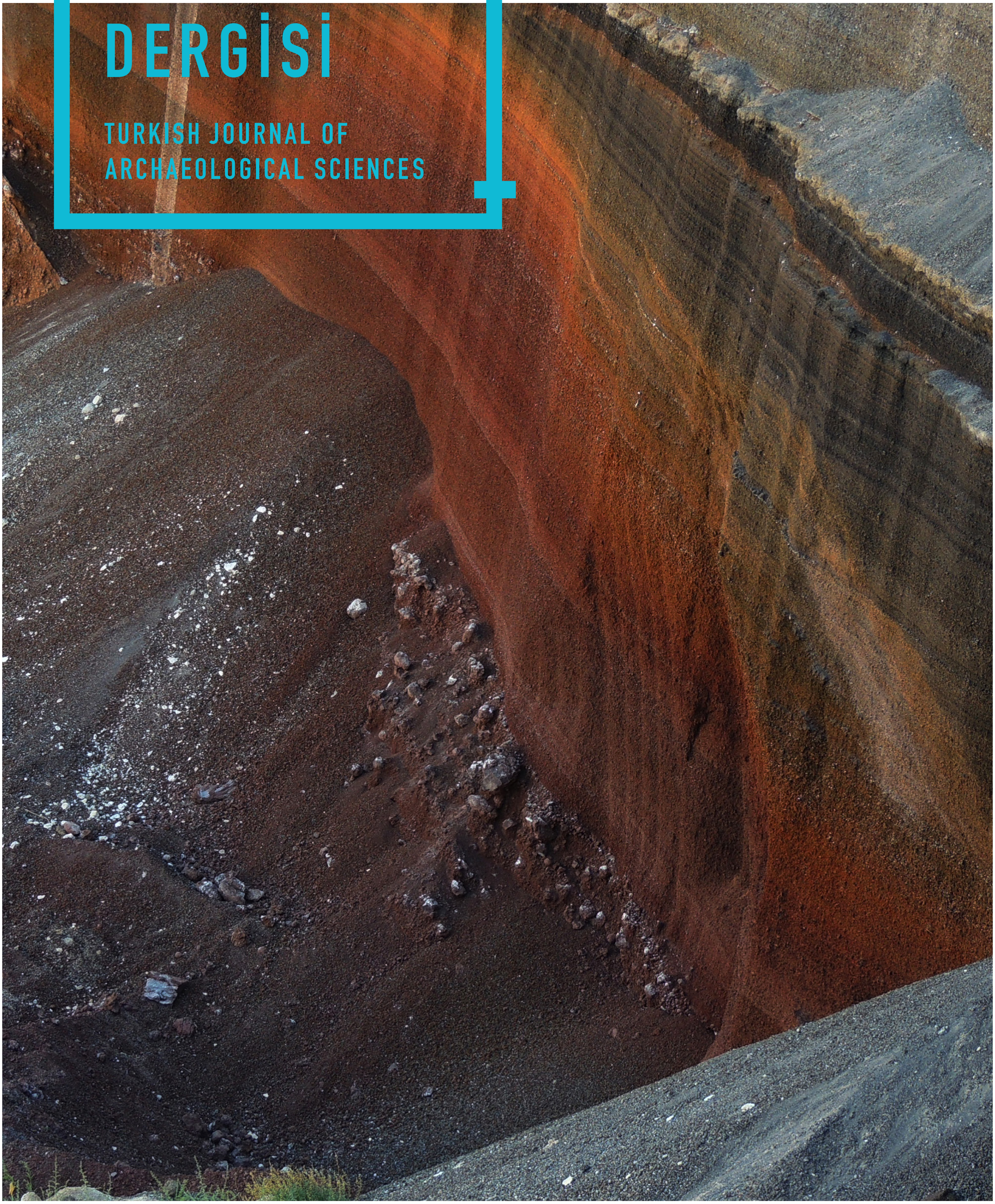
ARKEOLOJİ BİLİMLERİ DERGİSİ

TURKISH JOURNAL OF ARCHAEOLOGICAL SCIENCES

2021

ISSN 2822-2164



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TURKISH JOURNAL OF ARCHAEOLOGICAL SCIENCES

ISSN 2822-2164

AYRIBASIM / OFFPRINT

Yapım / Production

Zero Prodüksiyon Kitap-Yayın-Dağıtım San. Ltd. Şti.

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Kapak Fotoğrafı / Cover Photo

Kapadokya volkan külü birikim kesiti /Accumulation of volcanic ash, Cappadocia, G. Duru.

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Editörlerden

Dünyaya açılmamızı sağlayacak Arkeoloji Bilimleri Dergisi'nin ilk sayısı ile hepinize merhaba diyoruz.

Arkeoloji bir süredir geçmişin yorumlanmasında teknoloji ve doğa bilimleri ile yoğun iş birliği içinde yeni bir anlayışa evrilmekte. Üniversiteler, ilgili kurum ve enstitülerde her yeni gün açılmakta olan "Arkeoloji Bilimleri" bölümleri ve programları, geleneksel anlayışı yavaş yavaş terk ederek değişen yeni bilim iklimine adapte olmaya çalışmaktalar. Arkeoloji disiplininin geçmişi, geçmişte yaşayan insanların yaşam biçimlerini bütüncül bir şekilde anlamaya, hızla gelişen ve yaygınlaşan teknolojilerle her geçen on yılda daha fazla yaklaşıyor. Arkeolojik araştırmalar, sorgulama ve değerlendirme biçimleri, bu yeni bilim üretme biçimine dönüşüyor. Derginin editörleri olarak bizler, bu süreçte, bu dönüşüme katkı sağlayacak bir mecra oluşturmanın önemli olduğu kanısındayız.

Amacımız arkeoloji içindeki arkeobotanik, arkeozooloji, alet ve bina teknolojileri, tarihlendirme, mikromorfoloji, biyoarkeoloji, jeokimyasal ve spektroskopik analizler, coğrafi bilgi sistemleri, iklim ve çevre modellemeleri gibi farklı uzmanlık alanlarının çeşitlenerek yaygınlaşmasına katkı sağlamak ve arkeolojide bilimsel yöntem ve analizlerin geliştirilmesi ve uygulanması üzerine çalışan bilim insanlarını bir araya getirmek. Elbette yeni ve özgün metodolojik ve kuramsal yaklaşımlar üzerine yapılan araştırmalara da yer vereceğiz. Destek, katkı ve ilginizi derginin seyri ve gelişimi adına çok önemli görüyoruz.

Güneş Duru & Mihriban Özbaşaran

ARKEOLOJİ BİLİMLERİ DERGİSİ
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Note from the editors

We would like to take this opportunity to introduce ourselves to the world, and say 'hello' to the archaeological media with the very first issue of our new archaeological journal: The Turkish Journal of Archaeological Sciences.

For the past couple of decades archaeology has been evolving in close cooperation with new technologies and the advances in the natural sciences towards new understandings and interpretations of the past. More and more newly established departments and programs in universities and other relevant institutions focus on "Archaeological Sciences" as they try to adapt to a changing climate, and gradually abandon older traditions. Rapidly developing technological, methodological and analytical advances move us closer to understanding the way of life in past communities in a holistic way. Archaeological research programs, and the many innovative new ways of testing, inquiring and evaluating these all converge into this new way of producing 'science'. As the founding editors of the TJAS, we think it is important to have a medium that will contribute to this transformation.

Our goal is to contribute to the diversification and dissemination of different areas of expertise such as archaeobotany, archaeozoology, tool and building technologies, dating methods, micromorphology, bioarchaeology, geochemical and spectroscopic analyses, geographical information systems, climate and environmental modeling. We aim to bring scholars working on the development and application of scientific methods and analyses together in these volumes. We also seek to include in these pages recent advances in methodological and theoretical approaches. Your support, contributions and engagement with the archaeological science presented here are crucial to the progress and development of the journal.

Güneş Duru & Mihriban Özbaşaran

Documenting Near Eastern Neolithic Architecture: Aspects of 2D and 3D Recording of Built Environments

Moritz Kinzel[a]

Abstract

How do we document architectural contexts? For which purpose do we document them? Why are we documenting in 2D or 3D? By doing so, do we actually document all the aspects of an architectural context that we want to capture? How do we record structural changes over time (building phases)? These and other aspects require consideration when documenting architectural contexts in the framework of archaeological fieldwork. The choice of approaches defines the methods and techniques we apply to achieve the results and final product that we seek or wish to present. Based on a case study from Göbekli Tepe, various aspects of 3D Structure from Motion (SfM) -recording and modelling will be discussed in this contribution.

