

CORINTHIAN METALWORKING: THE FORUM AREA

(PLATES 99-104)

THE Corinthian metalworking industry commanded widespread respect in antiquity, and the bronzes that were produced in Corinth were admired and sought after throughout the ancient world.¹ Pliny wrote that Corinthian bronze was valued more highly than silver (*N.H.* 34.1, 34.6-8, 34.48), and even suggested that it was alloyed with gold and silver (*N.H.* 37.49). Pausanias tried to explain the extraordinary color of Corinthian bronze by saying that it was quenched in the waters of Peirene (II.3.3).² The archaeological evidence for this flourishing industry is limited, but the discovery of metallurgical remains of all periods in the Forum Area indicate that both large- and small-scale projects were undertaken here, involving the use of both bronze and iron.

WORKSHOPS

There are few traces of actual workshops; the only large-scale bronze foundry is located to the north of Temple G (Fig. 1).³ A pit is cut in the bedrock in the shape of a keyhole, measuring 2.20 × 1.70 m. at ground level and up to 1.50 m. deep. At the south side of the wide west end of the pit there is a steep stairway,⁴ with

¹ I am grateful to Charles K. Williams, II for permission to study the Corinthian metallurgical remains, for his advice and criticisms, and in particular for allowing me to participate in the excavation of three different areas where evidence for metalworking was being uncovered during the 1972 season. Also I am indebted to Nancy Bookidis for her suggestions about the material, and for the preparation of the photographs. Finally, I should like to thank the American School of Classical Studies for an Edward Capps Fellowship in 1975/1976, with which I was able to complete the research for this paper.

² Other references to Corinthian bronze include Josephus, *Vita* 13.68; Athenaeus, 199E; and Sidonius Apollinaris, *Carmen* V.48. For a particular bronze made in Corinth, see Plutarch, *Pyth. Or.* 12. Other references to Corinthian bronze are cited in H. Payne, *Necrocorinthia*, Oxford 1931, pp. 349-350.

³ Near the west end of the Gymnasium South Stoa, there is a second Corinthian large-scale bronze foundry. This contained numerous molds for statuary; it is dated to the 1st century after Christ. See 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, pp. 67-69.

⁴ Two keyhole-shaped foundries with roughly vertical rock-cut walls and stairways, here in the narrow end of the pits, were excavated in the Athenian Agora; one is dated to the 4th century B.C., and the other to the 2nd century B.C. See H. A. Thompson and R. E. Wycherley, *The Athenian Agora*, XIV, *The Agora of Athens*, Princeton 1972, p. 190, fig. 48, pl. 97:c; C. C. Mattusch, "Bronze- and Iron-working in the Area of the Athenian Agora," above, pp. 340-379, Foundry C (Deposit A 16:1), Foundry J (Deposit C 19:3).

toe-holds substituted for the two highest steps. At the center of the floor in the west end of the pit there is an oval hole approximately 0.19 m. deep, surrounded by traces of burning. In the narrow east end of the pit, a deep channel, perhaps a flue, is flanked by high ledges. Charcoal is embedded here and there in the walls of the pit and in the burned floor around the oval hole. Unfortunately, the fill of this pit, dated to the 1st century after Christ, contained no bronze-casting debris.

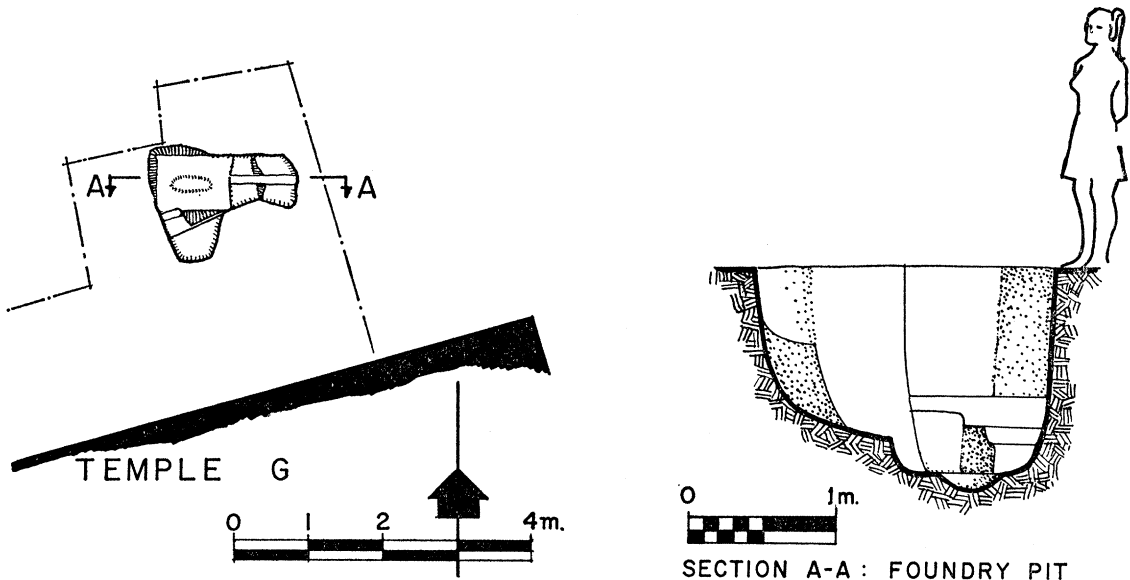


FIG. 1. Plan and section of foundry pit north of Temple G (C. K. Williams, II).

The earliest small-scale metallurgical operation was found in a 6th century B.C. courtyard in the Sacred Spring West. A late Protocorinthian floor level here was at least partly devoted to bronze casting: it yielded substantial amounts of bronze⁵ and there were many small holes in the floor, three of which showed definite traces of burning. One hole had a large bronze drip stuck inside its rim, and another had two vents at the sides, perhaps flues or holes for inserting bellows nozzles. A nearby well, which was apparently in use at the same time as the courtyard, yielded a broken section of a small bivalve mold for a spearhead.⁶ Such a mold could well have been packed into any of the holes in the courtyard for casting. Finally, one of the holes in the courtyard contained a fragmentary Archaic pan tile with a heavily vitrified round depression in its upper surface: the tile was no doubt used for setting down a small crucible, just removed from the fire.⁷

⁵ See C. K. Williams, II, "Corinth, 1972: The Forum Area," *Hesperia* 42, 1973, pp. 31-32.

