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Building Trajan's Markets

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Abstract

This paper examines the use of two building techniques at Trajan's Markets: "bonding" courses of *bipedales* and brick linings used as formwork for vaulting. The distribution of these two techniques provides evidence for the distribution of the workforce and the organization of the building site. The pattern of the bonding courses suggests that they were used as organizational tools by setting certain key heights and in at least one case by providing a "benchmark" level to which all walls were brought before proceeding. The pattern and detailing of the brick formwork used for the vaulting in some parts of the Markets suggest that the vaults (and possibly the walls) of at least two groups of rooms may have been contracted out to a particular crew of builders. Evidence from the changes in the pattern of the bonding courses, however, suggests that the way in which work was assigned may have varied from one part of the monument to another.*

Trajan's Markets are among the best preserved of the large brick-faced monuments remaining from Imperial Rome. Despite the extensive restoration undertaken when they were excavated by Corrado Ricci in the 1920s and 1930s,[1] substantial areas retain the original brick facing and concrete vaulting. Given the significant remains and the homogeneity of the materials, the Markets provide an opportunity to study the constructional details from one part of the complex to another, which in turn provides some clues as to how the construction process and labor were organized.[2]

The evidence for the organization of labor at Trajan's Markets has been gathered from an examination of two techniques used there: the so-called bonding (or leveling) courses of *bipedales*,[3] which are large bricks ca. 58 cm square, and the brick linings used as formwork for concrete vaulting. Courses of bipedales are common features in the brick-faced walls of many second-century buildings in Rome. They began to appear with regularity in the Flavian period, though even in the Trajanic period they were not used consistently. The use of brick linings as formwork for vaulting first appears in the Trajanic period, and indeed its use at Trajan's Markets may be the earliest example.[4] The brick linings at the Markets are particularly informative because they occur before the technique had become widespread. The patterns of use of both techniques at the Markets give some insight into the way in which such a large and complex project was planned and organized.

Most of our understanding of the building trade is based on the evidence from legal, literary, and epigraphic sources, but these tell only part of the

* I thank Lucrezia Ungaro and Roberto Meneghini of the X Ripartizione AA.BB.AA of the Comune di Roma for their support of my study of Trajan's Markets. Grants from the Meyerstein and Craven Funds at Oxford University, the Samuel H. Kress Foundation, the M. Aylwin Cotton Foundation, and the British School at Rome have made this work possible. I have also benefited greatly from conversations with Jim Coulton, Janet DeLaine, Margareta Steinby, and Bill Wallace as well as from the comments on the submitted version of this article from Larry Ball and Jim Packer. Finally, I am grateful to my husband, Tom Carpenter, for his help in all aspects of this project, from many hours of on-site measuring to offering valuable advice on drafts of this manuscript.

[1] Unfortunately, the major publications of the excavation and restoration consist of only a few articles and a pamphlet: G. Lugli, "I Mercati traianei," *Dedalo* 10 (1929–1930) 527–51; A. Pernier, "Rilievi e note sulla costruzione dei Mercati di Traiano in Roma," in *Atti del 3° Congresso nazionale di storia dell'architettura* (1938, pub. 1940) 103–13; C. Ricci, *Il Mercato di Traiano* (Rome 1929); and Ricci, "Il Mercato di Traiano," *Capitolium* 5 (1929) 541–55.

[2] All of the drawings and photographs accompanying this article are my own. The plans and sections of Trajan's Markets are based on my own measurements and were created using AutoCad R12.

[3] G. Lugli, *La tecnica edilizia romana con particolare riguardo a Roma e Lazio* (Rome 1957) 571 claims that the lower parts of the Markets were begun by Domitian and that the courses of bipedales only appear in conjunction with these parts; in fact, the entire fabric of the monument is Trajanic and the bipedalis courses occur throughout both the upper and lower buildings of the complex. On the Trajanic dating of the superstructure of the Markets: L.C. Lancaster, "The Date of Trajan's Markets: An Assessment in the Light of Some Unpublished Brick Stamps," *BSR* 63 (1995) 25–44.

[4] The Colosseum has been cited as having the earliest example of the technique: G. Cozzo, *Ingegneria romana* (Rome 1928) 215, but the bessales remaining along the intrados have anepigraphic brick stamps, which date to the second century A.D. or later: L.C. Lancaster, "Reconstructing the Restorations of the Colosseum after the Fire of 217," *JRA* 11 (forthcoming); hence, the brick linings cannot belong to the original Flavian phase of the building.

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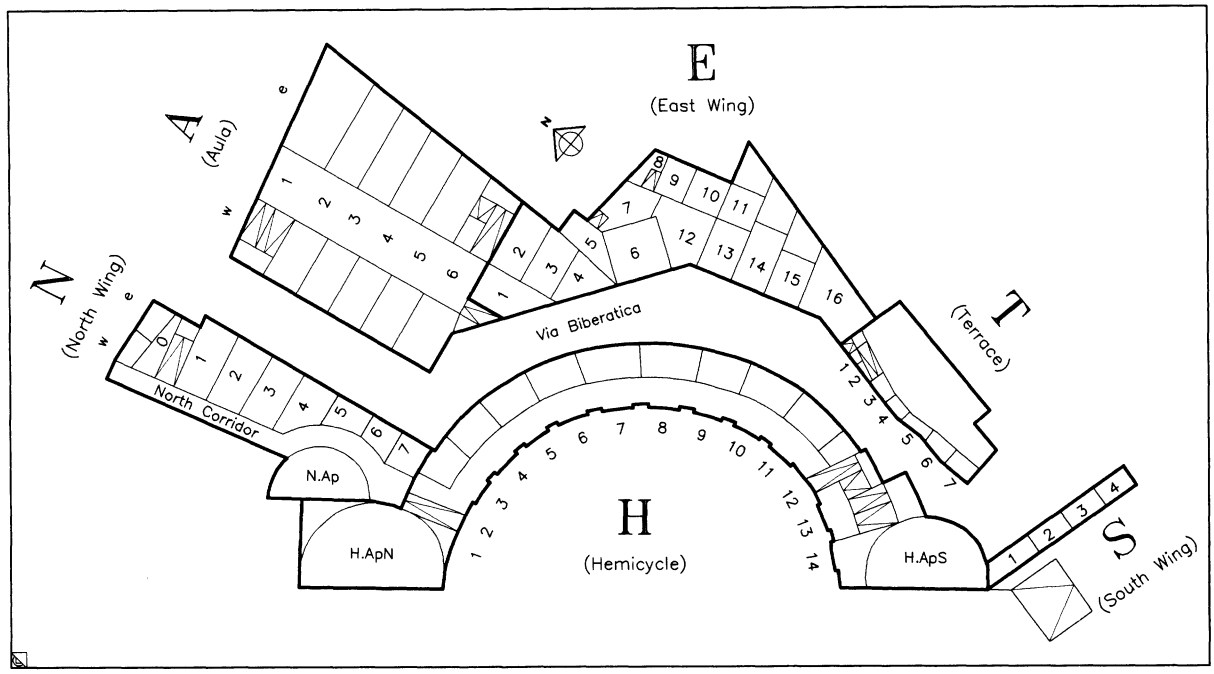

Fig. 1. Key to room numbers at Trajan's Markets. Both the lower and upper complexes are divided into three sectors: the lower complex includes the North Wing, the Hemicycle, and the South Wing, which are located on levels I–III, and the upper complex includes the Aula, the East Wing, and Terrace, which are located on levels III–VI. Each space has been given a code denoting its sector, level, and position. The first designation in the code is a capital letter referring to one of the six sectors. The second is a Roman numeral referring to the level. The last designation is usually a number locating the position of a space within the sector. For example, a typical room is labeled "H.II.14," which signifies that it is located in the Hemicycle sector on level II in position 14. The three major apsidal halls are simply referred to by their sector designation and "Ap," as in "N.Ap," "H.ApN," and "H.ApS." Stairs are referred to by their sector designation, followed by the numerals of the levels they connect and, where necessary, by a position number, as in "stair H.I/II.2."

story.[5] The legal sources (and often the literary sources as well) tend to provide information related to private as opposed to public building projects. From an examination of the quarry inscriptions on marble and the stamps on bricks, we have some idea of how production of two of the major materials used in public construction in Rome was organized,[6] but even so this tells us little about the workforce that actually put the materials in place on the building site. Detailed studies of the monuments themselves have rarely been integrated into the discussions of the building industry in Rome, though this is in large part due to the lack of information on many of the largest surviving monuments from ancient Rome.

One of the more difficult tasks in trying to integrate the archaeological material with what is known from other sources is making the connections with the various types of written evidence, which are often different in nature and intent. To provide a simple explanation for how these pieces of information fit together would inevitably result in a superficial image of the complex relationships between the parties involved in a large public building project such as Trajan's Markets. On the other hand, to make no attempt at sorting out the possibilities for how the archaeological material could relate to the written evidence would be to ignore an important source of information. The following discussion is, therefore, an attempt to present the archaeological material from the Markets and to place it into a context from which reasonable hypotheses can be made.

In the first two of the following sections, each technique is examined to determine why it was used at the Markets, and specific examples of its use are high-

[5] P. Brunt, "Free Labour and Public Works at Rome," *JRS* 70 (1980) 81–100; G. De Ruggiero, *Lo stato e le opere pubbliche in Roma antica* (Turin 1925); J.L.D. Pearse, *The Organisation of Roman Building during the Late Republic and Early Empire* (Diss. Cambridge Univ. 1974).

[6] For a review of marble production: H. Dodge, "Ancient Marble Studies: Recent Research," *JRA* 4 (1991) 28–50; for the brick industry: E.M. Steinby, "I senatori e l'industria laterizia urbana," *Tituli* 4 (1982) 227–37.

lighted to show the type of information that can be extracted. In the last section, the archaeological material is discussed in relation to what is known from other types of evidence.

COURSES OF BIPEDALES IN THE WALLS

Roman concrete walls, such as those at Trajan's Markets, are typically faced with triangular pieces of brick formed from squares sawn or broken along the diagonal. The triangles or brick fragments are often made from *bessales* (ca. 20 cm square) or *sesquipedales* (ca. 44 cm square). Periodically, "bonding" courses of whole bipedales appear in the walls. At the Markets the bipedalis courses are usually thicker than the average facing bricks and often have a yellowish cast, making them stand out from the surrounding brickwork. Unlike the bricks of the facing, which only occur on the exterior face of the wall, the courses of bipedales often penetrate through the core of the wall.

One of the earliest datable examples of the use of bipedalis courses occurs at the Colosseum,[7] the superstructure of which consists of a travertine and tuff skeleton of *opus quadratum* combined with radiating walls of brick-faced concrete. The bipedalis courses occur at level 2 at the base of a few of the radiating brick walls that are built on top of the opus quadratum walls at level 1. The technique is not used consistently, but the context suggests that it was intended to establish a level surface where the material changed from blocks of tuff to brick-faced concrete; the bipedalis courses never occur in the upper parts of the brick walls at the Colosseum. In other monuments in subsequent periods, courses of bipedales are used in various circumstances. In the Domitianic walls of the Domus Augustana they occur at irregular intervals, sometimes coinciding with putlog holes for scaffolding. At Trajan's Baths they occur only occasionally but usually in conjunction with architectural features such as at the springing of arches or at the sills of windows.[8] At the Pantheon, they occur at set intervals in the lower parts of the walls and at irregular intervals in the upper parts.[9] At the Baths of Caracalla, the courses of bipedales usually occur at regular intervals (but not always) and in conjunction with putlog holes.[10] The use of the technique is not consistent from one building to the next nor is it necessarily consistent within a single building. The courses of bipedales could have served numerous purposes depending on the situation and were used accordingly.[11]

At Trajan's Markets, the courses of bipedales often occur at definable points within the building: at the spring of vaults and arches, at the sill of windows, and at floor levels. In other cases, they do not mark any particular feature, and the abrupt change in the height of this last type may in some cases point to a change in the workforce. In what follows, the pattern of the bipedalis courses at the Markets is examined in terms of what it can reveal about the organization of construction and labor at the Markets.

Trajan's Markets consist of six different levels with over 140 rooms, for which there is no standard numbering system. The system that I use here is intended to give the reader an idea of the level and general location of a room without having to refer constantly to the plans and sections. A key and explanation are given in figure 1.

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[7] Earlier examples of the technique may exist. Carettoni mentions rows of "tegoloni," which occur every 12 to 17 courses, in the walls of the Neronian nymphaeum underneath the triclinium of the Domus Flavia, but he notes that they are not bipedales: G. Carettoni, "Costruzioni sotto l'angolo sud-occidentale della Domus Flavia (triclinio e ninfeo occidentale)," *NSc* 1949, 68. An early example of the use of courses of bipedales occurs in the east wall of room 44 of the Esquiline Wing of the Domus Aurea: L.F. Ball, "A Reappraisal of Nero's Domus Aurea," *Rome Papers* (*JRA* Suppl. 11, Ann Arbor 1994) 226–28, 251–52. This wall is part of a modification probably belonging to the Late Neronian or Early Flavian period.

[8] K. de Fine Licht, *Untersuchungen an den Trajansthermen zu Rom* (*AnalRom* Suppl. 7, Copenhagen 1974) 36.

[9] K. de Fine Licht, *The Rotunda in Rome. A Study of Hadrian's Pantheon* (Jutland Archeological Society Publications 8, Copenhagen 1968) fig. 99.

[10] J. DeLaine, "An Engineering Approach to Roman Building Techniques: The Baths of Caracalla in Rome," in C. Malone and S. Stoddart eds., *Papers in Italian Archaeology* IV, Pt. 4: *Classical and Medieval Archaeology* (*BAR-IS* 246, Oxford 1985) 196–98.

