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USING A TRADITIONAL METAL WORKSHOP IN MODERN CAIRO AS A "READY-MADE" LAB FOR STUDYING ASPECTS OF EARLY ISLAMIC METALLURGY

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Introduction

Finding out what things are made of, and how they are made, tells a great deal about the society that produced and utilized the objects found in archaeological excavations. The use of metal is one of the major technological achievements of ancient human societies, yet we still know very little about how and why people produced the metal objects they left behind. Metals can be identified using the well-known analytical techniques of materials science, and, indeed, the chemical analysis of ancient metal artifacts has become common practice. However, the archaeological reconstruction of the past, a major priority in this study of ancient materials, requires further information. One of the most intractable problems is that of identifying and distinguishing between various ancient metal production techniques and correlating these to specific products and materials.

A major tool for understanding the socio-economic reasons for the practice in certain places and at certain times of ancient crafts in general, and of metal production techniques in particular, is field and lab experiments, which also yield hypotheses as to the reasons for changes observed over time in these techniques. In modern archaeometallurgical research, experimental archaeology is applied to aspects of the human knowledge, labor, space, and time needed for the production and utilization of metal objects.[1] We would like to suggest the use of surviving traditional workshops as ready-made laboratories for such studies.

We present here the results of a metallurgical and sociological study of Islamic archaeological material from Caesarea. Some of the items found at Caesarea – small, coreless brass objects – seem to have been produced by means of sand-casting, one of the less-recorded metalworking techniques evidenced in archaeological findings. Seeking to understand how this technique may have worked in ancient times, we set out to observe its modern practice at a sand-casting foundry in the old center of Cairo. Studies of such traditional industries add the unattested human element to the silent archaeological and metallurgical data, playing an essential role in the reconstruction of the past.

The Archaeological Evidence

In August 1995 a magnificent hoard of more than 200 objects, mainly of metal but also including some pottery and glass, was uncovered in a hidden cavity under the "Temple Platform" in the excavations conducted by A. Raban of Haifa University at Caesarea in Israel. The spectacular metal finds include lamp stands, buckets, ladles, jugs, basins, bowls, trays, braziers, handles, feet, boxes and ewers (Figure 1). Some of the items are inscribed with benedictory texts for their owners, and some are decorated with arabesques and animal motifs. [2]

The hoard was found in a cavity 1.5 x 1 x 1.5 m in size, prepared deliberately in the side wall of a deep well dug during the Fatimid period into fills of the Abbasid period.[3] Its dating to the Fatimid period (end of tenth–beginning of eleventh century C.E.), mainly on the basis of the pottery findings and epigraphical analysis of several inscriptions carved on the metal objects,[4] is reinforced by the stratigraphic location of the cache.[5] The typology of the 118 metal objects[6] shows great diversity, attesting that the assemblage probably belonged to a merchant rather than to a metal workshop collection or a single household.[7]

A similar, much larger hoard from the same period was recently discovered by Y. Hirschfeld of the Hebrew University in his excavations at Tiberias.[8] Among the findings were unique metal frames of what could be identified as small sand-casting molding boxes, known as flasks.[9] Hoards of Muslim-period metalwork, particularly from the Fatimid era, are rare, and decidedly so in a stratigraphic archaeological context.[10] The uniqueness of the hoards from Caesarea and Tiberias provides us with an opportunity to study the metallurgy of the period in greater detail, providing raw material for socio-economic studies of Palestine under Fatimid rule.

Chemical Analysis

How and from what were these objects made? There were three major Islamic techniques for producing metal objects. Forging, used for plates and other relatively thin-bodied objects, involved a process of annealing and hammering. Lost-wax casting was used for solid, relatively large, thick objects, which were cast in a single closed disposable clay mold, sometimes over a clay core. Sand-casting used a double mold made of moistened sand pressed inside special frames to cast relatively small, solid metal objects. In order to study the production methods of the metals from the Caesarea Fatimid hoard, we analyzed a representative sample of slightly more than 20% of the finds (see Appendix 1).[11] Combined micro-structural and compositional analyses yielded a

Figure 1: Selected objects from the hoard (I. Ziffer, *Islamic Metalwork*, Tel Aviv 1996, Figure 92).

coherent picture of the connection between the mode of production and the chemical composition of these artifacts, indicating a deliberate choice of metals whose properties suited specific modes of production and utilization.

