Metin Albukrek).
Fig. 8: fine del ramo destro della "Galleria delle radici che pendono" (foto Metin Albukrek).

This last gallery is 37 m long, 1.5 m high, and contains water. It also incorporates the third chimney, at which the gallery is divided into two branches of 13 and 11 m length, respectively (Fig. 7). Both of these end with walls of stone slabs (Fig. 8). An observation of interest was the small patch of soot on a wall in the right-hand branch after the chimney, as it is a leftover from ancient construction or maintenance operations.

Fig. 9: stamped brick in the second chimney (photo Metin Albukrek).
Fig. 9: laterizio bollato nel secondo pozzo (foto Metin Albukrek).

Even though the "Gallery of Hanging Roots" looks like the extension of the "Main Wet Gallery", it more probably belongs to a different phase of construction. Firstly, the two galleries join at an angle and passage is only possible through a narrow opening near the bottom. Secondly, at the joining point, the ceiling structure of the "Main Wet Gallery" could be traced for half a meter continuing in the same direction, even though its lower section was closed. Moreover, the "Gallery of Hanging Roots" has barrel vaulted ceiling of brick as opposed to the flat stone ceiling of the "Main Wet Gallery". Our general impression is that the "Main Wet Gallery", constructed with large rectangular stone slabs, was the original tunnel. The vaulted galleries,

Fig. 10: entrance of the Big Cistern Tunnel (photo Metin Albukrek).
Fig. 10: ingresso al tunnel della Grande Cisterna (foto Metin Albukrek).

on the other hand, are possibly later additions made to increase the water catchment capacity of the system.
The widest point of the system is situated at its entrance, where the gallery is 0.75 m wide (Fig. 5). However, after this point, the width of the galleries varies between 0.33 and 0.57 meters. At two points the gallery becomes so narrow that negotiation of the passage was possible only by difficult crawling. The first of these is a tight squeeze 10 m after the entrance, while the second is a 5.5 m long "V" shaped passage towards the end of the "Main Wet Gallery".
A discovery of utmost significance is a stamped brick found in one of the niches of the second chimney (Fig. 9). The stamp was examined by epigraph Prof. Dr. Mustafa Hamdi Sayar from Istanbul University, and attributed to the fifth or sixth centuries A.D., inferring a possible date for the construction of the tunnel (Sayar, 2013). However, it is also possible that this date can be associated only with the second chimney, and thus, only with the "Muddy Gallery". Therefore, if our assumption about the different construction phases is accurate, and this gallery is indeed a later addition to the system, the original tunnel can be earlier than indicated by the stamped brick.

Big Cistern Tunnel

Surface surveys near the big open cistern identified the small entrance of a tunnel, from which fresh water was emerging (Fig. 10). Apparently, the tunnel was one of the water sources, if not the only source, to feed the cistern. The tunnel consists of a single gallery of 168 m length that roughly extends in east-west direction. The two chimneys located along this gallery have heights of 4.5 and 6.3 meters (Fig. 11). The width and the height of the tunnel vary between 0.45-0.7 m and 0.4-1.15 m respectively. The narrowest section occurs 20 m after the entrance, where the gallery width of 0.25 m makes it very difficult to negotiate (Fig. 12). Up to the 27th meter from the entrance, the ceiling was built by flat rectangular stone slabs, whereas vaulting was employed after this point. The vaults of Big Cistern Tunnel were predominantly constructed by bricks (Fig. 13) even though the first eight meters of vaulting was achieved by small, roughly shaped stones. Stone vaulting re-emerges only at the very end of the tunnel, this time in the form of large, rectangular, finely dressed slabs of 1 x 0.35 m dimensions (Fig. 14). Hence, once again we observe the use of different systems of ceiling in the same structure. However, in the Big Cistern Tunnel,

