

HOW THE CORINTHIANS MANUFACTURED THEIR FIRST ROOF TILES

ABSTRACT

The earliest known terracotta roof postdating the Bronze Age belongs to the 7th-century B.C. Old Temple at Corinth. Analysis of the surface markings preserved on its tiles suggests a hypothesis for the forming and finishing stages of tile manufacture. Individual tiles were built right side up on a mold, with a pair of profiled templates guiding the shape of the top. Replication experiments reveal that the template design for these tiles is much simpler than formerly believed. Nonetheless, it is likely that the Corinthians created their first tiles in imitation of an earlier terracotta roofing system with separate cover and pan tiles, perhaps developed outside the Corinthia.

The roof of the Old Temple at Corinth is essential to understanding the origins of Greek monumental architecture.¹ The building, which preceded the later Archaic temple dedicated to Apollo, is generally regarded as having incorporated the first terracotta roof tiles in post-Mycenaean

1. For the roof, see Weinberg 1939, p. 595; Roebuck 1955, pp. 156–157; Robinson 1976a, pp. 231–234; 1984; 1986; Winter 1993, pp. 12–16; Rhodes 2003, p. 87. The 7th-century temple is called the “Old Temple” here to distinguish it from its better-known successor on Temple Hill, the 6th-century peripteral building traditionally identified as a temple to Apollo (see the recent reassertion by Bookidis and Stroud [2004]). In an exhibition in 2006 entitled “The Genesis of Monumental Architecture in Greece: The Corinth Project” at the Snite Museum of the University of Notre Dame, and the accompanying symposium “Issues in Architectural Reconstruction” (January 22, 2006), both organized by Robin Rhodes, Rhodes argued that the temple

was dedicated to Zeus and Hera.

I was first introduced to the Protocorinthian tiles at Corinth as a member of the Greek Architecture Project at Corinth, directed by Rhodes (University of Notre Dame; Corinth Excavations). I am grateful for his permission to study these tiles further and to make use of unpublished work carried out by the project. I also thank Rhodes and Guy Sanders, director of the Corinth Excavations, for permission to publish the conclusions presented here on the design and construction techniques of the tiles, and for sponsoring the building of a kiln in Corinth for the firing of replica tiles. Sanders generously provided the resources I needed at Corinth to produce the replica tiles. John Lambert, ceramicist for the Greek Architec-

ture Project, designed and constructed the kiln. Through his re-creation of more than 20 tiles for a replica hipped roof in the Snite exhibition, and through consultation on site, Lambert provided valuable insight into the practical requirements of fabricating large replica tiles. I am further indebted to my wife, Allison Trdan, who labored tirelessly on the replication project and helped with the documentation and photography.

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Greece.² The Old Temple roof is classified in the “Protocorinthian” tile system, together with at least five other roofs from Corinth, Isthmia, Delphi, and Perachora.³ The system is dated to the 7th century B.C.,⁴ and the Corinth roof appears stylistically to have been the earliest.⁵ Because the Old Temple is the first building known with certainty to have had a tiled roof after Early Helladic structures such as the House of the Tiles at Lerna, it appears that the Corinthians “reinvented” the terracotta tile roof.⁶

Architectural terracottas provide useful evidence for reconstructing the appearance of early temples during an important period in the development of Greek monumental architecture.⁷ Tiles are the only evidence for restoring the appearance of many major 7th-century buildings for which little else remains of the superstructure, and whose foundations have often been obliterated by later construction activity or robbing. Whether or not Corinth may be credited with “reinventing” the roof tile, its coroplasts certainly played an important role in developing and disseminating the technology within the sphere of sacred architecture.

2. Williams 1980, p. 346; Robinson 1984, pp. 55–57; Heiden 1987; Roebuck 1990, p. 49; Wikander 1990, 1992; Winter 1993, p. 12; Glendinning 1996, p. 184; Winter 2000, p. 256; Gebhard 2001, pp. 54–55; Aversa 2002, pp. 233, 248; Rhodes 2003, p. 87. Felsch (1979, p. 25; 1990, pp. 312–314) argues that Lakonian tiles emerged as early as Protocorinthian tiles based on a stylistic dating of tile stamps, but his arguments have been received with skepticism: Wikander 1992, p. 155; Winter 1993, p. 95, n. 4. Arguments for dating tiles in Anatolia and Italy earlier than the Protocorinthian system are controversial: Işik 1991; Damgaard Andersen and Toms 2001; Schädler and Schneider 2004, pp. 45–49.

3. Winter 1993, pp. 12–18. A single fragment of a Protocorinthian tile from the Demeter and Kore sanctuary must represent a second roof of this system at Corinth: *Corinth* XVIII.3, p. 465, no. 68 (FC 105). Isthmia: *Isthmia* I, pp. 40–53; Hemans 1989. There are at least two Protocorinthian roofs at Delphi: *FdD* II, pp. 21–28. The number of roofs of this type at Perachora is unknown: Robinson 1976b, p. 247, n. 9; 1984, p. 55, n. 1; Rhodes 2003, p. 93. Winter (1993, p. 12) adopts the term “Protocorinthian” from *FdD* II, p. 26.

4. Corinth: Robinson 1976a, p. 212; 1984, pp. 55–57; Rhodes 1984, pp. 104–108; Salmon 1984, pp. 59–62; Wikan-

der 1992, pp. 152–153; Winter 1993, p. 12; see also n. 18, below. Isthmia: *Isthmia* I, pp. 1, 3–12, 55; Rhodes 1984, pp. 43–60, 104–108; Gebhard and Hemans 1992, pp. 34–40. No context date is available for Delphi: *FdD* II, p. 26.

5. A small peak added to the Isthmia eaves tile suggests that it is later than the unadorned Corinth eaves tile: *Isthmia* I, p. 50; Broneer 1976, p. 43; Robinson 1976a, p. 231; 1976b, p. 247, n. 9; Williams 1980, pp. 346–347; Rhodes 1984, p. 105; Heiden 1987, p. 20; Cooper 1989, pp. 26–28; Winter 1993, p. 17; Gebhard 2001, p. 56. Moreover, on the basis of the stone elements, the Isthmia temple almost certainly postdates the Corinth temple: Rhodes 1984, pp. 105–106; 2003, p. 92. Billot alone has argued that the Isthmia roof could predate Corinth’s because of the profiles of the eaves covers, although she mistakenly describes the gables of the Corinth eaves covers as perfectly straight and does not discuss the architectural similarities between the buildings described by Rhodes: Billot 1990, pp. 112–113; Badie and Billot 2003, pp. 283–284. The roofs at Delphi have been viewed as Kypselid projects that would postdate the Old Temple at Corinth: *FdD* II, p. 39; Robinson 1976a, p. 231, n. 93; 1984, p. 55; Heiden 1987, p. 22; Winter 1993, p. 17; Rhodes 2003, p. 93. The fragments from Perachora and the Demeter

and Kore sanctuary at Corinth are not clearly dated: see n. 3, above.

6. Lerna tiles: *Lerna* IV.1, pp. 253–274, 296, 305–307, figs. I:102b, I:104a, b. The argument for the existence of a “hybrid” terracotta roofing system using semicylindrical cover tiles and flat pan tiles in the Late Helladic (LH) period has been revived recently: Iakovides 1990; 2001, pp. 111–112, 135–137; Küpper 1996, pp. 104–110, 134–136; Badie and Billot 2003, p. 287. However, the lack of any evidence for a collapsed tile roof with both covers and pans indicates that these LH objects may not have been used as an interlocking tile system at all: Winter 1993, p. 10, with bibliography. Wheelmade cylindrical clay drain pipes similar to Mycenaean semicylindrical covers were common in Near Eastern architecture from the fourth through second millennium B.C.: Hemker 1993, pp. 104–107. Given the lack of any roof tiles clearly associated with Geometric architecture, there is no compelling case for Bronze Age continuity with the Protocorinthian system: Wikander 1988, p. 205; Winter 1993, p. 13, n. 1; Mazarakis Ainian 1997, pp. 272, n. 8, and 277–278; Skoog 1998, p. 25.

7. See, e.g., the opening remarks by W. D. E. Coulson at the First International Conference on Archaic Greek Architectural Terracottas organized by Nancy Winter: Coulson 1990, p. 11.

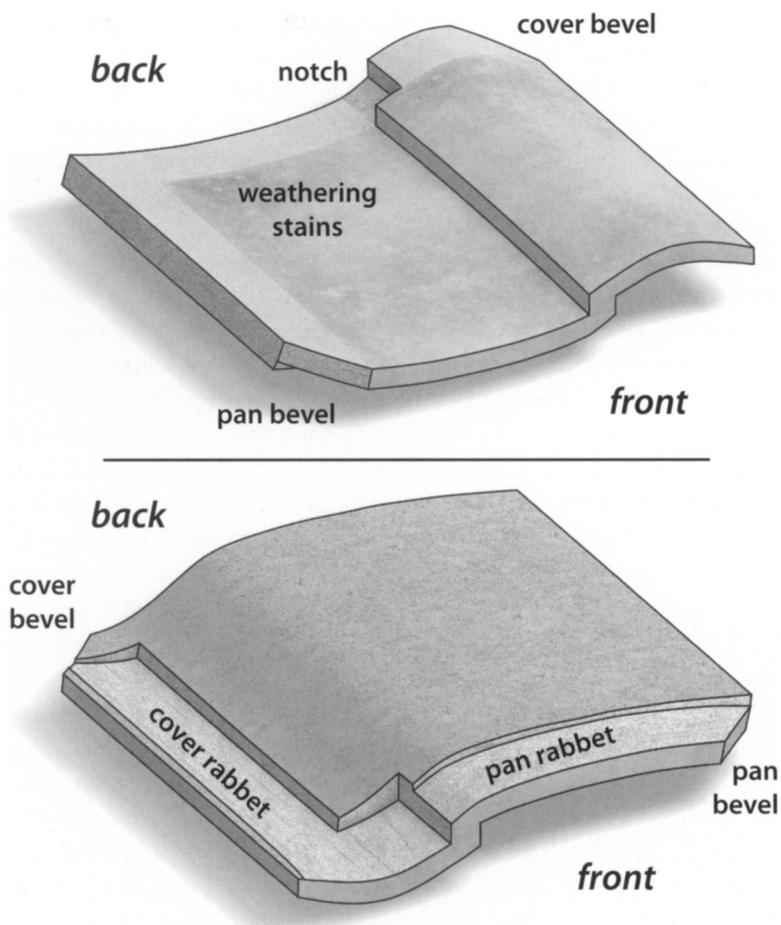


Figure 1. Top (*above*) and underside (*below*) of a regular Protocorinthian combination tile. P. Sapirstein

A ceramic roof has substantial benefits over the thatched constructions that must have prevailed in the 7th century B.C. Not only is ceramic more durable and resistant to fires,⁸ but also the heavy roof tiles would have distinguished a monumental temple from the relatively flimsy houses of Early Archaic Corinth.⁹ Much larger and more carefully crafted than any modern tile, the Protocorinthian tiles are well suited to a temple. Individual regular tiles are about 0.67 m wide, and each one weighs approximately 30–35 kg.¹⁰ As with later Mediterranean roofing systems, Protocorinthian tiles have separately articulated covers and pans, but the system is unusually complex because individual tile units are made in combination, with one cover and one pan attached to each other (Fig. 1). Unlike the peaked covers and flat pans of the subsequent “Corinthian” system, Protocorinthian covers are curved and the pans slightly concave, which gives the original tiles of Corinth a superficial resemblance to the later Lakonian system.¹¹

The Protocorinthian tile system represents the first appearance of an ancient technology in the archaeological record, and so has attracted theoretical speculation about its origins. Equipping the Old Temple with a tile roof was clearly advantageous, but the sophistication of the tiling system contradicts the general expectation for a technology to begin with

8. Wikander 1988, pp. 206–207; 1990, p. 289.

9. Salmon 1984, pp. 78–80; Rhodes 1984, 2003.

10. The figures presented here summarize my own measurements, some of which were taken during my work for Robin Rhodes, who is currently preparing a monograph on the architecture of the Old Temple.

11. Wikander 1990, p. 288; 1992, pp. 151–152.

a simple prototype and gradually acquire complexity through several generations of production. Tile making is not a trivial endeavor, and even the much smaller, handmade cover tiles of the Mediterranean were created by skilled specialists.¹² The idea that such complex tiles from the Old Temple at Corinth represent a sudden invention is objectionable to Ernst-Ludwig Schwandner, who has proposed an evolutionary sequence in which simple, curved Lakonian-type tiles gradually acquired the characteristics of the Protocorinthian system.¹³ Örjan Wikander argues forcefully against Schwandner's line of reasoning, however, and suggests instead that the system could have been invented in its complex form, perhaps inspired by nonceramic prototypes.¹⁴ Admittedly, both arguments are hampered by the lack of a definitive publication of the tiles from Corinth.

Fortunately, we are in a position to understand a great deal about the origins of this particular technology because roof tiles preserve a rich record of how they were shaped. Tiles are built from pliable clay, and tools used at different stages of the manufacturing process leave distinctive impressions on the surfaces.¹⁵ The analysis and interpretation of these marks indicate the original forming and finishing sequence,¹⁶ valuable evidence for assessing the technical origins of tiles such as those of the Protocorinthian system.

For a better understanding of the procedures used to create these tiles, I reexamined every inventoried Protocorinthian tile available and documented the surface markings on each fragment.¹⁷ By analyzing these data in comparison to the traditional methods for producing roof tiles and bricks described by ethnographers, I propose a plausible hypothesis for the forming sequence. Subsequently, I discuss the successful results of replication experiments to test the hypothesis. The study reveals that the techniques for manufacturing Protocorinthian tiles are considerably simpler than was formerly believed, but certain technical details indicate that the tile system must have had a predecessor.

