IMEKO International Conference on
Metrology for Archaeology and Cultural Heritage
Torino, Italy, October 19-21, 2016

# Archaeometric study of the glass from the early Christian basilica of Ayios Kononas, Cyprus

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***Abstract* – This paper presents the LA-ICP-MS analysis results of 40 selected glass pieces from the early Christian basilica of Ayios Kononas in the Akamas area. The site enlarges our knowledge on the glass consumption pattern in Cyprus and demonstrates possible new insights on the connectivity of the island with the surrounding regions. The obtained data provide an added value to the already recognized connectivity with Egypt and the Levant. Additionally, Ayios Kononas embraces promising indications concerning a connection with western Anatolia.**

## I. INTRODUCTION

Cyprus was an important hub on the East-West and South-North trade routes in late Antiquity because of its central geographical position in the eastern Mediterranean and the prevailing sea currents. Supported by a continuous economical growth this prosperous Roman province displayed an increasing building programme of early Christian basilicas between the 4th and mid 7th century AD.

From the perspective on glass consumption the central position of the island makes it a perfect case study for investigating the glass industry. It is well known that the Levant and Egypt were the major manufacturing centres of raw glass to supply the secondary glass workshops with broken chunks of raw glass [1], but both regions must have exported finished products as well.

The research on the glass material from Late Antique Cyprus has remained limited to the material study of glass in site excavation reports [2, 3, 4, 5]. Also the chemical analysis remained until recently restricted to the sampling of one single site [1], but since a few years we have carried out an intensive survey of the chemical composition of the Cypriot Late Antique glass [6, 7, 8].

In a first stage we identified five glass types when characterising the glass from Yeroskipou-*Ayioi Pente*, Kalavasos-*Kopetra* and Maroni-*Petrera* on a chemical and optical basis: Levantine 1, HLIMT[1], two types of HIMT (named HIMTa and HIMTb), Egypt 1 and HIT. Apart from Levantine 1 glass, which certainly has a Syro-Palestinian origin, all other recognized glass types most likely have been produced in Egypt [8].

Currently research is ongoing to define the ratio between imported finished products from Egypt and the Levant and imported Egyptian and Levantine raw glass to supply Cypriot secondary glass workshops for local productions. The three major glass groups observed are Levantine Levantine, HIMT and HLIMT. Two other types, HIT and Egypt 1 are represented in minor quantities, suggesting that objects made of this type of glass very likely have been imported as finished products - either as consumer goods or as gifts, souvenirs or pilgrim's tokens [6]. It is worth noting that there is a chronological/geographical distribution pattern. Chronologically we proposed the evolution of Egyptian productions from HIMT dominant in the 4th-5th c. AD to HLIMT/Foy-2 highly exported in the 6th-7th c AD. This hypothesis was further confirmed by recent research involving glass from the Balkan and from Carthage, Tunisia [11, 12]. From the geographical point of view we noticed that in Yeroskipou, the most western site on the island of Cyprus, there is about 50:50 ratio between Levantine and Egyptian materials, while moving eastwards towards Maroni and Kalavasos the amount of Egyptian glass drops consistently in favour of Levantine material with a ratio of 68:32 and 82:18 respectively [6]. This distribution pattern is in agreement with research on late antique pottery which suggests that West Cyprus was connected with the Aegean areas and Egypt, while the East of the island had connection routes with the Syro- Palestinian coast.

In this paper we discuss the major, minor and trace element data of the 4th-7th c. AD glass from the site of Ayios Kononas in order to compare the chemical composition obtained by means of LA-ICP-MS to previously published data of the material from Kalavasos, Maroni and Yeroskipou [6, 8]. This site of Ayios Kononas is located in the Akamas peninsula in the West of the island, north of Yeroskipou, allowing us to expand the coastline coverage (Figure 1). With this work we add another piece information to understand the regional differences and international connectivity and the chrono/geographical evolution

[1]This label was proposed in [6] similarly to the HIMT label proposed by Freestone in [9]. Since this group was alredy described in [10] and named 'Serie 2.1', hereafter we will refer to it as HLIMT/Foy-2

of glass production seen in our previous research.


