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LATE HELLENISTIC AND ROMAN TABLEWARE IN THE AEGEAN AND THE BLACK SEA REGION – WHY WE NEED CHEMICAL ANALYSIS

We need chemical analysis to unambiguously assign ceramic finds to archaeological wares. This is demonstrated using two examples: Eastern Sigillata *C from Pergamon or Çandarlı (Pitane) and Pontic* sigillata *from the Crimea, analysed using WD-XRF. The analyses have to provide representative information about the raw materials used in the clay body from which the pottery was made. At least fifteen elements have to be determined with great precision and accuracy. This needs samples of about 1.5 grams to be taken, and generally rules out non-destructive chemical analysis. Homogeneous chemical reference groups enable the reliable definition of archaeological ceramic wares. Pottery provenance can be determined in those cases where analysed local material is available for comparison. The examples of ceramic finds suspected to be Pergamene* sigillata *found in Delos and Histria demonstrate the significance of chemical analysis. Reference groups for tablewares found in NW- and SE-Crimea include four groups of Pontic* sigillata *and Bosporan* sigillata *which are shown to be different to reference groups of Moesian* sigillata.

Wavelength-dispersive X-ray fluorescence (WD-XRF) – Pergamon – Candarli – Eastern *Sigillata* C (ESC) – Pontic *Sigillata*

Chemical analysis for the definition of ceramic wares

The definition of a ware must be based on its chemical composition (including major and trace elements) determined by precise and accurate analysis using WD-XRF (not pXRF), ICP-MS, or NAA. For sherds to be attributed to the same ware they must have the same chemical composition. Differences within a group must be significantly smaller than between groups. MGR-Analysis (Daszkiewicz 2017) should be carried out to verify whether the matrix of the samples is identical (indicating use of the same clay). Similar fabrics should be checked macroscopically and in thin-section. Finally, when weighing up archaeological hypotheses it must be borne in mind that vessel shape alone is not always a reliable indicator of ware type nor can a vessel shape always be determined from small body sherds. By combining archaeological and laboratory analyses we can reliably attribute sherds to specific wares. The next step in determining geographical provenances is usually based solely on relatively secure archaeological hypotheses about the provenances of ceramic wares. A really secure attribution requires analysed reference groups of workshop finds, but these are rarely available. Limitations in the size of available samples as well as the capacities and costs of laboratory analysis mean that the best approach is to precisely analyse a fine powder obtained by drilling or pulverising small fragments of about 1.5 grams after having first removed any gloss or slip and other probably contaminated surface layers. Non-destructive analysis by pXRF or very small samples (e.g. taken by laser ablation) even for fine wares, may not be representative of the clay body of a sherd, and the sampling error should be known for each element.

Chemical reference groups for tablewares from the Eastern Mediterranean were established long ago in cooperation with numerous archaeologists. This was done, for example, for black gloss wares (Attic wares, Campana A, and a Cypriot black gloss group), for *sigillata* (ESA, ESB, ESC, ESD), for Late Roman Red Slip wares (e.g. ARS, LRC) and others. Schneider and Daszkiewicz gave a short overview in 2014 (for a table of mean compositions see Schneider 2000). **Fig. 1** shows that values of two significant chemical elements plotted in a diagram may be sufficient to demonstrate the differences between chemical groups. Here, two geochemically significant elements (magnesium and chromium, determined by WD-XRF) were used, but it should be pointed out that magnesium cannot be accurately analysed using pXRF or NAA. On the other hand, the attribution of an analysed ceramic object to a given group

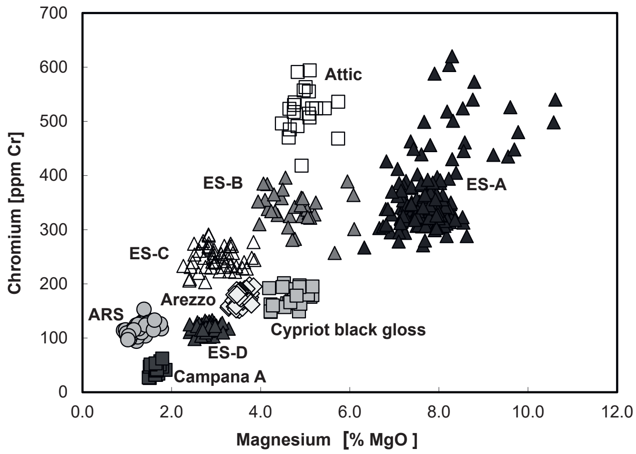

Fig. 1. Distinction of Hellenistic and Roman far-traded tablewares in the Eastern Mediterranean using a bivariate plot of chromium content vs. magnesium content.

needs all elements from a series of fifteen to twenty analysed elements to fall within the range of variation of a single production centre, which should be known or estimated from relevant experience. Elements probably influenced by chemical alteration, very often indicated by elevated contents of phosphorus and often also of barium and/or strontium, should not be included (Schneider 2017). Helpful tools for the interpretation of analysis results are series of bivariate diagrams or multivariate methods (cluster analysis, principal component analysis, discriminant analysis). Notwithstanding, the tables of the original analysis results are the only true basis for interpretation (e.g. Daszkiewicz et al. 2018) and, therefore, these data should be published (we try to put all our data in an open access databank).

Pergamon as a production centre of tablewares in the Hellenistic and Roman periods

To date a series of nearly 300 sherds of tablewares from Pergamon and Çandarlı sampled by O. Bounegru and for the most part by S. Japp have been analysed resulting in various distinctive groups (Schneider and Japp 2009; Japp 2014). WD-XRF and NAA analyses have revealed that Eastern *sigillata* C (ESC) was produced both in Pergamon and Çandarlı (Schneider and Mommsen 2009). The group of Pergamene ESC matches a clay sample from the Ketios valley, which is also where most of the analysed sherds come from. The products of the two centres can only definitively be distinguished using laboratory analysis. **Fig. 2** demonstrates that the geochemically significant ratios of calcium and strontium separate the more calcareous products of Çandarlı from those of Pergamon. The latter, in spite of lower calcium levels, generally have a higher strontium content.

An example of finds of hypothesized Pergamene *sigillata* from Delos shows how chemical analysis can change an archaeological interpretation (Meyza et al. 2009; Meyza and Peignard-Giros 2011). In fact only six of twenty analysed samples were ESC: two from Pergamon and four from Çandarlı (Daszkiewicz and Schneider 2009). This was corroborated by MGR-analysis and by WD-XRF. Analyses of another twenty sherds from Delos confirmed this picture, with a large proportion of sherds not matching products either from Pergamon or from Çandarlı; however, the analyses did lead to the definition of two new reference groups of non-calcareous *sigillata* in the Aegean (Daszkiewicz and Schneider 2011; Meyza 2014). The results obtained by applying other methods used traditionally in a geological laboratory, such as thin-section studies, SEM-EDS microanalysis, and XRD (Trzcinski, Wrobel and Kiesczszynski 2009; 2011), demonstrated very clearly why we need precise chemical analysis. **Table 1** presents the means of the last analysis results for ESC from Pergamon and Çandarlı (the small differences from the earlier means published in Schneider 2000 are due to the current larger number of analyses).

Imports of ESC at various sites can now securely be determined using the two reference groups. Consequently, finds of *sigillata* from Pergamon and Çandarlı have been attested at far distant sites such as Ptolemais/Libya, Chhim/Lebanon and Nymphaion/Crimea in a pilot project devised by H. Meyza and K. Domżalski. O. Bounegru selected eighteen sherds of probable Pergamene origin from Histria/Romania, of which, according to chemical analysis, only eight were made in Çandarlı and one in Pergamon. Another two sherds were identified as Pontic *sigillata*, whilst the remaining sherds could not be attributed.

