Mediterranean Archaeology and Archaeometry, Vol. 3, No1, pp. 13-30

ATTIC POTTERY PRODUCTION, IMPORTS, AND EXPORTS DURING THE MYCENAEAN PERIOD BY NEUTRON ACTIVATION ANALYSIS

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Received: 8-11-2002
Accepted: 25-2-2003

ABSTRACT

A set of 224 Mycenaean pottery samples from different sites in Attica, mainly from the Acropolis at Athens, Alimos, Perati, and Vourvatsi, was analysed by Neutron Activation to determine the locally produced and the imported ware types. Several new chemical reference patterns of workshops in Attica could be established. But, unexpectedly, during the Early Mycenaean period, represented by pottery from the south slope of the Acropolis at Athens, only a small number of the matt painted and unpainted vessels was produced locally, whereas the fraction of imported vessels identified by already known compositions is unusually high. The main part of the matt painted wares and the cooking vessels have patterns assigned to Aegina and were found to be imported from there. In contrast, the Early Mycenaean painted wares excavated at the south slope of the Acropolis come from the Peloponnese. Only in the subsequent Mycenaean periods local pottery production seems to begin at a larger scale in Attica and the number of imports decreased.

KEYWORDS: Ceramics, Provenancing, Bronze Age, Acropolis, Argolid, Aegina

INTRODUCTION

Provenancing of pottery by comparing its concentrations of mainly minor and trace elements is an old and well established method (Perlman and Asaro 1969; Jones 1986). There is general agreement today, that the elemental patterns in pottery characterize the clay pastes, which have been prepared by the ancient potters using a specific processing recipe. To produce a certain type of ware the potters seem to have followed a workshop-tested procedure, taking clay from one or several deposits, mixing it, levigating it, adding tempering material etc. Since, generally, this recipe was applied for longer periods of time, all products belonging to such a production series may be recognized

by the similarity of this elemental composition. Elemental changes by the firing are proven to be negligible for nearly all elements generally used for the comparison (except Br, Cogswell *et al.* 1996, and As). Also alterations due to long time periods of burial in the ground are rare and concern only a few elements like Ba, Ca and sometimes the alkalines (Buxeda 1999; Buxeda *et al.* 2002; Schwedt *et al.*, in press). If the elemental compositions are measured with high precision and comprise a large number of elements (≥ about 20), then the probability to find a similar elemental pattern in workshops of different regions is very small, i. e. the scatter of concentrations in a certain paste can be assumed to be smaller than the scatter in different pastes (Mommsen 2001a). This is a new formulation of the 'provenience postulate' (Weigand *et al.* 1977, p. 24) considering now potter's pastes instead of clay sources: the variability among different pastes must exceed the variability within a given paste.

To summarize, since chemical analyses determine clay paste compositions, which are the result of the refinement techniques employed by the ancient potters including a possible mixing of different raw clays, such raw clays taken directly from deposits will usually disagree in composition and, therefore, generally can not be used as reference material to determine provenance. Only potters clay or kiln wasters excavated in workshop areas will directly point to the origin of vessels. An analysis of raw clay samples helps only in very rare cases of ready to be used deposits and is not any more considered to be important.

In this paper we present the chemical patterns measured by Neutron Activation Analysis (NAA) in pottery of the Mycenaean time period excavated at several Attic sites. Sherds with similar compositions are placed in chemical groups. It will be discussed which of these groups belong most probably to a local Attic production and which can be assumed to be imported from neighbouring regions like Aegina or the Argolid. If the chemical grouping is compared to the archaeological classification of the sampled sherds and vessels according to ware types, decoration and production dates, new facts concerning the pottery production in Attica during Mycenaean times can be deduced.

SAMPLE CHOICE AND DESCRIPTION

During the last years data of a large number of samples from Attica have been accumulated in our Mycenaean data banks. Most of these samples have been taken in the years 1995-97 during visits of the magazines of different Museums in Greece as part of an ongoing project: Pottery production and distribution of Bronze Age settlements in Greece and the Aegean (Mommsen *et al.* 1995; Maran *et al.* 1997). The sherds and vessels sampled are in the possession of the Acropolis Museum (laboratory label Akro) and the National Archaeological Museum (label Kopr, Ligo, Pera, PRaf, Vour) at Athens, the Archaeological Museum at Piraeus (label Alim) and the Akademisches Kunstmuseum Bonn (label Ath, Eleu, Thor). The altogether 224 Mycenaean pottery sherds under investigation here have been excavated at different sites in Attica as indicated by the labels. The main part stems from the urban area of modern Athens, from the Acropolis excavations (label Akro 1-15, 17-41, 62-84), from the Early Mycenaean Well Z on its south slope (Akro 42-61, 85-100), from Alimos (Alim 1-44) near the old airport of Athens and from the Mycenaean tombs near Vourvatsi (Vour 1-28) situated not far from Alimos in direction to Cape Sunion. Samples from central/eastern Attica come from the sites Ligori, Kopreza, Perati, and Porto Rafti. Only a few samples from other parts are present (southern Attica: Thorikos, western Attica: Eleusis). The location of these different sites is indicated in the map given in Fig. 1.

The sherds cover a time period from the Middle Helladic (MH) to the Late Helladic (LH) period (2nd millennium BC). Most of the sherds from Well Z have been published by Mountjoy (1981) and are dated to the per-

