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Minoan Metal Vessel Manufacture: Reconstructing Techniques and Technology with Experimental Archaeology

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ABSTRACT

The equipment and processes used to manufacture Minoan metal vessels have not previously been investigated in detail. This study reconstructed the equipment and process by taking an interdisciplinary approach, combining archaeological research with practical metal-smithing. Initially, a comprehensive study of Minoan metallurgical technology was carried out and some of the vessels examined for evidence of their manufacture. Subsequently, Minoan metallurgical equipment such as hammers, an anvil and a hearth were replicated and used to create Minoan vessel forms including bowls, a hydria and a lekane. The results indicate that the simple tools found at many Minoan metallurgical sites are very effective for vessel making and that unhafted stone hammers, a common Minoan tool, are particularly suitable for making Minoan vessel forms. The process of creating these forms revealed that, unlike those of contemporary cultures in the region, Minoan vessels were formed predominantly by sinking, where the vessel is formed by hammering from the inside, and that only a limited amount of raising, working the vessel from the outside, was carried out. This may have been a result of technological limitations.

KEYWORDS

Aegean, experimental reconstruction, metallurgy, Minoan

Introduction

Bronze and precious-metal vessels were produced in Crete during the Bronze Age, largely during the palatial periods. Features of some EM ceramic vessels suggest skeuomorphic relationships with metal prototypes which may have been produced during this period, but for the most part extant material indicates that metal vessels appear in Minoan material from the Protopalatial period. Production appears to have flourished during the Neopalatial and Monopalatial periods and all but disappeared by the end of the LBA. More common vessel forms include hydrias, tripod cauldrons, pitchers, lamps and basins of various forms and, to a lesser extent, large cauldrons, cups and bowls (Fig. 1). The shapes of the vessels and the thinness of their walls attest to their manufacture by hammering rather than by casting of their final forms.

Previous detailed investigations of the vessels include Catling's and Matthäus's typologies of Minoan and Mycenaean bronze vessels (Catling 1964, Matthäus 1980) and Davis's catalogue of Minoan and Mycenaean precious-metal vessels (Davis 1977). Also, several papers have involved compositional analyses (Catling & Jones 1976, 1977, Mangou & Ioannou 1997; Éluère 1996, Soles & Stos-Gale 2004, Evely & Stos 2004). Some authors have discussed the construction and manufacturing methods of the vessels (Davis 1977, Matthäus 1980: 323-337, Evely 1993: 97–102, 2000: 381–387, Laffineur 1995), but there has been no investigation into the specific equipment adopted for Minoan vessel manufacture, or to describe the specific methods used in the process.

The aim of this study was to reconstruct the processes used to create these vessels by combining the examination and assessment of archaeological material, with the practical application of replicated metallurgical equipment to the manufacture of Minoan vessel types. During the initial stages of the project, a complete and up-to-date catalogue of extant Minoan metal vessels was compiled to allow for an assessment of technical trends. Then materials extant from known metallurgical installations were assessed for their potential use in vessel production and a number of Minoan bronze vessels in the Ashmolean Museum, Chania Archaeological Museum and the Ayios Nikolaos Archaeological Museum were examined for evidence of their manufacture. Finally, a set of replicated tools and equipment was created and used to attempt the manufacture of several Minoan vessel forms. This practical experimentation was carried out by the author, a metalsmith trained in hollowware production.

Evidence from the Vessels and Metallurgical Materials

A survey of the vessels indicates that most were made from a single piece of metal, but some larger types were made from multiple pieces riveted together (Fig. 1g & j). Close examinations of several vessels reveal that the billets from which they were hammered, which could be as thin as 2.5mm, were in some cases cast by the lost-wax method, especially for vessels with a handle of the same piece of metal as the body (e.g. Fig. 1e). Simpler billets may have been cast in open or closed stone moulds. The walls of the vessels were frequently hammered as thin as 0.5mm and sometimes less. Because such thin material is rather flimsy, the rims were thickened for structural reinforcement. Handles, legs and some rims were cast or forged separately and subsequently riveted to the body of the vessel. The holes through which the rivets pass were apparently punched

