VIRTUAL RECONSTRUCTION OF ARCHAEOLOGICAL SITES SOME ARCHAEOLOGICAL SCIENTIFIC CONSIDERATIONS

Avdat Roman Military Camp as a Case-study

Sorin Hermon
Archaeological Division, Department of Bible and Ancient Near Eastern Studies
Ben-Gurion University of the Negev
Beer Sheva, ISRAEL

Peter Fabian
Department of Bible and Ancient Near Eastern Studies
Ben-Gurion University of the Negev
Israel Antiquity Authority
Beer Sheva, ISRAEL

Imagination, or visualization… has a crucial part to play in scientific investigation. René Descartes 1637

The paper discusses some archaeological scientific implications of virtual reconstruction of archaeological sites, using as a case-study an animated 3D model of the roman military camp at Avdat, Israel. The critical discussion will explore and evaluate the potential of using 3D VRM (Virtual Reality Models) as a "daily" tool for the archaeologist, both during the excavation, consolidation of conclusions and for the presentation of its final results. The main argument to be stressed is that the impact of a "real", 3D visualization of archaeological data influences, and drastically improves, the understanding and the analysis of archaeological data, adding the third (and sometimes fourth) dimension to the archaeological explanation, and the need of the archaeologist to cope with it, thus opening new horizons of research, posing questions raised during the process of conceptualization of the 3D model.

1. THEORETICAL BACKGROUND FOR THE USE OF VISUALIZATION TECHNIQUES IN ARCHAEOLOGY

In order to understand the complexity of the real world, people draw pictures or build abstract descriptions, or **models**, in order help them understand problems. By selectively and carefully omitting details and including just the relevant factors, a model can provide a useful tool for understanding a particular problem. However, a model has a value only when it can provide insight on some situation, that is to answer a specific question, and the model **is** analyzable, *i.e.* accessible to critical evaluation (JONES 1996). Visualization tools can have two major uses: interpretive and expressive (GORDIN, EDELSON and GOMEZ 1996). Interpretive tools help users to view and manipulate visuals, extracting meaning from the information being visualized. Interpretive visualization helps to clarify difficult-to-understand and/or abstract concepts, making them more comprehensible (LEVIN, ANGLIN and CARNEY 1987). Expressive visualization helps users to visually convey meaning in order to communicate a set of beliefs. In this sense, visualization uses designed representations to help people understand complicated problems (in a way, it simplifies the process of understanding, it optimize it). Visualization tools and techniques (see NIELSON, HAGEN and MÜLLER 1997) enable scientists to explore their research data (in this case, collected during the process of excavation), to gain new scientific insights (new archaeological questions raised during the visual stimulus of the 3D VRM) and to communicate their discoveries to others (presentation to the public). Visualization helps to clarify what exists or to **change** the way scientists think. Since more than 60% of our mental processing power is devoted to visual processing and since once complex images are made visual, they can also become mobile, immutable and reproducible (LATOUR 1986), scientific visualization of archaeological information would improve dramatically the scientific interpretation of archaeological data.

Visualization allows the conversion of information that cannot be perceived by the human eye into forms suitable for this most highly developed human sense (BROWN 1997). It is invaluable for changing data into information (formulating conclusion from the raw archaeological material excavated), designing products (the archeological excavations) and supporting complex decision making (evaluation and interpretation of the archaeological information retrieved). Researches in cognitive psychology described how the "visualization ability" (the ability to manipulate or transform the image of spatial patterns into other arrangements, see EKSTROM, FRENCH and HARMAN 1976) improves by using better visualization tools (SEIN, *et al.* 1993) and thus perceiving the information in a more appropriate way. The implication is, the better the visual tool, the better the explanation and the interception, in our case of the archaeological information.

Visualization systems must provide feature-based tools that let the user extract regions, then visualize, measure, classify, abstract and track their revolution. The goal is to produce an image, automatically analyze and recognize objects in a scene and reconstruct a model (JAHNE 1991). The success of visualization for a problem-solving project depends on the task to be accomplished, the people involved and the representations formats used for the task and the people. The tasks involve a series of stages, or steps, modeling a *life-cycle*, a concept based on the idea of a model for **decision making** called Intelligence-Design-Choice (NEWELL and SIMON 1960). The intelligence phase consists of gathering information in an attempt to understand the nature of the problem. The design phase consists of constructing alternate solutions to the problem (solution analysis). In the choice phase, one or more of the alternatives are selected and presented. The final step will be the **implementation** of the solution. It is argued in this article that visualization of 3D VRM aid in all three phases of decision making in the archaeological research.

