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Evaluation of NAA data of samples from Sardis of the Anatolian Iron Age project and related material
(published by Kealhofer, L., Grave, P., Marsh, B., 2013, Scaling ceramic provenience at Lydian Sardis, Western Turkey, JAS 40, 1918 – 1934)

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Part of the Anatolian Iron Age (AIA) project 2005-2009 concerned measurements of elemental concentrations of samples from Sardis in Lydia, Turkey, from the Iron Age. The aim was to determine the origin of the different Lydian and Lydianizing pottery fabrics and types, i. e. the geographical site or region of the producing workshops. The samples have been taken from the sherds by drilling with a tungsten carbide burr. The well suited Neutron Activation Analysis method has been used performed at the Canadian Becquerel laboratory as told in the paper (p. 1921) or at the Canadian McMasters University research reactor as told at the project site in the internet: https://opencontext.org/projects/cbd24bbb-c6fc-44ed-bd67-6f844f120ad5 with the sample list including photos with a link to the csv file for downloading the NAA data (see Appendix 2). In the paper 2013, Table 1, 325 sample labels are recorded, but the sum of all labels is given as 305.

The csv file gives 294 concentration data sets and their description of the pottery measured from the site Sardis. Sample labels are 889 - 987 (incl. 4 repetition measurements), 3520, 3620 - 3785, sediments/clays 3901 - 3917, 3962 - 3968). Additional 32 data sets from there are supplied by Kerschner and Cahill with labels 1724 to 1766 (not continuously, 11 samples missing). These samples are stored in a databank comprising altogether 325 samples (+ 1 sample with similar label with a minus added).

The NAA measurements report concentration values of 25 elements:

As,Ba,Ca,Ce,Co,Cr,Cs,Eu,Fe,Hf,K,La,Lu,Na,Nd,Rb,Sb,Sc,Sm,Ta,Tb,Th,U,Yb,Zn

No experimental uncertainties are given, so a general 5% for all elements and samples is inserted into the bank. The raw data of the 325 samples are listed in Appendix 1.

The search for samples of similar composition pointing to a similar clay paste used in one or several neighbouring pottery workshops at a certain location and therefore to a common origin is done with the Bonn filter procedure (Mommsen et al. 1988, Beier and Mommsen 1994) considering experimental uncertainties and possible concentration variations (dilutions or enhancement) by the potter's recipes. The 19 elements

Ce, Cr, Cs, Eu, Fe, Hf, K, La, Lu, Nd, Rb, Sb, Sc, Sm, Tb, Th, U, Yb, K, Zn

have been used. Not considered during the group formation are 6 elements. Co and Ta (and W, not measured) are known to scatter, if a tungsten carbide (WC) burr has been used for the drilling during the sample taking. Sometimes Co values above 100 ppm are encountered that are certainly a measurement or recording error. As and Na are known to vary in pieces made in the same workshop due to firing conditions (As) or to pottery making practices (Na), respectively. They are not used, since they are measurable with NAA with an uncertainty of only about 1% and would because of their large weight influence or even dominate the group forming, since the uncertainties are considered. Ba and Ca scatter also due to a possible contamination during storage in the ground or for Ca also due to possible pottery making practices. Since as mentioned, experimental uncertainties are considered in the statistical grouping calculations, elements measurable with NAA with low precision (like K, Nd, Rb, Sb, Tb, U, Zn) can be included, but, not knowing their experimental uncertainties, are allowed to vary in the formed groups up to 15 - 20%.

Evaluating the data according to these conditions and choices of elements and their weights altogether 3 different groups of patterns could be formed. The first group of 8 patterns are very similar in composition and can be assigned to a production in the region of Sardis (SaGP, SaGQ, SaGS, SaGU, SaGV, SaGW, SaGX and SaGY). Six more groups well separated from each other are also present in the sample set from Sardis, but are not assigned to a production site and might be local products or imports (Sa-1, Sa-2,... Sa-6). Finally 2 groups (TeGB and EuGA) are close in composition to known groups in the Bonn databank (TeosB and EuA) and are possible imports from Teos and Euboea, respectively. In other data sets of this research group (Kinet Höyük, regional Troy, see below) more groups could be formed and compared to Bonn groups pointing to Miletos and Troy. Only groups with more than 3 members have been considered.

