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ANALYSIS AND EVALUATION OF BRONZE AGE CERAMICS FROM SOME CENTERS IN KARS AND ITS SURROUNDINGS[*]

Kars ve Çevresindeki Bazı Merkezlerden Ele Geçen Tunç Çağı Seramiklerinin Analizi ve Değerlendirilmesi

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ABSTRACT: Located in Turkey's Eastern Anatolia Region, Kars Province has been continuously inhabited since the Paleolithic Age due to its position on important trade routes connecting the Caucasus to Anatolia. Scientific excavations and surface surveys conducted in Kars and its surroundings provide important data on the region's ancient history. In this context, within the scope of surface surveys initiated in 2000 and continuing to the present day, the typological characteristics and additives of Bronze Age ceramic finds identified at Ziyarettepe Castle in the Central District, Tomarlı Castle in the Arpaçay District, and the Çardakçatı Settlement in the Sarıkamış District have been evaluated. The ceramic samples in question were then analyzed using X-ray fluorescence (XRF) technology. The basic chemical compositions of a total of seven ceramic samples taken from the three centers were determined, and the elemental distributions in these compositions were evaluated in detail. During the analysis of the ceramics, the mineral composition ratios of the inorganic additives used were examined through XRF technique in the form of internal, external, and general

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surface analyses; the average values of the results obtained were presented. The findings indicate that the raw materials used in the production of ceramics were largely sourced locally. Furthermore, the similarities observed in terms of content and form reveal cultural and technological interactions among Bronze Age communities in Kars and its surroundings.
Keywords: Eastern Anatolia, Kars, Bronze Age, Ceramic, X-Ray Fluorescence

ÖZ: Türkiye'nin Doğu Anadolu Bölgesi'nde yer alan Kars ili, Kafkasya'yı Anadolu'ya bağlayan önemli ticaret yolları üzerinde konumlanması nedeniyle, Paleolitik Çağlardan itibaren sürekli yerleşim görmüştür. Kars ve çevresinde gerçekleştirilen bilimsel kazı ve yüzey araştırmaları, bölgenin Eskiçağ tarihine ilişkin önemli veriler sunmaktadır. Bu doğrultuda, 2000 yılında başlatılıp günümüze kadar sürdürülen yüzey araştırmaları kapsamında; Merkez ilçedeki Ziyarettepe Kalesi, Arpaçay ilçesindeki Tomarlı Kalesi ve Sarıkamış ilçesindeki Çardakçatı Yerleşmesi'nde tespit edilen Tunç Çağı'na ait seramik buluntuların tipolojik özellikleri ve katkı maddeleri değerlendirilmiştir. Söz konusu seramik örnekleri, ardından X-Işını Floresans (XRF) tekniği kullanılarak analiz edilmiştir. Üç merkezden alınan toplam yedi seramik örneğinin temel kimyasal bileşimleri belirlenmiş; bu bileşimlerdeki elementel dağılımlar ayrıntılı biçimde değerlendirilmiştir. Seramiklerin analizi sürecinde, kullanılan inorganik katkı maddelerinin mineral bileşim oranları XRF tekniği aracılığıyla iç, dış ve genel yüzey analizleri şeklinde incelenmiş; elde edilen sonuçların ortalama değerleri sunulmuştur. Elde edilen bulgular, seramiklerin üretiminde kullanılan hammaddelerin büyük ölçüde yerel kaynaklardan temin edildiğini göstermektedir. Ayrıca, içerik ve form bakımından gözlenen benzerlikler, Kars ve çevresindeki Tunç Çağı toplulukları arasında kültürel ve teknolojik etkileşimlerin bulunduğunu ortaya koymaktadır.
Anahtar Kelimeler: Doğu Anadolu, Kars, Tunç Çağı, Seramik, X- Işını Floresans

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Introduction

Located within the borders of Erzurum-Kars Plateau in the Eastern Anatolia Region, Kars province lies between 39° 56' and 41° 06' north parallels and 42° 08' and 43° 41' east meridians. Located in the north-east of Anatolia, Kars province is a crossing point connecting Anatolia and the Caucasus (Atalay, 2004: 1 vd.; Günaşdı, 2016: 393; Ceylan et al., 2018: 33; Kocaman, 2014: 273).

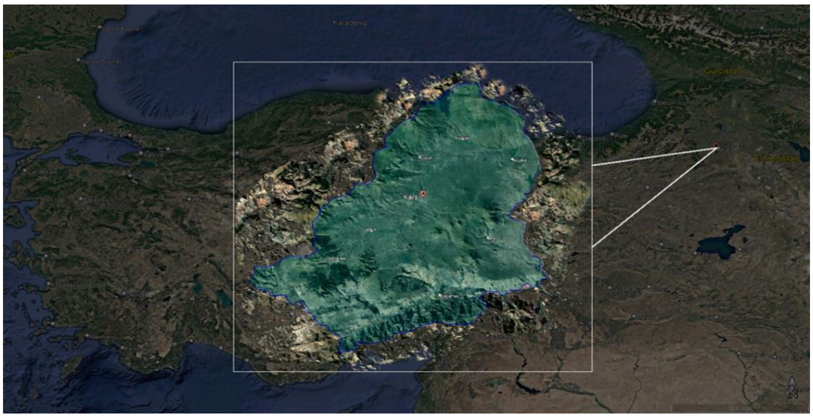

Figure 1: Physical Map of Kars Province

When we look at the geological structure, we can see that in the Pliocene period, while the Northern Anatolia and Eastern Anatolia faults were merging, the Kars Plateau was formed as a result of volcanic movements in the Kars region where the northern fault lines approached each other (Özgür, 2001: 15). The elevation of Kars province, which consists of high plateau plains and shows a general morphological feature, is 1900 m on average. Apart from the plateaus, the valleys forming the landforms consist of deep 'V' shaped young valleys, especially around Sarıkamış. In general, the areas of Arpaçay, Çıldır and Kür Valley are mostly volcanic lands (Demir, 2013: 17-37).

This geography, which has been inhabited since the Palaeolithic Age, has been home to many communities throughout history due to its location. The first scientific excavations and researches in the region were carried out by N. Marr in Ani in 1892-93 (Marr, 1921: 395-410). In 1942-44, İsmail Kılıç Kökten introduced Dündartepe, located 8-9 km south of Kars city centre, to the scientific world (Kökten, 1944: 667-668). Other studies in the region include the excavations and surveys carried out by Kemal Balkan and Osman Sümer in 1965 in and around Ani (Balkan and Sümer, 1967: 103), the Ani excavations carried out by Beyhan Karamağaralı in 1990 (Karamağaralı, 1998: 493), the Ani excavations conducted by Muhammet Arslan beginning in 2019 (Arslan, 2022: 209; Arslan, 2024: 275), the surveys by Savaş Harmankaya and Oğuz Tanındı in 1996 within the scope of the TAY Project (Harmankaya & Tanındı, 1996), and the Kars-Ardahan and Iğdır Provinces Surveys by Onur Özbek and Bakiye Yükmen in 1997 (Özbek and Yükmen, 2000: 37-42). In addition to these studies, within the scope of the "Eastern Anatolia Surveys Project" in and around Kars province, the surveys that started in 2000 under the direction of Alpaslan Ceylan and continued until 2014. After 2014, the Eastern Anatolia Surveys Project carried out by Akın Bingöl.

