



# Pottery production and distribution in prehistoric Bronze Age Cyprus. An application of pXRF analysis

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## ABSTRACT

Portable X-ray Fluorescence (pXRF) analysis of over 400 samples of Early and Middle Bronze Age Cypriot pottery from four widely separated sites identifies both local and non-local products at each. A series of analyses of sub-sets of the data highlights differences in the clays used at each site and for some distinctive types and wares. When assessed in the context of general typological, technological and stylistic factors these variations provide the basis for considering patterns of local production and inter-regional relationships across the island. Although the great majority of pots were locally made, particular wares and shapes were brought in from elsewhere. For some sites finer, more highly decorated vessels are mostly imports, but at others both simpler and more complex vessels were made of the same local clays. While small juglets or flasks may have been containers for transporting small quantities of rare substances, larger vessels are likely to have held less precious material. Open vessels, especially small bowls – some of which are plain, utilitarian items – represent another aspect of social behaviour and inter-regional relationships.

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## 1. Introduction

### 1.1. Context

The Bronze Age cultural system in Cyprus was initiated by a movement of people to the island in the late 3rd millennium BC. For the first few generations (the Philia phase of the Early Bronze Age) it was characterised by a uniformity of material culture indicating close connections between different parts of the island (Webb and Frankel, 1999). The social and economic networks involved the distribution of pottery of very similar fabrics and shapes from the north to other areas of the island (Dikomitou, 2010) and of copper from production areas in the foothills of the Troodos Range to sites on the north coast which were in turn linked into a broader eastern Mediterranean interaction sphere (Webb et al., 2006). By about 2200, during the succeeding Early Cypriot I–II period (hereafter EC I–II), this cohesive system broke down, perhaps because of a general collapse of the overseas economic systems and a reduced external demand for copper. In place of earlier ceramic uniformity regional technological and aesthetic styles developed, with increased local pottery production. During Early Cypriot III (EC III) and the first part of the Middle Cypriot Bronze Age (MC I–II) (about 2100–1800 BC) different patterns of social interaction emerged (papers in Hein, 2009) which can be

traced by both general stylistic analyses and by the movement of small quantities of particular wares (e.g. Dikomitou, 2007). Copper is likely to have remained a key commodity in establishing and maintaining these connections. The degree of variability in site-types and material culture across the island is slowly beginning to emerge with increased evidence from new, or newly published, sites. The four sites used here represent some of this variability (Fig. 1).

Local or regional production of pottery during this period can be argued for on general archaeological grounds, including inter-site differences in utilitarian vessels, technological and decorative styles, specific evidence of pottery manufacture (e.g. tools and wasters) and analyses of clays. While some more comprehensive studies of Cypriot ceramics integrate several approaches (e.g. Dikomitou, 2007, 2010), portable X-ray Fluorescence (pXRF) has also been employed (e.g. Mantzourani and Liritzis, 2006). In a previous study of Early Bronze Age pottery using pXRF we were able to differentiate clays which matched general models of regional style zones and the movement of specific items (Eccleston et al., 2011). In this paper we build on that initial work to explore these and related issues further. We have again exploited the well-known advantages of pXRF to analyse large samples in order to more clearly demonstrate which types of pottery were brought in to the sites. Our primary aim is not to locate specific sources or production centres but to identify the extent and nature of non-local pottery in contexts where most vessels were locally produced.

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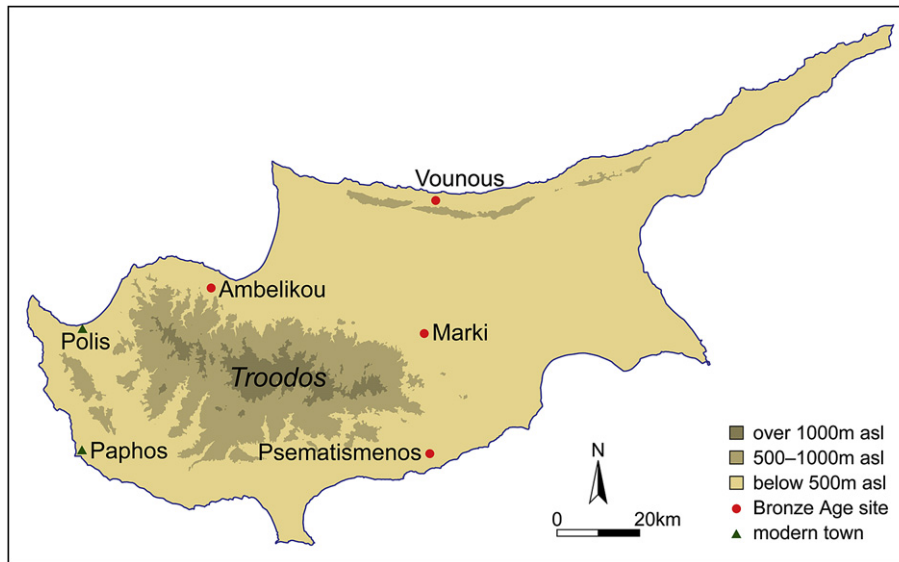


Fig. 1. Map of Cyprus showing archaeological sites and other places mentioned in the text.