Keywords: Near Eastern Neolithic architecture, 3D-recording, photogrammetry, Anatolia, Göbekli Tepe, digital data management

Özet

Mimari bağlamları nasıl belgeleriz? Hangi amaçlarla belgeleriz? Neden 2B ya da 3B belgeleme yapıyoruz? Bu şekilde mimariyi bağlamsal olarak elde etmek istediğimiz tüm yönleriyle birlikte belgelemiş olur muyuz? Zamanla meydana gelen yapısal değişimleri (yapı evrelerini) nasıl kaydederiz? Mimari kalıntıları ve onların arkeolojik bağlamını belgelerken konuyu çeşitli biçimlerde ele alan bu gibi soruları dikkate almalıyız. Soruların cevapları ise aslında ulaştığımız sonuçlar ve ihtiyaç duyduğumuz ya da ortaya koymak istediğimiz nihai durum için başvurduğumuz yöntem ve tekniklerle sınırlıdır. Bu bağlamda yazıda üç boyutlu (3B) Hareket ile Nesne Oluşturma/Structure from Motion (SfM) tekniğinin bu konudaki katkıları Göbekli Tepe örneği üzerinden çeşitli yönleriyle tartışmaya açılmıştır.

Anahtar Kelimeler: Yakındoğu Neolitik mimarisi, üç boyutlu belgeleme, fotogrametri, Anadolu, Göbekli Tepe, dijital veri yönetimi

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Makale gönderim tarihi: 25.12.2020; Makale kabul tarihi: 11.01.2021

Introduction

How to document building remains? How to make sense of the remains? Generations of architects and archaeologists have learned how to document buildings with traditional techniques and methods, for example, using 2D-representations of the reality with pencil on paper or with cardboard or plastic sheets and the help of local grid systems and reference points. This documentation process sees the careful selection of sections and positioning of elevation measurements; additional construction details were chosen to represent the buildings as such and to allow their 2D-reproduction in books, on information panels or as architectural models in museums. Once the scale was set, all other parameters—accuracy, precision, level of detailing etc. fell in place. However, drawings, as accurate and precise as they may be, are an interpretation of the reality. Dimensions are given in measurements and the pencil or inked lines represent area borders and traces of tooling or use. Yet, the density of information found in drawings combined with level measurements and annotations is so high that all relevant data can be recorded. In most cases, it is even possible to add data that is not even visible as projections of features above or below the documentation plane.

On the other hand, latest state of the art 3D-recording offers great data sets, which can be revisited whenever necessary and processed, even if the context no longer exists, which is the rule rather than the exception in the case of archaeological fieldwork. Therefore, it is all the more important that the 3D-recording is carried out properly and that the contexts are prepared accordingly. The necessity of this procedure is illustrated below by means of a case study from Göbekli Tepe. For a better understanding of the 3D-recording methods in use today the history and development of the method and the technology will be summarised and the weaknesses and strengths of the various approaches discussed.

Documenting Neolithic Architecture at Göbekli Tepe, Area L09-80 / Space 16/42

Excavations in area L09-80 at Göbekli Tepe[1] undertaken in 2001 (Figure 1) exposed 'rectangular' architecture dating to the Early and Middle Pre-Pottery Neolithic B (mid to late-9th millennium cal. BCE[2]) which was documented using traditional hand drawings in 2001[3] (ground plan; Figure 6) and in the following year[4] (elevations; Figure 7).

1 The Neolithic site of Göbekli Tepe (SE-Turkey) is located northeast of the modern city of Şanlıurfa in the Germuş mountains. Until comparatively recently, excavation (which began in 1995) have focused on the special (monumental) buildings with their T-shaped pillars (Schmidt 2006, 2012; Clare 2020). The architecture around the special buildings (Kurapkat 2014, 2015; Piesker 2014) has not been studied intensively so far (Kinzel et al. 2020; Kinzel and Clare 2020; Breuers and Kinzel in press.).

2 Kinzel and Clare 2020: 32-33.

3 by C. Winterstein.

4 by D. Kurapkat.

The PPNB residential architecture revealed at Göbekli Tepe has seen comparatively little investigation, as it was always overshadowed by the monumental architecture of the "special buildings" (Kurapkat 2015; Kinzel and Clare 2020).

In the course of the construction of a permanent protective shelter over the main excavation area (southeast hollow) of the site in 2017 and 2018, the chance arose to further excavate a PPNB residential unit (Space 16) in area L09-80. These investigations saw the removal of all remaining sediment deposits from this space down to floor level—Locus L09-80-122 (Tvetmarken 2017; Kinzel et al. 2020; Breuers and Kinzel in press; Schönicke in prep.). In addition to traditional recording techniques and hand sketches, during the 2017 field season the area was regularly photographed to produce SfM-based 3D-models. Height levels were taken with a dumpy level and additional reference points were measured with a total station (Leica TS06). It turned out that the architectural context of space 16 was much more complex than expected. The existing documentation barely covered the findings and certainly failed to capture them adequately. For this reason, and in order to get a better understanding of the contexts, we returned to space 16 in 2018. Especially the western walls were cleaned extensively with an industrial vacuum cleaner to clarify stratigraphic relations of the various walls in this area (Figure 2a, 2b and Figure 3). This time, high-resolution images were taken (with a Nikon D700 and D850) to produce a new 3D-model of the area based on the same reference points from 2017. All models were initially processed with Agisoft Photoscan[5] and re-visited for this contribution in Agisoft Metashape[6]. Orthographic scaled screenshots were produced with Metashape or Meshlab (Cignoni et al. 2008) for this contribution. The images were further processed with AutoDesk AutoCAD, Adobe Illustrator and Adobe Photoshop or Affinity photo and Affinity designer. Digital drawing tablets (Wacom intuos) supported the production of vector-based 2D-plans of the presented contexts.

Structure from Motion-Old Wine in New Bottles

Photogrammetry or stereo-photography is not a new method. It was introduced over one hundred years ago and helped to document difficult to reach parts of buildings and inaccessible areas and to reduce the time in the field (Finsterwalder and Hofmann 1968; Schwidefsky and Ackermann 1976; Stylianidis 2019). Photos have to be understood here as scaled representations of the world (Solf 1971). The differences between two photographic representations of the same points can be used to define the position and location of those points mathematically. However,

[5] Some of the processing was performed at ABAKUS2.0 at the eScience center at the SDU Odense, Denmark in cooperation with Emiliano Molinaro supported by DeIC and HUMlab at the University of Copenhagen.

[6] Agisoft Metashape is the updated version of Agisoft Photoscan.

complex contexts also showed the limits of this technology, as only points in the same plane were in scale and could be used to produce for example a scaled 2D-plan. Photogrammetry had a first revival with the establishment of personal computers and the possibility of using stereo-viewer and CAD-software to produce plans over photos (cf. Almagro 1988). However, most plans based on computer-supported photogrammetry of the late 1990s and early 2000s were lacking the quality of a hand drawing. Draftspersons now could only rely for the drawing on the photogrammetric image and not on the actual building (Petzet and Mader 1993, 162-165). This means optical and visual illusions, distortions or blurs may led to misinterpretations or incomplete records (Mader 2001).

The introduction of 3D-laserscanning presented for the first time a method that promised to provide 'objective' record data (Ioannides et al. 2014; Ioannides et al. 2016; Grussenmeyer et al. 2016; Historic England 2018). The laser scan promised a non-manipulated representation of reality. However, the choice of scanner location, laser width, resolution and density etc. all had a significant influence on the later result of the point cloud produced. The quality of the images taken at the same time could impact the colour of the point cloud or present difficulties when producing a convincing texture on the meshed surface.

Therefore, the laser scan technology was already showing certain limitations. Buildings need to be prepared for such documentation and any form of vegetation should be removed from the structure; generally speaking, any form of 'dirt' (e.g., soil, sediment, collapse material, etc.) resting on wall tops or floors should be cleared and removed to avoid incomplete recordings. However, this should be decided very carefully as "dirt" may actually represent the remains of wall mortar, roofing or floors, which should be documented as well. A clear decision can only be made on a case to case basis (cf. Weferling et al. 2001; Riedel et al. 2006; Heine et al. 2011; Martens and Messemer 2016; as well as Franz and Vinken 2017; Hoppe and Breitling 2018; CIPA 2019). In the case of the context discussed above (Space 16 at Göbekli Tepe), most of the remaining sediment material stemmed from fill deposits, Aeolian sediment and/or eroded Neolithic mortar material.

