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3-D Rendering and Animation at Tell Mozan/Urkesh

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Archaeological fieldwork can be divided into two major categories: the stratigraphic and the typological. The advent of computers has provided almost every aspect of our lives with new tools to help us improve the efficiency and quality of what we do. Archaeology is no exception: from calculators to advanced graphics applications, computers affect both the stratigraphic and the typological aspects, and yet they remain mere tools for our use. Therefore, the product of our labors is still founded on the data that we collect, and, even more powerfully, on our analysis of those data. The goal of this article is to focus on a very specific application of computers to archaeological work: the analysis of architectural space.[1]

Background

The incorporation of graphics with our work at Mozan has been a part of our project from the very beginning, and actually had its origins in the graphics work done at Terqa. Initially, the aim of the graphics project was to create drawings from sets of measured coordinates. As far back as 1982, the expedition was using the simplest of computers:

[1] It is important to note that while I have developed the 3-D aspect of digital graphics personally, the graphics program as an integrated toolbox for the archaeologist has been possible at Terqa and Mozan because of G. Buccellati's foresight as to the potential of computers and his encouragement in their implementation.

the Tandy 100, and a one-pen plotter.[2] Ever since then, the scope of our graphics work has grown with the technological advances and new software available. An important consideration has always been the element of cost, since we wanted to have computers available not only at home but also in the field, where it can truly affect our day-to-day strategy.

There have been two main approaches to the work on computer graphics at Mozan, one analytical and one analogical. The analytical approach reflects the initial goal of the program back in 1982: the ability to represent the stratigraphy from sets of coordinates. This has been primarily tied to the CAD (Computer Aided Design) applications, and is very useful because of its accuracy and impartiality. Since the measurements in the field are done mechanically with no sense of the data as a whole structure, there is no element of "aesthetic correction" when the data are transformed into a drawing by the computer.[3] The analogical approach has come more recently, and has as its goal the graphical representation of the stratigraphy as an understood whole. In this approach, the concept of the totality of the whole is essential, and it is always with this whole in mind that one produces the data. This is the converse of the analytical, because the graphics represent the understanding of the structure as a whole, something that transcends the features that we find in the ground.

The first step we took in using the computer as a tool was to modify the existing system (the one begun in 1982) to fit a commercial CAD program. In essence, the programs, as they were written by G. Buccellati for the Tandy 100, performed the basic functions of a CAD package, but to be able to take advantage of new technologies we needed to format the data that we were already producing to fit the format of a standard program. The CAD applications are the main programs employed in the analytical approach of the graphics program. The following steps all represent aspects of the analogical approach.

The second step we took (in 1996) was to add to our permanent facilities in the field a high-end flatbed scanner and PhotoShop 4.0. These two components enabled us to enhance and study either photographs that we had taken in the field of the stratigraphy,

[2] See Giorgio Buccellati in G. Buccellati and O. Rouault, *Digital Plotting of Archaeological Floor Plans*. Terqa Preliminary Reports, No. 12 (Malibu: Undena 1983) pp. 4-6. A popular article on our system, written by a member of the Terqa staff, was featured as the cover story on a computer magazine: Daniela Buia Quinn, "Archaeologists Trade Fedora and Leather for 100," *Portable 100: The Magazine for Model 100 Users*, October 1984, pp. 43-47.

[3] Buccellati, *op. cit.*, pp. 6-8.

or photographs that we had taken of objects in the laboratory. This capability was especially useful for the field photographs (overhead photographs, for example) in that we were able to digitally highlight certain aspects of the photos, and draw projections or clarifications on them. The laboratory photographs also benefited from the use of the Zoom and Sharpen tools, which allowed us to better define very small objects of which we have hundreds.

The third step, begun in 1997, was to move from the digital images to digital illustrations, primarily using Freehand 7.0. Digital illustration is very different from digital imaging because it creates pictures using point and line structure, rather than pixel structure. Digital images are composed of millions of dots that have codes attached to each one of them. These linked codes (the pixels) describe the color and the sharpness of that particular point; this can be a drawback if your image is simple but large, because a large number of points (or pixels) are used even though they are all the same. Digital illustrations, on the other hand, create lines described by the two endpoints; this means that, compared to a digital image, much less space is needed. Instead of giving a code that corresponds to black for each of the points along the line from A to B, one code is given at A telling the program to go to B with a black line. This is also the case for areas, where a digital image would code a pixel for every point in the area, while a digital illustration would merely code the whole by defining the outer boundary and the color of the inside.

