

Recreating Reconstructions: Archaeology, Architecture and 3D Technologies¹

Patricia S. Lulof

Introduction

Reconstructing the past from material remains and traces of architecture, unearthed by archaeological excavations, has been the main focus of archaeology ever since the first explorers discovered the built remains of ancient worlds. Using the term ‘reconstruction’ is quite difficult without confronting the relationship between hard data and uncertainties. However, reconstruction remains part and parcel of the main task of archaeologists to explain the past. The application of 3D techniques and digital methodologies in visualisation (modelling, scanning and photogrammetry) is by no means new for archaeology, but relatively new to other disciplines, like heritage studies, museology, conservation and restoration, and (art)-history. The many perspectives on the reconstruction of the spatial context, and the possibility of visualising the chronological phases through time (the ‘4D’ element), makes visual computing an innovative research tool for specialists in processes of construction and production. Reconstructions in 3D offer a virtual world where various kinds of experiment can be conducted by scientists from the humanities and beyond. Consequently, we have to reflect on the methods of digital research and the ways its results can be presented, including uncertainties, as well as empirically annotated. It is fundamental that reconstructions should be accessible, changeable, and correctible at any time. This is the paradigmatic difference between material models and historical models: 3D models can be changed any time. When the path that leads to the final reconstruction of material objects, however small, monumental or intangible, is thoroughly documented, it generates a vast amount of new data otherwise never encountered. It is these data that we want to use to understand fully the concept of reconstructing ancient and historical communities and the space they occupy.²

This chapter focuses on the understanding of ancient built structures, regarding them as complex material objects. It contributes to this volume as an analysis of the inner workings of a technological reconstruction, by following the steps of construction in the past. The theoretical ambition of this chapter is to (re-)define concepts of reconstruction and re-enactment of building procedures and to test their validity by bringing into play a specific and rich set of data, available in the stone foundations and terracotta roofs that made Archaic architecture in Italy. I would like to emphasise the great potential of the combination of comparative analysis of both ground plans and roofs of Archaic religious architecture, which effectuates the reconstruction of the entire construction of the building in such detail that it identifies originally applied building modules and building sequence. This is demonstrated by analysing the architecture and roofs of a concrete case study of one of the most important but also fiercely disputed Archaic built structures in Central Italy: the latest phase of the Etruscan Monumental Public Building in Acquarossa (Zone F), dated to the middle of the sixth century BC.³ In light of new investigations at the site with the help of digital methodologies we unravel a system of interactions between terracotta craftsmen and architects, working together in this enigmatic period at the dawn of the Archaic period.⁴

Methodology and aim

The best approach to exploring the socio-economic aspect of ancient architecture while performing empirical analysis of its archaeological remains, is to focus on technologies and building methods. Hence, we propose a methodology to study technology that combines *chaîne opératoire* – the framework that allows analysing the steps that unfold during the technological

process of constructing a building within a social environment – and conventional (empirical) research methods and innovative research tools, such as 4D modelling. The 3D tools and theoretical concepts act together to illuminate the construction process of Archaic architecture. When used for reconstructing practice, craft and construction, 4D modelling is, today, an important research tool, as it is impossible to visualise processes through time (the 4D element) without digital tools. This approach compels the combination of otherwise separately investigated fields, such as architecture and terracotta craftsmanship, and requires the archaeologist to move beyond traditional disciplinary boundaries and integrate different datasets, such as the analysis of ground plans and roofs. In this way, digital modelling guides the interpretative processes of reconstructing architecture, generating a vast amount of new data that otherwise would remain unnoticed.⁵

Transformations of architecture – being constructed, destroyed, rebuilt or repaired – need complex and technically demanding *chaînes opératoires*.⁶ The study of technology is an essential tool for understanding the materiality of the construction sequence of Archaic roofs, while stressing the importance of human *agency* in the transfer of these technologies.⁷ This last concept should seek the larger social dynamics of network interactions and the types of relationships between those in practice and in power. The application of 4D modelling during research into built environments offers new insights for reconstruction and re-enactment and a new approach for analysing data by showing the constructive choices of architects and craftspeople. The process of 4D modelling creates a versatile and unique context for abductive reasoning; what are the most likely explanations for archaeological and architectural remains, and what questions do they pose in themselves? In fact, 4D modelling requires question-generated research; questions raised only during the modelling process. The process of reconstructing unravels *chaîne opératoire* and unveils *paradata* otherwise invisible. Moreover, simulation of the construction sequence of built structures provides insight into the social organisation of historical workshops and the dynamics of craft communities. This social context of domestic architecture and roofs can be understood when the physical aspect of materiality is involved, by examining the construction sequence or the *chaîne opératoire* of these monuments.⁸

Acquarossa. The monumental building in Zone F

Acquarossa lies in the heart of Etruscan territory, close to the Lago di Bolsena, but far enough from the primal coastal centres to be regarded as a hinterland town. The town is named after the red-coloured creek surrounding the site, which is situated on a tufa-plateau (Figure 9.1). Excavations carried out by the Swedish Institute in Rome (1966-1978) revealed a large series of Etruscan houses and public buildings, inhabited from the late eighth century BC until shortly after the middle of the sixth century BC, when the town was suddenly abandoned, most probably because of an earthquake.⁹ The houses were left to crumble at the time and the remains of the foundations, the walls and the decorated roofs, as well as the thousands of household utensils, were all found *in situ*. It is one of the very few examples of an intact Etruscan townscape, with a unique set of family dwellings from the past. The excavations themselves were never fully published, however the architectural terracottas, and some specialised categories received ample attention and several exhibitions were organised. A fine presentation of the site is visible in the National Etruscan museum in Viterbo (Museo Rocca Alborno) which shows the archaeological finds from Acquarossa.¹⁰

