

Consumption, working and trade of Late Antique glass from north Adriatic Italy: An archaeometric perspective

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Abstract

The present chapter aims to investigate the circulation of glass in north Adriatic Italy during Late Antiquity. The assemblages considered are composed of vessels and working waste (including chunks) and come from Aquileia (sites: 'Domus delle Bestie Ferite' and 'Domus of Tito Macro') and Classe (sites: 'Building 6' and 'US 4381', located in the productive area of the harbour), both Late Antique cities located on the north Adriatic coast and connected with the Levant and North Africa by means of commercial routes.

An integrated approach, which involves archaeological characterisation, geochemical study and statistical analysis, has been applied. In both cities glass of Late Antique compositional groups already established in the published literature – HIMT, *série* 3.2 and Levantine 1 – were identified. The trade of raw glass and the secondary working activities of glass of the HIMT and *série* 3.2 groups were attested in both locations while Levantine 1 glass, less represented in both cities, was probably worked only in Classe and no evidence of raw glass trade was identified.

The chemical and isotopic results allow us to hypothesise, for the two cities, similar trade routes and analogous supply of raw materials and raw glass from the eastern Mediterranean.

Introduction

The archaeometric study of Roman and Byzantine glass has been the subject of a large number of studies in the past decades (see for instance: Mirti et al. 1993; Freestone et al. 2000; Freestone et al. 2003; Silvestri et al. 2008; Silvestri 2008; Foster and Jackson 2009, 2010). The widespread presence of glass all around Europe and the Mediterranean basin proves that large-scale production took place in this chronological frame. The archaeological evidence suggests that the production of glass took place in two different steps: primary production, when the raw materials were fused together to produce raw glass, and secondary production, when the raw glass was shaped into objects. Secondary production (glass-working) could take place virtually anywhere a chunk of raw glass or cullet could be re-melted and shaped, while primary production (glass-making) was dependant on the proximity of the raw materials, which in the case of Roman and Byzantine glass, were mainly sand, natron and wood as a fuel. The availability of sand of suitable mineralogical composition markedly restricts the area of possible supply to a few locations around the Mediterranean basin; for this reason the identification of productive sites has become a theme of great interest and geochemical data have been widely employed in an attempt to trace the provenance of glass (see for instance: Freestone et al. 2003; Henderson et al. 2005; Degryse et al. 2008, 2009; Degryse and Shortland 2009; Ganio et al. 2012a).

Primary production of glass on the Levantine coast has been proven, at least for the Byzantine period (Brill 1988; Freestone et al. 2000, 2002), but in the case of early Roman glass a clear consensus is still lacking and two possible models of production have been hypothesised: a centralised model, according to which the primary production took place only in a limited number of locations along the Syro-Palestinian coast, and a dispersed model, that hypothesises the existence of primary glass factories also in the western empire. The Late Antique period, and in particular the fourth–fifth century CE, is a key point of the history of ancient glass-making, strongly influenced by the political and socio-economical revolutions that followed the fall of the Roman empire: alongside ‘early’ Roman glass, new compositions of glass start to circulate and new technological solutions are adopted for colouring and opacifying, probably to compensate for the scarcity of certain raw materials or the reduced accessibility of certain locations.

In this context, the north Adriatic area of Italy is located in a strategic position, and represented a meeting point between eastern and

western Mediterranean; in addition, the area was connected to the Levant, northern Africa and the Transalpine area by means of terrestrial and maritime trade routes. The abundance of glass fragments brought to light during several decades of archaeological excavations, along with a few circumstantial evidence, encouraged the idea that primary glass production may have taken place in the area (Calvi 1968; Bertacchi 1987), while other scientists more prudently hypothesised the existence of secondary workshops (e.g. Buora et al. 2009). In any case the abundance of glass fragments, the presence of glass-working waste and chunks, the strategic position of the northern Adriatic area, paved the way to questions about the origin of the glass and in particular the provenance of the raw materials, and the existence of specific patterns of distribution.

Classe and Aquileia, both well-known harbours of the Late Antique period, are the subject of the present chapter, which aims to investigate whether the two harbours were characterised by similar patterns of glass distribution; in addition, the presence of glass-working wastes in Aquileia (including chunks) allows to investigate the presence of a glass-working activity in the city, so far only speculated. Clarifying the glass compositions that were traded, worked and used in the form of vessels, can provide valuable information about the role of the two cities and of the area in the Mediterranean glass trade network during the Late Antiquity.

Sites and materials

Sites

The cities of Aquileia and Classe represent two major sites of the Adriatic shore and hosted two of the largest Mediterranean harbours of the Antique and Late Antique times. Unlike Classe, which was founded as a city in the fifth century CE near Ravenna, as a consequence of the presence of the Imperial court in this city, Aquileia had a longer life, started in the early Roman times and continuing throughout the Late Antique period (Gallo et al. 2014 and references therein).

The assemblages from Aquileia here examined derive from two consumption sites. First, the Domus of Tito Macro (also known as Domus dei Fondi Ex Cossar), located along the via Annia not far away from the ancient harbour, and inhabited from first century BCE until the seventh century CE (Bonetto and Ghedini 2014). Second, the Domus delle Bestie Ferite, located in the forum area and inhabited between the first and the

sixth century CE. The two Domus had a residential function, even though in the area of Tito Macro some small shops and traces of metal forging have also been identified. A more detailed description of Aquileia and of the two sites is reported in Gallo et al. (2014) and Maltoni et al. (2016) and references therein.

