G Model
CULHER-3512; No. of Pages 8
ARTICLE IN PRESS
Journal of Cultural Heritage xxx (2018) xxx–xxx
Available online at
ScienceDirect
www.sciencedirect.com
Elsevier Masson France
EM|consulte
www.em-consulte.com

Case study

# A Byzantine connection: Eastern Mediterranean glasses in medieval Bari

Elisabetta Neri [a,*], Nadine Schibille [a,*], Michele Pellegrino [b], Donatella Nuzzo [b]

[a] IRAMAT-CEB, UMR5060, CNRS, université d'Orléans, 3D, rue de la Férollerie, 45071 Orléans cedex 2, France
[b] Università degli Studi A. Moro, Complesso Santa Teresa dei Maschi, strada torretta, 70122 Bari, Italy

INFO ARTICLE

*Historique de l'article :*
Reçu le 3 avril 2018
Accepté le 14 novembre 2018
Disponible sur Internet le xxx

*Keywords :*
Egypt II
Lithium
Boron
Soda ash
Recycled natron glass
Southern Italy
Typology

ABSTRACT

The transition from the Roman natron-based glass industry to the medieval ash-based tradition in Italy in the latter part of the first millennium CE is still poorly documented. The compositional data of eighteen glass fragments excavated from the Byzantine praetorium in Bari suggest that the development in the southern part of the Peninsula differs from that in the north. Analyses by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) identified the first significant group of glasses in Italy that were produced in and imported from the eastern Mediterranean during the last two centuries of the first millennium CE. Some samples exhibit the characteristics of early Islamic natron and plant-ash glasses, while two specimens are similar in major and trace element composition to post-Roman glasses most likely manufactured in Byzantine Asia Minor. These represent the only known vessels made from the Byzantine high lithium, high boron glass found so far in the western Mediterranean. The analytical results thus show that being under Byzantine hegemony was advantageous for trade connections in the medieval Mediterranean.



## 1. Introduction

Primary glass making has experienced a significant diversification and numerous technological innovations in the late first millennium CE ([1,2] and references therein). Between the eighth and twelfth centuries, natron-type glass was progressively replaced by either soda-rich plant-ash glass in the Mediterranean area or potash-rich plant-ash glass in central and northern Europe (e.g. [3–7]). These technological changes triggered a re-organization of the primary production in that the glass industry that was once concentrated in only a few locations along the Levantine coast and in Egypt multiplied and became increasingly decentralised. While these technological developments have been extensively studied in the context of northern Italy, little attention has been paid to how the south of the Italian Peninsula was affected by these transformations. Systematic typological and chemical analyses of glass artefacts from numerous sites in northern Italy revealed the exclusive use of Palestinian and Egyptian natron-type glasses until the seventh century CE [8–14]. Thereafter, recycling of these older natron-type glasses becomes increasingly common [9,11]. The first soda-rich plant-ash glasses appear in the Venetian area in the eighth to eleventh century CE, heralding a gradual transition from the use of natron to plant-ash glasses [15]. Venice might in fact have been instrumental in the import of the earliest soda-rich plant-ash glass to the Italian Peninsula, due to its strong cultural and economic link with the eastern Mediterranean [15]. In contrast, there is no systematic study on medieval glass finds from southern Italy. Judging from the small number of available data, imported Levantine and Egyptian natron-type glasses are the principal sources of supply until the sixth century CE as reflected in the glass assemblages from the late antique villa of Faragola [16] and the city of Herdonia [17]. In the seventh to ninth centuries, glass finds in Rome (Crypta Balbi), Salerno and St. Vincenzo al Volturno consist mainly of recycled natron glass [18–21]. To date, no soda-rich plant-ash glass has been identified among early medieval glass assemblages from southern Italy, implying a glass consumption model that is principally dependent on recycling.

This paper presents new archaeometric data of glass finds from medieval Bari to re-assess the trade and use of glass in southern Italy during a period when glass making changed dramatically. The material under investigation comes from the praetorium in the city of Bari in the south Italian region of Apulia. Bari had been hotly contested by the Lombards, Byzantines, Arabs, Berbers and Normans due to its strategic position on the Adriatic Sea [22–24]. After the establishment of the Byzantine Theme of Longobardia in the second half of the ninth century, later the catepanate of Italy, Bari

* Corresponding authors.
*Adresse e-mail :* nadine.schibille@cnrs-orleans.fr (N. Schibille).

https://doi.org/10.1016/j.culher.2018.11.009


Pour citer cet article : E. Neri, et al., A Byzantine connection: Eastern Mediterranean glasses in medieval Bari, Journal of Cultural Heritage (2018), https://doi.org/10.1016/j.culher.2018.11.009

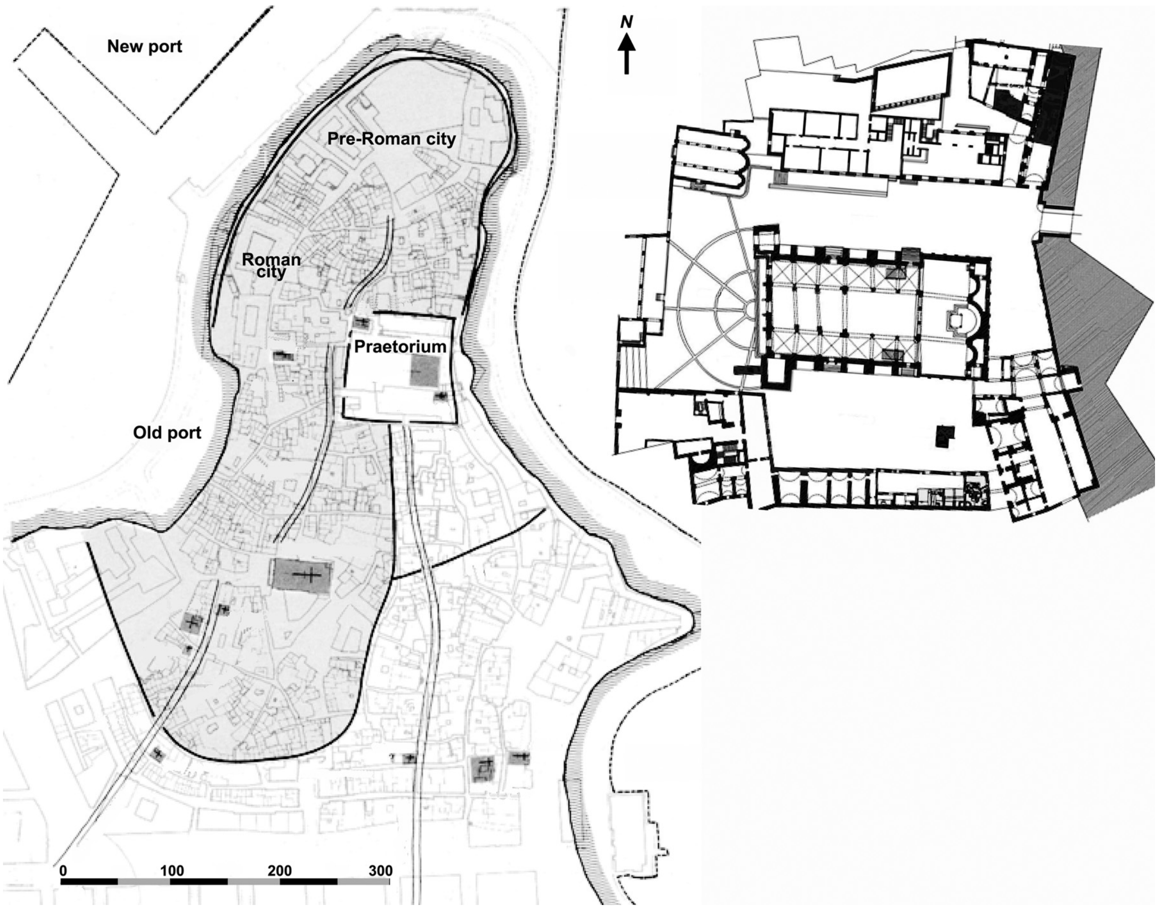


**Fig. 1.** Byzantine Bari and the Basilica of San Nicola. Left panel: Plan of the Byzantine city indicating the location of the praetorium; right panel: magnified ground plan of the 12th-century basilica (both adapted from [28]).

became the official residence of the Byzantine governor [25]. During Byzantine rule, the city and the territory of Bari were engaged in extensive commercial activities. Pottery finds show, for instance, that the city was able to sustain a varied pottery production, while at the same time specialised ceramics were imported [26]. Among the finds recovered during the excavations at Bari were numerous glass artefacts [27] that provide an ideal case study to explore the changing patterns of supply during the transitional period from natron-type glasses to plant-ash based recipes. We analysed the chemical composition of eighteen samples to determine the main glass types that were used in Bari and to discuss how the supply of glass to the city was affected by the new developments in glass making technologies.

