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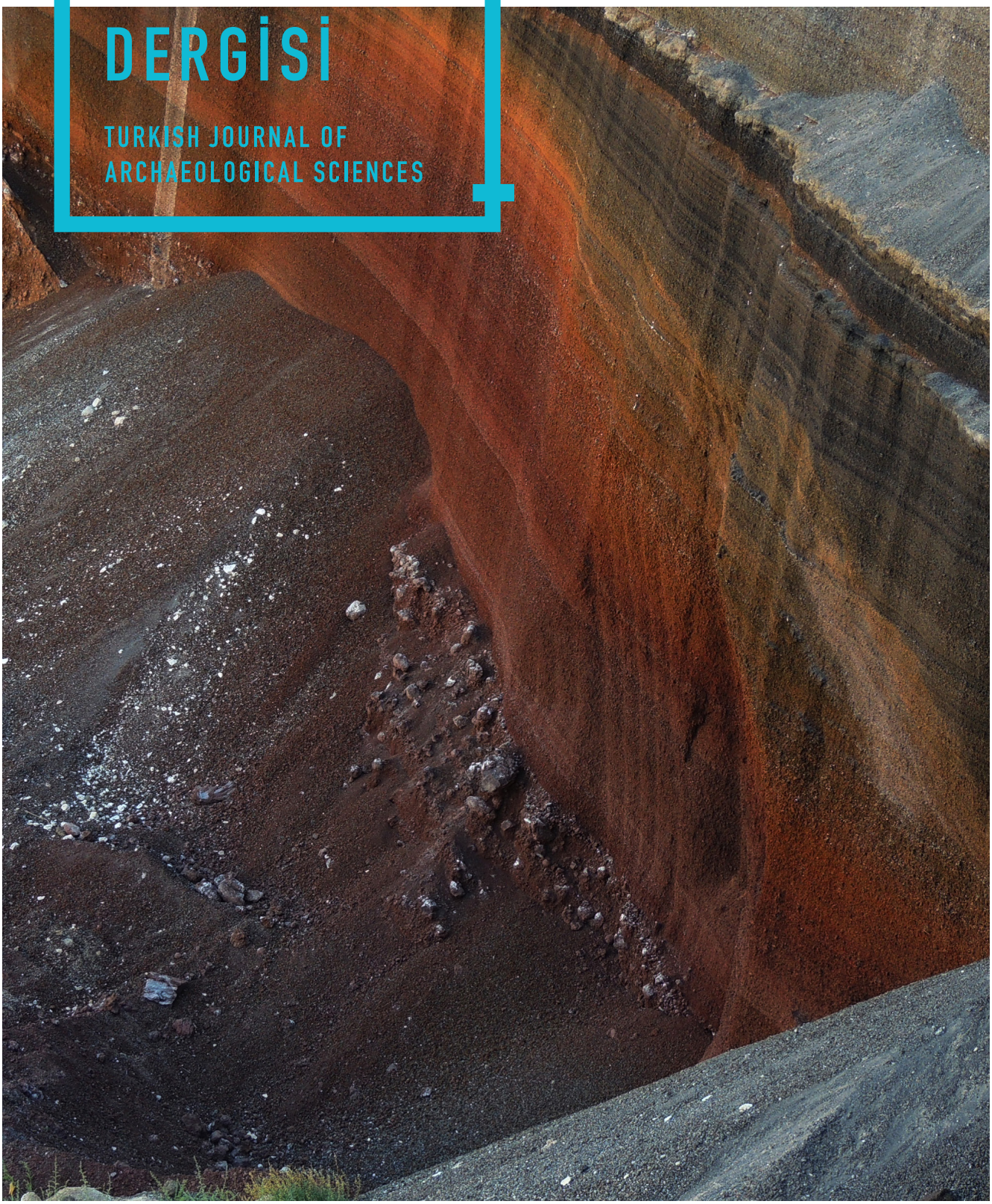

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Editörlerden

Dünyaya açılmamızı sağlayacak Arkeoloji Bilimleri Dergisi'nin ilk sayısı ile hepinize merhaba diyoruz.

Arkeoloji bir süredir geçmişin yorumlanmasında teknoloji ve doğa bilimleri ile yoğun iş birliği içinde yeni bir anlayışa evrilmekte. Üniversiteler, ilgili kurum ve enstitülerde her yeni gün açılmakta olan "Arkeoloji Bilimleri" bölümleri ve programları, geleneksel anlayışı yavaş yavaş terk ederek değişen yeni bilim iklimine adapte olmaya çalışmaktalar. Arkeoloji disiplininin geçmişi, geçmişte yaşayan insanların yaşam biçimlerini bütüncül bir şekilde anlamaya, hızla gelişen ve yaygınlaşan teknolojilerle her geçen on yılda daha fazla yaklaşıyor. Arkeolojik araştırmalar, sorgulama ve değerlendirme biçimleri, bu yeni bilim üretme biçimine dönüşüyor. Derginin editörleri olarak bizler, bu süreçte, bu dönüşüme katkı sağlayacak bir mecra oluşturmanın önemli olduğu kanısındayız.

Amacımız arkeoloji içindeki arkeobotanik, arkeozooloji, alet ve bina teknolojileri, tarihlendirme, mikromorfoloji, biyoarkeoloji, jeokimyasal ve spektroskopik analizler, coğrafi bilgi sistemleri, iklim ve çevre modellemeleri gibi farklı uzmanlık alanlarının çeşitlenerek yaygınlaşmasına katkı sağlamak ve arkeolojide bilimsel yöntem ve analizlerin geliştirilmesi ve uygulanması üzerine çalışan bilim insanlarını bir araya getirmek. Elbette yeni ve özgün metodolojik ve kuramsal yaklaşımlar üzerine yapılan araştırmalara da yer vereceğiz. Destek, katkı ve ilginizi derginin seyri ve gelişimi adına çok önemli görüyoruz.

Güneş Duru & Mihriban Özbaşaran

ARKEOLOJİ BİLİMLERİ DERGİSİ
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Note from the editors

We would like to take this opportunity to introduce ourselves to the world, and say 'hello' to the archaeological media with the very first issue of our new archaeological journal: The Turkish Journal of Archaeological Sciences.

For the past couple of decades archaeology has been evolving in close cooperation with new technologies and the advances in the natural sciences towards new understandings and interpretations of the past. More and more newly established departments and programs in universities and other relevant institutions focus on "Archaeological Sciences" as they try to adapt to a changing climate, and gradually abandon older traditions. Rapidly developing technological, methodological and analytical advances move us closer to understanding the way of life in past communities in a holistic way. Archaeological research programs, and the many innovative new ways of testing, inquiring and evaluating these all converge into this new way of producing 'science'. As the founding editors of the TJAS, we think it is important to have a medium that will contribute to this transformation.

Our goal is to contribute to the diversification and dissemination of different areas of expertise such as archaeobotany, archaeozoology, tool and building technologies, dating methods, micromorphology, bioarchaeology, geochemical and spectroscopic analyses, geographical information systems, climate and environmental modeling. We aim to bring scholars working on the development and application of scientific methods and analyses together in these volumes. We also seek to include in these pages recent advances in methodological and theoretical approaches. Your support, contributions and engagement with the archaeological science presented here are crucial to the progress and development of the journal.

