

Unwinding the Beads: novel approaches to the production,
use and life-histories of glass beads

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Abstract

The tangibility, mobility, and attractiveness of glass beads make highly personal objects that often bore significant meaning for those who made, wore, and used them. This thesis presents novel methodologies for the interdisciplinary archaeological and scientific study of glass beads, and new ways of approaching their meaning, object biography, and value.

In particular, techniques for conducting and interpreting use-wear analysis on glass, which has been undertaken very rarely to date, are developed via a combination of laboratory-based techniques and the wearing of replica beads by voluntary participants. The replication of glass beads using traditional technologies and wood-fired, hand-made furnaces, provides insights into the relationship between making, understanding, and using glass beads. It also raises questions about past archaeological approaches to bead typology, and about the archaeological visibility (or lack thereof) of furnaces.

The methods are applied to two distinct archaeological case studies. In the first, glass beads from burial contexts in Iron Age Abruzzo, Italy, are examined in terms of their colour, meaning, sensory properties, and value. In the second, glass beads from 1st millennium BCE to 1st millennium CE sites in the Wadi al-Ajal, Libyan Sahara, are examined from the perspective of use-wear analysis and chemical composition. These case studies are then examined in the broader context of the archaeological interpretation of glass beads, and new ways forward are suggested for the field.

The results illustrate the intertwined relationship – and perpetual dialogue – between manufacturing technology, use, and symbolic meaning. The holistic approach employed sheds light on the need to consider this dialectic in the study of glass beads, and archaeological artefacts more widely.

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Covid Impact Statement:

The original thesis project featured as only data set the glass beads from the burial sites of Fossa, Bazzano and Campovalano (Abruzzo, Italy) and the subsequent use-wear and chemical analysis of selected beads by pXRF, with LA-ICP-MS to be applied on a sub-sample set. The deriving results were meant to be interpreted through the lens of funerary archaeology and theoretical approaches on personhood. The Covid-19 outbreak has affected all my experimental and primary data collection activities, which were finally completed in February 2022, delaying this step in my research by over two years. Even though from September 2021 onwards it would have been technically possible to travel to Italy to undertake use-wear and chemical analysis on the glass beads, this was not really feasible in terms of timeframe, as at that time disruption to regular opening times of the museums still persisted, causing in the medium and long term even further delays to my project. In addition to that, use-wear analysis of experimental beads was also considerably slowed down in 2021, due to restricted access and closures in the first six months of the year. My supervisory team has been extremely supportive throughout, helping me to find ways to mitigate the impact of the pandemic and providing me with a new archaeological data set I could work on to successfully complete my PhD. To compare and contrast the results from use-wear analysis on experimentally generated replicas, in September 2021 I started working on glass beads from Fazzan, Southern Libya, which were already in possession of Dr Chloë Duckworth as part of assemblages that she chemically analysed and published. As a result, I also had to completely re-design the overarching rationale of the project and related research questions as now I had to merge two data sets that are not only geographically and chronologically distant, but also pertain to completely different contexts, on the one hand with the glass beads from burial sites in Italy dating to the 1st millennium BCE, and on the other hand the beads retrieved from settlement sites in Fazzan, with their broad chronology (1st millennium BCE – 1st millennium CE). In addition to that I also had to find a way to justify the adoption of theoretical frameworks around the material properties of glass and colour and the choice of use-wear analysis as a technique, opting for a case-study approach that allows me to draw wider considerations on glass beads as a category of artefacts in its own right.

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Chapter 1. Introduction

Glass beads have been made, worn, traded, and discarded for over three millennia. They have travelled across oceans, cultural contexts, and – as heirlooms or archaeological artefacts – through time. Due to their vast geographical and cultural scope, glass beads are usually studied within a particular anthropological or archaeological context, yet there are certain elements of the materiality of these fascinating objects which are universal – or at least widespread – across the category. The material affordances of glass – particularly its ‘hot-working’ potential and limitations, its sensory properties (colour, sound, thermal conductivity), and its degradation (wear, corrosion) – coupled with the transportability and value-shifting potential of beads mean that there is much to be gained from studying this object category across different cultural contexts.

To take one example of why it is important to fill this niche, we might consider archaeological typologies. The individual who studies the glass beads of a particular location or time period is most typically also a specialist in a range of other material and object categories. They may not be aware, for example, of the importance of understanding the manufacturing process of glass beads when considering which features of a bead are diagnostic of a particular category. Is the choice of whether to place three or four ‘eyes’ on a bead down to the way an individual was trained, or the vagaries of operating an ephemeral, outdoor bead-furnace? Such considerations require cross-cultural examinations of the object form, as well as experience of the manufacture of glass beads.

To take another example, we might consider use-wear, which for glass beads can reflect everything from where they were worn, to how long they were in use and what other materials surrounded them. Although the chemical properties of glass may vary, the majority of archaeological glass beads across the globe are of either the soda-lime-silica, or lead-rich types, meaning that the physical properties of hardness and brittleness remain broadly consistent within these categories. Use-wear analysis has shed great light on the function of metal and stone tools, but is still in its infancy when applied to glass. In developing this technique for the examination of glass beads, therefore, a global outlook can be an advantage, offering the potential for cross-cultural examination of the effects of use on the beads recovered archaeologically, and creating a platform from which future studies might proceed. Archaeology is at its best when it combines long- and short-term

perspectives, and considers the cultural and material, the local and the global. In the course of researching this thesis, I have conducted numerous practical experiments and multi-disciplinary investigations into the manufacture, use, meaning, discard and wear of glass beads from different cultural contexts. In the following pages, I present the findings I have made from use-wear analysis, experimental reconstruction of beads and bead furnaces, theoretical examination of the meaning of colour in glass beads, and archaeological analysis of beads in funerary and other contexts. The result is new ways of looking at glass beads from archaeological and historical contexts, which will act as a springboard for future studies, be they global or site-specific.

1.1 Scope/Rationale

By re-tracing the main 'life events' in the histories of glass beads, such as their production, use(s), discard in antiquity and current biographies, this thesis proposes new ways to look at this object category. But should we really talk about object biographies, as the concept of life-history presupposes a linear trajectory, with a beginning and an end point (Joyce & Gillespie, 2015)? In an attempt to examine glass beads from a holistic perspective which could take into account manufacture technology, use and symbology, a tool-kit was developed and applied to two separate case-studies: i) pre-Roman burial sites in Abruzzo, Italy for investigations on colour and ii) Garamantian settlement sites in south-western Libya for use-wear analysis.

If object biographical approaches are well established in archaeological studies, more often than not, when it comes to glass beads, their life-histories still tend to be tied to the idea of economic value, with a perspective that is still skewed on Western, capitalist societies and related modes of production and consumption (Appadurai, 1986; Kopytoff, 1986). The present work aims to move away from constructs that categorise beads as commodities by focusing on how their materiality and material properties may affect (through sensorial perception and their ability to elicit emotions) their symbolic meaning – and in this sense – value. Colour, shine and durability are some of the main attributes of glass beads, which mostly certainly shaped the way they were made, kept and possibly curated. Sensorial approaches to glass are novel, and the available literature concentrates either on colour in specific geographical and cultural contexts or discusses glass and the senses in broader terms (Duckworth, 2012, 2020a). In order to be able to explain the importance of colour in relation to glass beads, this thesis will explore the cross-cultural and culture-specific

implications of colour across different categories of materials using multi-faceted approaches, ranging from human biology to ethnography. This provides us with a different viewpoint from which to study glass beads and their place in past societies: as glass may have been likened to other materials in virtue of its properties and inner essence, and as such it may have had specific and multiple roles in the negotiation of identities, either as standalone agent or in conjunction with other substances. This particular perspective was applied to the study of colour distribution and patterns for approximately 3000 beads from assemblages from the 1st millennium BCE sites of Campovalano, Fossa and Bazzano, Abruzzo (Italy).

If this approach covers the meaning and symbolic use of beads, what about the practical implications of crafting and wearing such artefacts? If the societies that made beads may not necessarily be the final consumers, it is still important to understand manufacture processes, because they also underpin patterns of use and further symbolic thought. This is where experimental archaeology and use-wear analysis come into play, as they mutually complement each other in allowing us to come to grips with the constraints of glass as a material when worked but also to create reference collections of beads that can be used to assess wear formation through experiments. As use-wear analysis has hardly been applied to glass beads, the aims were twofold: on the one hand, I wanted to provide a sound methodology that could act as a springboard for future studies, whereas on the other hand, I had to test the limitations of this technique, both on replica bead sets and on archaeological beads from Fazzan.

1.2 Thesis Structure

The thesis is divided into three parts: part 1, which comprises Chapters 2 and 3, is concerned with topics around the manufacture of beads and the main characteristics of glass as a material, laying the foundations for further discussions on bead production as well as use. Chapter 2 focuses on the key concepts behind the science, technology and production of glass beads. The starting point is the bead-making *chaîne opératoire*, or the sequence of actions characterising the manufacture of glass beads in ancient and contemporary societies (Section 2.1). The affordances and behaviour of glass as a material from a chemical, physical and mechanical standpoint are analysed in Sections 2.2-2.4, as they will be relevant to the application of use-wear and chemical analyses to glass beads, which are presented respectively in Chapters 4 and 5 (Appendices D,E) and in Appendix C. The focus of this

chapter will subsequently shift onto the archaeology and ethnography of glass bead-making: as the *chaîne opératoire* cannot be entirely separated from other aspects such as glass manufacture, types of furnaces, and tools used in the production processes, these will also be touched upon.

Experimental archaeology and ethnography are indeed helpful tools to shed further light on bead-making and the use of furnaces apt for the purpose; however, we have to take this evidence with a pinch of salt, as there are risks of creating preconceptions around what a furnace should look like and how it should be operated. This point is addressed in Chapter 3, which discusses my personal experiences and reflections as an occasional bead-maker who crafted beads using a modern lamp as well as natural draft furnaces. Section 3.3 provides an overview of the role of experimental archaeology in the acquisition of valuable information with regards to bead-making as a practice and in its application in the manufacture of beads used in the necklace wearing experiment.

Part 2, which comprises Chapters 4 and 5, explores the potential of use-wear analysis of experimental and archaeological data-sets. Chapter 4 focuses on the development of use-wear analytical techniques on replica glass beads, which are used here as a reference collection. Sections 4.1-4.4 introduce use-wear analysis as a discipline, highlighting the research carried out up to the present day on obsidian and glass artefacts, including beads. Particular attention is dedicated to current problems within the field, as they informed me on how to build an effective framework for the interpretation of traces of wear on glass. Sections 4.5 and 4.6 describe the set-up and rationale for the glass bead wearing experiment and related recording of traces, whereas Sections 4.7 and 4.8 outline the protocols implemented for the cleaning, recording and categorisation of traces on bead datasets, with the main types of wear found on obsidian also being reported for comparison. A description of the various traces encountered on replica glass beads employed in the necklace wearing experiment is provided in Sections 4.9-4.10, alongside an explanation of their underlying mechanisms; the variables that contributed to wear formation — in particular polish — are also taken into account in Section 4.11. The results from this chapter (Section 4.12), are employed to inform our interpretation of traces of wear by use on archaeological specimens from Wadi al-Ajal (Fazzan, south-west Libya) discussed in Chapter 5. Here an archaeological background to the sites and related contexts containing beads is provided in Section 5.1. Research questions, sample selection criteria and limitations of the dataset are explored in

Sections 5.2-5.3. The traces of wear and manufacture, and the surface alterations due to degradation found on archaeological specimens have been analysed following the same methodology and categorisation of traces employed for the experimental replicas (Sections 5.4-5.10). The conclusions highlight that in the case of the use-wear traces on glass beads from Fazzan, their legibility is influenced by post-depositional polishes and other phenomena such as surface degradation due to corrosion (Section 5.11).

Part 3 discusses novel approaches to the symbology of glass beads. As colour is perhaps one of the most important and meaningful attributes of glass beads in the construction and negotiation of identities, Chapter 6 aims to define and discuss colour perception in relation to objects and raw materials at the intersection of nature and culture as biological, neuropsychological and linguistics approaches are employed (Sections 6.1-6.5). Colour is examined through the lens of ethnography, sensorial archaeology, affect and memory: the emphasis is placed on attributes such as brilliance which can be considered cross-cultural and to some extent 'cross-material' as they are integral to various artefacts, including glass and glass beads (Sections 6.6-6.11). The content of this chapter acts as theoretical scaffolding for the interpretation of the data around the use of colour among pre-Roman communities in Abruzzo in Chapter 7. The latter is similar in structure to Chapter 5, as Sections 7.1-7.4 introduce the archaeological context of the three Iron Age burial sites of Bazzano, Fossa and Campovalano. Sections 7.5-7.6 illustrate the rationale behind the sample selection criteria alongside the research questions and methodologies employed in the analysis of bead colour distribution and incidence within and across the cemetery sites used as case-studies. The colour of glass beads (and related combinations) is then analysed site by site for each period, taking into account bead configuration as well as ages, sexes and genders of the individuals who were interred with glass beads (Sections 7.7-7.10).

The final discussion and conclusions are contained in Chapter 8, which provides further insights into glass beads as an object category. The manufacture and use of glass beads from the Wadi al-Ajal are discussed with reference to experimental archaeology, bead and glass-making technologies. In addition, use-wear analysis results from experimental and archaeological datasets are compared (Sections 8.1-8.2). An in-depth exploration of the potential meaning(s) of glass beads from pre-Roman Abruzzo is presented in Sections 8.3-8.5, where the relationship between bead colours and shapes regarding specific forms of identity is investigated. Given the multi-faceted nature of the evidence provided in the

present work, Section 8.6 proposes an alternative model for the conceptualisation – and also study – of glass beads and their trajectories. Finally, recommendations for future work are provided in Section 8.7.

PART I. Glass bead-making and glass as a raw material

Chapter 2. Science, technology, and production of glass beads

This chapter discusses how glass beads are made: by doing so, this helps us to understand glass and bead-making technology, which in turn allows us to explore how glass beads are used. As such, the starting point of this chapter is a reconstruction of the bead-making *chaîne opératoire* based on the archaeological and ethnographic evidence. As the artificial nature of glass has an impact on how it can be worked to obtain beads and other objects but also on its ability to withstand mechanical stress due to use and degradation processes through time, the chemical, physical and mechanical characteristics of this material will be discussed as well in Sections 2.2-2.4. For the remainder of the chapter, glassmaking and bead-working sites alongside furnaces will be discussed, not only in terms of what survives archaeologically but also looking at traditional societies and crafts from India, Africa and the Mediterranean.

2.1 The *chaîne opératoire* of glass bead-making

Due to their relative simplicity of their manufacture, beads are among the earliest artefacts to have been crafted from glass by hot-working. Although glass beads were initially produced in a sporadic manner as early as 2500 BCE in Mesopotamia, these were not formed through hot-working, and were most likely accidental by-products of other technological processes, such as metal smelting (Peltenburg, 1971). The first deliberately-produced hot-worked glass beads arrived in Mesopotamia and Egypt approximately a thousand years later, in the mid-second millennium BCE (Shortland et al., 2018; Henderson, 2013, p. 8; Moorey, 1999, p. 190; Stern & Schlick-Nolte, 1994, p. 86). Since then, according to the manufacturing method applied, specific tools and structures have been employed in the production of beads: nevertheless, the main steps in the process of bead-making (*chaîne opératoire*) have remained unaltered for millennia (Figure 2.1). The starting material consists of pre-made glass, which is then worked more often hot than cold (Spaer, 2001, p.45). This glass is usually produced in purpose-built furnaces, but it can also be obtained by recycling local or imported scrap glass (Babalola, 2017). In the case of the modern powder glass bead industry of Ghana, finished products such as glass bottles or containers are employed in the making of the beads, and at times broken beads are also re-used (Lamb, 1976; Liu et al., 2001; Haigh, 2003).

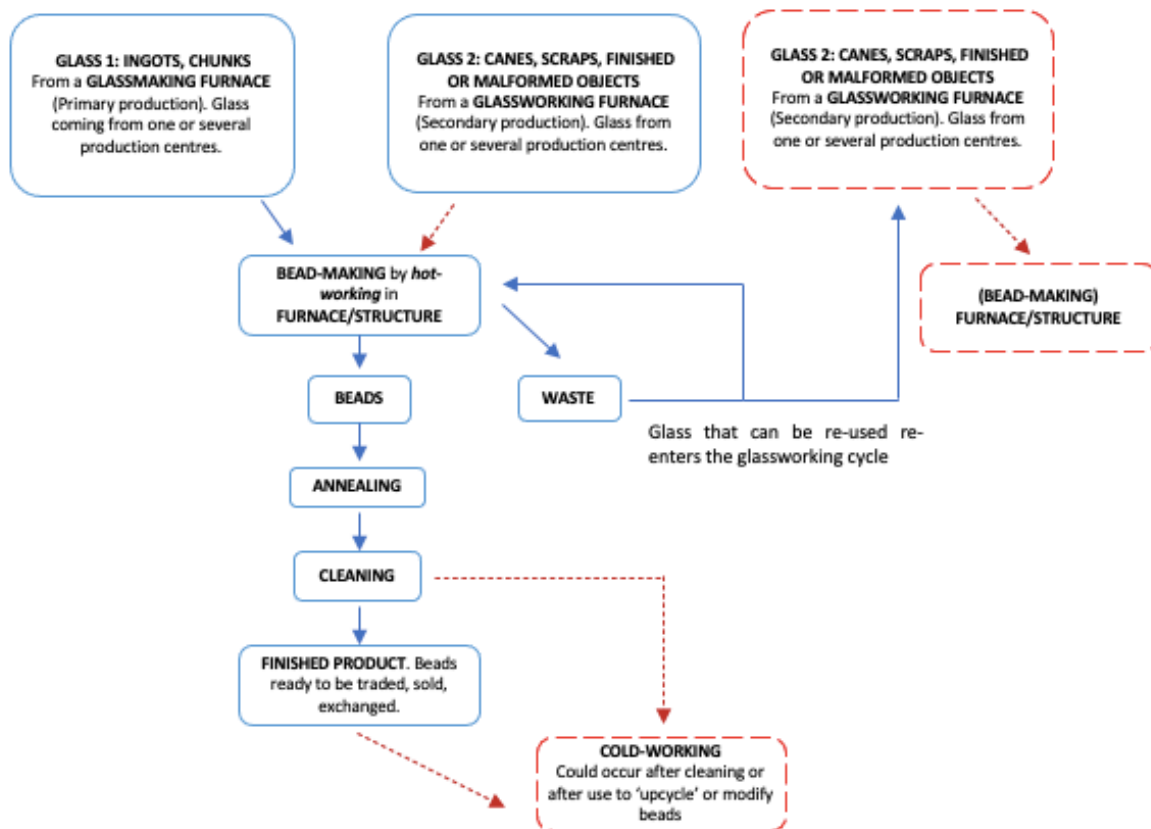


Figure 2.1: Glass bead-making chaîne opératoire: from raw materials to final product. The dashed red outlines indicate further possible steps (Diagram by the author).

As highlighted in Sections 2.6 and 2.7 we can infer from the archaeological record and ethnographic data that the types of technological know-how and furnaces required to make glass do not necessarily overlap with the skill set and structures employed in bead-making. This implies that in antiquity, glassmaking (or the manufacture of glass from raw ingredients, otherwise known as *primary production*) may not have taken place on the same site where glassworking (or the crafting of finished objects from pre-made glass, otherwise known as *secondary production*) occurred: in this latter case, glass as a 'raw' material may have come in a variety of forms, ranging from chunks, scraps or canes, thus having an impact on the type of structure required to craft beads.

To this day, beads are usually produced by using a localised heat source to soften pre-made glass. The workability and melting temperature of glasses vary depending on their chemical composition: most ancient glass from the Euro-Mediterranean area is so-called soda-lime-silica (SLS) glass, by virtue of its main components (Henderson, 2000, pp. 24-28; see also Section 2.3). When the glass has softened and has reached a low viscosity, which roughly occurs between 930° and 1020° C for SLS glass, it is worked into the desired bead shape. (Stern & Schlick-Nolte, 1994, pp. 22-23). A variety of tools and techniques – both reported in

Appendix A – can be employed to create the thread-hole or perforation¹ in the centre of the bead: metal rods, plant stalks or even air trapped within the glass can all be used for this purpose (Sode 1995; Kanungo 2004; Lamb, 1976; Liu et al., 2001).

In the Mediterranean basin and in continental Europe, most archaeological beads – including the assemblages from Abruzzo and Fazzan in the present work – are made with the winding technique, whereby the glass is coiled around a metal rod or mandrel, which was previously dipped in a coating agent (separator) to prevent the glass from fusing with the metal (Sode & Kock, 2001b). Today, studio bead-makers working with gas-powered lamps use a clay slip separator. In more traditional contemporary workshops, where beads are produced in a furnace, the rod is either coated with common cooking salt or it is left as it is: no separator is employed. An iron tool is used to strike the metal rod to facilitate the removal of the beads (Foulds, 2017, p.18; Kanungo, 2004; Stern & Schlick-Nolte, 1994). By doing so, the thread hole is loosened and the bead can slip off from the iron rod, which contracts faster than the glass when cooling down. Nowadays these films are removed chemically or the excess material can be reamed with a tool (Kanungo, 2004; Foulds, 2017, p. 18).

Once the beads are removed from the rod, they can be placed in vermiculite granules or ash to avoid being subject to thermal shock through rapid cooling (Kanungo 2004). After this step is completed, the beads are ready to undergo a further heat treatment, known as annealing, whereby an object is gradually brought to a temperature below its melting point – around 530° C for soda-lime-silica glass – so that it can be ‘soaked’ until the internal structure of the glass is stabilised (Stern & Schlick-Nolte, 1994, p. 23). As long as any temperature changes are steady and gradual, annealing helps to rid the glass of internal stresses, which, if not eliminated, might cause sudden cracks or breakages during use. This is particularly important when the glass is intended for further working or decoration once cold, particularly by etching or engraving (Lierke et al., 1995). Beads can be annealed in a variety of ways, according to furnace design and manufacturing methods: they can be either placed in an annealing chamber or in a separate annealing oven (lehr), or, as in the case of traditional workshops in Turkey and India, in a built-in tray within the bead-making furnace itself or in a clay pot next to it. When the beads are moulded, as in the case of contemporary Ghanian manufacture, they may be left to cool down within the mould they were made in

¹ In technical terms ‘perforation’ refers to beads manufactured by techniques such as moulding, whereby the hole is actually pierced through the glass with a rod, whereas the term ‘thread-hole’ is in relation to wound beads, as the central void (or hole) is created by coiling the glass around a rod.

for approximately one hour (Küçükerman, 1995; Sode, 1995; Sode & Kock, 2001b; Kanungo, 2004, Jones, 2011, p.8; Willoughby, 2005). After annealing, the beads may undergo further polishing or cleaning treatments in order to remove separator residues if required (Willoughby, 2005). In some instances, such as the traditional production of drawn beads in South-East Asia, annealing is an important part of the *chaîne opératoire*. The beads receive a heat treatment to smooth their surfaces (Francis, 1991). As no dedicated structures that can be directly associated with bead-annealing have been found in the archaeological record thus far, if annealing took place in antiquity, it almost certainly occurred in the same location as bead manufacture, as residual heat coming from the furnace could be easily exploited similarly to what is observed in contemporary traditional bead-making.

2.2 Chemical characteristics of glass

Before delving deeper into the chemical characteristics of glass, we need to briefly explain from which ingredients archaeological SLS glass is made and how the technology and the sourcing of raw materials changed over time, as this will be relevant in the discussion of glass degradation in relation to use-wear analysis in Chapter 5, Section 5.4. In ancient SLS glass the silica was typically derived from crushed quartz pebbles, or sand, and was deliberately combined with some form of alkali salt, consisting of soda (Na_2O) and potassium (K_2O), and with lime (CaO)². These additional ingredients are sometimes known as network modifiers, with the silica being the network former. Chemical analysis of archaeological remains coupled with historical records indicate that the source of the alkali flux, silica, and lime in glass varied over time and geographical location. Changes in the source and type of alkali are particularly diagnostic of technological change. During the Late Bronze Age (1550-1200 BCE), plant ash was the preferred source of alkali, but from the early Iron Age (800 BCE) in the Mediterranean and Levantine areas, this was replaced by the use of mineral alkalis. West of the River Euphrates, this mineral alkali, commonly referred to as natron, was used in glassmaking until the early Islamic/medieval period, approximated at around 800 CE (Henderson, 2013, pp. 22-24). There followed a re-introduction of plant ash as the main fluxing agent in the Mediterranean thought to be due to disruption to the trade routes by which natron was procured (Shortland et al., 2006), and – by the 11th century CE – the

² Almost any source of soda will include some potash, and vice-versa, due to substitution as they are closely related in valence terms and by atomic mass. This is also observed for Ca (Calcium) and Mg (Magnesium).

development of different glassmaking traditions in northern Europe, which used wood ash (Wedepohl et al., 2011).

From a scientific standpoint, glass is an X-ray amorphous material as it lacks in long range order, and as a consequence has no periodic atomic arrangement: unlike crystalline solids, the atomic particles in glass are not organised in a regular pattern which is periodically repeated over long distances throughout the material (Figure 2.2). For this reason, glass is a state of matter, the specific chemical characteristics of which are limited by the interplay between the viscosity (the measure of resistance to flow of a liquid) of the raw materials when molten, and the temperature regimes achievable in a given furnace technology. When compared to other materials, molten glass has a much higher viscosity, the range of which is dependent upon its chemical makeup and temperature (Shelby, 2005, p.3; Davison, 2003, p. 11; Carter & Norton, 2013, p. 21; Askeland & Wright, 2015, pp. 52-54).

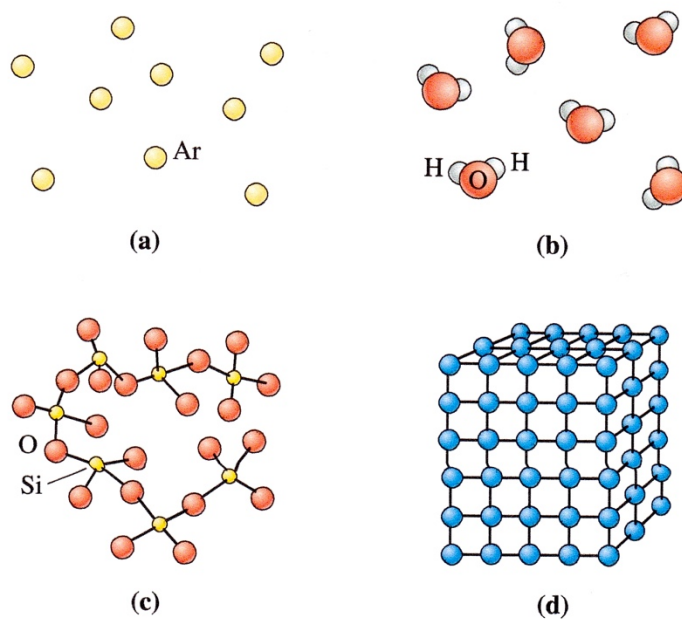


Figure 2.2: Types of atomic arrangements in different states of matter: (a) no regular ordering of atoms in inert monoatomic gases; short range order in water vapour (b) and silicate glasses (c); long-range order in metals, alloys, ceramics and some polymers (d) (Askeland & Wright, 2015, p.52).

Any organic, inorganic or metallic material can be a glass if it is cooled fast enough to prevent crystallisation, hence exhibiting a glass transition. This occurs within a temperature range known as the glass transition or transformation range, whereby when the glass is being heated its thermodynamic properties, such as heat capacity and expansion coefficient, shift from solid-like to liquid-like, exhibiting viscous flow (Pollard & Heron, 2008, p.156; Shelby, 2005, p.3). As shown in Figure 2.3, the glass transition range is usually expressed by

means of a volume versus temperature plot, which illustrates the behaviour upon cooling of a volume of liquid at a temperature well above the melting point of the material.

As a liquid is cooled to its melting point, T_m (the temperature of which is at standard pressure dependent upon chemical composition) the liquid may crystallise, decreasing abruptly in volume to attain the preferred thermal capacity, and reorganising its atoms to form a long-range order solid with periodic atomic arrangement. If the liquid exhibits sufficient resistance to flow for the rate of cooling employed, however, it will enter the super-cooled stage, progressively increasing in viscosity upon cooling. In this case, there is no sharp decrease in volume as the atoms slowly rearrange in an intermittent fashion, resulting in a substance which lacks long-range crystalline order (see below). At the glass transition temperature T_g (also known as fictive temperature) the melt presents such a high viscosity that it can no longer relax towards the equilibrium liquid, thus creating a glass. The process is highlighted in Figure 2.3 by a decrease in the slope of the f (fast-cooling) and s (slow-cooling) curves, as their trajectory tends towards the crystalline solid region (Shelby, 2005, pp. 3-7; Carter & Norton, 2013, p. 390).

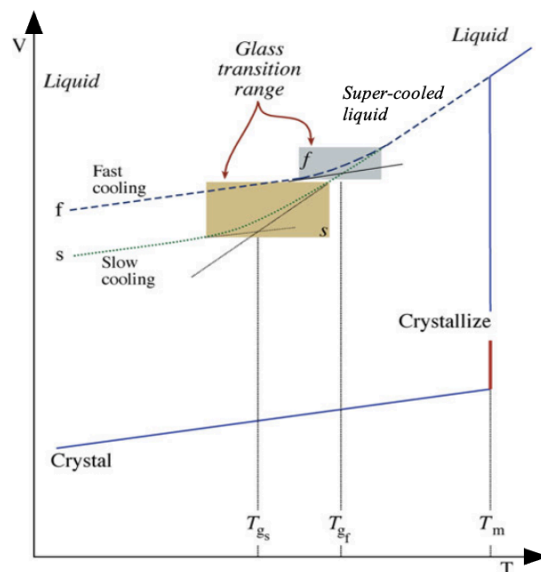


Figure 2.3: Plot of volume (V) versus temperature (T) for a liquid that forms a crystalline solid upon cooling at fixed temperature (T_m) and a glass forming at transition temperature (T_g). The latter depends on the cooling rate, which is either fast (f) or slow (s) and hence is shown here as T_{gs} and T_{gf} respectively (Carter & Norton, 2013, p.390).

