NEUTRON ACTIVATION ANALYSIS RESULTS OF BRONZE AGE POTTERY FROM BOEOTIA INCLUDING TEN LINEAR B INSCRIBED STIRRUP JARS OF THEBES

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ABSTRACT: Neutron activation analysis results are presented of about 200 pottery sherds from Boeotia dating to the Bronze Age and especially to the Mycenaean period. As in other regions of Greece, the new material again revealed mainly a distinct number of statistically distinguishable compositions, which as yet do not occur in our databank. This may be interpreted as a consequence of a regional production in only a few pottery workshops exploiting a limited number of clay beds or using a limited number of clay 'recipes'. The analysis of samples from the Linear B inscribed stirrup jars of Thebes gives further proof to an origin of these vessels in Chania, Western Crete.

Keywords: Aegean Bronze Age, Mycenaean pottery, Thebes, Orchomenos, Boeotia, Greece, Neutron activation analysis, chemical fingerprinting, provenance, Linear B inscribed stirrup jars

INTRODUCTION

In continuation of the project 'Pottery production and distribution of Bronze Age settlements of Mycenaean Greece and the Aegean' about 200 new samples from Boeotia were analysed by neutron activation analysis (NAA). The results have been added to the large Bonn pottery databank comprising meanwhile more than 2200 samples. Here, we will report only about these new measurements from Boeotia and their multivariate statistical grouping. The methodical and archaeological results will be discussed at a regional scale and in the light of the whole Greek databank of Bonn.

The well known method of 'chemical fingerprinting' applied in Bonn to classify pottery sherds according to their production 'recipes' as well as the general aims and the scope of our Mycenaean project have been already described at length in several earlier papers to which we refer to avoid perpetual repetitions (see Perlman and Asaro 1969, Mommsen et al. 1995, 1996, 1997, Maran et al.1997).

The Mycenaean pottery of Boeotia is not very well investigated by chemical analysis using NAA. Only a few sherds from this region have been analysed by the Berkeley group the results of which have been presented only recently without clear provenance assignments (Tomlinson 1996). A comparison of these date with our results is in preparation. Other analytical work (summarized in Jones 1986, p. 134 ff, p. 477 ff.) with optical emission or atomic absorption spectroscopy measured either only a very small number of overlaping elements or have not the high experimental precision needed for a succesful comparison with our data.

SAMPLE CHOICE

The many samples of pottery sherds from Bronze Age Greece analysed in the course of our project cover already many regions from Macedonia and Thessaly in the north and Locris in Central Greece to the Peloponnese, Melos and Crete. Now, with the results of about 200 samples from Thebes and Orchomenos in Boeotia we hope to fill an important further gap in central Greece and to detect chemical reference patterns for this region, if present. But, as in other regions of Mycenaean Greece, the availability of pottery products of clearly local Boeotian production like kiln wasters is scarce or even absent. We therefore have to rely again on arguments of frequency distributions to recognize reference patterns which was one of the reasons for the large number of samples chosen for analysis from these two places. A further argument strengthening a possible local provenance is a large chronological depth of the occurence of a chemical pattern. The time period covered by the sample choice was therefore extended, if possible, beyond the Mycenaean (Late Helladic(LH), 1600 - 1050 BC) to the Middle Helladic period, although the main part of the samples from Boeotia originate from the palatial and post-palatial (LHIIIA - IIIC) period.

Most of the pieces sampled derive from excavations conducted under the direction of the Ninth Ephorate of Antiquities at Thebes and are stored in the museum and magazines there. Mainly sherds and some whole vessels found in Thebes and Orchomenos and in cemeteries in the vicinity of Thebes have been chosen which, by archaeological means, can be classified as local, but some types are very similar to the well known wares of the Argolid. Of special archaeological interest are 10 samples of the over 30 large stirrup jars with Linear B inscriptions which have been excavated in the year 1921 by A. Keramopoulos in a palatial building at Thebes named Kadmeion.

NAA RESULTS OF THE NEW MATERIAL FROM BOEOTIA

The multivariate statistical grouping of the about 200 new samples (152 from Thebes and 47 from Orchomenos) using our modified Mahalanobis filter method (Beier and Mommsen 1994) revealed a result already known from the investigation of Mycenaean pottery of other Greek regions.