*Fig. 1. Distribution of the sites integrated in the research.*

## II. THE SITE AND THE MATERIAL

Surveys and excavations undertaken by the Danish Akamas project on the Akamas peninsula have brought to light the settlement of Ayios Kononas and the surrounding landscape characterised by scattered farms set in an infrastructure of roads and small natural harbours [13]. The Akamas region continuously remained a remote area with rural settlements so as at Ayios Kononas in Late Antiquity when a hamlet of several houses and a small ecclesiastical building occupied the area during the later 5th-6th c. AD. All of the 40 selected samples come from the basilica. Apart from a small piece of chunk and a crown glass windowpane all other objects are from different vessel shapes: lamps, bowls, goblets and a bottle. The typological study of the object samples allowed us to date the material. Only one hemispherical bowl can be ascribed to the 4th-5th c. AD, 15 fragments stemmed goblets, conical bowls and cylindrical lamp can be dated 5th-6th c. AD, 2 pieces from a bottle and a crown glass are more broadly dated 5th-7th c. AD, 15 hollow stemmed lamps belong to 6th-7th c. AD production and 7 fragments from undefined open vessel shapes and a raw glass chunk, can not be better dated than 4th-7th c. AD in agreement with the dating of the site.

## III. RESULTS

The major elements composition of the glass from Ayios Kononas indicates that all samples belong to the soda-lime-silica category typical of the first millennium AD. Analysing the minor and trace elements of the glass from Ayios Kononas apart from five pieces with a unique composition, we can cluster the material into three main groups: 24 samples have a Levantine glass composition, 6 fragments are HLIMT/Foy-2 and 5 are HIMT glass. In addition there is an object (sample AK3_4) with a exotic composition with high Sb, Pb and $Fe_2O_3$ resembling HIMT, one Mn-decoloured object (sample AK3_1) with a typical Levantine composition, one fragment (sample AK2_3) made of Roman glass with Sb-Mn mix composition, a raw chunk (sample AK1_3) made with plant ash as

*Table 1. List of analysed samples from the early Christian basilica of Ayios Kononas, Akamas.*

