

BRONZE- AND IRONWORKING IN THE AREA OF THE ATHENIAN AGORA

(PLATES 77-98)

DURING the course of the excavations conducted by the American School of Classical Studies in the region of the Athenian Agora, remains of foundries and smithies ranging in date from the 6th century B.C. to the 6th century after Christ were discovered in over twenty different locations,¹ each of which is given a letter of the alphabet on the site plan (Pl. 77) and in the Catalogue of Establishments below. Twelve of these appear to be actual workshops, for they have hearths or

¹ I am grateful to Homer A. Thompson for permission to study the Agora foundry remains and for his advice and encouragement; to Sara A. Immerwahr, who advised me in the preparation of a dissertation for the University of North Carolina at Chapel Hill, in which much of the following material was included; to James R. McCredie for help in all phases of my studies in Athens; and to the American School of Classical Studies for an Edward Capps Fellowship (1975/1976) which enabled me to prepare this publication. I am also grateful to T. Leslie Shear, Jr. for permission to re-excavate three Agora foundries in the summer of 1973; to Eugene Vanderpool, Jr. for his photographs of the material; to William Bell Dinsmoor, Jr. for the plans reproduced in Figures 3, 6, 7; to Alison Frantz for permission to include here four photographs which she took in the foundry of the Fratelli Nicci in Rome, Plate 97; and to Abigail Camp for her drawings, Plates 93-95.

There is little comparative material available in this field, and I must be held responsible both for the identification of objects and for the interpretation of their use. Many more items were studied and inventoried than could reasonably be included in this catalogue, and it is from the whole body of the material that my conclusions are drawn.

Substantial remains of large-scale bronze-casting workshops of various periods have also been excavated in the following locations in Greece. South slope of the Athenian Akropolis: S. Koumanoudes, *Πρακτικά*, 1878, pp. 8-9; N. Platon, *Δελτ* 19, 1964, *Χρονικά*, pp. 27, 32-34, figs. 5, 8, 9, pls. 23-28; E. Vanderpool, "News Letter from Greece," *AJA* 69, 1965, p. 353; G. Daux, "Chroniques des fouilles 1965," *BCH* 90, 1966, pp. 725-727; H. A. Thompson and R. E. Wycherley, *The Athenian Agora*, XIV, *The Agora of Athens*, Princeton 1972 (= *Agora* XIV), p. 189, note 89. Athens, southwest of the Olympieion, outside the precinct wall: excavated in 1939 by J. Travlos; unpublished. Olympia: R. Hampe and U. Jantzen, "Bericht über die Ausgrabungen in Olympia. Die Grabung im Frühjahr 1937," *Jahrb* 52, 1937 (= Hampe and Jantzen, "Bericht"), pp. 1-28; G. M. Young, "Archaeology in Greece, 1936-1937," *JHS* 57, 1937, p. 129; A. Mallwitz, "Die baugeschichtlichen Ergebnisse der Ausgrabungen 1954-1958," *Olympische Forschungen*, V, *Die Werkstatt des Pheidias in Olympia*, Berlin 1964, p. 42, pl. 24; E. Kunze, "Die Ausgrabungen in Olympia im Frühjahr 1956," *Gnomon* 28, 1956, p. 318; E. Kunze, "Olympia. Werkstatt des Pheidias," *Neue deutsche Ausgrabungen im Mittelmeergebiet und im vorderen Orient*, Berlin 1959, p. 280, Corinth: C. C. Mattusch, "Corinthian Metalworking: The Forum Area," below, pp. 389 ff. Corinth Gymnasium area: J. Wiseman, "Ancient Corinth: The Gymnasium Area," *Archaeology* 22, 1969, p. 222; J. Wiseman, "Excavations in Corinth, The Gymnasium Area, 1967-1968," *Hesperia* 38, 1969, p. 69, pl. 20: a, d. Demetrias, near Volos in Thessaly: excavated in 1973; unpublished. See also Nea Paphos in Cyprus: *Annual Report of the Director of the Department of Antiquities for the year 1970*, Nicosia 1971, p. 19; K. Nicolaou, "Archaeological News from Cyprus, 1970," *AJA* 76, 1972, pp. 315-316, pl. 66: 38.

casting pits, as well as debris such as broken molds, vitrified bricks from furnaces, scraps of waste metal, and slag. The other remains are either dumps situated in shallow holes and abandoned wells or cisterns, or simply isolated finds,² often scattered, and frequently from the area around the Hephaisteion.

During the Archaic, Classical and Hellenistic periods, metalworking establishments were distributed along the west side of the Agora and in the industrial region just outside it to the southwest. Two workshops for casting small-scale bronzes (D and G) and a fairly large iron smithy (E) were excavated to the north of the Hephaisteion. All of the other workshops were located to the east and south of the Hephaisteion or in the industrial region. During the Roman period, metalworking activities were concentrated in the area of the South Stoa and to the south of it, although again some metallurgical remains came from around the Hephaisteion.³ With only two exceptions (N and L), the workshops and dumps of Roman date all belong in the 3rd and 4th centuries after Christ. Three of the four workshops produced small-scale utilitarian castings (K, L, and M); the fourth yielded molds for large-scale sculpture as well as for smaller objects (N). No foundries or smithies have been excavated around the Agora that date between the 2nd century B.C. and the 3rd century after Christ, nor have any dumps been reported from the 2nd century after Christ.

Dumps are located in the same general regions as the workshops, but it is difficult to match dumps with workshops on the basis of similar finds. Most of the dumps contained at least some debris associated with bronzeworking; several of them contained purely ironworking debris (F, pothole north of the State Prison,⁴ X, U, and W), but a single deposit may yield iron, bronze, and even lead debris.

Ancient literary references to metalworking in the area of the Athenian Agora are scarce. A fragmentary inscription dated between 421 and 415 B.C. mentions the purchase of copper, tin, lead, wood, and charcoal to be used in the completion of the Hephaisteion cult statues and their pedestal (*IG I²*, 370-371).⁵ Two passages specifically mention bronzeworking being done in the area of the Hephaisteion (Andokides, *De Mysteriis*, 40; Bekker, *Anecdota Graeca* I, 316.23). And, most interesting of all, a lead tablet cursing three bronzeworkers (Agora IL 997) was found in a 4th century B.C. house (House D) outside the southwest limits of the Agora. The courtyard of the house contained a hearth and many scraps of both bronze and

² One of these is a mold fragment (Agora B 1621) which is much earlier than the rest of the Agora material: it comes from a context that was closed in the Submycenaean period. I am grateful to Evelyn L. Smithson for bringing this mold to my attention.

³ See W. B. Dinsmoor, *Hesperia*, Suppl. V, *Observations on the Hephaisteion*, Princeton 1941 (= Dinsmoor, *Hesperia*, Suppl. V), p. 1.

⁴ Recently identified by Eugene Vanderpool. See *The Athenian Agora: A Guide to the Excavation and Museum*, 3rd ed., Athens 1976, pp. 172-175.

⁵ See W. E. Thompson, "The Inscriptions in the Hephaisteion," *Hesperia* 38, 1969, pp. 114-118.

iron, but the curse suggests that the workshop was strictly a bronze smithy, and not a forge.⁶

CATALOGUE OF ESTABLISHMENTS

The following descriptions of metallurgical workshops and dumps are arranged chronologically.⁷ Where possible, attempts have been made to reconstruct details of the processes employed;⁸ the success of these attempts depends upon the condition of the workshops and upon the quality of the material from them. Dumps which contain the debris from particular workshops are discussed along with those establishments; the others are listed separately after the workshops. A representative catalogue is included after each foundry, but after a dump only if the objects are of particular significance.⁹

⁶ H. A. Thompson, "Excavations in the Athenian Agora: 1948," *Hesperia* 18, 1949, p. 217, pl. 39: 2; R. S. Young, "An Industrial District of Ancient Athens," *Hesperia* 20, 1951, pp. 222-223; *Agora* XIV, p. 177, fig. 41. Unfortunately, the appellation *χαλκεία* does not differentiate between a bronze founder and a bronze smith, nor does it help to explain the presence of iron in the House D workshop.

⁷ The dates assigned to each deposit were established by the Agora staff on the basis of associated pottery, except where otherwise noted.

⁸ All of the foundry remains which I have examined indicate that throughout antiquity only the lost-wax (*cire perdue*) method of casting, in its direct or indirect form, was used to produce both large and small bronzes. In the simpler direct method, a wax model is formed over a clay core, chaplets (pins) are stuck through the wax into the core to hold the core in place within the mold, and then the investment or mold is added. Baking hardens the mold and burns out the wax, after which the mold is packed in earth and molten metal is poured into the hollow left by the wax between the core and the mold. If the casting succeeds, a single bronze is produced: if it fails, the sculptor must begin again by making a new wax model. In the indirect process, a negative impression of the artist's model is used for the casting process, and the original remains intact. Besides being less hazardous than direct casting, the indirect method permits the production of unlimited copies of the model.

A brief glossary follows. *Armature*: the framework around which the clay core of a bronze made by the direct lost-wax method is molded. *Casting skin*: the blackened surface of the bronze resulting from contact between the molten metal and the clay mold. *Chaplet*: an iron or bronze pin that is stuck through the mold and the wax into the core to hold the core in place after the wax has been burned out of the mold. *Core*: the clay covering the armature around which the wax model is formed in direct lost-wax casting; in indirect casting, the core is poured into the interior of the wax impression taken from the master mold. *Forge* or *Smithy*: the workshop of an artisan who shapes metal by hammering. *Foundry*: the workshop where bronze is cast. *Funnel*: the cup at the entrance to the gate system into which the molten bronze is poured to reach the mold cavity. *Furnace*: the oven in which the alloy is melted preparatory to pouring it into the mold cavity. *Gate*: a channel, usually round in section, which receives the molten bronze from the funnel and conveys it to the mold cavity. *Gate system*: the complex of gates or pouring channels which conveys bronze from the funnel to the mold cavity. *Investment*: the mold which is built up around the wax, and into which the bronze is later poured. *Master mold*: the mold taken from a sculptor's model that is used to reproduce copies of the model in the indirect lost-wax process. *Patch*: a small metal piece, usually rectangular, inserted into the surface of a bronze during coldworking to conceal chaplet holes and other imperfections that cannot be filed away. *Slag*: the waste matter that separates from the pure metal during melting. *Vent*: a narrow round channel made of wax and attached to the wax over the core; it reaches to the exterior of the mold and allows air and gases to escape during pouring. *Y-gate*: a forked gate.

⁹ Foundries are here sometimes referred to as casting pits, for they functioned as such. Clay objects are all terracotta unless otherwise noted. The B, S, MC, IL, and BI numbers are those

A. ARCHAIC FOUNDRY. Deposit H 8:1. Mid-6th century B.C. Fig. 1; Pl. 78. L. 1.70, W. 0.60; max. D. 0.85.

In the eastern part of the area between the Metroon and the Temple of Apollo Patroos, and on the same level as the first Temple of Apollo, a roughly rectangular

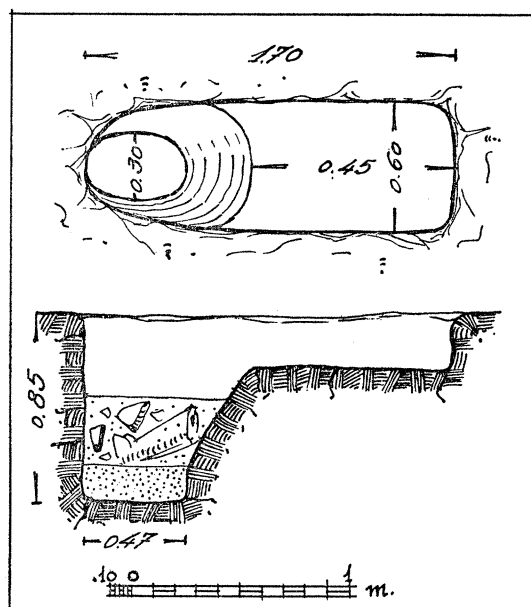


FIG. 1. Archaic Foundry. Plan and section (J. Travlos).

pit was cut into the bedrock along a north-south axis.¹⁰ In the north part of the pit, at a depth of 0.25 m., there was a smooth level floor 0.90 m. long. The walls and floor were reddened by fire, and ash and charcoal covered the floor, perhaps indicating

of the Agora inventory. H. refers to height, W. to width, L. to length, Th. to thickness, D. to depth, Diam. to diameter, and dim. to dimension(s), and pres. to preserved, all dimensions being in meters.

¹⁰ Excavation: H. A. Thompson, 1936. Publication: T. L. Shear, "The Campaign of 1936," *Hesperia* 6, 1937, pp. 343-344; H. A. Thompson, "Buildings on the West Side of the Agora," *Hesperia* 6, 1937, pp. 82-83, fig. 43; Hampe and Jantzen, "Bericht," p. 37; H. A. Thompson, "The Metal Works of Athens and the Hephaisteion," *AJA* 42, 1938, p. 123; R. Triomphe, "La fonte des statues de bronze à Olympie," *RevArch* 18, 1941, p. 256; D. H. Hill, *Catalogue of Classical Bronze Sculpture in the Walters Art Gallery*, Baltimore 1949 (= D. H. Hill, *Catalogue*), p. xv; F. Chamoux, *FdD* IV, v, *L'Aurige*, Paris 1955, p. 63; E. Harrison, review of Chamoux, *L'Aurige*, *AJA* 61, 1957, p. 298; *The Athenian Agora: A Guide to the Excavation and Museum*, 2nd ed., Athens 1962 (= *Agora Guide*), pp. 60, 155, 157, fig. p. 156; B. S. Ridgway, "The Lady from the Sea: A Greek Bronze in Turkey," *AJA* 71, 1967, p. 333, note 32; D. K. Hill, "Bronze Working," *The Muses at Work*, ed. C. Roebuck, Cambridge, Mass. 1969, p. 65; G. M. A. Richter, *Kouroi*, 3rd ed., London 1970, p. 9; W. Kimmig and O.-W. von Vacano, "Zu einem Gussform-Fragment einer etruskischen Bronzekanne von der Heineburg a. d. oberen Donau," *Germania* 51, 1973, p. 82; *Agora* XIV, pp. 137, 189, fig. 47, pl. 97: a, b. A black-figured amphora fragment from this foundry is dated as late as the mid-6th century B.C. (Agora P 13337); otherwise the deposit is dated on the basis of the style of the kouros mold.

that the furnace was erected here, with the bedrock walls forming part of its superstructure. An oval hole at the south end of the pit was cut to a depth of 0.85 m., narrowing towards the bottom. Traces of burning on the upper walls are a continuation of the burning in the northern section of the pit. The bottom of this end of the pit was thickly covered with ash and charcoal; above this were found many small fragments of a single terracotta mold, which, after mending, proved to be for the casting of a two-thirds life-size bronze kouros, **A3** (Pl. 79).

The base around the feet of the kouros mold (0.355×0.197 m.; Pl. 80: b) would have fitted neatly into the oval cutting in the pit (0.47×0.30 m.), and it is clear that the statue was cast here in an upright position. The presence of ash and charcoal suggest that the mold may have been baked in this position before the pour, although the space is limited.

Besides the feet, the mold preserves the legs, buttocks, hands and parts of the arms of the kouros, **A3** (Pl. 80: c). A non-joining fragment of the head showing the nostrils, mouth, and chin was also found (Pl. 80: a). The large mold consists of three layers of clay, ranging in thickness from about 0.006 m. in the innermost layer to 0.016 m. in the outermost layer. Both inner layers consist of smoothly applied, fine, hard, scorched clay; bits of bronze adhere in cracks and other imperfections in the inner mold surface. The outsides of both inner layers of clay were scored in places with a narrow spatulate instrument in order to improve the adhesion between the layers of the investment (e. g. B 1540; Pl. 78). The outermost layer of the mold is made of coarse red clay with some scorching. In places both the outermost and the middle layer of the mold had split apart despite the precautions that had been taken to prevent it.

There is evidence in the mold for the placement of four chaplets, although the chaplets themselves are gone. A small, roughly square hole measuring about 0.003×0.003 m. can be seen in each heel. Although large chunks of the mold are broken away around these holes, it can be seen that the chaplets were sunk deeply into the mold.¹¹ Another rectangular hole about 0.003 m. across leads vertically down for a distance of 0.060 m. from the right hand of the mold. A clay wrapping for this hole is separately molded; it consists of the same fine inner mold material, but it is not scorched like the inner layers of the mold. Part of the lower edge of this wrapping is intact, but none of the outer layer of the mold is preserved here. Similarly, on the left side of the mold, a vacant area stretches down from the hand for 0.070-0.080 m.; here the clay wrapping for the chaplet is lost, but beyond it the outer layer of the mold is intact. These two holes show the location of two chaplets which were fixed vertically into the outer mold below the hands to hold in place

¹¹ The chaplets may have resembled those which are preserved in the core and in the bronze of the Piraeus Kouros (Athens National Museum). These are made of iron, are square in section, and measure about 0.002 m. in thickness. The best-preserved chaplet, *ca.* 0.020 m. in length, is still wrapped in a thin layer of fine clay core material.

that part of the core which lay within the arms. The intact exterior layer on the left side of the figure proves that the chaplet did not go all the way through the investment, and that the outermost layer of the mold was added after the chaplets were inserted, covering them over completely.

Besides the mold for the statue and the fragment of the mold for its head, both from the casting pit, sections of a second mold used to cast the head of a youthful male statue, **A4** (Pl. 81), made of the same clay and on the same scale as the other mold, were discovered beneath the north room of the Metroon, in the same stratigraphic context as the casting pit.¹² Indeed, this mold probably came from the casting of the same kouros, since no molds for another torso were found, nor were there any other casting pits near by. If both heads were intended for the same body, one must have been rejected for some reason, perhaps because it was a mis-casting.¹³ The replacement head could have been modeled, invested, and poured in a second use of the original casting pit, or in a smaller makeshift pit.

It is not clear whether the original head was part of the same mold as the body, or whether the two parts were cast separately. It would have been unusual for the whole figure to be a single casting, for even during the Archaic period it was customary to cast a statue in parts so as to reduce the risks involved in the process. In this case, too, it is perhaps safer to assume that at least the head was cast separately from the body of the kouros, despite the lack of any original edges on the mold fragments, for if the mold had been cast whole, it would have extended well above the present level of the bedrock, and necessitated substantial building up of the walls of the casting pit so that the mold could be completely packed around with earth for the pour.

A rectangular cutting located 5.20 m. west of the casting pit, and measuring 0.75×0.50 m. and 0.90 m. deep, contained dumped material from the foundry.¹⁴ Parts of the gate system for the kouros mold were found here (e. g. B 1534 and B 1535). The cutting also yielded bricks, perhaps from the furnace, and a number of partially vitrified concave fragments of clay (e. g. **A5**; Pl. 78), which probably formed coverings for the bellows nozzles, to protect them from the extreme heat of the melting furnace.¹⁵

¹² The second mold for the head shows that the kouros had cast eyes and an undetailed mass of hair waving around the face, features that also appear on the Piraeus Kouros, whereas bronze statues from fairly early in the 5th century onwards tend to have inlaid eyes, and hair and other features worked in elaborate detail, as the Delphi Charioteer (Delphi Museum, inv. nos. 3484, 3540), the Artemision Zeus/Poseidon (Athens National Museum inv. no. 15161), and the Poseidon from Livadostro (Athens National Museum inv. no. 11761).

¹³ This was first suggested by H. A. Thompson, *Hesperia* 6, 1937, p. 83.

¹⁴ The cutting was too far from the casting pit to have held its furnace, nor did its walls bear any traces of the extreme heat generated by a furnace.

¹⁵ The only published parallels that I know were found in 12th century B.C. levels at Timna in Israel. See *Midianite Timna: Valley of the Biblical Copper Mines*, London 1971, p. 15; B. Rothenberg, *Timna: 6000 Years of Copper Metallurgy*, London 1972, pls. 32-34.

A large funnel from the casting pit, **A1** (Pl. 78), may have been used for pouring the body of the kouros. A similar funnel (B 1534; Diam. 0.160 m.) was discovered in the rectangular pit. Gates from the casting pit and from the rectangular pit are also large enough to have been used for this operation, two of them having diameters of 0.010 m. (e. g. **A2**; Pl. 78), the third, B 1539, a diameter of 0.015 m. and the fourth, B 1535, a diameter of 0.024 m.

The technique employed in the Archaic Foundry can be summarized as follows. The molds were built up near by, and the large mold, **A3**, was lowered into the deeper part of the pit, where it was baked in an upright position. The burned walls and floor in the shallow part of the pit suggest that a melting furnace was constructed here, using the bedrock walls as part of its superstructure. The baked mold, without having to be moved, and perhaps also the separate mold for the head, were packed around with sand. Then the charged crucible, which had been heated in the adjacent furnace, was used to pour the bronze. The replacement for the miscast head was cast in the same way, but was probably packed in a smaller area. Finally, the molds were broken up, the furnace was dismantled, and mold fragments, dripped bronze, and other debris that were not simply left in the casting pit were dumped into the rectangular pit near by.

The Archaic Foundry, unlike most of the other local metalworking establishments, was not outside, but at the edge of the Agora, next to the Temple of Apollo Patroos. The location and mid-6th century date of the foundry might suggest that the kouros cast there was intended as the cult statue of the early temple. The temple itself was destroyed during the Persian invasion of 480 B.C., when the entire city of Athens was sacked and the Akropolis burned. No doubt the bronze kouros, if it stood in the Temple of Apollo, was also destroyed at that time, unless it was carried off by the Persians. But a record of the statue had already been preserved when the debris from the casting was thrown back into the foundry in the middle of the 6th century.

Casting pit in bedrock between Temple of Apollo Patroos and Metroon

A1 (B 1536). Funnel. Pl. 78

Max. pres. dim. 0.136; reconstructed Diam. at rim 0.150.

Lip and part of bowl. Coarse, red crumbly clay.

Scorched inner walls slope inward, with setback of 0.004 in lower bowl.

From gate system of **A3**.

A2 (B 1537). Gate. Pl. 78

Max. pres. L. 0.120; Diam. (interior) 0.010.

Broken all around. Coarse, red crumbly clay around finer inner layers.

Narrow, scorched gate, nearly plugged with bronze at one end, thickly wrapped with outer clay which is heavier at one side for connection with body of mold.

From gate system of **A3**.

A3 (S 741). Mold for statue of Pls. 79, 80 kouros.

Max. pres. H. 0.750; L. base 0.355; W. base 0.197; max. pres. dim. of face fragment 0.070.

Mold, in three layers, for standing male figure, about two-thirds life-size, with left leg forward and hands clenched at sides in typical kouros pose. Non-joining fragment for chin,

mouth, and nostrils. Coarse, red clay around two fine inner layers.

Inner layer preserved on lower face, parts of right sole, heel, calf, thigh, hand, buttock. Second layer preserved most of the way up both legs, on right side of abdomen, and on both hands. Outer layer roughly follows second layer.

One uninventoried non-joining fragment may be part of the mold from one of the arms. Other fragments of this mold: **A1**, **A2**, B 1538-B 1541.

See **A4**, fragments of second mold for head.

For publications, see footnote 10 above.

Beneath north room of Metroon

A4 (S797). Mold fragments for head Pl. 81 of statue.

Five non-joining fragments. Coarse, red clay, scorched on interior.

a. Max. pres. dim. 0.144. Part of right ear, right side of face, hairline, back of head, and long hair on neck. Two clearly divided layers.

b. Max. pres. dim. 0.134. Part of left ear, hair, eye, cheek, nose, and mouth. Rectangular depression just above and behind mouth

(0.016 × 0.011; depth 0.003). Bit of bronze in nostril. Two clearly divided layers.

c. Max. pres. dim. 0.110. Unidentifiable curved inner surface, quite rough from burned-out organic inclusions. Layering unclear. (Not illustrated.)

d. Max. pres. dim. 0.097. Unidentifiable curved, smooth inner surface. Layering unclear. (Not illustrated.)

e. Max. pres. dim. 0.071. Unidentifiable curving inner surface, like that of c. Much thinner layers here than in the other pieces. (Not illustrated.)