During these calculations often cases of single samples occurred that matched statistically a group in all elements except in one, this one being often Cr, Cs, and Hf. Since NAA measures these elements with small uncertainties, these cases may be pointing to existing subgroups or just too bad measurements giving outlying values of these elements. Often, to lower the spread value (root mean square deviation) of an element in a group, these samples with a single outlying element have been sorted out increasing the number of non-assigned samples (217 singles). This high number of singles (27 %) would lead one to suspect an experimental low precision. Sometimes 2 samples with the same outlying element and a not very different deviation of the concentrations of these elements are sorted out also of a group and marked as a chemical pair, since in these cases a subgroup with this deviation in composition is more probable. Altogether 27 such single pairs are formed.

The Sardis groups

All the 8 groups described in this part can be assigned with high probability to a production at or close to Sardis. This is supported by matching sediment/clay samples, by samples from Sardis measured also in Bonn and by the close compositional similarity of these groups as shown below.

SaGP (local sediment/clay):

One large group named SaGP has the reference sediment/clay samples from the Paktolos river valley close to Sardis with labels 3903 and 3095 as members and can be therefore assigned to a production in this region close to Sardis. No other reference sediment/clay samples match any of the other groups except a sample with label 3906 in group SaQW, see below. The samples of this group and their best relative fit factor with respect to the group average SaGP are listed in the appendix 2. This group is not very different of the Bonn group SarP, deviating most in Rb and Cr, and, given the possible laboratory differences, might describe the same clay paste. The grouping values SaGP adjusted by a best relative fit factor of 1.04, are compared in Table 1, columns 1 and 2, to the group SarP.

Next we will describe these groups, where a known relation to a Bonn group exists. This concerns the group pairs in Bonn and here: SarS - SaGS, SarQ - SaGQ, SaGU - SarU and, not in this data set, but already published, KelA - KeGA (Lehmann et al., in press).

SaGS (same samples measured):
Helpful is that 4 samples measured in Bonn and all members of Bonn group SarS (labels Sard 34 – 37, Ephesian Ware) have been measured also in the AIA project (labels 987, 985, 984, 986 in the same sequence, group SaGS, in publication 2013, Tab. 3, only 3 samples taken – which?). The average concentration values of these 4 sample sets from both laboratories are shown in Tab. 1, columns 3 and 4 and a good agreement can be stated without any calibration. This agreement with the Bonn values has been already stated in the publication 2013 comparing measured standard materials. These samples from Sardis are the only ones in the groups SarS - SaGS. The appendix gives the sample list.

SaGQ(same sample measured):
In addition, another Bonn group assigned to a pottery workshop in the region of Sardis named SarQ is present here and named SaGQ. Concentration values are shown in Tab. 2, column 1. One sample of group SaGQ measured in this project (896) is also measured in Bonn (label Sard 60) and is, as expected, there member of a group called SarQ, see Table 2, column 2 for comparison. This supports the good comparability of the data of the two research laboratories except for the Cr values in this case that show a large unexplained difference. The appendix gives the sample list.

SaGU (same samples measured):
This large group of 50 samples is with high probability assignable also to Sardis. Two sample members with labels 899 and 964 have been also measured in Bonn (labels Sard 58 and 71) and are members of the Bonn group X023 (old name EpQP) of 4 samples. This makes now an assignment of Bonn group X023 to Sardis possible and we rename the group name X023 to SarU. The grouping values are compared in Tab. 3, columns 1 and 2. The concentrations agree statistically. The appendix gives the sample list.

excurse Kelenderis: KeGA (similar group values, same type of samples):
As mentioned, a forth group measured in Bonn has been also reported by Grave et al. 2008 concerning samples from Kinet Höyük and named KH3A2. It is similar in composition to the group KelA assigned with the help of kiln wasters to a production at Kelenderis (Lehmann et al., in press). Only the average grouping values of KH3A2 (Table 5, p. 1984 are published in 2008, no list of the mentioned 8 samples members is given there. The raw NAA data of the published groups are available now at the internet, see Appendix 2. Evaluating these data resulted in a group named KeGA of 28 members that can be compared to the Bonn group KelA. Both patterns are given in Table 2, columns 3 and 4. The concentration values of KeGA after a best relative fit with respect to group KelA (factor 1.05) agree with the ones of group KelA with the largest deviations of slightly higher Sm and Cr only. The samples of this group and their applied best relative fit factor with respect to the grouping values KeGA are given in the appendix. All these 28 vessel should have been made at workshops in Kelenderis. We did not check the ware types, but vessels of the 'Banded ware' should be part of this list of members. This supports again the good comparability of the data of the two research laboratories.