12. Ethnographic accounts of tile making in Italy and Greece: Hampe and Winter 1965, pp. 26–29 (Buonabitacolo), 49–50 (Minturno), 87 (Corigliano and Calopezzati), 107 (Segesta), 108 (Sciaccia), 133 (northern Euboea), 200, 206–208.

13. Schwandner 1990.

14. Wikander 1990, pp. 288–289; 1992, pp. 153–156. Wikander's argument that Corinth and Isthmia are first in the line of development is supported by Winter (1993, p. 12, n. 3).

15. Relatively few studies have focused on the techniques for manufacturing Archaic tiles. Winter (1993, pp. 304–308) summarizes several. The only study for Protocorinthian tiles is Rostoker and Gebhard 1981, discussed below. Brief studies of 6th-century tiles

at other Greek sites include *FdD* II, pp. 199–205; Schneider 1991; 1996, pp. 24–42, 55–115; Hübner 1997; Schädler and Schneider 2004, pp. 21–26. Studies of non-Greek Archaic tiles include *Acquarossa* VI.2, pp. 100–139; Hostetter 1994; Glendinning 1996, pp. 29–41.

16. Rye 1981, pp. 1–5, 58–95. For an application of the method, see Henrickson 1993.

17. Besides the tiles at Corinth discussed below, I also examined 137 fragments of the Protocorinthian roof stored in the Isthmia Museum and 18 fragments of Protocorinthian tiles at Delphi. I thank Elizabeth Gebhard and Dominique Mulliez for permission to study the Protocorinthian tiles at Isthmia and Delphi, respectively.

THE OLD TEMPLE AND ITS ROOF

The Old Temple occupied a site on Temple Hill before the well-known Archaic peripteral Temple of Apollo was built. Although there are no foundations of an earlier building in situ, hundreds of architectural members dumped on the northern side of Temple Hill before the construction of the 6th-century temple must belong to a substantial earlier building. Below the debris, excavators found a stratum filled with working chips that appear to date the construction of this Old Temple to either ca. 680 B.C. or the second quarter of the 7th century B.C.¹⁸

Every type of tile from the roof is represented among the thousands of fragments recovered during the excavations.¹⁹ Each regular combination tile has a set of bevels and notches removed from the curved cover and pan to permit it to interlock with its neighbors (Figs. 1 and 2, lower left). Incised setting lines and a zone along the back edges and side of the pan protected from weathering make it clear that tiles overlapped by about 0.1 m when installed on the roof. Because of this overlap, the notch at the back of the cover was necessary for accommodating the front resting surface of the cover above it. The opposite corners are beveled to accommodate the overlap of diagonally adjacent covers and pans (Fig. 2, lower left). The front edge on the bottom of the tile was rabbeted to keep the tile from sliding downslope out of position, and the free edge of the cover was also rabbeted on the underside to fit over the pan of the next tile in its horizontal course.

Specialized tiles were needed at the edges and corners of the roof. First are the combination tiles at the eaves, which have a peaked cover at the front, instead of the usual convex curve, and a flat base that would have rested on a horizontal fascia board (Figs. 2:*E* and 24, below).²⁰ At the top of the roof, narrow ridge tiles capped the uppermost course of regular tiles. The ridge tiles rise to a peak on the pan but have a rounded cover whose upper surface is thus domed (Fig. 2:*R*).²¹

An additional level of complexity is added by the roof being hipped, that is, sloping on all four sides. The hip tile is also a combination tile that takes the form of two halves of regular tiles meeting in a diagonal ridge that follows the diagonal line of the hip (Figs. 2:*Nh* and 22, below).²² Considering the relatively high number of hip tiles recovered from the deposit, as well as the complete lack of any tile of similar fabric that could be assigned to a raking sima, the roof almost certainly was hipped at both ends, rather

18. Robinson proposed a date of ca. 680 B.C., and Winter and Wikander settle on the second quarter of the 7th century, noting that the context date is just a terminus post quem. Rhodes suggests a lower date. See n. 4, above.

19. The discussion follows my own examination of the material, although thorough descriptions of the Old Temple roof tiles may also be found in Rob-

inson 1984 and Winter 1993, pp. 15–16. All of the 121 inventoried tiles from the Old Temple roof are stored in the Archaeological Museum at Ancient Corinth. These represent only a small percentage of the total recovered by the excavations of Weinberg, Roebuck, and Robinson.

20. As restored by Rhodes (2003, pp. 89–90, fig. 6:10).

21. Ridge tiles (13 total): Corinth Museum FC 31, FC 61, FP 294, FR 100, FR 104, FR 105, FR 106, FR 107, FR 108, FR 117, FT 215, FT 223, FT 227.

22. Hip tiles (a minimum of 11 examples): Corinth Museum FC 30, FC 67, FC 79, FP 77, FP 156, FP 313, FP 314, FP 315, FP 340, FP 343, FT 226.

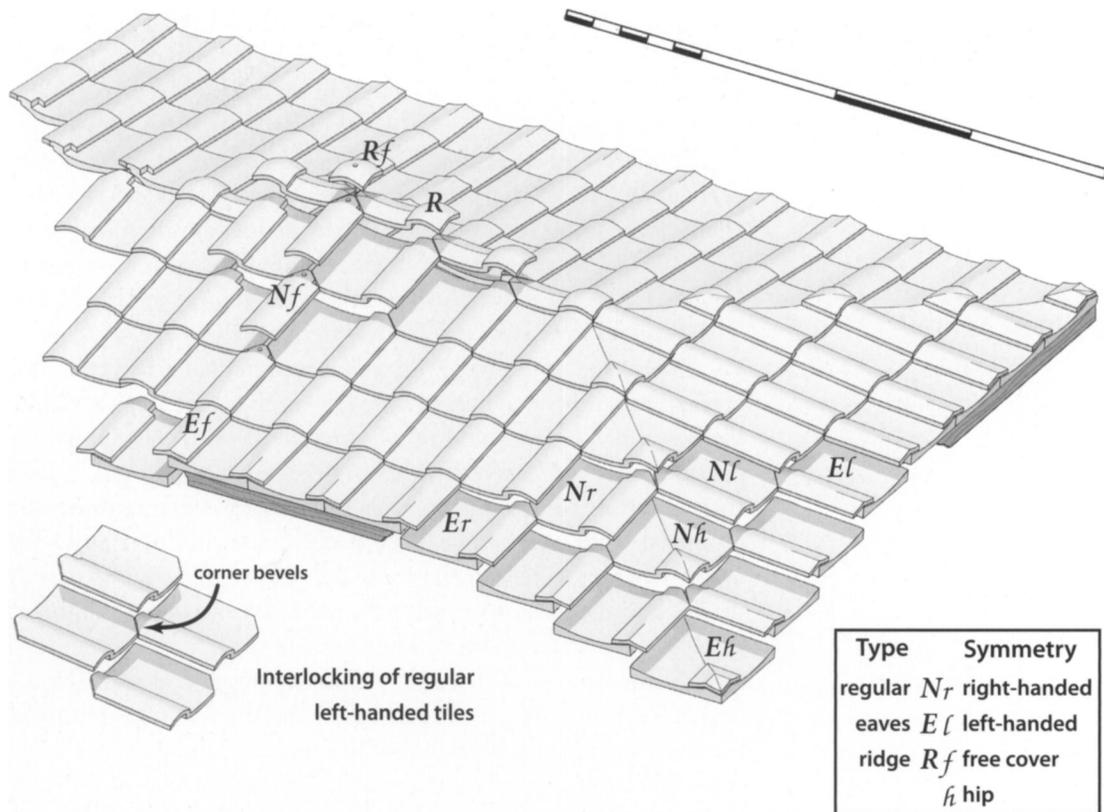


Figure 2. The Protocorinthian roofing system on the Old Temple at Corinth. P. Sapirstein

than having a pediment at one end and a hip at the other.²³ The hip tiles have a cover at the lower corner and pans to the left and right of the cover. Courses of regular tiles were set beginning at the hip pan. Consequently, the laying of each successive course of the roof must always have begun at the corners of the building with this special hip tile. Depending on which side of the hip tile pan they were to have been laid, regular tiles needed to be created in both left-handed and right-handed versions, that is, with cover attached to the left or right side of the pan (Fig. 2: N_l and N_r). The system of beveling and notching was applied symmetrically to both, so that the two forms are mirror images of each other; both share the same basic profile, their handedness determined only by the positions of the notch and bevels.

Too few examples are present in the corpus to determine whether the opposite-handed tiles were intended to meet in the center of every course.²⁴ Eaves tiles too had left- and right-handed versions,²⁵ but the special eaves hip tile necessary at the four corners of the roof has not been identified

23. A double-hipped roof at Isthmia also seems assured by the corpus of tile fragments excavated by Broneer: Hemans 1989, p. 258.

24. Left-handed regular tiles (a minimum of six examples): Corinth Museum FC 29, FC 80, FP 325, FP 327, FP 333, FT 210. Right-handed regular tiles (a minimum of 16 examples): Corinth Museum FP 76,

FP 103, FP 108, FP 110, FP 155, FP 157, FP 158, FP 164, FP 306, FP 329, FP 330, FP 337, FP 345, FT 217, FT 224, FT 228. Several other fragments could also be eaves or hip tiles. The total number of regular tiles in the deposit could be as high as 62 fragments.

25. Left-handed eaves tiles (a minimum of nine examples): Corinth Mu-

seum FC 81, FC 82, FP 161, FP 162, FP 163, FT 201, FT 211, FT 233, FT 236. Right-handed eaves tiles (a minimum of eight examples): Corinth Museum FC 63, FC 64, FC 86, FP 160, FP 334, FT 209, FT 234, FT 235. There are at least four more eaves tiles of uncertain handedness; altogether the deposit contains at least 27 fragments of eaves tiles.

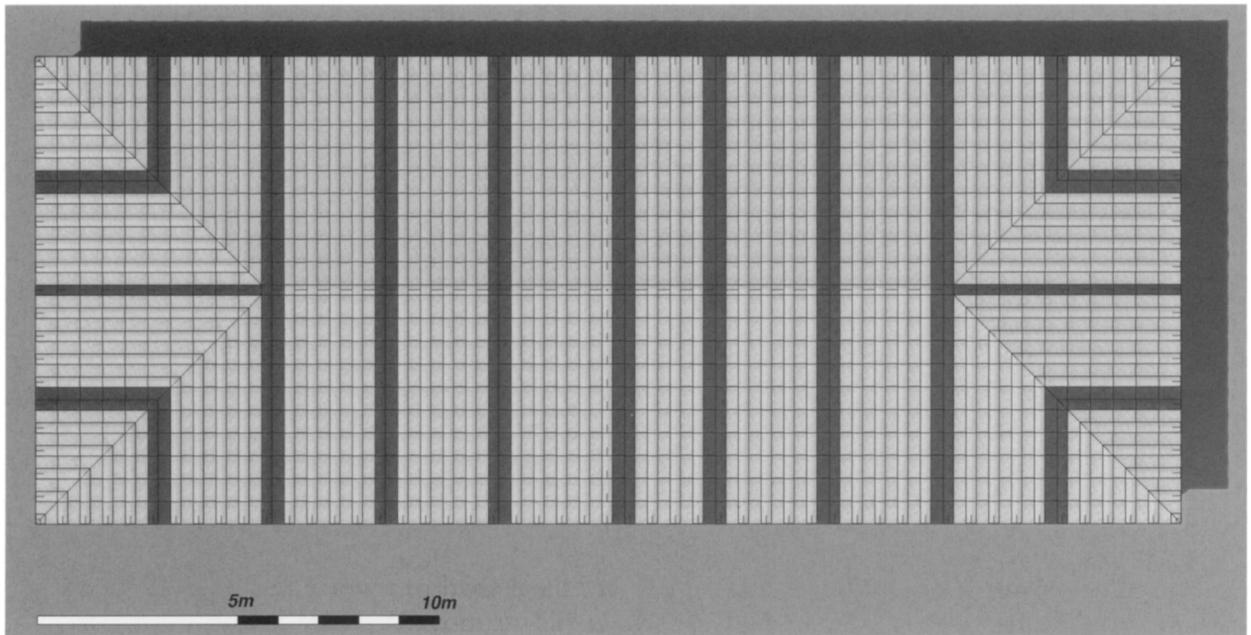


Figure 3. Top plan of the roof of the Old Temple, with one possible arrangement of the black tiles.
P. Sapiststein

among the preserved Corinth tiles (Fig. 2:Eb).²⁶ The final tile type is a free cover tile, which was placed over the pans where opposite-handed tiles met, probably including free covers at the eaves and presumably on the ridge as well (Fig. 2:Ef, Nf, and Rf).²⁷ Probably because of its relatively light weight, the free cover had a hole drilled near the back for an iron nail to anchor it in position.

Besides a slight modification to the eaves tile profile that will be considered below, the specialized tiles repeat the same curved cover and pan profile of the regular tiles, meaning that a substantial number of fragments have features diagnostic of more than one type. Most tiles had a buff finish, but roughly a fifth of the total were painted black on the faces visible on the assembled roof. There must have been a pattern of dark stripes on the roof at regular intervals (Fig. 3).²⁸ Despite the complexity of individual tiles, the overall impression of the assembled roof system is the simplicity of its conception, emphasized by the modular repetition of the combined profile of the concave pan and the convex cover (Fig. 2).

26. One example is identified at Isthmia: Hemans 1989, pp. 262–265, fig. 2. See also Rhodes 1984, pp. 89–90.

27. Free regular cover tiles (a minimum of six examples): Corinth Museum FC 78, FC 96, FC 98, FC 108, FC 109, FC 110. No certain example of a free eaves tile is unequivocally identified, but there are several small fragments that could also have broken from a normal eaves tile. No certain example of the free ridge cover has been identified at Corinth.

