Detecting Social Development through Manufacturing Processes
A case study of Palaikastro (Crete)

Maria Lowe Fri

Introduction

Can metalworking processes be a contributing factor in a town’s development during the Middle to Late Bronze Age? Does the archaeological evidence let us detect small scale operations, most probably to be considered for local use, which through organization became an ‘industry’ with skilled smiths who became important not only for the town itself, but also for trade elsewhere? If trade became a part of the industry, was this ‘only’ within the island itself or can contacts beyond Crete be detected? And how does this process affect a town?

In order to investigate this I have chosen to study the archaeological site of Palaikastro (Crete), which has evidence of several habitation phases with different manufacturing activities connected to the town. The archaeological evidence for casting and conducting finishing treatments on metal artefacts from Palaikastro consists of clay moulds, several crucibles, tuyères and stone hammers, to name a few examples. Although the metallurgical debris is well known and documented and points to metalworking activities, there have not, so far, been any attempts to pinpoint working areas or part(s) of the town, as for example, have been done with Quartier Mu at Mallia (Poursat 1982:677-88; Poursat 1996) and the Unexplored Mansion (Knossos) (Catling & Catling 1984:203-22). Therefore I will first examine the finds and their contexts in order to determine different activities connected to the metalworking process and try to pinpoint certain locations in the town for them. Secondly, can a development be discerned, such as from
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a small scale production to a larger and more organized production, and if so what could this have meant for the development of Palaikastro and their contacts beyond the town?

The site of Palaikastro

Palaikastro is situated in north-eastern Crete close to the shore and bay of Palaikastro (Figs. 1-2). There is evidence of activity at the site for an extended period – approximately 4,000 years – tracing back to the Neolithic period and continuing more or less throughout Roman times. The period addressed here is the Minoan period, c. 2600–1100 BC, when several phases of building construction can be traced. Palaikastro grew from a hamlet with a few houses from c. 2600 BC to a town c. 1930–1800 BC. Several of the houses show numerous rebuilding phases at Palaikastro due to earthquakes and fires until c. 1250 BC. In addition, the town was severely destroyed by the tsunami after the big eruption at Thera in c. 1530 BC, indicated by strata near the Palaikastro bay as well as in the town itself (Boyd et al. 2006:132; Bruins et al. 2008:203; for a general overview of Palaikastro and its periods cf. MacGillivray & Sackett 2010:571-81). The late occupation of the site, c. 1100 BC, is not to be found in the town itself, but is mainly situated on the Kastri Hill in the Palaikastro bay.

A survey of the area was conducted as early as in 1983 when the town’s outskirts were somewhat recognized, but the intriguing question of whether a so-called Minoan palace had been situated here remained unanswered (MacGillivray et al. 1984:129-59). In order to settle some

Fig. 1. Map of Crete. After Davaras 1976, Map 2.
questions from the 1983 survey, geophysical investigations have recently been undertaken and more architectural features of Palaikastro were identified. However, the enigma of a Minoan palace at Palaikastro awaits further investigations, although the more recent research has been somewhat promising in this respect (Boyd et al. 2006:123-34).

Evidence of metalworking processes

To identify a metalworking area or metal workshop certain equipment needs to be recognized. Detecting every aspect of the metalworking process in the archaeological record is most probably impossible since certain utensils, i.e. clogged up tuyères, were thrown away after use, and equipment made of wood decays in certain soil conditions. Bearing this in mind, what can we expect to find in contexts pointing to metalworking processes?

In order to carry out a smelting or melting process most central is a furnace of some kind. Although few furnaces have been detected on Crete this does not imply that metalworking activities were non-
existent. However, for example at Chrysocamino, a metalworking site in north-eastern Crete, pieces of a furnace have been identified (Betancourt 2006:109-23). If a furnace is not detected there can be other objects found that point to smelting and melting activities such as slag, metal droplets and spill (Catling & Catling 1984:219; Stos & Gale 2006:299-301). Furthermore, a smelting/melting process can be understood by finds of bellows and tuyères which are necessary for increasing and directing the air in the furnace. However, these are not always an indication of where the metalworking process took place, as they often are found with other discarded objects (MacGillivray et al. 1992:144; Blitzer 1995:508-9; Hemingway 1996:218-21).

