THE ARCHAIC ROOF TILES AT ISTHMIA
A RE-EXAMINATION

THE ARCHAIC TEMPLE at Isthmia and the similar early 7th-century temple at Corinth are the earliest known Greek structures to employ dressed ashlar masonry and a tiled roof.[1] Reconstruction of these temples is crucial not only for our understanding of the development of monumental building techniques but also for understanding the transition from early Iron Age architecture to the fully developed Doric order. In 1971, Oscar Broneer and William B. Dinsmoor, Jr. presented a reconstruction of the temple at Isthmia, but several of their conclusions have since been disputed.[2] At issue is the extent to which the building exhibits characteristics of the Doric style: whether or not it was colonnaded, its size and proportions, the shape of the roof, and whether or not the timber framework of the roof is an antecedent to the arrangement of triglyphs and metopes later found in the Doric order.

Huge numbers of tiles and building blocks were recovered in the excavations carried out by Broneer from 1952 through 1960.[3] After the temple was destroyed by fire, *ca.* 470 B.C., the debris was deposited in two gullies north and east of the temple platform.[4] Unfortunately, the foundations of the Archaic temple were almost entirely obliterated by the construction of the Classical temple. Broneer was able to reconstruct accurately the shape of the roof on the basis of the tiles, but he restored the size of the temple from remains that do not provide an exact width or length.[5]

In 1987, in connection with a study of the foundations of the temple and its floor, the roof-tile fragments that were found in the excavations of the 1950's were re-examined.[6] We felt that a numerical study of the thousands of terracotta roof tiles recovered by Broneer

[1] This study grew out of work at Isthmia during the summer of 1987. I am especially grateful to Elizabeth R. Gebhard, director of the University of Chicago excavations at Isthmia, who supported and encouraged this study. Bruce King and Richard Rinaolo of the University of Chicago assisted me in the laborious sorting of the tiles. Without their patience and hard labor this work would never have been completed. I am also indebted to Henry S. Robinson, James R. Wiseman, Maureen Kaplan, Robin Rhodes, and Elizabeth Gebhard for providing many useful suggestions that have improved this paper.

Works frequently cited are abbreviated as follows:

Broneer, *Isthmia* I = O. Broneer, *Isthmia*, I, *Temple of Poseidon*, Princeton 1971
Robinson = H. S. Robinson, "Roof Tiles of the Early Seventh Century B.C.," *AM* 99, 1984, pp. 55–66
Rostoker and Gebhard = W. Rostoker and E. Gebhard, "The Reproduction of Rooftiles for the Archaic Temple of Poseidon at Isthmia, Greece," *JFA* 8, 1981, pp. 211–227

[2] Broneer, *Isthmia* I. For an opposing view see R. Rhodes, "Early Corinthian Architecture and the Origins of the Doric Order," *AJA* 91, 1987, pp. 477–480 and "The Beginning of Monumental Architecture in the Corinthia," diss. University of North Carolina, 1984.

[3] Excavation reports by Broneer are in *Hesperia* 22, 1953, pp. 182–195; 24, 1955, pp. 110–141; 27, 1958, pp. 1–37; 28, 1959, pp. 298–343; 31, 1962, pp. 1–25.

[4] Broneer, *Isthmia* I, pp. 3, 12, 40.

[5] Broneer, *Isthmia* I, pp. 9–12.

[6] It is a testament to the foresight of Professor Broneer that all the fragments were saved, thus making this study possible more than thirty years after the excavation.

could be used to describe more precisely the size and configuration of the roof and would be an important step in settling several areas of disagreement. In addition, a number of new observations about the tiles and system of roofing have emerged since the completion of Broneer's publication. The most important of these studies, and the starting point for the methods used here to quantify the tiles, is the report by Henry S. Robinson on the roof of the similar 7th-century temple at Corinth.[7] The tiles and system of roofing at Corinth are nearly identical to those at Isthmia, and it was necessary to subject the collection at Isthmia to a similar analysis so that the two roofs could be compared.[8]

The Corinthian Archaic Roofs

In the first half of the 7th century the Corinthians developed a system of terracotta roof construction that is remarkable for its complexity. Six different types of moldmade tiles were manufactured for the various positions on a single roof.

At Isthmia, Broneer identified four types of tiles: combination pan/cover tiles, eaves tiles, ridge tiles, and hip tiles.[9] The combination pan/cover tiles and the eaves tiles are the most common types and were made in two varieties: one with the cover attached on the right and one with cover on the left (abbreviated hereafter as R-H and L-H, respectively).[10] Most important for the reconstruction of the overall shape of the roof is a series of hip tiles made to overlap the join of two sloping sides of the roof at the end of the building. Thus, at least one of the narrow ends of the temple was hipped rather than gabled, and Broneer believed both ends were hipped because no tiles were found that could have formed a raking cornice.[11] Ridge tiles are the least well preserved but their existence demonstrates that the building was rectangular rather than square.

A fifth type of tile was discovered at Corinth, the single cover tile, which prompted Robinson to restore each flank of the Corinth temple with R-H tiles on the right and L-H tiles on the left. The single cover tiles were used to cover the "seam" where R-H and L-H tiles abutted on each flank. This must have been the method of construction also at Isthmia. It would have allowed the covers of the pan/cover tiles to overlap the pans of the hip tiles at each corner.[12] No other explanation would readily account for the existence of two versions

[7] Robinson. Study of the tiles at Corinth has continued since 1939, with contributions from S. Weinberg, M. C. Roebuck, P. de Jong, I. Warner, D. Sanders, and C. Shumaker.

[8] An important study conducted by Elizabeth Gebhard and William Rostoker in 1979 replicated the combination pan/cover tiles of the Isthmia series and demonstrated the methods of their manufacture: Rostoker and Gebhard. Most recently Robin Rhodes has re-examined the remains of the Archaic temples at Corinth, Nemea, and Isthmia. He concluded, primarily on the basis of his study of the poros blocks, that these early temples had no colonnade and were covered by a "Chinese" roof: Rhodes, 1984 and 1987 (footnote 2 above).

[9] Broneer, *Isthmia* I, pp. 51–53.

