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4.2 THE BOWL GLASS SHERDS OF SAINT-SAVIN TYPE DISCOVERED AT HAITHABU: ANALYTICAL STUDY

Inès Pactat and Bernard Gratuze

4.2.1 INTRODUCTION

Important changes occurred in the Western glass manufacturing process during the Carolingian period, from the end of the 8th century (PACTAT et al. 2017). In recent years, the increasing number of analyses carried out on Western European glass dating from this transition period has highlighted the presence of a great variety of compositions. This diversity seems to reflect the use of local raw materials which enabled glassmakers to face the lack of natron glass (both raw and recycled glass).

If during the Merovingian period the Roman production system is still in effect, an increase in natron glass recycling is observed from the 7th century (MIRTI et al. 2001; FREESTONE 2015). This phenomenon stems directly from a progressive decline in raw glass imports from the Near East (GRATUZE et al. 2021), probably due to political and economic perturbations related to the Islamic conquest (PHELPS 2018). Raw glass production and natron exploitation were affected too. Similar alternatives, based on a vegetal flux, are then progressively adopted by the glassmakers both in the east and the west of the Mediterranean world. During the 9th century, soda-lime glass made from halophytic plant ash became the prevailing type of glass, firstly in the eastern Mediterranean and Mesopotamia (WHITEHOUSE 2002), then throughout the whole of the Mediterranean by the 12th century. In Western and Continental Europe, potash-lime glass made from forest plant ash developed from the end of the 8th century (WEDEPOHL/BAUMANN 1997; VELDE 2009; VAN WERSCH et al. 2015). The main flux was no longer soda but wood ash, a variable mix of potash and lime with high magnesia, phosphorus and manganese contents (WEDEPOHL/SIMON 2010). Despite the adoption of this new recipe, natron glass was still used until the end of the 12th century for specific productions. Medieval blue cobalt window glass was actually made with recycled ancient natron glass (BIDEGARAY/POLLARD 2018). Vividly coloured glass vessels, dated from the 10th–12th centuries, testified also the use of natron glass, such as cobalt blue vessels decorated with white opaque trails and spots, like the Saint-Savin reliquary bowl (STERPENICH/LIBOUREL 1997; BRILL 1999, 244; FOY 2001, 291–302; SIMON-HIERNARD/GRATUZE 2011; FOY et al. 2017; CASTELLI 2020; GRATUZE 2020). Several combinations can be connected with the same group: purple vessels with white decorations (PHELPS 2011) or vice versa (NEPOTI 1978, 221; EIVSON 2000, 81 fig. 14h; PHELPS 2011; RODRIGUES/BRUT 2017) and transparent green vessels with white decorations (DEL VECCHIO 2005; DI MURO 2011, 63). These particular productions were apparently reserved for privileged social classes, according to their archaeological contexts.

Thirteen dark blue fragments from Haithabu (ten decorated with white glass trails and three without any element of decoration) have been analysed by LA-ICP-MS (Abb. 241). Their composition is discussed below and compared with those of similar finds discovered in France (PACTAT et al. 2014; FOY et al. 2017) and Italy (GRATUZE 2020).

4.2.2 ANALYTICAL METHODS

The chemical composition was determined using LA-ICP-MS (Laser Ablation Inductively Coupled Plasma Mass Spectrometry) at the IRAMAT Centre Ernest-Babelon laboratory in Orléans (UMR 7065, CNRS-Université Orléans). This method requires no sample preparation and is particularly well adapted to composite or decorated glass objects (GRATUZE 2013; 2014). The glass fragments are placed inside an ablation cell, where a micro-sample, invisible to the naked eye

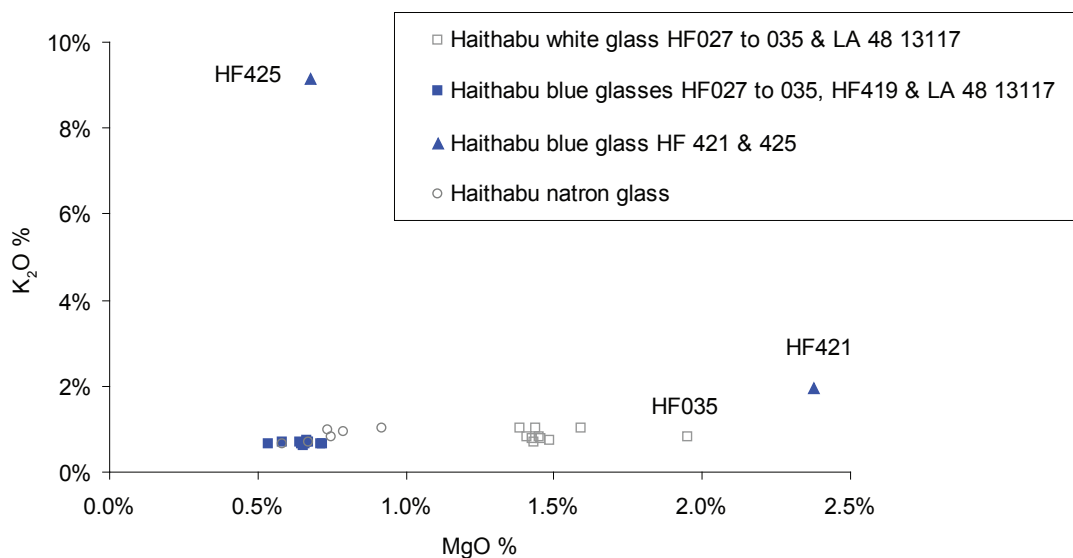


Fig. 263. Magnesia and potash concentrations of cobalt blue and white opaque glass compared with those of a group of natron glass funnel beakers from Haithabu dated between the end of the 8th and the 10th centuries.

(diameter < 100 μm), is extracted by a laser beam (266 nm UV beam generated by a NdYAG laser, whose frequency is quadrupled). This sampled material is carried by a gaseous flow of argon to the plasma torch of the Element XR (Thermo Fisher Scientific), where it is dissociated and ionised by the high temperature of the plasma (8000 °C). The different glass constituents are separated according to their mass/charge ratios and quantified by an electronic detector (electron multiplier associated with a Faraday cup). Accuracy and precision depend on a number of factors, including the mass and abundance of the measured isotopes and the background counts, but for most elements range from 5 to 10 relative %, for major and minor elements up to 20 relative %, for trace elements below 0.0001 wt%.

