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HELLENISTIC PRODUCTION OF TERRACOTTA ROOF TILES AMONG THE CERAMIC INDUSTRIES AT GORDION

Summary. *Recent excavation at the ancient city of Gordion in central western Turkey has recovered part of the collapsed terracotta tile roof of a large Hellenistic building built in the third century BC. The roofing system consisted of large rectangular pan tiles and long half-round cover tiles. The evidence from ethnographic and historical accounts of tile production, forming and finishing methods, and chemical composition determined by neutron activation analysis has yielded insights into the organization of this coarse-ware ceramic industry, its use of local resources, and its relationship to the other ceramic industries serving the city and the local economy.*

GORDION IN THE HELLENISTIC PERIOD

The site of Yassıhöyük, ancient Gordion, lies on the right bank of the Sakarya River, approximately 100 km south-west of Ankara in central western Turkey. The site consists of a 10–12 ha Citadel Mound, a 10–15 ha Lower Town enclosed by remnants of the city wall, and a 40–60 ha Outer Town on the opposite bank of the Sakarya River (Figure 1; for background see Voigt *et al*. 1997). The Yassıhöyük Stratigraphic Sequence (hereafter YHSS), based on the 1988–89 excavations directed by M.M. Voigt, provides the foundation for the following discussion. Voigt has defined ten archaeological phases, numbered downward from the present mound surface (YHSS 1–10). Table 1 provides information on the periods relevant here. Detailed discussions of the stratigraphy are available elsewhere (Voigt 1994; Voigt *et al*. 1997).

The Hellenistic period began with the Greek conquest of Anatolia under Alexander the Great in 334/33 BC (YHSS 3B). The Hellenistic (YHSS 3B-A) settlement at Gordion was concentrated on the Citadel Mound, potentially an area of 8–10 ha. Limited contemporary occupation or activity is found in the Lower and Outer Towns (Voigt *et al*. 1997, fig. 1). Beginning around 275 BC, the Galatians, a Celtic people, began moving into Anatolia and presumably soon reached Gordion (YHSS 3A; cf. Voigt *et al*. 1997; Mitchell 1993, 1–58).

Excavation in 1993–1997, in the north-western quadrant of the Citadel Mound overlooking the Sakarya River, exposed early Hellenistic (YHSS 3B) domestic structures. At the beginning of the later Hellenistic (YHSS 3A) phase, at approximately the time of the Galatians' arrival at Gordion, new domestic structures and a monumental building were built. The latter, designated

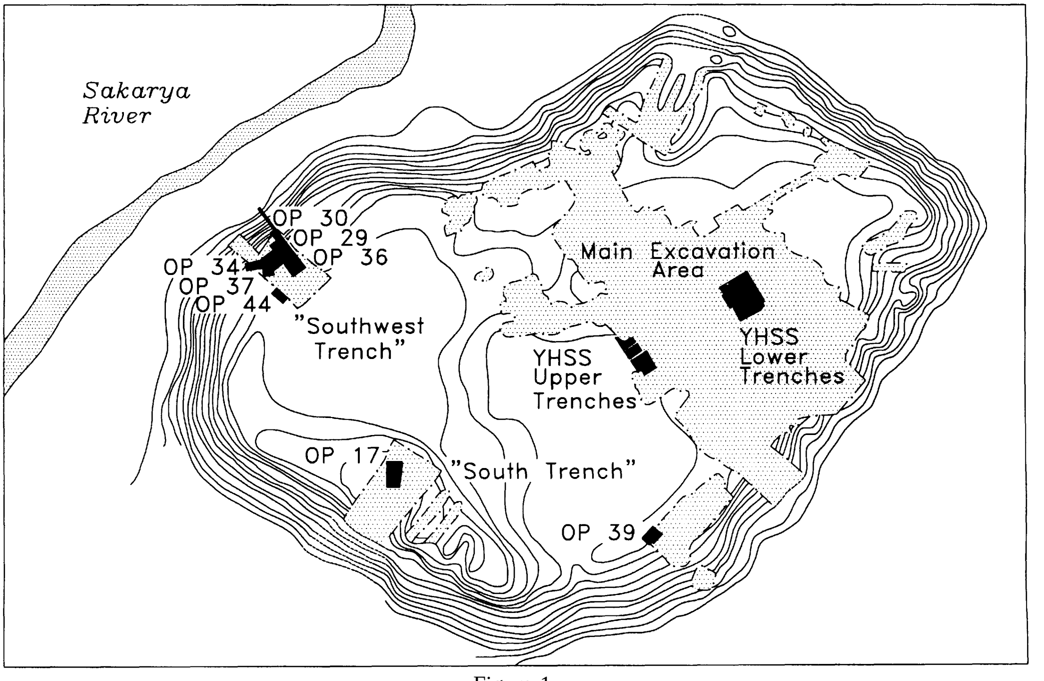

Figure 1
Gordion. Citadel mound with locations of trenches.

TABLE 1
The Yassıhöyük Stratigraphic Sequence (YHSS)

YHSS Phase	Period Name	Approximate Dates
2	Roman	1st century BC–3rd century AD
3A	Hellenistic (Galatian)	early 3rd century–189 BC
3B	Hellenistic	late 4th–early 3rd century BC
4	Late Phrygian (Persian)	550–330 BC
5	Middle Phrygian	700–550 BC

Building 1,[1] had ashlar wall socles approximately 1 m thick. A 16 m length of its northern and 5 m of its eastern walls were traces; 20 m^2 of the floor in its north-east corner was cleared (Figure 2). Its scale suggests that this was a public building, the first of this phase known at Gordion, one which formed the focus of the excavated area (Voigt *et al*. 1997, 12, fig. 17; Sams and Voigt in press). A blocked doorway and second floor suggest at least two phases of use (Voigt *et al*. 1997, fig. 17; Sams and Voigt in press). When the building burned, its terracotta tile roof had collapsed onto the floor. Although few artifacts other than tile fragments were found in the floor deposit, a painted bowl sherd (Voigt *et al*. 1997, 12, fig. 25) dates the final use of the building to the beginning of the second century BC. This destruction, identifiable across most of the settlement on the Citadel Mound, has been attributed to the Roman army commanded by