[11] Various explanations have been given for the use of courses of bipedales in Roman construction—that they marked the end of a day's work or of an assigned amount of work, that they provided a flat base for the putlog holes of scaffolding, and that they were aids in keeping the walls true and vertical: Lugli (supra n. 3) 570–72; W.L. MacDonald, *The Architecture of the Roman Empire* I: *An Introductory Study*[2] (New Haven 1982) 162–63; J.B. Ward-Perkins, *Roman Imperial Architecture*[2] (Harmondsworth 1981) 99; T.L. Heres, *Paries: A Proposal for a Dating System of Late-Antique Masonry Structures in Rome and Ostia* (Amsterdam 1982) 48–49; DeLaine (supra n. 10) 196–98; and also J. DeLaine, *Design and Construction in Roman Imperial Architecture: The Baths of Caracalla in Rome* (Diss. Univ. of Adelaide 1992) 222–25. A revised version of DeLaine's dissertation is currently in press: *The Baths of Caracalla: A Study in the Design, Construction, and Economics of Large-Scale Building Projects in Imperial Rome* (*JRA* Suppl. 25, Portsmouth, R.I., forthcoming).

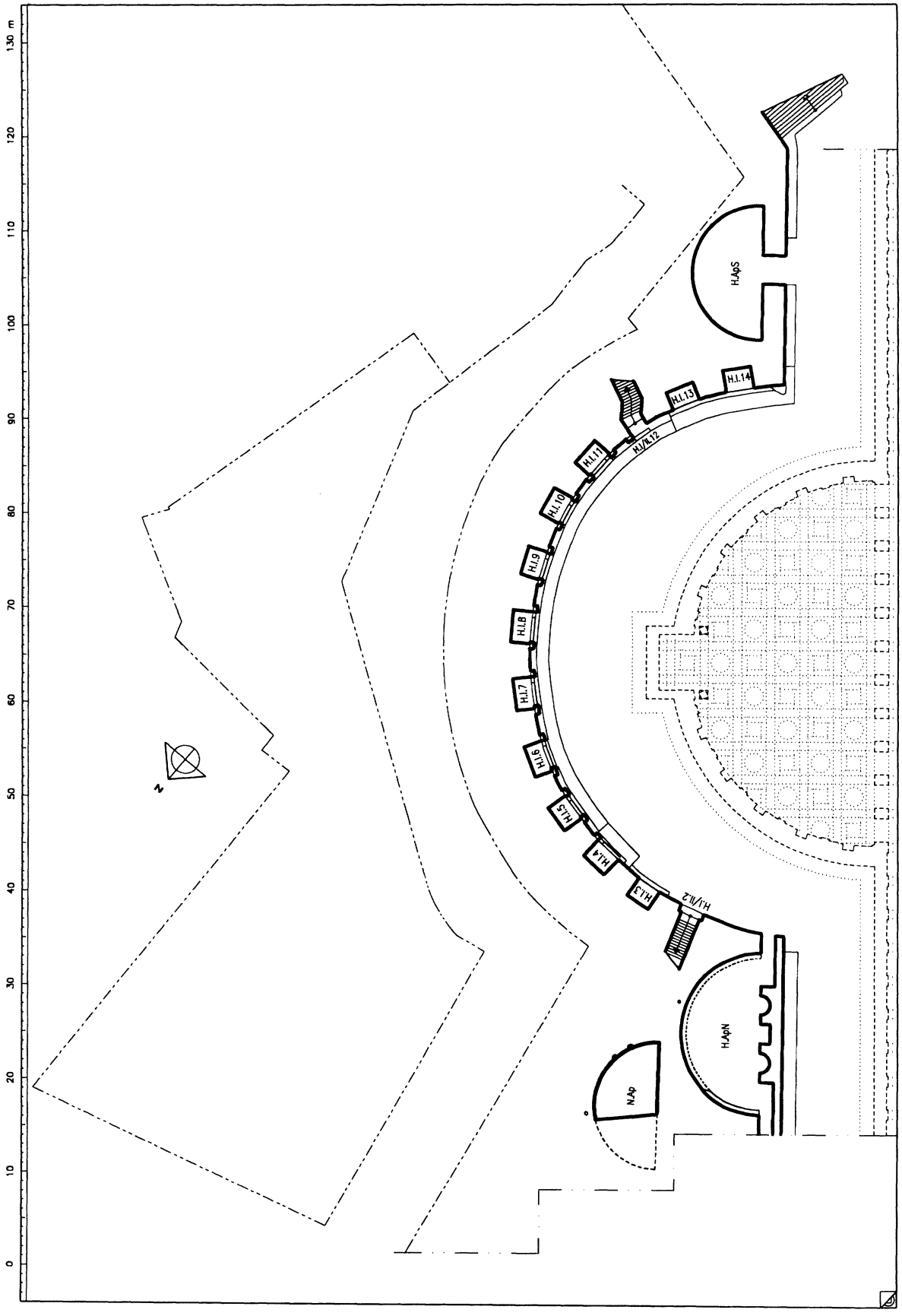

Fig. 2. Plan of level I. Scale 1:600.

Fig. 3. View of Hemicycle elevation at north end. Arrows indicate courses of bipedales.

Level I of the Hemicycle

The lower level of the northern part of the Hemicycle (fig. 2) was buried until the excavations of the 1920s, so the original brickwork there is well preserved.[12] The courses of bipedales in the Hemicycle facade wall are clearly distinguishable due to their light yellow color (fig. 3), and the pattern of the courses is shown in figure 4. The four courses of bipedales in the wall to the south (right) of stair H.I/II.2 run at continuous levels throughout the south part of the building. The uppermost one (21.61 masl)[13] occurs at the spring of the vaults of the level I alcoves.[14] The two lower ones (18.68 and 20.18 masl) align with no particular features, but they, along with the uppermost one, occur at roughly 5-ft vertical intervals above the course of bipedales capping the foundation (17.19 masl).[15]

The two lower bipedalis courses (18.21 and 19.80 masl) to the north (left) of stair H.I/II.2 do not align with those on the south. Rather, they align with the top of the relieving arch over a drain at the base of the wall (18.21 masl) and the spring of the arch over the door into H.ApN (19.80 masl). The third course (21.70 masl), however, aligns roughly with the uppermost course to the south of the stair (21.61 masl), and it also occurs at the base of the lower row of windows into H.ApN and at the spring of the semidome of N.Ap (fig. 5). The fourth course to the north

[12] L. Ungaro et al., "Emiciclo dei Mercati Traianei. Intervento di restauro delle cortine laterizie," *BullCom* 95:2 (1993) 181–99.

[13] The heights of the courses of bipedales are referred to according to the height above sea level (masl) and are indicated on the drawings with these heights. Although the bipedalis courses throughout the monument are not absolutely level, they do form a continuous plane, and in the following descriptions I refer to each unbroken course using an average height even though in reality it may fluctuate.

[14] At the south corner of H.I.3 the height of the bipedalis course at 21.61 masl was raised four brick courses to 21.83 masl. Since this room is almost a foot narrower than the other rooms, its vault had to spring from a slightly higher level to put its crown at the same height as the others. The course of bipedales continues at 21.83 masl toward the north until it meets the south wall of stair H.I/II.2.

[15] All references to feet are Roman feet unless otherwise indicated. Conversions have been made using a Roman foot of 29.40 cm, which is a measure that most consistently yields whole feet in various parts of the monument. In his study of the Forum of Trajan, Packer uses a Roman foot of 29.38 cm: J. Packer, *The Forum of Trajan: A Study of the Monuments* I (Berkeley 1997) 471. As stated above (n. 13), the heights of the bipedalis courses fluctuate so that the distance between courses at 18.68 and 20.18 masl varies between 1.44 and 1.58 m (4.90–5.37 ft), and the distance between courses at 20.18 and 21.61 masl varies between 1.45 and 1.53 m (4.93–5.20 ft).

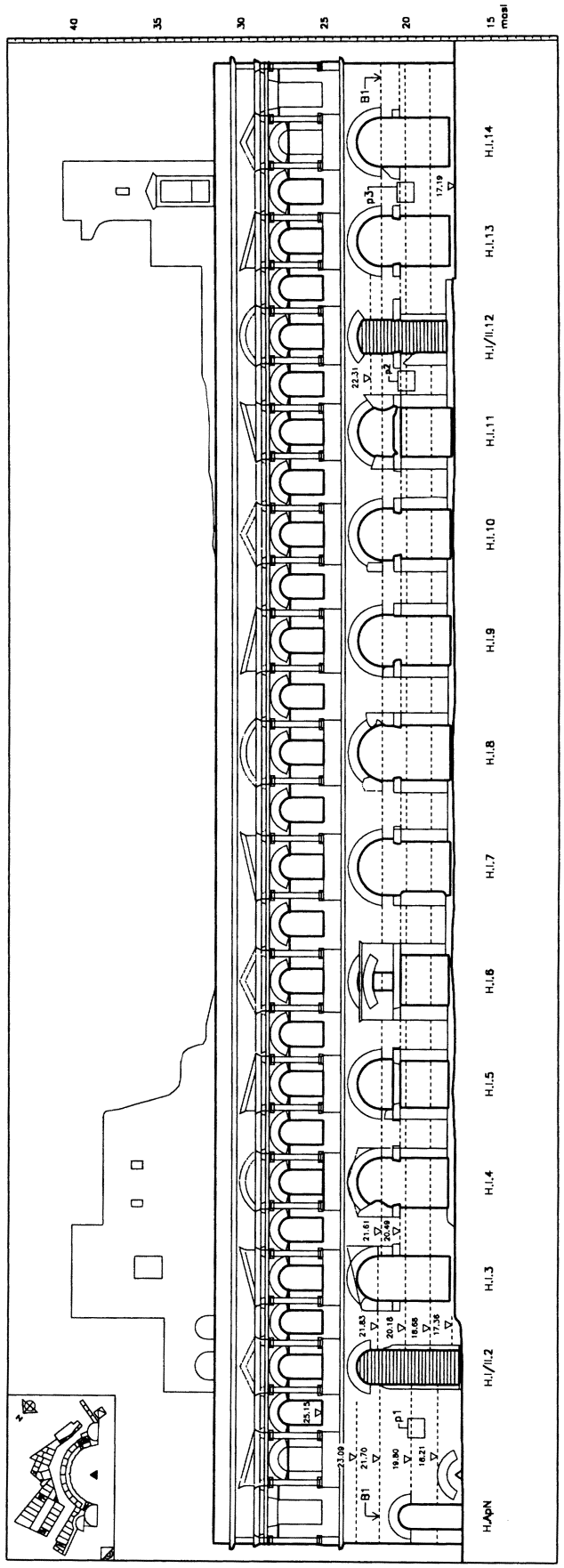

Fig. 4. Elevation of Hemicycle facade. Benchmark level is labeled B1. Locations of "pigs" are labeled p1, p2, and p3. Dashed lines represent bipedalis courses. Heights of bipedalis courses are given in meters above sea level. Scale 1:400.

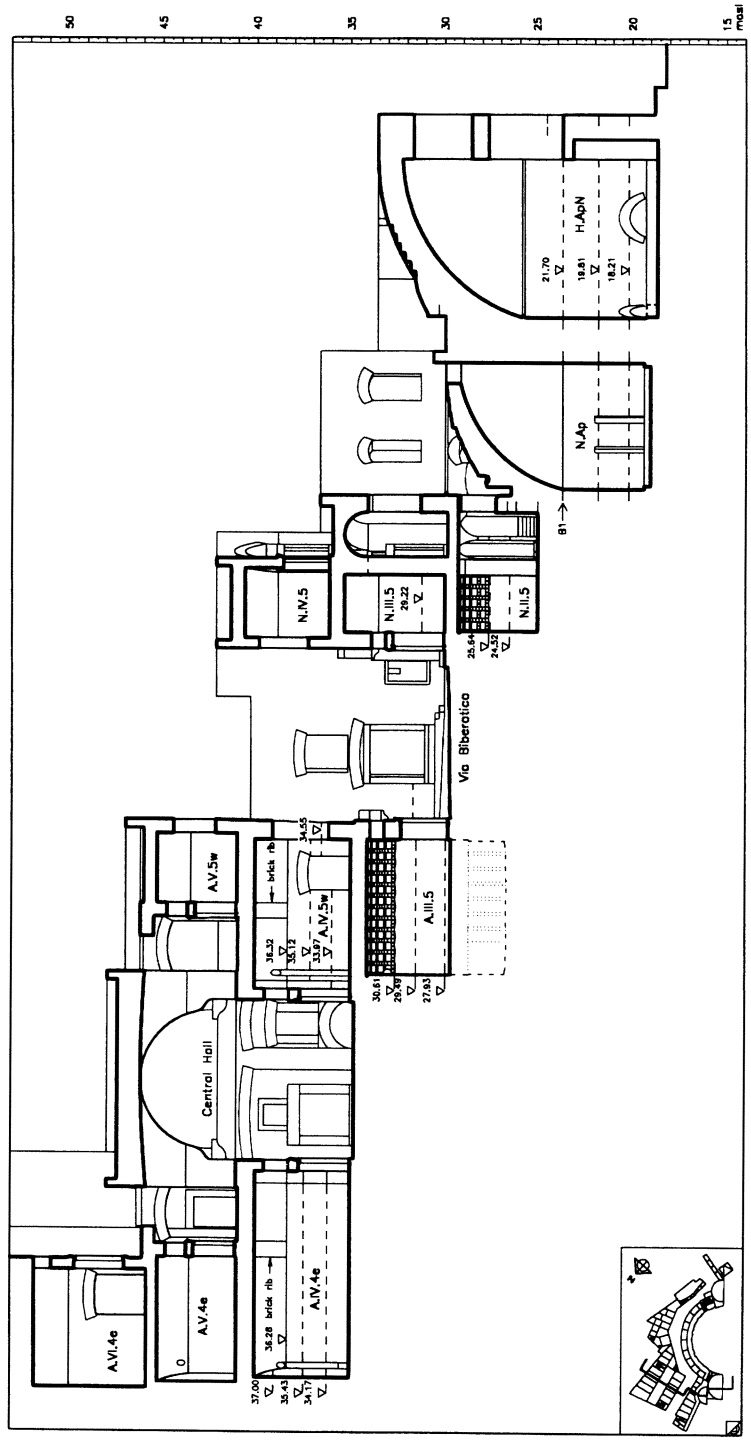

Fig. 5. Section through Aula and North Wing. Benchmark level is labeled B1. Dashed lines represent bipedalis courses. Scale 1:400.