In ancient times the city of Classe, currently an inland village in the surroundings of Ravenna, was located close to the sea and connected to Ravenna and to the Adriatic Sea by a channel system. The harbour of Classe was of recognised importance in the Late Antique period and it supplied the imperial court and inland areas. Trade between the city and the Levant and North Africa are evidenced by the recovery of large quantity of amphorae (Cirelli 2007, 2014; Augenti and Cirelli 2010, 2012). The harbour area also contained some productive workshops, testified by the presence of residues of metal forging and various circular kilns. One of the kilns, found in a warehouse named Building n. 6, was surrounded by several kilograms of glass fragments. The fragments include cullet, glass-working debris, chunks and partly melted fragments and testify the existence of a secondary workshop in the area, probably active between the fifth and the early sixth century CE. Another glass assemblage was excavated in a small dump located in the same area, named US 4381, dated mainly to the sixth century CE.

Materials

Samples subjected to archaeometric analysis were selected in order to be representative of each assemblage and to maximise the possibility of comparisons among sites. The samples from the two Aquileian sites are composed of tableware dated to the late third–seventh century CE. In particular, the Tito Macro assemblage includes 41 samples, including two chunks and a single piece of glass-working waste, while the Bestie Ferite assemblage comprises 61 samples of tableware. To enhance the possibility of comparisons between the two Aquileia sites, the same systematic approach was applied, selecting the most represented types in all the available colours. In the present chapter, only transparent or translucent glass is considered; samples are mostly naturally coloured in various shades of yellow, green, pale blue; a few deep blue samples are also present in the analysed assemblage.

Due to the activity conducted in the glass-working workshop of Classe, the vessel fragments, probably cullet, are highly fragmented and include a large variety of forms, often non-identifiable. With the aim of collecting a representative selection, a wide range of glass-working

debris, several chunks of different colour and a selection of samples from identifiable forms were chosen, alongside with some non-diagnostic fragments. A total of 74 samples, including 32 piece of glass-working waste and 5 chunks were selected. The largest group of the identified fragments are from drinking vessels, but other types, such as jugs, bottles, lamps and window panes, are also present. A larger number of beakers of the Isings 96, 106, 109 types and goblets of the Isings 111 type are represented in the excavated assemblage from this site and for this reason several samples of each type were selected for analysis. A summary of selected types, the relative abundance and dating are reported in [Table 9.1](#).

Samples are classified after Isings classification (Isings 1957); when not eligible, references to other typological classification (Crowfoot and Harden 1931; Sternini 1995; Uboldi 1999; Foy 2000; Israeli, 2008) are reported. n.d.= not defined. The general dating of

Table 9.1 Analysed fragments from Aquileia-Tito Macro (AQ TM); Aquileia-Bestie Ferite (AQ BF) and Classe, subdivided by macro type and type (dating and number of fragments analysed for each site also reported)

<i>Macro type</i>	<i>Type</i>	<i>Dating (cent. cE)</i>	<i>Classe</i>	<i>Aq TM</i>	<i>Aq BF</i>
beaker	Isings 96	4th–5th	6	3(+2)	–
	Isings 109	4th–5th	4	1	–
	Intermediate form Isings 109b/111	1st half of the 5th	–	3	–
	Isings 96/106/109?	4th–5th?	2	–	–
	Isings 106/b	5th–6th	3	–	–
	Isings 106/c	4th–early 5th	1	5	21
	Isings 106 late	5th	2	6	–
	Isings 116	4th–early 5th	–	2	8
	Isings 117	4th–early 5th	–	6	5
goblet	Isings 111	2nd half of the 5th–8th	3	5	11
	Isings 111?	5th–8th	1	–	–
drinking vessel	undefined	n.d.	3	–	–

(continued)

Table 9.1 (cont.)

Macro type	Type	Dating (cent. CE)	Classe	Aq TM	Aq BF
bottle	Isings 132	late 3rd –early 5th	–	–	2
	Isings 104	4th–5th	–	4	6
	Isings 87/120	late 3rd –early 5th	–	–	7
	Isings 126	4th–6th	1	–	–
	Foy (2000), p. 281, fig. 29, n.13	5th–6th	1	–	–
	Sternini 1995, p. 279, fig. 11, n. 131	4th–6th	1	–	–
	n.i.	n.d.	1	–	–
dish	Isings 118	4th–early 5th	–	2	–
lamp	–	late 3rd–early 5th	–	–	1
	Israeli (2008)	5th–7th century	1	–	–
	Ubold (1999), p. 639, tay. 123, n.9	6th–7th	1	–	–
	Crowfoot and Harden (1931) – A	4th–early 5th	–	1	–
window pane	–	n.d.	2	–	–
working debris	–	n.d.	32	1	–
	Chunks	n.d.	5	2	–
Total of analysed fragments			74	41(+2)	61

each form is here reported; for the specific dating of each fragment see Maltoni et al. (2015) for Classe and Gallo et al. (2014) for Aquileia-Bestie Ferite; in the case of Aquileia Tito Macro, in the absence of stratigraphic dating only the general dating of each form is assumed (see Maltoni et al. 2016).