Another example of the definition of a tableware is illustrated by five analysed sherds found at geographically diverse sites (Ptolemais/Libya, Chhim/Lebanon, Illychevka/NE-Crimea and Pergamon) and attributed to Late Roman Light-Coloured ware (LRLCW) (Domżalski 2002). Their place of production may be Pergamon, but the group does not match any of the various already existing chemical groups of pottery made at Pergamon and thus raises certain doubts.

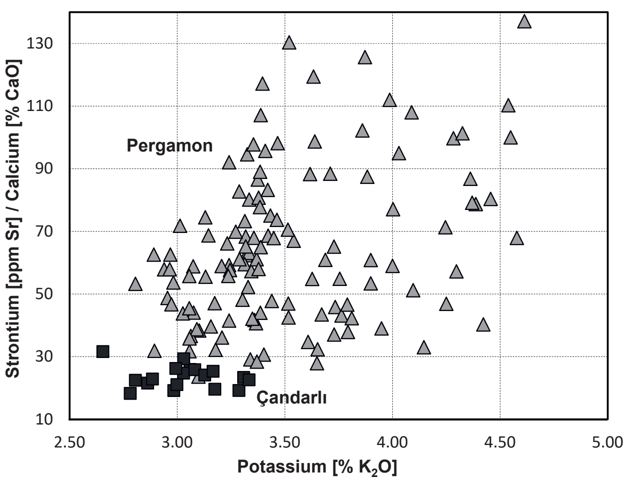

Fig. 2. Distinction of ESC from Pergamon and from Çandarlı in a bivariate plot of the strontium/calcium-ratio vs. potassium content.

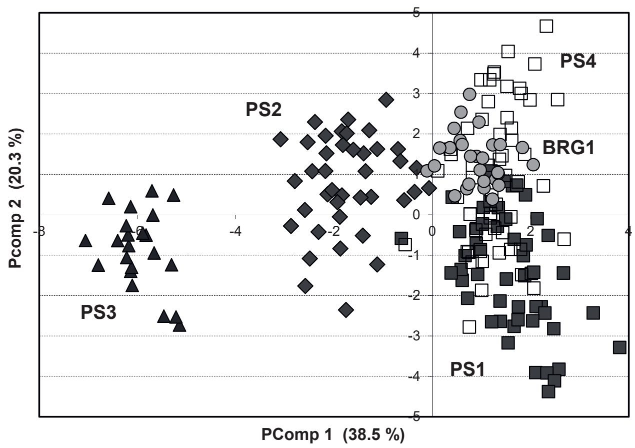

Fig. 3. Principal component analysis of chemical analysis results of Pontic *sigillata* (PS1, PS2, PS3, PS4) and Moesian *sigillata* from Butovo (BRG1); elements used are Si, Ti, Al, Fe, Mn, Mg, Ca, Na, K, Cr, Ni, Rb, Sr, Zr, Ba.

Ware (chem. group)	SiO_2 % by weight	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5
ESC-P (n=125)	**59.84**	**1.023**	**19.18**	**7.40**	**0.108**	**3.01**	**5.00**	**0.67**	**3.52**	**0.241**
std ±	2.11	0.075	1.52	0.52	0.017	0.44	1.87	0.27	0.43	0.102
ESC-C (n=18)	**55.91**	**0.895**	**17.03**	**7.14**	**0.108**	**3.49**	**11.30**	**0.86**	**3.05**	**0.217**
std ±	1.91	0.055	1.14	0.56	0.020	0.48	2.02	0.22	0.19	0.059
LRLCW (n=5)	**58.80**	**0.637**	**25.89**	**4.90**	**0.079**	**2.13**	**3.37**	**0.37**	**3.55**	**0.260**
std ±	0.88	0.101	0.69	0.34	0.005	0.22	0.89	0.20	0.07	0.018
BS (n= 10)	**69.42**	**0.838**	**14.42**	**6.19**	**0.096**	**1.91**	**2.80**	**1.56**	**2.57**	**0.203**
std ±	1.97	0.060	1.08	0.69	0.018	0.23	0.40	0.19	0.24	0.034
PS 1 (n=52)	**65.13**	**0.860**	**16.79**	**6.27**	**0.078**	**1.99**	**4.76**	**1.05**	**2.90**	**0.173**
std ±	2.38	0.050	1.27	0.62	0.027	0.33	1.45	0.16	0.23	0.055
PS2 (n=39)	**57.16**	**0.839**	**18.00**	**7.35**	**0.100**	**3.01**	**9.15**	**1.24**	**2.94**	**0.210**
std ±	2.57	0.047	1.38	0.46	0.034	0.30	2.72	0.15	0.22	0.180
PS3 (n=22)	**54.83**	**0.824**	**14.58**	**6.95**	**0.101**	**4.10**	**14.42**	**1.33**	**2.67**	**0.177**
std ±	1.90	0.036	0.62	0.36	0.012	0.42	2.02	0.15	0.24	0.040
PS4 (n=60)	**60.00**	**0.789**	**18.99**	**6.78**	**0.067**	**1.67**	**7.50**	**0.68**	**3.36**	**0.149**
std ±	2.71	0.061	1.79	0.58	0.018	0.16	1.83	0.22	0.32	0.040
BRG 1 (n=37)	**59.15**	**0.875**	**19.60**	**6.71**	**0.090**	**2.62**	**6.34**	**0.96**	**3.40**	**0.218**
std ±	1.57	0.019	0.77	0.40	0.004	0.33	1.12	0.12	0.20	0.074
PRG 1 (n=13)	**62.66**	**0.805**	**16.51**	**6.22**	**0.098**	**1.94**	**7.75**	**0.94**	**2.84**	**0.213**
std ±	0.76	0.015	0.37	0.15	0.009	0.09	1.10	0.15	0.12	0.070
PRG 2 (n=4)	**55.64**	**0.878**	**20.35**	**7.04**	**0.087**	**2.86**	**8.68**	**1.01**	**3.19**	**0.173**
std ±	0.37	0.017	0.33	0.10	0.006	0.34	0.34	0.09	0.24	0.004
PRG 3 (n=12)	**59.17**	**0.769**	**16.58**	**5.90**	**0.088**	**2.12**	**11.29**	**0.73**	**3.05**	**0.292**
std ±	1.17	0.034	0.98	0.31	0.015	0.22	1.23	0.09	0.12	0.078
Novae (n=23)	**62.31**	**0.788**	**15.97**	**5.50**	**0.050**	**2.04**	**8.79**	**0.94**	**3.27**	**0.335**
std ±	1.05	0.019	0.56	0.17	0.004	0.09	1.46	0.09	0.24	0.107

