Laboratory Investigations of selected medieval sherds from the Artemision in Ephesus

The study of medieval pottery from the Artemision in Ephesus by J. Vroom (in this volume) gives some insight into the material culture of the 'late' periods of the site (late Byzantine, Selçuk and early Ottoman periods). It also gave the opportunity to characterize medieval pottery manufactured in Ephesus: although the archaeological context and actual production structures are lacking, kiln furniture (tripods), molds and possible wasters constitute evidence for production of ceramics in the Artemision. A sampling of twenty-four medieval sherds was chosen by J. Vroom as representative of several types of ware (Figure 3), mostly presumed to have been locally manufactured, and was provided for analysis by S. Ladstätter. Samples were submitted to laboratory investigations, in Vienna for thin-section and heavy mineral analyses and in Lyon for chemical analysis.

The first objective of this study was to assess the mineralogical, petrographical and chemical compositions of the medieval pottery sherds and to compare them with already known data of Ephesian hellenistic and roman pottery products and raw materials, based on previously done studies[1]. A second objective was to consider the material of Ephesus within the context of medieval Asia Minor, together with the few available data on comparative material.

Thin-section and heavy mineral analyses of selected medieval sherds from the Artemision at Ephesus

by Roman Sauer

Preparation of the petrographical thin sections and the heavy mineral separation was organised by ICORT (Abteilung Archäometrie, Prof. B. Pichler).

From all selected samples both thin section and heavy mineral analyses have been performed.

Thin-section analyses

The thin-section analyses were used to characterise the various fabrics by their typical texture (optical properties of matrix, amount of temper, grain size, sorting, pore types etc.) and also to obtain some provenance information by analysing the mineralogical-petrographical composition of their inclusions (temper).

First by point counting analysis the proportion of matrix to temper was estimated (= volume percent). Grains > ≈15µ were considered as 'temper'.

For a standardised characterisation of the 'temper' particles and to enable graphical presentation of the results, the following method, developed for semiquantitative estimation of the proportions of different temper grains occurring in the ceramic thin-sections, was used.

[1] E. g. Sauer 1995; Sauer 1996; Schneider 2000; Ladstätter – Sauer 2001.

The relative grain proportions were classified as follows:

a) occurrences within one (representative) field of view

'dominant'	(more than 20 grains) :	A (80)
'very frequent'	(10–19 grains) :	B (50)
'frequent'	(5–9 grains):	C (30)
'subordinate'	(2–4 grains):	D (15)

b) occurrences within 5 fields of view

'moderate'	(5–9 grains):	E (10)
'rare'	(2–4 grains):	F (5)

c) The very rare constituents were classified as follows

'very rare' (more than one occurrence per thin-section)	G (3)
'traces' (one occurrence):	H (1)

All samples were analysed with the same magnification (200x).
For graphical presentation the listed frequencies were then replaced by the numbers (given in parentheses).

Graphical comparisons with results derived by conventional particle counting (e. g. 300 temper grains per thin-section) practically showed a very good comparability within the main constituents.

But the new applied method is significantly faster. Furthermore it showed also better results for the minor, but often more significant constituents, due to the fact that one is forced to screen the entire thin-section. Grain size was estimated by measuring of 50 temper grains. Sorting and roundness was estimated by standard comparison charts.

Heavy mineral analyses

Heavy mineral analyses facilitated to provide provenance information and to differentiate between the imported wares and local products. The heavy minerals were determined with the polarising microscope. 200 translucent heavy mineral grains (0,04–0,125 mm) were counted per sample[2].

Results

Based on their variable mineralogical and petrographical composition, texture and firing temperature the samples were grouped into six microscopically distinguishable fabric types (types A, B, B1, B2, C and D).

Furthermore, based on the comparison with already studied pottery and local clay raw materials (so far data already were available) it was tried to give an interpretation on the origin of the differed raw materials used for the analysed samples.

Analyses showed that the majority of the analysed samples (with the exception of fabric type A) was most likely produced from locally available, but petrographical different clay deposits.

Comparable raw materials are easily available at Ephesus or in the surroundings of Ephesus (e. g. Kuşadası).

2 The details of the applied technique are described in Sauer 1989/90/91.

Fabric type A was produced from an artificial stone paste. Based on its mineralogical petrographical composition the raw material used is not of local origin.

The results of the individual analyses are graphically presented on Farbtafel IV–V and listed on figures 1 and 2. Characteristic examples of fabric types and temper grains are shown on Farbtafel I–III.

Petrographical fabric type A (Farbtafel I, 1–4; III, 1)
Samples: EPH-ART 01, EPH-ART 03, EPH-ART 04

The samples show in thin section a colourless, light, partly brownish pigmented, glassy (isotropic, optical inactive) groundmass.

The temper content varies from 39 to 47% (mean: 44%). The 'temper' grains consist mainly of artificially crushed quartz grains. The sorting is poor, the roundness of most of the grains is very angular. But very rare relicts of well rounded quartz grains still can be found.

The average grain size of the grains is 0,10 mm (maximum grain size observed in thin sections is 0,64 mm).

The temper grains consist dominantly of monocrystalline quartz, subordinate of alkalifeldspars, opaque matter, rare chert, iron oxide concretions, polycrystalline quartz, pseudomorphs and molds of former carbonates, heavy minerals (zircon, rutile), traces of oxidised sheet silicates, clay clasts and crystalline rock fragments. Typical are the artificially crushed sand grains. The pores contain partially neoformed calcite.

The heavy mineral assemblage (only one sample was available for analysis: EPH-ART 04) consists of zircon (38%), rutile (26%), kyanite (15%), hornblende (6%), brookite/anatase (4%), staurolite (4%), not identified grains (3%), epidote/zoisite (2%), augitic clinopyroxen (1,5%), traces of tourmaline and diopsidic clinopyroxen.

The ware was produced in stone paste technique[3] and represents an imported ware. The quartz material is most likely derived from crushed, well rounded quartz sand grains ('desert quartz'). Despite a very characteristic heavy mineral assemblage could be obtained, at the moment no conclusive provenance interpretation can be given. To date no heavy mineral data of comparable wares were available for comparison.

Petrographical fabric types B, B1, B2 (Farbtafel I, 5–8; II, 1–3; III, 2)
Samples: EPH-ART 06, EPH-ART 18, EPH-ART 19, EPH-ART 20, EPH-ART 25, EPH-ART 09, EPH-ART 10, EPH-ART 12, EPH-ART 13 (all B), EPH-ART 17 (B1), EPH-ART 28 (B2)

The samples show in thin-section a reddish-brown or yellow-brown, carbonate free to slightly calcareous, micaceous, optical active to optical inactive groundmass.