Analytical methods

The chemical analysis of major, minor and trace elements was conducted by means of Wavelength Dispersive X-ray Fluorescence (WD-XRF) on all samples weighing ≥ 700 mg. These samples were prepared in fused discs. The measurement of Sn, Sb, Cl and S in all samples, and of the major, minor and some selected traces in samples with weight < 700 mg were performed by means of Electron Probe Micro Analysis (EPMA) on polished sections.

Isotopic analysis, Sr and Nd isotopic ratios were performed in cooperation with the Katholieke Universiteit Leuven, Belgium, by means of Multi Collector Inductively Coupled Plasma Mass Spectrometry. The sample preparation, instrumental parameters, analytical condition for XRF and EPMA analysis are fully reported in Silvestri et al. (2011a) and Silvestri and Marcante (2011). The detailed procedure for Sr and Nd isolation, quantification and definition of the isotopic ratios is reported in Ganio et al. (2012b).

Results and discussion

Compositional groups

The samples were chemically analysed in order to identify possible homogeneous compositional groups related to specific raw materials and/or production technologies. The XRF and EPMA analysis allowed all of the samples analysed to be classified as silica-soda-lime glass. The high soda content and the low concentration of magnesia, potash and phosphorus oxide are consistent with the use of natron as a flux, in accordance with the Roman and Byzantine glass-making tradition (Shortland et al. 2006). The complete analytical results on the samples from the Domus delle Bestie Ferite are published in Gallo et al. (2014), those from Classe in Maltoni et al. (2015) and those from Tito Macro in Maltoni et al. (2016). In the present work, the three assemblages are discussed in a comparative perspective.

On the basis of the content of the major and minor elements three compositional groups were identified: a first one, comparable to the reference group named HIMT (Freestone 1994); a second one that can be referred to the reference group Levantine 1 (Freestone et al. 2000), and a third one that is related to the so-called *série 3.2* group, reported by Foy and co-authors (Foy et al. 2003) (Figure 9.1). The same three compositions were identified in all the analysed assemblages, although with different internal

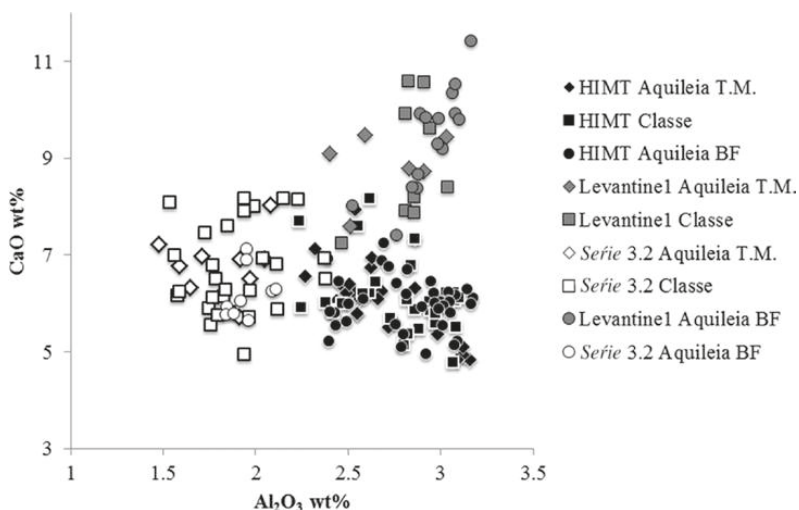


Figure 9.1 Binary diagram CaO vs Al₂O₃. Glass compositions are represented by colour: HIMT in black, Levantine 1 in grey, *série* 3.2 in white. The three sites are represented by different symbols: squares for Classe, diamonds for Aquileia Tito Macro and circles for Aquileia Bestie Ferite. Raw chemical data from Maltoni et al. 2015 for Classe; Maltoni et al. 2016 for Aquileia Tito Macro; Gallo et al. 2014 for Aquileia Bestie Ferite.

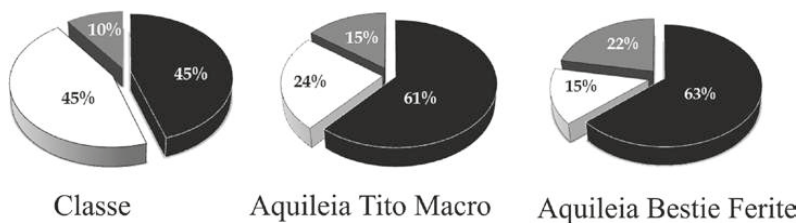


Figure 9.2 Pie-charts showing the relative distribution of the three glass compositions in the assemblages. Glass compositions are represented by colour: HIMT in black, Levantine 1 in grey, *série* 3.2 in white.

distributions. The three assemblages are dominated by HIMT, while in the distribution of Levantine 1 and *série* 3.2 a difference emerges: in Classe and Tito Macro the Levantine 1 glass is very scarce, conversely in the Bestie Ferite assemblage the proportion is inverted (Figure 9.2).