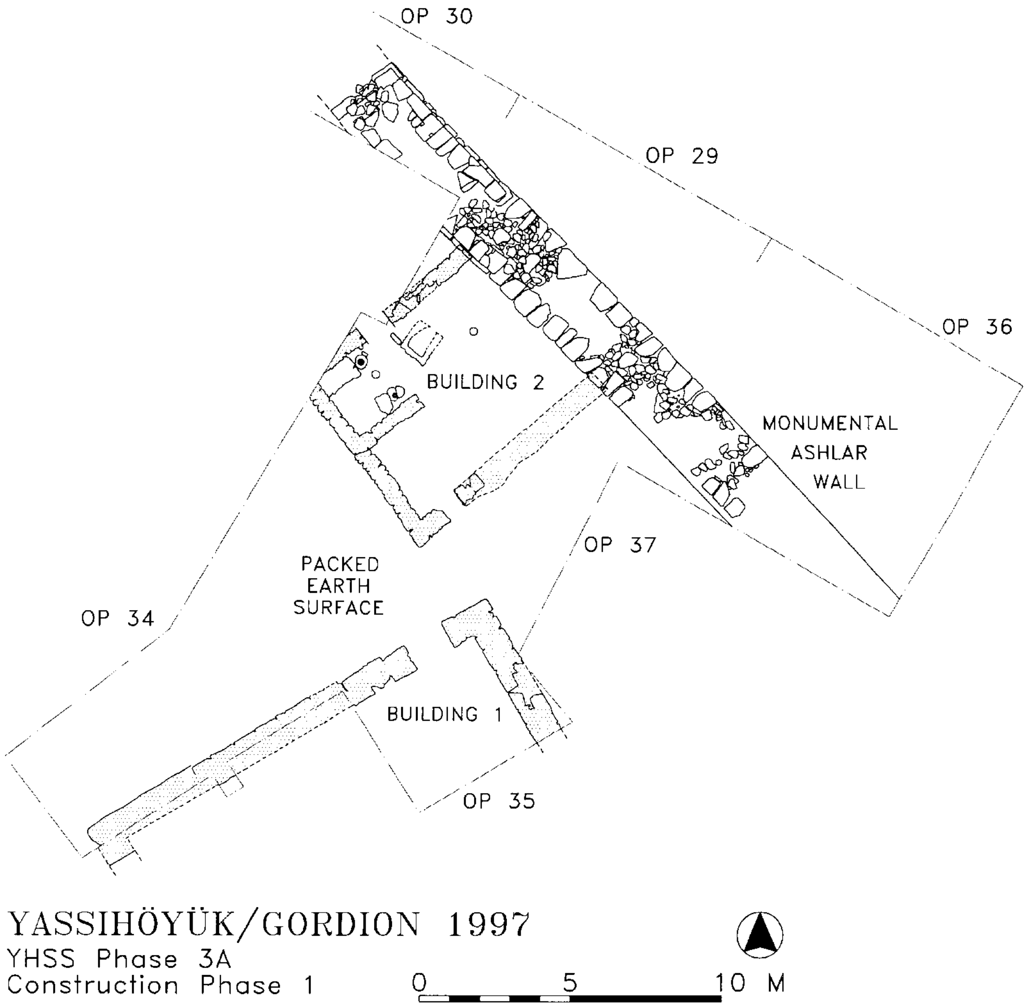

Figure 2
Plan of Building 1 in Operation 35 in the North-west Quadrant of the Citadel Mound.

Manlius Vulso, who reached Gordion in 189 BC (Voigt *et al*. 1997; Sams and Voigt in press; cf. Sams and Voigt 1990, 80 and figs. 4–9; DeVries 1990, 401–5).

THE TILES

Two types of tiles were found on the second floor of Building 1: large rectangular *pan tiles* and long half-round *cover tiles* (Figure 3). These form the two basic components of the roofing system. Decorative architectural terracottas, such as those used on tile-roofed buildings in earlier periods at Gordion (Glendenning 1995, 1996; see Winter 1990, 7–10 for glossary), were apparently not used on this building since none was found on either the floor or surfaces outside.

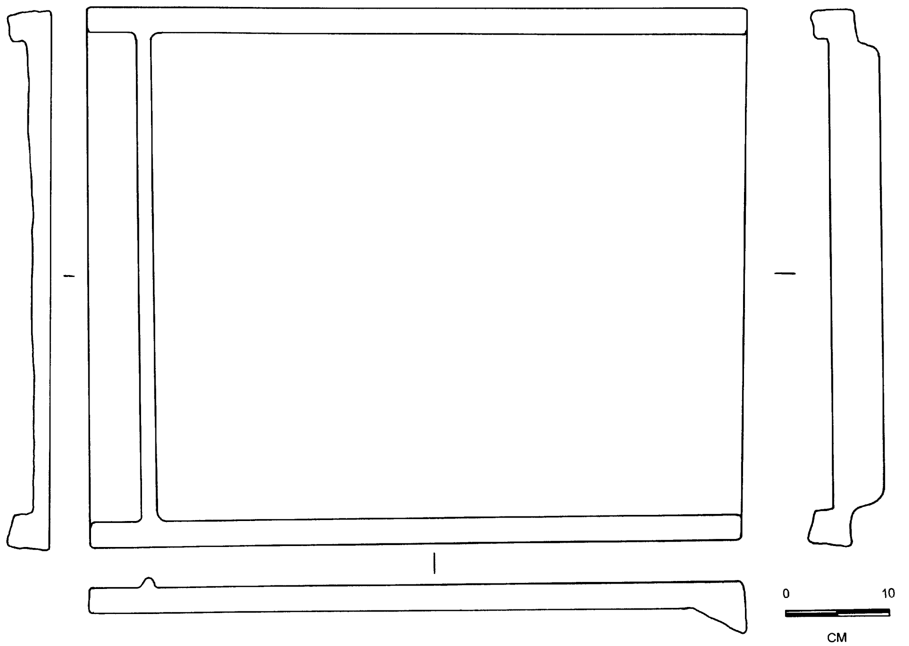

Figure 3
Drawing of pan tile (YH 47759).

Paste

Visual inspection suggests, and INAA results confirm (see below), that the same paste was used for both pan and cover tiles. The distinctive reddish-orange colour of the fabric (Munsell 5YR 6/6 'reddish yellow' [Munsell 1973]) is due to a relatively high mean concentration of iron (6.01%) and low calcium (2.54%) in the clay, when compared to most pottery paste groups defined thus far at Gordion (see below; also Henrickson and Blackman 1996, Appendix 2; unpublished analyses). Earlier architectural terracottas also tend to have reddish pastes with relatively high iron/low calcium values, with the colour often enhanced by red washes or slips (Glendenning 1995, 1996; unpublished INAA analyses). The temper consists of grit $\leq$0.5–1.0 mm in diameter or smaller, and includes quartz and carbonate particles. Although firing temperatures of these tiles have not been investigated directly, their resistance to crushing is comparable to that of pottery fired at $\pm$800ºC. The completely oxidized cores also indicate sustained, relatively high temperature firing. Both suggest use of a kiln.

The dimensions and features of both pan and cover tiles exhibit relatively small ranges of variation ($\leq$1 cm in overall dimensions), necessary if a serviceable roof were to result. Use of forms of jigs, documented in ethnographic accounts of traditional roof tile makers (Hampe and Winter 1965, *passim*), would both aid standardization and speed production.

Pan Tiles (Figure 3)

Description. Pan tiles are rectangular slabs of clay (63 $\times$ 50 cm, each dimension varying

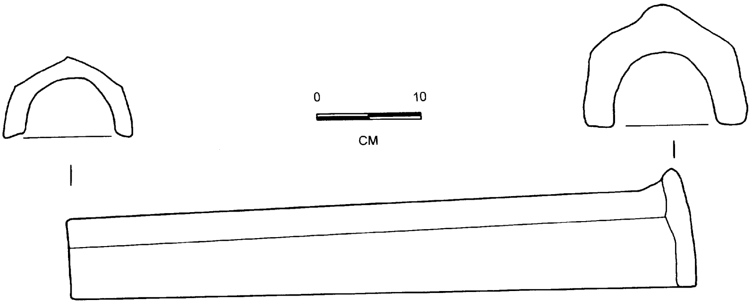

Figure 4
Drawing of cover tile (YH 47294).

by <1 cm, by ±2.0–2.5 cm thick).[2] The longer sides have a squared raised edge ±2 cm high and 2–3 cm) wide running from one end to the other. At one end, a rounded ridge runs from one side to the other 5–6 cm inside the end of the tile. The other end is open, but a heavy flange with a triangular cross-section is attached to its underside, with one side of the triangle extending the vertical surface of the end of the tile to a height of 4–5 cm. Parts of at least 14 pan tiles were recovered from the floor, based on counts of the upper right hand corner at the intersection of side and cross ridges.[3]

Forming and Finishing. Surface traces, patterns of breakage, and ethnographic accounts (Hampe and Winter 1965) make the basic forming sequence reasonably clear. Impressions on the undersides suggest that the basic slab was formed on the ground by pressing clay into a rectangular frame. Examination of surfaces of breaks within tile slabs indicates that the slab incorporated several lumps of clay. Just how the side ridges were formed remains unclear. Internal structure and texture rule out folding the edge upward or adding separate pieces of clay, and the interior angle shows no cutting scars. All of the surfaces, except the underside, were smoothed once the slab had hardened enough to handle. Surface markings indicate clearly that the rounded ridge across the upper end and the heavy triangular lower flange were late additions.