Of the 25 sample objects and parts of objects, 9 had been subjected to extensive thermo-mechanical treatment after casting, while the remaining 16 were left as cast, without any further treatment.[12] In all the as-cast brasses (6–12.5% zinc and up to 5.5% tin) and the two bronzes (5% tin and 1–2% zinc), the original dendritic and cast grain structures are visible (Figures 2–3), including coring. Lead was present in all the as-cast objects, in a quantity of 1.5Wt% or more of the overall metal composition. The addition of 20% lead to bronze or brass lowers the melting point, while the addition of 2% considerably lessens the viscosity of bronze; above this amount, the additive has hardly any effect on the fluidity of the metal.[13] It is thus apparent that lead was deliberately added to the brass and bronze in order to improve its fluidity, making it easier to cast relatively thick, complex objects and improving the imprint of decorative carved motifs on the surface of the cast.

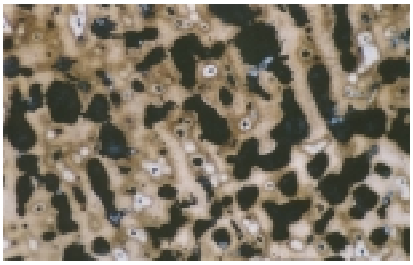

Figure 2: As-cast microstructure of a heart-shaped weight C97-24 x 250.

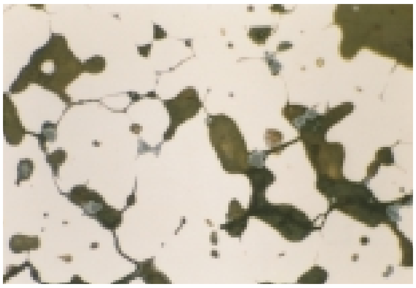

Figure 3: As-cast microstructure of a brazier-foot C97-23 x 625.

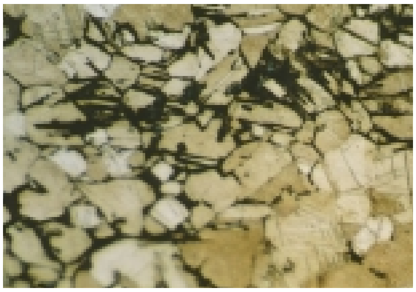

Figure 4: Hammered and annealed microstructure of a jug-handle C97-14 x 250.

All the mechanically treated objects (Figures 4–5) were made of a typical sheet metal relatively high in zinc (20–29%), low in tin (1.5–0.15%), and very low in lead (0.5–0.1%), suitable for hammering. It seems that the Islamic smith was aware that the presence of an appreciable amount of segregated lead can cause lines of weakness when the metal is hammered. After casting, these objects were homogenized (heated in order to dissolve the different phases inside the grains; H in the table in Appendix 1). Several samples still present coring (H/C), showing that the temperature and/or time were insufficient for the material to become fully homogenized. In all the forged objects (Figure 4), equiaxed grains with twins are observed, showing that these objects were hammered and annealed (W/A). Some show slip planes (Figure 5) and areas of deformed grains especially close to the surface (S), evidence of final cold working (W/A/W).

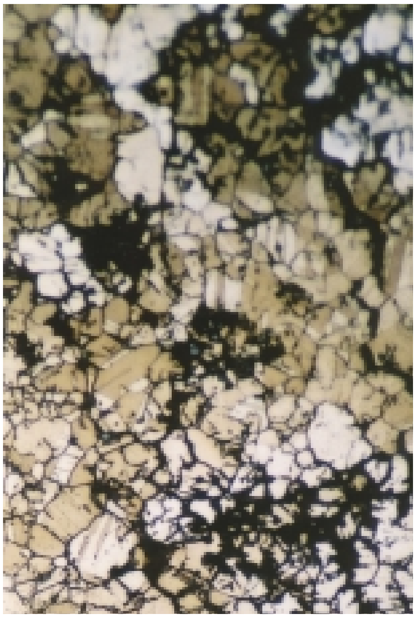

Figure 5: Hammered and annealed microstructure of a tray C97-7 x 625.