When we look at the history of the region, the Palaeolithic Age is identified with a certain chronology as Lower, Middle and Upper Palaeolithic Age (Kökten, 1947: 471) and provides data on the Mesolithic (Kökten, 1952: 176), Chalcolithic and Bronze Age. The first study on the known Bronze Age centers in and around Kars was conducted by Kökten. One of the centers identified is Dündartepe Höyük (Kökten, 1943: 601), located near the center of Kars, which was inhabited from the Bronze Age until the end of the Urartian Empire. Another is the Kurbanağa Settlement in the Kars-Kağızman district (Ceylan, 2008: 81). Although there are many settlements in the region, we have observed that some ceramic analyses are subject to a systematic spread from local to central in the light of the evaluations we have made for the centers that we think contain details in terms of findings.

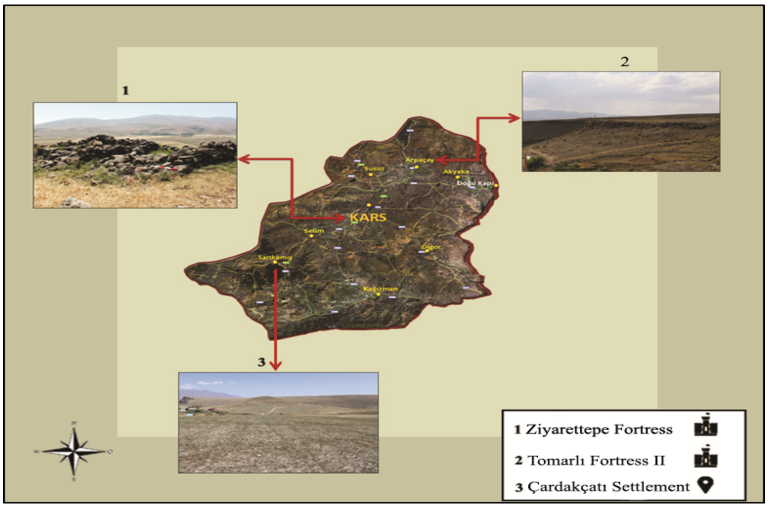

Figure 2: Kars Province Bronze Age Center Map

In this sense, the Bronze Age ceramics found in Arpaçay-Tomarlı Fortress II, Center-Ziyarettepe Fortress and Sarıkamış-Çardakçatı Settlement in and around Kars as a result of the studies conducted within the scope of Eastern Anatolia Surveys Project, which are the subject of our research, were analyzed by X-Ray Fluorescence (XRF) spectrometry. First of all, if we give brief information about the definition of ceramics and XRF spectrometry used in the analysis of ceramics.

Ceramic is derived from the Greek word "Keramos" meaning "clay soil, earthenware vessel". In European languages, it is generally translated as "ceramic" or "keramik" (Singer and Singer, 1964: 5; Şahin, 1983: 30; Arcasoy, 1983: 2; Ökse, 2012: 12; Tez, 2021: 23). Ceramics are usually made with clay, which consists of limestone, quartz (silica), mica and iron oxide rocks (Anılanmert and Rona, 1997: 1634).

X-rays were discovered by Wilhelm Conrad Röntgen, professor of physics, in 1895 (Riesz, 1995: 1536; Seliger, 1995: 25-31; Shackley, 2011: 7). Later, this technique was applied to archaeological materials in 1960 by E. Hall in his article "X-Ray Fluorescent Analysis Apllied to Archaeology" (Hall, 1960: 29-35). This method is an X-ray based study method in which the rays sent to the sample to be analyzed are absorbed by the atoms. Each element has a unique radiation and this radiation is called "Fluorescence". The recorded rays are evaluated and the minerals on the sample are detected and evaluated in this way (Kunç, 1985: 49; Gönüldaş, 2012: 36; Lopez, 2017: 14).

Today, XRF spectrometry has been used in many scientific studies and applied in different fields. When we look at the scientific studies used in this sense, respectively;

• "X-Ray Fluorescence Analysis of Archaic Greek Pottery": In this study, the results of the XRF analysis technique applied to Ancient Greek pottery from 2 different regions were compared and evaluated, and as a result of this evaluation, inferences were made about the raw material sources of the ceramics and accordingly their origins (Stern and Descoeudres, 1977: 73-86).

• "An Introduction to X-Ray Fluorescence (XRF) Analysis in Archaeology": In this study, the chemical components of archaeological artifacts are determined, providing information about the origin and production methods of the artifacts (Shackley, 2011: 7-44).

• "Characterization of Chalcolithic Ceramics from the Lisbon Region, Portugal: An Archaeometric Study": The main objective of the study was to evaluate the chemical and mineralogical characteristics of Chalcolithic ceramics using XRF analysis techniques and to provide information on whether they remained the same over time and whether they were produced locally (Chaves et al., 2022: 2422).

• "Interpreting Bronze Age Exchange in Sicily through Trace Element Characterization of Ceramics Utilizing Portable X-Ray Fluorescence (pXRF)": The XRF analysis technique applied to ceramic samples from southern Sicily provides a periodic and regional characterization of the elemental composition of the ceramics, with emphasis on the comparison of ceramic exchanges between the Early and Middle Bronze Age. Thus, the interconnection of the Sicilian peoples before the Aegean influence is established (Mckendry, 2015: 5).

• "Interpreting Bronze Age Exchange in Sicily through Trace Element Characterization of Ceramics Utilizing Portable X-Ray Fluorescence (pXRF)": The XRF analysis technique applied to ceramic samples from southern Sicily provides a periodic and regional characterization of the elemental composition of the ceramics, with emphasis on the comparison of ceramic exchanges between the Early and Middle Bronze Age. Thus, the interconnection of the Sicilian peoples before the Aegean influence is established (Fierascu et al., 2020: 1-13).

• "A Study of Ancient Pottery by Means of X-Ray Fluorescence Spectroscopy, Multivariate Statistics and Mineralogical Analysis": In this study, XRF analysis of the ceramics from the Orraon settlement in Greece was used to classify the basic components of the pottery and to identify the pottery group as locally produced. In addition, the compositional and mineralogical data are related to the selection of raw clay, firing conditions and various aspects of pottery production (Papachristodoulou et al., 2006: 347).