SaGV (similar group values):
This group of 13 samples can be matched also to a Bonn group named X029 (old name EphR) of 11 BoR (check *** all 11?) samples from Ephesos not yet assigned to a definite workshop(s), but archaeologically assumed to come from Lydia. Because of the compositional

similarity of SaGV to the other groups from Sardis the Bonn group X029 is now assignable also to Sardis and renamed in Bonn to SarV. Both patterns are compared in Tab. 3, columns 3 and 4. A good agreement in composition can be seen. Deviating concentrations considering the spread values (root mean square deviations) with decreasing +/- difference are Sm+Eu+... The appendix gives the sample list.

SaGW (new group):
This group of 5 samples is new to us. We assign it to a production in Sardis because of the close similarity of its composition to the other Sardian groups. The group concentrations are shown in Table 4, column 1. The appendix gives the sample list.

SaGX (new group):
New group of 9 samples, as for SaGW its composition points to Sardis. The group concentrations are shown in Table 4, column 2. The appendix gives the sample list.

SaGY (new group, with sediment/clay sample) :
New group of 24 samples, as for SaGW composition points to Sardis. A member of this group with label 3906 is a sediment/clay collected close to Sardis. The group concentrations are shown in Table 4, column 3. The appendix gives the sample list.

Discussion of the 8 groups assignable to Sardis: SaGP, SaGQ, SaGU, SaGW, SaGX, and SaGY very probably Sardis, SaGS and SaGV: different origin also possible

All these 8 groups just mentioned are very similar in composition and the spreads of the values often overlap. So, e. g. group SaGP, considering the spread values and using a best relative fit factor of 1.01, is statistically similar to group SaGU except for only a lower Cs value (see Table 5). More such occurrences of a one element excursion, especially for the 6 groups SaGP, SaGQ, SaGU, SaGW, SaGX, and SaGY, are summarized in Tab. 5. To add all members of these 6 groups in to one group would result in large spread values for mainly the elements Cs and Hf. If the measurement precision of these elements is low or has sometimes single outlying values, the whole summed group can be assigned to workshops in Sardis as has been stated by the AIA study for many members of these groups. Larger differences, but only for the elements Cr, Tb, Fe and Ca are found between groups SaGP and SaGQ. Group SaGS of only 4 samples measured in Bonn and by the AIA project has a somewhat larger distance to the Sardis cluster of 6 groups, but archaeologically it is certainly from Lydia. Also group SaGV as SaGS has a larger separation from the 6 other groups and might point to a workshop using a paste from a different workshop.

Table 5: Differences of the concentration values of single elements of the groups of the Sardis cluster (and vice versa with new factor 1.0+(1.0 - factor))

group	members	with	similar	except differing
		factor	to group	elements
				(-:lower, + higher)
SaGP	61	1.01	SaGU	Cs -
		0.83	..SaGV	…Cr- Cs+
			SaGW	Hf-

		1.02		
		1.03	SaGX	Cr-
		0.97	SaGY	Hf- Yb-
SaGQ	8	0.98	SaGX	Cs-
		0.94	SaGY	Cr+
SaGU	50	1.02	SaGW	Cs+ Hf+
SaGX	9	0.95	SaGY	Cs+Cr+

Further groups possibly assignable to known workshops: Teos (TeGB), Phyllis close to Lefkandi in Euboea (EuGA), Miletos (MiGD), Troy (TrGB):

These further groups are presented here and their patterns are possibly also known in Bonn. They have been formed using the Sardis data, the Kinet Höyük data and the Troy data (see appendix 2). If the assignments are archaeologically accepted and good, these groups may be used to calculate calibration factors.