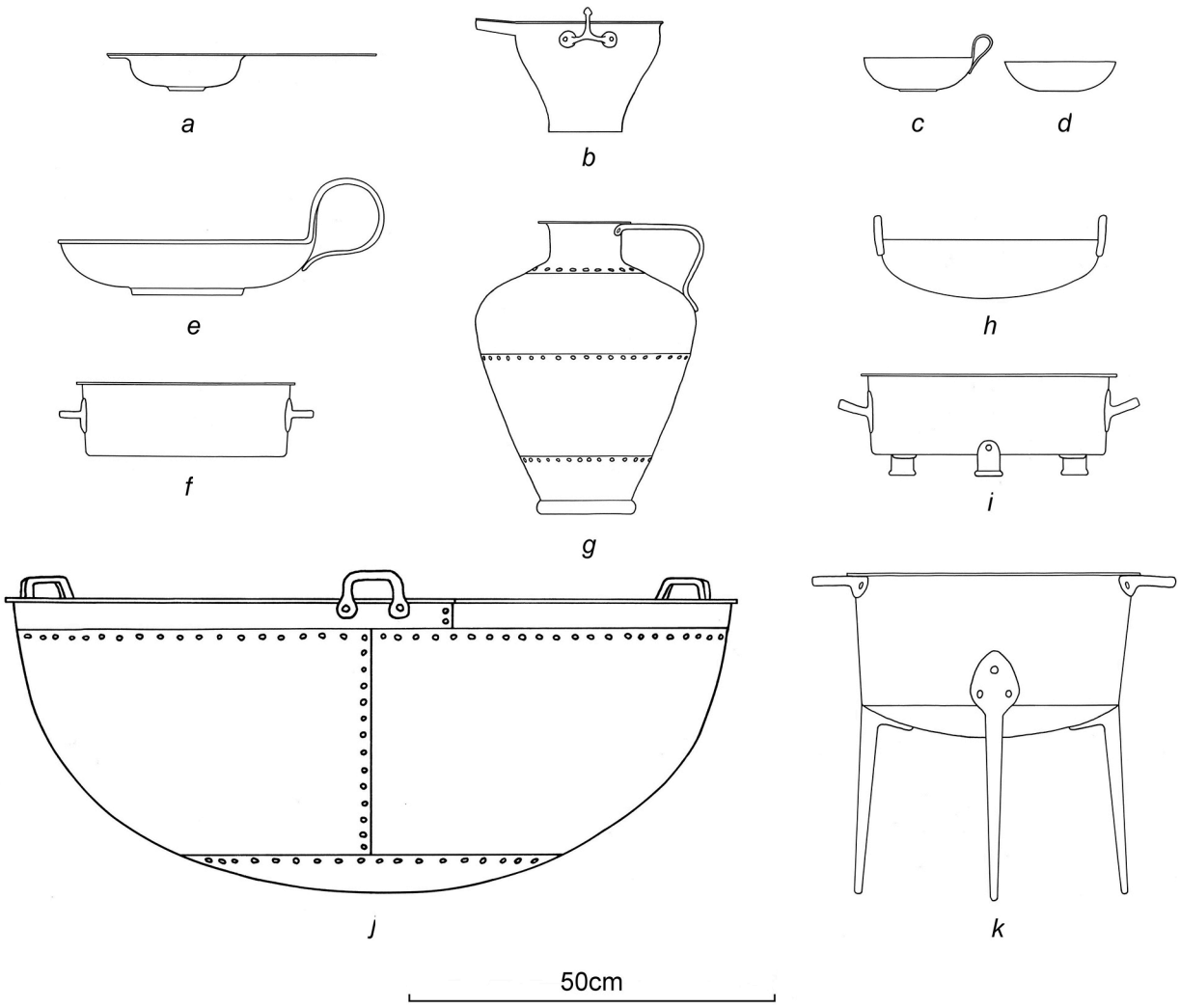


Fig. 1. Some Minoan bronze vessel types: a) lamp, b) lekane, c) one-handled cup, d) bowl, e) one-handled basin, f) pan, g) hydria, h) basin, i) tripod pan, j) cauldron, k) tripod cauldron.

through the sheet metal rather than drilled. Most rivets were made from pieces of rod which were hammered flat on both ends after being threaded through the vessel wall and more decorative rivets which had a bulbous, domed head on one end only were probably cast before being threaded through the vessel wall and hammered down on the other end.

