Part I

European Trade Beads
1. Introduction

Glass trade beads are important chronological markers across North America, including on archaeological sites of indirect and early European contact in what is now southern Ontario, Canada. Classified using the Kidd and Kidd (1970) typology as updated by Karklins (1982; 2012), they form a framework for subdividing Huron-Wendat sites spanning the period ca. 1580–1650 CE (Kenyon and Kenyon 1983; Fitzgerald et al. 1995). Three periods are generally recognized: Glass Bead Period 1 (1580–1600); Glass Bead Period 2 (1600–1625/30); and Glass Bead Period 3 (1625/30–1650), hereafter GBPs 1, 2, and 3 (Table 3.1).

The Huron-Wendat confederacy was a nexus for trade in early to mid-17th century Ontario, partly because trade was historically important to the Huron-Wendat people (Trigger 1976) and partly because French explorers, missionaries, and traders lived within Huron-Wendat territory from 1615 to 1650, but not in the territories of other Indigenous nations in southern Ontario. At this time, the French were the primary suppliers of glass beads in both Huronia and the rest of Ontario, except between 1629 and 1631, when they lost control of trade in the St. Lawrence valley to the English (Fitzgerald et al. 1995). Dutch traders were important to the south, in what is now New York state. The presence of Dutch beads in Ontario results in two proposed horizons that overlap with the Glass Bead Periods (Fitzgerald et al. 1995): the Dutch Polychrome Horizon (1609–1624) and the Dutch Cored Horizon (1624–1660s).

Researchers have long recognized that investigating the European origins of glass beads found in eastern North America is complicated by three factors: 1) European traders of different nationalities operated in adjacent areas; 2) trade...
among Indigenous peoples continued to flourish; and 3) European traders likely supplied themselves with beads from different production centers, including centers outside their home country.

<table>
<thead>
<tr>
<th>Glass Bead Period</th>
<th>Monochrome</th>
<th>Polychrome</th>
</tr>
</thead>
<tbody>
<tr>
<td>GBP 1 (1580-1600)</td>
<td><strong>Turquoise round (IIa31/40)</strong></td>
<td>Black striped red round (IIb1)</td>
</tr>
<tr>
<td></td>
<td><strong>Cobalt blue round and circular (IIa35, IIa55)</strong></td>
<td>Black striped and compound red round (IVb1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Red-in-white striped light aqua oval (IIbb23)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>White striped round clear gooseberry (IIb18)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>White striped dark blue oval (IIb67)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alternating red and white striped dark blue oval (IIb64)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Multi-layered ground faceted star/chevron (IIIm1)</td>
</tr>
<tr>
<td></td>
<td><strong>Frit cored beads</strong></td>
<td></td>
</tr>
<tr>
<td>GBP 2 (1600-1625/30)</td>
<td><strong>White tubular (Ia5) and oval (IIa15)</strong></td>
<td>Blue striped white tubular (Ib’2)</td>
</tr>
<tr>
<td></td>
<td><strong>Indigo tubular (Ia19) and oval (IIa57)</strong></td>
<td>Blue-in-white red round and oval (Ibb1, Ibb2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Round eyed beads (IIg4, IIg*)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Multi-layered chevron/star (IIIm1)</strong></td>
</tr>
<tr>
<td>GBP 3 (1625/30-1650)</td>
<td><strong>Red tubular (Ia1) and round (IIa1)</strong></td>
<td>Compound red round and circular (IVA1-IVA8)</td>
</tr>
<tr>
<td></td>
<td><strong>Turquoise tubular (Ia12/14) and round (IIa31/40)</strong></td>
<td></td>
</tr>
<tr>
<td>Dutch Polychrome (1609-1624)</td>
<td></td>
<td>Blue-in-white red round and oval (Ibb1, Ibb2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>White-in-red striped black oval (Ibb7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>White and blue striped white circular (IVb15)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>White striped on layered white and indigo round (IVb29-36)</td>
</tr>
<tr>
<td></td>
<td><strong>Dutch manufacture star bead (IVk3)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Red and blue striped on multi-layered white, red and blue (IVn3, IVn4)</td>
</tr>
<tr>
<td>Dutch Cored (1624-1660)</td>
<td><strong>Turquoise round (IIa31)</strong></td>
<td>Small circular cord light grey (IVA13)</td>
</tr>
<tr>
<td></td>
<td><strong>Round and circular black (IIa6, IIa7)</strong></td>
<td>Multi-layered tubular indigo (IIa12)</td>
</tr>
<tr>
<td></td>
<td><strong>Indigo tubular (Ia19)</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Table 3.1:* Characteristic beads of the Glass Bead Periods used in Ontario and elsewhere in the northeast, compiled from Fitzgerald et al. 1995. Bead types shown in boldface font have been subject to chemical analysis using INAA and/or LA-ICP-MS
Beads diagnostic of GBPs 2 and 3 are dominated by monochrome and monochrome-appearing (i.e., compound beads with monochromatic exteriors) beads. Their compositions have been studied in detail by previous researchers, using instrumental neutron activation analysis (INAA) (for a summary see Hancock 2013 and Annex B). Although they are more temporally and typologically diagnostic than some monochromes, polychromes have received less attention from archaeometrists. A few polychrome beads were included in INAA studies of Dutch beads, but these were analyzed as whole samples resulting in characterization of the entire bead rather than specific colors (Karklins et al. 2001; 2002). Two recent compositional studies have focused on Nueva Cadiz beads, a particularly well-known polychrome type with several variants, to understand differences between them (Dussubieux and Loewen 2021; Walder, Hawkins et al. 2021). In this paper, we add to our knowledge of glass beads from Huron-Wendat sites by presenting chemical analyses of individual glass layers of polychrome beads, including three distinctive types.

