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ARCHAEOLOGICALMATERIAL

MATERIAL ANALYSIS OF 'BATAVIAN' POTTERY FROM ROMAN DACIA: X-RAY FLUORESCENCE AND GRAPH CLUSTERING

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Abstract: This research presents a material analysis of pottery discovered at the Roman Dacia stationing site of the *ala I Batavorum milliaria*. Employing portable X-Ray Fluorescence Spectrometry (XRF) on 69 pottery fragments, the study investigates Batavian material identity, local pottery production, and potential cultural connections. Through agglomerative hierarchical clustering of elemental compositions, the analysis identifies distinct groups of ceramics, including likely imports from the Rhine area, local imitations of local imitations of regional grey ware, and common 'Dacian' pottery. The findings provide a quantitative approach to complement traditional ceramic analysis, supporting the concept of conserved practices in pottery production and offering insights into raw material procurement and production techniques. The study underscores the potential of elemental analysis for understanding material culture, production practices, and cultural exchange in the Roman period, while noting the need for further research with comparative data.

Keywords: *Batavian Pottery, X-Ray Fluorescence (XRF) spectrometry, Material Analysis, Cluster Analysis, Pottery Production.*

INTRODUCTION

Pottery is an important source for the reconstruction of socio-economic realities in Antiquity. It is not subjected to taphonomic decay as other materials and it forms the largest part of the preserved and archaeologically discovered material culture. For the Roman period, pottery reveals everyday life habits, as well as clues on socio-economic traits, migration and groups' interactions.

Typological analysis usually supports interpretations regarding trade routes and the exchange of goods, but is also revealing on cooking and eating habits.[1] The conclusions of 'traditional' types of analyses can be subsequently tested and enhanced through chemical analyses of the clay and the residues from the pots. The development of affordable portable analytical methods has made it possible to characterize significant quantities of samples. Artefacts can be analysed quickly, easily, and non-destructively using portable X-ray fluorescence spectrometry. This method meets the requirements of archaeologists who aim to obtain the maximum amount of information, non- (or minimally) destructive, from minute samples or directly *in situ* from intact objects. Thus, pottery analysis has received renewed attention in recent

[1] DAVIES 1971; DICKSON 1989; PEARCE 2002.

decades, with numerous published papers on the feasibility of portable chemical methods for ceramic classification and provenance research.

HISTORICAL CONTEXT

2.1. The troop. Our research question is circumscribed to Batavian material identity: the Batavians were some of the Roman Empire's best-established auxiliaries,[2] with a high-profile presence in the Principate army, but their material culture is remarkably unspecific. Unlike the neighbouring *Cananefates* tribe,[3] for example, who retain their hand-made pottery well into the 2nd C AD, the Batavians adopt Roman-style pottery and a generally 'Roman looking' material culture from the middle of the 1st C BC, when they emerge into history.

The history of the Batavian tribe is intertwined with their status of military ethos, providing elite soldiers for Rome's army. In exchange of these levies, they were exempt from paying taxes and the tribe controlled a rather large *territorium*.[4] Regardless these privileges and their proven quality as loyal and skilful soldiers, in 69 AD the relationship with the imperial power deteriorated gravely and in the context of the civil war from Rome, the Batavians were the protagonists of one of the fiercest rebellions of the 1st C AD. After peace was reached, the Batavians more or less came back to having the same status as before within the imperial fold. The troops recruited mainly from the mist of the tribe and having the *Batavorum* epithet were four cohorts and an *ala milliaria*.[5]

The *ala* was, of course, the elite troop. After stationing in Germania Inferior, in 112[6] we find it attested as part of the army of Pannonia Superior. It was likely deployed here in preparation for Trajan's Dacian wars, particularly the second one (105-106). A few years into Hadrian's reign, it was deployed to Dacia and stationed at Războieni-Cetate, located in Dacia Superior in the proximity of the XIII Gemina legion fort at Apulum (modern Alba Iulia).[7] It stationed here until the abandonment of the province.

2.2. The fort in Dacia. So, what do we have at Războieni, the home of the *ala Batavorum* from Roman Dacia? Visible on a magnetometric prospection,[8] we get a plan of the settlement open to interpretations. First of all, there is the *castrum*, the fort, the interior of which covers an area of about 5.2 hectares. It is a large precinct, almost double those of a normal auxiliary fort, but this comes as no surprise, as the troop was of 1000, not 500 men, plus the horses. The central components of the system have been identified (Fig.1): the administrative headquarters (*principia*), barracks, the commander's quarters (*praetortium*) and the grain storage (*horreum*). In addition, a large part of the fortification system consisting of two parallel ditches was detected.

Outside the fort, to the west, there is a cluster of buildings that were part of the village. Of course, most of the buildings in this *vicus* must have been made of easily perishable materials (wood, unburnt bricks) and on the geophysical representation we can only see those with stone foundations. Few buildings belonging to the western *vicus* can be clearly delineated and of these the most impressive is the one visible outside the fort, on its north-western corner: a 23 x 20 m building consisting of several rooms and situated about 20 m from the north-west corner of the fort. Some of the most important archaeological excavations undertaken at the site during the last few years are within this building, named Edifice I for publication purposes.

In the northern part of the area there is a high concentration of kilns, which confirms the field observations, as in that area there has always been a high density of ceramic materials, moulds, poinsons, and pottery debris (with green on Fig.1). It is very likely that most of the settlement workshops were located in this area.

The structures identified in the farthest northern area are also very important. First of all, we point out the yellow structure in the north-west, very visible on the plan, but which does not indicate an ancient feature, but the modern gas pipe which, being metallic, perturbs the magnetometer and produces an anomaly in reading the results in the whole surrounding area. Very interesting are the four clusters of stone buildings visible in the far east. These are more than 130 m away from the area that has been determined with certainty to belong to the *vicus* and are most likely *villa rustica* type complexes, administering land and serving to supply agricultural products to the fort and the villagers. *Villae rusticae* in close proximity to legionary and auxiliary troop camps are by no means unknown, however, and such building ensembles are documented.[9] One of the structures is atypical in that there were at least eight ovens between the smaller buildings. There is a possibility that this complex had a craft role.

However, as mentioned above, it is possible that numerous buildings, light constructions without stone foundations, existed between those visible on the magnetometer scan. The presence of these, as the minute features of all those identified non-invasively, can only be made out by intrusive archaeological investigation. What we know so far is that the *ala* created a local center around it – production and habitation alike – which was prosperous enough to become an economic hub for the area. The economic development of a settlement is deeply dependent on the local society and vice versa. An

[2] DERKS 2009; DERKS/TEITLER 2018.
[3] DE BRUIN 2019.
[4] ROYMANS 2004, 208.
[5] On the reorganization of the Batavian cohorts, see Alföldy 1968, 47-48. Cohorts I and II are documented for the first time outside of Britain for Pannonia in a diploma from 98 AD (CIL XVI 42). From there the first cohort is transferred to Dacia (Weiss 2002), the second to Noricum (CIL XVI 174). The Vindolanda tablets show that cohorts III and IX are still in Britannia around 90 AD (van Rossum 2004, 117; Birley 2009) The third cohort is attested in Raetia in a diploma from 107 AD (CIL XVI 55) and after 135 AD, it is transferred to Pannonia Inferior and replaced in Raetia by the Cohors IX (Lörincz 2001, no. 305). So, around 130 AD the four Batavian cohorts are in different provinces, with Dacia being the only province in which two Batavian units were stationed (one cohort and one ala).
[6] HAALEBOS 2000.
[7] AE 1997, 1782; MÓCSY, *Pannonia. B) Auxiliartruppen*, RE Suppl. IX, Sp. 618; PISO/BENEA 1984, 278; PETOLESCU 2002, 64; WAGNER 1938, 16; BĂRBULESCU 2012, 55; PISO 2014, 125-146.
[8] MISCHA/RUBEL/VARGA 2018.
[9] VON PETRIKOVITS 1979, 63; OLTEAN 2007, 145, 180 sqq.