4.2.3 RESULTS

According to their potash and magnesia contents, the 13 dark blue glass fragments and the 10 white opaque glass trails belong to three main chemical groups (Fig. 263; Tab. 43). Two of them contain only one undecorated glass sherd and are related to plant ash glasses. The first one (HF425) is characterised by high potash (K_2O 9.2%), lime (CaO 10.9%) and soda (Na_2O 6.4%) concentrations and corresponds to a mixed soda-potash glass, while the second one (HF421) is characterised by high soda (14.9%) and lime (7.8%) contents and moderate potash (2.0%) and magnesia (MgO 2.4%) concentrations, which is consistent with a halophytic plant ash glass. The third group consists of all the other glass fragments (ten decorated with white opaque glass trails or spots – HF027 to 035 and LA 48 13117 – and one undecorated fragment – HF419). These samples are natron glass, characterised by high soda (13.8–16%) and lime (6.5–8.9%) contents, low potash (0.63–0.76% for the blue glass and 0.69–1.0% for the white glass) and low to moderate magnesia concentrations (0.54–0.72% for the blue glass and 1.4–2.0% for the white glass).

The white glasses (which all belong to the third group) are characterised by high levels of antimony oxide (Sb_2O_3 2.0–4.6%), which was probably added as calcium antimonate (CaSb_2O_7). All the blue glass fragments are coloured by cobalt. Different chemical correlations between cobalt and other elements are observed in the three glass groups.

Table 43. Major and minor oxide concentrations of the cobalt blue and white opaque glass fragments from Haithabu. Mean composition and associated standard deviation are given for the glass used for comparison. Data in oxide weight per cent.

	% oxide	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	Cl	K ₂ O	CaO	MnO	Fe ₂ O ₃	CoO	CuO	SnO ₂	Sb ₂ O ₃	PbO
HF425 b	Blue glass	6.43	0.68	1.52	67.8	0.36	0.23	9.15	10.9	1.71	0.48	0.075	0.0060	0.013	0.014	0.23
HF421 b		14.8	2.37	2.22	67.05	0.21	0.70	1.96	7.77	0.48	1.14	0.12	0.1843	0.032	0.26	0.13
HF27 b		14.7	0.72	2.66	67.4	0.11	0.74	0.64	8.86	0.48	1.27	0.066	0.20	0.014	1.61	0.32
HF28 b		14.9	0.66	2.56	68.2	0.11	0.86	0.63	8.25	0.50	1.06	0.063	0.23	0.014	1.40	0.33
HF29 b		15.6	0.67	2.47	68.6	0.11	0.76	0.72	7.03	0.49	1.05	0.068	0.23	0.015	1.65	0.36
HF30 b		15.3	0.66	2.55	68.6	0.10	0.79	0.68	7.22	0.51	1.07	0.070	0.23	0.014	1.62	0.34
HF31 b		15.4	0.67	2.42	68.8	0.11	0.80	0.67	7.11	0.48	1.01	0.066	0.23	0.014	1.60	0.35
HF32 b		14.6	0.72	2.61	68.0	0.11	0.70	0.67	8.53	0.48	1.27	0.064	0.19	0.013	1.56	0.28
HF33 b		15.1	0.64	2.49	67.9	0.11	0.83	0.69	8.13	0.50	1.15	0.068	0.21	0.014	1.53	0.33
HF34 b		14.8	0.66	2.51	68.3	0.11	0.76	0.66	8.19	0.49	1.14	0.067	0.21	0.014	1.54	0.32
HF35 b		15.2	0.58	2.50	67.6	0.16	0.77	0.70	7.39	0.49	1.09	0.099	0.21	0.011	2.45	0.51
HF419 b		15.9	0.65	2.33	67.5	0.11	0.92	0.66	7.81	0.49	1.14	0.069	0.22	0.015	1.54	0.39
LA 48 13117 b		15.2	0.54	2.33	67.9	0.15	0.82	0.65	7.48	0.53	0.99	0.10	0.16	0.010	2.41	0.56
HF27 w		White glass	14.5	1.41	2.83	66.0	0.08	0.53	0.82	8.62	0.19	0.69	0.0006	0.028	0.020	3.88
HF28 w	14.6		1.43	2.65	66.6	0.08	0.58	0.69	7.98	0.18	0.78	0.0009	0.028	0.0064	4.00	0.09
HF29 w	14.4		1.44	2.80	67.8	0.09	0.55	1.00	7.34	0.20	0.88	0.0009	0.073	0.084	2.33	0.73
HF30 w	15.1		1.43	2.52	68.4	0.08	0.57	0.78	7.35	0.20	1.13	0.0048	0.043	0.0088	2.05	0.13
HF31 w	14.8		1.38	2.70	66.8	0.11	0.66	1.03	6.46	0.18	0.75	0.0006	0.029	0.027	4.60	0.20
HF32 w	13.8		1.59	3.35	64.8	0.08	0.57	1.02	8.40	0.21	1.00	0.0010	0.087	0.17	3.54	1.14
HF33 w	14.3		1.45	2.96	65.8	0.10	0.55	0.82	7.83	0.21	0.96	0.0008	0.076	0.092	3.91	0.62
HF34 w	14.1		1.46	2.94	66.0	0.11	0.45	0.78	8.43	0.17	0.97	0.0006	0.029	0.015	4.13	0.14
LA 48 13117 w	15.7		1.49	2.13	68.0	0.07	0.62	0.75	7.19	0.11	0.52	0.0011	0.015	0.0058	3.03	0.19
HF35 w	15.9		1.95	2.22	65.6	0.07	0.56	0.83	7.24	0.10	0.60	0.0009	0.025	0.010	4.44	0.18
French blue glass (20)	av.	16.0	0.62	2.54	67.9	0.15	0.78	0.81	6.95	0.46	1.06	0.060	0.34	0.024	1.66	0.40
	std.	0.8	0.04	0.22	0.6	0.06	0.13	0.22	0.36	0.10	0.14	0.015	0.16	0.012	0.28	0.21
	min	13.6	0.55	2.19	66.5	0.10	0.48	0.44	6.37	0.19	0.88	0.035	0.14	0.0084	1.10	0.12
	max	17.4	0.72	3.33	69.1	0.40	0.95	1.33	7.63	0.70	1.45	0.10	0.64	0.054	2.20	1.10
French white glass (17)	av.	15.9	1.24	2.41	67.2	0.10	0.77	0.86	6.74	0.25	0.60	0.0012	0.020	0.011	3.48	0.20
	std.	0.9	0.44	0.21	1.3	0.03	0.17	0.25	0.53	0.09	0.12	0.0006	0.010	0.009	0.94	0.29
	min	13.9	0.85	2.12	64.4	0.065	0.55	0.53	5.90	0.11	0.48	0.0004	0.0051	0.0022	2.15	0.051
	max	17.5	2.09	2.78	68.7	0.17	1.14	1.52	8.32	0.39	0.92	0.0025	0.047	0.029	5.42	1.32
Antique and early medieval glass (340)	av.	16.5	0.74	2.37	67.2	0.14	0.89	0.72	6.76	0.39	0.86	0.022	0.57	0.10	1.57	0.85
	std.	1.6	0.30	0.27	2.2	0.08	0.20	0.22	0.88	0.18	0.37	0.035	0.83	0.36	1.31	2.26
	min	10.9	0.27	1.61	51.7	0.015	0.41	0.25	4.66	0.053	0.30	0.0002		0.00002	0.14	
	max	21.5	1.85	3.47	71.8	0.63	1.42	1.49	10.6	0.79	2.96	0.31	5.0	4.7	7.2	21.9
Haithabu natron colorless glass (3)	av.	15.4	0.80	2.51	68.8	0.16	0.81	0.93	7.70	0.62	0.91	0.0028	0.23	0.073	0.27	0.45
	std.	0.7	0.10	0.15	0.6	0.02	0.09	0.12	0.64	0.06	0.08	0.0016	0.16	0.049	0.09	0.45
Haithabu natron white glass (2)	av.	14.5	0.63	2.31	65.4	0.11	0.79	0.67	6.98	0.48	0.68	0.0011	0.09	3.73	0.30	3.02
	std.	1.0	0.06	0.01	2.0	0.02	0.11	0.05	0.65	0.17	0.01	0.0001	0.02	0.21	0.02	3.90
Haithabu potash colorless glass (7)	av.	1.18	5.98	2.29	64.4	2.22	0.16	7.75	13.2	0.81	0.87	0.0009	0.008	0.0063	0.020	0.49
	std.	0.25	0.66	0.64	1.8	0.19	0.06	0.90	1.1	0.06	0.30	0.0002	0.002	0.0037	0.028	0.73
Haithabu potash white glass (6)	av.	0.99	5.54	2.06	57.8	2.01	0.17	5.75	12.3	0.71	0.76	0.0012	0.023	4.26	0.046	7.09
	std.	0.26	0.48	0.45	3.6	0.08	0.04	0.32	1.5	0.08	0.11	0.0005	0.009	0.78	0.057	2.81

