

DIGITAL DOCUMENTATION OF THE CAPPADOCIA GATE AT KERKENES IN YOZGAT, TURKEY

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INTRODUCTION: KERKENES AND CAPPADOCIA GATE

The Iron Age city on Kerkenes Dağı, near Şahmuratlı Village in Sorgun, Yozgat, Turkey (**Figure 1, 2**) is one of the largest settlements of its period in Central Anatolia. It was built as a single foundation c. 620 BCE to the east of the River Halys (*Kızıllrmak*), presumably by a Phrygian ruler, and was destroyed by fire c. 550 BCE, presumably by Croesus of Lydia or Cyrus the Great of Persia during their struggle. The archaeological and architectural evidence points primarily to Phrygian influence with various other Anatolian and Near Eastern cultural connections. The first survey and short excavation campaign at the site in 1926-1928 was carried out by Hans Henning von der Osten and Erich Schmidt of the Oriental Institute of the University of Chicago (von der Osten, 1928, 1929; Schmidt, 1929). This brief field work dated the city as "post-Hittite", now described as Iron Age, and helped possibly identify it as Pteria, a city mentioned by Herodotus in the *Histories* (Herodotus, 2009, I.76; Przeworski, 1929). A new campaign began in 1993 under the direction of Geoffrey D. and M. E. Françoise Summers with the support of the British Archaeological Institute at Ankara (BIAA) and Middle East Technical University (METU). This project became an experimental ground for state-of-the-art and non-destructive methods, using a range of new technologies, including aerial remote sensing, geophysical survey and digital photogrammetry. The documentation of the 271 ha urban settlement, including c. 750 urban blocks and surrounded by c. 7 km of walls pierced with seven gates, has been a work in progress, evolving with the development of new techniques and technologies for the last 30 years (Baturayoğlu Yöney *et al.*, 2002; Summers and Summers, 2010; Baturayoğlu Yöney, 2021).

The defensive circuit around Kerkenes is of a single build and formed of a dry-stone masonry wall with protruding towers and buttresses. It is clad with a stone glacis on the outside, and topped by a stone superstructure. There are no outworks or internal walls. The system makes efficient use of

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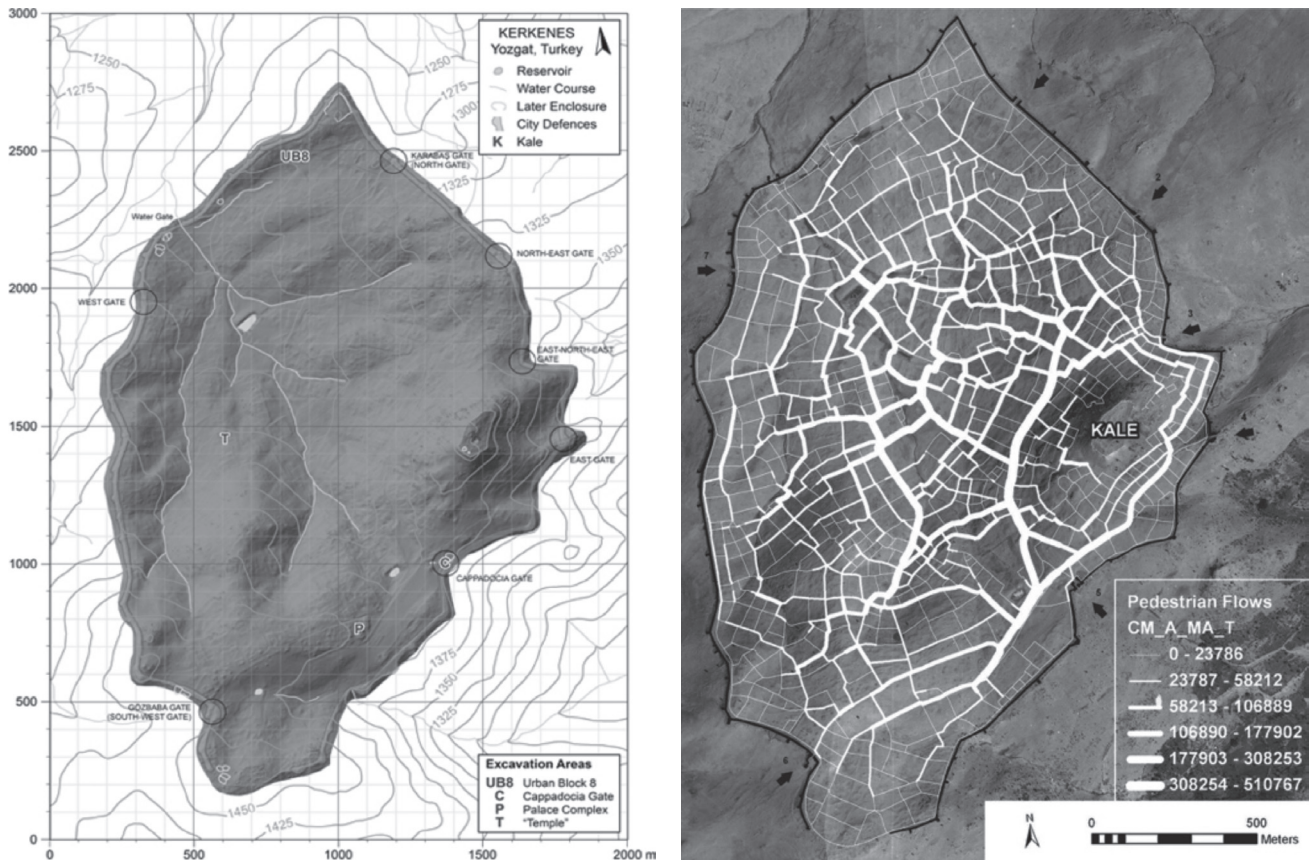


Figure 1. Plan of the archaeological site on Kerkenes Dağı. The excavated city gate – the Cappadocia Gate – (center right; C), the Palatial Complex (lower right; P), and the highest point of the site Kale (K). Urban Block 8 (top right; UB8) has been one of the study and excavation areas in recent years. (Map: Kerkenes Project)

Figure 2. Simulated traffic volumes of pedestrians on the street network at Kerkenes (Branting, 2007) clearly show the importance of the Cappadocia Gate (marked as level 5) in terms of the circulation in the city. It may be interpreted that it was the main gate among the seven entrance points. (Map: Kerkenes Project)

the existing topography; the walls follow the mountain ridge, and the individually planned gates are positioned at strategic points (Figure 3). The towers and buttresses are not located at regular intervals but rather at topographically weaker sections along the wall.

The material of the walls is crudely shaped granite, cut from extruded outcrops of bedrock on the mountain, making use of its natural fracture planes. There is a core of smaller rubble stones retained by wall faces of a “cyclopean” technique: a form of loosely fitted stonework of semi-shaped blocks stabilized with smaller chinking stones where necessary. Blocks vary in size with a limited attempt at coursing. The exterior wall faces appear to be formed of comparatively larger stones, while even larger flat stones were used to construct the glacis faces (Figure 4). The wall thickness is 5 ± 0.5 m with a height of c. 2 m on the interior side. The wall top may have been stepped where it descends steep slopes as indicated by the remains, and internal projections of 0.8-1.5 m may have been incorporated for ramps or stairways, none of which have survived. The towers along the wall and on either side of the gates were bonded with more carefully shaped prismatic stone blocks at the interior and exterior corners. The towers are generally 5-6 m in width and project some 10-12 m from the exterior face of the wall. These have not been placed regularly but rather at strategic and appropriate points where there is a rock-outcrop to form a base. The smaller buttresses generally protruding 2.5 m appear to be butted rather than bonded and might have been added later. Tumuli, shelters and animal pens constructed on top of the wall and tracks opened through the gateways in later periods obscure the original plan at many places, making interpretation more difficult. The amount of stone used for these later

1. For more detailed information about the construction system and characteristics of the wall, see Baturayoğlu Yöney (2021).

structures and the debris on either side of the wall indicates that there was a stone upper wall, perhaps narrower than the base and reaching several meters in height. However, no remnants of this upper wall have survived at any point along the 7 km long defenses. The walkways, their level(s) and the shape of the battlements are also unknown. The stone glacis encloses the visible exterior faces of the thick stone base, presenting a smooth and steep façade and making climbing up the wall more difficult for attackers. Its angle is around 60° but becomes steeper in rounded corners around sharp turns and towers (1).