## 2. Materials and methods

### 2.1. Archaeological context

The glass finds under investigation were recovered in the area of the praetorium, the seat of the Byzantine administration that was later occupied by the Basilica of San Nicola. Excavations conducted between 1980 and 2000 confirmed the location of the praetorium and revealed a complex archaeological sequence with three main phases. An early domestic phase, dating to the fourth to seventh century was followed by a public building connected to the development of the Byzantine praetorium in the ninth to eleventh century. Finally, the citadel was built in the second half of the thirteenth century CE during the Angiò reign (1266–1302 CE). The glass samples were retrieved from the first two phases in front of the southern bell-tower of the Basilica of San Nicola excavated in 1982, and inside the courtyard of abbot Elias to the south of the basilica during excavations in 1987 (Fig. 1). In both areas, the Byzantine nine- to eleventh- century structures were built over a late antique phase of occupation [28].

### 2.2. The glass artefacts

Eighteen glass artefacts were selected from a total of eighty-six fragments found in the praetorium of Bari. These samples were selected to cover the transitional period from natron to plant-ash glasses and to represent the entire range of typological categories encountered at the site. Their relative number reflects the overall occurrence of the individual types and in terms of colours, they range from colourless, to yellowish green and light green (Table 1). Thirteen samples (BA 03, 04, 07–17) can be attributed to the Byzantine period between the reigns of emperor Theophilos (829–842) and the Komnenoi (1005–1071) (Table 1). The remaining five samples (BA 01, 02, 05, 06, 18) have a relatively wide chronological span from the fifth to the eleventh century based on numismatic and ceramic evidence [27] that may occasionally be refined based on the glass type (see below).

Most of the forms correspond to common domestic ware (goblets, cups, bottles) and lamps (Fig. 2) of late antique typologies that are found all over the Mediterranean, including southern Italy (e.g. [27,29–31]). There are three types of plain beakers, Isings106b (BA 02) with a rounded edge and a grooved decoration under the

**Table 1**
LA-ICP-MS data of the eighteen glass samples from Bari (including typological and archaeological data). Major and minor oxides including chlorine [wt %], and trace elements [ppm].

| | Samples | Colour | Typology | Context | Archae. date | $Na_2O$ | MgO | $Al_2O_3$ | $SiO_2$ | $P_2O_5$ | Cl | $K_2O$ | CaO | $TiO_2$ | MnO | $Fe_2O_3$ | Li | B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Roman Sb | BA 03 | Colourless | Isings 111 | s. I, US 117 | 9–11th | 18.5 | 0.40 | 1.88 | 69.9 | 0.02 | 1.11 | 0.42 | 6.43 | 0.07 | 0.01 | 0.35 | 3.32 | 170 |
| Egypt II | BA 04 | Light green | Isings 111 | s. I, US 117 | 9–11th | 13.6 | 0.69 | 2.48 | 69.7 | 0.12 | 1.12 | 0.35 | 8.79 | 0.27 | 1.38 | 1.27 | 4.57 | 90.0 |
| | BA 05 | Light green | Goblet, Corinthian type | s. I, US 112 | 5–11th | 13.5 | 0.69 | 2.55 | 69.7 | 0.12 | 1.13 | 0.35 | 8.93 | 0.28 | 1.40 | 1.27 | 4.05 | 89.5 |
| | BA 09 | Light green | Small bowl, linear impressions | s. I, US 126 | 9–11th | 15.3 | 0.53 | 2.31 | 68.9 | 0.07 | 1.16 | 0.62 | 9.78 | 0.28 | 0.02 | 0.90 | 4.09 | 71.9 |
| | BA 10 | Light green | Bottle, short neck | s. I, US 117 | 9–11th | 14.2 | 0.73 | 2.43 | 69.4 | 0.14 | 1.04 | 0.41 | 9.94 | 0.29 | 0.25 | 1.07 | 4.96 | 95.6 |
| HLiB | BA 13 | Yellow-green | Variation Isings 106b | s. I, US 117 | 9–11th | 13.3 | 2.67 | 2.89 | 65.3 | 0.08 | 0.20 | 1.61 | 11.1 | 0.13 | 0.02 | 1.51 | 469 | ### |
| | BA 17 | Yellow-green | Isings 111 | s. I, US 3D-4E | 9–11th | 16.6 | 1.51 | 1.88 | 67.5 | 0.12 | 0.65 | 1.05 | 8.45 | 0.10 | 0.33 | 0.93 | 228 | ### |
| Soda ash | BA 01 | Colourless | Isings 106c | s. I, US 139 | 5–11th | 11.6 | 3.18 | 1.67 | 70.0 | 0.34 | 0.85 | 2.15 | 8.35 | 0.09 | 1.16 | 0.51 | 5.36 | 87.8 |
| | BA 07 | Colourless | Isings 111 | s. I, US 117 | 9–11th | 13.7 | 2.23 | 2.04 | 69.2 | 0.25 | 0.76 | 1.56 | 8.62 | 0.09 | 0.65 | 0.64 | 20.8 | 353 |
| Natron | BA 02 | Colourless | Isings 106b | s. I, US 130 | 5–11th | 16.5 | 0.95 | 2.38 | 68.1 | 0.14 | 0.88 | 1.06 | 7.57 | 0.11 | 0.79 | 0.78 | 10.3 | 152 |
| recycled | BA 06 | Colourless | Goblet, Corinthian type | s. I, US 112 | 5–11th | 16.5 | 0.75 | 2.53 | 68.2 | 0.14 | 0.82 | 1.07 | 7.29 | 0.12 | 0.71 | 0.83 | 19.0 | 155 |
| | BA 08 | Light green | Goblet, local type | s. I, US 117 | 9–11th | 15.7 | 1.69 | 2.72 | 67.5 | 0.16 | 0.69 | 0.98 | 7.52 | 0.17 | 0.78 | 1.38 | 8.72 | 136 |
| | BA 11 | Colourless | Isings 111 | s. I, US 123 | 9–11th | 17.4 | 0.75 | 2.36 | 68.2 | 0.11 | 0.98 | 0.65 | 7.38 | 0.13 | 0.79 | 0.78 | 6.42 | 153 |
| | BA 12 | Light green | Isings 111 | s. I, US 117 | 9–11th | 14.8 | 0.99 | 2.38 | 68.5 | 0.11 | 0.99 | 0.72 | 8.90 | 0.24 | 0.68 | 1.06 | 8.09 | 91.9 |
| | BA 14 | Light green | Isings 111 | s. I, US 115 | 9–11th | 16.2 | 0.88 | 2.46 | 67.7 | 0.17 | 0.85 | 1.10 | 8.07 | 0.14 | 0.82 | 0.88 | 10.8 | 151 |
| | BA 15 | Light green | Isings 111 | s. I, US 115 | 9–11th | 15.9 | 0.64 | 2.43 | 68.6 | 0.11 | 0.92 | 0.61 | 8.42 | 0.18 | 0.49 | 0.90 | 7.21 | 118 |
| | BA 16 | Light green | Isings 111 | s. I, US 3D–4E | 9–11th | 16.7 | 0.71 | 2.59 | 67.9 | 0.14 | 0.75 | 1.02 | 7.41 | 0.11 | 0.76 | 0.81 | 9.24 | 151 |
| | BA 18 | Light green | Isings 111 | s. I, US 19A | 5–11th | 17.8 | 0.82 | 2.30 | 67.6 | 0.12 | 1.08 | 0.62 | 6.68 | 0.19 | 0.97 | 0.94 | 5.11 | 169 |

