

Copyright Notice

Staff and students of this University are reminded that copyright subsists in this extract and the work from which it was taken. This Digital Copy has been made under the terms of a CLA Licence which allows you to:

- Access and download a copy
- Print out a copy

This Digital Copy and any digital or printed copy supplied to or made by you under the terms of this Licence are for use in connection with this module or course of study. You may retain such copies after the end of the course, but strictly for your own personal use.

All copies (including electronic copies) shall include this Copyright Notice and shall be destroyed and/or deleted if and when required by the University.

Except as provided for by copyright law, no further copying, storage or distribution (including by e-mail) is permitted without the consent of the copyright holder.

The author (which term includes artists and other visual creators) has moral rights in the work and neither staff nor students may cause, or permit, the distortion, mutilation or other modification of the work, or any other derogatory treatment of it, which would be prejudicial to the honour or reputation of the author.

Title of extract: **Variations of Ceramic Composition with Time**

Name of Author: **Attas, M., Fossey, J. and Yaffe, L.**

Title/Author of book/edition (if applicable):

Name of Visual Creator or other acknowledgement (if applicable):

Journal details –title/Vol/Year (if applicable): **Archaeometry Vol 24 pt 2 (1982)**

Publisher: **Research Laboratory for Archaeology and the History of Art**

Pages scanned: **181 - 190**

Course of Study (Module name and number): **Sparta CLAH5003**

Name of Designated Person

authorising scanning: *E.L. Hamis*

Date authorised: 07.09.16.

Moodle/Powerpoint

VARIATIONS OF CERAMIC COMPOSITION WITH TIME: A TEST CASE USING LAKONIAN POTTERY

M. ATTAS

Departments of Classics and Chemistry, McGill University, Montreal, Quebec, Canada

J. M. FOSSEY

Department of Classics, McGill University, Montreal, Quebec, Canada

and L. YAFFE

Department of Chemistry, McGill University, Montreal, Quebec, Canada

INTRODUCTION

The opportunity recently arose to examine directly the variations in the chemical composition of the output of a single pottery manufacturing centre over a period of several centuries. Possible causes of variation include non-homogeneity of a clay source, changes in the exploitation of clay sources by the potters, and changes in the potters' methods of clay preparation. It was expected that any chemical variations would be small, since several provenance studies have found that ceramics of various periods from a given region are generally similar in composition (e.g. Farnsworth *et al.* 1977 for Corinth, Millett and Catling 1967 for central Euboia). Nevertheless, it was felt that examination of pottery of a single style whose origin was well-established, and grouping the analytical data by period, would lead to more definitive results than had hitherto been obtained. The collection of Lakonian pottery in the Redpath Museum of McGill University proved ideal for such a study. The results of the analysis of eighty-two sherds from this collection are presented here.

THE MATERIAL

Donated to the Redpath Museum in 1928, this small collection of sherds was chosen to be representative of the most common types found during excavations at Sparta by the British School at Athens in the first three decades of the twentieth century. These excavations uncovered many important areas in and around Sparta, but most notable among them was the Sanctuary of Artemis Orthia, with its succession of temples, altars, and votive deposits (Dawkins 1929). The votive objects had been dedicated to the goddess from Late Geometric to Classical times; that is, from the eighth to the fourth centuries B.C. The quantity of finds at the sanctuary allowed the pottery to be arranged in a sequence of phases showing a continuous stylistic development. The popularity and uniformity of the style left no doubt that it was local, the output of, at the most, a small number of workshops. The sequence of phases was first set out by Droop (1908, 1929), and later refined by Lane (1934). The validity of the relative chronology was reaffirmed by Boardman (1963), who revised some of the absolute dates. Table 1 shows the names and approximate dates of each phase.

Table 1 *Chronology of Lakonian pottery (after Cook 1972)*

Date B.C.	Phase
1400–1200	Late Helladic IIIA and IIIB
750–690	Late Geometric
690–650	Subgeometric ('Transitional')
650–620	Lakonian I
620–580	Lakonian II
580–550	Lakonian III
550–525	Lakonian IV (and masks)
5th century?	Lakonian V
4th century?	Lakonian VI
3rd and 2nd century	Hellenistic

The McGill University Ethnology Collection has some sherds from all of these phases except Lakonian II. Six to ten sherds from each phase were chosen for sampling and analysis. The main criterion for *not* sampling a sherd was that it was too thin for the tungsten-carbide drill bit to penetrate an edge without damaging the painted surfaces. The sherds are illustrated in figures 1 and 2, arranged by archaeological groups. Most of the material comes from the Artemis Orthia sanctuary but is supplemented, for earlier and later periods, by pottery from other British excavations in the area of Sparta. These groups can be described as follows:

- SP80–SP89 Late Geometric sherds from the Khalkioikos Sanctuary on the akropolis at Sparta (Dickins 1907)
- SP90–SP93 Late Geometric sherds from the Sanctuary of Artemis Orthia (henceforth A.O.)
- SP94–SP97 Subgeometric (Transitional) sherds from A.O.
- SP11–SP19 Lakonian I sherds from A.O., mostly from bowls, cups, and skyphoi
- SP31–SP39 Lakonian III sherds from A.O., some from bowls and plates
- SP41–SP48 Lakonian IV sherds from A.O., from bowls, plates and cups
- SP51–SP56 Lakonian V sherds from A.O., mostly wall fragments
- SP61–SP69 Lakonian VI sherds from A.O., from bowls and cups

These pieces show the continuous stylistic development characteristic of Lakonian pottery, and constitute the main series of analyses. Several samples lying outside the stylistic tradition were also analyzed:

- SP01–SP07 Late Helladic III sherds from the Menelaion, a Mycenaean settlement near Sparta (Wace *et al.* 1909, Catling 1977)
- SP71–SP77 an assortment of sherds from Hellenistic tombs in the Sparta area, third to second century B.C. except for the Attic red-figure piece (SP71), from a squat lekythos, late fifth or early fourth century B.C.
- SPM1–SPM9 fragments of terracotta masks (probably votives), again found at A.O., mostly in the same strata as Lakonian IV pottery (Dickins 1929)



Figure 1a



Figure 1 Photographs of sampled sherds, in numerical order from upper left to lower right (a) SP01–SP07, SP80–SP97 (b) SP11–SP19, SP31–SP39.

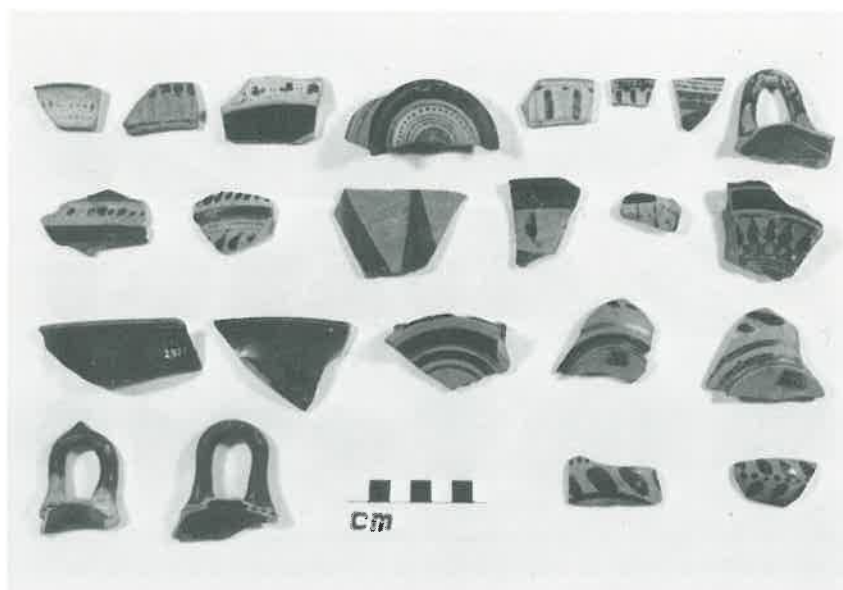


Figure 2a

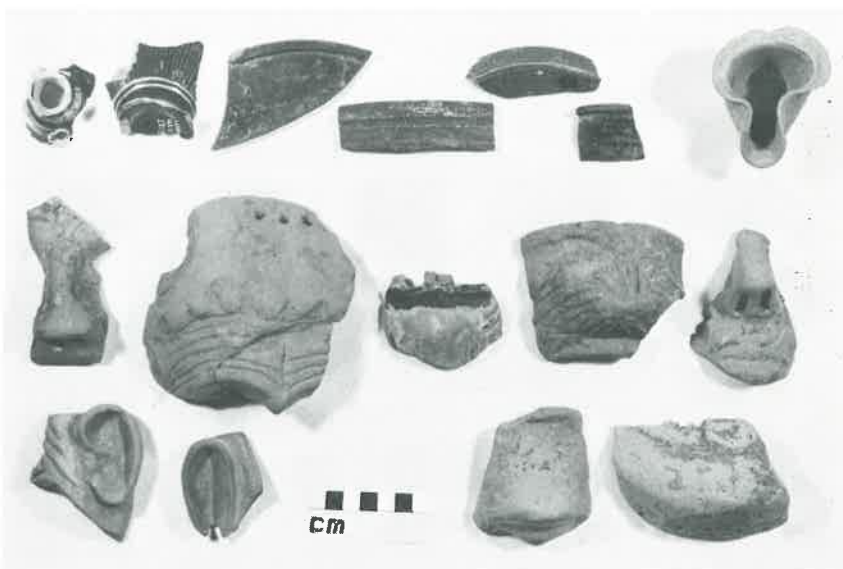


Figure 2 Photographs of sampled sherds, in numerical order from upper left to lower right (a) SP41–SP48, SP51–SP56, SP61–SP69 (b) SP71–SP77, SPM1–SPM9.