Much of what is labeled virtual reality today consists merely of three dimensional scenes displayed on a standard computer screen, with the user able to interactively explore the three-dimensional world, models being build on 360° photographic images (see also VRML). In essence, the goal of virtual reality is to synthesize stimuli that produce a realistic illusion of another world (JONES 1996:120), or to develop a virtual environment that is presented in such a way that the user perceives as real (ROSENBLUM and CROSS, 1997). This realism is more than graphical, since objects **must** act in physically appropriate ways. Three key issues are required from a virtual reality system: *immersion, interaction and visual realism* (BRYSON 1992). Since we, archaeologists, are trying to "reconstruct the past", our daily activity involves an "immersion in time", in order to understand our data. Thus, "visualization of the past" would be an integrated part of our scientific work, by its definition itself. The interaction of the user with the virtual environment should be balanced between rapid rendering speed (the displayed view must be updated quickly) and low control lag time (smooth tracking of input devices), based on the scientific archaeological needs, for an optimal exploration of the archaeological VR under investigation. The third issue is almost self-evident: the level of fidelity of the VR should be sufficient to "fool the user" (ROSENBLUM and CROSS, 1997), in order to provide maximum information by the visualization, which should be "as real as possible".

Another key issue of visualization is related to its potentiality in facing, accessing, managing, interpreting and sharing increasing amounts of information being generated by any (including archaeology) scientific field. Artificial reality environments (3D visualization, modeling and virtual reality) have a yet not entirely estimated, but probably immense, impact on our ability to assemble information from continuously increasing databases (TUFTE 1990). A potential goal of scientific visualization (FRIEDHOFF and BENZON 1989) is to represent data in ways that makes them perceptible, and thus able to engage human sensory systems. In this sense, the merging of several types of archaeological information (drawing/photos of sections, artifacts presented in their real spatial position, etc.) into one means of data-communication and representation (the 3D model) would drastically increase the manipulation of a large amount of archaeological information. The three main ways in which visualization can help us manipulating data are: **selective emphasis** (detection of previously hidden patterns by highlighting certain features of data and suppressing others), **transformation** (conversion of non-visual data into a visual image by mapping its values into visual characteristics – applicable in pattern recognition) and **contextualization** (provision of a visual context, or framework, within which data may be displayed) (ERICKSON 1993:5).

A key point of visualization (especially volume visualization, of 3D volumes) is the ability to **simulate *scientific*** phenomena (potential reconstructions extracted from the archaeological data) based on scientific rules and constraints, enabling the steering of experiments or simulations as they happen (during the process of archaeological excavations). An important application of visualization is in the interpretation of accurate prediction and understanding of experiments or numerical simulations, in order to recognize new phenomena (SILVER 1995). In this context, there are several simulations of archaeological issues applicable in the domain of visualization: simulation of possible shapes of architectural reconstructions of archaeological features, contextualization and presentation of spatial distribution of archaeological features of material culture, in order to understand spatial organization within the site or evaluation of synchronicity of structures or simulation of destruction processes that might have had occurred at the site.

2. DESCRIPTION OF THE ARCHAEOLOGICAL SITE OF AVDAT

The archaeological town of Avdat (NEGEV 1997) is located in Southern Israel, along the ancient spice route connecting the vast Arabian desert and its spice sources to the Gaza harbor and from there Europe, as a final destination for these spices (NEGEV 1966). It is part of a chain of Nabatean-Roman-Byzantine cities, as Nitzana, Shivta, Rucheibe and Mampsis (Figure 1). Earliest remains at the site may be attributed to the Nabatean period; the site flourished during the Byzantine period and was deserted prior the Arab conquest of the region. Two major earthquakes heavily disturbed the life of its inhabitants, the first in 363 AD, causing a temporal abandonment of the site in the Late Roman period and the second one in 633 AD, being fatal to the existence of the town (FABIAN 1998).