⁶ MF-70-44. Max. pres. L. 0.086 m. Broken all around. Two layers of clay, the inner one fine and scorched, the outer one rougher buff-to-pink clay. See C. K. Williams, II, "Corinth, 1970: Forum Area," *Hesperia* 40, 1971, pp. 3-10, no. 31, p. 30, pl. 7. See footnote 43 below.

⁷ MF-72-42. Max. pres. dim. 0.322 m. See C. K. Williams, II, *Hesperia* 42, 1973, no. 32, p. 31, pl. 11.

Another group of pits, dated to the late 6th and 5th centuries B.C., was excavated in the area of Buildings II and III in the southern part of the Forum Area. Again, some of the pits were fairly small and circular; others were substantially larger and rectangular to oblong. Traces of burning and of slag were found throughout.⁸ More direct evidence for metalworking came from a 5th century B.C. hearth under Building III which was thickly strewn with iron, both in small corroded lumps and in highly magnetic flakes, silvery in color.⁹ This was surely an iron smithy.

After the 5th century, no evidence has been found for Corinthian metallurgical workshops until the early Roman period. Two installations in the region of the Peribolos of Apollo, both early Roman in date, may be associated with the industry. The first possibility is a small oval structure measuring 2.16×1.00 m., with rubble and tile walls preserved to a maximum height of 1.10 m.¹⁰ Parts of two hypocaust supports were preserved within; one fragment of bronze was found near by. The second construction in this area was associated with numerous traces of bronze, and was consequently identified as a bronze foundry.¹¹ The structure consisted of a plastered brick bench over 5.00 m. long and less than 1.00 m. wide; a deep channel ran along either side of the bench, and bits of bronze lay on top of it. Because of the unusual appearance of this establishment, it has not been ascertained what went on here, but the lack of anything that might be identified as a casting pit suggests that this may instead have been a bronze smithy.

FOUNDRY DEBRIS: BRONZE STATUARY

Pausanias, in his description of Corinth, mentions half a dozen bronze statues in the region of the Agora (II.2.5-3.6). No complete statues have survived, nor have the excavations so far yielded substantial fragments of statues. However, many small pieces of statues have been excavated in the Forum Area, some apparently broken up with the intent to melt them for later re-use. Because of their fragmentary condition, many of these pieces, whose interiors as well as exteriors are visible, provide information about casting techniques that would not be available from better-preserved bronzes.

All of the Corinthian fragments were produced by the lost-wax method of casting, in its direct or indirect form.¹² A study of the interiors of these pieces will

⁸ C. K. Williams, II, "Corinth, 1971: Forum Area," *Hesperia* 41, 1972, pp. 149, 169-170; *idem*, *Hesperia* 42, 1973, pp. 12-19.

⁹ *Idem*, *Hesperia* 42, 1973, p. 16.

¹⁰ Compare an oval, bricklined workshop in the Athenian Agora, Mattusch (footnote 4 above), Foundry M (Deposit L 14:1).

¹¹ R. Stillwell and H. Askew, "The Peribolos of Apollo," *Corinth*, I, ii, *Architecture*, Cambridge, Mass. 1941, pp. 27-31, figs. 18, 19.

¹² Simply, in the direct method of lost-wax casting, a wax model was formed over a clay core and covered by a mold. Baking burned out the wax, destroying the model; then the molten metal was poured into the hollow left by the burnt-out wax. In the indirect method, molds were taken

illustrate how this is determined. In general two features help establish the use of the direct lost-wax process. The first is the negative imprint of the outer surface of the clay core, originally picked up in the wax and thence transferred to the poured metal. Thus the interior surfaces of such bronzes may have pock marks from air bubbles in the clay, or irregular projections and depressions from cracks and protuberances that existed in the clay core. Only a core that is completed before the wax is added can leave the imprint of its surface on the underside of the wax, and then on the underside of the bronze; such a core is used in the direct process.

The second distinguishing feature cannot be used independently to identify bronzes cast by the direct process, for it may also occur to a lesser extent on bronzes cast by the indirect process. This characteristic, namely varying thickness in the walls of a casting, is the result of coating the core unevenly with wax. This happens because the wax model is built up over a core whose contours do not correspond exactly to those of the finished work. Thus more wax is applied on some areas of the core than on others, and the metal walls that are poured to replace the wax will also vary in thickness.

The presence of an armature inside the core of an ancient bronze is clear proof that the direct process was used, but only in the case of well-preserved bronzes do these occur, and even there, the core and armature may have been removed after casting.¹³

A bronze that has been cast by the indirect method is often fairly easy to identify. First of all, the bronze has thin and regular walls, because the molten wax has been applied to the mold in very thin layers. Second, if the inner surface of the bronze is not badly accreted, it may preserve traces of the way in which the molten wax was applied to the mold. Brushmarks, drips, or smooth poured surfaces may be preserved on the interior of the metal exactly as they occurred in the wax when it was applied to the mold. The core, added last, was undoubtedly poured into the wax impression, as is done today. Here and there a bubble might have occurred and been transferred to the bronze, but not so often as irregularities would have appeared

from a model and used to form wax impressions; these, when filled with a core and surrounded with a clay mold or investment, produced bronze copies of the original.

Observations made by D. E. L. Haynes on the interiors of bronzes as indicative of techniques of production have greatly facilitated my study of the Corinthian bronze fragments: 'Appendix' to "Bronze Priests and Priestesses from Nemi," by S. Haynes, *RömMitt* 67, 1960, pp. 45-47; "Archäologische Gesellschaft zu Berlin 1961," *ArchAnz* 77, 1962, cols. 803-807; "The Technique of the Chatsworth Head," *RevArch* ser. 8, 1968, pp. 101-112; "Ancient Bronze-Casting Methods," *ArchAnz* 85, 1970, pp. 450-452. C. Boube-Piccot has made similar studies, but unfortunately accepts K. Kluge's early claim that sand casting was practiced during antiquity: *Les bronzes antiques du Maroc* I, Rabat 1969, pp. 33-44.

¹³ Examples of bronzes cast by the direct process are the Piraeus Kouros (Athens National Museum), the Metropolitan Horse (New York Metropolitan Museum of Art, acc. no. 23.69), the Delphi Charioteer (Delphi Museum, inv. nos. 3484, 3540), all with armatures, and, in my opinion, the Chatsworth Head (London, British Museum, reg. no. 1958 4-18 1), although Haynes disagrees: *RevArch*, ser. 8, 1968, pp. 101-112.

in a core for a direct casting, which was not liquid as it had to be solid enough to model.