| V | Cr | Co | Ni | Cu | Zn | Ga | As | Rb | Sr | Y | Zr | Nb | Mo | Ag | Cd | In | Sn | Sb | Cs | Ba | La | Ce | Pr | Nd | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | Hf | Ta | W | Pb | Bi | Th | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.13 | 9.70 | 1.06 | 2.40 | 6.65 | 15.2 | 2.45 | 16.9 | 4.96 | 471 | 4.94 | 48.8 | 1.41 | 0.14 | 0.15 | 0.16 | 0.00 | 0.69 | 6132 | 0.06 | 127 | 5.29 | 9.21 | 1.12 | 4.53 | 0.91 | 0.24 | 0.76 | 0.13 | 0.76 | 0.16 | 0.43 | 0.06 | 0.44 | 0.07 | 1.13 | 0.07 | 0.03 | 29.5 | 0.03 | 0.83 | 0.95 |
| 24.9 | 29.4 | 4.93 | 9.40 | 6.88 | 128 | 4.40 | 2.31 | 5.40 | 182 | 6.90 | 187 | 4.01 | 0.56 | 0.10 | 0.19 | 0.01 | 0.35 | 1.20 | 0.07 | 323 | 7.33 | 13.7 | 1.59 | 6.29 | 1.36 | 0.35 | 1.02 | 0.17 | 1.11 | 0.24 | 0.67 | 0.10 | 0.66 | 0.11 | 3.99 | 0.21 | 0.09 | 7.61 | 0.01 | 1.52 | 1.19 |
| 24.6 | 29.9 | 4.93 | 9.51 | 6.89 | 128 | 4.54 | 2.34 | 5.32 | 185 | 7.16 | 192 | 3.98 | 0.54 | 0.09 | 0.15 | 0.01 | 0.37 | 0.44 | 0.05 | 327 | 7.40 | 13.9 | 1.65 | 6.75 | 1.31 | 0.33 | 1.08 | 0.19 | 1.13 | 0.24 | 0.68 | 0.10 | 0.73 | 0.11 | 4.06 | 0.20 | 0.09 | 8.84 | 0.00 | 1.57 | 1.20 |
| 21.3 | 27.0 | 2.62 | 5.60 | 3.17 | 13.8 | 3.29 | 0.79 | 4.70 | 167 | 6.70 | 226 | 4.00 | 0.12 | 0.09 | 0.06 | 0.01 | 0.31 | – | 0.04 | 155 | 7.39 | 13.7 | 1.57 | 6.51 | 1.29 | 0.31 | 1.01 | 0.18 | 1.08 | 0.22 | 0.63 | 0.09 | 0.69 | 0.11 | 4.70 | 0.21 | 0.07 | 1.94 | 0.01 | 1.59 | 1.00 |
| 23.2 | 28.1 | 12.2 | 7.27 | 44.1 | 44.8 | 3.49 | 1.44 | 4.71 | 194 | 7.07 | 207 | 3.96 | 0.33 | 0.28 | 0.11 | 0.02 | 3.12 | 3.14 | 0.06 | 177 | 7.73 | 14.2 | 1.66 | 6.54 | 1.33 | 0.33 | 1.07 | 0.18 | 1.10 | 0.23 | 0.66 | 0.10 | 0.70 | 0.11 | 4.37 | 0.20 | 0.07 | 59.1 | 0.01 | 1.59 | 0.92 |
| 24.6 | 73.4 | 6.85 | 73.4 | 6.64 | 24.4 | 4.57 | 30.9 | 91.1 | ### | 5.04 | 31.3 | 3.10 | 0.86 | 0.01 | 0.02 | 0.01 | 0.55 | 55.2 | 61.5 | 79.6 | 8.27 | 15.4 | 1.60 | 6.19 | 1.18 | 0.23 | 0.89 | 0.15 | 0.86 | 0.17 | 0.46 | 0.06 | 0.46 | 0.07 | 0.73 | 0.17 | 0.43 | 1.58 | 0.01 | 2.77 | 1.32 |
| 19.7 | 32.0 | 17.1 | 32.1 | 265 | 43.2 | 2.82 | 39.2 | 31.7 | ### | 5.30 | 42.9 | 1.94 | 1.45 | 0.41 | 0.05 | 0.01 | 70.7 | 313 | 16.9 | 144 | 6.09 | 11.4 | 1.22 | 4.91 | 1.02 | 0.25 | 0.78 | 0.13 | 0.84 | 0.17 | 0.49 | 0.07 | 0.46 | 0.07 | 0.99 | 0.12 | 0.24 | 808 | 0.17 | 1.54 | 1.64 |
| 14.2 | 12.6 | 3.44 | 7.90 | 38.9 | 31.8 | 3.11 | 2.51 | 14.0 | 413 | 6.14 | 37.3 | 1.76 | 3.23 | 0.04 | 0.05 | 0.01 | 0.25 | 0.08 | 0.14 | 230 | 6.50 | 12.0 | 1.48 | 6.49 | 1.32 | 0.33 | 1.15 | 0.17 | 1.01 | 0.21 | 0.52 | 0.07 | 0.44 | 0.07 | 0.85 | 0.09 | 0.33 | 4.06 | 0.01 | 0.82 | 0.36 |
| 16.4 | 15.6 | 16.2 | 10.8 | 110 | 37.5 | 3.01 | 32.5 | 15.5 | 393 | 5.78 | 42.6 | 1.85 | 3.05 | 0.41 | 0.12 | 0.02 | 13.3 | 5.82 | 1.57 | 208 | 5.99 | 11.0 | 1.31 | 5.26 | 1.06 | 0.26 | 0.93 | 0.15 | 0.89 | 0.19 | 0.51 | 0.07 | 0.48 | 0.07 | 1.03 | 0.13 | 0.36 | 277 | 0.07 | 1.21 | 1.60 |
| 21.7 | 18.8 | 30.1 | 12.4 | 935 | 59.7 | 3.47 | 12.7 | 15.0 | 474 | 6.80 | 67.7 | 2.09 | 2.24 | 1.19 | 0.11 | 0.00 | 259 | 1823 | 0.29 | 274 | 7.30 | 12.3 | 1.48 | 6.22 | 1.26 | 0.32 | 1.10 | 0.17 | 1.07 | 0.22 | 0.59 | 0.09 | 0.58 | 0.10 | 1.49 | 0.12 | 0.35 | ### | 0.23 | 1.22 | 0.95 |
| 22.1 | 16.5 | 35.7 | 10.4 | ### | 102 | 3.87 | 18.7 | 23.0 | 452 | 7.17 | 67.2 | 2.56 | 2.14 | 1.58 | 0.13 | 0.00 | 188 | 3119 | 0.62 | 290 | 8.41 | 14.3 | 1.73 | 6.81 | 1.43 | 0.36 | 1.14 | 0.18 | 1.06 | 0.23 | 0.63 | 0.08 | 0.64 | 0.09 | 1.49 | 0.12 | 0.52 | ### | 0.22 | 1.48 | 1.01 |
| 25.9 | 48.7 | 35.6 | 39.5 | ### | 108 | 4.14 | 13.3 | 16.0 | 416 | 7.79 | 88.6 | 2.60 | 2.06 | 0.61 | 0.07 | 0.00 | 216 | 1702 | 0.30 | 294 | 8.54 | 14.5 | 1.77 | 7.17 | 1.38 | 0.35 | 1.17 | 0.21 | 1.20 | 0.25 | 0.68 | 0.11 | 0.69 | 0.11 | 1.96 | 0.15 | 0.31 | ### | 0.16 | 1.51 | 1.01 |
| 23.8 | 19.3 | 14.0 | 11.4 | 607 | 42.8 | 3.35 | 11.8 | 9.76 | 450 | 7.22 | 70.6 | 2.04 | 1.95 | 0.56 | 0.09 | 0.00 | 79.8 | 1441 | 0.15 | 284 | 7.41 | 12.6 | 1.54 | 6.36 | 1.27 | 0.35 | 1.15 | 0.18 | 1.13 | 0.24 | 0.61 | 0.10 | 0.60 | 0.09 | 1.54 | 0.11 | 0.29 | 581 | 0.07 | 1.11 | 0.98 |
| 22.8 | 27.9 | 74.3 | 11.1 | 408 | 96.2 | 3.60 | 7.08 | 7.65 | 268 | 6.95 | 169 | 3.48 | 1.23 | 2.67 | 0.11 | 0.06 | 259 | 1309 | 0.11 | 225 | 7.59 | 13.9 | 1.60 | 6.39 | 1.31 | 0.34 | 1.09 | 0.18 | 1.07 | 0.24 | 0.65 | 0.09 | 0.69 | 0.11 | 3.54 | 0.18 | 0.17 | ### | 0.14 | 1.50 | 1.01 |
| 23.0 | 20.3 | 38.8 | 13.0 | 869 | 66.7 | 3.68 | 11.5 | 16.5 | 483 | 7.14 | 84.7 | 2.36 | 2.34 | 1.40 | 0.07 | 0.00 | 371 | 1493 | 0.27 | 295 | 7.72 | 13.3 | 1.61 | 6.60 | 1.30 | 0.35 | 1.19 | 0.18 | 1.12 | 0.24 | 0.63 | 0.09 | 0.61 | 0.10 | 1.91 | 0.13 | 0.48 | ### | 0.30 | 1.34 | 1.03 |
| 21.6 | 22.3 | 26.7 | 9.41 | 930 | 62.5 | 3.47 | 9.85 | 10.6 | 321 | 6.88 | 121 | 2.87 | 1.32 | 0.82 | 0.12 | 0.00 | 261 | 1622 | 0.20 | 232 | 7.48 | 13.2 | 1.58 | 6.31 | 1.30 | 0.33 | 1.07 | 0.18 | 1.06 | 0.23 | 0.63 | 0.09 | 0.61 | 0.10 | 2.67 | 0.15 | 0.31 | ### | 0.18 | 1.39 | 0.99 |
| 22.6 | 15.7 | 24.8 | 10.1 | ### | 76.4 | 3.65 | 17.5 | 21.6 | 465 | 7.06 | 63.1 | 2.26 | 2.22 | 1.21 | 0.11 | 0.00 | 198 | 3286 | 0.54 | 296 | 7.87 | 13.6 | 1.61 | 6.54 | 1.33 | 0.35 | 1.08 | 0.19 | 1.10 | 0.23 | 0.63 | 0.09 | 0.58 | 0.09 | 1.43 | 0.12 | 0.59 | ### | 0.24 | 1.37 | 1.07 |
| 26.4 | 26.4 | 46.3 | 12.7 | ### | 50.7 | 3.76 | 17.6 | 11.1 | 456 | 7.47 | 110 | 2.66 | 2.75 | 0.89 | 0.13 | 0.03 | 123 | 2670 | 0.20 | 354 | 7.88 | 13.3 | 1.61 | 6.72 | 1.36 | 0.35 | 1.13 | 0.19 | 1.15 | 0.25 | 0.66 | 0.09 | 0.67 | 0.10 | 2.34 | 0.13 | 0.47 | ### | 0.17 | 1.34 | 0.97 |