ANALYSIS

There were 82 samples in all. These were analyzed by instrumental neutron activation at Brookhaven National Laboratory during 1976–1977, using the procedure developed by

Harbottle and Sayre for the analysis of ancient pottery. This involves simultaneous irradiation of vials containing pottery powder and United States Geological Survey standard rocks. As the Brookhaven procedure is quite routine and has been described in several publications (in greatest detail by Abascal *et al.* 1974), we can discuss the results directly.

RESULTS

For each sample, the concentrations of 18 elements have been measured (table 2). The average analytical precision of measurements made at Brookhaven has been determined by Bieber *et al.* (1976, p. 71). A few samples can be assigned a non-Spartan origin immediately, on archaeological and/or analytical grounds. For instance, the Attic red-figure sherd SP71 has concentrations of Cs, Sc, Lu, Cr, and Fe far greater than those of the rest of the samples. In fact, it matches a reference group of Attic pottery, established by Fillières (1978), which is on file at Brookhaven. The rest of the samples form a large, relatively cohesive group. Elemental standard deviations range from $\pm 10\%$ for iron and scandium, to $\pm 45\%$ for manganese, with an average around $\pm 20\%$.

The variations with time of the elemental concentrations can be traced by plotting a histogram for each archaeological group and lining up these histograms side by side (figure 3, a to f). This has been done using the computer program BMDP7D (Dixon and Brown 1977). Several patterns are evident. Some elements, such as Cs, do not change greatly from Mycenaean to Hellenistic times (figure 3a). Others, such as Cr, are more variable. In fact, Cr concentrations appear to rise gradually, if not from the Mycenaean period, at least from Geometric through to Lakonian VI (figure 3b). The terracotta masks and Hellenistic sherds do not follow this trend. This same pattern, a gradual rise in concentration from Lakonian I to Lakonian VI, is evident for the elements Na, K, Rb, and Sc as well. The Sc histograms are presented in figure 3c. Those for Na (figure 3d) are more scattered, but still rise, in this case from the Subgeometric, or Transitional, phase onwards. Another trend is also visible in figure 3d, the gradual reduction in the dispersion of each group, from a standard deviation of $\pm 29\%$ for Lakonian I, to $\pm 7\%$ for Lakonian VI. It is to be noted, however, that the masks and the early and late pottery groups are quite dispersed.

For the rare-earth elements, the mean concentrations of each group show a gradual decrease with time. Lutetium (figure 3e) is the clearest example. The mean falls from 0.79 parts per million (ppm) of oxide for Lakonian I to 0.62 ppm for Lakonian VI, with associated group standard deviations of $\pm 14\%$ and $\pm 11\%$ respectively. The decrease in dispersion visible in figure 3e is largely proportional to the falling mean concentration. Figure 3f shows the Hf concentrations, again decreasing gradually with time, from Geometric to Lakonian VI. The dispersions are irregular.

We may summarize the trends as follows: for the phases Lakonian I to VI, the group means rise gradually for the elements Na, K, Rb, Sc, and Cr; they fall gradually for most rare-earth elements and Hf; they remain the same for Cs, Th, and Fe, which are measured with high precision; and they do not follow any particular trend for the rest of the elements. The dispersions of the groups seem to shrink with time for the elements Na and Fe. (It must be pointed out, however, that these statistics are based on only a small number of sherds from each period, and that the dispersions are estimated much less precisely than the means.) For some elements, these trends can be extended back to Geometric, but the Mycenaean sherds, the Hellenistic pieces, and the masks do not fall into the same pattern. This means that the stylistic continuity

Table 2 Concentrations of 18 elements in the Lakonian pottery samples, expressed as parts per million of oxide, except for Na, K, Fe, and Ca, expressed as percentage of oxide