To characterize, if possible, other groups and to learn more about their possible origin a comparison with the groups known in the Bonn NAA data bank of groups is done. This revealed that further groups are present in the data of the AIA study and also known already in Bonn. This comparison made assignments of the newly formed groups with high probability possible and is reflected in the choice of their group names. The membership of the samples assigned to these groups of the now proposed provenance should be checked archaeologically. The list of the sample members is given in the appendix 2.

Bonn group TeosB assigned to workshop(s) at Teos or in its neighbourhood in northern Ionia is statistical similar to a group **TeGB** (fit factor 1.10***) with 14 samples as shown in Table 6***, columns 1 and 2. The member of TeGB with label 897 is also measured in Bonn, label Sard 63 that is member of TeosB. Larger deviating concentrations of AIA 897 considering the spread values (root mean square deviations) with decreasing +/- differences are Sm+La+Cr+Eu... These difference of the concentrations of samples from the same sherd measured in both laboratories show that comparisons of single samples have to be made with care, but comparisons of average concentrations patterns turn out to be more successful. Sample 897 has been assigned to local Sardis Macrogroup C by the AIA study. Included in group TeGB is sample AIA 3730, a bird bowl, No 20 in Fig. 4 of the 2013 paper. Eight samples in this group are from the AIA project concerning Kinet Höyük. Samples from Sardis 892, 3680,

Bonn group EuA assigned to the workshops close to Phyllis at Euboea is statistical similar to a group **EuGA** with 12 samples (fit factor 1.04) as shown in Table 6, columns 3 and 4. Deviating concentrations considering the spread values (root mean square deviations) with decreasing +/- differences are Lu-Yb-Cr+... Only 2 sherds (932 and 3754) from Sardis are in this group.

Bonn group MilD assigned to the Milesian workshops at the Kalabaktepe is statistical similar to a group **MiGD** with 6 samples (fit factor 0.98) as shown in Table 7, columns 1 and 2. Deviating concentrations considering the spread values (root mean square deviations) with decreasing +/- differences are Sm+La+... There are no members in this group in the Sardis data set.

Bonn group TroB assigned to workshop(s) at Troy itself or in the neighbourhood is statistical similar to a group **TrGB** with 20 samples (fit factor 01.04) as shown in Table 7, columns 3 and 4. Deviating concentrations considering the spread values (root mean square deviations) with decreasing +/- difference are Yb+Lu+Sm-...All members in this group are from the AIA Troy project.

Single sherds:

Sample AIA 1765, a Corinthian aryballos assigned to Sardis Macrogroup B and not to Corinth, is not given in the data set. But 2 further samples 3722 and 3759 shown in Fig. 6a of the paper and probably in the same Sardis subgroup 2.101 (Table 5b of the paper, 3 members) are members of a group of 5 samples (2 from AIA the Kinet Höyük and 1 from the AIA Troy project), that is close in composition the MYBE group of the north-eastern Peloponnes. (Are data for sherd 1765 available to check, if it fits this group also?)

Sherds shown in Fig. 4 of the paper belonging to local Sardis NAA group 1.1 and 1.2 are here also all in the groups SaGP, -Q, -U, or X and therefore probably local Sardis except AIA 925, that is a single.

Sherds in the dendrogram Fig. 6 (all assignments are exploratory and have to be checked!):
Sherd 3754 is in group EuGA and
Sherd 3679 (and 3747) is in a group of 13 sherds form the other 2 AIA projects mentioned before. This group is close to the Bonn group SamJ and might be from Samos.
The group of sherds in the dendrogram 3711, 944, 943, 941, and 942 are all in group SaGV not with certainty assigned to Sardis.
The next group 890, 951, 3646, and 3739 all are members of the group Sa-6 with 8 more members.
The next group of 6 sherds has 3 members 3733, 3734, and 897 of group TeGB assigned to Teos, but the other 3 are singles.
The remaining sherds in the 2 bottom groups of the dendrogram are all singles and not in any group.

Groups of unknown origin: Sa-1, Sa-2, Sa-3, Sa-4, Sa-5, Sa-6

The concentration data of these groups and the list of their members are shown in the appendix 2. Nothing can be archaeometrically concluded about these groups. The group members should be checked and discussed by an archaeologist. Sa-3 is not very different from the Bonn Aiolian group Aiolg.

Archaeological discussion of the proposed origin of the group members (missing)

Sardis groups:

The many samples taken at Sardis and by NAA assigned to a local production there do not contradict generally archaeological knowledge. (???) Exceptions are..???..