The site is located on the edge of Mt. Aqev, 619 m. above sea level, in the Negev desert of Southern Israel. Large potential

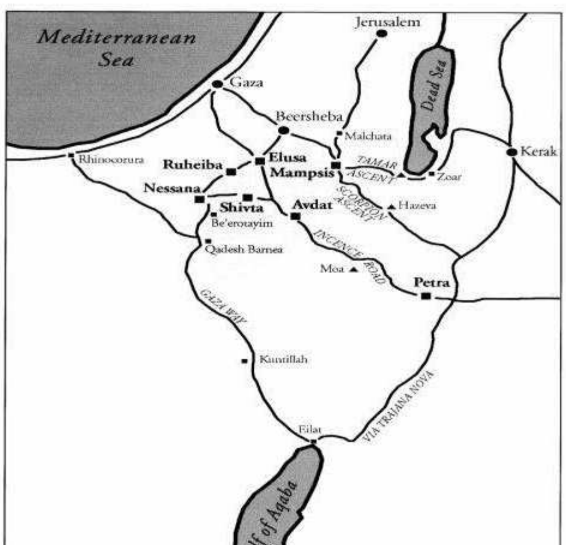

Figure 1. *Map showing the location of the ancient town of Avdat and other contemporaneous Late Roman-Byzantine towns in Southern Israel and their connecting routes.*

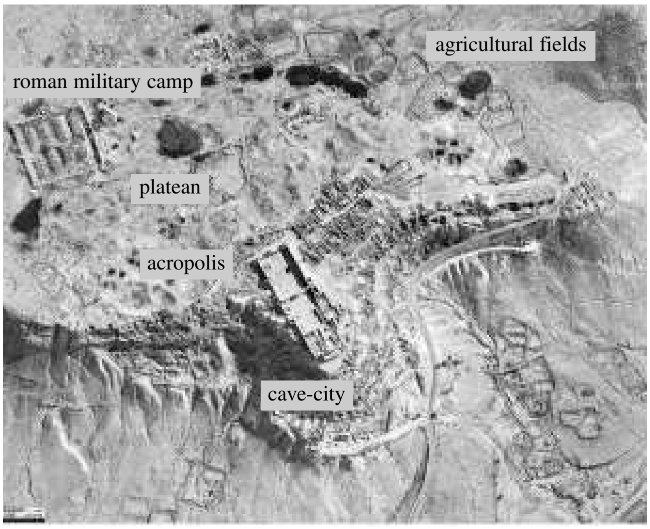

Figure 2. *Aerial photo showing main areas and architectural features of Avdat.*

agricultural fields, exploited with a dam system lied along the large basin of Nahal Zin, are discernible on the area south of the site. The remains of the settlement may be roughly divided into three parts: the "acropolis" in the center, the plateau on the east and the "cave city" on the western slopes (Figure 2). Roman period remains were uncovered on the acropolis and in the plateau area east of it, a loosely organized, non-walled Early and Late Roman settlement. It is characterized by large residential units scattered over a large area without evidence of central planning. A temple of Zeus-Oboda stood on the western edge of the plateau. The type of collapse in the Late Roman structures suggest that their destruction was a result of the 363 CE earthquake, well documented in Petra and Jerusalem.

The roman military camp (Figure 3) was erected in the Early Roman (1st century AD) period and was probably dismantled with the Bar-Kochba rebellion (WERNER 1999) in the second century AD. Its founding may be attributed to the need of military control over the spice route leading from Arabia to Gaza, following the falling of the Nabatean kingdom and the establishment of the Roman province of Arabia Felix. The soldiers dwelling at the site may have had