Sample	Na ₂ O(%)	K ₂ O(%)	Rb ₂ O	Cs ₂ O	BaO	Sc ₂ O ₃	La ₂ O ₃	CeO ₂	Eu ₂ O ₃	Lu ₂ O ₃	HfO ₂	ThO ₂	Ta ₂ O ₅	Cr ₂ O ₃	MnO	Fe ₂ O ₃ (%)	CoO	CaO(%)
SP01	0.51	1.2	66	4.4	642	25.8	38.1	87.7	1.5	0.574	4.21	12.2	1.42	195.0	1140	5.86	29.7	23.0
SP02	0.76	2.8	146	7.9	833	35.4	48.2	114.0	2.0	0.734	5.55	17.3	1.82	314.0	1340	6.67	36.5	6.4
SP03	0.58	1.8	79	4.7	776	26.9	37.8	85.0	1.5	0.636	4.24	13.3	1.34	180.0	1140	5.40	22.9	20.2
SP04	0.54	1.8	85	4.6	667	36.5	50.2	110.0	2.2	0.885	5.44	16.6	1.41	365.0	1180	7.72	42.0	13.2
SP05	0.78	2.3	133	5.9	543	33.4	46.4	105.0	2.0	0.626	5.02	15.5	1.55	377.0	948	7.10	43.3	11.0
SP06	0.75	2.9	146	7.2	742	35.1	48.4	115.0	2.0	0.592	5.48	18.1	1.95	313.0	1120	6.64	34.9	9.5
SP07	0.57	2.4	142	7.7	596	38.2	50.2	119.0	2.1	0.711	5.48	16.9	1.69	346.0	663	9.09	36.0	12.5
SP11	1.01	2.4	118	4.8	467	35.0	44.4	103.0	1.9	0.839	5.54	14.4	1.33	419.0	1180	7.69	40.9	9.4
SP12	0.65	2.4	143	6.1	546	31.3	46.7	106.0	1.9	0.667	6.06	15.0	1.90	296.0	1460	7.30	36.1	8.5
SP13	1.03	2.7	139	6.4	476	33.0	41.4	99.0	1.8	0.868	5.32	14.2	1.44	399.0	1220	7.11	36.4	8.1
SP14	0.71	2.5	142	6.6	618	33.9	54.4	124.0	2.3	0.981	6.50	17.3	1.79	293.0	1170	7.80	43.4	6.7
SP15	0.43	1.8	136	6.3	501	35.2	54.5	119.0	2.2	0.784	6.12	16.9	2.05	310.0	845	8.36	44.5	8.5
SP16	0.71	2.2	126	5.3	597	30.4	59.9	133.0	2.3	0.774	7.57	18.0	2.06	236.0	1210	7.73	29.7	4.5
SP17	0.68	2.0	86	3.7	653	29.8	46.2	102.0	2.1	0.746	6.07	15.2	1.72	338.0	1610	7.45	35.3	7.3
SP18	0.46	1.9	77	2.1	630	34.6	55.6	119.0	2.5	0.621	6.38	18.4	2.83	378.0	810	7.62	35.3	8.6
SP19	0.70	2.5	133	5.8	441	34.9	53.0	126.0	2.2	0.851	6.58	17.0	2.08	386.0	1500	8.80	42.7	6.1
SP31	1.12	2.7	165	7.4	574	35.8	44.0	98.9	1.8	0.718	5.82	15.6	1.93	437.0	1060	7.74	37.5	8.0
SP32	0.89	2.4	125	5.2	755	32.6	64.1	149.0	2.5	0.822	8.64	21.6	2.17	188.0	1570	8.55	31.9	7.4
SP33	0.62	2.7	144	7.3	797	33.5	54.6	132.0	1.8	0.644	5.60	14.8	1.21	370.0	2900	7.69	36.2	8.0
SP34	0.72	2.7	145	6.7	655	32.3	51.5	117.0	2.2	0.777	6.59	16.7	1.96	263.0	1290	7.21	36.1	5.3
SP35	1.03	2.8	154	7.4	594	34.6	40.3	97.6	1.9	0.678	5.75	15.0	1.49	419.0	1100	7.55	36.5	7.6
SP36	0.91	2.7	143	6.7	531	37.8	41.3	100.0	1.9	0.674	5.37	15.4	1.49	429.0	1100	8.31	37.5	6.6
SP37	0.82	2.5	145	7.1	688	35.9	57.7	136.0	2.5	0.870	6.87	18.8	1.77	285.0	961	8.16	31.7	7.1
SP38	0.94	2.6	151	7.6	468	34.7	39.8	96.6	1.8	0.628	4.98	14.0	1.50	400.0	1240	7.48	38.8	7.8
SP39	0.70	2.5	133	6.2	726	30.9	50.1	114.0	2.1	0.912	6.41	15.6	1.59	261.0	1690	7.19	37.5	6.1
SP41	1.03	2.9	158	7.2	618	34.5	43.2	103.0	1.9	0.620	5.52	14.8	1.65	404.0	1220	7.28	39.9	8.4
SP42	0.69	2.6	156	7.3	683	35.6	57.3	125.0	2.3	0.836	6.92	17.6	2.04	294.0	1480	8.03	44.1	5.2
SP43	1.03	2.6	111	5.1	586	33.6	43.8	102.0	2.0	0.648	5.77	14.7	1.69	409.0	1240	7.58	34.3	7.3
SP44	0.71	2.9	156	7.1	637	33.3	48.5	113.0	2.0	0.587	5.88	15.5	1.64	331.0	1600	7.36	43.9	5.2
SP45	0.68	2.8	154	7.2	678	34.7	57.2	121.0	2.4	0.665	6.68	19.1	3.36	299.0	1390	7.94	42.4	5.4
SP46	1.05	2.9	162	6.2	603	35.2	44.9	103.0	1.9	0.690	5.32	16.5	2.35	425.0	1040	7.47	36.1	6.4
SP47	0.77	2.7	152	7.3	703	35.0	50.7	112.0	2.2	0.611	5.63	17.1	2.38	332.0	1450	8.06	37.1	6.8

