

# The Archaeology of Construction

## A New Approach to Roman Architecture\*

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**Is there such a thing as the archaeology of construction?** In 1991, Catherine Arlaud and Joëlle Burnouf raised the same question about “the archaeology of buildings,”<sup>1</sup> a field whose identity and methodological positioning are still debated.<sup>2</sup> The recurrence of this question twenty-five years later might suggest that the analysis of built remains continues to require disciplinary reflection and to seek legitimacy relative to other branches of archaeology. But above all, it demonstrates that the scope of study has widened to include both buildings (completed projects) and construction (an active process). Indeed, the archaeology of construction seeks to read and interpret material traces that, as faint as they may be, tell us about a building’s construction, organization, and management. Its scholarly goals and research strategies have made possible a significant renewal in approaches to Roman architecture, which had hitherto been considered primarily from the standpoint of monument typologies, structural and decorative components, or its relationship to society. This archaeology has benefited from new excavation

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1. Catherine Arlaud and Joëlle Burnouf, “L’archéologie du bâti médiéval urbain,” *Les nouvelles de l’archéologie* 53/54 (1993): 5–69.

2. See, for example, Victorine Mataouchek et al., “Archéologie du bâti. Une démarche scientifique à part entière en butte à des enjeux antagonistes,” *Archéopages* 24 (2009), <http://dolia.inrap.fr/flora/ark:/64298/0139403>.

techniques, as well as from the growing role of archaeometric analysis, which has increased the available data relating to the material reality of construction operations and thus opened the way for a new kind of building history.

One significant example is the recent analysis of the Trophy of Augustus at La Turbie, in the Alpes-Maritimes department of France, which has shed light on the rhythms of the worksite of this monument, emblematic of Roman domination along Italy's borders, and currently preserved at a height of 35 meters.<sup>3</sup> Textual sources offer only imprecise information concerning the chronology of its construction: Pliny the Elder recorded the trophy's famous inscription, a dedication to Augustus made by the Senate and the Roman people in 7 or 6 BCE, but we do not know whether this date marks the beginning or the end of the project.<sup>4</sup> Studies of the upper substruction have provided important information about the organization and stages of the building process. A survey of the building's architectural structure and the stratigraphy of its construction, as well as the technical procedures for stonecutting and construction, has been accompanied by analyses of the lime mortar used as a cement in the internal cylinder. Petrographic analysis has revealed that the mortar's composition was homogeneous, which supports the hypothesis that this section of the monument was built over a brief period, if not all at once. Furthermore, the identification of pollens conserved in the mortar has made it possible to show the stages of construction, season by season. Large quantities of pine at the lower level suggest that this portion was constructed in spring, while a preponderance of myrtle two meters higher indicates that construction occurred in the late summer or early fall. In combination, these different scales of analysis enable us to grasp the material reality of a building and to uncover its history on almost a day-to-day basis.

This evolution of archaeological methods, in full swing since the 2000s, has significantly renewed our understanding of Roman monuments by facilitating a shift from the well-explored realm of architecture to that of construction. What this article proposes is thus a technological history of architecture or, put differently, a history that treats technology as a perspective from which to examine the built environment. In offering an assessment and open investigation of this new disciplinary orientation, I will attempt to characterize it by considering three crucial

3. Sophie Binnering, "La construction du trophée d'Auguste à La Turbie. L'étude de l'organisation et des rythmes du chantier," in *Arqueología de la construcción*, vol. 1, *Los procesos constructivos en el mundo romano. Italia y provincias occidentales*, ed. Stefano Camporeale, Hélène Dessales, and Antonio Pizzo (Madrid/Mérida: CSC/ Instituto de arqueología de Mérida, 2008), 89–106. [Throughout this article, the French term *chantier*, signifying both the construction site and the construction process, has been translated as "worksite." For a definition of *chantier* and its uses, see Janet DeLaine, "Conclusions," in *Arqueología de la construcción*, vol. 3, *Los procesos constructivos en el mundo romano. La economía de las obras*, ed. Camporeale, Dessales, and Pizzo (Madrid/Mérida: CSC/ Instituto de arqueología de Mérida, 2012), 321–28.—*Les Annales*.]

4. Pliny [the Elder], *Natural History, Volume II: Books 3–7*, trans. Harris Rackham (Cambridge: Harvard University Press, 1942), 3.136–38.

points: its innovations in regard to the archaeology of buildings, the scales of its investigations, and its relationship to history.

## From the Archaeology of Buildings to the Archaeology of Construction

The definition of terminology offers rich insight into the evolution of research. The archaeology of buildings and the archaeology of construction both refer to the same reality. Is the new term nothing more than a semantic flourish, or does it indicate a new disciplinary direction? The archaeology of buildings, also known as architectural archaeology, was first defined in France in the early 1980s, when urban rescue archaeology was applied to medieval dwellings.<sup>5</sup> As Yves Esquieu explains, its primary goal is, “generally speaking, the architectural study of preserved elevations when these studies are not confined to stylistic considerations.”<sup>6</sup> Its basic principle is to apply the methods of underground archaeology to elevated structures. It thus seeks to “dig into walls” by revealing the different identifiable layers of their elevations—as with layers of sediments in the ground—in order to define the successive phases of a building’s construction, occupation, alteration, and, in some cases, destruction. By reading sites vertically rather than horizontally (which, needless to say, presents distinct methodological problems),<sup>7</sup> the archaeological approach is, as it were, reversed. Unlike traditional excavations, this practice is not destructive, in that it is confined to the study of walls, with physical interference limited to samples taken for archaeometric analyses.

Archaeological studies of standing remains make it possible to correct typochronologies founded entirely on stylistic approaches, by favoring a comprehensive vision of a building’s history and a technical approach to its components.<sup>8</sup> What makes these studies distinctive is their development of a modular analysis of tools and materials as a way of supplementing morphological readings of elevations (figs. 1 and 2). Such analyses, which are easier when dealing with brick or rubble-stone wall facings, help to establish a relative typochronology at the scale of the building and encourage comparisons between buildings located on the same site or even in the same region.<sup>9</sup> In this respect, much of the development of building

