Bead carnival: chemical analyses of Merovingian beads from the cemetery of Lent-Lentseveld

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Bead Carnival
Chemical analyses of Merovingian beads from the cemetery of Lent-Lentseveld

by

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1. Introduction

During the past century and a half, hundreds of thousands of decorative beads have been excavated from (mostly female) rural inhumation graves across Europe dating between AD 450 and AD 700 (Fig. 1). Despite their ubiquity, their research potential has only started to dawn in the last decade. Before, they were used as a means of dating[135] and often dismissed as mere trinkets, as research focus was attuned to 'more interesting' grave goods such as biconical pots, weapons or fibulae.

Research on beads from the early medieval period has a lot to offer: beads are durable, portable, ubiquitous, and highly variable objects. Hence, they are a means to gain a better understanding of mercantile and other networks that facilitated long-distance trade.[136] Beads as objects of trade and particularly long-distance maritime trade is a well-documented phenomenon.[137] They are an appropriate proxy for this long-distance trade, since it is generally believed many were part of the cargo of ships whose prime purpose was the trade in spices, silk and incense.[138] How the trade was organised and how "foreign" beads penetrated every stratum of society in Western Europe remains unclear: the archaeological record just shows that this was the case (Fig. 2).

1. 1. Chemical analyses

So far, chemical analyses of Merovingian beads have revealed information about the types of raw glass used to produce them and the metal oxides used to colour them. Several studies have already shown that throughout Europe early medieval beads were made using similar raw glass, and were coloured with similar metal oxide 'colour recipes'.[139] Specific tiny green beads, occasionally found in graves of the late fifth and early sixth century, are made from high alumina glass and were most likely produced in India and/or Sri Lanka.[140] Others have shown that opaque white beads were either opacified by tin oxide or calcium antimonates.[141] As far as colouring and/or opacifying goes, the Late Roman period saw a shift from the use of lead-based opacifiers to tin-based opacifiers, which is also accompanied by a change in hue for the yellow beads.[142] There are some indications of a shift in the recipe for black glass as well, which became more concentrated in iron and lead than before.[143] More generally, even with tin-based colourants and opacifiers, lead remains an important ingredient to decrease the melting temperature of glass and increase its workability.[144] Consensus so far is that most beads were made in small batches by travelling craftsmen, often by using scrap glass or cullet.[145] If that was indeed the case, one would expect to find different recipes for beads of the same bead-type. In all these papers only a limited number of beads were analysed. To our knowledge apart from the unpublished work on the cemetery of Bossut-Gottechain a full study (typological *and* chemical) of all the beads of a given site has not been performed yet. However, in Pion's dissertation chemical analyses of glass beads from six Belgian cemeteries have been presented.[146]

In this work we want to highlight the added value of considering complete assemblages. Through these studies, we have a good understanding of the chemical composition of glass beads from Merovingian graves, the provenance of raw glass, (local) recycling and colouring. This paper tackles questions beyond glass types and colour recipes. We want to start considering beads not as individual objects, but as part of a broader assemblage: either the necklace they were part of, or the batch they were produced in. Potential questions include: how were strings of beads assembled, how closely do the chemical signatures of identical beads within a string/grave relate? Do we see evidence for identical beads within a string being produced together? What about identical beads from different graves and time-periods from the same cemetery? The answers to these questions can provide new insights into bead

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135 For example Koch 1977; Sasse/Theune 1997; Siegmund 1998.

136 Carter et.al. 2016.

137 Francis 2002; Wood 2011; Keileini et.al. 2019, Pion et.al. 2020.

138 Pion et.al. 2020 and references therein.

139 Sablerolles et.al. 1997, 306–311; Henderson 1999a; Heck/Hofmann 2000, 354–355; Heck/Hofmann 2002; Matthes et.al. 2003; Dijkstra et.al. 2010, 188–191; Mathis et.al. 2010; Peake/Freestone 2012; Pion/Gratuze 2014, Neri et.al. 2017, Boschetti et.al.2020.

140 Pion/Gratuze 2016.

141 Matthes et.al. 2004, 134–135; Vandino/Fiorentino 2020.

142 Tite et.al. 2008.

143 Mathis et.al. 2010.

144 Henderson 1999, 85–86.

145 Sablerolles et.al. 1997; Dijkstra et al. 2010, Crocco et.al. 2021, Henderson 1978; Callmer 2003.

146 Gratuze in Pion 2014, 299–376.

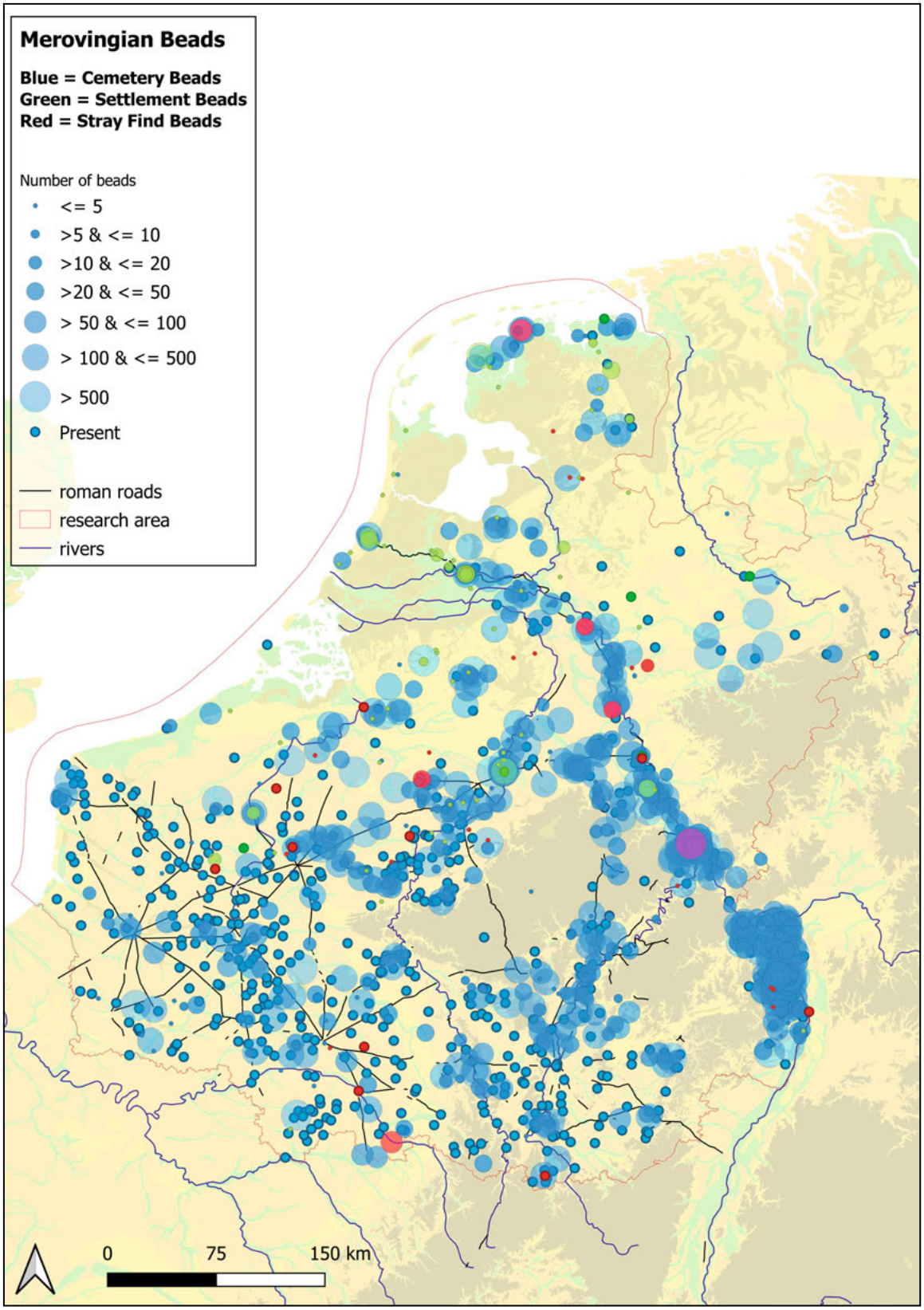

Fig. 1 Find locations of beads dating to the Merovingian period in northern Gaul. Source: www.earlymedievaleurope.org (Online Database ERC Rural Riches).

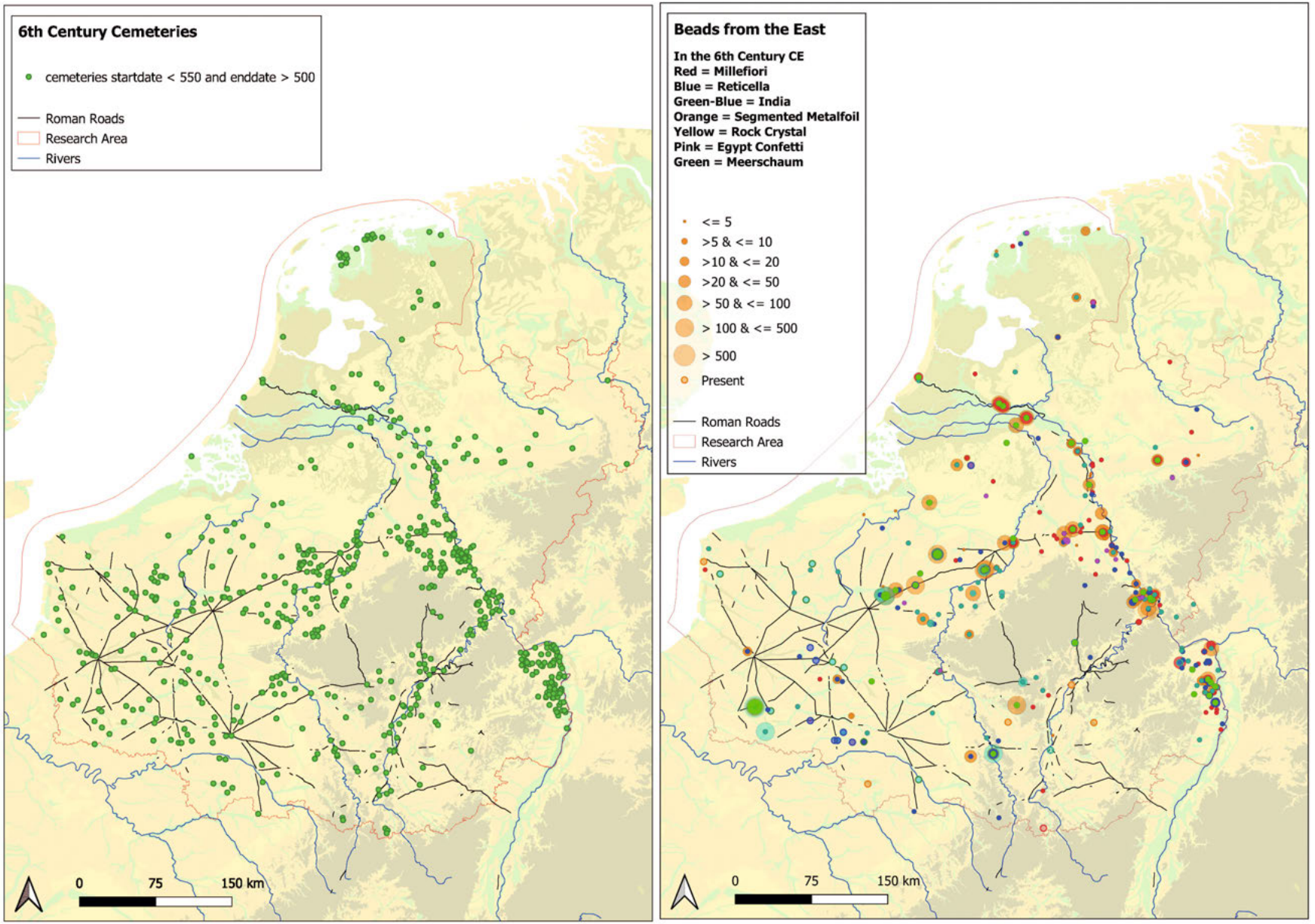

Fig. 2 Distribution of cemeteries dating to the 6th century in northern Gaul (left) and find locations of beads with an origin in the eastern Mediterranean or beyond in northern Gaul (right). Source: www.earlymedievaleurope.org (Online Database ERC Rural Riches).

use and exchange, as they can indicate: bead exchange across generations, whether beads were assembled into bracelets and necklaces only once, or strung and restrung into different compositions on several occasions, for example for the burial ritual itself. The answers to these questions in turn provide interesting possibilities to tackle questions about social networks, non-trade exchange relations, knowledge exchange, burial rites and a host of other social and cultural topics of early medieval society.

1. 2. Aim

In order to answer the questions above, a method to establish chemical 'bead-groups' needs to be developed. This is done using the beads from the sixth-century cemetery of Lent-Lentseveld, located near the town of Nijmegen in the Netherlands. The research presented here expands on previous work by considering the complete bead assemblage from Lent-Lentseveld[147]. The study consists of a complete approach ranging from photography, typology and provenance determination,[148] out of 1028 glass beads excavated in Lent 932 were analysed by portable X-Ray Fluorescence (pXRF) and 578 were analysed using Laser Ablation-Inductively Coupled Plasma - Mass Spectrometry (LA-ICP-MS).

Next/among the questions mentioned above, the aim of the research is two-fold. First, determining whether PCA analysis of the data obtained through LA-ICP-MS and pXRF yield the same results.[149] By incorporating the typological data in the analyses of both the pXRF and LA-ICP-MS results, we have developed a method (which will be elaborated upon below) to distinguish groups of beads using principal component analysis (PCA). Second, variability in chemical composition of identical beads within a grave/object (necklace, bracelet) are compared to the overall chemical variability of that specific bead-type and interpreted in light of trade and exchange patterns. In this preliminary study only one cemetery is considered. We plan to perform the same study on beads from the Merovingian cemeteries Els-'t Woud and Wijchen-centrum in a later article, to expand our research into the seventh century.

2. The beads from Lent-Lentseveld

The cemetery of Lent-Lentseveld (Fig. 3) is a small sixth-century cemetery of 79 graves that has been excavated by the municipality of Nijmegen in 2011 and 2015 in the village of Lent, north of the town of Nijmegen in the Netherlands (Fig. 4).[150] It dates between 500 and 600 CE. In total 1205 beads were found in Lent in 29 different graves: 26 inhumations and 3 cremations, found in 40 different 'groups'. The beads were mainly found in children's and women's graves: 7 children's graves, 19 women's graves and 1 man's grave.[151] In table S1 in the appendix an overview of all the beads per grave is provided. Most groups of beads were found near the neck or chest. It is most likely that these were necklaces, although they could also have been sewn onto the neckline of clothing. In two cases beads were found near an arm: these were probably bracelets. And in at least one case beads must have attached to a chatelaine, since they were found near the hip, just as several of the large glass 'spindle whorl beads'.

The vast majority of beads are made of glass (1028 pieces): 872 are monochrome and 155 polychrome. They were made with a variety of techniques: wound beads, drawn beads, perforated beads, folded beads and mosaic beads all occur in the same string of beads (Fig. 5). After glass, amber is the most common material with 164 pieces. Only a few beads are made of faience, rock crystal, marble, Meerschaum, terra

147 The chemical composition of several glass beads from Lent has already been analysed with hand-held XRF analysis (28 beads) and SEM analysis (5 beads) at the University of Delft in 2017 (Corbella 2017). All those beads were soda-lime-silica glass, and in terms of (de)colourants evidence for the use of lead stannate, tin, copper, iron and manganese was found, all typical for Merovingian beads. The report also noted the high lead content of the glass, which was probably added purposefully to make the glass more malleable (Corbella 2017, 14–18). In addition, several beads were analysed with μ-Computed Tomography (otherwise known as micro-CT), revealing the intricate methods with which the beads were made as well as the many air bubbles present in their glass matrix (Ngan-Tillard et.al. 2018).

148 Based on those from Pion 2014.

149 In particular regarding which beads group together chemically.

150 Hendriks 2021.

151 These are sex determinations based on a physical-anthropological study of the preserved skeletal material from the graves of Lent-Lentseveld (Van der Linde 2021).

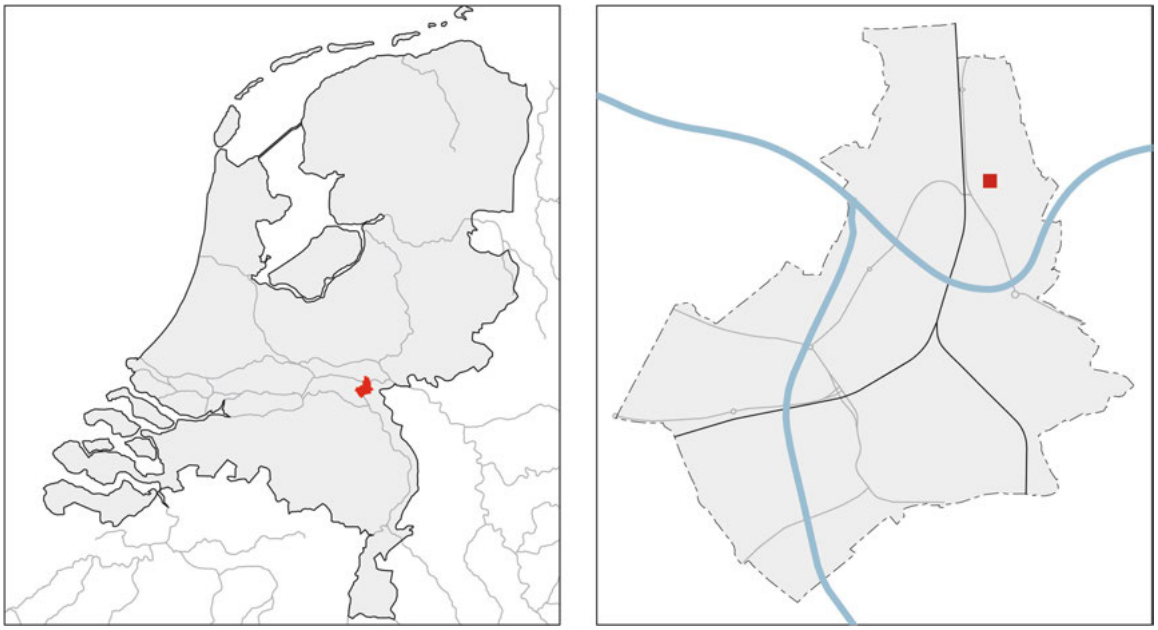

Fig. 3 Location of the sixth-century cemetery Lent-Lentseveld (Image by J. Hendriks, Municipality of Nijmegen).

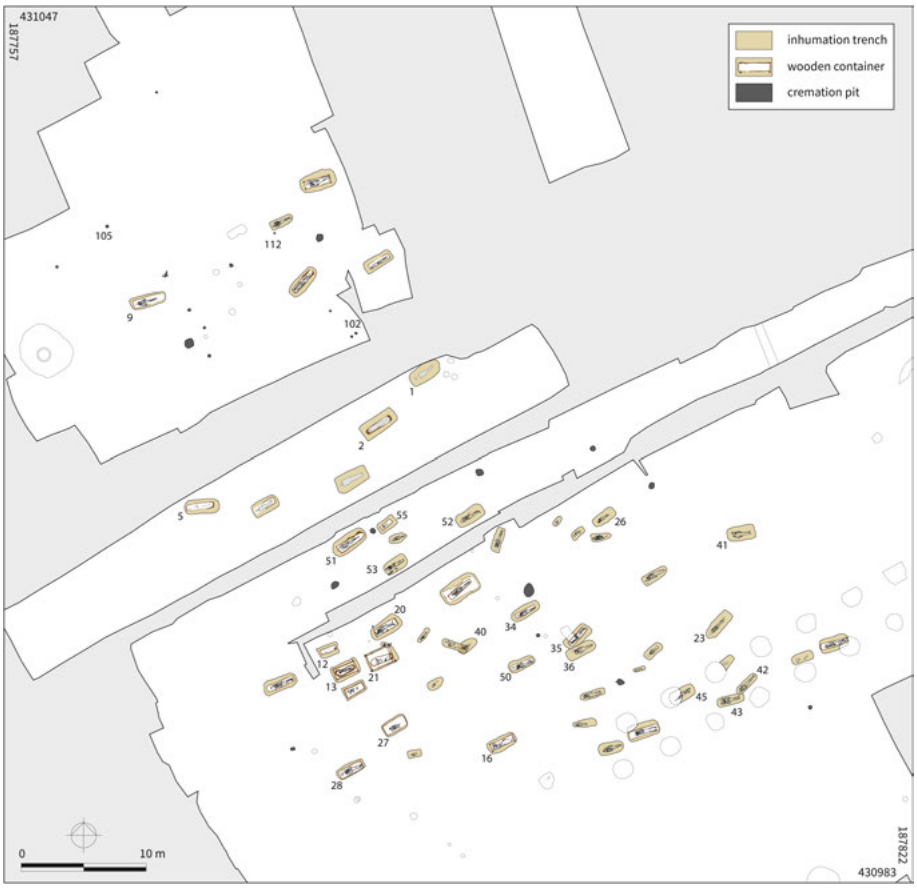

Fig. 4 Plan of the sixth century cemetery Lent-Lentseveld. Graves with beads are indicated by their grave number (Image by J. Hendriks, Municipality of Nijmegen).

Fig. 5 This string of beads consists of hundred-twenty-one beads of glass, amber and faience and was found around the neck of a young child in a grave from the 6th century cemetery of Lent-Lentseveld. The beads in this string were made with varying techniques and have origins in Europe, the Baltic, the Levant, Egypt, the region of modern-day Iraq and Iran, and India (photo: A. Dekker).

sigillata, beryllium and metal (Table 1). The beads from Lent have various provenances: Northwestern Europe, the Baltic, the Mediterranean[152], Egypt, Mesopotamia[153], and India.

Table 1 Overview of the materials out of which the beads excavated from the cemetery of Lent-Lentseveld were made.

Material	Amount of beads	Amount of graves
Glass	1028	28
Amber	164	22
Faience	5	3
Marble	3	3
Meerschaum	1	1
Beryl	1	1
Rock crystal	1	1
Samian ware	1	1
Metal	1	1
Total	**1205**	**29**

[152] The Mediterranean is admittedly a rather large area to refer to as a single bead-production region. For Lent, we refer mostly to this region in regards to beads made of materials such as Meerschaum/sepiolite and marble, that may have been sourced in various subparts of the Mediterranean quite widely spaced apart. Meerschaum for example, may have been won in the modern-day regions of Greece, Turkey, Crimea or Spain, amongst other candidates (Drauschke 2011, 57; Herdick 2000, 336 and 339).

[153] In this article we refer to the region between the Euphrates and Tigris rivers as 'Mesopotamia', which literally means 'land between rivers'. With this term we do not refer to the Mesopotamian empire, as it no longer existed in the sixth century.

Table 2 Bead making techniques and their provenances (based on Pion 2014).