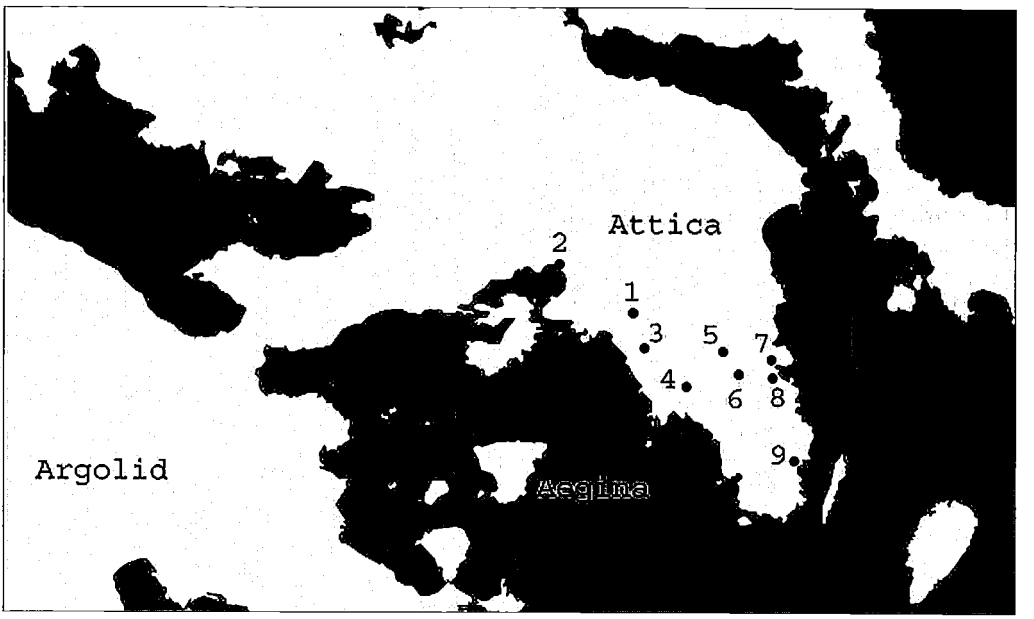

Fig. 1: Map of Attica and the location of the sites sampled (1 Athens, 2 Eleusis, 3 Alimos, 4 Vourvatsi, 5 Ligori, 6 Kopreza, 7 Perati, 8 Porto Rafti, 9 Thorikos)

iod LH IIB-IIIA1. The concordance of our labels and Mountjoy's catalog numbers is given in the appendix. The chamber tomb cemetery at Vourvatsi was abandoned after the destructions of the end of LHIIIB. From Perati a number of whole vessels dated to the LHIIIC period has been sampled.

ANALYTICAL PROCEDURE AND DATA EVALUATION

The Neutron Activation Analysis (NAA) procedure applied since many years in Bonn is a modified version of that given by Perlman and Asaro (1969) and is described at length in Mommsen et al. 1991. Pottery samples of about 80 mg are taken by drilling with a sapphire pointed drill usually at the back of the sherds. We analyse, if present above the detection limits, up to 30 minor and trace elements in these samples. Quantitative concentration values are obtained by comparison with our own pottery standard which is calibrated against the well known Berkeley pottery standard (Perlman and Asaro 1969). Therefore, our results can be directly compared to the data of the Berkeley group (Mommsen *et al.* 2002).

The chemical patterns of groups of samples with similar composition were obtained by a statistical filtering method developed in Bonn using a modified Mahalanobis distance as dissimilarity measure (Beier and Mommsen 1994). In contrast to the well-known cluster analysis methods resulting in dendrograms this filter method has several advantages, which turned out to be very important to form reliable groups of pottery of similar composition. It takes into account individual elemental measuring errors of the samples and the calculated spreads (root mean square deviations) of the groups formed. In addition, corresponding to the use of concentration ratios, all constant shifts of the measured values are corrected as well by this method. They occur due to experimental errors (technical dilutions like weighing errors) and to pottery making practices, i.e. varying dilutions of the pastes

by mainly non-plastic parts like sand or calcite. This statistical filter method is also able to consider elemental correlations, but it is usually applied in Bonn in its simple form neglecting correlations (Mommsen *et al.* 2002).

Since our databank of Greek samples contains now more than 4000 samples, only 'core' groups, i.e. groups of samples with spreads of a few percent (Mommsen 2001a), are formed in order to separate different pastes. In statistical descriptions each sample usually is represented as a point in the m-dimensional space of elemental concentrations, where m is the number of elements and each dimension corresponds to the concentration value of one element. Groups of samples of similar composition form clouds of neighbouring points in this space. If associated samples, which do not agree very well in one or two of the concentration values and which are located in the fringe areas of the clouds are added to the groups, larger spread values around the center point of the clouds which is given by the average group concentrations are obtained. This often results, considering the large number of samples in our bank, in a partial overlap of neighbouring groups known to represent different pastes. The formation of core groups avoids this unwanted result during the filtering procedure, but it has the consequence, that often not only one, but several closely related and chemically not very different groups are obtained, if the material from a small geographical region is investigated. In other words, instead of forming one chemical pattern for an extended cloud of points covering a large volume in concentration space, several core patterns are defined belonging to a number of smaller possibly adhering clouds and filling a smaller, reduced volume as indicated by the lower spread values. The interpretation of the presence of such core groups depends on the archaeological classification of the core group members. It might reflect only small recipe changes during the paste preparation in a workshop over time, but it also might point to a totally different production area, if by chance chemically very similar pastes in workshops in different regions are processed. Meanwhile, the second case was found for local material from the Argolid, Achaia, and Troy, which could only be separated statistically using the core group procedure (Hein *et al.* 2002, Mommsen *et al.* 2001b).

RESULTS AND DISCUSSION

The statistical investigation of the 224 samples from Attica using the filter method revealed the presence of three large clouds of points in different areas of the concentration space, each subdivided into several core groups. This distribution of points is also demonstrated in Fig. 2, which shows the result of a discriminant analysis of 177 samples assuming these 3 groups using 22 elements (all given in the Tables without As, Ba, Ca, Ga, Na, W, Zn, Zr because of missing concentration values). Before, the data have been corrected for dilution by a best relative fit to the group mean values. With very high probability the largest cluster of 123 samples represents the locally produced wares, as will be shown below, whereas the two other groups of 24 and 30 samples, respectively, are imports to Attica from Aegina and the Peloponnese. The average concentration values M and the spread values ì of the local group and the 2 import groups are given in Table 1. All associated group members as defined above are included here in these large groups, which characterize many different pastes in each of these areas. The often large spread values point to the presence of subgroups.