As usual with measurements of high precision about 20 % of all samples are found to be chemical loners and not members of one of the groups detected. All other samples have chemical patterns which may be allocated unequivocally to the different groups. As in the case of other regions previously included in our project most of the groups from Boeotia are new, since hitherto unknown chemical patterns are found. Excluding the Linear B inscribed jars, the material of Thebes and Orchomenos can be chemically classified into 9 groups. All these groups are well distinguishable by our filter method including a best relative fit to consider possible dilutions due to pottery making practices. The result of a discriminant analysis of these grouped sherds is shown in Figure 1 and ascertains the filter grouping. A relocation calculation does not change the group assignments. The average concentration values M and their spreads σ (root mean square deviations) of the 9 groups are listed in Table 1.

Three of the groups (*a, f* and *h*) can be presumably linked with specific places within Boeotia, while the groups *b, c* and *d* can be only assigned to this region in general. The groups named *a* and *f* appear only at Thebes (except one sherd with composition *a* from Eastern Locris added in Table 1) and the group *h* only at Orchomenos and not at any other site in Greece represented in our data bank. According to the dating of the group members to the period LH IIIA-C group *a* seems to represent the main Theban pattern during the palatial and post-palatial period. One sherd of a skyphos with a rosette decoration representing a leading form of the Northeastern Peloponnese belongs to this group. Presumably the Theban workshop or workshops imitated the decorative forms coming into use in other regions.

The only small group *f* is believed to be also locally produced at Thebes, since an uninscribed tablet from the Theban archives and a clay lump ready to be used for tablet preparation belong to it. In addition, two sherds of the 'Handmade Burnished Ware' which could, however stem from the same vessel, are also members of *f*. It can, thus, be assumed, that they were also locally produced. It has to be pointed out, though, that two other pieces of this ware from Thebes do not fall within this group and may represent a second group, since they form a pair. This particular kind of pottery makes it first appearance at the end of the palatial period (LH III B), but occurs most frequently in the post-palatial period. Since this rather coarse kind of pottery in shape, decoration and mode of manufacture differs from the Mycenaean pottery production, it is often associated with influences of foreign people from Italy and/or from the Balkan (Rutter 1975, 1990). At least in the case of *f* our analysis points to a production on a local basis and not to an import from abroad.

Since the still small group *h* of 8 members is found only in material from Orchomenos and has a long span of occurence there, it seems to represent the local fingerprint of that second center of Bronze Age Boeotia. As in the Argolid, where different pottery workshops were found being associated to the centers Mycenae and Tiryns, here also a connection of the pottery production with particular centers seems to emerge.

Groups *b* and the smaller groups *c* and *d* are mutually very similar and belong presumably also to a Boeotian production, although more analytical work from neighbouring regions like Euboea and Phocis has to be awaited to exclude an origin from there. Group *c* of 16 samples from Thebes and Orchomenos is found also in additional sherds from other regions, mainly Eastern Locris. These sherds are included in the patterns given in Table 1. Groups *d* and *c* differ mainly from *b* by gradually increasing Th and decreasing Co, Cr and Ni values. The pattern *b* is found in 4 of the 6 samples from pictorial craters, one such sample, a crater depicting sphinges, belongs to group *c* and one pictorial sherd remains as a chemical loner. As an unexpected result, a brick and a roof tile also belong to group *b* which enhances the probabilty of local manufacture for this group.

Group *i* occuring only in the material of Orchomenos is similar to a group of 22 sherds found at Loutraki - Katounas in Aitolo-Akarnania (group aitolo in Mommsen et al. 1997). It was considered to be the main group there. This similarity is still unexplained and the production place of these sherds is questionable. The long production time period MH II - SH IIIC of the members of this group comprising fine Grey Minyan and unpainted Mainland Polychrome pieces may point to a local Boeotian production and export to Western Central Greece. But the generally noticed decentralized production in Late Helladic Greece encountered in our studies and the low scale of pottery trade and interchange between Mycenaean regions contradicts such trade relations. The similarity might also be accidental or resolvable by measurements of further samples or of more, additional elements.