In the samples from Classe glass of HIMT and *série 3.2* compositions is equally distributed. The glass analysed at this site includes chunks and glass-working waste, which suggests that the two compositions were traded in the form of raw glass and locally worked. Similarly, at Tito Macro the presence (though scarce) of glass-working indicators of HIMT and *série 3.2* suggests that these compositions were also traded and worked here.

A detailed description of each compositional group is reported in the following paragraphs, and the mean values and standard deviations are included in [Table 9.2](#).

HIMT

The first compositional group to be discussed, corresponding to the literature group HIMT, includes the previously published groups FC/1 from Tito Macro (Maltoni et al. 2016), CL/1 from Classe (Maltoni et al. 2015) and AQ/1 from Bestie Ferite (Gallo et al. 2014). This composition is characterised by high soda, relatively low lime, very high iron, alumina, titanium, magnesium and manganese ([Table 9.2](#)), which suggests the use of a very impure sand, rich in accessory minerals, as that of the Egyptian coast between the Nile delta and North Sinai (Freestone et al. 2005; Freestone, et al. [unpublished manuscript](#)). This composition is well represented in archaeometric reports across the whole Mediterranean basin, in the northern provinces and the Balkans (e.g. Mirti et al. 1993; Freestone 1994; Foy et al. 2003; Foster and Jackson 2009; Conte et al. 2014; Nenna 2014; Rehren and Cholakova 2014; Ceglia et al. 2015).

Despite its widespread presence, HIMT glass does not represent a homogeneous and well-defined group and samples included in this group often show variable contents of the diagnostic elements, leading some scholars to subgroup in 'weaker' and 'stronger' HIMT depending on the content of their diagnostic elements (iron, manganese, titanium). The HIMT samples here investigated, differently, show an uncommon composition, characterised by extremely high contents of iron, titanium, manganese and alumina. Comparing the analysed samples with those reported in the archaeometric literature ([Figure 9.3](#)) all samples fall in the compositional range of the 'strong' reference groups. In particular, a relatively large group of samples with higher alumina and an iron content over 3.0 wt% Fe_2O_3 , is evidenced. Such 'very strong' subgroup, characterised by an extremely high content of iron (even above 4 wt% Fe_2O_3) and titania, is well represented in the north Adriatic assemblages under investigation, while in the previously published assemblages it is

Table 9.2 Mean value and standard deviation (in italics) of the major oxides for the compositional groups HIMT, HIT, Levantine 1 and *série 3.2**

	<i>n. samples</i>	<i>SiO₂</i>	<i>Na₂O</i>	<i>CaO</i>	<i>Al₂O₃</i>	<i>Fe₂O₃</i>	<i>MnO</i>	<i>TiO₂</i>	<i>MgO</i>	<i>K₂O</i>	<i>P₂O₅</i>	<i>SO₃</i>	<i>Cl</i>
HIMT	94	65.34	18.29	6.08	2.79	2.24	1.88	0.50	1.16	0.49	0.08	0.25	1.24
		<i>1.45</i>	<i>1.33</i>	<i>0.70</i>	<i>0.27</i>	<i>0.89</i>	<i>0.40</i>	<i>0.14</i>	<i>0.24</i>	<i>0.15</i>	<i>0.04</i>	<i>0.08</i>	<i>0.20</i>
HIT (blue)	6	65.82	19.24	6.03	2.71	2.46	0.22	0.49	1.11	0.40	0.01	0.29	1.27
		<i>1.70</i>	<i>0.85</i>	<i>0.46</i>	<i>0.16</i>	<i>0.62</i>	<i>0.13</i>	<i>0.16</i>	<i>0.14</i>	<i>0.07</i>	<i>0.01</i>	<i>0.04</i>	<i>0.15</i>
Levantine 1	31	67.47	16.49	9.11	2.86	0.80	0.60	0.27	0.35	1.03	0.14	0.18	0.95
		<i>1.89</i>	<i>0.97</i>	<i>1.07</i>	<i>0.19</i>	<i>0.41</i>	<i>0.45</i>	<i>0.21</i>	<i>0.27</i>	<i>0.58</i>	<i>0.07</i>	<i>0.05</i>	<i>0.30</i>
<i>Série 3.2</i>	45	68.33	19.05	6.59	1.89	0.74	0.77	0.12	0.63	0.49	0.04	0.29	1.35
		<i>1.57</i>	<i>1.12</i>	<i>0.80</i>	<i>0.20</i>	<i>0.34</i>	<i>0.28</i>	<i>0.05</i>	<i>0.15</i>	<i>0.21</i>	<i>0.02</i>	<i>0.09</i>	<i>0.21</i>

* It should be stressed here that within HIMT group, a sub-group named HIT is identified and due to its particular chemical composition, is considered separately here. Further details on HIT glass are reported in the text.

