COMPOSITIONAL CASE STUDIES: GLASS FROM THE GNALIĆ WRECK

Caroline *JACKSON*

In 2006 a major volume on the glass from the Gnalić wreck was published[1]. The publication consisted of a comprehensive catalogue of all the glass finds (excluding the beads) recovered to date. It provided a synthesis and interpretation of the range of glass forms represented in the assemblage, with respect to their potential origin and likely markets, as the origin or final destination of the ship was not known. Included in the publication was a short section concentrating on preliminary compositional data for the glass recovered, designed to determine whether scientific analysis of the glass compositions could shed any further light on the potential provenance of this glass[2]. This paper will explore further a sub-set of this data in the light of more recent publications which have arisen in the field. In the original publication and in this paper, the stylistic analysis of the glass is used as a basis for looking at patterns in the chemical analysis.

Introduction

In the late sixteenth and early seventeenth centuries the Adriatic played an important role in the trade and movement of goods, including glass. This is attested not only by a wealth of artefactual evidence found inland but also by underwater finds from shipwrecks or off-loaded ballast. This trade is particularly well represented at towns on the Dalmatian coast such as Dubrovnik, Zadar and Split and also centres within Italy, and at the coast, most notably at and in the vicinity of Venice.

Evidence from shipwrecks can provide an illustration of the movement of material at very specific points in time. In a twenty year period at the end of the sixteenth century and beginning of the seventeenth century it is estimated that over one hundred known ships perished on the eastern Adriatic coast; and in reality this figure may have even been as high as 1000[3]. This paper explores the glass remains from one of these wrecks.

In 1967 the remains of a ship was found by amateur divers, just off the rocky islet of Gnalić, a location at the entrance of a busy shipping route[4]. This merchant ship, containing a rich cargo, appears to have sunk some time in the 1580's, attested by the stylistic analysis of the finds and two cannons dated to 1582. Archaeological campaigns took place in the late 1960s, into the 1970s and then again in the mid 1990s[5]. To date in excess of 6500 pieces of glass have been excavated from the wreck and surrounding area, and there are many more finds still in situ. The glass appears to have been a substantial part of the cargo.

Because of the proximity of the wreck to Venice and the pre-eminence of Italian glass at this point in history, it was initially thought that the vessel was sailing from Venice, and as a small proportion of the glasses were Islamic in style, that the intended destination may have been Constantinople[6]. This theory could be substantiated if the identity of the ship could be discovered in official maritime records at this period. Of the recorded shipwrecks at the end of the 16th and beginning of the 17th century, Gasparetto[7] records only one that corresponds to the vicinity of Gnalić, that of the Gagiana which was sailing from Venice to Constantinople. However, many shipwrecks were not recorded and so the identification was not proved. More recently markets on the Dalmatian coast have been suggested as possible destinations, specifically Dubrovnik,

or that the ship would off-load at multiple destinations, indicative of a tramping pattern of trade[8].

Whilst the destination of the glass is one area of interest; the other is the likely origin of the glassware. Most early reports on the glass favoured a Venetian origin based upon the few decorative vessels recovered in the initial excavations[9]. Other suggestions include other Italian locations, central Europe or even local production of glass from centres flanking the Dalmatian coast, such as known glass manufacturing centres in Ljubljana or Dubrovnik[10].

Stylistic analysis

The glass cargo consisted of vessels, windows, half finished products such as mirrors and a small number of speciality wares such as coloured bowls and bottles, which might suggest the goods were intended for different markets.

Nearly 75% of the glass recovered to date was vessel glass; many of these were complete or only slightly damaged. Although this group included a range of tablewares, containers and a small proportion of coloured glass, over 90% were goblets. These goblets are very simple undecorated forms, manufactured in a simple two stage process whereby the bowl would be blown and then the foot applied. They are often misformed, contain many bubbles and are very poorly decolourised – seen in the different hues of all the vessels which range from a greenish to purplish hue. Because of these stylistic features and their poor quality, it has been suggested that these vessels were not produced in Venice or Murano, but more likely another workshop of the many known to be operating in northern Italy and Central Europe, or even more local to the shipwreck, such as around Ljublijana or Dubrovnik, as both had well documented *façon de Venise* industries at this time[11].