Ware (chem. group)	V ppm	Cr	Ni	(Cu)	Zn	Rb	Sr	Y	Zr	(Nb)	Ba	(Ce)	(Pb)	l.o.i. %
ESC-P (n=125)	**139**	**243**	**148**	**57**	**93**	**153**	**288**	**27**	**194**	**17**	**746**	**80**	**33**	**2.45**
std ±	29	28	19	10	11	15	72	4	22	3	169	13	12	1.58
ESC-C (n=18)	**121**	**239**	**157**	**51**	**90**	**142**	**263**	**25**	**170**	**16**	**715**	**73**	**23**	**3.38**
std ±	23	33	27	14	23	9	47	3	18	8	225	13	4	1.90
LRLCW (n=5)	**117**	**81**	**47**	**20**	**67**	**151**	**171**	**17**	**140**	**15**	**858**	**79**	**33**	**2.24**
std ±	5	57	30	4	3	12	11	1	6	2	131	3	9	0.38
BS (n= 10)	**111**	**123**	**47**	**28**	**76**	**86**	**231**	**27**	**253**	**14**	**455**	**68**	**19**	**2.05**
std ±	17	14	7	9	12	7	37	3	36	4	71	9	4	1.12
PS 1 (n=52)	**120**	**110**	**58**	**45**	**103**	**130**	**234**	**28**	**186**	**16**	**508**	**67**	**21**	**1.92**
std ±	13	12	8	14	13	12	58	3	20	3	104	12	6	0.77
PS2 (n=39)	**138**	**147**	**85**	**50**	**96**	**124**	**364**	**26**	**148**	**14**	**419**	**68**	**20**	**2.40**
std ±	17	15	10	10	14	16	70	3	18	3	76	12	10	1.30
PS3 (n=22)	**127**	**279**	**153**	**48**	**85**	**99**	**550**	**23**	**155**	**14**	**332**	**56**	**13**	**4.94**
std ±	16	22	14	14	11	8	86	2	15	3	71	5	6	2.11
PS4 (n=60)	**141**	**119**	**71**	**64**	**114**	**147**	**338**	**27**	**166**	**16**	**429**	**72**	**24**	**3.23**
std ±	17	11	10	23	23	17	147	3	16	2	88	10	8	2.19
BRG 1 (n=37)	**145**	**117**	**63**	**42**	**108**	**157**	**276**	**27**	**189**	**15**	**436**	**81**	**24**	**1.54**
std ±	13	6	6	13	8	10	37	4	17	1	56	9	6	0.74
PRG 1 (n=13)	**120**	**99**	**53**	**33**	**94**	**128**	**268**	**26**	**214**	**14**	**385**	**76**	**23**	**2.28**
std ±	10	4	6	10	6	8	17	4	14	2	50	10	6	1.17
PRG 2 (n=4)	**149**	**122**	**61**	**37**	**113**	**144**	**323**	**30**	**171**	**15**	**419**	**92**	**27**	**1.34**
std ±	4	5	4	2	5	14	30	2	7	1	18	4	2	0.31
PRG 3 (n=12)	**121**	**97**	**56**	**39**	**95**	**138**	**427**	**22**	**202**	**14**	**424**	**68**	**22**	**4.26**
std ±	11	5	7	10	5	9	41	4	13	1	62	10	5	1.44
Novae (n=23)	**126**	**99**	**47**	**31**	**111**	**131**	**306**	**25**	**190**	**14**	**372**	**71**	**32**	**2.92**
std ±	10	8	5	9	15	6	42	2	7	2	24	9	20	1.23

Table 1. WD-XRF means and standard deviations of significant tablewares: Eastern *sigillata* C from Pergamon (ESC-P) and from Çandarlı (ESC-C), Late Roman Light-Coloured ware (LRLCW), Bosporan *sigillata* (BS), Pontic *sigillata* (PS1, PS2, PS3, PS4) and Moesian *sigillata* (Butovo BRG1, Pavlikeni PRG1, PRG2, PRG3, and Novae). Samples with obvious alteration effects (e.g. in phosphorus levels) have been omitted, the mean of ESC from Pergamon includes two subgroups with somewhat different silicon, aluminium and potassium concentrations.

Pontic *sigillata* and other tablewares from the Crimea

A large series of samples archaeologically identified as Pontic *sigillata* were analysed from various sites, mainly in the Crimea. Sherds were collected by E. Kühnelt, who wrote a thesis on the ceramics from Alma Kermen, SW-Crimea (Kühnelt 2008). Other samples were provided by K. Domżalski from Nymphaion, NE-Crimea. Four chemical groups of Pontic *sigillata* (PS) were distinguished. **Table 1** shows that, with the exception of group PS3, the means are not very different and are very similar to the Moesian *sigillata* from Butovo both in major and trace elements. This can also be seen from a principal component analysis (PCA) in **Fig. 3,** where PS2 and PS3 are clearly separated, whereas PS1 and PS4 overlap one another and also overlap Moesian *sigillata* from Butovo (BRG1) and Pavlikeni (PRG1, PRG2, PRG3). Regarding the contents of magnesium and silicon in a bivariate diagram (**fig. 4**), BRG1 is clearly distinguished from PS1, and groups PS1 and PS4 do not overlap (this is also shown by PCA when only these groups are included in the calculation). Thus, the attribution of a sample may differ depending on which calculation (selection of elements/groups) or element combinations are used. Therefore, to securely attribute analysis results of a sample to a given chemical group, all individual data must be considered and interpreted taking into account mineralogical and geochemical rules and possible alteration effects. The individual analysis results for Pontic and Bosporan *sigillata* are given in **Table 2** (for Moesian *sigillata* part of the data are presented in Baranowski, Daszkiewicz and Schneider forthcoming).

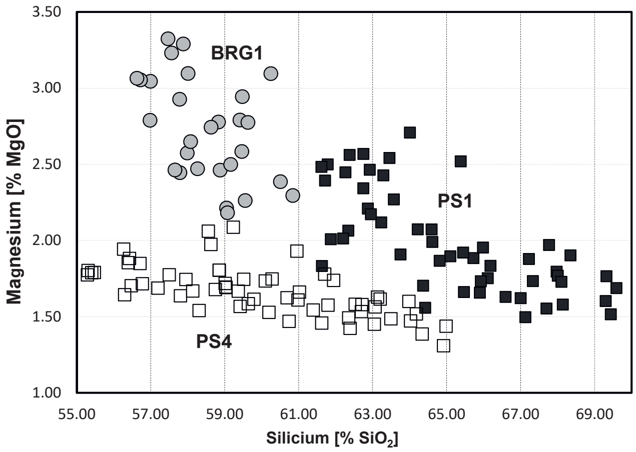

Fig. 4. Bivariate plot of magnesium content vs. silicium content of Moesian *sigillata* from Butovo (BRG1) and Pontic *sigillata* PS1 and PS4.