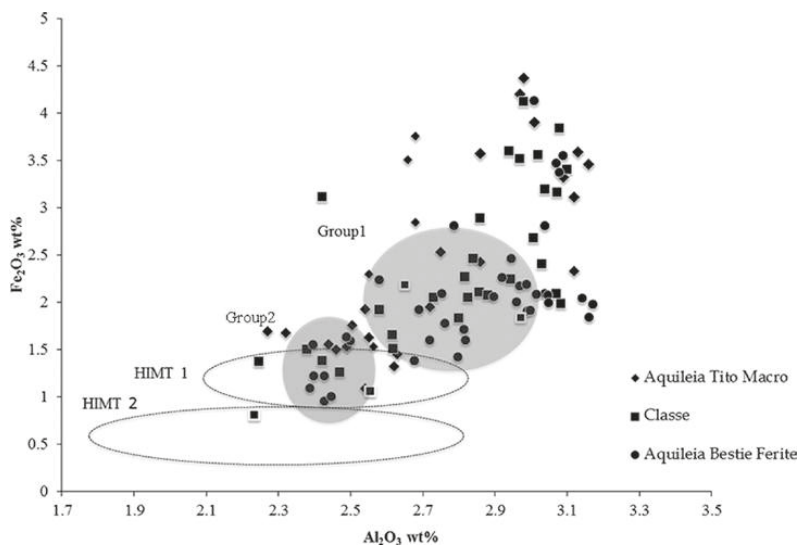


Figure 9.3 Binary diagram Fe₂O₃ vs Al₂O₃ of HIMT samples. Grey areas represent the compositional fields of Group 1 (strong) and Group 2 (weak) (Foy et al. 2003), dotted lines represent the compositional fields of groups HIMT 1 (strong) and HIMT 2 (weak) (Foster and Jackson 2009). Raw chemical data from Maltoni et al. 2015 for Classe; Maltoni et al. 2016 for Aquileia Tito Macro; Gallo et al. 2014 for Aquileia Bestie Ferite.

lacking or sporadically represented by isolated samples (Foy et al. 2003; Rosenow and Rehren 2014). The HIMT glass circulating in north Adriatic Italy seems to have a specific composition and it is possibly related to a specific primary production site that had a privileged commercial link with north Adriatic harbours.

Among the HIMT samples, eight samples (three from Classe and five from Aquileia Tito Macro) are intentionally coloured blue: five vessels (beakers and bottles), a chunk and two decorative drops applied on beakers. The decorative drops have a HIMT composition, and are coloured in one case by the addition of cobalt and copper (2737 ppm and 8242 ppm, respectively) and in the other case by copper only (49227 ppm) (Maltoni et al. 2016); the other six samples, including the chunk from Tito Macro, are coloured by cobalt (2204 ± 2190 ppm) and copper (2381 ± 927 ppm), show relatively high lead (2311 ± 2073 ppm), and have low (although not negligible) manganese, below 0.5 wt% MnO. Manganese is one of the distinctive elements of the HIMT glass, its

presence being related to an intentional addition, probably aimed to contrast the colouring effect of iron that, in such high concentrations, would turn the glass black (Freestone et al. 2005). HIMT glass with no manganese (dubbed HIT by Rehren and Cholakova 2010) is very rare: naturally coloured samples are known in Bulgaria (Rehren and Cholakova 2014, 2010) and Cyprus (Ceglia et al. 2015), deep blue HIT glass was identified only in Albania (Conte et al. 2014) and North Sinai (see samples 77 and 85 of table 1 in Freestone et al. 2002), and in the current assemblages, all dated to the fifth–sixth century CE.

The presence of a chunk of blue HIT glass from Aquileia suggests that blue glass was traded in the form of raw glass, but the low manganese invites a question about its provenance. As manganese is one of the distinctive traits of HIMT glass, and as it was added at the primary stage of production to counteract the dark colour of the glass, it is possible that it was deliberately excluded from the batch when the glass makers aimed to colour the glass blue, as decolouring was not necessary and probably not fruitful. On the basis of this evidence, it is possible to hypothesise that HIT blue glass was a product of the same primary furnaces of HIMT, and that colouring could also take place at this stage of production. The occurrence of blue glass with HIMT composition, i.e. the decorations of two cups Isings 96, in the north Adriatic assemblage further suggests that glass-colouring took place in the secondary workshop where the vessel was shaped, in addition to the primary stage. Glass-colouring was therefore conducted as needed, as shown by the chemical similarity between the vessel body and the base glass of the respective blue decoration.

Levantine 1

The second composition to be discussed corresponds to the reference literature group Levantine 1 and includes groups FC/2 from Tito Macro (Maltoni et al. 2016), CL/2 from Classe (Maltoni et al. 2015) and AQ/2 from Bestie Ferite (Gallo et al. 2014). This composition is characterised by low soda and high lime, relatively high alumina, low iron, magnesium, titanium (Table 9.2) and trace elements (Gallo et al. 2014; Maltoni et al. 2015, 2016) that are indicative of the use of a relatively pure sand, poor in heavy and accessory minerals and rich in feldspars and carbonates, consistent with a Syro-Palestinian provenance (Freestone et al. 2000). This composition is well represented in the Mediterranean basin as in the northern provinces (Freestone et al. 2000; Gorin-Rosen 2000; Foy et al. 2003; Freestone et al. 2008; Foster and Jackson 2009; Conte et al. 2014; Rosenow and Rehren 2014; Ceglia

et al. 2015). Levantine 1 samples from Aquileia and Classe are also characterised by high potash, on average above 1 wt% K_2O (Table 9.2), as already identified in some Levantine glasses (see, for instance, some of those excavated in the primary furnace of Dor (Freestone et al. 2000)). However, when evaluating the content of potash in natron glass, the possible vehicles of potash shall be taken into account: alongside with the potassium-bearing minerals of the sands, furnace ashes can also be responsible for the introduction of this element in the batch. The concentration of potash has been shown to increase with increasing time of permanence in the firing chamber (Paynter 2008). In the case of very high potash contents in natron glass, as in some samples from Classe (see also Maltoni et al. 2015), it is possible to relate this analytical evidence to the secondary working.

