Appendix G

Chemical analysis of Mycenaean pottery from the Menelaion and its vicinity

by R. E. Jones and J. E. Tomlinson

This section brings together two separate studies of Mycenaean pottery from the Menelaion and its vicinity. Although carried out at different times and under contrasting circumstances, they share one common, major aim of characterising chemically the locally-made pottery, the resulting data contributing to the broader effort on the part of the two laboratories concerned, the Fitch Laboratory and the Radiochemistry Laboratory at the University of Manchester, of defining the characteristics of pottery produced at the main centres of production in the Mycenaean world. The scope of the two studies should be explained at the outset: Part I presents the results of emission spectroscopy analysis of local LH IIIA–B fine wares and suspected imports from the excavations at the Menelaion, while the neutron activation analysis (NAA) programme in Part II investigated a wider range of the likely local fabrics, including cooking ware and 'Barbarian' ware, from the Menelaion as well as the North Hill and Profitis Elias. There was no overlap among the samples analysed in the two investigations, and clay prospection played only a very small part in the earlier of them. Pottery from the Menelaion of later date (Archaic and Black Glaze) analysed by both techniques will be reported separately.

PART I: ANALYSES BY OPTICAL EMISSION SPECTROSCOPY

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Introduction

The small programme of chemical analysis reported here was the first of its kind to be undertaken in the Fitch Laboratory, in 1974. The project, designed by H. W. Catling and the writer on the basis of the finds from the first years of excavation at the Menelaion, followed traditional lines. First, five of the most constantly recurring classes of pottery identified on the site, for which local production might reasonably be expected, were selected to determine the range of compositions in fine textured pottery made from those clays worked by Mycenaean potters at or in the vicinity of the site: these accounted for 46 samples of well-defined LH IIIA–B mainly wheel-made pottery. Second, a preliminary effort was made to locate such clays (using texture and plasticity as the sampling criteria) (FIG. G.1) and to ascertain their chemical comparability with the pottery.[1] Third, some twenty suspected imports were also sampled in 1976, the intention of their analysis being to make some comment about their possible origins. In particular it was hoped to shed light on the status of some of these imports, dated to LH II and classed by Catling as products of *either* Minoan workshops on Crete *or* Minoan potters working outside Crete.[2] A second aim was to investigate whether or not examples of LH IIA 'Palatial jars' came from a single (mainland) source. Some LH IIIA–B imports were also included. TABLE G.1 includes a brief description of the material analysed, including some coarse ware stirrup jar (SJ) fragments, the results of whose (chemical) analyses are reported more fully elsewhere.[3]

The first two aspects of the programme have already been published, albeit briefly by the writer,[4] together with illustration of the reference groups, as well as the results of analysis of other groups of relevant material: first, Mycenaean pottery of comparable type and date as for the Menelaion from

[1] Unfortunately, the chemical programme was completed before the discovery of the MH kilns at the Menelaion which could have provided useful if numerically limited reference material.

[2] H. W. Catling, 'Minoan and 'Minoan' pottery at the Menelaion, Sparta', in D. Evely, I. S. Lemos and S. Sherratt (eds.), *Minotaur and Centaur*, BAR 638 (1996) 70–8.

[3] H. Haskell, R. E. Jones, P. M. Day and others, *Aegean Late Bronze III Coarse Ware Stirrup Jars*, Fitch Laboratory Occasional Paper 5 (forthcoming).

[4] R. E. Jones, 1986, *Greek & Cypriot Pottery: A Review of Scientific Studies*. Fitch Laboratory Occasional Paper 1. British School at Athens, 210f.

TABLE G.1. Pottery analysed by OES.

Local reference groups

1–9	Angular and plain kylikes (LH IIIB)
10–19	Angular shallow bowls/conical cups (LH IIIB)
20–28	Coated goblets (LH IIIA1)
29–37	Handmade jugs (LH IIIA1)
38–46	Decorated pottery (LH IIIA1)

Suspected Imports

Publication number	Description (and date)	Findspot	Archaeological prognosis	Chemical assessment
NB 14	Palace Style jar, LH IIA	North Building		Peloponnese
ST. 10	Palace Style jar, LH IIA	M. 23 5 South Terrace		Peloponnese
X. 1	Palace Style jar frag., LH IIA	Dawkins Room 1 (Mansion II)		Local? (or Peloponnese)
NB. 70	Closed vessel frag. with tortoiseshell and ?spiral decoration, LM IA	G. 21 4 The North Building	Minoan import	Peloponnese
PD. 13	Rounded cup frag. LM II–IIIA1	H. 24 Wash Level Pottery deposit	Minoan import	Laconia?
CLO 26	Conical rhyton frag., LM IB	J24/J25 15 Mansion II construction level		Central Crete?
PH. 12	LH IIA bridge-spouted jug FS 103	Early wash level (H 24 25) over post-holes		Peloponnese
CLO. 25	LM IIIA1 flask frag.	H.25/J.25 Mansion II construction level		Central Crete
VI. 7	Covered cup, LM IB, ?Kythera	Dawkins House Room VI (Mansion I)	Minoan import	South Peloponnese
PH. 14	Marine Style: nautilus rhyton LM IB	Early wash level (H.25) over post-holes	Minoan import	Peloponnese
ET. 47	Decorated saucer FS 237, LH IIB	K. 25 East Terrace		Laconia?
WE 56	Pithoid jar frags. LM IIIA1	H. 25 6 east sector of deep wash level	Minoan import	Central Crete
ST. 727	LM IB vase frag.	M. 23/N. 23 South Terrace	Minoan import	Uncertain; similar to V17
WE. 62	LM IB frag.	H. 25 – east sector of deep wash level	Minoan import	Laconia?
V. 17	LH IIA closed vessel frag. with FM 61 motif	Dawkins House, Room V (Mansion II)		Uncertain; similar to ST727
PH 15	?	H. 25 25 early wash level over post-holes	?	Peloponnese
III. 10	Closed vessel b.f. LM II–IIIA1			Central Crete?
752	Coarse ware SJ: spout frag.; lod			W Crete
I. 13 (715)	Coarse ware SJ, LHIII B2: conical; bands	Dawkins Room I – Mansion II		W Crete
2213	Coarse ware SJ: disc/handle frag. flat handle			W. Crete

2296	Coarse ware SJ: false neck frag.	W Crete
2730	Coarse ware SJ: false neck frag.	W Crete
2772	Coarse ware SJ: spout frag.	W. Crete
2774	Coarse ware SJ: spout/shoulder frag.	W. Crete
SM75 M23/N23 LVI	Coarse ware SJ: ?	Uncertain
SM77 A.1 level 16	Coarse ware SJ: body sherds; lod(?)	W Crete
SM73 D1 Level C	Coarse ware SJ: should/handle frag.	W Crete
SM73B/D1 L3SF16	Coarse ware SJ: ISJ frag.	W. Crete
SM73 P level 12	Coarse ware SJ: ?	W. Crete

Clays (FIG. G.1)

Sample	Location
CL1	Clay from east bank of Eurotas immediately below the site
CL2–3	Clays from scarp by road below the site

sites in Laconia (Vaphio: Palaiopyrgi and Ayios Vasilios) (FIG. G.1) and beyond in the southern Peloponnese, and second later, Archaic, pottery from the Menelaion. Furthermore, three of the suspected imports have been published elsewhere: one example of Marine Style[5] (**945**) and two fragments of coarse ware stirrup jars (**752** and I. 13 (**715**)).[6]

Samples were taken from the pottery by breaking a small fragment from the sherds concerned, removing paint, slip or any concretion and grinding to powder in an agate mortar. The method of analysis was optical emission spectroscopy (OES), following the procedures set out by the writer.[7] The compositions of the samples with respect to the nine elements determined (in their oxide form), which are given in TABLE G.2, were then studied by univariate and multivariate statistical means. The similarity in the contents of most elements in two samples from a single vase, **1549A/B**, provides a reassuring assessment of the analytical procedure.

LOCAL REFERENCE GROUPS

At the time the analyses were carried out, the process of establishing the characteristic chemical compositions of pottery at the principal Mycenaean centres in the Peloponnese was already advanced.[8] But, although material from some ten sites (FIG. G.1) had been analysed by OES, there were significant lacunae, one of which was inland Laconia. In filling that gap, the work reported here was intended to determine whether chemical differences could be detected between the clays of, for example, central and southern Laconia and central Laconia and the Argolid.

Several points can be made about the Menelaion data: (1) each of the five groups has reasonable chemical coherence, (2) there is (natural) variation in the concentration of some of the elements, especially calcium, within the groups, (3) all the groups are made of calcareous clays and three groups — the kylikes, cups and coated goblets — and most of the handmade jugs are rich in aluminium, (4) the coated LH goblets have consistently higher magnesium contents than do the other groups but otherwise there is extensive overlap between the composition ranges of each group. The feature of high aluminium also features in the pottery from the neighbouring sites of Vaphio: Palaeopyrgi and Ayios Vasilios. It seems reasonable to suppose that all the groups, apart from the coated goblets, were

[5] P.-A. Mountjoy, R. E. Jones and J. F. Cherry, 'Provenance studies of LM IB/LH IIA Marine Style', *BSA* 73 (1978) 143–71.

[6] H. W. Catling, J. F. Cherry, R. E. Jones and J. T. Killen, 'The inscribed stirrup jars and West Crete', *BSA* 75 (1980) 45–113.

[7] Jones (n. 4), Appendix A.

[8] Jones (n. 4) 169–224.

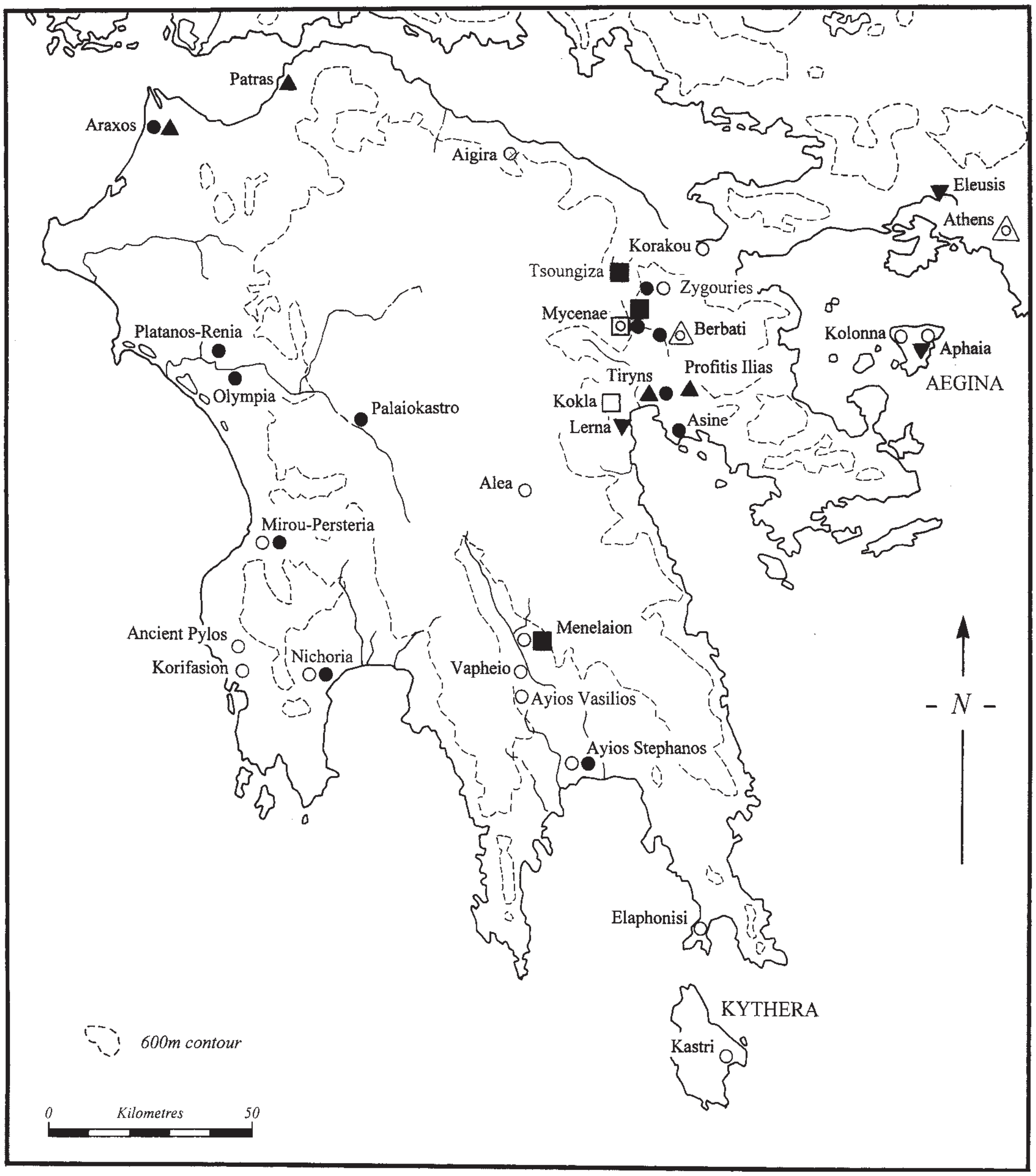

FIG. G.1. Map of sites in the Peloponnese for which Late Helladic pottery has been analysed chemically: ○ OES (Fitch Laboratory and/or Research Laboratory for Archaeology, Oxford); □ AAS (Fitch Laboratory); △ICP-ES (Fitch Laboratory); ● NAA at Berkeley, California (Asaro and Perlman data); ■ NAA at Manchester, UK; ▲ NAA at Bonn, Germany; ▼ NAA at other laboratories. Note that prehistoric pottery from several sites (not marked on the map) in the N.W. Peloponnese near Patras have also been analysed by H. Mommsen and co-workers at Bonn.

made from a number of related clays from the vicinity of the Menelaion. The coated goblets appear to stand apart from the other groups yet they share with the kylikes and the cups what is potentially an unusual chemical characteristic at least in the Aegean, that of a high aluminium content. What can be said is that the modern clays collected, all of them non-calcareous, have no connection chemically with the Mycenaean (or Archaic) pottery. Treating collectively the compositions from all five reference groups, 46 samples in total, for purposes of making inter-site comparisons, the writer has found that in discriminant analysis the Menelaion group, comprising all 46 samples, could be differentiated from groups representing Ayios Stephanos and Mycenae, in part due to the high aluminium contents at the Menelaion already alluded to.[9] Encouraging though this result is, the broader picture is much less

[9] Jones (n. 4) fig. 3.25 showing discrimimation of the Menelaion group from the Ayios Stephanos and Mycenae groups along the first canonical variable (accounting for 82% of the variance and dominated by the Al, Mg, Mn and Na contents).

