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A Complete Chemical Grouping of the Berkeley Neutron Activation Analysis Data on Mycenaean Pottery

H. Mommsen,* Th. Beier† and A. Hein‡

*Institut für Strahlen- und Kernphysik, University Bonn, Nussallee 14–16, 53115 Bonn, Germany, *Atomfysik, Chalmers tekniska högskola och Göteborgs universitet, Fysik och teknisk fysik, SE-412 96 Göteborg, Sweden, and GSI, Atomic physics, Planckstr. 1, 64291 Darmstadt, Germany and †Laboratory of Archaeometry, National Centre for Scientific Research ''Demokritos'', 15310 Athens, Greece*

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The Perlman–Asaro data bank contains nearly 900 data sets of Mycenaean and Minoan sherds which were sampled in different regions of Greece and Crete. The data were obtained from Neutron Activation Analysis measurements at Berkeley in the 1970s, and for each concentration value a corresponding uncertainty of measurement was also recorded. Parts of the contents of the data bank have been published before. Here, we present the first complete statistical analysis of the whole data bank, considering measurement errors as well as constant shifts of the data due to pottery making practices (''dilutions''). We establish new reference patterns for different regions of Greece and Crete and compare the results with the contents of our own group data bank in Bonn. For those parts of the data which have been published previously, a comparison between these studies and our recent investigation is presented.

Keywords: NAA, CERAMICS, PROVENANCING, CLUSTER ANALYSIS, MYCENAE, BRONZE AGE.

Introduction

In the late 60s the archaeometry group in Berkeley established a Neutron Activation Analysis (NAA) procedure for provenance determinations of pottery from archaeological excavations (Perlman & Asaro, 1969). In the following years a large number of sherds from Late Helladic (LH = Mycenaean) Greece and also of contemporary periods of Crete were analysed there. However, results were published only to a small extent and incompletely, because (Asaro & Perlman, 1973): ''The question of provenience of the vast quantities of Mycenaean wares has proved perplexing'' (p. 213); (the problem of interpreting the data) ''is a gigantic puzzle which will require much labour to solve to the degree that is capable of solution'' (p. 219). Finally, Perlman himself assembled the data of 878 Mycenaean sherds after about 10 years. In 1985 he handed over his handwritten concentration lists to the Manchester archaeometry group (V. Robinson and A. Hoffmann) and also to E. French for further investigations. After creating a data-bank file by typing in all the numerical values, the Manchester group kindly made this Perlman–Asaro data bank (PA bank) available to us at Bonn in 1990, from where all numerical values are available on request. Since then, we have been using the whole data bank for comparison with some of our own results. Meanwhile, other research groups as listed in Table 1 have also published investigations based on the PA bank. In this Table an overview is presented about the contents of the PA bank. Displayed are the sample numbers ordered by sample site, together with data on archaeological time period and the measurement-run number in Berkeley. This information was transferred to Bonn partly by copies of the handwritten Berkeley lists, partly it was taken from references where the data or part of it have already been discussed. These 12 references are also listed in the Table 1. In these publications, individual concentration data of 28% of the bank (250 samples from the Peloponnese except the Argolid) have been published already. An archaeological description is given for 78% (688 samples) of the sherds of the PA bank. According to Tomlinson, 1997 (footnote 4), ''the sherds were catalogued after their return to Greece by Dr E. B. French. A more complete catalogue, together with photographs of the sherds, is held by the Fitch Laboratory, British School at Athens.'' Figure 1 shows a map with all the Greek sites covered by the PA bank.

The purpose of this article is to present our own statistical evaluation of the PA bank and compare it with former classifications (cf. Appendix 2). In contrast to these former studies (cf. Table 1), we treat not only part of the data, but take the whole PA bank into account. This seemed important, since a close similarity of the concentration values has been reported for the different regions of Greece and Crete present in the

*E-mail: mommsen@iskp.uni-bonn.de
†E-mail: t.beier@gsi.de
‡E-mail: hein@ims.demokritos.gr

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Table 1. Contents of the NAA Perlman–Asaro data bank and references

Sites		No. of samples	Berkeley labels	and	run Nos	time periods	ref. (i,s)*
	Argolid						
1	Mycenae	78	MYC	46,47, 49–65	549	LH I–IIA (except 47: EHIII) (except 56: LHIIIA)	1,2,11(s)
				48	509	LH I–IIA	
				29–38,66–75	509	LH IIIA1	
				9–28	508	LH IIIB	
				39–45	514	LH IIIC	
				76–85,92	642	LH III	
2	Berbati	38	BRB	33–40	542	MH	1,11(s)
				21–30	512	LH I–II	
				1–10	511	LH IIIA	
				11–20	511	LH IIIB	
3	Zygouries	40	ZYGO	1–20	550	LH II–IIIA1	3,11(s)
				21–40	551	LH IIIA2–B	
4	Tiryns	45	TIR	1,2	358,428	?	1,11(s)
				3–14	514		
				15–34	515		
				35–45	516		
			3,6,8–10,17			LH I/II	
			5,11,14,15,18			LH IIIA	
			20,21,27–31,38			LH IIIA/B	
			4,13,16,19,23–26,35,36,41–45			LH IIIB	
						LH IIIB	
			12,22,32,34,39,40			LH IIIB/C	
			33(?),37			LH IIIC	
5	Asine	61	ASN	32–51	517	LH I–II (except 37: MH)	1,3,11(s)
				1–10	512	LH IIIA	
				11–31	513	LH IIIB	
				31	514	LH IIIB	
				52–61	525	LH IIIC	
	Corinthia						
6	Korakou	45	KRAK	1–40	545	LH I/II	11(s)
				21–40	546	LH III	
				41–45	636	Neol.– LH IIA	
	Achaia						
7	var. sites	20	ACHA	1–20	537	LH IIIB–C	4(i,s)
	Elia						
8	Olympia–Kolosakos	20	OLYM	1–20	541	LH IIIB	4(i,s)
9	Platanos–Renia	20	PLAT	1–20	540	LH IIIB–C	4(i,s)
	Arcadia						
10	Palaikastro	20	PKAS	1–20	536	LH IIIC	4(i,s)
	Messenia						
11	Peristeria	20	PERS	1–20	554	LH IIIA–B	4(i,s)
12	Chora Ano Englianos	20	CHOR	1–20	553	LH IIIB	4(i,s)
13	Nichoria	100	NICH	1–20	555	LH I	4(i),5(s)
				21–40	557	LH II	
				41–60	558	LH IIIA	
				61–80	556	LH IIIB	
				81–100	567	LH IIIC	
	Laconia						
14	Hagios Stephanos	30	STEP	1–10	525	LH IIIB	1,4(i),6
				11–20	526	LH IIIB	
				21–30	526	LH I–II	
	Attica						
15	Perati	25	PERA	1–10	542	LH IIIC	12(s)
				11–25	544	LH IIIC	
	Boeotia						
16	Eutresis	4	EUT	1–4	576	LH IIIB	7(s)
17	Gla	3	GLAS	1–3	576	LH IIIB	7(s)
18	Kallithea	4	KALL	1–4	576	LH IIIA–B	7(s)
19	Tanagra	4	TNAG	1–4	576	LH II–IIIB	7(s)
20	Thebes	48	THEB	1–3	573	LH II–IIIB	1,7(s)
				4–23	574	LH II–IIIB	
				24–43	575	LH II–IIIB	
				44–48	576	LH II–IIIB	

Table 1. Continued

Sites		No. of samples	Berkeley labels	and	run Nos	time periods	ref. (i,s)*
	Crete						
21	Knossos	20	KNOS	2–5,7–10,	221	?	8
				13–16,19–22,	221	?	
				27,31,38,39	221	?	
22	Phaistos	60	FEST	1–20	568	LM IIIA–B	1,8
				21–40	569	LM IIIB	
				41–60	570	LM IIIC	
23	Chania	45	CHAN	1–20	571	LM IIIB	8
				21	573	LM IIIB	
				22–41	572	LM IIIC	
				42–45	835	LM III	10
	Other						
24	Tell Abu Hawam	108	HWM	1–4	502	↑	1,9((s))
				5–18	505		
				19–38	506	Almost	
				39–58	507	all	
				59–75	522	LH IIIB	
				76–95	523		
				96–108	524	↓	
25	Kition	5	KIT	79,81–84	835	LM III	10
26	Hala Sultan Teke	2	HSTK	28,30	835	LM III	10

*i = Individual concentration data, s = single sherd description, references given: (1) Asaro & Perlman, 1973; (2) Karageorghis *et al.*, 1972; (3) Hoffmann *et al.*, forthcoming; (4) Tomlinson, 1997; (5) Hoffmann *et al.*, 1992; (6) French *et al.*, forthcoming; (7) Tomlinson, 1996; (8) Tomlinson 1991; (9) Hoffmann & Robinson in French, 1993 with ref. to sherd list; (10) Karageorghis, 1979; (11) Tomlinson, forthcoming; (12) Tomlinson, 1998.

PA bank, e.g. between Thebes and Crete (Asaro & Perlman, 1973; Catling *et al.*, 1980; Jones, 1996; Tomlinson, 1996) or between several groups of sherds from Nichoria and the Argolid (Hoffmann *et al.*, 1992). NAA yields a large number of elemental concentration values and thus many variables which can be used for discrimination. Therefore this similarity is rather unexpected. However, the homogeneity of the concentration values of Greek Bronze Age pottery from different regions is also ascertained by our own measurements (Hein *et al.*, 1999; Mommsen *et al.*, 1997). Considering the whole PA bank in a statistical analysis, a possible differentiation between the regions may be detected and ware groups or single pieces that have been traded may be recognized. A second reason for a renewed data analysis is that we use our own approach to find groups of sherds with similar composition, which lacks most disadvantages of conventional statistical procedures in use (Beier & Mommsen, 1994*a*). This allows a proper re-examination of the stability of the reference patterns already formed to characterize different production areas, workshops or production series in a particular workshop.

Furthermore, the results of the Berkeley measurements can be compared to the Mycenaean pottery groups established by the measurements in Bonn. This is possible because our whole NAA measurement procedure and data evaluation method follows the Berkeley system closely and our Bonn pottery standard was prepared from the same raw clay which was used for the well-known Berkeley pottery standard (Perlman & Asaro, 1969) and is calibrated carefully against it (Mommsen *et al.*, 1987, p. 457) Our standard experiences a remarkable long-term stability already reported in (Mommsen *et al.*, 1991) and proven by the fact, that recent measurements often resemble patterns well known from older work. Therefore, reference groups established from the PA bank can and have been employed (Mommsen *et al.*, 1996*a*, 1998) in provenance studies of our own data without any problem.

Statistical grouping method of the Perlman–Asaro data bank (PA bank)

The PA bank contains 878 samples from Greece and Crete and seven additional samples from Cyprus. Concentration values of 27 elements are quoted for each sample. In addition, the uncertainty (generally termed "error") of each value is included in the bank. These uncertainties inevitably result from the measurement process itself. They form a feature inseparably from these data and should be considered in any data evaluation. In all other existing studies on the dataset, they were not taken into account so far, possibly due to the lack of any established statistical method to handle them.

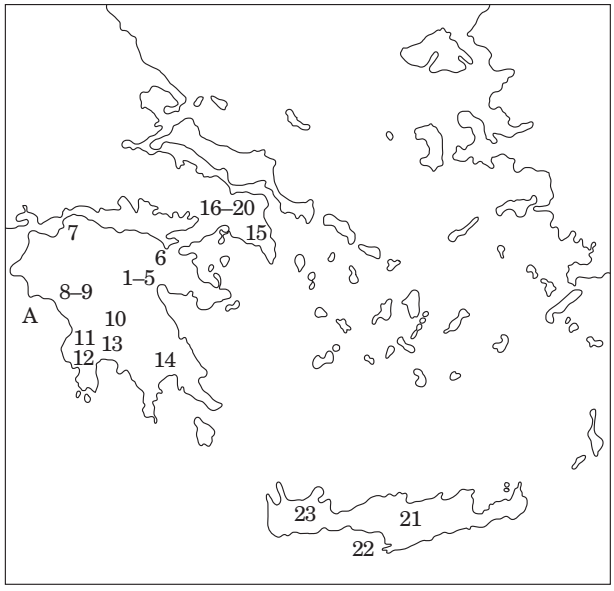

Figure 1. Map of Southern Greece and the Aegaean with the sites sampled and included in the Perlman–Asaro data bank [1–5 Argolid; 6 Korakou; 7 Achaia; 8 Olympia; 9 Platanos; 10 Palaikastro; 11 Peristeria; 12 Chora Ano Englianos; 13 Nichoria; 14 Hagios Stephanos; 15 Perati; 16–20 Boeotia; 21 Knossos; 22 Phaistos; 23 Chania; 24–26 Palestine and Cyprus (not shown); A cave of Katakolo].

We have long ago recognized the importance of considering these uncertainties of measurement in the statistical evaluation of the data (Mommsen *et al.*, 1988*a*), and we have developed our own methods which base on a modified Mahalanobis filter procedure (Beier & Mommsen, 1994*a*, *b*) which also is very suitable for recognizing single erroneous (outlying) concentration values for a single sample which should be treated with care in the statistical evaluation. We are going to outline the idea of our methods here and refer to the above articles for details of the technique and of the comparison with other statistical methods in use. A recent discussion of our method in relation to other schemes is also provided by Baxter (2001). A computer implementation employing standard software was recently presented by Beardah & Baxter (2001) who used part of the data of the present study for illustrative purposes. Applications by other research teams are presented, e.g., in (Gunneweg *et al.*, 1992; Gunneweg & Michel, 1999).

