Archaeometric and Archaeological Approaches to Ceramics

Papers presented at EMAC '05, 8th European Meeting on Ancient Ceramics, Lyon 2005

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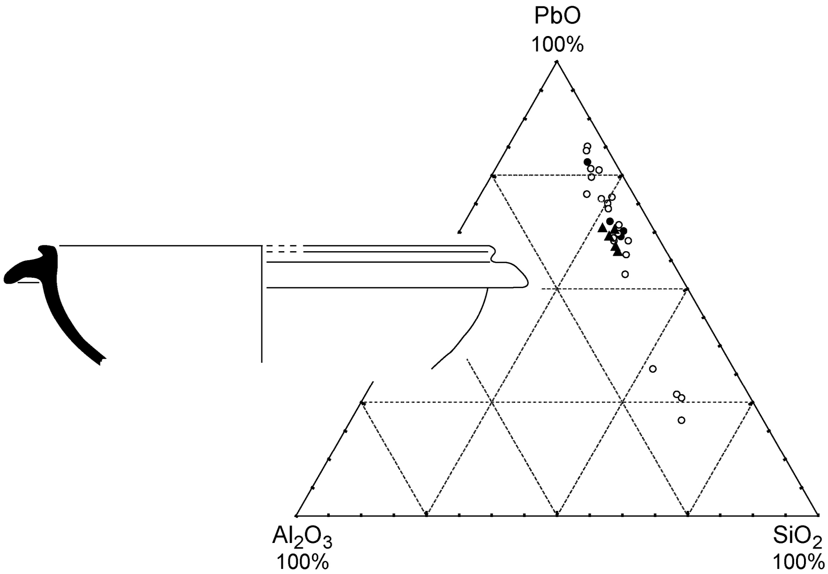

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Cover illustration (left): Late Roman glazed mortar found in Saint-Blaise excavations, possibly from northern Italy. [After C.A.T.H.M.A., Importations de céramiques communes méditerranéennes dans le midi de la Gaule (Ve - VIIe s.), in *A cerâmica medieval no Mediterrâneo ocidental*, 1991, Mertola, p. 39, fig. 28]

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THE FIRST BYZANTINE "GLAZED WHITE WARES" IN THE EARLY MEDIEVAL TECHNOLOGICAL CONTEXT

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Byzantine "Glazed White Wares" appear in Constantinople in the 7th century AD (Hayes 1992). They represent a significant break with the Late Roman typological repertoire and correspond to the beginning of the medieval development of glazes in Byzantium. Due to the chronological hiatus of several centuries between the Hellenistic and Roman glazed productions of Asia minor and the first Byzantine Glazed White Ware, the question of the (re)introduction of the glazing technique has been a longstanding question. Glazed production seems to have been continuously present in the Parthian, Sasanian, then Islamic territories, and an Eastern introduction had been conjectured. However, the alternative hypothesis of a Western input has more recently been favoured (Hayes 1992, p. 15), as archaeological excavations gave evidence for the presence and production of glazed wares in northern Italy and in the Balkans in the 5th–7th centuries, that is, in the period just preceding the appearance of Byzantine Glazed White Wares (Paroli 1992; Spieser 1991, p. 250). It was the purpose of the present pilot project to investigate in the laboratory this question of circulation of techniques with the help of an appropriate sampling, which included for the first time examples of the earliest Byzantine Glazed White Wares. Paste and glaze analyses were carried out in order to shed some light on the technological relationships between the latter and both "Eastern" and "Western" productions.

SAMPLING

The first requirement of our selection was that samples should come from well defined archaeological contexts, with dates as close as possible to the 7th century AD. Even though the precise origin of the samples was not identified, they were considered representative of well identified technological environments. The sampling consists of four batches, which were given general names referring to this environment for the sake of clarity. It should however be clear that the samples represent the more restricted contexts introduced below (Fig. 1):

— The "Byzance" batch (samples BYZ718-733) is representative of the first Byzantine Glazed White Wares (GWWI) as defined by J.W. Hayes (Hayes 1968; Hayes 1992).[1] It comes from the excavations at Saraçhane, *i.e.* the church of Saint Polyeuktos, in Istanbul. The samples are dated to the early 7th century AD and are thought to have been manufactured in Istanbul or its region (Hayes 1992, p. 12);

— The "Middle East" batch (LEV402; LEV404-414) comes from the basilica and pilgrimage complex of Saint Symeon, in Northern Syria. These samples, dated to the second half of the 8th–9th century, correspond to the first glazed wares appearing on the site (Orssaud 2001). Typological parallels can be found in Northern Syria, Iraq and Iran. Although later than GWWI, they were thought of interest as being representative of an early Islamic production, to be complemented by other data on earlier glazed wares of the region (see *infra*);

— The "Balkans" batch (BYZ623-625; BYZ627-628) is from Caričin Grad in Serbia, a city probably founded by the emperor Justinian. It had a short existence, from 530 to 615 according to texts, which makes it of particular interest for the present study. The samples are thought to be of local origin (Bjelajac 1990);

— The "Italy" batch comes from Saint-Blaise (LIS 62-63; NMA147) and Hyères (NMA146) in south-eastern France. The samples were found in contexts dated to the 5th–7th centuries and are thought to have come from northern Italy (CATHMA 1992).