Lab.-no.	find spot	SiO2 wt.%	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	V ppm	Cr	Ni	Zn	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	l.o.i. %
Pontic sigillata PS1																								
5181	Olbia	68,10	0,885	15,81	6,16	0,069	1,73	3,45	0,98	2,72	0,098		101	69		146	128		156		479			1,30
5182	Olbia	65,38	0,927	17,07	6,92	0,102	2,52	2,66	1,27	3,08	0,081		104	64		145	162		178		526			1,70
C437	Nymphaion	65,45	0,768	15,67	5,47	0,046	1,92	6,82	0,92	2,78	0,166	121	89	54	103	126	208	26	170	14	468	59	12	0,90
C438	Nymphaion	62,75	0,870	16,91	6,50	0,099	2,57	5,91	1,26	2,95	0,189	110	108	50	105	127	268	29	189	12	450	84	23	3,10
C440	Nymphaion	61,87	0,856	16,71	6,48	0,087	2,01	7,92	0,95	2,94	0,180	109	108	51	118	130	267	29	180	14	479	68	17	3,80
C442	Nymphaion	62,38	0,900	17,43	6,85	0,108	2,56	5,35	1,22	2,99	0,227	113	108	52	111	131	192	30	188	16	490	78	21	1,60
C443	Nymphaion	64,81	0,892	17,29	6,61	0,079	1,87	4,35	0,98	2,98	0,146	129	113	54	115	136	206	29	189	14	504	71	20	1,80
C444	Nymphaion	62,34	0,901	18,14	7,00	0,098	2,06	5,08	0,88	3,26	0,180	130	111	56	122	148	237	30	176	16	537	69	24	1,80
C445	Nymphaion	64,22	0,810	18,12	6,62	0,081	2,07	3,82	0,94	3,18	0,135	128	115	53	110	149	199	27	174	14	551	74	23	1,60
C448	Nymphaion	63,75	0,910	17,15	6,52	0,060	1,91	5,32	1,13	3,10	0,144	112	112	53	125	142	274	28	194	15	425	75	19	3,10
C454	Nymphaion	68,14	0,833	15,19	6,02	0,063	1,58	4,28	0,94	2,69	0,267	117	103	50	102	117	207	27	162	13	644	52	18	1,30
C456	Nymphaion	64,62	0,866	16,21	5,62	0,048	1,99	6,37	0,86	3,26	0,154	125	103	45	107	141	162	26	188	13	599	55	17	1,50
F216	Nymphaion	67,70	0,835	15,23	5,73	0,075	1,55	4,95	1,13	2,62	0,174	115	99	57	95	112	186	24	191	21	388	50	18	2,52
F217	Nymphaion	62,26	0,862	16,71	6,14	0,103	2,45	7,34	1,11	2,80	0,220	112	115	58	79	117	234	25	178	21	487	75	16	3,15
F218	Nymphaion	61,79	0,917	18,96	6,93	0,099	2,50	4,09	1,06	3,40	0,252	126	129	68	89	140	238	27	166	25	596	92	17	2,72
F802	Nymphaion	63,46	0,906	17,64	6,56	0,099	2,54	4,30	1,11	3,21	0,183	101	132	70	86	129	170	27	185	22	476	82	13	1,17
F808	Nymphaion	65,90	0,834	16,18	5,93	0,065	1,66	5,31	0,90	2,96	0,274	128	114	58	92	118	187	23	148	20	453	62	10	1,38
G782	Nymphaion	61,62	0,899	17,61	6,99	0,103	2,48	6,02	1,33	2,73	0,210	142	130	78	131	106	238	28	169	14	388	69	25	2,09
G801	Nymphaion	67,13	0,844	18,04	5,42	0,045	1,50	3,09	0,99	2,84	0,104	114	99	42	84	125	163	23	203	15	590	70	14	2,14
G815	Nymphaion	62,20	0,890	18,16	6,81	0,095	2,01	5,32	1,08	3,25	0,195	133	118	62	115	133	203	29	173	17	452	89	8	1,42
M648	Chersonesos	61,72	0,792	17,59	6,83	0,137	2,39	6,16	0,97	3,30	0,122	152	117	63	99	139	254	28	163	12	333	76	29	0,80
MD2573	Chersonesos	65,93	0,807	15,33	5,95	0,083	1,73	6,47	0,99	2,56	0,151	112	97	46	96	113	196	27	167	15	444	68	19	1,47
MD2577	Chersonesos	61,63	0,777	17,49	6,17	0,136	1,83	7,29	1,39	2,96	0,329	153	104	51	82	122	266	30	180	13	542	75	23	1,80
MD3175	Alma Kermen	69,32	0,870	15,27	5,36	0,041	1,77	3,39	0,93	2,93	0,122	123	106	53	134	140	173	25	219	15	959	64	20	1,66
MD3176	Alma Kermen	65,73	0,839	16,15	5,46	0,038	1,88	5,80	0,88	3,04	0,178	128	104	53	92	121	226	25	180	15	577	61	20	2,79
MD3179	Alma Kermen	67,98	0,747	14,32	5,10	0,038	1,80	6,27	0,87	2,70	0,179	109	95	49	89	124	268	24	192	14	467	57	17	2,84
MD3180	Alma Kermen	69,30	0,843	14,64	5,50	0,056	1,60	4,10	1,02	2,78	0,160	107	93	47	90	116	245	28	220	14	531	64	18	1,95
MD3182	Alma Kermen	66,11	0,915	17,43	6,32	0,070	1,75	3,04	1,28	2,92	0,163	131	107	60	100	138	217	28	183	15	429	77	21	1,59
MD3183	Alma Kermen	67,00	0,869	16,09	5,93	0,076	1,62	4,34	1,30	2,60	0,176	106	108	58	96	120	220	28	194	15	385	71	13	1,45
MD3184	Alma Kermen	63,23	0,921	19,02	7,09	0,098	2,12	3,09	0,95	3,36	0,121	119	113	64	105	131	362	27	185	17	807	65	28	3,54
MD3197	Alma Kermen	67,33	0,894	16,35	6,25	0,075	1,73	3,39	1,20	2,64	0,143	112	107	59	107	110	151	28	176	15	394	76	20	1,06
MD3201	Alma Kermen	64,01	0,921	17,70	7,13	0,112	2,71	3,03	1,23	3,02	0,143	111	88	60	109	133	185		172		457	65		1,67
MD3204	Alma Kermen	62,87	0,892	18,93	6,92	0,086	2,21	3,86	0,99	3,10	0,143	142	123	62	114	152	217	29	172	17	507	81	20	0,96
MD3205	Alma Kermen	62,92	0,901	18,76	6,99	0,084	2,46	3,77	0,88	3,10	0,129	128	122	65	118	144	192	28	160	18	534	72	25	1,22