We employ the picture common in statistical description, where each sample is represented by a point in the m-dimensional space (also termed "hyperspace") of elemental concentrations. m is the number of elements (or other variables) under consideration which is 27 in the case of the PA bank. Each dimension in the hyperspace corresponds to the concentration values of one chemical element. Data points close to a particular sample (or a particular group of samples) can be "filtered out" from the data bank. Generally speaking such filter methods are used to test the hypothesis "data point belongs to that group" and this hypothesis is by statistical means either accepted or rejected. For this purpose, as measure of the similarity of a data point to the chosen "filter point" (a sample or group under investigation), a squared modified Mahalanobis distance d^2 is calculated. Compared to other measures, Mahalanobis distances have the advantage that they can be easily converted into a "probability of chemical agreement", since they follow a reduced χ^2 distribution with m degrees of freedom if a normal distribution is assumed. Even moderate deviations from normality do not change these arguments. Our modified version has the further advantage that this holds true even for single samples since this distance is calculated considering the individual errors of the concentration values, a feature that separates our algorithm from most other multivariate cluster procedures. In addition, normalizing to the measurement uncertainties helps to decide, how many statistically separable clusters are present in a dataset, a task which is difficult to appraise from a cluster-analysis calculation that results in a dendrogram with its tree structure of several groups and subgroups. Furthermore, we always perform a best relative fit, when calculating modified Mahalanobis distances. Thus, a possible constant shift of all the concentration values of one sample is taken into account. These shifts can occur due to experimental errors in the measurement procedure (weighing errors, neutron flux inhomogeneities, etc.). On the other hand, they can also be due to varying pottery making practices. The amount of the non-plastic fraction within the pottery may change by levigating the clay in different ways or by diluting it, adding various amounts of e.g. sand or $CaCO_3$. In some cases a constant shift (dilution) is encountered by post-burial alteration or contamination. Buxeda i Garrigos (1999) reports a case where P and Ca concentrations were increased by several percent in some sherds, but such features occur only for a few elements. We state that there is no general way to differ between experimentally caused dilution and that due to pottery-making practices or post-burial alteration, if only NAA data are employed. The best relative fit is also performed, when average means and spreads (root mean square deviations) for a group of samples are calculated. This procedure results in pottery groups with reduced spreads of the concentration values, i.e., better defined "clouds" of points are obtained forming the groups. Already the Berkeley group had recognized the importance of considering dilution effects in provenance studies (e.g. Widemann *et al.*, 1975, p. 48).

An example for the group forming procedure is given in Beier & Mommsen (1994*a*). Detailed examples of group assignments of several samples can also be found in Akurgal *et al.* (in press) and Beardah & Baxter (2001). Usually we chose the 95% confidence limit (2σ) of group membership as cut-off distance for a group separation or a rejection of a single sample.

This corresponds to a $d^2 \simeq 1{\cdot}6$ for the number of degrees-of-freedom in the case of the PA bank, which is around 25. We do not take into account all elements. Although sodium (Na) is precisely measured, it is omitted in the filtering procedure, because it usually scatters widely in otherwise well defined groups of pottery (e.g. Karageorghis *et al.*, 1972, p. 193). The calculation of the best relative fit factors within a group is performed utilizing 25 elements, leaving out Ca as well. Ca is often found to represent the diluent occurring mainly in the non-plastic fraction of the pottery. However, the determination of the d^2 values in the filter procedure for assigning group membership is performed with m = 26 elements, including Ca.

The search for groups of samples of similar composition was carried out employing the following fixed conditions: Starting at some point in concentration space (e.g., with a single arbitrarily chosen sample), all samples with small squared distances d^2 are determined and a preliminary group is formed. Since these distances nearly follow a reduced χ^2 distribution with $m - 1$, i.e. 25, degrees of freedom, the cut-off distance can be chosen to correspond to a certain confidence level for group membership (here 1·6 as stated above, being equivalent to the 95% conficence level, cf. Beier & Mommsen, 1994*a*, *b*). When the procedure is repeated, employing the new average concentration values (group values) and their spreads, more and more sherds fulfill the membership criterion. These are added to the group as well, and the process is repeated iteratively. The spreads of the group values increase in each step, and therefore the distances to other samples are lowered, because they are calculated in units of the spreads. The procedure continues, until the whole cloud of neighbouring samples is detected and included in the group (cf. Figs 2 and 3 in Beier & Mommsen, 1994*a*).

In the filtering iteration the average group values and their spreads are used as starting point for the next step. Possible single outlying concentrations of a sample are not taken into account when calculating means and spreads. A concentration value is considered to be an outlier, if it does not fall within the three-sigma limits of the elemental distributions in a group.

A test for possible erroneous data is also performed during the tests for group membership. For each sample the numerical value of the most outlying element was inspected more closely. If this value was found to have an unreasonably high deviation from the according value of the group, whereas all other concentration values were in good agreement, the value was neglected from the further consideration, being most probably an unrecognized contamination or a typing error, resulting from the manual data transfer to the computer. A few of these typing errors were indeed found when comparing the stored data with the handwritten lists given by I. Perlman to the Manchester group.

Results of statistical grouping

In this section, we are going to describe the general results of our statistical investigation of the PA bank. For grouping by statistical means we employ only the concentration data of each sample and investigate the location of the corresponding point in hyperspace. All available archaeological information is discarded in the beginning not to bias any statistical investigation. For the inspection of the concentration values, at first our standard procedure with a 95% confidence level was utilized as described in the previous section. It revealed a large "cloud" of many neighbouring points in concentration space. Our standard procedure is not able to recognize any internal structure within this group, which contains more than half of the data bank. Slightly changing the critical d^2-cut-off value to a larger number (e.g. from 1·6 to 1·7), the number of samples matching this group even increases. This indicates, that still more sample points are located in the vicinity of the large cloud, i.e., the cloud has diffuse edges. The average concentrations M and their spreads (root mean square deviations) of this large group are given in Appendix 1(1), 1st column (termed "Peloponnese, sum group" there). In the last column of this table the average experimental errors of this group are presented as well. They are relatively large for the elements K, Rb, Hf and Ni, compared to our own measurements at Bonn.

In total, the large chemical sum group contains samples from many different sites and of different time periods, covering the whole LH. The occurrence of such a structure within the PA bank was unexpected, although it underlines our own results on concentration data of Mycenaean pottery (Hein *et al.*, 1999). The cloud covers only a narrow region in concentration space despite its large number of members. This can be concluded by looking at the average concentration values of this group and their spreads, which are obtained in our standard manner after a best relative fit. But for some elements (especially Ca, Co, Cr and Cs) a much larger scattering of the values, compared to the average measuring errors is found (Ca: 24% cp. 6%; Co: 9·6% cp. 1·3%; Cr: 13% cp. 1·9%; Cs: 25% cp. 3·3%, shown in Appendix 1(1)). Therefore a possible subdivision of the large group was investigated. It was broken into parts by employing a smaller statistical cut-off value of d^2. In practice, the same filtering procedure was used. Starting again at some point, now only samples with $d^2 \leq 1{\cdot}0$ were added, neglecting all samples at larger distances, which according to our usual statistical criteria would also belong to the group. In this way, "core groups" within the large cloud could be determined. This strategy already had to be applied for the grouping of part of our Mycenaean data from Achaia and the Argolid (Mommsen *et al.*, 1997). A more detailed description is given elsewhere (Mommsen 2001). The total number of samples in the core groups is less than the number in

Table 2. Group comparisons after best relative fit (using all 27 elements), the corresponding fit factor, and the most differing elements with the normalized concentration differences (in units of average elemental spread, minimum spread set to 3%). In the d^2 column, the value in parentheses indicates the d^2 which is obtained after omitting the most discriminating element

Group	2nd group	d^2 value	Fit factor of 2nd group	Most differing elements and normalized differences in ( ) (cf. Tables of group values)
MBP	EMBP	0·55	0·99	Ni(3),Co(3),Cs(2)
MBP	ACHP	0·82	1·00	Cs(4),Ca(3),La(2)
MBP	TAP	3·0 (1·9)	1·00	Cs(8),Co(4),Sm(4),Na(3),Rb(3),Dy(3)
MBP	MBGP (2 samp. Gla)	2·4 (1·5)	1·00	Ta(7),Cs(6),Ti(3),Ca(2)
MBP	PHAP	2·4 (1·9)	1·08	Cr(6),Ni(6),Co(4),Ta(4),Fe(3)
	PHBP	2·4 (1·9)	1·04	Cr(5),U(5),Ta(5),Ni(4),Th(3)
PHAP	EMBP	1·5 (1·2)	0·91	Cr(4),Fe(4),Na(3),Ta(3),Ni(2)
PHAP	PHBP	0·94	0·99	Co(3),Ni(3),Cr(2),U(2),Fe(2)
PHAP	PHCP	0·89	0·96	Fe(3),Co(3),Ni(2),Sc(2),Sm(2)
PHAP	PHDP	0·61	1·02	Eu(3),Dy(2)
PHAP	THEP	0·79	1·05	Ni(3),Co(3),Ta(2)
PHAP	THFP	0·85	0·97	Ce(3),Hf(2)
PHAP	PERP	1·5 (1·2)	1·06	Cr(4),Cs(4),Th(3),Ta(3),K(3)

the large cloud, since the total volume in the multi-dimensional concentration space spanned by the irregularly adhering core groups is smaller than that of the whole group. Thus, some points of the large cloud are now excluded from all of the core groups and considered either as "associated" or as chemical singles. Samples associated to a group are very close to it except for a few slightly deviating elements. Samples which are located somewhere in the middle region between the centres of two core groups can be assigned to each of these groups with nearly equal statistical probability.

In the following, the three-or-four letter labels for each of the groups are those by which the samples are denoted on our own data-bank system for later recognition, a system which is in use now for about 20 years. In general, they form a short mnemonic for the finding site of the majority of the samples together with a letter for distinguishing several groups from the same site and for special purposes. All reference groups from the PA bank have a "P" as last letter.

The results of the subdivision of the large group into the smaller core groups EMBP (Early Mycenae Berbati Perlman), MBP (Mycenae Berbati Perlman), ACHP (ACHaia Perlman), TAP (Tiryns Asine Perlman), are shown in Appendix 1(1), where the average concentration values M (the centre points) and their spreads σ of these groups are given. The chemical differences between the four core groups are restricted to only a few elements which show slightly different abundances. These differences are summarized in the upper part of Table 2. A best relative fit based on all 27 elemental concentration values of each group was performed towards the group MBP, resulting in fit factors of about 1·0 for the core groups. As an example, in Figure 2 the normalized differences of the elemental

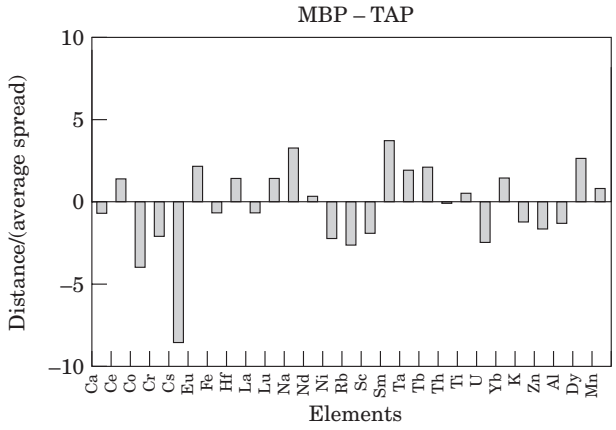

Figure 2. Normalized concentration differences (in units of average spread σ) between the Argive groups MBP (Mycenae Berbati Perlman), 275 samples, and TAP (Tiryns Asine Perlman), 25 samples. The main differing elements are Cs and Co (cf. Table 2, row 3).

concentrations (in units of the average spread values) are shown between the groups MBP and TAP. This bar diagram is a quantitative illustration of row 3 in Table 2. In Table 2, the small group MBGP (Mycenae Berbati Gla Perlman) which contains only two sherds was separated from the group MBP for reasons which will be explained later. Small groups and chemically single samples in the PA bank are also mentioned in this work because, according to our experience, they represent very often the first members of new groups which are enlarged by further members from future analyses.

In Appendices 1(2)–1(7), the remaining groups of samples from the PA bank are listed as obtained from

the statistical analysis. Their members have not been part of the large "Peloponnese" group (cluster 1) which has been discussed up to now.

Close to the first large cloud in concentration space another large group of points is located (cluster 2), adjoined to the group EMBP. This cloud was also separated into several core groups PHAP (PHaistos/Knossos-A Perlman), PHBP, PHCP, PHDP, THEP (THebes-E Perlman), THFP (THebes-F Perlman), and reaches to the group PERP (PErati-R Perlman). Again, only a few elements differ slightly among these adhering clouds of points. The concentration differences of these subgroups and their similarity in many elements can be deduced from the lower half of Table 2. In detail, the concentration values of these groups are presented in the Appendices 1(4) and 1(5). In general, the elemental abundances of the groups in the first interrelated large cloud (i.e., MBP, EMBP, ACHP, TAP, and MBGP) are by about 8–9% higher than those of this second large structure (cf. the calculated dilution factors listed in Table 2, column 4, rows 5–7).

All remaining samples are statistically well separated from these two large structures. They form several additional groups of points, not far from the main body of data, but clearly isolated and statistically well separable.

However, among them some are once more close to each other and form clusters (cluster 3: groups PE1P (PEristeria-1 Perlman), PE2P, CHOP (CHOra Ano Englianos Perlman) and NI4P (NIchoria-4 Perlman); cluster 4: groups STP (Hagios STephanos Perlman), M1P (group M1 Perlman, not localized) and HWM4P (Tell Abu HaWaM 4 Perlman)).

The two groups CHAP (CHAnia Perlman) and CREP (Chania-REE Perlman or CREam ware Perlman) and three smaller sets of samples from Tell Abu Hawam (HWM1P, HWM2P, HWM3P) give very different results from all the other samples. Each of these groups forms a well isolated cloud of points. Within the groups, the concentration values of some elements are far outside the general range covered by the PA bank. In particular, these groups exhibit the following characteristic features:

CHAP: low concentrations of Co, Cr, Fe, Ni, and Mn;
very high values of Ta.

CREP: very low in Ca, Co, Cr, Fe, Ni, and Mn;
very high values of Ta, Ti, Th, U, and of all rare-earth elements (REE).

HWM1P: very low in K, Cs, Rb, Th, U, and in all REE;
very high in Al, Co, Fe, Sc, and Mn.

HWM2P: very low values of Ca, Co, Fe, Ni, Mn and Zn;
very high in Ta, Ti, Th, U, and all REE;
—differences to CHAP: diluted by about 12%,
main discriminating elements: K, Ca, Fe.

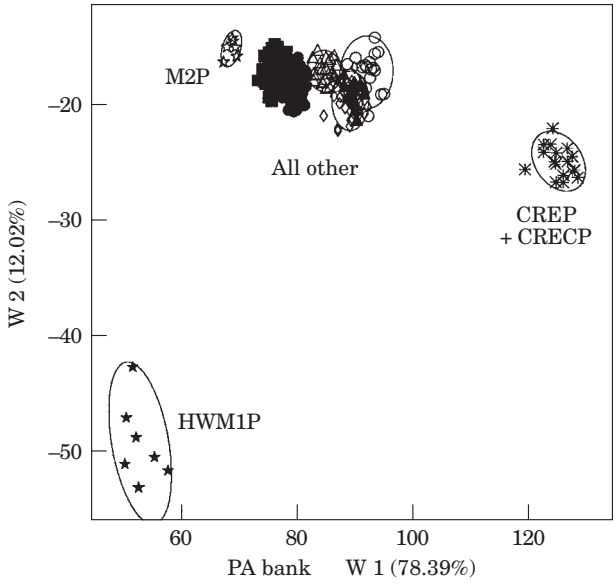

Figure 3. Discriminant analysis of all samples of the PA bank, which belong to groups with 6 and more members (620 samples), assuming 9 groups [cluster 1: Peloponnese (●); cluster 2: Phaistos/Knossos and Thebes (■); cluster 3: Messenian groups CHOP, NI4P and PE1P (△); group Hagios Stephanos (▲); other groups from Nichoria NI(2+3+5+6)P (◇), and group CHAN (○) from Chania]. Plotted are the dicriminant functions W1 and W2, which cover 78% and 12% of the between-group variances, respectively. The ellipses drawn are the 2σ boundaries of the groups.

