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The Elemental Analysis of Glass Beads

Technology, Chronology and Exchange

Laure Dussubieux, Heather Walder (eds)

Leuven University Press

The Elemental Analysis of Glass Beads: Technology, Chronology and Exchange

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The Elemental Analysis of Glass Beads

Technology, Chronology and Exchange

Edited by
Laure DUSSUBIEUX and Heather WALDER

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Acknowledgments

This book began over a discussion at a brief lunch break between analysis batches at the Field Museum in March of 2019, with a shared acknowledgement that while it is relatively easy to collect glass compositions, the process of data analysis through to interpretation and publication is often more time consuming and difficult. An edited volume offers a chance to connect different scholars who carried out laser ablation – inductively coupled plasma – mass spectrometry (LA-ICP-MS) analysis at the Elemental Analysis Facility of the Field Museum in Chicago, to determine the composition of glass beads from archaeological sites. It also serves as an incentive to publish datasets obtained over more than a decade.

The projects included in this volume are connected to different parts of the world and aim at addressing various anthropological questions related to chronology and human interactions. The publication of this book was preceded by a workshop. In preparation, each contributor had to read and comment on a manuscript written by one of their colleagues. The workshop included a "lightning-round" presentation of their article by each lead author, and collective in-depth discussions of each article. Although the pandemic prevented an in-person meeting that could have permitted additional informal interactions and exchanges on the side, the online workshop that took place Nov 13 - 15th, 2020 still provided invaluable opportunities for the participants to meet new colleagues, receive feedback on their work, discuss general topics about glass bead research and expand their geographic and temporal research horizons. Parallels could be drawn between the beads of Africa, North America and South and Southeast Asia, the trajectories of certain glass beads could be traced across continents and oceans, and the significance of studying beads could be explored from different angles.

We are thankful to the contributors for providing their chapter despite unique difficulties due to the pandemic, which included illness for themselves or family members as well as modified work schedules and difficulties accessing their offices and research facilities. Several colleagues provided feedback on parts of this volume during preparation, including Brad Loewen (Annex B), Bernard Gratuze and Lisa Niziolek. We are also indebted to the Negaunee Foundation support that provided funding for the workshop, which was used to partially offset the cost of open-access publishing once it was decided that the workshop itself would be online. We also would like to thank the KU Leuven Fund for Fair OA for providing funding covering one-third of the cost of open-access.

Laure Dussubieux & Heather Walder

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Foreword

Bernard Gratuze[1]

An abundant literature covers the topic of ancient glass, but it remains focused on certain geographical areas, periods, and types of objects. Europe, the Mediterranean area, and the Middle East have received the lion's share of the research interest of glass scholars when other parts of the world have been long neglected. Glass vessels have always attracted a lot of attention as they are sometimes extremely complex and beautiful objects discussed at length in terms of technology and style, whereas despite their key place in the history of glass, beads have been unevenly studied and sometimes totally ignored. In the first chapter (Dussubieux and Walder, this volume), a brief summary of the study of glass beads reminds us that a wider interest for this type of artifact stemmed from the more general use of scientific analysis able to extract additional information about glass recipes and technology of frabrication inaccessible to the simple macroscopic observation of the object.

Although many uncertainties surround the invention of glass in the ancient world and it is not possible to say with certitude when and where this new material was first created, it is firmly established that the earliest glass objects were beads (Henderson 2013: 8, 133). Today, anthropologists are recognizing the importance of glass beads for understanding human pasts. This book begins with a concise yet comprehensive review of current anthropological questions being addressed with glass bead analyses along four different themes: technological practices, trade and economic systems, colonial encounters and social identity (Carter et al., this volume, chapter 2). Such a chapter will be a useful resource for students and serious scholars of beads alike.

Glass bead studies can be challenging, and macroscopic studies alone can encounter some serious limitations due to the small number of attributes of some beads and the wide chronological and geographical spread of some bead typologies. This is where archaeometry comes into play. Since the early 1980s, chemical analyses have brought new dimensions to studies about the manufacturing processes and the provenance of glass material. Among the different techniques developed to study archaeological materials, Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) has become established over the last twenty years as one of the main archaeological tools for nearly non-destructive multielement analysis (Dussubieux et al. 2016; Speakman and Neff 2005).

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This technique has proved to be particularly well adapted to the study of large assemblages of small monochrome or polychrome objects such as glass beads (Hawkins and Walder, this volume). It is very fast and hundreds of objects can be analyzed in a few days, only a microscopic amount of material is sampled, the different colors of a polychrome bead can be targeted, and a large database can be generated.

Although the number of articles reporting on LA-ICP-MS of glass beads has been steadily growing over the years, no book has been specifically focused on this topic. Glass publications are often written by glass specialists who do not always tie their findings to the anthropological implications they suggest. Alternatively, anthropologists and archaeologists are limited in their interpretation due to their limited knowledge of glass chemistry. The authors of this volume, through conversations and internal peer review, have concentrated on combining rigorous chemical interpretation and anthropological interpretation. The present volume is therefore filling a gap in the literature of anthropological studies of glass beads through archaeometry, although it does not pretend to comprehensively cover the topic.

The articles in this book describe projects conducted at the Elemental Analysis Facility at the Field Museum in Chicago. Because of the North American location of this laboratory, almost one third of the book is dedicated to this part of the world where glass beads have been an important indicator of contact between the European and the Native populations. These chapters cover a range of questions from archaeologists wondering where beads were produced in Europe, and how indigenous and colonial networks of exchange moved these objects across the continent, from Alaska (Fenn et al., this volume), to coastal California (Panich et al., this volume), to the Southeast (Dalton-Carriger and Blair, this volume; Blair and Dussubieux, this volume).

Bead research on Indian Ocean exchange has been particularly fruitful in recent decades and several projects presented in this book take advantage of the important dataset of compositions already available. Carter et al. (this volume) explores central Thailand whereas Wood et al. (this volume) and Sarathi et al. (this volume) focused their research on two islands part of the Swahili corridor. More unusual is the African perspective offered by Trombetta et al., Klehm and Dussubieux, and Walz and Dussubieux (this volume), who present research from inland sites, a type of site that has garnered less attention from archaeologists working in this region. Indian glass beads were exported around the Indian Ocean and these small objects are better known from the data gathered outside India as data from Indian sites are extremely rare. With their study of the drawn beads of Indor, Rajasthan (13th century CE and onward), Trivedi and Dussubieux (this

volume) rectify this imbalance. The shared use of a standard suite of elements for statistical comparisons of glass groups within m-Na-Al glass makes it possible to trace subgroups through time and space in a way that no other region has available.

In some cases, major research areas overshadow smaller regional investigations. Nepal represents another geographic location with limited prior research in glass bead compositions (Aldenderfer and Dussubieux, this volume). Even in Iraq and Israel, two important places for glass manufacturing, there is limited study of glass bead production and use (Dussubieux, this volume; Larson and Dussubieux, this volume). Archaeometry can also play an important role in better understanding legacy museum collections, gaining new data from materials collected many decades earlier (Dussubieux, this volume). Archaeologists likewise pay close attention to contexts of archaeological sites on land, but shipwreck contexts for beads, and comparisons to the other cargo of those ships, have been limited, making Craig and Dussubieux's work another contribution to areas that are particularly neglected.

There is great value in reporting such regionally and chronologically diverse studies in the same volume. By bringing together these researchers to contribute to a single volume, methods and studies from other parts of the world could be recognized as useful for scholars working in different areas and time periods. Furthermore, since all work was done at the Elemental Analysis Facility (EAF), this volume both highlights the range of work done there and the usefulness of so many different studies done in the same lab, with the same analytical methods, making all our data more comparable and creating connections across regions. To conclude, this book highlights the potential of recent research carried out on beads, in The Field Museum's EAF, by coupling archaeological and historical studies with LA-ICP-MS analyses. It emphasizes the role of bead studies for understanding and redrawing ancient spheres of cultural influence and contacts, as well as exchange networks, whatever the place and period, and the importance of these objects as social markers. The results then clearly show that LA-ICP-MS has still potential for growth and will continue to revolutionize archaeology and to open new frontiers to future generations of archaeologists.

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Chapter 1

Contextualizing this volume in the field of glass bead studies

Laure Dussubieux[1] and Heather Walder[2]

1. Introduction

Glass bead studies, using increasingly sophisticated methods, have become important in examining archaeological questions related to technology, chronology, and exchange in the ancient world. In this introductory chapter, the goal is to provide a context for the case studies presented in this volume, within the broader field of glass bead studies. For that purpose, we briefly review the history of glass bead studies: early glass bead researchers made important discoveries just by looking at the physical attributes of beads and the traces left by their manufacturing. Also, parallels made with ethnographic observations have been key to understanding the ancient technologies developed for glass bead making. We will then discuss different techniques that are applied to the investigation of glass beads, because using multiple scientific compositional and material analysis methods can provide converging evidence to validate hypotheses about manufacturing and circulation. Finally, we will present a few key discoveries related to glass beads found in regions not covered in this volume. These reinforce the importance of these small artifacts for a better understanding of ancient societies.

2. Glass bead typology and ethnography

The first bead scholars were "amateurs" with a non-academic background, only motivated by their fascination with the objects. We can consider that the study of beads started with Horace Beck (1928) and his *Classification and Nomenclature of Beads and Pendants* published almost a century ago. This important work sought to provide a precise vocabulary for the description of beads and a nomenclature for their typology. Beck, a retired designer of microscope lenses, used a microscope

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for the observation of beads, showing the path for a scientific approach to bead studies (Hutchinson 2003). All kinds of materials (glasses, stones, and metals) were considered in Beck's 1928 volume but his geographical interest was mostly limited to artifacts from regions around the Mediterranean area and the Middle-East. The posthumous publication *A Handbook on Beads* by van der Sleen (1973) expanded bead research beyond these regions, for example, across the Indian Ocean and Western Africa. W. G. N. van der Sleen, a chemistry teacher and an adventurer, picked up a late interest in beads; he was already in his mid-sixties when he started collecting and studying them, travelling far and wide to increase his bead knowledge (Lap-Beerman 1967). Van der Sleen realized the importance of chemical analysis particularly for the "trade-wind beads" or beads circulating around the Indian Ocean in ships using the power of monsoons or trade-winds (van der Sleen 1956, 1973). Some of the chemical analysis results appear in Tornati and van der Sleen (1960) but some of the outcomes are quite puzzling (e.g., high phosphorus concentrations in Indian beads).

Several researchers followed in the footsteps of these two pioneers and refined regional bead typologies. Relevant to this present volume is the work by Kidd and Kidd (1970, 1983) who devised a classification system for European glass beads traded in the Americas. This classification, which is based on the forming techniques of the beads, their shapes, colors and decorations, was augmented by Karklins (2012) and is widely used in countries including Europe, of course, but also Africa, where relatively recent European-made beads can be found (e.g., DeCorse 1989; Hopewood 2009; Karklins and Bonneau 2019). In South Africa, Wood (2011) introduced the notion of bead series or groups of beads that share some physical attributes and that can be associated to a specific time period and sometimes, a place of origin. Wood's system has been widely adopted in this region (e.g., Bandama et al. 2018; Tournié et al. 2012; Antonites 2014; Koleini et al. 2017). Robust glass bead classification strategies developed for specific regions and time periods are essential to place new findings in a chronological context and to accurately infer the circulation of objects between regions as further exemplified by Calmer (1977), Guido (1978) and Then-Obłuska (2021).

Peter Francis Jr. became one of the most influential bead researchers at the end of the 20th century and produced many publications about beads made of all kinds of materials and from all over the world before his premature passing in 2002. He co-founded the Society of Bead Researchers in 1981, was the editor of the Society's newsletter *The Bead Forum,* and contributed subsequently to its journal: *BEADS* (Karklins 2002). He had a marked interest in what he called "Indo-Pacific beads," which are part of van der Sleen's "trade wind beads", small monochrome drawn beads found around the Indian Ocean and beyond. Although

his many publications, including his last book *Asia's Maritime Bead Trade: 300 BC to the Present* (Francis 2002), remain useful resources nowadays, they lack the perspective brought by the scientific analyses that started being more widely used at the end of the 1990s. His work remains, however, a solid foundation for current bead research (Carter et al. 2016).

An enduring methodological strategy that Peter Francis Jr. included in his work is the use of ethnographic observations (Francis 1991). He examined the waste produced by drawn bead production and he used this information to identify evidence of bead production at various atchaeological sites across South and Southern Asia. Alok Kanungo has pursued a similar ethnographic approach in India more recently, documenting traditional glass bead making (Kanungo 2001, 2004, 2016, 2022) and providing important clues for the identification of traces of ancient glass bead workshops in the archaeological record. Literature about West African traditional bead making explores a wide range of traditional craft practices, from the production of glass to be used to make ornaments by the Nupe in Central Nigeria (Nadel and Seligman 1940; Lababidi et al., forthcoming) to the realization of powder beads in Western Africa (e.g., Agyei et al. 2012; Francis 1993; Mauny 1949).

To conclude this section, we would like to mention attempts to re-create ancient processes as a way to test hypotheses about ancient glass beads. Different sources of inspiration or guidance can be used in experimental archaeology research, such as ethnographic accounts, ancient texts or iconography, and archaeological remains (e.g., Hodgkinson and Bertram 2020; Krzyżanowska and Frankiewicz 2015). Replicating glass bead production processes helps understand not only the beads themselves, but also the archaeological signature of production waste or discards that might be identified in areas of primary and secondary manufacture.

3. The scientific analysis of glass beads

Scientific analysis provides a range of information about glass technology, chronology and exchange that is not available otherwise. As a category, it includes elemental analysis but also other types of analysis that reveal the glass recipes ancient glassmakers employed and the coloring techniques they used (Bonneau et al. 2014). Martin Heinrich Klaproth, a German chemist, is usually credited with the first elemental analysis of glass at the end of the 18th century. It is important to note that 13 g of glass were necessary for him to obtain the concentrations of a few elements by means of wet chemistry (Caley 1949). Such early methods were impractical for the study of glass beads, since most weigh less than 1 g. Presently, a range of analytical techniques with different degrees of destructiveness are

available to glass researchers. The number of elements that can be measured varies widely. Ideally, researchers choose the least destructive method able to analyze the largest range of elements with the lowest detection limits, but in practice, availability of instrumentation and the expertise of those with whom archaeologists collaborate often influence the choice of method.

X-ray fluorescence (XRF) is a well-established method for obtaining the elemental composition of glass and glass beads in particular (e.g., Dong et al. 2015; Koleini et al. 2017; Polikreti et al. 2011). This technique is quick and cost effective, although limits of detection for certain elements are fairly high and therefore only a very limited number of trace elements can be determined with this technique. It can be used in a non-destructive way on non-prepared samples, but caution is advised when objects are corroded as it only probes layers of materials close to the surface. Scanning electron microscopy (SEM) with energy dispersive spectrometry (EDS) or with wavelength dispersive spectrometry (WDS) is also an X-ray fluorescence-based technique that uses a focused electron beam instead of using an X-Ray beam to excite the sample. The interaction of the electrons with the sample creates various signals (including X-ray fluorescence) providing information about the surface topography of the glass and its composition. The imaging capability of the SEM makes it possible to look at the composition of inclusions and other heterogeneities in the glass or to map the distribution of elements over the surface of the sample (e.g., Li et al. 2013; Shortland et al. 2018). SEM-WDS and electron probe micro-analyzers or EPMA are fairly similar technologies, but EPMA is able to detect a larger range of elements and with lower detection limits compared to SEM. It can probe tiny surfaces with a diameter smaller than 1 micron (e.g Purowski et al. 2012). Best results (for EPMA and SEM) are obtained on flat and polished samples usually coated with a conductive material such as carbon.

Neutron activation analysis (NAA) is a bulk technique able to quantify a large range of elements with a sensitivity that can reach the ppb level. It can be totally non-destructive. It has been used quite extensively for the study of ancient glass beads as exemplified by the work of Hancock in North America (Hancock 2013; Hancock et al. 1994, 2000), Davison in Africa (Davison 1972) and Rahman in Southeast Asia (Rahman et al. 2008).

Another bulk analytical technique used with ancient glass beads is atomic emission spectrometry (AES) also called optical emission spectrometry (OES), which can determine the concentrations of up to 70 elements including traces but requires that a small quantity of the bead (or the whole bead when very small) is dissolved into a solution (e.g., Zhang et al. 2005).

Today, an increasingly popular technique for the analysis of glasses and glass beads in particular, is laser ablation - inductively coupled plasma - mass

spectrometry (LA-ICP-MS) because it can analyze the smallest beads (~ 1mm in diameter) without visible damage. The laser can individually pinpoint the different colors of a polychrome bead. It is fast, so 40-50 beads can be analyzed in one day, and it is relatively affordable. Additionally, LA-ICP-MS can determine the concentrations of a very large range of elements (up to 60-65). For these reasons, the contributing authors of this volume have relied on LA-ICP-MS to analyze beads from sites that they are researching around the world. This work is especially valuable because the LA-ICP-MS dataset presented here has been obtained exclusively at the Elemental Analysis Facility (EAF) of the Field Museum, using the same approaches to quantification and data analysis, making the compositions highly comparable both to one another and to other published datasets generated there. In Annex A, Dussubieux provides a comprehensive overview of how these methodologies have been applied consistently under her supervision at the EAF, which has operated LA-ICP-MS for archaeological analyses since 2005. In Annex B, we summarize findings of previous scientific analyses of glass beads, which have identified temporally and geographically relevant compositional groups.

In combination with elemental analysis methods, additional tools are available to help define the structures of glasses and in some cases assist in identifying the ingredients or raw materials used in the production process. For example, X-ray diffraction (XRD) is able to identify the crystalline phase present in the glass, which is useful because it can help identify whether a particular mineral was brought by the raw materials or produced during the manufacturing process, generally to color and/or opacify the glass. XRD can be applied to a whole object in a non-destructive manner but better results are obtained on powdered samples (Zhu et al. 2012).

Raman spectroscopy is increasingly used to study glass and glass beads in particular because this technique can help identify the type of glass and provide insight into the coloring technology (e.g., Costa et al. 2019; Pinto et al. 2021; Prinsloo and Colomban 2008). This technique has the great advantage of being totally non-destructive and portable instruments facilitate the study of in-situ materials, artifacts that are difficult to move to scientific laboratories, or large objects that do not fit the fixed geometry of some benchtop instruments (Colomban et al. 2021; Sánchez et al. 2019). Raman is measuring radiations that are scattered by a material illuminated by a light beam (usually a laser). A small proportion of an incident beam directed at the surface of a glass object will be scattered in all directions. Although most of the scattered radiation will keep the same wavelength as the incident radiation, a very small quantity will have a different wavelength. This wavelength difference will be characteristic of the material (Pollard et al. 2007: 83).

The question of the provenance of the raw glass used to manufacture glass objects and more specifically beads is often difficult to elucidate because the absence of archaeological evidence (in the form of manufacturing tools, production waste, or unfinished objects) often prevents the identification of potential primary glass workshops. Isotope analysis can help connect the raw ingredient material to the region it was extracted from. It relies on the fact that the isotope ratios of certain elements entering the composition of glass remain unchanged through the manufacturing process and are identical, within analytical error range, in the initial raw material and in the final product (Brill and Wampler 1967). Isotope analysis in glass started with the measurement of lead isotope ratios by Robert Brill, who tried to link the lead in glass with a possible source region where it could have been procured (Brill 1969). Lead is often used (in combination with other elements) as an opacifier, as a flux (in place of or in combination with an alkali-rich ingredient), or as a primary glass-former (in later glasses), and thus is often present in minor to major concentrations in glass. Despite promising results, provenancing a colorant or an additive is not always ideal, as they can be imported and have a significantly different provenance compared to the glass itself (Barnes et al. 1986; Brill 1969; Brill et al. 1973, 1974; Shortland 2006). By contrast, silica, which is the primary consituent in glass, is generally assumed to come from a source such as sand from near the glass production site. This is because of its intrinsic low value, the large quantities of silica required to produce glass, and the expense of moving this ingredient over long distances; therefore, it can be inferred to be geochemically linked to the producing population/culture. Actually, the location of a primary glass workshop was quite likely chosen according to the proximity of a suitable silica source and the availability of fuel, also bulky but whose value depends on environmental availability. More recently, strontium (Wedepohl and Baumann 2000; Freestone et al. 2003) and neodymium (Degryse and Schneider 2008) isotopic systems have been used for provenancing lime and silica sources, respectively. Strontium is incorporated into glass with lime-bearing constituents and was found to be derived from beach shell and/or limestone in natron glass and from plant ash in glass made from halophytic (salt-tolerant) plants (Degryse et al. 2009). Neodymium originates from the heavy or non-quartz mineral component of the sand/silica used (Degryse et al. 2009). This approach has been used recently for a large-scale project conducted by Degryse and his colleagues aimed at identifying the primary provenance of natron glass from the Roman period in the Mediterranean (Degryse 2014) and for beads from different regions (e.g., Dussubieux et al. 2021; Van Ham-Meert et al. 2019) The development of new sampling tools that avoid the full destruction of small beads will certainly motivate even more research with this kind of approach (Seman et al. 2021).

4. A few notable discoveries related to glass beads

The array of methods and advances in archaeological sciences in recent decades has led to a florescence of research on glass beads worldwide. Although this volume only includes two major geographic areas of emphasis: Indian Ocean exchange networks and beads produced in Europe for trade to the Americas (and other regions of colonial interest) in the 16th to 19th centuries, we would like to highlight several other areas of bead studies. Although this section is by no means an exhaustive summary about glass bead research in general, these findings are extremely important to understanding the production, circulation, and meanings of glass beads in a more comprehensive fashion.

While the earliest origins of glass making are still ambiguous, archaeological evidence clearly shows that around the middle of the 2nd millennium BCE, prosperous glass industries were thriving concomitantly in Egypt and Mesopotamia (Shortland et al. 2018). Objects manufactured at this early period included beads. The trace elements signatures of glass artifacts found in both regions as determined by LA-ICP-MS have been key to differentiating the two industries and tracking them around the Mediterranean basin and beyond (Purowski et al. 2018; Shortland et al. 2007; Smirniou et al. 2012; Varberg et al. 2015; Walton et al. 2009). For example, the discoveries of Egyptian and Mesopotamian glass in Denmark have revealed contact between these regions dating from the fourteenth to twelfth centuries BCE. Although finished objects were traded, raw glass was also procured by beadmakers who would transform it into objects reflecting local tastes, as attested by the discovery of beads with a Mycenaean style manufactured with glass from Egypt and Mesopotamia (Smirniou et al. 2012; Walton et al. 2009) and the recovery of ingots on their way to secondary glass workshops, from the Late Bronze Age Uluburun shipwreck (Jackson and Nicholson 2010).

Subsequent cultures around the Mediterranean and across Europe continued to produce and exchange glasses for the production of beads and ornaments as well as other finished forms. The glass beads produced by Hellenistic and Celtic cultures in this region are a topic of current studies with LA-ICP-MS and other methods, shedding light on primary production centers and secondary workshop organization across Europe in both the early Iron Age Hallstatt (roughly the eighth to sixth century BCE) and the later La Tène (fifth to first century BCE) periods. The site of Sardis, in present-day Turkey, has recently been identified as a glass bead production site as early as during the eighth century BCE (Van Ham-Meert et al. 2019). Some glass beads found in present-day Poland at Hallstatt C-D sites are apparent imports to that region (Purowski et al. 2012; 2020). Later, La Tène imports of raw glass from Egypt and the Levant have been identified in

central Moravia, for example (Rolland and Venclová 2021; Venclová 2016). A comprehensive summary of the extensive ongoing research on Iron Age European glass production and exchange is beyond the scope of this introductory chapter, but it suffices to say it rivals the current flurry of studies about Indian Ocean exchange networks.

While around the same period (as early as the 5th century BCE) some of the glass production of the Levant was traded westward around the Mediterranean area and with Europe, glass beads from the same region were also exchanged eastward along what was called the "Proto-Silk Road" and have been found in China (Lü et al. 2021). There, it seems that the availability of this new vitreous material stimulated technological innovation leading to the first lead-barium glass obtained by mixing imported glass from the Mediterranean region and local lead and/or barium-containing minerals (Ma et al. 2022). The Silk Road was a very important route for the circulation of glass (and glass technology) between the Mediterranean world and China but its influence was not limited to its end points as glass can be detected all along its path (Fuxi et al. 2009).

Several chapters of this volume deal with glass beads found in Sub-Saharan Africa, but they are all concentrated in the eastern part of the continent. There, glass beads were mostly imported goods. In western Africa, recent discoveries of an indigenous glass bead making industry in the Ile-Ife region of Nigeria have revealed the development of a local glass recipe taking advantage of the availability of a pegmatite sand with high alumina concentrations that was mixed with high lime snail shells. This created a high lime - high alumina (HLHA) glass used to produce beads that were traded all over western Africa during the first half of the 2nd millennium CE (Babalola et al. 2018a, 2018b; McIntosh et al. 2017; Ogundiran and Ige 2015; Lankton et al. 2006). A lot of questions remain about the glass beads from Ile-Ife. What motivated this innovative way to manufacture glass? Why did it happen in this part of Sub-Saharan Africa and not elsewhere? As archaeological sites in the Global South continue to receive more scholarly attention, these are examples of questions that could be addressed with further LA-ICP-MS studies.

5. Conclusion

This chapter has shown how in the past decades (and almost century) we have seen major advancements in the way glass beads are studied. Yet, the importance of these small artifacts has often been neglected in favor of scholarship on glass vessels, ceramics, or metal objects, for example. Due to their small size, beads certainly have a more limited number of typological or functional attributes than

other larger artifacts, limiting the depth of the archaeological interpretation. With the increased use of analytical techniques, additional information can be extracted from ancient glass beads, making them more meaningful artifacts. With the more general use of these techniques and LA-ICP-MS more specifically, as evidenced by the different projects presented in this volume, glass bead research has jumped forward significantly in recent years as a dedicated archaeological specialization.

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Chapter 2

Glass beads and human pasts

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1. Introduction

Beads are amongst the oldest artifacts associated with modern humans (Bar-Yosef Mayer and Bosch 2019). Early shell and eggshell beads found at Middle Stone Age sites in Africa and Middle Paleolithic sites in Israel have been interpreted as examples for symbolic thinking, social signaling, and long-distance transportation of bead materials (Bar-Yosef Mayer et al. 2020; Steele et al. 2019). When glass was developed in the Middle East around 2500 BCE, beads were some of the first objects produced from this new technology (Henderson 2013:8; Moorey 1985). This long-standing and intimate connection between beads and humans makes them ideal objects for addressing a variety of anthropological questions related to their manufacture, trade, use, and meaning. In this chapter, we review a variety of case studies that demonstrate how glass beads in particular have been used to examine trade and economic systems, intercultural interactions and colonialism, social identity, and technological practices.

2. Technological practices

As archaeologists well understand, technological practices are social practices (Dobres 2000, 2010; Killick 2004; Pfaffenberger 1988, 1992) and a detailed understanding of bead production technology can illuminate social practices within a number of different arenas. Glass beads are important as objects in the social world both because they are beads—objects of adornment and exchange (Loren 2010; Spector 1976)—and because they are made of glass. Glass, as a material, is often desired and revered due to its specific properties, including shininess, brightness,

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smoothness, hardness, and reflectiveness, among other characteristics (Hamell 1983, 1987, 1992; Miller and Hamell 1986). Most commonly, investigations of beadmaking technologies are used to identify bead sources of manufacture, to build chronologies, and to establish connections between places of production and places of consumption. In some cases, the use of beads as chronological indicators can spur scholars to rethink traditional timelines and historical events (see Dalton-Carriger and Blair, this volume).

Studies of beadmaking technological practices, however, can also be used to examine social practices among bead makers, and others involved in the production side of the bead-making equation. As Francis (1994) has argued, studying beads and the technology of production can allow researchers to investigate historical migrations, technological organization, the social processes of learning, and social statuses among artisans and craft producers at multiple scales. Detailed studies of bead technology, combined with a theoretical and methodological approach grounded in the concept of object itinerary or object biography (Blair 2015), can also be used to explore social relationships among bead consumers (Blair 2017).

The study of glass beadmaking technological practices includes both the manufacture of glass, including obtaining the raw materials (Henderson 1985; Jackson et al. 2005; Jacoby 1993; Moretti and Hreglich 2013), and the production of beads from that medium, either by hot or cold working. The study of glassmaking has a long and robust history (e.g., Brill 1970; Brill 1988; Brill and Stapleton 2012; Caley 1962; Henderson 2013; McCray 1998; Turner 1956) and includes the examination of many objects other than beads. It is also a multidisciplinary endeavor, with the dynamics of glass production being investigated through historical documentation (such as glass recipe books) (Neri 1612; Toninato and Moretti 1992; Zecchin 1986), archaeological investigations of glass production sites (Cavalieri and Giumlia-Mair 2009; Hulst et al. 2012; Lankton et al. 2008), and through a variety of analytical techniques (Bonneau et al. 2014), including LA-ICP-MS, the subject of this volume.

Glass beads can be manufactured using a variety of methods (e.g., winding, drawing, molding, lapidary techniques). The diverse technological practices of bead manufacture have also been examined using many of the same sources of information as for glass manufacture: archaeological, documentary, and ethnoarchaeological, and materials science-based approaches (e.g., Kanungo 2000, 2004). In many cases, the raw glass producers and glass bead-makers were different communities, and glass bead-makers could use raw glass from multiple sources (see Trivedi and Dussubieux, this volume). While the two technological sides of glass bead making are often investigated independently, linking the multiple steps of the manufacturing process, often through the use of the concepts of *chaîne opératoire*

and bead production "communities of practice," has proven to provide powerful insights into the social dimensions of bead making technological processes (Blair 2015, 2016; Kelly 2016). For European glass and bead production, historical documentation of craft guilds combined with morphological investigations of the products of these guilds have provided rich descriptions of the social organization of craft production (Epstein and Prak 2008; Karklins 1993; McCray 1999a, 1999b; Trivellato 2006)

Babalola (2017; Babalola et al. 2018) likewise integrated multiple lines of evidence through his analysis of historical accounts and excavated glass beads and production material from the site of Igbo Olokun, in Ile-Ife, Nigeria. By combining excavation data and morphological analysis of glass beads and bead making debris with compositional analyses of beads and glass-lined crucible fragments, Babalola and colleagues identified the earliest recognized glass-making and bead-making locale in Sub-Saharan Africa. In addition to identifying and describing the technology of a previously unknown beadmaking center, this research also situated this glassmaking center as a key-driver for broader social changes in Yorubaland (Babalola 2017).

The practices of bead production also occurred in less formal settings and in some cases factory-made beads were transformed by grinding and refiring, and pieces of glass could be reworked or repurposed into new forms. Examples include the production of pendants out of remelted glass beads in North America (Walder 2013), the production of beads made by firing powdered glass and glass chips in West Africa (DeCorse 1989), and the reheating and molding of Indian Ocean glass beads in 11th century CE South Africa (Wood 2011; see also Klehm and Dussubieux, this volume, Figure 15.1). The study of such (re)production of beads is an important window into material tastes and the social practices of bead consumption.

3. Trade and economic systems

Due to their portability and durability in the archaeological record, glass beads have frequently been used to identify and examine ancient trade, interaction, and economic systems. At the most basic level, the appearance of glass beads can be a marker of contact and intercultural interaction between two regions, and changing styles of glass beads has facilitated their use as temporal markers (e.g., Bellina and Glover 2004; DeCorse 1989; Karklins 2012; Kidd and Kidd 2012; Spector 1976; Wood 2011). However, the examination of glass bead compositions has allowed for a more in-depth consideration of trade and economic networks through the identification of glass recipes that can be associated with specific

workshops or glass production traditions. Many of the chapters in this volume use beads to deepen understandings about long-distance, regional, and local exchange networks (see Aldenderfer and Dussubieux, this volume; Hawkins and Walder, this volume; Klehm and Dussubieux, this volume; Trombetta et al., this volume; Wood et al., this volume). In several cases, the use of LA-ICP-MS has facilitated the identification of sub-groups of glass types, which can also be differentiated chronologically and regionally (e.g., Dussubieux et al. 2010; Trivedi and Dussubieux, this volume). Compositional analysis using LA-ICP-MS is also useful for identifying different bead types and groups that are not obvious based on visual typologies or style (see Blair and Dussubieux, this volume; Larson and Dussubieux, this volume; Panich et al., this volume). In these cases, scholars are able to move beyond simplistic identification of connections between two regions to learn about the particular communities that may have come in contact with one another and how economic networks were organized.

In Southeast Asia small, monochromatic, drawn beads, sometimes called Indo-Pacific beads are ubiquitous at many sites dating from 500 BCE – to the second millennium CE (Francis 1990) (Figure 2.1). These beads look similar to one another, but compositional studies have identified numerous different recipes associated with different world areas and workshops (Carter 2016; Dussubieux and Gratuze 2013; Dussubieux et al. 2012; Lankton and Dussubieux 2013). Glass compositions from the sites of Khao Sam Kaeo and Khao Sek on the Thai peninsula are similar to glass produced at the site of Kopia in northern India (Dussubieux and Kanungo 2013; Dussubieux and Bellina 2017; Dussubieux and Bellina 2018). Elsewhere on the Thai peninsula at the site of Phu Khao Thong, glass recipes show affinities with objects produced at the site of Arikamedu in South India (Dussubieux et al. 2012). Studies of glass beads within mainland Southeast Asia have identified multiple intraregional exchange networks that linked different communities on the coasts and inland areas, and which shifted over time (Carter 2015; Carter et al. 2021; Dussubieux and Bellina 2018). Through the identification of specific bead recipes, archaeologists are able to move beyond one-dimensional interpretations that recognize glass beads merely as objects that represent contact with India, and instead have identified diverse economic networks linking different parts of South Asia and Southeast Asia, as well as more closely examining how different types of beads circulated within internal exchange networks.

Similarly, compositional studies of glass beads in southern and eastern Africa have elucidated the dynamic trade networks between these areas and the Indian Ocean region, including the aforementioned Indo-Pacific beads. The rise of Islam and breakdown of preexisting Sassanian exchange networks in the ancient world created an opportunity for traders from South or Southeast Asia, and from the

Middle East, to seek products such as gold and ivory. Glass beads associated with South Asian and Southeast Asian bead production appear at sites on the east African coast during the mid-late first millennium CE (Wood et al. 2017). Different bead types at sites in east and southern Africa demonstrate how participation in Indian Ocean exchange networks varied through time in these two areas (Wood 2015). Previously, it had been assumed that glass beads found in southern Africa in the first millennium were being traded inland via east African ports (Wood 2015). However, compositional studies reveal evidence for more direct trade between southern Africa and the Middle East, with glass beads likely from the Persian Gulf region found not only on the Mozambiquean coast (e.g., Wood 2015), but also nearly a thousand kilometers inland (e.g., Denbow et al. 2015; Klehm and Dussubieux, this volume). In these cases, beads are material indicators of diverse economic networks that are frequently tied to and affected by regional historic events (Robertshaw et al. 2010; Wood 2016).

Fig. 2.1: Example of Indo-Pacific beads from the site of Angkor Borei, Cambodia. Photo by Alison Carter.

Studies of glass beads can also clarify smaller scale exchange and economic networks, emphasizing the importance of understanding the local cultural contexts of these interactions. In the Arnhem Land region of northern Australia, a study of glass beads dating to the period of Macassan and European contact,

primarily post-1800 CE, has been used as evidence not just for contact between foreigners and Australian aboriginal communities, but also for understanding the economic activities between these groups (Wesley and Litster 2016). During this period, aboriginal groups were paid in material goods for their labor. Therefore, the presence of glass beads was not just evidence for contact or gifting between communities, but a material indicator of aboriginal participation in foreign maritime or colonial economic systems (Wesley and Litster 2016: 12).

4. Glass beads and colonial encounters

Glass beads are also important artifacts for studying a more specific kind of intercultural interaction: colonial encounters amongst Europeans and Indigenous communities. Glass beads were often intended to cross cultural boundaries, and the concept of "itineraries" serves as a useful way to envision the routes along which glass beads traveled throughout the world and the complex and overlapping values and meanings they accrued along the way (Blair 2015). Most of the glass beads associated with the spread of European colonialism were manufactured on the continent, with glass bead production centers such as Bohemia, Holland, and most famously Venice and Murano (Karklins 2012; Panini 2017; however see Fenn et al., this volume, for Chinese glass beads in North America). In Europe, glass beads remained a viable export business into the late 19th and earlier 20th centuries, supplying markets in North America, India, Africa, and the Pacific (Allen et al. 2018).

Worldwide, agents of numerous colonial powers used glass beads to facilitate initial contacts with local Indigenous groups. In the American Southeast and the Caribbean, for example, beads were a common component of early colonial "gift kits" intended to secure friendly relations with various Native peoples (Keehnen and Mol 2020). Centuries later in western North America, Spanish missionaries, Russian merchants, Euro-American trappers, and explorers flying various flags all carried glass beads as commodities that could be presented to tribes throughout California and the Pacific Northwest (Crull 1997; Panich et al., this volume) (Figure 2.2). Similarly, the British brought glass beads with them to Australia during the initial founding of their penal colony (Litster et al. 2018). In these contexts, beads—along with materials such as cloth and tobacco—served to facilitate social interactions during early encounters between Indigenous people and European colonists.

Fig. 2.2: Glass beads from an Indigenous residential area at Mission San José in central California, 1797-1840s. Photo by Lee Panich.

In time, Indigenous communities and colonists established more formal expectations about the role of beads, which in many cases served as a form of currency. While glass beads were certainly a medium of exchange, the term "trade bead" often carries the negative implication that colonists and Indigenous communities were not in fact operating on a level playing field with regard to the inherent value of the glass beads in questions. Yet, the actual value of glass beads for Indigenous people was a complex proposition (Loren 2013; Miller and Hamell 1986; Moffett and Chirikure 2016). In many cases, glass beads slid easily into existing economic and adornment practices involving beads made from shell, stone, ceramic, or bone—sometimes even being used to replicate specific patterns, such as those created by Meskwaki ribbon workers (Ackerman 2008). But as suggested by Turgeon (2004), the symbolic value of glass beads may have in part derived from their status as foreign objects, or difficult to obtain. Thus, as Stahl (2002:841) argues for the Banda region of Ghana, "the desirability of imported forms was likely predicated on the existing practices of taste for beads, which were subsequently transformed by the incorporation of new bead forms." No clearer does this transformation take place than in east and southern Africa, where early 16th century Portuguese traders encountered their African counterparts wishing to trade not just for glass beads, but glass beads produced in South Asia, and refusing in turn to accept European glass. During the colonial period, the importance of glass beads and their origins

shift dramatically, being offered as tokens to entice African children to attend missionary school (Klehm 2014; Klehm 2017:630).

Indigenous communities, moreover, were not passive recipients of glass beads, but rather drove the distribution of particular bead types across the globe. As noted by Panini (2017:19), Venetian bead producers responded to the tastes of people living in Africa, Asia, and the Americas for glass beads of particular shapes and colors. Indigenous people, for their part, valued the materiality of glass—its luster, hardness, and durability, among other attributes—and people in different times and places expressed distinct preferences for specific colors of glass beads. Some groups, like the Ohlone and other tribes in central California, appear to have desired white glass beads for their resemblance to shell beads, while for others, such as Iroquoian and Algonquian speaking nations in northeastern North America, glass bead colors appear to have mapped onto color symbolism within dynamic Indigenous worldviews (Hamell 1992; Klehm 2017:615; Panich 2014:743-744; Ostapkowicz 2018:8; Turgeon 2004:34; and see Agbe-Davies 2017). In some cases, however, the patterns of beadwork and the social practice of beading held more significance than the beads themselves, as among the Métis in Canada (Supernant 2021).

Given their importance in Indigenous regimes of value, glass beads also quickly expanded beyond the parameters of encounters with colonists. Beads that had been strung or packaged according to color at European factories were often separated by Indigenous recipients who reconfigured them in a variety of ways. Many were traded along existing exchange networks, sometimes preceding the arrival of Europeans themselves, whereas others were strung alongside beads of differing materials (Blair 2015; Dalton-Carriger and Blair, this volume; Walder 2018). To date, most archaeological research has focused on glass beads from excavation contexts, particularly burials, but recent studies have also considered the broader array of objects into which Indigenous people incorporated foreign beads, ranging from those dating to the earliest colonial encounters all the way to the 20th century (Allen et al. 2018; Ostapkowicz 2018). Whether from archaeological or ethnographic contexts, elemental analyses of beads—like those presented in the following chapters—can help reconstruct the various itineraries along which beads traveled and the complex ways they were recombined by Indigenous actors. Ultimately, these patterns underscore the notion that Indigenous people assigned their own value to glass beads and in so doing recontextualized these objects with complex and dynamic meanings.

5. Glass beads and social identity

Glass beads—worn on strings around the neck, waist and arms; sewn onto clothing and bags; worn as headdresses; made as offerings to the spirits or the deceased—play an active role in displaying and enacting various group and individual social identities. The social meaning of beads can vary widely: beads can be protective, warding off evil spirits (Donley-Reid 1990; Campbell Cole 2012); they may serve as a public acknowledgement of friendship bonds, a tangible manifestation of alliances and social networks (Wiessner 1982); they may serve as an indicator of individual prestige, with their status conferred from the difficulty undertaken to obtain these materials and the skill involved in their production, or because of restricted access (Trubitt 2003); they may be heirlooms that represent family lineage and one's heritage, never to be sold (e.g., Francis 1992); among other cultural uses; they may serve as gendered objects, both in terms of the beadmaking process and with who wears them (Sciama and Eicher 1998). The visibility of the beads, as well as their colors, patterns, and bodily placement, can be important components of creating culturally-recognized (and acceptable) aesthetics.

Ethnography and ethnoarchaeology demonstrate the ways that beads convey complex social and ideological meanings of being in the world. For example, beaded personal ornaments have long been associated with indexing ethnic identity among the Okiek hunter-gatherer and Maasai pastoralist communities, both located in modern Kenya (Klumpp and Kranz 1993). Among the Maasai, beadwork is seen as a woman's personal wealth, akin to the number of one's cattle for men (Klumpp 1987). As much as they appear similar in form and function, the perceived value of beads, and the "correct" patterns differ significantly between the two (Klumpp and Kranz 1993). Beyond ethnic affiliation, beads also are social cues for belonging within them. Quantity, color, and combinations of particular beads relate to various aspects of one's individuality: ethnicity, family lineage, gender, age-set, progress through a lifecycle (e.g., birth, initiation, marriage, motherhood, death).

The act of producing glass beads and beadwork is also rooted in identity making. For the Okiek and Maasai, beadwork is completed for women, by women (Klumpp and Kranz 1993). In Purdalpur, Uttar Pradesh, India, the various tasks of beadmaking means community building through the various peoples (of different ages, sexes, and families) involved: from those who operate the furnace and those who make various manufacturing tools, to those who dye the beads and those who clean and string them together (Kanungo 2000, 2004). Technology transfer is likewise a social process, as the knowledge of glassmaking passes down from person to person (McCray 1999a). However, bead production and its various social identities may be tied to inequalities as well. In Purdalpur, for example,

beadmaking has been deeply structured around caste (e.g., Francis 1994; Kanungo 2004).

The ownership and use of glass beads are subject to social conventions. For instance, cultural norms regarding heirloom beads vary significantly among cultural groups: e.g., who can wear them, and when; who inherits them; whether collections are curated or split during inheritance; whether heirloom collections are considered "open" and can have beads added to the family line (Francis 1992:15-17). Among the Bontoc peoples of the Philippines, beads are part of the *akon*, moveable heirloom wealth, inherited at the time of marriage; and others not inherited at the time of marriage follow strict social rules of ownership (Francis 1992:7). The Ifugao peoples share their heirloom beads, if only temporarily: loaned to the shaman when a family member becomes ill, and used to bedeck corpses (that are removed again before burial) (Francis 1992:6). Cultural expression and rules of convention dictate use in the past, just as the present: early Sanskrit and Buddhist literature refers to women and horses wearing glass, while other rules forbid the use of glass for shoe ornamentation (Kanungo 2004:126-127).

Valuation is embedded within situational contexts of meaning: where beads are found is as, if not more, important as where they originated (Moffett and Chirikure 2016; Klehm 2017:629). For instance, Indo-Pacific glass beads dating to 11th century CE, show signs of significant alteration after they reach southern Africa communities: they are crushed, reheated, and molded into larger, multicolored beads known as "garden rollers" to conform to local tastes (Wood 2011; Klehm and Ernenwein 2016:56). Sarathi et al. (this volume) suggest that glass beads, as an exotic foreign object, may have been important prestige items at Unguja Ukuu in Zanzibar, Tanzania. Among the Tanis of northeast India and northwest Burma, beads have their own oral histories, with origin stories from a mythical ancestor Abo Tani in Tibet (Campbell Cole 2012). Tani heirloom beads were rarely sold, except in times of great need, seen as symbols of wealth based on the size, color, and luster and having protective powers. Their worth further increased when passed down within the same family from generation to generation. Similar to the Ifugao people, beads may also be placed with the dead as a sign of respect for one's relative. Meanings are not static; beads can become "dead," or lose their value (and provide bad luck) if cracked (Carter et al. 2018). In the Diaspora, the significance of the color of glass beads found in burials of enslaved Africans and what they mean for religion, tradition, and other social indices remains hotly debated (Davidson 2020; DeCorse 1999; LaRoche 1994; Lee 2011; Stine et al. 1996). Adornment and aesthetics, protective and health charms, symbols of worldviews and "tradition," indices of socioeconomic status, and even as teethers for children have been posited and supported through varying evidence,

all at the intersection of enslavement, race, multiple ethnic identities, gender, and other factors (Lee 2011). Thus, context remains important: it is what these beads over other forms of material expression signify and do as part of social processes (Agbe-Davis 2017), which in turn change through time (Stahl 2010).

6. Conclusion

The chapters in this volume demonstrate the importance of glass beads as an archaeological and anthropological artifact. Many chapters also suggest directions for the evolution of glass bead research in the future. For example, Dussubieux's work at Kish, Iraq highlights the new understandings one can gain by examining legacy collections. While much research has been conducted on bead origins (e.g., workshops) and their final place of deposition, we still understand little about the movement of beads, making Craig and Dussubieux's study of glass beads from shipwrecks encouraging for better understanding bead exchange networks. Wood demonstrates just how complex these trade relationships may be, even within a confined time period. Klehm and Dussubieux further remind us that although beads may be an indicator of long-distance exchange, they also can inform about local and regional political dynamics. Several authors also note the importance of studying different types of beads together such as glass and stone beads (Dussubieux, this volume) or glass and shell beads (Walz and Dussubieux, this volume). Future work could move beyond identifying the presence of bead compositional groups and begin addressing *why* such groups exist, persist, and change over time. We also hope that the diverse papers in this volume and the discussions that took place between authors inspire continued communication across regions and time periods.

Glass beads, like beads more generally, are part of cultural, cognitive, and communicative systems of language, art, and symbolism (Bednarik 2001). As the case studies above and in this volume demonstrate, the study of glass compositions has especially allowed archaeologists to move beyond simplistic interpretations of beads as mere baubles and instead consider questions of contact, exchange, manufacture, use, and meaning in more depth. We acknowledge that studying the complex meanings of glass beads in various cultures, past and present, is subject to a number of conceptual challenges. Historical and modern contingencies have impacted the ways in which objects are used, and cultural categories may draw from the priorities and perceptions of ethnographers, ethnoarchaeologists, and archaeologists alike (Cunningham and MacEachern 2016). While interpretive approaches by researchers and conclusions vary, what remains is that glass beads actively mediate social lives across cultures through time.

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Part I

European Trade Beads

Chapter 3

Characterizing glass recipes for distinctive polychrome glass bead types in Ontario, Canada

Alicia Hawkins[1] and Heather Walder[2]

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

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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.

Glass Bead Period	Monochome	Polychrome
GBP 1 (1580-1600)	**Turquoise round (IIa31/40)** **Cobalt blue round and circular (IIa35, IIa55)**	Black striped red round (IIb1) Black striped and compound red round (IVb1) Red-in-white striped light aqua oval (IIbb23) White striped round clear gooseberry (IIb18) White striped dark blue oval (IIb67) Alternating red and white striped dark blue oval (IIb64) Multi-layered ground faceted star/chevron (IIIm1) **Frit cored beads**
GBP 2 (1600-1625/30)	**White tubular (Ia5) and oval (IIa15)** **Indigo tubular (Ia19) and oval (IIa57)**	Blue striped white tubular (Ib'2) Blue-in-white red round and oval (IIbb1, IIbb2) Round eyed beads (IIg4, IIg*) **Multi-layered chevron/star (IIIm1)**
GBP 3 (1625/30-1650)	**Red tubular (Ia1) and round (IIa1)** **Turquoise tubular (Ia12/14) and round (IIa31/40)**	Compound red round and circular (IVa1-IVa8)
Dutch Polychrome (1609-1624)		Blue-in-white red round and oval (IIbb1, IIbb2) White-in-red striped black oval (IIbb7) White and blue striped white circular (IVb15) White striped on layered white and indigo round (IVb29-36) **Dutch manufacture star bead (IVk3)** Red and blue striped on multi-layered white, red and blue (IVn3, IVnn4)
Dutch Cored (1624-1660)	**Turquoise round (IIa31)** **Round and circular black (IIa6, IIa7)** **Indigo tubular (Ia19)**	Small circular cord light grey (IVa13) Multi-layered tubular indigo (IIIa12)

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).

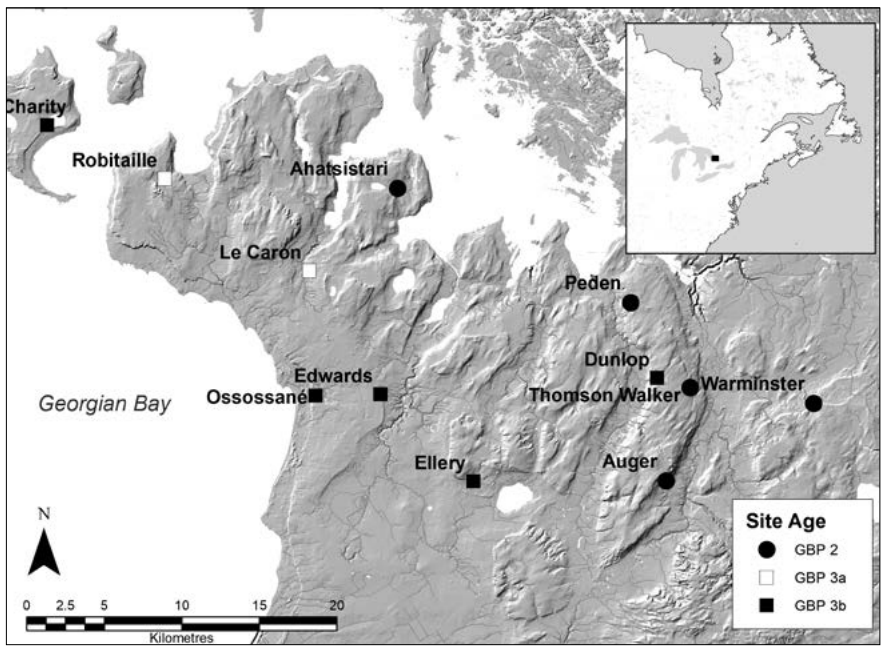

Fig. 3.1: Locations of Huron-Wendat sites with analysed glass beads described in this paper.

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.

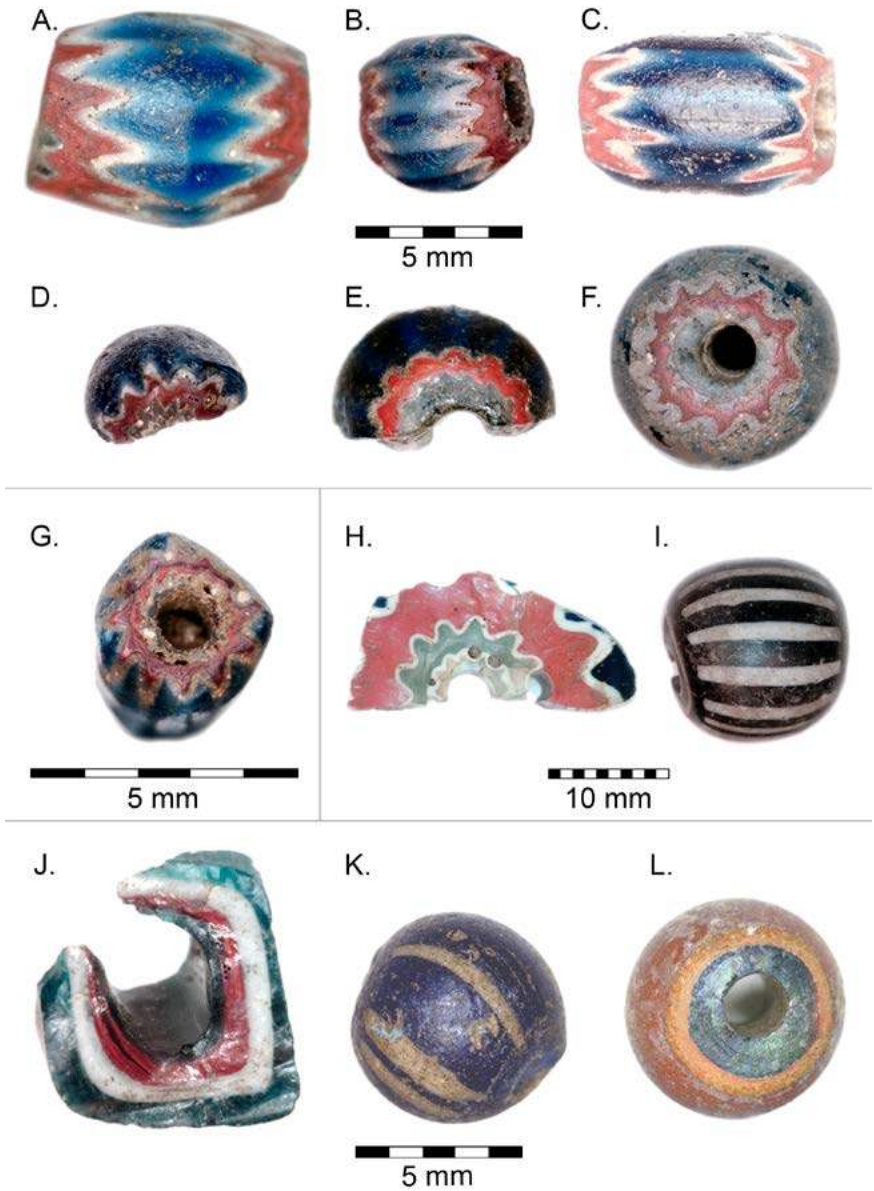

Fig. 3.2: Examples of the polychrome beads included in this analysis.

Image	Description	Kidd & Kidd	Sample ID(s) and colors (abbv.)	Site	Catalogue or Accession #	Curation Institution
A	Star chevron, barrel shaped, faceted, 5 layers	IIIm-	AG_11 (bl) AG_12 (r) AG_13 (w)	Auger	AG 4184	University of Toronto
B	Star chevron, faceted, round, 5 layers	IIIm-	AT_15 (bl) AT_16Bred AT_17 (w)	Ahatsistari	AT 348E 513N 20-25	Wilfrid Laurier University
C	Star chevron, faceted ends, 5 layers	IIIm-	AG_08 (bl) AG_09 (r) AG_10 (w)	Auger	AG 1360a	University of Toronto
D	Star chevron, barrel shaped, 7 layers, some faceting	IVk or IIIm?	AT_21 (bl) AT_22 (r) AT_23 (w)	Ahatsistari	AT 349E 511N 10-15	Wilfrid Laurier University
E	Star chevron, round/barrel shaped, 5 layers	IVk-	LC_30 (bl) LC_31 (w) LC_32A (r)	Le Caron	LC G13b20.9	Trent University
F	Star chevron, round, 5 layers	IVk-	PED_01B (bl) PED_02B (r) PED_03B (w)	Peden	PD 1986.01.0123.022	Huronia Museum
G	Star chevron, tubular, faceted ends, 5+ layers	IIIm-	LC_36 (bl) LC_37 (r) LC_38 (w)	Le Caron	LC J16E4.1	Trent University
H	Star chevron, giant, prod. waste? 7 layers	IIIm-	LC_33 (bl) LC_34 (r) LC_35 (w)	Le Caron	LC F15n15.16	Trent University
I	Black and white striped, 3 layers	IVb*	LC_26 (bk) LC_27 (w)	Le Caron	LC J18p3.249	Trent University
J	Nueva Cadiz Twisted – Red Variant, four layers	similar to IIIc'3	LC_42 (turq) LC_43 (r) LC_44 (w)	Le Caron	LC H16q6.47	Trent University
K	Blue with white stripes, round	Like IIb68	EL_18 (bl)	Ellery	EL 2539	University of Toronto Mississauga
L	Red IVa compound bead, 3 layers	Like IVa1	EL_26 (core, colorless)	Ellery	EL 96b	University of Toronto Mississauga

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

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_2O_3 and Zr (both contributed mainly from the silica-rich glass ingredient).

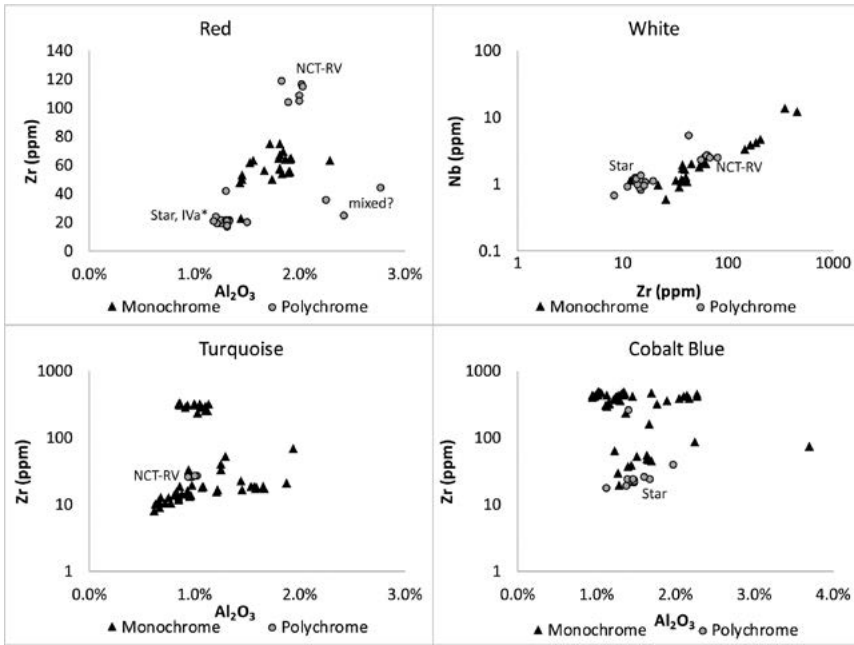

Fig. 3.3: Comparison of polychrome and monochrome beads: Al_2O_3 vs Zr in red (a), turquoise (c) and cobalt glass (d) and Zr vs Nb in white glass (b).

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_2O_3, while red glass from star-chevrons and red IVa* beads have low values of both Zr and Al_2O_3. Monochrome beads have intermediate values of both Zr and Al_2O_3. Three red samples from polychrome beads (one star-chevron and two red IVa*) have high values of Al_2O_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_2O_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_2O_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_2O_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_2O 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 IIa31 and IIa40 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_2O_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_2O, Na_2O, 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.

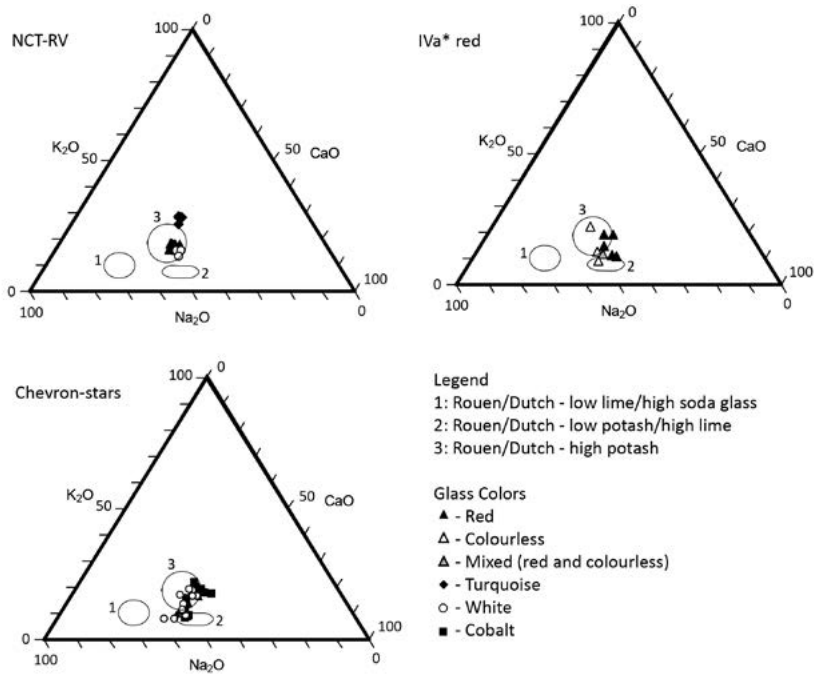

Fig. 3.4: Relative proportions of soda, lime and potash in different glass colours from three distinctive bead types, compared with glass groups determined for Rouen and Dutch beads.

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.

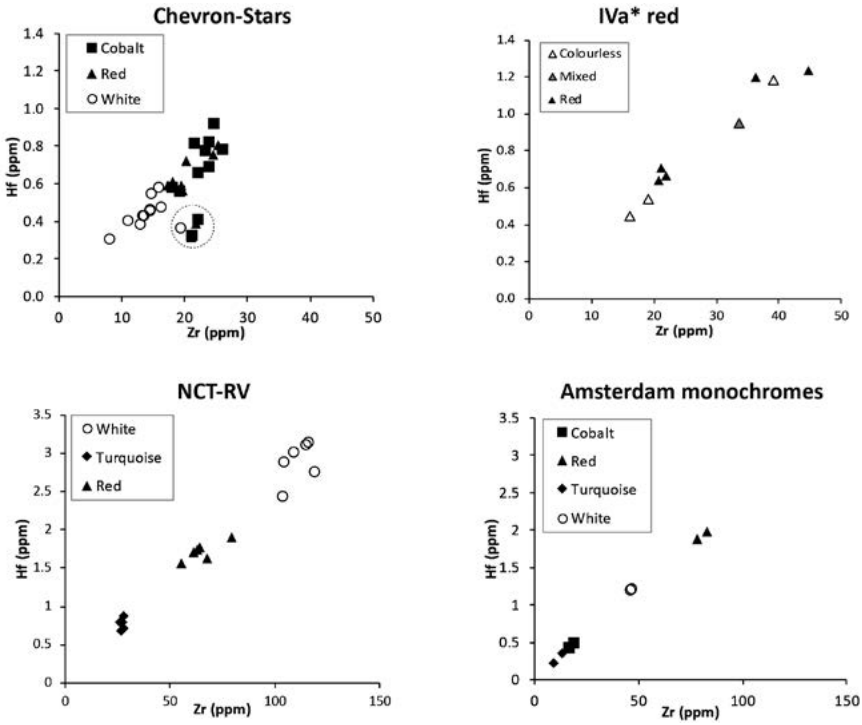

Fig. 3.5: Zr vs. Hf for distinctive polychrome bead types ((a) Chevron-star; (b) IVa* and (c) NCT-RV and monochrome beads (d) Amsterdam). Note different scales

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.

	REDUCED BASE GLASS (wt%)							COLORANT (wt%)			SUM
Sample ID	SiO_2	Na_2O	MgO	Al_2O_3	CaO	K_2O	Fe_2O_3	Fe_2O_3	CuO	SnO_2	Cu + Sn + Fe
Colourless Glass											
LC_55	67.02	14.17	3.88	1.09	10.63	2.54	0.67	0.66	0.02	0.01	*0.68*
EL_25	66.45	14.32	3.29	1.17	10.49	3.67	0.61	0.60	0.02	0.10	*0.71*
LC_53	67.19	12.89	2.97	1.90	8.17	5.98	0.90	0.89	0.14	0.05	*1.08*
CH_16	68.06	11.62	2.29	2.48	11.19	2.84	1.52	1.48	0.02	0.03	*1.54*
CH_17	68.39	11.34	2.21	2.55	11.37	2.75	1.39	1.35	0.06	0.12	*1.53*
Mixed sample?											
EL_26	67.55	12.81	2.27	2.15	10.20	3.11	1.91	1.83	0.64	0.73	*3.20*
Red Glass											
OSS_18	67.70	12.13	2.48	2.32	11.02	3.02	1.34	1.30	0.02	0.06	*1.38*
OSS_19	68.38	11.26	2.15	2.84	10.98	2.72	1.66	1.62	0.06	0.06	*1.73*
LC_51	64.96	11.39	3.48	1.31	10.50	5.23	3.13	2.81	1.39	2.65	*6.84*
LC_52	65.14	12.49	3.52	1.41	10.01	3.92	3.51	3.26	1.50	1.25	*6.01*
LC_54	64.62	12.32	3.43	1.41	9.76	5.32	3.15	2.91	1.98	1.50	*6.39*

Table 3.3: Composition of glass layers in red IVa* beads. Reduced base glass is calculated as described by Brill (1999).

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.

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Chapter 4

Simple blue (IIa40) beads from 17th century Mission Santa Catalina de Guale: Dating, origins, and elemental composition

Elliot H. Blair[1] and Laure Dussubieux[2]

1. Introduction

Opaque, drawn, turquoise-colored glass beads of simple construction, identified as Kidd and Kidd (2012 [1970]) IIa40 are one of the most ubiquitous types found on colonial sites in eastern North America. As noted by Francis (2009a), this ubiquity has resulted in numerous names used to refer to this bead variety, including Early Blue (Heisey and Witmer 1962), Estaufa Blue (Whitthoft 1966), Jamestown Blue (Whitthoft 1966), Childersburg Opaque Blue (Penman 1972, Dejarnette and Hansen 1960), Sugarcane Blue, Ichtucknee Plain (Goggin, n.d.), and Ichtucknee Blue (Deagan 1987). In part because of the ubiquity of this type, numerous compositional studies have been conducted, addressing questions of temporality and manufacturing source (e.g., Hancock et al. 1994; Kenyon et al. 1995; Hancock et al. 1996; Walder 2018). In this chapter we discuss the results of LA-ICP-MS analysis of twenty type IIa40 beads recovered from 17th century Mission Santa Catalina de Guale (SCDG), St. Catherines Island, GA, considering the temporality and origins of these artifacts.

2. Type IIa40 beads: Characteristics, origins, and chemistry

2.1. Characteristics

Despite the ubiquity of IIa40 beads on colonial sites in the Americas, the type has been the subject of limited direct inquiry (aside from compositional analysis). The most extensive discussion of the type has been by Francis (2009a), who makes a number of keen assertions and provocative hypotheses. While many studies note that this bead type is drawn, simple, turquoise blue, and often manufactured of

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unstable, leached, glass—Francis highlights two additional important attributes of this type.

First, many specimens of this variety exhibit the characteristic imperfections of the *a speo* rounding process, a method in which cut segments of bead cane are rounded by being reheated using a multi-pronged spit (Karklins 1993). This finishing technique—often resulting in conjoined beads and broken projections from the ends of the beads—was utilized by members of the Venetian *Paternostri* bead making guild and its expatriate members (Francis 2009a, b). Beads made using this technique are in many cases distinguishable from beads manufactured by the Venetian *Margareteri* guild, which used the *a ferrazza* finishing technique (stirring the cut segments over heat), and from beads rounded using the later, "hot-tumbling," method that used a rotating drum developed ca. 1817 (Figure 4.1).

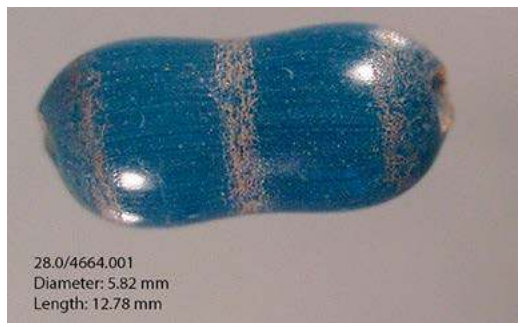

Fig. 4.1: A IIa40 bead recovered from Mission Santa Catalina de Guale, exhibiting the characteristic air bubbles of the type and conjoined due to the *a speo* manufacturing process.

The second attribute that Francis (2009a) discusses is the striated appearance of this type. He noted that many early descriptions of these beads note this characteristic, describing the striations as air holes or bubbles (Watt and Meroney 1937; Duffield and Jelks 1961), or having "a texture reminiscent of stripped sugarcane" (Harris et al. 1965; Harris and Harris 1967, 1973; Harris et al. 1999). He attributed this characteristic to the use of low-quality ingredients and poor production methods. He also suggested that—based on priority and descriptiveness—the type be referred to as "Bubble Glass Beads," rather than one of the other innumerable names used for the type.

In addition to noting these attributes for the type, Francis (2009a) also suggested that the type was likely correlated with the *turquí* beads of the Spanish cargo lists (Torre Revello 1943; Kelly 1992). While he notes that this descriptor could refer to color, it more likely indicates an erroneous assumption that the bead

type may have derived from Turkey. In fact, not all varieties identified as *turquí* in the Spanish cargo lists were blue; black, green, clear, and golden varieties of *turquí* were also identified (Kelly 1992; Francis 2009a).

2.2. The French connection

Based on these observations, Francis (2009a) made the provocative hypothesis that "Bubble Glass Beads" of all colors, including the IIa40 blue variety, were likely manufactured in France. He dismisses Venice as a possibility based on the poor-quality of the glass and Amsterdam based on the absence of the type in comparative samples (e.g., Karklins 1974, 1983, 1985; van der Sleen 1962, 1963a, b; van der Made 1976; Gawronski et al. 2010; Hulst et al. 2012). He supported this suggestion by arguing that historical documentation indicates that during the 16th century France was recruiting glass makers and beadmakers from Venice—primarily represented by members of the Venetian *Paternostri* guild, the guild responsible for the manufacture of the *a speo* finished type IIa40 beads. Francis deduced from these two points that *Paternostri* produced beads manufactured from low quality glass must be a product of the documented French industry, rather than the products of the better-established Venetian or Dutch industries.

This conclusion was also supported by Turgeon's (2001) analysis of French notarial archives, which showed that France was a major producer of glass beads during the late 16th and early 17th centuries. Additionally—paralleling Francis's conclusions—Turgeon (2001) notes that "turquin" was a specific category of glass bead manufactured in France, arguing that they were "undoubtedly the round turquoise beads, IIa40 in the Kidd classification… [and] are in a category of their own, perhaps because of the very particular chemical makeup of these beads."

This attribution of type IIa40 beads to French manufacture was initially met with some skepticism. In the years since this hypothesis was first proffered, however, some supportive evidence has emerged and a number of researchers have argued for a robust French industry (e.g., Walthall 2015). Dussubieux (2009; Dussubieux and Gratuze 2012) has reported compositional data on glass beads and ornaments manufactured and/or excavated from several sites in France, and recently, Karklins and Bonneau (2019) have reported on an assemblage of early 17th century beads and beadmaking wasters that were recovered from a site in Rouen. Much of this material shows evidence of the *a speo* finishing technique and a number of IIa40 beads—containing numerous "bubbles"—were included in the assemblage. Similarly, Loewen (2019), using primarily documentary evidence, argues for extensive 16th and 17th century glass bead industries in Normandy and Rouen and suggests that France was the likely source for most beads recovered from early 17th century northeastern North American sites.

In a recent, controversial paper, Kunz and Mills (2021) report ten IIa40 beads recovered from three late precontact sites in Alaska. Based on some equivocal radiocarbon dates, they argue that this bead type may have been manufactured in Venice as early as the 15th century. Nevertheless, all historical and archaeological evidence indicates that this bead type was not manufactured earlier than ca. 1560 (Blair 2021).

2.3. Compositional analyses of IIa40 beads

Because of their ubiquity on North American sites, Kidd and Kidd IIa40 beads have also been subjected to more compositional studies than almost any other bead variety in the colonial Americas. Following several early analyses that included small numbers of this type (Davison and Harris 1974; Karklins 1983; Lewis 1979; Chafe et al. 1986), the first extensive analyses were reported by Hancock et al. (1994). Using Instrumental Neutron Activation Analysis (INAA), Hancock and colleagues analyzed samples of blue beads from the Great Lakes that had been previously assigned to the stylistically defined Glass bead Periods I (~CE 1580 – 1600), II (~1600-1620), and III (~CE 1620 – 50) (Kenyon and Kenyon 1983, Fitzgerald 1990, Fitzgerald et al. 1995). Their key finding was that 16th century IIa40 beads tended to have lower sodium, calcium, and chlorine and higher copper than 17th century specimens. They also noted a lack of antimony, while tin was present in a number of specimens. This analysis was supplemented by several later reports (e.g., Kenyon et al. 1995; Hancock et al. 1996) that expanded the sample temporally and regionally and found that quantities of calcium, potassium, sodium, chlorine, copper can be used to segregate bead assemblages from the 16th through early 20th centuries (Kenyon et al. 1995).

Additionally, some have suggested that the hypothesized temporal patterning observed by Hancock and his colleagues might instead reflect changes in bead suppliers. Fitzgerald et al. (1995) suggest that the high copper content of the late 16th century beads reflects Basque supplied products of a Southern European industry while the low copper beads are the French-supplied products manufactured in France or, perhaps, Amsterdam.

Hancock and colleagues have also conducted a series of analyses of beads of different colors. Importantly, their work on white glass beads identified a chronological sequence of glass opacifiers where early beads (16th and early 17th centuries) were opacified with lead-tin, calcium antimonate was used starting during the late 17th century, and arsenic based opacifiers were used during the 18th and 19th centuries (Hancock et al. 1997; Hancock et al. 1999; Sempowski et al. 2000; Moreau et al. 2002; Moreau et al. 2006).

In the Upper Great Lakes region, Walder (2013, 2015, 2018) has also identified a number of temporally significant compositional groups for simple drawn, turquoise blue beads. Most notably, these include several 17th century groups characterized by a high zinc content, and a transition from high Mg and low P, to the reverse, around ca. CE 1700. Walder (2018) also documented increasing CaO over time in the Great Lakes region. Extensive analyses of type IIa40 beads dating from the 16th-18th centuries in East Tennessee have also been conducted by Dalton-Carriger and Blair, primarily using x-ray fluorescence spectrometry (XRF) and focusing on patterns in opacifier use (Dalton-Carriger and Blair 2015; Blair et al. 2017).

3. Mission Santa Catalina de Guale

3.1. The site

Thousands of type IIa40 beads have been recovered from colonial sites in the Southeastern United States (e.g., Lapham 2001; Brain 1979), including at 17th century Mission Santa Catalina de Guale, the location of one of the largest and most diverse bead assemblages documented from a Spanish colonial site (Blair et al. 2009).

The Guale people of the northern Georgia coast had one of the earliest and longest histories of sustained European contact of any native group in North America (Thompson and Worth 2011). This included a series of early encounters during the 16th century (Lyon 1976; Hoffman 2002, 1990; Worth 2009a, 2015; Jones 1978), and in 1587 the primary Franciscan Mission Period in *La Florida* began. By 1595 two Franciscans were stationed on the island of Guale (St. Catherines Island, Georgia) and additional missions were also established throughout the province. Two years later, however, five of the six friars stationed in the province were killed during the 1597 Guale rebellion and most of the coastal missions were destroyed (Francis and Kole 2011). Following the resolution of the revolt, friars were once again distributed among native villages of the North Georgia coast beginning in 1605, initiating a sustained 75-year period of missionization on St. Catherines Island and only ending in 1680 following slave raids by the British-allied Westos (Worth 1995; Bowne 2005; Worth 2009b).