All samples are sherds with glazes directly applied to the paste, without intermediary slip, unlike later Byzantine table wares which appear from the 11th century onwards (Papanikola-Bakirtzis 1999).

1 – This name does not imply that the pastes are white. The ware is "light-coloured, mostly light or pale brown or orange, sometimes reddish, on occasions fired partly grey, virtually never plain white" (Hayes 1992, p. 15).

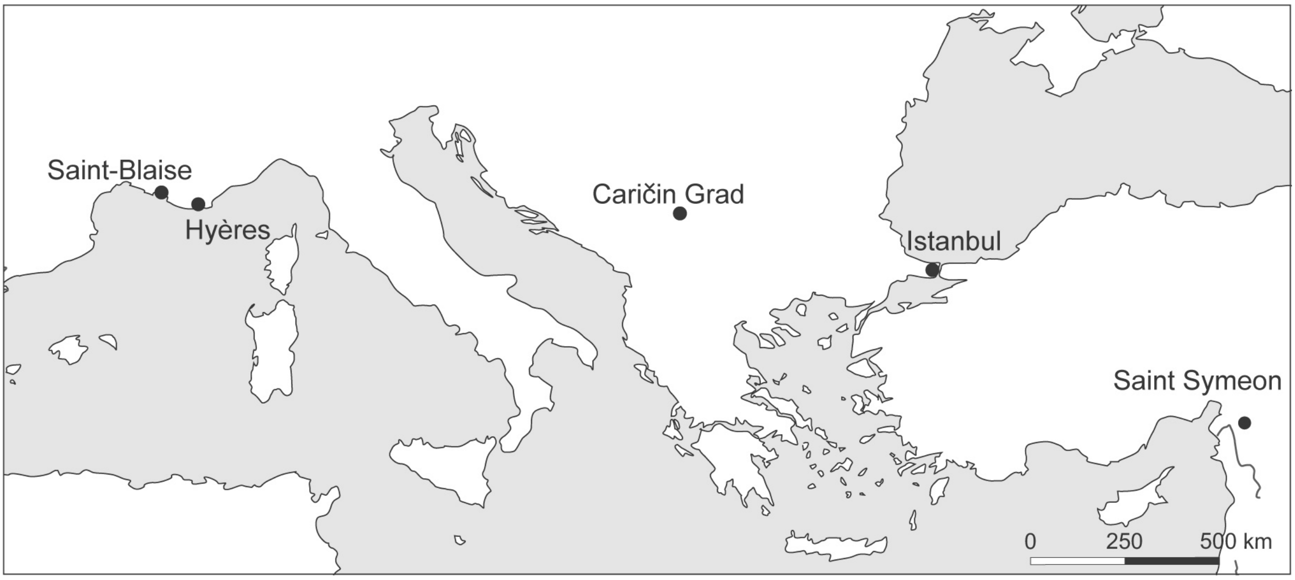

Fig. 1 – Location of the main sites mentioned.

PASTE AND GLAZE ANALYSIS

Pastes and glazes were investigated by elemental analysis. Paste analysis was carried out by WD-XRF at the "Laboratoire de céramologie" in Lyon, and glaze analysis by EDX coupled to a SEM at the "C2RMF" in Paris, thus allowing an examination of the microstructures as well. Special attention was devoted to accurate quantitative analysis in the case of heavy matrices, such as high lead glazes.[2] A larger number of samples was usually analyzed for their paste and a sub-sample selected for glaze analysis.

With the exception of the "Italy" batch, which is further split into (at least) two sub-groups closely related to typology,[3] the four batches of samples are moderately to very homogeneous and are well differentiated by paste analysis (Table 1). Three of them, the "Byzance", "Balkans" and "Italy" batches, have in common high contents of silicon and aluminium, close to 90% SiO_2 + Al_2O_3, which indicate that kaolinitic clays are likely to be main components of these pastes. The "Byzance" batch is further distinguished by lower contents of Ca, Mg and Mn. Batch "Balkans" shows distinctive features in its high contents of Mn, Sr, Ba. Other elements such as Ti and Zr allow further differentiation between the batches of kaolinitic pastes.