Cover Tiles (Figure 4)

Description. Cover tiles are elongated (±60 cm), with a U-shaped cross-section 7–11 cm high and 13–15 cm wide. Their ±1.5 cm wall thickness is less than that of the pan tiles. The interior height of the curve increases from ±6 cm at the plain end to ±8 cm at the elaborated end. The latter is enlarged, with three points which correspond to slight lengthwise faceting along the tile's outer surface. The outer surfaces are poorly smoothed. Parts of at least 17 pan tiles were recovered from the floor, based on counts of the lower right hand corner of the enlarged end.

Forming and Finishing. Curved to half-round tiles are a common traditional form. Ethnographic accounts show that a relatively thin slab of clay is rolled out within a frame, producing a standardized rectangle of clay which is then draped over a tapered rounded form (Hampe and Winter 1965, 27–30; abb. 17–18; taf. 12.4, 14.6, 15.1–6, 42.1–6, 48–9, 55.1–6). Adding clay and pinching yielded a

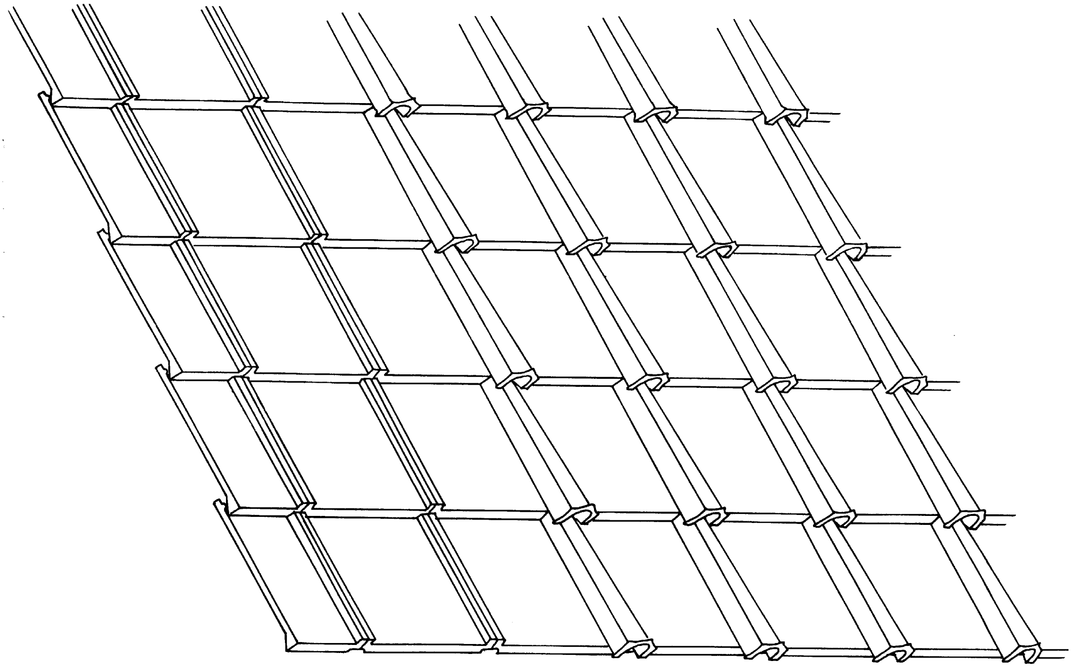

Figure 5
Reconstructed view of a portion of the tile roof, from left or right: a) cross-section showing overlapping of pan tiles; b) layout of pan tiles alone; and c) pan tiles with cover tiles added.

thickened end with points, which would help reinforce the curve of the clay so that the form could be withdrawn immediately and re-used (e.g., Hampe and Winter 1965, taf. 12.4). When installed, the elaborated end would provide a decorative touch.

THE TILE ROOF

Together, the pan and cover tiles yielded a weatherproof roofing system (Figure 5; cf. Glendenning 1995, 1996). The pan tiles were apparently held in place by sheer weight on a layer of clay on the sloping roof structure. No provision was made on their underside for holding them in place (e.g. knobs or other projections), nor are there holes for pegs or nails. Installation of pan tiles would proceed from eave to peak, with each row of pan tiles laid so that the lower flange would rest on the previous tile just below the cross-ridge (see Figure 5). This would assure that water would flow down the roof without getting under lower tiles.

Once the pan tiles had been laid, the cover tiles would cover the gap between adjacent pan tiles. The plain end of the cover tile would be butted against the lower edge of the next higher pan tile, with the larger elaborated end downslope (see Figure 5). Since the cover tiles are longer (±60 cm) than the distance between lower edges of pan tiles as installed (±55 cm), the next cover tile overlaps the lower by ±5 cm, providing a water-resistant cap. It is uncertain how the gap between the upper edges of pan tiles at the peak of the roof peak was protected, whether with regular cover tiles or larger ones specifically designed for use along the peak as in earlier periods (cf. Glendenning 1995, 1996; Winter 1990).

LOGISTICS: ESTIMATING TIME AND LABOUR

Estimating the gross time, labour, and resources involved in production of this tile roof helps define the craft and its artisans. Let us assume that Building 1 was 10×20 m overall; the wall lengths traced by excavation (5 m and 16 m) imply a roofed area well in excess of 80 m^2. Given the wall thickness of almost 1 m, a width of 10 m implies an interior free span of 8 m. Assuming a roof angle of around 30º (to promote rain runoff and cope with snow accumulation) and projecting eaves, the length of each slope from peak to eaves would be 6 m. The tiles would thus have to cover a total roof area of 240 m^2 (2×6 m $\times$ 20 m). Since each pan tile covers approximately 0.25 m^2 after overlapping, 960 would be required. Approximately the same number of cover tiles would be needed. For simplicity, it is assumed 1000 of each type are required.

Ethnography and records of pre- to early industrial tile (and brick) production typically document a small-scale rural craft conducted by groups of up to six workers, each member with particular tasks. The radius of distribution was generally <10–15 km (Peacock 1979, 6; Hampe and Winter 1965 *passim*; cf. Voyatzoglu 1974). Excavation and documentary data likewise suggest that in the ancient Mediterranean world tile production was a distinct craft, often associated with fired brick manufacture in the Roman world (Darvill and McWhirr 1984; McWhirr (ed.) 1979; McWhirr and Darvill 1978; Peacock 1979).

Four major phases of production activities may be distinguished, each requiring investments of time, labour, and other resources (cf. Greene 1979, fig. 7.3; McWhirr and Viner 1978, fig. 1):

1) acquisition and preparation of clay, and kiln building;
2) forming;
3) drying; and
4) firing (including gathering fuel).