## 1.2. Pottery wares and types

### 1.2.1. Red Polished ware

The broad tradition of Red Polished (hereafter RP) ware is characteristic of EC and MC sites in most parts of Cyprus. A general chronological evolution can be defined, which follows the broad groupings into RP I to RP IV defined 50 years ago by Stewart (1962). It is, however, becoming increasingly clear that there were significant regional and local variations in both form and techniques of production. The history, nature and extent of these differences are an important focus of research. During EC I–II, for example, RP from the central lowlands and south coast developed along different lines from that of the north. In the former areas a hard, gritty fabric was produced, with a characteristic surface appearance with deliberate (although unpredictable) mottled effects (Frankel and Webb, 2006: 104–105; Georgiou et al., 2011: 280–288). Fine incised decoration was rarely used. On the north coast vessels were made of softer clays with fewer inclusions, well suited to the fine incision which was the preferred mode of decoration (Stewart and Stewart, 1950). As well as chronological and regional differences, the quality of fabrics and surface treatment within the RP tradition also vary from one functional form to another. Although larger vessels may have had some simple incised decoration, finer and more complex patterns are generally only found on juglets, flasks and small bowls made of finer (often more calcareous) clays. In the northern areas, in particular, small bowls were also commonly fired black on the interior and on the upper exterior surface.

In the analyses presented below the RP material is divided into several sub-sets:

RP I–II: Earlier forms of RP with softer, finer fabric and a red-slipped well burnished surface, generally best known from sites on the central north coast.

RPm I–II: Earlier forms of RP with a harder, grittier fabric and distinctive, deliberately produced black patches or mottling of the surface, characteristic of the central and southern areas of the island.

RP III: Later forms of RP dated to EC III and MC I–II and found in most areas.

RP III (black top): Smaller vessels, primarily bowls, with a lustrous black interior which extends over the rim to the exterior, with oxidised red lower exterior body.

RP III (black top, fine incised): Similar to RP III (black top) but with finely incised decoration.

RP III (fine incised): Generally smaller vessels differentiated from other RP vessels by the use of finely incised decoration.

Pithos: RP III very large storage jars.

Cooking pot: A variety of RP III with a characteristic shape and fabric, used as a cooking vessel.

### 1.2.2. Drab Polished ware

Drab Polished ware (hereafter DP) is less well known than the more widespread and abundant RP. It is the most common EC and MC ware in western Cyprus but is found in small quantities elsewhere. DP is characterised by a fine, hard, orange-brown fabric, often with a distinctive blue core, and an orange-brown surface with relatively simple incised, impressed or relief decoration. The shapes differ from those of most RP vessels and previous analyses have also noted the distinctive nature of its clays (Summerhayes et al., 1996: 179; cf Knapp and Cherry, 1994: 77–78).

### 1.2.3. Devices

Within a general category of ‘devices’ we include spindle whorls, hobs, Coarse ware mealing bins or basins, mudbricks, a bellow’s nozzle and similar items. While there is every reason to assume that hobs (semicircular hearth-surrounds or pot-stands), mudbricks and mealing bins were locally made, this need not have been the case with whorls. Although whorls can often be classified within ceramic ware types, their context of production may have been significantly different and they may have moved between villages with their (probably female) owners, particularly in patrilineal marriage systems.

## 1.3. The sites and samples

The short-lived settlement at Ambelikou-Aletri, occupied during the first phase of the Middle Bronze Age, provides an ideal starting point for this investigation, not least because it has provided evidence for on-site pottery production. Although best known for some 70 years as a copper-mining site (Merrillees, 1984), the finds include more than four dozen complete jugs of very similar shape and several wasters from the catastrophic abandonment of a pottery workshop (Dikaos, 1945, 1946). These jugs and wasters — and by extension other vessels of similar fabric — were obviously made at the site. However, other pottery differs significantly in shape,

technique of manufacture and overall appearance, suggesting that at least some vessels were manufactured elsewhere. Pottery from the site was analysed in May 2011 while documenting the material in the Cyprus Museum in preparation for the publication of a belated report on the site. The samples include the full range of RP III wares and types listed above as well as examples of DP, which occurs as a consistent but small component (about 1%) of the overall assemblage. In total 89 RP III and 19 DP vessels and 9 devices, including two mudbricks, were analysed.