MD3207	Alma Kermen	66,19	0,793	15,98	5,54	0,035	1,83	5,76	0,75	2,93	0,194	130	111	53	97	123	210	25	164	14	541	53	134	1,63
MD3214	Alma Kermen	69,44	0,881	15,70	6,15	0,100	1,52	2,71	0,93	2,40	0,174	121	118	60	90	108	211	36	264	15	538	69	25	0,95
MD3220	Alma Kermen	62,95	0,888	16,95	6,58	0,099	2,17	6,23	0,96	2,99	0,181	125	113	58	100	122	238	29	177	19	475	61	20	2,76
MD3223	Alma Kermen	68,35	0,821	15,65	6,19	0,084	1,90	3,14	1,08	2,64	0,141	111	88	57	86	114	233		190		466	66		1,26
MD3492	Alma Kermen	67,77	0,860	16,25	5,88	0,078	1,97	3,26	1,07	2,74	0,124	108	115	58	99	125	198	27	186	15	444	62	28	1,10
MD3495	Alma Kermen	64,60	0,902	16,96	6,37	0,086	2,07	4,79	1,30	2,79	0,137	113	126	68	98	128	232	31	200	19	435	78	23	1,37
MD3504	Alma Kermen	63,29	0,907	18,47	6,99	0,095	2,43	3,61	1,04	3,04	0,138	132	129	62	105	138	208	31	189	18	508	70	26	1,02
MD3505	Alma Kermen	64,37	0,841	18,86	7,57	0,111	1,70	2,61	0,92	2,85	0,172	147	143	71	114	125	359	32	197	15	714	74	180	2,28
MD3507	Alma Kermen	67,23	0,843	15,96	5,42	0,039	1,88	4,37	1,15	2,97	0,148	121	109	57	92	134	253	26	211	17	580	74	24	2,01
MD3509	Alma Kermen	64,42	0,784	16,17	6,09	0,061	1,56	6,92	1,18	2,67	0,147	121	122	56	95	120	265	27	158	16	416	72	21	1,95
MD3587	Alma Kermen	62,75	0,913	17,32	6,90	0,103	2,34	5,30	1,22	2,93	0,233	109	106	65	122	134	340	39	192	21	430	27	46	2,42
MD3590	Alma Kermen	65,47	0,929	17,98	6,65	0,056	1,66	2,82	1,14	2,93	0,374	108	122	70	119	160	368		196		725	48		3,16
MD3594	Alma Kermen	66,59	0,906	16,65	6,39	0,071	1,63	3,58	1,27	2,74	0,171	107	107	58	123	145	228		201		379	65		1,46
MD3596	Alma Kermen	63,57	0,868	16,59	6,73	0,111	2,27	5,79	1,25	2,69	0,138	115	100	66	95	128	393		207		617	56		2,25
MD3615	Alma Kermen	68,01	0,761	14,37	5,07	0,026	1,77	6,31	0,84	2,58	0,263	102	82	39	111	131	283		210		395	32		1,62
MD3616	Alma Kermen	69,59	0,751	14,04	5,21	0,029	1,69	4,96	0,99	2,61	0,134	100	93	56	95	125	227		212		421	52		2,69
MD3620	Alma Kermen	65,10	0,831	16,08	5,42	0,039	1,90	6,68	0,83	2,94	0,174	108	112	52	102	133	273	26	198	16	618	70	23	2,54
MD3623	Alma Kermen	65,98	0,868	17,67	6,51	0,074	1,95	3,09	0,98	2,74	0,135	119	123	61	110	131	328	27	187	17	818	79	24	1,59
Pontic sigillata PS2																								
5183	Olbia	58,01	0,866	19,61	7,36	0,087	2,72	6,65	1,47	3,09	0,139	126	126	83	80	138	382	32	153		512	48		1,08
5186	Olbia	55,25	0,838	18,96	7,67	0,102	3,47	8,99	1,36	3,17	0,210		124	81		148	369		123		422			2,90
5188	Olbia	55,20	0,793	17,08	7,30	0,121	3,32	11,41	1,33	3,19	0,263		142	91		140	360		152		415			3,66
5261	Carthage	59,28	0,837	18,35	7,49	0,117	2,71	6,84	1,11	2,87	0,383	129	133	80	96	156	359	27	196	11	528	96	225	3,04
5279	Carthage	59,48	0,784	17,28	7,03	0,129	2,66	8,20	1,21	3,08	0,141	151	107	71	99	140	313	25	160	8	354	63	45	1,56
C441	Nymphaion	59,99	0,874	18,83	7,25	0,081	2,59	5,80	1,54	2,94	0,110	131	135	64	97	134	320	29	162	13	404	84	22	0,80
C446	Nymphaion	55,76	0,813	17,02	7,47	0,069	3,27	11,35	1,20	2,85	0,188	140	147	75	108	124	314	24	144	10	351	57	17	3,40
F797	Nymphaion	57,96	0,845	19,84	7,14	0,077	2,66	5,87	1,26	3,10	1,245	155	149	80	104	140	418	27	125	15	477	79	14	1,86
F800	Nymphaion	55,39	0,783	16,67	7,05	0,093	3,17	12,78	1,11	2,77	0,189	113	152	86	89	118	384	21	134	17	412	59	9	3,66
F804	Nymphaion	54,99	0,840	19,40	8,01	0,093	3,49	9,00	1,07	2,98	0,140	137	160	93	89	125	357	22	124	18	340	66	12	1,07
F805	Nymphaion	53,71	0,747	16,24	6,74	0,075	3,19	15,27	1,05	2,76	0,216	124	136	82	81	110	417	21	128	17	392	55	9	6,58
F806	Nymphaion	54,19	0,782	17,22	7,39	0,068	3,58	12,67	1,04	2,91	0,161	132	156	87	89	122	459	21	134	18	369	56	10	3,17
F809	Nymphaion	58,71	0,901	17,77	7,23	0,128	2,82	8,16	1,36	2,72	0,207	134	147	91	78	100	263	24	159	21	419	73	12	2,19
F812	Nymphaion	56,37	0,848	19,35	7,43	0,087	2,91	8,66	1,20	3,02	0,118	148	150	78	79	128	421	23	130	18	387	80	14	3,20
F814	Nymphaion	61,30	0,890	17,31	7,14	0,116	2,71	6,46	1,26	2,65	0,167	139	149	99	86	102	242	26	160	15	423	56	11	0,91
F816	Nymphaion	56,58	0,733	15,50	6,39	0,072	3,07	13,27	1,41	2,84	0,154	141	143	77	78	107	304	19	129	10	360	60	7	5,43
F828	Nymphaion	60,34	0,829	15,02	6,22	0,091	3,07	10,55	1,12	2,57	0,201	141	191	94	71	101	363	27	146	12	331	47	8	2,08
F829	Nymphaion	57,02	0,894	20,38	8,01	0,085	2,76	6,44	1,14	3,16	0,113	187	160	86	71	142	332	26	125	15	447	78	18	1,35