The goal of analyzing polychromes from archaeological sites in North America, in the broadest sense, is to trace these beads to their origins in European glass workshops, and thereby better understand trade and exchange networks of the early colonial period. To do so, it is necessary to investigate polychrome bead production methods and locations, via similarities and differences in the recipes of the glasses used to produce the various colors and in trace elements concentrations associated with different silica sources. Using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS), we compare glass recipes 1) between polychrome bead layers and monochromes of the same color and 2) within individual polychrome bead layers. We also identify potential problems with using LA-ICP-MS analysis for polychrome beads.

2. Background

2.1. Chemical analysis of glass beads in Ontario

Most compositional analyses of glass beads found in Ontario have employed INAA (summarized in Hancock 2013). Some recent analyses employed LA-ICP-MS (Walder et al. 2021). INAA was intentionally restricted to elements with isotopes with short half-lives (including Al, Ca, Cl, Co, Cu, Mn, Sn, As, K, Na, and Sb). This suite of elements is much smaller than that obtained using LA-ICP-MS but is sufficient to provide reliable information on opacifiers, colorants, and fluxes for most glass beads in this time period, which are mainly soda-lime. However, the absence of data for Fe and Pb is limiting in some cases. Because
INAA is a bulk analysis method, it produces chemical concentrations for the entire sample. It is therefore best suited to monochrome beads. For polychrome beads that are predominantly one color, it may be possible to approximately characterize the chemistry of that color using a bulk analysis method, such as INAA. For example, Karklins et al. (2002:116) state that in white tubular beads with blue and red stripes, the levels of red and blue colorants are rarely measurable. However, bulk analysis is not appropriate for chevron-star or other compound polychrome beads.

The large number of archaeological glass beads from Ontario and New York that have been characterized by INAA (n=3790) includes beads from only seven Huron-Wendat sites (Auger, Ball, Bidmead, Charity, Molson, Ossossané, and Train). Here, we present LA-ICP-MS analyses of beads from seven further sites (Ahatsistari, Ellery, Le Caron, Peden, Robitaille, Thomson Walker, and Warminster), as well as LA-ICP-MS analyses of beads from three of the sites in the original INAA group (Auger, Charity, and Ossossané). Later sites (GBPs 2 and 3) are better represented in both the existing INAA dataset and the additional dataset presented here (Figure 3.1).

This paper focuses on three polychrome bead varieties that are found on Ontario sites and beyond. Tubular multi-layer (turquoise-white-redwood) twisted beads with a square cross-section (IIIc’3) have long been associated with a group of beads generally referred to as “Nueva Cadiz” (Goggin n.d.; Fairbanks 1968). Here we use the term suggested by Fairbanks (1968:12), “Nueva Cadiz Twisted, Red Variety (NCT-RV),” for such beads from Ontario with a red interior layer as opposed to the “classic” or archetypal Nueva Cadiz varieties (Walder et al. 2021; Loewen and Dussubieux 2021). Those may be simple (e.g., Ic11) or compound (e.g., IIIc1) with a blue outer layer, a white middle layer, and a blue center, and are known from earlier, 16th century, Spanish colonial contexts in the Americas (Smith and Good 1982: 51; Kenyon and Kenyon 1983; Smith 1983). The NCT-RV beads with the red interior layer from the northeast have a later, 17th century date (Goggin n.d.; Fairbanks 1968) and are unlikely to relate to Spanish-influenced exchange.

The second group of beads examined are round, red compound beads (IVa1, IVa5), sometimes incorrectly referred to as “Cornaline d’Aleppo.” Cornaline d’Aleppo beads, sensu stricto, date to the 19th century, are red with white centers, and have gold or selenium as a colorant for the red glass (Billeck 2008). The glass in the center of the red compound beads from Ontario varies in color from dark green to black. Here we refer to them as “red IVa* varieties.” Finally, we examine chevron-star beads. Overall, chevron-star beads have a wide geographic range, long duration of use, and several color combinations. However, all of the varieties
examined here are cobalt blue, white and red. They vary in terms of the number of layers of glass, the number of points in the star and the finishing: some are round, while most are facetted. People used these beads into the 17th century and later (Goggin n.d.). Beads classified as IIIm1 (7 layers, ground) and IVk4 (5 layers, milled) are included in this study. These bead types also have been recovered from other 17th century sites in eastern North America, from within the French (e.g., Bradley 2014; Kenyon and Kenyon 1983), Dutch (e.g., Rumrill 1991; Wray 1983), and British spheres of influence (e.g., Lapham 2001). European glass production centers for these specialized types are beginning to be better understood (e.g., Van der Storm and Karklins 2021).

