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FROM PLAN TO VOLUME: THE NEED FOR ARCHAEOLOGICAL ANALYSIS IN 3D MODELING

1. Introduction[1]

Before looking into obtaining a complex vision (drawings, models and now 3D models) of available archaeological data, it is necessary to re-introduce a simple vision of these data in archaeology. An approach enabling one to naturally uncover archaeology's real potentials involves studying the data according to their composition, since it is the quality of the original materials of which they are made which allows them to be preserved; accurately understanding data from the past in their former reality; and finally defining what is out of range. What the archaeologist generally fails to understand is that it is necessary to know the material aspect of items should he want to analyze them, since the only evidence left by ancient peoples, other than texts, is of a physical nature. At this level, the technological as well as physical and chemical tools available today do not allow the acquisition of this knowledge by oneself. For the latter to be considered a tool, the archaeologist must first be able to ask the right questions, which is unlikely if, in a field like architecture, the researcher argues by plan and not by volume (Heinrich 1982, 1984) or if he looks upon the social or symbolic aspects of a construction, without first having looked into understanding the structure itself.

As an example, a house is in fact a place where the daily life of a population is expressed: lifestyle, worries, dangers, climatic characteristics, food supply and problems, technical aptitudes, family and social relationships, etc., so much so that the social and symbolic aspects generally prevail. Yet, if the study involves an incomplete monument whose physical limits are unknown, can one really believe that these conclusions will have any value? Discovering the original characteristics of a building is therefore a priority from which social and symbolic analysis will follow, whether it is for a house or any other construction. But in order to be sure to avoid entering into an imaginary world, one must know how to find the clues in the exposed remains, thus allowing a return to the original form while conceptualizing the theoretical limits in which those clues play a role. The evident impossibil-

[1] The text presented here is the result of Prof. J.-Cl. Margueron's thought. The intervention of Dr. J.-O. Gransard-Desmond is due to his work on the Red House at Mari (a significant practical case not developed for publishing reasons) with the preparation of its communication and publication. We thank Carol Osborne for the translation and Janine Hingston and Chris Esnault for corrections.

ity of combining fieldwork with theory compels the authors to stay within theoretical studies in this article, but fieldwork information is available in the bibliography[2]. Geographical and chronological characteristics do not pertain to this methodology. Although the theoretical point of view is based on cases going back to the Near-Eastern Bronze Age, involving mudbrick architecture, the applicable human and physical constraints are independent of time and space. Only the nature of these requirements is subject to modification in function of the country's climate and of the original materials of construction. For example, a mudbrick house does not react to heavy rain the same way as a stone or straw house.

2. Definition of a methodological basis

2.1 *Objectives*

In mudbrick architecture, particularly in the Near East, excavations always uncover incomplete buildings. Often, the height of the remaining walls does not amount to more than a few tens of centimeters, often with the site of the doors marked by installations such as bearings or threshold flagstones, if these were not removed in antiquity. Sometimes, this height can rise to one metre or slightly more, very rarely to two metres, and in one extremely rare case, higher. If a building burned down, some carbonized remains of its structures might still be visible. If a building was abandoned, usually only traces from scrubbing the walls remain. Not one single building has ever been found complete or in a state suggesting that everything about it is known, or even basic information about it, nothing which can compare to the Roman-Byzantine house of Bamuqa in Northern Syria. There, all that was needed was simply to replace the roof beams in their slots at the tops of the remaining walls to reinstall the original roof.

Archaeologists, even those specialized in architecture, generally content themselves faced with the degraded state of old buildings by reproducing only the outline of the walls at ground level without always giving the height of the walls found by using cross-sections or simply altimetric indications. This graphic translation most frequently erases the existence of volume and even removes the depth of the archaeological layer. For example, if one wants to create a representation of a house and portrait of the archaeologist living in it, one would come to the conclusion shown in Fig. 1, that is, the archaeologist reduced, like the wall, to his contact with the floor. What could one make of a man if there was only the outline of his feet? Well, practically nothing! So, what can be known of a building when limited to its contact with the ground?

[2] See Butterlin *et al.* 2006, XVII-XXXI and more precisely the section "Ouvrages" 1982, 2004 and "Articles" n. 71, 118, 128, 133; Margueron 2005, 2009.