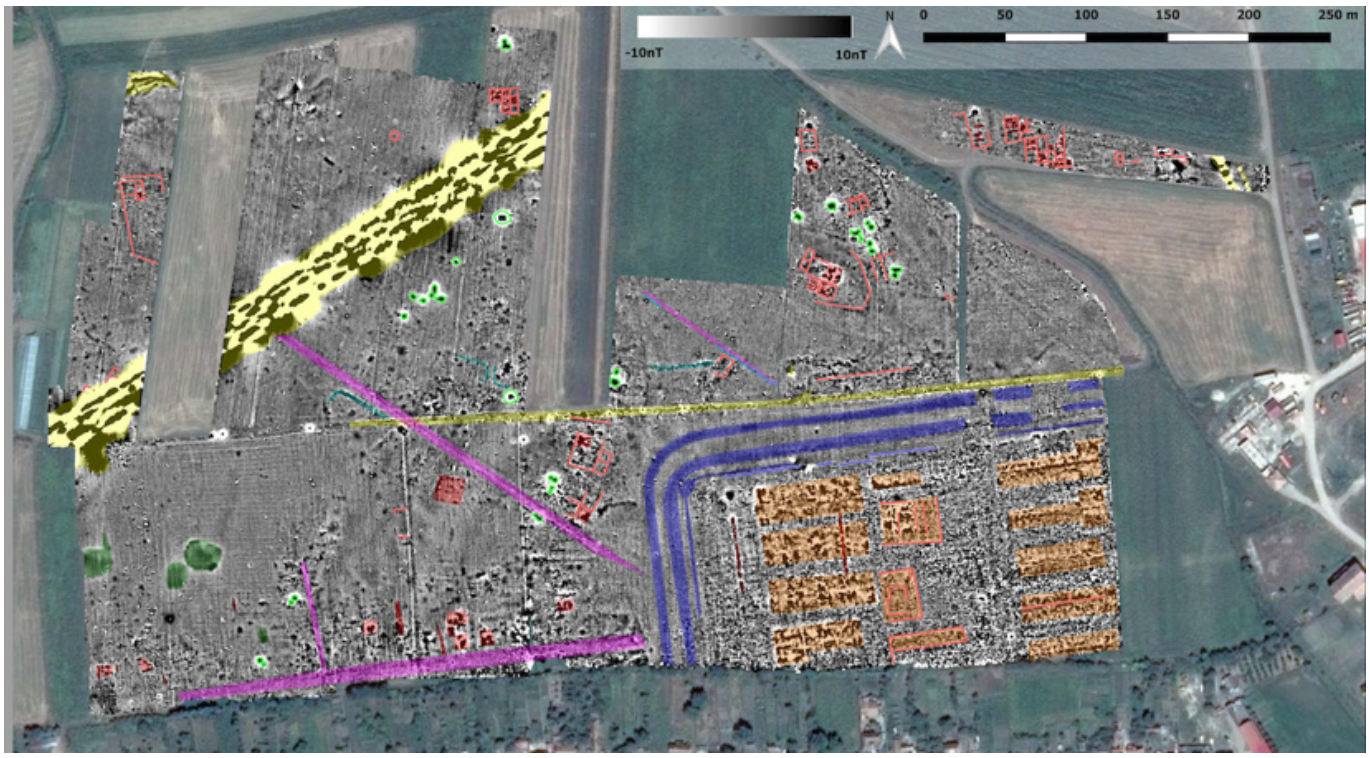

Fig. 1. Magnetometric map of the Războieni fort and settlement (after MISCHA/RUBEL/VARGA 2018).

agricultural production center encourages the development of different social patterns than a commercial hub, for example. Similarly, a rural settlement based on production for consumption generates a different society than a settlement marked by a constant monetary inflow.

2.3. Pottery analyses. Our current investigation is focused on pottery from this site. A previously undertaken quantitative and qualitative assessment of the pottery[10] showed that the range of forms from Războieni is quite high, consisting of ten different vessel categories. The most popular vessels, however, are the bowls, followed by jars and dishes. This essentially means that tableware and cookware were the two most used functional items. Regarding fabrics, the most common ones are the oxidised fabrics, followed by local *terra sigillata*, of which two types of imitations have been identified. The reduced fabrics showed a less significant quantity. The form types have been studied through the broader lens of forms. Within the reduced greywares fabric category, the main forms to be used at Războieni over the 2nd and 3rd C AD were the flat rim jars. Within the oxidised category, the flagons took up most of the quantity, followed by tabelwares: bowls and dishes.

Investigating pottery can provide valuable information about the raw materials used, the production processes employed, and the date and place of production.[11] There are numerous characterization techniques available that can shed light on these aspects. As the clay chemical imprint differs from region to region, but it can also be influenced by the burning techniques, we tried to see how the sample from the site of the *ala* shows.

[10] VARGA/CRIZBĂȘAN 2024.
[11] UZ *et al.* 2015, 628.

3. MATERIALS AND METHODS

3.1. Samples. The sample employed for the present chemical analyses consists in 69 pottery fragments coming from the site of Războieni-Cetate. Some were discovered during archaeological excavations, mainly from the *vicus*, other from older private collections, so without exact finding spots (but with the certainty they were discovered within the perimeter of the settlement). The selected samples correspond to the most representative pottery products of the studied site. (Annex 1)

3.2. Elemental analysis. XRF analysis were performed using a Bruker Tracer 5i X-ray fluorescence equipment, with no filter, beam path atmosphere, (air between sample and detector, no vacuum) and default configuration (8mm collimator, Be window). For quantitative results, the software supplied by the manufacturer was used for all samples, with two-step analysis for each run (high-Z sweep, followed by low-Z sweep) for a total run of 60 seconds/sample. The table of elemental concentrations, expressed in mg/kg, are available in Annex 2. Some values are below the limit of detection (<LOD) for the analytical method used.

3.3. Statistical analysis. Agglomerative Hierarchical Clustering (AHC) using the Ward's linkage method and Euclidian squared distances as a measure of similarity was used to group the samples into groups based on their common elemental composition. For the statistical analysis of the data the XLStat Microsoft Excel plug-in (Addinsoft, Paris, France) was used. The dendogram resulted by applying AHC visually represents the dissimilarity between the samples. Samples that are grouped together in the same cluster are considered to have more similar characteristics to each other than to samples in other clusters based on the features used for clustering.