[10] On the basis of a visual examination of the tiles, it appears as though there were separate left- and right-hand molds for the tiles. Rhodes assumes that the covers and pans were made separately and joined to make left- and right-hand versions. Rostoker and Gebhard, however, have replicated the tiles using a single mold for the complete tile, and this method seems likely to be correct because there is no evidence for a join between the pan and cover.

[11] Broneer, *Isthmia* I, p. 50.

[12] Robinson, p. 60.

of pan/cover and eaves tiles and the lack of special tiles to cover the transition to the hip tiles. Robinson also proposed that L-H and R-H tiles would have been used in equal numbers, joining each other at the center of each flank. It is not necessary, however, for the join to be precisely at the center of the flanks, and at each site more R-H than L-H tiles have been discovered.[13] No single cover tiles have yet been discovered at Isthmia, but this is not surprising considering that each tile was broken into more than thirty fragments on average, and such a tile could only be identified if its entire width were intact. At Corinth the presence of a nail hole at the upper end of the tiles aided in their identification.

The only type of tile not previously found at either site was the combination eaves-hip tile that sat at each corner of the roof. One of the important results of the present study was the discovery of one of these corner tiles.[14]

Structural or decorative differences between the series at Corinth and Isthmia are rather minor. At Corinth the pan/cover tiles include 24 black-glazed examples that formed a decorative pattern with the ordinary yellow pan/cover tiles. At Isthmia the eaves tiles show a small, raised triangular area in the center of each for decoration. Robinson considers this feature to be an advancement of technique beyond the Corinth roof and thus would date the temple at Isthmia slightly later.[15] Structurally the two roofs only differ in the presence or absence of nail holes for attaching the smallest of the tiles. At Isthmia nail holes are found in two ridge fragments;[16] at Corinth the single cover tiles had nail holes for attachment at their upper ends.

Sorting Procedure

Fragments of the Archaic roof tiles were discovered throughout the Isthmian sanctuary, but they came especially from two large deposits to the northwest and east of the Classical temple. While individual uninventoried fragments can no longer be assigned to precise excavation units, the greatest number came from the deep deposit northwest of the temple, and most of the remainder came from excavations directly east of the temple. The fragments were saved and stored, primarily in three locations: a huge pile just west of the Palaimonion, a much smaller pile further west, and another small pile near the Roman altar. The shape and fabric of the tiles are so distinctive that there is little likelihood that they can be confused with tiles of later periods.

All the fragments of tiles were sorted, including those previously inventoried. Then the fragments were counted and weighed and again examined for errors in identification. Thus, each tile was checked at least twice, and when a question arose all the sorters examined the fragment. For each type of tile, separate counts were made of each identifiable portion,

[13] At the narrow ends of the building an equal division between left and right is likely because of the triangular shape of the roof, but on the long sides the dividing line could have been placed below any of the horizontal ridge tiles.

[14] Thus there are no longer any important types missing. Along the ridge there would have been one single cover tile without a pan that would have covered the joint where right- and left-hand ridge tiles abutted: Robinson, p. 61. The prospect of ever identifying this particular tile seems impossibly remote.

[15] Robinson, p. 57.

[16] Broneer, *Isthmia* I, pp. 52–53: AT 21 (IT 373) and AT 22 (IT 228), illustrated in figure 62.

including L-H and R-H versions in the case of pan/cover and eaves tiles. Table A of Appendix A lists the counts, weights, and average weight per fragment from each type of tile.[17] Figure 1 in Appendix A shows the location of the most important identifiable fragments on the tiles. Also contained in Appendix A are observations made during the course of sorting.

Reliability of Counts

The circumstances of the destruction of the temple lead to the conclusion that the tile fragments recovered in the excavations at Isthmia are a random sample of the tiles from the original roof. After the temple was destroyed by fire the debris was dumped onto lower ground surrounding the temple or used as fill in the foundations of the Classical temple. No particular type of tile was selected for re-use or systematically removed from the debris. We also believe that our identification of the fragments was carried out in a meticulous and consistent manner. With the exception of ridge tiles, each type has at least one thick, unique, and easily identifiable portion that provides reliable and consistent counts.

The discovery of greater numbers of R-H tiles than L-H makes it appear at first that there is in fact a bias in the sample. Eaves and pan/cover tiles have fewer L-H than R-H fragments in a ratio of *ca.* 1:1.2. It can be demonstrated, however, that the unbalanced ratio between left and right counts can be attributed to other factors and has no effect on the reliability of our sample for computing the size of the roof.[18] The basic reliability of the sample is confirmed by the fact that the proportion of eaves to pan/cover tiles is the same for both left- and right-hand types. The largest count of the total number of ordinary pan/cover tiles is provided by fragments from the upper center of the R-H tiles (location A on Figure 1). From this figure the counts of R-H eaves tiles must be subtracted, leaving 307 R-H pan/covers.[19] Eaves-tile counts of 41 R-H pan/cover fragments make the proportion between eaves and pan/cover tiles 1:7.49. The calculation of this proportion for the L-H counts (256 ÷ 35) produces a nearly identical proportion, 1:7.31. Similarly, the proportion derived from adding left and right counts and dividing by eaves-tile counts [(307 + 256) ÷ 76] yields a proportion of 1:7.41. Regardless of how the sample is analyzed, the proportion of eaves to pan/cover tiles

[17] Some of the information we gathered is not used in the analysis that follows. The weights of the fragments, for example, did not prove to be useful in estimating the numbers of tiles. Rostoker and Gebhard (p. 212) have calculated that the average tile weighed about 30 kg. At Isthmia 378 tiles have been identified against a total calculated weight of 14,690 kg., indicating that about 28 percent of the weight has not been recovered.

[18] There are at least two possible reasons for the greater numbers of R-H than L-H tiles. First, as noted above (p. 253), greater numbers of R-H tiles may actually have been employed in the roof. Second, it is possible that there was an unequal spatial distribution of the R-H and L-H tiles after the destruction of the temple due to their position on the roof. Since the northwest corner of the temple stood nearest the large excavated portion of the north temenos deposit it should not be surprising to find slightly more R-H than L-H tiles. The west end of the north flank held only R-H tiles, the east half of the flank only L-H tiles. If fragments of the destroyed roof were pushed off the nearest ends of the Classical terrace, deposits directly to the east of the temple should represent equal portions of left and right, the northeast more lefts, the northwest more rights, etc. It should be noted that not all the deposits surrounding the temple have been excavated.