Practically nothing. Believing that life can be defined this way is unrealistic, and is not historically truthful. Thus, if one wishes to use architecture in the definition of the ways of life in the past, it is essential to return to its true dimensions, as is done, for example, with ceramics. Can one imagine what would remain of a ceramic object if only its contact with the ground would were represented? However, except for cases where excavation reveals only foundations, i.e. when one finds oneself below the level of real occupation of the building, one can work on this privileged zone which is the contact between the walls and their base, i.e. the place where all the forces emanate from the structure and where the building's stability is ensured. In fact, the walls transmit forces resulting from all the pressures exerted from the top of the building. Their point of support, i.e. the floor, expresses the totality of these forces. This is thus a track which the researcher can follow when examining the floorplan's characteristics, because some of them make it possible to reveal more of the structures, sometimes to the top of the building.

Thus the objective of any architectural study in archaeology can only be to find the original shape of buildings as defined during the excavations.

2.2 *Man, a measurement of architecture*

2.2.1 What is a building?

Before going any further, it is certainly useful to specify the fundamental characteristics of a building, whatever its function might be. Bruno Zevi (1959) has defined any construction as a portion of space issued from infinite space and placed inside a material shell, giving rise to an interior space where its foreseen activity takes place, and to an exterior space in which the closed space is set up. One can thus see the latter in two different ways, either from the outside, giving the perception of its outline and its facades in an open area, or from the inside, where one will then have the feeling of a finite world with visible limits. The building appears then like a box, the precise shape of which matters little at this point of the investigation. However one must wonder why man would build this box. The answer is simple: above all for protection; protection of oneself and of one's family against bad weather and the animal world, protection of property and especially food reserves, and protection against the aggressions of the world and other men, to ensure survival.

Although a building is a fixed point from the world, unlinked to the exterior, this constructed site cannot be a completely closed space: man does not build to be enclosed. Thus, it is a hollow volume which shelters man and/or some of his activities. It is not a sculpture (unless it is considered to be hollow).

If one needs to obtain a good knowledge of the building used by men at a given time in history and in a precise location, one will have to know in a general way:

– its complete morphology (walls, foundations, roof (if any), etc.),
– its internal organization (if any), and particularly the absence or presence of floors,
– the nature of relations between the inside and outside,
– the organization of internal relations horizontally,
– and the eventual organization of internal relations vertically.

Thus, to understand a building in order to use it as a historical source means to have understood all its components as mentioned above, and which will now be presented in detail.

2.2.2 Constraints in building construction

The fact that man uses a building as his base for life implies numerous and various characteristics:

– Man is a being of flesh and blood, with a height[3], a width[4] and a thickness, and thus a volume, and his dwelling (itself a volume defined by its height, width and length) reveals the average unit of men in his ethnic group. Indeed, architecture being made for man, man is the measurement of architecture.
– Man builds a house to protect himself, but he cannot live totally enclosed, as discussed before. As the centre of activities in connection with external space, he must be able to come and go as he pleases, the protective function then requires some access control and openings (doors).
– Man must travel towards the exterior (see above) as well as within the building: this creates specific axes of motion and a hierarchical organization of different spaces defined in the construction; these movements are both horizontal and vertical.
– Man must have light since he cannot go about in total darkness: hence a requirement for light sources, making their installation and a good use of open-air or covered spaces practical obligations.
– Man must breathe, for which reason air vents must be planned, either with openings in walls or in ceilings: a system of ventilation means both are in use. Generally, doors and windows are enough to ensure circulation, but in the event of harmful gases (such as with fires), it is necessary to be able to ensure their evacuation by special openings such as chimneys.
– Man's activity generates by-products that he must dispose of.
– All things considered, man must live in his house: that means eat, drink, sleep, and work in different ways.

[3] Although the hight of rooms with practical use (library, conservation room, etc.) and symbolic use (reception hall, throne area) is subject to other constraints, that of a room for day-to-day life should not be higher than four or five meters, which is even then quite high.

[4] That of the shoulders (an average of some sixty centimeters) being the widest, this already defines a limit under which architecture cannot be suitable if man needs it to evolve.