Technique	Type group	Provenance
Drawn Beads	A	India/Mesopotamia/Egypt/Syro-Palestinian coast
Wound Beads	B	Europe (mostly)
Folded Beads	C	Egypt/Syro-Palestinian coast
Perforated Beads	D	Mesopotamia/Egypt/Syro-Palestinian coast
Mosaic Beads	E	Egypt
Beads from other materials	F	Various Provenances
Prehistoric or Roman beads	G	Various Provenances

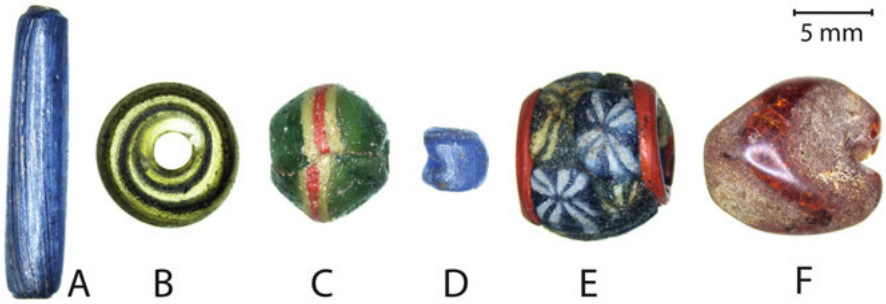

Fig. 6 Examples of beads from the cemetery Lent-Lentseveld made with various production techniques. A drawn bead with lines parallel to the perforation; B wound bead with concentric lines around the perforation; C folded bead with visible seam; D perforated bead with one irregular side; E: mosaic bead formed by various slices of mosaic glass; F: amber bead with cut and polished faces (photos: M.B. Langbroek).

3. Methodology

3. 1. Typology, Microscope

The beads found in Lent-Lentseveld have been categorised using the typology that was developed by Constantin Pion in 2014.[154] Extra information on this typology can be found in appendix 3. 1. Furthermore, their material, condition, production technique (Fig. 6), size, colour, decoration and provenance (based on typology: Table 2) were documented. Finally, all the beads were photographed using a camera on the stereomicroscope used to study the beads.

3. 2. Analytical methods

A complete description of the instrumentation and measurement conditions for both the pXRF and LA-ICP-MS analysis is provided in appendix 3. 2 and 3. 3. These are routine analysis, but never performed on such a large corpus, including every bead excavated on the site. In this section more time will be devoted to how PCA analysis was applied in this study to combine the information from both methodologies.

All monochrome beads from Lent-Lentseveld were analysed using pXRF. In polychrome beads, the different colours usually appear very close together, which makes analysis per colour inaccurate. Polychrome beads were therefore analysed only with LA-ICP-MS (see below). In total, 949 pXRF-measurements of 932 beads were taken.

[154] Pion 2014.

The beads to be analysed with LA-ICP-MS were selected as follows:

– Each colour of each polychrome bead was analysed individually.
– For monochrome beads a subsample of all identical (colour and typology) beads within a string were analysed. When only one or two identical beads were present, they were all selected for analysis. When three or more of the same bead-type were present in a string, two or more were selected. For example, if ten identical monochrome beads were present in a string of beads, usually about four were selected for analysis.

In total, 1008 measurements on 578 beads were performed: all polychrome beads and representative subsamples of monochrome beads per string.

In order to determine the base glass recipe a so-called "reduced" composition is determined,[155] averages for this are reported in appendix table S2. That is the composition rising solely from the sand and flux. The composition of the glass is recalculated to 100 % oxides not taking into account the elements associated to (de)colouring and/or opacifying (we are keeping the following oxides: Na_2O^* MgO^* $Al_2O_3^*$ SiO_2^* $P_2O_5^*$ K_2O^* CaO^* $Fe_2O_3^*$; the star indicates these are reduced compositions).[156] Iron is a more complicated oxide, as it does enter the glass as part of the silica source (usually present in sand), however, it is also used as colourant in, for example, black glass. Therefore if the reduced Fe_2O_3 concentration is below 1 we keep it as is, if not it is arbitrarily chosen to be 1 % and the other oxides are determined accordingly.[157] When this was done the value has an 'a' in superscript in S1.

3. 3. Principal Component Analysis

In this paper PCA's of the pXRF and LA-ICP-MS data will be performed, compared and interpreted in light of the chemistry, the typology, the age, the grave the beads were found in and the region in which the beads were produced. PCA has the ability to simplify high-dimensional data, such as the 21 components measured in pXRF analysis or the 58 components in LA-ICP-MS, and summarise these in two-dimensional plots. The data are geometrically reduced by projecting them into lower dimensions called principal components (PCs) that are uncorrelated.[158] Simply put: PCA compares the chemical data obtained by the pXRF or LA-ICP-MS measurements, and plots those chemical compositions that are most alike closer together than those that are less alike. As stated above, we are not so much interested in the specific chemical recipes of the beads, since the aim is to establish whether chemical groups can be identified for specific bead-types and/or for graves. This can then in turn provide information on whether multiple beads of a specific bead-type from one or several graves were produced with the same recipe or not, and how strings of beads present in burials were assembled.

In this article three representative case studies of a specific colour (black, green-blue/blue-green and red), will be presented. The selected colours occur in a representative part of the excavated strings of beads. For each colour group two different PCAs were made: one for the results of the pXRF analysis and one for the results of the LA-ICP-MS analysis.

For the pXRF measurements the PCA analyses were performed on results from beads from the Lent-Lentseveld graveyard by discarding the low-Z elements (below K), the Hg and Rh signals were not taken into account either.[159]

The following elements were used in the PCA analysis: K, Ca, Ti, Mn, Fe, Co, Ni, Cu, Zn, As, Sr, Sn, Sb and Pb. The matrix of the counts for each element after spectral deconvolution was transposed and PCA was performed with a transformation of the data to a mean of zero and standard deviation of one. This avoids that the major elements dominate the compounds, however it does give the same importance to each measured element. PCA's were performed using the Clustvis tool.[160]

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155 Panighello et.al. 2012.
156 Panighello et.al. 2012.
157 Panighello et.al. 2012.
158 Lever et.al. 2017.
159 Low-Z elements were not used because they are not reliably measured with pXRF. K and Ca sometimes are also excluded for this reason, but in our study the results are consistent with what was found in the LA-ICP-MS analysis, therefore we kept them. Rh is from the X-Ray tube and we do not expect large Hg contributions, rather the signal is due to small errors in decovolution due to spectral overlap of Hg M-lines with S K-lines and Au M-lines and Hg L-lines with Pb and As L-lines (all of which are present in the samples).
160 https://biit.cs.ut.ee/clustvis/; Metsalu/Vilo 2015.

For the LA-ICP-MS measurements the major and minor elements were considered for the PCA as well as trace elements, rare earth elements were not considered[161]. In order to have enough data to be statistically significant the PCA's were performed using data from three cemeteries (Lent-Lentseveld, Wijchen-Centrum and Elst- 't Woud). PCA's only considering elements typical for the base glass (Si, Na, K, Mg, Mn, Fe (except for black glass), Al, Ti, V and Ca) and considering elements, typical for (de) colouring and/or opacifying were also performed (Sn, Sb, Cu, Co, Pb, As, Zn, Ni). The groups found with the three different PCA's were largely the same. In some cases PCA's were also done for a subset of one bead-colour corresponding to a particular typology.

3. 4. Problems and pitfalls

3. 4. 1. Context

The beads studied in this paper were all deposited in graves. However, use-wear analysis of several strings of beads from Lent has revealed that the beads were worn (some significantly longer than others) before they were deposited in the graves.[162] Of course, the way beads were worn during life and by whom may be completely unrelated to the way they were finally deposited. Hence this assemblage might not tell us about the lives of the people buried in Lent. Instead, it provides insight into how strings of beads were assembled (perhaps especially for burial).

3. 4. 2. Glass

Whenever chemical analysis is performed on archaeological objects it is important to be certain the measured chemical composition corresponds to the actual original chemical composition of the object. Glass is a durable material that in the case of Lent-Lentseveld has suffered very little from corrosion. Corroded glass is characterised by iridescence[163] which was not noticed on those beads. Furthermore, when performing LA-ICP-MS analysis the first few seconds of data (which correspond to the surface layer) are not taken into account to avoid any influence from corrosion due to the burial ground. Any glass corrosion can easily be detected in the LA-ICP-MS as corrosion layers are typically enriched in Al_2O_3 and depleted in Na_2O. In the pXRF analysis these oxides were not taken into account.

3. 4. 3. PCA graphs

When studying the graphs in general, and in particular when looking for patterns or clusters for specific bead-types or graves, it is important to bear the scale of the X- and Y-axis in mind. On the one hand, if the graph is plotted on a very small scale, there will not be any clusters visible. On the other hand, if the graph is plotted on a very large scale, there may appear clusters where there actually are none. As this type of study of Merovingian glass beads has not been done at that scale before, establishing an 'honest' scale is very much trial and error. Adding to this, there is no consensus on what exactly forms a chemical group: how similar in composition do different beads of the same type have to be to be able to claim they are from the same chemical group? By using PCA, we are not so much establishing chemical groups in a quantitative way, but rather in a qualitative way: beads that appear in the same cluster in the graphs are more like one another than the beads that plot outside of that cluster. This means that the patterns that can be discerned from the PCA graphs cannot be interpreted in a quantitative nature: it cannot be claimed that beads of a specific bead-type that plot in a cluster were made from the same batch of glass. Instead, the furthest we wish to go with our interpretation of such type-clusters, is that the glass used to make these beads seems to have been manufactured with a more similar recipe in comparison to the glass used to make beads of other types that do not plot in the aforementioned cluster. In other words: the graphs show a relative ordering of bead groups.

While it would be tempting to interpret specific bead-type clusters as originating from the same bead-making event or workshop, fact remains that we are analysing the coloured glass used to make the beads, some of which may have been made on site for specific bead-making events and some of which may have been exchanged as previously fabricated

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[161] Rare earth element concentrations were nearly identical for most beads from the same type, so their contribution in the PCA was 0, hence we decided not to take them in the analysis.

[162] McGloin 2021; see Langbroek 2020 for an example of beads found in a settlement context.

[163] Except for high-lead glass such as the yellow opacified glasses.

coloured glass[164]. In theory then, as prefabricated coloured glass rods from the same production-event may have been transported to various locales, beads with similar compositions may have been made at different moments, in different workshops. However, if beads of the same specific bead-type from a string of beads found in a single grave have similar chemical compositions, their co-production during the same bead-making event does seem more likely.

4. Results

4. 1. Base glass recipe

The provenance attributed by visual examination of the beads concerns the place of manufacture of the glass beads.[165] This does not say anything, however, about the base glass recipe and provenance, i.e. where the raw glass was produced.

From the 1st millennium BCE through the Roman period glass in the Mediterranean was produced in large primary production centres in the Syro-Palestinian coast and Egypt. The recipes are characterised by the use of mineral soda as flux and this glass remains in use in Western Europe until the 9th century.[166] Mineral soda was sourced from evaporitic deposits such as the Wadi Natrun in Egypt and was not readily available in Western Europe. Hence, if the beads were made using mineral soda as flux the raw glass originates from the Mediterranean and was either freshly imported as glass cullet, or recycled.

Table S2 in the appendix provides a summary of the reduced compositions with the average reduced composition for each colour and type of bead in the assemblage based on the LA-ICP-MS results from the beads from Lent.

Most of the beads were made using mineral soda as flux. Glass beads which, according to their typology, were produced in Egypt are characterised by a higher concentration of both MgO and K_2O, usually 1–1.5wt-%, still within the range of mineral soda glass. Occasionally one of the oxides will be above 1.5wt-%, but these can still be considered to be fluxed with mineral soda. Beads made in Europe typically contain ~0.5wt-% of each oxide and never more than 1wt-%. They are also fluxed with mineral soda, but are characterised by lower concentrations of Fe or Mn than for the Egyptian material indicating a purer silica source (probably from the Syro-Palestinian coast). Among the beads thought to be manufactured in Egypt or the Syro-Palestinian coast and Mesopotamia a large proportion are fluxed using plant ashes as evidenced by the concentration of K_2O and MgO which are both above 1.5wt-%. This shows that the attribution to a production location based on style, also reveals something about the glass recipe used for manufacturing.

4. 2. Black: results

In the cemetery of Lent-Lentseveld several bead-types with black glass were excavated. The most common black bead-type in Lent is B1.1-01a (68 beads), followed by B1.1-01b (12 beads) and B1.8-01 (6 beads). These are all monochrome wound beads, and will be discussed in more detail below, as will polychrome black bead-types B5.4-02 and G1.3–02. Of these types, only one bead was excavated in Lent (Fig. 7).[167]

4. 2. 1. General chemistry (LA-ICP-MS results)

All the bead-types are characterised by elevated lead and iron contents except B1.1-01b that does not contain any lead and has an average reduced iron content of about 0.61 %. The dark/black colour can be attributed to iron for all bead-types except B1.1-01b.

Among the B1.1-01a beads there are two groups with extremely low Na_2O and high Al_2O_3 reduced concentrations. Since the low Na_2O concentration is not compensated by other fluxing elements and that it is well known that corrosion of glass leads to the loss of sodium and surface enrichment of Al_2O_3 it is possible this is due to corrosion. To rule out this possibility, a new reduced composition was determined where the Na_2O concentration was arbitrarily

[164] Crucibles with remains of yellow lead-tin oxide pigments (Heck et.al. 2003), yellow opaque glass and green-blue translucent glass have been excavated from several bead-production sites in Northwestern Europe. Other glass colours are systematically absent: these may have been imported as (inter)regionally prefabricated coloured glass rods (Matthes et.al. 2004; Pion 2014, 188; Dijkstra 2011, 314).

[165] Usually this was the place the colour was added and the glass was formed into beads.

[166] Phelps et.al. 2019; Shortland et.al. 2006.

[167] Cf. 7. 4. Appendix table S4.1.

Fig. 7 The black bead-types featured in this case study (photos: M.B. Langbroek).

chosen to be 18 (typical for roman natron glass). In this reduced composition the average Al_2O_3 is still between 11 and 12 wt-%, a composition typical for mineral soda glass found in East Asia, India and Turkey.[168] It, therefore, is likely that B1.1-01a beads have a provenance outside of Europe. High-alumina glass has already been demonstrated for a specific type of drawn bead[169] found in Merovingian graves across Europe dating to the late fifth and early sixth century.[170]

Another possibility would be that these black glasses are actually a three-component mixture of a base glass, lead, and iron from iron slag. This is the case for red opaque beads and at least one black bead dating between 450 and 650 from Eriswell, Suffolk.[171] This study using SEM-EDS showed that iron slag was added to the red glass to decrease the melting temperature and to black glass as a colourant. The slag is rich in iron, but also in K_2O and $Al_2O_{3,}$ which could explain the elevated Al_2O_3* calculated for our samples, and the more elevated K_2O in the B1.1-01a beads (1–2 wt-%) compared to the other black beads (<1.2 wt-%). However, one big difference with the black bead from Peake and Freestone is that in our beads Na_2O is near-absent compared to ~11 wt-% in 'their' black bead. The link with metallurgy is further strengthened by the presence of SnO in these glasses, which might also link the manufacture of black and yellow glasses as already suggested by Peake and Freestone. The lead source used for these beads also contains barium, resulting in BaO concentrations of 1000–2000 ppm for these glasses. The MnO concentrations are also elevated (up to 5 wt-%), presumably entering with the slag, yet due to the large amounts of iron, this is the main source of colour for these glasses.

168 Lankton/Dussubieux 2006; Dussubieux et.al. 2010.
169 Indo-Pacific tradewind beads, A1.1-01 beads.
170 Pion and Gratuze 2016.
171 Peake/Freestone 2012

4. 2. 2. PCA XRF

The first two PCA-components explain 55 % of the variation. The PCA plot based on the results of the pXRF analysis shows clear groups per bead-type (Fig. 8a).

To understand where these groups arise from it is important to note that the first component is dominated by lead, whereas the second component is dominated by Sr. This is illustrated in Fig. 9a where PbO and SrO concentrations determined by LA-ICP-MS are plotted and the groups clearly appear. On the right, the B1.1-01a beads form a clear group that is high in lead content, separated from B1.1-01b and B1.8-01 on the left. B1.1-01b forms two groups, one of which is similar to the group of B1.8-01 beads. The Roman bead G1.3–02 also plots in this group.

4. 2. 3. PCA LA-ICP-MS

The first two PCA-components explain 63 % of the variation. Clear groups per bead-type can be distinguished (Fig. 8b). Like in the pXRF PCA, the first component is dominated by lead. In contrast to the pXRF data, in this case the second component is dominated by transition elements, and strontium plays a smaller role (likely because of the smaller range of values for Sr as also seen in Fig. 9a).

The PCA plot shows two groups for B1.1-01a (as observed in paragraph 4.2.1), that were probably not distinguished by the pXRF due to the role aluminium plays in the separation of these groups (see Fig. 9b). As B1.1-01a beads are so small, the addition of lead may have been necessary to make the glass malleable enough to be able to wind these tiny beads. There is one clear B1.1-01a outlier, namely bead 81 from grave 40. It contains more iron than the other B1.1-01a beads and has a lower lead content. Chemically, it has more in common with bead-type B5.4-02 from grave 51, which was only analysed with LA-

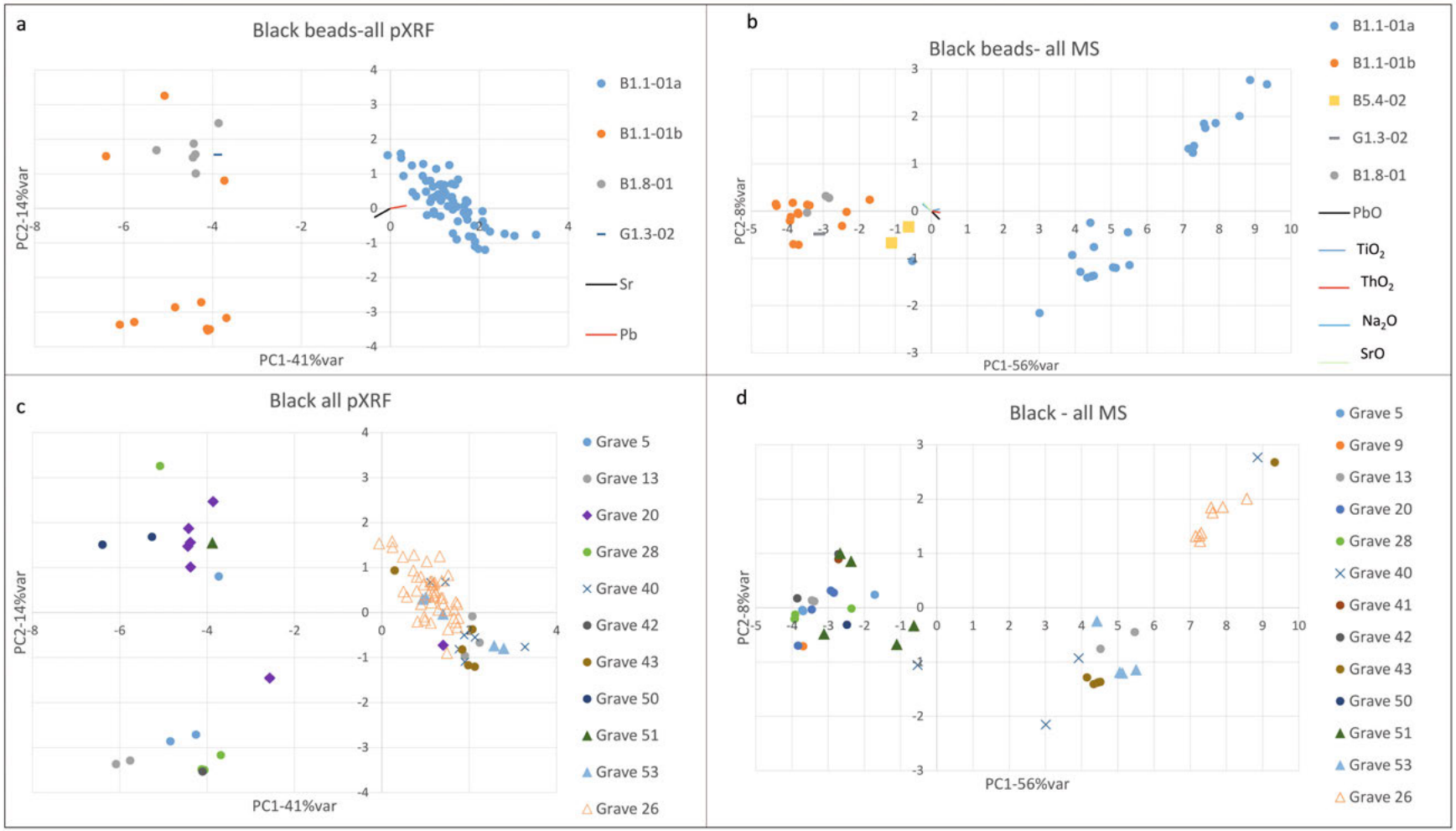

Fig. 8 Black beads: PCA results pXRF and LA-ICP-MS**.** By bead type a pXRF and b LA-ICP-MS; by grave c pXRF and d LA-ICP-MS. Main loadings are given in graphs a (Sr and Pb) and b (PbO, TiO_2, ThO_2, Na_2O and SrO).

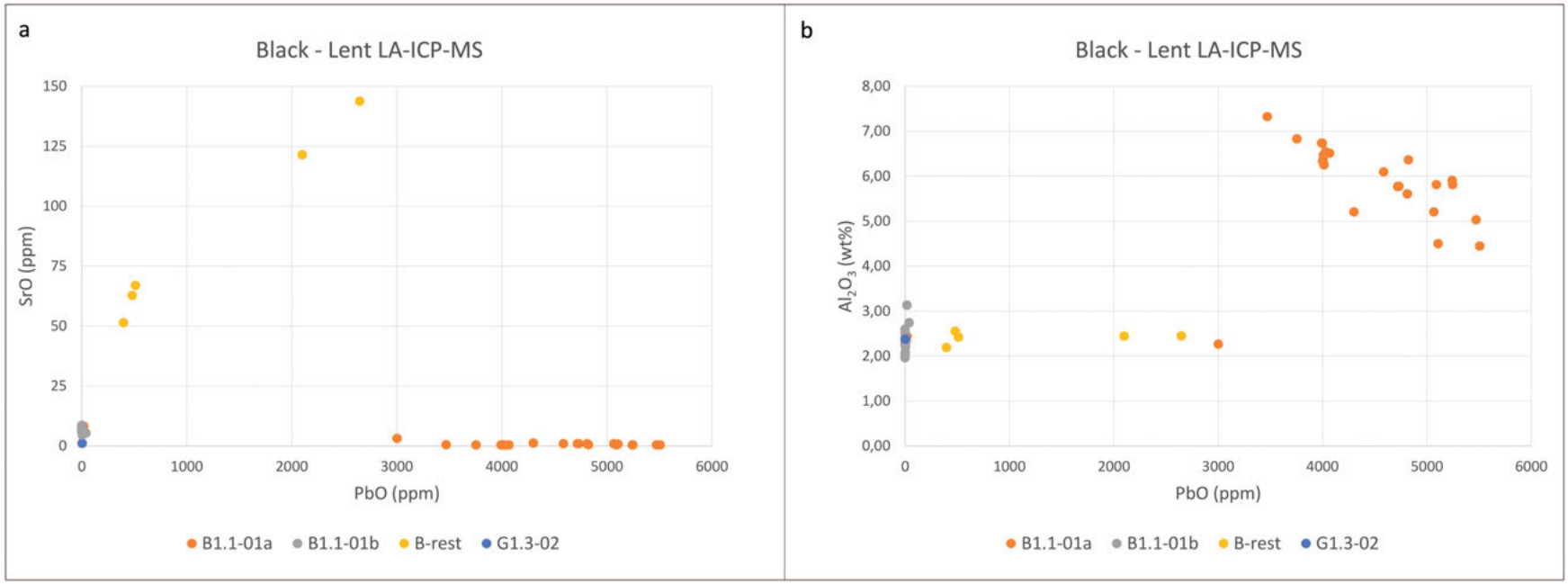

Fig. 9 Chemical composition of black beads: a Biplot black beads PbO vs SrO plotted per main bead-type (LA-ICP-MS); b Biplot black beads PbO vs AiO plotted per main bead-type (LA-ICP-MS).