Since the mid-1970s, significant archaeological work has been conducted at Mission Santa Catalina (Thomas 1987, 1988, 1993, 2009; Larsen 1990; Reitz et al. 2010; Blair 2015b; Blair et al. 2009). The bulk of the excavations have occurred within the central compound of the mission, including the excavation of the mission church, cemetery, friary, kitchen, and two wells, as well as more

limited excavations within the Native residential sector. These excavations have been well described by Thomas (1987, 1988, 1993, 2009, 2010, 2011), and further publications on this material are currently in preparation at the American Museum of Natural History.

Excavation of the mission cemetery, located beneath the floor of the church and containing a minimum of 431 individuals, has also provided considerable information on the biocultural and bioarchaeological makeup of the mission population (Schoeninger et al. 1990; Larsen 1990; Stojanowski 2005). Found with these individuals were numerous grave goods, including crosses, devotional medals, religious medallions, majolica vessels, bells, mirrors, rings, stone discoidals, and an engraved shell gorget with a coiled rattlesnake motif (Thomas 1988; Blair et al. 2009; Winkler et al. 2017). Additionally, the great majority of the almost 70,000 beads recovered from Mission Santa Catalina were found interred in the church cemetery.

3.2. The beads of Mission Santa Catalina de Guale

The bead assemblage from SCDG has been extensively described elsewhere (Blair et al. 2009) and primarily includes specimens manufactured from glass, but also includes jet, amber, carnelian, and rock crystal specimens. These objects were manufactured around the globe, likely including Venice, Amsterdam, France, Spain, Bohemia, China, India, and the Baltic region, and numerous publications have leveraged the size and diversity of this assemblage to explore questions of bead origins, chronology, manufacture, exchange, and social networks (Blair et al. 2009; Blair 2015a, b, 2016, 2017a, b).

Despite the extreme diversity found within this assemblage, including the presence of numerous rare varieties of molded, segmented, and blown beads, one of the most interesting and abundant types in the assemblage is the drawn, simple, turquoise blue Kidd and Kidd (2012[1970]) IIa40 bead. Comprising about 7.6% of the assemblage, the 5,265 whole and fragmentary specimens of this type were distributed across all contexts at the site.

4. Analysis of SCDG IIa40 beads – materials and methods

Twenty type IIa40 beads from burial contexts at Mission Santa Catalina de Guale were analyzed in 2014 using LA-ICP-MS at the Elemental Analysis Facility of the Field Museum of Natural History using the standard analytical protocols of that laboratory (see Annex A). This sample was chosen to include ten beads from early 17th century burials and ten beads from late 17th century burials (Table 4.1). The dating of these assemblages was based on the presence of temporally

significant opacifiers found in white beads in these same assemblages (Blair 2017b), the presence of temporally diagnostic bead types (see Smith 1983, 1987), and stratigraphic relationships between burials.

Context	IIa40 beads sampled	Date	Temporal Evidence
Burial A	5	Early 17th century	Stratigraphy
Individual 90	2	Late 17th century	50 white beads, analyzed with XRF, opacified with Sb
Individual 102	1	Late 17th century	51 white beads, analyzed with XRF, opacified with Sb
Individual. 134	1	Late 17th century	1 white bead, analyzed with XRF, opacified with Sb
Individual 139/140	1	Late 17th century	17 white beads, analyzed with XRF, opacified with Sb
Individual 238	5	Late 17th century	15 white beads, analyzed with XRF, opacified with Sb
Individual 318	5	Early 17th century	30 white beads, analyzed with XRF, opacified with Pb-Sn. Numerous pre-ca. 1630 diagnostic artifacts found with burial (e.g., a Nueva Cadiz bead, an eye bead, complex striped beads, a Clarksdale and flushloop bell)

Table 4.1: SCDG IIa40 bead sample analyzed by LA-ICP-MS

5. Results and discussion

5.1. Chronology

Supplemental Table S4.1 reports the full LA-ICP-MS results for the IIa40 beads analyzed from Mission Santa Catalina de Guale. As expected, all beads were manufactured from a soda-lime-silica glass, typical of most post-medieval European drawn glass beads (drawn Bohemian beads, dating to the 19th century, are a noted exception), and copper served as the primary colorant. All the beads also have small quantities of tin (115 – 4076 ppm) and lead (112 – 3536 ppm), while lacking any significant quantity of antimony (1 – 36 ppm). Initially we had hoped that the presence or absence of these ingredients might segregate the SCDG IIa40 bead population into two temporal groups, as is possible with opaque white (Blair 2017b) and black (Templin and Blair 2016; Templin 2017) beads. It seems, however, that for turquoise blue beads this elemental shift occurs at a later date (Dalton-Carriger and Blair 2015; Blair et al. 2017; Blair et al. 2021), post ca. 1680.

Additionally, while the dating of the SCDG burial contexts is relatively secure, few of the temporal markers identified by Hancock and colleagues seem to be particularly useful in distinguishing the early 17th century specimens from the late. For example, Figure 4.2 shows a sodium/calcium biplot of the SCDG samples overlaid on data reported by Hancock and colleagues (Hancock et al. 1994; Kenyon et al. 1995) for beads dating 1580-1760. While none of the SCDG beads match the 16th century recipe, further divisions within the 17th century are not apparent.

Potassium content, however, does appear to possibly serve as a temporal marker between the early and late 17th century specimens. Figure 4.3, a biplot of soda and potash, indicates two distinct groups (and a single bead, 28.1/4345.0001, with very low soda content caused by glass corrosion and leaching), with most of the late 17th century specimens distinguished by having greater than 4% potash, and those dating to the early 17th century having less than 2.6% K_2O. While this is a limited sample size, and might reflect variation between the products of specific glass houses or batches of glass, Kenyon et al. (1995) found a similar increase in potassium content through time, noting that potassium content increases to greater than 4% during the 1760-1840 period in Ontario.

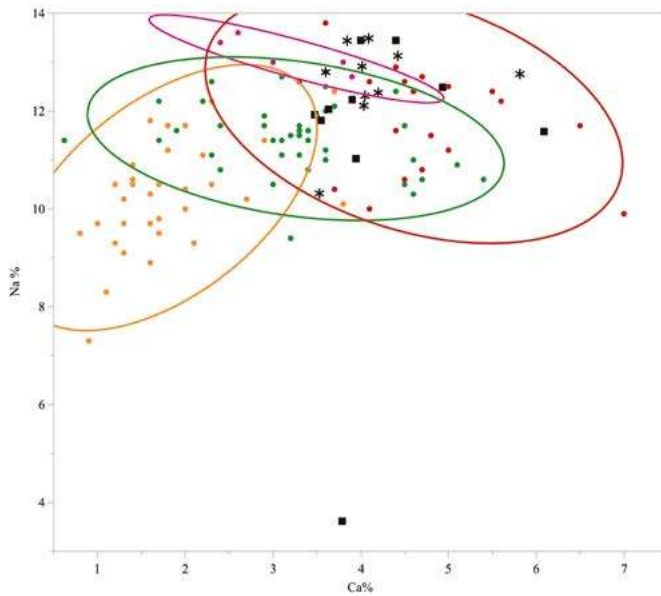

Fig. 4.2: Bivariate plot of Na and Ca elemental weight percent. Data for IIa40 compositions compiled from Hancock et al. (1994) and Kenyon et al. (1995), with 95% confidence intervals, are shown for 1580-1600 (orange), 1600-1620 (pink), 1620-1650 (green), and 1670-1760 (red). Early 17th century SCDG IIa40 beads are marked by asterisks, and late 17th century SCDG IIa40 beads are marked with squares.

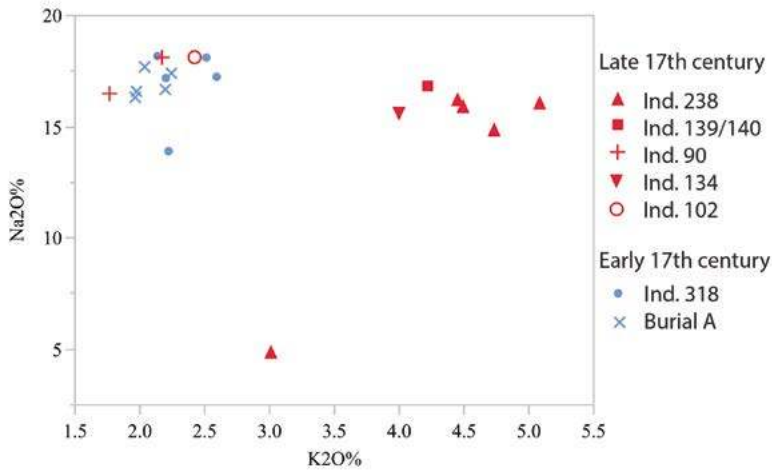

Fig. 4.3: Na_2O and K_2O biplot of Mission Santa Catalina IIa40 beads.

Similar patterning is also evident in several of the trace elements—notably B and Rb (Figure 4.4)—with boron elevated among the late 17th century specimens and rubidium elevated among the early specimens. This patterning is unsurprising because these elements are often associated with potassium content (Henderson 2013), and Moretti and Hreglich (2013) also note that the use of boron containing compounds is documented in late 17th century Venetian recipe books.

The temporal patterning of the IIa40 beads from Santa Catalina, however, is also confounded by several beads recovered with late 17th century burials (i.e., Individuals 90 and 102) plotting with the early 17th century samples. A closer look at the archaeological context for both of these individuals suggests that this is likely due to either heirlooming of some beads or the disturbance of earlier bead assemblages by later burials. For example, Individual 90 was found buried with more than 2,000 seed beads, that during excavation appeared to have been arranged as necklace strands lying across this individual's chest and neck (Blair 2009). Previous XRF analysis of 50 white beads revealed that they had all been opacified with calcium-antimonate, a late 17th century glass opacifier (Blair 2017b; Sempowski et al. 2000; Moretti and Hreglich 2005). Only 20 of the more than 2,000 beads found with this individual were larger beads, and the two analyzed IIa40 beads were the only two of this variety. The relative uniqueness of these beads with this burial suggest a different mode of acquisition. Heirlooming is certainly a possibility. An alternative possibility is that these anomalous

larger beads may have been originally associated with an earlier burial and were disturbed and then redeposited during the later interment of Individual 90. Such disturbance was quite common in the Mission Santa Catalina cemetery (Blair et al. 2009, Thomas 1988). This latter explanation most likely accounts for the earlier bead associated with Individual 102, where several beads were likely redeposited from an adjacent, earlier, burial (Blair 2009).

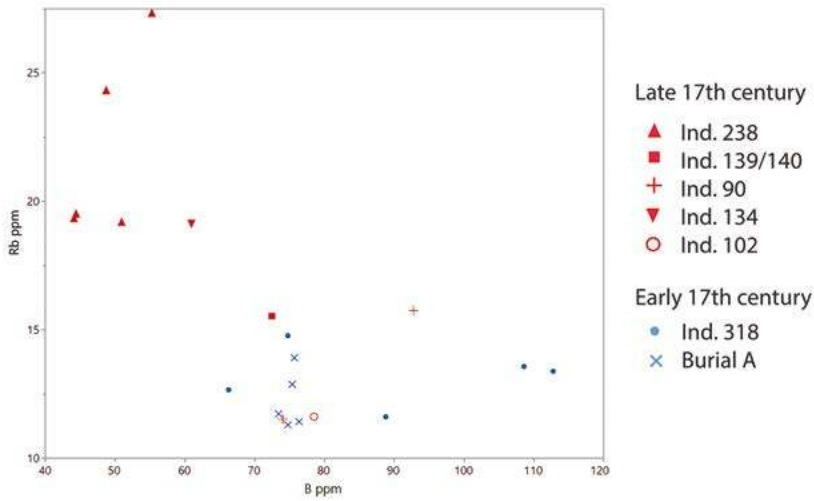

Fig. 4.4: Rb and B biplot of Mission Santa Catalina IIa40 beads.

5.2. Manufacturing source

Besides chronology, the other main goal in analyzing the IIa40 beads from Mission Santa Catalina was to evaluate Peter Francis's (2009a) hypothesis of French origin for the SCDG IIa40 beads. While little comparative data exists for French glass used in bead manufacture, Dussubieux (2009) analyzed 28 samples of glass ornaments from Rouen, France and compared those items to the composition of material recovered from Dutch factories (Karklins et al. 2001, 2002). In her analysis, Dussubieux (2009) identified three compositional groups within the Dutch and French material, defined by relative percentages of potash, soda, and lime. Figure 4.5 is a ternary diagram illustrating the three groups, with the SCDG IIa40 beads, Dussubieux's samples of turquoise blue glass from Rouen, and Karklins et al.'s (2001; 2002) samples of Dutch turquoise blue glass plotted. Three interesting observations can be made from this diagram. First, all early

17th century IIa40 beads from SCDG, as well as several of the late 17th century specimens (i.e., the intrusive or heirloom IIa40 beads interred with Individuals 90 and 102), fall within Dussubieux's (2009) group 1. This group, characterized by low lime, low potash, and high soda, primarily includes specimens of turquoise blue glass manufactured in Amsterdam. Second, none of the SCDG specimens fall within Dussubieux's group 3, which included most of the turquoise blue glass manufactured in Rouen. Finally, most of the late 17th century SCDG IIa40 beads do not fall within any of Dussubieux's (2009) compositional groups, suggesting a different place of manufacture.

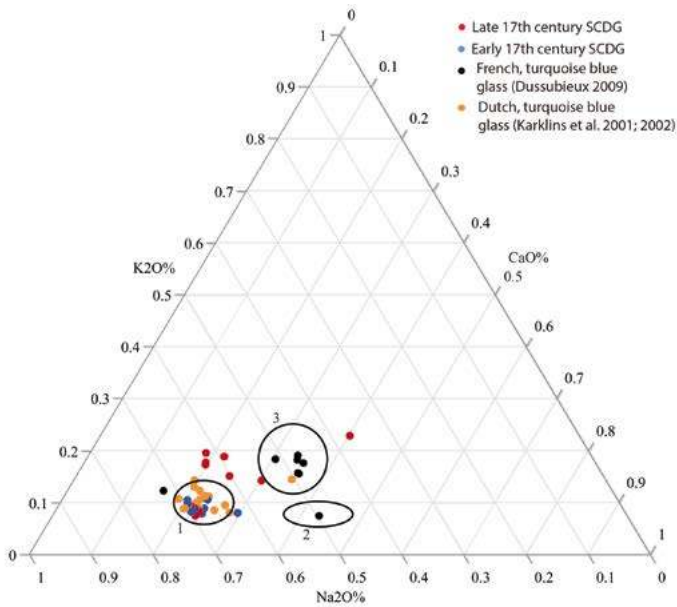

Fig. 4.5: Ternary diagram of soda, potash, and lime showing elemental groupings identified by Dussubieux (2009). Analyses of the SCDG material and French (Dussubieux 2009) and Dutch (Karklins et al. 2001; 2002) turquoise blue glass are plotted.

6. Conclusion and discussion

Analysis of a limited sample of type IIa40 beads from well-dated contexts at 17th century Mission Santa Catalina de Guale has yielded several important observations about the temporal dimensions and manufacturing sources of type IIa40 beads circulating in colonial North America during the 17th century. First, the transition from lead-tin to calcium antimonate opacified beads that occurred during the mid-17th century for both opaque white (Blair 2017b; Sempowski et al.

2000) and manganese-colored black (Templin 2017) beads does not seem to have simultaneously occurred for opaque turquoise blue beads. For this type, a post ca. 1680 date is more likely to mark this transition, which is unfortunately too late to be useful for dating purposes at Mission Santa Catalina.

Second, the elemental markers defined by Hancock and colleagues (Hancock et al. 1994; Kenyon et al. 1995; Hancock 2005, 2013) as being useful for segregating turquoise blue beads in Northeastern North America by temporal periods do not appear to be particularly useful in the Southeastern United States. This could be due to beads being supplied from different manufacturing centers, variation in intra-regional glass house production practices, the limited suite of elements analyzed by INAA, or the use of "the site," rather than short duration contexts (e.g., burials), as the analytical unit underpinning the sequence (see discussion in Marcoux 2012). Despite the inapplicability of the Northeastern sequence to Mission Santa Catalina, limited evidence suggests that potassium, boron, and rubidium content might be good temporal indicators during the 17th century. Alternatively, these might be markers of specific glass batches or glass house production practices.

Finally, the limited comparative data for 17th century French manufactured beads and ornaments (Dussubieux 2009) does not support Francis's (2009a) hypothesis for a French origin for the SCDG IIa40 beads. Instead, Francis may have been too hasty in his rejection of a Dutch source for this type. While he suggested that IIa40 varieties have not been identified in Dutch collections, Karklins (1974) did in fact identify a number of varieties that are described as having "abundant linear bubbles in the glass". This includes, for example, a IIa31 specimen, distinguished from IIa40 beads discussed here only by being transparent and a slightly different shade of blue. More recently, Bradley (2014) has identified a number of IIa40 specimens excavated from a 17th century Dutch factory, and he makes a strong case that many beads of this type found in Northeastern North America may have been manufactured in Amsterdam, particularly at the Carel-Soop glasshouse. Comparison with the Dutch compositional data compiled by Dussubieux (2009; see also Karklins et al. 2001, 2002) indicates that the early 17th century SCDG IIa40 beads have compositions that are consistent with Dutch origin. The late 17th century SCDG IIa40 beads match neither the French nor the Dutch comparative material, so perhaps Venice is the likely source for these items. These attributions, of course, are only tentative, because as Dussubieux (2009) points out, we still have very limited comparative data from France and virtually none from Venice.

Even with a small sample size, compositional analysis of these SCDG IIa40 beads is yielding important insights about the colonial bead trade in North America. Future work, with increased sample sizes, additional interregional

comparisons, and the acquisition of new comparative material from additional European manufacturing centers only promises to increase the potential benefits of this approach.

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Chapter 5

Glass trade bead analysis at Upper Hampton Farm (40RH41): A case study for 17th and 18th century Non-Cherokee habitation in East Tennessee Valley

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1. Introduction

Native American sites in the East Tennessee Valley of eastern North America tend to be inhabited for extended periods and span several archaeological time periods (Table 5.1). Where one ends and the other begins can often be difficult to discern and finding dateable materials is not always possible. Often sites are inhabited and abandoned over the course of hundreds of years and the addition of European trade goods often muddles the dating of archaeological contexts. Consequently, many time periods and sites are dated based on the presence or absence of index artifacts. Upper Hampton Farm (40RH41) is a prime example of this as the site has evidence for habitation stretching back to the Woodland period but also contains European trade goods. While little research was conducted on the site throughout the 20th century, New Deal Works Progress Administration (WPA) excavators identified the site as a Late Mississippian village with the assumption that the European trade goods originated from Spanish *entradas* (Kneberg 1952; Lewis and Kneberg 1993 [1946], 1958; Walker 1940a, 1940b, 1941). Trade goods coming from later English, French, or Spanish contexts were not considered, as many have argued that the East Tennessee Valley was abandoned during the 17th century, as the chiefdom level polities indicative of the Late Mississippian period collapsed at the end of the 16th century in the wake of the De Soto *entrada* (see Dickens 1979, 1986; Dobyns 1983; Kelton 2007; Kneberg 1952; Lewis and Kneberg 1993 [1946], 1958; Schroedl 1986; Smith 1987, 2002, 2004/2005). This hypothesized abandonment then allowed migrating Iroquoian speaking groups from the Great Lakes region to enter the East Tennessee Valley and take up residence, forming

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Period	Sub-period	East Tennessee Cultural Phase	Date Range
Archaic			7900 – 900 BCE
Woodland			900 BCE – CE 900
Mississippian	Early Mississippian	Martin Farm	CE 900 – 1000
		Hiwassee Island	CE 1000 – 1300
	Late Mississippian	Dallas	CE 1300 – 1600
		Mouse Creek	Mid CE 1400 – 1600
Early Contact		Dallas/Mouse Creek	1492 – 1568*
"The Forgotten Centuries"		Dallas/Mouse Creek; Proto-Cherokee?	1570 – 1630**
		Dallas/Mouse Creek; Proto-Cherokee?	1630 – 1680**
		Dallas/Mouse Creek; Proto-Cherokee?	Post ca. 1680**
Historic Period		Historic Cherokee	Post ca. 1700

* Date is based on the discovery of the Americas by Columbus and Juan Pardo's final entrada into the Southeast
** after Dalton-Carriger (2016)

Table 5.1: Cultural chronology of East Tennessee, adapted from Kimball (1985) and Sullivan and Harle (2010).

what became the Historic Cherokee of the late 17th and 18th centuries (see Dalton-Carriger 2016; Dickens 1979; Rodning 2002).

The time between the Early Contact and Historic periods in the region, often termed "the forgotten centuries" (Hudson and Tesser 1994), is a period in which groups of Native Americans were moving around the Southeast in response to European colonization. The availability of European trade goods increased but direct contact and written accounts of Native cultures are still sparse, especially in the interior. Indeed, most European artifacts recovered from sites in the region have traditionally been associated with either 16th century *entradas* or 18th century Cherokee communities. Not content with this situation, several years ago we initiated a project to search for 17th century contexts in the region (Dalton-Carriger 2011, 2016; Dalton-Carriger and Blair 2013, 2014, 2015). We hypothesized that many simple, largely non-diagnostic, glass beads from this period were likely misidentified as either early Spanish or later Historic beads, hidden among 16th and 18th century colonial assemblages. Knowing that simple, drawn, turquoise blue beads (Kidd and Kidd variety IIa40) were ubiquitous across this entire time period, and were chronologically diagnostic based on Venetian recipe books

and previous archaeometric studies (Hancock et al. 1994; Hancock et al. 1996; Hancock 2005; Hancock 2013; Kenyon et al. 1995; Walder 2018, see Annex B), we used both pXRF and LA-ICP-MS to analyze a sample of IIa40 beads from sites that were both well-dated and temporally ambiguous across the region. While we explore the full contours of this project elsewhere (Dalton-Carriger 2011, 2016; Dalton-Carriger and Blair 2013, 2014, 2015), here we focus specifically on our analysis of a small sample (n=6) of IIa40 glass beads from Upper Hampton Farm. Our analysis suggests a significant 17th century occupation of the site, a finding that does not conform to the standard ideas of abandonment and Cherokee re-occupation and instead hints at a continued 17th century occupation of the lower East Tennessee Valley.

2. Upper Hampton Farm (40RH41)

Upper Hampton Farm (40RH41) is located in Rhea County, TN on the west bank of the Tennessee River (Figure 5.1). The site comprises a multi component Native American occupation dating from the Early Woodland to the 17th century. During the 1930s and 1940s Franklin D. Roosevelt's New Deal program included the Tennessee Valley Authority (TVA) which sought to establish a series of dams in the East Tennessee Valley to control flooding and cultivate hydroelectric power. Consequently, thousands of square miles of farmland and many archaeological sites were destroyed via inundation. In order to preserve as much archaeological knowledge as possible, excavations became part of the Works Progress Administration (WPA). The WPA employed out of work farmers for public works projects led by archaeologists to excavate as many sites as possible before inundation (Dye 2016).

The main excavation, led by Thomas Lewis, Wendell Walker, Charles Nash, and Alden Hayes was conducted by the WPA in 1941 before the completion of the Watts Bar Dam in 1942. After excavation and a cursory examination, the artifacts were subsequently shelved due to World War II and are now part of the McClung Museum of Natural History and Culture at the University of Tennessee, Knoxville. Dalton-Carriger reexamined the artifacts as part of her graduate research from 2007 to 2016. The site is composed of Woodland period conical Hamilton burial mounds with associated village components and a Mississippian village. WPA excavators employed unit designations and Upper Hampton Farm is composed of nine units ranging from 85Rh41 to 93Rh41. 85Rh41 is further divided into 85VT1Rh41 and 85VT2Rh41 which indicate village test units within the larger unit. When the Smithsonian numbering system was put in place the entire site was re-designated as 40RH41, however artifacts are still labeled by their unit number.

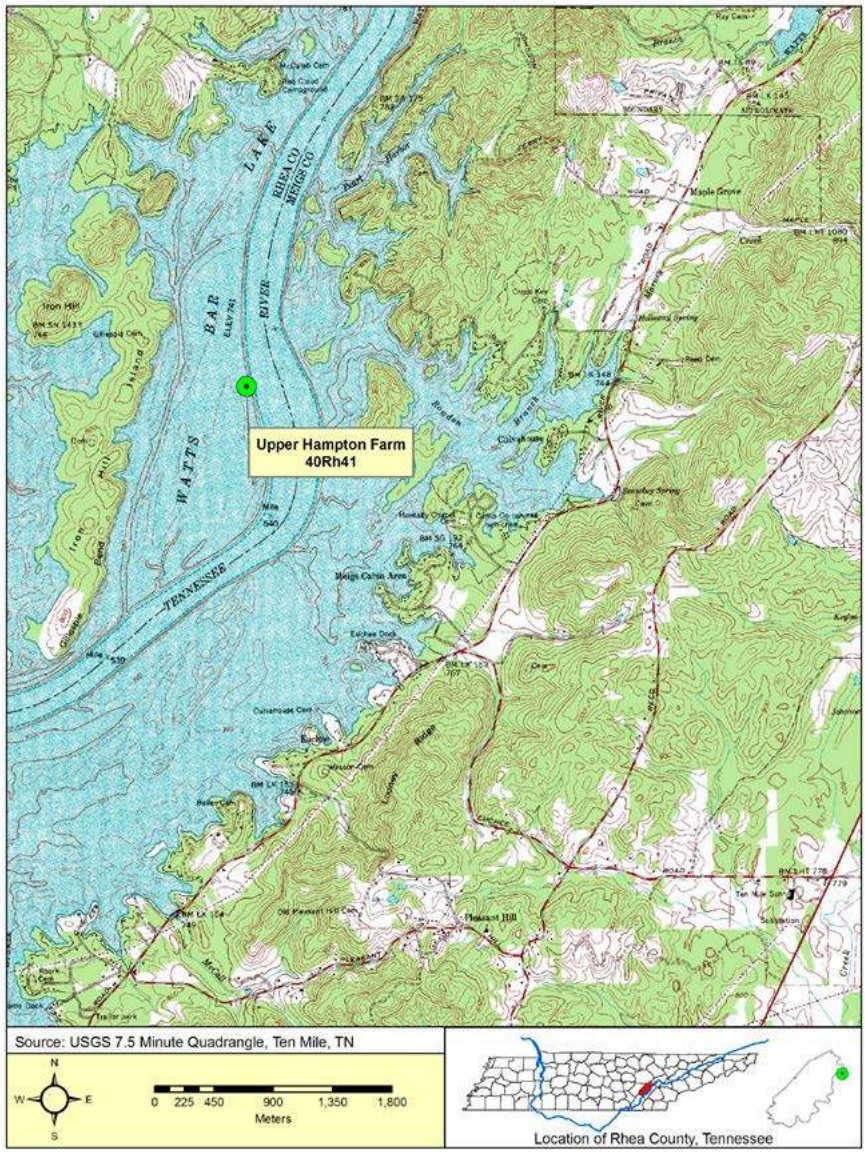

Fig. 5.1: Location of Upper Hampton Farm, Rhea County, Tennessee.

New analysis of the Mississippian village components (Dalton-Carriger 2011, 2016) revealed an interesting mixture of Late Mississippian Dallas and Mouse Creek phase cultural characteristics. While it is typical in the lower East Tennessee River Valley to see a sequence of Hiwassee Island and Dallas phase or Hiwassee

Island and Mouse Creek phase (see Table 5.1), the combination of Dallas and Mouse Creek phase cultural components together was unusual. Dalton-Carriger's (2011, 2016) analysis suggests that there was a well-established Late Woodland village with associated burial mounds that transitioned into the Early Mississippian period. During the Early Dallas (Middle Mississippian) phase, based on the pipe and ceramic style analyses, there appears to be a lull in the occupation of the site (Blanton 2012; Dalton-Carriger 2011). When the population increased during the Late Mississippian period, the resulting archaeological deposits show a "mixed" Dallas and Mouse Creek phase settlement. This may indicate an influx of people that coincided with the formation of the Vacant Quarter, when the Ohio River Valley was largely abandoned between CE 1450 and 1550 (Cobb and Butler 2002). The ceramic assemblage at Upper Hampton Farm includes a high frequency of plain and Dallas incised motifs, while the burials are interred in both extended (Mouse Creek) and flexed (Dallas) positions in the same areas throughout the village without segregation (Lewis and Kneberg 1993 [1946]; Polhemus 1987; Sullivan 1986). European trade goods were discovered in the Late Mississippian village and include glass beads and metal artifacts (Table 5.2). The European trade items were not segregated to a specific part of the village or strata separate from the other Late Mississippian components. Further analysis of the site and ceramics revealed that Upper Hampton Farm is void of all Historic Overhill Cherokee cultural characteristics, indicating that the European trade goods were not associated with the 18th century Historic Cherokee occupation of the region (Dalton-Carriger 2011, 2016).

Excavation Unit	Context	Association	Artifact Type
85RH41	Burial 4 – Infant		Brass Disc "Gorget"
85RH41	Burial 18 – Infant	House 2 or 3	Necklace of Shell, Glass, and Copper beads
85RH41	House 12 Floor		1 Turquoise Blue (IIa40) Bead; Brass Ring
85RH41		Ditch	Brass Tube Awl
85VT1RH41	Burial 3 – Infant		~48 Turquoise Blue (IIa40) Glass Beads
85VT1RH41	Burial 22 – Infant		1 Turquoise Blue Bead
85VT1RH41	House 1	Post Mold	1 Copper Bead; 1 Turquoise Blue (IIa40) Glass Bead, Brass Pendant
85VT1RH41	Square 39R1	Unnumbered House	1 Turquoise Blue (IIa40) Glass Bead
85VT1RH41		N/A	Triangular Copper Pendant

Table 5.2: European trade items excavated from Upper Hampton Farm.

3. "The forgotten centuries"

While the presence of Late Mississippian Dallas and Mouse Creek phase artifacts is clear, the presence of European trade goods in the village complicates the occupational history of Upper Hampton Farm. Hernando de Soto (1539-1544), Tristan de Luna (1559-1561), and Juan Pardo (1566-1567, 1567-1568) all led *entradas* into the interior Southeast, each exploring various parts of the interior, distributing trade goods, and producing written accounts of the Native peoples they encountered (Beck et al. 2006; Hoffman 2002; Weber 2009). Following these *entradas,* many researchers have proposed a depopulation event in which the East Tennessee Valley was largely abandoned during the 17th century, a time when multiple European powers attempted to conquer eastern North America and many Native American groups were subject to extinction due to the spread of disease from colonial sources. As a result, many groups abandoned their ancestral lands and became displaced populations, migrating across the Eastern Woodlands. Because of this assumption, research into the archaeology of the "forgotten centuries" has been somewhat sparse (see Ethridge and Hudson 2002; Polhemus 1982; Rodning 2002; Smith 1987, 1994, 2002, 2004/2005, 2006 [1989]; Wesson and Rees 2002), and consequently, any trade goods found in Late Mississippian contexts are usually attributed to the Early Contact period during the initial Spanish contact. This period was followed by an influx into the region of the Iroquoian speaking group that would become the Historic Cherokee, illustrating how turbulent the cultural landscape was during this time.

3.1. Depopulation

While some researchers have favored theories of depopulation due mainly to disease (see Dickens 1979, 1986; Dobyns 1983; Kelton 2007; Kneberg 1952; Lewis and Kneberg 1993 [1946], 1958; Smith 1987, 2002, 2004/2005, 2014), others disagree and instead argue that the introduction of major diseases into the interior Southeast did not occur until the late 17th century as research has shown that many Native groups remained stable throughout North America (for examples see Barrett 2002; Cameron et al. 2015; Crosby 1972; Hutchinson 2007; Jones 2015; Livi-Bacci 2003; Ramenofsky 1987; Warrick 2003). If these assumptions are correct, then Native groups may have continued to thrive well into the 17th century in the East Tennessee Valley and other parts of the Southeast (Anderson and Sassaman 2012; Kimball 1985; Sullivan and Harle 2010). Rodning (2002, 2004) and Marcoux (2008, 2010) have presented research opting for a synthesis of theories on Cherokee origins, hypothesizing that the culture was likely a regional phenomenon resulting from long-term historical processes stemming from the Late

Mississippian period, regional population movement, and short-term processes from European contact.

3.2. Rethinking chronology

Despite growing evidence that many Native groups continued to thrive well past initial European contact, the archaeological field is rife with biases towards using index artifacts to establish cultural time periods and habitation ranges producing an arbitrary Prehistoric/Historic divide (Panich and Schneider 2019). Indeed, recent research has suggested that long-held assumptions about population decline, abandonment, and collapse often rest on false assumptions and weak chronologies (e.g., Holland-Lulewicz et al. 2020; Kooiman and Walder 2019; Panich and Schneider 2019). These assumptions often assign Native sites to either Prehistoric or Historic contexts with the intervening time period largely ignored and misinterpreted based on the presence or absence of European trade goods (Panich and Schneider 2019). During the "forgotten centuries" it is unclear to what extent each group had contact with Europeans and our understanding of the distribution of artifacts as the "presence, absence, or abundance of ceramics, lithics, or European trade goods is affected by not only time but a myriad of factors. These include manufacture, use-life, exchange relations, adoption of technologies, and durability" (Holland-Lulewicz et al. 2020:2). New diagnostic dating methods as well as expanding our perception of the kinds of material evidence we use to determine Native occupation are needed to tease out the subtle differences between trade items and cultural periods (Kooiman and Walder 2019; Panich and Schneider 2019).

3.3. Chronological implications of glass bead chemistry

Over the last several decades, compositional analysis of European glass beads has emerged as an important technique for the relative dating of colonial contexts on North American sites (see Blair 2015, 2017; Burgess and Dussubieux 2007; Dalton-Carriger 2011, 2016; Dalton-Carriger and Blair 2013, 2014, 2015; Hancock 2005, 2013; Hancock et al. 1996; Hancock et al. 1994; Hancock et al. 2000; Hancock et al. 1997; Hancock et al. 1999; Kenyon et al. 1995; Moreau et al. 2006; Moreau et al. 1997; Walder 2015, 2018). The most notable example of this is the work conducted by Ron Hancock and his colleagues, examining the chemistry of drawn beads from a number of sites in Northeastern North America (summarized in Hancock et al. 2013). In their analysis of turquoise and copper-colored beads, they identified a number of different elemental signatures that were useful for distinguishing beads from different time periods. They noted that 16th century specimens contained less calcium, chlorine, and sodium than 17th century

specimens, while also being higher in copper (Hancock et al. 1994). In a later paper (Kenyon et al. 1995) they expanded this sequence, identifying temporally sensitive recipes for the late 17th to early 20th centuries.

In addition to their work with blue beads, Hancock and colleagues also conducted a series of analyses of beads of different colors. Most notably, their work on white glass beads identified a chronological sequence of glass opacifiers, where early beads (16th and early 17th centuries) were opacified with lead-tin, calcium antimonate was used starting during the late 17th century, and arsenic based opacifiers were used during the 18th and 19th centuries (Hancock et al. 1997; Hancock et al. 1999; Moreau et al. 2002; Moreau et al. 2006; Sempowski et al. 2000). This sequence is particularly important because it is both historically and empirically documented (Blair 2017; Moretti and Hreglich 1984, 2005, 2013; Rooksby 1962; Toninato and Moretti 1992; Turner and Rooksby 1959). In our own work in Southeastern North America, we see the same sequence as a key temporal indicator for simple, drawn, opaque beads of all colors, including turquoise blue (Blair 2017; Blair et al. 2017; Dalton-Carriger and Blair 2015; Templin 2017).

Working in the Upper Great Lakes region, Walder (2015, 2018) has also identified a number of temporally significant compositional groups for simple drawn, turquoise blue beads. Most notably, these include several 17th century groups characterized by a high zinc content, and a transition from high Mg and low P, to the reverse, around ca. CE 1700. Walder (2018) also documents opacifier changes consistent with those described above.

4. Analysis and results

Despite using different analytical methods, bead colors, and having samples from different regions, together these studies make clear that the compositional analysis of glass beads has enormous potential to identify temporal markers and relatively date Indigenous and colonial occupations in the Americas. Of the approximately 53 beads recovered during excavation at Upper Hampton Farm, six type IIa40 beads were selected for LA-ICP-MS analysis from two contexts: 85RH41 – Burial 18 (n = 2) and 85VT1RH41 – Burial 3 (n = 4) (Figure 5.2). Analysis was conducted at the Elemental Analysis Facility of the Field Museum in 2014, using the standard methods of that laboratory (see Annex A). Table 5.3 reports selected compositional data for these beads; complete results are included in the supplemental materials to this volume (Table S5.1).

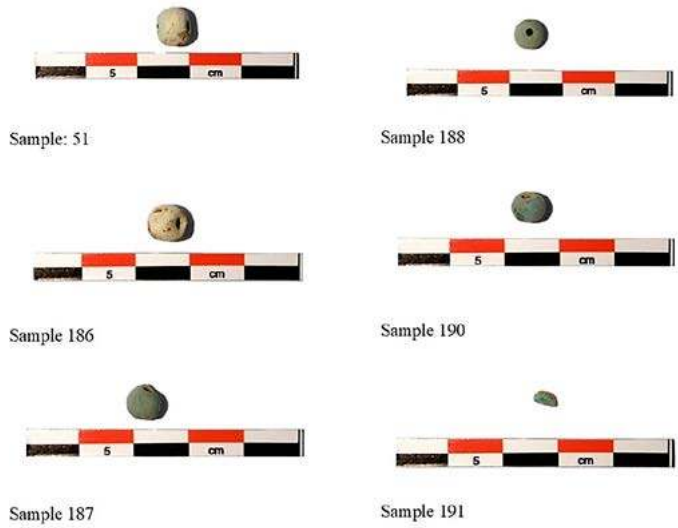

Fig. 5.2: Glass trade bead samples from Upper Hampton Farm.

Site/Unit	Context	Type	SiO_2 wt%	Na_2O wt%	MgO wt%	K_2O wt%	CaO wt%	CuO wt%	SnO_2 wt%	PbO wt%	Sb (ppm)
85RH41	Burial 18	IIa40	67.67	16.46	2	2.42	6.73	1.24	0.32	0.4	26
85RH41	Burial 18	IIa40	69.19	16.85	2.05	2.1	6.09	1.12	0.04	0.1	20
85VT1RH41	Burial 3	IIa40	67.97	15	2.21	2.04	7.11	1.42	0.04	0.05	516
85VT1RH41	Burial 3	IIa40	67.27	17.39	1.78	2.39	5.68	1.23	0.47	0.73	23
85VT1RH41	Burial 3	IIa40	64.29	18.41	2.41	2.46	7.82	1.27	0.01	0.02	525
85VT1RH41	Burial 3	IIa40	80.28	9.6	0.82	0.98	4.04	1.88	0.01	0.04	48

Table 5.3: Selected compositional data from Upper Hampton Farm.

Two things are immediately apparent from these data. First, all the beads, as expected, were manufactured from soda-lime-silica glass, typical of beads found on early colonial sites in the Americas that were manufactured in Venice, or by one of the European industries heavily influenced by expatriate Venetian glassmakers. With the exception of no. 191, which is heavily leached and depleted in sodium, calcium, magnesium, and potassium, all the Upper Hampton Farm beads have Na_2O in excess of 15% and CaO in excess of 5.7%. This is inconsistent with

the 16th century recipes reported by Hancock et al. (1994), suggesting that the Upper Hampton Farm beads cannot be attributed to the Early Contact period in the region. Second, while two of the beads (no. 51 and 188) have elevated tin and lead contents consistent with late 16th or 17th century manufacture, another two (no. 187 and 190) have little lead or tin but contain antimony in excess of 500 ppm. We suggest, based on the complete absence of antimony in more than 500 IIa40 beads analyzed using XRF from Mission *Santa Catalina de Guale* (abandoned in 1680) (Blair and Dussubieux, this volume) that the presence of antimony in these beads suggests a post-1680 date of manufacture (see also Sempowski et al. 2000; Walder 2018).

Comparison of the Upper Hampton Farm bead compositions with the data reported by Hancock and colleagues is similarly instructive. Figure 5.3 shows a biplot of Na and Ca content for beads reported by Hancock et al. (1994) and Kenyon et al. (1995) dating from ca. 1580 – 1760. 95% confidence intervals are drawn around beads dating 1580-1600, 1600-1620, 1620-1650, and 1670-1760. Figure 5.4 shows where the Upper Hampton Farm beads plot against these data; for the purposes of this figure, the Upper Hampton Farm data has been converted from oxides to elemental weight percent.

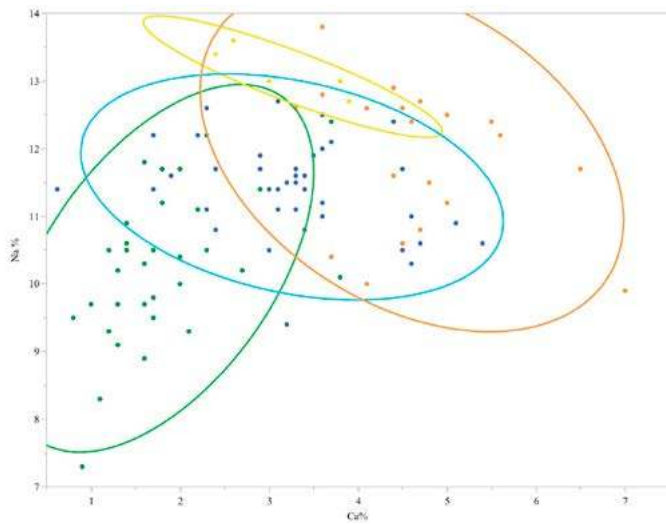

Fig. 5.3: Biplot Ca vs Na for data reported by Hancock et al. (1994) and Kenyon et al. (1995). Ellipses show 95% confidence intervals for beads dating 1580-1600 (green), 1600-1620 (yellow), 1620-1650 (blue), and 1670-1760 (orange).

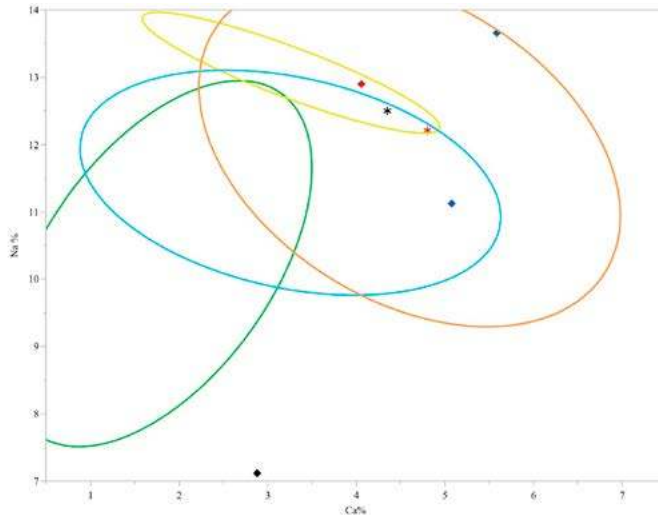

Fig. 5.4: Biplot of Ca vs Na for Upper Hampton IIa40 beads plotted against 95% confidence intervals for Hancock et al. (1994) and Kenyon et al. (1995) temporal groups: 1580-1600 (green), 1600-1620 (yellow), 1620-1650 (blue), and 1670-1760 (orange). Red points are lead-tin opacified beads, while blue points are antimony opacified beads. Asterisks are Burial 18, and diamonds are Burial 3.

While there is considerable overlap in these groupings, none of the Upper Hampton Farm beads fall within the 16th century ellipse. Together, the two lead-tin opacified beads (colored red in Figure 5.4) fall within the 1600-1620 ellipse, though one (no. 51) also falls within the 1620-1650 ellipse. The two high-antimony beads (colored blue in Figure 5.5) both fall within the 1670-1760 ellipse, while one (no. 187) also falls within the 1620-1650 95% confidence interval. A single bead (no. 191) does not fall within any of the groupings, instead its composition seems most similar to the disintegrated and leached beads reported by Hancock et al. (1994), having very low calcium and sodium.

When comparing these data to Walder's (2018) temporally diagnostic groups, several things are evident. First, none of the Upper Hampton Farm beads contain elevated zinc, and all specimens (except the heavily leached no. 191) fall within her Mg-low-P group, a pre-1700 recipe (Figure 5.5). Additionally, the CaO percentages (5.7% - 7.8%, excluding no. 191) for the Upper Hampton Farm beads are consistent with her pre-1670 Mg-low-P-low-Ca group.

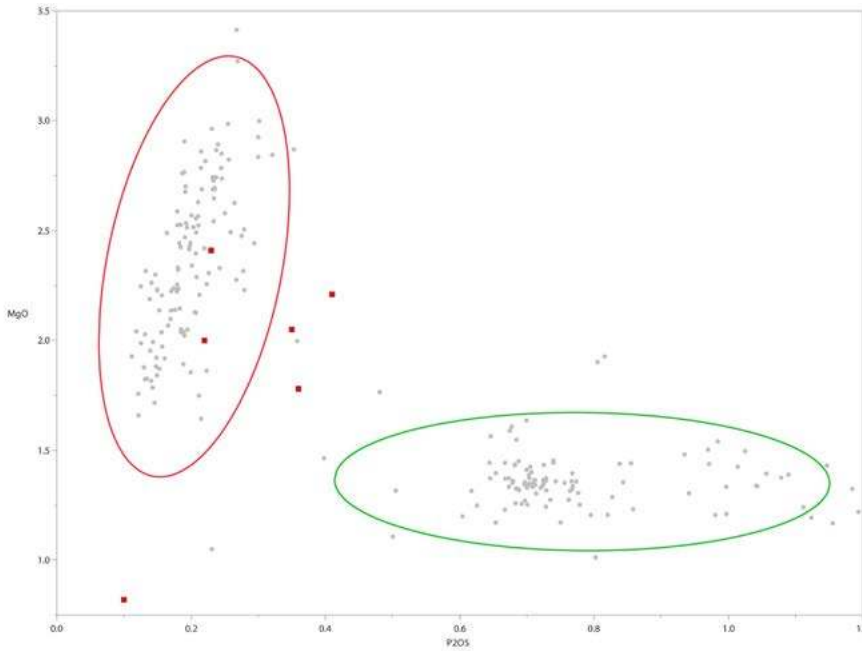

Fig. 5.5: Biplot of MgO vs P_2O_5 for Upper Hampton IIa40 beads (red squares) plotted against 95% confidence intervals for Walder's (2015, 2018) turquoise-blue bead Mg – low-P (red ellipse) and P- low-Mg (green ellipse) compositional groups.

5. Conclusion

While only six glass beads from Upper Hampton Farm were analyzed using LA-ICP-MS, these data provide important information on the chronological positioning of Burials 3 and 18, as well as the late occupation of the site in general. The beads from Upper Hampton Farm can all be dated to the 17th century or later. Based on opacifiers, we would argue that the two lead-tin opacified beads likely date prior to ca. CE 1680, while the two beads containing greater than 500 ppm antimony post-date 1680. These dates are also consistent with estimates based on comparisons with data published by Hancock and colleagues (Hancock et al. 1994; Kenyon et al. 1995) and Walder (2015, 2018). If we combine date estimates provided by these recipes with the opacifer data, we can suggest that Upper Hampton Farm Burial 18 is a pre-1680 17th century burial, while Burial 3 likely dates ca. 1680-1700.

The date estimates presented above indicate that the population of Upper Hampton Farm survived well into the 17th century and the European trade good assemblage cannot be attributed to early *conquistador* interaction or 18th century Historic Overhill Cherokee occupation. This data supports the arguments of Holland-Lulewicz et al. (2020), Panich and Schneider (2019), and Kooiman and Walder (2019) that high resolution chronologies are critical in understanding post-Contact Indigenous lifeways in the Southeast. While not elaborated in this paper, we also see similar patterns on other archaeological sites in the region (see Dalton-Carriger 2016). This pattern is likewise supported by Holland-Lulewicz et al.'s (2020) research at the Dyer site (9GE5) in central Georgia which shows Mississippian traditions persisting for nearly 130 years post contact with De Soto. They stress the importance of reconsidering post-Contact sites in not an intact or collapsed state but rather as centralized and decentralized as groups are migrating on the landscape and continuing with long held cultural traditions (2019:17). This dating method has proved integral in understanding 17th century habitation patterns in the East Tennessee Valley and helping to dispel many of the assumptions about depopulation. This analysis suggests habitation was much more long term and this study serves as a starting point for creating a dialog about Indigenous habitation after initial European contact. The turbulent nature of this time period, both culturally and historically, left many gaps in the archaeological record that need to be addressed in the future. Increasing the radius of this study to include surrounding states in the Southeast would further our understanding of European trade during the "forgotten centuries." Additionally, this study only reveals a fraction of the potential of the work that could be completed with glass beads. With the advancements in elemental testing, it may now be possible to create a nationwide glass bead database that can be used to help accurately date sites with trade beads.

Acknowledgements

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Chapter 6

Compositional analysis of compound drawn white glass beads from colonial California: Implications for chronology and dispersal

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1. Introduction

As exemplified throughout this volume, beads have been a material hallmark of intercultural interaction the world over. In particular, scholars and the public alike have long viewed glass beads as an important component of colonial encounters between Europeans and Indigenous peoples. In California, beads—both glass and shell—have been at the center of recent approaches to understanding how Native Californian societies persisted despite the impacts of Spanish, Russian, Mexican, and American colonialism. In these contexts, beads play a number of interpretive roles, serving as evidence of postcontact occupation, indicators of the reach of various economic networks, and markers for the persistence of cultural traditions ranging from mortuary practices to personal adornment (Arkush 2011; Crull 1997; Dadiego et al. 2021; Gamble and Zepeda 2002; Panich 2014; Ross et al. 2016).

Nevertheless, the complexity of shell and glass bead assemblages from colonial-era sites in California poses various challenges. With regard to shell beads, archaeologists' interpretations are facilitated by complex but well-established typologies (Bennyhoff and Hughes 1987; Milliken and Schwitalla 2012) that can be used to determine temporal associations and geographic provenance of particular assemblages in colonial contexts. Detailed glass bead typologies exist (Karklins 2012; Kidd and Kidd 2012; Meighan, in press; Ross et al. 2016), but most types offer only limited insights into exchange or chronology beyond simply marking post-contact occupation of sites. As in other regions of North

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[2] Field Museum, Chicago, USA
[3] University of California Santa Cruz, USA
[4] Basin Research Associates, Inc., USA
[5] Amah Mutsun Tribal Band of Mission San Juan Bautista, USA

America, the interpretative capacity of glass beads in California is hampered by the predominance of a few common bead types, their seeming stability over long periods of time, and uncertainties about the dispersal of particular bead types by various colonial agents.

Chemical compositional analysis offers an opportunity to expand the interpretive potential of glass beads from California and other North American contexts. Recent archaeometric research into the bead manufacturing process offers greater understanding of the chronological placement of particular glass bead types and, in some cases, the dispersal of glass beads from specific workshops in Europe or elsewhere (Blair 2015, 2017; Blair and Dussubieux, this volume; Burgess and Dussubieux 2007; Dadiego et al. 2021; Dalton-Carriger and Blair, this volume; Dussubieux and Karklins 2016; Hancock et al. 1997, 1999; Hawkins and Walder, this volume; Sempowski et al. 2000; Shugar and O'Connor 2008; Walder 2018; see Annex B). This work has employed several analytical techniques including laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS), instrumental neutron activation analysis (INAA), and x-ray fluorescence (XRF). Here we note that LA-ICP-MS offers two benefits over other analytical techniques: the possibility of spot analysis targeting specific layers of glass in compound beads and the comparability of data collected from different LA-ICP-MS laboratories.

In particular, drawn white glass beads of both simple and compound construction have been at the center of many important compositional studies. Much of this research has focused on determining the temporal patterns associated with particular opacifiers used during the manufacturing process. This work suggests a discernable transition from tin, to antimony, to arsenic, and finally to fluorine (Blair 2017; Hancock et al. 1997; Sempowski et al. 2000). Nearly all of this research, however, has focused on sites in eastern North America (see Table 1 in Blair 2017), and some of the diagnostic shifts in opacifiers predate the onset of permanent European colonization of California in 1769. It is therefore unclear whether the presumed sequence of white glass bead opacifiers noted in previous studies is useful for the analysis of assemblages from California or other sites on the Pacific Coast of North America (but see Blair 2011; Burgess and Dussubieux 2007; Dadiego et al. 2021).

Given these questions, we conducted a study of drawn compound white glass beads from the central California region intended to test the chronological sequence of opacifying agents. In California, compound white glass beads typically have two layers, and do not conform precisely to the descriptions offered by the original Kidd and Kidd (2012 [1970]) classification. Analysts often refer to the colorless-on-white varieties as IVa11 (despite their lack of a third layer) while white-on-

white varieties are typically classified as IVa13; some California bead researchers have even added a variety IVa20 to more accurately describe the compound white beads from the region (Van Bueren 1983). Despite lingering questions about typology, these beads are ubiquitous at sites from colonial California and were likely in use for a least a century, spanning from the late 1760s onward (Meighan, in press; Ross et al. 2016). Indeed, combined archaeological and documentary research indicates that Native people in the central California region—including the Pomo, Coast Miwok, Ohlone, and others—exhibited a preference for white glass beads as opposed to other colors (Panich 2014:743-744; Ross 1997:192-196; Silliman 2004:143-151).

A sample of 70 beads from three colonial contexts was analyzed via LA-ICP-MS at the Field Museum's Elemental Analysis Facility in 2019. In chronological order, the sites are the *asistencia* of San Pedro y San Pablo (1786-1800), Mission Santa Clara (1777-1840s), and the Toms Point trading post (ca. 1840s-1870). Though they were included primarily as a convenience sample, these sites cover most of the period during which compound white glass beads were actively used by Native Californians and Euroamerican colonists. Our results suggest a relatively late (ca. 1840) introduction of lead glass white beads using arsenic opacifiers into the region, as well as some potentially meaningful differentiation among the more common antimony-opacified soda-lime glass beads found at all three sites.

2. Background: glass beads in colonial California

Compared to other regions of North America, European colonization came late to California. A handful of expeditions reached the region by sea during the late 16th and early 17th centuries, and although glass beads likely played a role in those encounters, few archaeological examples are known (O'Neil 1992; Lightfoot and Simmons 1998; Ringelstein 2016). Beginning in 1769, Spain sought to extend its territorial control to California, establishing a series of religious missions, military presidios, and secular pueblos along the coastal strip between San Diego and the greater San Francisco Bay area. The missions were specifically designed to enculturate local Indigenous groups, but all three types of settlements played a role in the dispersal of glass beads. Colonists distributed glass beads as part of gift-giving practices, as enticements into the missions, and as payment for labor. Franciscan missionaries and Spanish military commanders ordered beads directly from suppliers in Mexico (who in turn obtained their beads from Europe), with cargoes arriving once or twice a year via ships from the Pacific Coast port of San Blas (Duggan 2016; O'Neil 1992; Panich 2014; Perissinotto 1998). Native people, for their part, had longstanding traditions associated with shell beads and in most

cases incorporated glass beads into these existing practices. Accordingly, glass beads have been noted at nearly all Native Californian sites—including mission residential areas, cemeteries, and autonomous villages—dating to the Spanish period (Panich 2014; Ross et al. 2016)

The Mexican War of Independence, beginning in 1810, marks a turning point in the history of glass beads in California, after which the waters become increasingly muddied. Due to the conflict, resupplies from San Blas stopped arriving, and colonists began trading more actively with foreign vessels that plied the Pacific Coast (Costello 1992; Igler 2013). Other colonial interests also began eyeing California. The Russian-American Company founded a mercantile outpost at Colony Ross in 1812, although the current scholarly consensus is that they did not import glass beads manufactured in Russia (Blair 2018:77). The Hudson's Bay Company also started traversing California in the late 1820s, and quickly became the primary source of glass beads throughout the region (Meighan, in press; Sousa 2021; Van Bueren 1983). Around the same time, a newly independent Mexico began shuttering the missions, a process that dragged on for more than a decade. By the mid-1840s, however, the missions were largely abandoned, and Colony Ross had closed its doors, leaving many Native Californians free to return to their ancestral homelands, potentially resulting in bead assemblages from diverse origins. The United States annexed California in 1846, and the subsequent gold rush resulted in dramatic upheaval for Native Californians who faced genocidal violence from the Anglo-American newcomers. Yet many Native people in the formerly missionized coastal zones were spared the worst excesses and used the skills they had acquired in the missions or at Colony Ross as an economic backstop that often connected them to new sources of material goods (Panich et al. 2021).

Despite (or perhaps because of) this complexity, early researchers in California largely ignored issues of glass bead origins. For example, in the 1940s Clement Meighan compiled one of the earliest and most comprehensive—but until now unpublished—glass bead typologies for the region. In it, he lamented, "It is not possible to identify the trade beads in California as 'Spanish,' 'American,' or 'Russian,' since the persons who traded beads to the Indians were merely middlemen and not the producers of the glass beads. Furthermore, all of the middlemen were obtaining their beads through the same market system, nearly always going back to the Venetian factories" (Meighan, in press). His pessimism regarding glass beads was echoed by other prominent 20th-century archaeologists, including James Bennyhoff (1977:43), who himself helped create an enduring regional typology for *Olivella* shell beads (Bennyhoff and Hughes 1987). More recent work, however, suggests that a combination of documentary research and archaeometric analysis of archaeological beads may help illuminate the origins

and temporal placement of many of the beads that passed through colonial and Indigenous hands in California and other areas of North America's Pacific Coast (Blair 2011, 2018; Burgess and Dussubieux 2007; Dadiego et al. 2021; Ross et al. 2016).

3. Materials

White glass beads represent an ideal starting point, given the patterns noted in previous compositional studies and their presence in nearly all assemblages from colonial-era sites in central California. Below, we provide details regarding the dates, occupants, archaeological contexts, and potential bead sources for the sites in our study (Figure 6.1).

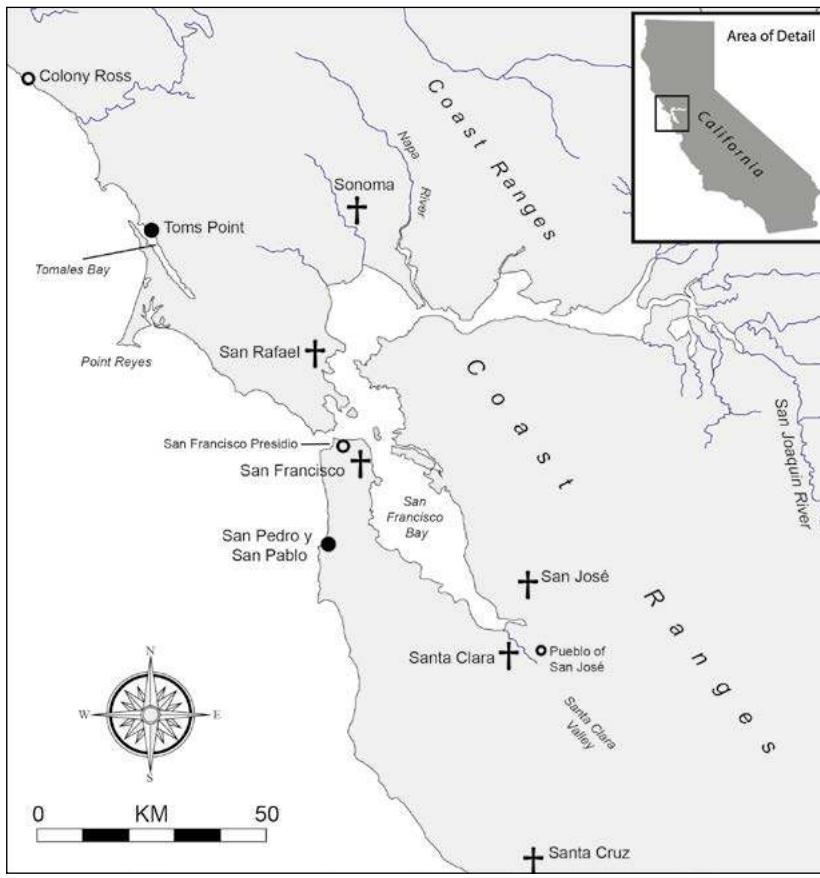

Fig. 6.1: Map of study area with places mentioned in text and other potential sources of colonial-era glass beads.

3.1. San Pedro y San Pablo (1786-1800)

The *asistencia* of San Pedro y San Pablo, CA-SMA-71/H, was founded in 1786 on the Pacific Coast of the San Francisco Peninsula. It was intended to serve as an agricultural outstation for Mission San Francisco de Asís, complete with a resident Native Californian population, but was largely abandoned by 1800. Today, the site is best known as the Sanchez Adobe, named for a later mid-19th century occupant. Early excavations at the site focused primarily on the original mission-period quadrangle, which revealed few artifacts dating to that time (Dietz 1979). More recently, construction activity resulted in the data recovery excavations of fifteen Native American burials, all of which appear to date to the late-18th century component of the site. A review of the death records for Mission San Francisco via the Huntington Library's Early California Population project indicates that approximately 150 individuals from various Ohlone communities were buried at San Pedro y San Pablo between 1787 and 1800 (Huntington Library 2006).

Twenty-five compound white beads from San Pedro y San Pablo were included in the LA-ICP-MS study. They were all recovered with Burial 7, an infant, who was interred with a total of 351 compound white glass beads and 895 clamshell disk beads. All of the compound white beads from Burial 7 were visually uniform two-layered colorless-on-white heat-rounded barrel-shaped beads (classified as IVa11, despite their lack of a third layer), measuring between 3.25 and 3.75 mm in diameter and 2.4 and 3.3 mm in length. For context, only six other burials contained glass beads, and Burial 7 was associated with nearly 97% of the compound white beads recovered during the excavations. Other glass beads recovered in large quantities included simple drawn beads of various colors including black (n=764), aqua (n=793), and off-white (n=1440). A few relatively uncommon wound glass beads, along with two burials with faceted jet beads, confirm the early colonial chronological placement of the cemetery. Given the early dates, the beads were likely purchased from agents in Mexico City, either as part of the annual resupplies from San Blas or possibly as provisions for the initial Spanish journeys into California in 1769. All of the materials are being reburied in accordance with the wishes of the Amah Mutsun Tribal Band of Mission San Juan Bautista; the beads will be further described in a future publication.

3.2. Mission Santa Clara (1777-1840s)

Mission Santa Clara, CA-SCL-30/H, is located near the southern extent of the San Francisco Bay, and was in operation from 1777 through to the 1840s. Like the *asistencia* of San Pedro y San Pablo, Mission Santa Clara was initially home to Ohlone people, although recruitment shifted towards interior Yokuts groups after 1810. Various archaeological projects associated with construction mitigation have

been conducted at Mission Santa Clara over the past several decades resulting in the collection of tens of thousands of glass and shell beads (Hylkema 1995; Allen 2010; Peelo et al. 2018). Contextual interpretation of beads from the site indicates that Native people left them as grave offerings, intentionally destroyed them in clandestine mourning ceremonies, incorporated them into objects such as baskets, and lost them incidentally during the course of daily life (Panich 2014).

The small assemblage of compound white beads analyzed here (n=10) was recovered from contexts associated with an adobe dormitory structure that housed Native Californians, likely longstanding Ohlone families (Panich et al. 2014). Eight of the beads in the sample were recovered from nearby colonial-era sheet midden (ca. 1790s-1840s), whereas one bead was from an interior room and another was from a discrete pit feature interpreted to have been part of an Indigenous mourning ceremony, circa 1815. Interestingly, the pit feature contained thousands of shell beads, but only a handful of glass beads, all of which appear to have been deposited intentionally. Taken as a whole, the assemblage from Mission Santa Clara potentially represents a range of bead sources given the varied depositional and chronological contexts. Compared to the beads from San Pedro y San Pablo, the Santa Clara beads exhibit more morphological variation. They include a mix of two-layered colorless-on-white (IVa11) heat-rounded circular and barrel-shaped beads measuring between 2.5. and 5.2 mm in diameter and 1.7 and 3.3 mm in length.

3.3. Toms Point Trading Post (ca. 1840s-1870)

The Toms Point trading post operated near the mouth of Tomales Bay, in Marin County, as part of the California coastal trade during the mid-19th century. The primary site associated with the trading post is CA-MRN-202, where an American settler, his Coast Miwok wife, and an unknown number of local Native people ran the establishment from the 1840s until approximately 1870. The trading post was likely near the site of Seglogue, a Coast Miwok settlement occupied from precontact times into the 1820s if not later (Schneider and Panich 2019). In addition, CA-MRN-201 is a smaller 19th-century site on the Toms Point landform and appears to be largely contemporaneous with the main trading post site.

Our LA-ICP-MS sample included compound white beads from both MRN-202 (n=30) and MRN-201 (n=5). The beads from MRN-202 were obtained from controlled excavations in shallow midden associated with what appear to have been outdoor activity areas and/or living spaces. Based on stratigraphic context and material associations, these deposits date to the trading post occupation period of ca. 1840-1870. Other beads recovered from these contexts include simple drawn white beads and red-on-white Cornaline d'Aleppo beads, the latter of which

fit well with the post-1840 dates of the trading post (Billeck 2008). Compound white beads comprise more than half of the total glass bead assemblage (n=68) from MRN-202. Beads from MRN-201 were recovered during systematic surface collection. Only seven glass beads were recovered, of which five were compound white beads (Panich et al. 2021). The Toms Point beads exhibit the most visual variation in our sample, including two-layered colorless-on-white (IVa11) and white-on-white (IVa13) heat-rounded circular and barrel-shaped beads ranging from 2.7 to 8.1 mm in diameter and 1.9 to 8.3 mm in length.

4. Results

The 70 beads from the three study sites were analyzed at the Field Museum's Elemental Analysis Facility from May to August 2019, using the protocols described in Annex A. Both the inner and outer layer of each bead were sampled where possible (Figure 6.2), although in some cases the analyst was unable to determine the exact boundary between the glass layers. The results presented here therefore rely on the chemistry of each bead's inner layer, which was successfully recorded for all 70 beads in the sample (the outer layer was only sampled for 38 beads; see Table S6.1 for full results). Further, a majority of the beads in our sample have colorless outer layers, in which case the inner layers are likely a better indicator for the presence of opacifying agents (see Figure S6.1 for examples). We note however, that the same broad patterns described below are present even if the analysis is limited to the results from the outer layers for the applicable beads (cf. Shugar and O'Connor 2008).

Fig. 6.2: Close-up of compound bead from San Pedro y San Pablo (sample SA-13) showing ablation craters in different glass layers. The bead measures ~3.5 mm in diameter.

4.1. Glass types

At the broadest level, the beads in our sample fall into two primary glass types. The vast majority (90%, n=63) are soda-lime glass. Most (n=58) of the soda-lime beads have calcium oxide (CaO) values ranging between approximately 7-12 weight percent and a general absence of lead (Figure 6.3a). These beads comprise the totality of the assemblages from San Pedro y San Pablo and Mission Santa Clara, as well as a majority of the beads from Toms Point. However, a subset of five soda-lime beads exhibits somewhat lower calcium oxide values (6.5-8 weight percent) as well as lead oxide (PbO) values between roughly 5-12 weight percent. These beads are only present at Toms Point and may represent a distinct glass recipe. A final subset of beads (n=7), all of which are from the post-1840 Toms Point sites, exhibits lead oxide values between 44 and 52 weight percent, which is characteristic of lead glass.

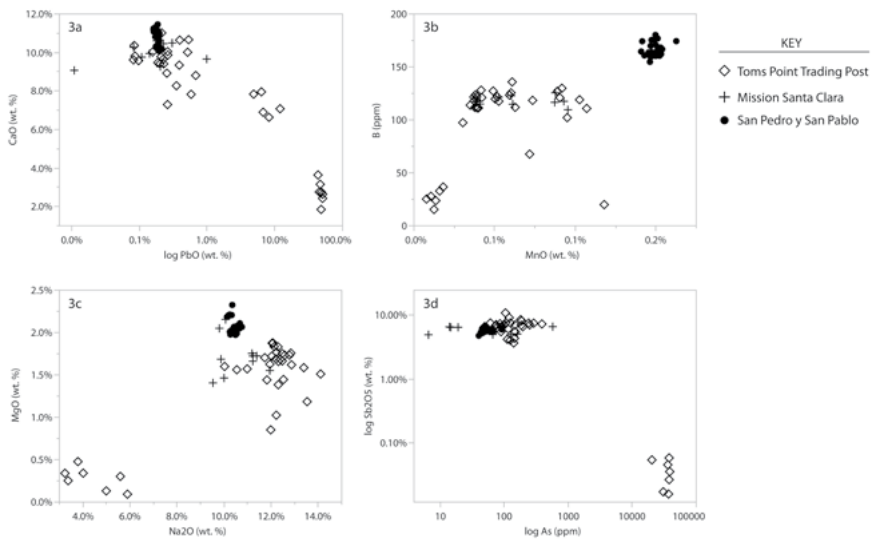

Fig. 6.3: Biplots of relevant LA-ICP-MS data from bead inner layers. (a) log PbO weight percent by CaO weight percent; (b) MnO weight percent by B parts per million; (c) Na_2O weight percent by MgO weight percent; (d) log As parts per million by log Sb_2O_5 weight percent.

Within the soda-lime beads, the colorless-on-white beads from San Pedro y San Pablo display a unique range of values, particularly related to boron and manganese oxide (Figure 6.3b). Although manganese was used as a colorant for black beads, the amounts present in the beads in our sample suggest that its

inclusion was not intentional but rather a product of variation present in the raw materials used to make the glass. Hancock et al. (1997:186) posit that differences in manganese in opaque white beads do not appear to follow temporal patterns and instead likely represent "real sub-groups" (and see Hancock et al. 1999). The beads from San Pedro y San Pablo similarly stand out with regard to MgO, CaO, and Na_2O (Figure 6.3c), adding to the argument that these beads were made with a slightly different base glass recipe than most of the other soda-lime beads in our study (cf. Walder 2018:308).

Indeed, when the data are reduced to the seven oxides most useful for understanding base glass composition (Brill 1999; Burgess and Dussubieux 2007), the beads from San Pedro y San Pablo exhibit a narrow range of values distinct from the other soda-lime beads (Table 6.1). Viewed graphically, the reduced compositional values for individual beads from San Pedro y San Pablo separate clearly from the other soda-lime beads from Toms Point and from most of the beads from Mission Santa Clara (Figure 6.4). That three of the beads from Mission Santa Clara do resemble the cluster from San Pedro y San Pablo—sites that overlap chronologically and which likely acquired beads from the same sources in Mexico—suggests that meaningful chemical subgroups are present in the region's vast assemblages of white compound beads.

Glass Type	SiO_2	Na_2O	MgO	Al_2O_3	K_2O	CaO	Fe_2O_3
All Soda-Lime Glass	68.2 ± 1.1 %	12.3 ± 1.4%	2.0 ± 0.3%	1.6 ± 0.2%	4.3 ± 0.6%	10.8 ± 1.1%	0.8 ± 0.1%
San Pedro y San Pablo	67.8 ± 0.5%	11.2 ± 0.2%	2.2 ± 0.1%	1.8 ± 0.0%	4.5 ± 0.1%	11.6 ± 0.5%	0.9 ± 0.0%
Other Soda-Lime	68.1 ± 1.2%	12.8 ± 1.3%	1.8 ± 0.2%	1.6 ± 0.2%	4.3 ± 0.7%	10.6 ± 0.9%	0.8 ± 0.1%
Soda-Lime w/ Lead	70.0 ± 0.8%	14.4 ± 1.0%	1.5 ± 0.2%	1.3 ± 0.1%	3.7 ± 0.7%	8.4 ± 0.6%	0.7 ± 0.1%
Lead Glass	76.1 ± 2.9%	8.7 ± 2.2%	0.5 ± 0.2%	0.6 ± 0.2%	8.4 ± 3.7%	5.4 ± 0.9 %	0.3 ± 0.1%

Table 6.1: Reduced average glass compositions for major categories of glass and specific base glass groups noted in text.

Still, the uniformity of the beads from San Pedro y San Pablo is noteworthy in itself. All 25 beads came from a single, early colonial-era burial that contained the vast majority of the compound white beads recovered from the site, suggesting that these beads may very well have been produced together at the same European

workshop. Moreau and colleagues (2002) make a similar argument based on the elemental homogeneity of a group of 18th-century white beads from Quebec that were apparently deposited together in a bag. In our view, the beads from this burial may represent a single strand of beads produced in Europe, obtained by Franciscan missionaries from merchants in Mexico, and given to an Ohlone family in central California during the early years of the Spanish mission system.

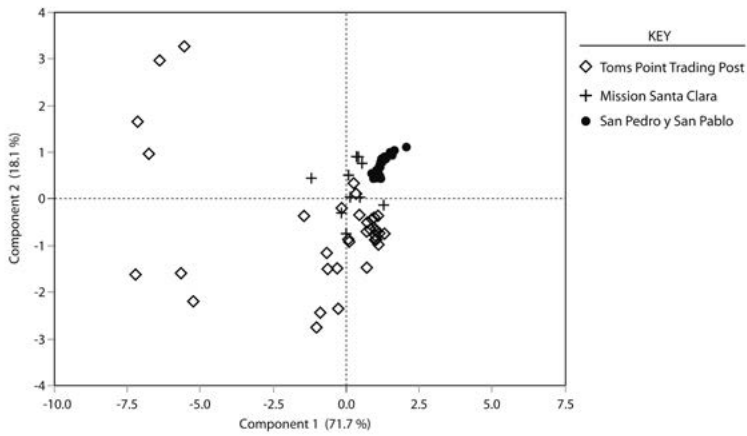

Fig. 6.4: Biplot of principal components derived from reduced compositional values of bead inner layers.

4.2. Opacifiers

Tin, antimony, and arsenic contributed to the main opacifying agents used for white glass beads during the time period in question (Blair 2017; Hancock et al. 1997; Moreau et al. 2002; Sempowski et al. 2000; Shugar and O'Connor 2008). Based on the existing literature, the generally accepted chronology is as follows. Tin was the dominant opacifier during the 17th century (ca. 1600-1700), antimony was used from the mid-17th century until the second half of the 19th century (ca. 1650-1900), and arsenic was introduced at some point in the late 18th century and continued to be used into the 20th century (ca. 1800-1950). Although tin was no longer used as an opacifying agent by the time of the Spanish invasion of California in 1769, we included it due to the possibility that glass beads acquired during earlier isolated encounters were handed down as heirlooms in the form of strands or other beaded objects to the residents of our study sites. Nevertheless, our analysis demonstrated that no tin-opacified beads are present in our sample.

All of the soda-lime glass beads were opacified with antimony and returned values for antimony pentoxide (Sb_2O_5) between 3.6 and 10.7 weight percent for the inner glass layer (Figure 6.3d). As noted above, five of the soda-lime beads exhibited lead oxide (PbO) values between roughly 5-12 weight percent in addition to the evidence for use of antimony as the main opacifying agent. While this result may point to lead-soda-lime glass, the presence of lead in white glass opacified with antimony is not rare; it can facilitate the precipitation of the calcium antimonate crystals and was used in some Venetian recipes to produce white antimonate opacifiers (Boschetti et al. 2020; Lima et al. 2012). Otherwise, the soda-lime beads in our study are consistent with antimony-rich beads reported elsewhere in the literature (e.g., Hancock et al. 1997:185).

The lead glass beads (n=7) exhibit evidence of arsenic opacifying agents, returning arsenic values between 20,000-40,000 ppm. These beads comprise 10 percent of the total sample, and are all from the Toms Point sites, two from CA-MRN-201 and five from CA-MRN-202. Although all seven of the arsenic opacified beads are classified as Kidd and Kidd variety IVa13 beads, the bead variety does not seem determinative of chemical composition. The Toms Point assemblage as a whole contains several antimony-rich IVa13 beads and the beads with significant lead and arsenic levels display marked visual variation with regard to size and shape (in addition to the typological problems of distinguishing between IVa11 and IVa13 beads). Still, some visual clues may be apparent between the two compositional groups, as suggested by Hancock and colleagues' original study (Hancock et al. 1997:185). From our Toms Point assemblage, the lead-arsenic beads have a chalkier, more opaque appearance, whereas the antimony-rich soda-lime beads exhibit a glassier, more translucent white hue (Figure 6.5).