Since 2015, the 4D Research Lab and my research group has been involved in the Acquarossa Memory Project, aiming at knowledge exchange and multidisciplinary archaeological research, using digital methods as (in-) tangible heritage.¹¹ We will use connected data (applications) and techniques as a new intermediary in the final dissemination of the products. Re-utilization and exploitation of (archaeological) heritage is the chief goal of

the project.¹² We discovered that some important clusters of foundations had been lying bare since the 1970s and were badly damaged.¹³ On the basis of the 3D models, we produce we will start reconstructing real houses, for tourist purposes. We have started with domestic and public architecture to see what difficulties we will encounter and to find solutions for them. After that we will build the other houses, and they can have different roof systems, as well as differences in superstructure, to present mudbrick walls as well as *pisé* (rammed earth) walls, to mark the different construction methods. The primary demand of the architects is focused on accurate and safe construction of the built environment of the selected replica houses.

We have also focused on the reconstruction of Zone F (in the NE of the plateau, close to Pian del Sale), where a relatively complete monumental building was excavated by the Swedish team in the early 1970s. It was the first building of this size and monumentality that attracted a lot of public and scientific attention. It consisted of a then unknown type of courtyard building with one wing with columns, a kind of portico, with a series of rooms around a court. The architectural terracottas were found at the very point where the roof collapsed, *in situ*. The roof was practically intact and meticulously reconstructed and is now visible in the museum in Viterbo (Figure 9.2).¹⁴

The building consisted of several building phases and certainly had an obvious public and central function, also perhaps a sacral function, as a sacral pit was discovered, belonging to the earliest phase. The earliest phase also shows a courtyard building, with one wing ascertained and a shed- and saddle roof and an exquisite decorative roof system; it was dated to the beginning of the sixth century BC.¹⁵ The later phase consisted, according to the excavators and later specialists, of two separate buildings that were built one after another in a short period (560-550 BC). The *portico* building A and *portico* building C, were set approximately at right angles to each other facing an open courtyard (Figure 9.3a). Both buildings consisted of rooms (two and four, respectively) fronted by a colonnade with wooden columns set at different spaces. The columns were of wood with delicately moulded bases and Etrusco-Doric capitals in *peperino* stone, two of them found *in situ*. Foundations of other spaces and rooms have been found in the complex, indicated by the excavators as separate buildings and rooms, but not forming part of buildings A and C. The tiled roofs of both buildings were decorated with four different types of revetment plaques showing mythical scenes as well as scenes of dancing and dining, and antefixes with female heads. The decoration was exclusively set on the façade, facing the courtyard. The buildings were destroyed shortly after 550 BC. The construction of the building complex was different from the other structures at the site, hence indicating a possible special function. Foundations were cut into the bedrock and in one case, blocks were used to build the wall (south), instead of using the *pisé* or mudbrick materials that were common at this site and elsewhere. The floors of the rooms were set higher than those of the *portico* and the slope was strongly descending towards the north, with a thick terrace wall to support the terrain. The court had pits and drains to receive superfluous rainwater and keep the courtyard dry.¹⁶

The first reconstructions of the later phase of Zone F were published by Carl Östenberg in 1970, and repeatedly discussed by Margareta Strandberg Olofsson, the main excavator, especially in her article in 1989, with her latest reconstruction and a full discussion because of critical attacks from Italian colleagues. In short, several options were presented and illustrated with 2D graphic reconstructions: Östenberg reconstructed the courtyard building with two wings, attached to each other and including the rooms at the corner where the two wings of the building meet, as well as the attached House D in the west (Figure 9.3b).¹⁷ Strandberg reconstructed the east wing (building A) as a separate temple with three cellae and a gabled roof with columns in front, and a separate long stoa-like *portico* (building C) (Figure 9.3c). She based this reconstruction on the find spots of the architectural terracottas in front of the built structures.¹⁸ The exhibited materials and models in the Museum in Viterbo are displayed

according to Strandberg's reconstruction, notwithstanding the fact that this reconstruction has been fiercely debated in the literature, right from the beginning, and the reconstructions have never been adjusted (Figure 9.2). Still today, the same drawings and small-scale models are displayed in the museum. However, following recent research and careful publications, it is now well-known that the typical Tuscan three-cella temple appeared in Central Italy, e.g. Etruria at the same time as the second decorative roof system that was introduced perhaps in 500 BC at the earliest.¹⁹ The recessed gable in Building A, as reconstructed by Strandberg Olofsson, can also be doubted, because this phenomenon originated in Campania and only appeared in Etruria in combination with the second decorative system, that is, much later.²⁰ A saddle-roofed façade with an open pediment and recessed gable seems very unlikely in Zone F of Acquarossa, especially since column- and mutulus plaques (figurative relief plaques used to decorate an open pediment), raking simas (upright tile elements along the sloping roof edges), obliquely cut keystones for the apex (wedge in the roof top revetment), and acroteria (figural terracotta sculptures on the top and corners of a roof) have not been found in the collapsed *debris* of the roofs.²¹