In contrast to a few years back, 3D-recording techniques based on Structure from Motion (SfM) methodology are used extensively. Structure-from-Motion or SfM is a term used in the field of computer vision and refers to an automatic process that recognises the spatial structure of objects based on corresponding features in images. In the process, two-dimensional images are 'transformed' into three-dimensional point clouds and finally meshed models. Due to the constant pressure of dwindling budgets and time, SfM technology offers a lot of opportunities for field archaeologists. The easy availability in terms of costs and accessibility of SfM software, e.g., as open source software, has made it possible for everybody to perform 3D-recordings from low-end to high-end quality and resolution. In recent years, it has become quite popular in archaeology and heritage management to use those software tools as an effective, low-cost method for generating detailed three-dimensional models of archaeological sites, features or artefacts. Although SfM-3D-recording leads to a reduction of time spent in the field doing recording work, it also requires more 'office' time to process the data[7]. In reality, enough time should also be allocated to the necessary preparations making a context ready for 3D-recording, i.e., ensuring that the sources of the required data (e.g., walls, contexts etc.) are actually visible to the camera.

In the case of the space 16 in area L09-80 at Göbekli Tepe, a total of eight hours on two days during the 2018 season were allocated to cleaning the context to record the data for a 3D-model with all the walls built in front of each other actual visible on first sight.

The remote control of the data is a weak point in the documentation flow as missing data or inadequate recorded images cannot be added or produced easily once you have left the site. Additionally, a 3D-model produced with SfM-technology is always only a model; due to the randomly selected starting point of the mathematic operation and the applied algorisms, each reconstruction process has a random result. In other words, point comparison of multi-images is a random process and results are in the best case almost similar to each other but not necessarily so. Failure is part of this reconstruction process. Compared to laser scanning, which is the recorded reflection of the emitted laser beam with minimal option of failure, SfM-technology involves a high number of failure rates, e.g., due to extreme light contrasts in the images, blur or low resolution of the digital images, etc. Incomplete datasets or models are a worst-case scenario; the missing data is in most cases lost as the context and findings are removed or modified. Therefore, some precaution should be taken when taking the images.

Technical Aspects – Photos and Mathematics

When SfM-technologies became more widely available, the excitement to be able to produce 3D-models was great and culminated in the production of thousands of digital models based on images, most of which can be regarded as attempts or failed attempts to reproduce contexts. In most cases, the photos are lacking the necessary overlap or differences in the contrast of the images are so high that they result in strange shapes and noise. In addition, most models were made in low resolution to cope with the limitations posed by the available computer hardware, e.g., inadequate graphic cards. Other models were lacking proper reference systems or a scale.

[7] Traditionally it was calculated that two third of worktime would be allocated to do hand drawings in the field and one third to produce a final plan at the office. With digital recording technologies, this time scheduler turned: nowadays recording may need one third to fifty per cent for executing the record in the field and fifty per cent to two third of the estimated time for the processing in the data at the office–off field.

It goes without saying that incomplete models are a worst case scenario for (archaeological) documentation.

Remarkably, in the early years of this technology only very few manuals were available; meanwhile, this has changed considerably, though the methods and guidelines are rarely taught (or followed) systematically. This is perhaps even more surprising as most of these manuals, which come from the software developers, e.g., Agisoft Metashape (Agisoft 2021), Meshroom (AliceVision 2020), Visual SfM (Wu 2013), ARC 3D (Tingdahl and Van Gool 2011), or from heritage institutions (e.g., Historic England 2017, 2018; Historic Environment Scotland 2018, Waldhäusl et al. 2013, also Busen et al. 2017), are freely available online.

The quality of the images is directly correlated to the precision and accuracy of the resulting model. Blurriness of images or (digital) noise due to too high ISO can be challenging, often leading to unsatisfying results. Although there can never be too many images, high numbers of photos can challenge the available hardware (memory) and jeopardise model processing. Too few images and images lacking sufficient overlap will eventually lead to incomplete models. High-resolution images may turn out to be too big to process due to computing power limitations (see e.g., Waldhäusl et al. 2013). The time needed for processing the data in high quality can easily stretch over several days or weeks depending on the existing computing power and the size of the available memory.

In practice, 3D reconstruction from images requires much more than just the actual SfM-progression. Current software solutions offer tools for pre-processing of images; such as lens correction and image masking, fully automated image matching, transition from sparse SfM-point clouds to dense Multi-View Stereo (MVS) point clouds and closed surface and colour reconstruction (meshing and texturing) of models. The technology and method needs a bit of practice; especially regarding proper image acquisition with correct sharpness and overlapping of images. When the image acquisition is done properly, the results of a SfM-workflow are comparable in detail, precision, and accuracy to those of hardware-based scanning with special devices (using e.g., terrestrial laser scanners or structured light scanners). SfM-based recording can even catch finer details than laser-scanning due to the higher resolution of the photo-sensible sensors of a camera (Kersten et al. 2014; Kersten et al. 2015).

3D-recording, for what Purpose?

Certainly, there is nothing wrong with storing data that would allow for the processing of higher quality models at later dates. In the case of a crisis (e.g., as in the case of the current pandemic) when it is not possible to conduct on site investigations–high-resolution models allow us to visit the site virtually; Virtual Reality (VR)-technologies mean than we can check details, measures and contexts, and the more detailed the model is, the better it fulfils this function.

Although, VR-systems certainly have their issues when it comes to hi-res-models with dense information, these will likely be remedied by the arrival of more powerful hardware. This strategy may also be of advantage when a site is too fragile to access or if it is located in a remote location; so far this option is still limited and not commonly used.

Therefore, a proper preparation of the contexts in question for documenting on site is needed to ensure that all relevant contexts are visible and not hidden. Finally, the question is always, which features should be recorded and for what purpose?

Field Recording - Preparing a Context

The cleaning of archaeological contexts prior to recording has always been a necessity, even in the case of traditional hand drawings. Digital recording is no exception and also requires a thorough cleaning of the archaeological contexts to ensure that everything that should be documented is actually visible. However, there are different intensities of cleaning; for example, while in traditional recording—e.g., drawings—the human eye can complete joints, shapes and borderlines of stones and it is possible to indicate findings, projections or hidden features with dotted or dashed lines, this is not immediately possible for digital recording. With digital recording, you only can document what the lens of the camera catches or the laser can reach and reflect. This must be considered when preparing a context for documentation. Indeed, one might even decide to make several 3D-recordings to document the different stages of cleaning. In some cases, it may be helpful to use an industrial vacuum cleaner to prepare the context; this has the advantage that the removed sediment is automatically collected and can be processed as well. Still, the features of the context should be carefully assessed to decide what has to be removed and what should stay and be present in the model.

Taking Images for SfM-based Models

In order to produce 3D-models based on photographs, some basic guidelines should be followed: Photos should have an overlap of at least 50-80%; photos should be taken in a convergent fashion; and photos should be taken at various angles, not only with one orientation as this helps to reduce possible distortions in the resulting model. Although not always possible, consideration should also be given to the time of day that the pictures are taken in order to provide the best lighting conditions. As a general guideline, morning and afternoon hours provide the best light for photography work; the light is low and images will not be too bright—thus not obscuring features—and also showing areas entirely in shadow. In general, large variations in brightness should be avoided for the generation of 3D-models. The number of moving objects in the images, e.g., people and animals, should also be limited; on the other hand, current software applications can recognize moving features and will eliminate them from the model.

For the area of L09-80, space 16 at Göbekli Tepe the photographs were first taken in two rounds moving around the entire space, which did not take more than 20 minutes per round. In a second step, the walls were recorded with over-lapping images taken parallel to the wall faces with slightly shifting angles, but with almost similar distance. Finally, some close-up detail shots and random overview shots were taken to fill gaps and to allow details to be visible. The photos were processed with the Agisoft Photoscan workflow into a low-resolution model in the afternoon of the same day to check the general quality of the dataset. This process may take one to two hours, depending on the total number of photos taken. Additional images were taken the following day to minimize the risk of missing data.