Other groups:

Miletus

Teos

Troy

Euboea

Groups of still unknown origin Sa-1 to Sa-6

Table 1: Group patterns of the AIA project SaGP and SaGS probably assigned to Sardis or its neighbourhood compared to matching Bonn groups SarP and SarS, respectively.
Given are average concentration values M in µg/g (ppm), if not indicated otherwise, of groups formed with the data of samples from Sardis and related groups formed with data measured in Bonn. σ is the standard deviation (root mean square deviation) in %. The individual samples have been corrected with a best relative factor given in Appendix 2 with respect to their grouping values. The groups of the AIA data are multiplied with the best relative fit factor with respect to the corresponding Bonn groups.

	SaGP 61 samples factor 1.04		SarP 10 samples factor 1.00		SaGS 4 samples factor 0.98		SarS 4 samples factor 1.00	
	M	σ(%)	M	σ(%)	M	σ(%)	M	σ(%)
As	29.8	35.	37.5	55.	25.5	84.	27.3	81.
Ba	809.	8.6	855.	14.	781.	14.	803.	5.4
Ca\%	2.64	30.	2.83	11.	2.22	5.0	2.61	10.
Ce	98.9	5.0	98.6	2.4	97.9	5.0	104.	4.5
Co	29.8	13.	28.3	2.5	114.	46.	--	
Cr	173.	5.4	151.	3.6	224.	13.	203.	9.9
Cs	21.7	18.	31.6	25.	11.9	13.	13.2	10.
Eu	1.91	6.4	1.77	1.8	1.85	6.7	1.76	3.9
Fe\%	7.22	5.0	7.49	5.8	4.87	5.0	5.14	3.9
Hf	5.23	10.	4.60	14.	6.75	5.0	6.94	9.8

La	49.3	5.0		45.4	2.3		49.0	5.0		49.3	4.2
Lu	0.54	5.4		0.59	3.4		0.59	8.5		0.58	3.1
Na\%	1.06	18.		1.01	18.		1.33	12.		1.51	11.
Nd	42.6	11.		40.6	6.6		40.9	5.0		45.7	4.7
Rb	157.	5.5		184.	2.9		132.	21.		170.	2.5
Sb	5.59	13.		7.85	26.		3.57	6.1		3.58	5.8
Sc	24.3	5.0		25.7	3.8		18.0	5.0		19.5	2.9
Sm	9.14	5.0		7.81	9.3		9.10	5.0		9.24	4.7
Ta	1.29	34.		0.90	6.7		7.05	33.		--	
Tb	1.32	15.		1.06	5.8		1.41	30.		1.20	4.6
Th	15.3	5.0		15.2	3.9		15.2	5.0		16.7	4.8
U	3.11	20.		2.64	8.9		3.49	14.		2.75	3.9
Yb	3.65	5.1		3.73	3.0		3.87	5.0		4.25	1.6
K\%	3.38	12.		3.49	6.1		3.31	31.		3.15	2.5
Zn	128.	9.7		145.	6.3		76.7	16.		95.1	6.2

Table 2: Group patterns of the AIA project SaGQ and SarQ probably assigned to Sardis or its neighbourhood and of KeGa and KelA assigned to Kelenderis compared to matching Bonn groups SarQ and KelA, respectively. Given are… see caption Table 1

	SaGQ 8 samples factor 0.98			SarQ 48 samples factor 1.00			KeGA 28 samples factor 1.07			KelA 64 samples factor 1.00	
	M	σ(%)		M	σ(%)		M	σ(%)		M	σ(%)
As	19.3	40.		31.7	46.		8.58	23.		10.4	28.
Ba	773.	19.		835.	9.3		435.	15.		418.	12.
Ca\%	1.68	5.0		2.81	21.		7.39	25.		6.67	32.
Ce	97.9	5.0		102.	3.5		79.0	5.0		79.5	1.6
Co	96.	48.		26.1	3.9		18.6	6.7		16.6	3.4