Marki-Alonia is an Early and Middle Bronze Age agro-pastoral settlement in the centre of the island which was occupied for about 500 years (Frankel and Webb, 1996, 2006). Although making use of copper sources a few kilometres to the south, its location was predicated on access to open agricultural land. We have previously argued that, while part of the integrated cultural system of the Philia phase of the Early Bronze Age, during the succeeding EC I–II it was within the general ceramic style-zone characteristic of the central and southern parts of the island. Previous analyses by Dikomitou (2010) suggest that much of the earlier (Philia) pottery was brought in to the site but most later vessels (EC I to MC II) are likely to have been made locally, with the exception of a few relatively rare fabrics, including DP (Summerhayes et al., 1996). Samples exported to Melbourne for analysis in the mid-1990s were re-analysed as part of this study. They represent some 400 years of occupation during the EC and MC periods. As well as 54 general RP sherds, the sample includes six finely incised RP III sherds, four RP black top bowl sherds (of which one has fine incision), two pithos fragments, 13 sherds of DP and four mealing bin or basin fragments.

The two other sites used here are both cemeteries. Bellapais-Vounous (hereafter Vounous) on the north coast of Cyprus provided for many decades the key assemblages for discussions of Early and Middle Bronze Age Cyprus (Dikaios, 1940; Dunn-Vaturi, 2003; Stewart and Stewart, 1950; Stewart, 1962) and much of our understanding of the period has been framed by its particular characteristics (Webb and Frankel, 2010). Material from these tombs is now widely distributed around the world: examples housed in the Australian Institute of Archaeology at La Trobe University were available for study and XRF analysis in 2010. The uniformity of fabric of most pottery suggests that almost all was made at or near the associated settlement. The samples used here include 41 undecorated RP I–II vessels, 11 finely incised RP I–II vessels and two small RPm I–II bowls, all dating to EC I–II.

Psematismenos-Trelloukkas on the south coast of the island is a recently excavated EC I–II cemetery (Georgiou et al., 2011). The 47 tombs provide a key reference point for re-assessing the archaeology of southern Cyprus and in discussions of ceramic variability and social interaction across the island. XRF analyses were carried out in the Larnaca District Museum in May 2010 during preparation of the material from the site for publication. The samples included here come from 122 plain RPm I–II vessels and 19 small, finely incised RP I–II flasks. In an earlier analysis (Eccleston et al., 2011) we have shown that these two groups of vessels differ in the elemental composition of their clays, providing the basis for an argument that the utilitarian RPm I–II vessels that make up the majority of the pottery at the site were made locally and the incised flasks brought in from elsewhere.

## 2. Analytical techniques

The use of portable XRF instruments is becoming increasingly common in archaeology (Shackley, 2011). The technique has several important advantages: it provides a quick and immediate assessment of the elemental composition of materials; large numbers of samples can be efficiently processed; it is portable and can therefore be taken to museums or into the field; and, importantly, it is non-destructive.

Although it is no substitute for other approaches to ceramic analysis, and has — as do all techniques — inherent problems (Shackley, 2010), it is an important addition to the archaeologist's toolkit.

In these analyses a portable Thermo Scientific Niton XL3t GOLDD (Geometrically Optimised Large Area Drift Detector) EDXRF analyser was used to determine the elemental composition of 391 items. The analyser has a 50 kV silver anode X-Ray tube. Due to the closely optimised geometry of the detector and a count rate of 180,000 cps, it is possible to undertake faster and higher precision measurements than was the case with previous portable Niton EDXRF analysers. The use of the same instrument and measurement protocols provided consistency, avoiding problems created by use of varied equipment and techniques.

Where possible readings were taken on a broken edge or failing that on an area of the surface where the slip was either not present or worn away, so that slips which generally have higher concentrations of Fe (Eccleston et al., 2011: 261, Fig. 4.2) were not covered by the oval 8 × 10 mm measurement window. The analyser was held by hand against the surface of more complete vessels. When sherds or smaller vessels were being analysed, the Niton XL3 'Smart Stand' was used to hold the samples. The advantage of this is that the analyser trigger could be activated remotely via emulation software running on a laptop computer and the X-Ray radiation was completely shielded by the barium-impregnated plastic lid on the sample stand. In most cases, it was possible to cover the entire detector window with the sample. Each sample reading was taken for 180 s using a combination of main and low range filters to optimise readings of heavier and lighter elements in the pre-calibrated 'Mining Mode'. The calibration algorithm for this mode is based on the principle of Fundamental Parameter Calibration. The algorithm used to count the fluorescence from the surface hitting the detector is optimised to take into account the relative quantities of particular elements.