Fig. 6.5: Comparison of glassier antimony-rich (left) and chalkier lead-arsenic beads (right) from Toms Point. The beads are samples TPT-9 and TPT-32, respectively. Scale is in mm.

5. Discussion and conclusion

The results of this study offer a baseline for future chemical compositional studies of white glass beads from California. As expected, our study confirms that 17th-century tin-opacified beads are not likely to be present in most California assemblages. With regard to chronology, the more interesting pattern is the separation of compound white beads into antimony-rich and arsenic-rich varieties. These groups have been previously documented in the literature, but nearly all of the published research on the matter has focused on earlier beads (particularly the switch from tin to antimony opacifiers) in eastern North America. Therefore, this study offers new regional and temporal data regarding the shift from antimony to arsenic opacifiers, as well as some potentially meaningful differences among base glass used to create the antimony-rich beads in our study.

With regard to the chronological placement of the arsenic-rich beads, we can compare our results to the small number of published chemical analyses of white glass beads from colonial California. Dadiego and colleagues (2021), for example, used LA-ICP-MS to analyze 100 opaque white glass beads (most of which were compound beads) recovered from a post-1820 deposit at Mission Santa Cruz. Despite the relatively late date, 99 were opacified with antimony while only one was a lead-arsenic bead similar to those in our study. Further north, Blair (2011) used XRF to analyze eight opaque white beads (including compound white beads) from a pre-1844 context at the Russian-American Company's Colony Ross (1812-1841). He determined that seven were opacified with a lead-arsenic compound while the other had an antimony-rich composition. These findings generally agree with our results that place lead-arsenic beads in the post-mission period (i.e., post-1830s) in central California.

It is also possible that there is chronologically diagnostic chemical variation within arsenic-rich beads as a whole. For example, we note that Hancock et al. (1997:190) assigned some temporal significance to the amount of sodium in their sample of arsenic-rich opaque white beads from eastern North America, presumably related to the presence of sodium oxide or soda as fluxes (Walder 2018:305). The seven arsenic-rich beads in our study exhibit Na_2O values of between 3.2 and 5.9 weight percent for both the inner and, where measured, the outer layers (see Figure 6.3c). Though we acknowledge the difference in analytical technique, the Na_2O weight percent values for the Toms Point beads generally seem to align with sodium percent values for the 1840±20 period identified by Hancock and colleagues (1997).

Despite these clues, we cannot fully address the timing of the introduction of arsenic opacified beads in California with the samples in our study. The lack of

such beads at San Pedro y San Pablo is not surprising, as the burials there all date to 1800 or earlier. The small sample from Mission Santa Clara lacks chronological precision but could conceivably cover the period from the early 1790s (the date of construction for the specific dormitory with which the beads were associated) until the 1840s when Native Californians abandoned the site. Of the beads from Mission Santa Clara, only the single bead from the pit feature that appears to have been filled around 1815 can be dated with any precision. Still, the lack of lead-arsenic beads at Mission Santa Clara corresponds well to the recent analysis of white glass beads from nearby Mission Santa Cruz, where only a single lead-arsenic bead was noted in a sample of 100 post-1820 beads (Dadiego et al. 2021). In our study, all seven of the lead-arsenic beads were from Toms Point, sites CA-MRN-201 and CA-MRN-202, which date from the 1840s to about 1870 and are only 40 km southeast of Colony Ross. Though some Spanish explorers and missionaries visited Toms Point, this area was largely outside the sphere of Spanish influence as the San Francisco Bay was the primary focus of missionary and military presence in the area (Schneider and Panich 2019).

Given these patterns, it is possible that the introduction of arsenic opacified white beads to central California has both a temporal and a geographical component. In general, they seem to have appeared relatively late. Arsenic opacified white beads in our study are only present at sites that date to the 1840s onward. Factoring the data from Mission Santa Cruz and Colony Ross, it is possible that they began appearing sometime in the 1820s or 1830s, but without a larger sample it is difficult to estimate exactly when their introduction occurred. Questions about chronology aside, it is notable that nearly all of the very small number (n=15) of lead-arsenic opacified beads thus far identified for California are all from sites in the same general region of the north-central coast. Previous research (Ross 1997) points to the Hudson's Bay Company as the likely source of many beads used by Native Californians at Colony Ross, and it is therefore possible that lead-arsenic opacified beads are associated with the onset of Hudson's Bay Company activity in California in the 1820s and 1830s. Nevertheless, Burgess and Dussubieux (2007) report that all of the compound white beads sampled from the Sullivan's Island collection, most of which likely originated at the Hudson's Bay Company's Fort Vancouver, were opacified using a calcium-antimony compound, further complicating the picture. These issues are ripe for future research.

Beyond questions about the relative timing of particular opacifiers, chemical analysis can also help illuminate more subtle patterns in glass bead distribution and use. In our study, we noted two subgroups that warrant further investigation (see Table 6.1). At Toms Point, five antimony-rich beads also had relatively high lead oxide values, a pattern which has a basis in glassmaking practices but has

yet to be widely reported in the literature on 19th-century white glass beads. A more concrete pattern was observed in beads from San Pedro y San Pablo, which stand out from most of the other antimony-rich soda-lime beads in our sample. This suggests that the beads in question stayed together from their origins in a European workshop all the way through to their deposition in California. That a small number of beads from Mission Santa Clara exhibited a similar chemical composition to the beads from San Pedro y San Pablo may point to important subgroups within the region's antimony-rich white glass beads.

Taken together, our findings underscore the importance of compositional analysis, as these chemical groupings are invisible to the naked eye and therefore their distribution in archaeological contexts cannot be a function of choice on the part of the past people who used the beads (Walder 2018:306). While we recognize the complex ethical issues involved in the excavation of burials and the analysis of accompanying grave goods, our results support Marcoux's (2012) observation that burials and other short duration contexts can be especially useful for refining bead chronologies—and in this case, chemical profiles. Each of these patterns will require future research to substantiate fully, but our study nevertheless offers an iterative perspective that will be useful for developing future glass bead compositional studies from California and western North America.

Acknowledgments

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Chapter 7

Glass beads and evidence for early "pre-contact" trade in Northwestern Alaska

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1. Introduction

The extent and types of interactions that occurred between Native populations and foreign (mainly Asian, but also European) explorers, fur trappers and traders in what is now Alaska and northwestern North America require further research. While preserved historic documents record some types of these encounters and archaeological work documents others (e.g., Giddings and Anderson 1986), many details are not reported and down-the-line outcomes of these exchanges remain unclear. Other forms of evidence linked to these interactions can be found in objects preserved as heirlooms by later historic and modern-day groups. Archaeological excavations continue to shed light on the range of materials involved in colonial-era interactions, as well as the origin and range of these material remains beyond the initial locations of exchange.

One form of exchange item, glass beads, can often be found in contexts dating from the earliest of these types of colonial encounters. As put by Peter Francis (1994: 281), "[s]mall, portable, durable, and often highly valued, they have always been part of the cargo of explorers and wandering merchants." Like many commodities of the colonial era, glass beads of many types and styles were produced exclusively for trade in colonial frontiers (Francis 2002). Shifts in attributes such as style, shape, and color occurred, according to consumer and manufacturer demands and limitations (Carter et al., this volume). Likewise, regional and global shifts in state-level economies also impacted the availability and distribution of materials (in this case glass beads) produced in any given workshop or factory.

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While individual production centers (e.g., Amsterdam, Venice, etc.) might share many commonalities in their glass bead attributes, even to the point of having similar or common "recipes" for raw material ingredients and proportions, there also is variation among the production centers (e.g., Adlington et al. 2019). Thus, glass beads produced by Venetian craftsmen may be differentiated from those of other regions of production, such as Amsterdam, by assessing chemical compositions and identifying variations in their base glass recipes (e.g., Dussubieux and Karklins 2016). Using compositional and stylistic differences, it should be possible to identify the potential source(s) for the glass beads traded into Alaska. In doing so, we may identify likely routes and possibly modes of transportation to the interaction zones, where glass beads crossed over into the hands of Native Alaskan populations and were utilized locally and/or continued to move via internal Indigenous networks.

Fig. 7.1: Glass beads from the Igliqtiqsiuġvigruak site (Swift Water Place), Alaska (photographs by T.R. Fenn).

The research presented in this paper summarizes results of compositional analysis on 13 glass beads (Figure 7.1) recovered from the archaeological site of Igliqtiqsiuġvigruak (Anderson and Anderson 2019), on the Kobuk River near Kiana, northwestern Alaska (Figure 7.2), and places them within an historical context. A final discussion of potential production sources/regions for the glass beads also is presented, along with some speculations on the avenues and mechanisms for distribution and trade.

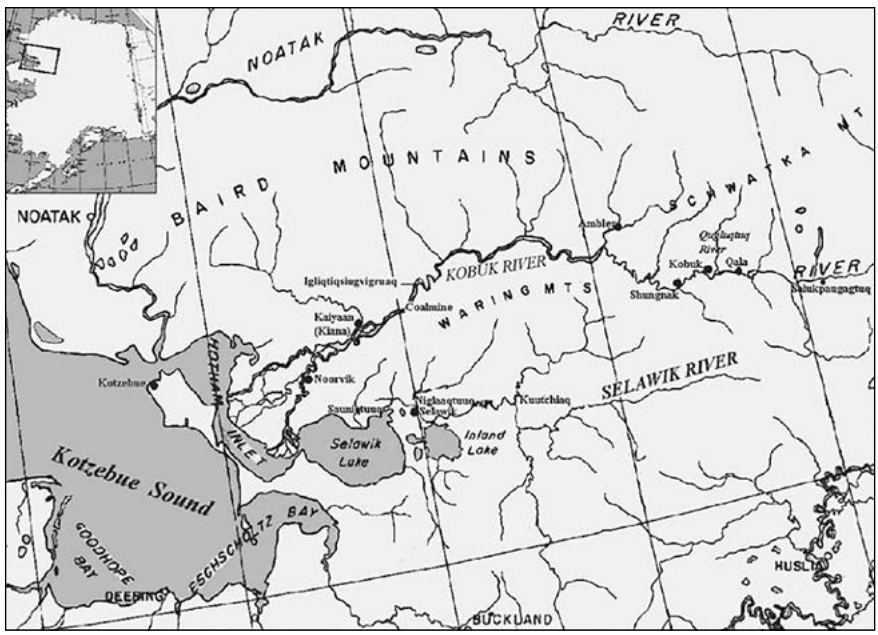

Fig. 7.2: Northwest Alaska, showing location of the Igliqtiqsiuġvigruak site (From Anderson and Anderson 2019: xxvi).

2. Historical context

Following its "discovery" by Vitus Bering in 1741, exploration of the coast of Alaska by non-Natives, primarily Russian fur traders, continued and increased throughout the 18th century CE. However, much of the early exploration and settlement in the region by non-Natives occurred south of the Bering Strait (Gibson 1976). Russian naval navigator Otto Von Kotzebue, eponymous discoverer of Kotzebue Sound, arrived in the region in 1816 while searching for the Northwest Passage, but headed south again, shortly afterwards along the coast of Asia (Kotzebue 1821).

Alexander Andreyevich Baranov was Chief Manager of the Russian colonies in North America during this time, from 1799-1818 (Khlebnikov 1973), but he also had an interesting history before this role. In fact, one of Baranov's early ventures, after his move to Irkutsk, Siberia, was establishment and management of a factory for making glass, and apparently "this venture was very successful" (Stefansson and Wilcox 1951: 67). Baranov, however, was not satisfied with these efforts and expanded his operations to the northeast by establishing posts for buying furs from Chukchi natives, including his principal post on the western coast of the Kamchatka Peninsula in the Sea of Okhotsk (Stefansson and Wilcox 1951: 67). Baranov traded furs with the Chinese to gain other items of commerce and consumables (e.g., tea). The Chinese demand for furs drove Siberian "backwoodsmen" to virtually exterminate valuable pelt animals in the region, and by 1740 merchants in Irkutsk, "desperate to maintain the tea trade," began "to purchase furs from the Hudson's Bay Company in London" (Stefansson and Wilcox 1951: 67).

However, the return of Bering's expedition, replete with "a fortune in sea otter and fox skins" portended the transition of Siberian hunters from the forests onto the seas where they hunted sea otters and similar animals for pelts. Many of the merchants of Irkutsk invested in fur-hunting enterprises, and the movement of those furs went through the port town of Okhotsk on the western side of the Sea of Okhotsk. The success of the Russian fur ventures in the North Pacific inspired European powers (notably Spain, France, and Britain) to send their own exploratory expeditions into the North Pacific. With pressure mounting, the merchants of Irkutsk implored Catherine the Great to take action by annexing the Aleutian Islands and even parts of the mainland (Stefansson and Wilcox 1951: 68), but to no avail with the Empress stating in 1769: "It is for traders to traffic where they will. I renounce forever all possessions in … America" (Stefansson and Wilcox 1951: 69).

Shortly afterwards, British Captain James Cook, on his third round-the-world voyage, traveled north from the South Pacific, where he regularly used glass beads as trade items with locals, and began exploring the northern coast of North America. Upon arriving in the Prince William's Sound region of Alaska in 1778, Cook encountered Native peoples "ornamented with sky-blue glass beads, about the size of a large pea" (Cook 1821: Chap. IV). Conversations with locals seemed to indicate greater value placed on beads of this color than those of white proffered by Cook (see also Francis 1988). Regardless, Cook (1821: Chap. IV) noted that any glass bead was highly valued and they would readily trade for them. Cook also observed the people possessing iron objects (e.g., spear points), and that they wished for more. Cook later observed "many beads of European manufacture among them, chiefly of a pale blue color, which they hang in their

ears, about their caps, or join to their lip-ornaments" (Cook 1821: Chap. V). Cook (1821: Chap. V) conjectured that "European" goods (i.e., iron and glass beads) arrived through trade networks connected to inland tribes, "from Hudson's Bay, or settlements on the Canadian Lakes", or "that the Russian traders from Kamtschatka [Kamchatka], have already extended their traffic thus far." On the mainland closer to Kodiak Island, Cook (1821: Chap. VI) again encountered locals "in possession of large iron knives, and of sky-blue glass beads, such as we had found amongst the natives of Prince William's Sound", who also greatly valued the latter. From this last encounter, Cook (1821: Chap. VI) posited that if these items were in fact derived from Russian fur hunters, then this group had not had direct contact with the Russians, for if they had, "we should hardly have found them clothed in such valuable skins as those of the sea-otter."

From this region, Cook (1821: Chap. VII) quickly moved west, anchoring at Unalaska Island in the Aleutians, where he encountered a native youth wearing a cap "ornamented with two or three sorts of glass beads," while another local from the island presented Cook with a note written in Russian. As Cook moved north into the Bering Strait, he distributed beads himself in small trading and gifting exchanges. However, they continued to see iron or steel objects, of "European or Asiatic workmanship", and some individuals had glass beads hanging from their ears (Cook 1821: Chap. IX). Upon returning to Unalaska Island, before heading south, Cook encountered Russian fur hunters, who are "settled upon all principal islands between Oonalaska [Unalaska] and Kamtschatka [Kamchatka], for the sole purpose of collecting furs," and learned they arrived from Okhotsk in 1776 and were returning in 1781 (Cook 1821: Chap. XI).

It is at this time that a wealthy Irkutsk merchant, Grigorii Shelekhov, placed a permanent colony (which had not previously been done by any other fur-hunting company) in "America." The posts of Three Saints Bay on Kodiak Island and Fort Alexander on Cook's Inlet (west of Prince William's Sound) were established in 1784 (Stefansson and Wilcox 1951: 69). It was at the port of Okhotsk, where Shelekhov was overseeing the reprovisioning of a supply ship to his American posts, that he offered Baranov, who accepted, the post of manager at Three Saints Bay for five years, with his "salary consisting of the revenue from ten shares in the Golikov-Shelekhov Company of Irkutsk" (Stefansson and Wilcox 1951: 70). After an arduous journey, which included the wrecking of the ship on which he sailed, Baranov finally arrived at the Three Saints Bay post in July 1791.

So, from this historical review, several details are already apparent. First, when Cook arrived in Alaska in 1778, sky or pale blue (and other) glass beads were already found amongst Native populations in and around Prince William's Sound on the east, at Unalaska Island in the Aleutians, and at several locations to the north as far

as Cape Prince of Wales in the Bering Strait. We also can suggest that Native people were getting beads indirectly through Indigenous networks, as some groups possess the items but show no apparent evidence for direct contact. Furthermore, many Russian fur hunters found in the area at the time derived from Siberia and worked for merchants based in Irkutsk. These same Russians, commonly transported furs back to Irkutsk by sailing to the port of Okhotsk, on the western side of the Sea of Okhotsk, which connects overland to Irkutsk. Additionally, these same merchants based in Irkutsk regularly traded with Chinese merchants who were supplied from Peking [Beijing] (Coxe 1780: 197-243). All these circumstances presage the materials and means for glass beads entering historic Alaska from European traders, both from inland North America and from Asia.

3. Background to the archaeological site and beads

Glass beads were recovered from archaeological excavations, beginning in 2010, at the site of Igliqtiqsiuġvigruak, "Swift River Place" in English (hereafter SWP), on the Kobuk River in western Alaska (Figure 7.2) (Anderson and Anderson 2019). The site comprises mainly Native Alaskan (Iñupiaq) archaeological materials, but some objects of non-Native origin, including a few iron items and glass beads, also were recovered. SWP is located north of the Aleutian Islands, and north of the Bering Strait, in the easternmost end of Kotzebue Sound, placing it on the edge of the Arctic Circle. That positions this site less than 300 miles from the current continental coast of Siberian Russia on the western side of the Bering Strait.

A total of 14 whole and fragmentary glass beads (13 were available for analysis) were recovered from two of the excavated houses at the site, twelve from House K and two from House I. House K was a large, single-roomed semi-subterranean house covering ~36 m^2, while House I was a small, single-roomed semi-subterranean house covering ~13.6 m^2 (Anderson and Lutz 2019: 5). The glass beads originate from floor midden excavations in both houses. These two houses were part of a village, which included more than 26 houses in total. The village was part of a larger settlement pattern of habitation sites scattered for several miles along this stretch of the Kobuk River. In general, the cultural materials recovered from excavation of these two houses were typical for a late-precontact riverine Iñupiaq community (Anderson and Lutz 2019: 19). Recovered materials included a variety of lithic debitage and organic objects (antler, bone, ivory, and wood), and comprised 867 artifacts relatively equally distributed between the two houses; 55% from House K, 45% from House I (Anderson and Lutz 2019: 19).

Dendrochronology and radiocarbon dating conducted on samples from the site have provided a working chronology for the site and houses. House I appears to

have been built around 1780 with a remodeling event in 1819, while House K was probably built around 1740 or soon after, and was continuously or intermittently occupied until at least the 1850s (Griggs et al. 2019). Oral histories indicate that the site in general appears to have been completely abandoned sometime before non-Native people settled in the area at the end of the 19th century, suggesting a conservative *terminus ante quem* of CE 1900 for Houses I and K, and the site as a whole (Griggs et al. 2019). House I is interpreted as a single-family home, while House K possibly belonged to either a "wealthy individual" or served as a "community house or 'men's' house", or maybe a combination of the two (Anderson and Lutz 2019: 65).

Non-local iron metal was found at the site as well, comprising only three pieces, all recovered from burials in House I, suggesting "that the metal was exceedingly rare and particularly highly valued" (Anderson and Lutz 2019: 65). However, no glass beads were found in any of the burials. The excavators note that the presence of "so few items of Western manufacture" is unusual in their experience, and that usually, "once metal shows up in an archaeological site in the region, it is plentiful in the form of nails or nail-like objects and flat sheets" and that the "same applies to glass beads: when present, they are usually abundant" (Anderson and Lutz 2019: 62). The excavators suggest that the community derived a major source of its wealth from trading.

Evidence of seal hunting equipment in House K indicates that at least some of the residents spent late spring or early summer at the coast, where they could have occasioned contact with coastal relatives and neighbors and found exchange opportunities (Anderson and Lutz 2019: 65). Archaeology conducted along beach ridges on Cape Krusenstern, at the mouth of Kotzebue Sound (ca. 170 km west of SWP), revealed Native houses contemporaneous with SWP containing a pale blue glass bead, an Asian-derived tobacco pipe bowl carved from ivory, and a few fragments of iron (Giddings and Anderson 1986). These beaches typically held small winter settlements, and larger spring-summer camps that included a trading market.

4. Elemental analysis of the glass beads

A total of 13 glass beads (Figure 7.1) from SWP were subjected to laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) at the Elemental Analysis Facility at the Field Museum, Chicago in 2014. More details about the instrumentation and the analytical protocol are available in Annex A. The beads comprise whole and fragmentary opaque blue beads with a range from dark blue (one) to blue (four opaque and two translucent) to turquoise (four) to blue-green

(one), and a single whole white opaque bead of compound construction (Table 7.1).

ID	Context	Object, Condition	Color[1]	Transparency	Bead Type[2]	Manufacture[1]
KOVA5199	House K	bead, whole	white	opaque	IVa	drawn
KOVA6138	House K	bead, whole	blue	opaque	IIa31	drawn
KOVA6139	House K	bead, whole	blue	opaque	IIa31	drawn
KOVA6228	House K	bead, whole	blue	opaque	IIa31	drawn
KOVA5787	House K	bead, half	blue	opaque	IIa31	drawn
KOVA5931	House K	bead, whole	blue-turquoise	opaque	WIb12	wound
KOVA5825	House K	bead, whole	blue-turquoise	opaque	WIb12	wound
KOVA5798	House I	bead, whole	blue-turquoise	opaque	WIb12	wound
KOVA6123	House K	bead, half	blue-turquoise	opaque	WIb12	wound
KOVA5343	House K	bead, half	blue-green	opaque	WIb12?	wound
KOVA6140	House K	bead, whole	blue-dark blue	opaque	WIb14	wound
KOVA6029	House K	bead, fractured shard	blue	translucent	--	--
KOVA5783	House K	bead, fractured shard	blue	translucent	--	--

[1] Determined and assigned by author (TF) based on visual inspection.
[2] This follows the classification system by Kidd and Kidd (1970).

Table 7.1: Glass beads recovered from Houses I and K at the Igliqtiqsiuġvigruak site (Swift Water Place), Alaska.

Glass Type	Soda-Lime Glass					Potash-Lime Glass							
	Hi-Na_ Lo-K	Hi-Na_Lo-K				Hi-K_Lo-Na_Mod-Al				Hi-K_vLo-Na_Lo-Al			
ID	KOVA 5199	KOVA 5787	KOVA 6138	KOVA 6139	KOVA 6228	KOVA 5931	KOVA 5825	KOVA 5798	KOVA 6123	KOVA 5343	KOVA 6029	KOVA 5783	KOVA 6140
Color-Opacity	w-op	bl-op	bl-op	bl-op	bl-op	bl-tq-op	bl-tq-op	bl-tq-op	bl-tq-op	bl-gr-op	bl-tr	bl-tr	bl-dk-op
Wt %													
SiO_2	67.99	68.17	67.26	69.11	66.69	64.35	67.93	55.14	63.78	66.97	70.42	68.75	64.82
Na_2O	10.69	14.03	14.50	12.88	15.70	2.60	2.90	4.31	3.03	0.77	0.65	0.54	0.20
MgO	1.27	1.14	1.12	1.39	1.35	0.31	0.20	0.42	0.22	0.27	0.10	0.10	0.26
Al_2O_3	1.36	0.84	0.85	1.06	1.03	5.94	1.51	8.37	6.10	2.86	1.39	1.33	3.58
P_2O_5	0.87	0.64	0.93	0.62	0.65	0.00	<dl	0.04	0.00	0.02	0.00	0.01	0.01
Cl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl
K_2O	6.87	4.74	5.53	5.09	3.67	16.29	16.19	16.14	15.55	16.50	18.17	18.20	18.79
CaO	8.78	8.62	9.48	9.22	9.13	8.65	9.78	15.30	10.11	7.35	7.25	9.04	9.60
Sb_2O_5	1.29	0.01	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00

Glass Type	Soda-Lime Glass					Potash-Lime Glass							
	Hi-Na_Lo-K	Hi-Na_Lo-K				Hi-K_Lo-Na_Mod-Al				Hi-K_vLo-Na_Lo-Al			
ID	KOVA 5199	KOVA 5787	KOVA 6138	KOVA 6139	KOVA 6228	KOVA 5931	KOVA 5825	KOVA 5798	KOVA 6123	KOVA 5343	KOVA 6029	KOVA 5783	KOVA 6140
Color-Opacity	w-op	bl-op	bl-op	bl-op	bl-op	bl-tq-op	bl-tq-op	bl-tq-op	bl-tq-op	bl-gr-op	bl-tr	bl-tr	bl-dk-op
MnO	0.08	0.04	0.01	0.01	0.03	0.03	0.01	0.01	0.00	0.01	0.76	0.77	0.71
Fe_2O_3	0.70	0.47	0.28	0.36	0.50	0.39	0.22	0.01	0.17	3.36	0.44	0.43	0.59
CuO	0.01	1.23	0.01	0.01	1.15	0.64	0.84	0.27	0.61	0.98	0.39	0.39	0.80
SnO_2	0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.00	0.02	0.02	0.01	0.01	0.01
PbO	0.07	0.04	0.00	0.00	0.04	0.28	0.09	0.00	0.04	0.08	0.06	0.07	0.06
ppm													
Li	22.40	16.34	21.80	35.36	13.35	15.52	14.31	6.36	5.85	7.35	48.47	50.48	57.90
Be	0.24	0.41	0.20	0.19	0.16	1.12	0.47	0.92	0.47	0.40	0.33	0.36	1.93
B	162.91	97.24	152.98	144.52	120.59	25.68	3.48	6.32	14.24	29.79	22.62	25.89	25.65
Sc	1.58	1.12	0.86	0.97	1.61	2.11	0.78	2.31	2.92	2.54	4.70	4.39	6.44
Ti	438.45	217.93	185.29	228.28	218.14	717.74	156.87	1066.09	843.34	625.06	299.95	292.34	743.56
V	12.26	6.72	5.57	7.57	8.09	11.72	4.01	18.47	12.60	11.45	12.62	12.53	17.18
Cr	8.13	3.96	5.30	4.02	4.75	5.54	0.69	7.88	5.70	3.98	2.49	1.89	7.16
Ni	3.21	56.76	54.62	70.14	77.93	4.68	7.44	6.14	7.01	34.70	26.62	25.86	56.42
Co	4.06	136.30	52.36	67.18	74.75	8.07	2.76	1.58	1.42	4.14	472.34	466.56	296.23
Zn	72.36	86.67	71.37	73.55	48.09	3844.94	2442.01	3028.65	3062.06	6546.06	1971.79	1984.72	4184.26
As	5.95	164.23	179.95	131.62	143.26	<dl	<dl	<dl	<dl	21.07	<dl	<dl	1.58
Rb	24.09	9.40	19.35	18.25	19.79	23.25	16.10	22.39	15.98	18.28	9.68	9.93	24.92
Sr	745.45	701.45	684.16	937.82	424.28	251.66	245.42	476.49	288.24	162.99	226.20	235.32	166.68
Zr	36.05	16.94	16.62	20.69	13.41	70.18	22.06	149.60	127.65	77.15	63.02	62.41	85.31
Nb	2.73	1.14	1.12	1.31	1.45	3.91	1.61	7.93	4.63	3.47	1.98	1.96	5.19
Ag	0.25	2.82	7.49	5.47	4.00	2.89	4.14	2.33	1.12	2.48	1.29	1.35	2.84
Cs	0.31	0.26	0.15	0.19	0.16	1.11	0.44	0.21	0.30	0.27	0.23	0.24	1.26
Ba	149.66	64.90	78.43	102.11	26.17	285.98	108.04	219.39	109.92	146.46	518.50	575.30	393.03
La	5.86	2.12	2.56	3.32	2.77	7.38	3.63	15.31	14.93	13.34	11.22	12.19	17.60
Ce	13.65	4.59	5.01	6.95	5.38	16.59	7.58	33.31	31.13	27.02	404.66	445.43	151.83
Pr	1.46	0.54	0.66	0.85	0.65	2.54	0.96	4.92	3.95	3.04	3.04	3.29	4.46
Ta	0.24	0.07	0.10	0.13	0.12	0.53	0.54	0.51	0.33	0.28	0.21	0.23	0.62
Au	0.11	0.26	0.23	0.23	0.24	0.17	0.38	0.10	0.09	0.09	0.06	0.05	2.03
Y	3.37	2.15	1.71	2.17	2.02	7.11	3.39	15.22	10.33	7.44	4.85	4.87	7.25
Bi	0.91	28.40	72.18	121.33	82.48	26.93	3.04	2.86	1.32	2.45	0.92	1.08	1.92
U	1.36	4.35	1.16	1.81	0.99	1.39	1.31	6.04	1.21	1.03	1.17	1.30	1.61
W	0.12	0.66	0.07	0.12	0.23	0.80	0.23	0.85	0.41	0.48	0.50	0.57	2.49
Mo	1.05	1.32	1.06	0.91	1.26	0.97	1.23	0.65	0.35	0.60	0.80	0.83	1.69
Nd	5.23	1.77	2.30	3.05	2.21	6.83	3.01	17.84	13.40	10.33	10.12	11.28	14.23
Sm	1.10	0.55	0.50	0.65	0.47	1.70	0.75	3.86	2.62	2.05	2.14	2.44	3.03
Eu	0.24	0.13	0.11	0.14	0.12	0.70	0.31	0.85	0.54	0.44	0.42	0.43	0.97
Gd	0.83	0.40	0.35	0.54	0.40	1.35	0.58	3.39	2.17	1.85	1.56	1.59	2.28
Tb	0.12	0.22	0.06	0.08	0.07	0.61	0.43	0.52	0.36	0.28	0.25	0.27	0.64
Dy	0.80	0.41	0.41	0.56	0.38	1.43	0.66	3.26	1.93	1.49	1.40	1.56	1.97
Ho	0.16	0.12	0.08	0.11	0.09	0.53	0.18	0.68	0.45	0.31	0.26	0.29	0.53

Glass Type	Soda-Lime Glass					Potash-Lime Glass							
	Hi-Na_ Lo-K	Hi-Na_Lo-K				Hi-K_Lo-Na_Mod-Al				Hi-K_vLo-Na_Lo-Al			
ID	KOVA 5199	KOVA 5787	KOVA 6138	KOVA 6139	KOVA 6228	KOVA 5931	KOVA 5825	KOVA 5798	KOVA 6123	KOVA 5343	KOVA 6029	KOVA 5783	KOVA 6140
Color-Opacity	w-op	bl-op	bl-op	bl-op	bl-op	bl-tq-op	bl-tq-op	bl-tq-op	bl-tq-op	bl-gr-op	bl-tr	bl-tr	bl-dk-op
Er	0.46	0.23	0.21	0.27	0.21	1.08	0.42	1.82	1.13	0.73	0.71	0.79	1.05
Tm	0.06	0.04	0.03	0.04	0.05	0.49	0.13	0.26	0.22	0.11	0.12	0.13	0.39
Yb	0.45	2.63	0.21	0.28	0.18	1.04	0.39	1.99	1.05	0.71	0.84	0.94	1.59
Lu	0.06	0.08	0.03	0.05	0.05	0.52	0.13	0.29	0.20	0.11	0.12	0.13	0.33
Hf	1.45	0.53	0.60	0.82	0.38	2.40	0.82	5.00	3.77	2.26	2.36	2.55	2.70
Th	1.87	0.69	0.84	1.14	0.92	4.17	2.77	8.97	5.62	4.36	6.02	6.53	5.52
Total	99.98	99.97	99.96	99.74	99.98	99.51	99.69	100.00	99.62	99.20	99.65	99.64	99.42

* "<dl" = less than detection limit of instrument.

Table 7.2: Chemical composition data for glass beads recovered from Houses I and K at SWP, Alaska.

The elemental analysis results are presented in Table 7.2. The glass beads from SWP all were made with high lime recipes (CaO wt% for all 13 beads: min. = 7.25, max. = 15.30, mean = 9.41, sd = 1.96). These recipes can be further divided into two main glass groups based on the soda (Na_2O) and potash (K_2O) concentrations: high soda-low potash and high potash-low soda (Figure 7.3a; see Annex B). The potash-lime glasses can be further divided into two subgroups based on their alumina (Al_2O_3) and soda concentrations with half having low soda (avg. = 3.2 ± 0.8%) and moderate alumina (avg. = 5.5 ± 2.9%), and half having very low soda (avg. = 0.5 ± 0.2%) and low alumina (avg. = 2.3 ± 1.1%) (Figures 7.3a and 7.3b; Table 7.3). One of the beads (KOV5825) was placed in the low soda-moderate alumina group, despite the fact that its alumina concentration fit better with that of the very low soda-low alumina group. Our choice was influenced by the typology of the bead that had the same color and flattened ends as other beads in that group. This subgroup's lime values also show the greatest variability, with one of the largest ranges and standard deviation. More careful scrutiny of the major, minor and trace elements for this group, however, indicates that with one exception in alumina, most elemental concentrations within the group are relatively similar. Average compositions for the main glass forming elemental oxides were fairly consistent within the very low soda-low alumina potash subgroup. Trace element variation in this group included the lowest strontium values in the collection.

	Soda Lime		Potash Glass	
	n = 1	n = 4	n = 4	n = 4
	White	Blue	Turquoise	Blue, Blue-green, Dark blue
	Hi-Na_Lo-K	Hi-Na_Lo-K	Hi-K_Lo-Na_Mod-Al	Hi-K_vLo-Na_Lo-Al
SiO_2	67.99	67.81	62.80	67.74
Na_2O	10.69	14.27	3.21	0.54
MgO	1.27	1.25	0.28	0.18
Al_2O_3	1.36	0.95	5.48	2.29
K_2O	6.87	4.76	16.04	17.92
CaO	8.78	9.11	10.96	8.31
Fe_2O_3	0.70	0.40	0.20	1.21

Table 7.3: Average chemical compositions by composition group for glass beads recovered from Houses I and K at SWP, Alaska. Concentrations are in wt%.

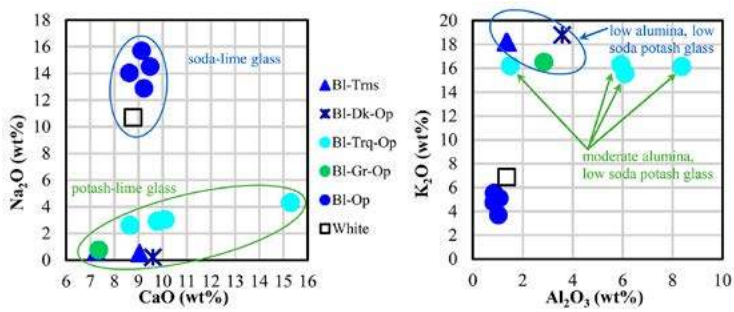

Fig. 7.3: Bivariate plots of soda (Na_2O) vs. lime (CaO) (a), and alumina (Al_2O_3) vs. potash (K_2O) (b) for the 13 SWP glass beads.

The two main glass groups also have very strong color associations; the soda-lime group comprises the lone opaque compound or "cored" white bead (see Sempowski et al. 2000:564) and all four opaque blue beads. An elevated concentration in antimony oxide (Sb_2O_5 = 1.3 %) provides both opacity and coloring for the white bead. Two of the four opaque blue beads in the soda-lime group derive their color from elevated copper concentrations (>1% by wt.), with only trace zinc (Figure 7.4), and all four have modestly elevated levels of cobalt (Co, 52-137 parts per million [ppm]), nickel (Ni, 54-78 ppm), and arsenic (As, 132-180 ppm) as well. The presence of iron (Fe_2O_3), in moderate concentrations (approaching half a percent), also could account for some of the bluish coloring.

The potash subgroup with moderate alumina comprises all opaque turquoise blue beads. Coloring for these beads derives mainly from added copper with elevated zinc contents, likely from brass shavings, although several beads also have elevated iron contents which could contribute to the color as well (Figure 7.4). The low alumina potash glasses comprise both translucent blue fragments, and the opaque blue-green and dark blue beads. The opaque dark blue and two translucent beads share many similarities in their glass recipes, including elevated values for several potential coloring elements/oxides (Figure 7.4). Elevated values for cobalt (the highest of all the beads) indicate some of the blue coloration came from this element, while higher copper and zinc values suggest some blue coloring also came with the possible inclusion of brass shavings, or at the least a copper pigment with high zinc content. The beads in this subgroup containing cobalt also have the highest average barium and cerium values. Manganese present in those same beads might also have been associated with the cobalt ore or pigments like smalt (see for example Giannini et al. 2017; Xia et al. 2019). This could suggest that in this cobalt-colored low alumina potash glass, barium and cerium could have been accidental additives brought in with the cobalt pigment. Based on overall similarity of composition, the two translucent glass bead fragments likely came from the same bead, and if not, from the same production workshop. The opaque blue-green bead seems to have gotten much of its green coloring from its high iron content, although nearly one percent of copper and elevated zinc concentrations, with no cobalt, indicate the potential addition of brass shavings for the blue coloring (Figure 7.4).

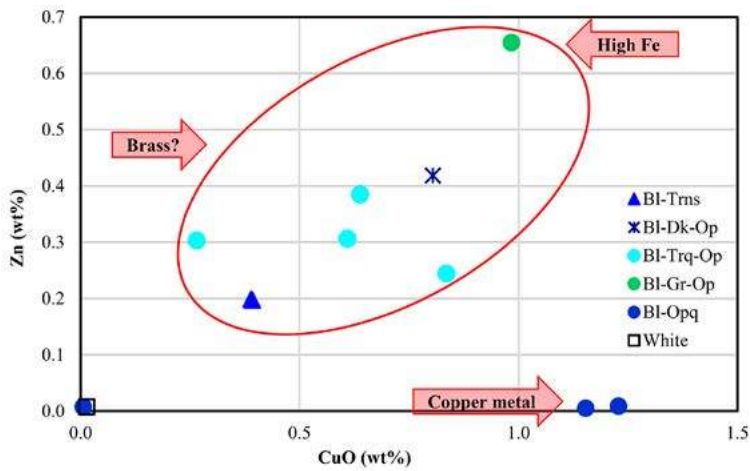

Fig. 7.4: Bivariate plot of copper oxide (CuO) vs. zinc (Zn) for the 13 SWP glass beads.

5. Possible provenance of the beads

5.1. Russia and China

Starting with the potash-lime glasses, we considered two possible origins for these beads: they might have been produced in Russia/Siberia or China. The soda-lime glass beads, discussed later, are more likely European in origin.

Prior to the 18th century CE, Russia relied on import from Europe to procure, among other items, glass beads (Bychkov 1997). The glass technology in use in Russia during the 18th century CE is connected to experiments of two scientists. Mikhail Lomonosov (1711–1765), occupant of the chair of Chemistry at the Academy of Sciences in St. Petersburg, started focusing his attention on glass production around 1750 and directed his research more specifically on potash-lime-silica (K_2O-CaO-SiO_2) and potash-lead-silica (K_2O-PbO-SiO_2) glass compositions from which were manufactured, in a factory located close to St. Petersburg, a variety of glass objects including glass beads (Karlsson 2012).

Lomonosov's successor as chair of Chemistry at the Academy of Science was Erik Laxman (1737–1796) who studied the possibility of substituting salts, including sodium carbonate, instead of wood ash used for production of the potash glasses of his predecessor. In the early 1780s, Laxman relocated to Nertshinsk, a town close to the frontier with China. He advised a nearby glass factory which was trying to set up glass production using soda-based flux, although the production never started. Laxman moved next to Irkutsk and founded, in association with Baranov mentioned earlier for his role in the Russian trade with Alaska, a glass factory at nearby Talzinsk, or now Tal'sy. The sand was brought from 80 km to the north, extracted along the Lake Baikal coast, and the flux was sodium sulphate extracted from a "clay salts" deposit in the vicinity of Lake Baikal (Bychkov 1997; Karlsson 2012). Small drawn beads were produced at this factory although the quality of the production was mediocre with the glass, mostly blue or white, being milky in appearance and its surface pock-marked. The beads were sold to Shelekhov's fur-trading company that would exchange them for furs in Alaska, at least for a period around the end of the 18th century CE (Bychkov 1997).

A few glass samples from the Tal'sy glass factory were excavated in 2009 with support from the National Science Foundation (Award 0939789). This was accomplished by David McMahan, Timothy L. (Ty) Dilliplane, Artur Kharinsky, Yury Lihkin, and Vladimir Tikhonov. They included samples taken from a deposit corresponding to the 18th or very early 19th centuries. The unpublished LA-ICP-MS analysis of these samples, which was carried out in 2021 at the EAF, indicates that they were manufactured from a soda-rich glass that could corroborate the use

of sodium sulfate as a flux (although sulfur was not measured). The glass is also characterized by high alumina concentrations (6-10%), and lime at around 3%. None of the compositions from the Tal'sy factory seem to match the compositions found at SWP, which at this time excludes this factory as the possible place of manufacture of the SWP glass beads (Figures 7.5a and 7.5b). Beyond the Tal'sy glass factory, we looked at other glass compositions in Russia and Siberia around the 18th to 19th centuries CE. Khramchenkova et al. (2017) and Khramchenkova and Sitdikov (2014) published a composition of glass beads and glass containers found in Kazan, Russia, a city located 800 km east of Moscow, showing the switch from potash-based recipes at the end of the 18th century CE to a soda-based one in the 19th century CE. The Kazan glass containers have generally very similar potash and lime concentrations compared to the SWP beads, but alumina is generally low (<1.42%) constituting a good match only for those SWP beads with the lower alumina concentrations. The beads from the same area have generally lower potash (<15%) and higher soda concentrations compared to the SWP beads (Figures 7.5a and 7.5b). Dovgalyuk and Tataurova (2010) published chemical compositions of eleven glass beads from 17th to 19th century sites in the Middle Irtysh area of western Siberia. These glasses divide into four categories: Na_2O–SiO_2, Na_2O–CaO–SiO_2, Na_2O–PbO–SiO_2 and K_2O–CaO–SiO_2. Several of the potash-rich beads have compositions similar to some of the SWP moderate alumina potash beads (Figures 7.5a and 7.5b).

Potash glass also was manufactured in China since at least the second half of the first millennium BCE, and although the recipes evolved through time, potash compositions continued to be used until very recently. Around CE 200, lead was added to potash glass and around CE 1200, a lime-potash composition appeared that was used until the beginning of the 20th century CE (Gan 2009). During the Yuan (1271-1368 CE), Ming (1368-1644 CE), and Qing (1636-1912 CE) Dynasty periods in China, the main glass manufacturer was established in Boshan, Shandong Province. Glass manufactured from this region was produced with fluorite (containing calcium), feldspar (containing alumina) and saltpeter (Curtis 2016), producing a potash-lime glass with relatively high alumina concentrations. This type of glass was produced until the beginning of the Qing Dynasty. Foreign technology was imported to Boshan during that period leading to the development of lower alumina glass with lower viscosity and producing better quality glass (Wang et al. 2016). Comparison with Chinese potash-lime glasses dating from the 14th to the 18th centuries CE offers a reasonably good match for the beads with the highest alumina concentrations (Figures 7.5a and 7.5b). We added to Figures 7.5a and 7.5b the data for 19th century beads found on Sullivans Island (Washington, USA) assumed to be imported from China and

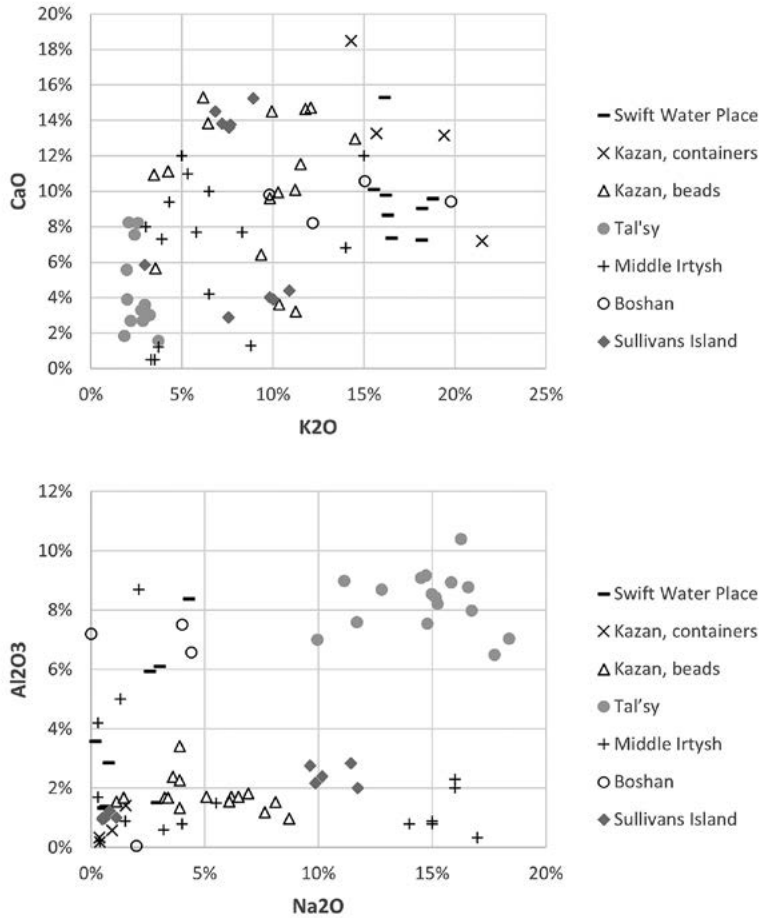

Fig. 7.5: Bivariate comparison plots of soda vs. alumina (a), and potash vs. lime (b) for the SWP potash glass beads and glass samples from contemporaneous sites in Russia/Siberia (Dovgalyuk and Tataurova 2010; Khramchenkova and Sitdikov 2014; Khramchenkova et al. 2017; Dussubieux, unpubl.) and China (Gan 2009: 35). Data from Sullivans Island also was added (Burguess and Dussubieux 2007).

possibly Boshan. A total of 124 beads were analyzed by LA-ICP-MS from that collection of over 56,000 beads and several compositional groups were identified, consistent with beads produced in Bohemia, Venice, and China. The Sullivan Island beads of Chinese origin do not match the SWP bead compositions, which suggests maybe different origins within China or different periods of production. Despite the very low soda-low alumina potash glasses not matching well with

these Boshan glasses, looking at the cobalt used to produce dark blue glass beads belonging to that group reveals an interesting clue for the provenance of this glass. The higher cobalt concentrations are accompanied by higher barium and cerium concentrations. In earlier potash glass widely spread in China, Southeast and South Asia, and possibly manufactured in China, higher cobalt concentrations are often accompanied by higher concentrations of barium and cerium among other elements (Dussubieux 2001: 171).

5.2. Europe

The SWP soda-lime glass was compared to European material as soda-lime composition characterizes glass beads produced in western Europe during the late Historic period (e.g., Dussubieux and Gratuze 2012; Dussubieux and Karklins 2016). Glass beads produced in Europe were widely traded to North America during the colonial eras of the 15th through 19th centuries CE, with Spanish, French, Dutch, and English traders sourcing beads from various glass workshops around the European continent. Considerable efforts have been made to examine European glass trade beads in the Great Lakes and Northeastern (e.g., Hancock et al. 1994, 1997, 2000; Hancock 2013; Walder 2018) regions of North America dating from the 16th and 17th centuries CE. Those efforts have demonstrated that most glass beads sourced from Europe at that time are generally soda-lime glasses, though wire-wound high potash and lead-silica glasses also were present. A few blue soda-lime glass beads from Alaska dating to this early period have recently been published, but the precise dating of their archaeological context (either late 16th or early 17th century) is in question (Kunz and Mills 2021; c.f. Blair 2021).

Comparatively fewer glass beads from later contexts of the 18th to 19th centuries CE have been subjected to elemental analyses (but see Shugar and O'Connor 2008; Panich et al., this volume). Rarer still are beads from archaeological contexts of that period in Alaska or western Canada. One batch of analyzed beads dating from the late 18th to late 19th centuries originated from the Sullivans Island site in Washington state (Burgess and Dussubieux 2007). The reduced average compositions for the SWP opaque blue beads (high soda-low potash group) compare very well with similar data for Venetian beads from the Sullivans Island site (see Burgess and Dussubieux 2007: 63, Table 3).

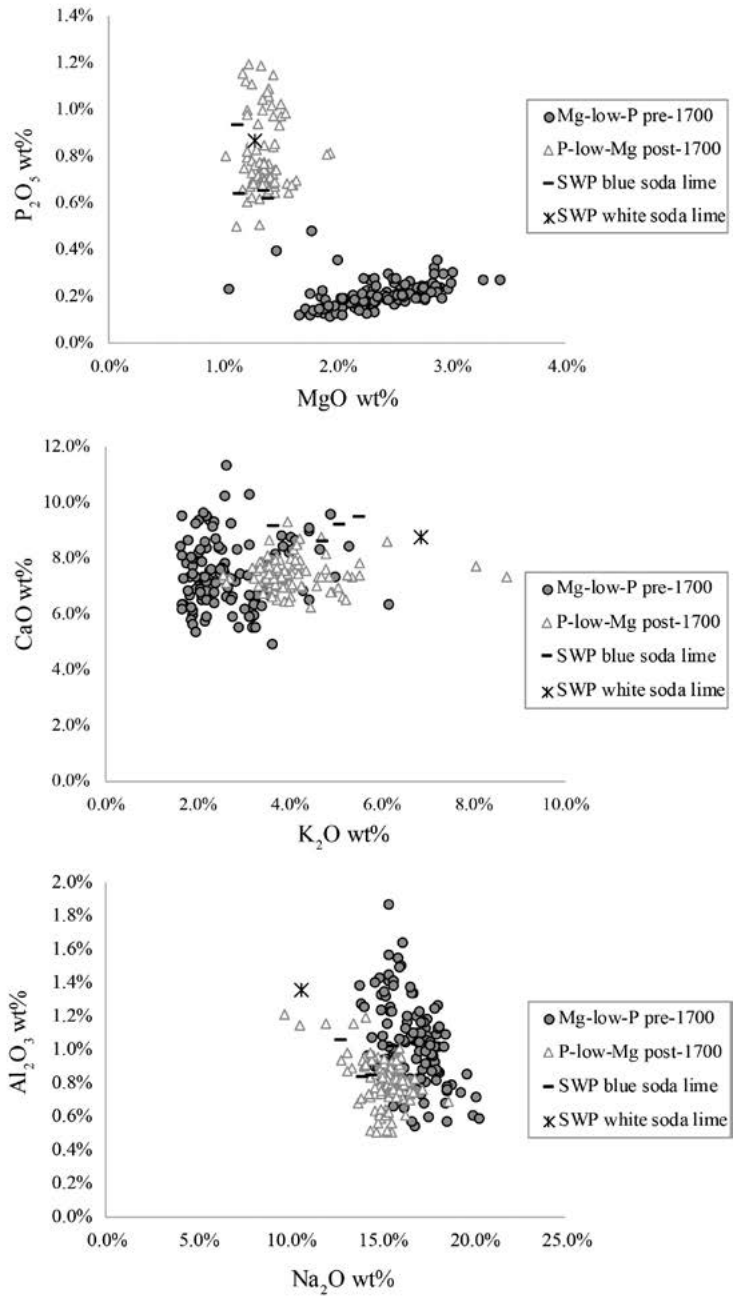

Fig. 7.6: Bivariate comparison plots of magnesium oxide versus phosphorous oxide (upper plot), potash versus lime (middle plot), and soda versus alumina (bottom plot) for the 13 SWP glass beads with the copper-colored beads in the dataset from Walder 2018.

Walder (2015, 2018) has analyzed beads from 18th century contexts related to French and subsequent British trade in the Great Lakes region and identified two temporally-sensitive subgroups of drawn blue soda-lime glass beads: a pre-CE 1700 manganese-low phosphorus (Mg-low-P) group and a post-CE 1700 phosphorus-low manganese (P-low-Mg) group. These subgroups are a consistent temporal pattern in both copper-colored and cobalt-colored blue beads, and the pattern persists in white beads also (Walder and Noël 2021). The post-CE 1700 sites, where beads predominantly of the P-low-Mg subgroup were recovered, range in age from ca. CE 1680 to 1781, and are best represented at the sites of Fort St. Joseph (20BE23) and Fort Michilimackinac (20EM52) in Michigan, and at Doty Island (47WN30 and 47WN671) and later components (Periods 3b/4) of the Rock Island (47DR128) site in Wisconsin (Walder 2018: 321). While these comparative sites range in occupation slightly earlier than the probable dates for SWP, they overlap in the 18th century, and the five soda-lime beads from SWP fit comfortably within the P-low-Mg post-CE 1700 subgroup for beads colored with copper (n=104) from Great Lakes sites (Figures 7.6a-c). Calcium, potassium, aluminum, and sodium are also consistently more similar to the post-CE 1700 copper-colored blue glass bead Great Lakes subgroup. Not surprisingly, the white bead's overall composition is less similar to the P-low-Mg subgroup than the IIa31 blue beads from SWP, since the subgroups were defined using only blue beads, not white ones. Regarding the white bead, a chronology of white opacified glass beads established by Sempowski et al. (2000) indicates that antimony-based white opacified beads were dominant in European trade from the end of the 17th century to the end of the 18th century CE. See Panich et al. (this volume) for additional discussion of 18th century CE white compound beads of this type.

Based on these comparisons, it seems that the five SWP drawn soda-lime glass beads likely were produced in European workshops. The mechanism of their arrival and ultimate deposition at the SWP site is unclear, but it seems most plausible through a series of down-the-line exchanges. Their consistency with the P-low-Mg post-CE 1700 subgroup identified in beads from sites around the Great Lakes, however, may suggest that they moved through internal networks from eastern North America into Canada and ultimately to Alaska.

6. Conclusion

Elemental analyses of 13 whole and fragmentary glass beads from the site of Igliqtiqsiuġvigruak (Swift Water Place), Alaska, revealed several new important patterns. First is that even within the small sample of beads analyzed, there are at least three different chemical composition groups identified, and possibly more

subgroups. Some of the compositional groups fall squarely along color and/or stylistic boundaries observed in the beads.

When compared to other compositional datasets from contemporary beads found in the same region and further away, some possibilities for provenance of the SWP beads emerge. Some SWP potash-rich beads share similarities with beads from China and with beads from Russian/Siberian sites. Other SWP beads, in the soda-lime recipe group, are more like European-made beads, particularly those from France and Venice, as are some other beads found at the Siberian sites. Peter Francis notes that Russian traders, many of whom were barred from major Chinese ports at this time, often purchased beads along the southern Mongolian border, and in fact some were taken from there onto expeditions to Alaska (Francis 2002: 67). During the early phases of Russian settlement in the Alaska frontier, many of these beads would have been exchanged for furs and foodstuffs essential to the Russian fur traders (Gibson 1976).

The location of several glass factories in the Irkutsk region, the connection of Baranov with those factories, and Baranov's links both to Irkutsk and Alaska, provide support for inferring the trade of glass beads from Siberia to Alaska. Likewise, the proximity of Boshan to Irkutsk and the 17th- and 18th century trade connections between these locations (Peking [Beijing] and Irkustk) suggest that the structure and mechanisms for exchange were already in place at the inception of the fur trade in Alaska. While there are not apparent direct links, based on compositions, to the Tal'sy factory near Irkutsk, this area still could have acted as a conduit, drawing beads and other items from the East (e.g., from Europe), through Russia and western Siberia. Likewise, the Boshan glass beads could have been traded north into Siberia and subsequently to Alaska, also potentially mapping onto the Irkutsk-Alaska trade network.

As for the beads of likely European origin, these could have moved up the west coast of North America during the 18th century, moving through colonial and Indigenous contexts along extant trade routes, or spread to what is now Alaska via multiple down-the-line connections in the Great Lakes region and eastern North America. Regardless, the inhabitants of Igliqtiqsiuġvigruak (Swift Water Place) were connected via multiple networks of exchange, comprised of various mechanisms of transport, as were many of the contemporary Native populations in Alaska in the 18th and 19th centuries CE.

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Part II

Glass Beads in South and Southeast Asia

Chapter 8

The exchange of beads in Central Thailand in the protohistoric period: Glass objects from Phromthin Tai

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1. Introduction and background

Phromthin Tai, sometimes spelled Promtin Tai, is a multi-component site located in Central Thailand, about 20 km from the provincial capital of Lopburi (Figure 8.1). The Thai Fine Arts Department undertook a small excavation in 1991, which uncovered prehistoric and Early Historic period artifacts. Since 2004, Dr. Thanik Lertcharnrit from the Department of Archaeology at Silpakorn University has led frequent excavations at the site (Lertcharnrit 2006). These more recent studies show evidence for habitation from the late Bronze Age period (approx. 700 BCE) through the mid-late first millennium CE or Dvaravati period (Lertcharnrit 2014). The most intensive habitation at the site dates to the Iron Age or protohistoric period (approx. 500 BCE – 500 CE) and in 2007 a cemetery was uncovered (PTT-S3) containing 36 individuals in 35 burials (Liu 2012). Although comprehensive radiocarbon dating of the burials has not yet been undertaken, burials can be divided into Earlier and Later Iron Age periods (Liu 2018, see Table S8.1 for details on the beads and their contexts). While beads were common throughout the cemetery matrix only 12 burials, which primarily dated to the Earlier Iron Age period, contained stone and glass beads as grave goods and of these just eight contained glass beads. Five subsequent field seasons between 2009 and 2019 have uncovered a further 34 burials from unit PTT-S4, although these burials have fewer beads than the S3 burials.

The protohistoric period was a time of great change in Southeast Asia. It is during this period that contact with South Asia began, as evidenced by South Asian products appearing in Southeast Asian archaeological sites, especially burials

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(Bellina and Glover 2004). Glass and stone beads are one common marker of this period across Southeast Asia (Bellina 2003). While early scholars assumed beads were largely imported as finished products, excavations in peninsular Thailand and Myanmar demonstrate the presence of stone and glass jewelry workshops using both local and South Asian beadmaking techniques to produce beads and ornaments for local markets (Bellina 2014, 2018; Dussubieux et al. 2020). Analysis of glass and stone beads has demonstrated that there was a great diversity of bead types in circulation, which represented different manufacturing, trading, and interaction networks both within Southeast Asia and between South Asia and Southeast Asia (Bellina 2014; Bellina and Glover 2004; Carter et al. 2021; Carter 2015, 2016; Dussubieux and Bellina 2018; Dussubieux et al. 2020; Lankton and Dussubieux 2013).

Several studies have noted differing intensities of interaction with South Asia, with an earlier period dating to the late first millennium BCE that was less intense but circulated higher-quality imported goods and a later period dating to the early-mid first millennium CE in which interaction was more frequent and contained higher quantities of mass-produced or lower-quality goods (Bellina and Glover 2004). These changing interaction networks extended to the exchange of beads, which saw differing types and qualities of beads moving on different networks within mainland Southeast Asia (Bellina 2003; Carter 2015). An earlier South China Sea exchange network connected sites primarily on the coasts or with coastal connections and especially circulated potash glass (Bellina 2014; Carter 2015; Hung et al. 2013). A later network circulated larger quantities of glass beads, largely made from high alumina mineral soda glass, connecting sites farther inland via the "Mekong Interaction Sphere" (Carter 2015; Carter et al. 2021).

Located in central Thailand near a highly productive copper mining and bronze-working region (Pigott 2019), the community at Phromthin Tai was well-suited to participating in interaction networks with communities in the north, east, and west (Lertcharnrit 2014). Previous studies of glass beads in mainland Southeast Asia have largely focused on Cambodia and northeast Thailand (Carter 2015; Carter and Lankton 2012), peninsular Thailand (Dussubieux and Bellina 2018; Lankton et al. 2008b), and most recently Myanmar (Dussubieux et al. 2020; Dussubieux and Pryce 2016). An analysis of beads from Phromthin Tai fills a geographic gap in our knowledge regarding the circulation of beads in this region. The goal of this study was to determine the types of glass beads and objects found at the site and begin connecting Phromthin Tai to existing glass exchange networks. In doing so, we aim to elucidate Phromthin Tai's place within these regional systems.

Fig. 8.1: Map showing the location of the Phromthin Tai site.

2. Materials

This chapter reviews the results of analyses of 63 glass artifacts, primarily beads, recovered from burial contexts (Figure 8.S1-S3). Carter recorded over 1000 glass and stone beads, of which approximately 960 were glass, from the 2007 excavation as part of her PhD dissertation research (Carter 2013). From this collection, 23 glass objects were analyzed using laser ablation - inductively coupled plasma - mass spectrometry (LA-ICP-MS) to represent the diversity of glass bead types found at the site. In addition to Carter's study, Dussubieux undertook analyses of an additional 25 glass objects provided by Dr. Lercharnrit. Of these, all but three objects were from Late Iron Age layers (1900-1500 before present [BP]) from the PTT-S3 unit. One sample (LAP020) is from an older Iron Age layer (2500-2000 BP) in PTT-S3 and two samples (LAP018 and LAP019) are from older Iron Age

layers (2500–2000 BP) in PTT-S4. A final group of 15 glass objects was selected and analyzed by Fenn, all from the PTT-S3 unit. Most of the glass beads in this study were drawn glass beads, sometimes called Indo-Pacific beads (Francis Jr. 1990), that are common across the ancient world and especially Southeast Asia. However, some additional unusual bead types as well as bangle and earring fragments were also examined. Analyses were undertaken in the Elemental Analysis Facility at the Field Museum in 2010, 2014, and 2018 (see discussion of analytical methods in Annex A).

3. Results

Results show four well defined glass groups including:

— 27 samples with a high potash composition
— 20 soda-rich samples with potash concentrations higher than 1.5% and high alumina concentrations
— 9 soda-rich samples with potash contents generally lower than 1.5% and rather high but variable alumina concentrations
— 3 more beads are soda-rich with potash concentrations lower than 1.5% and alumina level rather low
— 2 beads have a soda-potash mixed composition
— finally, three beads have a composition that might be explained by the sampling of weathered glass.

3.1. Potash glass

Potash glass is distinguished by its high levels of potash (approximately 15%) with low magnesia and soda concentrations (see Annex B). Several sub-types of potash glass were in circulation in Southeast Asia during the Iron Age period, with varying levels of alumina and lime (Carter 2016; Dussubieux 2016). These different sub-types suggest the presence of multiple workshops, although the exact locations are still unknown. Possibilities include Southeast Asia (Dussubieux and Pryce 2016; Dussubieux 2016; Lankton et al. 2008a) or China (Li 1999; Lin et al. 2019; Liu et al. 2015).

Twenty-seven beads in this study were assigned to the potash glass group with two sub-types represented (Figure 8.2; Table S8.1). Based on visual similarities with other beads examined and the contexts in which beads were found, Carter projected that there were an additional 61 potash glass beads within the 2007 burial contexts, with more possible examples from the cemetery matrix. Based on these estimates, approximately 29% of the glass objects found in burial contexts during the 2007 season could be made from potash glass. However, when considering

the overall assemblage from the PTT-S3 unit, including beads from the cemetery matrix and non-burial contexts, potash glass is estimated to make up only 17.5% of the total collection (Carter 2013).

All but one of the objects had alumina levels between 2-6% and lime levels of less than 1.5%, placing it in the low Ca-high Al potash glass sub-type. Two of these were translucent green fragments (LAP018 and LAP019) of a bangle or bracelet with a rectangular cross-section, similar to the Type E bangle type identified at Khao Sam Kaeo (Dussubieux and Bellina 2017: 557), and the remaining objects were drawn beads. Most beads (n=20) were various shades of blue; dark blue beads were colored with cobalt (approx. 300-500 ppm) while lighter blue or turquoise beads were colored with copper (approx. 1.25-3%). Two beads (LAP015 and LAP021) were opaque yellow and had elevated levels of lead (25-34%) and tin (3-5%) suggesting the use of lead-stannate as a yellow opacifier (Turner and Rooksby 1959). The violet bead (AKC01073_violet) was seemingly colored with manganese (3.3%), a common colorant in purple glass (Degryse and Shortland 2020). The sole colorless glass drawn bead (AKC00909) did not have elevated levels of any common decolorants and may be related to furnace conditions (Degryse and Shortland 2020; Henderson 2013). Low Ca-high Al potash glass is not uncommon in Southeast Asia, having been identified at sites in Myanmar (Dussubieux and Pryce 2016; Dussubieux et al. 2020), Vietnam (Lankton and Dussubieux 2006) and Cambodia (Carter 2013; Gratuze 2013).

One bead had a high Ca-low Al composition (LAP017). This bead was a colorless drawn faceted bicone, an unusual shape in South and Southeast Asian glass bead assemblages. As with the other low lime potash bead, there were not elevated levels of any elements to account for the coloring of this bead. High lime potash glass is comparatively rare in Southeast Asia and is usually associated with earlier periods (4th-3rd century BCE), especially the site of Ban Don Ta Phet, Thailand (Dussubieux 2016; Lankton et al. 2006) where several colorless beads with a similar composition were found (Dussubieux, unpublished results). Recent isotopic studies on potash glass beads from Myanmar indicate that this glass type has a distinctly different strontium and neodymium isotopic signature than the other potash sub-types (Dussubieux and Pryce 2016).

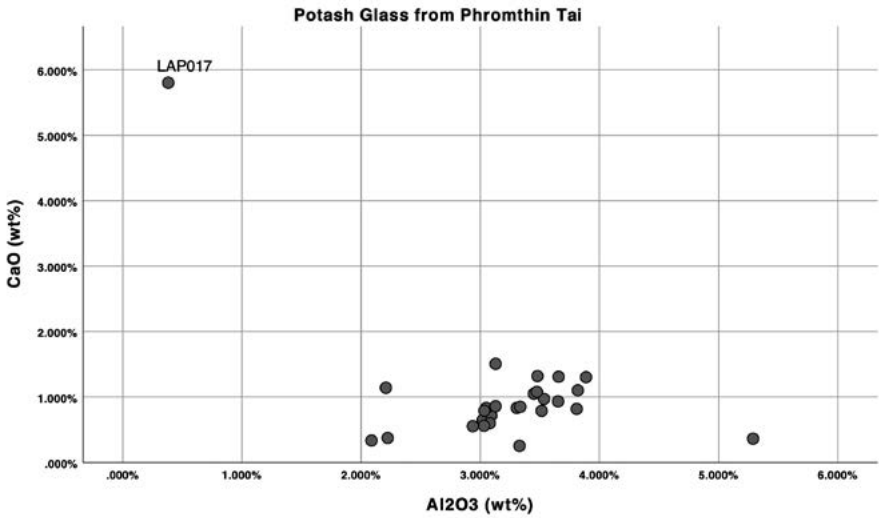

Fig. 8.2: Biplot of potash glass from Phromthin Tai showing the concentrations of alumina and lime. Most of the beads were low Ca-High Al potash glass, while one bead (LAP017) has a high lime concentration.

3.2. Mineral soda glass

The next major glass type found at Phromthin Tai were glass beads with high concentrations of soda (approx. 10-22%) and magnesia generally less than 1.5%, classifying them as a type of mineral soda glass. Within this group were two major sub-types: beads with high concentrations of alumina (5-12%), a common glass type known as mineral soda alumina glass (m-Na-Al), and those with moderate amounts of alumina (approx. 3-5%) and lime (approx. 4-8%) (m-Na-Ca-Al) (see further discussions in Annex B). In Carter's initial study of the PTT-S3 cemetery, it was estimated that 65.5% of the total glass assemblage consisted of m-Na-Al glass beads, but only a small number of these were found in burial contexts (approximately 3% of the assemblage), with the remaining amount having been found in the upper layers of the cemetery matrix (Carter 2013). In contrast, the m-Na-Ca-Al glass group was estimated to have made up only 12.4% of the total assemblage, but represented approximately 43% of the beads found in burial contexts (Carter 2013).

3.2.1 High alumina mineral soda glass (m-Na-Al)

Twenty drawn glass beads and one bicolor glass bi-cone belonged to the m-Na-Al glass group. Notably, there are multiple glass sub-groups within this group that correspond to different workshops, time periods, and geographic locations (Dussubieux et al. 2010). Of relevance to this study are four groups that have been found in Southeast Asia; we also include a newly described group identified in East and South Africa. The m-Na-Al 1 sub-group is widespread in South and Southeast Asia at sites dating from approximately the 4th century BCE to the early 2nd millennium CE (Carter 2016; Dussubieux and Allen 2014; Dussubieux et al. 2010). The m-Na-Al 2 sub-group has been found at sites in Africa, the western coast of India, and Southeast Asia at sites dating to the 2nd millennium CE (Dussubieux et al. 2010; Dussubieux et al. 2008; Dussubieux and Soedewo 2016; Carter et al. 2016; Carter et al. 2019). The m-Na-Al 3 sub-group has only been found at a limited number of sites in Southeast Asia, primarily peninsular Thailand, as well as northern India dating to the late centuries BCE (Dussubieux and Bellina 2018; Dussubieux and Kanungo 2013; Lankton et al. 2008a). The m-Na-Al 4 sub-group has also been found in later 2nd millennium CE sites in Southeast Asia as well as eastern Africa (Carter et al. 2016; Dussubieux 2009; Dussubieux et al. 2008; Dussubieux et al. 2010). The newly identified m-Na-Al 6 sub-group is close in composition to the m-Na-Al 2 sub-group, and has been found at sites that date from the 9-13th centuries CE, while the m-Na-Al 2 type dates to the 14th century CE onward (Dussubieux and Wood, 2021).

These sub-groups can be distinguished from one another via a principal component analysis (PCA) using the oxides and elements MgO, CaO, Sr, Zr, Cs, Ba, and U (Dussubieux et al. 2010). Beads from the Phromthin Tai site were compared to m-Na-Al 1 unpublished beads and objects from South India and Sri Lanka, m-Na-Al 2 beads from Chaul, India (Dussubieux et al. 2008), m-Na-Al 3 glass from Kopia, India (Dussubieux and Kanungo 2013), m-Na-Al 4 glass from Kuta Kareueng, Sumatra (Dussubieux 2009), and m-Na-Al 6 glass from Juani Primary School, Mafia Island, Tanzania (Dussubieux and Wood 2021). Although the timing of the Phromthin Tai site made it most likely that only m-Na-Al 1 or m-Na-Al 3 glass would be present, samples from the later m-Na-Al groups were included to determine if any of the beads might have been intrusive or bioturbated from upper layers.

Figure 8.3 displays a biplot of the first two components accounting for approximately 80% of the variance. The majority of the beads are most compositionally analogous to the m-Na-Al 1 sub-type. The m-Na-Al 1 beads came in a variety of colors, including an opaque red, orange, yellow, green, and black, and translucent turquoise blue. This glass type is amongst the most common and

widespread found in glass beads across Southeast Asia dating to the late centuries BCE and into the first millennium CE (Carter 2016; Dussubieux et al. 2010). The blue beads are colored by copper (0.7-1.5%) and the yellow opaque beads have elevated concentrations of lead (approx. 3-4%) and tin (approx. 0.5-1%) pointing towards the use of lead stannate as a colorant. Previous studies have observed that opaque red, black, and orange beads in this sub-type typically have elevated levels of copper, magnesia, lime, iron, and phosphorous related to their coloring (Dussubieux et al. 2011; Dussubieux et al. 2010). This is true for the beads in this collection, with the orange beads especially having high concentrations of MgO (approx. 1-3%). The presence of higher concentrations of magnesia, often combined with higher concentrations of phosphorus and lime for specific colors, was noted for other types of glass (e.g., natron glass) and was interpreted as resulting from the introduction of fuel ash to the glass melt, that in the case of copper orange glass could have been intentional to create a reducing environment to more easily obtain cuprite (Schibille and Freestone 2013). One opaque orange bead (LAP024) plots away from all known m-Na-Al groups and is notable for a high concentration of Cs; it is currently unclear why this bead is compositionally distinct.

The black and white bi-cone bead (AKC01043) is unique and may have been imitating agate beads (Francis Jr. 2002: 94-95). The opaque black glass base (AKC01043b) plots with the m-Na-Al 1 glass in the two-dimensional biplot, however it is notable for elevated levels of magnesium perhaps related to the coloring of the glass (Dussubieux et al. 2011; Lankton and Dussubieux 2006: 133-134), as well as high Cs, and lower U and Ba concentrations unlike other m-Na-Al 1 glass. The white stripe (AKC01043w) appears to sit on the surface of this glass and its composition is unusual; low levels of Na_2O suggest it was likely corroded.

One glass object (PTT02), a blue-green translucent chunk or bead fragment was assigned to the m-Na-Al 3 group. This glass type is strongly associated with early (4th – 3rd century BCE) glass bead production workshops located in peninsular Thailand and northern India at the site of Kopia (approx. 1st century AD) (Dussubieux and Kanungo 2013; Kanungo 2010; Lankton et al. 2008a). Elevated levels of copper in this sample (1.4%) likely account for its greenish color and indicate a direct connection to northern India rather than a connection with the 4th – 3rd BCE sites of peninsular Thailand that exclusively yielded opaque red and black and transparent greenish (colored naturally by the presence of iron) glass. A larger range of colors is available in northern India.

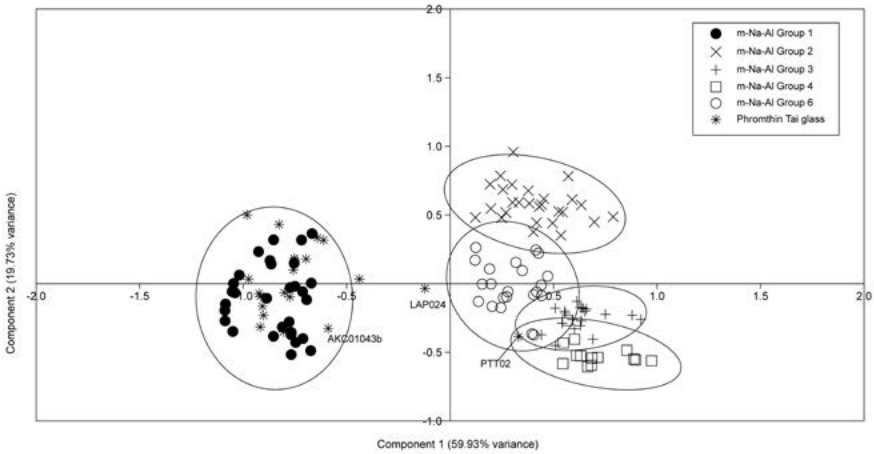

Fig. 8.3: A PCA of beads from Phromthin Tai and different groups of m-Na-Al glass.

3.2.1 Mineral soda glass with moderate amounts of alumina and lime (m-Na-Ca-Al)

Nine beads were assigned to the m-Na-Ca-Al group; all were drawn glass beads in dark blue, red, and black or dark green colors. This glass type frequently overlaps with the m-Na-Al type, but can be distinguished using a PCA of Na, Al, Rb, Zr, La, Hf, and Th (Dussubieux and Gratuze 2010) (Figure 8.4). The dark blue beads, seemingly the most common color of this glass type, were colored with cobalt (approx. 850-1200 ppm), while the opaque red bead had elevated concentrations of copper (1.4%) and iron (1.6%). The black bead also had elevated iron (1.7%). Although the dark blue potash glass and m-Na-Ca-Al dark blue beads looked similar to one another, the m-Na-Ca-Al beads tended to be slightly smaller (2.5-5 mm) than the potash glass beads (4-5 mm), with a deeper cobalt blue color.