Although other vessels were more carefully manufactured and of higher quality glass, some decorated or highly coloured, there was a notable absence of the decorative types normally associated with Venice. Thus, within the assemblage, there were no specific forms of glass which would normally be representative of vessels produced in Venice.

In addition to vessel glass, 700 circular window glass crowns and nearly 600 circular and rectangular mirror glass plates were found. Window panes were not commonly used in this period, and when used they would be purchased in multiples to provide a glazing pattern within each window. Their primary use would be for glazing in churches or building owned by rich patrons. The mirrors, both circular and rectangular and of standardized shapes and sizes, were incomplete, and were in transit to be finished with the mirroring of tin and mercury elsewhere[12].

Therefore, was the vessel sailing from Venice to Constantinople as Gasparetto[13] originally suggested, or to Dubrovnik or surrounding areas? The stylistically mixed consistency of glass and cargo in particular indicate the trading route may be more complex than a single point to point movement, and a large number of markets may have been served. It also indicates that the glass may not all be from one origin.

Thus the stylistic analysis threw up a number of questions relating to the origin of the glass on board the vessel and to its potential markets. Whilst the destination of the glass cannot be explored easily through the chemical analysis of glass, the potential to discriminate different groups of glasses and hence infer different points of origin or technology can be attempted.

Chemical analysis of the glass

In 1973 Robert Brill undertook a preliminary chemical analysis of the glass from the Gnalić shipwreck[14]. He studied seven samples from simple goblets to window glasses and bottles. All were soda-lime-silica composition with low concentrations of potash, magnesia and phosphorus indicative of the use of a soda-rich plant ash in manufacture – typical of this period. All glasses were decolourised with manganese which would account for their different hues ranging from purple to green. The 212 samples analysed in this study are also of the same general composition, despite the larger number of samples and forms analysed[15].

Since 1973 the number of comparative analyses of contemporary glasses with which to evaluate the compositions of these samples has grown. Comparison with published groups of glasses by Verità and Toninato[16], de Raedt[17], Šmit *et alii*[18] and others indicate that this glass is what is termed *vit-*

rum blanchum. Thought to be produced in Italy, it was used to produce colourless glass, but generally not of the highest quality. The high soda content of these glasses indicates they were manufactured using high-soda halophytic plant ashes, probably imported from the Levant, as documented for the production of fine quality Italian glasses[19]. Verità (1985) suggests that the highest quality colourless glasses, for example *cristallo*, would use crushed pebbles for manufacture, however, for the more common *vitrum blanchum* sands would be used and these could be procured from many differing regions around Italy or elsewhere. These glasses were commonly decolourised with manganese.

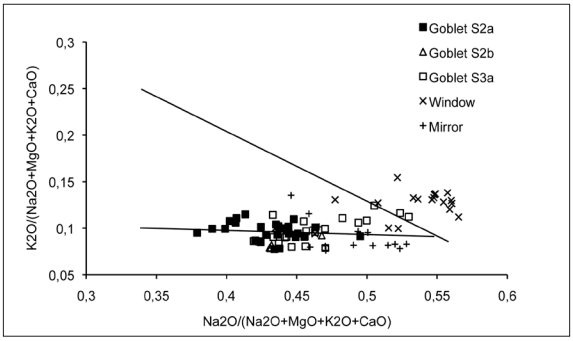

Fig. 1. Compositions of the main glass groups fron the Gnalić Wreck (trend lines indicate the two major *vitrum blanchum* groups published by *Spread of Façon-de-Venise* 2004).

Chemical groups related to the use of plant-ash alkalis

In a paper looking at the compositions of 16th century vessel fragments from Ljubljana, Šmit *et alii*[20] plotted the different ratios of alkali elements, scaling each to the total alkali to erase fluctuations in total alkali used. For the Venetian *vitrum blanchum* vessels two distributions were found. One distribution had an inverse correlation between sodium and potassium and the other one which had a relatively constant potassium concentration whilst the sodium concentration varied. The glasses from Slovenia corresponded with the latter group where the potassium content was relatively stable. This, they concluded, suggested that most of the vessels made of *vitrum blanchum* glass found in Ljubljana had been imported from Venice.