The Corinthian fragments of bronze sculptures, although small, number close to one hundred. Many of the pieces are identifiable, including fingers,¹⁴ fur,¹⁵ hair,¹⁶ drapery,¹⁷ a large claw,¹⁸ and part of an eye(?),¹⁹ as well as a number of patches that were used to conceal imperfections in the cast bronze (Pl. 99).²⁰ Most of these fragments were found in the Central Shops at the level of the Roman paving (MF 7935, MF 7936), but others came from the South Stoa, also in Roman contexts (MF 6317, MF 6319, MF 6322, MF 6440, MF 8016). Other pieces were found in the Southeast Forum Area (MF 2215), the Odeion (MF 1390), and miscellaneous locations (MF 1087, MF 1292, MF 6070, MF 6152). None of these fragments was found in association with molds, crucibles, slag, or other traces of the metal-working industry.

These fragments of bronze provide significant evidence for the procedures used to make large-scale bronzes. For example, one group of pieces with rough irregular undersides and generally thick walls (MF 7935: several fragments; maximum thickness 0.015 m.) must have been cast by the direct method. Other fragments bear interior markings from which it is possible to see the various ways in which the wax was applied to the molds in the indirect lost-wax process. Both MF 7935 a²¹ and MF 6440²² bear one set of brushmarks crossed diagonally by another set (Pl. 99).²³ The fact that the brushmarks which were applied first are still partly visible beneath the second coating shows how thinly the liquid wax was applied within the mold.

A single set of wide, clearly visible brushmarks appears on the back of MF 7935 b (Pl. 99).²⁴ Another piece, MF 7935 c,²⁵ has three wide drips, one pronounced,

¹⁴ MF 1292: G. R. Davidson, *Corinth*, XII, *The Minor Objects*, Princeton 1952, no. 489, pl. 47. MF 6317: *Corinth* XII, no. 487, pl. 47. MF 6440 (two): *Corinth* XII, no. 488, pl. 47.

¹⁵ MF 7935 (three fragments): *Corinth* XII, pl. 144: a, near B, C, and E.

¹⁶ MF-1087: *Corinth* XII, no. 492, pl. 47. MF 2215: *Corinth* XII, no. 491, pl. 47. MF 7935 (three fragments): *Corinth* XII, pl. 144: a, B.

¹⁷ MF 1390: *Corinth* XII, no. 493, pl. 47. MF 6322: unpublished. MF 7935 (three fragments): see *Corinth* XII, pl. 144: a, E.

¹⁸ MF 5560: *Corinth* XII, no. 490, pl. 47.

¹⁹ MF 7935: *Corinth* XII, pl. 144: a, below E, on its side.

²⁰ MF 7935 (nine): *Corinth* XII, p. 64 (identified as "tickets or other such objects"), see pl. 144: a above E. MF 7936(?), with double row of incised leaves: unpublished.

²¹ Fragment of wavy hair. Max. pres. dim. 0.065; Th. 0.003-0.006 m. For exterior, see *Corinth* XII, pl. 144: a, B.

²² Max. pres. dim. 0.054; Th. 0.001-0.002 m.

²³ These marks should not be confused with similar impressions that occur on the interior surfaces of molds used for casting statuary, which are the result of rasping smooth the exterior surface of the wax before investing it (with clay). If these marks reappeared on the bronze statue, as may sometimes have happened, they were removed. The inner surface of the bronze was naturally not retouched. For rasped mold surfaces, see Mattusch (footnote 4 above), nos. C12-C17.

²⁴ Max. pres. dim. 0.042; Th. 0.002-0.003 m.

²⁵ Max. pres. dim. 0.043; Th. 0.002-0.003 m.

the others fainter; all three drip in different directions, which suggests that the liquid wax was agitated to help coat the interior of the mold (Pl. 99). Traces of brushmarks are also visible. A thin rough projection at the right of the fragment did not occur in the wax, for it lies on top of a drip: instead, a crack which was formed in the clay core when it was poured into the wax impression later filled with bronze.

A similar wide drip on MF 7935 d²⁶ occurs in conjunction with protrusions (one is again on top of the drip) caused by the molten metal flowing into bubbles and imperfections in the clay core (Pl. 99). A smooth, spreading drip on MF 7935 e²⁷ shows that in this case the wax was poured into the mold (Pl. 100). The inner surface of MF 7935 f²⁸ has wide brush strokes, on top of which is a large protrusion where a bubble in the core prevented its complete adhesion to the wax (Pl. 100). Two fragments, MF 7935 g and MF 7935 h,²⁹ have brushmarks showing beneath poured wax (Pl. 100); on MF 7935 g, the wax has spattered as well. This pattern, which appears also on MF 7935 c (Pl. 99), suggests that the preliminary layers of wax were brushed on to ensure that every part of the mold was coated, and that afterwards more wax was simply poured in, probably to hasten the process of thickening the walls.

In contrast to the evidence for applying the wax in liquid form is MF 1390 a,³⁰ which has been deeply scored with a small spatulate instrument that was used to press non-molten wax into the mold (Pl. 100). Still another fragment, MF 6319 a, has two wide raised areas that are not drips, but that may reproduce strips of wax that were pressed onto the poured(?) wax, perhaps to fill cracks in the wax lining the mold (Pl. 101).³¹ The core also had a crack and holes that the bronze filled during the pour.³²

Nine bronze patches (Pl. 99)³³ and various fragments of bronze with the remains of patches in them (Pls. 100-102)³⁴ are also associated with the production of large-scale sculptures in bronze. Patches are needed when bubbles or other im-

²⁶ Fragment of animal fur. Max. pres. dim. 0.086; Th. ca. 0.004 m. For obverse, see *Corinth* XII, pl. 144: a, D.

²⁷ Max. pres. dim. 0.071; Th. ca. 0.003 m.

²⁸ Max. pres. dim. 0.070; Th. ca. 0.005 m.

²⁹ MF 7935 g: fragment of animal fur. Max. pres. dim. 0.039; Th. 0.003-0.004 m. For exterior, see *Corinth* XII, pl. 144: a. MF 7936 h. Max. pres. dim. 0.033; Th. 0.002-0.003 m.

³⁰ Max. pres. dim. 0.153; Th. 0.003 m. Width of blade of tool 0.004 m. A hammered bronze meander border is inlaid on the exterior in cut-out channels: Pl. 100. See also *Corinth* XII, no. 493, p. 65, pl. 47.

³¹ Max. pres. dim. 0.128; Th. 0.003 m. For exterior, see Pl. 101; also *Corinth* XII, no. 486, p. 65, pl. 47.

Evidence for the use of strips or slabs of wax was previously remarked upon by D. E. L. Haynes in *ArchAnz* 85, 1970, pp. 450-452.