Table 2 (Continued)

Sample	Na ₂ O(%)	K ₂ O(%)	Rb ₂ O	Cs ₂ O	BaO	Sc ₂ O ₃	La ₂ O ₃	CeO ₂	Eu ₂ O ₃	Lu ₂ O ₃	HfO ₂	ThO ₂	Ta ₂ O ₅	Cr ₂ O ₃	MnO	Fe ₂ O ₃ (%)	CoO	CaO(%)
SP48	0.99	2.8	152	6.0	733	34.3	41.9	99.0	1.9	0.616	5.22	15.4	2.42	411.0	1150	7.46	34.6	6.5
SP51	0.64	2.3	142	5.4	602	34.3	56.0	113.0	2.3	0.486	6.96	18.3	2.84	298.0	1650	8.18	42.1	6.0
SP52	0.97	2.8	148	6.0	568	33.8	48.0	106.0	2.0	0.580	5.17	14.6	2.63	405.0	1250	7.61	37.2	6.7
SP53	0.94	2.9	168	6.9	563	38.6	40.3	85.8	1.8	0.548	4.35	14.4	2.31	481.0	852	7.40	44.6	9.9
SP54	0.66	2.7	176	6.8	644	36.2	69.3	152.0	2.9	0.875	7.42	21.1	2.62	278.0	716	7.70	34.5	5.6
SP55	1.06	3.0	165	6.7	508	35.5	43.6	96.8	1.8	0.519	5.73	15.2	2.19	437.0	1120	7.62	38.3	7.1
SP56	0.91	3.0	175	6.3	559	35.6	44.6	99.8	2.2	0.701	5.09	16.6	2.06	406.0	1090	7.74	35.3	6.1
SP61	0.87	2.9	177	7.2	671	39.7	51.6	106.0	2.2	0.576	5.53	18.2	2.41	405.0	1210	8.76	41.1	5.7
SP62	0.89	2.9	168	6.9	592	34.5	44.5	99.2	2.0	0.521	5.00	16.2	2.03	403.0	914	7.09	35.9	6.4
SP63	0.96	2.8	168	7.0	470	36.0	44.6	102.0	2.0	0.690	5.22	16.8	2.04	430.0	1170	7.83	38.7	7.8
SP64	1.03	2.7	146	5.3	509	31.0	42.4	96.9	1.8	0.712	5.68	15.1	1.73	412.0	1270	7.07	37.2	5.8
SP65	0.80	3.2	172	6.5	655	37.0	46.5	100.0	1.9	0.574	5.46	16.6	2.74	442.0	1030	7.84	40.6	7.3
SP66	0.93	2.9	170	7.0	663	37.4	46.2	104.0	2.0	0.675	5.53	17.0	2.35	421.0	1250	8.12	50.5	7.2
SP67	0.86	3.0	174	6.4	702	35.1	68.5	147.0	2.0	0.565	5.71	16.4	2.17	405.0	1080	7.43	34.9	7.4
SP68	0.93	3.2	172	6.5	630	36.0	45.6	101.0	1.9	0.608	5.49	16.7	2.36	435.0	1160	7.86	38.5	7.4
SP69	0.93	2.7	156	5.8	578	34.5	45.6	102.0	1.9	0.707	5.64	15.8	2.49	405.0	1290	7.58	38.3	6.9
SP71	0.65	3.9	173	13.2	825	40.7	42.7	95.7	2.1	1.120	4.10	15.1	1.64	842.0	1070	8.88	50.7	6.6
SP72	0.45	3.1	162	6.7	552	33.6	47.0	102.0	2.1	0.741	4.31	16.3	1.77	325.0	1860	7.58	48.0	9.4
SP73	0.50	3.1	181	6.1	608	33.7	68.9	135.0	2.5	0.604	6.91	18.5	2.73	235.0	785	7.78	34.6	5.8
SP74	0.93	2.6	139	6.3	481	31.3	44.8	96.7	1.9	0.647	4.40	16.8	2.22	268.0	1400	7.08	30.1	12.3
SP75	0.71	2.6	152	7.3	541	32.3	46.7	100.0	2.1	0.614	3.93	15.9	2.38	269.0	1620	7.66	30.4	10.3
SP76	0.72	2.2	124	4.6	544	28.1	46.2	104.0	2.0	0.534	6.79	15.0	2.33	273.0	923	6.91	37.1	4.5
SP77	0.67	2.1	126	4.4	538	29.2	44.0	104.0	1.8	0.759	6.35	14.8	2.05	360.0	1450	7.19	43.0	2.8
SP80	0.65	3.4	185	6.7	734	35.6	54.6	118.0	2.4	0.716	6.31	18.7	3.15	242.0	592	7.86	32.7	5.7
SP81	0.62	2.9	155	6.0	723	33.9	58.2	112.0	2.5	0.889	6.47	18.1	2.92	254.0	558	7.69	28.3	8.1
SP82	0.82	3.2	168	6.5	518	35.5	43.1	94.8	1.7	0.684	5.04	17.0	1.96	432.0	993	7.19	42.9	7.0
SP83	1.02	3.8	168	5.3	921	33.2	62.8	135.0	2.4	0.615	8.56	21.6	3.40	154.0	450	7.14	33.5	n.d.
SP84	0.93	3.1	159	6.5	653	33.1	62.5	144.0	2.7	0.758	8.42	20.3	2.59	177.0	1050	8.59	31.5	8.8
SP85	0.70	3.2	170	7.0	897	35.1	55.0	117.0	2.4	0.694	6.00	18.2	2.36	254.0	685	7.77	28.1	9.5
SP86	0.56	2.7	136	6.7	657	33.6	53.5	125.0	2.2	0.665	6.41	16.0	2.19	288.0	389	8.02	39.0	6.8
SP87	0.49	2.6	129	6.0	679	28.5	52.9	123.0	2.1	0.644	6.75	16.8	2.68	155.0	435	6.76	25.9	10.8
SP88	0.64	2.9	139	6.4	656	31.9	57.8	123.0	2.6	0.603	6.57	16.7	2.20	239.0	599	7.07	28.5	6.4
SP89	0.60	2.9	141	7.4	626	34.6	55.9	123.0	2.5	0.684	6.17	17.8	2.30	274.0	450	7.76	53.5	6.8

