Kazuma Hashimoto, Kazumi Yokoyama, Izumi Nakai

Studying the Provenance of Pottery from Boğazköy, Turkey, using Heavy Mineral Analysis

Istanbuler Mitteilungen 66, 2016, 37–58 (Sonderdruck)

https://doi.org/10.34780/z390-56kc

Herausgebende Institution / Publisher:
Deutsches Archäologisches Institut

DEUTSCHES ARCHÄOLOGISCHES INSTITUT
ABTEILUNG ISTANBUL

ISTANBULER MITTEILUNGEN

BAND 66, 2016

PDF Dokument des gedruckten Beitrags
PDF document of the printed version of

KAZUMA HASHIMOTO – KAZUMI YOKOYAMA – IZUMI NAKAI

Studying the Provenance of Pottery from Boğazköy, Turkey, using Heavy Mineral Analysis

Sigel der Istanbuler Mitteilungen
IstMitt

Herausgeber und Redaktion:
Deutsches Archäologisches Institut, Abteilung Istanbul
İnönü Cad. 10, TR-34437 İSTANBUL – Gümüşsuyu

Satz, Gestaltung u. Reprographie: Linden Soft Verlag e.K., Aichwald.
Druck und Einband: AZ Druck und Datentechnik GmbH, Kempten.
Printed in Germany

ISBN 978-3-8030-1657-7 ISSN 0341-9142

KAZUMA HASHIMOTO* – KAZUMI YOKOYAMA – IZUMI NAKAI

Studying the Provenance of Pottery from Boğazköy, Turkey, using Heavy Mineral Analysis

Keywords: Boğazköy, Pottery, Archaeometry, Bronze Age, Iron Age
Schlüsselwörter: Boğazköy, Keramik, Archäometrie, Bronzezeit, Eisenzeit
Anahtar sözcükler: Boğazköy, Keramik, Arkeometri, Tunç Çağı, Demir Çağı

Introduction

This study provides insight into the use of heavy mineral analysis and mineral chemistry in pottery provenance research. Pottery provenance studies provide important information about the production and exchange or trade of pottery between different archaeological sites or regions, helping archaeologists to further understand social interactions[1]. To increase our understanding of social interactions among different archaeological sites or regions in ancient Central Anatolia, a project was undertaken in 2009 to study the provenance of pottery from several archaeological sites in the region using heavy mineral analysis through SEM-EDS[2].

Classically, petrographic analysis on thin sections of pottery by polarizing microscope has been used in pottery provenance study[3]. However, the amount of information in the thin sections is limited to the minerals exposed on the surface. Then, by polarizing microscope, mineral grains smaller than about 20 µm and opaque minerals are difficult to identify. Moreover, accurate identification of minerals using this method depends on the researcher's skill and experience

The authors would like to thank Dr. Andreas Schachner (Director of Boğazköy excavation) for providing us with the pottery samples and his support of this study. Our thanks also go to Dr. Sachihiro Omura and Dr. Kimiyoshi Matsumura (Japanese Institute of Anatolian Archaeology) for their support. Without it, this project would not be possible. Thanks also to Dr. Yoshinari Abe and Dr. Willy Bong Shun Kai (Tokyo University of Science) for their support and helpful discussions. Thanks also to Ms. Masako Shigeoka (National Museum of Nature and Science) for her skilled technical assistance. We are grateful to the members of the Boğazköy Excavation Team and the Kaman-Kalehöyük Excavation Team for their kind help in collecting samples.

Sources of illustrations: *Figs. 1–2* = Based on Maden Tetkik ve Arama Genel Müdürlüğü, Türkiye Jeoloji Haritasi (Ankara 2002) and modified by K. Hashimoto. – *Figs. 3–5* = K. Hashimoto.

* Corresponding author.

[1] Rice 1987.

[2] Scanning Electron Microscope Equipped with Energy Dispersive Spectrometer.

[3] Rice 1987; Freestone 1995.

with optical mineralogy. Therefore, we have established and improved heavy mineral analysis through SEM-EDS. Our method overcomes the abovementioned weaknesses of petrographic analysis on thin sections of pottery by polarizing microscope. Bulk chemical analysis is also common method in pottery provenance study[4]. We attempted the method, but heavy mineral analysis is superior as an indicator of provenance.

We have already investigated the provenance of several types of pottery from sites at Kaman-Kalehöyük, Alişar Höyük, Büklükale, and Boğazköy using our method especially to compare soil samples from the vicinity to pottery from the mentioned sites[5]. The developed method enables the analysis of c. 200 heavy mineral grains extracted from a large-sized sample (over 30 g), thus providing statistically meaningful and reliable data. The positive results of these studies have demonstrated that heavy mineral analysis is a useful tool for pottery provenance study especially in Central Anatolia because of the region's geological diversity.

Several pottery provenance studies have been conducted in Boğazköy through bulk chemical analysis (INAA) and petrographic analysis of thin pottery sections using polarizing microscopes[6]. In a previous study, we analyzed Assyrian Colony, Hittite, and Iron Age pottery excavated from Boğazköy using already heavy minerals analysis through SEM-EDS[7]. It revealed the likely provenance of Hittite cream ware by studying the heavy mineral proportions. However, due to a lack of reference sediment samples from around Boğazköy, we could not determine with certainty whether the pottery sample was imported.

Hence, the present study aims, first, to complete the reference database for the heavy mineral proportions of the natural sediments collected within a 25 km radius of Boğazköy. Second, we aim to differentiate between local and imported wares by comparing the heavy mineral proportion between the pottery and local natural sediments. Pottery clearly defined typologically and stylistically and excavated from different cultural periods was included in this study. The selected examples cover the Assyrian Colony Period, the Hittite Period, the various stages of the Iron Ages as well as the Galatian, Roman, and Byzantine Periods[8]. The third aim is to understand the pottery trade relationships between Boğazköy and previously investigated sites, Kaman-Kalehöyük, Alişar Höyük, and Büklükale. With this study, we hope to deepen the understanding of the production and distribution of pottery in each period as well as the interactions among sample sites in Central Anatolia.

Methodology

In this study, heavy mineral analysis through SEM-EDS was used to differentiate between imported and locally produced wares. Moreover, when similar heavy mineral proportions were found between Boğazköy and other sites, geochemical analyses of individual mineral grains were done using an EPMA[9] to confirm the finding.

4 Rice 1987.
5 Bong et al. 2010; Bong 2012; Hashimoto et al. 2013; Hashimoto 2014.
6 Kealhofer et al. 2009; Knappett et al. 2005.
7 Hashimoto et al. 2013.
8 For a general overview of the settlement history of Boğazköy cf. Schachner 2011.
9 Electron Probe Microanalyzer.

Heavy mineral analysis using SEM-EDS

Heavy mineral analysis is a useful method for specifying the provenance of pottery[10]. In the present study, heavy minerals are defined as minerals with densities greater than 2.82 g/cm^3. They are present in most natural sediments in small proportions and have great diversity in different geological units. Some heavy minerals are characteristic of a particular type of source rock (e. g., Fe-rich garnet is characteristic in a high-grade metamorphic rock source). These petrological characteristics provide important information to allow specifying the source of the sediment or pottery. As such, heavy minerals are a very sensitive indicator of provenance. Incidentally, light minerals such as quartz, feldspar, or clay are less diagnostic because they are very common on the earth's surface. Pottery is made from clay sediments. Therefore, if the proportions of heavy minerals in pottery and the sediment around an excavation site are analyzed and compared, their geological source can be specified.

Geochemical analysis of individual Fe-rich garnet grains using an EPMA

Many heavy mineral species show a wide range of chemical compositions that depend on petrogenetic controls (e. g., temperature, pressure, and chemical composition of parent rocks). Even if these heavy minerals were separated from their parent rocks, transported, and deposited, their chemical compositions are preserved. Therefore, by analyzing the chemical composition of the mineral grains, we can discern the petrogenetic controls of the parent rock. This information provides additional support to determine the provenance of pottery inferred by heavy mineral analysis. This geochemical study of detrital heavy minerals has long been applied to geological sediment provenance research with heavy mineral analysis[11]. This method can be used for sediment as well as pottery excavated from archaeological sites[12]. In this study, we analyzed Fe-rich garnet found in several pottery samples.

