HANDHELD XRF IN CERAMIC RESEARCH: A CASE STUDY FROM THE LOWER GUADALQUIVIR REGION

KÉZI XRF MÓDSZER A KERÁMIAKUTATÁSBAN: ESETTANULMÁNY AZ ALSÓ-GUADALQUIVIR RÉGIÓBÓL •

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Abstract

Handheld X-ray fluorescence spectrometer in the last 15 years become very popular and nowadays is a well-established device in archaeometry. This paper presents reflections based on the practice of using a spectrometer over the last years, trying to highlight both the advantages and disadvantages of this tool. To illustrate the potential of the device for research on more general than technical issues in archaeology, the results of spectroscopic analyses from two, closely located archaeological sites in western Andalusia, Setefilla necropolis and Setefilla settlement, is presented. Thanks to the potassium-titanium test it can be noticed that the results vary for each site, and the differences in elemental composition are interpreted as manifestations of the intentional use of different paste recipes for specific social practices.

Kivonat

A kézi röntgenfluoreszcens spektrométer az elmúlt 15 évben nagyon népszerűvé vált, és ma már jól bevált eszköz az archeometriában. Ez a tanulmány az elmúlt évek spektrométer-használati gyakorlatán alapuló észrevételeket mutat be, és megpróbálja kiemelni az eszköz előnyeit és hátrányait egyaránt. Annak illusztrálására, hogy a készülék milyen lehetőségeket rejt magában az inkább általánosabb, mint technikai kérdésekkel kapcsolatos régészeti kutatásokban, két, egymáshoz közel fekvő nyugat-andalúziai régészeti lelőhely, Setefilla nekropolisz és Setefilla település spektroszkópos vizsgálatának eredményeit mutatjuk be. A kálium-titán arány vizsgálatának köszönhetően megállapítható, hogy az eredmények az egyes lelőhelyeken eltérőek, és az elemösszetételben mutatkozó különbségeket a különböző kerámiapép receptek szándékos, meghatározott társadalmi gyakorlatokhoz igazodó használatának megnyilvánulásaként lehet értelmezni.

KEYWORDS: HANDHELD XRF, POTTERY STUDIES, POTASSIUM-TITANIUM TEST, ANDALUSIA, SETEFILLA

KULCSSZAVAK: KÉZI XRF, KERÁMIA TANULMÁNYOK, KÁLIUM-TITÁN ARÁNY, ANDALÚZIA, SETEFILLA

Initial remarks

The aim of this work is, on the one hand, to present the potential of a handheld X-ray fluorescence spectrometer for the study of archaeological ceramics, its advantages and disadvantages, and on the other hand, to demonstrate the usefulness of spectrometric results as a basis for formulating hypotheses in the field of social archaeology. The literature on the subject abounds with works presenting analysis results, but not all of them include data interpretations that are significant for understanding social phenomena.

Specialized analysis of archaeological artefacts has a remarkable tradition dating back to the 19th century. Researchers have long been interested in the material, from which the artefact was made, as well as its technology and chronology. Artefacts were sometimes sent to laboratories where chemical composition analyses were carried out. One of the earliest examples of interest in the chemical composition of artefacts is the work of Albin Węsierski, a researcher of the Ostrów Lednicki stronghold, who as early as 1870 collaborated with pharmaceutical laboratories by sending them medieval artefacts (Fogel 1991: 23).

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Another example is the research conducted by Hans Dragendorff, who in 1895 provided samples of terra sigillata pottery to a pharmaceutical laboratory at the University Dorpat (nowadays the University of Tartu) to determine their elemental composition (Helfert 2023, 409).

In the post-war period, chemical analyses of archaeological objects have been facilitated by the use of handheld spectrometers. Early models of portable spectrometers used for the analysis of artefacts appeared in the 1960s, with the University of Berkeley being the first academic centre where XRF was applied (Shackley 2011, 11). Interestingly, one of the first handheld spectrometers was developed in Krakow, Poland in the Experimental Department of the Nuclear Technology Office, officially named FAR-1 in 1968 (Manecki & Niewodniczański 1988, 647). It was also used for studying archaeological artefacts, especially coins. Ceramic materials began to be commonly examined using handheld spectrometers only in the current century.