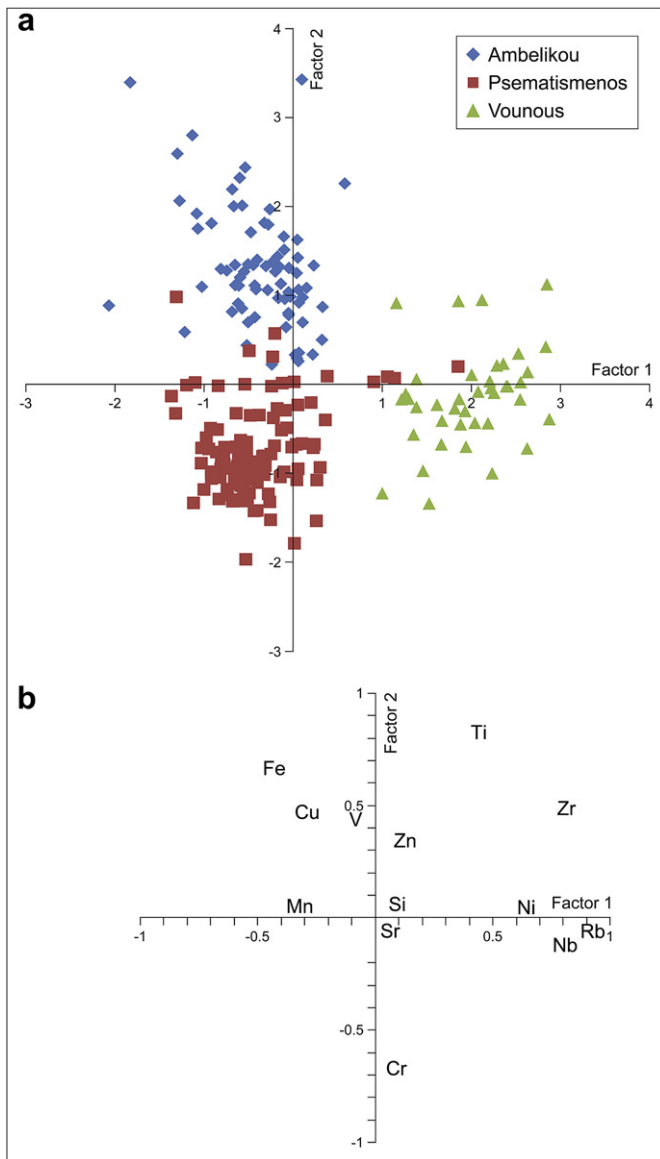
Values for 36 elements — Sn, Cd, Pd, Mo, Ag, Nb, Zr, Sr, Rb, Bi, As, Se, W, Pb, Sb, Re, Ta, Hf, Zn, Cu, Ni, Co, Fe, Mn, Cr, V, Ti, Ca, Cl, K, S, P, Si, Al and Mg — were recorded in ppm. The raw data saved by the analyser were exported into an Excel spreadsheet for numerical analyses. Where the concentration of elements was either absent or below the level of detection these were excluded from the analyses reported here. In addition, elements which displayed some large variations (Ca and Al) and those whose concentrations could have been significantly altered by post-depositional factors (K, S, P and Cl) were left out of these analyses. The effect of removing these data did not, however, have a significant impact on the patterns identified and discussed below.

## 3. Results

Trends within different sub-sets of the analytical data are explored and presented below using Principal Components Analysis (Varimax rotation). Each of these analyses of the data provides an insight into a different aspect of pottery production at varied scales of analysis both geographically and in terms of the finer classification of types and wares represented.

### 3.1. 'Local' plain RP samples from three sites

The first analysis (Fig. 2) includes only samples of plainer RP vessels which can be regarded as 'local' following the general approach indicated above for the three sites of relatively short duration (Ambelikou, Psematismenos and Vounous). The first two components of the PCA show that these sets of pottery from geographically distant sites differ significantly in the trace elements of the clays. This provides a very clear demonstration of the viability of the technique in discriminating between clays from separate

