1. Technology

The production of glass beads, from simple drawn monochrome types to complex polychrome examples, can be informative about both the networks of exchange circulating these objects and the timing of archaeological site occupations. However, a first-level question is to understand how beads were made. Technologically simple drawn monochrome beads are a hallmark of both the Indo-Pacific trade and colonial-era exchanges from Europe to the Americas. Although these beads may be visually quite homogeneous in appearance, comparisons of their chemical composition hint at varying production practices across time and space. In several papers in this volume, such hidden technological differences become apparent. For example, Blair and Dussubieux (this volume) found that even visually identical turquoise blue beads of type IIa40, recovered from the Southeastern United States, form several compositional groups, suggesting distinct places of manufacture. Their contribution also highlights the importance of exploring historical documentation of European beadmaking guilds and workshop locations to better understand production processes.

In this volume, we also demonstrate how Laser Ablation – Inductively Coupled Plasma – Mass Spectrometry (LA-ICP-MS) provides the opportunity to analyze different colored glass layers within polychrome beads. The European-produced polychrome beads of the 16th and 17th century were likely made in different locales including Venice, France, the Netherlands, and England, and understanding technological differences across workshops and even for specific well-known glass bead types, such as “Nueva Cadiz” is an ongoing research question for this time period (e.g., Loewen and Dussubieux 2021; Walder et al. 2021). Trace elements linked to silica sources for glass formers, as well as differences in base

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glass recipes within individual polychrome beads, have been identified (Hawkins and Walder, this volume). A similar approach of analyzing individual glass layers was applied to three polychrome beads from Zanzibar (Sarathi et al., this volume).

Technological differences can be useful for identifying patterns of exchange, and even tracing the paths of individual objects. Compound bead forms such as the drawn white varieties examined by Panich and co-authors (this volume) had distinct compositional groups that were associated with individual archaeological site contexts. These authors interpret this to mean that the beads were kept together in some fashion, perhaps in a bag, on a string, or attached to an object, all the way from their European origin to their deposition in what is presently California. Likewise, for Tel Anafa in northern Israel, technologically distinct beads with unusual compositions may be indicative of small-scale production in local or even domestic workshops (Larson and Dussubieux, this volume).

The complete chaîne opératoire of a bead will include its entire use-life from sourcing raw ingredients for glass through loss or discard in the archaeological record. There is evidence for recycling and repurposing of glass beads in many instances worldwide (e.g., Babalola 2017; Billeck 2016; Boschetti et al. 2016; Jackson and Paynter 2016). Two glass beads recovered at Unguja Ukuu, Zanzibar (Sarathi et al., this volume) had compositional and textural differences from others in the assemblage and likely were formed by crushing and reheating available m-Na-Al glass beads for raw material, perhaps gaining new meanings through this process.

Importantly, glass beads as an adornment technology may be utilized in ways that combine them with beads of other materials, including stone, shell, and/or bone, as Trombetta et al. (this volume) observed in the examination of a northwestern Ethiopian burial site. Panich et al. (this volume) identified a colonial-era pit feature associated with a mourning ceremony combining glass and shell beads in colonial California. Likewise, glass beads from a large archaeological project in northeastern Tanzania in the study by Walz and Dussubieux (this volume) included 44 different types of beads made of non-glass material. Ostrich eggshell, land snail shell, and glass beads also come from the same contexts at the Unguja Ukuu site in Zanzibar, off the coast of Tanzania (Sarathi et al., this volume). The combined use of glass beads with ornaments of other materials hints at the continuing importance of local and Indigenous technological practices such as shellworking or stone bead production after glass beads are introduced in colonial contexts or via long-distance trade.
2. Chronology

In recent decades, significant progress has been made in applying archaeometric methods to glass beads to better understand chronology, which is an important primary question in archaeological interpretations. Rethinking regional seriations of glass beads as well as historical periods of production contributes to the most basic of culture-historical research questions in archaeology: identifying the age of sites. Both inter-site and intra-site chronologies can be clarified through glass bead analyses. Dalton-Carriger and Blair (this volume) and Blair and Dussubieux (this volume) identified chronological differences in the beads buried as grave goods. They identified that individuals had been interred decades apart within the same mortuary context, with implications for a long-term Indigenous presence in the area even after European contact in what is now the southeastern United States. However, especially in burial contexts, heirlooming of beads is an important cultural consideration when developing chronological interpretations.