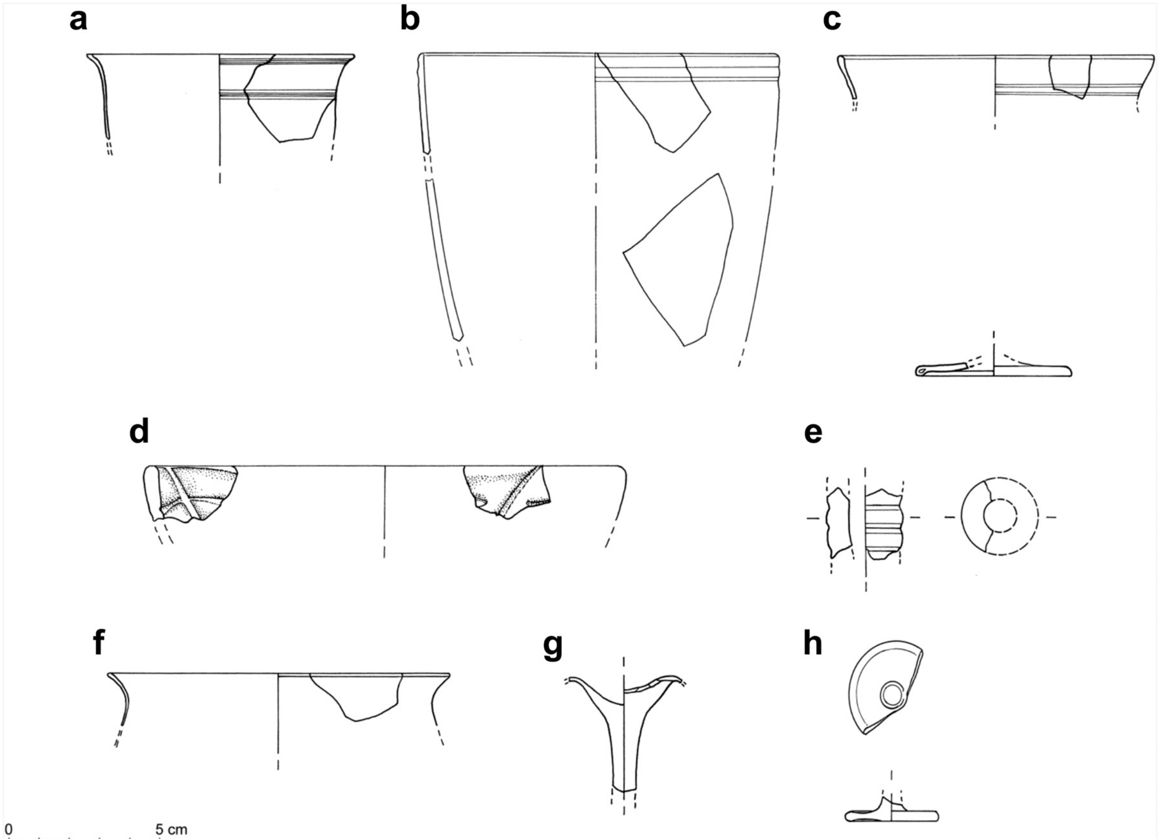


**Fig. 2.** Selection of analysed samples from Bari according to object types; a: Isings 106b type (sample BA 02); b: Isings 106c (BA 01); c: Isings 111 (BA 04); d: small bowl with linear impressions (BA 09); e: small bottle with a short neck and horizontal rings (BA 10); f: goblet of Corinthian type Dav. 12.716 (BA 05); g: stemmed goblet of Corinthian type Dav. 12.718 (BA 06); h: goblet with discoid base and solid stem (BA 08); (drawings: V. Acquafredda, M. Pellegrino).