Another characteristic of glasses of the Levantine 1 composition is the variable content of MnO, which ranges from negligible to more than 1 wt% MnO. In particular, samples from Aquileia and Classe, split in two groups, a first with high manganese (around 1.30 wt% MnO) and a second with very low or negligible manganese; differently, samples from Classe have a more gradual distribution and a tendency to lower concentrations of this element, between 0.03 and 0.91 wt% MnO (Figure 9.4).

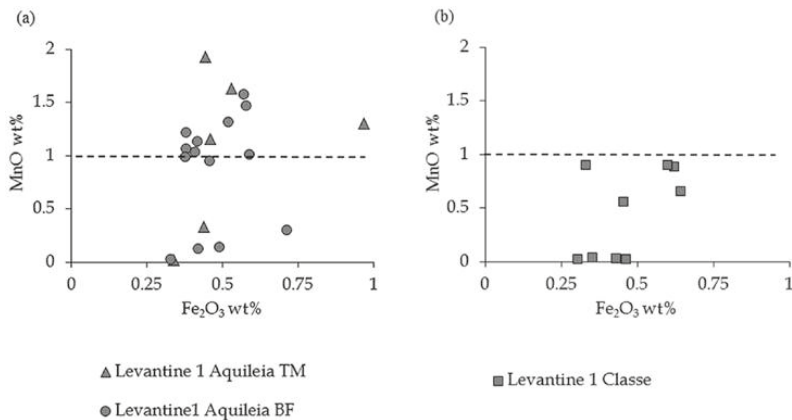


Figure 9.4 Binary diagram MnO vs Fe₂O₃ of Levantine 1 samples. (a) Glass from Aquileia; (b) glass from Classe. The broken line refers to the threshold of the intentional addition of manganese oxide according to Brems et al. (2012). Raw chemical data from Maltoni et al. 2015 for Classe; Maltoni et al. 2016 for Aquileia Tito Macro; Gallo et al. 2014 for Aquileia Bestie Ferite.

The existence of Levantine glass with or without manganese is testified also in primary production sites (see for instance Brill 1988) and the presence of this element in high concentration can be considered as deliberate productive choice, manganese being the main decolouriser available in Late Antique and Byzantine glass-making. However, manganese oxide below the conventional limit of intentional addition (1 wt% MnO according to Brems et al. (2012)), as found at Classe, suggests a certain degree of recycling. The two sites of Aquileia (Tito Macro and Bestie Ferite) show similar characteristics, suggesting a very low extent of recycling, while in the assemblage of Classe we can hypothesise that the Levantine samples underwent some recycling, that is consistent with the secondary working activity of the site.

Série 3.2

The final composition to be discussed, corresponding to the so-called *série 3.2* group, includes groups FC/3 from Tito Macro (Maltoni et al. 2016), CL/3 from Classe (Maltoni et al. 2015) and AQ/3 from Bestie Ferite (Gallo et al. 2014). It is a relatively rare Mn-decoloured composition, which, when identified, is recorded in Late Antique assemblages dated mainly around the fifth century CE. The main distinctive traits of this compositional group are very low alumina (usually below 2 wt% Al₂O₃), high soda and in some cases high iron, and the presence of manganese. The chemical composition of this glass reflects the relatively pure mineralogical composition of the sand employed for the primary production, rich in silica and poor in aluminium-bearing minerals (as potassium-feldspars), similar to that employed in the early Roman glass-making; on the basis of the chemical composition, Foy and co-authors (2003) hypothesise a Syro-Palestinian provenance, although in a different coastal segment with respect to Levantine 1, however, more recent studies (Schibille et al. 2017) suggest the Egyptian origin of this composition, although the precise locations of sand supply, that are different from that of HIMT glass, are unknown. *Série 3.2* glass is very well represented in Classe and in Tito Macro, less represented in the Bestie Ferite assemblage and relatively rare in the archaeometric literature: apart from the assemblages analysed in the present work, samples of this group are recorded in the Mediterranean basin both as vessels (Foy et al. 2003; Rehren and Cholakova 2014) and mosaic tesserae (Silvestri et al. 2011b). The presence of chunks of *série 3.2* composition from Classe and Aquileia Tito Macro should be noted, as they prove that this composition was actively traded as raw glass and locally worked.

Links between types and compositional groups

Investigating the links among compositional groups, types and sites, it is necessary to note that the two Aquileian assemblages have a higher degree of comparability than Classe in terms of forms, having in common the beakers Isings 106, 109, 116, the goblets Isings 111 and the bottles Isings 104 (Table 9.1). The degree of comparability between Classe and the Aquileian sites is lower due to their different functions (consumption sites for Aquileia and productive site for Classe), as already detailed in the section 'Sites'. A few types were analysed from both the Domus of Tito Macro and Classe: beakers Isings 96, 106 and 109 and goblets Isings 111. The only types in common among all the three assemblages are therefore the goblets Isings 111 and the beakers Isings 106 and 109, although with a very different relative abundance (Table 9.1). Investigating the possible relations between form and composition, some links were found: bottle Isings 104 (available only in Aquileia Tito Macro and Bestie Ferite) seem to be predominantly made with HIMT glass; cups Isings 96 (from Classe and Aquileia Tito Macro) are made with Levantine 1 or HIMT glass, but not with *série* 3.2 glass; the stemmed goblet Isings 111 is reported in HIMT and *série* 3.2 in all three assemblages, while Isings 111 made in Levantine 1 glass are only reported in the Bestie Ferite assemblage.