Rectangular pit 5.20 m. west of casting pit

A5 (B 1533). Covering for bellows Pl. 78 nozzle.

Max. pres. dim. 0.103.

Broken except at end. Red, unbaked clay, heavily vitrified towards end and on exterior.

Fragment of end of channel, curving in section. Vitrified exterior is bubbly and black, and has traces of bronze.

Sixteen similar uninventoried fragments. All may be parts of clay coverings for bellows nozzles.

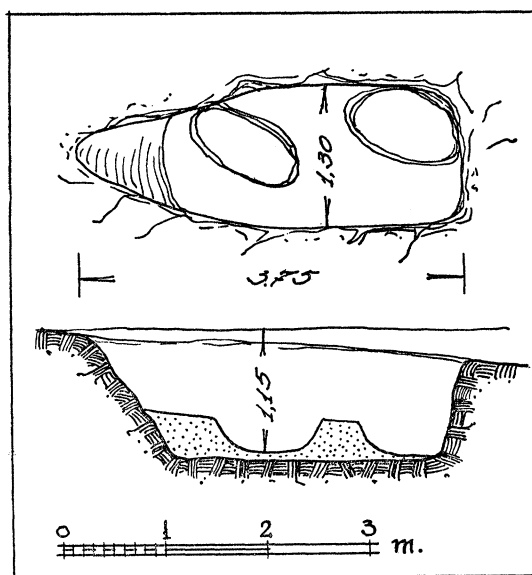


FIG. 2. Hephaisteion Foundry. Plan and section (J. Travlos).

B. HEPHAISTEION FOUNDRY. Deposit D 7: 3. Late 5th century B.C. Fig. 2; Pl. 82. L. 3.75; W. 1.30; max. D. *ca.* 1.15.

Ten meters southwest of the Hephaisteion and within its precinct wall was an irregular, pear-shaped cutting.¹⁶ Within it, at a depth of 0.80 m., two holes were dug in the sandy earth, the southeast one measuring 1.00×0.60 m., and the north-west one 0.80×0.60 m. Both holes extended down approximately 0.35 m. to bedrock; they contained charcoal and traces of burning, many pieces of molds, vitrified clay; and bits of bronze. The sandy packing in which the holes were dug also yielded mold fragments and carbon.

It has been suggested that this foundry, because of its location, its two interior holes, and the numerous mold fragments from it, was used for the casting of the cult statues of Hephaistos and Athena which were made for the Hephaisteion by Alkamenes between 421 and 415 B.C.¹⁷ The casting done here was certainly large scale: the mold fragments are large, as are the diameters of the preserved funnels, **B1** (0.080 m.; Pl. 82), **B 1487** (0.150 m.), and gates (0.009-0.023 m.). However, the poor state of preservation of the mold fragments prevents a sure identification as statues of the objects cast here. Most of the pieces are small and do not join. If more joins had been found, no doubt it would still be impossible to tell whether one or more statues were cast here, since even one statue would have been cast in several sections, each with its own mold. The most positive evidence for statuary is provided by a single fragmentary mold, **B2** (Pl. 82), with a hole for a rectangular chaplet,¹⁸ which was used for casting a segment of fairly large scale drapery folds. No other mold from the casting pit can be identified as a particular part of a figure. In fact, many of the molds were used to produce one or more large objects, with two perpendicular surfaces and a rounded-off angle between (e. g. **B3**; Pl. 82), perhaps to be identified as a rectangular stele.¹⁹

A number of heavily vitrified pieces of clay, some quite large, reddish in color, with bits of bronze adhering to them (e. g. **B4**; Pl. 82), may be mold fragments the exteriors of which were damaged by excessive heat.²⁰ But the funnels and many

¹⁶ Excavation: D. B. Thompson, 1936. Publication: H. A. Thompson, *AJA* 42, 1938, p. 123; D. B. Thompson, "The Garden of Hephaistos," *Hesperia* 6, 1937, p. 399, fig. 2 at B; W. B. Dinsmoor, *Hesperia*, Suppl. V, pp. 1, 105-110; D. K. Hill, *Catalogue*, pp. xv-xvi; G. P. Stevens, "Some Remarks upon the Interior of the Hephaisteion," *Hesperia* 19, 1950, p. 154; *Agora* XIV, pp. 142, 145-146, 189-190, 228.

¹⁷ W. B. Dinsmoor, *Hesperia*, Suppl. V, p. 109.

¹⁸ The chaplets evidently measured 0.002-0.003 m. in thickness, about the same size as those in the core of the Piraeus Kouros.

¹⁹ The only rectangular cast stele that I know about is in the Meletopoulos Collection in the Piraeus. See R. S. Stroud, "A Fragment of an Inscribed Bronze Stele from Athens," *Hesperia* 32, 1963, pp. 138-143. The single identifiable drapery fragment from the Hephaisteion Foundry, **B2**, might suggest instead that the molds produced a draped herm, such as the one from the 2nd century B.C. Mahdia shipwreck, for which see W. Fuchs, *Der Schiffsfund von Mahdia*, Tübingen 1963, pl. 7, but there is so far no evidence that bronze herms were ever erected in Athens.

²⁰ The fragments are curved, and since it is the convex exterior surface that is vitrified, and not

other mold fragments were used without mishap, being simply scorched on the interiors and not vitrified. Some fragmentary bricks are preserved (e. g. B 1486), presumably from the foundry's furnace, and it is also possible that the vitrified pieces are not damaged molds, but that, despite their odd contours,²¹ they come from within the furnace. If this is the case, the bits of bronze adhering to the vitrified pieces can be explained as splatters of molten bronze from the melt.

The Hephaisteion Foundry seems to have been used twice, possibly because of a failure (see preceding paragraph and **B4**). The mold fragments from the sandy packing of the pit belong to the first casting, in which the original rock-cut pit was packed with earth after the setting and baking of the molds. These molds were broken up after use and left in the pit, to be used as part of the packing around a second group of molds that were cast here. The mold fragments that were found in the two holes and in the upper fill of the pit are from this second casting.

Although the date of use of the foundry coincides with the date of the construction of the cult statues for the Hephaisteion, the fact that only a single mold fragment, **B2**, which could be for a statue was found in it makes this identification of the workshop uncertain. But the numerous molds for one or more large rectangular objects (e. g. **B3**) are unique among the Agora finds; they suggest the appealing theory that this workshop produced bronze stelai. Whatever was cast here, the fact that the foundry was dug within the temenos shows a connection with the temple or with the founders' patron deity.²²

Upper fill in casting pit

B1 (B 1492). Funnel. Pl. 82

Max. pres. H. 0.050; reconstructed Diam. 0.080.

Part of lip and wall. Fine, pinkish clay.

Lip and sloping walls of scorched funnel, curving inwards towards bottom. Unclear layering.

One similar uninventoried fragment. One fragment of larger funnel: B 1487 (reconstructed Diam. 0.150).

B2 (B 1495). Mold fragment for Pl. 82
drapery.

Max. pres. dim. 0.279.

Broken all around. Fine, pinkish buff clay.

Scorched, undulating inner mold surface,

largely pulled away, but clearly for large-scale drapery folds. Rectangular hole (0.006 × 0.011; D. 0.009) on ridge of one fold (ridge was furrow on finished product) originally held a small chaplet.

B3 (B 1494). Mold fragment. Pl. 82

Max. pres. dim. 0.314.

Broken all around. Fine, pinkish buff clay.

Interior scorched; mostly pulled-away surface is flat with a second side that is perpendicular to it; smoothed edge between. Two layers of clay.

Used for casting large-scale rectangular object.

Many similar uninventoried fragments, as well as B 1493.

the interior, it appears that the damage occurred during the baking of the molds instead of during the pouring of the bronze.

²¹ Compare **J4** and **J5** (Pl. 91), bricks from the lining of a cylindrical furnace, the concave interior surfaces of which were vitrified.

²² For a similar arrangement see V. Karageorghis, "Le quartier sacré de Kition: Campagnes de fouilles 1972 et 1973," *CRAI*, 1973, pp. 527-530.

B4 (B 1489). Vitrified clay.

Pl. 82

very hard, cracked surface having vitrified reddish traces. Fingermarks from working this surface visible.

Max. pres. dim. 0.089.

One edge intact. Pinkish buff clay.

Scorched fragment of clay with one gray,

Similar to B 1490.

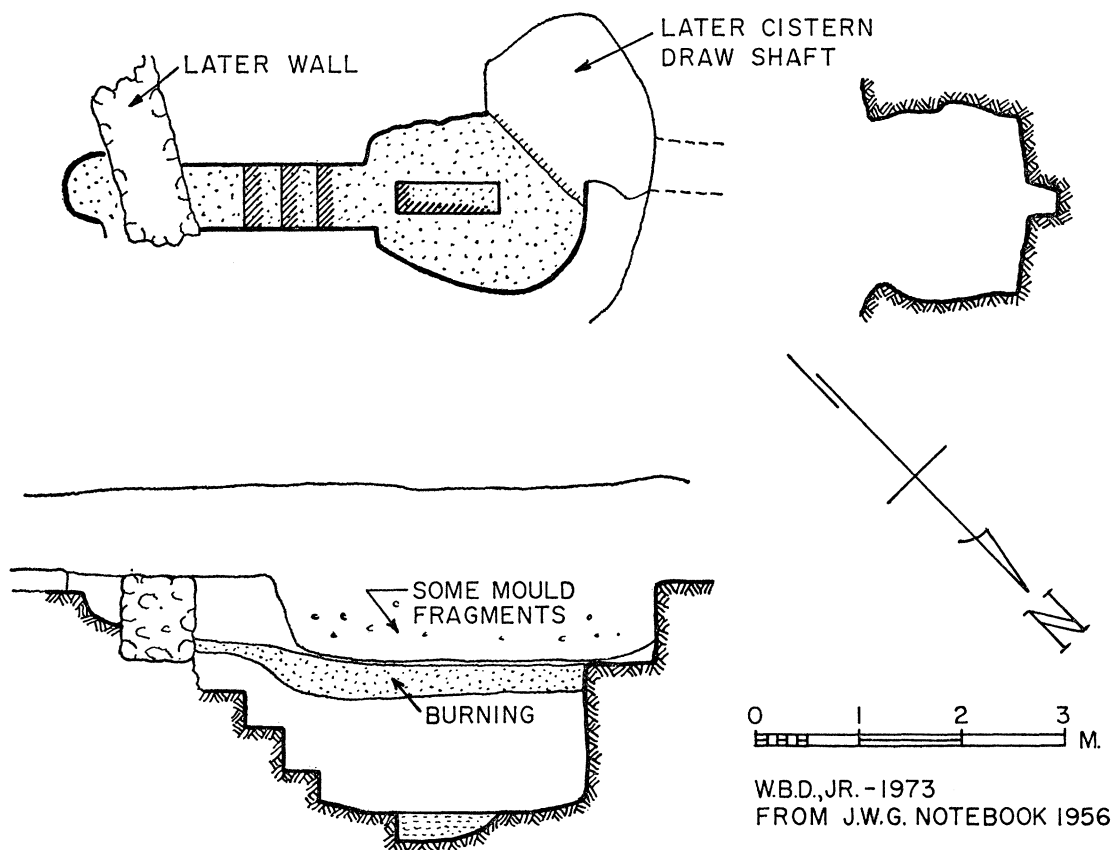


FIG. 3. Keyhole Foundry. Plan and sections.

C. KEYHOLE FOUNDRY. Deposit A 16:1. 350-325 B.C. or slightly later. Fig. 3; Pl. 83. L. 4.80; W. 1.70; D. 1.43; L. (of dromos) 3.10; W. (of dromos) 0.60.

A foundry shaped like a lopsided keyhole was cut into the bedrock outside the southwest corner of the Agora.²³ At the east, five steps led down into a dromos with two angular shoulders opening out into a roughly oval area 1.70 m. long, the north and south walls of which bowed out slightly from the vertical.²⁴ A rectangular cutting

²³ Excavation: J. W. Graham, 1956. Publication: H. A. Thompson, "Activities in the Athenian Agora: 1956," *Hesperia* 26, 1957, pp. 100-101, pl. 28; *Agora XIV*, p. 190. For the date of the deposit, see B. A. Sparkes and L. Talcott, *The Athenian Agora*, XII, *Black and Plain Pottery*, Princeton 1970, no. 830, pp. 132, 383, pl. 33.

²⁴ At the west, the pit wall was destroyed by a later cistern. The east end was built over later with a wall.

in the floor (1.00×0.30 m.), 0.30 m. deep at the east end, sloped upward to the level of the floor at the west end. The rock around the cutting was burned red, but within the cutting the rock was not discolored. The foundry yielded numerous fragments of molds for a life-sized draped statue, some debris associated with the coldworking of the statue, ash, and many pieces of brick.

An iron suspension loop from the fill within the Keyhole Foundry, **C24** (Pl. 86), raises the possibility that the molds were constructed on level ground and lowered into the pit before baking and casting,²⁵ although it probably would have been simpler to construct the molds inside the pit. The baking must have been done inside the pit, for ash and traces of burning were found on the floor. The rectangular cutting may have been intended to collect residual wax as it ran from the mold,²⁶ or to serve as a flue. Bricks found in the casting pit may have formed a base for a wooden partition constructed at the shoulders of the pit for the casting, so that less packing was required around the mold than if the entire pit had to be filled with sand. No traces of the furnace that was used to melt the alloy were found, but it can be assumed that it was constructed on ground level somewhere near by.

The mold fragments from the Keyhole Foundry consist of two layers of clay: the outer layer is coarse and red, with sandy, pebbly, and organic inclusions; the inner layer is finer, but also has some inclusions. The two layers frequently split slightly apart during baking (e. g. **C9**; Pl. 84). The outer layer may be as thick as 0.045 m., but it is normally about 0.025 m., whereas the fine inner layer ranges from 0.003 to 0.025 m. in thickness. Often the inner surface of the inner layer is lost (e. g. **C19**; Pl. 86), having been pulled away with the bronze when the mold was broken up after casting.

Fragments of numerous funnels, gates, Y-gates, and vents are preserved. The diameters of the funnels range widely, from 0.023 m. to 0.225 m., of the gates from 0.008 m. to 0.026×0.016 m. (**C5**, an oval gate; Pl. 83), and of the vents from 0.004 m. to 0.011 m. The gates and vents are usually circular in section, and the vents may be built into the termination of a mold (e. g. **C8**; Pl. 84), or into separately modeled cones (e. g. **C7**; Pl. 84).

An examination of a fragmentary funnel with its gate attached, **C3** (Pl. 83), shows that both funnel and gate were first constructed of very fine clay. The gate was apparently formed around a wax rod, just as is done today, for its circular interior is smooth and regular. The funnel is rough on the interior, and the practice seems to have been to model the funnel freehand, which is not done today. The funnel and gate were roughly coated with one or, as in this case, two layers of coarse, red clay, which reaches beyond the finer inner clay at the lip of the funnel. The lip and funnel were then self-slipped to cover the junction between the two layers of clay

²⁵ A modern hook of this size can lift at least half a ton.

²⁶ Collection of the wax is not necessary, as it is an inexpensive material; today it is normally burned up entirely during baking.

and to make a smooth pouring surface for the bronze. Since a gate sometimes appears alongside a mold surface surrounded by the same layers that form the mold (e. g. B 1189d; Pl. 84), it is clear that, as today, the gate system was constructed entirely in wax and attached thus to the wax model, before the simultaneous investment of the model and the gate system (Pl. 97: a).

Impressions made on the mold fragments by the rasp used to smooth the wax model²⁷ are easily distinguishable from the deep, irregular, random impressions made by the inclusion of organic matter such as straw or hair in the clay fabric of the molds. The different types of rasps and of strokes resulted in various marks on the inner surfaces of the molds: some of the marks are widely spaced and rounded (e. g. **C15**; Pl. 85); others are closely spaced and angular; they may be crosshatched (e. g. B 1189q), or occasionally curving, or simply crossed (e. g. **C14**; Pl. 85); some are short (e. g. **C12**; Pl. 85), and others long (e. g. B 1470). The rasp marks either follow the contours of the inner surface of the mold (e. g. **C16**; Pl. 85), or they cross them (e. g. B 1189o). Two different uses of the rasp may be recorded on one fragment (e. g. **C17**; Pl. 85), or some areas may be rasped and others not (e. g. B 1473). Bronze did not adhere in the rasp marks, as it did in cracks and imperfections in the clay (e. g. **C15**; Pl. 85). Bronze coagulated around the mouths of some of the gates, and it sometimes stuck to the inner walls of funnels (e. g. **C1**).²⁸

Many of the mold fragments are indentifiable: part of an arm, **C9** (Pl. 84), a hand, **C10** (Pl. 84),²⁹ a triangular overfold, **C11** (Pl. 85), a vertical pleat, B 1479, and perhaps even a flesh area from a male back or chest, **C8** (Pl. 84). These pieces, the over-all number of mold fragments, the lack of duplication of types, and the uniformity of the mold fabric indicate that a single draped statue was cast here. Several fragments preserve the ends of molds (e. g. **C8**, **C9**, **C10**, all on Pl. 84, and and B 1484), one, **C9**, for the mid-point of an arm, which proves that the statue was cast in pieces. The natural assumption that the statue was cast hollow by the lost-wax process is supported by the evidence of two mold fragments with traces of chaplets, **C18** (Pl. 85, arrow) and **C19** (Pl. 86, arrow), and of the mold for the arm, **C9**, the core of which is partly in place within the end of the mold. But it is impossible to prove which form of lost-wax casting was used here, even though the absence of the finished edge of a single piece mold might lead us to suspect that it was the direct lost-wax process.

Among the other finds from the workshop were eleven terracotta objects that may be identified as props used to support the molds during baking in the casting

²⁷ The rasp impressions in the clay result from applying the fine, wet, inner layer of investment to the wax after smoothing its surface with a rasp. The same method of smoothing the wax is used by founders today, with the same effect upon the inner mold surface.

²⁸ All of the bronze is corroded to a bright green, and is easily visible.

²⁹ The early 5th century B.C. Berlin Foundry Cup (Staatliche Museen, inv. no. F 2294; Beazley, *Attic Red-Figure Vase-Painters*, 2nd ed., Oxford 1963 [= *ARV*²], p. 400, no. 1) shows a workman attaching a separately cast hand to a statue (Side A, Pl. 98).

pit, **C21-C23** (Pl. 86), B 1457, B 1459. Sometimes triangular (**C22**) or even accordion-shaped (**C21**), these props were no doubt constructed to fit the irregularities of particular molds. Then, after baking, the molds remained in the pit to be packed in sand for casting.

Pumice was used to clean and polish the completed casting. Its presence within a foundry indicates that at least this preliminary stage of the coldworking of the bronze was done at the site of the casting.⁸⁰ Of the four pumice stones from the Keyhole Foundry, **C25** (Pl. 86), ST 813, ST 814, and one uncatalogued,⁸¹ ST 814 is blackened presumably from contact with the scorched casting skin of a bronze. Other finds associated with coldworking can only be identified tentatively. A lead wire with bits of bronze embedded in its one spatulate end, **C26** (Pl. 86), may have served as a material for inlays. A bone fragment, **C27**, and part of a small horn, **C28**, both on Plate 87, may be incidental finds, or they too may have been connected with the extensive coldworking and inlaying that had to be done on a bronze after the removal of the casting skin.⁸²

Despite the quantity of material from this foundry, little can be inferred about the identity of the statue. The mold for an overfold, **C11**, is like the overfolds found in the drapery of both male and female statues. It had already appeared on 5th century works such as the Athena Parthenos, and in the 4th century it is represented on such works as the Apollo Patroos from the Athenian Agora.⁸³ The molds from this foundry thus indicate only that the statue cast here was draped and probably standing: no other general feature can be recovered, neither the pose, nor the sex.

The Keyhole Foundry thus provides evidence for how the wax was worked, how the molds were constructed and supported, and perhaps even how they were lowered into the casting pit. The molds were used to cast a draped figure of life size, probably standing, and apparently conservative in style. The statue was cast in pieces, which were joined after casting. That some of the coldworking was done here is shown by the discovery of the pumice that was used to smooth the surface of the bronze.

⁸⁰ A Nolan amphora in Boston (Museum of Fine Arts, inv. no. 13.188) shows Hephaistos polishing a bronze shield with an object the shape, size, and pitted character of which identify it as pumice. It is mistakenly referred to as a "soft rubber" in L. D. Caskey and J. D. Beazley, *Attic Vase Paintings in the Museum of Fine Arts* II, London 1954, p. 36. See A. Burford, *Craftsmen in Greek and Roman Society*, London 1972 (= Burford, *Craftsmen*), fig. V.

⁸¹ An uninventoried pumice stone from this foundry was analyzed by George Rapp, Jr., and found to be Melian in origin. For pumice types, see G. Rapp, Jr., S. R. B. Cooke, and E. Henrickson, "Pumice from Thera (Santorini) identified from a Greek Mainland Archaeological Excavation," *Science* 179, 1973, pp. 471-473.

⁸² Bone was frequently used for the eyes of statues, and lead for their sockets and lashes. The coldworking of a statue is shown on the Berlin Foundry Cup (Side B, Pl. 98).

⁸³ The overfold of the Apollo Patroos is partly broken away, but its shape can still be distinguished. See *Agora* XIV, pl. 69.

- C1** (B 1189g). Funnel. Pl. 83
 Max. pres. H. 0.159; interior Diam. 0.225; Th. 0.037.
 About two thirds of circumference. Interior self-slipped.
 Large, heavy, ovoid bowl, scorched within towards base, with spots of bronze.
- C2** (B 1456). Funnel. Pl. 83
 Max. pres. H. 0.085; interior Diam. 0.120; Th. 0.034.
 Part of lip and bowl. Interior self-slipped.
 Ovoid funnel, scorched inside towards base of bowl.
- C3** (B 1462). Funnel and gate. Pl. 83
 Max. pres. dim. 0.089; reconstructed interior Diam. of funnel 0.080; D. of funnel 0.048.
 Profile complete. Outer layer of coarse, red clay around second finer layer that in turn folds over similar central layer. Funnel self-slipped.
 Shallow irregular funnel with vertical exterior walls overlaps top of smooth, scorched gate (Diam. 0.020).
- C4** (B 1189c). Funnel and gate. Pl. 83
 Max. pres. dim. 0.151; interior Diam. of funnel 0.072-0.077; D. of funnel 0.036.
 Funnel and part of gate complete. Funnel self-slipped.
 Slightly flaring funnel joins smooth circular scorched gate (Diam. 0.013).
 H. A. Thompson, *Hesperia* 26, 1957, pl. 28: a.
- C5** (B 1454). Funnel with oval Y-gate. Pl. 83
 Max. pres. dim. 0.147; Diam. of funnel 0.065.
 About one third of funnel circumference. Three layers of clay, outer one coarse and red, inner ones smoother. Funnel self-slipped.
 Roughly modeled vertical funnel, scorched within, one smooth, scorched, oval gate (Diam. 0.026×0.016), and traces of second oval gate to form Y-gate. Traces of bronze in preserved gate.
- Non-joining fragment of gate: B 1455.
- C6** (B 1189j). Gate. Pl. 84
 Max. pres. dim. 0.164.
 Section of mold containing gate.
 Circular, scorched gate with very smooth inner surface (Diam. 0.010).
- C7** (B 1189h). Vent. Pl. 84
 Max. pres. dim. 0.092.
 Tip of vent, broken at lower end.
 Cone with center pierced by roughly formed vent (Diam. 0.007). Some scorching and bit of bronze at broken end from near the vent's point of contact with mold surface.
 Similar pieces: B 1189i, B 1453.
- C8** (B 1469). Mold fragment and vent. Pl. 84
 Max. pres. dim. 0.239.
 Broken all around.
 Scorched, slightly concave inner surface with rasp impressions from wax; traces of bronze adhering. Ridges preserved along two edges of mold surface, with fingerprint visible at their angle. Vent (Diam. 0.009) projects diagonally from probable point of junction of edges to exterior of the mold. Preservation of vent and curve of exterior suggest that preserved part of mold composes half of the total profile and that reconstruction requires simply the addition of a second section like this one. Perhaps for an exposed flesh area on back or chest.
 Two similar uninventoried fragments.
 Similar profile: **C10**.
- C9** (B 1189a). Mold fragment for arm Pl. 84 with part of core.
 Max. pres. H. 0.185; Diam. of mold surface 0.090.
 Complete end of mold section and part of walls. Closely packed, fine, buff core.
 Exterior rounded at end, with walls flaring slightly away from it. Scorched mold surface, with clear impressions from rasped wax, preserves ring joining perpendicular walls, undoubtedly endpiece of mold for part of arm, separately cast from rest of arm. Numerous

bits of bronze adhere to imperfections in inner mold surface.