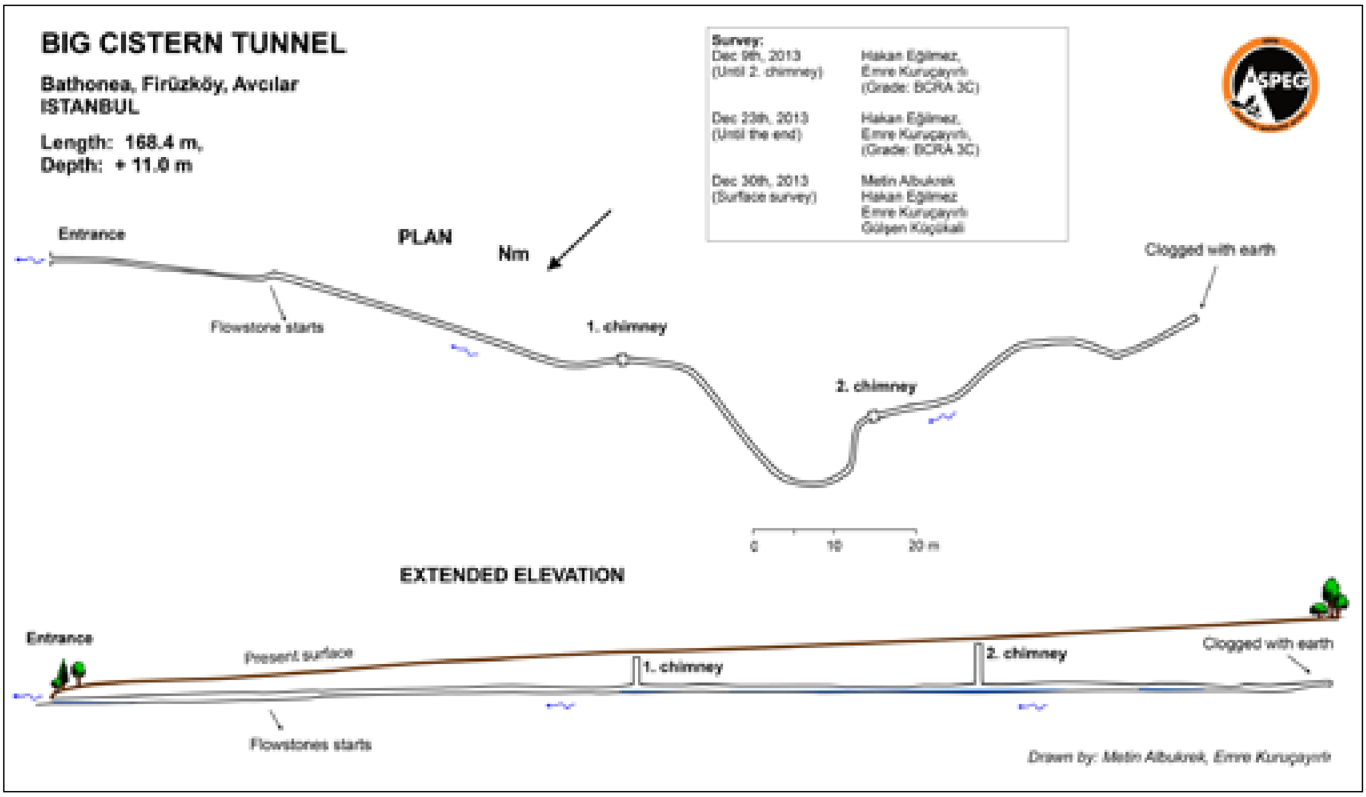

Fig. 11: plan of the Big Cistern Tunnel.
Fig. 11: planimetria del cunicolo della Grande Cisterna.

Fig. 12: the narrow section in the Big Cistern Tunnel (photo Metin Albukrek).
Fig. 12: restringimento nel cunicolo della Grande Cisterna (foto Metin Albukrek).

Fig. 13: big Cistern Tunnel (photo Metin Albukrek).
Fig. 13: cunicolo di alimentazione della Grande Cisterna (foto Metin Albukrek).

these distinct techniques cannot be attributed to distinct construction phases, which seemed to be the case in the Fountain Tunnel.
The tunnel ends with a fill of soil and rubble (Fig. 14). It is also to notice that broken pieces of plastic pipes were found in this final section of the tunnel, indicating that this ancient structure had attracted the attention of treasure hunters. It is very unlikely that such people would have the equipment and capacity to negotiate the entire tunnel. A more likely access point could be a chimney or a side gallery near the end of the tunnel that are no longer recognizable due to destruction. This would also explain the accumulation of soil and rubble at the end of the tunnel. The future removal of this fill would reveal the unknown extension of the structure.
Possibly the most interesting feature of the tunnel is the flowstone formations covering its floor. These formations begin at the 27th meter after the entrance and continue uninterrupted until the end of the tunnel. On the one hand, this phenomenon creates the environment of a natural cave inside a man-made structure, which invokes a unique experience for the researcher. On the other hand, the accumulation of flowstone raised the floor level, decreasing the height of the gallery and restricting movement. Thus, the original height of the tunnel must have been higher than currently measured. Moreover, flowstone created a very irregular floor with pools that may be as deep as 0.5 meters, which makes crawling even more cumbersome.