Table 2. WD-XRF analysis results for Pontic *Sigillata* and Bosporan Ware. Analysis of samples ignited at 900°C and then melted with lithium-borate, major elements given as oxides and normalized to a constant sum of 100%, trace elements Y, Nb, Ce and Pb determined with reduced precision.

Lab.-no.	find spot	SiO2 wt.%	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	V ppm	Cr	Ni	Zn	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	l.o.i. %
F830	Nymphaion	57,93	0,866	17,65	7,42	0,122	2,91	8,86	1,05	2,86	0,324	173	172	107	90	107	284	27	142	14	681	67	12	5,00
G651	Histria	59,69	0,882	19,77	7,33	0,072	2,59	4,95	1,54	3,04	0,133	132	139	72	92	136	334	30	153	14	408	75	42	1,28
G652	Histria	56,65	0,870	19,93	7,69	0,081	3,02	7,14	1,32	3,13	0,164	161	148	82	91	134	351	28	140	15	357	91	33	1,45
G784	Nymphaion	60,37	0,891	17,84	7,35	0,113	2,84	5,95	1,36	3,10	0,191	116	156	111	104	108	244	27	161	15	414	70	12	1,45
G787	Nymphaion	57,22	0,826	17,56	7,54	0,068	3,17	9,27	1,40	2,80	0,152	116	152	82	105	115	281	23	153	13	366	59	10	1,26
G788	Nymphaion	59,18	0,860	17,03	7,07	0,121	2,67	8,80	1,38	2,66	0,247	133	138	89	119	95	323	28	164	14	467	73	13	4,36
G797	Nymphaion	52,04	0,821	18,98	7,70	0,105	3,53	12,72	1,06	2,90	0,155	154	146	80	108	115	436	25	125	11	329	64	4	3,27
G803	Nymphaion	53,56	0,768	16,73	7,37	0,064	3,36	13,18	1,22	3,58	0,173	156	150	77	119	109	423	23	134	12	445	63	2	9,76
G813	Nymphaion	55,35	0,859	19,66	7,64	0,086	3,11	8,77	1,24	3,12	0,165	139	145	82	103	129	419	27	138	15	363	75	6	3,04
MD3172	Alma Kermen	57,91	0,917	17,85	7,74	0,196	2,87	7,81	1,12	3,32	0,270	129	141	75	96	112	399	29	188	17	522	67	13	2,97
MD3173	Alma Kermen	58,95	0,899	17,72	7,52	0,206	2,92	7,48	1,16	2,97	0,182	142	134	70	124	111	291	30	183	16	518	79	22	2,56
MD3174	Alma Kermen	62,91	0,814	15,33	6,02	0,106	2,78	7,71	1,49	2,66	0,178	131	167	86	84	103	364	27	165	11	359	54	21	2,65
MD3202	Alma Kermen	57,84	0,874	19,37	7,76	0,077	3,05	6,54	1,31	2,99	0,196	151	143	85	109	131	462	27	150	14	382	69	22	1,98
MD3206	Alma Kermen	56,68	0,804	16,73	7,13	0,066	3,16	11,06	1,52	2,72	0,139	126	150	72	87	115	386	24	154	10	361	51	21	3,97
MD3490	Alma Kermen	55,58	0,862	19,63	8,03	0,089	3,32	8,36	1,17	2,83	0,130	147	165	95	105	130	412	27	144	16	399	69	36	0,86
MD3499	Alma Kermen	58,21	0,921	18,88	7,97	0,183	2,97	6,48	1,15	3,08	0,173	159	155	81	111	128	333	28	175	16	595	83	34	1,91
MD3601	Alma Kermen	55,17	0,840	19,44	7,71	0,101	3,11	9,39	1,23	2,91	0,114	137	149	92	115	149	402		142		385			0,65
MD3602	Alma Kermen	53,43	0,798	17,23	6,94	0,082	2,57	14,94	1,03	2,80	0,186	111	135	90	103	133	384		148		357			4,51
MD3607	Alma Kermen	54,54	0,773	18,08	7,50	0,092	2,95	11,53	1,02	3,25	0,264	131	126	94	266	134	596		142		377		26	3,53
MD3608	Alma Kermen	54,47	0,815	17,62	7,83	0,064	3,63	11,44	1,10	2,90	0,130	125	154	95	108	146	441		127		393			1,16
MD3622	Alma Kermen	62,17	0,866	17,05	6,99	0,108	2,71	6,22	1,27	2,44	0,164	116	152	90	104	105	267	28	170	15	501	63	22	1,03
Pontic sigillata PS3																								
5180	Olbia	55,71	0,807	14,46	6,70	0,106	4,20	13,47	1,43	2,94	0,185		265	176		85	542		153		282			3,09
5184	Olbia	55,70	0,811	14,44	6,71	0,102	4,26	13,47	1,34	2,98	0,195		261	169		102	519		134		287			3,21
C435	Nymphaion	55,63	0,763	13,49	6,30	0,109	3,61	16,20	1,18	2,48	0,249	103	260	131	95	90	587	24	169	11	517	53	13	5,30
C439	Nymphaion	53,46	0,786	14,10	6,68	0,094	3,84	16,67	1,31	2,88	0,190	135	250	147	106	99	495	24	155	12	286	64	18	8,20
F219	Nymphaion	50,79	0,782	13,87	6,53	0,094	4,23	19,78	1,16	2,56	0,210	124	267	148	79	89	572	18	143	19	346	53	10	9,81
F798	Nymphaion	51,34	0,820	14,91	7,09	0,097	4,99	16,48	1,18	2,92	0,177	135	276	151	80	101	473	19	130	18	291	51	9	0,84
F799	Nymphaion	54,74	0,863	15,21	7,43	0,100	4,13	13,15	1,33	2,86	0,192	126	316	163	83	97	430	20	141	17	310	48	3	3,98
F807	Nymphaion	53,27	0,826	14,77	6,99	0,099	4,18	15,68	1,20	2,77	0,213	127	287	160	76	100	499	21	144	19	295	66	8	5,94
F813	Nymphaion	53,35	0,794	14,54	6,72	0,116	3,87	16,47	1,12	2,87	0,150	126	253	144	76	101	598	23	141	12	312	58	7	5,70
F817	Nymphaion	55,51	0,860	15,26	7,58	0,099	3,89	12,50	1,20	2,95	0,156	163	301	176	80	109	455	23	141	12	315	58	10	4,54
F819	Nymphaion	52,45	0,806	14,25	6,89	0,094	5,35	16,00	1,22	2,71	0,223	141	291	155	80	89	515	22	142	12	306	56	1	5,91
G783	Nymphaion	55,57	0,874	15,64	7,28	0,111	4,22	11,90	1,36	2,86	0,199	115	283	155	96	103	582	24	158	13	331	60	8	0,00
MD2571	Chersonesos	53,38	0,828	15,60	7,31	0,144	3,95	14,53	1,18	2,81	0,265	153	262	135	95	115	470	24	138	12	463	66	26	4,79
MD3203	Alma Kermen	55,30	0,856	15,12	7,23	0,099	4,33	13,02	1,39	2,53	0,128	116	296	144	76	106	739	22	169	12	330	51	19	6,13