The move into digital illustration allowed us to retrace the drawings of objects in the field and create architectural plans that we did not want to do with the CAD program. The drawings were then in the computer as files, and could be linked to the objects when they were referred to in the Journal portion of what we call the Urkesh Global Record, which is the totally integrated database of all the documentation for the site. The architectural plans were easy to print and manipulate as our understanding of the buildings changed; this was not possible with plans based on a digital image because each pixel had to be changed, making the process prohibitively time consuming.

What I am presenting here is the work done so far on the fourth step of our graphics program, 3-D graphics. In point of fact, 3-D projections, as analogical representation, had been incorporated in our studies of Mozan for almost as long as the CAD drawings, their analytical counterparts. As far back as the *Mozan 1* volume there is a chapter (done in association with the architecture department at UCLA) involving a 3-D reconstruction of temple BA.[4] We began both the CAD and the 3-D at such an early stage (1984) because they are two aspects of graphics that only a computer can accomplish. It must be noted that the pertinent chapter in *Mozan 1* was already introducing a system geared toward reconstructing alternative three-dimensional projections of buildings based on their architectural footprints. Its usefulness was limited, however, by the fact that it was available only on mini-computers, and thus not on a day-to-day basis during our work in the field.

Concerning the CAD, only a computer can draw a map based on coordinates without changing them; a human architect, even if just subconsciously, perfects the drawing, and this is the "aesthetic correction." With regard to 3-D renderings, only a computer can construct a model of a building and display the exact same building from any angle. This is the essence of what "virtual reality" predominantly means: the virtual co-presence of all fields of vision from any point of view.

My work with 3-D graphics began with a documentary film produced for television[5] on our excavations at Mozan, specifically the AK building. Some 3-D animated walk-throughs were needed to give shape to the structure as we had reconstructed it. A decision was made against contracting the animation to an outside firm in favor of having one of the expedition members produce the necessary sequences, as well as specific individual images. A reason for this was to maintain as much interaction as possible between the technical and the archaeological dimensions, and especially to develop tools that could continue being used interactively in the field. Now that technology has advanced enough to allow us to bring the capability to the field, we can build 3-D models of what the buildings might have been like in antiquity, and use these models as tools in defining our excavation strategies on a daily basis as called for by the field situation.

How 3-D Models are Created

The computer builds 3-D images by combining and modifying simple solid shapes; this allows us to create a "virtual" 3-D model of the excavations in the computer. Once

[4] Giorgio Buccellati and Andrea M. Parker, "Computer applications," *Mozan 1: The Soundings of the First Two Seasons*, Bibliotheca Mesopotamica 20 (Malibu: Undena 1988), pp. 100-104.

[5] This documentary is being produced for the *Televisione Svizzera Italiana* by Loris Fedele of TSI and Rick Hauser of Beyond Broadcast; the director is Rick Hauser. The project is a collaboration with IIMAS - The International Institute for Mesopotamian Area Studies, under the direction of Giorgio Buccellati and Marilyn Kelly-Buccellati.

the computer has created the model, a camera can be positioned at any angle within the program to create a corresponding picture of the model. This is much like building a model from wood and then taking slides of it to use for a presentation. There are, however, many obvious advantages to using the computer. The most important one is that we are able to modify the model quite quickly. This is critical in the field where, in order to use the model as a tool in shaping excavation strategy, we need to change and adapt the model as both our understanding and progress in the field change.

The ability to create in the 3-D model the projections we envision allows us to examine the excavations in a way that no 2-D representation can. Descartes suggests that while the human mind can imagine a triangle or a pentagon, it cannot imagine a chiliagon (1,000 sided figure).[6] When archaeologists see a floor plan, they try to imagine the building in space. But if the mind cannot create a complex 2-D figure, how can it even imagine a highly complex 3-D figure? A computer model helps the viewer see the building in three dimensions through images of the virtual model, or, even better, through an animation. In this way the viewer does not have to create the 3-D building in the imagination, but has only to assemble the building from the images produced by the computer. (I will come back to this in the section on Animation.)