The large group assigned to Attic production workshops will be described first. It consists of 11 core groups. The average concentration values M and the spreads ì of these 11 groups are given in Table 2. The 4 patterns named KRO-N, -P, -Q, and -S are chemically not very different. KRO-N has on the average 10 % higher concentrations compared to the other KRO-patterns with the main difference of a lower Cr value. Pattern KRO-Q differs from KRO-P by lower Ce, Ta, and Th values,

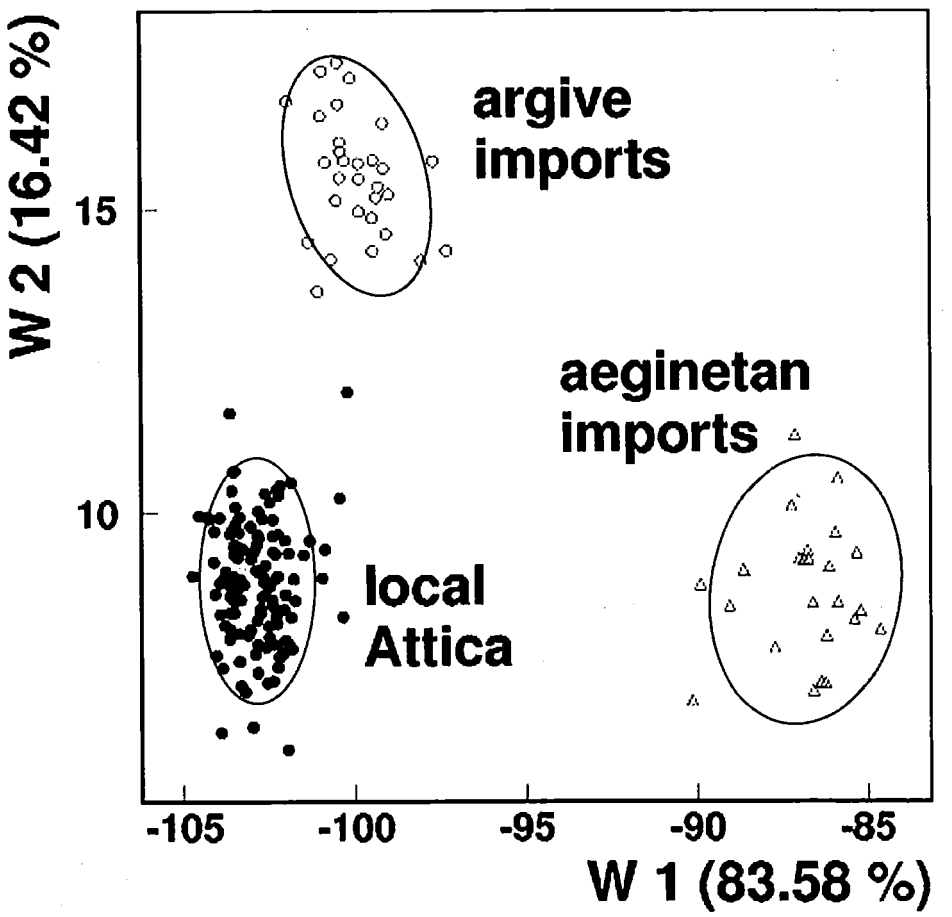

Fig. 2: Discriminant analysis of 177 samples of Mycenaean sherds from sites in Attica assuming 3 groups. Associated samples are included. Plotted are the discriminant functions W1 and W2 which cover 83.6 % and 16.4 % of the beween-group variance. The ellipses drawn are the 2ì boundaries of the groups.

KRO-S by lower Co and Ni and higher Hf values. Core group KRO-N is also by archaeological arguments separated from the other KRO-groups (see below). This supports our schema of the formation of core groups with low spread values. The other three KRO-groups can archaeologically not be distinguished. Further core groups in the local Attic set are the PER-A, -B, -C, and -D patterns found mainly in sherds from Perati. These four chemically again very similar groups have generally about 25 % lower concentration values compared to the KRO-groups. PER-C differs from PER-A only by a higher Cs value, whereas for PER-B and PER-D the Cs concentrations are much lower. There are further small differences between these core groups, as can be seen from the concentration values given in Table 2. If the dilution of the PER-groups is corrected, they move to the same general region of the multidimensional concentration space as the KRO-groups. Also in this region

of the concentration space are the patterns named VOUV, ALIN and VLIM, which contain not many members. The result of a discriminant analysis of the 123 samples assuming 7 groups in this first cluster is shown in Fig. 3 (calculated as Fig. 2). It serves again as example to demonstrate the separability of the core groups formed by the filter method. To avoid the necessity to show higher order results, the groups KRO-P and -Q and -S, PER-A and -C, and PER-B and -D have been unified for this calculation.

We now turn to the question why we can assign these patterns to production places in Attica. If no well-defined reference material like kiln wasters is present, one usually has to rely on distribution arguments. So, based initially on such arguments only, the largest group of 72 samples consisting of the four core groups KRO-N, -P, -Q, and -S and also the PER-groups (25 samples) have been assumed to represent the pastes used by Mycenaean Attic potters. But since provenancing by distribution arguments is not very stringent –by chance, the sherds sampled at a site could all be imports–, we sought after further arguments for a local production of these wares. Recently, Mycenaean data of sherds from the site Perati measured in the Berkeley laboratory and part of the Perlman-Asaro data bank have been evaluated in Bonn (Mommsen *et al.* 2002). For this set of sherds a chemical group called PERP (Perati-Perlman) could be formed. If it is compared to our Attic groups, it is found to be very similar in composition to our groups of samples from Perati (groups PER-, PER-A fits best), if for group PERP a dilution factor of 0.88 is applied. This chemical similarity of the now larger set of sherds from Perati was encouraging, it supports the use of the distribution argument: the PER-patterns seem to belong to the production site Perati. In addition, the assignment of the KRO-patterns to Attica is now backed also by a recent investigation of sherds from Ionia. A sample of a black figured colonette krater found at Smyrna dated to 560/550 BC has the KRO-P pattern. It is stylistically described as Attic import to Smyrna, as a piece of art of the Attic painter of London B76 (Tuna-Nörling 1995, Kat. 186). According to the provenience postulate it can be concluded, that the krater was produced with the same paste, which was used by Mycenaean potters much earlier. Furthermore, a number of sherds of the so-called Attic-Protogeometric ware found at Ephesos and archaeologically ascribed to a presumably Attic provenance match the KRO-patterns also. All this, *vice versa*, confirms with high probability that the pottery composition of the whole cluster can be assigned to Attic production workshops, the KRO-patterns presumably to the region of modern Athens. A larger number of export pieces of the KRO-workshop(s) is found in our databank not only in Ionia during the geometrical and classical periods, but also in Aegina at earlier times (Mommsen et al. 2001c). The KRO-P pattern was identified in 16 samples from there, eight sherds belong to the Mycenaean (LH) times and are contemporary to the sherds from the Acropolis, but eight other samples of fine and medium fine ware date to the Early Helladic (EH) II period. These early export pieces from Attica have about 13 % higher concentrations, comparable to the Early Mycenaean pattern KRO-N. In our sample set from Attica no EH material is present for comparison.