Crucibles have been found both in workshop contexts and together with metallurgical debris (as will be presented below from Palaikastro). They are found in different shapes and sizes for melting or smelting metal and directly point to casting activities (Evely 2000:346-52). Furthermore, to lift the crucible from the hearth it would be necessary to have tongs which could be made of metal or simple withies (Evely 2000:365), though the latter would most probably not be present in the archaeological material due to having been subjected to extreme heat in usage and later decaying soil conditions. Although the raw material is crucial for casting it is seldom found in attributed working areas, although copper ingots have been found for example at Kato Zakro (Platon, N. 1971:116-8). The raw material could also be represented as ore and scrap metal (Rice Jones 2007:71-96).

Moulds are a necessity for casting activities and when found provide a strong indication that casting processes have been undertaken in the vicinity. During the Bronze Age these were made of clay, sand, stone (Fig. 3), or even of metal, and they are represented by so-called permanent and non-permanent moulds. The permanent moulds would mostly be made of stone and if taken care of and preheated before casting, could last for a long time (for an overview of permanent moulds from different locations in Crete cf. Evely 2000:356-62). The permanent moulds consist of one or two parts, often depending on what was being cast. The two-part moulds would also need metal straps to prevent the two mould pieces from dislocating when casting and metal from running out of the mould at the joint line. These are not found in any abundance, but have for example been found at the Unexplored Mansion at Knossos (Catling & Catling 1984:218). The other non-permanent moulds were clay moulds used for the so-called
investment process (cf. Lowe Fri 2011:11-2), and sand moulds used for the so-called flask technique (cf. Lowe Fri 2011:13). In order to cast according to these methods, patterns of the items are necessary because the mould is constructed around the pattern, which at a later stage is removed. Wooden or clay patterns are therefore important if the flask technique was in use, however the archaeological evidence is scarce and to my knowledge only one pattern of wood has been found, and to add to this only a couple of clay patterns (Davey 1983:179-80; Strahm 1994:18, Fig. 13).

In addition, using the flask technique, wooden moulding-boxes to secure the casting operation would be necessary; however, these have never been located during excavations and even if they had been present they would have decayed (Lowe Fri 2011:13). For the investment process wax would be needed to make the pattern, which before casting is melted out and therefore very difficult to detect (Noble 1975:368-9). When cast, the clay and sand moulds are broken or opened in order to extract the cast item from the mould; it therefore cannot be reused. Although the clay moulds are discarded parts of these (investment

Fig. 3. A limestone mould with matrices for a trunnion axe and chisel. The stone mould, along with replicas of Minoan tools, was made by the sculptor Mr. Nigel Ratcliffe Springall, and is a part of research on Minoan chisels conducted by the author. Photo: M. Lowe Fri.
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process) have been found at several sites, but on the other hand sand moulds are rarely recognized. This means that sand moulds would be more or less invisible in the archaeological record.

A cast object usually needs finishing treatment(s) in order to be used or distributed (Fig. 4). The finishing treatments differ depending on what objects have been cast and judging from the different clay moulds found at Palaikastro, both everyday items such as tools and more ‘prestigious’ objects, cauldron and relief plaques, were produced (Hemingway 1996:226-39). In the case of a tool the cast object would have been cleaned from probable flash (if a two-part mould is not cautiously closed the fluid metal will run out of the mould and build up a thin outer lining around the cast object). In addition, the area where the running system/pouring cups were placed was also most certainly in need of being removed from the casting. This first step of the finishing process could be undertaken with a bronze chisel and stone hammer and would have been necessary regardless of whether a tool or decorative element was cast (Lowe Fri 2011:49, Fig. 30). Chisels and knives have been found at various sites related to metalworking processes as the finds from the Unexplored Mansion at Knossos demonstrate (Catling & Catling 1984:213-4).