The lamp-stand plate (no. 17) shows homogenization and a hammered zone in the center, with a rich tin bronze as-cast dendritic structure (Figure 6). It is evident that the brass plate was tin

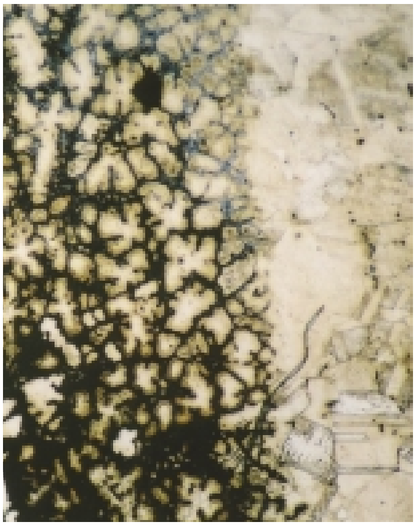

Figure 6: Tin soldering of a lampstand to a plate C97-17 x 250: Left side: dendritic rich tin solder. Right side: heated and hammered center part of the soldered plate.

soldered to a separately cast body by heating the parts together with the solder and then hammering the heated area.[14] A different use of tin, this time for plating, was detected in the presence of a thin layer of tin on the corroded surface of a jug body, near its base (no. 18). This is unique evidence of the tinning of vessels in the eleventh century, probably by means of a process similar to that still used today in the Near East.[15]

Remains of core material were observed in some of the heavy cast candlestick bases and in the thin-bodied lamp-stand and jug handle. The analyses of several preserved core samples are detailed in Appendix 2. The main core material is calcareous clay (Si + Ca) with lime (calcite) and some iron oxide, whose presence shows that the silt used for the core did not originate in the Nile and so that the objects cast over a clay core were not produced in Egypt. The calcareous clay is mixed in all cases with animal dung, providing small concentrations of fine fibers. All the clay cores (nos. 8–10, 16) use the same basic material, with slight variations in the amount and size of fibers mixed with the clay (up to 700μm long in no. 10; 300μm in no. 16, and 200μm in no. 9) and the burning level of this organic material. Contamination by gypsum was identified in core no. 8. This could have been caused by the close proximity, maybe even in the same workshop, of plaster core production to the clay cores for the lost-wax castings. The two white cores (nos. 14 and 15) were found to be made of unburned gypsum ($CaSO_4 2H_2O$), also known as plaster of Paris. The core materials clearly were chosen by their suitability to the exact metallurgical purpose. Calcareous clay cores were made to resist a thermal shock of c. 1000^{0}C from hot metal during the casting process. The plaster of Paris, totally unsuitable for thermal shock, was used for creating accurate solid shapes to be covered by thin sheet metal plating.

A comparison of the results of the surface analysis of the selected metals from Caesarea[16] with the metallographic and compositional results reveals additional factors related to the production methods:

(1) The more complex-shaped objects, such as lamp-stand bases and bodies (nos. 8–10, 16, and 19), were first modeled in wax and than cast using a lost-wax technique.[17] The imprints of the original clay slurry investment are still visible on the inner and hidden parts that were left unpolished. The three legs at the base of the lamp-stands were probably used as runners and risers (deliberate openings in the mold, used for pouring in the molten metal and releasing the gases produced during the cast), as attested by the depressions caused by contraction during solidification.

(2) The thin plate metals (nos. 1, 7, 13, and 18) were all made of unleaded brass and forged into their final shape by cycles of hammering and annealing.[18] Several long, round metal bodies (nos. 14 and 15) were made of a similar sheet metal of unleaded brass, rolled over a white plaster-like core.

(3) The small, simple, repetitiously shaped objects, such as weights, handles, separated legs, and lamp-stand plates (nos. 2–4, 5, 6, 12, and 22–25), were all cast. Their simple, recurring shapes, as well as the total absence of clay cores or clay-slurry negative marks, indicate that they could have been produced by sand-casting,[19] a technique that was known and used in this period, as attested by the frame found in Tiberias.[20]