In the first group (HF425), cobalt (CoO 0.075 %) is associated with arsenic (As₂O₃ 0.1 %) and bismuth (Bi 0.012 %). This type of association is characteristic of modern European glass produced after the first quarter of the 16th century (GRATUZE et al. 1996). The chemical composition of this sherd corresponds also to some glass compositions encountered in Europe after the 16th century. This glass fragment should thus be considered modern and intrusive.

The composition of the second group (HF421) is more puzzling. Here, cobalt (0.12 %) seems to be correlated to zinc (ZnO 0.27 %) and lead (PbO 0.12 %). This association is frequently encountered in European soda plant ash glass produced after the end of the 12th century. However, in this medieval glass, cobalt is also always associated with indium (In). According to its zinc and cobalt levels, the expected indium content for HF421 should be about 50 ppm (GRATUZE et al. 1995) and not 2 ppm. The measured content of indium is therefore far below the expected value for a glass belonging to that European group. It is also noted that most European soda plant ash glass has potash concentrations greater than magnesia, contrary to Near Eastern ones. We can therefore hypothesise that the glass fragment HF421 corresponds to an Islamic glass contemporaneous with the main group of blue and white glass sherds. The association between cobalt and zinc has already been sporadically noted for some Islamic glass and glazes dating from the late first and the beginning of the second millennium AD (GRATUZE et al. 1996; 2018; BRILL 1999, nos. 6349–6360). Cobalt blue glass rich in zinc is moreover little documented in Europe. Old findings from Haithabu (glass beads and vessels) have already shown the same association between soda plant ash base and cobalt-zinc ore (DEKÓWNA 1980, nos. PR14, PR15, PR16 and P16), as well as beads and raw glass chunks from Kaupang, in Norway (GAUT 2011). A window glass and the rim of a funnel beaker discovered in the 9th-century glass workshop of Méru, in France, are consistent, for their part, with a natron glass coloured with the same zinc-rich cobalt ore (PACTAT et al. 2017).

In the third group, cobalt seems to be associated only with antimony, as it is sometimes observed in natron glass dating from Late Antiquity and the Early Middle Ages. However, this combination reflects more the reuse of ancient glass containing both of these elements than a real association arising from the use of a specific variety of ore. In fact, this absence of typical chemical correlation between cobalt and any other elements prevails in nearly all the natron glass produced during Antiquity (GRATUZE et al. 1992).

We also notice that the white glass sherds in the third group contain systematically more magnesium than the blue glass fragments. This particular feature has already been described for some antique mosaic glass vessels with white patterns (NENNA / GRATUZE 2009) and enamels (HENDERSON 1991, 69). Two white magnesian glass tesserae were also found among the cullet in the workshops of San Vincenzo al Volturno, reinforcing the hypothesis that this material was indeed remelted during the Carolingian period (SCHIBILLE / FREESTONE 2013).

By comparing the trace element signature of these three groups of glass (Fig. 264) with those of natron and potash glasses originating from uncoloured funnel beakers decorated with white glass trails, discovered at Haithabu and dating from the end of the 8th to the 10th century (PACTAT et al. 2020), we note that:

- The mixed soda-potash glass HF425 and the potash glass funnel beakers have completely different trace element patterns compared to other glasses.
- The cobalt blue plant ash soda glass HF421, the cobalt blue and white glass fragments HF027 to 035, HF419 and LA 48 13117 present more similar signatures. However, the plant ash glass HF421 shows a slightly different trend from the other cobalt blue glasses and the uncoloured natron glasses. It is also noticeable that the natron glass funnel beakers and the natron cobalt blue glass sherds have fairly similar trace element signatures, while the opaque white glass trails present some differences associated with a wider variability. It can be also observed that the white glass of the funnel beakers (from both potash and natron groups) is opacified with tin oxide (SnO₂ 3.5–5.6 %) and not with calcium antimonate, contrary to the white glass trails of the natron cobalt blue glass. The similarity between the trace element patterns of these three groups can be interpreted in terms of a common geographical origin of the raw materials.

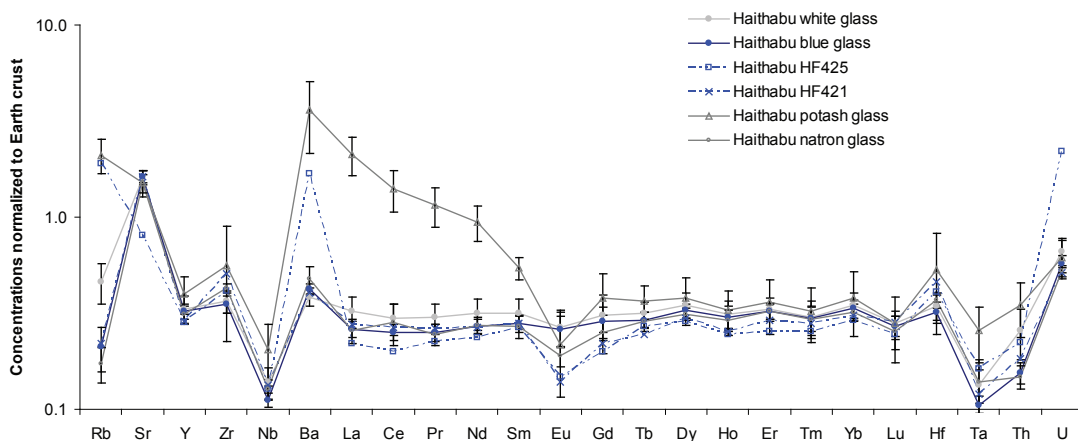


Fig. 264. Average patterns for trace elements of the three groups of cobalt blue and white opaque glass fragments compared with those of funnel beakers dated to between the end of the 8th and the 10th centuries and made respectively with potash (forest plant ash) and natron glass. Data are normalised to average continental crust (WEDEPOHL 1995).