When the Gnalić glasses are plotted with the data from Šmit *et alii*[21] the majority of the Gnalić glasses also lie on this 'stable-potassium' distribution, but there is some overlap with the higher negatively correlated group (fig. 1). On further scrutiny, it is apparent that the overlap with the negatively correlated group is contributed by window and mirror glasses. The vessel glasses all correlate with the glasses from Ljubljana and from Antwerp. Thus the vessel glasses from the Gnalić wreck fall within the same compositional group as the Venetian *vitrum blanchum* glasses. Assuming that *vitrum blanchum* glasses were made in Venice, then this would suggest that the Gnalić vessels were manufactured within, and imported, from Venice.

However, this explanation may be too simplistic. These particular compositional distributions within the glasses relate to the use of specific alkali sources – any discrimination between groups of glasses should indicate the use of different local alkalis at different manufacturing centres and so by definition, similarities between groups indicate the same or neighbouring manufacturing centre. However, the similarity in compositions may relate the way the glasses were made and the transfer of knowledge of glassmaking technology and the use of specific raw materials, rather than provenance. Historical documentation notes that, from the thirteenth century, glassmakers were 'enticed' from Murano against strict prohibition of the Serenissima[22]. By the fifteenth centuries there were factories in Germany, France, Belgium and England who employed Venetian (or Italian) craftsmen. The knowledge and use of specific raw materials would have travelled with the glassmakers[23]. In addition, whilst local raw materials were sometimes used, such as ferns in some Italian glasshouses, the movement and use of imported ashes was widespread. Some German glass factories used eastern European ashes, Russian ashes were imported to the Low Countries and some Italian factories imported Spanish barilla. However, the most prized and widely imported ash was from the Levant. European Levantine traders acquired ash specifically from Syria (and sometimes 'less favoured' ashes from Egypt) and imported them throughout Europe,

as far as England, for the manufacture of fine quality glasses[24]. Levantine ash therefore was the preferred alkali source for clear glasses at different manufacturing centres throughout Europe, and so it is no surprise that many glasses at this time have such a similar composition, although they may have been manufactured at different centres. Whilst the Gnalić glasses may indeed all have been manufactured in Italy, even Venice, this active trade in alkalis (as well as glass) and the existence of glassworks in and around Ljubljana, and along the Dalmatian coast, may indicate that the glass could equally have been produced elsewhere using imported alkalis.

Chemical groups related to the use of different sands

Because of the likelihood of the use of imported alkalis from a common source for glass manufacture at different centres throughout Europe, and certainly within Italy, at this time, the use of alkali profiles to discriminate between different glass groups has not proved fruitful. Therefore elements associated with other components in the glass need to be investigated to indicate potential provenance. For *vitrum blanchum* glasses it has been suggested that sand, rather than pure quartz pebbles, was used in production[25]. Therefore those elements which are associated with sands or sediments may be more promising discriminators between glasses produced at different centres. Jacoby[26] notes that whilst *lapis Ticini* (pebbles from the Ticino river), *lapes campanee Verone* (pebbles from the Veronese countryside) and *sablonum de Venetia* (sand from Venice) were used in Murano and other northern Italian glassworks, the former for high quality glasses, glassmakers in central Italy utilised locally available silica sources, imported specific sands for glassmaking or mixed sands[27]. The same may have occurred at other contemporary glassmaking centres.