³² Cf. 7935 c, d, and f, Pls. 99 and 100.

³³ All MF 7935.

³⁴ MF 6319 a, b: MF 7936 h-j.

perfections in the molten metal produce holes in the surface of the cast bronze. The flaws are repaired by cutting down the surrounding bronze to form neat rectangular or polygonal holes, usually 0.001-0.002 m. in depth, as MF 7935 i (Pl. 102; hole for polygonal patch at one edge), into which cut or cast bronze patches are set. The bottoms of the patch holes are carefully filed down to ensure a tight fit, as on MF 7935 j (Pl. 102), and the patches are concealed in the final coldworking of the statue, as on MF 7935 k (Pl. 102; six empty patch holes are partly preserved; seven patches are *in situ*, at arrows). The Corinthian patches (Pl. 99) all vary between 0.001 m. and 0.002 m. in thickness. Two are fragmentary polygons; the others are all rectangular. The largest one has a length of 0.055 m. The fact that the patches and the numerous bronze statue fragments were all found together in the area of the Central Shops suggests that they served as a source of metal for a workshop producing small-scale, probably utilitarian castings of the Roman period.

It was common practice during the Roman period to take copies of Greek originals by means of the indirect lost-wax process. As first observed by Kurt Kluge, it may be possible to identify bronze copies of bronze originals by an examination of patch holes.³⁵ If these holes are not angular, of uniform depth, and clearly cut out, but have smooth edges and rounded corners and are shallow, and if the original flaw within the hole is not visible, the bronze may be a reproduction of a bronze which had already lost its patches when the copy was made. These holes might then be reproduced with somewhat blurred contours in the overcast. They became shallower and less noticeable in the copy, so that the original flaw might not even be visible; apparently it was not considered necessary to recut and repatch the holes. Two Corinthian statue fragments illustrate the difference between cut patch holes and reproductions of patch holes. One of them, MF 6319 a,³⁶ has two deeply cut patch holes with clearly visible flaws within (Pl. 101). In contrast, the other, MF 6319 b,³⁷ has two shallow hollows with smooth, sloping sides and bottom and no apparent flaws (Pl. 102). Therefore, the latter is probably a copy of a bronze preserving a portion that was flawed and repaired in the original, but that lost its patches before the overcast was made from it.

FOUNDRY DEBRIS: SMALL BRONZEWORX

Small-scale bronze casting was clearly as important at Corinth as large-scale production, and many finds related to this industry come from the Forum Area. There is especially strong evidence for small-scale production during the 12th century after Christ. Although no actual excavation of casting pits is recorded, concen-

³⁵ K. Kluge, *Die antiken Grossbronzen: Die antike die Erzgestaltung* I, edd. K. Kluge and K. Lehmann-Hartleben, Berlin 1927, p. 117, note 2; Kluge identifies shallow hollows in a bronze torso in Florence (Archaeological Museum, inv. no. 1638) as reproductions, in a copy, of holes where patches had fallen out of the original before the copy was cast.

³⁶ Max. pres. dim. 0.128; Th. 0.003 m. Unstratified find.

³⁷ Max. pres. dim. 0.090; Th. 0.003-0.006 m. Unstratified find.

trated debris came from Room 4 of the Byzantine settlement in the Southwest Forum Area, including crucibles, clay molds, bronze and iron slag, and even an unfinished casting.³⁸ Of the sixteen crucibles from Byzantine levels in the Southwest Forum Area (Pl. 103: a),³⁹ six are from Room 4. The striking similarity among all of the crucibles may indicate that a single type of small-scale industry was being undertaken throughout the area. All of the crucibles are conical to roughly ovoid in shape, and all are 0.061-0.077 m. high and close to 0.010 m. thick. The average rim diameter is 0.064 m., and in some cases a rough spout is preserved at one side. The crucibles vary in color from gray to black and are heavily vitrified here and there, with some whitish accreted areas. Almost all of them preserve some bronze inside, and a few have splashes of the metal on the outside as well. Three crucibles have traces of heavy gray-to-white metal, probably lead, and one also has bronze and iron inside.

A heavy conical clay tube, MF 10107,⁴⁰ vitrified to a shiny, bubbly black around the narrower end, with a hole from one end to the other, was also excavated in the Southwest Forum Area (Pl. 103: b). It can be identified as a covering for a bellows nozzle,⁴¹ perhaps from the bellows used to fan the fire over which the small crucibles were heated.⁴²

Numerous bivalve mold fragments found in Room 4⁴³ were used to cast small ring-shaped objects, all with diameters of 0.022-0.023 m. (Pl. 103: c). The clay mold fabric is red and gritty, and is scorched in the channels for the rings. Many of the fragments have tiny conical funnels with both length and upper diameter of 0.013-0.014 m. The clay surface of the disk within the ring is sometimes concave

³⁸ H. S. Robinson and S. S. Weinberg, "Excavations at Corinth, 1959," *Hesperia* 29, 1960, pp. 230, 235, pl. 60.

³⁹ From Room 4: MF 10034 a-f. From the same area: MF 11001; MF 12999; MF 13124; MF 13125; MF 13177 a, b; MF 13178; MF 13179; MF 13180; MF 13307; MF-75-17. These crucibles were first interpreted as containers used to fuse colors for the glazes of Byzantine pottery: C. H. Morgan, *Corinth*, XI, *The Byzantine Pottery*, Cambridge, Mass. 1942, p. 22, fig. 17.

⁴⁰ L. 0.090 m. Complete; mended from three pieces.

⁴¹ Compare right-angled bellows nozzle shown in A. Mallwitz, *Olympische Forschungen*, V, *Die Werkstatt des Pheidias in Olympia*, Berlin 1964, pl. 25: 3. A bellows bag with the hind legs of the skin marked for or by such nozzles is shown on a red-figure krater from Caltanissetta and on a red-figure cup by Douris in the Cabinet des Médailles (inv. no. 542): both are illustrated in R. D. Gempeler, "Die Schmiede des Hephäst—Eine Satyrspielszene des Harrow-Malers," *Antike Kunst* 12, 1969, pl. 14: 3, and fig. 1.

⁴² Related finds from this area include an irregular bronze drip, MF-72-16, a flat-bottomed lump of spilled lead, MF-72-14, a fragment of lead wire, MF-72-15, and a clump of bronze with a clay-lined hole that must once have wrapped a stick, perhaps for stirring molten metal, which was burnt out in the process, MF-72-13.