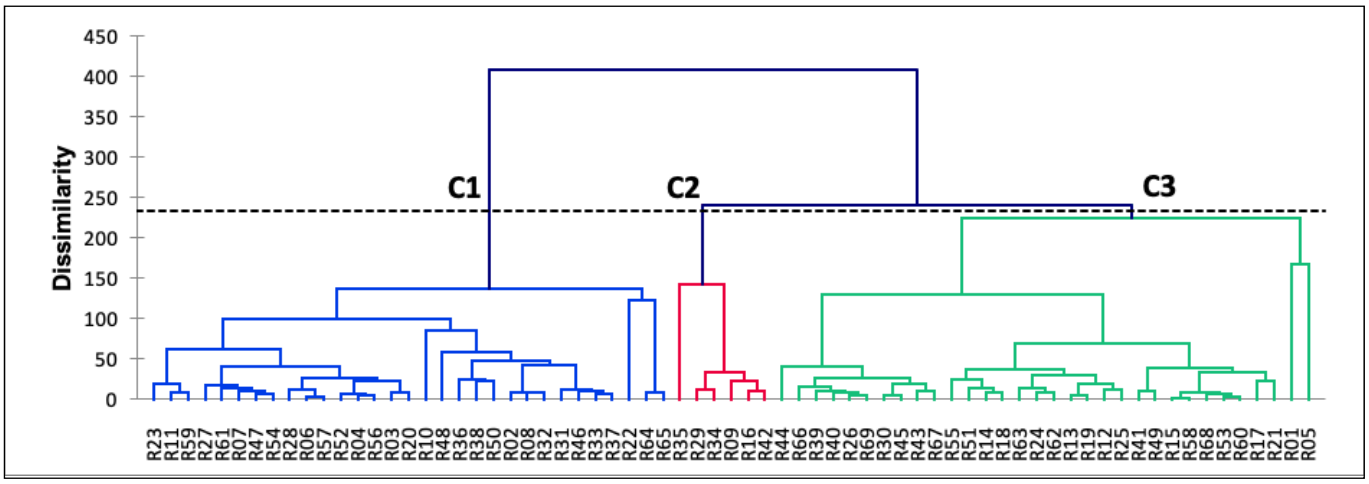

Fig. 2. Dendrogram showing the clustering of samples.

Fig. 3. Facepot with phallic symbols from Războieni (after VARGA/BOUNEGRU 2019, 230).

4. RESULTS AND DISCUSSION

4.1. Historical interpretation. In the examination of the results, we went from small to large, namely analysing sub-clusters and clusters starting from the artefacts whose origin we already knew (Figure 2).

By far, the most intriguing cluster is C3 that contains two artefacts which are known imports from the Rhine area, more exactly two fragmentary face pots (24 & 25). One of them is very fragmentary, with only the right eye of the human figure preserved, while the other is largely intact and has an interesting feature: two phallic representations, one on the back of the vessel and one on the left cheek of the human figure (Fig. 3).[12] In the 63-25 agglomeration we also have two beakers which are complete artefacts, unbroken and come from a private collection – thus we do not know the exact context of discovery (13 &19) (Fig. 4). Nonetheless, they have strong analogies in the Nijmegen area, where they are customary as funerary inventory.[13] As these two are unbroken beakers, we have always suspected them to come from graves. Additionally, the area of the fort and *vicus* has been the subject of constant agricultural works, and generally the state of the artefacts is worse, whereas the necropolis area was less exploited. Chemically, as they come from the same sub-cluster as the face pots, it is an excellent confirmation that they genuinely were imports from the Low Rhine area, brought here to be used for their owners' burials. The importing of funerary inventory makes sense from the perspective of the face pots as well. The earliest anthropomorphic continental Roman vases were found on the Rhine-Raetian border, exclusively as part of the Rhenish legionary repertoire of the first half of the 1st C AD.[14] Their distribution extends as far as the Upper Danube and the Low Countries, which is also the homeland of the Batavian troops; most anthropomorphic vessels come from Cologne,

[12] VARGA/BOUNEGRU 2019.

[13] AARTS/HEEREN 2017, 135.

[14] BRAITHWAITE 1984, 100.

Fig. 4. Funerary (?) beakers 13(a) &19(b) from Războieni.

Colchester and Nijmegen.[15] In Roman times, they continued to be used in burial rituals, but this function became adjacent to everyday use: in domestic altars, where sacrifices were offered daily in the name of a tutelary deity.[16] Three more pots are part of this sub-cluster (63, 62 & 12), of common forms and types, but good quality, so the possibility for them to be imports is high.

The sub-cluster of cluster C3 containing samples 44-67 is also intriguing. It contains most of the pottery that resembles the so-called Batavian grey ware (reduced domestic pottery) from the Low Rhine area.[17] Batavian grey ware (Fig. 5) is a type of Roman-period wheel-thrown ceramics that has only relatively recent been identified and defined in the Netherlands. Previous research has revealed that grey ware exhibits certain non-Roman characteristics, such as colour, particularly in the 2nd and 3rd C, and non-standardised typological variations. The oxidisation of coarse ware results in fabrics with brown, orange, and white (smoked) tones, while *regional grey ware* is characterised by various shades of grey. The high degree of variation in fabrics, colour, and vessel types suggests non-standardised regional or local manufacture.[18] Regarding typology and functionality, grey ware include a multitude of variations, due to the fact that they were home-made, functional pottery. The main groups are[19] bowls with a pronounced S-shape profile, pots with rolled and rounded rims, bowls with a flat rim, pots with a narrow, slightly sloping rim, pots with a narrow, solid rim and pots with an everted rim folded down. At Războieni, within the reduced grey wares fabric category, flat-rim jars emerged as the predominant form, followed by everted-rim pots. The bowls made in reduced fabrics were predominantly flanged, being more suitable for cooking or storing instead of serving.[20] (Fig. 6) In this particular instance, the analysed sherds are not imports, but rather local imitations. The combustion process in this instance is conventional, and it appears to have engraved a unique chemical imprint. The presence of burning-induce specificities indicates that these vessels were not stacked in a kiln, but rather subjected to a direct burning process, either in a pit or in the open air.[21] Should these artefacts be determined to be deliberate imitations of the specific grey ware of the Lowlands, this would be a significant development. The hypothesis that the artefacts were produced in a domestic environment suggests that the individuals in question relocated to Dacia with their family members, most likely their spouses. It is plausible that these women sought to maintain the customs, way of life and dietary habits of their place of origin. In essence, the foods people consume are deeply reflective of their social and cultural affiliations: social identity is often expressed and enacted through food,[22] with culinary practices serving as powerful tools for positioning oneself within a society. Hence, embracing, rejecting or emulating new foodways can signify changes within the social identity of individuals and communities.