Fig. 3.1: Locations of Huron-Wendat sites with analysed glass beads described in this paper.
2.2. Glass bead manufacturing in Europe and its relation to 17th-century glass beads in Ontario

Archaeologists have identified numerous European glass manufacturing centers producing beads for trade to North America. During the 17th century, workshops operated in France, the Dutch Republic, England, and the Venetian Republic.

2.2.1. France

Loewen’s (2019) review of documentary evidence for glass making in 16th and 17th century Normandy reveals it was the location of several small-scale, rural bead-making enterprises, as well as an urban production center in Rouen. Some manufacturing focused on rosary beads, some on other glass ornaments. Loewen (2019: 9) argues that, given that fur trade expeditions to North America were organized from this part of France, it is likely that some beads found in northeastern North American contexts were produced in Normandy. Loewen points out a “symmetry” between the Glass Bead Periods defined in North America and the periods during which different colonial powers controlled trade. In Ontario, GBP2, which is characterized by a predominance of white and navy-blue beads, corresponds roughly with a period during which Normandy was important in the fur trade. The first half of GBP3 corresponds with a period during which a Paris-based enterprise, the Compagnie des Cent-Associés, monopolized trade.

Recent documentation of a collection from Rouen (Karklins and Bonneau 2019) helps determine if beads from Normandy are the same types found at Wendat sites in Ontario. Glass tubes for producing the monochrome bead types common in GBP2 (Ia*/IIa* [oyster white], Ia18, Ia19) are found in the Rouen collections, along with production tubes for many other bead types not commonly found in Ontario.

By contrast, production tubes for some of the common GBP2 polychromes (Ib’2, IIbb1, IIbb2) are not represented in the Rouen collection. There is an example of a production tube for 7-layered chevron-star beads colored blue, white and red. With respect to common monochromatic beads from GBP3, there are production tubes and/or malformed beads in monochromatic colors common in GBP3 (red and turquoise), but none for a very common polychrome bead type, the red IVa* varieties, or for the IIIc’3 NCT-RV. Nevertheless, they propose that Nueva Cadiz-like beads found in northeastern contexts could have “originated in bead-making workshops scattered over northern France” (Karklins and Bonneau 2019:7). The finished bead part and the production tube in the Rouen collection indicate that the fashioning of tubes into beads may have happened in this location, but it is also possible that the glass production tube originally was made elsewhere. Dussubieux (2009) has published chemical data for waste objects excavated from a Rouen
workshop dating to the 17th century. Those of relevance here are red, turquoise, dark blue, and white tubes or rods, and several colorless rods, some of which may have been produced elsewhere (Dussubieux 2009: 97).

Information on 17th century bead making in Paris is limited. Turgeon (2001) documents a collection from the Jardins du Carrousel. Although this is a dump, rather than a production site, the presence of tubes as well as beads suggests production nearby. According to Karklins (2012), some beads in that collection may be imports. The collection includes monochrome types characteristic of GBP2 (white and navy beads) and of GBP1 or 3 (turquoise beads), but no polychrome types typical of either GBP2 or 3.

Dussubieux and Gratuze (2012) also analyzed beads from the Jardins du Carrousel, as well as from a second nearby location in Paris, the Cours Napoléon. This is a 17th to 18th century site, with a domestic context, but the recovered artifacts also include manufacturing waste products. Some beads in these collections resemble monochromatic beads from GBP2 (dark blue beads) and GBP1 or 3 (turquoise beads). The reported compositions indicate that some were likely imported from Bohemia and that others differ chemically from both Rouen and Dutch glass.

### 2.2.2. The Netherlands

There is strong documentary and archaeological evidence for local production of glass beads in the Netherlands (Karklins 1974; Baart 1988; Hulst et al. 2012, Van der Storm and Karklins 2021). Monochromes resembling those found at Ontario GBP2 and 3 sites are known from Dutch sites (Karklins 1974), as are polychrome types that are rare or unknown in French sites, including red IVa* varieties, chevron-star, and several types of true Nueva Cadiz (Karklins and Oost 1992), but not NCT-RV (IIIc’3) (Karklins pers. comm. 2020). Other polychrome bead types typical of GBP2 in Ontario (Ib’2 and IIbb1) are also found in Dutch (Karklins 1974), but not in French (Karklins and Bonneau 2019), collections. Many more beads are known from Dutch archaeological contexts (Karklins 1974) so this greater diversity is expected. Little (2010: 226) notes that the first appearance of NCT-RV (and faceted chevron-star beads) in the northeast of North America coincides with Italian glassworkers moving to the Netherlands.
2.2.3. England

Recent publications of material from glassworks in Hammersmith, England, likely active toward the mid-17th century, provide a picture of English bead types and their chemistry (Karklins et al. 2015; Dussubieux and Karklins 2016). This material contains many polychromes, including a few examples similar to beads found in GBP3 (IIbb*), but not red IVa* varieties, chevron-stars, or Nueva Cadiz-like beads. Karklins et al. (2015: 22) suggest that the colored glass used in bead production at Hammersmith may have been procured as ingots from other European centers.