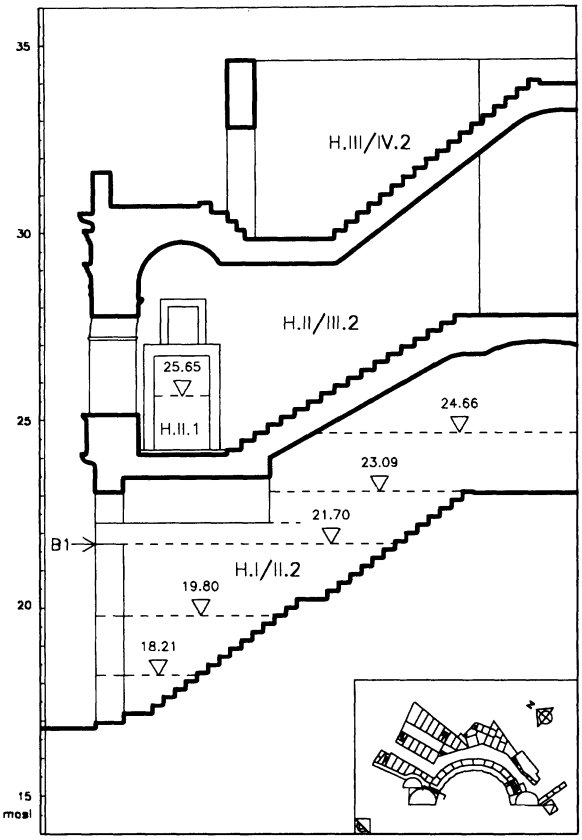

Fig. 6. Section through stair H.I/III.2. Benchmark level is labeled B1. Dashed lines represent bipedalis courses. Scale 1:200.

(23.09 masl) can be traced back along the wall of the stair H.I/II.2 where it aligns with the floor level of the North Wing rooms at level II (fig. 6).[16]

Thus, the walls to the south of stair H.I/II.2 seem to have been built in approximately 5-ft vertical intervals whereas those to the north were built in sections corresponding to the heights of particular elements such as arches, vaults, windows, and floors. The walls to either side of stair H.I/II.2 have a common level marked by the bipedalis courses that occur at the springing of the vaults of the Hemicycle rooms, at the sill of the windows in H.ApN, and at the spring of the vault of N.Ap (marked "B1" on the sections). The height of this level fluctuates as much as 26 cm (from 21.59 to 21.85 masl),[17] but such variations are not unusual even within a single, unbroken course of bipedales. The level marked by these courses seems to have been used as a type of "benchmark" for laying out the plan as the building grew in height. The sections of walling below the benchmark to either side of stair H.I/II.2 could have risen independently, but at some point during construction all walls were brought up to this common level before proceeding.

Using set heights to organize construction would have provided certain advantages. For example, periodically bringing all the walls to a common level would have been particularly useful in providing a level platform for surveying and laying out the terraces further up the hill.[18] Laying out the foundations on a hillside site was inevitably more difficult than on a flat site since there was no common plane from which to survey the next stage of the work.[19] Designing the Markets in such a way that major features aligned along a common level and using these levels to coordinate the workers and their progress would have allowed each stage of work to be controlled so that the laying out of the foundations of the next level could have proceeded before the vaults of the previous level were added. No written records from the Roman period survive to confirm whether or not such benchmark heights were typically used to organize the construction sequences,[20] but it would seem that the problems encountered in build-

[16] This course has no counterpart to the right of the stairway, since the floor level of the level II Hemicycle rooms is about a meter higher than that of the North Wing rooms and corresponds instead to the height of the travertine cornice (fig. 11).

[17] The continuous bipedalis course at 21.61 masl actually varies from 21.59 masl at H.I.4 to 21.75 masl at H.I.11. To the south of stair H.I/II.12, it varies from 21.78 to 21.85 masl.

[18] The date and extent of the excavation of the hillside against which the Markets are built is a debated issue with some authors arguing that Domitian had already cut back the Quirinal before Trajan came to power. Domitian did do work in the area, but the archaeological material shows clearly that the plan of the Forum and Markets of Trajan is substantially different from the remnants of the earlier Domitianic project: Lancaster (supra n. 3) and E. Tortorici, "La 'Terrazza domizianea', l'aqua Marcia ed il taglio della sella tra Campidoglio e Quirinale," *BullCom* 95:2 (1993) 7–24. Regardless of the amount of work completed by Domitian, the Trajanic builders would have had to do a substantial amount of "landscaping" before the foundations of each level could have been laid.

[19] The foundations of some rooms of the Markets are accessible. Those behind the room E.IV.6, which are now accessible by means of a small staircase located in E.V.9, are shown on the plan in figure 16. The foundations under A.III.2 and A.II.3 are now accessible by means of a stair along the back wall of A.III.4. These foundation walls extend at least 2.90 m below the level III floor (figs. 5, 10). For ancient surveying methods used on uneven terrain: J.P. Adam (A. Mathews trans.), *Roman Building: Materials and Techniques* (London 1994) 18–19.

[20] DeLaine (supra n. 10) 198 suggests that the courses of bipedales at the Baths of Caracalla could have been used to fix heights so that the builders would not always have to measure from the ground up when constructing some of the particularly tall walls there.

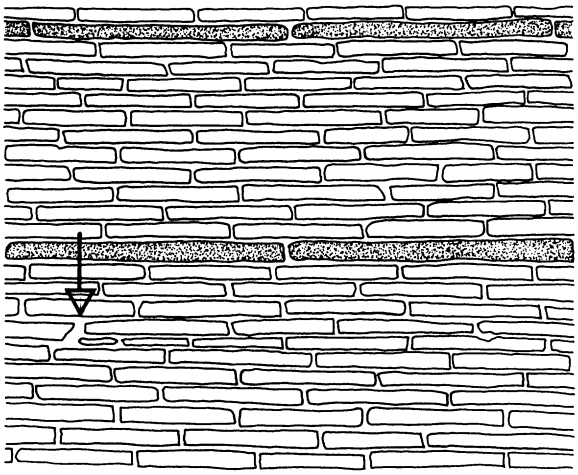

Fig. 7. Arrow indicates "pig" between H.I.11 and stair H.I/II.12 (p2 on fig. 4)

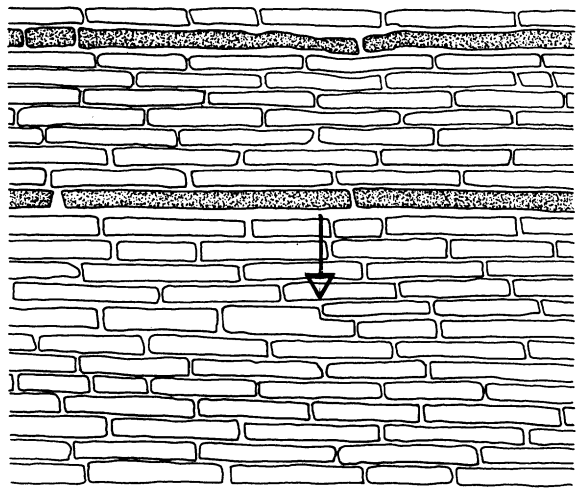

Fig. 8. Arrow indicates "pig" between H.I.13 and H.I.14 (p3 on fig. 4)

ing on a difficult and complex hillside site were taken into account from an early stage and that the design was planned so that some courses of bipedales would occur at logical and convenient stages in the building process.[21]

One other aspect of these walls provides some insight into the labor force. The fluctuations between the heights of the bipedalis courses are often accompanied by a change in the number of brick courses between them. The change usually occurs at the reentrant corners of the Hemicycle rooms where the discrepancies are easily resolved, but there are three instances in which the bricks are adjusted in the middle of the wall (fig. 4:p1–p3; figs. 7–9). In each case the adjustment is handled in a different manner. Such changes in the number of brick courses between the bipedalis courses, especially those in the middle of the wall, are probably the result of many masons working side by side, who periodically had to bring their work into alignment. Among brick masons in Britain today the disjunctions that occur between courses are called "pigs."[22] The masons themselves would have decided how best to correct the error; hence, the three different resolutions to a similar problem can be seen in the "pigs" along the Hemicycle facade. The joints between H.I.11 and stair H.I/II.12 (fig. 7:p2) and between H.I.13 and H.I.14 (fig. 8:p3) suggest that two masons working side by side were responsible for a stretch of wall a little over 11 ft long. This allows each brick mason about 5.5 ft, which is the span of an average-sized man's outstretched arms.[23] At the north end of the Hemicy-

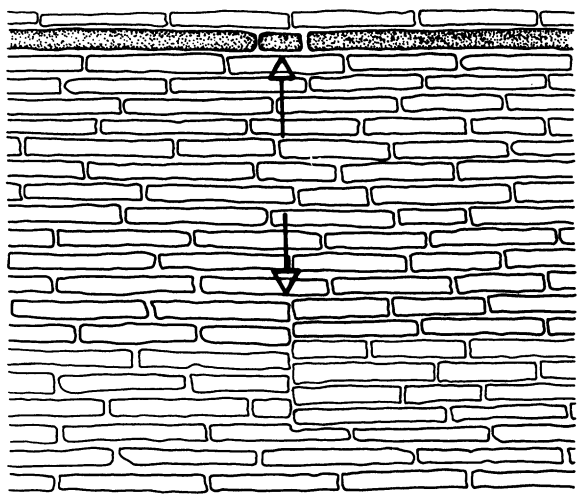

Fig. 9. Lower arrow indicates "pig" between H.I.1 and stair H.I/II.2 (p1 on fig. 4). Upper arrow indicates a brick fragment between two of the bipedales in the bonding course. It occurs directly above the "pig" and provides additional evidence that this "pig" marks a division between masons.

[21] An interesting parallel occurs in 16th-century Spain where the use of set heights to organize a building project is documented both in the building accounts and in the physical remains of the basilica at the Escorial. There, the contracting of the building was organized around the heights of 30 ft and 55 ft, and a stone inscribed *30 pies* records the point at which the 30-ft level was reached in 1577: G. Kubler, *Building the Escorial* (Princeton 1982) 82.

[22] I thank Michael Walsh, a former building contractor, for his observations on problems encountered in modern brick construction and on the terminology used to describe the results.

[23] In his Renaissance treatise on architecture, Filarete recommends that masons building his ideal city should stand three *braccia* apart (Florentine braccio = 58.36 cm), which would be 1.75 m or about 6 ft: J. Spencer, *Filarete's Treatise on Architecture* (New Haven 1965) 41.

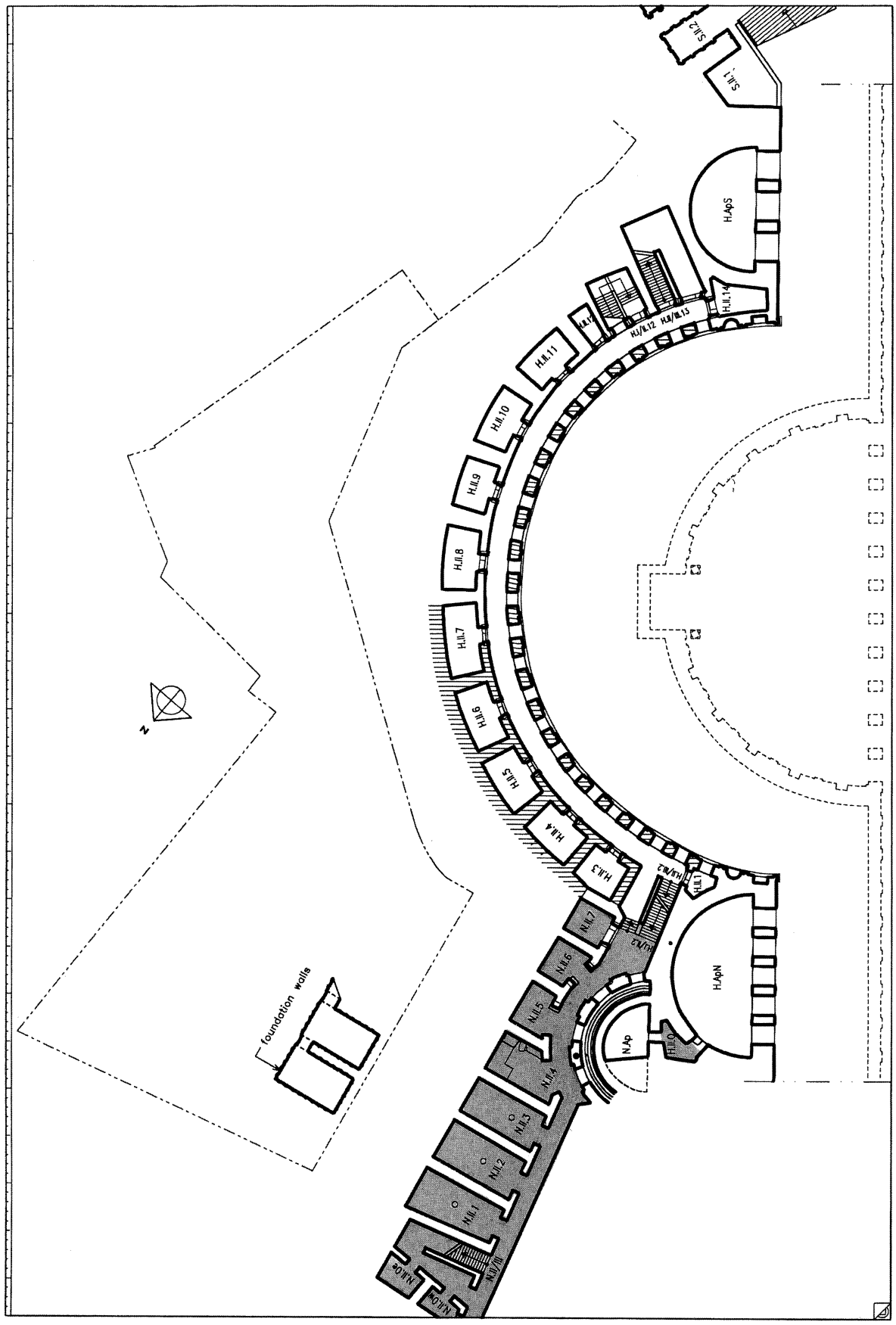

Fig. 10. Plan of level II. Gray shaded areas indicate the vaults with brick linings. Hatching indicates the walls with the bipedalis course at 25.15 masl. Scale 1:600.