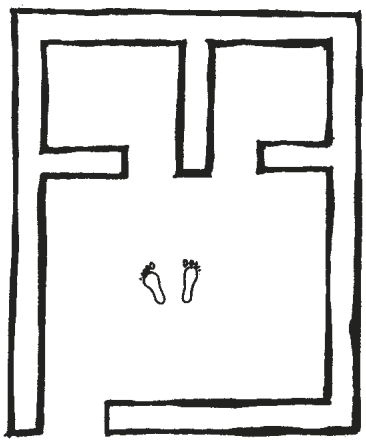

Fig. 1 – In the centre of the first room, a portrait of an archaeologist depicted using the same type of representation as the house he has just drawn (O. Callot).

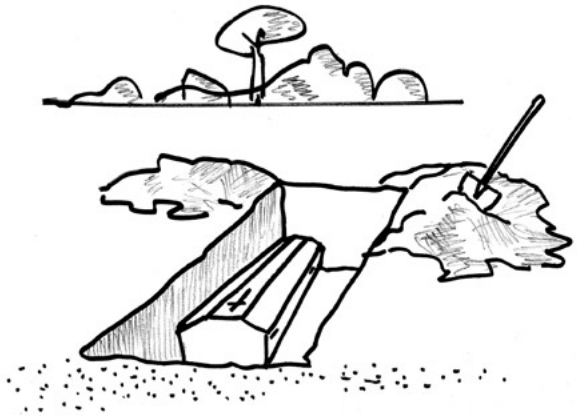

Fig. 2 – A construction cannot be a totally enclosed space unless it is a coffin (Ch. Esnault).

All these facets of man's activity in his chosen space for life, pertaining as much to archaeological analysis as to architectural analysis, must be regarded as parameters able to intervene in an analysis leading to the volumetric reproduction of a building. Without that human approach, the same study would not be related to a building or a living space but to a simple hermetically closed box, such as a coffin (Fig. 2).

2.3 *Analytical elements*

2.3.1 Archaeological analytical elements

The methods of a structure's destruction, and remains other than architectural, constitute the archaeological clues which allow the researcher to understand the construction and the organization of the building. Thus, in the palace at Mari, archaeological observations stressed the presence of varied materials and objects between the walls, with variable heights *in the ruins* filling the rooms (and not only the floors): hundreds of boards (room 5), seals (room 77), fragments of murals (room 220), paved floor elements (room 79) or simply a coating (room 220), baths, etc. From where could such a diverse, possibly miscellaneous stock originate unless from an entire upper floor? How could it be mixed with the ruins, which could only come from a structure, unless it had not been in daily use on that specific floor? Similarly, at Tell Madhur, archaeological clues are to be found within the walls. A large part of these walls only remained upright because they were buried under the ruins of the structure. Yet the volume of these ruins implies the presence of an upper floor, just like at the Red House at Mari. Finally, the last clue is the assessment of the building's collapse.

These three examples clearly show how an archaeological analysis enables an understanding of the construction, but this analysis should not be isolated. Not only should it consider the physical constraints of architecture, but also the documents' relations to each other (seriation and typology).

2.3.2 Architectural analytical elements

Besides the constraints brought forward relating to man's activity, certain architectural notions are important, mainly:

– The laws of physics control the building's stability. The concept of stability is as fundamental for life as it is in a building; it implies taking into consideration the existence of vertical loads or pressure loads, and of structural lines which conduct and distribute these tension fields. It should be known that, for example, a pillar, or any other foundation feature, must have something to support, sometimes in relation to the diffusion of light, prior to having any religious function. Regarding the principle of the relation between a plan and its rise, another example is that of facing pilasters in a hallway; these would mark a curved door and would not simply be a decoration on the wall. Two pairs of opposite pilasters allow the possible existence of a vestibule and a cross-sectioned passage on the upper level while lighting the hallway. Two lengthened and narrow spaces on the ground can reveal the existence of a two-step staircase. There are many examples to be found in the study of mudbrick architecture.

– A manufacturer, whether an architect, a contractor or a private individual, never does anything without reason when constructing a building. He always proceeds in relation to a goal which must be found.