| Sample | Date | Type | Group |
|---|---|---|---|
| AK4_10 | V-VII AD | bottle or jug | Levantine |
| AK1_8 | V-VI AD | conical bowl (Isings 134) | Levantine |
| AK1_5 | V-VI AD | conical bowl (Isings 134) | Levantine |
| AK4_1 | V-VI AD | conical bowl (Isings 134) | Levantine |
| AK4_8 | V-VI AD | conical bowl (Isings 134) | Levantine |
| AK4_2 | V-VI AD | conical bowl (Isings 134) | Levantine |
| AK1_10 | V-VI AD | conical bowl (Isings 134) | Levantine |
| AK1_9 | V-VI AD | conical bowl (Isings 134) | Levantine |
| AK3_9 | V-VI AD | conical bowl (Isings 134) | Levantine |
| AK3_2 | V-VI AD | conical bowl (Isings 134) | Levantine |
| AK4_7 | VI-VII AD | hollow stemmed lamp | Levantine |
| AK4_6 | VI-VII AD | hollow stemmed lamp | Levantine |
| AK1_7 | VI-VII AD | hollow stemmed lamp | Levantine |
| AK4_5 | VI-VII AD | hollow stemmed lamp | Levantine |
| AK2_10 | VI-VII AD | hollow stemmed lamp | Levantine |
| AK3_6 | VI-VII AD | hollow stemmed lamp | Levantine |
| AK3_10 | VI-VII AD | hollow stemmed lamp | Levantine |
| AK2_9 | VI-VII AD | hollow stemmed lamp | Levantine |
| AK3_3 | VI-VII AD | hollow stemmed lamp | Levantine |
| AK3_7 | V-VI AD | stemmed goblet (Isings 111) | Levantine |
| AK1_6 | V-VI AD | stemmed goblet (Isings 111) | Levantine |
| AK2_1 | IV-VII AD | undefined | Levantine |
| AK2_8 | V-VI AD | conical bowl (Isings 134) | Levantine? |
| AK2_7 | VI-VII AD | hollow stemmed lamp | Levantine? |
| AK4_4 | IV-VII AD | bowl | HIMT |
| AK4_3 | IV-VII AD | undefined | HIMT |
| AK3_5 | V-VII AD | crown glass | HIMT |
| AK1_1 | V-VI AD | cylindrical lamp | HIMT |
| AK2_5 | IV-V AD | hemispherical bowl (Isings 96) | HIMT |
| AK3_4 | IV-VII AD | undefined | HIMT? |
| AK1_4 | V-VI AD | conical bowl (Isings 134) | HLIMT |
| AK2_4 | VI-VII AD | hollow stemmed lamp | HLIMT |
| AK2_2 | VI-VII AD | hollow stemmed lamp | HLIMT |
| AK4_9 | VI-VII AD | hollow stemmed lamp | HLIMT |
| AK3_8 | VI-VII AD | hollow stemmed lamp | HLIMT |
| AK1_2 | V-VI AD | stemmed goblet (Isings 111) | HLIMT |
| AK3_1 | IV-VII AD | undefined | Mn-decoloured |
| AK2_3 | VI-VII AD | hollow stemmed lamp | Roman Sb-Mn |
| AK1_3 | IV-VII AD | chunk | Plant Ash |
| AK2_6 | IV-VII AD | undefined | High Al |

fluxing agent and a vessel (sample AK2_6) with exceptionally high Al. In Table 2 we report the average composition and the standard deviation of the main glass types found at Ayios Kononas and the individual outliers. A plot of $Fe_2O_3$ against $Al_2O_3$ is a good indicator of the sand used for glass production and help distinguishing the major groups. In Figure 2 we report a biplot of the concentration of these two elements for the Levantine, HIMT and HLIMT/Foy-2 glasses from Ayios Kononas and compare them to the material from our previous research on Cyprus [6]. The graph shows well that the compositional groups found in Ayios Kononas are very consistent with the material found elsewhere on the island. Also the trace elements demonstrate that the glass found at Agyios Kononas is similar to the other Cypriot material. Trace elements offer interesting information about the geochemistry of the sand used for glass making [14]. For example Nb is added to the glass batch with Ti-bearing minerals. HLIMT and Levantine 1 have the same Nb/Ti ratio, different from HIMT and Egypt 1 [8]. In Figure 3 we report the biplot of both elements for the glass from Ayios Kononas compared to other sites in Cyprus.

*Table 2. Average composition and standard deviation ($\sigma$) of the glass type found at Ayios Kononas.*