MD3209	Alma Kermen	56,93	0,867	14,54	7,08	0,098	3,93	12,63	1,34	2,43	0,159	130	292	140	78	101	437	24	172	12	286	53	8	2,72
MD3210	Alma Kermen	54,35	0,826	14,57	6,94	0,093	3,86	15,19	1,54	2,49	0,136	106	288	137	72	103	708	23	173	12	346	58	11	5,18
MD3211	Alma Kermen	56,61	0,750	13,81	6,32	0,104	3,58	14,85	1,56	2,29	0,128	127	231	133	85	98	549		158		275			4,90
MD3219	Alma Kermen	56,97	0,852	14,14	7,16	0,092	4,10	12,97	1,40	2,19	0,148	143	299	150	69	87	471	24	161	17	309	58	35	1,26
MD3513	Alma Kermen	56,21	0,882	15,46	7,31	0,084	4,26	11,00	1,58	2,70	0,511	132	320	171	103	108	665	25	176	13	296	56	84	4,47
MD3595	Alma Kermen	54,99	0,843	14,70	7,24	0,094	4,07	13,68	1,60	2,64	0,137	129	274	169	104	106	642		158		297			7,24
MD3597	Alma Kermen	55,34	0,813	14,20	7,00	0,092	3,92	14,74	1,36	2,39	0,142	102	281	169	84	106	540		164		302			4,16
MD3619	Alma Kermen	58,66	0,813	13,61	6,48	0,093	3,55	12,84	1,38	2,43	0,138	114	295	145	79	92	621	24	180	12	517	50	18	6,27
MD5101	Balaklava	56,41	0,840	14,81	7,05	0,126	4,23	12,03	1,11	2,97	0,431	114	291	175	101	116	518	17	187	11	618	51	12	3,79
MD5088	Balaklava	54,94	0,824	14,56	6,93	0,113	4,13	14,13	1,01	3,01	0,369	119	301	179	99	113	496	20	178	11	414	56	15	5,62
Pontic sigillata PS4																								
C455	Nymphaion	58,85	0,763	17,99	6,39	0,063	1,81	9,87	0,71	3,32	0,027	138	114	59		140	451	29	178	13	373	74	15	2,15
M645	Chersonesos	56,39	0,833	23,54	7,90	0,044	1,85	5,16	0,40	3,75	0,123	203	143	77	128	180	145	28	149	15	420	87	22	0,22
M646	Chersonesos	55,31	0,824	21,95	7,62	0,053	1,80	8,03	0,81	3,39	0,214	170	130	71	119	165	170	27	145	14	412	67	23	0,80
M647	Chersonesos	55,41	0,826	22,02	7,64	0,055	1,79	7,94	0,74	3,44	0,150	180	130	72	123	166	170	30	144	16	406	66	23	0,77
M649	Chersonesos	57,19	0,851	21,48	7,43	0,054	1,69	7,22	0,48	3,46	0,153	165	122	73	120	161	159	29	147	15	403	81	23	0,85
M650	Chersonesos	55,48	0,825	22,07	7,63	0,053	1,79	7,92	0,66	3,43	0,156	172	137	73	124	166	171	28	143	14	395	60	18	0,83
V204	Chersonesos	57,80	0,856	21,12	7,04	0,061	1,64	7,67	0,42	3,25	0,142	187	136	81	125	155	166	30	150	17	418	86	21	0,54
MD2572	Chersonesos	58,63	0,790	19,24	6,65	0,129	1,97	7,85	1,05	3,45	0,231	144	113	58	107	147	219	27	155	14	449	87	31	2,66
MD2574	Chersonesos	60,95	0,901	17,88	6,92	0,099	1,93	7,10	0,90	3,14	0,184	127	114	54	113	139	207	31	175	17	462	67	28	2,83
MD2575	Chersonesos	57,95	0,857	22,22	7,69	0,069	1,74	5,06	0,68	3,60	0,123	178	136	71	121	174	143	31	151	17	456	69	28	0,01
MD3178	Alma Kermen	62,35	0,839	17,65	6,43	0,074	1,49	7,29	0,55	3,19	0,133	136	111	66	86	140	297	31	174	15	362	71	20	1,93
MD3185	Alma Kermen	63,20	0,839	18,07	6,47	0,075	1,62	5,31	0,88	3,41	0,136	132	114	70	128	135	494	27	179	17	354	68	26	3,66
MD3187	Alma Kermen	59,23	0,770	18,08	6,36	0,126	2,09	8,51	1,76	2,90	0,178	127	106	61	96	128	324	28	162	14	463	61	22	1,35
MD3188	Alma Kermen	63,98	0,629	15,63	5,47	0,047	1,60	8,48	0,97	3,04	0,157	109	91	55	83	117	478	22	164	11	333	47	18	4,50
MD3189	Alma Kermen	64,99	0,697	16,50	5,95	0,046	1,44	6,57	0,64	3,05	0,127	131	101	58	72	135	285	23	157	14	338	63	18	1,20
MD3191	Alma Kermen	58,75	0,807	19,14	6,79	0,089	1,68	8,56	0,73	3,32	0,156	142	117	66	110	149	226	31	161	15	388	83	22	1,20
MD3192	Alma Kermen	58,85	0,763	17,99	6,39	0,063	1,81	9,87	0,71	3,32	0,233	138	114	59	97	140	451	29	178	13	373	74	15	2,15
MD3193	Alma Kermen	59,51	0,834	20,57	7,54	0,056	1,75	4,90	0,90	3,65	0,289	143	121	78	154	146	630	28	166	16	368	78	21	4,40
MD3194	Alma Kermen	63,07	0,747	18,74	6,66	0,064	1,56	5,11	0,40	3,50	0,157	130	108	81	116	131	608	22	166	13	389	60	23	5,80
MD3195	Alma Kermen	60,69	0,749	17,74	6,37	0,060	1,62	9,12	0,47	3,07	0,118	132	118	63	93	131	348	28	209	15	357	63	19	1,93
MD3196	Alma Kermen	56,43	0,809	20,41	7,32	0,070	1,88	8,61	0,61	3,69	0,176	161	119	69	112	160	318	30	154	17	406	81	25	1,69
MD3198	Alma Kermen	56,71	0,775	19,36	7,10	0,071	1,85	9,52	0,95	3,53	0,134	146	120	70	135	140	310	26	151	17	415	69	20	8,45
MD3199	Alma Kermen	59,04	0,873	20,78	7,33	0,053	1,69	6,16	0,39	3,58	0,120	147	128	76	98	159	214	29	152	17	422	74	23	1,20
MD3208	Alma Kermen	62,53	0,872	18,93	6,74	0,083	1,58	5,18	0,67	3,31	0,103	138	110	70	109	141	270	31	165	16	404	72	18	4,39
MD3213	Alma Kermen	59,37	0,849	20,73	7,20	0,057	1,67	5,94	0,67	3,38	0,131	143	119	75	114	146	336	27	158	17	392	85	19	3,28
MD3216	Alma Kermen	59,03	0,792	18,72	6,72	0,058	1,69	8,49	0,44	3,90	0,162	148	121	64	91	148	261	29	177	18	360	75	23	1,78
MD3217	Alma Kermen	60,28	0,758	17,24	6,29	0,063	1,75	9,46	0,79	3,17	0,203	125	115	57	84	129	477	26	186	15	440	62	22	2,63
MD3221	Alma Kermen	64,92	0,699	15,79	5,72	0,067	1,31	6,93	0,56	3,84	0,178	121	109	56	91	111	364	25	197	13	358	71	23	5,66

