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Going against the flow

Wells, cisterns and water in ancient Greece

Edited by Patrik Klingborg

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ABSTRACT

Despite the prevalent picture of the water supply in the ancient world as being dominated by fountains and aqueducts, the large number of excavated wells and cisterns show that these were the primary water sources for most individuals. Yet, little research has been done on their construction, function and use. This prompted the organization of the workshop *Going against the flow. Wells, cisterns and water in ancient Greece*, held at the Swedish Institute at Athens on 28–29 September 2017, and subsequent publication of the contributions in this volume. The ten papers presented here offer new evidence as well as a wide range of new perspectives on the use and function of wells and cisterns in ancient Greece. Considering the ubiquity of these installations in every type of setting during antiquity, from pan-Hellenic sanctuaries and civic centres to domestic workshops and remote farmhouses, it is hoped that the breadth of interest among the authors will allow other scholars to advance their own work further, illuminating new and exciting aspects of life in ancient Greece.

Keywords: wells, cisterns, water supply, ancient Greece, archaeology, climate, sanctuaries

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Cover illustration: section of typical ancient Greek cistern, by Patrik Klingborg
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JUTTA STROSZECK

5. The cisterns of the Athenian Kerameikos

Distribution and recent documentation

Abstract
From 2011 to 2016, a number of ancient cisterns were studied, in part excavated and documented during the excavation of the Kerameikos in Athens. The investigations took place within the framework of an ongoing research project concerning ancient water management on the site. Important information about the topographical position and functional devices of cisterns was also taken from the systematic analysis of diaries, plans and photographs from earlier excavations (the site has been under excavation for more than 150 years). The results of this work, concerning the features, dates and use of Athenian underground cisterns are presented here in overview, while the analysis of fills and layers will be presented elsewhere in detail.*

https://doi.org/10.30549/actaath-8-23-05

* The results presented in this study could not have been achieved without the co-operation of the many participants of the Kerameikos teams between 2011 and 2016 and the permission of the Greek Ministry of Culture and the Ephorate of Athens, represented by Dr Eleni Banou and Leonidas Bournias. I would like to thank them all. In particular, I am grateful to Volker Scheunert, Torben Keßler and Melanie Spiegelhalter, Raissa Andreopoulou, Elli Foto, and Panaiotis Gjumes, the experienced and competent excavator of wells and cisterns. I also want to thank Patrik Klingborg and both peer reviewers for their helpful comments. All measurements are in meters.

Introduction

In the archaeological site of the Kerameikos, the main topographical features are related to the river Eridanos—the only river that crossed the *asty* of Athens—and the roads following the river on both its banks: the course of the river determined both the position of the public defensive system of Athens in the area (mainly the two gates) and of the necropoleis along the roads outside the city walls (*Fig. 1*). Apart from these, many other features have also been excavated at the site. Within the city walls, there were a public gymnasium (the Pompeion) and large private houses south of the Sacred Gate and east of the Dipylon, while outside there were workshops and a bath house as well as several sanctuaries. In this chapter, I will consider cisterns found at the archaeological site and the information they can provide both for the research of Athenian and of Greek cisterns. The term (water) reservoir is used here for any kind of architectural water container, while cistern is used only for covered underground containers. Several cisterns have been completely excavated between 2011 and 2016. The results concerning the positioning, the layout and the interconnections of the cisterns as well as the building techniques and the periods of use are published here. Complementary to this, an article concerning the Kerameikos wells investigated during these years has recently been published.[1] Moreover, further studies on the final abandonment of the cisterns must be undertaken before a detailed account of their duration of use can be presented. Here I offer first conclusions.

During the late 6th and 5th century BC, the invention and development of waterproof mortars by ancient Greek engineers was a technological innovation that opened up new possibilities for the storage of water. Before that, cisterns in Athens depended on naturally waterproof rock formations or limestone ashlar blocks.[2] The joints between the latter were sealed by various methods to make the container waterproof, which ultimately led to the refinement of the method and to an increasingly extensive application of waterproof mortar.[3] The new technology allowed for an enormous improvement of water storage possibilities as it enabled safe storage below any building, public or private, within the bounds of the property, irrespective of the make-up of the ground into which they were built (e.g. bedrock, gravel or marl).

Patrik Klingborg has recently meticulously collected the available data about Greek cisterns in his Uppsala dissertation.[4] For the Kerameikos, 13 cisterns are listed in the catalogue. However, the material has recently been enlarged and enhanced through an intensive study of the excavation records and fieldwork to include 33 water reservoirs. During the 2016 season, another system of cisterns (Z 1-23-25), that had been excavated but not documented during the 1876 investigations conducted by Stefanos Komanoudis, was partly cleaned, re-excavated and documented (*Figs. 1–2*).

One reason for the absence of documentation from earlier excavations stands out, namely the difficulty excavating these features. The team needs to be specialized in order to be able to work in constricted space next to water pumps. Also, special safety precautions have to be taken, so as not to put the lives of the excavators at risk.

Consequently, the Kerameikos cisterns had not been numbered until 2003, when Thomas Teufel, in a Master's thesis, compiled a first systematic catalogue of water installations of the site.[5] Teufel's cistern catalogue was revised and enhanced during the subsequent campaigns. Furthermore, between 2011 and 2016 some individual wells and cisterns were excavated and completely documented. All known cisterns and wells were then plotted on the site plan with their numbers in order to avoid confusion (*Fig. 1*).[6] The new catalogue of Kerameikos cisterns, of course, can be enlarged any time by further archive and excavation work. In earlier reports, cisterns do occur in plans, but—with the exception of Bau Z, where they were treated in detail by Ursula Knigge and Karin Tancke[7]—few section drawings and even fewer photographs were available, not to mention capacity calculations or 3D documentation.

Water management will never be understood by looking only at one segment of a city. Thus, the updated catalogue of the Kerameikos cisterns provides the possibility for comparison with other sites in Athens. In the long run, co-operation between the Athenian excavators will produce a more coherent picture.

[1] Stroszeck 2017.
[2] Tanoulas 2017, 177; cf. Klingborg 2017, 57, no. 157.
[3] For instance, the vertical interior walls of the Pre-Mnesiclean Cistern on the Athenian Acropolis, dated between 510–479 BC, were covered with waterproof plaster. Tanoulas 2017, 177, fig. 3; 1992. Cf. *AvP* 1:4, 25.
[4] Klingborg 2017.

[5] Teufel 2003. The numbers in the author's catalogue are only provisional according to work in progress and architectural units and have been revised by now.
[6] Note that the rectangular open reservoirs found on the site are not included in *Fig. 1*.
[7] *Kerameikos* 17:1, 67–71, 90–95; *Kerameikos* 17:2, *Plan* 5, *Beilage* 8–10. The building is also discussed by Dylan K. Rogers in this volume, *Chapter 10*, pp. 210–211, with a plan included as *Fig. 5*.

Fig. 1. The Kerameikos in Athens: distribution of cisterns on the site. By Jutta Stroszeck and Raissa Andreopoulou, Athens, German Archaeological Institute, Kerameikos excavation.