• "Determination of Traces of Heavy Metals in Estuarine Waters of Barbacoas Bay, Colombia, by X-Ray Fluorescence Spectrometry": Unlike other studies, this study was conducted for the detection of heavy metals in water samples. By using XRF analysis technique; the importance of monitoring water pollution, living creatures in the bay and its effects on the environment and health were emphasized (Mazo-Gray et al., 1997: 57-64).

In general, XRF analysis technique is used for comprehensive and versatile studies in different disciplines. It provides the opportunity to use in a wide range of areas from archaeological artifacts to environmental samples. According to the area of use with the XRF technique, which has been used in the scientific studies mentioned above;

1- Ceramics: Mapping of raw material sources of ceramics, determination of their origins whether they are local production or not, degree of firing,

2- In Water Samples: By determining heavy metals in water; the effects on aquatic life, health and the environment were concluded.

The XRF analysis method, which is used to examine the chemical composition of archaeological artifacts and especially ceramics, helps to determine the raw material sources, production techniques, usage areas and geographical origins of ceramics.

With these archaeometric studies using XRF spectrometry, the chemical and mineralogical structures of the ceramics are presented in reports with percentage values, and in this way, we also learn about the effect of additives used in ceramic production on ceramics and the soil structure of the geography.

Purpose

The aim of the research is to provide a new perspective on the general description and characteristics of the Bronze Age ceramics found in Kars and its surroundings and to determine the mineral components of the ceramics by using the XRF analysis method; the raw materials with which the ceramics were produced, the production processes and the cultural interactions of the Bronze Age ceramics that differ in mineral components.

Method

Within the scope of "Eastern Anatolian Surveys Project", the typological characteristics and additives of a total of 7 Bronze Age ceramics found in 3 centers in Kars and its surroundings as a result of the surveys that started in 2000 and continued until today were firstly evaluated. Then, their detailed mineral compositions were analyzed using XRF technique.

As a result of these analyzes the basic components of the ceramics, the elements in these components and other properties were determined. The elemental compositions for each ceramic sample are given in percentages. In addition, the XRF data obtained within the scope of this study are supported by similar studies and studies used in different disciplines. In addition, XRF analysis data is a reliable method for understanding the production processes, raw materials used and the origin of Bronze Age ceramics in the Kars region, and has helped to make a general assessment of the ceramic production traditions of the region.

Findings

With the data obtained as a result of these analyses, the basic compositions of these ceramics and the minerals in these compositions were evaluated separately within each identified center. In addition to this, the ceramics were grouped as amorphous and form-giving, and 7 sherds of Bronze Age ceramics were analyzed and physically analyzed in terms of form, paste and additives, and this information was supported by photographs, hand and computer-aided drawings. These centers and ceramic analyses are listed below.

1. Tomarlı Fortress II (Kars-Arpaçay)

Tomarlı Fortress II is located on the hill rising to the west of Tomarlı Fortress I in the northwest of Tomarlı Village, 7 km east of Arpaçay district. The fortress was built on a rocky cliff that dominates the plain and agricultural fields to the West (Karageçi and Bingöl, 2020: 68).

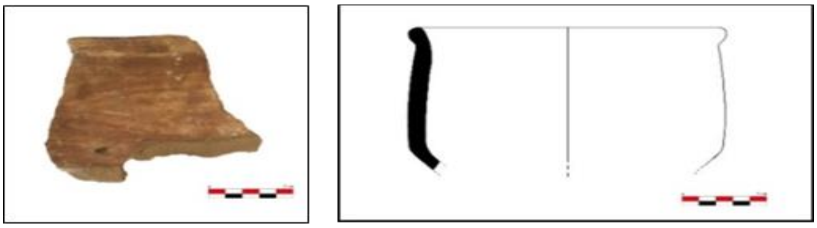

Figure 3: Tomarlı Fortress II-1 Ceramic Photograph and Drawing

When we analyze the sherd numbered II-1 from the Tomarlı Fortress firstly in terms of form; it is an everted rim sherd of a vessel with a diameter of 18 cm. It is wheel-made, burnished and slipped, and the inorganic additives are lime, mica, medium-large stoneware and medium-coarse sand. According to the Munsell color catalogue; it is 7.5 YR 5/6 in color.

Ceramic Analysis and Evaluation

<table>
<tr><th>Center Name</th><th colspan="2">Mine Class</th><th colspan="3">Day</th><th colspan="2">Time</th><th colspan="3">Duration</th></tr>
<tr><td>Tomarlı Fortress II-1 (Interior)</td><td colspan="2"></td><td colspan="3">24.6.2019</td><td colspan="2">15:44:32</td><td colspan="3">60 s</td></tr>
<tr><td>Element</td><td>Mg %
2.66</td><td>Al %
5.66</td><td>Si %
22.55</td><td>P %
1.90</td><td>S %
0.58</td><td>K %
6.38</td><td>Ca%
6.44</td><td>Ti %
0.41</td><td>Cr %
0.04</td><td>Mn %
0.07</td></tr>
<tr><td>Element</td><td>Fe %
4.94</td><td>Co%
0.01</td><td>Ni %
0.01</td><td>Zn %
0.01</td><td>As %
0.00</td><td>Se %
0.00</td><td>Rb %
0.01</td><td>Sr %
0.07</td><td>Zr %
0.02</td><td>Nb %
0.00</td></tr>
<tr><td>Element</td><td>Mo %
0.00</td><td>Ba %
0.07</td><td>Ta %
0.00</td><td>Hg %
0.00</td><td>Pb %
0.00</td><td>Th %
0.00</td><td></td><td></td><td></td><td></td></tr>
</table>

Center Name	Mine Class		Day			Time		Duration		
Tomarlı Fortress II-1 (Exterior)			24.6.2019			15:43:08		60 s		
Element	**Mg % 3.04**	**Al % 5.59**	**Si % 23.14**	P % 0.54	S % 0.62	**K % 7.22**	**Ca % 5.91**	Ti % 0.39	Cr % 0.05	Mn % 0.11
Element	**Fe % 5.92**	Co % 0.01	Ni % 0.01	Zn % 0.01	As % 0.00	Rb % 0.01	Sr % 0.08	Zr % 0.02	Nb % 0.00	Mo % 0.00
Element	Cd % 0.00	Sb % 0.01	Ba % 0.10	Ta % 0.00	Hg % 0.00	Pb % 0.00	Th % 0.00			