2.2.4. Venice/Murano

Venice is considered the European center of expertise in glass and bead making (Francis Jr. 1988), and many of the beadworks in other European centers were led by Venetian glass makers (Karklins 1974; Karklins et al. 2015). Karklins (2012: 81) asserts that Venice/Murano was the main supplier of glass beads to the Americas. Chevron-star and red round compound beads have long been associated with Venice. Unfortunately, no chemical data are available for beads of confirmed Venetian origin. Analyses of other types of glass may be informative, particularly those showing distinctive trace elements concentrations associated with specific silica sources (De Raedt et al. 2001). Because of the importance of Venetian expertise outside Venice, we may expect base glass recipes and colorants to be similar in other European locations (Little 2010). Differences are likely to occur in the raw materials (silica, fluxes), and these may help determine the location of production of the glass.

3. Materials

We analyzed polychrome beads of various types from seven Huron-Wendat sites at the Field Museum (FM) in May 2017 and March 2019, for a total of 61 analyses from 30 beads (see Annex A for methods) (Figure 3.2 and Table 3.2; Table S3.1). We added data from two polychrome beads (six glass layers) analyzed at Laurentian University (LU) using similar but not identical methods (Walder et al. 2021), for a grand total of 67 analyses from 32 beads. For comparative purposes, in Table S3.1 we show compositions of 179 monochromes from Huronia and the broader Great Lakes region (analyzed at the FM) and of 9 beads from ADS-Kg10 (Sempowski et al. 2001; Dussubieux and Karklins 2016), an Amsterdam bead-making factory from the first half of the 17th century, analyzed at LU.
Fig. 3.2: Examples of the polychrome beads included in this analysis.
<table>
<thead>
<tr>
<th>Image</th>
<th>Description</th>
<th>Kidd &amp; Kidd</th>
<th>Sample ID(s) and colors (abbv.)</th>
<th>Site</th>
<th>Catalogue or Accession #</th>
<th>Curation Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Star chevron, barrel shaped, faceted, 5 layers</td>
<td>IIIm-</td>
<td>AG_11 (bl) AG_12 (r) AG_13 (w)</td>
<td>Auger</td>
<td>AG 4184</td>
<td>University of Toronto</td>
</tr>
<tr>
<td>B</td>
<td>Star chevron, faceted, round, 5 layers</td>
<td>IIIm-</td>
<td>AT_15 (bl) AT_16Bred AT_17 (w)</td>
<td>Ahatsistari</td>
<td>AT 348E 513N 20-25</td>
<td>Wilfrid Laurier University</td>
</tr>
<tr>
<td>C</td>
<td>Star chevron, faceted ends, 5 layers</td>
<td>IIIm-</td>
<td>AG_08 (bl) AG_09 (r) AG_10 (w)</td>
<td>Auger</td>
<td>AG 1360a</td>
<td>University of Toronto</td>
</tr>
<tr>
<td>D</td>
<td>Star chevron, barrel shaped, 7 layers, some faceting</td>
<td>IVk or IIIm?</td>
<td>AT_21 (bl) AT_22 (r) AT_23 (w)</td>
<td>Ahatsistari</td>
<td>AT 349E 511N 10-15</td>
<td>Wilfrid Laurier University</td>
</tr>
<tr>
<td>E</td>
<td>Star chevron, round/barrel shaped, 5 layers</td>
<td>IVk-</td>
<td>LC_30 (bl) LC_31 (w) LC_32A (r)</td>
<td>Le Caron</td>
<td>LC G13b20.9</td>
<td>Trent University</td>
</tr>
<tr>
<td>F</td>
<td>Star chevron, round, 5 layers</td>
<td>IVk-</td>
<td>PED_01B (bl) PED_02B (r) PED_03B (w)</td>
<td>Peden</td>
<td>PD 1986.01.0123.022</td>
<td>Huronia Museum</td>
</tr>
<tr>
<td>G</td>
<td>Star chevron, tubular, faceted ends, 5+ layers</td>
<td>IIIm-</td>
<td>LC_36 (bl) LC_37 (r) LC_38 (w)</td>
<td>Le Caron</td>
<td>LC J16E4.1</td>
<td>Trent University</td>
</tr>
<tr>
<td>H</td>
<td>Star chevron, giant, prod. waste? 7 layers</td>
<td>IIIm-</td>
<td>LC_33 (bl) LC_34 (r) LC_35 (w)</td>
<td>Le Caron</td>
<td>LC F15n15.16</td>
<td>Trent University</td>
</tr>
<tr>
<td>I</td>
<td>Black and white striped, 3 layers</td>
<td>IVb*</td>
<td>LC_26 (bk) LC_27 (w)</td>
<td>Le Caron</td>
<td>LC J18p3.249</td>
<td>Trent University</td>
</tr>
<tr>
<td>J</td>
<td>Nueva Cadiz Twisted – Red Variant, four layers</td>
<td>similar to IIIc’3</td>
<td>LC_42 (turq) LC_43 (r) LC_44 (w)</td>
<td>Le Caron</td>
<td>LC H16q6.47</td>
<td>Trent University</td>
</tr>
<tr>
<td>K</td>
<td>Blue with white stripes, round</td>
<td>Like IIb68</td>
<td>EL_18 (bl)</td>
<td>Ellery</td>
<td>EL 2539</td>
<td>University of Toronto Mississauga</td>
</tr>
<tr>
<td>L</td>
<td>Red IVa compound bead, 3 layers</td>
<td>Like IVa1</td>
<td>EL_26 (core, colorless)</td>
<td>Ellery</td>
<td>EL 96b</td>
<td>University of Toronto Mississauga</td>
</tr>
</tbody>
</table>