Table 2 (Continued)

Sample	Na ₂ O(%)	K ₂ O(%)	Rb ₂ O	Cs ₂ O	BaO	Sc ₂ O ₃	La ₂ O ₃	CeO ₂	Eu ₂ O ₃	Lu ₂ O ₃	HfO ₂	ThO ₂	Ta ₂ O ₅	Cr ₂ O ₃	MnO	Fe ₂ O ₃ (%)	CoO	CaO(%)
SP90	0.85	2.9	153	6.0	640	33.0	65.2	156.0	2.7	0.608	8.06	20.8	2.33	187.0	735	6.89	26.1	6.6
SP91	0.75	3.2	149	7.1	811	35.3	58.3	134.0	2.6	1.270	6.96	20.7	2.31	293.0	2300	8.44	38.6	5.9
SP92	0.72	3.0	160	6.6	653	36.0	57.9	129.0	2.5	0.912	6.83	18.4	2.43	261.0	1810	8.87	39.9	4.7
SP93	0.55	2.8	143	7.0	822	35.7	55.3	121.0	2.5	0.779	6.53	19.2	2.31	269.0	1070	8.20	33.6	8.6
SP94	0.59	2.7	168	6.0	708	34.3	54.6	156.0	2.4	0.652	6.83	18.9	2.49	249.0	752	8.54	28.6	9.2
SP95	0.55	2.8	152	6.8	590	33.4	53.6	115.0	2.5	0.866	6.01	16.7	2.25	279.0	573	7.58	48.6	10.8
SP96	0.52	2.9	167	7.2	688	36.8	57.9	146.0	2.7	0.608	6.55	18.9	3.02	324.0	1360	9.07	n.d.	7.9
SP97	0.55	3.0	158	7.1	642	34.9	53.5	111.0	2.4	0.872	6.10	17.8	2.06	310.0	992	8.34	61.9	8.7
SPM1	0.74	2.8	137	6.4	641	30.9	60.9	147.0	2.5	0.691	8.12	18.8	2.91	184.0	1010	7.33	31.3	4.4
SPM2	0.56	2.9	133	6.7	735	31.4	55.0	127.0	2.4	0.922	7.03	17.1	2.33	238.0	1880	7.71	32.8	3.8
SPM3	0.80	2.4	109	4.6	491	25.4	43.9	104.0	1.9	0.522	6.60	14.7	1.89	277.0	788	6.08	31.9	5.1
SPM4	0.62	2.1	122	5.5	611	28.9	50.2	110.0	2.2	0.745	5.59	16.6	1.78	283.0	1520	7.67	32.7	5.0
SPM5	0.65	2.6	136	6.4	769	32.6	52.5	126.0	2.3	0.738	7.36	18.2	2.49	280.0	2190	8.17	36.6	5.6
SPM6	1.17	2.8	140	6.2	603	30.2	44.3	108.0	1.8	0.694	6.37	15.5	2.12	291.0	585	6.47	28.3	7.1
SPM7	0.36	2.3	127	5.7	616	28.3	59.8	183.0	2.3	0.755	6.84	18.7	2.34	166.0	932	7.19	53.4	1.0
SPM8	0.84	2.9	141	6.9	724	32.2	54.8	131.0	2.4	0.658	7.12	17.9	2.21	234.0	919	7.57	31.2	4.8
SPM9	1.07	3.0	128	6.5	600	32.2	41.7	87.7	2.0	0.514	5.06	13.5	1.74	383.0	1290	7.15	31.7	5.6