L09-80, Space 16: Some Building Archaeological Results

The 3D-recording process improved our understanding of space 16. What was clear from the start was that the building comprises not only space16, but also spaces 18, 96, and most probably the (upper floor?) space 42. The earliest structure in the area is represented by stone walls (L09-80-110, L09-79-50.1, and L09-79-52) which seem to make up the eastern part of a relatively large building (about 32 m^2) with a round to ovoid ground plan. Only the eastern curved wall of this earlier building was incorporated into the later structure when a major rebuilding in the area took place. As a result, a new and slightly smaller rectangular appearing main space 16 and a northern annex 18 were created inside the former ovoid structure. This main room was defined by remnants of the earlier curved wall segment (L09-80-110) to the east and newly built walls to the south, west and north (L09-79-9, L09-80-111/144 and L09-80-71). These new walls were bonded at (almost) right angles resulting in the half-rectangular and half-rounded ground plan of space 16. This room had a good quality and smooth plaster floor (L09-80-108 and L09-80-122) which included crushed, split limestone.

Following some potential earthquake destruction, a further modification of space 16 took place that incorporated an additional new set of walls (L09-80-63, L09-80-44, L09-80-43 and L09-80-65 to the north, east, south and west respectively). The relationship of these walls could only be clarified in the process of preparing the context for the 3D recording in 2018 (Figure 4). How the different walls connect with each other, i.e., the different building events, was only observable after a thorough cleaning of the walls and joints. The walls in question were set against and partly on top of the earlier stone walls. An exception was the southern wall (L09-80-43) which was constructed at some distance from the earlier exterior wall (L09-79-9), thus creating the small and narrow (ca. 1.5 m^2) space 96 and running in the west over the earlier wall L09-80-111/144.

In this building phase the ground floor area of space 16 was limited to ca. 14.6 m^2 (Figure 5), and four T-shaped pillars defined its interior, two of which (PVII and PVIII) were free-standing and situated in the western part of the room. The remnants of the other two (PIX and PX) were incorporated into the eastern wall (L09-80-44) of space 16. However, it is unclear where these T-shaped pillars originated; the preserved plaster floor shows only the footprints of a set of benches which were obviously removed in the last use phase before destruction or abandonment.

During the documentation process, the walls defining the western limits of space 16/42 were of particularly interest. The preserved wall remains show a series of wall structures placed in front of each other on the ground floor[8] and on the upper floor level. The initial ground floor wall (L09-80-144) is almost double the width of the wall segment belonging to the upper floor (L09-80-146[9]); wall L09-80-144 also connects in a right angle to the northern wall L09-80-71. The later walls L09-80-65 and L09-80-63—built in front of both—show the same feature. The later wall L09-80-15 of space 42 rests on a layer of broken wall stones, fist-sized stones and mixed sediment—possibly representing an earlier floor between space 16 and space 42 or a destruction layer. It is constructed in front of wall L09-80-146, partially resting on the earlier ground floor wall L09-80-144. Obviously, wall L09-80-65 takes over the function as load bearing structural element from the earlier wall to serve as a support for the beams and timbers of the floors/ceiling structure of space 42/16. The fact that this similar arrangement of ground floor- and upper floor walls was rebuilt after a destructive event points towards the re-building of a two-storey house unit.

Space 16 was probably covered by a structural ceiling, thus allowing for the construction of a second storey, namely space 42. This part of the building represents an upper floor which covered an area of at least 22.5 m^2. It was defined by a set of walls to the west, north and east (L09-80-15, L09-80-16 and L09-80-85/L09-80-90 respectively). The southern limit of the space remains unclear due to the bad state of preservation of this part of the building, though it seems likely that it could have been demarcated by the upper part of either the southern wall (L09-80-43) of space 16 or the southern wall (L09-79-16) of space 96. It is also likely that a roof covered this space, too. Interestingly, the superimposed spaces 16 and 42 could have been connected via a portal stone (Obj. GT17-WS-0080) that was found in the room-fill in the south-western corner of space 16. Upper floor space 42 connects to the north with space 18 (with approx. 2.1 m^2) through a wall opening (L09-80-16/L09-80-83).

8 Some would perhaps call it a basement; however, based on the terminology developed for the southern Levantine steep slope architecture of Basta (Gebel et al. 2006) and Ba'ja (Kinzel 2013), the term "ground floor" is preferred.

9 There is still also the possibility that wall L09-80-146 actually belongs to a neighbouring structure or was shared by two building units.

Another feature of the architecture became much clearer during the recording process and in the later 3D-model were traces of destruction. The bulking, tilting, and general deformation of the upper floor walls clearly indicates that an earthquake led to the destruction of the building and the partial filling of space 16[10].

Conclusion: 2D, 3D and What Next?

The use of digital recording methods is supposed to speed up the process of recording in the field. Additionally, it can provide data for more detailed and easier accessible results. Further, the 3D-models provide stunning visuals which can be used to show diachronic changes in architectural structures.

However, the efforts to produce satisfying 3D-recordings and to build archaeological analyses can easily equal or even exceed the time spent on traditional hand drawings. In fact, the time spent on cleaning and preparing for a digital recording is comparable to the time spent on site for traditional hand drawings and related studies of the building and the traces of its use-life (*Bauforschung*).

In contrast to the two-dimensional hand drawings, digital SfM-recordings can also capture the third dimension; these can provide the basis for a four-dimensional model.

The processing operation of SfM or modelling software is setting parameters that are comparable with decisions made in the drawing process. Which resolution (scale) is best suited to the anticipated purpose? Will the model be the basis for a fine detailed 3D-print; will it serve for a basic topographic model of the site and its built environment; will it be a high-resolution recording to produce later photo plans of archaeological features; and what are the limits presented by the available hardware?

The random calculation process of the software creates some uncertainty in relation to the “accuracy and precision” of a model; a digital model is merely a 3D-reconstruction of a context and not the reality (in contrast to a laser scan!). Each calculation process will result in a slightly different but close to similar result. So, what should be saved and preserved: the final model or the raw data?

What really matters is the raw-data and reference points, scales, and coordinates of models as these allow us to reprocess the data at a later date; lost and/or incomplete raw data cannot be reproduced, especially in respect to archaeological contexts which are in most cases already gone and not reproducible. It may also be good to think of a Plan B for a data backup. Experience

10 For a more detailed debate of the possible scenarios, see Schönicke in prep.

tells us that digital data storage and maintenance can be a challenge, e.g., due to the establishment of new standards, new file or storage formats or incompatible software updates.

In the case of Göbekli Tepe, the combination of traditional recording techniques with state of the art digital recording technologies has been very successful so far. On the one hand, this approach has reduced the actual time in the field, and on the other it has provided an additional record of contexts which may be removed in a later step of archaeological excavation work. This is true also for the documentation of the Neolithic built environment as demonstrated for area L09-80.

SfM/photogrammetry should be seen as an additional tool and not as a full replacement for traditional recording techniques, especially when it comes to the documentation of architecture. However, possessing high-resolution models of archaeological contexts may also help in future to study those contexts and features further, when access to sites is not possible or access is limited (e.g., due to lack of funds, pandemic events or armed conflicts).

Digital technologies also make it possible to consider the factor "time" in 3D models. In order to optimize building processes the building industry has developed so-called Building Information Modelling (BIM) technologies. BIM is used to plan, manage and monitor building sites during the construction process. Such approaches should be explored much more for archaeological contexts, especially as it may help us to simulate and better understand the impact of time on the built environment in the past.

As argued earlier (Kinzel 2008), models and recordings of architecture should reflect and represent time. Therefore, it is essential to understand the complexity of simultaneous site formation processes with different speed and pace contributing to the changes and continuity of Near Eastern Neolithic architecture (Kinzel et al. 2020). The 3D-recordings of space 16 in area L09-80 have not only contributed to a better understanding of the order of (buildings) events but will also enable us to present in future the results of the building archaeological studies in a much more condensed way.

The digital record does not replace the need to study and to understand the recorded structures (Großmann 2010, 75), and a digital 3D-model does not replace architectural documentation. In a nutshell, the digital record is a method and tool that provides the basis for a three-dimensional documentation of architectural and archaeological contexts over time.

Acknowledgements

For the support in the field, I would like to thank my colleague Lee Clare—German Archaeological Institute Istanbul; the Şanlıurfa Museum; and Necmi Karul—Istanbul University. I am grateful for the support of Lars Kjaer-HUMlab-Royal Library of Denmark, and Emiliano Molinari, eScience SDU/Odense in helping to tame ABAKUS2.0. Thank you to the Danish Institute in Damascus for funding a new camera and SfM software licenses to record Near Eastern Neolithic Architecture (NENA). I would like to thank numerous colleagues for ongoing discussions regarding best practice in recording: Cecilie Lelek Tvetmarken, Devrim Sönmez, Marek Z. Baranski, Antje Kinzel, Yasser Dellal, Julia Schönicke, and Thomas Kersten (HCU Hamburg). For the building documentation and recording works at Göbekli Tepe in 2001, 2002 and 2003, I am indebted to Dietmar Kurapkat and Claudia Winterstein. Finally, I would like to thank the reviewers for their constructive critic and very appreciated comments to make this a better contribution.