5. Arlaud and Burnouf, “L’archéologie du bâti médiéval urbain.”

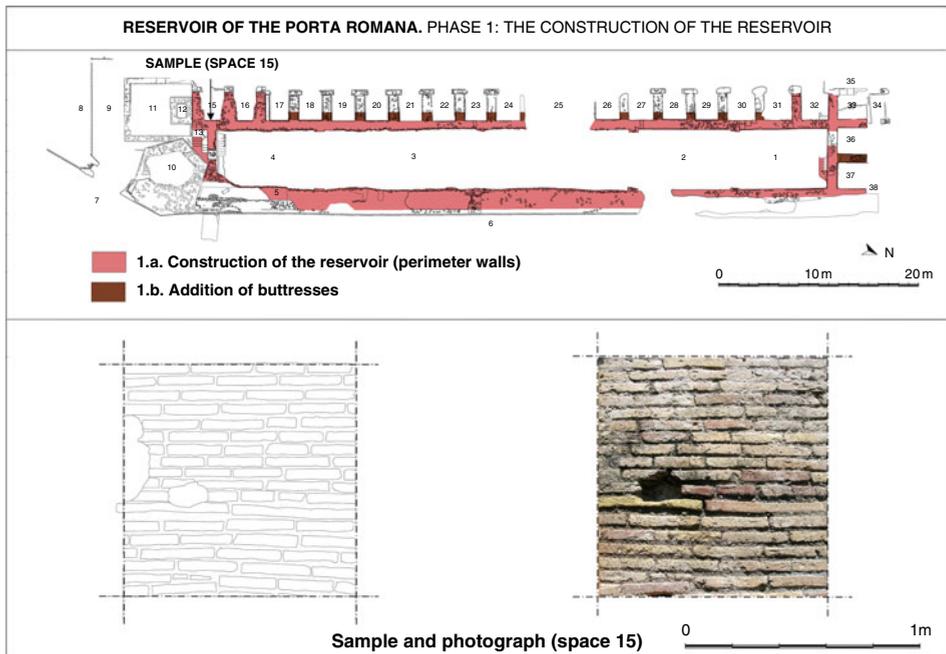
6. Yves Esquieu, “L’archéologie du bâti en France,” *Archeologia dell’architettura* 23 (1997): 133–40, here p. 133.

7. Isabelle Parron-Kontis, “Unités de construction et objets archéologiques,” in *Archéologie du bâti. Pour une harmonisation des méthodes*, ed. Isabelle Parron-Kontis and Nicolas Reveyron (Paris: Errance, 2005), 13–18.

8. For an assessment, see Nicolas Reveyron, “L’apport de l’archéologie du bâti dans la monographie d’architecture,” *In situ* 2 (2002), <https://journals.openedition.org/insitu/1200>.

9. For a synthetic study of *mensiocronologia* (modular analyses that produce typochronologies) and its application to the study of medieval Italian architecture, see Gian Pietro Brogiolo and Aurora Cagnana, eds., *Archeologia dell’architettura. Metodi e interpretazioni* (Florence: All’Insegna del Giglio, 2012), 60–63. For an example relating to antiquity,

Figure 1. An example of a modular analysis of brick masonry



*Ostia, reservoir at the Porta Romana. Source: based on Bukowiecki, Dessales, and Dubouloz, Ostie, l'eau dans la ville, pl. 8. Above - plan: J.-F. Bernard; CAD: J.-F. Bernard and A. Dervault. Below - tracing: L. Traversi; DTP: M. Brion; photo: H. Dessales, June 2006.*

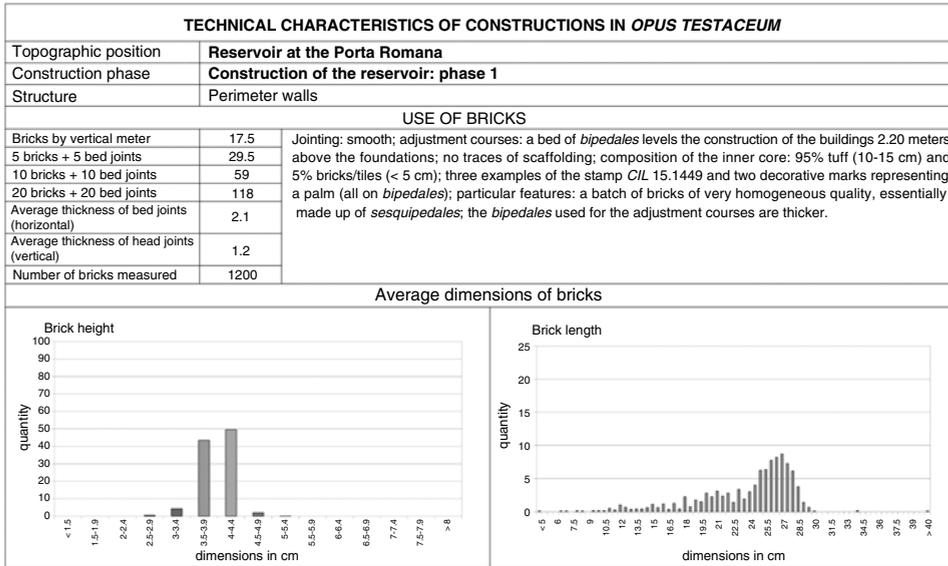
archaeology is due to the efforts of medieval archaeologists. In Italy, the Siena University group runs an active research center that has founded the journal *Archeologia dell'architettura* and published several theoretical and methodological syntheses on this topic.<sup>10</sup> In France, the archaeology of buildings is now well established and has been gradually incorporated into university curricula, particularly in medieval archaeology. The development of this approach is also the result of restorations of historical monuments, which depend upon preliminary studies. It requires the combined skill sets of architects and archaeologists, which can lead to problems of professional positioning in the analysis of artifacts and the shaping of restoration projects: does a particular task call for archaeologists specializing in architecture or for architects specializing in archaeology? While these skills might seem to complement each other, their combination can also create potential conflict between competing visions.

In the field, these surveys make it possible to corroborate textual sources; the merging of these two types of data, which Nicolas Reveyron calls the “dialogue

specifically Ostia and Rome, see Évelyne Bukowiecki, Hélène Dessales, and Julien Dubouloz, *Ostie, l'eau dans la ville. Châteaux d'eau et réseau d'adduction* (Rome: École française de Rome, 2008), 21, 30–32, and 197–98.

10. Brogiolo and Cagnana, *Archeologia dell'architettura*.

Figure 2. An example of a technical and statistical analysis of brick masonry



*Ostia, reservoir at the Porta Romana. Source: based on Bukowiecki, Dessales, and Dubouloz, Ostie, l'eau dans la ville, pl. 9. DTP: É. Bukowiecki.*

between the text and the building,”<sup>11</sup> is essential. Yet despite its undeniable contributions, the methodological identity of building archaeology remains a matter of debate. The workshop organized in 1994 by the École nationale du patrimoine (the French National heritage school) showed that no single disciplinary definition of the field exists, and called for reflection on ways to standardize its methods.<sup>12</sup> More generally, debates have centered on the discipline’s autonomy, and specifically on the danger of considering underground data and above-ground data independently of one another. Consequently, in the realm of rescue archaeology, in order to avoid this artificial distinction and promote a comprehensive approach, some have proposed abandoning the term and, by the same token, renouncing any claim to disciplinary independence.<sup>13</sup> In reality, this criticism rests on the fact that the methods of building archaeology are not fundamentally different from those of archaeological excavation: the scale of analysis, based

11. Reveyron, “L’apport de l’archéologie du bâti”; Philippe Bernardi, “Sources écrites et archéologie,” *Archeologia dell’architettura* 2 (1997): 141–45. For an example, see Philippe Bernardi and Andreas Hartmann-Virnich, “Fourniture et mise en œuvre de la pierre au Palais des Papes d’Avignon. Le quotidien d’un chantier,” in *Texte et archéologie monumentale. Approches de l’architecture médiévale*, ed. Philippe Bernardi, Andreas Hartmann-Virnich, and Dominique Vingtain (Montagnac: Monique Mergoïl, 2005), 105–36.