The polemical discussion on the reconstruction of the later phase of Zone F in Acquarossa gave us the opportunity and reason to re-think and re-construct the monument from scratch, using the Swedish architects' plans and drawings, as well as the detailed reports on the stratigraphy and find circumstances of the excavators, when available.²² We decided to make a 3D scan as well as a photogrammetric reconstruction (images set in Agisoft PhotoScan Software) of the actual remains of the site, produced by flying with an UAS (drone) under the protective roof construction that protects the foundation walls of Zone F today (Plate 9.1). With this 3D reconstruction of the actual state of the remains, following the data presented in the publications and covered by results from recent research into Archaic architecture and newly excavated parallels, we set to work on the 3D reconstruction of this building, entering images and plans in a digital model, using 3D Studio Max software, departing from the concept that Zone F had one building with three wings surrounding the courtyard, similar to buildings now known to have existed in the same period (Plates 9.1-3).²³

The reconstruction of the whole area of Zone F has been included: On the basis of available data from parallel sites we have taken all built structures as a starting point, and set off to re-create a built structure as a unity: a courtyard building including all available spaces, such as House D, and the fifth room at the angle where the two *portico* structures meet.²⁴ Perhaps some of these structures belonged to the earlier phase, but foundations and walls could possibly have been integrated in the later monumental complex, as was already suggested by the excavators.²⁵ We have also altered the idea that all columns should have the same height, as well as that all spaces should have the same height. We had to consider the strong slope of the terrain towards the north and adjusted the height of the walls as well as the columns to meet with the roof. We see that materials and elements could be adapted to serve the final product, in this case a built environment. Therefore, the columns in Building A could have been higher than in C, so that the wings with the rooms could have met at the corner, covered by the same roof. Including House D would make it possible to enclose a public space with a built structure surrounding a court. The western part, unfortunately, was completely destroyed, so it would have been equally possible to have a four-winged monument, just like contemporary Murlo, and suggested also for Satricum.²⁶

We suggest to return to Östenberg's original reconstruction and regard Zone F as one building and a public place where the people of Acquarossa gathered for games, festivals and symposia, suggested by the figurative decoration of the revetment plaques (Plate 9.3b).²⁷ The annotated 3D reconstruction with elements of augmented reality has been finished only very recently, and was obviously based on thorough research and discussions. It can be altered and

adjusted when new data reveal new information. A QR code enables the public to walk around inside Zone F.²⁸

Reconstructing the roof of the ‘new’ monumental complex was complicated, notwithstanding the fact that the roof elements and their position have been known from the first publications onwards, that is, the tiles and imbrices of type II, the female head antefixes and the revetment plaques.²⁹ Terracotta roofs need a sophisticated and solid sub-construction, like the timber truss. With help and advice from modern architects we came up with constructive solutions where we were in doubt. Here archaeological research and architectural expertise are indispensable.³⁰ We therefore suggest saddle roofs running in east-west (wing A) and in north-south (wing C) direction with antefixes and revetment plaques facing the courtyard. The roof of structure D could have been a shed or single-sloped and intersected with the slope of the saddle roof of wing C with diagonally cut tiles as a compluviate roof. The same solution could be suggested for the connecting roofs at the N-E corner, at the front, facing the courtyard. The back of the N-E corner of the roof proved to be the most difficult to construct. Several options have been proposed, but no definite proof has been given by the typology of the tiles. The presence of tiles belonging to a hipped roof type could prove decisive for one option in our reconstruction (Plate 9.2a). We had already decided to include as many spatial structures as possible, and we wished to include the N-E corner B structure as well, as a kind of connecting set of rooms between wing A and C. The small space in the far north with the diagonal thick wall that was interpreted as a terrace wall to protect the structure from sliding along the lower slope in particular needs clarifying (Figure 9.3a). It seems unlikely that this large space was left uncovered.³¹

Fragments to prove compluviate or hipped roofs (two connected roofs, V-shaped or the opposite concave or convex) have not been found during excavation. However, the roof definitely had round sky-light tiles, some of which have indeed been found in excavation. These permitted light into the rooms below and perhaps made windows at the eastern side of the building superfluous.³² The subsequent layering of the roof construction with light rafters of wood on top, which may have been covered with wattled mats of reed, provides an even surface for the rows of tiles.³³ The reconstruction of the interior of the monumental complex of Zone F cannot be certain, since no archaeological data are available that show the details of the inner rooms. Proof of entrances at several points have been adequately argued for, mostly on the basis of the plans of the foundation walls. In the final 3D model, different hypotheses are visualised as variations, leaving the actual remains and other data intact and accessible. The birds-eye view of the area shows how the latest phase of Zone F was constructed (Plate 9.2a-b).