Table 2 (cont.)

Lab.-no.	find spot	SiO2 wt.%	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	P2O5	V ppm	Cr	Ni	Zn	Rb	Sr	Y	Zr	Nb	Ba	Ce	Pb	l.o.i. %
MD3491	Alma Kermen	62,70	0,765	19,06	6,71	0,054	1,53	5,38	0,45	3,17	0,180	133	122	75	113	132	861	24	193	13	416	65	23	5,56
MD3493	Alma Kermen	61,02	0,817	19,64	7,72	0,247	1,66	4,83	0,81	3,08	0,177	153	135	88	122	130	374	28	185	15	693	62	69	5,07
MD3494	Alma Kermen	60,10	0,742	16,84	6,06	0,059	1,73	10,29	0,80	3,24	0,141	111	122	59	93	130	320	27	192	16	451	78	27	2,18
MD3496	Alma Kermen	62,71	0,699	17,48	6,13	0,047	1,58	6,77	0,91	3,51	0,172	135	113	67	106	142	342	24	162	15	334	61	20	3,03
MD3498	Alma Kermen	61,62	0,783	17,74	6,43	0,065	1,46	7,91	0,76	3,09	0,144	128	115	76	106	128	550	27	194	16	388	63	27	6,64
MD3500	Alma Kermen	62,39	0,707	17,19	6,20	0,054	1,42	8,73	0,33	2,89	0,088	128	110	68	108	121	794	23	179	14	761	70	21	8,43
MD3501	Alma Kermen	64,03	0,860	18,64	6,79	0,066	1,47	4,15	0,39	3,41	0,197	147	123	79	117	145	282	28	179	18	376	71	237	4,68
MD3508	Alma Kermen	58,56	0,727	18,38	6,54	0,057	2,06	9,40	0,74	3,41	0,126	138	121	69	107	142	422	27	169	14	343	72	25	3,73
MD3510	Alma Kermen	59,64	0,839	19,33	6,67	0,074	1,59	7,27	0,76	3,69	0,150	145	124	72	103	144	276	30	162	17	403	79	25	1,85
MD3511	Alma Kermen	60,98	0,732	17,82	6,31	0,058	1,61	8,33	0,78	3,24	0,133	144	121	65	90	134	318	28	174	15	361	71	21	2,30
MD3514	Alma Kermen	56,77	0,826	20,69	7,11	0,092	1,72	8,88	0,53	3,28	0,107	157	137	73	122	159	258	25	152	17	463	90	34	1,58
MD3515	Alma Kermen	63,05	0,715	17,73	6,31	0,051	1,45	7,07	0,60	2,91	0,129	121	115	74	123	126	670	23	146	14	664	66	21	7,24
MD3517	Alma Kermen	61,39	0,882	20,46	6,96	0,074	1,54	3,70	0,42	4,43	0,142	152	125	78	130	142	309	29	162	17	437	93	97	5,20
MD3584	Alma Kermen	61,70	0,783	18,98	7,04	0,069	1,78	5,02	0,79	3,70	0,150	142	118	89	170	153	388		167		407			7,20
MD3585	Alma Kermen	56,47	0,829	20,92	7,45	0,076	1,70	8,32	0,63	3,49	0,098	151	113	71	129	170	165		146		418			1,47
MD3591	Alma Kermen	55,29	0,826	22,16	7,89	0,053	1,77	7,98	0,60	3,30	0,123	163	124	82	187	195	204		150		407			0,53
MD3604	Alma Kermen	64,18	0,759	16,90	6,27	0,049	1,52	6,32	0,57	3,34	0,049	128	102	61	107	158	229		195		389			2,71
MD3609	Alma Kermen	60,20	0,827	18,21	6,80	0,074	1,53	8,11	0,72	3,39	0,153	120	114	67	94	156	261		171		369			2,26
MD3610	Alma Kermen	56,27	0,733	18,69	6,87	0,073	1,94	11,51	0,58	3,21	0,116	112	91	71	124	159	369		138		372			0,31
MD3611	Alma Kermen	63,49	0,688	16,70	6,24	0,066	1,49	7,32	0,70	3,18	0,113	125	104	64	78	144	284		158		416			2,94
MD3613	Alma Kermen	59,42	0,848	19,64	6,77	0,075	1,57	7,63	0,62	3,27	0,165	141	115	93	134	172	198		156		450			3,38
MD3614	Alma Kermen	57,50	0,860	21,08	7,59	0,079	1,78	6,10	1,14	3,77	0,107	140	123	89	144	168	281		149		454			3,85
MD3617	Alma Kermen	58,14	0,817	20,23	7,02	0,056	1,67	7,90	0,71	3,32	0,141	138	114	75	123	174	273		156		453			3,08
MD3621	Alma Kermen	61,94	0,842	18,80	6,65	0,068	1,74	6,44	0,37	2,98	0,171	139	128	74	122	139	519	30	184	15	427	77	24	7,92
MD3624	Alma Kermen	60,74	0,802	17,42	6,50	0,075	1,47	9,03	0,75	3,07	0,139	124	102	72	97	150	424	35	181	22	574	65	13	2,59
MD3626	Alma Kermen	63,13	0,729	18,64	6,60	0,047	1,63	5,18	0,68	3,25	0,125	125	120	71	110	126	754	25	158	15	1202	58	24	6,06
MD3627	Alma Kermen	59,01	0,712	17,40	6,10	0,062	1,72	11,00	0,72	3,15	0,122	132	119	62	94	132	337	27	176	15	604	72	22	2,52
MD3628	Alma Kermen	56,29	0,718	18,89	6,51	0,051	1,64	11,81	0,48	3,41	0,195	140	118	67	100	143	374	25	151	15	482	86	21	2,96
MD3629	Alma Kermen	59,79	0,836	20,06	7,26	0,080	1,61	5,18	0,58	4,47	0,126	148	123	94	127	145	311	29	166	18	404	82	28	6,49
MD5102	Balaklava	58,40	0,777	18,94	6,62	0,097	1,54	9,47	0,40	3,57	0,194	153	117	67	91	161	210	21	178	12	474	67	18	2,00
MD5091	Balaklava	56,67	0,816	21,61	7,48	0,058	1,68	7,45	0,38	3,71	0,159	161	127	81	115	189	178	23	173	15	457	76	19	0,83
MD5094	Balaklava	56,63	0,814	21,51	7,43	0,090	1,68	7,61	0,38	3,70	0,156	167	125	82	118	189	182	22	170	14	473	73	18	0,84
MD5085	Balaklava	55,45	0,775	21,67	7,41	0,108	2,11	7,98	0,56	3,81	0,116	159	127	84	133	197	245	21	166	12	458	75	21	0,79
Bosporan Ware																								
C457	Nymphaion	69,86	0,874	14,09	6,40	0,096	2,07	2,20	1,71	2,52	0,180	105	120	40	85	85	246	28	247	8	636	56	24	1,30
C459	Nymphaion	67,43	0,842	15,33	6,84	0,050	1,77	2,80	1,56	3,15	0,235	119	133	36	85	97	251	31	333	13	429	70	17	3,10
C460	Nymphaion	70,66	0,794	13,55	5,57	0,113	1,58	3,36	1,87	2,35	0,166	85	101	39	72	82	197	28	269	12	490	72	21	1,50
C461	Nymphaion	71,09	0,847	13,61	6,01	0,095	1,84	2,38	1,61	2,35	0,183	108	124	41	79	84	209	28	276	10	414	68	19	0,70
F223	Nymphaion	69,95	0,768	14,17	5,56	0,096	1,89	3,44	1,44	2,41	0,283	108	116	49	61	89	193	22	227	17	474	59	14	1,16
F225	Nymphaion	69,39	0,878	14,35	6,36	0,106	2,12	2,59	1,55	2,48	0,183	113	130	53	61	83	229	25	257	20	460	80	16	1,24
F226	Nymphaion	71,62	0,724	13,77	5,23	0,111	1,62	2,77	1,36	2,58	0,215	100	100	52	77	78	190	21	215	16	441	53	18	4,00
F228	Nymphaion	70,59	0,845	13,53	5,95	0,091	1,87	2,81	1,55	2,57	0,199	111	132	52	59	77	217	24	242	17	405	74	18	2,47
G798	Nymphaion	68,61	0,897	14,73	6,37	0,101	2,09	2,54	1,74	2,73	0,188	104	134	52	83	84	293	27	252	11	404	75	13	2,00
M643	Nymphaion	65,02	0,914	17,02	7,59	0,102	2,29	3,13	1,21	2,54	0,197	153	140	57	94	98	286	31	207	11	393	74	25	2,94

Table 2 (cont.)

At Alma Kermen the most frequent group of Pontic *sigillata* is PS4 (Chersonesian *sigillata*?), while only one sample of PS4 was detected among the Pontic *sigillata* analysed from NE-Crimea. Very probably PS4 was produced within SE-Crimea. Compared to the other reference groups the variation of strontium content in PS4, given as standard deviation in **Table 1**, is extraordinarily high. There is, however, no correlation with the also largely varying calcium content. In some cases elevated strontium is connected with elevated barium. An explanation may be that the sherds in Alma Kermen underwent a secondary alteration effect from soil surrounding the buried sherd. Ten samples of PS4 found in Chersonesos (provided by D. Zhuravlev) and Balaklava (provided by R. Szczypiorski-Karasiewicz) have lower strontium levels, possibly indicating different burial conditions. The latter samples are also distinguished by their higher aluminium and lower silica contents as a second group of PS4, probably representing the true Chersonesian *sigillata*.

Pontic *sigillata* PS4, local bricks, pottery, wasters from various sites in SW-Crimea (Alma Kermen, Chersonesos, Kazackaja, Balaklava, Charax) and clay samples, for example, from Sevastopol, represent a typical composition of SW-Crimea which differs from that of similar material in NE-Crimea, including Bosporan *sigillata* (BS) and local ceramics from Nymphaion (Daszkiewicz and Schneider 2005; 2006; Schneider 1996; Schneider, Daszkiewicz and Langner 2006).

Pontic *sigillata* groups PS1 and PS2 correspond to Pontic *sigillata* A (Domżalski 1996; 1999; Zhuravlev 2000). The only three analysed samples of Pontic *sigillata* B could not be securely attributed to any group. Pontic *sigillata* C is chemically correlated to PS3. The latter group, because of the geochemical relation to ophiolithic rocks, certainly was not produced in the northern Pontus (which cannot be excluded for PS1 and PS2) but more probably on the southern or eastern coast of the Black Sea. There is also no reliable clue to the places of production of analysed Late Roman tablewares such as Pontic Red Slip ware and Late Roman Pontic Burnished ware. From finds outside the Crimea, samples of Pontic *sigillata* were analysed from Olbia (PS1, PS2, PS3), Histria (PS2) and Carthage (PS2). No Moesian *sigillata* was detected among sherds from Crimea within our series of analyses.

In conclusion, it has to be said that many questions remain unresolved and can only be answered based on reliable chemical data from further samples collected in the future, as this would enable the secure definition of far-traded archaeological wares. For the geographical attribution of chemical groups we need to analyse reliably identified local ceramics from workshop finds, as we have done, for example, in the case of Moesian *sigillata*.

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