12. Parron-Kontis and Reveyron, *Archéologie du bâti*.

13. Mataouchek et al., “Archéologie du bâti.”

on stratigraphy, is comparable, and from this perspective hardly justifies considering buildings separately from the ground beneath them.

It is precisely on this point that the archaeology of construction can distinguish itself. First defined during fieldwork on Roman buildings conducted in the 2000s, it has since established itself as an independent branch of research. It studies the material traces of all implemented construction processes, from the production cycles of materials to the conception and realization of a monument, thus making it possible to reconstruct the functional organization of a worksite in its social, cultural, and economic aspects. The French term *archéologie de la construction* was first used in a study of the great reservoir of the Porta Romana at Ostia, published in 2008.<sup>14</sup> That same year, a European research network was formed that included the École normale supérieure in Paris, the University of Siena, and the Instituto de arqueología de Mérida, which organized a series of conferences on the topic.<sup>15</sup> While the archaeology of construction also uses the stratigraphic method to distinguish the different phases of a building, the scale of its approach is not limited to determining these phases' evolutionary sequence (construction, occupation, destruction). It seeks, within a particular phase, to establish micro-chronologies or stages of the construction process that can be measured in days, weeks, or months, as in the study of the Trophy of Augustus at La Turbie cited above.<sup>16</sup> The construction of the great reservoir near the Porta Romana in Ostia thus took place in a single phase that can be dated to the reign of Domitian, thanks to the discovery of stamped bricks.<sup>17</sup> Yet archaeological analysis has brought to light the various stages of this centralized and highly organized worksite, which consisted of eight successive operations: laying the foundations, raising the reservoir's walls, setting the adjustment courses, raising the vault, inserting lateral buttresses, building flying buttresses, raising the concrete vault, and finishing with a protective coating (fig. 3).

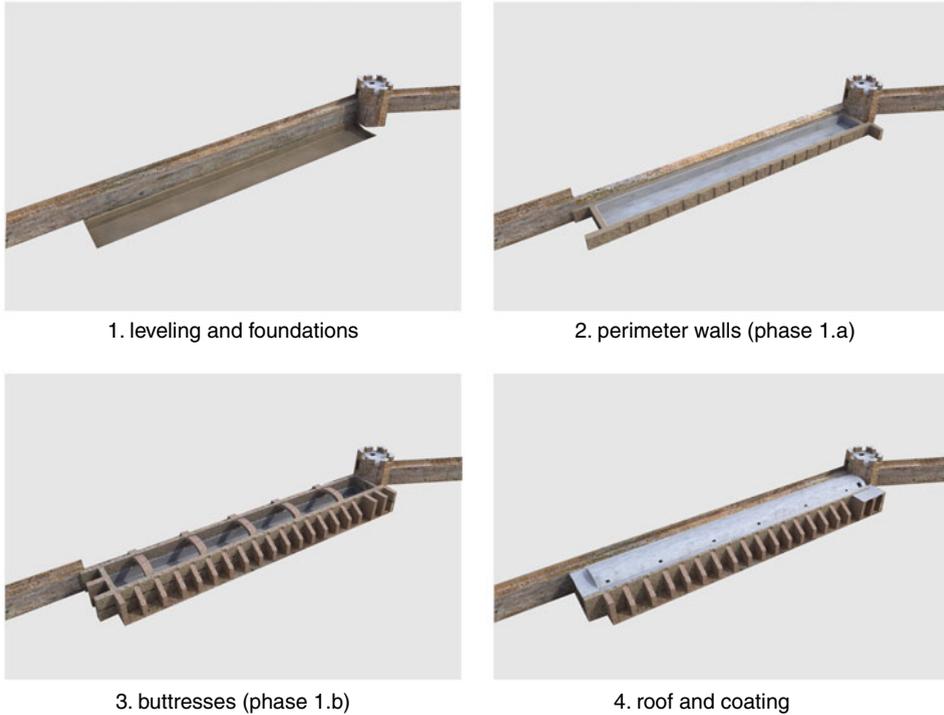
14. Bukowiecki, Dessales, and Dubouloz, *Ostie, l'eau dans la ville*, 21.

15. Five volumes are already available in the "Anejos de archivo español de arqueología" series (Madrid/Mérida: CSIC/Instituto de arqueología de Mérida): *Arqueología de la construcción*, vol. 1, *Los procesos constructivos en el mundo romano. Italia y provincias occidentales*, ed. Stefano Camporeale, Hélène Dessales, and Antonio Pizzo (2008); vol. 2, *Los procesos constructivos en el mundo romano. Italia y provincias orientales*, ed. Camporeale, Dessales, and Pizzo (2010); vol. 3, *Los procesos constructivos en el mundo romano. La economía de las obras*, ed. Camporeale, Dessales, and Pizzo (2012); vol. 4, *Las canteras en el mundo antiguo. Sistemas de explotación y procesos productivos*, ed. Jacopo Bonetto, Stefano Camporeale, and Antonio Pizzo (2014); vol. 5, *Man-Made Materials, Engineering, and Infrastructure*, ed. Stefano Camporeale, Janet DeLaine, and Antonio Pizzo (2017).

16. On work units, see, Tiziano Mannoni and Anna Boato, "Archeologia e storia del cantiere di costruzione," *Arqueología de la arquitectura* 1 (2002): 39–53, especially p. 45; Antonio Pizzo, "La arqueología de la construcción. Un laboratorio para el análisis de la arquitectura de época romana," *Arqueología de la arquitectura* 6 (2009): 31–45, especially p. 35.