Fig. 4. A probable tool kit for finishing treatment of as-casts. Photo: M. Lowe Fri.
A tool may not have had the required final shape after being cast, and additional work would have been conducted for example to reduce thickness close to a cutting edge for a V-shaped appearance. Different methods can be employed to achieve this kind of finishing treatment, i.e. cold working or annealing or both. The practices of both cold working and annealing are not uncommon during the Minoan period as have been shown on several daggers and double axes through metallographic studies (Northover & Evely 1995; Tselios 2008:125-7). The most uncomplicated way is cold hammering a tool into the desired shape using a stone anvil and stone hammers. Anvils are not found in large quantities, however stones used as hammers are not unusual in the archaeological evidence; both categories have, for example, been reported from Kommos (Blitzer 1995:484-6). If annealing is part of the finishing treatment then closeness to a hearth is required (Weinstein 1974:25). The cold hammering and annealing not only reduces thickness, forms a V-shaped cutting edge or other necessary adjustments needed after cast, but also helps in strengthening the as-cast item because the alloy’s structure changes in the process (Scott 1991, fig. 11 a-f; Northover & Evely 1995).

Now and then casting defects appear, for example from loose dirt in the mould, and in order to get the surface nice and smooth the object, regardless of whether it was a tool or decorative element, would need to be ground and polished. Pumice and/or sandstone is perfect for accomplishing this, and has been identified at several sites in Crete, e.g. at the Unexplored Mansion at Knossos and Kommos (Evely 1984:12, 75; Blitzer 1995:509-10). A tool with a cutting edge would also have to be sharpened, which would have been conducted using pumice, sandstone or whetstones. Proximity to a water basin would have been helpful in this process, but its presence is not critical for pinpointing the location of where finishing treatments might have been undertaken.

These are the essential stages – from casting to finishing treatments – making up the process of metalwork production. However, certain tools such as axes would have to be shafted to be rendered useable and ‘customer ready’, and this process could have left traces in the archaeological record, but is not required for identifying a metalworking area. This is also true for parts of cauldrons which were cast at Palaikastro, which also required additional work (soldering together) to achieve a finished product (Hemingway 1996:243).
The casting evidence from Palaikastro

Bearing in mind all of the casting equipment accounted for above and used in the production of metal artefacts, what can be identified in the archaeological record from Palaikastro?

There are clay pieces of what is believed to be a furnace with an inner lining of copper, and slags are also recorded (MacGillivray et al. 1989:419-21). Furthermore, there are several tuyères identified, indicating the use of bellows (Hemingway 1996:218-21, 251). There are also several crucibles of different types, some with an inner lining of bronze or copper droplets (MacGillivray et al. 1989:421; Hemingway 1996:221-6; Evely et al. 2012:2-4). Most interesting in trying to pinpoint activities at the site is that the clay used for at least some of the crucibles was collected from the Palaikastro surroundings (Evely et al. 2012:6). In addition, and very important for the casting industry, were the parts from at least twelve clay moulds used for the investment process, which were found for various objects such as double axes, chisels, cauldron handles and bars (Hemingway 1996:226-39).

The recorded evidence for casting at Palaikastro is not abundant, but it is convincing. At some point(s), casting has to have been an active manufacturing process in the Minoan town. The equipment that has not been traced so far in the archaeological record are bellows, metals bands and tongs. However, I would argue that the most important pieces of equipment to demonstrate evidence of casting activities are the crucibles and moulds.

The finishing treatment: evidence from Palaikastro

Casting an item is only the first step: the as-cast object needs further finishing treatments in order to acquire its final shape and appearance. Based on the above account, what equipment can be traced in Palaikastro that would indicate the implementation of finishing treatments?

For the first removal of joint flash and running system, chisels could have been used. These have been found at several locations at Palaikastro (Evely 1993:2-19; Sackett & Popham 1965:252-68). The final shaping of the as-cast object is by cold hammering or annealing (or both); hearths are identified and stone pounders/hammers are abundant, and in addition at least one whetstone has been identified. The need for water when grinding could be solved with a simple vessel, and pottery which could have functioned as such has been found. To
add to this, one interesting feature in Building 5 includes a bench and a basin adjacent to one another (MacGillivray et al. 1991:131), which could imply a working area.