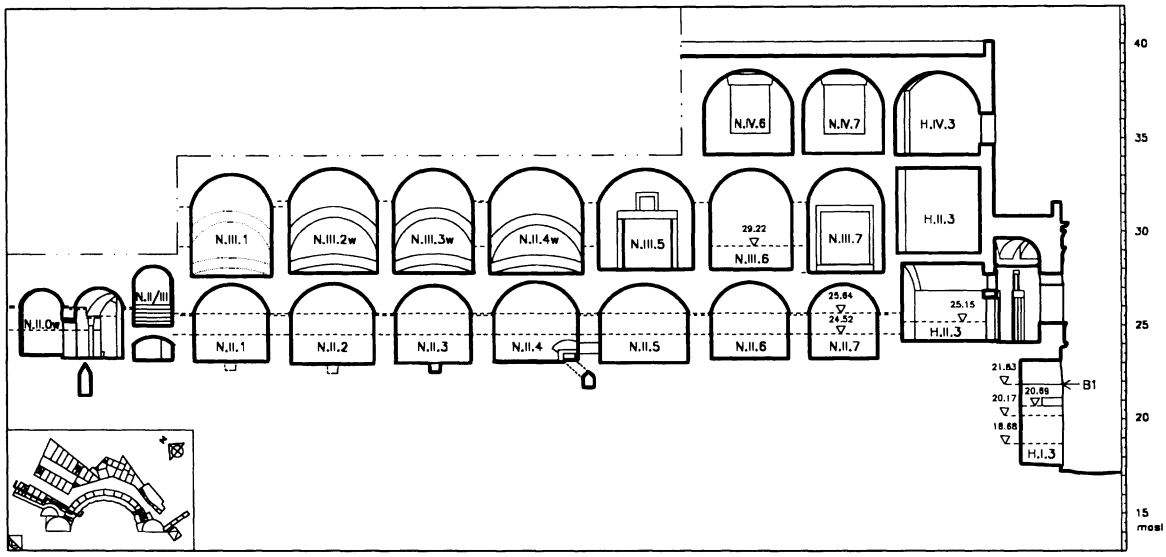

Fig. 11. Section through North Wing and Hemicycle. Benchmark level is labeled B1. Dashed lines represent bipedalis courses. Scale 1:400.

cle, where there is a longer stretch of unbroken wall, the "pig" (fig. 9:p1) occurs 8 ft (2.37 m) to the left of the north wall of stair H.I/II.2, so here the brick masons were spaced a little farther apart. We can never know exactly how many masons were working simultaneously on a given stretch of wall, but these fortuitous mistakes give some clue as to the typical spacing between masons.

Level II of the North Wing and Hemicycle

The brick facing in the level II rooms of the North Wing and Hemicycle (fig. 10) is fairly well preserved. The walls of the North Wing rooms have two courses of bipedales, at 24.52 and 25.64 masl, respectively (fig. 11). The lower one aligns with no particular feature, but it does occur 25 ft above the foundation course (17.19 masl). The upper course coincides with the springing of the vaults. These two courses end where the North Wing intersects the Hemicycle at room H.II.3, and a single bipedalis course at a different level (25.15 masl) runs throughout the walls of the rooms in the northern half of the Hemicycle as far as H.II.8, as shown on the plan in figure 10 and on the section in figure 12.

The change in the heights of the bipedalis courses between the North Wing rooms and the Hemicycle rooms is visible in two places: at a jog in the south wall of corridor H.II.2 and in the back wall of H.II.3 (figs. 10, 12). In the latter, the change occurs in conjunction with a bend in the wall and is marked by a "pig" (fig. 12:p4; fig. 13). The change in the heights of the courses of bipedales in room H.II.3 clearly occurs at a construction joint in the building, which is also accompanied by a 1.03-m change in floor level. The bricks are bonded, however, indicating that the two wings of the building were rising simultaneously. This building joint is even more pronounced at level III where it is marked by a jog in the north wall of H.III.3 (circled on fig. 14). The intersection between the two wings of the building is a logical place for a change in the workforce to occur, and as we shall see from further evidence discussed below, this probably accounts for the discontinuity in the brick courses visible in the north wall of H.III.3.

The pattern of the bipedalis courses in the Hemicycle may provide additional evidence for the way in which the work was divided. The course of bipedales (25.15 masl) that begins on the south side of the joint in H.II.3 continues throughout all the walls of the rooms in the northern half of the Hemicycle up to room H.II.8 (figs. 10, 12).[24] Curiously, between rooms H.II.7 and H.II.8 this course is replaced by one slightly higher (25.67 masl), which runs throughout all the walls of the rooms to the south of H.II.8 (fig. 12). The higher course is not aligned with any particular feature, though it occurs roughly at the same level as the course at the impost level of the North Wing rooms (25.64 masl). The back walls

[24] This is the same height as the sills of the windows along the Hemicycle Facade, which are also marked by a course of bipedales. It is still visible in places along the inner face of the wall throughout the length of the corridor. Since the bipedalis course in the Hemicycle Facade was clearly used to establish the window sill level, it does not necessarily indicate the work of any particular crew.

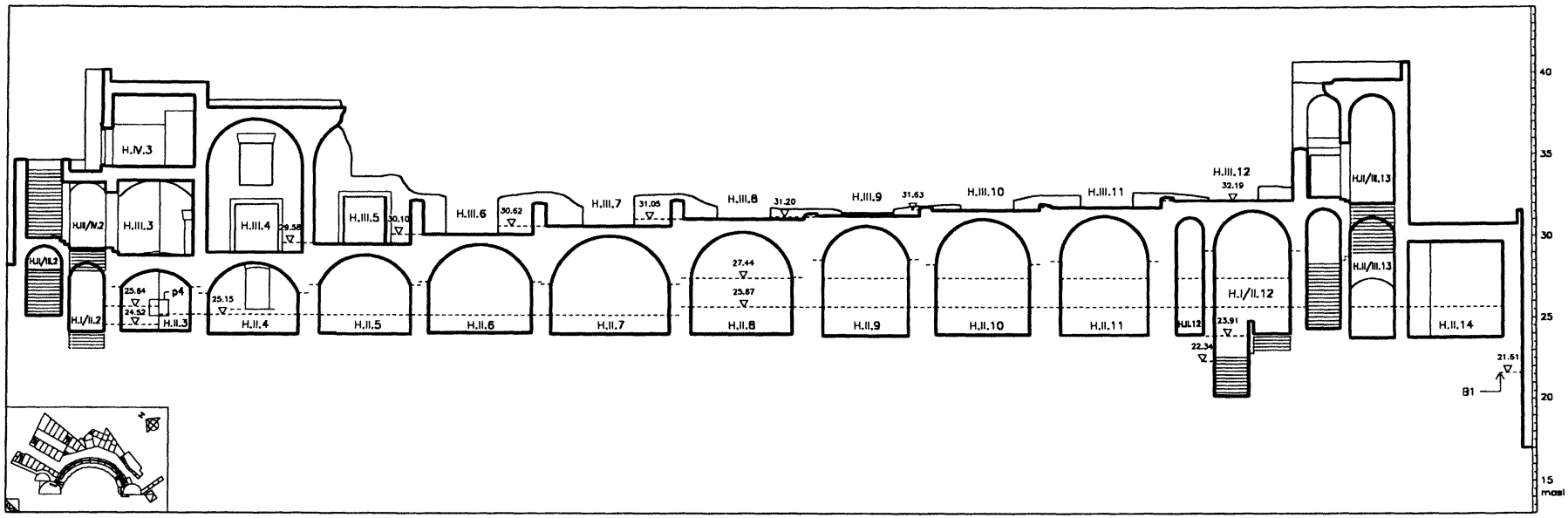

Fig. 12. Section through Hemicycle. Benchmark level is labeled B1. Location of "pig" is labeled p4. Dashed lines represent bipedalis courses. Scale 1:400.

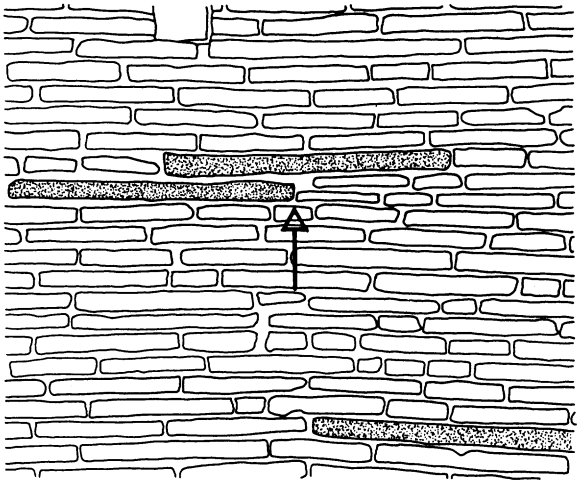

Fig. 13. Drawing of "pig" p4 on figure 12

of rooms H.II.8–H.II.12 also have a second course of bipedales (27.44 masl), which corresponds to the impost level of the vault in H.II.8.[25]

None of the bipedalis courses in the level II Hemicycle rooms appears to correspond to a set interval of feet above the foundation course as does the lower one (24.52 masl) in the North Wing, nor do any of the courses of bipedales in the levels above this. The use of bipedalis courses spaced at regular intervals above a datum point, which seems to have been employed at level I, was dropped at a fairly early stage in the construction process, although the intervals between some bipedalis courses in other parts of the complex sometimes do correspond to units of whole or half Roman feet. The lack of regularly spaced bipedalis courses in the upper levels may be partially explained by the differences in the topography of the two areas; the lower level of the Hemicycle was built on the flat plateau of the Forum area whereas the upper levels were built along the hillside in relation to the slope of Via Biberatica. At a certain point in the process, using regularly spaced courses of bipedales would no longer have been beneficial.

The change in the pattern of the courses of bipedales in the level II Hemicycle walls is located at the center of the wing, which is another logical place for a change in the workforce to occur.[26] During the course of construction, stairways are often critical elements that determine the scheduling of the work. Since they provide the major routes of access to the upper parts of the building, construction often begins nearby and then radiates out from them as work proceeds.[27] The change in the pattern of the bipedalis courses between H.II.7 and H.II.8 may be the result of two crews of brick masons each using one of the stairways for men and materials and then meeting in the center,[28] but if so the work was not distributed in terms of the walls and vaults of a set group of rooms, which seems to have been the case for the North Wing rooms, as we shall see below. The division in the back wall occurs between the dividing wall of H.II.7 and H.II.8 whereas along the front wall it occurs to either side of the doorway into H.II.7, so there is some degree of overlap at H.II.7.[29]

The change in the heights of the bipedalis courses at the center of the Hemicycle may well indicate a change of labor in the lower parts of the walls, but the same division would not necessarily hold true for the upper parts of the walls and for the vaults. The heights of these rooms increase toward the south to accommodate the rise in Via Biberatica, so the amount of work would have increased significantly toward the south. None of the original *extrados* of the level II vaults exists, but the remains of courses of bipedales on the exterior face and on the inside walls of the level III rooms along Via Biberatica mark the original levels of the extrados of the level II vaults, which formed the floor of the level III rooms (figs. 12, 15). These bipedalis courses show that the level II vaults were constructed as stepped terraces. The

[25] All of the level II Hemicycle vaults spring from a course of bipedales at the top of the side walls, but it is usually not carried around to the front and back walls (unlike the impost courses in the North Wing rooms, which run throughout all the walls at the same height). Since the Hemicycle rooms have different spans and heights, each of their vaults must spring from a different level (fig. 12).

[26] Similar types of changes in constructional features occur along the central axis of other Roman buildings. Changes in the heights of the bipedalis courses occur in the central section of the north facade wall of the Baths of Caracalla: DeLaine (supra n. 10) 196. At Trajan's Baths, an abrupt change in the height of the putlog holes occurs along the centerline of the apse of section E (along Via delle Terme di Traiano): L.C. Lancaster, *Concrete Vaulted Construction: Developments in Rome from Nero to Trajan* (Diss. Oxford Univ. 1995) 145, fig. 128A.

[27] The importance of stairways as regulating elements for the building sequence has been noted in the context of medieval construction: C. Bruzelius, "The Early Work on the Rebuilding of Saint-Denis in the Thirteenth Century: 1231–1241," in *Artistes, artisans et production artistique au Moyen Age* II (Paris 1987) 341; and J. James, *The Contractors of Chartres* (Dooralong 1979) 54–55, 67.

[28] The amount of work represented by the two bipedalis courses is not equal.

[29] Such overlaps can also be seen in the heights of the bipedalis courses of some walls in the Aula (e.g., E.IV.2 on fig. 17 and A.IV.5w on fig. 5).