17. Bukowiecki, Dessales, and Dubouloz, *Ostie, l'eau dans la ville*, 98.

**Figure 3. Ostia, reservoir at the Porta Romana, built against a late-Republican wall. Three-dimensional reconstruction of the worksite**



*Source: based on Bukowiecki, Dessales, and Dubouloz, Ostie, l'eau dans la ville, fig. 42. 3-D reconstruction: P. Martinez, K. Cain, and T. Gill.*

The approach of construction archaeology suggests a vision that is simultaneously diachronic (in that it considers the sequence of construction phases) and synchronic (as it focuses on the worksite, its organization, and the ways it was managed). It is concerned with a practical activity, namely construction, and attempts to recreate the entire operational chain without confining itself to the study of a completed process (i.e., a building).<sup>18</sup> Construction itself thus becomes the object of study and the focus of research: there is a shift in emphasis from a stratigraphic conception of the architectural object to a reconstruction of the ways in which it was built. In this respect, the archaeology of construction cannot be conflated with the archaeology of buildings or the archaeology of architecture, even if their approaches remain complementary. To define it in more positive terms, by specifying what it is rather than what it is not, one could say that it is above all an archaeology of the construction site considered as a “living organism,” in

18. On the concept of the operational chain as applied to the study of construction, see Binnering, “La construction du trophée d’Auguste à La Turbie,” 89–90.

all its dynamics and complexities.<sup>19</sup> Through an analysis of a building's material traces, this research thus reconstructs a set of completely non-material, invisible, and ephemeral operations: the conception of a building project, the rhythms of construction, and the resources, knowledge, and gestures of the artisans—clues that make it possible to understand the role of the patrons and the master builders that united their ambitions and techniques to bring a project to fruition.

## The Construction Site as a New Level of Study

Concentrating on worksites means considering a building not as a succession of phases of construction or transformation, but as the product of one or several acts of construction. In a seminal article, Tiziano Mannoni and Anna Boato set out to identify the archaeological indicators that reveal how a worksite was organized, subdividing them into different categories of production: architectural structures and components made of stone; mortar and plaster; terra-cotta structures and finishings; wooden structures; and metal structures.<sup>20</sup> For the medieval period in particular, where the archival corpus relating to construction is especially rich, the archaeological data can be placed in conversation with textual sources.<sup>21</sup> In the case of antiquity, where written accounts are far less varied and abundant, material sources provide the only real information about the nature and organization of worksites. One must, moreover, consider the initial stages of construction, including demolition work and debris management, the preparation of the terrain and the necessary infrastructure, as well as the physical and human impact of such operations as they affected the viability and occupation of the space through the flows of manpower and materials.<sup>22</sup> Diane Favro has called attention, for instance, to the relationship between the construction of the Arch of Septimius Severus and urban mobility in the neighborhood around the Roman Forum, which was conditioned by the logistics of this major worksite.<sup>23</sup> In the course of a monument's construction, seven main operations can be distinguished: the initial project, the preparation of the site, the setting up of infrastructure, the production of materials, their transformation, the construction of the building, and finally the finishing and decorative operations.<sup>24</sup> Recent research has contributed to our understanding of each of these stages.

19. Cairolì Fulvio Giuliani, "Cantiere e conoscenza," *Mitteilungen des Deutschen Archäologischen Instituts Römische Abteilung* 109 (2006): 427–29.

20. Mannoni and Boato, "Archeologia e storia del cantiere di costruzione."

21. Philippe Bernardi, *Métiers du bâtiment et techniques de construction à Aix-en-Provence à la fin de l'époque gothique (1400–1550)* (Aix-en-Provence: Publications de l'université de Provence, 1995).

22. Évelyne Bukowiecki, "Le stockage des briques à Rome," in *Arqueología de la construcción*, 3:161–80.

23. Diane Favro, "Construction Traffic in Imperial Rome: Building the Arch of Septimius Severus," in *Rome, Ostia, Pompeii: Movement and Space*, ed. Ray Laurence and David J. Newsome (Oxford: Oxford University Press, 2011), 332–60.

24. Janet DeLaine, "Conclusions," in Camporeale, Dessales, and Pizzo, *Arqueología de la construcción*, 3:321–28. For two other assessments, see Pizzo, "La arqueología de la

The well-established tradition of studying the design of ancient buildings has shown the importance of preparatory drawings,<sup>25</sup> models,<sup>26</sup> and in situ outlines for the planning of a building.<sup>27</sup> Several metrological analyses have also emphasized the role of measurements in the organization of worksites.<sup>28</sup> The originality of the research undertaken in recent years perhaps lies in its reconsideration of the relationship between projects and their realization, due to greater interest in architectural malfunctions, worksite “remorse,” defects, and modifications.<sup>29</sup> The Cahors aqueduct is a case in point: its construction was marked by a series of blunders, both in the implementation of its design and in assessments of leveling made throughout the process.<sup>30</sup> Far from embracing a static conception of Roman “genius,” this alternative building history makes it possible to consider the role of individuals, the importance of transmitted knowledge, and the inherent difficulties of any construction operation, as well as the eventual technical innovations associated with them, independently of the type of building being considered.<sup>31</sup>

The preparation of the worksite was particularly important. It required leveling and, at times, demolition, which resulted in the difficult problem of debris and how to recycle it. Archaeological analysis of the Gallo-Roman sanctuary at

construcción,” and Camporeale, “Archeologia dei cantieri di età romana,” *Archeologia dell’architettura* 15 (2010): 171–79.

25. Pontus Hellström and Thomas Thieme, eds., *Le dessin d’architecture dans les sociétés antiques* (Strasbourg: AECR, 1985).

26. Sabine Frommel, ed., *Les maquettes d’architecture. Fonction et évolution d’un instrument de conception et de réalisation* (Paris/Rome: Picard/Campisano, 2015), 15–36.

27. Carlo Inglese and Antonio Pizzo, *I tracciati di cantiere di epoca romana. Progetti, esecuzioni e montaggi* (Rome: Gangemi, 2014).

28. Christian Goudineau, *Les feuilles de la maison au dauphin. Recherches sur la romanisation de Vaison-la-Romaine* (Paris: Éd. du CNRS, 1979), 171–80; Véronique Mathieu, “Approche métrologique du quartier central de la station routière d’Ambrussum (Villetelle, Hérault),” in *Métrologie agraire antique et médiévale*, ed. François Favory (Besançon: Presses universitaires franc-comtoises, 2003), 83–104; Stefano Camporeale, “Le unità di misura nella progettazione architettonica della Mauretania Tingitana,” in *La mesure et ses usages dans l’Antiquité. La documentation archéologique*, ed. Catherine Saliou (Besançon: Presses universitaires de Franche-Comté, 2015), 79–100.

29. John Peter Oleson, “*Harena sine calce*. Building Disasters, Incompetent Architects, and Construction Fraud in Ancient Rome,” in *Building Roma Aeterna: Current Research on Roman Mortar and Concrete*, ed. Åsa Ringbom and Robert L. Hohlfelder (Helsinki: Suomen Tiedeseura, 2011), 9–27; Hélène Dessales, “L’architecture prise en défaut. Les malfaçons dans les bâtiments romains,” in *Peupler et habiter l’Italie et le monde romain. Études d’histoire et d’archéologie offertes à Xavier Lafon*, ed. Stéphane Bourdin, Julien Dubouloz, and Emmanuelle Rosso (Aix-en-Provence: Presses universitaires de Provence, 2014), 157–62.