Table G.2. The chemical compositions expressed as percentage elemxides (OES).

Local reference groups

1	26.6	12.1	2.1	9.5	0.89	0.50	0.085	0.037	0.026
2	25.1	16.3	2.1	10.7	0.96	1.40	0.086	0.043	0.026
3	25.5	11.4	1.4	9.2	0.91	1.01	0.128	0.040	0.026
4	27.0	12.4	2.3	9.2	0.92	0.54	0.088	0.031	0.021
5	28.4	16.7	1.5	9.3	0.87	0.46	0.075	0.034	0.020
6	24.0	11.3	2.0	9.3	1.00	0.57	0.084	0.034	0.024
7	30.0	20.4	3.6	11.8	1.00	1.50	0.088	0.036	0.022
8	22.0	17.5	2.3	9.8	0.96	0.71	0.110	0.038	0.025
9	22.4	18.0	1.2	9.0	0.93	0.42	0.132	0.043	0.028
10	24.2	10.6	1.3	7.4	0.87	0.40	0.091	0.034	0.021
11	22.5	9.6	1.2	12.2	0.84	0.69	0.090	0.041	0.029
12	26.3	14.6	2.1	8.2	0.85	0.44	0.102	0.033	0.024
13	26.5	12.0	2.7	9.2	1.00	0.43	0.080	0.047	0.029
14	27.1	13.5	2.0	9.5	0.92	0.58	0.119	0.042	0.030
15	27.0	14.3	2.3	8.2	1.04	0.62	0.105	0.063	0.035
16	27.7	14.0	2.2	11.3	1.14	0.69	0.110	0.061	0.030
17	27.5	12.6	2.3	9.6	1.04	0.69	0.094	0.041	0.028
18	29.0	13.3	1.2	9.4	1.00	0.70	0.078	0.046	0.028
19	27.6	17.7	1.5	10.3	1.00	0.49	0.124	0.043	0.030
20	27.7	16.8	2.8	11.7	1.00	0.60	0.086	0.048	0.032
21	27.0	14.5	3.8	7.8	0.95	1.20	0.087	0.042	0.028
22	25.0	11.1	3.2	10.4	1.01	0.68	0.071	0.048	0.033
23	20.0	13.6	5.0	9.9	0.98	0.71	0.142	0.042	0.036
24	29.5	13.5	4.5	10.0	0.97	0.62	0.076	0.047	0.035
25	27.0	16.0	3.7	10.5	1.12	0.51	0.109	0.047	0.037
26	22.0	21.8	4.0	9.7	1.06	1.48	0.111	0.046	0.036
27	28.5	15.1	3.0	9.8	1.03	0.94	0.101	0.046	0.034
28	24.2	12.7	3.4	11.0	1.01	1.05	0.086	0.050	0.037
29	24.7	14.9	2.6	9.8	0.99	0.55	0.093	0.041	0.030
30	20.0	10.0	2.8	10.0	0.85	0.60	0.090	0.037	0.025
31	25.0	14.0	2.8	11.0	0.86	0.80	0.110	0.043	0.023
32	25.0	14.0	3.0	11.0	0.85	0.67	0.120	0.039	0.027
33	18.9	10.1	2.6	9.0	0.84	0.60	0.106	0.037	0.027
34	18.0	8.3	1.4	8.5	0.84	0.66	0.113	0.034	0.031
35	21.6	7.4	3.1	9.7	0.77	0.32	0.134	0.032	0.020
36	21.3	17.3	2.4	10.4	0.98	0.56	0.142	0.051	0.038
37	21.8	10.3	1.4	9.7	0.89	0.72	0.081	0.036	0.025
38	21.4	11.0	1.8	7.9	0.79	0.65	0.148	0.028	0.024
39	23.3	13.7	4.2	10.0	0.88	0.53	0.117	0.049	0.029
40	18.8	9.4	1.7	8.8	0.81	0.48	0.091	0.034	0.022
41	21.0	13.7	2.5	10.7	0.86	0.50	0.094	0.037	0.024
42	17.1	7.8	1.2	7.4	0.75	0.66	0.128	0.038	0.033
43	17.0	12.0	2.7	11.3	0.88	0.48	0.122	0.051	0.035
44	19.1	9.8	2.1	8.0	0.80	0.48	0.084	0.034	0.024
45	20.9	9.5	2.2	8.7	0.82	0.63	0.118	0.032	0.027
46	19.4	8.6	2.6	8.9	0.87	0.83	0.109	0.036	0.027

Suspected Imports

No.		Al	Ca	Mg	Fe	Ti	Na	Mn	Cr	Ni
752		16.1	0.3	0.5	4.5	0.93	1.25	0.151	0.010	0.006
495	(NB. 70)	19.0	10.0	3.8	9.9	0.95	0.58	0.095	0.040	0.024
528	(PD. 13)	19.1	9.4	2.0	9.7	0.95	0.47	0.059	0.049	0.030
672	(X. 1)	16.6	12.0	2.7	9.4	0.81	0.81	0.130	0.045	0.039
675	(III.10)	17.5	8.9	3.5	13.1	1.12	0.74	0.114	0.065	0.060

715	(I. 13)	16.0	0.2	0.7	5.4	0.92	1.60	0.135	0.010	0.014
768	(CLO 26)	18.5	10.2	5.3	13.4	1.05	0.15	0.140	0.073	0.058
804	(NB. 14)	14.3	8.5	3.3	9.7	0.78	0.29	0.135	0.050	0.040
862	(PH. 12)	17.7	12.5	3.6	9.7	0.92	0.66	0.095	0.039	0.025
864	(ST. 10)	20.0	13.0	3.7	6.2	1.02	0.32	0.059	0.059	0.062
923	(CLO 25)	20.8	12.2	7.2	13.1	1.11	1.15	0.135	0.080	0.060
942	(VI. 7)	21.8	11.7	5.6	10.9	1.05	0.51	0.115	0.049	0.034
945	(PH 14)	16.0	12.7	3.8	10.1	0.85	0.37	0.106	0.044	0.044
1000	(V. 17)	18.0	11.7	4.2	9.8	0.84	0.37	–	0.053	0.042
1081	(PH 15)	17.7	12.7	2.3	9.7	0.87	0.41	0.120	0.059	0.044
1108	(ET. 47)	24.1	8.0	3.3	11.2	0.97	0.69	0.074	0.031	0.030
1549A	(WE 56)	14.4	12.0	8.3	12.4	1.08	1.20	0.112	0.082	0.074
1549B		16.2	15.4	9.4	12.6	1.16	1.14	0.115	0.089	0.074
1799	(ST. 727)	20.0	11.0	4.8	11.0	1.04	0.31	0.120	0.056	0.045
1860	(WE. 62)	15.5	12.3	2.8	10.4	1.00	0.55	0.130	0.045	0.046

satisfactory: the concentration ranges of the Menelaion group overlap for most elements with all those available from the Peloponnese that have been determined by OES. Not surprisingly, they are indistinguishable chemically from those representing the nearby sites in Laconia mentioned above (TABLE G.3). Further comment is given in the Discussion.

SUSPECTED IMPORTS

These are illustrated in FIG. G.3 and described in TABLE G.1, together with archaeological prognosis and chemical assessment of their origin. The composition of each suspected *import* was assessed by locating, using the 'visual-comparative' method, the optimal match with one or other reference group in the Fitch Laboratory's OES data bank whose content and extent has been set out in detail by the writer,[10] within the context of provenance studies of LB I–II and LB III Aegean pottery carried out before the mid-1980s.[11] Since that time, such studies have progressed in the case of LB I–II pottery, using for the most part atomic absorption spectrometry (AAS), at Kokla,[12] Vivara in the Bay of Naples,[13] Routsi and elsewhere.[14] One of the recognised issues in some of this later work has lain in reconciling the availability of well-defined reference groups at sites, say in the Peloponnese and Crete, against the fact that such groups need not give a reflection of the full range of compositions to be associated with production at a given period of time at those sites. This has arisen, for instance, in the course of trying to match the compositions of test samples to reference groups in central Crete in the LB I–II period: sometimes an unacceptable or unexpected number of test samples were found to be either unassigned or assigned to a group but with reservation. For the LH IIIA1 and 2 periods a major programme of AAS analysis has recently treated several classes of pottery found at Ayia Irini on Kea; examples of Mycenaean decorated, unpainted and monochrome wares were found to have several sources, including the N.E. Peloponnese.[15]

A case in point is found straightaway at the Menelaion. The following were identified on the basis of diagnostic Mg, Cr and Ni contents as having compositions matching those characteristic of central Crete which includes the Knossos area as well as the Mesara:[16] **1549** (WE 56), **923** (CLO 25), **768** (CLO 26). On the other hand, **675** (III.10) *could* be central Cretan, but the affinity is less strong owing to their lower concentrations in the three diagnostic elements.

West Crete, if not Chania, accounts well as the source of the coarse ware stirrup jar fragments, **752** and **715** (I. 13), as originally determined by Catling *et al.*[17] More complex is the question of *fine wares* from the Chania region in early LB III, since some of their compositions seem to be less distinctive than those of the coarser fabrics; for instance, the chemical data for so-called Brown and Grey wares found at Chania are not dissimilar to those characteristic of the southern Peloponnese and Kythera.[18]

[10] Jones (n. 4) chapter 3.

[11] Jones (n. 4) 475f and 468f respectively.

[12] R. E. Jones, 'Chemical analysis of some Mycenaean vases from Kokla', Appendix in K. Demakopoulou, 'Argive Mycenaean pottery: evidence from the necropolis at Kokla', in C. Zerner (ed.), *Wace and Blegen* (Amsterdam 1993) 76–80.

[13] R. E. Jones, 'Chemical analysis of the Aegean painted and unpainted wares from Vivara', in M. Marazzi and S. Tusa (eds.), *Vivara, centro commerciale mediterraneo dell'eta del Bronzo* II (Rome,1993) 303–16.

[14] See Jones (n. 12) 77f.

[15] C. Morris and R. E. Jones, 'The Late Bronze Age III town of Ayia Irini and its Aegean relations', in L. G. Mendoni and A. I. Mazarakis-Ainian (eds.), *Kea-Kythnos: History and Archaeology* (Athens 1998) 189–200.

[16] Jones (n. 4) 225.

[17] Catling *et al.* (n. 6). See also Jones (n. 4) table 6.12.

[18] Jones (n. 4) 465f.

TABLE G.3. Comparative OES data.