H. A. Thompson, *Hesperia* 26, 1957, pl. 28:a (before mending).

Similar end of mold section: B 1484.

C10 (B 1189f). Mold fragment for Pl. 84 hand.

Max. pres. dim. 0.134.

Broken all around.

Smooth, scorched inner mold surface preserves imprint of backs of four fingers, with joints and nails clearly marked. Bits of bronze adhere throughout. First two fingers have narrow vents (Diam. 0.004 and 0.007) going up to curved edge of mold, no doubt originally repeated in other side of mold. Connecting channel (Diam. 0.005) runs between vents at tips of fingers.

H. A. Thompson, *Hesperia* 26, 1957, pl. 28:a.

Similar profile: C8.

C11 (B 1189s) Mold fragment for Pl. 85 drapery.

Max. pres. dim. 0.247.

Broken all around.

Scorched piece of mold, perhaps for peplos overfold; smooth inner surface.

See Apollo Patroos (Agora S 2154) for same sculptural type: *Agora* XIV, pl. 69.

C12 (B 11891). Mold fragment for Pl. 85 drapery.

Max. pres. dim. 0.179.

Broken all around.

Scorched interior surface has some bronze adhering, as well as rasp marks cutting diagonally across the folds of drapery. Broad marks on exterior made by spatulate tool.

Other drapery: B 1189o, B 1189p, B 1479.

C13 (B 1474). Mold fragment. Pl. 85

Max. pres. dim. 0.125.

Broken all around. Layering unclear.

On interior, concave crosshatched rasped surface. Bronze; scorching. On exterior, parallel marks of toothed tool.

C14 (B 1475). Mold fragment. Pl. 85

Max. pres. dim. 0.086.

Broken all around. Layering unclear.

On interior, flat cross-rasped surface, preserving ends of stroke. Scorching.

C15 (B 1476). Mold fragments for Pl. 85 flesh surface(?).

Max. pres. dim. 0.141.

Broken all around.

Concave, rasp-marked inner surface with many cracks, all filled with bronze. Scorching.

C16 (B 1189b). Mold fragment. Pl. 85

Max. pres. dim. 0.167.

Broken all around.

Concave inner surface with lengthwise rasp marks. Smooth central area. Scorching. Large egg-shaped depression on exterior.

H. A. Thompson, *Hesperia* 26, 1957, pl. 28:a.

C17 (B 1189m). Mold fragment. Pl. 85

Max. pres. dim. 0.111.

Broken all around.

Concave inner surface has both fine, clearly defined rasp marks and rough, widely spaced, irregular ones. Scorching.

C18 (B 1468). Mold fragment for Pl. 85 drapery with chaplet hole.

Max. pres. dim. 0.271; Diam. of hole 0.012.

Broken all around.

Large piece, probably for wide drapery folds, with rasp marks. Much of inner surface pulled away. At one point, circular hole with flat, red-brown bottom may indicate location of iron chaplet. Scorching. Cracks filled with bronze.

Eight similar uninventoried fragments of molds for drapery, without chaplet holes.

C19 (B 1467). Mold fragment with Pl. 86 iron chaplet(?).

Max. pres. dim. 0.133; max. pres. dim. of iron 0.019.

Broken all around.

Inner mold surface lost. At break on one side, badly corroded bit of iron may be remains of chaplet.

C20 (B 1464). Marked mold fragment. Pl. 86

Max. pres. dim. 0.153.

Broken all around.

On interior, surface lacking, and heavy scorching. On exterior, series of straight lines scratched in wet clay with narrow, blunt instrument. Perhaps used as a guide in mold construction.

No known parallels.

C21 (B 1458). Prop. Pl. 86

H. 0.082; max. Diam. 0.130.

Complete but chipped.

Accordion-shaped prop, irregularly flattened at both ends, and higher at one side than at the other.

C22 (B 1460). Prop. Pl. 86

H. 0.114; W. 0.188; L. 0.227.

Profile intact: broken at sides.

Large, flat-bottomed support, roughly triangular in section, sloped towards base on exterior, and hollowed out on inner face to support mold.

Four similar uninventoried fragments. Other props: B 1457 and similar uninventoried piece; B 1459 and similar uninventoried piece.

C23 (B 1461). Prop. Pl. 86

Max. pres. H. 0.142; W. of base 0.147.

Broken at one end.

Flattened resting surface and part of diagonal support, roughly triangular in section. Crudely formed; impressions of fingertips clearly visible on outer surface.

C24 (IL 1420). Iron suspension loop. Pl. 86

L. 0.062.

Intact. Badly corroded.

Bolt (Diam. of head 0.023) with short stem curved to form suspension loop. Perhaps used to hoist completed molds into pit for baking.

C25 (ST 657). Pumice stone. Pl. 86

Max. dim. 0.047.

Intact.

Small, lightweight stone, flattened from wear on several sides, with three angular worn places.

Other pumice: ST 813; ST 814. See footnote 31.

C26 (IL 1414). Lead tool. Pl. 86

L. as bent 0.150.

Intact.

Slender instrument with one flattened, spatulate end; opposite end pointed; square in section. On one side of spatulate end, two dots of bronze are embedded in the incrustation.

C27 (BI 910). Bone fragment. Pl. 87

Max. pres. L. 0.070.

Broken at either end.

Small curving bone, green from contact with corroded bronze.

C28 (BI 911). Horn fragment. Pl. 87

Max. pres. L. 0.135.

Broken towards base.

Part of small curved horn, green from contact with corroded bronze. Burned patches on one side towards base.

D. INDUSTRIAL FOUNDRY. Deposit E 6: 5. 4th century B.C. Pl. 87. L. 0.80; W. 0.35; D. 0.15.

Next to the southwest corner of the "Arsenal", on the north slope of Kolonos Agoraios, three roughly circular, flat-bottomed terracotta molds were set close beside one another within a pit just large enough to accommodate them.³⁴ The molds were tightly packed around with fine sandy earth for the casting.

On top of the best-preserved mold, **D1** (Pl. 87), the inner mold surface begins

³⁴ Excavation: H. A. Thompson, 1937. Publication: *Agora* XIV, p. 189, note 89.

to curve over, indicating that a ring-shaped object was cast from it. The other two molds evidently produced similar bronze rings. Each of these was *ca.* 0.200 m. in exterior diameter, circular in section, and *ca.* 0.015 m. thick. The size of these bronze rings suggests that they may have been rings for door handles. If this is the case, the three molds represent a form of mass production, otherwise unattested in the Athenian Agora.³⁵

Each of the ring-forms was set at an angle within the mold, presumably so that the wax and excess bronze could run downwards and out through the spout provided at one side. Unfortunately, no traces of the gate system have been preserved. But the fine earth that was found packed firmly around the molds was undoubtedly used to secure and insulate them during the pour.

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| <p>D1 (B 1496). Fragment of mold for bronze ring. Pl. 87</p> <p>Max. pres. H. 0.123; Diam. 0.200-0.210.</p> <p>Top of mold and gate system lost. Smooth inner layer and core; coarse, red, crumbly outer</p> | <p>layer. Exterior plastered for preservation.</p> <p>Flat-bottomed mold for ring-shaped object (Diam. 0.155), with spout at one side for removal of wax. Scorching.</p> <p>Two similar uninventoried molds.</p> |
|---|--|

E. IRONWORKS. Deposit E 2: 3. Mid-4th century B.C. L. of pit 5.00; W. 1.50; D. 0.65.

A workshop that was probably an iron smithy was excavated at the north foot of Kolonos Agoraios.³⁶ The smithy was located in an open courtyard which had slag, ash, and charcoal mixed with black earth on its packed clay floor. The same materials were concentrated more heavily in a large pit in the floor.

Lightweight vitrified black slag with some poros white-to-green parts (e. g. B 1575) was found here; also found were heavy iron-bearing slag with black vitrified parts (e. g. B 1576), many rough lumps of iron slag with sluggish gray-to-mauve drippings (e. g. **E2**, **E3**, and B 1577), and a single hemispherical lump of iron-bearing slag, **E1**.³⁷ No tools were found to suggest what was actually produced in

³⁵ Another example of mass production was excavated at Olympia, also in a 4th century B.C. context. A series of three clamps was cast in a row within a single mold, with the intention that they be separated after removal from the mold, but this was never carried through because the casting failed (Olympia inv. Br. 1113). See W.-D. Heilmeyer, "Giessereibetriebe in Olympia," *Jahrb* 84, 1969, p. 18, fig. 23 on p. 17.

³⁶ Excavation: H. A. Thompson, 1939. Publication: T. L. Shear, "The Campaign of 1939," *Hesperia* 9, 1940, p. 300; D. B. Thompson, "Mater Caelaturae: Impressions from Ancient Metal-work," *Hesperia* 8, 1939, pp. 285, 289-290; *Agora* XIV, p. 188.

³⁷ This kind of slag, in which brown coloring and slight magnetism establish the presence of iron, appears in iron- and bronzeworking establishments and dumps of the Classical and Hellenistic periods, particularly in the area between the Southwest Fountain House and the Great Drain, but I have not been able to explain it. It is probably not tap slag (that is, slag that is drained from the bottom of the furnace into an adjacent hole), because it is not viscous, but rough and granular. Nor does it appear to be material left over from the bottoms of crucibles, again because it is not viscous, and because the fairly small size and hemispherical bottom do not match the large, shallow,

this smithy, but a clay impression from the cheek-guard of a helmet, T 1931, indicates that bronze as well as iron was worked, and one might suspect that this was an armorer's shop.

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| <p>E1 (B 1578). Iron slag. Pl. 87
 H. 0.049; L. 0.119; W. 0.114.
 Intact.
 Brown, roughly hemispherical lump of iron-bearing slag.</p> | <p>Much similar uninventoried material.</p> |
| <p>E2 (B 1579). Iron slag. Pl. 87
 Max. pres. dim. 0.109.
 Broken at one side.
 Heavy fragment of slag consisting of dull black, smooth, sluggish drips.</p> | <p>E3 (B 1581). Iron slag. Pl. 87
 Max. pres. dim. 0.197.
 Large fragment consisting of smooth, sluggish, gray-to-mauve drips, turning pink at ends, and projecting from irregular, rough, orange-to-brown iron-bearing lump. Heavy.
 Much similar uninventoried material. Also lightweight slag: B 1575, B 1580.</p> |

F. CISTERN. Deposit E 6: 3. Late 5th to 4th century B.C. Diam. at rim 1.27; D. 4.00 m.

Ten meters to the north of the Hephaisteion and within its precinct, a partly unplastered flask-shaped cistern contained a 0.50 m. thick layer of mud bricks above a 1.00 m. thick layer of ash, charcoal, and more mudbrick.³⁸ A large solidified mass of iron-bearing waste, approximately 1.20 m. across and 0.40 m. high (IL 633) was removed from the center of the cistern's floor. The contents and location of this cistern indicate that it may have served as a dump for the nearby 4th century B.C. Ironworks (E), although the date of the cistern may be slightly too early.

G. TWO IRREGULAR CUTTINGS. Deposit F 5: 5-6. 4th to 3rd centuries B.C. Pl. 88.

Cutting A: L. 0.90; W. 0.75; D. 0.75.

Cutting B: L. 0.90; W. 0.68; D. 0.40.

Two irregular oval holes were cut side by side in the bedrock to the northwest of the "Arsenal", on the north slope of Kolonos Agoraios.³⁹ The first (A) is reported to have contained iron waste and tiles in the upper fill, and charcoal and ash in its lower fill. Tiles, stones, and mudbrick seem to have been built into the lower fill to serve as packing for a flat-bottomed, roughly round mold, of which the outer layer of the lower portion, **G1**, is preserved. The mold lay as it had been packed for casting, as was the case with the molds in the Industrial Foundry (D).

The second cutting (B) was shallower than the first. The proximity of the two pits suggests that this one may have been a dump for the other, but the iron-bearing

flat-bottomed crucibles found in the Agora, all but one of which, **H10**, unfortunately date from the Roman period. For crucibles and crucible deposits, see **L2**, **M8**, **M9**, B 1007, B 1011, P 22795, P 30199.

³⁸ Excavation: D. B. Thompson, 1936. Unpublished.

³⁹ Excavation: D. B. Thompson, 1937. Unpublished.

slag and the lead that were scattered through the fill do not necessarily support its relationship to a casting pit for bronze.

G1 (B 1559). Mold fragment. Pl. 88

Max. pres. H. 0.071.

Part of outer layer of mold, plastered outside for preservation. Coarse, red, crumbly clay.

Flat-bottomed mold with slightly curving lower walls.

H. MUDBRICK FOUNDRY. Deposit C 9:18. Late 4th to early 3rd centuries B.C.
Fig. 4; Pl. 89. Mudbrick structure: L. 5.90; W. 2.12; D. 1.65.

About thirty meters southwest of the Hephaisteion, a pear-shaped structure was set into a pit cut to a depth of 1.65 m. in the bedrock.⁴⁰ The structure had an east-west orientation, and an opening in the narrow west end. Mudbrick walls lined the bedrock, and rested on a leveling course of tile fragments above a socle of small stones, together 0.51 m. high. The south wall, the stone socle of which rested on a lower bedrock ledge, was preserved to a height of 2.25 m.

Two floor levels were preserved, the lower one (1.10 m. above bedrock) of earth, and the upper one (1.25 m. above bedrock) of square, unbaked tiles. Fill under both floors yielded fragments of molds, small props, bronze drips, splatters and slag, hemispherical lumps of iron-bearing slag, fragments of mudbrick, and traces of burning. On the bedrock itself lay cinders, broken mudbrick, a few mold fragments, and some bronze. Three shallow pits were cut into the bedrock floor, one near the north wall, a second near the center of the structure, and the third towards the east end. The floor around these holes was discolored by burning.

At the east, beyond the preserved mudbrick wall, and immediately beyond the later drain, was a roughly rectangular cutting in the bedrock (L. 1.20; W. 0.70; D. 1.15), the bottom of which was about 0.50 m. higher than the floor in the mudbrick structure. A second cutting extended 1.80 m. beyond this one to the east (W. north-south 2.12; D. at east 2.00): its bottom was higher than that of the other cutting, being roughly even with the uppermost floor of the mudbrick structure, about 1.25 m. above its bedrock floor. The fill in both cuttings resembled that in the mudbrick structure, for it contained lumps of bronze, vitrified clay, bits of molds, and fragments of roof tiles, with a heavy layer of ash and cinders at the bottom.

Although there are quite a few mold fragments from the Mudbrick Foundry, most of them are nondescript (e. g. **H4**, **H5**, B 1420, B 1424-B 1426, B 1430-B 1433) and only one is recognizable as a mold for widely spaced drapery folds, **H6** (Pl. 90). One other small mold fragment, B 1442, may also be for drapery.

⁴⁰ Excavation: R. S. Young, 1936. Publication: T. L. Shear, *Hesperia* 6, 1937, pp. 342-344; *Agora* XIV, p. 190.

The rounded east end of the Mudbrick Foundry was later cut through by a terracotta water channel running north-south.

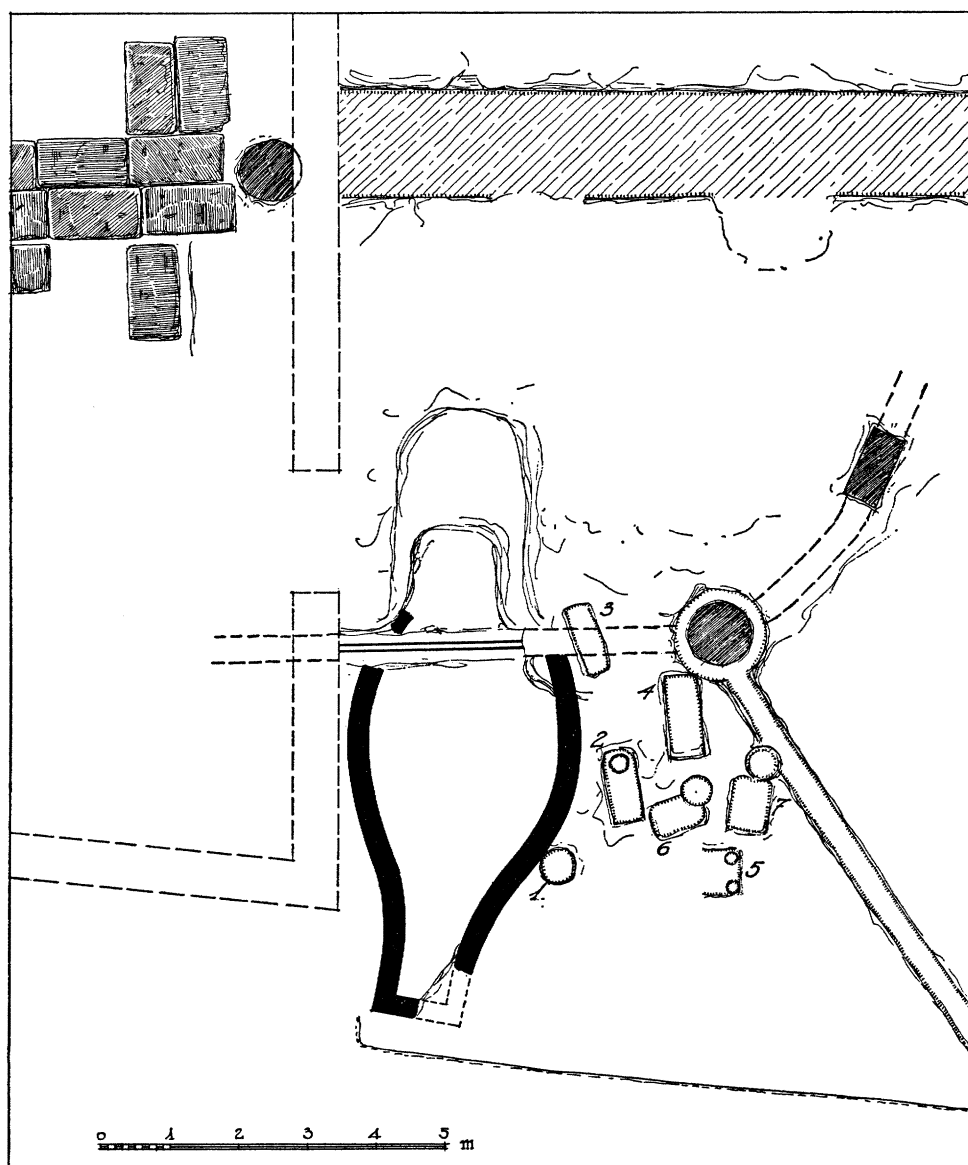


FIG. 4. Mudbrick Foundry. Plan (J. Travlos).

Both wide (**H5**; Pl. 90) and fine (B 1442), rasp-marked mold surfaces are preserved, but other molds have simply rough (B 1426) or smooth (B 1431) inner surfaces. On the backs of pieces of which the inner layer alone is preserved are finger impressions, made to improve the adhesion between layers (**H4**, **H6**; Pl. 90).⁴¹

Although the molds themselves provide little evidence for the kind of casting done here, the fragmentary gates are easily large enough to cast statuary, ranging in diameter from 0.008 m. (**H1**, B 1422) to 0.030×0.016 m. (B 1421). The funnels, however, all have much smaller diameters than those from the Keyhole Foundry (C), the largest being only 0.082 m. across.

The most unusual finds from the Mudbrick Foundry are fifteen small clay props, a number of which are intact or nearly so (e. g. **H7**, **H8**, both on Plate 90, and B 1440). They were crudely constructed, normally around sticks, the impressions of which have been left in the clay, as shown in the latex impression of **H8** (Pl. 90). The sticks may have been used to reinforce the wet clay, giving the small props the strength to support the molds during the earliest stages of baking. As the baking progressed and the props dried and hardened, the then unneeded sticks would be burnt out.⁴²

Of the many badly corroded bits of bronze from the Mudbrick Foundry, some can be identified as drips and splashes from the pour, and one piece retains the shape of the gate down the outside of which it must have spilled.⁴³ A single crucible fragment which was found outside the Mudbrick Foundry, **H10** (Pl. 90), is easily distinguishable from funnels by its heavily burned surface, covered thickly with bronze, by its shallowness, and by its wide mouth. The lightweight vitrified material from this foundry, often with bits of bronze adhering, appears to be slag which was removed from the surface of the melt (e. g. B 1434). Five hemispherical lumps of iron-bearing slag were also found (e. g. B 1417) and fragments of at least nine clay bellows nozzle coverings (e. g. **H9**, Pl. 90; B 1437, B 1441).⁴⁴ Finally, an uninventoried piece of lead wire is reminiscent of the lead tool from the Keyhole Foundry, **C26** (Pl. 86), and may have been used in coldworking.

The large mudbrick structure served as both working area and casting pit: most of the mold fragments were found here, as well as quite a bit of bronze, usually in the form of drips or splatters. The three irregular pits that were cut in the bedrock may well have held molds, but the fact that only the floor around them is burned suggests that the holes may instead have been intended to collect molten

⁴¹ The pieces of molds can be compared with those from the Archaic Foundry on which the backs were scored with a small spatulate instrument, also to promote adhesion between the layers of clay, as B 1540 (Pl. 78).

⁴² The props are much smaller than those from the Keyhole Foundry, **C21-C23**, and could not have supported large molds.

⁴³ This piece was not inventoried, as it was badly disfigured during cleaning.

⁴⁴ A few bronze shield fragments (e. g. B 504), made of thin hammered bronze, may represent scrap metal collected at the foundry for remelting.

wax. It is also possible that both stages took place here, and that after baking the molds were packed into these holes to secure them during the pour. The two floors in the mudbrick building lay on top of the packing around the molds, and it can be assumed that the pouring of the molten bronze took place from here.

The central cutting, along with the adjacent mudbrick structure, may have been used as an additional casting pit: it is deeply cut into the ground, to approximately the same level as the bedrock bottom of the workshop. Although there are no traces of burning on the walls of this pit, a layer of ash and charcoal found at its bottom may have been left over from the baking stage. The fill contained a few fragments of molds, lumps of bronze, bronze slag, and bits of the coverings for bellows nozzles.

Since the heaviest traces of burning were found in the easternmost cutting, as well as bronze waste, iron-bearing slag, and vitrified bellows nozzle coverings, perhaps we can assume that the furnace was located here. Besides, the pit lay at the same level as the upper floor in the workshop, which would have facilitated maneuvering the molten metal between the furnace and the molds.

After the molds were baked, the central cutting was packed with earth to about the same level as the floor of the mudbrick structure, so that the crucible could be lifted from the furnace at the east and poured easily down into the funnels of the molds packed into the two areas at the west.⁴⁵ After two periods of use, both in the late 4th to the early 3rd centuries, the Mudbrick Foundry went out of use, and the complex was filled in and spread over with its own casting debris.

H1 (P 8780). Funnel and two gates. Pl. 88

Max. pres. H. 0.176; Diam. of funnel at rim 0.075.

Funnel and parts of two gates. Two layers of pink clay; funnel self-slipped.

Roughly ovoid funnel, reddish inside, with circular scorched gate at its base (Diam. 0.018), and smaller gate (Diam. 0.008) branching off at a sharp angle from the first.