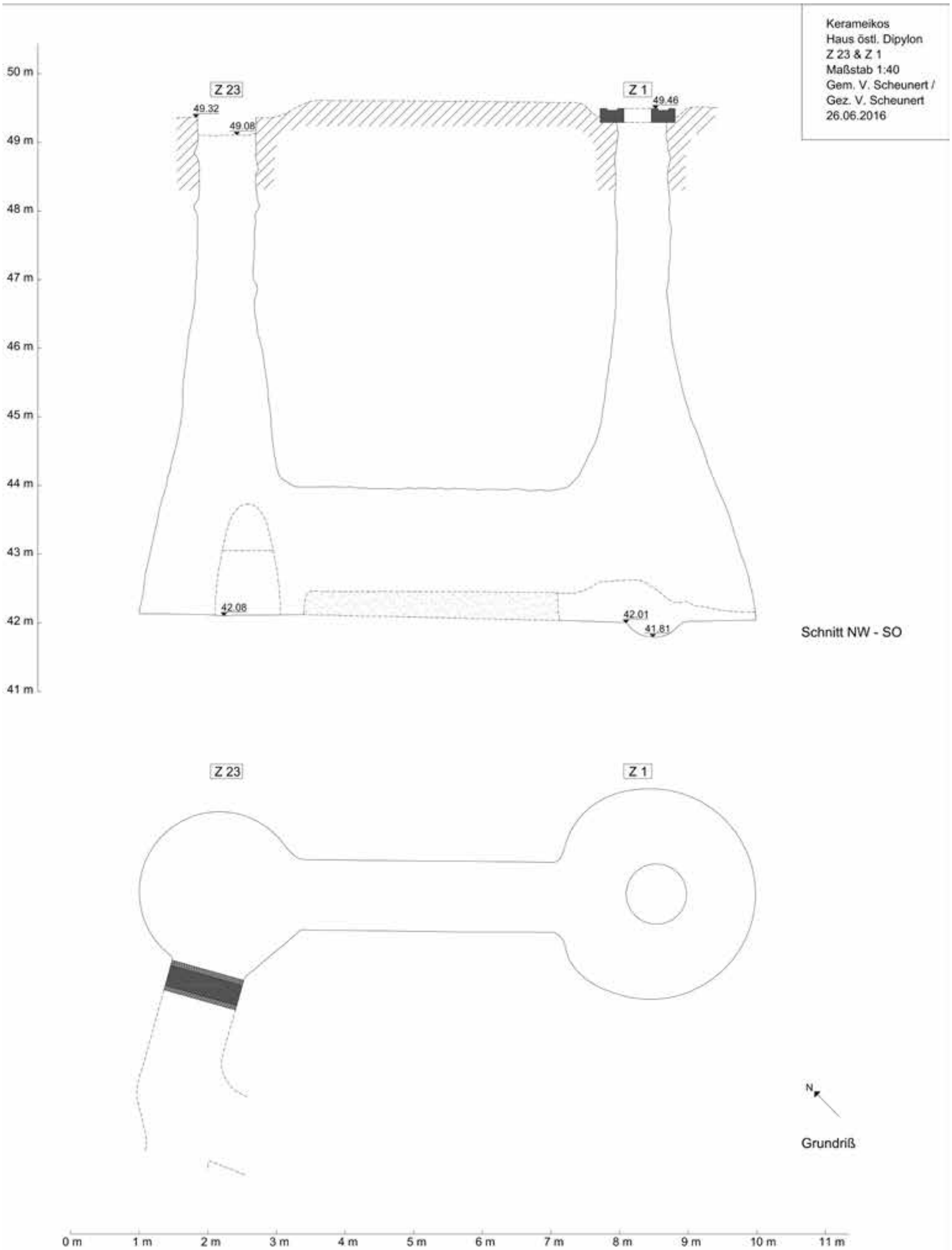

Fig. 2. Mansion east of the Dipylon, section and plan of cisterns Z 1 and Z 23. Drawing by Volker Scheunert.

Spatial positioning of cisterns

Ernst Curtius, in a 19th-century study on water in ancient Athens, posited a general geological reason for the distribution of cisterns or wells in the city: the higher-positioned areas had to have cisterns, he wrote, while the natural decline of the slopes towards the north favours the installation of wells.[8] This may well be so, but the Kerameikos cisterns allow for a more detailed appraisal. Due to the development of waterproof mortar, the location of cisterns became almost independent of the underground conditions into which they were constructed (rock, marl and clay levels or loose gravel). The decision to include a cistern within any architectural entity now depended on where the cistern was needed, and probably also on the ownership structures of the areas for which the cisterns were built. The plan (*Fig. 1*) visualizes a pattern where underground cisterns are either positioned in wealthy private houses inside the city wall (within the buildings Bau Z: Z 11-12-13, Bau Y: Z 7-8-9 and Bau X: Z 4, with probably others connected to it but as yet not excavated, and in the private mansion east of the Dipylon: Z 1-23-25-26) or in the bath complex along the Kerameikos road outside the Dipylon (Phase 1: Z 18-19-21 and Phase 2: Z 15-16-17). A single underground cistern has also been found in a small sanctuary along the Sacred Street (Z 27). Cisterns were positioned in well-ventilated rooms, in stoas, courtyards or in open court-like corridors, where they could be accessed easily for drawing water and where spilled water would not present a problem.

Construction techniques, forms and dimensions of underground cisterns

The oldest datable Kerameikos cisterns (system Z 18-21-19) belong to the first phase of the circular bath (i.e. the 5th century BC). They were dug directly into the soil as cylindrical shafts, slightly flaring towards the bottom (*Figs. 3–4*).[9]

Usually, the interior walls of the cistern chambers and tunnels were completely covered with lime mortar. At the earlier Kerameikos bath, dated to the late 5th century BC, the mortar contained 68.1% calcium carbonate. This was reduced to 56.3% in the system of the early 4th century BC. Three main layers of mortar were applied. The lowest levelling layer is tempered with coarse pebbles, the middle layer contains smaller stones and more lime mortar while the top layer consists of fine stucco. On top of this, the whole interior of the cistern was supplied with a lime plaster coat containing various hydrophobic substances (thickness about 1 mm, see below, *Fig. 7*).[10] This coating is highly polished. The surface is light brown to beige when well preserved and it is so shiny it reflects even today. On a few pieces of cistern mortar that fell from the walls of cistern Z 23, traces of fingerprints show that the mortar was applied with bare hands. The final polishing very likely was performed with smooth pebbles or marbles: in Morocco, where a similar technique is still in use today, polished, semi-precious stones are used to achieve the smooth, mirror-like surface that we also observe on ancient Athenian cisterns.[11] This waterproof surface lining probably contained organic material or bitumen, but more sampling is necessary.[12] As a result of the substances in use, the taste of the water may have changed.

In system Z 18-21-19, the shafts had a depth of 2.70 m and a mouth diameter of between

[8] Curtius 1847, 24–25.

[9] Stroszeck 2014b, figs. 4–6. Cf. Brinker 1990, fig. 9 (showing the digging of a flask-shaped cistern in the rock).

[10] For first analyses of the mortar cf. Stroszeck 2014b, 505.

[11] The technique is called *Tadelakt*, which means "to rub in" in Berber. Ochs 2007; Ziesemann & Krampfer 2007; Ochs 2009.