Garnet geochemistry is the most widely used geochemical tool to determine and discriminate sediment provenance because it shows a wide range of major element compositions that vary by petrogenetic controls[13]. The metamorphic massif in Central Anatolia is made up by low-grade regional metamorphosed ultramafic rock (ophiolite). From this geology, Ca-rich garnet (grossular) frequently occur, but Fe-rich garnet (almandine) rarely occur. Ca-rich garnet is only observed in low-grade regions including mafic rocks in the serpentinite bodies. We analyzed surface sediments, including high-grade regions and surrounding areas in Central Anatolia. Therefore, garnet geochemistry can potentially be used to characterize different geological systems, providing us with geological data to determine the provenance of pottery.

---

10 Peacock 1967; Williams 1977; Mange – Bezeczky 2007.

11 Yokoyama 1990.

12 Bong et al. 2010.

13 Mange – Morton 2007.

Abbildung aufgrund fehlender Digitalrechte ausgeblendet.

Fig. 1 Geological map of the Boğazköy region showing the collection point of sediment samples

Samples and Analytical Techniques

Reference sediment samples

Sediment samples were collected within a 25 km radius around Boğazköy and used for reference (*Figs. 1. 2*). *Figs. 1* and *2* show the geological and topographical maps around Boğazköy, respectively, and indicate the origins of the sediment samples. Forty-two sediment samples were collected from the surface of the mountain face, cultivated land, and the riverbed. Their locations are listed in Table 1.

As shown in *Fig. 1* and *2*, the ophiolitic masses surrounding the site form mountainous areas from east to west reaching up to a height of 1400 m. The site is located on the north slope of this mountainous region. A plane sedimentary rock region extends outward north of the site, which partly indicates the deep geological time (Permo-Trassic or Ordovician). These geographical features around Boğazköy indicate that it was difficult to carry raw materials for pottery around Boğazköy, except for the north part of the site. Volcanic rock regions are found only southwest and southeast of the site, and a mountainous area of sedimentary rock extends outward to the south.

Pottery samples

Forty-two pottery samples were collected to examine their origins. Most of them are amorphous body sherds so the actual vessel shape could not be determined. These non diagnostic sherds were

Abbildung aufgrund fehlender Digitalrechte ausgeblendet.

Fig. 2 Topographical map of the Boğazköy region showing the collection point of sediment samples

selected since heavy mineral analysis is destructive. Their dating is possible through comparison of their ware types with material from well dated contexts. Table 2 shows the list of pottery sherd samples. *Fig. 3* presents photographs of the pottery sherds indicating the period of each sample. These included two Assyrian Colony, thirteen Hittite, four Middle Iron Age, fourteen Late Iron Age, one Hellenistic, two Galatian, two Roman, and four Byzantine potsherds. There are several characteristic potsherds from each period, such as five cream ware sherds from the Hittite period (H-43, 44, 45, 46, 47)[14] and eight black polished ware sherds from the Late Iron Age (H-85, 86, 87, 89, 91, 92, 93, 94)[15].

Heavy mineral analysis through SEM-EDS

The procedures used for heavy mineral analysis follow those already described by Bong et al. and Hashimoto et al. so a detailed explanation is excluded here[16]. The pottery and sediment samples were washed in running tap water and sieved using a 355 μm mesh. Methylene iodide (2.82 g/cm^3) was used for separation according to the density. All minerals were identified using SEM-EDS (JEOL JSM-6610). Identifying heavy minerals using SEM-EDS is done according

---

14 Mielke 2007, 162: »White Lustrous Wheel-made Ware«.

15 Bossert 2000; Kealhofer et al. 2009.

16 Bong et al. 2010; Hashimoto et al. 2013.

ID	GPS data						Description	Geology	HM
	northing			easting					Pattern
S-20	40	03	32	34	43	37	CL	SR	A
S-23	40	06	45	34	49	40	CL	SR	A
S-25	40	06	20	34	54	20	RS		A
S-26	40	11	01	34	52	15	RS		A
S-28	40	09	23	34	46	25	RS		B
S-29	40	09	25	34	41	54	CL		A
S-30	40	08	60	34	35	17	CL		A
S-33	39	58	04	34	36	45	MF	OP	A
S-34	39	56	44	34	36	14	MF	OP	A
S-36	39	55	08	34	39	49	MF	SR	B
S-38	39	52	30	34	38	31	MF	SR	A
S-41	39	48	24	34	39	38	CL		B
S-42	39	49	26	34	44	55	MF	OP	A
S-43	39	49	40	34	47	06	MF	VR	B
S-45	39	51	56	34	42	45	MF	VR	A
S-46	39	54	21	34	45	04	MF	SR	A
S-48	40	00	53	34	35	36	MF	OP, SR	A
S-50	40	00	19	34	32	35	MF	OP	A
S-51	39	59	26	34	31	54	MF	VR	C
S-52	39	57	22	34	31	09	MF	SR	A
S-53	39	54	49	34	29	50	CL	SR	C
S-55	39	50	07	34	28	33	CL	SR	A
S-60	39	53	13	34	25	33	MF	LS	C
S-61	39	56	03	34	25	58	MF	SR	C
S-63	40	11	47	34	30	32	MF	OP	A
S-64	40	09	29	34	29	31	CL	SR	A
S-65	40	07	42	34	32	09	RS		A
S-67	40	10	39	34	40	24	MF	SR	A
S-68	40	06	07	34	32	17	CL		A
S-69	40	04	29	34	34	32	RS		A
S-70	40	02	49	34	36	23	RS		A
S-71	40	10	39	34	25	47	CL		A
S-73	40	08	20	34	27	10	MF	SR	B
S-75	40	05	10	34	26	17	MF	SR	A
S-77	40	03	36	34	27	18	MF	OP	A
S-79	40	01	19	34	29	30	MF	OP	A
S-80	40	01	41	34	31	22	MF	OP	A
S-82	39	58	58	34	29	51	MF	VR	C
S-91	40	04	57	34	39	15	MF	SR	B
S-92	40	01	25	34	36	59	RS		A
S-93	40	01	19	34	36	44	MF	SR	A
S-96	40	00	17	34	36	47	MF	SR	A

Table 1 List of local sediment samples showing their GPS position and description of the heavy mineral grouping. (MF: soil at mountain face, CL: surface soil from cultivated land, RS: river sand, OP: ophiolite, SR: sedimentary rock, VR: volcanic rock, LS: lime stone, HM pattern: heavy mineral pattern)

ID	Dating	Excava-tion	Site	Provenance	Type	Detail	HM group
Assyrian Colony period							
H-48	ACP	2011		71:620A-22	cream ware	cream slip (both sides)	4
H-51	ACP	2011		177:631	common ware		1
Hittite period							
H-52	OH	1977		IV 2-9:100	gray ware	polished gray slip	1
H-53	OH	1978		R3-90	gray ware	shinning grains (quartz), polished gray slip (one side)	5
H-43	HP	1977		III 3-4:38	cream ware	cream slip (both sides)	1
H-44	HP	1976		A22-78	cream ware	cream slip (both sides), polished (one side), shinning grains (quartz)	5
H-45	HP	1977		III 3-4:45	cream ware	cream slip (both sides)	2
H-46	HP	1977		III 3-4:15	cream ware	cream slip (both sides)	6
H-47	HP	1977		III 3-4:9	cream ware	cream slip (both sides)	1
H-49	HP	1977		IV 4-5:9	gold wash ware	gold wash (one side)	2
H-50	HP	1973		49B:77	gold wash ware	gold wash (one side)	1
H-54	HP	1973		40-14	gray ware		1
H-55	HP	1975		T12-5	common ware	polished (both sides)	6
H-56	HP	1976		A19-1	common ware		1
H-57	HP	1975		T12-21	common ware	white grains (lime)	6
Iron Age							
H-73	MIA?	1964	Büyükkale	BK II	Alisar IV		6
H-77	MIA?	1963	Büyükkale	BK II	common ware		1
H-79	MIA?	1965	Büyükkale	BK II	common ware		2
H-80	MIA?	1966	Büyükkale	BK II	common ware		6
H-58	LIA	1958	Büyükkale	BK10	gray ware	polished (both sides)	1
H-76	LIA?	1959			gray ware	polished (both sides), shin-ning grains (quartz)	5
H-82	LIA?	1963	Büyükkale	BK Ib	common ware		2
H-83	LIA?	1963	Büyükkale	BK Ib	common ware		2
H-84	LIA?	1963	Büyükkale	BK Ib	cooking pot	soot on the face	1
H-85	LIA?	1959			black polished ware	polished (one side)	2
H-86	LIA?	1959			black polished ware	polished (one side)	2
H-87	LIA?	1959			black polished ware	polished (one side)	2
H-89	LIA?	1964	Büyükkale	BK Ib	black polished ware	polished (one side)	1
H-90	LIA?	1986	Oberstadt, östl. Plateau	K.N:18	cooking pot	many shininng grain (albite), soot on the face	6
H-91	LIA?	1959			black polished ware	polished (both sides)	1
H-92	LIA?	1959			black polished ware	polished (both sides)	2
H-93	LIA?	1959			black polished ware	polished (both sides)	2
H-94	LIA?	1958-1960			black polished ware	polished (one side)	1
Post-Iron Age							
H-60	Hellenistic	1960	Büyükkale	M/18	gray ware	polished (both sides)	2
H-61	Galatia	1960	Büyükkale	M/18 (East?)	polychrome ware	red, black and white painted	2
H-62	Galatia	1960	Büyükkale	M/18 (West?)	red painted ware	red painted	2
H-66	Roman	1958	Büyükkale	BK10	common ware		2
H-67	Late Roman	1958	Büyükkale	BK10	cream ware	cream slip (one side)	1
H-68	Byzantine	2012	Mittleres Plateau	06/523	common ware	pithos	1
H-69	Byzantine	2012	Mittleres Plateau	08/1530:1554-30	cooking pot	soot on the face	2
H-70	Byzantine	2012	Oberstadt	Siedlung Oberstadt 354	common ware		1
H-71	Byzantine	2012	Oberstadt	Siedlung Oberstadt 2001-2	gold wash ware	gold washed, black core, shining grains (quartz)	6

