

The Manufacture of Minoan Metal Vessels: Theory and Practice

by

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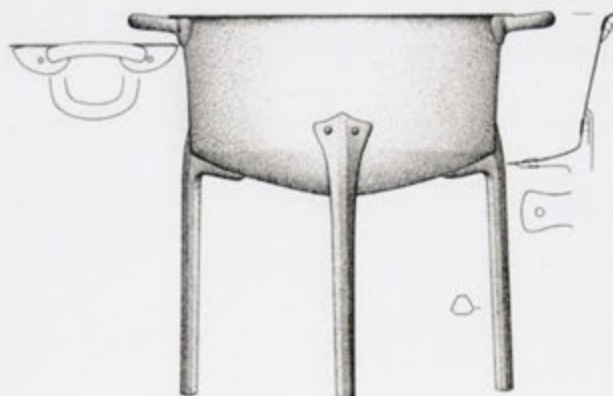


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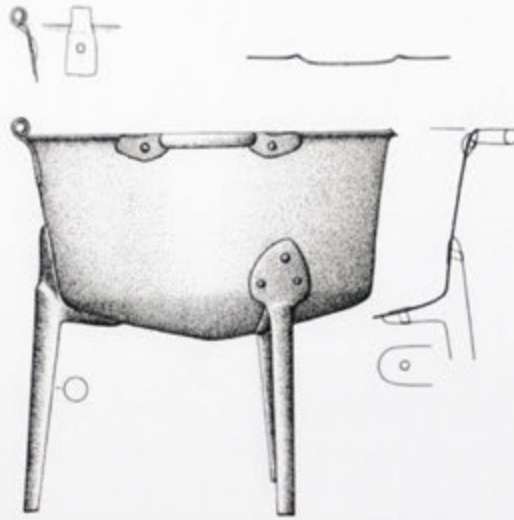


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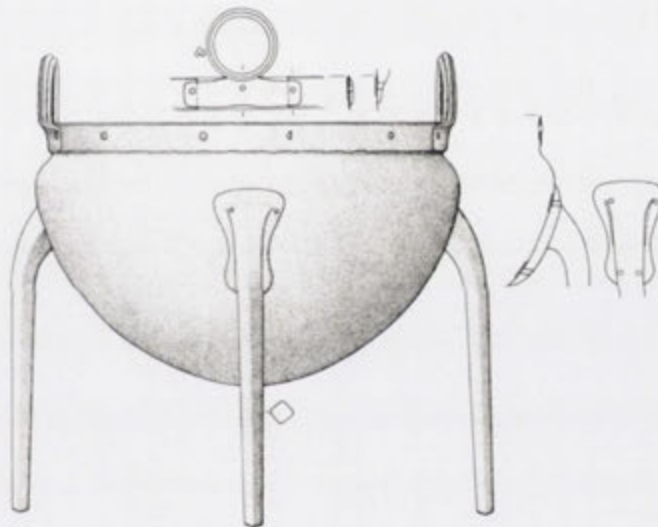


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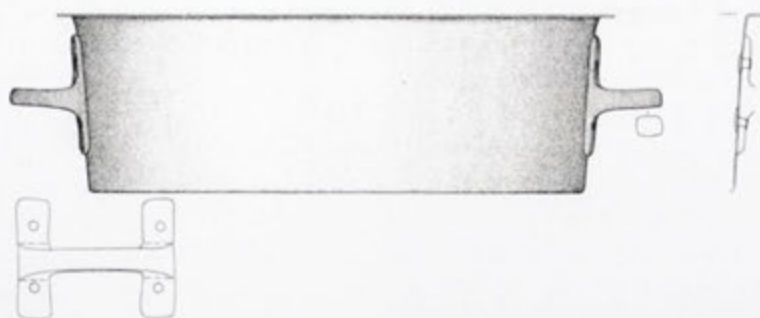


Figure 8. Pan: type 4A. Chania, tomb south of the law-courts, LM IIIA1. CM M119. *BKMK* no. 30. *Adapted from:* Matthäus, *BKMK*, pl. 5.

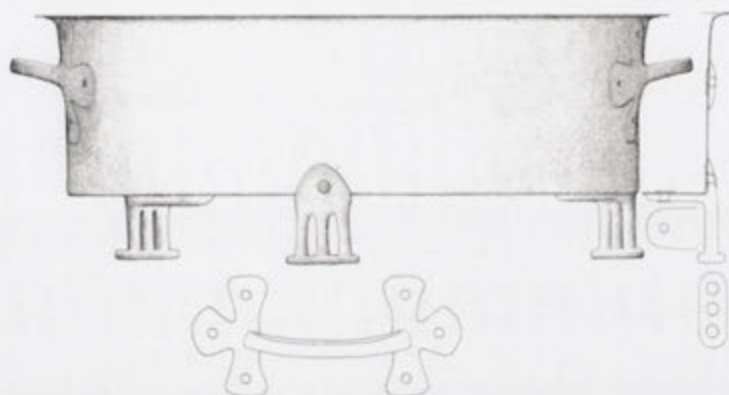


Figure 9. Pan: type 4B. HM 1086. Zapher Papoura, Tomb 14k, LM IIIA1. *BKMK* no. 37. *Adapted from:* Matthäus, *BKMK*, pl. 6.



Figure 10. Pan: type 12. Zapher Papoura Tomb 14c, LM IIIA1. *BKMK* no. 164. *Adapted from:* Matthäus, *BKMK*, pl. 19.



Figure 11. Two-handled basin: type 10C. Probably east Crete, Neopalatial. *BKMK* no. 124. *Adapted from:* Matthäus, *BKMK*, pl. 15.

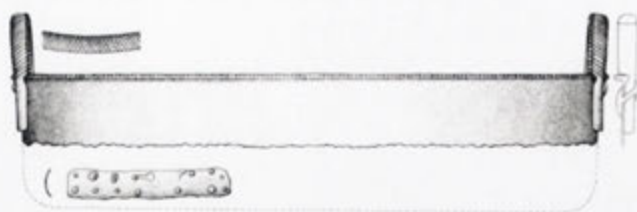


Figure 12. Two-handled basin: type 10E. Sellopoulo, Tomb 4, Burial I, LM IIIA1. *BKMK* no. 151. *Adapted from:* Matthäus, *BKMK*, pl. 17.



Figure 13. Small pan with a single vertical handle: type 15. HM 1091. Zapher Papoura, Tomb 14e, LM IIIA1. *BKMK* no. 178. *Adapted from:* Matthäus, *BKMK*, pl. 21.



Figure 14. Large pan with a single vertical hollow handle: Type 13A. AshM 1967.1214. ?East Crete, MM III – LM I. *BKMK* no. 166. *Adapted from:* Matthäus, *BKMK*, pl. 19.



Figure 15. Bowl: type 47A. Katsamba, Tomb B, LM II. *BKMK* no. 414. *Adapted from:* Matthäus, *BKMK*, pl. 49.



Figure 16. Bowl: type 49B. Palaikastro, Block N, Room 9, LM IB. *BKMK* no. 424. *Adapted from:* Matthäus, *BKMK*, pl. 50.



Figure 17. Bowl: type 50. HM 1085. Zapher Papoura. Tomb 14, LM IIIA1. *BKMK* no. 433. *Adapted from:* Matthäus, *BKMK*, pl. 50.



Figure 18. Bowl: type 51. HM 1528. Zapher Papoura, Tomb 14, LM IIIA1. *BKMK* no. 438. *Adapted from:* Matthäus, *BKMK*, pl. 50.



Figure 19. Hydria: type 20. HM 2079. Knossos, house SE of the South House, MM III – LM I. *BKMK* no. 210. *Adapted from:* Matthäus, *BKMK*, pl. 25.



Figure 20. Piriform vase: type 22A. HM 843. Knossos, NW Treasure House, LM IA. *BKMK* no. 252. Adapted from: Matthäus, *BKMK*, pl. 31.

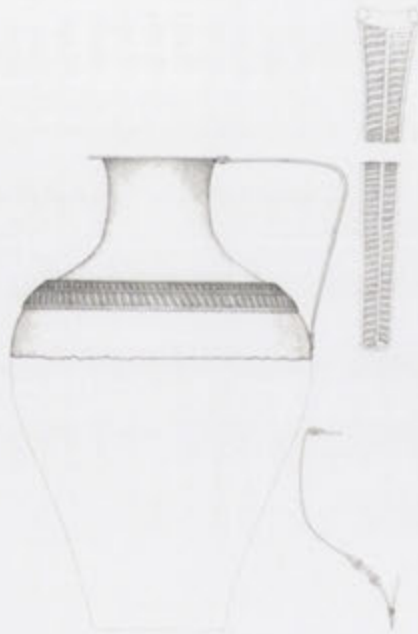


Figure 21. Piriform vase with masking-band: type 24. Sellopoulo, Tomb 4, Burial I or III, LM IIIA1. *BKMK* no. 282. Adapted from: Matthäus, *BKMK*, pl. 33.



Figure 22. Piriform vase with bird protome: type 27. Sellopoulo, Tomb 4, Burial 1, LM IIIA1. *BKMK* no. 296. *Adapted from: Matthäus, BKMK, pl. 35.*

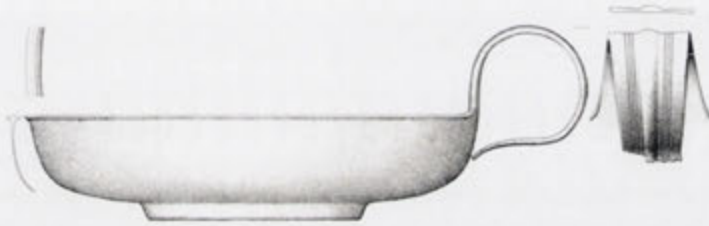


Figure 23. One-handed basin: type 32A. HNM 54. Piskokephalo, LM III. *BKMK* no. 311. *Adapted from: Matthäus, BKMK, pl. 37.*



Figure 24. One-handed basin: type 32D. HM 1082. Knossos, house in the vicinity of the palace, LM. *BKMK* no. 322. *Adapted from: Matthäus, BKMK, pl. 39.*

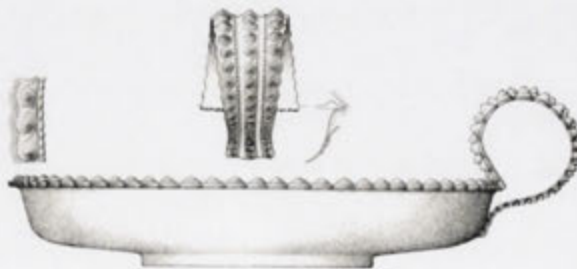


Figure 25. One-handed basin: type 32E. HM 1578. Mochlos, Block B, Room C, LM IB. *BKMK* no. 328. *Adapted from: Matthäus, BKMK, pl.40.*



Figure 26. Cup: type 33. Mochlos, Tomb 9, MM III – LM I. *BKMK* no. 338. *Adapted from:* Matthäus, *BKMK*, pl. 41.



Figure 27. Cup: type 35. Sellopoulo, Tomb 4, Burial I, LM IIIA1. *BKMK* no. 345. *Adapted from:* Matthäus, *BKMK*, pl. 41.



Figure 28. Cup: type 37C. Sellopoulo, Tomb 4, Burial III, LM IIIA1. *BKMK* no. 532. *Adapted from:* Matthäus, *BKMK*, pl. 42.



Figure 29. Cup: type 38B. Mochlos, Tomb 12, LM IB. *BKMK* no. 357. *Adapted from:* Matthäus, *BKMK*, pl. 42.



Figure 30. Copper ‘Vapheio’ cup inlaid with gold, electrum and silver. Said to be from Crete. *AGSW* no. 24. *Adapted from:* E. N. Davis, *The Vapheio Cups and Aegean Gold and Silver Ware* (London: Garland Publishing, 1977), fig. 96.



Figure 31. Cup: type 43. Zapher Papoura, Tomb 14. LM IIIA1. *BKMK* no. 368. *Adapted from: Matthäus, BKMK, pl. 43.*



Figure 32. Silver kantharos. Gournia, House Tomb 2, MM II. *AGSW* no. 12. *Source: Davis, AGSW, fig. 66.*



Figure 33. Pitcher: type 26. Sellopoulo, Tomb 4, Burial I, LM IIIA1. Matthäus *BKMK* no.294. *Adapted from: Matthäus, BKMK, pl. 35.*



Figure 34. Pitcher: type 28. Zapher Papoura, Tomb 99h, LM IIIA1. *BKMK* no. 298. *Adapted from: Matthäus, BKMK, pl. 36.*



Figure 35. Pitcher: type 29. HM 1004. Mouliana, Tholos A, LM IIIC. *BKMK* no. 300. Adapted from: Matthäus, *BKMK*, pl. 36.



Figure 36. Silver pitcher. HM 404. Knossos, South House, LM IB. *AGSW* no. 14. Source: Davis, *AGSW*, fig. 78.



Figure 37. Pitcher: type 30. HM 2192. Malia, property of Grammatikakis, LM IA. *BKMK* no. 302. Adapted from: Matthäus, *BKMK*, pl. 36.

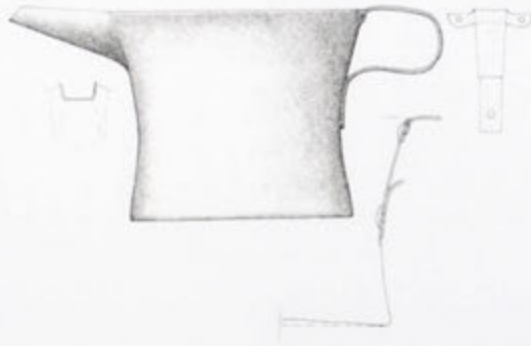


Figure 38. Pitcher: type 40. HM 2019. Gourmes, Tomb 2, LM IIIB. *BKMK* no. 363. *Adapted from: Matthäus, BKMK, pl. 43.*



Figure 39. Pitcher: type 31. HM 1090. Zapher Papoura, Tomb 14I, LM IIIA1. *BKMK* no. 303. *Adapted from: Matthäus, BKMK, pl. 36.*

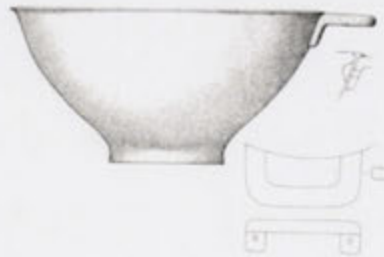


Figure 40. Lekane: type 44. Knossos, SW of the South House, LM IA. *BKMK* no. 370. *Adapted from: Matthäus, BKMK, pl. 44.*



Figure 41. Lekane: type 45B2. CM M115. Chania, tomb south of the law-courts, LM IIIA1. *BKMK* no. 403. *Adapted from:* Matthäus, *BKMK*, pl. 48.



Figure 42. Ladle: type 57B. Siteia region, LM II-III. *BKMK* no. 448. *Adapted from:* Matthäus, *BKMK*, pl. 52.



Figure 43. Ladle: type 57C. HM 1094. Zapher Papoura, Tomb 14, LM IIIA1. *BKMK* no. 449. *Adapted from:* Matthäus, *BKMK*, pl. 52.



Figure 44. Lamp: type 58B1. Sellopoulo, Tomb 4, Burial III, LM IIIA1. *BKMK* no. 456. *Adapted from:* Matthäus, *BKMK*, pl. 53.

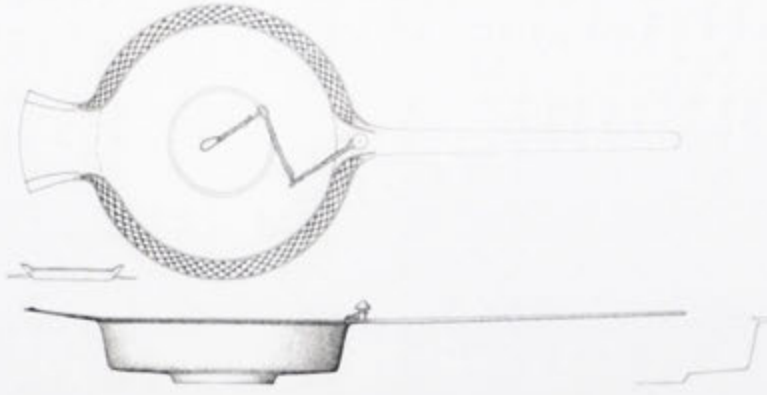


Figure 45. Lamp: type 58B2. HM 1093. Zapher Papoura, Tomb 14, LM IIIA1. *BKMK* no. 464. *Adapted from:* Matthäus, *BKMK*, pl. 54.



Figure 46. Brazier: type 59A. Zakro, palace Room 45a, LM IB. *BKMK* no. 466. *Adapted from:* Matthäus, *BKMK*, pl. 55.

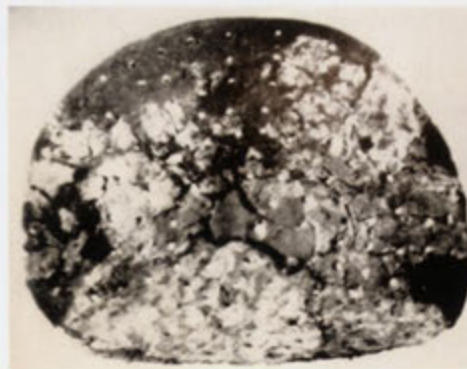


Figure 47. Sieve: type 60. Zakro, palace Room 45a, LM IB. *BKMK* no. 471. *Adapted from:* N. Platon, "Anaskaphi Zakrou," *Praktika tis en Athenis Archaologikis Etaireias* (1967): pl. 161b.

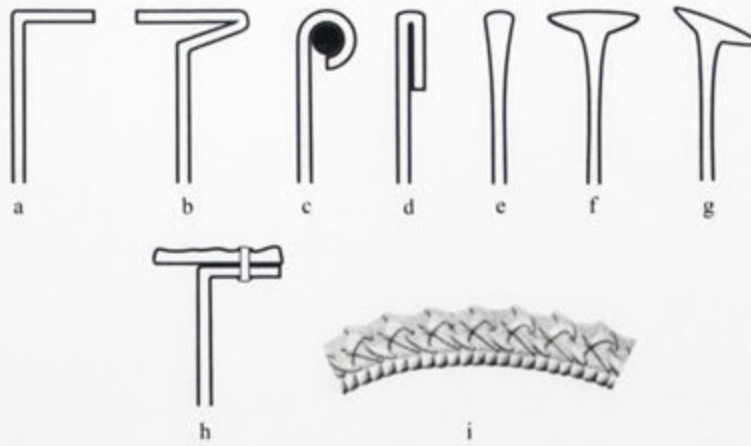


Figure 48. Rim types: a) folded out; b) folded out and in; c) rolled over wire; d) folded down; e) lightly thickened; f) heavily thickened; g) heavily thickened on a angle; h) separate rim riveted to folded-out rim; i) example of a separately-made rim with relief decoration (*adapted from: Matthäus, BKMK, pl. 39*).



Figure 49. Handles made from the same material as the vessel body: a) hammered strip; b) hammered strip riveted to body; c) hammered, hollow tube; d) massive strap-handle; e) massive rod-handle. *Adapted from: Matthäus, BKMK, pls 41, 52, 19, 37, 21.*

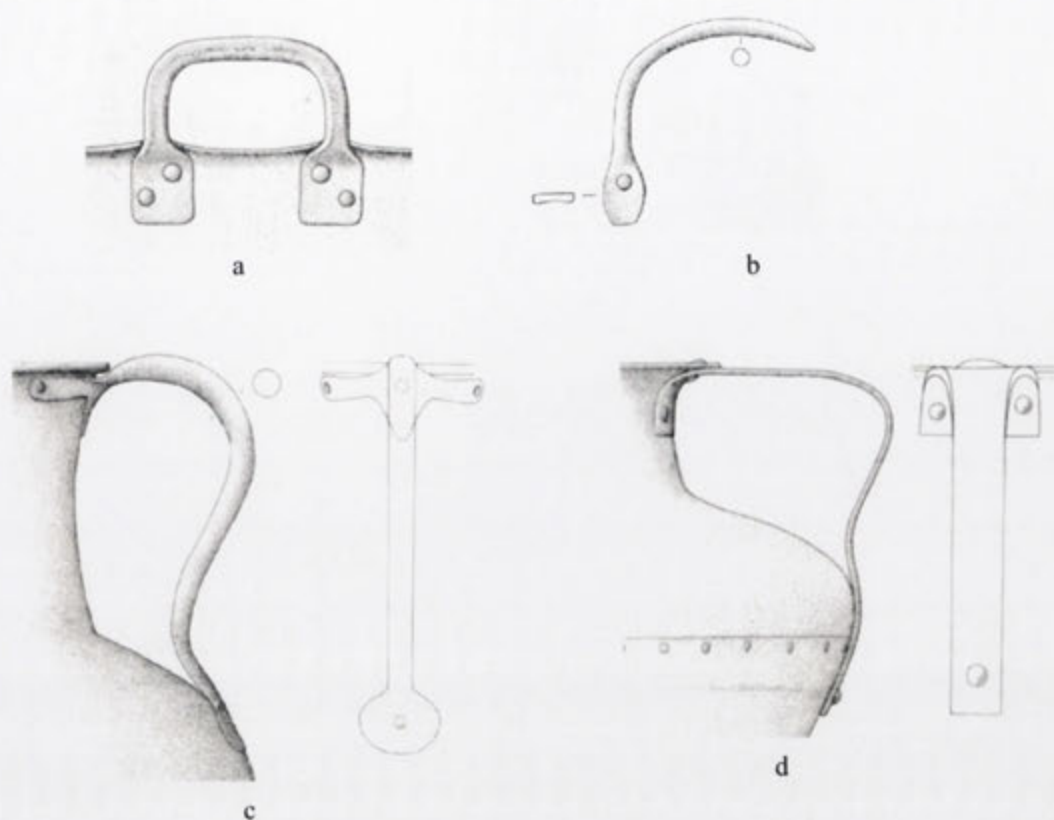


Figure 50. Separate, hammered handles: a) rectangular rod with splayed attachment-plates; b) round rod with splayed attachment-plates; c) complex hammered rod-handle with shaped upper attachment-plate and splayed lower attachment-plate; d) hammered flat bar. *Adapted from: Matthäus, BKMK, pls 1, 14, 36, 35.*

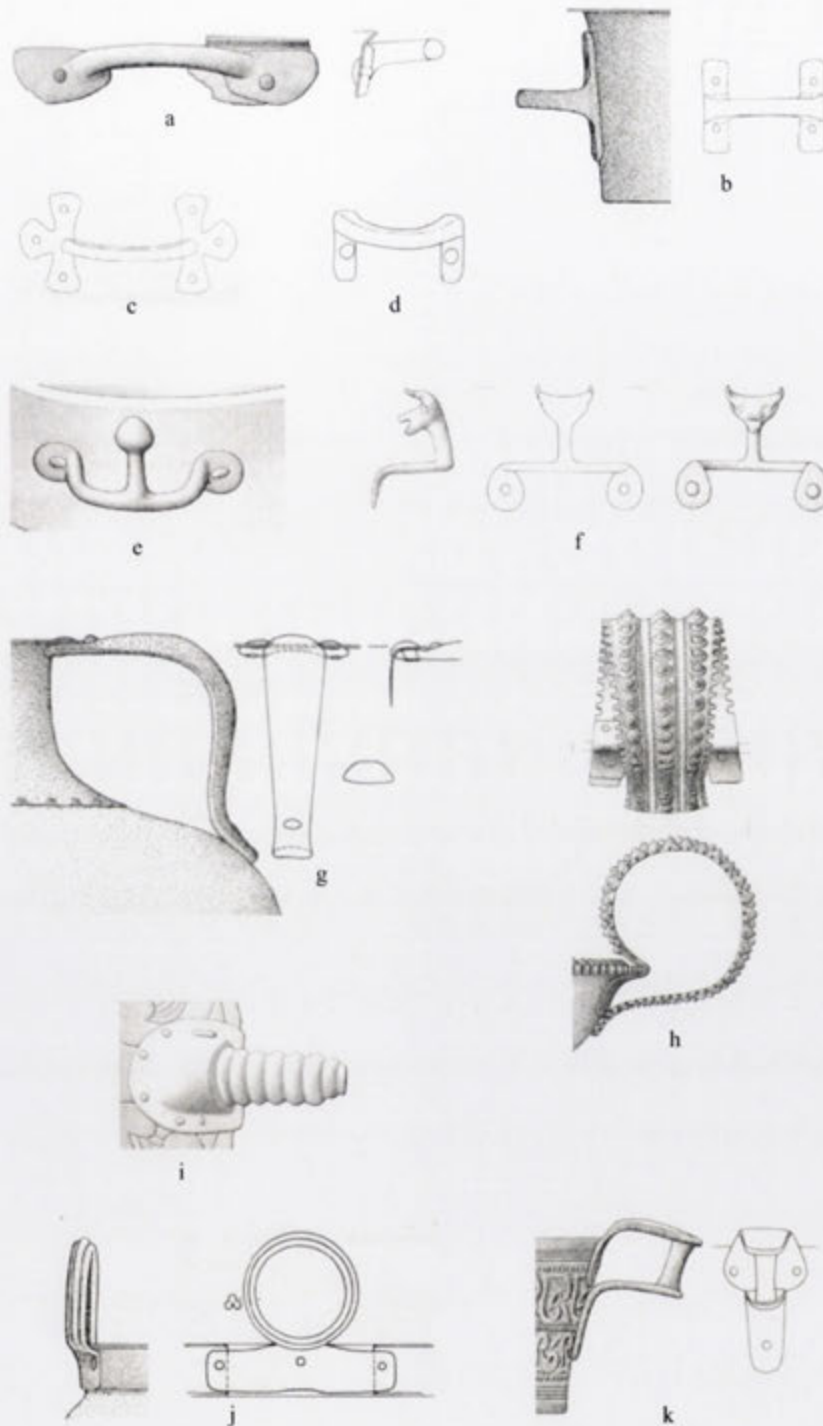


Figure 51. Separate, cast handles: a) to d) basic loop-handles with horizontal, bulbous attachment-plates (a), with vertical, upper and lower attachment-plates (b), with trefoil attachment-plates (c) and with vertical, lower attachment-plates (d); e) wishbone-handle; f) wishbone-handle with bull's head; g) hydria handle; h) relief-decorated handle for a broad-rimmed basin; i) hollow socket-handle for a brazier; j) ring-handle for a tripod cauldron; k) spool-handle. *Adapted from: Matthäus, BKMK, pls 8, 5, 6, 29, 19, 49, 40, 55, 10, 42.*

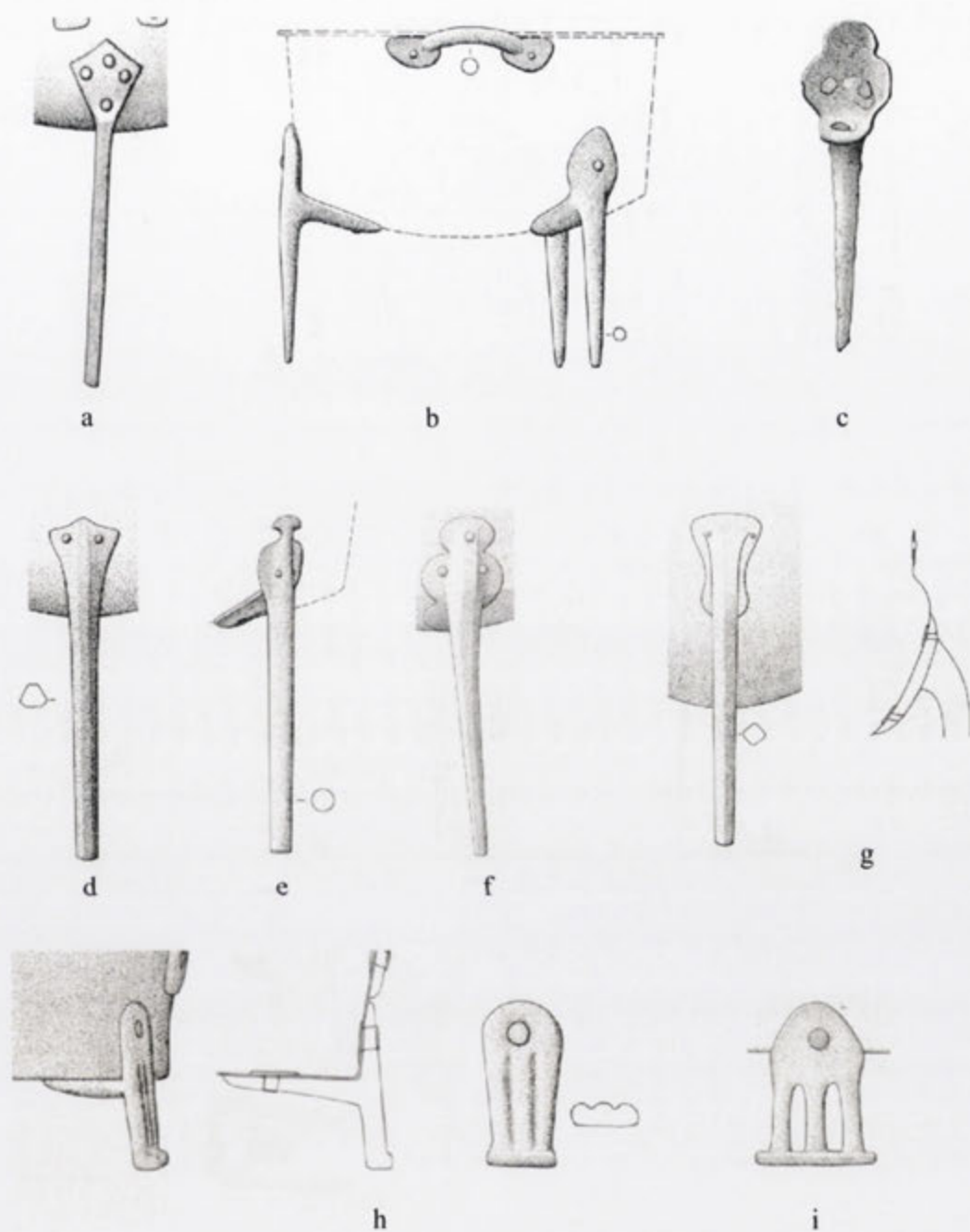


Figure 52. Leg types on tripod cauldrons and pans: a) hammered rod; b) to i) cast legs types.
Adapted from: Matthäus, BKMK, pls 7, 8 and 9.