rim, Isings 106c (BA 01) with unworked rim and a wheel-engraved decoration on the body, and a conical beaker (BA 13) with a concave base related to Isings 106b. The most prevalent vessel types are stemmed goblets, used as drinking vessels or lamps. These goblets circulated between the fifth and the eleventh century CE, displaying some variability in form but without any major technical and morphological differences [29,31]. They usually have simple shapes either conical (BA 03, 11, 14, 17), bell-shaped (BA 04) or globular (BA 05), with rounded edges and a tubular base ring (BA 07, 12, 15, 16, 18). A few objects belong to medieval Corinthian types (BA 05, 06) ([32] Fig. 12.716, 12.718) that have previously been identified in southern Italy in ninth- to eleventh-century contexts [33], while a goblet with a discoid base and solid stem (BA 08) possibly represents the output of a local production, since limited comparable material is known from southern Italy [34,35]. Their chronological occurrence allows us to constrain the date for these samples to the ninth to eleventh century CE. Finally, two remarkable pieces have the closest parallels in the early Islamic world. One fragment (BA 09) is a small bowl with a rounded rim and straight walls, decorated with linear impressions that have been obtained by tongs (Fig. 2). It is considered an unicum in the archaeological record of southern Italy, whereas numerous finds with similar patterns have been recovered from several sites in the eastern Mediterranean dating to the ninth to tenth century CE [27]. The other sample (BA 10) belongs to a small bottle with a short cylindrical ridged neck and horizontal rings around the neck (Fig. 2). Bottles with similar morphological features were quite common in Egypt, Israel, Syria, Iran and Iraq [27]. Hence, these two vessel typologies appear to have been developed in glass workshops of the Islamic east during the Umayyad and early Abbasid period.

### 2.3. Analytical methods

The cleaned, but otherwise unprepared glass fragments were first inspected under the stereomicroscope to determine their colour and subsequently analysed by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) at the Centre Ernest Babelon (CEB) of IRAMAT in Orléans using a Thermofisher Element XR combined with a Resonetic UV laser microprobe (ArF 193 nm). The analytical set-up and protocol as well as the conversion into fully quantitative results have previously been described in detail [36,37]. The analytical precision and accuracy of the measurements established by the repeated analysis of Corning A, B and D and NIST 612 are given as Appendix A, Supplementary material (Table S1). Accuracy is generally better than 5% relative for most major and minor elements, and better than 10% for most trace elements.

## 3. Results and discussion

### 3.1. Bari compositional groups

The glass finds from Bari are all soda-lime-silica glasses (Table 1), the majority of which classify as mineral soda glass with low magnesium and potassium oxide concentrations (< 1.5%), while three samples (BA 01, 07, 13) have elevated levels of both potash and magnesia (> 1.5%) conventionally attributed to the use of plant ash as the fluxing agent (Fig. 3a) [38]. The strontium to calcium ratios, alumina and soda levels of two of these samples (BA 01, 07) are consistent with soda-rich plant ash glasses from the eastern Mediterranean. In contrast, sample BA 13, together with sample BA 17 have unusually high strontium relative to calcium and exceptionally high lithium and boron concentrations (Fig. 3b, c). The

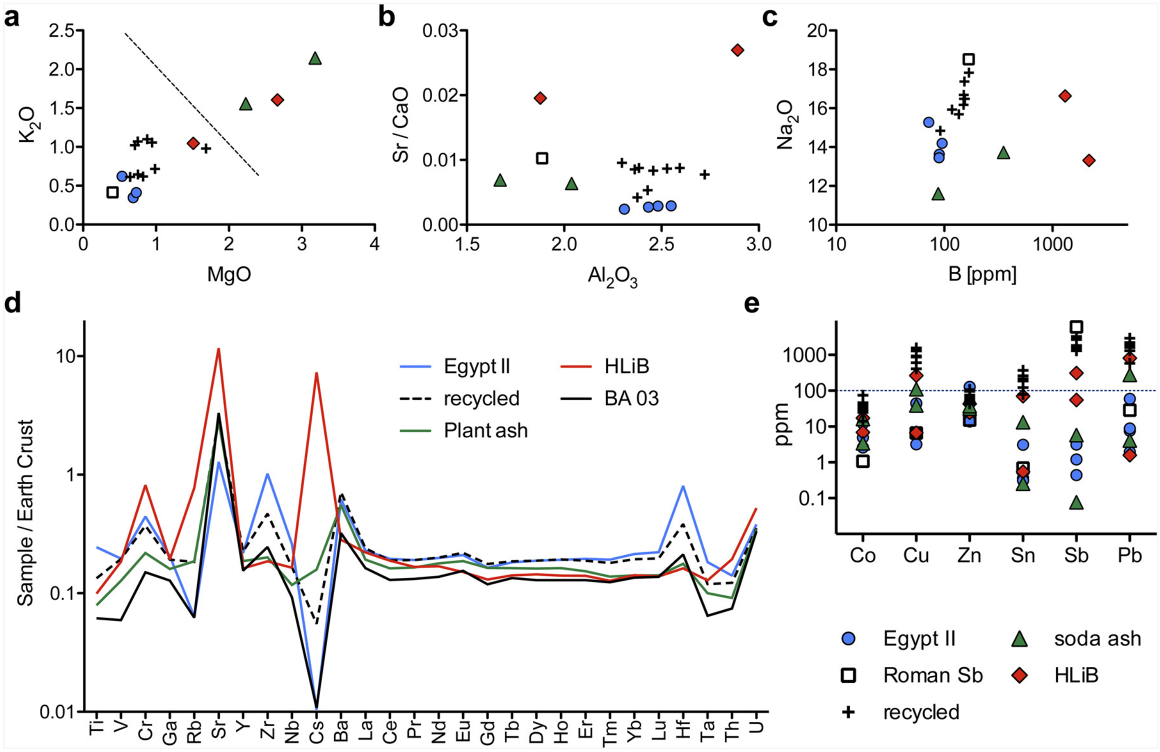


**Fig. 3.** Base glass characteristics of the glass samples from Bari; a: potash and magnesia concentrations separate the natron-type glasses from plant ash glasses; b: strontium to lime ratios versus alumina levels identify different raw ingredients. The low strontium levels of Egypt II are reflective of calcareous rocks and thus a continental silica source; c: soda and boron levels distinguish different glassmaking recipes; d: average trace element patterns of the five different glass groups from Bari normalised to the mean values of the upper continental earth crust [39]; e: elevated levels of transition metals point to a high incidence of recycling.

two samples also show trace element patterns (e.g. Cr, Rb, Cs, Th) that diverge from the profiles usually encountered in natron-type glasses of Levantine and/or Egyptian origin (Fig. 3d) [39], identifying different raw materials. Sample BA 17 exhibits furthermore clear signs of recycling in the form higher than usual magnesium and potassium oxides levels (Fig. 3a) and elevated copper, tin, antimony and lead (Fig. 3e).

The mineral soda glasses can be subdivided based on their major, minor and trace element contents (Fig. 3). Four samples (BA 04, 05, 09, 10) with moderate levels of aluminium oxide (about 2.4%) and soda (about 14%), high levels of titanium, zirconium and lime, and low strontium contents are clearly affiliated with ninth-century Egypt II [40]. Nine samples (BA 02, 06, 08, 11, 12, 14, 15, 16, 18) show intermediate compositional characteristics with lower heavy elements, somewhat higher strontium to calcium ratios and higher soda concentrations compared to the Egypt II samples (Fig. 3a–c). All nine samples have elevated concentrations (> 100 ppm) of copper, tin, antimony and lead, and to a lesser extent copper and zinc (Fig. 3e) as well as potash (Fig. 3a). It is generally accepted that recycling has an impact on the baseline levels of colouring, decolouring and opacifying elements due to the accidental introduction of coloured cullet to the glass melt, in addition to the contamination with fuel ash and components in the furnace atmosphere such as potash [41,42]. Hence, given the substantial contaminations through colouring agents, more than half of the analysed glasses from Bari exhibit clear signs of recycling and mixing of different types of natron base glasses some of which were presumably coloured and opacified. Interestingly, the samples made from this recycled glass represent either late antique forms (Isings 106 and 111) or local products (BA 06, 08) [34]. Judging from the relatively low strontium levels of some of these recycled glasses (BA 12, 15, Fig. 3b), it is reasonable to assume that part of the cullet was of the Egypt II type, while the elevated contents of antimony suggest the recycling of Roman glass (Fig. 3e).