30. Didier Rigal, “Avatars et réaménagements de l’aqueduc antique de Cahors,” in *Les réseaux d’eau courante dans l’Antiquité. Réparations, modifications, réutilisations, abandon, récupération*, ed. Catherine Abadie-Reynal, Samuel Provost, and Pascal Vipard (Rennes: Presses universitaires de Rennes, 2011), 47–62.

31. In the context of imperial architecture, see the exemplary case of the Basilica of Maxentius in Rome: Carlo Giavarini, ed., *The Basilica of Maxentius: The Monument, Its Materials, Construction, and Stability* (Rome: “L’Erma” di Bretschneider, 2005), 50–60.

Vieil-Évreux (in the Eure department in France) has brought attention to the working of stone in its successive layers of construction, but also during the sanctuary's ultimate demolition in the very late third or early fourth century CE, most likely to supply the only major worksite of the period, the late-antique rampart at Évreux, located six kilometers away.<sup>32</sup> A meticulous study of the debris—produced by carving, alterations, and sawing—makes it possible to follow the process of managing materials and recycling in the sanctuary's successive phases, the first of which goes back to the mid-first century CE.<sup>33</sup>

Infrastructure consisted of everything that was not visible once a structure had been built: technical galleries, storage spaces, and water conveyance and evacuation systems. The exemplary approach followed at the worksite of the Baths of the Wrestlers at Saint-Romain-en-Gal in ancient Vienna (now in the Rhône department in France), reveals the modalities of their implantation and their impact on urban organization.<sup>34</sup> Undertaken in the mid-60s CE, this construction challenged earlier land divisions, reconfigured the street layout, and introduced new water networks into the neighborhood.

At the outset of the construction process, the production of materials (stone, sand, clay, wood, and metals) rarely occurred on the worksite itself. There has recently been a rise in the number of studies of how stone and quarries were exploited.<sup>35</sup> In France, the pioneering work of Pierre Varène and Jean-Claude Bessac on stonecutting has, since the 1980s, spurred reflection on the evolution and interpretation of these gestures,<sup>36</sup> resulting in an “anthropology of construction.”<sup>37</sup> Depending on the requirements of the worksite and the quality of materials desired, supplies could be sought from a greater or lesser distance. Archaeometry proves essential to characterizing in geological terms the materials used and identifying their provenance. While there exists a long tradition of studying the decorative

32. Laurent Guyard, Sandrine Bertaudière, and Sébastien Cormier, “Construction, démolition, récupération. Réflexions autour du travail de la pierre sur le grand sanctuaire gallo-romain du Vieil-Évreux (Eure, France),” in Camporeale, Dessales, and Pizzo, *Arqueología de la construcción*, 3:225–42. See, too, the interesting study of “demolition permits” in Françoise Dumasy, *Le théâtre d'Argentomagus, Saint-Marcel (Indre)* (Paris: Éd. de la MSH, 2000), 149–58.

33. For broader reflections on the phenomena of reuse and recycling, see Jean-François Bernard, Philippe Bernardi, and Daniela Esposito, eds., *Il reimpiego in architettura. Recupero, trasformazione, uso* (Rome: École française de Rome, 2009).

34. Laurence Brissaud, “La construction des thermes publics des Lutteurs. Regards croisés sur un chantier urbain antique et son impact sur la ville (Saint-Romain-en-Gal, France),” in Camporeale, Dessales, and Pizzo, *Arqueología de la construcción*, 1:107–24.

35. Bonetto, Camporeale, and Pizzo, *Arqueología de la construcción*, vol. 4.

36. Pierre Varène, *Sur la taille de la pierre antique, médiévale et moderne* (Dijon: Centre de recherches sur les techniques gréco-romaines, 1974); Jean-Claude Bessac, *L'outillage traditionnel du tailleur de pierre. De l'Antiquité à nos jours* (Paris: Éd. du CNRS, 1986).

37. Jean-Claude Bessac, “Anthropologie de la construction. De la trace d'outil au chantier,” in Parron-Kontis and Reveyron, *Archéologie du bâti*, 53–61.

stone, notably marble, which was selected to play an aesthetic role in buildings, there is now growing interest in the less noble materials used in structural operations.<sup>38</sup> This is true of lime mortar<sup>39</sup> and of pozzolana, a volcanic ash which was added to mortar to enable concrete to set hard under water and ensured resistance to humidity and erosion. Research on the Caesarea Maritima port in Israel, built at the end of the first century BCE with two jetties representing a volume of 78,000 cubic meters of concrete, has established that 17,600 cubic meters of pozzolana were imported from the region around Pozzuoli, one of the main sources of this material, located in the Phlegraean Fields in Italy: its transportation would have required forty-four shiploads of 400 tons each.<sup>40</sup> A similar phenomenon can be observed in the construction of several buildings in Fréjus (in the Var department in France), known to the Romans as the Forum Julii, particularly around the port area.<sup>41</sup> The conveyance of specific materials thus had an impact that went far beyond the worksite itself; it also conditioned transportation arrangements and economic exchanges. The selection of these materials, which depended on an informed assessment of the physical qualities of rocks on the part of the builders, makes it possible to imagine the circulation of both knowledge and people in the major worksites of the ancient Mediterranean. Such data are also an invitation to consider the impact of materials production on technological innovation.<sup>42</sup> A final persuasive example is that of concrete vaults, whose preservation up to the present day exemplifies the success of Roman engineering. Lynne Lancaster's research has called attention to the relationship between the use of construction materials, empirical knowledge of which improved from the late first century BCE, and the elevation of large vaults across Rome.<sup>43</sup> These constructions were connected to the intense growth of the Tiber valley brick industry over the first century CE and access to abundant scoria from Mount Vesuvius after its eruption in 79 CE—the light weight of this rock proved particularly suited to building the upper sections of vaults. Yet while this geological catastrophe may have spurred innovation, imperial policy was the primary factor in creating the logistical and economic conditions needed for intensive use of these resources.

38. For constructions in earth, see Claire-Anne de Chazelles-Gazzal, *Les maisons en terre de la Gaule méridionale* (Montagnac: Éd. Monique Mergoïl, 1997).

39. Arnaud Coutelas, ed., *Le mortier de chaux* (Paris: Errance, 2009).

40. Gregory F. Votruba, "Imported Building Materials of Sebastos Harbour, Israel," *International Journal of Nautical Archaeology* 36, no. 2 (2007): 325–35.

41. Pierre Excoffon, "L'emploi de tuf volcanique et de la pouzzolane dans quelques constructions de *Forum Julii* (Fréjus, Var). Éléments de réflexion sur l'utilisation et la diffusion de la pouzzolane en Méditerranée occidentale," *Revue du Centre archéologique du Var* (2011): 171–81.