Thus, the third group of cobalt blue glass, with white opaque decoration, has chemical characteristics similar to those of the natron glass objects found at Haithabu whose raw glass was produced in the Near East during Antiquity or Early Middle Ages. As mentioned above, the natron glass imports fall steeply at the end of the 8th century, but the glass of the third group definitely dates from the 10th–12th centuries, as demonstrated by the wide distribution of this production throughout Western and Central Europe (KAT. PHÖNIX 1988; PEINE 2006; SIMON-HIERNARD / GRATUZE 2011; PACTAT et al. 2014; FOY et al. 2017; CASTELLI 2020; GRATUZE 2020).

Comparing now the composition of these objects from Haithabu (Tab. 43–45) with the composition of similar and contemporaneous French and Italian finds (Digne-les-Bains, Arles, Fenouillet and Vaison-la-Romaine: FOY et al. 2017; Baume-les-Messieurs: PACTAT et al. 2014; Saint-Savin: GRATUZE et al. 1997; Nevers, Amiens, Douai and Rouen: unpublished data; Vetricella: GRATUZE 2020), and the composition of a group of 340 ancient and early medieval glass fragments¹⁹⁴, we observe that all these glass fragments share similar compositional characteristics (for major, minor and trace elements, Fig. 265–268), which are related to Near Eastern ancient primary glass productions.

A comparison of titanium, aluminium and silica concentrations of Haithabu blue and white glass fragments with the main natron groups of the second half of the first millennium CE highlights a Near Eastern origin of the first (Fig. 269). Specifically, the cobalt blue glass fragments of the third group show strong similarities with the antique production of the Levantine coast, related to the Jalame workshop (WEINBERG 1988) and the low-manganese group (JACKSON / PAYNTER 2016). Moreover, the antimony content is very high (1.4–2.45 % Sb₂O₃) and would be more relevant to opacified glass. It is important to point out that antimony was no longer used in glass manufacturing after the 4th century (TITE et al. 2008). So these results are consistent neither with the dating of the blue and white vessels, that is to say, the 10th–12th centuries, nor with the evolution of the system of glass production at the end of the first millennium.

194 This group of 340 glass fragments was selected from 1,740 natron glass sherds (analysed at the Centre Ernest-Babelon) based on their antimony and manganese contents in order to cover the range of concentration measured in the Haithabu and French cobalt blue glass fragments decorated with white opaque glass. These 340 glass fragments are mostly dated to Antiquity and Early Middle Ages and originate mainly from western European countries.

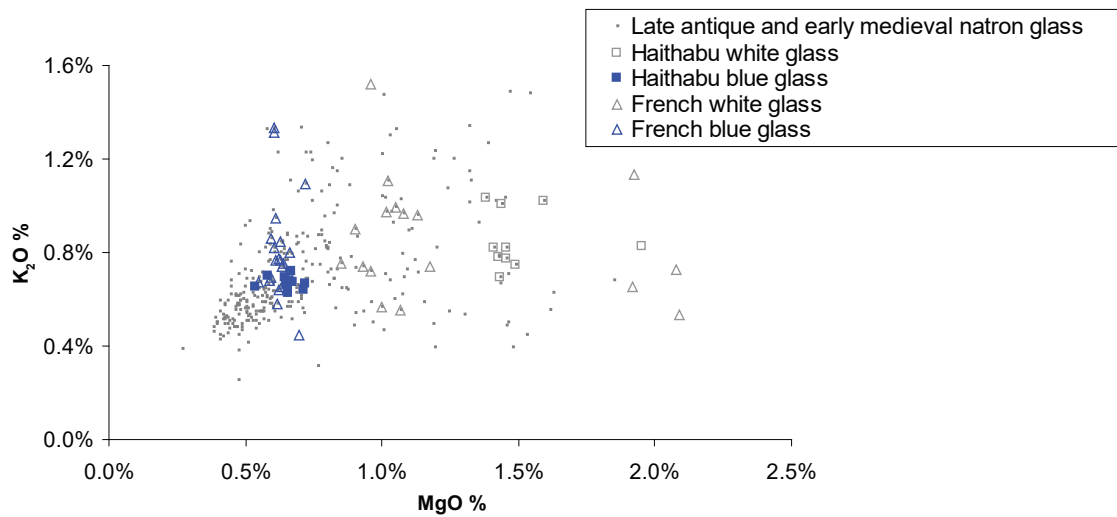


Fig. 265. Magnesia and potash concentrations of the cobalt blue and white opaque glass fragments from Haithabu compared with: (a) those of French cobalt blue and white opaque glasses; (b) with the 8th–10th centuries funnel beakers from Haithabu made with natron glass; and (c) with a group of 340 antique and early medieval natron glasses (see note 194).

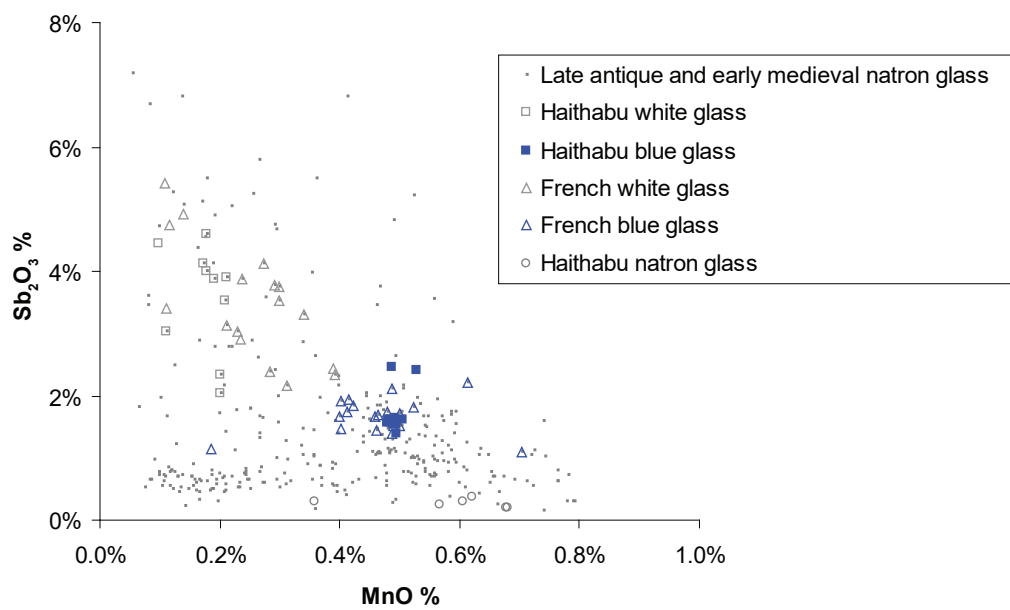


Fig. 266. Manganese and antimony oxide concentrations of the cobalt blue and white opaque glass fragments from Haithabu compared with: (a) those of French cobalt blue and white opaque glasses; (b) with the 8th–10th centuries funnel beakers from Haithabu made with natron glass; and (c) with a group of 340 antique and early medieval natron glasses (see note 194).