One sample (BA 03) differs sharply on account of its low levels of silica-related contaminants such as calcium, trace and rare earth elements, concurrent with low potash and magnesia and high soda contents (Fig. 3). These features together with high levels of antimony (6132 ppm) identify this sample as Roman antimony decoloured glass (Table 1). Typologically, this sample belongs to the Isings 111 family that was very common during the late Roman and early medieval period up to the eighth century CE [43]. The fact that this sample with a virtually pristine Roman antimony glass signature and a late antique typology was retrieved from a ninth- to tenth-century context suggests either that this object had survived intact or that it was residual material from the earlier occupation at the site.

The chromatic scale of the glass finds does to some degree coincide with the compositional groups. All Egypt II samples show a light green colour independent of the iron and manganese contents, the high lithium / high boron glasses express a more intense yellowish green colour, possibly due to the very low manganese contents insufficient to act successfully as decolorant, and the soda ash glasses are virtually colourless (Table 1). The group of recycled glass range from colourless to light green contingent on the manganese to iron ratios and the latter's oxidation state.

### *3.2. Glass consumption and supply in medieval Bari*

The high incidence of eighth- to ninth-century Egyptian glasses among the Bari assemblage in the form of recycled as well as largely unadulterated Egypt II fragments is remarkable, especially when compared to other Italian sites. Finds of Egypt II glass are generally rare outside of Egypt. However, some specimens have been identified among glasses from Syria-Palestine [2,44,45] and in some isolated cases in Italy [20], Spain [46] and Albania [47]. The presence of four samples of the Egypt II type that have not undergone substantial recycling and mixing can be explained by the relative

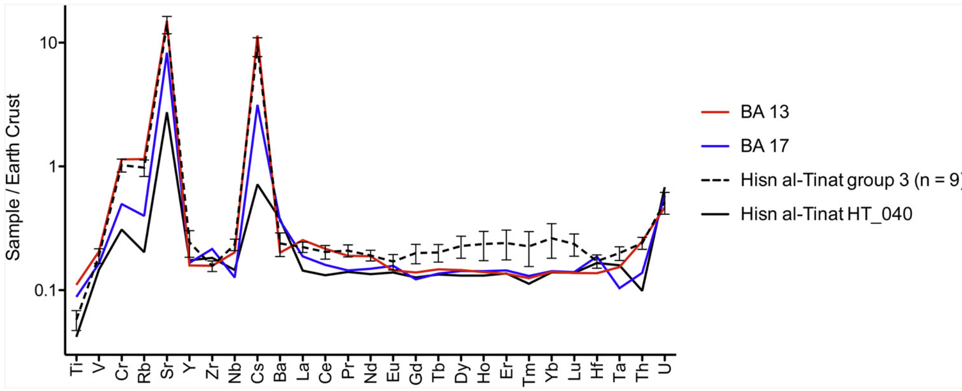


**Fig. 4.** Trace element patterns of the high lithium, high boron glass from Bari in comparison with similar samples from Hisin al-Tinat [52]. Averages were normalised to the mean values of the upper continental earth crust [39], standard deviations of the Hisin al-Tinat assemblage are given as error bars. HT_040 was singled out, because it shows a very similar REE profile to the samples from Bari.

chronology of this primary production group. Egypt II is attributed to between the last quarter of the eighth and the first three quarters of the ninth century CE [40]. Archaeologically, three of the four samples from Bari are dated to the ninth to eleventh century CE, while the date of sample BA 05 (Table 1) can now be refined to the late eighth to eleventh century CE due to its Egypt II signature. Two of the Egypt II samples, one bell-shaped goblet with white trail decoration (BA 04), the other a globular goblet (BA 05), cannot be unambiguously attributed to a specific secondary workshop tradition even though the latter is associated with a Corinthian type [32]. The other two Egypt II samples (BA 09 and 10), however, represent early Islamic vessel types from the ninth to tenth century similar to samples from the eastern Mediterranean, but scarce or non-existent in the Italian Peninsula [27]. Taken together the different pieces of evidence point to the import of finished glass artefacts, and possibly raw glass, from Islamic Egypt in the ninth or tenth century CE.

The two plant ash glasses from Bari (BA 01 and 07) have been produced from halophytic plants in line with the eastern Mediterranean soda-rich plant ash glass tradition [1,7]. With moderate magnesium and potassium concentrations (1.5% < MgO, $K_2O$ < 3.5%) and relatively low silica-related impurities such as aluminium, titanium and zirconium (Fig. 3, Table 1), their closest parallels are found in Syria-Palestine [1]. These two samples thus provide the first clear evidence of the import of soda-rich plant ash glass from the Islamic east to Byzantine southern Italy. This is reminiscent of the situation in north-eastern Italy, where soda-rich plant ash glasses from the eastern Mediterranean arrived as early as the eight/ninth century CE [10,15]. The two vessels from Bari correspond to late antique typologies (Isings 106, 111), and archaeologically they are attributed to the fifth to eleventh century (BA 01) and the ninth to eleventh century (BA 07). Given the soda-rich plant ash signature, however, the date of sample BA 01 can be attributed to the eighth century or later, when plant ash glasses begin to spread in the Islamic east. This clearly reflects the longevity of Isings 106 and 111 well into the early Middle Ages.

An ongoing economic and cultural exchange with the eastern Mediterranean is substantiated by the presence of Byzantine high lithium and high boron glasses. The high levels of lithium, boron and strontium reflect raw materials that are different from known first millennium primary production groups in Egypt and the Levant. It has been proposed that a mineral soda might have been extracted from the borate lakes of central Turkey for the production of these high boron glasses [48], supporting the hypothesis of primary glass making in Asia Minor, as first proposed by Robert Brill [49]. A primary production location in Asia Minor also implies the use of different silica sources, which may explain some of the atypical trace element patterns and increases in silica related contaminants such as chromium, nickel, thorium and above all caesium (Fig. 3d). In most other glasses caesium occurs at values below 1 ppm, whereas the high boron glasses reach levels of Cs in excess of 60 ppm (Table 1) [50,51] that is probably linked to the silica source [52]. Furthermore, there is evidence of two different high boron glass-making recipes, one based on mineral soda, the other using a plant ash component [49–51,53]. While mineral soda probably underlies sample BA 17, sample BA 13 with both magnesium and potassium oxides in excess of 1.5% is more likely the result of the addition of plant ash. High boron glasses have seldom been found outside of Asia Minor, only some isolated examples are known from Greece, Venice and Rome [50]. In terms of the lithium, boron and strontium levels, the two samples from Bari resemble a group of middle and late Byzantine glasses from Pergamon [50], and tenth- to twelfth-century bracelets from Hisin al-Tinat (Turkey) [51]. However, the glasses from Pergamon have consistently higher alumina contents (> 5%) and clearly represent a different primary production, while the bracelets from Hisin al-Tinat have notably lower titanium oxide and higher REE (Fig. 4). Although not a perfect match, the trace element pattern of group 3 from Hisin al-Tinat and especially of HT_040 are reasonably similar to the two samples from Bari to indicate a chemical and by extension geographical relationship. What is more, the high boron glasses identified to date [49–51,53] tend to be highly variable, which is reflected also in the standard deviations of the Hisin al-Tinat bracelets (Fig. 4). The outlier HT_040 was interpreted by the authors as being possibly the result of mixing two different glasses [51]. As mentioned above, our sample BA 17 likewise shows signs of mixing and recycling in the form of elevated colouring elements. The two fragments recovered from ninth- to eleventh-century contexts in Bari provide the first clear evidence for the circulation of vessels of this type of high lithium, high boron glass in the western Mediterranean. It is widely assumed to be a quintessentially Byzantine glass type, manufactured in all likelihood in Asia Minor [48,49,50], and it may thus not come as a surprise that it has been found in the context of the Byzantine Theme of Longobardia, highlighting the strong material link between southern Italy and Byzantine Asia Minor. With a late antique typology (Isings 106, 111), the two fragments supports once more the survival of these glass typologies into the late first millennium CE.