Besides the new groups a small number of sherds of formerly already known chemical compositions are found additionally. They can be assigned with high probability to workshops already located geographically like the one in the Argolid with pattern named

Mycenae/Berbati (Mommsen et al. 1988, 1995) (5 samples) or another one in Aigina (Mommsen et al. 1995) (also 5 samples). These few sherds could very well be import pieces from the workshops detected there.

A further small group j and one sherd n are members of groups detected before. They can not be assigned to a definite location of origin. Both these groups were first and only encountered in sherds from Eastern Locris. The material awaiting analysis from neighbouring regions may give a clue to their production place.

THEBAN LINEAR B INSCRIBED STIRRUP JARS

A special result is obtained for the Linear B inscribed large stirrup jars sampled in the Theban museum. Several of these jars have been chemically analysed before by optical emission and atomic absorption spectroscopy measuring 9 elements (Catling and Millet 1965, Catling et al. 1980). The early studies in 1965 suggested at first an origin from East Crete. After such inscribed jars had also been found in Chania, Western Crete, and after epigraphical studies of the inscriptions also linked these jars with the same region of Crete, a reconsideration of the data and the analysis of additional samples suggested Western Crete as the most probable place of their provenance (Catling and Jones 1977, Catling et al. 1980).

The higher precision of NAA and the large number of measurable elements by this method lead us to reanalyse a small number of these large inscribed jars. Nine of the samples taken from the jars with inventory Nos 839, 841, 844, 845, 846, 848, 852, 853, 854 (compare Raison 1968) form a group named e, only the 10th sample from jar No 842 is a chemical loner. This jar was assigned by Raison (1968, p. 111 ff.) on stylistical and typological grounds to another group together with several other jars not analysed by NAA. Due to unusally low Co, Cr and Ni values the group e of 9 jars is very different in composition from all other samples in our databank and thus easily separable. While the Bonn reference databank could not assign a production place, a statistically matching group of 19 samples from Chania (CHANIA) was detected during a check of the occurence of the new patterns in the Berkeley databank of Mycenaean pottery entrusted to us from Manchester by the courtesy of A. Hoffmann and V. Robinson. Since the Bonn pottery standard was calibrated against the Berkeley pottery standard our data can be compared directly with the Berkeley values. Table 2 lists the average concentration values of the 9 stirrup jars forming group e and of the 19 Chania sherds measured at the Berkeley laboratory. The Bonn data of the main group of Thebes a is also shown again for comparison.

In the group CHANIA some concentration values scatter at a larger scale then commonly encountered, indicating, that the group may be broken down to several subgroups, if more samples will be available. But even with these large spread values no overlap with any other group in the data available to us occurs.

The Chania samples analysed in Berkeley are described as part of a collection from sherds stemming from the excavation Kastelli of Tzedakis and Kanta in 1966 in Chania. According to the judgement of B. Hallager who compiled the sherd list sent to Berkeley, all sherds sampled were collected from trench B, level 5 and 11, and are believed to have been locally produced in different workshops in Chania. The group of 19 sherds contains a variety of vessel types and forms including big decorated stirrup jars and also coarse undecorated kitchen ware. But it should be mentioned that a number of further sherds from the same excavation which belong to the local workshop of Chania defined by Tzedakis (1969) analyse differently and are not members of the matching CHANIA group. The workshop producing the 19 sherds and the series of stirrup jars for export to Thebes must have used different clay sources or a different clay refinement technique compared to the Chania workshop mentioned by Tzedakis, or, if only one workshop in the region of Chania was engaged, the wares of these different groups must habe been produced in different production series. However, the similarity of the one Chania pattern in the Berkeley bank with our pattern *e* makes an origin of the inscribed Theban jars in Chania or its neigbourhood very likely.