This glass type shares a compositional similarity to a type of glass produced at Arikamedu, south India, called Arika glass, although it is distinct enough to be classified separately (Dussubieux and Gratuze 2013; Dussubieux et al. 2012; Lankton and Dussubieux 2013). Although seemingly related to Arikamedu glass, its production center is currently unknown, although one possibility is the site of Khlong Thom in peninsular Thailand, where it was found in large quantities (Lankton and Dussubieux 2013) and Phu Khao Thong where there is evidence of this glass having been worked (Dussubieux et al. 2012). Glass beads made from m-Na-Ca-Al glass have been found at numerous sites in mainland Southeast Asia dating from the late centuries BCE to the mid-first millennium CE, suggesting that its production was long-lived and well-circulated (Carter 2016; Dussubieux et al. 2020; Lankton and Dussubieux 2013).

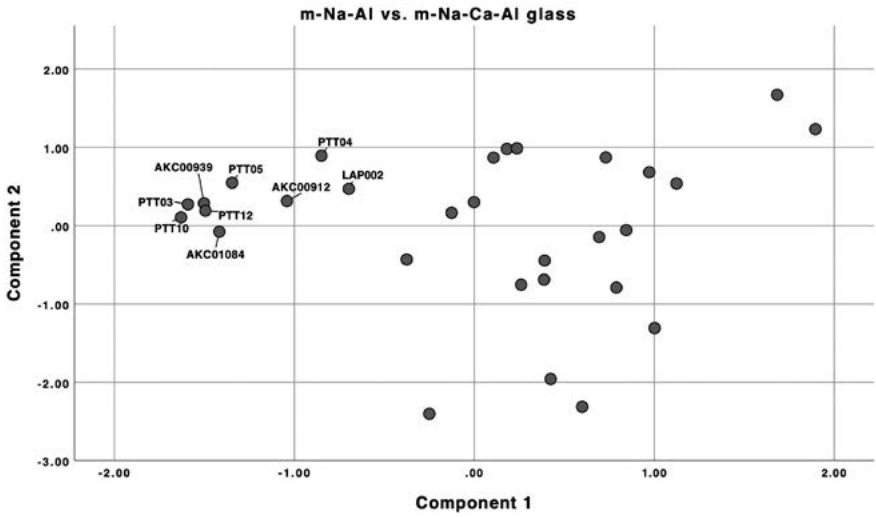

Fig. 8.4: Scatterplot of first and second components of a PCA to distinguish between m-Na-Al 1 and m-Na-Ca-Al glass accounting for 71.7% of the variance. The m-Na-Ca-Al glass beads are labeled.

3.3. Less common glass types

A small number of more unusual glass types were also identified in the Phromthin Tai assemblage. Three gold-glass beads were found in Burial 20. These small beads were originally segmented, and later broken into individual beads leaving a spherical bead with a jagged protrusion around the bead hole. One bead (AKC01057) was analyzed as part of the current study and found to be made from a soda-lime glass, typical of Mediterranean glasses made with a natron flux. The diffusion of this type of bead covers a huge area from Europe (Boon 1977) to Japan (Tamura and Oga 2016). Gold-glass beads were believed to have been imported from Egypt and the Mediterranean to India. Segmented gold-glass beads were found at the port site of Pattanam in Kerala, south India, and correspond mainly to contexts dating from the 3rd century BCE to the 3rd century CE (Abraham 2021). From India, those beads were traded into Southeast Asia. Recently, 43 gold-glass beads including segmented ones, with a composition originating from Egypt, were discovered at Pangkunk Baruk on Bali Island, a site dated from the 2nd to 4th century CE (Calo et al. 2020). Gold-glass beads also were found at the sites of Oc Eo, Vietnam, Kuala Selinsing, Malaysia, Ban Tha Kao, Thailand, and even Guangzho, China (Francis Jr. 2002; Lankton and Dussubieux 2006). Similar gold-glass beads have been reported at Khlong Thom and analysis indicates

they were also made from a Syro-Palestinian or natron glass (Lankton and Dussubieux 2013).

Two black beads with three white stripes, one complete and one broken, from Burial 20 appear to be imitating a striped agate bead (AKC01059) (Francis Jr. 2002: 94-95). Both the black and white portions of the broken bead were analyzed and found to be the same unusual glass type: a variety of potash glass with high levels of soda. Only a few other beads have been identified with a similar composition, including a blue-green glass bead from Ban Don Ta Phet and beads from southern India and Sri Lanka (Lankton and Dussubieux 2006: 139). It has been suggested that this high soda potash glass is a mixture of potash glass and Arikamedu glass, and that this particular glass type may have been made at Arikamedu (Lankton and Dussubieux 2006: 140).

A group of three collared white faience beads were found in Burial 18 and one bead was selected for analysis (AKC01093). This particular type of faience bead is fairly common at south Indian sites, including Arikamedu (Francis Jr. 2004: 510). In Southeast Asia, collared faience beads have also been found at Ban Bon Noen in central Thailand (Pilditch 1992). Pilditch reports that a blue-green glaze was visible on some of the faience beads from Ban Bon Noen under a microscope, however the Phromthin Tai beads appear to be unglazed. Due to their ubiquity at south Indian sites, Peter Francis Jr. (2004: 511) has speculated they may have been manufactured there. Unfortunately, the faience bead from Phromthin Tai was corroded making its original composition difficult to determine.

Lastly, there were three glass objects that were too weathered to obtain an accurate composition. One bead was analyzed from a group of 13 small black tubular beads that were identified in Burial 6 (AKC01022). This bead was quite curious in that it had high levels of alumina (16%) and iron (5%). The weathering and corrosion make further interpretation of this bead impossible at this time. The second object was an earring/ring fragment made from turquoise blue glass from Burial 7 (AKC00901). Although too corroded to determine the recipe, it appears similar to other turquoise glass ring/earring fragments from Phum Snay that were classified as potash glass (Carter 2010). Lastly, a colorless transparent glass chunk (PTT02) was also found to be too corroded to accurately determine its original composition.

4. Conclusion

Phromthin Tai's diverse glass collection demonstrates that this community participated in several bead exchange networks over the course of its long occupation. The predominance of potash glass beads in burials suggests people

at this site were connected to the larger South China Sea bead exchange routes during the early Iron Age that also included coastal sites in peninsular Thailand, as well as Sa Huynh and Dong Son sites in Vietnam, the Samon Valley and peninsular Myanmar, and southeast Cambodia (Carter 2015, 2016; Dussubieux et al. 2020; Dussubieux 2016; Lankton and Dussubieux 2013). Several unusual beads are similar to beads found largely in peninsular Thailand, such as those made with m-Na-Ca-Al glass, gold-glass beads, and faience and imitation agate beads, signifying a trade relationship with these communities or that they were part of the same trade network(s). The presence of numerous high alumina mineral soda glass beads in the cemetery matrix and upper layers indicate that people at this site maintained regional connections as bead exchange networks shifted in the early first millennium CE and exchange within the Mekong Interaction Sphere expanded (Carter et al. 2021). Lankton and Dussubieux (2013) had previously suggested the shift from potash to high alumina mineral soda glass took place between 200 BCE-200 CE, based on a lack of potash beads in cemetery layers at the site of Angkor Borei, Cambodia. Burial 20 at Phromthin Tai is especially important in this regard, as it contained both potash glass and m-Na-Al 1 glass and may help date the transition or overlap between these two exchange networks within mainland Southeast Asia (Carter 2015). Further investigations at this site would likely go far in helping to date these changing bead networks and filling a gap in understanding regional exchange networks across mainland Southeast Asia during the Iron Age period.

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Chapter 9

Shifting patterns of glass bead cargo of 15th – 17th century Philippines shipwrecks

Jennifer Craig[1] and Laure Dussubieux[2]

1. Introduction

Beads archaeologically excavated from Philippines islands are recognized as foreign products, but where they came from is still not clear. The main possibilities are that glass in Southeast Asia was produced within the region or from the wider Indian Ocean world including locations such as India and China (Craig 2021; Francis 2002; Junker 2018). Datasets for glass manufacture do exist for India (Dussubieux 2016; Dussubieux et al. 2010, 2012; Dussubieux and Kanungo 2013; Dussubieux and Gratuze 2013) and China (Henderson et al. 2018). Recognizing the Philippines is an archipelago with over 7000 islands, watery environments were certainly the mode of transportation (Pham et al. 2021); this study investigates what we know of glass bead shipment, using compositional analysis as a method of comparing glass recipes. With reference groups of possible production centers available for comparison, representative samples of glass cargo were selected from three shipwrecks excavated along the coast of the Philippines: Pandanan, Santa Cruz and Royal Captain Shoal wreck 2. All three shipwrecks are named after nearby geographic place names.

In Southeast Asia, it is more common to use ceramic seriation than compositional analyses to characterize a shipwreck cargo; ultimately the chronological and distribution information from ceramics recreates ancient exchanges. The 15th to early 16th century CE Chinese junk known as the Brunei shipwreck is an exception; glass cargo patterns are considered in tandem with ceramics, amongst other cargo, to better understand shipment (L'Hour 2001a, 2001b). This is an example of employing more holistic perspectives to cargo; by analyzing and comparing artefacts, ancient exchanges are enriched and customized (see Carter et al., Chapter 2, this volume). This paper presents the results of compositional

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analysis of 85 glass beads that were excavated, in some cases within ceramic jars, from three Philippines shipwrecks (Table 9.1). We return to this association of glass and ceramic jars in our discussion later.

In this chapter we draw upon three resources to address our question of glass bead provenance in the Philippines: 1) published ceramic cargo patterns in all three shipwrecks, which were used to date each site; 2) observations of glass cargo patterns within the three shipwrecks used as case studies here; and 3) the chemical compositions of glass that were on board the shipwrecks. Combining evidence from ceramics and glass cargo, we compare chronological and distribution information. These comparisons are contextualized with contemporaneous regional affairs to recreate ancient exchanges.

2. Three shipwreck archaeological sites

An excavation was conducted in 1996 at the northeastern section of Pandanan Island, southern Palawan (Dizon 1996) on a shipwreck with a Chinese-Vietnamese hybrid hull (Dizon 1996b:11; Orillaneda 2016a:85, 2016b:43). The site date range was derived from late 15th century Chinese and Vietnamese ceramics and a Chinese Yong-Le (1465–1487 CE) copper coin (Dizon 1996b; Orillaneda 2000). Other cargo on board included stone implements, metals (e.g., iron caldrons, bronze gongs, firearms, bronze cannons) and glass and carnelian beads (Brown 2004; Cayron 2006:29; Dizon 1996a: 66; Orillaneda 2000, 2016a). For this study, representative samples of 28 black and 13 red glass beads were analyzed with LA-ICP-MS.

In 2003 an excavation off Santa Cruz Island, close to Zambales of Luzon (Orillaneda 2003), was conducted on a shipwreck hull identified as a hybrid South China Sea Shipbuilding Tradition (Goddio et al. 2014:8, 10; Orillaneda 2003; Orillaneda 2012, 2016a, 2016b). The shipbuilding technique is seemingly Chinese but the materials are from the Southeast Asia archipelago (Orillaneda 2016a). Pointedly, scholars surmise the ship was built by Chinese diaspora in the Philippines (Goddio et al. 2014:8, 10; Manguin 2001:15) or Thailand (Flecker 2005; Orillaneda 2016b). The site date range was derived from Chinese, Burmese, Thai and Vietnamese porcelain and stoneware jars of the late 15th century (Dizon 2003). Alongside these ceramics were a variety of other materials: tin, copper and iron ingots from the Malaya Peninsula or eastern Sumatra, cast iron bowls, ship-used cooking iron cauldron and plate, net weights and weighing scales, bronze gongs, brass and copper spiral bracelets, bronze cannons, metal box, bronze crown, three corroded Chinese coins (Fahy 2014; Goddio et al. 2002; Orillaneda 2016b), green glass bracelets (Orillaneda 2016b:52), organic implements of wood

and stone, and glass and carnelian beads (Orillaneda 2001; Orillaneda 2016a). For this study, representative samples of 4 blue, 10 yellow, and 12 black glass beads were analyzed with LA-ICP-MS.

In 1985 an excavation took place on a shipwreck approximately 100km west of Palawan Island on the atoll reef named after the later British frigate *Royal Captain*. The timber remains were deteriorated and dispersed (Goddio 1988:35; Orillaneda 2012:424) though the cargo spread and location indicate it may have been a small local coasting vessel (Goddio 1988:128). The site date range was derived from late 16th to early 17th century blue and white wares (Brown 2009:167; Goddio 1988). Alongside the ceramics were a variety of other materials: bronze gongs, a bronze box, bronze Song coin (early or middle 13th century), bronze padlock, iron ingots, copper bracelets, ivory or bone counter (necklace?), a ring, and glass beads (Goddio 1988; Jubelin et al. 1985). For this study, representative samples of 9 red, 1 orange, 1 dark purple-grey, 3 yellow, and 4 white glass beads were analyzed with LA-ICP-MS.

Site/Shipwreck	**Pandanan**	**Santa Cruz**	**RCSw2**
approximate age	1460–1487 CE	1488–1505 CE	1573–1620 CE
possible cultural affiliation	Vietnamese-Chinese	South China Sea Tradition	Indigenous Filipino, Small coasting vessel
Glass bead samples for LA-ICP-MS	28 black 13 red	4 blue 10 yellow 12 black	9 red 1 orange 1 dark purple-grey 3 yellow 4 white
TOTAL beads analyzed	41	26	18

Table 9.1: Summary table of site contexts and glass artefacts analyzed in this study.

3. Cargo ceramic seriation

In Southeast Asia by the first half of the 15th century, there was a major power shift to the Ayutthaya Kingdom (now Thailand). Oversight of important kilns such as Si Satchanalai, Sukhothai, Mae Namnoi/Bang Rachan came under Ayutthaya monopoly (Sukkham 2018). The new directives under the Ayutthaya forces brought about a change in the ceramics trade that matched, and for a short time superseded, exports of Chinese (Jingdezhen and Longquan ceramics, for example), Vietnamese (Chu Dau and Go Sahn ceramics, for example) and Burmese (now

Myanmar; Twante ceramics, for example) ceramics (Brown 2009; Sukkham 2018). These ceramics supplied the market in shipments to several destinations in the region (Sukkham 2018). Shipments of such ceramics and the goods they stored occurred, according to nautical archaeologists, on many varieties of ships some of which were ocean-going hybrid vessels (Flecker 2007; Green 2011). The hybridity of the vessels was in relation to the building materials from Southeast Asia but the craftsmanship of Chinese (Manguin 1984). This scenario of hybrid ship and mixed ceramic cargoes we noted earlier in our shipwreck case studies of the Pandanan and the Santa Cruz (Orillaneda 2016a, 2016b). These correlations of ship construction technique and ceramic cargo help maritime archaeologists to narrow shifting patterns in shipping (i.e., Green et al. 1987; Maarleveld 1995; Orillaneda 2011), largely by means of ceramic seriation as the method to observe changes in cargo and date the shipwreck.

Seriation draws on archaeological materials from different stratigraphic proveniences to note changes of form over time thus producing chronology of manufacture (Orton and Hughes 2013). For each site's date range in our case studies, we summarize the relevant ceramic seriation. If more than one type of ceramic is available in the shipwreck's cargo, the dates of manufacture are compared to one another to seek overlap and narrow *terminus post quem* (earliest possible date) and *terminus ante quem* (latest possible date).

3.1. Pandanan ceramics

Pandanan cargo dated between 1460–1487 CE is largely Cham wares (Brown 2009; Dizon 1996b; Orillaneda 2012), with some Thai Maenam Noi 1 and 2 storage jars (Cort 2017) as well as some Sukhothai plates, and a small number of Minyao ceramics (Tan 1998/9).

In the Pandanan cargo ceramists have narrowed the date (1436–64 CE) of particular forms and designs of the Minyao wares from Jingdezhen kilns in eastern China (Brown 2009; Ketel 2011; Orillaneda 2016a:85, 2016b:43). Cham wares are a type of blue and white ceramic produced during the 13th to 17th century. In 1460 CE, exports began from the Go Sanh kilns in east central Vietnam (Brown 1988, 2009; Miksic 2009). Comparing the Minyao Chinese blue and white Cham with the Go Sanh Cham wares it is possible to establish the *terminus post quem* at 1460 CE.

The Thai wares establish the *terminus ante quem* at 1487 CE. Two different Thai wares were accounted for in the cargo: 1) Maenam Noi jars, and 2) Sukhothai plates. The jars were created as shipment containers for the Ayutthaya Kingdom (Cort 2017:273) in Maenam Noi kilns by the surrounding communities in the Ban Ko Noi area between 1360 to 1767 CE (Grave and Maccheroni 2009). Another

term for these storage jars is the same as the kilns they were made in, the Bang Rachan, which are "exclusively earthenware and stoneware and found on ships [in the South China Sea] dating from the 15th through 18th centuries" (Sukkham 2015: 324). The Pandanan is currently the only shipwreck to have carried the earlier variety of the jar at the beginning of their presence on shipwrecks (Brown 2009:185; Cort 2017:282). Next, the Sukhothai fish plates, from further north of Ayutthaya and of an earlier kingdom, were produced between 1450 and 1487 CE (Brown 2009:72), which narrows the *terminus ante quem* date of the Pandanan to 1487 CE.

3.2. Santa Cruz ceramics

The Santa Cruz shipwreck is dated between 1488–1505 CE. Santa Cruz cargo is largely Chinese ceramics and some Burmese, Vietnamese, and Thai wares. Since excavation, this shipwreck has always been assigned a date to the late 15th century (Dizon 2003). Stylistic and morphologic analysis of all the ceramics in comparison to collections on nearly every continent have dated the available forms and motifs to the Hongzhi period of 1488–1505 CE (Orillaneda 2012).

In the Santa Cruz the Chinese ceramics were mostly celadon from Longquan but also included other ceramics from eastern China kilns in Jingdezhen and Guangdong (Orillaneda 2001; Orillaneda 2012, 2016b), which were in production from the 13th to 19th centuries. The Burmese earthenware figurines are from the Twante kilns in production during the 15th century (Brown 2008). The Vietnamese wares are blue and white from Chu Dau kilns produced during the 13th to 17th century (Orillaneda 2003; Orillaneda 2016b). The Thai wares were from Si Satchanalai kilns (1351–1558 CE) and mid-15th century Maenam Noi kilns (Brown 2009; Cort 2017; Orillaneda 2003; Orillaneda 2016b).

3.3. Royal Captain Shoal wreck 2 ceramics

The RCSw2 had exclusively Chinese Zhangzhou kiln ceramics (Liu 2016) dated from motifs and styles to the Wanli Dynasty (1573–1620 CE) (Goddio 1988:115). In this case the ceramic identification and seriation dated the RCSw2 site to centuries earlier than the nearby British shipwreck *Royal Captain* (Curvas 1985, Alba 1988, FEFNA 1999).

4. Results: LA-ICP-MS analysis of glass beads

Through LA-ICP-MS analysis conducted in 2015 (see Annex A for more details about instrumentation and protocol), we identified three main compositional groups, which can be clearly distinguished from one another by observing the

varying levels of potash (K_2O) and magnesia (MgO) (see Figure 9.1). One group with higher levels of K_2O also contained a high concentration of lead (Pb), and was identified as a lead-potash (Pb-K) glass. The second cluster represents a glass with rather low K_2O and MgO that also has high soda (Na_2O) and high alumina (Al_2O_3) concentrations. It was identified as a mineral soda-high alumina (m-Na-Al) glass. The final cluster also has high Al_2O_3 concentrations and similar concentrations of K_2O as the m-Na-Al glass, but has exceptionally high MgO concentrations. These beads represent a newly identified glass type.

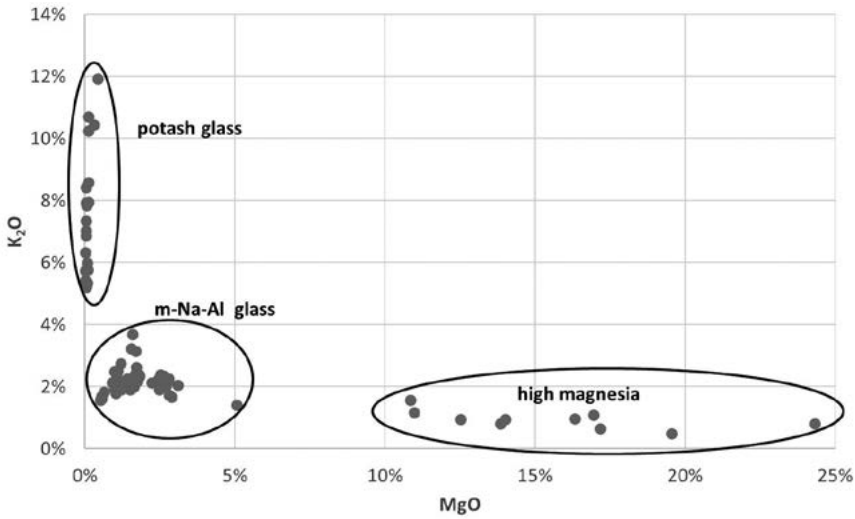

Fig. 9.1: The beads analyzed in this study plotted by MgO and K_2O, showing three main compositional groups. The dotted ellipsis on the bottom represents the Pandanan, the dash-dot circle in the corner represents the Santa Cruz, and the solid-line ellipsis at the top represents the RCSw2.

In Table 9.2 we summarize our LA-ICP-MS results of each shipwreck's different glass bead recipes organized by color. We present the average reduced compositions of the major glass compositions here to delineate groups. Some key trace elements were included because they can be colorants or other important markers. Using the reduced compositions, calculated taking into account only constituents brought by the silica-rich ingredient and the flux, avoids any diluting effects due to the addition of colorants.

	N	*SiO_2	*Na_2O	*MgO	*Al_2O_3	*P_2O_3	*K_2O	*CaO	*Fe_2O_3	Li	Rb	Sr	Zr	Cs	Ba	U
Pandanan																
red soda alumina group 2	13	59.6	17.9	1.2	9.1	0.1	2.1	4.5	2.9	22±5	51±10	237±23	170±19	0.7±0.1	344±41	196±147
black new type	11	64.6	1.8	14.7	11	0.1	1.0	2.0	4.6	15±8	6±2	165±86	213±52	0.1±0	16±8	171±77
black soda alumina group 2	17	59.7	19.9	2.2	7.4	0.2	2.2	4.3	3.8	14±4	50±16	210±46	182±39	0.7±0.2	395±76	235±62
Santa Cruz																
black soda alumina group 2	12	60.3	20.3	1.7	7.7	0.2	2.6	3.2	3.7	22±21	59±9	201±40	170±31	1±0.2	448±71	284±47
blue lead potash	4	69.3	1.8	0.3	0.7	0.0	19.2	7.9	0.8	4.5±1.7	6±1	22±15	4±3	0.2±0.1	19±11	0.2±0.1
yellow soda alumina group 4	10	70	17.5	1.1	5.8	0.2	0.2	2.2	2	41.8±9.1	9±4	59±7	657±1058	5.4±2.2	519±101	58±18
RCSw2																
yellow lead potash	3	82.1	0.5	0.6	0.7	0.0	15.7	0.4	0.4	10±8	25±10	66±107	13±17	0.3±0.5	36±47	0.3±0.5
red lead potash	9	81.5	0.7	0.1	0.9	0.0	15.3	1.2	0.4	6±6	29±10	6±8	22±60	0.1±0.1	32±70	0.3±0.2
white lead potash	4	73.8±	0.9	0.1	0.9	0.0	16.7	7.3	0.3	10±3	8±1	9±1	2±1	0.2±0.1	7±2	0±1
dark purple-grey lead potash	1	82.3	0.3	0.2	1.3	0.0	13.5	1.8	0.5	4	33	15	7	0.2	19	0.3
orange lead potash	1	59.3	0.7	0.8	3.6	0.2	22.2	6.9	6.1	10	51	73	153	1	132	3

Table 9.2: Glass beads and elemental glass compositions for shipwrecks Pandanan, Santa Cruz and Royal Captain Shoal wreck 2 (RCSw2). N is the number of glass beads per group/color (table 9.1). Average reduced compositions include an * and are measured by weight percent (wt%). Trace elements are measured in parts per million (ppm) and include their average and standard deviation.

4.1. Lead-potash glass

Twenty-six beads, 4 of them from the Santa Cruz and 22 from the Royal Captain Shoal, all coiled beads, were identified as lead-potash (Pb-K) glass, containing between 13.5 and 22 weight percent (wt%) of K_2O and between 46 to 60 wt% of lead oxide. Soda concentrations are generally low, as are MgO concentrations, suggesting the use of a rather pure K_2O source, possibly saltpeter (Dussubieux et al. 2020). With alumina concentrations mostly below 1% (with one exception), the silica source seems to have been rather pure. Lime (CaO) concentrations vary in a wide range (0.1 to 5%). The highest lime concentrations are found in white and opaque turquoise blue beads. The presence of higher CaO concentrations in the opaque beads suggests the possible use of calcium fluoride (CaF_2) as a white opacifier (Henderson et al. 1989; Borell 2010:149). As fluorine was not measured in our samples, it is impossible to confirm this hypothesis with our data. The opaque blue beads are distinguished from the white beads by the addition of copper (0.9 wt%), producing a turquoise blue color when present as Cu^{2+}. One orange opaque coiled bead contains higher CaO concentrations and also higher MgO, phosphorus oxide (P_2O_5), copper, and iron concentrations. The glass was probably colored with cuprite (Brill and Cahill 1988), and with iron added to the glass to facilitate the opaque orange color (Ahmed et al. 1977; Dussubieux et al. 2008; Carter et al. 2016). The higher concentrations of CaO, MgO, and P_2O_5 in the orange opaque glass might be explained by the intentional introduction of fuel ash to the glass melt, to create a reducing environment to more easily obtain cuprite (Schibille and Freestone 2013).

Lead-potash glass recipes appear to have begun around the 6th century in China and were initially used to produce glass vessels (Fuxi 2009:28). This glass recipe was used into the Ming Dynasty (1368–1644 CE) (Brill et al. 1991; Gratuze 2001:10). Lead-potash glass was manufactured over a very long period but two trace elements, rubidium (Rb) and lithium (Li), can be used to distinguish glass manufactured around the 14th century CE or later. Beads with a lead-potash composition found at Fort Canning, Singapore and dating from the 14th century CE (Borell 2010; Dussubieux and Gratuze 2010) have lower rubidium but higher lithium concentrations. Lead potash beads from the Philippines, excavated by Karl Hutterer at Tanjay from a burial that was dated to the late 15th to early 16th century based on associated porcelain ceramics (Laura Junker, personal communication), have higher rubidium and lower lithium concentrations. The lead-potash glass beads from the shipwrecks match closer the higher Rb and lower Li compositions found in the Philippines which aligns with the dating of the shipwrecks (both date to the end of the 15th century or later) (see Figure 9.2). Beads with similar compositions were found in jar burials found in the Cardamom Mountains of

Cambodia, dating from the 15th to the 17th century CE (Carter et al. 2016). The earlier mentioned shipwreck of the Brunei, located 22 nautical miles off the Sultanate of Brunei, includes cargo of two glass artefacts of Pb-K composition (Gratuze 2001), although the absence of data for Li precludes from making a more precise group attribution.

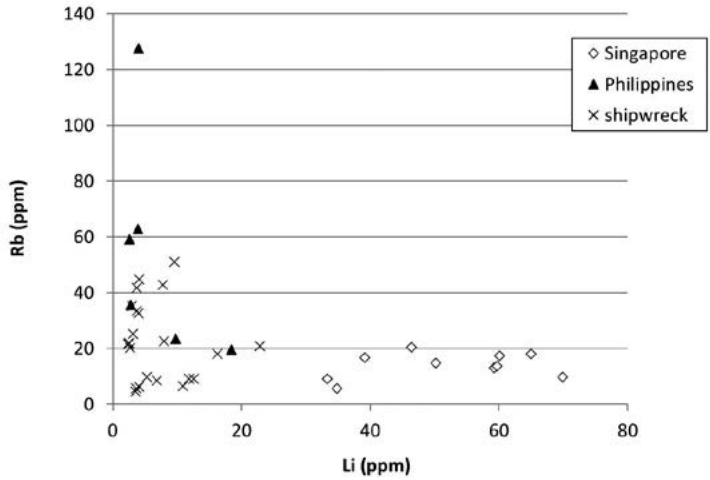

Fig. 9.2: A biplot of Rb and Li for lead-potash glass showing the difference between the earlier (14th century) Fort Canning beads and the later (15th – 16th century) beads from the (RCSw2) shipwreck beads and the Philippines (adapted from Carter et al. 2016: 405 figure 3).

4.2. High-alumina mineral soda glass beads

Fifty-one drawn or wound beads from the two earlier shipwrecks Pandanan (c. 1450–1487) and Santa Cruz (c. 1488–1505) have a soda-rich composition with Al_2O_3 concentrations, between 5 to 9 wt%, and relatively low MgO concentrations (generally lower than 1.5% although there are a number of exceptions). These were classified as belonging to the mineral soda – high alumina or m-Na-Al category. This glass, manufactured from a natural mix of an immature granite sand and soda rich efflorescence, was produced in South Asia (see Annex B for more details). Five different sub-groups were identified based on the concentrations of the following constituents: MgO, CaO, Sr, Zr, Cs, Ba and U (Dussubieux et al. 2008; Dussubieux et al. 2010; Dussubieux and Wood 2021). Additional sub-groups identified at the medieval site of Indor (Rajasthan) were recently recognized by Trivedi and Dussubieux (this volume; in preparation).

To determine what m-Na-Al sub-groups the shipwreck beads belong to, principal component analysis (PCA) was performed following the method

described by Dussubieux et al. (2010) and using the constituents listed above. The PCA compared the beads from the shipwrecks with a dataset available from the literature (Figure 9.3) and shows that all the beads (22) from the Pandanan belong to the m-Na-Al group 2 glass whereas the Santa Cruz beads split between the m-Na-Al group 2 (12 beads) and the m-Na-Al group 4 (10 beads).

The m-Na-Al group 2 glass is characterized in general by higher concentrations of U and lower levels of Cs, Ba and Zr when compared to the m-Na-Al groups 1, 3, 4 and 6 glass. The minimum uranium concentration measured in the shipwreck beads is quite high (close to 200 ppm) and corresponds to the maximum value measured in the glass beads from Chaul that serves as our reference for the m-Na-Al group 2 glass. Trivedi and Dussubieux (in this volume; in preparation) identified at the site of Indor, Rajasthan (14th century CE and onward) glass samples with higher U concentrations (> 200 ppm) suggesting that such glass was also available in India, although more work is needed to understand its exact composition, place of production, distribution and chronology. For now, we will still consider that the m-Na-Al shipwreck material with high U is part of the m-Na-Al group 2 glass but a common origin with the beads from Chaul is quite unlikely. The Pandanan red beads have a level of Fe_3O_2 (2.89 wt%) and CuO less than 1% (0.36 wt%) in line with the concentrations found in the m-Na-Al group 2 red glass. Black beads can be colored by the presence of manganese or iron. Both the Pandanan and Santa Cruz black m-Na-Al group 2 beads have low levels of MnO (0.12 wt%) but a rather high Fe_2O_3 level (ranging from 1.7 to 5.3 wt%). Dark glass contains an average of 2.2% of iron (as Fe_2O_3) in the m-Na-Al group 2 beads from Chaul (Dussubieux et al. 2008). In Southeast Asia, m-Na-Al group 2 glass material was identified in 15th to 16th century Cambodia (Carter et al. 2016) and 15th century Sumatra (Dussubieux 2009).

The m-Na-Al group 4 glass is characterized by low strontium and high cesium (Cs) concentrations. The high levels of Pb and tin (Sn) in the yellow Santa Cruz beads were probably due to the use of a lead stannate (Pb_2SnO_4), a yellow opacifier. The m-Na-Al group 4 also occurs at 15th to 16th century sites in Sumatra, in north-eastern India and Bangladesh (Dussubieux et al. 2008), and at a 17th to 19th century site in Kenya (Dussubieux et al. 2008, 2010). Other specimens of yellow glass m-Na–Al group 4 are the 404P glass bead from the Brunei shipwreck (Gratuze 2001) and in both the Okei and the Phnom Khnang Peung sites of the Cardamom Mountains (Carter et al. 2016).The m-Na-Al glass from the Brunei shipwreck seems to belong to this sub-group as indicated by the really low Sr concentrations (<100 ppm) and moderate U concentrations (~50 ppm). It is currently unclear where this subtype was manufactured. Kanungo (2004) posits a north Indian provenance. Indeed, its high Cs concentrations are similar to the m-Na–Al group 3 glass thought to originate in north India (Dussubieux and Gratuze 2013).

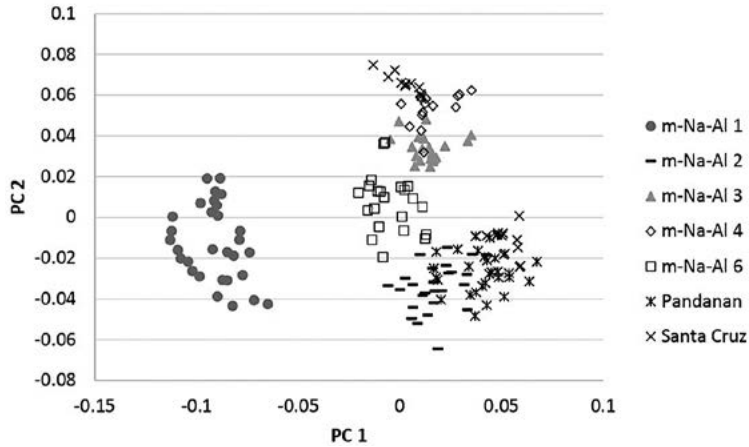

Fig. 9.3: PC1 and PC2 calculated for the m-Na-Al glass beads from the Pandanan and the Santa Cruz and the m-Na-Al 1 (unpublished), m-Na-Al 2 (Dussubieux et al. 2008), m-Na-Al 3 (Dussubieux and Kanungo, 2013), m-Na-Al 4 (Dussubieux, 2009) and m-Na-Al 6 (Dussubieux and Wood, 2021) glass groups.

4.3. Newly identified high magnesia-alumina glass

Eleven drawn beads have an unusual composition with low soda, potash and lime (< 3.4 wt%) high MgO (ranging from 5.0 to 24.3 wt%) and high Al_2O_3 (ranging from 7.2 to 13.8 wt%) concentrations that represents a newly identified glass type from the Pandanan. Trace elements have high concentrations with titanium (Ti) concentrations as high as 3500 ppm and U at 338 ppm. It seems that an immature sand like the one used for the m-Na-Al glass was melted with a magnesia-rich ingredient that would have been used as flux. High concentrations of iron (3.3 to 6.5 wt%) are certainly the cause of the dark color of the glass. Mg acts as the flux in this glass. It is an alkali-earth element, such as Ca, that was used as a flux in medieval European forest plant ash glass. It could have been a high alumina sand similar to that of the m-Na-Al glass mixed with a high magnesia (and high iron) ingredient. These newly identified high MgO - high Al_2O_3 beads were manufactured in a drawn technique common in India and could suggest that these beads were made there. We were curious if this recipe was similar to glass identified in the Cardamom Mountains of Cambodia, but that glass recipe has lower concentrations of both alumina (3–8 wt%) and magnesia (2–3 wt%) (Carter et al. 2016) so we do not think they are the same.

5. Discussion and conclusion

In the Pandanan wreck, two glass types were identified:
- 29 samples are m-Na-Al Group 2 glass
- 11 samples are high MgO and Al_2O_3 glass

In the Santa Cruz wreck, three glass types were identified:
- 12 samples are m-Na-Al Group 2 glass
- 10 samples are m-Na-Al Group 4 glass
- 4 samples are Pb-K glass

In the RCSw2, one glass type was identified:
- 28 samples are Pb-K glass

The glass bead compositional groups identified with LA-ICP-MS, combined with ceramic contextual information, can help to recreate ancient exchanges. In the three shipwrecks in our study there are ceramics and glass beads, and their material patterns must be considered in a holistic manner (Fahy 2015). By doing so we can tie together associated assemblages. Here we summarize the earlier section on cargo ceramic seriation and associate it with our results on the glass bead cargo. The Pandanan cargo carried m-Na-Al group 2 and high MgO and Al_2O_3 glass beads inside the Thai Maenam Noi 1 jars (Cort 2017; Orillaneda 2003). The Santa Cruz cargo carried three different glass bead chemistries in Thai and Chinese ceramics. The black m-Na-Al group 2 glass beads were stored inside the Thai Maenam Noi 2 jars (Cort 2017), the yellow m-Na-Al group 4 glass beads were packed in Thai ceramics of either tall-eared Maenam Noi jars or Si Satchanalai coconut-shaped jars and jarlets with ring-handles (Miksic 2013: 203; Orillaneda 2016b). The blue Pb-K glass beads were found associated with celadon (Orillaneda 2003), presumably from Longquan. The RCSw2 cargo carried exclusively Pb-K glass beads of varying colors in association with solely Chinese blue and white ceramics dated to the Wanli Dynasty (1573–1620 CE) (Goddio 1988:115). Beads and ceramics in the three Philippine shipwrecks discussed here are examples of the materials shipped as tribute.

Tribute shipments are the current hypothesis for why cargo associations exist in shipwrecks dated from the 15th to 17th century (Hall 2011; Miksic and Goh 2017). Tribute shipments are materials, services, or ceremonies that act as "tokens of subservice but not direct rule of distant provinces" (Miksic and Goh 2017: 42, 160). This extraction of tribute is largely associated with the Chinese Empire in relation to Southeast Asian vassals (Hall 1985; Miksic and Goh 2017). This time known as the Ming Ban commenced when Chinese emperors had forbidden private overseas trade in 1444 CE and it lasted 123 years, until 1567 CE (Brown

2009; Miksic and Goh 2017:519; Reid 1988). This left a gap in Chinese products sometimes referred to as the Ming Gap (1368–1488 CE) (Brown 2009). As mentioned earlier in the Ceramic Seriation section, Ayutthaya (Thai) ceramics monopolized the market at this time.

Ceramics from kilns in Si Satchanalai, Sukhothai, and Mae Namnoi/Bang Rachan flooded out from surrounding kilns of the Ayutthaya kingdom (1350–1767 CE) (Brown 2009: 23-29). During the 15th to 17th century (esp. 1448–1488 CE) this ceramic export largely shipped out the port of Nakhon Si Thammarat (on the east coast of the peninsula with access to the Gulf of Thailand) as it was a chief primary-rank city under the Ayutthaya Kingdom (Sukkham 2017), until around 1584 CE when Si Satchanalai and Sukhothai wares disappeared from maritime trade routes, signaling the termination of their productions (Sukkham 2018:803, table 1).

Backgrounding the regional affairs signaled by ceramics and foregrounding the shipwrecks from our study provides the setting to contextualize our glass. In a timeline of the shipwrecks and contemporaneous regional affairs (Figure 9.4) the Pandanan occurs within the Ming Gap (1368–1488 CE), Santa Cruz during the period of the market being flooded with Ayutthaya products, and the RCSw2 after the end of the Ming Ban (1352–1567 CE).

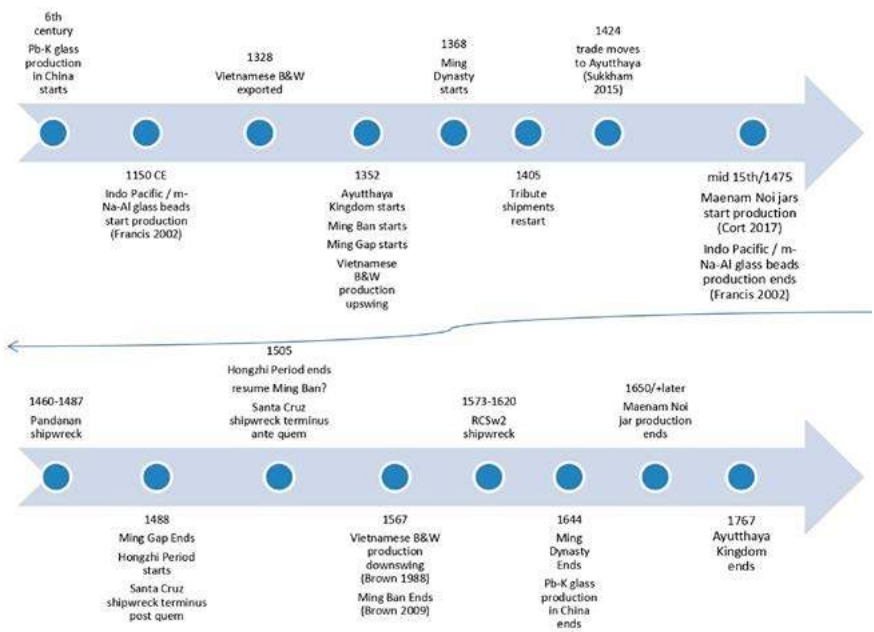

Fig. 9.4: Timeline of events, glass and ceramic production of artifacts discussed, shipwreck dates

Considering the timeline of events and the wrecking of the case studies (Figure 9.4) we can correlate the shifts in glass recipes with associated ceramics, which adds evidence to the maritime archaeology hypotheses of regional market shifts. The RCSw2 cargo of Pb-K glass in tandem with the re-entry of Chinese blue and white wares is likely an example of the market shift to Chinese products after the Ming Ban ceased in 1567 CE. In the case of the Santa Cruz, its cargo also included Pb-K glass in association with Chinese ceramics (in this case celadon). Our observation of patterns in glass cargo in tandem with the shift to Chinese ceramics adds to the mounting evidence in maritime archaeology that bootlegging occurred as the Ming Gap ended and was composed of very similar cargo to earlier tribute shipments (Fahy 2014; Orillaneda 2016b). Likewise, another noteworthy pattern is the drawn m-Na-Al glass beads and the Ayutthaya (Thai) Maenam Noi jars traded together in both earlier shipwrecks. The cargo of the shipwrecks Pandanan (1460–1487 CE) and the Santa Cruz (1488–1505 CE) represent a shift away from Chinese products during the Ming Ban (Brown 2009), as Ayutthaya ceramic production and export peaked (Sukkham 2018). We observe a similar phenomenon with the Indo-Pacific glass evidence, increasingly associated with m-Na-Al glass recipe where both the glass recipe and Ayutthaya ceramic production increased. This likely indicates that Francis' (2002) hypothesis, suggesting that production ceased as Maenam Noi ceramic production started, is incorrect. With the evidence of glass in these shipwrecks we can add to the argument, with Sumatran glass finds (Dussubieux 2009) and Cambodian burial jars (Carter et al. 2016), that the date of m-Na-Al glass in Southeast Asia markets should move later from the mid-12th century to at least the late 15th century. Aside from adding further evidence questioning Francis' Indo-Pacific bead production timeline, we also discovered a new glass recipe.

The most significant finding of this work is the newly identified high MgO and Al_2O_3 black glass beads. The manufacturing location of this glass is unknown. Very few beads have been analyzed from the 15th–16th century CE across China, India and Southeast Asia; therefore, additional examinations and analyses of glass beads from other contemporary sites are needed in order to determine the origins and range of exchange of this new glass type.

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Chapter 10

Sources of glass beads from the High Himalayas: 1200 BCE-CE 650

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1. Introduction

Although the Himalayas are often characterized as a barrier to the movement of people, their animals, and goods, extensive exchange routes are described in the historical literature by modern ethnographers, and even by archaeologists. The fabled Silk Roads crossed the Himalayas in the far northwest of the range and in multiple locations in Nepal. The Tea Horse route, which originated in Yunnan in southwestern China crossed the Himalayan arc along its eastern edge. Finally, innumerable local trade routes crisscrossed the mountains at the many passes which connected lowlands to highlands from Pakistan to China. But one question that has not been answered nor addressed in a systematic manner is the antiquity of that trade and how trade relationships may have changed through time before written history. This question is clearly related to the larger question of the timing of the peopling of the high Himalayan valleys. Although there has been limited archaeological research in them compared to surrounding regions, recent projects by multinational teams working in concert with Nepali archaeologists have demonstrated a permanent human presence in the Kali Gandaki valley of Upper Mustang, Nepal, that dates to ~1400 BCE. In contrast, significant populations existed in the northwestern Himalayas by at least 6000 BCE, in northern India by 7000 BCE, southwestern China by 7000 BCE, and the central Tibetan plateau by 2000 BCE. To varying degrees, each of these areas could have been participants in trade networks that involved the peoples of the high Himalayan valleys, and with this baseline of regional archaeological knowledge, it becomes possible to examine the directionality, intensity, and material relations expressed in the hypothesized trade relationships among them.

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In the absence of written records, archaeologists must rely upon what can be learned from the material record of the artifacts they encounter in their research. Archaeometry and archaeological science have become indispensable tools in modern archaeology and advances in this extensive research domain allow us to answer old questions and address new ones about the past. Although the material record analyzed by these methods remains limited in much of Himalayan archaeology, enough work has been done to track the provenance and origins of some artifact types, including textiles and metals but most prominently glass beads. In this manuscript, we will discuss the analysis of glass beads from two sites from Mustang, Nepal: Mebrak (450 BCE-CE 50) and Samdzong (CE 450-650), and the Raja Rani Dolpa site in Dolpo, Nepal (CE 782-880). We will also present new evidence of a faience bead from Lubrak, also located in Mustang and dated to 1269-1123 BCE (Figure 10.1). This deep time perspective, combined with other data, provides insights into the directionality and intensity of trade relationships in the high Himalayan valleys, and the analysis of glass beads has proven to be crucial to the exploration of this topic.

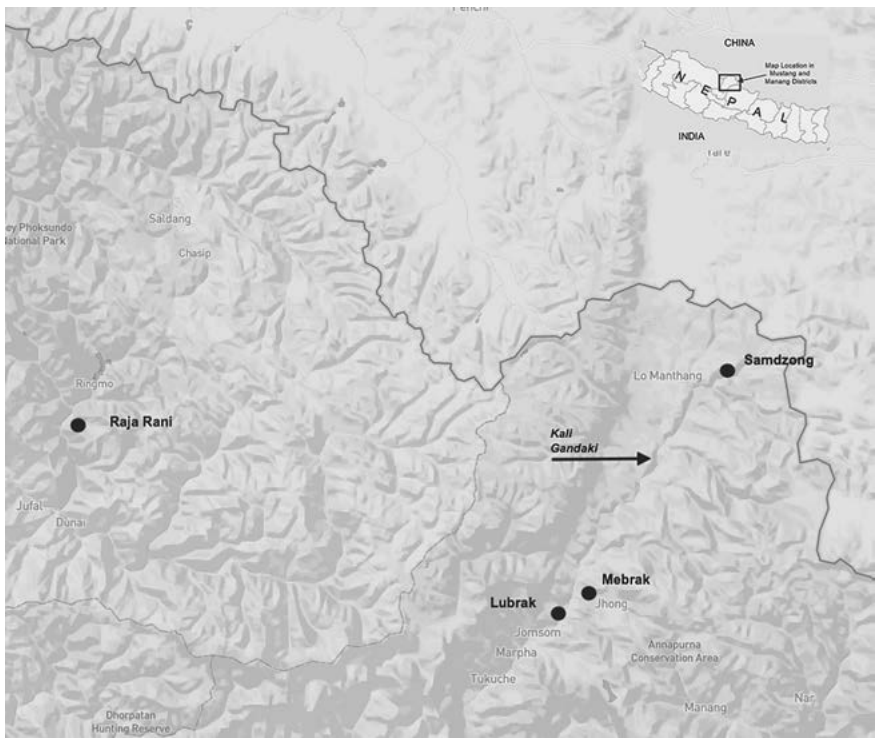

Fig. 10.1: Location of the archaeological sites discussed in this manuscript.

2. The historical and ethnographic context

Trade, at least as described in the historical record, has been multi-faceted in the high Himalayan valleys. Individuals, families, and whole villages have been among its actors (von Fürer-Haimendorf 1975). Local trade across the high passes was seldom monitored or controlled and was effectively performed by barter based upon commonly agreed-upon strict equivalences of commodities. However, at different times, state actors sought to regulate trade by the collection of taxes and the establishment of customs posts. There was considerable variability in the staging of trade. Since high passes were often impassable in the winter, traders from the plateau organized caravans on a seasonal basis. Goods were transported south in the late spring, and the caravans returned northward in the early fall. In some valleys, trade entrepots were developed along with seasonal trade fairs. Lowlanders seldom took their goods to the plateau themselves and used these entrepots to connect with highlanders.

Examples of goods that moved from the north into the lowlands in the historical era and well into the 20th century included wool, meat (sometimes on the hoof), precious stones, medicinal herbs, musk, and pashmina; moving north were finished products such as metals and finer textiles, grains, and rice (van Spengen 1995). Grains, including barley and buckwheat and rice were especially important as commodities moving north, and anthropologists have characterized this as the grain-salt-rice circuit (Fisher 1987: 88-90). This circuit was common in many Himalayan valleys. Historical documents rarely speak about the exchange of luxury items or the raw materials needed for their fabrication. Both the plateau and the surrounding lowlands had important centers that produced gold and silver jewelry and at least to the south, fine cotton textiles.

3. The sites and their contexts

Of the sites discussed in this manuscript, three (Lubrak, Mebrak, and Samdzong) are located in the Mustang District of north-central Nepal near the Kali Gandaki river, the primary drainage of this region. On the south, the Mustang District is bounded by Dhaulagiri and the Annapurnas; these mountains define the southern edge of the Himalayas. Together, they form a rain shadow that keeps the interior of Mustang relatively dry, a circumstance that has improved the preservation of organic materials as well as metals in the archaeological sites of the region.

The Kali Gandaki drainage is the primary north-south trade and transportation corridor from Nepal onto the Tibetan plateau in this region. The Kora La pass over the Himalayas is relatively low in elevation (4660 masl) and tends to be open

for most of the year and only closed during intense winter storms. This corridor served as the primary route for the trade in salt between the central Tibetan plateau and the lowlands to the south from at least the 18th century and likely served as a local trade route well before that (Dhungel 2002). Although much of the wealth generated by this trade left the valley, in relative terms, the inhabitants of the villages along the corridor benefitted from the secondary effects of the trade and thus maintained a high standard of living. This wealth is further reflected in the significant number of Buddhist monasteries and temples constructed along the corridor over the past six hundred years (Ramble 2008).

The Raja Rani Dolpa site is located in Dolpo, a district which lies to the west and adjacent to Mustang. Dolpo is one of the most isolated regions of Nepal. Unlike Mustang, there are no major north-south drainages that could serve as transportation corridors. Although there are high passes that cross the Himalayas to the plateau, these are closed much of the year. Consequently, trade from Dolpo to the plateau first runs eastward to the Kali Gandaki drainage and thence to the north. There is some local north-south trade that must cross very high interior mountain passes; goods from the north include meat and wool which are exchanged by barter for grains and rice. Some salt manages to be brought over the Himalayas into Dolpo but in minor quantities only. Because of this isolation, modern communities in Dolpo have been considered "impoverished" by most ethnographers who have worked there (e.g., von Fürer-Haimendorf 1975: 149). There is some evidence, however, that these signs of poverty are relatively recent.

3.1. Lubrak (1269-1123 BCE)

This site is found at ca. 3000 masl along the Pandak Khola, a small stream that drains into the Kali Gandaki river approximately three kilometers to the west. Two cist-tombs were found eroding out of the bank of the river after a major flooding event. The tombs, buried at least two meters below the modern ground surface, were constructed of flat slabs of stone about 1 m in length supplemented by smaller slabs of dry masonry. Although similar, the tombs displayed some variability in construction. Tomb B1 was roofed with slabs resembling an elevated, corbeled arch, while Tomb B2 had a less elevated, flatter roof. B1 was decorated with a crisscross "x-motif" drawn in red ochre on the ceiling and back walls while B2 showed no signs of decoration. Two sets of human remains were found, one from each of the tombs. A total of 34 complete ceramic vessels were recovered. Found with them were hundreds of disk-shaped bone beads, a few metal wrist bangles, and dozens of carnelian beads. Of greater interest is a small, highly patinated, light green bead of faience. Initial observation of the artifact labeled it as a glass bead, but subsequent analysis determined it to be faience. Although little about cultural

affiliations can be gleaned from this site at present, the ceramics appear to have been made locally while the bangles and carnelian beads suggest a connection to South Asia. A review of the literature from the region shows that the style of tomb construction has no parallel in Mustang or in the wider Himalayas.

3.2. Mebrak (400 BCE-CE 50)

This site, formally known as Mebrak 63 (Aldenderfer and Eng 2016; Simons 2020), is found at ca. 3600 masl to the east of the modern village of Jharkot along the Dzong Khola, a tributary of the Kali Gandaki river, which lies approximately 10 km to the west. The site is one of a series of caves some 30 m above the ground surface excavated in a sheer cliff face by ancient peoples. It is a communal tomb and was used sporadically over the dated range of the site and contains at least 42 individuals. Some individuals were partially mummified by the aridity of the climate. An important feature of mortuary practice was the bed coffin; the dead were placed carefully upon them but were pushed aside when newly deceased individuals were placed in the cave. The preservation of organic materials is extraordinary and includes a wide range of wooden, bamboo, textiles, leather, and other materials. Carnelian beads are abundant as are glass beads. Beads were commonly found loose in the deposit as bodies were shifted about, but Simons (2020: 67-68; 398) reports that a number of relatively intact bracelets or strings of beads were discovered. Metal artifacts, primarily bangles said to be made of bronze, were recovered but are not common at the site. The wide range of baskets, woven mats, and other organic artifacts speak to the local or near-regional fabrication of these artifacts. Simons (2020: 364) speculates that the artifacts found at Mebrak 63 suggests trade relationships to the north, west, and south. The remains of clothing are said to resemble styles from Central Asia. Glass and carnelian beads, the metals, and cotton fabrics all support a southward-facing set of trade relationships. Unfortunately, no archaeometric studies of artifacts were undertaken so the northern and western trade connections are uncertain at best.

3.3. Samdzong (CE 450-650)

Samdzong is found at 4000 masl on the Samdzong Khola, which flows westward into the Kali Gandaki river that lies some eight km to the south. A more direct route (ca. 5 km) over a local pass connects the site to the primary north-south corridor of the river, and the Kora La pass over the Himalayas is some 15 linear kilometers to the northwest. The site consists of 10 shaft tombs excavated into the soft conglomerate rock of a west facing cliff face (Aldenderfer and Eng 2016). A total of 105 individuals were recovered from these collective tombs. Although the context of the tombs was badly disturbed by a seismic event that took place

in 2009, it appears that the dead were placed upon low bed-like platforms or in some instances, directly upon the surface of the chambers. Most of the tombs contained quotidian artifacts, such as wooden trays, some ceramics, iron plates and arrowheads, and considerable amounts of horse tack. One tomb—Samdzong 5—contained copper cooking vessels and a cauldron, iron daggers, numerous glass beads, preserved textiles and other decorative objects. In addition to these artifacts, this tomb had an intact, almost square wooden coffin that contained a single individual. The complexity of the assemblage suggests that Samdzong 5 was the tomb of a local elite. Archaeometric and stylistic analyses of the copper vessels suggest a South Asian provenance for them. Three gold masks were also recovered. One was found in Samdzong 5 and the other two in chambers that contained mostly quotidian artifacts—Samdzong 1/3 and 1/4. Each of the Samdzong masks has strong stylistic similarities to masks found in western Tibet and northwestern India (Aldenderfer 2018). Although the provenance of the gold masks is unclear, detailed analyses of their fabrication suggest that the gold used to create them was recycled. A bronze medallion or mirror was also recovered from Samdzong 5. From a stylistic and compositional perspective, it is likely to have been made somewhere in Central Asia (Massa et al. 2019). A coarse, degummed Chinese silk colored with cinnabar was also found in Samdzong 5 as were the majority of the glass beads recovered from the site (Gleba et al. 2016). Most of the beads were found loose in the deposit, but some of them were attached to fabrics made of animal fibers, most likely either sheep or goat. The location of the beads in the deposit suggests that they were once part of an elaborate face covering or headdress that was attached to the gold mask found in the tomb (Gleba et al. 2016: 33-34). In sum, the assemblage recovered from Samdzong indicates that the site was part of a complex web of trade relationships that extended to the south, north, and west.

3.4. Raja Rani Dolpa site (CE 782-880)

This site, a complex of subterranean tombs excavated into a steep hillslope, is found near the modern village of Ralli in southern Dolpo at an elevation of ca. 2400 masl. The tombs are well constructed with well-laid stone masonry and are connected to the slope of the hillside by steep ramps. There also appear to be residential compounds located nearby. The tombs appear to have been looted in the past and there is little left of an original archaeological context. The contents of the tombs consist of a very small number of whole ceramic vessels, considerable iron horse tack, iron arrowheads, copper or bronze nose or earrings and bangles, wooden trays, and other metal objects of bronze and brass (Massa 2016). Although the mortuary pattern is quite distinct from that seen at Samdzong, the contents

of the tombs are quite similar. A large number of disk-shaped orange beads were recovered along with carnelian and blue-green segmented glass beads. Although not definitive, the directionality of trade appears to be toward the south.

In summary, the assemblages of artifacts from these sites indicate that trade becomes multidirectional over time. Lubrak has a strongly south-facing orientation of trade but the presence of faience suggests more complicated regional relationships. Mebrak is similarly south-facing but some artifact styles suggest connections to the west and north. Samdzong has south-facing connections as well but trade to the north and west has expanded considerably. The archaeometric analysis of the glass beads offers the possibility to provide nuance to these relatively coarse patterns of artifact provenance based upon what is known of metals, fabrics, and stylistic motifs on a range of artifacts.

4. Archaeometric analysis of the glass beads

A total of 92 glass beads and one faience bead were analyzed with LA-ICP-MS, the Elemental Analysis Facility at the Field Museum (Annex A) in 2011, 2015 and 2016 and 2020 (Table 10.1). Pictures of the beads are in Supplementary Materials Figure S10.1 and full compositions are in Supplemental Table S10.1.

The faience bead has a high silica (SiO_2) concentration (84%) and 8.0% of soda (Na_2O). Potash (K_2O) and magnesia (MgO) are low with respectively 1.1% and 0.2%. The alumina (Al_2O_3) concentration is rather low (1.6%). The greenish color of the bead owes to the presence of copper with a concentration (as CuO) of 3.1%.

Four main groups of glass were identified. They are visible in Figure 10.2, based on their soda (Na_2O), potash (K_2O) and alumina (Al_2O_3) concentrations:

- Close to two-thirds of the beads (62) have high soda, high alumina but low magnesia concentrations and correspond to a mineral soda-high alumina glass.
- A smaller group of glass beads (11) is also high in soda and alumina but magnesia concentrations > 1.5% suggests a soda plant ash – high alumina glass.
- Another group (15 beads) with high soda and magnesia concentrations > 1.5% has much lower alumina concentrations and belongs to the soda plant ash – low alumina group.
- The smallest group of all (4) has low soda but high potash concentrations and belongs to the potash glass type.

	Site and dating	Name	Color	Transparency	Technique	Shape	Dimension (mm)	Glass type
2020	Lubrak, Mustang 1269-1123 BCE	LU001	green	opaque	?	barrel	d=4, l=6	faience
2015	Samdzong, Mustang 450-650 CE	NEP001	turquoise blue	translucent	drawn	oblate	d=2.5	m-Na-Al 1
2015		NEP002	amber	transparent	drawn	oblate	d=3	m-Na-Al 1
2015		NEP003	colorless	transparent	drawn	oblate	d<2	m-Na-Al 1
2015		NEP004	black	opaque	drawn	oblate	d=2	m-Na-Al 1
2015		NEP005	black	opaque	drawn	oblate	d=2	m-Na-Al 1
2015		NEP006	black	opaque	drawn	oblate	d=2.5	m-Na-Al 1
2015		NEP007	orange	opaque	drawn	oblate	d=2-2.5	m-Na-Al 1
2015		NEP008	orange	opaque	drawn	oblate	d=2.5-3	m-Na-Al 1
2015		NEP009	orange	opaque	drawn	oblate	d=3	m-Na-Al 1
2015		NEP010	orange	opaque	drawn	oblate	d=2.5	m-Na-Al 1
2015		NEP011	orange	opaque	drawn	oblate	d=3	m-Na-Al 1
2015		NEP012	orange	opaque	drawn	oblate	d=2.5	m-Na-Al 1
2015		NEP013	orange	opaque	drawn	oblate	d=2.5	m-Na-Al 1
2015		NEP014	red	opaque	drawn	oblate	d=2.5	m-Na-Al 1
2015		NEP015	red	opaque	drawn	oblate	d=1.5	m-Na-Al 1
2015		NEP016	red	opaque	drawn	oblate	d=1.5	m-Na-Al 1
2015		NEP017	red	opaque	drawn	oblate	d=2.5	m-Na-Al 1
2015		NEP018	red	opaque	drawn	oblate	d=2	m-Na-Al 1
2015		NEP019	red	opaque	drawn	tube	d=2; l=3.5-4	m-Na-Al 1
2015		NEP020	red	opaque	drawn	oblate	d=2	m-Na-Al 1
2015		NEP049	yellow	opaque	drawn	oblate	d=2.5	m-Na-Al 1
2015		NEP050	yellow	opaque	drawn	oblate	d=2.5	m-Na-Al 1
2015		NEP021	green	opaque	drawn	oblate	d=3-4	m-Na-Al 6
2015		NEP023	green	opaque	drawn	oblate	d=2.5	m-Na-Al 6
2015		NEP024	green	opaque	drawn	oblate	d=3.5	m-Na-Al 6
2015		NEP027	green	opaque	drawn	oblate	d=3.5	m-Na-Al 6
2015		NEP029	green	opaque	drawn	oblate	d=5	m-Na-Al 6
2015		NEP030	yellow	opaque	drawn	oblate	d=3	m-Na-Al 6
2015		NEP031	yellow	opaque	drawn	oblate	d=3	m-Na-Al 6
2015		NEP032	yellow	opaque	drawn	oblate	d=6	m-Na-Al 6
2015		NEP043	yellow	opaque	drawn	tube	d=2.5; l=5	m-Na-Al 6
2015		NEP044	yellow	opaque	drawn	oblate	d=4	m-Na-Al 6
2015		NEP045	yellow	opaque	drawn	oblate	d=4	m-Na-Al 6
2015		NEP048	green	opaque	drawn	oblate	d=2.5	m-Na-Al 6
2015		NEP051	yellow	opaque	drawn	oblate	d=3	m-Na-Al 6
2015		NEP052	green	opaque	drawn	oblate	d=5	m-Na-Al 6

	Site and dating	Name	Color	Transparency	Technique	Shape	Dimension (mm)	Glass type
2015		NEP054	green	opaque	drawn	oblate	d=3	m-Na-Al 6
2015		NEP022	green	opaque	drawn	small segment, semi-rounded	d=3-4	v-Na-Ca
2015		NEP025	green	opaque	drawn	small segment, semi-rounded	d=3-4	v-Na-Ca
2015		NEP026	green	opaque	drawn	small segment, semi-rounded	d=3-4	v-Na-Ca
2015		NEP028	green	opaque	drawn	small segment, semi-rounded	d=3-4	v-Na-Ca
2015		NEP040	turquoise blue	translucent	drawn	segmented	d=11-12	v-Na-Ca
2015		NEP041	turquoise blue	translucent	drawn	segmented	d=11-12	v-Na-Ca
2015		NEP046	green	opaque	drawn	small segment, semi-rounded	d=3-4	v-Na-Ca
2015		NEP047	green	opaque	drawn	small segment, semi-rounded	d=3-4	v-Na-Ca
2015		NEP053	green	opaque	drawn	small segment, semi-rounded	d=3-4	v-Na-Ca
2015		NEP055	green	opaque	drawn	small segment, semi-rounded	d=3-4	v-Na-Ca
2015		NEP033	turquoise blue	translucent	drawn	segmented (2)	d=5; l=8	v-Na-Ca-Al
2015		NEP034	turquoise blue	translucent	drawn	segmented (5)	d=3; l=12	v-Na-Ca-Al
2015		NEP035A	turquoise blue	translucent	drawn	segmented (1)	d=4	v-Na-Ca-Al
2015		NEP035B	turquoise blue	translucent	drawn	segmented (1)	d=4	v-Na-Ca-Al
2015		NEP036	turquoise blue	translucent	drawn	segmented (2)	d=6	v-Na-Ca-Al
2015		NEP037	turquoise blue	translucent	drawn	segmented (2)	d=3-4; l=10	v-Na-Ca-Al
2015		NEP038	turquoise blue	translucent	drawn	segmented (1)	d=5	v-Na-Ca-Al
2015		NEP039	turquoise blue	translucent	drawn	segmented (1)	d=4	v-Na-Ca-Al

	Site and dating	Name	Color	Transparency	Technique	Shape	Dimension (mm)	Glass type
2015		NEP042	turquoise blue	translucent	drawn	segmented (4)	d=4; l=15	v-Na-Ca-Al
2011		SD5_01	turquoise blue	translucent	drawn	segmented (4)	d=5; l=15	v-Na-Ca-Al
2011		SD5_02	black	opaque	drawn	oblate	d=3	m-Na-Al 1
2011		SD5_03	black	opaque	drawn	oblate	d=2	m-Na-Al 1
2011		SD5_04	black	opaque	drawn	oblate	d=2	m-Na-Al 1
2011		SD5_06	green	opaque	drawn	oblate	d=5	m-Na-Al 6
2011		SD5_07	green	opaque	drawn	small segment, semi-rounded	d=4	v-Na-Ca
2011		SD5_08	green	opaque	drawn	small segment, semi-rounded	d=4	v-Na-Ca
2011		SD5_09	green	opaque	drawn	small segment, semi-rounded	d=4	v-Na-Ca
2011		SD5_10	green	opaque	drawn	small segment, semi-rounded	d=4	v-Na-Ca
2011		SD5_11	green	opaque	drawn	small segment, semi-rounded	d=3	v-Na-Ca
2011		SD5_12	green	opaque	drawn	oblate	d=2	m-Na-Al 1
2011		SD5_13	yellow	opaque	drawn	oblate	d=5	m-Na-Al 6
2011		SD5_14	yellow	opaque	drawn	oblate	d=5	m-Na-Al 6
2011		SD5_15	yellow	opaque	drawn	oblate	d=5	m-Na-Al 6
2011		SD5_16	yellow	opaque	drawn	oblate	d=5	m-Na-Al 6
2011		SD5_17	yellow	opaque	drawn	oblate	d=5	m-Na-Al 6
2011		SD5_18	yellow	opaque	drawn	oblate	d=3	m-Na-Al 1
2011		SD5_19	amber	transparent	drawn	oblate	d=2.5	m-Na-Al 1
2011		SD5_20	orange	opaque	drawn	oblate	d=3	m-Na-Al 1
2011		SD5_21	orange	opaque	drawn	oblate	d=2.5	m-Na-Al 1
2011		SD5_22	orange	opaque	drawn	oblate	d=2.5	m-Na-Al 1
2011		SD5_23	orange	opaque	drawn	oblate	d=2.5	m-Na-Al 1
2011		SD5_24	red	opaque	drawn	oblate	d=2	m-Na-Al 1
2011		SD5_25	red	opaque	drawn	oblate	d=2	m-Na-Al 1
2011		SD5_26	red	opaque	drawn	oblate	d=2	m-Na-Al 1

	Site and dating	Name	Color	Transparency	Technique	Shape	Dimension (mm)	Glass type
2016	Mebrak, Mustang 400 BCE-50 CE	2016-1	dark blue	translucent	drawn	oblate	d=3-4	K
2016		2016-2	dark blue	translucent	drawn	oblate	d=2	K
2016		2016-3	dark blue	translucent	drawn	oblate	d=2	K
2016		2016-4	yellow	opaque	drawn	oblate	d<2	m-Na-Al 1
2016		2016-5	green	opaque	drawn	oblate	d<2	m-Na-Al 1
2016		2016-6	turquoise blue		drawn	segmented (3)	>10	v-Na-Ca-Al
2016	RRD, Dolpo 782-880 CE	DOL001	orange/ red	opaque	?	disc		m-Na-Al ?
2016		DOL002	orange/ red	opaque	?	disc		m-Na-Al ?
2016		DOL003	orange/ red	opaque	?	disc		m-Na-Al ?
2016		DOL004	orange/ red	opaque	?	disc		m-Na-Al ?
2016		DOL005	turquoise blue	opaque	wound	oblate		K-Pb

Table 10.1: List of samples analyzed with LA-ICP-MS.

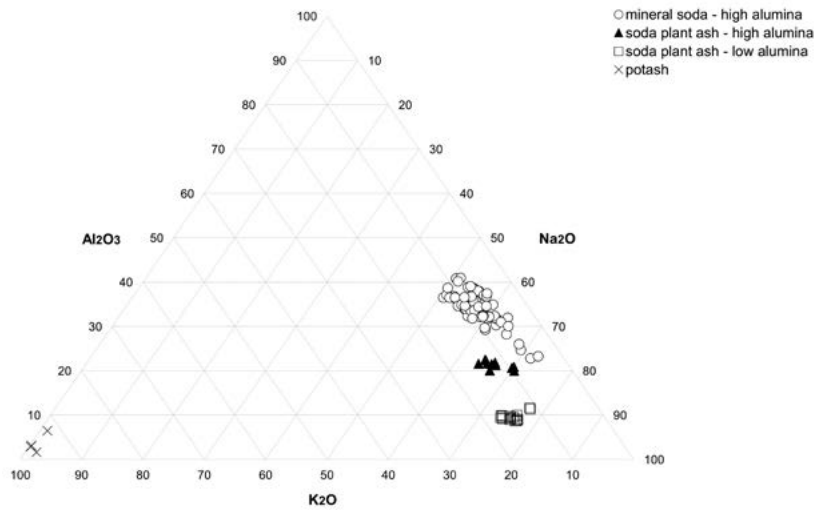

Fig. 10.2: Ternary diagram for soda (Na_2O), potash (K_2O) and alumina (Al_2O_3) concentrations for the beads from Nepal.

Additional sub-groups were identified based on trace element concentrations as summarized in Table 10.2. More details are given below.

	Mineral soda – high alumina glasses (62)			Soda plant ash – high alumina (11)	Soda plant ash – low alumina (15)	Potash glasses (4)	
	m-Na-Al 1	m-Na-Al 6	m-Na-Al ?	v-Na-Ca-Al	v-Na-Ca	K	Pb-K
*SiO_2	62.4 ± 2.8	59.0 ± 2.9	70.4 ± 1.1	62.7 ± 2.3	69.8 ± 1.1	75.5 ± 1.4	38.8%
*Na_2O	18.2 ± 2.3	18.7 ± 1.9	15.8 ± 0.3	18.7 ± 1.5	15.9 ± 1.3	0.1 ± 0.1	0.14%
*MgO	0.8 ± 0.2	0.9 ± 0.2	1.0 ± 0.1	2.5 ± 0.3	3.1 ± 0.2	0.26 ± 0.05	0.10%
*Al_2O_3	10.6 ± 1.4	11.6 ± 1.5	8.4 ± 0.6	6.0 ± 0.7	2.0 ± 0.3	0.9 ± 0.5	0.13%
*P_2O_5	0.14 ± 0.08	0.3 ± 0.2	0.29 ± 0.06	2.0 ± 0.9	0.39 ± 0.09	0.4 ± 0.1	0.00%
*K_2O	2.1 ± 0.3	3.5 ± 0.6	2.4 ± 0.2	3.3 ± 0.6	3.1 ± 0.2	20.3 ± 0.9	7.47%
*CaO	3.5 ± 0.7	3.7 ± 0.6	1.6 ± 0.4	6.0 ± 1.2	8.0 ± 1.3	2.2 ± 0.2	3.38%
*Fe_2O_3	2.4± 0.8	2.3 ± 0.4	-	1.9 ± 0.3	0.75 ± 0.08	0.4 ± 0.1	0.08%
PbO	-	-	-	-	-	-	49.2%
Ti	2514 ± 567	2373 ± 307	2167 ± 45	1350 ± 195	442 ± 88	332 ± 118	58.93
Sr	3756 ± 69	281 ± 23	80 ± 12	226 ± 47	333 ± 32	51 ± 4	7.51
Zr	471 ± 488	238 ± 34	244 ± 7	98 ± 15	53 ± 8	37 ± 26	2.72
Cs	0.5 ± 0.2	1.1 ± 0.3	3.0 ± 0.3	3.0 ± 0.6	0.4 ± 0.2	0.5 ± 0.4	0.05
Ba	650 ± 105	614 ± 126	294 ± 12	413 ± 85	114 ± 20	1079 ± 843	4.94
U	11 ± 4	42 ± 12	28 ± 3	210 ± 125	1.0 ± 0.2	0.6 ± 0.4	0.16

Table 10.2: *average reduced compositions and average concentrations for key constituents useful to separate the main groups and to recognize sub-groups for some of them. The composition of Pb-K was not reduced and was not averaged as only one sample has such a composition.

4.1 Mineral soda – high alumina glass

A large group of 62 samples have a soda-rich composition (Na_2O average = 17.4%) and high alumina concentrations (Al_2O_3 average = 10%). Magnesia concentrations in these samples are below 1.5% suggesting the use of a soda from mineral origin. Quantities of trace elements in this glass are fairly high and would suggest the use of an immature sand containing impurities. This glass is named mineral soda – high alumina or m-Na-Al glass and was identified initially in India where it was assumed to have been manufactured (Brill 1987).

Five different m-Na-Al subgroups named m-Na-Al 1, 2, 3, 4 and 6 will be considered here. They can be separated using principal component analysis

(PCA) based on the concentrations of the following constituents: MgO, CaO, Sr, Zr, Cs, Ba and U (Dussubieux et al. 2010; Dussubieux and Wood 2021). The m-Na-Al samples from Nepal separate into 3 groups (Figure 10.3). The beads from Samdzong split into two groups corresponding to the m-Na-Al 1 and 6 compositions. One sample from Mebrak belongs to the m-Na-Al 1 glass group and another to the m-Na-Al 6 glass group. Four samples from Dolpo fall close to m-Na-Al 3 and 4 glasses without matching perfectly any of the groups.

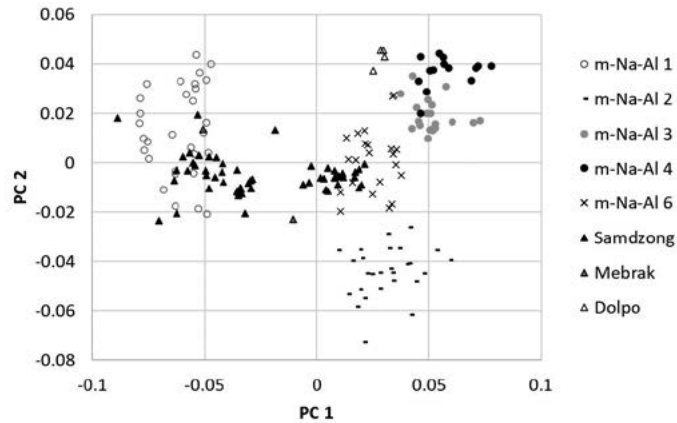

Fig. 10.3: Biplot representing PC1 and PC2 obtained using the concentrations of MgO, CaO, Sr, Zr, Cs, Ba and U from samples belonging to glass groups m-Na-Al 1 (unpublished data), m-Na-Al 2 (Dussubieux et al. 2008), m-Na-Al 3 (Dussubieux and Kanungo 2013), m-Na-Al 4 (Dussubieux 2009) and m-Na-Al 6 (Dussubieux and Wood 2021) and from m-Na-Al samples from Nepal.

Based on archaeological evidence, elemental and isotope (Sr and Nd) data, it has been established that the m-Na-Al 1 glass type was likely manufactured in Sri Lanka and in South India (Dussubieux et al. 2008; Dussubieux et al. 2021). The production started in the middle of the 1st millennium BCE (Gratuze et al. 2000; Dussubieux 2001) and seems to have continued until the beginning of the 2nd millennium CE (Dussubieux and Allen 2014). The distribution of the m-Na-Al 1 glass type was widespread, ranging from Southeast Asia (Carter 2015; Carter and Lankton 2012) to the east coast of Africa (Wood et al. 2017; Sarathi, this volume), the Red Sea region, 4th – 6th century CE. (Then-Obluska and Wagner 2019a and b), the Levant (Larson and Dussubieux, this volume), the Middle East (Dussubieux, this volume) and western Europe (Pion and Gratuze 2016; Gratuze et al. 2021) during the Merovingian period.