28. As now reconstructed by Rhodes (pers. comm.). Robinson first suggested

that there was one vertical row of black tiles for every five rows of yellow tiles, but later he restored a checkerboard pattern instead, based on the building model from Aetos: Robinson 1976a, pp. 233–234; 1984, pp. 58–59. See also Winter 1993, p. 16; 2002, p. 47. Checkered patterns are restored for the polychrome Archaic roof near Didyma: Schneider 1991, pp. 202–203; 1996, pp. 41–42. For the Old Temple roof, there are 23 black-slipped as compared with 98 yellow-slipped tiles in the corpus. My calculations suggest that close to a fifth of the regular and eaves

tiles are painted black. Preliminary reports claimed only a seventh of the tiles were black: Robinson 1984, p. 59, n. 15. Robinson arrived at this low proportion by dividing the number of right-handed black tiles (24) by the number of right-handed yellow tiles (139). However, he ignored the significantly lower count of left-handed tiles (104), which artificially inflated the yellow tile count relative to the black. Many of the fragments tallied by Robinson were subsequently discarded, so the tile counts are now lower.

TECHNIQUES FOR MANUFACTURING PROTOCOLINTHIAN TILES

REPLICATION EXPERIMENTS AT ISTHMIA

An experimental study of the roof tiles of the early Poseidon temple at Isthmia has already provided a number of important observations about the mass production of Protocorinthian tiles.²⁹ Rostoker and Gebhard worked through the entire process, from clay mining through firing, with a team of Greek workmen, some with experience in making bricks. Of particular concern to the question of technological origins is the manufacturing sequence used to make the replica tiles at Isthmia.³⁰ The Isthmia team assumed that because the top of the tiles is smooth and even compared with the rough underside, the top must have been formed in a mold. Furthermore, they found that the tiles are too large to be formed in a two-part press mold, because pressing the extensive surface area of the upper half of the tile into shape with a separate top mold requires more force than is mechanically feasible.³¹ The Isthmia team concluded that Protocorinthian tiles must have been produced upside down, with the clay for the replica tile built up on a molded bedding shaped like the upper surface of the tile. The team constructed large wooden molds framed by “flasks” to support the sides of the tile as clay was packed into the form.³² The flasks were profiled like the underside of the tile, also serving as templates used to guide the shaping of the exposed bottom surface of the tile. The experimenters packed clay into the form and vigorously pounded the exposed surface into position with a broad mallet, which left impressions over the whole underside.³³ They next cut the rabbeted shelves into the bottom surface and left the tile to dry. Because the clay tended to stick to the molds, the Isthmia team had to experiment with other ways to extract the tile. Their solution was to line the mold with fabric sheets that helped raise the tile off its bedding.³⁴ They fired the replicas at temperatures between 650° and 700°C, which gave the replica a coloring similar to that of the original Protocorinthian tiles.³⁵

Rostoker and Gebhard concluded that the Isthmia tiles could have been produced using simple materials and tools.³⁶ They observe that the “technical features of making tiles—even these giant tiles—present no obstacles that could not be overcome by an empirical approach and some ingenuity.”³⁷ The authors do not pursue the origins of the technology, but rather they suggest that the knowledge could have arrived with traveling Corinthian craftsmen, presumably those with experience from building the Old Temple at Corinth. The few Protocorinthian roofs that are preserved are so uniform that we should assume the design at Isthmia would have been more or less the same as it was at Corinth, but the Isthmia report does not pursue the ramifications of the experimental replications for the Old Temple roof.

Is it likely that this manufacturing technique was developed first for fully developed Protocorinthian tiles, as suggested by Wikander?³⁸ The shape of the Isthmia mold—which has a pan, cover, and notch built into its base and is held together by wooden pegs³⁹—is a complicated piece of

29. Rostoker and Gebhard 1981. The project is summarized in Gebhard 2001, pp. 57–58.

30. Because the roofs at Corinth and Isthmia were almost identical, Robinson (1984, p. 57, n. 8) followed the Isthmia replication method when describing the fabrication of the Corinth roof.

31. Rostoker and Gebhard 1981, pp. 220–221.

32. Rostoker and Gebhard 1981, pp. 220–221, fig. 16.

33. Rostoker and Gebhard 1981, pp. 221–222, fig. 18.

34. Rostoker and Gebhard 1981, pp. 222–223, fig. 23.

35. Rostoker and Gebhard 1981, pp. 222–223.

36. Rostoker and Gebhard 1981, pp. 225–226.

37. Rostoker and Gebhard 1981, p. 226.

38. See n. 14, above.

39. Rostoker and Gebhard 1981, p. 220, fig. 16.

woodworking, and suggests that its designers had a specific system in mind when creating the forms. Moreover, the molding technology suggested for Isthmia is far more sophisticated and on a much larger scale than any other ceramic molds attested at the time. A handful of terracotta molds dated to the 7th century B.C. have been recovered from the Potters' Quarter at Corinth, but none of these small figurine molds were excavated in contexts dating as early as the Old Temple.⁴⁰

In conclusion, although the Isthmia researchers discovered a way to create an imitation of a Protocorinthian tile, it is difficult to imagine how this elaborate molding process could have come about spontaneously in antiquity. In other words, the elaborate shape of the tiles and the complex molding techniques used at Isthmia argue strongly in favor of an adaptation of some existing tradition of tile making and against the idea that Corinthians invented the tile roof for the temples at Corinth or Isthmia.

PRIMARY FORMING TECHNIQUES AT CORINTH

Although the Isthmia team successfully produced several replica tiles, various aspects of their reconstruction are questionable.⁴¹ Surprisingly, they state that “no consideration was given to the tool marks at the time the tile experiment was planned and executed.”⁴² Instead, “one check that can be made on [their] forming procedure comes from the marks that were left on the surface of the ancient tiles by the original craftsmen.”⁴³ They present several photographs of surface markings on ancient tiles, which are described as corresponding to the markings from a knife, a spatula, and a long bar used on their replica tiles.⁴⁴ The authors do not explain the basis for these identifications, however, despite their importance for confirming the replication procedure, and there are reasons to doubt that these particular tooling marks were left on the surface before firing.⁴⁵

During my examinations of the ancient tiles, I found that the Isthmia researchers had overlooked a characteristic feature of every well-preserved, inventoried Protocorinthian tile fragment from Corinth, Isthmia, Perachora, and Delphi: a fine gravel coating on the underside (Fig. 4, left).⁴⁶ It is formed of small chips of mudstone that come from shale deposits

40. Fragments of six head molds are dated to the 7th century B.C.: *Corinth* XV.1, pp. 87–90, nos. 1–6. The majority are dated to the third or fourth quarter of the century, but no. 1, despite having been recovered with pottery dating to the third quarter of the century, was dated “at least as early as the early seventh century” on the basis of stylistic parallels with Near Eastern heads of the 8th and 7th centuries: *Corinth* XV.1, pp. 87–88. The relative dates of the Protocorinthian tiles at Corinth and this mold are uncertain, although the context date for the mold is later

than the Old Temple construction fills. See n. 4, above.

41. Elizabeth Gebhard and Frederick Hemans have themselves questioned the molding system chosen for Rostoker and Gebhard 1981: Gebhard 2003, p. 17. The terms “primary forming,” “secondary forming,” and “surface modifications” used in the following pages and in Tables 1 and 2, below, are adapted from terminology in Rye 1981, p. 62.

42. Rostoker and Gebhard 1981, p. 223. Coles’s book on experimental archaeology explicitly advises against

this approach: Coles 1979, pp. 38–39, 46–48, 160.

43. Rostoker and Gebhard 1981, p. 212.

44. Rostoker and Gebhard 1981, pp. 224–225, figs. 24–28.

45. That is, the illustrated marks may have been the result of postfiring chiseling of tiles, which is described as it occurs at Corinth: see n. 66, below.

46. At Corinth, 77 inventoried tiles preserve a rough gravel undersurface, while another 44 fragments have been retooled, eliminating the original texturing.

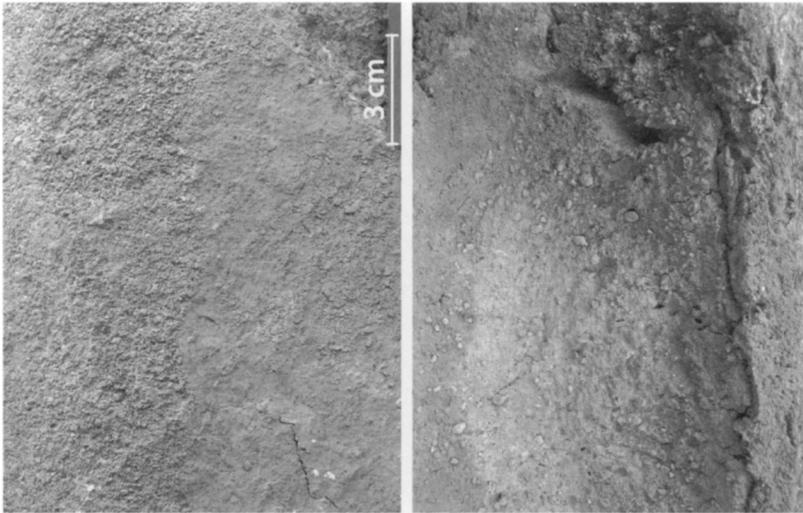


Figure 4. A parting agent of clay dust and gravel on the undersides of a Protocorinthian and a modern tile: Corinth FT 228 (*left*); and a cover tile from the village of Delphi (*right*). Approximately equal scale. Photos P. Sapirstein

outcropping in the Corinthia and are easily crushed into a fine gravel.⁴⁷ The particles form an even layer adhering only to the lowest surface of the tile, and they never exhibit any markings from canvas sheets or mallets like those used to fabricate the Isthmia replicas. Instead, the evenly distributed gravel adhering to the clay surface is better interpreted as a *parting agent*, defined in the ceramic literature as any material used to prevent clay from sticking to a working surface such as a mold.⁴⁸ Rather than canvas sheets, Corinthian coroplasts were using mudstone chips as a parting agent, similar to the gravel still used on handmade tiles found on older houses in Greek villages (Fig. 4, right). Ethnographers have documented the use of other materials such as dry clay, sand, or ash as parting agents on the lower surfaces of cover tiles made in Morocco, Italy, and Euboea,⁴⁹ and a separator layer has been noted on undersides of Classical Lakonian tiles from Kalapodi.⁵⁰ Because the parting agent adheres to the bottom of Protocorinthian tiles, the bottom must have been the molded surface, meaning the ancient tiles were formed right side up.

The selection of mudstone as a parting agent is logical given its use as tempering for the clay of the same tiles.⁵¹ All Protocorinthian tiles have roughly 15%–25% of this tempering material, where it serves to strengthen the tile while reducing shrinkage during drying. Mudstone is also a common tempering material in early Corinthian transport amphoras.⁵² The tile

47. Mudstone is a well-known tempering material for Corinthian ceramics: Farnsworth 1970, pp. 10–11; Whitbread 1995, pp. 334–335; 2003, pp. 6, 12, table 1.2. The same rough layer of tempering material appears on the undersides of Archaic tiles from Acquarossa: *Acquarossa* VI.2, p. 105, fig. 37.

48. Rye 1981, pp. 81, 146, fig. 65:c. Oddly, despite using sand as a “mold release coating” for bricks made in frames for their kiln, the Isthmia team failed to adapt the same method for

producing their tile replicas: Rostoker and Gebhard 1981, pp. 215, 222. See also Whitbread 1995, p. 296.

49. Bel 1918, p. 181 (ash); Hampe and Winter 1965, pp. 28 (dry clay dust), 50 (sand or clay dust), 107 (sand), 133 (sand).

50. Tiles from Kalapodi have a sandy coating on the underside for release from a mold: Hübner 1997, p. 141.

51. Whitbread (1995, p. 294, n. 4) identified mudstone tempering in four

Protocorinthian tiles. The Isthmia tiles also contain Acrocorinth shales: Rostoker and Gebhard 1981, pp. 212–214, n. 8.

52. Whitbread (1995, pp. 270–271, 294) compares the fabric of the tiles to Corinthian Type A' class 1 (early) amphoras. Although the Type A' amphora is not contemporary with the Protocorinthian roofing system, at least the Type A amphora that developed in the early 7th century has mudstone temper: Whitbread 1995, pp. 268–269.