ICP-MS and therefore does not appear in the pXRF plot. Typologically, both are atypical for 6th-century beads: the B1.1-01a bead from grave 40 is smaller and rounder than most other B1.1-01a beads, and the B5.4-02 bead is a very rare find in Merovingian cemeteries. The one example that is known from the cemetery of Broechem, though similar in technique, colour and decoration, has a very different 'look'.[172] These two beads might be examples of heirloom beads that had circulated for an extended period of time before being deposited in the grave.

The two groups detected for B1.1-01b beads in the pXRF PCA plot can still be distinguished in the LA-ICP-MS PCA plot, but are less pronounced. As only three B1.8-01 beads were analysed using LA-ICP-MS, they do not form as clear a group as they did in the pXRF plot, but plot close together nevertheless. Mirroring the pXRF plot, the Roman G1.3–02 bead appears on the left side with bead-types B1.1-01b and B1.8-01 characterised by lower Pb contents.

4. 2. 4. Groups per grave

In Figs. 8c and 8d, the same pXRF and LA-ICP-MS PCA analyses as above were plotted, but this time per grave instead of per bead-type. Generally, for both the pXRF and LA-ICP-MS PCA, within each bead-type group (as described above), beads from the same grave tend to cluster together. In the pXRF plot the large B1.1-01a 'cloud' is built up of smaller and larger groups of graves: the group consisting of beads from grave 26 is the most obvious. Groups from graves 13, 26, 42, and 43 (with one outlier) can also be distinguished. B1.1-01a beads from grave 40 display more of a scattered pattern, i.e. they are spread out rather than clustering together. The LA-ICP-MS plot clarifies the groups found with the pXRF PCA: the B1.1-01a beads from grave 26, accompanied by single examples from graves 40 and 43 form a separate cluster. In the other cluster groups from grave 13, and 43 can be observed. Mirroring the pXRF plot, B1.1-01a beads from grave 40 display a 'confetti' pattern.

In both the pXRF and the LA-ICP-MS PCA plots B1.1-01a beads from grave 53 plot a little further apart from one another than those from other graves. Taking into account the distance between repeat measurements on the same B5.4-02 bead from grave 51 (Fig. 8d), the B1.1-01a beads from grave 53 can still be considered to form a single group.

Multiple B1.1-01b beads were found in grave 5, 13 and 28. In the lower left corner of the pXRF PCA plot, several of these group together neatly grave by grave. The same groups per grave are displayed in the LA-ICP-MS PCA plot, where B1.1-01b beads from the same grave plot very close together. B1.8-01 beads were all, with one exception, excavated from grave 20. They form a clear group in the pXRF PCA plot, which is mirrored in the LA-ICP-MS PCA plot.

4. 3. Green-blue/blue-green

In the cemetery of Lent-Lentseveld several bead-types with green-blue or blue-green glass were excavated. The most common green-blue bead-type found in Lent is A2.1-04 (12 beads), followed by A3.6 (6 beads), C3.3-01 (5 beads) and D1.5–02 (4 beads). These will be discussed in more detail below, as will polychrome bead-types A1.2-06, B5.7-?, B1.6-01e and B1.1-08d, C2.1-01b and D1.1-02 (Fig. 10). Of these types, only two or three beads were excavated in Lent (appendix table S4.2). Green-blue or blue-green bead-types of which only one was found in Lent will not be discussed.

4. 3. 1. General chemistry

From the chemical analysis it can be observed (as in Fig. 11a) that most of the A-beads are Sb-opacified, whereas the C-beads and all but one B-bead are Sn-opacified. The exception is bead 4 from grave 36, whose attribution to type B is uncertain. The D-beads are split over both opacifiers: D1.1-02 are richer in Sn, whereas D1.5-02 beads are richer in Sb. Though it must be noted that for some of the beads there is a positive correlation between CuO and SnO_2, indicating that both materials came in together. Bronze might have been used as a colourant, rather than SnO_2 being added on purpose to opacify in those specific cases. The clusters in Fig. 11b correspond to specific graves and/or subtypes. As far as colourants, clusters by (sub)type are observed for A and C beads Figs. 11c and d, indicating the use of similar raw materials for colouring the glass.

[172] Vrielynck et.al. 2018, 13.

Fig.10 The green-blue/blue-green bead-types featured in this case study (Photos: M.B. Langbroek).

4. 3. 2. PCA XRF

The first two PCA-components explain 58 % of the variation. The X axis is dominated by antimony and the Y axis by zinc. The PCA plot shows some clear groups for specific bead-types (Fig. 12a). On the right, the A2.1-04 beads form a clear group, separated from other A, B and C types on the left. On the left, groups can be discerned for bead-types A3.6, B1.1-08d and D1.1-02. C3.3-01 beads also concentrate on the left and form a group with 2 outliers, not too far apart. Two bead-types plot in the left half of the graph, but do not seem to form clusters: B5.7-? and C2.1-02b. Other bead-types are scattered around the plot with examples on the right and the left: A1.2-06, B1.6-01e and D1.5-02. Three of the four D1.5–02 beads plot in the same part of the graph as A2.1-04 beads. Pion already noted the similarity between several types of A2 and D1 beads, and has suggested a common origin.[173]

[173] Pion 2014, 219–222.

4. 3. 3. PCA LA-ICP-MS

The first two PCA-components of the LA-ICP-MS analysis explain 54 % of the variation. The X axis is dominated by components typical for the silica source including titanium. In contrast, the Y axis is dominated by tin and lead. The LA-ICP-MS PCA plots show even clearer groups per bead-type than the pXRF PCA plot (Fig. 12b). From left to right, clusters of bead-types C3.3-01, A3.6, D1.1-02, C2.1-02b and A2.1-04 can be discerned. In contrast to the scattered pattern it displayed in the pXRF PCA, type A1.2-06 forms a group in the lower right corner. Similar to the pXRF PCA, three out of four D1.5–02 beads plot in the same group as A2.1-04. Coincidentally, most of these beads were excavated from grave 40: the D1.5–02 outlier is from grave 16. This group (including A1.2-06) distinguishes itself by higher levels of antimony and lower levels of tin, confirming LA-ICP-MS analyses on A2 and D1 beads found in Merovingian cemeteries in Belgium. It is likely that these beads were made by recycling

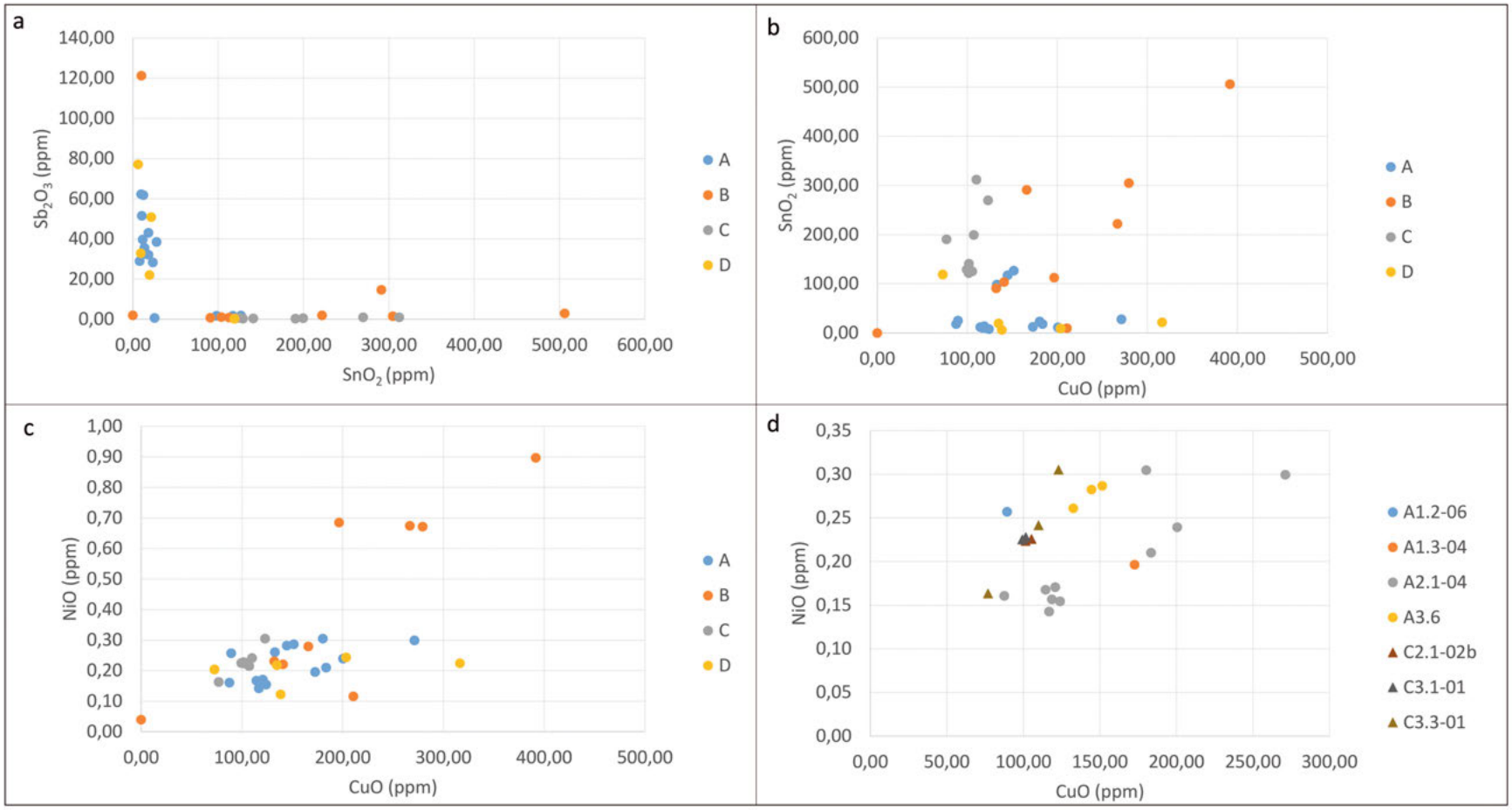

Fig. 11 Chemical composition of green-blue/blue-green beads (LA-ICP-MS). a SnO_2 vs Sb_2O_3 plotted per main bead-type; b CuO vs SnO_2 plotted per main bead-type; c CuO vs NiO plotted per main bead-type; d zoomed detail CuO vs NiO.

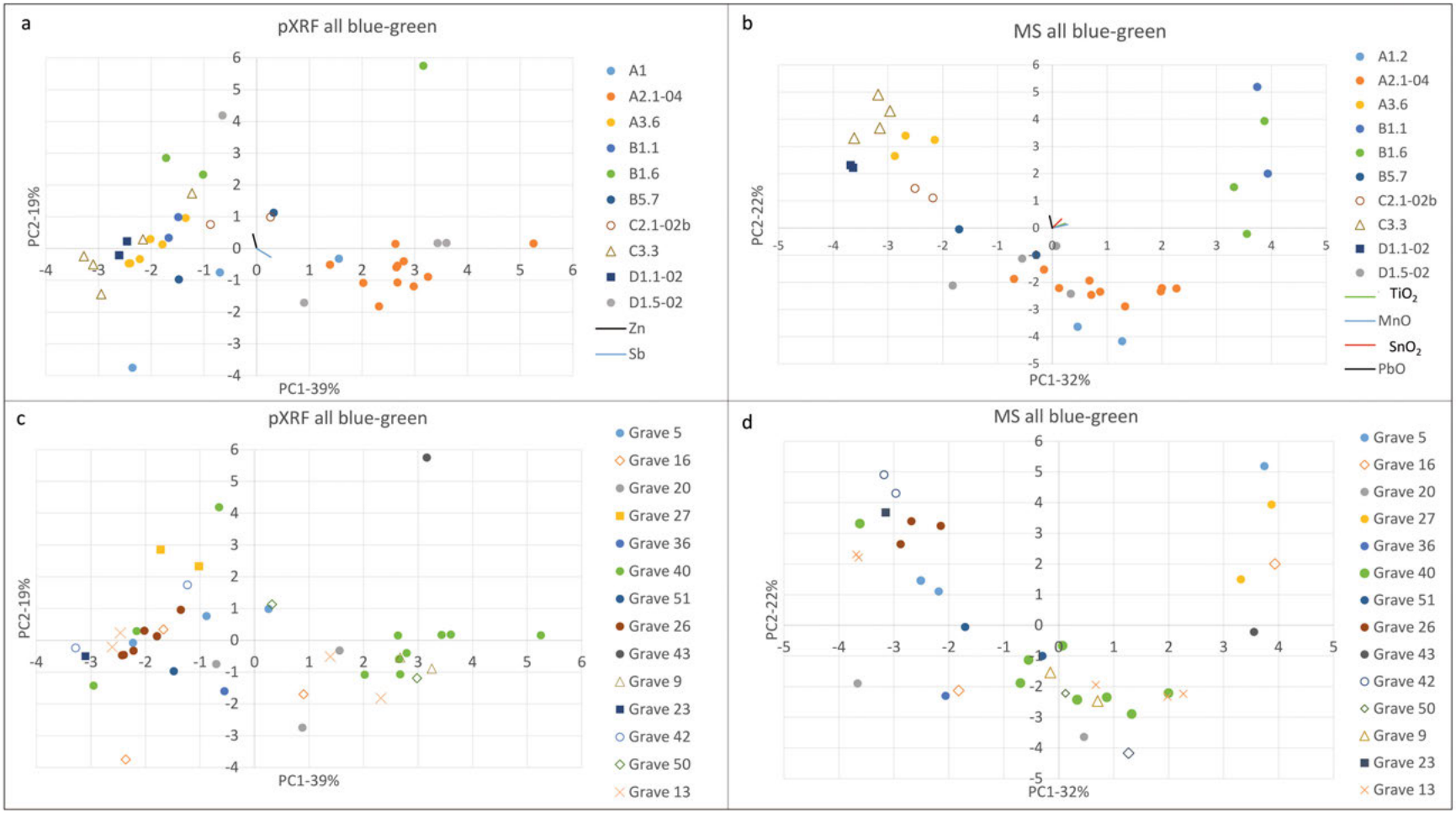

Fig. 12 Green-blue/blue-green beads: PCA results pXRF and LA-ICP-MS. a pXRF analysis plotted per bead-type; b LA-ICP-MS analysis plotted per bead-type; c pXRF analysis plotted per bead grave; d LA-ICP-MS analysis plotted per bead grave.

Roman tesserae.[174] In contrast to A, C and D beads, B bead-types B1.1-08d, B1.6-01e and B5.7-? do not form clear type clusters. As green-blue or blue-green is an uncommon colour in B-type beads, it is likely that these were made in small batches by recycling and mixing older glass. Bead-types B1.1-08d and B1.6-01e form a separate group in the upper right corner of the plot, whereas B5.7-? plots with the A, C and D types. This is unsurprising: the two identical B5.7-? beads from grave 51 are unique wound beads without, to the knowledge of the authors, parallels in other Merovingian cemeteries and were most likely imported from Egypt or the Syro-Palestinian coast.

4. 3. 4. Groups per grave

Generally, for both the pXRF and LA-ICP-MS PCA, within each bead-type group as they were determined above, beads from the same grave tend to cluster together (Figs. 12c and d). This is to be expected, as besides bead-types A2.1-04 and C3.3-01 the other green-blue or blue-green types occur in one or two graves only. It could indicate that beads of the same type in a single string of beads from Lent-Lentseveld were acquired at a single occasion.

Most A2.1-04 beads were excavated from grave 40. In the pXRF PCA plot per grave these beads cluster together in one group, with one outlier to the far right (this bead is closest to the A2.1-04 type, but looks different from the others in grave 40) and one a little to the left. Within the cluster of grave 40, A2.1-04 beads from grave 50, grave 9 and one from grave 13 are also present. The same pattern can be discerned from the LA-ICP-MS PCA plot per grave: a central group with some outliers. Two others from grave 13 plot more to the left with one of the outliers from grave 40 and further apart from one another than A2.1-04 beads from other graves. In the LA-ICP-MS PCA graph these two beads also plot apart from the other A2.1-04 beads, this time a little to the right with the same outlier from grave 40.

C3.3-01 beads were excavated from graves 23, 40 and 42. Only one piece was found in grave 23, and two in the other graves. In the pXRF PCA graph, the bead from grave 23 plots close to a bead from grave 40 and a bead from grave 42. The second beads from graves 40 and 42 are both outliers. In contrast, all 4 C3.3-01 beads measured with LA-ICP-MS form a clear group at the top left of the PCA plot and those from grave 42 plot side by side.

4. 4. Red: results

The most common red bead-type found in Lent is B1.1-03 (151 beads), followed by A3.1-07 (29 beads), E1.2 (14 beads), B5.2-02 (13 beads), B11.1-02a (12 beads), D1.2–04 (9 beads), E2.1 (8 beads) and B1.6-01b (7 beads). These will be discussed in more detail below, as will the other bead-types in appendix table S4.3 (Fig. 13). Of these less common types, two to four beads were excavated in Lent. Red bead-types of which only one example was found in Lent will not be discussed.

4. 4. 1. General chemistry

B-beads are in the lower-end corner of the SnO_2–CuO plot and contain more Sb than A, C and E beads (Fig. 14a), they are also characterised by lower SrO contents and higher PbO concentrations than the other bead-types (Fig. 14b). E beads are characterised by the highest SnO_2 concentrations and D-beads by the lowest SnO_2 contents. They contain more Sb_2O_5 than other bead-types (Fig. 14c). The A2.1-02 beads have the highest CuO concentrations apart from one D-bead, bead 56 from grave 40. The A2.1-02 beads also have elevated SnO_2 and Sb_2O_5 concentrations. D-beads are also characterised by higher CaO concentrations and lower TiO_2 concentrations than the other bead-types (appendix, table S2). The A2.1-02 and D1.2-04 beads from Lent are further characterised by elevated MgO* and K_2O* values which are characteristic of Mesopotamian plant ash productions, which were already found for the blue-green and green-blue A2 and D beads.[175]

4. 4. 2. PCA XRF

The first two PCA-components explain 51 % of the variance (Fig. 15a). The X axis is dominated by lead, strontium and elements typical for the colourant such as copper, nickel and zinc. The Y axis is dominated by iron, cobalt, antimony and tin. In Fig. 15a a clear separation between B-type beads on the right and A, C, E and G can be observed. Red

[174] Pion 2014, 219–222.

[175] Also attested by Pion 2014, 219–222; Gratuze 2013.

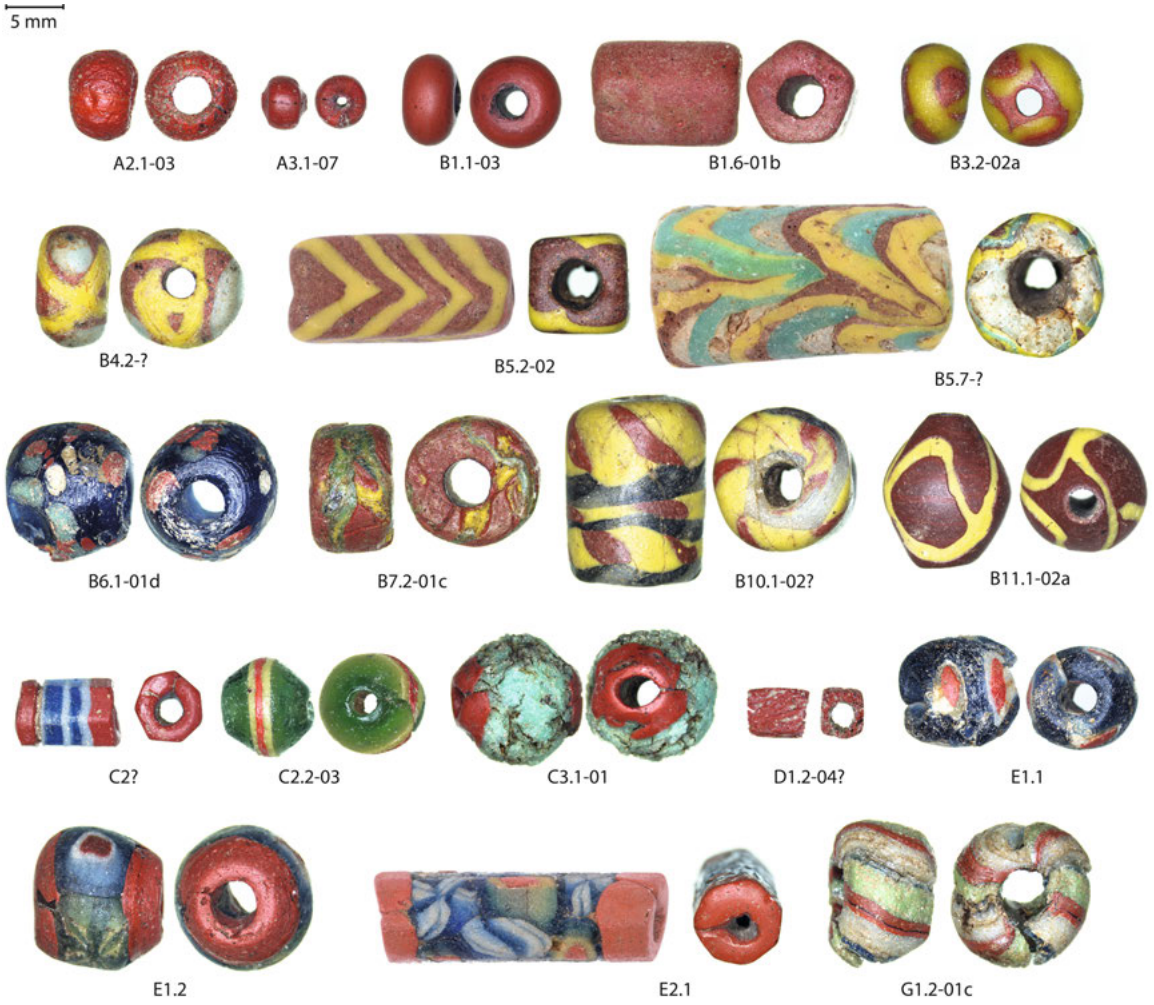

Fig.13 The red bead-types featured in this case study (Photos: M.B. Langbroek).