**Table 3.2:** Key to individual beads pictured in Figure 3.
4. Results

4.1. Methodological considerations

The polychrome analysis using LA-ICP-MS poses some methodological challenges. Obtaining a sample from a single color can be difficult. Polychromes may be quite small, with thin and overlapping individual layers or transparent outer layers (in type IVa*), and they may have mixing of glasses at their boundaries. Individual glass colors in beads with angled facets, such as chevron-stars, are particularly difficult to sample cleanly because glass layers are variable in thickness and overlap others beneath the visible surface of the bead. Because at the Field Museum the camera used to target the laser inside the ablation chamber provides little contrast, it is even more difficult to ensure that the correct glass color is targeted. Although we mitigated this by conducting analyses on broken edges or areas with the most distinction between glass layers, some analysis of mixed glass occurred. In some cases, data from individual ablations indicated that the laser cut through the surface glass color and into an underlying layer. To “clean up” compositional results with mixed glass colors, it is necessary to take photographs of the ablation area after analysis, and re-run samples if necessary. We used a high-resolution portable microscope (Dinolite AM413T) to produce images with magnifications ranging from 10× to 220×. We compared these with the raw signals of the expected coloring elements for each analysis point to identify any ablations that were “missed” or were mixed with other layers. We removed these before the final calculation of the glass sample’s composition (Table S3.1). Even following this manual data cleaning process, samples of glass compositions from polychromes are more heterogeneous than those from monochromes. In general, standard deviations for each element across four ablation points are greater for polychromes than for monochromes (see below and Table S3.1).

4.2. Comparison of glass of the same color between monochrome and polychrome beads

As described above, monochromes similar to those from Huronia are known from the few archaeologically reported glassworks in France, while polychromes similar to those from Huronia are known from Dutch contexts and inferred for Venice/Murano. If, in general, a French source can be inferred for monochromes and a different source for polychromes, we may expect slight differences in the chemical composition of glass of the same color in monochromes versus polychromes. Further, we note that previous studies of 17th-century European glass beads show that most are soda-lime glass, and that the chemistry of beads coming from France
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and the Netherlands overlaps (Dussubieux 2009; Dussubieux and Gratuze 2012; Dussubieux and Karklins 2016).

In the present study we examine the composition of monochromes versus polychromes mainly using biplots of Al$_2$O$_3$ and Zr (both contributed mainly from the silica-rich glass ingredient).

Fig. 3.3: Comparison of polychrome and monochrome beads: Al$_2$O$_3$ vs Zr in red (a), turquoise (c) and cobalt glass (d) and Zr vs Nb in white glass (b).

4.2.1. Red
We analyzed red portions of chevron-star, NCT-RV, and red IVa* polychrome beads (n=23) and compared them with compositions of 25 monochrome beads. Polychromes separate into three groups, which are easily differentiated from monochromes (Figure 3.3a). Red glass from NCT-RV beads have high values of Zr (>100ppm) and relatively high values of Al$_2$O$_3$, while red glass from star-chevrons and red IVa* beads have low values of both Zr and Al$_2$O$_3$. Monochrome beads have intermediate values of both Zr and Al$_2$O$_3$. Three red samples from polychrome beads (one star-chevron and two red IVa*) have high values of Al$_2$O$_3$ and relatively low values of Zr. All have low values for Cu, which may indicate that the ablation points may have overlapped colorless (IVa*) or white (star-chevron) glass layers.
The colorant process is represented in the compositions by CuO, Fe$_2$O$_3$, SnO$_2$, and PbO. Within the polychrome compositions, the red IVa$^*$ beads generally contain less of these ingredients. Both polychrome and monochrome red glass show a positive correlation between Pb and Sn. Possibly Pb and Sn were present in the red beads to facilitate reduction of copper into metallic copper or cuprite.