Both obsidian and manmade silica-based glass, respectively natural and artificial in origin, are encountered in the archaeological record. They share similar chemical and physical characteristics, as both contain high percentages by weight of silicon dioxide (or silica, SiO_2), with $>65\%$ SiO_2 for obsidian and typically between 50% to 70% for ancient human-made

glass (Freestone, 1991, pp. 39-40; Pollard & Heron, 2008, p. 77). Silicate glasses are composed of a three-dimensional network of silicon tetrahedra (SiO_4), which are the glass formers. The atoms of each unit or tetrahedron are covalently bonded, as the central silicon atom shares its four valence electrons with four surrounding oxygen atoms to obtain a stable outer energy shell of 8 electrons: the silicon cation, Si^{4+} is bonded to four O^{2-} anions. Covalent bonds form specific angles and bond-lengths, so each SiO_4 molecule has a predictable short-range order in the form of a tetrahedron (Figure 2.4). To achieve chemical stability, the O^{2-} anions are each bonded with either another silicon cation (Si-O-Si bond, or 'bridging oxygen') or a non-silicon cation ('non-bridging oxygen', on which more below). Only the oxygen bonds within a tetrahedron are of fixed direction and length, which is why the glass can be said to have short-range, but no long-range order (Shelby, 2005, pp. 81-82; Askeland & Wright, 2015, pp. 32-35; p. 53).

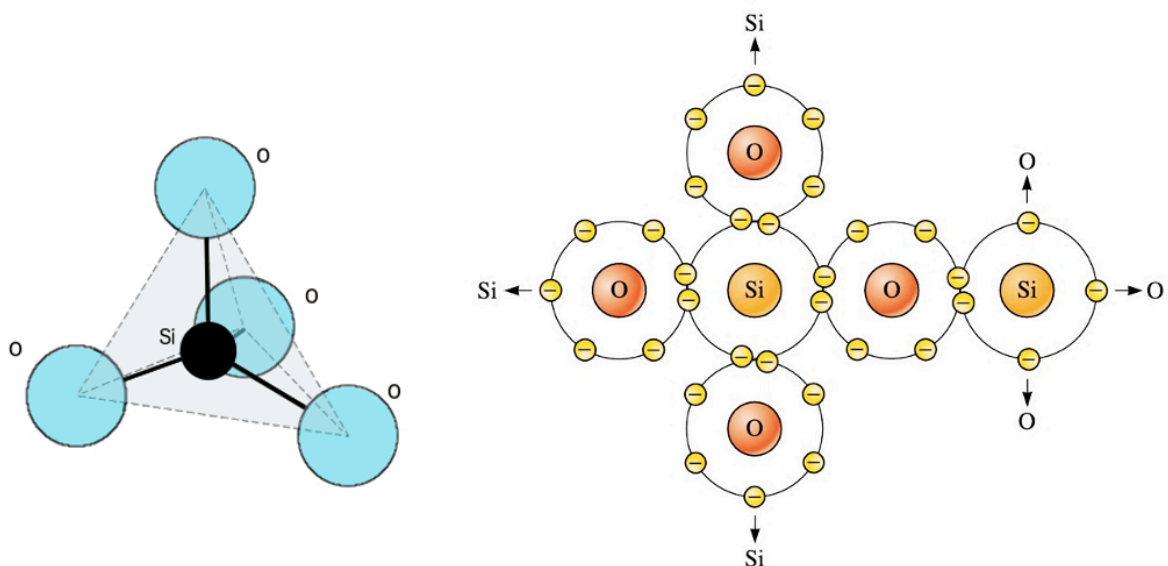


Figure 2.4: Three-dimensional representation of a silica tetrahedron (left) and schematic representation of covalent bonding (Pollard & Heron, 2008, p.149; Askeland & Wright, 2015, p. 34).

In archaeological SLS glass, alkali salts were obtained from evaporitic minerals such as natron, a source of relatively pure soda, or from the ashes of halophytic (salt-tolerant) plants and hard wood trees, which provided more variable ratios of soda to potash depending upon the species and the environment in which it grew. The addition of an alkali, known as the 'flux', helped to lower the melting point of the silica from 1710°C to a temperature attainable in ancient furnaces, up to $c.1200^{\circ}\text{C}$. As shown in Figure 2.5, the introduction of alkali salts causes the network to expand, due to the formation of non-bridging oxygen ions bonded to alkali cations Na^{+} and K^{+} . Because these cations are monovalent (singly-charged)

they do not form bridging bonds. This is what ‘opens up’ the glass network, but it also makes it susceptible to solubility in water.

To prevent alkali dissolution and increase the durability of soda-silica glass, lime (CaCO_3 , present in glass as CaO) was added as a stabiliser. The double electrical charge of Ca^{2+} cations strengthen the bonds within the network as each cation is bonded to two non-bridging oxygen anions. In most ancient glass recipes, it seems that lime was not added separately to the alkali and silica, but was entering the mix either as an impurity in the plant ashes, or as crushed seashells with the sand (Carter & Norton, 2013, pp. 115-117; Davison, 2003, pp. 4-6; Pollard & Heron, 2008; Henderson 1985; Tite et al., 2006).

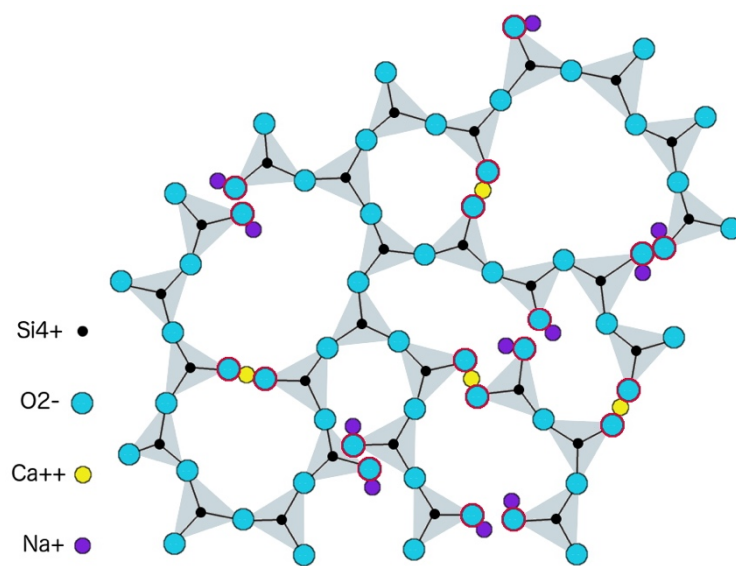


Figure 2.5: Two-dimensional rendition of the glass network. The non-bridging oxygen ions are circled in red (after Maraghechi et al., 2016, p.2).

2.3 Physical and mechanical characteristics of glass

Due to their high silica content, human-made glass, obsidian, flint and chert are hard and brittle materials, as they fracture with little plastic deformation. Unlike many other silica-based materials (e.g. quartz), however, they fracture in a predictable manner, due to the lack of crystalline structure in obsidian and glass, and the microcrystalline structure of flint and chert. Hardness is determined by the strength of individual bonds and by the density in the distribution of the atoms within the network. The Mohs hardness scale measures the resistance to abrasion of materials by applying a numerical range from 1 (softest; talc) to 10 (hardest; diamond). Glass scores between 4.5 and 6.5, depending upon its composition, with

obsidian at the harder end of this spectrum with an average value of 6 (Davison, 2003, p. 14; Duckworth, 2012, p. 316; Shelby, 2005, p. 188; Pollard & Heron, 2008, p.78; Henderson, 2000, p. 297).

Glass hardness can also be measured in resistance to cracking by using the Vickers indentation hardness test. A conical or spherical diamond indenter is charged with a load or force, and applied to the material. Soda-lime-silica glasses range from 2 to 8 Gigapascals (GPa) by comparison with ≈ 100 GPa for diamond, for example (Shelby, 2005, p. 190). Vickers tests performed on ancient glass samples have demonstrated that 4th century CE mineral soda-lime glass is less crack-prone than later potash glasses (especially 12th to 19th century CE European wood-ash glass), and is comparable in terms of hardness to contemporary commercial float glass. This is due to the fact that in mineral soda glass, the sodium ions are not as tightly packed in the network as with potassium, therefore creating more space which allows for compaction prior to cracking (Hasdemir et al., 2015).

As glass is characterised by strong interatomic bonds, its brittleness and related fracture behaviour are not intrinsic to the structure of the material itself, but are rather regulated by the presence of surface defects, which can arise from: i) abrasion due to contact with hard materials; ii) chemical attack, among the causes of which are the release of (NaCl) by contact with human skin when handling the glass with bare hands; iii) thermal stress, either through rapid temperature changes resulting in thermal shock, or by surface alterations deriving from over-extended heating, including the formation of crystals and the incorporation of dust particles; iv) incomplete melting of the batch constituents and accidental introduction of contaminants during glass manufacture (Shelby, 2005, p.192; Beauchamp, 2010, p. 172).

Fractures occur because any stress applied to the glass is directed at the peak of the flaw, hence reducing tensile strength and subsequently rupturing interatomic bonds (Davison, 2003, pp. 14-15). The extent of crack branching is directly proportional to the amount of energy related to crack propagation, through either directly-applied or residual stress. When substantial branching occurs, the glass will shatter into small fragments. As mentioned above, glass - along with other non-crystalline and microcrystalline solids such as obsidian or flint - fractures in a predictable manner. Specifically, it fractures conchoidally. In conchoidal fractures, no distinct cleavage planes are observed, so the crack does not propagate through the grains but instead travels along a single plane (Carter & Norton, 2013, pp. 333-334). As

illustrated in Figure 2.6, all glass fractures present three specific areas called mirror, hackle and mist, which are discussed below.

In proximity to the crack initiation site is a smooth and highly reflective zone known as mirror, the size of which is inversely proportional to the strength of the impact force. As the crack propagates, it changes trajectory either when it reaches critical velocity or intersects with either an inclusion, or variations in the internal (residual) stresses of the glass. This results in the development of very small cracks, which confer a rougher and less reflective texture to the surface in this region, known as mist. Hackle lines, which indicate the direction of travel of the fracture from its origin point, occur when crack branches extend outwards, forming ridges (Baca et al., 2016; Carter & Norton, 2013, pp. 333-334). Wallner lines, or 'rib marks' are fainter, and best observed through microscopy, with which they are sometimes detectable. These lines, which are conchoidal, also indicate fracture directionality and are located perpendicular to the direction of crack propagation (Ono & Allaire, 2021, p. 4; Baca et al., 2016; Davison, 2003, p. 15).

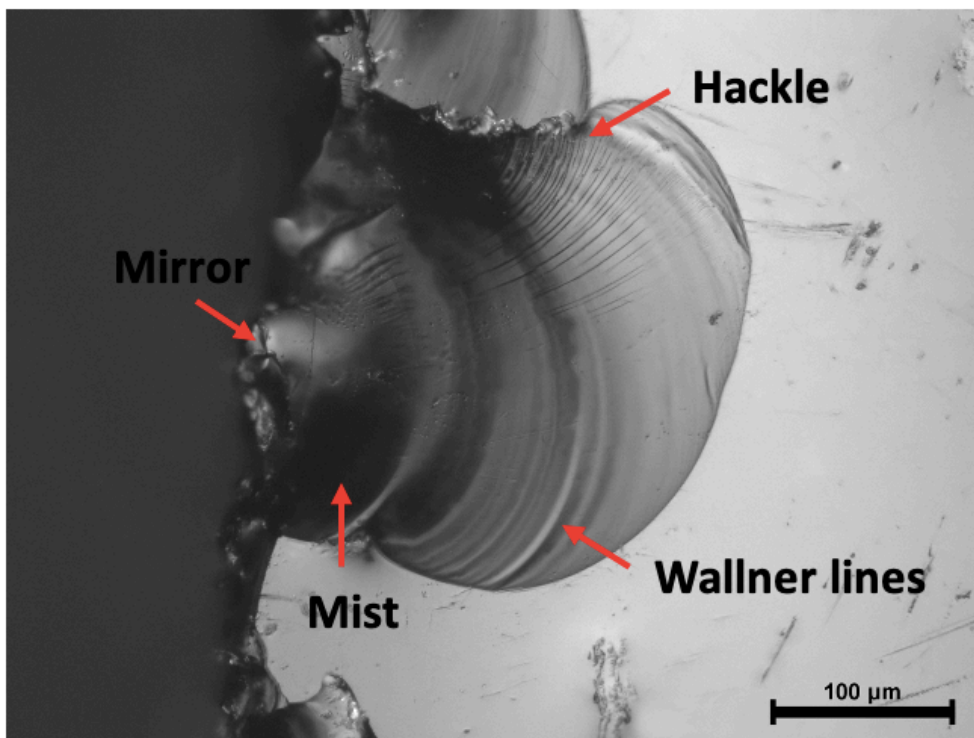


Figure 2.6: Fracture zones and Wallner lines on experimental glass bead (Picture and bead author's own).

Specific fracture morphologies, which can be replicated by Vickers indentation tests, can be observed when glass surfaces are subjected to either blunt or sharp impact (Figure 2.7). Sharp impact produces an impact cone which exhibits penetrating median-radial cracks, with

related pulverization of the fracture initiation site. Blunt impact results in Hertzian cone cracks, which, according to the load, can be complete or partial, respectively forming rings or c-shaped marks. The latter are caused by friction due to sliding wear, rather than by a localised blow as in the case of complete cracks (Quinn, 2016, pp. 6-33-6-38; Ben Abdelounis et al., 2009).

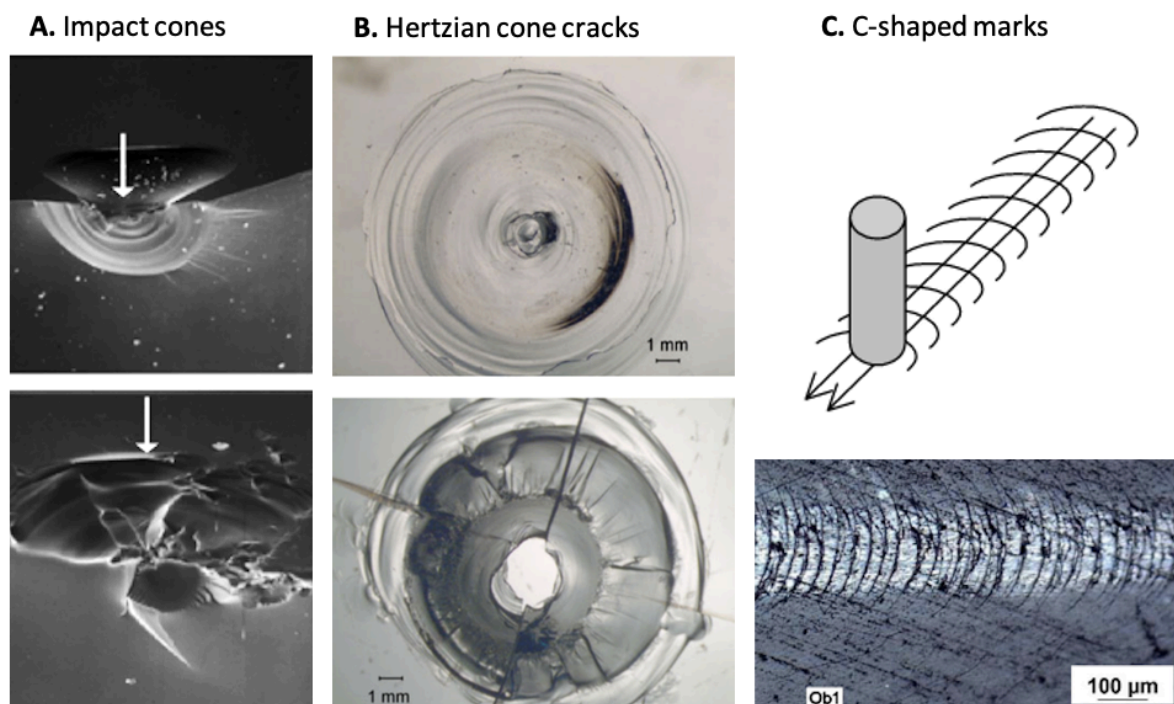


Figure 2.7: A: sharp impact cones, with arrows indicating the direction of the impact. B: cone cracks; mild to moderate blunt impact (top) and severe impact (bottom). C: illustration of friction direction causing C-shaped marks, whereby the glass is stationary and the object moves as indicated by the arrows (top); micrograph of c-shaped marks on obsidian (bottom) (Quinn, 2016, p. 6-33; p. 6-38; Ono & Allaire, 2021, p. 3; Ben Abdelounis et al., 2009, p. 625).

2.4 Peculiarities of glass: chemical deterioration, weathering, and other types of post-depositional damage

The main types of glass deterioration are summarised in Figure 2.8: they are visible on a macro- and microscopic scale, and often occur in combination. It is important to note that although obsidian is more durable because of the higher silica content when compared to human-made glass, glasses in general suffer greatly from post-depositional damage.

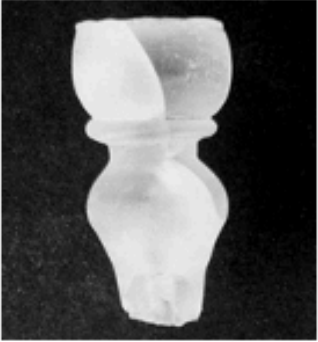
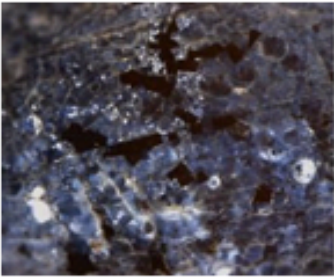

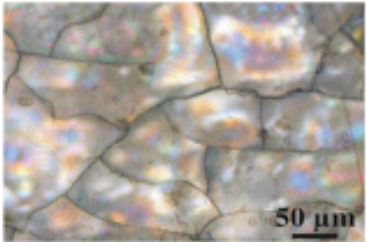
 <p>(Davison, 2003, p. 183)</p>	<p>Dulling: loss of original clarity and translucency, due to changes in the composition of the glass surface, which lead to an alteration of the refractive index, similarly to what observed for iridescence (van Giffen & Koob, 2018).</p>
 <p>(Zacharias et al., 2020, p. 63)</p>	<p>Iridescence: variegated colouration (gold, blue, pink hues) as a result of light interference caused by metal oxides present in the surface layers of the glass. When found on its own, iridescence can be observed at first as filmy patches. When the iridescent layer becomes very thick, it may flake away, as shown here (Davison, 2003, p.183).</p>
 <p>(Zacharias et al., 2020, p. 63)</p> <p>(Koob, 2006, p.17)</p>	<p>(Milky and enamel-like) weathering and pitting: opaque white or dull light brown to brownish black deterioration products. The incipient stage, as illustrated by the picture to the left, is termed <i>milky weathering</i>, as it is characterized by occasional small white spots or bands. As weathering progresses, the small deterioration spots will grow, and when they eventually detach, they will leave pits on the glass surface. The advanced stage of this process is known as <i>enamel-like weathering</i>, whereby most part of an object is covered by a thick white or brown laminar layer, which will disaggregate to expose highly iridescent pits and thin lamellae (Davison, 2003, pp.184-186).</p>
 <p>(Palomar, 2017, p.181)</p>	<p>Cracking: results from changes in temperature and humidity, which cause the alkali-depleted layer to shrink. Cracking can occur on the original surface of the glass or on the weathering crust. It is observed in particular when artefacts that were buried in wet soils start to dry (van Giffen & Koob, 2018).</p>

Figure 2.8: Main types of glass deterioration occurring during burial and their visual appearance. Note that very advanced iridescence and weathering will ultimately cause a total loss of the glassy nature, resulting in a silica-gel mass with sugary appearance (Picture author's own).

As mentioned above, the addition of an alkali flux decreases the viscosity of the melt but at the same time increases the solubility of the glass, meaning that a stabiliser such as lime must also be added to counteract this and to prevent recrystallisation. As a consequence, soda-lime-silica and related ancient glasses are more prone than obsidian to chemical

deterioration (corrosion), network alterations, weathering, and changes related to atmospheric factors. The extent to which a glass is vulnerable to these phenomena is dependent upon its chemistry and environmental conditions (including burial) over time (Gueli et al., 2020; Friedrich & Degryse, 2019; Martindale & Juracic, 2006; Clemente-Conte & Romero, 2008; Clemente-Conte et al., 2015; Pollard & Heron, 2008, p.166; Davison, 2003, p. 174).

The stability of soda-lime-silica glasses is dictated by the percentages of each major element and by how they interact with one another. The addition of modifiers including alkali oxides (soda or potash) and the oxides of the alkali earth metals (calcium but also magnesium, present in trace or minor quantities in lime) open up the silica network, increasing the susceptibility of glass to chemical corrosion. Overall, the higher the ratio of alkali flux to silica network former, the greater the likelihood for dissolution, but this is further complicated by the proportion of soda to potash in the flux. Mineral soda, which has very low potash, yields a more durable glass, as sodium has smaller cations which are more tightly bound within the network. The addition of lime increases the stability of glass by immobilising the alkali ions within the network (Jackson et al., 2012, pp. 490-491; Koob, 2006, pp. 13-14; Davison, 2003, p. 177; El-Shamy, 1973). Alumina (Al_2O_3), phosphorous (P_2O) and iron oxides (e.g. Fe_2O_3) are minor components that can – albeit marginally – contribute to glass durability. These oxides, which enter the glass batch either as impurities contained in the raw materials or during the glassmaking process as contaminants, have low solubility, meaning that they secure the alkali ions in place. If the deterioration of a given glass is affected by its composition, the main external agent responsible for corrosion is water, as it attacks the glass-forming molecules. For the majority of archaeologically-recovered glasses, the water would have been present in the soil. Furthermore, the chemical make-up of the burial environment (including its pH), combined with seasonal variations in temperature and moisture content may also act variously to affect the type and rate of corrosion undergone by a given glass. The most notable corrosion effects are de-alkalisation (leaching) and network dissolution mechanisms which cause over time differential iridescence, dulling, cracking, weathering and pitting, as shown in Figure 2.8 (Freestone, 2001, p. 617; Davison, 2003, p. 174; Koob, 2006, pp. 13-14).

De-alkalisation or ion exchange occurs when water draws the alkali cations out of the glass network, which, in order to preserve electrical neutrality, are replaced by positively charged

hydrogen ions (protons H^+) surrendered by hydronium ions (H_3O^+) present in the environment. On the one hand, this process results in the formation of an alkali-depleted and therefore silica-rich (or gel) layer on the glass surface, which acts as a protective barrier by slowing down further decay. On the other hand, the leached alkalis, coupled with hydroxyl ions generated by a reaction between water molecules and non-bridging ions in the glass, increase the alkalinity of the surrounding aqueous layer, especially if the solution is not replenished by additional water as it is the case for loamy or sandy deposits, which have a much higher percolation rate by comparison with clay-rich matrices. The silica-rich layer is newly attacked at pH 9, the value at which rapid de-alkalisation occurs, with alkali loss rate decreasing at higher pH values. When the values are below 9, the extraction rate is otherwise constant and independent from the pH (Koob, 2006, pp. 13-14; Davison, 2003, p. 175; Freestone, 2001, p. 617). Acidic environments can also damage the glass by ion-exchange processes, although when this happens, the alkali earth oxides of calcium and magnesium are leached alongside the alkali, causing the development of both an alkaline earth/alkali depleted layer and a hydrogen-enriched layer. Soda-lime-silica glasses are especially vulnerable to the loss of calcium when this is present in concentrations above 10 mol% and the pH of the surrounding environment is highly acidic (pH 0-3): as the solubility of lime increases under such conditions, so too does the rate of extraction. Elevated temperatures and temperature fluctuations can also catalyse the loss of alkali oxides from glass (Davison, 2003, p. 175; Jackson et al., 2012, p. 491; Koob, 2006, pp. 13-14; El-Shamy et al., 1972, p. 87).

Network dissolution, or silica hydrolysis, occurs under alkaline conditions. In this case, no gel layer is formed, but the glass will be instead progressively etched away as the bridging oxygen bonds in the network break down, ultimately causing the silica to dissolve. This mechanism, which is primarily pH dependent, is self-perpetuating. Silica – alongside network modifiers such as calcium and magnesium – is extracted at pH 9 and the depletion rate increases steeply as the pH rises above this. For this reason, de-alkalisation and network dissolution are in competition, with the fastest progressing mechanism prevailing (Davison, 2003, pp. 175-176; Jackson et al., 2012, pp. 491-492; Koob, 2006, pp. 13-14; Freestone, 2001, p. 618; Adams, 1984). As most soils contain water with intermediate pH, the most common type of corrosion recorded on archaeological glasses is due to ion exchange, resulting in the formation of a hydrated silica layer.

The work of Dussubieux et al. (2009) can give us an idea of how corrosion may alter the chemical signature of archaeological beads and to what extent glass degradation can hamper the detection of specific compositional groups. In this study, the analytical results obtained by two different US laboratories, MURR and Field Museum, and the application of two distinct protocols: raster sampling and spot analysis, were compared to test the reliability of LA-ICP-MS (Laser Ablation Inductively Coupled Plasma Mass Spectrometry) as a technique. As such, to detect major, minor and trace elements LA-ICP-MS was carried out on 52 glass beads unearthed from African contexts. Despite some discrepancies between the two labs, the results appeared in agreement as the majority of the beads, which showed varying degrees of corrosion, were made from soda-alumina glass – further characterised by a low uranium high barium (lU-hBa) group and by a high uranium high barium (hU-lBa) group – or plant-ash glass. Furthermore, the MURR measurements reported the presence of heavy degradation on six beads: in two cases, the specimens could not be ascribed to any glass type, whereas for the remaining four samples, which were broadly labelled as plant-ash glass, no further specific chemical groupings could be identified.

All of the severely corroded beads showed a conspicuous depletion in the levels of soda, with a loss between 78% and 97%wt of the initial content as seen in pristine glass. As a consequence, a reduction in the amount of potassium and magnesium was also commonly recorded across this sub-sample. An occasional decrease in the amount of lime was also noted, however, more often than not, this element had similar percentages as the ones found in undeteriorated glass. Another general trend is represented by a substantial enrichment in network forming elements (i.e., alumina, iron and titanium) and in this specific case also in trace elements, with the exception of lithium and arsenic. Three samples each displayed an increase in either manganese, potassium or phosphorus. If in the case of manganese it is unclear whether this element precipitated from the burial environment or if it migrated from within the glass, with regards to the mineral phases of potassium and phosphorus, they were contained in the soil as syngenite ($K_2SO_4 \cdot CaSO_4 \cdot H_2O$), gorgeyte ($K_2SO_4 \cdot 5CaSO_4 \cdot H_2O$), polyhalite ($K_2SO_4 \cdot 2CaSO_4 \cdot H_2O$) and hydroxyapatite ($Ca_5(PO_4)_3(OH)$) respectively. This denotes a variety in burial conditions: high amounts of potassium indicate the presence of wood ash as a by-product of burning, whereas soils that are rich in phosphorus may contain excrement, bone and vegetal tissue (Dussubieux et al., 2009, p. 158).

Buried glass is not only subject to chemical degradation, but it can also accumulate foreign material on its surfaces, equally causing alterations to its appearance. The nature of the encrustations derived from the soil, which may contain either calcium, sulphur, silica or a combination of the three, will depend on the surrounding environment and on climatic factors. In addition, when buried in close proximity to metals, glass can be stained with their corrosion by-products. In some cases, glass can also exhibit a brown layer as a result of attack by micro-organisms such as bacteria (Zacharias et al., 2020, p. 62; Palamara et al., 2016; Davison 2003, pp. 171-172).

Another factor which can impact on corrosion processes is phase separation, resulting from traits of immiscibility in the components of a glass batch, and causing differential corrosion depending on the chemistry of each phase. Phase separation in glass formation is regulated by the viscosity of the melt. In a relatively fluid melt, two separate layers, which are visible with a naked eye, will form. Conversely, if a particularly viscous melt is cooled to a temperature below the glass transformation region, this will result in a solid which presents microscopic droplets of one phase dispersed in the matrix of the other (Shelby, 2005, pp. 51-52, pp. 57-58). Phase separation phenomena can also cause the migration of alkalis towards the glass surface when the glass is cooled down slowly or held for a long time at a constant temperature, for example in the annealing process. The differential rate of cooling between the glass surface and interior translates into the presence of both homogenised and separated phases. When breakage occurs, alkali-rich surfaces are exposed because fractures develop along the boundaries between the network and the modifiers. These surfaces will oxidise and react, encouraging active chemical deterioration. Compositional heterogeneity resulting in differential corrosion can also result from the re-heating of the glass during hot-working, causing alkali depletion by volatilisation in exposed surfaces (Jackson et al., 2012, pp. 504-506; Greaves et al., 1997, p. 21).

2.5 The archaeological evidence for glassmaking

This section deals with the archaeological evidence concerning primary production centres, or sites where glass was manufactured from raw ingredients: batch preparation, the melting of raw materials, ingot or slab formation, and at times colouration, can be attributed to primary production (Henderson, 2013, p.18). Of course, not all glass is created equal, as the way this was made varies across space and time, according to the raw materials available (and by extension technological know-how), type, and scale of production.

Cuneiform texts from the library of King Assurbanipal in Nineveh, dating to the 7th century BCE but thought to be copies of Late Bronze Age (LBA) originals, refer to the use of three different types of furnaces employed in the manufacture of glass. Although glass almost certainly originated in Mesopotamia, however, no glassmaking furnaces have yet to be identified there, resulting in a gap in the knowledge regarding the genesis of glass production (Oppenheim, 1970; Smirniou & Rehren, 2011; Henderson, 2013, p. 157).

Most direct early evidence for glassmaking activities is in the form of crucibles, raw materials, glass and semi-finished glass bearing quartz and lime inclusions (Rehren & Pusch, 2005; Smirniou et al., 2018; Henderson, 1988; Biavati & Verità, 1989). A small number of LBA sites, the majority of which are located in Egypt and the Near East, have yielded most of this early glassmaking evidence. Frattesina in Veneto, Northern Italy also yields significant evidence for glassmaking during the Italian Final Bronze Age (c.1200-1000 BCE), thus post-dating the Mesopotamian and Egyptian sites (the East Mediterranean Bronze Age ends c.1200 BCE).