Each one of the seven gates along the wall has been individually planned. Their locations relate to the position of routes leading to the city, the concerns of military strategy and the internal urban dynamics. The position, monumental appearance and strong defensive structure of the Cappadocia Gate (**Figure 1, C**), located on the high southeastern ridge of



Figure 3. The wall follows the ridge of the mountain, making use of the topography for defensive purposes. The debris of the wall itself obscures it in some sections. (Photograph: Kerkenes Project)

Figure 4. The glacis on the exterior side is built with large and flat stone blocks and reaches the top of the lower/base wall, which was c. 2 m high on the interior. The information concerning the upper wall is rather limited. (Photograph: Kerkenes Project)



the city where the line of the wall forms an elbow, identifies it as perhaps the most important one among them. It is located adjacent to major public zones, including water reservoirs, potential stables and the “Palatial Complex” (Figure 1, P. Summers, 2000; Summers, 2022). A study on the frequency of the use of streets inside the city (Figure 2) also supports this view (Branting, 2004; Branting, 2007; Branting et al., 2007). From the gate, a road descended down the hillside towards the Cappadocian Plain, facing Mount Argeus (*Erciyes*) in Kayseri. Considering the ancient trade routes and connections in Central Anatolia, this was perhaps the most frequently used gate with the heaviest traffic of caravans.

The asymmetrical plan of the gate, which is similar to the design of the other gates along the wall appears to reflect the topography. Formed of two parts on either side of the passage and chamber, it has been modified and partially obscured by collapse and subsequent clearance, the construction of tumuli, shepherds’ shelters and animal pens, and clearing of pathways for animals. The passage is about 6m in width and at least 25 m in length. An inner chamber is located on the northeastern side of the passage. On the exterior, there are twin towers on the east and a single tower on the west with single towers on either side of the interior. The city wall butts against the gate structure on either side, indicating that the gate was built before the adjoining walls. This may be true for other gates as well, supporting the view that the whole system was planned together and that the gates were laid out and constructed first. The exterior glacis, on the other hand, is continuous, showing that it was built last (Figure 5) (1).

The main body walls are vertical without steps or recesses between consecutive stone courses. The wall faces were probably constructed a course or two in advance of the rubble core to function as formwork. The building stones differ in size with larger stones located on the corners and lower courses and large prismatic blocks preferred on the tower corners. The wall and glacis face stones were not shaped but fitted, leaving relatively minimal gaps or joints. The larger of these were chinked with smaller stones in order to increase stability. Timber beams were located along the wall face; these were leveled and may have been partially hidden by smaller stones bonded with mud. No traces of vertical, diagonal, or cross beams perpendicular to the wall faces have been observed. The timber beams, about 20-25 cm in thickness, were spaced at 1 m intervals. However, the beams along the niches surrounding the chamber on the interior side are not quite parallel. The lowest beams are parallel to the inclined ground surface, and they gradually become level as the wall rises. None of the beams within the gate walls have been preserved. All were probably burnt during the massive fire that destroyed the city, with only scattered remnants of charcoal left in the cavities. The charcoal remnants have been identified as black pine (*Pinus nigra*), a coniferous tree still frequently found in Central Anatolia (2).

The doors were located in the back section of the passage, behind the chamber. There were two sets of doors with a small space between them, where a statue was located (Figure 5). This statue, of probably a female goddess, was set on a carved plinth and was hidden behind a mudbrick wall at a later phase (Figure 6, C). The doors were made of wood and held together with iron bands and nails, some of which were recovered during the clearance of the chamber. In front of the outer set of doors, on the right side, there is a stepped altar, which was topped by a semi-ionic sculpture (Figure 6, A). There was another aniconic stele at the interior

2. For more detailed information about the construction system and characteristics of the gate, see Baturayoglu Yoney (2021).

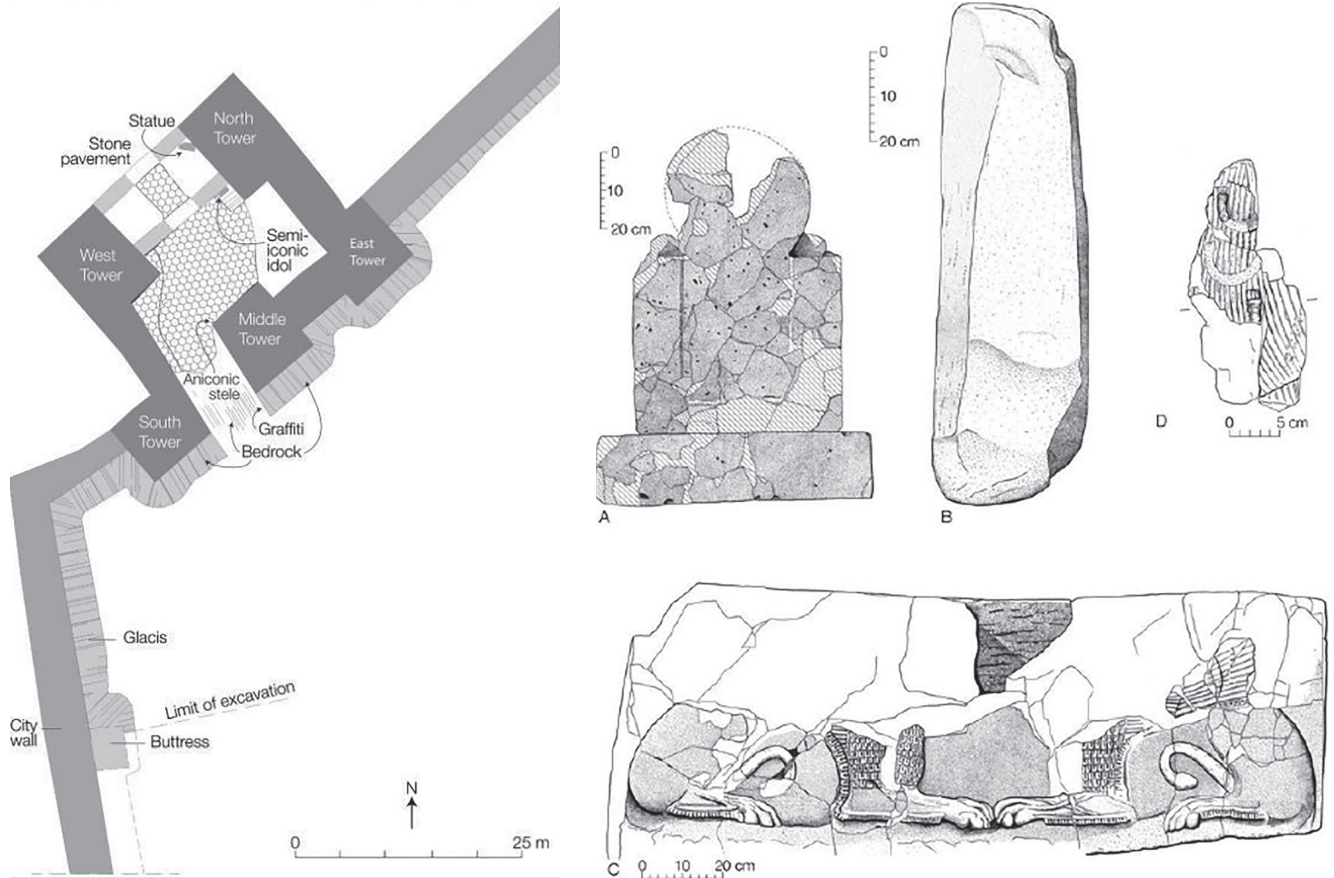


Figure 5. Block plan of the Cappadocia Gate, including features uncovered during the 2011 clearance (Osborne and Summers, 2014). (Image: Kerkenes Project)