– If an anomaly or an absurdity appears, it is very likely the result of poor excavation, the ignorance of the excavator, or erroneous reasoning, in any case certainly not from man's absurdity, whether he is from the Neolithic or the Middle Ages.
– An architect does not plan a construction starting with the ground floor to go on to add one (or several) floors, as the method of presentation that archaeologists use could suggest: he rather conceives the entire volume to be constructed and organizes its substructure (with its own requirements) according to the predefined layout of spaces above. This means that the ground floor displays all the constraints of the upper parts, and that these constraints can be revealed even in incomplete buildings, such as those uncovered during an excavation.

To what precedes more precise details should be added regarding the material used in the cases under study. To understand and restore the original volume of Near-Eastern architecture, it is necessary to keep in mind that this architecture has mudbrick as its raw material. Knowing the qualities and faults of the material is obviously essential, but it is necessary to really understand them and not simply be satisfied with *a priori* estimates and assumptions, as it is too often still the case[5]. There are however research centres on mudbrick architecture with which a collaboration can prove to be very profitable[6]. It is also indispensable to announce a track which has not yet been taken in consideration until now and which appears extremely productive. It relates to the methods of destruction of mudbrick architecture. A lot of information can be inferred through observing the ruins of a building towards understanding how it was destroyed, and from there, how it was before its destruction.

2.4 *Principles of methodology*

It is thus necessary to start from what is known, by specifying as precisely as possible what is contained in general information, and to move towards what has disappeared, what must be found and what could be deducted from what is known. For this, the researcher has two different sources available:
– archaeology, that is archaeological traces, clues and material in relation to technical aspects of the building;
– architecture itself, that is what remains of the monument, but also any information in relation to the fundamental architectural data. A starting point

[5] During a presentation in the *Rencontres Assyriologiques Internationales* in Leiden in July 1993, while a speaker disputed (on the basis of what?) the possibility of constructing an upper floor above walls 40 cm thick, one of the archaeologists present in the room shared his own experience on the matter: he had personally lived in houses with an upper floor and walls 40 cm thick.

[6] For example, the mission of Mari works in close collaboration with the CRATerre (International Centre for the preservation of mudbrick architecture), a branch of the Grenoble college of architecture, not only for restoration works but also towards an understanding of the characteristics of mudbrick architecture.

which is similar in both fields corresponds to these two sources: an inventory of archaeological data and an inventory of visible architectural characteristics.

At this point:

– the credibility of the excavation should have been established through its architectural information. Many plans are the product, not of an observation on-site, but rather of an interpretation on the excavator's part, and of a transformation of an archaeological reality which follows his logic. His precise initial information must be found;
– the stratigraphy of each room must also be defined, keeping in mind the methods of destruction and deposit relating to the building under study, and keeping in mind that buildings do not evolve the same way, and a strict analysis is necessary on this point.

Then, taking into account the results of these two analyses, the two inventories can be linked by establishing a connection between the architecture and the archaeology of the monument.

Different architectural parameters come into play at this stage:

– organization of the plan and its circulation,
– thickness of the walls,
– remaining height of walls, and volume to be filled by the collapsed structures,
– methods of filling,
– eventual possibility of a staircase,
– list of structural anomalies,
– data on foundations,
– stratigraphic positions of objects,
– types of erosion and deposit.

And the relation between all this information makes it possible to establish different complementary data relating to volume. However, this can only be done through a logical and progressive sequence, in which:
– each stage of the demonstration can be accompanied by drawings or 3D-models which emphasize the specific analysis or specific features. A drawing or a 3D-model is in the end only an expression of all these combined steps. It is necessary to warn against a practice which is becoming more frequent and is meaningless; it involves a desire to create the impression of volume by raising the foundation plan by a couple of metres and replicating this same plan on the top of the figure: all that has been done is to raise the foundation plan and no real research has referred to the building. Far from being an approach to volume, this method does nothing but introduce an illusion of volume, always very far from reality (Fig. 3).
– The last step consists in establishing a contradictory assessment in order to check the logical basis and range of the demonstration, and to ensure

the correct operation of all solutions adopted, individually and collectively. Finally, counter solutions must be presented; if they are difficult to establish, or if they do not take all data into consideration, they must be abandoned, because the best proposition is always one that takes into account the most evidence within a logical system. But if, on the contrary, one of these counter solutions offers a more complete, more efficient use of the data, then it would have to be preferred to the first solution, as it would mean the first had been developed for another reason, at the expense of effectiveness.