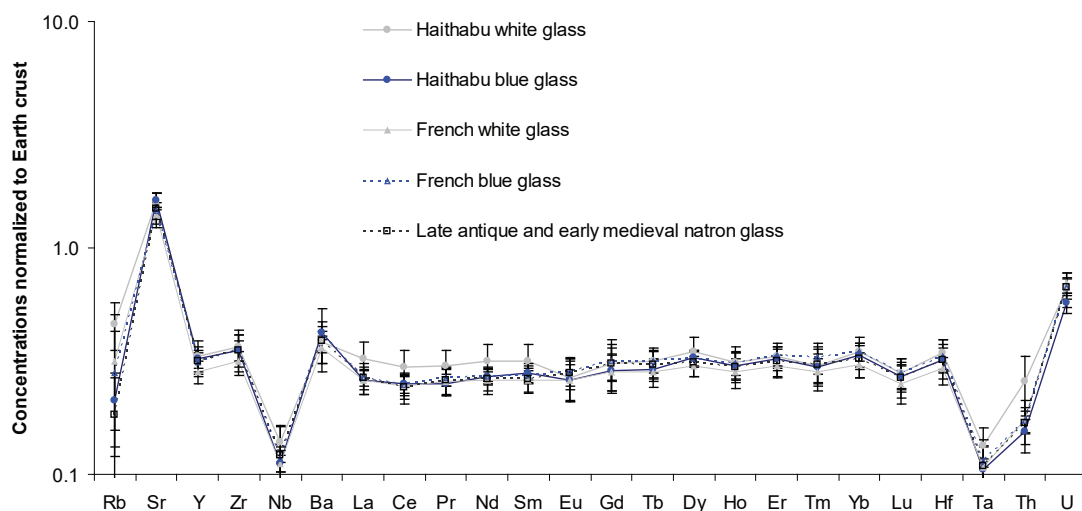


Fig. 267. Average patterns of trace elements of the third group of cobalt blue and white opaque glass fragments compared with: (a) those of French cobalt blue and white opaque glasses; (b) with a group of 340 antique and early medieval natron glasses (see note 194). Data are normalised to average Continental crust (WEDEPOHL 1995).

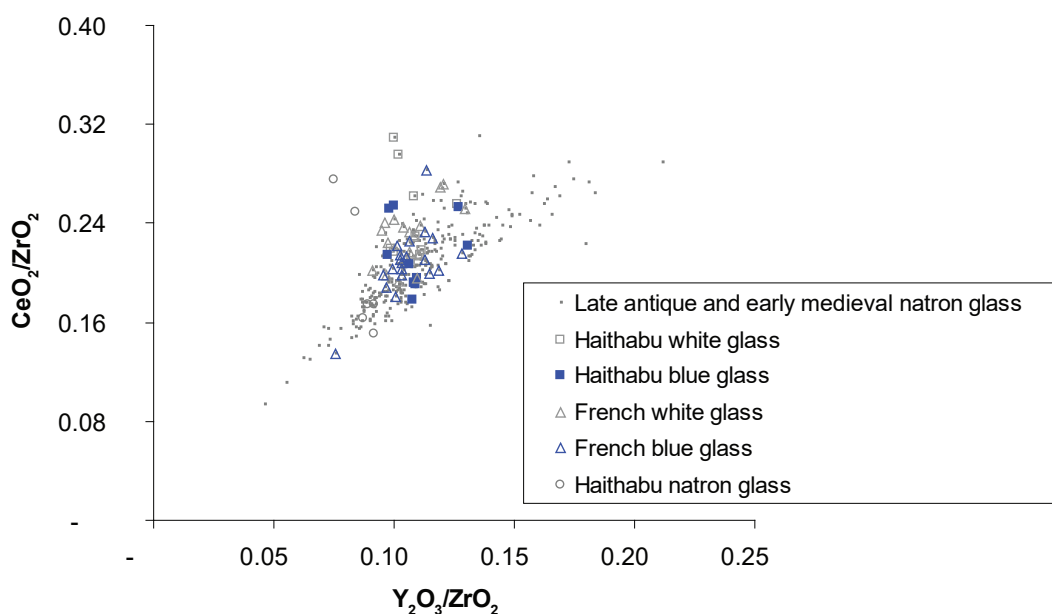


Fig. 268. Y_2O_3/ZrO_2 and CeO_2/ZrO_2 ratios of the cobalt blue and white opaque glass fragments from Haithabu compared with: (a) those of French cobalt blue and white opaque glasses; (b) with the 8th–10th centuries funnel beakers from Haithabu made with natron glass; and (c) with a group of 340 antique and early medieval natron glasses (see note 194).

Table 44. Trace element concentrations of the cobalt blue and white opaque glass fragments from Haithabu. Mean composition and associated standard deviation are given for the glass used for comparison. Data in parts per million of oxide (1 ppm=0.0001 %).