—differences to CREP: concentration values enhanced by about 11%,
discriminating elements: lower in REE.

HWM3P: very high concentration values of Al, Rb, Ce, Th, and U.

Depending on the d^2 chosen here, 96 samples of the PA bank are chemical singles and 4 samples form two pairs of points of mutual similar samples. This percentage of unassignable samples is not unusual in chemical fingerprinting.

To demonstrate the location and distribution of the groups of points in hyperspace, Figures 3–6 show the results of discriminant analyses at different "zoom levels" using all the dilution-factor corrected elemental values except Na. Only larger groups with more than 5 members are considered in these calculations. Figure 3 demonstrates, how similar in composition most of the groups are. Only the patterns M2P (group M2 Perlman, not localized), the largest group from Tell Abu Hawam HWM1P and the group CREP from Chania separate from the rest of the PA bank. Removing these 3 groups and assuming 11 groups for the remaining grouped samples, the result shown in Figure 4 is obtained. Here, the Peloponnesian groups (Cluster 1), the groups from Phaistos/Knossos and Thebes (Cluster 2), and the two groups from Messenia (Cluster 3: CHOP and PE1P) are treated as one group each. Finally, the results of resolving clusters 1 and 2 into their core groups are depicted in Figures 5 and 6.

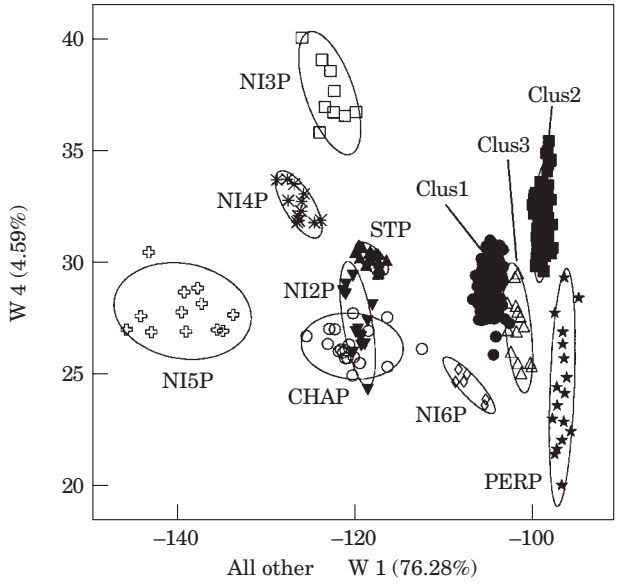

Figure 4. Discriminant analysis like in Figure 3 of the 590 samples of the "all other" cluster assuming 11 groups as depicted. Clus1 is the Peloponnesian cluster, Clus2 the Phaistos/Knossos and Thebes cluster, and Clus3 that from Messenia, groups CHOP and PE1P (group NI4P is separated here).

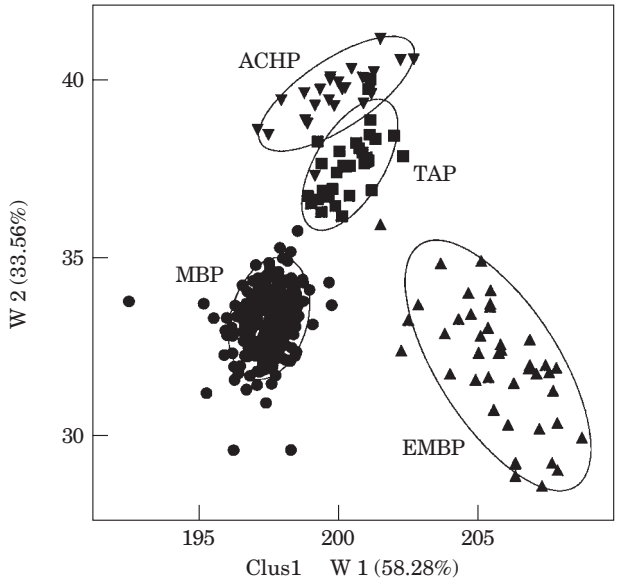

Figure 5. Discriminant analysis of the 374 samples of the Peloponnesian cluster assuming 4 groups.

Discussion of grouping results and comparison with published data

In the formation of groups and core groups, only the chemical concentration data have been used. Only after obtaining the grouping results, we start to compare our classification with the archaeological information provided.

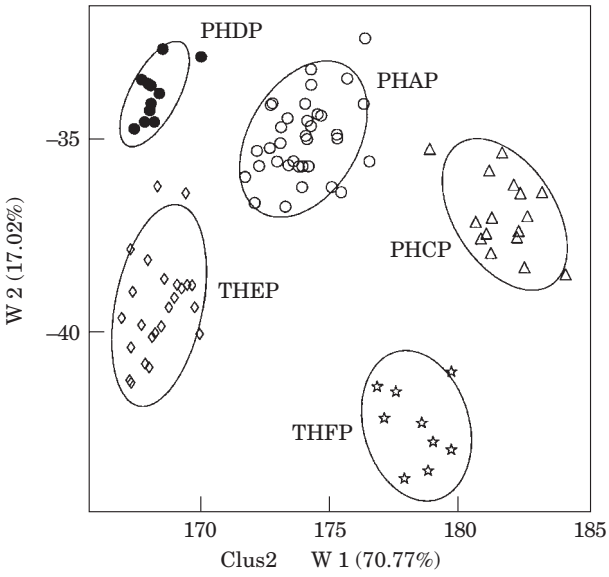

Figure 6. Discriminant analysis of the 95 samples of the cluster Phaistos/Knossos and Thebes assuming 5 groups.

Most of the groups and the core groups correspond to samples from different sites or can be assigned to a special time period. The members of each group are listed in Appendix 2, together with the best relative fit factor of each group member towards the corresponding group mean. Samples marked by a "-" sign are "associated" to a group only. The distance (d^2) of an "associated" sample to its group is by far the smallest, compared to the distances to all other groups. However, associated samples are not considered for the calculation of the mean values of their groups in order not to enlarge the spreads of the group too much. Otherwise, our subtle system of adjacent core groups would break down and the core groups would merge to the large structures.

I. Argolid and Achaia

In the columns 2–5 of Table 3 we present the assignment of the sherds from the different sites to the four core groups of the first large group. Most of the samples from the Argolid and also from Corinthia belong to a group here termed Mycenae/Berbati (MBP). This name was chosen, because this concentration profile is already known to us from our own measurements. The values of the group are identical to those of our own group with this name (MB) (Mommsen *et al.*, 1988*b*). (As mentioned above, to distinguish patterns of the PA bank from our own data also for future use, all groups of the PA bank are labelled with a "P" as the last letter.) As in our data, the MBP pattern is dominating in the Argive material. It was previously assigned to a workshop in the region of Mycenae/Berbati (Mommsen *et al.*, 1988*b*) with high probability. This is now ascertained by the analysis of

Table 3. Assignment of samples from different sites to 6 chemical core groups: MBP (incl. MBGP) = Mycenae/Berbati, EMBP = Early(LH I–II)? MBP, ACHP = Achaia/Elia, TAP = Tiryns/Asine, M1P, M2P = unlocated small groups; s = chemical single, o = samples belonging to other groups, s. Tables 5 and 6 and Appendix 2). Numbers in parentheses refer to associated group members

	Sites	No. of samples in the chemical subgroups EMBP	MBP	ACHP	TAP	M1P	M2P	s	o	Sum
	Argolid									
1	Mycenae	13(3)	54(3)	—	2	1	—	1	1	78
2	Berbati	1(4)	29	(2)	—	—	—	1	1	38
3	Zygouries	(1)	32(3)	—	—	1	—	3	—	40
4	Tiryns	1(3)	26	—	12(1)	—	—	2	—	45
5	Asine	5(1)	33(2)	(1)	8	1	—	6	4	61
	Corinthia									
6	Korakou	1(6)	16(9)	—	(1)	—	4	7	1	45
	Achaia									
7	var. sites	—	—	10(6)	—	(1)	—	3	—	20
	Elia									
8	Olympia	—	(1)	11(5)	—	—	—	1	2	20
9	Platanos	1	1	10(1)	—	—	—	3	4	20
	Arcadia									
10	Palaikastro	—	1(1)	(5)	—	—	—	3	10	20
	Messenia									
11	Peristeria			None				8	12	20
12	Chora A. E.	—	—	—	—	—	1	3	16	20
13	Nichoria	9(2)	2	1(1)	—	—	—	20	65	100
	Laconia									
14	H. Stephanos	9	1	—	—	—	—	2	18	30
	Attica									
15	Perati			None				5	20	25
	Boeotia									
16	Eutresis	—	3	—	—	—	—	—	1	4
17	Gla	—	2	—	—	—	—	1	—	3
18	Kallithea	—	2(1)	—	—	—	1	—	—	4
19	Tanagra	—	—	—	—	—	—	—	4	4
20	Thebes	1(2)	11(1)	—	—	1	—	4	28	48
	Crete									
21	Knossos			None				1	19	20
22	Phaistos			None				4	56	60
23	Chania	—	—	—	—	(1)	—	11	33	45
	Other									
24	Abu Hawam	1(5)	64(4)	—	3	—	(2)	10	19	108
25	Kition			None				1	4	5
26	Hala S.T.			None				—	2	2
	Sums	42(27)	277(25)	32(21)	25(2)	4(2)	6(2)			
		Total of 4 groups: 376(+75) = 451						100	320	885

several wasters from the workshop of Berbati which have been handed in by B. Wells. In the PA bank, also two wasters from Berbati are included (BRB 37, 38). The first of these samples is a proper member of group MBP. The second misfired sherd gives results very similar to MBP, but deviates by a small amount mainly in the Cr value. The distance (d^2) to the EMBP group is lower and, therefore, it was assigned to that group. However, with lower probability, a membership to MBP is not excluded. The pattern MB/MBP appears also in a larger number of Theban and other Boeotian samples of the PA bank which all have to be assumed to be imports from the Argolid, according to the concentration data. However, this contradicts our own findings of only a few imports from there to Boeotia (Mommsen *et al.*, 1998). The different results might be a consequence of the sample selections from Boeotia. Two samples from Gla (subgroup MBGP) have been included in the group MBP in Table 3. They show a strong deviation from the MBP concentration pattern particularly in their Ta and Cs values (cf. Table 2 and Appendix 1(4)) which might be real or due to a batch difference during the measurements. It has to be checked by analysing more samples from Gla, whether a unique chemical pattern exists for this site which can be distinguished from the Argive pattern. Only astonishingly few pieces from other parts of the Peloponnese belong to the pattern MB/MBP. Altogether, we detected in total seven more sherds from the sites of Elia, Arcadia, Messenia, and Laconia.

Tomlinson (forthcoming) evaluated the same data from the Argive and Corinthian sites (Mycenae, Berbati, Tiryns, Asine, Zygouries, Korakou) for each of these data sets separately. He continued earlier work of the Manchester group (Hoffmann *et al.*, forthcoming). For each of the sites, several groups were

Table 4. Overview of former grouping (Tomlinson, forthcoming) of the Argive and Corinthian sherds and comparison to our grouping. Shown are the numbers of group members. The members itself are given in Appendix 2. Associated samples are added to the groups. The factor is the best average fit factor of Tomlinson's cluster/group members to our group values (see text). Asine group 5 of 3 samples is not shown

Tomlinson grouping Clusters: Groups of site: (label)	I	II Group 1	II Group 2	V	III	IV Group 3	IV Group 4	Sum+singles	= total sum	
Mycenae (MYC)	13		39			6	7	65	11	76
Berbati (BRB)	15		16					31	7	38
Tiryns (TIR)	21			10				31	14	45
Asine (ASN)		24		7	8		7	46	12	61
Zygouries (ZYGO)	7		20		10			37	3	40
Korakou (KRAK)	13			13				26	19	45
Sums	69	24	75	13	17	18	6	14	236	66	302
Our grouping:										
In MBP	68	22	72	10		18	1	4	195	
Factor	0·95	0·99	1·01	0·99		1·05	1·10	0·94		
In EMBP		1	3	3			5	10	22	
Factor		1·00	1·00	0·98			1·04	0·94		
In TAP					17				17	
Factor					0·99					
Singles	1	1								
Sums	69	24	75	13	17	18	6	14	236	

found and it was stated that the sites Berbati and Zygouries could be chemically separated (cf. also Hoffmann and Robinson in French (1993), referred to as French (1993) in the following). By our procedure including dilution (best relative fit) effects, we are not able to detect any subgroups in the sherds corresponding to these sites. The samples from Berbati and Zygouries belong to only one chemical group MBP. The former result is thought to be a consequence of the archaeological information incorporated in the mathematical procedure at Manchester. Starting with the formation of groups defined by the different sites these groups were standardized separately by autoscaling and refined by "a combination of Principal Components Analysis (to identify and correct for the correlation effects) and Cluster Analysis (to search for groups)" (French, 1993) later on. This may have led to the reported discrimination. Tomlinson (forthcoming) mentions the close chemical similarity of some of the site-specific groups forming larger clusters. His group assignment of individual sherds is given by superscripts in Appendix 2 and an overview of his grouping and clustering is presented in Table 4. Considering best relative fit factors his clusters I, II, III and groups 1 of Asine and 2 of Korakou all merge to group MBP with a few members in group EMBP (see below) and 2 chemical singles. Averaging the individual fit factors given in Appendix 2 it turns out, that members of cluster I have about 5% higher and members of cluster III 5% lower concentration values compared to members of cluster II. This explains the cluster formation of Tomlinson. Our correction of constant shifts of the data puts the clay composition of different vessels on a common weight basis. It is the clay paste which determines provenance. All these separate reference groups of Tomlinson are made from the same clay paste MBP.