It's interesting to consider the relationship between theoretical currents in archaeology and archaeological science. The appearance of the first XRF spectrometers coincided with the birth of a new theoretical perspective called New Archaeology or processual archaeology with its program aimed to understand past societies through the analysis of cultural processes and their environmental contexts (Johnson 2008, 20-25). Processual archaeologists believed that the introduction of technical research tools and precise measurements can turn the results into objective facts and allow for the formulation of laws of cultural dynamics (Marciniak & Rączkowski 2001, 9-11). Methods adopted from the natural sciences were thought to ensure objectivity of cognition (Marciniak & Rączkowski 2001, 9). In consequence, an increasing amount of archaeological data was studied using scientific techniques. For this reason, X-ray fluorescence spectrometers, like other technical equipment, have become valued tools in archaeology.

In the next decades, the development of compact spectrometers took place, finding applications in geology, environmental sciences, and of course, archaeology, especially in the 21st century. From the beginning of the 1980s, another theoretical perspective, postprocessualism, emerged. The postprocessualists had a critical attitude towards the program of processual archaeology. They were convinced that it is crucial to consider the broader cultural, social, and symbolic contexts (Johnson 2008, 107; Jones 2002, 74-75) of the raw data generated by technical devices, such as handheld XRF, in order to construct multifaceted interpretations of the past. What is more, the emphasis on individual human actions sidelined more detailed analytical activities (Marciniak & Rączkowski 2001, 11). Changes in the perception of archaeology and its goals have diminished interest in archaeological science. In consequence, visible separation of archaeology and archaeological science took place. The results of specialized analysis will be utilized in this study to demonstrate their usefulness for social archaeology.

It is worth adding that the analysis of Andalusian ceramic samples using handheld spectrometers from the transition period between the Bronze Age and Iron Age has a several-year tradition. It has been argued that ceramics from some archaeological sites have different chemical characteristics (Krueger & Brandherm 2019), and the elemental composition of various types of ceramics characteristic of this region and period has been determined (Krueger et al. 2020, Krueger 2022b, 2023).

Handheld XRF in the archaeologist's practice

After presenting the general development of portable spectrometers in the context of the history of archaeological thought, it is necessary to focus on to the strengths and weaknesses of this analytical tool. There is no doubt that handheld X-ray fluorescence (XRF) analysers have some limitations, such as lack of laboratory precision, a limited detection range, and elemental interference (Chubarov et al. 2024; Holmqvist 2017; Hunt & Speakman 2015; Shackley 2011). Handheld XRF analysers can provide qualitative information about the elemental composition of a sample, but the precision of their quantitative results can fluctuate based on the calibration of the specific instrument in use. This is clearly evident in the case of trace elements. Determining elements with a low atomic number using handheld XRF is possible but subject to a relatively high margin of error. This is influenced by several factors such as the low-energy radiation emission by light elements, their low concentration in ceramics, or spectral interferences (Hunt & Speakman 2015, 627-629). Additionally, the method of sample preparation can also affect the results (Chubarov et al. 2024, 264-266; Marino et al. 2022; Niedzielski et al. 2020, 1457).

The scope of analysis is limited to the surface of an investigated artefact. Pottery is not a homogeneous material, and in consequence, surface analysis outcomes may show fluctuations. What is more, the temper can affect the results (Mecking 2017, 202). The solution is to carry out multiple analyses in different points of a sherd and calculate the average. However, the results of investigations using a handheld spectrometer will not be as precise as those obtained through destructive laboratory analyses.