Table 2 List of pottery samples with their archaeological context and heavy mineral grouping. (ACP: Assyrian Colony period, OH: Old Hittite period, MIA: Middle Iron Age, LIA: Late Iron Age, HM group: heavy mineral group)

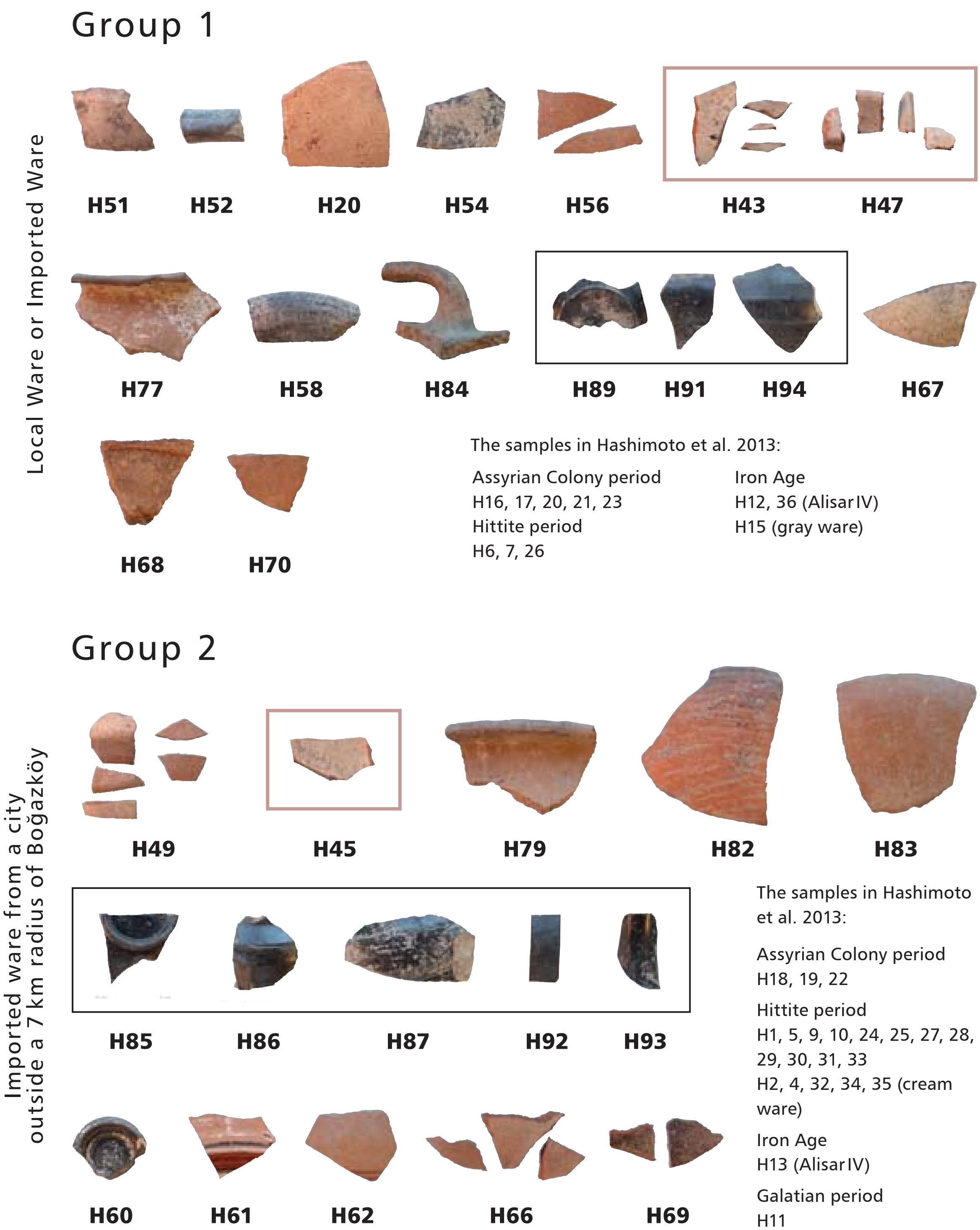

Fig. 3 Fortytwo pottery samples from Boğazköy examined in this study (all pottery scale 1 : 5)

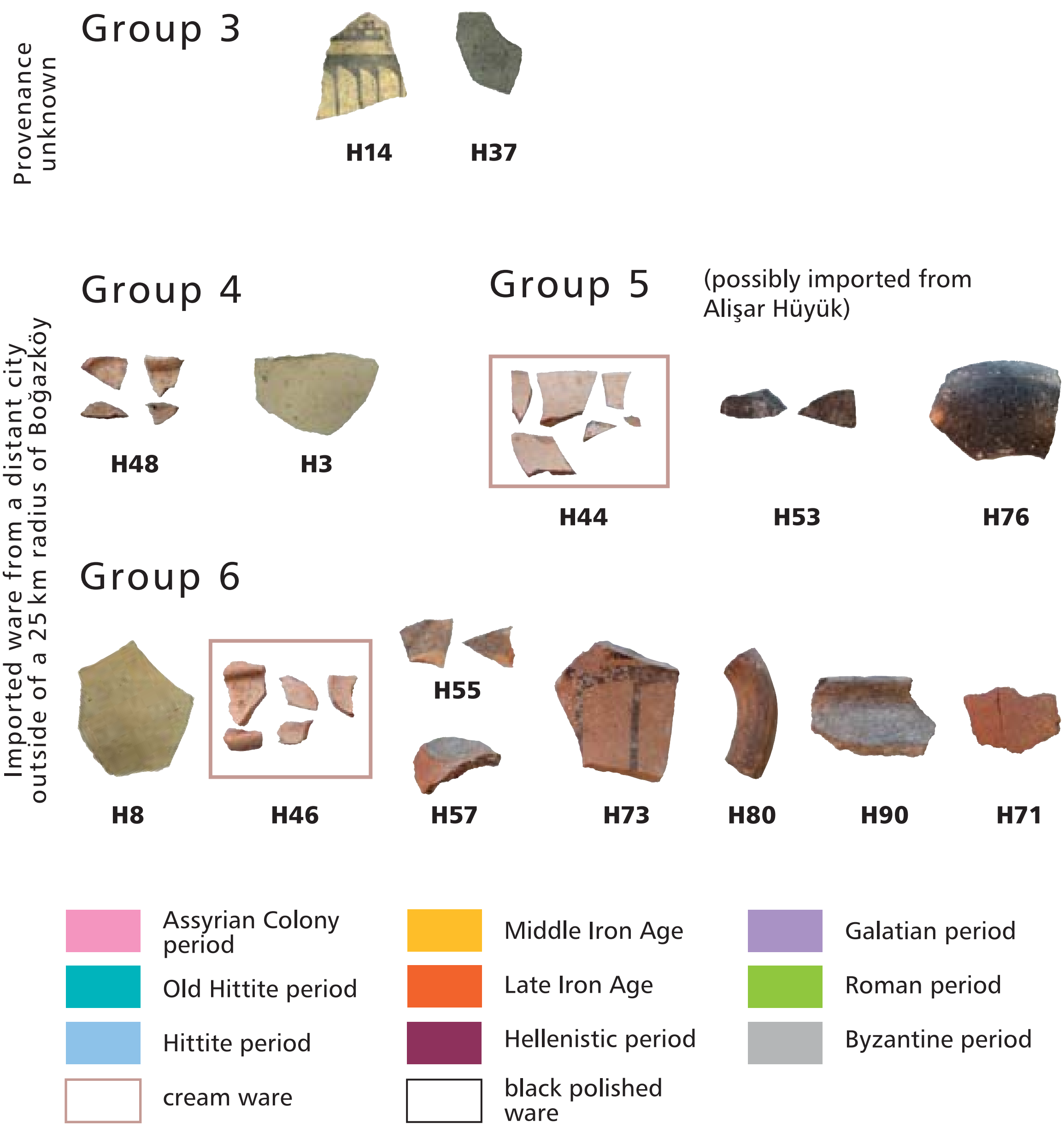

Fig. 3 cont.

to the chemical compositional signature of the heavy minerals; this is an original technique we developed[17]. Approximately 100–200 grains were identified in each pottery and sediment sample; thus, statistically significant data were obtained.