The typological and compositional characteristics of the medieval glasses from Bari testify to the active exchange between the Byzantine province of southern Italy and the Byzantine heartland on the one hand, and the Islamic world on the other hand. Even though a significant proportion of the glass supply at Bari was evidently dependent on recycled natron glass in line with other contemporary Italian sites (e.g. [8,11,20]), almost half of the glasses analysed correspond to raw glass produced in the late eighth century or later. This high occurrence of late first millennium glass imports constitutes an exception within the Italian Peninsula, where a maximum of 10% of the glass represents imported soda-rich plant ash glass from the eastern Mediterranean [8–14,18–21]. In this, the glass assemblage from Bari demonstrates close parallels with Venice, where up to 50% of late first millennium finds are soda-rich plant ash glasses from the Levant [15]. The productive and commercial set-up suggested by the present study of the glasses from Bari has a significant parallel in the ceramic finds insofar as the ceramics too are either of local production or imported from the Balkans and the Aegean [26]. The high proportion of imports of vitreous material at Bari may be related to the presence of the Byzantine governor and other government officials that strengthened commercial and diplomatic relations with the Byzantine and Islamic territories at large, especially after the city became the capital of the Byzantine catepanate of Italy in the tenth century. In fact, the *Chronicon Barensis* (Anonymi Barensis Chronicon, ad ann. 1045, 1051 and 1062) reports how the city of Bari became the epicentre of maritime traffic, because the Byzantine conquest stimulated the trade with Greece and the eastern Mediterranean.

## 4. Conclusion

The study of the glass finds from Bari provides new insights into how geo-political and technological developments in the medieval Mediterranean shape the production and supply of vitreous materials in southern Italy. The gradual transition from the Roman glass industry that used natron as fluxing agent to medieval ash-based recipes is reflected, for instance, in the systematic recycling and the presence of late first millennium glass types such as Islamic Egypt II, eastern Mediterranean soda-rich plant ash and Byzantine high lithium, high boron glasses. The variability of the glass fragments analysed sets the archaeological record of Bari apart from the rest of the Italian Peninsula with the possible exception of Venice. This shows that the Byzantine province of Longobardia was integrated into an extensive network of exchange that was controlled by a still thriving Byzantine Empire.

## Acknowledgments

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 647315 to NS). The funding organisation had no influence in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at https://doi.org/10.1016/j.culher.2018.11.009.

## Références

[1] M. Phelps, Glass supply and trade in early Islamic Ramla: an investigation of the plant ash glass, in: D. Rosenow, M. Phelps, A. Meek, I.C. Freestone (Eds.), Things that Travelled: Mediterranean Glass in the First Millennium CE, UCL Press, London, 2018, pp. 236–282.
[2] M. Phelps, I.C. Freestone, Y. Gorin-Rosen, B. Gratuze, Natron glass production and supply in the late antique and early medieval Near East: The effect of the Byzantine-Islamic transition, J. Archaeol. Sci. 75 (2016) 57–71.
[3] B. Velde, Glass compositions over several millennia in the western world, in: K. Janssens (Ed.) Modern Methods for Analysing Archaeological and Historical Glass, I, John Wiley & Sons, Chichester, 2013, pp. 67–78.
[4] A. Shortland, L. Schachner, I. Freestone, M. Tite, Natron as a flux in the early vitreous materials industry: sources, beginnings and reasons for decline, J. Archaeol. Sci. 33 (2006) 521–530.
[5] K.H. Wedepohl, K. Simon, The chemical composition of medieval wood ash glass from Central Europe, Chemie Der Erde-Geochem. 70 (2010) 89–97.
[6] D. Whitehouse, The transition from natron to plant ash in the Levant, J. Glass Stud. 44 (2002) 193–196.
[7] J. Henderson, S. Chenery, E. Faber, J. Kröger, The use of electron probe microanalysis and laser ablation-inductively coupled plasma-mass spectrometry for the investigation of 8th–14th century plant ash glasses from the Middle East, Microchem. J. 128 (2016) 134–152.
[8] G. Salviulo, A. Silvestri, G. Molin, R. Bertoncello, An archaeometric study of the bulk and surface weathering characteristics of Early Medieval (5th–7th century) glass from the Po valley, northern Italy, J. Archaeol. Sci. 31 (2004) 295–306.
[9] A. Silvestri, A. Marcante, The glass of Nogara (Verona): a ẅindowön production technology of mid-Medieval times in Northern Italy, J. Archaeol. Sci. 38 (2011) 2509–2522.
[10] A. Silvestri, G. Molin, G. Salviulo, Roman and medieval glass from the Italian area: bulk characterization and relationships with production technologies, Archaeometry 47 (2005) 797–816.
[11] M. Uboldi, M. Verità, Scientific analyses of glasses from Late Antique and Early Medieval archeological sites in Northern Italy, J. Glass Stud. 45 (2003) 115–137.
[12] M. Verità, A. Renier, S. Zechin, Chemical analyses of ancient glass findings excavated in the Venetian lagoon, J. Cult. Herit. 3 (2002) 261–271.
[13] M. Verità, M. Vallotto, Analisi chimica di reperti vitrei del IV secolo dC rinvenuti a Sevegliano (Udine), Quaderni Friulani Archeol. 8 (1998) 7–19.
[14] A. Zucchiatti, L. Canonica, P. Prati, A. Cagnana, S. Roascio, A.C. Font, PIXE analysis of V–XVI century glasses from the archaeological site of San Martino di Ovaro (Italy), J. Cult. Herit. 8 (2007) 307–314.
[15] M. Verità, Venetian soda glass, in: K. Janssens (Ed.), Modern methods for analysing archaeological and historical glass, John Wiley & Sons, Chichester, 2013, pp. 515–536.
[16] E. Gliozzo, M. Turchiano, F. Giannetti, I. Memmi, Late antique and early medieval glass vessels from Faragola (Italy), Archaeometry 58 (2016) 113–147.
[17] E. Gliozzo, M. Turchiano, F. Giannetti, A. Santagostino Barbone, Late antique glass vessels and production indicators from the town of Herdonia (Foggia, Italy): New data on Cao-rich/weak HIMT glass, Archaeometry 58 (2016) 81–112.
[18] I.C. Freestone, F. Dell'Acqua, Early medieval glass from Brescia, Cividale and Salerno, Italy: composition and affinities, in: D. Ferrari (Ed.) A*tti delle VIII Giornate Nazionali di Studio: Il vetro nell'alto medioevo*, AIHV; Imola, 2005, pp. 65-75.
[19] P. Mirti, P. Davit, M. Gulmini, Glass fragments from the Crypta Balbi in Rome: the composition of eighth-century fragments, Archaeometry 43 (2001) 491–502.
[20] N. Schibille, I.C. Freestone, Composition, production and procurement of glass at San Vincenzo al Volturno: an early medieval monastic complex in Southern Italy, PLOS One 8 (10) (2013) e76479, http://dx.doi.org/10.1371/journal.pone.0076479.
[21] M. Sternini, Il vetro in Italia tra V e IX secolo, in: D. Foy (Ed.) Le verre de l'Antiquité tardive et du haut Moyen Age: typologie, chronologie, diffusion. Association française pour l'archéologie du verre (huitième rencontre, Guiry-en-Vexin 18–19 novembre 1993). Musée archéologique départemental du Val d'Oise; Guiry-en-Vexin, 1995, pp. 243-289.
[22] V. von Falkenhausen and G. Cavallo, I Bizantini in Italia, Milano, 1982.
[23] V. von Falkenhausen, Bari bizantina: profilo di un capoluogo di provincia (secoli IX-XI), in: G. Rossetti (Ed.) *Spazio, società, potere nell'Italia dei Comuni*, Liguori; Napoli, 1986, pp. 195-227.
[24] F. Bulgarella, Le terre bizantine, in: G. Galasso, R. Romeo (Eds.), *Storia del Mezzogiorno II*, Il Medioevo, Rome, 1989, pp. 453–460.
[25] M.R. Depalo, G. Disantarosa, D. Nuzzo, Introduzione, in: M.R. Depalo, G. Disantarosa, D. Nuzzo (Eds.) Cittadella Nicolaiana - 1: Archaeologia urbana a Bari nell'area della Basilica di San Nicola Saggi 1982 - 1984-1987, Bari, 2015, pp. 15-18.
[26] S. Airò, Le ceramiche di Età medievale: produzione, commercio e consumo a Bari tra VIII et XIV secolo, in: M.R. Depalo, G. Disantarosa, D. Nuzzo (Eds.) Cittadella Nicolaiana - 1: Archaeologia urbana a Bari nell'area della Basilica di San Nicola Saggi 1982 - 1984-1987, Bari, 2015, pp. 251-258.
[27] M. Pellegrino, I manufatti vitrei, in: M.R. Depalo, G. Disantarosa, D. Nuzzo (Eds.) Cittadella Nicolaiana - 1: Archaeologia urbana a Bari nell'area della Basilica di San Nicola Saggi 1982 - 1984-1987, Bari, 2015, pp. 275-282.
[28] D. Nuzzo, M.R. Depalo, S. Airò, Archeologia urbana nella "Cittadella nicolaiana" di Bari. Nuovi dati dal riesame delle indagini degli anni Ottanta nell'area del pretorio bizantino, Temporis Signa, Archaeologia della tarda antichità e del medioevo 7 (2012) 79–106.
[29] G. Bertelli, La produzione vetraria di età altomedievale in Puglia. Notizie preliminari, in: C. Piccioli, F. Sogliani (Eds.), Il vetro in Italia meridionale e insulare. Atti del Primo Convegno Multidisciplinare (Napoli, 5-6-7 marzo 1998), Napoli, 1999, pp. 139-149.
[30] R. Giuliani, M. Turchiano, I vetri della Puglia centro-settentrionale tra Tardo Antico e Alto Medioevo, in: C. Piccioli, F. Sogliani (Eds.), *Il* vetro in Italia Meridionale e insulare. Il convegno multidisciplinare, VII Giornate Nazionali di Studi del Comitato Nazionale Italiano AIHV (Napoli, 6-7 dicembre 2001), Napoli, 2003, pp. 139-159.
[31] D. Stiaffini, Contributo ad una prima sistemazione tipologica dei materiali vitrei medievali, in: M. Mendera (Ed.), Archeologia e storia della produzione del vetro preindustriale, All'Insegna del Giglio, Firenze, 1991, pp. 177–266.