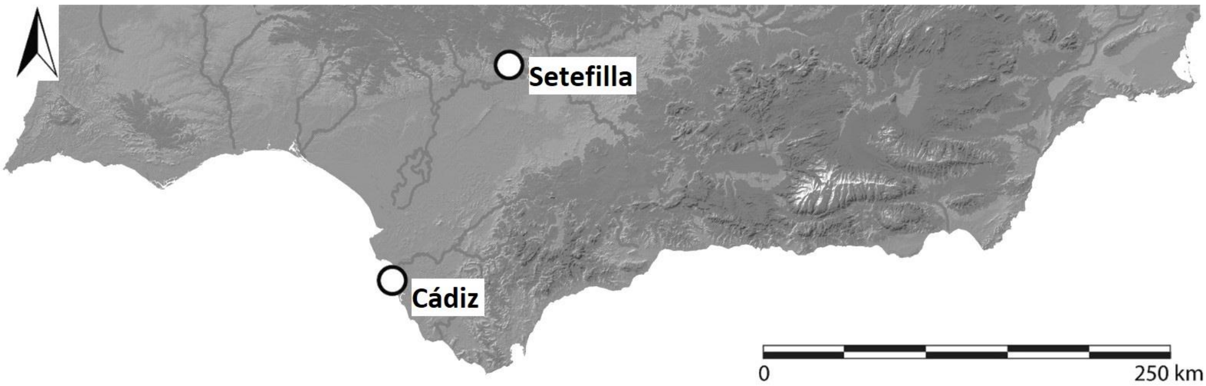

Fig. 1.: Location of Setefilla

1. ábra: Setefilla elhelyezkedése.

On the other hand, there are several arguments in favour of using handheld XRF. The spectrometer is relatively small and user-friendly, and it can be employed both in the laboratory and in the field (Shackley 2011). Besides pottery, it can also analyse other artefacts such as metals or obsidian. It enables determination of about twenty chemical elements depending on the device model and analytical mode. The analyses are quick and typically last from a few seconds to a few minutes. Its non-destructive character means that artefacts can be analysed in their natural state without special preparation. However, practice shows that, for example, grinding the sample can yield more precise results (Niedzielski et al. 2020).

Its greatest advantage, however, is that this device allows for obtaining important results to resolve archaeological problems. Rosemary Joyce, known primarily for her works in the field of social archaeology, posed a question about the value of conducting research using a handheld spectrometer (Joyce 2011). Her opinion was clearly positive and was based on the statement that technological issues are strictly linked to social relations. In the past, the choice of raw materials and technologies depended on factors such as tradition, beliefs or social organization. Using specific objects and techniques former communities could manifest their own identity or attachment to local traditions. From this perspective, results of XRF analysis may become of interest also to social archaeology (see also Krueger 2021, 448).

Setefilla case study

An exemplification of this viewpoint is the latest archaeometric research conducted on pottery samples from Setefilla necropolis and Setefilla settlement, archaeological sites located in south-western Spain.

These are sites of indigenous population situated approximately 150 km northeast of the main Phoenician colony on the Iberian Peninsula, Gadir (now Cádiz) (**Fig. 1**). Setefilla necropolis is one of the best-known sites in the Lower Guadalquivir region. It was excavated by J. Bonsor (Bonsor & Thouvenot 1928) in the 1920s and by M. E. Aubet (1975, 1978, 1980-81) in the 1970s. The archaeological materials from this site underwent numerous specialized analyses, mostly archaeo-metric (e.g., Brandherm 2022; Czarnetzki 2022; Krueger 2022a; Moreno 2022). The settlement, located less than 1 km to the north from the necropolis, is significantly less known. The most comprehensive work on it is the monograph edited by M. E. Aubet et al. (1983).