For the three small groups VOUV, ALIN and VLIM of the cluster the assignment to Attica is only preliminary. But until now no piece with these patterns has been found outside Attica. Pattern VOUV is identified in pieces from many different Attic sites. The workshop using paste VOUV exported its products throughout Attica, whereas the pastes represented by the patterns ALIN occur at the site Alimos only. Pattern VLIM has its geographical centre with six pieces in Vourvatsi, only one sherd with this composition was found in Alimos. But the number of samples of these small groups is to low to locate the corresponding workshops with high probability by distribution arguments.

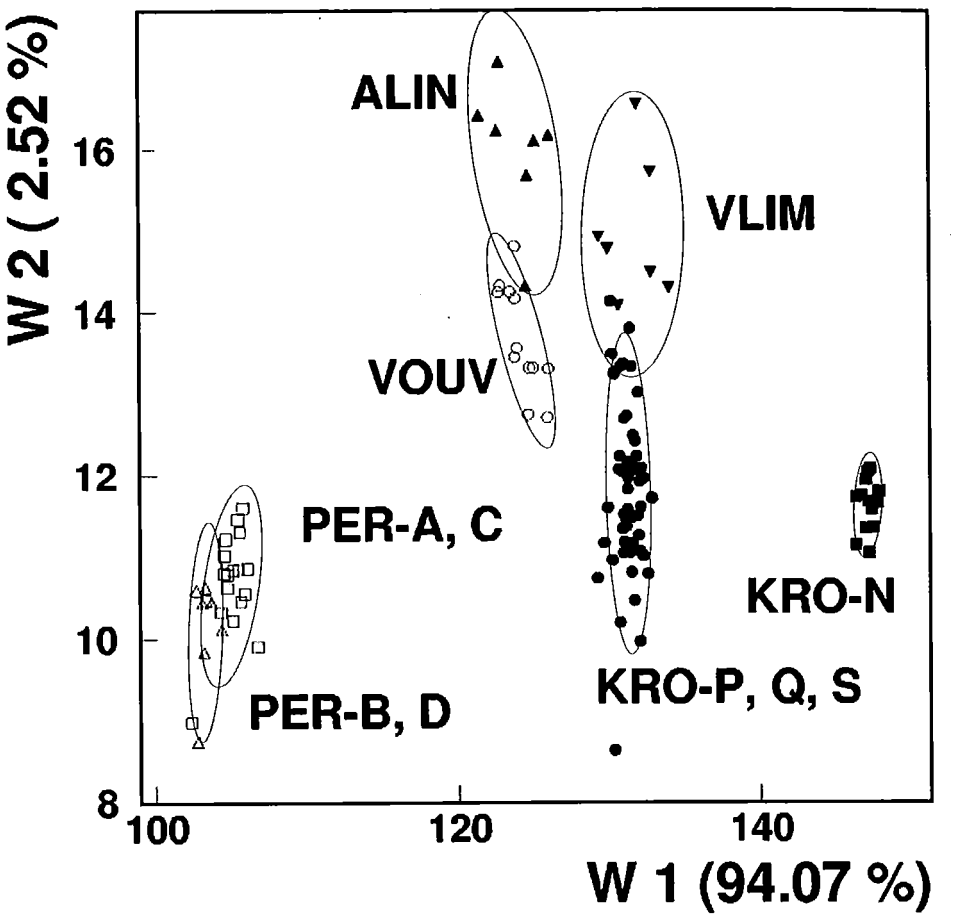

Fig. 3: Discriminant analysis of 123 samples of the local Attic cluster assuming 7 (core) groups (see text). Associated samples are included. Plotted are the discriminant functions W1 and W2 which cover 94.1 % and 2.5 % of the between-group variance. The ellipses drawn are the 2 ì boundaries of the groups.

Besides these chemical core groups of the Attic cluster just described several other (core) compositions were identified which already are known to us and which have been assigned before to different production workshops outside Attica. The 30 samples altogether of the second cluster have a composition of one of the core groups from the Argolid. The argive patterns MYBE and MBKR, assigned to the workshop at Berbati, and AEGD (= EMBP in Mommsen et al. 2002), first identified in Aeginetan import pieces, have been found (Mommsen et al. 1988, Buxeda et al. 2002, Mommsen *et al.* 2001c). Meanwhile, these patterns are secured by many investigations including wasters from Berbati, so that there is no doubt that these pieces are brought to Attica from the Peloponnese. The already mentioned evaluation of NAA data of Mycenaean sherds measured in Berkeley resulted in the same groups for the set of sherds from the Argolid (Mommsen *et al.* 2002). In this second cluster a new, presumably also argive

core group with enhanced K, Rb, and Cs values compared to pattern MYBE was noticed in the Mycenaean pottery of well Z (Akro 43, 47, 57, and 61 associated).