The m-Na-Al 6 glass has been recently identified among glass beads excavated on the east coast of Africa. It is present at sites dating from the 9th to the 13th century CE (Dussubieux and Wood 2021). The place of production for this glass is very uncertain at this point. Recent Sr isotope analysis conducted on m-Na-Al 6 glass samples revealed a fairly radiogenic signature that is compatible with an origin from the Indo-Ganges region (Seman et al. 2021) where this glass might have been produced.

The m-Na-Al ? glass is close in composition to the m-Na-Al 3 and 4 glasses but differs mostly by lower uranium concentrations.

All the beads with m-Na-Al 1 and 6 compositions were manufactured using the drawn technique that consists of producing glass tubes that are then snapped in segments to make the length of beads. The rough edges of the beads obtained this way are then polished by re-heating the beads placed in a pot with ashes to prevent them from sticking and the holes collapsing. This technique is still used in India nowadays (Kanungo 2016). The m-Na-Al 6 glass beads are opaque yellow and green. The m-Na-Al 1 glass beads are green and yellow too but also orange, red, black and amber. The m-Na-Al ? glass beads are all disc-shaped and orange and were created with a different technique difficult to determine. Although the use of LA-ICP-MS is not able to identify colorants, the presence of higher concentrations of some elements and previous findings can help identify possible coloring agents for most of the glasses. For yellow and green glasses higher concentrations of tin and lead suggest that lead stannate, a yellow opacifier, was used. In green glasses, the additional presence of copper (CuO = 0.5 to 0.8%) is noted. There is no obvious difference between the coloring technique used for the yellow and green m-Na-Al 1 and 6 glasses. Amber glass beads have higher concentrations of iron (> 3.5%). Black and colorless glass beads do not contain any element present in particularly high quantity. Orange, red and turquoise blue beads contain higher concentrations of copper that vary in a wide range (0.8-4% as CuO in the red glass; 1.8 to 3.5% in the orange glass and 0.6% in the blue glass).

4.2 Soda plant ash glass with high lime and alumina

The second group of soda-high alumina glass have magnesia and potash concentrations higher than 1.5% (respectively 2.4 and 3.2% on average) suggesting the use of soda plant ash. Phosphorus is also fairly high (1.1%). This is consistent with the use of halophytic plant (growing in salt rich soils) ashes. Lime and alumina are higher than 5%. If lime is often a constituent of the ashes, alumina is quite likely part of the sand. This glass will be called v-Na-Ca-Al for vegetable soda – high lime and alumina. Uranium concentrations are relatively high but extremely variable. They range from 23 to 354 ppm.

If high alumina glasses with relatively high trace element concentrations are associated with production from India, the use of soda plant ashes as a flux is highly unusual in this region. Soda plant ash glass with higher alumina concentrations can be found in Pakistan and Central Asia. Their presence was found in Afghanistan (Brill 1999), Uzbekistan (Abdurazakov 2009; Rehren et al. 2010) and Pakistan (Dussubieux and Gratuze 2003) for a wide period ranging from the 2nd century BCE to the 14th century CE. The glass samples from Pakistan found in Bara (200 BCE – CE 200) are the only ones that have trace element concentrations available. Those trace element concentrations are fairly different from the ones measured in the Nepalese v-Na-Ca-Al glass beads with (for example) twice the concentrations of Sr in the glass beads from Bara (490 ± 150 ppm) compared to the beads from Nepal and only 5 ± 9 ppm of U in the Pakistani glass when this element can reach more than 350 ppm in the Nepalese glass. More research is necessary to pinpoint exactly the region of manufacture of the v-Na-Ca-Al glass identified in Nepal.

All the samples in this group are segmented beads with a translucent turquoise blue color. All the glass beads contain copper in concentrations ranging from 0.4 to 1.7%.

4.3 Soda plant ash glass with high lime

Fifteen beads belong to the vegetable soda – lime or v-Na-Ca glass group. It is a soda-rich glass with potash and magnesia concentrations higher than 1.5%, which is characteristic of the use of halophytic plant ashes. This glass type has alumina concentrations that are always under 2.7%.

The earliest glass found in Mesopotamia was manufactured using soda plant ash as a flux and low alumina sand. The soda plant ash glass tradition continued in Mesopotamia, and Sasanian glassmakers produced such a glass from the 3rd to the 7th century CE (Mirti et al. 2008, 2009).

Using magnesia, phosphorus, lime, chromium, rubidium and lanthanum, the principal components were calculated for the Nepalese v-Na-Ca glass beads and for Sasanian and Early Islamic glass from the Iraqi site of Kish (Dussubieux, in press). Figure 10.4 shows PC 1 and 2 for these glass samples. First, it is important to note that the Sasanian glass composition varies in a wide range (Mirti et al. 2008, 2009). It is quite likely that Sasanian v-Na-Ca glass was manufactured in different places. All the v-Na-Ca samples from Nepal fall in the same broad area as the Kish glass with the exception of two glass samples. Those two glass beads are NEP040 and 41, two turquoise blue segmented beads containing copper (CuO = 0.4%) which quite likely acted as a colorant.

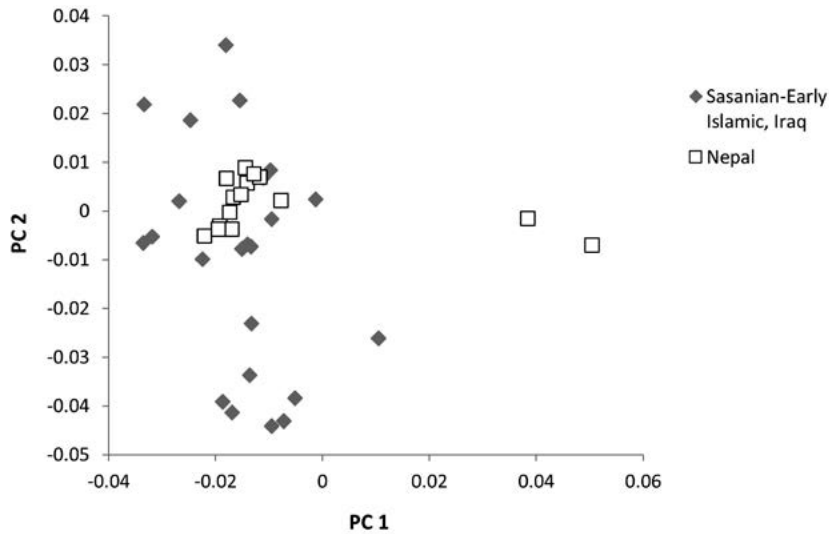

Fig. 10.4: PCA conducted on Sasanian and post-Sasanian glass samples from the site of Kish in Iraq (Dussubieux, in press) and the v-Na-Ca glass samples from Nepal.

All the other v-Na-Ca beads are opaque green drawn beads with rough edges. They contain copper (0.6 to 1.2%) and significant quantities of lead (11.6 ± 3.2%) and tin (0.9 ± 0.4%).

4.4 Potash glass

The four glass beads with higher potash concentrations and low soda levels are part of two distinct groups with very different lead content. Three beads (2016-1, 2 and 3) contain lead at the trace level while DOL05 has 49% of lead.

The non-lead potash glass samples will be discussed first. A (low lead)-potash glass is a glass type with potash as the major constituent after silica. Generally, constituents such as magnesia are fairly low (< 1%) suggesting a mineral origin for the potash (e.g., saltpeter). As indicated by a wide range of concentrations of lime and alumina, sands with a wide range of compositions were mixed with saltpeter. Based on the concentrations of these two oxides (CaO and Al_2O_3), three groups of potash glass were defined (Dussubieux and Gratuze 2010; Lankton and Dussubieux 2006; Lankton and Dussubieux 2013): a high Ca – low Al – K glass, a low Ca – high Al – K glass and a moderate Ca and Al – K glass (Figure 10.5).

Most of the high Ca – low Al – K glass samples were identified at Ban Don Ta Phet, Thailand (4th-3rd century BCE). Potash glass found in India generally fits within the moderate Al and Ca – K glass compositional range. From a general

point of view, potash glasses from Southeast Asia have either moderate alumina and lime composition or low Ca – high Al composition.

The origin of the potash glasses is still uncertain at this point even if a Chinese or a Southeast Asian origin (Dussubieux and Pryce 2016; Lankton et al. 2008) have been hypothesized.

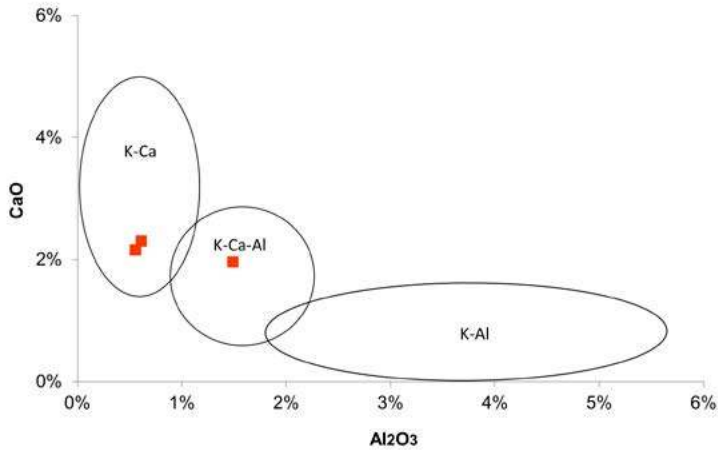

Fig. 10.5: Al_2O_3 vs CaO bi-plots for the potash glass samples found in Nepal with the area corresponding to the different potash sub-groups.

Two samples (2016-2 and 2016-3) fall into the high Ca – low Al – K glass while 2016-1 belongs to the moderate Ca and Al – K glass (Figure 10.5). Samples 2016-2 and 2016-3 are turquoise blue and both contain copper in significant quantities (1.6% CuO). Sample 2016-1 is a dark blue glass bead containing 350 ppm of cobalt. Two hundred and fifty ppm of arsenic was also detected in this glass bead suggesting the use of arsenic rich cobalt ores such as cobaltite (CoAsS). The combination of cobalt and arsenic is mostly present at the earliest sites with potash glass (in Southeast Asia) namely Ban Don Ta Phet (4th-3rd century BCE), and Khao Sam Kaeo (4th-2nd century BCE) (Dussubieux 2016).

Sample DOL001 also falls into the category of potash glass as potash is the main alkali present in this glass (7.5%); however, the main constituent in the glass is lead (49.2%). Silica is lower in this glass compared to the other samples with only 38.8% of this oxide. This glass also contains 3.4% of lime. All the other constituents in these samples have concentrations under 1%. The glass belongs to the K_2O-PbO-SiO_2 system that was used in China from the Tang Dynasty (CE 618-907) to the Yuan Dynasty (CE 1279–1368) (Gan Fuxi 2009). This blue

bead contains 0.6% of copper that certainly produces the blue color of the glass. DOL001 is a wound bead while 2016-1, 2 and 3 are drawn beads.

5. Discussion

The diversity of the compositions reflects the wide time span covered by the beads (Table 10.3).

	Faience	K	Pb-K	m-Na-Al 1	m-Na-Al 6	m-Na-Al ?	v-Na-Ca-Al	v-Na-Ca
Lubrak (1269-1123 BCE)	1							
Mebrak (ca. 400 BCE-100 CE)		3		1	1		1	
Samdzong (ca. 450-650 CE)				35	21		10	15
RRD (768-882 CE)			1			4		

Table 10.3: Distribution of the samples by types and periods.

The oldest bead is made of faience. Contemporaneous faience beads were found at the site of Gebusailu in western Tibet, in a region adjacent to Nepal. Based on manufacturing technique, typology and compositions, an Egyptian or a region influenced by the Egyptian faience technology was proposed for provenance (Cao et al. 2021). The Lubrak bead is different, being barrel-shaped, while the Gebusailu beads were segmented but similar compositions would indicate that the Nepalese faience bead was also an import from the west.

The potash glass beads found at Mebrak have compositions (high lime – low alumina potash glass and use of a cobalt associated with arsenic) from a period spanning the 4th to 2nd century BCE. The origin of this glass type is not certain although southern China is a possibility. The high lead – potash glass found in Raja Rani Dolpo is a later glass available starting around the 7th century CE.

The m-Na-Al 1 glass type was manufactured in Sri Lanka and South India starting around the middle of the 1st millennium BCE and continued being produced until the beginning of the 2nd millennium CE.

The presence of m-Na-Al 6 glass from a context dating to the 7th century CE or earlier is surprising, as up to now this glass has only been identified in Africa

and was associated with a period ranging from the 9th to the 13th century CE. It can be assumed that this glass was manufactured in India earlier than the 9th century CE but it went undetected due to the lack of data about Indian glass in India. Its place of production is possibly located in the Indo-Ganges region.

The m-Na-Al ? glass type is close in composition to the m-Na-Al 3 and 4 glasses without really matching the composition of these two glass types.

The two soda plant ash glass types seem to come from the west: Central Asia for the v-Na-Ca-Al glass and the Sassanian region for the v-Na-Ca glass.

There is a strong correlation between the compositions and the types of beads: the m-Na-Al 1 glass beads that form the larger group are drawn beads obtained from tube cut when cold and then polished with a rather wide range of colors. The m-Na-Al 6 glass beads are very similar in the way they were manufactured but they are only available in green and yellow colors. The m-Na-Al ? glass beads are very different, being disc shaped and orange. The v-Na-Ca beads are drawn beads obtained from snapped tubes of glass but they did not get polished the same way as the m-Na-Al 1 and 6 beads and present sharper edges. The v-Na-Ca-Al beads were obtained from tubes of glass pinched while still hot, producing segmented beads. The potash beads are drawn and polished like the m-Na-Al 1 and 6 beads but the lead-potash bead is wound.

As expected, the analysis of the glass beads confirmed our existing understanding of trade relationships in the region but also demonstrated new connections. Lubrak was characterized as having South Asian connections; although no precise provenance of the faience bead was determined, it is likely to have come from the Middle East or the west and is unlikely to have been fabricated in South Asia at this very early date. Mebrak was characterized as having clear South Asian connections as well but relationships to the north and west were hypothesized by the excavators of the site. The South Asian connection was reinforced with one bead from the Indo-Gangetic region and another from Sri Lanka/southern India. A northern connection is suggested by the presence of a Central Asia bead, and one surprise is the presence of a bead from southern China. The western connection has not been verified in this analysis, however. The bulk of the beads found at Samdzong come from the south: Sri Lanka/southern India and the Indo-Gangetic region. Northern connections are suggested by Central Asian beads and the west is suggested by a bead from Sassania. Dolpo has a single bead from southern China; the provenience of four other beads could not be determined with certainty but a connection to eastern Uttar Pradesh is hypothesized. This region of India lies just to the south of Dolpo so a connection to it is plausible. Just how these beads were traded into these sites is unknown but they reflect an increasingly wide network of trade relationships over time.

Acknowledgements

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Chapter 11

Inland from the sea: Rethinking the value of mineral soda alumina drawn glass beads from medieval North India

Mudit Trivedi[1] and Laure Dussubieux[2]

1. Introduction

Small drawn glass beads, specifically those previously termed 'Trade-wind' or 'Indo-Pacific' beads, have long been the lingua franca of Indian Ocean archaeological networks. As mass-produced, lightweight, readily transported items, they have been understood as the premier premodern commodity. Researchers have focused upon their distribution networks attempting to disentangle the patterns of their exchange and their social significance across different contexts of their production and consumption (Van der Sleen 1956; Francis 1990, 2002). Over the last two decades, elemental analysis, especially the use of trace element concentrations, has been critical to advances in their study.

Indian Ocean drawn glass bead assemblages in most regions include artifacts fashioned from a range of glasses including potash, plant ash and mineral soda-high alumina South Asian glass (Dussubieux et al. 2010; Lankton and Dussubieux 2008; Lankton et al. 2006; Carter 2016; Wood 2016). This compositional diversity has significantly circumscribed the presumed centrality of Indian craftsmen in the histories of the origin and diffusion of this technique. Instead, it is clear that in every phase of the Indian Ocean trade, drawn glass beads produced in South Asia entered into complex bead markets and found their way into assemblages where they were one kind of bead used amongst many others.

The greatest advance in the study of these networks and the role of beads made in South Asia has come through using trace element chemistry to establish definite compositional groups within each of these glass recipes. These compositional groups are understood as spatially and temporally discrete instances of these recipes, differentiated by structured variation in trace elements and major oxides related to flux and silica source. In the case of South Asian mineral soda-high

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alumina (m-Na-Al) glass, this approach led to the delineation of five major compositional groups (Dussubieux et al. 2010; Dussubieux and Wood 2021, see Annex B). Distinct in terms of their hypothesized area of origin within South Asia, and in terms of their patterned phases of exchange to sites in mainland and island South-East Asia, Eastern and Southern Africa and beyond, the m-Na-Al compositional groups have parsed the Indian Ocean South Asian bead trade into determinate patterns between regions.

Yet, the specific patterns of the production of these drawn glass beads *within* South Asia are poorly understood, especially for the period after the 5th century CE, ironically exactly when we know most about the export trade. The dearth of glass bead assemblage quantification, seriation and single-locus excavations within South Asia means we know little about the shifting geography of craft centers, communities of practice, their distinctive repertoires, and the specific innovations and developments in drawn glass bead technologies across the South Asian early medieval (600-1200 CE) and medieval periods (1200-1700 CE).

This paper presents the first analysis of a major second millennium CE glass assemblage, from Indor, Northern India. Of 6000 glass artifacts comprising bangles, beads, vessels, and glass processing debris, 218 samples were analyzed (see Table 11.1). The Indor results have significantly advanced our understanding of South Asian and m-Na-Al glass, providing evidence of 6 hitherto undetected new compositional groups of m-Na-Al glass, designated groups 7 through 12. A discussion of the significance, distinctive chemistry and insights into shifting patterns of glass supply and use at Indor is forthcoming in Trivedi and Dussubieux (in preparation).

Artifact type	Number of artifacts
Glass beads	211
Glass bangles	3960
Vessel fragments	637+
Fragments of Glass Processing debris (various types)	~475

Table 11.1: Vitreous artifact counts from the Indor Project

From this wider analysis, this paper contributes to this volume by focusing upon the 12 drawn beads that were sampled from Indor. It reveals hitherto unprecedented variation in drawn beads by compositional group. Through this first case-study of medieval South Asian drawn glass beads, this paper presents arguments about the complexities of drawn glass bead production and exchange within medieval

South Asia. It contrasts the evidence at hand for the long-distance trade of such beads within and beyond South Asia. From this it reflects on the opportunities such situated studies provide for understanding the use and rethinking the value of these distinctive beads. To do so, it comparatively situates the Indor drawn beads within m-Na-Al datasets and builds arguments, bringing together observations from their morphometric specificities, colorant chemistry and patterned forms of bead-use.

2. Drawn bead exchange networks and mineral soda alumina glass

Drawn glass beads in South Asia have attracted three kinds of scholarly attention: 1) syntheses of archaeological finds and comments on their distributions (Abraham 2016, 2013), 2) ethnoarchaeological study of one of the last surviving centers of drawn bead production at Papanaidupet (Stern 1987; Francis 1990, 2002; Kanungo 2016) and 3) elemental analyses of selected beads (Brill 1987, 1999; Varshneya et al. 1988; Basa 1994). As discussed above, in the past two decades the third approach has provided the most robust means of historicizing the production, exchange and use of these beads in the region.

Annex B provides an analytical summary of m-Na-Al compositional groups and an account of the distributions of groups 1 through 4 and 6 in detail. Here, three aspects are stressed. First, the analyses in this volume from Indor, Nepal, Kish and Mayotte (Aldenderfer and Dussubieux, this volume; Larson and Dussubieux, this volume; Wood et al., this volume) collectively provide evidence for drawn bead production in all of the new groups of m-Na-Al glass (7 through 12). This leads to the question of how we model and understand this heterogeneous nature of m-Na-Al drawn bead production. Earlier interpretations of m-Na-Al compositional groups have been culture-historical, i.e., that particular glass groups relate to specific production regions, bounded time-periods and exchange-networks. This picture was based largely on the analysis of the widely traded drawn beads and not to the same degree on the different social and technical scales at which bangle, wound bead, and later vessel production occurred in South Asian societies. The emerging picture of m-Na-Al glass now suggests the temporal, spatial and social overlap of compositional groups, suggesting complex networks of raw glass exchange between distinct communities of practice, taste and consumption (Trivedi 2020; Trivedi and Dussubieux, in preparation). In this context, this chapter provides the first analysis of drawn beads *within* South Asia in the period when their trade to destinations outside South Asia was at its peak.

Accumulating research has detailed how Group 1 glasses, known to originate from South India and Sri Lanka, and which circulated in the Bay of Bengal in the

Early historic period (400 BCE to 500 CE) were also traded much further and produced into later periods. Group 1 drawn beads, c. 500-700 CE were exchanged across long distances to sites in Zanzibar, Quseir al Qadim and Merovingian Europe (Pion and Gratuze 2016; Then-Obłuska and Dussubieux 2016; Wood et al. 2017). As reported in this volume, new evidence suggests that Group 1 beads also circulated in small numbers in the Middle East and the Levant, identified at the site of Kish in Iraq and Quseir, Egypt (Dussubieux, this volume; Then-Obłuska and Dussubieux 2016). Group 3 is understood to be Early historic and associated with the site of Kopia and the Ganga plains. Group 3 drawn bead circulation is less well understood but also appears to have been centered on the Bay of Bengal, and Group 3 beads have been prominently recovered at Khao Sam Kaeo and other sites on the Siamo-Malay peninsula (Dussubieux et al. 2010; Dussubieux and Kanungo 2013; Dussubieux and Bellina 2017).

In contrast, m-Na-Al Groups 2 and 4 provide concrete evidence for second millennium CE trade networks. Group 2 was hypothesized to be related to the western Indian site of Chaul, or its immediate region, and was widely traded to the Swahili coast as well as to Island South East Asia (Dussubieux et al. 2009, 2010; Dussubieux and Wood 2021) m-Na-Al Group 4 beads have been recovered in Southeast Asian glass assemblages and rarely in Swahili contexts (Carter and Beavan 2014; Carter et al. 2016, 2019). Forthcoming analysis from the Swahili coast, where both groups 2 and 4 had already been extensively documented, has revealed the existence of a previously unknown, m-Na-Al Group 6 (Dussubieux and Wood 2021).

In contrast, we have little evidence from South Asia for the second millennium CE. Groups 2 and 4 are both poorly understood in terms of their area of origin, raw glass trading networks (if any), artifact repertoires and geographies of production and use within South Asia. As a first data point on the early medieval period, Aldenderfer and Dussubieux (this volume) report Group 6 beads from early medieval (6th-7th centuries CE) Nepal. It is evident that there is extensive, regionally diverse drawn and wound glass bead production across the early medieval and medieval periods of South Asian history, with a geography likely distinct from that in prior epochs. The accumulated published data, despite its limits, allows for the recognition of discernable shifts in the distributions of glass beads over these periods. Kanungo's synthesis of the early medieval and medieval data indicates a clear concentration in North India, in the Yamuna plains and hills near Delhi, a region from which glass assemblages have hitherto been neither systematically described nor analyzed (Kanungo 2014:177-178). This article presents analysis of a small sample from one such site.

3. Indor: Historical and archaeological context

The valley of Indor is located a short distance south-west of Delhi in the region of Mewat in North India (Figure 11.1). Mewat is unique in North Indian medieval history, stereotyped as an enduring site of rebellion and intransigence towards the empires based at the capital cities successively raised at Delhi. In this context, the fortified city of Indor was built in the region of Mewat in the 14th century CE. Since 2015, Trivedi has directed, in collaboration with the Rajasthan Department of Archaeology and Museums, an archaeological survey and excavation project centered upon the valley and medieval city of Indor.

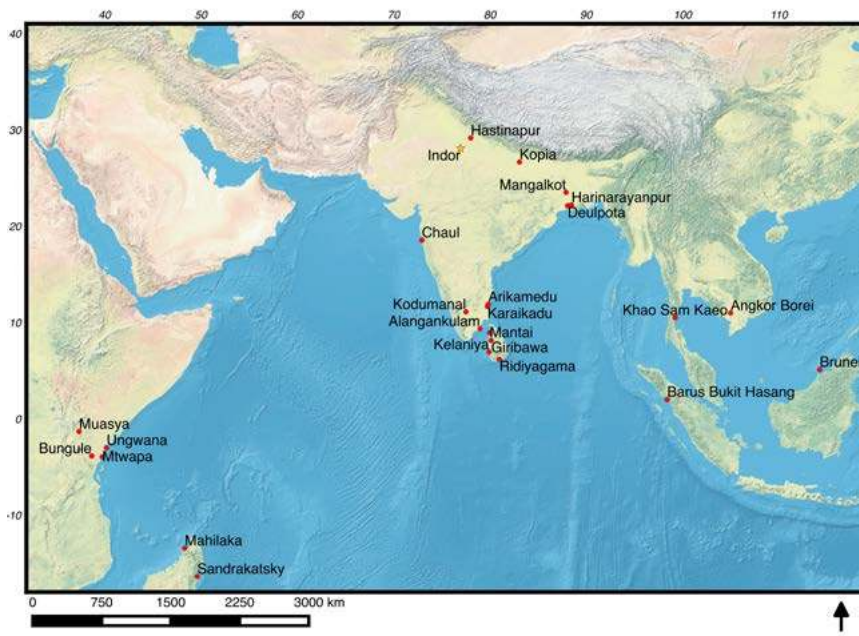

Fig. 11.1: Indor amongst major m-Na-Al drawn bead sites.

A 20 Ha fort, a monumental graveyard, and a series of occupied mounds in the valley comprise the hinterland of Indor, where a phase of urbanization is closely associated with the conversion of the lineage of the Khanzada of Mewat to Islam. Trivedi's research has established a settlement-history of the Indor valley over the last 1000 years, detailing successive phases of rapid urbanization and increase in settlement followed by fission and ruralization alongside later episodes of urban renewal. The wider survey has yielded vestiges of agrarian and military

infrastructures and traces of a range of craft-production activity, especially associated with the foundation of the city of Indor and Khanzada efforts at forging a regional polity in the 15th century. This includes clear evidence for extensive use and production of glass ornaments, especially bangles. Targeted excavations on the Lower Town A mound (Site IAS002) at Indor have allowed for the detailed seriation of medieval assemblages based on 36 radiocarbon dates. The excavated sample ranges between CE 1350-1960 and provides the first detailed window into medieval glass assemblages in North India excavated under controlled single-locus methods (Trivedi and RDAM 2015, 2016a, 2016b; Trivedi 2020). The Unit A excavated assemblage is divided into two phases here. Phase 1, CE 1350-1500, is a period of urban growth linked to the foundation of the Fort, when the Khanzada strive for ascendancy over Mewat, during which despite repeated sieges, the city of Indor flourished. Phase 2, CE 1500-1800, is a mixed period, moving between urban disrepair, incorporation into the Mughal empire and by the 18th century a new kind of urban formation (see Trivedi 2021 for an extended discussion).

The earliest occupation identified at Indor, dated to the 12th/13th century CE, included probable faience beads recovered as associated surface finds. Glass, including beads, is subsequently present from c. 1350 onwards and is available from every cultural phase at Indor after the conversion of the Khanzada and the construction of the city. Glass vessels and glass beads are less common than bangles at Indor. Table 11.1 above provides counts for different classes of vitreous finds from the Indor survey and excavations. Samples from each of these artifact categories (drawn and wound beads, blown glass vessels, glass bangles, glass working debris and crucible fragments) were selected for elemental analysis conducted at the Elemental Analysis Facility, Field Museum in 2019 (for protocols see Annex A). The results have yielded significant insights into cultural changes in medieval glass assemblages, shifts between recipes, and the growing intimacy of glass-working at North Indian small towns like Indor from the 15th through 18th centuries (Trivedi 2020; Trivedi and Dussubieux, in preparation).

3.1. The Indor glass bead assemblage

The Indor glass bead assemblage comprises 211 beads of which 152 were recovered from the controlled and targeted Unit A excavations on the Lower Town A Mound (Excavation details in Trivedi and RDAM 2016b). The remainder were recovered from surface collections made within the Fort of Indor and at other sites documented in the Indor Valley.

Drawn beads (n=146) dominate the glass bead assemblage, comprising 92% of the total. A small but valuable corpus of molded (n=6) and wound (n=10) beads were also recovered but are not discussed here. Of the 146 drawn glass beads excavated at Indor, all but four can be securely phased to the two periods outlined above.

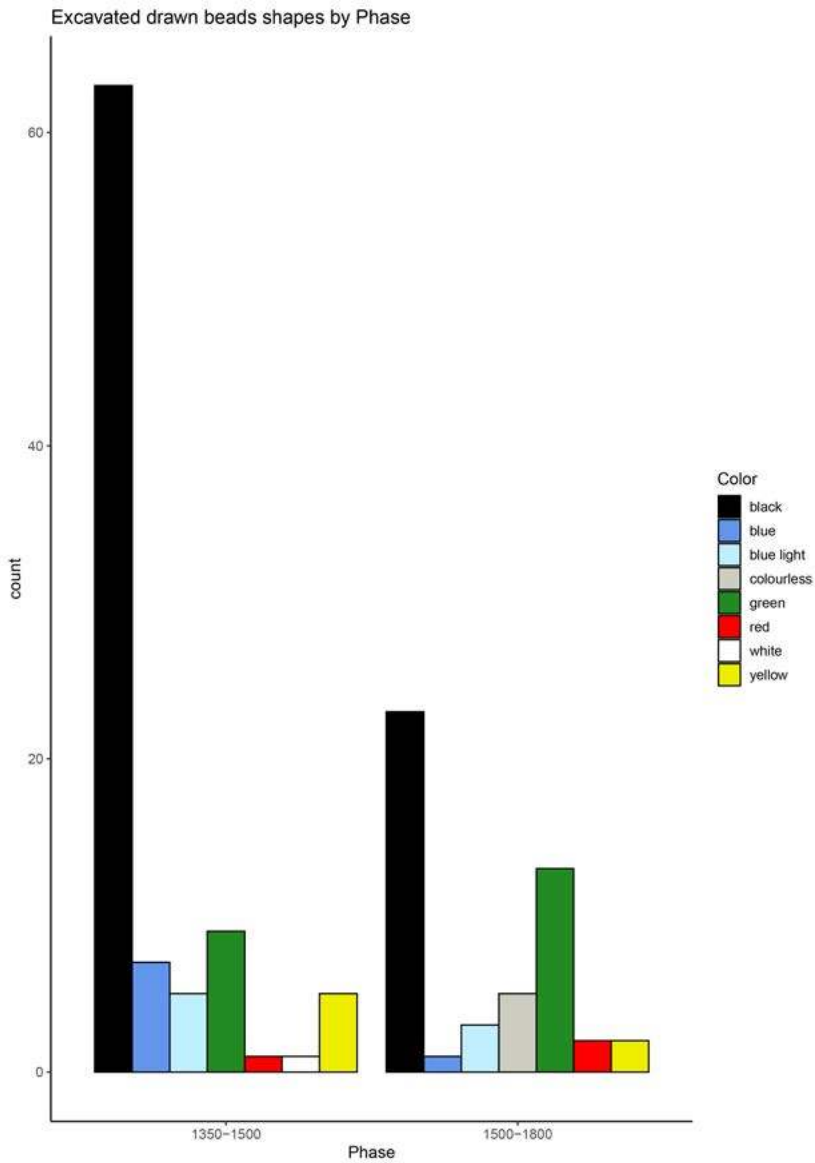

Fig. 11.2: Colors of drawn beads at Indor by phase.

Of these 142 beads, more than half date to the 15th century occupation. A few clear trends are apparent at the assemblage level. 62% of all drawn beads are black, a noteworthy trend, and in both periods, black beads are at least 40% of the assemblage. The next most common colors are a range of greens, in greater proportion after 1500. Blues occur in small but regular quantities; cobalt blue is readily distinguished from a lighter hue. Markedly, yellows (n=7) and reds (n=3) are particularly rare (Figure 11.2). These trends contrast sharply with the varying relative abundance of mineral soda alumina bead assemblages especially as traded to the East African coast. Comparable medieval South Asian drawn glass bead assemblages have not been published fully nor quantified.

Most of the Indor drawn glass beads are oblates or irregular cylinders, resulting from their bulk rounding by documented reheating and polishing processes (Kanungo 2016). Barrel shaped beads consistently occur at a low frequency, seemingly restricted to black and yellow glass. White and colorless beads are infrequent finds. Tubular drawn beads are very rare at Indor and only two were recovered.

These distinctive patterns of shape and color indicate a clear preference for black, green and blue annular, often irregular beads. They present the first trends of the exchange, use and consumption of drawn beads in medieval South Asia. We can expect these patterns to look very different for another site in North India with differences likely to be evidenced even at Indor in future excavation units in other elite neighborhoods. From this assemblage, 12 drawn glass beads were selected judgmentally (Table 11.2, Figure S11.1) to include samples from across stratigraphic and chronological divisions and distinct colors.

S. no	Sample name	Color	Diaphaneity	Period	Size	Shape	Group
1	GD001	Green	Translucent	1350-1500	very small	oblate	m-Na-Al-4
2	GD002	Blue	Translucent	1350-1500	very small	cylinder	m-Na-Al-4
3	GD010	Black	Opaque	1350-1500	small	barrel	m-Na-Al-10
4	GD015	Red	Opaque	1350-1500	small	barrel	m-Na-Al-4
5	GD031	Blue	Translucent	1350-1500	very small	broken cylinder	m-Na-Al-4
6	GD076	White	Translucent / Opaque	1350-1500	small	oblate	m-Na-Al-4
7	GD077	Yellow	Opaque	1350-1500	small	lenticular	m-Na-Al-2
8	GD84	Black	Opaque	1350-1500	medium	barrel	m-Na-Al-7
9	GD118	Colorless	Translucent	1500-1800	small	oblate	m-Na-Al-8
10	GD144	Green	Translucent	1500-1800	medium	oblate	m-Na-Al-3
11	GD146	Blue	Translucent	1500-1800	small	cylinder	m-Na-Al-4*
12a	GD165Gr	Green	Translucent	1350-1500	large	tube	m-Na-Al-9
12b	GD165Y	Yellow	Opaque	1350-1500	large	tube	m-Na-Al-9

Table 11.2: Description of analyzed drawn beads (GD146 is discussed below).

4. Results

The beads were analyzed at the EAF in 2019 (see Annex A for more details about instrumentation and protocol). All 12 drawn glass beads sampled from Indor are m-Na-Al glasses. However, in contrast to all prior studied assemblages of drawn glass beads in South Asia, and m-Na-Al drawn glass beads traded outside South Asia, this small sample of 12 drawn glass beads was unprecedentedly heterogeneous. Figure 11.3 presents a graphical summary of the 3D-Principal Component Analysis (PCA) used to classify m-Na-Al beads (as defined in Dussubieux et al. 2010; Trivedi and Dussubieux, in preparation, Annex B). The 12 Indor glass beads were classified to 7 different groups of m-Na-Al glass, namely Groups 2, 3, 4 and 7 through 10. These definite trends of compositional variation are summarized period-wise in Table 11.3. Group 6 drawn beads are notably absent, but bangles of these glasses do occur at Indor (Trivedi and Dussubieux, in preparation). The results are discussed in terms of the shift between periods, and the morphology and typology of the beads and the colorant chemistry.

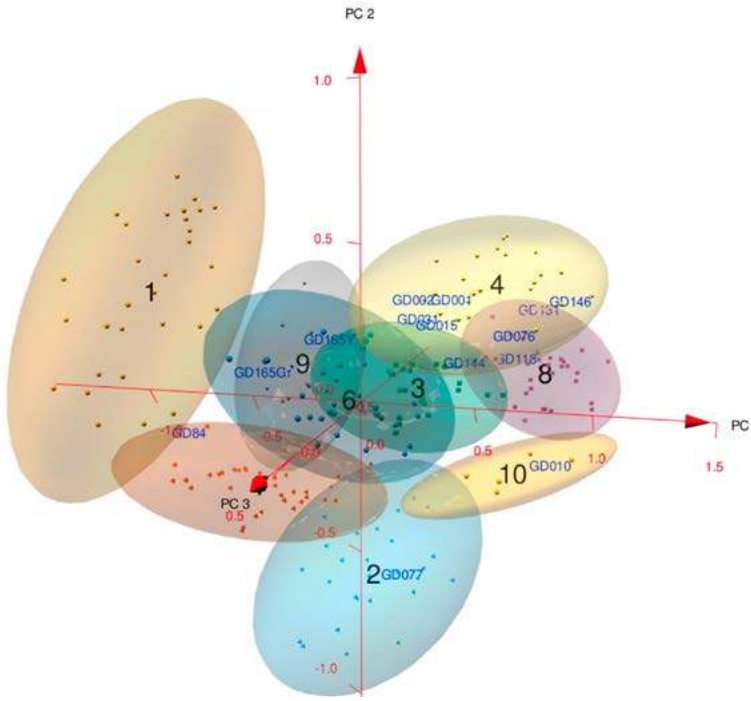

Fig. 11.3: Three-dimensional PCA plot with 95% confidence intervals of the defined m-Na-Al groups. (Groups 11 and 12 are excluded here for clarity). PCA was calculated using values for MgO, CaO, Sr, Zr, U, Ba, Cs following protocols defined for the analysis of m-Na-Al glass in Dussubieux et al. (2010).

4.1. Compositional diversity and shift in m-Na-Al groups between periods

From Indor's Phase 1, 1350-1500 CE, 9 drawn beads were sampled. Of these 5 are m-Na-Al group 4 and the other are single examples from Groups 2, 7, 9 and 10. Both the preponderance of Group 4 and the heterogeneity are notable in the context of the color preference towards black that structures the Indor drawn bead assemblage. Group 4 appears to contribute a range of colors (green, blue-green, white, cobalt blue and red) but black beads sampled were produced from Groups 7 and 10 glasses.

The evidence from Phase 2, CE 1500-1800 CE, indicates a shift with Group 3, 4 and 8 compositions, yet the small sample (n=3) precludes any generalization. These three beads are also distinguished by their rich and distinct colors in the Indor assemblage in bright green, colorless, and cobalt blue glass. These three groups are strongly associated in their trace and REE compositions and possibly

indicate different North India glass production signatures (Trivedi and Dussubieux, in preparation).

	1350-1500	1500-1800
2	1	
3		1
4	**5**	
Outlier to 4		1*
6		
7	1	
8		1
9	1	
10	1	

Table 11.3: Group-wise summary of Indor results by m-Na-Al group. (Greens indicate preponderance, gray shading conspicuous absence)

A note is needed on the Group 3 bead, as m-Na-Al Group 3 glasses have hitherto been understood as limited to the period c. 400 BCE to CE 500. The wider Indor analysis has demonstrated that Group 3 glasses continue into the second millennium CE. Trivedi and Dussubieux (in preparation) demonstrate that trace element trends appear to separate chronologically distinct eras of production within the PCA group. Group 4 and 8 are similar in composition, but Group 8 has consistently higher uranium levels. The sole Group 4 bead from Phase 2 (GD146) bears anomalously high uranium for Group 4 glasses, and this is discussed further below.

Within the limits of the sample size, it appears that Indor's Phase 1 witnessed bead supply from a wide range of producers working different m-Na-Al glasses beyond Group 4. As discussed below, this supply appears to be structured by color and intended use. Two provisional trends may be hazarded about Phase 2 from the small sample analyzed: (a) networks supplying beads to Indor may have contracted, a hypothesis we will test in further analysis and (b) shifts in use and preference are indicated in changed techniques and goals of bead color production.

4.2. Bead morphology and typology

The Group 4 beads from Phase 1 present a range of morphological characteristics providing insights into their production and likely patterns of use. GD001, a dull green bead, is distinguished by its irregular annular shape, indicative of indifferent bulk reheating at the polishing stage (see Figure S11.1). GD002 bears striations of lighter and darker aqua shades, likely indicative of a melt where colorant was not completely homogeneously mixed in. GD015, an opaque red barrel-shaped

bead, bears the distinctive darker colored striations, a known artifact of the drawing process. GD031 is a small dark (cobalt) blue barrel-shaped bead that was irregularly cut and then heat-treated, and used despite its markedly irregular shape. GD076, a rare white bead, was also heat rounded to an irregular shape. Across all colors, the morphological evidence suggests that Group 4 bead producers operated on a mass scale of production, and their products were likely incorporated into a range of beaded products where individual symmetry and appearance were not of concern.

In contrast, the sole Group 2 bead, GD77, a modified lenticular disc, displays prominent flat sides, possible signs of having been segmented with a tool, a trend evidenced in published Group 2 examples (Dussubieux et al. 2008). GD010 (Group 10) and GD084 (Group 7) are visually similar shaped black barrel beads notably produced from distinct m-Na-Al glasses. The three richly colored beads analyzed from the Phase 2 are also broadly more symmetrical. Bead roundness and asymmetry have been recorded to understand production processes and organize bead-series (Francis 1990; Wood 2016). These observations suggest that bead morphology may also indicate patterned forms of use: asymmetrical types were likely produced for incorporation into a range of beaded fabrics, clothes, and furnishings with more carefully finished specimens, and shapes like barrels were likely intended for other uses, where they would be more visible, in personal ornaments such as necklaces, or as beaded into higher-value fabrics.

GD165 is a distinctive bicolor drawn tubular bead. It is one amongst a series of types known to combine a yellow core over which a green or blue exterior is drawn. These types have a long history in South Asian assemblages. Similar in color, but not always also in form, these beads have been recovered from Early Historic through Medieval periods from sites in the Deccan (Nevasa, Navdatoli and Brahmapuri-Kolhapur where it was known from 15th century contexts). Specimens are also known from Mantai, Sri Lanka, and the type was traded to Thailand (Rodcharoen 2014), Sungai Mas, Malaysia (Davison 1972:170-171), and the Philippines (Dussubieux pers. comm.). East African finds include those in Group 6 glasses from Tanzania (Dussubieux and Wood 2021) and Mayotte (Wood et al., this volume). Both of GD165 yellow and green glasses are m-Na-Al Group 9. The uniqueness of GD165 in composition amongst sampled beads and its typological singularity amidst the Indor bead assemblage suggest indices of its value. This result helps provide another chronological and compositional anchor for the type and the cultural preference and value it indexes; the lack of compositional analyses of its cognates from other sites limits what can be asserted about how GD165 relates to this family of beads, and Group 9 glasses to their production.

4.3. Colorant chemistry

While the small sample analyzed precludes generalizations from these 12 beads to the structure of the Indor drawn bead assemblage in terms of m-Na-Al compositional groups, the colorant chemistry of the 12 beads from Indor discussed here allows for key observations about colorant knowledge and techniques in m-Na-Al glass-working traditions.

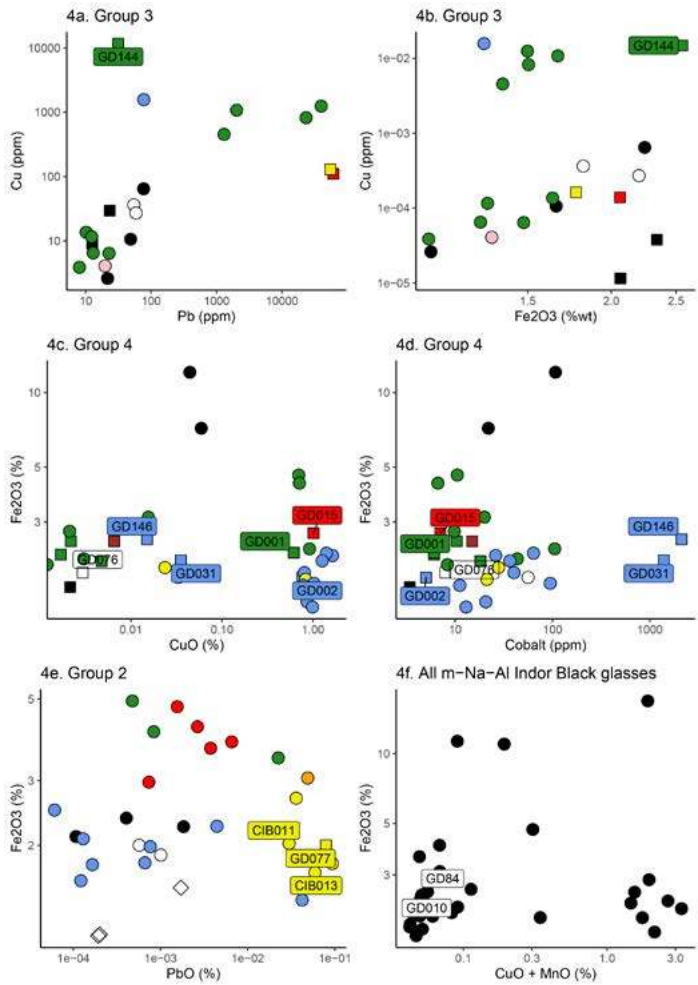

Fig. 11.4: Biplots (all scales log) for (a) Group 3 Cu (ppm) by Pb (ppm) and (b) Cu (ppm) by Fe_2O_3 (wt %). In these two plots circles are Kopia reference data from Dussubieux and Kanungo 2013, all colors represent bead colors, pink is colorless (c) Group 4 Fe_2O_3 (wt %) by CuO (wt %) (d) Fe_2O_3 (wt %) by Co (ppm), Reference data from Dussubieux et al. (2010). (e) Group 2 Fe_2O_3 (wt %) by PbO (wt %). Reference data from Dussubieux et al. (2008) (circles) and Dussubieux (this volume) (diamonds), Indor (square) (f) Fe_2O_3 (wt %) by CuO+MnO (wt %) for all black glasses analyzed from Indor (data from Trivedi and Dussubieux, in preparation).

Beyond the morphological traits observed above, Group 4 beads are known for a range of variation in both form and composition. In the 15th-17th century CE contexts of the Cardamom Mountain Jar Burials (CMJB) sites in Cambodia, Group 4 irregular oblates have been noted as bearing 'skewed striations' (Carter and Beavan 2014; Carter et al. 2016). In addition to this morphological irregularity, variability in Group 4 compositions has been noted: Dussubieux et al. (2008) and Carter et al. (2016) define a high-Mg m-Na-Al glass co-occurring with Group 4 beads. The Indor Group 4 beads do not cluster in this way, instead demonstrating irregular spread away from Group mean in most trace elements, with only GD076 displaying significant difference in major oxide levels with lower lime levels (see Table 11.4).

A shift within Group 4 colorant strategies is evidenced across the wide color spectrum of these beads at Indor. As discussed previously by Dussubieux et al. (2010; 2011), varying levels of iron and copper create desired black, green and red hues. Figures 11.4c and 11.4d indicate how the Group 4 red, green and light blue (GD001,2,15) beads recovered from Indor were produced through the addition of 1% CuO and between 1.7-2.7% Fe_2O_3. In contrast, GD031 and GD146 are high cobalt blues. Figure 11.4d makes clear that these are distinct from known Group 4 cobalt blues by an order of magnitude in Co concentrations (respectively 1394 and 2116 ppm). Such high levels of cobalt are striking, suggesting a deliberate shift towards ensuring richly colored blues. A further observation is necessary: Table 11.4 indicates GD146 and GD031 are themselves differentiated on account of GD146's anomalous U levels (304 ppm). This uranium elevation may result from the use of cobalt derived from a cobaltite-ore co-mineralized with uranium, as is known in regions adjacent to Indor (Baidya 2018; Singh 2012). Alternatively, as discussed at length in Trivedi and Dussubieux (in preparation) this may be a result of distinct South Asian silica sources with very high uranium. The latter trend distinguishes Indor Group 8 from Group 4 glasses. For these reasons GD146 is labeled here as an outlier to Group 4.

Sample name	GD001	GD002	GD010	GD015	GD031	GD076
Group	4	4	10	4	4	4
SiO_2cc	61.32	62.05	59.82	59.46	62.03	65.47
Na_2Occ	20.76	22.09	20.74	20.35	22.04	18.58
MgOcc	1.26	1.10	1.25	1.76	1.00	0.95
Al_2O_3cc	9.29	8.00	10.00	10.05	8.24	8.44
K_2Occ	3.64	3.63	3.51	3.72	3.22	3.92
CaOcc	1.39	1.31	2.20	1.90	1.35	0.75
Fe_2O_3cc	2.34	1.81	2.48	2.75	2.12	1.89
Sr	76.92	65.39	201.25	71.48	73.56	63.88
Zr	175.96	173.02	142.43	131.49	187.10	74.08
Cs	5.04	3.97	3.38	6.06	3.74	4.19
Ba	384.21	350.98	377.21	367.20	295.42	504.68
U	66.40	50.09	347.69	54.22	56.55	122.80

Sample name	GD077	GD084	GD118	GD144	GD146	GD165Gr	GD165Y
Group	2	7	8	3	4*	9	9
SiO_2cc	60.19	64.49	67.14	62.67	67.33	68.57	67.70
Na_2Occ	20.09	18.98	17.21	17.62	16.15	15.08	16.34
MgOcc	1.21	0.90	0.87	1.14	0.92	0.32	0.34
Al_2O_3cc	9.38	7.73	8.18	9.22	8.84	8.65	8.76
K_2Occ	3.04	1.85	3.67	3.27	2.97	3.86	4.17
CaOcc	3.85	3.49	1.27	3.46	1.21	2.21	1.31
Fe_2O_3cc	2.23	2.55	1.67	2.61	2.57	1.31	1.37
Sr	214.18	148.66	86.81	100.79	99.82	126.82	95.15
Zr	167.61	193.64	186.65	261.07	717.20	240.40	402.05
Cs	0.48	1.13	3.22	4.87	4.32	0.75	0.75
Ba	406.08	241.20	442.16	348.40	344.49	464.42	411.26
U	182.37	14.67	175.12	93.65	304.88	27.42	45.91

Table 11.4: Colorant corrected compositional data for the major oxides (wt%) and the trace elements (ppm) used in the PCA for discriminating between m-Na-Al groups.

Analyzed Early Historic Group 3 glasses include an "unusual transparent emerald green" (Dussubieux 2010:1651). This distinctive green glass was produced by modifications that included additions of significant amounts of copper (~2000 ppm) in combination with c. 2% lead (Dussubieux and Kanungo 2013:363). Figures

11.4a and 11.4b indicate that the visually similar GD144 is distant from the other Group 3 glasses not just in time but also colorant modification of base glass. GD 144 has only trace Pb (31 ppm). The 'emerald' hue results instead from the highest Cu (>11000 ppm) and Fe_2O_3 (2.55%) levels known in Group 3 glasses.

The sole Group 2 yellow bead, GD077, was noted above as sharing morphometric characteristics with contemporary Group 2 yellow beads traded outside of South Asia. Figure 11.4e demonstrates that chemically it clusters well with specimens analyzed from Chaul in western India and traded to Eastern Africa (Dussubieux et al. 2008). Interestingly, the two black beads, GD084 (Group 7) and GD010 (Group 10) fit two different compositional groups. Yet, both were colored by the same method involving the addition of only 2 to 2.5% Fe_2O_3 without any copper or manganese, which are other common additions involved in producing black in the Indor glasses (see Figure 11.4f).

5. Discussion

The results presented above demonstrate for the first time a wide range of m-Na-Al glasses concurrently in use and circulation within South Asia. The wider Indor results establish determinate shifts in glass bangle typology and raw glass use (Trivedi 2020; Trivedi and Dussubieux, in preparation) and in the groups used by m-Na-Al blown glass vessel producers. As drawn glass beads in South Asia have not been parsed into typologically or morphologically determinate series as is the case for second millennium East Africa (Wood 2016), within the subcontinent, regional scale geographic differentiation of drawn bead production, circulation and patterns of use is not yet possible.

Despite the limited sample size, the following trends are important: Drawn bead producers accessed a wide range of m-Na-Al glasses. Morphometric patterns in bead-finishing and within-compositional-group modifications of base glass for particular colors (Group 4 cobalt blues and Group 2 yellows) indicate patterns and shifts in production. In some cases, these trends reveal how production shifted towards more symmetrical richly colored beads likely responding to preferences and demands for particular uses. The discussion below considers the implications of the Indor drawn bead compositions in terms of how drawn bead production, exchange and value have been studied posing questions of interest to future studies.

5.1. Drawn bead production in South Asia: beyond the Papanaidupet model

The wide range of m-Na-Al compositional groups identified in Indor's drawn beads poses several questions about our models of their production. While Groups 2, 4 and 6 drawn beads appear to index enduring major drawn bead mass-production

centres with evidence for possibly divergent assemblages produced for export, we cannot assert much without further analyses of South Asian assemblages for the new Groups 7, 8, 9 and 10, or even for Group 3 drawn bead production in the second millennium CE.

The ethnoarchaeological observations made by Francis (Francis 1990) at Papanaidupet have led to the notion that the *lada*-technique based, proto-industrial scale production of drawn beads model underlies archaeological appraisals of all drawn bead production in South Asia. As extensively documented by Kanungo (2016), this model involves an entire small town / village community organized around the processing of beads after they have been drawn at a specially constructed furnace and workshop. Yet, Francis himself also documented much smaller scale production, *sans* special infrastructure, of drawn tubes and beads from them, skillfully manipulated out of a melt intended for producing many other items (Francis 1982:14). When we consider the evidence of Groups 7 through 10 we might do well to keep in mind other smaller-scale and mixed-modes in which drawn bead production may have been organized.

5.2. Compositional-group heterogeneity, drawn bead makers and m-Na-Al raw glass supply

The morphometric trends distinguishing Group 4 and 2 above likely indicate these come from distinct workshops/ craft-traditions where regular patterns of colorant chemistry, drawn bead processing, and investments in finishing beads appear tied to working a particular compositional group of m-Na-Al glass. Until direct evidence from an excavated workshop is analyzed, it is not possible to further specify whether single workshops were connected to multiple m-Na-Al raw glass producers or largely tied to one compositional group. As suggested above, one way of addressing these issues is by distinguishing who is producing which drawn beads from which m-Na-Al glass. Another is to use the data at hand and comparatively attend to the specific colorant-related modifications effected both within-groups over time and between-groups by artifact type within m-Na-Al glass to historicize and track techniques developed to modify glass to meet changing preferences.

The heterogeneity currently evidenced precludes any easy generalization from the 12 analyzed samples to the drawn bead assemblage (n=146). Yet, the absence of black beads from Group 4, and their contribution to the 'new' compositional groups 10 and 7 give pause. In the context of the preference for black and green drawn beads in the Indor assemblage, this may indicate that producers of the new compositional groups, Groups 7 through 12, preferentially supplied raw glass/ beads in colors distinct from known Group 4 and 2 repertoires. These observations,

currently qualitative, are supported by the recovery of black drawn beads in Groups 7 and 10 at both Indor and Mayotte (Wood, this volume) and colorless drawn beads in Group 8 from Indor and at Mayotte in Groups 9 and 11, i.e., not in Groups 2, 4 and 6. As more South Asian bead assemblages are quantified and analyzed, such associations between compositional group, color and method of producing color will need to be tested.

5.3. Inland and overseas: differential networks, different tastes?

The diversity of m-Na-Al compositional groups reported here is mirrored in the new analyses presented in this volume from Kish, Tel Anafa and Mayotte (Dussubieux, this volume; Larson and Dussubieux, this volume; Wood et al., this volume), where beads recovered span previously defined Groups 2 and 6 and newly defined Groups 7, 9, 10 and 11. There is no temporal overlap between these sites and the samples discussed in this paper from well-dated contexts between 1350-1800 CE at Indor. How then are we to understand the longevity of such bead-production in relation to the no doubt historically and socially specific patterns of their exchange and use? As argued here, archeometric and contextual data must be brought together to understand these specificities.

An overlapping complex set of networks has likely existed in every period structuring South Asian bead production and exchange. These networks can be schematized at three broad tiers of operation, joining raw glass supply from primary glass producers to bead-producers (likely mostly distinct), and then finished beads from bead-producers to beaders, and finally both finished beaded items and bulk-strung-beads to the differential Indian Ocean and intra-South Asian exchange networks. Within South Asia, bulk-beads and finished beaded products were likely exchanged across different distances and to distinct destinations, with the bulk-strung beads likely travelling shorter distances to beading communities and the latter more widely to consumers near and far. The archaeological contexts where the beads discussed in this paper were recovered, as part elite assemblages at Indor, suggest the latter trajectory.

At the Indor Unit A excavations, in domestic inter-floor fill contexts, where accumulation was rapid between series of mud-plastered floors, we have slight traces of indexing patterns of use. In one such loci (L34), an entire string of blue oblates likely broke and went to ground where the person stood; 30 drawn beads were recovered from less than 5 litres of sediment. To emphasize the importance of context: these 30 beads constitute 19.7% of the entire excavated assemblage. The adjacent loci, L35, contributed another 9%, n=14 from another such episode. None of these were included in the analyzed sample discussed here, but they resemble Group 4 beads in their morphometric irregularity. Their context and nature of

recovery suggests their use as strands either worn directly or beaded as strands into attire. Other beads, such as the Group 2 yellow GD076, or black barrel beads were usually recovered as solitary finds in particular loci, accidental singular inclusions in the archaeological record, a pattern suggesting their having been beaded singly, or stitched in serial form (not as a strand with only a stop-bead) into attire.

These context-of-recovery observations can be situated within the larger trends structuring the Indor drawn bead assemblage where demand for green and black is stable throughout, and annular beads of these colors are recovered at low frequencies across loci. As provisional hypotheses to be tested, the Indor results suggest that irregular and indifferently shaped beads may have been incorporated into quotidian uses, their value differentiated only by their relative availability in terms of abundance of colors at site – indicated by the rarity of blue overall and the recovery of so many blue beads in one loci (L34). More regularly finished, richly colored beads, and barrels (as opposed to annular) may in contrast have been produced by distinct workshops, answering specific demands for a different class of beads incorporated differently into attire, furnishings and life in ways that lead to different patterns of recovery from the first set. As a hypothesis, a hierarchy that joins bead morphology, use-value, and preference might explain the nature of production across workshops. Do differences of compositional group relate to who was producing which kind and color of drawn bead for which kind of use? Are irregular-shaped, mass-produced, broader-use drawn beads traded more widely and produced in particular m-Na-Al glasses against more symmetrical specially-shaped drawn beads originating from workshops operating at different scales of production, producing goods for targeted uses? Given these provisional hypotheses, it is particularly notable that m-Na-Al drawn beads traded to East Africa demonstrate very different frequencies of yellows, reds, different blues, greens and blacks in contemporary periods of the second millennium CE (Wood 2016) as compared to Indor. Anthropological insights into how preference and taste structure not just demand but production, linking communities of taste to communities of practice, may aid the interpretation of the complexities of m-Na-Al drawn bead production (Stahl 2002).

6. Conclusion: Reconsidering value in the archaeometry of beads

Hitherto, the archeometric evaluation of m-Na-Al bead exchange has been structured by the archaeological concepts of bead series and compositional group. This paper has suggested that attention to context, and residual evidence for patterns of use (elicited through bead morphology, provenience and nature of

recovery) alongside colorant preference and alteration in colorants can indicate ways to situate archaeometric data towards investigating not just exchange, but questions of temporally shifting preferences and socially specific taste. Arguably, from the scale of the loci to drawn bead assemblages compared across oceans, the use of beads structures trends just as significantly as the culture-historical accounts given of successive periods of bead-exchange. Cultural shifts, such as the embrace of Islam, as at Indor, likely shifted bead-preference in profound ways, but this first analysis of second millennium CE beads awaits comparative data from other South Asian contexts for such assessments.

In this context, recent arguments by Wynne-Jones (2020) to reorient the study of Indian Ocean networks away from long-distance exchange to 'standing still' are salient. Wynne-Jones exhorts archaeologists to attend less to exchange-value than to the archaeological emergent patterns of use-value in these diverse contexts joined by the networks such as the drawn bead trade. Far inland from the sea and as demonstrated above not unconnected to oceanic exchange, this reorientation of questions applies as much to Indor as to m-Na-Al assemblages outside of South Asia. The analytical challenge is to understand not just how these beads were made and traded, but as much how their value was emergent in their use. Drawn-bead archaeometry and its unique insights have particular contributions to make to this reorientation, especially when archaoemetric data are used dialectically, integrated with contextual, morphometric and assemblage-level data.

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Part III

Glass Beads in Africa and Western Indian Ocean

Chapter 12

Beads from the lowlands of Northwestern Ethiopia

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1. Introduction

Humans have long been fascinated with personal adornment and self-expression. For example, early evidence of pigment processing and use dates to the Middle Stone in Africa (e.g., Henshilwood et al. 2009), the Middle Paleolithic in Europe (e.g., Zilhão et al. 2010; Roebroeks et al. 2012) and the Levant (e.g., Hovers et al. 2003), and the Middle Paleolithic in Asia (Aubert et al. 2018). Evidence of ostrich eggshell engravings (Texiera et al. 2010; Assefa et al. 2018) and beads (Miller and Willoughby 2014) also dates to the Middle Stone in Africa, and advances in strontium sourcing now permit the identification of potential ostrich eggshell bead trade networks (Stewart et al. 2020). Many other items of personal adornment are also known from the archaeological record and include shell and stone beads and perforated bones and teeth (see Bednarik 2015).

The recovery of glass in Egypt and Mesopotamia dating to the 15th century BCE (Kemp et al. 2020; Shortland et al. 2018) documents its invention and development as a likely prestige item that was widely traded. The application of laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) permits the identification and quantification of particular trace elements that in turn can be used to both source manufacturing sites and reconstruct the extent and timing of trade networks all around the world (Koleini et al. 2019; Wood 2012).

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The study of glass beads with LA-ICP-MS has been extensively applied to document potential trade networks through the region of the Indian Ocean and especially South and East Africa (Robertshaw et al. 2010; Siu et al. 2020, 2021; Wood 2011, 2012). However, many of the archaeological sites where glass beads have been recovered, such as Chibuene (Wood et al. 2012) or Ibo Island (García-Heras 2021) in Mozambique, Mtwapa (Dussubieux et al. 2008) and Mambrui (Siu et al. 2021) in Kenya, are relatively close to the Indian Ocean while far inland sites appear to be rare (but see Klehm and Dussubieux, Walz and Dussubieux, both this volume; and Denbow et al. 2015). This situation is certainly the case for Ethiopia, with beads recovered from sites at Aksum, Konso, Koticha Kesi, and Mänz (for a recent compilation, see Karklins 2020), and a recent report of several beads in the northwestern part of the country (González-Ruibal and Falquina 2017, discussed below). Our survey work in the lowlands of northwestern Ethiopia adds to this body of work with the discovery of site GQ165 along the Shinfa River (known as the Rahad River in Sudan), a trunk tributary of the Blue Nile River. We here detail our work and the results of LA-ICP-MS on a subsample of beads recovered from the site.

2. Site GQ165

Site GQ165 (Gelegu-Qwara) was discovered in the lowlands of northwestern Ethiopia by pedestrian survey conducted as part of our Blue Nile Survey Project (Kappelman et al. 2014). The surveyed area is barren with no agricultural fields or villages. Inhabitants and officials in the general region were queried about the locations of any habitation sites and graveyards so these places could be avoided. We were told there were none in the area, and the local people including the elders further informed us that it had been uncultivated land for as long as they were aware. The team also contacted the head of the local village, and the national and regional representatives of Ethiopia's Authority for Research and Conservation of Cultural Heritage (ARCCH) reviewed the research permit with him.

Site GQ165 is located on the top of a low-relief narrow ridge of deflated fine-grained sediments (clays and silts) that comprise a heavily dissected ancient terrace deposit of the Shinfa River. Erosional gullies cut into the slopes of the ridge along its northwestern and eastern margins (Figure 12.1a-c). The active Shinfa River channel is located northwest of the site. The ridgetop is marked by a widely dispersed scatter of unworked basalt cobbles and boulders (Figure 12.1d-e). Given the uniform nature of the fine-grained sediments that comprise the ridge, these large rocks must have been collected from a gravel bar along the channel of the Shinfa River and carried up to the site. The basalt cobbles and boulders do not,

however, appear to be evidence of a structure, but the deflated and eroded nature of the ridgetop may preclude such a determination at this time; future excavation will be required to test this question.

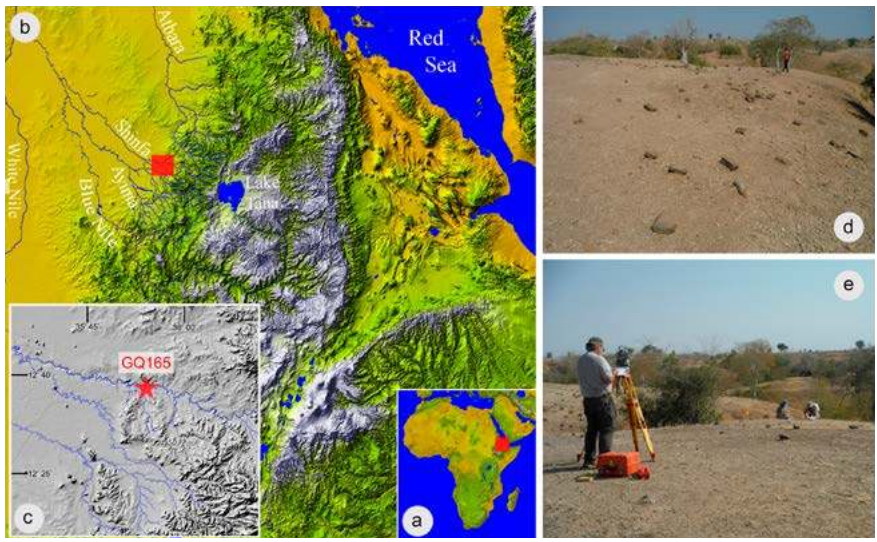

Fig. 12.1: Location of GQ165. (a) Color shaded relief image of Africa, Arabia, and the Horn of Africa, with red inset shown in (b) displaying NW Ethiopia and the major rivers, with red inset shown in (c) as a digital elevation map of the lowlands indicating the location of the archaeological site GQ165 (red star). (d) View to the north of GQ165 on the ridgetop showing the steeply sloping eastern margin of the eroded ancient river terrace and the isolated surface scatter of basalt cobbles and boulders. (e) Mapping of surface items at GQ165 using an EDM. (a, b) NASA/JPL http://photojournal.jpl.nasa.gov/catalog/PIA04965; (c) NASA/JPL SRTM https://www2.jpl.nasa.gov/srtm/

We conducted mapping with an electronic distance measuring instrument (EDM) to establish the extent of the site and the distribution of items across its surface (Figures 12.1 and 12.2). The collection of surface items was limited to those pieces that were likely to be damaged or destroyed by weathering or trampling. A variety of item types preserved as surface finds at GQ165 include ceramics (n=31), chipped stone (n = 46), ground stone (n = 11), nonhuman faunal remains (n = 7), and wood fragments (n = 3). These items are under study for a future publication. No metal items were recovered.

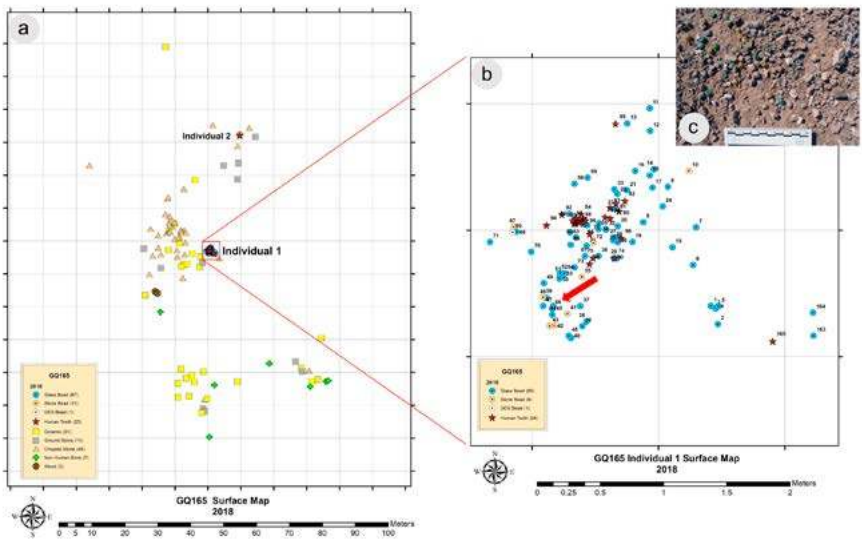

Fig. 12.2: Surface map of GQ165. (a) Map displaying the surface distribution with discrete clusters of items. The two sets of human remains are separated by approximately 36 meters. (b) Close-up map of the individual 1 showing the cluster of beads, and (c) close-up ~22 x 18 cm view. Scale bar in (c) is 10 cm.

Additionally, the remains of two humans were encountered, with both individuals naturally exposed by erosion on the surface of the ridge. The exposed skeletal remains are heavily weathered, exhibit probable trampling damage, and are fragmentary and largely unidentifiable. Both sets of remains are intermingled with beads (Figure 12.2c). We once again restricted the collection of materials to those items at risk of being damaged or destroyed by weathering or trampling. A total of 78 beads were collected (Figure S12.1), including 74 from individual 1 (ostrich eggshell: n=1; glass: n= 66; stone, n = 7) and four from individual 2 (glass: n= 1; stone: n=3).

2.1. Age of GQ165

With permission from the ARCCH, one tooth from each set of human remains was submitted for accelerator mass spectrometry (AMS) ^{14}C dating at the Keck Carbon Cycle AMS Facility (Earth System Science Department, The University of California, Irvine). High-resolution X-ray computed tomography (HRXCT) scans were first completed at The University of Texas HRXCT Facility (UTCT) for each tooth to produce a 3D archival record before AMS ^{14}C dating. Dates were calculated using Intcal20.14c (see Table 12.1: Reimer et al. 2009, 2013, 2020;

Stuiver and Polach 1977). The higher probability date for individual 1 is 1335±32 cal CE (71% probability) while individual 2 is 1339±22 cal CE (74% probability) at the 2 sigma distribution; the second and lower probability date for individual 1 is 1391±10 cal CE (21% probability) and for individual 2 is 1399±11 cal CE (29% probability), again at the 2 sigma distribution. These ancient dates confirm the information from the local inhabitants that, to the best of their knowledge, the area had not been occupied recently or during the time of their collective memory.

Speciman ID	UCIAMS #	Fraction of MC	± 1 SD	$D^{14}C$ (‰)	± 1 SD	^{14}C age (BP)	± 1 SD	CalBP (Intcal20.14c)					
								Mean CE	± 2 sigma	Proba-bility	Mean CE	± 2 sigma	Proba-bility
GQ165 - individual 1	203554	0.9273	0.0018	-72.7	1.8	605	20	1335	32	71%	1391	10	21%
GQ165 - individual 2	203555	0.9306	0.0018	-69.4	1.8	580	20	1339	22	74%	1399	11	29%

Samples analyzed at the Keck Carbon Cycle AMS Facility (Earth System Science Department, The University of California, Irvine). Radiocarbon concentrations are given as fractions of the Modern standard, $D^{14}C$, and conventional radiocarbon age, following the conventions of Stuiver and Polach (Radiocarbon, v. 19, p.355, 1977). Sample preparation backgrounds have been subtracted, based on measurements of ^{14}C-free calcite. All results have been corrected for isotopic fractionation according to the conventions of Stuiver and Polach (1977), with $d^{13}C$ values measured on prepared graphite using the AMS spectrometer. These can differ from $d^{13}C$ of the original material, and are not shown. Samples of tooth enamel were leached 50% with dilute HCl prior to hydrolysis with 85% phosphoric acid. CalBP calculated with Intcal20.14c (Reimer et al. 2020) with BP taken as 1950 CE.

Table 12.1: AMS ^{14}C Ages of GQ165.

2.2. Bead morphology

The metrics and characteristics of the glass and stone beads and single ostrich eggshell bead collected from GQ165 are provided in Table S12.1. The beads vary from less than 4 mm to nearly 9 mm in their maximum external diameter (Table S12.1; Figure 12.3a), and a plot of this value against the minimum external diameter shows that they closely approach roundness with a coefficient of determination (R^2) of 0.92 (Figure 12.3b). The ostrich eggshell bead plots near the middle of this distribution. A comparison of maximum external diameter against maximum length demonstrates that the stone beads are about one-half or less the dimensions of the glass beads, but variation in sample size between the glass beads (n = 67) and stone beads (n = 10) could influence this statistic. It is interesting to note that the maximum length of the single ostrich eggshell bead plots well below the range of the glass and stone beads, and is somewhat less than the average thickness of

1 to 2 mm that we have measured for modern and ancient ostrich eggs from the lowlands (Figure 12.3c). There is a general positive correlation between maximum external diameter and maximum hole diameter for the glass beads, with this trend probably reflecting manufacturing methods (Figure 12.3d). The beads are drawn with a flat end, rather than heat-rounded as would be Indo-Pacific beads (Francis 1990) that are common around the Indian Ocean. They represent a limited number of colors (red, yellow, blue-green and green; see also Table S12.1). In contrast, the stone beads have a more uniform and restricted maximum hole diameter, with no correlation to the maximum external diameter of the bead. This uniform hole size suggests that a standardized tool was used to drill these stone beads. The single ostrich eggshell bead has a relatively large hole for its diameter, but because eggshell is so much softer than stone, a larger hole might have been inadvertently produced due to the difficulty of controlling the motion of the drill bit in such a soft material. Also, natural abrasive wear between the internal surface of the much softer eggshell and the cord that it was strung on while worn could have served to enlarge the hole through time.

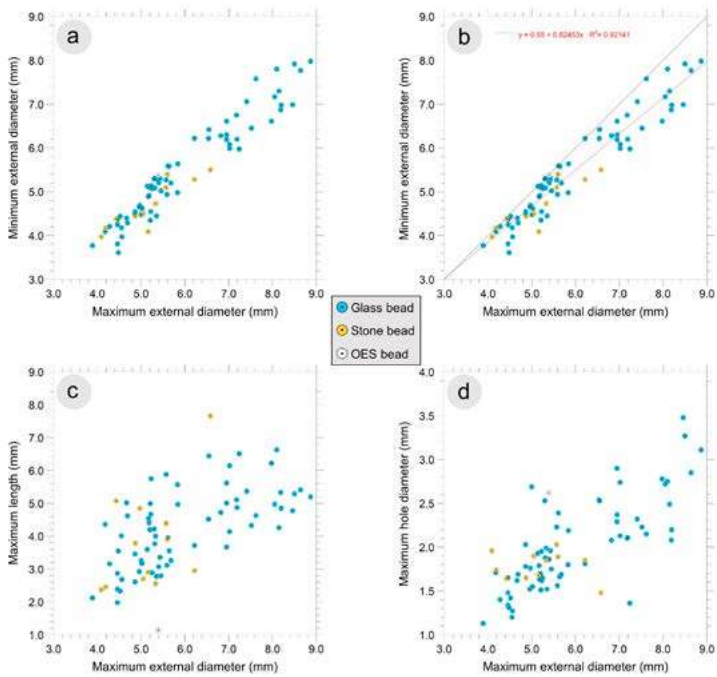

Fig. 12.3: Plots of GQ165 glass, stone, and ostrich eggshell bead metrics. (a) Maximum external diameter plotted against minimum external diameter for all types of beads. (b) same as a) with red line: $R^2 = 0.92$ for all materials and black line: $R^2 = 1$. (c) Maximum external diameter plotted against maximum length for all materials. (d) Maximum external diameter plotted against maximum hole diameter for all materials.

3. Glass bead chemistry and methods

The National Museum of Ethiopia and the ARCCH granted permission for the export of 20 glass beads for LA-ICP-MS analysis with return on completion of this study. The analyses were carried out at the Elemental Analysis Facility in September 2019 and March 2020 (see Annex A for analytical methods).