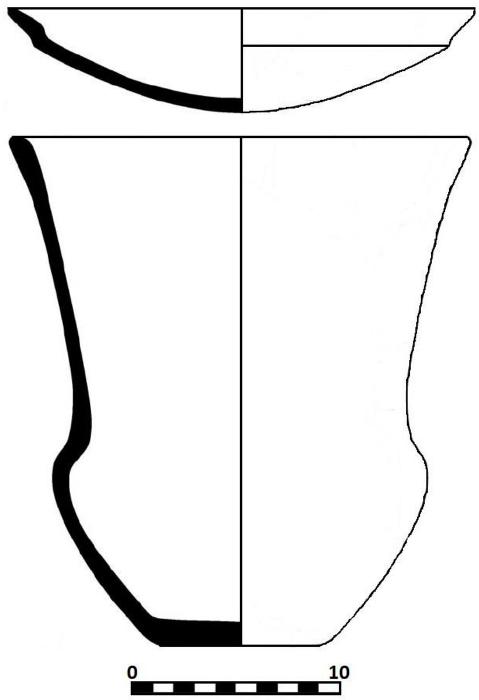

Fig. 2.: Example of a carinated bowl and *à chardon* vessel (digital drawing based on Aubet 1978, 192).

2. ábra: Példa egy karéjos tálra és egy à chardon edényre (digitális illusztráció Aubet 1978, 192 alapján).

The use of the handheld XRF enabled the obtainment of interesting results about the pottery from these two sites. It became possible to identify different elemental composition of Late Bronze Age/Early Iron Age local, handmade vessels: carinated bowls and *à chardon* containers (**Fig. 2., Table 1.** and **2.**, initial results and standard deviation values see Krueger 2022a, 2022b, 2023). These types of vessels constitute emblematic ceramic forms of the Lower Guadalquivir region used in settlements and in cemeteries.

The bowls belong to an open type characterized by the presence of a shoulder separating the rim from the body and very often they have burnished surfaces of dark colours. This type of ceramic vessel is widespread in Andalusia in the Bronze Age and the Early Iron Age. Very characteristic for the Early Iron Age is the *à chardon* vessel, it has a globular body and a bell-shaped neck. Due to the vessel's function as either an urn or a storage container, its size is typically large (Moreno 2023).

Table 1.: List of the samples from Setefilla necropolis and Setefilla settlement (stratigraphic trench 3). The range of the radiocarbon dates is based on Brandherm 2022.

1. táblázat: A setefillai nekropoliszból és településről származó minták listája (3. rétegtani árok). A radiokarbon kormeghatározás tartományai Brandherm 2022 alapján jelölve.

Sample ID	Inventory number	Form	Chronology	Location	Archaeological context
1	St. A. 148-172	*à chardon*	Early Iron Age (754–412 cal BC)	necropolis	grave A8
5	St. A. 173	*à chardon*	Early Iron Age (808–543 cal BC)	necropolis	grave A10
10	St. A. 102	*à chardon*	Early Iron Age	necropolis	grave A3
11	St. A. 592	*à chardon*	Early Iron Age (749–391 cal BC)	necropolis	grave A31
13	St. A. 30-44	*à chardon*	Early Iron Age	necropolis	grave A1
14	St. A. 54	bowl	Early Iron Age	necropolis	grave A1
16	St. A. 121	bowl	Early Iron Age	necropolis	grave A6
17	St. A. 83-103	*à chardon*	Early Iron Age	necropolis	grave A2
26	St. A. 632	*à chardon*	Early Iron Age	necropolis	grave A34
28	St. A. 776	bowl	Early Iron Age	necropolis	grave A38
35	St. A. 893	*à chardon*	Early Iron Age (749–408 cal BC)	necropolis	grave A43
36	St. A. 868	bowl	Early Iron Age (749–408 cal BC)	necropolis	grave A43
53	S-79-3-XI-1637	bowl	Early Iron Age	settlement	stratum XI
58	S-79-3-XIII-2252	bowl	Final Bronze Age	settlement	stratum XIII
61	S-79-3-XIIA-1777	bowl	Final Bronze Age	settlement	stratum XIIA
62	S-79-3-XIIB-2152	bowl	Final Bronze Age	settlement	stratum XIIB
63	St. A. 499	*à chardon*	Early Iron Age	necropolis	grave A24
67	St. A. 534	bowl	Early Iron Age	necropolis	grave A25
68	St. A. 542	bowl	Early Iron Age	necropolis	grave A27
73	S-79-3-X-1601	*à chardon*	Early Iron Age	settlement	stratum X
74	S-79-3-X-1601	*à chardon*	Early Iron Age	settlement	stratum X
75	S-79-3-IX-1467	bowl	Early Iron Age	settlement	stratum IX
80	S-79-3-VIII-1266	bowl	Early Iron Age	settlement	stratum VIII
87	St. A. 1085	bowl	Early Iron Age	necropolis	A61
88	St. B. 61	*à chardon*	Early Iron Age	necropolis	grave B1
90	St. B. 70	*à chardon*	Early Iron Age (830–569 cal BC)	necropolis	grave B2
91	St. B. 100	bowl	Early Iron Age	necropolis	grave B6
112	St. A. 894	*à chardon*	Early Iron Age (749–408 cal BC)	necropolis	grave A43
114	St. A. 79-57	*à chardon*	Early Iron Age	necropolis	tumulus fill
120	St. B. 79-6	*à chardon*	Early Iron Age	necropolis	grave B31
172	St. A. 541	*à chardon*	Early Iron Age	necropolis	grave A27