The "Middle East" batch is very different, due to high calcium and related high Mn and Sr contents. It constitutes a very homogeneous compositional group. Calcareous pastes, as well as synthetic pastes, are typical for fine table wares of Islamic tradition (*e.g.* Pérez-Arantegui *et al.* 1995; Daszkiewicz and Raabe 1999). Calcareous pastes are also widespread in Mesopotamia owing to the geology of the region (Schneider 1996, p. 131; Le Mière and Picon 2003, p. 179). In most samples high contents of lead in the paste, and in some cases of copper,[4] reveal the nature of the glaze, from which these elements would have diffused.

Glaze analyses show that all the glazes are high lead ones,[5] the alkali content being consistently low (below 1% with few exceptions, Table 2). They are coloured with copper for green glazes, and iron for orange-brown or greenish glazes when applied on oxidized or reduced pastes respectively.[6] Antimony is associated with copper in two samples in the "Middle East" batch, which may have been used to obtain a more vivid colour.

Samples in batch "Byzance" have a quite homogeneous high lead glaze over their kaolinitic pastes, showing little alteration and a fairly high aluminium content of circa 7 to 9% Al_2O_3. Such consistently high Al concentration, at some distance from the paste-glaze interface, may indicate that clay was used as a component of the glaze mixture. However, it is also possible that a lead compound was applied directly onto the paste, as the composition of the glaze after substraction of PbO and recasting to 100% roughly corresponds to the composition of the clay (Tite *et al.* 1998). Another indication of the manufacturing process is given by the thickness of the interface (Fig. 2, left), which suggests a single firing (Tite *et al.* 1998). The compositions of the crystals

2 – The φρz correction procedure, available on Isis-Oxford software, was applied.
3 – NMA146-147 correspond to mortars: CATHMA 1992, p. 67, fig. 2 no. 1; LIS 62-63 to closed forms decorated with applied petals: p. 67, fig. 2 nos. 2 and 3.
4 – Lead and copper had not been determined in old analyses of samples LIS 62-63 and NMA146-147.
5 – Definitions of high lead, lead-alkali and alkali glazes were taken from Tite *et al.* 1998 and Lauffenburger *et al.* 2001.
6 – The later case applies to ceramics either glazed on both sides, or glazed on one side with partial re-oxidation during cooling of the unglazed side.