The third cluster of 24 samples is made up of imports from Aegina (Mommsen *et al.* 2001c). The Aeginetan pottery products can often be identified already macroscopically by the presence of small inclusions of golden blinking mica (biotite) (Harland 1925, WÌnsche 1977). The two known main chemical patterns of Aegina, called AEG-A and AEG-P in Mommsen et al. (2001c) are located in this cluster. Pattern AEG-A is present at Aegina in many ware types, which have been produced locally there. The Aeginetan Red Slipped and Burnished ware (MH - LHII), the matt painted ware (MH - LHII), and many vessels from Aegina imitating the Mycenaean LHIII ware have this composition. From the Acropolis excavations (Akro 62 - 84) 10 of the 17 matt painted sherds were identified with this pattern AEG-A (cp. Table 3, line 1). The core pattern AEG-P and the very similar composition AEG-F were found at Aegina mainly in the Aeginetan EHIII red/brown/black polished ware and in the well known Aeginetan cooking pots of the MH - LHI periods, which are known to have been exported to many different places (Mommsen *et al.* 2001c, Zerner 1993). At Attica five of the six cooking vessels sampled from the Acropolis excavations (Akro 63, 75, 77-79) have these Aeginetan patterns and therefore. are classified to be imports from Aegina, the 6th cooking pot (Akro 76) is a chemical loner.

It is remarkably, that about a quarter of the vessels analysed are import pieces from the Argolid or Aegina. Only 3 more pieces, a painted skyphos (Akro 19) and an unpainted base (Akro 4) from the Acropolis and an undetermined piece from Thorikos (Thor 2) are imports from Boeotia, another vessel from Thorikos (Thor 8) found its way from Melos to Attica. The remaining 43 samples are not assignable to a group, they are all chemical singles and therefore either wrongly measured, contaminated or manufactured of an hitherto unknown paste. About 15-20 % of chemical singles are usually found in a chemical classification.

A conspicuous result is obtained, if the sampled Attic sherds are grouped according to their time of production (see Table 3). The oldest vessels stem from the Acropolis excavations at Athens and are cooking and matt painted vessels (Akro 62-84). As mentioned above, the cooking wares are all identified to be imports from Aegina (except one chemical single). Also most pieces of the matt painted ware have been produced at Aegina, only three sherds are locally produced and show pattern KRO-N. The sherds of Well Z from the south slope of the Acropolis, a rare settlement deposit including the domestic wares, are according to Mountjoy (1981) dated to the periods LH IIB - IIIA1. The only matt painted sherd sampled (Akro 45) from this well is also an Aeginetan import, whereas 11 unpainted sherds, mostly matt monochrom and/or burnished goblets (Akro 90-100) all are locally made and found to have also pattern KRO-N. However, none of the Mycenaean sherds from the well shows this composition, they are all imported from the Peloponnese except three singles and one sherd (Akro 59, a rim of a carinated cup) which was identified having pattern VOUV of still unknown, but very probably Attic provenance. During this Early Mycenaean time the pottery production in Attica seems to have been restricted to matt painted and unpainted wares, the sampled products of higher quality have the MYBE or related patterns, they are all imported. However, we state this result with some caution. Mountjoy (1981) assigned the Early Mycenaean material from Well Z to a local production. As already mentioned, in Achaia, a paste very similar in composition to the argive pastes was used (Hein et al. 2002) and even far away, in Troy, again a not very different pottery composition compared to pattern MYBE occurs (Mommsen *et al.* 2001b). The Attic potters might have been successful in locating a chemically similar clay deposit in Attica, if it exists also there, and might have used it. But this seems not very probable without an explanation why

they have stopped producing pottery with this appearently well suited paste in the following LH III periods (samples Akro 1-41 without 16, missing). Now, during the palatial period, the Attic patterns KRO-P,- Q,- S prevail which presumably are a paste variation of the paste KRO-N of the Early Mycenaean period. Although the number of Attic samples analysed is still very small, the potters seem to have rediscovered the recipes used for paste preparation in the EH periods, since the KRO-P pattern was already identified, as mentioned above, in EHII wares at Aegina. Three quarters of the 40 sampled LHIII sherds, a mixture of different painted and unpainted types, have the KRO-compositions and, therefore, are locally produced, none was identified as import from the Peloponnese during this period. The vessels analysed from the cemetery at Vourvatsi (28 pieces) are known to be dated not later than LH IIIB. Six of these samples have been also produced with paste KRO-P, -Q, or -S, but here again imports from the Peloponnese are present and also the other presumably Attic pastes VOUV and VLIM can be identified. To produce the set of 28 vessels analysed from Perati a different paste variation of the KRO-patterns was employed which now was diluted by about 25 %. The occurrence of these new PER-patterns might be due to one or several local workshop(s) at Perati or it might be a paste variation used in Attica during the late period LH IIIC. A few pieces with the PER-patterns were identified also at other Attic sites. But at Perati no import vessels from other known sites are found during this late time periods. However, the high number of chemical singles at Perati points to imports from still unknown sources. If the PER-patterns are late in time, the one sample from Vourvatsi (Vour 2, PER-D) might have been arbitrarily made by a diluted paste in earlier times.

CONCLUSION

The set of samples from Attica analysed by NAA resulted in a number of chemical patterns, which, according to different arguments, can be assigned with high probability to local Attic production workshops. Although no definite reference material such as kiln wasters is present, the distribution of the group members with its accumulation in Attic sites and, in addition, the archaeological classification of single export pieces from Attica, which are not to be disputed, ensured this formation of reference patterns for Attica. Now vessels produced locally and exported from Attica can be classified archaeometrically.

The clay paste resulting in the main Attic pattern KRO-P and its variations, assigned to the area around the Acropolis at Athens, was used by local potters during a long time period. It is identified earliest in EHII import wares found in Aegina, next in LH pottery from the Acropolis and Alimos excavations, in protogeometric export vessels from Attica to Ephesos and also in a colonette krater of a known Attic painter dated to the 6th century BC found in Ephesos. More work especially on EH material from Attic sites is needed to prove the processing of the KRO-P paste in Attica itself and to locate the exporting workshop during this period. At the moment this can be concluded only from the chemical similarity of sherds of the EH periods found at Aegina. Also the gap in the occurrence of this pattern appearing during the MH and Early Mycenaean periods should be filled or ascertained by additional analyses. It is noticeable that during these periods only the Attic KRO-N pattern was identified for the matt and unpainted wares, whereas for the cooking vessels imports from Aegina and for the painted Early Mycenaean wares of higher quality imports from the Argolid prevail. However, during the following Mycenaean periods local production seems to replace the imports, if our set of samples is representative. Another chemically not very different group of related patterns (PER-) can be assigned to Perati in eastern Attica. The corresponding pastes were used there during the LHIIIC period as proven also by NAA data in a Mycenaean databank of the Berkeley archaeometry group.