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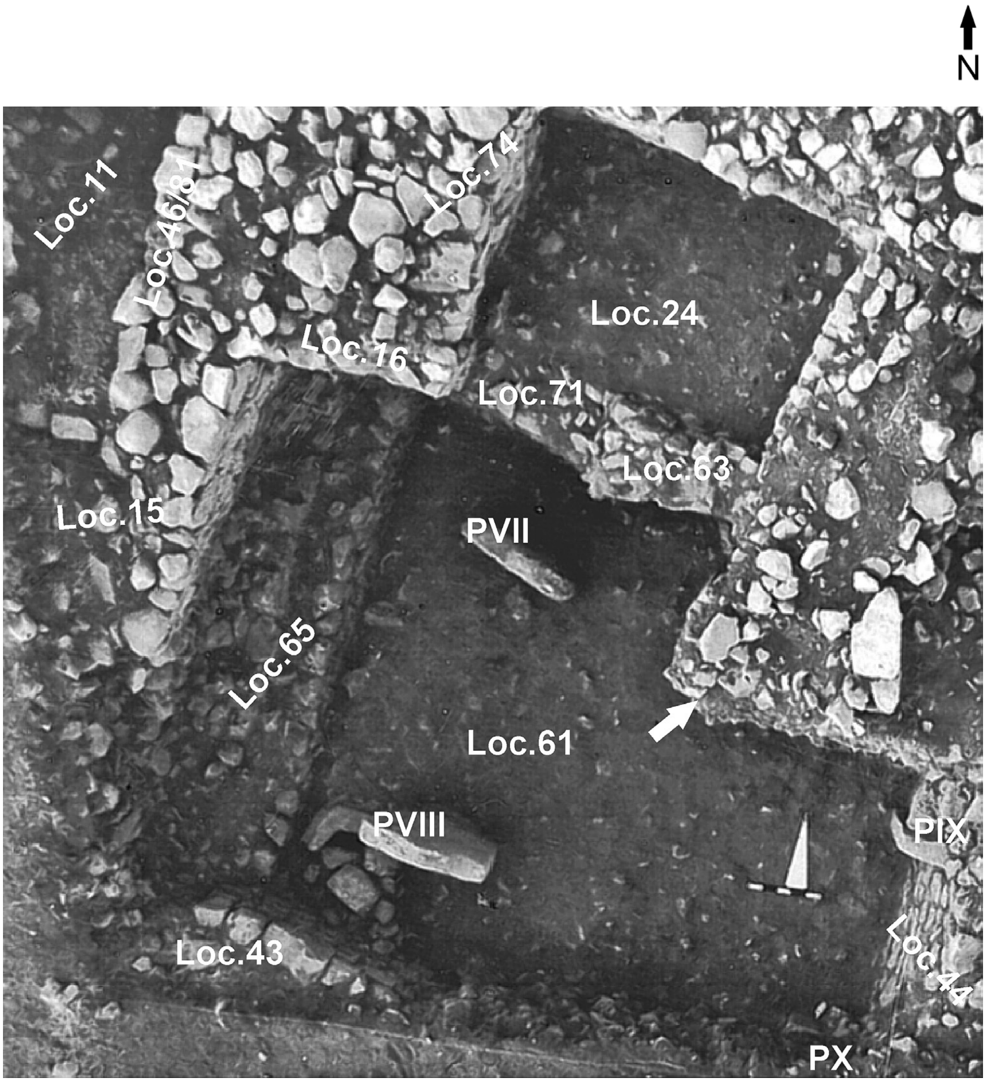


Figure 1. GT1999: L09-80, vertical shot of the area with walls exposed as documented (photo: K. Schmidt/DAI/Göbekli Tepe Archive 1999).

Figure 2. GT: L09-80, (a) wall loci L09-80-65 and L09-80-144 before cleaning (photo: D. Sönmez/DAI, 2017); (b) after cleaning (photo: M. Kinzel/DAI, 2018).

Figure 3. GT: L09-80, Cleaning of wall tops (Loci L09-80-65 and L09-80-144) to prepare for 3D-recording (photo: L. Clare/DAI, 2018).

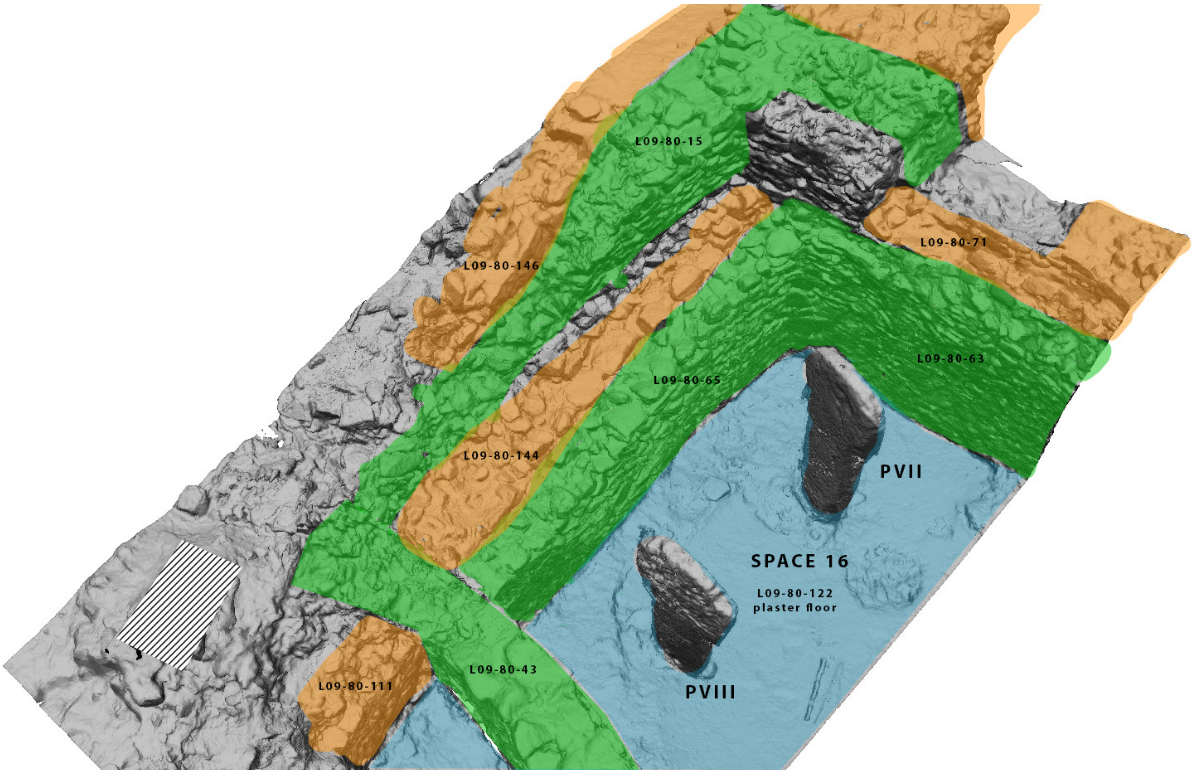


Figure 4. GT: L09-80, 3D-model with building phases of the relevant context discussed here early plaster floor (blue), earlier alterations of the structure (orange), later alteration (green), (M. Kinzel 2020).