	3										
Cr	278.	15.		148.	5.4		103.	5.0		92.7	5.5
Cs	17.7	9.9		22.7	19.		8.90	6.9		8.94	4.5
Eu	1.79	12.		1.81	2.2		1.31	9.8		1.25	2.9
Fe\%	6.48	5.0		6.58	5.7		4.75	5.0		4.60	1.8
Hf	5.72	9.1		5.86	13.		4.58	5.7		4.81	3.2
La	49.3	5.0		46.5	2.6		41.1	5.0		38.6	1.8
Lu	0.59	10.		0.59	4.4		0.40	5.0		0.44	3.5
Na\%	1.08	8.8		1.19	15.		0.59	10.		0.71	30.
Nd	40.5	7.9		42.2	4.4		34.2	10.		30.6	5.5
Rb	151.	10.		165.	4.0		145.	6.6		160.	3.8
Sb	5.67	11.		5.32	15.		1.71	6.5		1.37	13.
Sc	22.7	5.0		23.6	3.3		17.1	5.0		17.2	1.5
Sm	9.03	5.0		8.11	4.0		6.73	5.0		5.74	4.7
Ta	3.24	29.		0.99	4.8		1.55	26.		1.11	4.0
Tb	1.00	16.		1.11	5.9		0.97	21.		0.79	7.3
Th	14.5	5.0		15.3	2.7		14.0	5.0		14.4	1.6
U	3.72	17.		3.00	11.		3.02	16.		3.12	10.
Yb	3.68	5.0		3.85	4.2		2.78	5.1		2.97	4.2
K\%	3.54	5.0		3.34	3.9		3.31	20.		3.10	5.5
Zn	110.	13.		130.	4.7		117.	12.		111.	8.7

Table 3: Group patterns of the AIA project SaGU and SaGV probably assigned to Sardis or its neighbourhood compared to matching Bonn groups SarU and SarV, respectively. Given are… see caption Table 1

	SaGU			SarU			SaGV			SarV	

	50 samples			4 samples			13 samples			11 samples	
	factor 1.08			factor 1.00			factor 1.14			factor 1.00	
	M	σ(%)		M	σ(%)		M	σ(%)		M	σ(%)
As	39.0	32.		35.3	38.		20.6	93.		21.1	55.
Ba	907.	11.		862.	11.		759.	15.		683.	12.
Ca\%	2.40	37.		1.82	26.		5.40	51.		2.75	14.
Ce	102.	5.0		114.	2.3		88.6	7.9		90.5	1.5
Co	33.2	32.		26.1	1.0		46.0	64.		38.5	14.
Cr	179.	6.0		165.	3.2		321.	8.7		313.	3.5
Cs	36.4	18.		39.6	6.7		8.12	15.		7.39	5.3
Eu	1.99	6.7		1.95	1.6		1.65	6.6		1.54	2.6
Fe\%	7.70	5.0		7.26	2.6		5.78	5.0		5.88	2.5
Hf	4.92	14.		4.62	8.8		5.56	17.		5.58	3.2
La	50.9	5.0		51.0	2.1		46.1	8.4		44.1	1.7
Lu	0.55	6.2		0.56	3.4		0.52	5.0		0.54	2.5
Na\%	0.99	16.		0.78	14.		1.12	27.		1.17	4.1
Nd	46.9	14.		47.6	4.2		40.1	11.		42.1	11.
Rb	170.	6.7		172.	2.0		146.	7.1		149.	2.8
Sb	7.64	14.		8.02	15.		1.52	43.		1.97	45.
Sc	26.1	5.0		25.6	1.4		21.9	5.0		21.8	2.2
Sm	9.37	5.0		8.49	0.3		7.83	5.8		7.32	1.9
Ta	1.26	29.		0.83	6.9		2.16	61.		1.09	3.3
Tb	1.30	15.		1.03	5.7		1.13	26.		0.94	5.2
Th	15.8	5.1		17.0	1.2		16.3	9.6		17.7	1.5
U	3.10	22.		2.98	12.		3.35	30.		3.00	11.
Yb	3.63	8.1		3.56	6.2		3.37	5.0		3.59	2.9
K\%	3.6	23.		3.6	2.7		3.3	14.		2.9	2.4

	9			0			5			7	
Zn	136 .	12.		130 .	6.5		116 .	17.		109 .	2.5

Table 4: Group patterns of the AIA project SaGW, SaGX, and SaGY probably assigned to Sardis or its neighbourhood. Given are… see caption Table 1