[12] Samples contained what was probably chipped and ground limestone.

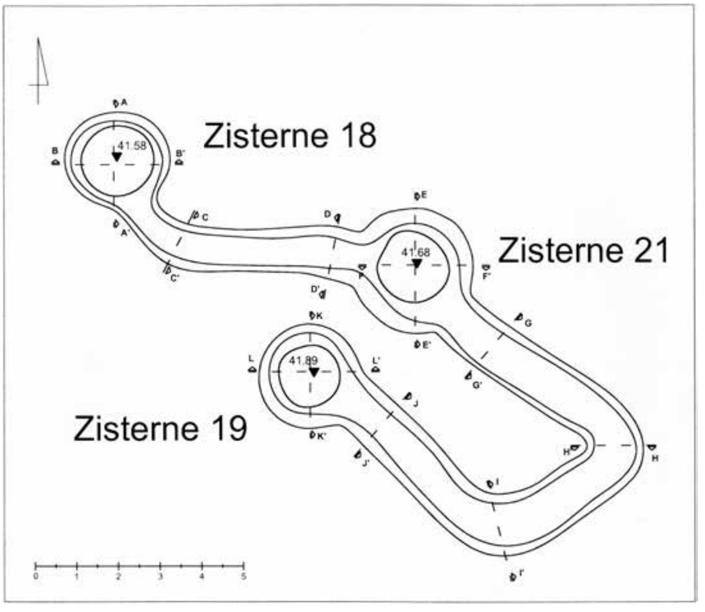

Fig. 3. Kerameikos bath, first phase, cistern system Z 18-21-19, plan. Drawing by Jutta Stroszeck and Jannis Nakas.

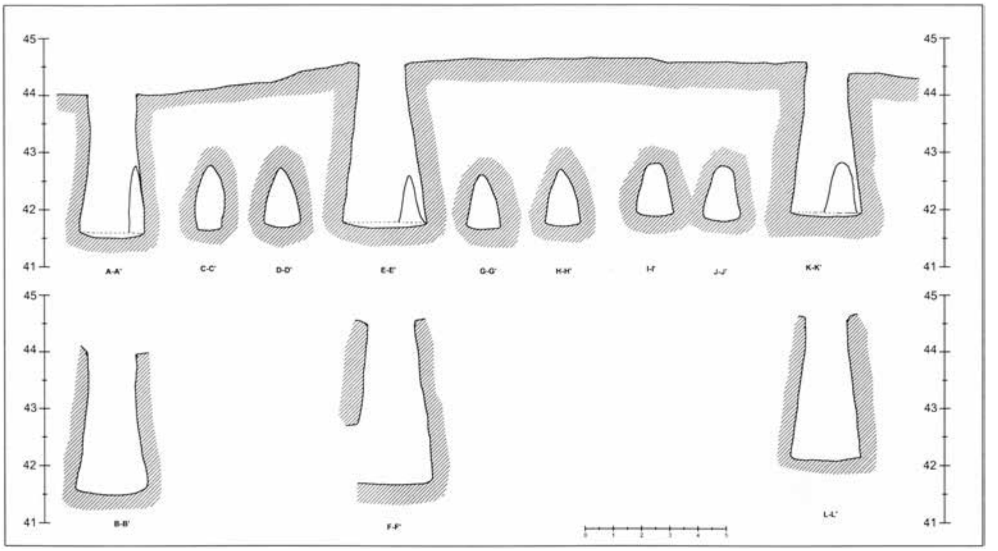

Fig. 4. Kerameikos bath, first phase, cistern system Z 18-21-19, sections unfurled. Drawing by Jutta Stroszeck and Jannis Nakas.

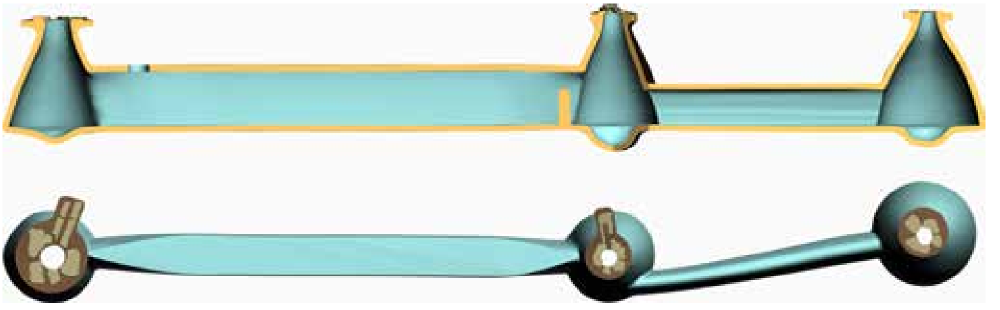

Fig. 5. Kerameikos bath, second phase, cistern system Z 15-16-17, digital reconstruction. Illustration by Thomas Bauer.

0.75 and 0.87 m. Three chambers were connected by two tunnels at the bottom of the cisterns, opening in the form of pointed oval or round vaulted passages. The tunnel between Z 18 and Z 21 is 1.68 m in height and has a pointed vault roof, while the one connecting Z 21 to Z 19 is lower, with a rounded arch-vault. The floors of both tunnels are slightly lowered towards the middle, so that water could flow there in a shallow groove. The levels of the passages, and accordingly the levels of the chamber floors, rise continuously from Z 18 (41.58 masl) towards Z 21 (41.68 masl) and 19 (41.89 masl), so that the floor of Z 19 is about 30 cm higher than the floor in Z 18 (*Fig. 4*). This accords well with a passage in Pliny the Elder (*HN* 36.52) which refers to cistern systems. According to Pliny, when two cisterns were connected, one should allow the water to settle while the other be used for drawing. Consequently, cistern Z 19 must have been the main drawing shaft, because of its higher floor level. Both tunnels are curved. Tunnel Z 21 to Z 19 even performs a complete U-turn, while there are curves in tunnel Z 18 to Z 21 just before the openings into the chambers Z 18 and Z 21 (*Figs. 3–4*).

Next in chronology, system Z 15-16-17 was built during the first half of the 4th century BC, along with the second phase of the Kerameikos bath, bordering the newly designed transversal road. The form of these cistern chambers is distinctively different from those of the earlier system: each cistern has a narrow, cylindrical neck, opening at some depth to form a wide, conoid chamber with a circular floor (*Fig. 5*).

Circular depressions in the floor are positioned directly below the mouth of the cistern. This type has been called “flask”- or “bell”-shape.[13] I will use the term *flask shape* here because it implies the narrow neck and a wide, open container below and because the term allows for variations (some cisterns that are more rounded in section) which I would not see as constituting a third form in its own right.[14] In system Z 15-16-17, all of the cistern was dug into the soil; the difference is in treatment after it was dug. The lower part was left unmodified (apart from the waterproof lining) while the upper part was reinforced/built up using small, roughly rectangular stones of a yellowish porous limestone arranged in circles (*Fig. 6*).

The final waterproof and polished coating that covered the whole of the inside of the structures made the two different building techniques invisible internally. A transitional or rather combinational form is represented by Z 23, where a very deep, cylindrical shaft is

[13] *AvP* 1:4, 23–25; Klingborg 2017, 20–22.
[14] The flask and bell forms are, to my mind, variations of the same type (with or without central depression), influenced by varying soil (or rock) conditions, chronology and various workshops. For Brinker’s distinction of flask and bell forms, see Brinker 1990, 99, 101, fig. 115.