Four uninventoried funnel fragments.

H2 (B 1418). Funnel and gate. Pl. 88

Max. pres. H. 0.094; Diam. of funnel at rim 0.045-0.050.

Most of funnel and gate. Coarse, red clay outer layer around finer inner layer.

Funnel with traces of bronze in bowl joins partially scorched smooth circular gate (Diam.

0.012). Flattening on one outer side for attachment to mold.

H3 (B 1419). Funnel and gate. Pl. 88

Max. pres. H. 0.099; Diam. of funnel at rim 0.045.

Part of funnel and split gate. Coarse, red clay divided from finer inner layer; funnel self-slipped.

Partly scorched funnel joins smooth circular gate (Diam. 0.016). Gate blackened, with bronze in crack at its lip.

H4 (B 1427). Mold fragment. Pl. 90

Max. pres. dim. 0.118.

Broken all around. Inner layer only.

Hard, scorched interior with widely spaced marks of large rasp. On back, impressions from pressing clay onto wax by hand.

⁴⁵ The closely knit arrangement of this workshop is seen in foundries even today, both because the pouring of the molten metal must be done quickly to prevent its congealing, and because molten metal is too heavy, precarious, and hot to carry for more than a few steps.

- H5** (B 1429). Mold fragment. Pl. 90
 Max. pres. dim. 0.042.
 Broken all around. Crumbly outer layer of clay; finer inner layer.
 Interior scorched concave channel has widely spaced marks of large rasp.
- H6** (B 1428). Mold fragment for Pl. 90
 drapery.
 Max. pres. dim. 0.084.
 Broken all around. Layering unclear.
 Scorched, undulating inner surface. On back, parallel finger impressions.
 Uninventoried fragment with similar fingermarks. Other mold fragments inventoried: B 1420, B 1424-B 1426, B 1430-B 1432, B 1442, B 1443.
- H7** (B 1438). Prop. Pl. 90
 H. 0.100.
 Intact. Coarse, reddish clay.
 Roughly rounded, vertical prop with waist, having flat resting surfaces at both ends, at slight diagonal to one another. Interior hollow and roughly rounded in section. On exterior, fingermarks.
 Twelve similar uninventoried pieces, mostly fragmentary, from fill in the area of the foundry.
- H8** (B 1439). Prop. Pl. 90
 Max. pres. dim. 0.140.
 Broken at either end. Coarse, reddish clay.
 Roughly rounded support with fingermarks on exterior. Impression taken from interior shows prop to have been formed around dry knotted stick with peeling bark.
- H9** (B 1436). Covering for bellows Pl. 90
 nozzle.
 Max. pres. dim. 0.063.
 Mended from two pieces, one from beneath floor of foundry, the other from furnace cutting to east of foundry. Coarse, red clay.
 Concave channel backed by shiny black vitrified clay which forms drips at mouth of channel.
 Two similar fragments: B 1437, B 1441.
- H10** (B 1562). Crucible fragment. Pl. 90
 Max. pres. dim. 0.155.
 Part of rim. Coarse, red clay. Heavily burned, flat rim, mostly covered with a thick, irregular layer of bronze, dripping towards the edge.

Fill like that from within the Mudbrick Foundry was excavated throughout the surrounding area. 4th century B.C. levels in the region yielded charcoal, bronze drips, slag, fragments of mudbrick, and small props like those from the foundry. 2nd century (after Christ) burned fill near by (Deposit C 9: 1) contained a well-preserved funnel. P 8145, the coarse, red gritty fabric of which is the same as that of mold fragments from the Mudbrick Foundry. In addition, a single piece of a crucible, **H10**, was discovered in fill near the foundry.

I. MANHOLE. Deposit C 8: 1. 1st century B.C. Hellenistic. D. 2.95.

A manhole southwest of the Hephaisteion precinct may also have received some of the trash from the Mudbrick Foundry.⁴⁶ It yielded lead, bronze (e. g. B 1556), and iron, some slag (e. g. B 1547 and B 1548), pieces of three or four lead clamps, vitrified clay from a metallurgical furnace, a piece of bronze wire, B 1557, perhaps used in coldworking, and a fragment of wavy hair from the head of a bronze statue, **I1**.

⁴⁶ Excavation: D. B. Thompson, 1936. Unpublished.

Fill over the manhole contained more metallurgical debris, including a Y-gate preserved in bronze, **I2**, a fragment of a bronze blade, B 1550, and a clay prop, B 1549, like those from the Mudbrick Foundry. Several large lumps of iron-bearing slag, one of which is hemispherical, that were found here are also like pieces from

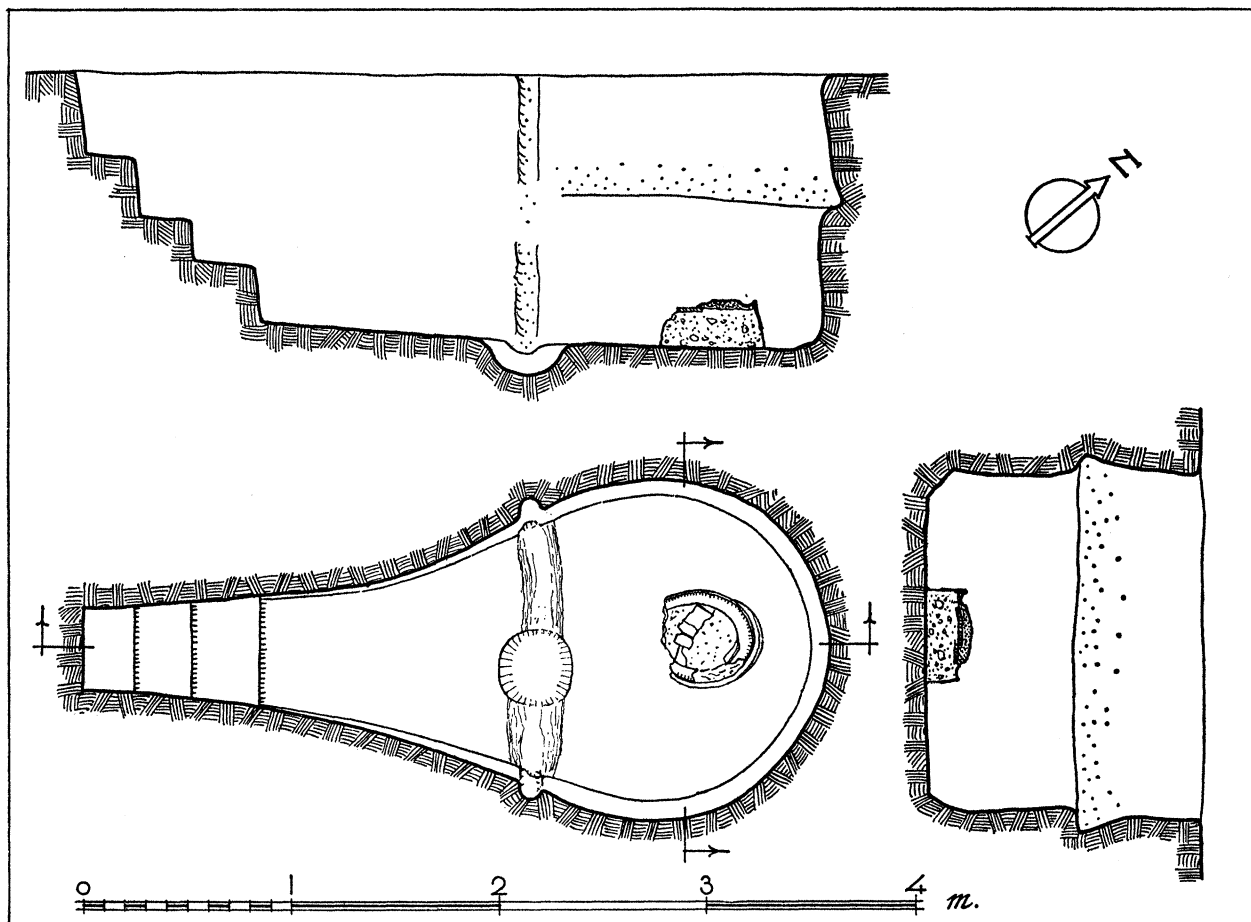


FIG. 5. House H Foundry. Plan and sections (J. Travlos).

the foundry itself. It is tempting to propose that the fragment of wavy bronze hair from the Manhole came from a statue cast in the Mudbrick Foundry.

I1 (B 1558). Fragment of hair from Pl. 91
head of bronze statue.

Max. pres. dim. 0.044; Th. 0.004-0.005.

Broken all around. Bronze.

Section of head with wavy locks from life-size statue; hair worked with a graver.

I2 (B 1249). Bronze Y-gate. Pl. 91

Max. pres. dim. 0.105; Diam. 0.010.

Broken at either end.

Solid left-over bronze from within Y-gate.

J. HOUSE H FOUNDRY. Deposit C 19:3. Second half of 2nd century B.C. Figs. 5, 6; Pl. 91. L. at ground level 3.78; L. at bottom of steps 2.68; W. at bottom of steps 0.45; max. W. of floor 1.70; D. 1.28.

On the west slope of the Areopagus, beneath Room 13 of House H, a flask-shaped foundry was cut to a depth of 1.28 m. in the bedrock.⁴⁷ At the south, three steep, narrow steps led down to the floor. In the wide north end of the pit a roughly

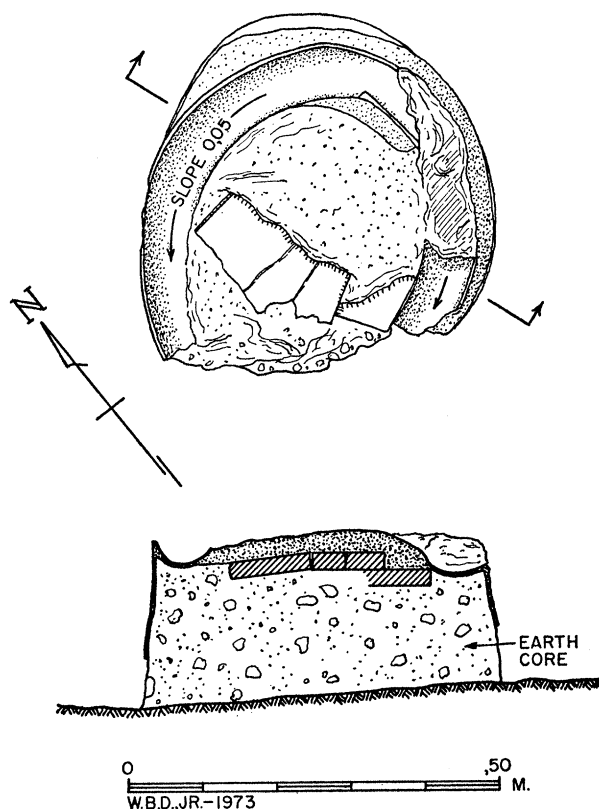


FIG. 6. House H Foundry, mold base. Plan and section.

round hole was cut in the floor (L. 0.38; W. 0.34; D. 0.18); grooves cut to the east and west of the hole continued vertically up the walls. In addition, a horizontal slit was cut around the east, north, and west walls, 0.60 m. above the floor.

An oval construction of tiles and terracotta, no doubt the base for a mold, was located on the axis of the foundry, 0.34 m. from its north end (max. pres. dim.

⁴⁷ Excavation: R. S. Young, 1947. Publication: H. A. Thompson, "The Excavation of the Athenian Agora, Twelfth Season: 1947," *Hesperia* 17, 1948, pp. 170-172, fig. 7; R. S. Young, *Hesperia* 20, 1951, p. 269, fig. 1 on p. 136; *Agora Guide*², pp. 115-117; *Agora* XIV, pp. 189-190, fig. 48, pl. 97: c.

The rounded north end of the pit lies partially beneath the north wall of Room 13.

0.44 × 0.43 m.; H. 0.25 m.). The base consisted of a thin outer wall of coarse, baked clay around a core of tile fragments and earth packing. A concave, scorched terracotta channel, 0.060-0.070 m. wide, followed around the top edge of the base, sloping down towards the south. Scorched terracotta that lay on the east side of this base may have been part of a mold. The floor around the base was burned.

The House H Foundry yielded mudbrick, charcoal, and a few small fragments of molds. Similar material and furnace debris were scattered throughout House H and the area to the north of it. The mold fragments are in poor condition and are unidentifiable (e. g. **J1**; Pl. 91), so that, although the casting pit is one of the largest in the region of the Agora, the molds give no idea of what was cast here. Three gates from the surrounding area, having the same fabric as the molds from the pit itself, are large enough in diameter to have been used for large-scale casting (two of them have the same diameter of 0.012 m.). From this evidence, from the size of the casting pit, and possibly also from the proportions of the mold base, it can be assumed that large-scale castings were produced here.

Both lightweight bronze slag (e. g. **J2**), which was apparently skimmed from the surface of the molten metal, and heavy, hemispherical iron-bearing slag (e. g. B 1531)⁴⁸ were found around the casting pit, as well as numerous fragments of the clay coverings for bellows nozzles (e. g. **J3**). Bricks from the fill of the casting pit (e. g. B 1524) were apparently used in the construction of the furnace, and may have been originally coated on their inner faces with a layer of clay which served as a protective lining, and which vitrified during the melt (e. g. **J4**; Pl. 91). The mud bricks themselves did not usually vitrify (**J5**, Pl. 91, is an exception), but apparently split away from their facings.⁴⁹

The presence of a pumice stone, B 1522, shows that some coldworking was done at the casting pit. A spiraling bronze wire, B 850, could have been used for inlays, but there is no proof of this.

The foundry was entered by the steps in the south end. The mold base at the north was probably constructed within the casting pit. The curving channel on top of it, sloping downwards to the south, may have been intended to serve as a runoff channel for wax during baking. The burned floor around the mold base further suggests that the baking took place here.

The vertical slots in the walls of the foundry could have held a wooden partition, erected to cut off the relatively small north end of the casting pit for packing the molds,⁵⁰ and the hole in the floor could have contained a post, but there is no direct

⁴⁸ Compare **E1** from the Ironworks. Other examples: B 1417 and uninventoried masses of slag from Well K 16:1(U).

⁴⁹ The bricks and their vitrified facings are flat. See below for curved vitrified bricks from this foundry.

⁵⁰ Brick crosswalls were discovered in an unpublished casting pit located outside the southwest corner of the Olympieion precinct, excavated by John Travlos in 1939. Mr. Travlos kindly showed me photographs of the pit.

evidence for this. Horizontal partitions might have been placed in the slots around the walls of the pit to further reduce the space to be packed with earth around the molds, but the slots may be explained more simply as breakage in the bedrock that occurred during the construction of the pit.

Traces of the furnace come primarily from the surface fill directly north of the foundry, where the furnace probably stood. A few bits of bronze, fragmentary bricks, slag, and pieces of vitrified clay facing from bricks (e.g. B 1560), were found here. The fill also contained many pieces of thin, curved bricks with one vitrified surface and a concave lower edge. Such bricks, commonly found with metal-working debris of the Roman period,⁵¹ were apparently used to line the interiors of cylindrical furnaces. Their peculiar construction, with one concave edge and one flat-to-convex edge, was no doubt intended to ensure a tight fit. The fact that some of the vitrified bricks from the House H Foundry are curved, whereas other bricks and brick facings are flat (e.g. **J4**, Pl. 91; B 1560), might mean that this furnace had a rectangular base and a cylindrical shaft.⁵²

J1 (B 1523). Mold fragment. Pl. 91

Max. pres. dim. 0.051.

Broken all around. Powdery, red clay exterior; hard interior. Layering unclear.

Scorched, concave interior surface with rasp marks.

One other inventoried mold fragment: B 1528.

J2 (B 1525). Bronze slag. Pl. 91

Max. pres. dim. 0.067.

Intact.

Heavy, bubbly mass, green to glassy brown and black. Probably skimmed off molten metal.

Numerous similar uninventoried pieces.

J3 (B 1526). Covering for bellows nozzle. Pl. 91

Max. pres. dim. 0.071; reconstructed Diam. 0.060.

Broken at sides.

Reddish clay channel covering with black glassy vitrification on exterior, ending in long drip. Traces of bronze.

Many similar uninventoried fragments.

J4 (B 1529). Vitrified clay facing. Pl. 91

Max. pres. dim. 0.123.

Broken at one side.

Brown-to-black, vitrified, flat piece of clay, ridged at two opposite sides, and forming drip at one end. Originally attached to flat object *ca.* 0.060 m. wide. Probably lining for inner face of brick in furnace.

Several similar uninventoried fragments as well as B 1560.

J5 (B 1530). Vitrified brick fragment. Pl. 91

Max. pres. dim. 0.092; Th. 0.058.

Broken all around.

Black, vitrified surface contains drops of bronze. Probably from inner face of brick-lined furnace.

The House H Foundry is the latest metallurgical workshop of the Greek period that has been excavated in the region of the Agora. Although a few dumps can be

⁵¹ **M12** and B 1498 from the Oval Workshop M; **L4** from South Square Debris L; B 1611 and B 1612 from Slag Pit W.

⁵² Compare pottery kilns shown on Penteskouphia plaques, as those illustrated in J. V. Noble, *The Techniques of Painted Attic Pottery*, London 1966, figs. 231, 235.

dated before the Herulian invasion, all of the later metalworking installations are post-Herulian, i. e. after A.D. 267.

K. "HELIAIA" METALWORKS. Deposit I-J 14-15. 3rd to 4th century after Christ or later.

After the destruction of the "Heliaia" during the Herulian invasion of A.D. 267, bronzeworking establishments were installed in the area. The debris from them was spread over the entire southern half of the peristyle of the "Heliaia" and eastward above the floor of the South Stoa.⁵³ The fill covering the area contained bronze slag (e. g. B 1544) and many bits of waste matter, perhaps drips from the pour, consisting of alternating layers of corroded bronze and red clay with charcoal adhering to them (e. g. B 1546). Also found were part of a large crucible with a vitrified interior and a trace of bronze on the lip, P 30199, solid bronze, perhaps a spill from a crucible, **K3** (Pl. 92), and bellows nozzles, now made of re-used amphora necks (e. g. **K1**, **K2** (Pl. 92)).⁵⁴ Finally, two fragments of a draped bronze statue, **K4** (Pl. 92), and one of gilded bronze, B 1256, probably also from a statue, were excavated in this area.

No actual casting pits were found here. Instead, it appears that the statue fragments were meant for the melt, and that the installations here were used not to cast statuary but to melt down available bronze that survived in the Agora.

K1 (P 23258). Bellows nozzle. Pl. 92

Max. pres. H. 0.075.

Upper neck and rim of amphora. Coarse, red clay.

Upper neck thickly coated with rough, bubbly mass of bronze and bronze slag. Re-used as bellows nozzle.

Amphora type of late 3rd century after Christ and later.

K2 (P 30198). Bellows nozzle. Pl. 92

Max. pres. H. 0.159.

Neck and part of rim of amphora. Coarse, red clay.

Wheel-ridged neck with scorching; slag on rim.

Six similar uninventoried fragments.

K3 (B 1545). Bronze waste. Pl. 92

Max. pres. dim. 0.055.

Heavy, solid mass of bronze with bits of charcoal embedded.

Similar uninventoried fragments. Lightweight bronze slag: B 1544.

K4 (B 263a, b). Bronze statue fragments. Pl. 92

Two non-joining fragments.

a. Max. pres. dim. 0.126; Th. 0.002-0.003. Lower end of drapery fold, broken above. Fine black patina.

b. Max. pres. dim. 0.160. Heavy flat piece of bronze, broken all around. Badly corroded.

⁵³Excavation: J. H. Oliver, 1953. Publication: H. A. Thompson, "Excavations in the Athenian Agora: 1953," *Hesperia* 23, 1954, p. 33; *Agora* XIV, p. 190.

⁵⁴These only appear in post-Herulian deposits: South Square Debris, **L3**; Oval Workshop, **M10**, **M11**. They represent a complete change from the roughly modeled clay coverings for bellows nozzles used during earlier periods, e. g. **A5**.

L. SOUTH SQUARE DEBRIS. Deposit O-P 15:1. Late 3rd to 5th centuries after Christ.

Finds similar to those from over the "Heliaia" (K) came from various other locations in the South Square area.⁵⁵ Frequently discovered remains include bellows nozzles made of re-used amphora necks (e. g. **L3**; Pl. 92),⁵⁶ fragments of furnace lining (e. g. **L4**),⁵⁷ pieces of crucibles (e. g. B 1011 and P 22795) and of the metal deposits from them, (e. g. **L2**),⁵⁸ some of which preserve the shape of the crucible's spout. The only mold fragment from this area, **L1** (Pl. 92), is unique among the Agora finds because it contains a bronze chaplet intact.

Fragments of four bronze statues were also excavated in the area of the South Square, **L5**, B 994, B 1005, and B 1342. Holes for now-lost patches in several of the pieces (e. g. **L5**, Pl. 92; ⁵⁹ B 1342a) indicate that these were not unfinished bronzes that were discarded because of failed castings, but statues that were completed and erected. Thus we can assume that the late metalworkers who were active throughout this area were not producing new statues, but were instead dismantling old ones. The objects produced from the remelted bronze were probably utilitarian, and may be represented in part by a spike, B 1232, and a small spatulate tool, B 977.

L1 (MC 915). Mold fragment with chaplet. Pl. 92

Max. pres. dim. 0.037.

Mold broken at one side. Coarse, red clay.

Part of mold, scorched on interior, for cylindrical-to-conical object. Tapering chaplet, round in section, embedded in mold.

L2 (B 981a-d). Fragments of metal deposit from crucible. Pl. 92

Four fragments of dark gray, heavy metal deposit from crucible, with white-to-red, hard accretion on side that contacted crucible. Two fragments preserve filling from narrow spout of crucible (b, d).

Other crucibles and heavy metal deposits: B 1007, B 1011, P 22795 (bronze and lead?).

L3 (B 1598). Bellows nozzle. Pl. 92

Max. pres. H. 0.238.

Upper shoulder and neck of amphora. Coarse, red clay.

Slightly tapering amphora neck with hole near base. Upper part of neck and rim heavily coated with brown-to-black slag containing bits of bronze.

A number of similar uninventoried fragments. A small terracotta tube, intact, may have been intended to be a bellows nozzle, but was never used as such: MC 1149.

L4 (P 22794). Furnace lining. Pl. 92

Max. pres. dim. 0.120; Th. ca. 0.025.

Broken at one end.

⁵⁵ Excavation: M. Crosby, 1952, 1954. Unpublished.

⁵⁶ For similar bellows nozzles, see footnote 54 above.

⁵⁷ Similar furnace lining has been found in Hellenistic and Roman contexts: House H Foundry, uninventoried fragments; Oval Workshop, **M12**, B 1498, B 1505; Slag Pit W, B 1611, B 1612.

⁵⁸ Compare other crucibles and crucible deposits: Mudbrick Foundry, **H10**; "Heliaia" Metalworks, P 30199; Oval Workshop, **M8**, **M9**.

⁵⁹ The stump of a bronze chaplet with a diameter of 0.003 m. is visible on the interior of this fragment (Pl. 92 at arrow). But the chaplet fused with the poured bronze during casting, so that it is invisible on the exterior of the fragment.

Curved brick with concave lower edge.
Vitrified concave inner surface.

Four similar non-joining fragments with heavy traces of bronze were not inventoried.

L5 (B 1004). Fragment of bronze statue. Pl. 92

Max. pres. dim. 0.073; Th. 0.003-0.009.

Broken all around.

Fragment of heavy casting, perhaps from angle of neck and chin of statue. Three rectangular holes for patches; bronze chaplet protrudes on interior (Pl. 92, at arrow).

Other statue fragments: B 994a-f, B 1005 a, b, B 1342a, b.

Other bronze objects: B 1232.

M. OVAL WORKSHOP. Deposit L 14: 1. Late 4th century after Christ. Fig. 7; Pl. 93. Workshop: L. 1.26; W. 0.85. Rectangular cutting: L. 1.74; W. 1.25; D. 0.60.