	SaGW 5 samples factor 1.00			SaGX 9 samples factor 1.00			SaGY 24 samples factor 1.00	
	M	σ(%)		M	σ(%)		M	σ(%)
As	45.7	47.		28. 3	54.		24.8	42.
Ba	839.	13.		824 .	13.		730.	9.1
Ca\%	1.99	9.0		1.6 4	6.7		2.24	37.
Ce	93.4	5.0		98. 7	5.0		93.6	5.0
Co	--			71. 2	48.		26.5	17.
Cr	176.	5.0		202 .	10.		155.	6.6
Cs	19.7	19.		24. 9	11.		17.2	12.
Eu	1.95	6.2		1.8 0	8.5		1.80	5.4
Fe\%	7.89	6.5		6.6 5	5.0		6.14	5.5
Hf	3.48	5.0		5.3 9	12.		6.04	10.
La	48.3	5.0		48. 6	5.0		47.0	5.0
Lu	0.50	7.1		0.5 6	5.0		0.54	5.9
Na\ %	0.71	35.		0.9 8	16.		1.17	13.
Nd	38.1	9.6		40. 5	9.7		38.2	8.4
Rb	157.	6.6		150 .	20.		134.	5.5
Sb	6.03	27.		5.7 1	7.8		5.60	24.
Sc	25.1	5.0		23. 1	5.0		21.1	5.0
Sm	8.71	5.0		8.8 6	5.0		8.86	5.0

Ta	--			3.58	43.		1.30	30.
Tb	1.31	8.2		1.60	30.		1.22	16.
Th	15.4	5.1		14.7	5.3		14.2	5.0
U	3.31	13.		3.62	17.		2.78	20.
Yb	3.55	5.4		3.68	5.0		3.71	5.0
K\%	3.83	25.		3.47	7.3		3.28	27.
Zn	116.	16.		112.	8.8		110.	12.

Table 5 s. above

Table 6: Group patterns of the AIA project TeGB and EuGA probably assigned to Teos and Euboea, respectively, compared to matching Bonn groups TeosB and EuA, respectively. Given are… see caption Table 1

	TeGB 14 samples factor 1.09			TeoB 224 samples factor 1.00			EuGA 12 samples factor 1.04			EuA 141 samples factor 1.00	
	M	?(%)		M	?(%)		M	?(%)		M	?(%)
As	22.6	53.		19.2	66.		17.8	58.		23.1	44.
Ba	604.	17.		560.	21.		687.	12.		708.	13.
Ca\%	7.66	13.		5.78	37.		3.97	35.		3.96	27.
Ce	85.2	5.0		85.6	6.0		80.4	5.0		80.4	3.1
Co	25.3	42.		19.8	14.		29.3	33.		23.3	4.1
Cr	169.	6.7		151.	8.3		188.	14.		154.	5.1
Cs	17.3	6.0		19.4	15.		10.1	10.		9.81	4.9
Eu	1.43	9.3		1.33	4.5		1.38	7.7		1.40	3.0
Fe\%	4.78	8.6		4.54	6.2		5.60	5.6		5.41	3.8
Hf	6.07	5.7		6.37	4.8		4.37	10.		4.39	6.8

La	43.4	5.0		40.5	5.0		40.4	5.0		38.1	2.4
Lu	0.45	5.1		0.48	4.6		0.43	7.2		0.49	4.9
Na\%	0.64	14.		0.68	25.		0.82	25.		1.06	16.
Nd	33.8	7.7		32.3	7.4		32.6	15.		33.0	5.3
Rb	134.	14.		145.	8.0		153.	9.0		166.	4.0
Sb	1.00	9.8		0.99	26.		2.22	35.		2.35	11.
Sc	19.1	6.9		19.7	4.5		22.2	5.0		22.5	3.1
Sm	6.69	5.0		5.87	7.1		6.81	5.0		6.23	4.9
Ta	2.05	54.		1.25	6.4		1.94	47.		1.02	4.9
Tb	0.95	14.		0.80	7.0		1.04	18.		0.85	7.3
Th	16.5	7.6		17.1	4.7		14.7	5.3		14.4	2.4
U	3.60	33.		3.33	15.		2.72	21.		2.39	10.
Yb	3.06	5.0		3.27	3.7		2.87	7.0		3.19	3.8
K \%	2.53	23.		2.60	7.2		3.63	15.		3.36	5.4
Zn	113.	14.		112.	13.		119.	18.		116.	12.