Fig. 6. Kerameikos bath, second phase, cistern Z 16 mouth and channel. Photograph: Kurt Gebauer.

combined with a slightly flaring lower part, and the chamber has no central depression (*Fig. 2*). The reasons for the use of one form or the other may be chronological, as in the Kerameikos bath, or functional, as Z 23 was again connected to a neighbouring cistern (Z 1), where the water was drawn. The earlier cylindrical form (Z 18-19-21) has the disadvantage that drawing vessels (most of them were made of clay) must have been easily broken when they hit the straight walls. This disadvantage is even more pronounced in cistern system Z 18-19-21, where there were obviously no kerbstones, but "rims" in coated mortar that formed the mouths of the cisterns, as found by the excavators *in situ*. The flask form with its flaring walls towards the bottom reduced this problem significantly.

The function of the shallow circular depressions in the middle of the bottom, a distinctive feature of many flask cisterns, has been disputed (Z 1: diameter 0.41 m; depth 0.20 m, see *Fig. 2*; Z 15: diameter 1.00–1.15 m; depth 0.24 m, see *Fig. 7*). They have both been interpreted as settling tanks (an additional cleaning mechanism to collect suspended matter in the cistern water) or as facilitating the drawing of water without breaking the vessels, even when there was little water left in the cistern.[15] This, also, will have been a clear advantage in the use of the developed and later flask form.

The connecting underground tunnels do occur in many of the cisterns, but the function of the tunnels and the reasons for the curving course between them is as yet unclear. Very likely there was more than one reason to build such tunnels in the first place. Apart from the obvious increase in volume, the circulation of air and the fluctuation of water may have played a role. One explanation for the curves may be the property boundaries above ground (the underground features had to remain roughly within the limits of the well-defined ownership boundaries of land above) or for geological reasons (e.g. the tunnels tried to avoid dangerous areas of loose ground).

The function of the cisterns

The primary scope of these underground architectural structures was water collection and storage for future use, for specific purposes such

[15] *Kerameikos* 17:1, 68, 70; Klingborg 2017, 48, n. 303.

as washing and cleaning[16] or as a drinking water resource in times of drought.[17] It is not always clear, though, how and whence the water reached a particular cistern. Cistern water in the Kerameikos had two main primary origins: rainwater and spring water. Since the 6th century BC the latter was delivered through a public pipeline from the Hymettos Mountain into the city, where it was distributed. During the 5th century BC, the pipeline was restored and partly enlarged. The distribution of a part of this water to cisterns makes these special: cisterns filled this way were probably of public character. The first Kerameikos bath system (Z 18-19-21), dating to the 5th century BC, received water through a branch channel deviating from a public pipeline that discharged into chamber Z 18. This is one argument out of several supporting that the Kerameikos bath was a public institution at least in its first phase.

Rainwater quality depended on the type of rain (in Athens, today as in antiquity, rainwater can contain desert sand) and on the cleanliness of all cistern parts, including the roofs where the water was collected, the *prolakkia* or settling basins where the water rested and where heavy parts transported with it could settle, the water conduits leading to the cistern mouth, and the cisterns themselves.[18]

The cisterns in the large private buildings in Bau Z (Z 11-12-13), Bau Y (Z 8-9-10), the mansion east of the Dipylon (Z 1-23-25 as well as probably Z 26), and the cisterns of the second Kerameikos bath (Z 15-16-17) all relied on collecting rainwater from roofs (*Fig. 1*). The latter system, in all probability, had more than one source for water collection. Several water conduits led water away from the two main bathing rooms towards the cistern system, so obviously the bathing water was reused. The cistern system was positioned within a 29-m-long space, probably a two-part stoa, bordering the northwestern outer wall of the bath complex. Two of the cisterns, Z 15 and Z 16, were both situated within the same stoa, opening onto a corridor, while Z 17 was positioned within the northeastern corner room of the bath, next to the entrance to the bath.[19]

Fig. 7. Kerameikos bath, second phase, cistern Z 15. Photograph: Jutta Stroszeck.

Z 16 and Z 15 were provided with water channels leading water from the northwest into their mouths, that is from the road outside the building, where the water was collected pre-

[16] *Kerameikos* 17:1, 70.
[17] Argoud 1981, 73.
[18] Brinker 1990, 80–81.

[19] The entrance to the Kerameikos bath of the second phase was from the side street connecting the Kerameikos street with the Sacred Street. On the southeastern side of the corner room, the roof probably rested on pillars that are not preserved today, and where only a foundation layer consisting of reused limestone blocks is preserved *in situ*. Cistern Z 17, which is positioned within this room, received its water from the connected cisterns Z 16 and Z 15 through a low tunnel.

sumably from the stoa roof declining to that side (*Fig. 6*).[20] The water was first collected in a *prolakkion*. Both cisterns Z 12 and Z 13 in Bau Z are situated in a corridor in front of the roofs of rooms B 3 and C 3.[21] Although no water channels were preserved, they must have collected the water from the roofs that were declining towards the courtyard of the building. Z 11, situated in a corner room, was for drawing only. In the mansion to the east of the Dipylon, Z 1, and presumably also Z 25, lay within a large peristyle courtyard and collected water from the roof of the peristyle, while Z 23 was situated under the peristyle roof and in front of a richly decorated room with a floor consisting of marble chips. The cistern was connected to a stone channel leading superfluous water away from the peristyle, probably towards the Proteichisma Moat, as it runs beneath all other walls in the area towards the city wall.

Differences in volume reflect differences in demand and availability of sealed collection surfaces.[22] The volume of both cistern systems of the Kerameikos bath could be calculated: the earlier could store 11 m^3, the more recent 53 m^3. So clearly, the water demand in the bath house of the second period was higher. This may reflect cultural change, either as more people used the bath or each individual used more water when they came to the facility. Yet, the volume falls within the capacity of cisterns of the private houses in Piraeus, which had a volume of between 30 and 60 m^3 each.[23] The other Kerameikos cisterns and systems are either only excavated in part or not preserved well enough for such calculation. A very small volume must be assumed for the fragmentarily preserved single cistern in the sanctuary at the South Hill (Z 27).

The volume of the cisterns was increased by the tunnels connecting the chambers.[24] In System Z 18-19-21, the rising floor levels of the chambers and the tunnels might have had an additional function, for instance, the purification of the water by settling and motion. Traces of ancient silt along the cistern walls show that the water level was usually rather low.[25] It did not normally reach the neck or mouth of a cistern.