There is a curious contrast between Minoan vessel forms and those of their neighbours. While smiths in Egypt, Anatolia and further east often produced tall, narrow shapes and closed forms with narrow necks (Fig. 2), Minoan smiths avoided tall, narrow forms and created closed forms by making open sections and joining their edges together with rivets. It is likely that this contrast is due to a difference in the techniques used to produce the vessels. There are two different hammering methods used to produce hollow forms. A technique called sinking involves hammering a disc of metal. Furthermore, none of these few tools come from metallurgical contexts and might easily have been used for many other non-metallurgical purposes. Stone hammers, however, are far more common in metallurgical contexts. These are for the most part elongated pestle-shaped stones and spherical cobble-stones of limestone, marble, sandstone or andesite. It is notable that these hammer-stones were not hafted but were hand-held. It is likely that stakes and some hammers were made from organic materials such as wood, and perhaps horn and bone, although thus far it appears that no artefacts of horn or bone have been identified as having been used for such purposes. The near-absence of extant alternatives suggests that wooden equipment was common, as it is in modern practice. Bronze tools may have been used too, but were perhaps less usual. Polishing stones with faces worn flat from use are also common at metallurgical sites. Types include emery, limestone, siltstone and marble.

Experimental Reconstruction

Based on the findings outlined above, a set of tools and the requisite equipment was collected or constructed for experimental reconstructions (Clarke 2012, 2013). The metal was annealed in a hearth designed after the pi-shaped hearths found at several Minoan settlements and occasionally in the vicinity of metallurgical remains (Shaw 1990) and a blowpipe to increase the temperature of the charcoal fire (Fig. 5). The hammer types used were the stone pestle-shapes and spherical cobble-stones described above (Fig. 6). Two wooden hammers were also tested and all raising and sinking was performed over wooden stakes and hollows. A limestone anvil was used for forging, the sheet was cut with chisels when required and holes were made for rivets with punches. The vessel's surfaces were cut back with a number of abrasive stones and charcoal and the final polish was achieved by burnishing with hard, polished stones such as haematite and agate (Fig. 7). All of this equipment worked very well and, surprisingly, the hand-held hammers were much better suited to creating some Minoan forms than a hafted hammer would have been.



a b

Fig. 2. a) Gold pitcher from Central Anatolia, Met 57.67 (after http://www.metmuseum.org/Collections/search-the-collections/30008817; 15 Jan 2013); b) Bronze flask from Egypt, MFA 29.1204 (after http://www.mfa.org/collections/object/flask-146747; 15 Jan 2013). Drawings by M. Dearden.

As well as a reconstruction of the Minoan metal-vessel manufacturing process, this exercise resulted in wider implications, particularly for the interpretation of metallurgical sites, the working practices of the smiths and the technology of the craft within the broader context of the Eastern Mediterranean. It is usually the case that we interpret a site as having been used for metal object production because of the presence of casting remains such as droplets, slag, crucibles, tuyères and so on. For vessel production, the only casting required was of the initial billet and of handles, legs and rims.

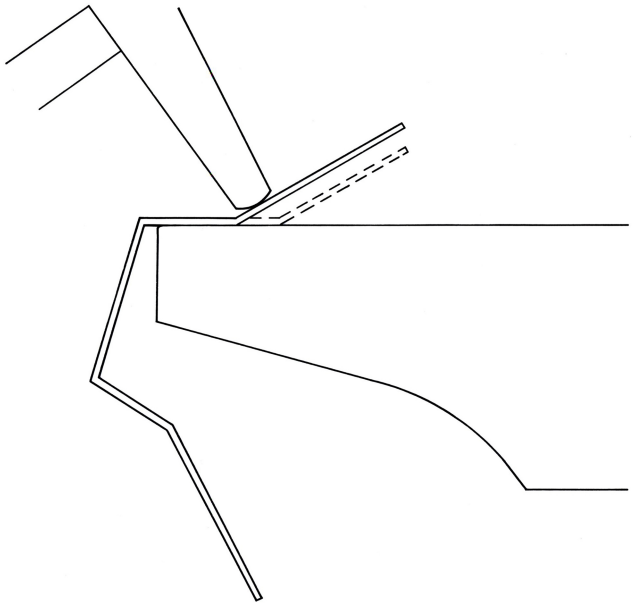


Fig. 3. Raising the wall of a vessel over a stake.