A 2-D representation with hypothesized walls is used to project excavation areas that will prove or disprove the hypothesis presented in the drawing. A 3-D plan, above and beyond that, allows us to have a spatial visualization and an interactivity that the 2-D plan does not. It is possible to begin with a 3-D model of the excavated area, add the unexcavated tell around the excavated area, and then place hypothetical walls inside the unexcavated portion. When the whole is displayed, not only is the excavated area shown, but through the semi-transparent tell surface the hypothetical walls can also be seen.

After the object is created, any perspective is possible, showing the hypothetical walls from floor level within the already excavated portions, allowing us to see the rest of the projected building through sections that are now semi-translucent. We can also reveal the projections between two units that are not contiguous, not only in two dimensions, but also in a third. All of the projections can be changed or shown as excavated very quickly, preserving even all the same camera angles, allowing us to compare old projections with what has been discovered.

[6] René Descartes, *Meditations on First Philosophy*, John Cottingham, Robert Stoothoff, and Dugald Murdoch, Eds. (Cambridge, England: Cambridge University Press, 1984) paragraph 72.

The object that we have created is now "virtually" real. It exists not in space the way a building does, but it exists as an analogy of a building. This analogy allows us to change the point of view and field of view however and whenever we want. A good example is a musical compact disk as compared to a live concert: at the concert there is a depth and an ambiance that the compact disk cannot recreate, but the disk has portability and accessibility (one can listen at will and isolate individual segments as desired). The comparison suggests one more point in favor of 3-D models: while the stereo channels in a musical disk are limited, so one cannot isolate individual instruments, a virtual reality 3-D model allows inspection of even the most hidden corner. The virtual model is very convenient because it can be modified spatially and studied, whereas the physical building cannot. If a building had been destroyed, it could be reconstructed again in virtual space, without ever damaging the excavation. What if it had a second story? That could be easily added, and in seeing the building with two stories in 3-D, the archaeologist might have a better idea of where to look for evidence of its existence. In this way, the virtual building can be what the real building was once (or a reconstruction that we can change as new evidence comes to light) but will never be again as a physical structure.

Animation

One of the drawbacks of the 3-D model is not in the model at all, but in our ability to perceive it. Let us first ask how the mind perceives space. Of course, the impressions of space must be tied to the impressions the mind gets from the senses. Since computer animation deals only with sight, I will leave aside the impressions from the other senses. The question then is: what are the impressions that the eyes give to the mind, and how does the mind then create an idea of space from them? First, humans have stereoscopic vision (i.e., two eyes), which gives the mind two two-dimensional perspectives on the same object simultaneously.[7] Stereoscopic vision allows the mind to compare the data separately from each eye and, through the subtle differences in angle, determine how far away an object is. This works well up to a point, but human eyes are so close together that after a certain distance the difference in not discernible. The second method is

[7] The idea that each eye sees only a two-dimensional image goes back as far as Aristotle, who, in the *De Anima* (419a), suggests that objects press on the air as a medium, and the air in turn presses on our eyes, creating a 2-D image.

actually a variation of the first, and is the principle behind 3-D animation. As one moves in relation to an object, the mind remembers the previous impressions given by the eyes, and takes note of the changes between the impressions that were created over time. The movement of the person creates the differences in the impressions, and this change in position is analogous to the distance between the two eyes of the person.

