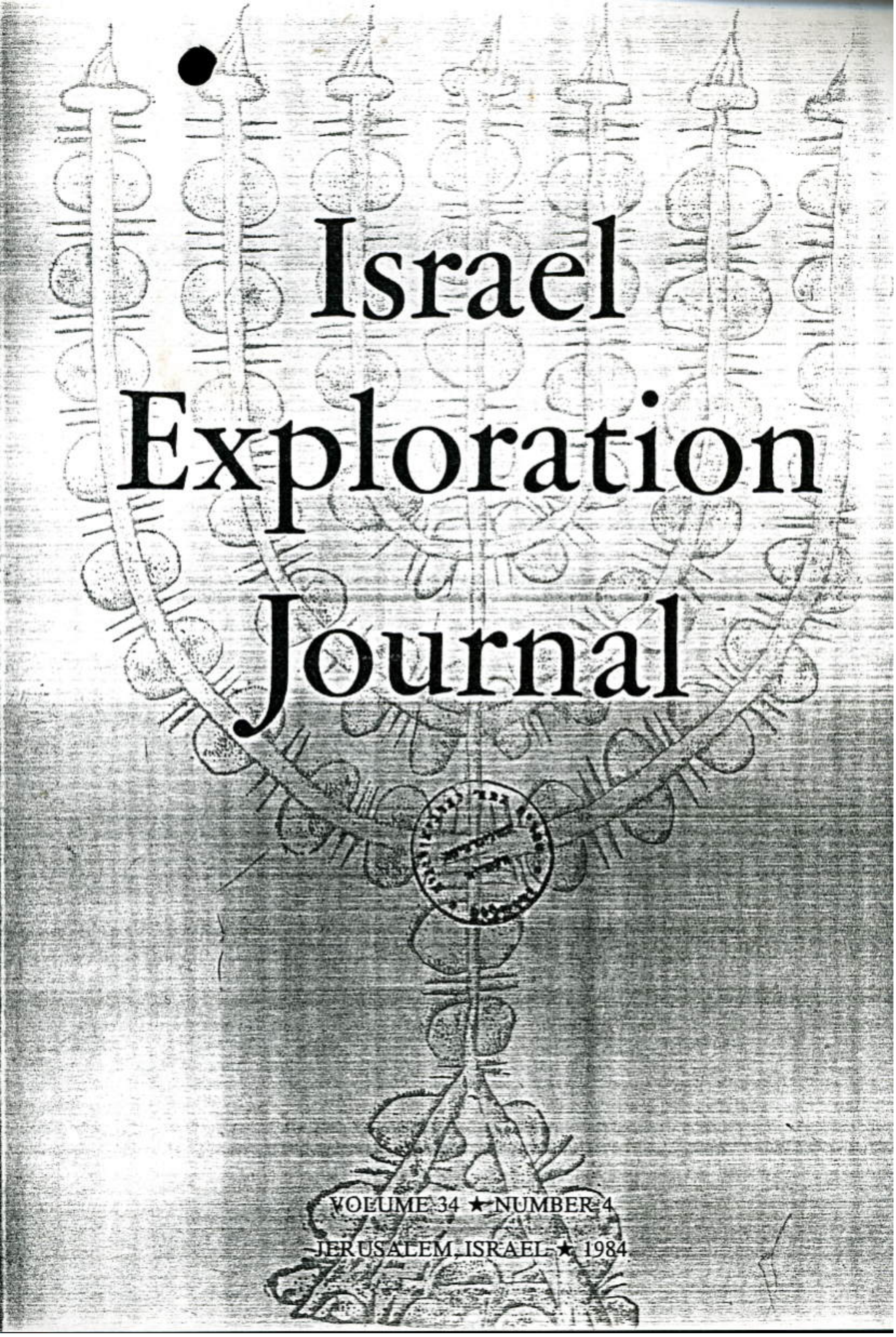

Israel Exploration Journal

VOLUME 34 ★ NUMBER 4

JERUSALEM, ISRAEL ★ 1984

Hellenistic Braziers from Israel: Results of Pottery Analysis

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THE article by L.Y. Rahmani[1] describes Hellenistic braziers from Samaria and seven coastal sites. In the present study, thirty-seven brazier fragments were analysed by neutron activation analysis with the objective of learning as much as possible about their places of origin. The system for conducting the analyses is a modification of that described by Perlman and Asaro.[2]

As is the case for all provenience studies,[3] the analytical data for the ceramics of interest are first separated into chemical groups, each of which contains specimens which are very similar in composition. The ultimate objective is to match the composition of each chemical group with reference material; the most commonly used reference material consists of pottery from a site where a strong case can be made for its manufacture at that site.