D beads plot in between both groups. To improve readability of the plots, separate figures were made for B1.1-03 beads and the other B-type beads and A, C, D, E and G bead-types (Figs. 16–18).

4. 4. 2. 1. A, C, D, E and G bead-types

A3.1-07 beads form a large group with several clusters in the top left (Fig. 16a). Both G1.2–01c beads plot within the same group, as do C2.?, C3.1-01 and several E1.2 and E2.1 beads. A2.1-03 beads do not belong to the same group: all 4 beads plot below it, together with three E1.2 beads. For E1.2 beads several other outliers, usually in pairs, can be discerned in every direction. In contrast, E2.1 outliers are always alone. Lastly, D1.2–04? beads form two diagonal lines through the middle of the graph. Since the components used for plotting the data are a composite of the contributions of different elements it is difficult to interpret this remarkable feature.

4. 4. 2. 2. B bead-types

B1.6-01b beads form 3 separate groups of two or three beads each (Fig. 17a). The separate groups all occur on the same line. B5.2-02? beads are also plotted in small clusters along a line, with several outliers in the margins of the graph. Concentrating in the same area, B11.1-02a beads form a loose group. Two B4.2–? beads from grave 27 plot together in the upper region of this group. Uncharacteristically, the red glass from the B5.7-? bead plots right along the same line as B5.2-02? and B11.1-02a beads: as was already explained above this is a unique wound bead without (known to the authors) parallels in other Merovingian cemeteries that was most likely import-

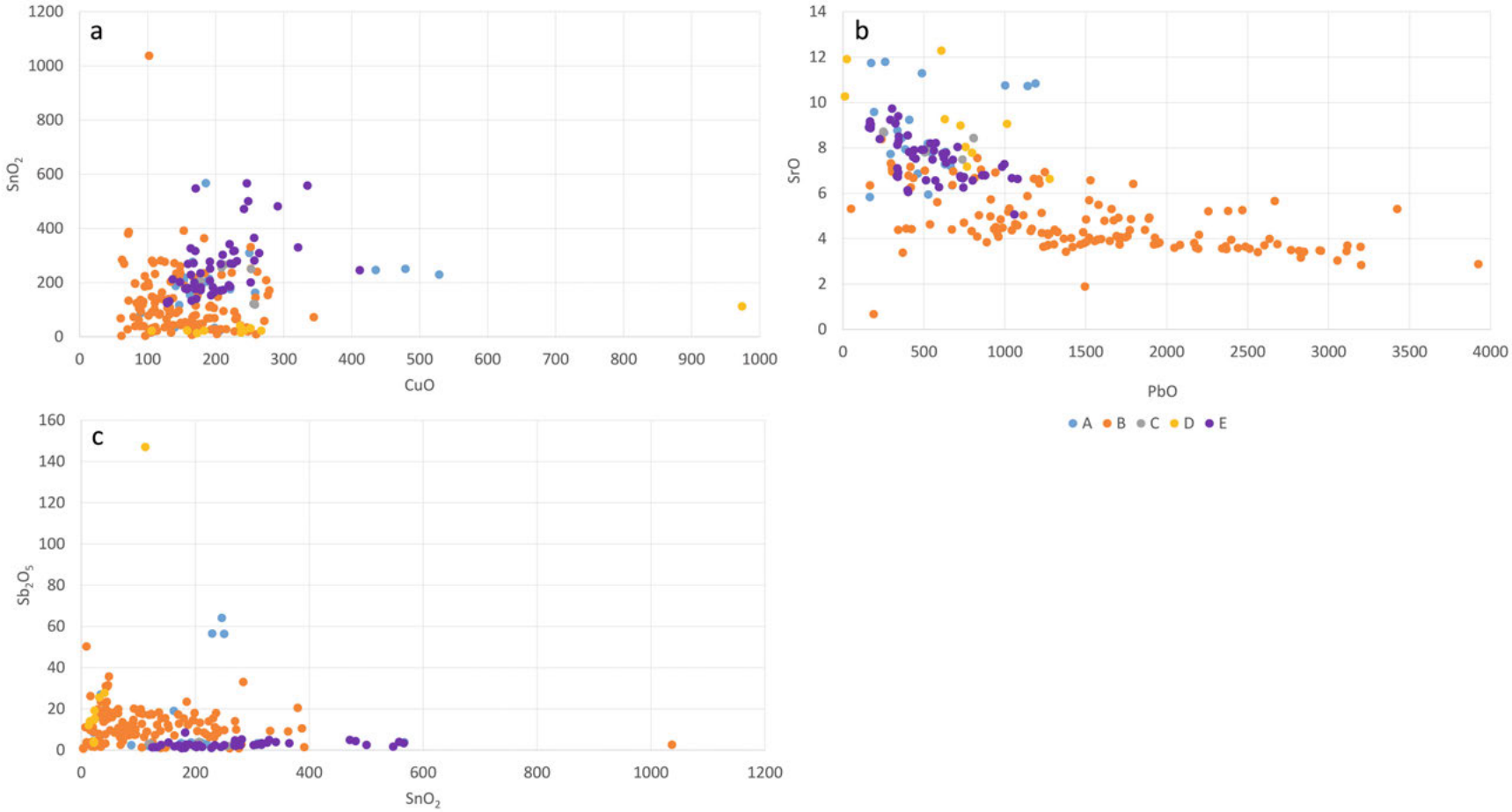

Fig. 14 Chemical composition of red beads (LA-ICP-MS). a CuO vs SnO_2; b PbO vs SrO; c SnO_2 vs Sb_2O_5.

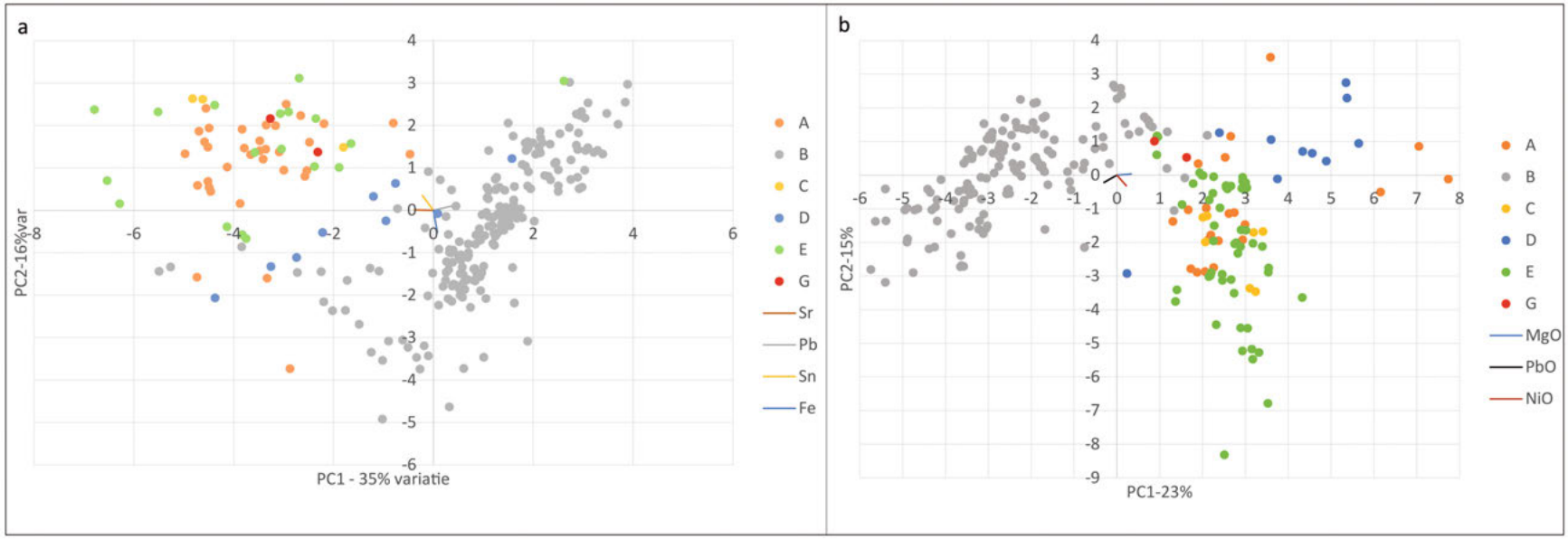

Fig. 15 Red beads: PCA results pXRF and LA-ICP-MS plotted per main bead-type. a pXRF; b LA-ICP-MS.

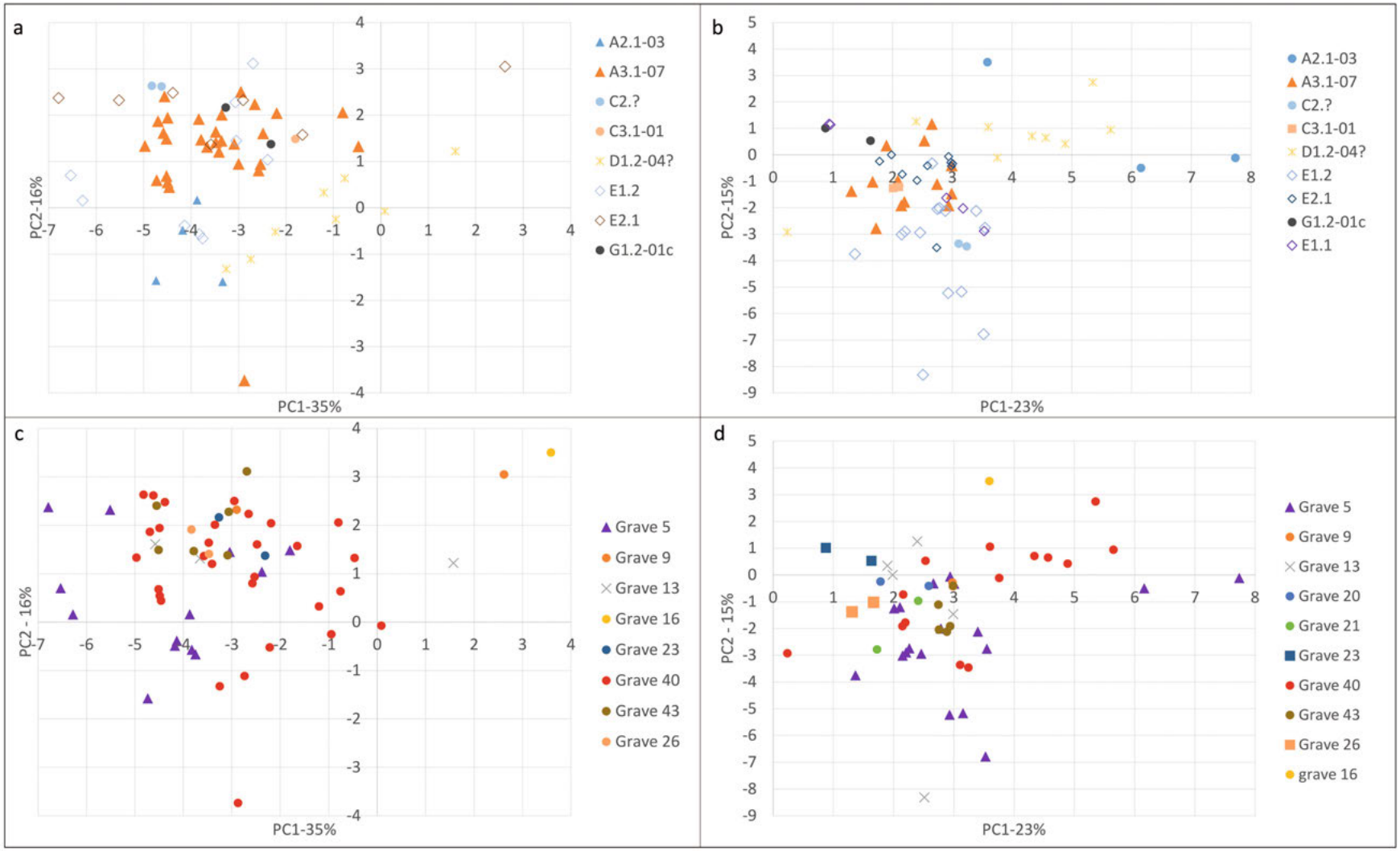

Fig. 16 Red A, C, D, E and G bead-types: PCA results pXRF and LA-ICP-MS. a pXRF by bead-type; b LA-ICP-MS by bead-type; c pXRF by grave; d LA-ICP-MS by grave.

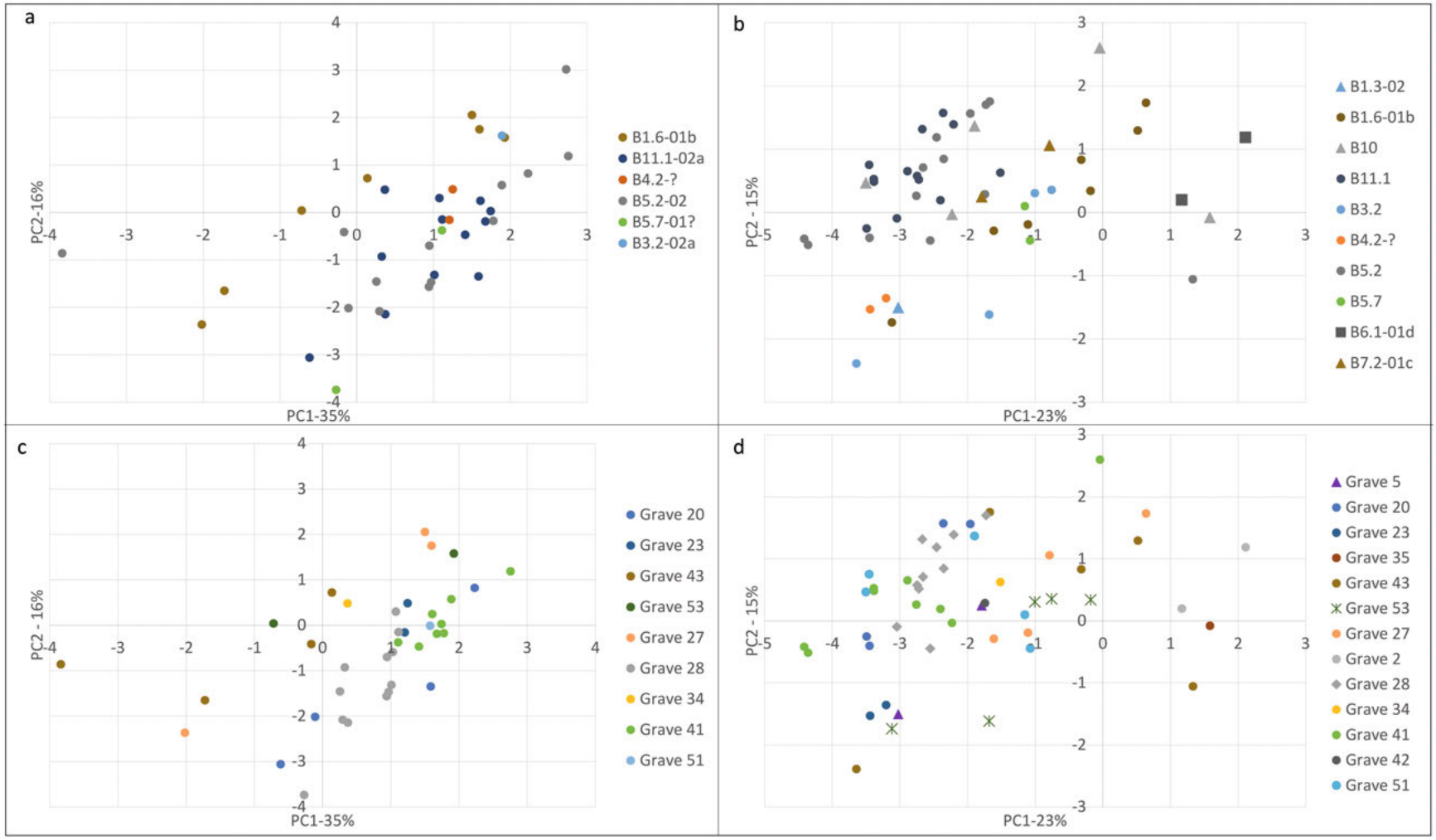

Fig. 17 Red B beads: PCA results pXRF and LA-ICP-MS. By bead-type a pXRF and b LA-ICP-MS; by grave c pXRF and d LA-ICP-MS.

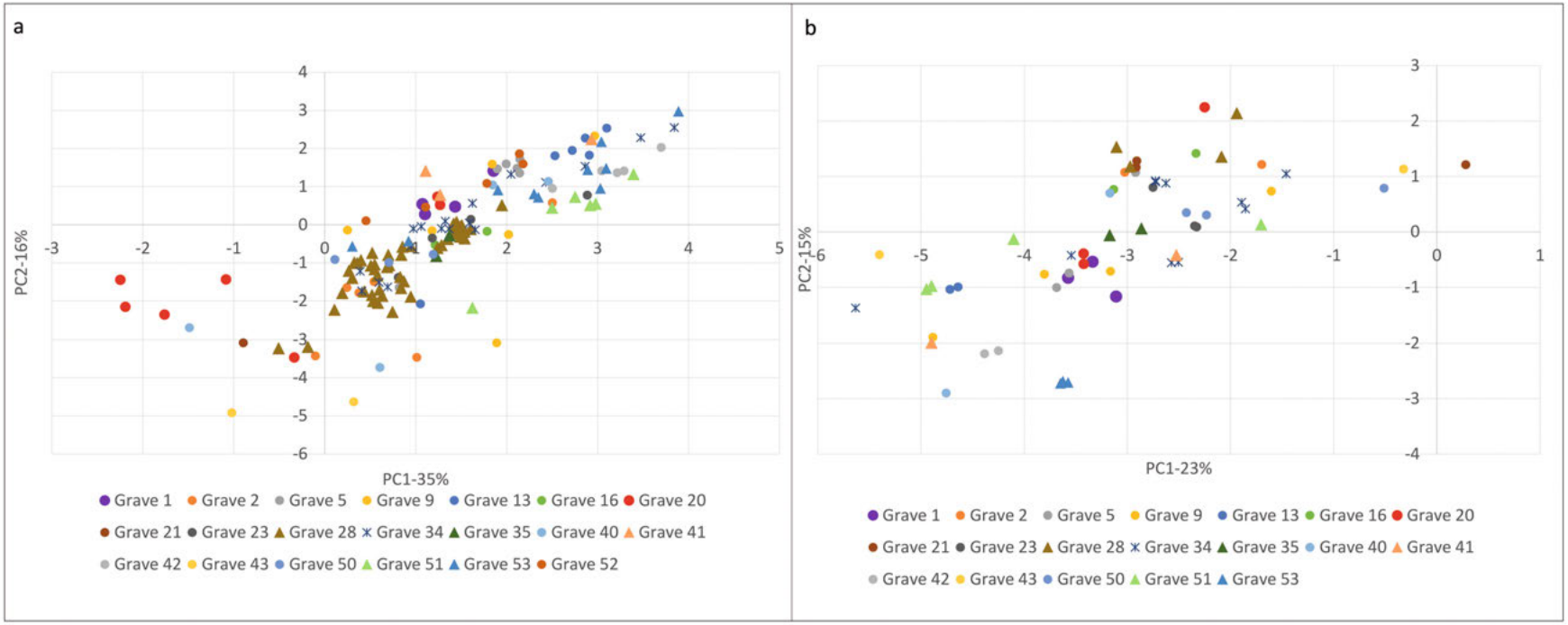

Fig. 18 Red B1.1-03 beads: PCA results. a pXRF; b LA-ICP-MS.

ed from Egypt or the Syro-Palestinian coast. The red glass used in their decoration seems to have more in common with European wound beads though.

4. 4. 3. PCA LA-ICP-MS

For the red glass the first two PCA-components only explain 38 % of the variation (Fig. 15b). The X axis is dominated by lead, strontium, magnesium and calcium. In contrast, the Y axis is mainly determined by tin, nickel, cobalt and sodium (elements mostly associated with the colourant (except sodium)). When the LA-ICP-MS PCA plot is compared to the pXRF PCA plot, it is clear they mirror each other with B beads on one side of the graph and A,C, E and G beads on the other side and the D-beads on the edge of the group formed by the A, C and G beads. Hence both methods are able to discriminate between the types and do so in a similar way. The mirroring is mostly due to the fact that in both cases the x-axis is dominated by the same elements (lead and strontium) but that in the case of the pXRF analysis Sr has a negative contribution and lead a positive contribution whereas for the LA-ICP-MS PCA Sr has a positive and lead a negative contribution.

4. 4. 3. 1. A, C, D, E and G bead-types

The PCA plot based on the results of the LA-ICP-MS analysis shows the same pattern as the pXRF PCA plot: a larger group of A3.1-07 beads with several clusters of two or three beads (Fig. 15b). C3.1-01 beads and several clusters of most E2.1, E1.1 and some E1.2 beads plot in the same area. A larger group of E1.2 beads plots below this 'main group', with one E2.1 bead and both C2.? beads. As was already noted in the pXRF PCA, A2.1-03 beads form their own loose group on the right of the graph, beyond the D-beads. D1.2–04 beads form a loose group to the top right of the main group, with one outlier in the far bottom left. In the top left corner both Roman G1.2–01c beads plot together with E1.1 beads. Probably, these E1.1 beads were made using shards of Roman millefiori glass (more below under 'Groups per grave').

4. 4. 3. 2. B bead-types (except B1.1-03)

The PCA plot based on the results of the LA-ICP-MS analysis shows the same pattern as the pXRF PCA plot: B1.6-01b beads plot in small groups along a line just to the left of most other B-beads (Fig. 15b). In the same region both B5.7-01 beads from grave 51 sit side by side. As already became apparent in the pXRF PCA, the red glass spirals on these Egyptian/ Syro-Palestinian coastal beads have much in common with 'European' red glass. Clusters of B5.2-02 and B11.1-02a beads plot together in the upper left side of the graph. Mirroring the pXRF PCA both B4.2–? beads from grave 23 plot close together. Several extra B bead-types were analysed with LA-ICP-MS. Both B7.2–01c beads do not form a cluster, and neither do both B3.2-02a beads. This was expected, because despite their classification as the same type, these beads do not resemble each other. Both B6.1-01d plot together, yet away from most other B beads: this is unsurprising, as this is a bead-type considered to have been imported from the Eastern Mediterranean. That leaves B10.1-02? beads, that feature a decoration of several rows of polychrome twists forming herringbone patterns that is sometimes referred to as a *reticella* technique.[176] Herringbone beads come in two categories: those with very fine twists, thought to have been made in the Eastern Mediterranean,[177] and those with coarser or 'imitation' twists that were made in Northwestern Europe.[178] The B10.1-02? bead from grave 35 has very fine twists, and is indeed plotted towards the right-hand side of the graph, with both Mediterranean B6.1-01d beads. The remaining four, two from grave 41 and two from grave 51, have much coarser twists and plot on the left-hand side with the other 'European' wound red beads.