ACKNOWLEDGEMENTS

This work was made possible by the commitment of J. Maran, who organized and prepared the travels to Greece and who chose the pieces to be sampled. We thank him very much for it. We are grateful also to all the Greek colleagues who contributed to this project and gave the permission to take the Attic samples in the different Greek magazins, especially to Dr. K. Demakopoulou (former director of the National Museum Athens), Mrs. Ch. Vlassopoulou (Ephor of the First Ephorate of the Greek Antiquity Service) and Mrs. K. Kaza (Second Ephorate). We also thank Dr. P. Mountjoy who acted as our advisor in selecting the pottery sherds. The help of the staff of the research reactor in Geesthacht irradiating the samples is thankfully acknowledged. The work was funded partly by the German Federal Minister of Education, Research, Science and Technology (BMBF) under contract No 03PO9BON.

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Table 1: Concentrations of elements of the 3 regional groups identified in the set of Attic samples: Average values M in Æg/g (ppm), if not indicated otherwise, and spreads ì in percent of M, corrected for dilution using all elements except As, Ba, Ca, and Na. All associated samples are included here.

	local Attica (11 core groups) 123 samples M +/- σ (%)		imports Aegina (6 core groups) 24 samples M +/- σ (%)		imports Argolis (6 core groups) 30 samples M +/- σ (%)	
As	37.9	43.	26.0	71.	40.2	97.
Ba	433.	21.	482.	38.	358.	30.
Ca %	7.05	50.	6.46	63.	8.79	22.
Ce	58.5	9.6	54.6	13.	62.0	3.1
Co	34.2	13.	19.3	18.	27.4	8.3
Cr	531.	21.	268.	61.	218.	10.
Cs	16.2	40.	5.74	21.	10.1	20.
Eu	1.09	6.2	1.06	10.	1.11	3.5
Fe %	5.16	9.0	4.47	5.1	5.19	4.5
Ga	20.0	38.	13.6	49.	20.6	57.
Hf	4.15	12.	4.75	8.3	3.56	8.2
K %	2.38	13.	1.92	17.	2.83	21.
La	26.7	8.8	25.2	13.	30.6	3.9
Lu	0.41	7.0	0.38	7.5	0.43	4.9
Na %	0.63	30.	1.30	30.	0.66	27.
Nd	23.7	14.	21.2	16.	25.3	13.
Ni	424.	19.	207.	63.	223.	22.
Rb	129.	11.	82.9	9.6	154.	9.1
Sb	1.41	34.	0.70	37.	0.71	22.
Sc	21.7	5.6	17.3	9.9	21.4	3.9
Sm	4.68	7.3	4.18	14.	4.45	5.3
Ta	0.77	7.8	0.72	6.9	0.80	5.3
Tb	0.68	7.1	0.62	12.	0.67	7.2
Th	9.82	7.4	9.20	12.	11.0	3.8
Ti %	0.46	23.	0.33	15.	0.43	14.
U	2.24	14.	2.16	19.	2.43	12.
W	2.03	21.	1.60	17.	2.27	16.
Yb	2.59	5.5	2.50	9.8	2.68	2.2
Zn	119.	19.	85.9	15.	114.	18.
Zr	177.	31.	200.	16.	148.	29.

Table 2: Concentrations of elements of the NAA core groups in local Attic sherds: Average values M in µg/g (ppm), if not indicated otherwise, and spreads σ in percent of M, corrected for dilution (as for Table 1); associated members are left out here.

	KRO-N 14 samples M +/- σ (%)		KRO-P 33 samples M +/- σ (%)		KRO-Q 10 samples M +/- σ (%)		KRO-S 7 samples M +/- σ (%)	
As	82.5	73.	35.2	50.	33.2	21.	32.5	52.
Ba	515.	20.	449.	14.	414.	19.	428.	21.
Ca %	3.06	27.	6.50	45.	6.54	21.	5.27	57.
Ce	74.2	2.0	66.0	4.8	58.9	4.9	60.9	6.1
Co	36.7	4.3	35.5	8.9	35.8	7.0	28.1	6.8
Cr	424.	3.3	543.	13.	609.	8.0	440.	9.1
Cs	11.4	3.1	13.9	19.	18.3	12.	15.6	14.
Eu	1.28	2.9	1.15	4.9	1.15	3.8	1.13	4.4
Fe %	5.87	2.1	5.00	7.0	5.48	5.9	4.63	4.5
Ga	22.3	60.	19.2	41.	26.2	26.	21.9	39.
Hf	4.52	3.9	4.51	12.	4.54	6.3	5.06	4.1
K %	3.08	1.8	2.56	8.0	2.51	2.9	2.60	12.
La	32.7	1.3	29.8	3.5	28.4	5.4	28.8	6.7
Lu	0.49	4.3	0.43	5.2	0.45	11.	0.44	5.6
Na %	0.78	11.	0.57	37.	0.69	9.6	0.69	19.
Nd	28.9	12.	25.7	13.	28.2	15.	28.1	16.
Ni	400.	4.4	412.	11.	435.	8.8	327.	5.3
Rb	157.	3.5	136.	7.6	134.	5.3	130.	15.
Sb	2.11	10.	1.29	24.	1.17	16.	1.16	16.
Sc	24.4	2.5	21.8	5.0	23.5	1.3	20.8	3.1
Sm	5.70	4.2	5.08	5.0	5.19	2.8	5.18	5.4
Ta	0.93	4.4	0.83	6.1	0.74	5.1	0.82	4.3
Tb	0.81	6.0	0.71	7.0	0.75	7.6	0.74	12.
Th	11.9	2.1	10.8	4.4	9.72	1.9	10.3	9.4
Ti %	0.47	5.9	0.45	20.	0.55	22.	0.54	21.
U	2.46	11.	2.43	14.	2.49	12.	2.41	15.
W	3.07	26.	2.23	17.	2.36	19.	2.07	13.
Yb	2.97	2.5	2.68	4.4	2.92	4.9	2.92	7.4
Zn	167.	8.7	115.	8.0	124.	3.1	109.	4.9
Zr	199.	13.	188.	34.	148.	56.	153.	65.