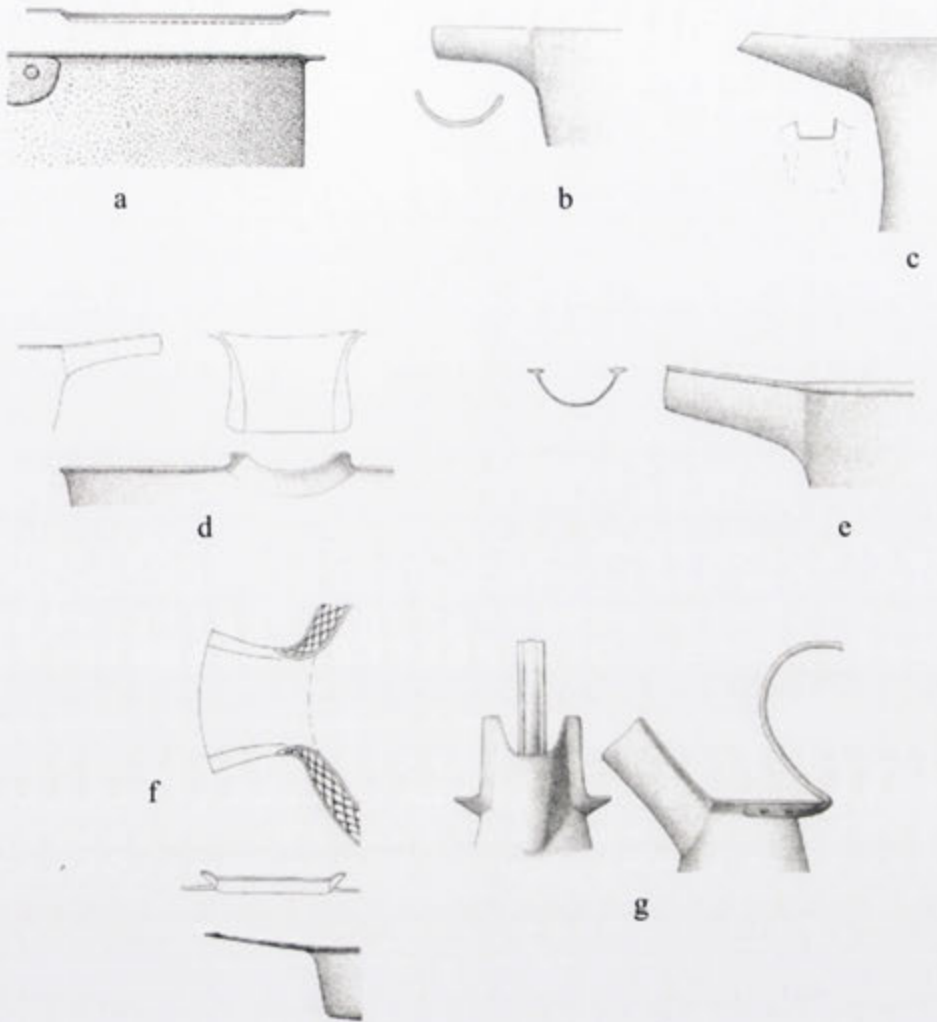


Figure 53. Spout types: a) adaptation of rim; b) to c) variations of rims made from a rim-provision. *Adapted from:* Matthäus, *BKMK*, pls 8, 41, 43, 48, 45, 54, 36.

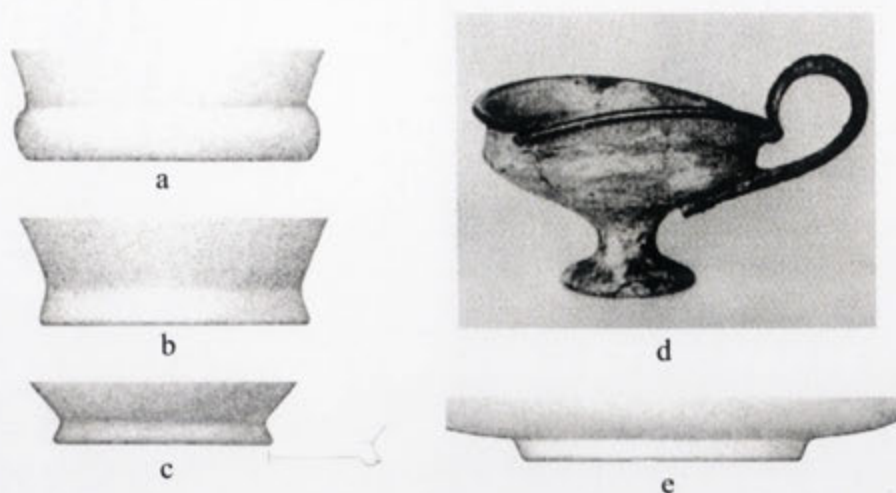


Figure 54. Base types: a) torus-base; b) splayed base; c) ring-base; d) kylix/goblet foot; e) dropped base. *Adapted from: Matthäus, BKMK, pls 31, 36, 37; Davis, AGSW, fig. 89.*

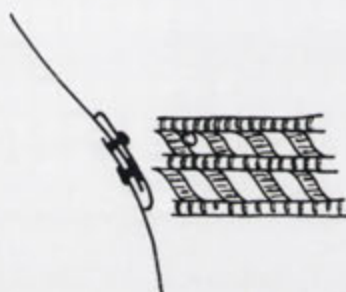


Figure 55. Attachment-method for the masking-band on BKMK no. 282. See Figure 21. *Adapted from: D. Evely, Minoan Crafts: Tools and Techniques: An Introduction, vol. 2, SIMA 92:2 (Jonsöred: Paul Åströms Förlag, 2000), fig. 153.*

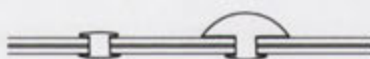


Figure 56. Cross-section of the rivet types. Flush-head rivet (*left*) and mushroom-head rivet (*right*).

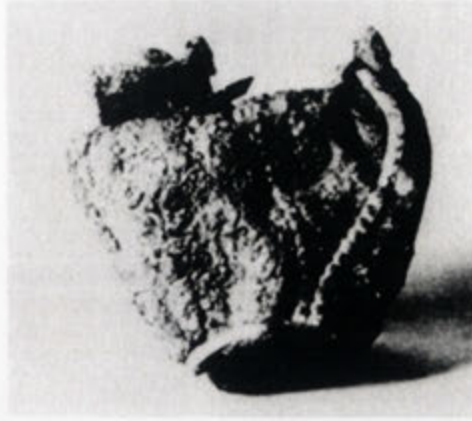


Figure 57. Silver ewer with silver overlays plated with gold and electrum. Zakros, storeroom in palace west wing, LM IB. HM 962. *AGSW* no. 13. Adapted from: Davis, *AGSW*, fig. 77.



Figure 58. Vessels from the Early Dynastic IIIA Royal Tombs at Ur: (left) electrum beaker, Penn B17691; (right) silver spouted beaker, Penn 17082B. Adapted from: R. L. Zettler and L. Horne, *Treasures from the Royal Tombs of Ur* (Philadelphia: University of Pennsylvania Museum of Archaeology and Anthropology, 1998), figs on 133, 136.



Figure 59. Gold pitcher from Central Anatolia, EBA II-III BC. Met 57.67. Source: Metropolitan Museum of Art, "Ewer Decorated with Concentric Circles," Metropolitan Museum of Art Collections, <http://www.metmuseum.org/Collections/search-the-collections/30008817> (accessed 2 February 2012).



Figure 60. Gold bottle from Troy IIg. Source: I. Antonova, V. Tolstikov, and M. Treister, *The Gold of Troy: Searching for Homer's Fabled City* (London: Thames and Hudson, 1996), fig. on 32.

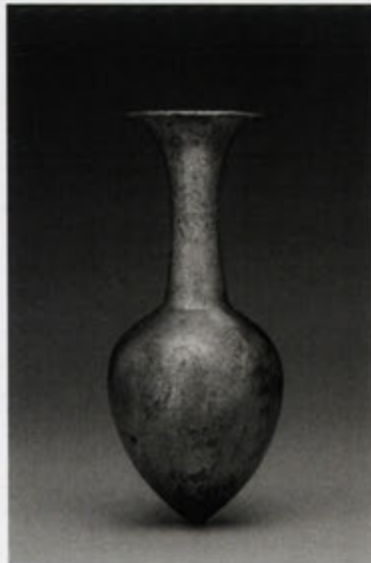


Figure 61. Egyptian bronze flask. Semna, 18th Dynasty. MFA 29.1204. Source: Museum of Fine Arts, Boston, "Flask," Museum of Fine Arts, Boston, Collections, <http://www.mfa.org/collections/object/flask-146747> (accessed 2 February, 2012).



Figure 62. Using a piercing saw to cut sheet metal on a bench pin.

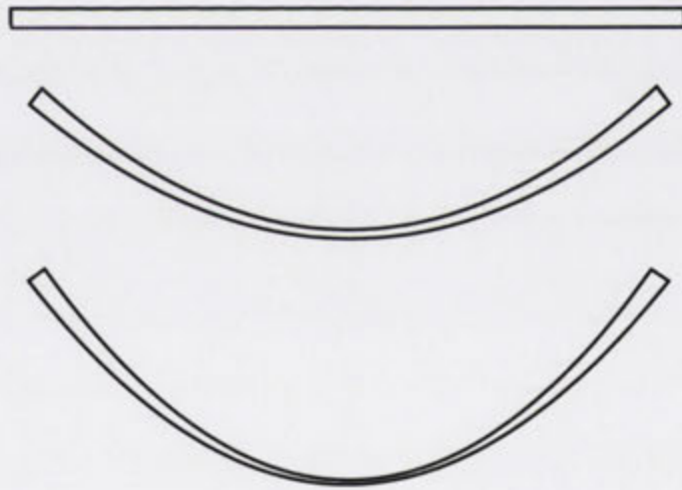


Figure 63. The effect of sinking or spiral-forging. From a flat sheet or billet (*top*), the form becomes successively more concave, causing the material to stretch and become thinner, particularly towards the centre.



Figure 64. Cross-section showing the movement of sheet metal being raised into a cup-form. Beginning from flat, the walls move upwards and inwards over successive raising rounds.

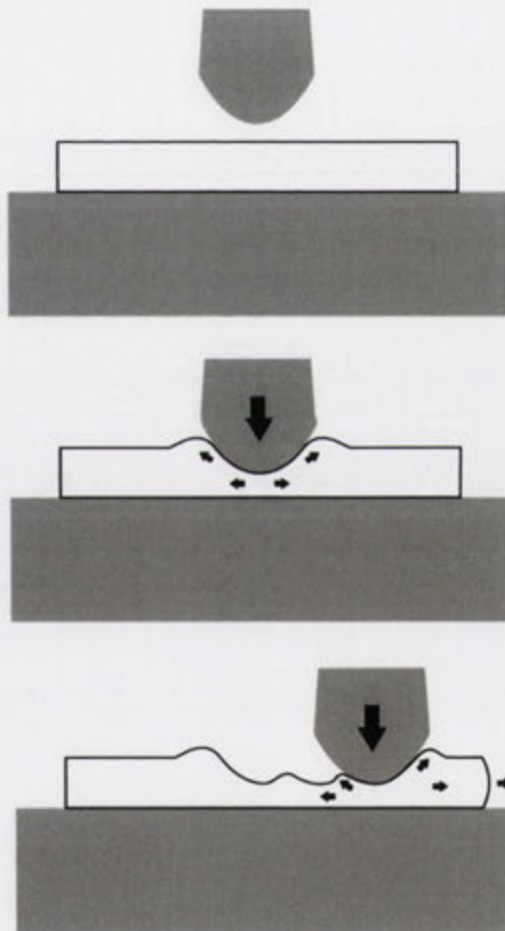


Figure 65. Cross-section showing the movement of metal being forged. The material surrounding the hammer blow is pushed outwards from the point of impact, leaving material directly under the hammer face thinner (*centre*). Subsequent hammer blows thin the material further and push surrounding material along the direction of hammering (*bottom*).



Figure 66. Straightening irregularities in metal with forging. The high areas of the previously uneven material (*hatched line*) are tapped down to conform to the anvil face.

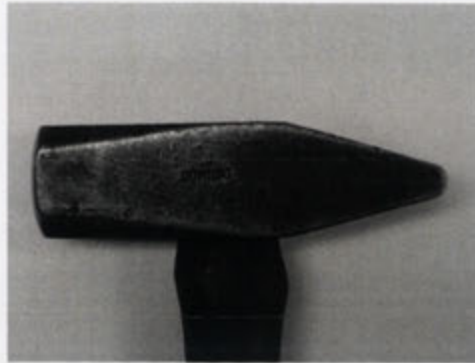


Figure 67. Forging hammer. One face is slightly convex and the other is a cross-peen face.

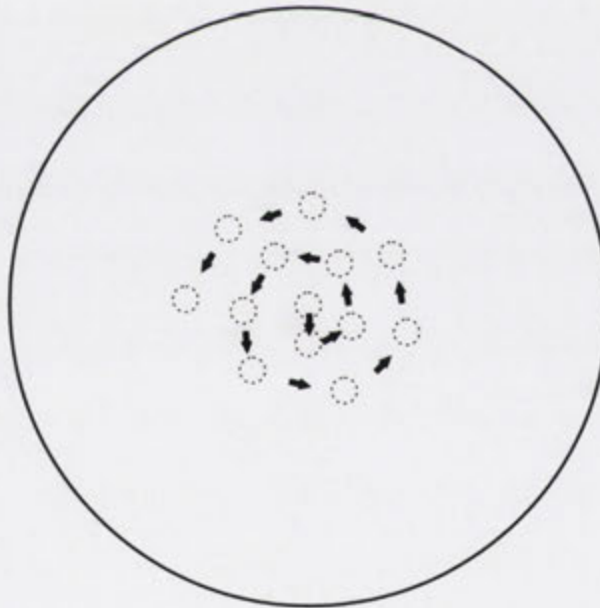


Figure 68. Spiral hammering motion used for spiral-forging or sinking a disc from centre to rim. For clarity, the hammer blows are shown far apart. In practice they overlap one another.



Figure 69. Sinking a disc with a convex hammer-face over a shallow hollow carved into a stump. Source: F. Loyer, *The Thames and Hudson Manual of Silversmithing* (London: Thames and Hudson, 1980), fig. 40.

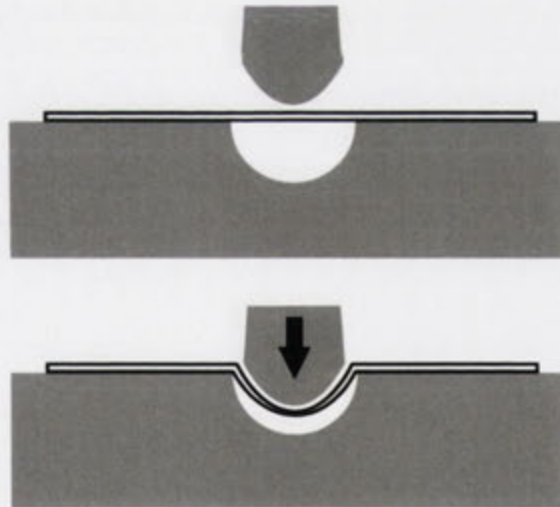


Figure 70. Sinking sheet over a hollow with a convex-faced hammer.



Figure 71. Modern hammers suitable for sinking: (top to bottom) heavy and light steel hammers, wooden pear-mallet. *Adapted from: K. Smith, Practical Silver-Smithing and Jewelry* (London: Studio Vista, 1975), fig. 8.



Figure 72. Crimping a disc with a cross-peen hammer into a wooden crimping stake. *Source: E. Brepohl, The Theory and Practice of Goldsmithing*, trans. Charles Lewton-Brain (Portland: Brynmorgen Press, 2001), fig. 6.12.



Figure 73. Raising a disc over a steel stake with a steel hammer. In this case the hammer-face is convex. *Source: N. C. Humez, *Silversmithing: A Basic Manual* (Boston: Little, Brown and Company, 1976), 99, bottom.*

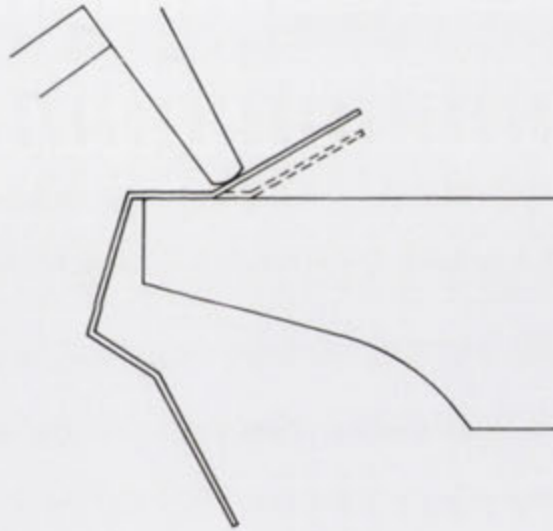


Figure 74. Cross-section of the raising process using a steel cross-peen hammer. Note how the hammer face strikes the wall of the vessel just above the point at which it touches the stake.

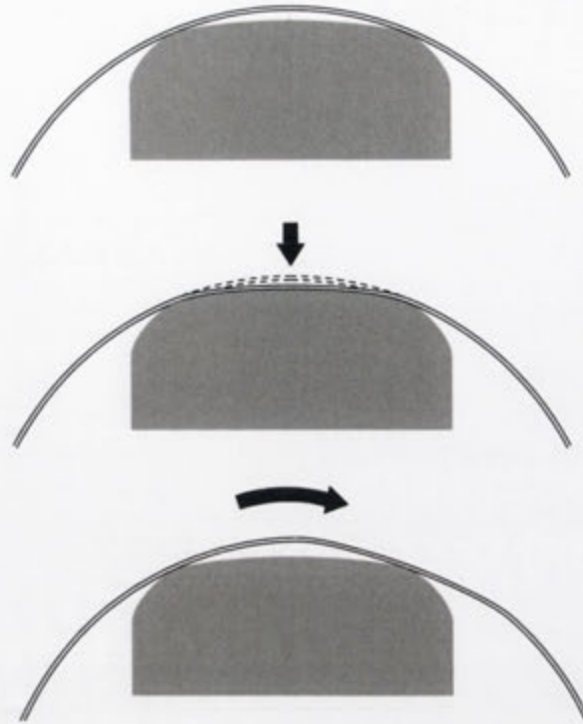


Figure 75. Cross-section of the raising process showing how a hammer blow flattens the arc of the vessel's wall into a chord against the flattened upper surface of the stake (in grey). The vessel is then turned slightly to repeat the action on the adjacent section of the wall.

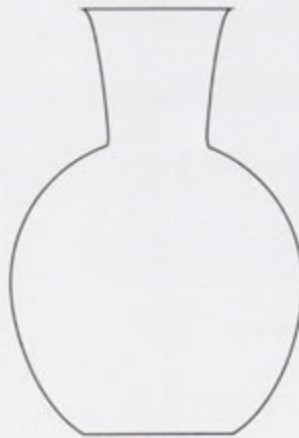


Figure 76. Closed, narrow-mouthed vessel form.

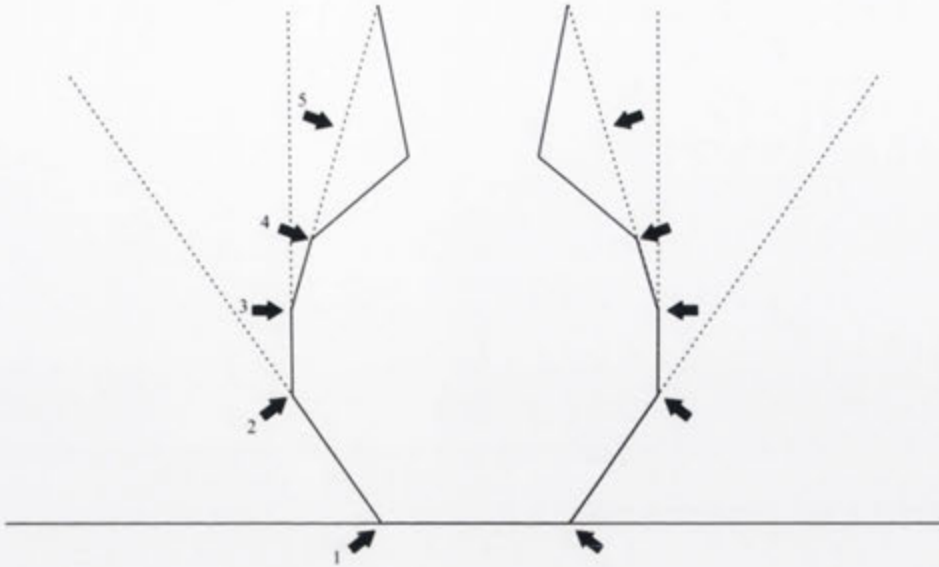


Figure 77. Stages required to hammer the vessel-form illustrated in Figure 76.

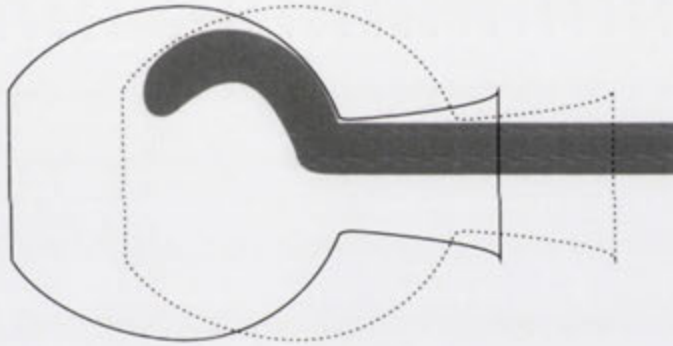


Figure 78. Using a stake to bring in the upper walls of a closed vessel. The solid line shows the position of the vessel over the stake for working the neck and shoulder. The dotted line shows the vessel's position to work the material closer to the base.

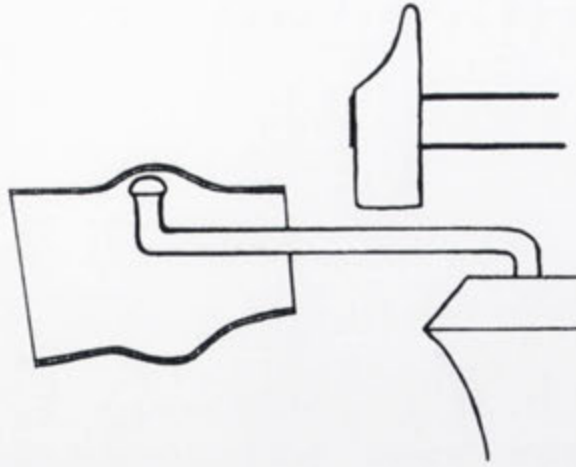


Figure 79. Creating a bulge in a vessel's wall with a snarling iron. Source: Brepohl, *The Theory and Practice of Goldsmithing*, fig. 6.24.

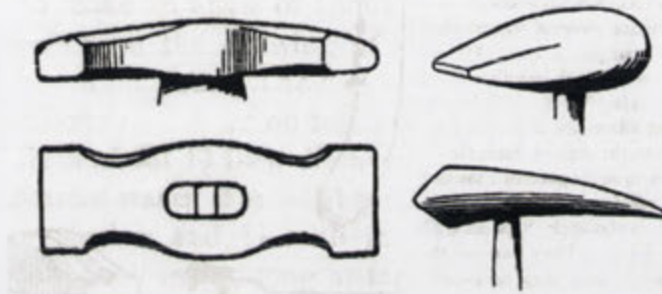


Figure 80. Raising hammers: (left, top and bottom) a typical steel raising hammer with cross-peen faces; (right, top) a raising mallet, which might today be made from wood or nylon; (right, bottom) a horn hammer with the larger end cut into a wedge for raising. Adapted from: H. Maryon, *Metalwork and Enamelling* (New York: Dover, 1971), figs 128-131.



Figure 81. A wooden raising stake held in a vice bolted to a wooden stump.



Figure 82. A selection of steel raising stakes. Shapes range from simple, straight forms (left) to increasingly complex forms (right). Adapted from: *Der Silberschmied: Lehr- und Handbuch*, (Stuttgart: Ruhle-Diebener-Verlag, 1982), figs 24-31.