Local and regional chronology-building is aided by glass bead analyses. Within a relatively confined area around San Francisco bay in colonial-era California, Panich and co-author’s contribution to this volume examines a single category of beads: drawn, compound white glass types, across three sites likewise shows the chronological value of compositional analysis, revealing “hidden” differences across this otherwise homogeneous category. By examining beads from sites securely dated with documentary records in the late 18th to mid-19th centuries, LA-ICP-MS provides an independent line of evidence that could be then used to clarify the occupational history of less-securely dated sites in the area. Similarly, in eastern and southern Africa, building refined chronologies of site occupations and regional settlement patterns is an important culture-historical project only now receiving adequate scholarly attention (see Walz and Dussubieux, this volume; Klehm and Dussubieux, this volume). For the site of Antsiraka Boira on the island of Mayotte off the north end of Madagascar, Wood and co-authors (this volume) identified compositional differences in glass beads within a temporally confined period cemetery site utilized in the 12th and 13th centuries CE.

In locations with a very long period of occupation, such as the Kali Gandaki valley of Nepal, bead compositions are useful for distinguishing changing trade connections through time. There, Aldenderfer and Dussubieux (this volume) identified a diversity of glass compositions representing a wide time span, illustrating how communities in the valley developed increasingly broader trade relationships over hundreds of years. Similarly, Tel Anafa in northern Israel was occupied from Hellenistic through medieval (Fatimid) periods and exhibits evidence of change over time in available glasses used for beadmaking (Larson
and Dussubieux, this volume). At Kish, another ancient city site occupied over thousands of years, analysis of glass beads from legacy collections at the Field Museum offers a way to obtain new chronological information for artifacts from excavations undertaken in the early 20th century, for which no intra-site archaeological context information was available (Dussubieux, this volume).

The study of Indian Ocean drawn glass bead assemblages has revealed a range of compositional groups that have both spatial and temporal distinctions. Specifically, for South Asian mineral soda-high alumina (m-Na-Al) glass, such groups are becoming better understood. In this volume, Trivedi and Dussubieux highlight the importance of examining medieval glass bead technologies, providing new insight into an era that has received less attention than earlier periods and identifying unrecognized chronological longevity of several of the m-Na-Al compositional groups. By highlighting use contexts of those beads at the site of Indor, the authors also raise important questions about “temporally shifting preferences and socially specific taste” related to bead styles. Tight contextual and chronological control of archaeological contexts allows for interpretations that connect temporal patterns to broader research questions addressing trade routes and regional connections.

3. Exchange

The use of a standard methodology for statistical studies (principal component analysis) of the compositions of mineral soda-high alumina (m-Na-Al) glass beads traded around the Indian Ocean is an especially robust tool for examining exchange networks. Many of this volume’s chapters make new contributions to understanding how these compositional groups can be interpreted to define patterns of exchange across this region, ranging from sites in present-day northern India (Trivedi and Dussubieux), central Thailand (Carter et al.) northwestern Ethiopia (Trombetta et al.), northeast Tanzania (Walz and Dussubieux), Zanzibar (Sarathi et al.), Mayotte (Wood et al.), and even the Middle East at the ancient city sites of Tel Anafa (Larson and Dussubieux) and Kish (Dussubieux). As more glass studies are undertaken globally, it is possible that other standardized suites of elements could be identified using PCA or other means as a way to identify statistically significant glass compositions in other world regions where exchange is a major question.

Understanding relationships between coastal and inland areas, especially for eastern and southern Africa is now possible through glass bead analyses. The analysis by Walz and Dussubieux (this volume) identified the earliest glass beads known for inland East Africa, from northeastern Tanzania, dated to the 8th to 10th centuries CE. Similarly, in Botswana, the results of analyses from related sites
Technology, chronology, and exchange examined through glass beads in the east-central area of that country provide evidence of early Indian Ocean trade items reaching the interior beginning in the 7th century CE (Klehm and Dussubieux, this volume). Trade routes along the east coast of Africa are likewise better understood through new data points including the islands of Mayotte (Wood et al., this volume) and Zanzibar (Sarathi et al., this volume).