Güneş Duru & Mihriban Özbaşaran

Raw Material Characteristics and Production Technology of Chalcolithic and Iron Age Değirmentepe Pottery (Malatya, Turkey)

Mehmet Bilgi Er[a], Asuman Günal Türkmenoğlu[b], Emine Hale Göktürk[c]

Abstract

A series of pottery samples provided from the survey investigations and excavations from Değirmentepe (Malatya), dating to Chalcolithic (Ubaid) and Iron Ages, were investigated by petrographic and X-ray diffraction (XRD) analyses to determine their textures, mineralogical compositions and microstructures. The sample microstructures and chemical (semi-quantitative) compositions were also studied by scanning electron microscope equipped with energy dispersive X-ray spectrometry (SEM-EDX). Although almost all samples consist of rock fragments originating from metamorphic and igneous rocks, larger grain sizes and higher grain to matrix ratios are recorded for Chalcolithic Age samples compared to the samples belonging to Iron Age. XRD investigations on representative samples of the two periods, revealed high abundances of quartz, feldspar, and pyroxene group minerals in all samples, the presence of hematite and mica minerals, as well. In the XRD traces of investigated sherds, the absence of clay minerals both in the bulk and in the clay fractions, supports a minimum firing temperature of around 800-850 °C, while the presence of mullite phase both in XRD and SEM-EDX results showed the possible use of high firing temperatures in the range of 950-1050 °C, starting from the Chalcolithic Age. Few exceptions observed may indicate possible use of different raw material and/or different manufacturing techniques.

Keywords: Değirmentepe, pottery, optical microscope, XRD, SEM-EDX

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Özet

Değirmentepe (Malatya) Höyüğü'nde yapılan yüzey araştırması ve kazı çalışmalarından elde edilen ve Kalkolitik (Obeyd) Çağ ve Demir Çağı'na tarihlenen çanak çömlek örneklerin dokusal, mineralojik ve mikro yapısal özellikleri, petrografik, X-ışını kırınımı teknikleri (XRD) kullanılarak belirlenmiştir. Örneklerin mikro yapıları ve yarı kantitatif kimyasal analizleri taramalı elektron mikroskop (SEM) ve enerji saçınımlı X-ışını (EDX) spektrometri teknikleri ile de çalışılmıştır. Hemen hemen bütün örneklerde gözlemlenen kayaç parçalarının, metamorfik ve volkanik kökenli olduğu ve bunun yanında Kalkolitik Çağ örneklerinin Demir Çağı örneklerine kıyasla daha kaba taneler içerdiği ve daha yüksek tane/ çimento oranına sahip olduğu belirlenmiştir. Her iki döneme ait çanak çömleklerden seçilmiş temsili örnekler üzerinde yapılan XRD analizleri sonucunda, kuvars, feldspat ile piroksen grubu minerallerin bütün örneklerde, hematit ve mika minerallerinin ise bazı örneklerde bulunduğu belirlenmiştir. Kalkolitik ve Demir çağlarına ait hem tüm kayaç hem de kil fraksiyonu örneklerinde yapılan XRD analizlerinde herhangi bir kil mineraline rastlanmamış olması en düşük pişirme sıcaklığının 800-850 °C'lerde olduğunu ortaya koymuştur. XRD ve SEM-EDX analizlerinde ise mullit fazının bulunması 950-1050 °C arası yüksek bir pişirme sıcaklığına Kalkolitik Çağ'dan itibaren ulaşılmış olabileceğini göstermiştir.

Anahtar Kelimeler: Değirmentepe, çanak çömlek, optik mikroskop, XRD, SEM-EDX

Introduction

Değirmentepe, a middle-sized mound covering 100x150 m², was 24 km away from Malatya in Eastern Turkey (Figure 1). The site has been completely submerged underwater due to the construction of Karakaya Dam on the Euphrates valley since 1987. Değirmentepe was firstly investigating during an archaeological survey in 1977 (Özdoğan 1977). The pottery samples collected during this survey belong mostly to the Late Chalcolithic Period. The site, therefore, was dated to Late Chalcolithic—transitional period in the published survey report. Starting from 1978, Değirmentepe was excavated for eight years as a part of Lower Euphrates rescue and assessment projects coordinated by the Middle East Technical University (Özdoğan 1977; Serdaroğlu 1977; METU Reports 1987).

Archaeological research revealed outstanding discoveries concerned with the culture, economy, architecture and religion of Değirmentepe from the Chalcolithic Age (the last half of fifth millennium BCE) to Late Roman—Medieval periods (5th to 15th century AD).

The most prominent levels 6-11 present the distinctive pottery type and architecture of Ubaid Period with the additional evidence regarding the economy, metallurgical activities, flint tool production and social life during the Chalcolithic—Ubaid Period (Esin 1981, 1982, 1984; Esin and Arsebük 1983; Esin and Harmankaya 1985, 1986, 1987; Esin et al. 1987). The level seven provided the main part of the information about the Ubaid Culture in the settlement. The Ubaid

Culture (5500-3800 BCE), which is named after Tell-al'Ubaid in Southern Mesopotamia, plays an important role in the urbanization of the Near East (Erarslan 2008). Ubaid Culture has been principally characterized by its distinctive painted pottery and tripartite dwelling type.

The pottery dated to the Ubaid Period recovered from Chalcolithic Age levels in Değirmentepe mainly consists of light colored pottery with greenish-gray or pink paste and slips, the painted Ubaid pottery and coarse dark colored cooking pots. Coba ware (or flint-scraped bowls) makes the main part of light colored wares which have irregular lines on the surface, probably made by flint tools. Painted Ubaid pottery, on the other hand, has a light colored decorated with geometrical shapes, branch mesh or leafs in red, black or brown color. The next group composed of handmade dark colored, brown or black cooking pots, tempered with chaff and grit (Esin 1986).

Değirmentepe, together with İkiztepe and Tülintepe, were assigned as selected sites that would provide the archaeological materials for the first and foremost archaeometric research in Turkey. These pioneer studies were initiated by The Scientific and Technological Research Council of Turkey (TÜBİTAK) at 1980. Thereafter, the archaeological materials belonging to various periods in Değirmentepe have been extensively studied by several researchers in the fields of anthropology, zooarchaeology, archaeobotany and geomorphology (Esin 1986). Değirmentepe pottery was investigated in detail and discussed in the sense of provenance and production technology by using several techniques like X-ray Fluorescence (XRF), Neutron Activation Analysis (NAA), X-ray Diffraction (XRD), Optical Microscope and Scanning Electron Microscopy-Energy Dispersive X-ray Spectrometry (SEM-EDX).

The primary work included the classification of pottery samples dated to Chalcolithic, Early Bronze and Iron Ages with the help of multivariate statistical methods on trace element concentrations determined by NAA and XRF (Birgül 1981; Esin et al. 1985). The results of this study indicated three different pottery groups which were found to be in good agreement with the typological classification (Esin 1986). The same samples were classified according to mineralogical and petrographic characteristics into three groups (Türkmenoğlu et al. 1985). Later on, X-ray powder diffraction analysis was performed to determine the crystalline phases and clay minerals in bulk powder samples and oriented clay fractions (Türkmenoğlu 1989). The firing temperature of Chalcolithic, Early Bronze and Iron Ages was estimated as 800-1000 °C (Türkmenoğlu and Göktürk 1996). The most recent archaeometric research on Değirmentepe pottery was a Master of Science thesis completed in 2011 (Er 2011). This paper presents the result of this thesis.