By far the most common forms of glass found on Gnalić were drinking vessels; the most abundant were two types of very simple undecorated goblet (types S2a and S3a) which together comprise over 3500 vessels. To investigate whether these may have been manufactured at the same place, those elements generally associated with the sands were examined. Iron oxide (Fe_2O_3) and alumina (Al_2O_3) are two components which are generally assumed to enter the glass with the sand, and the positive correlation between the two supports this[28]. However, although both oxides are correlated, each group has different mean concentrations; type S2a has greater than 0.7 wt% Fe_2O_3 and greater than 1.5 wt% Al_2O_3, and type S3a has lower concentrations of Fe_2O_3 and Al_2O_3. These differences may be a feature of a dilution or mixing effect where less sand is used in one glass batch recipe for one type of goblet giving the lower concentration, or when two sands are used but these are mixed in different ratios. When the trace elements barium (Ba) and zirconium (Zr) are plotted for the two glasses we can see two clear groups (fig. 2, except for three samples of S2a which fall into the S3a group). Thus whilst the manufacturing and shaping technology is similar for these two forms, the different styles appear to be manufactured using different raw materials. Although Ba is present at relatively low concentrations in plant ashes[29], its presence in these glasses is more likely to be from sedimentary sources such as sands, and this is supported by the correlation of Ba with other sediment related elements such as Al_2O_3, TiO_2 and Fe_2O_3. Similarly, in these glasses, Zr is strongly correlated with Al_2O_3 and Fe_2O_3, again suggesting its presence in the sand. De Raedt[30] has noted that Zr can be used as a good discriminator for glass provenences – Venetian glasses have Zr concentrations (below 40 ppm) whilst other *façon de Venise* glasses from the Low Countries and other localities outside Italy exhibit much higher Zr concentrations. The low, but different, Zr concentrations in the Gnalić vessels suggest that the two glasses may have been made at different locations, both of which may be Italian (Venetian). That these glasses may be of Italian origin is supported by the low ratio of La:Yb at 5-15, which Šmit *et alii*[31] found at ratios between 10-14 for Venetian *vitrum blanchum* glasses (although there is some debate about this as glasses thought to be of Slovenian origin also had a low ratio).

These compositional differences between groups are mirrored in other styles of glass from the wreck. Two vessels of very similar design, shape and technology are compared; the plain goblet with the low hollow foot and the decorated (mould blown) goblet with the low hollow foot (S2a and S2b[32]). Because of the similarity in design we may expect them to

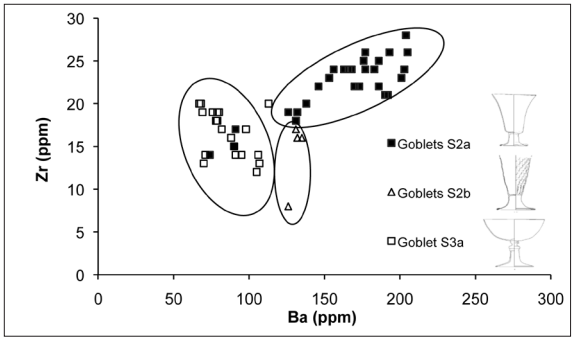

Fig. 2. Zirconium and barium concentrations for the major goblet groups.

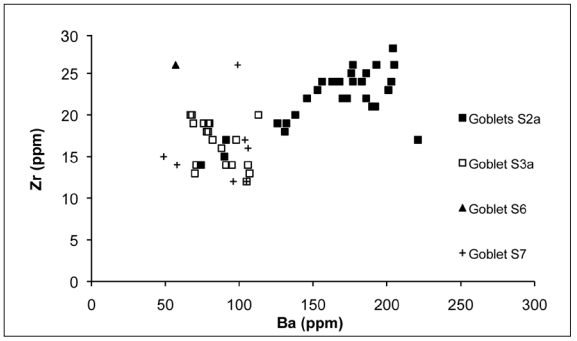

Fig. 3. Distributions of Lion stem goblets [S7(+)] and Ladder stem goblets [S6 (▲)].

be made of the same glass and probably within the same workshop. However, when Ba and Zr and plotted (fig. 2), it is clear that the decorated goblets are compositionally discrete. Three of the four analysed are tightly clustered (which may indicate a similar batch of glass) and fall at the very lower end of the S2a group, and one sample, with similar Ba concentrations, has very low Zr. Analyses of more glasses of this type may confirm this discrete group.