Figure 6. Cultic images excavated within the Cappadocia Gate during the 2011 clearance: A) Semi-ionic idol (S1); B) Aniconic stele (S2); C) Statue base (S3); D) Statue fragment with Phrygian fibulae (drawings by Ben Claasz Cockson; Osborne and Summers, 2014). (Image: Kerkenes Project)

corner of the middle tower (Figure 6, B). Perhaps due to the difficulty of precision shaping the granite, several sandstone blocks were utilized at the corner of the middle tower. Similar sandstone blocks may have formed the battlements over the upper wall. A covered water channel runs along the length of the outer passage, which is more steeply inclined towards the outside. The pavements, channel, sculptures and other smaller artefacts, as well as two human skeletons, have been uncovered during the clearance of the gate (Summers et al., 2021, 55-7).

DOCUMENTATION HISTORY OF THE CITY WALLS AND CAPPADOCIA GATE AT KERKENES

H. H. von der Osten and F. H. Blackburn documented the walls during a short survey, lasting three days and 133 stations in 1927 (von der Osten, 1928; Figure 7). They named the southeastern gate the “Large Gate” (Figure 8). Carried out with a field theodolite, “the error of closure” as indicated on the map in the publication was 1.5x4 m, a feat of cartographical skill considering the size and difficult topography of the site as well as the time constraint of three days. However, more significant errors have been noted in the placement of excavation areas and features within the well-surveyed outer wall. When the new period of research began in 1993, the gates were named according to their position rather than being numbered. First called the Southeastern Gate, the monumental structure that forms the focus of this article later received the name Cappadocia Gate as it faces the large Central Anatolian plain of the same name.

Following a documentation based on aerial photographs and satellite images of the city, the entire area of the site, including each of the gates, was topographically surveyed using a post-processed configuration of four Trimble 4600LS GPS receivers in 1997-2001 by Scott Branting. 1,4 million data points were collected by mounting three of the receivers on project team members, the fourth functioning as a base station, and collecting topographic data points, with an attested accuracy of $\pm 10\text{-}25$ cm, every 2 seconds as they carried the receivers over the ground surface (Branting and Summers, 2002). The resulting point cloud allowed the generation of 3D models of the ground surface, including the area of the Cappadocia Gate (Baturayoğlu Yöney *et al.*, 2002; Baturayoğlu Yöney, 2002).

Also, in 1997 the city wall was surveyed with a total station at 1:200 scale by Nilüfer Baturayoğlu Yöney and two undergraduate students in architecture under the guidance of the former director G. D. Summers. The survey followed the wall faces visible on the surface through the rubble. External towers were usually less visible due to the spread of fallen rubble down the steeper external slopes. A total of seven gates were identified along the wall. An eighth structure, named the "Water Gate" is the strongly defended outlet of the stream that originates within the city and supplies fresh water to the settlement but it did not provide pedestrian or vehicular access



Figure 7. H. H. von der Osten and F. H. Blackburn's survey at Kerkenes in 1927 (von der Osten, 1928; p. 88, fig. 7).

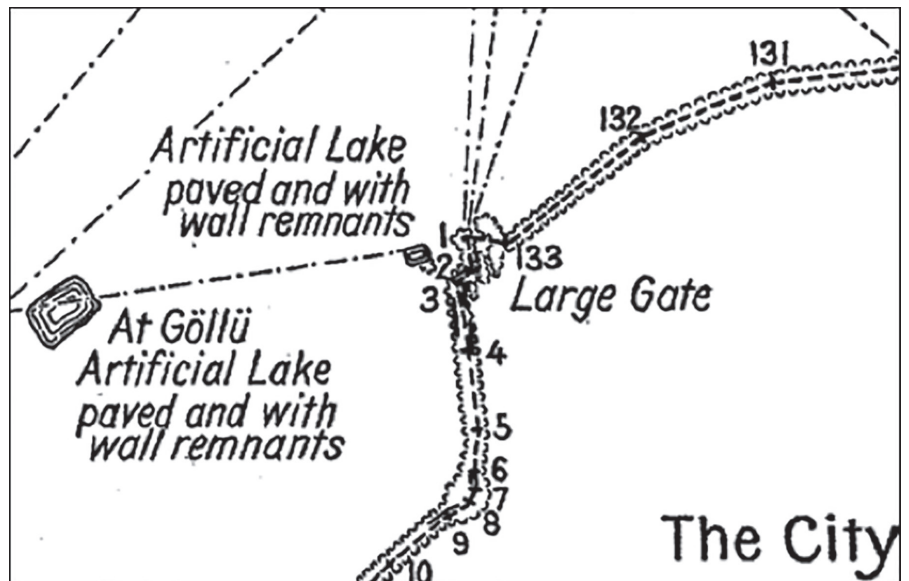


Figure 8. Detail showing Cappadocia Gate from H. H. von der Osten and F. H. Blackburn's survey at Kerkenes in 1927. The survey started and ended at the gate as indicated by stations 1 and 133 on either side (von der Osten, 1929; image cropped and enlarged from p. 20, fig. 11).

(Baturayođlu Yöney, 2002). Survey work also focused on the Cappadocia Gate. In addition to its comparative importance and size, it was selected because the visible parts, including stretches of wall and glacis together with the five towers that define the structure, suggested that it was perhaps better preserved. The survey and research not only aimed at determining the plan and construction system of the gate, but also at understanding the relationships between the bedrock, walls and glacis and determining the use of any other building materials in addition to local granite. Geophysical survey techniques used elsewhere at Kerkenes proved to be ineffective at the gate structures since they were covered with large amounts of collapsed granite rubble. Therefore, clearance and excavation were used for further investigation of the remains.

The first detailed plan of the Cappadocia Gate was drawn from a survey conducted during the 1997–2001 seasons by Ömür Harmanşah and Nilüfer Baturayođlu Yöney. This survey made use of the initial techniques applied at Kerkenes: previously produced balloon and blimp photographs were taken to the field for verification on the ground; points visible on the photographs that had been marked with white lime, together with features that could readily be identified on the ground, were plotted with a total station; and the photographs were digitized into CAD software. Following the clearance of the rubble on the outside of the gate structure in 1999 the glacis faces were documented as flat surfaces by Ömür Harmanşah. However, the complexity of the curvatures and inclinations resulting from the topography made it impossible to transform these detailed drawings into foreshortened architectural elevations. In 1999–2000 Kemal Gülcen of the METU Faculty of Architecture Graduate Program in Conservation of Cultural Heritage - Photogrammetry Laboratory prepared detailed façade drawings under the direction of Emre Madran using stereographic photogrammetry. A simple photogrammetry method based on single-image rectification was utilized for other wall faces and pavements (Baturayođlu Yöney, 2002; Baturayođlu Yöney, 2021; F. Summers et al., 2003).