Table. 2.: Elemental composition (in wt%) of samples taken from hand-made bowls and *à chardon* vessels.

2. táblázat: Kézzel készített tálból és à chardon edényből származó minták elemösszetétele (tömeg%-ban).

Sample	Mg	Al	Si	P	S	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ba
1	3.138	11.439	22.531	0.176	0.400	0.776	3.267	0.429	0.018	0.016	0.033	7.356	0.003	0.002	0.006	0.008	0.053
5	2.274	14.268	21.981	0.151	0.207	1.631	3.633	0.495	0.019	0.000	0.251	6.355	0.003	0.004	0.006	0.005	0.094
10	2.709	9.606	19.844	0.093	0.366	0.209	4.472	0.784	0.024	0.002	0.064	6.350	0.003	0.001	0.008	0.005	0.167
11	6.135	10.542	24.457	0.107	0.381	0.447	2.854	1.005	0.034	0.016	0.038	5.105	0.003	0.004	0.007	0.006	0.247
13	5.550	11.735	23.967	0.197	0.348	0.212	3.512	0.579	0.025	0.011	0.049	7.916	0.004	0.003	0.009	0.005	0.132
14	3.560	8.912	20.165	0.116	0.393	0.209	2.973	0.724	0.034	0.011	0.046	7.569	0.004	0.002	0.008	0.005	0.134
16	8.876	11.473	24.393	0.147	0.191	0.156	2.697	0.816	0.029	0.013	0.021	7.093	0.004	0.001	0.006	0.002	0.085
17	5.322	8.144	19.279	0.386	0.096	0.405	6.953	1.051	0.023	0.000	0.102	5.805	0.004	0.000	0.008	0.005	0.436
26	5.616	10.114	21.711	0.121	0.176	0.333	2.569	0.967	0.042	0.008	0.032	6.275	0.004	0.002	0.008	0.001	0.177
28	4.661	12.228	23.691	0.144	0.184	0.870	2.911	1.039	0.029	0.002	0.058	5.419	0.004	0.000	0.006	0.006	0.276
35	4.403	9.007	23.345	0.086	0.241	0.320	2.699	0.901	0.032	0.007	0.034	5.284	0.003	0.003	0.006	0.005	0.188
36	5.729	11.264	23.731	0.125	0.171	0.175	2.810	0.802	0.033	0.022	0.037	5.949	0.003	0.003	0.006	0.004	0.179
53	0.780	9.352	24.660	0.072	0.220	2.646	1.191	0.456	0.016	0.013	0.028	5.884	0.003	0.005	0.008	0.007	0.043
58	2.177	7.731	21.168	0.298	0.248	1.639	3.287	0.765	0.030	0.002	0.105	6.450	0.004	0.001	0.007	0.006	0.244
61	1.148	9.616	21.700	0.201	0.225	3.186	2.444	0.568	0.013	0.004	0.047	6.216	0.003	0.000	0.005	0.002	0.159
62	0.756	10.552	25.820	0.114	0.258	3.187	1.315	0.342	0.008	0.011	0.026	5.280	0.002	0.003	0.008	0.005	0.117
63	1.179	7.746	18.521	0.106	0.190	0.060	2.555	0.865	0.029	0.004	0.080	6.183	0.004	0.001	0.006	0.005	0.132
67	0.869	6.922	20.392	0.064	0.209	0.127	1.507	0.944	0.032	0.009	0.008	5.655	0.004	0.002	0.005	0.004	0.086
68	0.969	8.336	20.803	0.059	0.182	0.164	3.247	0.551	0.022	0.009	0.032	5.831	0.003	0.002	0.006	0.005	0.016
73	1.285	8.047	20.415	0.075	0.193	0.974	3.149	0.482	0.017	0.014	0.028	6.653	0.003	0.001	0.006	0.004	0.047
