

**3. F. Buccellati (IIMAS – International Institute for Mesopotamian Area Studies), *3D Models as Vehicles for Archaeological Research: Stratigraphy, Emplacement and Construction*.** 3D architectural models are becoming increasingly prevalent in archaeological research, and serve a variety of scholarly needs. They can be placed into two different categories: those models which are ends-in-themselves and those models which are vehicles for further research. Those models which are ends-in-themselves are the conclusion of a research project; examples include a reconstruction of an ancient building, or the placing of the volume of a structure within the urban landscape. These are the majority of models which are seen today – to a large extent because it is exactly that communication which is the goal of many of these models; others use the visual aspect to consider light, perception or visibility.<sup>1</sup> These models are of great use to archaeologists, and have become a fundamental tool in our field.

There is, however, a second category of 3D architectural models: those models which serve as a vehicle for research which has an end result something other than the 3D model. Such models tend to be less visible in the field, as they are not part of the conclusion of a research project but rather serve that end as a tool for research. This article aims to highlight such 3D models, bringing to the fore the potential for models to contribute directly to archaeological research without necessarily being a part of the end result.

In particular, I will present three types of research questions that are possible only thanks to the use of three-dimensional data, but where the models constructed are built only in function of a non-visual result. The first group is linked to the modeling of stratigraphic volumes in the archaeological record; here the size of the excavated areas and their chronological sequence can help understand better the material coming from an excavated area. Second, the distribution of objects within the earthen matrix, or emplacement, can aid in understanding not only the objects but also their function, use in relation to other objects and even the space in which they were contained. The third group uses 3D models to precisely define the architectural remains as uncovered in the archaeological record and use the quantity of the constructed space to better understand the process of construction and the impact of decisions made in function of the building.

One of the most compelling uses of 3D models as vehicles for archaeological research is the examination of stratigraphic connections. Before the advent of 3D modeling, the Harris matrix<sup>2</sup> was developed to investigate and represent

- 1 One interesting example of the study of light is the study of the Emake cella at Babylon by M. G. Micale, *From Drawing to Vision. The Use of Mesopotamian Architecture Through the Construction of Its Image*, in W. Boerner and S. Uhliz (eds), *Cultural Heritage and New Technologies (Workshop 11 "Archaeology and Computer")*, Magistrat der Stadt Wien 2007: 2–4 (disk). A visibility study on the presence of genii in Neo-Assyrian palace reliefs is currently being prepared as a dissertation thesis by P. Serba at the Goethe University of Frankfurt a.M.
- 2 E. Harris, *Principles of Archaeological Stratigraphy*, London – New York 1979; E. Harris, M.

stratigraphic relationships. The matrices produced map the physical relationship between stratigraphic units, which leads to an understanding of the chronological sequence that gave rise to the archaeological record as discovered. What the Harris matrix can represent in a schematic fashion, a 3D model can represent as 3D volumes, providing a much more complex and rich representation of the stratigraphy. A typical Harris matrix depicts, in an abstract way, the relationships between all the distinct volumes in the archaeological record; a 3D model can represent the same relationships, but do so by simulating those spaces in a virtual space.

The Harris matrix itself has been the object of several digital projects,<sup>3</sup> primarily focusing on ease and accuracy of recording and display. By nature, however, such projects maintain the abstract and relational character of the original method, representing thus the relationships between the stratigraphical units without representing their volumes or the spatial relationships between them.

A 3D model of stratigraphic relationships, on the other hand, defines the volumes of the stratigraphical units, adding two types of information to the relationships present in a Harris matrix: a reconstruction of the spatial relationships between the units as well as a numerical calculation of the volumes as modeled. A 3D model contains the volumes by reconstructing in a virtual three-dimensional space the stratigraphic relationships rather than the representation that a matrix provides. Additionally, the 3D model can calculate the precise volume (normally expressed in cubic meters) of the 3D solids; one must note, however, that the accuracy of the calculations is based on precision of the original 3D model.