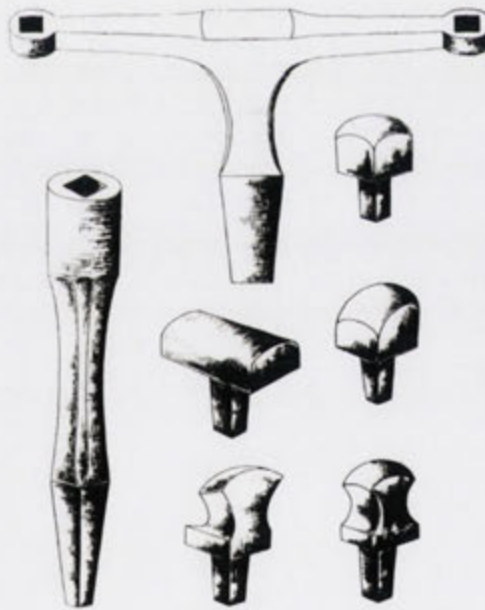


Figure 83. A steel stake system with several different stake-faces which fit into sockets in stake-holders. Adapted from: *Der Silberschmied: Lehr- Und Handbuch*, figs 34-40.



Figure 84. Planishing a hemispherical bowl. The vessel is rotated clockwise (dotted lines show position of finger and thumb, and overlapping hammer blows applied in a spiral or concentric circles. *Adapted from: Smith, Practical Silver-Smithing and Jewelry, fig. 69.*

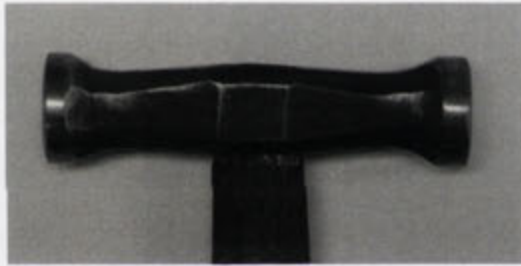


Figure 85. Planishing hammer with one flat and one slightly convex face.



Figure 86. Adjusting the profile of a vessel: high and low spots in the vessel's profile (indicated by broken lines) are brought down by tapping the surface and brought out with localised planishing.



Figure 87. A hammered copper sphere with the faceted surface characteristic of planishing.



Figure 88. A typical set of equipment for polishing a hammered vessel: (left to right) medium-grade steel file; 400, 600 and 1200 grade emery paper wrapped around aluminium flat-bar; tripoli polish with a nylon-bristle wheel and calico buff; metal polish; rags for cleaning; polish-impregnated felt cloth.



Figure 89. Caulking a vessel's rim by forging it back down into the wall. Adapted from: Smith, *Practical Silver-Smithing and Jewelry*, fig. 19.

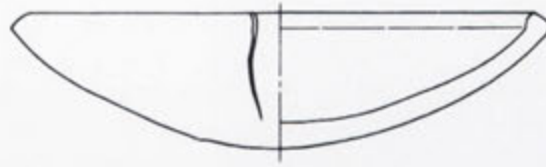


Figure 90. Bronze proto-vessel with a vertical crack. Enkomi Foundry Hoard, LC III. Adapted from: H. Matthäus, *Metallgefasse und Gefassuntersatze der Bronzezeit, der geometrischen und archaischen Periode auf Cypern, mit einem Anhang der bronzezeitlichen Schwertfunde auf Cypern*, Prähistorische Bronzefunde. Abteilung II; Bd.8 (München: C. H. Beck, 1985), pl. 7.142.

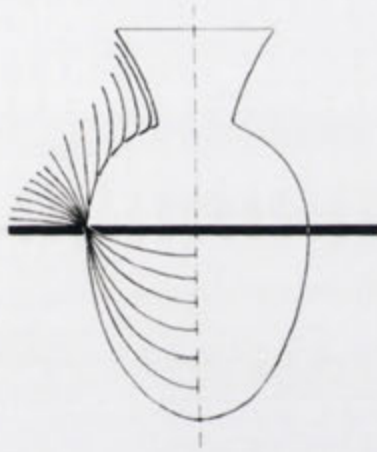


Figure 91. Method for transforming a billet into a vessel with spiral-forging and subsequent raising. Adapted from: B. Cellini, *Abhandlungen über die Goldschmiedekunst und die Bildhauerei*, trans. Max Fröhlich and Ruth Fröhlich (Basel: Gewerbemuseum Basel, 1974), 80.

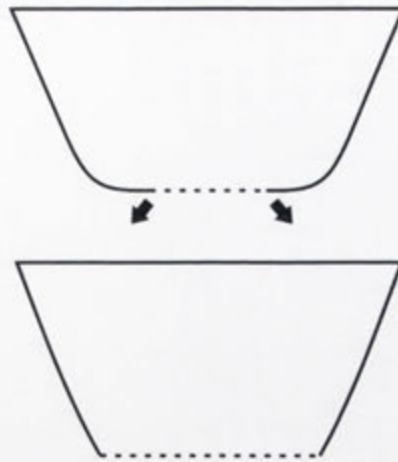


Figure 92. Cross-section showing a vessel with a hole cut in the base (*above*). The hole is subsequently stretched out to the desired diameter (*below*).



Figure 93. Bronze 'Vapheio' cup from Mochlos which is thought to have been cast.
Adapted from: Matthäus, BKMK, pl. 42.



Figure 94. Sumerian Early Dynastic III copper cup (Met 1989.291). The form, texture of the surface and nature of the relief decoration indicate manufacture by casting. *Source:* Metropolitan Museum of Art, "Conical Beaker with Relief Decoration of Bovines and Birds of Prey," Metropolitan Museum of Art Collections, <http://www.metmuseum.org/Collections/search-the-collections/30006121> (accessed 30 December 2011).



Figure 95. Egyptian Eighteenth Dynasty bronze bowl (Met 30.8.67). Metallographic images of this vessel indicate that it was made by casting (see **Figure 96**). *Source:* Metropolitan Museum of Art, “Votive Bowl Dedicated to the Goddess Hathor by Lady Nefrether,” Metropolitan Museum of Art Collections, <http://www.metmuseum.org/Collections/search-the-collections/100001191> (accessed 30 December 2011).



Figure 96. Metallographic image of the Egyptian bowl shown in Figure 95 at 4x magnification. The fact that the dendrite and grain structures are intact shows that the vessel was made by casting with no subsequent hammering. *Source:* H. E. Winlock, “An Egyptian Flower Bowl,” *MMS* 5, no. 2 (1936): fig. 3.



Figure 97. Roman stone bivalve mould for casting pewter pateras. AshM AN1836 P,126, 147-8). Leswyn, St. Just, Cornwall. Photograph by the author.

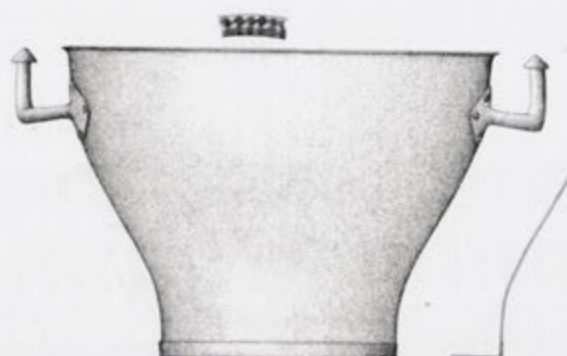


Figure 98. Bronze lekane with cast rim decoration (NM 7292). Dendra, Stomion cist of Chamber Tomb 2, ?LH IIIB. *BKMK* no. 399. Adapted from: Matthäus, *BKMK*, pl. 47.

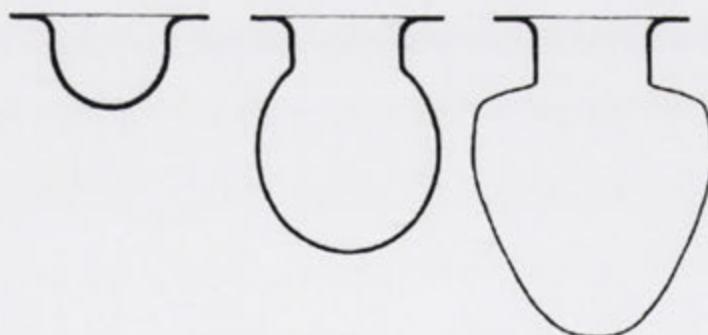


Figure 99. Pernot's theory of the Vix crater having been hammered from a cast proto-vessel. (left to right) The initial, cast vessel and bi-axial expansion during hammering. Adapted from: M. Pernot, "Étude technique de quelques objets en bronze," in *La tombe princière de Vix*, ed. Claude Rolley (Paris: 2003), fig. 195.

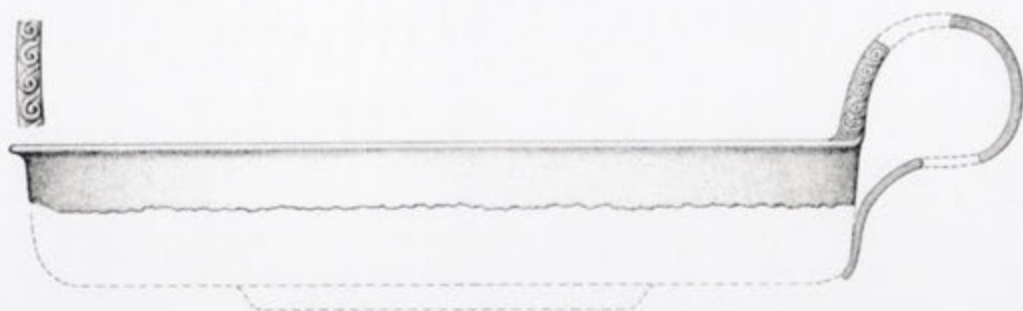


Figure 100. Damaged bronze one-handed basin with cast decoration on the rim and handle edges. Sellopoulo, Grave 4, LM IIIA1. *BKMK* no. 312. Adapted from: Popham, Catling, and Catling, "Sellopoulo," fig. 22.27.



Figure 101. Hammering a vessel over a core. The material on either side of the hammer blow (*large arrow*) would be forced to bow outwards (*small arrows*) and the material under the hammer would be planished thinner, thus stretching it.



Figure 102. Silver lion's head from Ur. Dromos of Puabi's tomb PG 800. Penn B17064. Adapted from: Zettler and Horne, *Treasures from the Royal Tombs of Ur*, 51.



Figure 103. Cross-section showing the likely method by which the silver lions' heads from Ur were made. A central timber core coated with a thick layer of bitumen, resin or wax is set inside the roughly-hammered form and finer shaping and details are completed by chasing, using the core only as a support while chasing the surface of the head.



Figure 104. Gold bull's head on the lyre from the "King's Grave", PG 789, Ur. Penn B17694B. Adapted from: Zettler and Horne, *Treasures from the Royal Tombs of Ur*, 53.



Figure 105. Gold octopus cup. NM 7341. Dendra tholos, “king’s burial,” LH II-III A. Davis, *AGSW* no. 116. Adapted from: P. Demargne, *Aegean Art: The Origins of Greek Art*. London: Thames and Hudson, 1964, pl. 303.



Figure 106. Use of a core to create relief decoration on a ‘Vapheio’ cup. The core, indicated in grey, would be locked into the cup by the relief forms.



Figure 107. Bronze socketed sledgehammer heads. Ayia Triada, ?MM III-LM I. *Source:* J. W. Shaw, *Minoan Architecture: Materials and Techniques* (Rome: Istituto Poligrafico dello Stato, 1973), fig. 41.



Figure 108. Clay-lined hearth. Knossos, Unexplored Mansions, Pillar Hall H, LM II. *Source:* M. R. Popham, *The Minoan Unexplored Mansion*, 2 vols. (Athens: British School of Archaeology at Athens, 1984), pl. 29(e).



Figure 109. Pi-shaped hearth. Kommos, North House, Room N16, LM III A1. *Source:* M. C. Shaw, "Late Minoan Hearths and Ovens at Kommos, Crete," in *L'habitat Égéen préhistorique*, ed. Pascal Darcque and René Treuil, BCH Suppl. 19 (Athens: École française d'Athènes, 1990), fig. 8.



Figure 110. A metalsmith using a portable hearth, depicted in the New Kingdom Tomb of Rekhmire, Thebes. *Adapted from:* É. Prisse d'Avennes, *Atlas of Egyptian Art* (Cairo: American University in Cairo Press, 2000), 120.

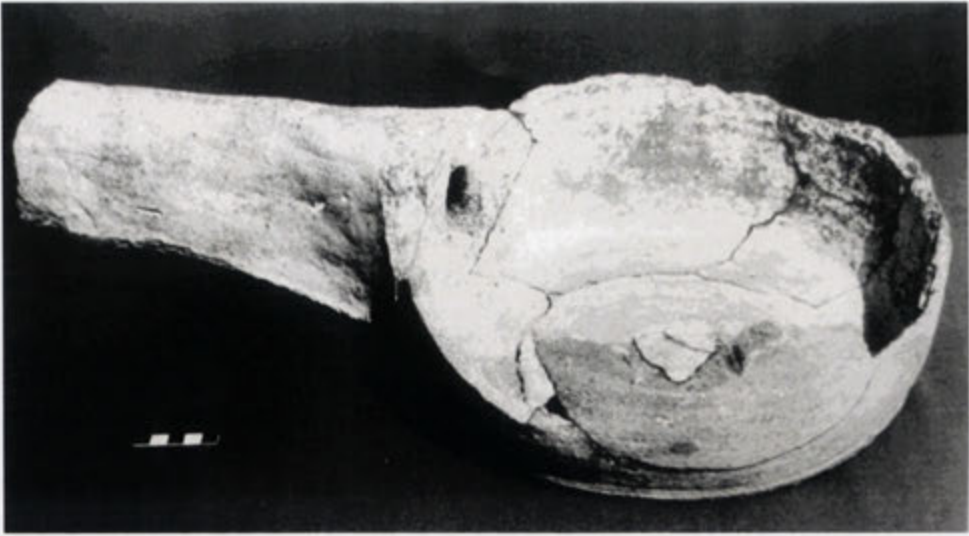


Figure 111. Clay pot bellows. Kommos, LM. *Source:* H. Blitzer, "Minoan Implements and Industries," in *Kommos I: Part 1*, ed. Joseph W. Shaw and Maria C. Shaw (Princeton: Princeton University Press, 1995), pl. 8.80A.



Figure 112. Reconstruction of hand-pumping the pot bellows from Prepalatial Chrysokamino. *Source:* P. P. Betancourt and J. D. Muhly, "The Pot Bellows," in *The Chrysokamino Metallurgy Workshop and its Territory*, ed. Philip P. Betancourt, *Hesperia Supplements* 36 (Princeton, N.J.: American School of Classical Studies at Athens, 2006), fig. 8.2.

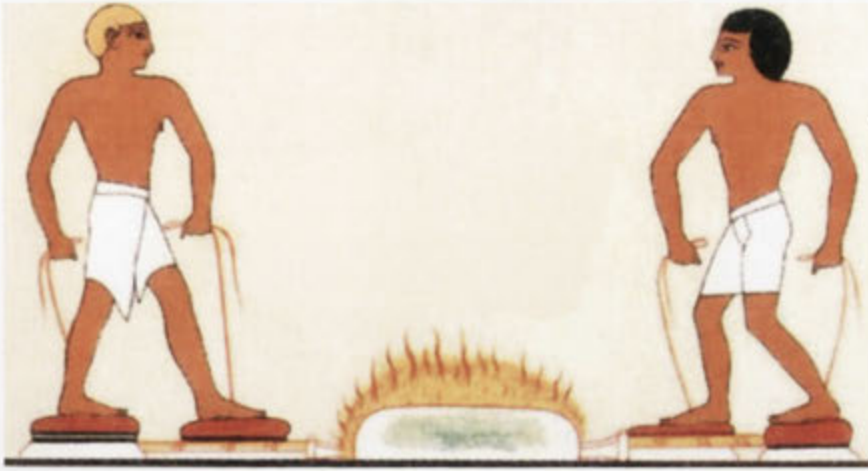


Figure 113. Two New Kingdom Egyptian metalworkers pumping pot bellows in pairs with their feet. Tomb of Rekhmire, Thebes. Adapted from: É. Prisse d'Avennes, *Atlas of Egyptian Art*, 119.



Figure 114. Native Colombians metalsmiths in the 16th Century AD. The two workers on the left are using blowpipes to heat a hearth containing a crucible. The worker on the right is forging with an unhafted hammer on a stone anvil. Source: G. Benzoni, *History of the New World by Girolamo Benzoni, of Milan, Shewing his Travels in America from A.D. 1541 to 1556: With Some Particulars of the Island of Canary*, trans. W. H. Smyth (London: Hakluyt Society, 1857), 251.



Figure 115. New Kingdom Egyptian metalworkers using green withies to manipulate a hot crucible over a hearth. Tomb of Rekhmire, Thebes. Adapted from: Prisse d'Avennes, *Atlas of Egyptian Art*, 119.

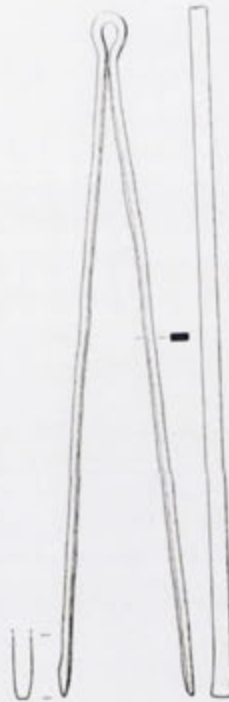


Figure 116. Bronze tongs. Mochlos, House C3, LM IB. Source: T. M. Brogan, "Metalworking at Mochlos before the Appearance of the Artisans' Quarters," in *Aegean Metallurgy in the Bronze Age*, ed. Iris Tzachili (Athens: Ta Pragmata Publications, 2008), fig. 6.

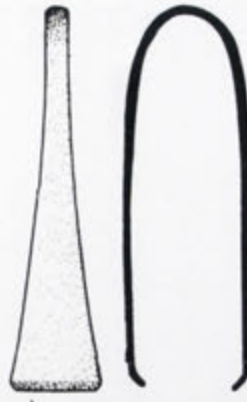


Figure 117. Bronze tongs/tweezers. Knossos, Unexplored Mansion, Room L, LM II. *Source:* Popham, *The Minoan Unexplored Mansion at Knossos*, pl. 205.1.

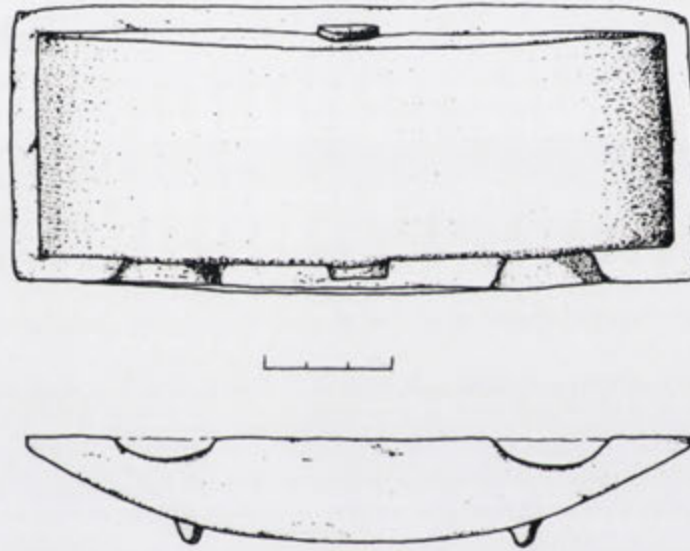


Figure 118. Bronze mould for casting a double axe. Vasiliki, House on NW side of hill, EM II. *Source:* R. D. G. Evely, *Minoan Crafts: Tools and Techniques: An Introduction*, vol. 1, SIMA 92:1 (Göteborg: Paul Åströms Förlag, 1993), fig. 21.

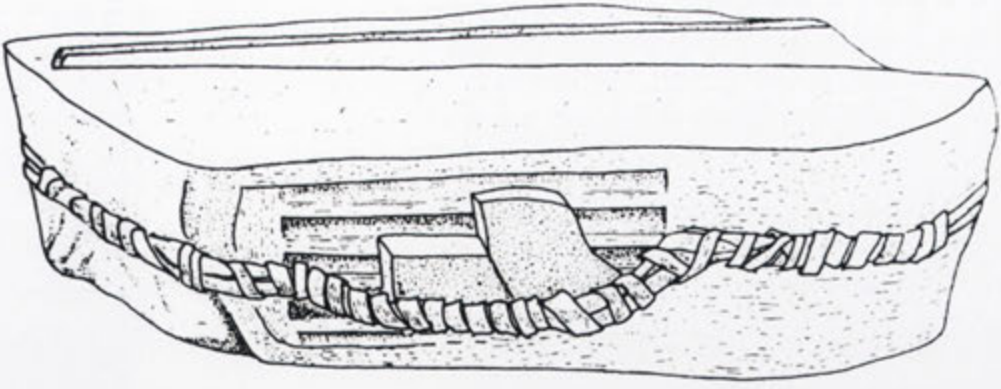


Figure 119. Stone mould with multiple open matrices for billets and matrices, repaired with copper strip. A matrix for a possible chisel can be seen on the upper surface and matrices for rod-shaped billets on the near surface. Gournia, House E10, LM I. *Source:* Evelyn, *Minoan Crafts* 2, fig. 142.3.

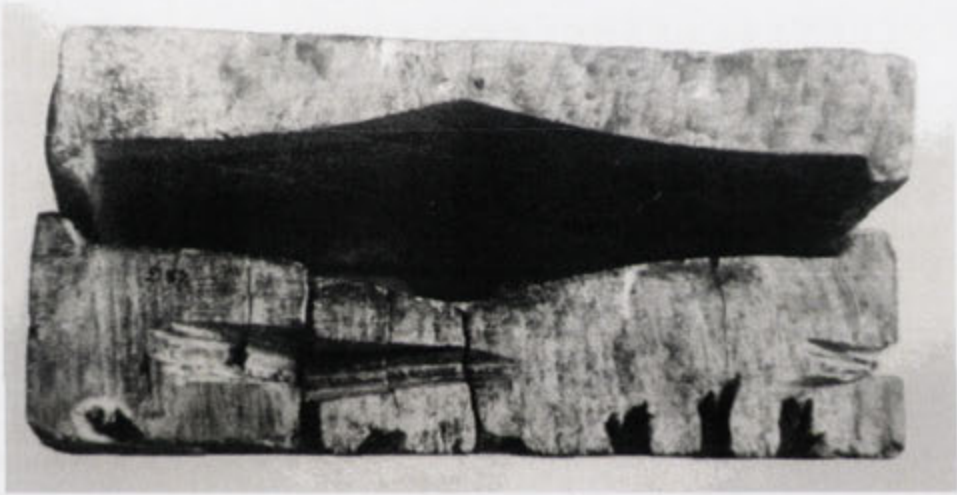


Figure 120. Stone bivalve mould for casting a double-axe. Malia, NW area of palace, LM I-II or MM III. *Source:* Evelyn, *Minoan Crafts* 2, pl. 87.1.



Figure 121. Stone bivalve mould for 'mulberry' earrings. Mochlos, LM I or later. *Source:* Evelyn, *Minoan Crafts* 2, pl. 91.1.

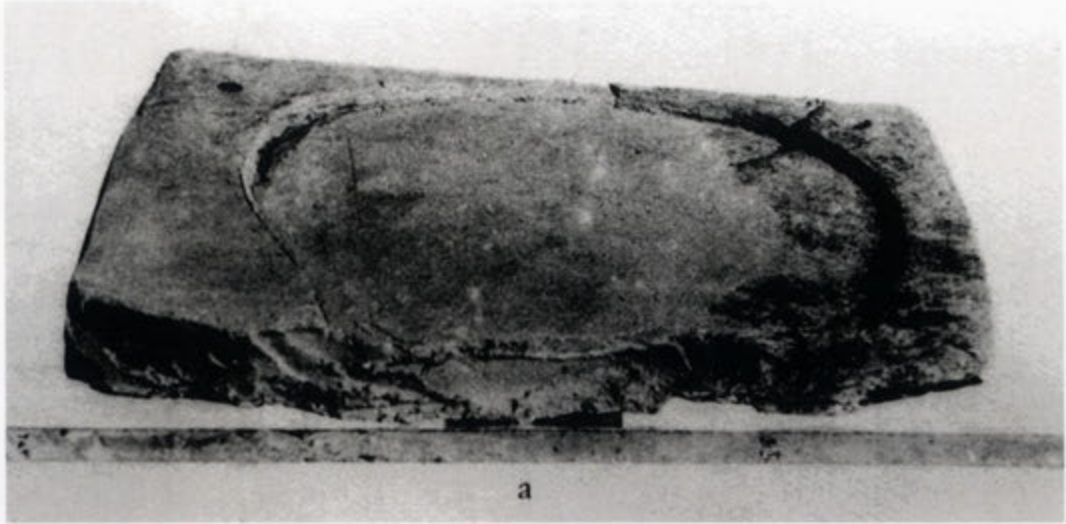


Figure 122. Talc schist bivalve mould for an ovoid disc-billet. Malia, NW area of palace, MM III. *Source:* F. Chapouthier and P. Demargne, *Palais III - Troisième rapport*, ÉtCrét 6 (Athens: École française d'Athènes, 1942), pl.52.2a.



Figure 123. Part of a three-part stone mould for a ring. Poros, date unknown. *Source:* Evelyn, *Minoan Craft* 2, pl. 91.3.



Figure 124. Clay mould with two matrices for casting small billets. Knossos, Unexplored Mansion, LM II. *Source:* Popham, *The Minoan Unexplored Mansion*, pl. 207.7.



Figure 125. Used lost-wax mould for casting a double-axe. Kommos, Hilltop Houses, LM IIIA2-B. *Source:* Blitzer, "Minoan Implements and Industries," pl. 8.78G.



Figure 126. Lost-wax mould for casting a hollow hand. Phaistos, SW wing of palace, MM I-II. *Source:* C. Laviosa, "Una Forma Minoica per Fusione a Cera Perduta," *Annuario* 45-46 (1967/68): fig. 1.

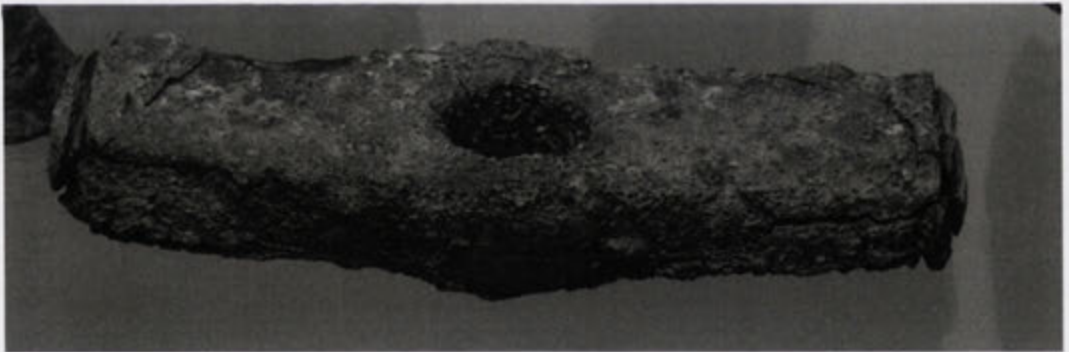


Figure 127. Bronze double-hammer. Cyprus, Enkomi Foundry Hoard, LC III. Photograph by the author.