Matching different stylistic groups to compositions to indicate coherence or differences within and between groups is reflected in other vessel styles. Two examples of ladder stem goblets make a discrete and tight compositional group; both samples have such a similar composition that they overlie each other, suggesting they were probably made from the same batch of glass (fig. 3, S6). It has been suggested by Lazar and Willmott[33] that these ladder stem vessels are an English product. Could this explain the difference in composition from the other vessel glasses, or is it likely that these were manufactured in Italy or elsewhere and ultimately destined for an English market rather than being manufactured in England? Although forming a discrete group, they do conform to the general *vitrum blanchum* composition. Conversely, 7 examples of lion mask stem vessels show a different compositional pattern. Although this style of vessel was an Italian innovation, it is likely they were manufactured at other locations throughout Europe[34]. This is reflected in their compositional distribution, which lies as a wide scatter within the *vitrum blanchum* compositional group, with some pairs clustering together, indicative of manufacture at a small number of centres (fig. 3, S7).

Drinking vessels were not the only large consignment of glass amongst the cargo, 1300 pieces of flat glass consisting of mirrors, flat blanks and window glass constituted almost 25% of the remaining assemblage. The flat pieces are clearly cast, and some of these may have been used for mirrors. The window glass came in various standardised disk sizes, all produced by the crown method. With these glasses, there are no stylistic criteria which may help to group these glasses to common manufacturing locations. And, it might be expected that the compositions of these flat pieces would be varied – they are simple to manufacture, do not require any specific colorants or decolourants, and so could be manufactured at almost any centre.

Figure 4 shows that the window and mirror glasses fall within the same general composition of *vitrum blanchum* glasses as the vessels, with low Zr concentrations and diverse Ba concentrations. The cast sheet glass forms a very discrete compositional group – indicating that is may have been manufactured from the same batch of glass, or at least in the same workshop. It also falls within the distribution of the S3a goblets which may suggest a common origin.

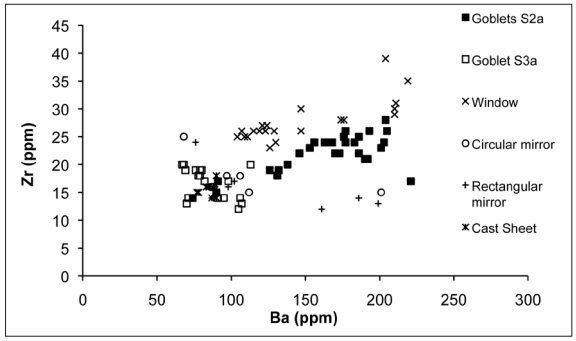

Fig. 4. Compositional distributions of window, mirror and flat glass.

The mirrors, whether rectangular or circular show a wide distribution of Ba concentrations which overlap with each other. They appear to have been made with a variety of different sands and probably at different centres which produced both circular and rectangular shapes. In general, the window glass has a higher concentration of Zr than the other flat glasses, and has a similar but higher ratio of Zr to Ba as the S2a goblets, although the two distributions do not overlap. This is also seen in fig. 1 which shows that the window glasses form a separate group from the other glasses based upon their alkali element ratios, indicative of a different source of alkali. The mirrors and window glass seem to be manufactured at different centres, even though they require very similar glass working technologies. Thus even with very simple glass shapes, and ones which have no distinguishing stylistic features, there seems to be some specialisation between different functional types of glasses which is probably related to location of manufacture.

Comment

What can we conclude from this? The first conclusion is that all the glass analysed from the wreck conforms to a very similar composition, no high quality glasses such as cristallo were found, and all the other glasses, regardless of whether they are vessels, windows or mirrors, are of a composition which matches that defined as *vitrum blanchum* by other researchers. All glasses have low concentrations of Zr which de Raedt[35] suggests may indicate an Italian (possibly Venetian) origin. However, there appear to be different manufacturing groups within this overall composition, which is reflected in differences in trace elements associated with the sands used to manufacture the glasses.

In some cases these compositional groups can be linked to different stylistic groups, indicative of different manufacturing centres specialising in the production of different vessels. This is true even of the very simple shapes such as the plain goblets, or the 'flat cast glass', which potentially could be the mainstay of a number of different glass workshops. Some styles, shapes or functional objects however, were clearly made at a number of centres. The lion stem goblets show a wide variation in composition, as do the mirrors.