	ppm oxide	Li ₂ O	B ₂ O ₃	TiO ₂	V ₂ O ₅	Cr ₂ O ₃	NiO	ZnO	GaO	As ₂ O ₃
HF425 b	Blue glass	42	261	863	21	14	86	91	4.1	999
HF421 b		43	385	1177	32	49	27	2664	7.2	15
HF27 b		10	440	1005	27	18	36	72	4.8	55
HF28 b		6	452	987	27	18	40	73	4.8	58
HF29 b		11	445	906	25	17	39	80	5.2	55
HF30 b		10	433	906	24	16	40	77	5.1	55
HF31 b		10	457	914	25	17	36	76	5.2	59
HF32 b		11	442	999	28	19	37	71	4.5	54
HF33 b		12	452	972	27	19	38	78	4.9	56
HF34 b		8	453	990	28	18	38	76	4.8	56
HF35 b		8	445	767	28	17	39	71	6.1	53
HF419 b		11	465	972	28	18	40	78	4.7	57
LA 48 13117 b		8	437	720	29	16	38	51	5.0	53
HF27 w		White glass	12	472	1069	25	23	8	116	3.4
HF28 w	8		473	974	23	23	7	117	3.2	101
HF29 w	14		504	1080	26	25	10	173	4.5	96
HF30 w	14		509	954	22	22	10	134	4.2	104
HF31 w	11		507	1020	28	22	16	182	4.5	99
HF32 w	12		442	1316	31	27	12	222	4.1	92
HF33 w	12		497	1224	32	29	11	184	4.3	107
HF34 w	10		480	1297	29	27	25	129	3.8	109
LA 48 13117 w	24		537	741	19	14	7	69	2.8	204
HF35 w	26		505	806	19	17	7	123	3.5	146
French blue glass (20)	av.	11	486	906	28	31	33	98	5.2	49
	<i>std.</i>	3	46	175	4	43	8	24	0.3	9
	min	5.7	415	693	21		19	46	4.4	35
	max	19	637	1493	37	170	47	163	5.7	70
French white glass (17)	av.	13	489	810	21	37	9.2	83	3.5	135
	<i>std.</i>	5	41	104	3	38	4.9	22	0.4	82
	min	2.8	425	701	16		6.4	54	2.9	64
	max	21	553	1070	28	98	27	134	4.3	393
Antique and early medieval glass (340)	av.	14	533	936	27	21	21	244	8.0	63
	<i>std.</i>	12	88	287	8	19	15	930	12	124
	min		218	460	11		3.8	15		7.4
	max	140	1085	3686	94	170	123	15997	73	2222
Haithabu natron colorless glass (3)	av.	27	444	1224	32	23	14	243	4.2	18
	<i>std.</i>	9	19	81	3	0	2	76	0.8	4
Haithabu natron white glass (2)	av.	21	436	1077	26	19	16	91	3.4	17
	<i>std.</i>	11	32	196	6	1	1	37	0.3	3
Haithabu potash colorless glass (7)	av.	40	694	1677	24	20	13	428	7.0	7
	<i>std.</i>	9	171	857	8	5	6	263	0.9	2
Haithabu potash white glass (6)	av.	36	606	1324	19	17	19	506	6.2	12
	<i>std.</i>	12	94	250	2	1	2	372	0.6	3

	Rb ₂ O	SrO	Y ₂ O ₃	ZrO ₂	Nb ₂ O ₃	Cs ₂ O	BaO	Bi	ThO ₂	UO ₂	
	149	268	6.8	83	2.4	1.2	979	119	1.9	3.7	HF425 b
	17	543	6.9	103	2.5	0.25	235	0.12	1.6	0.88	HF421 b
	17	604	8.8	82	2.3	0.2	266	0.35	1.5	0.96	HF27 b
	14	576	8.4	77	2.3	0.2	259	0.33	1.5	1.0	HF28 b
	15	503	6.8	68	2.0	0.19	220	0.32	1.2	0.91	HF29 b
	17	509	7.0	72	2.0	0.18	222	0.33	1.2	0.83	HF30 b
	13	497	6.8	69	2.1	0.2	229	0.35	1.1	0.89	HF31 b
	18	584	8.5	78	2.3	0.2	266	0.30	1.5	0.99	HF32 b
	17	558	8.1	73	2.2	0.2	255	0.35	1.4	0.98	HF33 b
	16	566	8.2	75	2.3	0.2	258	0.35	1.4	0.97	HF34 b
	28	503	8.1	64	2.0	0.4	258	0.46	1.4	1.2	HF35 b
	15	531	7.3	69	2.1	0.2	246	0.41	1.2	1.0	HF419 b
	11	507	7.3	56	1.8	0.1	236	0.48	1.1	0.9	LA 48 13117 b
	32	582	8.9	80	2.8	0.71	242	0.38	2.4	1.0	HF27 w
	26	546	8.0	71	2.5	0.50	218	0.42	2.0	0.99	HF28 w
	41	517	7.5	75	2.6	0.83	224	0.46	2.2	1.0	HF29 w
	28	539	7.4	75	2.3	0.46	205	0.43	1.6	0.95	HF30 w
	52	429	6.3	62	2.5	1.0	220	0.40	2.0	1.0	HF31 w
	43	582	10	93	3.4	1.1	259	0.44	3.4	1.1	HF32 w
	37	548	8.6	80	3.2	1.1	259	0.44	2.8	1.1	HF33 w
	33	567	9.7	77	3.0	0.88	246	0.40	2.6	1.6	HF34 w
	26	510	6.4	59	1.8	0.38	184	0.29	1.2	1.2	LA 48 13117 w
	42	547	6.9	69	2.2	0.57	199	0.45	1.5	1.3	HF35 w
	22	485	7.5	72	2.2	0.46	253	0.42	1.5	1.1	French blue glass (20)
	11	41	0.7	12	0.3	0.38	50	0.19	0.2	0.1	
	9	381	5.7	54	1.5	0.17	188		1.0	1.0	
	48	558	8.5	111	2.7	2.0	419	0.77	1.7	1.3	
	25	465	6.8	64	2.1	0.6	210	0.47	1.5	1.2	French white glass (17)
	15	40	0.8	7	0.3	0.4	30	0.45	0.2	0.1	
	11	384	5.3	53	1.6	0.2	161	0.24	1.2	1.0	
	64	526	8.3	77	3.1	1.8	272	1.9	1.8	1.4	
	14	495	7.6	72	2.3	0.32	227	0.63	1.4	1.1	Antique and early medieval glass (340)
	8	88	1.1	16	0.8	0.3	47	0.72	0.4	0.1	
	4.1	330	5.3	40	1.2				0.74	0.79	
	52	1061	18	196	13	3.7	419	5.0	3.4	1.6	
	15	513	7.6	89	2.5	0.15	286	0.19	1.3	0.92	Haithabu natron colorless glass (3)
	3	59	1.1	4	0.3	0.09	44	0.08	0.3	0.03	
	11	475	7.4	84	2.2	0.09	257	0.30	1.2	0.82	Haithabu natron white glass (2)
	0.4	74	0.9	5	0.2	0.03	71	0.17	0.1	0.04	
	179	515	10	129	4.2	4.2	2210	0.06	3.1	1.1	Haithabu potash colorless glass (7)
	33	72	3	91	1.8	2.3	878	0.04	1.2	0.2	
	148	491	9.0	95	3.5	3.8	2002	0.77	2.8	0.99	Haithabu potash white glass (6)
	27	91	0.6	18	0.7	1.6	900	0.19	0.6	0.26	

Table 45. Rare earth element concentrations of the cobalt blue and white opaque glass sherds from Haithabu. Mean composition and associated standard deviation are given for the glass used for comparison. Data in parts per million of oxide (1 ppm = 0.0001 %).