Anvils are missing from the archaeological record, but experimental work shows that a separate anvil is not the most important object when cold hammering (Lowe Fri 2011:50-1). There is no report which identifies the presence of pumice or sandstone, but recognizing these as having been used for grinding and polishing can be difficult, especially if only small pieces are found. Although some of the equipment related to finishing treatments is lacking, I would still conclude that there is sufficient material to recognize that finishing treatments have been conducted at Palaikastro, at least in part.

**Casting equipment: contexts and dates**

Archaeological evidence arguing for casting activities is present at Palaikastro. However, the material, so far, has only been accounted for without reference to specific contexts or dates or phases at Palaikastro town. What different processes related to the manufacturing chain can we discern if we consider the distribution of these objects in the town and also consider the long time-span of the Minoans? Will the same ‘positive’ pattern emerge, as the material at first indicates? And does the material point to a gradual, developmental process regarding casting activities, from small scale production towards an ‘industry’?

At Palaikastro there are two find contexts that point to the casting process. The first is in Building 1, which is set within the time span of 1570–1500 BC. In the following period 1490–1460/40 BC the building was destroyed by fire; the building was further reoccupied and probably destroyed during the period 1400–1320 BC (MacGillivray et al. 1988:259-65, 271-4; MacGillivray et al. 1989:419-22, 429). The earliest finds from a casting operation are from Building 1 and consist of copper slags, parts of a possible furnace and part of a crucible which date from 1570–1500 BC (MacGillivray et al. 1989:419-21). From these finds it was concluded that a small-scale (s)melting and casting operation was performed nearby the building. This could be further confirmed by a recent article by Evely et al. (2012), where a total of six crucibles from Building 1 are recorded and associated with the abovementioned finds. However, the finds do not come from secure contexts, but from disturbed layers due to several building phases (MacGillivray et al. 1989:444-5).
During 1440–1400 BC Building 1 was rebuilt and used again. During this later occupation there is evidence of food processing in the form of querns, stone pounders and rubbers. The later finds also include half an investment process mould for a double axe. The mould suggests bronze working in this later period, too, though this is somewhat uncertain and could come from disturbed levels, and should therefore be associated with the earlier finds from the building. A bronze knife was found near the finds, but this is associated with seeds (MacGillivray et al. 1989:429) and I have therefore ruled this out as having been associated with metalworking processes. Furthermore, two small pieces from a mould were found in Building 1 and date from 1400–1320 BC (Hemingway 1996:251). In addition to this, a tuyère was found in the street south of the building (Hemingway 1996:251; unfortunately no further details are published concerning the last two finds).

The second context is a so-called ‘deposit’ which indicates metalworking activities found in a small yard, against a wall close to Building 5 (Hemingway 1996:215; the context described seems more likely to be a pit and not a deliberate deposit as Catling has already commented on, cf. Catling 1997:52-3). The houses connected to this small yard (Buildings 4 and 5, and Building 1 is only c. ten metres away) were all in use around 1250 BC (Hemingway 1996:215). The deposit contained a mixture of pottery (dates from 1250 BC), small stones and equipment for metal production such as tuyères, crucibles and moulds for the investment process (Hemingway 1996:215-8, catalogue of the finds cf. 218-37). The finds were clearly used as metal residue is found on the tuyères and in the crucibles. The moulds, used for the investment process, were to cast various artefacts such as double axes, sickles, relief plaques and parts of a cauldron (Hemingway 1996:237-9). Hemingway believes that the debris from casting came from a local workshop, but the problem is identifying where in Palaikastro this may have been (Hemingway 1996:243).

**Equipment for finishing treatments: contexts and dates**

The excavated finds – although not numerous – point to different casting processes in at least one location at Palaikastro. Before continuing with the equipment for finishing treatments it should be noted that there are many more examples of stone pounders, hammers etc. which could be connected with the process of finishing treatments rather than casting.
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equipment. I have chosen to account for five different contexts which represent the whole area, and I am convinced that presenting more of these finds will not change the overall picture. In trying to understand the equipment in relation to the process of finishing treatments, their contexts and dates, what picture emerges of the metalworking activities at Palaikastro?