4. 4. 4. Groups per grave

4. 4. 4. 1. A, C, D, E and G bead-types

In both the pXRF and LA-ICP-MS plots per grave (Fig. 16c and d), some clusters per grave can be discerned for nearly every bead-type. For C2.?, C3.1-01 and G1.2-01c this is unsurprising, as these types were found in one grave only. Besides these, the three A2.1-03 beads from grave 5 plot together, whereas the one found in grave 16 does not. Similarly, D1.2-04 beads from grave 40 form a separate group from the one found in grave 13. Furthermore, most clusters observed above for type A3.1-07 corre-

176 See Guido 1999, 64–66 on why the term *reticella* is erroneous.
177 Pion 2014, 228; Koch 1997, 147.
178 Guido 1999, 64–66.

spond to specific graves. The three E1.1 beads from grave 35 plot quite close together, and the identical E1.1 beads made from Roman mosaic glass from grave 21 plot right on top of one another. They were probably made from the same shards of a Roman glass millefiori bowl. E1.2 mosaic beads also plot in pairs that usually come from the same grave. In terms of mosaic patterns there can be quite a variety within the E1.2 category. Those beads that plot together as pairs generally feature identical mosaic patterns. Both E2.1 beads from grave 9, that have an identical appearance (Fig. 19), also plot right on top of each other in the LA-ICP-MS PCA plot (Fig. 16b and d). This suggests the possibility that pairs of mosaic beads remained together from production to deposition. This is remarkable, as mosaic beads were most likely imported from Egypt. The remaining E2.1 beads do not cluster per grave. As none of these beads have an identical appearance in terms of mosaic patterns, this is unsurprising.

4. 4. 4. 2. B bead-types

In both the pXRF and LA-ICP-MS PCA graphs (Fig. 17c and d), a clear 'zone' of beads from grave 28 (grey) and 41 (green) can be discerned. Each zone consists of B11.1-02a and B5.2-02 beads that plot in clusters of two or three beads. These bead-types are found together in several graves in Lent (graves 20, 28 and 41, all dating to P2), and the red and yellow glass used to make them is often remarkably similar in appearance. For grave 20, two separate groups consisting of a B5.202 and a B11.1-02 bead can be observed. In terms of appearance, each of these groups form a definite 'set' (Fig. 20). This suggests that B11.1-02 and B5.2-02 beads were produced

Fig. 19 Mosaic beads from grave 9 and grave 5 with similar mosaic patterns and similar chemical compositions (Photos: M.B. Langbroek).

together and subsequently stayed together as a set. Keeping in mind the different clusters B11 and B5 beads occur in, it is possible that they were produced and/or acquired at several occasions. The separate 'zones' for graves 28 and 41 may indicate a slightly changed red glass recipe. In contrast, both B5.2-02 beads from grave 43 plot about as far apart as the graph allows: one with the other B5.2-02 beads, the other within range of the non-B bead-types. Furthermore, clusters per grave can be discerned for bead-types B3.2-02a, B4.2-?, B5.7-01? and B6.1-01d. This is unsurprising, as these types were found in one grave only. It does strengthen the theory that these sets of identical beads were acquired at the same time. For bead-type B1.6-01b, only two specimens from grave 27 plot together. The remaining five from graves 27, 53 and 43 form a 'confetti pattern' in both pXRF and LA-ICP-MS plots. No clusters per grave appear for bead-types B7.2-? and B10.1-02? either. The fact that none of the beads of these types have an identical appearance might explain their 'confetti

Fig. 20 B5.2 and B11 beads from grave 20, each pair forming a separate chemical cluster in the PCA. The beads from each cluster were found side by side during the excavation (Photos separate beads: M.B. Langbroek; Photo String of beads: A. Dekker, Municipality of Nijmegen).

behaviour' in both graphs. The B10.1-02 beads from graves 51 and 41, that feature two of these beads each, were clearly purposely sought out to be strung together to form a symmetrical string of beads. It is likely that these beads were acquired at several occasions, as was already suggested for the strings of beads from graves 20, 28 and 41 above, and strung as part of symmetrical strings at a later date, possibly for the burial itself.

4. 4. 4. 3. B1.1-03 beads

B1.1-03 beads do not plot in a specific type cluster. Instead, they occur in the complete range of B beads in the PCA plot. In Fig. 18a, the pXRF PCA graph for B1.1-03 beads are plotted per grave. For most graves, B1.1-03 beads form one or two specific clusters: chemically, B1.1-03 beads from the same grave are more alike than B1.1-03 beads from other graves. However, for graves 20, 34, 41, 51 and 53 some outliers that plot away from the clusters can be discerned. For graves 9, 40 and 43 no clusters can be discerned: B1.1-03 beads from these graves are scattered. Although fewer measurements of B1.1-03 beads were taken with LA-ICP-MS, the same pattern can be discerned from Fig. 18b, the LA-ICP-MS PCA graph for B1.1-03 beads. Again, they seem to mostly cluster by grave, with the exception of more scattered patterns in graves 9, 40 and 43.

5. Discussion

5. 1. Comparison of LA-ICP-MS and pXRF data

The method developed in this paper shows that pXRF analysis is able to discriminate between groups and that the groups found by performing PCA analysis on the pXRF data are the same as those found performing LA-ICP-MS analysis. The LA-ICP-MS analysis allows more precise interpretation and understanding of the groups and of the recipes for glass making, but if we are interested in finding patterns pXRF analysis is sufficient. By performing pXRF analysis on complete graveyards and choosing a few beads for LA-ICP-MS analysis based on the pXRF results the best results are obtained in a cost-effective way. LA-ICP-MS analysis allows to measure separately different colours of beads with complicated multi-coloured patterns, which is impossible using pXRF.

In order to do the type of analysis performed in this paper large datasets are necessary, it is the condition for statistical tools to be able to show patterns. So relatively rare bead-types cannot always satisfactorily be described, except if they behave like other, more common bead-types.

5. 2. European beads vs non-European beads

Both the pXRF and LA-ICP-MS PCA analyses have demonstrated a distinction between B-type beads (wound beads) and A-, C-, D- and E-type beads. Almost all the beads (bar the ones of Indian/Turkish/East Asian high alumina glass) are fluxed with mineral soda, indicating that the original raw glass was of Mediterranean origin (Egypt and the Syro-Palestinian coast).

The main difference between beads thought to be of Northwestern European making and imported finished beads is the lead content, especially for the black glasses. Lead oxide (PbO) addition has many beneficial properties: it increases the brilliance of the glass and it lowers the softening point making it easier to work. It is also a way to stretch the glass, i.e. by adding relatively cheap and easily available lead to the more expensive imported glass more glass is made.[179] The presence of lead in B-type beads,[180] elevated iron contents and metals not necessary to obtain the desired colour is well documented.[181] It has led to the hypothesis that metallurgical waste[182] and slags were incorporated in the glasses for colouring purposes.[183] By using these materials as colourants many metals are incorporated, besides the ones desired for the colour. We have also observed the co-occurrence of copper-tin (Cu-Sn) and/or zinc (Zn) in some glasses and the high lead contents in particular of the black glasses. Hence, we propose that bronze might also have been used as colourant rather than slags. Most likely all those different by-products of the metallurgical process were used for glass colouring.

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179 Henderson 1999, 85–86.

180 Or at least in beads with a Western European origin.

181 Pion 2014, 179 and references therein; Peake/Freestone 2012

182 Such as lead from cupellation processes (Matthes et.al. 2004, 133–134) or lead salvaged from Roman ruins.

183 Pion 2014, 179.

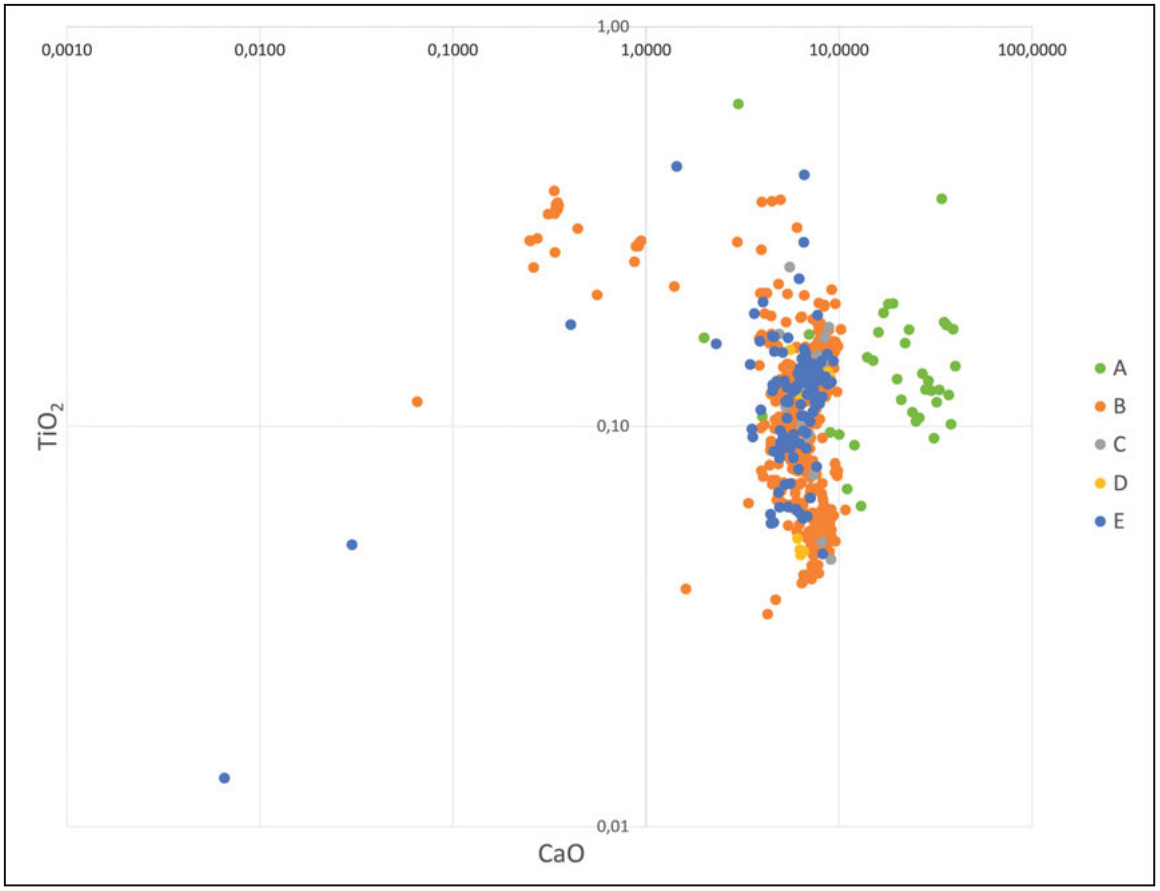

Fig. 21 TiO_2 vs CaO for different bead-types (LA-ICP-MS data, logarithmic scale).

A large proportion of the beads thought to be manufactured in Egypt or the Syro-Palestinian coast and Mesopotamia is fluxed using plant ashes as evidenced by the concentration of potassium oxide (K_2O) and magnesia (MgO) which are both above 1.5 wt-% (A1.1 green beads, A1.2 green, blue and blue-green beads; A2.1 and D1.2 red beads). This proves that the attribution to a production location based on style, also reveals something about the glass recipe used for manufacturing. D1.2 red beads are also characterised by higher calcium oxide (CaO) concentrations and lower titanium oxide ($TiO_{2)}$ concentrations than the other bead-types. In general, as shown in Fig. 21, A-beads contain more calcium oxide (CaO) than the other types and D beads less titanium oxide ($TiO_{2)}$. These A and D beads were clearly made with different recipes in comparison to other bead-types, likely indicating an origin in Egypt, the Syro-Palestinian coast or Mesopotamia.[184]

One of the important questions regarding glass production, trade and forming during the Late Antique and Merovingian period is the extent of recycling. Import of primary glass produced in the Mediterranean and worked in secondary workshops around the Roman empire is well documented.[185] The practice of recycling during the Roman imperial period is attested by both archaeological evidence and the writings of poets such as Strabo and Martial.[186] There is no doubt that this continued after the fall of the Western Roman Empire. A good indicator of recycling is mixed technologies such as the co-occurrence of Sb and Mn in colourless glass.[187] Yet large-scale systematic recycling of Roman Imperial glass is only noticed from the mid-7th century onwards in Britain[188] and later in Western Europe.[189]

184 Cf. Pion 2014, 219–222; see also Gratuze 2013.

185 Freestone 2015.
186 Paynter/Jackson 2016.
187 Freestone 2015.
188 Paynter/Jackson 2016.
189 Phelps et.al. 2018.

Also, evidence for the large-scale import of Roman glass tesserae for recycling occurs mainly from the ninth century onwards in the low countries,[190] with the exception of blue window glass in the 7th century.[191] The imported natron-beads from Egypt and the Syro-Palestinian coast as well as the plant-ash based glasses from Mesopotamia excavated in Lent were most likely made from fresh glass in those locations. For the high-lead B-beads produced in Northwestern Europe the picture is more complicated. At the very least they were produced using imported glass from Egypt and the Syro-Palestinian coast. For coloured glass it is hard to determine whether or not it was recycled. The addition of lead for opacifying and of different colouring agents does not allow the examination of trace element concentrations to discern the occurrence of recycling. Mixed tin (Sn) and antimony (Sb) or antimony (Sb) as opacifiers could be indicators of recycling. But for all the beads (including the B-beads), there is more tin (Sn) than antimony (Sb) present, though it must be noted that on average B-beads have more elevated antimony (Sb) concentrations than other beads, as evidenced in Fig. 22. Hence, we conclude that the imported finished beads were prepared from fresh glass and that the locally manufactured "European" beads were most likely produced using fresh primary glass with the addition of lead and colouring elements done in situ. The *occasional* addition of some old glass is evidenced by the presence of Sb (a technology which disappeared in the 4th century CE) in some of the glasses.

5. 3. Clusters per type (PCA)

In each of the three case studies presented above, clear groups per bead-type were discerned. As both green-blue/blue-green and red case studies have shown a clear separation between A-, C-, D- and E-type beads originating in the eastern Mediterranean or beyond and B-type beads originating in Northwestern Europe, these groups will be discussed separately below.

5. 3. 1. A-, C-, D- and E-type beads

In each case study, a separation between A2 and D beads (with the exception of D1.1-02) on the one side and A3, C and E beads on the other side was observed. Each cluster may have been produced in a separate region: the first in Mesopotamia,[192] the second in Egypt or the Syro-Palestinian coast or Egypt.[193] Although only one A1.2 bead-type was analysed, the blue-green A1.2-04 seems to have more in common with A2 beads than A3 beads. This points towards an origin in Mesopotamia as well, which has been suggested for A1.2 beads before.[194] Generally, clear chemical groups per specific bead-type could be discerned in both the Egyptian/Syro-Palestinian coastal and Mesopotamian clusters; we coin them 'type-groups'. As many C beads were only found in one grave, more analyses of these specific bead-types from other cemeteries are needed to establish whether we are in fact dealing with type-groups for C beads as well. Type-groups can be interpreted in several ways: different bead-types may have been produced at different points in time and thus reflect diachronic changes in recipe linked to raw material access. Alternatively, different glass recipes can reflect different workshops/manufacturing places for identical bead-types as well as contemporary different bead-types. A combination of these two scenarios is the most likely, as the production of drawn A3 beads and mosaic E beads demands such specific skill-sets that their co-production within the same workshop at the same time seems unlikely. We did notice that the red glass used in E2.1 and E1.2 beads (hexagonal vs globular mosaic beads) is chemically close, yet distinctive; it has been suggested before that hexagonal mosaic beads may be older than globular mosaic beads,[195] which could be reflected by their chemical composition. Supporting this, E2.1 beads plot much closer to E1.1 beads made out of Roman mosaic glass and G beads dating to the Roman period than E1.2 beads. Unfortunately, such specific dating information is not available for most other bead-types.

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190 Bidegaray/Pollard 2018, Crocco et.al. 2021.

191 Mirti et.al. 2000. Crocco et.al. 2021 provide a short summary of the use of glass tesserae for bead making. They point to early examples in Italy where abandoned villa's were turned into workshops and the villa was dismantled to be used as raw materials (including the mosaics for making glass). Interestingly, they also note that no glass tesserae were recovered from Merovingian sites in the Netherlands in combination with glass making, which contrasts with the Carolingian period where it is common and there seems to be an organised import of tesserae especially used for recycling.

192 Cf. Pion 2014, 219–222.

193 Cf. Pion 2014, 198–200.

194 Pion 2014, 215–219.

195 Volkmann/Theune 2001, 531–534.

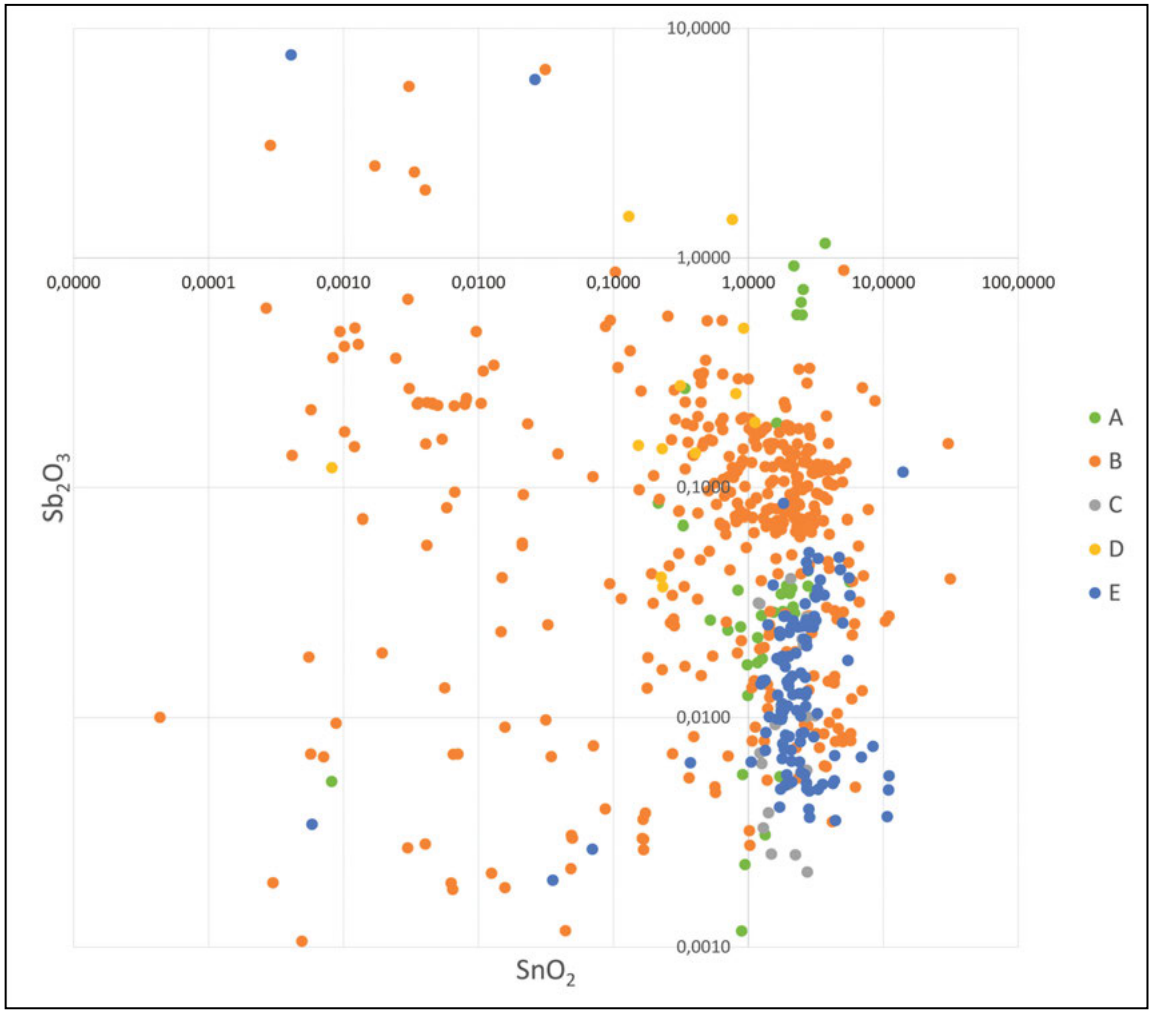

Fig. 22 Biplot of SnO2 and Sb2O3 content per measurement, sorted per main bead-type (LA-ICP-MS).

5. 3. 2. B-type beads

Groups for specific B-type beads could be distinguished in the PCA graphs. The most striking example is the group of B1.1-01a beads. As was already suggested above, based on their chemical composition, these tiny black wound beads were made out of a three-component mixture of a base glass, lead, and iron from iron slag. All other B beads tend to plot together in a large cluster that contains slightly overlapping type-groups. Several type-groups, such as black B1.8-01 and red B4.2–? tend to consist of beads from one grave only. Most other B bead-types, such as black B1.1-01b and red B1.6-01b appear in several groups, possibly indicating different workshops, bead-making events, or slightly changing coloured glass compositions over time. The same can be said for red B1.1-03 beads that occur across the entire B-bead range. Within this range, the chemical variation of European red glass during the sixth century CE is probably reflected. The similarity in chemical composition of groups of bead-types B11.1-02 and B5.2-02 remains noteworthy. As in Lent both bead-types are often found together on a string, it seems likely that these bead-types were produced during the same bead-making event.

Fig. 23 Symmetrical string of beads from Lent-Lentseveld Grave 20 (Photo: A. Dekker).

5. 4. Clusters per grave

Within the chemical groups that were established for many bead-types above, beads from the same grave often cluster together. This suggests a rather organised bead production and exchange: it indicates that specific bead-types were probably made together, exchanged together, strung together and eventually buried together. This applies to bead-types with both 'European' and 'non-European' origins: groups per grave were just as often found for A, C, D and E bead-types as for B bead-types. During the exchange of beads from the Eastern Mediterranean and beyond into Europe beads with similar composition, presumably from the same bead-making event or workshop, were kept together somehow, possibly in bags or strung onto long strands that could be coiled. However, for several B bead-types two or three groups per grave were discerned, for example for the red bead-types B1.1-03, B11.1-02 and B5.2-02 from graves 20, 28 and 34. The two or three chemical groups per grave may indicate that these beads were made and acquired at several occasions and strung together at a later date, perhaps for the burial itself. The symmetrical design of these strings of beads[196] demonstrates they were assembled purposefully (Fig. 23).