id.	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	Fe_2O_3	V	Cr	Ni	Cu	Zn	Rb	Sr	Zr	Ba	La	Ce	Pb
Istanbul (batch "Byzance")																						
BYZ718	0.43	0.66	22.37	67.04	0.10	1.19	0.87	1.135	0.0230	6.03	130	84	33	26	48	59	41	274	308	56	106	369
BYZ719	0.30	0.61	17.12	73.84	0.06	1.55	0.27	1.184	0.0207	4.90	90	71	27	33	48	73	42	347	298	43	102	220
BYZ720	0.33	0.47	18.72	71.86	0.10	1.26	0.24	1.081	0.0275	5.79	79	69	31	34	40	54	28	325	272	47	95	87
BYZ721	0.27	0.52	23.51	65.57	0.16	1.43	0.35	1.179	0.0278	6.82	115	92	39	33	49	75	35	277	348	39	94	307
BYZ722	0.26	0.57	21.05	68.55	0.10	1.22	2.39	1.078	0.0271	4.61	94	79	29	33	46	58	55	297	283	53	114	240
BYZ723	0.25	0.55	19.84	69.71	0.08	1.69	0.31	1.239	0.0172	6.11	131	112	31	36	47	109	33	314	260	35	58	651
BYZ724	0.21	0.45	19.93	69.72	0.09	1.01	0.37	1.033	0.0185	6.99	142	88	29	29	34	51	34	282	230	35	67	696
BYZ725	1.46	0.81	16.82	70.99	0.36	1.98	1.46	0.856	0.0349	5.07	120	80	31	20	54	71	*202	242	508	35	69	114
BYZ726	0.21	0.56	19.08	71.20	0.08	1.39	0.37	1.088	0.0156	5.88	110	87	25	19	47	80	33	272	225	45	97	211
BYZ727	0.36	0.62	20.22	69.29	0.11	1.72	0.46	1.187	0.0161	5.86	105	83	26	37	46	80	63	305	382	59	103	181
BYZ728	0.24	0.54	21.63	66.97	0.10	1.53	0.90	1.143	0.0204	6.74	134	103	40	31	39	84	40	282	347	39	82	469
BYZ729	0.20	0.46	18.12	73.14	0.08	1.25	0.38	1.068	0.0174	5.15	88	74	25	31	36	65	32	316	268	49	82	265
BYZ730	0.37	0.72	22.74	66.39	0.13	1.79	0.49	1.211	0.0230	5.94	143	98	49	39	45	86	43	274	371	55	102	699
BYZ731	0.18	0.57	22.34	67.98	0.09	1.31	1.82	1.116	0.0216	4.42	93	88	31	33	45	63	48	285	405	50	103	265
BYZ732	0.17	0.61	23.12	67.75	0.08	1.21	0.45	1.214	0.0225	5.22	126	92	33	25	47	66	40	275	331	46	103	232
BYZ733	1.91	1.09	19.38	67.48	0.14	1.57	1.37	0.857	0.0326	5.88	90	76	33	66	49	60	*223	191	436	32	72	1621
m	**0.45**	**0.61**	**20.37**	**69.22**	**0.12**	**1.44**	**0.78**	**1.104**	**0.0229**	**5.71**	**112**	**86**	**32**	**33**	**45**	**71**	**41**	**285**	**330**	**45**	**91**	**414**
σ	**0.50**	**0.16**	**2.11**	**2.44**	**0.07**	**0.26**	**0.65**	**0.114**	**0.0057**	**0.77**	**21**	**12**	**6**	**10**	**5**	**15**	**10**	**36**	**78**	**8**	**17**	**377**
Caricin Grad (batch "Balkans")																						
BYZ623	1.20	0.98	23.64	62.72	0.22	1.65	1.96	0.745	0.0448	6.66	157	139	56	21	66	82	366	154	570	40	68	135
BYZ624	1.62	1.03	19.89	66.69	0.14	1.94	1.40	0.773	0.0891	6.22	140	101	49	29	63	91	371	183	735	44	77	172
BYZ625	1.63	1.26	20.36	65.47	0.28	1.92	1.79	0.773	0.0607	6.11	134	105	44	23	73	85	365	174	861	40	67	1415
BYZ627	1.77	1.23	19.85	65.20	0.38	2.15	2.38	0.767	0.0814	5.87	133	82	38	29	65	96	422	183	1090	38	71	898
BYZ628	1.59	2.06	18.39	65.23	0.25	2.29	2.06	0.875	0.0702	6.57	161	106	65	38	91	110	226	182	814	45	80	4368
m	**1.56**	**1.31**	**20.43**	**65.06**	**0.25**	**1.99**	**1.92**	**0.787**	**0.0692**	**6.29**	**145**	**107**	**50**	**28**	**72**	**93**	**350**	**175**	**814**	**41**	**73**	**1398**
σ	**0.21**	**0.44**	**1.94**	**1.44**	**0.09**	**0.24**	**0.36**	**0.051**	**0.0174**	**0.33**	**13**	**21**	**11**	**7**	**11**	**11**	**73**	**12**	**190**	**3**	**6**	**1744**
Saint-Blaise and Hyères (batch "Italy")																						
LIS 62	2.06	1.36	19.18	66.09	0.06	1.96	0.71	0.951	0.0250	7.49	122	152	63	nd	59	86	64	295	359	57	80	nd
LIS 63	1.37	1.03	20.99	64.53	0.09	1.73	0.32	1.076	0.0185	8.71	160	127	53	nd	54	88	62	310	423	59	70	nd
NMA146	1.04	1.03	18.24	69.22	0.08	3.06	0.96	0.625	0.0178	5.54	82	65	39	nd	92	176	59	292	1046	42	84	nd
NMA147	1.04	1.26	15.95	70.59	0.10	4.47	1.25	0.573	0.0385	4.58	94	64	39	nd	67	164	83	297	460	54	105	nd
Saint Symeon (batch "Middle East")																						
LEV402	0.88	6.48	13.06	48.50	0.25	3.05	19.07	0.749	0.1198	7.58	154	210	195	47	61	83	293	125	270	19	71	1052
LEV404	1.15	7.24	13.26	47.00	0.41	2.44	19.59	0.720	0.1320	7.70	156	223	218	67	81	78	319	121	265	22	70	1875
LEV405	0.73	7.02	12.72	46.08	0.31	2.87	21.52	0.709	0.1155	7.56	152	209	201	67	73	79	320	120	285	20	62	1896
LEV406	1.16	6.59	13.11	48.13	0.39	2.91	18.88	0.717	0.1323	7.47	148	219	217	146	94	58	302	121	309	23	66	3443
LEV407	1.09	6.41	13.03	47.10	0.43	2.85	20.33	0.717	0.1328	7.51	147	212	214	84	93	63	318	123	323	22	64	2231
LEV408	1.10	7.19	13.31	47.32	0.33	2.62	19.09	0.729	0.1276	7.71	168	224	216	66	76	88	311	121	266	23	69	2966
LEV409	0.83	6.81	12.91	45.67	0.60	2.42	21.39	0.707	0.1213	7.34	146	217	182	775	84	*32	319	112	267	24	66	9845
LEV410	1.13	7.27	13.39	47.46	0.32	2.40	18.96	0.730	0.1242	7.77	163	226	220	89	73	93	303	120	289	25	69	2675
LEV411	1.18	7.23	13.28	47.52	0.33	2.55	18.84	0.726	0.1230	7.71	152	224	218	139	75	84	298	120	282	27	65	3326
LEV412	0.70	6.64	12.88	46.74	0.29	3.09	20.89	0.722	0.1192	7.54	150	207	201	83	84	70	377	120	299	19	64	2140
LEV413	1.08	6.50	13.15	47.02	0.42	2.94	19.80	0.715	0.1315	7.68	157	210	219	156	87	63	325	119	257	19	67	3815
LEV414	1.16	6.49	13.26	47.46	0.29	2.92	19.62	0.726	0.1329	7.62	158	221	217	78	94	69	323	124	295	26	64	1668
m	**1.02**	**6.82**	**13.11**	**47.17**	**0.36**	**2.76**	**19.83**	**0.722**	**0.1260**	**7.60**	**154**	**217**	**210**	**150**	**81**	**75**	**317**	**121**	**284**	**22**	**66**	**3078**
σ	**0.18**	**0.34**	**0.20**	**0.78**	**0.09**	**0.25**	**0.98**	**0.011**	**0.0063**	**0.12**	**7**	**7**	**12**	**200**	**10**	**11**	**22**	**3**	**20**	**3**	**3**	**2281**