| Group | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | MnO | $Na_2O$ | $K_2O$ | MgO | CaO | Cl | $P_2O_5$ | Li | B | Nb | Sb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Levantine (22) | 70.5 | 3.27 | 0.45 | 0.07 | 0.02 | 14.1 | 0.58 | 0.59 | 9.5 | 0.77 | 0.087 | 3.89 | 64.28 | 1.47 | 0.20 |
| $\sigma$ | 1.3 | 0.25 | 0.08 | 0.01 | 0.01 | 1.2 | 0.16 | 0.12 | 1.2 | 0.14 | 0.033 | 0.38 | 22.41 | 0.15 | 0.34 |
| HLIMT (6) | 66.9 | 2.59 | 1.02 | 0.17 | 1.15 | 16.5 | 0.68 | 0.97 | 8.8 | 0.81 | 0.113 | 6.53 | 135.02 | 2.79 | 252.48 |
| $\sigma$ | 0.9 | 0.19 | 0.08 | 0.02 | 0.18 | 1.3 | 0.11 | 0.12 | 0.8 | 0.05 | 0.013 | 0.68 | 15.10 | 0.26 | 128.48 |
| HIMT (5) | 64.6 | 2.98 | 2.42 | 0.47 | 1.96 | 18.5 | 0.49 | 1.06 | 6.2 | 0.97 | 0.086 | 5.24 | 180.03 | 5.04 | 7.78 |
| $\sigma$ | 0.9 | 0.24 | 0.51 | 0.09 | 0.27 | 0.6 | 0.07 | 0.14 | 0.9 | 0.12 | 0.018 | 0.70 | 21.27 | 0.78 | 9.00 |
| Sb-Mn Roman | 69.2 | 2.04 | 0.42 | 0.07 | 0.18 | 19.0 | 0.60 | 0.44 | 6.3 | 1.04 | 0.077 | 3.87 | 199.81 | 1.28 | 4197.56 |
| Mn-decoloured | 68.8 | 3.08 | 0.47 | 0.07 | 1.17 | 16.4 | 0.43 | 0.59 | 7.6 | 1.12 | 0.076 | 3.48 | 94.41 | 1.26 | 0.25 |
| Plant Ash | 68.4 | 1.71 | 0.70 | 0.13 | 0.12 | 16.4 | 1.83 | 1.50 | 7.7 | 0.81 | 0.435 | 5.33 | 151.82 | 1.99 | 87.62 |
| High Al | 57.2 | 13.83 | 2.68 | 0.39 | 0.09 | 12.6 | 5.50 | 0.90 | 5.7 | 0.34 | 0.098 | 95.41 | 710.13 | 20.60 | 8.31 |

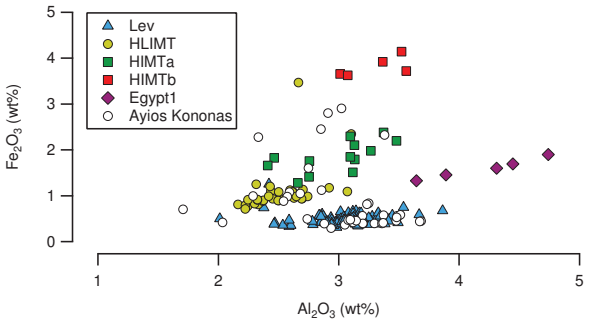


*Fig. 2. Relation between $Fe_2O_3$ and $Al_2O_3$ of the Ayios Kononas glasses versus the three prior analysed sites, Yeroskipou, Maroni and Kalavasos [6].*

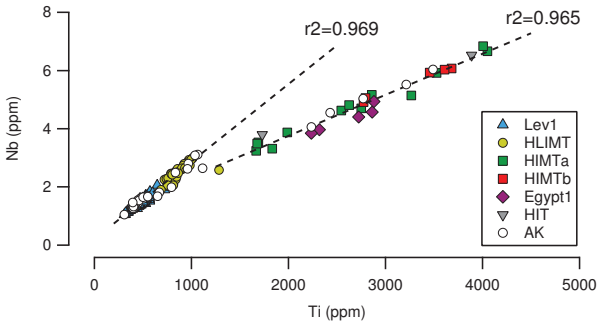


*Fig. 3. The relation between Nb and Ti can discriminate different sources of sand for the glasses analysed here and those from [8].*