Besides occurring in one or several groups per grave, occasionally beads of the same type from the same grave display a 'chemical confetti pattern' that were clearly made (and acquired?) at different occasions. In appendix table S5 it is documented per grave whether specific bead-types from that grave form a 'chemical group(s)' or display a 'chemical

[196] The beads from Lent-Lentseveld were lifted from the grave *en bloc* and carefully excavated later on, thereby documenting the original order of the beads as much as possible.

Table 3 Results from appendix table S5 summarised per bead-period

	P1	%	P1–P2	%	P2	%	P2–P3	%
Group-grave	3	75 %	6	60 %	2	33 %	0	0 %
Combination-grave	0	0 %	2	20 %	4	66 %	1	100 %
Confetti-grave	0	0 %	0	0 %	0	0 %	0	0 %
?	1	25 %	2	20 %	0	0 %	0	0 %
Total graves	4	x	10	x	6	x	1	x

confetti pattern' in the PCA graphs above. For eleven graves no confetti patterns occur and for seven graves a combination of groups and confetti patterns was documented. No pure 'chemical confetti pattern' graves occur. Once these are sorted per bead period (Table 3), a pattern emerges: the earliest strings of beads (P1) only display chemical groups whereas strings of a later date more often display combinations of chemical groups and confetti patterns. Whether this is an actual pattern remains yet to be confirmed by studying the chemical compositions of glass beads of other colours from Lent, and by conducting similar research on the beads from other Merovingian cemeteries in the region. Tentatively, such a pattern could be explained by the fact that people were just starting to (re)settle the region during the late fifth and early sixth century.[197] In a region inhabited by few people, there may have been fewer opportunities to acquire or make beads. Additionally, no evidence for bead production has been excavated in northwestern Europe during this period.[198] Possibly, the strings of beads interred in the earliest graves of Lent were brought to the region by the settlers themselves.

Regardless of the possibility that strings of beads dating to P1 had more 'integrity' than strings of beads dating to later periods, the chemical clusters observed per grave indicate that the strings of beads found in Lent were not assembled by collecting beads one at a time. Rather they appear to have been strung at one or two occasions with clear symmetry in mind, using groups of the same bead-type that were made and exchanged together. Clearly, strings of beads were not disassembled and reassembled into different compositions time and again: that would have resulted in more chemical variability than the clear patterns observed here. The fact that strings sporting the same bead combinations can be found in graves across Europe supports this theory and proffers the idea that complete strings of beads may have been exchanged instead of individual beads.[199] This concurs with the generally accepted results on the chronology of bead ensembles: In most bead typologies it is not the individual bead-type, which may have been produced over and over again over a long timespan, but the entire ensemble that is dated.[200]

6. Conclusion and Future Research

For this article, a method to distinguish chemical bead-groups in the glass bead assemblage excavated from the Merovingian cemetery of Lent-Lentseveld was developed. This was achieved by incorporating typological bead data in the results of both the pXRF and LA-ICP-MS analyses of nearly every glass bead from the site and by using principal component analysis to distinguish between chemical groups. Additionally, making separate PCAs for the pXRF and LA-ICP-MS analyses has demonstrated the applicability of pXRF when aiming to establish chemical (bead-)groups based on the colouring elements.

The three case studies for black, blue-green/green-blue and red beads presented above have demonstrated that many bead-types form specific chemical groups. Chemical groups were established for both bead-types with provenances in the eastern Mediterranean and beyond as well as for bead-types

197 Theuws 2020.

198 Pion 2014, 180–191.

199 Langbroek in prep.

200 It is for instance reflected in the *Perlenkombinationsgruppen* developed by Frank Siegmund for the German Rhineland (Siegmund 1998).

that were produced in Northwestern Europe. Bead production and exchange appears to have been uniformly organised, at least for the imported beads (A, C, D and E beads). Within most type groups, beads excavated in the same grave were found to cluster together, although the occasional 'chemical confetti pattern' does occur in strings dating to the middle and late sixth century. Most likely, this indicates that the strings of beads buried with the dead were strung with groups of beads that were made and exchanged together. The beads excavated in Lent were clearly not acquired or exchanged one at a time and the possibility that complete strings of beads were exchanged cannot be ruled out.

The chemical analysis of the different bead-types confirmed the presence of plant ash glasses from Mesopotamia and glasses whose base compositions can be attributed to Egypt and the Syro-Palestinian coast as established through the typological analysis. Furthermore, the beads produced in Northwestern Europe were found to be characterised by the use of metallurgical waste for colouring and opacifying[201]. Little evidence for recycling is found in this relatively early assemblage. It will be interesting to see whether this (and the other observations made above) is also the case for contemporary bead sets from other cemeteries in the region and how this evolves in later periods. In order to answer these questions we are currently working on processing the results of the chemical analyses of the bead assemblages of the nearby cemeteries Elst-'t Woud and Wijchen-Centrum.

[201] Peake/Freestone 2012.

7. Appendices

7. 1. Appendix 1: Graves with beads

Table S1 Overview of graves with beads from the cemetery Lent-Lentseveld. A drawn beads; B wound beads; C folded beads; D perforated beads; E mosaic beads; F cut beads.

Grave	Sex	Age	Position beads	Number of beads	number of bead groups	Material	Bead techniques	Provenance beads	Date beads	Period
1	female(?)	adult	neck	10	1	glass	B	Europe	500–600	P1–P3
2	female(?)	adult	neck	52	1	glass, amber, faience	B, F, A	Europe, Baltic, Egypt, Syro-Palestinian coast, Mesopotamia, Roman	480–530	P1
5	female(?)	adult	neck	72	1	glass, amber	B, F, A, E, C	Europe, Baltic, Egypt, Syro-Palestinian coast	530–570	P2
9	female	adult	neck	25	1	glass, amber	B, F, A, E	Europe, Baltic, Egypt, Syro-Palestinian coast	500–550	P1–P2
12		3–4	?	1	1	amber	F	Baltic	500–600	P1–P5
13		5–6	neck, hip	82 + 22	2	glass, amber	B, F, A, E, C, D	Europe, Baltic, Egypt, Syro-Palestinian coast, India	500–550	P1–P2
16	female	adult	neck, hip	26 + 1	2	glass, amber, marble, beryllium	B, F, A, D	Europe, Baltic, Egypt, Syro-Palestinian coast, Roman	480–530	P1
20	female	adult	neck,loose bead, hip	92 + 1	2	glass, amber	B, F, A, E	Europe, Baltic, Egypt, Syro-Palestinian coast, Mesopotamia	500–550	P1–P2
21		5–6	belt?	12	1	glass, amber, faience	B, F, A, E	Europe, Baltic, Egypt, Syro-Palestinian coast, Roman	480–530	P1
23	female	adult	neck	32	1	glass, amber	B, F, A, C	Europe, Baltic, Egypt, Syro-Palestinian coast, Roman	480–530	P1
26		5–6	neck, arm	61 + 37	2	glass, amber	B, F, A	Europe, Baltic, Egypt, Syro-Palestinian coast	540–560	P2
27		4–5	belt	7	1	glass, faience	B	Europe, Roman	530–570	P2
28	female	adult	neck, loose bead	109	1	glass	B	Europe	500–550	P1–P2
34	female	adult	neck, arm/ stomach, hip, knees	98 + 5 + 1 + 1	4	glass, meerschaum	B, F, A	Europe, Baltic, Mediteranean	500–550	P1–P2
35	female	adult	chest, hip	41 + 1	2	glass, amber	B, F, E, C	Europe, Baltic, Egypt, Syro-Palestinian coast	500–550	P1–P2
36	female	adult	chest	11	1	glass, amber	B, F, A, D	Europe, Baltic, Egypt, Syro-Palestinian coast	480–530	P1

Grave	Sex	Age	Position beads	Number of beads	number of bead groups	Material	Bead techniques	Provenance beads	Date beads	Period
40		young child	neck	120	1	glass, amber	B, F, A, E, C, D	Europe, Baltic, Egypt, Syro-Palestinian coast, Mesopotamia, India, Roman	500–550	P1–P2
41	female	adult	neck	27	1	glass, amber	B, F	Europe, Baltic, Mediteranean	530–570	P2
42	female	adult	neck	28	1	glass, amber	B, F, C	Europe, Baltic, Egypt, Syro-Palestinian coast	500–550	P1–P2
43	female	adult	neck, bag	46 + 31	2	glass, amber	B, F, A, E	Europe, Baltic, Egypt, Syro-Palestinian coast	530–570	P2
45	female	adult	disturbed grave	5	1	glass, amber, faience	B, F	Europe, Baltic, Roman	480–610	P1–P3
50	female	adult	neck, hip	19 + 1	2	glass, amber, marble	B, F, A, E	Europe, Baltic, Egypt, Syro-Palestinian coast	500–550	P1–P2
51	female	adult	neck	46	1	glass, amber	B, F, D	Europe, Baltic, Egypt, Syro-Palestinian coast	550–600	P2–P3
52	female	juvenile	neck	7	1	glass	B	Europe	480–610	P1–P3
53	female	adult	neck, loose bead	66 + 1	2	glass, amber	B, F, A, C	Europe, Baltic, Egypt, Syro-Palestinian coast, India	530–570	P2
55		infant	chest	5	1	glass, amber	B, F, A, C	Europe, Baltic, Egypt, Syro-Palestinian coast	530–570	P2
102	male	19–28	(cremation)	1	1	glass	B	Europe	480–610	P1–P3
105	?	20–40	(cremation)	1	1	glass	B	Europe	480–610	P1–P3
112	?	?	(cremation)	1	1	glass	E	Egypt	530–570	P2

7. 2. Appendix 2: Reduced compositions

Table S2 Summary of the reduced compositions with the average reduced composition for each colour and type of bead in the assemblage based on the LA-ICP-MS results from the beads from Lent.

Colour	type	Na_2O*	MgO*	Al_2O_3*	SiO_2*	P_2O_5*	K_2O*	CaO	Fe_2O_3	Which beads	Remark
Black	B1.1-01a	18.26 ± 1.07	1.18 ± 0.09	3.06 ± 0.79	66.71 ± 0.36	0.22 ± 0.09	0.85 ± 0.13	8.71 ± 0.57	1a	G20B30; G20B32; G20B36; G40B81	40–60 wt-% Pb
		3.16 ± 1.36	0.53 ± 0.03	13.16 ± 0.72	75.71 ± 1.51	0.79 ± 0.19	3.42 ± 0.59	2.22 ± 0.52	1a	G13B42; G13B52; G40B71; G40B64; G43B34; G43B57; G43/2B3 and G43/2B30	40–60 wt-% Pb
		18	0.39 ± 0.03	12.57 ± 0.85	63.84 ± 1.04	0.95 ± 0.31	2.59 ± 0.28	0.66 ± 0.08	1a		
		0.55 ± 0.17	0.47 ± 0.03	15.28 ± 1.05	77.59 ± 1.19	1.16 ± 0.38	3.14 ± 0.34	0.80 ± 0.10	1a	G40B68; G43B30; G43B19; G43B31; G53B43; G53B59; G53B66; G26/1B6; G26/1B8; G26/1B11; G26/1B12; G26/2B1; G26/2B2; G26/2B3;	40–60 wt-% Pb
		18	0.45 ± 0.02	11.12 ± 0.53	63.99 ± 0.95	0.67 ± 0.17	2.89 ± 0.74	1.89 ± 0.47	1a		
	B1.1-01b	17.06 ± 1.71	0.75 ± 0.19	2.48 ± 0.34	69.73 ± 2.33	0.11 ± 0.04	0.74 ± 0.14	8.51 ± 1.23	0.61 ± 0.29	G9B1; G13B29; G13B64; G16B10; G16B17; G20B2; G28B21; G28B81; G28B101; G28B102; G42B23; G50B19; G5B45; G5B55; G5B9	no Pb
	B10	16.95 ± 0.33	1.05 ± 0.12	2.81 ± 0.08	68.47 ± 0.46	0.17 ± 0.06	0.80 ± 0.04	8.75 ± 0.70	1a	G51B11 (2×); G41B9	3–4 % Pb
	B5.4-02	14,9	1,08	3,88	69,41	0,43	1,22	8,08	1a	G51B15 (2×)	20–25 wt-% Pb
	B5.7-01c?	17,25	0,95	2,76	68,32	0,14	0,83	8,75	1a	G42B14	4 wt-% Pb
	G1.3-02	19,25	0,74	2,63	68,67	0,08	0,5	7,13	1a	G51B40	no Pb
Blue	A1.2-01	12.94 ± 0.10	3.69 ± 0.01	2.27 ± 0.02	68.69 ± 0.01	0.26 ± 0.00	2.46 ± 0.02	8.68 ± 0.10	1a	G20B8; G20B12; G20B57	0.6–0.7 wt-% Pb
	A1.3-01	19,43	1,19	2,92	65,91	0,14	0,76	8,64	1a	G36B10	0.1 wt-% Pb
	A3.1-01b	17.92 ± 2.41	1.45 ± 0.25	3.57 ± 1.64	69.25 ± 0.12	0.46 ± 0.21	1.22 ± 0.39	5.13 ± 0.07	1a	G43B28 (2×); G43B47	0.1 wt-%¨b
	A3.2-01	19,33	0,93	2,72	67,79	0,09	0,74	7,39	1a	G53B58; G43/2B31	2–3 wt-% Pb
	A3.4-01a	17.65 ± 0.43	1.20 ± 0.07	2.78 ± 0.09	67.38 ± 0.20	0.14 ± 0.01	0.80 ± 0.03	9.06 ± 0.15	1a	G36B5; G36B7; G20B18	0.5–1.5 wt-% Pb
	B1.1-06a	15.98 ± 2.75	0.64 ± 0.20	2.52 ± 0.07	70.88 ± 1.83	0.11 ± 0.03	0.88 ± 0.26	8.11 ± 1.19	0.87 ± 0.12	G20B22; G20B25; G20B90; G43B25; G13/2B18	
	B1.1-06b	17.03 ± 2.09	0.68 ± 0.25	2.46 ± 0.15	70.55 ± 2.23	0.09 ± 0.04	0.73 ± 0.24	7.62 ± 1.13	0.84 ± 0.16	G34B3; G34B4; G34B16; G34B23; G34B26; G34B28; G34B32; G34B35; G34B40; G34B41; G34B92; G5B10; G5B60; G9B11; G16B7; G16B12; G16B23 (2×); G28B8; G28B11; G28B12; G28B72; G35B7; G35B31; G40B6; G13B9; G20B49; G20B75; G40B16; G40B69; G41B12; G41B14; G41B17; G42B21; G43B48; G45B2; G34/2B1; G34/2B5	
	B1.1-07	16.23 ± 1.59	0.73 ± 0.23	2.38 ± 0.57	69.84 ± 1.92	0.13 ± 0.02	0.77 ± 0.17	8.96 ± 1.25	0.95 ± 0.08	G5B44; G28B34; G28B36 (2×); G51B16; G13/2B6	
	B1.1-11a	16,077	0,556	2,59	71,541	0,172	0,78	7,764	0,519	G40B105	
	B1.1-12	16.80 ± 1.15	0.73 ± 0.15	2.68 ± 0.07	70.38 ± 0.63	0.11 ± 0.01	0.68 ± 0.00	7.84 ± 1.19	0.77 ± 0.40	G51B8; G35/2B1 (2x)	
	B1.5-02a	16.37 ± 0.37	0.39 ± 0.01	2.47 ± 0.10	71.35 ± 0.15	0.07 ± 0.00	1.86 ± 0.42	6.48 ± 0.16	1a	G34B99 (6×)	
	B1.5-02b	19,84	0,6	2,21	70,35	0,04	0,51	5,68	0,77	G35B16	
	B6.1-01d	19,71	0,78	2,33	68,53	0,06	0,55	7,07	0,97	G2B26; G2B34	

Colour	type	Na_2O*	MgO*	Al_2O_3*	SiO_2*	P_2O_5*	K_2O*	CaO	Fe_2O_3	Which beads	Remark
Blue	**C1.4-01**	19.04 ± 2.56	0.70 ± 0.08	2.32 ± 0.09	68.64 ± 1.64	0.05 ± 0.02	0.97 ± 0.59	7.31 ± 1.43	0.97 ± 0.06	G35B11; G42B5; G42B22; G53B19	
	C2	19.18 ± 0.62	0.71 ± 0.11	2.32 ± 0.14	70.18 ± 0.94	0.07 ± 0.06	0.67 ± 0.13	6.01 ± 0.43	0.87 ± 0.11	G40B13; G40B32; G55B4; G5B63; G5B66	
	C3.3-01	19.95 ± 0.35	0.89 ± 0.14	2.23 ± 0.17	68.22 ± 0.38	0.04 ± 0.00	0.48 ± 0.03	7.31 ± 0.18	0.89 ± 0.20	G23B3; G23B27; G42B10; G42B19; G40B104	
	D	18.25 ± 1.71	0.54 ± 0.10	2.33 ± 0.29	70.21 ± 1.18	0.09 ± 0.05	0.69 ± 0.32	6.93 ± 0.99	0.97 ± 0.06	G40B118; G36B1; G36B8; G40B95; G51B39	
	E1.1	18.45 ± 1.16	1.11 ± 0.22	2.78 ± 0.34	66.89 ± 1.30	0.18 ± 0.08	1.00 ± 0.23	8.58 ± 1.02	1a	G21B1; G35B15 (2×); G35B36 (2×); G21B6; G21B7; G35B17 (2×)	
	E1.2	17.87 ± 1.26	1.05 ± 0.22	2.77 ± 0.22	67.97 ± 1.45	0.14 ± 0.06	1.20 ± 0.72	8.04 ± 1.25	0.97 ± 0.11	G5B34 (2×); G5B19 (2×); G13B20; G5B27; G5B31; G5B61; G43B12; G43B42; G5B4; G5B53; G4B58 (2×); G5B41 (2×)	
	E2	19.54 ± 0.52	0.84 ± 0.20	2.38 ± 0.30	68.38 ± 1.45	0.07 ± 0.04	0.66 ± 0.18	7.18 ± 1.09	0.96 ± 0.14	G13B19 (2×); G20B43; G9B8 (2×); G9B21 (2×); G13B1; G40B65; G50B9 (2×); G13B30	
	G1.2-01c	19,83	1,1	2,77	65,86	0,12	0,73	8,6	1a	G23B16; G23B20	
	G1.2-05	7,57	0,28	1,46	85,46	0,06	1,91	2,83	0,43	G40B19 (2×)	
Blue-Green; Green-Blue	**A1.2**	14,86	3,96	2,3	67,31	0,22	2,45	8,14	0,77	G40B89; G20B14	
	A1.3-04	16,46	0,59	2,72	70,97	0,16	1,02	7,26	0,83	G16B5	
	A2.1-04	17.20 ± 1.09	1.25 ± 0.20	2.37 ± 0.11	67.31 ± 0.74	0.31 ± 0.12	1.12 ± 0.29	9.53 ± 0.91	0.91 ± 0.10	G9B5; G40B57; G40B88; G40B127; G50B7	
	A3.6	20.11 ± 0.19	0.75 ± 0.02	2.18 ± 0.11	69.06 ± 0.39	0.04 ± 0.00	0.45 ± 0.01	6.75 ± 0.14	0.66 ± 0.02	G26/2B5; G26/2B10; G26/2B14	
	B1.1-?	17,21	1,25	3,03	68,33	0,2	0,93	8,06	1a	G16B26	
	B1.1-01b (?)	19,28	0,9	2,74	68,95	0,07	0,58	6,48	1a	G5B9	
	B1.1-11a	14,24	0,44	1,16	73,22	0,13	0,5	9,66	0,66	G20B47	
	B1.6-01e	17.37 ± 0.49	1.21 ± 0.08	2.93 ± 0.22	68.65 ± 0.15	0.19 ± 0.02	0.90 ± 0.02	7.74 ± 0.08	1a	G27B2; G27B4; G43B46	
	C3.3-01	21,24	0,91	2,18	67,12	0,14	0,4	7,32	0,68	G42B10; G42B19	
	D1	16.56 ± 1.82	1.35 ± 0.67	2.29 ± 0.05	68.77 ± 1.85	0.44 ± 0.31	1.45 ± 0.65	8.16 ± 1.96	0.97 ± 0.04	G40B20; G40B43; G16B19	
Brown	**E2.1**	19.30 ± 1.12	1.21 ± 0.03	2.53 ± .02	66.26 ± 0.79	0.15 ± 0.03	0.85 ± 0.16	8.79 ± 0.29	0.90 ± 0.05	G5B15; G5B56; G40B65	
Colourless	**A3.1-07**	17.59 ± 0.95	1.32 ± 0.12	2.69 ± 0.15	67.13 ± 1.34	0.24 ± 0.06	1.03 ± 0.14	9.03 ± 0.73	0.98 ± 0.04	G21B9; G13B43; G13B72; G40B94; G40B96; G40B101; G53B14; G55B5; G43/2B28	
	A3-rest	0,951220279	0,11799665	0,14997465	1,335883926	0,059261599	0,142547267	0,728585064	0,043860156	G20B9; G20B59; G43/2B2	
	A4.1-01	17.15 ± 1.03	1.13 ± 0.14	2.65 ± 0.12	68.63 ± 1.07	0.12 ± 0.04	0.72 ± 0.13	8.64 ± 0.65	0.95 ± 0.10	G13B26 (2×); G13B40 (2×); G20B4 (2×); G36B2 (3×)	
	A4.2-01	17.51 ± 0.89	1.18 ± 0.13	2.77 ± 0.34	67.95 ± 0.89	0.15 ± 0.04	0.89 ± 0.20	8.58 ± 0.86	0.96 ± 0.07	G34B30 (2x); G34B61 (2×); G2B13 (2×); G2B13 (2×); G34B73; G2B15 (2×); G13B4 (2×); G13B44 (2×); G40B37 (2×); G40B44 (2×); G43B10 (3x); G43B33 (2×); G43B38 (2×); G53B23; G53B60; G53B68 (3×); G23/1B47 (2×); G26/1B55 (2×); G43/2B26 (2×); G43/2B27 (2×); G43B38; G26/1B47 (2×); G26/1B55 (2x); G53B23; G53B26 (3×)	
	A4.3-01a	16,76	1,13	2,69	68,92	0,12	0,73	8,68	0,97	G2B45; G2B47	
	B1.1-11a	15.65 ± 0.09	0.45 ± 0.01	2.68 ± 0.07	72.28 ± 0.24	0.14 ± 0.02	0.47 ± 0.02	8.02 ± 0.21	0.32 ± 0.02	G34B5; G34B6; G34B8; G34B11; G34B21; G34B78; G34B80; G34B81; G34B83	