Modern Sociological Documentation

The three major Islamic techniques for producing metal objects – forging, lost-wax casting, and sand-casting – have parallels in traditional crafts preserved to this day. Studying these traditional industries could add valuable data to our combined archaeological and metallurgical knowledge by focusing on the human aspects as an essential element in the reconstruction of the past.[22] Here, we present a short summary of our documentation of the sand-casting method as still practiced in a traditional foundry in modern Cairo, located with the help of the Israeli Academic Center in Cairo. We documented the foundry's work over two visits in November 1999 and March 2000, and we subsequently analyzed sand and metal samples from the casting process, using the same routine as that used for the archaeological material (see Appendix 3).[23]

Location

The foundry is situated in the area of the "old fish market" (Suk el Samak) behind Han el Halili (Figure 7), in the old center of modern Cairo – the area that, around 1,000 years ago, was the political and

Figure 7: The location of the sand-casting foundry.

economic center of the Fatimid dynasty. From the outside, it looks exactly like all the other living and working units in the neighborhood. However, it is the only sand-casting foundry in the region, and customers come there from as far away as Alexandria, Upper Egypt, and even other Arab countries. It has been operating in the same way for at least three generations, producing sand-cast brasses of varying function, shape, and size by duplicating objects brought in by the customer.

Distribution of labor

The foundry is owned and run by four brothers. The eldest is the manager, responsible for incoming orders and payments, while the other three perform all the production tasks, from making the molds to casting and finishing the metals. Each brother has specific responsibilities during the production process. The workshop has an apprentice, the ten-year-old son of the second brother.

Operating space

The entrance to the foundry is from the side, facing a small, separate unit used as an office. To the left of the entrance is a rectangular workspace (c. 12 x 3 m), which is divided into two major functional sections (Figure 8), the first devoted to molding and the second to casting. A workbench with three sand-molding stations (1.5 x 1 m each) occupies the left side of the first section. A flat stone in the middle of each sand station (Figure 9) is used as a bottom-board for the drag (bottom) and the cope (top) parts of the mold. Patterns for casts are shelved or hung on the wall above the workbench. Along the opposite wall, facing the workbench, prepared molds are arranged in piles on the floor.

Figure 8: The inside of the foundry.

Figure 9: The sand-molding workbench.

A weighing station for finished products, located at the right end of the sand-molding bench, marks the border between the two work zones. On the left side of the casting area is a niche where sieved wet sand is piled, held in place by a partition 0.4 m high. The right side of the niche is where the molds are opened after casting (Figure 10). A sieve, for sifting used sand before it is returned to the pile, hangs from the wall in the

Figure 10: Opening the molds and separating the cast objects.

Figure 11: Melting the brass.

center of the niche. Opposite the niche, next to the wall, is the gas-operated melting furnace (Figure 11), located beneath the floor near the rear right-hand corner of the foundry, with a conical chimney opening in the roof above it. Casting tools and materials are stored near the rear wall of the foundry. A small pit (c. 0.5 m in diameter) in the earth-packed floor opposite the furnace is used for setting aside hot tools and the slag skimmed from the crucible and the ladle during casting. Molds for casting (Figure 10 and 12) are placed on a wooden beam lying at a slight tilt on the floor, parallel to the partition of the sand niche.

Figure 12: Casting the molds.

Production process

The work is carried out on demand; if possible, a customer order is put into production almost immediately, and the cast objects are sometimes ready in less than half a working day. The customer pays by weight. On a normal work day, some 50–60 molds may be prepared and cast in 2 to 3 sessions, in which up to 200 kg of metal are melted. The end products comprise about half or less of the total amount of cast metal. The remainder fills the pouring cup, sprue (the channel through which the molten metal is fed into the mold), runners, and feeders (the channels connecting the objects). It is cut off (Figure 10) and recycled in the next melt.

The molding material is a mixture of equal portions of local yellow sand, taken from the workers' dwelling area, and crushed fired bricks (Figure 13), collected from ruined structures in the immediate vicinity of the foundry. Lab analysis (Appendix 3) showed the material to be composed of potassium feldspar grains of 2–3mm covered in clay mixed with iron oxide, aluminum and magnesium, creating unified grains of 30–40mm. The brick material is added to the sand as a binder. This baked Nile silt (with amphibole and plagioclase feldspars), mixed with some calcium and quartz grains of sand, is manually crushed in the foundry to a powder of 50mm grain size. Experience has shown the craftsmen that this mixture makes very good molding sand. In the course of a whole working day, only one mold collapsed and had to be remade, while the cast surfaces came out smooth, maintaining all the fine detail of the models.