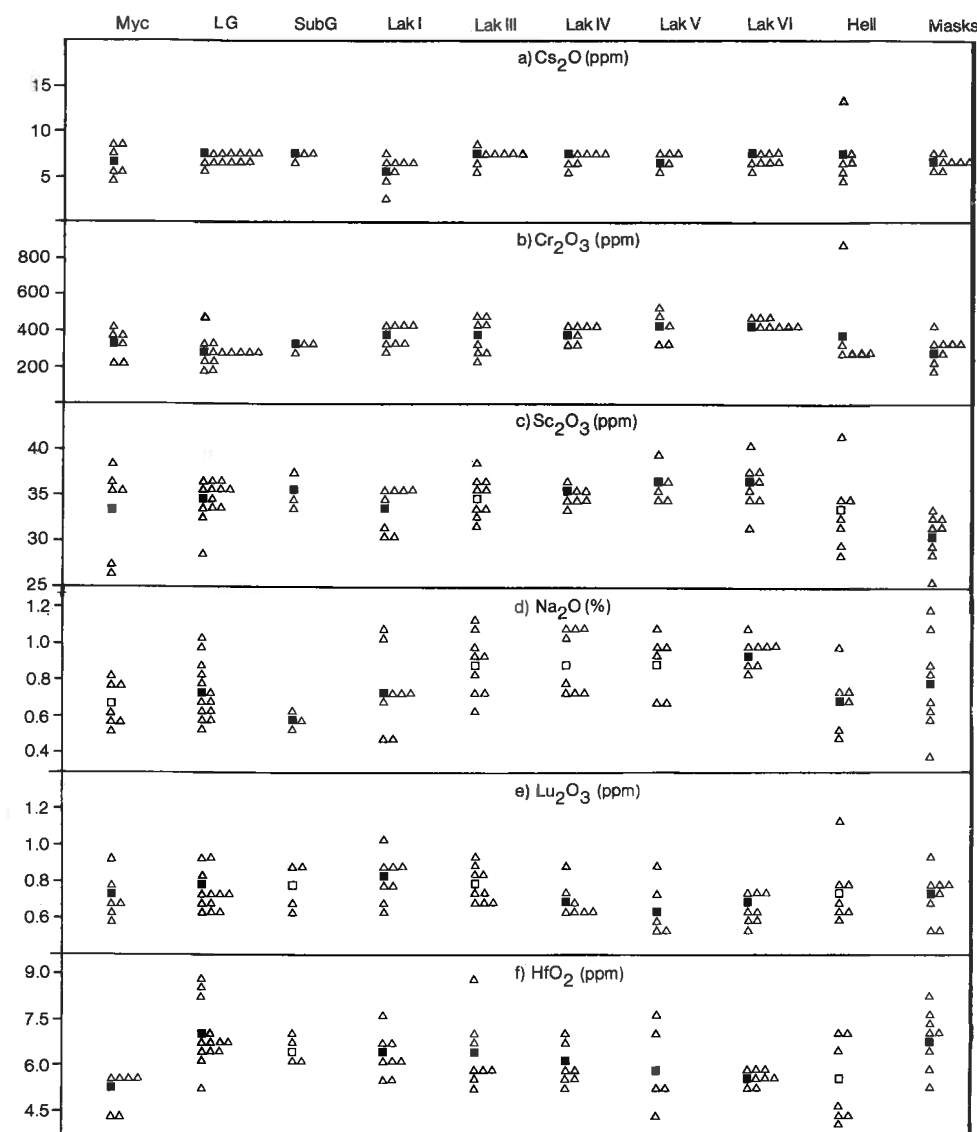


Figure 3 Histograms showing the variation in the concentrations (expressed as oxides) of the elements Cs, Cr, Sc, Na, Lu, and Hf for ten archaeological groups (see text). Group means are denoted by filled squares if they are superimposed on a sample concentration and by open squares otherwise.