In some cases it is not possible to find suitable reference material and provenience cannot be assigned with confidence. However, even in such cases one can obtain useful information from the groups themselves. For example, if the members of a group have stylistic characteristics which are not found in other groups, the chemical groups can serve as an aid in classifying the pottery. Furthermore, if the members of the group are found at many sites, one can delineate the distribution pattern of the wares.

It should be pointed out that different chemical groups do not necessarily have different proveniences. A case in point is a study of terra sigillata in which ideal reference material was available.[4] The reference material consisted of terra sigillata kiln wasters obtained in proximity to excavated kilns. Such material is ideal, because it is unlikely that it would have been brought in from outlying places. At Lyons the kiln wasters fell into three distinct chemical groups. This signifies that three clay sources were used, essentially at one place.

STATISTICS OF POTTERY GROUPS

The comparison of pottery groups with each other or with reference material is based upon statistical criteria which do not reveal explicitly whether they 'match' or 'do not

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1 Above, pp. 224–231.

2 I. Perlman and F. Asaro: Pottery Analysis by Neutron Activation, *Archaeometry* 11 (1969), pp. 21–52.

3 We use the term 'provenience' to indicate where the pottery was made, not where it was excavated.

4 F. Wideman *et al.*: A Lyons Branch of the Pottery-making Firm of Ateius of Arezzo, *Archaeometry* 17 (1975), pp. 45–59.

match' but assign probabilities to these generalizations. Therefore the analytical data must be set out in a form which is compatible with the statistics.

The measurements consist of the abundances of an element in all the members of a group; the values obtained may be designated as x_1, x_2, x_3, etc., for the different members. The average or mean value (M) is one of two parameters which characterize this group. The deviation of each member from the mean is given by $M-x$, and it will be found that most of the x's cluster around M. The number of members which deviate more and more from M rapidly becomes much smaller. The distribution follows a bell-shaped curve known as a normal distribution curve. Although the slope of the curve remains the same for different elements, the width of the 'bell' (the spread) changes according to the homogeneity of the x values for each element. The yardstick for expressing the spread is the root-mean-square deviation, σ, which is calculated from M and the x values in the set. Thus the paired numbers, M and σ, give all the essential information for describing the distribution of x values.

As a rough guide for visualizing this distribution, about two-thirds of the group members will have x values which deviate from M by less than 1 unit of σ, most of the remainder will fall between 1 and 2σ, and only about 4% will lie beyond 2σ. To illustrate how rapidly the curve falls off, calculations show that the odds are only one in a million for finding a member which deviates by 5σ.

It is clear from the above that, if the deviation from M for any number x is expressed in units of σ, one can obtain the probability that x belongs to the group. For example, if $(M-x)/\sigma$ lies between 0 and 1, there is a good probability that the specimen belongs to the group because two out of three of its members fall within this interval.

It has been mentioned that one can calculate the probability that any value x is a member of a group. One must use a mathematical equation which expresses the whole distribution curve from the two parameters, M and σ, and then calculate the probability of finding the value x in the group from $(M-x)/\sigma$. Fortunately, statistical tables dealing with the normal distribution curve list these probabilities for a broad range of $(M-x)/\sigma$ values which are symbolized by the letter Z. To be explicit, we are using the simple equation: $Z = (M-x)/\sigma$.

The discussion thus far is based on the statistics which pertain to a single chemical element; it might appear that this is sufficient to decide whether a piece of pottery is or is not a member of a group. However, this is a risky procedure because two clay bodies will almost always contain several elements which accidentally have the same abundance. This factor, among others, dictates that a considerable number of elements be measured. In our routine for analysis more than 20 elements are measured.

Table 2 on p. 236 shows the group parameters for 20 elements in four groups discussed further below. Initially we use the data in Columns 1 and 2 (groups 1a and 1b) to justify their separation into two chemical groups. In this example, we are comparing groups with each other through their Z values, rather than a single specimen with a group.

In comparing group with group, there is an expression for Z which is more complex than $Z = (M-x)/\sigma$, but the statistical significance of Z is the same. The column in Table

2 headed by Z, 2/1 lists the Z values calculated by comparing the data in Column 2 with those in Column 1. It is seen that the Z values scatter widely for the different elements.

The next matter to be discussed concerns the importance attached to the measurement of 20 elements. Each element has its own distribution curves for the two groups, because the elements in clays vary independently of one another. Therefore the Z values among the elements should have the same kind of statistics as do the members of a single group for a single element.