Building 5 at Palaikastro is mainly thought of in the light of the so-called Palaikastro Kouros statuette made of ivory and gold. The interpretation of the Kouros has been as a religious object and Building 5, or at least part of it, has therefore been discussed as functioning as a shrine (Driessen 2002:87-95). The Kouros was found broken in several locations in the building and in the Plateia just outside the building (Sackett et al. 2002:21-31). This famous ivory statuette dates from 1490–1460/40 BC and if considering the house, where parts of it were found, what else is from this period? There are masses of pottery of various kinds (fine and coarse wares) but also finds such as five bronze chisels, unfinished ivory pegs in the shape of column bases, a pierced ivory disc, unworked ivory and ivory stripes, obsidian flakes as well as smaller bits and six blades, a bone point, three impressed sealings, several stone tools such as pounders with different degrees of use-wear, and a quern (Sackett et al. 2002:31-3). In a room adjacent to these finds was a bench with a vessel situated in the level of the bench, which meant that water could be within reach when working. This could be interpreted as a workshop (MacGillivray et al. 1991:131).

Evely has proposed that this area of the house might have been an ivory workshop, and taking into account the tools found in these rooms, and comparing them to the toolbox probably used to make the Kouros, it seems very likely (Moak 2002:65-83; Sackett et al. 2002:32). I agree with the interpretation, but would add that ivory was probably not the only thing being processed in this workshop; the stone tools accounted for by Evely seem very worn. Can working with a chisel and stone as a hammer on ivory cause this level of wear? In order to fully understand and interpret this, experimental work needs to be undertaken and all of the material from the house must finally be published.

Also of interest regarding equipment associated with finishing treatments is Block N. The block probably consists of two buildings occupied between 2200–1460/40 BC and a limited reoccupation during the later phase of the Late Bronze Age (Sackett & Popham 1965:252-68). The finds associated with the finishing treatments here are connected
with the 1570–1500 BC period and consisted of two stone pounders, a stone rubber, a whetstone, a small stone polisher, a stone hammer and a bronze knife. Other than the abovementioned finds, the reports account for masses of pottery including finer ware, coarse ware and storage vessels which cannot be associated directly with the process of finishing treatments of metal. Nothing in the house points to large scale activities and more likely finds such as an odd loom weight and stone pounders suggest things for everyday use. These finds were also scattered all over the house and not found together, which would be more probable if a workshop was found. One interesting object that could point to a large scale activity is the potter’s wheel from this block – is this to be related to the crucibles which were found in Building 1 and made of clay from the vicinity? Although interesting, no evidence of metalworking processes in Block N has been detected.

One of the wells excavated in 1994 contained several stone tools, including one that Evely (2007:167) recognizes as having been used for shafting tools due to the very specific wear pattern left on the pounder/hammer. Out of context it is hard to interpret, and the tools do not indicate any specialization; essentially, they could be from any household ‘do-it-yourself’-kit. If also taking into account the fact that the houses were not situated in the town ‘centre’, but on Kastri and near the modern shoreline, the picture remains the same. House A (near the shoreline south of Kastri and east of the main town of Palaikastro) (Fig. 2) contained objects which could be associated with finishing treatments of metal such as a roughly built bench and two stone troughs for coarse grit as well as stone rubbers, a doubled-edged bronze knife, a piece of obsidian and a bronze awl (Bosanquet 1901-1902:306-8).

In House B (situated west of the ridge) most finds relate to the later phase of Palaikastro and consist of (from a working perspective) bits of obsidian and pumice, a green stone polisher and a limestone pounder, which Bosanquet attributed to a stone mason. Finds also included a bronze chisel, a stone trough and, in the cellar, a small deposit of a bronze double axe and three pithoi jars (Bosanquet 1901-1902:310-6).