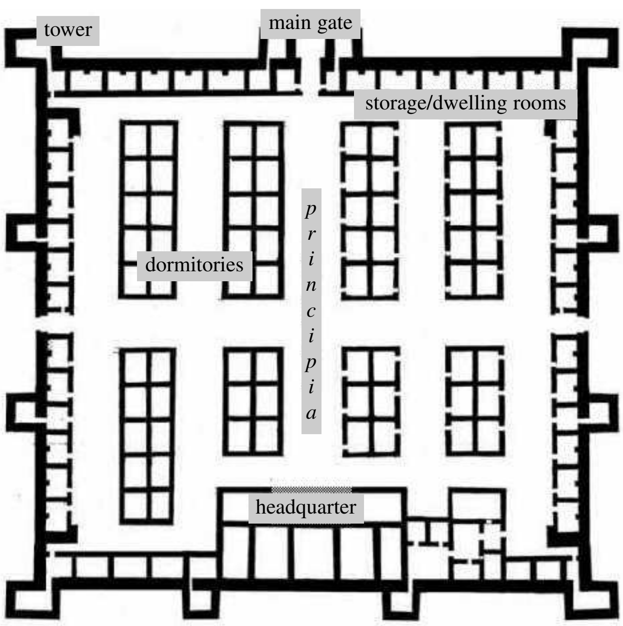

Figure 3. *Plan of the Roman military camp after excavation.*

belonging to the 3rd legion Cyrenaica, more precisely to the 6th Cohort *Hispanorum*, as testified by a small statue with an inscription on its base, found in one of the military strongholds along the spice route, not far from Avdat (FIGUERAS 1992).

The size of the camp is 100 x 100 m: a square building with 12 towers along its surrounding walls. Along the walls, 36 enclosure rooms (dwelling or storage) are clustered in 6

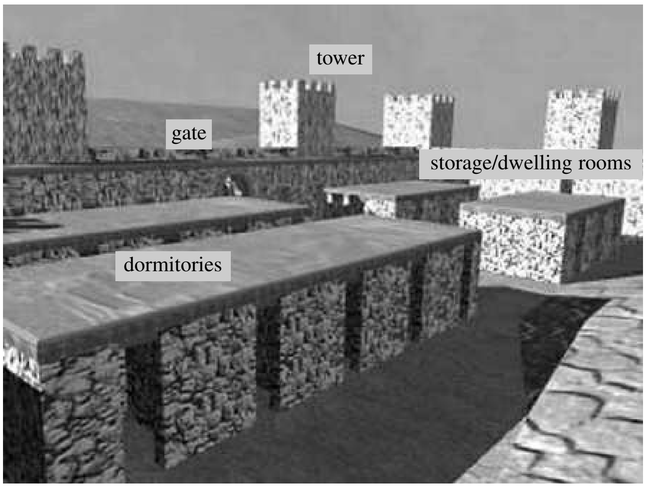

Figure 4. *Partial view of the 3D reconstruction of the roman military camp.*

groups. There are 5 clusters of 10 rooms and 3 of 6 rooms. Each room has standard sizes of 3.8 x 5.2 m, being dormitories of probably 8 soldiers each (Figure 4). The uniqueness of the site is reflected in its nature, as a permanent camp for a standard roman cohort of ca. 500 soldiers and in its singularity, reflected in its excellent state of preservation and internal organization (FABIAN in prep. 1).

3. DESCRIPTION OF THE 3D MODEL OF THE ROMAN MILITARY CAMP

The animated model was created with 3D Studio Max program, using existing photos and plans prepared prior, during and at the end of the archaeological excavation of the site. The texture of the walls and pavement is based on the texture of the wall stones of the architectural remains, as extracted from the photos. The sizes of the rooms' walls were estimated according to the amount of collapse and its orientation, as found during the excavation. The camp was probably abandoned in an organized way by the roman army and left intact in ancient times, without evidences of stone robbing. The general pattern of collapse suggests a dynamic destruction, probably the result of an earthquake. Therefore, the amount of stones found on the floor, their orientation and their sizes and the preservation of the walls of some structures served as a base for calculating the original height of the structures' walls.

The morphology of the roofs was estimated according to the width of the rooms and the architectural remains – since no arches were found, the roof was probably supported by horizontal beams and mud-brick filling (Figure 4). Further support for this reconstruction is found in the layer of collapsed and melted mud-brick material found on the floor of the rooms. This layer contained probably also remains of the plaster material covering the interior sides of the walls, otherwise built entirely of stones. The preservation of the size and morphology of some walls enabled the