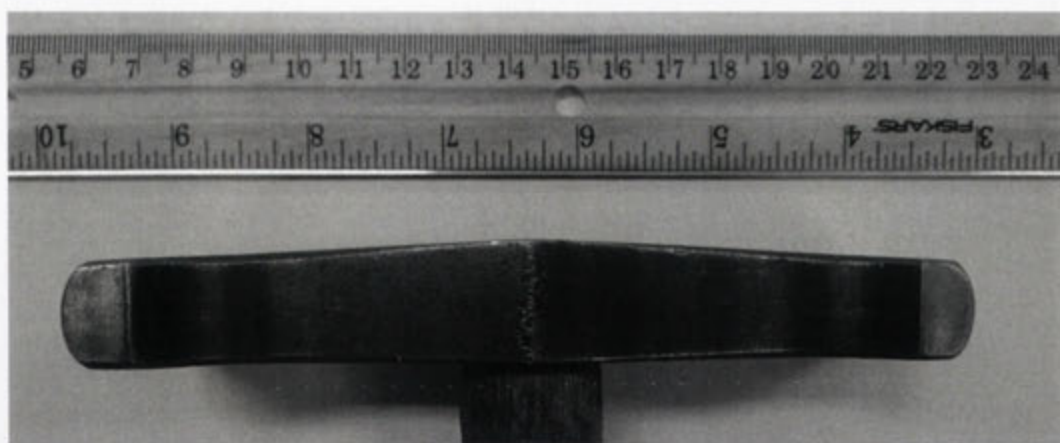


Figure 128. Modern steel raising hammer. Photograph by the author.



Figure 129. Bronze mallet with two rectangular faces. Psychro, modern or MM III-LM.
Source: J. Boardman, *The Cretan Collection in Oxford: The Dictaeon Cave and Iron Age Crete* (Oxford: Clarendon Press, 1961), pl. 17.

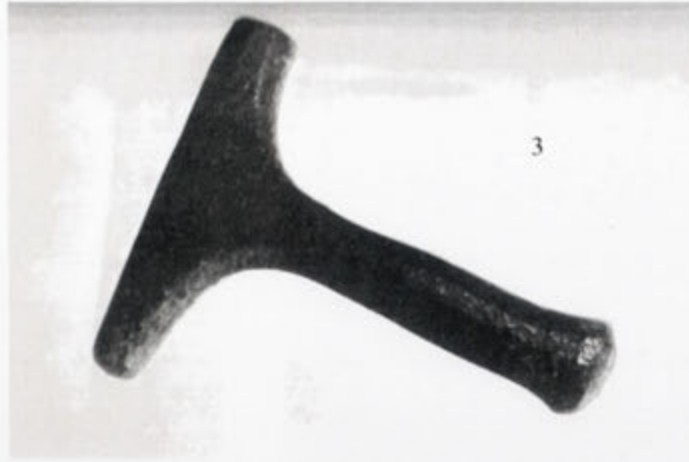


Figure 130. Bronze hammer/T-stake. Samba Pediados, date unknown. *Source:* Evelyn, *Minoan Crafts* 1, pl. 22.3.



Figure 131. Bronze rectangular block. Malia, MM III-LM IB. *Adapted from:* J. Deshayes and A. Dessenne, *Fouilles exécutées à Mallia: Exploration des maisons et quartiers d'habitation (1948-1954)*, *ÉtCrét* 11 (Athens: École Française d'Athènes, 1959), pl. 20.1.



Figure 132. Small socketed bronze hammer. Provenance unknown, ?LM I. Photograph by the author.



Figure 133. Bronze hammer. Malia, Quartier Mu, MM II or LM III. Adapted from: J.-C. Poursat, *Artisans minoens: les maisons-ateliers du quartier Mu*, ÉtCrét 32 (Athens: École Française d'Athènes, 1996), pl. 43k.

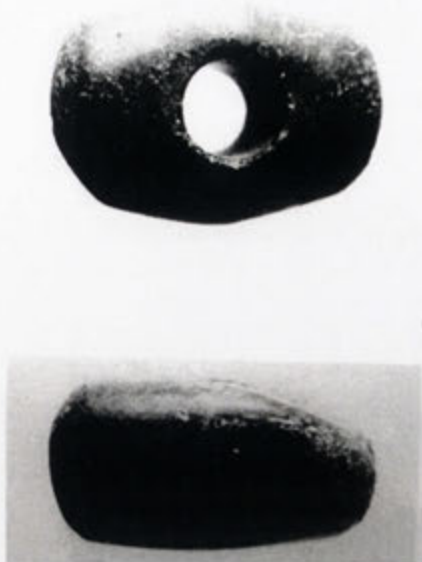


Figure 134. Serpentine socketed hammer. Malia, Quartier Mu, outside the area of the workshops, date unknown. *Adapted from: Poursat, *Artisans minoens: les maisons-ateliers du quartier Mu*, pl. 40c.*



Figure 135. Igneous spherical cobble. Knossos, Unexplored Mansion, LM II. *Adapted from: Popham, *The Minoan Unexplored Mansion*, pl. 208.10.*



Figure 136. Marble pestle. Knossos, Unexplored Mansion, LM II. Unexplored Mansion, Knossos, LM II. *Adapted from: Popham, The Minoan Unexplored Mansion, pl. 209.13.*



Figure 137. ?Limestone pestle. Malia Quartier Mu, Atelier de Fondeur, MM II. *Adapted from: Poursat, Artisans minoens: les maisons-ateliers du quartier Mu, pl. 41a.*



Figure 138. Igneous 'neolithic' axe. Knossos, Unexplored Mansion, LM II. *Adapted from:* Popham, *The Minoan Unexplored Mansion*, pl. 218.1.



Figure 139. Stone hammer-axe. Poliochni, Lemnos. *Adapted from:* C. G. Dumas, "Searching for the Early Bronze Age Aegean Metallurgist's Toolkit," in *Metallurgy, Understanding How, Learning Why: Studies in Honour of James D. Muhly*, ed. Philip P. Betancourt and Susan C. Ferrence (Philadelphia: INSTAP Academic Press, 2011), fig. 17.2.

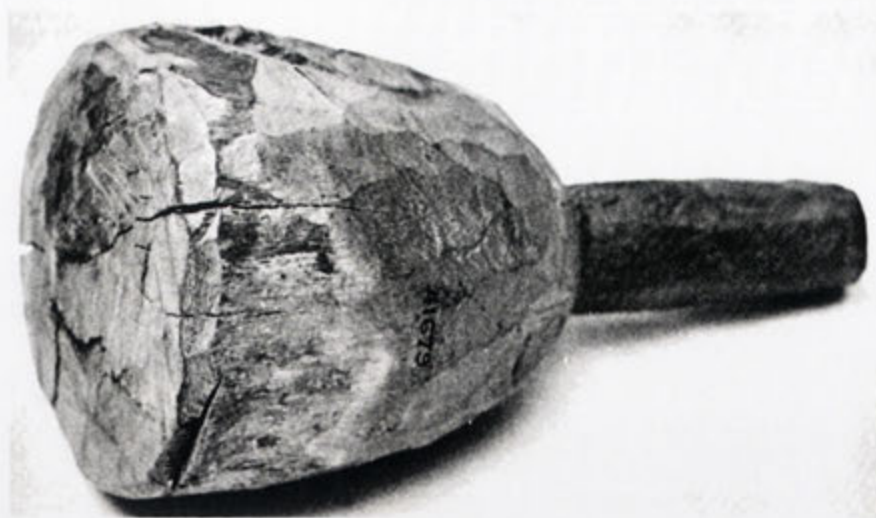


Figure 140. Wooden mallet. Thebes, Tomb of Mentuhotep, New Kingdom. *Adapted from:* G. Killen, *Ancient Egyptian Furniture*, vol. 1 (Warminster: Aris & Phillips, 1980), pl. 16.

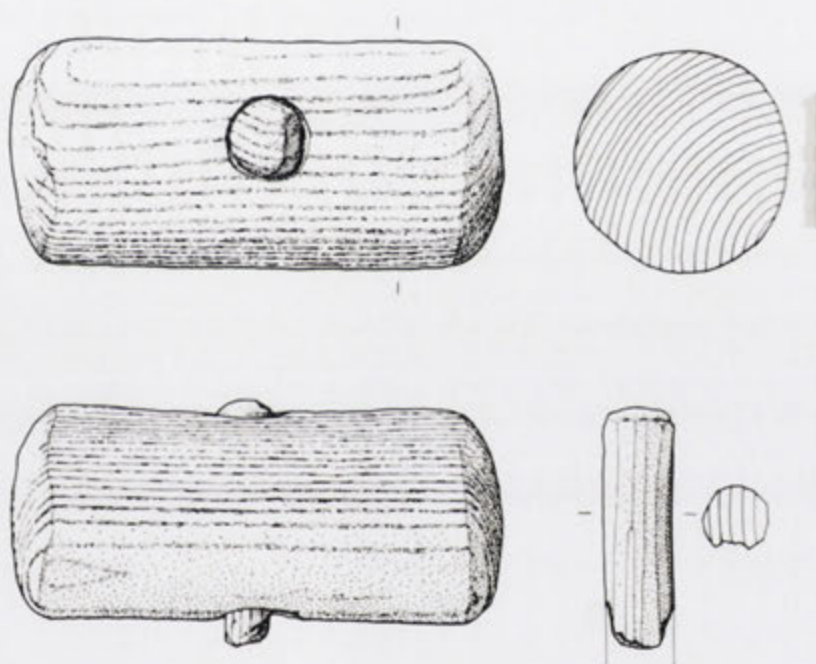


Figure 141. Wooden mallet. Breidden Hillfort, Iron Age. *Adapted from:* W. J. Britnell and C. Earwood, "Wooden Artefacts and Other Worked Wood from Buckbean Pond," in *The Breidden Hillfort*, ed. C. R. Musson (London: Council for British Archaeology, 1991), fig. 69.



Figure 142. Wooden hammer. Flag Fen, Bronze Age. *Adapted from:* M. Taylor, "The Wood," in *The Flag Fen Basin: Archaeology and Environment of a Fenland landscape*, ed. Francis Pryor (Swindon: English Heritage, 2001), fig. 7.58.



Figure 143. New Kingdom Egyptian metalsmiths depicted using unhafted hammers: hammering vessels (*upper register, third figure from left and bottom register, far left*) and forging on an anvil with a round cobblesstone (*lower register, second figure from right*). Tomb of Rekhmire, Thebes. *Adapted from:* Prisse d'Avennes, *Atlas of Egyptian Art*, 120.



Figure 144. Sandy limestone anvil/mould. Kommos, House with the Snake Tube, LM IIIB. *Adapted from:* Blitzer, "Minoan Implements and Industries," pl. 8.59C.



Figure 145. Fine-grained black crystalline limestone anvil. Mochlos, Artisans' Quarters, Building A, final LM IB. *Adapted from:* T. Carter, "The Stone Implements," in *Mochlos IC*, ed. Jeffrey S. Soles and Costis Davaras (Philadelphia: INSTAP Academic Press, 2004), pl. 23.



Figure 146. Bronze s-stake. Ayia Triada, ?LM I. *Adapted from: Evely, Minoan Crafts 1, pl. 22.23.*



Figure 147. New Kingdom Egyptian depiction of a metalsmith using an s-stake to raise a vessel. The stake seems to lean against a timber support. Tomb of Rekhmire, Thebes. *Adapted from: Prisse d'Avennes, Atlas of Egyptian Art, 120.*



Figure 148. Bronze anvil/stake. Zakros Palace West Wing, LM IB. *Adapted from: N. Platon, Zakros: The Discovery of a Lost Palace of Ancient Crete (New York: Scribner, 1971), 24.*



Figure 149. A method for securing a stake. *Source:* G. K. Johnson, "An Experiment in Ancient Egyptian Silver Vessel Manufacture," *JANES* 8 (1976): fig. 4.



Figure 150. An Egyptian smith working on a vessel over a stake tied to a post. Unas, Old Kingdom. *Adapted from:* S. B. Hassan, "Excavations at Saqqara 1937-38," *Annales du Service des Antiquités de l'Égypte* 38 (1938): pl. 96.



Figure 151. Sandy limestone slab with hollows. Kommos, House with the Press, LM IIIB.
Adapted from: Blitzer, "Minoan Implements and Industries," pl. 8.59D.



Figure 152. Caulking a rim. Left to right: uncaulked rim, partially caulked rim, heavily caulked, T-section rim.

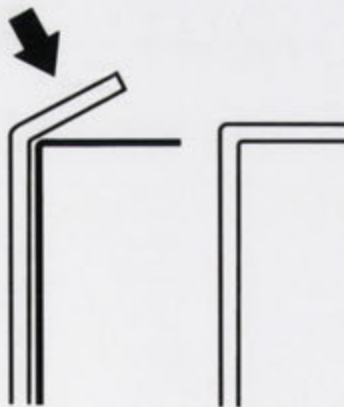


Figure 153. Folding a rim. The edge of the wall is forged over the edge of a working surface such as a stump or anvil.

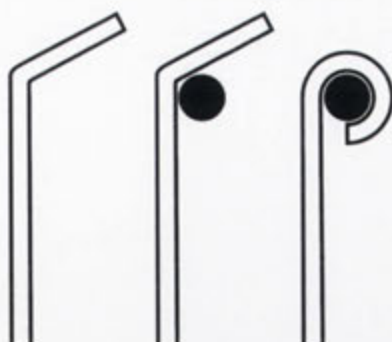


Figure 154. Rolling a rim. Left to right: rim partially folded, wire in place, rim forged over wire.



Figure 155. Marble whetstone/polisher. Knossos, Unexplored Mansion, LM II. *Adapted from: Popham, *The Minoan Unexplored Mansion*, pl. 208.5.*



Figure 156. Quartzite polisher. Knossos, Unexplored Mansion, ?LM II. *Adapted from: Popham, *The Minoan Unexplored Mansion*, pl. 208.8.*



Figure 157. Emery finishing tool. Kommos, House with the Snake Tube, LM IIIA2-B.
Adapted from: Harriet Blitzer, "Minoan Implements and Industries pl. 8.71B.

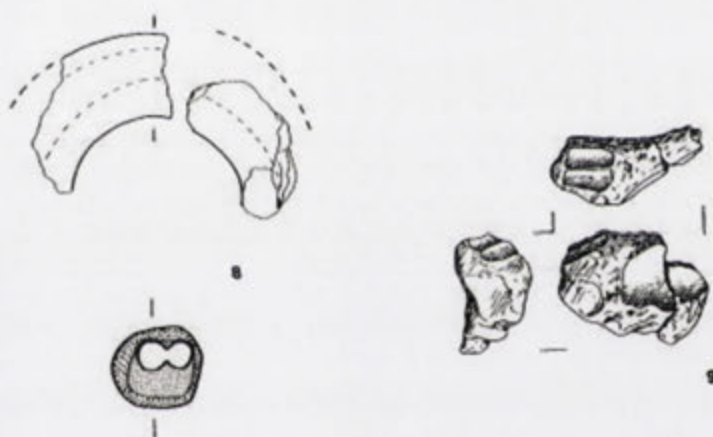


Figure 158. Fragments of a lost-wax mould for a possible cauldron handle. Palaikastro, LM IIIA2 or LM IIIB. *Adapted from:* S. Hemingway, "Minoan Metalworking in the Postpalatial Period: A Deposit of Metallurgical Debris from Palaikastro," *BSA* 91 (1996): figs 6.8, 6.9.

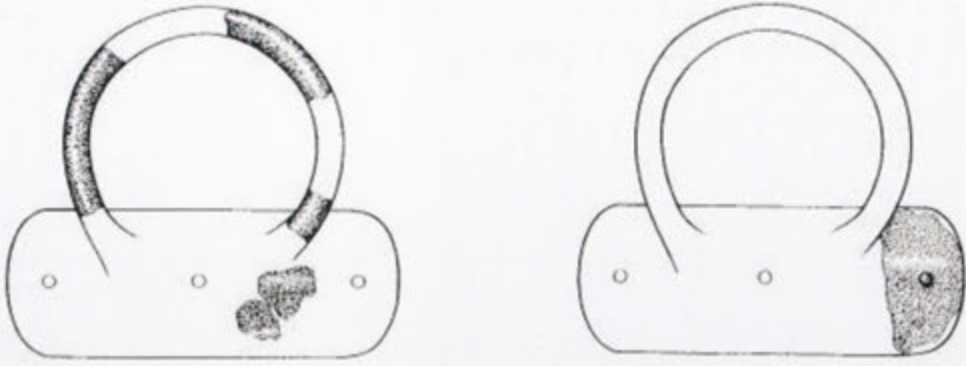


Figure 159. The type of cauldron ring-handle which the lost-wax mould from Palaikastro might have made. Palaikastro, LM IIIA2 or LM IIIB. *Adapted from:* Hemingway, "Minoan Metalworking in the Postpalatial Period," figs 11.4 and 11.5.

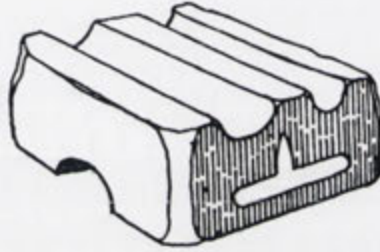


Figure 160. Stone swage block. Palaikastro Block ξ, ?LM. *Adapted from:* R. C. Bosanquet and R. M. Dawkins, *The Unpublished Objects from the Palaikastro Excavations 1902-1906*, BSA Suppl. 1 (Athens: British School of Archaeology at Athens, 1923), fig. 105.



Figure 161. Bronze chisel with a curved, flared cutting end. Psychro, LM. *Adapted from:* Evely, *Minoan Crafts* 1, fig. 5.

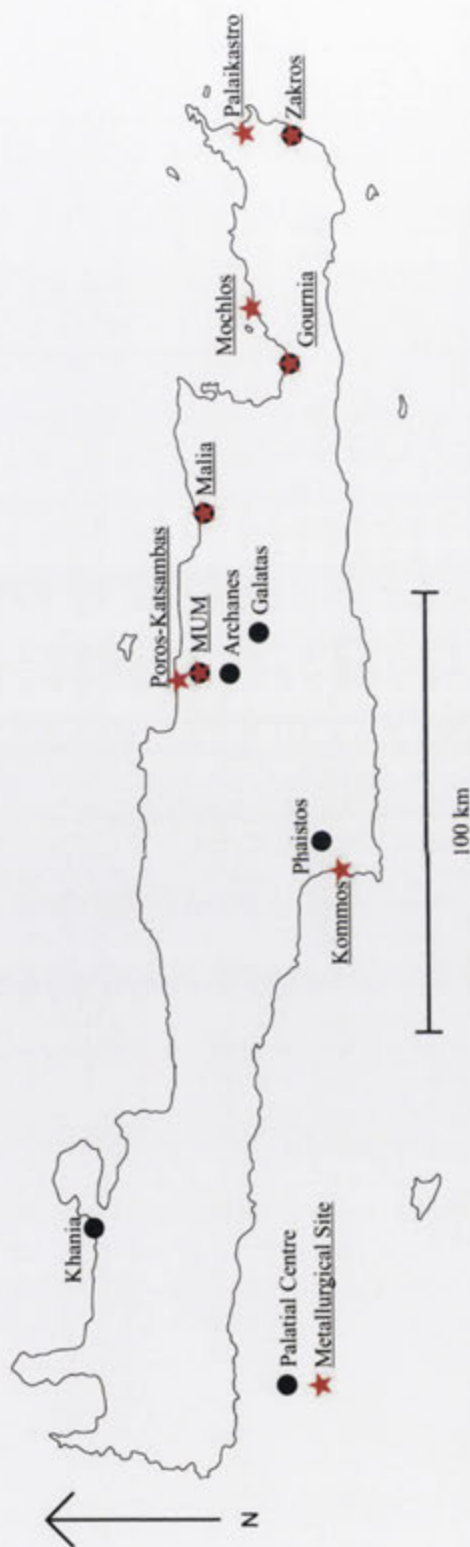


Figure 162. Map showing the locations of the metallurgical sites discussed in Chapter Five.

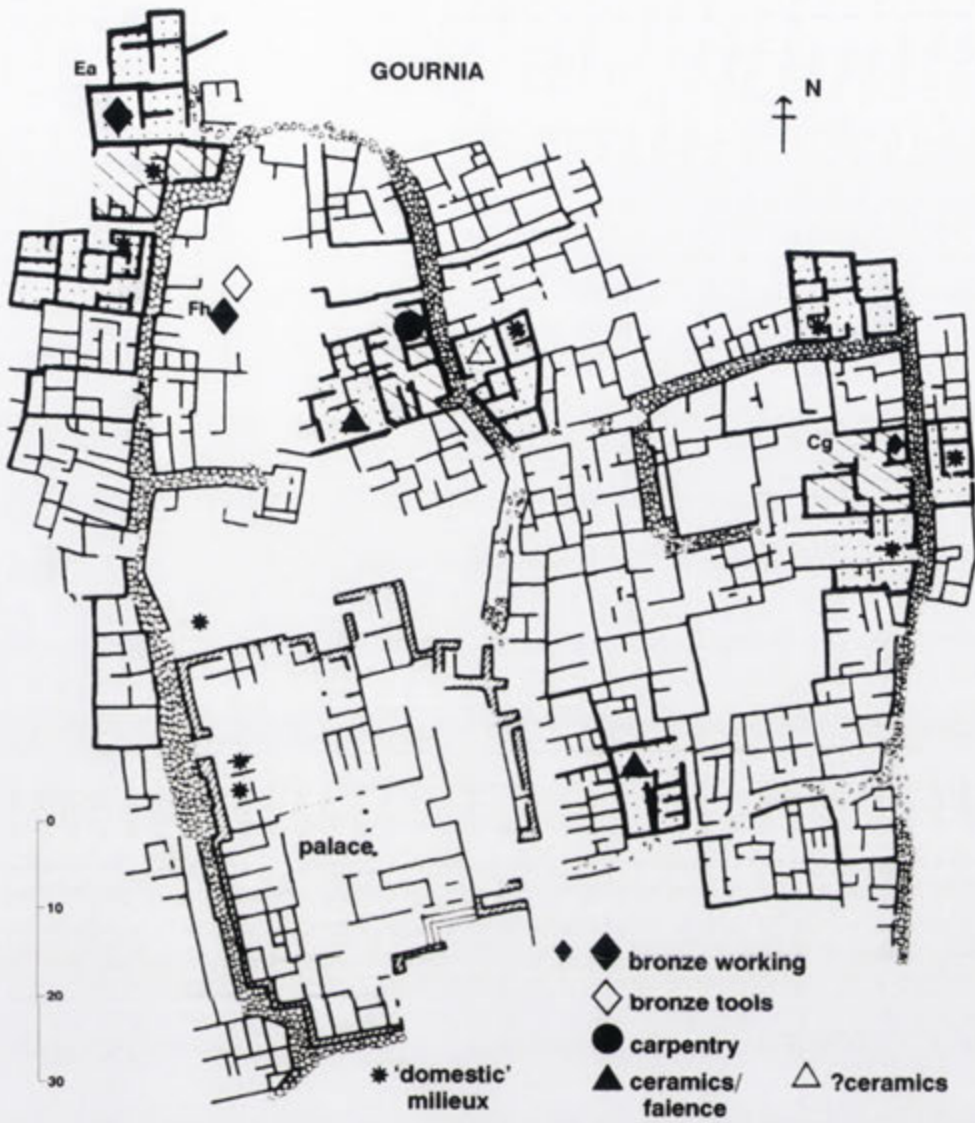


Figure 163. Plan of Gournia showing locations of metallurgical remains in houses Ea and Fh (top left) and Cg (centre right). Adapted from: Evely, *Minoan Crafts 2*, fig. 133.

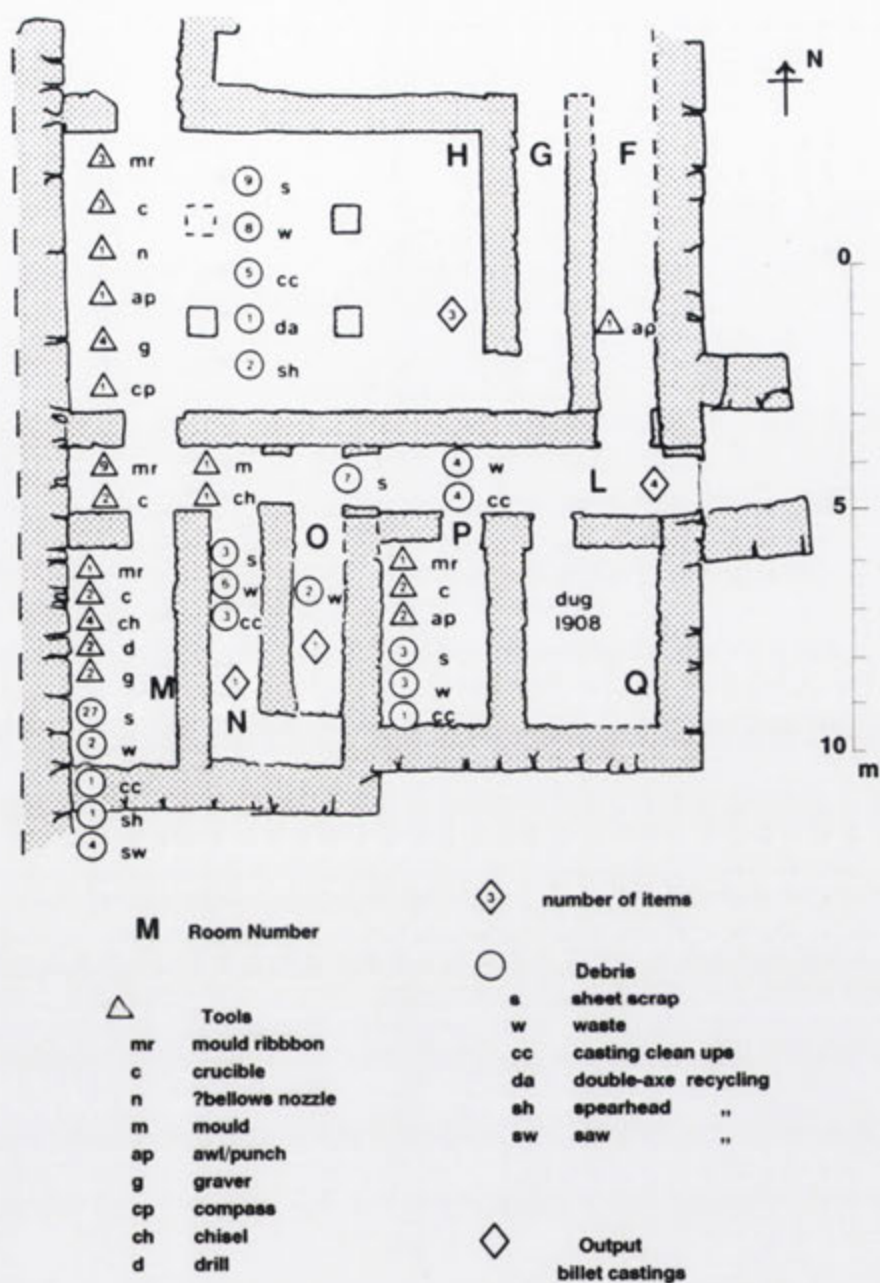


Figure 164. Plan of the Unexplored Mansion at Knossos and metallurgical remains.
Adapted from: Evelyn, *Minoan Crafts 2*, fig. 134.