which we observe from Lakonian I to Lakonian VI is paralleled by an analytical continuity. The composition of the ceramics is not absolutely constant, but changes slowly and gradually with time. The shrinking dispersions may reflect a more vigorous or centralized procedure for extracting and purifying the clay, but the analytical data do not permit firm conclusions in this respect, and no visible variation in the generally excellent quality of the fabric is evident either.

The potential value of such trends for dating pottery whose decoration is uninformative

has been pointed out by Harbottle, who with Fillières has found similar trends in terracotta figurines from the Athens Agora (personal communication 1980). In the present study, however, the scatter in the elemental concentrations for each chronological group is too great to allow any regression curve which would be archaeologically useful to be drawn.

CONCLUSION

These results point to the exploitation of a single clay bed for the three centuries spanned by the phases of the Lakonian style. Although for most elements the Mycenaean, Geometric, and Hellenistic sherds and the terracotta masks do not follow the trends set by these phases, almost all are still closer in composition to Lakonian I to VI pottery than to late Helladic pottery from sites less than 100 kilometres away to the south or to the north-east (Ayios Stephanos and Berbati respectively, Bieber *et al.* 1976). The results of this study give us confidence in working, on a regional basis, with compositional reference groups for ceramics whose ages may range over a few centuries, and show us what to expect in the way of short-term compositional variations.

ACKNOWLEDGEMENTS

Our debt to Drs Harbottle and Sayre of Brookhaven National Laboratory is manifold. They offered us the many facilities of BNL during 1976–77, and guided Michael Attas through the activation analyses and data processing, providing advice and encouragement all along. The Redpath Museum of McGill University graciously accorded us permission to sample and photograph the sherds. Financial support was obtained from the National Research Council of Canada.

REFERENCES

- Abascal, R., Harbottle, G. and Sayre, E.V., 1974, Correlation between terracotta figures and pottery from the Valley of Mexico and source clays by activation analysis, in *Archaeological Chemistry* (ed. C. W. Beck), Washington, 81–99.
- Bieber, A. M., Jr., Brooks, D. W., Harbottle, G. and Sayre, E. V., 1976, Application of multivariate techniques to analytical data on Aegean ceramics, *Archaeometry* 18 (1), 59–74.
- Boardman, J., 1963, Artemis Orthia and chronology, *Annual of the British School at Athens* 58, 1–7.
- Catling, H. W., 1977, Excavations at the Menelaion, Sparta, 1973–76, *Archaeological Reports for 1976–77*, London, 24–42.
- Cook, R. M., 1972, *Greek Painted Pottery*, second edition, London.
- Dawkins, R. M., ed., 1929, *The Sanctuary of Artemis Orthia at Sparta*, London.
- Dickins, G., 1906/07, Excavations at Sparta, 1907. The Hieron of Athena Chalkioikos, *Annual of the British School at Athens* 13, 137–154.
- Dickins, G., 1929, The masks, in Dawkins (1929), 163–186.
- Dixon, W. J. and Brown, M. B., eds., 1977, *BMDP-77: Biomedical Computer Programs P-Series*, Berkeley.
- Droop, J. P., 1907/08, Excavations at Sparta, 1908. The pottery, *Annual of the British School at Athens* 14, 30–47.
- Droop, J. P., 1929, The Laconian pottery, in Dawkins (1929), 54–116.
- Farnsworth, M., Perlman, I. and Asaro, F., 1977, Corinth and Corfu: a neutron activation study of their pottery, *American Journal of Archaeology* 81, 455–468.
- Fillières, D., 1978, Contribution à l'étude de la production et de l'exportation des amphores dites marseillaises et des céramiques grecques d'Occident du Midi de la France au moyen d'analyses par activation neutronique avec traitement taxinomique des résultats, doctoral thesis (3e cycle) University of Paris I – Panthéon-Sorbonne.
- Lane, E., 1933/34, Lakonian vase-painting, *Annual of the British School at Athens* 34, 99–189.
- Millett, A. and Catling, H. W., 1967, Composition patterns of Minoan and Mycenaean pottery: survey and prospects, *Archaeometry* 10, 70–77.
- Wace, A. J. B., Thompson, M. S. and Droop, J. P., 1908/09, Excavations at Sparta, 1909. The Menelaion, *Annual of the British School at Athens* 15, 108–157.