[19] Eaves and pan/cover tiles are identical at the upper end, and thus counts from the upper notch (location A, Fig. 1) are a combination of these two types of tiles.

falls within the narrow range from 1:7.3 to 1:7.5. This is a good indicator that the sample is random and that the identification procedures were accurate.[20]

Sixteen unique fragments of hip tiles (including the eaves/hip tile) were counted, and the proportion of hip tiles to pan/covers is 1:35.19 [(307 + 256) ÷ 16]. The proportion of hips to eaves is 1:4.75 [(41 + 35) ÷ 16].[21]

The analysis that follows assumes that all the different types of tiles are preserved to a similar degree. That is to say, for example, that if 25 percent of the pan/cover tiles are preserved, then approximately 25 percent of the hip and eaves tiles should also be preserved. The degree to which this is true determines the accuracy of the statistical reconstruction of the size of the roof. Although there is no way to determine with precision how closely the sample actually conforms to this pattern, the proportions cited above are an indicator that it does. The discussion and Table 2, below, present the statistical probability of this assumption. Appendix A provides all the data from the survey. Table 1 lists the total numbers of tiles based on the identification and counts of the best preserved portion of each type of tile.

TABLE 1: Summary of tiles represented by the most reliable counts

Type		Count
Right-hand pan/covers	(348–41)	307
Left-hand pan/covers	(291–35)	256
Right-hand eaves tiles		41
Left-hand eaves tiles		35
Hip tiles		15
Eaves/hip corner tile		1
Ridge tiles have unreliable counts		—
Total		655

THE SIZE OF THE ROOF ON THE ISTHMIA TEMPLE

The roof was composed of rigidly interlocking tiles whose combined dimensions were fixed. In contrast to terracotta-roof designs of later periods, where the amount of overlap

[20] On the other hand, counts of L-H and R-H fragments from the lower center join of pan/covers (location C, Fig. 1) are similar. It is, however, impossible to determine what percentage of the lower-edge fragments duplicate counts from the thicker join just above (location B, Fig. 1). The counts from the upper notch remain the most reliable statistic for our sample.

[21] Robinson (p. 59) reports the following tile counts at Corinth: 139 R-H yellow pan/covers, 24 R-H black-glazed pan/covers, 104 L-H pan/covers, and 8 hip tiles. The weight of all fragments is 4,295 kg. Robinson does not provide separate counts for the eaves tiles or the black-glazed L-H pan/cover tiles. At Corinth, where 8 hip-tile fragments were found, the proportion of hips to eaves and ordinary pan/covers is 1:40.75 as compared to a proportion at Isthmia of 1:43.5 using Robinson's formula of combined eaves and pan/cover counts. Robinson assumes that R-H and L-H tiles would have been equal in number and doubles the larger R-H counts for his sample size.

between separate pans and covers could vary greatly and there is no direct relationship between the tiles and the structure of the building, the size of this Archaic roof of the 7th century could only be increased in whole-tile increments. Since the roof was hipped, at least on one end, each side held the same number of horizontal rows of tiles.[22]

The significance of these features for this analysis is that the numbers of each type of tile can be determined precisely for a roof of any given size.[23] With each additional horizontal row of tiles, 4 hip tiles are added regardless of the length of the building, 8 eaves tiles are added plus 2 more for each increase of 1 tile to the flanks, and the pan/cover tiles increase at a far greater rate.[24]

Because the proportions of the numbers of one tile type to another vary so greatly for roofs of different sizes, the size of the original temple roof can be calculated on the basis of the proportions discovered in the sample of roof tiles at Isthmia.[25] The sample percentage of the three variables (pan/covers, eaves, and hip tiles) can only be approximately equal to each other for one size of roof. This roof would have had 11 horizontal rows of tiles with 1560 pan/cover tiles, 204 eaves tiles, and 44 hip tiles. Our sample preserves approximately 36 percent of each type of tile in that hypothetical roof: 563 pan/cover tiles represents 36 percent of 1560, 76 eaves tiles represents 37.2 percent of 204, and 16 hip tiles represents 36 percent of 44. The overall dimensions would have been approximately 12.5 × 47 meters.

The probability, however, that the sample is such a precise indicator is extremely unlikely. Because the sample count of hip tiles is small (16), any change in that number would affect the calculations. If, for example, we had discovered one additional hip tile, the indicated length would be nearly three meters shorter. Clearly this number is a poor indicator of the true length of the building. On the other hand, a difference of many hip tiles would be necessary to alter the width. Only if we were to find more than 20 hip tiles would a 12-row building be favored over an 11-row building. Similarly, the sample of hip tiles for a 10-row

[22] Each tile covered an area 0.57 × 0.57 m. The rigid system of interlocking connections between each tile fixed this dimension. The addition of a horizontal row of tiles to each flank would increase the width of the roof by about 1.14 m. (2 × 0.57 m.).

[23] The slope of the roof has little bearing on any of the calculations. For example, if the roof were 14 meters wide, eaves to eaves, each 3 meters of height between the eaves and ridge would require the addition of only 1 row of tiles. The calculations used throughout this analysis are presented in terms of the number of horizontal rows of tiles on each side from top to bottom, excluding the row of tiles at the ridge of the roof. For example, at the narrow end of a hipped roof with 10 rows of tiles there would be 20 tiles along the eaves. Of these 18 would be eaves tiles and there would be 1 corner eaves/hip tile at each end. The second row from the bottom would have 16 pan/cover tiles and 2 hip tiles, the third row 14 pan/cover tiles and 2 hip tiles, etc.

[24] Pan/cover tiles are calculated by the formula

$$8\,[(n-2)+(n-3)+(n-4)+\ (\ldots)]+2\,(n-1)$$

for each tile added to the length, where n = the number of horizontal rows.