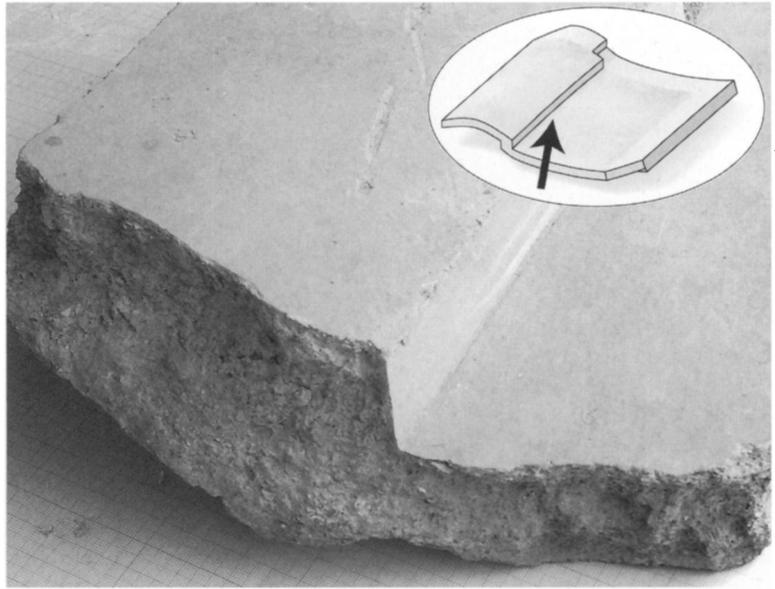


Figure 5. Break face across the cover-pan joint revealing the continuous fabric: Corinth FP 342. P. Sapirstein

clay itself is fine bodied, and, in breaks, it usually has fired reddish brown in the core compared with the buff surface.⁵³

Another important clue to the primary forming technique can be found at the joint between the cover and pan, where it is obvious that the combination tiles were not pieced together from separate units. Because Protocorinthian tiles rarely break along this cover-pan joint and the fabric is uniform when exposed in a break section, the whole tile must have been constructed as one seamless unit (Fig. 5).⁵⁴

Less obvious is how the top was formed. The entire upper surface is coated by a smooth slip that conceals the dark tempering material. In most cases, the slip's application removed any surface markings that might indicate how the top was formed. The slip has partly broken away on a few exceptional fragments to reveal an undersurface with fine grooves that run from side to side, although it is uncertain whether these grooves are the result of the molding process or just a secondary feature caused by smoothing (Fig. 6). At least we may conclude that the top was not formed in the same way as the bottom, because there is no evidence for a layer adhering to a parting agent covered by the slip. The top of a tile was intended to be visible when installed on the roof, and it has been polished smooth in comparison with the rougher but molded underside.

If the upper surface was not formed in a press mold, at least the consistency of profiles of several different tiles suggests that the upper surface was shaped using a standardized template of some kind (Fig. 7). Overlaid

53. The Munsell surface color reading is 10YR 7/4 (very pale brown) on more than half the tiles, but for others the clay ranges within 7.5YR–2.5Y/7–8/3–6, and weathering produced deeply saturated oranges up to 5YR 7/8 (reddish yellow) in a few spots. Where exposed in break faces, the fabric

approaches 5YR 7/4 (pink) and 7.5YR 7/6 (reddish yellow), although a sixth of the Corinth tiles were fired throughout to the surface color. Color readings were taken from *Munsell Soil Color Charts*, New Windsor 2000.

54. Also noted by Winter (1993, p. 13, n. 6).

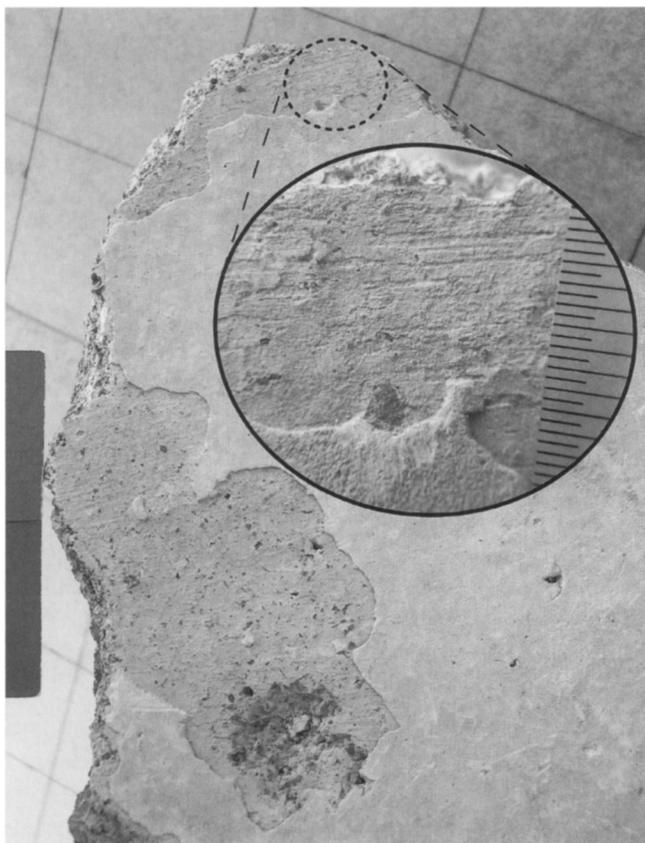


Figure 6. Longitudinal striations exposed beneath flaked slip: Corinth FP 326. Scale: two 0.03 m cards at left; 0.5 mm minor gradations in inset. P. Sapirstein

sections in Figure 7 show that the thicknesses of individual tiles vary, but the profiles of the top and underside are very consistent, even between regular and eaves tiles (Fig. 7: FT 211). The highest variability is at the free end of the cover where the underside has been cut back to form a rabbet. This operation appears to have distorted the upper profiles.

A logical alternative to using a two-piece mold for producing these consistent profiles for the top is a template frame. The frame would be similar to the simple rectangular wooden frames used for making bricks: clay is packed into the brick mold and the upper surface “struck” flat by running a straightedge over the frame to remove the excess.⁵⁵ The curved upper side of a Protocorinthian tile could be struck by replacing the flat brick frame with parallel templates attached at the front and back sides of the mold. These templates would guide the straight-edged scraper used to strike the upper surface down to the desired profile (Figs. 8 and 18, below). Traditional Mediterranean cover tiles were formed in this way, with a smoothing board drawn over a sheet of clay packed into a low wooden

55. Both mud bricks and fired bricks are made in such frames: Dobson [1850] 1971, vol. 1, pp. 27–29, 70, fig. 7; Bel 1918, p. 51; Hampe and Winter 1965, pp. 28 (Buonabitacolo), 49 (Minturno), 51 (Pisticci), 207; Birmingham 1967, p. 34; Matson 1985,

pp. 67–68; Kingery and Vandiver 1986, pp. 241–242; Wright 2005, pp. 99–105. The tops of small bricks might be smoothed with an open hand instead of a straightedge. In Dobson’s terms, a brick is “stricken” with a “strike”: Dobson [1850] 1971, vol. 1, p. 27.

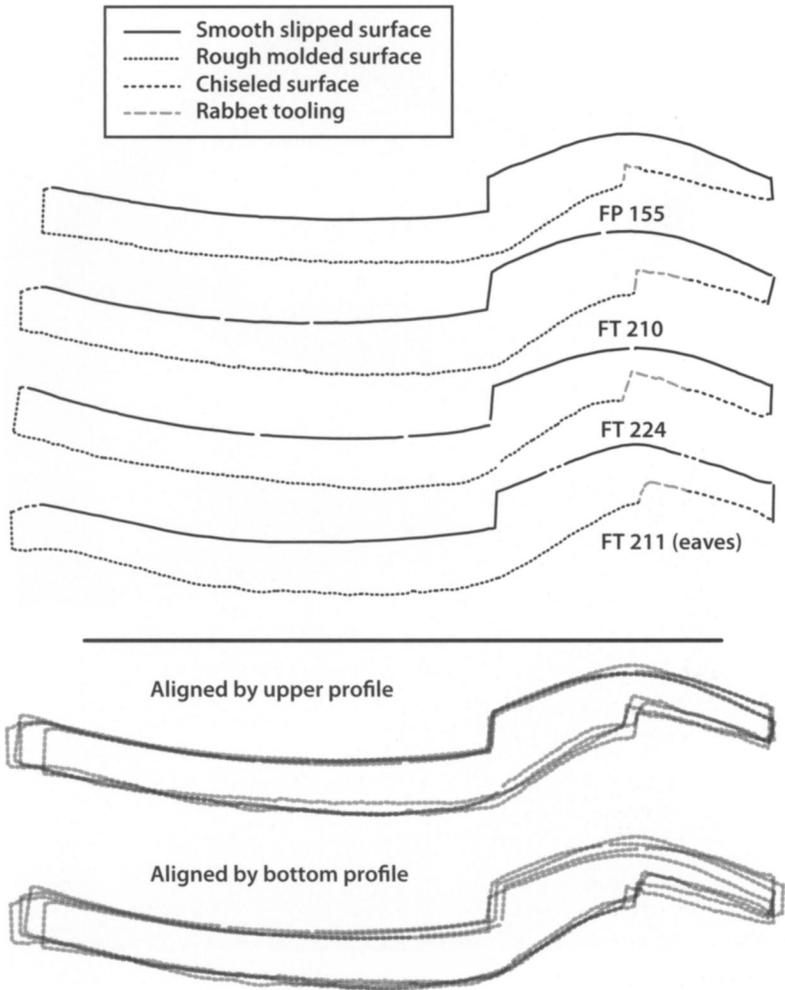


Figure 7. Comparison of sections (above) taken through the midpoints of several complete tiles. Overlays (below) are darkest where several different tile sections coincide.

P. Sapirstein

frame,⁵⁶ and the method is still known to modern coroplasts.⁵⁷ The method is similar to that employed by the Isthmia team, whose open-topped form had templates built into the sides, although their templates served only to guide the shaping of the bottom of the replicas.⁵⁸

The edges of Protocorinthian tiles do not preserve markings that can prove the existence of such a template. Because the front face of the tile and the long sides of the cover were visible on the assembled roof, they have been smoothed with the same slip as upper surfaces. Thus, any tooling marks have been removed. The back face and the free side of the pan, however, were not slipped, although the markings on these surfaces are

56. Tilemakers around Fès used a sharp-edged board to flatten clay into a trapezoidal frame: Bel 1918, pp. 178–183. The same technique is clear in the photographs from Minturno: Hampe and Winter 1965, pl. 15:4. See also Dobson [1850] 1971, vol. 1, p. 42, and vol. 2, pp. 56–66, 67–68; Rye 1981, p. 81. Admittedly, in modern practice, a

flat sheet of clay is formed first and then draped over a profiled cover-tile mold, but this particular method is impossible for so large and heavy an object as a Protocorinthian tile.

57. Approaching the problem from the perspective of a ceramicist, John Lambert immediately selected a board for striking out the first replica

tiles destined for the Snite exhibition (see n. 1, above), although at the time he had seen only drawings of the tiles.

58. See Rostoker and Gebhard 1981, p. 221, fig. 17, where the “upper roof tile” in the caption refers to the underside of the finished tile.

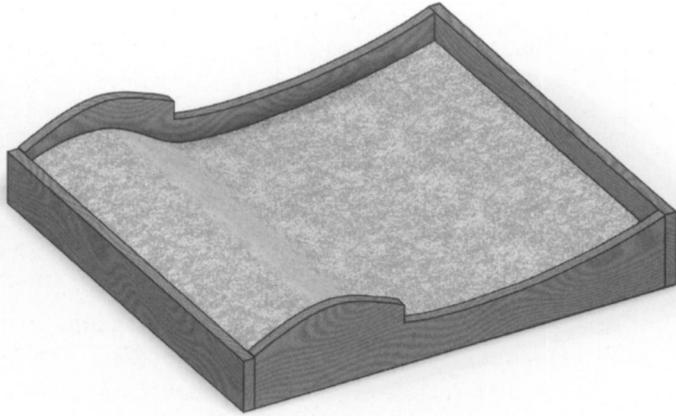


Figure 8. Protocorinthian regular-tile base mold and frame: hypothetical system (*above*); experimental system prepared with mudstone gravel parting agent (*below*). P. Sapirstein

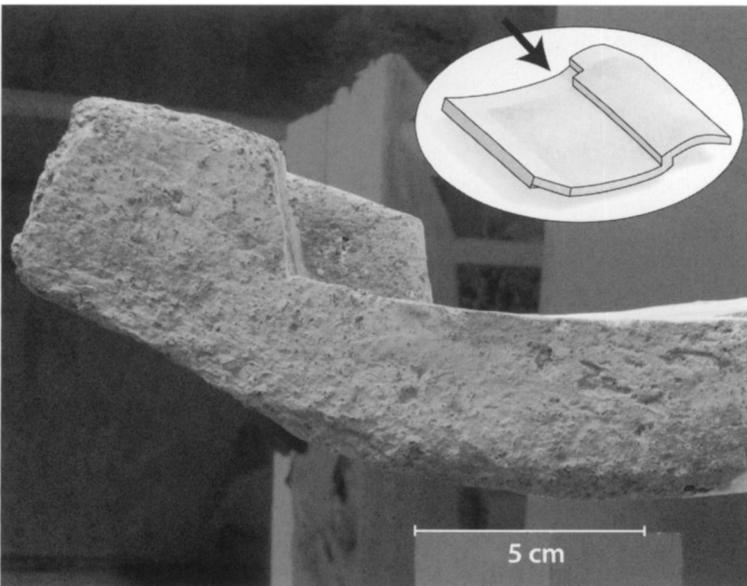


Figure 9. Back face with longitudinal hollows left by a blade stroke: Corinth FP 110. P. Sapirstein

generally unhelpful in analyzing the forming techniques. Some edges have an uneven face with small lumps raised around pieces of temper lodged in the clay body. Commonly, the rough surfaces have striations that must have been left by a cutting blade (Fig. 9). These strokes suggest that a knife was used on the sides, probably to separate the clay from the template frame. The knife cuts might also be explained as secondary trimming, if for some reason the tiles were molded at a larger dimension than needed and were subsequently cut down. As a result, it is unclear whether the frame was exactly the size of one tile, or whether it was somewhat larger.⁵⁹

Based on these observations, I propose that the primary forming of a Protocorinthian tile took place on a mold consisting of a curved bedding for the bottom, with profiled templates framing the front and the back. Clay was packed into the mold after it was covered with a fine mudstone parting agent. The upper profile of the tile was shaped by dragging a straightedge between the template frames. The templates may have been set farther apart than the full depth of a finished tile, which would have required trimming with a blade after the tile was molded. The template frames were a pair of wooden boards united in a stable four-sided frame that fit around the base mold (Fig. 8). Similar framing systems have been proposed for Archaic and Roman roof tiles.⁶⁰

SECONDARY FORMING TECHNIQUES AT CORINTH

After its top was profiled and smoothed, the Protocorinthian tile would have been complete except for the notches and bevels needed to accommodate the 0.1 m overlap between neighboring tiles (Fig. 10). The surface markings of these features suggest that they were cut away from the volume of the tile after it was molded. The notch frequently has drag marks and smeared wads of clay on its inner surfaces, indicating that it had been cut out with a blade while the clay was still damp and sticky (Fig. 11). The blade often cut down into the opposite face of the notch, again suggesting that the clay was fairly soft when it was cut.