A small oval workshop was cut into the bedrock to the south of the Roman Bath, with its south side against the cover of the Great Drain.⁶⁰ A brick wall forming its western half was preserved to a height of 0.68 m. above the flat bedrock floor. A low crosswall extended 0.58 m. from the north wall.

To the west of the crosswall, a mold base rested on the bedrock floor. It was made partly of stacked tiles and partly of tiles, earth, and stones, and it was covered with a layer of roughly worked clay. Around it lay a thick concentration of ash and wood charcoal, and the bedrock was discolored by fire, presumably from the baking of the molds. Traces of bronze and a few small mold fragments lay in the fill around the mold base.

A slot directly above the crosswall, partly filled with concreted material and charcoal, and a corresponding slot in the south wall of the foundry may have served as flues for the draft from the fire that baked the mold. The crosswall itself may have been built to reduce the area around the molds that had to be packed with earth before casting.

Just beyond the east end of the oval structure was a rectangular cutting in the bedrock which probably served as a dump for the installation, since the fill that covered the workshop extended into this pit.

The Oval Workshop was used for the production of small utilitarian objects. The funnels are uniformly small (e. g. **M1**, Pl. 93; B 1152, B 1508, and B 1511). The fine, lightweight mold fragments are all for small objects (Pl. 93) such as a nail, **M4**, a boss, **M5**, a bowl, **M2**,⁶¹ and blades, **M3** and **M6**. Fragmentary, wide, shallow bowls, vitrified on the interior, may be the crucibles from which the bronze was poured, **M8** and **M9**. Bronze, **M13**, bronze slag, B 1499, charcoal, traces of iron, and fragments of tiles were also among the debris. Three bellows nozzles made of re-used amphora necks (e. g. **M10** and **M11**; Pl. 94) came from the workshop,⁶² as

⁶⁰ Excavation: A. W. Parsons, 1936; M. Crosby, 1956; C. C. Mattusch, 1973. Unpublished.

⁶¹ Compare the 6th century (after Christ) molds for bowls from the Large- and Small-Scale Foundry, **N2** (Pl. 95).

⁶² Similar bellows nozzles came from the "Heliaia" Metalworks, **K1** and **K2**, and from South Stoa Debris, **L3**.

well as numerous fragments of curved bricks (e. g. **M12**, Pl. 94; B 1498, and B 1505) whose original function as the inner surface of a cylindrical furnace is suggested by the heavy vitrification of their interior surfaces.⁶³

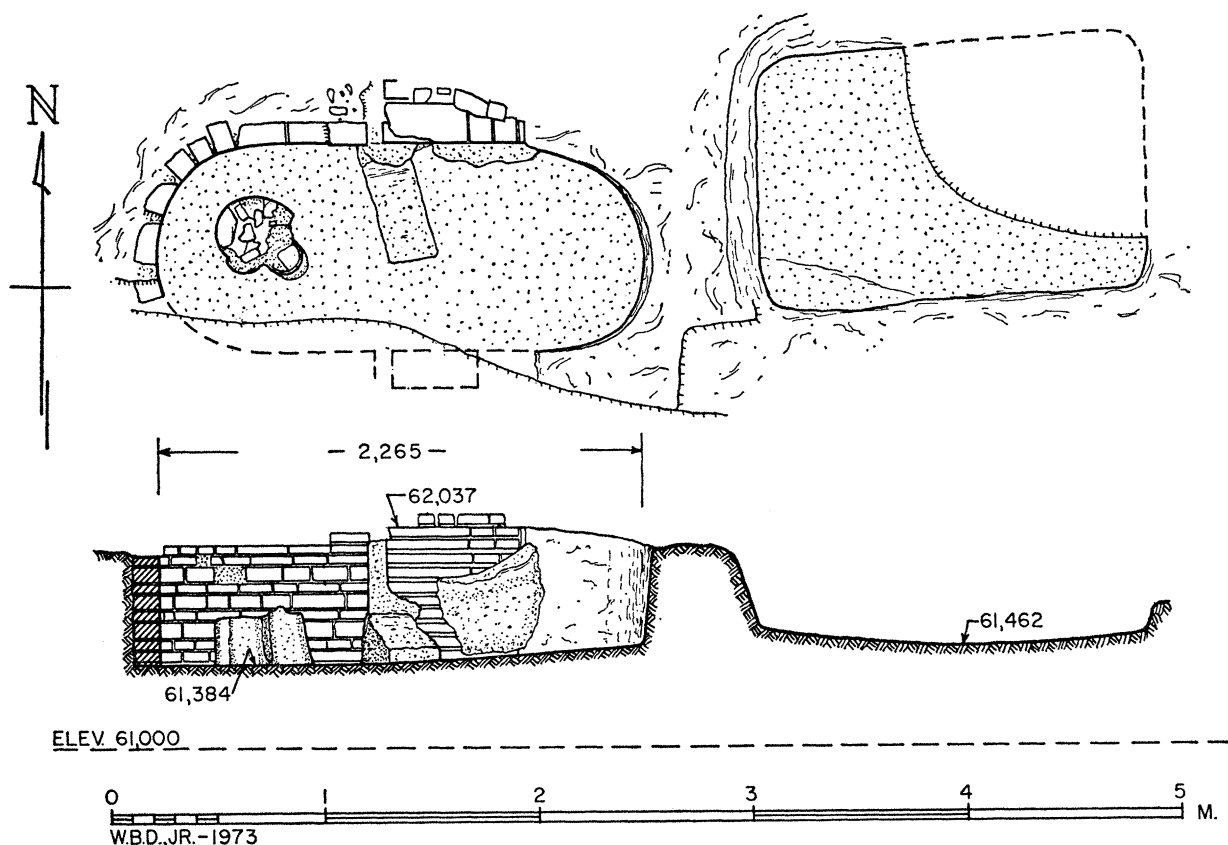


FIG. 7. Oval Workshop. Plan and section.

M1 (B 1153). Funnel and Y-gate. Pl. 93

Max. pres. dim. 0.062; Diam. funnel 0.020-0.025.

Broken below; rim chipped. Fine, pinkish buff clay. No visible layering.

Small oval funnel with vertical rim; Y-gate. Interior scorched. Rough finger impressions from modeling.

M2 (B 1149). Funnel, gates, and mold. Pl. 93

Max. pres. dim. 0.147; D. of funnel 0.020.

Broken all around; part of rim of funnel preserved. Fine, buff clay with imprints of hair(?) inclusions. No visible layering.

Part of funnel; four gates; curving inner mold surface. Scorched interior. Perhaps mold for bowl.

M3 (B 1152). Funnel, gate, and mold. Pl. 93

Max. pres. H. 0.080.

Broken below; part of lip missing. Fine, pinkish buff clay. No visible layering.

⁶³ Similar fragments of vitrified curved bricks come from both Hellenistic and Roman contexts in the Agora: House H Foundry (J), uninventoried fragments; South Stoa debris, **L4**; Slag pit (W), B 1611, B 1612.

Oval funnel with vertical lip; oval gate; slightly curved mold surface with edge at top. Scorched interior. Perhaps mold for blade.

Compare **M6**.

Other inventoried funnel fragments: B 1508, B 1511.

M4 (B 1147). Fragment of bivalve mold for nail. Pl. 93

Max. pres. dim. 0.046.

Broken at one end. Fine, pinkish buff clay. No layering.

Flat-backed section of bivalve mold, with finished upper surface, for nail with conical head and round shaft. Scorched interior.

M5 (B 1148). Mold fragment. Pl. 93

Max. pres. dim. 0.055.

Broken all around. Buff-to-reddish clay.

Mold for boss, or perhaps for pyxis lid, with circular, concave knob and smooth, spreading sides. Scorching.

M6 (B 1151). Mold fragment. Pl. 93

Max. pres. dim. 0.052.

Broken all around. Fine, buff-to-reddish clay.

Flat mold surface with one squared corner, and, opposite, a section of curved edge. Scorching. Probably mold for blade or tool with one curved edge.

Compare **M3**.

M7 (B 1514). Mold fragment. Pl. 94

Max. pres. dim. 0.079.

Broken all around. Fine, pinkish buff clay.

Flat, curving, inner mold surface above, which joins at a lower level flat, straight, inner mold surface. Scorching; traces of bronze. Perhaps a mold for part of a lock or similar fixture.

Other inventoried mold fragments: B 1150, B 1501, B 1509, B 1510, B 1512, B 1513, B 1516-B 1518.

M8 (B 1506). Crucible fragment. Pl. 94

H. 0.044; reconstructed Diam. at rim 0.250.

Profile preserved. Coarse, red, crumbly clay.

Flat-bottomed bowl with wide sloping walls and vertical rim. Dull black vitrified interior.

M9 (B 1507). Crucible fragment. Pl. 94

Max. pres. dim. 0.135; reconstructed Diam. at rim 0.220.

Part of rim and walls preserved. Coarse, red, crumbly clay.

Shallow bowl with wide sloping walls and plain vertical rim. Dull black vitrified interior.

M10 (B 1519). Bellows nozzle. Pl. 94

Max. pres. H. 0.211.

Upper shoulder and neck of amphora, mended from a number of pieces. Red, micaceous clay.

Sloping shoulder, tapering, scorched neck, and part of rim. Small round hole in lower neck. Wheel-ridged. Heavy, black glassy vitrification on rim. Re-used as bellows nozzle.

M11 (B 1520). Bellows nozzle. Pl. 94

Max. pres. H. 0.190.

Part of neck of amphora, mended from many pieces. Coarse, red clay.

Slightly tapering, scorched neck, sagging above from heavy, shiny black vitrification; bits of bronze. Re-used as bellows nozzle.

Fragments of two or more similar amphora-neck bellows nozzles were not inventoried.

M12 (B 1497). Furnace lining. Pl. 94

Max. pres. dim. 0.127.

Broken at one end. Coarse, powdery, red clay.

Rectangular curving brick, heavily vitrified on concave surface. Lower edge also concave, probably to fit tightly over adjoining brick.

Many similar fragments, e. g. B 1498, B 1505.

M13 (B 1503). Bronze waste. Pl. 94

Max. pres. dim. 0.035.

Small lump containing corroded bronze, charcoal, earth, and pebbles.

Other inventoried bronze waste and slag: B 1499, B 1500, B 1504.

N. LARGE- AND SMALL-SCALE FOUNDRY. Deposit P 16: 3. 6th century after Christ. Pl. 95.

A bronze-casting establishment was excavated against the southeast corner of the south apse of the Church of the Holy Apostles.⁶⁴ The west end of the structure was destroyed by the builders of the church, leaving a tile floor laid on bedrock, two brick piers of the south wall (each 0.40 m. wide; max. pres. H. 1.12 m.) with a narrow flue(?) between them, and a portion of the north wall, which established the width of the structure as 1.05 m. Supports made of rounded pieces of tile surrounded by baked clay that were found within the structure, **N3** (Pl. 95), suggest the use of a hypocaust system in the foundry, probably for the baking of the molds before casting.⁶⁵

Many of the fine, lightweight mold fragments from this foundry were used for large-scale casting (e. g. B 1600-B 1608),⁶⁶ in particular for the flesh and drapery of a life-size statue, **N1** (Pl. 95), B 1602, B 1603 (B 1601 with chaplet hole). Smaller, thin-walled mold fragments preserve the profiles of at least two wide-mouthed ovoid bowls, each with a vertical foot, a height of about 0.083 m., and a rim diameter of 0.200 m., **N2**. This workshop is the only one in the vicinity of the Agora which clearly produced both large and small bronzes.

N1 (S 1860a, b). Fragments of mold Pl. 95
for bronze statue.

Th. 0.022-0.024.

Two non-joining fragments. Coarse, red clay outer layer; fine, smooth, scorched inner layer. Lightweight fabric.

a. Max. pres. dim. 0.369. Large smooth mold surface with contours suggestive of nude chest or back. Much bronze adheres to inner surface.

b. Max. pres. dim. 0.250. Mold for parts of a series of well-defined vertical drapery folds.

Many other fragments of the same fabric, probably from the same molds. Inventoried: B 1600-B 1608.

N2 (S 1863). Mold fragments for Pl. 95
bowls.

Reconstructed upper Diam. of two bowls *ca.* 0.190, 0.230; Th. of molds 0.010.

Many non-joining fragments, broken all around. Fine, hard, red clay, thin and lightweight; scorched interior; bronze in cracks.

Parts of base, wall, and rim of molds for at least two wide-mouthed ovoid bowls with wide horizontal strip (W. 0.035) inside rim of each. Two fragments, each preserving a pair of diagonal gates attached to foot of vessel, show that the bowls were cast upside down.

Small funnel may be from similar casting: B 1599.

N3 (MC 1037a, b). Hypocaust supports. Pl. 95

a) H. 0.239. b) H. 0.114.

Broken brickbats surrounded by coarse, baked, red clay.

Two roughly cylindrical supports for hypocaust system; each support scorched on one side.

⁶⁴ Excavation: M. Crosby, 1954; C. C. Mattusch, 1973. Publication: *Agora* XIV, p. 190.

⁶⁵ In Corinth, a small oval metalworking installation with hypocaust supports on its floor was found in the area of the Peribolos of Apollo. Charles K. Williams, II informs me that it dates to the early Roman period.

⁶⁶ The mold fabric is similar to that of the molds from the Oval Workshop, e. g. **M1**, **M2**, **M7**.

The following deposits all contained dumped foundry or smithy debris. The earliest of them (O) may have been a casting pit, but it could not be excavated completely, and so this is uncertain. All of the other deposits are apparently dumps. None of them can be assigned with any certainty to a particular workshop, and a number of them are dated to periods for which there is no evidence for workshops.

O. RECTANGULAR PIT. Deposit D 16:11. 500-480 B.C. L. (north-south) 2.70.

A rectangular pit was cut into the bedrock east of the portion of the Great Drain that ran southwest of the Agora.⁶⁷ Traces of burning on its west wall suggest that it was a foundry, but this is not certain. The lower fill yielded charcoal, a small funnel, B 1582 (reconstructed Diam. 0.050 m.), many small unidentifiable mold fragments of fine, sturdy fabric, B 1583-1585, and traces of bronze slag and of mudbrick.

P. DEPRESSION IN BEDROCK. Deposit C 8:9. 5th century B.C.

A rough depression in the bedrock to the southwest of the Hephaisteion precinct yielded casting debris which may have come from more than one metalworking establishment.⁶⁸ Besides mudbrick, wood charcoal, and two fragmentary funnels, B 1552 and B 1553, the latter with part of a gate attached, a large, heavy pyriform mold was uncovered, **P1**. Its large size and heavy fabric suggest that it did not come from the same workshop as two much smaller and more lightweight mold fragments from this dump, both probably for drapery, B 1554 and B 1555.

P1 (B 1551). Mold fragment.

Pl. 96

Max. pres. dim. 0.304.

Broken above and at one side. Outer layer of coarse, red clay; inner layer of finer, scorched clay.

Heavy pyriform mold with vertical hole

(max. pres. depth 0.128) at one side for casting a solid, roughly cylindrical object (Diam. 0.049). Smooth, scorched channel loops around broken top of hole; its ends meet at one side and run side by side to break. Scorched area at break suggests that the mold continued here, fed by the parallel channels.

Q. IRREGULAR PIT. Deposit C 8:8. Third quarter of 5th century B.C. Diam. 1.00; D. 1.00.

An irregular pit in the bedrock to the southwest of the Hephaisteion precinct yielded two gates (Diam. of each 0.023 m.), one (B 1569) with its total length preserved, and spreading surfaces at either end for attachment to the mold.⁶⁹ In

⁶⁷ Excavation: E. L. Smithson, 1949; a later wall which cut lengthwise through the east side of the pit prevented its complete excavation. Publication: H. A. Thompson, "Excavations in the Athenian Agora: 1949," *Hesperia* 19, 1950, p. 330.

⁶⁸ Excavation: D. B. Thompson, 1936. Unpublished.

⁶⁹ Excavation: D. B. Thompson, 1936; a modern wall lying across the pit prevented its complete excavation. Unpublished.

addition, a number of large well-preserved fragments of molds for a draped(?) statue (e. g. B 1573 and B 1574) and a fragmentary bellows nozzle covering, B 1572, were found. Finally, two short props were preserved, B 1570 and B 1571, similar to those from the later Mudbrick Foundry, **H7** and **H8**, except that these were formed around triangular and rectangular objects, not around twigs.

R. UNFINISHED WELL CUTTING. Deposit F 6: 2. Last quarter of 5th century B.C. Upper Diam. 0.95; D. 2.00.

Excavation of an unfinished well cutting north of the Hephaisteion and beneath the later "Arsenal" yielded the rims of two small funnels and ten fragments of small molds, perhaps for tools.⁷⁰ These do not bear any marked resemblances to molds from foundries in the area, nor do they particularly resemble one another, which suggests that they do not represent a single effort, but that they were thrown here at random.

S. POTHOLE. (No deposit number.) Second half of 4th century B.C.

In the 4th century street to the north of the State Prison,⁷¹ a soft spot covered by three worn boulders was found to contain a large hemispherical lump of iron slag, B 1593,⁷² and many fragments of plaster, all no doubt dumped here in an effort to improve the street surface.⁷³

T. CISTERN. Deposit E 3: 1. First half of 3rd century B.C. Depth 5.40.

A flask-shaped cistern at the north foot of Kolonos Agoraios contained mold fragments (e. g. B 350), a funnel, a gate, and a bit of the vitrified clay covering of a bellows nozzle, as well as two bronze styli, B 311 and B 316, and a bronze nail, B 351.⁷⁴

U. WELL. Deposit K 16: 1. 1st century B.C. Hellenistic. Diam. 1.35 by 2.00.

A well lying to the south of the road that bordered the Agora on the south yielded 41 roughly hemispherical, iron-bearing lumps of slag.⁷⁵

V. FILL IN THE STATE PRISON.⁷⁶ Deposit D 18: 3. 1st century B.C.

Mold fragments with a powdery fabric, but with well-preserved inner surfaces, often rasp-marked (e. g. S 1439, B 1586, and B 1588-B 1590), were found in fill

⁷⁰ Excavation: D. B. Thompson, 1936. Unpublished.

⁷¹ See footnote 4 above.

⁷² Similar pieces of the 4th to 3rd centuries B.C.: Ironworks, **E1**; Mudbrick Foundry (H), B 1417; House H Foundry (J), B 1531.

⁷³ Excavation: M. Crosby, 1947. Unpublished.

⁷⁴ Excavation: H. A. Thompson, 1936. Unpublished.

⁷⁵ Excavation: D. B. Thompson, 1958. Unpublished.

⁷⁶ See footnote 4 above.

above the southernmost of the three eastern rooms of the State Prison, and in a partly excavated pit in the same room, B 1591, B 1592, and B 1594.⁷⁷

Late Hellenistic fill in three other locations in the region of the State Prison yielded dumped material from metalworking establishments, although no actual workshops, casting pits, or hearths were identified in the area. Hemispherical lumps of slag were most commonly found, but lead and lead slag(?) were also excavated here.

W. SLAG PIT. Deposit L 15:1. Second half of 1st century after Christ. L. 4.40; W. 2.70; max. D. 0.70.

After the destruction of the South Square in 86 B.C., a pit with sloping floor and walls was cut in the bedrock 0.90 m. in front of South Stoa II and about ten meters from its east end.⁷⁸ The pit, which was cut through the floor of the South Square, was rectangular in plan, and contained ash, charcoal, slate-blue slag with iron in it (e. g. B 1609), fragments of furnace lining, B 1611 and B 1612, and vitrified bricks (e. g. B 1613) and tiles (e. g. B 1610). It may well be that an entire dismantled furnace was discarded here. Later the floor of the South Square was rebuilt on top of the pit.

X. SOUTH STOA II DUMP. Deposit M-N 15:1. Pre-Herulian.

Shallow holes dug within the limits of South Stoa II (max. depth 0.40 m.) are reported to have contained solid carbon 0.15-0.20 m. thick, but no metallurgical finds were saved.⁷⁹

Y. WELL. Deposit M 17:1. Fill of late 3rd century after Christ. Total D. of well 35.30.

A household well just to the south of the Agora proper, which went out of use at the time of the Herulian invasion, contained iron and bronze slag in its post-use fill, as well as lead, charcoal, vitrified concave bricks from furnace lining, and a funnel fragment, B 1614.⁸⁰ Other metallurgical finds were heavy chunks of mixed bronze and lead deposits from wide-mouthed, shallow, flat-bottomed crucibles, and a small, clay, flat-bottomed crucible(?) with a deposit inside of heavy, yellow, brown and gray metal, B 1616 (Diam. 0.090).⁸¹

⁷⁷ Excavation: M. Crosby, 1947. See M. Crosby, "The Poros Building," *Hesperia* 20, 1951, p. 182.

⁷⁸ Excavation: H. A. Thompson, 1959. Publication: H. A. Thompson, "Activities in the Athenian Agora: 1959," *Hesperia* 29, 1960, pp. 360-361; H. A. Thompson, "Activity in the Athenian Agora, 1960-1965," *Hesperia* 35, 1966, p. 43; *Agora* XIV, p. 71.

⁷⁹ Excavation: M. Crosby, 1953. See H. A. Thompson, *Hesperia* 29, 1960, p. 360.

⁸⁰ Excavation: E. Vanderpool, 1937. Foundry material unpublished.

⁸¹ Compare R. F. Tylecote, *Metallurgy in Archaeology*, London 1962, fig. 31:17.

CONCLUSIONS

Although the remains of ironworking from the area of the Athenian Agora are substantial, particularly from the dumps, only one iron smithy has been found (E), and the material from it and from the dumps is not sufficient to reconstruct the nature of the work done by ironsmiths working near the Agora. The same problem arises with the bronze smithy (House D), for here, too, few technical insights result from simple observation of hearth and slag. Far more rewarding are the remains from bronze foundries and dumps: these provide a great deal of information about ancient casting, the details of which are often closely paralleled in modern foundry practice.

The lost-wax method of bronze casting is amply attested; evidence is provided for how the wax was worked, how molds were made, how the bronze was cast, how furnaces were constructed, and how the bronze was finished after casting. The general procedure was fixed, but differences in details can be observed from one workshop to another. Unfortunately, the technical features of lost-wax casting which are represented among the remains from the area of the Athenian Agora are so alike in both direct and indirect methods that I have so far been unable to establish which method was used in particular workshops.

All of the foundries around the Agora appear to have been fairly temporary establishments. Two were installed for the production of single statues which were probably erected near by (A and C). Four other workshops also produced large-scale castings (B, H, J, N). Large bronzes and apparently also some small ones were cast hollow in the environs of the Agora at all periods, according to the evidence provided by chaplets or by chaplet holes, **A3**, **B2**, **C18**, **C19**, **L1**, B 1601, and by a partially preserved core, **C9**.⁸²

In antiquity, the surface of the wax was often smoothed with a rasp, as is done today. Then wax rods were attached where there were to be gates and vents, chaplets of iron (e. g. **C19**), or bronze (e. g. **L1**, **L5**) were thrust through the wax into the core,⁸³ and the wax and its attached gate system were invested. (Compare modern examples, Pl. 97.)

Ancient molds were normally constructed of two distinct layers of clay, a smooth inner layer which was scorched during the pour, and an outer layer. In our earliest example, however, a third layer was added. (Compare modern three-layered investment, Pl. 97: b.) The thick, heavy molds of the Greek period in the area of the Agora are usually made of fairly coarse, reddish clay with various clearly visible inclusions,

⁸² Ancient testimonia (Philo Byzantius, *De Septem Miraculis*, 4; Quintilian, *Orat.* 2.1-12, 7.1-2), the Berlin Foundry Cup (Pl. 98), and all extant bronze statues attest to the universality of this practice in antiquity. The Foundry Cup (Side A) may also suggest that the models themselves were made in separate sections.