	Al	Ca	Mg	Fe	Ti	Na	Mn	Cr	Ni
Vaphio									
VAPH1	25.0	19.0	2.8	9.9	0.90	0.99	0.131	0.035	0.019
VAPH2	25.0	18.3	3.3	10.3	1.03	1.85	0.124	0.041	0.022
VAPH3	25.0	12.8	3.4	12.3	1.03	0.85	0.107	0.049	0.019
VAPH4	24.7	18.9	2.4	8.1	0.80	1.22	0.090	0.033	0.014
VAPH5	25.0	18.0	3.9	9.4	0.99	1.13	0.122	0.041	0.018
Ayios Vassilios									
AYVA1	25.0	14.8	4.2	12.4	1.10	0.79	0.108	0.053	0.027
AYVA2	25.0	14.3	2.4	10.6	1.04	1.05	0.121	0.035	0.020
AYVA3	24.5	13.5	4.1	12.2	0.98	0.53	0.081	0.046	0.028
AYVA4	24.5	14.1	3.0	9.1	0.98	0.60	0.074	0.040	0.022
AYVA5	23.8	16.1	2.9	9.8	1.03	1.30	0.103	0.034	0.017
Knossos LM IB (*GCP* Appendix III)									
Mean (16)	20.3	15.1	5.1	9.5	0.95	1.34	0.077	0.065	0.043
s.d.	2.4	4.6	2.3	1.3	0.10	0.30	0.015	0.011	0.016
Knossos LM IIIB (*GCP* Appendix III)									
Mean (24)	17.6	13.2	6.4	10.0	0.92	1.23	0.092	0.064	0.058
s.d.	3.1	4.3	1.6	1.3	0.12	0.34	0.022	0.010	0.010
Chania Red ware (*GCP* app III)									
Mean (19)	15.9	0.9	0.7	6.5	0.87	0.86	0.067	0.016	0.008
s.d.	2.8	0.5	0.2	1.2	0.13	0.37	0.031	0.005	0.002
Chania LM IIIC ware									
Mean (14)	15.0	6.9	1.0	6.2	0.93	1.15	0.046	0.020	0.011
s.d.	3.9	2.1	0.4	1.6	0.21	0.36	0.020	0.007	0.004
Ay. Stephanos (*GCP* 212f, table 5.1)									
502.048	16.7	9.0	2.7	10.6	1.18	1.90	0.092	0.051	0.030
502.049	23.0	1.2	0.3	6.6	1.20	0.64	0.052	0.022	0.010
502.050	16.7	6.2	2.4	8.0	0.86	1.10	0.066	0.039	0.027
502.051	18.5	10.2	3.8	10.8	1.23	1.67	0.180	0.033	0.038
502.066	14.7	7.1	2.1	7.2	0.88	1.70	0.074	0.032	0.031
502.067	19.6	7.0	2.5	7.7	0.86	1.85	0.073	0.027	0.021
502.068	13.0	5.2	1.7	6.8	0.84	1.90	0.092	0.045	0.020
502.069	14.2	8.1	2.1	6.6	0.83	1.60	0.090	0.028	0.029
502.070	16.8	5.4	2.0	7.7	0.81	0.92	0.064	0.022	0.024
502.071	16.0	13.0	3.4	8.2	0.88	1.60	0.100	0.032	0.023
502.072	17.8	12.2	3.0	7.3	0.78	0.32	0.078	0.025	0.040
502.073	16.7	14.6	3.0	6.3	0.83	0.50	0.106	0.027	0.040
502.074	16.2	9.2	1.9	5.8	0.88	0.85	0.082	0.024	0.016
502.075	17.0	9.9	3.0	7.7	0.90	0.76	0.076	0.038	0.045
Kythera, Kastri (*GCP* App II)									
Mean (16)	18.3	12.6	3.1	11.4	0.86	0.77	0.101	0.038	0.033
s.d.	2.0	2.8	0.3	2.2	0.09	0.22	0.028	0.005	0.007
Palace Style from Mycenae (*GCP* table 3.9 Gp. 15)									
1	17.5	13.4	3.1	7.2	0.69	0.62	0.108	0.039	0.042
4	14.0	11.2	2.8	6.2	0.62	0.61	0.101	0.032	0.028
5	13.2	8.5	2.7	7.0	0.66	1.20	0.122	0.033	0.037

ABBREVIATIONS
s.d. = standard deviation
GCP = R. E. Jones, *Greek Cypriot Pottery: a review of scientific studies* (1986).

As a consequence, there *may be* some West Cretan fine ware imports at the Menelaion whose compositions are too similar to the local Menelaion group for them to be recognised as such. In any case, the evidence is equivocal for **1000** (V. 17) and **1799** (ST 727) which form a loose grouping: their compositions are not typical of central nor west Crete nor can they be matched with centres in the southern Peloponnese. Their closest association is apparently with **III.10** (675).

The remaining samples, which include the Marine Style example, (PH 14) **945**, and the Palace Style jars, can be loosely classed as Peloponnesian. The latter do not form a uniform chemical group, but whether that need imply that there were several centres in the Peloponnese remains to be seen; the characteristics of its rather coarse fabric may, for example, give rise to wider concentration ranges than in corresponding fine wares. **672** (X.1) resembles in most elements the local reference groups but it may be more safely regarded as from the southern Peloponnese. All that can said about the other two 'palatial' jars, **804** (NB.14) and **864** (ST.10), is that they are similar to each other (apart from an anomalous Ni content in the latter) and differ from **672** (X.1). The high aluminium content of **1108** (ET 47) suggests possible local manufacture, and **528** (PD 13), **1089** (PH 15) and **1860** (WE 62) bear similarity in many elements with the local compositions. The remainder could be from the Argolid, southern Laconia or Kythera.

PART II: NEUTRON ACTIVATION AND STATISTICAL ANALYSIS OF LATE HELLADIC POTTERY FROM THE MENELAION, THE NORTH HILL AND PROFITIS ELIAS

R. E. Jones and J. E. Tomlinson

INTRODUCTION

This section presents the results of a statistical evaluation of the chemical data for 81 potsherds from the North Hill, Profitis Elias and the Menelaion. The samples were selected by H. W. Catling in 1987 for analysis by Neutron Activation (NAA) as part of the INSTAP/University of Manchester programme to extend the Asaro-Perlman database.[19] They encompass a range of wares from fine decorated pottery to handmade and kitchen wares, and represent the LH II to IIIC periods.

LOGIC OF SAMPLE SELECTION

Samples (see catalogue; TABLE G.4) were drawn from the North Hill Latsis Fields Wash level and the Profitis Elias Erosion Gully for the practical reason that material from these contexts is, on the whole, in a better state of preservation than material from other parts of the site, and there was no shortage of them in either context. The former is rich in earlier material (LH II to IIIA), and the latter is late 13th century BC (LH IIIB and IIIC).

Taking the NAA sherds by sets, the rationale for sampling was as follows :

North Hill Material

MEN 1–10 represent standard decorated table wares in use at the period before and during the construction and occupation of Mansions 1 and 2.

MEN 11–20 are supposed to comprise monochrome goblets, the standard ?drinking vessel, in use at the same time as 1–10.

MEN 21–30 are samples from undecorated uncoated goblets (probably the commonest undecorated shape in the period referred to for 1–10)

MEN 31–40 represent a very distinctive handmade fabric which seems peculiar to the Menelaion used almost exclusively for large water pots (jugs and hydriae) — the floruit coincides with the occupation of Mansions 1 and 2.

MEN 41–50 are a cross section of the kitchen fabrics in use, particularly for tripod cooking pots and button-based jugs, in the lifetime of Mansions 1 and 2.

Profitis Elias Material

MEN 51–60 are samples from deep bowls which, in the light of the evidence of the Aetos sites, was the standard decorated table ware shape at the end of the 13th to the start of the 12th centuries BC.

[19] F. Asaro and I. Perlman, 'Provenience studies of Mycenaean pottery employing Neutron Activation Analysis', in V. Karageorghis (ed.), *Acts of the International Archaeological Symposium: 'The Mycenaeans in the Eastern Mediterranean'* (Nicosia date), 213–24.The data were kindly released to the University of Manchester Chemistry Department for statistical evaluation.

Table G.4. Catalogue of sherds analysed by NAA
(Groups as submitted and described by H. W. Catling. Individual details by E. B. French)

MEN 01–10: LH II–IIIA Decorated fragments from North Hill (Latsis Fields) Deposit		
01	SM NHS S	Vapheio cup; Foliate band; Pinkish buff with red
02	SM NHS S	Ephyrean goblet; Spiraliform; Fine buff, polished, with brown
03	SM NHS S	Ring base, ?cup; Linear as preserved; Fine buff, soft, with brown
04	SM NHS S	?Cup body sherd; Running spirals; Fine buff, soft, with brown
05	SM NHS S	?Cup; Running spirals; Fine warm buff, soft, with red
06	SM NHS S	?Goblet; ?Decoration; Fine pink, soft, white slip with red
07	SM NHS S	Goblet body sherd; Papyrus; Fine buff with red/brown
08	SM NHS S	?Vapheio cup; Linear as preserved; Fine buff with pale brown
09	SM NHS S	?Goblet; Linear as preserved; Fine buff with pale red
10	SM NHS S	Kylix base; Linear on top, mono below; Fine buff burnt, with black/brown
MEN 11–20: LH IIB–IIIA1 Monochrome or Banded fragments from North Hill (Latsis Fields) Deposit		
11	SM NHS S	Goblet rim and handle; Banded rim as preserved; Fine buff, once well polished
12	SM NHS S	Goblet rim; Mono; Warm buff, polished, red brown paint
13	SM NHS S	Open body sherd; Mono; Warm buff, polished, red brown paint
14	SM NHS S	Open body sherd; Mono; Warm buff, polished, red brown paint
15	SM NHS S	Open body sherd; Mono, ?MH or earlier; Buff core, brown streaky paint
16	SM NHS S	Kylix stem; Mono stem, two fine lines above; Warm buff, brown paint
17	SM NHS S	Broad flat vertical handle; Mono out; Warm buff, dark brown paint
18	SM NHS S	Small flat vertical handle; Mono out; Warm buff, dark brown paint
19	SM NHS S	?Cup handle; Mono out; Warm buff, dark brown paint
20	SM NHS S	Torus base, ?krater; Mono out as preserved; Dark buff burnt, black/brown paint
MEN 21–30: LH IIB/IIIA1 Plain Goblets from North Hill (Latsis Fields) Deposit		
21	SM NHS S	Goblet body sherd with handle; Undecorated; Fine pale buff, soft
22	SM NHS S	Open body sherd; Undecorated; Fine buff, polished, fired pale out
23	SM NHS S	Goblet body sherd with handle; Undecorated; Soft warm buff
24	SM NHS S	Open body sherd; Paint traces, very worn; Soft warm buff
25	SM NHS S	Open body sherd; Undecorated; Soft warm buff
26	SM NHS S	Open body sherd; Undecorated; Soft warm buff
27	SM NHS S	Open body sherd; Undecorated; Fine grey buff
28	SM NHS S	?Closed body sherd; Undecorated; Fine grey buff
29	SM NHS S	Open body sherd; Undecorated; Fine hard red core, fired brown
30	SM NHS S	Open body sherd; Undecorated; Hard grey core, fired brownish
MEN 31–40: LH IIIA1 Plain Handmade wares from North Hill (Latsis Fields) Deposit		
31	SM NHS S	Rounded handle; undecorated; Fine warm buff
32	SM NHS S	Closed body sherd; Undecorated; Fine warm buff
33	SM NHS S	Closed body sherd; Undecorated; Fine warm buff
34	SM NHS S	Closed body sherd; Undecorated; Fine warm buff
35	SM NHS S	Closed body sherd; Undecorated; Fine warm buff
36	SM NHS S	Closed body sherd; Undecorated; Fine warm buff
37	SM NHS S	Closed body sherd; Undecorated; Fine warm buff
38	SM NHS S	Closed body sherd; Undecorated; Fine warm buff
39	SM NHS S	Closed body sherd; Undecorated; Fine warm buff
40	SM NHS S	Closed body sherd; Undecorated; Fine warm buff
MEN 41–50: LH IIB/IIIA1 Kitchen wares from North Hill (Latsis Fields) Deposit		
41		Body sherd apparently open; Undecorated; Coarse red/brown with grit and mica
42		Body sherd apparently open; Undecorated; Coarse red/brown with grit and mica
43		Body sherd apparently open; Undecorated; Coarse red/brown with grit and mica
44		Body sherd apparently open; Undecorated; Coarse red/brown with grit and mica
45		Body sherd apparently open; Undecorated; Coarse red/brown with grit and mica
46		Body sherd apparently open; Undecorated; Coarse red/brown with grit and mica
47		Body sherd apparently open; Undecorated; Coarse red/brown with grit and mica
48		Body sherd apparently open; Undecorated; Coarse red/brown with grit and mica
49		Body sherd apparently open; Undecorated; Coarse red/brown with grit and mica
50		Body sherd apparently open; Undecorated; Coarse red/brown with grit and mica
MEN 51–60: LH IIIB/IIIC Decorated Deep Bowls, etc. from Prophitis Elias Erosion Gully Deposit		
51	SM PE 11 603	Body sherd with handle; Linear as preserved.; Very soft pinkish buff, worn red paint
52	SM 77 PE 1 605	Rim; Rim line out, mono in; Very soft pinkish buff, brown paint
53	SM 77 PE 1 605	Rim; Encrusted out, mono in; Very soft pinkish buff, brown paint
54	SM 77 PE 1 605	Rim; Encrusted out, mono in; Very soft pinkish buff, brown paint
55	SM 77 PE 1 605	Body sherd; Triglyph out, mono in; Very soft pinkish buff, brown paint

56	SM 77 PE 1 605	Body sherd; Triglyph and Antithetic spiral out, mono in; Very soft pinkish buff, brown paint
57	SM 77 PE 1 605	Flat base, ?stirrup jar; Linear out, worn in; Very soft pinkish buff, brown paint
58	SM 78 PE 1 1005	Ring base; Linear out, worn in; Very soft pinkish buff, red paint
59	SM 78 PE 2 1009	Rim; Worn and encrusted; Very soft pinkish buff, ?red/brown paint
60	SM 78 PE 3 10??	Handle; Splash out, mono in; Very soft buff, brown paint
MEN 61–70: LH IIIB Undecorated Kylikes from Prophitis Elias Erosion Gully Deposit		
61	SM 77 PE C 600	Stem; Undecorated; Soft buff
62	SM 77 PE C 600	Lower body; Undecorated; Soft pale buff
63	SM 73 PE 3 610	Rim, carinated; Undecorated; Soft pinkish buff
64	SM 73 PE 3 610	Base with centre concavity; Undecorated; Soft buff
65	SM 73 PE 3 610	Base, conical beneath with knife mark; Undecorated; Soft buff
66	SM 73 PE 3 610	Base, flat; Undecorated; Soft buff
67	SM 78 PE 4 1012	Rim, carinated ?Shallow Angular Bowl; ?Linear; Soft buff
68	SM 77 PE 10 602	Lower body and stem; Undecorated; Soft pale buff
69	SM 77 PE 10 602	Base with centre concavity; Undecorated; Soft pale buff
70		Rim, carinated; Undecorated; Soft warm buff
MEN 71–81: LH IIIB/IIIC Kitchen ware Beaker fragments from Prophitis Elias Erosion Gully Deposit (except MEN 71, from Aetos Stone Mound Deposit)		
71	SM 78 A2 9	Flat base with string mark; Undecorated; Soft red
72	SM 77 PE C	Rim and neck; Undecorated; Hard pale red
73	SM 77 PE C	Flat base; Undecorated; Hard gritty red
74	SM 77 PE 2 609	Rim and straight collar neck; Undecorated; Hard gritty red
75	SM 77 PE 3 610	Rim and neck; Undecorated; Hard pale red
76	SM 77 PE 3 610	Flaring rim and neck with handle; Undecorated; Hard gritty dark red/brown
77	SM 77 PE 3 610	Horiz. flat handle; Undecorated; Fine hard red
78	SM 77 PE 10 602	Rim and neck with handle; Undecorated; Hard gritty red
79	SM 77 PE 11 603	Body sherd ?closed; Undecorated; Hard gritty red
80	SM 78 PE 2 1008	Closed flat base; Undecorated; Hard gritty red
81	SM 78 PE 4 1012	Flat base with string mark; Undecorated; Hard gritty red

MEN 61–70 represent the undecorated kylix which, whether having carinated or smooth profile, was the commonest undecorated table shape at the period when the deep bowl was the standard decorated shape.