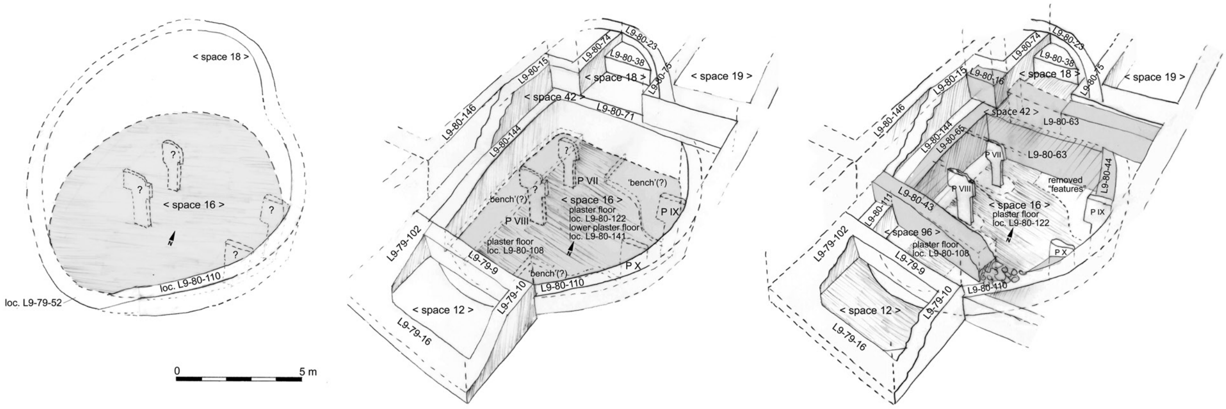
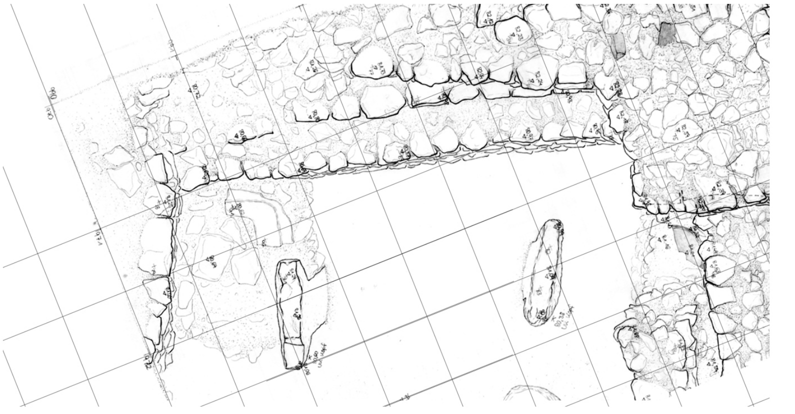
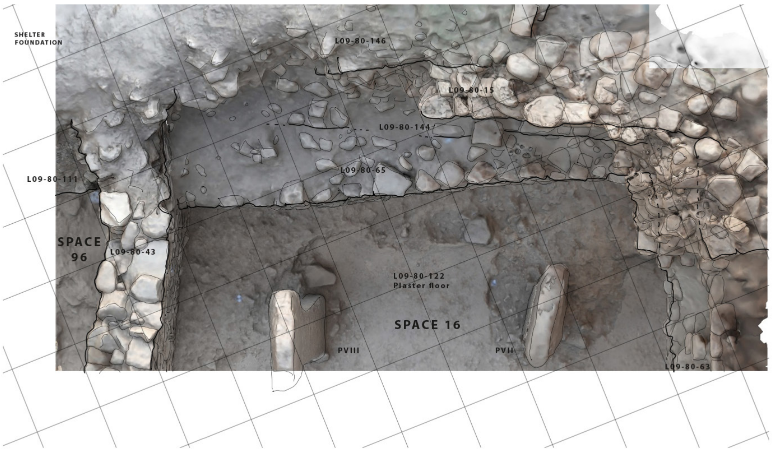


Figure 5. Göbekli Tepe, L09-80 Building development in the area around space 16 (after Kinzel et al. 2020).



Göbekli Tepe 2001 hand drawing (after C. Winterstein)



Göbekli Tepe 2001 Orthophoto of 3D-model and tracing of stones (after M.KInzel - D. Sönmez 2017)

Göbekli Tepe 2001 Orthophoto of 3D-model and tracing of stones (after M.KInzel 2018).

Figure 6. Top: Göbekli Tepe 2002 hand drawing (original scale 1:20) by C. Winterstein (DAI/Göbekli Tepe Project Archive 2001). Middle: Göbekli Tepe: L09-80, space R16/42 SfM Modell 2017 (based on 280 images processed with Agisoft Photoscan – High Quality; by M. Kinzel and D. Sönmez); Göbekli Tepe 2017: L09-80, R16/42 wall loci L09-80-144, L09-80-65, L09-80-146, L09-80-15, L09-80-43, L09-80-63, (Floor Loc. L09-80-122). Bottom: Göbekli Tepe 2019: digital 3D-model of area L09-80 with spaces 12, 16, 18 and 96 (based on SfM-recording by M. Kinzel 2018; processed in 2019 and edited in 2020).

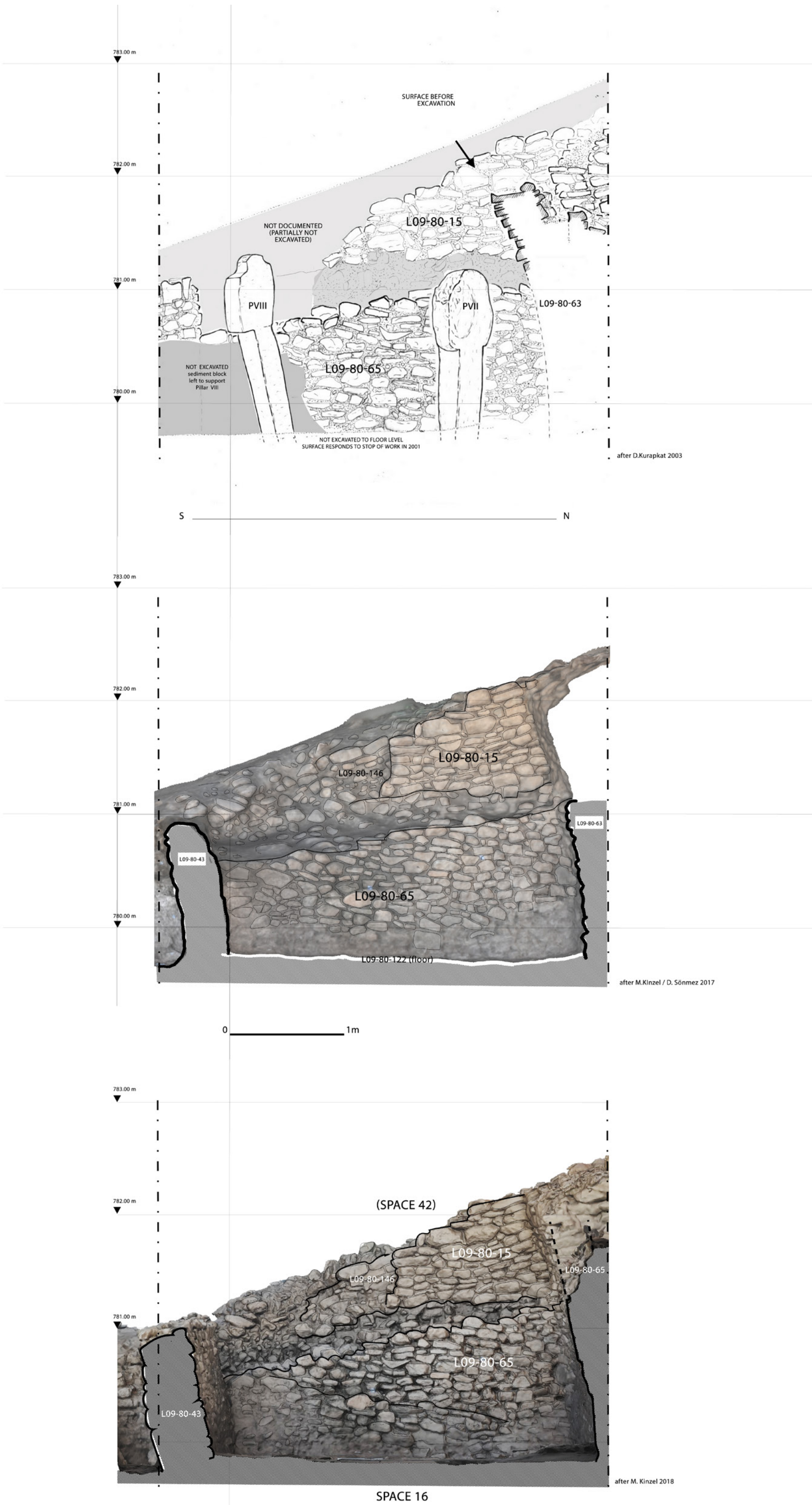


Figure 7. L09-80 elevation of wall L09-80-65/15 and 144 (hand drawing 2002 by D. Kurapkat, 3D-model 2017 by M. Kinzel, D. Sönmez, 3D-model 2018, by M. Kinzel, edited by M. Kinzel 2020).