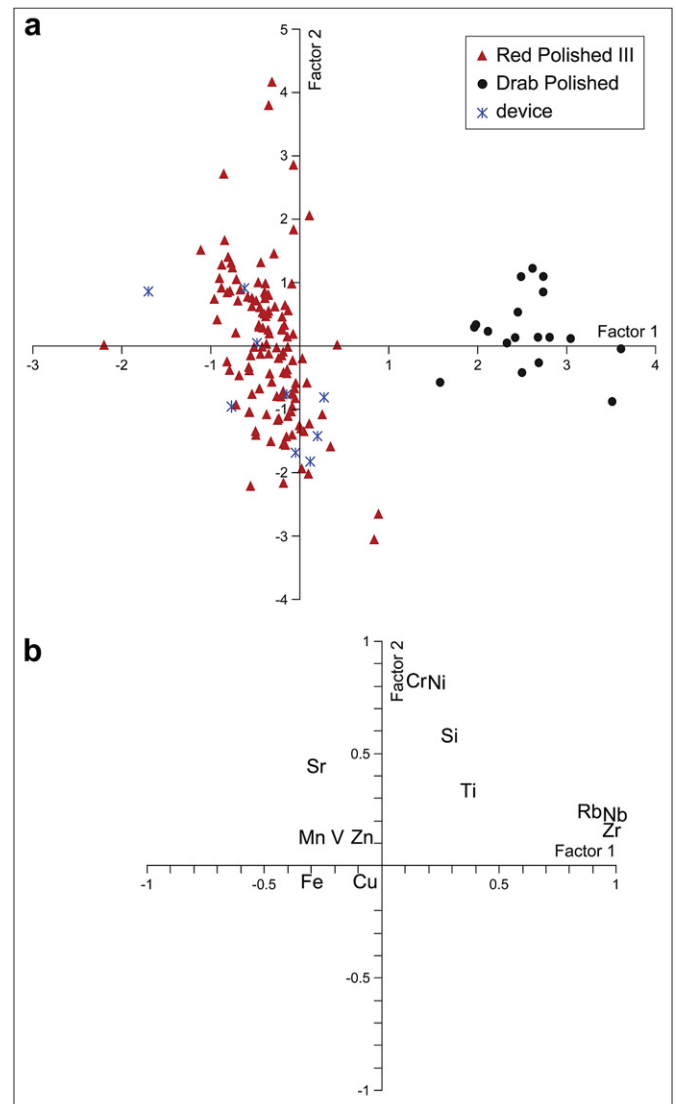


**Fig. 2.** PCA of undecorated vessels from Ambelikou, Vounous and Psematismenos. a. Plot of the first two components, b. Factor scores of significant elements.

regions. Whether or not pottery was made at the specific site (as can be confidently argued for Ambelikou) or in its immediate vicinity, this fits with a model of local production and consumption of at least the plainer, most common vessels.

### 3.2. The full Ambelikou assemblage

Fig. 3 presents the analysis of all the samples from Ambelikou. This includes the different varieties of RP III, the DP samples and other clay items, grouped here into three broad classes. What is immediately obvious is the separation of DP from all the other samples. DP can therefore be seen not only to have a distinctive array of shapes, surface treatments, clay preparation and firing techniques but also made use of clays quite different in their chemical composition from all other items, with high concentrations of Rb, Zr and Nb. There can be no doubt that these vessels were made elsewhere and brought to Ambelikou: the most likely source is from the west of the island, either from near Polis or in the Paphos district where this pottery is most at home (Graham, 2006; Crewe et al., 2008) (see 3.5 below). The majority of the RP III material, including the jugs and



**Fig. 3.** PCA of all clay artefacts from Ambelikou. a. Plot of the first two components, b. Factor scores of significant elements.

wasters from the pottery workshop, forms a relatively tight cluster, grouping together with the devices and with the mudbricks which must certainly be made of local clays. Some RP III vessels, however, fall outside this main Ambelikou field. The significance of this is seen more clearly in the analysis of RP III material alone (Section 3.3).

### 3.3. RP III from Ambelikou

The variability within the RP III series at Ambelikou is shown in Fig. 4, where the DP imports, the devices and mudbricks are not included in the PCA. There are some individual outliers, but most of the RP III vessels group together. This includes the jugs from the pottery workshop, other items of daily use, the large storage jars (pithoi) and the cooking pots. There is no reason to see any of these vessels as other than locally made. The same is probably also the case with some of the RP III black-topped vessels, but others group together suggesting that the difference in appearance may not only reflect a specific and deliberate approach to firing but also a use of particular clays or place of manufacture.

A significant sub-set of the fine incised RP III vessels, however, separates as a loose group, together with one of the