The C2 cluster contains local pottery specimens. In this case, local means from the site, not the province, as we also have moulds and refusals. These artefacts becoming a conglomerate confirm the archaeologists' and pottery specialists' opinions which put them in the category of pots

[15] BRAITHWAITE 2007, 397
[16] BRAITHWAITE 2007, 396;
[17] COLLINS *et al.* 2009.
[18] COLLINS *et al.* 2009, 171.
[19] COLLINS *et al.* 2009, 175-181.
[20] VARGA/CRIZBĂȘAN 2024.
[21] RYE 1981, 96-98; COLLINS *et al.* 2009, 192.
[22] HASTORF 2016; TWISS 2012; TWISS 2019.

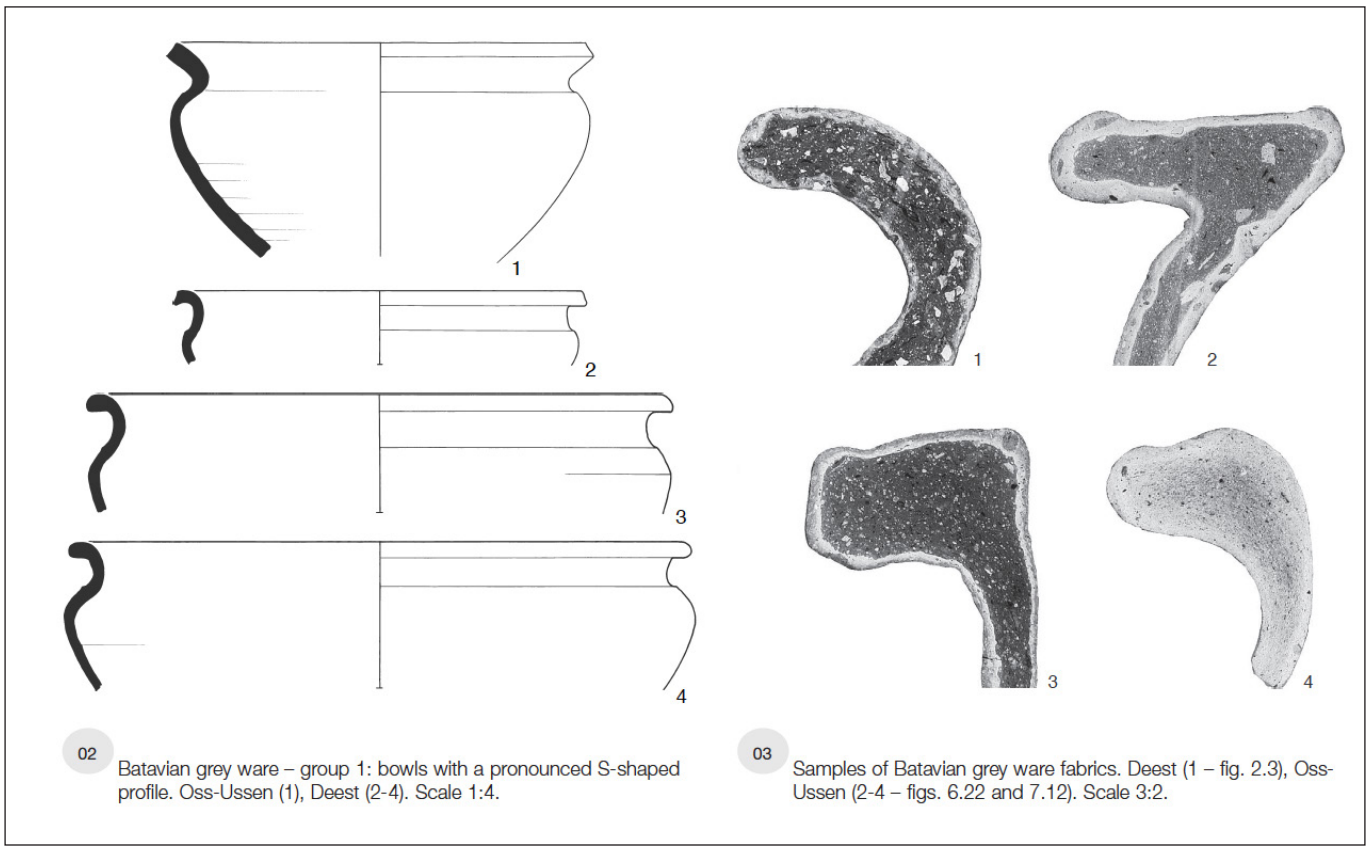

Fig. 5. Regional grey ware (Collins et al. 2009, 175).

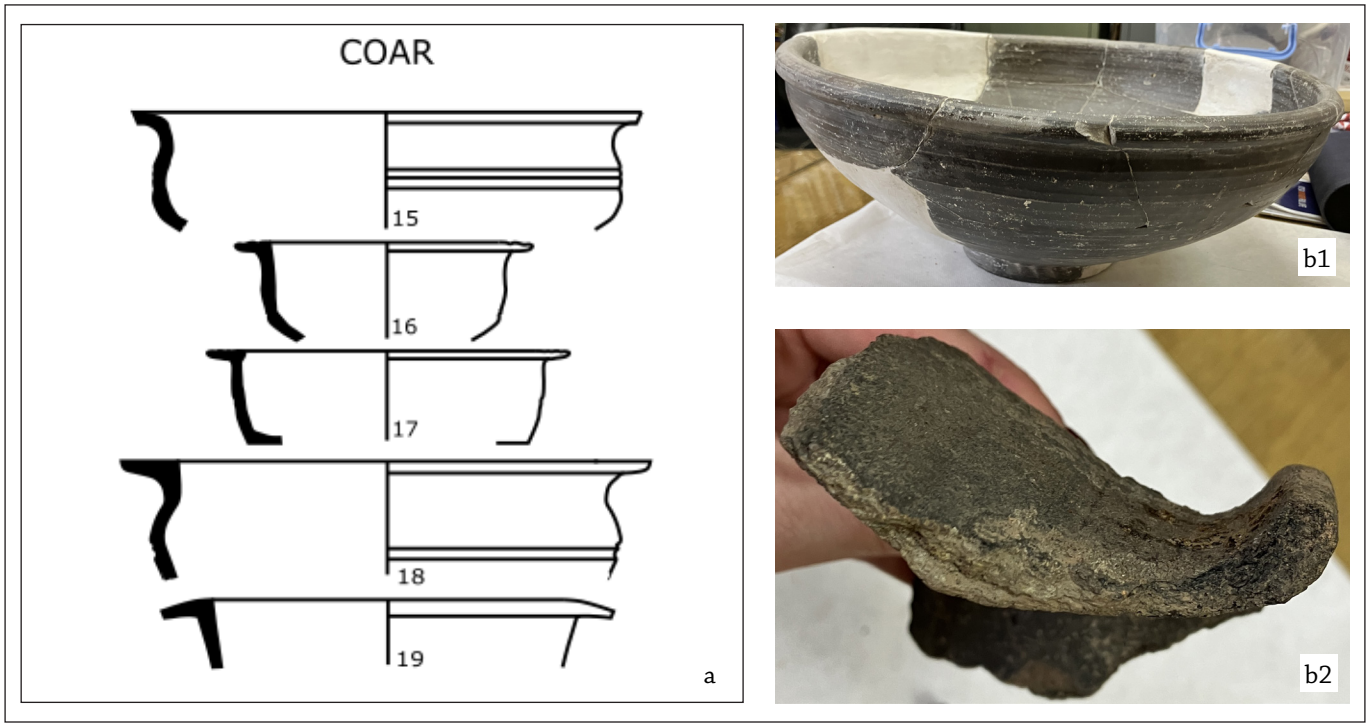

Fig. 6. Bowls made in reduced fabrics from Războieni, typologically and chemically resembling the Rhineland grey ware: drawing (a – Varga, Crizbășan 2024, 7) & photos (b1 & b2).

produced by local workshops from the village. Even when working on larger samples, attempts to distinguish individual pottery workshops based on chemical composition have rarely been successful,[23] as clay came from the same sources and employed burning techniques were often similar.