Concerning the samples from Tell Abu Hawam, many belong to the pattern MB/MBP and are therefore imports from the Argolid. This has been noted already in French (1993) where many different Argive groups are reported. In our evaluation nearly all the members of the Tell Abu Hawam groups *F–K* merge again and belong to only one pattern MBP (cf. Appendix 2). The result corroborates the important role of the MB/MBP pottery workshop in long-range trade. According to our data and a data evaluation performed in Jerusalem (Yellin & Maeir, 1992; Gunneweg *et al.*, 1999), its sherds have been found in Asia Minor, Cyprus, Palestine, Egypt and even in Spain (Karageorghis *et al.*, 1972; Mommsen *et al.*, 1990, 1992, 1996*a*).

There is a second Argive group present in our own (Bonn) data which was first detected in several samples from Tiryns including some wasters, and also in material from Asine (Mommsen *et al.*, 1988*b*). We termed it therefore Tiryns/Asine (TA). It was assigned with high probability to a workshop at Tiryns or somewhere in its neighbourhood in the southern Argolid. This

pattern is also present in the PA bank, as was already stated by Asaro & Perlman (1973) and Tomlinson (forthcoming), cf. Table 4, cluster V. Here, it is correspondingly named TAP. In the PA bank, 20 of the 25 sherds forming this group were found at the sites Tiryns and Asine. This supports our own assignment of the origin of this pattern. This pattern does not occur very frequently outside the Argolid. No other sherd is detected in the Greek material of the PA bank except one from Korakou (KRAK 28) which can be associated to this group. However, three sherds with this pattern were found in Tell Abu Hawam. Again, this was already noted by Asaro & Perlman (1973, 2 sherds mentioned), and also by French (1993). Possibly, the TA/TAP pottery workshop was not engaged in long-range trade as much as its northern neighbour MB/MBP. However, a few additional samples with its pattern have also been detected at Qantir in Egypt (Mommsen *et al*., 1996*a*).

A third subgroup is formed mainly by samples from Achaia and Elia. We term it ACHP (ACHaia Perlman), and again it is known to us from our own material from Achaia. It corresponds to our own pattern named Ach-a (Achaia-a) (Mommsen *et al*., 1997; Mommsen & Maran, 2000–2001) which was found in samples from the region of Patras only and therefore assigned to this production region. The data of the PA bank ascertain the pattern Ach-a and extend its range also to the region of Elia. This was already indicated by a clay sample from a pliocene claybed at the cape of Katakolo in Elia which was found to match the pattern Ach-a except for a higher Ca content considering a best relative fit factor of 1·34. The value of this factor points to a large dilution consisting besides Ca of some other elements which are not determined in Bonn. According to our experience, an agreement in NAA-data composition of raw clay and pottery is very rare and exceptional. We encountered it for the first time in this case. The pattern ACHP of the PA bank gives further evidence for a connection between the regions Achaia and Elia concerning pottery production in the LH. Group ACHP as well as our own group Ach-a are chemically very similar to the group MB/MBP. Only Ca and Cs differ considerably between the Achaia groups and the MB/MBP pattern (cf. Table 2). Therefore, a provenance from the north western Peloponnese or the Argolid, respectively, can be assigned with sufficient probability only for the samples in the core groups. For sherds not falling into one of the core groups but being very similar to the Achaia and the MB/MBP group, only a provenance from "either Achaia/Elia or Northern Argolid" can be concluded. It is recalled here that the grouping into core groups was done without knowledge of the sites where each sample was found. The distributions presented in Table 3 resulted only after the group formation, thus indicating that most of the sampled material of each region is indeed distinguishable and locally produced with high probability. In addition, slightly different patterns exist between different sites which become visible when applying a proper statistical data analysis. In comparison to the grouping of Tomlinson (1997), group ACHP (53 sherds including associated samples) contains nearly all the members of his groups 3 (14 samples of a total of 23) and 4 (24 samples of a total of 27), cf. Appendix 2. Like Ach-a/ACHP both groups of Tomlinson have also reduced Ca and Cs concentrations compared to MB/MBP. The spread values of the group ACHP are reduced compared to the spreads of Tomlinson's group 3 and 4 due to the consideration of dilutions and due to the choice of samples belonging to core groups only.

The fourth large core group EMBP of the Argolid group is a core group of data points which are located between the clouds of points from groups MBP on one side and samples from Phaistos in Crete (group PHAP) on the other. The discrimination between the groups EMBP and PHAP is statistically easy and can also be recognized by comparing the concentration values directly, as the groups differ in many elements by about 8%, as already mentioned (Table 2). On the other hand, many samples from this core group are very similar to the core group MBP, and a discrimination between the two groups requires the full power of our own grouping method including correlations. The group EMBP is again known to us. It was detected only recently in sherds from Aigina which are archaeologically classified as imports from the Argolid (Mommsen *et al*., 2001). Its name EMBP ("Early"? MBP) was chosen because it contains a large number of "early" samples from Mycenae (10 out of 20 dated LH I–II) and Nichoria (9 out of 20 dated LH I) As mentioned, one of the two misfired sherds from Berbati also belongs to it with higher probability than to the group MBP. Both wasters were dated to the Middle Helladic (MH) period (E. French in Tomlinson, forthcoming). The sherds of this group which were imported to Aigina can not be distinguished by archaeological means from products of the MB/MBP workshop. Therefore, this group might indicate a different workshop in the Argolid. Alternatively, it might even represent an early "recipe" variation in the MBP workshop or reflect a long-time exploitation of a claybed with slightly changing elemental concentrations with depth or horizontal extension. On the other hand, also about one third of the samples analysed from Hagios Stephanos belong to this pattern. A provenance of this pattern somewhere from the Peloponnese seems fairly certain. The presence of this "early" group in the PA bank was already reported for the Argive and the Nichoria samples, respectively, by Hoffmann *et al*. (forthcoming and 1992). Our group EMBP corresponds well to cluster 3 in Hoffmann *et al*., 1992. It contains the same 9 samples from the 20 LH I sherds from Nichoria. Furthermore, it includes all the Hagios Stephanos and Nichoria samples of group 2 in Tomlinson's (1997) investigation of the same Peloponnesian data. The two small groups M1P and

Table 5. Assignment of samples from different sites of the southern and western Peloponnese to further chemical groups. Numbers in parentheses refer to associated group members

	Sites	No. of samples in the chemical subgroups PE1P	PE2P	PE3P	PE4P	CHOP	CHPP	NI2P	NI3P	NI4P	NI5P	NI6P	STP	Sum
	Arcadia													
10	Palaikastro	4(2)	—	—	—	1(1)	—	—	1(1)	—	—	—	—	10
	Messenia													
11	Peristeria	2	3	2	1	—	—	1(2)	(1)	—	—	—	—	12
12	Chora A. E.	(2)	(1)	—	1	9	3	—	—	—	—	—	—	16
13	Nichoria	(1)	—	1	—	(1)	(1)	11(7)	7(3)	12(1)	12	6	2	65
	Laconia													
14	H. Stephanos*	—	—	—	—	—	—	—	—	—	—	—	15(2)	17
	Other†	—	—	—	1	—	—	2(1)	1(3)	—	—	—	1	9
	Sums	6(5)	3(1)	3	3	10(2)	3(1)	14(10)	9(8)	12(1)	12	6	18(2)	129

*One sample from Hagios Stephanos is associated to group CHAP of Table 6. †See listing in Appendix 2.

M2P are data points situated near the edges of the large Peloponnesian group. They contain samples from different finding sites and are given for the sake of completeness. Because of the small number of members nothing can be concluded from these data.

II. Southern Peloponnese

Table 5 shows the distribution of samples from the southern Peloponnese (Arcadia, Messenia, and Laconia) into the other chemical groups. The 20 samples each from Palaikastro and Peristeria are chemically inhomogeneous and allocated to several small groups. One of the samples found in Palaikastro belongs definitely to the MBP group, and another one is closely associated to it. These two samples therefore have to be considered as Argive imports. Their archaeological description is given in Tomlinson (1997) together with that of the other pieces from Arcadia, Achaia, Elia, Laconia, and Messenia (cf. Table 1). Five more samples from Palaikastro are associated to the group ACHP which most probably originates from Achaia/Elis. These samples may therefore originate from there as well. Two samples (PKAS 7, 8) form a chemically similar pair but are isolated from all the others and therefore considered as singles. Four samples (+two more associated ones) belong to a new group termed PE1P. This group contains also two samples from Peristeria which is in Messenia, not far away from Palaikastro. As shown in Table 5, samples from Peristeria are also contained in several other groups. Besides a large number of 8 chemical singles from this site, only sample pairs or triples (PE2P–PE4P) have been detected with specific similar chemical compositions in each of these little groups. Samples PERS 6 and 7 form again a chemically similar but isolated pair. More samples from both sites mentioned last or also from neighbouring sites in Arcadia and Messenia have to be analysed before patterns assignable to these regions can be defined, if any exist. More than 100 samples have already been taken by us and are waiting to be processed in Bonn. At the moment, the origin of the different patterns PE · P can not be stated. Tomlinson's study (1997, Table 2) also reflects this inhomogeneity for the two sites. He is able to assign only 13 and 8 samples, respectively, to his clusters. Because of this unusual inhomogeneous distribution there might have been no local pottery production in the LHIII in this region and all pieces analysed might be imports from somewhere else. On the other hand, the sample number analysed at present is too small to finally draw this conclusion.

For the sites Chora Ano Englianos and for Nichoria as well as for Hagios Stephanos in the south, the normally encountered site-specific patterns are obtained which are statistically well separable from each other and from the rest of the data. These patterns have not yet been detected in our own data in Bonn.

The group CHOP from Chora is Tomlinson's (1997) group 6, except for the samples PKAS 4 and 5 which form a close pair and which are assigned here to PE1P.

The 100 samples from Nichoria form 6 larger groups 5 of which are not yet represented in our data at Bonn. The known group is identical with the pattern EMBP from the Argolid. Therefore, the group name NI1P is omitted. If conclusions from the sample distribution are drawn, at least some of these groups can be considered to be locally produced. Our results agree well with those of Hoffmann *et al.* (1992) who form 5 clusters and also with Tomlinson's grouping (1997) with almost similar sherd assignments. Instead of only five single sherds stated by Hoffmann *et al.*, we obtain 14 sherds not assigned to any group, according to the chosen probability criterion. In Tomlinson's study, this number amounts to as many as 21. Groups NI2P and NI3P contain a few members from sites other than Nichoria, whereas the other groups are only represented at this site. On the other hand, two samples from Nichoria analyse similar to MBP (NICH 87 and 98), two more similar to ACHP (NICH 59(–) and 93). Also a few samples belonging to other Peloponnesian groups were found in Nichoria, i.e., NICH 94 and 99

Table 6. Assignment of samples from different sites of Attica, Boeotia and Crete to further chemical groups. Numbers in parentheses refer to associated group members

		No. of samples in the chemical subgroups									
	Sites	PERP +PESP	THEP	THFP	PHAP	PHBP	PHCP	PHDP	CHAP	CREP	Sum
	Attica										
15	Perati	16(4)	—	—	—	—	—	—	—	—	20
	Boeotia										
16	Eutresis	—	1	—	—	—	—	—	—	—	1
17	Gla	—	—	—	—	—	—	—	—	—	
18	Kallithea	—	—	—	—	—	—	—	—	—	
19	Tanagra	—	—	4	—	—	—	—	—	—	4
20	Thebes	—	21	5	(2)	—	—	—	—	—	28
	Crete										
21	Knossos	—	2	—	2(1)	—	1(2)	11	—	—	19
22	Phaistos	—	—	—	33(3)	4	15(1)	—	—	—	56
23	Chania	—	—	—	—	—	—	—	19(2)	11(1)	33
	Other*	1	(2)	(1)	(1)	1	—	—	(2)	(6)†	14
	Sums	17(4)	24(2)	9(1)	35(7)	5	16(3)	11	19(4)	11(1+6)	175

*See listing in Appendix 2. †Samples of Group CRECP from Cyprus, see text.

are members of STP, NICH 46(–) is an associated member of CHOP, and a few more belong to the other small and still unlocated Peloponnesian groups. The cluster correspondence to the studies of Hoffmann *et al*., 1992 (cluster no.) and Tomlinson, 1997 (group no.) reads:

EMBP = cluster 3 (only LHI members agree) = group 2 (all 13 members agree)
NI2P = cluster 1 (partly) = group 8 (all 11 members agree)
NI3P = cluster 5 (without NICH 69) = group 12 (all 6 members agree)
NI4P = cluster 2 (many more members) = group 9 (contains all our 12 core samples and 8 more members)
NI5P = cluster 4 (3 more members) = group 11 (all 7 members agree)
NI6P = cluster 1 (partly) = group 10? (only the 2 Nichoria members agree)

The last pattern of Table 5, STP, is found in two thirds of the samples from Hagios Stephanos. This group might represent a local workshop there, as we again conclude from the sample distribution. One sherd of this pattern (HWM 16) was exported to Tell Abu Hawam, two (NICH 94, 99) to Nichoria. The group corresponds to Tomlinson's (1997) group 1. It contains the same 13 samples from Hagios Stephanos and also sample NICH 94. In the Bonn data, this group is not represented up to now. It is not very different from the small group M1P which shows approximately 6% higher concentration values and differs in Cr and Ni.

III. Attica, Boeotia, and Crete

The assignments of the samples from Attica, Boeotia, and Crete to their presumably local groups are presented in Table 6. The 25 Attic samples, all from Perati, separate clearly from all other sherds. All Perati samples (except 5 singles) belong to only one group PERP. This group is distinguished by extraordinary high concentrations in Cs, Cr and Ni, compared to all other samples of the PA bank. The spreads in the alkaline concentrations are rather large (K: 20%, Rb: 27%, Cs: 36%) what may indicate the presence of possible subgroups due to clay inhomogeneities or, if existing, due to exchange reactions during burial. This result agrees with Tomlinson's work (1998) who forms a core pattern for Perati of 10 samples (cf. Appendix 2).

Two of the samples marked "associated" to the Perati group PERP in Table 6 are presented tentatively as a separate group PESP (PErati-S Perlman) in the Appendices 1(4) and 2. This pair shows the highest Cr values encountered in the PA bank. However, the samples have unusually large differences for some element concentrations and are mutually diluted or concentrated by 10%, respectively.