MEN 71–81 are from the kitchen fabric shape which replaced the tripod cooking pot and button based jugs of the earlier history of the site and is the contemporary of 51–60 and 61–70.

ANALYTICAL PROCEDURE

The NAA procedures used at Manchester are detailed by Taylor and Robinson[20] who also discuss the statistical treatment of the data. The samples' compositions were grouped using cluster analysis (Ward's method and RELOCATE on z-scored data) and principal components analysis, and the assignments of samples to groups were checked using the Mahalanobis procedures in the MANHATTAN (MAHALA) program, developed at Manchester.[21] Data for all 24 elements were used in the statistical evaluation.

RESULTS

1. Statistical Evaluation of the Menelaion Data

Analysis of the 81 samples' compositions (TABLE G.5) showed there to be five individual outliers[22] (MEN 18, 25, 43, 78 and 80) and an outlying pair of sherds (MEN 44 and 46). Re-analysis of the

[20] R. J. Taylor and V. J. Robinson, 'Neutron Activation Analysis of Roman African Red Slip Ware kilns', *Archaeometry* 38.2 (1996) 231–43.

[21] For the MANHATTAN program the groups are pre-defined (by cluster analysis in this case) in terms of the means and standard deviations of the elements. For each sample, the Manhattan distance to the centre of each group is defined in units of standard deviation, σ, of the elements concerned. In using the MANHATTAN program to refine groups obtained from Cluster Analysis a sample was deemed to be a member of a group if its total distance to the group centre is less than the number of elements measured (i.e. an average of 1σ per element). For groups to be deemed separable a group-group distance of greater than 1σ averaged over all the elements (and in terms of the standard deviations of *both* groups) was deemed satisfactory. Thus the groups were refined such that none of the groups were within a distance of 1σ of any of the others, and no sample was at a average distance of less than 1σ of more than one group centre.

[22] An outlier is a sample whose nearest neighbour is at a relatively great distance (by comparison with the values experienced between samples in the remainder of the population), i.e. its chemical composition is significantly different to the range of compositions encountered in the population as a whole. Since the standardisation procedures employed for statistical evaluation of the data are strictly only valid for a homogeneous population, outliers must be removed from the population in order to understand the relationships between the other samples.

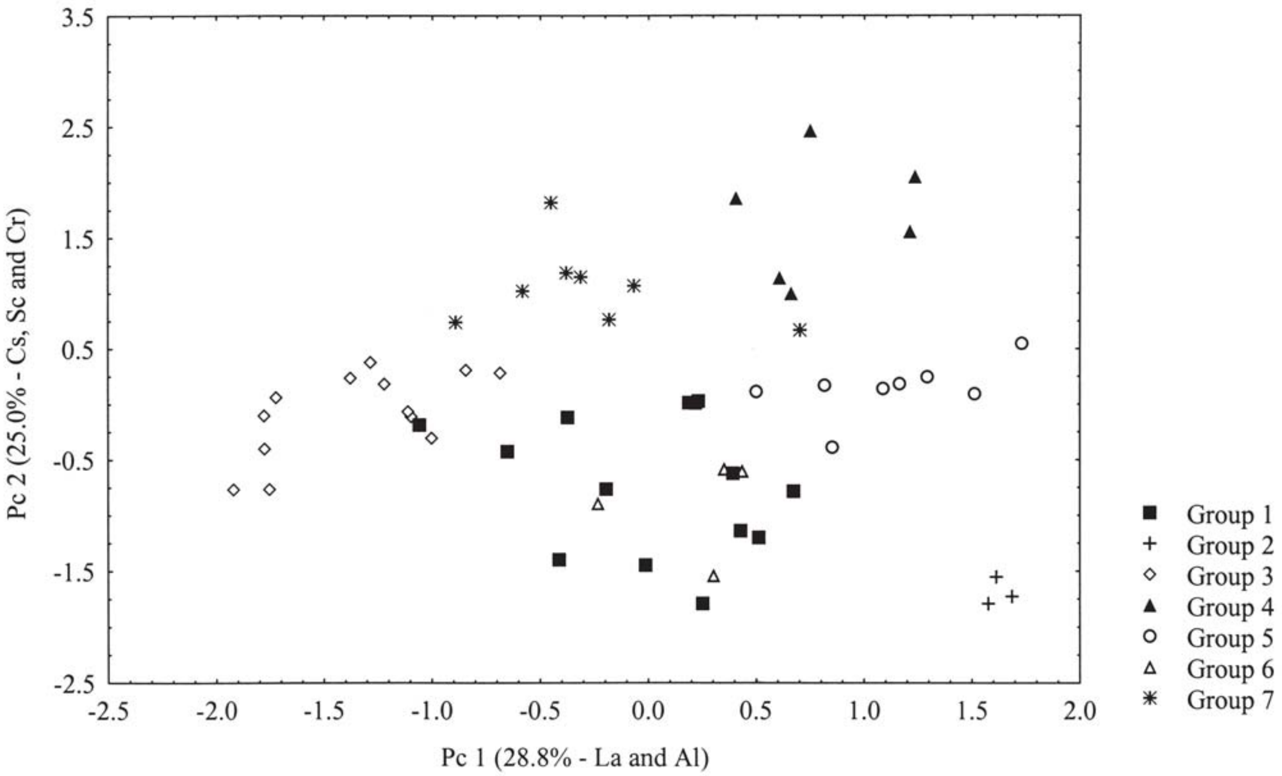

FIG. G.3 Plot of the first two principal components resulting from principal components analysis of the NAA data, making up the seven groups. (-)La and Al are the dominant elements on PC1 (28.8% of the total variance) and (-)Cs, Sc and Cr on PC2 (25%).

remaining 74 sherds, and refinement of the groups obtained resulted in seven chemical groups (TABLES G.6 and G.7), distinctly separable in both Mahalanobis and Cluster Analysis, containing a total of 56 of the sherds. A further twelve sherds are loosely associated[23] with one or other of the seven groups, leaving thirteen sherds unassigned (see TABLE G.6). A visual but partial representation of the relationship between the seven groups is given in FIG. G.3; although the first two principal components account for little over half the total variance, the groups separate quite satisfactorily.

The archaeological significance of the groups defined is, at first glance, somewhat unclear: in a population chosen to represent local wares, groups might be expected to have separated on chronological grounds, and/or on the basis of fabric. However, in this case, each of the different ware types is represented in several of the groups, and, likewise, most of the groups comprise several different ware types, as well as both earlier (LH II to IIIA) and later (LH IIIB and IIIC) pottery. Nevertheless, some tentative suggestions as to the significance of the groups may be made:

The two small groups, Groups 2 and 6, each comprise a single ware type. Group 2 is the chemically most distinct of the seven groups defined, and comprises just three of the ten LH IIB/IIIA1 Kitchen Wares analysed. Since four of the remaining seven samples of this ware are outliers it seems clear that the bulk of the early Kitchen Wares are chemically quite distinct from other local wares, both earlier and later. Group 6 comprises four of ten LH IIIB/C Decorated Deep Bowls, the other six samples of this ware being assigned to Group 3, which is chemically quite different to Group 6. (The major difference is in the Sm values, which are much lower in Group 6, but there are also significant differences in Cs, Rb, K, La and others.) Thus, it appears that this ware type forms two homogeneous groups, quite different from each other chemically, and one of which (Group 6) is also quite different from other local wares at the site.

[23] i.e. their average distance from the group centre in question is greater than 1 σ, but less than 1.5 σ.

Of the remaining five groups defined here, only Group 4 does not contain a mixture of earlier and later material. This group is dominated by LH II–IIIA decorated pottery, and perhaps represents the earlier fine wares at the site. The other groups, Groups 1, 3, 5, and 7, each contain a number of different ware types which span the earlier and later periods. Indeed, these four groups — and especially Groups 1, 3, and 7 — are the most similar in terms of their chemistry.[24]

Group 5 is dominated by LH IIIB undecorated kylikes, and, as it is also home to LH IIIA1 plain handmade wares, may perhaps be identified as representing local manufacture of the undecorated finer wares. Group 1 contains almost all the assigned LH IIIB/C Kitchen ware Beaker fragments, but cannot be said to represent only this fabric, as it is also home to half of the LH IIB/IIIA1 Plain Goblets analysed. Group 3, as mentioned above, contains six of the ten LH IIIB/C Decorated Deep Bowls analysed, but also a further seven samples representing five different wares. Finally, Group 7 is a truly mixed bag, comprising samples from five different ware types.

2. Comparison with other Chemical Reference Groups

The MANHATTAN program was used to compare the chemical profiles of (i) the seven groups, and (ii) the 81 individual sherds with some 86 chemical reference groups from the Manchester-Berkeley database (TABLE G.8); (iii) the 1,945 individual samples from these sites (TABLE G.8) with the chemical profiles of the seven Menelaion groups in order to test for Menelaion-type compositions occurring elsewhere.

(i) Only two of the seven Menelaion groups prove similar[25] to any of the above reference groups: Group 4, while quite similar chemically to a number of Argolid reference groups, shows closest affiliation with a group of 'early' (LH I and II) sherds from the southern Peloponnese; and Group 1 associates with a group of Mycenaean pottery from the Peloponnese interpreted as representing Messenian production.[26]

(ii) Only two samples prove similar in chemistry to any of the reference groups. One of these, MEN 76 (a member of Group 1) is most similar to another Messenian reference group.[27] The other sample, MEN 23 (an outlier) associates with a group interpreted as being of North West Peloponnesian production.[28] Finally, it is noted that the feature of high Al found in the OES compositions of the local reference groups also occurs in some of the NAA groups; the mean values in Menelaion groups 3, 6 and 7 are significantly higher than in any of those identified by the writer in Mycenaean pottery from the Peloponnese outside the Argolid with the exception of one from Nichoria.[29]

(iii) A total of 145 sherds prove similar to one or other of the Menelaion groups, but, of these, 117 are of Argolid compositions and associate with Group 4.[30] Likewise, a further two samples associating with Group 1 are from Messenian reference groups.[31] The remaining affiliations, occurring only with Groups 1, 3 and 7, may be more significant:

[24] The Manhattan distances between groups 1, 3, and 7 range from 1.35 σ to 1.48 σ on average. Groups 1 and 5 are also quite close (at 1.16 σ), but Group 5 is rather less similar to Groups 3 and 7 (at 2.56 σ and 1.68 σ respectively).

[25] i.e. the Manhattan distance between group centres is less than 1 σ.

[26] Group 4 is most closely associated with Peloponnese Group 2 which comprises LH I–II pottery from Ayios Stephanos and Nichoria, but which is noted as displaying a chemical profile similar to that of Argolid pottery groups (Tomlinson 1997, n. 46). This Menelaion group has $d < 1\sigma$ with several Argolid groups, but the lowest value (and therefore the closest similarity) is with the early Peloponnesian group. Group 1 proves similar to Peloponnese Group 10 which contains sherds from Palaiokastro, Chora Ano Englianos, Peristeria and Nichoria, and is chemically most similar to Peloponnese Groups 8 and 9 which are dominated by pottery from Nichoria (Tomlinson 1997, n. 46). The coarser wares from the Menelaion prove quite different chemically to the coarse ware groups established from Argolid (Mycenae) data (Tomlinson, in preparation, n. 46).

[27] Peloponnese Group 9, dominated by pottery from Nichoria and interpreted as local to western Messenia (Tomlinson, 1997, n. 46). The sample could thus be considered 'ambiguous' since it has $d < 1$ with two distinct groups (Menelaion 1 and Peloponnese 9).

[28] This is Peloponnese Group 5 which contains sherds from a number of sites, but as it is most similar, chemically, to a North-West Peloponnesian group, it has been interpreted as a North-West Peloponnesian variant (Tomlinson 1997, n. 46).

[29] Peloponnese Group 12. (Tomlinson 1997, n. 46: table 2 and Appendix II.)

[30] Since the profile of Menelaion Group 4 resembles Argolid-type compositions, these associations are most likely coincidental. Most of these samples are from findsites in the Argolid and Corinthia (Asine, Berbati, Korakou, Mycenae, Tiryns, Zygouries), but there are also a number of associating samples found elsewhere (Peloponnese, Cyprus) but previously noted as showing Argolid-type chemical profiles.

[31] These are samples from Peristeria and Nichoria, assigned to Peloponnese Groups 10 and 8 respectively (Tomlinson 1997, n. 46.)