Thus, compositional evidence indicates that the glasses are all of the same general composition, but that it is likely these were manufactured at different centres. Are these manufacturing centres widely dispersed within Italy or do these compositions reflect different workshops within a closely defined area? Alternatively, were glasses made elsewhere, outside of Italy? Low Zr concentrations have been used as an indicator of Italian glass production, but Šmit *et alii*[36] have challenged this based on their finds from glasses recovered in Ljubljana. Clearly, the consignment aboard the vessel must have been manufactured within a constrained time period, one which probably did not precede the date of the wreck by more than a year or so, and so the differences in composition cannot be linked to differences over time, giving us an enviable snap-shot of trade in glass at a very specific moment.

How was the cargo assembled, loaded and traded? It is most likely that the ship was conducting point to point trade, where the entire cargo was loaded at a single point of origin and offloaded at its final destination – the complex loading of such a ship with this volume and variety of cargo would suggest that picking up and offloading at many points along the coast would be unrealistic (Radic-Rossi pers. com). The diverse nature of the cargo (of which glass was only one part) would suggest that while the ship may have been loaded at a single port, its cargo was one collected from different manufacturing cen-

tres. Preliminary reports on some of the other finds onboard the ship, such as bells, domestic ceramics, seals and candlesticks indicate provenances in the Baltic, Germany, Piza and Venice[37].

The intended market is also a matter of speculation. As far as the glass is concerned, most of the assemblage is of lower quality plain drinking wares which were for everyday use and relatively low value. The flat glasses for mirrors and windows were of a higher value but again could be destined for almost any market. The existence of small consignments of specialist glassware on the ship would indicate glasses were *produced* for specific (and possibly different) markets as they are all of the same general compositional type, rather than being *products* of widely different geographic centres such as England or the Islamic world.

In conclusion, using our understanding of the material at the present time, the compositional analysis of the glass from the Gnalić shipwreck indicates that the glass cargo on board was all *vitrum blanchum*; subtle differences in composition indicate that different styles of glasses, most notably vessel glasses, were manufactured at different centres. The low concentrations of some trace elements suggest these centres were probably located within Italy, although it is still unclear if *vitrum blanchum* was made only in Italy or further afield. The glass could then have been transported to the ship for loading at a single location, which may have been Venice. The destination of the ship is not known, but the final destination of its cargo may have been multiple locations, with the glass making an onward journey to different markets after being unloaded.

NOTES

1 LAZAR, WILLMOTT 2006.
2 JACKSON 2006.
3 BRUSIĆ 2006, noted in GLUŠČEVIĆ 2006.
4 GASPARETTO 1973.
5 BRUSIĆ 2006.
6 GASPARETTO 1973, p. 81; PETRICIOLI 1973, p. 92.
7 GASPARETTO 1973, p. 81.
8 LAZAR, WILLMOTT 2006, p. 77; BIKIĆ 2006.
9 PETRICIOLI 1973; BRILL 1973.
10 LAZAR AND WILLMOTT 2006, p. 77.
11 LAZAR, WILLMOTT 2006, p. 73.
12 *Studies of deterioration* 2008.
13 GASPARETTO 1973.
14 BRILL 1973.
15 JACKSON 2006.
16 VERITÀ, TONINATO 1990.
17 DE RAEDT 2001.
18 *Spread of Façon-de-Venise* 2004; *Trace element* 2005.
19 ASHTOR, CEVIDALLI 1993.
20 *Spread of Façon-de-Venise* 2004; *Trace element* 2005.
21 *Spread of Façon-de-Venise* 2004; *Trace element* 2005.
22 ASHTOR, CEVIDALLI 1983, p. 504.
23 JACOBY 1993, p. 72.
24 ASHTOR, CEVIDALLI 1983, p. 488.
25 VERITÀ 1985.
26 JACOBY 1993, p. 73.
27 JACOBY 1993, p. 76.
28 JACKSON 2006, p. 89, fig 3.
29 BARKOUDAH, HENDERSON 2006, p. 307.
30 DE RAEDT 2001, p. 1014. *Trace analysis* 2001.
31 *Trace element* 2005.
32 LAZAR, WILLMOTT 2006, p. 27.
33 LAZAR, WILLMOTT 2006, p. 35.
34 LAZAR, WILLMOTT 2006, pp. 35-38.
35 DE RAEDT 2001.
36 *Trace element* 2005.
37 STADLER 2006; MILEUSNIĆ 2006; SCHICK 2006; TERZER 2006.