CONCLUSION

The NAA results of the Boeotian pottery samples underline the previous findings of our project concerning the pottery of the Greek Bronze age and especially of the Mycenaean period. In Boeotia as in the other regions studied so far, local products prevail. Pottery was produced with a few different production 'recipes' in one or only a few regionally centralized workshops, as the small number of Boeotian groups with different patterns shows. This production comprised many different ware types including coarse products like roof tiles up to pottery of the highest quality like pictorial jars. Although in some regions like Achaia with no known existing palace a regional centralized production can be observed as well (Mommsen et al. 1997), this production in regions like the Argolid or Boeotia may well have taken place under palatial supervision. The two main Boeotian patterns *a* and *b* seem to appear at the beginning of the palatial time. The small scale of material interchange and trade between the different palatial regions can be verified for Boeotia, too, and may be explained by the existence of local workshops producing for the palace and/or the Boeotian markets. Nevertheless, there was a close contact and exchange of new styles and ideas between the different regions, leading, for instance, to the imitation and integration of prototypes from the Argolid (i. e. the rosette skyphos) into the local ceramic repertoire.

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Table 1: Groups found in the material from Thebes, concentrations of 30 elements: averages M in $\mu g/g$(ppm), if not indicated otherwise, and spreads σ in % of M

	a (47 samples)		b (29 samples)		c (21 samples)		d (5 samples)		f (5 samples)		g (6 samples)		h (10 samples)		i (8 samples)		j+Locris-m (18 samples)	
	M	σ (%)	M	σ (%)	M	σ (%)	M	σ (%)	M	σ (%)	M	σ (%)	M	σ (%)	M	σ (%)	M	σ (%)
As	4.41	46.	7.90	40.	19.3	39.	14.2	17.	4.16	45.	9.26	20.	6.74	43.	10.8	43.	5.47	37.
Ba	367.	14.	372.	25.	693.	10.	543.	8.3	222.	44.	490.	21.	496.	61.	443.	9.7	355.	16.
Ca%	7.22	27.	6.65	28.	3.87	30.	4.29	8.0	8.41	26.	10.1	47.	3.93	35.	2.18	71.	6.15	29.
Ce	53.1	2.4	58.0	4.3	77.8	2.2	76.7	8.4	51.1	2.7	57.8	1.5	58.3	3.3	67.6	5.3	48.6	4.3
Co	41.2	5.2	34.7	7.7	22.5	4.6	27.8	13.	41.3	15.	29.4	6.1	18.6	13.	33.0	3.8	49.4	5.7
Cr	509.	7.3	437.	11.	168.	4.6	256.	16.	960.	18.	339.	12.	236.	11.	448.	6.8	656.	18.
Cs	4.24	6.6	5.91	13.	9.52	6.8	7.53	6.0	3.44	13.	4.64	20.	5.18	7.6	5.77	4.9	5.77	8.0
Eu	1.06	5.1	1.03	5.0	1.36	2.8	1.33	4.3	0.93	7.3	1.06	2.8	1.08	2.6	1.30	3.7	0.90	5.5
Fe%	5.47	2.9	5.25	3.1	5.20	4.2	5.02	2.3	4.48	0.9	4.46	2.9	4.10	7.6	5.39	4.3	6.02	4.0
Ga	–		59.6	78.	39.2	72.	26.2	27.	13.9	32.	56.1	3.8	20.3	16.	25.5	11.	19.8	13.
Hf	3.51	6.5	3.39	8.5	4.48	6.8	4.46	2.3	4.05	12.	3.74	5.1	4.86	10.	4.77	10.	3.00	11.
K %	2.00	5.3	2.61	10.	3.25	7.1	2.98	5.1	1.18	19.	2.47	8.3	2.25	12.	2.46	4.6	2.25	11.
La	23.5	5.0	26.9	4.6	36.7	2.2	34.8	4.1	23.5	3.8	25.4	8.3	28.0	3.8	31.9	2.9	22.4	4.9
Lu	0.42	24.	0.41	22.	0.54	19.	0.44	13.	0.35	16.	0.38	6.9	0.40	12.	0.59	23.	0.36	6.5
Na%	0.54	14.	0.63	14.	1.10	21.	1.21	5.4	0.30	64.	0.72	5.3	0.92	18.	0.98	10.	0.55	21.
Nd	22.0	13.	21.8	17.	32.7	8.9	29.0	10.	20.0	16.	23.8	11.	23.3	11.	29.9	9.4	19.4	9.1
Ni	538.	8.1	467.	21.	159.	33.	286.	32.	666.	19.	351.	18.	152.	11.	389.	8.1	767.	7.2
Rb	98.6	4.3	130.	7.7	166.	5.0	143.	5.3	67.8	11.	104.	11.	124.	3.5	133.	2.8	118.	7.4
Sb	0.46	21.	0.60	17.	2.33	8.8	1.79	10.	0.53	15.	0.93	25.	0.47	16.	0.59	11.	0.56	18.
Sc	20.4	2.9	20.3	4.0	21.6	3.9	19.9	1.3	15.0	3.0	17.3	5.0	15.7	9.8	20.6	3.6	21.1	3.8
Sm	4.12	7.2	4.20	6.1	6.12	3.1	5.76	2.6	3.54	13.	4.31	4.9	4.77	3.6	5.77	2.9	3.58	6.5
Ta	0.70	4.4	0.77	6.8	1.03	6.8	0.94	3.0	0.71	6.2	0.74	8.2	0.82	4.6	0.95	4.3	0.68	5.2
Tb	0.66	8.3	0.63	8.4	0.84	14.	0.80	9.2	0.58	12.	0.66	8.4	0.67	6.0	0.82	7.2	0.51	8.4
Th	8.42	2.3	9.57	2.6	14.0	3.0	12.2	2.9	8.01	2.0	9.31	2.1	10.2	2.5	11.1	4.1	8.56	2.8
Ti%	0.46	21.	0.55	46.	0.50	20.	0.53	23.	0.39	31.	0.77	28.	0.46	18.	0.57	14.	0.40	21.
U	1.68	9.7	2.12	12.	2.35	4.8	2.09	3.9	1.27	11.	2.02	13.	2.32	13.	2.65	8.1	1.73	5.5
W	1.59	17.	1.89	15.	3.51	11.	3.02	8.8	1.44	7.8	2.02	6.9	1.78	8.9	2.09	8.1	1.52	15.
Yb	2.31	6.5	2.29	4.9	2.95	4.3	2.82	5.6	2.05	6.2	2.34	11.	2.44	5.7	2.93	4.7	2.12	5.3
Zn	94.6	6.7	96.7	7.7	111.	6.4	100.	5.8	75.1	7.4	78.5	6.8	90.8	9.4	112.	5.2	103.	8.1
Zr	174.	18.	165.	19.	230.	20.	204.	29.	210.	21.	191.	16.	224.	17.	253.	12.	148.	30.