Clay Acquisition/Preparation and Work Area (Table 2)

The logistics of transportation provide a strong argument for local production. The gross volume of clay required for the Building 1 tiles may be estimated (Table 2). Thus something in the order of 7–10 m^3 clay would be required. This large volume, and weight, presents a major transportation problem.[4] Since the location of the clay sources remains unknown (see below), the scale of effort required to move the clay must remain uncertain. Nonetheless, it would probably have been preferable to move the raw clay to a workshop near or within the settlement rather than to carry finished tiles

TABLE 2
Volume of Clay Required for Building 1 Roof Tiles

	Length	Width of slab	Thickness	Clay volume (each tile)	Clay volume (1000 tiles)
Pan tile	63 cm	50 cm	2.0–2.5 cm	6500–8200 cm^3	6.5–8.2 m^3
Cover tile	60 cm	20 cm	1.0–1.5 cm	1200–1800 cm^3	1.2–1.8 m^3
Total					7.7–10 m^3

to the building on the Citadel Mound from a more distant workshop. Whether carts or pack animals were used, a large number of trips would be required, conducted by either tile workers or others (cf. Voyatzoglu 1974). The potential usefulness of the Sakarya for transport in antiquity is uncertain, due to the effects of later alluviation on the river's regime (Marsh 1997).

The location of tile workshops of any period at Gordion remains unknown. Intensive surface survey has explored an appreciable area of the Outer Town, but no convincing evidence for a possible tile workshop, such as production debris or kilns, has yet been identified from surface evidence (Dickey and Sumner 1992; M. Voigt, pers. comm.). If the workshop were on the ancient valley floor east of the current river course, or along the city wall like at least one Middle Phrygian kiln (YHSS 5, 700–550 BC; see Johnston 1970, 180–93), the 4–6 m of post-Roman alluviation would have covered it (Marsh 1997).

Once transported to the workshop, the clay would have had to be prepared for use: broken up, wetted, tempered, and blended (e.g. Hampe and Winter 1965, abb. 16, taf. 14.6). Digging and moving the clay during the previous year and allowing it to weather over the winter (cf. Peacock 1979, 6; Greene 1979, 198, fig. 7.3; Carter 1979) would ease preparation. This would, however, require planning up to a year ahead. Clay preparation could also begin before the weather was appropriate for actual production, although ethnographic accounts suggest that clay for tile and pithoi (oversize storage jars) is prepared as needed (e.g., Voyatzoglu 1974, 19–20).

Excavation and ethnographic accounts show a consistent preference for kiln rather than clamp (open) firing of tile (Peacock 1979, 5–6; Hampe and Winter 1965, *passim*; Carter 1979, 198–200). The complete oxidation and hardness of the tile fabric suggest use of a kiln at Hellenistic Gordion (cf. Hampe and Winter 1965 *passim*). One would have to be built. This need not have been a large job; the structure is relatively simple and materials, such as mudbrick, readily available. Traditional tile and brick kilns tend to be round, with internal diameters of 2–3 m, firing chamber walls 2–3 m or more high, and either closed or open tops (Hampe and Winter 1965, abb. 20, 40, 41, 83, 84, 112, 114, 123). If production were infrequent, as argued below, a temporary structure would suffice for the project. Building could be done either prior to or parallel to early stages of tile production by members of the workshop.

Forming

Estimating production time must rely on epigraphic, ethnographic, and archaeological data. Ethnographic data suggests that a work gang of up to six men is reasonable (Peacock 1979, 6; cf. Voyatzoglu 1974). Ethnographic studies of present-day traditional workshops do not give daily production figures, but the photographs of work areas, methods of production, and numbers of tiles seen drying suggest that up to 200 cover tiles daily would be feasible, with one or two artisans directly involved in forming (Hampe and Winter 1965, taf. 14.6, 15.1–6, 42.1–6, 45, 48–9, 55.1, 55.3–6).[5] If a workday is taken to be eight hours, this implies 25 cover tiles per hour. While this might be feasible for cover tiles, figures for pan tiles might well have been lower, given their greater size and complexity of shape. Making six per hour would yield 50 per day. Graffiti on bricks produced by Roman military workshops explicitly document that one worker could make 200–220 per day (Spitzlberger 1968, 86–7, 104; abb. 10.6, 8). This ought to provide an upper limit for pan tile production figures, given the greater amount of forming the latter require. Therefore production estimates discussed below will concentrate on production rates ranging from 50–200 tiles daily. Note that even higher rates of production, up to 300 tiles per day, do not dramatically reduce the gross time requirements.

The final two production stages — drying and firing — may place more severe constraints on the pace of production.

Drying

The necessity for thorough drying before firing essentially restricts production to the dry summer months, June through August at Gordion. In some years even those months have almost weekly rain, often heavy (Devlet 1974).[6] In such years, production would have to be abandoned or drying sheds built, a considerable additional investment (e.g. Hampe and Winter 1965, taf. 12.4; Carter 1979, fig. 3.3; cf. Greene 1979, fig. 7.1–2; Peacock 1982, figs. 70–2). The pan tiles present more problems than do the covers. The large slab would have to be thoroughly dry before it might be moved. Its thickness would increase drying time, especially in comparison to cover tiles whose curved shape and thinner walls would aid air circulation and thus speed drying. In the Near East, mudbricks are usually allowed to dry for a week before being moved (personal observations by authors). A large work yard where tiles could be left to dry before firing would be required, one large enough for perhaps a week's production (50–200 m^2 depending on daily production). Thus space for drying suggests that the workshop would likely be on the edge of the settlement or beyond. Inevitably some tiles would be broken when handled before firing, lowering effective production figures.

Firing

Fuel, kiln capacity, and losses due to breakage and firing failures are primary considerations. Large amounts of fuel would have to be gathered, perhaps by junior members of the work gang, for the sustained firing times (cf. Voyatzoglu 1974, 22–3). Evidence from charcoal indicates that various sources of fuel were locally available (Miller 1993).

Pan tiles present the larger kiln firing problem, with their sheer size, thickness, and potential breakability. While round kilns are efficient for firing traditional tiles, which resemble the Gordion cover tiles, rectilinear ones might be better for the pan tiles. Both round and rectilinear Roman tile kilns are known (McWhirr 1979, table 1; Carter 1979, fig. 3.4; Peacock 1982, figs. 69–71). Most ethnographic photographs show tiles standing on end in kilns; this would facilitate heat circulation (Hampe and Winter 1965, taf. 32.4–5). Allowing for both the cumulative thickness resulting from the side ridges and opposing flange on the underside, and spacing between, each pan tile on end would occupy approximately 10 × 50 cm of kiln floor space. Thus no more than twenty would fit in each square metre of kiln floor area. Ethnographic (Hampe and Winter 1965, abb. 20, 40, 41, 83, 112, 114, 123) and Roman (McWhirr 1979, table 1; Peacock 1982, figs. 69–71) kilns suggest a floor area of 3–6 m^2, allowing perhaps 60–100 pan tiles per layer. While multiple layers would increase firing

TABLE 3
Length of Production Cycle

Activity	Time
Forming	1 day
Drying	7 days
Firing	2 days
Total	10 days

TABLE 4
Tile Production Time Estimates

Daily production (tiles)	Total forming days	Activities on Days into Production			Total Working Days
		Forming	Drying	Firing	
50	20 days	Days 1–20	Days 2–27	Days 8–29	29
100	10 days	Days 1–10	Days 2–17	Days 8–19	19
150	7.5 days	Days 1–7	Days 2–14	Days 8–16	16
200	5 days	Days 1–5	Days 2–12	Days 8–14	14
250	4 days	Days 1–4	Days 2–11	Days 8–13	13
300	3.3 days	Days 1–4	Days 2–11	Days 8–13	13

capacity (e.g. Hampe and Winter 1965, taf. 32.4, abb. 20), fewer than 40 pan tiles could be fired in each cubic metre of kiln volume even with two layers. Cover tiles, however, would each require no more than a 10 × 10 cm area of the kiln floor, allowing at lease 100 per square metre of kiln floor, five times the number of pan tiles (cf. Hampe and Winter 1965, taf. 32.4–5).