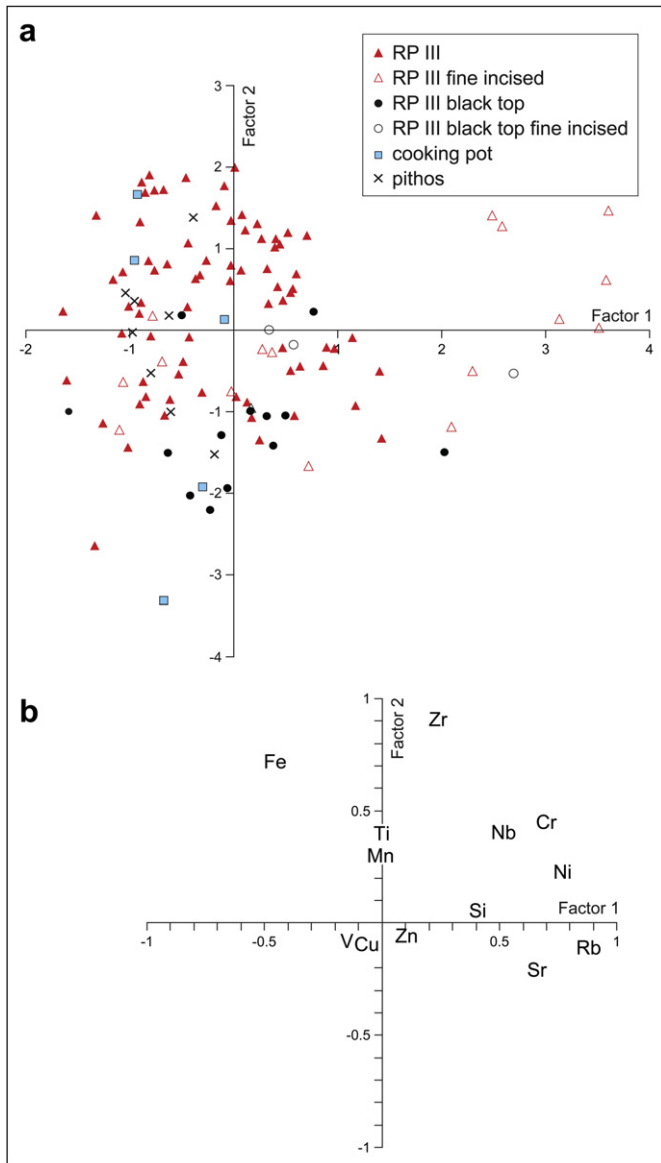


Fig. 4. PCA of RP pottery from Ambelikou. a. Plot of the first two components, b. Factor scores of significant elements.

incised black-topped vessels. These more highly decorated vessels were made of significantly different clays. Even if finer, naturally sorted or deliberately prepared clays were used it is unlikely that the profile of trace elements would differ to this extent from that used for other vessels, suggesting that many, if not all, of these pots were brought to Ambelikou from elsewhere. This cannot have been in the west, where vessels of this type do not occur. Instead it is likely that any imported vessels come from the north coast or the central lowlands. That they do not form a tight cluster may suggest that they come from several manufacturing centres, located within a similar geological zone and using somewhat similar clays.

### 3.4. The Marki assemblage

The PCA illustrated in Fig. 5 includes all the analysed sherds from the long-lived settlement at Marki. Vessels of different wares tend to separate into discrete groups. Once again the DP samples are clearly distinct, characterised by higher concentrations of Zr, Nb and Rb. The finer RP vessels (both black-topped bowls and finely incised

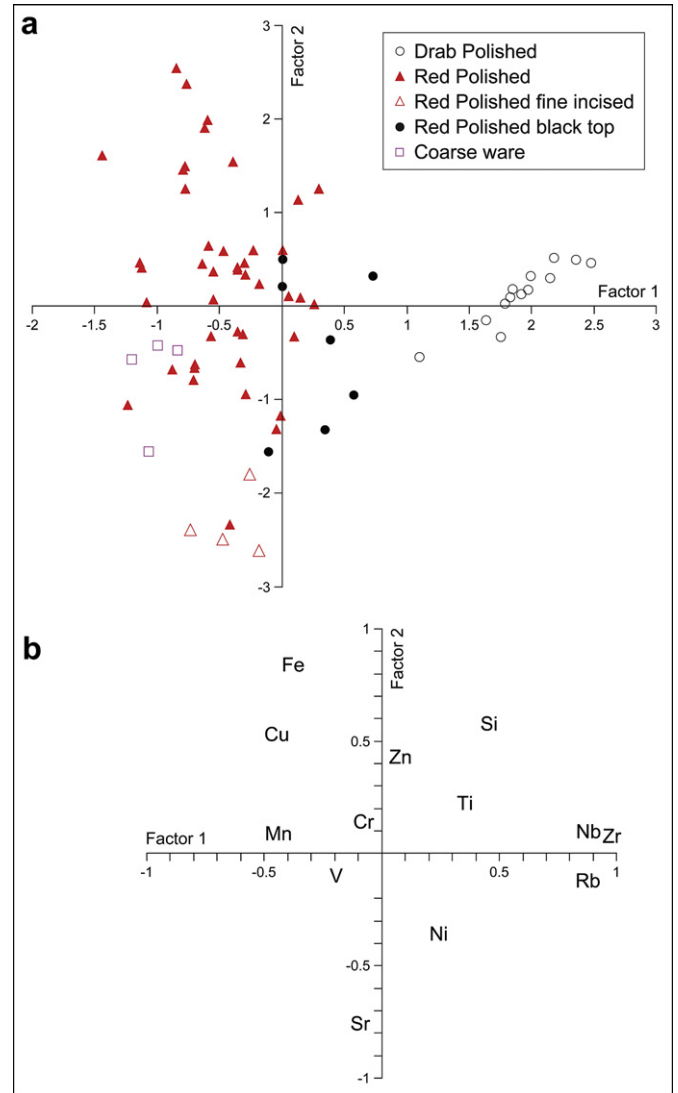


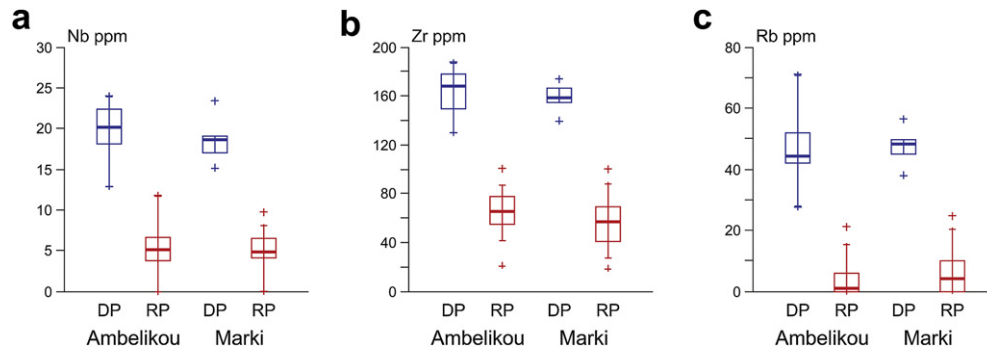
Fig. 5. PCA of pottery from Marki. a. Plot of the first two components, b. Factor scores of significant elements.