Center Name	Mine Class		Day			Time		Duration		
Tomarlı Fortress II-1c			24.6.2019			15:46:04		60 s		
Element	**Mg % 2.46**	**Al % 4.48**	**Si % 17.40**	P % 0.01	**S % 11.13**	**K % 10.08**	**Ca% 7.13**	Ti % 0.35	Cr % 0.08	Mn % 0.12
Element	**Fe % 6.39**	Co % 0.02	Ni % 0.02	Zn % 0.01	As % 0.00	Sn % 0.02	Rb % 0.01	Sr % 0.10	Zr % 0.03	Nb % 0.00
Element	Mo % 0.00	Ba % 0.09	Ta % 0.00	Hg % 0.00	Pb % 0.01	Th % 0.00	Cu % 0.01	Sb % 0.01	Au % 0.01	

Table 1. XRF Laboratory Results of Fragment II-1 of Tomarlı Fortress

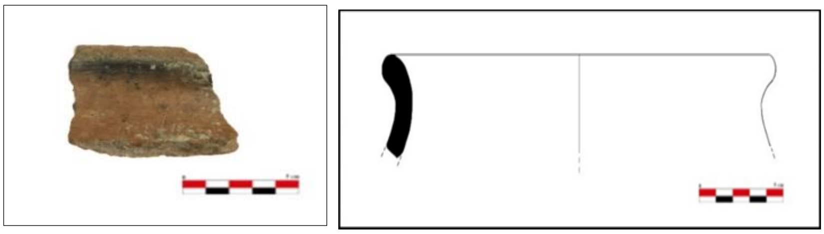

Figure 4: Tomarlı Fortress II-2 Ceramic Photograph and Drawing

The sherd numbered Tomarlı Fortress II-2 is a sherd of a vessel in terms of form, with an everted rim with a diameter of 22 cm. The wheel-made, burnished and slipped vessel is well baked with the same slip and paste color. In terms of inorganic additives lime, mica, small stones, fine-medium sand were used. According to the Munsell color catalogue, the color is 7.5 YR 6/4.

Ceramic Analysis and Evaluation

Center Name	Mine Class		Day			Time		Duration		
Tomarlı Fortress II-2 (Interior)			24.6.2019			16:12:10		60 s		
Element	**Mg % 1.76**	**Al % 7.44**	**Si % 24.44**	P % 0.24	S % 0.06	**K % 4.46**	**Ca % 5.21**	Ti % 0.62	Cr % 0.04	Mn % 0.15

Element	**Fe %** **6.93**	Co% 0.01	Ni % 0.01	Zn % 0.01	As % 0.00	Rb % 0.01	Sr % 0.04	Zr % 0.03	Nb % 0.00	Cd % 0.00
Element	Sb % 0.01	Ba % 0.06	Ta % 0.00	Hg % 0.00	Pb % 0.00	Th % 0.00	Cu % 0.01			

Center Name	**Mine Class**		**Day**			**Time**		**Duration**		
Tomarlı Fortress II-2 (Exterior)			24.6.2019			16:10:38		60 s		
Element	**Mg %** **1.92**	**Al %** **5.46**	**Si %** **18.50**	P % 0.16	**S %** **8.59**	**K %** **8.61**	**Ca %** **6.33**	Ti % 0.58	Cr % 0.05	Mn % 0.18
Element	**Fe %** **7.51**	Co% 0.01	Ni % 0.02	Zn % 0.01	As % 0.00	Rb % 0.01	Sr% 0.06	Zr % 0.03	Nb % 0.00	Cd % 0.00
Element	Ba % 0.09	Ta % 0.01	Hg % 0.00	Pb % 0.00	Th % 0.00					

Center Name	**Mine Class**		**Day**			**Time**		**Duration**		
Tomarlı Fortress II-2c			24.6.2019			16:15:27		60 s		
Element	**Mg %** **2.72**	**Al %** **5.31**	**Si %** **20.74**	P % 0.40	**S %** **3.40**	**K %** **5.11**	**Ca %** **8.04**	Ti % 0.49	Cr % 0.04	Mn % 0.21
Element	**Fe %** **8.15**	Co% 0.02	Ni % 0.02	Zn % 0.02	As % 0.00	Rb % 0.01	Sr % 0.06	Zr % 0.03	Nb % 0.00	Cd % 0.00
Element	Mo % 0.00	Sn % 0.02	Sb % 0.01	Ba % 0.07	Ta % 0.01	Hg % 0.00	Pb % 0.01	Th % 0.00	Cu % 0.00	

Table 2. XRF Laboratory Results of Fragment II-2 of Tomarlı Fortress

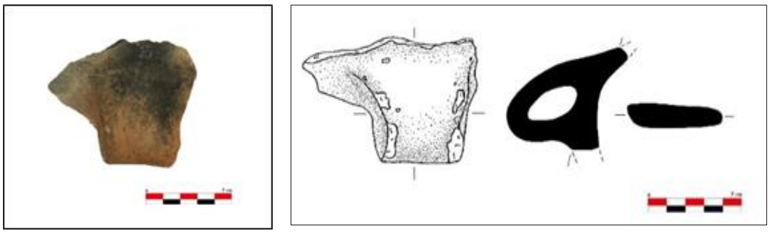

Figure 5: Tomarlı Fortress II-3 Ceramic Photograph and Drawing

Tomarlı Fortress II-3 is a handle fragment detached from the body of a vessel. The handle, which is moderately fired, is glazed and lined. The lining color differs from that of the body. Its color has become mottled black due to the uneven flow of air into the kiln during firing and the effects of physical deformation during subsequent use. The additives used are lime, mica, small-medium pebbles, and fine-medium sand. According to the Munsell color catalog, it has a color of 7.5 YR 6/6.

Ceramic Analysis and Evaluation

Center Name	Mine Class		Day			Time		Duration		
Tomarlı Fortress II-3 (Interior)			24.6.2019			16:40:33		60 s		
Element	**Mg % 2.48**	**Al % 4.49**	**Si % 21.74**	**P % 2.11**	S % 0.52	**K % 3.58**	**Ca % 9.38**	Ti % 0.46	Cr % 0.05	Mn % 0.16
Element	**Fe % 6.75**	Co% 0.03	Ni % 0.02	Zn % 0.02	As % 0.00	Rb % 0.01	Sr % 0.09	Zr % 0.02	Nb % 0.00	Mo % 0.00
Element	Cd % 0.00	Sb % 0.01	Ba % 0.09	Ta % 0.01	Hg % 0.00	Pb % 0.00	Th % 0.00	Cu % 0.01		