Reconstruction of roof-building is indispensable when one studies architectural terracottas. We aim to create an innovative interdisciplinary approach to source and reconstruct roof production, focusing on the distribution of moulds, as well as roof construction techniques, in order to study the later phase in the production process (the actual roof decoration), production tools (*matrix* or mould), and building techniques, and using Zone F as a case study, the workshops manufacturing architectural terracottas in Acquarossa between 680 and 530 BC.³⁴

Focusing on the accurate, closest to a true and real, construction of the monumental building of Zone F (and its roof) at the site, we made a set of 3D scans in the National Etruscan Museum in Viterbo (Museo Rocca Alborno). We implemented these 3D scans into the model (Figure 9.2 and Plate 9.3a-b). For the dynamic 4D model, showing the different phases of the structure in monumental Zone F, we worked with a vast data collection that is needed for a refereed virtual model. These data should become visible, available and controllable. Although some work has been done on the conceptual aspects of this process (the so-called *London Charter*), it remains fundamental in 3D modelling to create a new publication format that

enables us to follow each step and argument, as well as annotate them, for reconstructing built heritage from Antiquity. The model of Zone F will be published in an annotated system that has been developed recently for the 4D Research Lab at the University of Amsterdam.³⁵ Finally, it remains important that 3D models should be open-access and correctible. This is exactly what makes 3D models and 3D reconstructions innovative: they can be changed and deleted at the same time.³⁶

Conclusions

Investigating craft communities, building technologies and processes has never been thoroughly undertaken for the Archaic period and the region of Central Italy, or for this exceptionally rich category of materials, or for the craftspeople producing architectural terracottas. Reconstructing ancient architecture and re-enacting building processes with 4D modelling as a research tool, has proven elucidating. The socio-economic dynamics of craft production in sacred areas and networks between sanctuaries have only recently been addressed in a wider context; connections have been made with the phenomenon of the urbanisation of the region.³⁷ With the exception of a project on the petrography of architectural terracottas from the earliest phase, technical, science-based research and computer-based methods, like petrography, x-ray imaging, and 3D GIS or 4D modelling, have not yet been used for Archaic architecture and this material group to address the reconstruction of production. 4D modelling as a research tool enables us to re-enact or perform the building process, thus encountering construction issues and production problems, solving them or discussing them while entering the actual production chain. It reveals *chaîne opératoire* while processing *paradata* and emphasises new data and intense research questions about what can be reconstructed and what is actually lost and can never be retrieved. Moreover, analysis of the *chaîne opératoire* may reveal the different social groups involved in the building process, completion, maintenance, destruction and rebuilding of these objects according to the developments in construction technology. Reconstructing the roof with all its elements within a 3D model, is no less than the actual production of a replication, which forces us, during the process, to look at details of technical adaptations and rethink the actions of the craftsmen at work. This combination of reconstruction, re-enactment and replication creates a synthesis that is needed to understand and clarify construction methods and architecture in the period under study in this chapter, to reveal actions of specialised craftspeople and, when compared with other groups, eventually shed light on their influence on society. This interdisciplinary approach combined innovative methodologies with traditional research tools, creating a unique opportunity that will result in insights into chronologies, production, and consumption of Ancient architecture and its terracotta roofs between circa 700 and 550 BC. The archaeological research group that operates in the field of re-enactment, replication and reconstruction has set its aim on the preparation of data for the reconstruction, as a research experiment which transforms traditional data (ranging from archaeologically excavated foundations and numerous (terracotta) roof decorations), drawings and previous reconstructions, and has built advanced digital 3D models, taking this case study as a starting point. The digital reconstructions have been used as a research tool, the usage of which necessitates scholars to test hypotheses in a much more detailed way (i.e. architectural and structural in this case-study) than with research based on descriptions or two-dimensional reconstructions only. It has been, in fact a true Experimental Archaeology project, using 3D software programs and computers to literally re-build a vanished building, block after block. We closely collaborate with modern architects and engineers, both in the past and at this very moment. Stone foundations, columns of wood and stone, stone entablature and wooden roof structures, terracotta roof decoration, all materials and their function in the building structures, have been studied in detail in order to argue for a specific reconstruction. Finally, it has been very important to be able to show hypotheses and assumptions in the model that was

created. We have developed a specific database in which the 3D models can be stored together and connected with their data. In this we introduce a new publication format for digital models, complete with variations and annotations. The results of the architectural investigation into data complexes that once belonged to the well-known Monumental Building in Acquarossa and to Archaic structures in Pre-Roman Italy in general, have been processed to publish dynamic 3D models that can be discussed, peered at and referred to as an archaeological publication, with annotations and levels of uncertainties. It is stressed that in performing actions to create models, to visualise choices and decisions in this built space, a wide variety of new data and knowledge has been produced that would otherwise have gone unnoticed.

We hope that in this chapter we have shown that it is possible to encounter the impossible: return to the past and relive the experience of ancient building technology and learn from it by understanding the choices and processes. From today on, studying ancient architecture cannot be done without reconstructing the lost built environment, recreating and replicating the technology of architecture step by step, re-enacting and visualising the process in lucid and transparent digital models and finally, understanding the magnificent monuments and their architectural and environmental context.

Bibliography

Audouze, Françoise, 'Leroi-Gourhan, a Philosopher of Technique and Evolution', *JArchaeolRes*, 10:4 (2002), 277-306.

Barceló, Juan A., 'Visual Analysis in Archaeology. An Artificial Intelligence Approach', in *Morphometrics for Nonmorphometricians*, ed. by Ashraf M.T. Elewa (Berlin/Heidelberg: Springer Verlag, 2010), pp. 93-156.

Dobres, Marcia-Anne, 'Technology's Links and Chaînes, The Processual Unfolding of Technique and Technician', in *Contemporary Archaeology in Theory, The New Pragmatism*, ed. by Robert W. Preucel and Stephen A. Mrozowski, (Malden/Oxford: Wiley-Blackwell, 2010), pp. 124-146.