Chemical analyses of the materials from Frattesina revealed a specific signature for this glass, which is of the mixed-alkali type known as low magnesia high potassium (LMHK), thus differing widely from Egyptian and Mesopotamian plant-ash compositions, which are known as 'high magnesia' glass (HMG) due to their relatively elevated magnesia and potash coming from the plant ashes used in their manufacture, by comparison with later 'low magnesia' (LMG) glasses that were made using a mineral alkali (Biavati & Verità, 1989; Henderson, 1988, Towle et al., 2001; Angelini et al., 2004, Henderson et al., 2015, Reade, 2021, p. 8). In particular, the recovery of glassmaking debris from Egyptian LBA sites allows us to shed some light on the methods employed in the manufacture of glass, which was mostly carried out in two stages.

Based on the evidence from Amarna and Qantir-Piramesses, crushed quartz and plant ash were initially roasted in a ceramic pan or jar provided with a lime parting layer at a temperature ranging between 750° C and 850° C. This process is undertaken in order to sinter (partially fuse) the raw materials, resulting in a compact, semi-fused material known as 'frit', which can be crushed and re-heated to a higher temperature, resulting in a more efficient yield by decreasing the difference in volume between a crucible or furnace charge and the final product (Smirniou & Rehren, 2011; Nicholson & Henderson, 1999, p. 199). In

this second stage, the crushed frit was re-melted in a cylindrical crucible at a temperature between 1000° and 1100° C, possibly with additional flux, resulting in the formation of a glass ingot in the shape of the bottom of the crucible. Fritting, which appears to be more frequently associated with the production of plant- or wood- ash glass, is later documented during the medieval and post-medieval periods (12th to 17th centuries CE) in Western Europe (Henderson, 1985; Smedley et al., 1998; Paynter & Dungworth, 2011). We can surmise that glass was produced in furnaces with foundations such as the ones unearthed within building O45.1 in Amarna, where amongst the wider evidence for pyro-technological activities related to the production of pottery, two similar-sized and -shaped structures denominated Furnace 2 and 3, were thought to be employed for the making of faience and glass respectively (Figure 2.9).

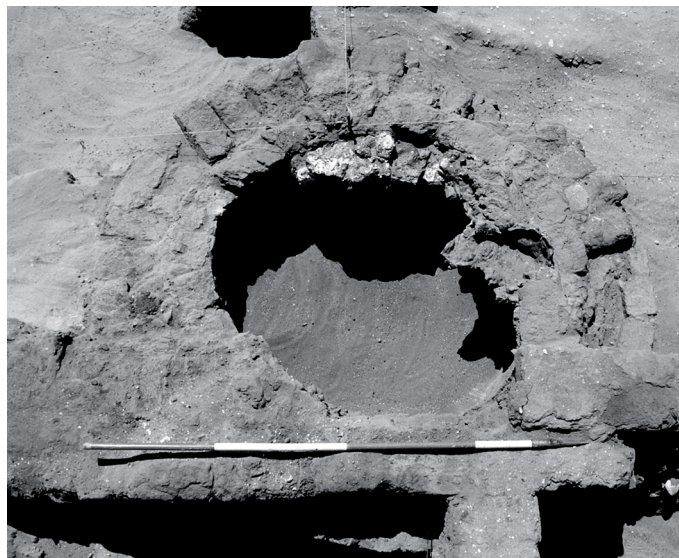


Figure 2.9: Amarna O45.1, furnace 3 after excavation. The vitrified clay can be seen on the top half of the furnace (From Nicholson, 2007, p. 40).

The finds retrieved in association with the two furnaces during their excavation in 1993-1994 included faience and faience moulds, crucibles, raw glass and glassy slag, which are consistent with the evidence collected approximately a century earlier by Petrie for other areas of the site (Nicholson & Jackson, 2000; Nicholson & Hart, 2007). Furnace 3 is thought to have been for glass – rather than faience – production due to evidence for a higher operating temperature including vitrification of the furnace lining, and the presence of apparent ingot moulds compatible with contemporary glass ingots recovered from the Uluburun shipwreck in Turkey, and remains of cobalt-blue glass at the site. An experiment carried out by Jackson et al. (1998) demonstrated that a furnace constructed of similar raw materials to the same sub-structure and topped with a domed roof was capable of achieving

and maintaining glassmaking temperatures, and even of producing blue glass in a single stage operation, without fritting (though the resultant ingots did not have the depth or evenness of those known archaeologically).

Beside the possibility that the processing of raw materials and subsequent glass production may have occurred on Rhodes during the 4th and 3rd centuries BCE, as indicated by sand deposits rich in lime but low in iron, and by glassy slags, semi-finished glass and vitrified clay (Triantafyllidis, 2000, 2003), no further substantial evidence of primary production centres dating between the 8th century BCE and the 1st century BCE has been discovered (Henderson 2013, p. 94; Scott & Degryse, 2014). Due to the lack of archaeological data, very little is known about the production model(s) during the 1st millennium BCE: although yet to be seen, it appears likely that large glass manufacturing centres located in the Mediterranean and the Levant would have coexisted with regional glassmaking workshops present in western Europe (Conte et al., 2018). As a consequence, for the Early Iron Age we are able to chemically identify a change in glass recipe due to the adoption of natron in the Mediterranean as the prime source of soda instead of plant-ash, but not to determine the various stages of glass production including the presence or absence of intermediary ones such as fritting, nor to identify whether these stages occurred in the same locations or were geographically separated.

Concerning the Roman/Late Antique and early Islamic periods, our knowledge is mostly limited to Egyptian and Syro-Palestinian manufacturing sites, dating between the 4th and the 8th century CE (Nenna et al., 2000, 2005; Nenna, 2003, 2007; Gorin-Rosen, 2000; Freestone et al., 2000; Scott & Degryse, 2014; Brems et al., 2018). These factories, which were conveniently located in close proximity to raw material sources – respectively natron from the Wadi Natrun and sand of the Belus River near modern Akko – employed large ‘tank’ furnaces which exploited reverberatory heat to fuse the glassmaking materials (Henderson 2013, p. 18; Gorin-Rosen, 2000; Rehren & Freestone, 2015; Scott & Degryse, 2014). The prototype for such structures may be represented by two 1st- 2nd century CE reverberatory furnaces found at Beni Salama, Egypt, which not only differ in length between each other (6.1 and 7 m), but also appear to be less standardised in design and size than the later Levantine specimens of Apollonia and Bet Eli’ezer, Israel, which date to the 6th-7th century CE and the 8th century CE respectively and are 4m in length (Freestone et al., 2008; Nenna, 2015). The adoption of tank furnaces may have to do primarily with the invention of

glassblowing, but also with the demand for architectural glass, which resulted in larger quantities of artefacts (namely vessels, but also mosaic tesserae and windows) being produced.

From the evidence collected at Bet Eli'ezer, Israel, where 17 tank furnaces were unearthed, we can reconstruct how these structures worked: in order to exploit reverberation or radiation heat, the melting chamber (in which the raw materials were placed) was separated from the firing chamber, which was provided with two stoke-holes thanks to an internal partition, whereas the chimney was located at the rear, as pictured in Figure 2.10 (Gorin-Rosen, 2000). The glass production was likely seasonal as it would exploit the summer winds for air circulation through the firing chamber, and could produce up to 8 or 9 tonnes of glass per firing as attested by the evidence collected from other Israeli sites, such as Apollonia and Bet She'arim (Gorin-Rosen, 2000; Freestone et al., 2000). It is likely that all processes, from fritting to production of glass were carried out in a single stage, as these structures would gradually reach 1100°C.

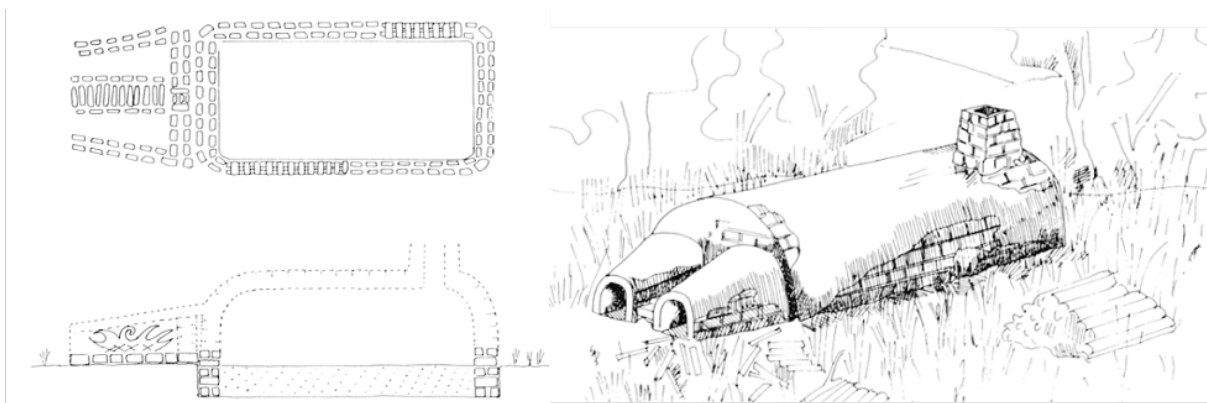


Figure 2.10: Plan, section and reconstruction of a tank furnace (Gorin-Rosen, 2000, p. 53, drawings by M. Miles).

The final product would have consisted of a glass slab, which was left to cool down until ready to be removed from the furnace by dismantling the superstructure. The slab was then broken into chunks and traded to glassworking centres (Gorin-Rosen, 2000; Nenna, 2015).

A recent ethnographic example of glassmaking in large furnaces may shed some light on possible ancient processes. This is the traditional glass production that took place until the 1990s in Jalesar, Uttar Pradesh, India: in this case, large circular furnaces were used for the purpose. After the initial roasting of the sand to eliminate any organic impurities, mineral soda (*reh*) was introduced to form the batch, which was then melted in relatively small quantities at a time, for 30 consecutive days. Every three days, a fresh sand and soda

mixture, alongside glass chunks from the previous melt, was poured into the furnace, so that they could react with the frit that had already formed (Sode & Kock, 2001a). The failed glass slab retrieved at Bet She'arim presents horizontal layers of different compositions, suggesting that ancient tank furnaces would also have been repeatedly charged with small amounts of batch (Freestone et al., 2000, p. 71).

Alok Kumar Kanungo suggested that the end of 1st to 3rd century CE subterranean furnace unearthed during the 2004-2009 excavations at Kopia, Northern India, may have had a similar superstructure and purpose to the specimens recorded in the Levant and Uttar Pradesh. This hypothesis, however, is primarily based on the mention by the inhabitants of Kopia of the past existence of remains of domed furnaces and of a large glass slab. Fragments of crucibles, beads, bangles, rods and tubes indicate that glass working and making may have both occurred at the site, but whether the excavated furnace was used in the manufacture of glass it remains contentious, and as such, further work will be required to ascertain where primary production was undertaken at Kopia (Lankton, 2018). The archaeological record for glassmaking centres becomes even more scanty as we move further east: in China, in particular, no evidence for primary production sites such as furnaces or semi-fused glass has been recorded to date, despite the abundance of glass with signatures (i.e., potassium and lead-barium glasses) that are typical of the region, indicating the likelihood of local manufacturing (Henderson et al., 2018).

Archaeological evidence for primary production is reported in sub-Saharan West Africa. The site of Igbo Olukun in Ile-Ife (Yorubaland, SW Nigeria) has yielded – alongside glass beads and related manufacturing debris – glass lined crucibles and primary production waste, attesting to an indigenous glass and bead-making tradition that dates back to at least the 11th century CE. Chemical analysis of the assemblages established that the majority of the glass found within the crucibles and used in the crafting of beads is characterised by distinctively high lime and high alumina (HLHA) concentrations, with values of > 10% for both oxides. In addition, a further glass group characterised by low lime and high alumina (LLHA, with CaO <8%) was also identified. The alumina and lime contents in HLHA and LLHA glasses do not match with any of the coeval compositional groups from Europe, the Middle East and South Asia (respectively soda-lime-silica and Medieval wood-ash glass, high lead and soda-alumina glasses). HLHA glass and its cognate group LLHA present chemical signatures distinct to Ile-Ife, and deriving from the use of locally available geological materials, including

immature pegmatitic³ sands most likely collected from local ponds or rivers. If the lime source in HLHA glass is perhaps attributable to snail shells, LLHA glass does not contain pure calcium carbonate but rather a copper rich ingredient (yet to be identified) bearing lime, magnesia and small quantities of phosphorus (Babalola et al., 2018a; Ogundiran & Ige, 2015; Freestone, 2006a; Lankton et al., 2006). Beside the compositional homogeneity between finished objects, raw glass and production waste, further proof of the local nature of this glassmaking industry is provided by the fact that the colour of the glass within the crucibles reflects the colour repertoire of the beads. It is also worth noting that crucibles in association with primary glass production waste have not been encountered in other Sub-Saharan African sites, which means that their use is specific to Ile-Ife (Babalola, 2017; Babalola et al., 2018b). The Yoruba tradition of glassmaking established at Ile-Ife during its Classical period (12th-15th century CE) shows evidence of an uninterrupted glassmaking legacy that extends into the 17th and 18th centuries in Osogbo (Ogundiran & Ige, 2015, Babalola et al., 2018a).

The excavations carried out at Igbo Olukun, which will be discussed in further detail below and in Section 2.7 due to the glassmaking and glassworking character of the site, did not provide us with clear evidence of structures that can be ascribed either to the production of raw glass or beads (Babalola et al., 2018a). More recent primary glass production is also documented for central Nigeria, where a particular type of raw black glass, known as *bikini*, was locally made from the 19th century until approximately 50 years ago by the *Masagá* glassmakers in Bida, Nupeland (Robertshaw et al., 2009; Duckworth, 2020b, p. 328; Lababidi et al., 2023). Over time, *bikini* glass was gradually mixed with - and then completely replaced by readily available, colourful European bottle glass (*kwálaba*), as once remelted, the latter could be directly used in the crafting of objects (Robertshaw et al., 2009, pp. 83-84).

Ethnographic and experimental work was carried out on *bikini* glass production by Lababidi et al. (2023). It entailed interviews with glassworkers, the building and firing of replica furnaces and the subsequent chemical analysis of the glass, related raw materials and furnace remnants. The making of *bikini* glass was a collective effort, as a whole family was involved in the activity: outside every home there would be an *estwa* or workshop, where separate wood-fuelled furnaces for glassmaking and glassworking (each with a specific design according to function) could be found. The *bikini* furnace was constructed by first excavating a pit between 0.4 and 1 m deep, depending on the desired amount of glass

³ Pegmatite is an igneous rock compositionally very close to granite (Babalola et al., 2018a, p. 101)

(Figure 2.11). A domed superstructure (measured in the ethnographic study at 0.74m in height) was built up from the edges of the pit. The latter would contain the raw materials and the fuel, which were both fed through the stoke-hole located at the top of the furnace. Bellows were placed in front of another opening at the base of the structure. To produce *bikini*, the sand previously excavated from the furnace pit, alongside clay, mineral soda collected from Lake Chad and *tswanbi* (raw glass from previous firings collected from within the furnace) were finely ground together. The resulting powder was sieved to remove larger inclusions, and wetted to form a mixture which was then worked into loaves ready for melting. To keep the furnace constantly running at the optimal temperature to obtain glass, eight bellow operators would work in three-hour shift patterns for approximately five days. After the *bikini* was made, the furnace was left to gradually cool for a further three to five days to allow for the annealing of the glass, which would eventually be removed from the furnace by dismantling its superstructure (Lababidi et al., 2023, pp. 401-404; Robertshaw et al., 2009, pp. 83-84).



Figure 2.11: Bikini glassmaking furnace (Lababidi et al., 2023, p. 404)

Although Nupeland has not provided any archaeological evidence for the primary production of glass, the various stages documented for the re-creation of *bikini* glassmaking and the physical evidence produced such as raw glass and related materials, finished objects and especially vitrified furnace fragments, find parallels with the artefacts retrieved in Igbo Olukun. The chemical composition of the vitrified production debris from Igbo Olukun is very

similar to the furnace remnants collected in Bida, as in both instances the furnace walls had absorbed additional soda (evaporated from the raw materials), potash, lime and phosphorus (deriving from fuel). Furthermore, several pits were excavated in Igbo Olukun, three of which were between 0.4m and 1m deep, as well as another very deep bell-shaped pit (> 2.2 m deep) with a shallow channel leading to it (Figure 2.12). The strong resemblance between these negative archaeological features and the base of *bikini* furnaces may tentatively indicate that the pits could have been related to glassmaking. The evidence is far from conclusive, however, as no ashy deposits or presence of furnace lining were recorded for any of the pits. As the deposits were heavily disturbed, the finds contained within them did not provide any meaningful associations that would help in identifying the exact function of such features (Lababidi et al., 2023, pp. 419-422; Babalola et al., 2018a, pp.95-96).

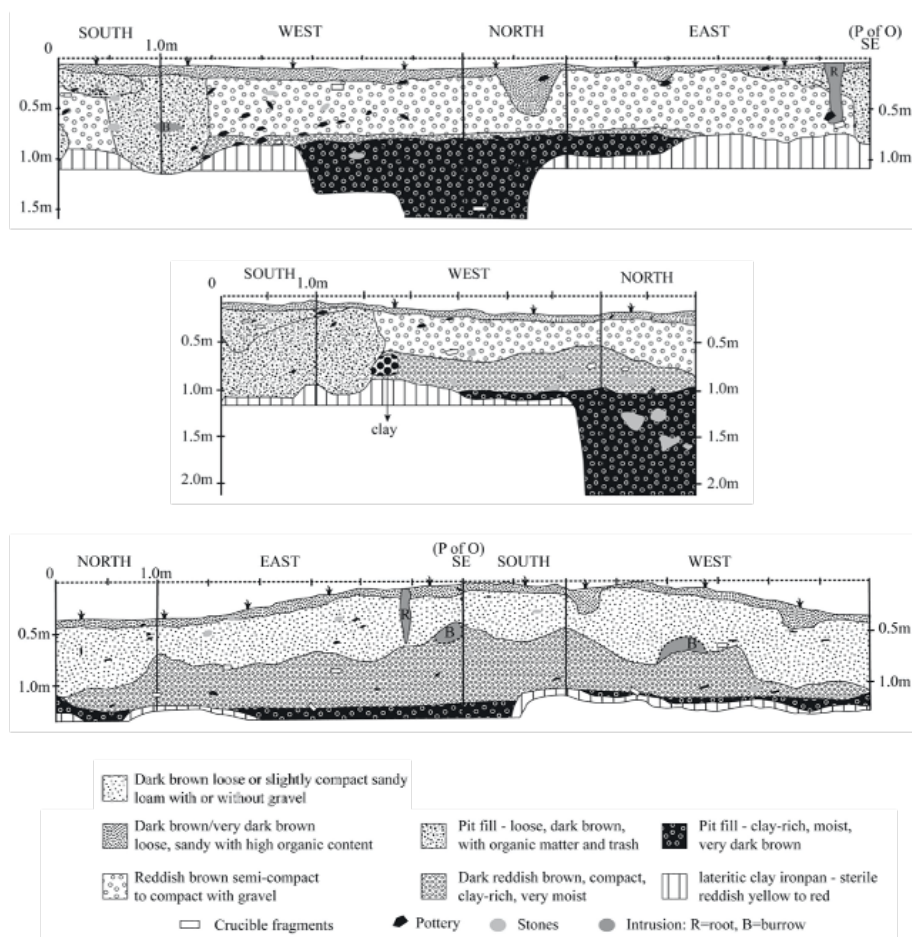


Figure 2.12: Sections of excavated pits in Igbo Olukun, units IO-B, IO-C and IO-D (Babalola et al., 2018a, pp. 96-97).

2.6 Bead-making furnaces and structures: the archaeological evidence

Bead-making structures generally fall under the category of secondary production centres, which is where the ready-made glass is further worked into objects (Henderson, 2013, p.18).

As previously discussed in Section 2.1, such a categorisation implies that the primary production of raw glass itself does not necessarily occur on the same premises where the making of the beads is taking place although this does not preclude the possibility, as reported below (Foulds, 2017, p. 16; Shortland, 2007; Francis, 1999). In general, archaeological evidence for bead-making is very faint and usually consists of glass working debris, crucibles, and broken or malformed beads. Identifiable bead furnaces have yet to be found, and pits or hearths – where present – are often the only surviving evidence that might be linked to bead manufacture.

For the first thousand years of glassmaking our evidence is restricted to the sites of Amarna and Frattesina, as discussed below. At Amarna, during the excavations of the courtyard belonging to the building complex M50.16, workshops specialised in the production of beads and amulets in various materials were unearthed (Hodgkinson, 2015a,b). It is possible that glass bead manufacture and the decoration of glass vessels were carried out at the site. No furnace remains were found to indicate this, but small pits with traces of charcoal, some of which had been later filled with dumped vitrified waste, have been interpreted as structures connected with glass bead-making (Figure 2.13).



Figure 2.13: Amarna, M50.14: potential evidence of a bead-making furnace, with vitrified mudbricks overlying a surface with stake-holes, with unknown function (Hodgkinson 2015b, p.282).

Compelling evidence is given by the presence near such pits of metal rods (mandrels) of the sort used for bead-making, several broken and whole beads, glass canes and ingot chunks. Other tenuous unstratified evidence was recovered from spoil heaps and surface layers in the form of fragments of crucibles, possibly used for ingot making or the melting of the glass from which canes were pulled (Hodgkinson, 2015b).

The settlement of Frattesina yielded evidence of several domestic crafts, such as the working of bone, copper, amber and in particular glass, which was used for the manufacture of beads. No furnaces or structures of any sort were found: the finds, most of which came from walkover surveys, consist of crucibles and beads, broken or whole, and chunks of glass (Bietti-Sestieri, 1984; Towle et al., 2001; Pearce, 2019).

For the 1st millennium BCE, the evidence for bead-making is limited to the Hellenistic period or the Late Iron Age (400-100 BCE). Several types of beads, glass canes, and fragments of glass vessels dated to between the late 3rd and the early 2nd century BCE, were retrieved on Rhodes in its homonymous town from a layer which was used to level the floor of a house (Davidson-Weinberg, 1969; Triantafyllidis, 2003). None of the glass material excavated was in primary deposition, making it likely that this belonged to a nearby workshop. Interestingly, crucibles with internal partitions, with evidence that they had been used to melt glass of different colours simultaneously, were also found. These are similar in shape to the ones used in contemporary traditional bead-making in Turkey (Davidson-Weinberg, 1969; Willoughby, 2005).

Salvage excavations carried out in the same area report on the discovery of small parts of a structure that may have been a glass furnace, but these findings have not been published in detail and are only briefly reported (Triantafyllidis, 2003). Albeit scant artefactual evidence indicating bead-making activity has also been retrieved from various Late Iron Age sites in France, Switzerland, Germany and Great Britain (Robinson, 2003). A similar picture can be painted for the Roman period, whereby bead-making sites remain largely undetected, or may briefly feature in grey literature reports: the recent discovery of a post-hole containing glassworking debris, scrap vessels and beads dating around the 4th century CE during trial trenching undertaken at Brislington Meadows (Bristol, UK), provides clues that bead-making, perhaps as a domestic production, was carried out on the premises, along industrial-scale iron-working and metal casting (Leonard, 2022). Considering the limited amount of data

available for Iron Age and early Roman glass production centres, it is unsurprising that we know very little about where beads were manufactured.

Later periods may also provide some insight. The Viking trading settlement of Ribe in Denmark was an important bead-making centre between 700-900 CE. Here tools, millefiori canes, glass scrap in various forms, and fragmented or whole beads were found within or around hearths, some of which had evidence for several phases of use (Sode, 2004). The hearths, seven in total, were made from fired clay and most were rectangular, measuring on average 0.55m in length and 0.25m in width (Bencard et al., 1990, pp. 99-104). A single hearth had a circular shape, which led to its potential interpretation as a natural draft furnace, although no traces of a superstructure were found (Peterson, 2019; Bencard et al., 1990, pp. 99-104). Other evidence, such as a loom weight possibly re-used as a nozzle, indicates that bellows or blowpipes were likely employed to reach and maintain the correct temperature (Krzyżanowska & Franckiewicz, 2015; Bencard et al., 1990, pp. 99-104). On a general note, we cannot discard the possibility that beads may have also been crafted over open hearths, small structures or even braziers, all of which could have used charcoal as fuel and bellows or blowpipes to direct and concentrate the heat, as shown in Figure 2.14 (Krzyżanowska & Franckiewicz, 2015; Gam 1990; Stern & Schick-Nolte, 1994, p.24).



Figure 2.14: Experimental bead-making from glass canes using an open hearth (Krzyżanowska & Franckiewicz, 2015, p.114).

Could bellows also have been used in the pits found at sites such as Amarna? The use of such tools is in general quite contentious, due to the ephemerality of the archaeological

evidence (Hodgkinson & Bertram, 2019, p. 5; Hodgkinson 2015b). When open hearths or small structures were used with charcoal fuel, beads might have been crafted by either chunk-gathering, which is the melting and shaping of a chunk of glass previously collected on a heated rod (Stern & Schick-Nolte 1994, p.28), or by melting the glass in a crucible, which was then collected with a metal rod (Gam, 1991).

Alternatively, beads may have been produced by winding pre-formed glass canes, as in the case of Ribe (Bencard et al., 1990, pp. 99-104; Krzyżanowska & Franckiewicz, 2015) and as indicated by evidence from sites including Amarna for several fragments of coloured glass cane. Experimental archaeology has proven that it is possible to make beads from glass canes without bellows in either open hearths or in small furnaces built on top of them, but in previous experimental attempts to achieve this, contamination with ashes and volatiles from the charcoal was observed on the surface of the beads. This contamination has not been recorded on archaeological specimens, leaving an open debate about the validity of this manufacturing hypothesis (Krzyżanowska & Franckiewicz, 2015; Hodgkinson & Bertram 2019; Gam, 1991). For discussion of the use of small, wood-fired glass bead furnaces in my own experiments and previous work undertaken by Wiesenberg (2018), see Chapter 3.

As previously mentioned in Section 2.5, archaeological evidence for bead-making in Sub-Saharan Africa was recorded at Igbo Olukun, in Ile-Ife, 11th to 15th century CE. No remnants of bead-making structures as such were encountered, but the 2011-2012 excavations yielded 13,000 beads and 800 crucible fragments, some of which were also used for glassmaking, and almost 3 kg of production waste (Babalola et al., 2017; Babalola 2018a). The beads, measuring on average less than 5mm in diameter, are cylindrical or more rarely tubular or oblate. They were made with the drawing technique⁴, by punching of the hot glass gather with an iron rod to obtain hollow glass canes, as also reported for the *Lada* technique in Southern India (Section 2.7). The production debris consisted of collapsed and fragmentary tubes, glass canes, droplets, fragments of bead and crucible glass, partially-fused beads and cullet, intended here as waste glass fragments that could not be identified as pertaining to any of the aforementioned categories. Impressions on the vitrified outer surface of the crucibles indicates that they were placed in a charcoal bed, while the glass adhering to their inner walls suggests that the majority were used to reheat it for bead-making (Figure 2.15).

⁴ For a detailed description of the methods and processes that can be employed in the crafting of drawn beads, please refer to Appendix A.

Crucibles were ovoid or barrel-like and present in a range of sizes: it has been estimated that – according to capacity – between 180,000 and 1,080,000 beads could have been manufactured in a single crucible use, implying large-scale bead production, not solely intended for local consumption. The beads made here were traded across a wide region through trans-Saharan networks, and ultimately were also to reach the Americas (Babalola et al, 2018a, pp. 97-98; Babalola et al, 2018b; Babalola, 2017; Ongudiran & Ige, 2015).

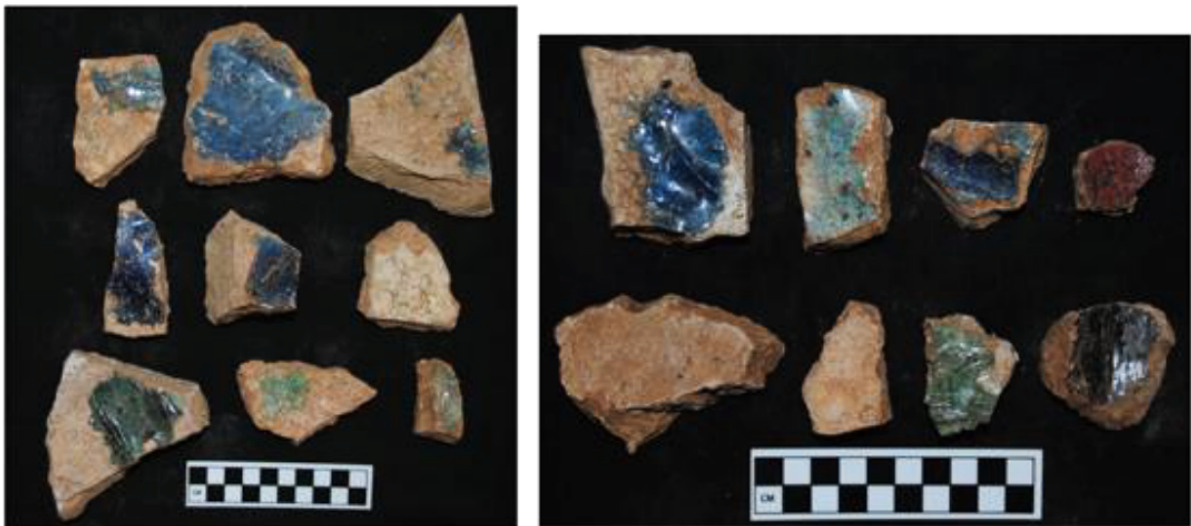


Figure 2.15: *Bead-making crucible fragments from Igbo Olukun (Babalola et al., 2018b, p. 17).*

2.7 The ethnographic evidence for bead-making furnaces

As previously stated, we cannot ascertain the types and variety of structures or furnaces employed in antiquity with the purpose of crafting beads, but ethnographic data, when taken with a pinch of salt and some practical understanding of thermodynamics and the craft of bead-making, can help us to reflect upon those and to make some inferences about the scale and organisation of production.