Center Name	Mine Class		Day			Time		Duration		
Tomarlı Fortress II-3 (Exterior)			24.6.2019			16:39:02		60 s		
Element	**Mg % 2.98**	**Al % 5.68**	**Si % 22.82**	P % 0.36	S % 0.41	**K % 4.88**	**Ca % 8.75**	Ti % 0.46	Cr % 0.03	Mn % 0.15
Element	**Fe % 5.92**	Co% 0.01	Ni % 0.02	Zn % 0.01	As % 0.00	Rb % 0.01	Sr% 0.08	Zr % 0.02	Nb % 0.00	Nb % 0.00
Element	Ba % 0.07	Ta % 0.01	Hg % 0.00	Pb % 0.01	Th % 0.00	Cu % 0.00				

Center Name	Mine Class		Day			Time		Duration		
Tomarlı Fortress II-3c			24.6.2019			16:43:56		60 s		
Element	**Mg % 2.74**	**Al % 5.32**	**Si % 24.88**	P % 0.33	**S % 2.48**	**K % 3.14**	**Ca % 6.43**	Ti % 0.34	Cr % 0.05	Mn % 0.13
Element	**Fe % 6.12**	Co% 0.01	Ni % 0.02	Zn % 0.02	As % 0.00	Rb % 0.01	Sr % 0.07	Zr % 0.02	Nb % 0.00	Cd % 0.00
Element	Sb % 0.01	Ba % 0.06	Ta % 0.01	Hg % 0.00	Pb % 0.02	Cu % 0.00	Se % 0.00	Tl % 0.00	Th % 0.00	

Table 3. XRF Laboratory Results of Fragment II-3 of Tomarlı Fortress

XRF results in ceramics usually show which elements are present and how much of them. These elements include basic minerals such as silicon (Si), aluminum (Al), iron (Fe), calcium (Ca), sodium (Na) and potassium (K). When we look at the components of the main additives of ceramics;

- Lime / Limestone, Calcium (Ca)-Magnesium (Mg)

[various proportions of Iron (Fe), Aluminum (Al), Silicon (Si), Sulfur (S) are also present (Lime, 2025)].

- Mica, Aluminum (Al)-Silicon (Si)

[contains varying proportions of Iron (Fe), Magnesium (Mg), Potassium (K) and Sodium (Na) (Mica, 2025].

- Quartz contains the minerals Silicon (Si)-Oxygen (O)

[with varying proportions of Lithium (Li), Sodium (Na), Aluminum (Al), Titanium (Ti) and Magnesium (Mg) (Nesse, 1991: 261)].

Under normal conditions, the dough undergoes chemical changes and loses its plasticity at least at 450-500°C. Baking takes place at 700°C. Accordingly, the melting process of the minerals in the dough and color changes occur at this stage (Ökse, 2012: 43).

Taking into account the firing of the vessel and the physical deformations it has undergone up to the present day, the additives used for the paste, especially the stoneware and lime, are noticeable. In addition, the dye element contents of both the paste and the slip are different from each other. As can be seen from the analysis reports, the results are presented separately as internal-external and general analysis. Accordingly, SiO_2 (Silicon), which varies between 21.03-21.22% when we take the average of the general values of the ceramics numbered 1,2 and 3 of Tomarlı Fortress II, is very important in terms of the hardness and durability of the ceramic. The average ratio of the mica additive, which is found as visible small shiny particles on the ceramic and has Al-Si (Aluminum-Silicon) in its basic composition, varies between 26.27-27.29%. 5.24% Al_2O_3 (Aluminum Oxide) increases the refractory properties of ceramics and helps to maintain form at high temperatures. When we consider the chemical interactions and functional role of minerals, Al_2O_3 (Aluminum Oxide) also increases the thermal conductivity and durability of ceramics, allowing for better quality products. 6.49-8.18% CaO (Calcium Oxide) lowers the firing temperature of ceramics and makes the structure more homogeneous, reducing the risk of cracking of ceramics due to sudden heat loss during firing. 5.75-6.07% Fe_2O_3 (Iron Oxide) adds coloring effect to ceramics. Depending on the degree of firing, it gives the ceramics red, brown and sometimes black tones, as in the ceramic samples numbered 2 and 3 of Tomarlı Fortress II above. The high percentage of 7.89% K_2O (Potassium Oxide) in the internal, external and general analysis results gives the ceramics a less porous, firmer and waterproof structure in a functional sense (Çalbay, 2019: 47-55).

2. Ziyarettepe Fortress (Kars-Center)

Ziyarettepe Fortress is located on a hill with an altitude of 1805 m between Esenkent and Soylu villages at the 35th km of Kars-Ani highway.

The entrance gate of the fortress, which has a round plan and is surrounded by walls, is in the east direction (Karageçi, 2016: 258; Belli and Yardımciel, 2016: 5; Bingöl, 2016_a: 287; Bingöl, 2016_b: 494; Bingöl and Karageçi, 2017: 268; Ceylan et al., 2018: 241).

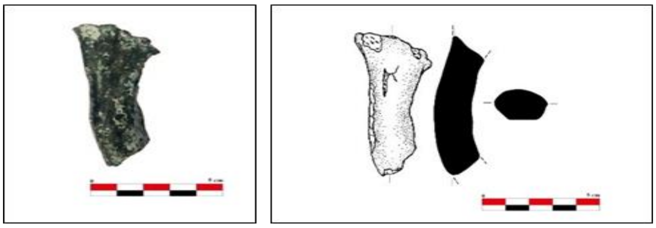

Figure 6: Ziyarettepe Fortress-1 Ceramic Photograph and Drawing

The sherd numbered Ziyarettepe Fortress 1 is a handle fragment detached from the body of a vessel. The handle is well baked; burnished and slipped. The additives consist of lime, mica, medium-coarse sand, medium-small stones. Mica, which is one of the additives; is observed intensely on the handle fragment and on the handle.

Ceramic Analysis and Evaluation

Center Name	**Mine Class**		**Day**			**Time**		**Duration**		
Ziyarettepe Fortress-1 (Interior)			21.6.2019			15:05:33		60 s		
Element	**Mg % 1.69**	**Al % 4.93**	**Si % 7.38**	P % 0.22	**K % 1.53**	**Ca % 21.73**	Ti % 0.40	Cr % 0.04	Mn % 0.31	**Fe% 7.07**
Element	Co % 0.01	Ni % 0.02	Cu % 0.01	Zn % 0.01	As % 0.01	Rb % 0.02	Se % 0.00	Rb % 0.03	Sr % 0.07	Zr % 0.04
Element	Nb % 0.01	Cd % 0.00	Sn % 0.02	Ba % 0.17	Ta % 0.00	Hg % 0.00	Pb % 0.04	Th % 0.00	**V % 0.21**	