In the 2009 season, architectural fieldwork focused on the documentation of the Cappadocia Gate once again to form the basis of a project for conservation, strengthening and enhancement for presentation and visitor security. The survey and documentation were carried out by M. Çıngı Salman, Erdoğan Cambaz and Nazlı Mavuşođlu with Nilüfer Baturayođlu Yöney acting as architectural preservation consultant. The documentation was approved by the concerned Regional Commission on the Conservation of Cultural and Natural Property in 2010. This new survey made it possible to draw the plans, sections and elevations of the gate structure, making it possible to understand how the walls were constructed on the existing bedrock and other topographical features.

The implementation of this ensuing conservation project, focusing on structural strengthening, visual enhancement and ensuring public safety, was carried out over two seasons with a grant provided by the United States Department of State Ambassador's Fund for Cultural Preservation and the support of the district governor and the mayor of Sorgun, Yozgat. Erkan Kambek acted as the field supervisor, while Nilüfer Baturayođlu Yöney was the consultant for the Kerkenes Team. In 2010, the glacis encircling the front of the middle and east towers was repaired and partially rebuilt to its original height, stabilizing the wall behind it, and the wall top was compacted. Unstable wall faces and fill on the interior

3. For more detailed information about the 2009-2011 survey and intervention to the Cappadocia Gate, see Baturayoğlu Yöney (2021).

4. Financial support for the ongoing monitoring and maintenance of the Cappadocia Gate by the current project was received from the Merops Foundation and the United States National Science Foundation (NSF) Senior Archaeology Grant Award #1624105. Funding was also received for the described ongoing augmented reality development by the United States National Endowment for the Humanities (NEH) Digital Humanities Advancement Grants HAA-256218 and HAA-277278. Rekare Architecture (Istanbul) carried out the field work and data processing.

sides of the middle tower were temporarily removed. In 2011, the interior faces of the north and west towers were dismantled and rebuilt using new timber beams. The interior face of the middle tower, which had completely collapsed during the winter, was dismantled, and the unstable wall faces and infill around the interior walls of the chamber were also temporarily removed. A similar intervention was carried out along the east side of the front gate passage as well (3). Following the retirement of G. D. Summers as project director in 2012, the work was suspended for several years.

Under the new project director, Scott Branting, the gate has been annually monitored and maintained since 2015 (4). Every year plants have been removed from the walls, the glacis, the gate passage and the chamber to minimize the impact that root activity might have on the integrity of the stone structure. At the same time, small chinking stones have been placed between the larger dry-laid stones of the walls and glacis to further minimize movement. In addition, c. 700 aerial photographs taken with a quadcopter (DJI 2s and 3s) combined with c. 300 ground-based photos of select walls and features within the gate have been collected every season since 2016. These photographs have been used to generate successive photogrammetric 3D models using Agisoft Metashape v. 1.2 to 1.7, previously called Photoscan (**Figures 9-10**). A typical model consists of up to 152,891,850 points within the generated dense cloud. The overall model error within Metashape has been sub-centimeter over the 7-year period, though some areas of specific models are less precise than this average. These annual models were overlain and compared from year to year within various versions of CloudCompare 2.x software in order to assess the displacements and deformations on the strengthened and untouched portions of the gate. The data collection and monitoring are carried out by Scott Branting, Dominique Langis-Barsetti and Jessica Robkin. Despite the annual monitoring and maintenance as well as the prior removal of unstable wall faces and infills during the conservation project in 2009-2011, partial collapses have occurred in various sections of the gate due to environmental conditions, such as heavy rainfall.

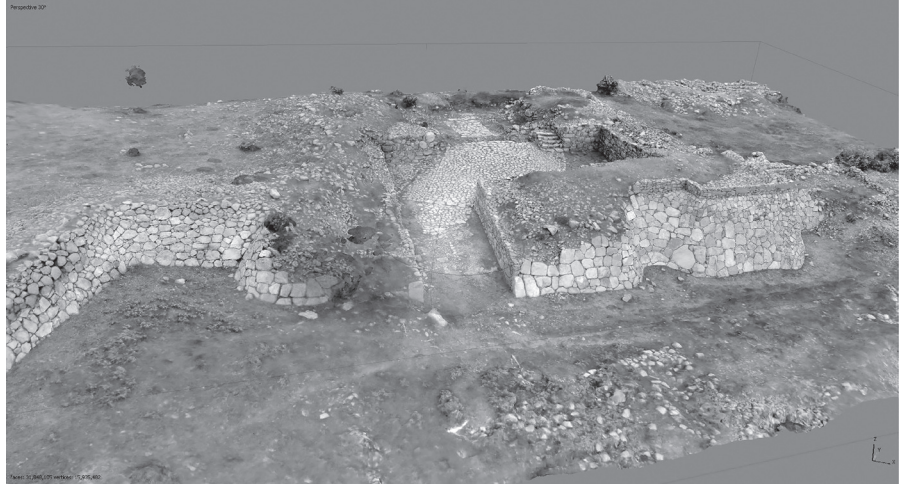
2019 SURVEY OF CAPPADOCIA GATE

In order to carry out another campaign of structural strengthening, restoration and partial rebuilding for the preservation and enhancement of the Cappadocia Gate, a new survey was carried out in 2019 by M.



Figure 9. Photogrammetric 3D UAV model of the Cappadocia Gate, showing the monument from the west. The image was produced by Scott Branting, Dominique Langis-Barsetti and Jessica Robkin in 2018. (Image: Kerkenes Project)

Figure 10. Photogrammetric 3D UAV model of the Cappadocia Gate, showing the monument from the south. The image was produced by Scott Branting, Dominique Langis-Barsetti and Jessica Robkin in 2018. (Image: Kerkenes Project)



Çıngı Salman and Doğan Tekin with Nilüfer Baturayoğlu Yöney acting as architectural preservation consultant for the Kerkenes Team. This survey utilized new methods and instruments of survey and was based on data collected with a 3D ground laser scanner. Its small size and lightness make it easy to use at sites like Kerkenes, where access is problematic due to rough topography and a lack of accessible roads.

The fieldwork, in this case, was completed in a single day. The data was then modified in order to form a coordinate system for drawings, and orthographic images were obtained at a scale of 2 mm/pixel (Figures 11-13). The methodology is explained in more detail below in Section 4. The CAD drawings were produced from these orthographic images (Figures 14-17).

Figure 11. Orthographic image of the Cappadocia Gate: South Elevation. The images were produced by M. Çıngı Salman, Doğan Tekin and Nurçe Düzalan Salman from 3D laser scan data in 2019-2021. (Image: Kerkenes Project)

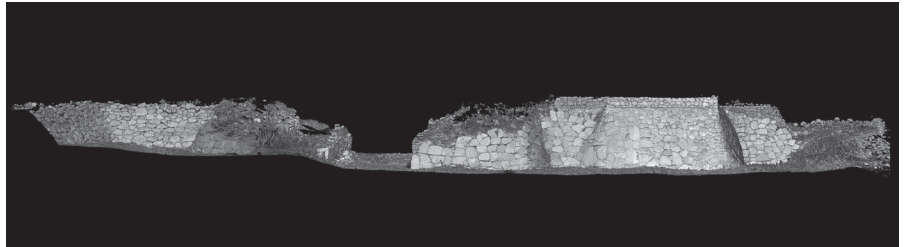


Figure 12. Orthographic image of the Cappadocia Gate: West Elevation of the Gate Passage. The images were produced by M. Çıngı Salman, Doğan Tekin and Nurçe Düzalan Salman from 3D laser scan data in 2019-2021. (Image: Kerkenes Project)