Whatever its capacity, a kiln could not be fired more frequently than every other day. Loading would begin each firing cycle. Firing would then start with several hours at relatively low initial temperatures to drive off the remainder of the moisture, in order to avoid later cracking or exploding. Once reached, firing temperature was maintained long enough to oxidize the entire thickness of the tile. Slow cooling would then be necessary to avoid cracking. Finally, the kiln could be unloaded and reloaded. The complete firing cycle would require at least two days (Hampe and Winter 1965; cf. Voyatzoglu 1974, 22–3). In order to keep pace with ongoing production, a kiln would have to be large enough to handle at least two days' production. Thus, even if daily production were only 50 pan tiles, firing every second day would require a kiln capacity of at least 3 m^3.

Finally, not every tile fired will be usable. Forming and firing defects, compounded by repeated handling, would inevitably result in losses due to breakage and failure at all stages of production. The limited ethnographic data available suggests that at least a 10% loss rate might be expected during firing alone (Rice 1987, 173–4, table 6.1 [pottery not tile]).

Production Cycle Duration (Tables 3–4)

How long might it take to produce the 1000 pan and cover tiles? Treating the tiles made in a single working day as a group, the following elapsed times may be suggested (Table 3). The production cycle for a single day's production would thus be in the order of 10 days, from forming through removal from the kiln.

Thus, eight days after the first tiles were made, firing could begin on alternate days, but drying time would mean that a backlog would always await firing, as long as forming continued. Drying would have to continue until seven days after forming had ended. The final firing could then be completed two days after that. Daily production at rates of 100 or more pan tiles might present firing problems. Two days' production at 100 tiles per day would require a kiln with 6 m^3 capacity. At such rates the unfired backlog could become a problem, but less than daily production could ease matters. Table 4 shows that 14–29 days would be needed to produce either 1000 pan or cover tiles, depending on daily rates ranging from 50–200 tiles. In sum, an estimated 33–43 working days would be required for the forming and firing of all of the tile required.

Adding on an arbitrary 10 days for clay preparation, kiln construction, and other activities, an estimate of 43–53 working days results (with daily production of 50–100 pan tiles or 200 cover tiles). Production is unlikely to have been continuous day after day from start to finish. Allowing for time off (e.g. bad weather, 'weekends', or 'holy days'), the estimated total working days translate to two to three months. Given that the reasonable working season is approximately three months (June–August), producing the tile for the Building 1 roof would require most if not all of the time available in one year.

Climate constraints, the durability of the tiles, and the limited demand, all indicate that this must have been a part-time seasonal craft. A tile 'workshop' or production gang could furnish the tile to roof perhaps one structure the size of Building 1 in a year. Given the limited number of Hellenistic buildings with tile roofs at Gordion, it is not clear whether such part-time work even would be available yearly. Yet the quality of the tiles and the level of expertise evident suggests ongoing experience. How could such expertise be maintained?

The traditional organization of pithos production on Crete provides an attractive model. The pithos makers were itinerant specialists, travelling each summer, as crews of six men, from their village of Thrapsano to work for weeks or an entire production season in different regions, using local materials known to them from previous sojourns. The production groups consisted of two potters, a kiln-man, a clay preparer, a wood-cutter, and a carrier (Voyatzoglu 1974, 18–19; cf. Blitzer 1990). A similar division of labour would be appropriate for a tile work group. Tile makers could have served a region rather than just a single town. Peacock (1979, 6–7) notes 'considerable mobility' among tile and brick makers eighteenth–nineteenth century Europe, moving from one small workshop to another. This model would allow the maintenance of competence, with a single work group serving a region rather than a single settlement. It is also easier to see tile makers travelling longer distances than their products.[7]

TILE PRODUCTION AND THE STATE ELITE

Tile roofs and decorative architectural terracottas seem to have been used primarily, if not exclusively, on elite or public buildings at Gordion in the first millennium BC (Glendenning 1995, 1996). Domestic structures typically had a roof consisting of a wooden beam framework covered with a layer of rushes and sealed with mudplaster, as in the Hellenistic houses excavated across the Citadel Mound (Sams and Voigt 1991; DeVries 1990, 401). Such roofs had been used on large elite ceremonial and service buildings during the Early Phrygian period (YHSS 6A [*c*. 700 BC]; Voigt 1994, 272–3, pls. 25.5, 26.5.1–2). Even into recent decades, the typical roof in the present-day village of Yassıhöyük was a layer of mud plaster over rushes; some houses in the village today still have such roofs. Tile roofs on houses have become common in the village only since the 1960s (cf. METU 1965, photos *passim*; personal observation).

Buildings with tile roofs represent a considerable investment, of which the labour and materials involved in production of the tile is only part. A number of other crafts were required. The Hellenistic, and earlier, tiles are considerably thicker and larger than modern tiles (the latter perhaps 20×25 cm;

cf. Glendenning 1995, 1996; Winter 1990). The weight per unit roof area must have been considerably greater than today.[8] A strong roof structure founded on heavy walls with good foundations would be necessary. The wall socles are ashlar masonry approximately 1 m thick and 50–70 cm high. Unless blocks were recycled from other buildings, stone cutters would have to cut the ashlar blocks, and stone masons lay the stone foundations and wall socles. Mudbrick makers and masons, usually specialists in villages would have to make and lay up the rest of the wall height. The roof structure would require experienced carpenters. The cumulative cost suggests elite/state sponsorship of the construction. This then raises the problem of the relationship of the tile makers to the state.

In the absence of evidence for interior columns or posts, the roof structure of Building 1 would have had to span at least 7–8 m. This would require heavy timbers, cut from sizeable trees which would have been rare and thus expensive (cf. Liebhart 1988, 102–31). Logs from the late eighth century BC Midas Mound tomb chamber at Gordion demonstrate that such trees took centuries to grow in the local environment; other dendrochronological dates document reuse of structure timbers sometimes cut even centuries earlier (Kuniholm 1988). Many if not most large local trees useful as structural timber were probably cut centuries earlier for the ambitious Early and Middle Phrygian construction programmes in the elite quarter of the Citadel Mound (950–700 BC and 700–550 BC; see DeVries 1990, 373–97, and especially figures 4, 7, 26; Miller 1993). As a result, just the structural timber needed to support a tile roof would be a major investment. The walls could have been built and a temporary roof of mudplaster over rushes installed until the tiles were completed; this would have been the bedding necessary for the tiles in any event. Only the elite are likely to have had the resources to afford such construction projects.