Table 1 – Paste analysis (WD-XRF): elemental compositions of the samples in the four batches considered.
Major and minor elements Na to Fe in pourcents of oxides, trace elements V to Pb in ppm; the means m and standard deviations σ of homogeneous batches are indicated; nd: not determined; data with an asterisk were not taken into account in the calculation of m and σ.

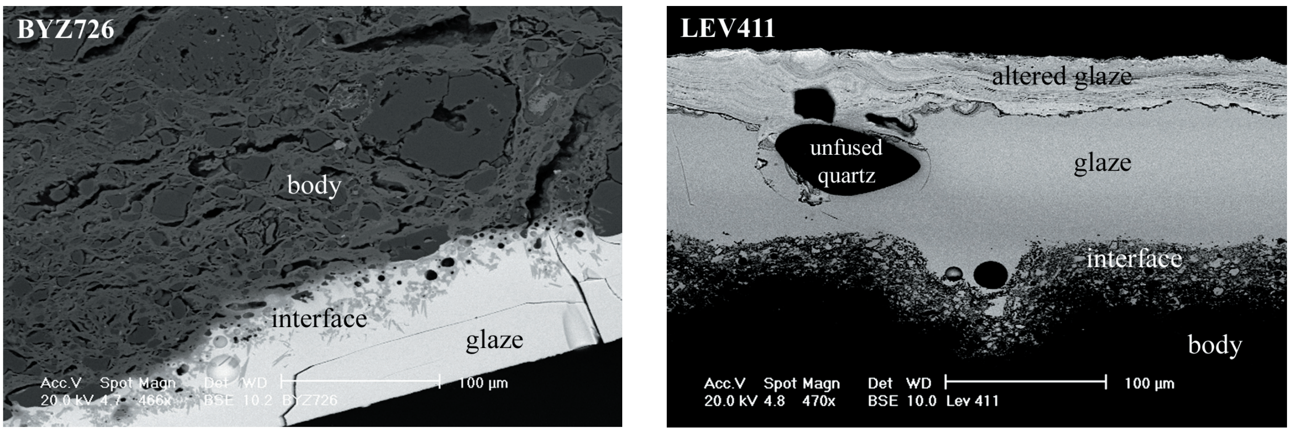

Fig. 2 – SEM backscattered electron images of samples BYZ726 (left, batch "Byzance") and LEV411 (right, batch "Middle East"). In addition to different compositions of bodies and glazes, the structure of the interface and of the localized alteration features are quite dissimilar. © C2RMF.