Table 2ff: Concentrations of elements of the NAA core groups in local attic sherds

	PER-A 9 samples M +/- σ (%)		PER-B 3 samples M +/- σ (%)		PER-C 6 samples M +/- σ (%)		PER-D 3 samples M +/- σ (%)	
As	42.7	28.	38.0	14.	34.5	25.	27.3	42.
Ba	342.	30.	336.	17.	340.	34.	–	
Ca %	9.00	38.	7.33	27.	8.87	16.	12.8	22.
Ce	45.0	5.5	46.9	6.2	45.2	5.0	40.9	3.8
Co	30.0	9.1	33.9	5.7	27.6	10.	32.1	10.
Cr	487.	9.6	449.	12.	462.	5.7	437.	2.0
Cs	20.7	12.	9.64	24.	29.5	5.2	11.9	8.9
Eu	0.92	6.0	0.93	3.5	0.97	3.9	0.91	2.6
Fe %	4.38	7.4	4.58	9.6	4.64	4.5	4.49	4.4
Ga	14.0	36.	31.8	93.	16.9	58.	12.2	13.
Hf	3.62	11.	3.64	19.	3.31	5.4	2.87	3.6
K %	1.62	9.1	1.15	6.3	1.57	11.	1.65	23.
La	20.5	4.8	20.9	3.4	21.5	5.4	20.4	2.3
Lu	0.35	8.7	0.36	6.5	0.35	13.	0.33	11.
Na %	0.69	32.	0.80	5.6	0.76	16.	0.55	24.
Nd	18.3	18.	19.6	16.	17.7	18.	19.3	15.
Ni	365.	13.	446.	7.3	381.	18.	441.	5.9
Rb	97.7	7.4	58.7	9.1	102.	7.1	83.6	16.
Sb	0.87	18.	1.05	39.	1.53	23.	0.98	19.
Sc	18.7	4.0	19.7	2.9	18.4	5.9	17.8	5.2
Sm	3.56	5.1	3.70	5.2	3.71	4.4	3.68	1.7
Ta	0.63	9.0	0.69	9.0	0.62	7.8	0.57	4.7
Tb	0.57	10.	0.61	7.1	0.59	6.8	0.53	8.4
Th	7.44	4.0	8.03	7.5	7.66	4.4	6.90	1.0
Ti %	0.36	27.	0.39	13.	0.36	20.	0.43	32.
U	1.77	19.	1.64	7.0	1.80	21.	2.03	10.
W	1.57	19.	1.50	22.	1.43	8.2	1.32	11.
Yb	2.21	3.7	2.27	5.0	2.18	2.1	2.10	2.0
Zn	83.8	16.	105.	20.	87.7	9.6	103.	37.
Zr	171.	14.	166.	20.	167.	19.	127.	21.

Table 2ff: Concentrations of elements of the NAA core groups in local attic sherds

	VOUV 11 samples M +/- σ (%)		ALIN 6 samples M +/- σ (%)		VLIM 6 samples M +/- σ (%)	
As	47.6	70.	28.2	58.	32.4	40.
Ba	528.	22.	408.	17.	461.	35.
Ca %	11.9	41.	6.04	20.	6.10	20.
Ce	52.6	8.2	51.5	1.5	59.0	4.4
Co	36.8	5.1	40.9	8.8	36.1	12.
Cr	643.	5.6	841.	13.	592.	8.0
Cs	12.9	8.3	15.1	15.	31.2	24.
Eu	0.99	2.8	1.01	3.5	1.12	4.1
Fe %	5.65	2.0	5.67	3.3	5.96	8.5
Ga	21.1	36.	22.2	22.	25.8	23.
Hf	3.75	6.1	3.98	2.7	3.78	4.9
K %	2.50	9.8	2.45	5.0	2.57	5.6
La	23.1	5.5	24.8	7.2	25.9	4.1
Lu	0.41	6.2	0.39	9.0	0.44	19.
Na %	0.44	31.	0.80	6.4	0.64	14.
Nd	21.3	9.2	22.4	14.	23.8	15.
Ni	480.	6.1	576.	3.1	535.	8.5
Rb	125.	5.7	138.	11.	165.	7.7
Sb	2.24	17.	0.97	15.	1.44	19.
Sc	22.6	2.8	22.5	1.3	23.1	5.4
Sm	4.28	5.4	4.69	4.1	4.61	2.0
Ta	0.77	5.0	0.67	5.7	0.79	4.1
Tb	0.63	7.5	0.68	10.	0.65	6.8
Th	9.98	3.1	9.08	2.0	10.3	4.9
Ti %	0.50	28.	0.53	21.	0.45	13.
U	2.15	10.	1.98	8.4	2.78	20.
W	1.66	14.	1.69	6.9	2.06	17.
Yb	2.46	3.0	2.44	7.0	2.54	2.3
Zn	146.	36.	106.	9.8	169.	23.
Zr	165.	37.	188.	30.	181.	15.