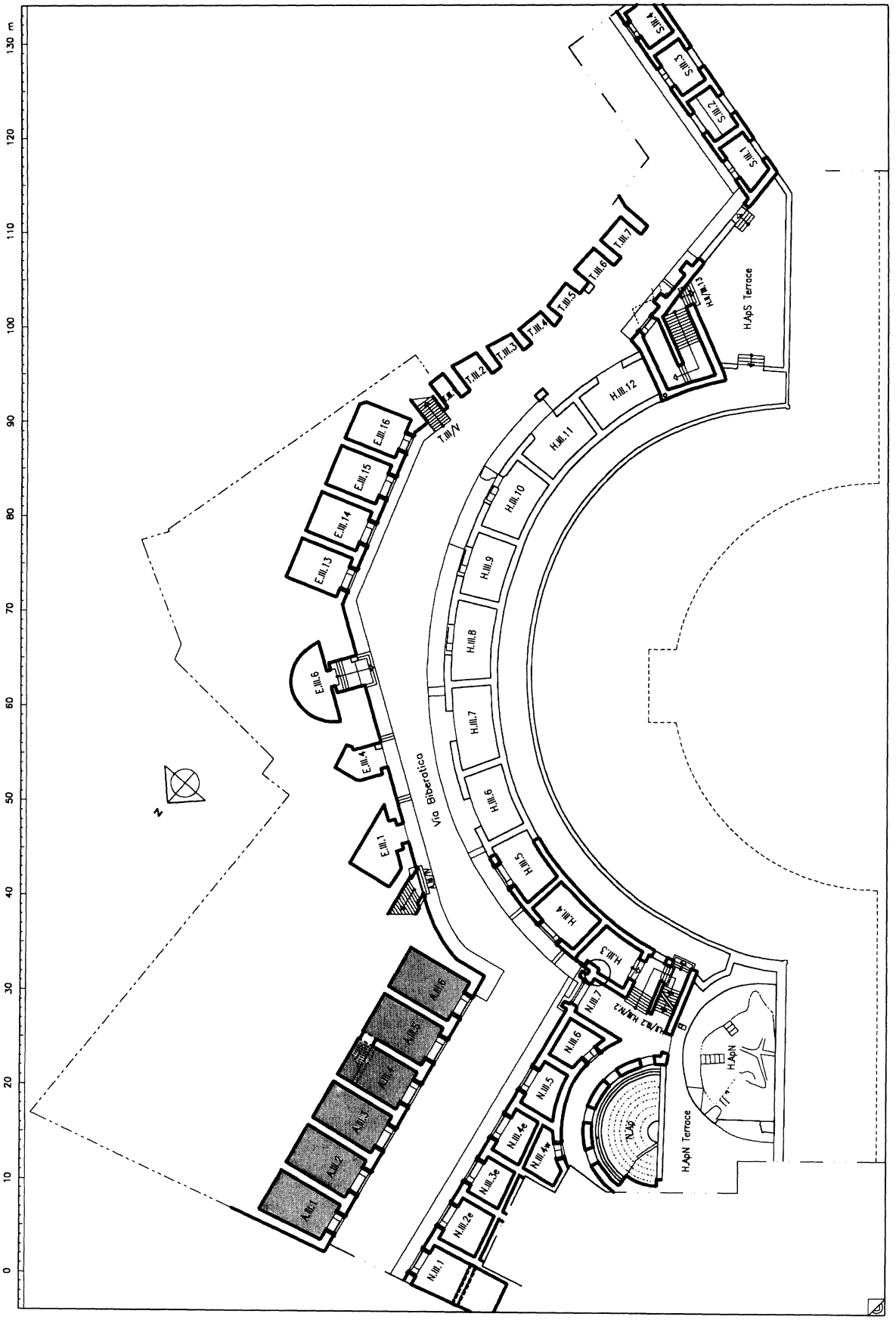

Fig. 14. Plan of level III. Gray shaded areas indicate vaults with brick linings. Scale 1:600.

Fig. 15. View of rooms along Via Biberatica showing courses of bipedales (indicated with arrows) marking floor levels of H.II.5 and H.III.6

pattern of construction indicates that the process must have proceeded from the lowest room (H.II.3) with each vault added at a slightly higher level as the work proceeded toward the south. Given that the taller, thicker walls at the southern end would have taken longer to complete, the construction of the lowest vaults at the northern end could have begun while the south walls were still being built. Since construction of the vaults had to start from the lowest one at the north end and work toward the highest one at the south end, the number and distribution of masons would have changed as work proceeded. In such a complex area where the topography of the site shaped the configuration of the architecture, the way in which work was assigned must have changed to account for the differences from one part of the monument to the next and from one level to another.

Levels III and IV of the Aula and East Wing

The evidence for courses of bipedales in the East Wing and Aula is preserved primarily in the walls of levels III and IV (figs. 14, 16). Heavy restoration due to extensive reuse at levels V and VI in the medieval period and later has eliminated most traces of the bipedalis courses in the uppermost parts of the monument, but some are still discernible at levels III and IV.

As in the lower complex, the abrupt changes in the heights of the bipedalis courses tend to occur on either side of stairways and at changes of orientation. The heights of the two lower courses (34.17 and 35.43 masl) in the east Aula rooms do not continue in the rooms of the East Wing on the south side of stair A.IV.6e (fig. 17). A change in the orientation of the plan occurs here, and the differing heights of the courses of bipedales may signal a change of workforce between the two wings. Some additional evidence for a change here can be found in the brick ribs built into the vaults of the rooms on either side of stair A.IV/V.6e. The ribs were added to reinforce the vault supporting the front wall of the level V rooms above (fig. 5). All of the ribs in the Aula vaults (A.IV.1e–5e, A.IV.2w–6w) are built with well-defined, straight edges whereas the rib in the room on the other side of the stair (E.IV.3) is constructed so that the bricks are staggered to "tooth" into the surrounding concrete.[30] The conditions on either side of the stairway are identical yet subtle differences in the way the ribs were constructed suggest a change in the workforce on either side of the stair.

Another shift in the orientation of the plan occurs in the East Wing at E.IV.12 (fig. 16), and an obvious construction joint divides the two different phases of construction (fig. 18). Room E.IV.12 is an awkward triangular space located between the apsidal room E.IV.6 and the rooms E.III.13–E.III.16. The

[30] The vault of E.IV.2, which should also have a rib, is covered with plaster, and its intrados is not visible.

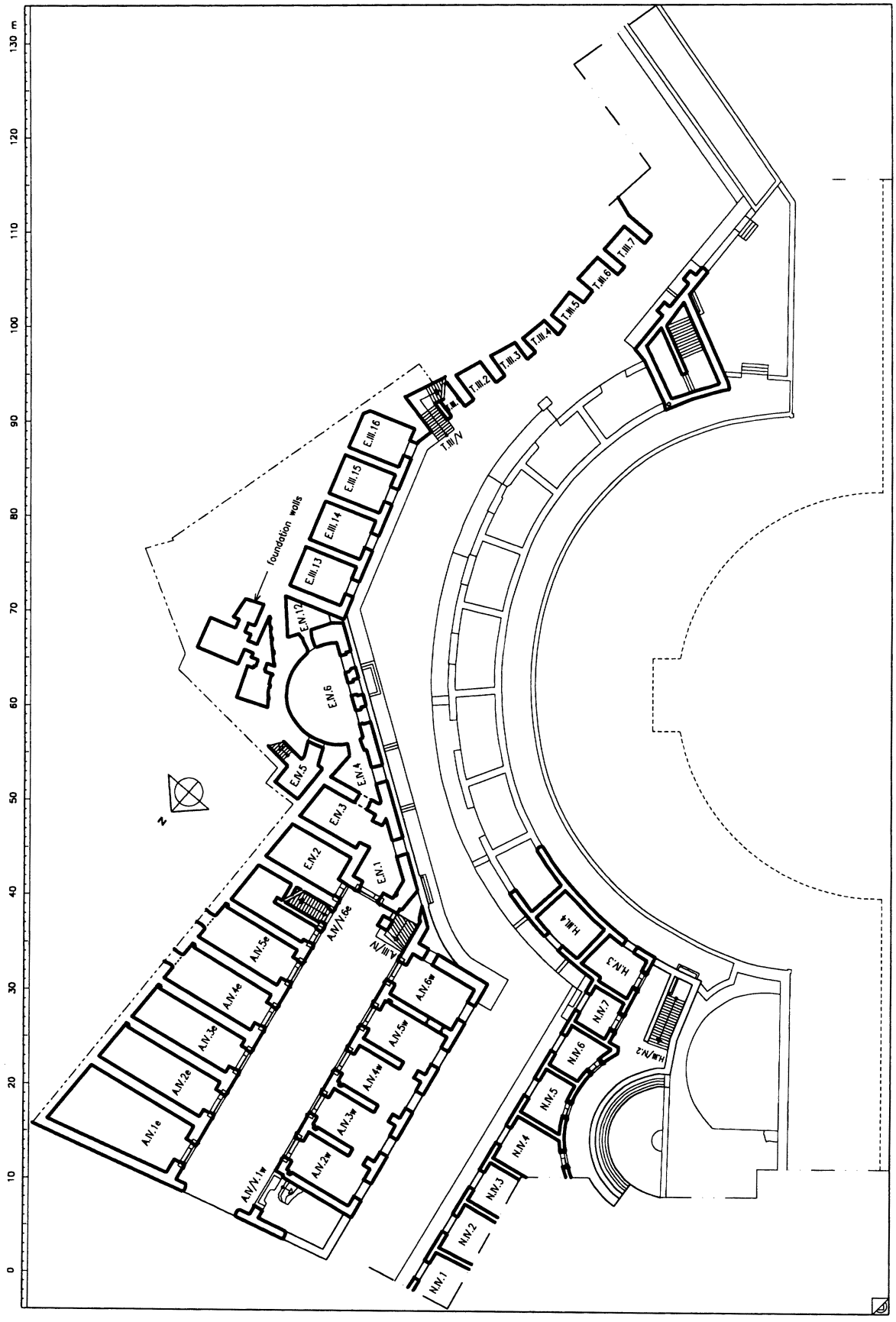

Fig. 16. Plan of level IV. Scale 1:600.

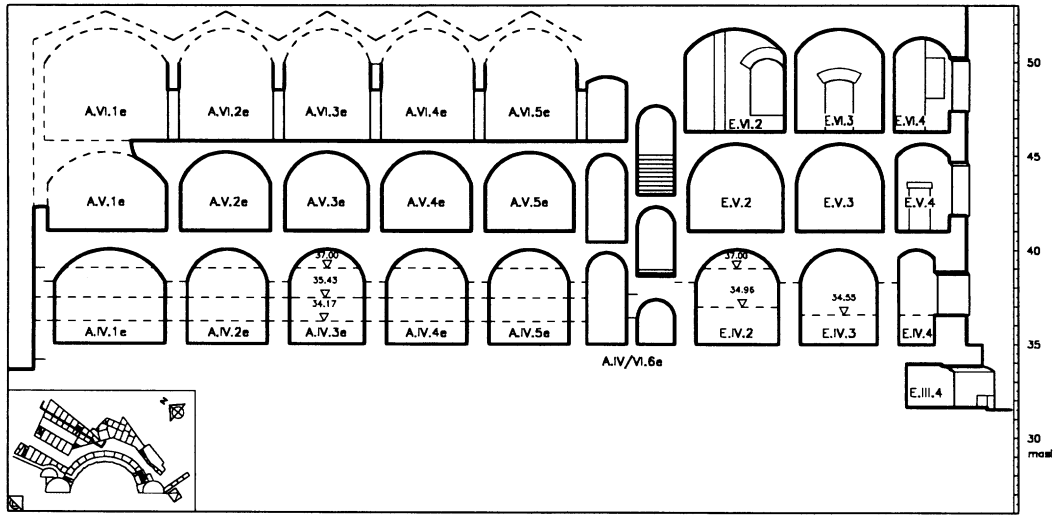

Fig. 17. Section through Aula and East Wing. Dashed lines represent bipedalis courses. Scale 1:400.

present doorway into this room has been cut into the south end of E.IV.6, and it is unclear how or if this space was accessed in antiquity. The lower parts of the walls of E.IV.12 are unfaced and retain the vertical grooves of posts supporting the formwork boards. A window overlooking Via Biberatica has been cut in the corner of the room. A telling feature is that the northwest jamb of the window is faced, showing that E.IV.6 was constructed first and that E.III.12 was built up to it.[31] A course of bipedales in the walls of E.IV.13–E.IV.16 roughly aligns with the present floor level of E.IV.6 (fig. 19), and this course may have acted as a benchmark level much like the one (B1) at level I discussed above.

Summary

The courses of bipedales in the walls at Trajan's Markets typically occur in conjunction with constructional features, such as at the top of foundations, at the spring of vaults and arches, and at floor levels, though in some cases, the bipedalis courses align with no particular feature. The abrupt changes in the heights of this latter type often occur at logical points in the building: at the center of the Hemicycle, at the change of orientation between the Hemicycle and the North Wing, and at the intersection of the Aula and East Wing. As we shall see from the evidence presented in the next section, the change between the North Wing and the Hemicycle is probably explained by the use of different crews of workers. The changes at the center of the Hemicycle and at the intersection of the Aula and East Wing could also be explained in a similar manner, but the evidence in these places is more ambiguous and is open to other interpretations.

In at least one place (fig. 4:B1) along the level I Hemicycle wall, the bipedalis courses seem to mark a type of benchmark level. Work in each sector appears to have progressed independently to a certain point, and then all walls were brought to a roughly common level before starting again. At an even smaller scale the work between individual masons can sometimes be distinguished by the "pigs" left in the brickwork where the brick courses went out of alignment and had to be brought level again before a bipedalis course was added. It seems clear that, regardless of the way in which the masons were organized, they were periodically required to bring their work into alignment, which is revealed by both the "pigs" and the benchmark bipedalis courses.