The present study is an attempt to explore the potential of more advanced techniques such as SEM-EDX, along with additional intensive petrographic studies and XRD investigations, for characterizing the potteries belonging to Chalcolithic and Iron Ages in order to assist the understanding of technological characteristics of pottery production in Değirmentepe.

Materials and Methods

Samples

Chalcolithic Age pottery samples consist of twenty-two sherds dated to the Ubaid Period. One group of samples (Sample No: 156, 157, 160, 165, 176, 177, 205, 209, 210, N1, N2, N3) were already present in the collection of previous studies in METU (Birgül 1981; Esin et al. 1985; Esin et al. 1989) and the rest (Sample No: E1, E2, E3, S1, S2, S3, S4, S5, S6 and S7) were obtained from the collection of Istanbul University, Prehistory Department.

The Iron Age pottery group consists of seventeen sherds. They were collected from three different grids (16J, 16I and 17I).

The photographs of Chalcolithic samples are given in Figure 2(a) and Iron Age samples are given in Figure 2(b).

Methods

Thin section preparation was carried out at the Thin Section Laboratory of the Geological Engineering Department in METU. The optical examination was carried out in the laboratories of Geological Engineering Department of METU by using Olympus CX31 model petrographic microscope.

X-Ray powder diffraction analyses of all the samples were carried out at the METU Central Laboratory by using "Phillips PW 3710" X-ray diffractometer with Cu Kα radiation with a Ni filter at a scan speed of 2°/min. XRD analyses were performed on nine non-oriented powdered samples and two clay fractions of powder samples (Jackson 2005).

Scanning electron microscope analyses were performed on six samples from Chalcolithic Age (Sample No: 210, N1 and S1) and from Iron Age (Sample No: 230, 246 and 248). Targets prepared using fresh fracture surfaces of pottery samples (approx. 1x1x2 cm) were coated with Au-Pd film to provide the electrical conducting layer to prevent the surface charging. SEM coupled with EDX analyses were performed at the METU Central Laboratory. Quanta 400F Field Emission SEM (FE-SEM) coupled with EDX was used in the measurements.

Results and Discussion

Petrographic and Mineralogical Analyses

Petrographic and mineralogical analyses were performed on three main parts of the clay paste: the non-plastic part (rock fragments, mineral grains and other inclusions), the clay matrix (clay-sized material) and pores which are empty spaces in the clay matrix.

Fragments of metamorphic, volcanic and sedimentary rocks were identified in thin section analyses of all samples (Table 1). Polycrystalline metamorphic rock fragments composed of large feldspar grains and extrusive igneous rock fragments were identified in the most of the samples, regardless of the period (Figure 3).

Table 1. Rock fragments identified in the samples.

Rock Class	Rock Type	Sample No and Age	
		Chalcolithic Age	**Iron Age**
Metamorphic	Schist	S4, S5	244
	Polycrystalline quartz	160, 165, 176, 210, N3	
	Phyllite	205	189
	Unclassified	157, 160, 165, 177, 187, 189, 205, 209, 210, E3, N1, N3, S4, S5	223, 224, 230, 231, 233, 235, 237, 238, 244, 246, 249
Igneous	Intrusive igneous	189, E1	
	Volcanic igneous	189, 156, 157, 165, 176, 177, 210, E1, N1, N2, S1, S2	223, 224, 228, 231, 235, 237, 238, 239
	Unclassified	209, E3, S7	
Sedimentary	Chert	165	231
	Limestone	156, 160, 205, N3, S5	233

Limestone fragments and small calcite grains which are both primary calcites were mostly detected in the Chalcolithic Age samples. Calcite grains dispersed in the clay matrix of three samples (Chalcolithic Age samples 205 and 209 and Iron Age sample 224) indicate the use of calcareous clay for production (Figure 3 and 4). The presence of limestone fragments is notable for estimation of firing temperature of the pottery. It indicates that the decomposition of calcium carbonate could not be completed yet during firing. Observation of reaction rims around calcite grains as in Sample 224 given in Figure 5 also support the uncompleted calcite decomposition (Fabbri et al. 2014).

The fragments of chert and phyllite/schist were also encountered in few samples dated to Chalcolithic and Iron Ages in thin section analysis.

Crystals of feldspar, plagioclase, quartz, pyroxene and hornblende are found in almost all of the samples investigated via thin section analysis (Table 2). Feldspar group minerals are one of the most common mineral groups in the earth's crust and were identified with different grain sizes in all of the samples during thin section analyses as expected. Plagioclase feldspar grains were differentiated with polysynthetic twinning under polarized light. All feldspar grains were identified as natural inclusions which were probably weathered and originated from metamorphic

Table 2. Common and less common minerals detected in thin section analyses. Px= Pyroxene, Hbl= Hornblende, Mca= Mica, Bt= Biotite, Pl= Plagioclase, Fsp= Feldspar, Asf= Alkali Feldspar, Qzt= Quartz.

Sample No	Dating	Px	Hbl	Mca	Bt	Pl	Fsp	Afs	Qzt
187	Iron Age	+				+	+		
189	Iron Age	+	+	+			+		
223	Iron Age					+			
224	Iron Age		+		+		+		
227	Iron Age						+		
228	Iron Age	+					+		
230	Iron Age	+				+	+		
231	Iron Age	+			+	+			
233	Iron Age					+	+	+	+
235	Iron Age	+		+	+	+		+	
237	Iron Age	+		+	+	+	+		
238	Iron Age		+	+	+	+	+		
239	Iron Age	+	+	+	+		+		
244	Iron Age			+			+		+
246	Iron Age	+		+	+			+	
248	Iron Age					+	+		
249	Iron Age	+				+	+		
156	Chalcolithic Age					+	+		+
157	Chalcolithic Age	+				+			
160	Chalcolithic Age	+		+			+		+
165	Chalcolithic Age	+					+		
176	Chalcolithic Age	+				+			
177	Chalcolithic Age								+
205	Chalcolithic Age				+		+		
209	Chalcolithic Age	+	+			+			+
210	Chalcolithic Age	+				+	+		+
E1	Chalcolithic Age		+				+		
E2	Chalcolithic Age				+	+	+		
E3	Chalcolithic Age	+	+			+	+		
N1	Chalcolithic Age		+			+	+	+	
N2	Chalcolithic Age	+	+			+	+		
N3	Chalcolithic Age	+					+		
S1	Chalcolithic Age			+		+	+		+
S2	Chalcolithic Age					+	+		+
S3	Chalcolithic Age	+					+		
S4	Chalcolithic Age			+			+		
S5	Chalcolithic Age						+	+	
S6	Chalcolithic Age	+					+		
S7	Chalcolithic Age						+	+	

Table 3. Three most intense d – spacings* of the minerals used in XRD analysis. Qzt= Quartz, Fsp= Feldspar, Pl= Plagioclase, Di= Diopside, Hem= Hematite, Mca= Mica, Mul= Mullite, Mc= Microcline.