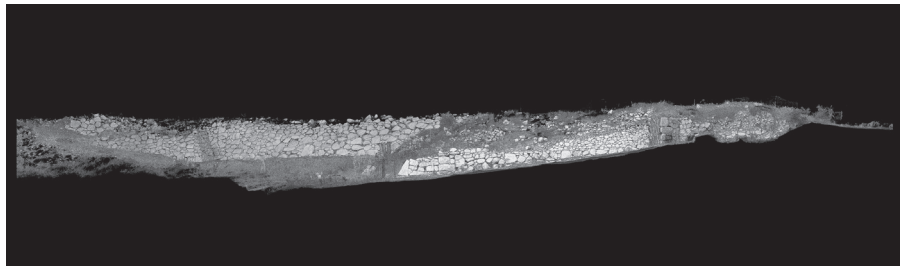
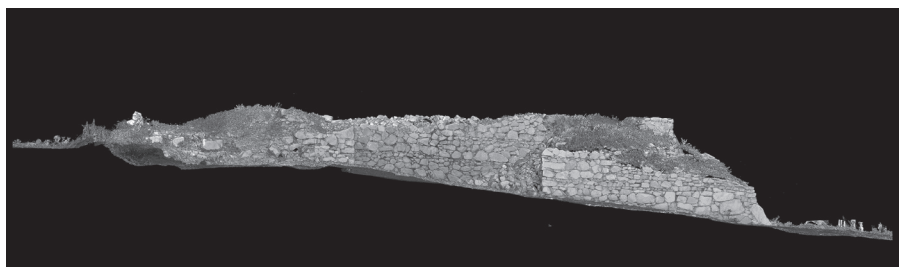


Figure 13. Orthographic image of the Cappadocia Gate: East Elevation of the Gate Passage. The images were produced by M. Çıngı Salman, Doğan Tekin and Nurçe Düzalan Salman from 3D laser scan data in 2019-2021. (Image: Kerkenes Project)



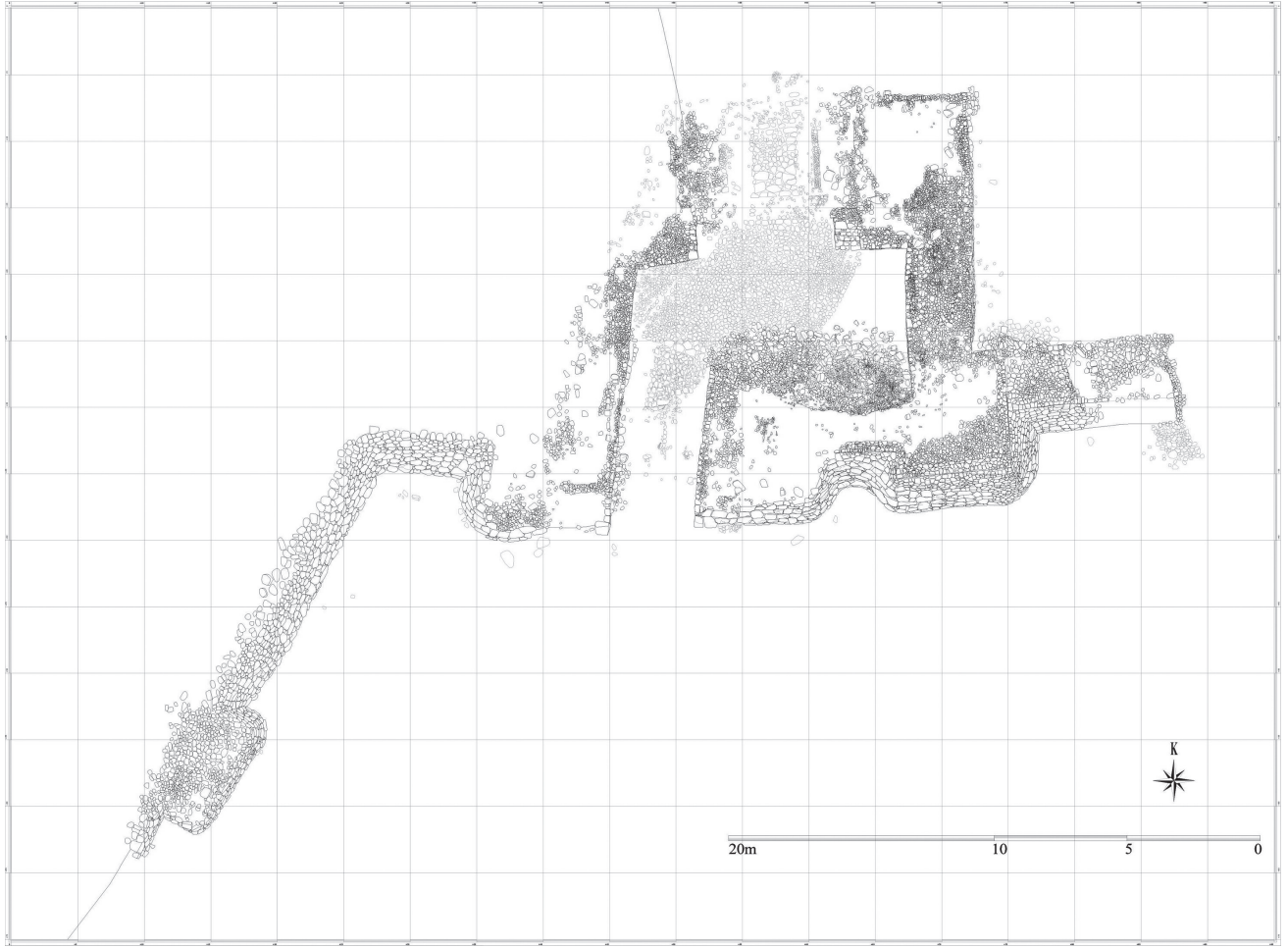


Figure 14. Plan of the Cappadocia Gate. The drawings were produced by M. Çıngı Salman, Doğan Tekin and Nurçe Düzalan Salman from 3D laser scan data in 2019-2021. (Image: Kerkenes Project)

A field-check was carried out, also in a single day, during the pandemic in 2021. The new structural strengthening and architectural conservation project will be based on this data and drawings and will be produced in 2023 by a multi-disciplinary team. Similar work at other cultural heritage sites around the world has demonstrated the efficacy of this approach (for example, Shanoer and Abed, 2018; Kushawa et al., 2020; Walters et al., 2020), though the uniqueness of the architecture in the Cappadocia Gate makes it a particularly interesting case.

A COMPARISON OF THE ARCHITECTURAL DOCUMENTATION METHODS APPLIED AT THE CAPPADOCIA GATE

The architectural documentation of the Cappadocia Gate in 2009 was carried out with a Leica TCR 407 total station. The frontal distance standard deviation of this instrument is 2 mm+2 ppm, and its angular precision is 7" (gradian seconds). According to the U.S. Institute of Building Documentation (USIBD) Document C120-C220 Specification (2016), the level of accuracy (LOA) of this survey and documentation was expected to be LOA20 (5 cm-15 mm). This data made it possible to draw the plans, sections and elevations of the gate structure at a scale of 1:50, based on a digital 3D model or point cloud formed from c. 2,000 survey points. It was possible to integrate all of the formerly produced wall face and ground surface drawings into this system and to construct accurate architectural