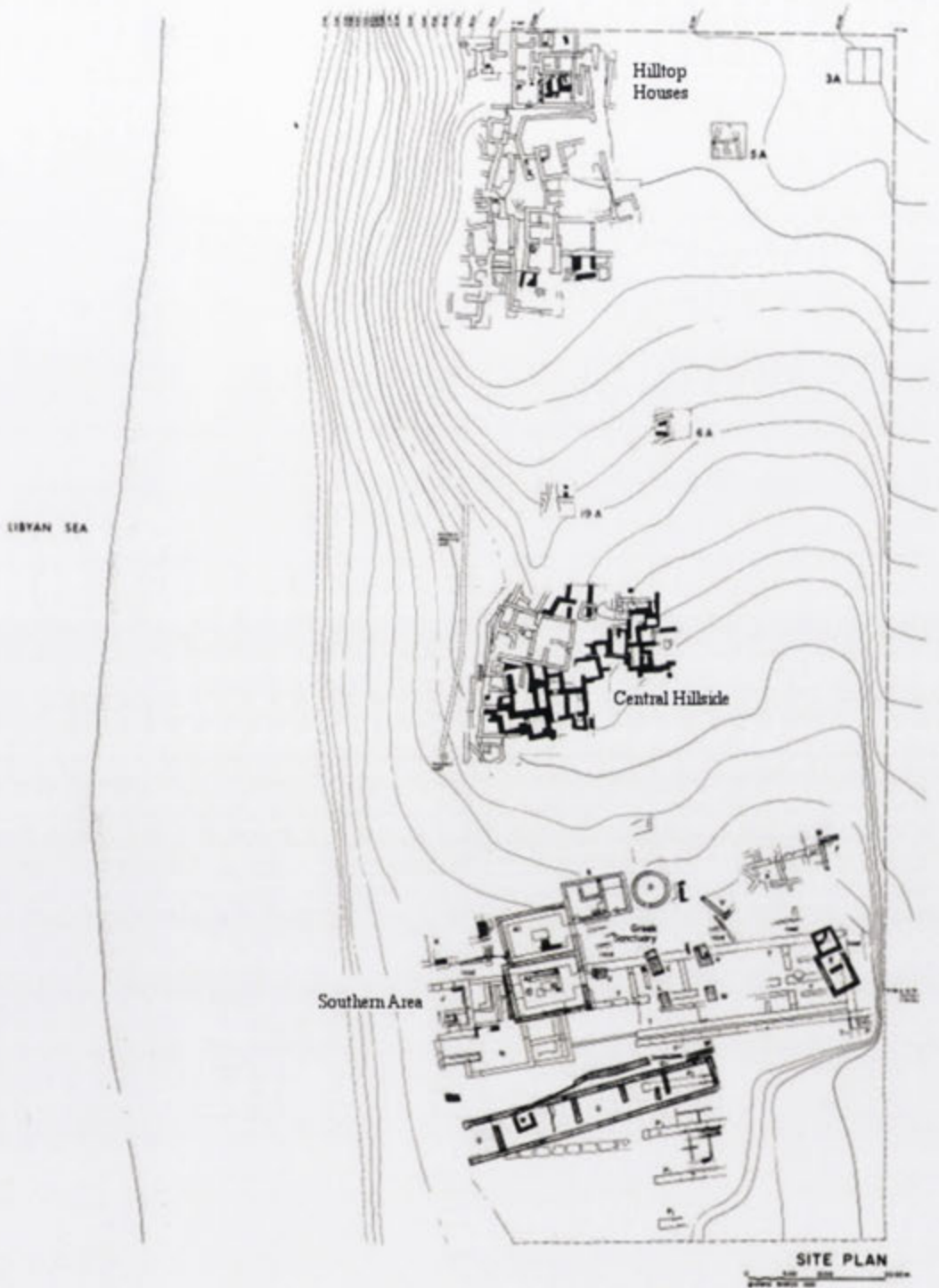


Figure 165. Map of Kommos, showing the Hilltop Houses, Central Hillside and Southern Area, which contained the LM IB Southern Harbour Complex. Adapted from: J. W. Shaw and M. C. Shaw, eds., *Kommos I: The Kommos Region and Houses of the Minoan Town. Part 1: The Kommos Region, Ecology, and Minoan Industries* (Princeton: Princeton University Press, 1995), pl. 2.12.

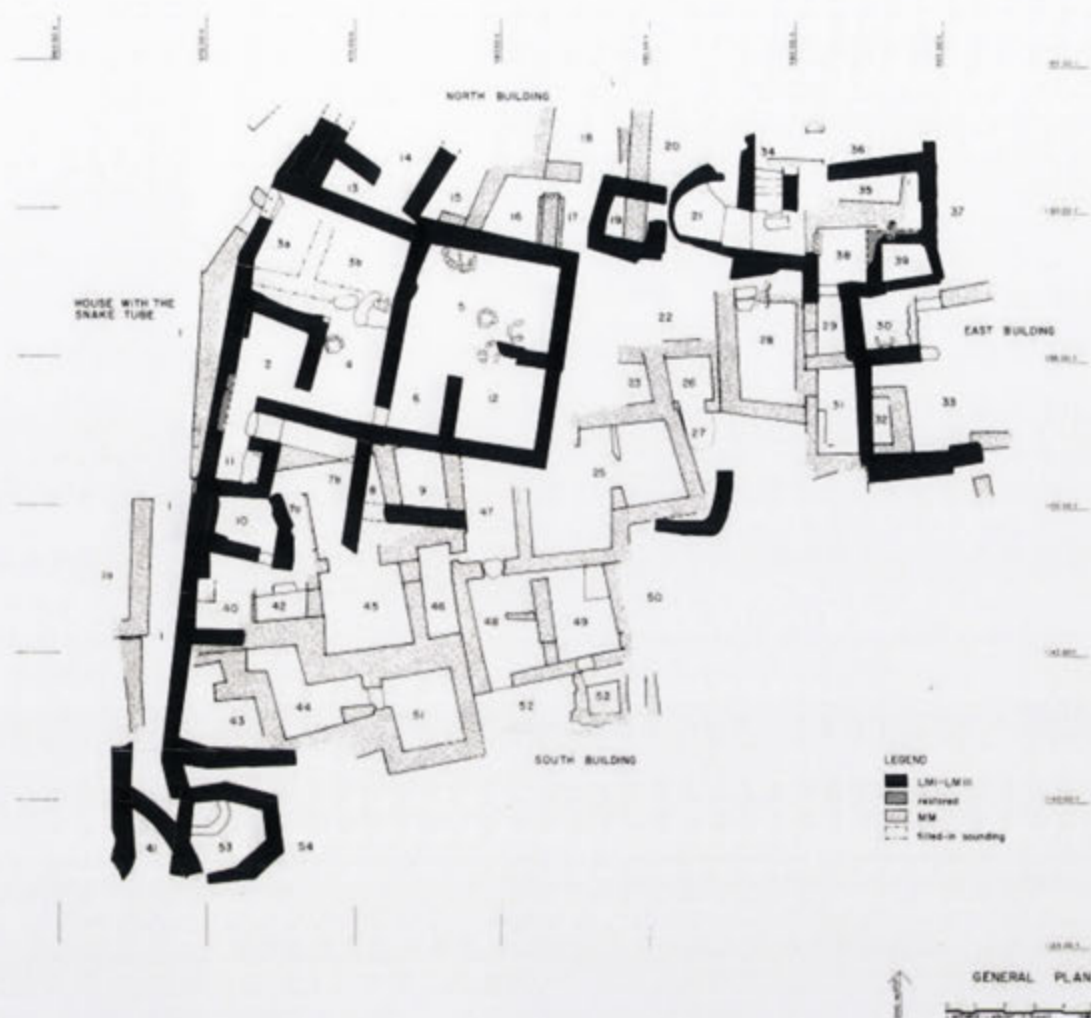


Figure 167. Plan of the Central Hillside at Kommos: metallurgical remains were found in the vicinity of the House with the Snake Tube. *Adapted from: Shaw and Shaw, Kommos I: Part 1, pl. 2.15.*

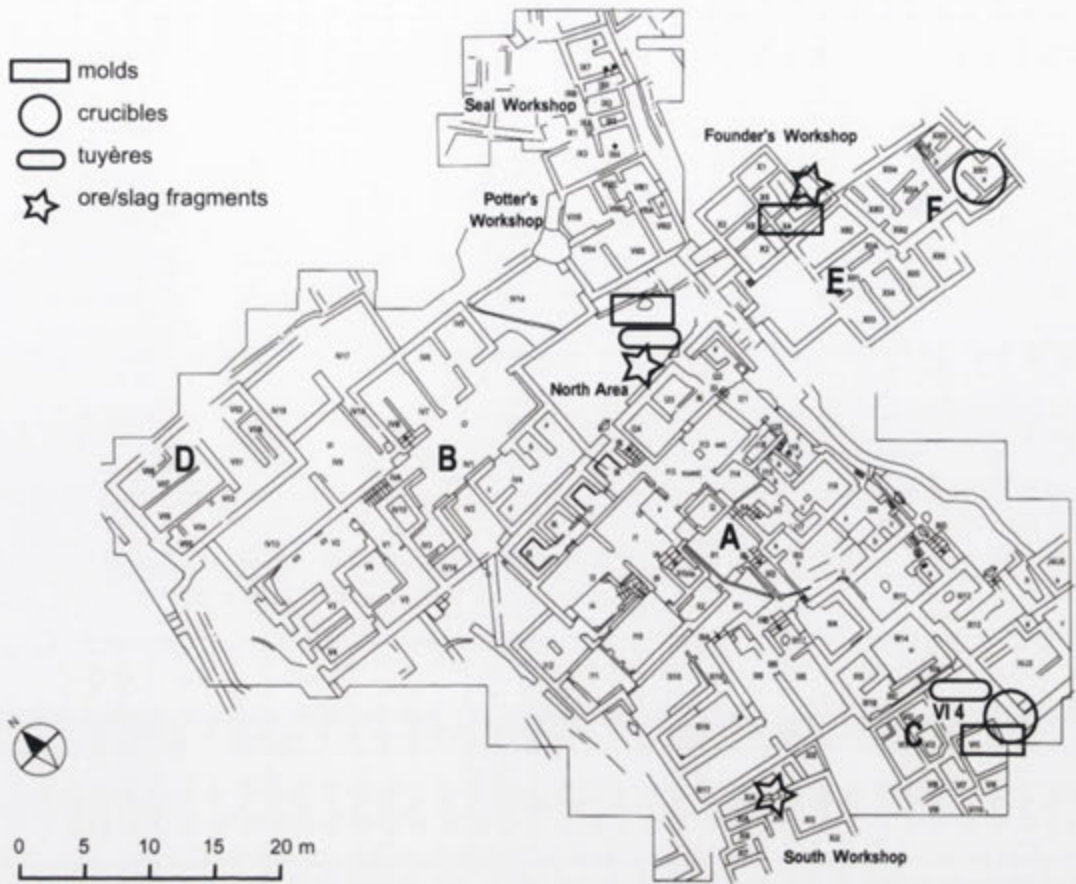


Figure 168. Plan of Malia Quartier Mu and locations of metallurgical material: the Founder's Workshop, South Workshop, the North Area and Building C. Building B is also discussed in this chapter. *Adapted from:* J.-C. Poursat and C. Oberweiler, "Metalworking at Malia Quartier Mu: High or Low Technology?," in *Metallurgy: Understanding How, Learning Why: Studies in Honor of James D. Muhly*, ed. Philip P. Betancourt and Susan C. Ferrence (Philadelphia: INSTAP Academic Press, 2011), fig. 13.1.

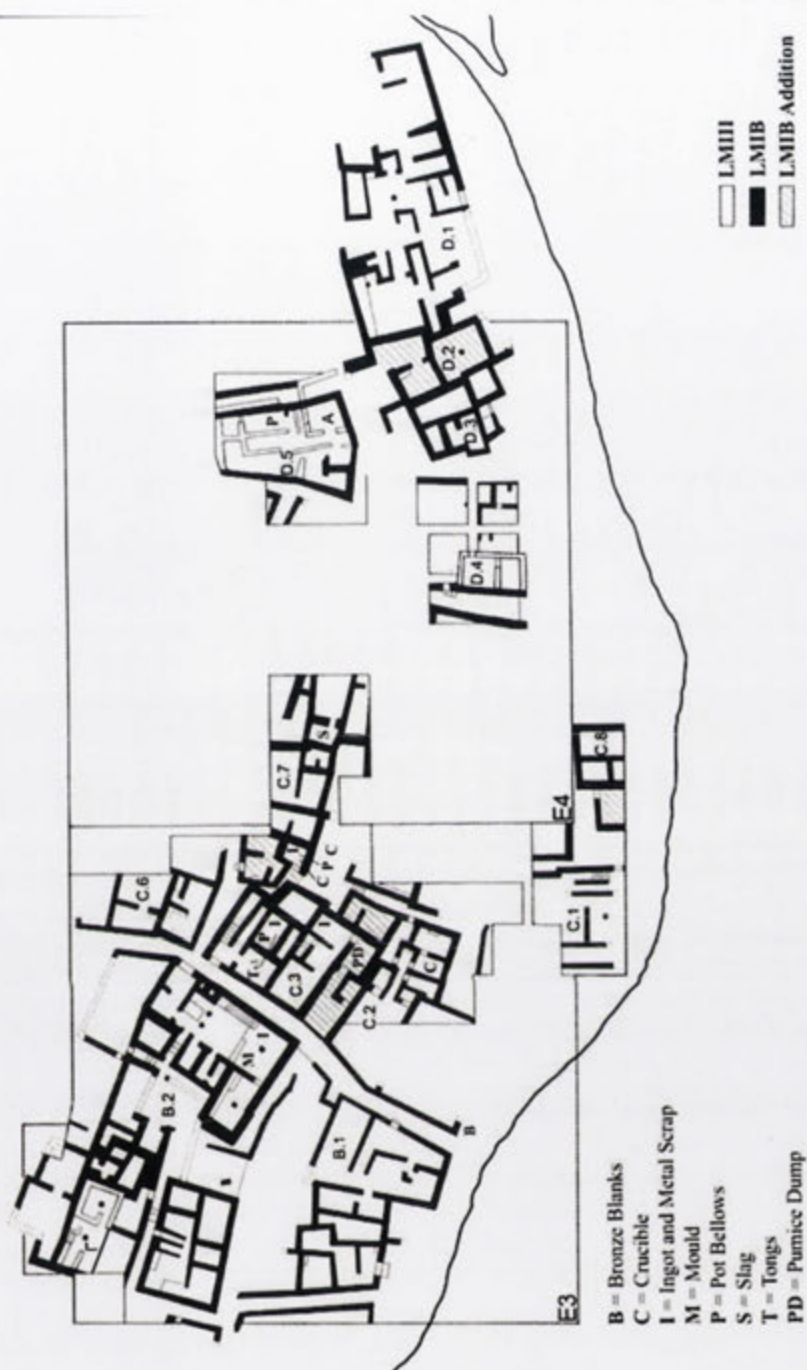


Figure 169. Metallurgical materials in the LM IB settlement at Mochlos: Houses C2, C3 and C7 (left centre). Adapted from: Brogan, "Metalworking at Mochlos," fig. 3.

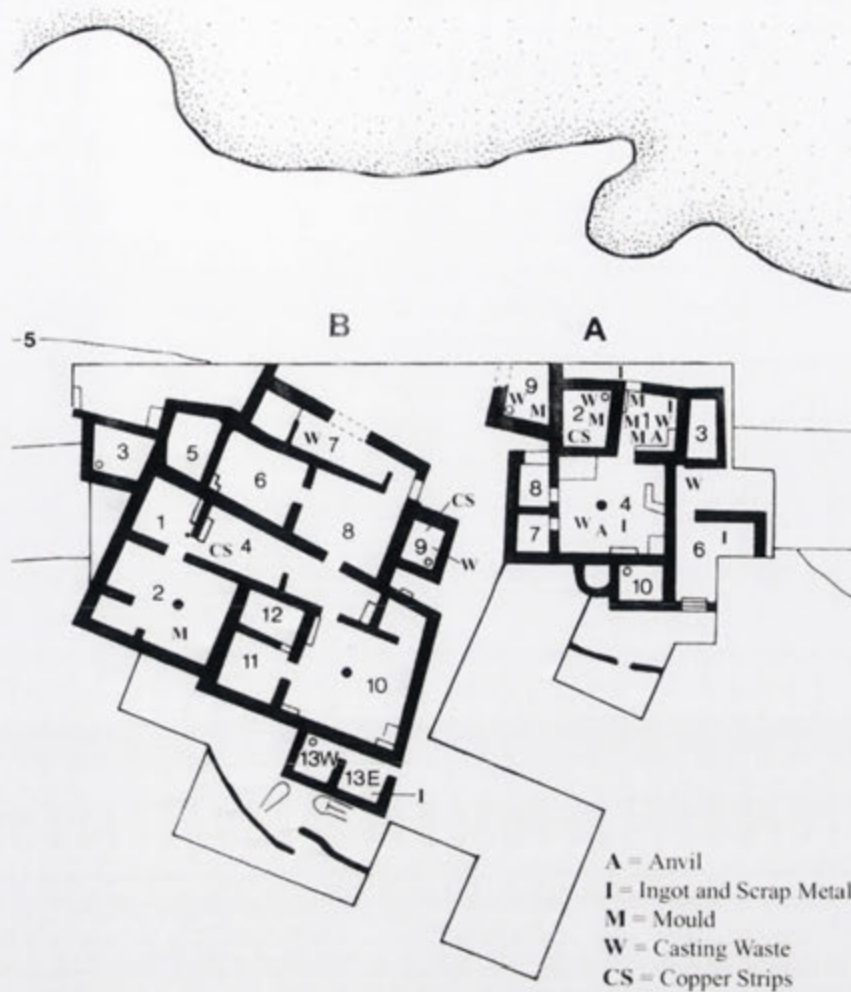


Figure 170. Metallurgical material at the Artisans' Quarter, Mochlos. *Adapted from:* Brogan, "Metalworking at Mochlos," fig. 1.

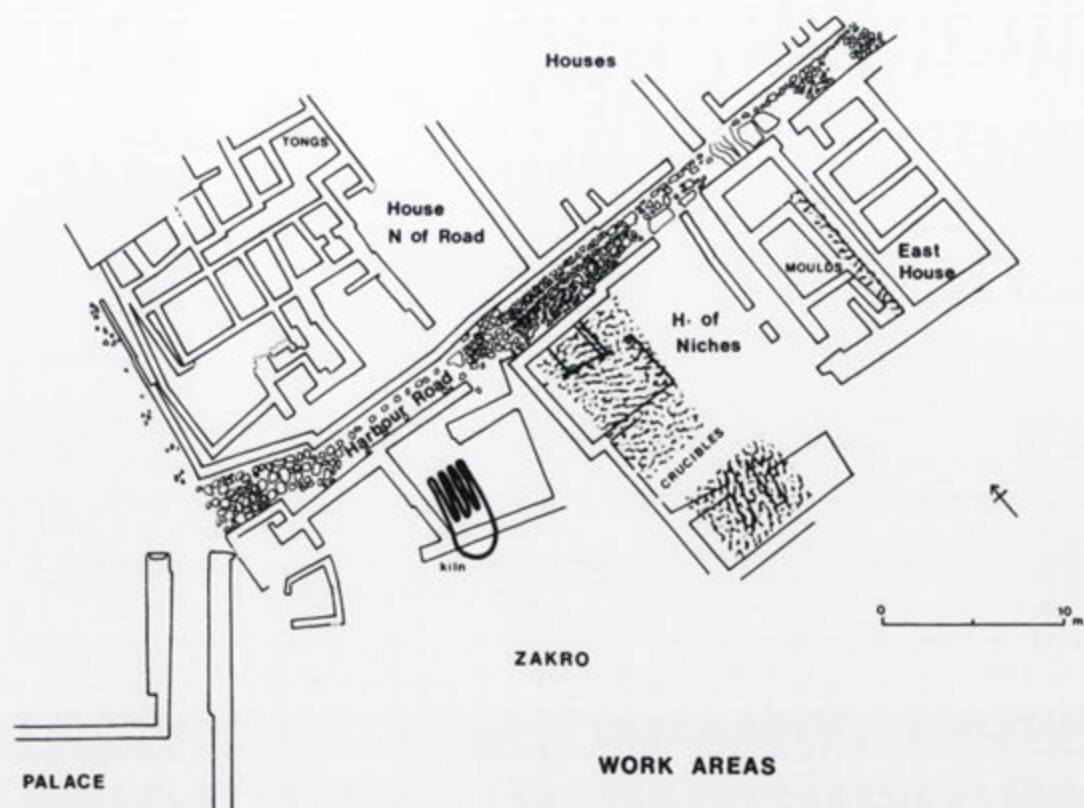


Figure 171. Plan of the houses north-east of Zakros palace showing metallurgical remains in the House of Niches and the 'fingering' kiln. Adapted from: Evelyn, *Minoan Crafts* 2, fig. 135.

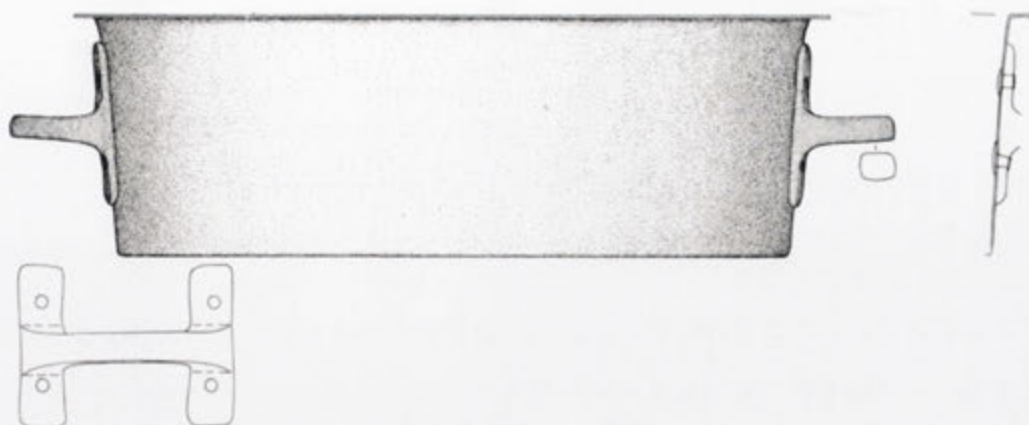


Figure 172. Two-handled pan. CM M119. *Adapted from: Matthäus, BKMK, pl. 5.*



Figure 173. Two-handled pan. CM M119.



Figure 174. Two-handled pan. CM M119.



Figure 175. Two-handled pan. CM M119. Detail: loop-handle.



Figure 176. Two-handled pan. CM M119. Detail: inside rivet-heads.

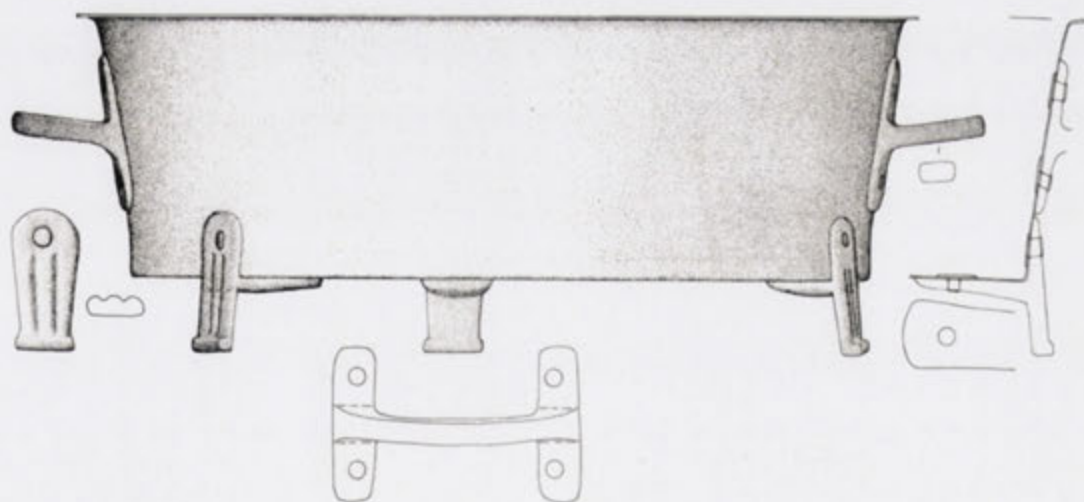


Figure 177. Tripod pan. CM M118. *Adapted from: Matthäus, BKMK, pl. 6.*



Figure 178. Tripod pan. CM M118.



Figure 179. Tripod pan. CM M118. Detail: loop-handles.



Figure 180. Tripod pan. CM M118. Detail: front view of a leg.



Figure 181. Tripod pan. CM M118. Detail: side view of a leg and its bracket.

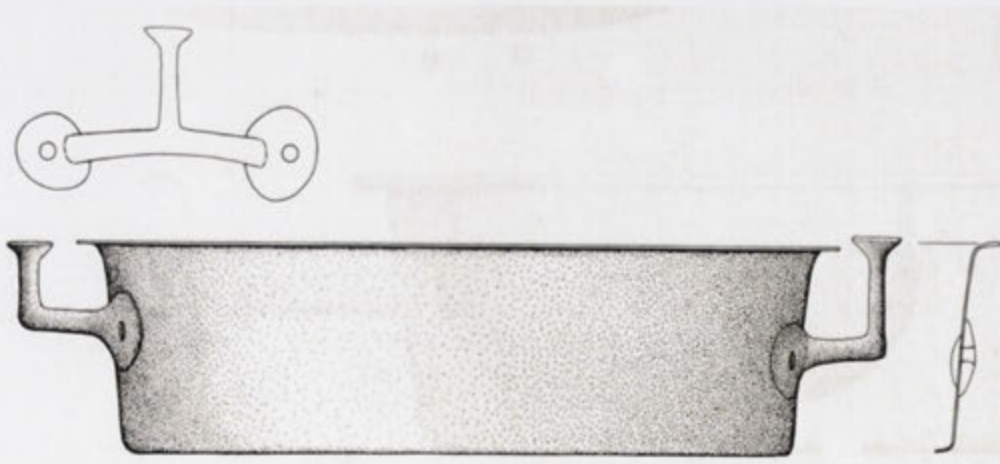


Figure 182. Restored two-handled pan. AshM AE494. *Adapted from:* Matthäus, *BKMK*, pl. 6.



Figure 183. Restored two-handled pan. AshM AE494.



Figure 184. Restored two-handled pan. AshM AE494. Detail: wishbone-handle.

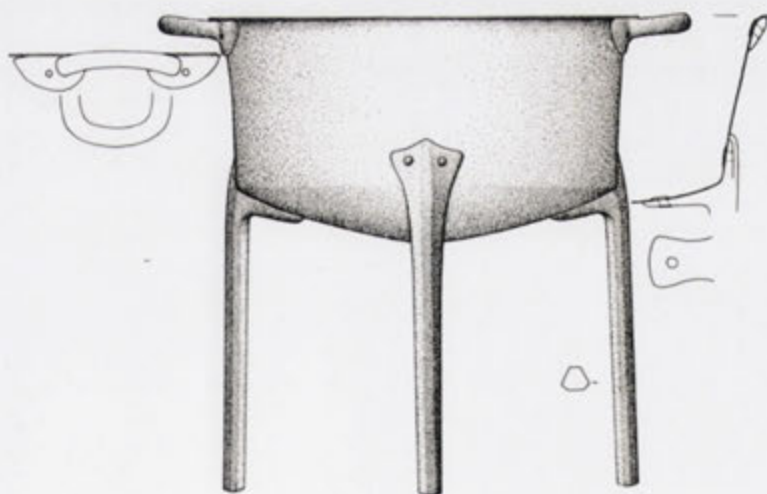


Figure 185. Tripod cauldron (1). CM M116. Adapted from: Matthäus, *BKMK*, pl.7.