On the underside, the rabbeted shelves have tool casts of a different character. The rabbet surfaces have lengthwise strokes with crisp edges that sometimes preserve the width of the narrow straightedge used to trim the surface (Fig. 12). Unlike the markings on the notch, the long stroke-paths are relatively smooth, and pieces of the temper in the fabric have been fractured and dragged along the surface by the blade (as seen also along the lower edge of the chiseled surface on Fig. 16, below). The

59. Cutting down the tiles is an unnecessarily complicated system. A large mold several tile units deep could be formed in the frame and the individual tiles cut apart later, although this would have been difficult at the dimensions of the Protocorinthian tiles. The smaller, mass-produced modern tiles are formed one at a time: see n. 12, above.

60. Rook 1979; *Acquarossa* VI.2, pp. 104–109; Schneider 1991, pp. 198–199, fig. 4, followed by Hübner 1997, pp. 136, n. 19, and 149, fig. 11; Schneider 1996, p. 24; Schädler and Schneider 2004, p. 23; Warry 2006, pp. 7–36. Rook first proposed a frame system for Roman tiles, where excess clay was cut down with a wire: Rook 1979, pp. 298–301, fig. 16:3. Wikander suggested that

grooves on the surfaces of the pan tiles from *Acquarossa* were the marks of a smoothing board instead of a wire: *Acquarossa* VI.2, pp. 105–106, fig. 38. Flat pan tiles were made in Italy until recently, but the manufacturing techniques were not documented: Hampe and Winter 1965, pp. 38 (Montecorvino), 102 (Santo Stefano di Camastra), 207.

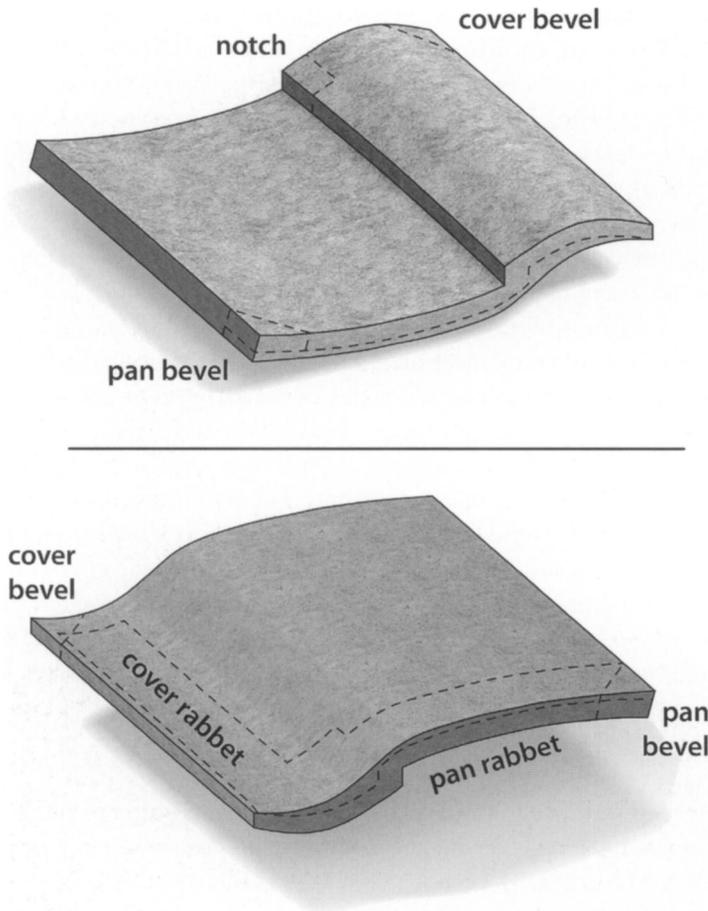


Figure 10. Top and underside of a Protocorinthian tile after primary forming, with dashed lines indicating the volumes to be trimmed away in later operations. P. Sapirstein

fact that the clay had stiffened enough to develop a smooth surface under the stroke and hold fragments of temper up against the tip of the tool indicates that the clay must have dried close to a leather-hard state by the time the rabbets were cut out. Since the rabbets are on the underside of the tile, which was resting on the mold bed during the primary forming, the artisans must have waited until the tile had stiffened enough to lift it from the base mold. Fingerprints were impressed deeply into the back and side surfaces of a few tiles. Because the tile would have been too stiff to accept such deep imprints after it had hardened enough to be lifted, the prints probably record premature attempts to slide the tile free from its mold while the clay was still too soft (Fig. 13).

It is less clear when the corner bevels were cut. Their surfaces exhibit a variety of secondary tooling marks suggesting that they were cut and recut at different times during the finishing sequence. Finally, most tiles have incised setting guidelines on the upper surfaces. The incisions have crisp, clean edges consistent with having been cut while the clay was still leather hard.⁶¹

The surfaces that would be visible on the assembled roof were polished as part of the finishing process. Several tiles have a fine clay coating up to 1.5 mm thick that has split away from the tempered fabric of the body (see Fig. 6, above). In most cases, this layer appears to be an applied slip, and it is particularly distinct when an excess wad of the material has been wiped

61. Rye 1981, pp. 66–67, 90, fig. 47:b.

Figure 11. Cut marks on the notch:
Corinth FP 164. Scale: 0.03 m card at
 bottom of field. Photo P. Sapirstein

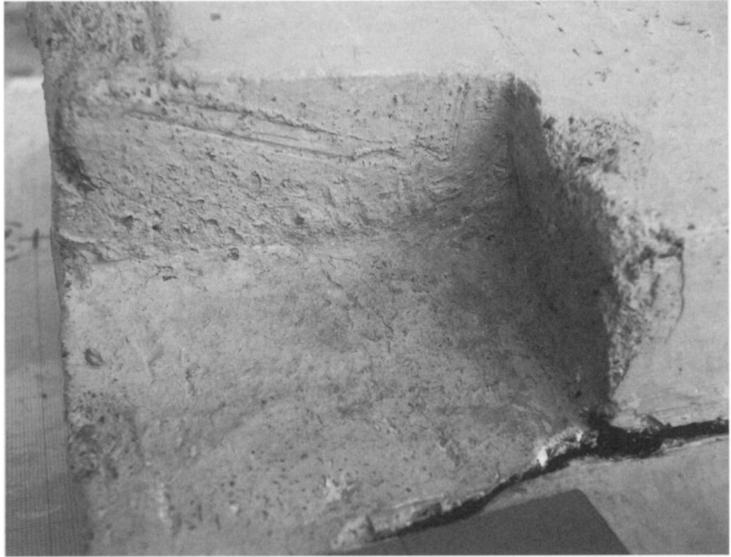


Figure 12. Lengthwise strokes in the
cover rabbet: Corinth FC 65.
 Scale: two 0.03 m cards at top of field.
 P. Sapirstein



inside the edges of the notch (Fig. 14). Its coloring in no way differs from the fabric below it, suggesting that the slip was prepared from the same clay as the rest of the tile. In many cases, however, the smoothed surface is difficult to distinguish from the rest of the fabric, and it is possible that some part of the polish was self-slipped—that is, produced by smoothing the tempered body clay with moistened fingers to draw finer particles to the surface.⁶²

62. Rye 1981, pp. 89–90. Some Archaic tiles from near Didyma were polished in this fashion: Schneider 1996, p. 56. Most Protocorinthian tiles have a distinctive, clean coating that is more consistent with an applied slip.

There is a similar slip on later architectural terracottas at Corinth: Whitbread 1995, p. 296; Bookidis 2000, p. 388. A distinctive slip coating was applied to the 7th-century roof from Ephesos: Schädler and Schneider 2004, pp. 23–

24, 61–66. I thank Elizabeth Gebhard and Frederick Hemans (pers. comm.) for sharing with me their belief that the Protocorinthian tiles at Isthmia were not slipped.

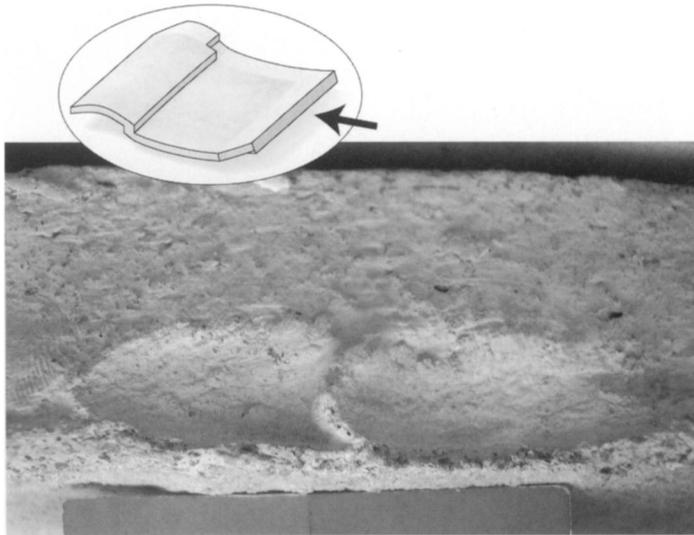


Figure 13. Fingerprints on the bottom edge of the free side face of the pan: Corinth FT 210. Scale: two 0.03 m cards at bottom of field. P. Sapirstein



Figure 14. Back view of a notch with wads of excess slip wiped over the edges: Corinth FP 330. Scale: 0.03 m card at left. P. Sapirstein

The tiles that were painted black have a second dark coating, which must have been applied after the tile was slipped and had dried to a leather-hard state.⁶³ The paint fired to a matte dark brown, and it is often cracked. Many times the paint has red splotches or is entirely reddish brown, due to an uneven application or perhaps an imperfectly controlled reduction phase during firing.⁶⁴ Only the visible faces of the tile were consistently painted

63. Described as “glaze-paint” in Robinson 1984, pp. 57–58. Here the term “paint” is preferred as long as it is uncertain whether the black coating is a vitrified glaze: Rye 1981, p. 54; Jones 1986, pp. 760–761; Hamer and Hamer 2004, pp. 163–167, 333–334.

64. In light of recent analyses of the black gloss on other ceramics, it

seems more likely that the black paint is produced by the reduction of iron oxides. Manganese is another possible colorant that was detected in recent preliminary tests of 6th-century paint on terracotta sculpture at Corinth: Bookidis 2000, p. 392, n. 54; Winter 2002, p. 49. However, manganese has not been detected in other roughly

contemporary Greek or Lydian ceramics: Jones 1986, pp. 762–763, 812; Schneider 1991, p. 202; Maniatis, Aloupi, and Stalios 1993; Hostetter 1994, pp. 48–49; Schneider 1996, p. 56; Henrickson, Vandiver, and Blackman 2002; Papadopoulos 2003, pp. 210–212.

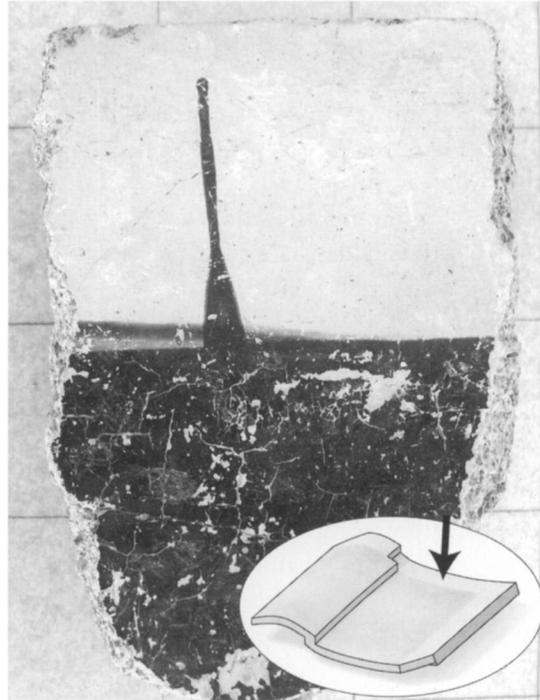


Figure 15. Black paint dribbled over the reserved back edge: Corinth FP 317. Scale: 0.05 m background grid. P. Sapirstein

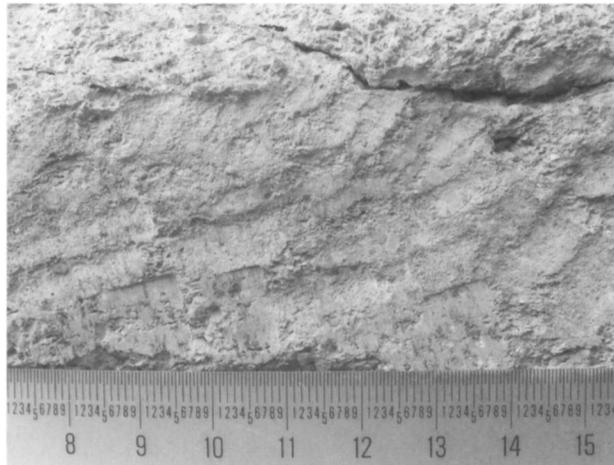


Figure 16. Chisel marks on the cover rabbet with leather-hard tooling intact along the lower edge; break along the upper edge: Corinth FP 163. Photo P. Sapirstein

black. The paint was applied only as far as the incised setting guidelines, stopping short of the back and sides in the areas that would be overlapped by adjacent tiles after installation. Some black-painted tiles had dribbles of the dark wash running toward the back edge, showing that the tile had been flipped up to stand on end while it was painted (Fig. 15). Clearly, these tiles were painted very late in the manufacturing process, after the tile was strong enough to be upended and the guidelines had already been incised.