Earl, Graeme, 'Modelling in Archaeology, Computer Graphic and other Digital Pasts', *Perspectives on Science*, 21:2 (2013), 226-244.

Edlund-Berry, Ingrid, 'The Language of Etrusco Italic Architecture: New Perspectives on Etruscan Temples', *AJA*, 112:3 (2008), 441-447.

Frischer, Bernard, 'From Digital Illustration to Digital Heuristics', in *Beyond Illustration, 2D and 4D Digital Technologies as Tools for Discovery in Archaeology*, ed. by Bernard Frischer and Anastasia Dakouri-Hild (Oxford: BAR International Series 1805, 2008), pp. v-xxii.

Hermon, Sorin and Joanna Nikodem, '4D Modelling as a Scientific Research Tool in Archaeology', in *Layers of Perception. Proceedings of the 35th International Conference on Computer Applications and Quantitative Methods in Archaeology* (CAA, Berlin, Germany, April 2-6, 2007), ed. by Axel Posluschny et al. (Bonn: Dr. Rudolf Habelt, 2008), pp. 140-146.

Hermon, Sorin, 'Scientific Method, chaîne opératoire and Visualization: 3D Modelling as a Research Tool in Archaeology', in *Paradata and Transparency in Virtual Heritage*, ed. by Anna Bentkowska-Kafel and Hugh Denard (Farnham: Ashgate, 2012), pp. 13-22.

Hodge, A. Trevor, *The Woodwork of Greek Roofs*, (Cambridge and New York: Cambridge University Press, 1960).

Hopkins, John N., *The Genesis of Roman Architecture* (New Haven: Yale University Press, 2016).

Huvila, Isto, 'The Unbearable Complexity of Documenting Intellectual Processes: Paradata and Virtual Cultural Heritage Visualisation', *Human IT*, 12:1, (2012), 97-110.

Lindenhout, Elizabeth van 't, 'Constructing Urban Landscapes in Latium Vetus in the Archaic Period', in *Current Approaches to the Archaeology of first Millennium B.C. Italian Urbanism*, ed. by Elizabeth C. Robinson (Portsmouth Rhode Island: *JRA Supplements* 97, 2014), pp. 127-144.

Lounsbury, Carl R., 'Architecture and Cultural History', in *The Oxford Handbook of Material Culture Studies*, ed. by Dan Hicks and Mary C. Beaudry (Oxford: Oxford University Press, 2010), pp. 484-501.

Lulof, Patricia S., 'The Art of Reconstruction and the Image of Power', in *Interpretando l'antico. Scritti di archeologia offerti a Maria Bonghi Jovino*, ed. by Cristina Chiaramonte Treré et al. (Milano: *Quaderni di ACME*, 134, 2012), pp. 111-130.

Lulof, Patricia S., et al., 'The Art of Reconstruction. Documenting the Process of 4D Modeling, some Preliminary Results', in *Proceedings of the 2013 Digital Heritage International Congress (DigitalHeritage)*, ed. by Alonzo C. Addison et al. (Marseille: IEEE Xplore 2013), Vol. 1, pp. 333-337.

Lulof, Patricia S., 'Reconstructing Rome's Golden Building Age. Temples from the last Tarquin to the Roman Republic (530-480 BC)', in *Current Approaches to the Archaeology of First Millennium B.C. Italian Urbanism*, ed. by Elizabeth C. Robinson (Portsmouth Rhode Island: *JRA Supplements* 97, 2014), pp. 113-126.

Lulof, Patricia S., 'Networks and Workshops. Construction of Temples at the Dawn of the Roman Republic', in *Arqueología de la Construcción V. Man-made materials, Engineering and Infrastructure (5th International workshop on the Archaeology of Roman Construction, Oxford 11-12 April 2015)*, ed. by Janet Delaine and Stefano Camporeale (Madrid: *Anejos de AespA* 77, CSIC Press 2016), pp. 331-342.

Lulof, Patricia S., and Christopher Smith, 'The Age of Tarquinius Superbus. Ancient History and Archaeology: an Introduction', in *The Age of Tarquinius Superbus. Central Italy in the late Sixth Century BC. Proceedings of the Conference (November 7-9, 2013, Rome)*, ed. by Patricia S. Lulof and Christopher Smith (Leuven: *BABesch Supplements* 29, 2017), pp. 3-13.

Lulof, Patricia S., and Maarten H. Sepers, 'The Acquarossa Memory Project. Reconstructing an Etruscan Town', *Giornale di Archeologia e Calcolatori*, 28 (2017), 69-78.

Lulof, Patricia , Ilaria Manzini, and Carlo Rescigno *Deliciae Fictiles V: Networks and Workshops. Architectural Terracottas and Decorative Roof Systems in Italy and Beyond*. Proceedings of the Fifth International Conference held at the University of

Campania “Luigi Vanvitelli” and the National Archaeological Museum in Naples (March 15-17, 2018). (Oxford and Philadelphia: Oxbow Books 2019).

Lulof, Patricia S., ‘Connecting Foundations and Roofs. The Satricum Sacellum and the Sant’Omobono Sanctuary’, in *Etrusco-Italic Architecture in its Mediterranean Setting*, ed. by Charlotte Potts (Oxford: Oxford University Press, pending).