Table 3: Overview of grouping results of the 224 sherds from Attica: distribution of the sherds from different sites, periods, and ware types into the NAA groups
[KRO-N, -P, -Q, -S, PER-A, -B, -C, -D, VOUV, ALIN, VLIM = probable local Attic groups; AEG-A, -F, -P = imports from Aegina; MYBE, MBKR, AEGD = imports from the Argolid (see text); other = 3 from Boeotia(found at Acropolis and at Thorikos) and 1 from Melos(Thorikos); s = chemically ungrouped single]. Associated members (-) are added to the groups.

archaeological groups			NAA groups									totals
			local Attic groups						Aegina	Pelop.		
label	Site	description	KRO-N	KRO-P, KRO-Q, KRO-S	PER-A, PER-B, PER-C, PER-D	VOUV	ALIN	VLIM	(AEG-A. AEG-F, AEG-P, oth.gr.)	(MYBE, MBKR, AEGD, oth.gr.)	other	s	
	mod. Athens												
Akro	Acropolis	matt painted	3						10			4	17
(62-84)	(MH/LHI/II)	cooking pots							5			1	6
Akro	Well Z,	matt pain.(45),							1				1
(42-61,	south slope	unpain.(90-100)	11										11
85-100)	(LHIIB-	Mycenaean				1				20		3	24
	IIIA1)	(all other)											
Akro	Acropolis	pain.,unpain.,		30		4					2	4	40
(1-41)	(LHIII)	(16 miss.)											
Vour	Vourvatsi	before LHIIIC		6	1	4		6		9		2	28
Alim	Alimos	undet. LH		20	1	1	7	1	6			8	44
Ath	Athens	undet.		1						1		2	4
	central/eastern Att.												
Pera	Perati	LHIIIC			19							9	28
Ligo	Ligori	undet.				1						2	3
Kopr	Kopreza	undet.			4							1	5
PRaf	Porto Rafti	undet.										2	2
	southern Att.												
Thor	Thorikos	undet.							1		2	5	8
	western Att.												
Eleu	Eleusis	undet.		1		1			1				3
total no of sherds in NAA groups			14	50+(8-)	21+(4-)	11+(1-)	6+(1-)	6+(1-)	17+(7-)	25+(5-)	4	43	224
in the regional groups				108 + (15-) = 123					24	30			177

APPENDIX

CONCORDANCE OF CATALOG NUMBERS IN MOUNTJOY 1981 AND BONN LABORATORY LABELS

Mountjoy 1981 shows drawings of the Mycenaean sherds from well Z analysed here by NAA. The matt painted sherd Akro 45 is an Aeginetan import, Akro 49 belongs to NAA group VOUV, Akro 85 is a chemical single, Akro 43, 47, 57, and 61 form a new, presumably argive core group called MYBA very similar in composition to MYBE (see text), and all others are members of known argive core groups (MYBE. MBKR, AEGD).

Cat.No.	Akro	Cat.No.	Akro
276	45	310	50
285	89	316	54
289	49	325	56
293	87	334	59
296	51	344	58
298	86	350	55
300	43	351	52
303	85	353	60
304	46	355	57
305	47	360	48
306	42	362	61
308	53		

LIST OF GROUP MEMBERS, ASSOCIATED MEMBERS[-] AND INDIVIDUAL FIT (DILUTION) FACTORS [IN ( )] OF THE PRESUMABLY ATTIC GROUPS:

1. Group KRO-N of 14 samples:

Akro 67 (1.01), 68 (1.00), 82 (0.96), 90 (1.01), 91 (1.05), 92 (0.94), 93 (0.97), 94 (1.01), 95 (0.98), 96 (1.10), 97 (1.03), 98 (1.00), 99 (0.88), 100 (1.08)

2. Group KRO-P of 38 samples:

Akro 1 (0.85), 5 (1.12), 6 (1.01), 9 (1.02), 10 (0.97), 12 (0.93), 15 (1.11), 17 (0.98), 20 (1.10), 23 (0.92), 26 (1.05), 28- (1.11), 31 (0.97), 35 (0.95),
Alim 1 (1.01), 4 (1.00), 5 (0.97), 6 (0.99), 7 (1.02), 8 (1.02), 21 (1.01), 22 (0.99), 28 (0.98), 32 (0.98), 33 (0.90), 34 (0.99), 35 (1.00), 36 (1.00), 37 (0.99), 39 (0.92),
Ath 4 (0.96),
Eleu 3- (1.01),
Vour 4 (1.13), 5- (0.98), 8- (1.03), 18 (0.92), 23 (1.01), 28- (0.95)
(33 core samples + 5 associated samples (marked -))

3. Group KRO-Q of 11 samples:

Akro 2 (0.98), 8- (1.06), 13 (1.00), 18 (0.92), 21 (1.02), 22 (1.03), 29 (1.00), 30 (0.98), 33 (1.01), 34 (0.98), 36 (1.00)
(10 core samples + 1 associated samples (marked -))

4. Group KRO-S of 9 samples:
Akro 3- (1.01), 27 (1.10), 38 (0.90), 39 (0.91), 41 (1.05),
Alim 17 (0.97), 19 (0.95), 25- (1.25), 40 (0.88)
(7 core samples + 2 associated samples (marked -))

5. Group PER-A of 11 samples:
Alim 26 (0.86),
Kopr 1- (0.75), 5 (0.99),
Pera 1- (0.97), 4 (1.14), 10 (1.07), 16 (1.05), 18 (1.12), 20 (0.96), 25 (1.03), 27 (1.07)
(9 core samples + 2 associated samples (marked -))

6. Group PER-B of 4 samples:
Kopr 2- (0.87),
Pera 9 (1.04), 15 (0.97), 21 (1.14)
(3 core samples + 1 associated samples (marked -))

7. Group PER-C of 7 samples:
Pera 5 (1.12), 7 (1.05), 11 (0.95), 12 (0.93), 14 -(0.95), 19 (0.99), 23 (0.99)
(6 core samples + 1 associated samples (marked -))

8. Group PER-D of 3 samples:
Kopr 4 (1.06),
Pera 22 (1.00),
Vour 2 (0.95)

9. Group VOUV of 12 samples:
Akro 7 (0.99), 14 (1.14), 32 (0.89), 37 (1.04), 59 (1.00),
Alim 2 (1.06),
Eleu 2 (1.05),
Ligo 3 (0.98),
Vour 12 - (0.96), 14 (0.99), 17 (0.95), 21 (0.94)
(11 core samples + 1 associated samples (marked -))

10. Group ALIN of 7 samples:
Alim 3 (1.02), 9 - (1.02), 11 (0.99), 13 (0.94), 14 (1.05), 15 (0.99), 18 (0.99)
(6 core samples + 1 associated samples (marked -))

11. Group VLIM of 7 samples:
Alim 20 (0.99),
Vour 1 - (1.00), 13 (1.06), 15 (1.00), 16 (0.95), 19 (1.00), 26 (0.98)
(6 core samples + 1 associated samples (marked -))