	Qzt	Fsp	Pl	Di	Hem	Mca	Mul	Mc
d-spacing (Å)	3,34	3.74-3.78	4,03	2,98	2,7	10.01-9.96	3,39	3,24
	4,25	6.60-6.30	3.17-3.21	2.51-2.52	2,51	5.00-4.98	3,42	4,22
	1,81	3.45-3.49	2.92-2.95	2,88	3,68	4.48-4.45	5,39	3,37

* In the order of decreasing intensity

and igneous rocks. Quartz is also present in the samples dated to Chalcolithic and Iron Ages. There is no indication of the use of quartz and feldspar as temper. Hornblende grains were detected in thin sections with its strong paleochroism. Mica particles which probably originated from mica bearing schist-phyllite rock were mostly dispersed in clay matrix in Iron Age samples.

Hematite (Fe2O3) is a fully oxidized form of iron oxide and one of the common minerals in the soil. It has a red or reddish brown color in thin sections. The grains of hematite were identified with having red or reddish brown colors in all the samples of Chalcolithic Age (except samples N3 and S4) and Iron Age in thin section analyses (Figure 6). Hematite could also be formed during firing stage. Oxidizing conditions and temperature around 750 °C during firing cause hematite formation which turns the color of the sample to reddish-brown (Maritan et al. 2006; Nodari et al. 2007)which continues to retain iron in a (distorted. Samples N3 and S4 have grayish and dark colors, which can be caused by a reducing atmosphere during firing (Figure 2(a)).

Mullite which is an alumina silicate mineral is rarely found in natural form (Lee and Rainforth 1994). Synthetic mullites which are primary (2Al2O3·SiO2) and secondary mullite (3Al2O3·2SiO2) may be formed at elevated temperatures 950-1000 °C, 1050-1150 °C respectively (Iqbal and Lee 2004; Lee et al. 2008). Diffraction lines of 3.40 and 5.39 Å in XRD patterns of five samples belonging to Chalcolithic Age (S1, 210) and Iron Age (Samples No: 230, 246, and 248) are attributed to mullite (Table 3) (Chen 1977). Although the two split lines expected at 3.39 and 3.42 Å are not observed in their patterns (Figure 7), it has been already reported that those lines may be merged when mullite is newly formed at high temperatures which make their identification difficult (Chakraborty and Ghosh 1978). Supporting the XRD observations, mullite crystals with a distinct needle like shape were also clearly detected in SEM analysis of sample S1 (Figure 8). The result of micro-chemical investigations on those crystals indicating the presence of calcium, magnesium, and iron contents does not support the expectations for the typical stoichiometric 3:2 alumina-silica ratio (Figure 8). This contradiction was already stated in a previous study with a probable cause of the overlapping of the glass and crystal phases (Lee et al. 2008). The identification of mullite in mineralogical and microstructural analyses of pottery samples provides valuable information for the estimation of firing

temperatures. The presence of mullite crystals, especially in Chalcolithic Age samples, indicates that they might have been fired at temperatures above 1050 °C (Tite and Maniatis 1975a).

The existence of elongated pores in samples N3 of Chalcolithic Age and 248 of Iron Age indicates the possible presence of chaff as an inclusion. The EDX analyses of these inclusions indicate the presence of phosphorus (P), chlorine (Cl) and carbon (C) that confirms the results of morphological investigations of these pores and plant traces (Figure 9).

Calcite was observed in samples of Chalcolithic Age (Sample Code: 157, 165, 177, 205, 209, E2, E3, N2, S1, S3, S4) and Iron Age (Sample Code: 224, 233, 237, 246) during thin section analyses and its existence was also confirmed with SEM investigations. These occurrences observed on the pore walls in the form of pore linings are interpreted as micritic (secondary) calcite and are believed to arise from the deposition during burial conditions (Velde and Druc 1999; Fabbri et al. 2014). This conclusion mainly depends on the small crystal shapes cumulated on the surface of the pottery (Figures 10 and 11) and related EDX analysis.

The scanning electron microscopy provides high magnifications (up to X 2-3.000.000 times) and the opportunity to examine the morphology even at the nanometer scale. The degree of vitrification can be determined by the formation of a network of glassy phase and isolated pores or absence of flaky clay particles in the ceramic matrix (Tite and Maniatis 1975b). Nine samples (Sample No: 160, 176, 210, N3, S1 of Chalcolithic Age and 228, 230, 239, 244 of Iron Age) have well vitrified body/matrix and small grain size characteristics when compared to the rest. The developments of glassy phases and glass networks which surrounded the boundaries of mineral grains were clearly observed in SEM analysis (Figure 12).

Considering the matrix color, samples display wide range of colors under cross-polarized light, changing from mostly reddish brown to greenish—beige and occasionally darker colors. A reddish color indicates the use of oxidizing atmosphere due to the formation of ferric oxide (Fe^{3+}) during firing, while a darker color indicates the application of a reducing atmosphere or insufficient air circulation and the presence of ferrous oxide (Fe^{2+}) (Rice 1987; Nodari et al. 2007). Considering these facts, samples N3, S1, S4 and S7 of Chalcolithic Age with dark colors were probably fired in reducing atmosphere, while most of the samples have reddish color indicating oxidizing atmosphere (Figure 2(a)).

Distributions of non-plastic grains (mineral grains and rock fragments) in the studied samples were investigated by examining the thin sections with optical microscope. The investigation suggests that the rock fragments consist of large particle sizes which change from coarse to fine sand sizes (1.00-0.1 mm). On the other hand, sizes of mineral grains have very fine sand sizes (<0.1 mm). Based on these observations, Chalcolithic Age samples have larger grain sizes and a higher grain/matrix ratio than those of the Iron Age. That may indicate the use of different

method of raw material processing for the elimination of coarser particles during ceramic production in the Iron Age.

Production Technology

The results of petro-mineralogical analysis is generally in line with previous grouping by Türkmenoğlu (Türkmenoğlu et al. 1985). The identification of mullite phase in this research contributes to the estimation of firing temperature around 1050 °C.

It can be noted that Iron Age samples have more compact and amorphous bodies when compared to those of the Chalcolithic Age samples. Studies at higher magnifications with scanning electron microscope revealed the presence of spherical pores in Chalcolithic Age samples which are very similar to those seen in Iron Age samples (Figure 13). These spherical pores were probably developed because of the compaction of the ceramic body during firing in the 1100-1200 °C range (Kayani 1996).

Bulk samples of two potteries belonging to Chalcolithic Age (N3, S4) revealed diffraction lines at d values of 14-8 Å proposing a possible presence of some clay fragments in their structure. For this reason, oriented clay fractions of these pottery samples were analyzed by XRD for further investigations. However, clay fractions only contain amorphous structure, which indicates minimum firing temperatures in the range of 800-850 °C. This observation has already been stated in a previous study (Türkmenoğlu 1989). Therefore, the diffraction lines observed in bulk samples of N3 and S4 may be attributed to the presence of mica minerals.

Conclusion

Mineralogical analyses along with microstructural studies and chemical analyses of Değirmentepe (Malatya) pottery belonging to Chalcolithic (Ubaid Period) and Iron ages showed that almost all samples investigated contain rock fragments, originating from metamorphic and igneous rocks. However, larger grain sizes and higher grain to matrix ratios are recorded for Chalcolithic Age samples compared to those belonging to the Iron Age. This indicates the use of different raw material and/or different manufacturing technologies, such as different sieving procedures in both periods.