74	1.595	9.843	22.990	0.143	0.386	0.923	3.266	0.384	0.007	0.012	0.033	6.463	0.003	0.001	0.005	0.004	0.273
75	1.657	8.542	23.267	0.131	0.220	0.932	2.866	0.586	0.017	0.012	0.022	5.942	0.003	0.002	0.004	0.006	0.180
80	1.125	6.695	19.545	0.311	0.301	1.528	3.393	0.623	0.018	0.010	0.043	6.457	0.003	0.002	0.006	0.005	0.355
87	2.322	8.043	22.000	0.112	0.222	0.149	1.910	1.013	0.049	0.005	0.033	5.545	0.004	0.001	0.006	0.004	0.134
88	2.360	8.657	21.205	0.129	0.520	0.126	2.396	0.828	0.025	0.005	0.028	6.092	0.003	0.001	0.005	0.005	0.124
90	1.341	10.841	22.876	0.178	0.190	2.276	6.834	0.505	0.003	0.009	0.029	4.378	0.002	0.005	0.006	0.009	0.137
91	1.339	7.194	18.098	0.161	0.155	0.149	3.527	1.255	0.057	0.002	0.021	4.313	0.004	0.001	0.005	0.005	0.316
112	3.093	5.158	12.663	0.000	0.105	0.035	1.590	0.340	0.000	0.001	0.012	5.548	0.002	0.000	0.006	0.009	0.000
114	1.226	7.138	17.348	0.197	0.130	0.429	7.223	0.522	0.010	0.008	0.033	6.494	0.003	0.002	0.007	0.006	0.096
120	0.441	5.751	17.219	0.001	0.129	0.352	2.247	0.249	0.012	0.015	0.054	2.799	0.001	0.017	0.015	0.016	0.015
172	0.407	6.783	17.475	0.044	0.135	0.085	2.234	0.833	0.027	0.008	0.039	5.741	0.003	0.001	0.005	0.006	0.053

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31 samples from two sites, the necropolis and the settlement of Setefilla, were analysed. 14 samples were taken from bowls and 17 were taken from *à chardon* vessels (see **Table 1**). The vast majority of the samples are dated to the Early Iron Age (840/820–500 BC), only three pieces are dated to the Final Bronze Age (1300/1200–840/820 BC). All samples dated to the Final Bronze Age are from the settlement.

The samples were measured three times in different points of a sample using the analytical mode provided by the spectrometer manufacturer: Major Mud Rock (15 kV, 25 μA). This is a commonly used factory calibration intended for the analysis of ceramics and soils. The acquisition time of each measurement was 15 seconds and vacuum pump was employed. The accuracy of the readings was verified by analysing a sample of contemporary pot with a known chemical composition. Then the average of the results was calculated. The initial analysis of the results revealed that the only element that significantly differentiates the samples is potassium. Therefore, the K-Ti test was applied. The test, which allows for grouping artefacts based on their chemical characteristics, holds significant value, first emphasized in the article on the origin of cuneiform tablets (Goren et al. 2011).