What are these differences that the mind discerns in the sequence of images presented to it, either through the eyes at a moment in time or through the movement of the head over a period of time? The differences that we perceive are the result of how the mind analyzes the input from the visual senses through geometry. The first difference is based on light. When we see a tree that casts a shadow, we can estimate how tall the tree is, since we sense where the light is coming from, and know other objects that cast shadows in the sunlight, and so by comparison one knows the tree's height. The second difference is based on distance. The farther an object is, the smaller it seems in comparison to its actual size. This is the principle behind perspective in art: as an object recedes into the picture, it must shrink relative to its actual size. The third difference is based on position. As one moves relative to an object (or the object moves) our movement causes us to see something different about an object. Based on the distance moved, one knows something about the size and position of the object through the differences in the sequence of images that the eyes created while in motion. Consider a building. You stand in front of the main doors, and all you can see is the façade: the building has no perceptible depth. Move to the corner of the building, and you can see down two sides, the façade and the new face that meets it at the corner. Now you can use the change in distance to see that the second face recedes. Now move a bit farther from the main doors, while still looking down the side of the building. The image changes based on your movement. This gives you an even better understanding of the depth of the building.

With all these data, the mind produces a model of the space an object occupies. This is what happens if you look at a real building or at a physical model of a building.[8] A computer, on the other hand, allows us to see only a screen, and our movement does nothing to enhance our understanding of the space that the model on the screen occupies.

What can a computer model do to surmount this problem of spatial recognition? While we do not normally use the computer to form physical objects, creating three dimensions

[8] To a certain degree, this idea of spatial recognition can already be found in such early thinkers as Descartes in the *Optics* (paragraph, 137-140).

in real space as a physical model can, we can create three dimensions as a projection over time, through animation. An animated sequence allows the computer modeler to give an audience the sense of three dimensions by aligning a variety of different points of view, simulating the motion of a person around an object. By "flying" around the model of a building, the human eye gets the same impressions it would if the person was walking around a physical model—the computer technician merely creates the model as a series of images over time, rather than as a body in space.

There are of course limitations to a computer model. One is that the viewer, because the model is temporally presented and not spatially, has no choice as to what to look at or for how long. This is a definite disadvantage, to be sure, but it can also be an advantage. Models are often confusing in their complexity, and, if accompanied by a speaker or a tape, the listener is never quite sure what part of the model the speaker is talking about. In computer animation, the preset motion of the camera can "point" to a specific area merely through the action of its motion. In a film, when the camera follows a person in a crowd from far away, we understand what the object of the shot is very quickly, because it is in the center of the screen throughout the movement of the camera. The same principle can be true for computer modeling: the camera can pick out a specific feature within all the architecture by placing it in the center of its motion.

The limitation just described applies to fixed-format sequences as found in a motion picture, because in this case the viewer cannot interact with the animation. The computer modeler, on the other hand, can stop and move back and forth over a sequence and study a particular portion. This is how we pick what views to show in the documentary, but it is also a valuable tool available on most computers. When the animations are viewed, the movie can be stopped at any time, and one can go back and forth frame by frame. An archaeologist in the field can use this to study a sequence to understand the connections between the pieces, and make projections as to what might be found nearby.

Borges "reports" a cartographic experiment whose aim it was to produce a map that was on a 1:1 scale, reproducing the surface of the earth exactly.[9] He meant it as an ironic joke, but with the computer this is no longer so far fetched or impractical. This is the second major benefit of using the computer: we can change the scale of the model. Not only can we see a building in relation to the rest of the site in an aerial view, but we can also walk through the building as if we were the archaeologist walking about.

[9] J.L. Borges and A.B. Casares, *Extraordinary Tales*, transl. A. Kerrigan, London: Souvenir Press, 1973, p. 123.

Analogously, "dynamic" maps can reproduce the landscape in a certain area, for instance in order to calculate the effects of dams on the region.[10]

Illustrations

In Fig. 1, some images are taken from "virtual" cameras in the 3-D modeling program. These stills show different views of the same model: the virtual reconstruction of royal building AK at Mozan/Urkesh (see above, Chapter 3; see also *PDS* 2.1-3).

Let me begin with the 2-D floor plan (see also *PDS* 2.1). Superimposed on the floor plan are arrows corresponding to the camera angles used to take the four views of the virtual model. With frozen images of the model it is important to have a floor plan to refer to for orientation; in animations, however, this is less critical. First of all, the motion of the camera gives the viewer a sense of direction, and secondly a floor plan can be simulated with a camera placed directly above the model looking straight down.

The first image is a view looking south along one of the main walls of the building. One can see the doorways that lead from the central corridor to Sectors A and B, as well as the mirror architecture reflected over the center wall that divides the two sectors.