With Group 1: two sherds from Chania, three from Palaikastro (Crete), and eight Base Ring ware from Cyprus.[32] With Group 3: one sherd found at Zygouries. With Group 7: one sherd from Kommos, one from Chania, and ten from Ayios Stephanos.[33]

3. Comparison with 'Barbarian' Ware sherds from the Menelaion

Three 'Barbarian' ware sherds from the Menelaion[34] were analysed by NAA (at Manchester — see Acknowledgements) and their compositions (AP 79, 84 and 86 in TABLE G.5) compared with those of the seven Menelaion groups using the MAHALA program. No chemical matches or associations were found, however.

SUMMARY

Statistical evaluation of the neutron activation data for 81 Late Helladic sherds from the Menelaion at Sparta has resulted in the definition of seven chemical groups containing a total of 56 of the samples. Some of these groups appear be ware-based while others are more mixed. Indeed, not one of the eight different ware types analysed forms a single homogeneous compositional group. There is no evidence of group formation on chronological grounds.

Comparison of the Menelaion data with that of other Greek and Cypriot reference groups showed few chemical matches: Group 1, and one of its members, MEN 76, are similar to groups from Nichoria in Messenia; one outlier, MEN 23, associates with a North-West Peloponnesian group; and Group 4, comprised of LH II–IIIA decorated fragments, proves most similar to another group of 'early' (LH I–II) pottery from elsewhere in the South Peloponnese.

Menelaion-type compositions from other find-sites within the Manchester-Berkeley database are found in sherds from Zygouries, Kommos and Chania. Other similarities are most probably due to regions having pottery with similar chemistry to that found at the Menelaion (Chania and Palaikastro on Crete; perhaps Episkopi on Cyprus and Ayios Stephanos in Laconia). The three 'Barbarian' ware sherds prove to be different in composition to all seven Menelaion groups defined in this study.

PART III: DISCUSSION

The OES-based study at the Menelaion belonged to the late phase of the original approach to composition and provenance work in the Aegean, whereby the chemical compositions of decorated and plain pottery found at Mycenaean and Minoan sites that were probably production centres were defined in a 'broad brush' manner. The intention was to identify composition types that were characteristic of a site or more likely a region. The results presented above are typical of that approach: the chemical data for the five reference groups suggest local or regional manufacture; a high aluminium content is a potential distinguishing feature of central Laconia, but in all other respects the compositions are not distinctive within the Peloponnese as a whole.

Programmes of NAA in the Aegean have by and large adopted a similar philosophy with regard to sample selection as that of OES, but have enjoyed the considerable advantage of high resolution discrimination of chemical composition groups. Again this is seen clearly at the Menelaion: there are four main NAA composition groups representing local production among the finer wares at the North Hill and Profitis Elias sites, in contrast to the broad single group evident in the corresponding OES data. Group 1, consisting of the plain goblets and kitchen ware beakers which have a coarser textured

[32] The five Cretan sherds are assigned to local west and east Cretan reference groups. Similarites in compositions found at Chania and in Messenia have been previously noted (e.g. Tomlinson 1997, n. 46), and since (i) east Cretan and west Cretan compositions are quite similar, and (ii) similarities are noted here between Menelaion Group 1 and some Messenian compositions, it is quite probable that these five asociations are also coincidental. The eight Cypriot sherds are all members of a Base Ring group which comprises sherds of this ware from a number of sites on the island, but showing closest chemical similarities with local wares from the Episkopi region. (Bryan *et al.*, 1997, n. 46.)

[33] The samples from Zygouries, Kommos and Chania are all outliers within their respective datasets. The samples from Ayios Stephanos, however, are members of Peloponnese Group 1 which is interpreted as representing the local LH III production at this site. (Tomlinson 1997, n. 46.)

[34] These are three (nos. 1, 6 and 8) of the eight sherds analysed petrographically by Whitbread who, while suggesting a local origin for the 'Barbarian' ware pottery at the Menelaion, notes that a technological distinction may be made between this ware and other wares (coarse, pithos, kitchen beakers and micaceous) examined in his study. Most of the fabrics contained metamorphic rock fragments such as schist, phyllite and crystalline limestone with lesser quantities of limestone, sandstone, siltstone and mudstone. See I. K. Whitbread, 'Petrographic analysis of Barbarian Ware from the Menelaion, Sparta', in J. M. Sanders (ed.), *Philolakon: Lakonian Studies in honour of Hector Catling* (Oxford 1992) 297–306. For details of 'Barbarian' pottery found at the Menelaion, which includes a description of sample no. 1 (and see fig. 2 and pl. 5a), see H. W. Catling and E. A. Catling, ''Barbarian' pottery from the Mycenaean settlement at the Menelaion, Sparta', *BSA* 76 (1981) 71–82.

clay than the pottery in Groups 3, 5 and 7, is probably the most distinctive of the NAA groups having low calcium and lower concentrations in most other elements. The distinctions between Groups 3, 5 and 7 are more subtle, occurring in several elements but not including the rare earths. The coarse kitchen ware is poorly characterised, its compositions being distributed over several of the chemical groups. The lack of a consistent correlation between these composition groups and archaeological criteria such as pottery class/type or date should not be regarded as problematic, since collectively they do not encompass wide element concentration ranges.

From the collective results, there is clear evidence for the use of both calcareous and non-calcareous clays at the Menelaion. Information on their sources in the Mycenaean period at the Menelaion, however, is as yet very limited but nevertheless revealing. There are two indications that these clays were not located in the Eurotas valley below the site: first, the three modern clays described in TABLE G.1 bear no resemblance chemically with the pottery analysed by OES, and second it is established that there is a significant chemical contrast between the pottery from respectively the Menelaion and Sparta. Seven LH III decorated sherds from the Menelaion now in McGill University's Ethnology Collection (Redpath Museum) in Quebec, Canada were analysed by NAA by Attas *et al.*[35] who compared their compositions with those of Geometric and later decorated pottery mainly from the Artemis Orthia Sanctuary, as well as some Hellenistic pottery from tombs in the Sparta area. The Mycenaean sherds did not have uniform compositions, nor did they resemble the later pottery, there being differences in the contents of Hf and Cs among other elements. The presence of the Middle Helladic kilns on the Menelaion hill is relevant here, pointing surely to the Mycenaean potters' clays occurring close to the site on the nearby terraces.[36] For the time being, no further significance should be read in to the present NAA composition groups from the Menelaion beyond what has been stated here; it suffices to say that as a fuller understanding of the compositions of Laconian emerges from future work (see below), a re-assessment may call for the merging of some of them.

Wherever the sources of clays used at the Menelaion, traditional potters working during the present century in Sparta and to the south in the Eurotas Valley seem to have employed clays associated with the valley rather than its hinterland. L. Mangalousis, whose workshop was located (in 1991) in Odos Menelaou in Sparta, reported using a mix of three clays from south of the town for the production of a range of wares including imitation Siphniot *tsoukalia* and, latterly, flower pots. Two other centres may be mentioned: Chania and Tarapsa, 20–25 km to the south of Sparta, where tiles and bricks were made and possibly, earlier in the century, *Koronaika pitharia* as well.[37]

Before turning to the imports, the results for the three examples of Handmade Burnished ware deserve attention here. That their compositions are not internally uniform nor do they associate with the local Groups mentioned above can best be interpreted as corroborating Whitbread's view that this pottery was doubtless made locally but not of the common or traditional potters' clays.

The OES analyses have provided a low level of information about the origins of the imports; for a number of samples it has only been possible to make associations of origin. Central and, to a lesser extent, West Crete are implicated, as are parts of the Peloponnese. The indications are that Palace Style was probably manufactured at more than one location in the Peloponnese: one example, X.1 **672**, can be linked to the southern Peloponnese, and NB14 **804** and ST10 **864** to elsewhere. To these can be added the three examples of the same class found at Mycenae analysed by the same technique (TABLE G.3) and on the basis of composition taken to be local.[38] Their Mg, Cr and Ni contents are within the same range as those of 672 X. 1 but significantly lower than those of the other two from the Menelaion. To West Crete are assigned the two SJs considered here, as well as nine of the ten other SJs to be published elsewhere.[39] There seem to be no other secure imports from this region among the samples analysed.

As for the NAA data, the most interesting result concerns the small Group 4, consisting mainly of LH II–IIIA decorated fragments and having higher Rb, Cs and lower Hf, Ta and Th than the local groups. It associates chemically with LH I–II pottery in, on the one hand, southern Laconia (Ayios Stephanos) and the Nichoria region in Messenia, and, on the other, the Argolid. Whether this finding

[35] M. Attas, J. M. Fossey and L. Yaffe, 'Variations of ceramic composition with time: a test case using Lakonian pottery', *Archaeometry* 24.2 (1982) 181–90. Full compositions are given in this paper.

[36] Recent clay prospection at the Menelaion by I. K. Whitbread and N. J. Brodie (pers. comm.) has revealed several potentially suitable red but few pale clays; their analyses are not yet complete.

[37] These and other pottery-making locations have been studied by the Centre for the Study of Traditional Pottery in Athens (B Psaropoulou, pers. comm. 2/2000).

[38] Analysed by OES in the Fitch Laboratory and by NAA in the Lawrence Berkeley Laboratory (*GCP* table 3.9, Group 15: 1, 4 and 5); illustrated in *BSA* 25 (1921–23) pl. LIa and d.

[39] H. W. Haskell *et al.* (n. 3).

is consistent with a single source is not yet clear but what is clear is that the groups of 'early' (LH I/II) pottery defined from Ayios Stephanos, Nichoria, Asine and Mycenae, as well as Menelaion Group 4, are somewhat different, chemically, from the 'later' (LH III) local pottery groups from these sites. Possible Messenian links are to be found with some goblets (and kitchen ware) in Group 1.

Turning to the possibility of Menelaion-type compositions being found elsewhere, the bulk of associations noted in this regard are most probably coincidental. However, associations of sherds found at Zygouries, at Kommos, and at Chania, are more likely to be indicative of Menelaion exports.

Looking to the future of laboratory-based work in Laconia, it is important to acknowledge the change in emphasis that has occurred since the present study was completed away from the site-specific focus towards a more regionally-based, diachronic enquiry. This is exemplified in the work currently in progress by I. K. Whitbread and N. J. Brodie that arises directly from the Laconia Survey and the Laconia Rural Settlement Survey, examining the chemical and petrographic compositions of prehistoric pottery of EH to LH date from a range of sites in the Sparta area. At a more advanced stage but similar in approach is the Fitch Laboratory's investigation of Middle Helladic pottery from Lerna initiated by C. Zerner, which later transformed itself into a geographically wider enquiry into the production of Minyan, Dark Burnished and in particular Lustrous Decorated ware of the period transitional to Mycenaean from Ayios Stephanos, Kastri on Kythera, as well as sites in the Argolid.[40]

As a broader framework of data for Laconian pottery is built up, so a programme of chemical analysis of specifically LH pottery may usefully be accommodated within it. For example, the likely local LH fabrics at Amykleon, Pellana, Skoura as well as further material from Vapheio and Ayios Vasilios should be characterised by NAA (or inductively-coupled plasma emission spectroscopy, ICP-ES) to establish the relationship between their characteristic compositions and the groups identified at the Menelaion; major differences should not be predicted. Immediately beyond Laconia, LH material from Kastri and maybe other contemporary sites on Kythera should certainly be included. Only when the process of building up a diachronically-based and combined chemical-petrographic database has been extended to other regions of southern Greece and to Crete will it be opportune to focus on a single class such as the Palace Style to determine its centres of production; the success of such an investigation would depend heavily on analysing chemically and petrographically representative examples of this style from as many known findspots as possible. Other Early Mycenaean classes that could be investigated are Vapheio cups and those suspected imports at the Menelaion in TABLE G.2 whose origin remains uncertain following the OES analyses reported here. More specifically, six of the eight examples of Vapheio cups found at Vivara in the Bay of Naples analysed by AAS were assigned to one broad group which probably represented production at more than one centre in the southern Peloponnese, that is in southern Laconia (but not including Kythera) and Messenia. Clearly, a more precise identification of origins would be valuable.[41] In undertaking such programmes of analysis, two requirements need to be counterbalanced: on the one hand, as already mentioned, to apply more rigorous criteria in terms of availability of reference data and combination of techniques in their design, and on the other hand for the archaeological community to encourage projects which will exploit maximally and optimally the accumulated databases which themselves take time and effort to build up. In acknowledging here the continuing contribution to the LH database in the Peloponnese made in recent years by H. Mommsen and co-workers at the University of Bonn, using NAA,[42] it should be recognised that much has already been achieved. As FIG. G.2 indicates, whereas the coverage of sites by OES in the Peloponnese was extensive, there has been a concentration of effort on the part of NAA laboratories in the Argolid and Achaia; other regions have received significant but less intense coverage. What is needed now is greater integration and co-ordination of effort between laboratories and a greater move towards explaining the significance in petrographic terms of the apparently site-specific chemical composition groups.[43]

The Bonn group has also examined the data for LH pottery from the Peloponnese analysed at Berkeley,[44] using a quite different statistical evaluation methodology to that at Manchester.

[40] Jones (n. 4) 416f for some of the early results at Lerna. C. Zerner, I. K. Whitbread and R. E. Jones, in preparation, 'The Middle Helladic Pottery at Lerna: a conspectus', to be submitted to *Hesperia.*

[41] Jones (n. 13).