4.2.2. White

White portions of chevron-star and NCT-RV analyzed (n=18) were compared with 27 monochrome white beads. In this case, we examined the values of two trace elements associated with silica sources (Nb and Zr). The polychrome beads cluster, based on bead type, into three groups that largely do not overlap with the monochrome beads (Figure 3.3b). Star-chevrons have low Nb/low Zr values; NCT-RV have moderate Nb/moderate Zr values, and one white on black bead has a high Nb value but a moderate Zr value.

White glass from polychrome beads was opacified with varying quantities of tin (Sn) and lead (Pb), a recipe similar to most soda-glass monochromes. In polychrome white samples, the mean values for cobalt (Co) (38 ppm in polychromes, 18 ppm in monochromes) and iron oxide (Fe$_2$O$_3$) (0.63% in polychromes, 0.41% in monochromes) are elevated compared with monochrome white beads, likely due to sampling overlap or contamination from adjacent blue and red layers, respectively.

4.2.3. Turquoise

Turquoise blue glass colored by copper (Cu) occurs only in the NCT-RV polychrome glass recipes (n=6). Comparison of Zr and Al$_2$O$_3$ in a group of 57 monochrome beads shows that the values for these elements, as well as others, cluster tightly for the NCT-RV turquoise glass (Figure 3.3c). Additionally, monochrome turquoise beads separate into at least three groups. In NCT-RV turquoise glass samples, mean Na$_2$O is lower than in the monochrome comparative samples (8.96% versus 15.0%); mean CaO is higher (7.23% versus 5.70%); and CuO (the copper colorant) is higher (3.01% versus 1.27%). Together, these compositional differences indicate a distinctive base glass recipe for NCT-RV turquoise glasses. None of the turquoise monochrome beads, composed mainly of Ila31 and Ila40 types, clearly matched this composition.

4.2.4. Cobalt blue

Of the cobalt blue samples (n=13), most came from chevron-star beads; one each came from a tubular IIIa12 and a IIb68 example. The latter, a round, medium-sized blue bead with white stripes, is compositionally similar to most monochrome
comparative samples (n=53). The chevron-star blue glass shows low values of Zr (Figure 3.3d) and elevated quantities of Sn, Pb, and Fe as compared to monochrome compositions, possibly from unintentional sampling or intrusion of red or white glass layers, but potentially introduced during production.

4.2.5. Black

There is no recipe for true black glass; glasses that appear black in color are very dark versions of other glass colors such as blue, purple, green, or amber. We collected one sample of “black” glass from a polychrome bead (type IVb*, sample LC_26). Its recipe does not correspond with any analyzed black-appearing monochrome e.g., type IIa7 beads (n=17) from Ontario, Quebec, or the Upper Great Lakes spanning the period ca. 1600–1760 CE (Walder 2018; Walder et al. 2021; Walder and Noël, 2021). Manganese (MnO avg. 6.1%, Table S3.1) is responsible for coloring in those monochrome beads. Conversely, the black portion of LC_26 contains 0.3% MnO, along with 641 ppm of Co and 1.4% Fe$_2$O$_3$. While a black appearance also can be achieved in a very dark cobalt-colored bead, this is not the case here, as Co-levels in LC_26 are lower than the mean 1430 ppm for cobalt-colored monochrome beads in the comparative sample (Table S3.1). Rather, the perceived “black” colored portion of the polychrome LC_26 bead is likely a very dark greenish glass, the result of an iron and sulfur compound (Schreurs and Brill 1984) although sulfur (S) is not quantified with LA-ICP-MS.

4.3. Composition of glass of different colors within individual beads

All of the glass layers in the analyzed polychrome beads are silica-based soda-lime glass. We examined the reduced base glass recipes (Brill 1999) and compared the proportions of K$_2$O, Na$_2$O, and CaO (fluxes and a stabilizer) to the proportions described and grouped by Dussubieux (2009) for European glass artifacts. No polychrome bead sample’s composition fits the low lime/high soda glass Group 1 found for Dutch/Rouen glass (Figure 3.4). Most of the rest of the glass falls into either Group 2 (low potash, high lime) or Group 3 (high potash). There are differences in glass compositions between bead types and pertaining to color. The NCT-RV beads have distinctive base glass recipes for each color; turquoise glass has a high potash content and does not fall within the defined groups, while both the red and white glass fall into Group 3. The proportions of potash, soda, and lime in the different colored layers of the chevron-stars overlap and fall into both Groups 2 and Group 3. Similarly, most of the glass in the red IVa* group also falls into either Group 2 or Group 3.
Fig. 3.4: Relative proportions of soda, lime and potash in different glass colours from three distinctive bead types, compared with glass groups determined for Rouen and Dutch beads.