The temper content varies from 7,1–21,5% (mean: 14%). The arithmetic mean of the grain size of the temper grains is 0,08 mm (maximum grain size: up to 2,6 mm). The sorting of the temper grains is moderate to poor. The roundness is subangular to angular. The 'temper' is a natural constituent of the clay and was not intentionally added.

The temper grains consist dominantly of muscovite, very frequent monocrystalline quartz and frequent oxidised sheet silicates. Subordinate occur alkalifeldspars, iron oxide concrections and opaque matter. Moderate frequent are pseudomorphs and molds of former carbonates and biotite, rare are heavy minerals, limestone, polycrystalline quartz and crystalline rock fragments, very rare occur albite (typically with dark inclusions), siltstone/shale fragments, chert, plagioclase and molds of outburned organic tissues (plant material). In traces appears brown volcanic glass.

The crystalline rock fragments consist of quartz-feldspar and quartz-mica fragments, phyllite, and mica schist. The rare sedimentary rock fragments consist of calcite cemented silt to sandstones, and poorly preserved limestone grains (sparite, marble).

[3] Tite 1987.

Typical is the presence of albite with black inclusions, both as single grains and within crystalline rock fragments.

The glaze shows two layers, a lower layer (slip) with fine quartz and occasionally mica (thickness is variable between about 0,04 and 0,1 mm) and an upper glass layer (occasionally with relicts of corroded quartz) with inclusions of non determined crystals (very variable, thickness range 30 µ–0,2 mm). A thin, slightly birefrigent surface layer indicates probably alteration of the glaze.

The heavy mineral assemblage (arithmetic mean of 10 samples) consists of garnet (58%), rutile (15%), brookite/anatase (9%), zircon (6%), epidote/zoisite (3%), tourmaline (3%), hornblende (2%), titanite (2%), kyanite (2%), chromian spinel (1%), traces of augitic and diopsidic clinopyroxen.

Comparable petrographical and heavy mineral compositions have been relative commonly observed within Ephesian pottery products[4]. Raw materials with very similar composition can be found within (?) Neogene clay deposits (e. g. south of Ephesus near Kuşadası), occasionally at decalcified horizons, above marly Neogene deposits and locally within also alluvial or colluvial clays.

Petrographical fabric type B1 (Farbtafel II, 1)
Sample: EPH-ART 17

The sample shows a higher temper content (21,5%) and slightly more coarse grained particles. The crystalline rock fragments consist very frequent of micaschist and phyllite. The rare sedimentary rock fragments consist of calcite cemented sandstone and poorly preserved limestone grains (sparite, marble). Very rare are mollusc fragments.

The raw material was probably a locally available (?) alluvial clay.

Petrographical fabric type B2 (Farbtafel II, 2–3)
Sample: EPH-ART 28

The sample is probably strongly overfired and shows frequent pores of leached particles (partially filled with secondary calcite) and iron oxide concretions.

The raw material is most likely also a locally available weathering clay. The differing heavy mineral assemblage (high content of titanium oxide minerals (brookite, anatase etc.!) corresponds to a heavily weathered clay but can also be influenced by overfiring (e. g. garnet becomes oxidised during high temperatures) and cannot be identified anymore.

Petrographical fabric type C (Farbtafel II, 4–5; III, 3–8)
Samples: EPH-ART 07, EPH-ART 08, EPH-ART 11, EPH-ART 15, EPH-ART 14, EPH-ART 16, EPH-ART 27

The samples show in thin section a reddish-brown to dark brown, micaceous, optical active or inactive groundmass. The temper grains are well to moderately sorted and the roundness ranges from angular to subangular.

The temper content varies from 4–9% (mean 6%). The arithmetic mean of the grain size is 0,039 mm (maximum grain size: 0,4 mm).

The natural temper grains consist dominantly of muscovite and very frequent oxidised sheet silicates. Frequently monocrystalline quartz, opaque matter, iron oxide concrections can be observed. Subordinate occur alkalifeldspars, rare biotite, very rare are pseudomorphs and molds

[4] E. g. in Roman common Ware, Peacock 45 Amphorae (group A), bricks etc.; Sauer 1995. For a comparable fabric of late Roman tableware from Ephesus see Ladstätter – Sauer, in this volume.

of former carbonates, crystalline rock fragments, heavy minerals and albite. In traces occur polycrystalline quartz and siltstone.

The crystalline rock fragments consist of few quartz-feldspar and quartz-mica fragments, phyllite, mica schist and epidote-quartz-albite particles. Typical are albite with opaque inclusions. Occasionally calcareous rhizolites can be observed.

The heavy mineral assemblage (arithmetic mean of 7 samples) consists of epidote/zoisite (49%), hornblende (28%), garnet (9%), brookite/anatase (5%), titanite (4%), rutile (3%), tourmaline (1%), kyanite (1%), traces of zircon, augitic and diopsidic clinopyroxen.

The glaze shows two layers, a lower layer with finely crushed quartz (thickness variable between about 0,08 and 0,1 mm) and an upper glass layer 0,06 mm). The lower layer is partially missing. A thin, slightly birefrigent surface layer indicates probably alteration of the glaze.

Typical is the very fine grained fabric. It is not clear whether the used clay was already naturally very fine or was it intentionally treated. Similar clays are locally available. But exact parallels are not very frequent within the studied Roman pottery of Ephesus.

Petrographical fabric type D (Farbtafel II, 6–8)
Samples: EPH-ART 21, EPH-ART 22, EPH-ART 23, EPH-ART 24

The samples show in thin-section a reddish-brown to brown, micaceous, optical active, calcareous groundmass.

The temper content varies from 18–28% (mean. 23%). The arithmetic mean of the grain size of the temper is 0,15 mm (maximum grain size: 2,8 mm). The sorting of the temper grains is very poor, the roundness is subangular to angular.

The grains consist dominantly of monocrystalline quartz and muscovite. Relatively frequent are heavy minerals, subordinate occur alkalifeldspars, iron oxide concrections and opaque matter, moderate are albite, rare are polycrystalline quartz, oxidised sheet silicates and crystalline rock fragments, very rare are biotite and traces of chert.

The crystalline rock fragments consist of quartz-feldspar and quartz-mica fragments, phyllite, mica schist, epidote-quartz-albite fragments. Typical again is the presence of albite with dark opaque inclusions.

The heavy mineral assemblage (4 samples) is dominated by epidote/zoisite (86%), additional small amounts of hornblende (4%), garnet (2%), zircon (2%), titanite (2%), rutile (2%), brookite/anatase (1%), kyanite (1%), tourmaline (1%) and traces of corundum can be observed.