[42] For instance, H. Mommsen, Th. Beier, D. Heimerann, A. Hein, D. Ittameier and Ch. Podzuweit, ' Neutron activation analysis of selected sherds from Prophitis Ilias (Argolid): a closed LH II settlement context', *J. Arch. Science* 21 (date) 163–71. H. Mommsen, Th. Beier, D. Heimerann, U. Diehl and Ch. Podzuweit, ' Provenance determination of Mycenaean sherds found in Tell el-Amarna by neutron activation analysis', *J. Arch. Science* 19 (date) 295–302.

[43] R. E. Jones, 'Current trends and issues in Mediterranean ceramic studies' in F. Burragato, O. Grubessi and L. Lazzarini (eds.), *Proc. 1st European Workshop on Archaeological Ceramics* (Rome date) 13–21.

[44] H. Mommsen, Th. Beier and A. Hein, 'A Complete chemical grouping of the Berkeley Neutron Activation Analysis Data on Mycenaean pottery', to be published.

Encouragingly, the results are broadly similar, but with fewer, larger groups formed using the method at Bonn.[45] Furthermore, the results of these evaluations fit well with data for additional Peloponnesian LH sherds analysed at Manchester and Bonn. The overall NAA picture emerging is as follows: the bulk of the samples from Berbati, Mycenae, Korakou and Zygouries forms a single chemical group (or related groups) assigned to the northern Argolid — while very few sherds from the rest of the Peloponnese have this chemistry, the majority of Mycenaean exports in Cyprus and the Near East conform to it. A second, smaller group (or groups), chemically distinct from the first, is dominated by material from Tiryns and Asine and assigned to the southern Argolid. The group (or groups) of 'early' (LH I/II) pottery (mentioned above) from Asine, Mycenae, Nichoria and Ayios Stephanos, and a north-west Peloponnese group (or groups) dominated by samples from Achaia and Elia, are both very similar to the northern Argolid profile(s). In the southern Peloponnese groups have been attributed to western and eastern Messenia (dominated by pottery from Chora Ano Englianos (ancient Pylos) and Nichoria respectively), and to (LH III) pottery from Ayios Stephanos.

Finally, mention should be made, in advance of their publication in a second *Menelaion* volume, of the analyses of later pottery from the Menelaion. In brief, this pottery contrasts chemically with the Mycenaean pottery, a finding which in the light of the work mentioned above at the Artemis Orthia Sanctuary should indicate that the later pottery was made of clays from the Eurotas river or its immediate environs. In the case of Black Glaze analysed by NAA, two groups were identified by J. Scott,[46] both of them with low calcium and both securely differentiated from the Mycenaean groups (TABLE G.9), especially in Lu, Rb, Cs and Ce for Group 1, and Hf, Rb, Cs and Lu for Group 2.

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45 The Bonn method allows for a constant shift in all the concentration values of a given sample. These shifts can occur due to experimental errors in the measurements, but can also be due to varying pottery making practices (e.g. levigating the clay in different ways; diluting it with the addition of sand, limestone, etc.). Mommsen *et al.* (n. 43) comment: '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.' The Manchester method does not allow for such a shift, and does not therefore 'correct' for such variations in potting practices. Thus, there is a tendency to form smaller, more numerous groupings. Some of these groups may indeed be related by dilution effects, but these dilutions themselves may reflect technological differences between production centres, or within a single centre, which will be of interest to the archaeologist.

he provenance of Greek Black Glaze pottery: a study by neutron activation analysis', unpublished PhD thesis, Manchester University 1994. There were five outliers and two apparent outliers in addition to groups 1 and 2.

TABLE G.5. NAA compositions.
Elemental data quoted to 3 significant figures and expressed in parts per million (p.p.m.) except where noted as a percentage (%).

	Na%	Al%	K%	Ca%	Sc	Ti%	V	Cr
MEN01	.322	7.82	2.35	8.08	20.7	.430	116.	265.
MEN02	.515	9.85	3.08	6.10	23.2	.444	159.	281.
MEN03	.607	9.99	2.64	5.20	22.2	.581	119.	211.
MEN04	.506	8.64	1.73	10.4	17.0	.500	97.5	145.
MEN05	.252	7.65	2.43	11.5	19.1	.398	118.	252.
MEN06	.278	8.75	2.48	6.91	23.2	.399	125.	310.
MEN07	.482	8.40	2.19	7.21	21.5	.511	119.	252.
MEN08	.433	8.28	2.40	9.64	21.6	.453	126.	242.
MEN09	.390	8.23	2.55	8.59	23.3	.460	129.	235.
MEN10	.705	9.43	3.01	6.14	22.7	.568	156.	261.
MEN11	.606	10.1	2.92	5.63	20.5	.552	127.	169.
MEN12	.587	9.24	2.89	4.12	21.8	.465	142.	260.
MEN13	.641	9.25	2.39	1.71	19.3	.518	116.	161.
MEN14	.721	9.61	2.99	3.93	21.7	.507	142.	294.
MEN15	.451	8.89	2.35	8.78	19.9	.481	131.	247.
MEN16	.394	9.46	2.74	8.06	26.5	.504	165.	273.
MEN17	.440	9.59	2.62	3.88	24.0	.594	132.	328.
MEN18	1.27	9.14	.861	9.49	21.1	.536	139.	230.
MEN19	.645	8.18	2.14	8.01	21.1	.498	126.	348.
MEN20	.514	9.91	2.48	8.83	22.2	.562	142.	210.
MEN21	.518	9.94	2.45	6.70	21.7	.522	111.	213.
MEN22	.545	8.82	1.62	11.1	20.0	.491	122.	236.
MEN23	.648	6.86	1.25	5.70	15.5	.401	92.2	261.
MEN24	.334	9.16	1.11	9.64	18.1	.502	83.8	169.
MEN25	.673	10.6	2.20	.366	21.3	.615	145.	247.
MEN26	.572	9.48	3.02	6.58	22.2	.510	116.	213.
MEN27	.721	9.54	2.46	7.26	22.0	.487	127.	216.
MEN28	.824	9.07	1.34	8.00	17.8	.497	119.	158.
MEN29	.544	7.98	2.08	9.60	17.0	.439	109.	140.
MEN30	.638	8.30	1.66	4.13	18.6	.478	117.	255.
MEN31	.625	9.06	2.23	8.22	22.4	.480	151.	273.
MEN32	.581	8.37	2.73	5.84	18.6	.425	129.	205.
MEN33	.475	8.48	2.39	6.37	17.5	.415	119.	187.
MEN34	.424	9.47	1.49	6.32	18.4	.458	98.	208.
MEN35	.520	9.64	2.86	6.26	18.6	.406	150.	218.
MEN36	.503	8.47	2.23	7.99	17.6	.472	128.	149.
MEN37	.518	9.78	2.76	6.41	20.5	.473	114.	210.
MEN38	.428	9.93	2.44	4.75	21.8	.473	148.	266.
MEN39	.439	7.68	1.88	9.80	18.1	.351	114.	200.
MEN40	.485	8.05	1.86	7.13	19.1	.446	119.	209.
MEN41	.539	7.90	1.82	.760	16.8	.527	104.	147.
MEN42	.499	6.89	1.63	1.04	15.1	.467	88.	138.
MEN43	.506	8.07	1.65	.850	16.5	.382	117.	300.
MEN44	.370	9.65	1.24	1.89	17.5	.658	205.	118.
MEN45	.501	7.56	1.45	1.10	15.2	.473	102.	131.
MEN46	.403	9.47	1.30	1.48	18.4	.572	185.	123.
MEN47	.552	7.58	1.13	1.41	13.5	.431	97.8	136.
MEN48	.525	7.11	1.29	.954	13.9	.404	91.4	113.
MEN49	.523	6.86	1.59	1.35	13.9	.455	100.	116.
MEN50	.309	10.8	2.34	3.11	22.4	.536	125.	273.
MEN51	.506	10.2	2.46	6.44	22.5	.555	123.	246.
MEN52	.555	10.5	2.73	4.81	22.4	.483	126.	257.
MEN53	.558	9.75	2.01	4.69	22.0	.514	96.	285.
MEN54	.584	10.2	1.79	6.98	21.5	.545	130.	249.
MEN55	.560	9.84	2.30	3.86	20.7	.574	101.	212.
MEN56	.593	9.47	2.49	4.98	21.3	.577	118.	261.
MEN57	.528	9.45	1.79	4.89	19.3	.499	105.	237.
MEN58	.429	9.89	1.66	4.88	19.6	.581	94.4	251.
MEN59	.590	9.09	1.68	3.85	16.0	.576	77.1	207.
MEN60	.458	10.5	1.94	6.20	19.6	.546	98.6	209.
MEN61	.463	8.25	2.50	10.7	17.3	.450	95.8	163.

MEN62	.786	9.01	1.58	14.4	18.4	.439	84.1	154.
MEN63	.321	8.36	2.27	9.17	16.4	.511	89.7	153.
MEN64	.498	8.47	2.11	9.08	18.1	.423	107.	184.
MEN65	.622	8.79	2.50	4.99	20.8	.533	134.	271.
MEN66	.428	8.05	2.50	11.0	17.4	.417	115.	186.
MEN67	.548	9.33	2.17	7.53	18.9	.491	110.	217.
MEN68	.802	8.78	1.74	11.1	18.6	.473	98.8	168.
MEN69	.465	8.61	2.44	9.80	18.1	.473	89.6	179.
MEN70	.549	10.2	2.15	5.23	20.4	.536	129.	247.
MEN71	.521	9.07	2.43	3.47	18.5	.468	122.	170.
MEN72	.522	8.78	1.96	2.72	17.7	.495	124.	171.
MEN73	.411	8.82	2.39	2.33	18.6	.477	121.	177.
MEN74	.572	9.03	1.94	1.23	20.4	.494	133.	164.
MEN75	.523	9.94	2.50	2.85	21.1	.526	158.	205.
MEN76	.601	8.60	2.05	1.84	19.7	.519	128.	247.
MEN77	.600	7.88	1.73	.673	16.8	.485	111.	159.
MEN78	.489	13.0	1.75	.294	21.6	.548	188.	115.
MEN79	.362	8.32	1.87	1.61	18.7	.432	123.	189.
MEN80	.397	10.1	1.32	1.38	22.1	.607	210.	128.
MEN81	.381	8.06	2.05	.790	19.6	.474	125.	108.
AP79	.503	9.53	2.35	.895	20.4	.578	126.	173.
AP84	.442	5.31	1.70	1.10	15.1	.368	92.4	137.
AP86	.232	7.31	1.62	1.06	21.3	.543	120.	198.

	Mn	Fe%	Co	Rb	Cs	La	Ce	Sm
MEN01	836.	4.84	35.4	141.	13.3	30.9	58.0	5.12
MEN02	750.	5.21	27.3	152.	8.02	35.8	63.7	6.24
MEN03	726.	5.54	24.9	152.	6.84	47.2	89.8	7.68
MEN04	507.	4.13	18.3	120.	4.26	40.2	71.2	6.54
MEN05	1338	4.51	33.1	128.	9.85	28.6	52.1	4.81
MEN06	906.	5.56	34.9	156.	12.8	33.1	64.4	5.41
MEN07	1016	5.79	25.3	140.	6.65	33.0	61.7	5.21
MEN08	917.	5.21	28.3	141.	8.12	32.1	58.0	4.99
MEN09	954.	5.86	30.0	173.	9.15	34.0	66.4	5.83
MEN10	520.	5.29	28.0	164.	8.84	41.5	82.1	7.44
MEN11	457.	4.32	25.2	157.	6.28	46.0	89.4	8.54
MEN12	574.	5.48	25.0	161.	8.98	37.4	73.6	6.57
MEN13	270.	4.20	22.5	130.	6.04	46.6	93.6	8.63
MEN14	533.	4.83	25.9	153.	7.33	32.4	63.0	5.80
MEN15	978.	5.77	27.9	131.	6.86	32.9	63.9	6.12
MEN16	997.	6.20	35.7	187.	9.92	37.1	68.1	6.08
MEN17	483.	5.63	33.2	120.	5.96	39.0	78.5	6.87
MEN18	822.	4.74	27.8	79.0	7.42	35.8	71.5	6.16
MEN19	1126	5.45	27.8	124.	7.16	27.8	54.1	4.84
MEN20	738.	5.34	26.6	138.	6.44	43.2	81.8	7.49
MEN21	525.	4.79	24.6	143.	6.15	44.8	89.7	7.99
MEN22	971.	4.29	24.7	132.	6.26	38.1	70.8	6.74
MEN23	571.	4.17	19.7	85.7	3.87	27.5	51.4	4.99
MEN24	536.	4.17	23.5	75.4	2.96	38.8	75.9	6.74
MEN25	485.	3.41	36.2	155.	7.90	52.1	99.0	8.67
MEN26	841.	5.43	28.2	149.	6.60	44.1	85.7	7.70
MEN27	651.	4.99	27.1	137.	6.42	44.7	85.3	7.75
MEN28	399.	4.22	20.0	79.8	5.36	38.9	74.3	6.92
MEN29	580.	4.13	21.4	122.	5.01	37.8	73.8	6.52
MEN30	388.	3.97	26.5	138.	5.93	36.0	75.6	6.62
MEN31	776.	5.53	24.8	145.	7.89	36.5	65.8	6.23
MEN32	1101	4.91	20.5	153.	7.92	32.7	60.9	5.60
MEN33	811.	4.58	19.5	130.	7.37	31.5	58.9	5.34
MEN34	1025	4.93	20.3	94.0	4.68	34.8	65.0	5.85
MEN35	1012	5.03	20.0	153.	8.61	32.5	62.4	5.52
MEN36	783.	4.43	20.7	107.	6.18	34.4	63.7	5.90
MEN37	1028	5.03	27.9	141.	6.68	43.0	84.2	7.03
MEN38	847.	5.77	23.3	136.	7.93	37.6	71.1	6.30
MEN39	976.	4.71	21.4	128.	7.96	31.7	58.8	5.59
MEN40	992.	5.03	21.0	138.	8.48	35.9	65.7	6.00