A surprising feature of Protocorinthian tiles is the chiseling usually found on their joint surfaces (Fig. 16). It has left distinctive tool casts of a narrow blade in places where the fabric otherwise appears rough and broken. In most cases, the chiseling removed the pale buff surface of the tile to expose the reddened fabric of the core. Because this color differentiation

appears only through firing, the chiseling must have occurred after firing.⁶⁵ Apparently, the tiles were adjusted to fit one another during installation on the roof.⁶⁶ Furthermore, traces of what may be a lime mortar adhere to the surfaces of a few fragments, where the mortar would have sealed the joints between tiles or else shored up pieces that sat too low.⁶⁷ Another postfiring feature of Protocorinthian tiles is the dark, irregular staining of the surface that coincides with the incised setting guidelines. Exposure to rain and soot after the roof was in place must have created the stains.

HYPOTHESIS FOR THE MANUFACTURING SEQUENCE

On the basis of the surface markings considered to this point (Table 1), I propose a manufacturing sequence for regular Protocorinthian tiles, outlined in Table 2. Surface markings and ethnographic analogies suggest a concise series of events, although the relative order of stages 4–6 appears to have varied on individual tiles. To test the general feasibility of this hypothesis for the forming and finishing of tiles, I have produced replica tiles. These replication experiments were part of a collaborative project in Ancient Corinth to experiment with clay deposits mined around Acrocorinth.⁶⁸

TABLE 1. SURFACE MARKINGS ON ROOF TILES GROUPED BY MANUFACTURING STAGE

<i>Manufacturing Stage</i>	<i>Surface Marking</i>
Primary forming	Gravel parting agent Blade marks loosening sides from frame
Secondary forming	Soft clay: notch, corner bevels Leather-hard clay: rabbets, some corner bevels
Surface modification	Soft clay: slip, smoothing Leather-hard clay: incised setting guidelines
Postfiring modification	Chiseling Weathering

65. For the color differentiations of the fired fabric, see n. 53, above.

66. I found it easy to chisel fired replica tiles and discarded ancient Corinthian tiles from the excavations as long as the fragment was more than 0.02 m thick and firmly supported. Postfiring tooling of Archaic tiles has been noted before, but the distinction between postfiring chiseling and other trimming marks has not been clearly explained: *FdD* II, p. 205; *Isthmia* I, p. 53, nos. AT 25, AT 26; Robinson 1984, p. 58; Schneider 1991, pp. 199–200, 204–205, figs. 12, 13; Hübner 1997, pp. 136, 150, fig. 15; *Alt-Ägina* I.3, p. 42, pl. 39:2; *Acquarossa* VI.2, pp. 125–126.

67. A distinctive pale mortar containing a fine aggregate adheres to the joint faces and undersides of many tiles, but it is uncertain whether this conglomerate is a man-made mortar or a natural burial accretion. I thank Ruth Siddall for examining tiles FC 29, FC 110, FP 158, FP 309, FP 311, FP 312, FP 333, FP 339, and FT 210 under a magnifying lens and providing me with this information. Robinson (1984, p. 62, n. 20) reported that tiles FP 312, FP 338, FP 342, and FP 345 had unfired wads of clay adhering to their undersides, and he cited a parallel at Isthmia (*Isthmia* I, p. 52, AT 14). However, I was able to find wads of fired clay adhering to only two tiles,

FP 338 and FP 345, suggesting that these tiles had picked up some foreign material after they had dried and while being moved around the workshop or placed in the kiln. FP 312 and FP 342 presently do not have fired or unfired clay adhering to their undersides; Robinson may have been describing some calcareous accretions on these tiles that resemble dried clay.

68. Other participants in the project between 2004 and 2006, besides myself, were Guy Sanders, Robin Rhodes, John Lambert, and Allison Trdan. See n. 1, above. The replica tiles summarily discussed here were successfully fired in 2006. A detailed report will be published separately.

TABLE 2. HYPOTHETICAL MANUFACTURING SEQUENCE FOR REGULAR PROTCORINTHIAN TILES

PRIMARY FORMING (Fig. 8)

1. Each tile is formed right side up on a base mold. In preparation for packing with clay, a parting agent composed of the same mudstone used to temper the clay is sprinkled over the mold.
2. The upper surface of the tile is shaped in an open-topped form with templates at its sides. After clay is packed into this frame, the top profile is trimmed down with a straightedge between the pair of profiled templates at the front and back.
3. The template frame is removed after the top surface has been formed. The sides of the tile may first be cut free from the frame by running a blade along the edges, or the tile may be trimmed to the desired overall length and depth.

SECONDARY FORMING AND SURFACE MODIFICATION (Fig. 10)

4. A notch is cut into one end of the cover soon after the primary formation is completed. Its location determines the handedness and orientation of the tile, for it always appears on the back side of the finished product.
5. All surfaces of the tile visible on the assembled roof—the top, front, and both sides of the cover—are slipped and smoothed.
6. A pair of corner bevels is cut into the clay by the time it has become leather hard.
7. After the tile has dried sufficiently to be removed from the base mold, it is lifted off the mold, and rabbets are cut in the underside.
8. Some tiles are coated with a dark paint.
9. Setting guidelines are incised along the back and sides of the upper surface once the clay is leather hard and after any paint has been applied.

POSTFIRING MODIFICATION

10. All tiles are heavily retooled along the overlapping edges in order to create a tight joint with neighboring tiles.
-

REPLICATION EXPERIMENTS AT CORINTH

We began with a clay base mold with vertical boards on its four sides. The completed mold with its frames in position created a square interior area 0.7 m per side (Fig. 8, above). Because we expected the replica to shrink during drying and firing, the dimensions were slightly larger than a finished Protocorinthian tile. Over the base mold we sprinkled a thin layer of crushed mudstone screened with a 1 mm mesh. We then packed the mold with lightly wedged slabs of clay that had been tempered with a coarser grade of crushed mudstone (Fig. 17). One mold could hold about 45 kg of wet clay before the top of the upper templates was overfilled.

When the mold was full, it was possible to level the surface with a wide straight board by repeatedly drawing it over the surface. Once the edges were flush with the template frames, we smoothed the full surface of the tile with a few gentle strokes (Fig. 18). This process required some patience because the clay was sticky enough that the board would open gashes in the surface if it was pulled with too much force or caked with drying clay. Occasionally, fragments of temper caught by the smoothing board were dragged along the surface, creating grooves that needed to be polished over with another pass or patched with a roll of clay. After approximately 10 minutes, an acceptably even surface was prepared over the entire top of the tile. Although the surface was flush



Figure 17. Packing clay slabs into the base mold to form a replica tile.
Photo A. Trdan



Figure 18. Striking out the upper surface of a replica tile. Photo A. Trdan

with the templates, the smoothing board left shallow striations running from side to side on the tile, parallel to the direction of the stroke, which were reminiscent of the grooves that are visible below the slip on a few ancient Protocorinthian tiles (compare Fig. 6 to Figs. 18 and 23). Further smoothing was needed to achieve the level of polish typical of an ancient Protocorinthian tile.

At this point, we could remove the template frames for access to cut out the notch and bevels (Fig. 19). Next we applied a thin coating of fine



Figure 19. Cutting and removing clay with a metal spatula to create a notch. Photo A. Trdan

clay slip that had been prepared from the same clay as the tempered fabric, and then smoothed the surface carefully with moistened fingers. Although Protocorinthian tiles have brushlike marks on their upper surfaces, we found in the experiments that the hairs of a brush tend to leave deep, hard-edged narrow grooves in the soft clay. Hand smoothing worked better; the grooves of our fingerprints left faint ridges that closely resemble those on the surface of Protocorinthian tiles, suggesting that hands rather than brushes were used in antiquity. It appears that the coroplasts applied the slip immediately, before the body clay had time to stiffen. Applying slip and smoothing the surface soon after the tile is formed ensures that the layer is well bonded to the tempered fabric of the tile, minimizing the development of cracks in the slip because of differential rates of shrinkage. The surface of the slip was polished as the slip was applied. We found during the experiments that, if one waits until the clay dries to a soft leather-hard consistency, polishing produces a low-gloss burnish unlike the matte slip on the ancient fragments.

After the notch and bevels were cut and the upper surfaces and sides polished, the replica was nearly complete. In the heat of a Corinthian summer, the tile could dry to a leather-hard state within six hours, even while shaded. At this stage, we could nudge the whole tile around the base mold, showing that the parting agent had effectively prevented it from sticking. We could test when the tile was ready to be removed by gently pressing on the sides at the same positions where fingerprints are preserved



Figure 20. After drying, the replica tile is stiff enough to remove from the base mold and stand on end (*left*); the clay is resistant but can be trimmed by peeling off layers with a metal spatula (*right*). Photos A. Trdan



Figure 21. A fired replica Protocorinthian tile. Photo A. Trdan

on some of the original Protocorinthian tiles (see Fig. 13, above). Within 16 to 24 hours the tile was stiff enough to allow us to push it off the mold and lean it against a wall for trimming out the rabbets.⁶⁹ We found that the most efficient way of cutting the rabbets into the now stiff and resistant clay was to peel off layers with the rectangular tip of a scraper tool (Fig. 20). We left the tile to finish drying in a sheltered space, and it was ready to fire within a week. After firing, the full-scale replica (Fig. 21) bore a striking resemblance in its coloring and surface markings to an ancient Protocorinthian roof tile.

69. The drying times varied slightly from one replica to the next, depending on the initial dampness of the clay and the weather. Every tile we made was left to dry overnight, when the rate of evaporation was much lower.

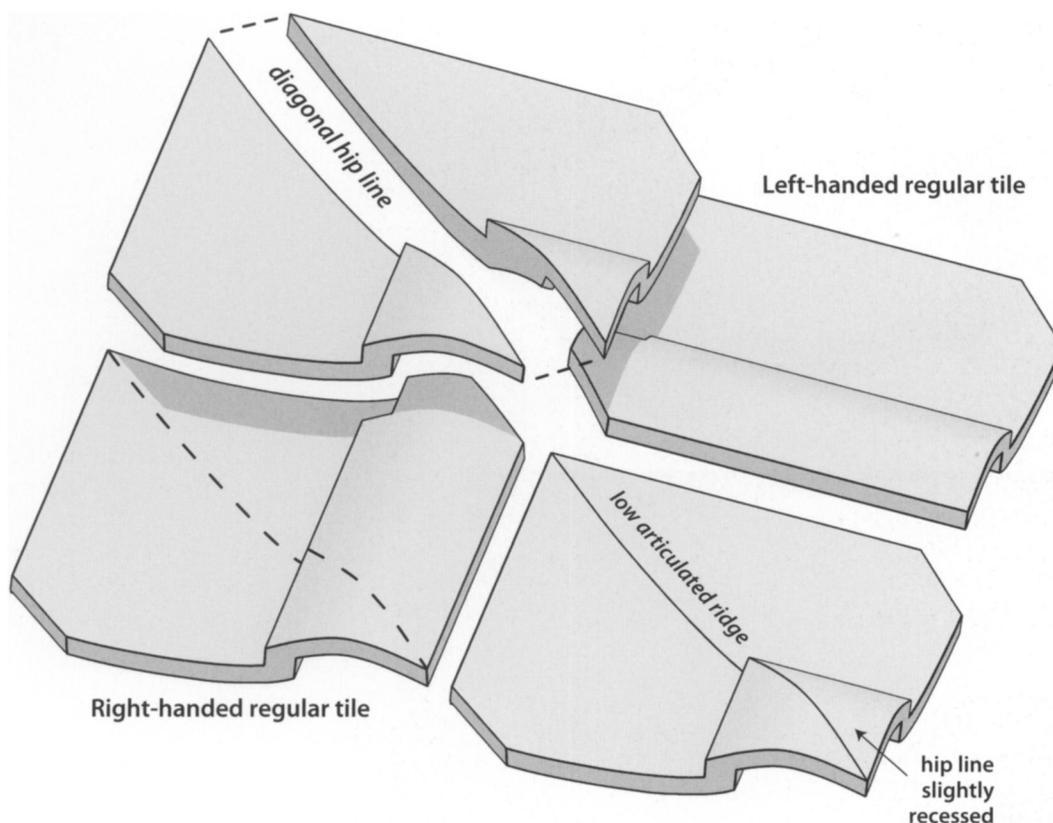


Figure 22. Geometry of a Protocorinthian hip tile. P. Sapirstein

MODIFICATIONS FOR PRODUCING SPECIALIZED TILES

This understanding of the forming sequence for regular Protocorinthian tiles suggests a number of conclusions about the origins of the technology of ceramic roofs. Despite the complexity of individual tiles, the production stages show that the conception and design of these tiles are simple and straightforward. The template-forming technique can also be applied effectively to the specialized tiles.

For example, hip tiles combine the intersecting curved surfaces of two regular tiles from two different slopes of the roof meeting on the diagonal. Careful observation of the preserved fragments of hip tiles reveals that each tile is shaped exactly like the halves of two regular tiles from opposite slopes of the roof attached along the hip line (Fig. 22).⁷⁰ However, hip tiles always have a seamless fabric over the hip line. As with the regular combination tiles, the entire hip tile was formed at once as a single unit, not by joining two bisected regular tiles. On first encounter, such a sophisticated shape seems extremely difficult to create. The problem is simplified, however, by the template approach used for the regular tiles. Starting with the regular-tile frame with its pair of profiled templates at the front and back sides, the obvious solution for the hip tile is to add a second pair of profiled templates at right angles to the first (Fig. 23; compare Fig. 8, above). The two pairs of templates guide the shaping of the two halves meeting along a diagonal at the hip.