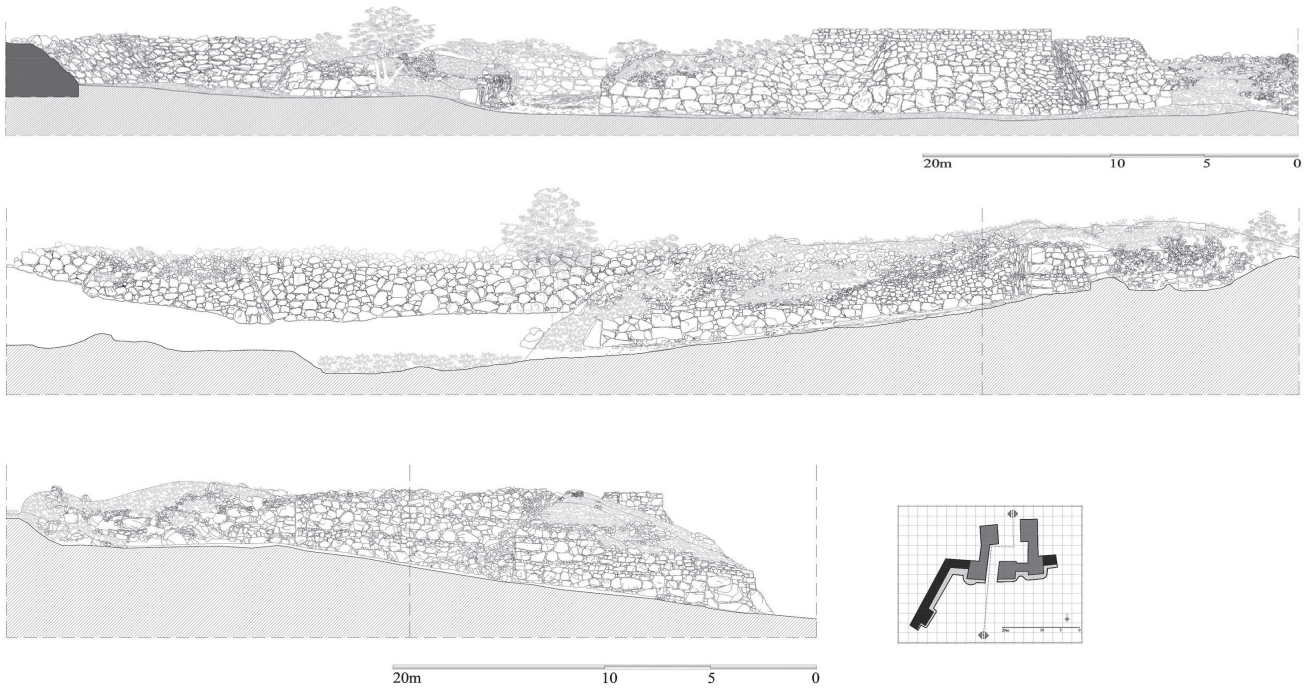


Figure 15. South (Exterior) Elevation of the Cappadocia Gate. The drawings were produced by M. Çingı Salman, Doğan Tekin and Nurçe Düzalan Salman from 3D laser scan data in 2019-2021. (Image: Kerkenes Project)

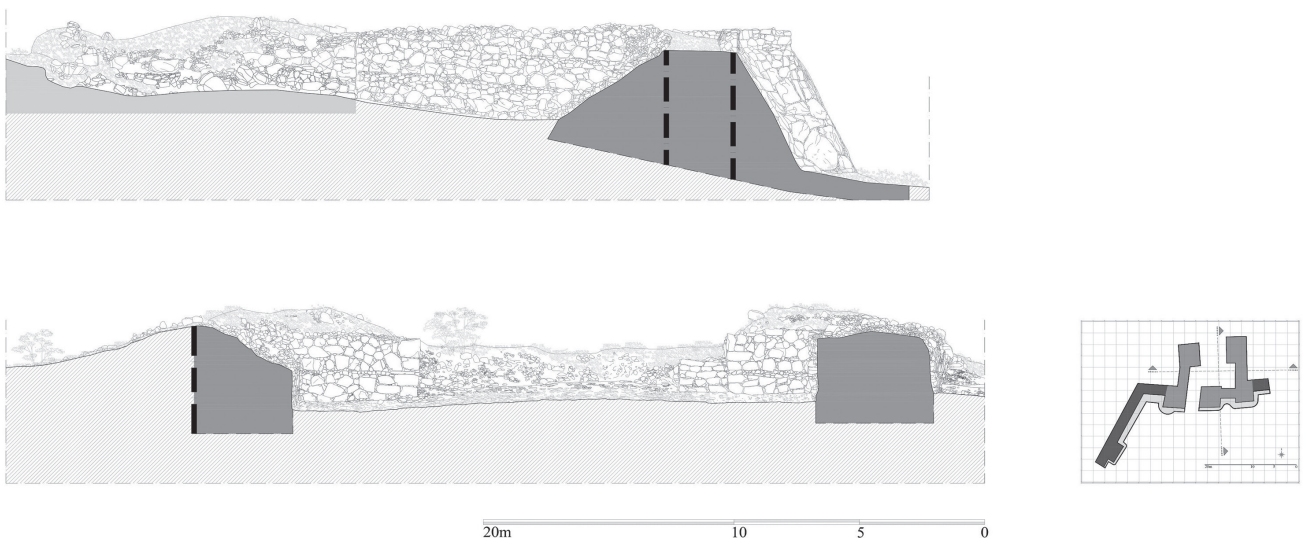
Figure 16. Sections through the Cappadocia Gate: West (top) and East (bottom) Elevations of the Gate Passage. The drawings were produced by M. Çingı Salman, Doğan Tekin and Nurçe Düzalan Salman from 3D laser scan data in 2019-2021. (Image: Kerkenes Project)

Figure 17. Sections through the Cappadocia Gate: East (top) and North (bottom) Elevations of the Gate Chamber. The drawings were produced by M. Çingı Salman, Doğan Tekin and Nurçe Düzalan Salman from 3D laser scan data in 2019-2021. (Image: Kerkenes Project)

sections showing the relationship between the various parts of the structure, surfaces and sub-surfaces that had been revealed by clearance and excavation (**Figures 18-20**).

The documentation in 2019, on the other hand, was carried out with a Leica RTC 360 ground laser scanner. This instrument can measure 2 million points per second and collects data horizontally over 360° and vertically over 300°. Its three internal HD cameras can take 360° photographs at each scan station for coloring the point clouds. Its location precision is 1.9 mm per 10 m. It is controlled with a tablet, which may also be used for preview of the measurements and automated combination of the data collected. The data obtained at the different stations are then connected in Leica Cyclone software, creating a single 3D point cloud.

2D images and 3D models may be produced, using the 3D point clouds obtained with the ground laser scanner. The end product contains not



only visual information but also three-dimensional geometric data. The 360° instrumental scan and survey of the Cappadocia Gate in 2019 was carried out to produce the architectural documentation of the structure (**Figures 14-17**). Therefore, the instrument set-up points were chosen at the most favorable locations around the monument in order to reproduce a detailed digital model. The survey was carried out in high resolution (432 megapixels). During a single day of the survey, 21,782,388,897 points were collected at 89 stations. The combined data produced from different station points after bundle adjustment has a maximum error ratio (tolerance) or precision of 3 mm. Therefore, the level of accuracy (LOA) of this documentation is LOA40 (5 mm-1 mm).

The data collected through the 360° laser scanning was matched and aligned in the field and on the tablet using Leica Cyclone Field software. Cyclone software matches the data and images according to color and coordinate information and makes necessary data adjustments automatically. Then the data was transferred to the computer for levelling and further processing, also on Leica Cyclone software. The laser scans were first relatively combined, then “free levelling” and optimization was carried out. Each station’s data was also manually controlled with the data of another station, whose data overlaps with the first one.

Then the laser scan data was cleaned in detail on Leica Cyclone software. The data for those areas that would be used for plans, sections and elevations was selected from the clearest scans and combined in order to produce scaled orthophoto renders. These orthophotos with 3D coordinated data were combined into series following the coordinates and transferred to AutoCAD software for architectural drawing (**Figures 11-13**).