Once this work is done, it remains to be seen if the result fits within a series or if the document represents an anomaly in relation to what was known until now. Further research would then begin, which would consist of checking the analyses of other constructions or leaving aside this result until new discoveries support or modify its basic reasoning. It would be necessary under such conditions to take care not to introduce from the anomaly significant features in relation to the current production, and therefore in relation to the way of thinking. The source of information would only become interesting when other monuments offer identical typological characteristics, because it would then be legitimate to engage in comparison and to transfer certain specific features from a singular example to the series as a whole.

Despite his talent, no researcher is immune to a lack of information which forces the archaeologist to recreate some parts which are not well known or unknown, forcing him to infer the final result. Now, as technology simplifies his work, the archaeologist simply cannot submit his results as a single reconstruction. Fig. 4 presents an attempt to provide a range of possibilities with several drawings in order to draw attention to the hypothetical nature of items for which no information is known, for example the location of windows. This solution, which had the merit of scientific honesty, is nowadays no longer sufficient. Indeed, quickly, not only just one of the hypotheses is becoming the only possible restitution (Fig. 4,d), but also the different assumptions do not provide enough accurate information on what is field data, what is archaeological restitution, what is interpretation from comparison with other similar documents and finally what is pure speculation. Therefore, if the project obtains sufficient funds to perform 3D modeling, future architectural and urban analysis would use scientific 3D modeling based on fuzzy logic (Niccolucci, Hermon 2004) (Fig. 5).

3. Conclusion

It is clear that initially, there is no possibility of using a model which would lead the methodology. In research of this type, beginning with a model means starting with an assumption; it is a risk to not see clues or facts which