## IV. DISCUSSION

In Ayios Kononas the majority of the material is Levantine. If we exclude the objects with exceptional or undefined compositions, 24 objects from Ayios Kononas, that is the 69%, was manufactured with Levantine glass, while 11 objects (31%) are made of Egyptian glass, i.e. HIMT and HLIMT/Foy-2. The absence of Egypt 1 and HIT glass may point at the minor importance of this center. In Yeroskipou we found much more Egyptian material, likely because the church is located in proximity to the major harbour of Paphos [6]. Ayios Kononas is a rural settlement similar to Kalavasos-*Kopetra* and Maroni-*Petrera* and this could explain the limited amount of Egyptian material. It is noteworthy that the only object dated 4th and 5th c. AD is a hemispherical bowl (sample AK2_5) made of HIMT glass. Also the crown glass piece and the cylindrical lamp fragments dated 5th-7th and 5th-6th c. AD respectively are made of the HIMT. The other fragments belonging to this glass type cannot be dated accurately. Conversely all the objects dated between the 5th and the 7th c AD are made of Levantine and HLIMT/Foy-2 glass.

### A. *Recycling old glass*

Besides the major compositional groups there are some isolated examples of other glass types. Sample AK2_3 is a hollow stemmed lamp typologically dated between the 6th and the 7th c. AD which has a mix Sb-Mn Roman composition. It is generally accepted that this glass composition is the result of recycling Mn-decoloured and Sb-decoloured glass [15, 16, 17, 18, 19]. The discovery of this glass artefact is rather puzzling because recycling would reasonably involve the addition of Sb and Mn-cullet together with common Late Antique glass resulting in a slight increase of Mn and Sb levels and eventually other recycling markers as Co, Cu, Zn and Pb. The present piece probably can be explained by the use of large amounts of old Roman decolourised glass material such as window-panes recovered from ruined buildings.

Recycling was a common practice in ancient times [20]. The criteria to detect recycling in variable glass metals is generally based on thresholds levels of Co, Cu, Zn, Pb and Sb [8]. In Ayios Kononas, as for the rest of the island, recycling is rather limited probably because of the proximity of Cyprus to the manufacturing centers of raw glass which guaranteed a continuous supply.

### B. *A possible connection with Anatolia*

Sample AK2_6 is a green vessel rim fragment with exceptionally high $Al_2O_3$ (13.83 wt%), B (710 ppm), Li (95 ppm) and low Cl (0.34 wt%) which is very uncommon in Early Byzantine assemblages. However several contemporary objects with similar compositions were found in Ana-

tolia at Pergamon and Sardis [21, 22, 23]. Also in Western Anatolia Brill reports high B and Li glass from Aphrodisias, but the amounts of Al are lower [21]. Based on the analytical data from Early Byzantine glass until Iznik period glazes (15-16th century) it is believed that a flux agent with high boron and lithium was quarried and used in Anatolia [23, 24]. They suggested that there was a possible primary production of glass occurring in this region but the glass is presumed to be distributed at a local level. One main difference between the glass found at Ayios Kononas and the Anatolian material is the higher amount of $K_2O$ in the Cypriot glass (5.5 wt%), which is normally associated to plant ash. However, the use of plant ash as fluxing agent is to be excluded since the levels of Mg and P are too low. Here we would like to propose the possibility that the Anatolian glass found in Cyprus was the result of mixing a local borax rich flux with obsidian rather than sand. The Anatolian region is rich in obsidian and remelting it into glass is is feasible when grinded to powder and mixed with an amount of soda comparable as when sand is used. It was demonstrated by an experiment in the Roman furnace reconstructed in Velzeke, Belgium [25]. The final composition would be similar to the glasses found in Pergamon, Sardis and to the sample analysed here with the exception of CaO which would be lower than the 5-6 wt% found in the glasses. At this stage of research it is not excluded that a recipe containing three components - obsidian, lime and the Anatolian B-rich flux - was used. Whatever is the technological origin of this glass type, it is of extreme interest to note that sample AK2_6 is the only object of this composition found in Cyprus so far. Unfortunately we cannot date the vessel because it is not possible to define more precisely the exact shape. Seeing the total absence of this type of glass at the south coast it becomes compulsory to investigate the glass from settlements at the north coast like for instance Polis to verify a possible organized import of Anatolian glass.