⁴³ MF 10035, MF 10036, MF 10037. See also *Hesperia* 29, 1960, p. 235, pl. 60: b, c. Bivalve molds are piece molds constructed in two parts that join one another for casting small simple objects with a minimum of undercut and projecting parts. A wax model may or may not be used. A funnel is usually incorporated into one end of such molds. Although the bivalve molds discussed here are clay, they may also be made of stone. If the latter is the case, there is the possibility that the molds were used for impressing sheet metal, and not for casting molten metal, but these would not have funnels.

and sometimes convex, so that the halves fit neatly into one another, but it is not clear how they were held together during casting.⁴⁴ Two of the molds, MF 10035 and MF 10037, preserve part of a second ring (Pl. 103: c, lower row), and these pieces, as well as the uniform size and shape of all the rings, match the appearance and dimensions of an unfinished and probably miscast bronze ornament, MF 10029,⁴⁵ discovered in the same room, and no doubt one of many such objects produced here (Pl. 103: d). The ornament, perhaps a belt buckle, is apparently complete; it consists of an oval ring joined by a rectangle to a circular ring, attached in turn to a half circle. But no coldworking was done to finish the piece, and irregular seams are visible along all sides, both inside and out, where the molds joined each other. In addition, a second seam crosses both sides of the circular ring, indicating that the mold had more than one section, each one constructed on a bivalve principle. A bronze lump attached to the outside of the oval ring corresponds to the funnels visible within the molds, and represents the excess bronze left in the funnel after the pour; this excess would ordinarily have been removed during the coldworking of the piece. The excess bronze within the oval ring is concave on one side and convex on the other, as are the central disks on the molds themselves.⁴⁶

The question of how the parts of small bivalve or piece molds were joined can be solved by an examination of three other molds, all from the Central Shops, and all dating to the Roman period. The first is a mold for a handle (of a mirror?), MF-71-241,⁴⁷ whose two joining halves fit neatly along smooth edges, one of which is concave, the other convex (Pl. 104: a, d). Most interesting is the fact that they were secured by a thin over-all coating or outer investment of fine clay, which was probably brushed on wet like slip. The mold itself, of tan clay, with a tiny lip above, appears to have been molded in halves around the model. Then an outer, reddish layer of clay investment was used to join the halves; it also comprised most of the funnel around and above the inner lip. The irregular interior of the funnel indicates that it was formed freehand.

The second mold from the Central Shops, MF-71-242,⁴⁸ was used to produce a tang(?) resting on a hexagonal plate (Pl. 104: b). This one is also constructed in two sections that join neatly along concave and convex edges, but here the line of the joint is irregular. An inner brown-to-tan layer of clay forms the mold; this

⁴⁴ A pair of irregularly placed notches on either side of the funnel of one fragment are certainly too small to have aided in joining.

⁴⁵ Max. pres. L. 0.080; Th. ca. 0.004 m. For a study of failed castings from Olympia, see W.-D. Heilmeyer, "Giessereibetriebe in Olympia," *Jahrb* 84, 1969, pp. 1-27.

⁴⁶ Twenty-two bronze implements from Room 4. MF 10018, including pins, hooks, combs(?), and other small tools, may also have been produced in this workshop. Some are cast and some hammered, which raises the problem of whether one workshop might produce both kinds of bronzes. Illustrated in *Hesperia* 29, 1960, p. 235, pl. 60: d.

⁴⁷ Max. pres. dim. 0.075; D. of funnel 0.012 m. The fragment preserves part of a rim and the base of a handle, separated by a flat fillet from which extend two rounded tongues, slightly flaring at the ends.

⁴⁸ Max. pres. dim. 0.078 m. Mold and funnel partly preserved; broken below.

mold was held closed by an over-all outer layer of red clay, now broken, which again formed the funnel.

The third piece mold, MF-71-80,⁴⁹ was closed in a similar way (Pl. 104: e-h). It must have been used to cast part of a furniture leg: a lower rectangular section, with a depression in its bottom, is surrounded by a cylindrical section with three groups of horizontal incised and raised bands.⁵⁰ The two mold sections are formed of coarse, pinkish buff clay, baked hard, and partly scorched inside. They meet along smooth horizontal edges, and are attached to one another by a thin outer investment of the same red clay, barely visible for its having broken away when the mold was dismantled (see Plate 104: h at arrow). The smooth edge on the top of the upper section of the mold indicates that it probably joined yet another mold section.

These three utilitarian piece molds with their thin investments holding the parts together undoubtedly illustrate the way in which the bivalve molds from Room 4 were secured during casting. The fact that the three molds from the Central Shops are all of Roman date, while the ring-shaped molds from the Southwest Forum Area are Byzantine, suggests technical continuity of Corinthian workshops.⁵¹

There are relatively few metallurgical finds of any period from the Forum Area that do not come from the region of the Central Shops and from Buildings II and III. The only notable exceptions are the late 6th century B.C. industrial courtyard in the Sacred Spring West, the two early Roman installations in the area of the Peribolos of Apollo, and the 12th century (after Christ) workshops in the Southwest Forum Area. The lack of substantial archaeological evidence for large-scale production in the Forum Area obviously must not be interpreted as meaning that Corinthian metalworkers did not make many large-scale bronzes. Rather, it is reasonable to assume that most Corinthian foundries and smithies were located outside the civic center of the city. In fact, a 1st century (after Christ) foundry complex with numerous mold fragments for statuary was excavated in the Gymnasium area by the University of Texas during the 1967 through 1969 seasons. The fragmentary material from the Forum Area clearly indicates that Corinthian techniques for metalworking were sophisticated. A study of the better-preserved Gymnasium debris will undoubtedly throw further light on Corinthian techniques. Ancient authors support the archaeological evidence heartily with the praise that they accord to the quality of both large and small Corinthian bronzes.