It has not been possible to carry out a comprehensive and integrated accuracy check between the surveys of 2009 and 2019 because excavation and clearance at the site continued through this period and there were no fixed coordinate points available. Some of the earth-covered areas in the 2009 total station survey have been cleared to expose wall faces, which were documented for the first time during the 2019 ground laser scan survey. Meanwhile, the strengthening work carried out at the monument with the purpose of stabilizing the exposed walls between 2009 and 2019, changed its appearance and the surrounding topography in part. In addition, it was observed that some of the drywall faces surveyed in 2009 were somewhat deformed and changed their location and coordinates.

In order to compare the surveys of 2009 and 2019, the plan and section drawings produced from the 2009 total station point cloud were juxtaposed and compared with the orthophotos produced from the 2019 ground laser scan data. The difference or deviation between the two data sets was identified to be max. 2 cm on wall faces (**Figures 18-20**). Therefore, the level of accuracy (LOA) of the 2009 total station documentation is proven to be LOA20 (5 cm-15 mm), and partially in the range of LOA30 (15 mm-5 mm). These standard evaluations are true for both measured and represented accuracy. Here, these values represent only the “shell” (superstructure and exterior vertical and horizontal enclosures) as the monument does not present any other building elements. LOA30 and LOA40 are both acceptable accuracies for heritage applications (USIBD C220, 2016).

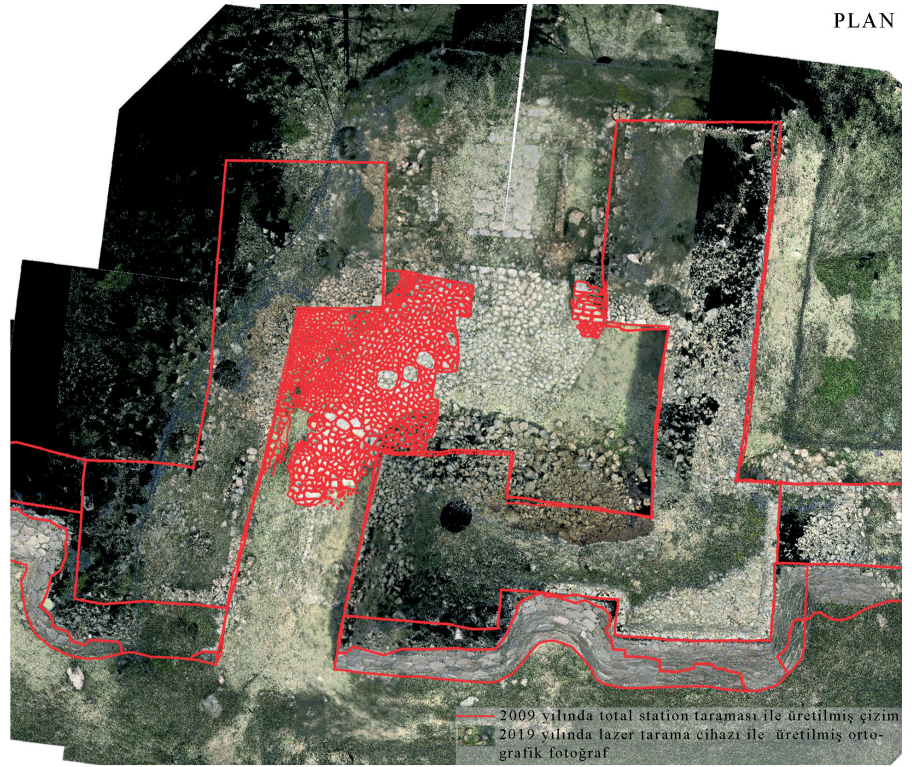


Figure 18. Cappadocia Gate: The comparison of the plan produced from the 2009 total station point cloud (in red) and the combined orthophoto produced from the 2019 ground laser scan data. The image was produced by M. Çingir Salman, Doğan Tekin and Nurçe Düzialan Salman in 2022. (Image: Kerkenes Project)

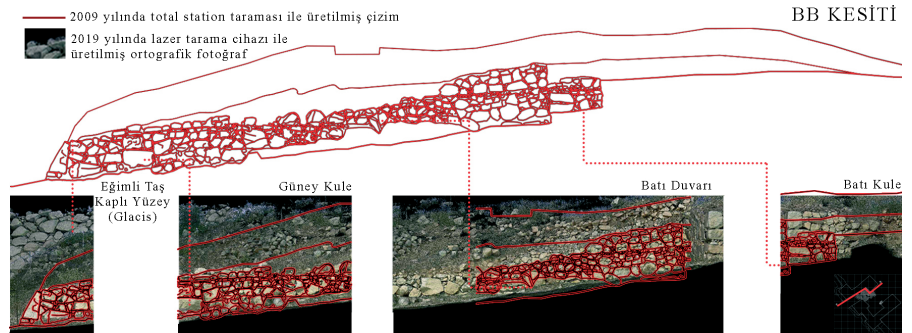


Figure 19. Cappadocia Gate: The comparison of the section through the Gate Passage showing its West Elevation produced from the 2009 total station point cloud (in red) and the combined orthophoto produced from the 2019 ground laser scan data. The image was produced by M. Çingir Salman, Doğan Tekin and Nurçe Düzialan Salman in 2022. (Image: Kerkenes Project)

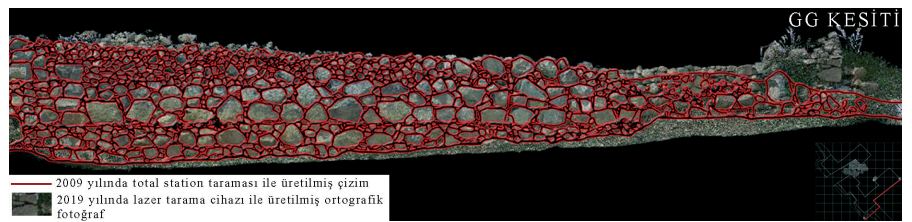


Figure 20. Cappadocia Gate: The comparison of the East Elevation produced from the 2009 total station point cloud (in red) and the combined orthophoto produced from the 2019 ground laser scan data. The image was produced by M. Çingir Salman, Doğan Tekin and Nurçe Düzialan Salman in 2022. (Image: Kerkenes Project)

CONCLUSIONS AND FUTURE RESEARCH

The survey, documentation, monitoring and preservation of the city wall and its gates, especially those of the Cappadocia Gate, have been challenging concerns since the beginning of the current research phase in 1993 (Baturayoğlu Yöney, 2021). One of the characteristics of the Kerkenes Project has been the constant use of contemporary and cutting-edge techniques and technologies. From aerial photographs to various models of total stations and photogrammetric equipment, the methods have evolved into UAV and laser scanner modelling in the recent years.

Beginning with the 1997-2001 surveys, each decade resulted in a new survey and documentation project for the city wall and Cappadocia Gate. Aerial images, total station points, hand drawings, stereographic photogrammetry and single image rectification were used in combination during the first documentation phases. The scale of the resulting data was adequate for 1:200 and 1:100 architectural drawings, which were used in publications accordingly (Baturayoğlu Yöney, 2002; Baturayoğlu Yöney, 2021; Osborne and Summers, 2014). The evolution of technologies made a second series of surveys for documenting the gate possible in 2009. The use of a reflectorless total station enabled reading of point data directly from the reflective surfaces of the granite blocks. The survey in 2009 enabled the rectification and accurate documentation of the wall faces and stone pavements (Baturayoğlu Yöney, 2021). Together with the former photogrammetry, this survey generated an integrated point cloud of the monument, from which the required 1:50 scaled drawings for the implementation of the structural strengthening and presentation project could be produced. The accuracy of this survey and documentation (measurement and representation) has been proven to be in the range of 2 cm (LOA20-30).