	ppm oxide	La ₂ O ₃	CeO ₂	PrO ₂	Nd ₂ O ₃	Sm ₂ O ₃	Eu ₂ O ₃	Gd ₂ O ₃	Tb ₂ O ₃	Dy ₂ O ₃	Ho ₂ O ₃	Er ₂ O ₃	Tm ₂ O ₃	Yb ₂ O ₃	Lu ₂ O ₃	HfO ₂	Ta ₂ O ₃
HF425 b	Blue glass	6.6	11.9	1.5	6.4	1.4	0.19	0.80	0.17	1.1	0.20	0.53	0.08	0.58	0.09	2.0	0.18
HF421 b		8.3	16.1	1.8	7.2	1.5	0.18	0.88	0.16	1.1	0.20	0.61	0.08	0.62	0.10	2.3	0.13
HF27 b		8.7	14.6	1.8	8.1	1.7	0.42	1.4	0.22	1.4	0.28	0.76	0.11	0.76	0.11	1.8	0.13
HF28 b		8.3	14.7	1.8	7.6	1.6	0.29	1.2	0.19	1.3	0.26	0.73	0.10	0.69	0.11	1.8	0.12
HF29 b		7.0	17.2	1.5	6.7	1.4	0.30	0.9	0.16	1.1	0.20	0.60	0.08	0.63	0.07	1.5	0.10
HF30 b		7.1	15.5	1.5	6.8	1.5	0.28	1.0	0.17	1.1	0.20	0.63	0.08	0.62	0.08	1.5	0.11
HF31 b		6.9	17.5	1.5	6.5	1.2	0.25	1.1	0.17	1.2	0.20	0.62	0.07	0.57	0.08	1.4	0.10
HF32 b		8.6	15.0	1.9	8.2	1.6	0.43	1.4	0.22	1.3	0.26	0.75	0.10	0.81	0.11	1.8	0.14
HF33 b		8.1	14.3	1.8	7.6	1.6	0.34	1.3	0.18	1.3	0.26	0.72	0.09	0.70	0.10	1.7	0.12
HF34 b		8.2	14.5	1.8	7.5	1.5	0.34	1.1	0.19	1.3	0.27	0.69	0.09	0.68	0.09	1.6	0.12
HF35 b		8.6	16.1	1.9	7.8	1.5	0.41	1.4	0.21	1.3	0.26	0.75	0.10	0.69	0.10	1.4	0.12
HF419 b		7.5	14.2	1.7	7.1	1.4	0.36	0.9	0.19	1.2	0.24	0.65	0.08	0.64	0.10	1.5	0.12
LA 48 13117 b		6.9	12.4	1.5	6.6	1.3	0.28	0.88	0.19	1.2	0.22	0.59	0.08	0.57	0.08	1.3	0.09
HF27 w		White glass	10.4	17.1	2.1	9.1	1.8	0.37	1.4	0.22	1.5	0.29	0.78	0.10	0.80	0.11	1.9
HF28 w	9.0		15.5	1.9	8.2	1.5	0.27	1.1	0.21	1.3	0.25	0.68	0.09	0.65	0.09	1.6	0.13
HF29 w	9.6		23.2	1.9	8.4	1.6	0.39	1.3	0.20	1.3	0.21	0.72	0.08	0.66	0.09	1.7	0.13
HF30 w	8.3		16.3	1.7	7.4	1.5	0.33	1.2	0.18	1.3	0.24	0.66	0.08	0.58	0.09	1.5	0.14
HF31 w	9.2		18.3	1.9	7.5	1.6	0.31	0.83	0.16	1.0	0.19	0.57	0.05	0.66	0.09	1.4	0.13
HF32 w	12.9		21.2	2.6	11.1	2.2	0.45	1.7	0.26	1.7	0.32	0.84	0.13	0.87	0.12	2.2	0.20
HF33 w	11.3		20.8	2.4	9.8	1.8	0.39	1.6	0.22	1.4	0.26	0.74	0.10	0.74	0.12	1.9	0.18
HF34 w	11.7		19.7	2.4	10.3	2.1	0.40	1.6	0.24	1.6	0.30	0.83	0.11	0.81	0.11	1.7	0.17
LA 48 13117 w	6.8		12.3	1.5	6.2	1.3	0.19	0.67	0.17	1.1	0.21	0.56	0.08	0.54	0.07	1.4	0.10
HF35 w	8.3		14.9	1.7	7.2	1.4	0.38	1.1	0.20	1.2	0.23	0.61	0.08	0.62	0.09	1.5	0.12
French blue glass (20)	av.	8.0	15	1.8	7.3	1.4	0.37	1.3	0.21	1.2	0.25	0.70	0.10	0.69	0.10	1.6	0.13
	std.	0.7	1	0.1	0.6	0.1	0.05	0.2	0.02	0.1	0.03	0.07	0.02	0.06	0.02	0.2	0.02
	min	6.1	11	1.3	5.6	1.1	0.26	0.9	0.17	1.0	0.17	0.52	0.06	0.54	0.06	1.3	0.09
	max	9.0	18	2.1	8.0	1.6	0.48	1.9	0.26	1.4	0.30	0.83	0.14	0.81	0.14	2.3	0.17
French white glass (17)	av.	7.9	15	1.7	7.0	1.4	0.34	1.1	0.18	1.1	0.23	0.63	0.09	0.61	0.09	1.4	0.12
	std.	1.1	2	0.2	0.7	0.1	0.07	0.2	0.03	0.1	0.03	0.07	0.01	0.08	0.02	0.2	0.04
	min	6.4	12	1.4	6.2	1.2	0.26	0.61	0.16	1.0	0.18	0.53	0.067	0.47	0.067	1.3	0.07
	max	11	19	2.4	8.5	1.8	0.51	1.5	0.26	1.4	0.32	0.77	0.11	0.76	0.15	1.8	0.26
Antique and early medieval glass (340)	av.	8.0	14	1.8	7.1	1.4	0.36	1.2	0.20	1.2	0.24	0.67	0.09	0.65	0.093	1.6	0.12
	std.	1.3	2	0.3	1.0	0.2	0.06	0.2	0.03	0.2	0.04	0.10	0.02	0.11	0.02	0.4	0.04
	min	5.6	10	1.2	5.3	0.67	0.19	0.46	0.13	0.79	0.16	0.47	0.054	0.45	0.051	0.90	0.069
	max	17	30	3.5	13	2.4	0.73	2.6	0.38	2.1	0.5	1.4	0.2	1.8	0.2	4.2	0.6
Haithabu natron colorless glass (3)	av.	8.1	18	1.7	7.5	1.5	0.26	1.0	0.19	1.2	0.24	0.68	0.08	0.66	0.08	1.9	0.13
	std.	1.5	5	0.3	1.1	0.3	0.03	0.2	0.03	0.1	0.04	0.09	0.02	0.09	0.02	0.1	0.02
Haithabu natron white glass (2)	av.	7.3	17	1.5	7.2	1.3	0.24	1.1	0.19	1.2	0.23	0.68	0.09	0.60	0.10	1.7	0.14
	std.	0.8	5	0.2	0.3	0.1	0.01	0.1	0.02	0.1	0.04	0.05	0.01	0.07	0.01	0.3	0.02
Haithabu potash colorless glass (7)	av.	63	86	7.8	26	3.0	0.32	1.5	0.25	1.5	0.28	0.81	0.11	0.83	0.11	2.9	0.30
	std.	17	22	2.1	6	0.4	0.16	0.7	0.06	0.5	0.09	0.32	0.04	0.37	0.05	1.9	0.12
Haithabu potash white glass (6)	av.	65	82	7.7	25	2.7	0.24	1.5	0.23	1.3	0.24	0.70	0.09	0.68	0.09	2.2	0.26
	std.	12	21	1.7	5	0.3	0.09	0.2	0.02	0.1	0.03	0.07	0.01	0.11	0.02	0.4	0.05