Very similar petrographical compositions and heavy mineral assemblages can be found in various Ephesian pottery products[5]. Very similar raw materials can be found in the surroundings of Ephesus within loamy and clayey deposits of the Küçük Menderes, but also locally as slightly sandy weathering clays (e. g. developed above altered sericite quartzite or mica schist)[6].

5 E. g. Roman kitchen ware (Group A), Peacock 45 Amphorae (Group B); Roman bricks etc.; Sauer 1995. For unguentaria with a similar fabric see Sauer – Ladstätter, in this volume.

6 Sauer 1995 with several clay analyses.

sample number	mineralogical / petrographical fabric type	very fine, vitrified	coarser grained („micaceous“)	non calcareous	calcareous	partiallly isotropic/vitrified	totally isotropic/ vitrified	slag	reduced	oxidised	low firing temperature	high firing temperature	firing level not defined	temper particles 15µ-0.2mm (vol%)	temper grains >0.2mm (vol%)	total temper content >15µ (vol%)	grain size mm (arith.mean of 50 grains)	maximum grain size (mm, 50 grains)	largest grain in thin section (mm)	sorting	roundness	well rounded grains
	character of groundmass													temper properties								
EPH-ART 01	A	x		x			x			x		x		30,5	8,5	39,0	0,01	0,29	0,64	4	6	
EPH-ART 03	A	x		x			x			x		x		28,0	18,5	46,5	0,01	0,31	0,72	4	6	tr
EPH-ART 04=ART02	A	x		x			x			x		x		37,3	9,6	46,9	0,11	0,29	0,56	4	6	tr
EPH-ART 06	B		x		x	x				x		x		12,4	0,2	12,6	0,07	0,32	0,52	3	4-5	
EPH-ART 18	B		x	x-		x				x		x		11,4	4,1	15,5	0,09	0,40	0,52	3-4	4-5	
EPH-ART 19	B		x	x-						x	x			14,9		14,9	0,07	0,24	0,52	3	4-5	
EPH-ART 25	B		x	x-						-x	x			12,2	1,1	13,3	0,11	0,55	1,00	4	4-5	
EPH-ART 09	B		x	x						x			x	6,3	0,8	7,1	0,07	0,16	0,48	3	4-5	
EPH-ART 10	B		x		x?	x				x		x		13,0	1,9	14,9	0,07	0,22	0,48	3	4-5	
EPH-ART 12	B		x	x						x			x	10,5	0,8	11,3	0,05	0,19	0,36	3	4-5	
EPH-ART 13	B		x	x-		x				x		x		15,0	0,5	15,5	0,06	0,36	0,60	3	4-5	
EPH-ART 20	B -B1		x	x-		x				x		x		10,6	3,3	13,9	0,09	0,53	1,10	4-5	4-5	
EPH-ART 17	B1		x	x-						x	x			11,6	9,9	21,5	0,11	0,60	1,20	4-5	4-5	
EPH-ART 28	B2		x	x-		x				x		x		5,0	5,3	10,3	0,10	0,57	2,60	4-5	4-5	
EPH-ART 07	C		x	x-		x				x		x		3,6		3,6	0,04	0,07	0,16	2	4-5	
EPH-ART 08	C		x	x-		x				x		x		4,1		4,1	0,04	0,10	0,40	2	4-5	
EPH-ART 11	C		x	x						x			x	5,2		5,2	0,04	0,09	0,30	2	4-5	
EPH-ART 15	C		x	x					x-				x	7,2		7,2	0,04	0,17	0,40	2-3	4-5	
EPH-ART 14	C		x	x-		x				x		x		6,8	1,9	8,7	0,03	0,10	0,28	2-3	4-5	
EPH-ART 16	C		x	x						x			x	6,0		6,0	0,05	0,30	0,36	2-3	4-5	
EPH-ART 27	C		x	x					x-				x	6,1		6,1	0,03	0,12	0,28	2-3	4-5	
EPH-ART 21	D	x-		x						x			x	14,1	3,6	17,7	0,15	1,22	2,60	5	3-5	
EPH-ART 22	D		x	x						x			x	15,4	9,6	25,0	0,10	0,30	0,96	5	3-5	
EPH-ART 23	D		x	x					x-				x	11,7	16,7	28,4	0,21	1,08	2,80	5	3-5	
EPH-ART 24	D		x	x		x				x			x	10,8	9,4	20,2	0,15	1,00	1,80	5	4-5	

sample number	monocrystalline quartz	polycrystalline quartz	volcanic quartz	chert	K-feldspars	plagioclase	albite	volcanic plagioclase	muscovite	biotite	oxidised sheet silicates	carbonate grains	dissolved carbonates (molds)	plant remains	siltstone/ sandstone fragments	shale fragments ‚not resorbed‘	crystalline rock fragments in general	quartzite	volcanic rock fragments	volcanic glass brown	volcanic glass colourless	heavy minerals	opaque material	iron oxide cemented agglomerates	slag particles/ overfired grains ...
	semiquantitative mineralogical and petrogrphical composition of temper particles > 15µm																								
EPH-ART 01	a	g		d	d	h							g			h	g		h		h	g	d	g	
EPH-ART 03	a	g		g	d	h							g			h						g	d	g	
EPH-ART 04=ART02	a	g		g	d	h					g					h						g	f	f	
EPH-ART 06	b	d			d				a	g	c		c	g	g		g					g	d	d	
EPH-ART 18	b	g		h	c		g		a	f	b		d		g		g					g	d	g	
EPH-ART 19	c	g			d		g		a	d	d	f					g					g	d	d	
EPH-ART 25	c	g			d		g		a	f	d	c			g		f					g	d		
EPH-ART 09	b	h			d	h			b	f	d		g				g						d	c	
EPH-ART 10	b	f			d				a	d	c		g			g	g	h				g	d	d	
EPH-ART 12	c	g		h	d	h	g		a	g	d		g				g					h	d	c	
EPH-ART 13	c	g		h	d	h	g		a	d	c		g				g					g	d	c	
EPH-ART 20	b	g		h	d	h	g		a	g	d		d				g					g	f	d	
EPH-ART 17	b	f		h	c		g		b	g	c	g	d		g		d					f	d	c	
EPH-ART 28	b	g			d		g		c	g	c		g				g					d	d	c	g
EPH-ART 07	d				g				a	g	a		f		g							g	c		
EPH-ART 08	d	g			g				b		c		f		g		h					g	g	c	
EPH-ART 11	d				d		g		a	g	c	h	g				h					f	c	d	
EPH-ART 15	d				d		g		b	g	b						g					g	c	d	
EPH-ART 14	c	g			d				c	g	a		g				g					g	d	c	
EPH-ART 16	c				c		g		a	g	a		g									g	d	c	
EPH-ART 27	c	g			d		g		a	c	d						g					g	d	d	
EPH-ART 21	b	g			d		d		b	g	f						f					c	d	d	
EPH-ART 22	b	g			d		d		b	g	d						f					c	d	d	
EPH-ART 23	b	d			d		g		c								f					c			
EPH-ART 24	b	f		g	d		f		c		g						f					d	d	d	