XRD investigations on selected representative samples of both periods, revealed high abundances of quartz, feldspar, and pyroxene group minerals in all samples and hematite and mica minerals in few samples. The analysis underlies the use of micaceous raw materials mostly in the Iron Age. This evidence may also support the use of different sources for the raw materials in both periods. In the XRD traces of the investigated sherds of Chalcolithic and Iron ages, the absence of clay minerals both in the bulk and clay fractions, supports a minimum firing temperature of around 800-850 °C, while the presence of mullite phases detected by the XRD and

SEM-EDX, a product of chemical reactions occurring around 1050 °C, showed the possible use of high firing temperatures in the range of 950-1050 °C, from the Chalcolithic Age onwards. This type of application usually results in good mechanical properties, low permeability and high chemical resistivity of the pottery. The vitreous-glassy morphology and secondary pores (results of high firing temperature applications) containing needle-like crystal structure of mullite as detected by SEM-EDX investigations of both Chalcolithic and Iron Age samples support these evidences.

All these observations indicate a rather advanced ceramic production technology used in Değirmentepe from the Chalcolithic Age onwards (5th millennium BCE).

Acknowledgements

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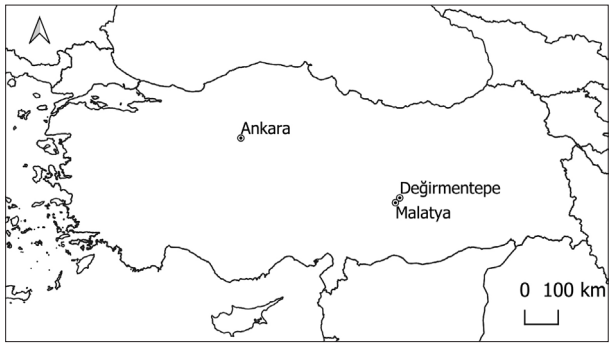

Figure 1.
Map showing the location of Değirmentepe.

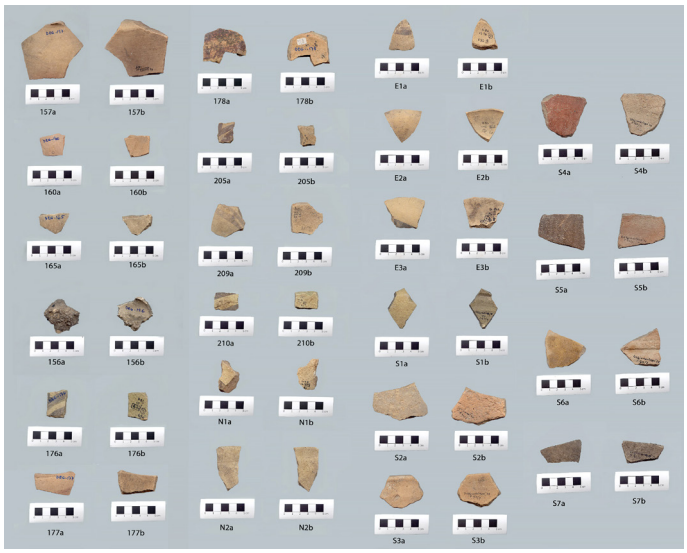

Figure 2(a).
Photographs of Chalcolithic Age pottery samples.

Figure 2(b).
Photographs of Iron Age pottery samples.

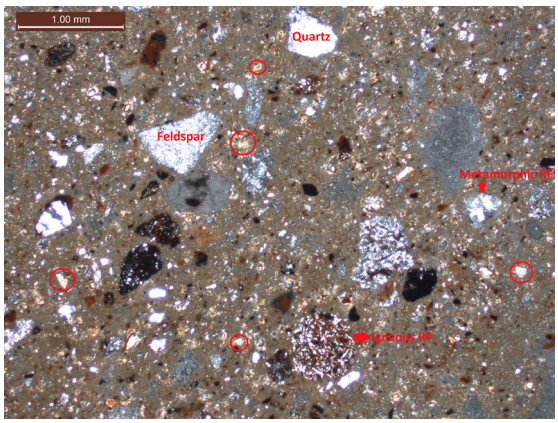

Figure 3. Rock fragments identified in Chalcolithic Age sample 205. Red circle indicates the small calcite dispersed in the clay matrix.

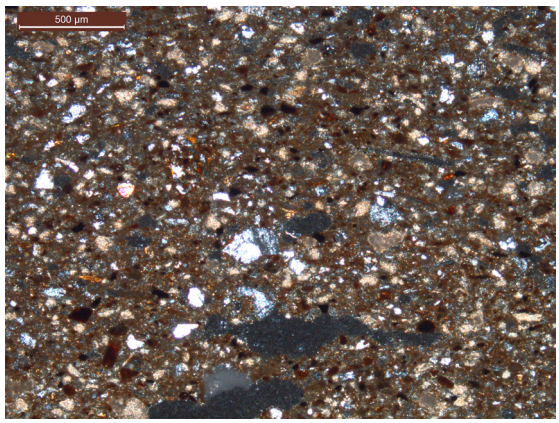

Figure 4. Thin section image shows calcite grains dispersed in clay matrix of Chalcolithic Age sample 209.

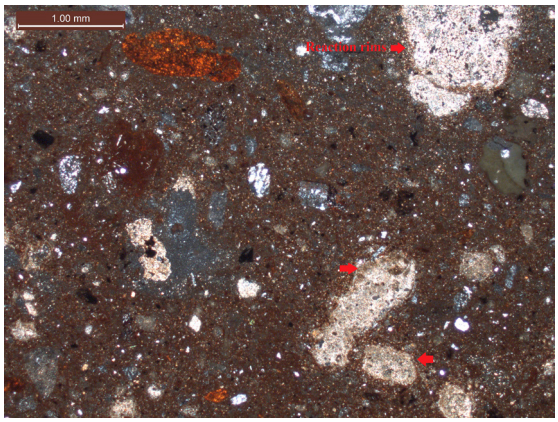

Figure 5. Thin section image shows reaction rims around calcite grain in Iron Age sample 224.

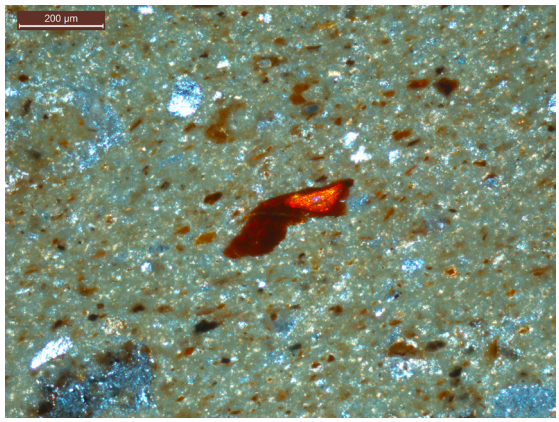

Figure 6. Thin section image shows hematite grains in Iron Age sample 224.