4. Results

To be able to compare the concentrations of the major constituents of all the beads regardless of their colors, their reduced compositions were calculated taking into account only SiO_2, Na_2O, MgO, Al_2O_3, K_2O, CaO and Fe_2O_3 so as to eliminate the diluting effect of certain colorants (Table 12.2).

	Average	1 SD
SiO_2	61.60%	2.00%
Na_2O	16.50%	1.20%
MgO	4.20%	0.50%
Al_2O_3	6.30%	0.60%
K_2O	3.70%	0.50%
CaO	6.20%	0.80%
Fe_2O_3	1.40%	0.30%

*Excludes GQ165-66, -72, and -99.

Table 12.2: Reduced concentrations for the main constituents of GQ165 beads.

For the majority of beads (n=17), the concentrations of magnesia and potash are higher than 1.5%. This value is usually indicative of the use of halophytic plants as a source of soda. Lower concentrations for both these constituents would rather point to a soda flux of mineral origin (Shortland et al. 2006). Among soda plant ash, two types depending whether their alumina concentrations are below or above 4% were identified. With an averaged reduced concentration of 6.3%, all the samples belong to the high alumina soda plant ash (v-Na-Al) glass group.

The provenance of high alumina soda plant ash glass is very uncertain but similar compositions can be found in Central Asia. Soda plant ash glass with high alumina are fairly common in regions in Afghanistan (Brill 1999), Uzbekistan (Abdurazakov 2009; Rehren et al. 2010), and Pakistan (Dussubieux and Gratuze 2003) for a wide time period ranging from the 2nd century BCE to the 14th century CE. If the glass from Pakistan that is fairly early (200 BCE to 200 CE) also

has a very different trace element pattern with fairly high trace elements such as uranium, it can be excluded; but then comparisons with the other regions are more difficult, since available compositions do not include trace elements. A recent publication by Siu et al. (2020) focused on v-Na-Al glass found at the Kenyan sites of Mambrui and Malindi (15th-16th century CE) points in the same direction and also proposes a Central Asia origin for this type of glass.

The v-Na-Al glass group was described by Robertshaw et al. (2010) for glass beads found in southern Africa, and two sub-groups were identified. These two sub-types correspond to the Mapungubwe oblate (MO), 1240-1300 CE, and the Zimbabwe (Z), 1300-1430 CE, bead series that can be separated using alumina and zirconium concentrations. Both elements are added to the glass with the sand thus suggesting that two distinct sand sources were used for the two v-Na-Al sub-types. The v-Na-Al glass from GQ165 belongs to the MO v-Na-Al sub-type as shown in Figure 12.4.

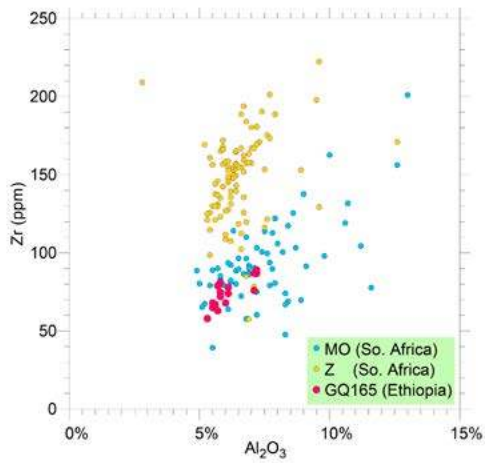

Fig. 12.4: Comparison of Southern Africa glass beads from v-Na-Al glass subgroups Mapungubwe oblate (MO) and Zimbabwe (Z) (Robertshaw et al. 2010) with GQ165.

Unpublished data from glass beads from Kenya indicate that v-Na-Al glass beads are particularly abundant during a period ranging from the 13th to 15th century CE (Table 12.3). These v-Na-Al Kenyan beads belong to the MO v-Na-Al glass group. The v-Na-Al glass from Mambrui and Malindi, also related to the MO sub-group, was found in a 15th to 16th century CE context.

Site	Century CE
Gedi	13th to 17th
Jumba Ruins	14th to 15th
Manda	13th to 16th
Mnarami	14th to beginning of 15th
Mbaraki	14th

Table 12.3: v-Na-Al glass bead from Kenyan sites.

Three beads from GQ165 differed from the v-Na-Al glass group (Table S12.2). Sample GQ165-72 is one of the outliers. It is covered with a whitish layer of powdery-looking material that shows that the glass has deteriorated. The composition measured for this bead has 76% of silica and is depleted in alkali ($Na_2O + K_2O$ <3 %) suggesting that only corroded glass was sampled and measured. This bead will be excluded from the discussion.

Sample GQ165-99 is a black bead made of a silica-based material that has 23% of alumina (Al_2O_3) and 14% of iron (calculated as Fe_2O_3). It is possibly made from ceramic (Table S12.2).

GQ165-66 is the third bead that has an unusual composition (Figure S12.1). It is made from a glass containing 20% of soda (Na_2O) and a relatively low concentration of magnesia (MgO). It is usually accepted that soda glass with magnesia concentrations below 1.5% was manufactured with a flux of mineral origin. This glass has also a relatively high alumina concentration (6.4%) and belongs to the mineral soda-high alumina glass group (m-Na-Al). This glass, manufactured from a natural mix of an immature granite sand and soda rich efflorescence, was produced in South Asia (see Annex B for more details).

Dussubieux et al. (2010) have identified five sub-groups for the m-Na-Al glass in the Indian Ocean trade network, based on the concentrations of a range of constituents (Table 12.4). Bead GQ165-66 seems to be a closer match to the composition of the m-Na-Al sub-group 1 glass characterized by higher strontium, zirconium, and barium concentrations, and lower cesium and uranium concentrations.

	MgO		CaO		Sr		Zr		Cs		Ba		U	
	Mean	1 SD	Mean	1 SD	Mean	1 SD	Mean	1 SD	Mean	1 SD	Mean	1 SD	Mean	1 SD
m-Na-Al 1	0.70%	0.70%	2.50%	1.10%	333	86	502	140	0.5	0.3	895	290	9	9
GQ165-66	0.50%	-	3.20%	-	347	-	347	-	0.4	-	684	-	8	-
m-Na-Al 2	1.00%	0.20%	4.80%	0.90%	233	52	153	66	0.6	0.3	353	87	110	41
m-Na-Al 3	1.30%	0.20%	2.50%	0.40%	121	25	145	36	3.4	0.6	357	122	58	22
m-Na-Al 4	0.80%	0.20%	1.30%	0.50%	99	25	298	61	3.7	0.8	635	260	107	39
m-Na-Al 6	0.80%	0.20%	2.50%	0.70%	235	88	216	35	1.5	0.4	402	166	57	22

Data from Dussubieux et al. 2010 and Dussubieux and Wood 2021.

Table 12.4: Concentrations for diagnostic elements of m-Na-Al sub-groups 1 to 4 and 6, and GQ165-66.

The m-Na-Al 1 glass, likely from Sri Lanka and/or South India (Dussubieux et al. 2010), was used to manufacture small drawn beads starting at least in the 3rd century BCE. In Africa, this glass type is fairly rare. Current research has recorded the presence of a significant quantity of m-Na-Al 1 beads at only one site, Unguja Ukuu on the Island of Zanzibar, that dates from the 7th to early 11th century CE (Wood et al. 2017; Sarathi et al., this volume). Only two other known sites with m-Na-Al 1 glass yielded one bead each: Ungwana on the Kenyan coast that dates from the 9th to 16th century CE (Dussubieux et al. 2008:814); and Mahilaka in northwest Madagascar that also dates from the 9th to 16th century CE (Robertshaw et al. 2006).

Sample GQ165-66 is one of the three red beads analyzed (Figure 12.5). The other two red beads have a different composition and, along with the majority of the GQ165 beads, belong to the high alumina soda plant ash (v-Na-Al) glass group. However, typologically, these three beads are fairly alike in being drawn and having flat rather than rounded ends. The red color is slightly different with a duller red for the m-Na-Al 1 glass beads, and also more bubbles in the glass matrix are visible.

Fig. 12.5: "Red" glass beads from GQ165. Munsell colors: GQ165-39 = 10.0R3/8 (barn red); GQ165-66 = 7.5R4/6 (antique rose); and GQ165-98 = 10.0R3/8 (barn red). Beads GQ165-39 (individual 1) and GQ165-98 (individual 2) belong to the v-Na-Al glass type, while GQ165-66 (individual 1) belongs to the m-Na-Al 1 glass type.

5. Discussion

The majority of the beads from site GQ165, which dates to approximately 1337 cal CE, belong to the v-Na-Al glass type that is found at different sites on the east coast of Africa dating from the 14th to 16th century CE. However, although the compositions of these Ethiopian and East Africa coast beads are similar, their typologies are distinct. The beads from GQ165 are drawn with thick walls. Drawn beads are often roundish but many of the GQ165 beads instead have flat ends. The typology of the GQ165 beads set them apart from other beads with a v-Na-Al composition such as the one found in Southern Africa (Robertshaw et al. 2010) or along the eastern coast of Africa (Siu et al. 2020). These features suggest a common source of raw materials but possibly different bead making workshops.

The m-Na-Al 1 bead GQ165-66 is surprising both because it is a fairly rare glass type in eastern Africa and also, when present, is associated with earlier contexts. In Zanzibar, m-Na-Al 1 beads from Unguja Ukuu date to the 7th to early 11th century CE (Wood et al. 2017), while in Southeast Asia, where these kinds of beads are also found, they are more common until the 11th century CE. We cannot exclude the possibility that GQ165-66 was an heirloom bead and that the time of its burial was much later than the time of production. The typology of this bead is indistinct from the typology of the other red beads manufactured from v-Na-Al glass. Were all of these beads manufactured at the same location, with perhaps the use of m-Na-Al 1 recycled glass and v-Na-Al glass? Future work and the recovery of more beads from GQ165 may answer these questions.

The beads studied here link site GQ165 in the lowlands of northwestern Ethiopia to the Indian Ocean exchange network. Study of other material cultures from site GQ165 may offer additional insight into the antiquity of these trade networks. For example, contact between the northern Ethiopian highlands and the lowlands of eastern Sudan has been documented since the 1700s (Bruce 1790), and has long been suggested for ancient times. In the mid-1950s, Arkell (1954) recognized that there were similarities between the cultural materials of both regions on the basis of the ceramic surface collections from Aqordat located in the Bereka valley of Eritrea. Later investigators (e.g., Clark 1980, 1988; Sadr 1991) also recognized these similarities. Archaeological investigation in the Gash Delta of eastern Sudan led Fattovich (1989) to combine the four Aqordat sites with two Eastern Sudan sites (sites of ES3 and M2) to form the "Agordat group." This group, on the basis of eastern Sudanese sites, is securely dated to 2500-1500 BCE. On the basis of ceramic similarities to this group, layers 5 and 4 of Danei Kawlos, a site close to Quiha in northern Ethiopia, probably also date to this time (Negash 2001). Clark (1988) further argued that the decorated Quiha pottery in Tigray is similar to that of Agordat (Arkell 1954) and therefore the pottery of the Atbai Tradition of Eastern Sudan (Fattovich et al. 1984).

The only other archaeological report for sites in this region of the lowlands of northwestern Ethiopia is by González-Ruibal and Falquina (2017). They excavated the site Kuter 4, which is approximately 20 km WSW of GQ165, with the discovery of a single glass bead (González-Ruibal and Falquina 2017: Fig. 24-2). There are four stratigraphic units at Kuter 4 (González-Ruibal and Falquina 2017: Fig. 4) that range in age from ~1200 to 1900 cal CE (González-Ruibal and Falquina 2017: Fig. 25), but the unit that produced the single bead is not given. They also excavated the site Tach Gerara, which is approximately 30 km SSW of GQ165 (González-Ruibal and Falquina 2017: Fig. 24-3), with the discovery of three glass beads. These authors group the site of Tach Gerara with the "Jebel Mahadid

Tradition" that they place in the late 15th to early 17th centuries (González-Ruibal and Falquina 2017: 190). LA-ICP-MS studies will likely be required to test their hypothesis that the glass beads are from Europe (González-Ruibal and Falquina 2017: 197). It is likely that future work in the Ethiopian lowlands will produce more archaeological sites with beads.

6. Conclusion

Site GQ165 represents the first reported ancient site in the lowlands of northwestern Ethiopia with human remains interred with beads. The documented assemblage of artifacts suggests the presence of a horticultural group using a combination of chipped and ground stone and pottery. The abundance of chipped stone implements and absence of iron implements at such a recent age appears unusual. Detailed studies of this and additional sites in the region are required to fully evaluate and test this preliminary observation. The low variety in bead trace element composition suggests limited inter-regional trade connections, but the single m-Na-Al 1 bead suggests that much remains to be learned from site GQ165. Future work is certain to provide more information about the lifeways of these peoples.

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Chapter 13

Inland glass beads in Northeast Tanzania, 8th-17th centuries CE

Jonathan R. Walz[1] and Laure Dussubieux[2]

1. Introduction

This chapter reports glass bead data from archaeological sites in Northeast Tanzania. The archaeological investigation of areas inland of East Africa's Swahili Coast has origins decades ago; however, only recently have the scale, funding, and quality of some inland projects begun to match the established trends of coastal archaeology (Kusimba and Walz 2018). During 2001-2006, Walz completed a systematic, regional scale project in inland Northeast Tanzania, which identified settlements and unique evidence of connections to the coast and wider Indian Ocean during the last centuries of the first millennium CE and the first half of the second millennium CE (Walz 2005, 2010, 2013, 2017). Glass beads were among the artifacts documented at archaeological sites in the vicinity of Mombo (Walz and Dussubieux 2016), a present-day town located approximately 100 kilometers from the coastline of the Indian Ocean.

Based on the application of LA-ICP-MS to a sample of 62 glass beads from 11 archaeological sites, this chapter documents glass chemical compositions to address the chronological associations and origin places of the beads. This evidence enhances our understanding of inland-ocean ties and the political economy of communities living in the outer landscapes of contemporaneous Swahili towns along the coast.

The pre-18th century glass beads from the vicinity of Mombo are unique to the interior of East Africa and historically significant. Such glass beads are somewhat common at multiple archaeological sites at the Indian Ocean coast of this and other areas in the ocean basin. However, the inland beads in Northeast Tanzania include early glasses (for East Africa), and they have multiple likely origins, including the Middle East and South Asia, among others. Perhaps most

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importantly, analysis of the glass beads demonstrates the continuity and longevity of coast-inland exchange in Northeast Tanzania over the span of a millennium (8th-17th centuries).

2. Background

The relationship between Swahili coastal and inland African communities has long been denied (for the historiography, see Walz 2010: 35–67; Kusimba and Walz 2018). There remain many questions about the character of the relationship. Inadequate research in inland areas of the coast of eastern Africa enabled the representation that the 'coast' and 'hinterland' were separated places with distinct rather than entangled relations and pasts. This glass bead project is part of a longer-term effort to test the assumption of separation using systematic material and other evidence retrieved through a regional scale project conducted across Northeast Tanzania.

2.1. Northeast Tanzania

This region lies at the intersection of multiple environments and human communities with distinct livelihoods. The Pangani (Ruvu) River flows from northwest to southeast, entering the Indian Ocean at Pangani Bay. Components of the Eastern Arc Range – East and West Usambara Mountains and South Pare Hills – offer diverse physical and natural resources to communities. The East Usambara Mountains approach the Indian Ocean coast to within 15 kilometers and can be seen by sailors from more than fifteen kilometers offshore. All four language families of Africa are represented in wider northern Tanzania. In addition, hunter-gathers, pastoralists, agriculturalists, and urbanites have all occupied the region during the last few centuries. These geographical factors and the diversity of its communities, coupled with evidence from documents and oral traditions from recent centuries, suggest connectivity among communities and across the coast-interior in the deeper past is a hypothesis to be tested (Walz 2010, 2013, 2017). Archaeological reconnaissance by Soper (1967) provided material evidence for human settlement in the region during the last two millennia. Since Soper's informal assessment, more systematic survey (Walz 2010) and excavations (e.g., Walz 2010; Biginagwa and Ichumbaki 2018) have been conducted in the region's lowlands from inland to the marine coast.

2.2. Archaeological field project

The systematic archaeological project conducted in lowland Northeast Tanzania (Walz 2010) employed a survey universe divided into five survey areas around known 19th century caravan halts reported in oral traditions and historical documents. One survey area was at Pangani Town along the Indian Ocean coast. The other survey areas proceeded northwest along a natural inland corridor. The project identified 238 archaeological sites, 210 of which were within the survey universe (Walz 2010, 2013). The Mombo Survey Area – the vicinity of focus in this chapter – yielded 81 archaeological sites (Walz 2010). Fifty-six of the sites at Mombo are characterized by TIW/TT (Triangular Incised Ware-Tana Tradition) and/or Group B ceramics, dating to the second half of the first millennium CE and the first half of the second millennium CE, respectively (Soper 1967; Chami 1994, 1998; Horton 1996). Sites in the Mombo Survey Area cluster along a low ridge west of the seasonal Mkomazi River, in low-lying areas between the Mkomazi River and the West Usambara Mountains, and along the skirt of these mountains. These sites include, but are not limited to, Jamali 3 (Site 189), Kwa Mgogo (Site 177), Kwa Mkomwa (Site 135), and UIimboni (Site 110) (Figure 13.1).

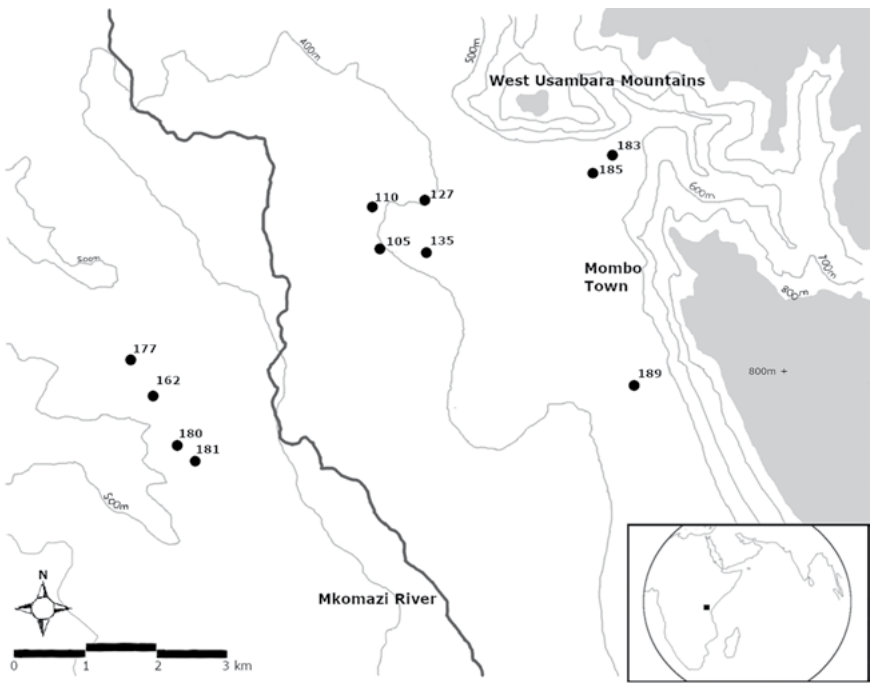

Fig. 13.1: Map of archaeological survey area near Mombo Town in Northeast Tanzania. Sites marked as numbered dots (see also Table 13.2).

2.3. Bead finds

The larger archaeology project recovered beads (of any type) at 49 of the 210 (23.3%) identified sites. The project bead assemblage includes 194 *types*, based on raw material, method of manufacture, shape, color, and opacity. One hundred and fifty of the 194 bead types are made of glass. The other 44 are made of non-glass material: semi-precious stone (e.g., carnelian and rock crystal), coral, ivory, ostrich eggshell, mollusk shell (marine or terrestrial), metal (e.g., copper alloy or iron), or ceramic. Beads are distributed across the survey universe but are particularly common at sites on the coast and at some localities more than 40 kilometers inland. As might be expected, beads made of glass dating to the last few centuries are common (Kirkman 1974; Karklins 1992). This chapter emphasizes glass beads from the Mombo Survey Area selected for testing by LA-ICP-MS.

Thirty-one of the 81 (38.3%) identified sites in the Mombo Survey area yielded beads. Of these 31 sites, sixteen (51.6%) produced glass beads only, five (16.1%) had non-glass beads only, and ten (32.3%) had both glass and non-glass beads. The majority of these sites had fewer than five total beads identified during surface investigations. Other sites, like Kwa Mkomwa (Site 135), yielded copious beads. A surface grid survey at Kwa Mkomwa generated 341 glass beads of 23 types. Another site, Kwa Mgogo (Site 177) produced 34 glass beads during excavations of intact archaeological strata associated with TIW/TT, Group B, and other contemporaneous ceramics. In addition, Kwa Mgogo (Site 177) produced other direct indications of coast-interior links (e.g., marine shells as well as a few foreign and coastal ceramics) and evidence of non-glass beads, such as copper alloy cones, carnelian spheres, ostrich eggshell discs, and more than 500 perforated land snail shell discs. These last beads were made on-site (Walz 2010, 2013, 2017; Kusimba and Walz 2018: 435-437).

3. Materials and methods

For the 62 glass beads analyzed from the Mombo Survey Area, LA-ICP-MS was conducted in two batches: Batch 1 (24 beads in 2015-16, only 18 of which produced results and are reported in this chapter) and Batch 2 (44 beads in 2017-18). These legally exported artifacts were analyzed at the Elemental Analysis Facility at The Field Museum of Natural History in Chicago, Illinois, USA.

All Batch 1 beads were retrieved from intact strata at Kwa Mgogo (Site 177) dated to the late first millennium and early to middle second millennium CE. The uniqueness of these early inland finds motivated tests of all 34 excavated glass beads from Kwa Mgogo (Site 177). The chemical compositions of the glasses suggested their origins in time and space (Walz and Dussubieux 2016).

This chapter presents new compositional data from the 44 glass beads tested in Batch 2. The new data builds on previously reported data from Batch 1 (Walz and Dussubieux 2016) in two ways. Batch 2 includes ten additional glass beads excavated from Kwa Mgogo (not previously run in Batch 1) and 34 additional glass beads from ten other archaeological sites in the Mombo Survey Area (see Discussion). The 34 additional glass beads were sampled randomly from the site bead assemblages, most of which included less than five total beads. Some emphasis was placed on Kwa Mkomwa (Site 135), with nine beads selected for LA-ICP-MS tests, because of the large number of glass beads documented there (see above).

See Annex A for a description of the analytical equipment, procedures, and methods used to conduct LA-ICP-MS of the glass beads at the Elemental Analysis Facility at The Field Museum of Natural History.

4. Results

Sixty-two compositions were obtained from the glass beads tested from inland Northeast Tanzania in 2015 (Walz and Dussubieux 2016) and 2017 at the Elemental Analysis Facility at The Field Museum. Like in Batch 1, several beads (JW02, JW10, and JW42) in Batch 2 had low alkali contents reflecting a high state of corrosion of the analyzed glass and will not be discussed further.

The remaining 59 glass samples were separated into five groups:

— 17 soda glass samples with magnesia < 1.5% and high alumina (> 4%) manufactured from a mineral soda – high alumina glass;
— 16 soda glass samples with magnesia > 1.5% and high alumina (> 4%) manufactured from a soda plant ash – high alumina glass;
— 16 soda glass samples with magnesia > 1.5% and low alumina (< 4%) manufactured from a soda plant ash – low alumina glass;
— 8 glass beads with a soda composition of variable magnesia and potash concentrations but generally low alumina (< 3%); and
— 2 glass beads with low soda concentrations (0.3%), but containing significant concentrations of potash (6%) and high concentrations of lead (48%).

Fig. 13.2: Glass beads from Northeast Tanzania analyzed with LA-ICP-MS in 2017 (individual photos are not available for beads analyzed in 2015). Beads are sorted by glass group.

See Annex B for elaborations about the glass compositions discussed in this chapter and the volume.

4.1. Mineral soda – high alumina glass

Seventeen samples belong to the mineral soda – high alumina or m-Na-Al glass that in addition to low magnesia (< 1.5%) and high alumina (> 4%) concentrations also is characterized by high trace element concentrations. This glass, manufactured from a natural mix of an immature granite sand and soda-rich efflorescence, was

produced in South Asia (Brill 1987). Five different sub-groups have been identified based on concentrations of the following constituents: MgO, CaO, Sr, Zr, Cs, Ba, and U (Dussubieux et al. 2008; Dussubieux et al. 2010; Dussubieux and Wood 2021). Additional sub-groups identified at the medieval site of Indor (Rajasthan, India) recently were recognized by Trivedi and Dussubieux (this volume; in preparation). See Annex B for more background on m-Na-Al sub-groups.

Based on the seven listed constituents, a comparison of the m-Na-Al compositions from Northeast Tanzania with the compositions of the five initial sub-groups was conducted with principal component analysis (PCA). Figure 13.3 shows that most of the samples from Tanzania fall in the m-Na-Al 6 glass group.

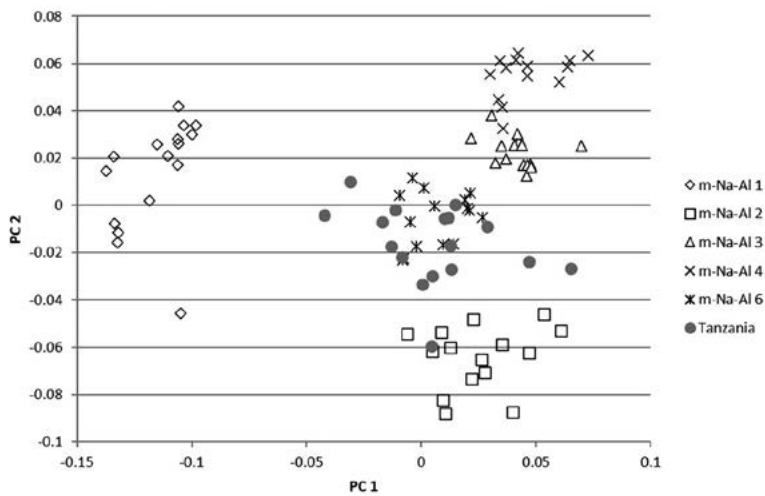

Fig. 13.3: PCA of m-Na-Al groups against Northeast Tanzania glass beads.

One bead, sample JW48, fits the m-Na-Al 2 glass group. Four samples do not match any m-Na-Al sub-groups on the graph. Two samples (JW27 and JW46) have particularly high uranium concentrations (179 and 189 ppm) whereas two others (JW09 and JW44) have concentrations for the same element intermediary between the values usually found in the m-Na-Al 1 and 6 glasses (19 and 32 ppm). The four outlier samples are likely to be part of recently identified new groups (Trivedi and Dussubieux, this volume; in preparation).

4.2. Soda plant ash – high alumina glass

Sixteen samples are manufactured from a soda glass with high magnesia (> 1.5%) and high alumina (> 4%) concentrations. On average, lime concentrations are

5.4%. This glass likely was manufactured from soda plant ash and a high alumina sand, vegetable soda – high alumina or v-Na-Al glass. Its trace elements are generally lower when compared to m-Na-Al glass. Soda plant ash – high alumina glass is found in Central Asia (Dussubieux and Kusimba 2012; Then-Obłuska and Dussubieux 2016; Carter et al. 2019; Siu et al. 2020). The glass for the v-Na-Al beads found in Northeast Tanzania might have been produced in Central Asia (i.e. between eastern Iran and central India), but there is no certainty about where the beads themselves were manufactured.

Robertshaw et al. (2010) identified two v-Na-Al glass sub-groups in southern Africa: the Mapungubwe Oblate (MO) bead series dating 13th-14th century and the Zimbabwe (Z) bead series dating 14th-15th century, with higher soda, phosphorus, and barium but lower magnesia compared to the former. Siu et al. (2020) distinguished four different sub-groups: types A, B, C and D. Types C and D only include glass vessels and therefore are not relevant for this study. Siu et al. (2020) placed the MO bead series in type A glass and the Z bead series in type B glass. Also in type A are the glass beads found at Mambrui, Kenya (15th-16th century), that form the core of the glass material in the study by Siu et al. (2020). The compositions of the v-Na-Al beads from Northeast Tanzania are very close to the compositions of the beads from Mambrui (Table 13.1). Trombetta et al. (this volume) showed that glass beads with compositions indistinguishable from those in Northeast Tanzania and Mambrui occurred in Ethiopia dated from the middle 14th century.

		Type A		Type B
	Tanzania	**Mambrui**	**Mapungubwe Oblate**	**Zimbabwe**
Na_2O (%)	15.4±1.7	16.1±1.1	12.40±2.09	14.56±2.89
MgO (%)	4.2±0.5	4.33±0.59	5.28±1.84	4.01±0.74
Al_2O_3 (%)	5.6±0.3%	5.55±0.41	7.18±1.43	6.51±1.14
K_2O (%)	3.2±0.3%	3.15±0.55	3.30+/0.58	3.54±0.60
CaO (%)	5.4±0.7%	5.50±0.87	6.13±1.73	6.54±1.30
Ti (ppm)	1095±252	1268±247	1422±413	1421±244
Sr (ppm)	371±33	361±46	489±120	487±104
Zr (ppm)	67±11	69±12	119±25	200±38
Ba (ppm)	375±21	407±30	486±126	635±175

Table 13.1: Comparison of v-Na-Al compositions of glass beads from Northeast Tanzania against glass beads of Type A [found at Mambrui, Kenya and Mapungubwe, South Africa] and Type B [found in Zimbabwe] (Siu et al. 2020).

4.3. Soda plant ash – low alumina glass

Sixteen glass samples have a soda-rich composition with magnesia and potash concentrations higher than 1.5% and alumina concentrations lower than 4%. On average, lime in this glass measures 6.5%. These glass samples were manufactured from soda plant ashes rich in sodium but also calcium, and with magnesia, potash, and a relatively pure silica with low alumina concentrations. These beads are considered vegetable soda – lime or v-Na-Ca glass. Since at least the middle of the 2nd millennium BCE (during the Late Bronze Age), the Middle East has served as a soda plant ash – low alumina producing region. This trend continued through the Sasanian period and later during the Islamic period (e.g., Mirti et al. 2008, 2009; Schibille et al. 2018; Shortland et al. 2018), although this type of recipe also might have been used in Egypt and/or the Levant.

To understand the similarities and differences between the v-Na-Ca beads from Northeast Tanzania and other soda plant ash glasses, the Tanzania beads were compared with four glasses using principal component analysis and the concentrations of MgO, P_2O_5, CaO, Cr, Rb, and La (Figure 13.4). The four glasses against which the Tanzania beads were compared include a v-Na-Ca glass thought to be manufactured in Egypt in the 14th century (Dussubieux, 2017) and three different v-Na-Ca glasses identified at Chibuene, Mozambique (Wood et al. 2012):

— v-Na-Ca 1: the most abundant v-Na-Ca glass type at Chibuene and associated with the 8th-10th century CE;
— v-Na-Ca 2: significantly high amount of chromium correlated with the presence of nickel; found at Chibuene in samples of glass sherds or wastes associated with the 8th-10th century CE; and
— v-Na-Ca 3: in the form of bluish or greenish drawn glass beads it contains higher trace elements, such as Rb, Ce, Cs, Ba, La and U and is associated with the earliest context of 7th-9th century CE.

Most of the samples from Northeast Tanzania fall into the v-Na-Ca 1 group although these samples do not form a tight cluster. Some of the Tanzania beads were affected by corrosion which might have slightly impacted the concentrations of some elements. One sample (KMT23), with a higher concentration of Cr (137 ppm, while the average for the remainder of the v-Na-Ca glass was 35 ppm), was manufactured using a sand with different proportions of trace elements. Sample JW24 has a composition similar to that of Egyptian glass samples.

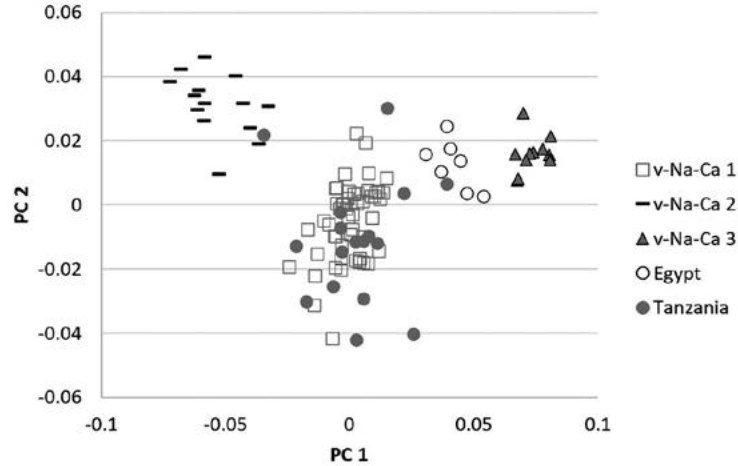

Fig. 13.4: PCA of v-Na-Ca groups against Northeast Tanzania glass beads.

The v-Na-Ca 1 glass group was used to manufacture Zhizo beads recognized in southern Africa (Robertshaw et al. 2010). These are drawn beads with marked longitudinal striations on their surface that are similar to the v-Na-Ca 1 beads found in Northeast Tanzania. Sample JW24, with an Egyptian glass composition, does not match the description of Zhizo beads. It is a large roundish bead with a smooth surface which confirms a difference in origin and perhaps in date.

4.4. Soda glass with variable potash and magnesia and low alumina

A group of eight beads are made from a soda glass with low alumina concentrations (< 3%) but highly variable potash (1.1 to 8.5%) and magnesia (0.05 to 2.8%) concentrations when compared to the three glass groups described above (Figure 13.5).

Those soda glass beads have a composition and distinctive typologies that link them to European production. The various compositions might indicate the beads derive from different regions in Europe and/or that they were manufactured during different periods. Beads JW19 to JW23, JW40, JW50, and JW52 are drawn beads with a dark blue color produced by the presence of cobalt in concentrations between 323 and 562 ppm. The presence of cobalt is associated with higher concentrations of Ni, As, and Bi, which is the signature of cobalt ore extracted from the mines in Schneeberg (Erzgebirge), Germany, from the 15th-18th century (Gratuze et al. 1996).

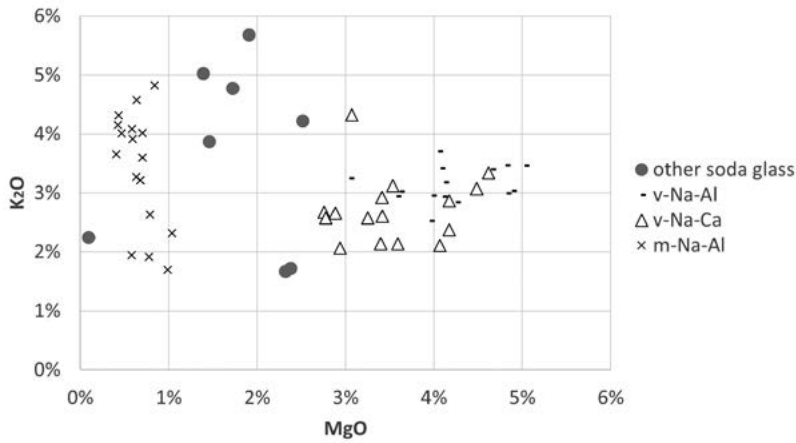

Fig. 13.5: MgO vs K_2O in glass groups vs soda glass of Northeast Tanzania beads.

4.5. Lead-potash glass

JW06 and JW07 are wound blue beads that contain 48% of PbO. The other elements present in significant quantities include silica (41%), potash (6%), and lime (2%). All of the other elements appear in concentrations less than 1%. Potash lead silicate glass has a long tradition in China that starts in the 2nd century (Fuxi, 2009) and continues until very recently (Burgess and Dussubieux, 2007).

The blue color of the beads is quite likely due to the addition of ~2000 ppm of copper. This glass also contains arsenic (~4000 ppm). Arsenic might have been added to the glass as an opacifying agent. This element can be used to produce a white opacifier. Arsenic white has been used in Chinese enamels at least since the second quarter of the 17th century (Kerr and Wood 2004: 647).

5. Discussion

The glass beads from Northeast Tanzania and glass composition results produced using LA-ICP-MS provide new information about the human past in Northeast Tanzania, especially about connectivity to broader networks over a millennium. The data contribute to knowledge about the long-term history of this area and East Africa, in general, and further challenge the tired representation that a 'coast'-'hinterland' dichotomy prevailed in pre-colonial East Africa. This and other archaeological evidence detailed elsewhere (Walz 2010) replace such assumptions and representations with evidence of dynamism, exchange, and the integration

of external items into the practices of inland African communities from the 8th century to the 17th century.

5.1. Contributions of glass compositional analysis

Compositional analysis of 62 glass beads selected from 11 sites in the Mombo Survey Area has aided interpretation of Northeast Tanzania in three basic ways (Table 13.2):

— confirmation of multiple glass groups (and their chronological span of manufacture), including beads of the earliest glass known in East Africa, i.e., v-Na-Ca;
— clarity about places of glass origin: Iraq/Iran (e.g., v-Na-Ca), South Asia (m-Na-Al 1), (likely) Central Asia (v-Na-Al), Europe (soda glass with variable potash and magnesia and low alumina), and China (lead-potash glass) [although it is not certain that select glasses were made into beads in these specific regions, see Annex B]; and
— clarity that coast-inland exchange occurred over the span of a millennium (8th-17th century CE) with representative and overlapping glass groups throughout this extended period.

Site Number (Name, if any)	Number of Bead Samples	Glass Composition Type or Origin (Number of Samples)	Date of Glass (CE)	Site Chronology based on Tested Samples
105	2	m-Na-Al 2 (1)	14th c. or later	13th-16th c. or later
		v-Na-Al (1)	13th-16th c.	
110 (Ulimboni)	1	v-Na-Ca 1 (1)	8th-mid-10th c.	8th-10th c.
127	1	Europe (1)	15th-18th c.	15th-18th c.
135 (Kwa Mkomwa)	9	m-Na-Al (1)	?	8th-16th c.
		m-Na-Al 6 (2)	9th-13th c.	
		v-Na-Al (4)	13th-16th c.	
		v-Na-Ca 1 (1)	8th-mid-10th c.	
		v-Na-Ca [Egypt] (1)	14th c.	
162	1	Europe (1)	15th-18th c.	15th-18th c.
180	1	m-Na-Al (1)	?	?
181	3	Europe (3)	15th-18th c.	15th-18th c.
183	1	m-Na-Al (1)	?	?
185	11	v-Na-Al (11)	13th-16th c.	13th-16th c.

Site Number (Name, if any)	Number of Bead Samples	Glass Composition Type or Origin (Number of Samples)	Date of Glass (CE)	Site Chronology based on Tested Samples
177 (Kwa Mgogo)	28	corroded (2)	?	8th-13th plus 17th c. or later
		m-Na-Al (1)	?	
		m-Na-Al 6 (10*)	9th-13th c.	
		v-Na-Ca 1 (12**)	8th-mid-10th c.	
		v-Na-Ca 2 (1***)	?	
		Pb-Si-K (2)	2nd quarter of 17th c. or later	
189 (Jamali 3)	4	corroded (1)	?	15th-18th c.
		Europe (3)	15th-18th c.	

* Seven of these beads were published previously (Walz and Dussubieux 2016) as m-Na-Al 2, but due to new evidence on compositions in the region have been revised to m-Na-Al 6.
** Ten of these beads were published previously (Walz and Dussubieux 2016).
*** This bead was published previously (Walz and Dussubieux 2016).

Table 13.2: Summary of archaeological sites, glass bead samples, glass compositions, and chronology in Northeast Tanzania.

These outcomes help to enhance understandings of the region's history and political economy, including Indian Ocean exchange networks and trends in African consumption across time. No inland site in Tanzania greater than 50 kilometers from the marine coastline had yielded glass beads confirmed by LA-ICP-MS to pre-date the 16th century CE. Thus, the Mombo Survey Area now has the earliest glass known in inland East Africa: v-Na-Ca 1 beads from the 8th-10th century CE. Three sites – Kwa Mgogo (Site 177), Kwa Mkomwa (Site 135), and Ulimboni (Site 110) – produced at least one bead and as many as 14 beads of this glass. Interestingly, only a few sites at the coast of Tanzania have yielded these early glass beads (e.g., Unguja Ukuu in Zanzibar, see Wood et al. 2017; Sarathi et al., this volume). Beads of v-Na-Ca l glass are somewhat more common in southern Africa, including at sites in the Kalahari Desert and at Great Zimbabwe (e.g., Denbow et al. 2015; Wood 2016; Wood et al. 2016; Klehm and Dussubieux, this volume).

Partially overlapping or subsequent to the beads of v-Na-Ca glass are the beads of m-Na-Al 6 (9th-13th century CE) and v-Na-Al (13th-16th century CE) glasses, respectively. The former likely are made of glasses from South Asia and the latter have Central Asian compositions strikingly similar to MO beads, common in southern Africa (Robertshaw et al. 2010) and at Mambrui, Kenya (Siu et al. 2020),

and in Ethiopia (Trombetta et al., this volume). The m-Na-Al 6 glass was used to make beads also called Indo-Pacific K2 and East Coast varieties (Robertshaw et al. 2010; Wood 2011). In general, it appears that during the first half of the second millennium CE, glass beads in Northeast Tanzania shift from an exclusive origin in Iraq/Iran to include glass origins in Central Asia and northern India. This trend may be characteristic of wider East and Northeast Africa. All 11 of the tested beads from Site 185 (located near the Zimui River at the base of the West Usambara Mountains, Figure 13.1) are of v-Na-Al glass. This site may have facilitated exchange between communities in the lowlands and highlands. In the middle of the second millennium CE (starting as early as the 15th century CE) beads from Europe and, somewhat later, China appear in inland Northeast Tanzania, in recent centuries becoming very common (see Background). From LA-ICP-MS tests, the earliest European beads vary in their glass compositions in space and time. Included among European beads from the project (but untested by LA-ICP-MS) are moulded beads from Venice and Bohemia (e.g., Karklins 1992; Walz 2010). Overall, the results from Northeast Tanzania suggest a remarkable longevity of bead exchange inland over the span of more than a millennium (8th-17th centuries and beyond).

5.2. Political economy and beads

People in Northeast Tanzania secured and remade their livelihoods by producing, exchanging, and consuming goods. A political economic perspective on these activities, conscious of the limitations and opportunities of the setting, achieves scalar integration by considering contemporaneous societies and residues of interaction and power. Connectivity viewed through an interactionist perspective emphasizes "how societies structure their interactions through material culture that is used to send social signals….[It is] simultaneously alert to the historically specific and the processual….[and] it pays attention to underlying spatial and geographical structures" (Mitchell 2005:24-25). In this perspective, mutually constitutive interactions among the region's communities formed a system of value [see Prestholdt (2008) for an instructive example from 19th century East Africa relevant to glass beads].

In eastern and southern Africa, bead studies slowly are shifting to integrate beads of African origin (e.g., Miller et al. 2018; Insoll 2021) into overall interpretations of assemblages and the political economy. Beads of local origin are often most common at sites. At Kwa Mgogo (Site 197), for instance, glass beads comprise less than 5% of the bead assemblage, which is dominated by locally-made land snail shell beads. In addition, there is a tendency for archaeologists working in the region to study the presence, quantities, and origins of beads, but not integrate

them into understandings of the region's history, or to engage ways foreign beads were (re)made, combined with local beads, or consumed alongside them to meet African purposes (e.g., Ogundiran 2002; Walz 2015; Moffett and Chirikure 2016). Such efforts begin to better address Africa-Indian Ocean entanglements, as with the example below: a brief overarching narrative about Northeast Tanzania.

5.3. Regional narrative

In the late first millennium CE and during subsequent centuries, the lower Pangani Basin experienced population growth, semi-specialized craft production, the beginnings of political differentiation among sedentary communities, and elaborations of ritual tied to consumption (Walz 2010, 2017). The material signatures of these developments include comparatively large settlement clusters in the Mkomazi River Valley near Mombo, Swahili architecture of coral at the coast, greater frequencies of non-local (including foreign) items, increased shell bead and iron production, and, eventually, specialized pastoralism and terraced cultivation in and around the Eastern Arc Mountains (e.g., Walz 2010, 2013; Biginagwa and Ichumbaki 2018). Excavated burials with burned shell disc beads at Kwa Mgogo and a massive ash mound with discarded land snail shell beads at Gonja Maore (in the lowlands west of Mombo) are indicative of ritual practice at a scale that treats beads as social symbols. A recovered sequence of beads of carnelian and glass at Kwa Mgogo (Site 177) indicates that foreign beads were being integrated alongside non-glass beads for personal adornment.

In the lower Pangani Basin, there were "pulses" of connectivity and at least partial integration into global commercial networks from the late first millennium CE to recent centuries. The quantity and diversity of external items increased circa 1000 CE and again circa 1500 CE. The earliest group of non-local artifacts at inland sites included copper alloy ornaments (likely from further inland) and shells and glass beads from the wider Indian Ocean. Evidence of substantial iron production to the west (along the skirt of the South Pare Hills) also surged circa 1000 CE (Walz 2010). While beads made of glass from South Asia and Central Asia show that early objects from Indian Ocean networks reached into Northeast Tanzania, this occurred alongside an increased production of beads of marine shell along the coast 750-1100 CE. The Swahili site of Shanga in the Lamu Archipelago (northern Kenya) exemplified this trend (Horton 1996). The early simultaneous interest in both marine shell beads and beads of glass along the coast may have been driven by the desire to signal associations with and/or differentiations from other communities on the African mainland (see above for interactionist perspective). The multiple origins and aesthetic characteristics of beads and their mobility and endless (re)combinations better enabled social signaling (in life and by discard or

adornment at burial).

By the 12th century, the production of marine shell disc beads at the coast declined dramatically (e.g., Sarathi et al., this volume), followed by a brief surge in the production of tubular beads of marine shell (e.g., Horton 1996:323). At Kwa Mgogo (Site 177), the excavation of strata dated to this period identified beads of v-Na-Ca 1, m-Na-Al 6, and v-Na-Al glasses but also a few finely made marine shell disc beads (of *Anadara* sp.) and, in the immediately subsequent excavation levels, 16 tube beads of marine shell (of *Strombus* spp.). These marine shell beads recovered from an inland site are the same sizes and forms as the beads identified at Shanga in Kenya. Thus, patterns in the material assemblage at Kwa Mgogo mirrored coastal trends of this period. Overall, the material evidence from across the region bolsters arguments for connectivity among contemporaneous communities living in different regional settings and suggests that the production, exchange, and consumption of glass and shell beads played an important role in intergroup relations across Northeast Tanzania since the middle to late first millennium CE.

At first, glass beads from Asia reinforced previously established bonds developed through food exchange and the exchange of other objects where communities with different life-ways intersected. From 750-1100 CE, coastal and inland communities tended to make shell disc beads from different materials: primarily marine shell at the coast and land snail shell at inland sites. The simultaneous timing of disc bead production across these settings is unlikely to be coincidental. Smith (1999:117) highlights the role of "raw-material substitution" in sending social signals that forge intergroup ties. Shell disc beads in this region had a value beyond simple use, namely as "sign vehicles" that maintained and reinforced socio-economic relationships on a mosaic landscape with diverse societies. By participating in bead making, emulation, and consumption (public display, ritual acts, and ancestor veneration), communities negotiated their positions in a wider social network, benefitting from links to webs that buoyed them during periods of downturn or calamity.

The relatively swift halt to local bead production in particular at the coast during the earliest century of the Swahili "Golden Age" (CE 1250/1350-1550) indicates a partial interruption to the regional economy. Inland groups were now predominantly receiving MO v-Na-Al beads, as evidenced by the many glass beads at Kwa Mkomwa (Site 135) and Site 185. Whereas shell discs of land snail had been made almost exclusively at sites along the ridge opposite the Mkomazi River, glass beads during the 13th-16th centuries concentrate in lowland areas nearer to the mountains. It may be that exchange between coastal and inland communities could no longer depend on balanced input from coastal communities,

coastal people being increasingly ingrained in new systems of value enabled by new objects of importance for display and consumption (e.g., including beads of v-Na-Al glass and, even later, the lead potash glasses of China and European beads). Thus, it appears balanced coast-inland ties grew leading up to the Swahili "Golden Age," based on the importance of shell disc beads as common goods that could be produced and their distributions controlled by local communities. By 1200-1350 CE and in the following centuries, however, glass beads and other far-flung objects became the focus of residents at the littoral, drawing them away from more balanced and holistic engagements. The relationship of coastal settlements with inland groups thereby became increasingly imbalanced. Glass beads during this time increased in prominence at inland sites to facilitate social differentiation (access and display of prestige items). However, this did not always prove to be the case, as beads were sometimes used for inland purposes other than differentiation, putatively including as items in healing practice (Walz 2015).

The unique character of resources (elephant ivory, minerals, and dense human population in the proximal mountains exploited by slavers) in Northeast Tanzania may have insulated it against some uncertainties. Inland, exchange and alliances (cooperation) served as alternatives to violence (conflict) in times of resource depletion or local instability. Kin ties, blood brotherhoods, and systems of reciprocity reinforced mutual connections. Developing moral economies supported by narratives that stressed balance and decried instability provided insurance in an attempt to diminish vulnerability. In late Swahili and early Portuguese times (especially through the 16th century CE), raids became more pronounced because the social meaning of pan-regional symbols and exchange systems faded. Rotating markets at geographical intersections arose during this period that enabled territorial linkages among newly fragmented groups. More stable food production resulting from terracing, irrigation strategies and, later, the arrival of specialized pastoralists eventually led to greater accumulations of social wealth and new political forms (Walz 2010). Millions of glass beads flooded East Africa in these more recent centuries, serving as a mark of significance in power plays.

6. Conclusion

This chapter articulates the significance of LA-ICP-MS analysis of 62 glass beads from 11 archaeological sites in the Mombo Survey Area of Northeast Tanzania. Results show five glass groups and many glass sub-groups, which provide information about the beads' origins and chronology and have further implications for understanding the region's political economy. Northeast Tanzania has a rich

past. Glass origins include different areas of Asia through time, the earliest of which dates to the 8th-10th century CE. The tested beads provide a chronology of a millennium that goes through the 17th century CE. Glass beads later than the 17th century CE already were known from the area and can be easily identified macroscopically. Compared with other contemporaneous areas in Tanzania's hinterland, glass beads at Mombo are unique.

This glass bead evidence enhances understandings of inland-ocean connectivity and the political economy of communities in the region, including those living in the outer landscapes of urban Swahili settlements. Early and substantial coast-hinterland interactions occurred. The identified chronology of bead origins and use provides new insights into this little-studied inland area. Connectivity across a mosaic of environments and among people of different lifeways forged social bonds and ameliorated uncertainties. The outcomes of global exchange and local production and consumption in Northeast Tanzania reverberate up to the present. Glass beads and knowledge about their compositions help archaeologists to (re-)make African history.

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Chapter 14

Glass beads at Unguja Ukuu in the late 1st millennium CE: Results of the 2018 excavation in Zanzibar

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1. Introduction

The site of Unguja Ukuu on the island of Zanzibar (Unguja) (Figure 14.1) was a substantial settlement. Located on the island's southern coast, Unguja Ukuu was first systematically excavated and studied in the early 2000s, when its significance as a trading port with links both to the African interior and parts of the Indian Ocean World were archaeologically confirmed (Juma 2004). Abdurahman Juma was impelled to excavate the site due to the discovery of 8th century gold coins from the Islamic World at the site in 1866 and, secondly, Neville Chittick's surface survey report of the site in which he suggested that Unguja Ukuu, along with Manda in contemporary Kenya, was one of the most significant Swahili settlements on the East African coast during the second half of the 1st millennium CE (Chittick 1966; Pearce 1967). Juma's (2004) excavations revealed an occupation sequence that spanned the 6th to 9th centuries CE and a reoccupation in the 11th century. Lastly, the site again was reoccupied in the 15th and 16th centuries. A conclusive date for the beginning of the current occupation of the site was unclear.

Since Juma's (2004) pioneering work at Unguja Ukuu, other archaeologists have explored various aspects of the site and its occupation history. The general emphasis has been on the site's connections with the Indian Ocean World rather than the African continent. For example, an excavated artifact identified as an "incense burner" with traces of copal dated to the 8th century CE was interpreted to have belonged to a wealthy local/foreign merchant with links to other regions of the Indian Ocean World, given its non-African character (Crowther et al. 2015). Previous research that employed LA-ICP-MS to trace the original places of manufacture of glass beads found at Unguja Ukuu provided baseline data to reconstruct Unguja Ukuu's international trade networks (Wood et al. 2017). The

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results of that article are mostly confirmed by the data presented here. This chapter also preliminarily examines the roles of imported beads in relation to other beads and artifacts in the cultural context of use and meaning.

Fig. 14.1: The location of Unguja Ukuu in Zanzibar, with other important archaeological and modern settlements identified.

Other publications concerning Unguja Ukuu attempt to reconstruct the everyday lives of its inhabitants. The layout of the site's earliest occupation sequences, the soil geochemistry of a daub house from the site, and common recovered artifacts have been studied in some detail (Fitton and Wynne-Jones 2017; Sulas et al. 2019). Other researchers have worked on the diet of the inhabitants but thus far have focused on the marine fauna of the zooarchaeological assemblage (Faulkner et al. 2018). A paper currently in preparation assesses all the faunal remains and animal-related products found at the site.

2. Context

Between February and May 2018, the lead author conducted excavations at Unguja Ukuu as part of his dissertation research funded by Fulbright-Hays and National Geographic. These excavations were designed to retrieve as many artifacts and ecofacts as possible within the sampling methodology. By sieving and subjecting to flotation all excavated matrix, the project recovered a representative sample of materials. The intensive excavation process paid dividends as evidenced by the overall assemblage size and uniqueness of individual artifacts discovered. To provide perspective on the types and quantities of select finds, consider the

following records of finds. More than 11,000 (combined) ostrich eggshell and giant land snail shell beads were found from the occupation sequences dating between the 6th and 11th centuries CE. These consisted of blanks as well as completed and partial beads, suggesting extensive manufacture of these beads at the site (Sarathi 2020; see also Walz 2010). Furthermore, a rock crystal cabochon identified as a seal with the word *lillah* inscribed was retrieved, in addition to carnelian and other stone beads comparable to those produced in the region at this time period. Also, the shattered remains of small glass bottles, or vials, like those reported by earlier excavators of the site (Juma 2004) were recovered in the thousands. Lastly, a total of 1,720 glass beads were discovered in the emphasized occupation sequence. In addition to beads and other ornaments, excavations yielded thousands of potsherds, both imported and domestic. Preliminarily, the imported potsherds consist primarily of Islamo-Sassanian sherds and the locally produced pottery consists mainly of sherds of Triangular Incised Ware/Tana Tradition (TIW/TT) (Sarathi 2020; see also Juma 2004).

The catalogue above enables us to place in some context the 1,720 glass beads and study them in relation to other local and imported beads of different materials used by the inhabitants of the site. One question that immediately arises is whether glass beads and other glass artifacts originate in the same places. Placed in the context of non-local artifacts as a whole, we were compelled to examine whether the trade pattern frequencies, networks, local uses of different kinds of imported objects resemble one another. In this paper, we modestly begin to reconstruct broader patterns of artifact relation and use linked to Unguja Ukuu. We examine the sourcing of glass beads with LA-ICP-MS and use what limited evidence is available to reconstruct possible ways in which these beads were deployed, used, and valued locally.

3. Method

The Unguja Ukuu glass beads described in this paper were retrieved exclusively by flotation and 100% screening (<1mm) of soil excavated from what was a midden. The beads were never found in associations that suggested possible stringing. The most common artifacts excavated from the midden were faunal remains and potsherds. Some iron and copper artifacts, iron slag, shell beads, and a single piece of gold wire were also recovered. The midden lies at the edge of the contemporary tidal zone. It was selected for excavation for this very reason; it is unlikely that the midden would have survived for more than a few more years with the rate of sea level rise and erosion observed at the maximum reaches of the daily high tide and especially the spring high tide.

Soil was preliminarily screened at the site of excavation and large artifacts removed. What remained in the screen was then bagged and labeled before transport to the field station out of which Sarathi operated. There, the bags of soil were subject to careful and controlled flotation. The entire matrix was subject to flotation, with no sampling. The recovered materials were sun-dried before being painstakingly sorted by hand. When the sorting was completed, Sarathi and Walz classified the beads according to a basic typology. The list of samples with details for both the typology for the glass beads developed by the authors (Figure S14.1) and the samples selected for LA-ICP-MS are in the Supplementary Materials (Table S14.1). At least one sample from each bead type was chosen for analysis. The beads were distributed fairly evenly among the seven strata (Table 14.1) encountered during the excavation, as can be seen in Figure 14.2 and Table S14.2. An overwhelming number of beads were manufactured using the drawn technique with a translucent blue glass. They represent 81% of the bead corpus. The chosen samples were analyzed with LA-ICP-MS at the Elemental Analysis Facility (Field Museum, Chicago) by Sarathi and Laure Dussubieux in August 2019.

Layers	Date(s)
1	12th-16th (?) century CE
2	10th-12th century CE
3	8th-9h century CE
4	8th-9th century CE
5	8th-9th century CE
6	8th-9th century CE
7	6th-8th century CE

Table 14.1: Dating the broad contexts from which the beads were excavated. The dates derive from the excavations of Juma (2004), which took place only a few feet from Sarathi's 2018.

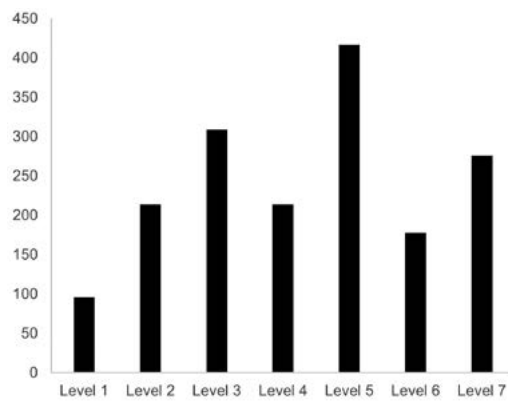

Fig. 14.2: The total number of beads (of all types) per level.

4. Results

Seventy-four beads were analyzed (see Annex A for analytical protocol). One bead composition was eliminated, as it was corroded glass (Bead 84). Three beads were polychrome and the different colors that were part of them were analyzed. Seventy-six compositions are available (Table S14.2). Three glass types were identified (Table 14.2):

— 53 compositions belong to the mineral soda – high alumina (m-Na-Al) glass groups,
— 22 compositions revealed a high sodium plant ash recipe (v-Na-Ca),
— Bead 15 has a high lead composition.

	Average	SD	Average	SD	Sample 15
SiO_2	67.3%	3.4%	69.0%	3.4%	24.5%
Na_2O	18.1%	2.2%	14.7%	1.2%	0.1%
MgO	0.5%	0.2%	3.3%	0.8%	0.1%
Al_2O_3	8.9%	1.5%	2.6%	0.9%	0.3%
K_2O	2.2%	0.8%	2.6%	0.4%	0.1%
CaO	3.1%	0.8%	7.4%	1.7%	0.5%
PbO	-	-	-	-	73.1%

Table 14.2: Average reduced compositions with standard deviation (SD) of the glass beads in the m-Na-Al group and the v-Na-Ca group and composition of the high lead glass bead.

4.1. m-Na-Al glass type

Close to 70% of the measured compositions belong to the mineral soda – high alumina (m-Na-Al) glass. From a general point of view, the m-Na-Al glass contains soda as the most abundant constituent after silica. The distinctive feature of this type of glass is its high alumina content, which varies from 5 to 15%. It also contains small amounts of potash and lime (2-3%) (Dussubieux 2001; Dussubieux and Gratuze 2003). Magnesia in this glass is rather low (lower than 1.5%), suggesting the use of soda taken from a mineral source (See Annex B). Table 14.2 shows the average reduced composition (calculated by only taking into account the oxides listed in the table) for the m-Na-Al glass samples found at Unguja Ukuu. Sample 70 was excluded from the average although it fits into the definition of the m-Na-Al glass. It is a black glass with higher concentrations of MgO, but also P_2O_5 and CaO. These constituents certainly were added (voluntarily or not) to the glass by wood or plant ashes within a reducing atmosphere that would have facilitated the black color of the glass.

The high alumina concentration in the glass is a marker of an Indian provenance. In this region glass was manufactured from a natural mix of immature sand and soda-rich efflorescence called in some part of India *reh* (Kock and Sode 1995; Brill 2003; Gill 2017). The m-Na-Al glass group was divided into five subgroups (m-Na-Al 1, 2, 3, 4 and 6) based on the variation of the concentrations of a number of constituents: Mg, Ca, Sr, Zr, Ba, Cs and U (Dussubieux et al. 2010; Dussubieux and Wood, 2021). Recently, additional groups were identified at the site of Indor in Rajasthan, dating from the 14th century CE and onward (Trivedi and Dussubieux, this volume; in preparation). For more details about the m-Na-Al glasses in general, see Annex B.

Figure 14.3 represents the principal components 1 and 2 calculated using the concentrations of MgO, CaO, Sr, Zr, Cs, Ba and U in the Unguja Ukuu m-Na-Al glass beads and in glass beads belonging to the five glass groups mentioned above. Most of the UU m-Na-Al glass beads have a m-Na-Al 1 composition. Two beads (11 and 25) fall in the area of the m-Na-Al 2 glass. Bead 19, with a lower Zr concentration than the ones found in the group m-Na-Al 2 was certainly made from a different sand. Two beads (27 and 70) belong to the m-Na-Al 6 group. Beads 36 and 81, with lower U levels and higher Cs levels than the levels in m-Na-Al 6 fall close but outside of this group. It is noteworthy that these two beads have extremely similar compositions with a relative difference for the concentrations of the same oxide or element of less than 10% for most of them. It is possible that samples 19, 36 and 81 are part of these newly discovered groups found at Indor in Rajasthan dating from the 14th century CE and onward (Trivedi and Dussubieux, this volume). More research is needed before further interpretation.

In South India and Sri Lanka, small drawn beads were made from a locally manufactured glass, called m-Na-Al 1. The 3rd century BCE – 2nd century CE settlement of Giribawa, located in the northwestern part of Sri Lanka is a possible production center for that glass group (Dussubieux et al. 2021). The same type of glass is also found in South India, suggesting that it might have been manufactured there as well. At this point, no primary glass manufacturing center has been excavated in South India, but preliminary evidence for glass bead making is available (see Abraham 2016). The small m-Na-Al 1 drawn beads from South India/Sri Lanka were quite likely exported as such to Southeast Asia starting around the 3rd or 2nd century BCE, becoming dominant in Southeast Asian glass bead assemblages after the 5th century CE (Dussubieux and Gratuze 2010) and until the 11th century CE (Dussubieux and Allen 2014). Although the m-Na-Al 1 glass beads were also traded westward, this glass type remains rare in Africa where the only place it is found in significant quantities is Unguja Ukuu (Wood et al. 2017).

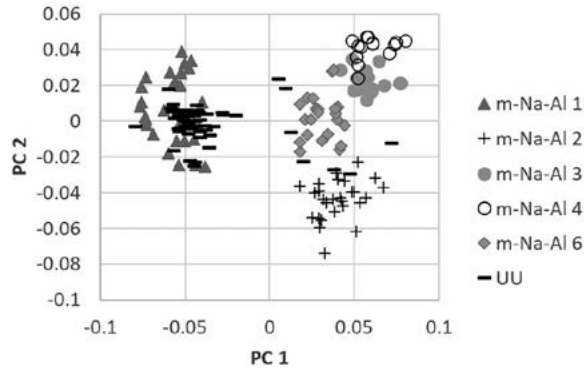

Fig. 14.3: Principal components 1 and 2 were calculated using the concentrations of MgO, CaO, Sr, Zr, Cs, Ba and U for samples belonging to glass groups m-Na-Al 1 to 4 and 6 and the glass samples from UU. The m-Na-Al 1 glass samples are unpublished data from Sri Lanka and South India, the m-Na-Al 2 glass samples are beads from Chaul (Dussubieux et al. 2008), the m-Na-Al 3 glass samples are beads from Kopia (Dussubieux and Kanungo 2013), the m-Na-Al 4 glass samples are glass vessel fragments from Sumatra (Dussubieux 2009) and the m-Na-Al 6 glass samples are from the eastern coast of Africa (Dussubieux and Wood 2021).

M-Na-Al 2, the glass used for the manufacture of the Khami Indo-Pacific beads, has been identified at many sites dating from the 14th to the 19th centuries CE located in southern Africa (e.g., Robertshaw et al. 2010; Wood et al. 2009) and the east coast of Africa (Dussubieux et al. 2008). The site of Chaul, a port in Maharashtra, yielded m-Na-Al 2 glass beads and could have been a point of departure for these beads for distribution around the Indian Ocean. Bead production at Chaul is attested by evidence found at this site (Gogte et al. 2006) and by the mention of the production of beads at a site called "Chawle" by Venetian merchant named Caesar Frederick who travelled along the west coast of India (Federeci and Hickock, available online).

The m-Na-Al 6 is expected to have been manufactured in India although concrete archaeological evidence for that is still missing; however, the fairly high strontium isotope ratio measured for this glass (Seman et al. 2021) matches the strontium isotope signatures found in the east part of Uttar Pradesh. The m-Na-Al 6 glass was identified based on material found on the Eastern Coast of Africa where it was assigned a period ranging between the 9th century CE and the 13th century CE (Dussubieux and Wood 2021). The m-Na-Al 6 glass beads from the Eastern Coast of Africa have the same composition as the Indo-Pacific K2 and East Coast beads identified earlier (Robertshaw et al. 2010; Wood et al. 2009) and that belong to a slightly shorter time window (10th – 13th century CE). Our understanding of the diffusion of this glass is still partial due to its very recent discovery.

4.2. Soda plant ash glass

Close to 30% of the samples have composition high in soda with magnesia and potash concentrations > 1.5% that indicate the use of halophytic (salt-tolerant) plant ashes as a soda rich flux. In addition to soda, potash and magnesia, this ingredient generally contains a variable proportion of lime. It is mixed with rather pure silica obtained by crushing quartz pebbles or other silica rich material. This type of glass is the earliest known glass type. By the middle of the 2nd millennium BCE, production centers manufacturing such a glass operated in both Egypt (e.g., Rehren and Pusch 2005; Smirniou and Rehren 2011; Smirniou et al. 2018; Tite and Shortland 2003) and Mesopotamia (e.g., Degryse et al. 2010; Shortland et al. 2018). Starting around the 9th - 8th century BCE, soda from mineral deposits (e.g., natron) replaced soda plant ash in Egypt and in the Syro-Palestinian region. Toward the end of the 1st millennium CE the use of natron declined (Shortland et al. 2006) and a return to plant ash occurred. The soda plant ash glass tradition may have continued uninterrupted in Mesopotamia and Sasanian glassmakers produced such a glass from the 3rd to the 7th century CE (Mirti et al. 2008, 2009).

To understand the connection of the Unguja Ukuu soda plant ash beads with other soda plant ash glasses found in Sub-Saharan Africa, the compositions of the beads were compared with the compositions of some glass thought to be from Egypt, dating from the 14th century CE (Dussubieux 2017) and of three different v-Na-Ca glasses identified at Chibuene, Mozambique (Wood et al. 2012):

- v-Na-Ca 1: it is the most abundant v-Na-Ca glass type and was found similar in composition to Middle-Eastern glass such as can be found at the site of Nishapur. At Chibuene, it was associated with the 8th to 10th century CE period.
- v-Na-Ca 2: this glass type has significantly high amounts of chromium correlated with the presence of nickel. It was found in samples in the forms of glass sherds or wastes. At Chibuene, it was associated with the 8th to 10th century CE period.
- v-Na-Ca 3: this glass usually in the form of bluish or greenish drawn glass beads contains higher trace elements such as Rb, Ce, Cs, Ba, La and U. It was associated at Chibuene with the earliest context possibly ranging from the 7th to the 9th centuries CE.

Comparison was made using principal component analysis on the Unguja Ukuu v-Na-Ca glass samples taking into account the concentration of MgO, P_2O_5, CaO, Cr, Rb and La that were found useful to separate soda plant ashes found at the site of Chibuene (Wood et al. 2012) (Figure 14.4).

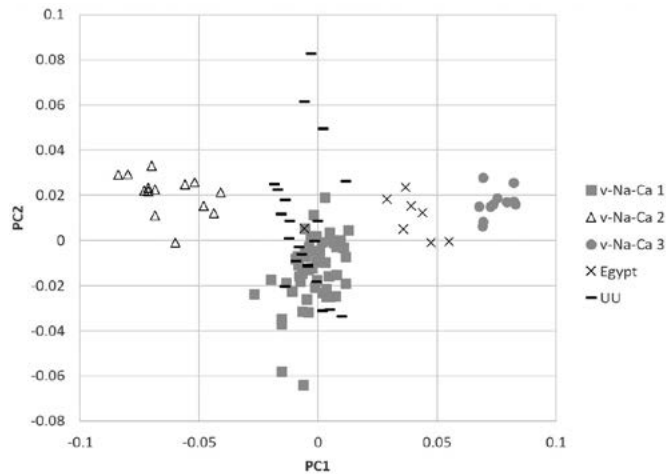

Fig. 14.4: Biplot representing PC1 and PC2 obtained using the concentrations of MgO, P_2O_5, CaO, Cr, Rb and La from samples belonging to glass groups v-Na-Ca 1, v-Na-Ca 2, v-Na-Ca 3 (Wood et al. 2012), and a v-Na-Ca glass from Egypt (Dussubieux 2017) and the beads from UU.

The Unguja Ukuu v-Na-Ca glass beads are distinct from groups v-Na-Ca 2, 3 and from the glass from Egypt. The compositions match the v-Na-Ca 1 glass with a few samples falling outside of this group, mostly due to an important variation of the phosphorus and other constituent concentrations suggesting maybe several source locations within the Middle East. Comparative data for beads from this region are scarce and limit our efforts for a more precise source location.

4.3. Lead glass

Finally, Bead 15 has 73.6% of lead and 24.5% of silica. All the other constituents present in this bead have concentrations below 1%. The color of this bead is "turquoise-green" certainly due to the presence of 0.32% of CuO detected in the glass. High lead compositions are common for glass with an emerald color found in different points of the Islamic word in contexts dating from the 9th to the 11th century CE. Although all those glasses have more than 50% of lead, the other constituents of the glass have concentrations that may vary suggesting that different workshops producing that kind of glass might have existed (Brill 1999, volume 2:182-183; Freestone 2020; Wypyski 2015).

5. Discussion

This new study reports results similar to those obtained by Wood et al. (2017) that found that close to 70% of the beads from Unguja Ukuu derived from South Asia and close to 30% from the Near/Middle East. In fact, the proportion of South Asian glass might even be more important. Among the beads recovered during the 2018 excavation, 81% of the beads were translucent blue drawn beads. We found that these beads belong to the m-Na-Al 1 glass type. This suggests that all these translucent blue drawn beads might have the same composition, and all come from South Asia.

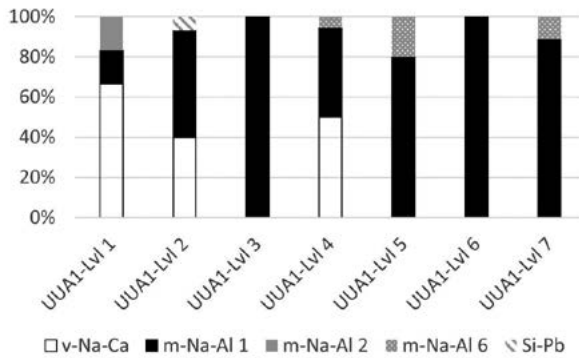

Fig. 14.5: Distribution of the glass types by contexts. UUA2-Lvl 2 was omitted as only one bead from this context was analyzed.

Both glass types are associated with production dating from the end of the millennium CE in line with the dating of the site. Figure 14.5 indicates that the earliest glass might have been the m-Na-Al 1 glass, an observation also made by Wood et al. (2017). The presence of m-Na-Al 6 beads, dated from the 9th to 13th century CE, in the earliest levels of the excavations at Unguja Ukuu is surprising and cannot be explained. The only m-Na-Al 2 glass bead was found in level 1 (12th – 16th century CE), which agrees with the dating of that kind of glass (14th century CE and onward). The v-Na-Ca glass beads are present in the levels 1 to 4 that are dated from the 8th to 9th century CE (level 3 and 4), from the 10th to 12th century CE (level 2) and 12th to 16th century CE (level 1). The v-Na-Ca 1 glass is generally associated with contexts dating from the 8th to the 10th century CE and their presence in later contexts might be due to beads being passed down generations and disposed of at a later date than when they were produced. The high lead glass was found in level 2 (10th – 12th century CE) which agrees

fairly well with the period for the manufacturing of that type of glass (9th to 11th century CE).

Beads 36 and 81 have m-Na-Al compositions that are slightly different from the other m-Na-Al glasses we analyzed but that are extremely similar to each other. Further, these beads do not present a smooth exterior under magnification. Instead, they appear cracked and riven with faults in which sand particles adhere (Figure 14.6). Their texture and the cracking suggest that they were produced by reheating crushed beads, but that the process did not achieve the smoothness of beads produced in the Middle East or South Asia because the beads were not heated to high enough temperatures. Melting crushed glass requires a temperature of about 1000 ˚C or a little less and can be achieved in an open fire (Schultz and Walder 2016). Producing beads from recycled glass was practiced in Sub-Saharan Africa in ancient times as well as more recently. Garden roller beads that can be found in the Southern part of Africa (10th - 12th century CE) were manufactured from crushed glass placed in a one-piece clay mould that was then broken to retrieve the bead (Robertshaw et al. 2010; Wood 2011). Wood (2016) notes reworking of beads in Gao and Chibuene.

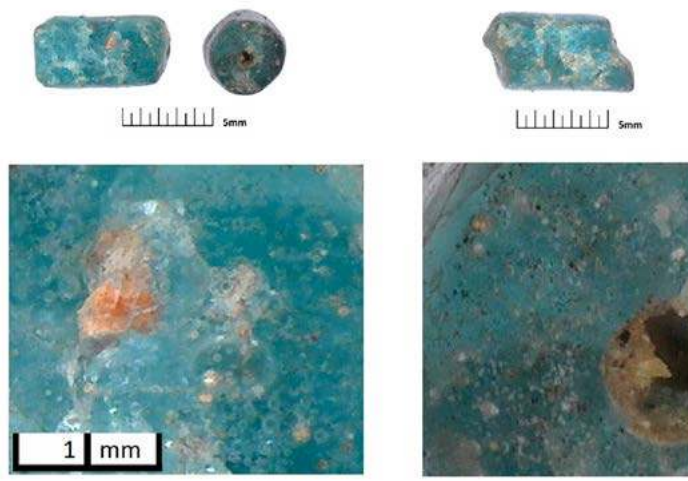

Fig. 14.6: Beads 36 and 81 with magnified pictures of their surface.

Still today, colorful beads are produced in Western Africa from recycled glass crushed and placed in a mold that can accommodate several beads at a time (e.g., Agyei et al. 2012; Liu et al. 2001). It seems quite likely that beads 31 and 86 were shaped from the same batch of recycled glass. Were those beads produced at the

site of Unguja Ukuu itself? No archaeological evidence (e.g., mold) supports this hypothesis; the fact that the compositions of the beads are different from all the other m-Na-Al glass beads seems to make it unlikely that some of them were recycled on site into new beads. It does not seem either that the difference between the m-Na-Al compositions of beads 31 and 86 and the other beads could have been induced by the recycling process: no presence of residual colorants in the recycled glass or no specific increase of trace elements (some are more abundant, and some are not) are visible in the compositions of the two beads.