[25] Table B of Appendix B lists numbers of each tile type for hypothetical roofs having 8 to 15 horizontal rows of tiles on each flank and proportions varying from 1:1.5 to 1:6. The reader can refer to these numbers to calculate the percentage of each type that the sample represents. The roof sizes used in the table were selected to cover the range of possible sizes of the building. While the width of the building could only be increased by adding additional horizontal rows as indicated in the table, the proportions of width to length can vary on an almost continuous scale.

TABLE 2: Possible roof sizes based on a probability of 5% or more*

Proportion of Width to Length	8	9	10	11	12	13	14
1:2.5						X	
1:3				X	X		
1:3.5			X	X	X		
1:4			X	X			
1:4.5			X	X			
1:5		X	X	X			
1:5.5		X	X				
1:6		X					

*The calculations were made using the number of pan/cover tiles in our sample to compute the expected count and then calculating the probability of our sample of eaves tiles and hip tiles separately, eliminating any roof that did not provide a 5% probability for both eaves and hips.

building should number 12 or 13. A change in one row of tiles only alters the width of the building by *ca.* 1.14 m.; thus the sample count is an excellent indicator of the width of the original building.

There are several mathematical formulas that can be used to compute the likelihood of obtaining a particular sample selected at random. One such formula (a "two-tailed" test) compares the sample to the expected mean.[26] Table 2 indicates all the possible roof sizes for which our sample has at least a 5 percent chance of occurring.

CONCLUSIONS

The stylobate dimensions were restored by Broneer as 14.018 × 40.05 m., or 44 × 125 ancient feet, but it should be noted that the dimensions of his restoration were not fixed by the remains. While there are blocks *in situ* that mark the outer foundations at the north and east sides of the temple, the southern and western limits of the building had been completely removed by later building activities.[27] Broneer restored these missing sides on the basis of rows of holes in the bedrock that he believed supported scaffolding during the construction and the relationship of these holes to the irregular remains of the floor. The positions of these few remaining blocks do, however, indicate that the minimum width of the temple must be at least *ca.* 11.5 m.

The 5% test admits the possibility that the roof could have held 13 rows of tiles but only at the outer range of the test and only within a narrow limit, with a proportion very close to

[26] The formula used is z = (r−np)/sqrt(npq), where r = number of tiles found, n = the original number of tiles in the building, p = probability of finding an example, and q = 1−p. Z represents the number of standard deviations away from the mean. A z-score greater than 1.64 indicates that the probability of occurring in a random sample is less than 5 percent. See D. H. Thomas, *Figuring Anthropology*, New York 1976, pp. 161–178 and 218–221, and H. M. Blalock, Jr., *Social Statistics*, New York 1972, pp. 177–188.

[27] Broneer, *Isthmia* I, p. 9.

1:2.5. At the other end of the range indicated in the test, roofs of 9 tiles all have a proportion of 1:5 or greater between the width and length of the building and are very unlikely on the basis of the blocks remaining *in situ*. For architectural reasons as well those roofs are very unlikely, having a length of over 50 meters. The significance of this statistical analysis is that the width of the temple of Poseidon can be shown with a high degree of certainty to be within the range 11.4 to 13.7 m. with a proportion of at least 1:3.

A building with 11 horizontal rows on each flank should be favored for other architectural reasons. Robin Rhodes has noted that each vertically ascending row of tiles was probably supported on its own rafter.[28] In his reconstruction the number of rafters would be symmetrical about a central member supporting the ridge pole, and therefore the number of rows of tiles would be odd rather than even.

The conclusions presented here do not radically contradict the reconstruction proposed by Broneer. On the contrary, they support several of its most important aspects. Both reconstructions suggest that the temple had a colonnade, for otherwise the cella would have been very broad (9 to 11 meters wide), which is very unlikely at that early date. In addition, the hip/eaves tile supports the conclusion there was a continuous slope from ridge to eaves.[29] The length of the temple cannot be determined with any precision, but it should be noted that Broneer's reconstruction of 125 ancient feet of 0.32 m. each is well within the limits established by the statistics. It is also noteworthy that the 11-row building indicated here would be very close in size to the late 7th-century Temple of Apollo at Thermon.[30]

It has also been suggested that the temple at Isthmia might have been hipped at one end only and that the other end could have held a gable as in later Doric buildings. If that were the case, our sample indicates that the roof would have held 10 rows of tiles and that the building would have had a ratio very close to 1:2.2 between the width and the length. This ratio would be highly unusual for a temple of 7th-century date. An additional argument against the hypothesis is the fact that the sample would comprise approximately 78 percent of such a roof. This is hardly likely considering that so much of the Archaic destruction deposits has not yet been excavated.

It is encouraging to discover that so much of the building has been recovered in the areas already excavated (*ca.* 36 percent). Not only does this imply an accurate count in our survey, but it suggests that a statistical study of the stone building blocks would provide additional information on the size and configuration of the cella and perhaps a definitive answer to the question of whether the building had a colonnade. Such a study is planned after the conclusion of excavation in 1989, as is an update on newly discovered tiles.

[28] Rhodes, 1984 (footnote 2 above), pp. 89–98.

[29] See the discussion of the eaves/hip tile in Appendix A.

[30] The 7th-century temple at Corinth has no remains *in situ*. The only possible way of restoring the size of that temple would be to conduct a statistical study similar to the one presented here. Although published data on the roof tiles is incomplete, the proportions of tile types listed by Robinson are very similar to those of the Isthmia temple.