---

[17] Bong et al. 2010.

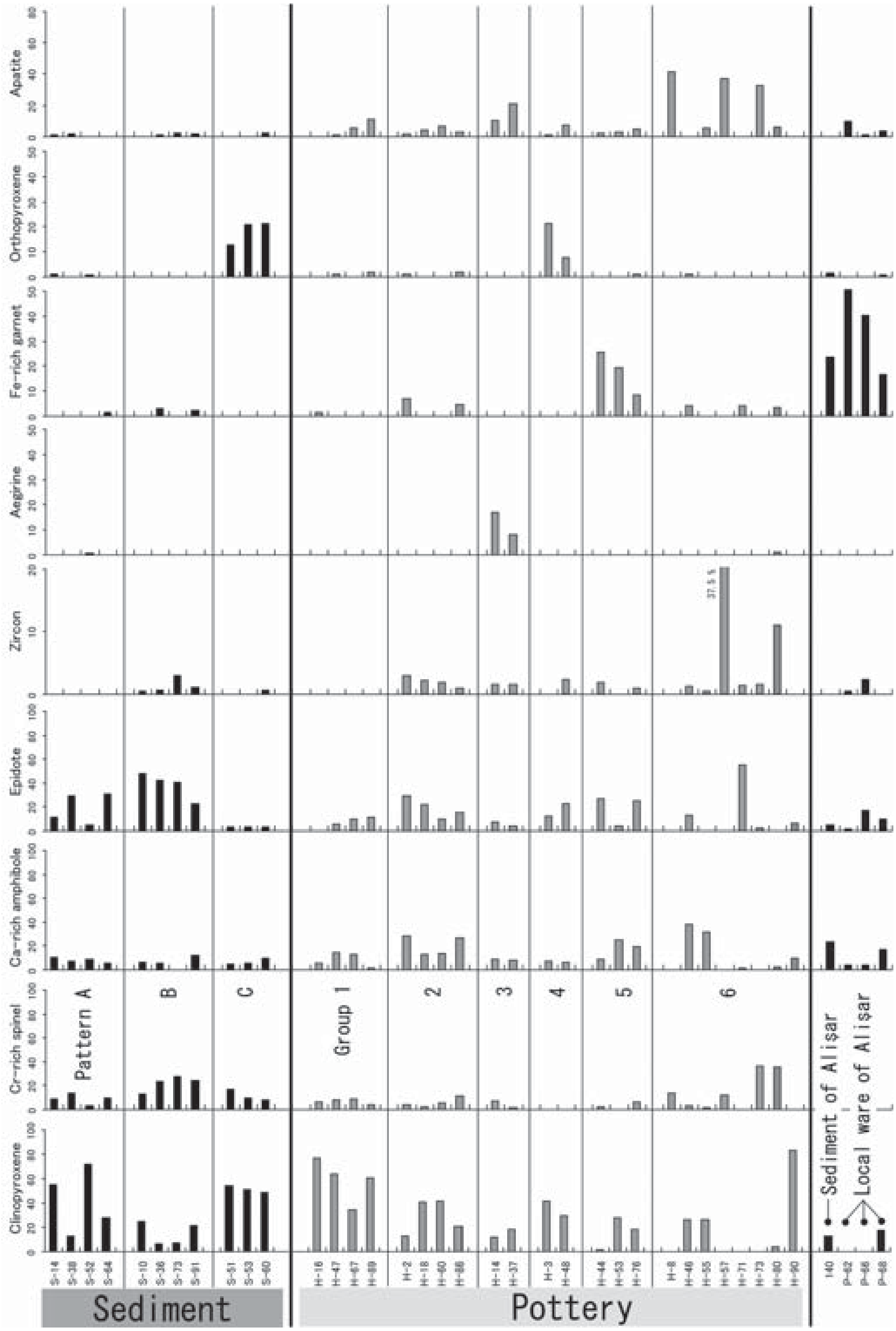

Fig. 4 Modal proportions of heavy mineral components in pottery samples and local sediments

	cpx	spi	amp	epi	zir	aeg	gar	opx	apa	gro	tit	pum	TiO_2	il	tou	all	mon	Na-amp	Total
Pattern A																			
S-20	64	5	1	82						2	4	3	1						162
S-23	42	9	17	60		1			1	2	2	10	4	6					154
S-25	13	32	3	87			10	1	1	6	5	5	1	9					173
S-26	135	2	5	11						1	3	1		1					159
S-29	3	34	3	61					4	9	15	25	1	12		1		3	171
S-30	48	30	4	56					3	6	5	2	1	11					166
S-33	74	28	22	15		5			2	15	7	2		6					176
S-34	8	73	15	12		5	1			24	7	2	1	12					160
S-38	21	23	13	50					3	13	5	27		14					169
S-42	111	9	25	8			3	1		3				3					163
S-45	127	10	26	10			1					2		2					178
S-46	2	24	4	95			1		1	10	12		1	9				6	165
S-48	56	7	11	69				1	3	9	5	1	3	5					170
S-50	1	138							1	14	2		1	7					164
S-52	117	5	14	8		1		1		2	5	6		4					163
S-55	48	69	36	15				1	1	4	4	1		17					196
S-63	163			2				2	1	6									174
S-64	48	17	10	53			3			2	5	22	1	9				3	173
S-65	128	11	11	6				1		3				2					162
S-67	42	38	2	47						7	6	5	2	8					157
S-68	149	3	16	3						1		1		1					174
S-69	58	25	3	1						3	1	1		2					94
S-70	107	27	10	6				1		3		5		6					165
S-71	39	10	8	72			3		5	7	8	11		6				2	171
S-75	7	97	4	12		1			1	20	6	3	5	13					169
S-77	150		3																153
S-78	144	2	3											1					150
S-80	156	3	4																163
S-92	113	20	4	3		2		1		3		3		1					150
S-93	91	22	11	11		1			1	4	6	5		2				1	155
S-96	60	14	14	56			1	3	2	2	4	2	2	2					162
Pattern B																			
S-28	82	36	19	24	1					6	2	5		7					182
S-36	11	40	10	72	1		5		2	4	11	2		9				2	169
S-41	134	16	9		1	1		2		3		2		4			2		174
S-43	87	3	54	6	1		1	6	3	1	4			2					168
S-73	13	48	2	71	5				4	3	13			4			1	9	173
S-91	38	44	22	40	2		4		3	4	7	2	4	7				1	178
Pattern C																			
S-51	95	30	9	6		1		22		3				8					174
S-53	71	14	8	5				29	1	1	1			8					138
S-60	83	14	16	5	1			36	4	7				3					169
S-61	15	97	5	6				18		6	4	3	1	9					164
S-82	84	9	3	1				70						1					168

Table 3 Number of heavy minerals (counts) in sediment samples. Mineral abbreviations: cpx: clinopyroxene; spi: Cr-rich spinel; amp: Ca-rich amphibole; epi: epidote; zir: zircon; aeg: aegirine; gar: Fe-rich garnet; opx: orthopyroxene; apa: apatite; gro: Ca-rich garnet; tit: titanite; pum: pumpellyite; TiO_2: TiO_2 polymorphs; il: ilmenite; tou: tourmaline; all: allanite; mon: monazite; Na-amp: Na-rich amphibole

Geochemical analysis of individual Fe-rich garnet grains using an EPMA

Three pottery samples (H-44, 53, 76) were subjected to geochemical analyses of garnet samples. We analyzed the chemical compositions of Fe-rich garnets in the samples using an EPMA (JEOL JXA-8800). Microprobe analysis was conducted using a 15 kV acceleration voltage and a 20 nA defocused beam current with a 2-µm diameter spot. Approximately 50 grains of Fe-rich garnet were analyzed per sample, except for H-76, for which 23 grains were analyzed.