[23] ADAN-BAYEWITZ *et al.* 2009, 2517.

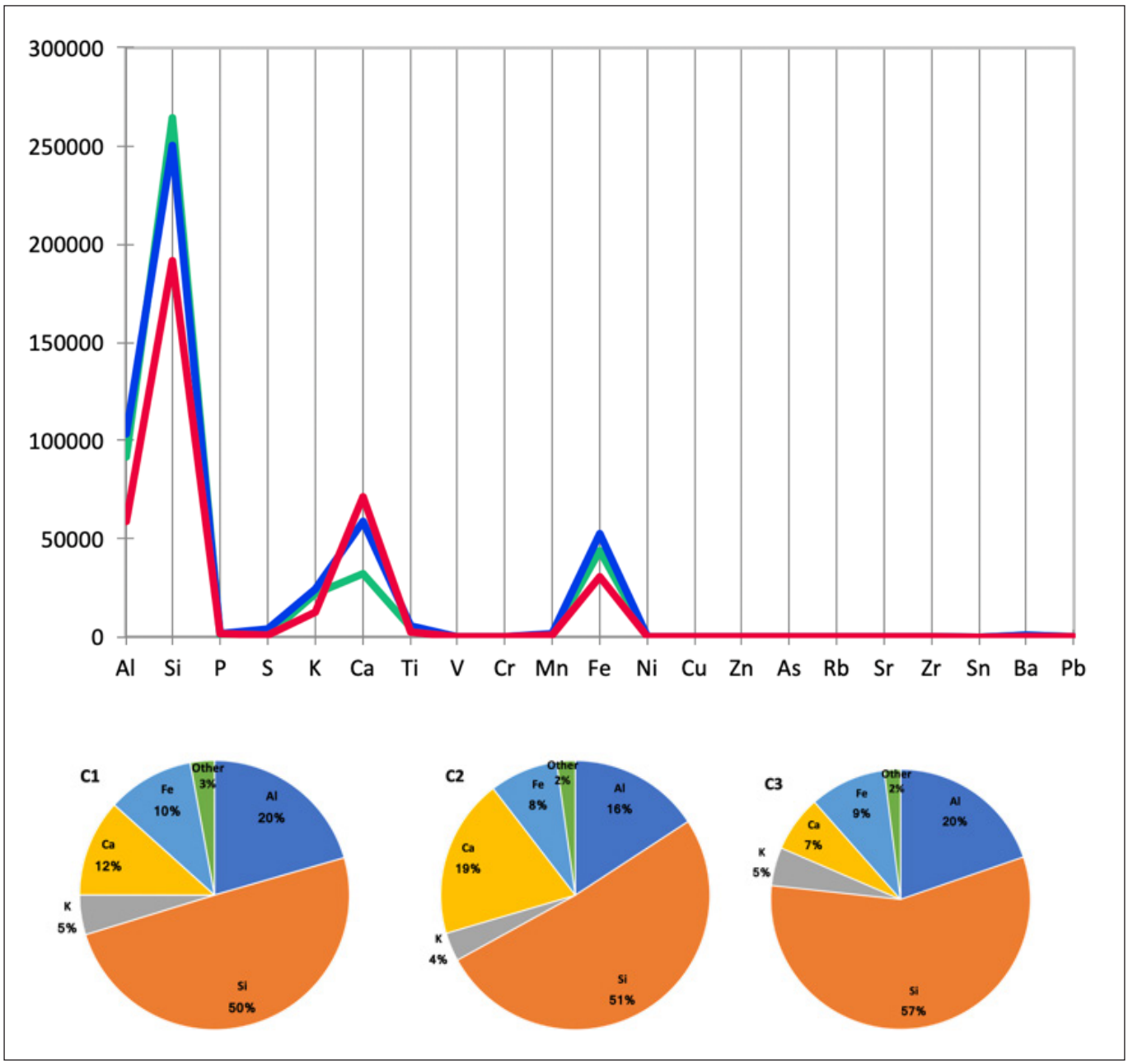

Fig. 7. Line graph illustrating the average elemental composition of the three clusters of ceramic sherds.

The C1 cluster contains more or less common 'Dacian' pottery. It includes local products, both oxidized and reduced, fine wares and course wares, cooking as well as serving vessels. Going into the sub-clusters, they don't display particular or unexpected specificities. This cluster is an excellent control cluster, because it confirms that certain models (*terra sigillata*, stamped pottery) are local products, as we have assumed in the past.[24]

4.2. Elemental composition. The elemental composition is dominated by Si, Al and Ca, representing about 50%, 20% and 15% of the total elemental content. These elements are accompanied by K and Fe in lesser amounts and traces of P, S, Ti, V, Cr, Mn, Ni, Cu, Zn, As, Sr, Ba and Pb. Some variabilities about the elemental contents are observed between the samples grouped in the 3 clusters.

Fig. 7a presents a line graph illustrating the average elemental composition of the three clusters of ceramic sherds. The X-axis displays various elements (Al, Si, P, S, K, Ca, Ti, V, Cr,-Mn, Fe, Co, Ni, Cu, Zn, As, Rb, Sr, Zr, Sn, Ba, Pb), and the Y-axis represents the concentration of these elements in mg/kg, consistent with Annex 2.

By inspecting the graph, we can observe the following general trends in the average elemental composition for each group:

Cluster 1 (Blue): Al and Si exhibit the highest average, with very well-articulated. Other elements are generally low, with a small peak visible for Ca (highly likely coming from Ca-rich temper, such as shell fragments or crushed limestone, added to improve its workability, reduce shrinkage during drying and firing, and enhance the strength of the final product)

[24] VARGA/CRIZBĂȘAN 2019.

Cluster 2 (Red): This group displays a different pattern. While Al and Si still show high average concentrations, the relative difference between these and other elements appears less extreme than in Clusters 1 and 3. Notably, Cluster 2 shows a more significant average concentration of Fe and Ca compared to the others.

Cluster 3 (Green): This group shows relatively high average concentrations of Al and Si compared to other elements. The concentrations of most other elements are considerably lower. There appears to be a noticeable peak for Ca, although smaller than Al and Si.

Fig. 7b presents the elemental display of each cluster. The graphs allow for a direct comparison of the average abundance of each measured element across the three groups, highlighting which elements are most responsible for the observed dissimilarities between the clusters, suggesting variations in raw material sources, production techniques, or potentially the origin of the pottery.