Importance of Finds

The establishment of Constantinople/Istanbul as the new capital of the Roman Empire in 330 A.D. transformed this relatively small town into an imperial metropolis. Recent archaeological work in the Küçükçekmece Lake Basin evidenced that this major undertaking by Constantine the Great had its major effects also on the close vicinity of the new capital. In the immediate centuries following this event, certain settlements in these areas appear to have undergone a similar transformation to the capital, but at a more modest scale. This is most clearly manifested by the discovery of monumental, apparently imperial, buildings of Late Roman and Early Byzantine periods by the Küçükçekmece Lake, at the ancient settlement, which can possibly be Bathonea (AYDINGÜN, 2013). As a parallel phenomenon to the capital, the growth of population in this town must have necessitated the construction of large and sophisticated structures for water supply and storage. Thus, it does not come as a surprise that the four large open cisterns of Istanbul, all of which date to the fifth and sixth centuries A.D. (CROW et al., 2008), find their more modest counterpart at this settlement 22 km to the W. Likewise, it is equally natural that the stamped brick discovered in one of the tunnels could be dated to these centuries. Since this brick is associated with a gallery, which we think to have been a later addition to the original tunnel, the evidence possibly indicates a progressive growth of population and the consequent necessity to expand the system during this period.
From an archaeological perspective, the two tunnels explored at this site represent an exceptional discovery because they are found in an intact, undestroyed situation. Apparently, these structures managed to escape the attention of illicit diggers to a major extent. This seems to have happened because

Fig. 14: end of the Big Cistern Tunnel (photo Metin Albukrek).
Fig. 14: parete terminale del cunicolo della Grande Cisterna (foto Metin Albukrek).

all the possible entrances to the tunnels were closed by stone slabs and overlying fills of soil, with the exception of the mouth of the Big Cistern Tunnel. However, even this entrance was a small cavity well hidden under bushes, making it difficult to prospect. The evidence for illicit digging in this structure was observed only at its end, which should have been possible through a different access point than the present tunnel entrance. The low temperature of the water and the extremely narrow passages must also have contributed to the unpopularity of the tunnel among local treasure hunters.

Thanks to this situation, we were able to examine the construction techniques of a water supply structure from late antiquity in its largely intact form. This gave us the chance to identify different techniques of construction, which can be attributed to distinct building episodes, at least in the case of the Fountain Tunnel. It is also because of their undestroyed situation, that the tunnels are still capable of collecting underground water and transferring to the surface. As this process has been going on for several centuries, a thick layer of flowstone got the chance to accumulate on the floor of one of the tunnels, creating the visual impression of a natural cave inside a man-made structure.

Finally, these tunnels are two rare representatives of the qanat system in ancient Turkey. The scarcity of qanat structures in Turkey constitutes a contrasting phenomenon with other regions of the Near East as they made frequent use of the system. Iran is the country, where the qanat system is used most extensively in both ancient and modern times. Therefore, this system is traditionally believed to have been invented in ancient Iran by the Persians, even though some examples from eastern Arabia predate the Persian period (HILL, 1996; MAGEE, 2005). Nevertheless, it was the Persians, who apparently introduced the system to Egypt in the fifth century B.C., from where it was later absorbed into the Saharan regions of Libya and Algeria. Romans, who most probably adapted the qanat system in North Africa, effectively combined it with their aqueducts. Several examples of this system are known in Roman territories in Europe, Egypt, Syria and the Levant (WILSON, 2008). Hence, in the light of the evidence from its neighbors, the scarcity of qanat in ancient Turkey is not easy to explain. This situation is particularly surprising, as Assyrian King Sargon II (722-705 B.C.) refers to the Urartians of Eastern Anatolia as possible users of qanat as early as the eighth century B.C. (HILL, 1996).

However, a water supply tunnel discovered and explored at Troy in NW Turkey in the early 2000's changed this picture to some extent. The tunnel has a length of 160 m and incorporates four chimneys and was apparently built to extract underground water (KORFMANN, 2002; KORFMANN et al., 2006). Thus, it displays the typical features of the qanat system. Similar to our Fountain Tunnel, the tunnel from Troy most likely constitutes later galleries added to an original one (KORFMANN, 2002). Moreover, similar to our Big Cistern Tunnel, the Trojan structure contains a deposit of flowstone, which enabled dating by means of Uranium-Thorium method. Based on this scientific dating and the stratigraphic association of small finds, researchers proposed a very broad time span for the use of the structure that extends from the third millennium B.C. to the third century A.D. (KORFMANN et al., 2006). If the dating of this structure is accurate, it provides the first evidence to testify the use of the qanat system before the first millennium B.C..

In sum, along with this find from Troy, the recent discoveries in the Küçükçekmece Lake Basin made invaluable contribution to our understanding of the use of qanat in ancient Turkey. Archaeological fieldwork in the Küçükçekmece Lake Basin is still underway and may expose new water supply or storage facilities.

Acknowledgements:
We would like to thank to our sponsors MARPORT, TÜRSAB, Istanbul Avcılar Municipality, HENKEL, and ELKENZ.

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