The material from Boeotia forms several groups. One of them is similar to the core group MBP which is thought to sort out imports from the Argolid to Boeotia. Except for a few export pieces to other sites, the two other groups detected in Boeotia, THEP and THFP, contain only Theban samples and again are assignable to regional production, all the more since both patterns are known to us and correspond in their compositions to our groups a-theb and b-theb which are formed from our own data of samples from Thebes as well (Mommsen *et al*., 1998). The concentrations of both groups are very similar to those of the Cretan group PHAP which consists of samples mainly from Phaistos. However, a statistical separation was possible by core-group formation. Also the groups THEP and PERP from Thebes and Perati, respectively, were

discernible, although they are again very similar to each other. In contrast to the Peloponnese, the regions sampled in Attica, Boeotia and also Central Crete show generally higher Cr and Ni values. Tomlinson (1996) groups the Boeotian samples of the PA bank into only two clusters A and B, termed *X* and *Y* in Appendix 2 here. He assigns 9 samples to his cluster B. All of them are MBP, according to our own data evaluation, and Tomlinson explicitly mentions the similarity of the B cluster to the Argive samples. Many of the members of Tomlinson's cluster A are contained in THEP. The differentiation of the Theban samples from the chemically very similar sherds from Central Crete is possible only, if Tomlinson's cluster A is not considered as a whole but subdivided into the two chemically very similar core groups a-theb/THEP and b-theb/THFP. Like our pattern a-theb, pattern THEP is linked to Thebes since nearly all sherds of this group come from there. For THFP/b-theb only a regional Boeotian provenance could be concluded (Mommsen *et al.*, 1998). The small group THFP contains only 5 sherds from Thebes and also all 4 samples from Tanagra. It might therefore represent a local production variation of this site which has to be checked analysing more samples.

All three Cretan sites Knossos, Phaistos, and Chania, which are represented in the PA bank exhibit their own chemical pattern, according to our evaluation. The two largest core groups for Phaistos (PHAP and PHCP) are very similar to each other and also similar to two patterns established in the Bonn laboratory for samples from Knossos and Phaistos (yet unpublished, a group KP given in Mommsen *et al.* (1995) corresponds to PHAP). The new pattern PHBP shows a small deviation from PHAP in the Co and Ni values. Pattern PHDP is present only in material from Knossos. In our own (Bonn) data, a chemical difference between sherds of the two sites is not detectable. Both our patterns corresponding to PHAP and PHCP show up at both places. The separation of the two sites in the PA bank is only due to a small difference in the elemental values of Eu (and Dy) for PHAP and PHDP. The difference of the Eu concentrations after a best relative fit of group PHDP to PHAP (factor 1·02, cf. Table 2) is only 0·18 ppm, corresponding to 3·1 in units of σ_{ave}(= 0·059 ppm). This small deviation might be a batch difference, since the samples from Knossos and Phaistos were measured at Berkeley in separate runs (cf. Table 1). If both groups PHAP and PHDP are merged, agreement with our own results is obtained, which exhibit only two larger groups for Central Crete.

The third Cretan site of the PA bank is Chania. Our investigations of these samples coincide with earlier research on the same data. Asaro & Perlman (1973) mention a strong inhomogeneity. This can be partly reduced by a best relative fit, but regarding the 45 samples from this place about one quarter remain chemical singles. The samples are all part of a collection from sherds of presumably local production originating from the Kastelli excavation of Tzedakis and Kanta in 1966 (Tzedakis, 1969). They have been collected from trench B, level 5 and 11, and are dated LH IIIC and LH IIIB. Two groups (CHAP and CREP) could be formed which exhibit concentration values very different from the remaining Greek samples. In particular, the Ta values are about twice as large as usually encountered in Greek pottery (Hein *et al.*, 1999). In group forming, extraordinary relative dilution corrections had to be applied for group CHAP which amount to up to about 30% (lowest factor 0·62 (for CHAN 7), highest 1·28 (for CHAN 34), cf. Appendix 2). This points to a strong variability in the clay refining techniques and pottery making "recipes" of the producing workshop. The pattern CHAP (19 samples) was presented and discussed in Mommsen *et al.* (1998, pattern CHANIA). It was employed to match the compositions of 9 Linear B inscribed jars from Thebes which were analysed in Bonn. As the group of 19 sherds from Chania contains a variety of vessel types and forms including big decorated stirrup jars as well as coarse undecorated kitchen ware, its origin from one or several pottery workshops in the Chania region seems very likely. Therefore, the inscribed jars are thought to be imports from there. In the PA bank, one sample found in Mycenae (MYC 20) and another one from Hagios Stephanos (STEP 14) are also associated to this pattern. The samples CHAN 2 and 6 and FEST 39 which are considered to be singles in the present study, are also close in their chemical composition.

The second group from Chania (CREP) consists of 12 samples and exhibits even more exceptional concentration values, compared to the general Greek compositions. B. Hallager who also compiled the sherd list sent to Berkeley, identified 7 samples of this "Cream Ware" group (CHAN 8, 13, 15–16, 19, 20–21) as excavated at trench B, level 11. He assigned them to the local workshop defined by Tzedakis (1969). Except for the chemical singles CHAN 8 and 13, these sherds belong to pattern CREP. Also six of the seven Cypriot samples (all except KIT 81) exhibit a pattern CRECP which is very similar to CREP. They have been measured in the same run as four of the Cream Ware samples from Chania (CHAN 42–45). These four Cream Ware samples and the samples from Cyprus have been sent by Karageorghis to Berkeley for analysis, since "even with a naked eye one could discern this similarity" (Karageorghis, 1979, p. 201). The Berkeley results confirmed the similarity of these sherds also with respect to chemistry. According to the grouping presented here all Cypriot samples are more diluted (due to lower REE) by about 5% than the Chania Cream Ware sherds on the average. After a best relative fit with a factor of 1·05, they deviate significantly only in Co and Mn which are now higher, but only by 3 and 2 σ_{ave}, respectively. This difference is so small that it is most probably a batch difference (run 835 was presumably measured much later than the

runs 570–573). As another explanation, these samples may be considered to be members of a slightly changed production series of this workshop and therefore are exports from Chania to Cyprus, if the assignment of this pattern CREP to local production in the Chania region is correct.

IV. Tell Abu Hawam

Finally, the grouping results of the 108 samples analysed from Tell Abu Hawam will be summarized and compared to the study of French (1993). As already mentioned and shown in Table 3, most of the samples can be certainly assigned to an Argive origin and belong to the group MBP. The subdivision of the pattern MBP into separate groups from Mycenae, Berbati and Zygouries could not be reproduced by our methods. Three samples show the TAP pattern, as already reported by French (1993). All the 15 samples taken from pictorial jars can be assigned to pattern MBP (HWM 6, 7, 14, 34, 38–42, 44, 47, 65, 67, 69) except one (HWM 43) which belongs to pattern TAP. In our evaluation, the sample HWM 16 shows pattern STP and is not associated to TAP as mentioned by French (1993). Only one sherd (HWM 19) clearly belongs to the group EMBP. Five more are associated with this group (HWM 21, 28, 55, 59, and 68), and sample HWM 3 is associated to THEP. This might be true as well for HWM 2 which is considered to be a single in this study. The sample HWM 57 analyses similar to PHBP and samples HWM 1 and 78 are associated to a small, unlocated group termed M2P which contains a few samples from Corinthia. The sample HWM 70 is a chemical single here. This sample was mentioned by Asaro & Perlman (1973) as being similar to two other samples measured in Berkeley, one from Larnaca and one from Tell Ashdod, of unknown origin. Nine more samples are also singles. As these singles, the 16 remaining samples have very different compositions. They form 4 groups identical to the groups *A*–*D* mentioned in the study of French (1993). They are

HWM1P, 7 samples, Cypriot White Slip Ware = group *B*;
HWM2P, 3 samples from the same vessel, Cream Ware = group *A*, mentioned already in Asaro & Perlman (1973);
HWM3P, 3 samples from the same vessel, Syrian bottle = group *C*;
HWM4P, 3 samples, ''Anatolian'' Grey Ware = group *D*.

Conclusions

In this study we have grouped all samples of the PA bank into several groups or considered them as being singles. In contrast to former evaluations not only parts of the data, but the complete PA bank of 878 samples has been allocated to groups of similar chemical composition. These groups that have been established correspond in all applicable cases to those which were formed from our own (Bonn) concentration data on Mycenaean and Minoan pottery. From this agreement, a number of satisfactory conclusions can be drawn. First of all, the measurements carried out up to now in Berkeley as well as in Bonn have been precise and correct. Also, all conclusions drawn so far from our own data are confirmed by similar findings in the PA bank which contains a sample collection totally independent of our own. During the Mycenaean period, regionally different pottery groups prevail in the regions covered by our own as well as by the PA bank data despite the typological and stilistical homogeneity of the Mycenaean pottery. This is established by a careful chemical analysis. For each region only a few main patterns are detected which have to be identified with ''production series'', each of them having its own ''recipe''. Many of these patterns are found to be present during the whole Mycenaean period. This shows a continuity of the production technology during this time. Considering the large number of samples investigated, it now seems better justified to state that the production of pottery took place in all regions in an amount suitable for all local needs. The chemical patterns within the pottery are distinguishable between different regions of Greece, and therefore a trade of clay and also an extensive trade of pottery vessels can not be concluded from the joint evidence of the Mycenean pottery data of Berkeley and Bonn. In apparently all workshops, the production comprised many different types of ware, including coarse products up to pottery of the highest quality like pictorial jars. Therefore, material interchange and trade of pottery between the regions was not necessary for any local demand, and it is found to be non-significant. Only a few import pieces are detected generally at the different sites in Greece. It is an interesting open question whether this picture will be confirmed by the analysis of about 1000 more Mycenaean samples from the other regions of Mainland Greece which are waiting to be processed in the laboratory in Bonn.

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Appendix 1: Group mean values

Appendix 1 (1): Element concentrations of pottery groups in the Perlman–Asaro data bank: averages M in μg/g (ppm), if not indicated otherwise, and spreads σ in % of M, after a best relative fit of each sample towards the group mean (performed utilizing all concentration values except Ca and Na). Average values of the uncertainty ("error") of measurement (mainly due to counting statistics) averaging over all samples of the Peloponnese sum group are given in the last column

	Peloponnese sum group		EMBP 42 samples		MBP 275 samples		ACHP 32 samples		TAP 25 samples		Ave meas. error
	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))	Δ(%)
Al%	8·11	5·6	7·91	4·2	8·31	4·3	8·03	4·1	7·95	2·6	2·4
Ca%	9·18	24	8·35	24	9·53	14	5·55	32	8·73	14	5·9
Ce	62·0	3·4	63·5	3·7	62·2	2·7	61·0	4·3	64·8	2·2	1·6
Co	28·9	9·6	34·9	9·2	28·8	5·2	28·3	5·4	23·9	4·2	1·3
Cr	250	13	280	11	243	8·2	274	6·8	203	9·6	1·8
Cs	8·60	25	12·0	23	9·06	7·6	6·48	9·6	4·98	5·6	3·3
Dy	4·53	5·3	4·64	3·7	4·47	4·1	4·78	6·9	5·0	4·6	3·1
Eu	1·21	7·8	1·24	5·0	1·19	7·5	1·26	6·3	1·36	5·2	4·6
Fe%	5·26	5·2	5·03	5·9	5·33	3·7	5·41	3·4	5·22	2·8	1·4
Hf	3·67	14	3·43	9·8	3·62	13	4·15	10	4·24	9·6	8·3
K%	2·45	21	2·73	20	2·57	15	2·44	13	2·10	19	11
La	31·5	4·1	32·1	3·2	31·9	3·3	30·0	3·2	31·3	2·6	2·0
Lu	0·39	5·5	0·41	4·4	0·39	5·1	0·42	5·1	0·42	4·6	4·5
Mn	921	12	886	20	925	8·2	971	17	975	6·7	1·1
Na%	0·66	39	0·42	24	0·59	27	0·82	18	1·30	22	2·0
Nd	28·2	6·7	28·9	6·6	28·3	6·4	28·1	7·2	28·9	8·9	6·4
Ni	223	20	314	14	212	12	220	12	165	11	8·7
Rb	147	20	156	18	156	12	139	16	112	14	12
Sc	21·2	5·1	21·4	2·7	21·5	4·0	21·4	4·0	20·1	2·6	0·3
Sm	5·18	3·7	5·29	2·2	5·12	2·7	5·31	3·7	5·71	2·4	0·7
Ta	0·83	6·3	0·85	7·6	0·82	4·6	0·85	5·2	0·88	2·9	0·9
Tb	0·79	8·2	0·80	7·4	0·78	8·1	0·81	8·1	0·90	5·8	6·3
Th	10·8	3·8	10·7	4·4	11·0	3·0	11·0	3·1	11·0	2·3	1·4
Ti%	0·44	6·2	0·43	4·9	0·45	6·0	0·47	5·3	0·46	4·7	4·0
U	2·36	7·9	2·49	5·9	2·35	4·6	2·30	5·8	2·13	3·4	1·4
Yb	2·71	5·2	2·78	4·3	2·70	5·1	2·84	4·5	2·88	4·1	3·8
Zn	120	13	117	15	123	9·9	113	14	104	11	6·8

Appendix 1 (2): Element concentrations: averages M in µg/g (ppm), if not indicated otherwise, and spreads σ in % of M, after a best relative fit of each sample towards the group mean (performed utilizing all concentration values except Ca and Na)