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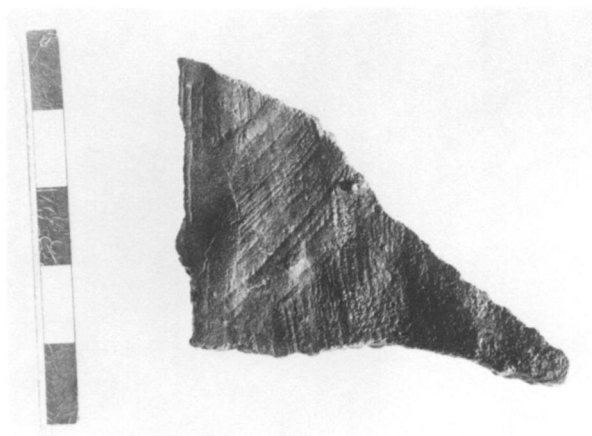
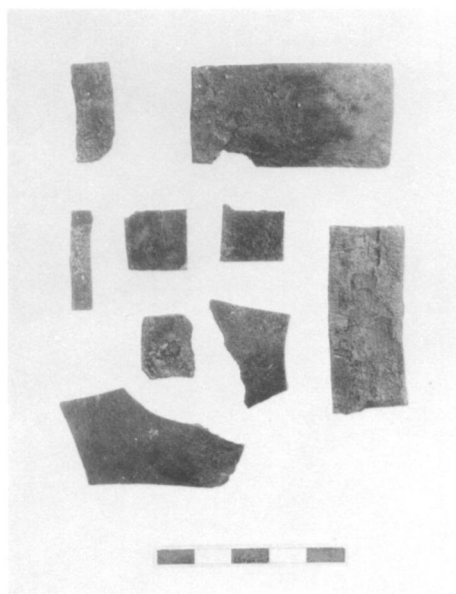
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⁴⁹ H. of lower section 0.039; H. of upper section 0.046 m. Mended from joining fragments.

⁵⁰ Compare plaster molds for "knobs" and "stems" illustrated in C. C. Edgar, *Greek Moulds*, Cairo 1903, nos. 32244-32250, pls. XVII, XXXI.

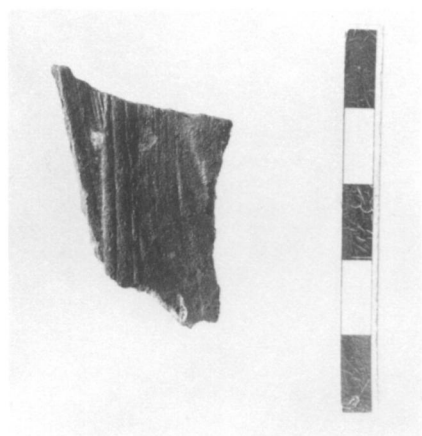
For a similar type of leg, but of much earlier date, see legs of throne represented on a volute krater by Kleophon in Ferrara: illustrated in G. M. A. Richter, *The Furniture of the Greeks, Etruscans and Romans*, London 1966, fig. 109.

⁵¹ There is no evidence in the Athenian Agora at any period for the use of this technique, nor is there evidence for continuity of procedural details from the Greek to the Roman period.