The two images on the right-hand side of the first page (see also *PDS* 2.3) are two shots taken from the southeast with the same camera, but one with the projected walls and the second with the excavated portion surrounded by the tell surface. The juxtaposition of the two can be used to demonstrate many aspects of the building. First, it demonstrates the excavated area in proportion to the projected area. Also, the images give a sense of space that allows us to examine circulation patterns and function with more ease and greater understanding. The juxtaposition of the two allows us to demonstrate the transition from known to projected, in terms of circulation and function.

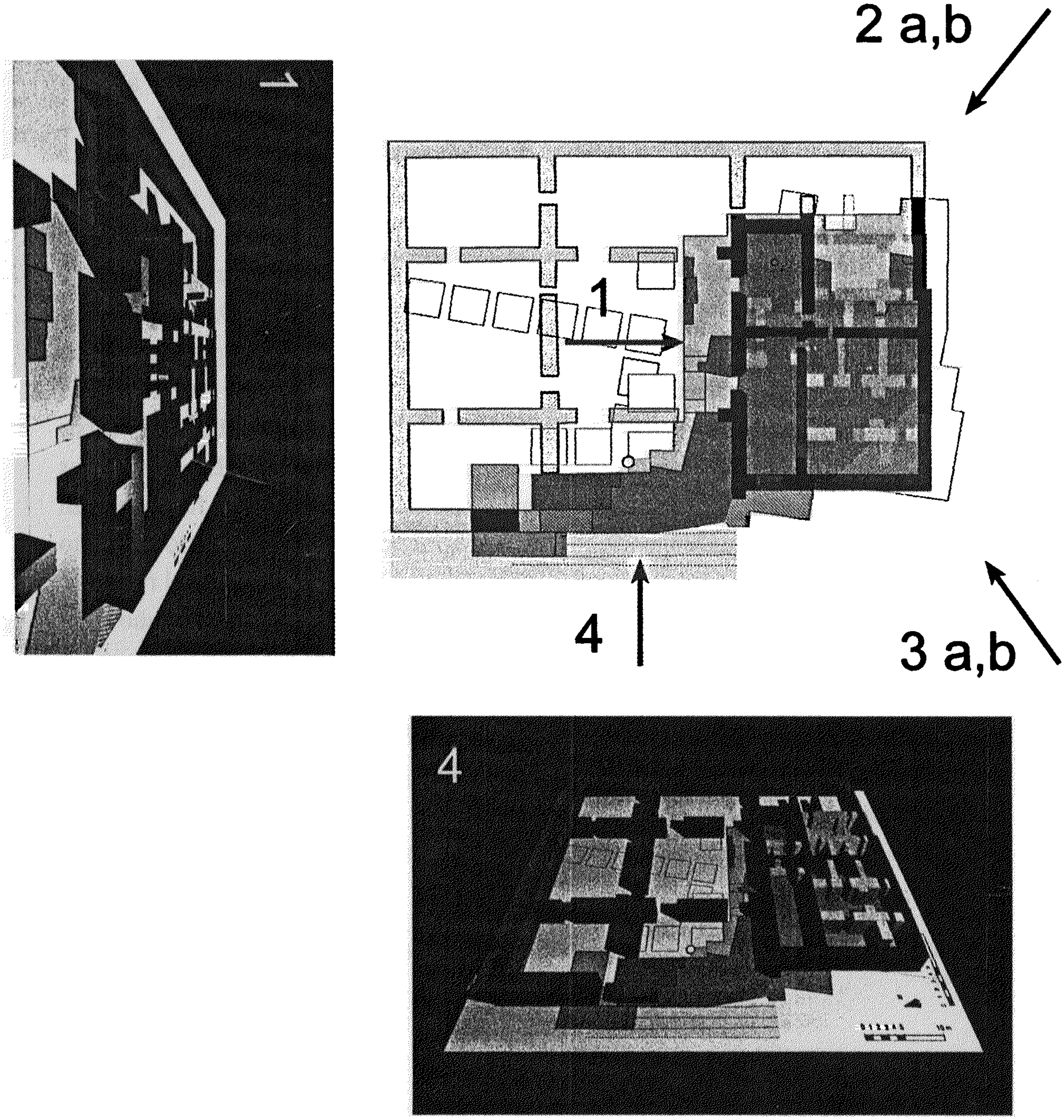
The two illustrations on the right side of the second page (Views 3a and b) show the same camera angle, but one is of the 3-D model and the other is of the actual excavation. Each illustration gives the reader a particular understanding that the other cannot. The digital image is an interpretation that allows the archaeologist to isolate and highlight the architectural elements that together make up the building. The photograph, on the other hand, is taken from a hydraulic platform at the site a week before the end of the excavations of the 1997 season. It shows the walls as they were found, and so is not an