Although it is not possible to affirm that some glass beads were shaped on site, it is quite likely that glass beads were purely imported products. Shell blanks, partially formed beads and the presence of thousands of finished beads indicate that a thriving shell industry developed at Unguja Ukuu. Another consideration that this new bead study from Unguja Ukuu would like to explore is how imported glass beads were incorporated into a preexisting system of production and display of land snail shell and ostrich eggshell beads. More than 11,500 shell beads were excavated, roughly seven times the number of imported glass beads (N = 1,720). This suggests that glass beads were incorporated into robust bead-using culture and likely gained a new meaning in the process and throughout occupation.

The temporal distribution of the beads offers some insight into changing patterns in the trade bringing beads to Unguja Ukuu between the 6th and 12th century CE. As can be seen in Table S14.2, some patterning certainly is present, but assessing whether the limited presence of a single bead type in three or fewer layers is due to factors concerning taphonomy of excavation errors or due to genuine changes in the bead trade network is difficult. On the whole, it seems that the bead networks remained stable through the site's occupation until its abandonment post-1100 CE.

Shell beads of the types and quantities mentioned above suggest, for instance, the presence of a regular supply of ostrich eggshells from the mainland or from other parts of the island if ostriches existed on Unguja at that time (Prendergast et al. 2016). No ostrich remains were identified in the Unguja Ukuu excavations. Alternatively, completed ostrich eggshell beads from the mainland may have been exchanged to inhabitants at Unguja Ukuu. Giant African land snails (*Lissachatina* spp.) were collected for bead production as well (see Walz 2010, 2017). Thus, the social deployment of glass beads must have taken place on the backdrop of shell beads. The glass beads came in different colors, while the shell beads were white or off-white. Without strong evidence one way or the other of how shell and glass beads were worn together or separately and what objects they were attached to, we are limited in our ability to further explore the relationship between and juxtaposed by the deployment of various bead types at Unguja Ukuu over time. Interestingly, the shell beads were found in various stages of manufacture: blanks,

finished beads, and partially finished beads were all found in significant quantities at the site (also see Walz 2010). Imported glass beads from distant regions could have served as symbols of status or identity, in which familiar objects were given greater value due to their foreignness or because they mimicked local materials of value.

The imported glass beads also must be placed in the context of other imported goods found at the site: glass vials/bottles and Islamo-Sassanian Ware in particular. Both of these types of objects were sourced to the Middle East and likely traveled the same routes as the beads that originated from this region. Islamo-Sassanian sherds were favored for use as bead-grinders for the manufacture of shell beads at Unguja Ukuu. Little evidence remains of how Islamo-Sassanian sherds, small imported bottles of eggshell-thin glass, and imported glass beads arrived or were deployed together. However, as the three major objects of importation during the entirety of the pre-Islamic occupation of the site, they were likely used together and gained value from association with each other. The use of Islamo-Sassanian sherds to make shell beads from local raw materials further indicates, we argue, the incorporation of imported materials in unique ways that helped to make local objects, such as beads worn on the body or in the hair.

6. Conclusion

This chapter examined the results of the analysis by LA-ICP-MS of a sample of excavated glass beads from the Swahili urban site of Unguja Ukuu in Zanzibar, Tanzania. Excavations revealed the extensive use of glass beads throughout the occupation sequence at the site, but especially in the later first millennium CE. Chemical tests indicate that the glass of most bead from Unguja Ukuu was made in South Asia. Such trade is evident at the site across different occupation sequences. Furthermore, the trade in, modification of, and use of glass beads at the site should be placed in a larger context of the assemblage recovered at the sites during this and previous excavations. Beads were not the only objects of glass that were imported to Unguja Ukuu and other East African sites. For instance, thin glass vessels, that are currently under study, were imported from the Middle East as well. These observations reveal that imported glass beads likely were prestige goods of not insignificant value that linked early Swahili sites to far-flung networks in the Indian Ocean World. While oceanic trade networks continued to operate and transcend local changes, an understanding of imported glass beads requires taking into consideration human expressions that impacted economies of scale and on-site practices. This paper primarily helps to reconstruct networks of glass bead origin and exchange – itineraries of beads – but also begins to raise

heretofore obscured questions about the relationships among (local and foreign) beads and other artifacts in an assemblage and their potential uses in this context.

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Chapter 15

Chemical analysis of precolonial Indian Ocean glass beads found in the southern African interior: linking global objects to local and regional change

Carla Klehm[1] and Laure Dussubieux[2]

1. Introduction

During the first millennium CE, trade in gold and ivory linked developing trade centers in sub-Saharan Africa to a vast Indian Ocean exchange network spanning a diverse array of markets in Africa, the Middle East, India, China, and Southeast Asia (Beaujard 2019; Mitchell 2005). This Indian Ocean trade supported the flow of exotic goods such as glass beads and ideas to eastern and southern Africa (Mitchell 2005; Wood 2015). The dispersal of Indian Ocean glass beads has helped archaeologists reconstruct over 1500 years of trade links across multiple continents.

These beads play a particularly important role for including places where written documents of this trade do not exist nor cover. For example, glass beads from the 7th century CE onwards provide material proof of linkages from the Middle East and India to areas a thousand miles into the southern African interior. The application of laser ablation – inductively coupled plasma – mass spectrometry (LA-ICP-MS) for the determination of the elemental compositions of Indian Ocean glass beads has been highly successful in tracing these connections, as Africans engage in this global economy through trade in exotic animal skins, ivory, gold, and other products (e.g., Denbow et al. 2015; Dussubieux et al. 2008; Walz and Dussubieux 2016, this volume; Wood et al. 2012).

However, the far reaches of the Indian Ocean trade network such as the African interior has been far less studied compared to the coastal regions, and often not incorporated into discussions about this proto-global economic system, let alone as a case study where global objects interact with, and impact, local and regional scales.

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This chapter will discuss Indian Ocean glass beads found in east-central Botswana (southern Africa): their chemical composition, the relationship to known typologies, and how these bead types relate to the sociopolitical and economic changes taking place in the southern African interior from approximately the 7th-17th centuries CE.

2. Background

The meeting of Indian Ocean air with the landmasses of south Asia, southern Arabia, and eastern Africa brings monsoon seasons that reverse the wind and currents in the winter and summer seasons. This reversal has allowed for travelers and traders for 2400 years to sail back and forth between India and Southeast Asia every six months, and from India to the east coast of Africa in a matter of weeks, in what is now known as the Indian Ocean trade network (Beaujard 2019; Wood 2012). Maritime trade routes also included points further south such as the southern African port towns of Sofala and Chibuene in Mozambique (Sinclair et al. 2012; Wood 2015; Wood et al. 2012).

Early indicators of Indian Ocean trade come in the form of glass beads from the Middle East and India beginning in the seventh and eighth centuries CE at the site of Chibuene, Mozambique (Sinclair et al. 2012; Wood et al. 2012) and throughout the southern African Interior (Robertshaw et al. 2003, 2006, 2010; Wood 2011, 2015). These trade routes appear distinct from those involved in the East African coast until the late 15th-17th centuries CE, deduced partly from the distinct types of trade beads found in the East Coast and southern African regions (Wood 2015). Trade goods from southern Africa included ivory, gold, rhinoceros horn, skins, iron, and potentially enslaved people (Huffman 2007). Copper and tin were also utilized to create copper and bronze beads and jewelry objects (Huffman 2007:85-89). Expanding Indian Ocean trade across southern Africa by the tenth and eleventh centuries CE coincided with the establishment of kingdoms, states, and class-based hierarchies throughout the region (Huffman 2007). Portuguese involvement beginning in the early 16th centuries CE altered trade networks and irrevocably changed the nature of Indian Ocean trade (Wood 2012).

Botswana sits on a large plateau that spans the interior of southern Africa and contains the sand-filled depression known as the Central Kalahari basin. To the north of the Kalahari lies the Okavango Delta, the world's largest freshwater inland delta, host to a tremendous variety of wildlife, such as antelope, hippopotamus, and elephants, the latter two important for trade in ivory. To the east and south are better-watered, hardveld lands well-suited for agriculture and livestock herding, with basement schist rich in gold and copper. Also, east of the

Kalahari is the Makgadikgadi Salt Pans, one of the largest evaporate deposits in the world, long mined for its salt (Denbow et al. 2015). Seasonal flooding also draws large concentrations of game. West of the Okavango, the Tsodilo Hills, a set of quartzite inselbergs over 30 meters high, serves as a rich source of specular hematite, a culturally significant and symbolic silvery material used both in personal adornments and material artifacts for thousands of years (Robbins et al. 1998). The diversity of environments and resources in Botswana has meant these communities have been involved in regional and long-distance exchange networks since the Middle Stone Age (Nash et al. 2016).

3. Materials

Chemical analysis of 69 Indian Ocean glass beads from Botswana are included in the Results section, below. These beads originate from five Iron Age archaeology sites in Botswana, southern Africa (Figure 15.1). All five sites used the same size mesh (2-3mm), which allowed for consistent recovery of glass beads among them.

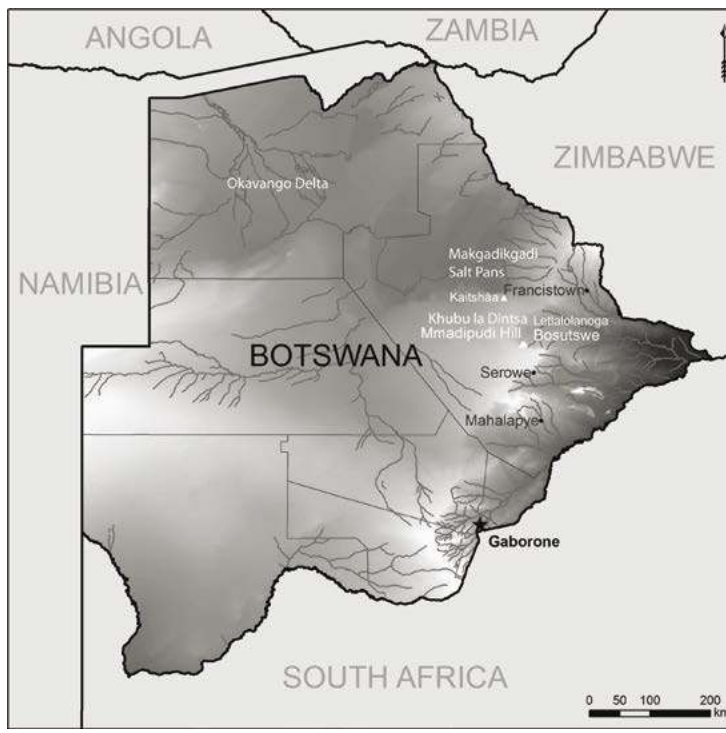

Fig. 15.1: Location of archaeological sites in Botswana mentioned in text. Adapted from Klehm and Ernenwein 2016 (original image by E. Ernenwein).

Four of these sites—Khubu la Dintša, Mmadipudi Hill, Queen's Ground Site, and Letlalolanoga—cluster around, and are intimately related to the polity of Bosutswe, briefly discussed below. The final site, Kaitshàa, located 90 km to the north of Bosutswe, overlaps with the occupation of Bosutswe and would have been one of its regional trade partners.

Bosutswe, a 3 ha hilltop polity located at the eastern edge of the Kalahari in east-central Botswana, was occupied from CE 700-1700 (Denbow 1999; Denbow et al. 2008; Denbow and Miller 2007). During this period, it served as a major regional and long-distance trade center. Evidence such as Indian Ocean glass beads and non-local ceramics from locations further north, east, and south suggest strong trade linkages across thousands of kilometers (Denbow 1999; Robertshaw et al. 2010; Wilmsen et al. 2009). Hundreds of glass beads and thousands of ostrich eggshell beads attest to a productive local economy and exchange supported by cattle herding, subsistence farming, and iron and bronze manufacture. Raw materials such as specular hematite, wild game, and salt that came from the Okavango, Tsodilo Hills, and Makgadikgadi, were brought to Bosutswe, exchanged for food and other non-local items such as glass beads and metal jewelry. Bosutswe's prominence as a powerful regional polity peaks between CE 1200-1450. The increased accumulation of goods such as glass beads with other status indicators such as metals (especially copper, bronze, and gold) and cattle consumption corresponds to the development of an elite faction of peoples, known as Lose (Denbow and Miller 2007). Lose distinguish themselves from other people at the site through different architectural styles and their exclusive use of decorated Lose ceramics, a mimic of the motifs of their gold-producing ally, Mapungubwe, which lies 350 km to the east. Although Bosutswe was the central polity, it is important to note Bosutswe was surrounded by dozens of supporting smaller hilltop and non-hilltop sites that were likely crucial to its ability to survive and thrive for a thousand years (Klehm 2017; Klehm et al. 2019).

3.1. Khubu la Dintša

Khubu la Dintša is a small (0.95 ha) hilltop site located 15 km northwest of Bosutswe. It was excavated in 2010 and 2011 by the author (CK) (Klehm 2013, 2017). Dating from ca. CE 1220-1450, Khubu la Dintša falls into the later portion of Bosutswe's occupation: significantly, in the "Lose Period" when Bosutswe was at its apex of material wealth and political influence in the region. Artifacts and features were consistent with a small agropastoral occupation: ceramic sherds, wild and domesticated fauna, silcrete and quartzite lithics and metal tools, and the foundations of grain bins where sorghum and millet would have been stored. Items of personal adornments such as ostrich eggshell beads, cowry shell beads, copper,

iron, and bronze beads, and Indian Ocean glass beads relate to how social identities were expressed. Two hundred and twenty-nine glass beads were recovered during excavation, 22 of which underwent chemical analysis in 2012 (results published in Klehm 2013).

3.2. Mmadipudi Hill

Mmadipudi Hill is located 3 km west of Bosutswe, on another visibly prominent large hilltop approximately 3 ha in size. Mmadipudi Hill underwent test excavations in both 2011 and 2014 (by CK), for a total of 8 sq meters of excavation, with cultural materials to a depth 1.5 meters below datum (Klehm and Ernenwein 2016). The population at Mmadipudi Hill slightly precedes the settlement of Bosutswe (ca. CE 550) but is abandoned sooner (ca. CE 1200). Thirty-two glass beads have been recovered, 20 of which underwent chemical analysis in 2012, 2015, and 2018 (some results published in Klehm 2013; Klehm and Ernenwein 2016).

3.3. Queen's Ground Site

Queen's Ground Site is located 1.5 km southeast of Bosutswe, among the seasonal streams that would have supported good grazing. The site stretches over about 2 ha of surface scatter and eroded materials and is defined by a partial ring of vitrified animal dung: a remnant of the large (30 m + diameter) animal kraal where cattle, goat, and/or sheep would have been kept. Three 1 sq meter test units were excavated in 2017 (by CK). In addition to the ceramic sherds and lithic debris, a human burial was found accompanied by a utilized stone with long, u-shaped grooves suggesting shell bead manufacture. One glass bead was recovered and underwent chemical analysis in 2018.

3.4. Letlalolanoga

Letlalolanoga is a small (0.75 ha) agricultural site located along one of two streams that frame an alluvial plain north and northwest of Bosutswe and is 3 km NE of Bosutswe (Klehm et al. 2019). Four square meters of test excavations dated the site to the 13th and 14th centuries CE: the Lose period once again. The relatively shallow (25 cm) cultural deposit attests to both the ephemeral nature of the site and significant deflation and erosion. Two glass beads were found, and both underwent chemical analysis in 2018 (published in Klehm et al. 2019).

3.5. Kaitshàa

Kaitshàa is located 90 km north of Bosutswe, on an escarpment that runs along the southern border of Sua Pan, the largest of the three Makgadikgadi Salt Pans. The community at Kaitshàa harvested salt and ivory for trade beginning as early

as the late 7th century CE (Denbow et al. 2015). Two hundred and twenty-five glass beads were recovered, 24 of which underwent chemical analysis in 2012 (published in Denbow et al. 2015)

4. Results

In total, 69 glass beads were analyzed using LA-ICP-MS in 2012, 2015, and 2018 at the Elemental Analysis Facility, Field Museum in Chicago (see Annex A for instrumentation and protocol of analysis). The results from chemical analysis of glass beads from Khubu la Dintša, Mmadipudi Hill, Queen's Ground Site, Letlalolanoga, and Kaitshàa are summarized below. The full description and compositional tables of the Botswana bead analysis and a representative photo can be found in Tables S15.1 and S15.2 and in Figure S15.1.

The Botswana glass beads are made of soda-rich glass that can be further divided into three groups based on their magnesia and alumina concentrations (Figure 15.2):

— 41 beads have magnesia concentrations higher than 1.5% and alumina concentrations lower than ~5%.
— 24 beads have magnesia concentrations higher than 1.5% and alumina concentrations higher than ~5%.
— 4 beads have lower magnesia concentrations (< 1.5%) and alumina concentrations higher than 6%.

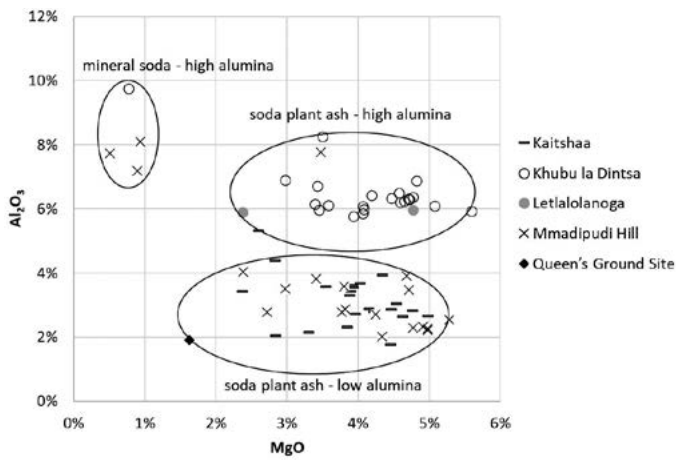

Fig. 15.2: MgO vs Al_2O_3 for the 69 beads from Botswana that are part of this study.

4.1. Soda plant ash with low alumina composition

The 41 soda glass beads with low magnesia and alumina concentrations split into two groups and will be described in more detail below: one large group of 40 objects originates in the Middle-East while the second group with only one bead corresponds to a European production.

Forty soda-rich beads have relatively low alumina concentrations (<4.4%), with an average lime concentration of 6.2%. The concentrations of potash and magnesia in these glass samples are higher than 1.5%, which indicate that they were manufactured using halophytic plant ash that was used in ancient times as a soda-rich flux. Glass manufactured with such ingredients is called v-Na-Ca (vegetable soda, or plant-ash - lime) glass. The majority of beads from Mmadipudi Hill (n=16) and Kaitshàa (24) are v-Na-Ca glass beads.

The v-Na-Ca glass tradition that originated in Mesopotamia during the Late Bronze Age continued with the Sasanian glassmakers from the 3rd-7th centuries CE (Mirti et al. 2008, 2009). If the Arab invasion of the 7th century CE caused the fall of the Sasanian Empire, the expansion of the Muslim world served as a vector of diffusion for the v-Na-Ca glass that became the dominant glass type after the 8th century CE through the Middle-East and the Mediterranean region (Phelps 2018; Schibille 2019).

At the site of Chibuene in Mozambique, three different soda plant ash (v-Na-Ca) glasses were recognized (Wood et al. 2012):

— V-Na-Ca 1: it is the most abundant v-Na-Ca glass type and was found similar in composition to Middle Eastern glass such as the one found at the site of Nishapur, northeastern Iran. At Chibuene, it was associated with the 8th to 10th century CE period. The Zhizo series beads are manufactured from v-Na-Ca 1 glass.

— V-Na-Ca 2: this glass type has a significantly high amount of chromium correlated with the presence of nickel. It was found in samples in the forms of glass sherds or wastes. At Chibuene, it was associated with the 8th to 10th century CE period.

— V-Na-Ca 3: this glass usually in the form of bluish or greenish drawn glass bead contains higher trace elements such as Rb, Ce, Cs, Ba, La and U. It was associated at Chibuene with the earliest context possibly ranging from the 7th to the 9th century CE and is therefore known as the Chibuene series.

Using magnesium, phosphorus, calcium, chromium, rubidium and lanthanum concentrations to conduct principal component analysis, comparison among the 40 v-Na-Ca beads from Botswana and the Chibuene v-Na-Ca glasses shows that the majority of the beads belong to glass type v-Na-Ca 1 while five beads belong to glass group v-Na-Ca 3 (MH006, MH013, KC4181, KC183, KC4093) (Figure 15.3).

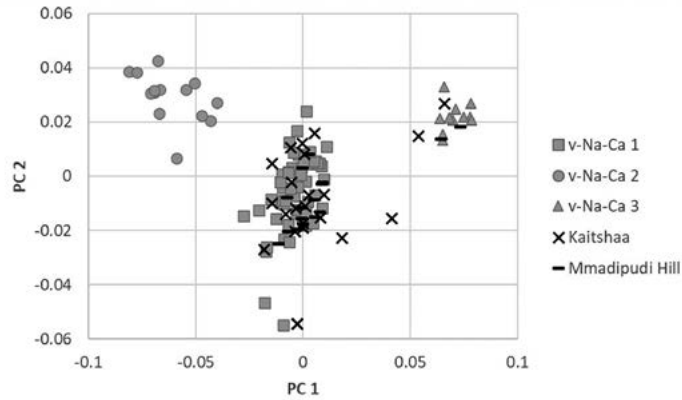

Fig. 15.3: Scatter plot representing PC1 and PC2 calculated using the concentrations for MgO, P_2O_5, CaO, Cr, Rb and La for the Botswana v-Na-Ca beads and different types of v-Na-Ca glass types found at Chibuene.

In the v-Na-Ca 1 glass group, 13 beads from Kaitshàa and 11 beads from Mmadipudi Hill contain significant concentrations of cobalt (124 to 621 ppm), which would have been added to color the beads a blue or dark blue color. The cobalt is associated with high concentrations of zinc in these glasses. Other colors also existed in these earlier beads: MH011, for example, does not contain any significant quantities of cobalt, but instead contains higher concentrations of lead (4.6%) and tin (0.5%) suggesting that an opacifier such as lead stannate was used to color the bead in yellow.

One glass bead, from Queen's Ground Site, is also manufactured from plant ash but with a low alumina sand, seen as the outlier in Figure 15.2. The bead contains ~5% of antimony (as Sb_2O_3), which was used as an opacifier or a discolorant at different periods but that would have been very unusual for a v-Na-Ca glass from the Middle East. The recipe and the presence of antimony seems compatible with European glass bead production that used antimony to opacify beads from the mid-17th centuries to the mid-19th centuries CE (Sempowski et al. 2000), although European beads are found in southern Africa as early as the 16th century CE (Koleini et al. 2020).

4.2. Soda plant ash with high alumina composition

Twenty four beads belong to another subtype of plant ash beads and contain high alumina concentrations and an average lime concentration of 6.9% This glass type is called vegetable soda - high alumina or v-Na-Al glass. Almost all the beads from Khubu la Dintša (N=19/20), all the beads (N=2) from Letlalolanoga,

and a few (N=4) from Mmadipudi Hill are made from v-Na-Al glass. Although widespread, the provenance of this glass type is uncertain although we proposed in the past an origin from Central Asia (Carter et al. 2019; Then-Obłuska and Dussubieux 2016). New research seems to point in the same direction (Siu et al. 2020). This type of glass was described by Robertshaw et al. (2010) in Southern Africa and two sub-groups were identified. These two sub-types correspond to the Mapungubwe Oblate (ca. 1240-1300 CE) and the Zimbabwe (ca. 1300-1430 CE) bead series. The v-Na-Al beads have all compositions similar to that of the Mapungubwe Oblate beads (Figure 15.4). However, K73-1 and K71-3, two beads from Khubu la Dintša, are red which is a color that is absent from the MO bead series, which makes us question the glass attribution for these two beads.

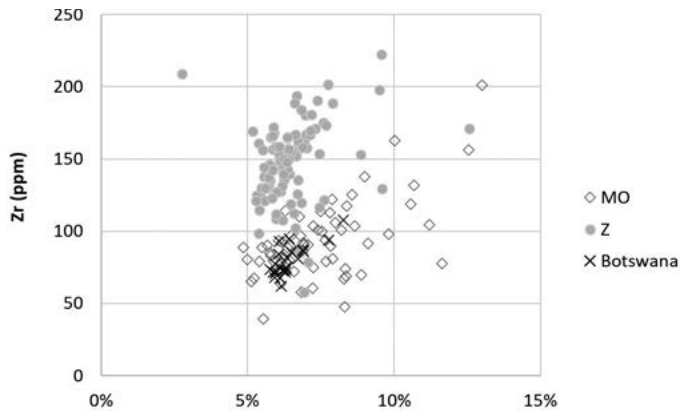

Fig. 15.4: Bi-plot for the Al_2O_3 and Zr concentrations of MO and Z bead series (Robertshaw et al. 2010) and of the v-Na-Al glass beads from Manda.

4.3. Mineral soda with high alumina composition

The four beads with mineral soda and high alumina also have high trace elements. They represent mineral soda high alumina or m-Na-Al glass. This glass, manufactured from a natural mix of an immature granite sand and soda rich efflorescence, was produced in South Asia (see Annex B for more details). Five different sub-groups were identified based on the concentrations of the following constituents: MgO, CaO, Sr, Zr, Cs, Ba and U (Dussubieux et al. 2008; Dussubieux et al. 2010; Dussubieux and Wood 2021). Additional sub-groups identified at the medieval site of Indor (Rajasthan) were recently recognized by Trivedi and Dussubieux (this volume; in preparation).

Based on the seven constituents listed above, a comparison of the m-Na-Al compositions from Botswana with the composition of the 5 initial sub-groups was conducted with principal component analysis (PCA). Figure 15.5 shows that 3 of the samples from Botswana fall within the m-Na-Al 6 glass group.

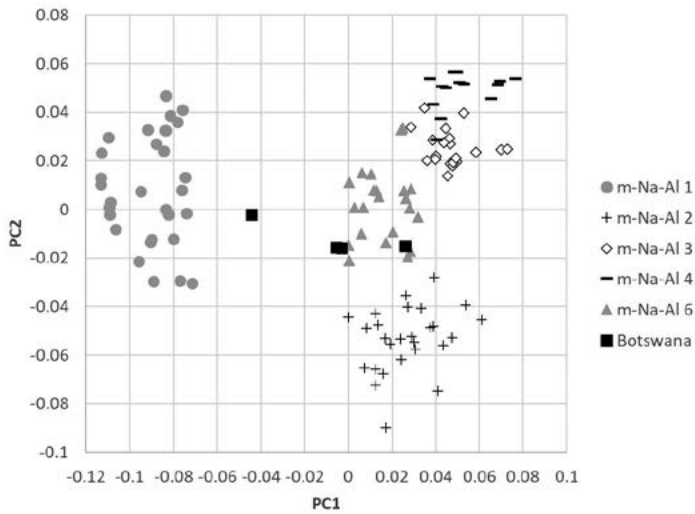

Fig. 15.5: Biplot representing PC1 and PC2 obtained using the concentrations of MgO, CaO, Sr, Zr, Cs, Ba and U from samples belonging to glass groups m-Na-Al 1 (unpublished), m-Na-Al 2 (Dussubieux et al. 2008), m-Na-Al 3 (Dussubieux and Kanungo 2013), m-Na-Al 4 (Dussubieux 2009) and m-Na-Al 6 (Dussubieux and Wood 2021) and Botswana.

Three beads (MH007, MH008, K64-2) fall into the m-Na-Al 6 glass group. Sample M75-1 has an intermediate position between the m-Na-Al 1 and 6 group. Its uranium concentration (11 ppm) is characteristic of the m-Na-Al glass type but strontium and barium are lower in M75-1 than what is usually found in this glass. It could belong to one of the new glass groups discovered recently by Trivedi and Dussubieux (this volume; in preparation) at the site of Indor in contexts dating from the 14th century CE onward.

The m-Na-Al 6 glass has been recently identified among glass beads excavated on the east coast of Africa. It is present at sites dating from the 9th to the 13th century CE (Dussubieux and Wood 2021). The place of production for this glass is very uncertain at this point. Recent Sr isotope analysis conducted on m-Na-Al 6 glass samples revealed a fairly radiogenic signature compatible with an origin from the Indo-Ganges region (Seman et al. 2021) where this glass might have been produced.

5. Discussion and conclusion

In summary, the analytical results obtained from 69 glass beads from Botswana offer a chronology that stretches from the 7th to the 19th century CE, as recapitulated in Table 15.1. The earliest beads, the Chibuene beads, found at Mmadipudi Hill and Kaitshàa represent a small quantity of beads (5 in total). Higher densities of beads are visible for the 8th to 10th century CE period, with a high proportion of Zhizo beads at two sites (Mmadipudi Hill and Kaitshàa) and later for the 13th to 14th CE period with an important quantity of Mapungwabe Oblate beads at the site of Letlalolanoga. The m-Na-Al 6 beads that are dated from an intermediary period (9th to 13th century CE) are fairly rare with only 4 specimens identified. Only one bead, found at the Queen's Ground site, was identified as European. The beads in the Bosutswe region follow the trajectory of Indian Ocean trade in Africa and beyond through European contact.

Series	Glass Type	Date Range	Appearance	Sites and abundance
Chibuene	Soda plant ash - lime v-Na-Ca 3	7th to 9th centuries CE	Drawn, slightly rounded edges Smooth, translucent, "satiny" glass Small (2.5-3.5mm), short-to-standard length Grey or pale hues of blue, yellow, blue-green, or green Tubular or cylindrical	MH, 2 KAI, 3
Zhizo	Soda Plant ash - lime v-Na-Ca 1	8th to mid-10th centuries CE	Cut, drawn Primarily blue, but also yellow, blue-green, and green Translucent (sometimes blues almost transparent), but found with whitish, opaque patina due to corrosion.	MH, 14 KAI, 21
K2 Indo-Pacific, East Coast Indo-Pacific	Mineral soda - high alumina m-Na-Al 6	Mid-10th to early 13th centuries CE	Drawn, but smaller (2-3.5mm diameter, 1.2-4mm long) Tubular with rounded edges Translucent to transparent Shiny, durable (no Zhizo-like patina) Blue-green and green (K2); brownish-red, green, yellow, and black (EC)	MH, 3 KLD, 1
Mapungubwe Oblate	High alumina soda - plant ash v-Na-Al MO	Early 13th to early 14th century CE	Drawn, heat-rounded beads Uniform in size (2-3.5mm) and shape Primarily oblate Often black, as well as blue-green, green, yellow, bright orange	MH, 1 LET, 2 KLD, 21
European	Soda plant ash	17th – 19th c AD, but perhaps as early as the 16th c CE	Many shapes and colors, see Koleini et al. 2020	QGS, 1

Table 15.1: Recapitulation table for the group attribution of the Botswana beads in this study.

The presence of Chibuene beads at the sites of Mmadipudi Hill and Kaitshàa complement other evidence at other Botswana sites such as Nqoma in the Tsodilo Hills and Thabadimasego in the Makgadikgadi Pans (e.g., Daggett et al. 2012; Wilmsen and Denbow 2010) of early signs of Indian Ocean trade in the Interior (see also Robertshaw et al. 2010). Direct trade between the Persian Gulf and southern Africa continued amongst African partners for nearly 1000 km — the distance of these sites from the Mozambiquean coast (Wood 2015). Thus, it is clear that Indian Ocean trade corridors are extensive from early on. The trade mapped onto long-standing exchange networks that had extended across the African interior for hundreds of years prior, rather than a purely "externally" influenced opportunity (Denbow et al. 2008; Wilmsen et al. 2009). The Chibuene corridor likely ran from the coast inland across the Zimbabwe plateau to the Makgadikgadi Pans before reaching the Boteti River, which would have provided a link across the Kalahari to sites in the Okavango Delta and Tsodilo Hills. Products such as specularite, salt, and ivory appear to underpin early trade products from Botswana: the location of Kaitshàa, like Thabadimasego, strongly suggests they were engaged in salt production.

As the regional economy continued to strengthen and expand, African interior communities began to coalesce into large, sedentary agropastoral polities. By 1000 CE, these are seen in hilltop polities such as Bosutswe and Zhizo (after which the bead series is named; see Wood et al. 2012) in east-central Botswana, as well as K2 in the nearby Shashe-Limpopo river confluence area of South Africa (approximately 350 km from Bosutswe). Long-distance trade corridors shift further south, centering on the Bosutswe and Shashe-Limpopo regions (Wilmsen et al. 2009). The desire for products such as ivory from places such as Kaitshàa remains important in these regional trade networks, however, and the relatively few Zhizo beads found at Kaitshàa are in association with ivory fragments that are not found during earlier periods (Denbow et al. 2015). The corresponding abundance of Zhizo beads at Mmadipudi Hill, as at Bosutswe (see Robertshaw et al. 2010), attests to the growing importance of this area around the first millennium CE.

The 13th-mid-15th centuries CE in the Bosutswe region represent the apex of Bosutswe's power and influence in local and long-distance trade networks (Denbow and Miller 2007). Indo-Pacific and Mapungubwe Oblate series beads are found in significant quantities, not just at Bosutswe (Robertshaw et al. 2010) but at the sites of Mmadipudi Hill (m-Na-Al glass beads), Khubu la Dintša (m-Na-Al and v-Na-Al glass beads), and Letlalolanoga. Letlalolanoga's location in the alluvial plain northeast of Bosutswe suggests an increase in agricultural activities at this time: it is proximal to seasonal streams, and in soil that is advantageous

for dryland cultivation of the sorghum, millet, and cowpeas that would have been grown. The population in and around Bosutswe was expanding, due in part to increased economic activity; in parallel, there would have been a rise in environmental stress on the local environment (e.g., decreasing soil productivity, increasing scrubland due to heavy grazing of cattle, decreasing numbers of wild game; see Atwood 2014; Klehm 2017), further so considering that the adjoining land had been used, with increasing intensity, for over half a millennium by this period of time. The two v-Na-Al glass beads from Letlalolanoga likely reflect the needs of a growing population, as a supporting agricultural homestead tending to croplands in the nearby alluvial plain (Klehm et al. 2019). Satellite communities may have buffered Bosutswe from the environmental impacts of population aggregation, economic intensification, and rainfall variability by providing access to subsistence goods, other natural resources such as good grazing lands and water, and even trade items across a broader area.

As with Letlalolanoga, Mmadipudi Hill is important because Bosutswe did not emerge and operate in isolation: surrounding smaller hilltops and non-hilltop sites contributed significantly to the growth and maintenance (Klehm and Ernenwein 2016). These were communities responsible for growing crops, mining raw materials for stone tools, smelting iron and other metals; they were herding outposts, or possibly even temporary camps for traders and hunter-gatherers traveling to the Bosutswe region, who would have brought salt, animal skins, specular hematite, ivory, rhino horns, and ostrich feathers (Denbow 1999; Wilmsen 1989:74). At Mmadipudi Hill in particular, the high concentration of lithic elements including debris, cores, flakes, and tools, versus concentrations at Bosutswe and Khubu la Dintsa, suggests there may have been more specialized activity taking place at the site (Klehm 2013:153-168; Klehm and Ernenwein 2016:54). Rather than complying with the general narrative of metal tools replacing those of stone as technology progresses, these lithics are found in abundance after the Taukome to Toutswe transition (approximately 1000 CE), further suggesting they are an intentional product for local consumption that continues to have demand as the economy in the Bosutswe region steadily increases (Klehm and Ernenwein 2016: 54). Eventually, however, the growing importance of Bosutswe may have been influential in the abandonment of Mmadipudi Hill, as shortly after the m-Na-Al 6 (Indo-Pacific series) beads the site is no longer occupied: there are no Mapungubwe Oblate beads or any other cultural materials at Mmadipudi Hill after the 12th century CE (Klehm unpublished data; Klehm and Ernenwein 2016:56-57).

This is also the period—known as the Lose Period—during which status differentiation emerges throughout the region: notably at Mapungubwe, but also at Bosutswe. At Bosutswe, elites are distinguished from other residents through high status items such as glass beads and metal jewelry, as well as cattle ownership and consumption: the majority of the glass beads from Bosutswe are found in the Lose elite areas of the site (Denbow and Miller 2007). Yet, excavations at Khubu la Dintša recovered 229 glass beads in greater concentrations than any of the Lose elite households at Bosutswe (Klehm 2017:615-617). These Khubu la Dintša glass beads, as well as Lose ceramics also found at the site, suggest that Khubu la Dintša played an important, intimate role in Bosutswe's success. Bosutswe dealt with issues such as water sources, arable land, vegetation suitable for grazing, and pests and disease that likely would have increased through its long-term occupation and increasing wealth. The surrounding population such as at Khubu la Dintša would have been integrally involved, either benefitting socially and economically from inclusionary network strategies or by providing the necessary protection for Bosutswe to thrive. The resulting family, clan, and kinship obligations that came with increasing network size and the status goods involved impacted the degree of stratification in the region (Klehm 2014, 2017). As status was gained through differential access to social networks on the Kalahari frontier, coalescing power may have been a precarious venture, but one that also led to the durability of a polity for over a thousand years.

Finally, although the occupation of Queen's Ground Site dates to the Zhizo period (Klehm, unpublished data), the European glass bead relates to dwindling Indian Ocean trade in the following centuries. After Bosutswe's allied polity, Mapungubwe (South Africa) collapsed at the end of the 13th century CE and was replaced by Great Zimbabwe (and later the Butua state); the influence of Bosutswe begins to fade and trade routes shift further north once again to accommodate these new regional powers (Denbow et al. 2008). Interestingly, the Khubu la Dintša v-Na-Al bead collection appears to primarily be comprised of Mapungubwe Oblate beads, rather than Zimbabwe series beads, even though the site dates to the latter. This suggests that there may be recirculation of beads in the African interior, or alternatively a different trade route existed in Botswana that circumvented Great Zimbabwe's hegemony. In the coming centuries, Europeans traded with Khami (the capital of Butua) and Sotho-Tswana communities throughout the region, during a time marked not just by the end of Indian Ocean trade, but also the beginning of a period of violence and disarray in southern Africa, the *Difaqane* (Tlou and Campbell 1997). Although life would have been difficult in Botswana, the same resources that had drawn people to it for thousands of years continued to provide for those living there.

Botswana is a region that is generally underappreciated for its importance in precolonial global networks. The comparative lack of archaeology here versus coastal regions of Africa (e.g., the East African Swahili Coast) or other better-known sites in South Africa and Zimbabwe tend to lead to overlooking the importance of interior connections (see also Walz 2017, 2018; Walz and Dussubieux 2016 for similar examples from the East African interior). This is further hindered by the lack of written documents of the African interior's involvement. However, glass beads are part of a growing set of material culture with good sourcing (e.g., ceramics, Wilmsen et al. 2009, 2019) that demonstrates how deep and extensive these trade networks truly were, and how deeply these political and economic transformations impacted the lives of those involved.

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Chapter 16

Morphology and elemental composition: provenancing glass beads from 12th – 13th century Mayotte

Marilee Wood,[1] Laure Dussubieux,[2] Mudit Trivedi[3] and Martial Pauly[4]

1. Introduction

This chapter examines glass beads that were excavated from an archaeological site, known as Antsiraka Boira, on the island of Mayotte (Maore in English), the most southeasterly of the four main islands in the Comoros Archipelago, which lie east of the north end of Madagascar at the north entrance to the Mozambique Channel (Figure 16.1). The site, which dates from about 1100 to 1250 CE (Pauly 2013, 2018), lies near the town of Acoua in the north-west part of the island of Grand Terre and comprises a graveyard that contains 69 burials. An area of 150 m^2, which included 29 interments, was excavated by Martial Pauly in 2012 and 2017. Over 20,000 glass beads were recovered from two thirds of those graves and 64 samples were chosen for chemical analysis using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) at the Elemental Analysis Facility (EAF) (Field Museum, Chicago) by Laure Dussubieux in 2015 and 2016. The objective was to use glass composition to help determine the region where the glass was manufactured. In addition, morphological examination was employed to suggest where the beads were created since glassmaking and beadmaking might have been separate professions and glass was widely traded in antiquity. Knowledge of the source of both the glass and the beads can be useful in reconstructing trade patterns, in this case in the Indian Ocean.

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[2] Field Museum, Chicago, USA
[3] Stanford University, USA
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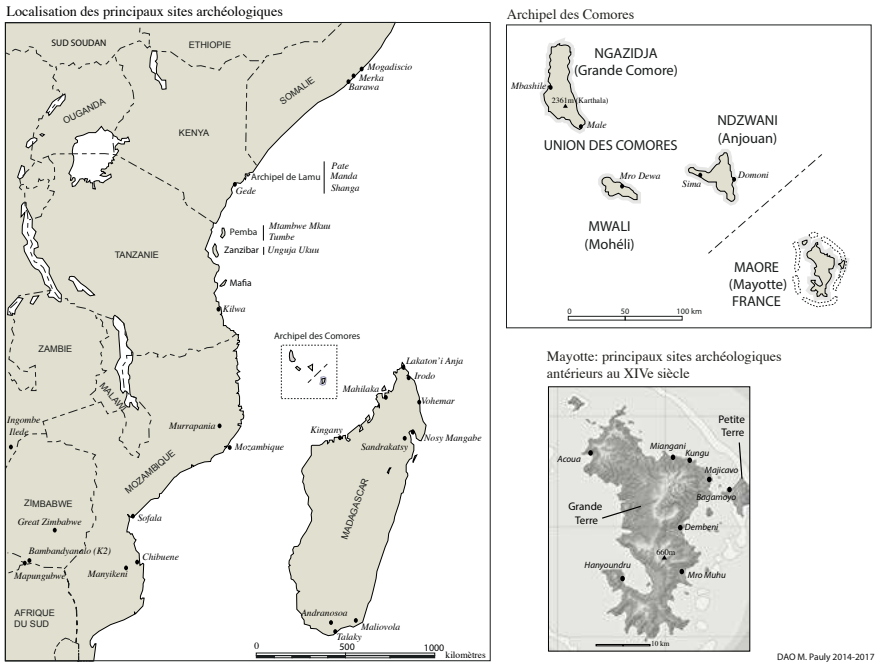

Fig. 16.1: Map of key archaeological sites in eastern Africa; the Comoros Archipelago and Mayotte (by M. Pauly).

2. Background

The inhabitants of the Comoro Islands are related to Swahilis, most of them using a language related to the Bantu family and practicing Islam in its Sunni denomination. However, the inhabitants of Acoua, as well as some other areas on Mayotte, speak a Malagasy dialect and have historical and cultural links with Islamized communities living in the north of Madagascar.

During this period, when Islam had been accepted in much of the Swahili corridor (i.e., coastal regions of Africa's east coast stretching from northern Kenya to southern Mozambique), Muslim burial norms as practiced in the Western Indian Ocean usually contained little funerary furniture. Therefore, the presence of provisions and burial ornaments in the graves document a phase of cultural syncretism that accompanied the beginnings of the Islamization of this society (Pauly and Ferrandis 2018).

The presence of such burial adornments is quite exceptional, although a second necropolis, Mtsanga Miangani (11th to 13th century), also located in the north of Grande Terre (see Figure 16.1) exhibits similar characteristics, including the presence of glass beads (Ferrandis 2018). The arrangement of beads on the skeletons makes it possible to restore their function, at least for this population: long necklaces were worn only by women and children while accumulations of beads found in the pelvic region of many skeletons of both sexes and all ages probably represent loincloths adorned with beads.

3. Materials

Of the 23,519 beads from the excavations, most came from the excavated burials: 85.5% are made of glass, 14% of shell (*maxima tridacna* shell and land snail *Achatina*) and 0.5% of semi-precious stone (carnelian, beryl, agate) and coral. The glass beads are either drawn (93%) or wound (7%). The selection of beads for analysis was not random but attempted to include all types and colors found at Antsiraka Boira. In total 65 analyses were performed at the EAF (see Annex A) from 64 beads (one bead is bicolored and both colors were tested). One analyzed bead is not glass. It is a black bicone that is likely made of jet; this type of bead was popular in (and probably made in) Iran (Francis 1989). In addition to our LA-ICP-MS analysis of beads from this site, another study using X-Ray fluorescence and Raman spectroscopy was completed by Fischbach et al. in 2016. This technique is especially useful in identifying glass colorants.

4. Results

Three main groups of glass were identified: plant ash soda-lime (v-Na-Ca), plant ash soda-elevated alumina (v-Na-Al) and mineral soda-elevated alumina (m-Na-Al) (see Table S16.1 for the elemental compositions of the Antsiraka Boira beads and Annex B for more details about the glass groups). The first two types were represented by one or two beads each, and the remaining 60 are m-Na-Al. The significance of the presence of v-Na-Ca and v-Na-Al beads will be discussed, and the m-Na-Al beads will be separated into various groups, some of which have only recently been identified. All beads will be compared to similar ones in southern Africa, the East Coast and Madagascar in the search for trade patterns and connections between Mayotte and the other regions. For images of all analyzed beads see Figure 16.5d and for descriptions of the beads see Table 16.1.

Figure	ID	Sépulture	how made	shape	diameter	length	diaphaneity	Munsell #	Color group	Glass type/ group
5D-1	AB 001	SP 01	wound	bicone	7	6 to 7	opaque		black	m-Na-Al 6
5D-2	AB 003	SP 01	drawn	oblate	4.6	2.1	opaque	10R 4/4	brick-red	m-Na-Al 6
5D-3	AB 005	SP 01	drawn	tube	4.4	4.8	opaque	10R 4/4	brick-red	m-Na-Al 6
5D-4	AB 008	SP 02	drawn	tube	4	3.8	tsl-op	5Y 8/6	yellow	m-Na-Al 6
5D-5	AB 009	SP 02	drawn	tube	2.7	3.5	tsl-op	5Y 8/6	yellow	m-Na-Al 6
5D-6	AB 011	SP 04	drawn	cylinder	4	2.8	opaque		black	m-Na-Al 12
5D-7	AB 013	SP 04	drawn	tube	2.5	2.8	tsp	2.5B 5/6	turquoise	m-Na-Al 6
5D-8	AB 014a	SP 05	drawn	cylinder	3.2	3.1	tsl-op		white	m-Na-Al 6
5D-9	AB 014b	SP 05	drawn	cylinder	3.2	2.6	tsl-op		white	m-Na-Al 6
5D-10	AB 014c	SP 05	drawn	cylinder	3.2	2.2	tsl-op		white	m-Na-Al 6
5D-11	AB 016	SP 05	drawn	tube	4	5.2	opaque		black	m-Na-Al 6
5D-12	AB 017	SP 05	Jet bead	barrel	4.4	5.2	opaque		black	stone
5D-13	AB 019	SP 05	drawn	cylinder	4	3.4	tsl-op	5BG 5/4	blue-green	m-Na-Al 6
5D-14	AB 022	SP 08	drawn	barrel	4.9	6.2	tsp	5B 4/6	blue-green	m-Na-Al 6
5D-15	AB 024	SP 08	drawn	cylinder	2.8	2.3	tsp-tsl		colorless	m-Na-Al 11
5D-16	AB 025	SP 08	drawn	tube	2.4	3.2	tsp-tsl		colorless	m-Na-Al 11
5D-17	AB 028	SP 09	drawn	cylinder	3.5	2.3	tsl	10G 6/4	green	m-Na-Al 6
5D-18	AB 029	SP 10	wound	cylinder	6.3	5.8	opaque		black	m-Na-Al 7
5D-19	AB 030	SP 10	drawn	cylinder	3.1	2.1	tsl	2.5B 5/6	turquoise	m-Na-Al 6
5D-20	AB 031	SP 10	drawn	cylinder	3.3	2.1	tsl-op	5GY 6/4	green	m-Na-Al 6
5D-21	AB 032	SP 10	drawn	oblate	2.6	2	tsp	2.5Y 7/6	amber	m-Na-Al 6
5D-22	AB 033a	SP 10	drawn	tube	2.2	1.7	op-tsl	5Y 8/6	yellow	m-Na-Al 2
5D-23	AB 033b	SP 10	drawn	tube	2.2	2.4	op-tsl	5Y 8/6	yellow	m-Na-Al 2
5D-24	AB 037	SP 10	drawn	cylinder	6.5	4.6	opaque	10R 4/4	brick-red	m-Na-Al 6
5D-25	AB 038	SP 10	drawn	cylinder	4.9	4.2	opaque	10R 4/4	brick-red	m-Na-Al 6
5D-26	AB 040	SP 10	drawn	cylinder	3.1	2.6	op-tsl	10G 6/4	green	m-Na-Al 6
5D-27	AB 041	SP 15	drawn	cylinder	2.8	2.1	opaque		black	m-Na-Al 6
5D-28	AB 042	SP 15	drawn	cylinder	3.5	2.4	opaque		black	m-Na-Al 6
5D-29	AB 043	SP 15	wound	bicone	5.7	7.5	opaque		black	m-Na-Al 2
5D-30	AB 044	SP 15	drawn	tube	4.7	4.7	tsl-op	10G 6/4	green	v-Na-Ca
5D-31	AB 045a	SP 15	drawn	tube	2.3	2.3	tsp	2.5Y 7/6	amber	m-Na-Al 7
5D-32	AB 045b	SP 15	drawn	tube	2	2.5	tsp	2.5Y 7/6	amber	m-Na-Al 7
5D-33	AB 045c	SP 15	drawn	tube	2	2.4	tsp	2.5Y 7/6	amber	m-Na-Al 7
5D-34	AB 047a	SP 24	drawn	tube	2.1	2.5	tsp	2.5B 5/6	turquoise	m-Na-Al 11
5D-35	AB 047b	SP 24	drawn	tube	2.1	2.6	tsp	2.5B 5/6	turquoise	m-Na-Al 11
5D-36	AB 048	SP 30	drawn	cylinder	6.3	5.3	opaque		black	m-Na-Al 6
5D-37	AB 049	SP 30	drawn	cylinder	5.7	5.3	opaque		black	m-Na-Al 6
5D-38	AB 052a	SP 30	drawn	tube	2.4	3	tsp		colorless	m-Na-Al 9

Figure	ID	Sépulture	how made	shape	diameter	length	diaphaneity	Munsell #	Color group	Glass type/ group
5D-39	AB 052b	SP 30	drawn	tube	2.6	2.9	tsp		colorless	m-Na-Al 9
5D-40	AB 055	SP 34	wound	cylinder	7	4.3	opaque		black	m-Na-Al 6
5D-41	AB 056	SP 34	drawn	cylinder	4.1	3	tsp-tsl	2.5B 5/6	turquoise	m-Na-Al 9
5D-42	AB 057	SP 39	wound	bicone	9.4	8.5	opaque	10R 4/4	brick-red	m-Na-Al 6
5D-43	AB 058	SP 39	wound	Sub-sphere	7.2	7.5	opaque	10R 4/4	brick-red	m-Na-Al 6
5D-44	AB 060	SP 39	wound	bicone	6.5	7.7	opaque		black	m-Na-Al 6
5D-45	AB 064	SP 39	drawn	cylinder	3.9	2.9	tsp-tsl	5BG 5/4	blue-green	m-Na-Al 9
5D-46	AB 065	US 1001c-35	wound	bicone	6.7	8.7	opaque	10R 4/4	brick-red	m-Na-Al 2
5D-47	AB 066	US 1001 -23	drawn	cylinder	8.4	5.6	tsp-tsl	2.5B 5/6	turquoise	v-Na-Al
5D-48	May001	SP 18	drawn	tube	5	5.1	opaque	10R 3/6	brick-red	m-Na-Al 6
5D-49	May002	SP 18	drawn	tube	3.8	2.9	opaque	10R 3/6	brick-red	m-Na-Al 6
5D-50	May003	SP 18	drawn	cylinder	5.3	3.7	opaque	10R 3/6	brick-red	m-Na-Al 6
5D-51	May004	SP 18	drawn	oblate	5.4	3.4	tsl/tsp	2.5B 4/8	turquoise	m-Na-Al 6
5D-52	May005	SP 18	drawn	tube	5.2	4.2	tsl/tsp	2.5B 4/8	turquoise	m-Na-Al 7
5D-53	May006	SP 18	drawn	tube	2.9x5.6	4.3	tsp/tsl	2.5B 4/8	turquoise	v-Na-Ca
5D-54	May007	SP 18	wound	bicone	6.8	8.4	opaque		black	m-Na-Al 6
5D-55	May008	SP 18	wound	thick ring	6.7	5.6	opaque		black	m-Na-Al 6
5D-56	May009	SP 18	wound	thick ring	7.1	?	opaque		black	m-Na-Al 6
5D-57	May010	SP 14	drawn	tube	3.5	8.3	tsl/op	10BG 4/4	blue-green	m-Na-Al 6
5D-58	May011	SP 14	wound	lenticular	6	1.5	opaque		black	m-Na-Al 10
5D-59	May012	SP 14	drawn	tube	?	?	tsl	7.5BG 5/6	turquoise	m-Na-Al 6
5D-60	May013	SP 14	?	?	?	?	?	?	b-g & yellow	m-Na-Al 6
5D-61	May014	SP 14	?	?	?	?	?	?	b-g & yellow	m-Na-Al 6
	May016	SP 18	?	powder	?	?	?	?	yellow	m-Na-Al 6
5D-63	May017	SP 14	drawn	oblate	5.6	3.8	tsp/tsl	2.5B 4/6	turquoise	m-Na-Al 6
5D-64	May018	SP 14	drawn	?	?	?	tsp/tsl	2.5B 4/6	turquoise	m-Na-Al 6

Table 16.1: Descriptions of all analyzed Antsiraka Boira beads.

4.1. V-Na-Ca glass beads

Two beads (AB044 and May006) are made from a soda-rich glass containing low alumina concentrations. Their magnesia and potash levels are higher than 1.5% suggesting the use of a flux obtained from halophytic plant ashes. Glass of this type, v-Na-Ca, was the earliest human-made glass produced, dating back to the 16th century BCE (Brill 1970; Kemp et al. 2020; Sayre and Smith 1974). In the beginning of the 1st millennium BCE, the Mediterranean world switched to making glass fluxed with a mineral soda (m-Na-Ca), frequently called natron glass (Sayre and Smith 1961; Turner 1956). That tradition continued up to the 8th to 9th century CE before a return to fluxing glass with plant ashes (Phelps 2018; Schibille et al. 2019). However, Mesopotamia and Central Asia apparently did not switch to making glass with mineral soda but continued producing soda plant ash glass (Shortland and Rehren 2020:352).

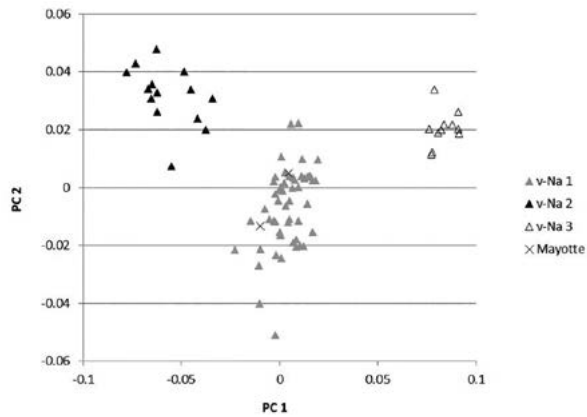

Fig. 16.2: Biplot reporting on PC 1 and 2 obtained using the magnesium, phosphorus, calcium, chromium, rubidium and lanthanum concentrations in the v-Na (equivalent to v-Na-Ca) glasses from Chibuene (Wood *et al.* 2012) and in AB044 and May006.

At the site of Chibuene, in southern Mozambique, three different v-Na-Ca glasses were recognized (Wood et al. 2012). Using magnesium, phosphorus, calcium, chromium, rubidium and lanthanum concentrations, a comparison between the two Antsiraka Boira beads and the Chibuene v-Na-Ca glasses shows that the beads from Mayotte belong to glass type v-Na-Ca 1 (Figure 16.2). It has been hypothesized that this glass was manufactured in the Iraq/Iran region (Wood et al. 2012). This glass is the type used to make Zhizo beads, which were the main bead type found in southern Africa between the 8th and mid-10th century (Robertshaw et al. 2010; Wood et al. 2012), as well as many of the beads recovered

from Unguja Ukuu, a 7th to 11th century port in Zanzibar (Wood et al. 2017 and see Sarathi, this volume), which is about 800 km north of Mayotte. Importation of beads made of this type of glass appears to have ceased in about the mid-10th century, so these two v-Na-Ca beads from graves dating to the 12th to 13th century probably represent heirlooms.

4.2. V-Na-Al glass beads

One soda-rich bead, AB066, contains potash and magnesia concentrations higher than 1.5%, suggesting the use of plant ash as the soda source but, unlike the v-Na-Ca beads, its alumina concentration is elevated (> 4%) indicating that it belongs to the v-Na-Al glass type. Such glass was ubiquitous in southern Africa between the mid-13th and mid-15th centuries. Robertshaw et al. (2010) identified two closely related versions of this glass in that region: the Mapungubwe Oblate [MO] series (circa 1240 to 1300) and the Zimbabwe [Z] series (circa 1300 to 1430). Enormous numbers of beads of both series have been found at archaeological excavations in that region and in smaller numbers at sites on the East Coast and Madagascar (Robertshaw et al. 2006). The glasses used to make these two series are similar but must have come from different locations in the same region. They can be separated both morphologically (Wood 2011) and by concentrations of certain elements, particularly P_2O_5, BaO, Zr and MgO (Robertshaw et al. 2010). The bead AB066, which came from US 1001 (a trench that is not associated with a grave), is rather large, drawn, translucent turquoise in color and the glass is filled with bubbles that result in a pitted surface. Chemically the glass fits comfortably within the MO series (Figure 16.3) but morphologically it does not since most MO beads are small, oblate and the turquoise-colored ones are opaque and softer in color than the bead from Antsiraka Boira. In addition, MO glass is largely free of bubbles or other inclusions.

Beads made of the MO subgroup glass are also found in limited numbers at several East Coast sites with occupations in the 13th and 14th centuries, including Gedi, Jumba Ruins, Manda, Mnarami and Mbaraki in Kenya (Trombetta et al. this volume), as well as at Unguja Ukuu (7th to 10th century) (Wood et al. 2017) and Songo Mnara (15th to 16th century) (Wood et al. 2022) in Tanzania. About a quarter of these East Coast beads are wound, the rest are drawn. Wound beads of this glass are extremely rare in southern Africa and are suggested to have been made there by reworking imported drawn beads (Wood 2011). Robertshaw et al. (2006) identified v-Na-Al glass beads (Z series) at the sites of Mahilaka (10th – 15th century CE) and Sandrakatsy (13th – 16th century CE) in Madagascar. They have also been identified at Ingombe Ilede (late 15th to early 17th century) and Isamu Pati (13th to 14th century) in Zambia (Robertshaw and Wood 2017).

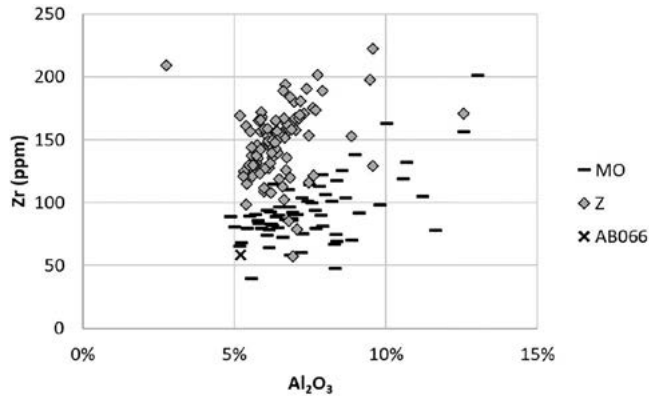

Fig. 16.3: Biplot reporting on the alumina and zirconium concentrations of samples belonging to the MO and Z series (Robertshaw et al. 2010) and of AB066.

Dussubieux and Kusimba (2012), Then-Obłuska and Dussubieux (2016) and Carter et al. (2019) have proposed that Central Asia might have been the provenance of v-Na-Al glass. Using comparisons of trace elements, Siu et al. (2020) have recently confirmed this hypothesis but the question of where the beads were made is still unknown. Various iterations of this glass cover a time span from at least the 2nd century BCE to the 16th century CE. Siu et al. (2020), who worked with beads that dated from the 9th to the 16th century CE, have identified four types. They hypothesize that the glass was shipped to India where it was made into beads but admit that no glass of this type has been found there.

4.3. M-Na-Al glass beads

The remaining 60 analyzed glass beads from Mayotte have an m-Na-Al glass composition. While m-Na-Al glasses contain soda as the most abundant constituent after silica, their distinctive feature is their high alumina content, which varies from 5 to 15%. Alumina is introduced to the glass with poorly refined sand. The sand composition is similar to that of granite and contains a small amount of potash and lime, and relatively high concentrations of iron, titanium and other trace elements, such as rare earth elements (Dussubieux 2001; Dussubieux and Gratuze 2003). Magnesia in this glass is rather low (lower than 1.5%), suggesting the use of soda from a mineral source. A mixture of carbonate, sodium sulfate and chloride with low proportions of calcium and magnesium called *reh*, available in the Ganga Valley (Wadia 1975), was used as the flux.

M-Na-Al glass can be divided into a growing number of groups. Initially, groups m-Na-Al 1 to 4 and 6 were defined based on different glass constituents:

MgO, CaO, Sr, Zr, Ba, Cs and U (Dussubieux et al. 2008; Dussubieux et al. 2010). Group m-Na-Al 2, which previously encompassed nearly all m-Na-Al beads found in eastern and southern Africa between about the 10th and 17th centuries, has recently been divided in two (Dussubieux and Wood, 2021). The Dussubieux and Wood article notes that the new group, m-Na-Al 6, has lower U and slightly higher Cs than Group 2 and appears to be present between the late-9th/10th to 13th century while Group 2 is found from about the late 14th century onward.

Recently the analysis of a large number of glass samples from a well-dated medieval South Asian assemblage from the site of Indor in Rajasthan, North India, has led to the detection of a range of new m-Na-Al groups, which have been named Groups 7 through 12 (Trivedi and Dussubieux, in preparation; Trivedi and Dussubieux, this volume, for more details see Annex B). One member of this group, Group 11, was identified concomitantly at the site of Kish in Iraq (Dussubieux, this volume). This analysis from Mayotte provides the most important evidence to date for the long-distance exchange of beads in these hitherto undetected groups.

Figure 16.4 represents the principal components 1 and 2 obtained using the concentrations of MgO, CaO, Sr, Zr, Ba, Cs and U from samples belonging to the ten relevant m-Na-Al glass groups and from the m-Na-Al beads found at Antsiraka Boira [AB]. Figure 16.4 and Table 16.2 below provide a summary of the m-Na-Al samples from AB and the groups to which they belong.

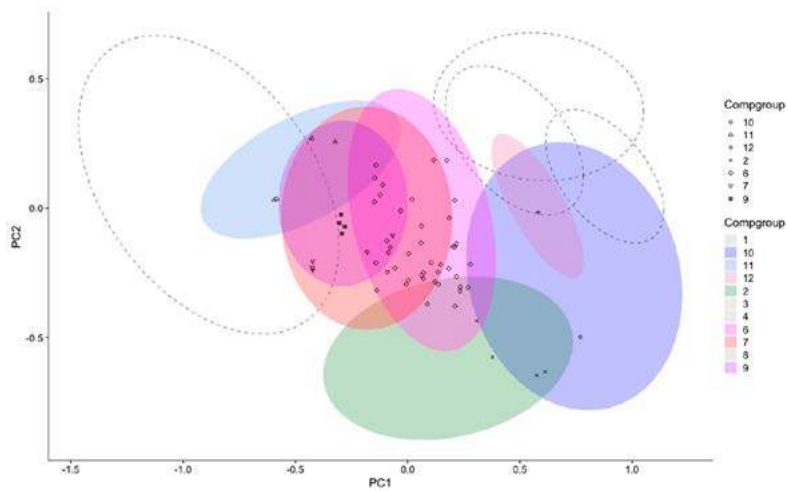

Fig. 16.4: Scatter plot representing PC1 and PC2 calculated using the concentrations for MgO, CaO, Sr, Zr, Cs, Ba and U in samples belonging to glass groups m-Na-Al 1 (unpublished data), m-Na-Al 2 (Dussubieux et al. 2008), m-Na-Al 3 (Dussubieux and Kanungo 2013), m-Na-Al 4 (Dussubieux 2009) and m-Na-Al 6 (Dussubieux and Wood 2021), m-Na-Al 7 to 12 (Trivedi and Dussubieux, in preparation) and in the m-Na-Al samples from Mayotte (Antsiraka Boira) m-Na-Al beads.

Group	2	6	7	9	10	11	12
black wound bicone		AB043 AB060 May07			May11 lenticular		
black wound square		AB055	AB029				
black wound sphere		May08 & 09					
br-red wound bicone	AB065	AB057					
br-red wound sphere		AB058					
black drawn		5					AB011
br-red drawn		7					
white drawn		3					
colorless drawn				AB052a & b		AB015, AB016	
amber drawn		AB032	AB044, AB045a, b & c				
yellow drawn	AB033a & b	AB08 & 09 + powder					
blue-green drawn		9	May05	AB056, AB064		AB047a & b	
green drawn		3					
blue-green with yellow-core drawn		May13 & 14					

Table 16.2: Antsiraka Boira m-Na-Al beads by type and glass group (simple numbers in group 6 denote numbers of beads of that type, bead identities for these can be found in Table 1).

Table 16.2 outlines which sorts of beads (based on method of manufacture and color) occur in each glass group, but obviously the analyzed beads represent a small sample so it is probably not complete. As is evident, 70% of the analyzed m-Na-Al beads were made from Group 6 glass, a type that appears to be important across a range of archaeological sites including medieval Indor (Trivedi and Dussubieux, in preparation), where this glass was found in the form of glass-working debris.

Bead May011 appears as an outlier due to its unusually high uranium concentration (348 ppm), which places it in Group 10 along with samples from Indor that also contain exceptionally high U. This bead is black, wound and has an unusual lenticular shape. As can be seen in Figure 16.5A, there are many of these beads stacked next to each other in situ which, along with the image of them cleaned and restrung (Figure 16.5B), illustrates how uniform they are in size and shape. This is unusual in wound beads of the period suggesting they may have been formed in molds.

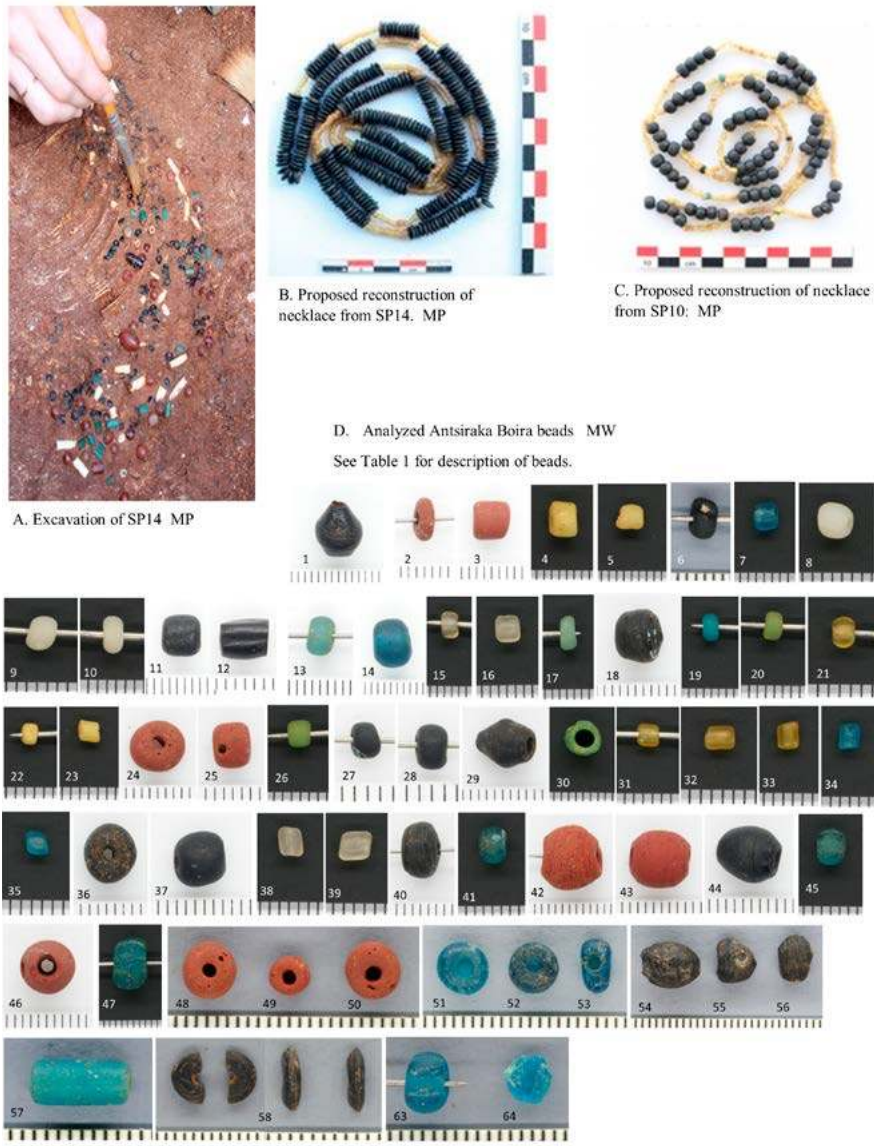

Fig. 16.5: Images of beads mentioned in the text and all analyzed beads. Photo credits: MP is Martial Pauly, MW is Marilee Wood.

AB011, a drawn black bead which, apart from a small white inclusion, is indistinguishable from other small drawn black m-Na-Al beads, is another outlier and belongs to Group 12. This glass, distinguished by elevated barium and uranium concentrations, is also known from Indor.

The beads that belong to Groups 7, 9 and 11, which occur at Indor, are all (with the exception of AB029) small (2 to 2.5mm diameter), drawn, transparent-to-translucent and mostly tubular (Figure 16.6A). In Group 7 they appear in amber/pale yellow or blue-green/turquoise and in both Groups 9 and 11 they are colorless or blue-green/turquoise (Figure 16.6A). Sample AB029 is a black squarish wound bead that morphologically does not relate to the other Group 7 beads.

The three Group 2 beads, which are believed to date from the late 14th century onward in eastern Africa, are discussed below.

Table 16.2 provides a summary of the colors available across different m-Na-Al glass groups and types. Group 6 glass included all colors apart from colorless, which was found exclusively in Groups 9 and 11. Black wound beads appear mainly in Group 6 with single examples in Groups 7 and 10 whereas black drawn ones are all Group 6 apart from one in Group 12. Brownish-red wound and drawn beads belong to Group 6 apart from one wound Group 2 example. Opaque white beads and blue-green beads with yellow cores appear only in Group 6 glass while monochrome blue-green/turquoise samples occur in Groups 6, 7, 9 and 11. Opaque yellow beads appear in Groups 2 and 6 but the transparent/translucent pale yellow samples are found, along with amber-colored beads, only in Groups 6 and 7. Few green beads were found and all belong to Group 6. Overall, black is the most common color found in the Antsiraka Boira assemblage at 61% with transparent/translucent yellow second at 14% and opaque red at 12%.

The colorless beads do not contain any discoloring ingredients or any specifically low iron concentrations. This suggests that careful control of the furnace atmosphere rather than a specific recipe was used to obtain the colorless glass. The amber beads appear to have been colored with the addition (from 3.6% to 7%) of iron. White beads are uncommon in m-Na-Al glasses but three (see Figure 16.5D 8 to 10) are part of the m-Na-Al 6 glass group. They are characterized by the absence of any detectable opacifying agent and, as is the case with the colorless beads, iron concentrations are similar to the other beads. Black Group 6 beads were colored with added iron or manganese or with no specifically high element concentrations. Black beads of Group 2 glass were similarly colored except manganese was not used. Both drawn and wound black beads appear to have been made of both glass types.

The Antsiraka Boira m-Na-Al blue-green and turquoise beads contain between 0.3 and 1.1% copper which is likely the coloring agent. Traces of tin and lead indicate that the copper was introduced in the form of bronze that contained from 6 to 30% lead and from 3 to 7.5% tin. Copper is also involved in the coloration of brick-red beads with copper concentrations ranging from 0.6 to 1.4% - values that are close to those in the turquoise beads. Two Group 6 beads and two Group

2 are opaque yellow. They all contain a significant concentration of tin and lead: 0.22-0.25% tin and 1.74-1.94% lead for the Group 6 samples and 0.20-0.28% tin and 2.43-3.97% lead for the Group 2 beads. In addition, the yellow core of a long bicolor blue-green tubular bead (Figure 16.6C) made of Group 6 glass contains 0.44% tin and 10.66% lead. $PbSnO_3$, a yellow opacifier, was certainly used to color and opacify these glasses. The same elements are also present in one opaque green Group 6 bead (AB040) whose color might have been obtained using a yellow opacifier in a blue glass matrix. Copper is present in this glass (0.47%) as well as in the long tubular blue-green beads from SP14 (SP stands for *sepulture* or grave). It is often difficult to assess the degree of opacity of some opaque and translucent green and yellow beads because their opacity is likely due to the presence of lead stannate ($PbSnO_3$) which creates yellow crystals (Rooksby 1964). In a turquoise blue matrix (due to the presence of copper in the glass), the yellow crystals give an opaque green appearance to the glass.

In sum, in the Antsiraka Boira m-Na-Al bead assemblage, Group 6 beads appear in all colors mentioned apart from transparent colorless whereas Groups 7, 9 and 11 are composed almost entirely of transparent colorless, amber or blue-green/turquoise beads.

5. Comparisons with other eastern African archaeological sites

Mayotte's position on the southern edge of the Swahili corridor encourages investigating its trade links. It has been demonstrated that during this period (12th to mid-13th century) glass beads traded into southern Africa and the East Coast were somewhat different, suggesting they had somewhat different trading partners and patterns (Wood 2005, 2011). Robertshaw et al. (2006) noted that glass beads from Mahilaka in northwestern Madagascar appear to be more closely related to East Coast beads than to those found in southern Africa. Here, Antsiraka Boira's glass beads will be placed in relation to these others.

Antsiraka Boira's glass bead assemblage is unlike most in eastern Africa because the beads came from burials and had been personal adornments of the interred. Other assemblages are made up of stray beads that were lost or broken and discarded so archaeologically they are found, usually in small numbers, around or in dwellings or other gathering points or in middens. Thus, the traditional way of comparing sites, that is, by noting bead counts per square meter of deposit, their method of manufacture, color, size etc., is not particularly useful. Here we will pay attention to several unusual beads that might suggest links of some sort between sites. These include black wound beads that are shaped in such a way that they appear almost square in profile (Figure 16.5C). In addition, they have not

been marvered so the wind marks stand out (Figure 16.5D-18 & 40). A few lightly marvered bicones, created in the same manner with visible wind marks, appear in black (Figure 16.5D-1 & 29) and in brick-red (Figure 16.5D-42). Perhaps the most unusual are the black wound lenticular disc beads that are so uniform in size and shape they may have been formed in molds (Figure 16.5A, B & D-58). Looking at drawn beads, those made of colorless, yellow-tinted or amber-colored transparent glass or opaque white glass are exceptionally rare except at Antsiraka Boira. Finally, the long bicolored tubular beads of blue-green to greenish glass, some with a yellow core (Figure 16.6C), have not been found elsewhere.

Transparent amber/pale yellow and colorless m-Na-Al beads are very rare in eastern Africa and absent in southern Africa apart from one transparent amber-colored bead (CHB292) from Chibuene, Mozambique (Wood et al. 2012). In addition, two colorless beads (PR298 and PR306) were analyzed from Mahilaka in northwest Madagascar (Robertshaw et al. 2006) but curiously one is made of m-Na-Al glass while the other is of v-Na-Al glass.