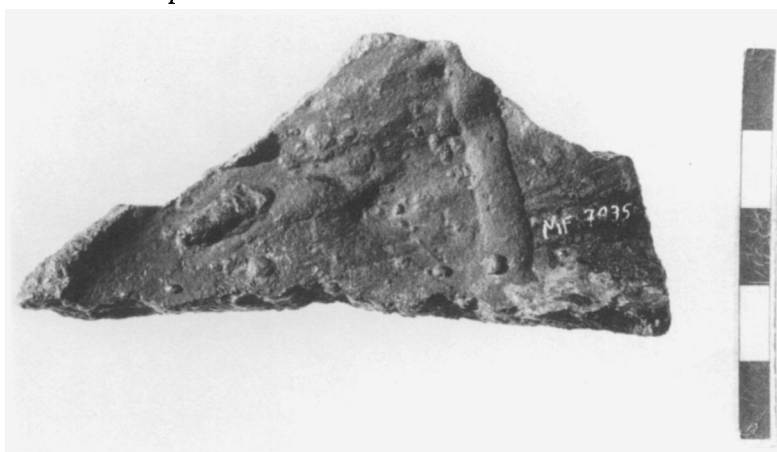


MF 7935 a: interior

MF 7935: patches



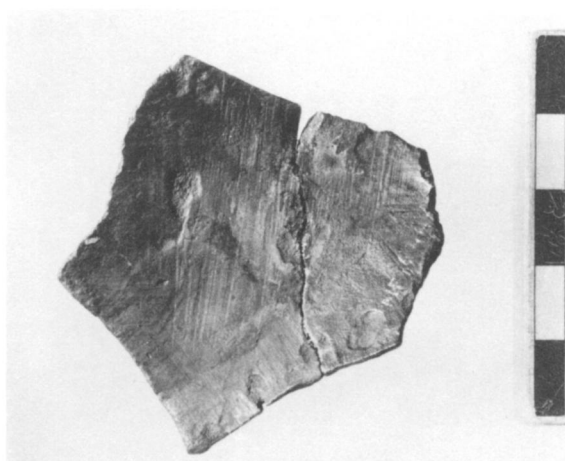
MF 7935 b



MF 7935 d



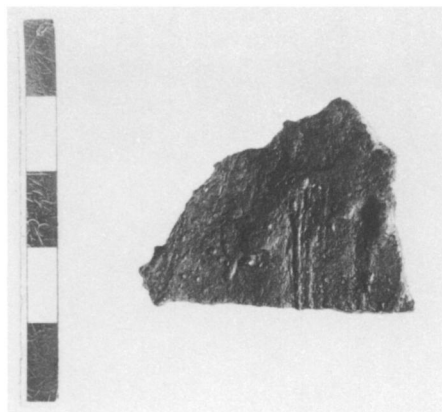
MF 7935 c



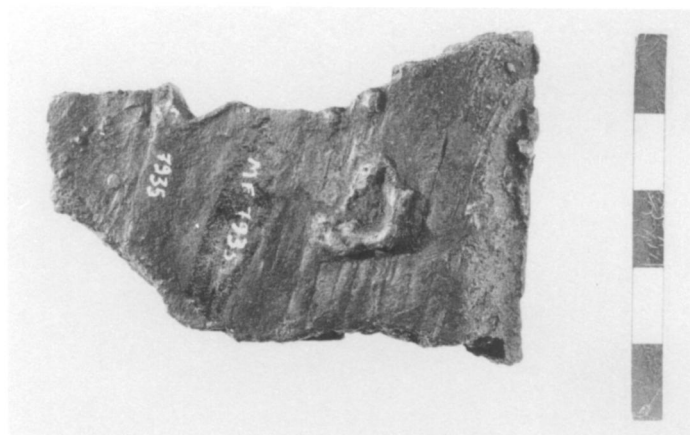
MF 6440



MF 7935 e



MF 7935 g



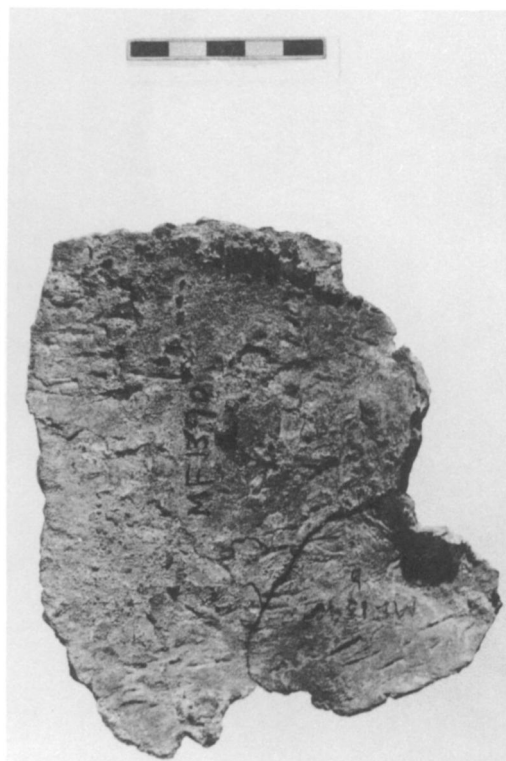
MF 7935 f



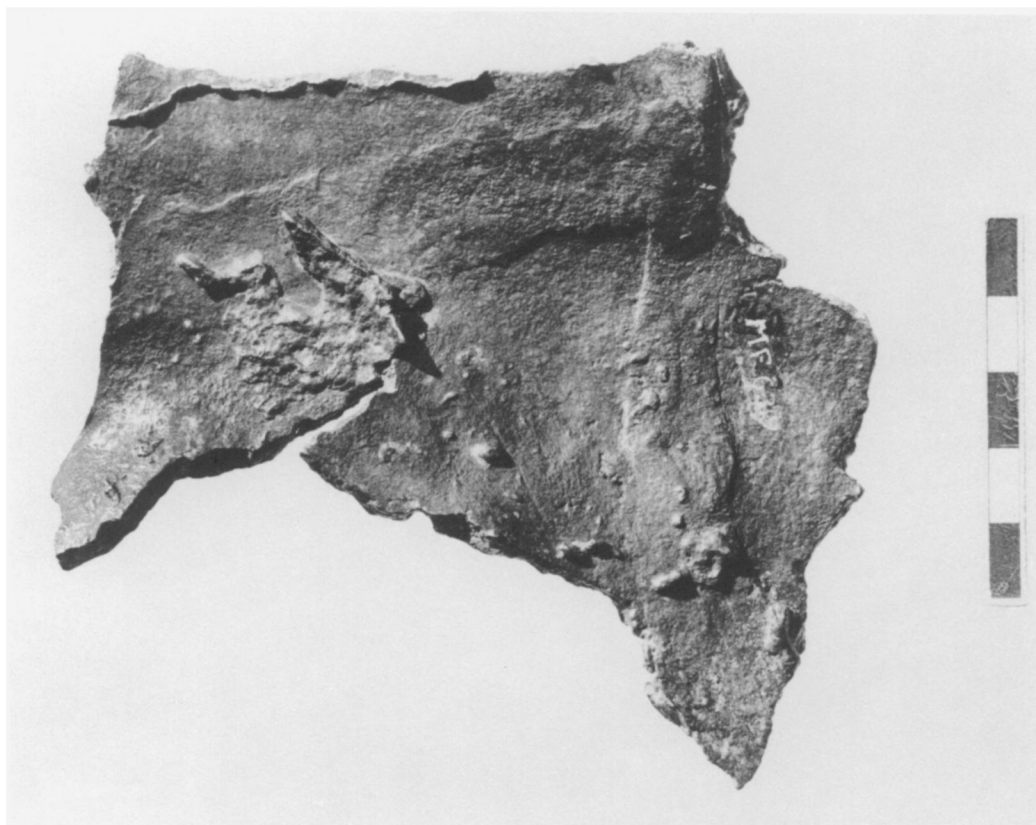
MF 7935 h



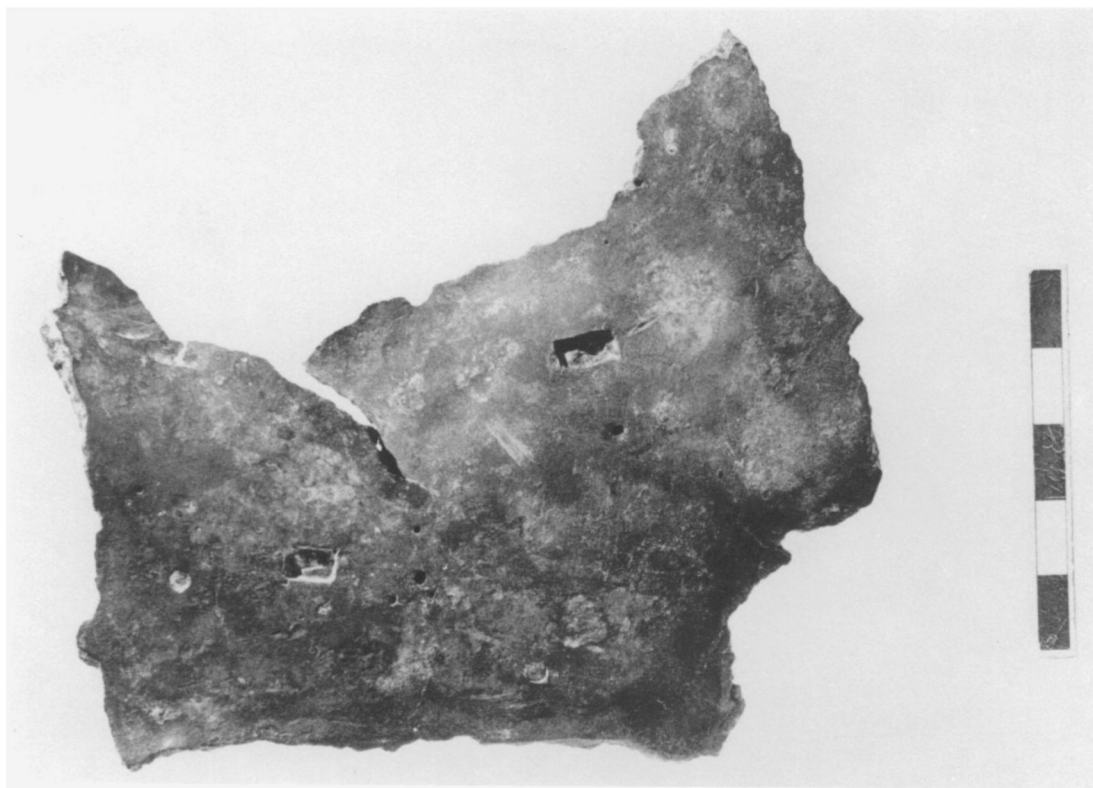
MF 1390 a: exterior



MF 1390 a: interior



interior



exterior

MF 6319 a

CAROL C. MATTUSCH: CORINTHIAN METALWORKING: THE FORUM AREA