Table 7: Group patterns of the AIA project MiGD and TrGB probably assigned to Miletos and Troy, respectively, compared to matching Bonn groups MilD and TroB, respectively. Given are… see caption Table 1

	MiGD 6 samples factor 0.98			MilD 143 samples factor 1.00			TrGB 20 samples factor 1.04			TroB 70 samples factor 1.00	
	M	σ(%)		M	σ(%)		M	σ(%)		M	σ(%)
As	13.5	32.		19.7	46.		21.3	26.		30.5	80.
Ba	528.	14.		588.	24.		670.	18.		697.	25.
Ca\%	4.35	33.		5.61	26.		5.77	19.		5.48	34.
Ce	96.2	5.0		97.3	4.5		65.2	5.0		67.2	4.1
Co	20.9	22.		22.7	12.		20.9	8.0		19.8	8.4
Cr	159.	11.		195.	18.		173.	8.0		165.	11.
Cs	10.9	10.		10.7	8.6		8.97	8.8		8.67	10.
Eu	1.38	5.0		1.35	4.3		1.21	6.5		1.18	5.4

Fe\%	4.21	5.0		4.44	6.3		4.36	5.0		4.17	4.4
Hf	5.10	8.7		5.39	16.		4.40	11.		4.79	9.8
La	49.4	5.0		46.4	3.9		33.7	5.0		32.2	4.4
Lu	0.49	7.9		0.49	5.5		0.34	5.0		0.38	6.0
Na\%	0.94	13.		1.13	23.		0.86	16.		0.95	22.
Nd	35.7	15.		37.4	6.6		28.1	5.7		25.6	7.9
Rb	182.	7.1		190.	7.9		126.	6.1		131.	7.8
Sb	1.43	6.0		1.54	17.		1.58	12.		1.63	28.
Sc	13.1	5.0		14.2	6.9		16.4	5.4		16.5	4.4
Sm	8.32	5.0		7.12	8.1		5.39	5.0		4.70	6.9
Ta	2.28	32.		1.43	5.6		1.09	22.		0.82	7.3
Tb	1.32	18.		1.07	6.5		0.82	10.		0.66	7.3
Th	22.6	5.0		23.3	7.2		14.3	5.6		15.0	6.1
U	3.90	16.		3.75	14.		3.32	15.		3.34	9.1
Yb	3.75	5.3		3.70	5.4		2.16	6.8		2.47	4.3
K\%	3.46	22.		3.14	8.4		2.94	15.		2.80	10.
Zn	85.9	22.		81.5	13.		94.3	19.		96.0	9.2

References:

Beier, Th., Mommsen, H., 1994, Modified Mahalanobis filters for grouping pottery by chemical composition, Archaeometry 36, 287 – 306.

- the same, 1994, A method for classifying multidimensional data with respect to uncertainties of measurement and its application to archaeometry, Naturwissenschaften 91, 546 – 548.

Grave, P., Kealhofer, L., Marsh, B., Gates, M.-H., 2008, Using neutron activation analysis to identify scales of interaction at Kinet Höyük, Turkey, JAS 35, 1974 – 1992.

Grave, P., et al. (2013). "Cultural dynamics and ceramic resource use at Late Bronze Age/Early Iron Age Troy, northwestern Turkey." Journal of Archaeological Science 40(4): 1760-1777. ???

Kealhofer, L., Grave, P., Marsh, B., 2013, Scaling ceramic provenience at Lydian Sardis, Western Turkey, JAS 40, 1918 – 1934

Kealhofer et al. 2014 Troy ???

Kerschner and Cahill, private communication

Lehmann, G., Shalev, Y., Mommsen, H., Ben-Shlomo, D., Daszkiewicz, M., Schneider, G., and Gilboa, A., in press, The Kelenderis Pottery Workshop(s): Newly-Identified Agents in East Mediterranean Maritime Exchange Networks in the Achaemenid Period, Levant

Mommsen, H., Kreuser, A., Weber, J., 1988, A method for grouping pottery by chemical composition, Archaeometry 30, 47 – 57.