id.	Na_2O	MgO	Al_2O_3	SiO_2	K_2O	CaO	TiO_2	Fe_2O_3	CuO	PbO	others
Istanbul (batch "Byzance")											
BYZ724	<dl	<dl	8.3	29.8	<dl	0.2	0.2	3.7	<dl	57.7	
BYZ726	<dl	0.2	8.7	31.3	0.5	0.2	0.6	3.6	<dl	54.8	
BYZ727	<dl	0.2	6.9	28.7	<dl	0.7	0.6	2.4	<dl	60.5	
BYZ728	<dl	0.3	8.3	27.4	0.9	2.6	0.0	3.3	<dl	57.1	
BYZ731	<dl	0.1	9.0	26.4	<dl	0.2	0.4	2.2	<dl	61.3	0.3 ZrO_2
Caricin Grad (batch "Balkans")											
BYZ623 (side 1)	0.5	0.3	8.3	25.9	0.4	1.0	0.3	2.8	<dl	60.6	
BYZ623 (side 2)	0.2	0.3	7.6	24.1	0.3	0.7	0.2	3.2	<dl	63.4	
BYZ624 (side 1)	0.5	0.3	10.9	32.5	0.7	1.1	0.5	3.5	<dl	50.0	
BYZ624 (side 2)	0.3	0.2	7.5	26.5	0.4	0.9	0.3	3.0	0.1	60.9	
BYZ625	0.5	0.4	6.4	22.4	0.6	1.0	0.2	2.3	<dl	66.2	
BYZ627 (side 1)	0.3	0.4	6.7	23.0	0.2	1.0	0.2	2.3	<dl	65.9	
BYZ627 (side 2)	0.3	0.3	6.3	22.6	0.5	1.0	0.1	1.8	<dl	66.9	
BYZ628	0.1	0.3	5.9	17.1	0.6	0.9	<dl	2.6	<dl	72.5	
Saint-Blaise and Hyères (batch "Italy")											
LIS 62	0.4	0.7	6.9	26.3	0.3	1.0	0.3	2.8	<dl	60.4	0.6 SnO_2
LIS 63	0.3	0.3	4.9	16.8	<dl	0.2	0.3	2.6	<dl	74.6	
NMA146	<dl	1.0	6.5	30.1	<dl	0.2	0.6	3.8	<dl	57.9	
NMA147	<dl	0.7	5.5	30.4	0.5	0.9	0.0	2.0	<dl	59.9	
Saint Symeon (batch "Middle East")											
LEV405	0.5	0.3	0.2	30.7	0.0	1.2	<dl	0.2	3.6	63.2	
LEV406	0.5	0.5	0.3	26.2	<dl	0.6	<dl	0.1	3.4	67.4	1.1 Sb_2O_3
LEV407 (side 1)	0.5	0.5	0.2	26.2	<dl	0.5	<dl	0.0	3.1	68.2	0.9 Sb_2O_3
LEV407 (side 2)	0.4	0.5	0.1	25.7	<dl	0.7	<dl	0.3	2.3	69.5	0.6 Sb_2O_3
LEV410	0.3	0.4	0.3	31.2	<dl	1.1	<dl	0.5	1.5	64.7	
LEV411	0.4	0.1	0.5	28.5	0.2	0.9	<dl	0.1	4.1	65.2	

Table 2 – Glaze analysis (SEM-EDX): elemental compositions of the samples in the four batches considered. Major and minor elements in pourcents of oxides; two results are given when glaze is present on both sides of the sample; data correspond to the mean of 3 analyses or more; dl: detection limits; SnO_2 is present in LIS 62 as small cristals of cassiterite.

concentrating at the interface, as estimated by EDS spot analyses, seem compatible with the felspars containing lead already described notably by Molera *et al.* (1993). Sample BYZ727 presents atypical features within the "Byzance" batch, as it includes many small crystals of tin oxides[7] unevenly dispersed throughout the glaze.[8] The role of these crystals, which do not act as opacifiers, and the reason for their presence, still need to be clarified.

The "Balkans" batch globally has features similar to the "Byzance" batch, with high lead, aluminium-rich glazes. Interfaces show heterogeneous micro-structures including lead felspars which may be present throughout the thickness of the glaze.[9] Batch "Italy" also shows high-lead, aluminium-rich glazes, with the additional features of cassiterite crystals in sample LIS 62 and of localized zones of iron-rich clay under the glaze in samples LIS 62 and LIS 63. The latter are possibly related to the plastic decoration of these samples. For both batches, though to a lesser extent for the "Italy" one, the composition of the glazes after subtraction of PbO and renormalisation to 100% matches the composition of the body.

The "Middle East" batch shows remarkably pure high lead glazes over calcareous bodies. In this case, it is clear from the compositions that lead was not applied by itself, but in combination with silica. Furthermore, raw materials low in impurities must have been carefully chosen. The interface has a complex structure and includes Si-Ca-Pb crystals and As-rich components. Patches of alteration are frequent at the surface (Fig. 2, right), with typical layered structures being observed which are probably responsible for the opaque appearance and for a change in colour from green to turquoise in these zones.

The main compositional features of the glazes are shown in a ternary diagram $PbO-SiO_2-Al_2O_3$ (Fig. 3, top left). Two groups of high lead glazes are well distinguished according to their aluminium content, the "Middle East" batch constituting one of the groups, being singled out by its low concentrations of aluminium. We may note that several of the Al-rich glazes plot close to the eutectic point of the $PbO-SiO_2-Al_2O_3$ system. The main characteristics of pastes, glazes, interfaces and micro-structures are summarized in Table 3. From this synthesis it is clear that our samples of Byzantine Glazed White Wares share the same general features with samples from Caričin Grad, Saint-Blaise and Hyères, whereas samples from Saint Symeon are very different.

7 – Typical dimensions are below 1 μm.

8 – The average glaze composition of sample BYZ727 is very similar to those of other samples within batch "Byzance".

9 – They are responsible for the opaque aspect of these glazes.