⁸³ Chaplets are rarely preserved because when molds are broken up after casting they normally split where the chaplets were set.

such as sand, straw, hair, and shells. But molds from foundries of the Roman period consist of a much thinner, lightweight, buff-to-pink fabric. Both layers are of fine clay, and inclusions are barely noticeable. These molds lack almost entirely the imperfections found in the inner surfaces of Greek molds, which tend to collect bronze during the pour. (Compare **C15**, Pl. 85, with **N1**, Pl. 95.)

The funnels which received the molten bronze vary greatly in size during the Greek period, especially in the Keyhole Foundry (diameters range from 0.014 m. to 0.225 m.), and it can be assumed that larger ones simply fed larger molds than the smaller ones. In contrast, no funnels from the Roman period are particularly large, even in the Large- and Small-Scale Foundry (N: Diam. of preserved funnel in B 1599 is 0.070 m.), and those used to cast small objects are generally no more than about 0.025 m. in diameter.

The foundries around the Agora seem to have comprised normally both working area and casting pit. Molds were propped up for baking in the casting pit (two types of props: **C21-C23** and **H7, H8**), and an attempt might be made to collect the wax, as in the Keyhole Foundry (see modern parallel, Pl. 97: c), although the wax could be burned up entirely within the mold, as generally happens today. Then the molds were packed around with sandy earth in the pit for the pour. (See the Industrial Foundry, D, Pl. 87, and compare modern packed molds, Pl. 97: d.)

No foundations of a metallurgical furnace are preserved anywhere in the Agora area. Apparently furnaces were completely dismantled and dumped after use, for pieces of them are frequently found in workshops and dumps. Also, the furnaces were more vulnerable than the casting pits, since they were not cut into bedrock, but must have rested on the contemporary ground level. Curved vitrified bricks, such as **M12**, found in contexts dating from the Greek and Roman periods may be identified as furnace lining; they indicate that the furnaces were normally cylindrical.⁸⁴ This might be expected from the evidence provided by the circular plans of 7th to 5th century B.C melting furnaces excavated at Olympia,⁸⁵ by Archaic and Classical vase paintings,⁸⁶ and even by Hellenistic braziers⁸⁷ (Pl. 96; compare the modern melting furnace shown in Pl. 97: c).

⁸⁴ The furnace for the House H Foundry might have had a cylindrical shaft resting on a rectangular base. See above, p. 367.

⁸⁵ Hampe and Jantzen, "Bericht," p. 35, Oven S2, p. 40, Oven S6.

⁸⁶ Agora red-figure oinochoe P 15210 (Pl. 96; G. Van Hoorn, *Choes and Anthesteria*, Leiden 1951, p. 90, no. 227; T. B. L. Webster, *Art and Literature in Fourth Century Athens*, London 1956, p. 18; *Agora Guide*², p. 160); Akropolis red-figure kylix fragment no. 166 (Beazley, *ARV*², p. 92, no. 64); Berlin Foundry Cup (Pl. 98; Beazley, *ARV*², p. 400, no. 1); British Museum black-figure oinochoe B 507 (Beazley, *Attic Black-Figure Vase-Painters*, Oxford 1956 [= *ABV*], p. 426, no. 9; Oxford red-figure kylix G 267 (Beazley, *ARV*², p. 336, no. 22); black-figure vase in the Edwards Collection, whereabouts unknown (drawing in H. Blümner, *Technologie und Terminologie* IV, Leipzig 1887, fig. 52 on p. 364).

⁸⁷ The similarity between braziers and furnaces was recognized earlier by P. N. Ure, *The Origin of Tyranny*, Cambridge 1922, pp. 203-205.

Wide-mouthed vitrified bowls with heavily slagged interiors such as **H10** and the similar bowls attested by metallic deposits (e. g. **L2**) can be recognized as crucibles, and it is tempting to suggest that they rested on top of the furnace shafts, as shown in vase paintings.⁸⁸ Bellows are represented by the clay coverings that were used to protect their nozzles. Those of the Archaic, Classical, and Hellenistic periods consisted of roughly modeled clay, no doubt molded directly over the wooden(?) nozzle (e. g. **A5**), whereas by the time of the post-Herulian workshops a new type of nozzle had been devised, which consisted of a re-used amphora neck (e. g. **M10**).

Little evidence for the coldworking of cast bronzes is preserved in the Agora area, but the Keyhole Foundry and House H Foundry both yielded pieces of pumice (e. g. **C25**), the presence of which strongly indicates that at least the preliminary coldworking was done in the same workshop or foundry where the molds were probably constructed, and where they were baked and cast.

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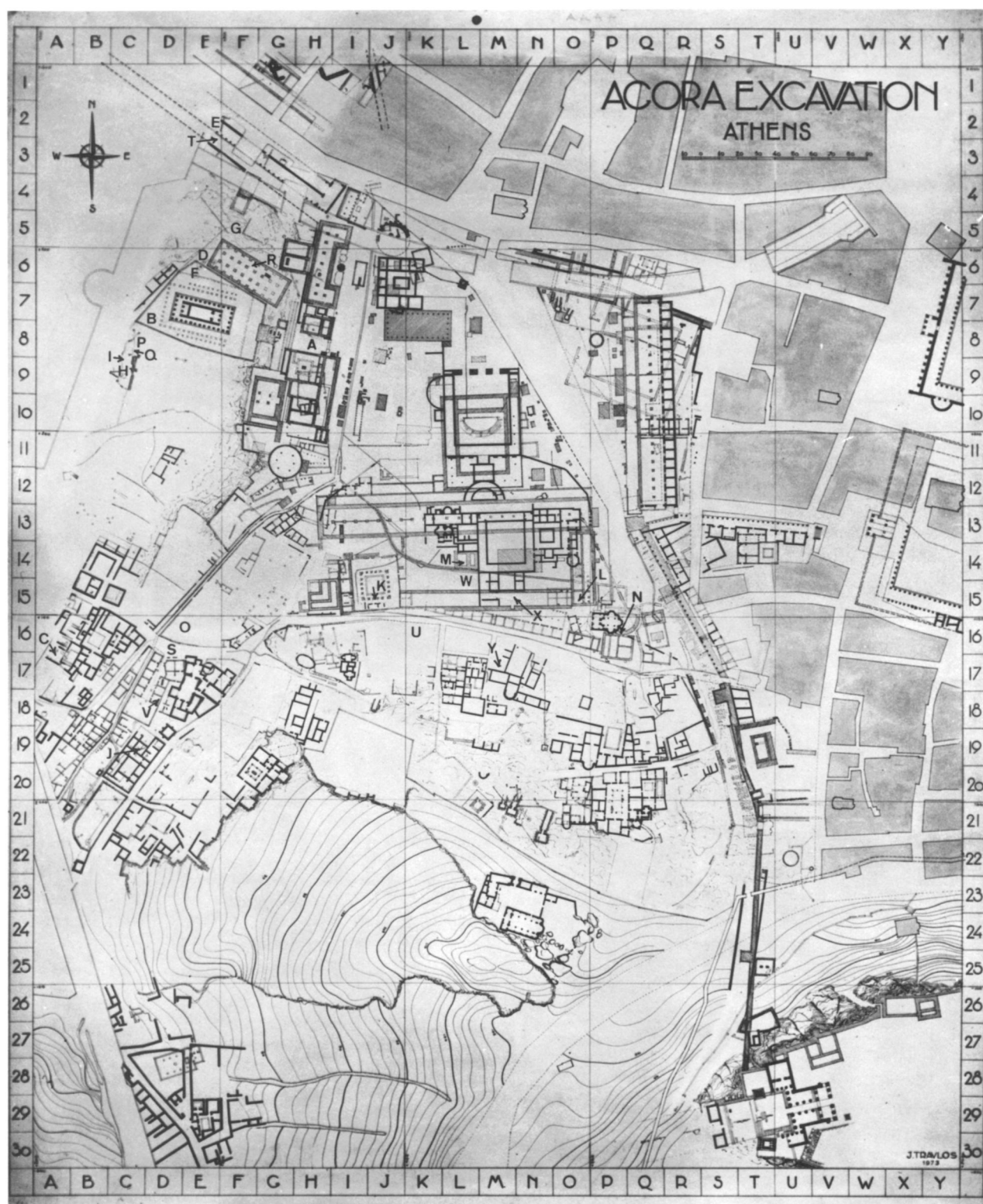
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⁸⁸ See footnote 86 above for references. Also compare the Hellenistic brazier with pot on top, from the Agora (Pl. 96).

Smelting was certainly not done in such furnaces, since the bulkiness of ore does not encourage taking it far from its source for reduction. Besides, it is very unlikely that a workshop which was engaged in producing metal objects would also undertake the altogether different process of smelting.

The fragments of melting furnaces from the Agora show only that the structures must have been cylindrical. But by adding the evidence of vase paintings, we can arrive at a tentative reconstruction of their function. A lidded crucible (no traces of lids among the Agora material) containing the alloy rested on top of the cylindrical shaft of the furnace, which contained the fire, and which was fueled through a large stoking-hole in front and fanned through a bellows hole behind (this hole is not shown in vase paintings, although the bellows are often visible). The same type of furnace, sometimes even shown with the lidded crucible on top, was also used in the smithy, except that there the metal was held with tongs and extended into the furnace through the stoking hole: British Museum B 507 (Beazley, *ABV*, 426, no. 9; Burford, *Craftsmen*, pl. 29); and Akropolis 166 (Beazley, *ARV*², p. 92, no. 64; Casson, *Technique*, fig. 54). Smithy furnaces might have different shapes: Boston Museum of Fine Arts 01.8035 (Burford, *Craftsmen*, pl. 30); and Caltanissetta inv. no. 20371 (*Antike Kunst* 12, 1969, pl. 14:4).

There is no evidence from the Agora to support the theory advanced by K. Kluge that the metal in such furnaces ran down through the shaft, out at the base, and through a channel to the molds. See K. Kluge, *Die antiken Grossbronzen* I, Berlin 1927, pp. 11-13; K. Kluge, "Die Gestaltung des Erzes in der archaisch-griechischen Kunst," *Jahrb* 44, 1929, p. 8; and K. Kluge in Hampe and Jantzen, "Bericht," pp. 34-35.



CAROL C. MATTUSCH: BRONZE- AND IRONWORKING IN THE AREA OF THE ATHENIAN AGORA



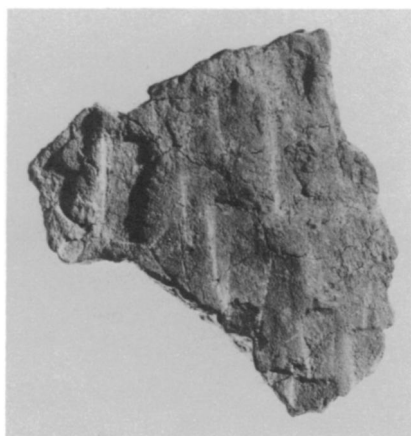
Archaic foundry (A)



A1



A2



A3: B 1540



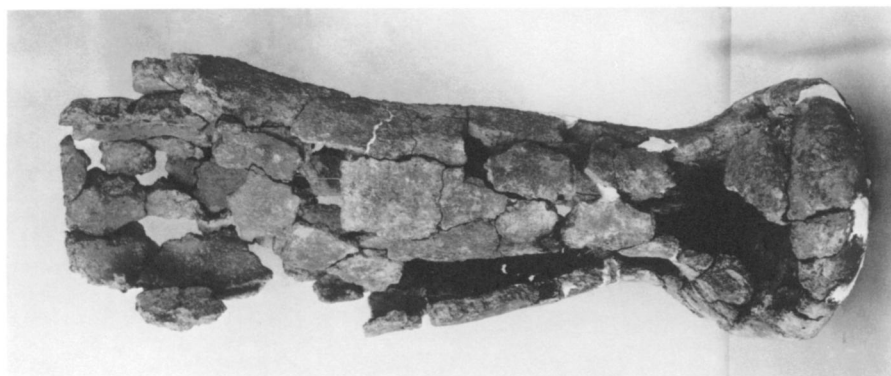
A5



a. A3: back



b. A3: left side



c. A3: front

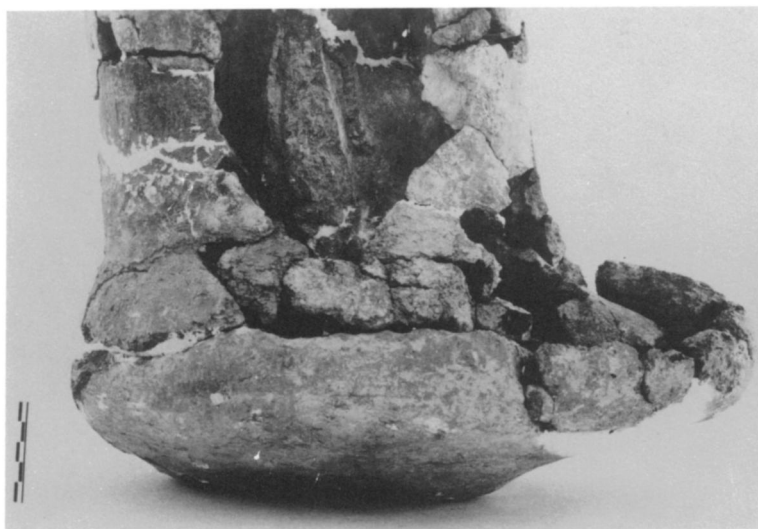


d. A3: right side

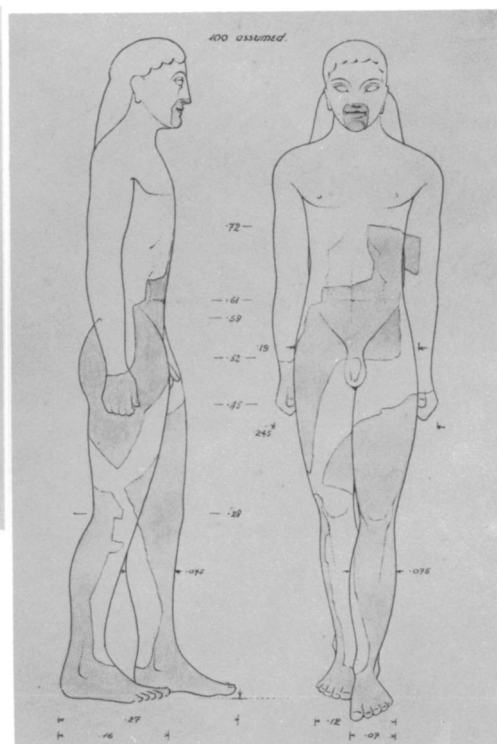
CAROL C. MATTUSCH: BRONZE- AND IRONWORKING IN THE AREA OF THE ATHENIAN AGORA



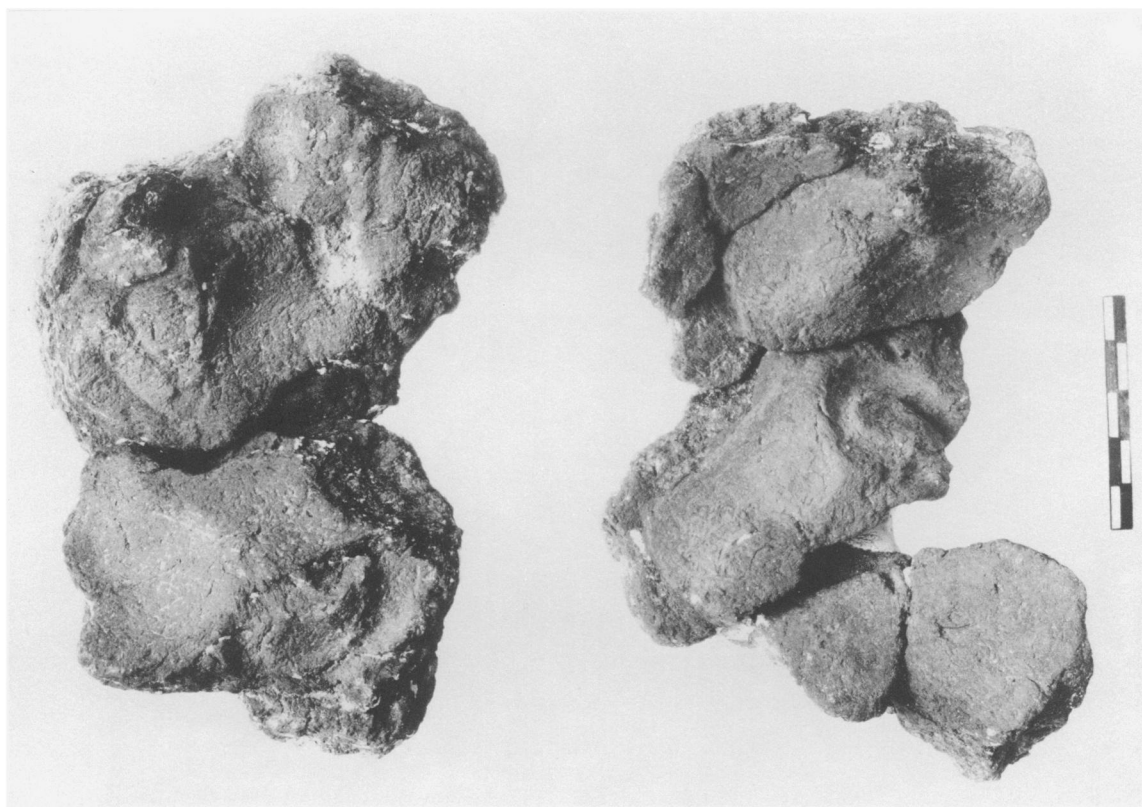
a. A3: mold for face of kouros; plaster cast



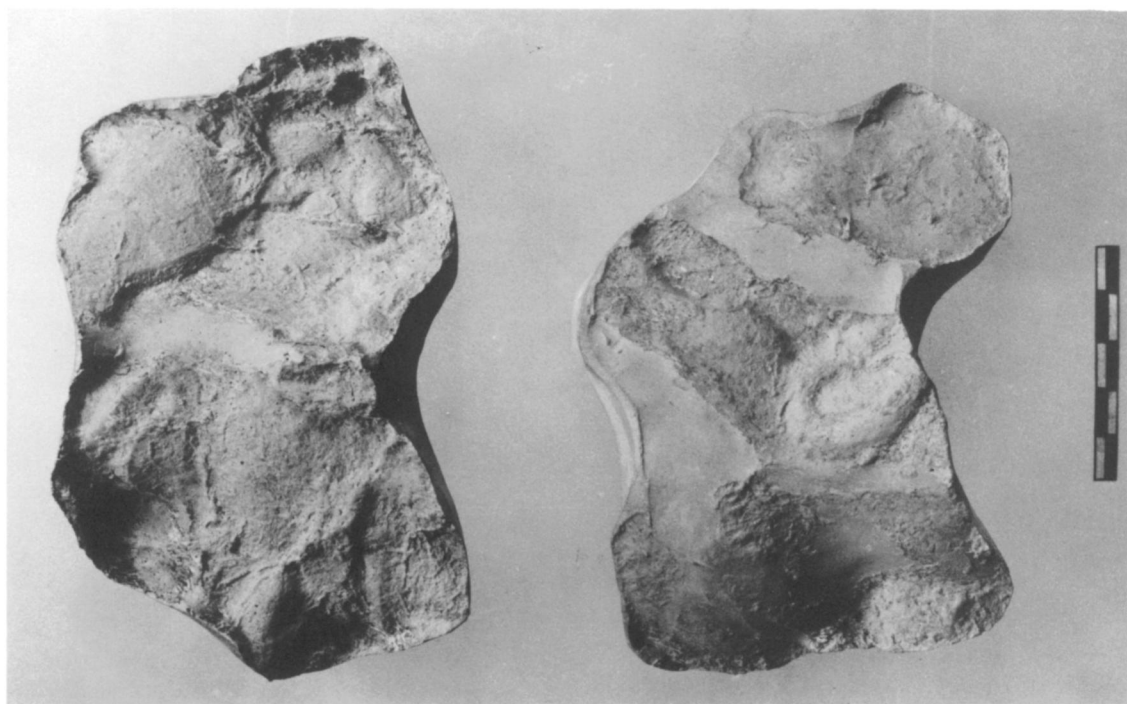
b. A3: base of mold



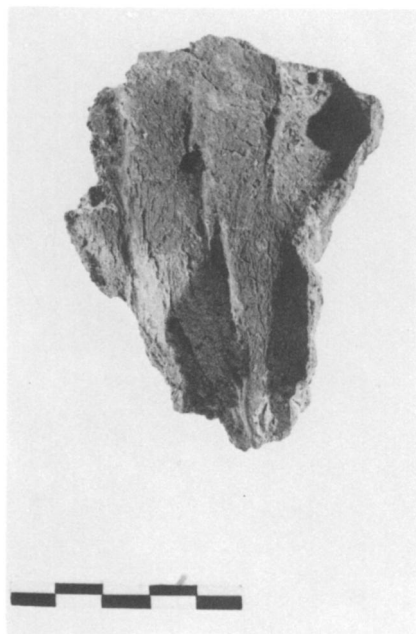
c. Reconstructed drawing of kouros



b. A4: plaster casts



a. A4: head



B4

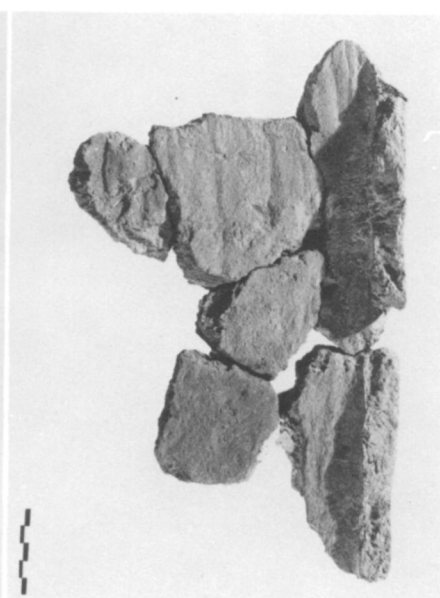
Hephaisteion foundry (B)



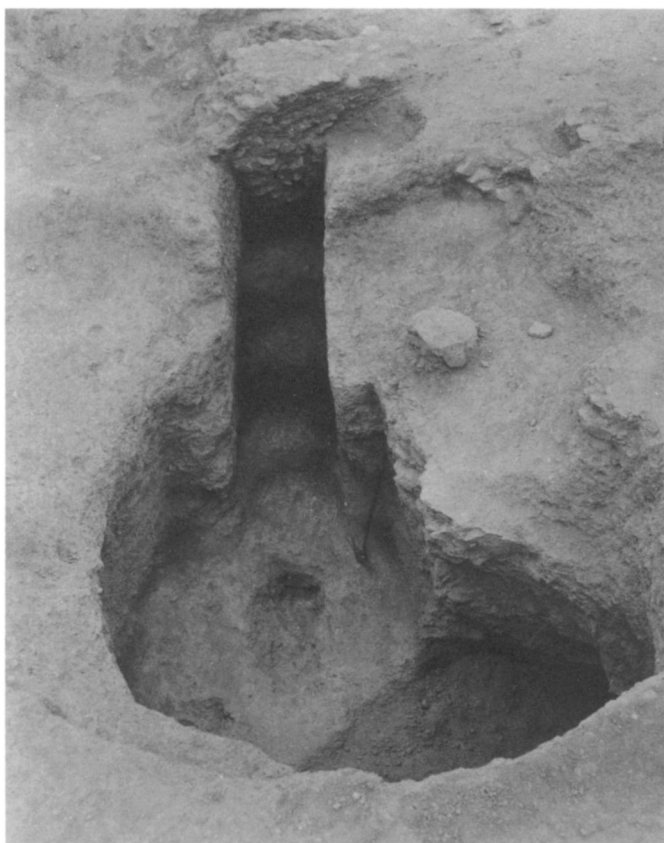
B1



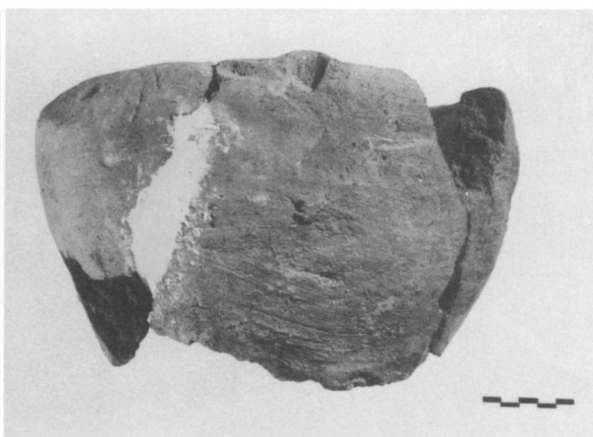
B2



B3



Keyhole foundry (C)