Some, but not all underground cisterns, had so-called footholds or climbing holes (βαλβίς[26]) along the cylindrical part of the chamber. As a rule, these were covered with the same waterproof coating as the whole interior of the cisterns. Klingborg has convincingly argued that these depressions are sometimes very shallow and do not seem suited to the purpose of climbing up and down.[27] The cleaning of bottle-shaped cisterns, in any case, could not have been done without a ladder, as the flaring walls of their lower part could not be reached or provide enough purchase for the feet. The chambers themselves rarely have these holes. During excavation, we used a wooden ladder to climb up and down the cisterns, and it worked well. Possibly, the footholds may have had a function during the building process (e.g. for scaffolding as with some rock-cut holes in the Kerameikos wells B 18 and B 19).[28]

Mouths and covers

There is much individuality in the covers of cisterns and there were obviously no standard, easily available, mass-produced lids in marble

20 Cf. Brinker 1990, 112, figs. 150a–b (“*Mündungskanal*”).
21 *Kerameikos* 17:2, 67, *Beilage* 5 (called Zi 2 and Zi 3).
22 Klingborg & Finné 2018, 116–120.
23 Klaus-Valtin von Eickstedt, lecture 15 March 2011 at the German Archaeological Institute in Athens.
24 Cf. Argoud 1981, 75.
25 Compare Z 1, Z 18, Z 21 and Z 23. Modern silt is preserved in cisterns Z 15 and Z 16.
26 I am very grateful to Charalampos Kritsas, who informed me about the ancient term.
27 Klingborg 2017, 45–46.
28 Stroszeck 2017, 49, figs. 2, 3b.

Fig. 8. Kerameikos bath, first phase, cistern Z 21, mouth and the elevated collar in stucco placed next to it. DAIAthens KER 3728. Photograph: Kurt Gebauer.

or clay for that purpose. Rather, they seem to have been made for each single cistern separately, which suggests also that the cisterns and their openings were not standardized in production. Wooden lids can be assumed, but none are preserved today. In the Kerameikos, the earliest preserved cistern rims (for the system Z 18-19-21, *Fig. 8*) consisted of broad rims made of waterproof mortar, obviously the same coating as the interior walls of the chambers and tunnels (Z 18, Z 19). There were also flat marble plaques used as lids (e.g. for the two drawing holes in the passage between Z 15 and Z 16). Kerbstones mostly consisted of Piraeus limestone. They are rather rarely found *in situ*, because they could be removed for further use elsewhere at any time (cf. the latest kerbstone for Z 17). There is a form consisting of a high rectangular block with the opening hole cut out of the centre. This type usually is made out of a single block (Z 26).[29] A circular, collar-like terracotta *puteal* was found in Z 11 in Bau Z, in a fill that can be dated to the late 4th century BC.[30] Another round *puteal* belonged to the first phase of use of Z 17. The tallness of these structures aimed at preventing pollution of the water or accidents by animals and men.

Another version is preserved on the Late Hellenistic cistern Z 1. This cistern, as many others in Athens, was abandoned after the Sullan attack on the city on 1 March 86 BC. The attack was focussed on the gates and walls in the Kerameikos area, leading to vast destruction. This kerbstone consists of a flat slab of Piraeus limestone with a broad elevated rim along all sides and around the mouth.[31] This type of kerbstone narrowed the opening of the cistern for more efficient drawing by reducing the danger of battering drawing vessels. At the southern part of the west side, a loop-opening probably functioned to recollect spilled water and to fix a rope.[32] A flat marble slab consisting of a roughly hewn plaque in secondary use, equipped with a bronze handle to facilitate the

[29] Cf. Stroszeck 2017, fig. 18a.

[30] Cf. *Kerameikos* 17:1, 56, 245, no. 1104; *Kerameikos* 17:2, pl. 24.3. For *puteals*, see Lang 1949.

[31] Length 1.07 m; width 0.95 m; diameter of the opening 0.41 m.

[32] Stroszeck 2017, fig. 19.

Fig. 9. Kerameikos bath, second phase, Z 16, separation wall. Photograph: Jutta Stroszeck.

lifting of the cover, serves as a lid here. A circular depression carved into the slab received the ring handle, so it would not protrude when not in use.

The mouth of a cistern can be elevated over time in order to fit the rising surrounding floor levels (Z 10 and Z 11 in Bau Z[33]; Z 17 in the circular bath). The likely latest datable underground cistern, Z 6 in the area of "Bau X", was still in use during the 6th century AD. It was covered with a round terracotta lid provided with a central knob. The collar-like kerbstone of this cistern has a notch along the rim to steady the lid on top of it.

Kerbstones could be replaced or removed and reused several times. Cistern mouths formed in *Tadelakt* mortar technique (Z 18 and Z 19, *Fig. 8*) seem to belong to the original phase when the cistern was first built. These stucco mouths were in part destroyed and covered when the area was levelled for the new bath house in the early 4th century BC.

"Separation walls"

In system Z 15-16-17 of the second phase of the Kerameikos bath, a separation wall was found in Z 16 at the entrance of the rectangular tunnel connecting Z 16 and Z 15 (height 1.04 m; thickness 0.28 m; *Fig. 9*). The wall closes 2/3 of the opening towards the rectangular tunnel (overall height 1.58 m), leaving open the upper third, thus allowing air within the cistern to circulate.[34] It is covered with the same polished lining as the rest of the cistern. Therefore, it is not always easy to discern if these walls were there from the start, and as such, part of the original system or if they were added at some later point when the whole cistern was fitted with a new lining.

Another such wall in cistern system Z 1-23-25-26 (height 1.09 m; thickness 0.48; height of the opening 1.68 m) also closed the lower 2/3 of the tunnel entrance. The tunnel that starts behind this wall branches up after a few metres, but this part could not be excavated further in 2016.

The function of these walls is not completely clear, which is why Klingborg decided to use the neutral and descriptive term I use here, too.[35] Klingborg, and the first excavator of Z 16, Kurt Gebauer who in his diary called the wall in Z 16 a "barrage", interpreted the function of these walls in connection with the process of self-cleaning of the collected water. Because of the existence of this wall, water in the collect-

33 *Kerameikos* 17:1, 55–56, 86; *Kerameikos* 17:2, *Taf.* 24.1–4, *Beilage* 8.2, 9.1.

34 Gebauer, the first excavator, interpreted it as a "*Staustufe*" (barrage).

35 Klingborg 2017, 50–51.

ing chambers behind this barrier (Z 15 and the connecting passage) was forced to settle so that only clean water would flow over the wall into the drawing chamber Z 16. This sounds reasonable because the whole structure is lined. Leaving the space above the separation wall open ensured also that air could pass freely between the chambers, which will have improved the water quality as well.[36]

Drawing water was not performed equally from all chambers of a system. It seems that the northwestern corner rooms in which Z 5, Z 11 and Z 17 are situated were especially fitted for regular use, as they all had waterproof floors of burnished pebbles set in lime mortar (*Fig. 1*). There are rope marks on the mouths of several cisterns and the kerbstones at Z 1 and Z 26, while they are absent on others.

Ropes attached to vessels were obviously the main, but not the only drawing devices for cisterns. I suspect that mechanical drawing devices were in use only for wells with plenty of water and subject to repeated drawing action during the day.

There is no hint to the use of a swing beam or *shaduf* (*keloneion*) at cisterns, but because of the relatively small depth to be reached in cisterns, the swing beam may still have been used. This device is very rarely preserved anyway. There is little evidence for beam racks on cisterns. Werner Brinker interpreted the lack of rope traces on the mouth of a cistern as an indication that a centred mechanism in the form of a pulley was used.[37] In the lower fill of cistern Z 15, dating to the 3rd century BC, a bronze hook was found that once held the wooden pulley disc over which the rope of a centred drawing mechanism could be worked.[38]

[36] During excavation, an immediate draught was noted whenever two or all three of the cistern lids were opened contemporaneously.