[32] G.R. Davidson, Corinth XII: The minor objects, Objects. Princeton, (1952).
[33] S. Catacchio, Vetri, in: P. Caprino, F. Ghio, M.A. Sasso (Eds.) I*l complesso di S. Maria del Tempio Lecce. Scavi (2011-2012)*, Galatina, 2013, pp. 137-152.
[34] E. Andronico, Vetri da Reggio Calabria, Bova e Lazzaro (Monte San Giovanni), in: A. Coscarella (Ed.) Il vetro in Italia: testimonianze, produzioni, commerci in età basso medievale: il vetro in Calabria: vecchie scoperte, nuove acquisizioni: atti XV Giornate nazionali di studio sul vetro AIHV, Università della Calabria Aula Magna, 9-11 giugno 2011, Università della Calabria, 2012, pp. 131-150.
[35] C. Raimondo, I vetri del castrum bizantino di S. Maria del Mare, in: A. Coscarella (Ed.) Il vetro in Calabria. Contribuzione per una carta di distribuzione in Italia, Soveria Manelli, 2003, pp. 307-316.
[36] B. Gratuze, Glass characterization using laser ablation-inductively coupled plasma-mass spectrometry methods, in: L. Dussubieux, M. Golitko, B. Gratuze (Eds.), Recent Advances in Laser Ablation ICP-MS for Archaeology, Series: Natural Science in Archaeology, Springer, Berlin, Heidelberg, 2016, pp. 179–196.
[37] N. Schibille, A. Meek, B. Tobias, C. Entwistle, M. Avisseau-Broustet, H. Da Mota, B. Gratuze, Comprehensive chemical characterisation of Byzantine glass weights, PLOS One 11 (2016) e0168289.
[38] C. Lilyquist, R.H. Brill, Studies in Early Egyptian Glass, Metropolitan Museum of Art, New York, 1993.
[39] B.S. Kamber, A. Greig, K.D. Collerson, A new estimate for the composition of weathered young upper continental crust from alluvial sediments, Queensland, Australia, Geochimica et Cosmochimica Acta 69 (2005) 1041–1058.
[40] B. Gratuze, J.N. Barrandon, Islamic glass weights and stamps - analysis using nuclear techniques, Archaeometry 32 (1990) 155–162.
[41] I.C. Freestone, The recycling and reuse of Roman glass: analytical approaches, J. Glass Stud. 57 (2015) 29–40.
[42] S. Paynter, Experiments in the reconstruction of Roman wood-fired glassworking furnaces: waste products and their formation processes, J. Glass Stud. 50 (2008) 271–290.
[43] L. Saguì, B. Lepri, La produzione del vetro a Roma: Continuità e discontinuità fra tardoantico e altomedioevo, in: A. Molinari, R. Santangeli Valenzani, L. Spera (Eds.) L'archeologia della produzione a Roma (secoli V-XV): Atti del convegno internazionale di studi Roma 27-29 marzo 2014, Collection de l'École française de Rome 516 Roma, Bari, 2016, pp. 225-241.
[44] S. Fiorentino, T. Chinni, E. Cirelli, R. Arletti, S. Conte, M. Vandini, Considering the effects of the Byzantine–Islamic transition: Umayyad glass tesserae and vessels from the qasr of Khirbet al-Mafjar (Jericho, Palestine), Archaeol. Anthropol. Sci. 10 (2018) 223–245.
[45] I.C. Freestone, R.E. Jackson-Tal, I. Taxel, O. Tal, Glass production at an early Islamic workshop in Tel Aviv, J. Archaeol. Sci. 62 (2015) 45–54.
[46] J. de Juan Ares, N. Schibille, Glass import and production in Hispania during the early medieval period: the glass from Ciudad de Vascos (Toledo), PLOS One 12 (2017) e0182129.
[47] E. Neri, B. Gratuze, N. Schibille, The trade of glass beads in early medieval Illyricum: towards an Islamic monopoly, Archaeol. Anthropol. Sci. (2018) 1–16.
[48] M. Tite, A. Shortland, N. Schibille, P. Degryse, New data on the soda flux used in the production of Iznik glazes and Byzantine glasses, Archaeometry 58 (2016) 57–67.
[49] R.H. Brill, Chemical analyses of the Zeyrek Camii and Kariye Camii glasses, Dumbarton Oaks Papers 59 (2005) 213–230.
[50] N. Schibille, Late Byzantine mineral soda high alumina glasses from Asia Minor: a new primary glass production group, PLOS One 6 (4) (2011) e18970, http://dx.doi.org/10.1371/journal.pone.0018970.
[51] C. Swan, T. Rehren, L. Dussubieux, A. Eger, High-boron and high-alumina middle Byzantine (10th–12th century CE) glass bracelets: a western Anatolian glass industry, Archaeometry 60 (2018) 207–232.
[52] P. Degryse, Glass Making in the Greco-Roman World: Results of the ARCHGLASS Project, Leuven University Press, 2014.
[53] [53] R.H. Brill, Chemical Analyses of Early Glasses, The Corning Museum of Glass, Corning, New York, 1999.

Pour citer cet article : E. Neri, et al., A Byzantine connection: Eastern Mediterranean glasses in medieval Bari, Journal of Cultural Heritage (2018), https://doi.org/10.1016/j.culher.2018.11.009