ABSTRACT

In the 1580s a merchant ship sank off the Croatian coast at Gnalic, close to the modern day town of Biograd. On board was a rich cargo; to date over 4000 glass vessels, as well as crates containing windowpanes and mirror plates have been recovered. The dating of the ship, the location of the wreck on the Adriatic coast, and the types of material being carried, including the large contingent of glass, indicate an Italian provenance, possibly Venetian.
Of the glass vessels recovered, some were stylistically of Italian origin, thus agreeing with this initial assessment. However, the majority of the recovered vessels were plain beakers and goblets of a very simple design, which have no characteristic features to indicate where they were produced. Other vessels could have originated from Central Europe or the Islamic world; their inclusion in the cargo might have been a result of orders for specific markets. The window and mirror glass have no characteristics which would indicate their provenance. Such a mixed assemblage indicates a complex trade pattern for the vessel. With this in mind, chemical analyses of a sample of glasses from the wreck were conducted to establish whether the stylistic groups were compositionally different or had a similar composition indicative of a common manufacturing location, and whether a potential provenance could be assigned to the glass vessels which may provide clues to the direction and trade routes of the ship.

Key words: glass transport, Venice, Adriatic coast, Gnalić, Central Europe, Islamic world, beakers, window and mirror glass.

Un esempio di analisi della composizione: il caso dei vetri del relitto di Gnalić

Negli anni Ottanta del Cinquecento una nave mercantile affondò presso la costa croata di Gnalić, vicino alla città moderna di Biograd (Zaravecchia). A bordo vi era un ricco carico; finora sono stati recuperati oltre 4000 contenitori di vetro, come pure casse contenenti lastre di vetro e specchi. La datazione della nave, la posizione del relitto rispetto alla costa adriatica e le classi di materiale che esso trasportava, compresa l'ampia quantità di vetri, indicano una provenienza dall'Italia, probabilmente da Venezia. In accordo con la valutazione iniziale, si è constatato che alcuni dei recipienti di vetro erano di origine italiana. Tuttavia la maggior parte di essi erano bicchieri e coppe di forma molto semplice, privi di caratteristiche che indichino dove sono stati prodotti. Altri oggetti potrebbero aver avuto origine nel Centro Europa o nel mondo islamico e la loro inclusione nel cargo potrebbe essere stata risultato di ordini per specifici mercati. I vetri per finestre e per specchi non hanno caratteri che rivelano la loro provenienza. Tale assemblaggio misto indica per la nave un complesso modello commerciale. Con queste premesse, sono state effettuate analisi chimiche di un campione di bicchieri dal relitto per stabilire se i gruppi stilistici abbiano composizione diversa o una composizione simile indicativa di un luogo di produzione comune, e se una ipotetica provenienza possa essere assegnata ai recipienti di vetro che possono fornire indizi sulla direzione e le rotte commerciali della nave.

Parole chiave: trasporto marittimo del vetro, Venezia, costa adriatica, Gnalić, Europa centrale, mondo islamico, bicchieri, vetri per finestre e specchi.

REFERENCES

ASHTOR E., CEVIDALLI G. 1983 - *Levantine alkali ashes and European industries*, "Journal of European History", 12, pp. 475-522.