APPENDIX A: DETAILS OF THE SURVEY PROCEDURES

PAN/COVER TILES (Fig. 1)

Counts were initially made of six different portions of both L-H and R-H pan/cover tiles: each of the four corners, the upper center of the tile where the pan joined the cover and a notch for the overlapping tile was made, and the lower center portion of the tile where the

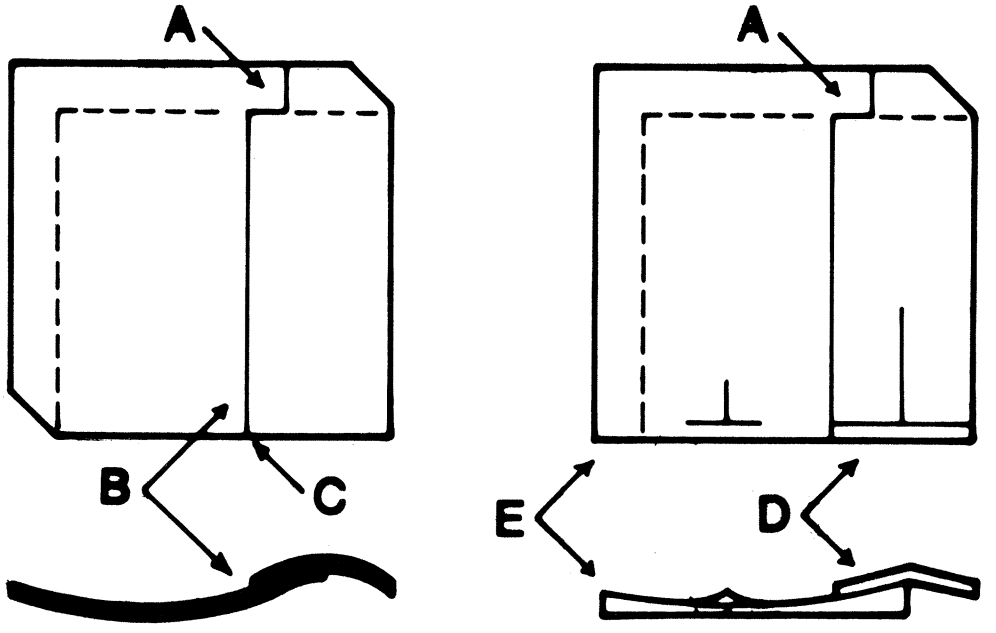

FIG. 1. The location of key identifiable fragments. Letters identify the fragments listed in Table A

pan and cover joined. The most reliable counts were obtained from the upper center join of pan and cover (A), where the tile is thickest and best preserved, and also where the roughly cut notch in the finished upper surface of the tile makes the orientation easily identifiable. This kind of fragment may, however, belong to either a pan/cover or an eaves tile, and the eaves-tile counts must be deducted from the total number to determine the number of pan/cover tiles represented in our sample.

Counts from the lower center portion of the tile were inflated. In our first count we separated both the small fragments that preserve only the lower finished edge that overlapped the tile beneath it (C) as well as fragments 0.08 to 0.10 m. further up the tile that preserve the rough cutting of the underside where the overlap ended (B). Because the overlap had broken from many of the tiles, there was a good possibility that many of these tiles

were counted twice. After completing our first sort those groups were resorted and counted again. Separate counts for each type of fragment are listed in Table A.[31]

TABLE A: Counts and weights of Isthmia Archaic roof tiles

	Number of fragments	Weight of all frags. in category (kg.)	Avg. wt. per frag. (kg.)
Right-hand types			
(A) Upper join of pan and cover	**348**	874.37	2.52
(B) Lower join of pan and cover	358	618.01	1.73
(C) Lower edge of join only*	110	59.86	0.54
(D) Lower right corner of eaves w/ cover	**41**	76.19	1.86
(E) Lower left corner of eaves	26	52.16	2.01
Left-hand types			
(A) Upper join of pan and cover	**291**	751.48	2.58
(B) Lower join of pan and cover	357	633.59	1.77
(C) Lower edge of join only*	124	57.60	0.46
(D) Lower left corner of eaves w/ cover	**35**	73.02	2.09
(E) Lower right corner of eaves	16	29.48	1.84
Fragments undistinguished by right or left			
Pan corners w/ bevels	248	290.69	1.17
Squared pan corners	289	655.78	2.27
Cover corners w/ bevels	376	274.84	0.73
Squared cover corners	199	149.66	0.75
Eaves peaks	33	19.95	0.60
Eaves covers	17	9.07	0.53
Hip-tile fragments			
Fragments with pan and cover	**15**	44.00	2.93
Lower points of cover	5	3.17	0.63
Eaves/hip corner tile	**1**	4.13	4.13
Ridge-tile fragments	15	10.83	0.72
*Misc. unsortable fragments***	13,529	10,114.29	0.75
Total	16,199	14,684.71	0.91

Numbers in bold face are the most significant counts and are used in the analysis above; see Table 1, p. 255 above. For letters, see Figure 1.

*This figure is duplicated in other counts. See discussion below.
**Fragments too small to be identified.

[31] Corner fragments were initially separated into L-H and R-H types on the basis of the observation that the upper top edge is rougher than the others. After completing approximately half the counts the corner fragments were no longer sorted by left and right because we reached the conclusion that this roughness could

EAVES TILES (Fig. 1)

Next to the ordinary pan/cover tiles, eaves tiles are the most abundant. As in the case of the pan/covers the combined thickness of cover and pan guarantees a high degree of preservation from a place in the tile that is easily identified. Where the peak of the cover is preserved (D) the thickness reaches a maximum of 0.095 to 0.10 m. Forty-one R-H and 35 L-H fragments from the lower ends of these tiles have been counted.

The center of the eaves tiles is distinguished by a "widow's peak"; only 33 of these have been found. Low counts on these fragments are clearly a result of the thinness of the tile at this point (0.03 to 0.045 m.) and the small size and friable nature of the peak itself.

From the lower corner without the cover 26 R-H and 16 L-H fragments were counted (E). Although this is a fairly thick portion of the tile, it is not preserved so well as the much thicker end with the cover. Similarly low counts were found for the corners of pans of ordinary pan/cover tiles.[32]

HIP TILES

Hip tiles are thickest (0.065 to 0.075 m.) at the upper corner of the cover, and this portion of the tile is easily identifiable. Corners of the pans, however, are indistinguishable from ordinary pan/cover corners, and the only other identifiable fragments are from the lower concave corner of the cover. Relatively few (5) hip fragments were found in the tile pile: most were identified when excavated and inventoried at that time.

Broneer lists only one fragment from the lower corner of the covers (IT 932), but one other was inventoried (IT 131). Three others were found in our search. Low counts on these cover fragments is a function of their thinness: 0.025 to 0.035 m. in the center and 0.04 to 0.045 m. along the sides.