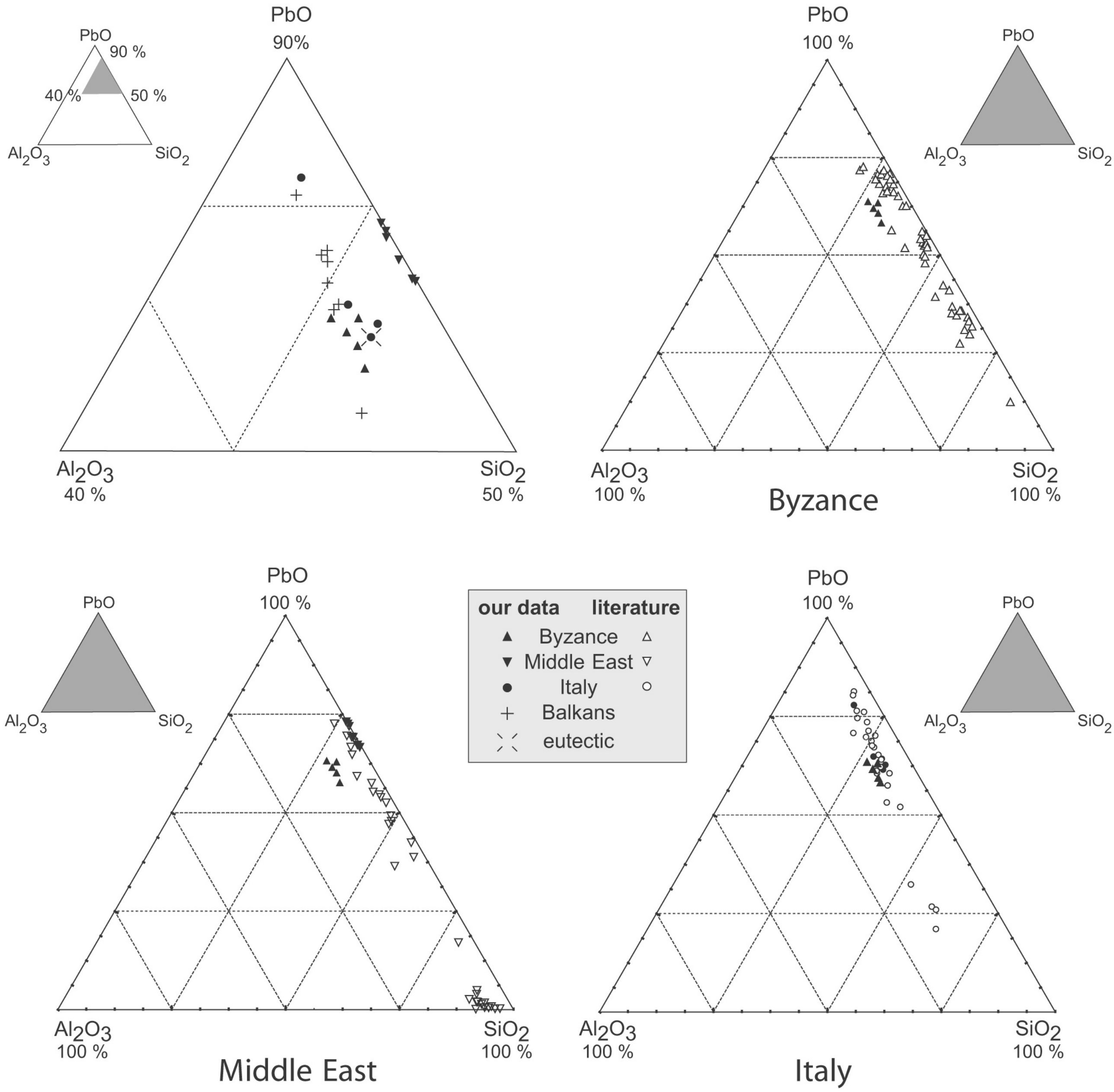

Fig. 3 – Ternary diagrams PbO-SiO_2-Al_2O_3, showing our sampling with the eutectic of the system (top left) and comparisons with data from the literature for Byzantine (top right), Middle Eastern (bottom left) and Italian productions (bottom right). Points next to the SiO_2 pole mostly correspond to alkali glazes.

	batch "Byzance" Istanbul	batch "Balkans" Caričin Grad	batch "Italy" St-Blaise, Hyères	batch "Middle East" St Symeon
body	kaolinitic paste	kaolinitic paste	kaolinitic paste	marly paste
interface	lead-felspars	lead-felspars	lead-felspars	Ca-Mg silicates
glaze	high lead glaze Al-rich	high lead glaze Al-rich	high lead glaze Al-rich	very pure high lead glaze
crystals in glaze	no	sometimes lead felspars	sometimes cassiterite	lead antimoniates, cassiterite, As-rich microcrystals

Table 3 – Summary of the data concerning bodies, glazes, interfaces and microstructures.