LEGEND: for further explanation see text (methods)
frequencies: a: dominant, b: very frequent, c: frequent, d: subordinate, e: moderate, f: rare, g: very rare, h: traces
sorting: 1: very well, 2: well, 3: moderate, 4: poor, 5: very poor, 6: bimodal
roundness: 1: well rounded, 2: rounded, 3: subrounded, 4: subangular, 5: angular, 6: very angular
tr.= traces

Figure 1: Thin section analyses

sample number		EPH-ART01	EPH-ART03	EPH-ART04	EPH-ART06	EPH-ART18	EPH-ART19	EPH-ART25	EPH-ART09	EPH-ART10	EPH-ART12	EPH-ART13	EPH-ART20	EPH-ART17	EPH-ART28	EPH-ART07	EPH-ART08	EPH-ART11	EPH-ART15	EPH-ART14	EPH-ART16	EPH-ART27	EPH-ART21	EPH-ART22	EPH-ART23	EPH-ART24
fabric type		A	A	A	B	B	B	B	B	B	B	B	B-B1	B1	B2	C	C	C	C	C	C	C	D	D	D	D
zircon	%	n.a.	n.a.	37,9	n.a.	4,4	5,9	8,6	7,0	4,9	3,7	8,9	6,0	1,9	9,7	0,0	0,5	0,5	0,0	0,5	0,5	0,0	1,0	1,9	0,0	4,9
rutile	%	n.a.	n.a.	26,2	n.a.	14,6	10,3	14,1	17,9	11,3	18,4	14,2	18,4	7,6	20,6	3,3	1,0	3,3	0,5	5,5	7,4	0,5	1,9	1,4	0,0	6,4
brookite/anatase	%	n.a.	n.a.	3,9	n.a.	4,9	6,9	5,0	4,5	7,4	5,1	14,6	4,0	10,0	31,0	5,0	1,0	0,9	3,9	17,4	3,0	0,5	0,5	0,5	0,5	2,5
titanite	%	n.a.	n.a.	0,0	n.a.	0,5	1,0	0,5	0,0	0,5	0,5	0,4	0,0	1,9	13,5	3,3	3,0	2,8	5,8	7,5	3,5	2,9	0,5	2,8	1,9	1,0
monazite	%	n.a.	n.a.	0,0	n.a.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
tourmaline	%	n.a.	n.a.	0,5	n.a.	0,0	3,4	4,1	2,0	1,0	5,5	0,0	0,0	13,8	0,0	0,0	0,0	1,4	0,0	0,5	1,0	0,5	1,0	2,3	1,4	0,0
garnet	%	n.a.	n.a.	0,0	n.a.	70,2	69,1	64,1	62,7	71,9	59,0	56,6	67,7	47,6	10,3	6,7	14,8	9,3	6,3	9,0	11,4	3,4	0,5	0,5	0,5	5,9
staurolite	%	n.a.	n.a.	3,9	n.a.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
kyanite	%	n.a.	n.a.	15,1	n.a.	0,5	0,5	0,0	0,0	2,0	0,9	0,9	2,5	1,0	7,1	1,7	0,0	0,5	0,5	3,0	0,5	0,5	0,0	0,0	0,0	3,4
epidote/zoisite	%	n.a.	n.a.	1,9	n.a.	4,9	1,5	2,7	0,5	0,5	2,3	0,9	0,5	10,5	0,6	11,7	57,6	67,0	63,6	22,9	46,0	72,2	92,8	88,8	91,3	69,1
hornblende	%	n.a.	n.a.	5,8	n.a.	0,0	0,5	0,0	3,5	0,5	1,8	1,3	0,5	4,3	3,2	65,0	22,2	14,4	18,4	33,3	23,8	19,5	1,9	1,9	4,3	6,4
chloritoide	%	n.a.	n.a.	0,0	n.a.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0
andalusite	%	n.a.	n.a.	0,0	n.a.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
apatite	%	n.a.	n.a.	*	n.a.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
chromian spinel	%	n.a.	n.a.	0,0	n.a.	0,0	0,5	0,5	0,5	0,0	2,8	2,2	0,5	0,0	0,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
sillimanite	%	n.a.	n.a.	0,0	n.a.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
clinopyroxene (augite)	%	n.a.	n.a.	1,5	n.a.	0,0	0,5	0,5	0,0	0,0	0,0	0,0	0,0	0,0	0,6	0,0	0,0	0,0	0,5	0,0	0,5	0,0	0,0	0,0	0,0	0,0
corundum	%	n.a.	n.a.	0,0	n.a.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5
clinopyroxen(diopside)	%	n.a.	n.a.	0,5	n.a.	0,0	0,0	0,0	0,5	0,0	0,0	0,0	0,0	0,0	1,9	0,0	0,0	0,0	0,5	0,5	1,0	0,0	0,0	0,0	0,0	0,0
hypersthene	%	n.a.	n.a.	0,0	n.a.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
?oxidised pyroxen	%	n.a.	n.a.	0,0	n.a.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
diallage	%	n.a.	n.a.	0,0	n.a.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
? = not determinable	%	n.a.	n.a.	2,9	n.a.	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	1,0	0,6	3,3	0,0	0,0	0,0	0,0	1,0	0,0	0,0	0,0	0,0	0,0
glaucophane	%	n.a.	n.a.	0,0	n.a.	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
counted translucent grains	%			206	0	205	204	220	201	203	217	226	201	210	155	60	203	215	206	201	202	205	208	214	208	204