An excellent example of the use of 3D modeling to show stratigraphic relationships is the analysis done of the Red House at Sheikh Hamad.<sup>4</sup> Kreppner uses 3D volumes, which he calls cuboids, to express the 4947 deposits which were identified by the excavators during the excavation. The Red House contains 90 rooms and 5 courtyards, and covers an area of 5400 square meters.<sup>5</sup> These volumes are abstractions, as they are composed of six measurements: north–south, east–west, lowest and highest points;<sup>6</sup> thus the cuboids are all aligned to a fixed axis, and because of the abstract nature of the measurements they do not necessarily reflect the excavated volume (a pit would be represented as a cube, and a sloping

Brown, and G. Brown, *Practices of Archaeological Stratigraphy*, London – San Diego 1993.

- 3 Perhaps the first digital project based on the Harris matrix was a portion of the Bonn Archaeological Software Package (BASP) (<http://www.uni-koeln.de/~al001/basp.html>). While the Harris-matrix-generating portion of this project is outdated, most of the current programs (e.g. ArchEd, Stratify or the Harris Matrix Composer) are iterations of that original program.
- 4 F.J. Kreppner, Site Formation Processes in the Lower Town II of Dur-Katlimmu. The Case of the Red House, in R. Matthews, J. Curtis (eds), *Proceedings of the 7<sup>th</sup> ICAANE 12–16 April 2010, British Museum and UCL, London, Wiesbaden 2012*: 217–228.
- 5 Kreppner, Site Formation Processes, cit.: 218.
- 6 Kreppner, Site Formation Processes, cit.: 219.

accumulation would presumably have been smaller in volume than is represented in the model). On average, a cuboid represented 5.23 m<sup>3</sup> of soil.<sup>7</sup>

Kreppner's analysis looks at the three-dimensional data as volumes of soil, and considers the amount of soil which yielded material from the main use-phase of the building – a surprisingly low 1.33% of the total volume of the recorded deposits, or 345.06 m<sup>3</sup>.<sup>8</sup> This is an excellent example of how a 3D model can serve as a vehicle for archaeological research without being based on visible representation.

Considering the example of the Red House, one might wonder if such an analysis might bear fruit when combined with a study of objects. Distributional analysis is a mainstay of archaeological research,<sup>9</sup> looking at the find-spots of objects to determine the function of rooms, for example, or the interrelation of different object classes.

3D models can expand on this type of analysis by adding information based on the vertical dimension of distribution. Such analyses, based on three dimensional data, are a vehicle for archaeological research because the distribution revealed gives us more information about the objects and their relationships, providing confirmation for hypotheses or posing new questions.

The excavations at Tell Hamoukar in Northeastern Syria provide an excellent example of the potential of 3D data. The excavations in area B during the 1999 and 2001 seasons uncovered 91 stamp seals and 193 clay sealings with a large number of parallels between them in terms of design and type.<sup>10</sup> Of particular interest was a tripartite building discovered during the 2001 season, where the majority of the sealings were found.

The distribution of sealings within the tripartite building was interesting in two respects:<sup>11</sup> the sealings were not distributed evenly throughout the rooms (they were found primarily in loci 132 134 and 135), and the sealings were also found

7 Kreppner, *Site Formation Processes*, cit.: 224.

8 Kreppner, *Site Formation Processes*, cit.: 224.

9 Studies on the seals from Arslantepe, in particular, are of interest as an example of the link between function and distribution: M. Frangipane and A. Palmieri, A Protourban Centre of the Late Uruk Period, in M. Frangipane and A. Palmieri (eds), *Perspectives on Protourbanization in Eastern Anatolia: Arslantepe (Malatya). An Interim Report on 1975-83 Campaigns* (Origini 12/2), Roma 1983: 287–454; P. Ferioli and E. Fiandra, Clay-Sealings from Arslantepe VI A: Administration and Bureaucracy, in M. Frangipane and A. Palmieri (eds), *Perspectives on Protourbanization in Eastern Anatolia: Arslantepe (Malatya). An Interim Report on 1975-83 Campaigns* (Origini 12/2), Roma 1983: 460–468.