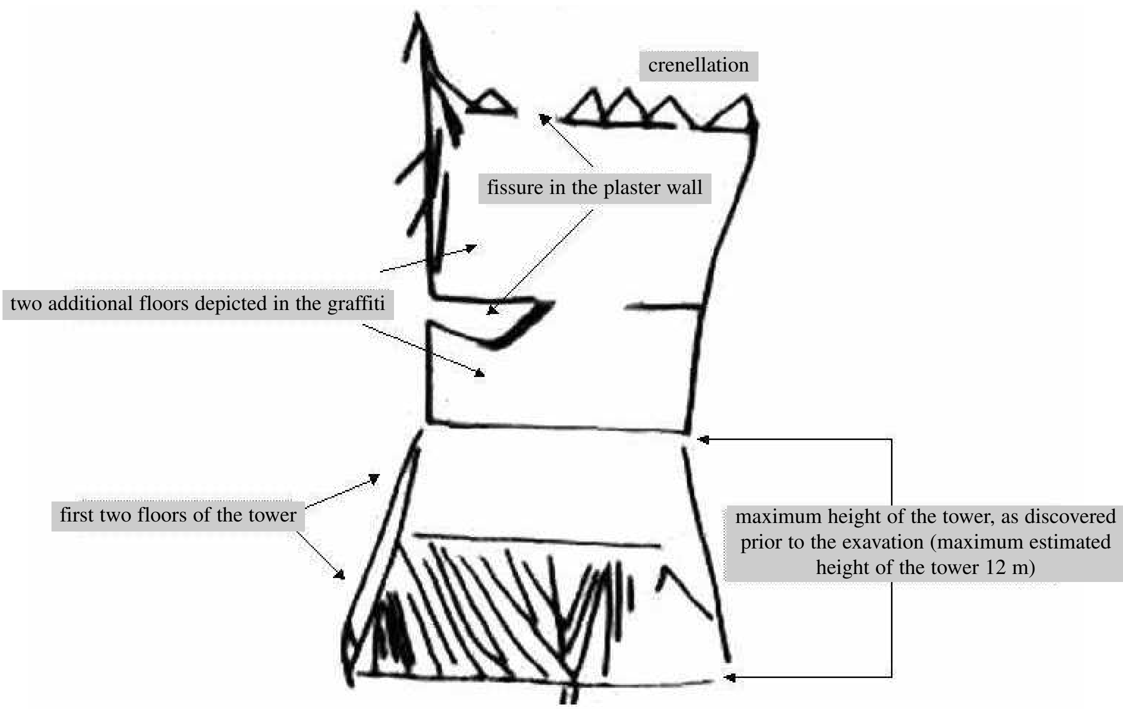

Figure 5. *Graffiti found on the wall of a nearby fortified building depicting most probabily its tower.*

reconstruction of rooms without any windows, the ventilation being obtained through the door openings. Since these rooms served as dormitories, the main activities of the soldiers being performed outside, the absence of windows should not be surprising.

The shape of the towers and their height could only be estimated. Crenellation was assumed that existed, according to a graffiti found in a nearby military stronghold (Figure 5), belonging to a same period, depicting a roman soldier and a schematic representation of a tower (FABIAN in prep. 2). There is no evidence for windows along the walls of the towers; the access to the towers' roofs was probably done through a system of wooden ladders, since no stone steps were found inside the towers. The roofs of the raw of rooms adjacent to the surrounding walls (described as storage/dwellings) could have been used as patrol trails, and thus the exterior walls were higher than the top of these rooms (Figure 4). This suggestion is supported by the presence of stone steps found on the interior parts of the surrounding walls, adjacent to these rooms and in proximity to the towers.

Finally, the model was completed by adding the different entrances and main gate, pavement along main streets and the headquarter building. The animation of the model enabled merging real pictures shot during various stages of the excavation with the final plan of the site and the virtual reconstruction, viewed from different angles. Thus, a "realistic" model of the site, combining its history of excavation and its final result with the virtual reconstruction, could be observed from different angles, "flying" in time and space throughout the area of the site.