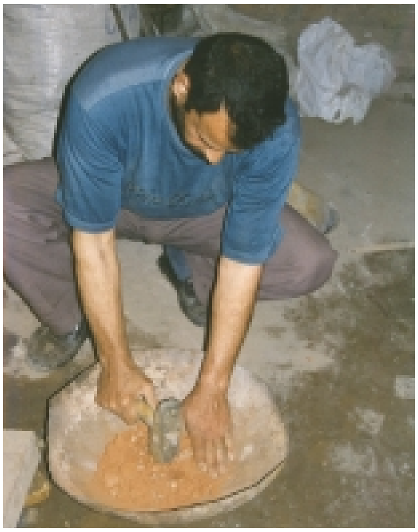

Figure 13: Crushing bricks.

Two workers make the sand molds. First, they fill the drag with a wet sand mixture, using the flat stone in the middle of the sand station to press and smooth both sides (Figures 9 and 14). The objects to be cast are placed in the drag, embedded in the sand, and joined together with rods. The exposed surface is dusted with parting powder (Figure 15) made of crushed bricks, and then the cope is added on top and filled with sand. The two-box mold is now turned over, the two parts are separated to allow removal of the models, and the negative impressions are cleaned by air blowing. A pouring cup and a sprue are pre-

Figure 14: Filling the mold with sand.

Figure 15: Dusting the sand mold.

pared by finger carving in the upper part of the drag, and the finished, closed, two-box mold is stacked along with other prepared molds on the tilted wooden beam, now insulated by a thin layer of wet sand, in two step-like rows of five molds each, awaiting casting.

The casters use brass scrap metal. The main source material, chipped and drilled brass powder, is cleaned of excess iron using a magnet (Figure 16). According to WDS analysis of the end-material (Appendix 3), the metal composition of the cast is relatively similar but obviously not identical to that of the Fatimid metal. The Cairo sand-cast brass is made of copper, with 24% zinc, 1.5% tin, and over 1% lead. Iron content is higher than in antiquity but does not exceed 2%.

Figure 16: Cleaning the brass scrap.

All the workers are engaged in the casting process. One shifts the molds to and from the casting bench; another pours the molten metal (Figure 12); and two others open the molds (Figure 10) and separate and clean the cast objects. The cleaned brass powder is melted, along with brass pieces left from previous castings, in a 50-liter crucible inside the furnace. A color change in the smoke, from light to darker blue, indicates that the melting process is complete, upon which the furnace lid is opened, crushed glass flux is added, and floating slag is skimmed off. Using a ladle, the molten metal is poured into the waiting molds (Figure 12), about five at a time. The end of each pouring is marked when the cup at the top of the sprue is full. There are no risers, and the metal flow in the mold is controlled mainly by gravity, filling the objects through the runners. The higher sprue serves as a reservoir of molten metal, controlling its progressive solidification and preventing contraction of the cast.

The molds are transferred to the niche, to be opened immediately after casting (Figure 10), once the metal on top of the pouring cup has changed from a shining liquid to a darker, oxidized solid. Scrap metal and used sand are immediately recycled for further molding and casting. The end products are washed, weighed, and presented to the customer.

Discussion and Conclusion

Metal artifacts emerge from field excavations relatively mute and, in all but a few cases, without any written "manual" describing the details of their production, utilization, and deposition. Reconstructing the history of ancient metal artifacts therefore demands supplementation of the archaeological evidence with analytical data that may assist in revealing the technical parameters of the find's "life cycle." In our case, analysis of the metals from the Fatimid hoard discovered at Caesarea revealed how and from what these objects were made. Three different production modes were identified: (1) Sheet metal objects made of unleaded brass were forged into shape through cycles of hammering and annealing and sometimes were rolled over a gypsum core. (2) Heavy-bodied objects with complex shapes were cast by the "lost-wax" method from higher zinc brasses containing significantly more lead. The molding and coring material for these objects was simple clay mixed with animal dung. (3) The small, simple, repetitiously shaped objects that bear no clay core or clay-slurry negative marks were probably made using a sand-casting technique.