Center Name	**Mine Class**		**Day**			**Time**		**Duration**		
Ziyarettepe Fortress-1 (Exterior)			21.6.2019			15:02:59		60 s		
Element	**Mg % 1.89**	**Al % 8.18**	**Si % 27.02**	P % 0.15	**K % 1.74**	**Ca % 4.99**	Ti % 0.40	Mn % 0.49	**Fe % 4.57**	Co % 0.01
Element	Ni % 0.02	Zn % 0.01	As % 0.00	Rb % 0.01	Sr % 0.04	Zr % 0.02	Nb% 0.00	Ba % 0.09	Ta % 0.00	Pb % 0.05
Element	Th % 0.00									

Center Name	**Mine Class**		**Day**			**Time**		**Duration**		
Ziyarettepe Fortress-1c			21.6.2019			15:05:33		60 s		
Element	**Mg % 1.86**	**Al % 6.84**	**Si % 25.13**	P % 0.21	**K % 2.96**	**Ca % 5.43**	Ti % 0.27	**V % 0.28**	Cr % 0.04	Mn % 0.18
Element	**Fe % 8.08**	Co % 0.01	Ni % 0.02	Zn % 0.02	As % 0.00	Rb % 0.02	Sr % 0.05	Zr % 0.05	Nb % 0.01	Mo % 0.00
Element	Sn % 0.02	Sb % 0.01	Ba % 0.15	Ta % 0.01	Hg % 0.00	Pb % 0.01	Th % 0.00			

Table 4. XRF Laboratory Results of Fragment No. 1 of Ziyarettepe Fortress

According to the analysis results, the overall average of high SiO2 mineral values is 23.17%. The high silica content in the ceramics indicates both that the clay is rich in quartz and that the ceramics are durable. 10.71% CaO (Calcium Oxide) reduces the risk of cracking in the ceramics, making them more durable.

Unlike the others, this ceramic sample contains 0.28% V (Vanadium) mineral. It has high hardness, strength and durability according to the areas where it is used (Greenwood and Earnshaw, 1997: 976; Vanadium, 2025). Vanadium (V) is used as a coloring dye in ceramics. However, this mineral is found in Konya-Seydisehir boksite, Şırnak-Silopi and Mardin asphaltite deposits in Turkey (Vanadium, 2025). Since the study area consists of the province of Kars and its surroundings, it gives the idea that this ceramic came to the region through trade or some other means (Çalbay, 2019: 81).

3. Çardakçatı Settlement (Kars-Sarıkamış)

Çardakçatı Settlement is located on a flat area south of Çardakçatı Village, 25 km southeast of Sarıkamış. It has an area of approximately 15,000 m2 at an altitude of 1740 m above sea level (Karageçi and Bingöl, 2020: 67).

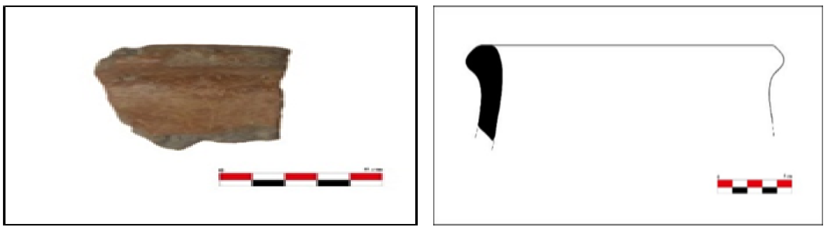

Figure 7: Çardakçatı Settlement -1 Ceramic Photograph and Drawing

The sherd from Çardakçatı Settlement-1 is a sherd of a vessel in terms of form, with an everted rim with a diameter of 20 cm. The wheel-made, burnished and slipped vessel is well baked. Lime, mica, fine-medium sand and small stones were found as admixtures.

Ceramic Analysis and Evaluation

Center Name	Mine Class		Day			Time		Duration		
Çardakçatı Settlement-1 (Interior)			24.6.2019			14:52:26		60 s		
Element	**Mg % 2.12**	**Al % 8.03**	**Si % 28.02**	P % 0.13	**K % 2.73**	**Ca % 2.98**	Ti % 0.51	Cr % 0.03	Mn % 0.06	**Fe % 4.66**
Element	Co % 0.01	Ni % 0.01	Zn % 0.01	As % 0.00	Rb % 0.01	Sr % 0.08	Zr % 0.02	Nb % 0.00	Sb % 0.01	Ba % 0.08
Element	Ta % 0.00	Pb % 0.01	Th % 0.00							

Center Name	Mine Class		Day			Time		Duration		
Çardakçatı Settlement-1 (Exterior)			24.6.2019			14:50:48		60 s		
Element	**Mg % 1.95**	**Al % 6.45**	**Si % 26.33**	P % 0.31	**K % 3.93**	**Ca % 5.26**	Ti % 0.43	Cr % 0.03	Mn % 0.12	**Fe % 5.75**
Element	Ni % 0.01	Cu % 0.01	Zn % 0.01	As % 0.00	Rb % 0.01	Sr % 0.09	Zr % 0.03	Nb % 0.00	Sb % 0.01	Ba % 0.10
Element	Ta % 0.00	Hg % 0.00	Pb % 0.01	Th % 0.00						

Center Name	Mine Class		Day			Time		Duration		
Çardakçatı Settlement-1c			24.6.2019			14:54:08		60 s		
Element	**Mg % 3.14**	**Al % 7.96**	**Si % 25.68**	P % 0.30	K % 2.38	**Ca % 3.99**	Ti % 0.42	Cr % 0.03	Mn % 0.15	**Fe% 6.07**
Element	Co % 0.01	Ni % 0.01	Cu % 0.00	Zn % 0.01	As % 0.00	Rb % 0.01	Sr % 0.09	Zr % 0.09	Nb % 0.00	Ba% 0.8
Element	Ta % 0.00	Hg % 0.00	Pb % 0.01	Th % 0.00						

Table 5. XRF Laboratory Results of Fragment Number 1 from Çardakçatı Settlement

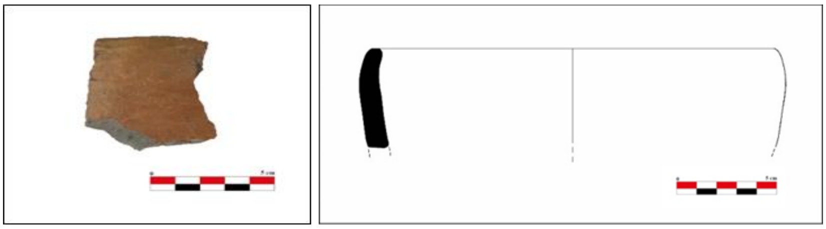

Figure 8: Çardakçatı Settlement -2 Ceramic Photograph and Drawing

The sherd from Çardakçatı Settlement-2 is an inverted rim sherd of a vessel with a diameter of 20 cm. It is burnished and slipped. The sherd is wheel-made and very well fired and lime, mica, fine-medium sand and small-medium pebbles were used as additives. The color description according to the Munsell color catalogue is 10 YR 6/6.