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- Makalenin altına şekiller ve tablolar için bir başlık listesi eklenmelidir. Görsellerde gerektiği takdirde kaynak belirtilmelidir. Her şekil ve tabloya metin içerisinde gönderme yapılmalıdır (Şekil 1 veya Tablo 1).
- Görseller Word dokümanının içerisine yerleştirilmemeli, jpg veya tiff formatında, ayrı olarak gönderilmelidir.
- Görüntü çözünürlüğü basılması istenen boyutta ve 300 dpi'nin üzerinde olmalıdır.
- Görseller Photoshop ve benzeri programlar ile müdahale edilmeden olabildiğince ham haliyle gönderilmelidir.
- Excel'de hazırlanmış tablolar ve grafikler var ise mutlaka bunların PDF ve Excel dokümanları gönderilmelidir.

Tarihlerin ve Sayıların Yazımı

- MÖ ve MS kısaltmalarını harflerin arasına nokta koymadan kullanınız (örn.: M.Ö. yerine MÖ).
- "Bin yıl" ya da "bin yıl" yerine "... binyıl" kullanınız (örn.: MÖ 9. binyıl).
- "Yüzyıl", "yüz yıl" ya da "yy" yerine "yüzyıl" kullanınız (örn.: MÖ 7. yüzyıl).
- Beş veya daha fazla basamaklı tarihler için sondan sayarak üçlü gruplara ayırmak suretiyle sayı gruplarının arasına nokta koyunuz (örn.: MÖ 10.500)
- Dört veya daha az basamaklı tarihlerde nokta kullanmayınız (örn.: MÖ 8700).
- 0-10 arasındaki sayıları rakamla değil yazıyla yazınız (örn.: "8 kez yenilenmiş taban" yerine "sekiz kez yenilenmiş taban").

Noktalama ve İşaret Kullanımı

- Ara cümleleri lütfen iki çizgi ile ayırınız (—). Çizgi öncesi ve sonrasında boşluk bırakmayınız.
- Sayfa numaraları, tarih ve yer aralıklarını lütfen tek çizgi (-) ile ayırınız: 1989-2006; İstanbul-Kütahya.

Kısaltmaların Yazımı

- Sık kullanılan bazı kısaltmalar için bkz.:

Yaklaşık:	yak.	Circa:	ca.
Bakınız:	bkz.	Kalibre:	kal.
Örneğin:	örn.	ve diğerleri:	vd.

Özel Fontlar

- Makalede özel bir font kullanıldıysa (Yunanca, Arapça, hiyeroglif vb.) bu font ve orijinal metnin PDF versiyonu da gönderilen dosyalar içerisine eklenmelidir.

Metin içi Atıflar ve Kaynakça Yazımı

- Her makale, metin içerisinde atıf yapılmış çalışmalardan oluşan ve "Kaynakça" olarak başlıklandırılan bir referans listesi içermelidir. Lütfen metin içerisinde bulunan her referansın kaynakçaya da eklendiğinden emin olun.
- Metin içerisindeki alıntılar doğrudan yapılabilir: '…Esin (1995)'in belirtmiş olduğu gibi' ya da parantez içerisinde verilebilir: 'analiz sonuçları gösteriyor ki … (Esin 1995).'
- Aynı parantez içerisindeki referanslar yayın yılına göre sıralanmalı ve ";" ile ayrılmalıdır: '… (Dinçol ve Kantman 1969; Esin 1995; Özbal vd. 2004).'
- Aynı yazarın farklı yıllara ait eserlerine yapılan atıflarda yazarın soyadı bir kere kullanılmalı ve eser yılları "," ile ayrılmalıdır: '... (Peterson 2002, 2010).'
- Aynı yazar(lar)ın aynı yıl içerisindeki birden fazla yayınına referans verileceği durumlarda yayın yılının yanına harfler 'a', 'b', 'c' gibi alfabetik olarak koyulmalıdır.
- Tek yazarlı kaynakları, aynı yazar adıyla başlayan çok yazarlı kaynaklardan önce yazınız.
- Aynı yazar adıyla başlayan fakat farklı eş yazarlara sahip kaynakları ikinci yazarın soyadına göre alfabetik sıralayınız.
- Aynı yazara ait birden fazla tek yazarlı kaynak olması durumunda kaynakları yıllara göre sıralayınız.
- Dergi makaleleri için doi bilgisi varsa kaynakçada mutlaka belirtiniz.

Aşağıda, farklı kaynakların metin içerisinde ve kaynakçada nasıl yazılacağına dair örnekler bulabilirsiniz.

Tek yazarlı dergi makaleleri, kitap içi bölümler ve kitaplar

Metin içerisinde:

Yazarın soyadı ve yayın yılı (Esin 1995).

Sayfa sayısı bilgisi verilecekse:

Yazarın soyadı ve yayın yılı, sayfa sayısı (Esin 1995, 140).

Dergi makalesi:

Bickle, P. 2020. Thinking Gender Differently: New Approaches to Identity Difference in the Central European Neolithic. *Cambridge Archaeological Journal* 30(2), 201-218. https://doi.org/10.1017/S0959774319000453

Kitap içi bölüm:

Esin, U. 1995. Aşıklı Höyük ve Radyo-Aktif Karbon Ölçümleri. A. Erkanal, H. Erkanal, H. Hüryılmaz, A. T. Ökse (Eds.), *İ. Metin Akyurt - Bahattin Devam Anı Kitabı. Eski Yakın Doğu Kültürleri Üzerine İncelemeler*, İstanbul: Arkeoloji ve Sanat Yayınları, 135-146.

Kitap:

Peterson, J. 2002. *Sexual Revolutions: Gender and Labor at the Dawn of Agriculture*. Walnut Creek, CA: AltaMira Press.

İki yazarlı dergi makaleleri, kitap içi bölümler ve kitaplar

Metin içerisinde:

Her iki yazarın soyadı ve yayın yılı (Dinçol ve Kantman 1969, 56).

Dergi makalesi:

Pearson, J., Meskell, L. 2015. Isotopes and Images: Fleshing out Bodies at Çatalhöyük. *Journal of Archaeological Method and Theory* 22, 461-482. https://doi.org/10.1007/s10816-013-9184-5

Kitap içi bölüm:

Özkaya, V., San, O. 2007. Körtik Tepe: Bulgular Işığında Kültürel Doku Üzerine İlk Gözlemler. M. Özdoğan, N. Başgelen (Eds.), *Türkiye'de Neolitik Dönem. Yeni Kazılar, Yeni Bulgular*, İstanbul: Arkeoloji ve Sanat Yayınları, 21-36.

Kitap:

Dinçol, A. M., Kantman, S. 1969. *Analitik Arkeoloji, Denemeler*. Anadolu Araştırmaları III, Özel sayı, İstanbul: Edebiyat Fakültesi Basımevi.

Üç ve daha çok yazarlı dergi makaleleri ve kitap içi bölümler

Metin içerisinde:

İlk yazarın soyadı, "vd." ve yayın yılı (Özbal vd. 2004).

Dergi makalesi:

Özbal, R., Gerritsen, F., Diebold, B., Healey, E., Aydın, N., Loyet, M., Nardulli, F., Reese, D., Ekstrom, H., Sholts, S., Mekel-Bobrov, N., Lahn, B. 2004. Tell Kurdu Excavations 2001. *Anatolica* 30, 37-107.

Kitap içi bölüm:

Pearson, J., Meskell, L., Nakamura, C., Larsen, C. S. 2015. Reconciling the Body: Signifying Flesh, Maturity, and Age at Çatalhöyük. I. Hodder, A. Marciniak (Eds.), *Assembling Çatalhöyük*, Leeds: Maney Publishing, 75-86.

Editörlü kitaplar

Metin içerisinde:

Yazar(lar)ın soyadı ve yayın yılı (Akkermans ve Schwartz 2003).

Akkermans, P. M. M. G., Schwartz, G. M. 2003. (Eds.) *The Archaeology of Syria. From Complex Hunter-Gatherers to Early Urban Societies (c. 16.000-300 BC)*. Cambridge: Cambridge University Press.

Web kaynağı:

Soyad, Ad. Web Sayfasının Başlığı. Web Sitesinin Adı. Yayınlayan kurum (varsa), yayın tarihi. Erişim tarihi. URL.