MEN41	503.	4.59	22.5	103.	4.58	45.9	86.1	8.24
MEN42	287.	3.54	14.7	107.	3.97	42.8	79.5	8.78
MEN43	270.	5.23	12.1	102.	7.34	44.2	91.5	9.02
MEN44	1002	6.94	20.6	75.3	5.23	52.4	109.	8.76
MEN45	395.	4.34	19.7	105.	3.77	39.6	76.1	6.64
MEN46	885.	7.23	21.9	73.7	5.42	55.3	113.	9.45
MEN47	495.	3.78	16.1	91.1	3.71	34.9	67.1	5.88
MEN48	531.	4.27	16.6	83.2	2.78	36.3	68.8	6.14
MEN49	385.	4.17	16.8	85.7	4.08	32.5	72.5	5.79
MEN50	889.	6.28	23.9	121.	7.26	36.3	75.6	6.33
MEN51	770.	4.48	32.5	138.	7.42	43.2	84.6	7.25
MEN52	625.	4.25	29.8	146.	7.03	42.7	86.7	7.22
MEN53	866.	5.41	29.5	114.	5.43	40.7	80.5	6.82
MEN54	665.	4.36	26.8	102.	5.14	41.9	79.2	6.92
MEN55	774.	5.26	28.0	127.	6.18	44.5	85.0	7.56
MEN56	614.	4.33	28.2	123.	6.75	43.6	81.8	7.23
MEN57	679.	4.29	23.9	74.8	3.55	37.1	74.8	3.58
MEN58	603.	4.13	25.4	72.2	3.38	35.4	73.6	3.46
MEN59	486.	4.18	21.1	68.7	2.86	38.3	78.6	3.55
MEN60	797.	5.11	25.7	48.4	2.32	38.8	77.2	3.49
MEN61	1692	4.30	22.7	99.5	5.08	32.6	64.9	5.39
MEN62	892.	4.16	23.2	61.7	5.42	36.4	70.6	5.99
MEN63	980.	4.01	20.8	80.6	4.13	30.7	64.2	5.04
MEN64	1628	4.91	23.6	118.	5.29	35.3	74.5	6.01
MEN65	1218	4.83	30.2	114.	6.53	34.7	69.8	5.95
MEN66	898.	4.24	23.5	106.	5.52	32.2	61.7	5.25
MEN67	863.	4.69	24.2	118.	6.13	34.3	67.4	5.81
MEN68	1082	4.79	23.0	81.0	6.08	35.7	69.3	5.81
MEN69	1328	4.59	24.5	107.	4.94	33.7	65.9	5.52
MEN70	1186	4.83	30.0	113.	6.47	38.2	75.3	6.14
MEN71	1271	5.27	26.0	115.	5.87	39.1	77.1	6.53
MEN72	889.	4.44	22.7	116.	5.49	38.8	75.6	6.54
MEN73	1128	5.52	25.5	117.	5.98	37.5	78.8	6.11
MEN74	1390	4.94	22.2	127.	6.29	40.3	84.7	6.93
MEN75	1203	5.47	26.0	142.	7.05	43.7	82.8	7.01
MEN76	755.	5.32	28.7	137.	6.88	41.2	81.2	6.73
MEN77	624.	5.21	22.7	103.	5.40	40.7	80.0	7.23
MEN78	280.	7.06	14.5	117.	6.37	49.6	85.1	7.55
MEN79	1333	5.77	24.4	115.	6.04	34.0	76.8	5.84
MEN80	2787	8.05	19.8	104.	7.48	53.4	100.	10.2
MEN81	739.	5.17	20.0	93.1	5.26	44.7	91.7	7.34
AP79	551.	5.24	24.7	113.	5.88	38.5	102.	6.86
AP84	317.	3.58	18.3	92.0	4.18	33.5	73.4	5.82
AP86	1529	5.63	42.6	71.4	4.40	49.5	120.	8.86

	Eu	Dy	Yb	Lu	Hf	Ta	Th	U
MEN01	1.29	4.98	3.03	.390	3.76	.747	9.70	3.00
MEN02	1.30	5.74	3.07	.491	3.89	1.03	12.1	6.51
MEN03	1.58	6.08	3.88	.483	6.79	1.34	16.2	3.02
MEN04	1.59	6.03	2.86	.414	5.67	1.21	12.2	3.52
MEN05	1.16	4.63	2.55	.341	3.13	.643	8.95	2.73
MEN06	1.17	4.61	2.91	.389	3.59	.895	10.9	2.84
MEN07	1.36	5.09	3.17	.368	4.52	.947	11.7	2.68
MEN08	1.29	4.60	2.87	.371	3.54	.852	11.0	2.40
MEN09	1.28	3.92	3.05	.412	3.47	1.14	12.0	2.28
MEN10	1.29	5.25	3.26	.511	6.01	1.45	15.0	2.69
MEN11	1.64	6.68	3.32	.593	6.39	1.50	15.2	5.66
MEN12	1.49	5.22	3.02	.468	5.14	1.54	13.7	3.38
MEN13	1.66	6.32	3.33	.539	7.75	1.74	15.1	3.51
MEN14	1.15	5.18	2.73	.452	4.55	1.26	11.7	4.00
MEN15	1.30	5.48	2.64	.427	4.00	.982	11.1	3.26
MEN16	1.35	4.89	2.68	.440	3.63	.937	13.0	2.83
MEN17	1.55	5.01	3.36	.491	6.02	1.46	14.3	2.42
MEN18	1.15	4.87	2.68	.423	4.96	1.50	14.0	3.36
MEN19	1.11	4.61	2.15	.346	4.12	.825	10.5	2.28

MEN20	1.72	5.61	3.37	.503	5.62	1.44	14.6	3.48
MEN21	1.81	6.07	3.15	.494	6.34	1.57	16.3	2.98
MEN22	1.52	5.70	2.72	.415	4.53	1.24	12.7	2.94
MEN23	1.15	4.55	2.38	.355	4.51	.890	9.52	2.41
MEN24	1.32	5.45	2.93	.440	5.33	1.24	12.9	2.99
MEN25	1.82	7.08	3.83	.536	7.21	1.54	16.4	2.95
MEN26	1.63	6.10	3.41	.480	6.28	1.46	15.0	2.89
MEN27	1.71	5.50	3.30	.507	6.39	1.53	14.9	3.48
MEN28	1.64	6.03	2.73	.407	6.08	1.39	13.3	4.27
MEN29	1.41	5.49	2.68	.421	5.76	1.27	12.0	3.33
MEN30	1.51	5.69	2.83	.475	6.61	1.32	12.6	2.12
MEN31	1.35	4.77	2.96	.479	4.55	1.13	13.5	4.57
MEN32	1.38	4.65	2.55	.374	4.50	1.16	11.1	4.41
MEN33	1.34	4.56	2.18	.408	3.42	.942	10.8	4.56
MEN34	1.07	4.90	2.77	.444	3.76	1.02	12.3	5.06
MEN35	1.32	4.30	2.34	.436	3.54	1.16	11.3	5.78
MEN36	1.47	4.90	2.47	.403	3.72	1.08	11.2	4.35
MEN37	1.45	5.54	3.12	.449	4.45	1.18	14.6	3.33
MEN38	1.36	5.08	2.70	.468	3.86	1.24	13.7	5.23
MEN39	1.21	3.89	2.21	.428	3.28	.820	10.8	5.62
MEN40	1.21	4.22	3.02	.452	4.71	1.13	12.1	5.07
MEN41	1.57	6.73	3.55	.523	6.29	1.67	13.7	2.15
MEN42	1.98	6.29	3.32	.446	6.53	1.35	12.3	2.26
MEN43	1.73	6.67	2.34	.407	4.67	1.29	11.0	2.82
MEN44	1.73	7.23	3.47	.501	5.92	1.94	15.9	4.30
MEN45	1.31	6.16	3.50	.454	6.33	1.39	11.9	2.21
MEN46	1.54	7.17	3.71	.536	6.45	1.61	16.7	4.10
MEN47	1.27	5.13	2.69	.365	5.87	1.33	11.1	2.46
MEN48	1.40	4.98	2.40	.411	5.44	1.40	11.4	2.40
MEN49	1.12	4.65	2.87	.394	6.36	1.18	11.7	2.33
MEN50	1.13	4.41	3.20	.451	4.55	1.31	14.3	4.26
MEN51	1.64	4.54	2.81	.451	4.71	1.28	16.0	3.18
MEN52	1.28	5.95	2.84	.456	4.88	1.37	15.2	2.98
MEN53	1.44	5.23	3.16	.474	5.30	1.54	15.2	3.20
MEN54	1.44	5.54	3.14	.476	4.53	1.30	15.4	3.02
MEN55	1.73	6.17	3.01	.462	5.06	1.92	15.6	2.72
MEN56	1.30	5.09	2.99	.464	4.86	1.34	15.5	3.32
MEN57	1.28	5.53	2.70	.469	4.16	1.21	14.7	2.93
MEN58	1.15	5.94	2.64	.448	4.55	1.10	14.3	3.36
MEN59	1.23	5.92	2.92	.485	5.34	1.04	14.8	3.10
MEN60	1.40	6.11	2.71	.465	4.72	1.52	15.4	3.44
MEN61	1.25	5.62	2.32	.404	4.18	1.11	11.8	3.26
MEN62	1.08	5.77	2.31	.423	3.85	.759	13.2	2.71
MEN63	1.29	5.32	2.19	.380	3.94	1.05	11.4	2.79
MEN64	1.48	5.13	2.37	.437	4.67	.937	13.5	3.56
MEN65	1.25	6.20	2.94	.483	3.97	1.05	12.5	4.27
MEN66	1.19	4.62	2.47	.413	3.68	.857	11.6	2.97
MEN67	1.24	5.21	2.47	.443	4.18	1.30	13.4	2.88
MEN68	1.14	5.56	2.60	.435	4.59	1.01	13.0	3.06
MEN69	1.11	5.14	2.49	.423	4.20	.924	12.3	3.19
MEN70	1.46	5.36	2.85	.468	4.55	1.31	14.9	3.26
MEN71	1.30	6.72	2.95	.494	4.55	1.19	13.9	3.55
MEN72	1.12	5.56	2.54	.408	5.66	1.21	13.4	2.70
MEN73	1.13	5.58	2.53	.423	5.36	1.11	14.3	3.20
MEN74	1.38	5.37	3.27	.447	5.51	1.41	14.1	2.84
MEN75	1.39	6.35	3.17	.473	4.88	1.26	15.2	2.75
MEN76	1.59	5.73	3.09	.501	5.83	1.27	13.7	2.88
MEN77	1.32	6.25	3.11	.466	6.59	1.49	14.0	2.82
MEN78	1.15	5.91	3.16	.469	5.92	1.66	18.8	3.31
MEN79	1.51	5.91	2.89	.431	4.63	1.27	14.3	2.77
MEN80	1.83	7.22	3.73	.609	5.97	1.85	20.6	5.96
MEN81	1.58	5.10	2.70	.451	4.71	1.13	13.0	2.99
AP79	1.50	5.52	3.81	.497	7.59	1.66	15.2	2.71
AP84	1.61	5.16	2.36	.377	6.52	1.22	12.5	1.90
AP86	1.62	6.52	3.38	.530	6.02	1.30	15.0	4.07

Table G.6. Assignments of samples to groups (NAA data).

	Group 1	*Group 2*	*Group 3*	*Group 4*	*Group 5*	*Group 6*	*Group 7*	*Outliers*
Number of Group Members (+ associated)	14 (+2)	3	13 (+3)	6	8 (+3)	4	8 (+4)	13
Decorated fragments LH II–IIIA	04	–	(03, 10)	01, 06–09	–	–	02	05
Monochrome or Banded frags LH IIB–IIIA	–	–	(17), 20	15	–	–	12, 14 (16, 18)	111, 13, 19
Plain Goblets LHIIB/IIIA1	22, 24, 28–30	–	21, 26–27	–	–	–	–	23, 25
Plain Handmade wares LH IIIA1	–	–	37	–	(33) 34, 36	–	31, (32, 35), 38, 40	39
Kitchen wares LH IIB/IIIA1	(41), 45	47–49	–	–	–	–	50	42–44, 46
Decorated Deep Bowls, etc. LH IIIB/IIIC	–	–	51–56	–	–	57–60	–	–
Undecorated Kylikes LH IIIB	–	–	70	–	61, (62–63), 64, 66–69	–	65	–
Kitchen ware Beaker frags. LH IIIB/IIIC	71–74, 76–77, 79, (81)	–	75	–	–	–	–	78, 80

TABLE G.7. Chemical profiles of the Menelaion groups (NAA data).
Elemental data quoted to 3 significant figures and expressed in parts per million (p.p.m.) except where noted as a percentage (%). The third column shows the standard deviation expressed as a percentage of the element's mean value.