Miller, Paul M., *Continuity and Change in Etruscan Domestic Architecture* (Oxford: Access Archaeology Archaeopress, 2017).

Naso, Alessandro, *Architetture dipinte. Decorazioni parietali non figurate nelle tombe a camera dell’Etruria meridionale (VII-V secolo a.C.)* (Roma: Bibliotheca archaeologica 18. L’Erma di Bretschneider, 1996).

Noordegraaf, Julia, et al., ‘Cinema Parisien 3D: 3D Visualization as a Tool for the History of Cinemagoing’, *Journal of Film and Screen Media*, 11 (2016), 45-61.

Nylander, Carl, *Architettura etrusca nel Viterbese: Ricerche svedesi a San Giovenale e Acquarossa 1956-1986*: Catalogue of the Exhibition at Viterbo (Rome: De Luca, 1986).

Opgenhaffen, Loes, and Maarten H. Sepers ‘3D Modelling: Crossing Traditional Boundaries between Different Research Areas’, in *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* (2015), Vol. XL-5/W4, pp. 411-14.

Östenberg, Carl E., *Case etrusche di Acquarossa* (Rome: Multigrafica, 1975).

Potts, Charlotte R., *Religious Architecture in Latium and Etruria c. 900-500 BC* (Oxford: Oxford University Press, 2015).

Roux, Valentine, ‘Technological Innovation and Developmental Trajectories, Social Factors as Evolutionary Forces’, in *Innovations in Cultural Systems, Contributions from Evolutionary Anthropology*, ed. by Michael J. O’Brien and Stephen Shennan (Cambridge Mass: The MIT Press 2009), pp. 217-234.

Russel, Ben, and Elisabeth Fentress, ‘Mud-Brick and *pisé de terre* between Punic and Roman’, in *Arqueología de la Construcción V. Man-Made Materials, Engineering and Infrastructure (5th International Workshop on the Archaeology of Roman Construction, Oxford 11-12 April 2015)*, ed. by Janet Delaine and Stefano Camporeale (Madrid: *Anejos de AespA* 77, CSIC Press, 2016), pp. 131-145.

Ryan, Nick, ‘Documenting and Validating Virtual Archaeology’, *Giornale di Archeologia e Calcolatori*, 12 (2001), 254-273.

Rystedt, Eva, *Acquarossa IV: Early Etruscan Akroteria from Acquarossa and Poggio Civitate (Murlo)* (Stockholm: Paul Åströms Förlag, 1983).

Sapirstein, Philip, ‘How the Corinthians Manufactured Their First Roof Tiles’, *Hesperia*, 78 (2009), 195-229.

Staccioli, Romolo A., *Modelli di edifici etrusco-italici. I modelli votivi* (Firenze: Sansoni, 1968).

Strandberg Olofsson, Margareta, 'On the Reconstruction of the Monumental Area of Acquarossa', *Opuscula Romana*, XVII:12 (1989), 163-183.

Strandberg Olofsson, Margareta, *Acquarossa V: 1. The Head Antefixes and Relief Plaques: a Reconstruction of a Terracotta Decoration and its Architectural Setting* (Stockholm: Paul Åströms Förlag 1984).

Torelli, Mario, 'Review of Acquarossa vols. I-V', *Gnomon*, 58:3 (1986), 259-267.

Torelli, Mario, 'Fictilia Tecta. Riflessioni storiche sull'arcaismo etrusco e romano', in *Deliciae Fictiles IV. Architectural Terracottas in Ancient Italy. Images of Gods, Monsters and Heroes*, ed. by Patricia Lulof and Carlo Resigno (Oxford: Oxbow Books, 2011), pp. 3-15.

Turfa, Jean M., and Alwin G. Steinmayer, 'The Comparative Structure of Greek and Etruscan Monumental Buildings', *Papers of the BSR*, 64 (1996), 1-39.

Ward-Harvey, Ken, *Fundamental Building Materials* (Boca Raton Florida: Universal Publishers, 2009).

Wendt, Leni, et al., *Acquarossa VII. Trial Trenches, Tombs and Surface Finds* (Stockholm: Paul Åströms Förlag 1994).

Wikander, Charlotte, *Acquarossa I: The Painted Architectural Terracottas. 1. Catalogue and Architectural Context* (Stockholm: Paul Åströms Förlag, 1981).

Wikander, Charlotte, *Acquarossa I: The Painted Architectural Terracottas. 2. Typological and Decorative Analysis* (Stockholm: Paul Åströms Förlag 1988).

Wikander, Charlotte, and Örjan Wikander, 'The Early Monumental Complex at Acquarossa', *Opuscula Romana*, XVIII:11 (1990), 189-205.

Wikander, Örjan, 'Acquarossa' in *Enciclopedia dell'Arte Antica* (1993).

Wikander, Örjan, *Acquarossa VI: The Roof-Tiles. 1. Catalogue and Architectural Context* (Stockholm: Paul Åströms Förlag 1986).

Wikander, Örjan, *Acquarossa VI. The Roof-Tiles. 2. Typology and Technical Features* (Stockholm: Paul Åströms Förlag 1993).

Wikander, Örjan, *Roof-Tiles and Tile-Toofs at Poggio Civitate (Murlo). The Emergence of Central Italic Tile Industry* (ACTA Rom-4, Stockholm: Paul Åströms Förlag, 2018), Vol. 63.