[37] Brinker 1990, 123.

[38] Cf. Brinker 1990, fig. 77.

Cistern workshops

All in all, since at least the late 5th century BC, the underground cisterns in Athens were built in a highly effective and professional way and with considerable knowledge of soil conditions, statics and building material properties. The preconditions were availability of undisturbed underground space and the existence of a water source.[39] The order for a cistern must have included details such as volume requirements, property conditions, nature of the soil and availability of materials needed. They were probably made by specialized work teams, in which the diggers worked hand in hand with the mortar-workers and the polishers, as the cisterns bear features in common all over the city. The similarities in form and function of contemporary underground flask cisterns and related systems in other places, mainly in Piraeus, but also in Olynthus,[40] in Samos,[41] Miletus and Pergamon[42] make it probable that knowledge, or even specialized work teams, travelled from Athens to those places that entertained a broad variety of cultural interchange with Athens (see map in *Chapter 1*, *Fig. 3*).

When in use, cisterns must have been cleaned regularly, at least once a year, and thus the date of construction and the first period of use can very rarely be determined.[43] Sometimes, dates can be deduced from the structures to which the cisterns belonged. Decisive here is the level of the original cistern mouth for the first phase of use. One of the latest cisterns is Z 6, positioned within a 6th-century AD horizon in the area of Bau X (not yet excavated).

Of the results in mapping all known water reservoirs in the Kerameikos, perhaps the most

[39] Undisturbed e.g. by other structures such as sewers.

[40] Klingborg 2017, nos. 289–307.

[41] Klingborg 2017, no. 378, fig. 13.

[42] Miletus: Klingborg 2017, nos. 398–401. Pergamon: Brinker 1990, figs. 18, 119; Klingborg 2017, nos. 402–410; *AvP* 1:4.

[43] Klingborg 2017, 52–56, 91–92.

Fig. 10. Kerameikos bath, second phase, Z 17: cut-out central part of the floor and opening of passage to Z 16. Photograph: Jutta Stroszeck.

striking feature is that underground cisterns mainly occur from the Classical to the Hellenistic periods, with the exception of Z 6 that may have been built during Late Antiquity.[44] Dates provided by the fill of a cistern are sometimes helpful in dating the end of its period of use. In this case, the latest fill layers to be found testify to the last use before abandonment. If a cistern was filled to the top homogenuously, the fill dates to the moment a cistern definitely ceased to function as an architectural device (e.g. Z 18-19-21). According to its fill, Late Classical Kerameikos cistern Z 10 was in use until the 6th century AD.

Changes and damage

Classical and Hellenistic underground cisterns in Athens are surprisingly stable structures that are not liable to damage, and many of them are still well preserved today. The reasons for this may be the way in which the chambers and tunnels were mostly built, i.e. using a kind of corbelled technique in order to avoid pressure on weak points, and a water-resistant, strong mortar for the interior lining.[45] There are deliberate changes. For instance, the necks of cisterns that were in use over a longer period were repeatedly raised in accordance with the rising living surfaces within a house (e.g. Z 17).[46] Another alteration was also fundamental for the function: in both cisterns Z 17 and in Z 16, the circular central depression in the floor was cut out during the Hellenistic period in order to let the groundwater fill the chamber. In so doing, the cisterns were virtually turned into wells (*Fig. 10*).[47] Obviously the ground water had risen to a level that made collecting rain water superfluous.

Damage may have been caused by long periods of use, causing considerable wear to the lining. This is visible mostly on the necks of cisterns that were extensively exposed to drawing and to sunlight. In some cases, the coarse pebble and mortar layer below the coating is what remains today (Z 15, Z 16). Other damage is caused by external factors, such as deliberate human destruction, by roots or earthquakes, and cracks occur in the surface of the interior wall coating. In some places, these cracks were repaired in antiquity by using another layer of the coating along the damage (Z 15). When cracks were not repaired, sometimes parts of the mortar completely broke away over time, leaving holes. As a result, the undisturbed natural soil layers through which the feature was cut

[44] This cistern is situated in the unexcavated area just southeast of the so-called Bau X. It remains uncertain if it was in fact built during Late Antiquity or if an older cistern was adjusted and continued in use (i.e. 6th century AD).

[45] Cf. Brinker 1990, 1–33, 102–103, 124–125, fig. 9.
[46] Cf. Brinker 1990, figs. 16–17.
[47] Stroszeck 2014b, 506. For wells being turned into cisterns see Argoud 1981, 75.

are now visible. For example, the local marl can be seen at the damaged areas of Z 23 and Z 1.

Fills and drawing vessels

Several cisterns in the Kerameikos preserved "layers of activity" that can be dated.[48] In contrast to fills that were brought in after partial or complete abandonment (dumps containing mainly fragmentary pottery), the activity fills usually contain complete drawing vessels, oil lamps, coins and other small finds related to activities around a cistern in use. These finds represent objects that occasionally fell in through the mouth of a cistern. Thus, they gather around the centre of the bottom, where they sometimes form a little heap as in the case of Z 1, Z 15, Z 16 and Z 17. The layers in Z 16 and Z 17 can be dated just before 86 BC. Similar drawing vessels were used in both cisterns and in wells.[49] In cistern Z 1, a broken but complete drawing vessel, a *kados*, was found,[50] while in cistern Z 16 a plain trefoil jug, found in a layer of use centred under the cistern opening, may have been used for the same purpose.[51]

In comparing activity layers from wells and cisterns, a striking difference can be observed: while the activity layers of the wells, as a rule, contain a combination of complete drawing and drinking vessels in quantity, cisterns only yielded a number of drawing vessels. This may indicate the different uses of well and cisterns water, in particular that cistern water was not regularly drunk. On the other hand, the most striking quantities of jugs and drinking bowls come from Early- and Middle Hellenistic layers in the wells B 1 and B 34. This means, they might reflect a habit that is lost in cistern layers because these were cleaned regularly.

The complete filling-up of cisterns may be seen as a deliberate act by which one tried to avoid internal collapse of the cisterns and to prevent related accidents. Deep voids and openings in the ground must have posed a real danger for later use of the areas and subsequent building activity. By filling the cisterns completely, the installations were not only deliberately put out of use, but the area above also secured for further use. The replenishment fills contain a mass of earth and stones, heavily fragmented pottery, often with levigated break lines and other, usually broken small finds and fragmented debris of various nature and provenance. The finds have a common *terminus ante quem,* as they were filled in at one certain moment in history. Cistern Z 1 to the east of the Dipylon was never filled up above the latest preserved activity layer. This can also be observed in other cisterns.[52] If a cistern remained unfilled, it either remained open with the intention of further use, or it was completely forgotten after some event followed by destruction of the buildings the cisterns once belonged to. But how could the existence of a cistern be forgotten? If water was scarce, why did the owners not use it again? The mansion east of the Dipylon, for instance, would not have been inhabited without groups of slaves and other household members who knew the whereabouts of the cisterns.