	Group 1	*Group 2*	*Group 3*	*Group 4*
Na%	.534 ± .122 (23)	.534 ± .016 (3)	.559 ± .056 (10)	.393 ± .079 (20)
Al%	8.57 ± .496 (6)	7.18 ± .364 (5)	9.91 ± .315 (3)	8.40 ± .386 (5)
K	1.81 ± .373 (21)	1.34 ± .238 (18)	2.43 ± .322 (13)	2.39 ± .124 (5)
Ca%	4.84 ± 3.94 (81)	1.24 ± .247 (20)	5.82 ± 1.60 (27)	8.20 ± 1.02 (12)
Sc	18.2 ± 1.40 (8)	13.8 ± .267 (2)	21.6 ± .718 (3)	21.7 ± 1.32 (6)
Ti%	.482 ± .024 (5)	.430 ± .026 (6)	.528 ± .034 (6)	.456 ± .039 (9)
V	115. ± 13.4 (12)	96.5 ± 4.60 (5)	122. ± 16.2 (13)	124. ± 5.61 (5)
Cr	179. ± 39.2 (22)	122. ± 12.3 (10)	233. ± 25.9 (11)	259. ± 27.3 (11)
Mn	798. ± 365. (46)	470. ± 76.0 (16)	807. ± 215. (27)	935. ± 62.8 (7)
Fe%	4.69 ± .613 (13)	4.07 ± .261 (6)	4.92 ± .450 (9)	5.51 ± .403 (7)
Co	23.3 ± 2.88 (12)	16.5 ± .320 (2)	28.1 ± 2.02 (7)	30.3 ± 4.03 (13)
Rb	114. ± 18.7 (16)	86.7 ± 4.01 (5)	132. ± 14.8 (11)	147. ± 14.8 (10)
Cs	5.39 ± 1.08 (20)	3.52 ± .667 (19)	6.44 ± .626 (10)	9.47 ± 2.91 (31)
La	38.6 ± 1.92 (5)	34.6 ± 1.93 (6)	43.0 ± 1.83 (4)	32.7 ± 1.04 (3)
Ce	76.6 ± 3.74 (5)	69.5 ± 2.76 (4)	83.3 ± 3.66 (4)	62.1 ± 3.50 (6)
Sm	6.62 ± .339 (5)	5.94 ± .184 (3)	7.24 ± .481 (7)	5.45 ± .441 (8)
Eu	1.40 ± .165 (12)	1.26 ± .141 (11)	1.54 ± .176 (11)	1.28 ± .062 (5)
Dy	5.84 ± .373 (6)	4.92 ± .242 (5)	5.62 ± .506 (9)	4.78 ± .536 (11)
Yb	2.90 ± .273 (9)	2.66 ± .235 (9)	3.10 ± .196 (6)	2.95 ± .185 (6)
Lu	.443 ± .032 (7)	.390 ± .023 (6)	.474 ± .019 (4)	.393 ± .023 (6)
Hf	5.60 ± .690 (12)	5.89 ± .462 (8)	5.22 ± .712 (14)	3.81 ± .398 (10)
Ta	1.29 ± .103 (8)	1.30 ± .111 (8)	1.42 ± .192 (13)	.928 ± .133 (14)
Th	13.2 ± .852 (6)	11.4 ± .262 (2)	15.2 ± .509 (3)	11.1 ± .777 (7)
U	3.01 ± .551 (18)	2.40 ± .065 (3)	3.12 ± .255 (8)	2.74 ± .369 (13)

	Group 1	Group 2	Group 3	Group 4
Na%	.534 ± .122 (23)	.534 ± .016 (3)	.559 ± .056 (10)	.393 ± .079 (20)
Al%	8.57 ± .496 (6)	7.18 ± .364 (5)	9.91 ± .315 (3)	8.40 ± .386 (5)
K	1.81 ± .373 (21)	1.34 ± .238 (18)	2.43 ± .322 (13)	2.39 ± .124 (5)
Ca%	4.84 ± 3.94 (81)	1.24 ± .247 (20)	5.82 ± 1.60 (27)	8.20 ± 1.02 (12)
Sc	18.2 ± 1.40 (8)	13.8 ± .267 (2)	21.6 ± .718 (3)	21.7 ± 1.32 (6)
Ti%	.482 ± .024 (5)	.430 ± .026 (6)	.528 ± .034 (6)	.456 ± .039 (9)
V	115. ± 13.4 (12)	96.5 ± 4.60 (5)	122. ± 16.2 (13)	124. ± 5.61 (5)
Cr	179. ± 39.2 (22)	122. ± 12.3 (10)	233. ± 25.9 (11)	259. ± 27.3 (11)
Mn	798. ± 365. (46)	470. ± 76.0 (16)	807. ± 215. (27)	935. ± 62.8 (7)
Fe%	4.69 ± .613 (13)	4.07 ± .261 (6)	4.92 ± .450 (9)	5.51 ± .403 (7)
Co	23.3 ± 2.88 (12)	16.5 ± .320 (2)	28.1 ± 2.02 (7)	30.3 ± 4.03 (13)
Rb	114. ± 18.7 (16)	86.7 ± 4.01 (5)	132. ± 14.8 (11)	147. ± 14.8 (10)
Cs	5.39 ± 1.08 (20)	3.52 ± .667 (19)	6.44 ± .626 (10)	9.47 ± 2.91 (31)
La	38.6 ± 1.92 (5)	34.6 ± 1.93 (6)	43.0 ± 1.83 (4)	32.7 ± 1.04 (3)
Ce	76.6 ± 3.74 (5)	69.5 ± 2.76 (4)	83.3 ± 3.66 (4)	62.1 ± 3.50 (6)
Sm	6.62 ± .339 (5)	5.94 ± .184 (3)	7.24 ± .481 (7)	5.45 ± .441 (8)
Eu	1.40 ± .165 (12)	1.26 ± .141 (11)	1.54 ± .176 (11)	1.28 ± .062 (5)
Dy	5.84 ± .373 (6)	4.92 ± .242 (5)	5.62 ± .506 (9)	4.78 ± .536 (11)
Yb	2.90 ± .273 (9)	2.66 ± .235 (9)	3.10 ± .196 (6)	2.95 ± .185 (6)
Lu	.443 ± .032 (7)	.390 ± .023 (6)	.474 ± .019 (4)	.393 ± .023 (6)
Hf	5.60 ± .690 (12)	5.89 ± .462 (8)	5.22 ± .712 (14)	3.81 ± .398 (10)
Ta	1.29 ± .103 (8)	1.30 ± .111 (8)	1.42 ± .192 (13)	.928 ± .133 (14)
Th	13.2 ± .852 (6)	11.4 ± .262 (2)	15.2 ± .509 (3)	11.1 ± .777 (7)
U	3.01 ± .551 (18)	2.40 ± .065 (3)	3.12 ± .255 (8)	2.74 ± .369 (13)

	Group 5	Group 6	Group 7
Na%	.517 ± .122 (24)	.502 ± .072 (14)	.536 ± .130 (24)
Al%	8.68 ± .497 (6)	9.73 ± .607 (6)	9.41 ± .819 (9)
K	2.15 ± .366 (17)	1.77 ± .131 (7)	2.54 ± .418 (16)
Ca%	9.19 ± 1.78 (19)	4.96 ± .964 (19)	5.29 ± 1.73 (33)
Sc	18.0 ± .587 (3)	18.6 ± 1.74 (9)	21.7 ± 1.24 (6)
Ti%	.457 ± .26 (6)	.550 ± .038 (7)	.485 ± .036 (7)
V	105. ± 12.5 (12)	93.8 ± 12.0 (13)	140. ± 13.5 (10)

Cr	182. ± 22.6 (12)	226. ± 21.6 (10)	266. ± 25.1 (9)
Mn	1162 ± 349. (30)	641. ± 131. (20)	822. ± 221. (27)
Fe%	4.61 ± .266 (6)	4.43 ± .458 (10)	5.37 ± .502 (9)
Co	22.8 ± 1.53 (7)	24.0 ± 2.12 (9)	25.2 ± 2.74 (11)
Rb	104. ± 12.4 (12)	66.0 ± 12.0 (18)	140. ± 16.4 (12)
Cs	5.49 ± .585 (11)	3.03 ± .558 (18)	7.80 ± .760 (10)
La	34.1 ± 1.23 (4)	37.4 ± 1.52 (4)	35.8 ± 1.66 (5)
Ce	66.6 ± 3.93 (6)	76.0 ± 2.24 (3)	68.5 ± 4.69 (7)
Sm	5.69 ± .270 (5)	3.52 ± .053 (2)	6.18 ± .246 (4)
Eu	1.24 ± .157 (13)	1.27 ± .106 (8)	1.28 ± .118 (9)
Dy	5.14 ± .336 (7)	5.88 ± .247 (4)	5.10 ± .654 (13)
Yb	2.50 ± .139 (6)	2.74 ± .120 (4)	2.96 ± .168 (6)
Lu	.425 ± .017 (4)	.467 ± .015 (3)	.468 ± .016 (3)
Hf	4.12 ± .381 (9)	4.69 ± .490 (10)	4.40 ± .455 (10)
Ta	1.03 ± .137 (13)	1.22 ± .215 (18)	1.21 ± .167 (14)
Th	12.4 ± .845 (7)	14.8 ± .457 (3)	12.9 ± .945 (7)
U	3.54 ± .769 (22)	3.21 ± .237 (7)	4.66 ± .950 (20)

TABLE G.8. Comparative NAA data[47]

Region	*Sites/Areas Represented*	*Groups*
Boeotia	Thebes, Gla, Eutresis, Kallithea, Tanagra	3
Attica	Perati	1
Argolid-Corinthia	Asine, Berbati, Korakou, Mycenae, Tiryns, Zygouries	29
Peloponnese(other)	Achaea, Ayios Stephanos, Chora Ano Englianos, Nichoria, Olympia-Kolosakos, Palaiokastro, Peristeria, Platanos-Renia	12
Crete	Chania, Kommos, Knossos, Palaikastro, Phaistos	21
Cyprus	Akhera, Arpera, Enkomi, Episkopi Phaneromeni, Hala Sultan Tekke, Kalavassos Ayios Dhimitrios, Kition, Maa, Maroni Zarukas, Pyla Verghi	20

[47] J. E. Tomlinson, 'Statistical analysis of Neutron Activation Data on Mycenaean pottery from Gla, Thebes, Eutresis, Kallithea and Tanagra in Boeotia', *Proceedings of the Third International Congress of Boeotian Studies in Greece, Thebes, 4–8 September 1996* (forthcoming); J. E. Tomlinson, 'Chemical analysis of some Mycenaean pottery from Perati, Attica', *AE 1995* (1998) 227–30; S. M. A. Hoffmann, V. J. Robinson, E. B. French and R. E. Jones, 'The problems of the North East Peloponnese and progress to its solution: effects of measurement errors and element-element correlations in defining ceramic reference groups', in D. Adan-Beyitz, M. Artzy and F. Asaro (eds.), *Nuclear Chemistry and its Influence on Modern Science* (forthcoming); J. E. Tomlinson, 'Statistical analysis of Neutron Activation Data on Mycenaean pottery from the Argolid and Corinthia', *Well Built Mycenae. Fascicule 34: Technical Reports* (forthcoming); J. E. Tomlinson, 'Statistical evaluation of the Asaro-Perlman Neutron Activation Data on Mycenaean pottery from the Peloponnese', *BSA* 92 (1997) 139–64; J. E. Tomlinson, 'Provenance of Minoan Ceramics by Multivariate Analysis of Neutron Activation Data' (Ph.D. Thesis, University of Manchester; 1991), and J. E. Tomlinson and V. J. Robinson, 'Neutron Activation Analysis of Minoan pottery from Crete: the search for reference groups' (in preparation); N. D. Bryan, S. M. A. Hoffmann, V. J. Robinson and E. B. French, 'Pottery sources in Bronze Age Cyprus: a provenance study by Neutron Activation', *RDAC* (1997) 31–64.

TABLE G.9. Chemical profiles of black glaze groups 1 and 2 from the Menelaion (NAA data from J. Scott). Elemental data quoted to 3 significant figures and expressed in parts per million (p.p.m.) except where noted as a percentage (%). The third column shows the standard deviation expressed as a percentage of the element's mean value.

	Group 1 (9 samples)	*Group 2 (7 samples)*
Na%	.364 ± 0.07 (9)	.289 ± 0.05 (17)
Al%	10.0 ± 0.52 (5)	11.5 ± 1.32 (11)
K	1.52 ± 0.50 (33)	1.25 ± 0.39 (32)
Ca%	3.85 ± 0.83 (21)	2.59 ± 0.84 (32)
Sc	21.9 ± 1.86 (8)	20.3 ± 2.15 (11)
Ti%	.576 ± 0.02 (4)	.704 ± 0.05 (7)
V	98.3 ± 20.2 (21)	103. ± 22.0 (21)
Cr	266. ± 49.8 (19)	172. ± 23.6 (14)
Mn	1128 ± 212. (19)	962. ± 107. (11)
Fe%	6.21 ± 0.26 (4)	6.69 ± 0.71 (11)
Rb	42.7 ± 9.35 (22)	44.3 ± 15.0 (34)
Cs	1.23 ± 0.51 (42)	1.73 ± 0.55 (32)
La	47.5 ± 2.93 (6)	61.8 ± 7.16 (12)
Ce	92.9 ± 4.63 (5)	119. ± 12.3 (10)
Dy	6.51 ± 0.01 (15)	7.85 ± 0.56 (7)
Lu	.573 ± 0.01 (3)	.638 ± 0.04 (6)
Hf	6.78 ± 0.46 (7)	8.61 ± 0.54 (6)
Th	16.8 ± 1.06 (6)	20.3 ± 2.41 (12)
U	4.21 ± 1.18 (28)	4.81 ± 0.91 (19)