42. Carla Maria Amici, *Architettura romana. Dal cantiere all'architetto, soluzioni concrete per idee progettuali* (Rome: "L'Erma" di Bretschneider, 2016).

43. Lynne C. Lancaster, *Concrete Vaulted Construction in Imperial Rome: Innovations in Context* (Cambridge: Cambridge University Press, 2005).

Once they had been delivered to the worksite, materials were transformed and adapted to the needs of each building. Brick and rubble-stone were recut from larger blocks near the ongoing construction, consistent with a well-known operational chain.<sup>44</sup> For concrete constructions, ditches and containers designed for stocking quicklime were planned, as were places for mixing mortar. The excavation of the Sanctuary of Mars Mullo in Allonnes (in the Sarthe department in France) provided a spectacular insight into the traces left by a short-lived worksite, especially the discovery of stonecutting and metal workshops fossilized below the level at which the temple was built.<sup>45</sup>

Structural work revolved around the building of foundations and elevations, as preserved remains attest. Archaeological analysis makes it possible to characterize these operations through morphological studies and by creating a typology of their constituent parts in terms of the materials used and their arrangement. Working in close collaboration with archaeologists over recent years, specialists in civil engineering have significantly expanded research by modeling the structural behavior of buildings in their environment.<sup>46</sup> These diagnoses of building stability have proved essential for guiding restoration work, and they considerably enrich archaeological interpretations of the original designs of monuments, as well as the factors that made them vulnerable. Furthermore, various material marks, though often very faint, can reveal how ancient worksites were managed and the logistical issues they faced. The characterization of these marks leads to typologies that identify the different phases of the construction process: lifting machines, scaffolding and vault centering,<sup>47</sup> tool traces,<sup>48</sup> temporary doors and windows<sup>49</sup>—all of which can tell us how structural features were positioned and how the worksite developed. The most recent discoveries include symbols made with red paint directly on surface panels, found in a number of second- and third-century CE monuments in Italy and the provinces of the empire: lines (functioning

44. Évelyne Bukowiecki, "La taille des briques de parement dans l'*opus testaceum* à Rome," in Camporeale, Dessales, and Pizzo, *Arqueología de la construcción*, 2:143–52.

45. Véronique Brouquier-Reddé and Katherine Gruel, eds., "Le sanctuaire de Mars Mullo chez les Aulerques Cénomans (Allonnes, Sarthe), V<sup>e</sup> siècle av. J.-C.–IV<sup>e</sup> siècle apr. J.-C. État des recherches actuelles," *Gallia* 61, no. 1 (2004): 291–396; Christophe Loiseau, "Les métaux dans les constructions publiques romaines. Applications architecturales et structures de production (I<sup>er</sup>–III<sup>e</sup> siècle apr. J.-C.)," in Camporeale, Dessales, and Pizzo, *Arqueología de la construcción*, 3:117–30; Amici, *Architettura romana*, 15–36 and 53–102.

46. See, for example, Giavarini, *The Basilica of Maxentius*, 75–91 and 161–225.

47. Anne Baud et al., *L'échafaudage dans le chantier médiéval* (Lyon: Service régional de l'archéologie, 1996). For an example from antiquity, see Jean-Pascal Fourdrin, "L'utilisation des échafaudages dans le chantier de construction de l'enceinte antique de Bayonne," *Arqueología de la construcción*, 3:203–24.

48. Bessac, *L'outillage traditionnel du tailleur de pierre*.

49. See the analysis of the construction site of the Theater of Marcellus in Rome by Paola Ciancio Rossetto and Marialetizia Buonfiglio, "Teatro di Marcello. Analisi e riflessione sugli aspetti progettuali e costruttivi," in Camporeale, Dessales, and Pizzo, *Arqueología de la construcción*, 3:51–70.

as a kind of guiding thread for the worksite and used to indicate levels), triangles (most likely as reference points),<sup>50</sup> fully coated blocks,<sup>51</sup> and inscriptions indicating different stages of a project's progress. Of course, because they were intended to be covered up by decorative features, these marks are not always visible.

Finally, the finishing work gave the building its definitive "skin." Its purpose was decorative, not structural. In addition to the intended aesthetic function, the facade ensured that buildings were better protected against moisture and erosion. This work was undertaken by specialized craftsmen, such as stonecutters, mosaicists, painters, and plasterers.

This research approaches the different stages of worksites at various scales: from the individual perspective of studies of specific buildings, to the collective approach of regional or thematic overviews of construction techniques.<sup>52</sup> The latter in particular make it possible to understand the context of innovations and the ways that they spread throughout Italy and the Roman provinces, as well as their transmission into the medieval period.<sup>53</sup>

## An Economic History of Construction

The archaeology of construction lies at the intersection of several research traditions. It brings together the archaeology of technology and economic history—fields that have recently played an increasing role in the study of the ancient world.<sup>54</sup> Indeed, the spread of artisanal practices, the transmission of knowledge, the identity of craftsmen, and the relationship between patrons and executors have all attracted rising interest. Construction is part and parcel of this reflection, if only due to the various professions upon which it depended: architects, builders, levelers, stonecutters, carpenters, masons, mosaicists, painters, plasterers, and joiners.<sup>55</sup>

50. Évelyne Bukowiecki and Hélène Dessales, "Les thermes publics d'Itálica. Regards croisés sur deux chantiers de construction," in Camporeale, Dessales, and Pizzo, *Arqueología de la construcción*, 1:191–207 and 200–201, fig. 9; Redha Attaoui, "Segni di cantiere nella 'Palestra' di Villa Adriana, Tivoli," in Camporeale, Dessales, and Pizzo, *Arqueología de la construcción*, 1:49–66.

51. Pier Luigi Tucci, "Red-Painted Stones in Roman Architecture," *American Journal of Archaeology* 115, no. 4 (2011): 589–610.

52. For a summary of the sixty-six examples explored in the first three volumes of *Arqueología de la construcción*, see Camporeale, "Archeologia dei cantieri di età romana."

53. On the example of the diffusion of bricks and other forms of architectural terra-cotta across the Roman world, see Évelyne Bukowiecki, Rita Volpe, and Ulrike Wulf-Rheidt, eds., *Il laterizio nei cantieri imperiali. Roma e il Mediterraneo* (Florence: All'Insegna del Giglio, 2016).