Beginning in the north, Shanga, in Kenya's Lamu Archipelago (Horton 1996), produced 9 black wound beads and 4 brick-red ones in Trench 8, which dates from about the 12th to the mid-13th century. Most of these were analyzed with LA-ICP-MS by Robertshaw in the early 2000s (unpublished) and all form part of the m-Na-Al glass type; they probably belong to group 6 or one of the other newly identified groups. Three might be related to those from Antsiraka Boira because – like those – the Shanga beads were wound with thick strands of glass and were lightly marvered if at all. Two Shanga beads are brick-red, one is roughly spherical and the other ovoid (Figure 16.6D-1). The third is a black sub-sphere, rather squarish in profile (Figure 16.6D-2) like many of the Mayotte beads. One additional Shanga bead might be related. It is a black disc from the same area as the wound beads. From a photo it appears to be similar to the Antsiraka Boira lenticular disc beads. However, its diameter measures about 13 mm while all 383 of the Mayotte lenticular beads measure 6 mm. The Shanga bead therefore is not a match.

Manda, another site in the Lamu Archipelago, produced wound beads in period IIa, which corresponds to Antsiraka Boira's dates. Morrison (1984) records 39 black bicones, 9 black spheroids and one brick-red bicone. It is possible some of these are like the unusual ones from Mayotte, but we unfortunately have no photos of them to verify this. In addition, one drawn colorless bead was recorded.

Fig. 16.6: Images of beads from other sites. Photo credits: C is M. Pauly, all others M. Wood.

Moving south to Mafia Island in Tanzania, the Juani Primary School (Crowther et al. 2016) beads, where the m-Na-Al 6 glass type was first recognized, include a few beads that are similar to unusual ones from Antsiraka Boira [AB]. One

black wound bead (Figure 16.6E-1) was formed in the same manner as the AB unmarvered rather square ones with highly visible wind marks. Another is a white bead (Figure 16.6E-2) similar to AB's white beads. Finally, a variation of the long blue-green tube beads with yellow cores from AB is found at Juani, but the Juani beads are smaller in diameter, almost spherical in shape and the outer layer is transparent blue glass while the outer glass on the AB tubes is usually translucent and blue-green in color (Figure 16.6E-3). The glasses used to make the two types are both m-Na-Al 6 but vary somewhat in composition.

Sanja ya Kati was a stone town on a small island south of Kilwa Kisiwani that was active from the 11th to mid-13th century. Beads from there that are part of the collection at the British Institute in East Africa (BIEA) in Nairobi include five wound brick-red spheres/sub spheres and one black wound squarish bead (Figure 16.6F) that are similar to those at AB.

In southern Africa one transparent amber-colored drawn bead was found at Chibuene, a port in southern Mozambique that served as an entry point for imported goods that were traded into the interior between about the 8th and 10th centuries but the site was occupied well beyond that time (Wood et al. 2012). This bead (CHB 292) was analyzed at EAF and was assigned to the m-Na-Al Group 2 but can now be ascribed to the m-Na-Al Group 11. In the interior, at the late 10th to early 13th century site of K2 (and related sites) near the confluence of the Limpopo and Shashe rivers, thousands of transparent turquoise tubular beads were found along with two small colorless drawn beads from a residential setting (Wood 2005:95). These too can possibly be placed in m-Na-Al Group 6 or another newly recognized group.

Turning to Madagascar, 31 glass beads from Mahilaka (roughly 9th to 15th century) on the northwest coast were analyzed with LA-ICP-MS by Robertshaw et al. (2006). All but one were made of m-Na-Al glass. Beginning with wound beads, two brick-red samples, PR308 and 297, (Figure 16.6G-1 & 2) are similar to AB beads and two, PR309 and 310, (Figure 16.6G-3) look similar to the squarish black AB beads. PR301 (Figure 16.6G-4) is a black lenticular disc bead that resembles those at AB but is somewhat larger (10mm) than the AB examples. Finally, the rare transparent drawn beads at Mahilaka include PR298 and 306, which are colorless (but PR306 is made of v-Na-Al glass), PR286 which is yellowish and PR288 which is amber-colored (Figure 16.6G-5 & 6). From the information available at this time, it looks like the glass beads from AB are more closely related to those at Mahilaka than those at other eastern African sites. These observations are strengthened by the PCA results for Mahilaka's m-Na-Al beads (Figure 16.7) which show a striking similarity to those of Antsiraka Boira. It is not surprising that beads from these two sites have similarities in that Mayotte lies closer to

Madagascar (roughly 300 km) than any other land mass and other trade between them is present, for example the presence of chlorite schist (a metamorphic stone from Madagascar's east coast) vessels at AB and, as has been mentioned, AB's inhabitants speak a Malagasy dialect. It also appears that both the AB and Mahilaka assemblages are more closely related to assemblages on the East Coast than to those in southern Africa.

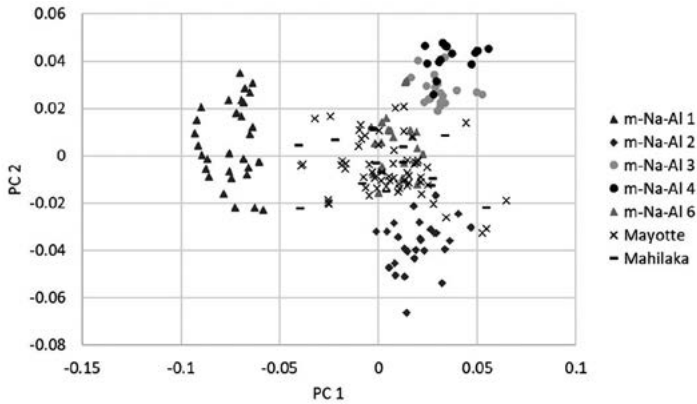

Fig. 16.7: Scatter plot representing PC1 and PC2 calculated using the concentrations for MgO, CaO, Sr, Zr, Cs, Ba and U in the Antsiraka Boira (Mayotte) and Mahilaka (Madagascar) (Robertshaw et al. 2006) m-Na-Al beads and in different types of m-Na-Al glasses.

6. Discussion

Pauly and Ferrandis (2018) provide a comprehensive description of the burials at AB, their contents, and how they can inform cultural practices, so will not be discussed here. Turning next to contextualizing some of the unusual beads found at AB, a plant ash (v-Na-Ca) bead (AB044 – see Figure 16.5D 30) was found in grave SP15. This was the burial of a heavily adorned (2235 beads) child of about 5 years that contained a large drawn tubular bead made of translucent/opaque green v-Na-Ca glass. Its large perforation and light green color resemble some beads found at Unguja Ukuu (i.e., UU 262 – see Figure 16.6H) (Wood et al. 2017) but not Zhizo beads from southern Africa which are made of the same glass type. The translucent turquoise v-Na-Ca bead (May 006), which was (unusually) flattened after being heat rounded (see Figure 16.5D 53), came from a woman's grave - SP18 (698 beads). It too resembles beads from Unguja Ukuu but not those from southern Africa. It appears that v-Na-Ca beads at Unguja Ukuu and up and down

the eastern seaboard went out of circulation sometime in the mid-10th century. Thus, these Antsiraka Boira v-Na-Ca beads may represent heirlooms that possibly were seen as a form of protection or ancestral connection.

The only v-Na-Al bead that was analyzed came from trench US 1001, which was not associated with a burial. It represented upper layers that dated to about the 14th to 15th century based on the ceramic assemblage (Pauly and Ferrandis 2018). This fits well with our present knowledge indicating that beads of this glass are found in eastern Africa at sites that date between the 13th and 16th centuries.

Of the three analyzed beads that belong to m-Na-Al group 2, two (AB033 a and b) came from SP 10 while the third (AB065) came from US 1001, the non-burial context where the v-Na-Al bead was found, so it likely represents a later period. However, the presence of Group 2 beads in SP 10 is difficult to explain. In a study of Tanzanian assemblages (Dussubieux and Wood 2021) it was established that in eastern Africa, assemblages of Group 6 beads appear in 9th/10th to 13th century contexts while Group 2 beads appear after the late-14th century CE. It might indicate this grave (containing a child adorned with 1592 glass beads and 8 of shell) represents a later intrusive deposit, but that seems unlikely given that the other grave goods, including the other glass beads, do not suggest this. This grave was undisturbed and was quite likely one of the latest at the site. It is perhaps possible that a few Group 2 beads made their way to Mayotte two centuries before they became the dominant bead type in eastern Africa. The earlier occurrence of Group 2 glasses at Angkor and Hirapur (Carter et al. 2019; Pawar et al. 2014) may suggest that this is the first indication of an earlier trade in Group 2 beads to Mayotte and perhaps to other eastern African venues.

Although it appears from our analysis that Group 6 beads dominate the Antsiraka Boira assemblage, this is possibly not the case. Beads were chosen for analysis with the aim to test all types present so many are underrepresented. For example, only one Group 10 bead, a wound black lenticular bead, was analyzed but 383 were found in a single grave.

7. Conclusions

The glass beads from Antsiraka Boira represent an astonishing assemblage for eastern Africa since large cemeteries that include grave goods are exceedingly rare in the region. LA-ICP-MS analysis has added substantially to the information we can learn from the beads. All but one v-Na-Al and two v-Na-Ca beads (which date to periods outside that of the burials) are made of m-Na-Al glasses that were produced in South Asia. In addition, recent discoveries of new m-Na-Al glass groups, first Group 6 followed by Groups 7 to 12, show that these beads were

made of a range of these glasses, suggesting diverse places of origin within South Asia. In addition, the presence of these newly identified glass groups in Mayotte provides evidence that they were traded outside of South Asia.

It appears that Antsiraka Boira's glass bead assemblage is most closely related to that found at Mahilaka in northwest Madagascar, then to assemblages of the period on the East Coast. Similarities with beads in southern Africa are restricted to small drawn types possibly made of Group 6 glass.

Antsiraka Boira's beads provide us with a window through which we can see not only the types of beads being imported in this confined period but also some idea about how they were being used. The value ascribed to glass beads was made evident through their presence, often in large numbers, in burials, which occasionally included older beads that were probably heirloomed for two or more centuries. The bead supply displays a heterogeneity, including a range of producers, colors, and types of drawn and wound beads, which could be seen as the signature of a complex and mediated market structured by shifting preferences in the Comoros during this time of significant cultural and religious change. Thus, even within the small sample of glass beads analyzed from Mayotte we have clear evidence for differentiated glass bead supply within m-Na-Al glasses.

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Part IV

Glass Beads in the Middle-East

Chapter 17

Elemental composition of glass beads from the eastern Mediterranean region: Chronology and provenance of material from Tel Anafa, Israel

Katherine A. Larson[1] and Laure Dussubieux[2]

1. Introduction

Tel Anafa is a small tel site, located in northern Israel along the eastern edge of the Hula Valley, near the confluence of the headwaters of the Jordan River and the Golan Heights. The name of the site before the 20th century is unknown. Excavations conducted by the University of Missouri/University of Michigan team under the direction of Saul Weinberg and Sharon Herbert, over 10 seasons from 1968 to 1986, indicate the presence of a small yet dynamic community with intermittent bursts of activity (Weinberg 1971; Herbert 1994). Ceramic and lithic assemblages attest to the earliest occupation of the tel during the Bronze and Iron Ages, and scattered walls and simple inhumation burials document continued habitation during the second millennium CE.

The most significant occupation of Tel Anafa occurred during the late Hellenistic (ca. 125–75 BCE) period, when the tel was dominated architecturally by a single large domestic residence, dubbed the Late Hellenistic Stuccoed Building (hereafter LHSB) by the excavators (Figure 17.1). The primary structure of the LHSB consisted of suites of rooms oriented around a central open, colonnaded courtyard. A suite of rooms with mosaic floors, stuccoed plaster walls, stone-lined fire pits, and an interior drainage system, located along the east side of the courtyard, has been identified as a private bath. The most elaborate rooms of the LHSB, including the bath, were decorated with painted and gilded wall stucco. Small mudbrick structures built against the ashlar masonry of the south and west LHSB walls were likely used for storage, cooking, and minor household industries such as agricultural processing and textile production (Wells et al. 2012; Larson

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[2] Field Museum, Chicago, USA

and Erdman 2018). Approximately 35 meters south of the LHSB, exploratory excavations revealed a series of poorer quality structures with basic cooking and food preparation installations along a road composed of cut limestone blocks, roughly contemporaneous to the LHSB. Coins and pottery attest to the economic and cultural connections of the LHSB residents with the coastal Phoenician cities of Acco, Tyre, and Sidon and the wider *koine* of the Hellenistic eastern Mediterranean (Berlin 1997). The LHSB occupants abandoned the settlement around 75 BCE for unknown reasons, but perhaps as a result of ongoing political tumult in the region and the rise of the Hasmonean kingdom to the south; there is no trace of destruction or conflagration at the site.

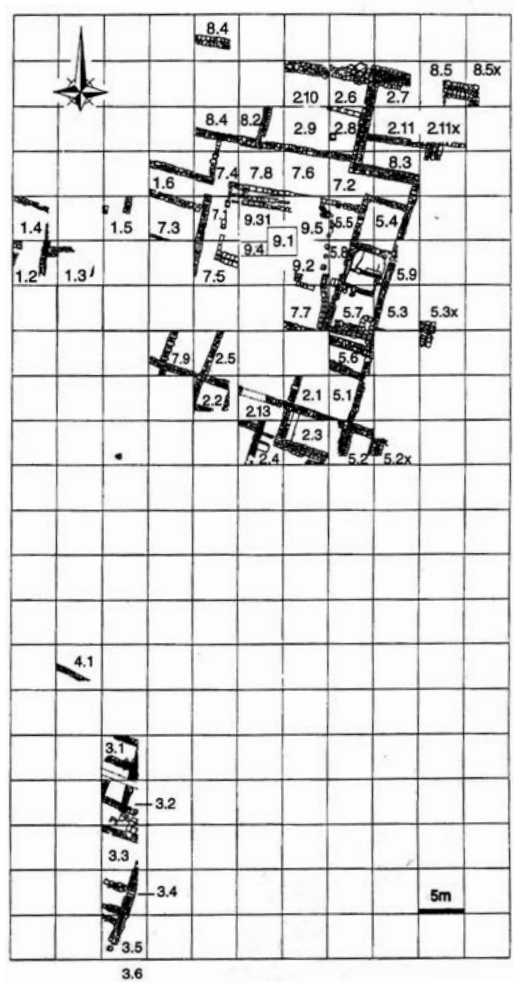

Fig. 17.1: Site Plan of Tel Anafa, showing excavated areas and trench numbers. (Image © Kelsey Museum, University of Michigan).

Early Roman (late first century BCE – mid first century CE) Anafa was more modest, with a dramatic shift in the customs and habits of the occupants. The architecture consisted of small, rubble structures. Roman-style weaponry, fibulae, and ceramics suggest that the site may have been a Roman military outpost, possibly occupied by retired Roman soldiers, adjacent to the nearby newly established city of Caesarea Philippi (Berlin 1997, 30-32; Merker 2012, 253-255).

More ephemeral remains bookend these two major phases of occupation at Anafa. Middle and Late Bronze Age Anafa appears to have been a quite significant settlement based on the residual ceramics found in later levels, the early architectural remains having been disturbed by the deep Hellenistic construction. Late Bronze II (1400–1200 BCE) seems to have been particularly vibrant, with a large quantity of both local ceramics and imports from Cyprus and Greece (Herbert 1994: 148–56; Dever and Harrison 2018).

In the late Abbasid to Fatimid period (9th–12th century CE), scattered late walls and accompanying ceramics indicate the presence of a modest community (Herbert 1994: 144–48; Boas 2018). Grose described the vessel glassware as "undistinguished," generally confirming the 9th-12th century pottery dates (Grose 2012: 80). Several inhumation burials, representing 17 children and 5 adults, were found in the northwestern area of the tel. Lacking grave goods beyond beads made from glass, stone, and shell, these burials are of indeterminate date and may be contemporaneous to or centuries later than the medieval settlement.

2. Glass from Tel Anafa

Among the more significant groups of finds from Tel Anafa were hundreds of fragments of sagged glass drinking bowls (Weinberg 1970; Grose 2012). The quantity, quality, and secure dating of the Tel Anafa glass vessels facilitated the identification of late Hellenistic glasses elsewhere in the eastern Mediterranean and helped lead to the recognition of Syro-Palestine as a center of glass production during the last two centuries BCE, before the invention of glass blowing (Grose 1979; Jackson-Tal 2004). Ten samples of vessel glass from Anafa were analyzed by Dr. Robert Brill but have not been carefully investigated or subject to comparative discussion (Brill 1999: 53; Grose 2012: 83–84).

The non-vessel glass found at Anafa, consisting of beads, pendants, and counters (Larson 2018a; b), has received less attention in the scholarly literature. Like the ceramics, wall plaster, and terracotta figurines, the objects of adornment in glass reflect both pan-Hellenistic styles and local tastes. Polychrome beads found in late Hellenistic strata include several types of eye beads, both stratified and cane, and trailed beads. Most have dark matrixes with light colored decoration,

usually white or yellow. Monochrome beads and pendants appear in transparent colors of blue, blue-green, amber, and brown, as well as opaque white, so far as color can be determined. The monochrome beads were manufactured in several ways, with shape being loosely connected to manufacturing technique. Cylindrical beads tend to have been folded, while spherical and oblate beads were almost certainly wound. Multiple manufacturing types also occur in the Hellenistic bead workshop assemblages from Delos and Rhodes (Weinberg 1969: 144–45; Nenna 1999: 128–36). Typologically comparable assemblages of glass beads from the Late Hellenistic sites have been published from Rhodes (Weinberg 1969; Triantafyllidis 2000), Delos (Nenna 1999), Jebel Khalid (O'Hea 2002), and Jerusalem (Zuckerman 1996; Nenner-Soriano 2006). A few unique styles of glass beads found only at Anafa or other sites in the immediate region may be products of a local industry (Larson 2018a: 96).

Very little chemical analysis has been conducted on glass beads from Hellenistic and Roman period sites, even for sites with published bead assemblages (cf. Smirniou et al. 2018b). The Anafa analysis project, therefore, is one of the first comprehensive, large sample scientific studies of glass beads from a Hellenistic period eastern Mediterranean site.

3. Results

In 2007, 90 laser ablation – inductively coupled plasma – mass spectrometry (LA-ICP-MS) measurements were conducted at the Elemental Analysis Facility (Annex A) on 72 beads and counters found at Anafa, yielding 69 identifiable compositions from 57 objects (Figure S17.1; Table S17.1). The different colors of polychrome objects were analyzed individually. Twenty-one compositions were eliminated due to corrosion. For some beads, the glass of a given color was extremely corroded, although some pristine glass could be measured on a different color. The change in the composition caused by the addition of a coloring ingredient (e.g., by causing the decrease of the silica content of the glass) can make a given glass more sensitive to corrosion.

Among the 69 compositions discussed here, six main glass types were identified (Table 17.1):

— The majority of the samples (52) have a soda-lime composition with concentrations of potash and magnesia below 1.5% indicating the use of soda taken from mineral deposits.

— 8 additional samples with soda-lime compositions have K_2O concentrations > 1.5% but MgO concentrations below 1.5%.

— 1 soda-lime bead has magnesia and potash concentrations higher than 1.5% indicating the use of soda obtained from soda plant ash.
— 6 beads are characterized by high lead concentrations (44.6%) with soda, magnesia and potash concentrations suggesting that lead was added to a soda plant ash glass.
— 1 bead has a high lead concentration (63.6%) and very little of any element except for silica
— 1 bead has a soda-rich composition with a high alumina (5.8%) concentration.

	mineral soda-lime	higher K_2O-soda-lime	higher MgO and K_2O-soda-lime	high lead-soda-lime	high lead	soda-high alumina
SiO_2	70.0 ± 3.3	68.6 ± 3.2	70.2%	32.9 ± 0.4	35.8	67.0%
Na_2O	14.5 ± 1.6	12.4 ± 1.9	13.9%	9.9 ± 0.3	0.01	16.2%
MgO	0.5 ± 0.1	0.7 ± 0.3	2.6%	2.15 ± 0.08	0.02	0.5%
Al_2O_3	2.4 ± 0.3	2.8 ± 0.6	0.3%	1.01 ± 0.01	0.17	5.8%
P_2O_5	0.12 ± 0.06	0.18 ± 0.08	0.3%	0.241 ± 0.003	0.03	0.2%
K_2O	0.8 ± 0.2	1.8 ± 0.3	1.8%	2.17 ± 0.06	0.03	3.0%
CaO	7.5 ± 1.4	8.0 ± 1.2	5.0%	4.7 ± 0.3	0.14	1.7%
Fe_2O_3	0.9 ± 1.2	1.4 ± 1.2	3.2%	0.60 ± 0.02	0.04	4.1%
PbO	1.2 ± 3.9	0.9 ± 1.6	0.003%	44.6 ± 0.8	63.6	0.2%

Table 17.1: Average concentrations in wt% with standard deviation for the glass groups identified at Tel Anafa. Only one sample is available for the higher MgO and K_2O-soda-lime, high lead, and soda-high alumina glasses; therefore, the data for these glass types is the composition of the sample.

3.1. Mineral soda-lime glass

Fifty-two beads have a soda-lime composition with an average soda concentration of 14.5% and an average lime concentration of 7.5%. Low concentrations of potash and magnesia (< 1.5%) indicate the use of soda taken from mineral deposits (e.g., natron) (Tite et al. 2006).

The use of mineral soda-lime compositions started around the 10th century BCE (Schlick-Nolte and Werthmann 2003) at primary glass production centers located in Egypt and the Syro-Palestinian region. The glass was distributed widely throughout the Mediterranean basin as raw materials to be transformed in secondary glass working centers or as finished materials (Degryse et al. 2014). The use of natron started declining around the 8th century CE and totally disappeared toward the end of the 1st millennium CE (Tite et al. 2006; Phelps et al. 2016; Schibille et al. 2019).

Glass manufactured from sand collected in the Levantine or the Egyptian region presents distinct trace element patterns. The sand found in the south-east part of the Mediterranean basin and along the Levantine coast derives from the Nile drainage into the Mediterranean Sea. The sediments are moved primarily by wave-induced longshore current with a selective process causing a change in the proportion of certain minerals such as zircons (Barfod et al. 2020). This makes it possible to separate glasses made from Egyptian and Levantine sands based on elemental ratios such as Y/Zr and Ce/Zr. Egyptian sand tends to have higher zirconium concentrations which will produce lower ratios whereas glass made from Levantine sand will exhibit higher ratios (Van Strydonck et al. 2018). The Tel Anafa beads, with higher Ce/Zr and Y/Zr values are consistent with the trace element pattern observed for the Levantine glass (Figure 17.2).

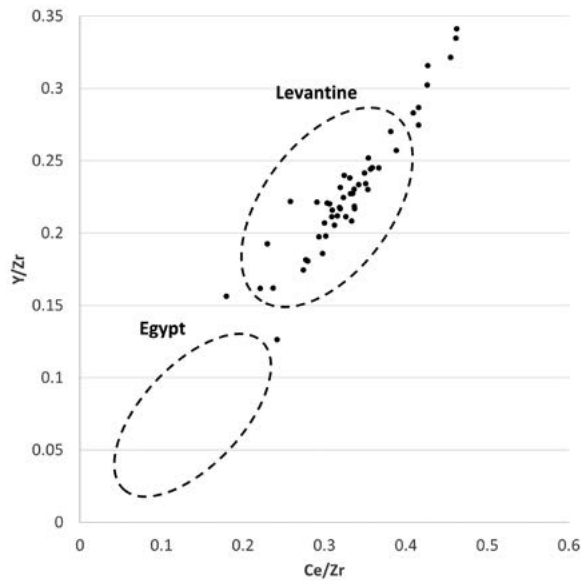

Fig. 17.2: Ce/Zr vs Y/Zr for the natron soda-lime glass from Tel Anafa with areas corresponding to Egyptian and Levantine productions. Ellipses are just meant to help visualize the areas corresponding to glass from Egypt and glass from the Levant (Van Strydonck et al. 2018; Then-Obłuska and Wagner 2019a, 2019b).

For the Hellenistic period, evidence for primary glassmaking workshops is scarce. Possibilities include Beirut and the region of the Belus River (Henderson 2013: 215–22), both located along the Levantine coast. Regarding secondary manufacture of beads, glass workshops on the Aegean islands of Rhodes and Delos

provided evidence of glass bead production dating from the Hellenistic period (Weinberg 1969; Nenna 1999). Analyses by Brill (1999) show that a mineral soda-lime glass was used. If the glass found in Rhodes is fairly similar to the glass from Tel Anafa, we observed that the alumina concentrations are slightly lower for the Rhodes samples (2.1 ± 0.2%) based on Brill data compared to the Tel Anafa beads (2.4 ± 0.3%). The significance of such a difference is difficult to understand in the absence of a wider range of elements and especially trace elements for the Rhodes samples that would allow a more comprehensive comparison. It is interesting to note that the alumina values provided by Triantafyllidis et al. (2012) for core-formed glass vessels from Rhodes are more aligned with the values obtained at Tel Anafa.

3.2. Higher potash soda-lime glass

A small proportion of samples (8 compositions) have a soda-lime composition but compared to the previous group, potash concentrations are generally higher, above 1.5%. Although it is usually accepted that natron soda-lime glass exhibits potash and magnesia concentrations below a 1.5% limit, while soda plant ash glass has concentrations for both these elements above it, it is quite exceptional to have a hybrid situation with potash concentrations above 1.5% and magnesia below 1.5%. Some trace elements such as Rb are also higher in this "hybrid" glass compared to the natron soda-lime glass (Figure 17.3).

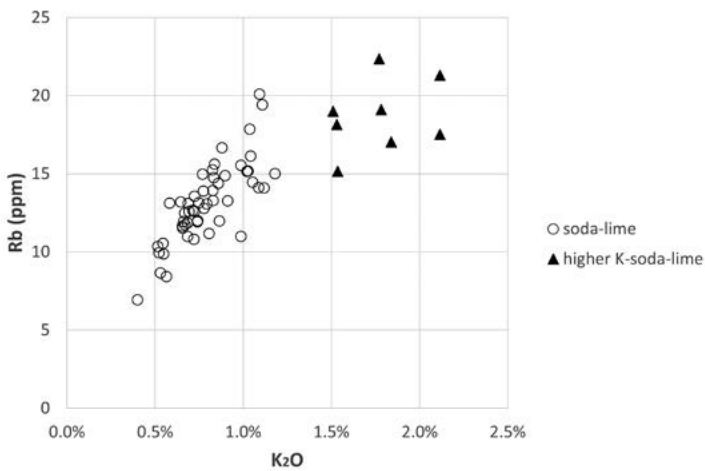

Fig. 17.3: K_2O vs Rb for the natron soda-lime and the higher potash soda-lime glasses from Tel Anafa.

Enrichment in K_2O and modification of the concentrations of other major or trace elements (including Rb) were observed at the surface of glass material subjected to high temperatures (Chataignier et al. 2020; Gratuze, personal communication). For the Tel Anafa higher potash soda-lime glass beads, the signal for potassium does decrease in some instances when glass deeper in the objects is sampled by the laser, but the concentrations presented here are corrected from surface or other variations by eliminating the parts of the signal that are not stable. The excess of K_2O could possibly be explained by glass recycling. Three dark glass samples (BD52cBlack, BD40Black and BD53) all contain non-negligible concentrations of antimony, copper, cobalt, lead and manganese, that would suggest that several colored or opaque glasses were mixed together; however, this observation can also be made for some glass samples from the mineral soda - lime glass group. Also in this group we have colorless glass with very low concentrations of any coloring elements. From a general point of view and beyond the dark glass samples, the colorants in the mineral soda-lime and the higher potash soda-lime glass are fairly similar: white glass contains higher antimony concentrations (calcium antimonate is a white opacifier) and some dark glasses have fairly high manganese concentrations (< 3%).

Some polychrome beads (e.g., BD 40 and BD 52) were made from both natron soda-lime and soda-lime with extra potash glasses, indicating that the two different compositions do not mean the beads were produced in different workshops or at different times. Rather, it seems that a single bead workshop might have procured glass from two distinct sources.

A similar higher potash soda-lime glass was identified at Nubian sites dating mostly from the Meroitic period (first–third centuries CE) (Then-Obłuska and Wagner 2019a, 2019b). It exhibits a similar K_2O-Rb correlation and, like the Anafa beads, was attributed based on the Ce/Zr vs Y/Zr values to a Levantine provenance. This could indicate that this glass was produced in a Levantine workshop over the course of several centuries, from the final centuries BCE and throughout the first half of the first millennium CE, although we cannot exclude recycling in the later periods. The production seems fairly small scale as it has not been widely identified in the literature to date.

3.3. Higher MgO and K_2O-soda-lime

One single bead (BD 29, Figure S17.1) has a soda-lime composition with potash (2.6%) and magnesia (1.8%) higher than 1.5% suggesting that soda was obtained from plant ashes. This bead is extremely corroded, but it seems that its original color was turquoise blue which is supported by the presence of 2.2% of copper (as CuO).

The earliest glass industries of the second half of the 2nd millennium BCE, remains of which have been found in Mesopotamia and Egypt, produced a glass from a rather pure silica source and soda plant ashes (Tite and Shortland 2003; Rehren and Pusch 2005; Smirniou and Rehren 2011; Shortland et al. 2018; Smirniou et al. 2018a). Different trace elements have been identified based on the provenance of the glass. Notably the concentrations of Cr and La exhibit different patterns (Figure 17.4). Lower Zr and Ti concentrations (respectively <15 ppm and 300 ppm) are also measured in Mesopotamian glass while the concentrations for these elements are generally higher in the Egyptian glass. Bead BD29 fits the Mesopotamian pattern for Zr and Ti with respectively 8 ppm and 94 ppm (Shortland et al. 2007).

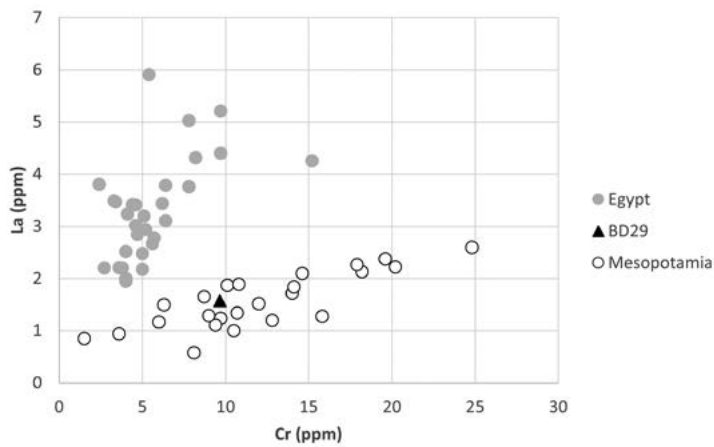

Fig. 17.4: Cr vs La for some LBA Mesopotamian and Egyptian glass (Shortland et al. 2007) and for sample BD19.

This bead was initially catalogued based on context as belonging to the Hellenistic/Roman phase of occupation, but the composition makes clear that it is a residual object from the Late Bronze Age phase of the site, probably Late Bronze II (1400–1200 BCE). It is thus the only glass object from this early period identified at Anafa. Like ceramics from Cyprus and Mycenae coming to Anafa in this period (Dever and Harrison 2018: 299), it demonstrates the connection of the occupants of the site with extensive LBA exchange networks. The likely Mesopotamian origin of the glass adds another node to the Anafa import exchange network, perhaps mediated by nearby LBA megasites of Dan and Hazor.

3.4. High lead-soda-lime

Six beads (BD 101a-f, Figure S17.1) are characterized by high concentrations of lead. These form part of a group of thirteen wound beads which were found with a child burial on the northwest slope of the tel, dated broadly to the second millennium CE (Herbert 1994: 147). By calculating the reduced composition of the glass (in other words, without lead), it appears that lead was added to a base soda-lime glass (Na_2O = 18 to 19% and CaO = 9%). With potash and magnesia concentrations higher than 1.5% (K_2O = MgO = 4 %), the flux of this base glass was probably plant ash.

These beads contain 1.5% of copper (as CuO), used to either obtain turquoise blue, green or red glass. With reduced conditions, copper is in the Cu^+ form that precipitates as cuprous oxide (Cu_2O) forming red crystals in the glass. The addition of lead improves the solubility of the cuprous oxide in the glass (Brill and Cahill 1988). We can therefore assume that, although the beads now appear whitish due to chemical corrosion of the original surface, they were originally red, and that lead was added as part of the coloring process. Higher potash and magnesia concentrations might have been the result of the addition of wood ashes in the glass to serve as an internal reducer to facilitate the production of Cu^+.

3.5. High lead

Sample BD 10 (Figure S17.1) contains 63.6% of lead and 35.6% of silica. All the other constituents of the glass have concentrations below 1%. The bead is amber in color suggesting maybe a contribution of iron in the coloring process; however, the concentration of this constituent is extremely low (Fe_2O_3 = 0.04%). Lead glasses appear at a rather late period as suggested by Sayre and Smith (1961), who defined an Islamic-lead glass perhaps introduced around the 8th to 10th century CE. Emerald green glass dating from the 9th to 11th century CE is a type of glass manufactured from recipes that vary but usually contains fairly high concentrations of lead close to the one measured in BD10 (Brill 1999, vol. 2: 182-183, 204; Freestone 2020; Wypyski 2015). The site of Al-Basra (800-1100 CE) in Morocco yielded a few beads with lead concentrations ranging from 24 to more than 80% of lead (Robertshaw et al. 2010). These published data indicate a dating for this bead toward the end of the 1st – beginning of the 2nd millennium CE.

3.6. Soda-high alumina

Sample BD 14 (Figure S17.1), a transparent green, spherical, drawn bead, has 16.2% of soda and a low magnesia concentration (0.5%) suggesting a soda flux taken from a mineral source. The alumina concentration is 5.8% indicating the use of a high alumina sand. Mineral soda – high alumina (or m-Na-Al) glass

composition is characteristic of south Asian production (Brill 1987). Based on the concentrations of MgO, CaO, Zr, Sr, Cs, Ba and U it is possible to distinguish at least 5 sub-groups of m-Na-Al potentially produced at different periods and/or different locations (Dussubieux et al. 2008; Dussubieux et al. 2010; Dussubieux and Wood 2021; [also see Annex B]). Using principal component analysis and the 7 constituents listed above, it is possible to separate the sub-groups and to attribute BD 14 to the m-Na-Al 6 glass type.

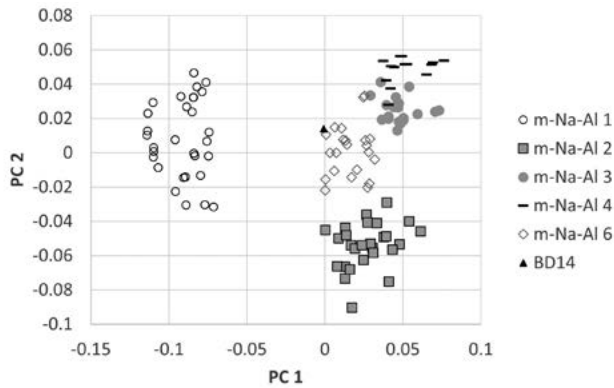

Fig. 17.5: PC1 (accounting for 57.7 % of the variability of the dataset) vs PC2 (23.6 % of the variability) calculated for glass groups m-Na-Al 1 (unpublished), m-Na-Al 2 (Dussubieux et al. 2008), m-Na-Al 3 (Dussubieux and Kanungo 2013), m-Na-Al 4 (Dussubieux 2009) and m-Na-Al 6 (Dussubieux and Wood 2021) and BD14

M-Na-Al 6 is a glass that was identified on the East Coast of Africa at sites dating from the 9th to 13th century CE (Dussubieux and Wood 2021). More recently, this glass was identified at a Nepalese site dating from 450-650 CE, suggesting that this glass could have been manufactured at an earlier period but maybe its trade was initially limited to South Asia (Aldenderfer and Dussubieux, this volume). The place of production for this glass is very uncertain at this point. Recent Sr isotope analysis conducted on m-Na-Al 6 glass samples suggests an origin in the Indo-Ganges region (Seman et al. 2021).

The emerald green color of BD 14 is due to the presence of copper in the glass (0.9% as CuO). The fairly high concentration of iron (Fe_2O_3 = 4.1%) may have also contributed to the color of this glass.

BD14 was found in locus 2030, a post-occupational fill along the main south wall of the LHSB. While it was initially catalogued as a possible Roman object based on typology and context, chemical analysis clearly suggests a later date. A 9th-13th century date corresponds to the late Abbasid-Fatimid settlement phase.

4. Discussion

The question of the origin of the beads is divided into two parts: where was the glass manufactured, and where were the beads produced? The broad provenance of the glass itself can be inferred based on general compositional trends. For the single bead of the Late Bronze Age, the glass is consistent with Mesopotamian, rather than Egyptian, production. In the late Hellenistic and early Roman period, the glass had a more proximate origin, sourced from sands from the nearby Levantine coast. In the latest period of occupation of the site, beginning in the late 1st millennium CE, the glass was more heterogeneous, often with unclear sourcing. The exception is a single bead with origins in South Asia, potentially the Indo-Ganges region. The lack of glass with clearly Egyptian provenance in all periods is noteworthy.

The identification of the location of the workshop at which the majority of the beads were manufactured is more challenging. First, bead workshops might be small scale and have left little trace in the archaeological record. Second, a given bead workshop will likely share the composition of the glass it uses with other workshops that procured their glass from the same primary glass source. Therefore, chemical analysis alone is not able to characterize the bead production coming from one single bead producing center, at least in the ancient Mediterranean and Middle East.

The unusual glass compositions (notably, the high potassium soda-lime of the Hellenistic-Roman phase, and the high lead soda-lime of the Abbasid-Fatimid or later) found in small quantities of the Tel Anafa beads may point toward local production in a small-scale workshop. The dominant model for glass production in the ancient Mediterranean and Near East has been of primary production in a relatively small number of glass making workshops, largely located in Egypt and along the Levantine Coast, where raw ingredients of silica-rich sand and flux, either halophytic plant ash or natron, were readily available. A somewhat larger number of more local, or at least regional, secondary workshops, staffed by (semi-) professional and possibly itinerant glass workers, established in towns and cities, worked glass into objects using imported raw glass and/or collected materials for recycling (Jackson 2012; Rehren and Freestone 2015). Although the scale of production grew over time, perhaps transitioning from a more attached system centered in the palaces and temples of Egypt and Mesopotamia in the Bronze and Iron Ages to a system of greater free enterprise in the later first millennium BCE, the basic structure of the industry presumably remained unchanged. This model is based on archaeologically excavated workshops, scientific analysis, and experimental reproductions, primarily focused on vessels.

Recent experimental work suggests that—perhaps unsurprisingly—bead making may have been more ephemeral than vessel manufacture in the same period. Since 2014, Frank Wiesenberg, under the auspices of the Borg Furnace Projects at Villa Borg in Germany has built a series of wattle and daub wood-fired furnaces optimized for bead making (Wiesenberg 2018, 2020; see also www.glasofenexperiment.de). Wiesenberg has successfully replicated ancient bead styles using wood fuel over an open-top furnace which resembles the directed heat of a torch, rather than the enclosed furnace used by glass blowers from the Roman period through present. Furthermore, Wiesenberg is also documenting the weathering and destruction process of the furnaces. In fewer than five years, the bead furnaces have deteriorated significantly, leaving minimal archaeologically recoverable evidence. Relatedly, Hodgkinson and Bertram have demonstrated that beads of the type found in New Kingdom Egypt could have been manufactured in domestic workshops, using technology from metallurgy, leaving little to no trace in the archaeological record aside from the few glass rods such as have been found in domestic courtyards (Hodgkinson and Bertram 2020).

Indication of small-scale glass bead production in the Hellenistic period comes from Delos, one of the most extensively excavated Hellenistic settlements with a well-published glass assemblage. Assorted manufacturing debris of canes, tubes, rods, and plaques have been found in three structures in residential areas of the city, each presumed to represent a workshop context despite the lack of any indication of a firing structure (Nenna 1999: 159-165). An additional deposit of beads and debris, thought to represent an additional workshop dated to approximately 100 BCE, was discovered in the Aphrodision of Stesileos in 2006 (Douthe and Durvye 2016). A similar pattern holds true on Rhodes, where thousands of glass beads and associated bead-making debris were found in a late 3rd century–2nd century BCE deposit, with no associated pyrotechnical remains (Weinberg 1969; Triantafyllidis 2000). Very little is known about how these workshops would have been organized or administered. However, Nenna suggested that the Delos system, in which glass beads were made locally, was likely true for most Hellenistic cities, even though the archaeological literature has yet to fully document it.

Glass bead making in the ancient eastern Mediterranean could have been more common, more local, and more ephemeral than has been recognized. Interestingly, this model may hold true in both the late Hellenistic/early Roman and Abbasid/Fatimid stages of the site's occupation, given the unusual compositions of higher potash soda-lime and high lead soda-lime in those assemblages, respectively. Indeed, the use of multiple glass compositions within a single bead, as is seen in BD 40, BD 46, and BD 52c, indicates a much more complex system of glass provision and manufacture than has previously been recognized.

This is not to suggest that glass bead production necessarily took place at Anafa, where no rods, wasters, or other glass debris were identified during the excavation. However, only about 10% of the tel was exposed, and glass bead making or other industries may have taken place in another section of the site, such as the partially excavated structures on the south slope (Figure 17.1, trenches 3.1-3.4; see also Larson 2018a: 95–96). While it has long been suggested that there was a 2nd-1st century BCE glass workshop in the Hula Valley which supplied Tel Anafa and contemporaneous sites (Weinberg 1973), the only traces of such an industry we might expect to find, particularly for a bead workshop, would be wasters, scraps, and other manufacturing debris—not infrastructure such as furnaces or kilns.

For the most part, among the beads from Tel Anafa, the chemical composition of the glass does not correspond with bead shape, decoration, or manufacturing technique (see Table S17.1 and Figure S17.1). For example, the higher potash soda-lime glass appears variously in blue and black base glass, yellow and white trails and canes, in plain beads, eye beads, and trailed beads. Unusual typologies of a double trailed cylindrical blue bead, a chevron bead, and shell-shaped spiral pendants, types which are unique to Anafa or only found at sites within the Hula Valley and Upper Galilee, may be further indication of a local bead industry. Interestingly, only one sample from these 'local' types was composed of higher potash soda-lime glass. Therefore, although archaeological/typological study and scientific analysis both point to local industry, they do not align around specific objects, much less point to a discrete and identifiable 'workshop' (Costin 2020). More research and comparative data from other sites of the period are needed.

5. Conclusion

Analysis of glass beads from Tel Anafa generally conforms to what is known about glass production in the region during the periods the site was occupied. Analysis did reveal some surprises, including unusual glass compositions for some Hellenistic and Abbasid/Fatimid beads which may indicate local production, revised dating for several beads based on composition rather than context at this multiphase site (notably the identification of a rare Late Bronze Age glass bead), and the identification of a bead produced thousands of miles away in south Asia.

As chemical analysis of glass has become more precise and less expensive, researchers have been able to analyze larger quantities of material, revealing intricacies in assemblages that smaller sample sizes miss. Models of a generation ago, in which only a small number of objects from a site were selected for analysis, obscure a more nuanced picture. Nor is a representative sampling method always viable, as chemical composition does not map neatly onto macroscopic

identifications. The Anafa analysis results demonstrate the importance of analyzing larger quantities of material, and not assuming homogenous or representative composition from only a few results. Invariably, the rarer and more interesting compositions are likely to be missed. Projects like the Anafa beads, or Boschetti et al. on beads from Campo Marchione in late antique Italy (Boschetti et al. 2020), provide more representative results of the complexities of the ancient world.

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Chapter 18

South Asian beads at the site of Kish, Iraq

Laure Dussubieux[1]

1. Introduction

The Middle East is central to the history of glass as it is in Mesopotamia that the cradle of glass making was found (Moorey 1994:189-192). It is also a place where one of the earliest glass industries developed (e.g., Degryse et al. 2010; Shortland et al. 2018). Later, it became the epicenter of Islamic glass production, known for elaborate glass containers adorned in different ways using molded, relief cut or enameled decorations (e.g., Carboni and Whitehouse 2001; Walton 2012) that were exported all over the Indian Ocean (e.g., Carboni 2013; Perret and Jaafar 2014; Swann Needell 2018), the Mediterranean area (e.g., Gomes 2015; de Juan Ares and Schibille 2017) and beyond (An Jiayao 1991).

Middle Eastern glass is characterized by the use of soda plant ashes as a flux and a relative pure sand obtained from crushed quartz pebbles (Freestone and Gorin-Rosen 1999). Literature about various aspects of Middle Eastern glass is abundant, but few publications include or are dedicated to glass beads. Much research is needed to establish a chronology of glass beads found in the Middle East, to determine their provenance, to identify production centers, and to understand their circulation within the region and between the Middle East and surrounding areas. Regarding elemental characterization, data for glass beads produced in the Middle East were mostly obtained from artifacts recovered from sites outside this region that imported and consumed Middle Eastern beads. Two chronological periods were explored in depth: the Late Bronze Age and 1st millennium CE. A very specific elemental signature indicates that Middle Eastern glass beads were largely distributed starting during the Late Bronze Age, with findings in Egypt (Kemp et al. 2020), Northern and Eastern Europe (Varberg et al. 2015; 2016) and Southern Europe (Walton et al. 2009). Another massive diffusion of glass beads coincides with Islamic traders expanding their geographic reach around the Indian Ocean,

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starting at the end of the 1st millennium CE, with circulation along the east coast of Africa (Wood et al. 2012; 2017) and in South and Southeast Asia (Chaisuwan and Naiyawat 2009).

More unusual and unexplored is the idea that the Middle East could have been a destination for glass imports and more especially for glass beads manufactured in India. This article examines a group of beads from the Iraqi site of Kish. They are drawn beads manufactured in the way Indian makers were mass producing beads from drawn tubes. The glass compositions of these beads obtained using laser ablation – inductively coupled plasma – mass spectrometry (LA-ICP-MS) confirm their South Asian origin and reveal that bead circulation between India and the Middle East occurred over a long period, showing a sustained glass connection between the two regions.

2. Background

The site of Kish is located in what is now South-Central Iraq, about 80 km south of modern Baghdad and 12 km east of Babylon. The site, occupied from the Ubaid (6500-3800 BCE) to the Abbasid (750-1258 CE) period, extends 5 miles in length and 2 miles in width and was divided in the past by the ancient course of the Euphrates, which has since moved westward toward its current location. Kish is an important archaeological site as it was one of the earliest cities in the world.

For ten seasons, from 1923 to 1933, the site was excavated by a joint Oxford-Field Museum expedition directed by Stephen Langdon of Oxford University. Langdon spent very little time at Kish after he nearly died during one of his visits, but he was assisted by two successive field directors. Ernest Mackay was in charge of supervising the field work from 1923 to 1926. He left prematurely to excavate the great Harappan city of Mohenjo-daro in the Indus Valley. Charles Watelin, a French archaeologist replaced Mackay but unfortunately died shortly after the end of the 10th season of excavation. A consequence of this quick succession of excavation supervisors (and premature passing of one of them) is a very sketchy publication of the findings from Kish (Langdon 1924; Mackay 1929; Moorey 1978). Artifacts found at Kish during those ten excavation seasons were divided between the Iraq National Museum, the Ashmolean Museum in Oxford, and the Field Museum.

Among the 32,000 objects received by the Field Museum are a little more than 400 individual glass beads. Their state of preservation is extremely variable, from crumbling beads or fragments deeply affected by weathering to pristine-looking beads. This paper focuses on this latter group of beads. They all have in common small size (<2 mm to 5 mm), production by the drawn technique, cold cutting of

bead-size segments and polishing for a rounded finish. Their color range is limited and includes transparent amber, translucent turquoise blue, milky white, opaque green and black.

Information about the presence of similar materials in the Middle East is scarce. Francis (1989) reports that approximately 55 beads (37.9% of the total bead assemblage he observed at the British Museum) from Siraf, an Iranian port on the Persian Gulf occupied from the Sasanian period to the 11th century CE, were small monochrome drawn beads. Recent excavations at the port site of Sumhuram, Oman (300 BCE – 500 CE) yielded a number of beads featuring the same characteristics as the beads found at Kish: they are small monochrome drawn and rounded beads. However, the color range is slightly different: although it includes similar opaque green, translucent turquoise and black beads like at Kish, other colors such as opaque yellow, opaque red and translucent dark blue are also present (Lischi 2018). Small shiny monochrome drawn and rounded beads with a dark color, very similar to the black beads from Kish, were published by Morrison (1991) reporting on beads and seals of Shabwa in Syria (13th century BCE to 3rd century CE). Tel Anafa in Israel, a site with a principal occupation dating to the Hellenistic period (1st century BCE) but with earlier (Late Bronze Age) and later (Islamic) components, also yields a small translucent green drawn bead, different in color with the beads from Kish but similar in the manufacturing technique (Larson and Dussubieux, this volume). Small monochrome drawn and rounded beads seem much more abundant (or have attracted more attention) in what is now modern Egypt, Sudan, Eritrea and Northern Ethiopia. They were recovered at a range of port sites along the Red Sea such as Quseir (Egypt, Early Roman and Islamic periods), Marsa Nakari (Egypt, Late Roman period), Berenike (Egypt, Early and Late Roman periods), and Adulis (Eritrea), and also further inland such as at Shenshef (Egypt, 4th / 5th to 6th century CE), and Sikait (Egypt, Late Roman period), at many Nubian Nile Valley sites (4th to 6th century CE), and further south at the Aksumite sites of Aksum (Ethiopia, 3rd to 5th century CE) and Maryam Anza (Ethiopia, 4th to 5th century CE). The opaque green, opaque orange, and translucent turquoise blue colors are the most common with proportions varying geographically, with more green beads northward and more orange beads southward (Then-Obłuska 2021).

3. Materials and methods

Small drawn beads (n=122) were identified in 6 different catalogue numbers (Table 18.1; Figure 18.1), representing a little more than one quarter of the beads from Kish housed at the Field Museum. Catalogue number 156051 is a string

(the stringing for all the beads is modern) of 26 drawn beads comprising mostly tiny opaque green and a few translucent turquoise beads with diameters of 2 mm and below. One black bead and one turquoise bead are bigger with diameters of respectively 3 and 5 mm. Although no other type of glass bead is part of this string, a few carnelian beads and one quartz bead were combined with the drawn beads. No context info is available for this catalogue number. Catalogue number 228817 is a mix of mostly black drawn glass beads, glass beads of diverse shapes and colors obtained by different manufacturing technologies, and stone beads including carnelian. The drawn beads are mostly black, one bead is turquoise blue, and two beads are very pale in color and appear almost white. The Field Museum records indicate a possible post-Sasanian context for this catalogue number. Catalogue number 228825 is a string of glass beads including drawn beads, mostly black but also amber, blue turquoise and opaque green, and also segmented beads and wound beads. The contrast is striking between the drawn beads, which are shiny and look like new and the other beads (obtained with other techniques and not included in this study) that appear dark due to weathering affecting them all, although with different degrees of gravity. These beads were found in a post-Sasanian context. A post-Sasanian context was also associated with catalogue numbers 228853 and 229107. Catalogue number 228853 includes roughly as many black and turquoise blue drawn glass beads (respectively 7 and 9) combined with a few other beads (wound, segmented) and stone beads. Two additional catalogue numbers (228821 and 229107) contained small drawn beads from a post-Sasanian context.

Fig. 18.1: © Courtesy of The Field Museum, Cat. No. 156051, 228817, 228825, 228853 (starting top left and going clockwise) Photographer Laure Dussubieux (different magnifications were used).

Catalogue number	context info	list of drawn beads for this catalogue #	reference	color of analyzed beads
156051	no context	1 black (3 mm), 1 turquoise blue (5 mm), 5 turquoise blue and 19 green (< 2mm)	KIB103	black
			KIB104	opaque green
			KIB105	opaque green
			KIB106	opaque green
			KIB107	turquoise blue
			KIB108	turquoise blue
			KIB109	turquoise blue
228817	possibly Post-Sasanian	18 black (3 mm), 1 turquoise blue (4 mm), 1 turquoise blue and 2 milky white (2 mm)	KIB112	milky white
			KIB113	black
			KIB114	turquoise blue (2 mm)
			KIB115	milky white
			KIB118	turquoise blue (4 mm)
			KIB119	black
			KIB121	black
228825	post-Sasanian	32 black (2-3 mm), 4 amber (2 mm), 1 turquoise blue and 1 green (2 mm)	KIB164	black
			KIB169	black
			KIB175	black
			KIB177	amber
			KIB178	turquoise blue
			KIB181	amber
			KIB182	green
			KIB183	amber
228853	post-Sasanian	7 black and 9 turquoise blue (< 2mm)	KIB201	black
228821	post-Sasanian	10 black (2-3 mm) and 5 turquoise blue (< 2 mm)	not analyzed	
229107	post-Sasanian	5 black (2-3 mm)	not analyzed	

Table 18.1: List of the catalogue numbers including drawn and rounded monochrome glass beads from Kish with description and list of the objects analyzed with LA-ICP-MS.

A representative sample of 23 drawn beads was selected for LA-ICP-MS as indicated in Table 18.1. Beads from all colors were analyzed and only catalogue numbers 228821 and 229107 were not sampled because similar beads from a post-Sasanian context from other catalogue numbers were already included.

4. Results

The beads from Kish discussed here were analyzed at the Field Museum Elemental Analysis Facility in 2016 and 2017. See compositions in Table S18.1. For details about the instrumentation and protocol see Annex A. The reduced composition of the base glass was calculated, representing only the contribution of the sand and the flux (ingredient to lower the melting point of the silica rich ingredient), to eliminate the diluting effect introduced by the addition of coloring and/or opacifying ingredients. The constituents included in this reduced composition re-calculated to 100% are: silica (SiO_2), soda (Na_2O), magnesia (MgO), potash (K_2O), phosphorus oxide (P_2O_5), lime (CaO), alumina (Al_2O_3) and iron oxide (Fe_2O_3). For major and minor elements (Table 18.2), the results are fairly homogeneous, and all the beads are manufactured from a soda (Na_2O) glass. Low concentrations in magnesia (MgO < 1.5%) suggest a mineral source for the soda. Lime is low (CaO < 4.5%) whereas alumina (Al_2O_3) is fairly high with concentrations around 8% or higher suggesting the use of a high alumina sand.

	min	max
SiO_2	59.8%	70.5%
Na_2O	13.1%	21.6%
MgO	0.3%	1.4%
Al_2O_3	7.9%	10.9%
P_2O_3	0.05%	0.20%
K_2O	2.0%	4.3%
CaO	1.3%	3.4%
Fe_2O_3	1.1%	4.9%

Table 18.2: Reduced average composition of the drawn monochrome beads from Kish.

The glass identified among the beads from Kish is very similar to the mineral soda – high alumina or m-Na-Al glass. The m-Na-Al glass is a soda glass with high alumina concentrations (>5%) that was probably manufactured from a natural mix of an immature granite sand and soda rich efflorescence identified and assumed to be produced in India (Brill 1987) (see Annex B for more details). Initially, five different m-Na-Al glasses (m-Na-Al 1, 2, 3, 4 and 6) were identified based on the concentrations of the following constituents Mg, Ca, Sr, Zr, Cs, Ba and U (Dussubieux et al. 2010; Dussubieux and Wood 2021). Additional glass groups, including glass group m-Na-Al 11 (the only one of these new groups that is relevant here) were recently recognized from the study of material from the site

of Indor in Rajasthan, India, dating from the 14th century CE and onward (Trivedi and Dussubieux, this volume; in preparation). Using principal component analysis (PCA) and the GAUSS v. 8.0 software, provided by Archaeometry Laboratory at the Missouri University Research Reactor, the data obtained from the drawn beads from Kish were compared to reference data for m-Na-Al 1, 2, 3, 4, and 6. Figure 18.2 identifies 4 sub-types of m-Na-Al glass at Kish: 2 beads fall in the area for the m-Na-Al 1 glass, 3 beads correspond to the m-Na-Al 2 glass group, 13 beads belong to the m-Na-Al 6 group and 6 beads fall in an area where no reference data are present. These 6 samples have a composition corresponding to m-Na-Al 11 (Table 18.3). Bead KIB177 plots close to the Kish beads in group 11. This bead contains more uranium than the other beads (24 ppm) in this glass group. KIB177 is an amber bead identical visually to beads KIB181 and 183 in the m-Na-Al 6 glass group. They are all colored the same way. They all contain 3.5 to 3.9% of iron (as Fe_2O_3). The uranium concentration of KIB177 is in the lower range for m-Na-Al 6 glass. Bead KIB177 seems to fit better in glass group m-Na-Al 6.

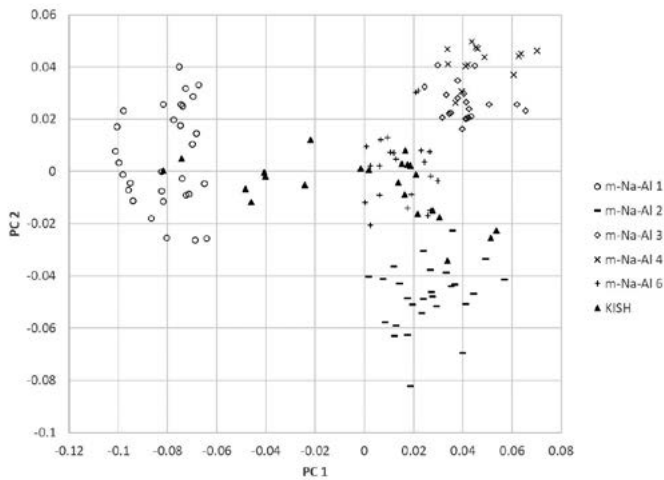

Fig. 18.2: Principal components 1 and 2 were calculated using the concentrations of MgO, CaO, Sr, Zr, Cs, Ba and U for samples belonging to glass groups m-Na-Al 1, 2, 3 4 and 6 and for the samples from Kish. The m-Na-Al 1 glass samples are unpublished data from Sri Lanka and South India, the m-Na-Al 2 glass samples are beads from Chaul (Dussubieux et al. 2008), the m-Na-Al 3 glass samples are beads from Kopia (Dussubieux and Kanungo 2013), the m-Na-Al 4 glass samples are glass vessel fragments from Sumatra (Dussubieux 2009) and the m-Na-Al 6 glass are from the site of Juani Primary School (Dussubieux and Wood 2021).

The m-Na-Al 1 glass was manufactured in South India and Sri Lanka as demonstrated by the combination of archaeological evidence, elemental compositions, and Sr and Nd signatures of glass found in those regions (Dussubieux

et al. 2021). For a better understanding of the chronology and the diffusion of this glass, it is necessary to turn to research conducted outside of South Asia. The m-Na-Al 1 glass was widely distributed and spanned more than a millennium. Although the production of this glass seems to have started around the middle of the 1st millennium BCE (Dussubieux et al. 2010), it appears in large quantities in Southeast Asia at the very beginning of the 1st millennium CE (Carter 2015) and became one of the main glass types in this region until the very beginning of the 2nd millennium CE (Carter 2015; Carter and Lankton 2012; Dussubieux and Allen 2014).

Around the Indian Ocean, travelling westward, its presence is more subdued. On the east coast of Africa, only one site has yielded a significant number of m-Na-Al 1 beads: Unguja Ukuu, 7th to early 11th century, located on the Island of Zanzibar (Wood et al. 2017; Sarathi et al., this volume). Isolated finds (one single bead) appeared at Ungwana, 9th – 16th century, on the Kenyan coast (Dussubieux et al. 2008:814) and Mahilaka, 9th – 16th century in northwest Madagascar (Robertshaw et al. 2006).

Northward, the m-Na-Al 1 glass beads seem to have travelled through the Red Sea. At the port of Quseir, a single opaque yellow m-Na-Al 1 glass bead was identified. Coming from an Islamic context (14th century CE) it was interpreted as a Roman period object re-used during the Islamic period (Then-Obłuska and Dussubieux 2016). A number of m-Na-Al 1 glass beads were also found in the Nubian Nile Valley region, dating the 4th – 6th century CE (Then-Obłuska and Wagner 2019a, b). Potentially many more m-Na-Al 1 glass beads could be present along the Red Sea, based on glass typology (Then-Obluska 2021). Further west, thousands of m-Na-Al 1 glass beads produced with the drawn technique were found recently at a number of Merovingian cemeteries dating from the 5th to 6th century CE located in France, Belgium, the Netherlands, Germany, Switzerland, Spain and Serbia (Martin Pruvot and Gratuze 2019; Pion and Gratuze 2016). Although a wide range of colors was available for these beads (yellow, black, orange with a red core, red and green), green is by far the most common color.

Initially, the m-Na-Al 2 glass was identified at sites dating from the 9th to the 19th century CE, located on the west coast of India and the east coast of Africa (Dussubieux et al. 2008). Recently, additional analysis of more beads from the east coast of Africa refined the chronology for this glass and suggested an occurrence from the 14th century CE onwards. It has been established that the Indo-Pacific Khami beads from Southern Africa and the m-Na-Al 2 beads found on the Eastern Coast of Africa shared the same composition and can be now both assigned to a period starting around the 14th century CE (Dussubieux and Wood 2021). It has already been suggested that Chaul in Maharashtra could have been an entry point

for these beads into the Indian Ocean trade, and possibly a place of manufacture (Dussubieux et al. 2008; Gogte et al. 2006). Glass beads made in "Chiawle" (interpreted as Chaul) that the Portuguese would bring to ports along the east coast of Africa are mentioned in the travel account of Caesar Frederick (Federeci and Hickock, online), a Venetian merchant who visited the western part of India in the 16th century CE. Also, Seshan (2019) mentions the trade of glass beads departing from Chaul to Persia, Mozambique and China during the 16th – 17th century CE, indicating a certain importance of this item of trade. A recent study using Sr, Nd and Pb isotope analysis suggests that although the m-Na-Al 2 glass beads might have been indeed manufactured in Maharashtra at such a site as Chaul, the raw glass was quite likely procured from a different region, possibly in the west part of Uttar Pradesh (Dussubieux et al. 2021). The m-Na-Al 2 glass beads have been abundantly distributed in Southern Africa and along the Eastern Coast of Africa and they can also be found in Southeast Asia.

	MgO	CaO	Sr	Zr	Cs	Ba	U
m-Na-Al 1	**0.70%**	**2.50%**	**333**	**502**	**0.5**	**895**	**9**
	0.70%	1.10%	86	140	0.3	290	9
Kish	**0.36%**	**3.32%**	**342**	**549**	**0.6**	**746**	**7**
	0.05%	0.14%	9	0	0.1	27	1
m-Na-Al 2	**1.00%**	**4.80%**	**233**	**153**	**0.6**	**353**	**110**
	0.20%	0.90%	52	66	0.3	87	41
Kish	**0.66%**	**1.67%**	**163**	**243**	**0.6**	**388**	**240**
	0.62%	0.65%	59	48	0.1	29	70
m-Na-Al 3	1.30%	2.50%	121	145	3.4	357	58
	0.20%	0.40%	25	36	0.6	122	22
m-Na-Al 4	0.80%	1.30%	99	298	3.7	635	107
	0.20%	0.50%	25	61	0.8	260	39
m-Na-Al 6	**0.80%**	**2.50%**	**235**	**216**	**1.5**	**402**	**57**
	0.20%	0.70%	88	35	0.4	166	22
Kish	**0.52%**	**2.48%**	**223**	**293**	**1.2**	**422**	**78**
	0.10%	0.41%	44	70	0.3	57	28
m-Na-Al 11	**0.65%**	**2.63%**	**200**	**207**	**0.8**	**388**	**14**
	0.19%	0.98%	74	60	0.3	130	5
Kish	**0.55%**	**2.58%**	**248**	**173**	**0.7**	**349**	**11**
	0.21%	0.53%	89	54	0.3	101	3

Table 18.3: Comparison of the average concentrations for diagnostic oxides or elements in the different m-Na-Al groups and in the samples from Kish attributed to group 1, 2, 6 and 11.

The m-Na-Al 6 was recently identified. Like all the other m-Na-Al glass it is expected to have been manufactured in India although concrete archaeological evidence for that is still missing; however, the fairly high strontium isotope ratio measured for this glass (Seman et al. 2021) matches the strontium isotope signatures found in the east part of Uttar Pradesh. The m-Na-Al 6 glass was identified based on material found on the Eastern Coast of Africa where it was assigned a period ranging between the 9th and the 13th century CE. The m-Na-Al 6 glass beads from the Eastern Coast of Africa have the same composition as the Indo-Pacific K2 and East Coast beads identified earlier (Dussubieux and Wood 2021) that belong to a slightly shorter time window (10th – 13th century CE). Our understanding of the diffusion of this glass is still partial due to its very recent discovery. M-Na-Al 6 beads are extremely abundant in Southern and coastal East Africa, and this glass type was certainly distributed in Southeast Asia, where it was previously mistaken for m-Na-Al 2. Interestingly, m-Na-Al 6 glass was identified at the Samdzong site located in upper Mustang, Nepal, dating from the 450-650 CE period (Aldenderfer and Dussubieux, this volume). This could suggest a production prior to the 9th century CE. At that time distribution seems limited to South Asia, perhaps only northern South Asia. After approximately the 9th century CE, the Indian Ocean market would have been available to circulate the m-Na-Al 6 glass more widely.

The m-Na-Al 11 glass group was found at the site of Indor, Rajasthan, India, dating from the 14th century CE and onward. The geographical and chronological distribution of this glass is poorly known as it was recently discovered. This glass type was also spotted at Antsiraka Boira, Mayotte dating from the 12th to 13th century CE period (Wood et al., this volume)

5. Discussion

This study demonstrates that some glass beads found at Kish were manufactured in South Asia. Four different sub-groups of Indian glasses were identified in the bead compositions, indicating different production periods and distribution routes (Table 18.4). The results obtained through elemental analysis are consistent with the beads' manufacturing technique: they are all small drawn and rounded glass beads. In India, industrial scale proportions of such beads were manufactured using a very efficient technique, known as the *lada* process, which created drawn tubes that were broken or cut into bead lengths once the glass was cool. The resultant segments were reheated to obtain drawn and rounded monochrome glass beads. Kanungo (2016) provides a recent and comprehensive ethnographic account of the production of *lada* drawn beads in India.

Catalogue number	Context	Glass type (with number of samples in each)	Sample name
156051	no context	m-Na-Al 1 (2)	KIB107 and 108
		m-Na-Al 11 (5)	KIB103, 104, 105, 106, 109
228817	possibly Post-Sasanian	m-Na-Al 2 (2)	KIB112 and 115
		m-Na-Al 6 (5)	KIB113, 114, 118, 119 and 121
228825	Post-Sasanian	m-Na-Al 2 (1)	KIB178
		m-Na-Al 6 (7)	KIB164, 169, 175, 177, 181, 182, 183
228853	Post-Sasanian	m-Na-Al 6 (1)	KIB201

Table 18.4: Recapitulation of the glass type attribution for all the samples analyzed with LA-ICP-MS.

5.1. Possible chronology

Catalogue number 156051, for which no context information is available, included two beads with a m-Na-Al 1 composition. The five other beads from the same catalogue number belong to the m-Na-Al 11 glass group. The m-Na-Al 1 beads were distributed temporally and spatially far and wide, although it seems that the timing of the diffusion is different depending on the direction. These beads are found very abundantly in Southeast Asia throughout the whole first millennium CE until the 11th century CE. Going the opposite direction, the distribution follows different patterns. Before the 9th century CE, glass beads are rare on the Eastern Coast of Africa. One of the earliest significant glass bead findings in this area, at the site of Unguja Ukuu on the Zanzibar Island dating from the 7th to the 11th CE comprised a large proportion of m-Na-Al 1 glass beads, but this is a very unique occurrence (Wood et al. 2016; Sarathi et al., this volume).

Another route seems to have transported beads from India through the Red Sea starting at the beginning of the 1st millennium CE. M-Na-Al 1 beads seem to date from the 4th to 6th century CE in the Red Sea region (Then-Obłuska and Wagner 2019a, b) and from the 5th to 6th century CE in Europe (Pion and Gratuze 2016), which could suggest a more intense circulation of these beads from South India/Sri Lanka, through the Red Sea in the direction of Europe around the mid-1st millennium CE. The more important availability of the m-Na-Al 1 glass beads for the international trade around the 4th to 6th century CE observed through findings in the Red Sea region and in Europe might indicate a stronger probability that some of this production was also directed toward the Sasanian Empire possibly through the Persian Gulf around the same period. Based on the data available at

this time, the m-Na-Al 11 glass seems to be associated with later periods (12th century CE and onward). This conflicts with the dating of the m-Na-Al 1 glass beads in the same catalogue number, and therefore by inference, archaeologically associated with these m-Na-Al 11 glass beads. Further research could reveal that the m-Na-Al 11 glass group was manufactured over a longer period extending in the first millennium CE. Conversely, we cannot exclude that the context of the beads was 12th century CE or later and the m-Na-Al 1 were heirlooms.

For the other catalogue numbers, the m-Na-Al 6 and m-Na-Al 2 glass were found together in a possibly post-Sasanian context. Assuming no stratigraphic disturbances, the presence of two chronologically distinct glasses could indicate either that the deposit dates from the transition period between the two glasses (13th to 14th century CE) or that the older beads were curated and were used with newly acquired ornaments, dating the finding to the 14th century CE or later. These two options place the beads in a later period than a Post-Sasanian context would entail (right after the 7th century CE). Notably, the 13th to 14th century CE corresponds to a period of expansion of the Mongols and the establishment of the Ilkhanate over a region going from modern Pakistan to Turkey, possibly facilitating and stimulating exchange between South Asia and the Middle East. Ilkhanid ceramics were found at and around Kish (Gibson 1972).

5.2. Further considerations on the circulation of beads between South Asia and the Middle East

Other research of glass beads from Kish (Dussubieux 2021) indicated that a string of translucent dark blue, opaque green and yellow beads dating from the 2nd to 1st century BCE (catalogue number 228806) were made from a glass type likely manufactured somewhere in South or Southeast Asia. This previous study showed an early circulation of glass beads from South or Southeast Asia to Iraq that started at the end of the 1st millennium BCE. The present study is showing that these exchanges continued during the first millennium CE and possibly beyond.

As early as the 3rd millennium BCE, Mesopotamia imported from India a range of goods that included hard woods, metals, semi-precious stones, shell, ivory and animals (Lahiri 1992; Pearson 2003; Ratnagar 2004). The glass beads found at Kish were found with other types of beads, including carnelian beads. Four of these carnelian beads, from catalogue number 228817 (which contained 6 glass beads of group m-Na-Al 2), were analyzed using LA-ICP-MS. The carnelian beads' compositions were compared to those of geological samples collected from two sources from the Deccan Trap located in Gujarat (Mardka Bet and Ratanpur) and some samples found at Shahr-i-Sokhta in eastern Iran assumed to have a local origin (Carter and Dussubieux 2016). Comparison of the carnelian bead

compositions was carried out using principal component analysis (PCA) and the GAUSS software with the following elements: Na, Mg, Fe, Be, B, As, Nb, Sb, Cs, Ta and U. Out of the four carnelian beads tested, one has a composition close to that of Shahr-i-Sokha, one cannot be associated to any of the three sources available for comparison and two of them can be attributed a Mardka Bet origin. The latter could indicate that glass and carnelian beads might have followed similar trade routes and reached Kish in the same cargo.

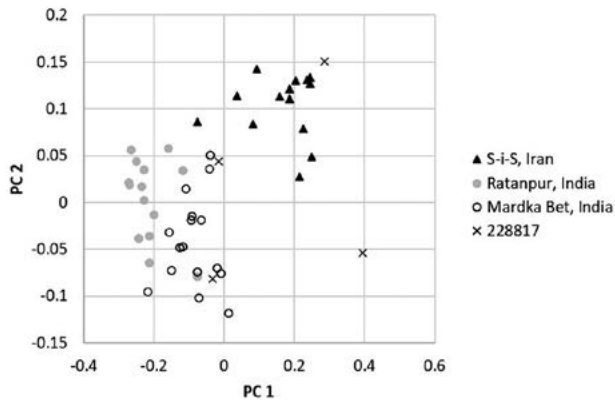

Fig. 18.3: PC1 vs PC2 calculated using Na, Mg, Fe, Be, B, As, Nb, Sb, Cs, Ta and U for carnelian samples taken from different sources: Mardka Bet and Ratanpur in Gujarat, India and Shahr-i-Sokhta in Iran and four beads from catalog number 228817.

It is well established that the Sasanian Empire traded with India and Sri Lanka but the goods acquired in South Asia are usually qualified as "luxury goods." Glass beads generally are not categorized this way; however, silk (originally from China) is listed in the goods traded between Sri Lanka and the Sasanian Empire (e.g., Frye 1993; Malekandathil 2002). One could assume that silk, with embroidery including glass beads (especially the tiny ones) was traded instead of the beads by themselves. The Indian beads of m-Na-Al 1 compositions found in European burial contexts were arranged in ways indicative of use as part of the decoration of the clothing worn by the deceased, rather than strung into jewelry such as necklaces or bracelets (Martin Pruvot and Gratuze 2019; Pion and Gratuze 2013).

It is quite likely that the small monochrome drawn and rounded beads had a wider distribution in the Middle East than is represented in the archaeological record. The beads are fairly small (sometimes less than 2 mm), making their recovery difficult in the absence of fine mesh sieving. Additionally, unlike

ceramics or other classes of artifacts, beads have generated little interest. In generally, they suffer from low recovery rates and poor context recording, except for burial features, which demand a more delicate excavation approach and where these beads appear often clustered, making them more visible.

6. Conclusion

This study demonstrates that glass beads in Iraq at the site of Kish were imported from India, based on elemental composition. The lack of precise archaeological context information limits the interpretation of this finding; however, results are showing that the beads from catalogue number 156051 exhibit a different pattern from that of the beads that are part of the other catalogue numbers included in this study. Catalogue number 156051 reveals a recently identified m-Na-Al 11 glass type and two m-Na-Al 1 glass beads, the only ones identified in this study. Comparison with similar material found in the Red Sea area and in Europe suggests that the m-Na-Al 1 beads from catalogue number 150651 are dating from the 5th to 6th century CE.

The beads that are part of catalogue numbers 228817, 228825 and 228853 have m-Na-Al 2 and 6 compositions that are found around the Indian Ocean at sites respectively dating from the 14th century CE and onward and from the 9th to the 13th century CE, suggesting later dating for these beads. These beads could date from the Ilkhanid period (13th-14th century CE).

The presence of carnelian beads with a composition matching that of a source located in Gujarat could suggest that both types of beads left through the same Indian port. Although it is uncertain at this point where the m-Na-Al 6 beads were manufactured in India, concurring evidence indicates that m-Na-Al 2 glass beads transited through the port of Chaul in Maharashtra for distribution around the Indian Ocean.

Other researchers have shown that Indian beads were travelling through the Red Sea (Then-Obłuska and Wagner 2019a, b). The present study indicates that a route through the Persian Gulf was certainly another possibility. More work, which could include the small drawn beads from Siraf, a port on the Persian Gulf, will be necessary to confirm that and clarify the chronology of beads from India (and possibly Sri Lanka) around the Persian Gulf. This study shows the need to re-evaluate old collections excavated decades ago in the Middle East for similar materials. The possibility of a new m-Na-Al glass group (m-Na-Al 11) to add to the 5 other groups already identified will also need further investigation to confirm its chronology and delimit its area of diffusion and exact provenance.

This study of beads from Kish more firmly established the global status and distribution of these small drawn and rounded monochrome beads manufactured in India. This type can be found in every corner of the Old World, showing that ancient trade networks were far reaching and circulated articles as unassuming as those beads. It is all the more surprising to find these beads at Kish, since Iraq at that time was the location of numerous glassmaking and glass-working workshops able to manufacture sophisticated glass objects locally. Although the Indian beads might not have looked spectacular taken individually, they might have been part of the decoration of precious textiles that were certainly considered as prestige goods due to their overall beauty, scarcity and remote provenance.

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Chapter 19

Technology, chronology, and exchange examined through glass beads

Heather Walder[1] and Laure Dussubieux[2]

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

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 multi-directional 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.

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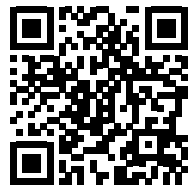
Appendix
Supplementary Materials



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