monochrome RP vessels) differ from the generic RP and Coarse ware bin or basin fragments (essentially immovable facilities). In this case, however, this may not mean that they were brought in from elsewhere. Unlike Ambelikou, Marki is situated at the interface of the igneous Troodos massif and the sedimentary formations of the central lowlands. A variety of clays were available in the immediate vicinity and potters here may have deliberately selected and prepared finer, more calcareous clays when manufacturing finely incised vessels (for a more complete discussion, based on data from Electron Microprobe Analysis, see Summerhayes et al., 1996: 179–180).

### 3.5. DP ware from Ambelikou and Marki

At both Ambelikou (Section 3.2) and Marki (Section 3.4) the rarer DP samples separate from the majority of RP vessels. In both cases the PCA indicates that the main factor is the higher concentrations of Zr, Nb and Rb. The similarity in the relative quantities of these elements for both the DP and RP samples is shown in Fig. 6. While there is as yet insufficient evidence to argue for a specific manufacturing centre, this suggests considerable homogeneity for the clays as well as the





**Fig. 6.** Box-and-whisker plots of concentrations (ppm) of four elements demonstrating the similarity of imported DP at the two sites and their difference from locally produced RP.

technology and shapes of DP. In discussing the results of Neutron Activation Analysis carried out by King et al. (1986), Knapp and Cherry suggest that similar indications of the homogeneity of clays used for DP in several river valleys in the southwest indicate production at a 'supralocal' level (Knapp and Cherry, 1994: 74–80). Unfortunately the dataset is not comparable to ours. Of the more significant elements only values for Rb are available (King et al., 1986; Knapp and Cherry, 1994: Table 4). The Rb values in ppm for the 11 DP sherds sampled (Knapp and Cherry, 1994: Table 4) are in the order of two to three times as great as those measured at Ambelikou and Marki. This may be due to a systemic difference in the techniques used, but if real then it suggests that the DP found at Ambelikou and Marki was not made in the same area as the DP vessels tested by King et al.

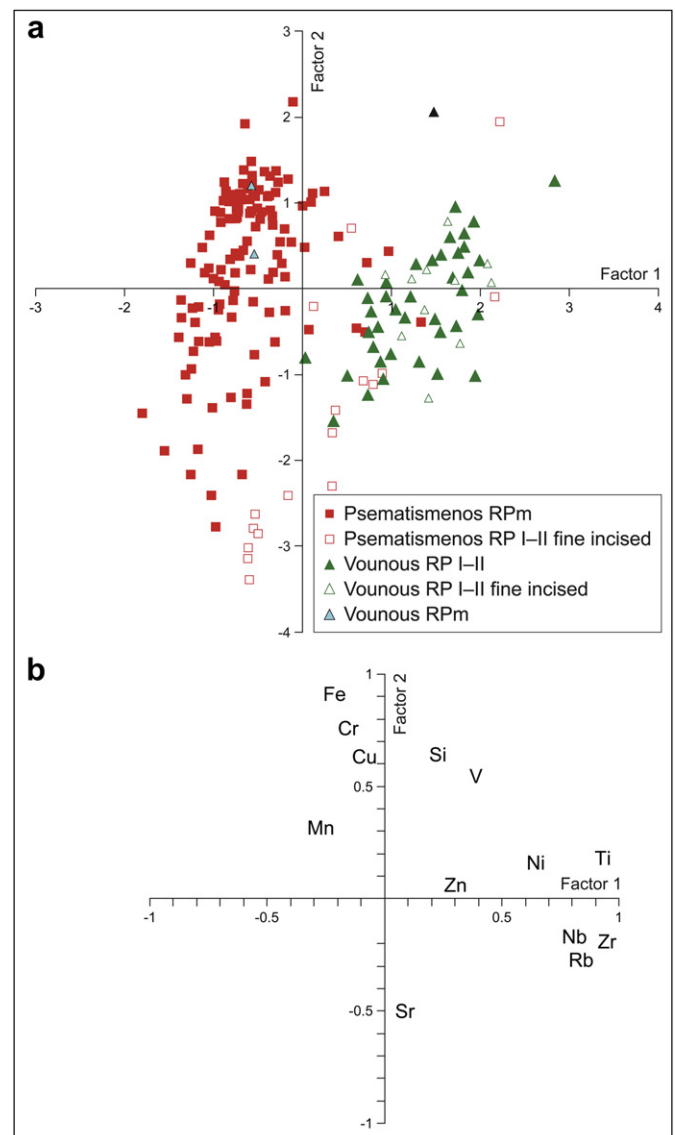
### 3.6. RP plain and fine incised vessels from Vounous and Psematismenos