Thanks to this tool, it can be seen that the group from the settlement exhibits relatively similar characteristics: it is characterized by high levels of potassium and generally low titanium content, while the samples from the funerary context are characterized by a relatively high levels of titanium and low potassium content (**Fig. 3**). There are some exceptions like sample 5 and 90, but despite this, the tendency is clear.

In general, high potassium content in pottery is related to the presence of high quantities of feldspar used as a temper, this is characteristic of pottery from various archaeological cultures (Iordanidis et al. 2009, 297, Mecking et al. 2017, 200). Potassium-rich minerals are illite (Darab 1972), muscovite (Reichenbach & Rich 1969), vermiculite and biotite (Wilson 2004). It has been observed that in case of handmade Neolithic ceramics, high potassium contents are found predominantly in coarse pottery (Mecking et al. 2017, 201). It has been also suggested that, apart from its natural occurrence in rocks, potassium levels can be raised by adding wood ash (Mitrai & Davit 2001, 25).

In the case of vessels from Setefilla, no clear petrographic differences were detected between vessels from the settlement and those from the cemetery. The high potassium content is also characteristic of carinated bowls, which cannot be classified as "coarse pottery". Probably these trends cannot be associated with changes in tempering material, as there are no visible differences between the pottery from the settlement and necropolis in petrographic terms: the vast majority of samples from the settlement and the Setefilla necropolis belong to the same group classified by V. Moreno Megías as Group I (Moreno 2022, 216-218). Therefore, the high potassium content may be associated with the addition of wood ash to the clay used to produce vessels used in the settlement.

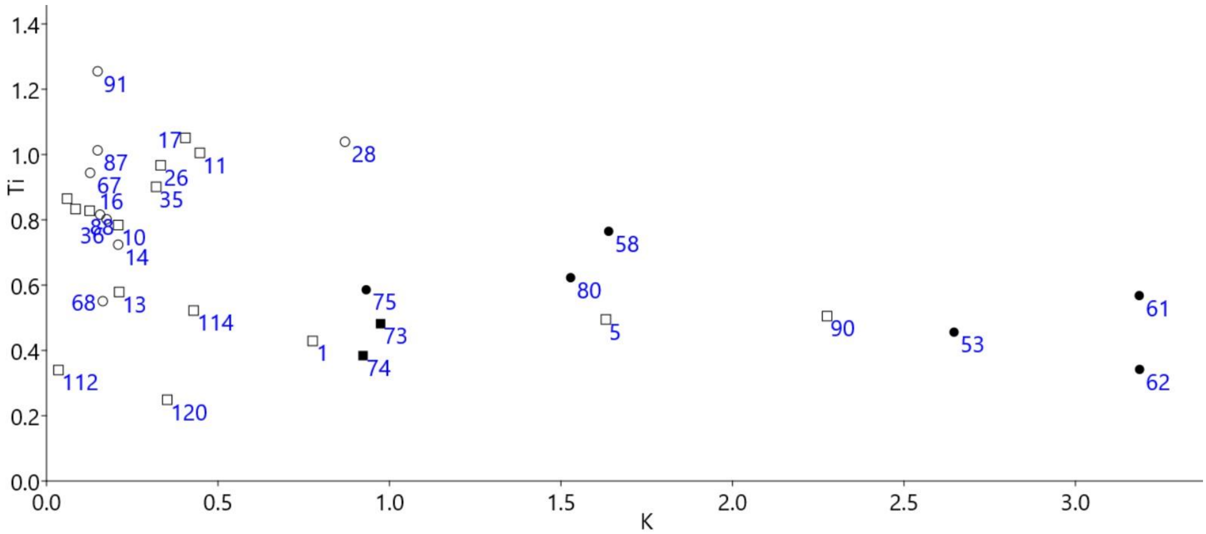

Fig. 3.: K-Ti test of the samples. Data plotted as wt%. Description of symbols: circle – bowl from the necropolis; black circle – bowl from the settlement; square – *à chardon* from the necropolis; black square – *à chardon* from the settlement.