Ceramic Analysis and Evaluation

Center Name	Mine Class		Day			Time		Duration		
Çardakçatı Settlement-2 (Interior)			24.6.2019			15:00:29		60 s		
Element	**Mg %** **3.64**	**Al %** **7.21**	**Si %** **23.67**	P % 0.38	K % 3.80	**Ca %** **5.68**	Ti % 0.44	Cr % 0.04	Mn % 0.08	**Fe %** **6.74**
Element	Co % 0.02	Ni % 0.02	Cu % 0.01	Zn % 0.01	As % 0.00	Rb % 0.01	Sr % 0.03	Zr % 0.01	Nb % 0.00	Ba % 0.03
Element	Ta % 0.01	Hg % 0.00	Pb % 0.01							

Center Name	Mine Class		Day			Time		Duration		
Çardakçatı Settlement-2 (Exterior)			24.6.2019			14:59:04		60 s		
Element	**Mg %** **4.97**	**Al %** **7.31**	**Si %** **24.58**	P % 0.13	K % 2.13	**Ca %** **5.76**	Ti % 0.32	Cr % 0.03	Mn % 0.06	**Fe %** **5.41**
Element	Co % 0.01	Ni % 0.02	Cu % 0.01	Zn % 0.01	As % 0.00	Rb % 0.01	Sr % 0.02	Zr % 0.01	Ta % 0.00	Pb % 0.01

Center Name	Mine Class		Day			Time		Duration		
Çardakçatı Settlement-2c			24.6.2019			15:03:05		60 s		
Element	**Mg %** **4.07**	**Al %** **6.73**	**Si %** **25.01**	P % 0.31	K % 1.90	**Ca %** **5.30**	Ti % 0.36	Cr % 0.06	Mn % 0.11	**Fe %** **6.93**
Element	Co % 0.02	Ni % 0.02	Cu % 0.01	Zn % 0.01	As % 0.00	Rb % 0.01	Sr % 0.02	Zr % 0.01	Sb % 0.00	Ba % 0.03
Element	Ta % 0.01	Hg % 0.00	Pb % 0.0							

Table 6. XRF Laboratory Results of Fragment Number 2 from Çardakçatı Settlement

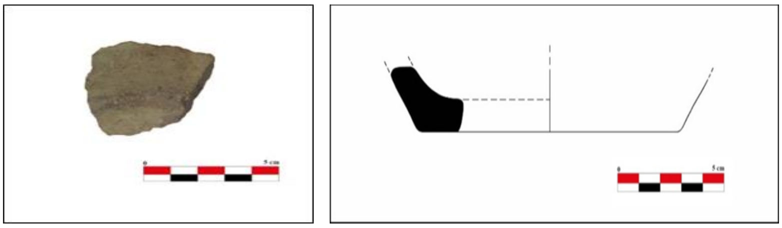

Figure 9: Çardakçatı Settlement-3 Ceramic Photograph and Drawing

The sherd numbered Çardakçatı Settlement-3 is a sherd of a vessel in terms of form with a flat bottom, expanding outwards and a diameter of 12 cm. The burnished and slipped vessel is well fired. Lime, mica, fine-medium sand and small stones were used as additives in the wheel-made pottery. In addition to inorganic additives grass was also used as organic additive. The color description according to Munsell color catalog is 10 YR 6/3.

Ceramic Analysis and Evaluation

Center Name	Mine Class		Day			Time		Duration	
Çardakçatı Settlement-3 (Interior)			24.6.2019			15:18:23		60 s	
Element	**Mg % 3.27**	**Al % 6.40**	**Si % 26.01**	P % 0.24	K % 2.34	**Ca % 4.96**	Ti % 0.46	Cr % 0.08	Mn % 0.15	**Fe % 6.69**
Element	Co % 0.00	Ni % 0.03	Cu % 0.01	Zn % 0.01	As % 0.00	Rb % 0.01	Sr % 0.03	Zr % 0.02	Nb % 0.00	Cd % 0.00
Element	Ba % 0.00	Ta % 0.00	Hg % 0.00	Pb % 0.01						

Center Name	Mine Class		Day			Time		Duration		
Çardakçatı Settlement-3 (Exterior)			24.6.2019			15:17:04		60 s		
Element	**Mg % 3.98**	**Al % 6.47**	**Si % 25.42**	P % 0.19	K % 1.69	**Ca % 7.07**	Ti % 0.41	Cr % 0.06	Mn % 0.14	**Fe % 5.21**
Element	Co % 0.01	Ni % 0.02	Cu % 0.00	Zn % 0.01	As % 0.00	Rb % 0.01	Sr % 0.03	Zr % 0.01	Ba % 0.03	Hg % 0.00
Element	Pb % 0.00									

Center Name	Mine Class	Day	Time	Duration
Çardakçatı Settlement-3c		24.6.2019	15:19:54	60 s

Element	**Mg % 4.58**	**Al % 5.87**	**Si % 23.34**	P % 0.36	K % 2.03	**Ca % 9.23**	Ti % 0.35	Cr % 0.05	Mn % 0.18	**Fe % 5.68**
Element	Co % 0.01	Ni % 0.02	Cu % 0.00	Zn % 0.01	As % 0.00	Se % 0.00	Rb% 0.01	Sr % 0.03	Zr% 0.02	Nb % 0.00
Element	Cd % 0.00	Sb % 0.00	Ba % 0.05	Ta % 0.00	Pb % 0.00	Th % 0.00				

Table 7. XRF Laboratory Results of Fragment Number 3 from Çardakçatı Settlement

According to the analysis results, the Si (Silicon) ratio of the ceramic, whose main components are SiO2, Al2O3, CaO and Fe2O3 as in other ceramic samples, is quite high. This shows that the ceramic contains a lot of silica and since it is a component of the additive mica, it is seen intensively on the ceramic surface. The proportion of Al2O3, which increases the durability of the ceramic and allows for better quality and thermal conductivity, varies between 6.24-7.08%. High CaO (Calcium Oxide) with an average of 7.08% is more common in the outer and 3c general analysis than in the inner layer analysis. This can be explained by the primer components applied to the outer surface of the ceramic or the degree of ceramic firing and the effect of the air flow entering the kiln during firing. Again, Fe2O3 (Iron Oxide) in the ceramic, which underwent different oxidations during firing, gave its brown color as in this ceramic sample and its average value varies between 5.86%-6.36%. In addition, the Fe (Iron) mineral ratio of the settlement in the 2c analysis is higher than the internal and external analyses, indicating that there was more oxidation due to the firing conditions (Çalbay, 2019: 95).