Destruction layers also exist. This kind of layer contains material from the use of the cistern (e.g. drawing mechanism, fragments of the rim) or its nearer vicinity, but in a state of destruction, and masonry stones, roof tiles or fragments of plaster and mortar from walls. Sometimes, there are complete bodies of various animals (a dog in Z 17) and even human bones. On top of destruction layers that can be

48 Cf. Klingborg 2017, 53–56, fig. 31.

49 Klingborg 2017, 88–91, figs. 36–37; Stroszeck 2017, 58–59, figs. 37–43.

50 Kerameikos, inv. 15208.8; H 24.4 cm.

51 Stroszeck 2017, 59, 81, fig. 41.

52 Klingborg 2019, 49–50.

dated to the period just before 86 BC, both in Z 16 and Z 17, a thick and very compact layer of clayish mud was brought in before these cisterns were used again (they already had been turned into wells by this point). The clay cannot have fallen in by chance, as it was evenly distributed in the chambers and the passage between the two chambers. It was very clean and free of finds. Excavation of this layer was difficult, as the mud was very heavy and difficult to sieve. Considering this, it seems that the clayish mud must have had a filtration function for the water that emerged from the natural marl rock. Presumably this was common practice. Pliny the Elder (*HN* 31.23) refers to the intentional use of earth acting as a filter in hydraulic architecture. Layers of that kind can best be called clay filter layers.

Debris layers are also found. These contain many fragmented and almost complete items unrelated to water storage or the use of the cisterns. The cisterns that remained open without a cover for a certain period may have been used as dumps over a longer period, as reflected by growing heaps of all kinds of debris accumulating in the chamber. The material from these layers covers a large time span. Animal bones show deterioration that only occurs when they are exposed to weather and sun over a longer period.[53]

Towards the purpose of the Kerameikos cisterns

Water demand can be calculated for private use according to the number of members of the household, taking into account their need for drinking, preparation of food, personal washing, house cleanliness and production activities such as the manufacturing of clothes. The outcome can vary further according to the living conditions (e.g. winter or summer, periods of peace or siege). Calculations vary greatly here.[54] Brinker and Günther Garbrecht calculated a minimum of 10 litres per person per day for cooking, drinking, bodily hygiene and other cleaning, in the case of siege. Klingborg and Martin Finné have recently demonstrated that cisterns that were used throughout the year could provide up to twice the volume of their complete capacity because more water could be collected during regular use.[55] This influences the water amount provided by cisterns and also considerations about the number of people that can survive on cistern water in case of need. Various additional factors are likely to influence this calculation, e.g. the existence of wells in the same house.

The use of cisterns on a single site has to be seen—on a more general scale—in relation to the availability of other water sources, the quality and use of cistern water in society. Cistern water is of lower quality compared to spring or well water, which makes it prone to be used for drinking only in periods of need.[56] Yet water, even of lesser quality, was precious. Athenians were familiar with using, collecting, storing, cleaning and reusing water constantly in industrial contexts. The reuse and conditioning of water in the silver mines at Lavrion may offer a good parallel for the use of cistern water by households and baths—reduced in scale, but similar in effect.[57]

According to the buildings in which underground cisterns have been found in the Kerameikos, some primary functions of cistern water can be observed: it was obviously used for bathing, perhaps for special procedures in bath-

[53] "*Abschilferung*". I owe this observation to Norbert Benecke.

[54] Cf. Brinker 1990, 16–17.

[55] Brinker 1990, 15, 17; Klingborg & Finné 2018.

[56] On the water quality of cisterns cf. Brinker 1990, 75–79; Klingborg 2017, 83–86.

[57] Kakavojannis 2005, 225–229; Papadimitriou 2017, 402–403.

ing (perhaps soaping and cleaning), and for cleaning.[58] Cistern water was also used in activities performed in courtyards. For example, Z 1 lies within the peristyle of a huge mansion where water may have been used for the plants that presumably grew there.

Tancke characterized the volume of the Bau Z cistern system as beyond family needs. Therefore she assumed a function connected to industrial production, for instance, wool and flax preparation at an industrial level, related to the subsequent production and cleaning of clothes.[59] A pithos inserted into the floor next to Z 11 in Bau Z may have been used for fulling and washing clothes.[60] The mosaic pavement around the cisterns could have been used in these processes for drying flax or wool.[61] It seems likely that cistern water was used in the Athenian households for this purpose, as this was one of the main occupations of Athenian women during the Classical period, and the more so, because the same buildings that were equipped with a cistern system also had wells for drinking water.[62] With respect to their overall layout, the cistern systems of Bau Z, Y and X are very similar to system Z 15-16-17 of the second phase of the Kerameikos bath. The repeated distribution pattern (roofed corner room with pebble mosaic floor to the northeast, two other cisterns connected to this underground by tunnel with openings in a courtyard or under a stoa roof) make similar patterns of function a probability. Cistern water must also have played a role in potters' workshops, as well as in bakeries and butchers' shops.[63]

Beyond that, cistern water also obviously played a role in the cult performed in a small sanctuary just outside the Sacred Gate during the Classical period.[64] The capacity of this single, oval, cistern chamber with a central depression in the floor probably did not exceed 2–4 m^3, although the poor state of preservation makes calculations uncertain.

In comparison to wells, underground cisterns seem to be somewhat more private and more industrial in character—as there are no cisterns in the Pompeion area or near the gates and along the city walls.

The abandonment of cisterns

Two main positions, argued by John Camp and Klingborg respectively, have been put forward regarding why underground cisterns were increasingly built in Athens during the 4th century BC. Both see this development triggered by necessity: because of a large drought during the 4th century[65] or—in accordance with Aristotle and Procopius—as a reaction to imminent risks such as sieges and warfare during this critical period.[66]

The almost complete abandonment of this type of cistern at the end of the Hellenistic period, as almost no new ones are constructed later than this, is striking. There may be many reasons for this, and even a combination of reasons seems likely:

[58] Clear distinctions were made between water for drinking and bathing. Pausanias (7.27.4), in writing about ancient Pellene in Achaia on the Peloponnese, notes that the inhabitants there—because they had so few springs providing them with drinking water—used rainwater for bathing. Implicitly this means that they were storing rainwater, unless we want to assume that they only bathed when it rained.

[59] *Kerameikos* 17:1, 69–71.

[60] *Kerameikos* 17:1, 55–56, 70; *Kerameikos* 17:2, pls. 24.1–2. Cf. Klingborg 2017, no. 165 (part of system 47).

[61] *Kerameikos* 17:1, 70.

[62] *Kerameikos* 17:1, 69.

[63] Brinker 1990, 15.

[64] Mattern in print.

[65] Camp 1977, 22–23, 148, 150, 152–155; 1982, 15–16; 1991; Hodge 1992, 60.

[66] Klingborg 2017, 124–125; Arist. *Pol.* 1330b.

1. CLIMATE

Camp has argued that a continuous drought during the 4th century BC, possibly attested in textual sources, led to an immense drop of the aquifer in wells, although it still rained occasionally during those years.[67] The Athenians reacted by turning to water harvesting and underground storage of water by building cisterns. That the main water supply in Athenian houses during the 5th century BC was via wells, is mirrored by the history of Bau Z: during the 5th century BC phases Bau Z 1 and Bau Z 2 had two wells but no cisterns, while an elaborate cistern system in Bau Z 3 dates to the end of the 4th century BC.[68]

It is problematic that the same type of cistern was obviously already in use earlier, and that this type must have been developed during the 5th century (e.g. Kerameikos Z 18-19-21). Also, water harvesting must have been an issue from the moment clay tiles were used for roofs,[69] as the experience of a heavy rain falling on a sealed surface of this kind would definitely provoke the question of how to collect this water.