The tile makers provided a useful and highly visible product, but one with low inherent value and for which demand was infrequent. While only the elite may have had the resources to erect buildings with tile roofs, this does not mean that the state controlled the craft and artisans. Ethnographic evidence consistently shows that tile production, as with most basic ceramic crafts, is the province of relatively poor, independent specialists (cf. Hampe and Winter 1965; Güner 1988; Rye and Evans 1976; Sarawati and Behura 1966). In ancient Mesopotamia, mass-production of basic pottery types seems to have been an independent craft, with potters perhaps obligated to provide specific numbers of vessels yearly to state institutions (Potts 1997, 150–62; Stein and Blackman 1993). Attached or elite-controlled crafts tend to concentrate on smaller, high value items or trade goods, while lower-valued commodities tend to be produced by independent artisans (Sinopoli 1988; Costin 1991; Stein and Blackman 1993).

SAMPLE CHOICE, PREPARATION, AND STATISTICAL ANALYSIS

In order to provide a new perspective on tile production and its relationship to other ceramic crafts at Gordion, chemical analysis by means of instrumental neutron activation analysis (INAA) was undertaken. Samples were taken from the corner fragments used as the basis for the count of minimum number present in order to assure that each came from a separate tile. This yielded 13 samples from pan tiles and 16 from cover tiles.[9] Samples were prepared by first burring off all surfaces, then crushing the sample to a fine powder with a ceramic mortar and pestle. In order to mitigate the possible effects of coarse temper heterogeneity, a much larger sample volume than actually needed for analysis was prepared. At least a cubic cm chunk from each tile was crushed, yielding ≥6 gm of powdered sample. Of this a 100 ± 5 mg subsample (<2%) was taken for analysis. INAA chemical analysis was carried out at the Smithsonian Institution's Center for Materials Research and Education INAA facility, using the 20 MW NBS Research Reactor at the National Institute of Standards and technology. The analytical protocol was a modification of that outlined by Blackman (1984).

Initial multivariate statistical analysis of the chemical data for all of the 29 tiles samples together, using Mahalanobis distance and Hotellings T^2 statistics (Sayre 1975), indicated a degree of homogeneity comparable to those of ceramic and/or clay groups previously defined for earlier periods at Gordion (see Table 5 and Henrickson and Blackman 1996, Appendix 2 for means and coefficients of variation).[10] This mean tile chemical composition was then compared to those groups; no statistically significant connection was found. The entire database of all individual Gordion pottery samples (N = 644) from periods ranging from Middle Bronze (YHSS 10, *c*. 1600–1500 BC) through Hellenistic (YHSS 3, *c*. 330–189 BC) was then tested against the mean tile composition. Not one ceramic sample had a statistically significant probability of belonging to the tile chemical composition group. Finally, the mean tile composition was tested against the database of clay samples collected from the area of Gordion, mostly from the Sakarya River drainage, each fired at 650ºC and 850ºC. These temperatures bracket the general range of firing temperatures used at Gordion in the first millennium BC pottery industry and for tiles. Not a single clay sample had a statistically significant relationship to the mean tile group composition (Table 5).

Looking at the 29 tile samples alone, bivariate plots using either pairs of elements or principal components distinguished three groups, which were tested for statistical significance using Mahalanobis distance measure and validated (Figure 6).[11] One comprised all 13 pan tile samples, the other two subsumed the cover tiles (6 in Group CT-A, 10 in Group CT-B; see Figure 6 and Table 5). The differences among groups are not simply the result of adding varied amounts of mineral temper. While all of the tile composition groups are essentially low in calcium and high in iron, each has distinctive relative abundances of rubidium, chromium, and rare earth elements (Table 5). Thus three distinct clay sources were being used, although those for the pan tile and CT-B pastes may be related. None of the clays came from the Sakarya River, whose sediments are calcareous and relatively low in iron (e.g. Table 5: Groups B3, Clay1, Clay2).

The tiles must have been made using clay sources not as yet identified or sampled, ones not so far known to have been exploited by the other ceramic industries from the Middle Bronze Age through Hellenistic times (1600–189 BC). Specific working properties of clay needed for coarse ware production, here large slabs, and the apparent long-standing preference for a strongly reddish tile fabric might dictate choice of a different clay source from those favoured by the contemporary pottery industries which concentrated on reduction-fired (grey) common wares and buff finer wares. This dichotomy suggests an isolation of tile production from the other ceramic industries.

The heterogeneity among the tile pastes themselves is noteworthy given that components of a single tile roof might be

TABLE 5
Chemical Group Means and Coefficients of Variations

	Na %	K %	Ca %	Sc ppm	Cr ppm	Fe %	Co ppm	Zn ppm	Rb ppm	Cs ppm	Ba ppm	La ppm	Ce ppm	Nd ppm	Sm ppm	Eu ppm	Tb ppm	Yb ppm	Lu ppm	Hf ppm	Ta ppm	Th ppm
Building 1 (Operation 35): All Hellenistic Roof Tiles (N = 29)																						
Mean	1.152	1.882	2.54	26.7	230.5	6.01	31.0	80.3	115.1	5.92	363.	36.5	64.5	24.2	6.24	1.51	0.963	3.46	0.491	4.75	0.897	9.66
c.v.	9.7	16.8	17.4	10.7	12.8	7.4	10.0	24.1	26.7	8.7	24.9	11.3	13.0	32.5	7.8	6.1	13.6	11.4	13.5	7.9	9.5	17.4
Building 1 (Operation 35): Hellenistic Pan Tiles (N = 13)																						
Mean	1.129	2.098	2.46	27.0	233.8	6.03	31.7	71.7	142.6	5.75	361.	35.7	60.6	19.4	6.12	1.49	0.976	3.40	0.518	4.75	0.919	9.49
c.v.	7.8	13.8	12.5	5.87	6.0	4.0	5.4	25.7	16.3	9.0	27.8	5.8	5.8	38.7	2.9	3.1	14.4	9.8	11.6	5.2	9.3	7.3
Building 1 (Operation 35): Hellenistic Cover Tiles [Group CT-A] (N = 6)																						
Mean	1.023	2.846	1.95	22.5	182.8	5.37	26.3	87.7	105.0	6.40	440.	41.5	75.4	30.0	6.53	1.45	0.942	3.32	0.456	5.23	0.931	11.91
c.v.	3.1	12.5	28.3	4.3	7.6	4.6	6.5	23.2	6.6	6.7	15.4	11.7	14.5	21.2	8.7	4.8	7.0	7.6	12.9	5.3	9.2	16.6
Building 1 (Operation 35): Hellenistic Cover Tiles [Group CT-B] (N = 10)																						
Mean	1.258	1.623	2.83	28.9	254.9	6.36	32.9	87.0	85.5	5.85	318.	34.4	63.3	26.8	6.21	1.56	0.959	3.62	0.476	4.46	0.848	8.52
c.v.	4.8	10.1	11.4	7.3	4.8	4.8	6.7	19.5	9.6	6.9	17.4	9.8	9.2	20.6	10.7	7.9	16.6	13.8	14.6	5.8	7.9	12.6
Chemical Group B-1 (N = 7 [includes 1 clay sample])																						
Mean	1.33	2.57	6.12	12.8	155.	4.17	19.4	91.3	107.	7.12	536.	31.5	55.5	24.0	4.35	1.07	0.635	1.76	0.260	4.32	0.861	9.41
c.v.	15.9	12.4	25.0	7.9	17.8	5.7	12.1	7.5	12.7	9.5	21.3	5.8	7.9	10.5	8.9	7.1	12.0	14.6	24.1	16.2	12.3	9.0
Chemical Group B-3 (N = 78 [includes 58 clay samples])																						
Mean	0.838	2.20	13.9	14.2	272.	4.03	22.3	83.7	98.0	11.6	367.	28.5	49.9	20.8	4.19	0.970	0.610	1.95	0.281	3.67	0.936	8.27
c.v.	28.4	17.7	24.2	18.0	17.5	16.3	16.3	19.2	13.4	21.8	21.8	7.2	7.7	17.1	8.7	10.3	14.5	10.1	15.0	12.2	10.4	11.9
Chemical Group C-1 (N = 7 [includes 4 clay samples])																						
Mean	0.635	1.93	15.8	11.6	281.	3.30	19.3	75.5	81.2	8.91	380.	22.3	39.1	15.9	3.27	0.740	0.492	1.71	0.235	2.67	0.735	7.25
c.v.	20.7	16.9	16.7	11.2	25.5	11.0	11.9	10.3	12.1	12.2	17.6	7.6	8.0	15.9	5.0	7.6	15.9	20.5	28.7	11.4	11.3	7.9
Chemical Group Clay 1 (N = 25 [all clay])																						
Mean	1.14	2.45	8.59	16.5	192.	5.12	27.0	85.1	93.5	8.36	411.	33.5	59.2	24.8	5.05	1.26	0.724	2.25	0.323	3.89	1.10	9.10
c.v.	33.0	21.4	20.6	6.8	9.3	6.2	6.0	10.2	15.0	15.7	16.2	4.7	5.1	16.1	5.1	5.2	13.0	5.0	13.7	6.3	7.9	8.3
Chemical Group Clay 2 (N = 13 [all clay])																						
Mean	0.742	1.81	21.2	11.1	230.	3.11	17.5	67.1	99.3	18.3	370.	25.1	43.6	18.5	3.71	0.810	0.521	1.74	0.265	3.24	0.865	8.80
c.v.	30.3	22.5	34.5	10.8	22.8	11.5	13.7	15.9	13.6	13.3	15.2	9.4	9.0	17.3	11.4	9.5	20.3	13.2	10.6	16.7	12.7	12.0