54. For an historiographical assessment, see Jean Andreau, *L'économie du monde romain* (Paris: Ellipses, 2010), 13–49.

55. For a reflection on the artisanry of construction, see Hélène Dessales, "Les savoir-faire des maçons romains, entre connaissance technique et disponibilité des matériaux. La connaissance des roches et son application par les *structores*. Le cas pompéien," in *Les savoirs professionnels des gens de métier. Études sur le monde du travail dans les sociétés urbaines*

This renewed archaeological approach also participates in a multidisciplinary network around the history of construction, the significant expansion of which is testified by regular national and international conferences<sup>56</sup> and the creation of professional associations, such as the Association francophone d'histoire de la construction (Francophone association for the history of construction) in 2010. This discipline can be defined in several ways, revealing its particularities: it is both a technological history of construction<sup>57</sup> and, more broadly, a social and economic history.<sup>58</sup> The application of the concept of economy to architectural history has, moreover, become widespread since the publication of Werner Szambien's work, which clearly showed the interplay between financial and aesthetic concerns in the architectural projects of the Classical age.<sup>59</sup>

In the history of Roman architecture more particularly, it was Auguste Choisy who first explored the concept of economy in the light of technical observations in his *Art de bâtir chez les Romains*, published in 1873.<sup>60</sup> This original contribution by a civil engineer engaged with two disciplines that were not, in principle, directly within his field of expertise: law and economics. Choisy conceived of the Roman worksite at a practical level, as a microcosm of society that inherited the same processes of internal management. He thus defined the art of building as a constructive system, an "organizational reality"<sup>61</sup> that architectural analysis alone could not perceive: "The edifices of antiquity have often been described from the perspective of architecture, but the details of their construction are still only vaguely known."<sup>62</sup> To understand how worksites functioned, he analyzed the structure of buildings, taking their remains as so many traces of the undertaking's internal organization. The Roman constructive system could be summed up by a primary goal, the "quest for economy," understood in the precise sense of "rigorously economical thinking": "as I looked more closely at what was left of their monuments, it seemed to me impossible to overlook the use of a host of artifices

*de l'Empire romain*, ed. Nicolas Monteix and Nicolas Tran (Naples: Centre Jean Bérard, 2011), 41–63.

56. See Santiago Huerta's foundational article, "Historia de la construcción: la fundación de una disciplina," in *Actas del Sexto Congreso nacional de historia de la construcción*, ed. Huerta et al., (Madrid: Instituto Juan de Herrera, 2009), 1:xiii–xix. For its connection to cultural studies, see Antoine Picon, "Construction History: Between Technological and Cultural History," *Construction History* 21 no. 6 (2005): 5–19. For an historiographical assessment of divergent approaches, see Guy Lambert and Valérie Nègre, "L'histoire des techniques. Une perspective pour la recherche architecturale?" *Les cahiers de la recherche architecturale* 26/27 (2012): 76–85.

57. Valérie Nègre, "Pour une histoire technologique de l'architecture," in *Édifice et artifice. Histoires constructives*, ed. Robert Carvais et al. (Paris: Picard, 2010), 17–22.

58. Robert Carvais, "Plaidoyer pour une histoire humaine et sociale de la construction," in Carvais et al., *Édifice et artifice*, 31–43.

59. Werner Szambien, *Symétrie, goût, caractère. Théorie et terminologie de l'architecture à l'âge classique, 1550–1800* (Paris: Picard, 1986), 158–64.

60. Auguste Choisy, *L'art de bâtir chez les Romains* (Paris: Ducher, 1873).

61. *Ibid.*, 165.

62. *Ibid.*, 1.

designed, if not to reduce manpower, at least to simplify it.”<sup>63</sup> Roman worksites were therefore conceived in terms of mechanisms of repetitive production—the standardization of materials, the simplification of tasks, the minimization of labor specialization, and the uniformity of buildings—that made it possible to identify the two guiding principles that were constantly at work: reduced costs and speedy execution. For Choisy, the quest for economy, in the sense of limiting expenses, thus constituted the primary characteristic of Roman construction and offered an explanation for its technical innovations. What made his thinking unique was the way he worked these considerations into his approach, participating in the birth of the social sciences in late nineteenth-century France.<sup>64</sup> His *Art de bâtir* ends with a long analysis of the organization of worker cooperatives, in which the history of technology merges fully with social history.

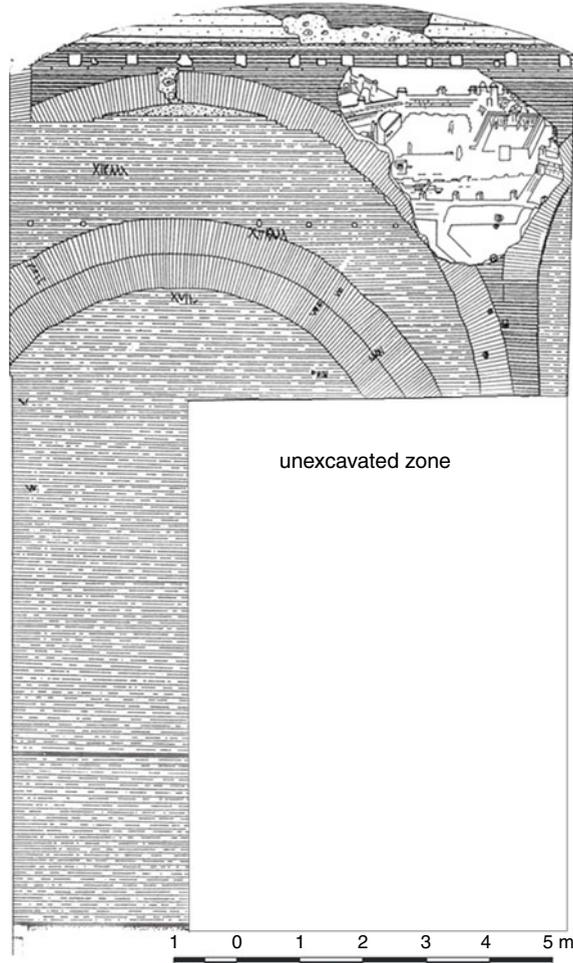
This approach proved foundational for evaluating the internal economy of worksites, but also for understanding them as economic phenomena. Recent studies of the Roman period have considered the construction sector as an indicator of economic vitality.<sup>65</sup> Janet DeLaine’s study of the Baths of Caracalla in Rome constitutes, in this respect, a methodological reference point for the discipline. Instead of analyzing this colossal structure through its complex architecture or thermal characteristics, she focuses on the dynamics of its construction between 211 and 216 CE. Such a perspective on the building’s fabric reveals the logistics, or overall logic, of the imperial construction project at its origin. The other contribution of this study is that, in order to evaluate the cost of the monument and various operations, it adopts a quantitative rather than a qualitative approach. In terms of manpower, at least 7,200 men on average were directly involved in the production of materials and construction, to which must be added 1,800 men and pairs of oxen for transportation in the region around Rome. As for the building’s total costs, one third went to the production of materials and transportation, with total expenditures valued as high as twelve million sesterces, or a third of what it took to supply Rome with wheat. For these estimates, DeLaine draws on an 1843 manual by Giovanni Pegoretti, aimed at practicing engineers and architects, which gives very precise production costs and timeframes for

63. *Ibid.*, 6 and 20.