Traditional low-domed furnaces, very similar to the glassmaking specimen found in Tell el-Amarna, are still in use for the making of wound beads in Turkey, Egypt and India (Nicholson & Hart, 2007; Küçükerman, 1995; Sode, 1995). These furnaces are in general quite large, and can accommodate from five bead-makers, as attested for the Izmir area in Turkey, to a maximum of 20, as documented for the manufacturing centre of Purdalpur, in Northern India (Willoughby, 2005; Kanungo, 2004). The furnaces in Purdalpur are dismantled and then rebuilt every six to twelve months: this may partly explain why the archaeological traces for structures of this type are so faint (Sode, 1995; Kanungo, 2004, p. 140). The Indian and

Turkish furnaces are built inside a workshop and provided with a roof which may have an opening. The furnace construction material consists of either clay mixed with straw, as in India, or fire-bricks which are subsequently lined with clay, as for the Turkish furnaces (Sode, 1995; Sode & Kock, 2001b; Küçükerman, 1988, p. 49). In Purdalspur, to protect the bead-makers from radiation heat and to create individual workstations, clay plates are placed vertically inside the pit which constitutes the base of the fire chamber as shown in Figure 2.16 (Kanungo, 2004, p.140).

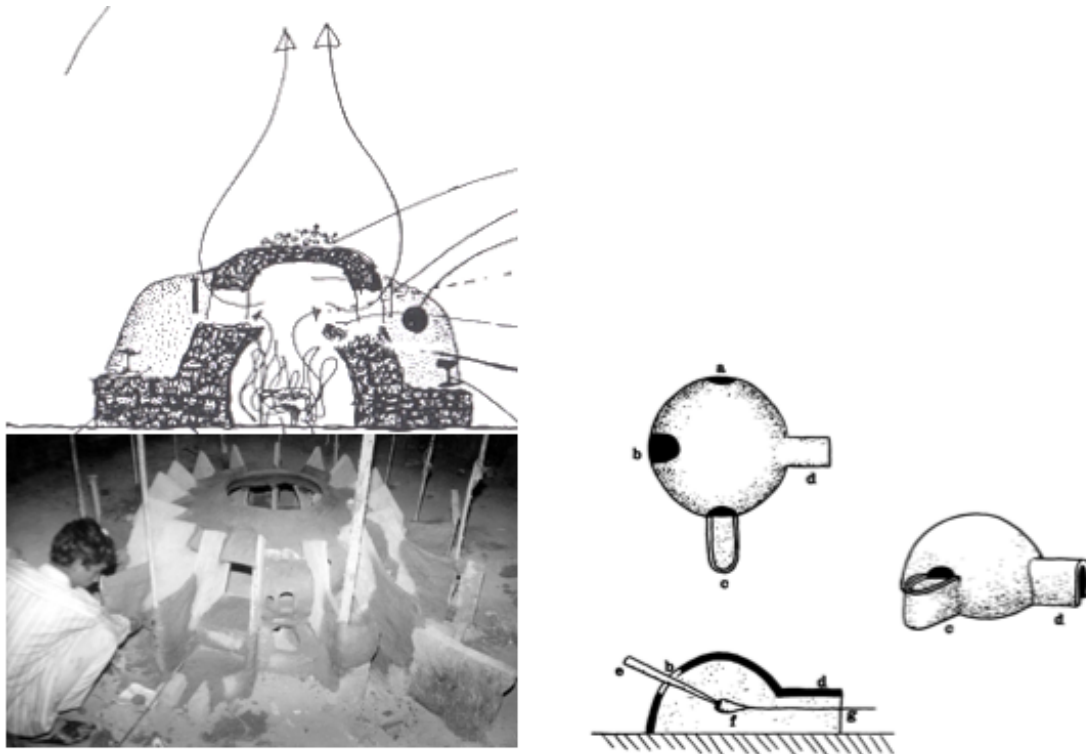


Figure 2.16: Low-domed furnaces. Top left: Turkish bead furnace (Küçükerman, 1988, p.48). Bottom left: furnace building in Purdalspur (Kanungo, 2004, p. 140). Right: Furnace in Papanaidupet, used for the Lada technique (Francis, 1991, p. 29).

It is unclear from the reports whether the furnaces from Izmir were built from the ground up, but the mention of a clay and mortar floor for the combustion chamber implies that there was no foundation cut (Küçükerman, 1995). In both cases the glass, which was heated in a crucible sitting on a ledge above the firing chamber, was worked with a metal rod (Kanungo, 2004, p. 142). Differences in design between the Turkish and the northern Indian furnaces are minimal: given that neither type possesses a chimney as such, variations may consist of the presence or absence of an aperture at the top of the dome, and in the number of working ports (Willoughby, 2005; Küçükerman, 1995; Sode & Kock, 2001b). The similarities between these constructions may be due to the fact that both are devised to work the glass by winding. In Purdalspur the manufacture of bangles and other small glass

objects takes place at the same furnace as is used for bead-making (Kanungo, 2004, p. 139). Domed furnaces in the town of Papanaidupet in Andhra Pradesh, India, present slightly different characteristics as they are built for a specific drawing method which employs the *Lada*, or a very long iron tube: the glass is heated in the built-in trough to the side and is then worked on the *Lada* from the glory-hole located at the back. To create hollow canes, the whole length of the glass is pierced with another rod, which is then used to pull the glass through the channel at the front (Francis, 1991, pp. 29-30).

If, at a first glance, low-domed furnaces may all look the same, the variations in their design reflect specific cultural traits in relation to technological needs and scale of production. Even within a single tradition, significant differences in furnace construction may be observed: bead-making furnaces in West Africa, which are mostly employed for the production of beads using moulds, present significant variations in design and size. The furnaces can be rectangular with a dome on top, or smaller and conical, as observed in Ghana (Haigh, 2003). In Bida, Nigeria, shaft-like or beehive furnaces are employed in the production of beads with a technique akin to the Turkish and Indian examples, with the difference that in this case bellows are employed (Liu et al., 2001; Alemaka et al., 2015). Similarities between West African bead furnaces include the use of locally-sourced clay in their construction, and the use of a sheet of iron to separate the firing from melting chambers (Haigh, 2003).

It also worth noting that the same furnace can be used for the making of different objects, as is the case for beads and bangles produced in Bida by the *Masagá*, in cylindrical furnaces built with no cut foundations. They measure between 0.5 and 0.55m tall and are fuelled by small branches of local redwood (Figure 2.17). As is the case for *bikini* furnaces, these structures also have a top stoke-hole (provided here with indentations to rest the iron rods when working the glass) and a lateral opening for bellows. Three or four glass-workers, each specialised in either beads or bangles, can use the furnace at the same time (Lababidi et al., 2023, pp. 404-406).



Figure 2.17: Masagá glassworking furnace for the production of bangles and beads (Lababidi et al., 2023, p. 405)

The wide variety of furnace shapes described above may be less a feature of glass bead-making specifically, and more a cultural phenomenon of West and sub-Saharan Africa more broadly, as has been observed for iron smelting. The cultural impetus for regional variation combined with vast differences in climatic conditions and raw material availability underpin the presence of different but contemporary technological traditions, reminding us of the dangers, as well as the benefits, of directly linking archaeological to ethnographic evidence (Killick, 2015, pp. 312-313), or indeed of making too many generalisations from the scant archaeological evidence of bead production that does survive.

Regardless of the particular characteristics of the furnaces described above, all are capable of reaching bead-making temperature within two hours of the initial firing (Willoughby, 2005; Küçükerman 1988, p. 61). The type of fuel employed can be wood, brushwood or dung, and whenever possible the bead-makers try to minimise any waste: the furnaces in Kurudere, Izmir, burn on average 100-150kg of pinewood a day, and the wood that is doused at the end of the working day to put out the fire is often re-employed in the next firing (Küçükerman 1988, p. 56, p. 61; Liu et al., 2001; Kanungo, 2004; Willoughby, 2005).

2.8 Bead-making sites and related interpretative problems

Although the differentiation between primary centres, where the glass was manufactured from raw ingredients, and secondary production centres, where the glass was worked into objects, is widely accepted (Rehren & Pusch, 2005; Shortland, 2007; Henderson, 1985), evidence in the archaeological record for glassmaking and glassworking structures – let alone bead-making furnaces – is elusive.

In general, glassmaking and glassworking furnaces are rarely well preserved and most of the time no superstructures survive, revealing a partial and incomplete picture (Jones, 2011, p. 9; Henderson, 2013, p.18). Poor in situ preservation can result not only in the degradation of the feature, but also in the decay of the glass itself, especially if it was chemically unstable to begin with (Pollard & Heron, 2008, pp. 176-177). Even when structural evidence is present, its interpretation may be complicated. Glazing of the internal surfaces of a furnace may imply primary glassmaking, but could also be the result of accidental spattering or spillage of glass during working (Taylor & Hill, 2008). As a result, clues that could help us to distinguish primary from secondary production centres are few and very specific: if a fritting oven or frit were recovered on a site, this is a clear indicator that glass was made from raw ingredients, which could have been imported or locally sourced (Henderson 2013, p.18). For the earliest glassmaking in particular, there are no data available to infer what – if any – was the standard design of a glassmaking furnace (Nicholson & Jackson, 2018, p.92), but the size of a furnace is both limiting and enabling in terms of what activities might have occurred there, and so it can be a good indicator of the type of production carried out. In general, glassworking furnaces and hearths would be of smaller dimensions than those used for the primary production of glass (Nicholson & Jackson, 2018, p. 93; Henderson, 2013, p.18; Bencard et al., 1990). In any case, the evidence for structures should always be combined with the information provided by related assemblages, especially when a single site yields multiple high-temperature structures, which could be used for other pyrotechnological activities such as ceramic or metal production (Nicholson & Jackson, 2018, Mass et al., 2001), or which may have served multiple purposes.

Certain combinations of artefacts within a site's assemblage might imply the presence of both primary and secondary glass production – making and working – at the same site, as appears to be the case for Igbo Olukun (Babalola, 2017). If we consider further

archaeological evidence from sites such as Amarna or Rhodes, as well as the ethnographic observation of contemporary Turkish beadmakers who use the same furnace equally to make beads and to produce their own glass from raw materials, it is clear that glassmaking is not always a separate activity to the working of glass (Küçükerman, 1988, p. 59). Furthermore, the same category of artefacts may have had multiple or different functions according to the context of retrieval: on the basis of the evidence collected in Qantir-Piramesses and Lisht for the 13th and 14th centuries BCE, we can infer that crucibles could have been used for both colouring the glass during primary production and melting the glass for glassworking (Smirniou et al., 2018; Nicholson & Jackson, 2018, pp. 92-93; Rehren & Pusch, 2005). Glassmaking crucibles were distinguished by the discolouration of their internal walls, a result of the lime partition layer used to facilitate the extraction of the finished ingots (Smirniou et al., 2018). An indication that such types of crucibles could have been employed also in glassworking is given by the presence of fully fused glass with no apparent inclusions or intermediate crystals adhering to their inner surfaces (Smirniou et al., 2018, p. 512).

The crucibles retrieved from Ife also tell a similar story, as they would have been likely employed for glassmaking and glassworking, as discussed in Section 2.6. In particular, the presence of quartz grains within the glass matrix (hence unrelated to the crucible fabric make-up) and the high soda content of the ceramic in contact with the glass melt indicate that raw materials were directly introduced into some of the crucibles. Evidence of the addition of colourants to the melt has also been documented in the form of swirls within the crucible glass (Babalola et al, 2018b; Babalola et al., 2020).

As shown by ethnographic research, different types of debris, which are reported in Appendix A, are distinctive of certain bead-making techniques, reflecting specific processes or actions (Francis, 1990, 1991). This could be very important as most of the time it is impossible to infer how the manufacture of beads was carried out by only relying on the excavation of features or strata. It must also be taken into account that the structures employed in the making of the beads might have also been used for the manufacture or decoration of vessels and bangles, as highlighted in Sections 2.6 and 2.7.

To summarise, the archaeological evidence for bead-making is ephemeral at best, as in most cases it is not possible to infer either the size of the structures or how they exactly looked. In

addition, a one-size-fits-all approach is not viable, as there are many culture and context specific factors that may have influenced the way beads were crafted: the source of raw glass and the type of fuel/raw materials available, the scale of production and the level of specialisation are all bound to affect furnace design(s) and the organisation of labour (Costin, 1991). Experimental archaeology, when combined with archaeological, scientific and ethnographic data – as in the present work – becomes a useful tool to reflect on a given technological practice, by testing hypotheses in order to disprove or validate theoretical assumptions.

Chapter 3. Challenging the myth of hyper-specialisation through experimental archaeology

This chapter contains personal reflections on bead-making as a practice, from the use of different equipment and furnaces to the finished product. In particular, I was able to compare and contrast beads made with a modern lamp versus specimens manufactured in open-air structures. The conclusions I was able to draw from my observations proved very useful in the detection of the causes behind the presence of manufacture surface alterations on experimental and archaeological beads that underwent use-wear analysis. Even though I may not have turned into a bead master, my experience and limitations as a maker provided me with valuable insights, which allowed me, amongst the other things, to challenge the following (implicit) pre-conceptions in archaeological and ethnographic glass bead studies:

- In antiquity glass was worked at lower temperatures because of a lack of know-how (Grose, 1989, p.31; Moorey, 1999, p. 204)
- Bead-making is a highly specialised activity
- If an experiment fails, it must mean that a certain structure or technique was not used in the past
- There must be a 'right way', or better, a prescriptive way to make beads (Wiesenberg, 2018)
- Variations among beads of the same type are always intentional

In order to address these points, replica soda-lime-silica glass beads were crafted from Moretti Effetre canes on several occasions, using modern and ancient techniques. To begin with, lamp-wound beads were made on two separate occasions under the guidance of Mike Poole, an expert bead-maker, specialising in the reproduction of archaeological and historic beads, which he crafts by lamp-working. A first batch of monochrome beads was manufactured in December 2018 at the Wolfson Laboratory at Newcastle University, after which followed a visit in March 2019 to Mike's studio (Tillerman Beads) in Todmorden (UK), where not only was I able to take photographs of the beads he made with specific techniques, but I also received one-to-one tuition so that I could learn how to apply complex decorations to beads, such as stratified eyes, millefiori, zig-zags and twisted canes. On the one hand, the photographic documentation collected has resulted in the creation of a visual step-by-step guide to glass bead types, which is contained in the present work in Appendix A,

on the other hand, the experience I gained in bead-making provided me with a skill set that I could transpose onto the crafting of beads in a small natural draft furnace.

In June 2019 I attended the archaeological park of Roman Villa Borg in Perl (Saarland, Germany), where every summer, period replica furnaces are built and fired by experimental archaeologists alongside experienced glassworkers specialised in ancient techniques. Whilst there, I had the opportunity to take part in the construction and use of a small bead-making furnace: this spurred me to construct my own so that I could investigate each step of the *chaîne opératoire* as reported below.

3.1 The building, firing and demise of a small natural draft furnace

If the glassworking kilns of Villa Borg are reconstructed on the basis of Roman and Medieval evidence (Wiesenberg, 2018), and on earlier experiments carried out by Taylor and Hill (2008), the same does not apply to bead-making furnaces, which, due to the gaps in our knowledge of secondary production centres in antiquity, are not designed around any particular archaeological or ethnographic model. As there is no exact way to reconstruct a bead-making furnace, and I wanted to investigate the nature of the skillset required to successfully craft beads in a small natural draft structure, it was decided to replicate Villa Borg's design, as this has proved to be apt in the crafting of beads by cane winding without the use of bellows (Wiesenberg, 2018).

A small furnace was constructed with the help of C.N. Duckworth and V.A.L. Lucas in May 2019 in the grounds of Jarrow Hall Anglo-Saxon Farm and Bede Museum, Tyne and Wear, UK. This first attempt was a partial failure as we were not able to reach prime bead-making temperature (approximately between 930° and 960°C) due to the fact that that not only did the structure have a keyhole shape and a wide, short chimney, which together were not suitable for drawing hot air towards the top, but also the placement of the stoke-hole against the direction of prevailing winds inhibited air circulation. Nonetheless, after clearing the area, in September 2019 it was decided to build a new furnace at the same location, but with the stoke-hole facing in the opposite direction. In just three hours, the furnace, which measured 0.7m long, 0.51m high and with walls 0.06m thick, was built from the ground up by shaping coils and small bricks from heavily grogged clay. The base was U-shaped with slightly converging ends: to increase the airflow within the structure, three round openings, placed at regular intervals at the rear, were created (Figure 3.1). The superstructure consisted of a firing chamber with related stokehole and a chimney, which was

approximately 0.3 m tall. Its mouth, measuring 0.14m in diameter, was provided with slits to protect the bead-maker from heat radiation and to facilitate the winding of the glass around the mandrel. Once the building of the furnace was completed, this was left to air-dry for two days to prevent severe breakage when fired. When the structure was heated for the first time, due to the lack of straw, which is usually employed to strengthen the building mixture, the clay expanded creating some cracks, which could be easily repaired.



Figure 3.1: The building and firing of natural draft bead-making furnaces (Pictures author's own).

Beads were made over a four-day period: the furnace, which was fuelled with kiln-dried hard wood from beech and ash, would easily reach 1000°C in two to three hours from the initial firing, depending on atmospheric conditions (e.g., wind). The temperature was recorded by a thermocouple, placed at the base of the firing chamber towards the rear. Even without relying on numerical readings, the white colour of the flame and the intense reverberation heat coming from the structure were good visual indicators for the attainment of a suitable temperature range for bead-making. In the time-frame of the experiment, we crafted beads for approximately three hours a day, with the fire being doused at the end of each session.

As shown in Figure 3.2 below, we successfully managed to make intricate – albeit imperfect – beads and although some of them shattered due to sustained thermal shock as explained in the following section, the majority survived. Immediately after having been made, the beads were placed in vermiculite, and as the furnace was not left to cool down gradually, they were subsequently annealed in small batches at temperature of 520°C for two hours by using the Vecstar furnace located at the Wolfson Laboratory.



Figure 3.2: Jarrow Hall Anglo-Saxon Farm and Bede Museum, September 2019: The making of an eye bead in a small wood-fuelled furnace. (Pictures by C.N. Duckworth).

After the experiment was concluded, the furnace was left to the elements for two years to document the degradation process, as pictured in Figure 3.3. As the furnaces at Jarrow Hall and Villa Borg are constructed from the ground up, they have no foundation cut, which means that if they collapsed, or the clay superstructure was removed, we would be left with a very ephemeral feature, comprising of ashy and charcoal-rich patches. In addition, it is likely that such furnaces were not meant to be permanent installations and although they could be maintained regularly, over time and multiple firings the heat would eventually cause them to crack in an irreparable manner, and for this reason it would have been more time efficient to remove the decrepit structure to then build a new furnace, as this can be done (as shown by our experiments) in under a day. As a result, the transient nature of small outdoor furnaces might explain why our main clue indicating that bead-making was taking place at a site is the presence of diagnostic debris.



JARROW HALL ANGLO-SAXON FARM AND BEDE MUSEUM (UK) JUNE 2021



VILLA BORG (GERMANY), JUNE 2019

Figure 3.3. Furnace degradation and removal of superstructure. The red circle on the top left picture indicates the area where a glass cane melted on the inside of the chimney (Pictures by Marco Romeo Pitone and author's own).

As for most of antiquity glass was relatively difficult to acquire, canes or vessel fragments, which are found on secondary production sites as mentioned in Chapter 2, might have been saved for future bead-making and/or glassworking, or even traded for re-melting, although the same cannot be said for other scrap materials. In particular, the best markers for bead-making activities are broken or malformed beads, which are likely to occur when using any type of outdoor structure. If these beads were made with a separator, they may not have been recycled because if the glass were to be re-melted, the clay would have contaminated the batch, creating a less durable product. In some instances – although this is purely context dependant – polychrome beads may have not been re-fused.

During our experiment, we observed that different variables, such as furnace design and experience or lack of experience of the bead-maker, or even the dryness of the wood, the presence or absence of wind or a shelter, and the way the furnace is managed can influence the way beads look. The following sections will explore in greater depth the implications of making beads in small furnaces and how the process and outcomes differ from lamp-winding and the use of other structures.

3.2 Bead-making and cane-winding: lamp versus small furnace

Whether wound beads are made in a furnace or with a lamp, they are crafted by rotation and are for this reason seamless (Spaer 2001, p.45). Wound beads are always annular at first, but can become rounder if additional glass is coiled around the mandrel or wire. In this process it is always very important to re-heat the bead before applying further amounts of glass. The size of the mandrel and the absence or presence of tapering on its end will affect the overall diameter and appearance of the bead perforation (van der Sleen 1973, p. 23). A well-made bead will always have the perforation in its centre, and a dimple will be present around the thread hole on the side which is the closest to the tip of the mandrel. This is created by the action of twirling the glass on the mandrel over the heat, with the mandrel kept perfectly perpendicular to the flame.

Experiments carried out since 2014 at the Archaeological Park of Roman Villa Borg and by the author at Jarrow Hall, have proved that purpose-built small furnaces can produce, to a certain extent, a concentrated long flame, which is essential for this technique to be applied successfully. In this case the heat distribution is not homogenous, thus the hot glass will be stiffer in comparison to flame-working. This results in slight adjustments in the techniques employed to craft the beads. In the case of a natural draft furnace, as the glass is heated in a slightly uneven way, gravity will play a very important part. Especially when decorations such as eyes are applied, to form a dot on the bead it will not be sufficient to press the end of the cane on the body of the bead and 'burn' the glass off by pulling the cane away from the flame as it would occur by lamp-working (Appendix A). The bead will instead have to be rotated at the same time as the eye is being made so that the cane can thin out until it can be burnt off.

Beside the level of experience of the bead-maker, another important factor which can impact on the finished product is the overheating of the glass. For this reason, it is very important to know where the exact working range of the heat source is and for how long the glass can

withstand high temperatures. As observed in lamp-wound beads, if the glass is placed too close to the hottest part of the flame, it will overheat, leading to the formation of bubbles which will eventually burst, producing textural alterations (Figure 3.4). A similar appearance has been recorded on beads crafted using a small wood-fuelled furnace, although in this case the underlying causes are completely different. Slightly stiff glass, concurrent with an excessive amount of separator remaining wet, will lead to the formation of bubbles. The glass, still too cold to be coiled around the mandrel, drags the clay slip around each wind, resulting in a finished product with small voids partly filled by traces of separator. If the latter degrades over time, it might be very hard to distinguish what caused the alteration in the first place.

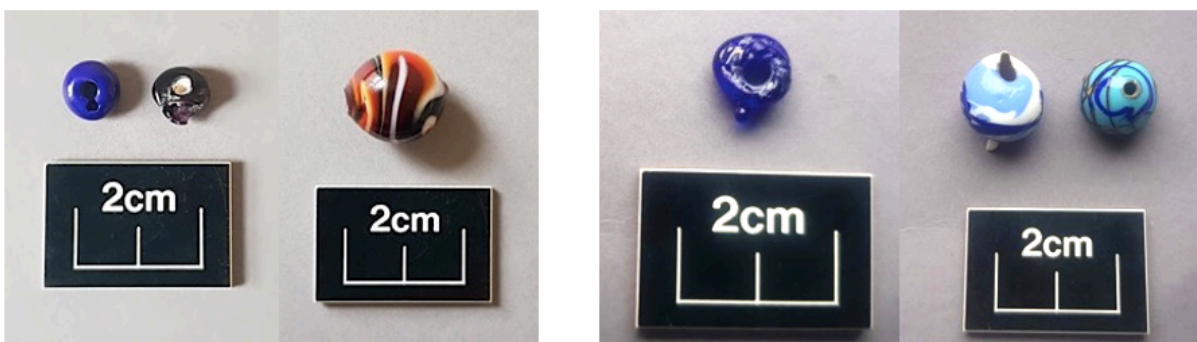


Figure 3.4: Beads showing alterations. On the left lamp wound-beads and on the right beads made in small furnace. In both sets of pictures, air bubbles which have burst are visible on the surface of the beads to the left. On the right, beads displaying a thinning of the ends (Pictures author's own).

On the other hand, if the bead is kept in the flame of a lamp or a furnace for too long it will sag towards the centre, thinning at the extremities. In this case the final shape will resemble a lemon (Mike Poole, *pers. comm.*). Saggy beads can result as well from decreased control of the mandrel combined with the use of a diffused and unstable flame, as observed when working in a small furnace. In order to lessen the effects of heat radiation when working the glass, handles can be attached to the mandrels, and although this is very effective to protect hands from burning, it can make it harder to place the winds of glass one on top of the other to form the initial bead. It has to be said however that the use of handles may be one method among many others, as there is bound to be some variation – across time and space – in mandrel shape and size: when annular beads found in the archaeological record present an uneven distribution of the glass winds which results in stark variations in thickness between their top and bottom sections, this may have to do with the fact that long tapered rods were used to craft multiple beads at a time, meaning that the use of short and thin mandrels like the specimens retrieved in Nuzi and still used by contemporary bead-makers, is

not always guaranteed (Vandiver, 1983). In any case, if the temperature is not hot enough to uniformly melt the glass and to correct the shape, the outcome will be irregular beads, displaying signs of thinning at both ends. If the body of the bead was only partly melted, which means that the single winds would still be raised, we could infer that this was made using a structure where the heat is not constant.

In some instances, the chemical composition of the glass can influence the way a bead looks. Some colourants present in ancient glasses can be very unstable and have proven to deteriorate if subjected to prolonged and intense heat. This appears to be true for the opaque yellow glass crafted in Egypt during the 2nd millennium BCE, the colour of which was formed by lead antimonate crystals being added to the glass melt at low temperatures. If exposed to high temperatures for an excessive amount of time, the yellow glass would turn white in patches. This reaction is dependent on the correlation between the technological knowledge applied to the production of the raw material, and the degree of control exerted on the working of the glass at a later stage (Shortland 2002; Duckworth et al. 2012).

The main difference between a lamp and a large furnace, similar to the ones employed by contemporary bead-makers, is that the former uses the heat deriving directly from the flame, whereas the latter exploits the heat in an indirect manner, as the crucible sits on a surface immediately above the firing chamber. If a natural draft furnace like the ones from Jarrow Hall and Villa Borg was employed to craft beads, the glass would be placed straight into the flame, as in lamp-working. Due to the very scant archaeological evidence, it is unclear which and how many types of furnaces were employed and to what extent they could produce a concentrated flame or even what type of heat they relied on for the making of the beads. In this case, our discriminant should be the stability of the temperature, rather than the type of structure employed. This means that we might be able instead to distinguish beads crafted at a constant temperature from beads made using a structure or a method for which the temperature fluctuates.

When working with a wood fuelled furnace, drops in the temperature, whether minor or major, can be determined by the actions of the stoker, who might need to add or re-arrange the wood in the structure, or by climatic factors, such as the wind blowing. This, combined with the ability of the structure to retain the heat, can provide a variable outcome. If a furnace is built and maintained in way that minimises the effects of the shifts in temperature, the beads produced could be as flawless as the ones crafted by lamp.

Conversely, if the furnace is poorly insulated, exposed to the elements or stoked incorrectly, the finished beads might present an uneven surface, as the glass, once the heat is lost, becomes too stiff to be worked any further. For the decorations, which at times might be slightly raised, it can be difficult to assess whether that was an intentional act, or if that is dictated by constraints of working the glass in a small structure with an unstable temperature. In addition, sudden changes in temperature, which are mostly caused by the introduction of a fresh batch of fuel, can narrow the period of time in which the glass can be worked. In particular, if new wood is added whilst making a bead, the furnace will temporarily lose heat, producing a lot of soot and ash whilst trying to burn off the fuel. As a result, the glass will turn black and become unworkable until the right temperature is restored. As it may take a minute or two, which is more than the time required to craft a bead, ash particles may be incorporated within the glass surface in a permanent manner, resulting a in bead with pock-marked appearance. This, in addition to fluctuations in temperature, will increase the chances of breakage.

3.3 Final remarks

Francis (1999, p. 55) argued that producing beads with a lamp makes the crafting of more intricate decorations possible, due to the degree of control that can be applied to the intensity of the flame. However, on the back of the experience gained, I believe that this is not necessarily true, as bead-making in furnaces requires a slightly different understanding of the material and the way this can be worked. As a consequence, glass in antiquity was not worked at lower temperatures because of a lack of know-how. Glass can be relatively unpredictable and so are small outdoor furnaces: especially in the case of a bead with a complex decorative scheme, the bead-maker has to plan their actions in advance. In case of a partly inefficient set-up or structure, however, flexibility may be required: the bead-maker knows that if the bead is worked for too long when fluctuations in heat intensity occur, as soon as it is removed from the fire it will break in half, which means that the final product will be a reflection of the circumstances under which it was made and could thus be different from what was initially envisaged. In this light, unintentional variations among beads of the same type can be expected.

From the experiments I conducted on an outdoor wood-fired furnace and from my involvement in bead-making in a very small structure which employed bellows and charcoal and that was loosely inspired by Late Bronze Age Egyptian types used for copper smelting,

both structures and types of fuel produced similar results and most of the considerations made so far, also apply to this particular case (Figure 3.5). These results prove that bead-making is not necessarily a prescriptive activity that is rigidly bound to specific furnace designs.



Figure 3.5: Oxford University Parks, May 2022: cane-winding in a small structure with bellows. This was a public outreach event coordinated by A. Hodgkinson as part of the 'Late Bronze Age Glass' conference organised by D. Rosenow and V. Sainsbury at the Weston Library. (Picture author's own).

Beads can thus be successfully made from canes from any structure, as long as a concentrated flame is obtained by trapping and channelling the heat, demonstrating that glass in antiquity was not worked at lower temperatures, especially if we consider that mastery in pyro-technology had already been acquired with antecedents such as pottery and metals, that require firing temperatures in the region of 900°-1100° C. This may hint at frequent cross-craft interactions, as also shown by the archaeological record, as more often than not bead-making may have taken place alongside other high temperature activities (see Chapter 2). In addition, the implications of making beads from glass canes are several: for a start, glass canes are derived from secondary glass production, which means that they have been previously made in a glassworking furnace. If glass could be already worked on a site, beads – alongside other artefacts – could have simply been made by furnace-winding, saving time and fuel. The scenarios in which glass canes could have been employed are possibly

two: either these were used in a workshop that had several furnaces, each specialised in the production of a specific object including beads, or the glass canes were acquired from elsewhere as 'raw material'. If the making of the beads from canes was seen as a technique to be applied to a particular structure, it is likely that this would have been quite small in size, in order to minimize building material and fuel waste.