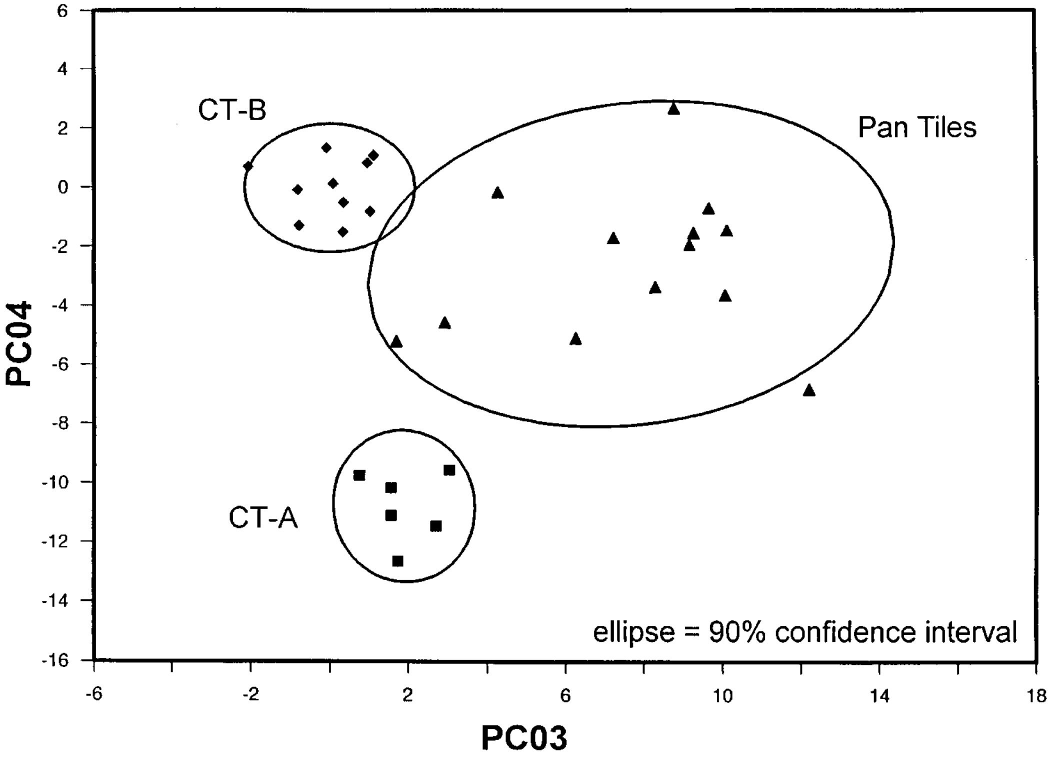

Figure 6
Scatter plot showing separation of pan (PAN) and cover tile (CT-A and CT-B) groups based on principal components.

expected to represent production during a limited period of time, probably by a single workshop. On a long-used building such as this one, however, roof repair might account for at least one separate group. The blocked doorway and associated second floor suggests at least one major renovation of the building. Cover tiles are more likely to break than pan tiles, and one cover tile composition (CT-B) is more closely related to that of the pan tiles than the other.

TILE MAKING AMONG THE CERAMIC CRAFTS AT HELLENISTIC GORDION

Tile making was not an isolated craft. Indeed, its products could only be used in combination with work done by other crafts in building construction. Nonetheless, it stood in isolation from other ceramic crafts. Although pottery generally draws the great majority of attention, and represents by far the greatest volume of production, other classes of ceramic artifacts were important in the ancient world. The more specialized ceramic crafts at Gordion (pithoi, moulded figurines, and tile), seem to have been independent of one another through much of the first millennium BC, based on criteria such as clay sources exploited or repertoires or forming and finishing methods. Each served distinct and only partially overlapping 'market segments' of the urban population. Various potters produced fine and common wares, pithoi, and probably figurines for use by both the elite and general population. Architectural terracottas seem to be the only ceramic items made for use only by the elite.

Specialist potters seem to have produced most of the pottery assemblage at first millennium BC Gordion (Henrickson 1993, 1994, 1995). Paste composition groups tend to crosscut shape and size categories, with varying degrees of continuity in use of clay sources from period to period (Henrickson and Blackman 1996; unpublished analyses). Fine or painted wares may have been sub-specialities, but INAA investigation has concentrated on the predominant medium grit-tempered wares. Household production of pottery is unlikely, as is elite control of the craft (Henrickson 1993, in press; Costin 1991; Sinopoli 1988; Stein and Blackman 1993).[12]

Among the coarser wares, and larger products, ethnographic studies indicate that both pithos and tile production are generally distinct craft specializations (cf. Hampe and Winter 1962, 1965; Blitzer 1990; Voyatzoglu 1974; Güner 1988). Preliminary results from paste composition analyses of Middle Phrygian pithoi suggest use of local clays (unpublished analyses). Ethnographic studies of traditional pithos production indicate that specialists make these vessels in isolation, both physical and technological, from other potters. Although pithos production shares some basic forming methods with the general pottery industry, these oversize vessels represent a number of forming and firing challenges distinct from those affecting smaller pottery (Voyatzoglu 1974, 1984; Blitzer 1990; Hampe and Winter 1962, 1965; Henrickson 1995). Tile and architectural terracotta production are also essentially unrelated to other ceramic crafts in terms of working methods (e.g. Hampe and Winter 1965; cf. Glendenning 1995). Although recent work on the architectural terracottas at Gordion has concentrated on the earlier Phrygian era (YHSS 5–4, *c*. 700–330 BC; Glendenning 1995, 1996), the general working methods continued into the Hellenistic period (see above).