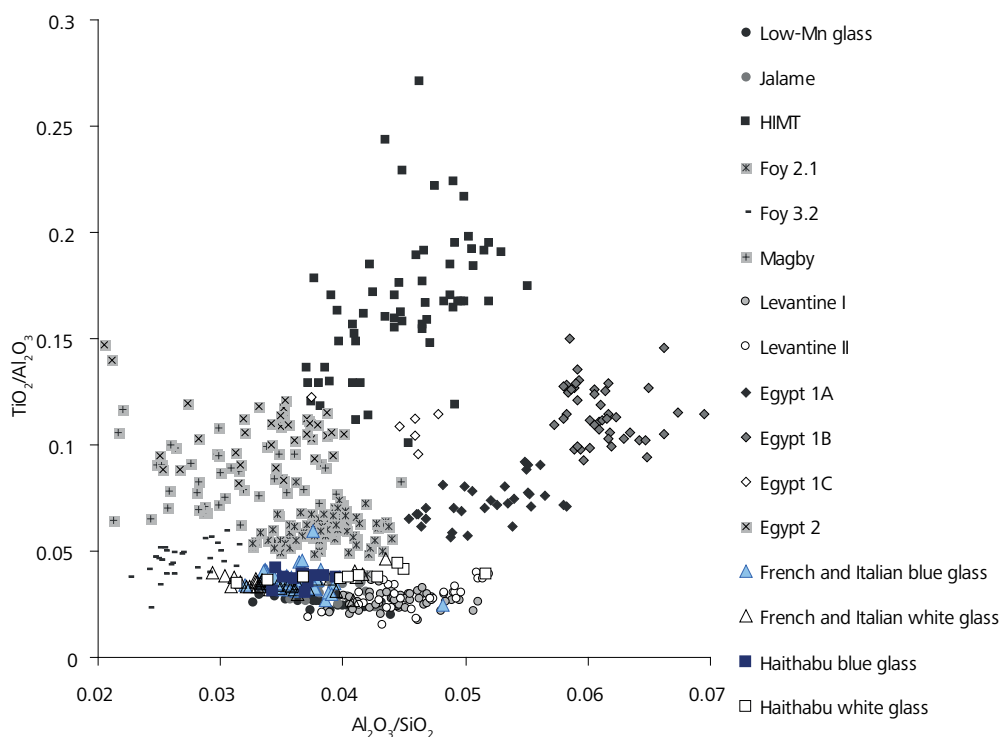


Fig. 269. $\text{Al}_2\text{O}_3/\text{SiO}_2$ and $\text{TiO}_2/\text{Al}_2\text{O}_3$ ratios of the cobalt blue and white opaque glass from Haithabu compared with: (a) those of French and Italian cobalt blue and white opaque glasses; and (b) those of the main natron groups of the second half of the first millennium.

We therefore suggest that this production was probably executed by recycling antique opaque blue glass, like tesserae. Such a practice is reported by the German monk Theophilus at the beginning of the 12th century in *De diversis artibus*, where he mentions that the Frankish glassmakers picked up old tesserae and vivid-coloured glass vessels from ‘pagan’ (Roman) sites (HAWTHORNE/SMITH 1979, 59). Recycling ancient tesserae as a source of coloured glass was also highlighted, for instance, for the manufacturing of *reticella* rods and blue window glass in the 9th-century glass workshop of San Vincenzo al Volturno (SCHIBILLE/FREESTONE 2013), of window glass in the late 8th-century glass workshop of Müstair (WOLF et al. 2017) or of the previously mentioned medieval cobalt blue window glass (BIDEGARAY/POLLARD 2018).

Concerning the white opaque trails on blue glass, even though they show slightly different patterns and a broader variability, they probably have also a Near Eastern origin. The addition of a large amount of antimony as opacifying agent (2–4.6 % Sb_2O_3) makes the results of the analysis difficult to interpret and limits the geographical identification.

4.2.4 CONCLUSION

We can therefore conclude that the raw materials used to make the Haithabu glass (HF027 to 035, HF419 and LA 48 13117), as well as the several French and Italian Saint-Savin type glasses, share the same geographical origin, which is probably the Near East, somewhere on the Levantine coast. The two other glass sherds (HF421 and 425) do not belong to Saint-Savin’s bowl group. One of them (HF421) is a Near Eastern Islamic glass, probably contemporaneous with the 10th–12th century blue and white vessels, while the other one (HF425) is a modern European glass which can be dated between the beginning of the 16th and the end of 18th centuries.

Due to the growing number of these finds, we may wonder how such a large amount of natron glass was still available to glassmakers. It is noticeable that this type of glass was not only used to make this type of vessel but was also used for the production of cobalt blue glass panels originating from various Western European cathedrals (STERPENICH/LIBOUREL 1997; BRILL 1999; BIDEGARAY/POLLARD 2018) dating from the 11th and 12th centuries. According to their tin concentrations, which remain low (0.01–0.015 % for the cobalt blue glass and 0.06–0.17 % – average 0.04 – for the white glass), these glass sherds do not seem to originate from intensive and repeated recycling practices. The production of these vessels highlights the use of a large amount of cobalt blue and opaque white antique glass at the end of the 10th century in Western Europe. If the origin of that glass may still be subjected to debate, it echoes the writings of Theophilus on the recovery and recasting of tesserae for the manufacture of coloured windowpanes.

Volker Hilberg
Haithabu 983–1066

Band 1

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Die Ausgrabungen in Haithabu

Neunzehnter Band

Herausgegeben von Ralf Bleile

VOLKER HILBERG

Haithabu 983–1066

Der Untergang eines dänischen Handelszentrums
in der späten Wikingerzeit

Mit Beiträgen von
Johannes Fried, Bernard Gratuze, Stephen Merkel und Inès Pactat

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