Discussion and Conclusion

The XRF technique, which we used in the analysis and evaluation of ceramics, which is the main subject of our study, is one of the important methods used because it is fast, accurate, reliable, gives precise results and does not cause damage to the analyzed samples.

The evaluation of the results of the analysis of the Bronze Age ceramics found in Kars and its vicinity using the XRF technique provided important information on raw material sources, production techniques and geographical origins.

The findings of our research are limited to a total of 7 ceramic groups sampled from Arpaçay-Tomarlı Fortress II, Center-Ziyarettepe Fortress and Sarıkamış-Çardakçatı Settlement where Bronze Age ceramics were identified. Their basic compositions and the elements in these compositions were analyzed and evaluated by XRF technique, especially the technical properties.

In general terms, the ceramic data consists of rim, base and handle sherds which were subjected to photography, drawing and identification. The majority of our study material consists of well or moderately fired pottery sherds. In addition to firing, which plays an important role in determining the quality of the ceramics, the additives are also of great importance. In this sense, it is noteworthy that fine sand constitutes the majority of the additives in the analyzed ceramics. Small stoneware is one of the most common additives along with fine sand. Medium stoneware is generally found in ceramics where medium sand is used. In addition to organic additives inorganic additives such as mica, quartz and lime (limestone) were also used. The mineral ratios of the inorganic additives used in the evaluation of the ceramics were analyzed by XRF technique in stages by internal, external and general analysis and presented by taking average values.

High temperatures cause irreversible changes in the structure of materials. The changes in the chemical structure of the ceramics as a result of firing and the effect of these changes on the mineral values in them are seen in the ceramic composition ratios in the centers we have given above with the analysis results. In this sense, the high proportions of Si (silicon) in the composition of quartz and mica can be considered as a very important mineral in terms of the hardness and durability of the vessels with the effect of good firing. Quartz, in particular, is an important additive as it acts as a skeleton in ceramics and prevents deformation. Fe (iron), which varies according to the centers, is the most abundant mineral in nature. It is a mineral that undergoes different oxidations during firing and forms a red, brown and almost black color scale when exposed to more degrees of firing. It is very important in terms of both hardness and coloring in ceramics with the effect of firing, and it was also seen in these ceramic samples.

In particular, the 0.28% Vanadium(V) mineral, which was found in the Kars-Center/Ziyarettepe Fortress, one of the centers we studied, is found in the asphaltite deposits of Şırnak-Silopi, Mardin and in the bauxites of Konya-Seydişehir in Turkey. Whether this mineral came to the region through trade or some other means or whether this mineral is also present in the region may be a new research topic in terms of pedology. Thus, the XRF analysis method also provides information about the sources of the raw materials used in the production of ceramics. During the Bronze Age, it is also known that the raw materials used in the production of ceramics were transported to other regions through regional trade. Therefore, Bronze Age ceramics found in different regions not only show the existence of trade relations between the regions where the raw materials were transported, but also provide information about their origins. The issue of origin here is related to the geographical region to which the ceramics belong according to their raw materials.

XRF and X-Ray Diffractometry (XRD) techniques are used to analyze the chemical composition of ceramic samples whose raw material is clay in order to determine whether the ceramics belong to the places where they were recovered and to determine their source and origin. However, we only used the XRF technique. Thus, if the ceramics of Kars and its surroundings, except for one ceramic sherd, are considered to belong to the region from which they were obtained, according to the results of the analysis, we can learn the geochemical properties of local raw materials from the high proportion of Silicon (Si) as the main component, as well as Aluminum (Al), Magnesium (Mg), Calcium (Ca) and Iron (Fe) minerals. In this way, the chemical composition of soils in a particular region can create a distinct profile in the analysis results.

In addition, with the functional role of minerals and their chemical interactions;

1. SiO2 (Silicon Dioxide): Increasing hardness and durability in ceramics.

2. Al2O3 (Aluminum Oxide): Increases the refractory properties of ceramics, enabling them to withstand high temperatures in the furnace during firing.

3. CaO (Calcium Oxide): Provides structural homogeneity in ceramics by stabilizing the firing temperature.

4. Fe2O3 (Iron Oxide): It plays an important role in determining the color of ceramics, revealing colors in shades of brown and black, especially red, in ceramics that undergo different oxidations during firing, are very important components in terms of evaluating the effects of minerals on ceramics.

The coexistence of SiO2 and Al2O3 contributes to the high heat resistance properties of ceramics in mechanical strength and refractory properties. The combination of CaO and SiO2, on the other hand, provides both homogeneous distribution and reduces the possibility of cracking or deformation of ceramics when fired. Again, according to the CaO and SiO2 ratios, the degree of firing of ceramics is also estimated. CaO, which is especially high in CaO, provides homogeneous distribution and helps the ceramics to be fired faster, at low temperatures and to obtain quality goods. According to the results of XRF analysis, if we consider the functional role of minerals and their chemical interactions, as mentioned above, they make a great contribution to ceramics both mechanically and aesthetically.

If we make a general evaluation according to both the period and XRF analysis results of the Bronze Age ceramics found in Kars and its surrounding centers, we can see that the Bronze Age is the period when ceramic production was fully developed and advanced. Plus, various ceramic styles emerged in different regions of Anatolia, especially in Kars and its surroundings, which is our study area. Based on the results of the XRF analysis of Bronze Age ceramics, the characteristics of the raw materials used are revealed, but we have noted that the ceramics generally contain a high proportion of silica and that the effect of the compositions makes a great functional contribution to the ceramics. With this function, the more durable ceramics reveal the idea that they were used as daily use or storage vessels. The high proportions of Al_2O_3 (Aluminum oxide) and CaO (Calcium Oxide) indicate that ceramics with high refractory properties were produced in accordance with the firing techniques used in this period. In addition, the aesthetically prominent Fe_2O_3 (Iron Oxide) ratios reveal red tones in oxidative firing and brown and black tones in reduced firing depending on the degree of firing.

Finally, the ceramic data obtained from the identified centers and centers;

- The raw materials and production techniques of the ceramics,
- The mineral richness and clay ratio of the soils of the region with the analysis results,
- The most clear evidence that Kars and its surroundings have been continuously inhabited since the Bronze Age with their periodization,
- The centers with a high density of ceramics are the most important data in terms of being the major administrative centers in the region.

In general, the ceramics produced and the mineral ratios in the XRF analysis results show that there are a wide range of differences from raw material selection to production techniques. Especially the changes in CaO and SiO_2 ratios provide important clues about the intended use of these ceramics and the conditions they were exposed to.

Our findings are in line with the studies in the literature above, and the findings and results obtained will make an important contribution to illuminate the Ancient Age history of the region and the XRF analysis technique we use will be an example for new studies.

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