4.4. Distinctive bead types

4.4.1. Chevron-stars

Chevron-star beads have a long duration of manufacture, beginning in the 15th century, and are considered to have been produced in Venice (Allen 1983; Francis Jr. 1988) and, possibly, in the Netherlands (Baart 1988; Francis Jr. 1988). They vary in the number of layers, colors, and points in the star; in the methods used to expose the star; and in size. Chevron-star beads analyzed here come from six Ontario archaeological sites spanning GBPs 2 and 3. They include one “giant” (Hayes 1983, cover image), two “milled” (IVk3- or IVk4-like, as in Kidd and Kidd 1970), and eight faceted beads. Most have four or five layers; at least two have seven layers. Within the group of faceted beads, some are almost round in form, most are oval or barrel-shaped, and one is a tube with faceting restricted to the ends.
As described in section 4.3, the proportions of major ingredients of the different colors of glass in the chevron-stars overlap, suggesting the same base glass recipe was used for different colors. The possibility that chevron-stars were produced in several European locations led us to examine trace elements that are useful in distinguishing silica made from different sands, such as Zr, Nb, and Hf (De Raedt et al. 2001; Dussubieux 2009; Dussubieux and Karklins 2016). De Raedt argues that Zr and Hf are low for Venetian glass compared with façon de Venise glass. The relatively low values of both Zr and Hf in the analyzed chevron-stars are consistent with those determined by De Raedt et al. (2001) for Venetian glass. For most layers analyzed, the average ratio of Zr to Hf is 31, regardless of the shape of the bead or the location or age of the site (Figure 3.5a). White glass tends to have the lowest values for both elements, red intermediate, and cobalt blue the highest. We note that two beads from Ahatsistari have a different ratio of Zr to Hf for all three glass colors (average Zr/Hf=60, circled in Figure 3.5a), with the exception of one white glass layer. Both beads have a faceted barrel shape, which also occurs
in the main group. The ratio of Si to Zr does, however, vary between glass colors even after correcting for diluting effects of colorants, suggesting possible use of slightly different sands.

These data suggest that 1) beadmakers produced the same forms using materials from different locations (perhaps indicative of distinct workshops), and 2) they produced chevron-stars of different forms (milled, faceted, giant) using glass produced from the same silica sources. Potentially both of these workshops are in the Venice/Murano area, but further research is needed. Furthermore, the presence of chevron-star production tubes at sites in France (Karklins and Bonneau 2019) and the Netherlands (Karklins 1974; Van der Storm and Karklins 2021), opens up the possibility that tubes were produced in Venice/Murano and beads were then fashioned from them in northern Europe.

4.4.2. Red IVa*

As described above, this bead type is reported to have been produced in multiple European centers. Typologically, these are red with a variably colored, usually dark, core (Kidd and Kidd 1970), but they may also have a clear glass layer over the red glass and a lighter-colored, orange-ish-red layer between the opaque red layer and the core (Figure 3.2). The presence of the clear outer layer made these beads particularly difficult to analyze. We used both the glass composition and the analysis notes to interpret which ablations represent red glass and which represent colorless glass.

We analyzed eleven individual red IVa* beads from four Wendat villages: Le Caron, Ossossané, Charity, and Ellery. For each bead, we analyzed either red or colorless glass, but not both. In some cases, compositions are very similar among beads from the same site (e.g., red glass from LC_51, LC_52, and LC_54, colorless exterior layer of CH_16 and CH_17) and less similar between sites (e.g., red glass from Le Caron versus that from Ossossané). Red glass was colored using copper, but iron and tin were also added as reducing agents (Dussubieux 2009: 108–9). To help determine which analyses sampled colorless glass (either interior or exterior layers) and which sampled red glass, we summed the values of copper, iron, and tin (Table 3.3). Variation in colorants in the “colorless” interior glass from two beads from Ellery (EL25 and EL_26) suggests that the appearance of this glass core, which would not have been visible once the bead was strung, may have been less important than that of the red glass and that substantial variability in its ingredients may have been acceptable.
### Table 3.3: Composition of glass layers in red IVa* beads. Reduced base glass is calculated as described by Brill (1999).

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Colourless Glass</th>
<th>Red Glass</th>
<th>Mixed sample?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\text{wt%}$</td>
<td>$\text{wt%}$</td>
<td></td>
</tr>
<tr>
<td>LC_55</td>
<td>SiO$_2$ 67.02</td>
<td>Fe$_2$O$_3$ 0.66</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Na$_2$O 14.17</td>
<td>CaO 6.02</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MgO 3.88</td>
<td>CuO 0.67</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Al$_2$O$_3$ 1.09</td>
<td>K$_2$O 0.66</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FeO 10.63</td>
<td>Cu + Sn + Fe 0.68</td>
<td></td>
</tr>
<tr>
<td>EL_25</td>
<td>66.67</td>
<td>64.80</td>
<td>0.01</td>
</tr>
<tr>
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<td>67.36</td>
<td>65.80</td>
<td>0.01</td>
</tr>
<tr>
<td>CH_16</td>
<td>67.49</td>
<td>65.80</td>
<td>0.01</td>
</tr>
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<td>66.20</td>
<td>0.01</td>
</tr>
<tr>
<td>OSS_18</td>
<td>67.20</td>
<td>66.20</td>
<td>0.01</td>
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<tr>
<td>OSS_19</td>
<td>68.44</td>
<td>67.20</td>
<td>0.01</td>
</tr>
<tr>
<td>LC_51</td>
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<td>0.01</td>
</tr>
<tr>
<td>LC_52</td>
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<td>64.14</td>
<td>0.01</td>
</tr>
<tr>
<td>LC_54</td>
<td>64.62</td>
<td>63.62</td>
<td>0.01</td>
</tr>
</tbody>
</table>