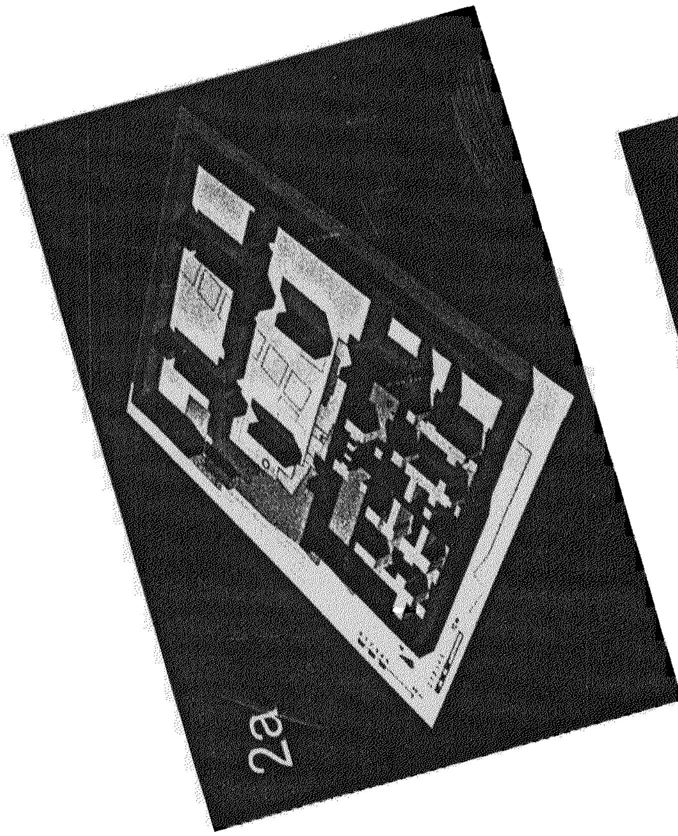
[10] John Noble Wilford, "Revolutions in Mapping," *National Geographic*, 193/2 (February 1998), pp.12-15.

Fig. 1 A system of renderings organized to convey the concept of a 3-D model

These illustrations are still images taken of a "virtual" 3-D model. Arrows on the floorplan show the orientation (in the X,Y plane) of each virtual camera that took the pictures, while the pictures themselves are positioned so as to be in the direction of the camera axis. The orientation in the Z plane varies in each view. The axial orientation shown on the floorplan helps imagine the layout of the building in three dimensions, if one considers the virtual photos as "windows" onto the 3-D model and the floorplan as another photo taken from directly overhead.

View 1 gives the impression of the size and the layout of the building, especially of the two "vaults" in the foreground. View 2a shows the building with the projected walls, while view 2b shows only the excavated part with the tell surface around it. Views 3a and 3b contrast the 3-D model with a photograph taken of the physical excavations. View 4 shows what the projected doorway looks like in relation to the service areas that have already been excavated and the projected sectors to the north and east.