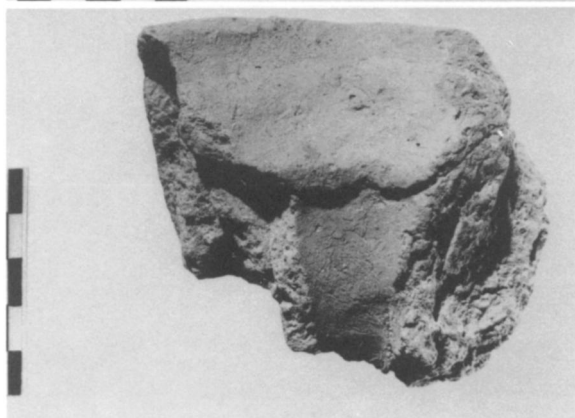
C1



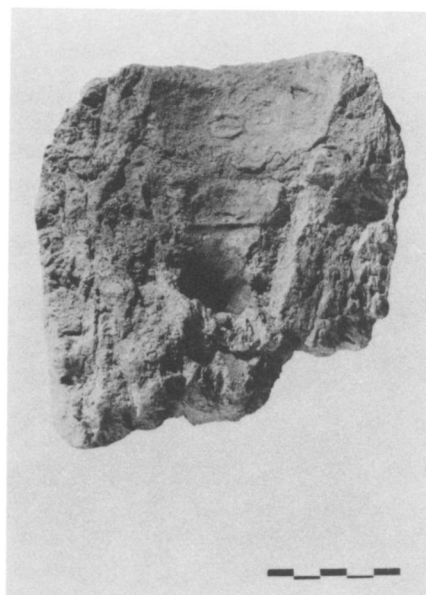
C4



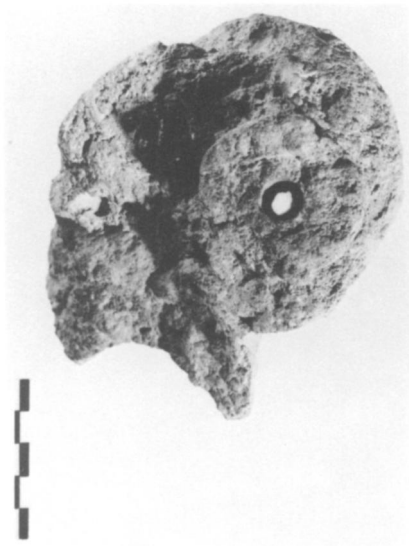
C2



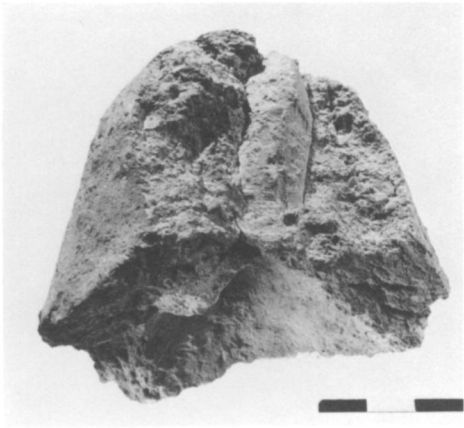
C3



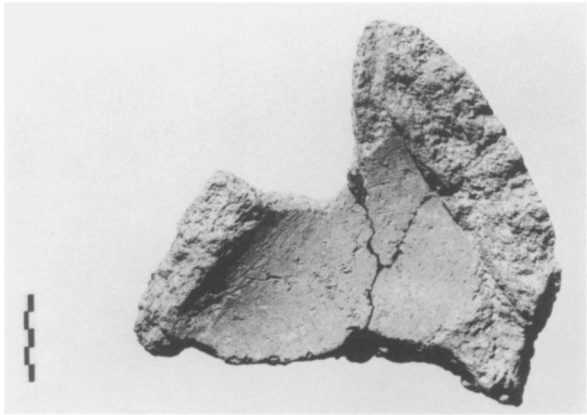
C5



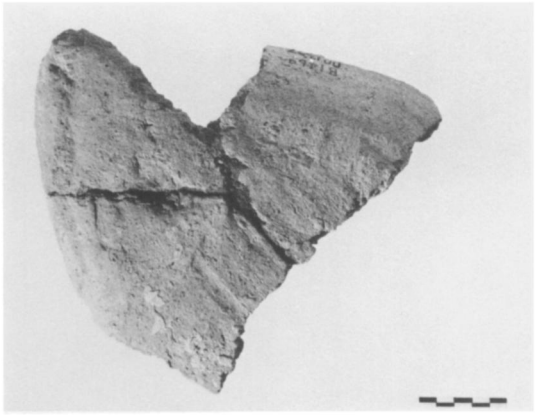
C6



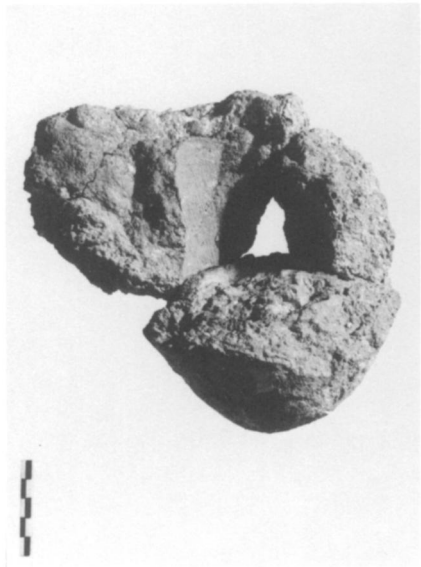
C7



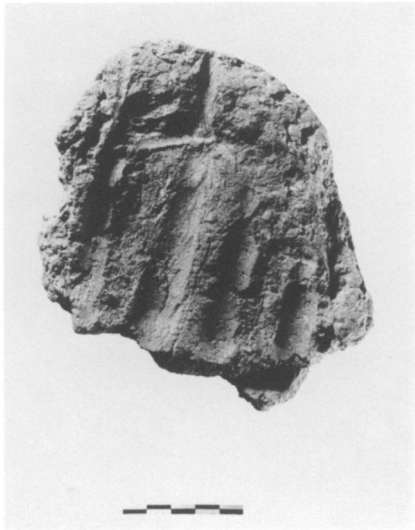
C8: interior



C8: exterior



C9



C10



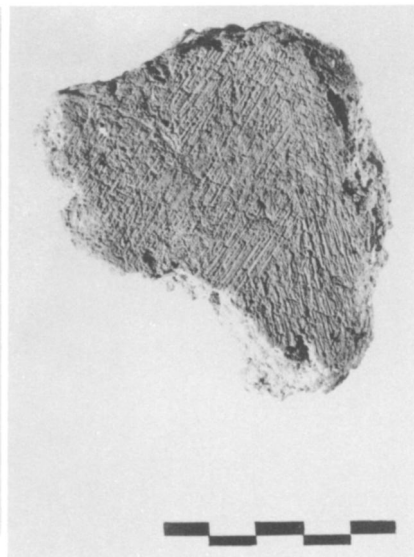
B 1189d



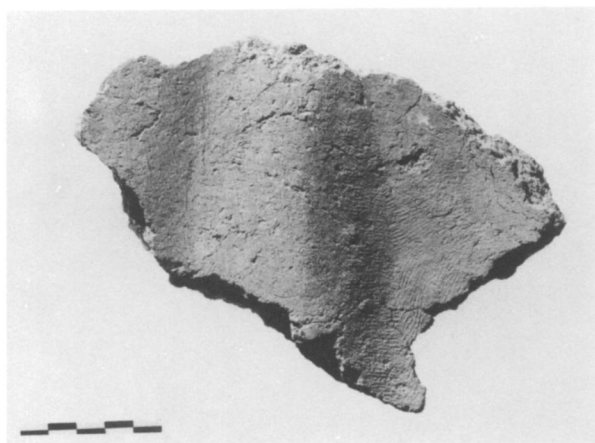
C11



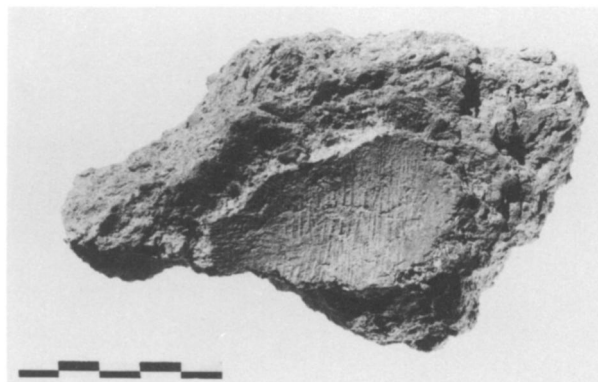
C13



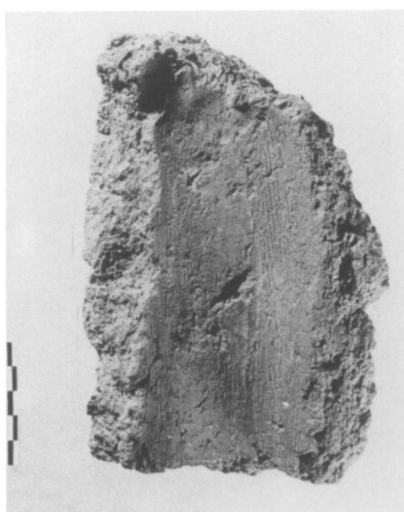
C14



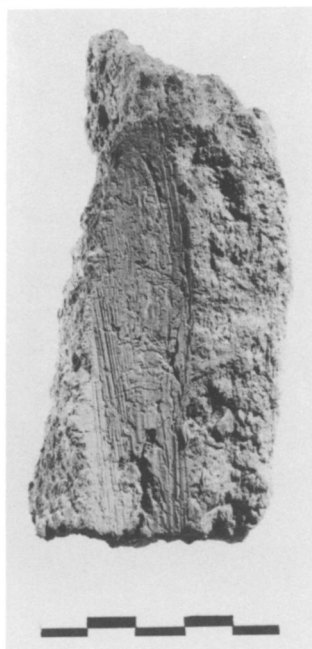
C12



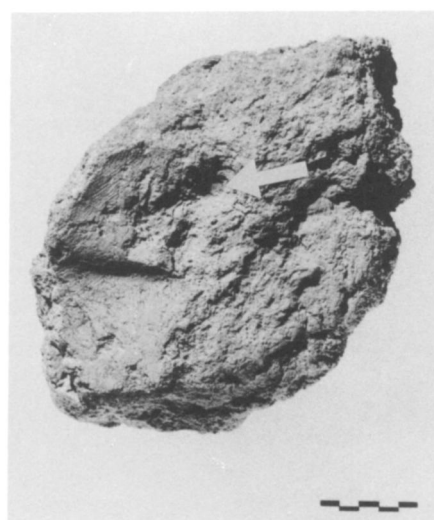
C15



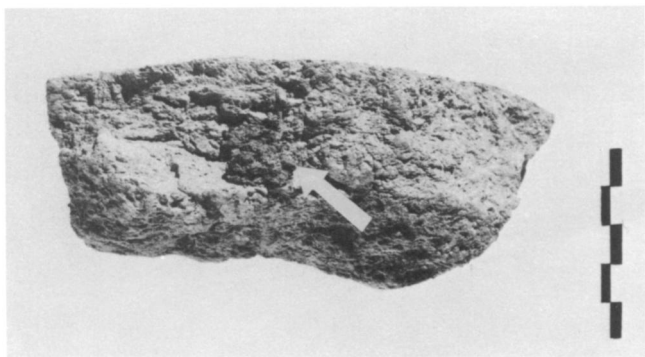
C16



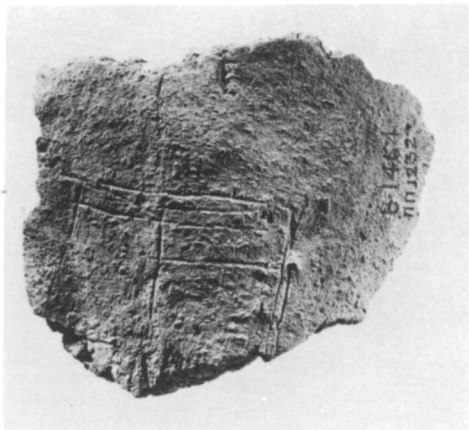
C17



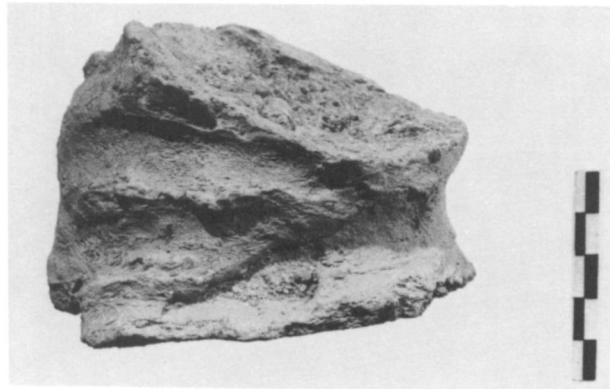
C18



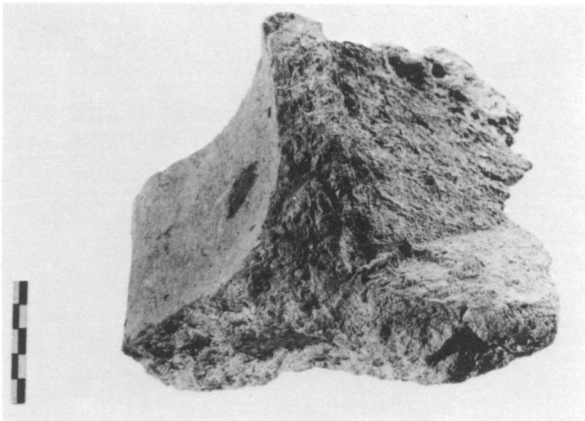
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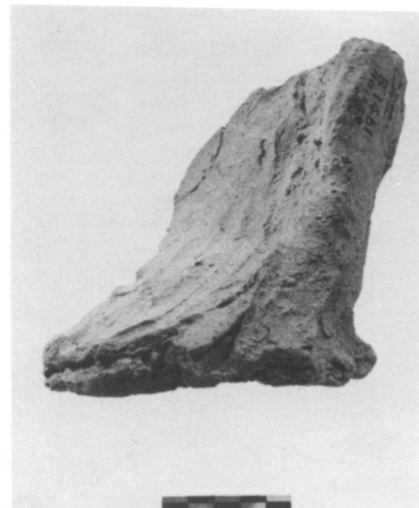
C20



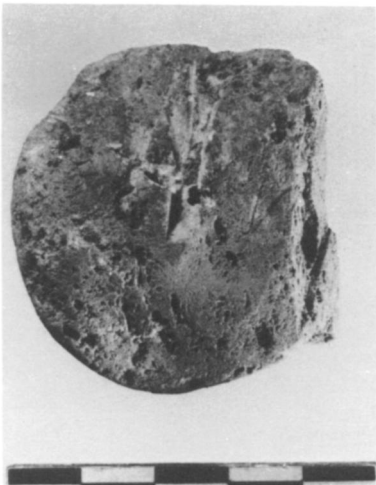
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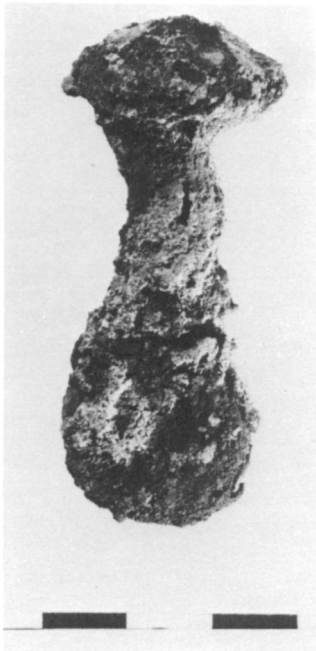
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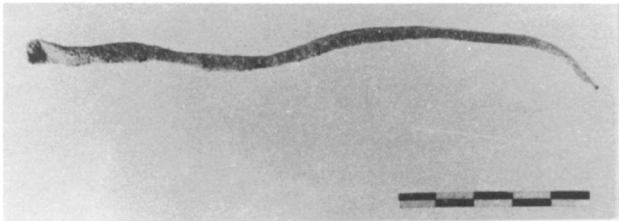
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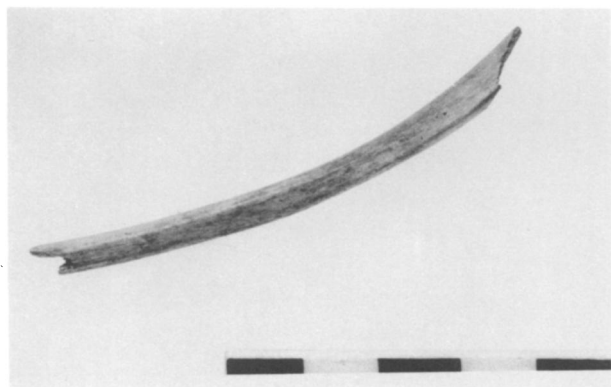
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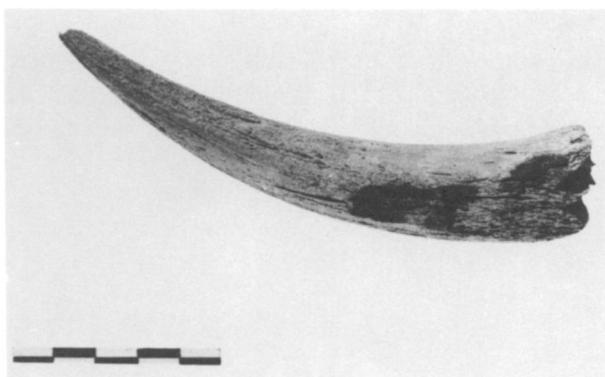
C24



C26



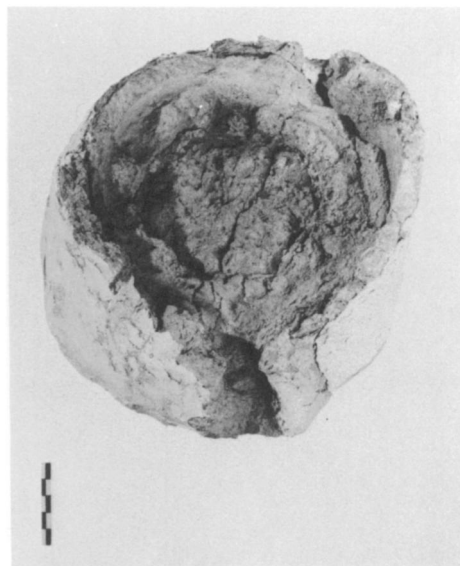
C27



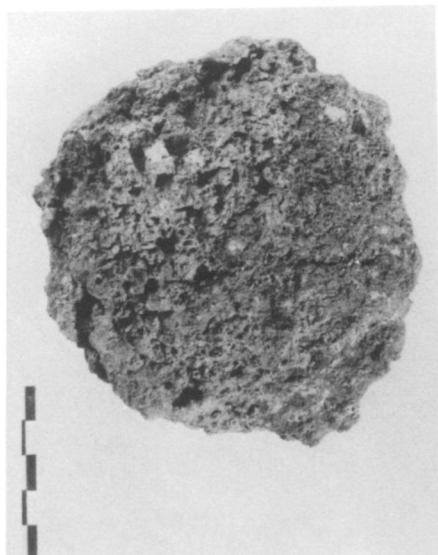
C28



Industrial foundry (D)



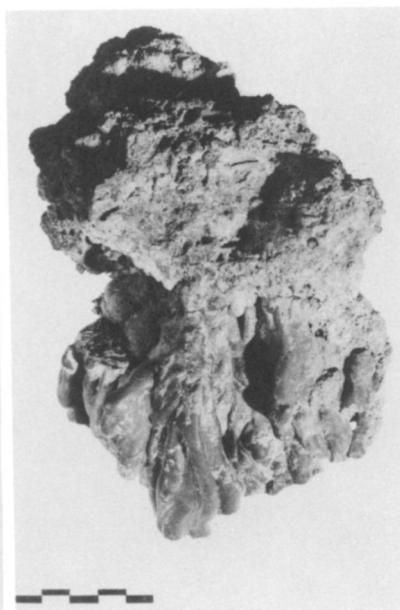
D1



E1



E2



E3



Two irregular cuttings (G)