70. Broneer (*Isthmia I*, p. 50) recognized this essential characteristic of the hip-tile geometry.

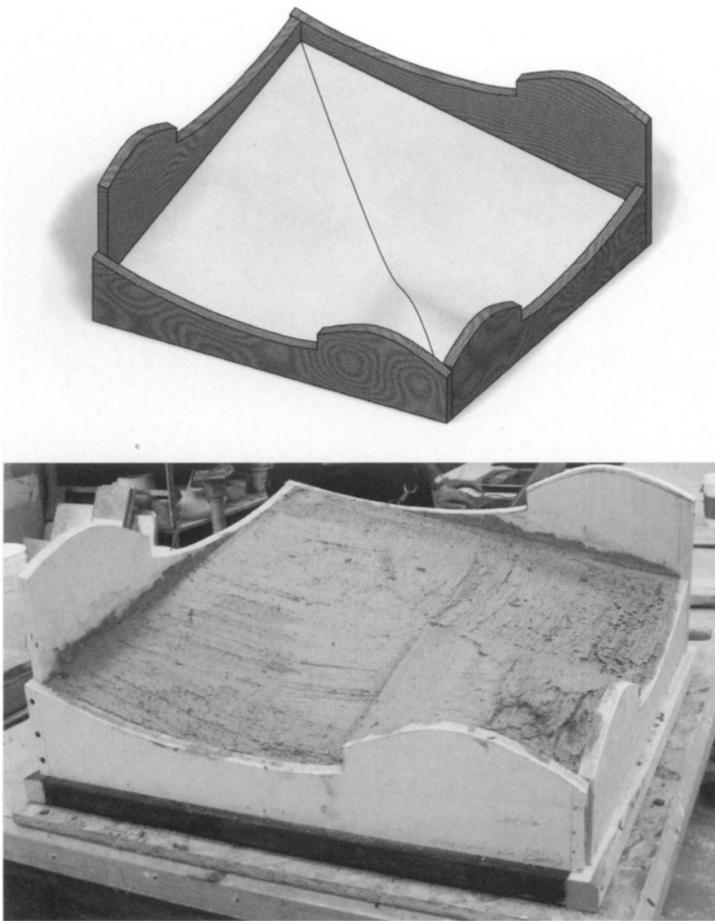


Figure 23. Base mold and template system modified for producing a hip tile: hypothetical system (*above*); experimental system packed with clay after preliminary smoothing (*below*). P. Sapirstein

Measurements of the preserved fragments of Protocorinthian hip tiles show that the two halves are positioned relative to one another commensurate with the slope of the roof. The designers must have anticipated that the hip tile would interlock best if created exactly as it would be positioned on the roof. It is possible to reproduce the slope with the template frames by elevating the back frame relative to the front frame at approximately the angle of the roof (Fig. 23).⁷¹ In this configuration, a smoothing board can be dragged across the top of the templates in both directions without damaging the opposite side of the hip tile. After the tile is shaped in such a frame, the manufacturing sequence can proceed in the same way as for the regular tiles, with the omission of the notch cutting. In this system, the complex geometry of a hip tile exploits a very simple and logical derivation from the regular-tile template system. The transition over the hip cover from a ridge to a recessed cusp along the hip line is not a decorative feature, but rather the form that results from the addition of the second pair of template frames (Fig. 22, lower right).

The eaves tiles, too, can be generated by a simple alteration of the regular-tile mold and the templates. The front face has a horizontal base with a shallow rabbet cut into the underside that would have rested on a straight fascia board. Rather than having a normal convex curve, the cover

71. I produced hip tiles at the University of Notre Dame with the help of John Lambert.

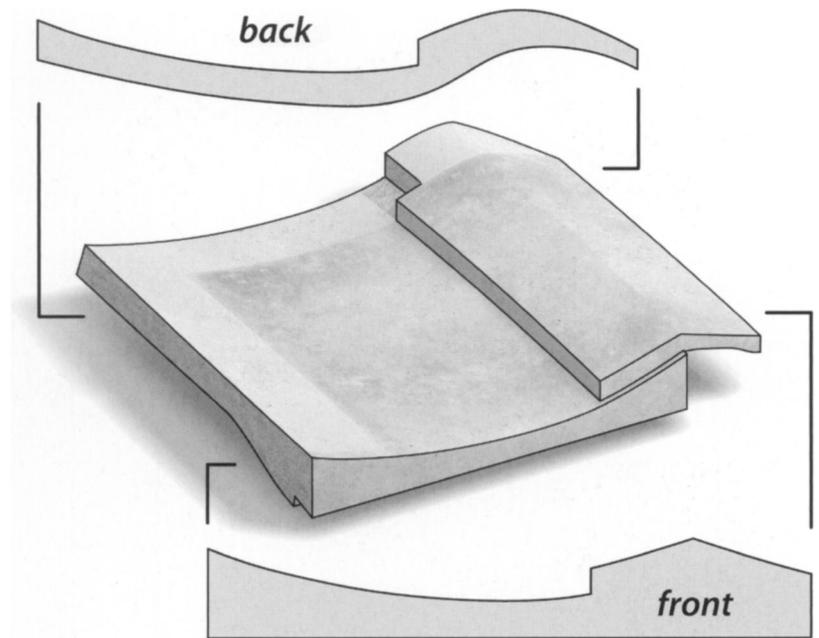


Figure 24. A restored eaves tile showing the profiles at the back and front faces before secondary trimming. P. Sapirstein

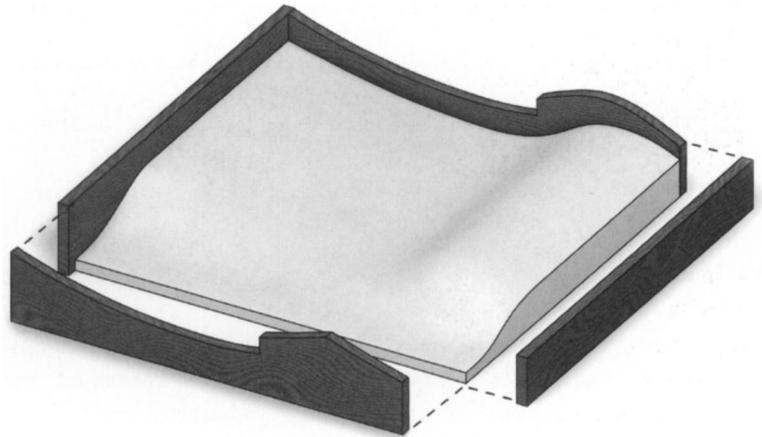
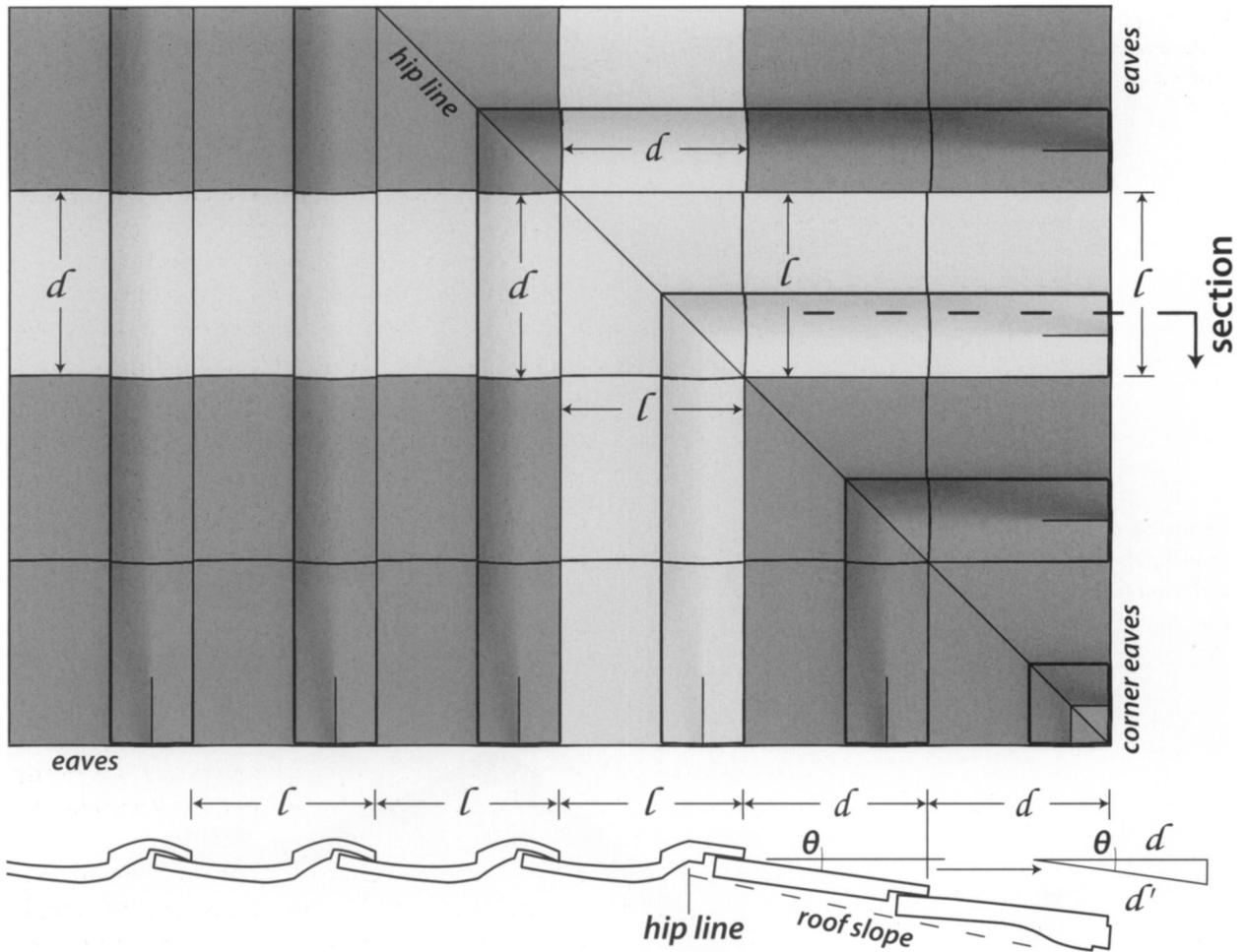


Figure 25. Modified base mold and template system for producing an eaves tile. P. Sapirstein

is peaked, responding to the peak of the adjacent pans meeting below it (Fig. 24; see also Fig. 2:E, above). The peak of the cover at the front is gradually transformed toward the back into the normal convex curvature of a regular cover. For the base, a special mold would have been used that was flat at the front with a smooth transition to the regular-tile profile at the back (Fig. 25). The designers constructed a normal base mold, probably in clay, and carved out the transition to the horizontal front edge.⁷² For the peak of the cover, a modified template would have been used at the front of the tile paired with a regular profiled template at the back. The board-smoothing process on the upper surface produces the same smooth transition between the peaked and rounded cover profiles that is found on the original Protocorinthian eaves tiles.

72. The base could have been produced in other materials, but clay is well suited to this sort of carving.



MODULARITY IN PROTOCOLINTHIAN ROOFS

Despite the apparent complexity of Protocorinthian tiles, their design reflects a simple process for mass-producing units to a consistent profile capable of interlocking on a roof. The decision to build a hipped roof may also be attributed to this simplicity of conception. That is, by continuing the horizontal course of normal eaves tiles around all four sides of the building, each side of the roof could be constructed using the standard templates. The hip roof eliminated the need for developing a specially profiled raking sima to cap the end of a gable.

An important repercussion of designing a hipped roof is that every element must be based on a consistent module. The *length* of the regular tiles on one end of the building must equal the *depth* of the regular tiles at the other side of the hip because both groups of regular tiles must be spaced evenly to interlock across the hip (Fig. 26). It would be possible to have unequal length and depth dimensions only under two alternative situations: (1) if the building did not have orthogonal walls, or (2) if the tiles on the ends and flanks of the building had different spacings, with length and depth measurements reversing over the hip line. We may safely assume from the corpus of architectural fragments that the Old Temple had

Figure 26 (*opposite*). Plan and section of the corner of a Protocorinthian roof with a square hip module.

P. Sapirstein

orthogonal walls.⁷³ The second case may be excluded because the regular tiles preserve only one narrow range of measurements for their lengths and depths. Moreover, the hip tiles have square covers and the hip line runs at 45° to the tiles in plan. As a result, the only possible configuration is for the tiles to have equal spacings for the length (along the course), l , and depth (in the upslope direction), d , such that $l = d$ over the hip (Fig. 26). The exposed portion of every tile is square in plan, and the entire roof could be measured out in square modules equal to one tile minus the overlap.⁷⁴

Because the tiles are set at a slope, however, the exposed depth (d) of the tile along its upper surface will be slightly greater than its length along the course (l).⁷⁵ Referring to the roof section in Figure 26, for a tile slope of angle θ , the exposed depth dimension at the stance of a tile, d' , equals $d/\cos \theta$. Using the weathering lines as indicators of the original setting positions of individual tiles, it is possible to estimate this tile slope, θ , based on the deflection. The average exposed dimensions of the tiles from the Old Temple are length $l = 0.552$ (extrapolated from 11 tile measurements) by exposed depth $d' = 0.557$ (extrapolated from 16 measurements), and the tile slope may be estimated at slightly lower than 1:7.⁷⁶ Such a low slope is to be expected,⁷⁷ and it is corroborated by an analysis of the profiles of the hip tiles themselves⁷⁸ and the even lower slope of the timber cuttings on the cornice blocks.⁷⁹ This 5 mm increase in depth of a tile exposed over 0.552 m was easily accommodated by the relatively broad overlap area of 0.09–0.13 m. The builders could have designed the tiles using a perfectly square module without being aware of the necessary depth deflection (d') on the tiles as they were set on the roof.