To see what this means, let us suppose that groups 1a and 1b are really part of a single distribution or, in the language of statistics, they are parts of the same *population*. In the case of 20 elements, about 13 elements (two-thirds of 20) would have Z values between 0 and 1, about five would have Z values between 1 and 2 and about one would have a Z value greater than 2. The Z, 2/1 values show that in only three elements is Z smaller than 1 and 13 elements cover the range of $Z = 2$ to $Z = 5.3$. Obviously one must consider these as separate groups. Each of the other groups in Table 2 are likewise distinguishable from the others.

PROVENIENCE OF HELLENISTIC BRAZIERS

Before discussing what has been learned about the provenience of these wares, attention is called to Table 1. The left-hand column lists the laboratory serial numbers for the 37 brazier fragments and next to these are their registration numbers. The next column indicates where each specimen was found, except for Nos. 2 and 24, where the place is not known.

Under the heading 'chemical group', each of the 24 specimens in the four groups of Table 2 is identified, as well as nine other pieces which are minor compositional variants of the groups 1a–1d. The provenience of these 33 braziers will be discussed presently.

Three other braziers described as 'Israel local' can be assigned provenience to a specific site in Israel. No. 10 cannot be assigned a provenience, because its composition has not yet been seen in any reference materials which have been analysed.

With regard to provenience, we turn first to the 24 braziers which fall into the four groups of Table 2 and the nine 'variants' for which data are not shown. Although the groups are distinctly different in composition, they all have a general pattern which we associate with the Aegean area. Unfortunately, our samplings of reference materials from this region are scanty at present and none give a satisfactory statistical match with the braziers. In the interest of brevity we will not show the data for the Aegean reference materials which have been analysed. The fact that the 33 braziers do show distinguishable differences suggests that they were not all made at the same place.

In the absence of enough information to assign specific provenience to these braziers, it is worth commenting on where they were *not* made. First and foremost, we have a vast amount of reference material covering sites in Israel; none of these braziers could possibly have been made at any of them. We have also analysed material from western and southern coastal Anatolia, and again the braziers could not have been made there.

Table 1. Concordance of the brazier fragments.

Lab. No.	Reg. No.	Find spot	Chemical group	No. in Rahmani's catalogue
1	P.1517	'Akko	Ib	1
2	P.1090	Unknown	Ia	2
3	71.908	'Akko	Ia	3
4	69.5885	'Akko	Ia	4
5	69.5783	'Akko	Ib	5
6	69.5640	'Akko	Ia	6
7	62.717	Caesarea	Ia	7
8	I.10599	Ascalon	Ia	8
9	32.2362A	Samaria	Id	9
10	32.2362B	Samaria	Unknown	10
11	32.2362C	Samaria	Ia	11
12	32.2362D	Samaria	Ic variant	12
13	I.4192	Ascalon	Ib	13
14	32.2492	Gaza	Ib	14
15	81.803	'Akko	Ic variant	15
16	71.907	'Akko	Ia variant	16
17	72.532	Jaffa	Id	17
18	69.5639	'Akko	Ia	18
19	47.2074	'Akko	Ic variant	19
20	47.2075	'Akko	Ic	20
21	69.5784	'Akko	Ia	21
22	69.5665	'Akko	Ia	22
23	69.5638	'Akko	Israel local	23
24	P.1594	Unknown	Israel local	24
25	69.2006	Ashdod	Israel local	25
26	47.1886	'Akko	Ic	26
27	70.881	'Akko	Ic	27
28	Dor 40920/1	Dor	Ia variant	
29	Dor 40885	Dor	Id	
30	Dor 10157	Dor	Ib variant	
31	Dor 40821/2	Dor	Id	
32	Dor 40230	Dor	Ib	
34	Dor 40402	Dor	Id variant	
35	Dor 40312/3	Dor	Id variant	
36	Dor 40980	Dor	Ib variant	Separate item
37	Dor 24106	Dor	Ib	
38	Dor 10270	Dor	Ic	

The same can be said about Cyprus, from which large amounts of reference materials have been analysed. This negative information strengthens the conclusion that the braziers had an Aegean origin.