10 M. Gibson *et al.*, Hamoukar: A Summary of Three Seasons of Excavation, *Akkadica* 123/1 (2002): 11–34; C. Reichel, Administrative Complexity in Syria during the 4th Millennium BC: The Seals and Sealings from Tell Hamoukar, *Akkadica* 123/1 (2002): 35–56.

11 It is unclear from the publication if a computerized 3D model was used by Reichel (*Administrative Complexity*, cit.), but the analysis presented is entirely based on a three-dimensional perception and visualization of the archaeological record.

well above the floor level in some areas.<sup>12</sup> The uneven horizontal distribution could not be explained – Reichel excludes the storage/office division suggested by Ferioli and Fiandra for other sites because of the types of containers sealed.<sup>13</sup> The vertical distribution, however, is interpreted as the consequence of a second story in the building;<sup>14</sup> additionally, Reichel suggests that ceramic vessels were stored on the ground floor while baskets were stored above, based on the backs of the sealings found in the two layers.

What makes this study a particularly good example of 3D modeling as a vehicle for research, however, is the analysis of one group of sealings made from the same seal, called “seal C”. Reichel posits: “if the spatial distribution of the sealings reflects administrative procedures that once were performed, then seals that were found on several sealings should certainly show a recognizable pattern in the building plan”.<sup>15</sup> Due to the fact that the sealings bearing the impression of seal C were found distributed over both floors and primarily on basket containers (as opposed to two other groups of sealings from seals “A” and “B”), and due to the presence of sealings from seal C in another context outside of the tripartite building (locus 210), Reichel suggests that the owner of seal C was involved in the distribution of material from another locale. Thus it is the 3D model employed by Reichel which allows him to reach a broader conclusion regarding the material in question: a hypothesis which does not have the 3D model as the solution, but rather uses it as a vehicle to investigate the research question and corroborate information from other sources.

There is a second example of three-dimensional data and emplacement – Roaf and Killick’s study of the ceramic material found at the site of Nineveh.<sup>16</sup> Apart from the delightful style in which the article is written, it is worth mentioning because it shows how the mapping of three-dimensional data can help define typological change over time.

During the 1931–32 season M. Mallowan excavated the “Prehistoric Pit” at Tell Kuyunjik, ancient Nineveh.<sup>17</sup> Mallowan decided to define the pottery by numbering the layers from bottom to top, defining a total of 5 layers. Each layer contained a large amount of material, as the depth of the excavated pit was 90 feet, more than 27 meters. The last layer contained a mix of incised, excised and painted pottery, and was, according to Mallowan’s scheme, named Ninivite 5, a term which remains in use today. Due to the lack of architectural features the

12 Reichel, *Administrative Complexity*, cit.: 48.

13 Ferioli and Fiandra, *Clay-Sealings from Arslantepe VI A*, cit.: 460–468; Reichel, *Administrative Complexity*, cit.: 46

14 Reichel, *Administrative Complexity*, cit.: 49.

15 Reichel, *Administrative Complexity*, cit.: 48.

16 Roaf and Killick, *A Mysterious Affair of Styles: The Ninevite 5 Pottery of Northern Mesopotamia*, *Iraq* 49 (1987): 199–223.

17 Roaf and Killick, *A Mysterious Affair of Styles*, cit.: 200–201, 214.

stratification of the material was often unclear, so Mallowan felt that a more refined distinction was not possible.<sup>18</sup>

Roaf and Killick,<sup>19</sup> in the early 1980s, examined evidence from a number of sites (including their own work at Tell Muhammad Arab) and developed a hypothesis as to the chronological sequence of these types of decoration. Returning to the evidence published by Mallowan<sup>20</sup> from the excavations at Nineveh several decades earlier, they were able to sort the sherds by decoration type and the depth at which they were found;<sup>21</sup> this evidence supported their hypothesis regarding the typology of Ninevite 5 ceramics. This return to published three-dimensional data (even if not represented in a 3D model) is another example of how spatial information can act as a vehicle which enables archaeologists to answer broader questions.