The hipped roof forced Greek builders to plan a structure conforming to the square spacing modules of the tile grid. The foundations of the temple must have been rectangular and calculated so tiles could be installed at the correct spacing.⁸⁰ Thus, at Corinth we can begin to speak of an architect who calculated the number of tiles needed for the entire project and who carefully measured out the foundations to ensure that the walls would fit the modular dimensions of the roof.

73. Although the plan is not preserved in situ, the wall blocks and the tiles have orthogonal sides: Rhodes 1984, 2003.

74. Rhodes (1984, p. 97) described this phenomenon as a “design square.”

75. See Rhodes 1984, pp. 97, 125, n. 208.

76. Given that $l = d$, then $\theta = \cos^{-1}(l/d')$, or 7.7°, equivalent to a 1:7.4 slope. Because the lower end of a regular tile was tilted up to rest on the tile below it, the rafter slope actually would be slightly steeper. Of course, there was some variability in the measurements of l and d , and with only 27 measurements in the population, the accuracy of θ using this method is low. An error of

$\pm 2^\circ$ should be a safe estimate, giving a tile slope between 1:5.9 and 1:10.

77. In order to keep tiles from sliding off the roof: Rook 1979; Liebhart 1988, pp. 155–156; Wikander 1988, pp. 207–208. Robinson (1976a, p. 228) proposed a low slope on the basis of two blocks whose association with the roof is unlikely. Rhodes (1984, pp. 89–90, 96–98) restored a Chinese roof with a 1:7 slope on the basis of hip tiles at Corinth and Isthmia. He notes (p. 97) that the “design square” of the Corinth tiles implies a low roof slope. See also Hemans 1989, p. 265.

78. The sides appear to have been formed with a relative inclination of roughly 8°, although I must admit an

error of at least $\pm 1^\circ$ by this method due to the curvature of every tile profile.

79. Rhodes 2003, p. 90.

80. For the relationship of blocks to the spacing of tiles at Isthmia, see Rhodes 1984, pp. 70–82. Individual cuttings on the cornice blocks from Corinth exhibit more variability: Rhodes 1984, pp. 98–101; 2003, pp. 91–92. Similar observations have been made about regular block units and modularity in tiles: Liebhart 1988, p. 153; Cooper 1989, p. 41; Gebhard 2001, pp. 47, 51–53, 59. Modular Archaic tile designs at Didyma and Ephesos: Schneider 1990, pp. 214–218; 1991, pp. 203–206; 1995; 1996, pp. 27–38; Schädler and Schneider 2004, pp. 27–29.

CONCLUSIONS

In summary, the fundamental design process behind the roof of the Old Temple is very simple. The architects and coroplasts began with a pair of curved profiles for the bottom and top of a combination cover and pan tile. Using these profiles as templates, they generated tiles that were intended to interlock in a square grid that governed the overall dimensions of the building. They abandoned the asymmetrical roofing systems found in some building models of earlier date in favor of a hipped roof whose eaves were articulated identically on all four sides.⁸¹ Every type of tile has been adapted logically from the same regular cover-pan profile to its special position on the roof,⁸² meaning that the complexity of the geometry of specialty tiles is due purely to functional modifications to the regular-tile molding system. Perhaps the only elaboration of this roof that is purely decorative is the occasional use of black tiles among the yellow (see Fig. 3, above).

Despite the simplicity of the design process, its implementation is inefficiently labor-intensive. The double curvature of the covers and pans created difficulties aligning and interlocking individual tiles, since minor distortions introduced during the fabrication and firing of tiles could produce substantial misalignments during the laying process. The misalignments were illustrated by the initial installation of the roof tiles in the exhibition at the Snite Museum, where gaps in joint surfaces opened up to 0.01 m because of slight deviations in the tiles (Fig. 27).⁸³ Furthermore, the secondary hand-cutting of notches and rabbets only exacerbated these mismatches, because they could not be tooled in exactly the same way each time. The joints had to be chiseled back after firing for their final installation on the roof in order to achieve the tight seal necessary for protecting the woodwork from rainwater. Although it would have been much more efficient to devise a way to mold the rabbeted shelves into the bottom of the tiles so that they would be of identical dimensions, the coroplasts neglected to do this. Instead, the builders had to chisel back every tile on the construction site. Thus, the Protocorinthian system was appropriate for an early monumental temple, but the tiles are unsuitable for mass production. Forming and trimming of combination tiles is so inefficient that they were eventually dropped as a standard.⁸⁴

With these technical factors in mind, we can now reconsider the origins of the Protocorinthian system. It appears that we are not examining the market production of a Corinthian tile factory of the 7th century B.C., but rather an isolated project to roof a new type of temple with more than a

81. While building models provide too little evidence to generalize about the appearance of 8th-century B.C. roofs, several from Perachora, the Argive Heraion, and Aetos have steep roofs terminating at a pedimental space over a shallow front porch: Schattner 1990, pp. 22–26, no. 1; 28–31, no. 4; 33–39, nos. 6–9; 182, 189. The gable over the door can be explained in prac-

tical terms if it served to divert rainwater away from the entrance of the building: Mallwitz 1961, pp. 133–134. See also Heiden 1987, pp. 23–26; Winter 1993, p. 18.

82. Although not investigated in detail here, the design approach for the ridge tile is similar to that of a hip tile because the ridge combines two regular tiles meeting at a change of slope on

the roof. See *Isthmia* I, pp. 49–50.

83. For the Snite exhibition, see n. 1, above.

84. Combination tiles are a standard feature of the Corinthian roofing system and several early relatives, but regular Corinthian tiles are usually made as separate covers and pans after ca. 540 B.C.: Winter 1993, p. 82.

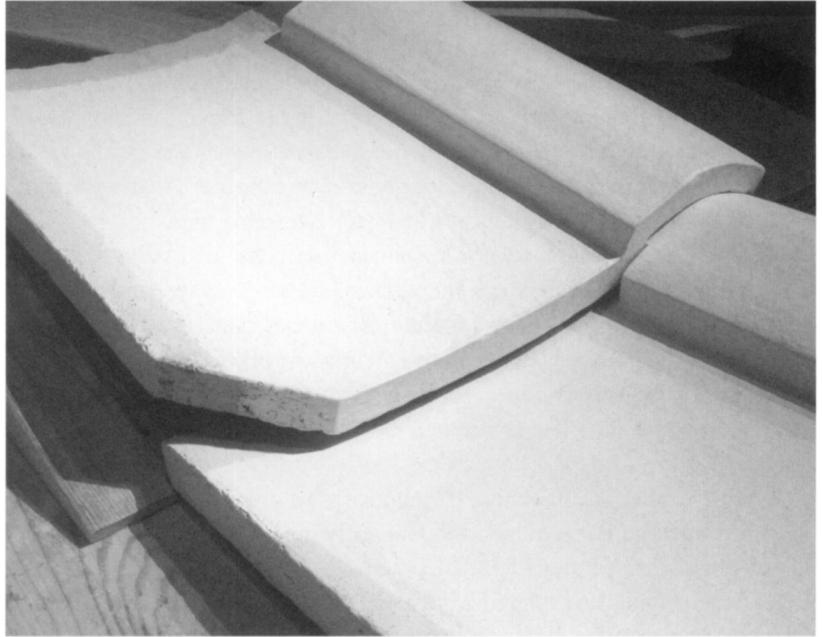


Figure 27. Fired replica tiles on display in the Snite Museum, University of Notre Dame, with slight misalignments before trimming with a chisel.

Photo P. Sapirstein, courtesy R. Rhodes

85. Estimates for the size and numbers of tiles required for the Isthmia roof vary: Rostoker and Gebhard 1981, p. 224 (estimating 1,900 tiles); Rhodes 1984, pp. 91–96 (giving a wide range of possible building dimensions and tile numbers); Hemans 1989 (giving a wide range of tile counts from a statistical analysis of fragments); Gebhard 2001, p. 58 (ca. 1,820 tiles).

86. See nn. 51 and 52, above.

87. See nn. 55 and 56, above.

Molded bricks appear as early as the eighth millennium B.C. in Anatolia: Aurenche 1993, p. 84.

88. Roebuck 1955, p. 157; Rhodes 1984, p. 102; 2003, pp. 88–89, fig. 6:10.

89. Schwandner 1990, p. 292.

I thank Charles Williams, Fred Cooper, and Robin Rhodes for bringing this to my attention.

90. Rhodes 1984, p. 107; Schwandner 1990, pp. 295–296; Rhodes 2003, pp. 87–88. Cooper (1989, pp. 30–32) discusses the issue.

thousand massive tiles.⁸⁵ The basic set of techniques used to make these tiles must have been well known to potters, who had been constructing enormous storage vessels for generations and had already identified suitable clay beds and tempering materials for the heavy tile fabric.⁸⁶ The clever molding techniques may be compared to the wooden frames used to mass-produce mud bricks since the beginning of cities in the Near East.⁸⁷ With mud bricks probably used for the upper parts of the walls of the Old Temple itself,⁸⁸ the adaptation of brick frames to strike the upper surfaces of Protocorinthian tiles certainly would have been within the creative capacity of Corinthian coroplasts. It requires only a few obvious modifications to the templates to produce specialized tiles, and the designers could have worked out the correct configuration of the frames with a few test units at the beginning of the job. The need for cutting the notches and bevels would have been apparent immediately after attempting to set a few test units. Since these features are not built into the molds, the designers may have been working out these sorts of problems as they went along. Moreover, the need to resort to chiseling to correct misalignments on each tile argues against the designers having much experience in creating other monumental roofs. In all, the simplicity of its conception and the technical inefficiency of its implementation suggest that the Protocorinthian roofing system was a new design. The tiles could well have been invented specifically for Corinth's early temple.

Still, it is difficult to support Wikander's scenario in which the system was invented entirely without precedents in fired clay. As already observed, the basic element of the design for the whole roof begins with the curved profile of the cover and pan. One might expect roof tiles to be curved for purely technical reasons in order to funnel water down the roof more efficiently.⁸⁹ The articulation of the covers as a separate entity raised above the pan, however, implies a familiarity with earlier tile roofs,⁹⁰ because all

Protocorinthian tiles are molded in combination, only simulating tile roofs with separate covers and pans. Although he disagrees with Schwandner's hypothetical antecedents leading up to the combination tile, Wikander is forced to propose an implausible origin for the Protocorinthian roof: wooden shingles.⁹¹ Wikander does not present any evidence that Late Geometric buildings had shingled roofs, and he does not illustrate a shingling system that is profiled like Protocorinthian roof tiles.⁹²

There is no need to resort to this illusory wooden-antecedent hypothesis, as the resemblance between the assembled Protocorinthian system and other 7th-century roofs with separate covers and pans is striking.⁹³ The Corinthians, of course, were free to design any sort of curved profile over the full length of their combination tiles. They might have designed a profiled tile that could not have been separated into cover and pan elements at all, but instead they produced a system that ostensibly differed little from Winter's early Argive "regional" system.⁹⁴ Thus, without going so far as inventing another evolutionary sequence without sufficient evidence, I propose that Corinthians went to the trouble of articulating distinct cover and pan elements in combination tiles in imitation of some preexisting design that used separate cover and pan tiles: at least one earlier tile roof.⁹⁵

Nevertheless, in light of the technical analysis, Schwandner's elaborate evolutionary sequence of hypothetical stages leading to the tile roof of the Old Temple at Corinth remains unsupported. Although Protocorinthian tiles seem to improve upon a simpler predecessor, there is no reason to postulate that a monumental Corinthian tile-roofed temple existed before the Old Temple was constructed on the prominence of Temple Hill. According to Winter's chronology, there is a gap between the Protocorinthian system and the first decorated roofs at Corinth, with the latter not appearing until at least the end of the 7th century B.C.⁹⁶ Considering the inefficiencies of the Protocorinthian system, it is equally possible that the Corinthians were no more than distantly acquainted with the predecessor of the Protocorinthian roof.⁹⁷ The tiled roof may have been introduced into Mediterranean Iron Age architecture at any center that had contact with Corinth by the early 7th century B.C.

91. Wikander 1990, p. 289; 1992, p. 156. This explanation is not accepted by Skoog (1998, p. 26).

92. Although Wikander does not refer to it, Benndorf (1899, pp. 21–37) had already argued at length that tile roofs were derived from wooden prototypes based on a comparison of Anatolian rock-cut and built tombs with preserved wooden roofs in European vernacular architecture.

93. For example, compare the

plain tiles in the reconstruction of the Corinth roof to the 7th-century roof from Ephesos: Schädler and Schneider 2004, p. 117, pl. 21.

94. Winter 1993, pp. 149–157.

95. This "prototype" theory has been entertained by others, albeit without much supportive evidence. Billot proposes a predecessor in the form of Winter's Argive system: Billot 1990, pp. 121–122; Badie and Billot 2003, pp. 283–289. Cooper (1989, pp. 19–20,

29–32) favors a similar "prototype roof" before the Protocorinthian system, an idea that she attributes to J. J. Coulton. See also Rhodes 2003, p. 88. For a discussion in relation to the Lakonian system, see Skoog 1998, pp. 21–26.

96. Winter 1993, pp. 18–20; 2000, p. 256.

97. This possibility is mentioned by Cooper (1989, pp. 31–32).

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