Results and Discussion

Classification of the sediment samples

The results for the heavy mineral counts in the sediment samples are shown in Table 3 and *Fig. 4*. All 42 samples analyzed in this study and 15 additional samples (S-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16) previously reported by Hashimoto were classified into three patterns – A, B, and C according to their heavy mineral proportions and geological consideration[18].

Pattern A[19]

We defined the sediment samples derived from ophiolite as Pattern A. The sediment samples collected in the ophiolite region are S-4, 5, 6, 13, 14, 33, 34, 48, 50, 77, 79, and 80. These sediments include clinopyroxene, Cr-rich spinel, Ca-rich amphibole, epidote, pumpellyite, Ca-rich garnet, titanite, and ilmenite, but not zircon. In mafic or ultramafic rock forming ophiolite, clinopyroxene, Cr-rich spinel, Ca-rich amphibole, and ilmenite are included. In addition, one feature of ophiolite is its inclusion of a few zircon grains appearing in common sediments. Mafic or ultramafic rock in ophiolite is often weakly metamorphosed and changed into serpentinite, metagabbro, and metabasalt. Therefore, epidote, Ca-rich garnet, titanite, and pumpellyite also commonly occur as heavy minerals in ophiolite.

The heavy mineral proportions of each sample in Pattern A are somewhat different. There are regional differences with regard to the degree of metamorphism. Therefore, the heavy mineral proportions change greatly in a small area.

Sediment samples[20], which have the same features as Pattern A, are found in a non-ophiolite region (*Figs. 1. 2*). The region where these samples were collected surrounds an ophiolite region and is lower in altitude than the mountainous ophiolite region (*Figs. 1. 2*). Thus, the region was formed by sediment transported from the ophiolite region (Pattern A). Therefore, we also grouped these samples into Pattern A.

Pattern B[21]

Several sediment samples that include zircon and common heavy minerals in Pattern A (clinopyroxene, Cr-rich spinel, Ca-rich amphibole, epidote, etc.) were defined as Pattern B. The region

---

18 Hashimoto et al. 2013.

19 Pattern A encompasses the following samples: S-1, 2, 4–9, 11–16, 20, 23, 25, 26, 29, 30, 33, 34, 38, 42, 45, 46, 48, 50, 52, 55, 63–65, 67–71, 75, 77, 79, 80, 92, 93, 96.

20 S-1, 2, 7, 8, 9, 11, 12, 15, 16, 20, 23, 25, 26, 29, 30, 38, 42, 45, 46, 52, 55, 63–65, 67, 68, 70, 71, 75, 92, 93, 96.

21 Pattern C covers samples S-10, 28, 36, 41, 43, 73, 91.

where these samples were collected was formed from old sedimentary rock before the Middle Miocene. Old sedimentary rock often includes zircon, which has strong resistance to weathering[22]. The topographic map (*Fig. 2*) shows that the Pattern B region is lower than the mountainous ophiolite region in altitude. Considering these points, we surmise that the Pattern B region was formed by mixing the sediment of local old sedimentary rock and the sediment flowing from the mountainous ophiolite region.

Pattern C[23]

Pattern C sediment samples are characterized by high amounts of orthopyroxene, a mineral occurring in mafic igneous rock. Pattern C samples were collected in the southwest volcanic rock region of the site, suggesting that the volcanic rock sediment spread throughout the Pattern C region.

Classification of pottery samples and identification of pottery source

The numbers and proportions of heavy minerals in the 42 pottery samples are shown in Table 4 and *Fig. 4*. These samples and the 37 samples[24], previously analyzed by Hashimoto[25] were classified into six groups (Groups 1–6) according to their heavy mineral proportions. The pottery sherds are classified into Groups 1 to 6 in *Fig. 4*. Thus, by comparing the heavy mineral proportions of the pottery samples with those of the sediment samples, we identified the provenance of the pottery samples.

It is difficult to distinguish local and imported ware clearly. Arnold surveyed the ethnographic literature for geodesic distance between the potter's working area and the clay resource area[26]. His study found that in 84 % of all the case (N= 111) the clay sources lay within a 7 km radius around a given settlement. It is known that several pottery kilns were found in Upper City of Boğazköy[27]. Therefore, we assumed, in present paper, that 'local' is the ware made from the clay sediment of the area within a 7 km radius of Boğazköy and 'import' is the ware made from the clay sediment of the area outside a 7 km radius of Boğazköy.

Group 1[28]

Twentyseven pottery samples have heavy mineral content similar to Pattern A and were identified as Group 1. The clay of these sherds includes clinopyroxene, Cr-rich spinel, Ca-rich amphibole, epidote, etc., but not zircon.

The similarity between the heavy mineral proportions of Pattern A and those of Group 1 suggests that Group 1 sherds were produced using clay from the ophiolite region and/or the sedimentary rock region surrounding the ophiolite. In the case of Boğazköy, the area within a 7 km radius is only Pattern A. Therefore, we suggest that local pottery is only found in Group 1.

---

22 Deer et al. 1992.
23 Pattern B comprises samples: S-51, 53, 60, 61, 82.
24 H-1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37.
25 Hashimoto et al. 2013.
26 Arnold 1985.
27 Müller-Karpe 1988.
28 H-6, 7, 12, 15, 16, 17, 20, 21, 23, 26, 36, 43, 47, 50, 51, 52, 54, 56, 58, 67, 68, 70, 77, 84, 89, 91, 94.

ID	Dating	cpx	spi	amp	epi	zir	aeg	gar	opx	apa	gro	tit	pum	TiO_2	il	tou	all	mon	Na-amp	Others	Total
Group 1																					
H-51	ACP	151	1	21	18		1	2	1	1	1	5	5								207
H-52	OH	131	8	44	5					1	5	6	2	1							203
H-50	HP	60	13	1	2					2	1										79
H-54	HP	159	15	19	1				1		4	1		1	1						202
H-56	HP	55	14	53	52						4	15	11		2						206
H-43	HP	29	2	5	11							4	1		6				1		59
H-47	HP	128	16	29	11				2	2	1	11			1						201
H-77	MIA?	3		9	17					6		21	15	1	3				4		79
H-58	LIA	48	10	62	36			1	1	7	3	30		4	4				1		207
H-84	LIA?	6	5	26	3					17	3	32	7	1							100
H-89	LIA?	33	2	1	6				1	6		2		1	2						54
H-91	LIA?	26	11	65	65				1	5	4	27	1	4	3						212
H-94	LIA?	4	14	14	17				1	6		9		2	3				2		72
H-67	Late Roman	41	11	15	12					7	4	17		3	9						119
H-68	Byzantine	14	15	58	69					8	3	36		3	5						211
H-70	Byzantine	7	7	53	69					9	1	51		2	1						200
Group 2																					
H-49	HP	83	14	20	62	1					1	14	2	3	4	1					205
H-45	HP	99	16	32	22	4			1	5	8	9	2	2	10				1		211
H-79	MIA?	4	14	9	9	3		1		11	3	5	5	10	2			2			78
H-82	LIA?		6	34	96	5				13	1	31		11	4		1	1			203
H-83	LIA?	45	13	19	8	6		3	4	30		11	2	20	4	1			1		167
H-85	LIA?	19	12	2		4		5		5				7	1						57
H-86	LIA?	45	25	58	33	2		10	4	6	3	12		3	11					Al_2SiO_5(1)	213
H-87	LIA?	70	17	36	37	1				7	5	24	1	2	6		1				207
H-92	LIA?	25	17	64	49	3		3	3	15		27	1	6	2						215
H-93	LIA?	69	15	11	15	4		1	1	38	3	25		23	9						214
H-60	Hellenistic	91	12	30	22	4	1	1	1	15	6	7	2	22	3	2					219
H-61	Galatia	5	1	3	4	3			1	6		12		5		3			1		44
H-62	Galatia	17	7	11		1				4	3	9	5	1	1						59
H-66	Roman	12	49	7	12	2	2	1	1	10	4	23		11	20						154
H-69	Byzantine	30	72	12	31	1	1	2		11	6	14		6	19						205
Group 4																					
H-48	ACP	66		15	51	5			17	16		7		6	39						222
Group 5																					
H-44	HP	4	6	20	58	4		56	1	6	13	25		9	13					Al_2SiO_5(3)	218
H-53	OH	65	1	58	9			45	1	7	1	37			3	1	2			Al_2SiO_5(2)	232
H-76	LIA?	42	16	46	58	2		20	3	11	3	20		3	5	3					232
Group 6																					
H-46	HP	45	5	66	22	2		7	2	1	1	11		4	5					Zn-spi(1), Al-spi(1), sta(1)	174
H-55	HP	55	3	66		1				12	2	62	5	1	1						208
H-57	HP		1			3				3				1							8
H-73	MIA?	2	72	1	4	3		1		64		4		9	16				19		195
H-80	MIA?	3	29	2		9	1	3		5	1	2		17	7			3			82
H-90	LIA?	174		21	14															volcanic cpx and amp	209
H-71	Byzantine	1		4	115	3		9		1		3		3	58	11					208