BRICK LININGS AS THE FORMWORK FOR VAULTING

The vaults at Trajan's Markets were built using two different types of formwork, and the distribution of the two types provides additional evidence for the manner in which the project was organized. From Republican times, Roman concrete vaults were constructed using wooden formwork on a timber centering that was removed once the concrete had

[31] With the exception of a couple of filled wall openings (e.g., in H.II.4 on fig. 12 and in E.IV.6 on fig. 19), the only other places at the Markets where this type of faced joint is visible are in the north wall of the Aula (to be discussed further in a future article).

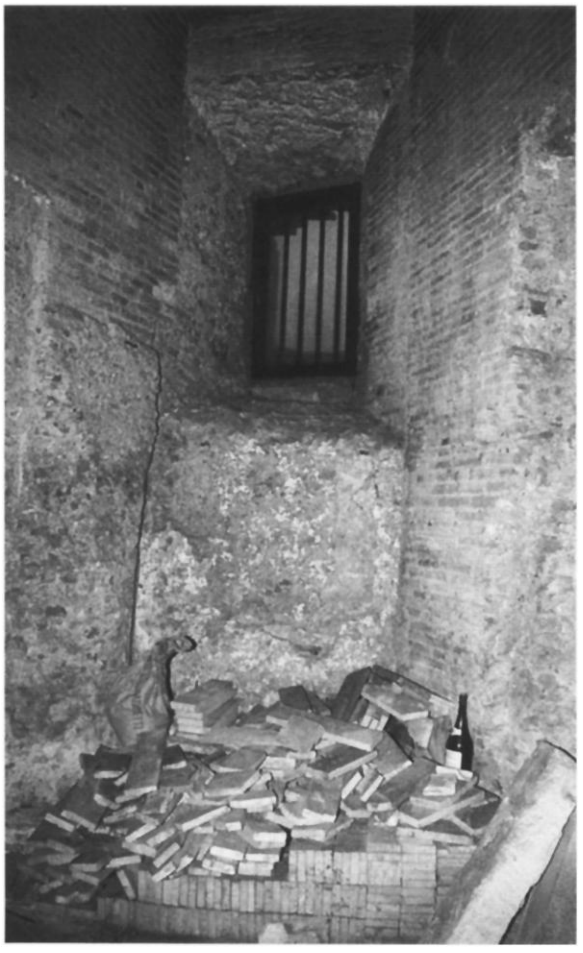

Fig. 18. View of construction joint in E.IV.12. Note that the left side of the window jamb is unfaced whereas the right side is faced showing that it existed before the wall to the left was added.

stabilized.[32] In the Trajanic period, an alternative technique developed in which the concrete was laid on a lining of bricks that was placed over the wooden formwork. The linings usually consisted of a layer of bipedales or sesquipedales with a grid of bessales covering their joints (fig. 20). When the wooden centering and formwork were removed, the brick linings remained adhered to the *intrados* of the vault, though the larger bricks have often fallen or been removed leaving only the grid of bessales visible (fig. 21).

In explaining the purpose of the brick linings, most recent discussions have simply followed one or the other of the explanations offered by the engineers Auguste Choisy and Giuseppe Cozzo.[33] The explanation first given by Choisy in the 19th century was that the brick linings were used to reduce the amount of wooden formwork needed for the centering of the vaults, thereby reducing the cost. He proposed a model in which a layer of bipedales was placed over a light wooden centering. Another layer of bricks was then bound to the first layer with mortar, thereby creating a rigid skin on which the concrete could be laid. According to him, the centering could have then been removed when the concrete had only been laid halfway up the vault and reused for another vault while the first was still under construction.[34]

Choisy's proposal was influenced by a technique commonly used in Spain and southern France in the 18th and 19th centuries,[35] sometimes called "timbrel vaulting" or in the United States the "Guastavino System." This vaulting technique was used to build vaults without centerings by binding two layers of bricks laid flat to create a rigid curve, much in the same way laminated bent wood is made rigid.[36] The strength of this type of vault relies on the ability of the binding material, usually some type of mortar, to resist tensile and shear stresses. One problem with Choisy's theory is that, unlike true timbrel vaults, most examples of the Roman linings did not consist of two solid layers of bricks. Rather, the second layer usually consisted of a grid of smaller bricks, which could not have performed the same binding function as the second layer of bricks in the timbrel vaulting.

Cozzo pointed to the problems inherent in Choisy's explanation and argued that the linings were used as a backing for stucco work since he believed the stucco adhered better to the brick than to the concrete.[37] However, often the locations in which the brick linings occur in Roman monuments, such as

[32] In modern concrete construction the formwork on horizontal structural members such as beams, girders, and arch soffits is removed after 7–14 days and sometimes longer depending on the strength and deflection considerations: J.J. Waddell and J.A. Dobrowolski, *Concrete Construction Handbook*[3] (New York 1993) 25.16.

[33] For general discussions on this technique: A. Choisy, *L'art de bâtir chez les romaines* (Paris 1873) 60–67; Cozzo (supra n. 4) 179–82; C.F. Giuliani, *L'edilizia nell'antichità* (Rome 1990) 96; MacDonald (supra n. 11) 159; Lugli (supra n. 3) 668–69, 681, pl. CCVI.2; G.T. Rivoira (G. Rushforth trans.), *Roman Architecture and Its Principles of Construction under the Empire* (Oxford 1925) 93; and G. Giovannoni, *La tecnica della costruzione presso i romani* (Rome 1925) 38.

[34] Choisy (supra n. 33) 60–67. Followed by Rivoira (supra n. 33) 93, Giovannoni (supra n. 33) 38, and MacDonald (supra n. 11) 159.

[35] Choisy (supra n. 33) 70–71.

[36] G.R. Collins, "The Transfer of Thin Masonry Vaulting from Spain to America," *JSAH* 27:3 (1968) 176–91.

[37] Cozzo (supra n. 4) 181–82. Followed by Lugli (supra n. 3) pl. CCVI.2 and M.E. Blake, *Roman Construction in Italy from Tiberius through the Flavians* (Washington, D.C. 1959) 94, 163.

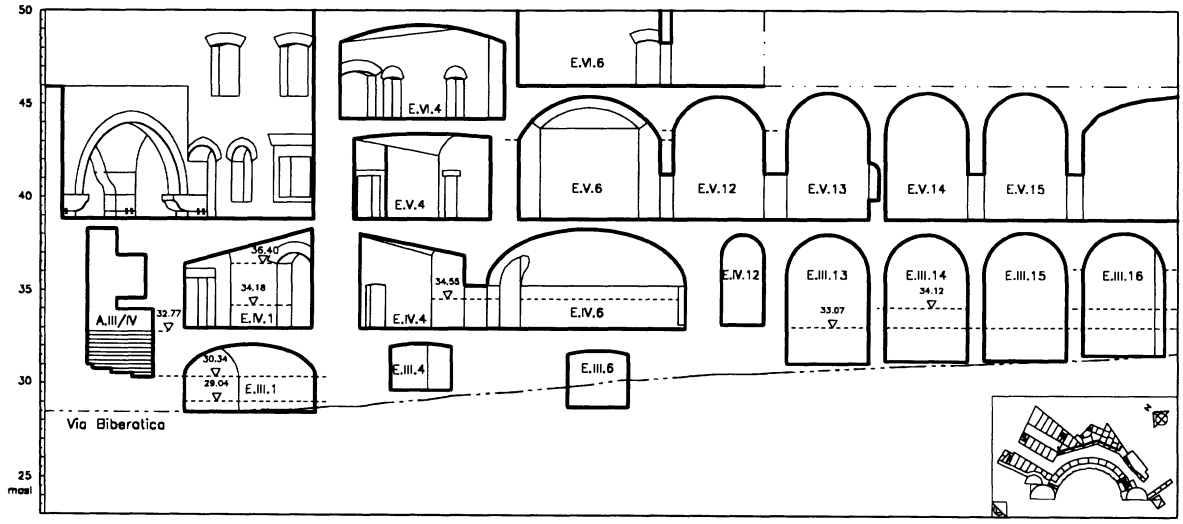

Fig. 19. Section through East Wing. Scale 1:400.

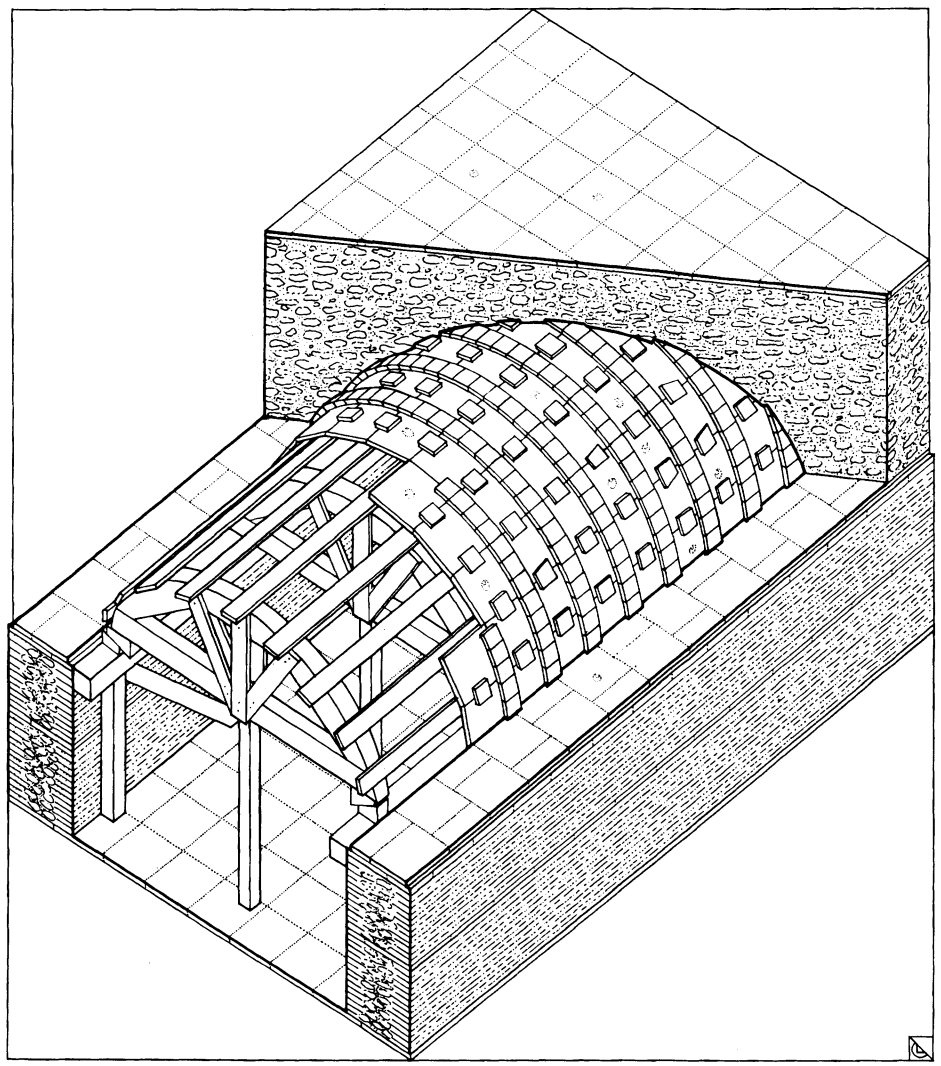

Fig. 20. Reconstruction of centering for a vault built with brick linings

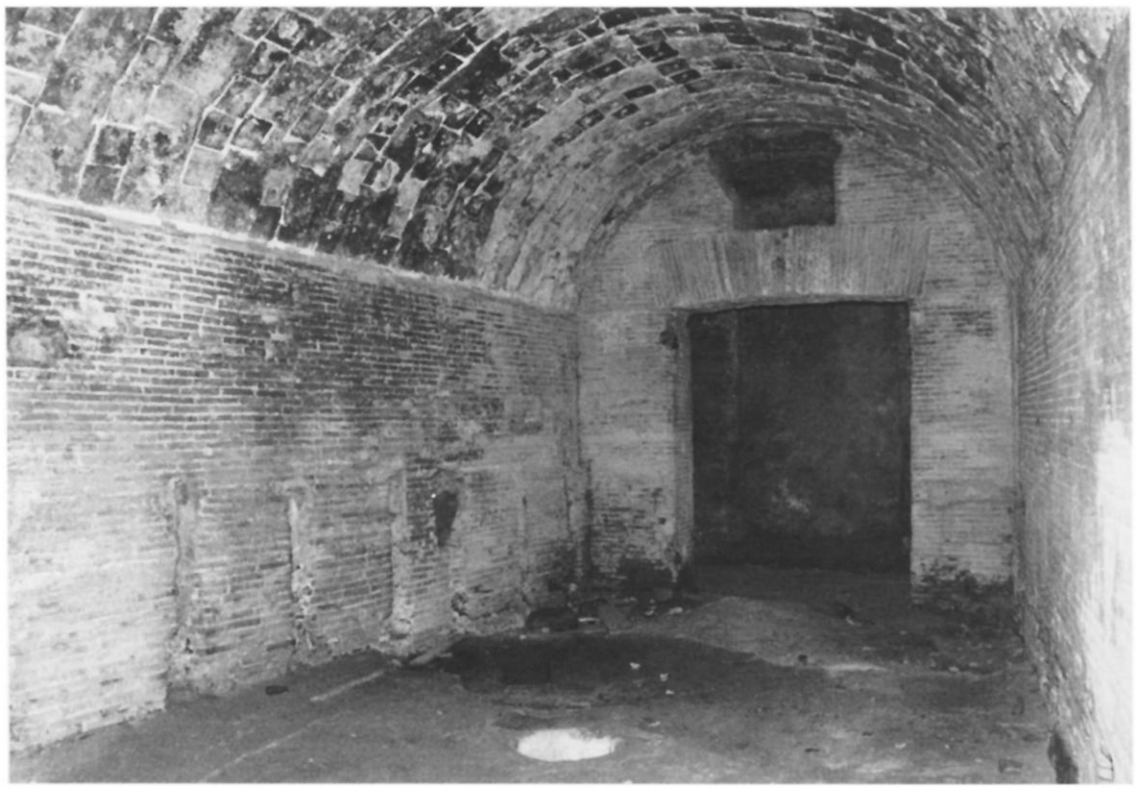

Fig. 21. View of N.II.1 with brick linings on intrados

on the vaults of *praefurnia* and small, utilitarian stairways, were not ones where heavy stucco was typically used. Contradicting Cozzo's proposal is Vitruvius's statement that tiles reject the initial layer of plaster because of the dryness from being fired in a kiln. He notes that a layer of lime must be applied to bond the plaster to the tile.[38] Indeed, one often finds in examples of brick linings from Ostia that a thick layer of lime putty was used as the binding material between the two layers of brick.[39]

As suggested by Choisy, the use of whole bipedales or sesquipedales could have reduced the necessary formwork somewhat, but often broken bricks were used on small and irregularly shaped vaults and would have required continuous planking for support. Therefore, the decision to use this technique was probably not governed exclusively by the desire to reduce the amount of wood. The bricks could not have been reused and, as a result, employing them was probably more expensive than employing the wooden planks alone,[40] many of which would have been used anyway to support the bricks.