The explanation for the disappearance is—according to Camp—that after the 4th century BC, the climate changed again, water levels rose, and thus wells were used again instead of cisterns. If we argue that the cisterns had been built in the first place because the water level had fallen, causing the wells (as the other sources of water in Athens) to fail, one could argue that the cisterns were made superfluous by sufficient well water after the 4th century BC, when the proposed dry period came to an end (see this volume, *Chapter 2*).

2. STRATEGIC

Klingborg has argued that the primary factor for the proliferation of cisterns during the 4th century BC was the changing experience of warfare, in particular sieges, in the Greek world from *c.* 400 BC, driving individual Athenians to secure their water supply. This was done by constructing cisterns, Klingborg argues, because they were viewed as more reliable, and therefore more secure, than wells and other types of water sources. This responds in part to the fact that cisterns were abundant in Athenian private houses, but on the other hand, they were not limited to the area within the city. On the contrary, cisterns were built exactly on the spot that suffered the most during various sieges of Athens, in front of the Dipylon (Z 15-16-17, Z 18-21-19).

After these main positions, several other possible scenarios exist:

3. DURABILITY

It is also possible that nothing particular had changed—some cisterns were still functioning in good shape after centuries of use and thus there was no need to dig new ones. This argument is based on the observation that many of the cisterns were still in good shape when excavated. Other cisterns were altered several times and eventually abandoned, such as Z 15 in the Kerameikos, which—together with the underground passage connecting it to Z 16—went out of use during the early 3rd century BC and was completely filled in after 86 BC.

4. DENSITY

The ground was already crowded with water devices, so it would have been dangerous to build new structures. This is clearly seen around

[67] Camp 1977, 22; Hodge 2000, 29; Dem. 50, 61.
[68] Stroszeck 2014a, 115.
[69] Clay roof tiles were known from the Mycenaean period, but occur regularly in the Greek *poleis* from the 7th century BC, see Koutsoumpou 2017, 160; Mazarakis Ainian 2017, 181; Morgan 2017, 195–197, figs. 19.2–4.

the Athenian Agora as well as in the Kerameikos (*Fig. 1*).[70]

5. REDUNDANCY

There was no need to build new cisterns after the Hellenistic period because safer, more reliable and effective systems of water supply were used. If this was the case, an investigation into what the new water supply was and how it worked is necessary.

A second line of this argument may be related to the properties of cistern water and to its specific uses: the use of this water in private houses may have become obsolete, because processing wool and household manufacturing of clothing was outsourced to more industrialized production in specialized workshops. In other words, a cultural change had taken place that meant the use of this water, or at least the effort of building new cisterns in private houses, was no longer required. This falls among a sociocultural group of reasons that certainly could bring about change.

6. LOSS OF KNOW-HOW

The underground cisterns had been built in hundreds all over Athens, very likely by specialized teams. It is therefore possible, that for some reason (e.g. because of "mission accomplished", i.e. each house had a cistern system after one or two generations), the technical knowledge of how to build these cisterns and the specialized workmen were no longer available.

7. MATTERS OF FASHION

This circumstance will occur in combination with the other reasons. As other features in architecture, underground cisterns may have fallen out of fashion after some time. This is a weak argument but may have played a role.

Water storage during the Roman and Late Roman period

After the Sullan conquest of Athens in 86 BC, with the exception of Z 6 in the area south-east of the Sacred Gate, no new underground cisterns were built in the Kerameikos area.[71] Yet, the position of some cisterns was not forgotten, and a few were reused in the Late Roman potters' workshops. When reservoirs were built in Roman and Late Roman times, they were mostly rectangular, open structures above ground, in the Kerameikos as elsewhere in the densely distributed industrial areas around the city. Similar combinations, for example, are visible in the entrance area of the new Acropolis Museum south of the Acropolis. These basins received water from a well next to them. In many instances, much older wells were reused for this purpose, for example B 34, B 39 and B 44 in the Kerameikos. As a rule, these installations are connected to workshop activities, mainly of potters, on the site. By further research in diaries and plans, many more open basins of this type are likely to be rediscovered.

Summary

The Kerameikos cisterns offer new information about the distribution of cisterns within architectural structures: the Kerameikos bath in front of the Dipylon, as well as four large private houses immediately inside the city walls were equipped with large underground water storage systems consisting of more or less flask-

[70] Klingborg 2017, fig. 44.

[71] As Z 6 has not been excavated yet, it remains unclear if it was built during Late Roman times. It certainly was in use during that period, but as in other cases the neck of an earlier cistern may simply have been extended.

like chambers, usually connected by tunnels. Only one tunnel was built with limestone walls covered with slabs (between Z 15 and Z 16). In the bath and houses Bau Z, Y and X a drawing chamber, provided with a waterproof burnished pebble mosaic floor, was located in the north-western corner. One cistern is situated in the courtyard of a small sanctuary (Z 27) outside the city walls. There are no cisterns in the area of the defensive system or of the Pompeion, or in the necropolis or in the workshop areas outside the city walls.

The chronology confirms in part what can be seen in other excavations around Athens. Most cisterns were built during the 4th century BC, while at least one cistern system can be dated earlier, to the late 5th century BC (Z 18-19-21). No new cisterns were built after the early 1st century BC. The history of abandonment is more complicated. Some cisterns fell into disuse as early as the 3rd century BC, while others remained in use until 86 BC. A few cisterns were reused during the Late Roman period.

As a rule, the interior of the cisterns is completely lined with hydraulic mortar. Water was collected from roofs sloping to the outside of the building (Kerameikos bath) or towards the interior courtyard of the houses (Bau Z, House East of the Dipylon). Within the systems, there are cisterns mainly for drawing (Z 5, Z 11, Z 17, and Z 19) and others mainly for collecting water. In system Z 15-16-17, the water settled in a *prolakkion* before it was led to the cistern mouth via a covered limestone channel. Used bathing water was led to the tunnel connecting cistern Z 15 for recycling. The Kerameikos material also provides further information about the function of cistern water: it was used for bathing in the public bath and a tavern-like brothel (Bau Z, Y), and most likely also for cleaning cloth or fulling.

Alterations of cisterns are also observed. Intentional alterations are adaptations to higher floor levels and the introduction of separation walls between chambers. Damage in the form of cracks and the ancient repairs to them can be observed in Z 15. There seems to be a difference between wells and cisterns with respect to drawing mechanisms; cisterns, as a rule, were not provided with mechanical devices such as tie racks or *keloneia*. Among the objects found inside cisterns, drawing vessels are less common than in wells. Also, in contrast to wells, there are no significant numbers of drinking vessels.

Lastly, the density of underground channels and cisterns in private houses, taverns and baths found in the Kerameikos provides new insights into the reasons why cisterns of this type went, for the most part, out of fashion during the Late Hellenistic period.

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