all elements used for best relative fit and group comparisions except As, Ba, Ca and Na

Table 2: Concentration patterns of the Theban group e of Linear B inscribed stirrup jars, of a group of sherds excavated at Chania and measured in Berkeley and of the main Theban group a for comparison, concentrations of 30 elements: averages M in $\mu g/g$(ppm), if not indicated otherwise, and spreads σ in % of M

	e(Thebes) 9 samples		CHANIA 19 samples		a(Thebes) 47 samples	
	M	$\pm\sigma$(%)	M	$\pm\sigma$(%)	M	$\pm\sigma$(%)
As	8.61	46.	–		4.41	46.
Ba	254.	17.	–		367.	14.
Ca%	4.18	34.	5.41	32.	7.22	27.
Ce	84.4	9.3	86.9	6.7	53.1	2.4
Co	13.9	5.3	14.5	29.	41.2	5.2
Cr	99.4	5.6	120.	17.	509.	7.3
Cs	6.50	12.	6.77	15.	4.24	6.6
Eu	1.49	5.8	1.47	8.2	1.06	5.1
Fe%	4.36	6.3	3.73	24.	5.47	2.9
Ga	24.7	7.9	–		–	
Hf	7.81	8.2	6.45	16.	3.51	6.5
K %	2.17	19.	2.26	15.	2.00	5.3
La	42.9	7.8	42.7	5.7	23.5	5.0
Lu	0.59	25.	0.46	4.6	0.42	24.
Na%	0.70	16.	0.62	17.	0.54	14.
Nd	35.3	15.	37.2	10.	22.0	13.
Ni	82.7	20.	79.0	30.	538.	8.1
Rb	102.	4.9	107.	10.	98.6	4.3
Sb	1.02	15.	–		0.46	21.
Sc	14.9	3.3	15.0	4.1	20.4	2.9
Sm	6.42	8.0	6.78	6.2	4.12	7.2
Ta	1.70	5.9	1.60	8.4	0.70	4.4
Tb	0.91	8.4	0.96	6.6	0.66	8.3
Th	13.2	5.4	12.7	7.0	8.42	2.3
Ti%	0.45	30.	0.50	6.1	0.46	21.
U	2.57	8.2	3.19	9.9	1.68	9.7
W	1.82	6.8	–		1.59	17.
Yb	3.26	6.4	2.94	4.8	2.31	6.5
Zn	73.7	6.3	88.5	15.	94.6	6.7
Zr	382.	13.	–		174.	18.