Table 4 Number of heavy minerals (counts) in pottery samples. Mineral abbreviations: Al_2SiO_5: Al_2SiO_5 polymorphs; Zn-spi: Zn-spinel; Al-spi: Al-spinel; sta: staurolite; the others are listed in Table 2 and 3

However, the Pattern A region extends outside that radius, so we cannot eliminate the possibility that Group 1 also includes imported pottery.

Group 2[29]

Thirty-seven pottery samples have heavy mineral compositions similar to Pattern B and were identified as Group 2. These sherds include zircon in addition to clinopyroxene, Cr-rich spinel, Ca-rich amphibole, epidote, etc. The similarities between the heavy mineral proportions of Pattern B and those of Group 2 suggest that the Group 2 sherds were produced in the old sedimentary rock region surrounding the ophiolite. The pattern B region is distributed outside a 7 km radius of the site. Therefore, we suggest that the Group 2 sherds represent pottery imported from a city outside a 7 km radius of Boğazköy.

Group 3[30]

Two pottery samples that include a high amount of aegirine were found and identified as Group 3 (*Fig. 4*). These sherds also include clinopyroxene, Ca-rich amphibole, apatite, titanite, and pumpellyite. Aegirine commonly occurs in ophiolite. However, we did not find a sediment sample containing a high amount of aegirine. Therefore, we could not decide whether Group 3 sherds were imported.

Group 4[31]

Two pottery samples with high amounts of orthopyroxene were found and identified as Group 4. These sherds also include clinopyroxene, Ca-rich amphibole, epidote, and ilmenite, all heavy minerals commonly occurring in volcanic rock. Comparing the sediment samples with Group 4, we found similarities with Pattern C. However, Group 4 sherds do not include the Cr-rich spinel found in Pattern C, so it is clearly not the source for Group 4. Therefore, we suggest that Group 4 sherds were imported from a distant city outside a 25 km radius of Boğazköy.

Group 5[32]

Three pottery samples containing a high amount of Fe-rich garnet were found and identified as Group 5 (*Fig. 4*, Table 4). These sherds also include clinopyroxene, Ca-rich amphibole, epidote, etc. These heavy minerals commonly occur in high-grade metamorphic rock. The heavy mineral composition of Group 5 differs from those of all other sediment samples. Therefore, we suggest that Group 4 was imported from a distant city outside a 25 km radius of Boğazköy.

Group 6[33]

All other pottery samples outside of Groups 1–5 are classified as Group 6 (*Fig. 4*, Table 4). The heavy mineral compositions of these sherds differ from those of all other sediment samples.

---

[29] H-1, 2, 4, 5, 9, 10, 11, 13, 18, 19, 22, 24, 25, 27, 28, 29, 30, 31, 32, 33, 34, 35, 45, 49, 60, 61, 62, 66, 69, 79, 82, 83, 85, 86, 87, 92, 93.

[30] H-14, 37.

[31] H-3, 48.

[32] H-44, 53, 76.

[33] H-8, 46, 55, 57, 71, 73, 80, 90.

Therefore, we suggest that Group 6 was imported from a distant city outside a 25 km radius of Boğazköy.

Sample H-8. H-8 includes TiO_2, titanite, apatite, ilmenite, and Cr-rich spinel (*Fig. 4*). TiO_2, apatite, and Cr-rich spinel are highly resistant to weathering. Therefore, we suggest that the source of H-8 was probably the old sedimentary rock region.

Sample H-46. H-46 includes clinopyroxene, Ca-rich amphibole, epidote, and titanite (*Fig. 4*). The grains of clinopyroxene, Ca-rich amphibole, and titanite are large and rectangular, reflecting features commonly seen in plutonic rock.

Sample H-55. H-55 includes clinopyroxene, Ca-rich amphibole, and epidote (*Fig. 4*). As discussed above, the grain features of these minerals are common in plutonic rock. However, unlike H-46, H-55 does not include titanite. Therefore, we suggest that H-55 and H-46 have different sources.

Sample H-57. H-57 includes TiO_2, zircon, apatite, and Cr-rich spinel (*Fig. 4*). Since these minerals are highly resistant to weathering, we suggest that the source of H-57 was the old sedimentary rock region. However, unlike H-8, H-57 does not include titanite, suggesting that the sources of H-57 and H-8 are different.

Sample H-71. H-71 includes epidote, tourmaline, and ilmenite (*Fig. 4*). However, we could not discern the geological character of its source.

Sample H-73 H-73 includes Cr-rich spinel, apatite, and Na-rich amphibole (*Fig. 4*). However, we could not discern the geological character of its source.

Sample H-80. H-80 includes TiO_2, zircon, apatite, and Cr-rich spinel (*Fig. 4*). Since minerals highly resistant to weathering are included, we suggest that the source of H-80 was the old sedimentary rock region.

Sample H-90. H-90 includes only clinopyroxene, Ca-rich amphibole, and epidote (*Fig. 4*). All of these are euhedral, a feature common in volcanic ash. Therefore, we suggest that the source of H-90 was the volcanic ash region.

Comparison with pottery from other sites

To understand the pottery exchange relationships at Boğazköy, we compared the heavy mineral compositions of the pottery from this site with those from the sites of Kaman-Kalehöyük, Alişar Höyük, and Büklükale. Results showed that Group 5 (H-44, 53, 76) is similar to the local pottery of Alişar Höyük, as both include Fe-rich garnet, Ca-rich amphibole, and epidote (*Fig. 4*). These minerals commonly occur in high-grade metamorphic rock. High-grade metamorphic rock is not present within 25 km of Boğazköy. Based on the comparison of our heavy mineral data, we tentatively conclude that Group 5 was imported from Alişar Höyük.

EPMA analysis of individual Fe-rich garnet grains

We found that Group 5 sherds have similar heavy mineral compositions as the Alişar Höyük local pottery. To determine whether their sources are the same, we analyzed the chemical compositions of individual Fe-rich garnet grains in both samples. The chemical compositions are plotted in a Ca-Mg-Fe+Mn triangular figure (*Fig. 5*). Group 5 was classified into two groups