Figure 186. Tripod cauldron (1). CM M116.



Figure 187. Tripod cauldron (1). CM M116.



Figure 188. Tripod cauldron (1). CM M116. Detail: loop-handle with knob and chevrons.



Figure 189. Tripod cauldron (1). CM M116. Detail: decorative attachment-plate on a leg.



Figure 190. Tripod cauldron (1). CM M116. Detail: bracket on a leg attached under the base.

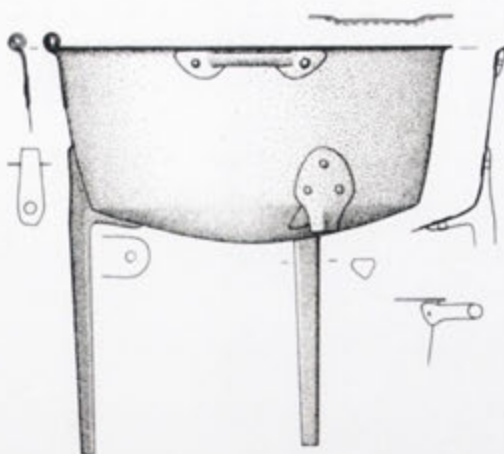


Figure 191. Tripod cauldron (2). AshM 1967.1213. *Adapted from: Matthäus, BKMK, pl. 10.*



Figure 192. Tripod cauldron (2). AshM 1967.1213.



Figure 193. Tripod cauldron (2). AshM 1967.1213.



Figure 194. Tripod cauldron (2). AshM 1967.1213. Detail: rim-loop attached with one rivet.



Figure 195. Tripod cauldron (2). AshM 1967.1213. Detail: broken end of a leg with bubbles in the material.



Figure 196. Two-handled basin. AshM 1967.1216. *Adapted from: Matthäus, BKMK, pl. 15.*



Figure 197. Two-handled basin. AshM 1967.1216.



Figure 198. Two-handled basin. AshM 1967.1216. Detail: rim folded out and in.



Figure 199. Two-handled basin. AshM 1967.1216. Detail: forged rod-handle and flared hole where a rivet used to be.

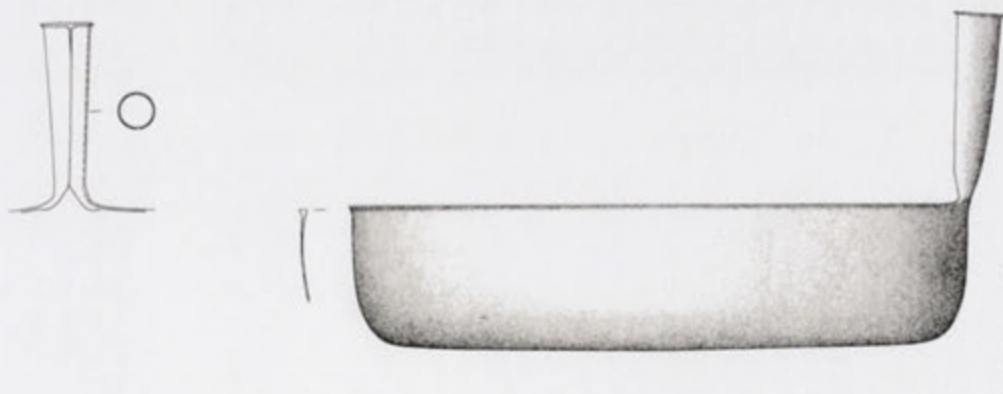


Figure 200. Pan with hollow, vertical handle (1). AshM 1967.1214. *Adapted from:* Matthäus, *BKMK*, pl. 19.



Figure 201. Pan with hollow, vertical handle (1). AshM 1967.1214.



Figure 202. Pan with hollow, vertical handle (1). AshM 1967.1214. Detail: hollow handle and rim.

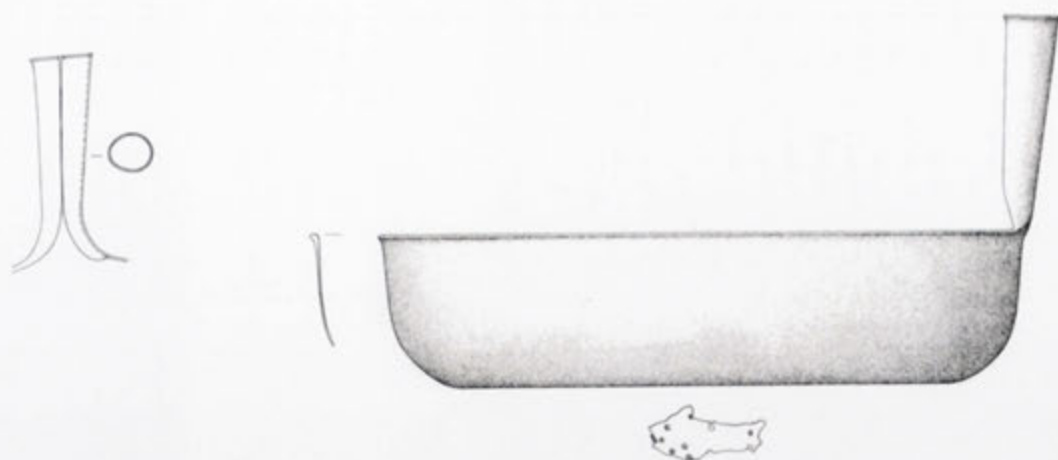


Figure 203. Pan with hollow, vertical handle (2). AshM 1967.1215. *Adapted from:* Matthäus, *BKMK*, pl.19.



Figure 204. Pan with hollow, vertical handle (2). AshM 1967.1215.



Figure 205. Pan with hollow, vertical handle (2). AshM 1967.1215. Detail: hollow handle and rim.



Figure 206. Pan with hollow, vertical handle (2). AshM 1967.1215. Detail: repair-patch on the underside of the pan.

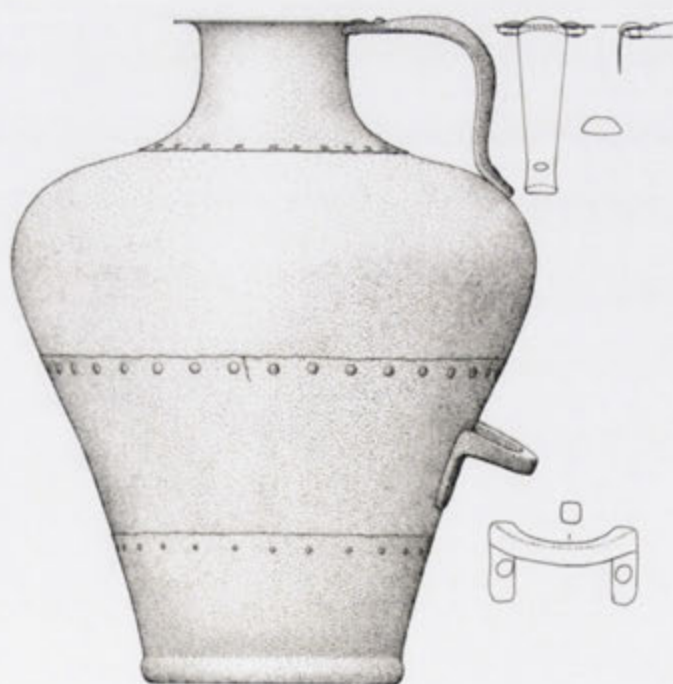


Figure 207. Hydria. CM M12. *Adapted from: Matthäus, BKMK, pl. 29.*



Figure 208. Hydria. CM M12.



Figure 209. Hydria. CM M12.

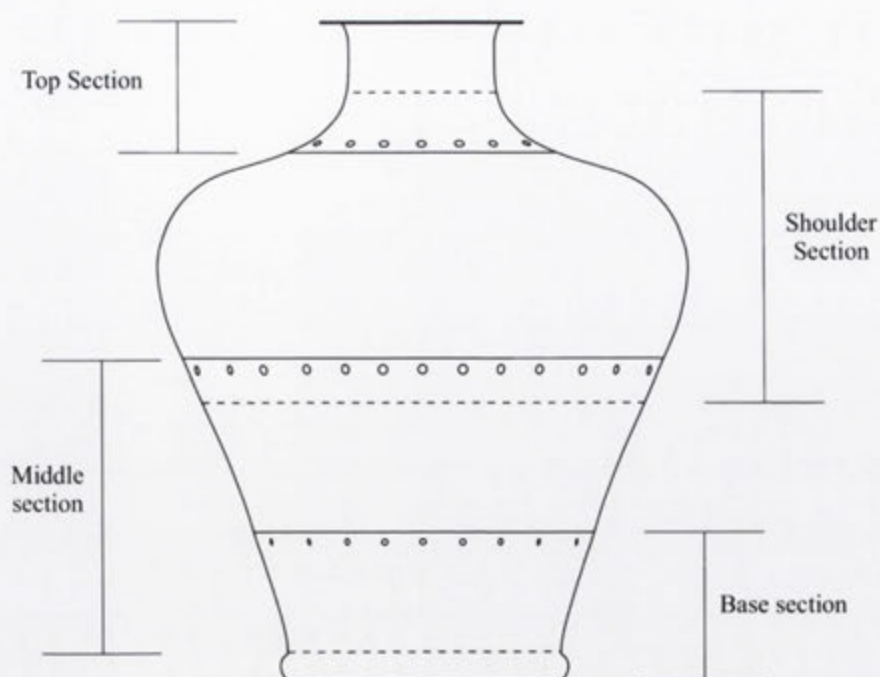


Figure 210. Diagram of the hydria and its sections. CM M12. Broken lines indicate the edges of the sections inside the vessel.



Figure 211. Hydria. CM M12. Detail: riveted seam between the top section and shoulder section.

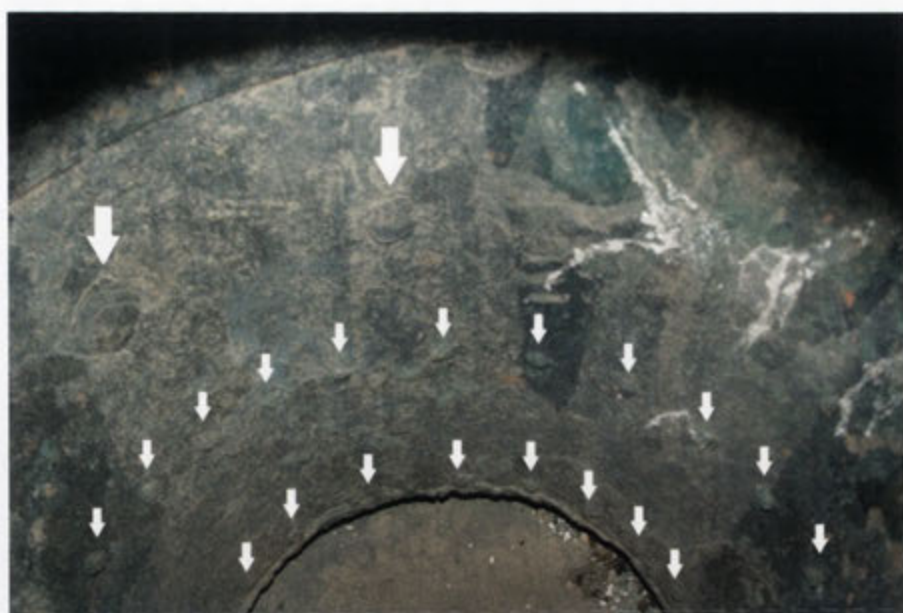


Figure 212. Hydria. CM M12. Detail: inside the hydria. The bottom edge of the shoulder section is visible in the upper-left corner. Rivet heads are indicated with arrows. The two rivet heads in the upper left hold join the lower handle to the wall and the rivets of the current bottom seam are just below. The ragged lower-edge of the middle section is at the bottom; immediately above this, a row of rivet-heads from the seam which held on the original base can be seen.



Figure 213. Hydria. CM M12. Detail: upper handle attached with mushroom-rivets and with a small bulge next to the rim.



Figure 214. Hydria. CM M12. Detail: lower end of the upper handle riveted to the top of the shoulder.



Figure 215. Hydria. CM M12. Detail: lower loop-handle.



Figure 216. Hydria. CM M12. Detail: horizontal raising marks on the bottom section.



Figure 217. Hydria. CM M12. Patch of small dents on the shoulder indicative of a repair.



Figure 218. One-handed basin. ANM 54. *Adapted from: Matthäus, BKMK, pl. 37.*



Figure 219. One-handed basin. ANM 54.



Figure 220. One-handed basin. ANM 54.



Figure 221. One-handed basin. ANM 54. Detail: thickened rim and close-up of the handle decoration, viewed from inside the basin.



Figure 222. One-handed basin. ANM 54. Detail: the thickened rim and back of the handle.



Figure 223. One-handed cup. CM M64.



Figure 224. One-handed cup. CM M64.



Figure 225. One-handed cup. CM M64. Detail: end of the strap-handle riveted to the body.



Figure 226. One-handed cup. CM M64. Detail: centre-punch point in the centre of the foot and inscribed circle around the circumference of the foot.



Figure 227. Beaker with spout. CM M62.



Figure 228. Beaker with spout. CM M62.

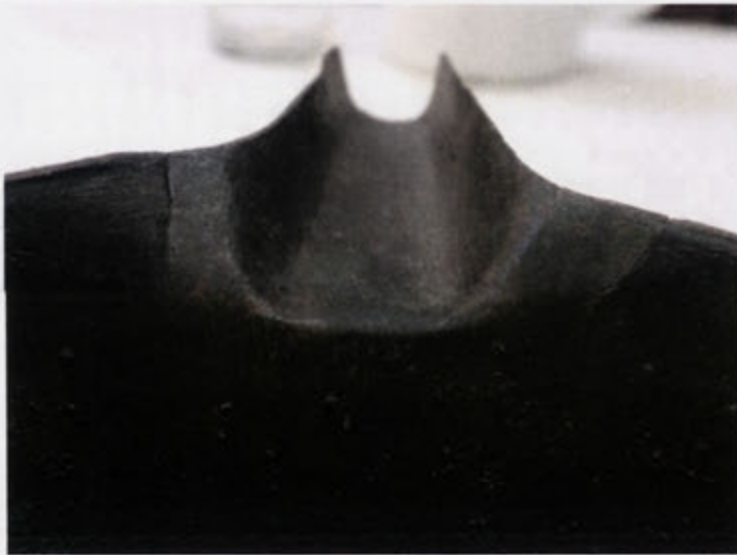


Figure 229. Beaker with spout. CM M62. Detail: rim thinning on either side of the spout and sharp fold in the wall where the spout leaves the body.



Figure 230. Beaker with spout. CM M62. Detail: bent-sheet handle.



Figure 231. Kalathos or lekane. CM M60.



Figure 232. Kalathos or lekane. CM M60.



Figure 233. Kalathos or lekane. CM M60. Detail: heavily-thickened rim.

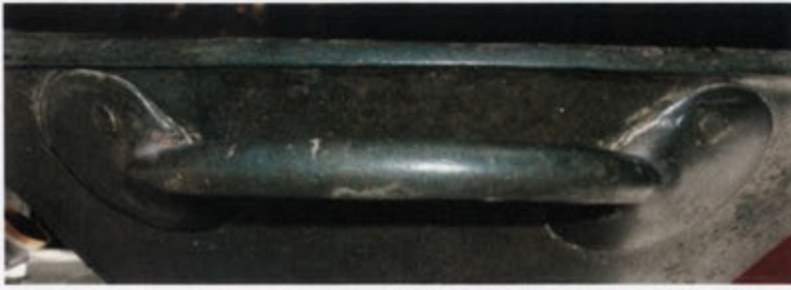


Figure 234. Kalathos or lekane. CM M60. Detail: loop-handles.



Figure 235. Kalathos or lekane. CM M60. Detail: bubbles in an attachment-plate around the rivet-hole.

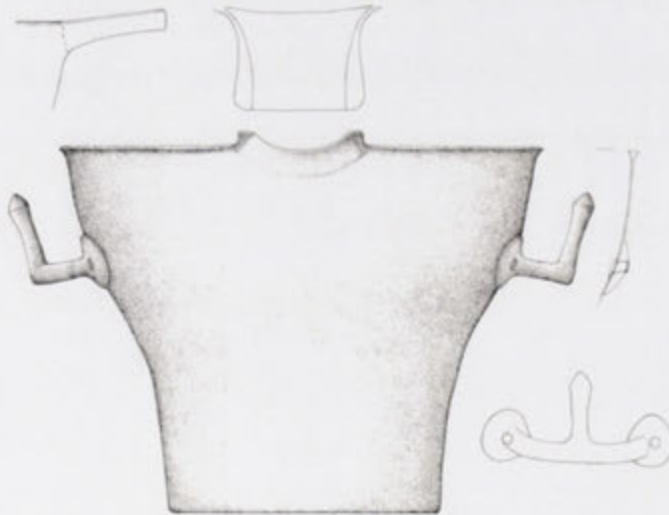


Figure 236. Lekane with handles and spout. CM M115. Adapted from: Matthäus, *BKMK*, pl. 48.



Figure 237. Lekane with handles and spout. CM M115.



Figure 238. Lekane with handles and spout. CM M115.



Figure 239. Lekane with handles and spout. CM M115. Detail: thickened rim narrowing towards spout, which has folded-out rims.



Figure 240. Lekane with handles and spout. CM M115. Detail: wishbone-handle without rivet heads on the outside of the attachment-plate.



Figure 241. Lekane with handles and spout. CM M115. Detail: wishbone-handle with rivets passing completely through the attachment-plates.



Figure 242. Straight-walled bowl with dropped foot. CM M114. *Adapted from: Matthäus, BKMK, pl. 50.*



Figure 243. Straight-walled bowl with dropped foot. CM M114.



Figure 244. Ladle with dropped base. CM M63.



Figure 245. Ladle with dropped base. CM M63.



Figure 246. The first copper bowl made during initial experimentation: the foot is dropped, the rim folded out and the inner surface burnished to a polish.



Figure 247. The second bowl made during initial experimentation: the foot is dropped, the rim caulked and the inner surface burnished to a polish.



Figure 248. Copper hydria made for the experimental reconstructions. cf. figures 207 and 208.



Figure 249. The four sections of the reconstructed hydria.



Figure 250. Sterling silver one-handed basin made for the experimental reconstructions. cf. figures 218 and 219.



Figure 251. Hearth used for the reconstructions based on the design and dimensions of the pi-hearth at the Unexplored Mansion, Pillar Hall H. cf. figures 108 and 109.



Figure 252. The selection of stone hammers used for the reconstructions: (*left to right*): two granite pestles, an oblong fine-grained igneous stone, granite pestle, marble pestle, basalt cobblestone. cf. figures 135, 136 and 137.



Figure 253. Beech carver's mallet replicating New Kingdom Egyptian wooden mallets. cf. figure 140.



Figure 254. Oak hammer replicating the Flag Fen hammer. cf. figure 142.

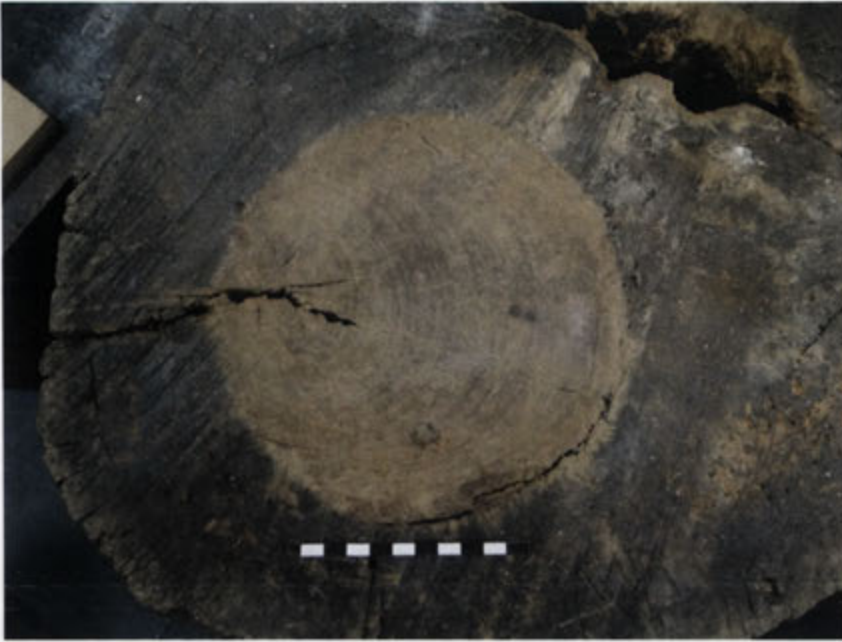


Figure 255. Large, shallow hollow carved into a eucalyptus stump.



Figure 256. Small hollows carved into a pine stump. The dimensions of one hollow relative to the hammer being used are illustrated.



Figure 257. Hardwood stake held in a vice used for raising.

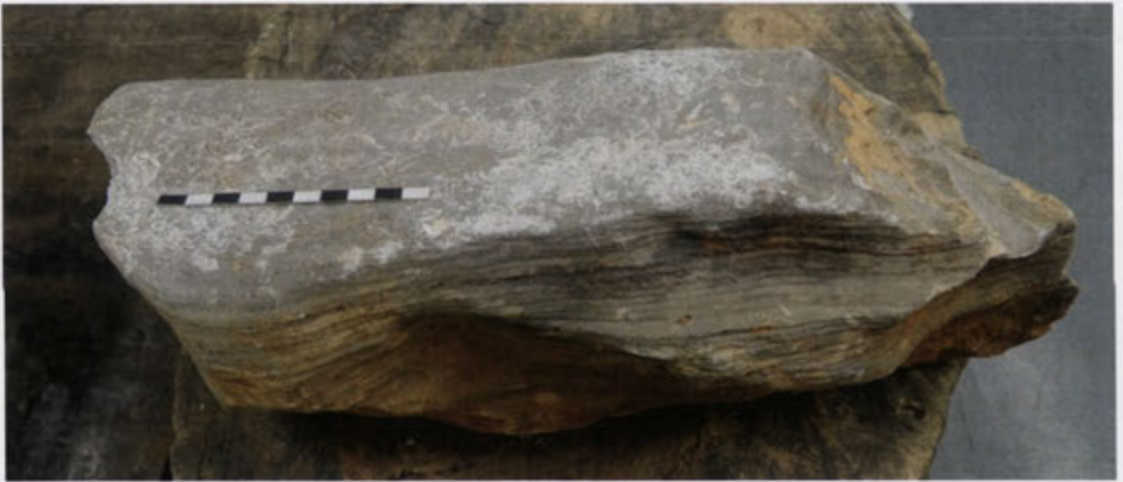


Figure 258. Limestone anvil. cf. figures 144 and 145.



Figure 259. Chisel forged from sterling silver rod. cf. figure 161.



Figure 260. Sterling silver punch.



Figure 261. Tools tested for finishing.



Figure 262. Annealing a billet buried in the hearth using an aluminium blow-pipe.

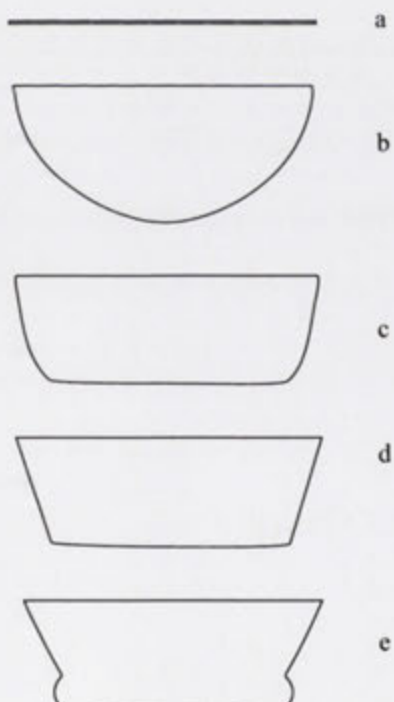


Figure 263. The stages required to make the base-section of the copper hydria: a) the unhammered billet; b) the billet sunk into a deep bowl; c) the base flattened; d) the walls raised straight; e) the base-bulge shaped and additional raising on the wall.



Figure 264. Sinking a copper hemisphere with a granite pestle into a small hollow in a eucalyptus stump.



Figure 265. Shaping the bottom-end of a hydria-section after a hole was cut in the base of the concave form.



Figure 266. Raising a hydria-section with a granite pestle over a wooden stake.

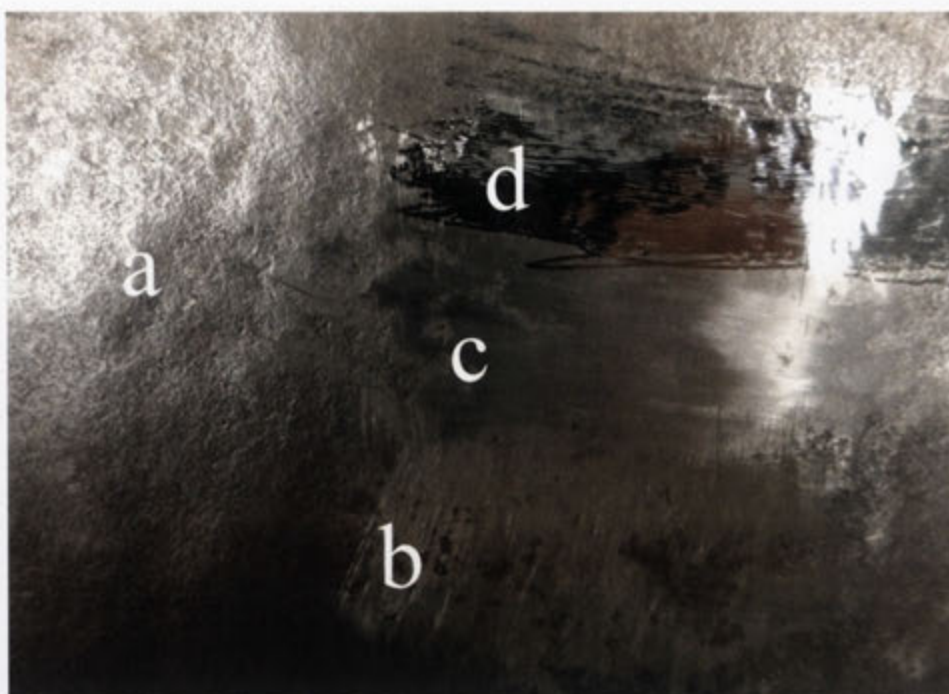


Figure 267. Test patches of finishing with different tools: a) unfinished surface remaining on the vessel after hammering; b) cut with fine-grained igneous stone; c) polished with charcoal; d) burnished with haematite.



Figure 268. Cutting a hole in the base of a hydria-section using a sterling silver chisel with a flared, curved cutting-face and a basalt cobblestone as a hammer.



Figure 269. Channel created in the thick wall of the top-section of the hydria with the sterling silver chisel.



Figure 270. Tested hole-making methods in thin material (front): (*left*) Rostoker's method, (*centre*) punched hole with rupture prongs, (*right*) punched and cut back with abrasive.



Figure 271. Tested hole-making methods in thin material (back): (*left*) Rostoker's method, (*centre*) punched hole with rupture prongs, (*right*) punched and cut back with abrasive.



Figure 272. Rostoker's method for hole-making tested on 2 mm copper sheet.