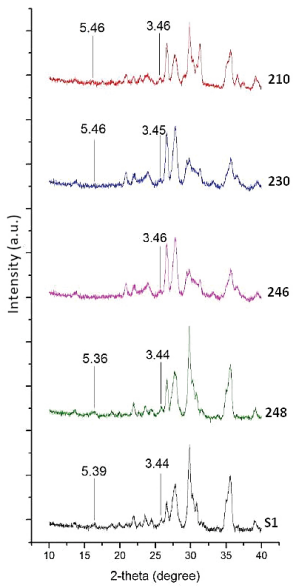

Figure 7. XRD traces of samples S1, 210 (Chalcolithic Age), 230, 246, 248 (Iron Age) indicating the presence of mullite (a.u.=arbitrary unit).

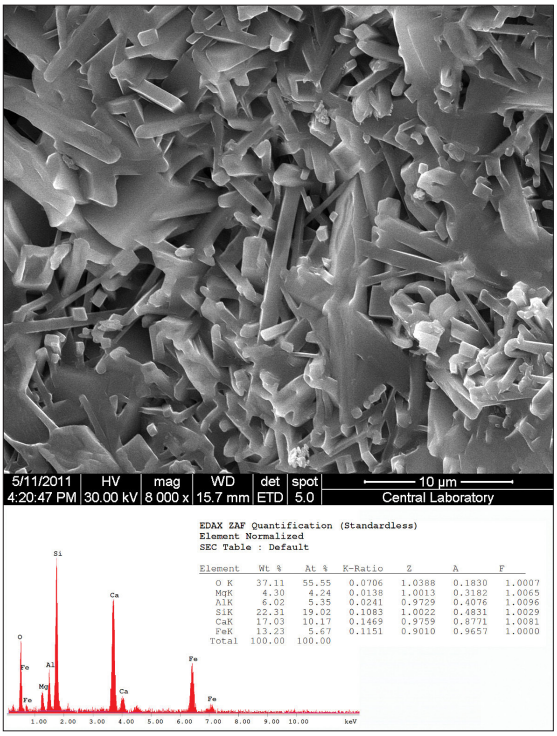

Figure 8. Needle like mullite crystals in glassy matrix in Sample S1 (Chalcolithic Age).

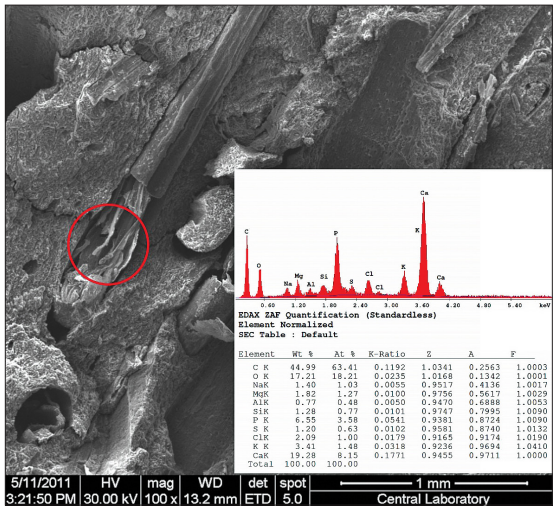

Figure 9. SEM micrograph and EDX analysis of chaff is a possible organic additive in Sample N3 (Chalcolithic Age).

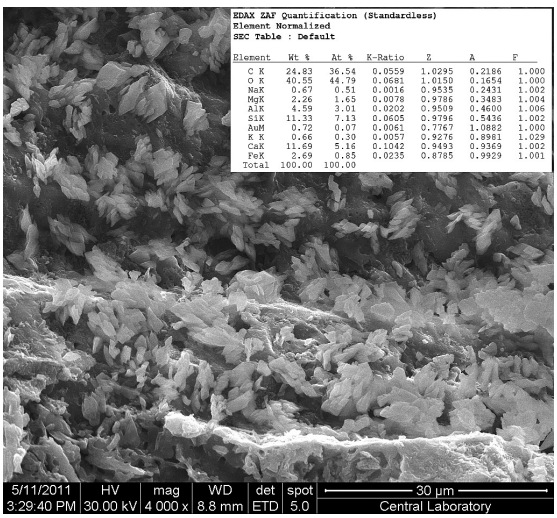

Figure 11. SEM micrograph of micritic calcite formation, Sample 246 (Iron Age).

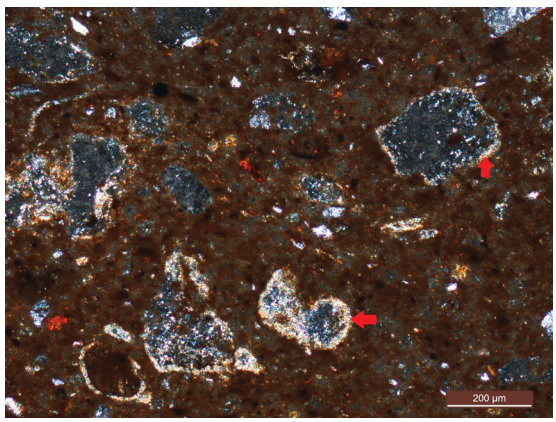

Figure 10. Photomicrograph of secondary calcite formation, Sample 246 (Iron Age).

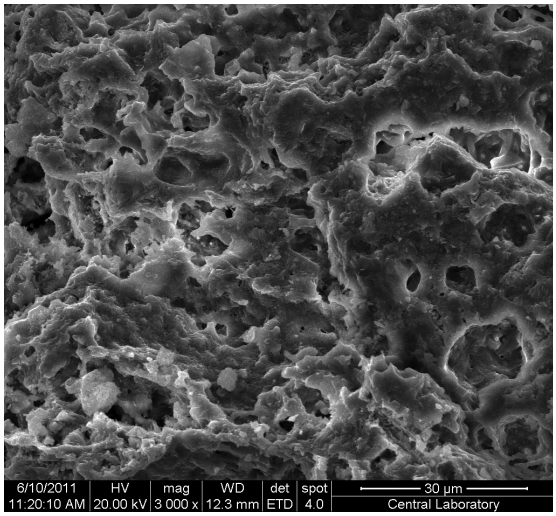

Figure 12. SEM micrograph of vitrified body, Sample 210 (Chalcolithic Age).

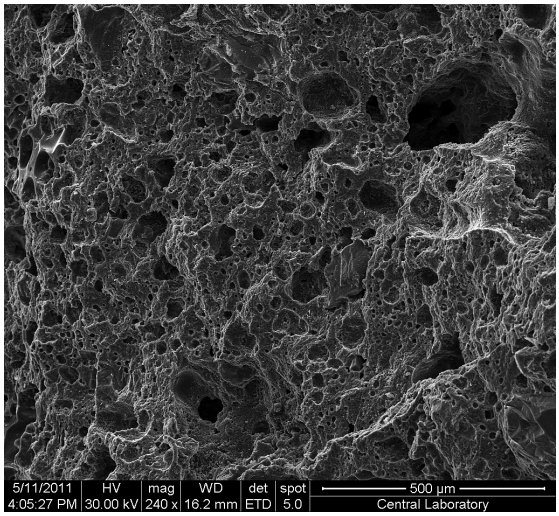

Figure 13. SEM micrograph of spherical pores, Sample S1 (Chalcolithic Age)

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Özel Fontlar

- Makalede özel bir font kullanıldıysa (Yunanca, Arapça, hiyeroglif vb.) bu font ve orijinal metnin PDF versiyonu da gönderilen dosyalar içerisine eklenmelidir.