One of the specimens, No. 25, was definitely made in southern coastal Israel (see description, above, p. 229). Large amounts of pottery have been analysed from Ashdod,

Table 2. Composition of members of four chemical groups.*

Element**	Group 1a (10 members) M ± σ	Group 1b (6 members) M ± σ	Z,2/1	Group 1c (4 members) M ± σ	Group 1d (4 members) M ± σ
Ca %	1.3 ± 0.3	1.35 ± 0.17	0.4	1.6 ± 0.3	1.23 ± 0.23
Ce	105.5 ± 9.6	120.5 ± 6.5	3.7	96.4 ± 11.8	98.9 ± 5.0
Co	16.49 ± 2.38	20.10 ± 1.38	3.8	11.15 ± 0.94	14.46 ± 1.54
Cr	159 ± 38	185 ± 48	1.1	124 ± 12	83 ± 14
Cs	13.71 ± 2.8	15.77 ± 1.24	2.0	14.0 ± 5.0	10.5 ± 1.0
Eu	1.38 ± 0.08	1.59 ± 0.13	3.6	1.26 ± 0.07	1.13 ± 0.04
Fe %	4.42 ± 0.17	4.73 ± 0.15	3.8	3.61 ± 0.21	3.99 ± 0.21
Hf	7.19 ± 0.53	7.99 ± 0.45	3.2	5.51 ± 0.29	7.12 ± 0.63
La	49.7 ± 1.8	56.11 ± 7.38	2.1	50.70 ± 5.82	39.04 ± 2.31
Lu	0.36 ± 0.02	0.397 ± 0.020	3.6	0.348 ± 0.015	0.334 ± 0.025
Na %	1.57 ± 0.08	1.52 ± 0.13	0.9	1.75 ± 0.16	1.59 ± 0.17
Ni	96 ± 23	115 ± 16	1.9	96 ± 12	68 ± 11
Rb	158 ± 17	195 ± 11	5.3	128 ± 14	163 ± 24
Sc	13.94 ± 0.82	14.27 ± 0.41	1.1	11.38 ± 0.55	12.04 ± 0.61
Sm	5.69 ± 0.27	6.56 ± 0.56	3.6	5.54 ± 0.33	4.61 ± 0.28
Ta	1.59 ± 0.07	1.64 ± 0.08	1.3	1.72 ± 0.20	1.60 ± 0.09
Th	31.10 ± 2.13	35.39 ± 1.27	5.0	27.02 ± 2.86	29.86 ± 3.56
Ti %	0.36 ± 0.03	0.36 ± 0.04	0.0	0.26 ± 0.08	0.36 ± 0.03
U	6.91 ± 0.91	8.35 ± 0.42	4.3	3.86 ± 0.58	6.55 ± 0.83
Yb	2.52 ± 0.08	2.75 ± 0.12	4.2	2.29 ± 0.16	2.37 ± 0.19

* Group 1a: Nos. 2–4, 6–8, 11, 18, 21, 22; Group 1b: Nos. 1, 5, 13, 14, 32, 37; Group 1c: Nos. 20, 26, 27, 38; Group 1d: Nos. 9, 17, 29, 31.

** All abundances in the data columns are in units of parts-per-million except those indicated by %.

Ascalon and other places on the coast and inland. Many compositional variations were found, but all shared distinctive characteristics which have not been found elsewhere.

Table 3 shows the composition of brazier No. 25 together with two groups of local wares from Ashdod. These groups from Ashdod are entered in order to illustrate variations which are encountered in this region — in this case even at one site. The column headed by Z,1/2 lists the Z values comparing No. 25 with Ashdod group 1. At the bottom of the Z,1/2 column is a summary of the number of elements which fall within different intervals of Z. It is seen that the distribution of Z does not comply with the requirements of a statistical match. There are too few elements for which Z is less than 1, and too many for which Z lies between 2 and 3. Nevertheless it can be seen that the composition of No. 25 is similar to that of Ashdod group 1. The column headed by Z,1/3 gives the Z values in comparing No. 25 with Ashdod group 2. Here it is seen that the fit is remarkably good. Since this piece was found at Ashdod (see Table 1), it is very likely that it was made there rather than elsewhere in the vicinity.

Nos. 23 and 24 are dissimilar to one another but were both made from calcareous clays, a characteristic of pottery made in the northern coastal region of Israel and at

Table 3. Composition of No. 25 and two groups of local wares from Ashdod.