Composition is a useful tool for identifying the provenance of glass beads, especially in locations where past communities could access glass beads from multiple production sources with distinctive glass chemistries (e.g., Carter et al., this volume). The Kali Gandaki valley of north-central Nepal is one such location, and the highly varied compositions of glass beads from sites there illustrate multidirectional trade occurring for centuries from 1200 BCE onward, with beads likely originating from the Middle East, South Asia, Central Asia, and southern China (Aldenderfer and Dussubieux, this volume). Likewise, Fenn and co-authors (this volume) identified at least three major glass compositional groups from a small assemblage of glass beads (n=13) associated with an 18th century Native Alaskan community. The compositions were tied to the various colors represented and were indicative of glass production centers in China, Russia or Siberia, and Europe at that time, illustrating how remote locales might be connected to multiple networks of exchange. Craig and Dussubieux (this volume) detected patterns of 15th to early 16th century interaction in the Philippines by identifying distinct compositional groups for glass beads from shipwreck cargos. The three vessels in that study were carrying beads of different compositions likely as a part of “tribute shipments” associated with relationships between Southeast Asian vassal kingdoms and the Chinese Empire. Studies of glass beads in all of these contexts associated with long-distance trade help delineate both regional and inter-regional economic exchange networks.

4. Future directions

Used alone in glass bead analyses, as in this volume, LA-ICP-MS provides a treasure trove of information, but some in-depth studies, especially those related to questions about provenance and technology, can benefit from combining this technique with others. For example, although LA-ICP-MS has been quite successful at defining sub-groups suggesting the use of different sources of raw materials and certainly can identify the existence of several workshops, connecting a glass to a specific production region is often difficult. A wider use of isotope analysis (Sr-Nd-Pb) in tandem with LA-ICP-MS should help connect glasses to more specific areas based on their geology (assuming that the sand is procured near the site of manufacturing). The destructiveness and labor-intensive aspects of
isotope analysis certainly limit its wide use, but new developments in the use of laser ablation as a way of sampling objects could alleviate these inconveniences in the future. As far as determining the technology developed by ancient glass makers to color and opacify the glass, when using LA-ICP-MS, we need to rely on other studies published in the literature to connect the quantities of different elements with the coloring ingredients that were added. A more accurate interpretation of the data can be done when adding Raman or XRD measurements that can identify mineral phases in the glass.

The use of LA-ICP-MS for glass bead studies, either by itself or in combination with other methods, offers ways for archaeologists to “excavate the collections” and glean meaningful new insight from curated artifacts. This strategy is especially useful for collaboration with descendant communities. Because it is only minimally destructive, LA-ICP-MS offers a way to help answer research questions of interest to First Nations and Indigenous peoples without requiring additional costly and destructive excavations of sites. Research using minimally invasive techniques has been highlighted as a priority for many Native American groups (Glencross et al. 2017; McMillan et al. 2019; Sanchez et al. 2021). Reconstructing Indigenous trade networks and interactions during periods of early colonial intrusion is one especially important question that can be investigated utilizing previously collected artifacts, since glass beads were so often part of these initial material exchanges.

Outside of laboratories in North America and Europe, there are relatively few locations with LA-ICP-MS available and being used for glass bead studies. Along the east coast of Africa and in South Asia, in countries around the Indian Ocean, increased access to LA-ICP-MS would allow heritage researchers to analyze beads from archaeological contexts there more easily. We hope that expansion in the area of archaeometric research on glass beads in non-Western countries could lead to more collaboration among archaeologists and local stakeholders, and ultimately training more archaeologists of diverse backgrounds to apply this technique in research of interest to their own communities.

The Elemental Analysis Facility (EAF) at the Field Museum in Chicago is one of only a few laboratories dedicated to archaeometry and specializing in the study of ancient glass beads. Knowledge of chemistry and experience operating and maintaining the scientific instrumentation are combined with the anthropological training and regional expertise of researchers who bring glass beads for LA-ICP-MS analysis there. As Carter, Blair, and co-authors demonstrate in this volume’s second chapter, scholars are addressing a broad range of anthropological questions through glass bead studies, investigating social identity, colonialism, and intercultural exchanges. The EAF is a unique research center that has produced compositional datasets for thousands of glass beads from global contexts. A final
future direction we see is a need for additional facilities like this to be organized and supported worldwide, so that archaeologists may continue using these methods to investigate chronology, technology, and exchange in past human cultures.

**References**


Appendix
Supplementary Materials

As further reference to this volume, an online repository was created. This repository contains:

- Compositional datasets and additional images (S)
- Annex A: Glass analysis with LA-ICP-MS at the EAF (Laure Dussubieux)
- Annex B: Glass compositions (Laure Dussubieux and Heather Walder)

The material is hosted on the website of Leuven University Press. These datasets, images and annexes, which should be viewed in connection with a reading of the relevant articles, may all be accessed under the URL: www.lup.be/glassbeads