RIDGE TILES

Ridge tiles were the most difficult to identify, and our counts surely underestimate them. These counts are low because ridge tiles have no especially thick and uniquely shaped portion that identifies them easily. The pans vary from 0.027 to 0.042 m. in thickness and the covers from 0.025 to 0.04 m. Small fragments of ridge tiles are thus easily confused with small fragments of pan/cover tiles.

Five fragments from ridge cover tiles have been identified, having no preserved portion of the pan or connection to the pan but sufficiently large to leave no doubt about their identification (IT 375, 938, 939, and 2 new fragments from the tile pile). Four others (IT 228, 945, and 2 new fragments) preserve a portion of the pan and cover, or the connection between them. Finally, 6 fragments of ridge pan tiles (IT 371, 373, 930, 946, and 2 new fragments) preserve a substantial portion of each side below the peak.[33]

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not be consistently observed and was an unreliable indicator of the orientation of the tile. These counts are listed in Table A under "Fragments undistinguished by right or left".

[32] It is also possible to confuse these eaves corner fragments with the corners of ordinary pan/cover tiles.

[33] It is not certain that fragments IT 874, 944, and 947, listed by Broneer in his catalogue (p. 53), are ridge tiles.

Two holes for nailing ridge tiles to the roof were found by Broneer in IT 228 and another example in IT 373. In IT 228 one of the holes contained some lead. We found no holes in the newly identified fragments or in any other fragment of any type, and this scarcity suggests that nails were used only occasionally, not as a regular feature of fixing the ridge tiles to the roof.

Eaves/Hip Tile

The survey found one of the four combination eaves-hip tiles that rested at the corners of the roof (Fig. 2). Its two joining fragments preserve about two-thirds of the cover that sat at the corner of the building and a small piece of the pan to one side.[34] The full width of the cover is preserved (0.241 m.), set back the normal distance (0.012 m.) from the edges of the tile. Broneer suggested a tile with a half-cover on each side meeting at the corner, and Robinson shows in his reconstruction (by C. Shumaker) a full (but flat) cover on each side. This new tile shows that each side had a full peaked cover. The top has a peak in the center at the intersection of three ridges that slope up the roof and along each of the adjacent eaves (Fig. 3).

The underside of this corner tile has a cutting (as do all the eaves tiles) sloping upward 0.068 m. from the outer edge and terminating at the back in a narrow vertical edge 0.011 m. high. This cutting defines the shape of the upper part of a horizontal member (probably wood) upon which the eaves sat. The width of this supporting member (*ca.* 0.055 m.), as well as the amount that the tile projected outward (*ca.* 0.015 m.), can be restored from the remains of a thin layer of mortar on the outer, bottom edge of the tile that was applied to both tile and wood after both were installed. This mortar was probably applied with a trowel, and some of the excess forms a small lip where the tile and wood joined. This feature can be observed on many eaves fragments in addition to this eaves/hip tile.

On a roof hipped at both ends each side has a row of eaves tiles along the flank of the building. This corner tile is the only tile of all those preserved that can be placed in its original orientation because the two bottom edges form a right angle that sat horizontally. Thus this is the only tile from which the slope of the roof can be measured, and the only tile that can provide good evidence on the question of whether the eaves were flat or sloped.[35]

[34] Preserved length and width, 0.28 × 0.17 m.; height, 0.115 m.; weight, 4.13 kg.

[35] The eaves of the roof would rest on a horizontal member regardless of whether they were flat (as on a "Chinese" roof) or sloped. Rhodes (1984 [footnote 2 above], pp. 89–90) has concluded that the Archaic temples at Corinth and Isthmia had "Chinese" roofs (flat eaves) on the basis of his discovery of the upper end of a flat-bottomed hip tile at Corinth that he would restore on the corner of the roof. The term "Chinese" roof is somewhat misleading because the Corinthian roofs had very little slope, and horizontal eaves (if they had existed) would have been barely noticeable unless they projected for a considerable distance. The hip tiles were made to overlap adjacent flanks of a sloping roof, and thus one might expect that they would have been bent along the underside of their entire length to fit easily over the corner. The evidence at Isthmia, however, raises doubts that this was the case. Such a bent (or angular) fragment should be easily identified, but no fragment from the upper end of a hip tile has ever been identified at Isthmia; only the lower, bent portions have ever been found. This lack must be explained by assuming that the upper corners of the pan portion of the tile are in fact not bent and are therefore indistinguishable from the corners of ordinary pan/cover tiles. The tile identified by Rhodes at Corinth preserves none of the lower end (i.e., the cover end) and is the only fragment from either