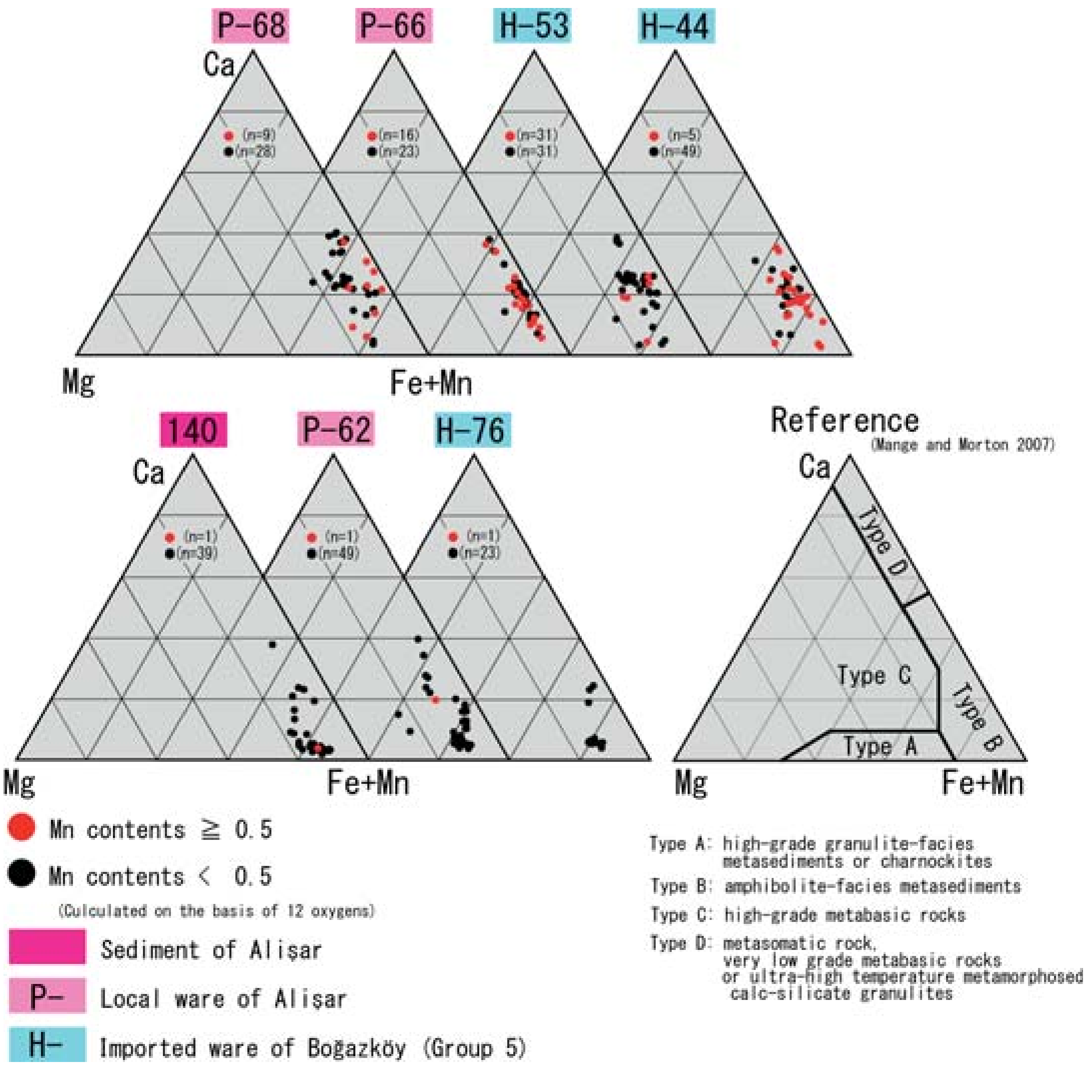

Fig. 5 Ca-Mg-Fe+Mn triangular figure showing the chemical compositions of Fe-rich garnets from the Boğazköy pottery samples (Group 5), local pottery samples, and local sediment of Alişar Hüyük

by the chemical composition of Fe-rich garnet. The Fe-rich garnets in H-53 and H-44 are rich in Fe+Mn and Ca, and many have an atomic ratio greater than 0.5 Mn. This Fe-rich garnet chemical composition character of H-53 and H-44 matched that of two local potsherds from Alişar Höyük (P-66 and P-68). On the other hand, H-76 includes the Fe-rich garnet grains rich in Fe+Mn and forms small clusters in the triangular figure. This composition also matched that of a local potsherd and a sediment sample from Alişar Höyük (P-62 and 140). Therefore, we found that all Group 5 sherds and the local pottery from Alişar Höyük are comparable in both heavy mineral composition and the chemical composition of the Fe-rich garnet grains. Therefore, the possibility that Group 5 was imported from Alişar Höyük is further supported. H-44 is a fine thin cream ware from the Hittite period, whereas H-53 is a slipped gray ware that was uncommon during that time. H-76 is a gray ware from the Late Iron Age. Therefore, our mineral analysis results suggest the possibility of a pottery trade relationship between Boğazköy and Alişar Höyük during the Hittite period and Late Iron Age.

Transition of the pottery source over time

Assyrian Colony period

Ten pottery samples from the Assyrian Colony period presented here and in a previous study[34] were classified into three source groups (Groups 1, 2, and 4). Group 1 (n = 6) were either local to Boğazköy or imported. Group 2 (n = 3) were imported from a city outside a 7 km radius of Boğazköy. It should be noted, however, that one cream ware sherd (H-48) was classified into Group 4, which is an imported pottery group from a distant city outside a 25 km radius of Boğazköy. Therefore, we suggest that pottery exchange was conducted with a distant city during this period.

Hittite period

Thirty-five pottery samples from the Hittite period presented here and in in a previous study were classified into eight source groups (Groups 1, 2, 4, 5, H-8, 46, 55, 57)[35]. Local wares or imported wares comprised a total of 9 samples (Group 1: n = 9). Wares imported from a city outside a 7 km radius of Boğazköy included nineteen samples (Group 2: n = 19). Wares imported from a distant city outside a 25 km radius of Boğazköy included seven samples (Group 4: n = 1; Group 5: n = 2; Group 6: n = 4). Therefore, it seems possible that pottery trade was conducted with a distant city during this period. Two of the possibly imported samples (H-44, 46) are cream ware. As described above, H-44 was likely imported from Alişar Höyük. Therefore, these results show the specific provenance of the cream ware.

Iron Age

Twenty-four pottery samples from the Iron Age were classified into seven source groups (Groups 1, 2, 3, 5, H-73, 80, 90). Local or imported wares numbered nine samples (Group 1: n = 9). Wares imported from a city outside a 7 km radius of Boğazköy included nine samples (Group 2: n = 9). Wares imported from a distant settlement outside a 25 km radius of Boğazköy numbered four samples (Group 5: n = 1; Group 6: n = 3). Therefore, we suggest that pottery trade was conducted with a distant city during this period.

Alişar IV painted potsherds common during the Middle Iron Age were classified into Groups 1 (local or imported) and 2 (imported). One Alişar IV painted potsherd (H-73) was classified into Group 6. Therefore, we suggest that Alişar IV pottery was exchanged with a distant city outside a 25 km radius of Boğazköy.

Eight black polished ware sherds common during the Late Iron Age were classified into Groups 1 (local or imported) and 2 (imported).

---

34 Hashimoto et al. 2013.

35 Hashimoto et al. 2013.

Post-Iron Age

The pottery samples from the Hellenistic, Galatian, Roman, and Byzantine periods were classified into Groups 1 (local or imported) and 2 (imported). Only H-71 from the Byzantine period was classified into Group 6, which probably was imported from a settlement outside a 25 km radius of Boğazköy.

Conclusion

In this study, we established a database of the modal proportions of heavy mineral proportions for the sediments collected in the Boğazköy region. This database allowed us to differentiate locally produced pottery from imports and thus to investigate the pottery exchange network between Boğazköy and other sites during each cultural period.

Furthermore, we investigated the provenance of pottery excavated from the strata of Boğazköy across time. Among the sampled pottery sherds those produced from local clay can be separated from clays from within a 25 km radius of the site, and examples from outside a 25 km radius of the site. Wares imported from outside a 25 km radius of Boğazköy were found in the Assyrian Colony, Hittite, Iron Age, and Byzantine periods. The results suggest there was an active exchange of pottery during the relevant periods not only between Boğazköy and its immediate hinterland but, although limited, with even more distant regions.

Heavy mineral analyses and geochemical analyses of individual Fe-rich garnet grains from two potsherds from the Hittite period, and one potsherd from the Late Iron Age, show close connections to samples analyzed with the same methods from Alişar Höyük. This indicates a possible relationship between Boğazköy and Alişar Höyük by pottery exchange. This information is important for understanding the socioeconomic contexts of the Hittite period and Late Iron Age.

Abstract: To understand the production and distribution of pottery at Boğazköy (Turkey), we investigated the provenance of pottery excavated from the strata from each period, including the Assyrian Colony, Hittite, Iron Age, Galatian, Hellenistic, Roman, and Byzantine. We conducted heavy mineral analysis through SEM-EDS and geochemical analysis of individual Fe-rich garnet grains collected from pottery samples. This is part of a larger project started in 2009 that has revealed the provenance of pottery excavated from other archaeological sites in central Anatolia. The present study established the method to differentiate between local ware and imported ware excavated from Boğazköy through comparing the heavy mineral proportions of pottery to those of local sediments within a 25-km radius of the site. A comparative study of heavy mineral proportions of pottery from Boğazköy and those from pottery at three other sites investigated in a previous study (Kaman-Kalehöyük, Büklükale, and Alişar Höyük) suggests the possibility of a pottery exchange between Boğazköy and Alişar Höyük. This finding is further supported by the similarity of their Fe-rich garnet compositions, which are revealed by geochemical analysis yielding important information for understanding socioeconomic contexts of the Hittite period and Late Iron Age in Anatolia.