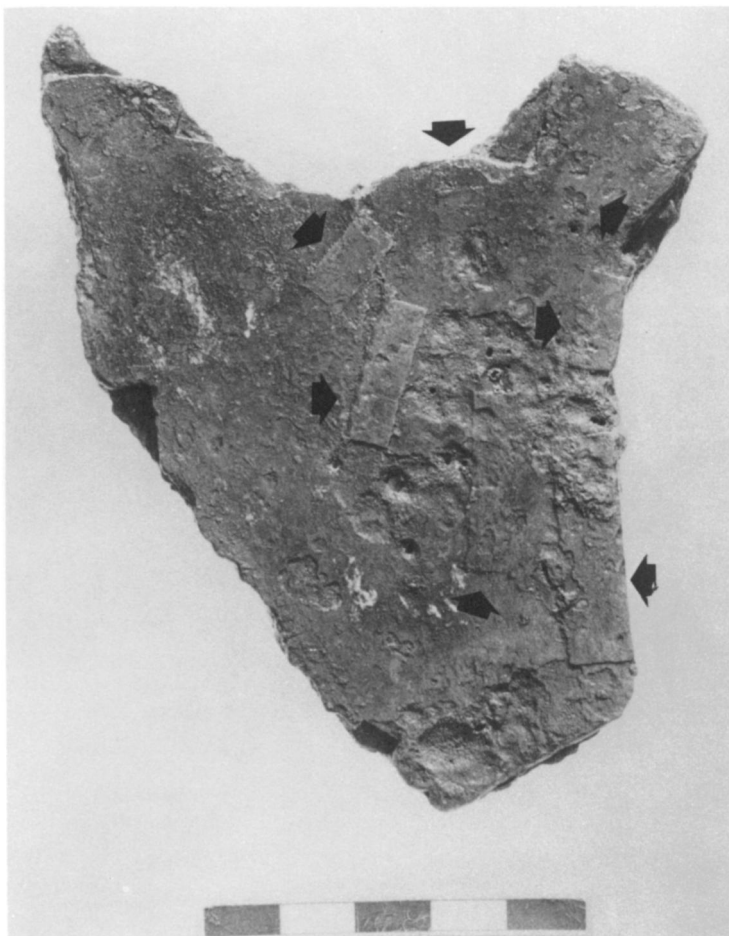
MF 6319 b



MF 7935 j



MF 7935 i



MF 7935 k



a. Crucibles



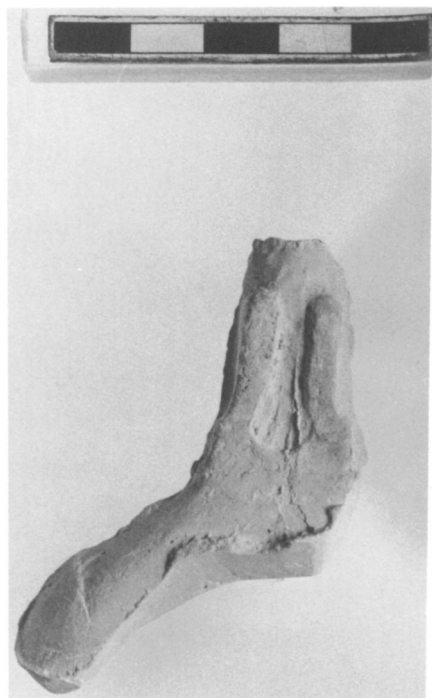
b. MF 10107



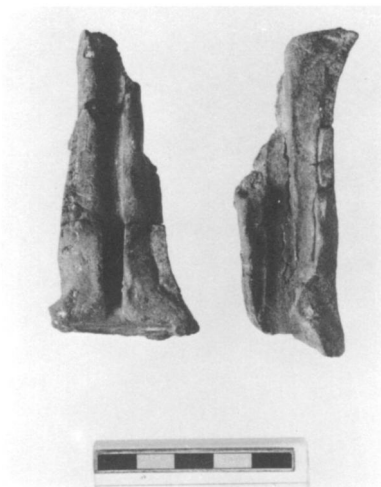
c. Bivalve ring molds



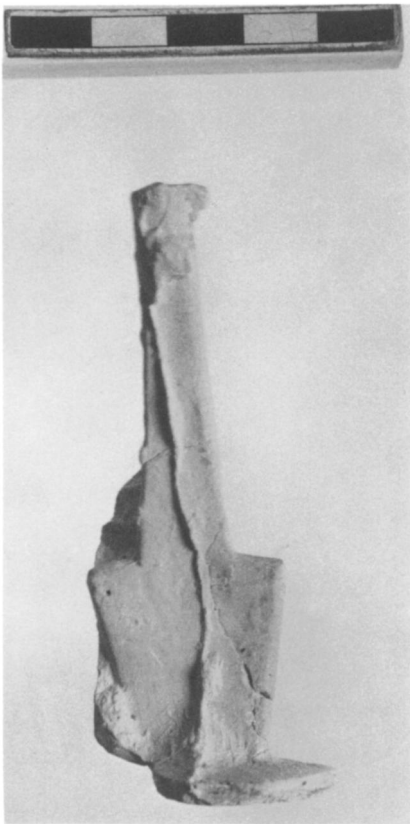
d. MF 10029



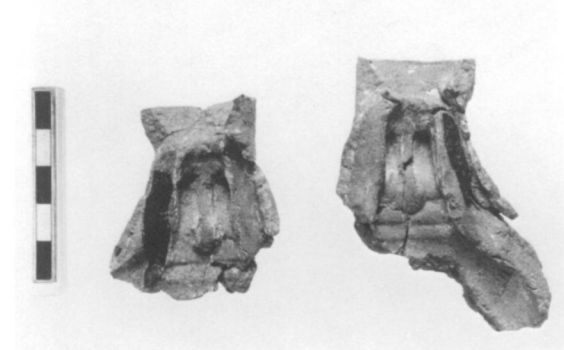
a. MF-71-241: cast



b. MF-71-242



c. MF-71-242: cast



d. MF-71-241



e. MF-71-80:
section of
cylindrical
portion



f. MF-71-80: cast



g. MF-71-80: whole



h. MF-71-80:
section of rectang-
ular portion