The examples presented above have focused on the accumulations and objects found within the archaeological record, but what of the architecture itself? 3D models of architecture are among the most common examples of volumetric models, but the majority are focused on presenting a reconstruction of the buildings found in the archaeological record. As such, these 3D reconstructions are the result of the research project, the 'end' of the project – and they can be very useful, on many levels. However, 3D models of architecture can also serve as vehicles for other types of research questions, where the 'answer' is not the model itself. The example for this type of 3D model comes from my own research into the AP Palace at Tell Mozan.

The AP Palace at Tell Mozan, ancient Urkesh, was built during the Akkadian period, dating to the second half of the third millennium (Fig. 1).<sup>22</sup> The Palace was built within the inner city, on the west side; the building's western wall in fact was partially situated on the foundations of the inner city wall, which had been removed by that point.

The building was constructed over earlier cultural remains, and as such the build-site was not leveled completely before construction began, but was stepped

18 M.E.L. Mallowan, Ninivite 5, in K. Bittel and A. Moortgat (eds), *Vorderasiatische Archäologie: Studien und Aufsätze: Anton Moortgat zum Fünfundsechzigsten Geburtstag gewidmet von Kollegen, Freunden und Schülern*, Berlin (1964): 148.

19 Roaf and Killick, *A Mysterious Affair of Styles*, cit.

20 Mallowan, *Ninivite 5*, cit.

21 Roaf and Killick, *A Mysterious Affair of Styles*, cit.: 214–215.

22 Several publications on diverse aspects of the AP Palace have appeared, see in particular G. Buccellati and M. Kelly-Buccellati, *The Seals of the King of Urkesh: Evidence from the Western Wing of the Royal Storehouse AK*, *Wiener Zeitschrift für die Kunde des Morgenlandes* 86 (1996): 65–100; Eidem, *Der Monumentale Palasthof von Tall Mozan/Urkesh und die Stratigraphische Geschichte des Abi: Bericht über die 15. Kampagne 2002*, *Mitteilungen der Deutschen Orient-Gesellschaft zu Berlin* 136 (2004): 13–39; G. Buccellati, *The Monumental Urban Complex at Urkesh: Report on the 16<sup>th</sup> Season of Excavations, July-September 2003*, *Studies on the Civilization and Culture of Nuzi and the Hurrians* 15 (2005): 3–28; F. Buccellati, *Wie wird ein Palast gebaut und warum?*, in P. Breunig and C. Trümpler (eds), *Werte im Widerstreit. Von Bräuten, Muscheln, Geld und Kupfer. Ausstellungskatalog Wiesbaden 4*, Frankfurt 2012: 31–33.



Fig. 1. The AP Palace at Tell Mozan, ancient Urkesh (photo by the author).

so as to be terraced. Two stepped levels are present in the areas of the palace uncovered to date. The western area was a service area as determined by the large number of seal impressions found, the layout of the rooms and the installations present. The eastern area comprising of the formal wing was stepped up about 2 meters, with areas such as the stone courtyard.

In an upcoming monograph,<sup>23</sup> I have examined the archaeological record of the AP Palace, looking at the construction process through the lens of a *chaîne opératoire*, calculating the energy needed to achieve such a construction by means of a series of algorithms, and applied those results to understanding the architecture of the AP palace and how our understanding of the ancient's concepts of monumentality and prestige may be rooted in evidence from the archaeological record. At the core of this analysis was a 3D model which rendered the AP palace not as a reconstruction but rather as the archaeological record as the result of the excavation process (Fig. 2). Thus the stone foundations and lower wall courses, the initial red mudbricks and the later remodeling were all present as distinct

23 F. Buccellati, *Three-Dimensional Volumetric Analysis in an Archaeological Context: The Palace of Tupkish at Urkesh and Its Representation* (Bibliotheca Mesopotamica, Vol. UMSX 15), Malibu, CA forthcoming.