ARKEOLOJİ BİLİMLERİ DERGİSİ
TURKISH JOURNAL OF ARCHAEOLOGICAL SCIENCES

Submission and Style Guideline

Submission Criteria for Articles

The content of the manuscripts should meet the aims and scope of the Turkish Journal of Archaeological Sciences (cf. Aims and Scope).

Manuscripts may be written in Turkish or English. The translation of articles into English is the responsibility of the author(s). If the author(s) are not fluent in the language in which the article is written, they must ensure that the text is reviewed, ideally by a native speaker, prior to submission.

Each manuscript should include a Turkish and an English abstract of up to 200 words and five keywords in both Turkish and English. Citations should not be included in the abstract.

If the author(s) are not fluent in the language of the manuscript, a translation of the abstract and the keywords may be provided by the editorial board.

Manuscripts, figures, and other files should be sent via wetransfer or e-mail to **archaeologicalsciences@gmail.com**

Submission Checklist

Each article must contain the following:

- Authors (please provide the name-last name and contact details of each author under the main title of the manuscript)
- Affiliation (where applicable)
- E-mail address
- ORCID ID

The manuscript should contain:

- Title
- Abstract (in English and Turkish)
- Keywords
- Text
- References
- Figures (when applicable)
- Tables (when applicable)

Scientific Standards and Ethics

- Submitted manuscripts should include original research that has not been previously published or submitted for publication elsewhere.
- The manuscripts should meet scientific standards.
- Manuscripts should use inclusive language that is free from bias based on sex, race or ethnicity, etc. (e.g., “he or she” or “his/her/their” instead of “he” or “his”) and avoid terms that imply stereotypes (e.g., “humankind” instead of “mankind”).

Style Guide

Manuscript Formatting

- Manuscripts should be written in Times New Roman 12-point font, justified and single-spaced. Please submit the manuscript as a word document.
- Words in foreign and ancient languages should be *italicized*.
- Titles and subtitles should appear in **bold**.
- Titles and subtitles should not be numbered, italicized, or underlined.
- Only the first letter of each word in titles and subtitles should be capitalized.

References

Cf.: In-Text Citations and References

- In-text citations should appear inside parenthesis (Author year, page number).
- Footnotes and endnotes should not be used for references. Comments should be included in footnotes rather than endnotes.
- The footnotes should be written in Times New Roman 10-point font, justified and single-spaced, and should be continuous at the bottom of each page.

Figures and Tables

- Please provide a caption list for figures and tables following the references. Provide credits where applicable. Each figure and table should be referenced in the text (Figure 1, or Table 1), but please do not include figures in the text document.
- Each figure should be submitted separately as a jpg or tiff file.
- Images should be submitted in the dimensions in which they should appear in the published text and their resolution must be over 300 dpi.
- Please avoid editing the figures in Photoshop or similar programs but send the raw version of the figures if possible.
- Tables and graphs prepared in Excel should be sent as both PDF and Excel documents.

Dates and Numbers

- Please use BCE/CE and please avoid using dots without dots (i.e., BCE instead of BC or B.C.).
- Please use a dot for numbers and dates with 5 or more digits (i.e., 10.500 BCE).
- Please avoid using dots for numbers and dates with 4 or less digits (i.e., 8700 BCE).
- Please spell out whole numbers from 0 to 10 (e.g., "the floor was renewed eight times" instead of "the floor was renewed 8 times").

Punctuation

- Please prefer em dashes (—) for parenthetical sentences: "Children were buried with various items, the adolescents—individuals between the ages of 12-19—had the most variety in terms of grave goods."
- Please prefer an en dash (-) between page numbers, years, and places: 1989-2006; İstanbul-Kütahya.

Abbreviations

- Commonly used abbreviations:

Approximately:	approx.	Figure:	Fig.
Confer:	cf.	*Id est:*	i.e.,
Circa:	ca.	*Exempli gratia:*	e.g.,
Calibrated:	cal.		

Special Fonts

- If a special font must be used in the text (e.g., Greek or Arabic alphabet or hieroglyphs), the text in the special font and the original manuscript should be sent in separate PDF files.

In-Text Citations and References

- Each article should contain a list of references in a section titled "References" at the end of the text. Please ensure that all papers cited in the text are listed in the bibliography.
- Citations in the text may be made directly, e.g., 'as shown by Esin (1995) ...' or in parenthesis, e.g., 'research suggests ... (Esin 1995)'.
- References within the same parenthesis should be arranged chronologically and separated with a ";", e.g., '... (Dinçol and Kantman 1969; Esin 1995; Özbal et al. 2004).'
- In references to the studies by the same author from different years, please use the last name of the author once, followed by the years of the cited studies, each separated by a ",", e.g., '... (Peterson 2002, 2010).
- More than one reference from the same author(s) in the same year must be identified by the letters 'a', 'b', 'c' placed after the year of publication.
- When dealing with multiple papers from the same author, single authored ones should be written before the studies with multiple authors.
- When dealing with papers where the first author is the same, followed by different second (or third, and so on) authors, the papers should be listed alphabetically based on the last name of the second author.
- When dealing with multiple single-authored papers of the same author, the papers should be listed chronologically.
- Please provide the doi numbers of journal articles.

Below, you may find examples for in-text citations and references.

Single-authored journal articles, book chapters, and books

In-text:

Last name and publication year (Esin 1995).

If the page number is indicated:

Last name and publication year, page number (Esin 1995, 140).

Journal article:

Bickle, P. 2020. Thinking Gender Differently: New Approaches to Identity Difference in the Central European Neolithic. *Cambridge Archaeological Journal* 30(2), 201-218. https://doi.org/10.1017/S0959774319000453

Book chapter:

Esin, U. 1995. Aşıklı Höyük ve Radyo-Aktif Karbon Ölçümleri. A. Erkanal, H. Erkanal, H. Hüryılmaz, A. T. Ökse (Eds.), *İ. Metin Akyurt - Bahattin Devam Anı Kitabı. Eski Yakın Doğu Kültürleri Üzerine İncelemeler*, İstanbul: Arkeoloji ve Sanat Yayınları, 135-146.

Book:

Peterson, J. 2002. Sexual Revolutions: *Gender and Labor at the Dawn of Agriculture*. Walnut Creek, CA: AltaMira Press.

Journal articles, book chapters, and books with two authors

In-text:

Last names of both authors and publication year (Dinçol and Kantman 1969, 56).

Journal article:

Pearson, J., Meskell, L. 2015. Isotopes and Images: Fleshing out Bodies at Çatalhöyük. *Journal of Archaeological Method and Theory* 22, 461-482.
https://doi.org/10.1007/s10816-013-9184-5

Book chapter:

Özkaya, V., San, O. 2007. Körtik Tepe: Bulgular Işığında Kültürel Doku Üzerine İlk Gözlemler. M. Özdoğan, N. Başgelen (Ed.), *Türkiye'de Neolitik Dönem. Yeni Kazılar, Yeni Bulgular*, İstanbul: Arkeoloji ve Sanat Yayınları, 21-36.

Book:

Dinçol, A. M., Kantman, S. 1969. *Analitik Arkeoloji, Denemeler*. Anadolu Araştırmaları III, Özel sayı, İstanbul: Edebiyat Fakültesi Basımevi.

Journal articles and book chapters with three or more authors

In-text:

Last name of the first author followed by "et al." and the publication year (Özbal et al. 2004).

Journal article:

Özbal, R., Gerritsen, F., Diebold, B., Healey, E., Aydın, N., Loyet, M., Nardulli, F., Reese, D., Ekstrom, H., Sholts, S., Mekel-Bobrov, N., Lahn, B. 2004. Tell Kurdu Excavations 2001. *Anatolica* 30, 37-107.

Book chapter:

Pearson, J., Meskell, L., Nakamura, C., Larsen, C. S. 2015. Reconciling the Body: Signifying Flesh, Maturity, and Age at Çatalhöyük. I. Hodder, A. Marciniak (Eds.), *Assembling Çatalhöyük*, Leeds: Maney Publishing, 75-86.

Edited books

In-text:

Last name(s) of the author(s) and publication year (Akkermans and Schwartz 2003).

Akkermans, P. M. M. G., Schwartz, G. M. 2003. (Eds.) *The Archaeology of Syria. From Complex Hunter-Gatherers to Early Urban Societies (c. 16.000-300 BC)*. Cambridge: Cambridge University Press.

Web source:

Last name, Initial of the first name. Title of the web page. Title of the website. Institution (where applicable), publication date. Access date. URL.