Fig. 7 includes plain RP I–II and Rpm I–II together with finely incised RP I–II vessels from Vounous and Psematismenos. The major differentiation between the plain wares from these two sites seen in Fig. 2 is still evident. The finer incised RP I–II vessels from Vounous, however, fall within the same field as the plain RP I–II vessels. It is therefore possible to argue that all these vessels were made in the same production area, at or near Vounous. The situation is different with the samples from Psematismenos. Here the finer, incised RP I–II vessels are made of significantly different clays from the plain, utilitarian Rpm I–II. The decorated vessels are all small flasks which are also technologically different from the more common hard-fired, gritty mottled ware. They are unlikely to have been made at Psematismenos and may have been brought to the site as containers, perhaps of a substance or substances associated with burial rites, or for their intrinsic value (Georgiou et al., 2011: 263, 336; Eccleston et al., 2011: 269, Figs. 4.9, 4.11). Similarly, two small bowls of Rpm I–II found at Vounous are both typologically and technologically like those from Psematismenos and other sites in the centre and south of the island and are made of similar clays. These vessels are undoubtedly imports to the north coast from the centre or south. They were clearly, however, not moving as containers and so represent some other type of exchange or interaction.

## 4. Varied forms of interaction

The results of these analyses clearly demonstrate the value of pXRF, especially where there is a good match between expectations based on conventional typological and stylistic analyses and this characterisation of the elemental composition of the clays. The several analyses of sub-sets of the XRF data provide valuable insights into different aspects of pottery production and distribution. In

particular, the identification of imported vessels is important for understanding the extent to which pottery was moving between regions and establishing the contemporaneity of vessel types and the sites in which they have been found.



**Fig. 7.** PCA of plain and decorated finer wares from Vounous and Psematismenos. a. Plot of the first two components, b. Factor scores of significant elements.

It is generally understood on stylistic and technological grounds (e.g. Frankel, 1974; Frankel and Webb, 2007) as well as through archaeometric analyses (e.g. Dikomitou, 2007) that for most of the Early and Middle Bronze Age in Cyprus most pottery vessels were made and used within local communities, although some regionally distinctive wares were distributed away from their place of manufacture. Elsewhere we have argued on the basis of breakage and replacement rates that pottery at Marki and other sites was produced at a level of elementary specialisation (Frankel and Webb, 2006: 152), rather than at a household level (Frankel, 1974, 1988; Frankel and Webb, 1996: 110–111) or by more specialised producers (Stewart, 1962: 290; Herscher, 1978: 736).

The predominantly local production and consumption of pottery would appear to be confirmed by the results of the analyses presented here. It is also clear that some particular wares and vessel types were imported. This is most obviously the case with the DP vessels which appear to have been routinely transported in small numbers from one part of the island to another in the EC and MC periods. They are not present, however, in either of the two EC I–II data-sets examined here and do not appear to have been moving beyond their production area in the west prior to EC II. As the majority of DP vessels at Marki, Ambelikou and elsewhere in the centre and south are medium to large-sized closed forms, this may have involved a trade in a specific commodity or commodities produced and consumed in some quantity. Other vessels, as noted above, may have been moving for different reasons. The small finely incised RP I–II flasks found in the tombs at Psematismenos were perhaps containers of more exotic substances (such as precious oils or opium). The small undecorated Rpm I–II bowls which made their way northward from the central lowlands or south coast to Vounous are likely to reflect a different perhaps more personal context of interaction.

The copper-mining village at Ambelikou, while producing a full range of well-made RP III vessels, also imported some finer, decorated items. The small juglets in this group may have been containers of rare substances, but the incised bowls must again represent some other form of interaction. However, unlike the plain Rpm I–II bowls imported to Vounous, these are not everyday items but are of higher quality and presumably of some intrinsic aesthetic or social value. Together with the more regular flow of medium to large DP containers, this suggests that Ambelikou maintained a complex set of connections with other sites and regions of the island which reflect different contexts of interaction and multiple motivations. While the finer RP III juglets and small bowls are likely to have come from areas to the north, the DP vessels and their contents reached Ambelikou from the west, quite possibly by sea. In both cases the linkages and exchange networks are likely to have been built around the distribution of copper from the Ambelikou ore-body. Further analyses using different approaches on a wider sample of vessels from these and additional sites, however, will be required to test and develop these suggestions.

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## Appendix. Supplementary data

Supplementary data related to this article can be found online at doi:10.1016/j.jas.2011.12.032.

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