There is no certain way to determine if beads were made in a particular type of structure, although we might surmise that their size and the presence of a separator (or lack thereof) could be to some extent useful discriminants. In the case of large beads with an internal diameter > 1.0 cm, such as the specimens from Campovalano (TT. 18, 162, 243, 282, 412), if we accept the validity of ethnographic parallels with contemporary workshops in Turkey and India where no separator is used on long, often tapered rods, we can hypothesise that such beads, especially if they contain iron oxide within the thread-hole, may have been crafted in a large furnace (Figure 3.6).



Figure 3.6: Campovalano, T. 282: large bead with potential remnants of iron oxide within the thread-hole (Picture author's own).

Independently from their dimensions, most beads from Abruzzo and Fazzan seem to show traces of clay slip or accretions inside the thread-hole: we know from the archaeological record that mandrels coated in calcite and clay were used in Nuzi, northern Iraq, as early as the 2nd millennium BCE (Vandiver, 1983). In a similar manner, beads from the Uluburun shipwreck, dating to the 14th century BCE, still bore traces of the separator, meaning that this was not mechanically removed, which could also be the case for the archaeological beads that are the subject of this research (Ingram, 2014). The visual examination of the assemblages discussed in this thesis has also shown that a number of beads did not present

any manufacture-related patinas in the thread-hole, which means that the separator might have either been removed in antiquity or might have degraded during pre- or post-depositional processes. In addition, it is also possible that a minority of wound beads were crafted without the use of a separator (Spaer, 2001, p.46). This is a stark reminder that there is no such thing as set way to make beads, as some steps in the *chaîne opératoire* may display traits of variability, and although some beads may look the same, this does not necessarily mean that they were made following exactly the same procedures. Conversely, it is also possible for the same technique to present variable outcomes, because no bead-maker uses the exact same approach (Spaer 2001, p. 43, Kanungo, 2004).

All in all, the experiments carried out at Jarrow Hall have taught me that bead-making is not necessarily a highly specialised activity: as opposed to other glassworking activities such as glassblowing, which requires years of practice to become proficient, anyone can really make beads as the simplest types can be mastered quite quickly once acquainted with the material. If some archaeological beads are undoubtedly an expression of refined craftsmanship, many others are imperfect by our modern standards, but this does not mean that they were not good enough to be worn, as they would have anyway possessed highly coveted qualities which are part of their essence, such as colour, shine and durability. As a consequence, the most important factor in bead-making appears to be the skillset related to the construction and firing of furnaces. In our case, the furnace design could have been improved upon, as a longer chimney with a narrow top and a shorter flue would have amplified the draft effect. Considering this was built by individuals that have had no extensive practical knowledge of this type, nor fire-management abilities comparable to the ones of ancient societies, the whole feat was an accomplishment. In this sense, I think experimental archaeologists should always consider their positionality in terms of own craft experience when testing hypotheses, which means that if for instance a structure does not work, perhaps an incorrect approach was used.

PART II. Use-wear analysis on glass beads: methods and applications to
experimental and archaeological data-sets

Chapter 4. Development of use-wear analysis for glass beads

This chapter discusses the development and application of use-wear analytical techniques on replica glass beads employed in the bead-wearing experiment. The results presented here aim to act as a comparative baseline for the observation of traces on archaeological beads described in Chapter 5. As all the wear types encountered can be the result of either use, manufacture or accidental damage, in the results section it was chosen to divide the different traces based on their morphology, as the giveaway for the action that caused them is rather obvious from their placement, quantity and distribution. Particular attention will be paid to polish appearance and development in relation to different stringing and bead contact materials. Lastly, the role of individual variables and their combinations as contributing factors in trace formation will be analysed.

a) Background

4.1 Use-wear analysis as a discipline

Use-wear analysis is a technique used to study wear traces present on an artefact through the recording of surface and edge alterations caused by manufacture, use and handling, which may have occurred at any stage of the life-cycle of an object (Adams et al., 2009, p. 46; Marreiros et al., 2015, p. 8; Walton, 2019). Macroscopic evidence of wear is characterised by linear indentations known as striations and it is termed as macrowear analysis, whereas microwear analysis is mostly used to detect traces of wear that cannot be appreciated otherwise, such as polish. As most use-wear studies focus on flint and chert tools, the way to describe wear traces relies heavily on this research strand (Van Gjin, 2012). Although each raw material displays unique mechanical properties that can influence wear formation processes, the same general observations and terminology can be largely applied to different materials and other categories of objects, such as beads or ornaments, which are intended here as perforated items of variable shape and dimensions, which can be either sewn on garments or worn on the body in a variety of configurations (Clemente-Conte et al., 2015, p. 59; Alarashi, 2016; Pedergnana & Ollé, 2017).

The history of use-wear analysis is deeply intertwined with theoretical approaches and technological advancements in the field of microscopy and imaging. For this reason, different methodologies and techniques have been developed over time to answer questions concerning the use of tools and their significance in past societies within a given theoretical framework. Although the earliest attempts to determine archaeological stone tool use and function were made between the second half of the 19th and the beginning of the 20th century (Marreiros et al., 2015, pp. 5-7; Stemp et al., 2016), the methodological foundations for current use-wear analysis were laid by Sergei Semenov, first published in Russian in 1957 then followed by the English language translation in 1964, with the title of “Prehistoric Technology”. Supporting Marxist theories, Semenov (1964) aimed to understand the socio-economic organisation of past societies through the study of edge damage as a marker of function on stone and bone tools (Keeley, 1980, p. 1). In particular, the focus of the research was on striations and their orientation, as these were good indicators of the kinematics of a tool (Semenov, 1964, pp. 16-21; Vaughan, 1985, p. 12; Stemp et. al., 2016; Pedergnana & Ollé, 2017). Semenov (1964) became the advocate for what is now referred to as the low-power approach, which entails the use of a stereomicroscope with a magnification range between 5x and 60x – in general < 100x (Marreiros et al., 2015, p. 9; Keeley, 1980, p. 2). To validate hypotheses, ethnographic analogy and experimentation were also employed (Stemp et al., 2016). The application of this technique challenged the typological attribution of lithic industries based on form, as in Semenov’s view if a tool did not present traces of wear, its use – and therefore function – could not be ascertained (Marreiros et al., 2015, pp. 7-8).

Criticisms were soon raised against the low-power/edge damage approach, as fractures observed at such magnification may not necessarily represent use and could be the consequence of intentional retouching (Keeley, 1974; Keeley & Newcomer, 1977). To further complicate interpretation, tools may have had more than one function, or in certain instances their active area could have been the handle, rather than the edge. Tools with no retouch, or the lack of intentional knapping to (re-)sharpen or modify the edges, may have been also used if these showed traces of wear (Marreiros et al., 2015, p. 8). In addition, this methodology could only roughly identify the type and degree of hardness of materials worked by a tool (Keeley & Newcomer, 1977; Yerkes, 2019). To overcome these problems, Keeley (1980, pp. 12-14) promoted the use of a metallographic incident light microscope

with magnification range between 50x and 500x, as this technique, otherwise known as the high-power approach, allowed the attribution of different types of polish to specific materials (Yerkes, 2019, p. 1). The results of microwear analysis carried out on archaeological tools were then compared with traces present on experimental replicas, which underwent blind testing (Keeley & Newcomer, 1977; Odell & Odell-Vereecken, 1980). Unaware of what processes the replica tools went through, analysts attempted to detect wear, the type of motion and the material being worked. As blind tests showed some degree of inaccuracy, this created scepticism towards the effectiveness of microwear analysis (Bamforth, 1988; Stemp et al., 2016). With a general improvement in image processing technology and the development of more rigorous protocols for blind testing, this method has proved to be effective in the detection of artefact use (Stemp et al., 2016; Yerkes, 2019). As a result, blind tests are still being undertaken on a variety of tools (Hamon & Plisson, 2008; Rots et al., 2016; Hayes et al., 2017).

More recently, the undisputable value of both low and high-power approaches has met general consensus and the two are often used jointly. Low magnifications are employed to assess the artefact's surface as a whole and to isolate smaller areas for subsequent microwear analysis at high magnification (Van Gijn 2013; Vaughan, 1985, p. 10; Clemente-Conte et al., 2015; Yerkes, 2019). Most studies also include the use of experimentally generated reference materials, as direct use-wear comparisons between replicas and archaeological artefacts may help to validate hypothesis concerning tool use and their socio-economic significance in ancient societies (Walton, 2019). In the last thirty years, the analysis of organic and inorganic residues on tool surfaces has become an integral part of use-wear analysis investigations (Marreiros et al. 2015, pp. 16-17; Stemp et al., 2016). In addition, a growing interest in microwear analysis has been recorded on materials such as bone (Kononenko et al., 2010; Buc, 2011; Stemp et al., 2016; Antonites et al., 2016), shell (Lammers-Keijsers, 2008; Cuenca-Solana et al., 2010, 2017), quartz and quartzite (Lemorini et al., 2014; Clemente-Conte et al., 2015; Venditti et al., 2016; Pedergrana & Ollé, 2017), obsidian (Hurcombe, 1992; Kononenko 2007, 2011; Stemp 2016; Stemp et al., 2015, 2018, 2019a, 2019b) and metals (Dolfini, 2011; Dolfini & Crellin, 2016; Molloy et al., 2016; Horn, 2017; Horn et al., 2017; Crellin, 2018).

4.2 Limitations of use-wear analysis

Use-wear analysis is a valid technique for assessing artefact use, but there are still flaws, some of which are of a methodological nature while some others are more intrinsic to the discipline itself. These, reported below, need to be highlighted and appropriately addressed.

Trace formation processes on any material still cannot be fully explained (Werner, 2018; Stemp et al., 2016; Van Gijn, 2013). This is because variables such as hardness and surface microtopography of the material of a tool, the material(s) being worked or coming into contact with it and the type, pressure, and angle of motion, can all lead concurrently to the formation of macro and microwear traces (Van Gijn, 2013; Keeley & Newcomer, 1977). Moreover, tools may have had multiple uses (Kononenko 2007). Residue analysis may help to discriminate between different traces, although starch residues especially may be deposited on surfaces through contamination (Rots et al., 2016). In particular, the problem around quantification and causes of polish development, which was brought to the fore by Keeley (1974), is yet to be solved, as polish can also occur during manufacturing and post-depositional phases (Hurcombe 1992, pp. 12-15; Clemente-Conte et al., 2015, p. ; Marreiros et al., 2015, pp. 14-16).

Taphonomic and post-depositional processes also have an impact on polish, striations, and patinas. Soil composition and the leaching of minerals or water into it, trampling, excavation, cleaning/conservation and storage activities could obliterate or alter extant wear marks, and at the same time cause new patinas, lustre or striations (Keeley & Newcomer, 1977; Levi Sala 1986; McBrearty et al., 1998; Marreiros et al., 2015, pp. 17-18; Venditti et al., 2016; Stemp et al., 2016). More specifically, as discussed in Sections 2.3 and 2.4, materials such as obsidian and glass appear to be highly affected by such processes (Martindale & Jurakic, 2006; Conte & Romero 2008; Clemente Conte et al., 2015, pp. 73-75).

Use-wear analysis is qualitative, interpretative, and subjective (Van Gijn, 2013; Ibáñez et al., 2019). This is partly due to the fact that the life trajectory of the artefact being analysed is unknown (Kononenko 2007; Van Gijn, 2013). Also, most of the conclusions inferred will depend on the competence of the analyst and on which areas of an artefact they decide to focus (Van Gijn, 2012). For this reason, quantitative studies in controlled conditions should be undertaken concurrently (Stemp et al. 2016). However, these should be approached with

caution, especially in the case of quantitative experimental tests, as the variables which impact on wear formation are largely regulated by human actions (Van Gijn 2013).

Use-wear analysis as a discipline is still lacking a shared, consolidated methodology and terminology, with a consistent framework in microwear analysis. As different interpretative streams coexist, a given technique is used to answer particular questions within one specific framework (Evans et al., 2014). In addition, the absence of a set protocol for the cleaning of experimental tools hampers the compatibility of different analyses (Van Gijn 2013). Moreover, most of the research focuses primarily on tool function, and as a consequence, production processes are very often overlooked (Dolfini & Crellin, 2016). In the case of artificial materials, such as metal or glass, a slightly different methodological approach may be needed (Van Gijn 2013; Dolfini & Crellin 2016). In order to gain further understanding of glass beads as a class of artefacts, the present work, which intends to set out new lines of enquiry and procedures, investigates the relationship between chemical, and manufacturing processes, wear by use and corrosion/post-depositional damage.

4.3 Use-wear analysis on obsidian and glass

As use-wear analysis has been carried out on obsidian in greater volume, natural and human-made glasses, which may present similar patterns in wear formation, are here considered jointly. The implications of compositional variations between the two materials and within glass itself in relation to trace development will be investigated in this thesis by means of experimental archaeology, use-wear, and chemical analyses to bead data sets. In order to provide an overview on use-wear analysis carried out on glass and obsidian, in the next paragraphs the emphasis will be placed on categories of artefacts such as tools and ornaments and on the methods and rationales applied to their study.

4.3.1 *Obsidian tools and ornaments*

Use-wear, technological, and residue analyses of obsidian tools and ornaments have been utilised to answer wider questions concerning the acquisition of the raw material, craft activities and the socio-economic and ritual dynamics of human groups (Kononenko, 2007; Torrence et al., 2009; Beyin, 2010; Astruc et al, 2011; Alarashi, 2016; Stemp, 2016; Stemp et al., 2018, 2019a, 2019b). Use-wear analysis of obsidian relies greatly on comparative experimental approaches, which entail a variety of tools being used to work at different intervals of time a range of materials, such as a variety of plants, wood, hide, bone, and

antler. Experimental protocols were used for the first time by Semenov (1972) and implemented by Hurcombe (1992). This methodology, at times combined with residue analysis, has been employed in the last decade to study archaeological obsidian artefacts in Papua New Guinea (Kononenko, 2007, 2011; Kononenko et al., 2015), New Zealand (Rose, 2019) and Mesoamerica (Stemp, 2016; Walton, 2019). Experimental programmes have been also applied to quantitative studies to identify wear on specific classes of artefacts, such as Maya blood-letting implements: three obsidian blades, which were used to cut raw beef to simulate blood-letting practices, were subjected to Laser Scanning Confocal Microscopy (LSCM) and scale-fractal analysis based on relative area (RelA). The first technique allows to capture and merge multiple images to construct a 3D model of an object, whereas the second is based on the premise whereby the geometrical dimensions of objects can be fractional instead of integer (i.e., one-, two- or three- dimensional). As such, surface roughness and wear were measured at multiple scales, and in relation to the order and the spacing of microtopographical features. The combination of LSCM and area-scale fractal analysis RelA allowed the successful documentation of the microtopography of the blades, although in only one case was it possible to discriminate used from unused surfaces (Stemp et al., 2015). In addition, a fragment of an Anatolian bracelet dating to the aceramic Neolithic was studied in qualitative and quantitative terms: tribological analysis, which allowed the measurement of the profile of the artefact and its surface topography, provided valuable insights on the manufacturing technology of this ornament (Astruc et. al., 2011).

4.3.2 Glass tools and ornaments

The literature on glass tools is scant, and focuses on assemblages retrieved in Australia, Canada and Argentina dating between the late 18th and 20th century (Martindale & Jurakic, 2006; Clemente-Conte & Romero, 2008; Ulm et al., 2009). Such tools are commonly made from glass bottle fragments, some of which may have been used as expedient tools and therefore may have not undergone any intentional retouch. In addition, edge alterations may have been caused by post-depositional processes (Martindale & Jurakic, 2006; Clemente-Conte & Romero, 2008). These studies attempted to assess glass tool use and function in the wider frame of post-contact interactions and the economic and social organisation of the communities which were the subject of the enquiry (Martindale & Jurakic, 2006; Clemente-Conte & Romero, 2008; Ulm et al., 2009). The methods applied are not fully cohesive, as they ranged from low-magnification examinations of artefacts

(Martindale & Jurakic, 2006) to microwear and residue analysis (Clemente-Conte & Romero, 2008; Ulm et al., 2009). The studies, which included experimental protocols, also featured trampling tests (Martindale and Jurakic, 2006; Clemente-Conte & Romero, 2008).

The paucity of available publications also extends to glass beads, although the potential of use-wear analysis on this class of artefacts, which should be combined with ethnographic approaches, chemical and residue analyses, has been acknowledged (Langley et al., 2018). In the same way as glass tools, currently no standard analytical protocols have been applied to the study of glass ornaments in general, favouring instead a case-by-case methodological approach which aims at answering specific research questions. In addition, more often than not, observations around potential wear by use fall under the remit of studies with either lines of inquiry that do not actively contemplate use-wear analysis as such, or with a focus on ornaments as an artefact category irrespective of raw materials. From this perspective, hypotheses around the function of Romano-British glass bangles in relation to their size were tested by carrying out experiments whereby volunteers wore large to medium replica bangles as armlets or anklets, whereas smaller bangles were employed as hair ornaments or as purse-stiffeners. These experiments placed the emphasis on personal reflection and experiences around the wearing of bangles, and although it is mentioned that use-wear analysis will be performed on these replicas at a later date, no papers have been published as of yet in this regard (Ivleva, 2018).

In one instance, photographic evidence of macroscopic traces of manufacture, use and surface degradation of La Tène glass beads and bangles is provided within the context of investigations into the *chaînes opératoires*, the compositional analysis of raw glass recipes, as well as the social value and symbolism of these artefacts (Rolland, 2021). The traces shown, which can be seen with a naked eye, pertain to a small selection of beads and bangles and have the purpose of providing additional information concerning production processes and modes of consumption, rather than to set out a methodology for use-wear analysis or discuss the potential of this technique (Rolland, 2021, pp. 122-123; pp. 130-133; p. 231). Glass beads within ethnographic collections have been recently analysed, but the presence of traces of wear was only mentioned in passing (Guzzo Falci et al. 2019). Technological and functional macro and microwear analysis was also carried out on glass beads retrieved from the settlement of Aghram Nadharif, Libya, whereby traces of rounding, polishing and striations were recorded around the thread-holes (Cristiani, 2006). As these observations

were carried out in the context of a wider assemblage containing stone and faience beads, no specific terminology for glass microwear was adopted and no research on the chemical and physical properties of glass and subsequent wear formation processes were undertaken.

At present, the most complete attempt at microwear analysis is exemplified by the research undertaken on glass and amber beads retrieved from Merovingian burials in Lent-Lentseveld, Netherlands, as use-wear analysis was carried out on a total of 86 glass beads, comprising archaeological specimens as well as replicas, which were all examined with a stereomicroscope with magnifications up to 160X. The replicas included four strings of glass beads worn by re-enactors for five to ten times a year for ten years but also glass beads which were especially crafted to be employed in experiments (Mc Gloin 2021a, 2021b). These were designed to mimic wear formation processes under given conditions and consisted in: i) the tumbling of amber and glass beads for intervals of 25, 50 and 100 hours. To simulate contact wear, the beads were placed either loose or strung together in pouches made out of pigskin because of its similarity to human skin, and textiles such as leather and wool, which were present in the archaeological record; ii) the spinning of three glass beads using a leather string which was tied at its ends. To replicate bead-wearing motion, the beads in this configuration were subsequently mounted on a spindle attached to an overhead mechanical stirrer and were then spun for 25, 50 and 100 hours; iii) the handling of a single glass bead with bare hands for up to 150 hours to assess how traces form upon contact with human skin and to compare the data obtained with the results produced by tumbling in a pigskin pouch (McGloin, 2021b).

The experiments were partly inconclusive as they did not yield an abundance of traces due to their relatively short duration. Nonetheless, the work carried out has highlighted the importance of reference materials, demonstrating that use-wear analysis can be successfully applied to glass beads and that this technique can be used to reconstruct their life-histories. Because of its exploratory nature, this study has raised further questions around the potential for methodological setbacks and the interpretation of traces. Although casts of the bead surfaces have been retained for future analysis at high magnifications, a low power approach was applied to establish the general distribution and main types of manufacture and use traces. This technique can indeed provide us with a good idea of wear formation on beads; however, it does not allow the detection of polishes nor the detailed observation of the morphology of traces or the surface microtopography, as, especially in the case of hard

materials such as glass, the adoption of high magnifications is advisable (Keeley, 1980, pp. 2-3). In addition, the type of relationship between a probable variation in the chemical make-up of glass beads, trace formation and post-depositional alterations still remains to be ascertained. The research presented in this thesis intends to fill such gaps by combining low- and high-power approaches in the analysis of archaeological and experimental glass beads, taking into account raw material properties, object manufacture processes and chemical make-up, potential modes of use, and context of retrieval.

4.4 Future directions of use-wear analysis

At present, one of the main research concerns is around the standardisation and quantification of microwear traces (Marreiros et al., 2015, p. 10). Branches of engineering such as tribology, the science of friction and wear, metrology, which is the scientific study of measurement, and also profilometry, or the roughness quantification on the profile of a surface, have been applied along with their methodologies to record the surface topography of both experimental and archaeological samples (Stemp & Stemp, 2003; Vargiolu et al., 2003; Astruc et al., 2011; Stemp, 2014; Stemp et al., 2016; Macdonald et al., 2018). A potentially promising technique for measuring surface roughness is LSCM (for technique definition please see Section 4.3.1; Evans et al., 2008; Stevens et al. 2010; Stemp & Chung, 2011; Stemp et al., 2013; Van Gijn, 2013; Clemente Conte et al., 2015, p. ; Werner, 2018; Ibáñez et al., 2019). LSCM is less expensive and time consuming than Scanning Electron Microscopy (SEM), as with SEM only small samples, which need to be coated in gold, can be analysed (Marreiros et al., 2015, p. 12; Stemp et al., 2016). Also, new sampling methodologies entailing the use of silicone casting material have been devised to collect surface data from artefacts that cannot be transported to analytical facilities (Astruc et al., 2011; Dolfini & Crellin, 2016; Macdonald et al., 2018).

The field of use-wear analysis is in constant evolution, encompassing research frameworks ranging from techno-functional approaches and related kinematics enquiries, through to object biography studies. It has been argued by Van Gijn (2012) and Walton (2019) that a more holistic approach is required: this thesis aims to redress the imbalance by taking into account glass bead ethnography, raw material properties and potential symbology, technological *chaînes opératoires* with related potential cross-craft interactions in object manufacture, and ultimately the archaeological context of retrieval.

The study of microwear and residue traces on ornaments is relatively recent, and most of the research is centred on Palaeolithic and Mesolithic beads manufactured from shell and animal teeth (d'Errico et al., 2005; Cristiani & Borić, 2012; Vanhaeren et al., 2006, 2013; Cristiani et al., 2014; Langley & O'Connor, 2015; d'Errico & Backwell, 2016; Rigaud & Gutiérrez-Zugasti, 2016; Margarit et al., 2018). Research has been also carried out on beads and bracelets crafted from different types of stone (Astruc et al., 2011; Groman-Yaroslavski & Bar-Yosef Mayer, 2015; Alarashi, 2016; Glover & Kenoyer, 2019; Martínez-Sevilla, 2019) and organic materials such as amber and jet (Van Gijn, 2006, 2014). Novel studies have focused on pre-colonial ornaments in different materials from Caribbean and South American archaeological contexts, as well as from ethnographic collections (Guzzo Falci, 2015, 2017; Guzzo Falci et al., 2019, 2020a).

The function per se of such artefacts appears to be quite clear, as beads and other ornaments are made to be worn in the form of necklaces, bracelets or garments. The focus of attention is placed instead on raw materials (Glover & Kenoyer, 2019; Guzzo Falci et al., 2020), evidence for stringing techniques (Cristiani et al., 2014; Guzzo Falci et al., 2019, 2020a), the potential presence of applied materials for decoration such as ochre (Pitarch Martí et al., 2017), and on the symbolism of such objects (Alarashi, 2016). Approaches revolving around an object-biographical framework have also been applied to bodily ornaments (Guzzo Falci, 2015; Guzzo Falci et al., 2020a, b).

As a result of the stringing of the beads and their subsequent use, traces are mostly located around the perforations. As most beads are crafted with the use of a bow drill, special attention has been dedicated to technological traces located inside the perforation itself (Viola et al., 2017; Glover & Kenoyer, 2019). Guzzo Falci et al. (2019) noted that variables such as thickness, type of attachment and position and tension of the string, determine the distribution and the amount of wear produced on beads. For instance, the looser the beads are strung, the greater the surface area with traces. They also observed that strings of different materials appear to create similar wear. Moreover, the interaction between string and human skin, which is naturally acid, is another variable to be considered, as they respectively attract dust or present dirt, oils or even pigments on their surfaces. One of the issues highlighted by this study, which can be transferred to archaeological contexts, is the fact that occasional wearing of ornaments may not display an abundance of traces (Guzzo Falci et al., 2019).

b) Methods

4.5 Experimental archaeology and use-wear analysis

Experimental archaeology and use-wear analysis were used in combination to:

- Assess the difference between modern bead-making techniques and ancient manufacturing methods alongside the type of skill and technology involved in the process. Wound beads were crafted for the purpose on separate occasions by using natural draft wood-fired furnaces as well as a gas-powered lamp.
- Gain insight on possible modes of use of the beads by employing experimentally generated replicas in a bead-wearing experiment, thus creating a reference collection that could act as comparative material for use-wear analysis of archaeological specimens retrieved in Fazzan.
- Establish through use-wear analysis which traces may pertain to the manufacture of beads versus traces which can be considered markers of wear by use on both experimental and archaeological beads.

In addition, as use-wear analysis applied to glass beads is a sub-discipline still in its infancy (see above), this provided me with the opportunity to test the overall efficacy of this technique and to detect the presence of any limitations in relation to glass as a material. In particular, the results from use-wear analysis undertaken on the archaeological dataset have been correlated to the chemical data in order to gauge the relationship between post-depositional processes, glass durability and trace formation phenomena, as further illustrated below.

4.6 The bead-wearing experiment: set-up and rationale

This experiment, which involved eleven volunteers (including myself) who were asked to wear a necklace for ten months, was designed to test wear formation processes, originally with the intention to compare the data produced with the results of use-wear analysis undertaken on the bead assemblages from Abruzzo. Necklaces comprising of two blue glass beads each and an additional bead in either amber or metal (copper-alloy) were created for the bead-wearing experiment: the choice of configuration, strings, beads in non-glassy materials and colour of the glass beads was informed by the archaeological record for the burial sites in Italy. Although selected beads from Fossa, Bazzano and Campovalano could not be examined, the materials and general principles applied to the experiment were easily

transferred onto the study of the Fazzan assemblages. If the amber and copper alloy beads – which, although not specified, are likely to have been made in brass, as opposed to bronze in the archaeological record – were purchased online, a number of lamp-wound beads were crafted in December 2018 at the Wolfson Laboratory for the purpose of the experiment, as the use of a torch allowed for a good degree of uniformity and replicability of the glass beads. The choice of cobalt blue soda-lime-silica glass canes (Effetre Moretti in colours Transparent 060 and Pastel 246) broadly reflected the chemical composition of the archaeological specimens, not only from Abruzzo but also from Fazzan.

The experimental necklaces were strung by always following the same sequence, with a metal or amber bead followed by two glass beads (Figure 4.1). As amber and copper alloys (both bronze and brass) score respectively 2-2.5 and 3 on the Mohs scale as opposed to much harder glass (Kipfer, 2021), by consistently arranging the beads in the same fashion it has been possible to compare and contrast traces of wear by use produced on glass in contact with softer materials as well as glass on glass. In order to have a marker representative of a nearly unused surface, the face of the glass bead which was not in contact with any other bead acted as control in all cases, as shown in Figure 4.1. The choice of stringing material relied on the absence of archaeological evidence collected from the burials, which means that in all likelihood organic materials were employed for this purpose. As a consequence, it was decided to opt for strings either made out of a flax/cotton mixture or leather, hence introducing a further variable into the experiment to gauge the impact that different fibres may have on polish appearance and formation. It has to be noted that cotton came into fruition in Europe during the Roman period; however, in particular the interest here lay in flax, due to the fact that linen textiles are attested in first millennium BCE Italy and in particular in Etruscan funerary contexts (Gleba, 2012, p. 220; Gleba 2008, p. 64).



Figure 4.1: Vegetal string, amber bead and sample necklace used in the experiment: the arrows indicate the different faces (sides) of the glass beads in contact with different or no materials. The stringing technique used allowed the adjustment of the length of the necklace but at the same time making it possible for the beads not to interact with the knots. Picture author's own

In order to evenly spread every possible necklace combination across sub-groups of participants, before assigning the necklaces to each person (including myself), the volunteers were asked to complete a self-assessment form (see Appendix B) to evaluate on a weekly basis the amount of time – ranging from 1-2 hours to > 10 hours per week – spent i) doing physical activity ii) being exposed to steam through cooking iii) being outdoors. In addition, they were asked to specify the type of physical activity undertaken and the preferred mode of wearing the necklace (tight around the neck versus loose; concealed by clothes placed on top, or in plain sight). The rationale behind the questionnaire, with answers from respondents summarised in Table 4.1, was to roughly estimate the potential range of motion of the beads when worn around the neck and to account for the presence of agents which may contribute to trace formation, such as higher amounts of grit particles, sweat/moisture or skin oils.