Untersuchungen zur Herkunft von Keramik aus Boğazköy, Türkei, mittels Schwermineralanalysen

Zusammenfassung: Um die Produktion und Verteilung von Keramik in Boğazköy (Türkei) zu verstehen, haben wir die Herkunft von Keramik aus Schichten jeder Epoche – Zeit der assyrischen Handelskolonien, Hethitisch, Eisenzeitlich, Galatisch/Hellenistisch, Kaiserzeitlich und Byzantinisch – untersucht. Dafür haben wir Analysen der Schwerminerale mittels REM-EDS (Rasterelektronenmikroskopie in Kombination mit energiedispersiver Röntgenspektroskopie) und geochemische Analysen an einzelnen eisenreichen Granatpartikeln von Keramikproben durchgeführt. Dies ist Teil eines größeren, seit 2009 laufenden Projektes, das die Herkunft von Keramik untersucht, welche von verschiedenen Ausgrabungen in Zentralanatolien stammt. In der vorliegenden Studie dient die Methode zur Unterscheidung zwischen lokalen und importierten Waren, die in Boğazköy ausgegraben wurden, durch den Vergleich der Verhältnisse von Schwermineralen in der Keramik und denen in den lokalen Sedimenten innerhalb eines 25-km-Radius. Eine vergleichende Untersuchung der Verhältnisse von Schwermineralien in der Keramik von Boğazköy und in der von drei anderen Fundorten, die in einer früheren Studie untersucht wurden (Kaman-Kalehöyük, Büklükale und Alişar Höyük), legt die Möglichkeit eines Austauschs zwischen Boğazköy und Alişar Höyük nahe. Diese Feststellung wird durch die Ähnlichkeit ihrer eisenreichen Granat-Zusammensetzung unterstützt, die durch geochemische Analysen aufgezeigt wird, und liefert damit wichtige Informationen für das Verständnis des sozioökonomischen Kontexts der hethitischen Periode und der späten Eisenzeit in Anatolien.

Ağir Mineral Analizi Yoluyla Boğazköy Keramiğinin Köken Araştirm

Özet: Boğazköy keramiğinin üretimi ve dağılımını anlamak için, Asur Kolonileri, Hitit, Demir Çağı, Galat/Hellenistik, Roma ve Bizans'ın içinde bulunduğu tüm dönemlerin tabakalarından gelen keramiğin kökenini araştırdık. SEM-EDS ile ağır mineral analizleri ve keramik örneklerinden toplanan demir bakımından zengin granat partikülleri üzerinde jeokimyasal analizler yürüttük. Bu çalışmalar, 2009'da başlayan, Orta Anadolu'daki başka arkeolojik yerleşmelerden gelen keramiğin kökenini saptayan daha büyük bir projenin parçasıdır. Çalışmamız, Boğazköy'den elde edilen ithal mallar ile yerel malları, keramiklerdeki ağır mineral oranlarını yerleşmenin içinde bulunduğu 25 km çapındaki alanda bulunan yerel çökellerinkiyle karşılaştırarak birbirinden ayırt edebilen bir yöntem oluşturmuştur. Boğazköy'deki keramiklerin ağır mineral oranları ile başka üç yerleşmenin keramiğindeki oranları araştıran daha önceki karşılaştırmalı bir çalışma (Kaman-Kalehöyük, Büklükale ve Alişar Höyük) Boğazköy ve Alişar Höyük arasında bir keramik değiş tokuşu olabileceğini önermektedir. Bu bulgu, örneklerin jeokimyasal analiz yoluyla elde edilen demir zengini granat bileşimlerinin benzerliğiyle de desteklenmiştir. Jeokimyasal analizler, Anadolu'nun Geç Demir Çağ ve Hitit Dönemi sosyoekonomik kontekstlerini anlamada önemli bilgiler sağlamıştır.

Bibliography

Arnold 1985 — D. E. Arnold, Ceramic Theory and Cultural Process (Cambridge 1985)

Bong 2012 — W. S. K. Bong, The Development and Application of Heavy Mineral Analysis, Single-Mineral Geochemistry Analysis and Trace Heavy Mineral Element Analysis to the Provenance Study of Archaeological and Forensic Materials (PhD thesis Tokyo University of Science 2012)

Bong et al. 2010 — W. S. K. Bong – K. Matsumura – K. Yokoyama – I. Nakai, Provenance Study of Early and Middle Bronze Age Pottery from Kaman-Kalehöyük, Turkey, by Heavy Mineral Analysis and Geochemical Analysis of Individual Hornblende Grains, JASc 37, 2010, 2165–2178

Bossert 2000 — E. M. Bossert, Die Keramik phrygischer Zeit von Boğazköy, Boğazköy-Hattuša 18 (Mainz 2000)

Deer et al. 1992 — W. A. Deer – R. A. Howie – J. Zussman, The Rock-Forming Minerals (Longman 1992)

Freestone 1995 — I. C. Freestone, Ceramic Petrography, AJA 99, 1995, 111–115

Hashimoto 2014 — K. Hashimoto, Provenance Study of Pottery from Boğazköy and Büklükale, Turkey by Heavy Mineral Analysis (Master's thesis Tokyo University of Science 2014)

Hashimoto et al. 2013 — K. Hashimoto – W. S. K. Bong – A. Schachner – K. Yokoyama – I. Nakai, Provenance Study of Pottery from Boğazköy, Turkey by Heavy Mineral Analysis: A Preliminary Report, in: A. Schachner, Die Arbeiten in Boğazköy-Ḫattuša 2012, AA 2013, 177–186

Kealhofer et al. 2009 — L. Kealhofer – P. Grave – H. Genz – D. B. Marsh, Post-collapse: The Re-emergence of Polity in Iron Age Boğazköy, Central Anatolia, OxfJA 28, 2009, 275–300

Knappett et al. 2005 — C. Knappett – V. Kilikoglou – V. Steele – B. Stern, The Circulation and Consumption of Red Lustrous Wheelmade Ware: Petrographic, Chemical and Residue Analysis, AnSt 55, 2005, 25–59

Mange – Bezeczky 2007 — M. A. Mange – T. Bezeczky, The Provenance of Paste and Temper in Roman Amphorae from the Istrian Peninsula, Croatia, in: M. A. Mange – D. T. Wright (Eds.), Heavy Minerals in Use, Developments in Sedimentology 58 (Amsterdam 2007) 1007–1033

Mange – Morton 2007 — M. A. Mange – A. C. Morton, Geochemistry of Heavy Minerals, in: M. A. Mange – D. T. Wright (Eds.), Heavy Minerals in Use, Developments in Sedimentology 58 (Amsterdam 2007) 345–391

Mielke 2007 — D. P. Mielke, Red Lustrous Wheelmade Ware from Hittite Contexts, in: I. Hein (Ed.), The Lustrous Wares of Late Bronze Age Cyprus and the Eastern Mediterranean. Papers of a Conference, Vienna 5th–6th of November 2004, Contributions to the Chronology of the Eastern Mediterranean

13 = Österreichische Akademie der Wissenschaften. Denkschriften der Gesamtakademie 41 (Vienna 2007) 155–168

Müller-Karpe 1988 A. Müller-Karpe, Hethitische Töpferei der Oberstadt von Hattuša: ein Beitrag zur Kenntnis spät-großreichszeitlicher Keramik und Töpferbetriebe unter Zugrundelegung der Grabungsergebnisse von 1978–82 in Boğazköy (Marburg 1988)

Peacock 1967 D. P. S. Peacock, The Heavy Mineral Analysis of Pottery: A Preliminary Report, Archaeometry 10, 1967, 99–100

Rice 1987 P. M. Rice, Pottery Analysis: A Sourcebook (Chicago 1987)

Schachner 2011 A. Schachner, Hattuscha. Auf der Suche nach dem sagenhaften Großreich der Hethiter (Munich 2011)

Williams 1977 D. F. Williams, The Romano-British Black Burnished Industry: an Essay on Characterization by Heavy Mineral Analysis, in: D. P. S. Peacock (Ed.), Pottery and Early Commerce (London 1977) 163–220

Yokoyama et al. 1989 K. Yokoyama – K. Amano – A. Taira – Y. Saito, Mineralogy of Silts from the Bengal Fan, in: J. R. Cochran – D. A. V. Stow (eds.), Proceedings of the Ocean Drilling Program, Scientific Results 116 (College Station TX 1989) 59–73

INHALT

KURZMITTEILUNG

TABLE OF CONTENTS

NOTE