Colour	type	Na_2O*	MgO*	Al_2O_3*	SiO_2*	P_2O_5*	K_2O*	CaO	Fe_2O_3	Which beads	Remark
Colourless	**B10.1-2**	18,57	0,49	2,1	71,52	0,04	0,51	6,19	0,59	G51B11; G51B29	
	B5.7-01?	18,53	0,45	1,88	72,21	0,03	0,48	5,96	0,46	G28B35	
	B6.1-?	17,1	0,5	2,69	70,11	0,1	0,75	8,44	0,31	G35B4	
	G1.2-01c	19,81	1,16	2,73	65,83	0,14	0,74	8,58	1a	G23B16; G23B20	
	E2.1-03?	19,76	1,12	2,49	66,42	0,17	0,86	8,18	1a		
Green	**A1.1-01**	17,45	2,29	5,66	66,41	0,15	2,05	5,01	0,99	G40B66; G53B64	
	A1.2-04	14,54	3,84	2,58	67,55	0,26	2,41	7,86	0,95	G40B110; G40B125	
	A2.1-04	17.07 ± 1.17	1.36 ± 0.20	2.48 ± 0.20	66.20 ± 1.17	0.39 ± 0.22	1.43 ± 0.44	10.08 ± 0.97	0.98 ± 0.04	G13B18; G13B71; G13B77	
	A3.1-04a	19.04 ± 1.61	0.87 ± 0.16	2.43 ± 0.21	69.73 ± 0.61	0.08 ± 0.05	0.61 ± 0.14	6.44 ± 0.89	0.80 ± 0.15	G53B46; G53B51; G53B60; G13/2B22	
	A3.1-04b	19.02 ± 2.06	0.95 ± 0.42	3.06 ± 0.83	67.95 ± 1.15	0.16 ± 0.23	0.80 ± 0.56	7.29 ± 1.64	0.76 ± 0.16	G43B4; G43B11; G43B29 (2×)	
	B1.1-08c	15,94	0,66	3,49	70,5	0,15	0,81	7,52	0,92	G16B6	
	B1.1-08d	16.68 ± 1.34	0.71 ± 0.22	3.18 ± 0.63	70.18 ± 1.15	0.17 ± 0.08	0.81 ± 0.20	7.28 ± 0.91	0.98 ± 0.04	G34B7; G34B33 (2×); G34B43; G34B51; G34B98; G5B48; G5B51; G13B12; G16N4; G16B20 (2×); G35B19; G35B29; G35B41; G50B8	
	B1.1-11?	18.94 ± 0.40	0.94 ± 0.05	2.38 ± 0.15	67.65 ± 1.30	0.08 ± 0.01	0.60 ± 0.07	8.54 ± 0.71	0.88 ± 0.12	G34B14; G23B9; G23B23	
	B1.14-?	16.16 ± 0.83	1.86 ± 1.07	3.91 ± 1.88	68.16 ± 1.90	0.70 ± 0.50	1.36 ± 0.55	6.97 ± 0.98	0.89 ± 0.18	G13B39; G13B53 (2×)	
	B1.8-01	18,03	1,1	2,59	67,21	0,17	0,86	9,04	1a	G50B16	
	B10.1-02a	14,3	0,8	4,2	70,08	0,14	0,88	8,83	0,77	G41B15	
	B12.1-03	16,96	1,21	2,62	68,22	0,15	0,88	8,96	1a	G20/2B1	
	B2.1-01a	18,25	0,88	2,67	68,82	0,1	0,79	7,52	0,96	G35B28; G35B40	
	B6.1-?	18,3	1,31	3,46	63,79	0,09	1,12	10,92	1a	G51B37	
	B6.1-01d	19,86	0,64	1,83	70,46	0,03	0,43	6,22	0,53	G2B36; G2B34	
	B7	17.37 ± 0.74	0.95 ± 0.13	3.70 ± 0.40	68.32 ± 0.67	0.17 ± 0.02	0.82 ± 0.08	7.67 ± 0.69	1a	G5B11; G5B54; G27B1	
	C1.4-02	21,34	0,73	2,05	68,34	0,04	0,42	6,48	0,6	G13B14	
	C2.1-02b	17,92	0,62	2,28	72,04	0,04	1,07	5,4	0,64	G5B63; G5B66	
	C2.2-03	19	1,7	2,46	65,75	0,34	1,5	8,25	1a	G53B22; G53B31	
	C3	21.00 ± 0.79	0.75 ± 0.13	2.26 ± 0.11	68.13 ± 1.12	0.04 ± 0.01	0.45 ± 0.06	6.78 ± 0.63	0.59 ± 0.04	G5B24; G5B35; G23B3; G40B53	
	D1.1-02	21,73	0,62	1,99	68,48	0,03	0,4	6,21	0,55	G13B16; G13B73	
	D1.5?	18,77	0,83	2,32	68,99	0,13	0,69	7,27	1a	G40B36; G40B60	
	E1.2	18.11 ± 0.90	1.22 ± 0.08	2.66 ± 0.10	67.22 ± 1.07	0.20 ± 0.06	1.00 ± 0.11	8.60 ± 0.29	0.99 ± 0.02	G5B42; G5B32; G5B27; G5B31; G5B61; G43B12; G43B42; G5B4; G5B53; G5B58; G5B41	
	E2-3	18.97 ± 0.90	1.13 ± 0.06	2.61 ± 0.14	66.32 ± 0.55	0.16 ± 0.01	0.99 ± 0.29	8.82 ± 0.57	1a	G13B19 (2×); G13B1; G20B48; G5B15; G5B56; G21B4; G13/2B4	
	G1.2-01c	19,65	0,73	2,1	69,57	0,05	0,49	6,79	0,62	G23B16; G23B20	
Orange	**A2.1-02**	13.00 ± 0.30	2.42 ± 0.04	3.12 ± 0.21	64.20 ± 0.14	0.89 ± 0.03	2.27 ± 0.10	13.11 ± 0.22	1a	G5B25; G5B70 (2×)	
	D1.2	13.71 ± 1.14	2.51 ± 0.46	2.89 ± 0.57	65.09 ± 1.80	0.98 ± 0.25	2.60 ± 0.66	11.22 ± 1.10	1a	G13B58; G13B68; G40B42; G40B47; G40B76	

Colour	type	Na_2O*	MgO*	Al_2O_3*	SiO_2*	P_2O_5*	K_2O*	CaO	Fe_2O_3	Which beads	Remark
Purple	**B1.1-08d**	13	0,76	3,64	71,87	1,53	0,91	7,28	1a	G34B7	
	B1.1-09b	18,15	0,59	2,39	70,52	0,07	0,7	7,16	0,42	G34B85	
	B?	18.01 ± 0.76	0.58 ± 0.07	2.65 ± 0.20	69.32 ± 1.78	0.08 ± 0.01	0.67 ± 0.08	8.22 ± 0.99	0.46 ± 0.17	G5B3; G5B21; G5B40; G13B21; G13B61	
Red	**A2.1**	12.96 ± 2.84	2.78 ± 0.70	3.05 ± 1.15	63.95 ± 1.41	1.08 ± 0.52	2.95 ± 1.39	12.23 ± 2.12	1a	G5B25 (3×); G5B37; G5B47; G5B67; G16B14	
	A3.1-07	17.66 ± 1.33	1.31 ± 0.12	2.93 ± 0.22	66.57 ± 0.86	0.42 ± 0.08	1.33 ± 0.16	8.79 ± 0.55	1a	G21B9; G13B43; G13B72; G40B94; G40B96; G40B101; G53B14; G55B5; G43/2B28; G43/2B4; G43/2B5	
	A3.4-05	17,55	1,34	2,99	66,19	0,55	1,43	8,95	1a	G40B14	
	A3.5-03	16,28	1,34	3,11	67,15	0,49	1,23	9,4	1a	G36B9	
	B1.1-03b	16.02 ± 1.32	0.80 ± 0.23	3.54 ± 0	70.18 ± 1.51	0.26 ± 0.12	0.96 ± 0.30	7.22 ± 0.84	1a	G1B1; G1B9; G5B13; G5B20; G13B13; G13B18; G16B3; G16B9; G20B53 (2×); H20B88; G35B34; G35B37; G40B103; G40B120; G42B2; G50B5; G50B13; G51B19; G53B21; G53B36	
	B1.1-03c	16.42 ± 0.80	0.76 ± 0.17	3.40 ± 0.56	70.14 ± 1.18	0.19 ± 0.05	0.85 ± 0.18	7.23 ± 0.65	1a	G21B8 (2×); G34B2; G34B12; G34B13 (2×); G34B24; G34B31 (2x); G34B46; G34B79; G1B7; G2B22; G2B23; G5B7; G9B3; G9B13; G23B12; G23B15; G28B3; G28B6; G28B10; G28B16; G41B2; G41B4; G42B7; G43B14; G43B45; G50B14; G51B10; G51B25; G52B1; G52B2; G105B1	
	B1.1-03d	17.16 ± 1.34	0.83 ± 0.10	3.62 ± 0.53	69.70 ± 0.51	0.18 ± 0.05	0.82 ± 0.15	6.68 ± 0.70	1a	G21B2; G9B9; G9B19; G51B18	
	B1.1-08d	12,77	0,7	3,11	74,28	1,16	0,99	5,99	1a	G34B7; G34B51	
	B1.6-01b	16.96 ± 0.68	1.24 ± 0.09	3.11 ± 0.19	68.55 ± 0.43	0.24 ± 0.07	1.02 ± 0.06	7.88 ± 0.39	1a	G27B3; G27B5 (6×), G27B6; G43B9; G43B41; G53B16; G53B35	
	B10.1-02	17.52 ± 1.34	0.86 ± 0.20	3.18 ± 0.42	68.65 ± 2.05	0.16 ± 0.03	0.89 ± 0.11	7.74 ± 0.58	1a	G35B6; G51B11; G51B29 (2×); G41B9; G41B10; G41B15 (2×); G41B16; G41B19	
	B11.1-01	15,78	0,55	2,78	71,45	0,16	0,75	7,53	1a	G28B45	
	B11.1-06	17,24	0,82	3,16	69,35	0,15	0,83	7,44	1a	G51B33 (2x)	
	B11.3-01e	18,57	1,02	2,57	67,68	0,18	0,87	8,12	1a	G2B1	
	B11.3-02a	16.14 ± 0.50	0.67 ± 0.07	3.17 ± 0.23	70.98 ± 0.62	0.20 ± 0.02	0.79 ± 0.05	7.05 ± 0.55	1a	G2B1; G34B1; G20B3; G20B89; G28B1; G28B9; G28B43; G28B60; G28B62; G41B23	
	B3.2	17.05 ± 0.32	1.13 ± 0.04	3.17 ± 0.47	68.89 ± 0.44	0.20 ± 0.01	1.03 ± 0.03	7.54 ± 0.57	1a	G53B12; G43/2B16; G53B15; G53B47; G53B61	
	B4	15,76	0,83	3,75	70,26	0,19	1,14	7,07	1a	G43B23; G23B17; G23B19	
	B5.2	16.20 ± 0.74	0.74 ± 0.21	3.38 ± 0.83	70.41 ± 1.01	0.18 ± 0.02	0.86 ± 0.26	7.22 ± 0.52	1a	G20B1; G28B61; G28B88; G43B6; G43B43; G20B91; G28B39; G28B44; G28B59; G42B16; G41B6; G41B8; G41B21	
	B5.7	15.74 ± 1.11	0.86 ± 0.24	4.01 ± 1.65	70.08 ± 1.02	0.32 ± 0.19	1.05 ± 0.37	6.95 ± 0.65	1a	G51B32; G51B1; G28B35; G41B18; G42B14	
	B6	17.25 ± 1.06	0.96 ± 0.35	3.13 ± 0.33	68.35 ± 2.42	0.25 ± 0.04	0.91 ± 0.13	8.14 ± 1.03	1a	G35B4; G2B26; G2B34; G2B49	

Colour	type	Na_2O*	MgO*	Al_2O_3*	SiO_2*	P_2O_5*	K_2O*	CaO	Fe_2O_3	Which beads	Remark
Red	**B7**	17.22 ± 0.81	0.92 ± 0.20	3.20 ± 0.28	68.84 ± 1.23	0.28 ± 0.32	0.88 ± 0.18	7.66 ± 0.73	1a	G34B37; G5B11; G51B17; G51B36; G5B54; G35B2; G35B3	
	C	16.16 ± 0.60	1.37 ± 0.04	3.12 ± 0.19	66.84 ± 0.60	0.43 ± 0.05	1.74 ± 0.44	9.36 ± 0.29	1a	G40B13; G40B32; G55B4; G53B22; G53B31; G5B24; G5B35	
	D1.2	13.41 ± 1.51	2.76 ± 0.30	2.24 ± 0.21	64.43 ± 1.16	1.12 ± 0.21	3.13 ± 0.77	11.91 ± 0.71	1a	G5B43; G40B47; G40B56; G13B81; G40B18; G40B27; G40B38; G40B52; G40B52; G40B55; G40B77	
	E1.1	17.39 ± 2.08	1.30 ± 0.18	2.97 ± 0.36	66.46 ± 0.53	0.48 ± 0.09	1.61 ± 0.64	8.79 ± 0.61	1a	G35B15 (2×); G35B36 (2×); G21B6 (2×); G35B17 (2×)	
	E1.2	16.33 ± 0.97	1.35 ± 0.14	3.12 ± 0.33	67.35 ± 0.96	0.40 ± 0.18	1.58 ± 0.52	8.88 ± 0.71	0.99 ± 0.03	G5B34 (3×); G5B19 (3×); G5B42 (4×); G5B32 (4×); G13B20 (2×); G5B27; G5B31 (2×); G5B61; G43B12 (2×); G43B42; G5B4 (3×); G5B53 (3x); G5B58 (4×); G5B41 (3×)	
	E2	17.71 ± 1.41	1.29 ± 0.13	2.88 ± 0.43	66.46 ± 0.61	0.37 ± 0.12	1.28 ± 0.31	9.02 ± 0.43	0.99 ± 0.02	G13B19; G20B43 (4×); G9B8 (2×); G9B21 (2×); G13B1 (3×); G20B48 (5×); G40B65 (2×); G50B9 (3×); G5B15 (4x); G5B56 (2×); G21B4 (2×); G13B30 (2×)	
	G1.2-01c	20,44	1,08	2,61	65,48	0,39	0,88	8,12	1a	G23B16; G23B20	
White	**B1.1-04a**	18.21 ± 1.06	0.69 ± 0.09	2.40 ± 0.28	70.25 ± 0.60	0.09 ± 0.03	0.62 ± 0.08	6.98 ± 0.62	0.75 ± 0.19	G13B24; G13B41; G16B8; G16B22; G16B25; G23B26; G36B11; G40B62	
	B1.1-04b	18.28 ± 0.73	0.80 ± 0.49	2.33 ± 0.28	70.49 ± 1.53	0.09 ± 0.08	0.54 ± 0.10	6.77 ± 0.90	0.70 ± 0.20	G34B18 (2×); G34B22 (7×); G34B34; G34B49; G34B89 (2×); G9B16; G16B13; G16B15; G40B7; G41B7; G42B17; G45B1; G51B21; G51B23	
	B1.1-06b	16,73	0,65	2,76	69,66	0,09	0,73	8,37	1a	G5B60	
	B1.1-12c	17,48	0,75	2,55	70,49	0,1	0,67	6,95	1a	G35/2B1	
	B1.6-01c	17,41	1,17	2,87	68,55	0,17	0,99	7,84	1a	G43B8; G43B24; G53B28	
	B1.7-02 (?)	16,74	0,72	2,73	70,63	0,19	0,83	7,29	0,86	G13B7	
	B10.1-02b?	18,87	0,49	1,9	71,63	0,02	0,44	6,15	0,51	G41B19	
	B11.3-01e	16,4	0,51	2,54	71,81	0,12	0,59	7,53	0,51	G2B1	
	B11.9-?	18,75	1,03	2,65	67,59	0,1	0,87	8,02	1a	G51B13	
	B12.1	17.90 ± 0.18	0.88 ± 0.21	2.37 ± 0.25	69.65 ± 0.92	0.09 ± 0.01	0.66 ± 0.05	7.60 ± 0.79	0.85 ± 0.08	G13/2B3; G20/2B1; G34/4B1 (2×)	
	B2-4	18.53 ± 0.87	0.97 ± 0.14	2.55 ± 0.21	68.85 ± 0.45	0.10 ± 0.05	0.75 ± 0.21	7.33 ± 0.77	0.92 ± 0.12	G35B28; G35B40; G53B15; G23B17; G23B19	
	B5	17.42 ± 0.84	0.83 ± 0.30	2.55 ± 0.36	69.39 ± 1.91	0.09 ± 0.03	0.74 ± 0.15	8.05 ± 1.55	0.94 ± 0.16	G13B11; G51B15; G51B32; G51B1; G41B18; G35B5	
	B6	19,1	1,66	2,4	67,58	0,09	0,65	7,8	0,71	G51B37; G35B14	
	B7	18.62 ± 0.98	1.73 ± 1.09	2.40 ± 0.33	68.02 ± 0.82	0.13 ± 0.07	0.72 ± 0.08	7.46 ± 0.61	0.91 ± 0.12	G34B37 (2×); G5B11; G35B2; G35B3	
	C	18.40 ± 1.04	1.15 ± 0.03	2.40 ± 0.37	68.32 ± 1.69	0.13 ± 0.07	0.85 ± 0.35	7.95 ± 1.21	0.80 ± 0.26	G40B10; G40B13; G40B32; G55B4	

Colour	type	Na_2O*	MgO*	Al_2O_3*	SiO_2*	P_2O_5*	K_2O*	CaO	Fe_2O_3	Which beads	Remark
White	**D**	18,3	1,47	1,82	71,36	0,02	0,43	6,17	0,42	G40B8; G40B11	
	E1.1	17.29 ± 0.75	1.80 ± 1.29	2.43 ± 0.29	67.64 ± 1.30	0.15 ± 0.07	1.18 ± 0.50	8.70 ± 0.95	0.82 ± 0.21	G21B1 (2×); G35B15 (2×); G35B36; G21B6; G21B7; G35B17 (2×)	
	E1.2	17.74 ± 0.85	1.18 ± 0.09	2.75 ± 0.20	67.57 ± 0.99	0.19 ± 0.04	1.01 ± 0.21	8.60 ± 0.35	0.96 ± 0.05	G5B34; G5B42; G5B19 (3×); G5B32; G13B20; G5B27; G5B31; G5B61; G43B12; G43B42; G5B4; G5B53; G5B58	
	E2-3	18.99 ± 0.67	1.14 ± 0.09	2.59 ± 0.09	66.46 ± 0.64	0.15 ± 0.02	0.86 ± 0.11	8.87 ± 0.37	0.93 ± 0.06	G20B43; G9B8; G9B21; G13B1; G20B48; G40B65 (2×); G5B15; G5B56; G21B4; G13B30 (2×); G13/2B4	
	G1.2-01c	18,91	1,15	2,68	66,12	0,15	0,8	9,24	0,96	G23B16; G23B20	
Yellow	**A4.3-01a**	17,64	1,12	2,68	68,18	0,11	0,78	8,53	0,95	G2B45; G2B47	
	B1.1.-11b	18,65	1,02	2,46	67,85	0,1	0,63	8,44	0,85	G23B8; G23B28; G23B30	
	B1.1-02a	17,57	1,21	2,94	67,79	0,19	1,04	8,27	1a	G43/2B8; G43/2B9; G43/2B14	
	B1.1-02b	17.00 ± 0.85	0.97 ± 0.24	3.30 ± 0.59	68.99 ± 1.42	0.17 ± 0.06	0.76 ± 0.14	7.83 ± 0.56	0.99 ± 0.05	G34B27; G1B2; G1B4; G2B21; G5B6; G5B14; G9B6; G13B6; G13B63; G23B29; G28B26; G28B30; G35B39; G40B2; G40B4; G40B102; G41B3; G41B24; G42B3; G42B6; G50B11; G53B1; G53B27; G43/2B13; G43/2B15	
	B1.1-02c	16.88 ± 0.91	0.82 ± 0.19	3.36 ± 0.61	69.58 ± 1.12	0.22 ± 0.39	0.74 ± 0.14	7.41 ± 0.52	0.98 ± 0.04	G34B9; G34B10; G34B19; G2B40; G5B2; G5B52; G9B18; G13B17; G28B14; G28B15; G28B22; G40B85; G40B98; G41B5; G42B1; G42B8; G42B12 (2×); G43B1; G43B15 (2×); G50B10; G51B12; G51B26; G52B6; G53B5; G53B18; G102B1	
	B1.1-02d	17.75 ± 0.55	0.99 ± 0.24	3.80 ± 0.58	68.49 ± 1.10	0.12 ± 0.01	0.68 ± 0.07	7.17 ± 0.19	0.99 ± 0.01	G9B10; G51B20; G51B41; G52B3	
	B1.1-06b	13,22	0,39	9,36	69,73	0,07	0,48	5,97	0,79	G34B32 (2×)	
	B1.1-11b	18,26	1,35	2,67	67,02	0,15	0,78	8,85	0,93	G2B30; G43B20; G43B37	
	B1.1-12b	16,32	1,21	2,92	69,1	0,13	0,82	8,51	1a	G51B1; G51B2	
	B1.4-01a	16,84	1,02	3,35	68,54	0,13	0,86	8,25	1a	G13B36; G51B5; G51B6	
	B1.5-02b	17,75	1,27	2,75	68,26	0,19	0,9	7,92	0,96	G55B1; G55B3	
	B1.5-03a	20,26	1,19	2,49	65,43	0,12	0,69	8,97	0,85	G35B9; G13/2B2; G13/2B8	
	B1.5-03b	18,37	1,18	2,59	67,93	0,14	0,79	8,11	0,88	G35B18; G43B3	
	B1.5-03c	16,94	0,91	2,36	68,77	0,09	0,64	9,41	0,89	G13/2B7	
	B1.6-01b	1,89	0,2	10,97	83,44	0,26	1,54	0,7	1a	G27B3	
	B10.1-02	17.10 ± 1.52	0.90 ± 0.14	3.80 ± 0.50	68.54 ± 1.43	0.13 ± 0.03	0.79 ± 0.12	7.73 ± 0.99	1a	G35B6; G51B11; G51B29; G41B9; G41B10 (2×); G41B13 (2×) G41B15 (2×); G41B16; G41B19	