5. CONCLUSIONS

Ceramic analysis has been concerned with categorizing sherds to vessel types based on form, function, and style as a means to define a given material culture at a specific time. Individuals living in the same cultural, social, and physical environment tend, to a degree, to acquire a similar worldview, resulting in common behavioral traits that may be visible in material culture.[25] Drawing upon the preceding elemental analysis and cluster classification of ceramic sherds, this study provides insights into pottery production practices and potential cultural connections from the site of Războieni-Cetate.

Our findings indicate that elemental analysis, as presented in Annex 2 and visualized through cluster analysis in Fig. 2, offers a complementary and quantitative approach to traditional ceramic analysis based on morphology and style. he clustering of sherds with similar elemental compositions supports the notion of conserved production practices, potentially indicating continuity in both raw material procurement, through consistent sources of clay and temper, and adherence to established production "recipes," as reflected in shared elemental signatures.

While the current dataset lacks comparative elemental profiles of pottery samples from regions like the Low-Rhine area (as mentioned in your previous text), the methodology employed here provides a framework for future investigations. Should more elemental data from verified imports become available, direct comparisons with the identified clusters could potentially provide chemical evidence to support or refute importation hypotheses.

Similarly, the concept of local imitation of specific pottery types, such as Batavian greyware with its distinctive burning technique, could be further explored through elemental analysis. If the unique firing process of such wares results in a discernible elemental signature, future research could investigate whether locally produced sherds exhibit similar characteristics, thus providing material-level evidence for imitation.

Finally, the identification of distinct elemental clusters may correlate with the output of local workshops producing pottery of consistent composition. Integrating archaeological evidence regarding workshop locations with the elemental groupings observed in this study could strengthen our understanding of local production centres and their material contributions.

In summary, this research highlights the potential of elemental analysis to enrich interpretations of material culture, production systems, and cultural interactions in Roman period ceramic studies. While broader comparative data are essential to confirm and refine these interpretations, the preliminary results affirm the value of scientific approaches in investigating the persistence of traditions and the interplay between local and non-local pottery production.

[25] HARUSH/GROSMAN 2021, 2.

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ANNEX 1. THE ANALYSED SAMPLES.

ID	Sample	Burning	Context
1	Lamp	Oxidised	Edifice 1
2	Lamp mould	Oxidised	Edifice 1
3	Lamp mould	Oxidised	Peregiesis
4	Poinson	Oxidised	Pottery workshop
5	Lamp	Oxidised	Peregiesis
6	TS cup	Oxidised	Pottery workshop
7	Cup	Oxidised	Pottery workshop
8	Lamp	Oxidised	Peregiesis
9	*Patera* handle	Oxidised	Edifice 1
10	*Teracotta*	Oxidised	Peregiesis
11	Bowl	Reduced	Edifice 1
12	Strainer	Oxidised	Edifice 1
13	Cup	Reduced	Peregiesis
14	Lamp mould	Oxidised	Peregiesis
15	Stamped pot	Oxidised	Edifice 1
16	Mould	Oxidised	Peregiesis
17	Stamped pot	Oxidised	Peregiesis
18	Stamped pot	Reduced	Edifice 1
19	Beaker	Oxidised	Peregiesis
20	Lamp mould	Oxidised	Peregiesis
21	Mould	Oxidised	Peregiesis
22	Cup wall	Oxidised	Peregiesis
23	*Teracotta*	Oxidised	Peregiesis
24	Facepot	Oxidised	Edifice 1
25	Facepot	Oxidised	Edifice 1
26	Mould	Oxidised	Peregiesis
27	Rim	Reduced	Edifice 1
28	Rim	Reduced	Edifice 1
29	Rim	Reduced	Edifice 1
30	Rim	Reduced	Edifice 1
31	Rim	Reduced	Edifice 1
32	Rim	Reduced	Edifice 1
33	Stamped pot	Oxidised	Edifice I
34	Flagon	Reduced	Edifice 1
35	Bowl	Oxidised	Edifice I
36	Bowl	Oxidised	Edifice I
37	Bowl	Oxidised	Edifice I
38	Rim	Oxidised	Edifice I
39	Rim	Reduced	Edifice 1
40	Beaker	Oxidised	Edifice 1
41	*Turibulum*	Oxidised	Edifice 1
42	Ceramic waste	Reduced	Edifice 1
43	Rim	Reduced	Edifice 1
44	Rim	Reduced	Edifice 1
45	Rim	Reduced	Edifice 1
46	Beaker	Reduced	Edifice 1
47	Rim	Reduced	Edifice 1
48	Stamped bowl	Reduced	Edifice 1
49	Handle	Oxidised	Edifice I
50	Rim	Oxidised	Edifice 1
51	Beaker	Oxidised	Edifice 1
52	Snake pot	Oxidised	Peregiesis
53	Stamped pot	Reduced	Peregiesis
54	*Sigillata* mould	Oxidised	Peregiesis
55	*Sigillata* mould	Oxidised	Peregiesis
56	Stamped pot	Oxidised	Peregiesis
57	Stamped pot	Oxidised	Peregiesis
58	*Sigillata* mould	Oxidised	Peregiesis
59	*Sigillata* mould	Oxidised	Peregiesis
60	Lamp	Oxidised	Edifice 1
61	*Teracotta*	Oxidised	Peregiesis
62	Plate	Oxidised	Edifice 1
63	Lid	Oxidised	Edifice 1
64	Flagon	Oxidised	Edifice 1
65	Plate	Oxidised	Edifice 1
66	Bowl	Reduced	Edifice 1
67	Pot wall	Reduced	Edifice 1
68	Pot wall	Reduced	Edifice 1
69	Pot wall	Reduced	Edifice 1

ANNEX 2. THE CHEMICAL RESULTS.