If information about the human aspects of production is not added, however, this archaeometallurgical data remains of limited value to the ongoing study of ancient human cultures. In our case, all three major ancient Islamic techniques for producing metal objects have parallels in traditional crafts still practiced today. The study of these traditional industries, such as the Cairo sand-casting foundry, provides additional technical data, while at the same time shedding light on the people and the culture behind the metal object.

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2. See Y. Arnon, "The Caesarea Hoard: Why Was It Hidden?" in I. Ziffer, *Islamic Metalwork*, Tel Aviv 1996, pp. 53*–56*; and M. Sharon, "The Caesarea Bronze Hoard: The Epigraphic Find," *ibid.*, pp. 56*–57*.
3. See Z. Bar-Or, "A Hoard of Bronze Vessels from Caesarea," in Ziffer, *Islamic Metalwork* (above, note 2), pp. 51*–52*; and A. Lester, Y. Arnon, and R. Polak, "The Fatimid Hoard from Caesarea: A Preliminary Report," in M. Barrucand (ed.), *L'Egypte Fatimide: Son art et son histoire,* Paris 1999, pp. 233–234.
4. Arnon, "The Caesarea Hoard"; and Sharon, "The Caesarea Bronze Hoard" (above, note 2).
5. See Sharon, "The Caesarea Bronze Hoard" (above, note 2).
6. Described in detail in Lester et al., "The Fatimid Hoard" (above, note 3), pp. 236–242.
7. *Ibid.*, p. 241.
8. See Y. Hirschfeld and O. Gutfeld, "Discovery of Fatimid Vessel Hoard at Tiberias," *Qadmoniot*, 32 (1999), pp. 102–107 (Hebrew); and E. Khamis and R. Amir, "The Fatimid Period Bronze Vessel Hoard," *ibid.*, pp. 108–114 (Hebrew).
9. See S. Hurst, *Metal Casting: Appropriate Technology in the Small Foundry*, London 1996.
10. See J.W. Allan, *Metalwork of the Islamic World: The Aron Collection*, London 1986; and R. Ward, *Islamic Metalwork*, London 1993.
11. The detailed proceedings and results of the qualitative and quantitative chemical analyses and the metallographic studies will be published in full in S. Shalev, "The Metallurgy of the Fatimid Hoard from Caesarea," in A. Raban (ed.), *Caesarea,* 3: *Annual of the American School of Oriental Research*, Chicago (forthcoming).
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14. See O. Untracht, *Metal Techniques for Craftsmen*, London 1969, pp. 178–180.
15. See H.E. Wulff, *The Traditional Crafts of Persia*, Cambridge, Mass., 1966, pp. 31–32.
16. As detailed in S. Shalev, "A Hoard of Fatimid Metal Objects from Caesarea," *Archaeology and the Natural Sciences*, 6 (1998), pp. 31–36 (Hebrew).
17. For the technical aspects of the method see Hurst, *Metal Casting* (above, note 9), pp. 60–83 and 157–170.
18. For a detailed technical discussion of vessel production methods see Trotzig, *Craftsmanship and Function* (above, note 1).
19. See Hurst, *Metal Casting* (above, note 9), pp. 43–49.
20. See Khamis and Amir, "The Fatimid Period Bronze Vessel Hoard" (above, note 8), p. 108.
21. E.g., Wulff, *Traditional Crafts of Persia* (above, note 15), pp. 18–31; Hurst, *Metal Casting* (above, note 9), pp. 157–172.
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23. For a detailed explanation of the method and a glossary of the technical terms see Hurst, *Metal Casting* (above, note 9), pp. 38–59 and 199–226.

Appendix 1: List of metal samples from Caesarea (C97), their metallography and chemical composition