n.a = not analysed
* removed due to HCL treatment

Figure 2: Heavy mineral analyses

Sample number	Inv. Nr.	Type J. Vroom	mineralogical / petrographical fabric type	Laboratory sample id. (Lyon)	Chemical group	remarks
EPH-ART 01	Art 65 K11	1 monochrome turquoise glazed ware A	A	BYZ 426	synthetic paste	Art01+Art02+Art04 from the same object!
EPH-ART 02	Art 65 K11	1 monochrome turquoise glazed ware A		BYZ 427	synthetic paste	ART02 = ART04
EPH-ART 03	Art 65 K11	1 monochrome turquoise glazed ware A	A			
EPH-ART 04	Art 65 K11	1 monochrome turquoise glazed ware A	A			
EPH-ART05	Art 66 K17	2 monochrome turquoise-blue glazed ware B		BYZ 428	b	ART05 = ART06
EPH-ART 06	Art 66 K17	2 monochrome turquoise-blue glazed ware B	B			
EPH-ART 18	Art 82 K240	6 unglazed relief ware	B	BYZ 440	b	
EPH-ART 19	Art 65 K11	6 unglazed relief ware	B	BYZ 441	b	
EPH-ART 25	Art 66 K17	8 monochrome green glazed oil lamp	B	BYZ 447	b	
EPH-ART 09	Art 66 K17	4 brown and green sgrafitto ware B	B	BYZ 431	b	
EPH-ART 10	Art 66 K17	4 brown and green sgrafitto ware B	B	BYZ 432	b	
EPH-ART 12	Art 80 K83	5 monochrome green glazed ware	B	BYZ 434	b	
EPH-ART 13	Art 80 K83	5 monochrome green glazed ware	B	BYZ 435	b	
EPH-ART 20	Art 65 K9	6 unglazed relief ware	B -B1	BYZ 442	b	
EPH-ART 17	Art 65 K15	6 unglazed relief ware	B1	BYZ 439	outlier	
EPH-ART 28	Art 65 K15	9 tripod stilt	B2	BYZ 449	marginal / c	
EPH-ART 07	Art 65 K15	3 brown and green sgrafitto ware A	C	BYZ 429	c	
EPH-ART 08	Art 65 K1	3 brown and green sgrafitto ware A	C	BYZ 430	c	
EPH-ART 11	Art 80 K83	5 monochrome green glazed ware	C	BYZ 433	c	
EPH-ART 15	Art 65 K15	5 monochrome green glazed ware	C	BYZ 437	c	
EPH-ART 14	Art 65 K5	5 monochrome green glazed ware	C	BYZ 436	c	
EPH-ART 16	Art 65 K5	5 monochrome green glazed ware	C	BYZ 438	c	
EPH-ART 26	Art 65 K12	8 monochrome green glazed oil lamp		BYZ 448	c	
EPH-ART 27	Art 65 K12	8 monochrome green glazed oil lamp	C			ART27 = ART26
EPH-ART 21	Art 65 K11	7 unglazed domestic ware	D	BYZ 443	d	
EPH-ART 22	Art 80 K83	7 unglazed domestic ware	D	BYZ 444	d	
EPH-ART 23	Art 66 K17	7 unglazed domestic ware	D	BYZ 445	d	
EPH-ART 24	Art 80 K83	7 unglazed domestic ware	D	BYZ 446	marginal / d	

Figure 3: List of Concordance

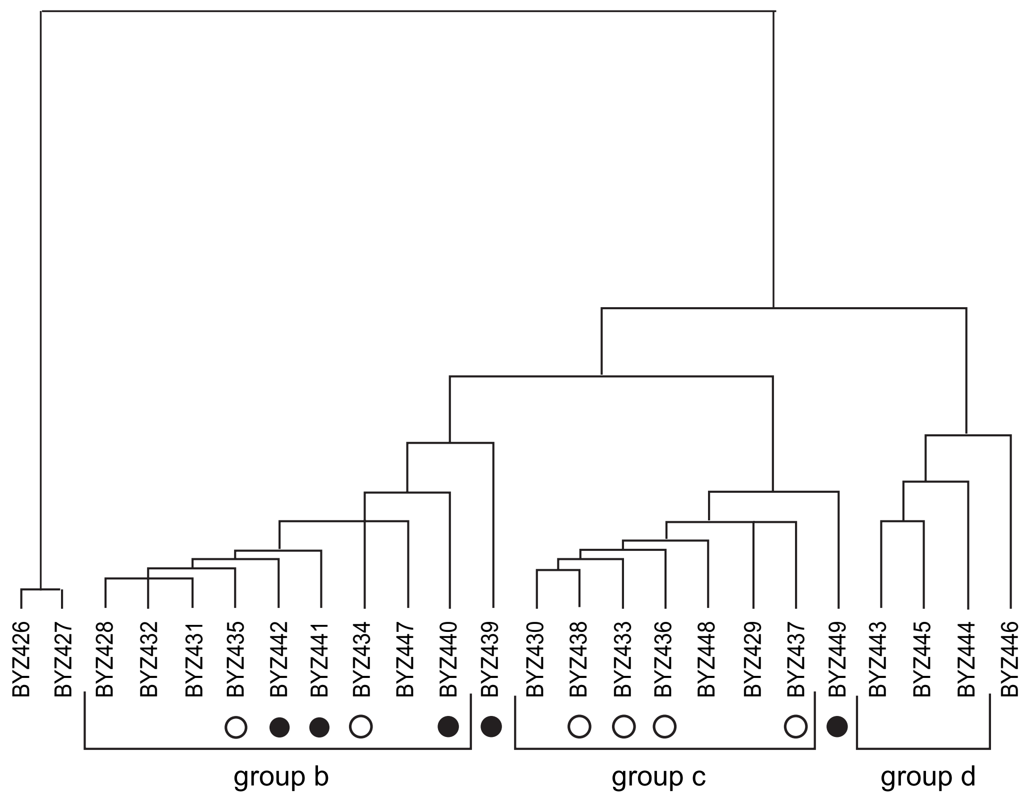

Figure 4 : Classification of medieval ceramics from the Artemision in Ephesus. Hierarchical clustering analysis, applied to 17 chemical elements (see text). Chemical groups are underlined. Samples taken as references for local production are indicated by black (types 6 and 9) and white (type 5) dots.

Chemical analysis

by Yona Waksman

Chemical analysis and classification of samples according to chemical composition

Chemical analysis was carried out by Wavelength Dispersive - X Ray Fluorescence (WD-XRF) in the 'Laboratoire de Céramologie' in Lyon. Twenty-four elements were quantified, seventeen of which were taken as active variables in multivariate statistical treatments used to classify ceramics into groups of similar chemical composition. These include major and minor elements in ceramics (MgO, Al_2O_3, SiO_2, K_2O, CaO, TiO_2, MnO, Fe_2O_3) and trace elements (V, Cr, Ni, Zn, Rb, Sr, Zr, Ba, Ce).