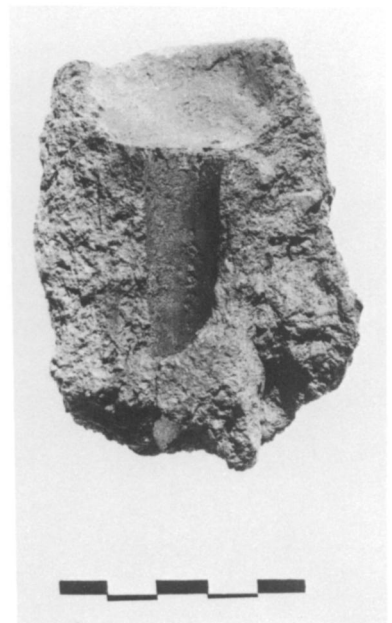
G1



H1



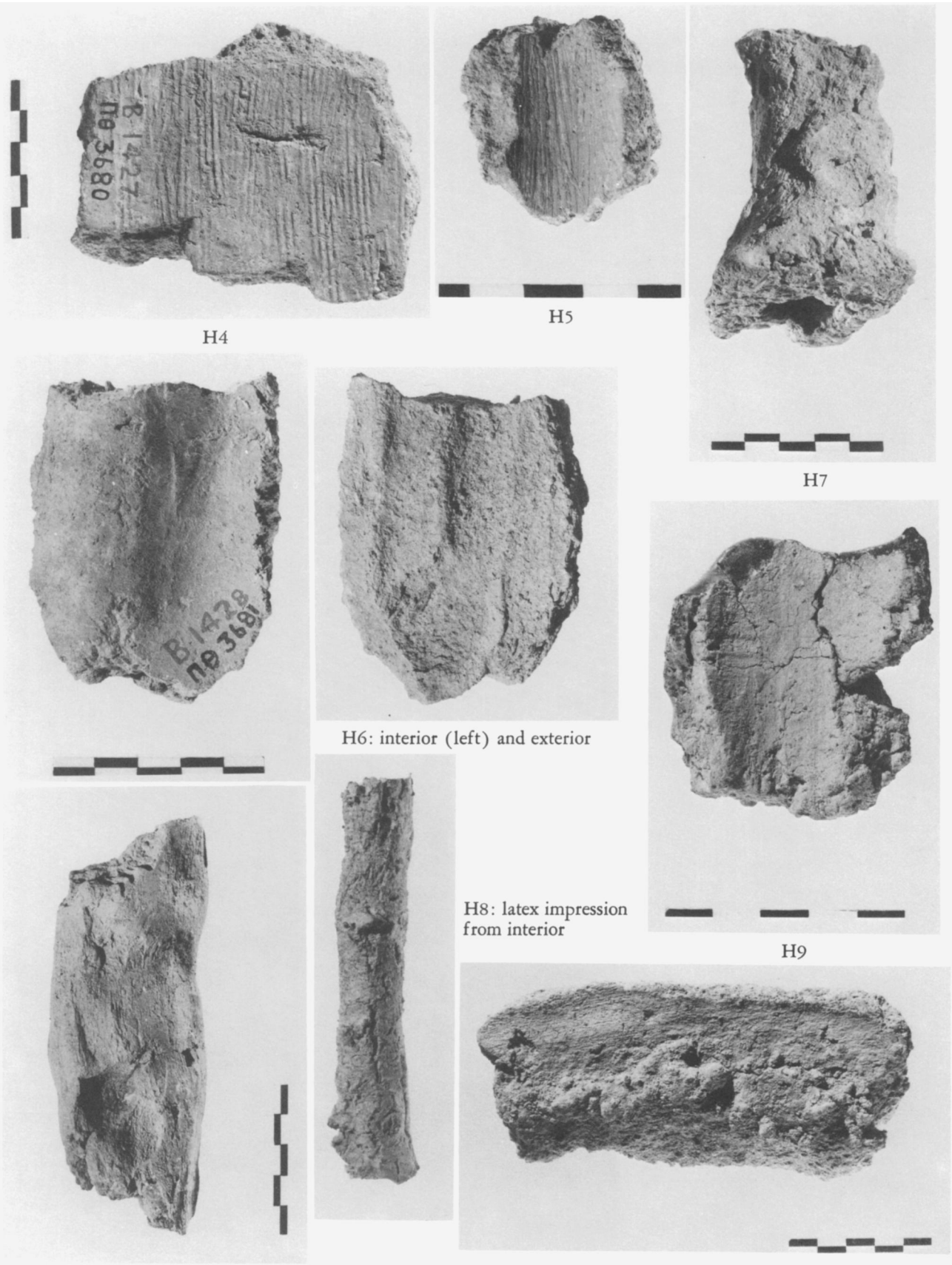
H2

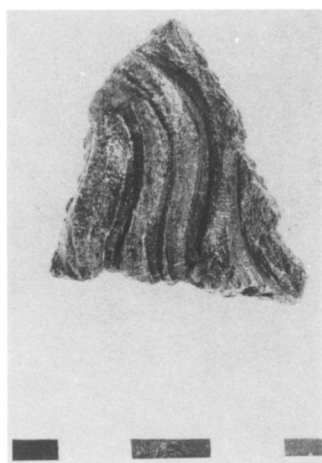


H3

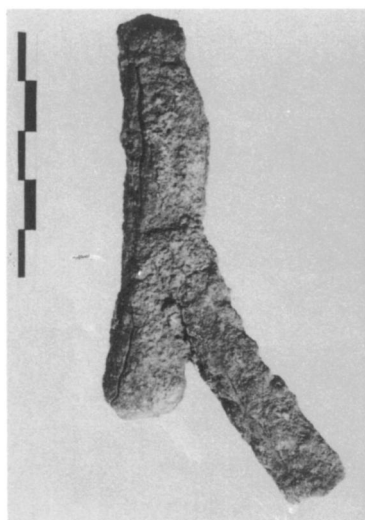


Mudbrick foundry (H)





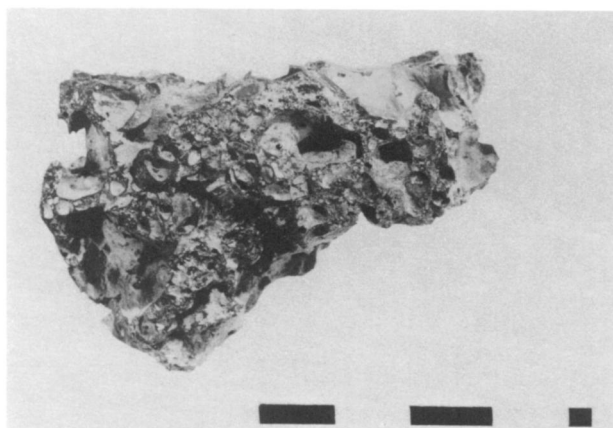
I1



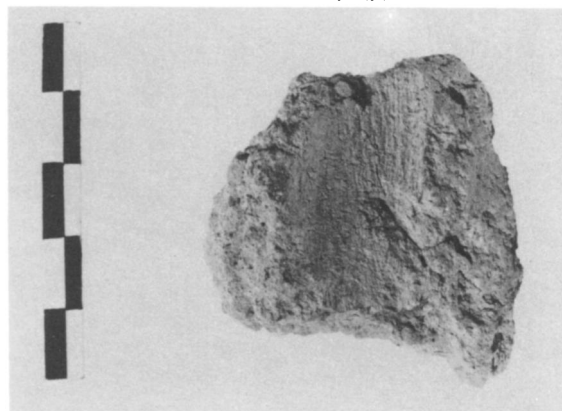
I2



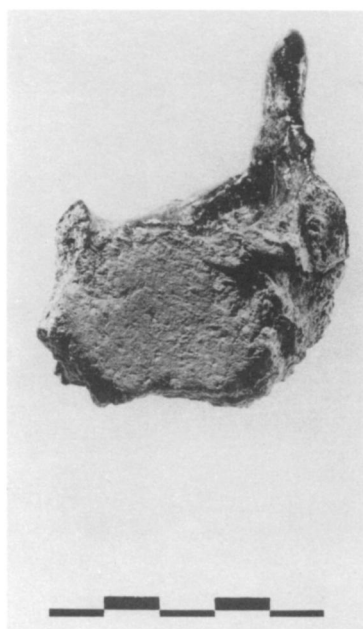
House H foundry (J)



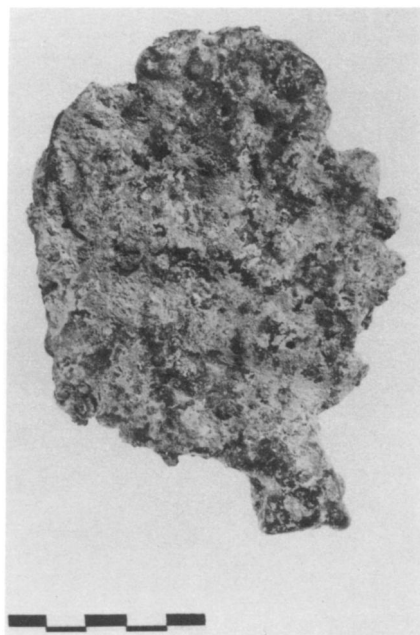
J2



J1



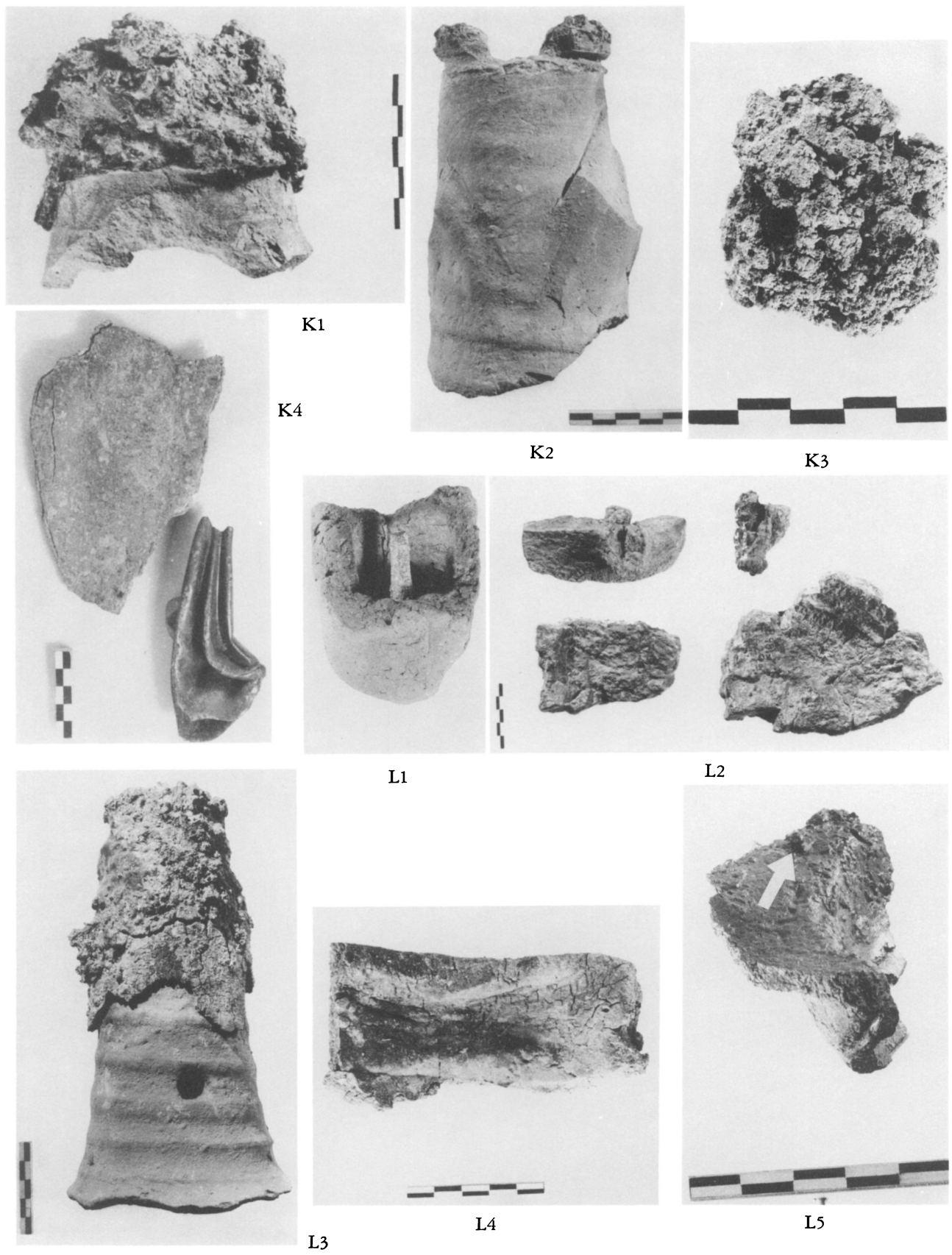
J3



J4

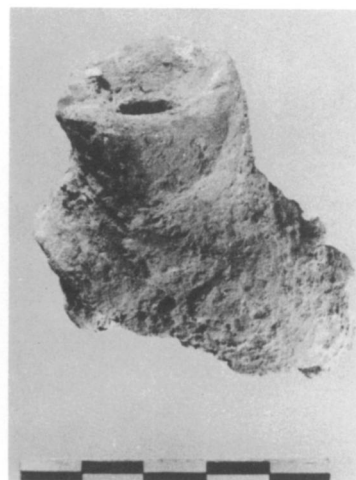


J5





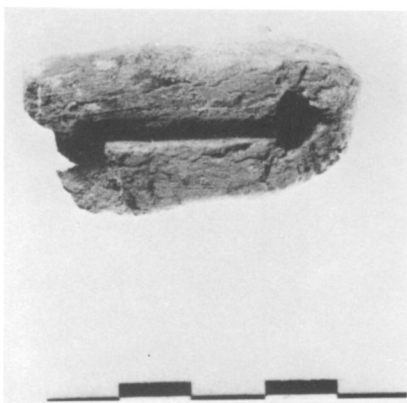
Oval workshop (M)



M1



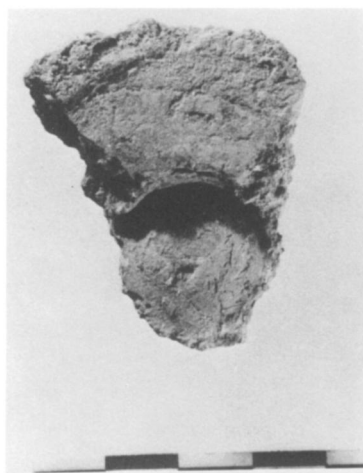
M1: restored drawing



M4



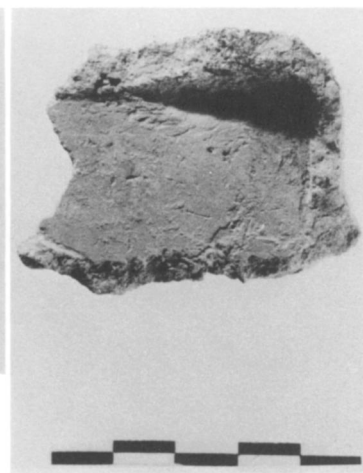
M2



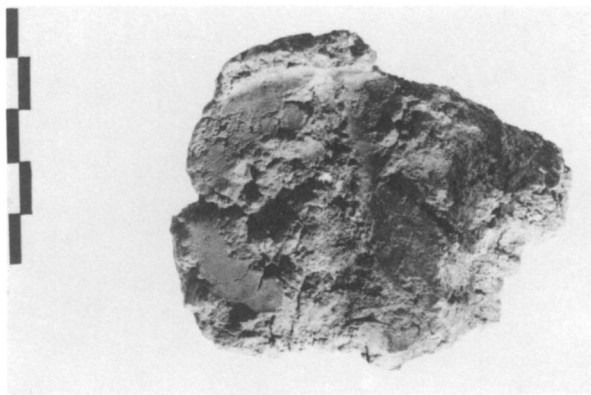
M5



M3



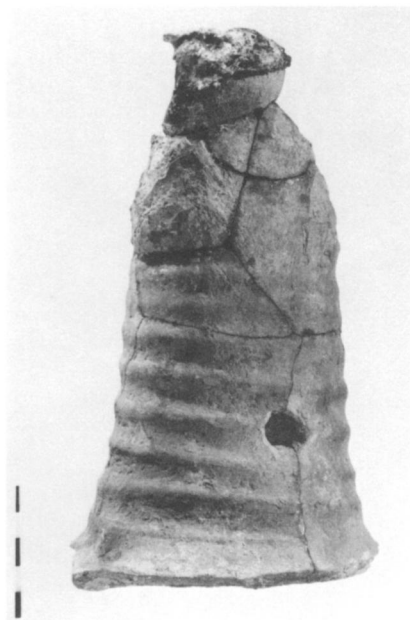
M6



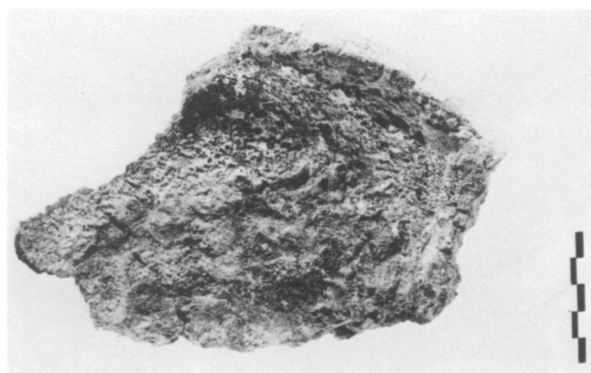
M7



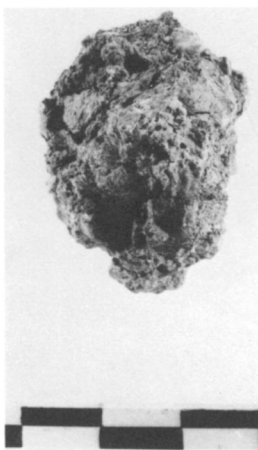
M7: restored drawing



M10



M8

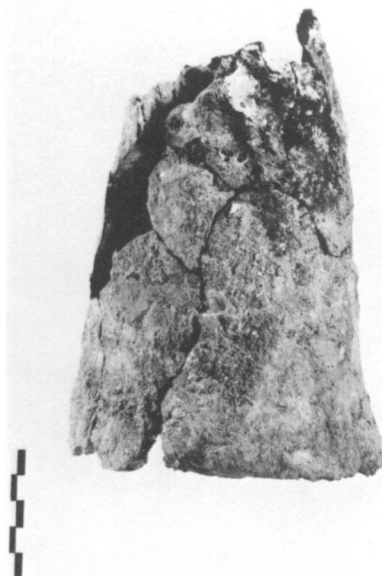


M13

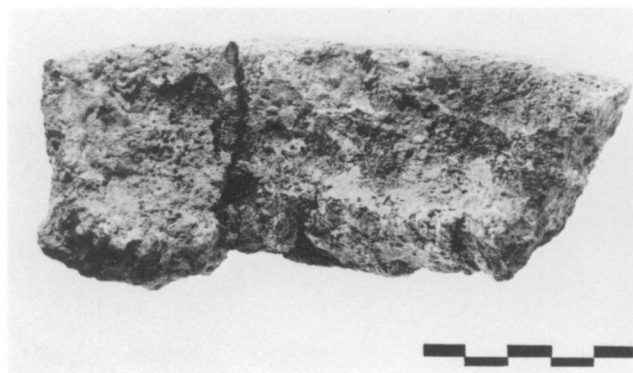


M8: restored drawing

B1505



M11



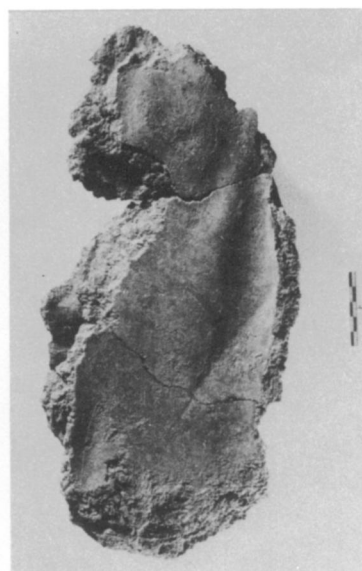
M9



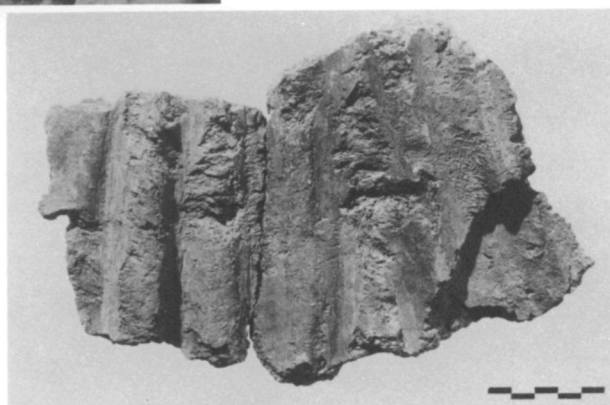
M12



Large- and small-scale foundry (N)



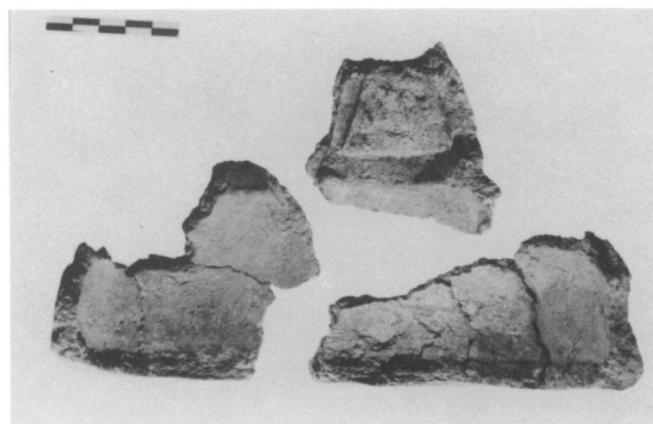
N1a



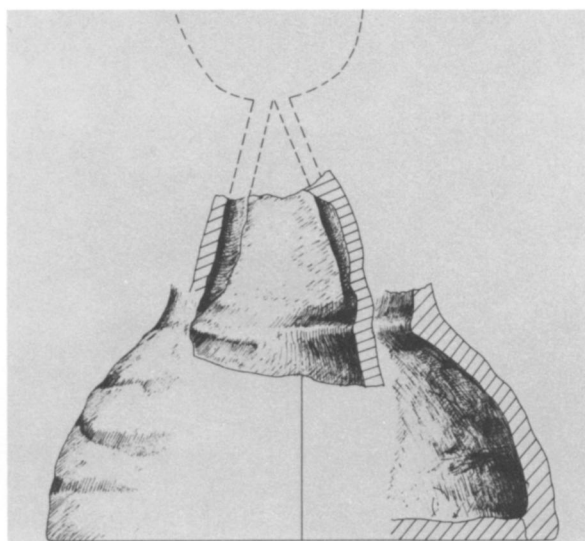
N1b



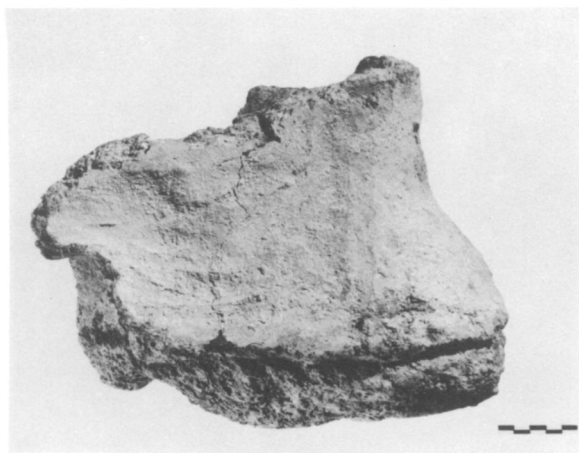
N3



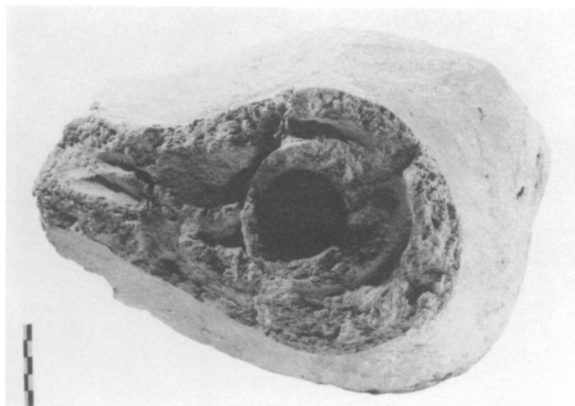
N2



N2: restored drawing



a. P1: side view



b. P1: top view



c. Hellenistic brazier (P 17989)
and cooking pot (P 2393)



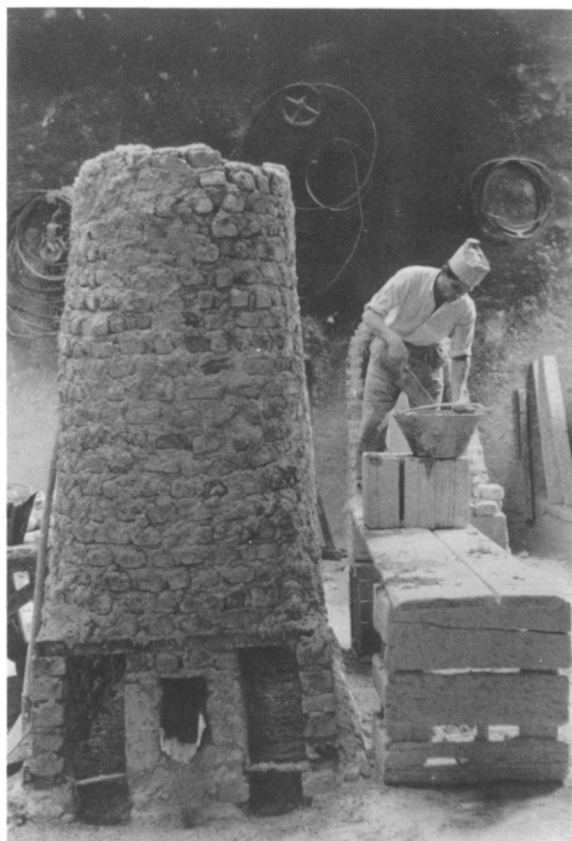
d. P 15210



a. Attachment of wax gate system to wax model



b. Application of outer layer of investment



d. Pouring of bronze into funnels of molds packed in sandy earth

c. Oven for baking molds



Side A



Side B

Berlin Foundry Cup (inv. no. F 2294). Courtesy of the Staatliche Museen