The preferential use of specific composition for certain types may be related to different factors, from the colour of the glass to its cost, and it may have been influenced by the availability and the regularity of supply. It is also possible that different compositions (differing in colour or price) were used to satisfy the needs of different segments of the glass market. Unfortunately the different ratios of the few common forms do not allow a full interpretation of the links between type and composition, and further studies will help to shed light on this topic. However, it is useful to underline that the three assemblages have a pattern of glass compositions and vessel forms that suggest a dating before the sixth century CE, although this indication is not fully supported by the available archaeological data.

Isotope analysis

The chemical analysis of the glass finds from Aquileia and Classe highlighted the similarity between the materials from the two cities in terms of glass compositions. The discovery of specific characteristics and the homogeneity of certain groups (as for instance HIMT and HIT) in the two cities raises questions about the provenance of the glass and the possible locations of supply.

Isotope analyses, and Sr and Nd in particular, has proved to be a valuable tool to trace the provenance of the raw materials of glass, giving information on the carbonatic fraction and the heavy-non quartz fraction of the sand, respectively (see, for instance, Degryse et al. 2009 and references therein). Isotope analyses were conducted on a selection of finds from Tito Macro, Bestie Ferite and Classe, selecting the samples on the basis of their chemical composition, giving preference to those with lower evidence of recycling, avoiding the intentionally coloured samples and selecting, when possible, raw glass and glass-working indicators. A total number of 50 samples were chosen and full analytical results are given in: Maltoni et al. (2015) for Classe, Gallo et al. (2015) for Aquileia-Bestie Ferite and Maltoni et al. (2016), for the Aquileia-Tito Macro samples.

All analysed samples have an absolute content of Sr of about 400–600 ppm, that is indicative of glass produced with coastal sands rich in shells. The isotopic ratio of strontium is always lower than that of modern oceanic sea water ($^{87}\text{Sr}/^{86}\text{Sr} = 0.7092$) (Figure 9.5a) and, although the samples are well distributed between the value of modern oceanic water and that typical of continental limestone (0.7080) (Freestone et al. 2009), the samples of Levantine 1 and *série 3.2* composition have a higher Sr isotope ratio with respect to HIMT. Despite the generally low levels of Sr isotope ratio in HIMT, the use of continental limestone as a primary source of carbonates in these samples can be excluded, as their absolute content of Sr is markedly higher than the expected value of 100–150 ppm (Brems et al. 2013a). Therefore, taking into account the geochemical evidence of the higher contents of certain elements (magnesium, titanium, and iron) in HIMT than other groups (Table 9.2), the lowest values of $^{87}\text{Sr}/^{86}\text{Sr}$ (Figure 9.5a) in HIMT samples suggest that in these samples Sr is introduced also by minerals rich in Fe, Mg and Ti with low isotopic ratios other than carbonates, such as for instance amphiboles and pyroxenes.

On the basis of the chemical and isotopic evidence, HIMT glass is hypothesised to be of Egyptian provenance, where coastal sands are strongly influenced by the contribution of the Nile, while Levantine 1 is hypothesised to be of Syro-Palestinian origin, where coastal sands are rich in shells. *Série 3.2* glass, originally considered as a Syro-Palestinian primary group (Foy et al. 2003), was more recently interpreted as of Egyptian provenance (Schibille et al. 2017). The three groups here identified are therefore hypothesised to be of eastern Mediterranean origin, and this is confirmed by the low negative value of ϵNd , that is between –3.5 and –5.5 in all the analysed samples (Figure 9.5b). When comparing