Classification of samples was obtained by hierarchical clustering analysis applied to standardized data, using euclidian distance and centroid linkage[7]. The corresponding diagram, called a dendrogram, initially represents each sample as a vertical bar at the bottom of the figure (Fig. 4). The two samples the most alike in elemental composition are connected by an horizontal link, which lies all the lower as the samples are chemically similar. The two samples are then fused into a 'pseudo sample' of average composition. The same process is repeated, with the linkage being formed at growing heights, until all the samples are connected. The resulting diagram constitutes the dendrogram. It shows clusters of samples of similar composition linked at a lower level,

[7] E. g. Picon 1984.

all the clusters being ultimately linked together at the top of the diagram. This representation is however not sufficient in itself to define compositional groups. It does not take into account the significance of elemental differences between clusters, and a further examination of the data is still needed.

Sherds included in a given compositional group are expected to be made from similar raw material. Inference on a common origin of these sherds are based on their belonging to a same group, but geological context and archaeological evidence should also be taken into consideration.

Chemical groups and locally produced wares

The analyzed ceramics are clustered in the dendrogram into three main chemical groups, a few sherds remaining marginals or unassigned (Figs. 3–5).

Two sherds (BYZ 426, BYZ 427), corresponding to monochrome turquoise glazed ware A (type 1), stand together as outliers in the sampling. They are not made out of clay and their manufacture corresponds to a completely different technology. These samples are therefore not comparable with the others. Their pastes are synthetic[8], that is artificial, man-made mixtures. The main component is a siliceous material (quartz), cemented by a glassy phase. In the Ephesus samples, the concentrations in SiO_2 are close to 90%[9]. Elements such as sodium and potassium, which could have acted as flux, are present in fairly low concentrations (around 1%). Small amounts of lead are also present, in quantities which seem too low to consider it a fluxing agent of the paste[10], and it is more likely that it diffused from the glaze[11]. Clay must have been included in the initial mix, as indicated by the high aluminium content[12]. Ethnographic studies report the use of a plastic clay such as montmorillonite in the manufacture of 'faïence' in traditional iranian workshops[13]. A mixture of quartz with a significant amount of montmorillonite would actually well account for the observed high aluminium and comparatively low fluxes contents[14].

The technique of synthetic paste appears very early in Egypt and in Mesopotamia. Closer to the period considered, it was in use in the Islamic world[15], and flourished later on in Ottoman times, for instance in the workshops of Iznik where ceramics and tiles with synthetic pastes were famous[16].

There is no evidence that synthetic pastes were manufactured in medieval Ephesus and ceramics of type 1 are considered as imports[17].

Most samples are included in chemical groups b, c and d (Fig. 4). Some are attested to be local either by their function, like the tripod stilts used to pile up glazed ware in kilns (type 9), or by archaeological evidence. The latter case concerns type 6 (wares with molded decoration found

8 A number of designations are found, including fritware, stonepaste (e. g. Mason – Tite 1994), siliceous paste (Soustiel 1985), and faïence (Centlivres-Demont 1971).

9 Our experimental set-up is calibrated for the analysis of clayey material and may not be fully appropriate for characterizing synthetic pastes. The present results should therefore be considered indicative.

10 The global fluxes content appears surprisingly low when compared to the literature values, but see preceeding note.

11 Although glaze analysis was not undertaken, it can be supposed from previous analyses of similar turquoise glaze to be either alkaline (Pérez-Arantegui et al. 1996) or lead-alkaline (Scott – Kamilli 1981, unpublished analyses by Waksman and Roumié of medieval ceramics manufactured in Beirut), with copper as coloring agent. Pastes of lead-glazed ceramics often contain significant amounts of lead due to diffusion from the glaze, as can be seen in Figure 5 (except for type 1 and possibly type 2, all the glazes in our sampling are most probably high-lead ones).

12 The aluminium concentrations are comparable to those of medieval examples found in Syria (Franchi et al. 1995) and Lebanon (François et al. 2003).

13 Centlivres-Demont 1971.

14 We would like to thank M. Picon for suggesting the use of montmorillonite.

15 Mason – Tite 1994.

16 Atasoy – Raby 1989; Tite 1989.

17 See Vroom's contribution, in this volume.

together with their molds), and, less securely, type 5 (dominant on the site, with an example of this category found with parts of a tripod stuck to it). Samples of types 9, 6 and, to a lesser extent, of type 5 were therefore taken as local references and used to define chemical groups corresponding to Ephesus production.

Groups b and c both contain such reference samples, indicated by black (types 6 and 9) and white (type 5) dots in figure 4. They are composed of tablewares and lamps (Fig. 3). Group c differs mainly from group b by higher contents of aluminium, iron, vanadium and zirconium and lower contents of silicium, calcium, strontium and nickel (figure 5). The latter element is however quite variable within both groups, a characteristic also shared to some extent by chromium.

Group b includes three out of four wares with molded decoration (type 6) and is thus considered as securely local. The fourth sample of this type (BYZ 439) is not part of any chemical group and constitutes a chemical outlier within the sampling. This sample is singled out by mineralogical and petrographical analyses as well, but it probably corresponds to another locally available clay (Sauer *supra*). Group b also includes: one ceramic with greenish-turquoise glaze (type 2), whose paste has nothing in common with the samples with turquoise glaze and synthetic paste of type 1; one of the glazed lamps (type 8); the two representatives of a type with sgraffito decoration (type 4); and two samples with green glazes belonging to type 5.

The remaining four samples of type 5 are part of chemical group c. Group c also includes the other glazed lamp and the two representatives of another type decorated with the sgraffito technique (type 3). A tripod stilt is marginal to the group. Although local references within chemical group c only consist in samples of type 5, the group is likely to correspond to Ephesian production. Besides the dominant percentage of ceramics of type 5 on the site, similar clays are locally available (Sauer *supra*) and the group bears some chemical resemblance with late roman lamps attested to be Ephesian (cf. infra).

Chemical data indicate that at least two different clays were probably used in the workshop(s) to manufacture tablewares. The two compositional groups might correspond to the output of different Ephesian workshops, or to different periods of production. It could be argued that some categories appear in both groups (type 5, type 8, sgraffitos). But plain monochrome glazed ceramics of type 5 were produced over long periods. And sgraffitos in groups b and c are of a different type. Such hypothesis could not be tested anyhow given the absence of stratified contexts. The distribution of samples in two groups could also indicate that both clays were indifferently used to manufacture tablewares.