	PE1P 6 samples		PE2P 3 samples		PE3P 3 samples		PE4P 3 samples		CHOP 10 samples		CHPP 3 samples	
	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))
Al%	6·97	2·8	8·13	11	7·99	5·8	7·75	2·4	7·00	4·5	8·18	4·7
Ca%	10·0	24	7·46	20	1·9	127	1·67	35	7·55	17	3·32	50
Ce	61·9	2·7	69·5	4·3	74·2	3·1	48·9	4·1	62·5	3·1	66	9·1
Co	25·6	6·4	21	19	37·6	1·3	12·6	3·4	19·4	16	18·7	9·8
Cr	241	21	282	6·6	386	4·1	311	6·8	277	3·5	384	31
Cs	2·91	36	4·79	25	5·76	8·2	3·40	12	2·03	47	2·15	14
Dy	5·00	4·1	4·26	37	6·02	7·1	4·23	15	5·09	2·8	4·85	9·3
Eu	1·35	3·1	1·45	3·1	1·58	4·5	1·05	8·8	1·30	3·4	1·21	4·4
Fe%	4·92	7·0	5·64	1·8	5·84	6·8	4·91	3·8	4·75	4·9	4·88	6·8
Hf	3·80	8·2	4·88	8·6	5·31	8·3	4·72	15	4·20	12	5·17	15
K%	1·44	25	0·64	60	2·08	14	1·58	21	1·32	28	1·25	15
La	31·5	1·6	33·3	2·5	37	13	25·3	11	30·8	2·3	31·3	7·6
Lu	0·40	4·8	0·42	8·6	0·53	8·0	0·42	5·5	0·42	6·6	0·43	7·5
Mn	934	19	575	43	1011	1·9	297	38	509	15	368	19
Na%	0·34	34	0·42	55	0·44	37	0·42	112	0·45	14	0·59	50
Nd	29·6	6·2	30·5	6·9	35·2	12	22·7	28	28·4	7·9	26·9	6·8
Ni	206	8·6	206	22	294	11	186	9·1	186	10	213	33
Rb	87·1	35	47·8	17	138	11	91·7	21	66·3	35	65·1	30
Sc	18·2	5·8	19·9	11	19·9	7·3	16·3	3·4	15·8	0·0	17·1	6·2
Sm	5·59	1·8	6·16	2·1	6·69	2·9	4·44	10	5·58	1·3	5·43	4·5
Ta	0·82	2·8	1·08	12	1·13	3·4	0·85	9·7	0·85	4·0	0·98	9·9
Tb	0·91	4·5	0·97	4·5	1·08	5·2	0·69	9·9	0·88	6·6	0·84	12
Th	10·5	1·7	12·5	5·9	12·4	2·7	10·6	3·1	10	2·7	11·6	6·4
Ti%	0·40	3·6	0·49	3·1	0·53	3·0	0·41	8·9	0·41	4·9	0·48	9·1
U	2·07	17	2·05	11	2·51	11	2·25	8·5	2·80	17	2·53	14
Yb	2·75	4·0	2·84	11	3·52	4·2	2·75	9·1	2·90	3·8	3·12	4·3
Zn	91·9	13	60·5	41	150	6·7	77·5	20	72·9	18	93·2	7·4

Appendix 1 (3): Element concentrations: averages M in µg/g (ppm), if not indicated otherwise, and spreads σ in % of M, after a best relative fit of each sample towards the group mean (performed utilizing all concentration values except Ca and Na)

	NI2P 14 samples		NI3P 9 samples		NI4P 12 samples		NI5P 12 samples		NI6P 6 samples		STP 18 samples	
	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))
Al%	7·16	9·0	8·85	5·0	8·20	3·5	6·80	5·0	7·19	9·8	8·63	4·7
Ca%	3·36	70	6·94	13	4·25	25	2·12	81	2·02	70	5·96	26
Ce	75·2	6·3	75·1	2·9	79	3·7	83·6	12	64·8	13	73·7	4·2
Co	27·3	8·6	36·2	12	26·1	9·0	30·6	22	11·9	27	24·9	6·1
Cr	225	16	322	11	294	10	240	24	323	4·8	285	10
Cs	6·02	13	3·10	45	1·69	32	4·98	38	4·67	29	7·85	9·4
Dy	6·14	6·4	5·44	3·7	6·24	13	8·58	8·1	5·23	6·4	5·26	5·3
Eu	1·63	5·7	1·48	5·3	1·62	4·3	2·25	8·6	1·28	8·3	1·42	6·3
Fe%	4·32	11	6·48	5·9	5·52	5·5	4·32	8·9	3·67	25	5·09	3·1
Hf	4·90	13	3·82	10	5·50	7·0	4·85	12	5·78	8·0	5·23	9·9
K%	2·03	16	1·16	55	1·44	21	1·69	29·0	1·55	12	3·00	12
La	39	4·2	37·3	2·2	40·5	2·8	46·1	6·2	33·6	3·3	36·1	2·8
Lu	0·49	4·4	0·48	5·2	0·51	5·5	0·61	4·5	0·46	8·8	0·45	4·8
Mn	712	33	1072	11	693	29	808	19	254	49	632	16
Na%	0·57	25	0·21	101	0·52	19	0·50	31	0·45	43	0·73	12
Nd	36·5	5·8	30·8	7·6	33·2	7·7	47·5	13	29·4	6·8	34·5	5·5
Ni	169	19	311	26	215	14	206	14·0	116	20	229	17
Rb	123	17	66·7	37	70·6	29	106	37·0	120	23	151	15
Sc	17·2	6·0	25·2	3·8	19·5	3·0	16·7	5·5	15·5	4·3	20·6	2·4
Sm	7·02	4·8	6·24	3·2	6·98	2·6	9·49	8·7	5·76	5·4	6·07	3·4
Ta	1·06	9·2	1·18	40	1·13	5·1	1·04	5·4	1·05	4·7	1·07	6·2
Tb	1·12	4·5	1·00	10	1·05	7·9	1·57	12	0·91	6·7	0·94	7·5
Th	11·4	6·8	12·7	4·2	12·7	4·5	11	4·6	10·4	4·0	12·5	3·1
Ti%	0·44	8·6	0·54	4·8	0·51	2·8	0·43	4·4	0·46	7·2	0·48	3·7
U	2·41	13	2·32	6·5	2·76	12	2·11	12	2·56	11	2·84	8·3
Yb	3·45	4·3	3·42	4·8	3·55	4·9	4·22	11	3·15	7·5	2·99	3·5
Zn	119	16	123	19	130	14	120	21	75·6	11	121	9·9

Appendix 1 (4): Element concentrations: averages M in μg/g (ppm), if not indicated otherwise, and spreads σ in % of M, after a best relative fit of each sample towards the group mean (performed utilizing all concentration values except Ca and Na). The group values of MBP (Appendix 1(1)) are displayed here for comparison with MBGP

	PERP 17 samples		PESP 2 samples		THEP 24 samples		THFP 9 samples		MBGP 2 samples		MBP 275 samples (App. 1(1))	
	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))
Al%	6·46	5·9	7·00	1·8	6·87	5·0	7·92	3·4	7·74	1·9	8·31	4·3
Ca%	10	17	7·19	6·9	9·21	25	9·29	15	7·05	9·1	9·53	14
Ce	48·7	5·8	56·8	4·5	52·4	4·2	62·1	2·4	62·4	1·4	62·2	2·7
Co	32·3	13	31·3	21	39·9	11	33·7	5·5	26·6	1·5	28·8	5·2
Cr	608	8·7	745	5·0	499	14	498	17	261	4·1	243	8·2
Cs	26·3	36	6·88	4·4	5·02	16	6·45	9·4	6·47	3·8	9·06	7·6
Dy	4·10	3·7	4·88	6·8	4·01	5·6	3·92	5·4	4·32	7·2	4·47	4·1
Eu	1·04	5·6	1·24	10	1·18	7·2	1·12	9·7	1·20	6·3	1·19	7·5
Fe%	4·98	9·8	5·86	7·0	5·53	4·8	5·28	3·8	5·51	1·4	5·33	3·7
Hf	3·97	8·7	5·30	7·1	3·26	8·7	3·26	7·5	4·25	13	3·62	13
K%	1·41	20	1·33	15	2·18	14	2·66	16	1·88	13	2·57	15
La	23·2	7·1	27·7	5·8	24·8	4·4	29·5	3·7	30·2	2·0	31·9	3·3
Lu	0·37	5·1	0·43	48	0·34	6·0	0·35	7·2	0·41	7·1	0·39	5·1
Mn	775	14	853	23	887	16	770	9·8	855	11	925	8·2
Na%	0·65	36	0·54	4·1	0·54	17	0·60	11	0·54	2·0	0·59	27
Nd	22·6	11	29·5	7·2	23·3	7·1	26·3	6·6	25·1	6·4	28·3	6·4
Ni	462	14	465	5·8	544	13	426	5·3	194	9·0	212	12
Rb	102	27	83·6	37	111	14	147	10	122	10	156	12
Sc	21·1	6·1	23	2·1	20·7	2·5	21	1·3	21	0·7	21·5	4·0
Sm	4·46	3·5	5·38	6·2	4·43	3·5	4·66	2·4	4·97	1·5	5·12	2·7
Ta	0·74	5·1	0·87	7·4	0·76	9·6	0·90	12	1·07	0·5	0·82	4·6
Tb	0·72	7·8	0·85	20	0·71	11	0·68	6·3	0·77	8·1	0·78	8·1
Th	8·06	3·5	9·62	7·8	8·41	5·8	9·87	2·4	11·8	1·1	11	3·0
Ti%	0·43	5·4	0·52	5·9	0·44	5·5	0·48	4·5	0·51	3·1	0·45	6·0
U	2·03	18	2·52	28	1·97	14	2·58	9·8	2·35	1·3	2·35	4·6
Yb	2·52	4·5	3·15	9·5	2·28	4·4	2·45	6·9	2·79	3·8	2·70	5·1
Zn	96·2	19	104	18	107	11	99·9	7·4	104	6·2	123	9·9

Appendix 1 (5): Element concentrations: averages M in μg/g (ppm), if not indicated otherwise, and spreads σ in % of M, after a best relative fit of each sample towards the group mean (performed utilizing all concentration values except Ca and Na)

	PHAP 35 samples		PHBP 5 samples		PHCP 16 samples		PHDP 11 samples	
	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))
Al%	7·25	6·7	7·33	6·7	8·10	3·5	6·94	3·2
Ca%	8·13	20	10·8	9·3	7·64	25	8·97	23
Ce	55	2·7	57·4	3·3	54	3·5	53·8	3·2
Co	33·3	6·0	28·8	1·8	39·8	5·2	30·7	7·0
Cr	432	12	333	5·9	459	8·1	390	5·4
Cs	6·82	19	7·89	8·8	8·61	9·3	6·44	15
Dy	4·17	4·6	4·11	4·1	4·13	5·2	4·47	3·7
Eu	1·10	7·3	1·06	8·4	1·08	8·3	1·26	3·0
Fe%	5·49	3·8	5·19	2·2	6·28	3·6	5·23	1·8
Hf	3·78	8·9	3·99	7·4	3·60	8·1	3·67	8·8
K%	2·39	17	2·54	12	2·50	22	2·07	22
La	27·6	3·0	28·7	2·2	27·6	2·7	26·9	4·3
Lu	0·36	6·1	0·37	5·1	0·38	4·4	0·35	5·8
Mn	920	15	824	4·5	853	12	70	14
Na%	0·78	25	0·61	3·2	0·67	37	0·67	26
Nd	23·5	7·1	25·3	9·4	23·7	7·6	24	6·9
Ni	382	11	291	6·8	494	7·5	397	8·8
Rb	117	14	137	13	143	18	94·8	13
Sc	20·6	5·4	20·1	2·7	24·2	4·6	20·1	3·0
Sm	4·62	2·4	4·71	1·9	4·49	3·0	4·66	1·7
Ta	0·91	5·7	0·95	3·3	0·92	8·0	0·88	6·8
Tb	0·74	8·8	0·77	6·1	0·72	8·4	0·67	4·9
Th	9·45	2·9	9·56	3·2	10	3·4	9·04	3·6
Ti%	0·43	5·4	0·43	7·4	0·43	6·0	0·41	6·5
U	2·35	11	2·88	4·7	2·33	3·9	2·87	16
Yb	2·43	4·0	2·47	5·6	2·46	3·3	2·46	4·5
Zn	114	13	125	6·1	125	0·0	90·8	9·8

Appendix 1 (6): Element concentrations: averages M in µg/g (ppm), if not indicated otherwise, and spreads σ in % of M, after a best relative fit of each sample towards the group mean (performed utilizing all concentration values except Ca and Na)

	CHAP 19 samples		CREP 11 samples		CRECP 6 samples	
	M	(σ(%))	M	(σ(%))	M	(σ(%))
Al%	7·59	6·5	8·68	10	8·34	4·5
Ca%	5·40	32	0·64	52	0·54	40
Ce	87	6·9	138	11	121	1·8
Co	14·5	28	8·24	14	10·7	8·2
Cr	120	17	119	8·2	121	6·0
Cs	6·77	15	6·69	13	6·78	11
Dy	5·53	5·6	9·05	19	8·50	12
Eu	1·47	8·0	2·57	7·9	2·09	7·5
Fe%	3·73	24	1·57	23	1·42	6·2
Hf	6·62	11	9·27	13	9·63	7·6
K%	2·26	15	1·68	17	1·53	15
La	42·7	5·7	66·2	5·4	56·2	6·3
Lu	0·46	4·9	0·69	11	0·65	9·7
Mn	340	33	97·5	12	122	11
Na%	0·62	16	0·41	25	0·39	28
Nd	37·2	10	63·5	7·4	53·7	4·8
Ni	79	29	59	32	55·4	26
Rb	107	10	106	12	96·7	13
Sc	15	4·1	16·2	9·3	15·5	5·0
Sm	6·78	6·1	11·6	6·1	10	6·2
Ta	1·60	8·7	2·20	9·8	2·13	2·1
Tb	0·96	6·5	1·46	24	1·16	20
Th	12·7	7·3	15·8	7·8	16·3	4·3
Ti%	0·50	6·6	0·68	7·8	0·68	5·3
U	3·19	10	3·85	8·6	3·91	3·3
Yb	2·94	4·5	4·48	9·9	4·26	8·3
Zn	88·4	15	83·3	19	78·9	18

Appendix 1 (7): Element concentrations: averages M in µg/g (ppm), if not indicated otherwise, and spreads σ in % of M, after a best relative fit of each sample towards the group mean (performed utilizing all concentration values except Ca and Na)