BARKOUDAH Y., HENDERSON J. 2006 - *Plant ashes from Syria and the manufacture of ancient glass: ethnographic and scientific aspects*, "Journal of Glass Studies", 48, pp. 297-321.
BIKIĆ V. 2006 - *Venetian influences in the Eastern Adriatic hinterland*, in *The Heritage* 2006, pp. 201-210.
BRILL R. H 1973 - *Analyses of some finds from the Gnalić wreck*, "Journal of Glass Studies", 15, pp. 93-97.
BRUSIĆ I. 2006 - *Tre naufragi del XVII o XVIII secolo lungo la costa Adriatica orientale*, in *The Heritage* 2006, pp. 63-70.
DE RAEDT I. 2001 - *Composition of 16-17th Century façon-de-Venise Glass Excavated in Antwerp and Neighbouring Cities*, PhD Thesis, University of Antwerp.
GASPARETTO G. 1973 - *The Gnalić wreck: identification of the ship*, "Journal of Glass Studies", 15, pp. 79-84.
GLUŠČEVIĆ S. 2006 - *Previous research on historical glass in the region*, in LAZAR, WILLMOTT 2006, pp. 9-14.
JACKSON C. M. 2006 - *Results of the analysis of the Gnalić glass*, in LAZAR, WILLMOTT 2006, pp. 87-93.
JACOBY D. 1993 - *Raw materials for the glass industries of Venice and the Terraferma, about 1370-about 1460*, "Journal of Glass Studies", 35, pp. 65-90.
LAZAR I., WILLMOTT H. 2006 - *The glass from the Gnalić wreck*, Annales Mediterranea, Koper.
MILEUSNIĆ Z. 2006 - *The pottery from Gnalić wreck*, in *The Heritage* 2006, pp. 106-107.
PETRICIOLI S. 1973 - *The Gnalić wreck: the glass*, "Journal of Glass Studies", 15, pp. 85-92.
SCHICK M. 2006 - *The sleigh bell finds from Gnalić wreck*, in *The Heritage* 2006, pp. 110-112.
Spread of Façon-de-Venise 2004 - Ž. ŠMIT, K. JANSSENS, O. SCHALM, M. KOS, *Spread of Façon-de-Venise glassmaking through Central and Western Europe*, "Nuclear Instruments and Methods in Physics Research", B 213, pp. 717-722.
STADLER H. 2006 - *The brass candlesticks, sconces and chandeliers from Gnalić wreck*, in *The Heritage* 2006, pp. 107-109.
Studies of deterioration 2008 - L. K. HERRERA, A. DURAN, M. L. FRANQUELO, M. C. JIMENEZ DE HARO, A. JUSTO ERBEZ, J. L. PEREZ-RODRIGUEZ, *Studies of deterioration of the tin-mercury alloy within ancient Spanish mirrors*, "Journal of Cultural Heritage", 9, 1, pp. 41-46.
TERZER C. 2006 - *The lead seals from Gnalić wreck*, in *The Heritage* 2006, pp. 112-114.
The Heritage 2006 - *The Heritage of the Serenissima*, a cura di M. GUŠTIN, S. GELICHI, K. SPINDLER, Koper.
Trace analysis 2001 - I. DE RAEDT, K. JANSSENS, J. VEECKMAN, L. VINCZE, B. VEKEMANS, T. E. JEFFRIES, *Trace analysis for distinguishing between Venetian and façon-de-Venise glass vessels of the 16th and 17th century*, "Journal of Analytical Atomic Spectrometry", 16, pp. 1012-1017.
Trace element 2005 - Ž. ŠMIT, K. JANSSENS, E. BULSKA, B. WAGNER, M. KOS, I. LAZAR, *Trace element fingerprinting of Façon-de-Venise glass*, "Nuclear Instruments and Methods in Physics Research B", 239, pp. 94-99.
VERITÀ M., TONINATO T. 1990 - *A comparative analytical investigation on the origins of the Venetian glassmaking*, "Rivista della Stazione Sperimentale del Vetro", 4, pp. 169-175.
VERITÀ M. 1985 - *L'invenzione del cristallo muranese: una verifica analitica delle fonti storiche*, "Rivista della Stazione Sperimentale del Vetro", 1, pp. 17-29.

Caroline JACKSON
Department of Archaeology
University of Sheffield
Sheffield S1 4DT
e-mail: c.m.jackson@sheffield.ac.uk