No.	***Object type (sample)***	***Field No.***	***Microstructure***	***Chemical Composition***
C97-1	Bucket	96-401	H + W/A/SW	Cu + 9%Zn + 1.5%Sn (+ 0.2Pb)
C97-2	Heart-shaped weight	96-384	As-Cast	Cu + 6%Zn + 5.5%Sn + 2%Pb
C97-3	Tray-feet	96-398	As-Cast	Cu + 6%Zn + 1.5%Sn + 29%Pb
C97-4	Handle	96-364	As-Cast	Cu + 1%Zn + 5%Sn + 18%Pb
C97-5	Lampstand-plate	95-3501/3	As-Cast	Cu + 6.5%Zn + 5.5%Sn + 4.5%Pb
C97-6	Brazier-feet	95-3507	As-Cast	Cu + 9%Zn + 3.5%Sn + 3%Pb
C97-7	Tray	96-418	H + W/A/W	Cu + 14%Zn (+ 0.05%Sn) + 0.5%Pb
C97-8	Lampstand-base (neck)	95-3502/1	As-Cast	Cu + 10%Zn + 1.5%Sn + 8%Pb
C97-9	Lampstand-base (feet)	95-3502/1	As-Cast	Cu + 10%Zn + 1.5%Sn + 3%Pb
C97-10	Lampstand-body	95-3497/2	As-Cast	Cu + 6%Zn (+ 0.5%Sn) + 19%Pb
C97-11	Bucket-handle (ring)	96-413	H/C + W/A/W	Cu + 16.5%Zn (+ 0.5%Sn +0.5%Pb)
C97-12	Bucket (handle)	96-413	As-Cast	Cu + 10%Zn (+ 0.5%Sn) + 12%Pb
C97-13	Ladle (handle)	96-403	H/C + W/A/W	Cu + 11%Zn + 1%Sn (+ 0.5%Pb)
C97-14	Jug (handle)	95-3521	H + W/A/W	Cu + 9.5%Zn + 1.5%Sn (+ 0.1%Pb)
C97-15	Lampstand-body	96-631	H + W/A/W	Cu + 14%Zn (+ 0.15%Sn + 0.1%Pb)
C97-16	Lampstand-base	96-623	As-Cast	Cu + 12.5%Zn + 3%Sn + 10%Pb
C97-17	Lampstand-plate	96-416	H + W + Solder	Cu + 16%Zn (+ 0.5%Sn + 0.3%Pb)
C97-18	Jug (base)	95-3521	H + W/A/W + T	Cu + 20%Zn (+ 0.5%Sn + 0.3%Pb)
C97-19	Lampstand-base	96-622	As-Cast (+W)	Cu + 7.5%Zn + 4%Sn + 5%Pb
C97-20	Box-lid	95-3496/2	As-Cast (+W)	Cu + 11.5%Zn + 1.5%Sn + 1.5%Pb
C97-21	Box-body	95-3496/2	As-Cast	Cu + 6.5%Zn + 3.5%Sn + 7.5%Pb
C97-22	Handle	96-380	H/C + W/A/SW	Cu (+ 0.7%Zn + 0.4%Sn + 0.4%Pb)
C97-23	Brazier-feet	96-388	As-Cast	Cu + 8%Zn + 1.5%Sn + 2.5%Pb
C97-24	Heart-shaped weight	96-386	As-Cast	Cu + 2%Zn + 5%Sn + 2%Pb
C97-25	Handle	96-381	As-Cast (+SW)	Cu + 8%Zn + 4%Sn + 1.5%Pb

* H = homogenized; C = coring; W = worked; A = annealed; S = surface; T = tinning (tin plating)

Appendix 2: List of core samples of metals from Caesarea (C97) and their composition

No.	***Object type (sample)***	***Field No.***	***Sample type***	***Composition***
C97-8	Lampstand-base (neck)	95-3502/1	Clay core	Calcareous clay
C97-9	Lampstand-base (feet)	95-3502/1	Clay core	Calcareous clay
C97-10	Lampstand-body	95-3497/2	Clay core	Calcareous clay
C97-14	Jug (handle)	95-3521	Plaster core	Gypsum
C97-15	Lampstand-body	96-631	Plaster core	Gypsum
C97-16	Lampstand-base (neck)	96-623	Clay core	Calcareous clay

Appendix 3: Samples from the sand-casting workshop in Cairo (Ca99) and their compositional results

No.	***Object type (sample)***	***Tech. Term***	***Sample type***	***Composition***
Ca99-1	Metal cast scrap	Melt	Metal	Cu + 24%Zn + 1.5%Sn + 1%Pb
Ca99-2	Casting yellow sand	Molding mat.	Sand	Loess clay
Ca99-3	Crushed brick powder	Binder	Bricks	Nile silt + Ca + Si
Ca99-4	Used sand mixture	Black sand	Sand+Bricks	55% Loess clay + 45% Nile silt