### C. *A raw chunk of plant ash*

A chunk of raw pale green glass was found within the remains of the church and it happens to be made of plant ash as indicated by high $K_2O$ (1.83 wt%), MgO (1.50 wt%) and $P_2O_5$ (0.435 wt%). Kalavasos-*Kopetra* already yielded an object made with naturally coloured plant ash glass, but the two pieces cannot be related as they show different compositions. A strange observation is that Ayios Kononas material comprises a chunk of raw glass with a plant ash composition but no finished product. Further evaluation of glass assemblages from other contemporary Cypriot sites are needed to better understand its early presence.

## V. CONCLUSIONS

This paper demonstrates that the Ayios Kononas glass assemblage is very similar to those in the other sites on the southwestern coast, e.g. Yeroskipou, Kalavasos and Maroni. Levantine glass is everywhere predominant, although the Egyptian glass - represented by HIMT and HLIMT/Foy-2 - takes a much larger part at Yeroskipou, nearby Paphos. The dating of the objects confirms the chronological evolution of HIMT and HLIMT/Foy-2 glass production in Egypt. The comparison with the material available on the other sites of the island allows to further develop the regional differences on the island and inter-regional connections between Cyprus and the surrounding manufacturing centres. Seeing the newly recognized presence of a high Al vessel likely referring to a connection with the Anatolian peninsula, it is compulsory to look at more material from settlements on the northern coast. The analysis of the trace elements, in particular the level of transition metal elements, such as Co, Zn, Sb, Pb and Cu, provides evidence for the occurrence of glass recycling which remains still to a limited degree because of the continuous supply of fresh raw glass from the manufacturing areas.

## VI. ACKNOWLEDGEMENTS

The authors are thankful to the Department of Antiquities for providing access to the material. In particular we wish to express our gratitude to Jane Fejfer for having granted us permission to study the material excavated during the Danish Akamas Project. We would like to thank also Bernard Gratuze and Nadine Schibille for their collaboration with the LA-ICP-MS analysis.

## REFERENCES

[1] I. C. Freestone, M. Ponting, and M. J. Hughes. The origins of Byzantine glass from Maroni Petrera, Cyprus. *Archaeometry*, 44(2):257–272, may 2002.

[2] S. W. Manning. *The Late Roman Church at Maroni Petrera: Survey and salvage excavations 1990-1997, and other traces of Roman remains in the lower Maroni Valley, Cyprus.* A. G. Leventis Foundation, Nicosia, 2002.

[3] M. C. McClellan. Glass. In M. L. Rautman, editor, *A Cypriot village of late antiquity: Kalavasos-Kopetra in the Vasilikos Valley*, pages 217–234. Journal of Roman Archaeology - Supplementary series no 52, Portsmouth, 2003.

[4] S. H. Young. A Preview of Seventh-Century Glass from the Kourion Basilica, Cyprus. *Journal of Glass Studies*, 35:39–47, 1993.

[5] S. H. Young. Glass. In A. H. S. Megaw, editor, *Kourion: Excavations in the Episcopal Precinct*, chapter 16, pages 485–526. Dumbarton Oaks Research Library & Collection, Washington D.C., 2008.

[6] A. Ceglia, P. Cosyns, K. Nys, H. Terryn, H. Thienpont, and W. Meulebroeck. Late antique glass distribution and consumption in Cyprus: a chemical study. *Journal of Archaeological Science*, 61:213–222, sep 2015.

[7] A. Ceglia, P. Cosyns, K. Nys, H. Terryn, H. Thienpont, and W. Meulebroeck. Light through glass: The spectrum of Late

Antique glass from Cyprus. *Journal of Archaeological Science: Reports*, 7:614–624, jun 2016.

[8] A. Ceglia, P. Cosyns, N. Schibille, B. Gratuze, and W. Meulebroeck. Provenancing raw materials: trace elements of Early Christian glass from Cyprus. *Journal of Archaeological Science*, submitted.