64. Robert Carvais, “Auguste Choisy: pour un usage des sciences sociales au service de l’histoire de la construction,” in *Auguste Choisy (1841–1909). L’architecture et l’art de bâtir*, ed. Javier Girón and Santiago Huerta (Madrid: Instituto Juan de Herrera/Escuela técnica superior de arquitectura, 2009), 121–50, [http://www.augustechoisy2009.net/es/ponencias.php?id\\_nav=11](http://www.augustechoisy2009.net/es/ponencias.php?id_nav=11).

65. Janet DeLaine, “The Baths of Caracalla: A Study in the Design, Construction, and Economics of Large-Scale Building Projects in Imperial Rome,” special issue, *Journal of Roman Archaeology*, supplementary series 25 (1997); DeLaine, “Bricks and Mortar: Exploring the Economics of Building Techniques at Rome and Ostia,” in *Economies beyond Agriculture in the Classical World*, ed. David J. Mattingly and John Salmon (London: Routledge, 2000), 230–68; Andrew Wilson, “The Economic Impact of Technological Advances in the Roman Construction Industry,” in *Innovazione tecnica e progresso economico nel mondo romano. Atti degli Incontri capresi di storia dell’economia antica*, ed. Elio Lo Cascio (Bari: Edipublia, 2006), 225–36.

Figure 4. Rome, Baths of Trajan (gallery of the *città dipinta*)



*Elevation of the wall at the end of the gallery containing the so-called città dipinta, with a number of dates indicated on the brick facing. Top right: the part of the wall with the fresco of the città dipinta, built during an earlier phase. Source: based on Volpe, "Le giornate di lavoro," fig. 4.*

traditional construction activities in mid-nineteenth-century Italy.<sup>66</sup> Of course, these more modern data had to be combined with hypotheses concerning the number of days worked per year and hours worked per day in Roman antiquity.<sup>67</sup> Even

66. Giovanni Pegoretti, *Manuale pratico per l'estimazione dei lavori architettonici, stradali, idraulici e di fortificazione per uso degli ingegneri ed architetti* (Milan: A. Monti, 1843). For a discussion of Pegoretti's data compared with other sources, see the case of the columns and capitals examined in Simon Barker and Ben Russell, "Labour Figures for Roman Stone-Working: Pitfalls and Potential," in Camporeale, Dessales, and Pizzo, *Arqueología de la construcción*, 3:83–94.

67. DeLaine, "The Baths of Caracalla," 207–24.

Figure 5. Rome, Baths of Trajan (room with *mosaico della vendemmia*)



Detail of an inscription bearing a calendar date: PR(idie) N(onas) (*the eve of the Nones*). Photo: Stefano Castellani (Archivio della Sovrintendenza Capitolina ai Beni Culturali).

though they shed only partial light on specific aspects of construction, DeLaine also consulted ancient textual sources, such as the epigraphic corpus<sup>68</sup> and the Edict of Diocletian which, in 301 CE, set maximum prices for construction materials and daily salaries for various craftsmen.<sup>69</sup>

In Rome, an important discovery made by Rita Volpe's team in the Baths of Trajan has greatly enriched our knowledge of the timeframe of construction: a series of inscriptions, painted in red on brick facing, reported daily progress made on the building and indicated calendar dates (figs. 4 and 5).<sup>70</sup> These exceptional data show that masons were capable of building ten square meters a day. This finding can be correlated with Évelyne Bukowiecki's work on the brick-cutting methods used in Rome, which shows that in Trajan's time a square meter of wall facing might consist of seven to nine whole bricks cut into some sixty fragments.<sup>71</sup> A laborer would thus make use of an average of 600 cut bricks (or 80 whole

68. Hélène Jouffroy, *La construction publique en Italie et dans l'Afrique romaine* (Strasbourg: AECR, 1986).

69. Marta Giacchero, ed., *Edictum Diocletiani et collegarum de pretiis rerum venalium in integrum fere restitutum e Latiniis Graecisque fragmentis* (Genoa: Pubblicazioni dell'Istituto di storia antica e scienze ausiliarie dell'Università di Genova, 1974).

70. Rita Volpe, "Le giornate di lavoro nelle iscrizioni dipinte delle terme di Traiano," in *Epigrafia 2006. Atti della XIV<sup>e</sup> Rencontre sur l'épigraphie in onore di Silvio Panciera con altri contributi di colleghi, allievi e collaboratori*, vol. 1, ed. Maria Letizia Caldelli, Gian Luca Gregori, and Silvia Orlandi (Rome: Quasar, 2008), 453–66; Rita Volpe and Federica Michela Rossi, "Nuovi dati sull'esda sud-ovest delle terme di Traiano sul Colle Oppio. Percorsi, iscrizioni dipinte e tempi di costruzione," in Camporeale, Dessales, and Pizzo, *Arqueología de la construcción*, 3:69–82.

71. Bukowiecki, "La taille des briques de parement," 150 (an assessment of whole bricks of the *sesquipedales* variety).

bricks) per day. This matches up with DeLaine's estimates, based on Pegoretti's textbook, which suggest that laborers laid a thousand bricks a day, or 500 to 700 bricks a day in the case of more refined constructions.<sup>72</sup> It is thus possible to "calculate" the duration and, by the same token, the cost of a construction worksite using fired bricks or, more generally, small-unit bonds.

These various data offer new perspectives for assessing the history of technology and the social and economic history of Roman antiquity. Thus considered as the endpoint of one or several construction operations, architecture can be analyzed in terms of production and circulation, like any other object of material culture. As a specific branch of archaeology, the archaeology of construction now stands as an autonomous discipline, based on increasingly close exchanges with other fields of study, such as geology and civil engineering. It fully participates in the new field that is the history of construction, examining technology as the wellspring of history, and analyzing architecture as above all a process of making—that is, a dynamic process of construction. Pierre Gros provides an illuminating account of this evolution:

*If one wished to define, in simple terms, the relationship between the old and the new school, and to understand the extent to which, far from being mutually exclusive, they complete one another, one might say that there has been a shift from Vitruvius's De Architectura to Alberti's De Re Aedificatoria—in other words, to simplify matters and to confine oneself exclusively to the books' titles, from a descriptive, taxonomic, and implicitly normative conception of built entities to the modalities of their construction.*<sup>73</sup>

These perspectives have opened up a new approach that closely associates the histories of forms, of materials, and of knowledge, and which seeks to break down traditional chronological barriers, such as those between antiquity and the Middle Ages, in order to develop a genuine history of construction.

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72. DeLaine, "Bricks and Mortar," 234.

73. Pierre Gros, "Conclusions," in Camporeale, Dessales, and Pizzo, *Arqueología de la construcción*, 3:257–65, here p. 250.