The amount of Zr and Hf in red IVa* beads suggests that these were made in multiple centers. Several samples have low amounts of these elements, comparable to the amounts in chevron-star beads (Figure 3.5b); these are possibly products of Venice. Others, including both the red and the colorless glass, have elevated values of Zr and Hf, indicative of a different silica source and, possibly, of production in northern Europe.

#### 4.4.3. Nueva Cadiz Twisted, Red Variety

As noted above, a distinct twisted polychrome type (IIIc’3) with a turquoise outer layer, a white center, and a red inner layer (Kidd and Kidd 1970; Kenyon and Kenyon 1983: 64) occurs in small numbers at Ontario GBP3 sites. We reiterate that these are not considered to have any relationship with the archetypal Nueva Cadiz beads originating from French and Dutch workshops and distributed via Spanish colonial trade to the Americas, generally in the 16th century.
Four NCT-RV (type IIIc’3) beads from Le Caron and one each from Thomson Walker and Ellery show clear differences between the base glass for different colors. In the turquoise glass, the proportion of soda, lime, and alumina is lower, while that of potash and silica is higher (Figure 3.4, Table S3.1). The difference between the base glass for the red and white portions of the beads also differ, but less markedly.

A biplot of Zr and Hf shows a clear difference in the values for each of the different colors (Figure 3.5c). Only the turquoise glass values are similar to those De Raedt et al. (2001) found for Venetian glass. The higher values for the red and white glass resemble values for northern European glass from Antwerp (De Raedt et al. 2001). Ratios of Si to Zr are also markedly different between glass colors in the NCT-RV beads. Figure 3.5d shows striking similarity with the mainly monochromatic beads from Amsterdam analyzed at Laurentian University, (Table S3.1) with the exception of the white beads, which are lead-opacified (and therefore contain less silica).

4.4.4. Other bead types

We also analyzed polychrome bead types that are less distinctive or common, or that are not associated with Venice in the literature, namely, LC_26, a three layered (black-white-black) round bead with white stripes (IVb*), and LC_18, a compound cobalt blue-white-blue tube (IIIa12). These beads all have elevated levels of Zr and Hf, indicating manufacture using a different source of silica, potentially from northern Europe.

5. Conclusions

While methodologically polychromes are more challenging to analyze because of overlap of glass layers and inter-color contamination, analyses of these beads are informative. Comparison of polychrome and monochrome bead compositions showed that for all colors analyzed, monochrome and polychrome glass compositions differed. This could indicate that European workshops had different processes for these various bead types, and/or that traders obtained beads from more than one merchant or producer when supplying ships for colonial exchange.

The only Cu-colored turquoise glass in this study comes from NCT-RV beads, and its base glass recipe differs from that of the red and the white layers in the same beads. The proportion of Zr and Hf is quite low and comparable to that of Venetian glass, as is the case for monochrome turquoise beads recovered from a Dutch factory site (Kg-10). The proportions of Zr and Hf are higher for both red and white glass, as is also the case for the Dutch site. Further testing is needed to
determine whether NCT-RV beads were produced in northern Europe using local material and if the raw material for turquoise glass was supplied from Venice or from elsewhere in southern Europe. Comparison with “true” 16th century Nueva Cadiz beads shows differences in the ingredients and production histories (Walder et al. 2021).

Within our small sample of red IVa* beads, the colorless glass is of variable chemistry. We interpret this to mean that the composition and color of the interior glass, which would not have been visible, was of little consequence and was less controlled than that of the red glass.

The base glass recipes for chevron-stars and the red IVa* beads indicate that the different colors of glass were made using high-potash or low-potash/high-lime glass. The concentrations of Zr and Hf are suggestive of a Venetian origin; the presence of production tubes for chevron-star beads in French and Dutch contexts implies that these tubes were traded and that the actual beads were produced in northern Europe. Chemical analysis of these production tubes and chevron-star beads from Venice would be helpful in interpreting these findings.

This study provides evidence that the polychrome beads exchanged in northeastern North America, particularly in southern Ontario among the Huron-Wendat, originated in glasshouses in many parts of Europe, hinting at early trajectories of emergent global trade networks.

Acknowledgments

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References