Volunteer	Glass Bead Set	String	Bead	Physical activity (hrs/week)	Steam exposure (hrs/week)	Outdoors (hrs/week)	Wearing preference
4	4	Leather	Metal (Cu Alloy)	8-10	4-6	8-10	tight, in plain sight
1	1	Leather	Metal (Cu Alloy)	6-8	6-8	6-8	Loose, in plain sight (on top of clothing)
7	7	Leather	Amber	2-4	1-2	2-4	loose, in plain sight
10	10	Leather	Amber	2-4	2-4	4-6	tight, in plain sight
5	5	Leather	Amber	4-6	2-4	2-4	tight, in plain sight
12	12	Flax/cotton	Metal (Cu Alloy)	2-4	8-10	2-4	loose, in plain sight
8	8	Flax/cotton	Metal (Cu Alloy)	>10	4-6	>10	loose, in plain sight
6	6	Flax/cotton	Metal (Cu Alloy)	4-6	2-4	4-6	loose, concealed
3	3	Flax/cotton	Amber	6-8	2-4	4-6	loose, concealed
11	11	Flax/cotton	Amber	8-10	8-10	>10	tight, concealed
14	14	Flax/cotton	Amber	2-4	4-6	6-8	tight, in plain sight

Table 4.1: Answers from respondents of questionnaire, with resulting assigned necklace configuration and related variable distribution. The necklaces, unless stated otherwise, were worn in contact with bare skin (Table author's own).

It may be argued that physiological differences between men and women – such as neck circumference and the presence of a more or less prominent thyroid cartilage or Adam's Apple – may affect necklace placement and hence wear on the beads; however, sex was not deemed to be a relevant variable in the experiment. This is because the dimensions and shape of the hyoid bone, thyroid and cricoid cartilages, all of which can be considered as the 'internal scaffolding' of the throat and neck, vary not only according to sex, but also age, body proportions and race, with these same factors impacting neck muscle size too. As a result, sexual dimorphism, which is not particularly marked in humans if compared to other species, is just one of the many variables that affect the anatomy of the neck (de Bakker et al., 2019; Urbanová et al., 2013; De La Paz et al., 2023). From the use-wear data of glass bead replicas it emerges that stringing material and amount of physical activity are among the

factors that may have had greater influence in wear formation, independently from sex, as the highest values for polish, rounding, attrition and abrasion were equally distributed between men and women (Section 4.11).

The sex data for the participants, two thirds of whom were females, are reported below in Table 4.2: the skew towards women tells us more about the bias around glass bead (and by extension perhaps jewellery as a whole) wearing in our largely cisgendered and heteronormative society. It was in fact quite difficult to recruit men as volunteers for the experiment, as they seemed to express some reticence at the idea of wearing a glass bead necklace. This behaviour was also observed in Volunteer 10, who, before seeing the necklace, was worried that the latter would look “too feminine”.

Volunteer/ Glass Bead Set	1	3	4	5	6	7	8	10	11	12	14
Sex	F	F	F	F	F	M	F	M	M	F	F

Table 4.2: Sex data for volunteers in bead-wearing experiment (n=9, as the entries in red refer to necklaces that could not be examined). Table author’s own.

Once the forms were returned, the glass beads were numbered, separated in sets and recorded as reported in Section 4.7. Each possible necklace combination was matched with different levels of physical activity, steam exposure and time spent outdoors, so that the range of these variables could be compared within the same sub-group of participants wearing the same type of necklace and across different groups who shared some common elements such as the same bead in other material or the same type of string. Once assembled, the necklaces were handed out to the participants in February/March 2019, with the recommendation of not swimming, showering or bathing whilst wearing them, as partial or complete immersion in (soapy, salty or chlorinated) water could cause severe damage especially to amber beads and would have accounted for an extra unwanted variable.

When the necklaces were returned in November/December 2019 to be subsequently analysed, the volunteers were asked on average how many days a week they had been wearing them so that an estimate of use-duration, which will be discussed in relation to traces of wear in Sections 4.11 and 4.12, could be drawn. In addition, the participants who wished to do so, provided some feedback on their bead-wearing experience, which was very informative in terms of sensorial perceptions of the necklace and how the wearers interacted with it, as reported below.

The necklaces belonging to volunteers 1 and 14 could not be examined, as they were not handed back because they either went missing, as is the case for volunteer 1, or were never worn (volunteer 14). Although these unforeseen events did not invalidate the experiment, they resulted in a smaller sample set destined for use-wear analysis and in a slightly uneven distribution of variables, as discussed further below.

4.7 Cleaning and recording of experimental and archaeological beads

Before the start of the necklace wearing experiment, replica glass beads, copper alloy and amber beads were measured to observe any variation in dimensions or shape which could potentially impact on the formation of traces during their interaction and to match glass beads of similar size for the creation of necklaces (Table 4.3). Each pair of glass beads was numbered as a set, with each bead within the set having a unique identifier, consisting of the number of the set plus .1 or .2: for example, bead 1 of set 1 would be 1.1, whereas the second bead in this set would be 1.2.

To establish the presence of any major manufacturing traces, prior to necklace assembly, the glass beads were observed under a digital microscope Dino-Lite Edge AM4815ZTL, with magnification range of 10x-140x. Since each bead would have been in contact with different materials once strung, for both sides of each bead – arbitrarily labelled for all sets as A and B (e.g., Bead 7.1 side A, bead 4.2 side A) – micrographs were taken, and their placement within necklaces was recorded at the time of stringing them together, so that any variations in terms of trace distribution, extent and morphology deriving from use could be noted at a later date. This system was not applied to the copper alloy and amber beads, as they were not subject to use-wear analysis as this was not the focus of the experiment.

<i>Bead set</i>	<i>Glass Bead</i>	<i>External \emptyset</i>	<i>Thread-hole \emptyset</i>	<i>Thickness</i>	<i>Bead</i>	<i>External \emptyset</i>	<i>Thread-hole \emptyset</i>	<i>Thickness</i>
1	1.1	0.9 cm	0.3 cm	0.5-0.55 cm	Metal (Cu alloy)	1.2 cm	0.3 cm	1 cm
	1.2	0.9 cm	0.3 cm	0.65 cm				
3	3.1	1 cm	0.35 cm	1 cm	Amber	0.9 cm	0.4 cm	1.1 cm
	3.2	1.15 cm	0.3 cm	1.15 cm				
4	4.1	0.9 cm	0.25 cm	1.1 cm	Metal (Cu alloy)	1.1 cm	0.25 cm	1 cm
	4.2	0.9 cm	0.25 cm	1.1 cm				
5	5.1	0.95 cm	0.35 cm	1 cm	Amber	1.1 cm	0.4 cm	1.1 cm

	5.2	0.95 cm	0.28 cm	1.1 cm				
6	6.1	0.95 cm	0.3 cm	1.05-1.15 cm	Metal (Cu alloy)	1.1 cm	0.3 cm	0.9 cm
	6.2	0.9 cm	0.3 cm	1.15 cm				
7	7.1	0.85 cm	0.28 cm	0.5-1.1 cm	Amber	1.9 cm	0.3 cm	0.4 -1.1 cm
	7.2	0.9 cm	0.28 cm	1.05-1.15 cm				
8	8.1	0.9 cm	0.35 cm	1.1 cm	Metal (Cu alloy)	1.1 cm	0.3 cm	0.9 cm
	8.2	0.9 cm	0.3 cm	1.18 cm				
10	10.1	0.95 cm	0.3 cm	0.6 cm	Amber	1.3 cm	0.4 cm	1.2 cm
	10.2	0.9 cm	0.25 cm	0.6 cm				
11	11.1	0.85 cm	0.3 cm	0.4-0.6cm	Amber	1.3 cm	0.35 cm	1 cm
	11.2	0.8 cm	0.28 cm	0.6 cm				
12	12.1	0.9 cm	0.28 cm	0.7 cm	Metal (Cu alloy)	1 cm	0.3 cm	1 cm
	12.2	0.8 cm	0.25 cm	0.6 cm				

Table 4.3: Measurements of individual glass beads and of beads in other materials assigned to each set. If glass beads tend to be globular or doughnut-like in shape, copper-alloy and amber beads are respectively globular and discoidal with a convex profile. Spare bead sets 2 and 9 have not been used and therefore they do not feature in the table. Table author's own.

Once the bead-wearing part of the experiment was concluded, the necklaces were disassembled and the glass beads were immersed in 15% Hydrochloric acid (HCl) solution for 15 minutes and then rinsed with distilled water in order to remove grease and dirt from the surfaces, in line with cleaning procedures applied to obsidian artefacts. This method has been employed on experimental beads only as HCl – or any other mineral acid – can etch ancient glass, especially when low in lime (Davison, 2003, p. 203). After the beads were cleaned, they were always handled with gloves to preserve the legibility of traces which otherwise could have been masked by greasy residues given by the contact with bare skin. Each side of the glass beads was analysed and photographed again with the Dino-Lite to document any substantial surface alterations, and, in addition to that, a reflected light metallographic microscope Res Micro Leica DM2700 MH RL equipped with a Leica MC170 HD camera (magnification range: 50x-500x) was employed in the detection of polish and to determine trace micromorphology on areas of interest previously identified at lower magnifications (Appendix D). During all microscopic examinations, the beads were kept in place at the preferred angle by pressing them gently into blu-tack, which was lined with

thermoplastic flexible plastic sealing film Parafilm M[®], so that the adhesive would not stick to the glass surfaces leaving residues behind.

Since the metallographic microscope has a very narrow focal point covering only small sections of a given subject at a time, multiple shots with different depths of field were taken by moving the focus across the whole frame. The resulting images were then stacked with the software Helicon Focus Pro in order to produce a single sharp picture. Once this step was completed, all of the photographs obtained from both microscopes were then labelled with numbers in sequential order followed by the letter D or M, standing for digital or metallographic microscope respectively, the bead and side code and the magnification used (e.g., D1_B3.1_A_50x). The location of the micrographs taken with the metallographic microscope was recorded on Dino-Lite overall shots of the corresponding bead side, at whichever low magnification was deemed to be the most suitable, usually between 30x to 60x. In addition to the beads used in the necklace experiment, a small number of further replica glass beads (lamp-wound and furnace-made at Jarrow Hall and Villa Borg) were recorded with this method to see if there were any variations in manufacture surface alterations which could be traced back to the use of a given technology, the results of which are provided below.

Traces of wear observed on experimental and archaeological beads, which are discussed in Sections 4.10-4.11 and in Chapter 5 (Sections 5.4-5.11) , were entered in an Excel database provided with hyperlinks related to their corresponding micrographs, which can be found in Appendices D and E. The location of the traces was recorded on each bead face as being i) on the edge along the thread-hole ii) on the body away from the edge iii) on both. Each side of the replica beads was described individually, with the aim of capturing variations in traces deriving from the contact with different materials, whereas in the case of the Fazzan assemblage, as the configuration of the beads remains unknown, the traces were documented for each specimen as a whole by always keeping track of the side(s) on which specific traces were recorded. Besides the present work, no detailed observation of glass beads has been carried out with a metallographic microscope, and for this reason the categorisation of traces applied here relied for the most part on what has been observed for obsidian tools, for which we refer the reader to the section below.

4.8 Categorisation of traces of wear on obsidian and glass tools

Wear mechanisms on artefacts can be explained by tribology, which is the science of friction, lubrication and wear on surfaces in relative motion (Hamon, 2008, p. 1506). The combination of underlying mechanisms that produce specific types of traces on non-flint ground stone tools was theorised by Adams et al. (2009). If the morphology of traces reported in this case is inherent to the chemical and physical properties of granular rocks, the main wear mechanisms will produce similar outcomes on glass and obsidian, which means that to some extent we can translate between results from different materials. This applies also to breakage patterns in flint, obsidian and glass, which, despite being respectively cryptocrystalline and non-crystalline, exhibit conchoidal fracture and are thus easy to work due to their high silica content, as reported in Chapter 2. In addition, obsidian and glass present variability in their chemical make-up, which means that their mechanical behaviour and subsequent traces of wear will differ accordingly (Clemente-Conte & Romero, 2008; Clemente-Conte et al., 2015, pp. 72-73). Based on use-wear analysis performed on experimental and archaeological tools and in minor part on beads, the main attributes recorded in both glasses are: edge damage or scarring, striation, edge rounding or smoothing/abrasion, and polish (Hurcombe, 1992, pp. 25-27; Martindale & Jurakic, 2006; Cristiani, 2006; Conte and Romero, 2008; Kononenko, 2011, pp. 18-19; Clemente-Conte et al., 2015, p. 74; McGloin 2021a, b). These different features and their corresponding tribological mechanism(s), described in the sub-sections below, can all coexist on the same artefact. Accurate descriptions of traces of wear and of the actions contributing to their formation on glass beads will be provided in the results chapters.

4.7.1 *Edge damage*

Edge damage (Figure 4.2), otherwise known as scarring, is represented by macro- or microscopic fractures such as flakes, scars or chips (Hurcombe 1992, pp. 25-26; Martindale & Jurakic, 2006; Clemente-Conte et al., 2015, pp.74-75).

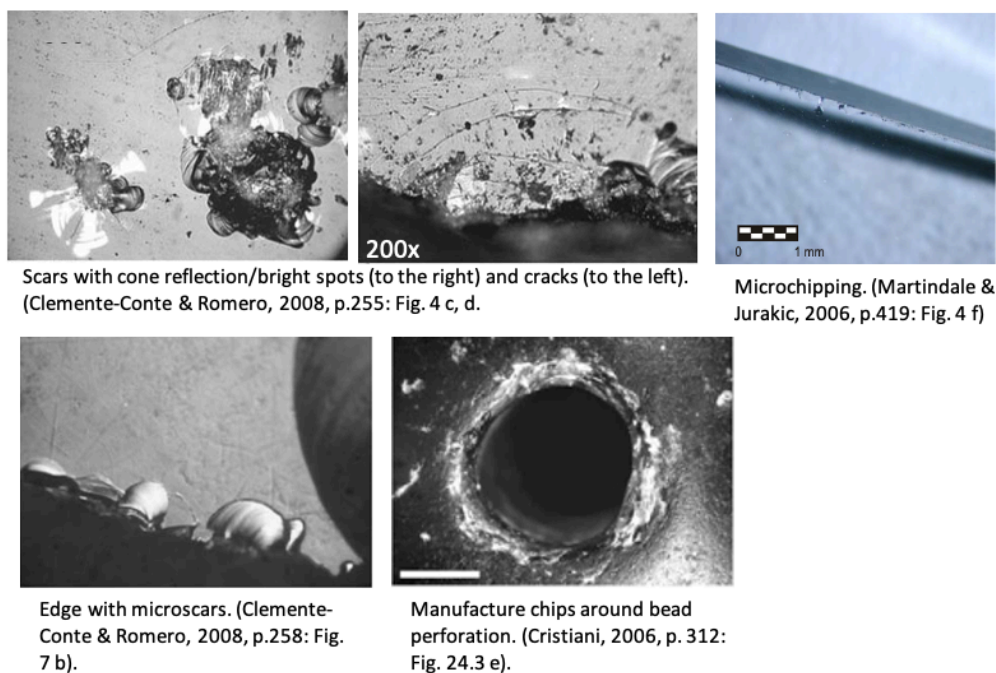


Figure 4.2. Different types of scarring, or edge damage observed on glass.

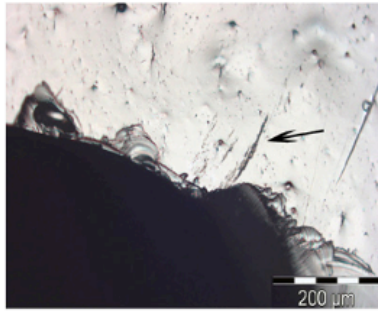
In tribological terms such traces are the by-product of fatigue wear, which is caused by the application of a mechanical stress on a surface. The angle and shape of the edge of a tool, the force applied to it, the type of material worked and action undertaken are some of the factors that contribute to fracture formation (see above; Kononenko, 2011, p. 18). These features appear quite rapidly on hard materials such as glass and obsidian, regardless of circumstances (Hurcombe, 1992, p. 25-27; Kononenko, 2011, pp. 7-8; pp. 18-19). For this reason, it can be very hard to differentiate scarring given by deliberate retouch or unintentional damage from scarring resulting from use (Kononenko, 2011, p. 7). Conversely, it has been argued that the size and pattern of the scars on glass can differentiate accidental microchipping from intentional retouch (Martindale & Jurakic, 2006).

4.7.2 *Striation*

Striations and their orientation are the prime indicators for the kinematics, rather than function, of a tool: the type and amounts of striations are regulated by variables such as the worked material and the speed and force applied during contact (Clemente-Conte et al., 2015, pp.74-75). As observed for edge damage in glass and obsidian, striations also develop very quickly, being more prominent and more varied in terms of shape when compared to other raw materials (Martindale & Jurakic, 2006; Kononenko 2011, p. 18; Clemente-Conte et al., 2015, pp.74-75). Also, the natural surface topography of obsidian and glass impacts on the development of striations (Hurcombe, 1992, p. 25-27; Kononenko, 2011, pp. 7-8; pp. 18-

19). In particular, the development of striations – but also polish – can be explained with the semi-plastic dissolution of surfaces given by the interaction with another material, which causes the formation of a silica-rich gel layer (Kamminga, 1979; Anderson, 1980; Hurcombe, 1992, p. 15;). As a consequence, according to the state of the surface (i.e., the depth and distribution of the gel layer), striations are characterised by a combination of fatigue, adhesive wear, and abrasive wear in variable proportions. Adhesive wear occurs when two surfaces, which are in contact and are thus bonded by molecular interactions, repeatedly slide over one another under pressure. This process releases energy in the form of frictional heat, subjecting surface asperities to plastic deformation and causing the pre-existing bonds to dissolve. As in the case of fatigue wear, particles will be loosened from either or both surfaces, becoming abrasive agents (Mansur-Francomme, 1983; Hurcombe, 1992, p. 15; Adams et al, 2009, pp. 46-47; Askeland & Wright, 2015, pp. 824-825). Scratches and troughs produced by abrasive wear are not only caused by loose particles between two surfaces, but they can also be due to free-flying abrasives or to the movement between materials with different hardness, whereby the softer surface will be more prone to abrasion (Adams et al, 2009, p. 47; Askeland & Wright, 2015, pp. 825).

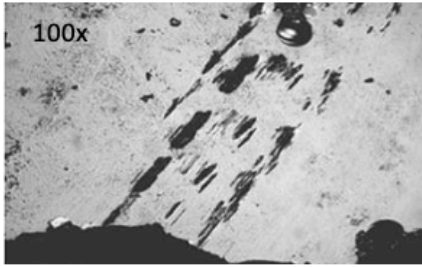
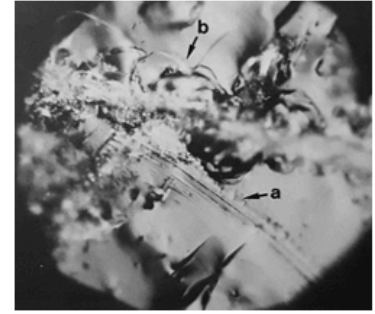
Striations on obsidian have been classified by their morphology, dimensions, number and orientation (Figure 4.3). According to their shape, striations have been categorised by Hurcombe (1992, p. 37, pp. 57-58) as follows: i) Sleeks, with straight sides and smooth base are caused by plastic displacement of surface material; ii) Rough bottomed, with irregular or straight sides and a rough base, which result from both material displacement at the surface and fracture damage at the bottom; iii) Intermittent striations, which are spaced small grooves arranged in a line, with the underlying cause of their formation being the same as sleeks; iv) Fern-like striations, which present a central line from which other linear grooves depart at an angle, perhaps occur when the surface is at an intermediate gel state; v) Flaked striations, which represent fracture damage; and vi) Crescent row striations, which are partial Hertzian cracks.



A. Rough bottom striations.
(Kononenko, 2011, p.165: Plate 24A).



B. Crescent row striations and C. Fern-like (a) and flaked striations (b).
(Hurcombe, 1992: Plates 100, 90).



D, E. Intermittent striations (right) and chaotic sleeks (left).
(Clemente-Conte & Romero, 2008, p.255-57: Figs. 4 b, 6 d).

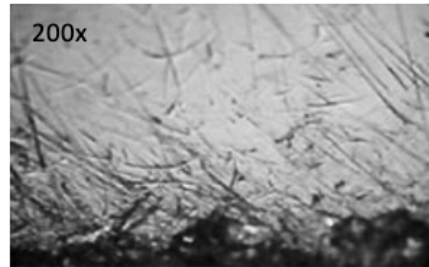


Figure 4.3. Striations on obsidian at the top, and striations on glass at the bottom.

4.7.3 Edge rounding

Edge rounding (as shown in Figure 4.4) is created by the hardness of the material worked and the contact with grit and soil concurrently with the duration of the activity, which means that it is primarily caused by abrasive wear (Adams, 2009, p. 46; Kononenko 2011, p. 8; Clemente-Conte et al., 2015, p.74; Walton 2019). The rounding of edges is the consequence of erosion and smoothing of a surface, which alongside other features given by abrasion, like bevelling, exfoliation, pitting and comet-like striations, easily develops on obsidian and glass (Clemente-Conte et al., 2015, p.74; Martindale & Jurakic, 2006). Different scales of edge rounding have been recorded, ranging from very slight to intensive (Kononenko, 2011, pp. 18-19).

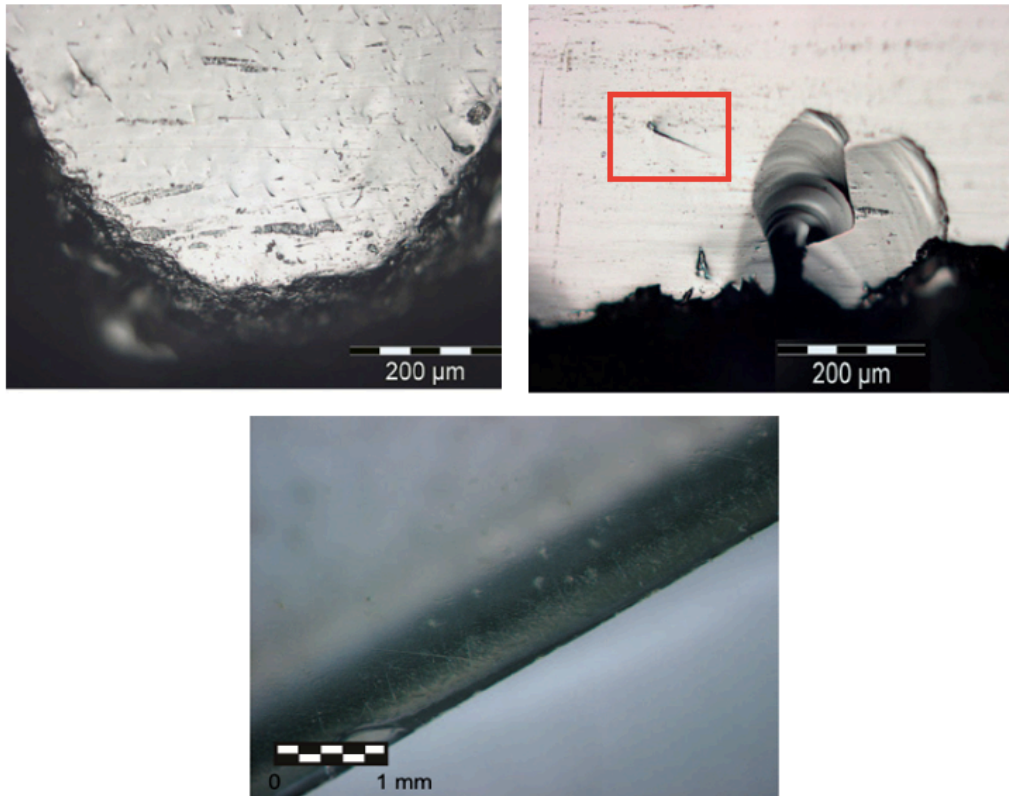


Figure 4.4. Top left: Edge rounding on obsidian, produced by sawing soft wood for 15 minutes. Top right: Comet-like striation outlined in red. (Kononenko, 2011, pp.163, 161: Plates 21 A,10 B). Bottom: Beveling and pitting on glass from scraping goat hide. (Martindale & Jurakic, 2006, p. 421: Fig. 5 d).

4.7.4 Polish

Polish is a tribo-chemical phenomenon, as the mechanical actions which underpin the removal of material that are attributable to fatigue, adhesive and abrasive wear promote chemical interactions which result in the formation of films on the worked artefact. In particular, the contact of obsidian and glass with smoothing agents – and especially with silica and/or water – weakens the glass network, leading to the development of a hydrolysed amorphous silica gel layer, to which polishing particles are attracted, and as they cannot be removed, they are bonded on the surface of the tool used. The presence of polish (and residues) can be thus considered as additive (Fullagar, 1991, pp. 2-3; Hurcombe, 1992, pp. 14-15; Hamon, 2008, pp. 1506-1508; Adams, 2002, 2014; Adams et al, 2009).

On highly reflective surfaces such as the ones of obsidian and glass, polish, which is usually combined with a rounding or flattening of the edges, is less visible because it tends to be dull as shown in Figure 4.5 (Hurcombe, 1992, p. 26; Clemente-Conte et al., 2015, p. 74). The softer the contact material, the further from the edges the polish will be located, whereas polish developed from hard materials affects localised areas, causing concurrently the

detachment of microchips. In particular, softer materials such as dry hide, can cause opaque, frosted and pitted polish (Martindale & Jurakic, 2006). Polish is usually described using attributes such as intensity and smoothness (Fullagar, 1991; Kononenko, 2011, p. 18). Four stages have been recognised for polish development on obsidian tools, and only stages 3 and 4, which describe advanced polish, can be associated with specific worked materials (Fullagar, 1991; Walton, 2019). These stages are described in more detail in the methodology Section 4.7, to which the reader is referred.

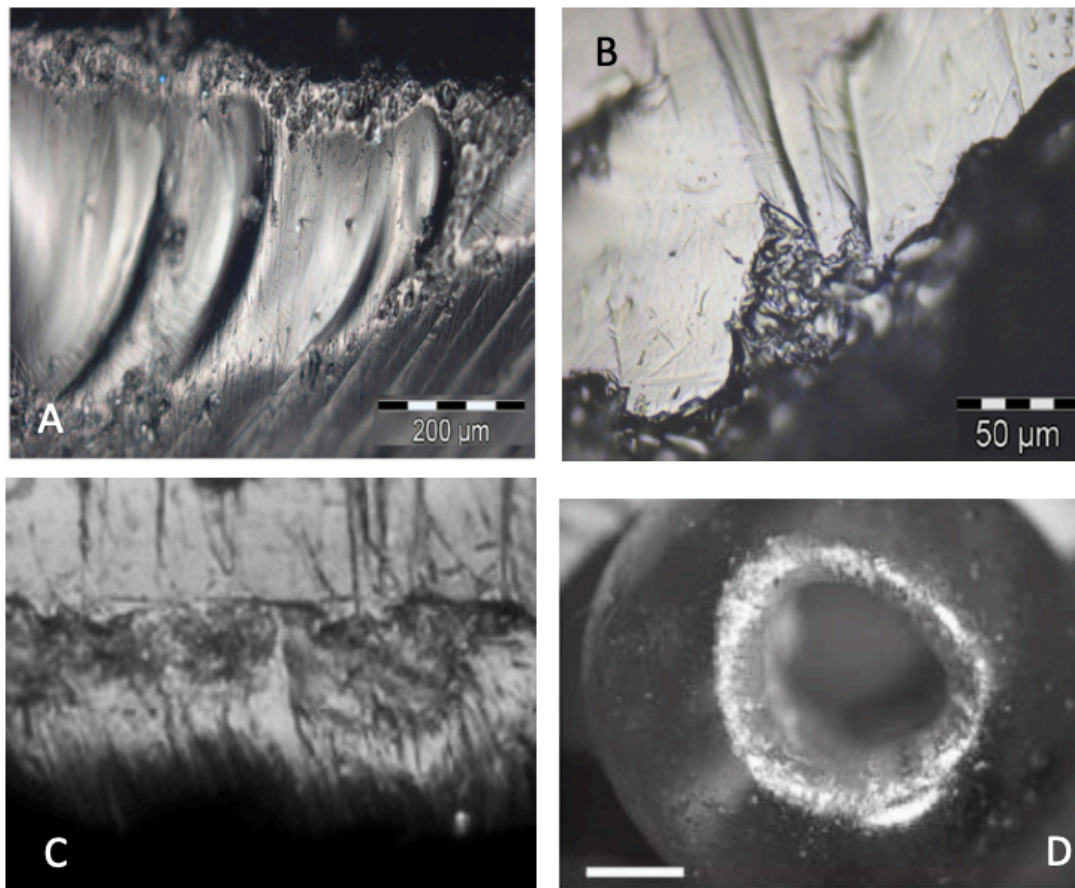


Figure 4.5. A-B: Polish, rounding and striations on obsidian (Kononenko, 2011, pp. 167,185: Plates 30B, 77F). C: Micro-polish and striations due to woodworking (Clemente-Conte & Romero, 2008, p. 256: Fig. 5 f). D: Polish on glass bead (Cristiani, 2006, p. 316: Fig. 24.5 f).

Polish – and surface damage in general – are not only connected to use, but also it can be frequently the by-product of post-depositional processes and as such it should not be used as a standalone discriminant for wear (Martindale and Jurakic, 2006). This is because any form of (chemo)-tribological wear, including the ones caused by trampling, excavation, retrieval, and conservation of artefacts, can produce micro-abrasions, striations, polish and edge rounding (Clemente-Conte & Romero, 2008; Clemente-Conte et al., 2015, pp.74-75; Martindale & Jurakic, 2006). As post-depositional traces may be mistaken for alterations produced by use, when performing use-wear analysis, we always have to take into account

the physical and chemical properties of glass. Traces of wear should be read as a stratigraphy, which means that they should be assessed in relative chronological sequence whenever superimpositions are present. When this is the case, more often than not post-depositional wear usually forms on top of weathered surfaces. In particular, when polish appears as an intensely bright and smooth feature (i.e., as a sheen or as bright spots), this is more likely due to taphonomic processes, which may involve movement caused by soil activity, trampling, bioturbation, and the settling of sediments under pressure. Contact with metal, likely caused by excavation activities with a trowel or any bladed tool in the same material, also can produce polishes of similar brightness and texture (Levi Sala, 1986; Hurcombe, 1992, p. 49; Rots, 2015 p. 96).