Winter, Nancy A., 'The Origin of the Recessed Gable in Etruscan Architecture' in *Deliciae Fictiles III, Architectural Terracottas in Ancient Italy: New Discoveries and Interpretations*, ed. by Ingrid Edlund-Berry et al. (Oxford: Oxbow Books, 2006), 45-48.

Winter, Nancy A., *Symbols of Wealth and Power: Architectural Terracotta Decoration in Etruria and Central Italy, 640-510 B.C.* (Supplement to the *Memoirs of the American Academy in Rome* 9. Ann Arbor: University of Michigan Press, 2009).

Winter, Nancy A., 'Traders and Refugees: Contributions to Etruscan Architecture', *Etruscan Studies*, 20 (2017), 123-157.

Endnotes

¹ I thank Jill Hilditch, author in this volume, for sharing her thoughts and ideas with me. We refer to each other's chapters to reinforce an archaeological understanding of agency and technology – we're using the same theoretical principles to perform our own investigations. The 3D model of the Monumental complex of Zone F has been executed in close collaboration with Mikko Kriek, 3D modeller of the Amsterdam Center of Ancient Studies and Archaeology. The Acquarossa Memory Project was funded in 2017-2018 by the Netherlands Organization for Research (KIEM-NWO): Living in the Past. Reconstructing Etruscan Houses in Acquarossa (file 314-98-103). I also thank the 4D Research Lab and Jitte Waagen in particular, for the drone applications.

² Frischer 'Digital Illustration'; Earl, 'Modelling in Archaeology'; Hermon and Nikodem '4D Modelling'.

³ On the Acquarossa Memory project: Lulof and Sepers, 'On the Acquarossa Memory Project'; Miller, *Continuity and Change*; pp. 37-40, 116-117, 171-174; Strandberg Olofsson, *Acquarossa V*, and 'On the Reconstruction,' extensively on Zone F, Wikander and Wikander, 'The Early Monumental Complex', and Winter, *Symbols of Wealth*, pp. 229-231, 235-237, 539-543. An overview is published by Potts, *Religious Architecture*, pp. 31-50. The importance of roofs for reconstructing the often unknown architecture is underlined in the same publication: pp. 51-61.

⁴ *Deliciae Fictiles V* Conference in Naples, 15-18 March 2018, aimed to discuss the network between patron elites and specialised craft communities that were responsible for the sophisticated terracotta decoration of architectural complexes in Italy between 600 and 100 BC. The Proceedings of the conference will be published as *Deliciae Fictiles V Networks and Workshops* in 2019 by Oxbow Books.

⁵ On the value of 3D modelling in reconstructing architecture: Barceló, 'Visual Analysis'; Hermon, 'Scientific Method'; Lulof et. al, 'The Art of Reconstruction'; Earl, 'Modelling in Archaeology'; Opgenhaffen and Sepers, '3D Modelling'; Lulof, 'Networks and Workshops' and Lulof, 'Connecting Foundations'.

⁶ Lounsbury, 'Architecture'; Audouze, 'Leroi-Gourhan' and Dobres, 'Technology's Links'. See, for the full explanation of *chaîne opératoire*, the chapter by Jill Hilditch in this volume.

⁷ Roux, 'Technological Innovation'; Lulof, 'Networks and Workshops'; Lulof and Sepers, 'The Acquarossa Memory Project'.

⁸ Frischer, 'Digital illustration'; Hermon, 'Scientific Method'; Lulof, 'Connecting Foundations'.

⁹ Until now, no explanation has been given for the sudden departure of the inhabitants; the suggestion of an earthquake comes from Prof. Örjan Wikander (personal information). Already suggested in Wikander, *Acquarossa VI:2*: "la sua fine potrebbe risalire al 550/525 a.C. circa. Poiché mancano tracce di devastazioni belliche, si può sospettare che Acquarossa sia stata distrutta da un terremoto".

¹⁰ The best overview of the site and its history of excavations, Wikander, *Acquarossa VI:2* and the bibliography by Wikander and Wikander in Wendt et. al, *Acquarossa VII*.

¹¹ On the Acquarossa Memory Project: Lulof and Sepers, 'The Acquarossa Memory Project', with bibliography. The final model of Zone B has been thoroughly analysed and prepared for an annotated model, which will serve the architect in building the holiday homes.

¹² The project focuses on the role of current trends in (virtual) heritage management in the scientific experience of the research group in several aspects of digital humanities and archaeology.

¹³ We intend to clean the site in 2019 and make high-resolution 3D scans as well as drone photogrammetry documentation. After which we will cover the remains with protective textiles, which will not allow weeds and foliage to grow into the tufa blocks.

¹⁴ The monumental building, its architecture and the roof elements have been published on several occasions, the main starting point in *Acquarossa V*, by Strandberg Olofsson. The latest comments are by Winter, *Symbols of Wealth* (Roof 4-5 and 4-9) and Chapter 9; see also Miller, *Continuity and Change*, pp. 175-179.

¹⁵ Wikander, *Acquarossa I:1* and Wikander and Wikander, 'The Early Monumental Complex'; with a completely different decorative roof system: Winter, *Symbols of Wealth*, Roof 2-15; the final publication of the early phase of Zone F will appear shortly by Ö. Wikander.

¹⁶ Winter, *Symbols of Wealth*, Roofs 4-5 and 4-9, with previous literature and notes on the differences in chronology, pp. 230-31, 235-36.