3. ábra: A minták K-Ti aránya. Az adatok tömeg%-ban ábrázolva. Szimbólumok: kör - a nekropoliszból származó tál; fekete kör – a településről származó tál; négyzet – a nekropoliszból előkerült *à chardon* edény; fekete négyzet – a településről előkerült *à chardon* edény.

Another option is that that there was a gradual geological variation in the local clay deposits. These formations could have varied in potassium content. The high potassium concentration could also have been caused by weathering of biotite during which potassium is released and enters the soil (Wilson 2004, 251). The same applies to muscovite (Reichenbach & Rich 1969). Therefore, the clay itself, from which the vessels are made, can be a source of potassium. This could be the reason for the varying potassium content in vessels from two archaeological sites. It seems unlikely that differences in potassium content result from postdepositional processes; other studies (Stoner et al. 2014; Stoner & Shaulis 2021) have ruled out such a possibility.

What seems probable is that clay with slightly diverse chemical characteristics was sourced from other locations, or ceramic paste was prepared differently for vessels used for funerary purposes compared to those used in the settlement. The changes in potassium content suggest the use of special clays for different purposes: domestic and ritual. Differences in the chemical composition of the clay, although not visible macroscopically and microscopically, may reflect the need to produce pottery used as urns or as burial accompanying vessels. In this context, the presence of two samples (5 and 90) with a high potassium content in the necropolis is particularly interesting. Perhaps the vessels from which the samples originated were initially used as utilitarian containers in domestic environment, and at a certain point, it was decided to use them as funerary vessels. It should be emphasized that this applies to only two samples out of over thirty included in the study.

Ethnoarchaeological studies show that the selection and processing of clay are not random processes. Potters, when making specific choices, are guided by knowledge and experience, which include practical, social, ritual or symbolic factors (Gosselain & Livingstone Smith 2005, 41). The function of ceramic vessels may influence the choice of raw materials and production techniques: pottery used in ritual contexts may be produced using rare raw materials or more complex techniques to reflect their unique cultural significance.

It is worth mentioning O. Gosselain's research on the interaction between culture and technology in the context of ceramic studies in Africa. This author notes (Gosselain 1999, 218) that the use of sherds from vessels that belonged to deceased individuals to produce new ceramics may symbolize the continuity of life and connection with ancestors.

In the case of the ceramics from Setefilla, it is difficult to unequivocally interpret the detected differences in the elemental composition of sherds from the settlement and the necropolis, but issues related to cultural prohibitions and precepts seem to be a probable cause of the observed changes. This can be inferred because the examined vessels come from a settlement (profane sphere), and from a necropolis (sacred sphere). The preparation of vessels by the potter for different purposes was likely governed by distinct rules and practices.

Conclusions

Handheld X-ray Fluorescence (XRF) analysers despite their important limitations, offer several advantages; the most significant is the possibility to carry out a non-destructive elemental analysis of archaeological artefacts. The XRF results presented in this study complete the traditional image based on macroscopic attributes of the pottery: it is possible to verify that there were differences in the production of carinated bowls and *à chardon* vessels in two archaeological sites, one that is less than a kilometer away from the other. If we consider artefacts, including ceramics, as embodiments of norms and concepts, then the results of spectroscopic analysis can be interpreted as an exemplification of the belief in the close relationship between technological issues and social relations.

Contribution of the author

Michał Krueger Conceptualization, Methodology, Validation, Formal analysis, Investigation, Writing – Original Draft, Writing – Review and Editing, Visualization, Funding acquisition.

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