Placing the brick linings between the formwork boards and the wet mortar of the concrete would have formed a barrier that would have both protected the wooden formwork from the lime[41] and prevented the wood and mortar from sticking as the concrete set.[42] Hence, a more plausible explanation for the use of the brick linings is that they facilitated the removal of the centering and increased the longevity of the formwork, which could have been reused. The technique of using reeds, presumably for a similar purpose, often occurs in the post-antique period, as can be seen from the impressions on some of the reconstructed vaults at the Tabularium at Rome and the Emissarium at Albano, and may have also been used occasionally in Roman times.[43]

During the second century A.D., the technique be-

[38] Vitr. *De Arch.* 7.4.2–3.

[39] A very clear example occurs along the vault of the stairway in the Caseggiato del Serapide (III.10.3) at Ostia.

[40] For the reuse of formwork, see J.J. Rasch, "Zur Konstruktion spätantiker Kuppeln vom 3. bis 6. Jahrhundert," *JdI* 106 (1991) 368 n. 169.

[41] Vitruvius (*De Arch.* 7.1.2) was concerned about the damage to wood caused by lime when he advised that fern or straw be placed as a buffer between the wooden planks of flooring and the top coat of lime mortar.

[42] DeLaine 1992 (supra n. 11) 249.

[43] A vault from a first-century B.C. building in Pompeii (I.3.31) has the impressions of reeds along its intrados: Adam (supra n. 19) fig. 434. Blake cites a similar example from a first-century B.C. villa at Tivoli: M.E. Blake, *Ancient Roman Construction in Italy from the Prehistoric Period to Augustus* (Washington, D.C. 1947) 346 n. 41. Middleton notes a vault with the impressions of reeds on its intrados under the

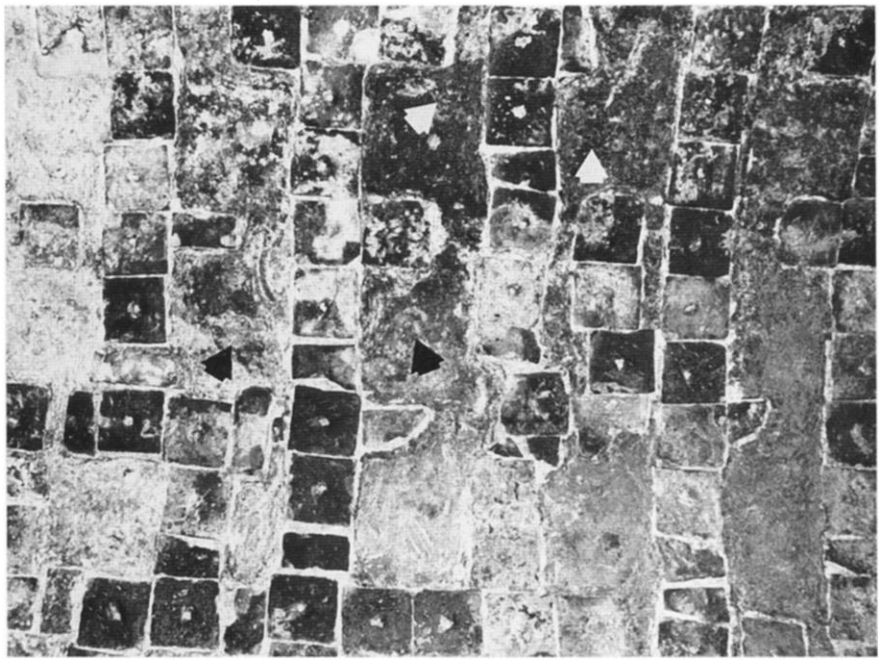

Fig. 22. Detail of remains of brick lining on intrados of N.II.1 showing holes in bessales. Arrows indicate impressions of brick stamps where the bipedales have fallen away.

came common in and around Rome. For example, of the 102 Hadrianic and Antonine buildings at Ostia that have some trace of vaulting remaining, 53 of them have at least one vault using the brick linings. A comparison of the use of the technique from one building to another shows that it is unrelated to the function of the space in which it occurs. Brick linings are used in a variety of different types of buildings, and they are found on many different sizes and types of vaults. The use of the technique seems to have been simply a matter of preference on the part of the builders. The choice could have been based on a variety of factors for which we have no direct evidence, such as the availability of the bricks or the particular skills (or lack thereof) of the labor force.

Both types of formwork (i.e., wooden planks and brick linings) were used at Trajan's Markets, though the wooden type was more common. The brick linings occur in only two isolated groups of rooms: in the level II North Wing rooms and in the level III Aula rooms (figs. 5, 10, 14).[44] The linings consisted of a layer of bipedales with a grid of bessales covering the joints. The bipedales rarely remain in situ, but fragments of a few can be seen where the vaults and walls intersect. In some rooms the impressions of the brick stamps on the bipedales can still be seen in the mortar between the bessales (fig. 22).[45] At the spring of the vaults the impost was formed by two courses of bipedales, the upper one set back a few centimeters to form a ledge to accept the lowest bricks of the linings (fig. 23). This last feature is unique to the Markets; later examples typically have an impost formed by a single course of bipedales. In both groups of rooms the lower of the two courses of bipedales at the impost of the vaults continues on the front and back walls separating the lunettes from the lower walls. Although courses of bipedales also formed the impost of most of the vaults using wooden formwork, they did not usually continue in the lunette walls as do those with brick linings.[46]

The brick linings at the Markets display one other unusual feature: each remaining bessalis has a hole chipped out of the center (fig. 22). No signs of metal

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Basilica Nova: J.H. Middleton, *The Remains of Ancient Rome* I (London 1892) 67.

[44] Rows of bessales can also be seen on the intrados of the vault of the substructure of the terrace between the two apsidal halls (H.II.0). This space is only accessible through a hole in the upper part of the wall of H.ApN. Blake mentions that the vaults of the rooms on level IV of the Aula were "laid on a lining of bipedales," but there is no evidence for this in these rooms: M.E. Blake, *Roman Construction in Italy from Nerva through the Antonines* (Philadelphia 1973) 26.

[45] For a more detailed discussion of the brick stamps and the supply of brick to the site, see Lancaster (supra n. 3) 23–44.

[46] Exceptions occur in the level I Hemicycle rooms where the benchmark course of bipedales (fig. 4:B1) coincides with the impost level of the vaults.

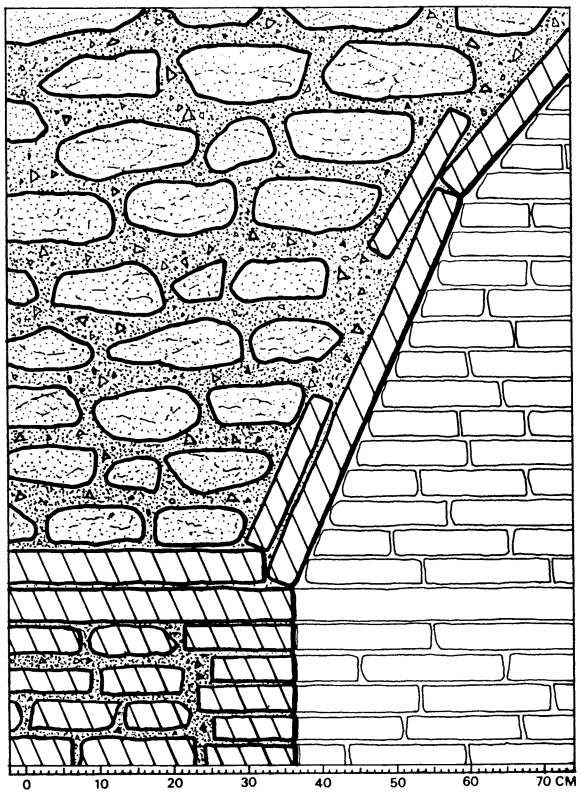

Fig. 23. Detail of brick linings at Trajan's Markets. Scale 1:10.

Fig. 24. Detail of remains of brick linings in room under the latrine at the Forum of Caesar. Arrow indicates bessalis with hole in center.

nails or clamps exist in any of the holes, and the way in which the ancient mortar has filled them shows that the bessales were never fastened to the intrados with metal additions of any kind. The holes were apparently intended to help provide a key by allowing the mortar to ooze through while still wet. Evidently chipping the hole into each brick was soon deemed unnecessary since it appears in only one other example of brick linings in and around Rome. Of over 100 buildings with brick linings that I have examined in Rome, Ostia, and Tivoli, the only other occurrence of this feature is on the linings of the vaults of the tabernae at the Forum of Caesar (fig. 24).[47] These vaults were part of the Trajanic renovations to the slopes of the Capitoline during the construction of the Forum of Trajan and are contemporary with those at the Markets. Other Trajanic examples of the brick linings occur at Sette Sale and at the Atrium Vestae, but the bessales of neither of these buildings have holes; the examples at the Markets and the Forum of Caesar stand out as unusual even from the other Trajanic examples in nearby buildings.

The brick linings at both Trajan's Markets and the Forum of Caesar are among the earliest examples of the technique used in Rome, and in both monuments they are only used in isolated groups of rooms. The appearance of the brick linings in the vaults of some groups of rooms and not in others could be explained as the result of independent crews of builders contracting for set amounts of work. Furthermore, the peculiar hole in the bessales of all three groups of vaults may be the "signature" of a particularly innovative crew of builders who were perhaps experimenting with the first tentative trial runs of the technique and who contracted to work both at the Markets and on the renovations to the Forum of Caesar. At the Forum of Caesar, the crew was responsible only for the vaults since the walls of opus quadratum were preexisting. At Trajan's Markets, the vaults in both groups of rooms are divided from the walls by a course of bipedales, which might suggest that they too were built separately; on the other hand,

[47] C.M. Amici, *Il Foro di Cesare* (Florence 1991) figs. 57–58. On Amici's plan and section the vaults with the brick linings are those of the barrel-vaulted rooms between the two stairways (i.e., rooms 4–8, not labeled on drawing).

the skills, tools, and materials necessary for building both walls and vaults would have been similar, so the walls could just as easily have been built by the same crew.

Significantly, the period during which the brick linings first appear, the early second century, was one of expansion for the brick industry. Almost 25% of the known types of brick stamps were in use during the Trajanic period compared to a little less than 10% from the second half of the first century.[48] In addition, the number of named *figlinae* (clay beds or brickyards) increased from nine during the period A.D. 80–97 to 29 during the period A.D. 98–113.[49] Hence, the decision to use this new type of brick formwork at the Markets and at the Forum of Caesar may have been provoked by the prevailing market forces.

ORGANIZATION OF LABOR

A study of the courses of bipedales and the brick linings on the vaults at Trajan's Markets gives an idea of the way in which the work was carried out and possibly how the workforce was divided in some places. Some courses of bipedales correspond to certain constructional features, others to benchmark levels established during the construction, and still others to possible changes in the workforce. The presence of the brick linings on some vaults at the Markets may indicate that groups of rooms or vaults were built by a particular crew of builders.

Various works examining the epigraphic, literary, and legal evidence for the building industry in Rome have appeared in the past few decades.[50] Martin has recently gathered evidence from legal sources for the organization of private construction in Rome and has discussed the use of different types of building contracts and the obligations of the contracting parties.[51] Although the evidence for the use of these contracts comes largely from the context of private construction, we know from various sources that contractors, or *redemptores*, were employed for public building projects during the Imperial period,[52] and presumably the contractual obligations were similar to those in private construction.[53]

The two basic types of contracts available to the Roman contractors were *stipulatio* and *locatio conductio*.[54] Stipulatio was based solely on an oral promise and involved fewer requirements of each of the parties than did locatio conductio, about which there is more evidence in the legal sources. Contracts of locatio conductio, which were apparently more common for construction projects, could be used in three ways: *locatio conductio operis* (the *locator* lets out a job to be completed by the *conductor*), *locatio conductio operarum* (the locator lets out his own labor to the conductor, i.e., day labor), and *locatio conductio rei* (the locator lets out the object of the contract to the conductor).[55] A contract of locatio conductio included a final inspection (*probatio*) and an agreed-upon price (*merces*).

The type of contract chosen could have depended upon a number of factors such as the size and na-

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[48] *RE* Suppl. 15 (1978) 1494, s.v. Ziegelstempel von Rom und Umgebung (E.M. Steinby).

[49] E.M. Steinby, "La cronologia delle figlinae doliari urbane dalla fine dell'età repubblicana fino all'inizio del III sec.," *BullCom* 84 (1974–1975) 110–11.

[50] Supra n. 5; infra n. 51.

[51] S.D. Martin, *The Roman Jurists and the Organization of Private Building in the Late Republic and Early Empire* (Brussels 1989) 19–72.