4. DISCUSSION AND CONCLUSIONS

The application of visualization methods in archaeology is usually limited to the final stages of archaeological data interpretation, mainly after the conclusion inference stage, for the presentation of large architectural features, in the shape of virtual reality models used especially for the wide public or in education. Thus, most of the visualization applications are used for the presentation of data, visualizing past monuments, rather than during the process of data analysis, even though visualization is mostly used during the process of understanding the data (see above), and not merely as an artistic tool. This issue was clearly stated by MILLER and RICHARDS, who concluded that: "…the catalyst for visualization in archaeology has not been the search for improved techniques for discovering new knowledge but rather for improved ways for presenting existing knowledge to the public" (MILLER and RICHARDS 1995:19). However, the above-mentioned authors did not recognize the embedded potential of visualization techniques for the scientific archaeological research, their main concern being only in the danger of "manipulation of audience" and "give large number of people access to the past", which could have been manipulated by the "custodians of heritage" (MILLER and RICHARDS 1995:21, also see FRANCISCO, THOMSON and ROSCH 1991). Moreover, since people seem to prefer to work with their problems using representations they already know, often basing decisions on an initial starting value rather than on a "rational" exploration of the entire range of alternatives (KAHNEMAN, SLOVIC and TVERSKY 1982). Thus, they are less reluctant to adopt a "new" method, as the frequent, constant use of 3D VRM, "sticking" to "traditional" methods of 2D perception, presentation and interpretation of archaeological data (even though in most cases, the data itself is three-dimensional). Since the main goal of this paper is to propose the use of visualization techniques during the process of conclusion inferences from the archeological data, suffice is to say at this moment that in any case, the "objectivity" of any scientific result and its publication depend on the publisher itself and his commitment to a scientific, "objective" work, not always traceable.

In opposition to the previously quoted opinion regarding the applicability of visualization techniques in archaeology (MILLER and RICHARDS 1995), several applications of visualization and virtual reconstruction in the archaeological scientific research were presented in past years (PETERSON, FRACCHIA and HAYDEN 1995, CHALMERS *et al.* 1995, FORTE and GUIDAZZOLI 1996), just presenting a few, culminating with the publication of a comprehensive book relating the use of scientific visualization in archaeology (BARCELLÓ, FORTE and SANDERS 2000).

Following the experiment conducted by us regarding the virtual reconstruction of the roman military camp of Avdat, and the theoretical background presented above, several key issues were raised regarding the application of visualization tools in the process of archaeological explanation:

One of the main advantages of visualization is, by its definition, its high visual stimulus – since archaeologists are interested in the reconstruction of the past, and traditional representation of archaeological data is bi-dimensional, a large part of the discussion and debate concerning the interpretation of the excavation remained untouched, or, moreover, non- percept. Only during the process of creating and analyzing the 3D model, new questions, as the presence/absence of windows in the peripheral towers of the camp, the access mode to the towers and roofs of buildings, the height of towers and the angle and distance of the view-point of guardians in the tower, aroused and were debated. Moreover, questions regarding visibility, related to light intensity, could be simulated and discussed during the preparation of the 3D model.

An important issue in the interpretation of spatial organization of sites with multiple structures is clarifying their contemporaneity in time. In traditional methods, one of the more common possibilities to establish their chronological relation is by analyzing their cultural material remains. However, this method may hint only for a similar culture and not time-synchronicity, an important issue regarding interpretations concerning intra-site organization, economy, social organization, etc. "Raising" the buildings of the roman military camp to the third dimension, questions as possibility of passage between structures, accessibility to a possible second floor or illumination of rooms could be discussed. Moreover, through simulation of possible spatial distributions of structures, questions regarding the existence of several stages of construction, architectural corrections or diachronic changes were discussed in a more efficient way.

Another problem faced with the aid of the 3D model was the simulation of possible destruction processes, raising or "destroying" walls, in different directions, by different intensities and by various processes, dynamic (earthquake, flood, human interaction, etc.) and static (erosion, natural collapse due to deterioration, etc.). The simulated results were confronted to the data retrieved during the archaeological excavation. Thus, the simulation aided to the understanding of the formation processes of the archaeological site and post-depositional processes that activated at the site.

Finally, the possibility to rotate the model and observe it from different angles eliminated the problem of dead-angles existing in a static, two-dimensional drawing. Thus, more information could be presented, the possibility to view the model from any orientation widening the discussion upon its interpretation.

Several other applications and uses of 3D models are available in various fields related to archaeological data: VIM (Virtual Information Management – the model can be used for image analysis and processing, storing and extracting from it desired features), digital archiving, the model containing digital information, linkable to existing data-bases, both numerical or visual (pictures of objects, drawings of sections, etc.) and presentation of the model through the WWW, both for education and popularization of science, and also for Cultural Heritage Management.

Thus, our final conclusion from this experiment is that working with a 3D model widened our sphere of research, aiding in both answering existing questions, but also posing new questions for research, expressed during the process of building and analyzing the model. Therefore, we may conclude that there is a need for a change of concept in the perception of the archaeological explanation – there is a need for the incorporation of a "real" reconstruction of the past, and "virtual reality", or 3D visualization, are ideal tools.

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