COMPARATIVE DATA

In order to evaluate how representative each batch could be for its respective "technological context", we compared our data, obtained on a very limited sampling, with previous research. However this notion of technological context should be seen in a very broad sense, as the data taken into consideration cover a large period, roughly from the 3rd to the 12th century in the case of Italian and Middle Eastern productions.[10] Actually, none of them strictly corresponds to the period of interest. Yet it was thought that such a comparison could on one hand give indications to support or question our own results, and on the other hand enable them to be placed in a chronological perspective.

Fig. 3 (top right) shows the comparison in the PbO-SiO_2-Al_2O_3 system of GWWI with later Byzantine Glazed White Wares (Vogt and Bouquillon 1996; Armstrong *et al.* 1997; Lauffenburger *et al.* 2001).[11] The latter are either high-lead or alkali-lead glazes. Samples of GWWI are not particularly well integrated in this group, as they have some of the highest aluminium contents. It is noticeable at this point that, at a period which cannot be precisely defined as yet,[12] GWW evolved towards more alkali-rich glazes. In the next ternary diagram (Fig. 3, bottom left), GWWI are compared to glazes of Parthian, Sasanian and Middle Eastern early Islamic wares (McCarthy *et al.* 1995; Pérez-Arantegui *et al.* 1996; Tite *et al.* 1998; Daszkiewicz and Raabe 1999; Hill *et al.* 2004).[13] With few exceptions, all of later date,[14] GWWI may be distinguished as the only high lead samples bearing significant aluminium concentrations. This comparative set of data includes high lead, alkali-lead and low to lead-free alkali glazes.[15] Samples from Saint Symeon are included in the former group, and remain among the purest lead-silicon mixtures. The last ternary diagram (Fig. 3, bottom right) shows the comparison between GWWI and Italian "vetrina pesante" (Aurisicchio *et al.* 1993; Walton and Tite 2005).[16] The diagram shows a very good correspondence between GWWI and the majority of the "vetrina pesante" considered, with the exception of a few samples having higher SiO_2 contents. This similarity is however less apparent on raw data, as the average aluminium content in "vetrina pesante" glazes is circa 5% Al_2O_3, and, furthermore, several pastes are moderately calcareous (circa 10% CaO). It would be necessary to examine a well defined corpus of "vetrina pesante" from late Roman production sites to further support what may appear to be a confirmation of our results.

CONCLUSIONS AND PERSPECTIVES

Both pastes and glazes of a sampling of the earliest Byzantine Glazed White Ware present more resemblance to late Roman production from the Balkans and northern Italy than to Middle Eastern production. The former associate kaolinitic pastes with high-lead, Al-rich glazes whereas the latter present high lead Al-poor glazes over calcareous pastes. The manufacturing process also appears to be different. In the first case the glaze may result from the direct application of a lead compound to the paste and from a single firing. In the second case a lead-silica compound was used.

These results support the hypothesis of a re-introduction of the glazing technique in Byzantium via regions which were then the Western provinces of the Byzantine empire, rather than due to an Eastern input. However, lead glazes with Al contents close to the PbO-SiO_2-Al_2O_3 eutectic may have existed in China at the same period (Wood 1999, p. 192) and the role that these productions could have played still needs to be investigated. The connection between the first Byzantine Glazed White Wares and late Roman "Western" productions needs to be confirmed on the basis of a larger sampling coming from well attested production sites.

Although Middle Eastern ceramics do not seem to have been the main influence in the re-introduction of the glazing technique in Byzantium, their role could have been decisive later on, in the evolution of subsequent production of Byzantine Glazed White Ware towards alkali-lead glazes. However further research in this direction would depend critically on the availability of well dated material.

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10 – As far as we know, no comparative data are available for balkanic productions.

11 – We excluded of this comparative corpus what had been considered an incidental and short-lasting appearance of alkali glazes in Byzantine Jordan in the 6th century: Freestone *et al.* 2001.

12 – The comparative samples come from museums and not from excavation contexts.

13 – From Hill *et al.* 2004, only means of compositional groups were available. Mean Al_2O_3 of "Moderate Pb" group was taken as 3.29%, Table 3, p. 600. High lead tin-opacified glazes were not included in the comparative corpus.

14 – Sample 15/6 from Raqqa, 9th c.: 4.83% Al_2O_3, Daszkiewicz and Raabe 1999, p. 135; sample SJN 12.4 from Iran, 10-11th c.: 4.1% Al_2O_3, Tite *et al.* 1998, p. 243.

15 – The validity of such a diagram in the latter cases is questionable, but was adopted to show Al contents and alkali and lead-alkali glazes simultaneously, which plot in this case close to the SiO_2 pole.

16 – We did not consider here earlier Italic lead glazed wares, which will be taken into account in further work.

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