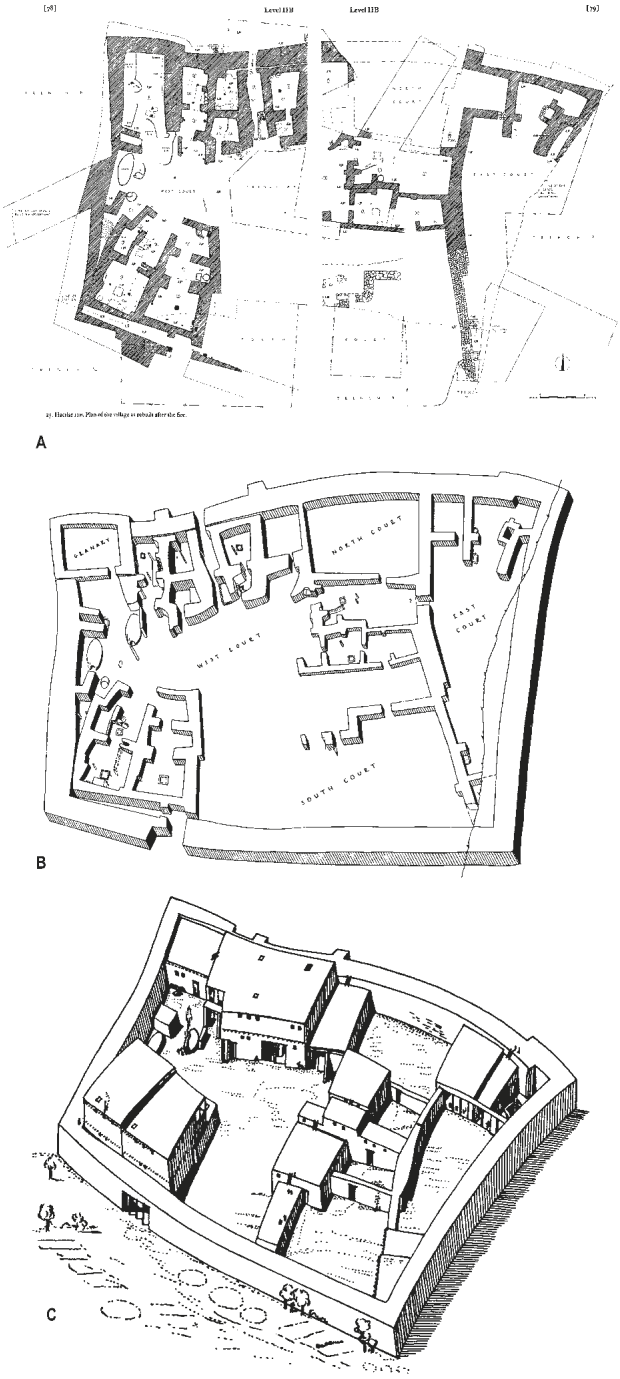

Fig. 3 – When reconstruction only considers the raised plan of the walls (Hacilar, Mellaart 1970, figg. 25-27 – J. Mellaart).

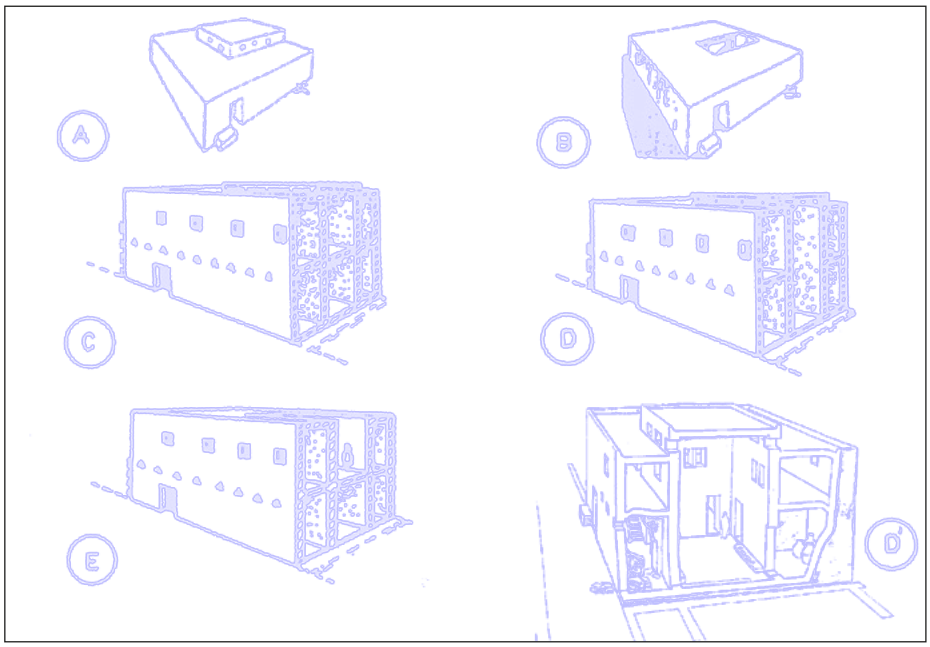

Fig. 4 – Different reconstruction hypotheses for the Red House of Mari (Margueron 1996, except D', published individually in Margueron 2004, fig. 153).