Colour	type	Na_2O*	MgO*	Al_2O_3*	SiO_2*	P_2O_5*	K_2O*	CaO	Fe_2O_3	Which beads	Remark
Yellow	**B11-12**	16,81	0,86	3,1	69,51	0,14	0,7	7,89	0,98	G28B45; G51B33; G2B1; G34B1; G20B3; G20B89; G28B1; G28B9; G2843; G28B60; G28B62; G41B23; G51B13; G13/2B3; G34/4B1	
	B3-4	17.18 ± 1.04	1.10 ± 0.12	3.50 ± 0.64	68.54 ± 0.93	0.17 ± 0.04	0.87 ± 0.15	7.65 ± 0.68	1a	G51B28; G53B12; G43/2B16; G53B47; G53B61; G43B23; G23B17; G23B19	
	B5.2-02	16.41 ± 1.02	0.74 ± 0.20	3.34 ± 0.41	70.16 ± 1.14	0.16 ± 0.04	0.73 ± 0.09	7.47 ± 0.68	0.99 ± 0.02	G20B1; G28B61; G28B88; G43B6; G43B43; G20B91; G28B39; G28B44; G28B59; G42B16; G41B6; G41B8; G41B21	
	B5.7	16.02 ± 0.96	0.95 ± 0.24	3.35 ± 0.63	69.25 ± 1.57	0.15 ± 0.07	0.78 ± 0.11	8.53 ± 0.57	0.96 ± 0.04	G51B32; G51B1; G28B35; G41B18; G42B14	
	B6	17.87 ± 1.34	0.94 ± 0.36	2.76 ± 0.39	68.45 ± 1.39	0.13 ± 0.06	0.83 ± 0.18	8.16 ± 1.11	0.85 ± 0.17	G51B3; G51B37 (2×); G2B26; G2B34	
	B7	16.80 ± 2.54	0.95 ± 0.17	3.55 ± 0.71	68.99 ± 1.54	0.35 ± 0.36	0.74 ± 0.11	7.63 ± 0.84	0.98 ± 0.04	G5B11; G5B54; G27B1; G51B17; G51B36	
	C	17,04	1,2	2,72	67,56	0,18	1,57	8,74	0,97	G53B22; G53B31	
	E1	17.28 ± 0.67	1.24 ± 0.09	2.81 ± 0.18	67.44 ± 1.23	0.18 ± 0.02	1.05 ± 0.32	9.01 ± 0.95	0.98 ± 0.03	G35B17; G5B34; G5B42; G5B32; G5B27; G5B31; G5B61; G43B12; G43B42; G5B4; G5B53; G5B58; G5B41	
	E2	17.99 ± 0.81	1.20 ± 0.07	2.82 ± 0.35	66.92 ± 0.97	0.15 ± 0.04	0.80 ± 0.10	9.12 ± 0.54	1a	G13B19 (2×); G20B43; G9B8; G9B21; G13B1; G20B48; G50B9 (2x); G5B15; G5B56	
	E3.1-?	19,11	1,08	2,57	66,69	0,18	0,8	8,57	1a	G13/2B4	
	G1.3-02	18,46	0,52	2,24	71,07	0,05	0,48	6,66	0,52	G51B40	

7. 3. Appendix 3: Typology, Measurements and data-processing

7. 3. 1. Typology

Pion's typology is based on the seriation of over 21.000 beads found in six Merovingian cemeteries from Belgium. It was later adjusted and improved by Vrielynck, Mathis and Pion in 2018.[135] As bead collections from sites across Europe show remarkable similarities,[136] a typology based on early medieval bead collections from Belgium can be applied to early medieval bead sets found in the Netherlands without difficulty. In this typology, each bead-type is dated to one or multiple periods (P1, P2, P3, P4 or P5) within the Merovingian era (Table S3). It is structured based on the techniques used to manufacture Merovingian beads, a factor that had not been considered in previous typologies.[137] In Europe only evidence for the production of wound beads has been excavated, whereas other forming techniques were used in the Mediterranean, Egypt, the Syro-Palestinian coast, the region of Mesopotamia, and India.[138]

7. 3. 2. pXRF

X-Ray fluorescence allows determining the major and minor elemental composition of beads. In this research portable XRF (pXRF) was used. In general pXRF is an excellent semi-quantitative analytical tool. Allowing to recognize groups, determine relative abundances of elements, etc. It is usually cheaper than, for example, LA-ICP-MS analysis, and its portable nature means analysis can be performed non-destructively in the field. One of the major drawbacks of pXRF for the analysis of glass is its inability to accurately measure low-Z elements in particular Na and Si which are major elements from the glass. When (p)XRF and LA-ICP-MS analysis of the same objects are performed in the same conditions it is possible to use those to calibrate the full suite of pXRF analysis in order to obtain quantitative results.[139] Since this would not offer more insights in our research questions this was not performed for this article.

Table S3 Overview of the bead periods by Pion 2014, with Legoux phases and date-approximation.

Period	Legoux 2004	Date (approximation)
P1	MA1	480–530
P2	MA2	530–570
P3	MA3	560–610
P4	MR1	600–640
P5	MR1/MR2	620–670

The set up used for bead analyses was designed at Liege University by the team of IPNAS (*Institut de Physique Nucléaire Atomique et Spectroscopique*). The design answers to specific needs regarding archaeological material studies. The set-up is light and easy to use in museums or directly in the field.

It includes an industrial X-ray generator that powers the X-ray beam and detector. The X-ray beam is produced by a tube type end-window Magnum developed by Moxtek Inc (Orem, USA). The detector is an air-cooled silicon drift detector (SDD) with an active area of 5 mm² developed by BRUKER (Billerica, Massachusetts, USA). The X-ray source and detector are located on the same support as the power supply. The support was designed and printed for this specific purpose with the 3D printer of the lab. It is fixed on a mobile platform, also made at IPNAS, allowing independent vertical and horizontal movement. The distance between the set up and the sample was fixed to 8mm. In order to target the analysed area and to adjust the distance, two laser diodes are attached to the head.[140] All the movements are controlled by a personal digital assistant (PDA) which exchanges data with micro-controllers integrated into the system allowing accurate positioning of the detector.

For the measurements performed on the beads, objects were placed on a polymer grid printed in the IPNAS laboratory and they were facing the XRF beam that was a size of 1 mm on the sample. It was set to be in action for 60 seconds, at 39 kV, and 120 A.

The signal of the detector is amplified and analysed by a multi-channel recorder coupled to a microcomputer running JavaSpectre that allows to visualise and to analyse the obtained spectra.[141]

135 Vrielynck et al. 2018.
136 Langbroek 2023.
137 E.g. Siegmund 1998.
138 For a detailed discussion on bead techniques and their provenances, see Pion 2014, 178-229 and references therein.
139 Adlington et al. 2020.
140 Strivay et.al. 2016.
141 Hocquet et.al., 2008.

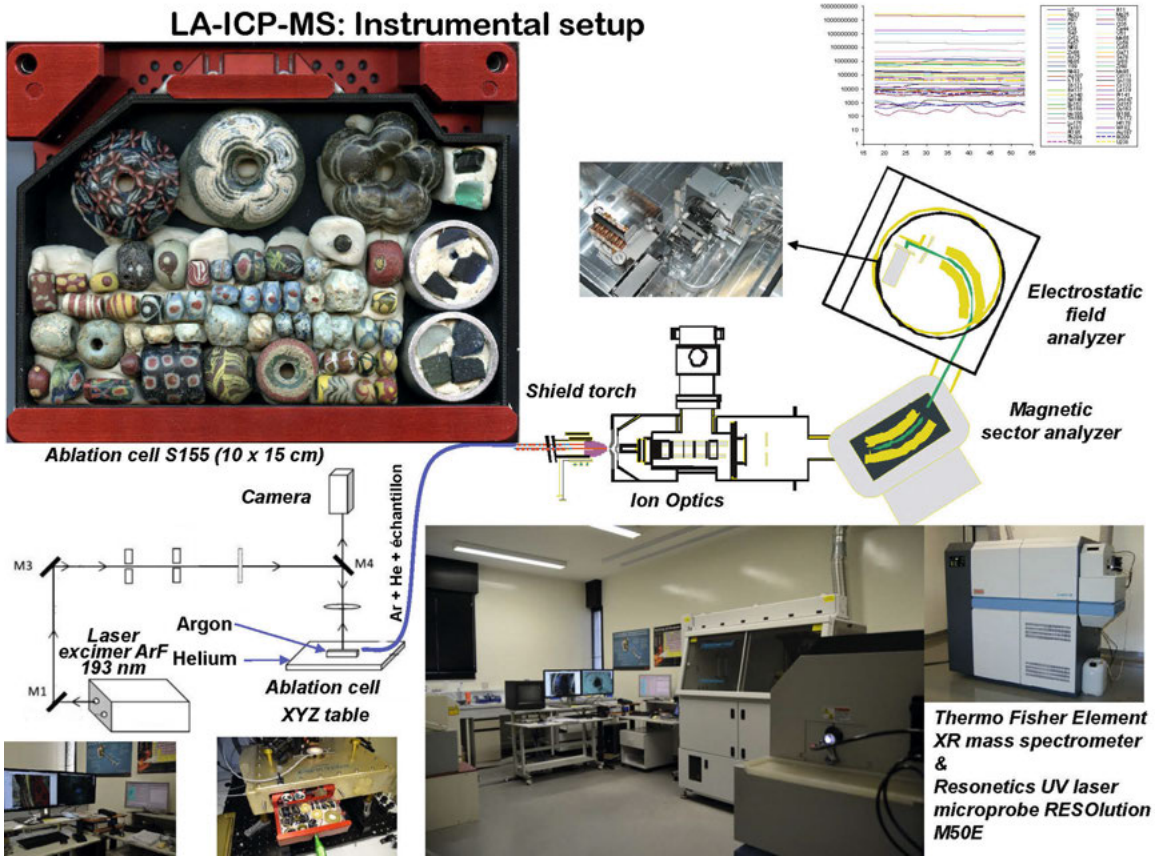

Fig. S3 Instrumental setup of the LA-ICP-MS analyses (Image by B. Gratuze).

After the measurements peak deconvolution and integration was performed and the number of counts for the mean peak of each element was determined. Those counts are used for the PCA analysis.

7. 3. 3. LA-ICP-MS

578 beads from Lent-Lentseveld have been analysed with LA-ICP-MS. Sampling through laser ablation allows both to perform the analysis in a minimally invasive way (the beads remain intact), and to perform spatially resolved analysis (i.e. for polychrome beads a particular colour can be targeted).

LA-ICP-MS is an analytical method widely applied in glass research. It allows determining the chemical composition of objects; with its large linear range and low detection limits simultaneous determination of major, minor and trace elements are possible. This is another important difference with XRF analysis, the possibility to measure the lighter elements. This method requires no sample preparation and allows a nearly non-destructive analysis, invisible to the naked eye; it is particularly well adapted to composite or decorated glass objects such as beads.[142]

The analyses of the glass beads were carried out by LA-ICP-MS. The instrumentation consisted of a Resolution M50E UV laser probe from Resonetics/ASI (Eximer ArF laser working at 193 nm equipped with the S155 cell) coupled with a Thermo Fisher Scientific ELEMENT XR mass spectrometer.[143] This mass spectrometer offers the advantage of being equipped with a three stage detector: a dual mode (counting and analog modes) secondary electron multiplier with a linear dynamic range of over nine orders of magnitude, associated with a single Faraday collector which allows an increase of the linear dynamic range by an additional three orders of magnitude. This feature is particularly important for laser ablation analysis as dilution of the sample is

142 Gratuze 2014, 2016.
143 Gratuze 2016.

impossible compared to ICP-MS with liquid sample introduction. For glass, it is therefore possible to analyse major, minor, and trace elements in a single run regardless of their concentrations and their isotopic abundance. With the standard analytical protocol, sodium, aluminium, silicon and potassium are systematically analysed with the Faraday collector while dual mode SEM is used for other elements.

The beads are placed inside an ablation cell, where a micro-sample, invisible to the naked eye (diameter < 100 micrometres), is extracted by the laser beam. This sampled material is then carried to the plasma torch of the mass spectrometer by an argon/helium gas flow (1 l/min Ar + 0.65 l/min He) where it is dissociated and ionised by the high temperature of the plasma (8000° C). The different glass constituents are separated according to their mass/charge ratios by the double focussing mass spectrometer and quantified by the electronic detector (secondary electrons multiplier or Faraday cup according to the ion beam intensities).

Analytical parameters were as follow: the excimer laser was operated at 5.5 mJ with a repetition rate of 10 Hz, ablation time was set to 50 seconds: 20 seconds pre-ablation, so that transient signal and possible surface corrosion or contamination could be removed, and 30 seconds collection time corresponding to 9 mass scans from lithium to uranium. The signal was measured in counts/second, in low resolution mode for 58 different isotopes. The fifty-eight elements include all major, minor (except sulphur) and trace elements which are usually present in glass samples.[144] Blanks were run periodically between each series of 20 analyses. Spot sizes were set to 100 μm, but their diameter could be reduced progressively down to 30 μm when saturation occurred for elements such as manganese, copper, tin antimony and lead. During analysis live counts were continuously observed: when element spikes signifying the presence of inclusions were observed, results were discarded and a new site selected. Homogeneity and agreement between runs carried out on the same type of glass were consistently good. To enhance detection limits on opacified glasses, specific analytical menus were tested on white and yellow opacified glasses as well as on red glasses. For some of these glasses, manganese, copper, tin and lead, were analysed with the Faraday collector instead of the dual mode secondary electron multiplier.

Calibration was performed using five reference standards: NIST610, Corning B, C and D, and APL1 (an in-house reference glass used for chlorine determination), were run periodically (every 15 to 20 samples) to correct for eventual drifts. The standards are used to calculate the response coefficient (k) of each element. The measured values were normalised against ^{28}Si, the internal standard. Concentrations are calculated assuming that the sum of the concentrations of the measured elements is equal to 100 weight percent. In total, 58 elements were recorded. For the major and minor elements accuracy and precision were within 5 % relative and within 10 % for most trace elements. In order to validate the obtained concentration results, glass reference standards Corning A and Nist 612 are regularly analysed as unknown samples throughout the analytical sequence. The average values obtained during the analysis for these glasses are presented in the table of results and agree within 5 to 10% with the certified ones.

144 Gratuze 2016.

7. 4. Appendix 4: Bead-types per colour

Table S4.1 Overview of the black bead-types, the graves they were found in and the amount of measurements taken with pXRF and LA-ICP-MS featured in this case study.

Grave	**5**	**9**	**13**	**20**	**26**	**28**	**40**	**41**	**42**	**43**	**50**	**51**	**53**	**total**
Type	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	**XRF/MS**
B1.1-01a	x	x	3/2	1/0	47/8	x	7/4	x	x	5/4	x	x	5/4	**68/22**
B1.1-01b	3/2	1/1	2/2	x	x	4/4	x	x	1/1	x	1/1	x	x	**12/11**
B1.8-01	x	x	x	5/3	x	x	x	x	x	x	1/0	x	x	**6/3**
B5.4-02	x	x	x	x	x	x	x	x	x	x	x	0/1	x	**0/1**
G1.3-02	x	x	x	x	x	x	x	x	x	x	x	1/1	x	**1/1**

Table S4.2 Overview of the green-blue/blue-green bead-types, the graves they were found in and the amount of measurements taken with pXRF and LA-ICP-MS featured in this case study

Grave	**5**	**9**	**13**	**16**	**20**	**23**	**26**	**27**	**34**	**36**	**40**	**42**	**43**	**50**	**51**	**total**
Type	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	XRF/MS	**XRF/MS**
A1.2-06	x	x	x	x	2/1	x	x	x	x	x	x	x	x	x	x	**2/1**
A2.1-04	x	2/2	3/3	x	x	x	x	x	x	x	6/4	x	x	1/1	x	**12/10**
A3.6	x	x	x	x	x	x	6/3	x	x	x	x	x	x	x	x	**6/3**
B1.1-08d	x	x	x	1/1	x	x	x	x	1/0	x	x	x	x	x	x	**2/1**
B1.6-01e	x	x	x	x	x	x	x	2/2	x	x	x	x	1/1	x	x	**3/3**
B5.7-?	x	x	x	x	x	x	x	x	x	x	x	x	x	x	2/2	**2/2**
C2.1-02b	2/2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	**2/2**
C3.3-01	x	x	x	x	x	1/1	x	x	x	x	2/1	2/2	x	x	x	**5/4**
D1.1-02	x	x	2/2	x	x	x	x	x	x	x	x	x	x	x	x	**2/2**
D1.5-02	x	x	x	1/1	x	x	x	x	x	x	3/3	x	x	x	x	**4/4**

Table S4.3 Overview of the red bead-types, the graves they were found in and the amount of measurements taken with pXRF and LA-ICP-MS featured in this case study.

Grave	**1**	**2**	**5**	**9**	**13**	**16**	**20**	**21**	**23**	**26**	**27**	**28**	**34**	**35**	**36**	**40**	**41**	**42**	**43**	**50**	**51**	**52**	**53**	**55**	**105**	**total**
Type	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	XRF/ MS	**XRF/ MS**
A2.1-03	x	x	3/3	x	x	1/1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	**4/4**
A3.1-07	x	x	x	x	2/2	x	x	1/1	x	2/2	x	x	x	x	x	18/3	x	x	4/3	x	x	x	1/1	1/1	x	**29/13**
B1.1-03	4/3	7/2	7/3	6/4	6/2	3/2	7/3	2/2	5/3	x	x	46/4	18/10	2/2	x	4/2	3/2	5/2	2/2	3/3	6/4	5/2	10/3	x	0/1	**151/61**
B1.6-01b	x	x	x	x	x	x	x	x	x	x	3/3	x	x	x	x	x	x	x	2/2	x	x	x	2/2	x	x	**7/7**
B3.2-02a	x	x	x	x	x	x	x	x	x	x	x	x	1/0	x	x	x	x	x	0/1	x	x	x	0/3	x	x	**1/4**
B4.2-?	x	x	x	x	x	x	x	x	2/2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	**2/2**
B5.2-02	x	x	x	x	x	x	2/2	x	x	x	x	5/5	x	x	x	x	3/3	1/1	2/2	x	x	x	x	x	x	**13/13**
B5.7-?	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	1/2	x	x	x	x	**1/2**
B6.1-01d	x	0/2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	**0/2**
B7.2-01c	x	x	0/1	x	x	x	x	x	x	x	1/1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	**1/2**
B10.1-02?	x	x	x	x	x	x	x	x	x	x	x	x	x	0/1	x	x	0/2	x	x	x	0/2	x	x	x	x	**0/5**
B11.1-02a	x	x	x	x	x	x	2/2	x	x	x	x	5/5	1/1	x	x	x	4/4	x	x	x	x	x	x	x	x	**12/12**
C2?	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	2/2	x	x	x	x	x	x	x	x	x	**2/2**
C2.2-03	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	0/2	x	x	**0/2**
C3.1-01	x	x	1/2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	**1/2**
D1.2-04?	x	x	x	x	1/1	x	x	x	x	x	x	x	x	x	x	7/8	x	x	x	x	x	x	x	x	x	**8/9**
E1.1	x	x	x	x	x	x	x	0/2	x	x	x	x	x	0/3	x	x	x	x	x	x	x	x	x	x	x	**0/5**
E1.2	x	x	7/11	x	0/1	x	x	x	x	x	x	x	x	x	x	x	x	x	2/2	x	x	x	x	x	x	**9/14**
E2.1	x	x	2/2	2/2	x	x	1/1	x	x	x	x	x	x	x	x	2/1	x	x	x	1/1	x	x	x	x	x	**8/7**
G1.2-01c	x	x	x	x	x	x	x	x	2/2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	**2/2**

7. 5. Appendix 5: Chemical groups

Table S5 In this table it is documented per grave whether specific bead-types from that grave form one 'chemical group' (green), multiple 'chemical groups' (yellow) or display a 'chemical confetti pattern' (red) in the PCA graphs. Sometimes a '+' is added, to indicate the presence of one or two 'chemical outliers'.

Grave	Date	Age	A1.2-06	A2.1-03	A2.1-04	A3.1-07	A3.6	B1.1-01a	B1.1-01b	B1.1-03	B1.6-01b	B1.6-01e	B1.8-01	B4.2-?	B5.2-02	B5.7-?	B6.1-01d	B10.1-02	B11.1-02a	B11 + B5	C2.?	C2.1-02b	C3.1-01	C3.3-01	D1.1-02	D1.2-04	D1.5-02	E1.1	E1.2	E2.1	G1.2-01c	Summary
1	P1–P3	adult								+																					?
2	P1	adult								+																					group
5	P2	adult							+																						group
9	P1–P2	adult																													combi-nation
13	P1–P2	child			+																										group
16	P1	adult																													?
20	P1–P2	adult								+																					group
21	P1	child								+																					group
23	P1	adult																													group
26	P2	child																													group
27	P2	child									+																				combi-nation
28	P1–P2	adult								+																					group
34	P1–P2	adult								+																					?
35	P1–P2	adult																													group
40	P1–P2	child																													combi-nation
41	P2	adult								+																					combi-nation
42	P1–P2	adult								+																					group
43	P2	adult																													combi-nation
50	P1–P2	adult								+																					?
51	P2–P3	adult								+																					combi-nation
52	P1-P3	child								+																					?
53	P2	adult								+																					combi-nation

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Zusammenfassung: Karneval der Perlen. Chemische Analysen merowingerzeitlicher Perlen aus dem Gräberfeld von Lent-Lentsefeld

In diesem Artikel wird eine Methode erläutert und getestet, mit der chemische Gruppen von Perlen aus einem einzigen merowingischen Gräberfeld unterschieden werden können. Dazu wird die gesamte Glasperlenansammlung des Gräberfeldes von Lent-Lentseveld aus dem 6. Jahrhundert sowohl mit pXRF als auch mit LA-ICP-MS chemisch analysiert und mit Hilfe von Hauptkomponentenanalysen (PCA) chemische Gruppen pro Perlentyp und pro Grab identifiziert. Die Ergebnisse sind vielversprechend. Für importierte Perlentypen aus dem östlichen Mittelmeerraum und weiter östlich werden klare chemische Gruppen pro Perlentyp erkannt, und sowohl für importierte als auch für europäische Perlen werden unterschiedliche Gruppen pro Grab identifiziert. Diese Befunde deuten darauf hin, dass im 6. Jahrhundert mehrfach Perlen über große Entfernungen nach Lent importiert wurden und dass die Perlen, sobald sie aufgereiht waren, in der Regel als ein bestimmtes Set zusammenblieben. Die in Lent ausgegrabenen Perlen wurden eindeutig nicht einzeln erworben oder ausgetauscht, was die Möglichkeit eröffnet, dass ganze Perlenstränge ausgetauscht wurden. Bei künftigen Untersuchungen wird es interessant sein festzustellen, ob dieselben Muster bei Perlenansammlungen aus anderen merowingischen Gräberfeldern in der Region zu erkennen sind.

Abstract: Bead Carnival. Chemical analyses of Merovingian beads from the cemetery of Lent-Lentseveld

In this article a method with which chemical groups of beads from a single Merovingian cemetery can be distinguished is explained and tested. In short, this is accomplished by chemically analysing the complete glass bead assemblage of the 6th-century cemetery Lent-Lentseveld with both pXRF and LA-ICP-MS, and using Principal Component Analyses (PCA) to identify chemical groups per bead-type and per grave. The results are very promising: for imported bead-types from the Eastern Mediterranean and further East clear chemical groups per bead-type are recognised, and for both imported and European beads distinct groups per grave are identified. These findings suggest that in the 6th century beads were imported over long distances to Lent on several occasions, and that once strung, beads tended to remain together as a distinct set. The beads excavated in Lent were clearly not acquired or exchanged one at a time, which opens up the possibility that complete strings of beads were exchanged. In future research it will be interesting to establish whether the same patterns can be recognised for bead assemblages excavated from other Merovingian cemeteries in the region.