**Metalworking at Palaikastro**

Despite the limited data that can be associated with the metallurgical working process reported from Palaikastro one can conclude that the process of metalworking has been part of the activities in the town from
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at least c. 1570–1500 BC and until c. 1250 BC. The finds, however, are not as plentiful as one may wish in order to identify a big and prosperous workshop. But, I find it interesting that the relevant metallurgical finds are all situated in the same part of the town, which could point to a probable work area used for a long period of time. One can also further speculate that since the mould fragments found are from the investment process, and were not reused, the activities here could have been on a much larger scale than they appear today. For now it is impossible to determine whether the metalwork was ever produced on such a scale that the products were exported, which would point to a development of the metalworking activities. I would suggest not. Rather, what was produced was also used at Palaikastro, independent of the different Minoan phases, something that the archaeological record from other parts of the town also confirms.

The equipment associated with finishing treatments can be identified in many locations in the town, but in order to pinpoint a working area or workshop for metals the associated materials would need to have been found in a more limited area. The finds, so far reported, seem to indicate that the inhabitants were involved in small scale activities, mostly in a domestic context, and the tools for finishing treatments were probably part of the household toolbox. Regarding, for example, the stone pounders, there are several activities they could have been used for other than metalworking (food processing etc.). In order to investigate this problem further use-wear analyses must be completed and published. I would like to add to this picture the interesting finds in Building 5, which could point to a workshop for ivory. Building 5 is opposite to Building 1, the so-called ‘deposit’ is situated close to Building 5, and Block N is 40–50 metres away. Could this close spatial relation indicate that the workshop quarter of Palaikastro was situated here, and that it was in continuous use and therefore independent of the long time-period accounted for?

I implied in my introduction that metal production could have developed into a large scale business, perhaps even leading to trade and contacts beyond Palaikastro. However, based on the known archaeological finds this seems unlikely, and certainly cannot be concluded based on metalworking activities only. One important fact to bear in mind is that the south-eastern coastline where Palaikastro is situated is difficult for boats to anchor because of the unpredictable winds. Therefore Palaikastro probably would not have been a big and flourishing harbour,
but on the other hand the Minoan palace and town of Kato Zakros (Fig. 1), which is situated a few miles south of Palaikastro, has a bay which is sheltered from the hard winds and a flourishing harbour did exist there (Platon, L. 2010:509). The raw material for metalworking was imported to Crete as local resources were meagre, if used at all, during the Bronze Age (for a recent discussion of copper sources in Crete cf. Tzachili 2008:327-9). This of course meant contacts beyond Palaikastro, but how far did they reach? The largest quantity of imported copper came from Lavrion and Cyprus (Stos-Gale et al. 1997; Évely & Stos 2004:267-70), and was probably distributed to Palaikastro from the harbour at Kato Zakro along with other materials (Platon, N. 1971:116-8).

In order to further interpret the development processes at Palaikastro other materials must be considered, such as the vast quantity of pottery that has been found here. The pottery is both locally produced and from other parts of Crete. The imports, where ceramics are concerned, have mainly been characterized as Knossian and from eastern Crete. The influences from Knossos seem to have lasted over a long period of time, and especially from c. 1460–1320 BC (MacGillivray 2007:158). According to MacGillivray (2007:158) the so-called stirrup jars were not produced at Palaikastro, and the production centre was probably in central Crete. There are also indications of contacts beyond Crete with an imported jar handle from Thera (MacGillivray et al. 1987:152). To add to this recent research implies that pottery from Palaikastro also found its way elsewhere in the island as for example at Chrysocamino, Mochlos and Petras (eastern part of Crete) (Nodarou 2007:81). The pottery therefore seems to indicate that Palaikastro had links within and beyond Crete, something that the metalworking processes do not imply.

From the archaeological evidence it is obvious that metal production has been a part of Palaikastro’s manufacturing history and infrastructure, and that skilled workers were a part of this process. However, one cannot claim to trace social development through a growing organized production of metals. In order to examine this further all craft production activities traceable at Palaikastro must be taken into consideration as the metalworking processes do not, for now, allow more comprehensive interpretations. If all traceable activities could be summarized and understood together, the scale of different industries could be evaluated and the dispersal of their materials could be
investigated. For starters, the pottery from the town could be analyzed and pottery from Palaikastro could be identified at other locations, as in the case of Mochlos. However, in order to move forward, the studies of the different buildings must be completed and published. Then – maybe – we can begin interpreting the social development of Palaikastro through the various kinds of production that took place within and beyond the town.

References


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