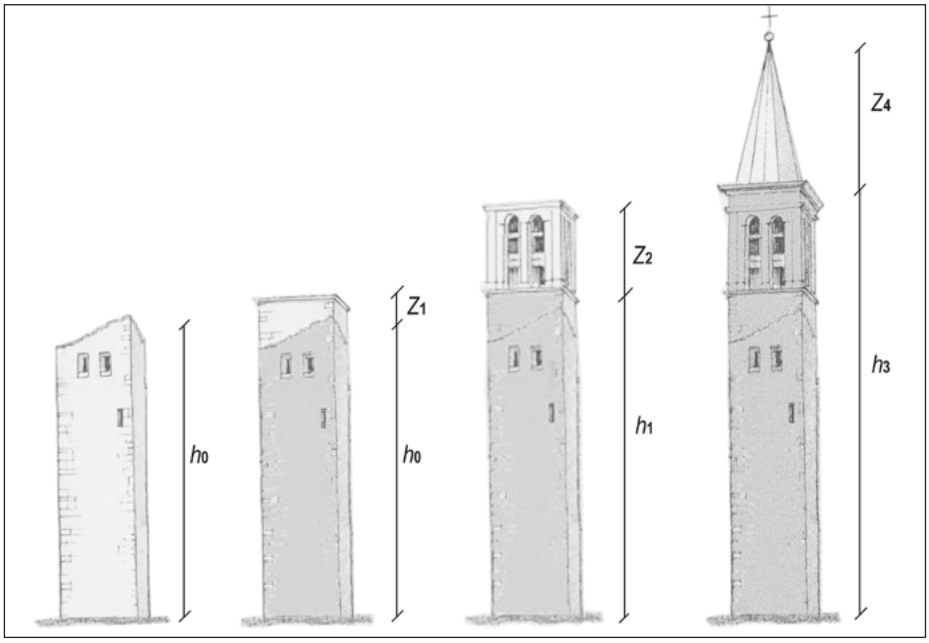

Fig. 5 – From a model based on the remains of the bell tower (h0) of Spoleto cathedral (Italy) to a possible final result (Z4) (Niccolucci, Hermon 2004, figg. 3-9).

would change the direction of thinking towards a new course. In the case of Bronze Age Near-Eastern architecture, it means *a priori* that this architecture is naturally without other floors; it means challenging a situation and an analysis which lead to the conclusion that an upper floor exists and to its reproduction in 3D models.

Architecture is not just an approach to the overall volume created by this material structure. Without an accurate knowledge of what the building was, one can not elaborate any social or symbolic study. It is thus the first step, a mandatory stage; that is why architectural reproduction must meet the following requirements:

– the archaeologist will first use a deductive method, starting with the document, the credibility of which will have been established beforehand. He will then take note of some characteristics likely to need an explanation as regards the proposed methodology. In relation to other objects offered by archaeological documents, the strength of architecture is to obey both physical laws which must be integrated in a structured organization, and human needs;
– the logical consequence of the point above is that an architectural reproduction is only justified by demonstration;
– this demonstration can only be logical, and not unrealistic: the goal is not to fire the imagination, but to highlight a coherent set of technical facts, a set which leads to the possible definition of a lifestyle;
– the rejection of a proposal can only be done by an argued demonstration of the impossibility of the suggested proposal: when a proposal is the consequence of a convergence of different clues and sources, it cannot be countered by one argument without having shown the invalidity of all existing arguments which lead to it. For example, just a few burned seeds from space G of the Round House at Tepe Gawra (Iraq) can certainly not question the results of an analysis which combined the issues of circulation, ventilation, lighting, protection against rain, etc. Other facts could explain the presence of these burned seeds: transfer, collapse of the floor, covering before the end of combustion by a collapsing section of the wall (Margueron 2009);
– reproductions must not be, as was the case in Kubba (1987), hypotheses based on a simple idea, but rather the product of converging clues which lead to the same conclusion;
– if data is insufficient and clues are rare, it is necessary to create a reproduction founded not in the imagination but rather on architectural logic;
– archaeological reconstruction models proposed must be based on fuzzy logic.

In order to obtain a credible and well-argued 3D model, a partnership must take place between archaeologist, focused on architecture, architect and data-processing specialist. In this collaboration, the first two must lead the latter's work. Although data-processing researchers are indeed essential to the

development of tools specific to archaeology, only a data-processing technician working with data provided by archaeologist and architect is required to produce a 3D model. Only within a collaboration in which everyone applies his specific field of expertise could 3D modeling be effective and useful for archaeological research.

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ABSTRACT

Prior to 3D modelling, the volume of the remains of monuments was represented in two dimensions by means of drawings. The problem of analysing archaeological documents had already arisen with significant consequences on the final result, in particular when only the foundations of the structure had been found. Instead of an argued reconstruction, the reconstruction was an elevated projection of the plan drawn up by the excavator, the superstructure thus being merely a product of his imagination. Since then, the use of information technology has not changed the situation at all: the final document still lacks scientific value; the superstructure is still a product of the imagination. However, the authors point out, it could be obtained scientifically for any remains using the convergence of multiple indicators pointing in the same direction and towards the same conclusion.