Element	No. 25	Ashdod, group 1 (27 members) M ± σ	Z.1/2	Ashdod, group 2 (19 members) M ± σ	Z.1/3
Ca %	4.4	5.0 ± 0.7	0.9	5.0 ± 0.9	0.7
Ce	62.2	65.9 ± 2.2	1.7	65.8 ± 3.0	1.2
Co	20.9	18.7 ± 0.9	2.5	19.3 ± 1.1	1.5
Cr	123	116 ± 6	1.2	118 ± 7	0.7
Cs	1.8	1.7 ± 0.3	0.5	1.7 ± 0.3	0.5
Eu	1.45	1.50 ± 0.10	0.5	1.46 ± 0.07	0.1
Fe %	4.45	4.05 ± 0.15	2.7	4.28 ± 0.18	0.9
Hf	10.33	11.48 ± 1.02	1.1	10.18 ± 1.00	0.2
La	28.9	30.4 ± 1.1	1.4	30.7 ± 1.8	1.0
Lu	0.41	0.43 ± 0.63	0.7	0.42 ± 0.2	6.5
Na %	0.54	0.67 ± 0.06	2.1	0.68 ± 0.06	2.1
Ni	72	47 ± 16	1.6	50 ± 15	1.5
Rb	59	59 ± 13	0.0	54 ± 10	0.5
Sc	14.58	13.38 ± 0.55	2.2	14.00 ± 0.56	1.0
Sm	5.62	5.85 ± 0.21	1.1	5.87 ± 0.24	1.0
Ta	1.30	1.26 ± 0.06	0.7	1.33 ± 0.05	0.6
Th	7.46	7.78 ± 0.31	1.0	7.63 ± 0.40	0.4
Ti %	0.71	0.67 ± 0.03	1.3	0.65 ± 0.03	2.0
U	2.28	2.12 ± 0.14	1.1	2.07 ± 0.18	1.2
Yb	2.89	3.10 ± 0.23	0.9	2.93 ± 0.27	0.2
			0–1: 8 1–2: 8 2–3: 4		0–1: 13 1–2: 5 2–3: 2

inland sites in the north. Column 1 in Table 4 gives the group parameters for a group of 22 vessels from Tel 'Akko and in Column 2 are the data for brazier No. 24. We have no reference group which gives a good statistical match for this piece; however, we have carried out many analyses on pottery which displays the same pattern, and some has compositions which are quite similar to No. 24. This pattern is found in many chemical groups from sites ranging from Dor in the south and northwards to Megadim, 'Akko, and Sarepta in Lebanon. There can be little doubt that No. 24 was made somewhere along this strip.

No. 23 in Column 3 is highly calcareous, as evidenced by a Ca (calcium) value of 28.2%. Since almost all of the calcium would be present as calcium carbonate, the calcium content is equivalent to about 70% limestone! This explains the buff fabric colour noted by Rahmani (above, p. 229).

It should be pointed out that limestone almost completely lacks all the elements that we measure other than calcium. These elements are found in the clay component and therefore the dilution by limestone depresses their abundances severely. This effect can be seen from the low values for the large majority of the elements in No. 23. However, two elements (Cr and U) are as high as or higher than is usually found in other pottery.

Table 4. Composition of Nos. 23 and 24 and a group of local wares from 'Akko.

Element	'Akko group (22 members) M ± σ	No. 24	No. 23
Ca %	15.5 ± 2.2	12.8	28.2
Ce	64.9 ± 6.4	68.9	22.0
Co	9.26 ± 1.06	11.10	4.64
Cr	111 ± 13	98	189
Cs	2.86 ± 0.57	4.49	0.4
Eu	1.31 ± 0.14	1.22	0.69
Fe %	3.03 ± 0.23	3.69	1.66
Hf	3.29 ± 0.41	4.75	1.09
La	33.6 ± 3.2	32.9	15.9
Lu	0.36 ± 0.04	0.30	0.29
Na %	0.22 ± 0.07	0.45	0.22
Ni	82 ± 21	68	122
Rb	74 ± 11	108	15
Sc	11.65 ± 0.96	11.92	7.25
Sm	5.64 ± 0.60	5.53	2.88
Ta	0.82 ± 0.11	1.13	0.24
Th	9.39 ± 0.85	9.19	2.71
Ti %	0.33 ± 0.13	0.42	0.30
U	3.20 ± 0.89	2.96	8.72
Yb	2.45 ± 0.29	2.13	1.85

We could not find a satisfactory statistical match for No. 23 with any reference material. However, reference groups from several sites inland from the northern coast display the same pattern. For example, 'Samaria' bowls from Hazor had similarly high values for Ca, high values for U and Cr and very low values for all other elements. Since this pattern has not been seen elsewhere, it seems likely that No. 23 came from this region. Brazier No. 23 was found at 'Akko, whereas the other 11 braziers found at 'Akko were 'Aegean imports'.

The data for No. 10 are not shown in this report. Its composition is not like that of any of the others, and we have no reference material which is anything like it.

Finally, we would like to point to an interesting phenomenon. On all the specimens made locally, Nos. 23, 24 and 25, were animal heads in relief, rather than the bearded male heads which generally appear on the imports. Of the latter, only No. 29 from Dor has an animal motif.