4.9 Categorisation, spatial distribution and frequency of traces of wear on glass beads

The traces of wear observed on the glass beads analysed in the present thesis are as follows:

- Fractures, which are not restricted to edge scarring only, but can also be found on the body of beads as accidental or use-related damage, correspond to conchoidal fractures or (micro)-chipping, Hertzian cones/cracks and hairline cracks.
- Striations, classified in sleek, rough bottomed, intermittent and flaked types (Hurcombe, 1992, pp. 37) with their salient characteristics described in greater detail in Section 4.9.3. In the case of glass beads no crescent-crack rows as observed by Hurcombe were recorded,⁵ and, besides one uncertain example, fern-like striations are also absent from both replica and archaeological assemblages. In addition, comet-like striations and more rarely pits, were observed.
- Pits, with their presence/absence, size and distribution recorded respectively as per Table 4.5 and Figure 4.6, which will be considered in the following paragraphs.
- Polish, which was diagnosed on the basis of its brightness and texture following the ranges provided by Hurcombe (1992, pp. 36-37). In addition, polish formation was categorised in stages, according to Kononenko (2011, p. 8, via Fullagar, 1991) as reported in Table 4.4. As polish may present variations in appearance and development on individual faces of the beads, intermediate values have also been recorded.

⁵ Hurcombe (1992, p. 58) reports that crescent-crack rows differ from partial Hertzian cones as they present an additional central sleek running across their length.

Brightness	Texture	Polish stages
Intense	Very Smooth	1 <i>Very light</i> : Limited contact with another/bead material, similar to natural bright spots. Very slight rounding due to abrasion (physical removal of material).
Bright	Smooth	2 <i>Light</i> : Levelling and polishing of peaks, flaking of surfaces. Physical removal still prevalent, but presence of polishing agent/water.
Fairly bright	Slightly smooth	3 <i>Developed</i> : Further polishing of peaks, surface flaking and deepening of sub-surface cracks. Polishing agent/water are crucial. Usually observed on tool used in wood/plant-, skin- and bone-working.
Fairly dull	Bumpy	4 <i>Well developed</i> : ranges from extensive polish to featureless surface (as usually seen on flint and obsidian sickle gloss from processing cereals) due to the action of water, polishing agent and silica particles.
Dull	Rough	

Table 4.4: Table summarising the main attributes of polish and the stages of polish development which were applied during the recording process. Please note that brightness and texture as listed above do not represent a linear progression and in this sense are unrelated to polish development stages. (Table author's own).

- Rounding, which is usually observed on the working edge of tools, on glass beads occurs not only along the edge of the thread-hole but also on areas subject to abrasion and polish due to prolonged contact with other beads. This rounding was categorised here as very slight, slight, medium and intensive as per Kononenko (2011, p. 8) and Fullagar (1986, p. 80). The same classification system has been applied to abrasion and attrition, both explained below.
- Abrasion, defined here as an erosive process leading to the removal of surface material through friction and heat produced by the continuous rubbing of a glass bead against another bead or the string, which generates in turn a rough surface accompanied by striations (Sussman, 1988, p. 18). When abrasion affects the edges of the thread-hole this will result in their rounding.
- Attrition, which, although in tribological terms falls within abrasive wear and for this reason is in general not necessarily recorded as a separate phenomenon to abrasion, is here intended as the substantial removal of topographic highs in often circumscribed (small) areas, resulting in a rough surface with no associated striations (Sussman, 1988, p. 18).
- Other surface alterations, due to not only manufacture (specifically by the hot working of glass) but also caused by weathering/corrosion processes as in the case of the archaeological beads.
- Residues, which were noted only on archaeological beads.

Whenever applicable, the measurements of striations, fractures and pits were recorded using the parameters outlined in Table 4.5. If on the one hand length and depth are

somewhat subjective, on the other hand striation width, pit and fracture size were calculated in accordance with Hurcombe (1992, p. 37). Due to the broadly spherical shape of the beads allowing for any positioning, striation orientation was recorded in relation to thread-hole and bead placement at the moment of microscopic observation.

Measurements				Orientation
Striations	Striations	Striations, Pits, Fractures	Pits, Fractures	Striations, Fractures
Length:	Width:	Depth:	Size:	Parallel
Long	Narrow (< 2 µm)	Shallow	Small (< 2 µm)	Perpendicular
Short	Wide (> 2 µm)	Deep	Medium (> 2 µm-6 µm)	Oblique
Long +Short	Narrow +wide	Shallow + deep	Large (> 6 µm-10 µm)	Concentric
			Very large (> 10 µm)	Chaotic (observed only for striae running in different directions with a tendency to overlap).

Table 4.5: Table summarising the measurements applied to different traces and the modes of orientation of striae (Table author's own).

All traces were also recorded in terms of their spatial distribution and frequency or prevalence, as illustrated in Figure 4.6. Each trace was also interpreted bearing in mind what factors contributed to their appearance, which can be referred back to the following actions/processes (or a combination thereof):

- Manufacture, including the making of beads and the removal of the separator where observed.
- Use
- Uncertain action, which could also include accidental damage, often represented by very large fractures on the body of the bead.
- Post-depositional/weathering processes, reported only for the Fazzan beads, refer to both the formation of traces that do not represent wear by-use, and chemical corrosion, both due to burial environment, modes of retrieval and storage of the beads.

The use-wear data collected for the replica and archaeological beads will be presented in Sections 4.9-4.11 and in Sections 5.4-5.11 respectively , with the results of the experimental beads being also cross-examined with the variables relating to necklace use, and with the

chemical composition of the Fazzan beads being linked to glass degradation processes and traces of wear.

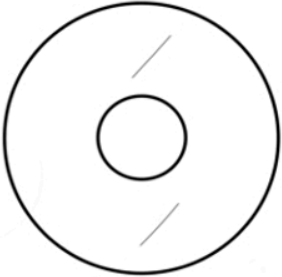


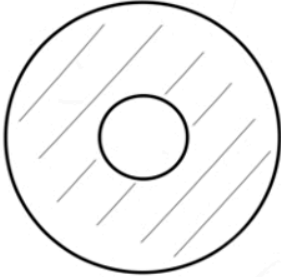
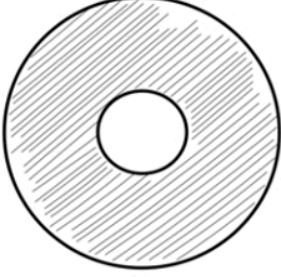
Distribution			Frequency
			Rare
A. Isolated	B. Sparse in clusters	C. Dense in clusters	Occasional
			Frequent
	D. Sparse throughout	E. Dense throughout	Very Frequent

Figure 4.6: Distribution and frequency of traces on glass beads, loosely based on Adams et al. (2009, p. 50).

c) Results

4.10 Use-wear analysis on experimental beads

When assessing traces on experimental beads the first variable to consider is use-duration: it has been calculated that wearing the necklace for the full ten-month period amounts to approximately 5040 hours. Since the participants were instructed to remove the necklace when going to bed, this final figure was calculated by subtracting from the initial sum six hours from each day, which represent the average time dedicated to sleep. As illustrated in Table 4.6, the volunteers who were assigned bead sets strung with leather wore their necklaces consistently during the experiment, whereas across the vegetal string group there is more variation although most individuals had worn their necklace for a considerable length of time.

<i>Bead set</i>	<i>Contact Materials</i>	<i>String</i>	<i>Average percentage days worn (100%=5040 hours)</i>
12	Cu Alloy, Glass	Flax/cotton	100%
6	Cu Alloy, Glass	Flax/cotton	95%
11	Amber, Glass	Flax/cotton	80%
3	Amber, Glass	Flax/cotton	75%
8	Cu Alloy, Glass	Flax/cotton	60%
10	Amber, Glass	Leather	100%
5	Amber, Glass	Leather	100%
4	Cu Alloy, Glass	Leather	100%
7	Amber, Glass	Leather	100%

Table 4.6: Table reporting the contact and string materials for each bead set, with related use-duration.

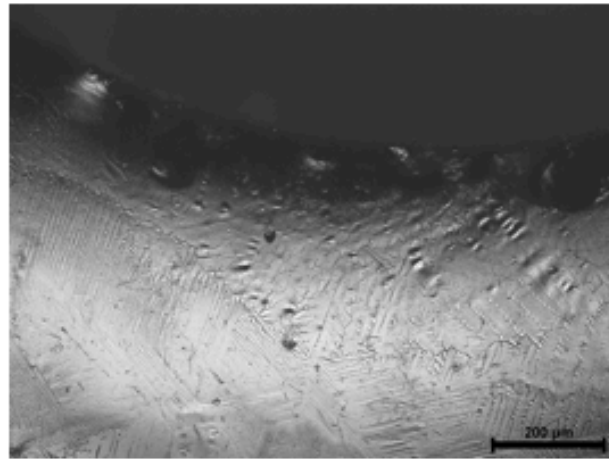
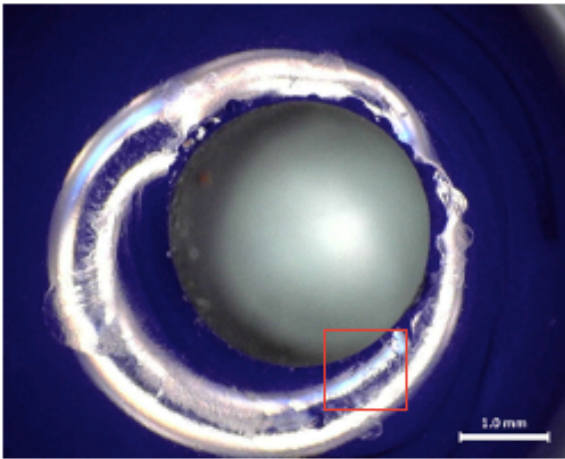
Nevertheless, all bead sets yielded traces of wear, and since their frequency appears to be only partly correlated to use-duration, the impact of necklace wearing preferences, exposure to steam, physical activity and further variables out of our control have to be reckoned with. The interaction between these different factors will be discussed separately in Section 4.11.

4.9.1 Surface alterations due to manufacture

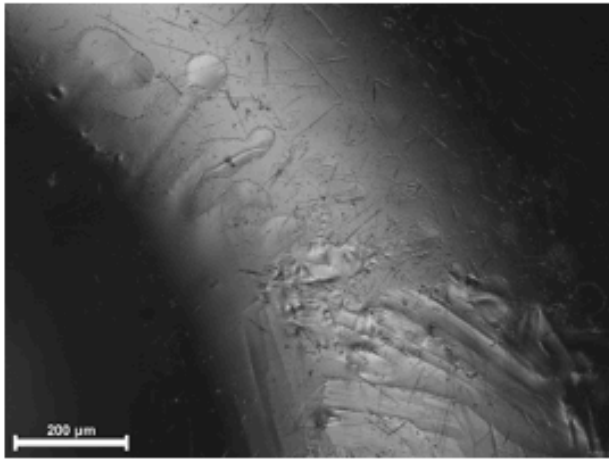
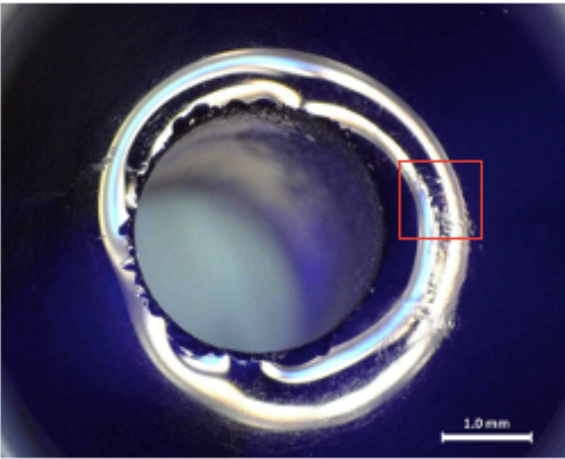
Surface alterations are defects that may arise when the hot glass is worked into beads. As reported in Chapter 3, they can be due to thermal stress such as rapid cooling, inconstant or prolonged heat exposure, but also to the chemical interaction of the glass with the surrounding environment (e.g., separator, humidity levels and in case of outdoor structures,

free-flying ash particles). The combination of such factors will trigger devitrification processes, causing the glass surface to partly re-crystallise whilst absorbing and/or reacting with foreign particles and water vapour (Brow, 2010, pp.110-111,114). As shown in Figure 4.7, the most common alterations recorded on the beads used in the experiment are dendrites, pores, and uneven textures such as depressions/indentations, occurring either in isolation or in association. Pores, in particular, are characterised by a perfectly circular shape with a smooth base, differing from pits derived from use which tend to be associated with striations and present a different overall morphology, with irregular edges, variable depth and base texture. More generally, surface flaws are not always present on both faces of a bead (see bead 7.1), and in the instance of bead set 8, which shows substantial traces of wear, they were not observed at all: this is to be partly expected, as such alterations will be obliterated through constant use.

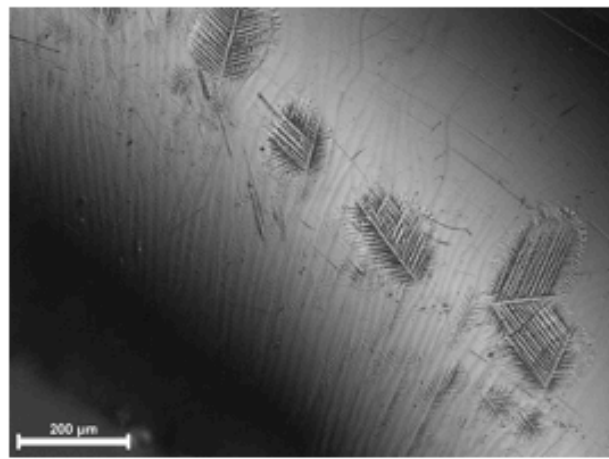
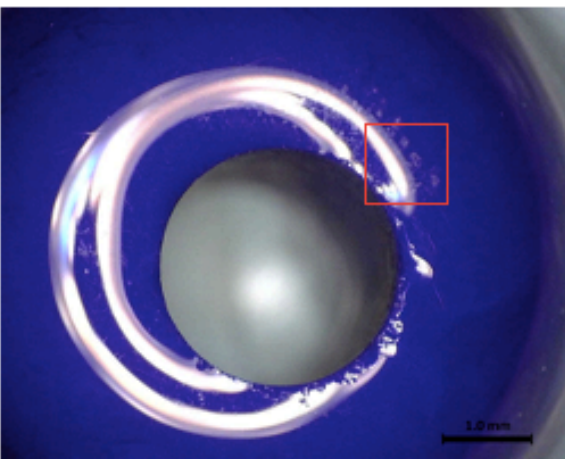
Surface defects were also recorded in unused replica specimens made with a lamp as well as natural draft furnaces as described in Chapter 3. In particular, in the latter case, spherulites (which were found in our use-wear reference collection only on bead 3.2 B) alongside ashy specks and imprints could be observed even at low magnifications (Figure 4.8). The differences between lamp-wound and furnace replica beads are caused by the equipment used in their crafting, which also means that in turn both types will be slightly dissimilar from archaeological specimens. This is a reminder of the importance of comparing and contrasting multiple datasets, as in object biographical terms experimental beads will never be a faithful reproduction of beads made and worn in the past.



B 10.1 A: Dendrites, pores of variable sizes

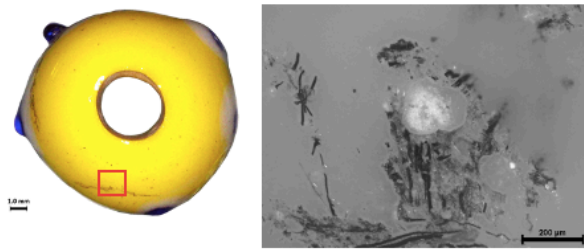


Bead 7.1 A: uneven textures, depressions and indentations

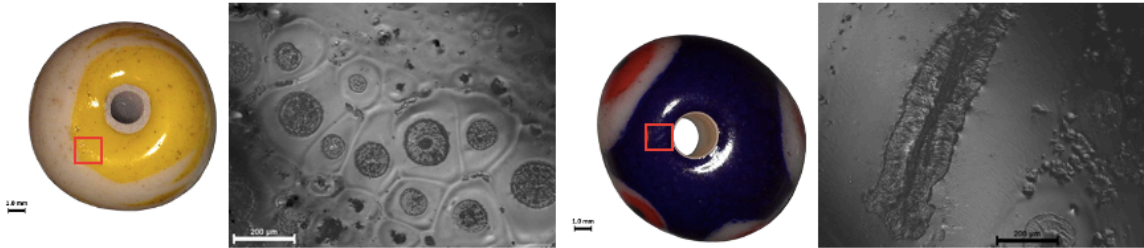


Bead 6.2 B: Dendrites

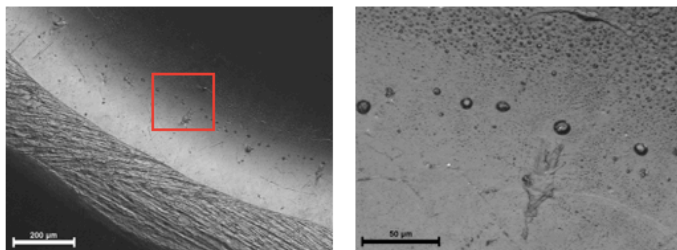
Figure 4.7: Manufacture surface defects on lamp-wound beads used in the necklace wearing experiment. (Micrographs author's own).



Jarrow Hall: Organic material (ash/fuel by-products) fused into the glass



Villa Borg: Spherulites, pores and organic material fused into the glass (left). Spherulites and imprint from ash particle? (right)



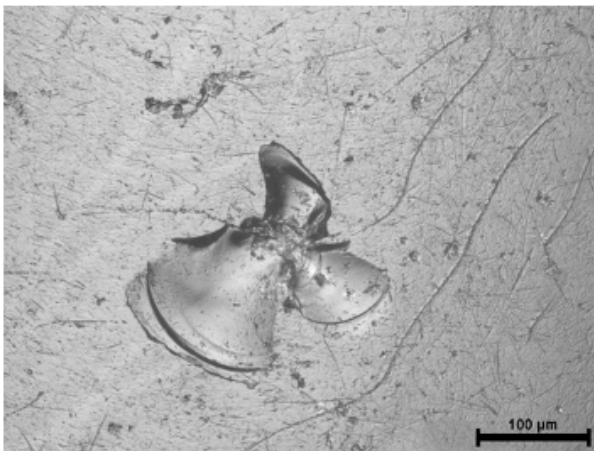
Lamp-wound bead: Dendritic patterns, pores of variable sizes

Figure 4.8: Manufacture surface defects on unworn beads made by lamp winding and in natural-draft furnaces. (Micrographs author's own).

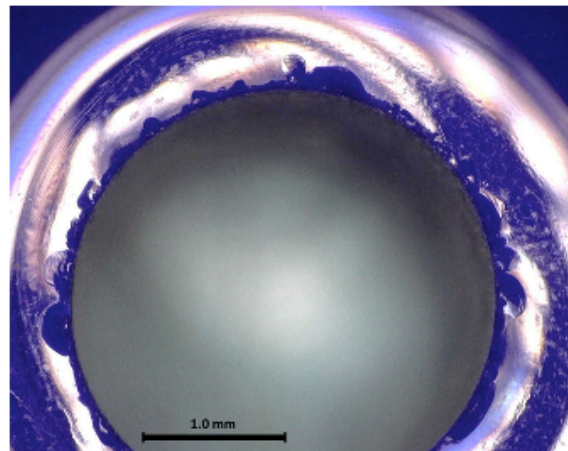
4.9.2 Fractures

The main types of fractures encountered on replica beads are pictured in Figure 4.9. Sharp impact cones, either resulting from collision with another bead or by accidental damage caused for instance by dropping the bead on the ground between the manufacture and stringing phases, were recorded in equal measure along the edges and on the bodies of beads, with the exception of sets 7 and 3 (for fracture behaviour in glass please consult Section 2.3). With the exception of bead 3.2, small conchoidal fractures otherwise known as micro-chips were observed in variable degrees of distribution and size along the edge of the thread-hole of the remaining beads. These micro-chips can be seen with the naked eye and although they are not always necessarily found on beads, they are characteristic of manufacture by the winding technique. This is due to the fact that once cooled down, some beads may remain stuck to the mandrel and as a consequence they have to be pulled and twisted at times with the aid of tools until they can be released, thus creating micro-fractures. In addition, hairline cracks were also recorded along the edges of the control faces of beads

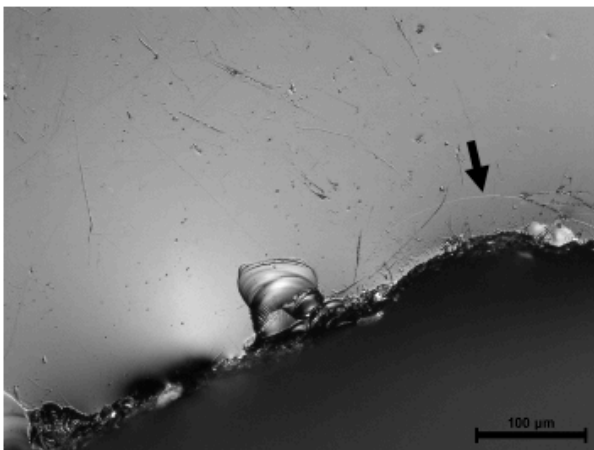
7.2, 8.1 and 12.2. This type of fracture was also detected on obsidian and glass implements, as a result of trampling or of retouching by means of a hammer tool (Hurcombe, 1992, p. 48; Clemente-Conte & Romero, 2006, p. 255). As seen on tools, these partial fractures are associated with the flaking of the edge. In the case of glass beads we can hypothesise that they may be in connection with the removal of the beads from the mandrel, as this process causes micro-chipping of the thread-hole area. As the name suggests, hairline cracks are very thin and therefore if a load is constantly applied on the area, as it would be the case during use, they may propagate below the surface until conchoidal fracture occurs. In this respect, this may explain why hairline cracks were visible on bead faces which exhibited less wear.



Bead 5.1 A (glass-on-glass, leather): sharp impact cone on body of bead, either due to use or accidental damage. The fracture is also partly covered by pits from use. Scale 200X.



Bead 5.2 B (control, leather): Micro-chips around thread-hole edge from manufacture. Note that the concentric grooves located further away from the edge are not striations but very faint, incomplete dendrites. Scale 100X.



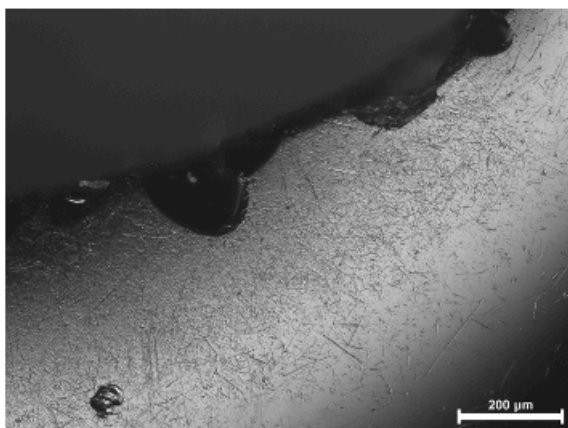
Bead 7.2 B (control, leather): Hairline crack indicated by arrow. Light to moderate polish is also visible on a small area of along the edge, located immediately below the fracture to the left. Scale 200X.

Figure 4.9: Fractures on used replica beads. (Micrographs author's own).

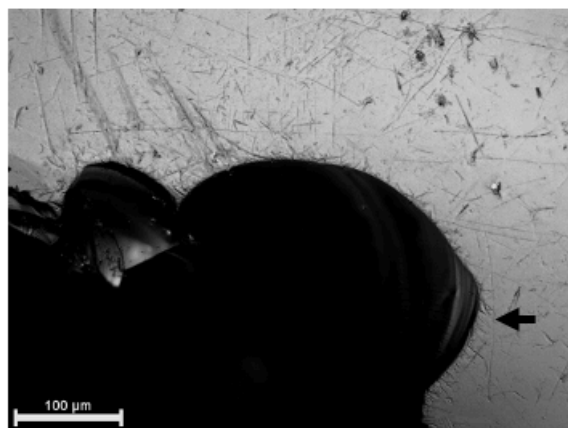
4.9.3 Striations

Striations recorded on the surfaces of the beads are mostly determined by the contact with other beads and in minor part by the action of the string, which is visible especially around the thread-hole. The striations encountered on experimental beads are consistent with the

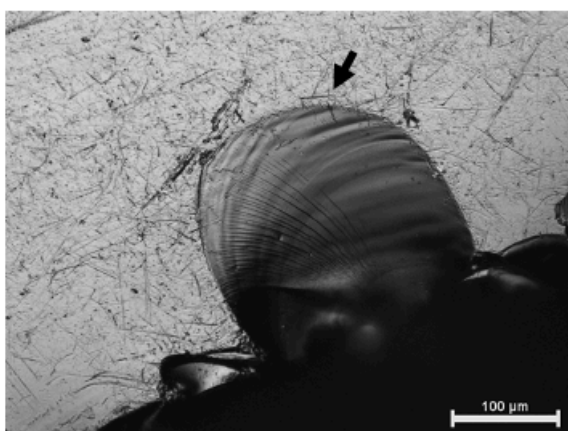
types found on obsidian tools: their descriptions, provided below, will take into account their morphology and the underlying causes of their development, contact materials, frequency, distribution and orientation. These attributes are also reported in the tables in Appendix D. Sleeks, usually narrow with variable length and depth, are the most common striation type present on all beads (Figure 4.10): although for the most part they are due to use, they can be also caused by manufacturing processes, as explained for rough bottom striations further below.



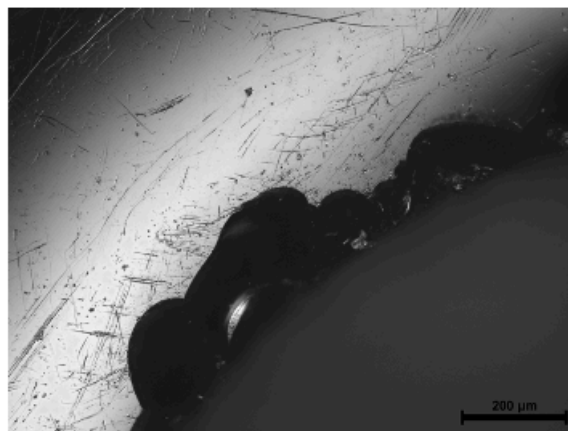
Bead 11.2 A (glass-on-glass, flax/cotton): chaotic sleeks along edge and body. Scale 100X.



Bead 6.2 A (glass-on-glass, flax/cotton): shallow u-shaped sleeks and short sleeks perpendicular to micro-chips (indicated by arrow), due to string action. Scale 200X.



Bead 5.2 A (glass-on-glass, leather): chaotic sleeks and short sleeks extending within micro-chip, as indicated by arrow. Scale 200X.



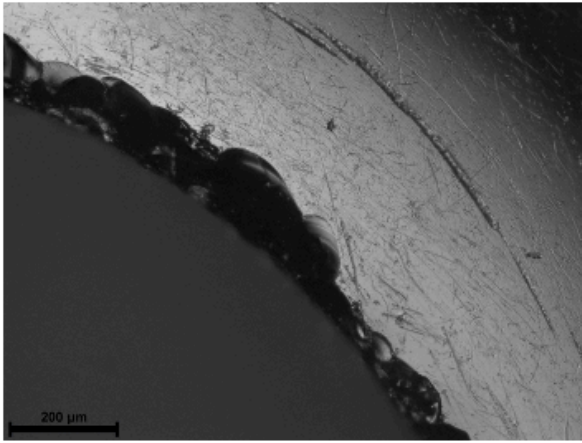
Bead 7.1 A (glass-on-amber, leather): oblique and parallel sleeks intersecting along and away from thread-hole edge. Scale 200X.

Figure 4.10. Sleek striations from use and their distribution on beads. (Micrographs author's own).

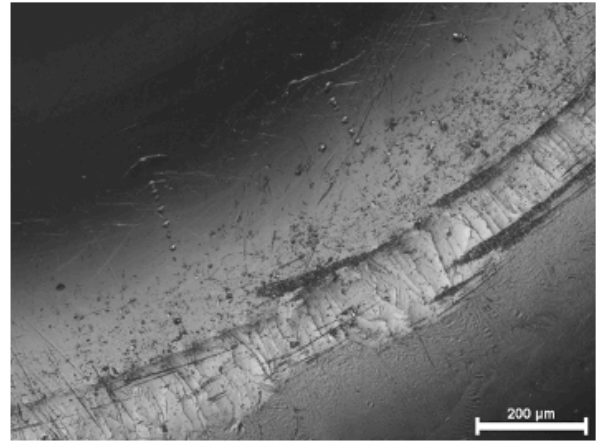
Irrespective of the material, sleeks caused by bead-on-bead contact are very frequently encountered on the body of beads and are arranged in a chaotic fashion, often overlapping: this is due to the fact that with motion, the beads swing from side to side moving up and down at the same time; sometimes they may even slightly rotate on their axis if the thread-hole is loose enough around the string. Although in some instances chaotic striae may extend from the body into the micro-chips along the thread-hole (bead 8.2 B), in general the sleeks

recorded on the edges and corresponding micro-fractures are on average shorter, as it is likely they were produced by the multi-directional, short-range sawing action of the string against the glass surface. At times overlaying, they are often organised in clusters of variable density with parallel, perpendicular or slightly oblique orientation (bead 4.2 B). The spatial distribution and density of sleeks – and other striations in general – is influenced by several factors, such as the degree of uniformity of the individual beads in terms of their thickness and topography, the percentage of the bead surface in contact with another bead, and the shape/profile of the latter. As a result, in the case of glass-on-glass interaction sleeks are tightly packed on the majority of the surface, whereas when glass beads are in contact with amber or copper alloy beads, sleeks tend to be organised in clusters with variable density, which are often located on topographic highs (beads 6.2 A, B; 4.2 A). This occurs especially when the glass beads are slightly lopsided and therefore the points of contact with other beads are limited to certain areas (bead 7.1 A). The same observations can be applied to the control sides, although the accidental and thus limited interaction of this bead face with items of clothing, bare skin or more rarely the knot of the string, results in sparse sleeks, which can be either very long and therefore more similar to scratches, or very short, found more sporadically on the body and along the thread-hole.