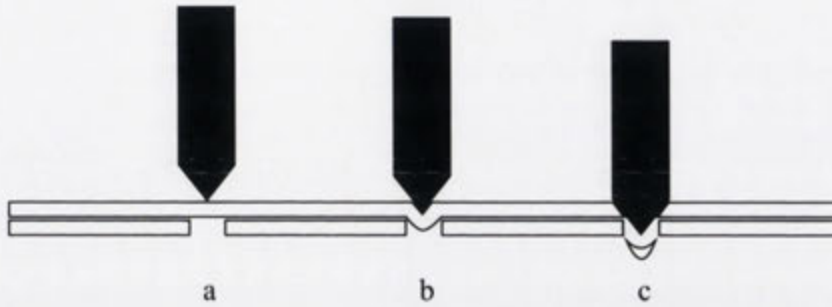


Figure 273. Making a hole in sheet by punching through a pre-formed hole in another sheet: a) the un-punched sheet laid over a hole in another sheet; b) the punch initially pushes the sheet, creating a dimple on the reverse; c) the tip of the punch and the corners of the pre-formed hole shear off the dimple, leaving a hole.

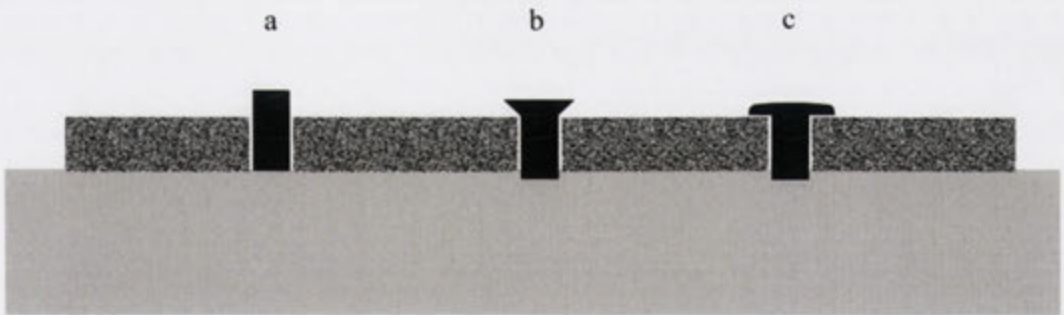


Figure 274. Cross-section of the stages of creating the first head of a rivet with a jig (dark grey) on a wooden surface (light grey): a) the pre-cut rivet-shaft placed in the jig; b) initial forging of the head which causes the bottom end to dig into the wood; c) the first head completed.



Figure 275. Copper rivets with the first head formed.

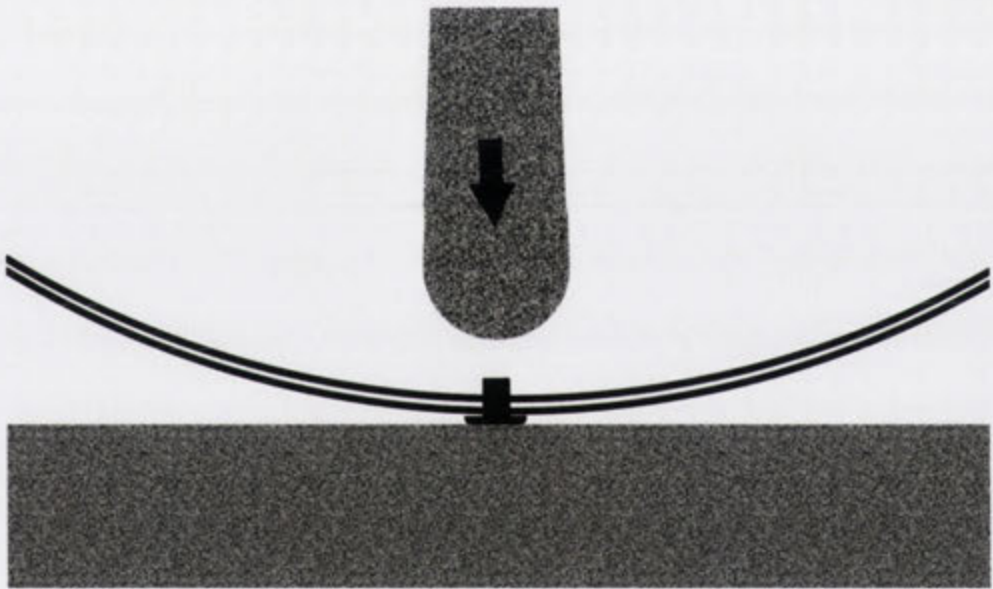


Figure 276. Cross-section showing the second rivet-head being closed to join two vessel-sections. The first rivet-head, which is on the outside of the vessel, is supported on the limestone anvil while the second head is hammered from inside the vessel.



Figure 277. Closed rivets on the outside of the reconstructed hydria.

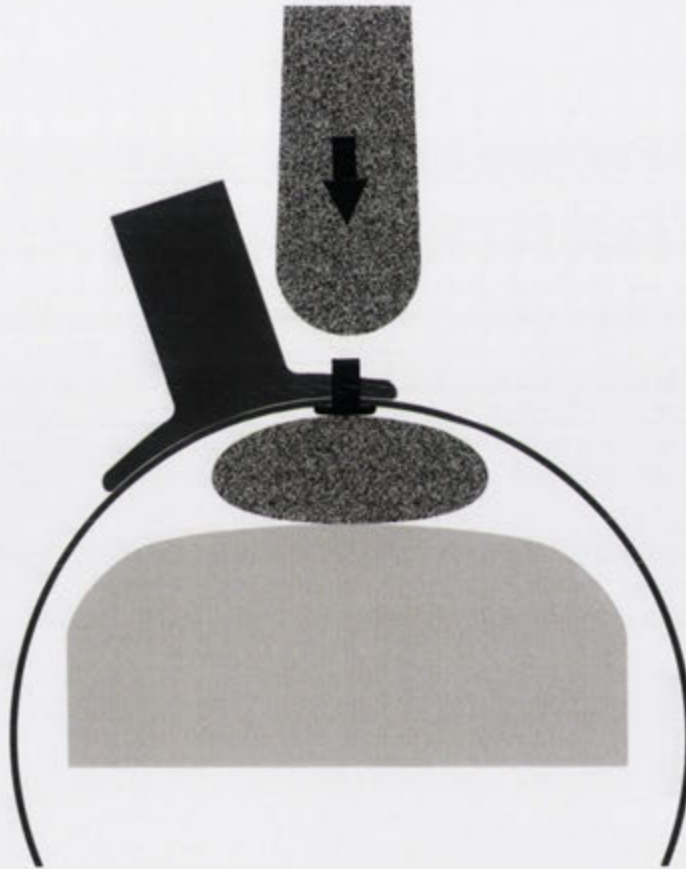


Figure 278. Cross-section showing the second rivet-head being closed to join a handle attachment-plate to a vessel-section which is too narrow to hammer the rivet-head from the inside. The vessel is held over a stake (light grey) which has a suitable stone on top of it. The first rivet-head sits against this while the second is forged closed.



Figure 279. Repair patch on the reconstructed hydria.

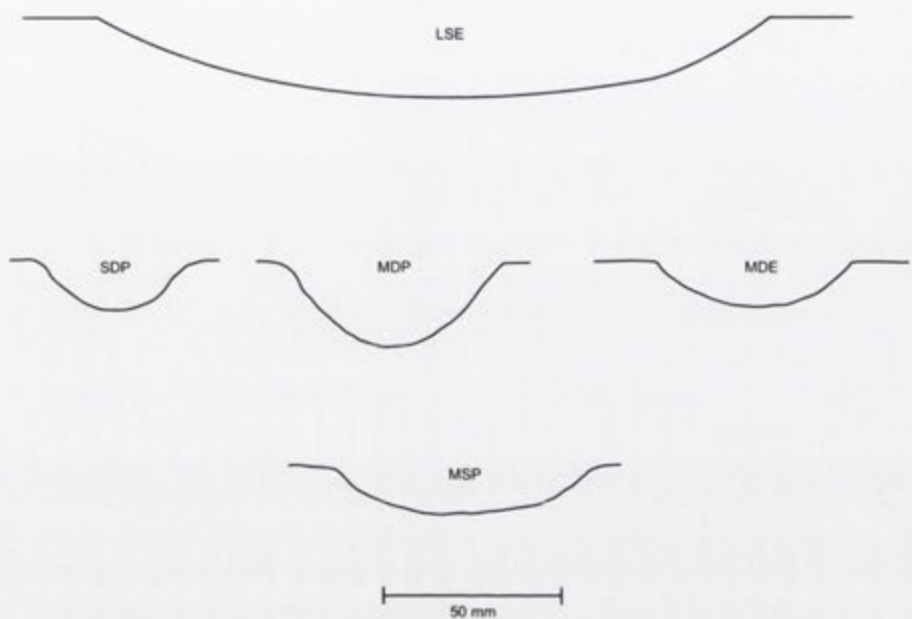


Figure 280. Cross-sections of the wooden hollows used in the reconstructions.

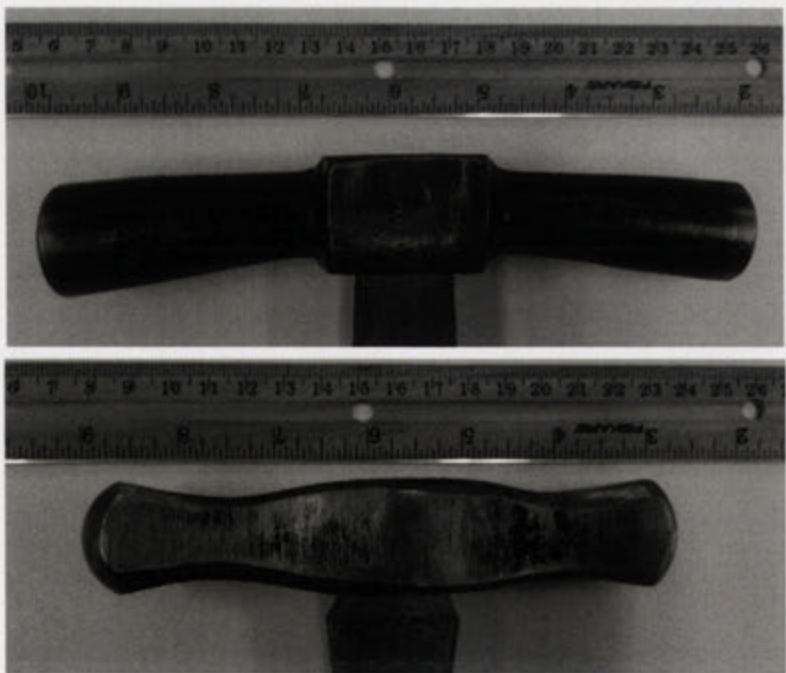


Figure 281. Steel hammers used for sinking in experiment 1. The large hammer (*top*) has large and shallow convex faces similar to those of a cobblestone. The smaller hammer (*bottom*) has small faces with high-domed convex faces similar to those of a pestle.

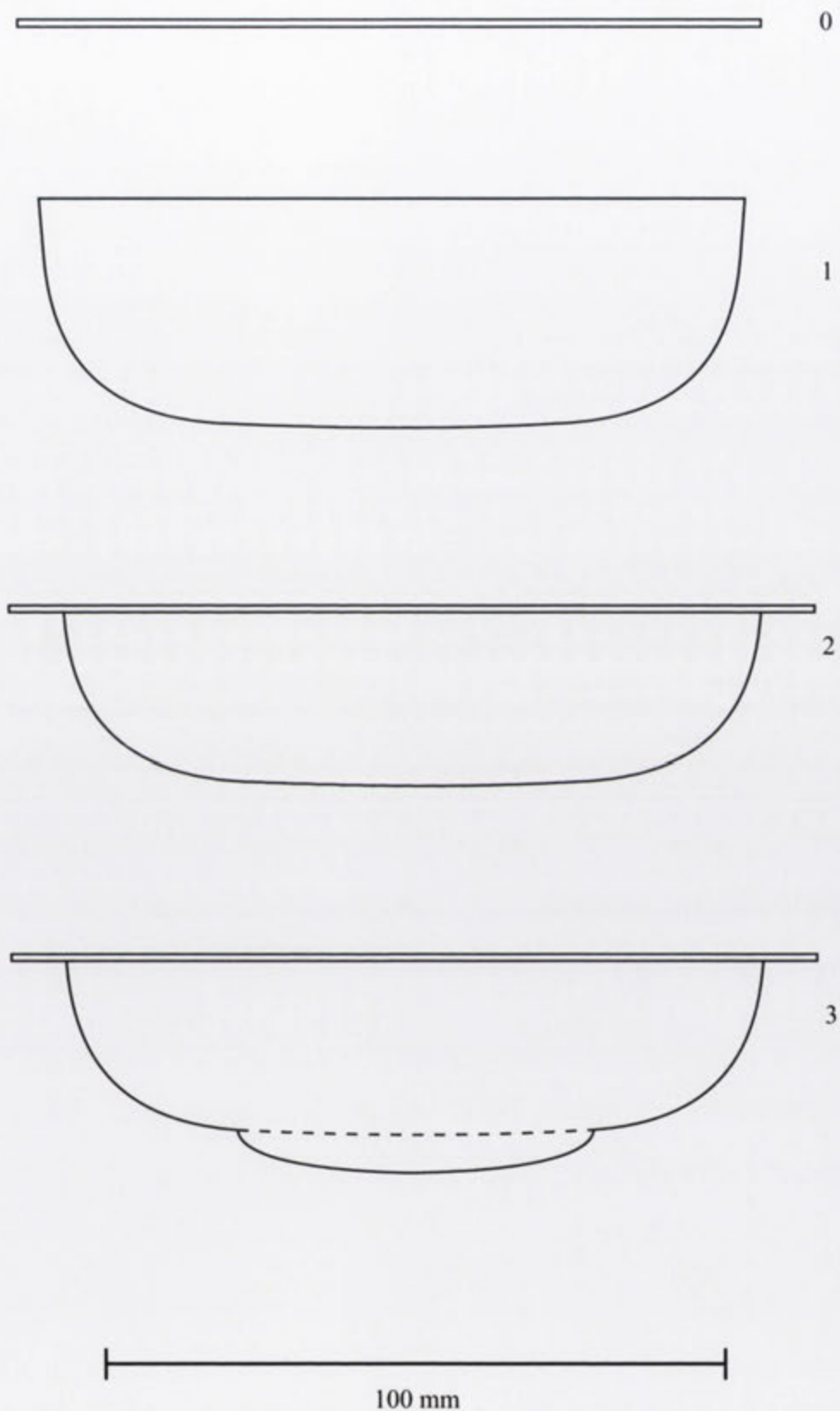


Figure 282. The three stages of experiment 1: bowl with dropped foot and out-turned rim.



Figure 283. Experiment 1: side view.



Figure 284. Experiment 1: top view.

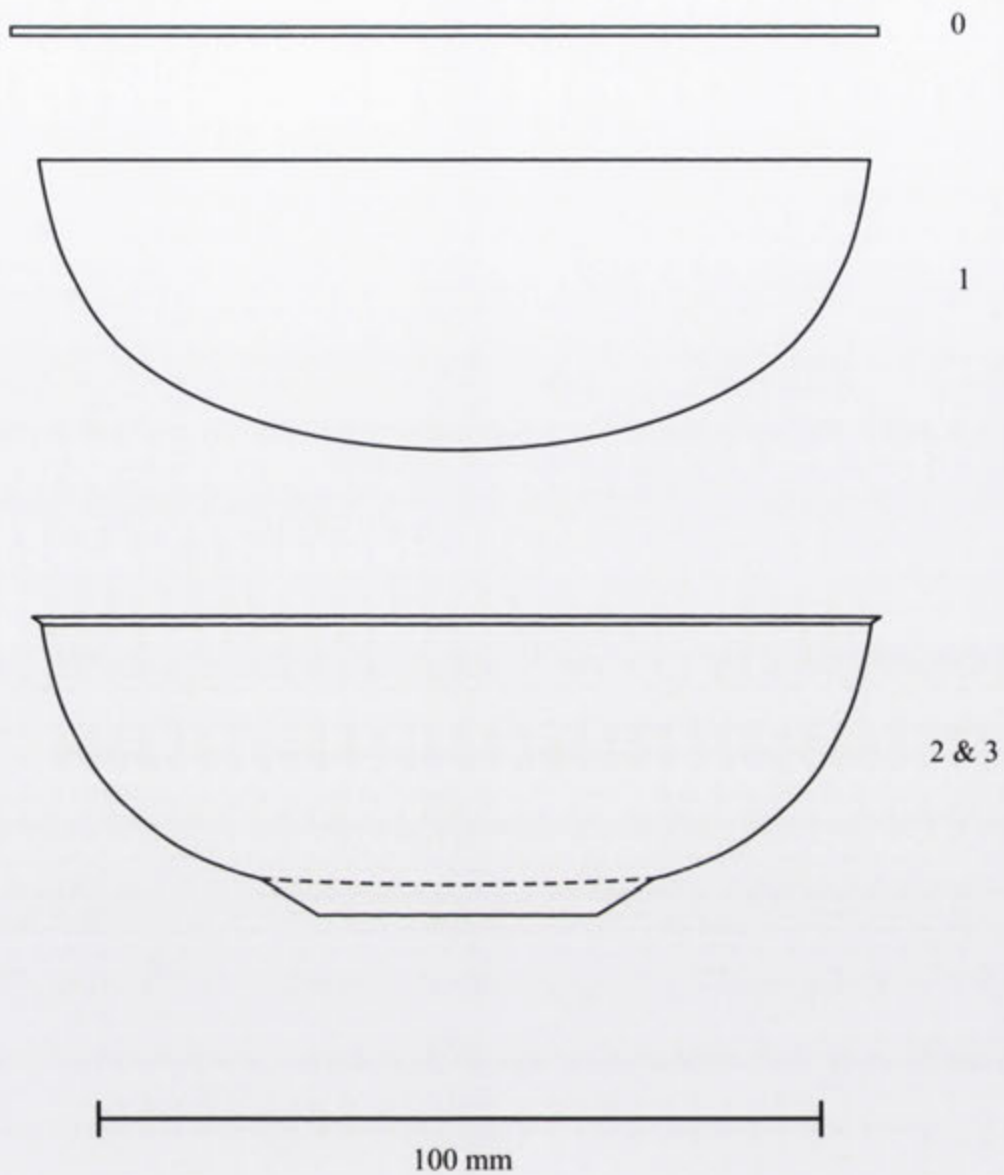


Figure 285. The three stages of experiment 2: bowl with dropped foot and caulked rim.



Figure 286. Experiment 2: side view.



Figure 287. Experiment 2: top view.

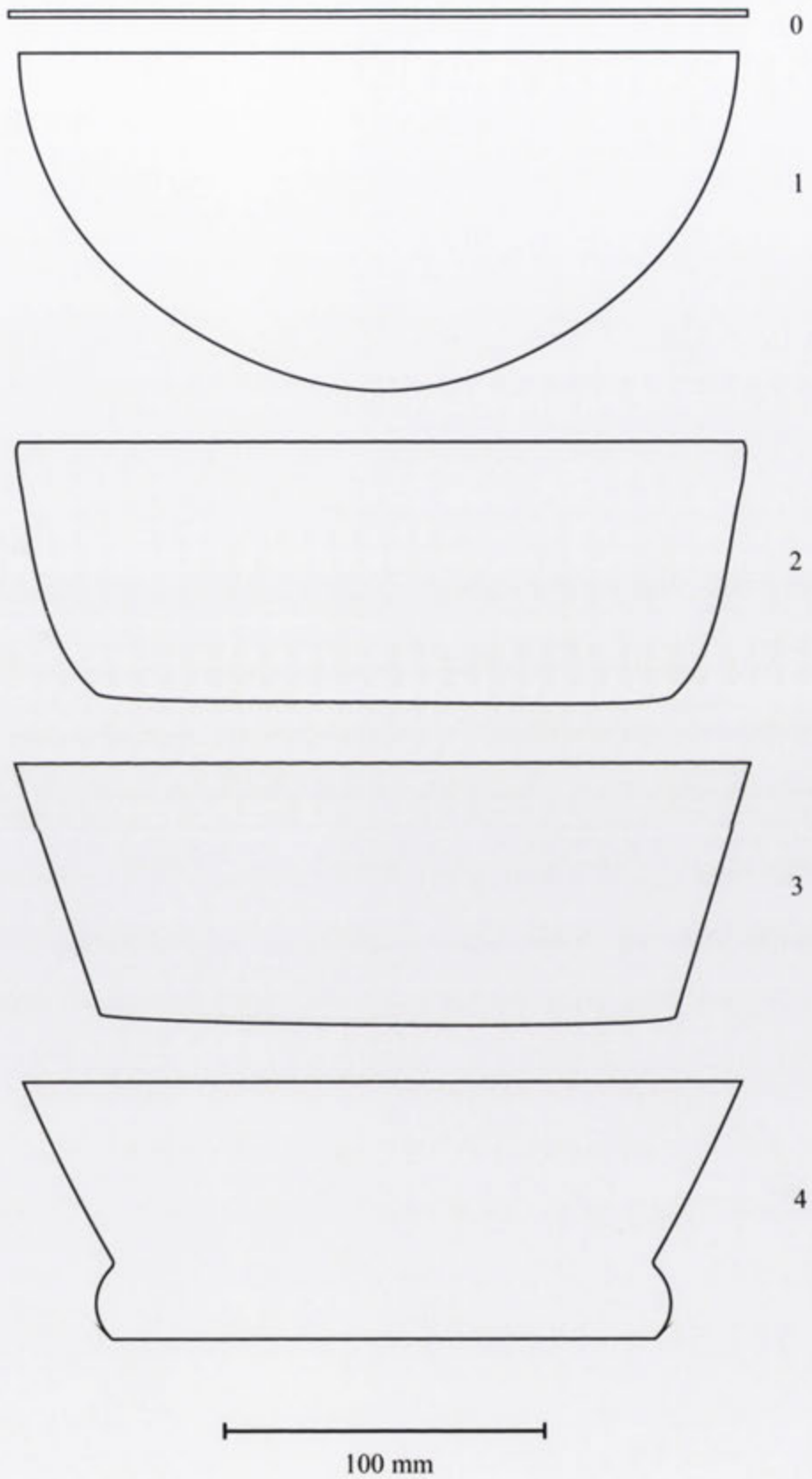


Figure 288. Experiment 3.1: hydria base.



Figure 289. Experiment 3.1: side view.



Figure 290. Experiment 3.1: top view.

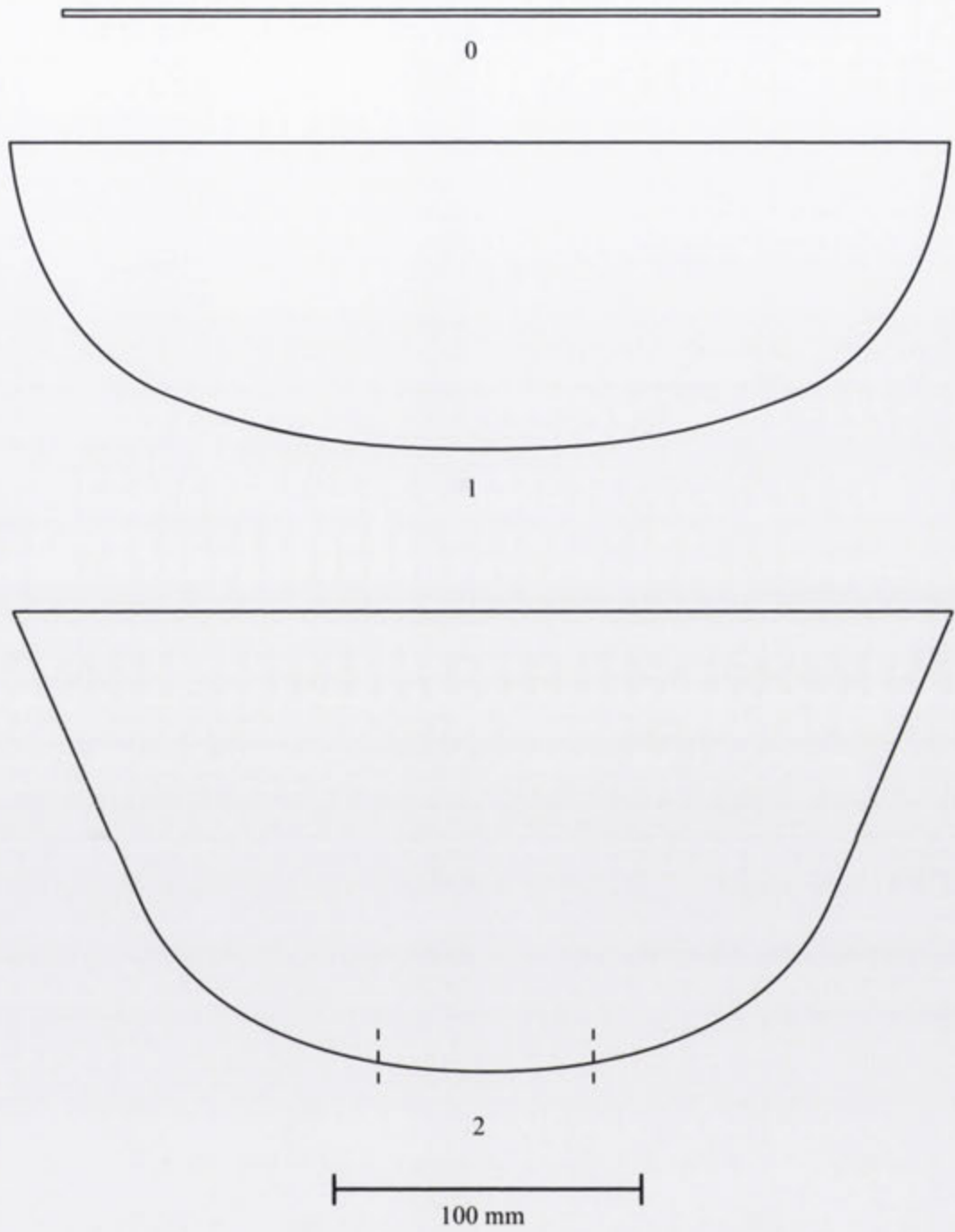


Figure 291. Experiment 3.2: hydria middle section. Stages 1 and 2.