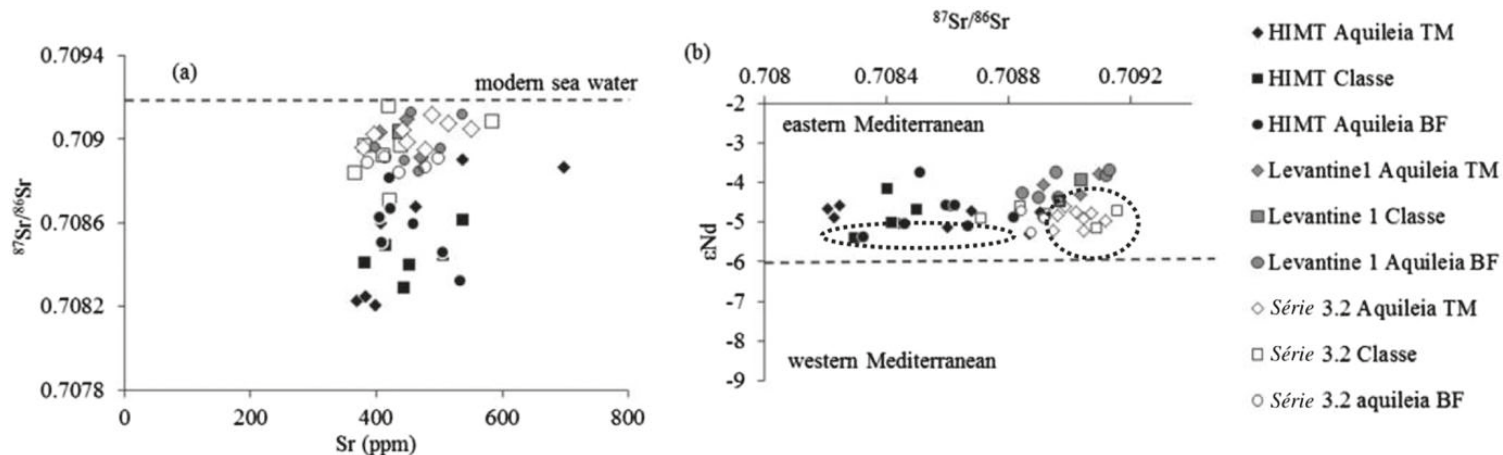


Figure 9.5 Binary diagrams of the isotopic data. (a) Sr vs $^{87}\text{Sr}/^{86}\text{Sr}$; (b) ϵNd vs $^{87}\text{Sr}/^{86}\text{Sr}$. Dotted lines represent $^{87}\text{Sr}/^{86}\text{Sr}$ of modern sea water (Brems et al. 2013a and references therein) and ϵNd value that discriminates eastern and western Mediterranean sand (Brems et al. 2013b and references therein) in Figures 5a and 5b, respectively. In Figure 5b dotted ellipses represent the compositional fields of Levantine 1 (right) and HIMT (left) glass as reported in Degryse (2014). Raw isotopic data from Maltoni et al. 2015 for Classe; Gallo et al. 2015 for Aquileia Bestie Ferite; Maltoni et al. 2016 for Aquileia Tito Macro.

the present samples with those reported in the literature for Late Antique and Byzantine glass (Freestone et al. 2003; Degryse et al. 2008; Degryse 2014; Freestone et al. unpublished manuscript), a minor difference is found: the previously published samples have slightly more negative values (between -6 and -5 as ϵNd), which is still consistent with the eastern Mediterranean sediments, but could indicate a small difference in the location of supply.

Another interesting trend is found when Levantine 1 and *série 3.2*, are compared (Figure 9.5b): despite the similarity in their Sr isotope signal, the two compositions have a small difference in their ϵNd values that reflect a different geochemical origin of the sand, as already suggested on the basis of their chemical composition.

Conclusions

The present work addresses the circulation of glass during Late Antiquity in north Adriatic Italy. It considers the two major harbours of the timespan under investigation, Classe and Aquileia, in a comparative perspective. The chemical and isotope analyses, performed with comparable techniques characterised by high standards of precision and accuracy, allowed comparisons to be made between the assemblages from the two cities and with the reference groups, already published in the literature.

During the fourth–sixth century CE the two cities of Classe and Aquileia were supplied by similar trade routes and the same glass compositions, with comparable chemical features, were imported and locally shaped.

All the three assemblages (Classe, Aquileia-Tito Macro and Aquileia-Bestie Ferite) are dominated by HIMT glass. Glass of this type found in this area shows specific compositional features with very high iron, titanium, alumina and manganese, opening the way to the hypothesis of preferential trade routes between specific primary production locations and the north Adriatic area. Levantine 1 and *série 3.2* glass were also identified, although with different internal distributions. The glass-working workshop of Classe seems to have been regularly supplied by fresh glass of HIMT and *série 3.2* compositions, while Levantine 1 was probably less available. A general scarcity and absence of chunks of the Levantine 1 compositional type at Tito Macro and Classe, suggest a possible difference in the patterns of trade and consumption compared to

the Bestie Ferite assemblage. This may be related to a small difference in dating or other unknown reasons.

The existence of a chunk and some vessels of intentionally coloured HIT glass demonstrates that glass-colouring took place also at the primary stage of production, at least for this specific Late Antique composition, and that HIT blue glass was traded in the form of chunks in Aquileia.

The existence of a link between certain typologies and specific glass compositions was investigated, and some indications were given, but further studies and more data are required to confirm the identified trends.

As expected for glasses of the above-mentioned compositions, on the basis of the isotopic composition, all analysed samples are consistent with an eastern Mediterranean provenance. However, the present study revealed some interesting trends that shed more light on glass circulation during the Late Antique periods: an Egyptian provenance is supported for HIMT while the Syro-Palestinian provenance is supported for Levantine 1; *série 3.2* composition, originally considered as a Syro-Palestinian provenance, has a slightly different isotope signal with respect to the others groups and this suggests the exploitation of different sand sources, probably of Egyptian provenance, although different from those of HIMT glass.

In summary, the combination of isotopic and chemical data supports the hypothesis of an eastern Mediterranean origin for the Late Antique glass here analysed, which may be produced in few primary workshops located on the Syro-Palestinian and Egyptian coasts and then imported to the northern Adriatic area in the form of chunks. The secondary working activity in the area of Aquileia and Classe is confirmed and the centralised production model is fully supported for Late Antiquity.

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