¹⁷ Known to have been part of the earlier phase, this structure has also been regarded as 'still standing and probably in use' in the later phase, Wikander and Wikander, 'The Early Monumental Complex', pp. 197-98.

¹⁸ Östenberg, *Case etrusche*; Strandberg Olofsson, *Acquarossa V*; Torelli, 'Review of Acquarossa', carefully deconstructs the arguments in favour of the reconstruction as a gabled roof and temple, carefully explaining not only that a temple is ridiculous, but suggesting rethinking the structure in the light of the finds in Murlo and Satricum where similar courtyard buildings were discovered. In 1989 Strandberg Olofsson, 'On the

Reconstruction' published a reaction to the critical notes and re-evaluated her reconstruction without changing it.

¹⁹ On the second decorative system and the introduction of the Tuscan three-cella temple: Lulof, 'Reconstructing Rome's Golden', pp. 119-23, with references.

²⁰ Winter, 'The Origin', p. 45, regards the reconstruction of the recessed gable of Strandberg Olofsson as 'anomalous' and chronologically unjustified.

²¹ Strandberg Olofsson, 'On the Reconstruction', in reaction to Torelli, 'Review of Acquarossa'; Winter, *Symbols of Wealth*, disregards the dispute. However, she does speak out on the rareness of the gabled roof in this period in Winter, 'The Origin', p. 45. The technical terms in describing terracotta roof elements that were implemented in an Archaic roof are best explained in the figure on p. 6, Winter, *Symbols*.

²² Östenberg, *Case etrusche*; Wikander, *Acquarossa I:1*; Strandberg Olofsson, *Acquarossa V* and 'On the Reconstruction', published the basic drawings and photos of the excavations. A preliminary report on the first phase of Zone F (Wikander and Wikander, 'The Early Monumental Complex') presents a lot of information referring to the site, fundamental to the understanding of the later monumental complex. The final excavations report on the so-called second phase of Zone F has yet to be published.

²³ Fieldwork was executed in May 2018. I thank Mikko Kriek and Jitte Waagen for the technical preparation of the model with the help of drones and photogrammetry models, and the ACASA Research Fund for making the project possible. Part of the 3D Model discussed and presented in this chapter was funded within the NWO-KIEM project, see note 11.

²⁴ The drains running along the foundations just outside the row of columns meet in the angle between structure A and C, which means again that these wings were connected. Torelli, 'Review of Acquarossa' sees this as proof of 'struttura porticate ad un solo piovente'.

²⁵ Wikander and Wikander, 'The Early Monumental Complex', p. 197.

²⁶ On the contemporary monumental courtyard buildings discovered after Zone F: Potts, 'Religious Architecture', pp. 141-143 (general), p. 142 (Murlo with bibliography) and Van 't Lindenhout, 'Constructing Urban Landscapes', pp. 131-133 (Satricum, with bibliography).

²⁷ Torelli, *Fictilia Tecta*, pp. 5-7.

²⁸ The reconstruction in 3D will be projected when the visitor uses the application at the site itself, and it will be made available on the website we plan to develop for the Archeological Park of Acquarossa; <http://www.2vr.in/V-1KZL> (checked on March 14th, 2019).

²⁹ See above, note 15.

³⁰ Hodge, *The Woodwork*, pp. 17-40; see also Hopkins, *The Genesis*, pp. 55 and 104. As in tomb architecture, Naso, *Architetture dipinte*, p. 286, figure 2, 293, figures 218-219.

³¹ The 'terrace' wall already formed part of the earliest phase of the monumental complex, but also is well-connected to the back wall of wing C with structure B, Wikander and Wikander, 'The Early Monumental Complex', fig. 9. Solutions will be discussed in the near future, together with the Swedish specialists. I thank Prof. Wikander for sharing his thoughts with us.

³² Wikander, *Roof-Tiles*, p. 145 (compluviate and hipped roofs) and p. 195 (skylight tiles).

³³ Suggested by Turfa and Steinmayer, 'The Comparative Structure', pp. 19-20, Figure 3; Sapirstein, 'How the Corinthians', pp. 313-314 suggests this method for the Protocorinthian roof tiles. See also Miller, *Continuity and Change*, pp. 198-200 and pp. 173-74 for the rejection of this system.

³⁴ Acquarossa is an exemplary site to study the concept of workshops and their impact. C. Wikander, *Acquarossa I:1*, *Acquarossa I:2* and Ö. Wikander, *Acquarossa VI:1*, Winter, *Symbols of Wealth*, chapter 8, esp. pp. 513-14: Around 560 BC., there is a major shift in practice, where only public buildings receive decoration and domestic structures carry undecorated or modestly decorated roofs.

³⁵ The 4D Research Lab of the University of Amsterdam already has an initial system in place for storing built heritage information digitally (Noordegraaf et al., 'Cinema Parisien 3D'). An interactive website has been activated with access to other media. The models will be completely accessible and dealt with as a scientific publication, as is argued for in a wider context, Ryan, 'Documenting and validating', Huvila, 'The Unbearable Complexity'.

³⁶ In this project, dynamic digital reconstructions are to be preferred above static replications, like the exhibited replication of the façades of Zone F in the Etruscan Museum in Viterbo.

³⁷ See the recently published volume P.S. Lulof et al. *Deliciae Fictiles V, Networks and Workshops in Italy*.