(all elements used for best relative fit and group searches except As, Ba, Ca and Na)

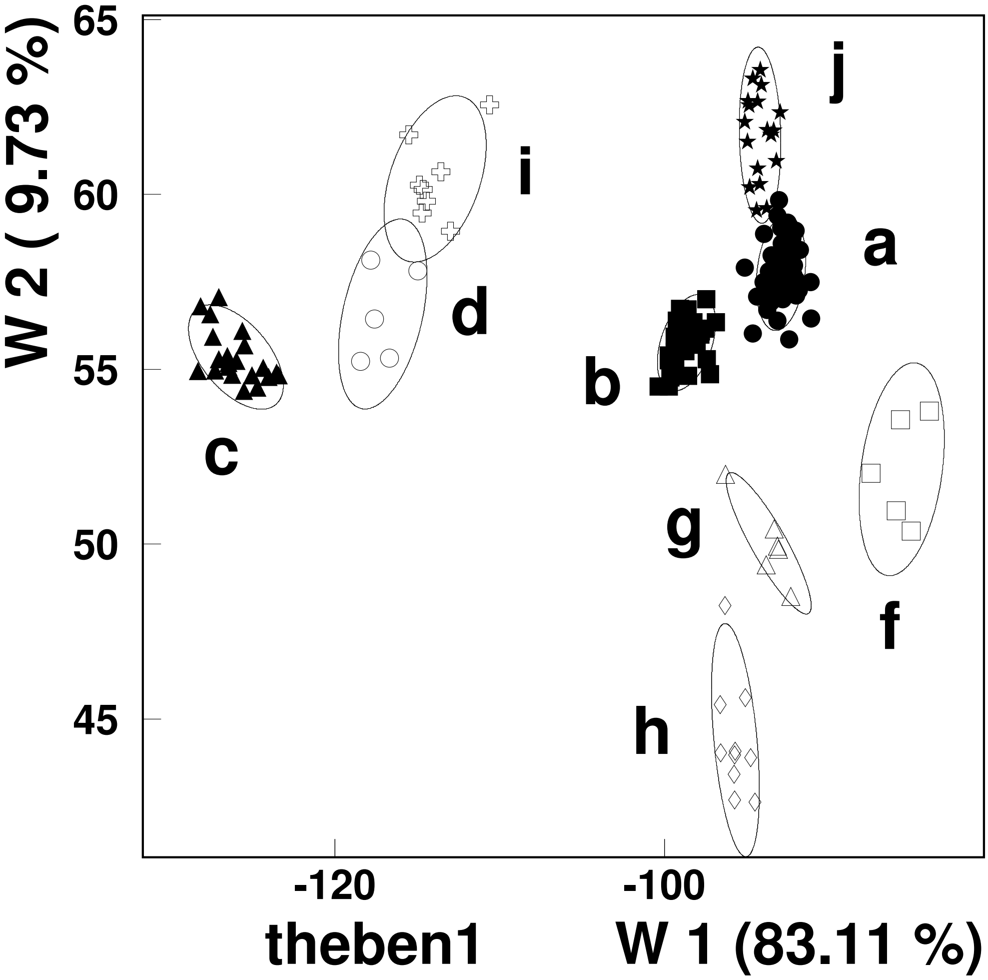

Figure 1: Discriminant analysis of 149 samples of Greek Bronze Age pottery from Boeotia assuming 9 groups. Plotted are the discriminant functions W1 and W2 which cover 83.1 %and 9.7 % of the between group variance. The ellipses drawn are the 2σ boundaries of the groups.