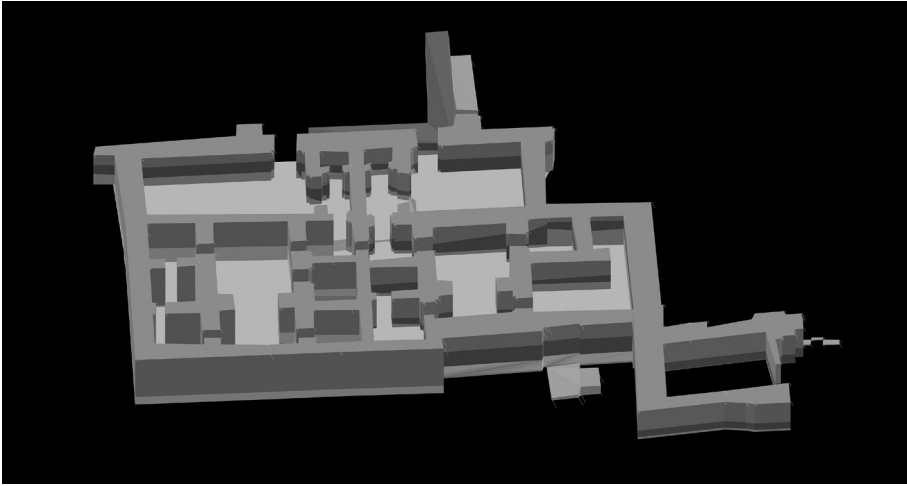


Fig. 2. 3D Model of the AP Palace (elaboration by the author).

elements in the model. The three-dimensional data used to create the 3D solids were taken in the field using a total station, while a specially coded plug-in for AutoCAD was used to create 3D solids with centimeter precision.

The power of this 3D model lies not in its ability to present a viewer with a highly accurate rendering of the archaeological record (the model has many advantages, but visual appeal is not one of them), but in the capability to calculate the exact volume of the many complex solids which make up the model. Over one hundred distinct 3D solids make up the model of the AP Palace,<sup>24</sup> and some of them have more than a dozen faces; such a calculation would be impossible by hand. As an example of the kind of data which can be derived from such a model, the total volume of the mudbrick walls in the model is 991.38 m<sup>3</sup>. From this, one can determine the number of mudbricks used: after having removed 1/6 of the volume for mortar, the total volume of the mudbricks used in the construction is 826.15 m<sup>3</sup>, which corresponds to 51.634 bricks of the 40 × 40 × 12 cm size.

In the monograph just mentioned, I use these data to calculate the amount of stone and brick needed for the palace, and go on to consider the manpower, materials and skillsets needed to construct the palace. The decisions (for example as to the materials used, such as with the large stone courtyard) taken when planning the construction, coupled with this volumetric information, gives a

24 A number of the 3D solids are a reconstruction of missing walls, and as such are not part of the archaeological record, but these are set directly on the models of the existing walls and raise the eroded walls to the height of the tallest wall found.

body of data founded in the archaeological record with which to consider aspects of monumentality and prestige in palatial architecture. The aim of this paper, however, is another – a consideration of 3D models as vehicles for research. The case of the AP Palace has shown how a 3D model can be used as a vehicle to accurately estimate volumes of construction materials needed, which can be further used when considering the energetics of construction. In addition, and very importantly, such an approach to 3D visualization can serve in helping to define excavation strategy: this is because by articulating the volumes, and not just the floor plans, one can more sharply focus on the overall coherence of the structure, and thus project possible alternative developments of a building of which only a portion has been excavated.<sup>25</sup>

3D models are one of the most important new tools that an archaeologist has, as they can be used directly to reconstruct and display the visual aspects of the ancient built environment. But 3D models also play another role, as vehicles to enable new paths of research. Here, visualization serves on the one hand to stimulate research questions that can elude us if only phrased in words or tabulated in figures (as with stratigraphy or with emplacement); and on the other to effectively produce new data (as with the volumetric information that makes possible energetic calculations of a monumental construction effort). This ability lies at the core of digital scholarship – digital tools which allow researchers to reach conclusions which were previously beyond our grasp.

25 G. Buccellati and M. Kelly-Buccellati, *Mozan 1: The Soundings of the First Two Seasons* (Bibliotheca Mesopotamica 20), Malibu 1988: 100–104.