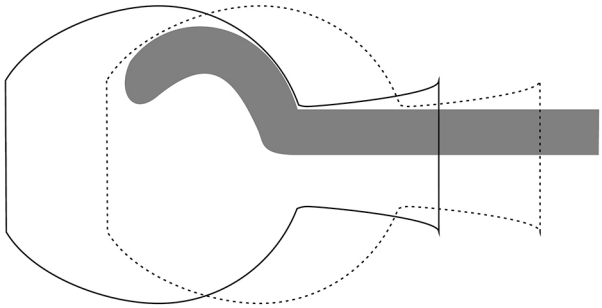


Fig. 4. Using a stake to create a closed vessel.

The bulk of the process consisted of hammering and the final stages of polishing with abrasives. The temperatures required for annealing the metal are so low that a cooking hearth would suffice. So, if casting is performed at a separate location, the remains we can expect to find are a simple hearth, some stone hammers and polishing stones and perhaps some simple bronze tools such as chisels and punches. The same can be said of many other Minoan metalworking processes including the annealing and forging of precast billets into tools and many jewellery-making processes such as gold sheet-work, wire-working and granulation. This range of equipment is extremely common in houses and sites interpreted as domestic contexts, so how are we to distinguish a non-casting metallurgical installation from a domestic site, and are they necessarily separate? Clearly we cannot limit the evidence for metallurgical practice at a location to the presence of casting remains.

Summary of the Findings

During the course of the practical experimentation, the process of hammering metal over several months using hand-held stone hammers caused a significant amount of damage to the hands and wrists. Some of these injuries, such as carpal tunnel syndrome and tendinitis, have the potential to lead to long-term damage and possibly, with the increased likelihood of premature osteoarthritis, to cause permanent

disability. When one considers that mastery of the vessel-making techniques used by Minoan smiths would have taken several years, it seems unlikely that an individual would have been occupied with hammering full-time since within a few years they would have become incapable of working any longer. The same problem exists for smiths producing tools, since these also required extensive hammering. This suggests one of two scenarios for these workshops. Within a workshop which operates only part-time, smiths might produce wares for some of the year to



Fig. 5. Annealing in a pi-shaped hearth with a blowpipe.



Fig. 6. Stone hammers used for the experimental reconstructions.

augment other work such as agriculture. Within a full-time workshop, labour might be organised so that no individual is hammering constantly. Several smiths might work on the same vessel, reducing hammering time for each individual, or tasks may have been rotated so that an individual may change from hammering to polishing, casting or hole-punching, for example. Such work practices would help to reduce the likelihood of a smith developing permanent physical damage, thus prolonging their working life to allow mastery of the craft and its passing to the next generation. The technological contrast between vessel-making in Crete and her neighbours may be significant. It was noted above that bronze tools, including stakes for raising, were apparently rare in Crete and wooden stakes were probably more common. It is possible that this is why Minoan smiths did not produce tall and narrow or closed vessels. To produce vessels of these shapes, the stake must be long and narrow. Since the stake must bear thousands of heavy hammer blows, it is very unlikely that a wooden stake would be suitable. A narrow wooden stake would bounce, making precise hammering impossible, and it would eventually break. A thick wooden stake does not present these problems, but also does not allow narrow or closed vessels to be created. The implication is that while Minoan smiths usually produced vessels with extensive sinking and raising over wooden stakes, smiths abroad were using bronze stakes. It is difficult to say why this is the case. Complete ignorance of the technique seems unlikely, especially considering the strong influence of Egyptian crafts on Minoan. One explanation may be that there was little incentive to alter techniques because the vessels already served their purposes well. If individual forms had specific symbolic significance then alteration might have been undesirable. It also appears that Minoan vessels were admired abroad. Their presence in the Mycenaean Shaft Graves and their depiction in Theban tombs suggest that this was the case.



Fig. 7. A copper hydria produced with replicated Minoan equipment. Photo J. Kuhnen.

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