Metin içi Atıflar ve Kaynakça Yazımı

- Her makale, metin içerisinde atıf yapılmış çalışmalardan oluşan ve "Kaynakça" olarak başlıklandırılan bir referans listesi içermelidir. Lütfen metin içerisinde bulunan her referansın kaynakçaya da eklendiğinden emin olun.
- Metin içerisindeki alıntılar doğrudan yapılabilir: '…Esin (1995)'in belirtmiş olduğu gibi' ya da parantez içerisinde verilebilir: 'analiz sonuçları gösteriyor ki … (Esin 1995).'
- Aynı parantez içerisindeki referanslar yayın yılına göre sıralanmalı ve ";" ile ayrılmalıdır: '… (Dinçol ve Kantman 1969; Esin 1995; Özbal vd. 2004).'
- Aynı yazarın farklı yıllara ait eserlerine yapılan atıflarda yazarın soyadı bir kere kullanılmalı ve eser yılları "," ile ayrılmalıdır: '... (Peterson 2002, 2010).'
- Aynı yazar(lar)ın aynı yıl içerisindeki birden fazla yayınına referans verileceği durumlarda yayın yılının yanına harfler 'a', 'b', 'c' gibi alfabetik olarak koyulmalıdır.
- Tek yazarlı kaynakları, aynı yazar adıyla başlayan çok yazarlı kaynaklardan önce yazınız.
- Aynı yazar adıyla başlayan fakat farklı eş yazarlara sahip kaynakları ikinci yazarın soyadına göre alfabetik sıralayınız.
- Aynı yazara ait birden fazla tek yazarlı kaynak olması durumunda kaynakları yıllara göre sıralayınız.
- Dergi makaleleri için doi bilgisi varsa kaynakçada mutlaka belirtiniz.

Aşağıda, farklı kaynakların metin içerisinde ve kaynakçada nasıl yazılacağına dair örnekler bulabilirsiniz.

Tek yazarlı dergi makaleleri, kitap içi bölümler ve kitaplar

Metin içerisinde:

Yazarın soyadı ve yayın yılı (Esin 1995).

Sayfa sayısı bilgisi verilecekse:

Yazarın soyadı ve yayın yılı, sayfa sayısı (Esin 1995, 140).

Dergi makalesi:

Bickle, P. 2020. Thinking Gender Differently: New Approaches to Identity Difference in the Central European Neolithic. *Cambridge Archaeological Journal* 30(2), 201-218. https://doi.org/10.1017/S0959774319000453

Kitap içi bölüm:

Esin, U. 1995. Aşıklı Höyük ve Radyo-Aktif Karbon Ölçümleri. A. Erkanal, H. Erkanal, H. Hüryılmaz, A. T. Ökse (Eds.), *İ. Metin Akyurt - Bahattin Devam Anı Kitabı. Eski Yakın Doğu Kültürleri Üzerine İncelemeler*, İstanbul: Arkeoloji ve Sanat Yayınları, 135-146.

Kitap:

Peterson, J. 2002. *Sexual Revolutions: Gender and Labor at the Dawn of Agriculture*. Walnut Creek, CA: AltaMira Press.

İki yazarlı dergi makaleleri, kitap içi bölümler ve kitaplar

Metin içerisinde:

Her iki yazarın soyadı ve yayın yılı (Dinçol ve Kantman 1969, 56).

Dergi makalesi:

Pearson, J., Meskell, L. 2015. Isotopes and Images: Fleshing out Bodies at Çatalhöyük. *Journal of Archaeological Method and Theory* 22, 461-482. https://doi.org/10.1007/s10816-013-9184-5

Kitap içi bölüm:

Özkaya, V., San, O. 2007. Körtik Tepe: Bulgular Işığında Kültürel Doku Üzerine İlk Gözlemler. M. Özdoğan, N. Başgelen (Eds.), *Türkiye'de Neolitik Dönem. Yeni Kazılar, Yeni Bulgular*, İstanbul: Arkeoloji ve Sanat Yayınları, 21-36.

Kitap:

Dinçol, A. M., Kantman, S. 1969. *Analitik Arkeoloji, Denemeler*. Anadolu Araştırmaları III, Özel sayı, İstanbul: Edebiyat Fakültesi Basımevi.

Üç ve daha çok yazarlı dergi makaleleri ve kitap içi bölümler

Metin içerisinde:

İlk yazarın soyadı, "vd." ve yayın yılı (Özbal vd. 2004).

Dergi makalesi:

Özbal, R., Gerritsen, F., Diebold, B., Healey, E., Aydın, N., Loyet, M., Nardulli, F., Reese, D., Ekstrom, H., Sholts, S., Mekel-Bobrov, N., Lahn, B. 2004. Tell Kurdu Excavations 2001. *Anatolica* 30, 37-107.

Kitap içi bölüm:

Pearson, J., Meskell, L., Nakamura, C., Larsen, C. S. 2015. Reconciling the Body: Signifying Flesh, Maturity, and Age at Çatalhöyük. I. Hodder, A. Marciniak (Eds.), *Assembling Çatalhöyük*, Leeds: Maney Publishing, 75-86.

Editörlü kitaplar

Metin içerisinde:

Yazar(lar)ın soyadı ve yayın yılı (Akkermans ve Schwartz 2003).

Akkermans, P. M. M. G., Schwartz, G. M. 2003. (Eds.) *The Archaeology of Syria. From Complex Hunter-Gatherers to Early Urban Societies (c. 16.000-300 BC)*. Cambridge: Cambridge University Press.

Web kaynağı:

Soyad, Ad. Web Sayfasının Başlığı. Web Sitesinin Adı. Yayınlayan kurum (varsa), yayın tarihi. Erişim tarihi. URL.

ARKEOLOJİ BİLİMLERİ DERGİSİ

TURKISH JOURNAL OF ARCHAEOLOGICAL SCIENCES

Submission and Style Guideline

Submission Criteria for Articles

The content of the manuscripts should meet the aims and scope of the Turkish Journal of Archaeological Sciences (cf. Aims and Scope).

Manuscripts may be written in Turkish or English. The translation of articles into English is the responsibility of the author(s). If the author(s) are not fluent in the language in which the article is written, they must ensure that the text is reviewed, ideally by a native speaker, prior to submission.

Each manuscript should include a Turkish and an English abstract of up to 200 words and five keywords in both Turkish and English. Citations should not be included in the abstract.

If the author(s) are not fluent in the language of the manuscript, a translation of the abstract and the keywords may be provided by the editorial board.

Manuscripts, figures, and other files should be sent via wetransfer or e-mail to **archaeologicalsciences@gmail.com**

Submission Checklist

Each article must contain the following:

- Authors (please provide the name-last name and contact details of each author under the main title of the manuscript)
- Affiliation (where applicable)
- E-mail address
- ORCID ID

The manuscript should contain:

- Title
- Abstract (in English and Turkish)
- Keywords
- Text
- References
- Figures (when applicable)
- Tables (when applicable)

Scientific Standards and Ethics

- Submitted manuscripts should include original research that has not been previously published or submitted for publication elsewhere.
- The manuscripts should meet scientific standards.
- Manuscripts should use inclusive language that is free from bias based on sex, race or ethnicity, etc. (e.g., “he or she” or “his/her/their” instead of “he” or “his”) and avoid terms that imply stereotypes (e.g., “humankind” instead of “mankind”).