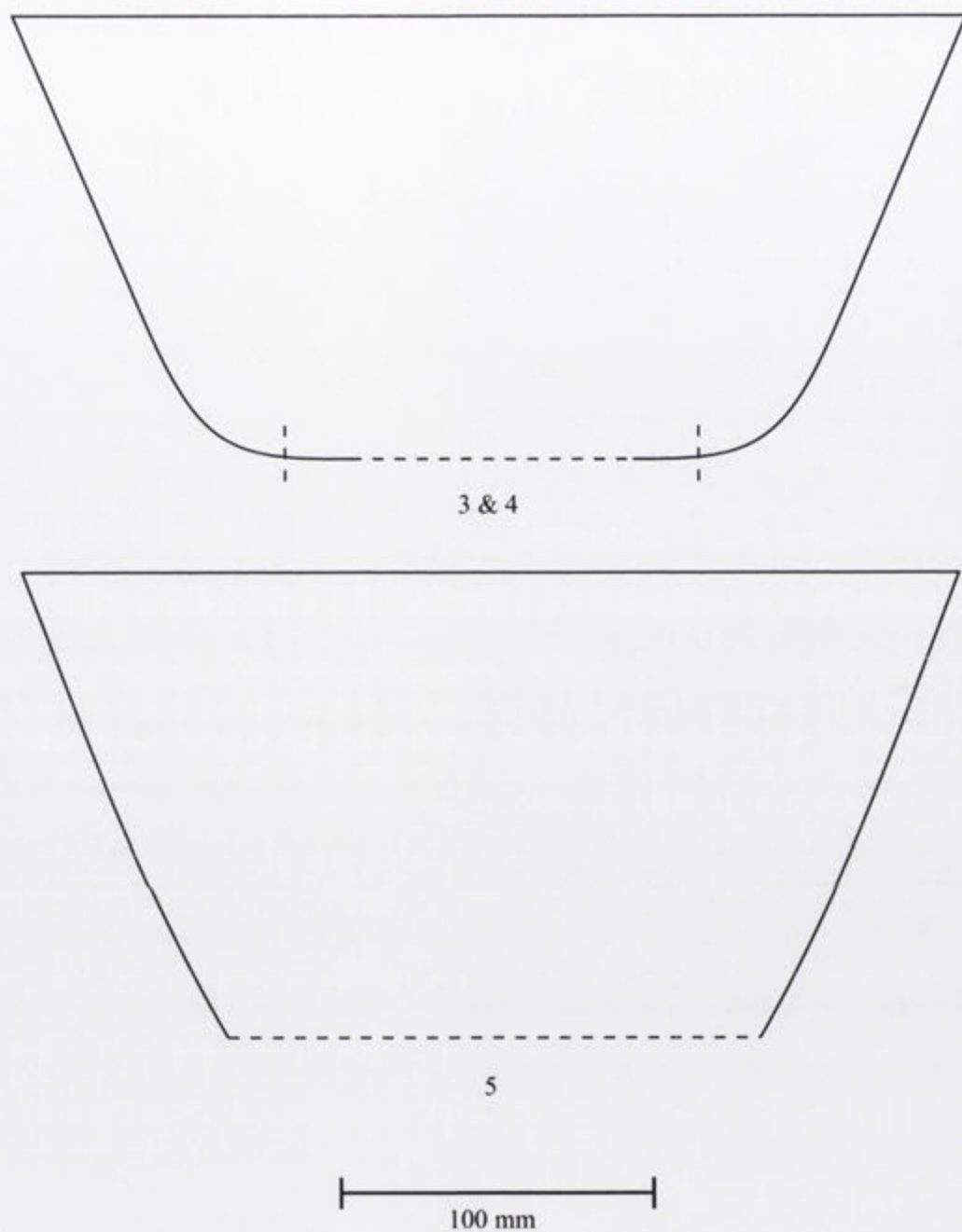


Figure 292. Experiment 3.2: hydria middle section. Stages 3 to 5.



Figure 293. Experiment 3.2: side view. White patches on the lower-left are silver solder which was used to repair tears during the shaping stages.

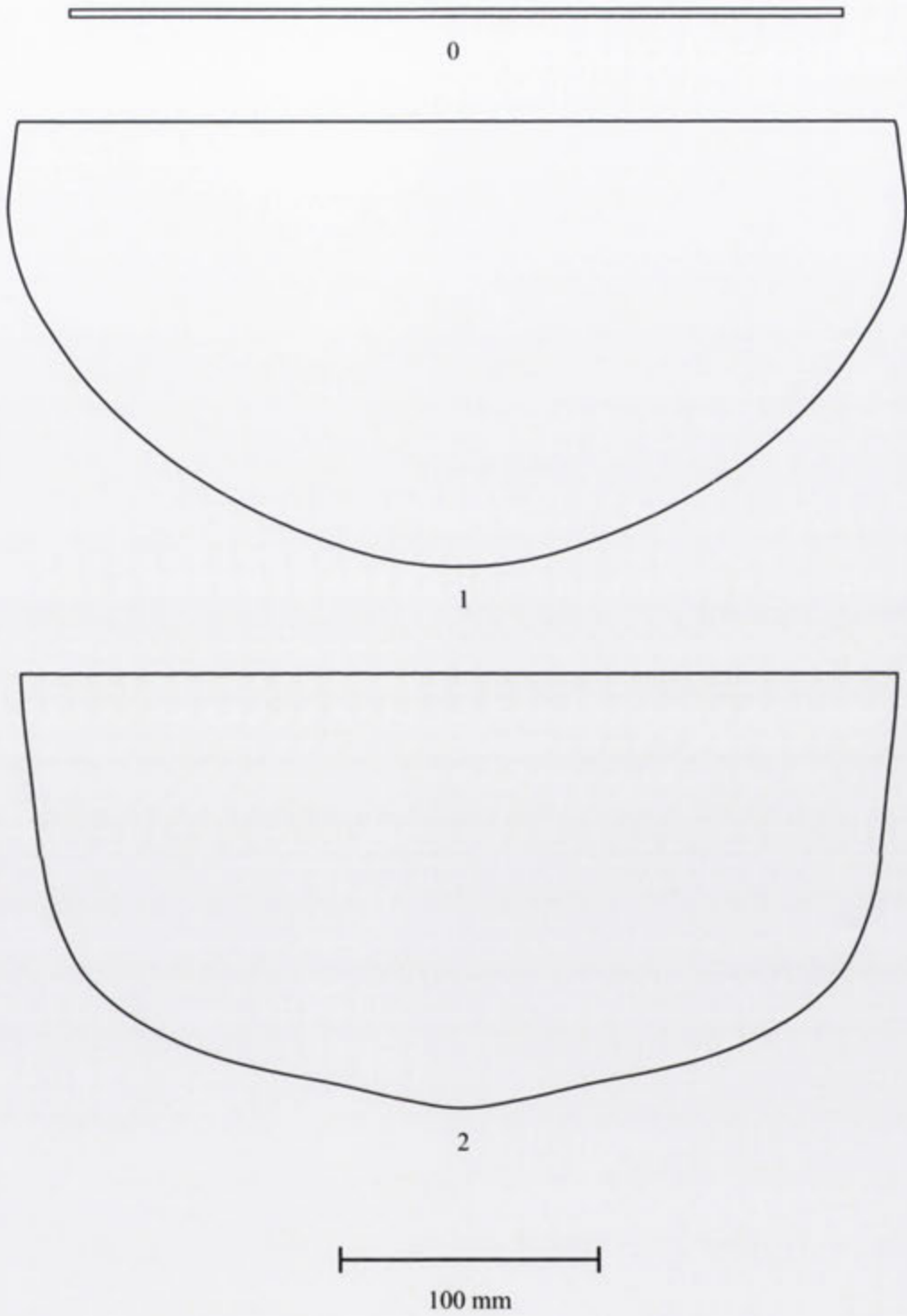


Figure 294. Experiment 3.3: hydria shoulder section. Stages 1 and 2.

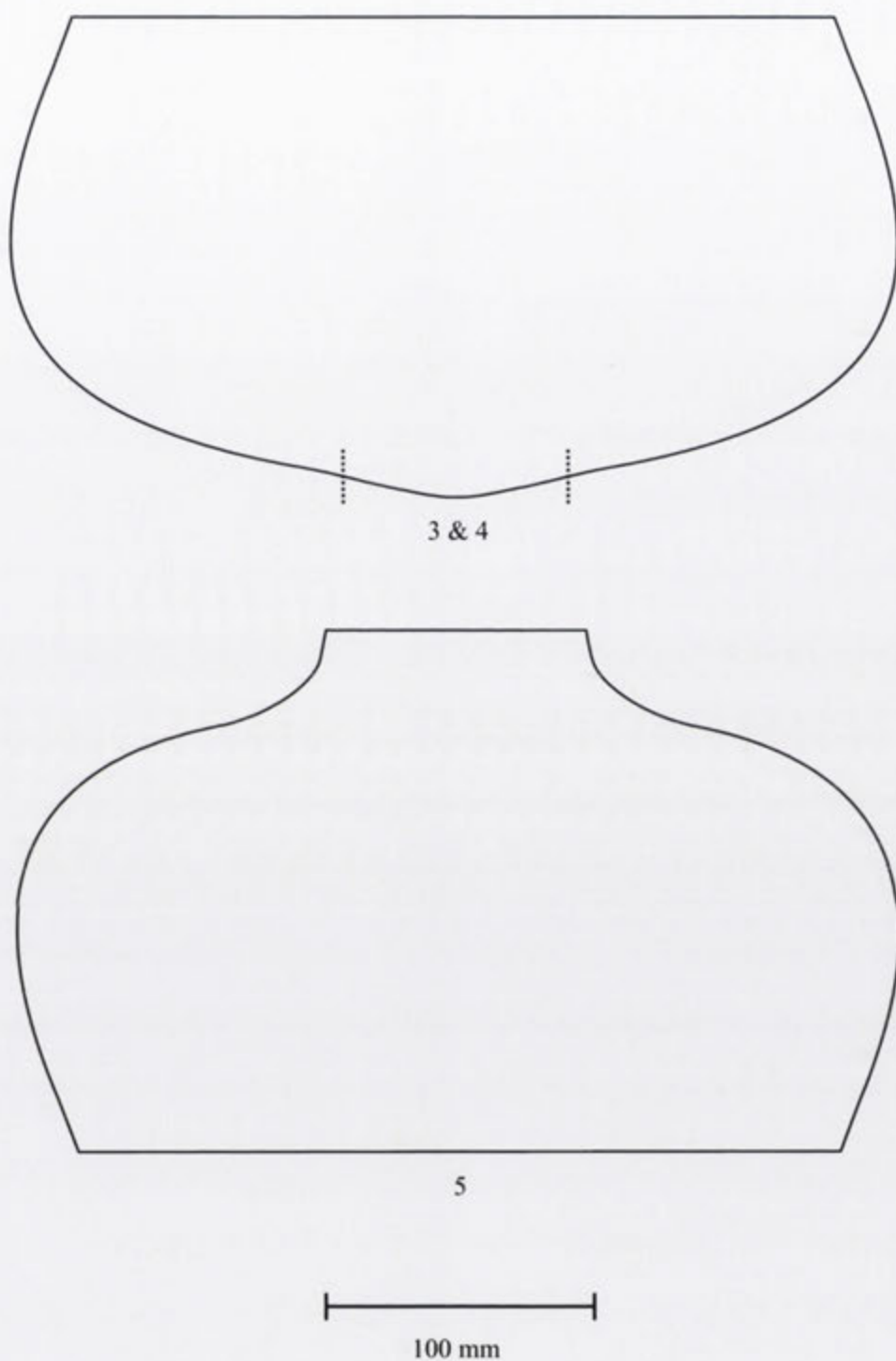


Figure 295. Experiment 3.3: hydria shoulder section. Stages 3 to 5.

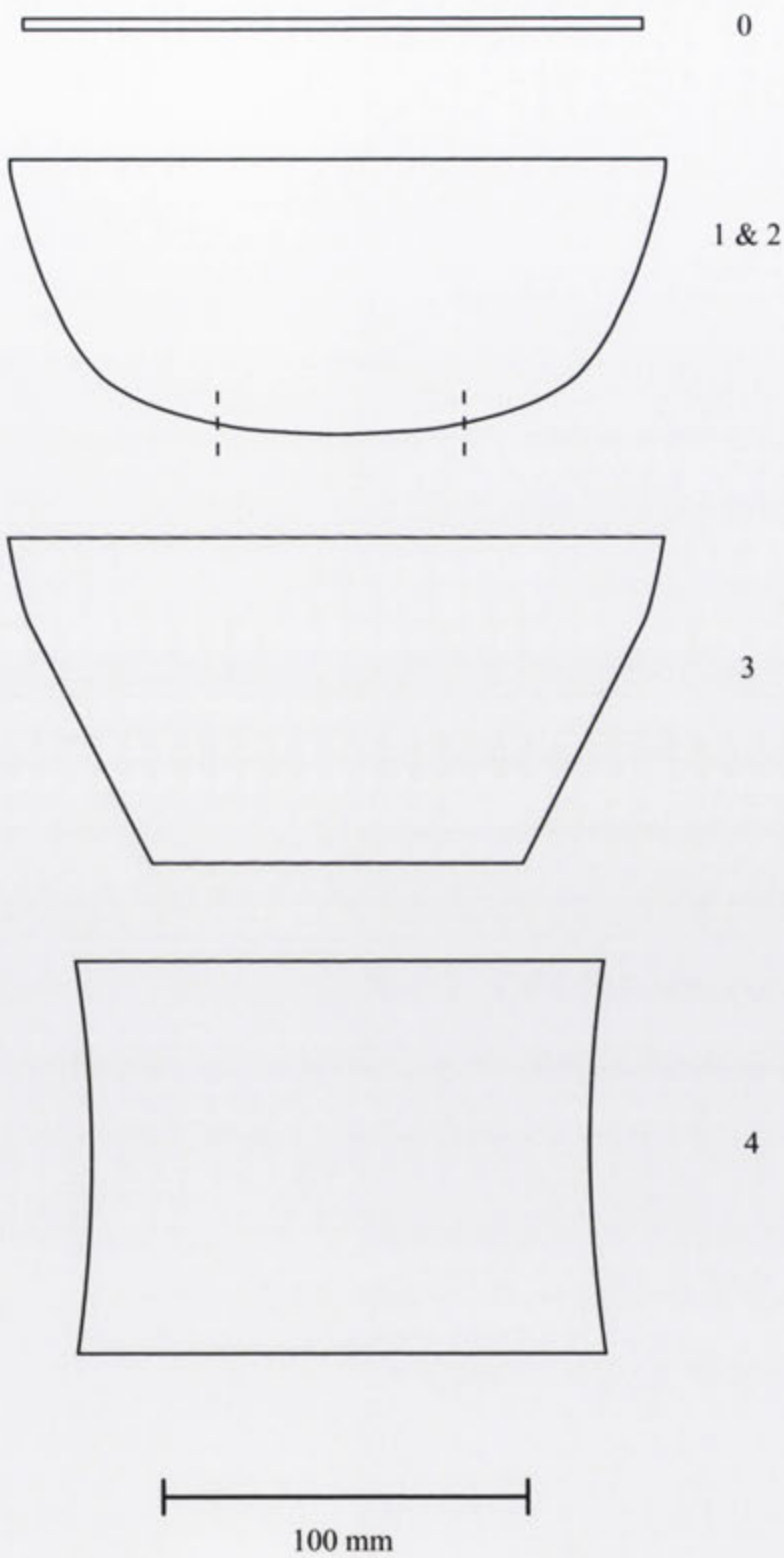


Figure 296. Experiment 3.4: hydria top section. Stages 1 to 4.

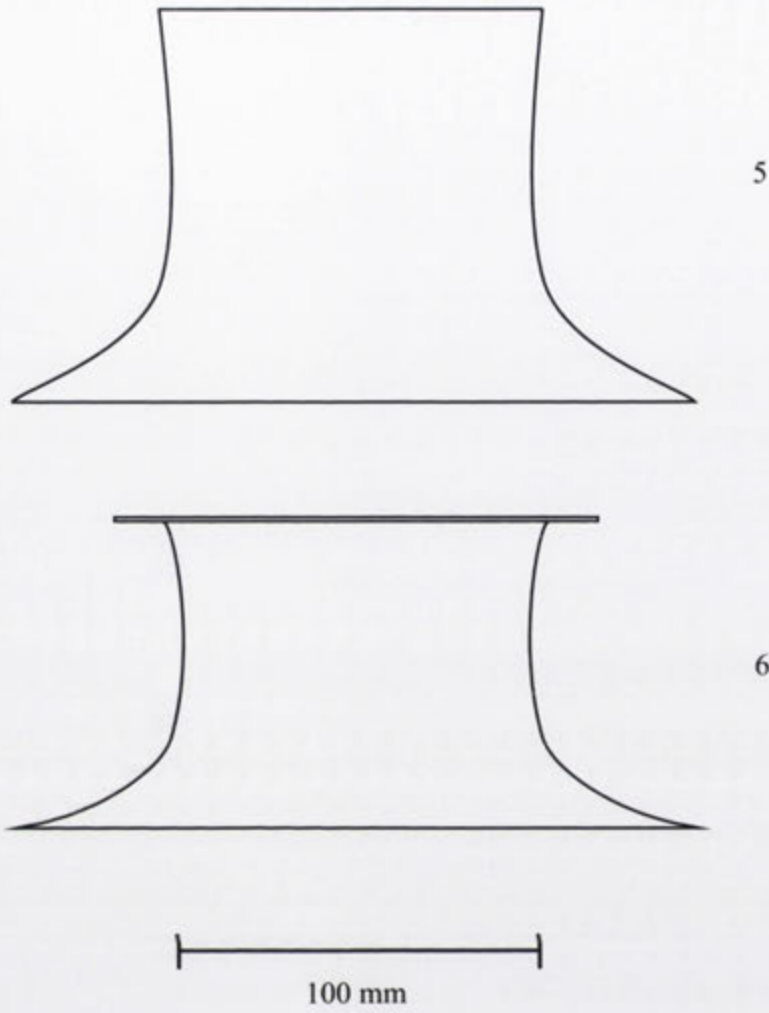


Figure 297. Experiment 3.4: hydria top section. Stages 5 and 6.



Figure 298. Experiment 3.4: side view.



Figure 299. The four sections of the hydria (experiment 3) hammered, fitted together and ready to be joined.



Figure 300. The handles shaped and with holes punched, ready to be attached to the body of the hydria. Front view (*left*) and profile view (*right*).



Figure 301. The lower half of the hydria (experiment 3). The base and middle section are riveted together, the repair patch is in place and the lower handle is in place.



Figure 302. The upper half of the hydria (experiment 3). The top section and shoulder section are joined together and the upper handle is in place.

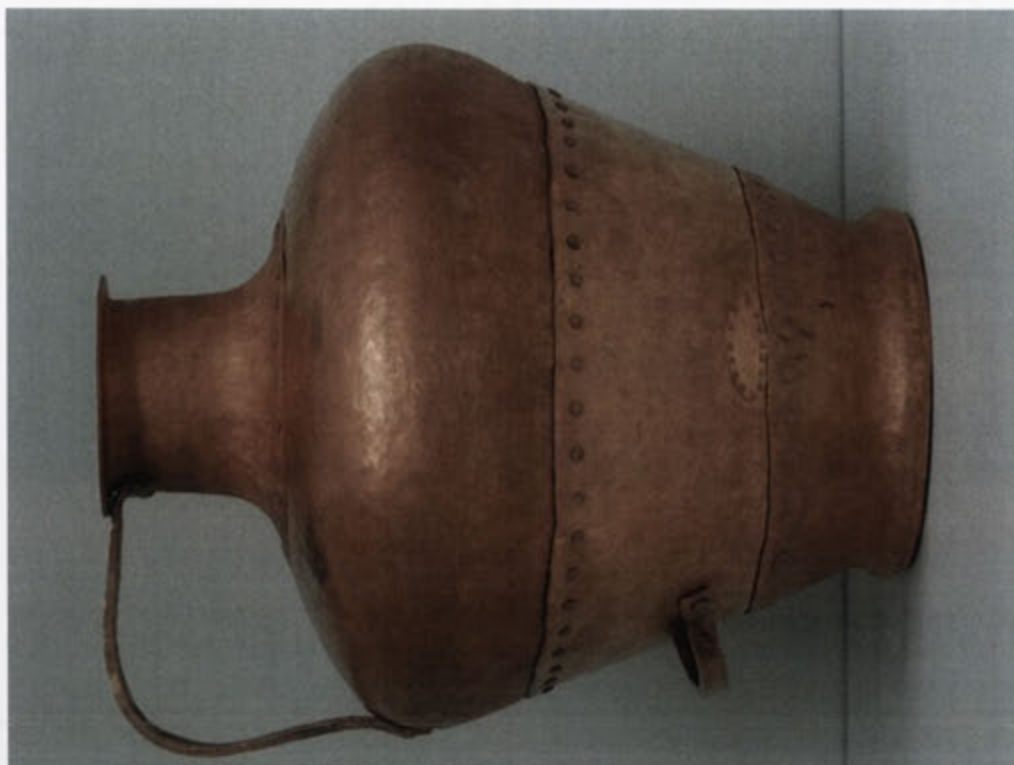


Figure 303. The hydria (experiment 3) pieced together and ready to finish.



Figure 304. The hydria polished.

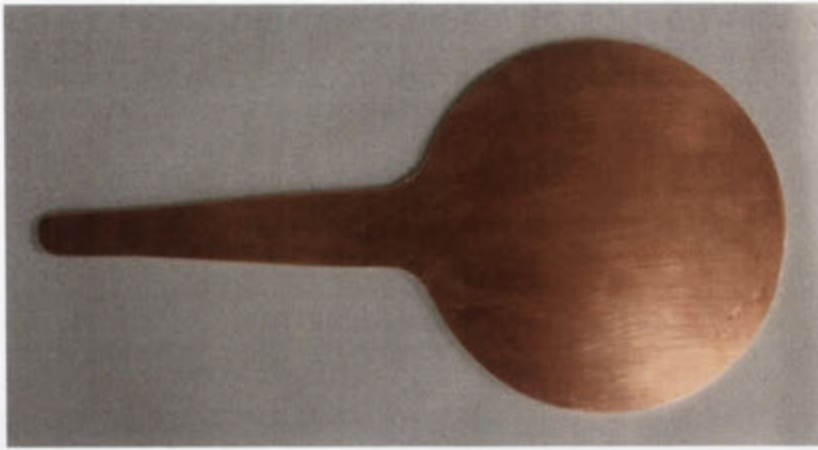


Figure 305. The billet for the copper one-handed basin (experiment 4).



Figure 306. Copper one-handed basin after three rounds: top view.



Figure 307. Copper one-handed basin after three rounds.

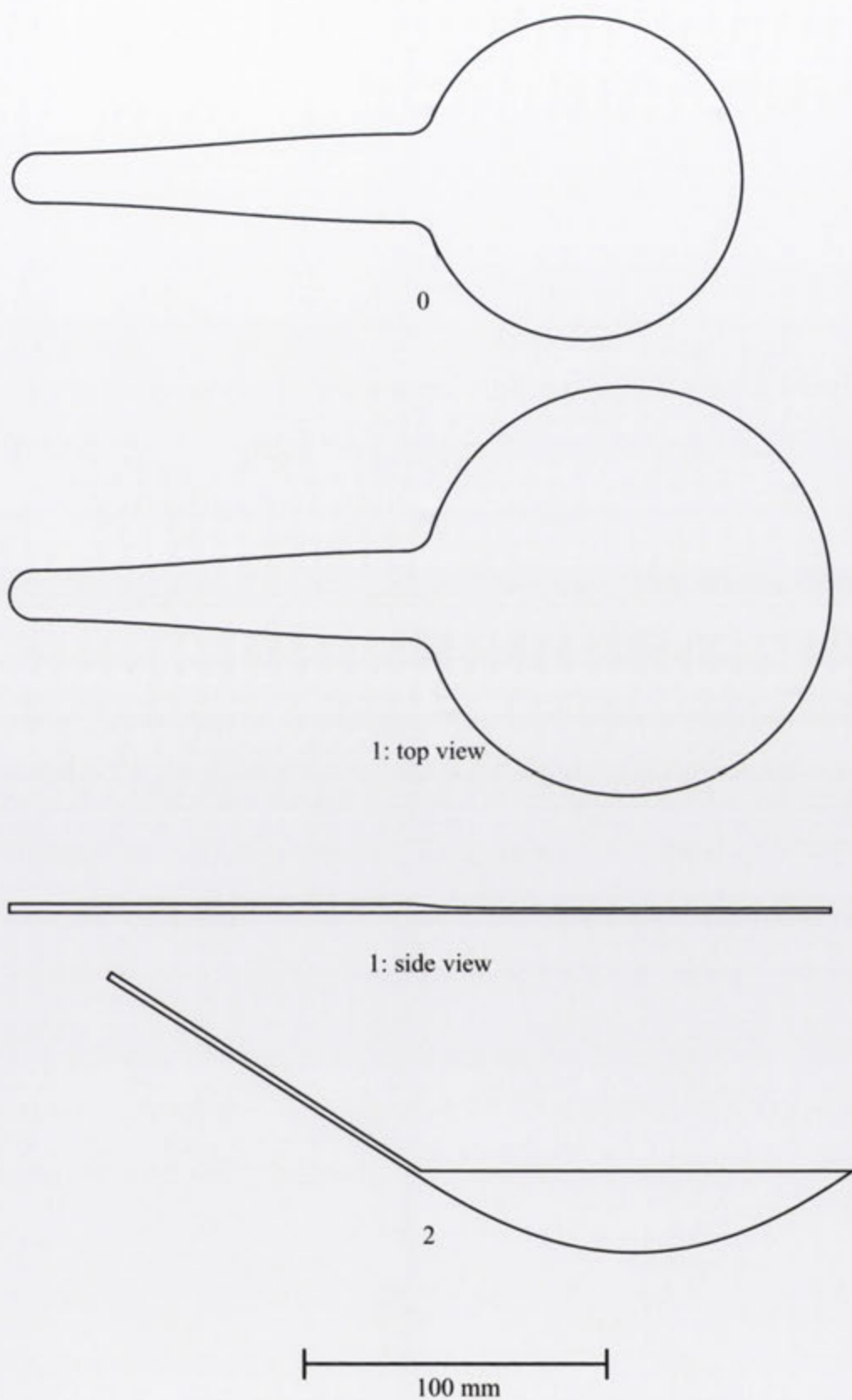


Figure 308. Stages 1 and 2 of experiment 5: sterling silver one-handed basin.

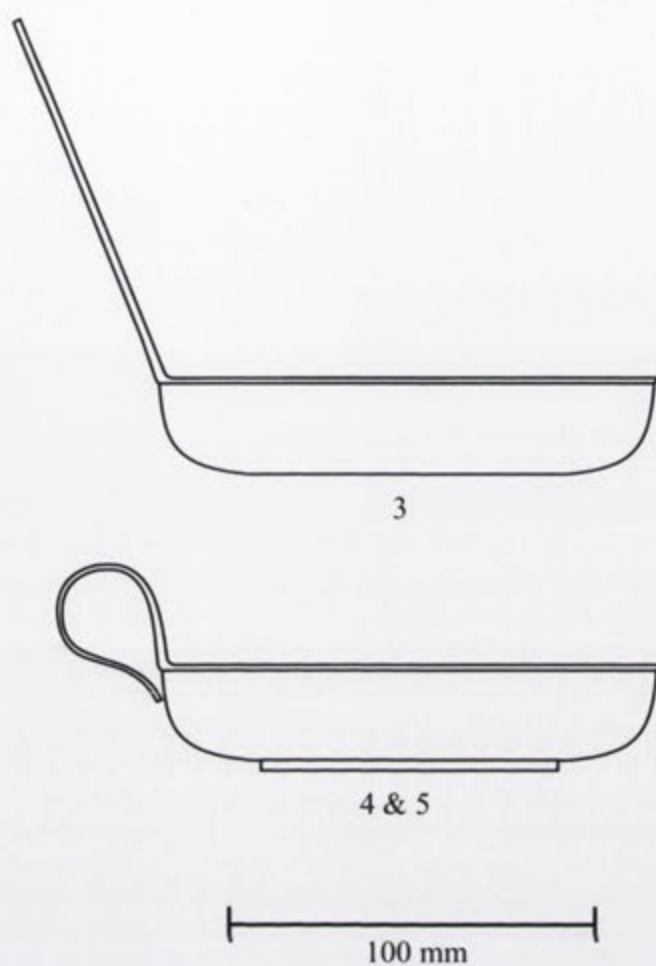


Figure 309. Stages 3 to 5 of experiment 5: sterling silver one-handed basin.



Figure 310. Finished sterling silver one-handed basin.