[52] Frontinus (*Aq.* 2.119), in his description of the maintenance board in charge of the water supply, indicates that the water commissioner must consult with a variety of people to determine which projects should be carried out by contractors and which should be carried out by the gangs of slaves kept for routine maintenance. The letting of contracts to private contractors, or redemptores, is borne out by inscriptions as well. One example dating from A.D. 88 records that L. Paquedius Festus, who calls himself a *redemptor operum Caesar(is) et puplicorum* (sic), repaired part of a tunnel for the Aqua Claudia: *CIL* XIV, 3560.

Other more direct evidence for the use of private contractors for public building projects can be seen in the late first-century or early second-century funerary inscription of the freedman Claudius Aug. l. Onesimus, which states that he was a *redemptor operum Caesar(is)*: *CIL* VI, 9034. This is sometimes cited as evidence for the creation of a public works department, but in another inscription from Reate, the redemptor P. Mucius Nedymus uses the plural phrase, *operum Caesarum*, to describe his work: *CIL* IX, 4694. Pearse (supra n. 5) 38 n. 54 has cogently argued that the latter inscription suggests that the phrase simply indicates the patron or patrons of the work rather than a governmental department. Indeed, a redemptor on the imperial staff makes little sense since the title itself implies that he took part in some sort of competitive bidding process and was not a salaried employee.

[53] Two texts from the *Digest of Justinian* imply that the *curator operum publicorum* was in charge of paying redemptores for work done at public expense under the Antonines, though the nature of the work is not indicated: *Dig.* 50.8.11; *Dig.* 50.10.2.1.

[54] For a detailed discussion of these contracts, see Martin (supra n. 51) 19–41.

[55] S.D. Martin, *Building Contracts in Classical Roman Law* (Diss. Univ. of Michigan 1981) 2, 84 n. 20. These distinctions are not classical and were not made by the Roman jurists, but they are useful in distinguishing between the different situations in which the contracts could be used.

ture of the project, the financial resources of the builder, or the available number of skilled and unskilled workers. An overriding consideration for someone hiring out his services must have been the financial viability of the enterprise. At the most basic level, a person with very little capital could simply work for a daily wage on a contract of locatio conductio operarum. For the more entrepreneurial types who could provide securities to take on larger amounts of work,[56] a contract of locatio conductio operis would have allowed the redemptor to take on more responsibility for organizing the labor and materials for the project and with it the concomitant possibility of greater profit in the end.

A builder taking a job on contract could negotiate for either a task fee for the whole job or a task rate based on measured intervals. If a task fee was adopted, a common pay scheme was for half the amount to be paid before work began and the other half after approval of the work.[57] This method is attested in the *lex parieti faciundo Puteolana* of 105 B.C., which records a building contract for the construction of a wall around the Temple of Serapis at Puteoli.[58] Similar pay schemes are attested in Hellenistic Greek building contracts,[59] and evidence from Roman jurists show that it was still used in the Augustan period.[60] In such a scenario, the survival of the independent contractor may have depended on his ability to contract for discrete amounts of work, thereby allowing him to collect his fee within a reasonable amount of time. If a task rate was specified, the amount due to the builder was established by an architect or a *mensor aedificiorum* either at the end of the job or at set intervals.[61]

At Trajan's Markets, the two groups of rooms with the brick linings may be the work of a single crew of builders working both at the Markets and on the renovations at the Forum of Caesar. The detail of the hole in the center of each bessalis of the brick linings is unusual, and it could indicate that some sort of standard was established by the foreman of the crew. The fact that the brick linings at the Markets occur in two groups of rooms, each belonging to a different building and level, would suggest that the method was not established by a site supervisor in charge of a particular area. The appearance of the technique with the very same detail on the other side of the Forum of Trajan in the renovations at the Forum of Caesar does imply a certain amount of independence of movement that might be expected from a redemptor (or a partnership of redemptores)[62] who negotiated separately for each job.

A question that arises is whether or not each of the groups of rooms with the brick linings represents a reasonable amount of work for a crew of builders to complete in a single season. Unfortunately, there is little evidence for the actual number of masons making up a typical building crew working on an imperially sponsored project. Theoretically, the maximum number of masons is limited to the number that would fit side by side at arms length along any one wall. The absolute minimum number would be two since the two brick-faced sides of a wall had to rise simultaneously with one mason on either side. That masons typically worked in pairs on opposite sides of a wall is shown clearly on an early fourth-century wall painting from the Tomb of Trebius Justus on the Via Latina outside of Rome.[63]

A calculation of the time it would have taken to

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[56] The provision for providing guarantors was a common element of Greek and Roman building contracts: A. Burford, *The Greek Temple Builders at Epidauros* (Liverpool 1969) 104–105, 135–38; Martin (supra n. 51) 131–36.

[57] Martin (supra n. 51) 31 n. 49, 114–20.

[58] *ILLRP* 518 = *CIL* I, 698.

[59] Burford (supra n. 56) 97.

[60] This method of payment is referred to by Labeo, an Augustan jurist: *Dig.* 19.2.60.4.

[61] Martin (supra n. 51) 32. Two inscriptions from Rome (*CIL* VI, 8933 and 37759) record imperial freedmen, each working as a *tabularius mensorum aedificiorum*, who were presumably the accountants recording the work of the surveyors. Five other inscriptions from Rome record *mensores aedificiorum* (*CIL* VI, 1975b, 9622, 9623, 9625, 3686). Both Columella (*Rust.* 5.1.3) and Pliny the Younger (*Ep.* 10.17b) speak of the role of *mensores* in establishing the amount of work done. For the role of the architect, see Burford (supra n. 56) 106. A similar practice is attested in Renaissance Florence where the cost of hiring a professional measurer would be shared by the two contracting parties. The actual measuring would then take place in the presence of a witness for each of the parties: R.A. Goldthwaite, *The Building of Renaissance Florence* (Baltimore 1980) 144.

[62] Although the evidence for partnerships among building contractors is relatively rare in the Roman world (Martin [supra n. 51] 48–49), there are examples of partnerships in other commercial endeavors, such as in the brick industry: T. Helen, *The Organization of Roman Brick Production in the First and Second Centuries A.D.: An Interpretation of Roman Brickstamps* (Helsinki 1975) 113–15, and in shipping: J. D'Arms, *Commerce and Social Standing in Ancient Rome* (Cambridge, Mass. 1981) 54–55.

[63] F. Coarelli, *Dintorni di Roma* (*Guide archeologiche Laterza*, Bari 1981) 132–33; MacDonald (supra n. 11) pl. 130b; Adam (supra n. 19) fig. 181.

lay the concrete of the walls and vaults of the level II rooms of the North Wing serves to give some idea of whether this was a reasonable amount of work for a contractor to complete.[64] Since a single pair of masons is an absurdly low number, I have used an arbitrary minimum of 10 pairs of masons, which would give roughly a pair of masons per room for level II of the North Wing, to calculate the maximum number of days required. As we have seen from the "pigs" on the Hemicycle facade, a typical spacing was from 5 to 8 ft apart. A spacing of about 8 ft would allow for a maximum of 80 pairs of masons, thereby yielding the minimum number of days required. Given this range for the maximum and minimum number of masons and assuming that a mason could lay 500 pieces of brick facing a day and 1,500 pieces of *caementa* a day,[65] laying the brick and concrete walls of the rooms of the North Wing would have taken between 2.8 and 22.6 days.[66] The number of masons who could work simultaneously on the vaults is somewhat lower since the area where they could stand is limited to the two impost sides of the centering, so the maximum possible number of pairs of masons for the vaults is reduced to 44. Therefore, laying the vaults would have taken between 2.2 and 9.7 days. This gives a total range of between 5.0 and 32.3 days to lay both the walls and the vaults. These figures do not reflect the additional time it would have taken to erect scaffolding and centering nor do they account for the time the centering had to remain in place while the concrete was curing, but they do suggest that the vaults could have been completed within a month with as few as 10 pairs of masons (though there were probably more). If one assumes that these masons built the walls as well, a crew of this size could have completed all the work within a few months.

The two groups of rooms with the brick linings are not part of the same building unit, and if they were built by the same crew of builders, the implication is that a single crew was not necessarily responsible for constructing more than a single story of any one group of assigned rooms before moving to another area. In such a scenario, the crew associated with the level II North Wing rooms would have moved to the other side of Via Biberatica to begin work on the level III rooms, which formed the platform on which the Aula was built. When the vaults of the first group of rooms were strong enough to support another level, a different group of builders (consisting of either day labor or a contracting crew) could have moved in and begun work. Alternatively, the walls could have been built by one group and the vaults by another. In either case, this "leap frog" method of building would have been particularly effective for a multistory, terraced structure like Trajan's Markets.

One of the most commonly cited discussions of the archaeological evidence for the use of different crews of workers on an imperially sponsored public building in Rome is that of the engineer Cozzo regarding the Colosseum. In 1928, he proposed a model in which the amphitheater was divided into quadrants, with each quadrant built by a different crew; his proposal, however, was based on a misinterpretation of the evidence and lacks basis.[67] The material at Trajan's Markets supports the idea of a more varied system. At the Markets, the pattern of bipedalis courses and brick linings suggests that the work was distributed in much smaller units and that the means of distribution was flexible enough to allow for the different requirements from one part of the complex to another. For example, even if the walls and/or the vaults of the level II North Wing rooms and the level III Aula rooms (those with the brick linings) were constructed by the crew of a single con-

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[64] I thank Janet DeLaine for discussing with me the method of calculating the manpower required for the construction of the Baths of Caracalla as defined in her doctoral dissertation: DeLaine 1992 (supra n. 11) 292–345, though any errors in the calculations at Trajan's Markets are my own.

[65] The figures used here are taken from preindustrial estimating manuals for fine facing work and for rough work, respectively: J.T. Rea, *How to Estimate: Being the Analysis of Builders Prices* (London 1902) 72; R. Elsam, *The Practical Builder's Perpetual Price-Book* (London 1825) 111; B. Langley, *The London Prices of Bricklayers Materials and Works* (London 1749) 83, 87, 100–101. These figures are very conservative, since the caementa (pieces of broken brick and stone that made up the aggregate on the inside of the wall) could probably be laid much more quickly than the rough brickwork cited in the building manuals; therefore, the resulting estimates should give the maximum rather than the approximate time necessary to lay the walls and vaults.

[66] At Trajan's Markets, there are approximately 100 pieces of brick per m^2 in fine brick facing, approximately 700 pieces of caementa per m^3 in the core of walls, and approximately 500 pieces of caementa per m^3 in vaults.

[67] Cozzo (supra n. 4) 223–25. The differences in construction that he attributed to different work groups are actually due to a rebuilding after a fire severely damaged the monument in A.D. 217: Lancaster (supra n. 4).

tractor, evidence from the bipedalis courses in other parts of the complex suggests that the entire project was not simply divided into units of rooms and parceled out to a number of different contractors each working independently. Some parts of the monument may have been built in much smaller units consisting of sections of walling or vaulting, which could have been assigned to day labor or to a contracting crew working for a task rate rather than a task fee. The details regarding the distribution of crews of workers on large imperial monuments remain ambiguous without further written documentation from the period, but the evidence from Trajan's Markets gives some insight into the nature of the system that allowed such large and complex projects to be completed in the relatively short time spans (5–10 years) so common in the Roman Imperial period.[68]

Trajan's Markets represent an unusual building type constructed on a difficult hillside site, and a study of the techniques of using courses of bipedales in the walling and brick linings for the formwork of vaulting provides some indication of how the work was organized and executed at this monument. In later examples of buildings in which brick linings are used, the linings are usually employed consistently throughout the building, and their existence cannot be used as evidence for a particular crew of workers. Likewise, the way in which courses of bipedales were used varies from building to building; what may be true or valid for one building may not necessarily be for another. The reasons for using a particular building technique often changed according to the situation and over time. Studies of the brick industry in Rome have shown that it underwent a gradual change from the first to the third centuries, with the production moving more and more into the hands of the emperor and the state.[69] In a similar way, one can imagine that changing political and economic conditions affected the organization of labor for public building projects in Rome during the Imperial period. Duncan-Jones observes that "Rome was able to muster and organise labour in a way that produced results on a scale not usually associated with primitive European economies,"[70] and the evidence from Trajan's Markets hints at some of the complexities with which Roman architects and builders were faced and how they confronted these issues.

CLASSICS DEPARTMENT
ELLIS HALL
OHIO UNIVERSITY
ATHENS, OHIO 45701-2979
LANCASTE@OHIOU.EDU

[68] Colosseum (ca. 72–80); Trajan's Forum (106–112); Trajan's Baths (104–109); Pantheon (118–128); Baths of Caracalla (211–216). At Trajan's Markets, a brick stamp on one of the lower treads of stair H.I/II.2 can be dated to the years after A.D. 107, thereby indicating that work had not progressed very far before this date: Lancaster (supra n. 3) 31. A terminus ante quem is more difficult to establish, but presumably the complex was well on its way to completion by the time the Forum of Trajan and the Basilica Ulpia were dedicated in A.D. 112, as noted in the *Fasti Ostienses*: G. Calza, "Un nuovo frammento di Fasti Annali (anni 108–113)," *NSc* 1932, 188–205. In fact, an inscription recently found behind the Aula supports the idea that the Markets were actually considered part of the Forum complex in antiquity: R. Meneghini, "Mercati di Traiano: Scoperte nell'area della Torre delle Milizie," *ArchLaz* 12:1 (1995) 163–66.

[69] E.M. Steinby, "L'organizzazione produttiva dei laterizi: Un modello interpretativo per l'instrumentum in genere?" in W.V. Harris ed., *The Inscribed Economy* (*JRA* Suppl. 6, Ann Arbor 1993) 141; H. Bloch, *I bolli laterizi e la storia edilizia romana* (Rome 1947) 334–40 (reprinted from *BullCom* 64–66 [1936–1938]).

[70] R. Duncan-Jones, *The Economy of the Roman Empire*[2] (Cambridge 1982) 2.