[9] I. C. Freestone. Chemical analysis of "raw" glass fragments. In H. Hurst, editor, *Excavations at Carthage*, volume II, chapter Appendix, page 290. Oxford University Press, 1994.

[10] D. Foy, M. Picon, M. Vichy, and V. Thirion-Merle. Caracterisation des verres de la fin de l'antiquite en mediterranee occidentale: l'emergence de nouveaux courants commerciaux. In D. Foy and M.-D. Nenna, editors, *Échanges et commerce du verre dans le monde antique, Actes du colloque de l'Association Française pour l'Archéologie du Verre*, pages 41–85, Aix-en-Provence et Marseille, 2003. Maison de l'Orient et de la Méditerranée Jean Pouilloux.

[11] A. Cholakova, T. Rehren, and I. C. Freestone. Compositional identification of 6th c. AD glass from the Lower Danube. *Journal of Archaeological Science: Reports*, 7:625–632, jun 2016.

[12] N. Schibille, A. Sterrett-Krause, and I. C. Freestone. Glass groups, glass supply and recycling in late Roman Carthage. *Archaeological and Anthropological Sciences*, 2016.

[13] J. Fejfer. *Ancient Akamas: Settlement and Environment Pt.1. Aarhus: Aarhus University Press.* 1995.

[14] M. Ganio, O. Bonnerot, J. Carsello, P. Degryse, L. Dussubieux, D. Gimeno, and M. Walton. Red opaque glasses: a single primary production? In *40th International Symposium on Archaeometry*, volume 56, Los Angeles, jul 2014.

[15] S. Paynter. Analyses of colourless Roman glass from Binchester, County Durham. *Journal of Archaeological Science*, 33:1037–1057, 2006.

[16] A. Silvestri, G. Molin, and G. Salviulo. The colourless glass of Iulia Felix. *Journal of Archaeological Science*, 35(2):331–341, feb 2008.

[17] H. E. Foster and C. M. Jackson. The composition of late Romano-British colourless vessel glass: glass production and consumption. *Journal of Archaeological Science*, 37(12):3068–3080, dec 2010.

[18] E. Gliozzo, B. Lepri, L. Saguì, and I. Turbanti Memmi. Colourless glass from the Palatine and Esquiline hills in Rome (Italy). New data on antimony- and manganese-decoloured glass in the Roman period. *Archaeological and Anthropological Sciences*, 2015.

[19] S. Paynter and C. Jackson. Re-used Roman rubbish: a thousand years of recycling glass. *Post-Classical Archaeologies*, 6:31–52, nov 2016.

[20] D. Keller. Social and economic aspects of glass recycling. In J. Bruhn, B. Croxford, and G. D., editors, *TRAC 2004: Proceedings of the Fourteenth Annual Theoretical Roman Archaeology Conference*, number April, pages 65–78, Oxford, 2005. Oxbow Books.

[21] R. H. Brill. *Chemical analyses of early glasses*. Corning Museum of Glass, New York, 1999.

[22] N. Schibille. Late Byzantine mineral soda high alumina glasses from Asia Minor: a new primary glass production group. *PloS one*, 6(4):e18970, jan 2011.

[23] T. Rehren, P. Connolly, N. Schibille, and H. Schwarzer. Changes in glass consumption in Pergamon (Turkey) from Hellenistic to late Byzantine and Islamic times. *Journal of Archaeological Science*, 55:266–279, mar 2015.

[24] M. S. Tite, A. J. Shortland, N. Schibille, and P. Degryse. New Data on the Soda Flux Used in the Production of Iznik Glazes and Byzantine Glasses. *Archaeometry*, 58(1):57–67, feb 2016.

[25] S. Cagno, P. Cosyns, and K. Janssens. La production de vaisselle en vitrum obsianum au Ier siècle après J.-C. Un état de la question à partir de l'eétude du fragment R1610 (MRAH-Bruxelles). *AFAV Bulletin*, pages 21–26, 2010.