	M1P 4 samples		M2P 6 samples		HWM1P 7 samples		HWM2P 3 samples		HWM3P 3 samples		HWM4P 3 samples	
	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))	M	(σ(%))
Al%	9·71	5·6	6·48	6·1	9·19	8·7	8·28	1·6	10·1	4·8	7·77	2·0
Ca%	5·76	49	10·6	13	2·49	39	0·49	61	5·21	45	5·06	14
Ce	80·5	1·4	49·6	3·9	14·8	27	99·7	2·2	83·3	1·7	67·7	4·0
Co	25	8·7	19·8	9·3	40·7	20	7·83	2·5	21·4	1·8	20·7	1·7
Cr	197	13	358	15	215	46	122	2·9	132	6·1	164	13
Cs	8·21	16	6·11	5·5	1·06	60	6·90	4·4	9·21	4·1	9·49	5·6
Dy	5·55	5·5	4·05	3·9	3·75	10	6·04	1·4	5·44	1·8	4·43	7·6
Eu	1·52	4·9	1·04	9·1	0·87	8·3	1·56	5·3	1·30	6·1	1·27	7·8
Fe%	5·18	7·4	4·26	2·5	8·41	6·7	1·48	2·4	5·62	2·0	4·18	2·7
Hf	4·99	6·0	4·44	11	2·48	18	9·30	4·9	4·92	8·7	4·31	11
K%	2·84	26	1·66	16	0·75	38	1·32	11	1·98	16	2·85	9·1
La	38·4	3·0	24·8	4·9	8·93	7·7	46·7	1·9	40·7	2·4	33·7	5·0
Lu	0·48	3·8	0·34	6·9	0·37	12	0·49	5·0	0·43	5·1	0·37	4·1
Mn	844	7·5	580	10	1156	19	123	5·2	433	13	664	9·7
Na%	0·81	31	1·02	21	1·18	28	0·35	2·2	0·22	20	0·81	11
Nd	34·8	6·3	22·5	7·6	10·6	14	45·4	6·7	38·7	7·1	29·2	6·0
Ni	146	21	234	16	92·3	28	42·4	45	79·4	32	110	15
Rb	154	18	80·6	13	55·1	36	123	15	200	15	160	12
Sc	22·2	3·8	16·6	1·4	41·2	7·5	15·8	0·4	20·9	1·5	17	1·2
Sm	6·53	3·6	4·33	4·8	2·50	4·7	7·56	1·6	6·38	2·1	5·15	2·6
Ta	1·16	11	0·76	9·0	0·76	87	2·08	0·8	1·27	1·7	0·77	2·0
Tb	1·02	4·7	0·69	9·6	0·61	14	1·01	7·2	0·97	7·2	0·67	13
Th	14	5·1	8·43	7·4	2·75	14	16·6	1·2	15	1·7	15·6	9·0
Ti%	0·50	7·5	0·36	4·4	0·49	13	0·61	1·7	0·51	5·2	0·38	3·8
U	2·60	8·4	2·31	14	0·66	8·6	4·34	0·9	3·67	17	3·38	8·0
Yb	3·13	7·1	2·36	4·4	2·42	8·1	3·63	7·7	2·99	4·6	2·39	5·4
Zn	118	15	103	18	104	38	64·3	9·5	139	11	98	12

Appendix 2: Listing of group members, associated members and best relative fit factors to the group mean [in ( )] utilizing 25 elements (all except Ca and Na)

Appendix 2(1): Overview and sequence of groups in the following list:					
Argolid	1. EMBP	2. MBP	(2a: MBGP)	3. TAP	
Other	4. ACHP	5. PE1P	6. PE2P	7. PE3P	8. PE4P
Peloponnese:	9. CHOP	10. CHPP			
	11. NI2P	12. NI3P	13. NI4P	14. NI5P	15. NI6P
	16. STP				
Attica:	17. PERP	(17a: PESP)			
Boeotia:	18. THEP	19. THFP			
Crete:	20. PHAP	21. PHBP	22. PHCP	23. PHDP	
	24. CHAP	25. CREP	(25a: CRECP)		
special:	26. M1P	27. M2P			
	28. HWM1P	29. HWM2P	30. HWM3P	31. HWM4P	

Appendix 2(2): Presentation of the groups

Explanations:

Superscripts: Equal superscripts designate groups formed in former statistical analysis. Samples marked "associated" in these publications are added to the groups. Ungrouped samples are left blanc.

Argolid and Corinthia: Tomlinson (forthcomimg) finds several groups for each of the sites separately (Nos 1–6 in our Table 1, site labels ASN, BRB, KRAK, MYC, TIR, ZYGO). His site-specific groups are shown by superscript numbers (e.g. ASN n^1: Asine sample n in Asine, group 1 a.s.o.). The following groups from different sites are described as being chemically similar and form clusters: (I) Berbati, Korakou, Mycenae, Tiryns, and Zygouries, in each case group 1; (II) Berbati, Mycenae, and Zygouries, in each case group 2; (III) Asine and Zygouries, group 3; (IV) Asine and Mycenae, group 4; (V) Asine and Tiryns, group 2; Asine, group 1 is similar to Tiryns, group 1 from cluster I and to Mycenae, group 2 and Zygouries, group 2 from cluster II (cf. Table 4 above).

Peloponnese: The remaining Peloponnesian sites (Nos 7–14 in Table 1) are treated by Tomlinson (1997) as one set. He detects 12 groups designated here by superscript letters *a–l*.

Attica: Tomlinson (1998) forms a core group defining the composition of pottery from Perati using the 10 samples designated with superscript letter *p*.

Nichoria: Samples from Nichoria (No. 13 in Table 1) are assigned by Hoffmann *et al.* (1992) to 5 clusters and marked here by numbers 1–5 (corrections according to note 5 in Tomlinson (1997) are considered).

Boeotia: Samples from Boeotia (Nos 16–20 in Table 1) are grouped by Tomlinson (1996) into two clusters A and B designated here by superscript letters *X* and *Y*.

Tell Abu Hawam: Hoffmann et al. (1993) find 10 groups designated here with letters *A–J* and a few individual sherds similar to a Peloponnesian composition (*K*).

1. Group EMBP of 69 samples:
(42 core samples+27 associated samples [marked "-"])

MYC 13 (1·08), 31^2 (0·97), 37-^2 (1·00), 41-^2 (1·02), 46^3 (1·01), 49^3 (1·08), 50^3 (1·03), 51^4 (0·95), 52^4 (0·97), 54^3 (1·00), 55^4 (0·94), 61^4 (0·95), 63^4 (0·94), 65^4 (0·93), 71^3 (1·07), 85- (1·07),
BRB 7- (1·15), 14-^2 (1·04), 15- (1·11), 35-^2 (1·01), 38^2 (1·06),
TIR 9- (0·93), 17 (0·92), 25- (1·09), 37- (0·92),
ASN 5- (1·04), 36^4 (0·94), 40^4 (0·94), 45^4 (0·91), 50^1 (1·00), 51^4 (0·95),
ZYGO 8-^2 (1·00),
KRAK 15 (0·97), 22- (1·01), 23-^2 (1·00), 26- (0·99), 32- (1·07), 37-^2 (0·95), 38-^2 (0·98),
PLAT 8^d (1·01),
NICH 11^{b3} (0·91), 12^{b3} (0·99), 13^{b3} (0·93), 15^{c3} (0·91), 16^3 (1·05), 17^{b3} (0·99), 18^{b3} (0·95), 19^3 (0·94), 20^{b3} (0·98), 82-^{e3} (1·08), 92-^{e3} (1·09),
STEP 17^b (0·99), 21 (1·00), 22 (1·05), 23^b (0·96), 24^b (0·92), 25^b (0·93), 26^b (0·99), 27^b (0·94), 28^b (0·97),
THEB 8-^Y (0·98), 14^Y (0·95), 18-^X (1·10),
HWM 19^F (1·02), 21-^J (1·02), 28-^J (1·00), 55-^J (1·02), 59-^F (1·12), 68-^K (1·10)

2. Group MBP of 300 samples:
(275 core samples+25 associated samples [marked "-"], 2 Gla samples in group 2a)

MYC 9^2 (1·02), 10^2 (1·00), 11^1 (0·93), 12^2 (1·00), 14^2 (1·04), 15^2 (1·04), 16^2 (1·01), 17^2 (1·05), 18^2 (1·00), 19^2 (1·00), 21^2 (1·00), 22^2 (1·04), 23^2 (1·00), 24^2 (1·00), 25^2 (1·01), 26^2 (1·02), 27^2 (1·02), 28^2 (1·05), 29^2 (1·04), 32^2 (1·01), 33^1 (0·93), 34^2 (0·99), 35^2 (1·01), 36 (0·96), 38^2 (1·04), 40-^2 (0·97), 42 (1·07), 43^3 (1·10), 44- (0·98), 47^2 (1·03), 48^1 (0·91), 53^1 (0·95), 56^2

MYC (0·98), 57[1] (0·92), 58[4] (0·95), 59 (0·87), 60[2] (1·05), 62[1] (0·91), 64[1] (0·90), 66[2] (0·96), 67[2] (1·01), 68[2] (0·99), 69[1] (0·92), 70-[2] (1·01), 72[2] (0·97), 73[2] (0·98), 74[1] (0·93), 75[2] (0·95), 76[2] (0·98), 78[1] (0·92), 79[1] (0·95), 80[2] (0·98), 81 (1·11), 82[1] (0·93), 83[2] (0·97), 84[1] (0·95), 92 (1·02),

BRB 1[1] (0·97), 2[2] (1·02), 4[1] (0·96), 5[1] (0·95), 6[2] (1·03), 8[2] (1·07), 9[1] (0·95), 10[1] (0·96), 12[2] (1·00), 16[2] (1·01), 17[2] (0·99), 18[2] (1·03), 19[2] (1·10), 20[2] (1·02), 21[2] (0·99), 22[1] (0·94), 23[1] (0·93), 24[2] (0·99), 25[1] (0·96), 26[1] (0·95), 27[1] (0·96), 28[1] (0·96), 29[2] (0·99), 30[1] (0·93), 33[1] (0·93), 36[2] (1·05), 37[1] (0·97), 39[1] (0·93), 40[2] (0·99),

TIR 1 (1·09), 3[1] (0·94), 4[1] (0·95), 5[1] (1·00), 6[1] (0·95), 8[1] (0·95), 11[1] (0·97), 12[1] (0·98), 13[1] (0·98), 14[1] (0·97), 15[1] (0·97), 16[1] (0·95), 18[1] (0·94), 20[1] (0·95), 21[1] (0·97), 26 (1·03), 27 (1·02), 28[1] (0·99), 29 (1·03), 30[1] (0·95), 31[1] (1·01), 35[1] (1·00), 38[1] (1·00), 41 (1·06), 43[1] (0·98), 45[1] (1·00),

ASN 1[1] (0·98), 2[1] (0·97), 4[1] (1·00), 6[1] (1·00), 7[1] (1·01), 8[4] (0·92), 9[1] (1·01), 10[1] (0·95), 11[1] (0·99), 12[1] (0·98), 14[1] (0·98), 15[1] (1·02), 16[3] (1·05), 17[3] (1·03), 18[3] (1·07), 19[1] (1·02), 20[1] (0·99), 21[4] (0·92), 22- (0·96), 25[3] (1·10), 28[3] (1·04), 29[3] (1·06), 30[3] (1·09), 32[1] (0·98), 33[1] (1·00), 34[1] (0·96), 35[1] (1·03), 39- (0·98), 41[1] (0·99), 43[3] (1·04), 44[1] (0·98), 46[1] (0·99), 47[1] (1·00), 48[1] (0·98), 49[4] (0·97),

ZYGO 1[2] (1·01), 2[3] (1·04), 3[2] (1·01), 4[3] (1·01), 5[2] (1·02), 6[2] (0·99), 7[3] (1·09), 9[2] (0·99), 10[2] (0·98), 11[2] (1·00), 12[3] (1·08), 13[1] (0·96), 14[2] (1·01), 15[3] (1·04), 16[2] (1·01), 17-[1] (0·96), 18[1] (0·97), 19[3] (1·09), 20[2] (1·01), 22[1] (0·94), 23[2] (1·00), 24-[3] (1·03), 25-[3] (1·02), 26[2] (0·99), 28[2] (0·99), 29[1] (0·94), 30[2] (1·00), 31[2] (1·01), 32[3] (1·04), 33[2] (1·01), 34[2] (0·98), 35[1] (0·96), 36[1] (0·95), 37[2] (1·00), 38[3] (1·04),

KRAK 1[1] (0·92), 3-[1] (0·94), 4[1] (0·95), 5[1] (0·96), 7 (0·90), 8[1] (0·95), 11[1] (0·97), 12[1] (0·98), 14-[1] (0·97), 16-[1] (0·94), 17-[1] (0·96), 20-[2] (1·01), 24-[2] (0·99), 25[2] (1·00), 27[1] (0·95), 29- (1·02), 31[2] (0·96), 33-[2] (0·98), 34[2] (0·97), 35[2] (1·00), 36[2] (0·97), 39[2] (0·98), 40[2] (1·00), 43- (1·05), 45[1] (0·96),

PLAT 3 (1·02),

OLYM 2-[*d*] (0·98),

PKAS 11- (0·98), 12 (0·98),

NICH 87[*c*3] (0·92), 98[*c*3] (0·92),

STEP 12 (0·96),

THEB 2[*Y*] (0·88), 3[*Y*] (0·98), 9[*Y*] (0·97), 13[*Y*] (1·04), 16[*Y*] (0·98), 20[*Y*] (0·97), 25- (1·25), 26[*Y*] (0·99), 28[*Y*] (0·94), 31[*Y*] (0·98), 36[*Y*] (0·97), 44[*Y*] (0·96),

EUT 2[*Y*] (0·96), 3 (0·94), 4 (0·99),

KALL 1[*Y*] (0·98), 2- (0·97), 3 (1·05),

HWM 4[*G*] (1·08), 5[*F*] (1·05), 6[*F*] (1·01), 7[*F*] (1·16), 8[*F*] (1·11), 9[*F*] (0·99), 11-[*F*] (1·17), 12[*F*] (1·01), 13[*F*] (1·07), 14[*F*] (1·02), 15[*I*] (1·03), 18[*I*] (1·05), 20[*F*] (1·05), 22[*F*] (1·09), 23[*F*] (1·01), 24[*F*] (1·03), 25[*K*] (1·00), 26[*F*] (1·03), 27[*F*] (1·03), 29[*F*] (1·06), 30[*J*] (1·00), 31[*H*] (0·98), 32[*H*] (1·03), 33[*F*] (1·10), 34-[*I*] (1·08), 35[*F*] (0·97), 36[*F*] (0·96), 37[*F*] (0·98), 38[*F*] (1·07), 39-[*I*] (1·12), 40[*G*] (1·01), 41[*I*] (1·01), 42[*J*] (1·03), 44[*I*] (1·02), 45[*I*] (0·99), 46[*F*] (0·99), 47[*I*] (1·05), 48[*G*] (0·96), 49[*F*] (1·04), 50[*H*] (1·03), 52[*F*] (0·96), 53[*H*] (1·02), 54[*H*] (1·05), 56[*H*] (1·03), 58[*I*] (1·02), 60[*F*] (1·00), 61[*F*] (1·06), 62-[*G*] (0·95), 63[*F*] (0·99), 64[*F*] (1·08), 65[*F*] (1·02), 66[*F*] (1·03), 67[*G*] (1·06), 69[*G*] (1·04), 71[*F*] (0·97), 76[*H*] (0·98), 77[*F*] (1·00), 79[*F*] (1·03), 80[*H*] (0·99), 82[*G*] (1·02), 83[*I*] (1·03), 84[*I*] (1·08), 85[*K*] (1·03), 86[*I*] (1·06), 87[*H*] (1·01), 88[*I*] (1·03), 89[*J*] (1·15), 101[*F*] (1·04)

2a. Subgroup MBGP of MBP:
(2 samples from Gla)