Style Guide

Manuscript Formatting

- Manuscripts should be written in Times New Roman 12-point font, justified and single-spaced. Please submit the manuscript as a word document.
- Words in foreign and ancient languages should be *italicized*.
- Titles and subtitles should appear in **bold**.
- Titles and subtitles should not be numbered, italicized, or underlined.
- Only the first letter of each word in titles and subtitles should be capitalized.

References

Cf.: In-Text Citations and References

- In-text citations should appear inside parenthesis (Author year, page number).
- Footnotes and endnotes should not be used for references. Comments should be included in footnotes rather than endnotes.
- The footnotes should be written in Times New Roman 10-point font, justified and single-spaced, and should be continuous at the bottom of each page.

Figures and Tables

- Please provide a caption list for figures and tables following the references. Provide credits where applicable. Each figure and table should be referenced in the text (Figure 1, or Table 1), but please do not include figures in the text document.
- Each figure should be submitted separately as a jpg or tiff file.
- Images should be submitted in the dimensions in which they should appear in the published text and their resolution must be over 300 dpi.
- Please avoid editing the figures in Photoshop or similar programs but send the raw version of the figures if possible.
- Tables and graphs prepared in Excel should be sent as both PDF and Excel documents.

Dates and Numbers

- Please use BCE/CE and please avoid using dots without dots (i.e., BCE instead of BC or B.C.).
- Please use a dot for numbers and dates with 5 or more digits (i.e., 10.500 BCE).
- Please avoid using dots for numbers and dates with 4 or less digits (i.e., 8700 BCE).
- Please spell out whole numbers from 0 to 10 (e.g., “the floor was renewed eight times” instead of “the floor was renewed 8 times”).

Punctuation

- Please prefer em dashes (—) for parenthetical sentences: “Children were buried with various items, the adolescents—individuals between the ages of 12-19—had the most variety in terms of grave goods.”
- Please prefer an en dash (-) between page numbers, years, and places: 1989-2006; İstanbul-Kütahya.

Abbreviations

- Commonly used abbreviations:

Approximately:	approx.	Figure:	Fig.
Confer:	cf.	*Id est:*	i.e.,
Circa:	ca.	*Exempli gratia:*	e.g.,
Calibrated:	cal.		

Special Fonts

- If a special font must be used in the text (e.g., Greek or Arabic alphabet or hieroglyphs), the text in the special font and the original manuscript should be sent in separate PDF files.

In-Text Citations and References

- Each article should contain a list of references in a section titled "References" at the end of the text. Please ensure that all papers cited in the text are listed in the bibliography.
- Citations in the text may be made directly, e.g., 'as shown by Esin (1995) ...' or in parenthesis, e.g., 'research suggests ... (Esin 1995)'.
- References within the same parenthesis should be arranged chronologically and separated with a ";", e.g., '... (Dinçol and Kantman 1969; Esin 1995; Özbal et al. 2004).'
- In references to the studies by the same author from different years, please use the last name of the author once, followed by the years of the cited studies, each separated by a ",", e.g., '... (Peterson 2002, 2010).
- More than one reference from the same author(s) in the same year must be identified by the letters 'a', 'b', 'c' placed after the year of publication.
- When dealing with multiple papers from the same author, single authored ones should be written before the studies with multiple authors.
- When dealing with papers where the first author is the same, followed by different second (or third, and so on) authors, the papers should be listed alphabetically based on the last name of the second author.
- When dealing with multiple single-authored papers of the same author, the papers should be listed chronologically.
- Please provide the doi numbers of journal articles.

Below, you may find examples for in-text citations and references.

Single-authored journal articles, book chapters, and books

In-text:

Last name and publication year (Esin 1995).

If the page number is indicated:

Last name and publication year, page number (Esin 1995, 140).

Journal article:

Bickle, P. 2020. Thinking Gender Differently: New Approaches to Identity Difference in the Central European Neolithic. *Cambridge Archaeological Journal* 30(2), 201-218. https://doi.org/10.1017/S0959774319000453

Book chapter:

Esin, U. 1995. Aşıklı Höyük ve Radyo-Aktif Karbon Ölçümleri. A. Erkanal, H. Erkanal, H. Hüryılmaz, A. T. Ökse (Eds.), *İ. Metin Akyurt - Bahattin Devam Anı Kitabı. Eski Yakın Doğu Kültürleri Üzerine İncelemeler*, İstanbul: Arkeoloji ve Sanat Yayınları, 135-146.

Book:

Peterson, J. 2002. Sexual Revolutions: *Gender and Labor at the Dawn of Agriculture*. Walnut Creek, CA: AltaMira Press.

Journal articles, book chapters, and books with two authors

In-text:

Last names of both authors and publication year (Dinçol and Kantman 1969, 56).

Journal article:

Pearson, J., Meskell, L. 2015. Isotopes and Images: Fleshing out Bodies at Çatalhöyük. *Journal of Archaeological Method and Theory* 22, 461-482.
https://doi.org/10.1007/s10816-013-9184-5

Book chapter:

Özkaya, V., San, O. 2007. Körtik Tepe: Bulgular Işığında Kültürel Doku Üzerine İlk Gözlemler. M. Özdoğan, N. Başgelen (Ed.), *Türkiye'de Neolitik Dönem. Yeni Kazılar, Yeni Bulgular*, İstanbul: Arkeoloji ve Sanat Yayınları, 21-36.

Book:

Dinçol, A. M., Kantman, S. 1969. *Analitik Arkeoloji, Denemeler*. Anadolu Araştırmaları III, Özel sayı, İstanbul: Edebiyat Fakültesi Basımevi.

Journal articles and book chapters with three or more authors

In-text:

Last name of the first author followed by "et al." and the publication year (Özbal et al. 2004).

Journal article:

Özbal, R., Gerritsen, F., Diebold, B., Healey, E., Aydın, N., Loyet, M., Nardulli, F., Reese, D., Ekstrom, H., Sholts, S., Mekel-Bobrov, N., Lahn, B. 2004. Tell Kurdu Excavations 2001. *Anatolica* 30, 37-107.

Book chapter:

Pearson, J., Meskell, L., Nakamura, C., Larsen, C. S. 2015. Reconciling the Body: Signifying Flesh, Maturity, and Age at Çatalhöyük. I. Hodder, A. Marciniak (Eds.), *Assembling Çatalhöyük*, Leeds: Maney Publishing, 75-86.

Edited books

In-text:

Last name(s) of the author(s) and publication year (Akkermans and Schwartz 2003).

Akkermans, P. M. M. G., Schwartz, G. M. 2003. (Eds.) *The Archaeology of Syria. From Complex Hunter-Gatherers to Early Urban Societies (c. 16.000-300 BC)*. Cambridge: Cambridge University Press.

Web source:

Last name, Initial of the first name. Title of the web page. Title of the website. Institution (where applicable), publication date. Access date. URL.