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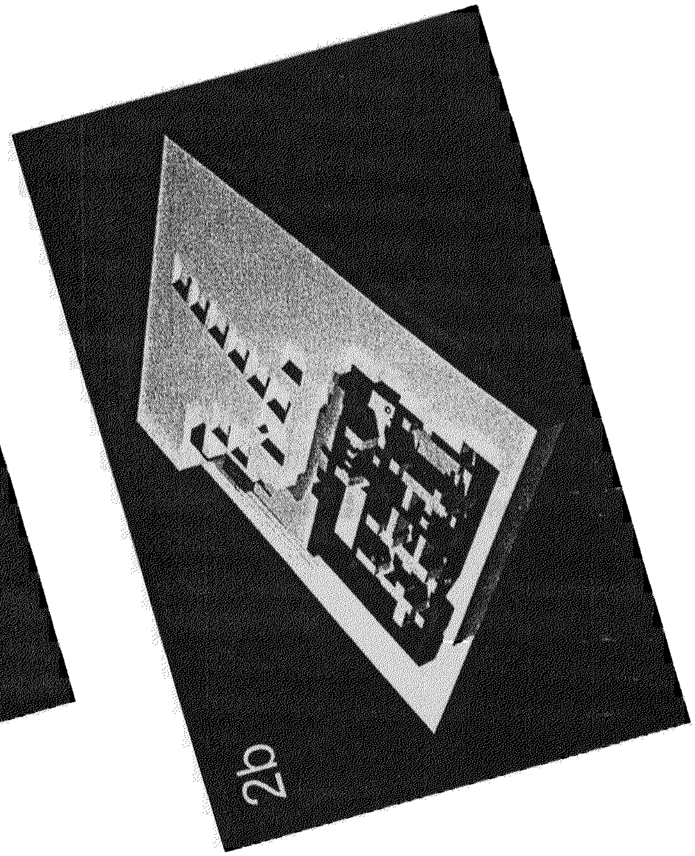
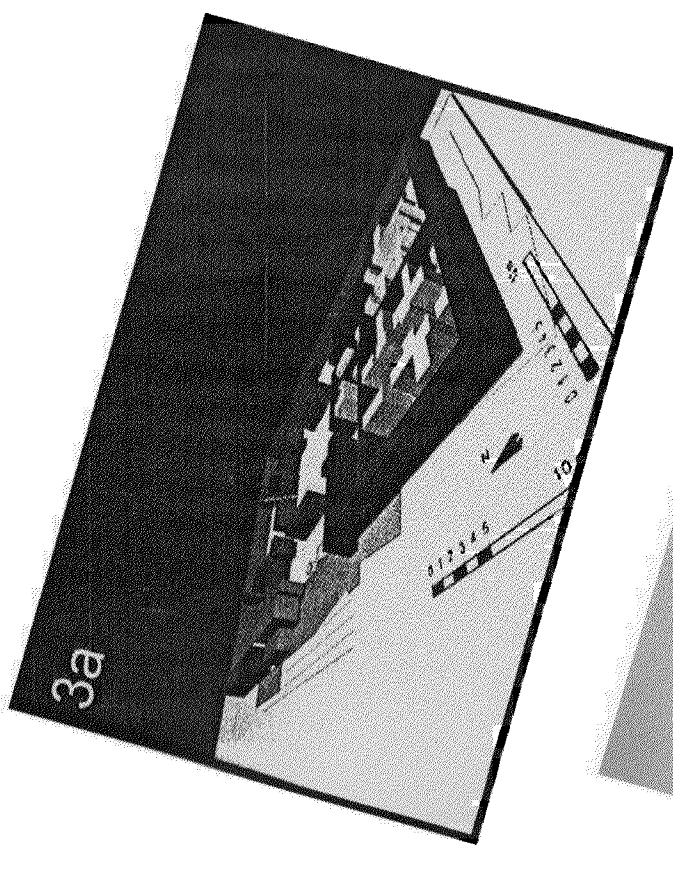

2b


3a
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interpretive illustration but a documentary one. Not only do the two illustrations allow the reader two different understandings, but each illustration helps the reader understand the other. The image helps to isolate the walls from other elements that may otherwise be difficult to distinguish, while the photograph shows what has actually been excavated and the material with which the walls were constructed.

The fourth view (see also *PDS* 2.2) shows how the virtual model can be used as a tool for excavation, not just presentation. This illustration is taken looking east, and shows the area that seems to be the main entrance to the AK building. The portion of the building that has the floors shaded and lighter internal walls is the excavated area, while the portion around it with the white floors and only the main sector walls is the current projection of the building.