The choice of clays may have been more selective for wares which had to meet specific technical requirements, such as cookwares. It is not clear whether some of the unglazed wares of type 7 had this function[18]. In any case, they correspond to a separate chemical group (group d), and to a sample (BYZ 446) which is marginal to this small group in several respects although it shares most of its characteristics. They are characterized by comparatively higher contents of silicium, chromium and nickel and lower contents of potassium and rubidium (Fig. 5). The compositions of the four samples of type 7 analyzed are not homogeneous. These samples are more coarsely tempered than the others (Sauer *supra*). Temper could be a factor of heterogeneity, furthermore as the small sampling cannot pretend to fully define type 7.

Group d does not include any reference sample but is considered to be local both on archaeological and on mineralogical and petrographical grounds (Sauer supra and Vroom in this volume).

General chemical features of samples in groups b, c, d comprise fairly high iron and aluminium content and fairly low to low calcareous content. The latter characteristic already differentiates the medieval sherds from several earlier Ephesian ware previously analyzed (cf. *infra*). Abundant micas in the fine fraction of the temper, in which muscovite is well-preserved (Sauer *supra*), pro-

18 See e. g. Vroom, in this volume, pl. 5 no. 38.

id.	type	(Na_2O)	MgO	Al_2O_3	SiO_2	(P_2O_5)	K_2O	CaO	TiO_2	MnO	Fe_2O_3	V	Cr	Ni	Zn	Rb	Sr	Zr	Ba	(La)	Ce	(Pb)
Synthetic pastes																						
BYZ426	1	1,24	0,27	7,79	86,66	0,09	1,13	0,58	0,614	0,014	1,39	61	57	5	18	19	269	150	113	20	64	1383
BYZ427	1	0,96	0,27	7,63	87,71	0,09	0,86	0,36	0,610	0,013	1,30	51	44	12	13	16	254	147	93	27	66	1142
Group b (n=9)																						
BYZ428	2	1,35	4,22	21,35	54,81	0,21	3,90	4,24	0,977	0,097	8,58	140	208	280	124	195	275	168	723	61	125	201
BYZ432	4	1,35	4,03	20,68	56,27	0,24	3,90	3,78	0,961	0,099	8,39	142	209	291	124	183	261	179	738	62	122	540
BYZ431	4	1,34	4,19	21,03	54,98	0,27	4,00	4,22	0,973	0,100	8,59	138	220	301	140	188	262	175	795	54	124	546
BYZ435	5	1,29	3,99	20,74	54,97	0,29	4,25	4,72	0,934	0,102	8,37	136	218	294	125	183	275	168	724	59	119	884
BYZ442	6	1,22	3,93	19,69	57,70	0,23	3,59	4,01	0,968	0,093	8,33	135	214	319	119	171	252	177	677	55	115	30
BYZ441	6	1,45	3,84	20,25	55,57	0,47	3,88	4,95	0,915	0,104	8,33	142	199	277	129	162	228	162	756	53	121	113
BYZ434	5	1,46	3,35	22,38	54,29	0,28	4,40	3,42	1,013	0,111	9,01	138	204	229	138	199	248	170	778	52	119	512
BYZ447	8	1,31	3,53	20,74	54,36	0,24	3,93	6,14	0,960	0,093	8,15	134	196	208	121	171	279	179	763	63	116	2969
BYZ440	6	1,49	3,58	21,98	55,53	0,23	4,21	3,32	1,024	0,093	8,29	137	159	182	125	196	340	195	835	62	127	53
m		**1,36**	**3,85**	**20,98**	**55,39**	**0,27**	**4,01**	**4,31**	**0,969**	**0,099**	**8,45**	**138**	**203**	**265**	**127**	**183**	**269**	**175**	**754**	**58**	**121**	
σ		**0,09**	**0,30**	**0,83**	**1,07**	**0,08**	**0,24**	**0,87**	**0,034**	**0,006**	**0,25**	**3**	**18**	**47**	**7**	**13**	**31**	**10**	**46**	**4**	**4**	
unclassified																						
BYZ439	6	1,40	2,89	17,56	61,19	0,27	3,23	4,70	0,980	0,089	7,47	131	155	192	111	137	226	248	661	55	108	37
Group c (n=7)																						
BYZ430	3	1,43	3,36	24,07	52,55	0,26	4,19	1,45	1,036	0,131	11,05	203	164	108	154	178	168	234	916	72	143	2109
BYZ438	5	1,42	3,25	24,20	52,60	0,27	4,33	1,44	1,049	0,114	11,05	194	159	98	158	185	168	257	929	71	142	286
BYZ433	5	1,51	3,30	23,48	52,65	0,30	4,30	2,39	1,031	0,130	10,64	194	167	106	144	182	168	258	932	77	139	187
BYZ436	5	1,46	3,52	23,83	52,58	0,30	4,39	1,48	1,039	0,090	10,96	203	179	126	154	176	168	252	922	80	141	1217
BYZ448	8	1,36	3,77	23,62	52,01	0,47	4,14	2,03	1,013	0,116	11,15	215	222	144	156	179	208	239	998	76	134	424
BYZ429	3	1,33	3,29	24,48	51,25	0,27	4,14	1,35	1,019	0,130	11,07	201	161	88	149	(134)	149	212	898	70	154	>9999
BYZ437	5	1,46	4,08	24,04	51,25	0,29	4,40	1,46	1,032	0,146	11,56	218	218	156	161	181	157	236	875	76	153	293
m		**1,42**	**3,51**	**23,96**	**52,13**	**0,31**	**4,27**	**1,66**	**1,031**	**0,122**	**11,07**	**204**	**181**	**118**	**154**	**180**	**169**	**241**	**924**	**75**	**144**	
σ		**0,06**	**0,31**	**0,34**	**0,64**	**0,07**	**0,11**	**0,39**	**0,012**	**0,018**	**0,27**	**9**	**27**	**25**	**6**	**3**	**19**	**16**	**38**	**4**	**7**	
marginal to group c																						
BYZ449	9	1,44	2,96	22,19	56,28	0,28	3,63	1,64	1,101	0,100	9,85	196	168	118	132	(148)	149	255	670	67	124	3116
Group d (n=3)																						
BYZ443	7	1,85	3,22	18,81	61,42	0,13	1,62	2,15	1,082	0,088	9,43	181	387	331	79	85	119	214	344	39	79	29
BYZ445	7	1,69	3,59	18,37	61,23	0,74	2,27	1,98	1,050	0,119	8,74	168	446	332	104	103	115	222	425	37	76	95
BYZ444	7	1,54	4,29	18,44	60,58	0,56	2,27	1,75	0,999	0,159	9,17	162	429	409	97	98	81	204	463	42	83	130
m		**1,69**	**3,70**	**18,54**	**61,08**	**0,48**	**2,05**	**1,96**	**1,044**	**0,122**	**9,11**	**170**	**421**	**357**	**93**	**95**	**105**	**213**	**411**	**39**	**79**	
σ		**0,16**	**0,54**	**0,24**	**0,44**	**0,31**	**0,38**	**0,20**	**0,042**	**0,036**	**0,35**	**10**	**30**	**45**	**13**	**9**	**21**	**9**	**61**	**3**	**4**	
marginal to group d																						
BYZ446	7	0,91	2,17	20,15	63,14	0,19	2,43	0,89	1,057	0,113	8,75	153	290	272	105	125	70	271	401	50	105	36