GLAS 1 (1·00), 2 (1·00) (factors to fit MBP: 1 (1·00), 2 (0·99))

3. Group TAP of 27 samples:
(25 core samples+2 associated samples [marked "-"])

MYC 39 (1·06), 45 (0·96),

TIR 2[2] (1·01), 19[2] (0·95), 22[2] (0·98), 23[2] (0·96), 24 (1·05), 32- (0·99), 33 (0·92), 34[2] (1·01), 36[2] (0·99), 39[2] (0·97), 40[2] (1·00), 42[2] (0·97), 44[2] (0·98),

ASN 3[2] (0·96), 13 (1·11), 23[2] (0·99), 26[2] (1·03), 27[2] (0·98), 31[2] (1·05), 52[2] (0·95), 56[2] (1·00),

KRAK 28- (1·05),

HWM 10[*E*] (0·96), 17[*E*] (1·09), 43[*E*] (1·01)

4. Group ACHP of 53 samples:
(32 core samples+21 associated samples [marked "-"])

BRB 3-[2] (1·02), 13- (1·17),

ASN 58- (0·94),

ACHA 1-[*g*] (1·03), 2-[*c*] (0·94), 3- (0·86), 4-[*d*] (1·01), 6[*c*] (0·98), 7[*d*] (1·01), 8[*d*] (1·03), 9[*d*] (0·98), 10-[*d*] (1·01), 11 (0·97), 12[*d*] (1·01), 13-[*c*] (0·94), 14[*c*] (0·95), 17[*c*] (0·95), 18[*c*] (0·93), 20 (0·88),

PLAT 1[*c*] (0·95), 2[*d*] (1·03), 4[*d*] (0·99), 5-[*d*] (1·04), 7[*c*] (0·91), 9[*c*] (0·90), 10[*d*] (1·01), 11[*c*] (0·93), 13[*c*] (0·93), 17 (0·97), 19[*e*] (1·09),

OLYM 1-[*d*] (0·99), 3- (1·07), 4-[*d*] (1·01), 5[*d*] (0·97), 6[*d*] (1·02), 7-[*d*] (1·04), 9[*e*] (1·12), 10[*d*] (0·99), 11[*d*] (1·04), 12[*d*] (1·03), 13[*d*] (1·01), 14[*d*] (1·00), 15[*c*] (0·97), 16[*e*] (1·08), 17-[*e*] (1·15), 18[*e*] (1·18),

PKAS 1-[*d*] (1·01), 2-[*d*] (1·01), 9-[*d*] (1·01), 13-[*d*] (1·01), 15-[*c*] (0·97),

NICH 59-[*c*3] (0·96), 93[*c*3] (0·97)

5. Group PE1P of 11 samples:
(6 core samples+5 associated samples [marked "-"])

PKAS 4[f] (1·02), 5[f] (0·95), 10-[e] (1·04), 14 (0·87), 16- (0·92), 18 (0·95),
PERS 18 (1·13), 19[e] (1·09),
CHOR 8-[e] (1·06), 9- (1·17),
NICH 69-[i] (0·83)

6. Group PE2P of 4 samples:
(3 core samples+1 associated sample [marked "-"])

PERS 9 (1·05), 10 (0·97), 11 (0·98)
CHOR 2-[g] (1·13)

7. Group PE3P of 3 samples:

PERS 3[i] (0·99), 8[i] (1·00),
NICH 49[2] (1·00)

8. Group PE4P of 3 samples:

OLYM 19 (0·97),
PERS 4 (1·04),
CHOR 10[g] (0·98)

9. Group CHOP of 12 samples:
(10 core samples+2 associated samples [marked "-"])

PKAS 3[f] (0·96), 17-[f] (1·02),
CHOR 4[f] (1·02), 5[f] (1·04), 6[f] (0·99), 11[f] (1·01), 12[f] (0·98), 15[f] (0·98), 16[f] (0·99), 18[f] (0·99), 20[f] (1·02),
NICH 46-[f1] (0·98)

10. Group CHPP of 4 samples:
(3 core samples+1 associated sample [marked "-"])

CHOR 1[g] (1·06), 14[j] (0·96), 19[g] (1·04),
NICH 43-[a2] (0·94)

11. Group NI2P of 24 samples:
(14 core samples+10 associated samples [marked "-"])

KRAK 41 (0·82),
PLAT 16[h] (1·08), 18- (0·90),
PERS 2-[h] (1·01), 14 (1·02), 16-[h] (1·03),
NICH 14[h1] (1·09), 25[h1] (1·00), 29-[i2] (0·99), 44[h1] (1·06), 48[h1] (1·00), 51[h1] (1·01), 52-[h1] (1·04), 55[2] (1·01), 56[h1] (1·04), 81[2] (0·81), 83-[2] (0·99), 84-[1] (1·07), 85[i2] (0·93), 88-[2] (1·01), 90[i2] (0·91), 91-[1] (1·12), 95[h1] (1·07), 100-[2] (0·95)

12. Group NI3P of 17 samples:
(9 core samples+8 associated samples [marked "-"])

ASN 61-[5] (1·11),
PLAT 6[c] (0·99), 20-[c] (1·04),
OLYM 8- (1·02),
PKAS 6- (1·07), 20[c] (1·03),
PERS 20-[c] (1·04),
NICH 32[l5] (0·96), 33[l5] (0·93), 34[l5] (0·92), 36-[5] (1·02), 37[5] (0·97), 38-[5] (1·02), 39[l5] (0·95), 65-[5] (1·03), 78[l5] (0·92), 80[l5] (0·92)

13. Group NI4P of 13 samples:
(12 core samples+1 associated sample [marked "-"])

NICH 26[i2] (1·02), 47-[a1] (1·09), 61[i2] (1·01), 62[i2] (1·02), 64[i2] (1·01), 67[i2] (0·95), 70[i2] (1·02), 72[i2] (0·96), 73[i2] (0·99), 74[i2] (0·94), 75[i2] (0·96), 77[i2] (0·97), 79[i2] (1·01)

14. Group NI5P of 12 samples:

NICH 5[4] (1·07), 7[K4] (1·00), 10[K4] (0·97), 21[K4] (0·98), 22[K4] (0·99), 24[K4] (0·98), 31[K4] (0·95), 57[4] (1·03), 66[4] (1·02), 68[4] (0·89), 86[4] (1·07), 96[K4] (0·99)

15. Group NI6P of 6 samples:

NICH 3[1] (1·10), 4[1] (1·02), 9[1] (1·05), 42[1] (0·96), 54[j2] (0·88), 60[j1] (0·96)

16. Group STP of 20 samples:
(18 core samples+2 associated samples [marked "-"])

NICH 94[a3] (1·00), 99[3] (1·08),
STEP 1[a] (0·98), 2 (0·95), 3 (0·93), 4[a] (1·02), 5[a] (1·03), 6[a] (1·02), 7[i] (0·93), 8[a] (1·02), 9[a] (0·99), 10-[a] (1·00), 11[a] (1·02), 13- (0·98), 15[a] (1·00), 18[a] (1·01), 19[a] (1·01), 20[a] (1·00), 30[a] (0·96),
HWM 16[E] (1·01)

17. Group PERP of 19 samples (not included here: 2 samples, see group 17a):
(17 core samples+2 associated samples [marked "-"])

ASN 54 (1·05),
PERA 1 (0·97), 2[p] (1·02), 3[p] (0·96), 5[p] (0·99), 9[p] (1·00), 10 (0·92), 12[p] (1·03), 13 (1·04), 14 (1·21), 16[p] (0·99), 17 (0·88), 18[p] (0·97), 19- (1·03), 21[p] (1·00), 22- (1·02), 23[p] (0·99), 24[p] (1·02), 25 (0·85)

17a. Subgroup PESP of PERP: (2 samples)

PERA 4 (0·95), 7 (1·05), factors to fit PERP: 4 (0·79), 7 (0·91)

18. Group THEP of 26 samples:
(24 core samples+2 associated samples [marked "-"])

BRB 34- (1·01),
THEB 4[X] (1·03), 5[X] (0·97), 15[X] (1·13), 21[X] (1·11), 22[X] (1·00), 23[X] (0·97), 27[Y] (0·88), 29[X] (0·99), 30[X] (0·99), 32[X] (1·01), 33[X] (1·05), 35[X] (1·09),

THEB 37^{X} (0·99), 39^{Y} (0·92), 40^{X} (1·00), 41^{X} (0·99), 42^{X} (0·99), 43^{X} (1·06), 45^{X} (1·00), 46^{X} (0·97), 47^{X} (0·94),
EUT 1^{X} (0·96),
KNOS 4 (0·98), 14 (0·95),
HWM 3- (0·94)

19. Group THFP of 10 samples:
(9 core samples+1 associated sample [marked "-"])

ASN 60-^{5} (0·98),
THEB 1^{X} (1·03), 6^{Y} (0·92), 7^{X} (1·03), 12^{X} (1·02), 17^{X} (1·01),
TNAG 1 (1·00), 2 (1·00), 3 (1·01), 4 (1·00)

20. Group PHAP of 42 samples:
(35 core samples+7 associated samples [marked "-"])

ASN 59-^{5} (0·95),
THEB 10- (0·93), 48-^{Y} (0·90),
FEST 3 (1·06), 7 (0·97), 8 (1·02), 9 (1·00), 13 (0·98), 14 (0·92), 15 (0·93), 17- (0·95), 19 (0·99), 21 (0·98), 22 (0·97), 25- (0·99), 28 (1·05), 30 (1·02), 31 (0·98), 32- (1·00), 34 (0·98), 35 (1·07), 36 (1·00), 37 (1·03), 38 (0·99), 40 (1·00), 41 (1·02), 43 (1·04), 44 (0·99), 45 (1·06), 48 (0·92), 49 (1·02), 50 (1·10), 51 (1·04), 53 (0·98), 55 (1·00), 56 (1·04), 57 (0·98), 59 (1·03), 60 (0·97),
KNOS 2 (0·94), 5- (0·99), 22 (1·17)

21. Group PHBP of 5 samples:

FEST 6 (0·96), 10 (1·06), 11 (0·94), 46 (1·03),
HWM 57^{J} (1·01)

22. Group PHCP of 19 samples:
(16 core samples+3 associated samples [marked "-"])

FEST 1 (0·97), 4 (0·95), 5 (0·95), 12 (0·98), 16 (1·01), 20 (1·04), 23 (0·93), 24- (0·96), 26 (0·99), 29 (0·98), 33 (0·96), 42 (1·09), 47 (0·96), 52 (0·99), 54 (1·04), 58 (1·01),
KNOS 9 (0·99), 38- (0·99), 39- (1·18)

23. Group PHDP of 11 samples:

KNOS 3 (0·96), 7 (0·98), 8 (1·07), 10 (0·99), 13 (0·94), 15 (1·07), 19 (1·02), 20 (1·06), 21 (0·98), 27 (0·99), 31 (0·94)

24. Group CHAP of 23 samples:
(19 core samples+4 associated samples [marked "-"])

MYC 20- (0·84),
STEP 14- (0·97),
CHAN 1 (0·93), 4 (0·91), 5- (0·93), 7 (0·62), 10- (1·09), 11 (0·95), 14 (1·16), 17 (0·88), 22 (1·11), 24 (1·08), 25 (0·92), 27 (1·05), 28 (1·24), 30 (1·15), 31 (1·09), 32 (0·94), 34 (1·28), 36 (1·01), 38 (1·10), 40 (1·09), 41 (1·01)

25. Group CREP+CRECP of 18 samples:
(11 core samples+1 associated sample [marked "-"]+6 samples from Cyprus included here to show the fit factors)

CHAN 3- (1·04), 15 (0·95), 16 (0·94), 19 (0·86), 20 (0·91), 21 (0·90), 23 (1·14), 37 (1·02), 42 (1·12), 43 (1·02), 44 (0·94), 45 (1·10),
KIT 79 (1·03), 82 (1·13), 83 (1·01), 84 (1·00),
HSTK 28 (1·02), 30 (0·96)

25a. Group CRECP of 6 samples (= subgroup of **CREP**):

KIT 79 (1·00), 82 (1·09), 83 (0·99), 84 (0·99),
HSTK 28 (0·99), 30 (0·94)

26. Group M1P of 6 samples:
(4 core samples+2 associated samples [marked "-"])

MYC 77 (1·00),
ACHA 15- (1·10)
ASN 57 (1·01),
ZYGO 40 (0·98),
THEB 24 (1·00)
CHAN 29- (0·98)

27. Group M2P of 8 samples:
(6 core samples+2 associated samples [marked "-"])

KRAK 9 (1·03), 18 (0·93), 19 (1·05), 42 (1·12),
CHOR 17^{e} (0·91),
KALL 4 (1·00),
HWM 1-^{I} (1·03), 78-^{K} (0·92)

28. Group HWM1P of 7 samples:

HWM 90^{B} (1·00), 91^{B} (1·00), 94^{B} (1·06), 95^{B} (1·04), 96^{B} (0·88), 97^{B} (0·98), 99^{B} (1·00)

29. Group HWM2P of 3 samples:

HWM 102^{A} (1·01), 103^{A} (1·00), 105^{A} (0·99)

30. Group HWM3P of 3 samples:

HWM 106^{C} (0·97), 107^{C} (1·05), 108^{C} (0·98)

31. Group HWM4P of 3 samples:

HWM 72^{D} (1·01), 73^{D} (0·99), 74^{D} (1·00)

List of 100 chemical singles including two single pairs of mutual similar samples:

MYC 30
BRB 11
TIR 7, 10
ASN 24^{1}, 37, 38, 42, 53, 55
ZYGO 21^{2}, 27, 39
KRAK 2, 6^{1}, 10, 13, 21^{2}, 30, 44
ACHA 5, 16, 19

PLAT	12, 14, 15[c]
OLYM	20
PKAS	19
PERS	1, 5, 12, 13, 15, 17
CHOR	3, 7, 13
NICH	1^4, 2^4, 6^1, 8^2, 23^1, 27, 28^1, 30, 35^1, 40^2, 41^1, 45^4, 50, 53, 58^1, 63^2, 71^{i2}, 76, 89^{e3}, 97^1
STEP	16, 29
THEB	11^Y, 19, 34^Y, 38
GLAS	3
PERA	6, 8, 11, 15, 20
FEST	2, 18, 27, 39
KNOS	16
CHAN	2, 6, 8, 9, 12, 13, 18, 26, 33, 35, 39
KIT	81
HWM	2, 51^K, 70^C, 75^B, 81, 92^B, 93^B, 98^B, 100^B, 104

two pairs:

PKAS	7^j, 8^j
PERS	6^g, 7