mg/kg	Al	Si	P	S	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Rb	Sr	Zr	Ag	Cd	Sn	Sb	Ba	Hg	Tl	Pb
R01	178059	421222	1333	79	17577	45844	4891	??	83	1533	45233	<LOD	166	30	81	25	<LOD	34	204	170	<LOD	<LOD	20	<LOD	287	<LOD	<LOD	67
R02	85427	202814	2100	2266	20354	129876	4820	211	125	1297	47603	<LOD	65	48	115	13	<LOD	171	467	147	<LOD	<LOD	16	<LOD	758	<LOD	<LOD	31
R03	77487	242147	829	1884	21015	53698	5755	221	179	897	51729	<LOD	74	48	126	14	<LOD	119	342	169	<LOD	<LOD	23	<LOD	568	<LOD	<LOD	42
R04	111218	260266	721	329	22493	34380	5729	200	178	1079	50647	<LOD	72	41	120	18	<LOD	140	367	147	<LOD	<LOD	<LOD	<LOD	408	<LOD	<LOD	27
R05	130791	306302	340	8211	42926	19471	3509	95	96	389	46574	<LOD	45	17	121	122	<LOD	155	389	134	<LOD	<LOD	24	<LOD	<LOD	<LOD	<LOD	84
R06	85531	258201	791	2196	20890	57218	5813	200	165	1164	48979	<LOD	86	62	181	18	<LOD	125	320	160	<LOD	<LOD	<LOD	<LOD	526	<LOD	<LOD	25
R07	113993	271117	1191	563	23780	38713	6233	189	196	1348	56973	<LOD	86	61	131	16	<LOD	173	209	174	27	<LOD	<LOD	<LOD	706	<LOD	<LOD	26
R08	86472	208671	1449	588	18978	87604	4856	226	154	694	53913	<LOD	78	61	134	21	<LOD	175	398	163	<LOD	<LOD	15	<LOD	490	<LOD	11	50
R09	42712	203472	160	<LOD	14214	6255	2339	130	27	349	21493	<LOD	34	15	75	31	<LOD	82	242	150	<LOD	<LOD	26	<LOD	269	<LOD	<LOD	89
R10	95411	195278	1978	1041	16299	123359	4701	246	180	5818	56879	<LOD	79	50	148	23	<LOD	152	283	182	<LOD	<LOD	<LOD	<LOD	432	<LOD	<LOD	40
R11	160363	292162	1141	472	25868	31335	6371	162	193	1475	55574	<LOD	88	46	120	15	<LOD	114	238	165	<LOD	<LOD	<LOD	<LOD	627	<LOD	<LOD	62
R12	84571	305298	500	179	21118	8720	5029	112	116	588	45184	<LOD	53	33	86	15	<LOD	102	141	155	<LOD	<LOD	<LOD	<LOD	576	<LOD	<LOD	<LOD
R13	92388	280312	691	<LOD	23171	39782	5653	167	147	1088	46644	<LOD	80	39	90	12	<LOD	128	350	161	<LOD	<LOD	22	<LOD	545	<LOD	<LOD	30
R14	104973	256305	1608	<LOD	25747	23775	3789	152	108	562	46167	<LOD	47	34	111	17	<LOD	127	274	146	<LOD	<LOD	18	<LOD	412	<LOD	<LOD	44
R15	70093	249922	403	565	22778	25141	4014	164	101	605	39268	<LOD	55	41	106	9	<LOD	128	258	147	<LOD	<LOD	<LOD	<LOD	465	<LOD	<LOD	36
R16	56030	204080	901	<LOD	13793	37859	2611	145	61	691	28654	<LOD	37	24	136	18	<LOD	101	219	147	<LOD	<LOD	22	<LOD	376	<LOD	<LOD	49
R17	87188	221940	858	<LOD	13937	45009	3969	189	97	467	33724	<LOD	52	20	80	20	<LOD	103	580	151	<LOD	<LOD	<LOD	<LOD	385	<LOD	<LOD	45
R18	142693	265696	856	389	29836	24120	4745	170	149	757	44875	<LOD	73	43	130	15	<LOD	135	348	146	<LOD	<LOD	18	<LOD	350	<LOD	<LOD	49
R19	104333	300617	605	267	25168	30559	5912	133	129	800	48751	<LOD	65	40	92	17	<LOD	115	235	158	<LOD	<LOD	16	<LOD	484	<LOD	<LOD	34
R20	67821	234818	718	2754	26144	45988	5927	231	174	831	54491	<LOD	86	40	162	16	<LOD	166	350	157	<LOD	<LOD	18	46	736	<LOD	<LOD	24
R21	79769	233312	1399	105	15346	24781	3644	187	144	2757	34576	<LOD	56	34	147	20	<LOD	95	439	190	<LOD	<LOD	<LOD	<LOD	424	<LOD	<LOD	37
R22	92931	313613	3189	2517	34609	25073	5427	107	139	1200	51657	<LOD	71	47	205	36	<LOD	130	567	147	<LOD	<LOD	18	63	1726	<LOD	<LOD	107
R23	104651	317722	768	787	32002	9672	6238	106	151	1286	54613	<LOD	85	57	124	18	<LOD	131	231	161	50	<LOD	<LOD	<LOD	883	<LOD	<LOD	83
R24	69665	271715	610	602	21412	25321	4771	160	81	1302	36556	<LOD	72	25	75	24	<LOD	100	335	139	<LOD	<LOD	21	<LOD	565	<LOD	<LOD	66
R25	107413	317966	645	895	26380	30515	4300	91	81	797	45568	<LOD	72	34	100	10	<LOD	108	277	157	<LOD	<LOD	<LOD	<LOD	578	<LOD	<LOD	56
R26	77396	266324	1749	610	22929	29739	4926	178	147	862	42165	<LOD	48	53	130	14	<LOD	135	168	134	<LOD	<LOD	<LOD	<LOD	430	<LOD	<LOD	32
R27	111316	241644	1372	465	27719	71418	4946	215	202	1798	57561	<LOD	73	68	223	10	<LOD	161	230	158	<LOD	<LOD	<LOD	<LOD	407	<LOD	<LOD	32
R28	111872	238526	1652	212	16842	88521	4797	199	158	1502	51220	<LOD	87	64	161	23	<LOD	124	296	139	<LOD	<LOD	15	<LOD	611	<LOD	<LOD	39
R29	66748	186814	1112	246	11059	88360	2779	166	72	742	33964	<LOD	35	23	156	18	<LOD	102	112	114	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	40
R30	94265	283814	1178	78	20220	18823	5041	160	166	789	52566	<LOD	71	78	123	22	<LOD	126	159	130	<LOD	<LOD	<LOD	<LOD	599	<LOD	<LOD	36
R31	87422	243547	2777	689	24617	70823	5841	226	182	1376	55074	<LOD	81	50	142	27	<LOD	157	311	135	22	<LOD	<LOD	<LOD	556	<LOD	<LOD	<LOD
R32	92972	213036	2282	401	18528	78924	4296	227	171	1321	50456	<LOD	64	26	129	21	<LOD	157	397	150	<LOD	<LOD	24	<LOD	592	<LOD	<LOD	42
R33	90951	257067	2389	<LOD	25176	52064	5634	203	135	1039	39250	<LOD	61	46	128	14	<LOD	143	316	162	<LOD	<LOD	<LOD	<LOD	561	<LOD	<LOD	33
R34	54022	196305	1264	<LOD	12346	40369	2576	161	65	414	30602	<LOD	25	14	83	8	<LOD	104	137	136	<LOD	<LOD	<LOD	<LOD	355	<LOD	<LOD	30