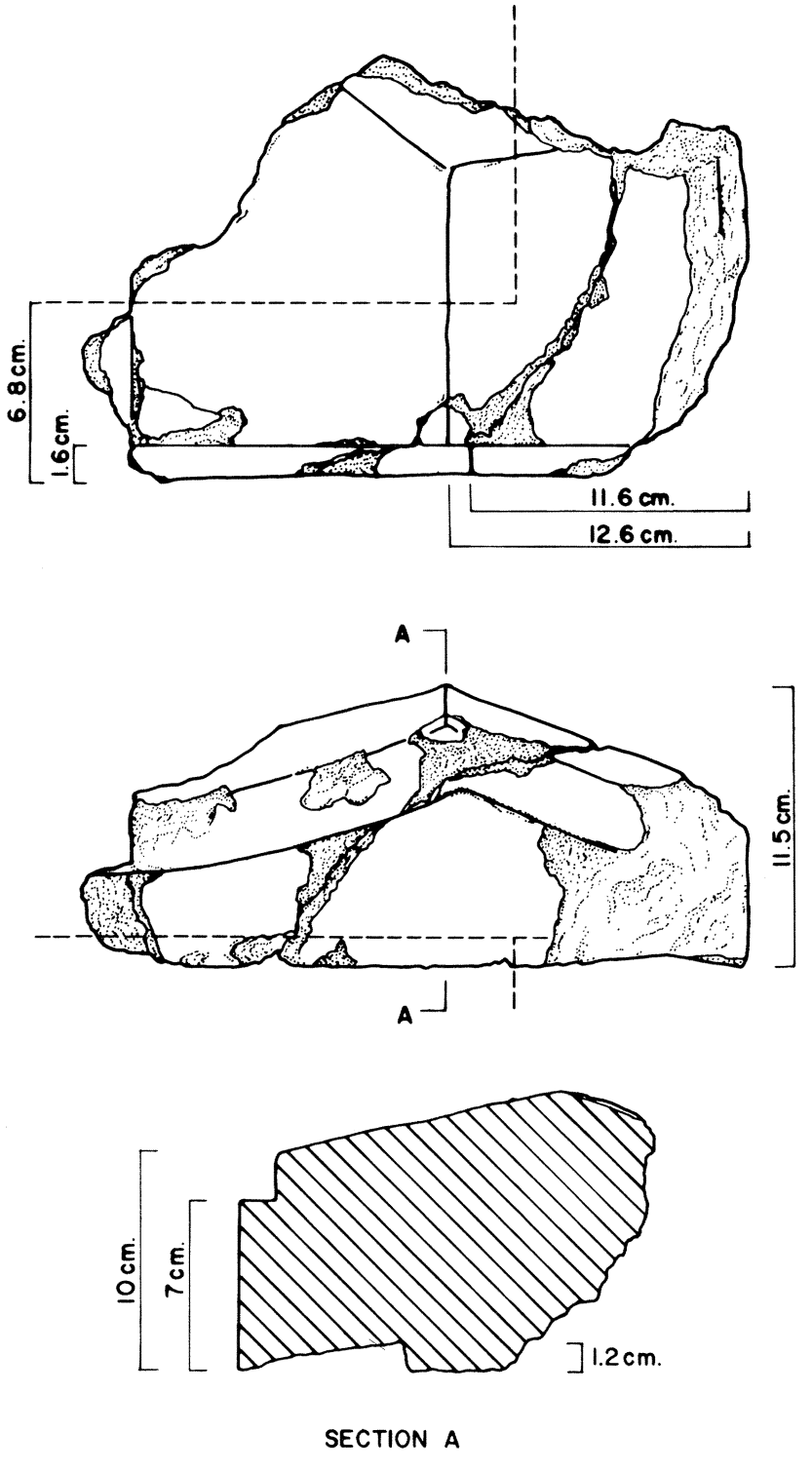

FIG. 2. Plan, elevation, and section of the corner eaves/hip tile. Drawing by Richard Rinaolo

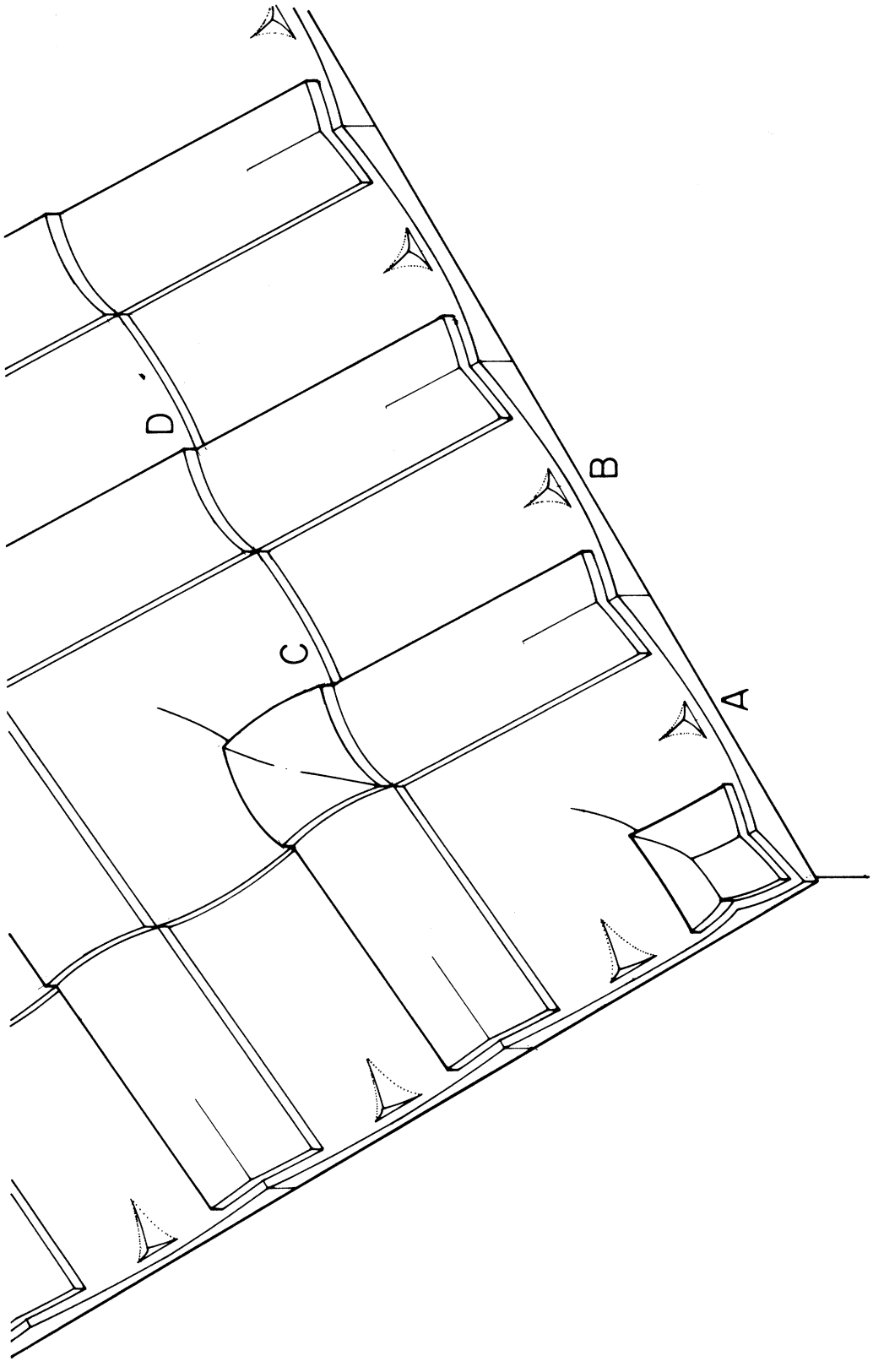

FIG. 3. Restored view of the corner of the roof: A) corner eaves/hip tile, B) eaves tile, C) hip tile, D) pan/cover tile