The distinctiveness of the tile pastes demonstrates that tile production relied on clay resources unrelated to those used by the local pottery industry, suggesting that architectural tile production was a separate craft. While these clay sources have not yet been identified, they need not have been distant from Gordion, just not within the Sakarya River drainage in the immediate area of the city. Two other rivers flow nearby through geologically distinctive regions (Erentöz 1975); clays from these drainages have not yet been sampled.[13] Around Gordion itself, the extensive alluviation 4–6 m deep from Sakarya overbank flooding after the Hellenistic period may have buried clay sources used in antiquity (Marsh 1997), although pre-alluvial and more recent samples tend have similar compositions. Further survey and sampling in the rest of the valley and local region may yield a more complete picture of resources, although identification of clay sources used in antiquity is problematic. It is clear that the tile craft is distinct from the other ceramic crafts not only in working methods but even in choice of clays.

The relationship between moulded figurine production and the pottery vessel industry(s) remains uncertain. No figurines have been sampled for paste analysis, but at least two lines of evidence suggest this also was a distinct craft. The basic forming methods — moulding of separate components (Romano 1995) — are distinct from those of potters (Henrickson 1993, in press). The evidence from Hellenistic figurine workshops at Gordion provides contradictory evidence on the relationship to potters. The debris in one

Hellenistic potter's workshop included both figurine moulds and small unfired pottery vessels (Edwards 1959; Romano 1995), suggesting figurine makers may have worked with, or near, potters who made small fine buff ware vessels. A second Hellenistic figurine workshop excavated in 1994–97 (Sams and Voigt in press), however, yielded numerous figurine and mould fragments and paint pots, but no evidence whatever for any type of pottery production. While the context of the first workshop is uncertain, the association of the second with a monumental, presumably public, building within an area defined by a massive perimeter wall, suggests the artisans might have been under elite control. This contrasts strongly with the other ceramic crafts which were most likely independent. Their products, however, had religious significance (Romano 1995; cf. Stone and Zimansky 1994), unlike those of all other ceramic crafts.

A multidimensional approach to the ceramic crafts, concentrating here on the production of roof tile, yields a broader picture of the ceramic 'industry' at Hellenistic Gordion. Ethnography, working methods, archaeological evidence, and data on the chemical composition of clays and pastes together contribute to the definition of several essentially independent specialist crafts. Each had a distinctive scale and organization, repertoire of working methods, and often even distinct clay choices. Most were probably part-time or seasonal. All, except perhaps the figurine makers, were probably independent artisans rather than state or elite controlled. Individual and detailed characterizations of these crafts aid monitoring of long-term change or continuity within each, better assessment of differential impacts of alien traditions, and contribute to reconstruction of the urban and regional economy at ancient Gordion.

Acknowledgements

In 1994–1996, the Gordion Excavation Project was supported by a grant to M.M. Voigt from the National Endowment for the Humanities, an independent federal [U.S.] agency, and a Social Sciences and Humanities Research Council [Canada] grant to T.C. Young, Jr. Building 1 was excavated in 1995. The instrumental neutron activation analyses (INAA) have been carried out by Blackman at the Smithsonian Centre for Material Research and Education's INAA Facility using the National Institute of Standards and Technology's 20 MW research reactor. The authors would like to thank the staff of the Reactor Operations Division and the Nuclear Methods Group for their invaluable assistance. M. Glendenning sorted much of the tile and assembled the restored cover and pan tiles; he will discuss these tiles further in his own work. T. Castillo (1995) carried out basic sorting of tile in the sherdyard. We have benefitted from discussion with many colleagues including M.M. Voigt and M. Glendenning. Figures 1–2 were prepared by S. Jarvis, Figures 3–5 by R. Henrickson, and Figure 6 by M.J. Blackman.

All errors and matters of interpretation remain the authors' responsibility.

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NOTES

1 Published in Voigt *et al*. (1997, 12, fig. 17) simply as the building in Operation 35.

2 Roman pan tiles (*tegulae*) range in size from 51 × 36 × 3.5 cm to 35 × 30 × 2.5 cm (Spitzlberger 1968, 104).

3 Although more than 1100 tile fragments were recovered, the minimum number of each type of tile present was determined by counts of a single readily

identified corner from each. Given that each pan tile would cover an area of approximately 0.25 sq m (allowing for overlap), a minimum of approximately 4 m^2 of pan tiles were recovered from a roofed area of 20 m^2. Some tiles evidently are missing.

4 In comparison, pithos makers in Crete need 600 kg of clay per day to make 10 pithoi (Voyatzoglu 1974, 19), perhaps somewhat over half a cubic metre (cf. Henrickson 1995 for estimates of clay volume).

5 In one case, Hampe and Winter show a woman working (1965, taf. 55.2).

6 Personal experience in June–August field seasons in 1988–1990, 1992–1997. Heavy weekly rain, at least several centimetres in the space of perhaps an hour, marked the 1988 and 1997 seasons. In contrast, 1990 was exceptionally dry.

7 Alternatively, tile production at Gordion might have been a second speciality craft practised by pithos makers, since demand for either is limited and intermittent. Ethnographic studies, however, indicate that pithos, pottery, and tile production are generally distinct craft specializations (cf. Hampe and Winter 1962, 1965; Blitzer 1990; Voyatzoglu 1974, 1984; Güner 1988).

8 Writing on Roman tile, Brodribb (1987, 11–12) notes 'The average weight of 41 complete *tegulae* [pan tiles] . . . works out at 13.6 lbs (29.98 kg [sic]) each, and . . . *imbrices* [cover tiles] at 5.6 lbs (12.34 kg [sic])' and in another case where the tile sizes are given and similar to those at Gordion '. . . *tegulae* . . . measuring 550 × 380 mm and weighing 25 lbs (55 kg [sic]) each with *imbrices* [cover tiles] 550 mm long and weighing 8 lbs (17.6 kg [sic]) each'. If we may assume that conversion of pounds to kilograms, clearly incorrect, used 'kg = (2.2) × lbs' instead of the correct 'kg = lbs/(2.2)', which would make sense in terms of the heft of tiles of similar size handled at Gordion, pan tiles would weigh 6–11.5 kg, cover tiles 2.5–3.5 kg. Thus 1000 each of pan and cover tiles, as we have assumed for the Gordion roof, would weigh a total of perhaps 8,000–15,000 kg. Taking this simply as an order of magnitude estimate, the roof structure would clearly require a large investment to provide adequate support.

9 One each of pan and cover tiles were not available for sampling.

10 Fifteen elements (K, Sc, Cr, Fe, Co, Rb, Cs, La, Ce, Sm, Eu, Yb, Hf, Ta, Th) were used. Each sample was then tested against the group, determining that not one sample need be rejected. We use the term 'probability of group membership' for simplicity. The probabilities cited are, more precisely, the probability that a sample selected at random from a single population will have a Mahalanobis distance from the centroid of that population that is equal to or greater than that calculated. This is the logical equivalent of the likelihood of the sample having been drawn from that population.

11 Initially using four elements (K, Cr, Fe, Rb) due to the subgroup sizes but later with seven.

12 The only ceramic/baked clay artifacts which might have been made within individual households were low-fired domestic items, such as hearth trays or braziers.

13 To the north-west, the Porsuk Çay flows within 3–4 km of Gordion, joining the Sakarya *c*. 5 km downstream. The Ankara Çay is less than 20 km to the north and joins the Sakarya *c*. 20 km downstream.

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