mg/kg	Al	Si	P	S	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Rb	Sr	Zr	Ag	Cd	Sn	Sb	Ba	Hg	Tl	Pb
R35	70924	121702	4425	3737	9923	244170	3410	164	60	1325	37595	<LOD	39	59	215	<LOD	<LOD	157	196	128	<LOD	<LOD	<LOD	<LOD	436	<LOD	<LOD	33
R36	155349	218103	3201	<LOD	26920	100114	4997	234	172	1065	54856	<LOD	92	56	180	31	<LOD	145	392	135	24	<LOD	<LOD	<LOD	341	<LOD	<LOD	34
R37	81399	242035	2399	258	22869	52232	5357	210	145	951	45471	<LOD	62	37	116	23	<LOD	137	371	127	<LOD	<LOD	<LOD	<LOD	584	<LOD	<LOD	27
R38	172489	256130	1610	<LOD	15561	53159	5752	197	173	1115	51478	<LOD	75	34	136	19	<LOD	102	314	143	<LOD	<LOD	17	<LOD	472	<LOD	<LOD	26
R39	72115	252000	1277	<LOD	19642	22371	4386	191	120	1879	38682	<LOD	45	49	146	15	<LOD	103	204	113	<LOD	<LOD	<LOD	<LOD	430	<LOD	<LOD	28
R40	92233	254447	1179	<LOD	19405	28945	5354	197	134	1505	49660	<LOD	67	69	135	10	<LOD	132	167	132	<LOD	<LOD	15	45	552	<LOD	<LOD	34
R41	84944	224316	1013	<LOD	17554	78864	3666	181	138	876	49926	<LOD	62	76	105	15	<LOD	129	396	149	<LOD	<LOD	<LOD	<LOD	361	<LOD	<LOD	<LOD
R42	64472	238590	1659	<LOD	15746	13165	3165	160	82	445	32656	<LOD	30	28	100	25	<LOD	101	124	145	<LOD	<LOD	28	<LOD	267	<LOD	<LOD	<LOD
R43	67348	219150	1292	916	19606	53342	4084	199	142	629	47216	<LOD	70	62	141	17	<LOD	138	139	98	<LOD	<LOD	<LOD	<LOD	886	<LOD	<LOD	26
R44	56746	202840	2004	553	16021	59041	3167	181	112	544	33918	<LOD	43	109	124	19	<LOD	127	167	92	<LOD	<LOD	<LOD	<LOD	547	<LOD	<LOD	22
R45	111023	278661	1091	185	27429	30122	5607	168	167	1375	54434	<LOD	85	60	128	20	<LOD	132	230	130	28	<LOD	<LOD	<LOD	705	<LOD	<LOD	39
R46	72650	248710	3393	232	23365	34105	4397	193	157	539	49589	<LOD	57	63	131	22	<LOD	143	184	142	22	<LOD	<LOD	<LOD	611	<LOD	<LOD	23
R47	109135	271545	1977	225	22953	42729	6689	217	219	1546	59540	<LOD	88	39	147	14	<LOD	136	301	166	<LOD	<LOD	<LOD	<LOD	713	<LOD	<LOD	32
R48	85177	253107	2188	442	25568	71440	5169	200	157	727	41492	<LOD	50	96	104	28	<LOD	138	493	129	<LOD	<LOD	<LOD	<LOD	412	<LOD	<LOD	125
R49	117838	266174	1363	<LOD	12501	48876	4704	160	122	1158	44885	<LOD	74	83	86	8	<LOD	93	276	154	<LOD	<LOD	<LOD	<LOD	355	<LOD	<LOD	<LOD
R50	135267	234033	2031	927	24350	78018	5037	211	201	3619	53269	<LOD	87	56	142	14	<LOD	144	287	143	<LOD	<LOD	21	<LOD	577	<LOD	<LOD	38
R51	121869	279005	2788	4890	30401	40761	4680	150	140	724	46316	<LOD	75	61	112	12	<LOD	124	358	147	<LOD	<LOD	<LOD	<LOD	440	<LOD	<LOD	45
R52	88090	272890	633	1805	31516	36215	5702	194	175	728	48753	<LOD	82	23	129	18	<LOD	129	439	135	<LOD	<LOD	<LOD	<LOD	451	<LOD	<LOD	21
R53	74475	247228	565	1447	22835	31806	4211	184	128	917	38813	<LOD	54	29	105	10	<LOD	130	262	168	<LOD	<LOD	<LOD	<LOD	411	<LOD	<LOD	27
R54	96723	272646	1097	1221	23495	40859	6144	194	203	1889	54802	<LOD	69	43	182	11	<LOD	129	294	172	<LOD	<LOD	<LOD	<LOD	444	<LOD	<LOD	45
R55	95959	263315	1345	1190	19463	16502	4328	148	108	558	51145	<LOD	57	30	199	26	<LOD	101	392	129	<LOD	<LOD	<LOD	<LOD	497	<LOD	<LOD	55
R56	80871	242094	927	502	26078	55990	5144	213	163	704	50085	<LOD	71	37	140	7	<LOD	146	361	142	<LOD	<LOD	<LOD	<LOD	591	<LOD	<LOD	43
R57	94833	249134	1553	2254	20486	86318	5509	205	176	1081	49848	<LOD	77	55	196	14	<LOD	120	428	154	<LOD	<LOD	<LOD	<LOD	625	<LOD	<LOD	27
R58	70950	241340	582	229	23726	33217	4060	174	107	533	41537	<LOD	63	39	125	17	<LOD	127	271	145	<LOD	<LOD	<LOD	<LOD	620	<LOD	<LOD	31
R59	157146	276718	1212	300	26780	38861	6324	186	214	1609	62129	<LOD	80	93	162	18	<LOD	122	242	170	<LOD	<LOD	<LOD	<LOD	639	<LOD	<LOD	51
R60	77533	253521	687	<LOD	20811	27904	5215	193	138	990	46002	<LOD	69	32	95	18	<LOD	120	293	168	<LOD	<LOD	<LOD	<LOD	467	<LOD	<LOD	24
R61	88275	253121	1051	17154	25122	39736	6447	233	197	1439	59246	<LOD	91	61	161	17	<LOD	145	243	168	<LOD	<LOD	<LOD	<LOD	571	<LOD	<LOD	36
R62	65336	252837	435	4109	24654	27523	4937	184	135	575	43257	<LOD	62	27	115	17	<LOD	113	210	130	<LOD	<LOD	22	<LOD	395	<LOD	10	67
R63	79950	276844	659	406	22314	30651	4659	151	136	724	41424	<LOD	54	42	104	29	<LOD	128	268	152	<LOD	<LOD	<LOD	<LOD	429	<LOD	<LOD	84
R64	95545	241659	690	41214	25878	54412	5505	203	155	845	58114	<LOD	79	64	179	19	<LOD	151	224	138	23	<LOD	<LOD	<LOD	584	<LOD	<LOD	53
R65	116512	242419	686	30160	30009	38070	4942	196	141	1067	54537	<LOD	75	37	164	16	<LOD	154	244	154	<LOD	<LOD	<LOD	<LOD	759	<LOD	<LOD	65
R66	71805	219490	1471	499	16717	39290	4322	225	168	717	41136	<LOD	58	44	142	19	<LOD	133	144	154	<LOD	<LOD	17	<LOD	488	<LOD	<LOD	17
R67	84171	248780	1210	466	21220	44071	4937	196	174	1716	50708	<LOD	68	101	146	14	<LOD	151	124	119	<LOD	<LOD	<LOD	<LOD	795	<LOD	<LOD	24
R68	76543	233777	738	<LOD	20242	20177	3991	201	126	1813	40360	<LOD	67	29	123	17	<LOD	120	334	146	<LOD	<LOD	<LOD	<LOD	334	<LOD	<LOD	25
R69	80440	258981	800	<LOD	22625	13413	4529	183	172	1337	42139	<LOD	66	51	143	15	<LOD	140	164	134	<LOD	34	<LOD	<LOD	712	<LOD	<LOD	37