The slope of the roof is measured by adding the slope of the pan to the thickness of a typical pan/cover tile that would have overlapped it above. There is a small segment of the pan preserved for a length of 0.045 m. on one side of this eaves/hip tile. If the slope of this segment were extended for the full length of the tile (0.57 m.), it would rise 0.04–0.05 m., and the thickness of a pan/cover tile is *ca.* 0.05 m. Thus the total rise over 0.57 m. would be 0.09 to 0.10 m. It shows that the slope of the eaves was approximately 1:6. It seems likely that the eaves tiles rested directly upon the rafters and that the slope of the entire roof was *ca.* 1:6. The horizontal wooden member described above was probably attached to the lower ends of the rafters.

APPENDIX B: SUPPORT FOR THE STATISTICAL DISCUSSION

The roof of the temple restored by Broneer would have been wider than the one indicated by the statistical survey, with a proportion of about 1:2.9 and 13 horizontal rows of tiles on each flank. That 13-row building would have held approximately 1828 pan/cover tiles, 196 eaves tiles, and 52 hip tiles. Our sample of pan/cover tiles would represent 30.8 percent of the original roof (563 of 1828); the eaves sample would be 38.8 percent (76 of 196) and the hip tiles would be 30.8 percent (16 of 52).

To test the hypothesis that Broneer's reconstruction is correct we would need to make the following assumptions: 1) that the sample is random and 2) that the sample size is

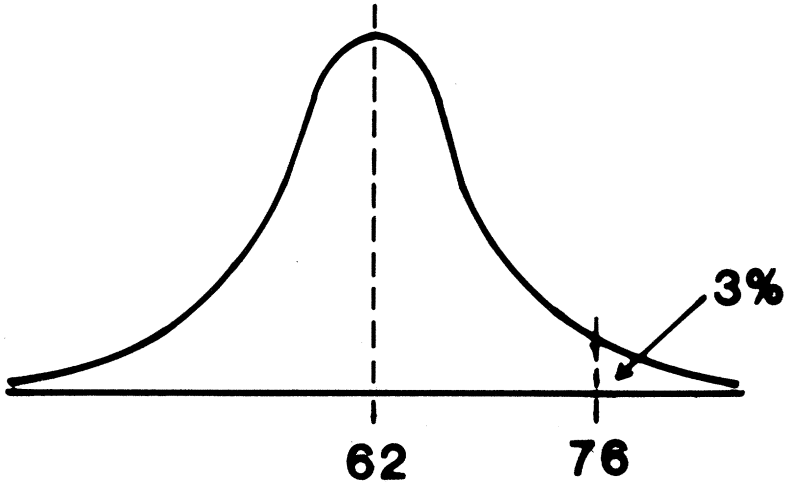

FIG. 4. Probability of obtaining a sample of 76 eaves tiles with an expected frequency of 62 eaves tiles

temple that has been identified as the upper end of a hip tile. The most complete hip tile at Isthmia is preserved only 16 cm. beyond the join of cover and pan, but even at that point the pan is almost flat on the underside. Under the cover portion (lower end) of all the hip tiles there is a deep bend or angle, but the hip tiles must typically have been flat at the upper end of the underside of the tile. In sum, since there is no evidence that any hip tiles were bent at the upper corner, the flat fragment of a hip tile at Corinth cannot be considered atypical and cannot be used to reconstruct flat eaves.

TABLE B: Numbers of tiles in various hypothetical roofs

Proportion of Width to Length	Horizontal Rows of Tiles 8	9	10	11	12	13	14	15
*Pan/cover tiles**								
1:1.5	280	368	468	580	704	840	988	1148
1:2	392	512	648	800	968	1152	1352	1568
1:2.5	504	656	828	1020	1232	1464	1716	1988
1:3	616	800	1008	1240	1496	1776	2080	2408
1:3.5	728	944	1188	1460	1760	2088	2444	2828
1:4	840	1088	1368	1680	2024	2400	2808	3248
1:4.5	952	1232	1548	1900	2288	2712	3172	3668
1:5	1064	1376	1728	2120	2552	3024	3536	4088
1:5.5	1176	1520	1908	2340	2816	3336	3900	4408
1:6	1288	1664	2088	2560	3080	3648	4264	4828
Eaves tiles								
1:1.5	72	82	92	102	112	122	132	142
1:2	88	100	112	124	136	148	160	172
1:2.5	104	118	132	146	160	174	188	202
1:3	120	136	152	168	184	200	216	232
1:3.5	136	154	172	190	208	226	244	262
1:4	152	172	192	212	232	252	272	292
1:4.5	168	190	212	234	256	278	300	322
1:5	184	208	232	256	280	304	328	352
1:5.5	200	226	252	278	304	330	356	382
1:6	216	244	272	300	328	356	384	412
Hip tiles	32	36	40	44	48	52	56	60

*Note that our sample size exceeds the numbers of tiles for hypothetical roofs having 8 rows and a proportion of 1:2.5 or less, 9 rows with a proportion of 1:2 or less, and 10–11 rows with a proportion of 1:1.5.

30.8 percent (using the pan/covers as a baseline measurement)[36] with an expected frequency for the eaves tiles of 62. We would accept Broneer's hypothesis if the observed frequency of eaves tiles (76) has a 5 percent or greater chance of occurring under these conditions.[37] Figure 4 shows that the probability of obtaining 76 eaves tiles under these conditions is less than 5 percent, and we must reject a roof of 13 horizontal rows.

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[36] We could also use the eaves-tile figure of 38.8 percent and test the hypothesis using the variation of the pan/cover counts against the expected frequency. In either case the result would be the same.

[37] In this example the z-score is 1.886 (see footnote 26 above). The standard deviation is 7.5.