Figure 5 : Chemical compositions of ceramics from medieval contexts, Artemision excavations at Ephesus. Major and minor elements Na_2O to Fe_2O_3 in %, others in ppm; elements not used in the classification are in brackets. Mean compositions (m) et standard deviations (σ) of the chemical groups are indicated. Samples are ranked as in the dendrogram (Fig. 4). Analyses of synthetic pastes (BYZ426, BYZ427) are indicative only. Other indicative data are in brackets.

bably account for the high aluminium, iron and magnesium content. They were brought in by the Küçük Menderes river from the metamorphic formations of the Menderes east of Ephesus. Chromium and nickel are also present in fairly high concentrations which might reflect the influence of ophiolitic outcrops around the Menderes.

Medieval and classical ceramics production in Ephesus

Previous chemical analysis of ceramics found in Ephesus has focused mainly on Greek and Roman ceramics[19], although attempts to characterize medieval wares were made as well[20].

Data for hellenistic and roman Ephesian production provided by Schneider (Freie Universität, Berlin) are the most readily comparable to ours. The analytical methods used in Lyon and in Berlin are the same (WD-XRF) and data had previously been exchanged between the two laboratories. 'Ephesus fine wares'[21], 'Graue Platten'[22] and ceramics with appliqué molded decoration[23] all have similar chemical compositions, which are quite different from those of the medieval productions. The latter are in general less calcareous and have higher concentrations of iron and titanium and, less significantly, of sodium. The reference group provided by Schneider however corresponds only to part of the production, and he mentions that the range of clays used in the classical period is actually larger[24].

This diversity appears explicitly in a study of archaic to late Roman Ephesian lamps[25], where several chemical groups are distinguished. One of them[26] is quite different from the others. It corresponds to a roman production of lamps of type Loeschcke VIII. Wasters of these lamps attest to their manufacture in Ephesus[27]. These analyses were performed by INAA (Instrumental Neutron Activation Analysis) and can be compared with our results only for a limited number of elements. Still, similarities in composition can be noted for elements determined by both analytical methods. Visually, these lamps also have the very fine fabric characteristic of wares of our groups b and c[28]. Although further analyses of this type of Ephesian lamps by XRF would be necessary to reach a conclusion, we can suppose that within the clays available on the site, some may have been used both in the classical and medieval periods. But the main part of the Roman production of fine wares seems to be made from other, more calcareous, clays. Closer parallels could possibly be found in Roman common ware, as suggested by the petrographical data (Sauer *supra*).

Ephesian production in the context of medieval Western Asia Minor

Ephesus may now be added to the few western Anatolian sites which had up till now been archaeologically identified as production centers of ceramics in the medieval period. Some of them had been characterized for their local production, such as Pergamon[29] and, more recently, Nicea/Iznik[30] by chemical analysis, and Sardis[31] by petrographical analysis. Reference groups for medieval wares manufactured in Ephesus, Pergamon and Iznik have been constituted, which can be distinguished chemically.

19 Dupont 1983; Hughes et al. 1983; Jones 1986; Hughes et al. 1988; Zabehlicky-Scheffenegger et al. 1996; Schneider 2000; Zabehlicky-Scheffenegger – Schneider 2000; Akurgal et al. 2002.
20 Demirci et al. 1996.
21 Schneider 2000.
22 Zabehlicky-Scheffenegger et al. 1996.
23 Zabehlicky-Scheffenegger – Schneider 2000.
24 Schneider 2000, 532.
25 Hughes et al. 1988.
26 Hughes et al. 1988, 470, cluster b.
27 Hughes et al. 1988, 463.
28 S. Ladstätter, pers. comm.
29 Waksman et al. 1996, Waksman – Spieser 1997.
30 As yet unpublished analyses in the Laboratoire de Céramologie. We would like to thank V. François and N. Özkül for providing these samples from Iznik.

Besides the local production, some categories of imports were considered. It is noticeable that wares very similar to Ephesus' green and purple sgraffitos of type 3 are present in Pergamon[32], Sardis[33] and Iznik. In the latter three sites, the very close compositions of the examples analyzed point to a single origin. This origin is however different from the one of the Ephesus examples, which are included in our chemical group c and are thus very likely to be Ephesian. On the basis of petrographic analyses, Kamilli proposed that examples found in Sardis were manufactured there[34], an attribution which could not be tested by chemical analysis. She also presented as possibly Sardian turquoise-glazed sherds very similar to Ephesus' type 2[35], an example of which is included in our local chemical group b.

It thus appears that both wares (types 2 and 3) were manufactured in at least two production sites, which are likely to be Sardis and Ephesus. This association of turquoise-glazed ware (with clay paste) and polychrome sgraffito is reminiscent of Eastern Anatolian and Syrian types[36]. Although it would be unwise to draw any conclusion given the small sampling considered, these results may somehow strengthen Scott's hypothesis of a continuation in western Anatolia of the Syrian pottery traditions after the fall of the Crusader States[37].

Conclusion

Ephesus has known a long tradition of pottery production. In the medieval period, scarce but clear evidence for local production were found in the Artemision. Medieval sherds, including attested local ware, were analyzed for their mineralogical, petrographical and chemical compositions. A range of products manufactured in medieval Ephesus could be foreseen and an initial characterization of these wares is provided. Comparisons with data available on clays used in the earlier periods point to some similarities, and also illustrate the variety of clay materials available on the site. Analyses distinguish at least three different clay materials which are likely to have been used by medieval potters in Ephesus. Comparisons with other medieval ceramics from the region, which present typological parallels with the Ephesian material, also gave some insight into pottery production and influences in medieval Asia Minor.

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31 Scott – Kamilli 1981.
32 Waksman et al. 1996, Fig. 2, middle; Waksman – Spieser 1997, Fig. III, nos. 61. 69. 70.
33 Chervinsky et al. 1996.
34 Scott – Kamilli 1981.
35 Scott – Kamilli 1981, 686, Fig. 7; Vroom, in this volume, No. 24.
36 Vroom, in this volume.
37 Scott – Kamilli 1981, 686.

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