Following the suspension of the current phase of work between 2012 and 2014, the condition of the unmonitored monument, including partial collapses around the middle tower and the gate chamber, made a new survey and documentation phase necessary. This work was carried out in 2019-2020 with a 3D ground laser scanner, resulting in considerably more detail and reducing the length of the field-work to a single day. The point cloud model obtained from the c. 22 billion survey points, as opposed to the c. 2,000 collected in 2009 and the orthographic images produced from these, made a much more detailed and precise documentation possible. The accuracy of this survey and documentation (measurement and representation) has been proven to be in the range of 3 mm (LOA40), which is acceptable for heritage applications. The thirty-year comparison of documentation reflects the technical evolution in the field. The Kerkenes team has been able to continually utilize state-of-the-art methods and hopes to continue this tradition in the following years. Such applications of new technologies also provide younger team members with an opportunity to learn and practice in the field, especially through the formalized field school at Kerkenes that has been ongoing since 2016.

This is also vital for the structural analysis, monitoring and preservation of the monument. Annual monitoring has also become much easier with models developed from UAV images, also obtained in a single day in the field, and with comparisons of the 3D photogrammetric models it is possible to observe the stability of the structure and its movement. Such monitoring is fundamental for the upkeep of the unstable dry wall structure in order to avoid annual collapses due to movement. Building Information Models applied to Heritage (H-BIM) have become a common tool for collecting and disseminating data obtained in various categories of research as well as changes/deformations through time and interventions at various scales. Beyond their use for architectural documentation, the 3D models created through laser scans or with other survey methods, could also be used for H-BIM (Biagini et al., 2022). Thus, such models do not only serve architects but also cultural heritage specialists. The type of data integrated and disseminated may even include intangible heritage elements. The Cultural Heritage Abstract Reference Model (CHARM) is one such tool developed in Europe and used in archaeological

applications. However, creating combined digital and conceptual models and datasets, as well as enabling semantic data traceability, is not an easy task (Giovannini, 2021). The future of the Kerkenes Project and the Cappadocia Gate, in terms of the sustainability of the research and the monument, would also depend on the creation and utilization of such models. This kind of tools are also valuable for integrating data produced at the site and elsewhere after the season is over, and enable the collaboration of international researchers from different backgrounds on the team from wherever they are. These models can also incorporate and provide a working space for architectural documentation and the creation of reinstatement or hypothetical reconstruction proposals based on digital and semantic datasets, facilitating the life-cycle management of the monument.

Beyond research, maintenance and conservation, simplified 3D models may also be a useful tool for the promotion, interpretation and understanding of archaeological remains. Augmented Reality (AR) and Virtual Reality (VR) models of the Cappadocia Gate, or other structures at the site, could be used to enhance visitor experiences, for education and information dissemination purposes (4). Audiences of different ages and interests may experience the model of the remains and/or a virtual reconstruction both at the site or online. The Kerkenes Team is already working on such models and hopes to make these available to the public in the near future.

Therefore, survey and documentation with new and emerging technologies is not an end in itself. In addition to the field-school, these activities are aimed at providing the best possible understanding of the monument and the best solutions to its unique preservation problems. Going forward, the project will continue to utilize new and emerging technologies in order to better undertake the preservation of the Cappadocia Gate. This job, in itself, presents another interesting and evolving challenge. The structural integrity of the gate in antiquity relied on the leveling beams that supported the wall faces. They were burnt down to scattered bits of charcoal during the final fire that destroyed the city, and the subsequent years of exposure have only left behind horizontal cavities, which filled with small stones from the rubble core of the walls (Baturayoğlu Yöneş, 2021). Without the support of the beams, or the support of the stone collapse, which filled the chamber and supported the wall faces for centuries, but was completely removed during the clearance in the 1997-2001 and the 2009-2011 seasons, it is only a matter of time before the elements and gravity completely bring down the unstable and outward leaning wall faces. It is only through constant monitoring, occasional rebuilding, and annual maintenance that we can hope to preserve this fragile monument. Therefore, the detailed documentation, monitoring and conservation efforts are all crucial elements necessary for the ongoing preservation of the Cappadocia Gate and the other structures with similar architectural characteristics at Kerkenes.

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TÜRKİYE, YOZGAT, KERKENES'DEKİ KAPADOKYA KAPISININ SAYISAL OLARAK BELGELENMESİ

Türkiye sınırları içinde Yozgat İli, Sorgun İlçesi, Şahmuratlı Köyü'nde bulunan Kerkenes, Orta Anadolu'daki en büyük Demir Çağı yerleşimlerinden biridir. 1926-1928 yıllarında H. H. von der Osten (Chicago Üniversitesi Yakın Doğu Araştırmaları Enstitüsü) başkanlığında gerçekleştirilen kısa süreli arazi çalışmasının ardından çağdaş araştırmalar 1993 yılından itibaren G. D. Summers (ODTÜ ve Ankara İngiliz Arkeoloji Enstitüsü) başkanlığında yürütülmüş olup, 2014 yılından beri yeni kazı başkanı (Scott Branting, Orta Florida Üniversitesi) tarafından sürdürülmektedir. Son 30 yılda Kerkenes Projesi, ileri ve kalıntılara zarar vermeyen arkeolojik araştırma ve belgeleme yöntem ve teknolojilerinin denendiği ve uygulandığı bir araştırma alanı olmuştur; bugüne dek kullanılan yöntemler arasında elektronik teodolit (*total station*), Küresel Konumlandırma Sistemi (GPS), insansız hava aracı (UAV) ve lazer-tarayıcı ile belgelemeye ek olarak, uydu ve hava fotogrametrisi ile jeofiziksel teknolojiler sayılabilir. 7 km uzunluğundaki şehir surları ve üzerindeki yedi kapının belgelenmesi ise geleneksel ve ileri yöntemleri bir arada kullanan ve halen devam eden zorlu bir süreçtir. Surların güneydoğu bölümünde yer alan gösterişli ve karmaşık bir yapı olan Kapadokya Kapısı, teknolojilerin evrimini izleyerek birden çok kez belgelenmiştir. Bu makale, bu eşsiz anıtın betimi ve araştırma tarihçesini takiben, mimari, taşıyıcı sistem ve yapı teknolojileri ve malzeme özellikleri konusundaki bilgilerimizin derinleşmesi ile birlikte belgeleme sürecinin nasıl evrildiğini aktarmakta, bugüne dek kullanılan farklı yöntemleri tartışarak karşılaştırmakta ve yapıda gelecekte gerçekleştirilecek belgeleme, izleme ve koruma çalışmalarına yönelik ipuçları sunmaktadır.

DIGITAL DOCUMENTATION OF THE CAPPADOCIA GATE AT KERKENES IN YOZGAT, TURKEY

Kerkenes, located at the Village of Şahmuratlı near Sorgun/Yozgat in Turkey, is one of the largest Iron Age settlements in Central Anatolia. Following a brief campaign in 1926-1928 by H. H. von der Osten of the Oriental Institute at the University of Chicago, contemporary research at the site began in 1993 under G. D. Summers (METU and British Institute of Archeology at Ankara) and continues under the current director (Scott Branting, University of Central Florida) since 2014. In the last 30 years, the project has become an experimental ground for state-of-the-art and non-destructive methods and technologies of archaeological research and documentation with methods ranging from total station, GPS, UAV and laser-scanner surveys to satellite and aerial photogrammetry and geophysical technologies. The survey of the 7 km city wall and its seven gates has been a challenging work-in-progress, incorporating both traditional and advanced methods. The Cappadocia Gate, a conspicuous

and complex structure on the southeastern section of the walls, has been documented several times as survey technologies evolved. This article provides a description and the research history of this unique monument. It summarizes the evolution of the documentation process with our understanding of its architectural, structural and technological/material characteristics, and discusses and compares the various methodologies that have been used, providing insights for future work on its survey, monitoring and preservation.

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