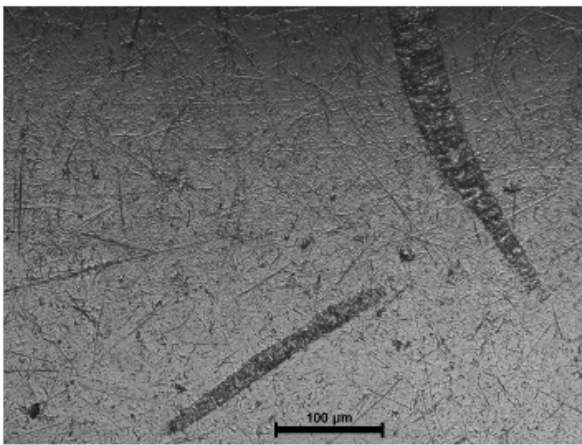
Rough bottomed striations are rare across the whole sample and even within sub-sets where they appear to occur the most – such as glass-on-glass, amber-on-glass (both string types, but leather in particular) and the two control groups – they were not recorded for all bead faces; in the instance of glass-on-copper alloy and vegetal string they were completely absent. On average wide and deep, rough bottomed striations were mostly located on the body of the beads, either as isolated features or as agglomerates. When concentric or parallel to each other, rough bottomed striae – and wide sleeks – can be ascribed to manufacture stages, and in particular to the use of a diamond reaming tool to remove the separator, which would have resulted in a scraping action with rotatory motion (Figure 4.11, beads 7.2 A, 3.1 A, 6.2 B). This can be stated with relative certainty as rough bottom striations are not only at times overlapped by other striations, indicating that they are earlier in the sequence, but they were also observed on unworn beads which underwent the same cleaning process. Standalone striations of this type are more difficult to interpret, but they may be related to a single event, especially when there are no superimpositions with other traces to indicate otherwise.



Bead 7.2 A (glass-on-glass, leather): Rough bottomed striae with concentric and parallel orientation, respectively observed on the body and along the edge of the bead. Scale 100X.



Unworn lamp-wound bead: Rough bottomed striations on body of bead. Scale 100X.



Bead 3.1 A (glass-on-glass, leather): Close-up of chaotic sleeks and random rough bottomed striations, which are also overlain by occasional sleeks. Scale 200X.

Figure 4.11: Rough bottomed striations on unworn and worn beads. (Micrographs author's own).

Intermittent striations, which are relatively uncommon, indicate that the highest load of a force is applied perpendicularly to a surface (Hurcombe, 1992, p. 58), hence creating discontinuous grooves which may be caused here by the necklace rocking from side to side when the person is walking or being physically active. On average narrow and deep, intermittent striations have different lengths and when short, they can be shallow. These striations, with oblique, parallel or perpendicular orientation are sparsely distributed on the body of the beads, but can also be localised on the edge, where they are for the most part in isolation, although exceptions are present (beads 11.1 A, 3.1 B, 7.2 B). Intermittent striae can be found in association with sleeks and/or comets, and although they may overlap, they usually do not have the same orientation (beads 4.1 B, 7.2 B); at times, this type of striation develops from a sleek or a rough bottomed striation, in all respects becoming their tail end, which indicates that there was a change in the force applied on the bead surface (beads 7.2 B, 11.1 A). Slight variations in occurrence were also recorded, as intermittent striations on the glass-on-glass and leather string sides of the beads appear to be more frequent when

compared to faces of the beads with the same contact material but strung with flax/cotton fibres (Figure 4.12).

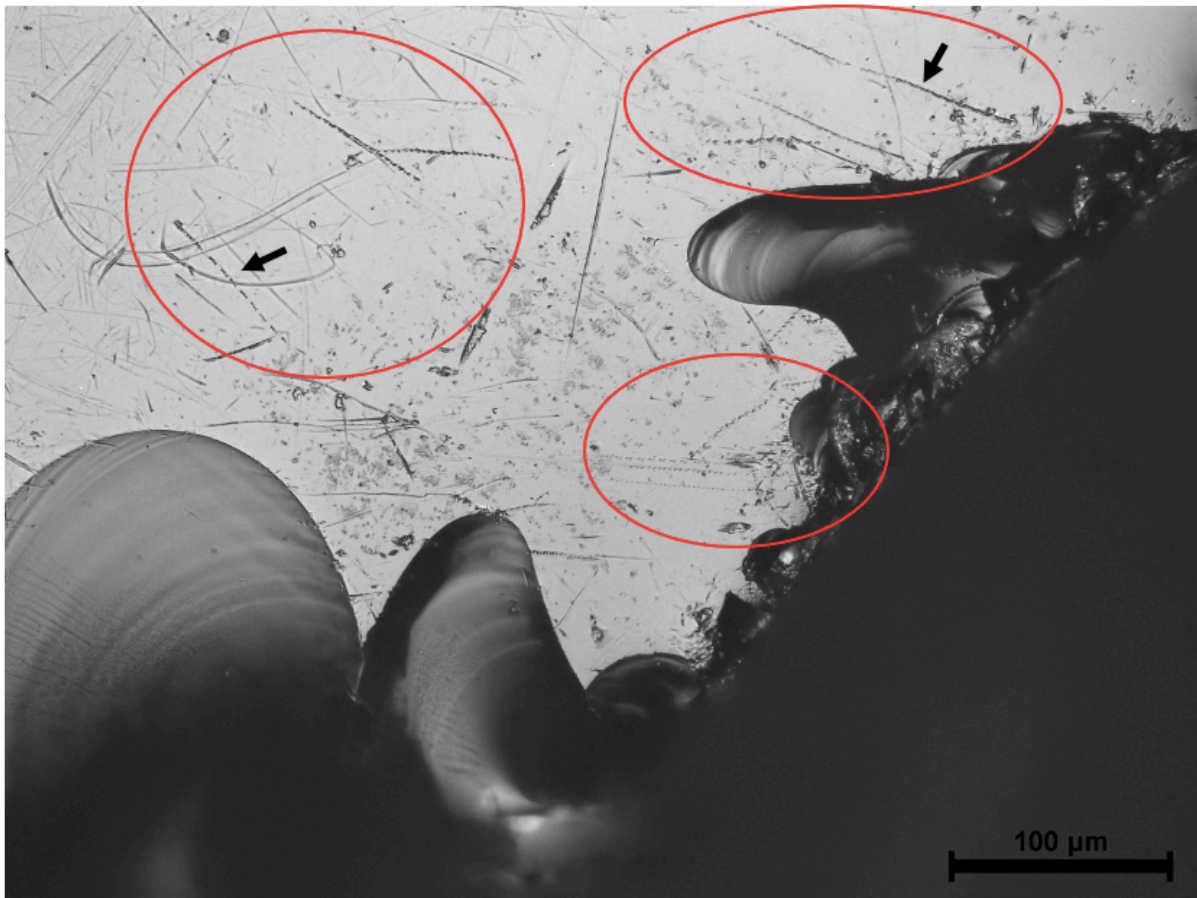
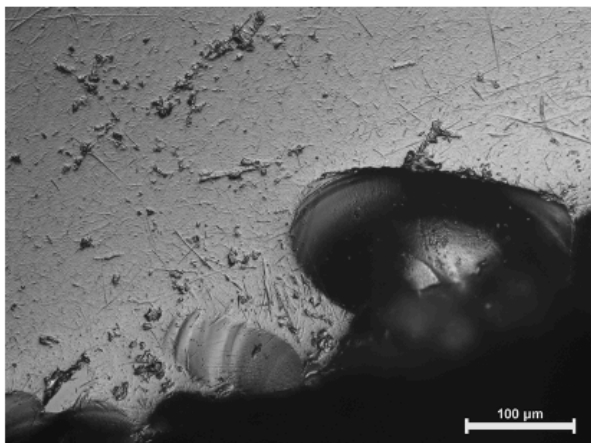


Figure 4.12: Bead 11.1 Side A (glass-on-amber, flax/cotton). Intermittent striations circled in red, with changes in force applied indicated by black arrows. Scale 200X. (Micrographs author's own).

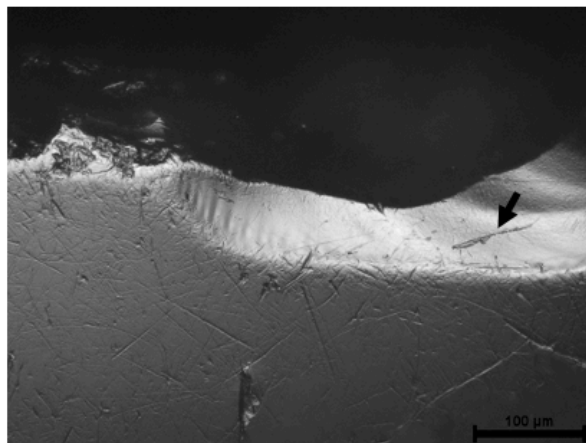
In addition, intermittent striae appear to be less abundant across both glass-on-glass groups when compared to the control sides for both animal and vegetal string. The reason as to why such discrepancies exist has likely to do with use-duration and the presence of other variables related to modes of use, rather than a difference in stringing material.

Flaked striations are generally rare and detected in isolation on glass bead surfaces. Nevertheless, their occasional presence was observed on the faces of beads which were strung with flax/cotton (beads 3.2 A-B, 6.1 A, 8.1 A, 8.2 A-B, 11.1 A-B, 12.1 A), with the use of leather string recorded only for beads 4.1 A and 5.2 A. A secondary factor is seemingly the contact with glass or copper alloy beads in equal measure (respectively beads 3.2 A, 5.2 A, 8.1 A, 8.2 B, 11.1 B and 4.1 A, 6.1 A., 8.2 A, 12.1 A) although it has to be said that there are isolated examples of flaked striations with the same frequency on one single control side and on a glass-on-amber side (beads 3.2 B, 11.1 A).

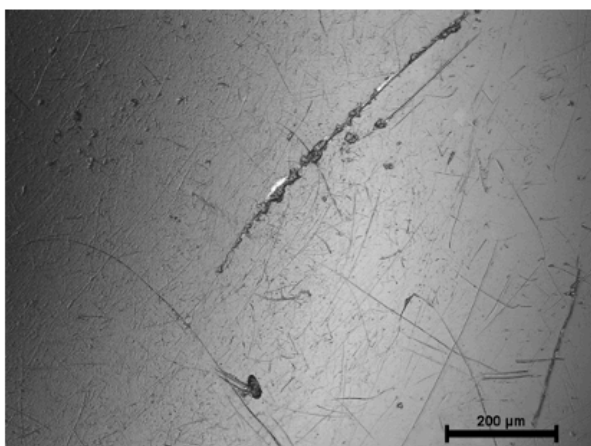
Concerning the glass-on-glass with vegetal string combination, flaked striations are encountered as single traces on both the body of the beads and the thread-hole edges, whereas in the case of glass-on-copper alloy beads, irrespective of the string material, they are distributed in clusters and often can be found on (and more rarely within) manufacture micro-chips along the edges (Figure 4.13).



Bead 12.1 A (glass-on-copper alloy, flax/cotton): flaked striations along micro-chips and small cluster located away from the edge. In both cases flaked striations interact with sleeks, either by being covered or covering them. Scale 200X.



Bead 8.2 A (glass-on-copper alloy, flax/cotton): individual flaked striation within microchip, indicated by arrow. Abrasion, slight edge rounding and bright polish are also visible along the edge. Scale 200X.



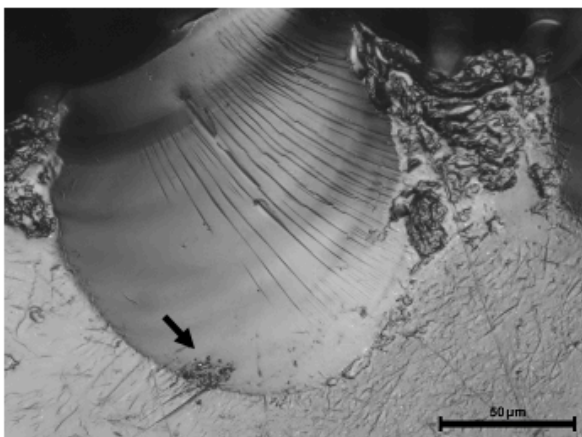
Bead 8.1 A (glass-on-glass, flax/cotton): individual flaked striation on body of bead, overlying chaotic sleeks. Scale 100X.

Figure 4.13: Flaked striations from use and their distribution on beads. (Micrographs author's own).

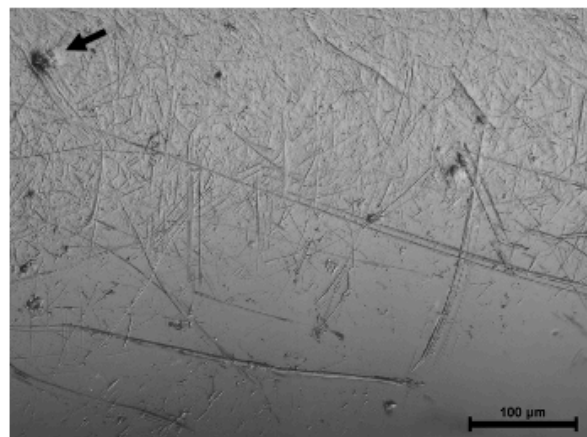
Flaked striations can be explained by the forceful scraping and sawing of the string and/or of beads against the glass surface, and by the amount of grit present. In beads strung with vegetal fibre, flaked striae observed along the thread-hole area could be partly justified by the action of the string itself in this specific material, as such striations are often encountered on obsidian tools which are employed in the processing of siliceous hard or soft wood, hard palm, bamboo and plants such as *graminae*, or true grasses (Walton, 2019, p. 419; Kononenko, 2011, pp. 25,49; Hurcombe, 1992, pp. 40-41, 42-43). Flaked striations caused by glass-on-glass and glass-on-copper alloy contact could be due to the fact that, although for

different reasons, both materials may have a greater abrasive potential: glass is relatively smooth and hard, which means that any type of debris will immediately adhere onto its surface, whereas in the case of copper alloy, the rough finish of the beads which were specifically used in the experiment would have been the main determining element, although, as we will see, the input of other variables cannot be ruled out.

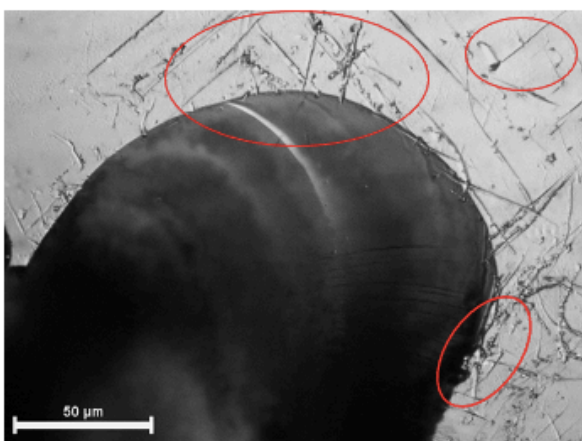
Comet-like features are generally found on flint and quartz implements and consist of pits with short, shallow trails, resembling a tail (Keeley, 1980, p.61; Sussman, 1988, p. 13). In the case of glass beads, these ‘comets’, which are similar to the ones recorded on obsidian (Hurcombe, 1992, p. 43), often present only one relatively lengthy trail which is more like a sleek striation, hence the decision to label these traces as striae. Exceptions do of course exist, as individual comet-like pits were recorded in two separate instances (3.1 B, 10.2 B). Comet-like striations, on average short, rare, and isolated, were equally observed on the edges and bodies of bead faces used as controls, but also when in contact with glass, amber and copper alloy, and strung with either animal or vegetal fibres (Figure 4.14).



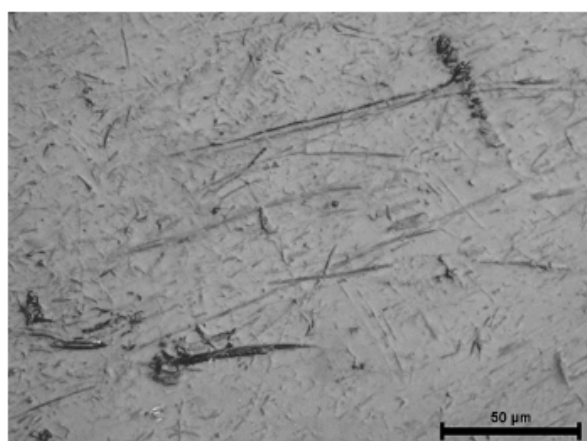
Bead 10.2 A (glass-on-glass, leather): comet-like pit . Scale 500X.



Bead 3.1 B (glass-on-amber, leather): chaotic sleeks, pits and comet-like pit indicated by arrow . Scale 200X.



Bead 4.2 A (control face, leather): clusters of small comet-like striae circled in red. Scale 500X.



Bead 4.1 A (glass-on-copper alloy, leather): chaotic sleeks, pits and comet-like pit indicated by arrow . Scale 200X.

Figure 4.14: Previous page. Comet-like pits and striae from use and their distribution on beads. (Micrographs author's own).

Comet-like striae were recorded only on a few specimens for each necklace configuration subgroup, and were more frequently observed on beads which already showed abundant traces of wear by use. Albeit less frequent than on beads strung with flax/cotton, they were recorded as being slightly more prevalent on beads associated with leather string when organised in clusters or sparse throughout. When found as single traces, they are more commonly seen on glass-on-glass and vegetal string combinations. Although in all cases the contact with glass appears to yield the greatest amounts of comet-like striations, this could be partly due to the higher number of beads in this material to begin with, which may skew the overall data patterns. On silica-rich materials such as obsidian and flint, comet-like features are generally produced by cutting wet and soft grass, whereas on quartz they are only observed when working fresh bone and soaked antler. In the case of glass, we can infer that the main agent contributing to the formation of these traces may be a higher degree of moisture, which is in all likelihood retained for longer within the strings and may be dependent on the type and intensity of the physical activity undertaken by the volunteers, especially in the case of occasional striae, either sparsely distributed or clustered (Hurcombe, 1992, p.171; Keeley, 1980, pp. 60-61; Sussman, 1988, p. 13). Volunteer 10 reported for instance that after the first three months of wearing the necklace, they started not taking it off when showering or swimming, and although their levels of overall physical activity were low (2-4 hours per week), the regular contact with water would have been enough to warrant the development of comet-like striations. In a similar manner, volunteer 8 stated that sometimes they would put the beads in their mouth to relieve stress, and although this individual already fell within the highly active group (>10 hours per week), the presence of saliva on the bead surfaces and perhaps on the string may have been a conducive factor.

Fern like-striae occur very rarely on obsidian, and although their formation processes are still obscure, it has been hypothesised that they would develop on tools used for a relatively long time and with strong polishing agents (Hurcombe, 1992, p. 58). These traces were not recorded in the sample set. However, bead 4.2 A presents a patch of abrasion resembling a fern-like striation (Figure 4.15). Its slightly oblique orientation and its location along and away from the edge indicate that this stria likely formed due to (leather) string action, which is consistent with what was reported by Hurcombe, who observed that fern-like striations result from scraping dry hide (1992, p. 182, plate 51).

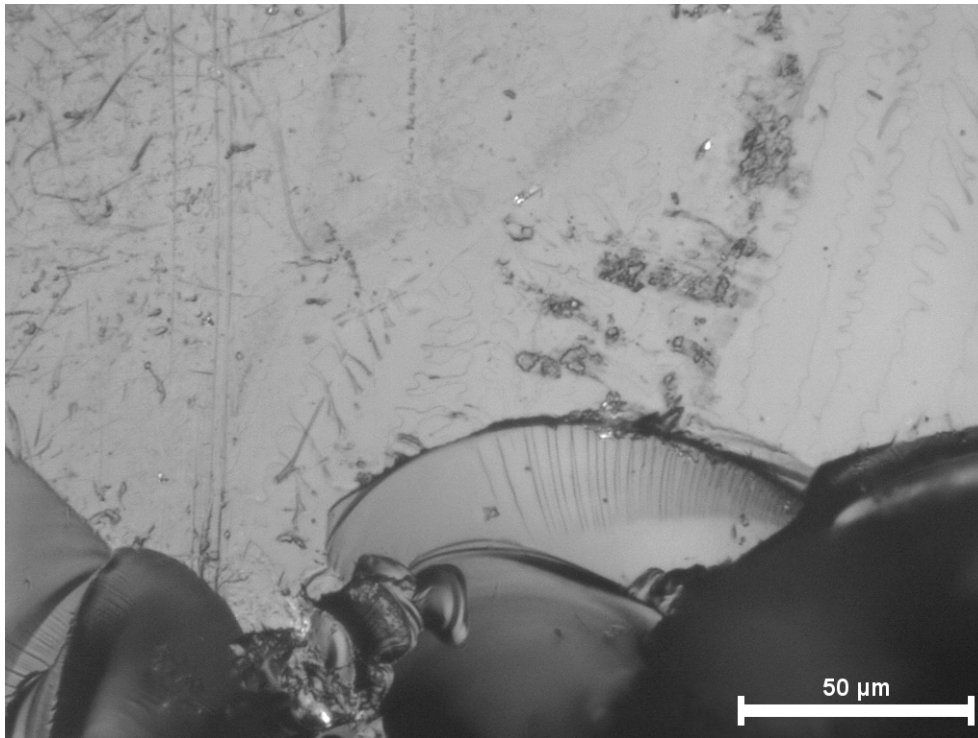


Figure 4.15: Potential fern-like striation on bead 4.2 Side A. Scale: 500X (Micrograph author's own).

4.9.4 Polish and rounding

Polish on experimental beads is in connection to use, whereas on archaeological assemblages, as we will see in Section 5.8, there is a chance that this may be also related to post-depositional processes. As in general traces of wear by use – as much as corrosion – tend to develop on already damaged surfaces, polish progresses more readily along the edges of the thread-hole whenever micro-chips are present. Polish and rounding or smoothing are usually distributed in clusters and located on peaks along the edge but also (albeit more rarely) on the bodies of beads.

The occurrence of polish and rounding can be explained by string kinematics and by the presence of greasy residues and abrasive particles which can be trapped within the string and/or are deposited in and around the thread-hole. Concurrently leading to the formation of polish, abrasive wear given by constant bead-on-bead interaction – which is directly correlated to string tension and range of motion – is the primary cause of edge rounding. It is unclear to which degree the contact between beads may affect the development of polish along the edge. However, on globular specimens – whereby the body is the highest topographic point – the presence of polish and smoothing could be largely attributable to bead-on-bead contact. For all these reasons, descriptions of polish and related rounding of

edges and bodies will be categorised by string material, then grouped by bead type irrespectively of the string used and finally the two datasets will be cross-examined, so that it will be easier to estimate the role of these variables and how they relate to each other.

When observing the distribution of polish stages according to string type in Figure 4.16, despite the slightly higher number of beads strung with flax/cotton fibres,⁶ this appears to be relatively even between the two categories, as ranges from very light to well-developed polish are recorded for both. In particular, developed to well-developed polish seems to be prevalent with flax/cotton. The same broad considerations apply to smoothing, although in this instance leather does not seem to produce intensive edge rounding, which appears to be a prerogative of vegetal string only. These remarks are further reinforced by the fact that necklaces with leather string were all worn for the totality of the ten months of the experiment, whereas the vegetal fibre sample is not only more heterogeneous in terms of use-duration but its overall percentages are also lower (see Section 4.6).

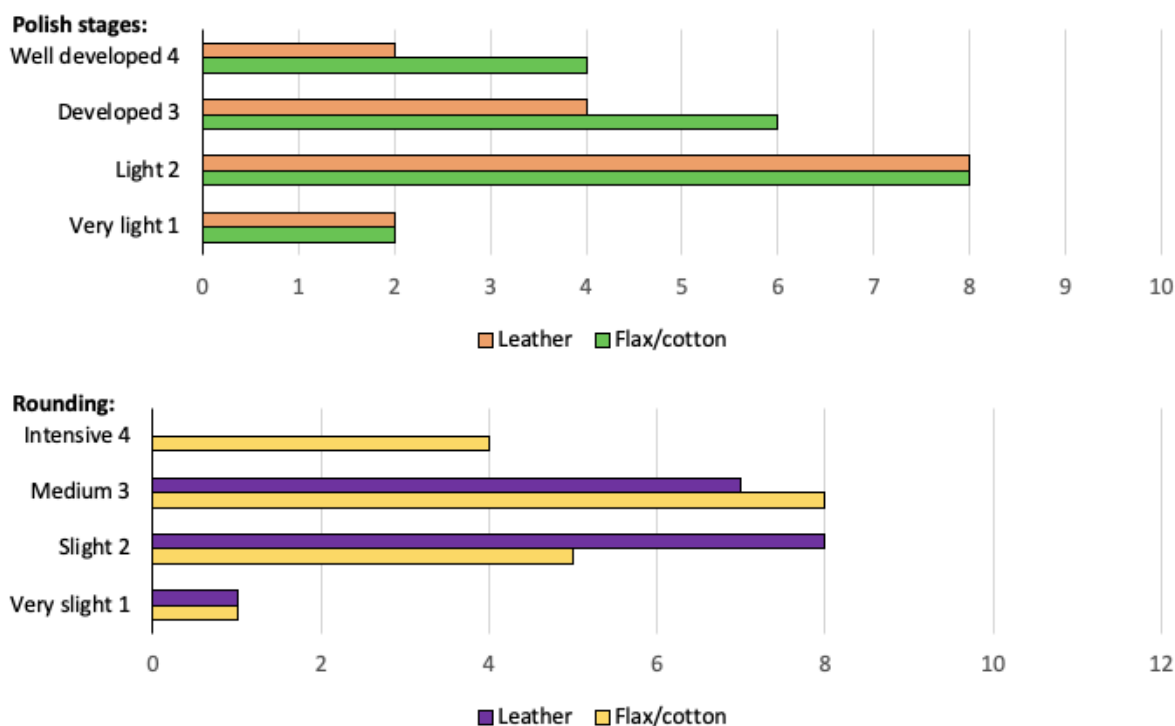


Figure 4.16: Distribution of polish stages (top) and rounding/abrasion intensity (bottom) across leather (n beads= 8) and flax/cotton (n beads= 10) strings for bodies and edges of beads. In the case of multiple ranges for the same bead face, the highest value has been selected as most representative.

⁶ The number of beads strung with leather was meant to be the same, but as explained in Section 4.6, by the end of the experiment two bead sets were unavailable.

In the case of bead materials, well-developed polish and medium to intensive rounding were especially noted for faces in contact with copper alloy and glass beads, with amber bead and control sides yielding overall lighter levels of polish and rounding (Figure 4.17). We can postulate that this is a consequence of the higher degree of abrasion produced by glass and copper alloy, as already hypothesised for flaked striations.

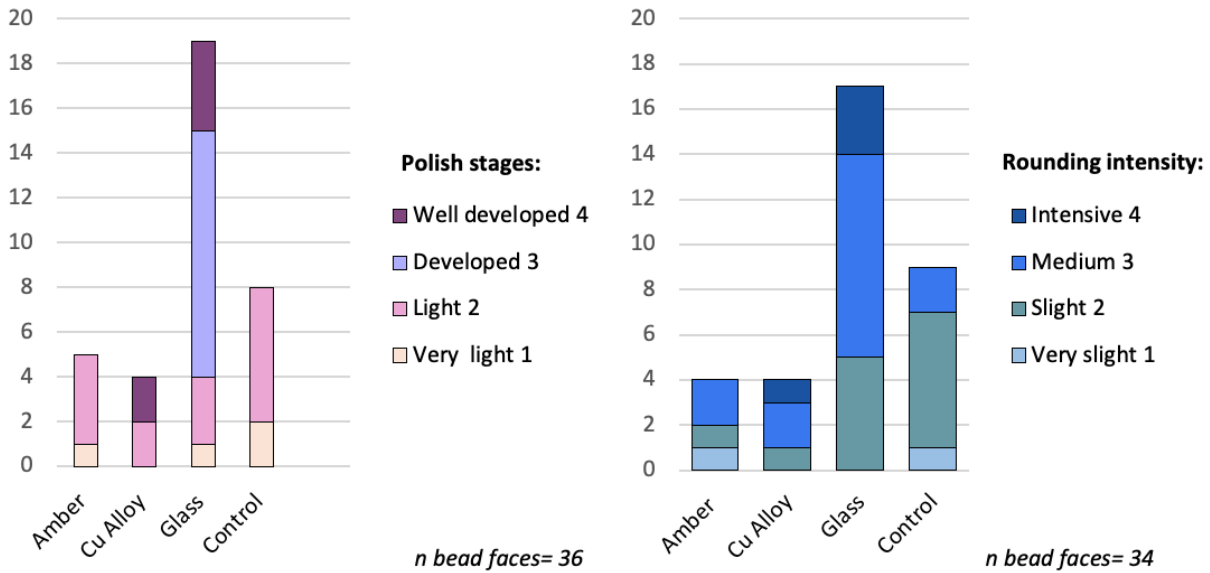


Figure 4.17: Distribution for bodies and edges of polish stages (left) and rounding intensity (right) irrespective of stringing material across bead faces in contact with amber, Cu alloy, glass and controls. In the case of multiple ranges for the same bead face, the highest value was selected as most representative.

Polish and rounding recorded along the edges of the thread-hole for all bead faces display some variation, either in relation to the string and/or concerning bead-on-bead interactions. When very light to light, polish is not diagnostic of the contact with a specific material: found across all bead faces and for both string types, it generally ranges from bright to fairly dull, with slightly smooth to bumpy texture and it is associated with very slight to moderate rounding. As shown in Figure 4.18, very light polish was recorded on glass in contact with amber and flax/cotton string (bead 3.1 B) and on two control faces with leather (beads 4.2 B, 5.2 B), suggesting that in both scenarios string (and bead) action was minimal. As the figures are slightly skewed in favour of strings in vegetal fibres, this fact may partly explain why advanced polish is more frequently encountered on all categories of faces of beads strung with this material. Well-developed polish was recorded for glass-against-glass faces in beads strung with both vegetal (beads 8.2 B, 12.1 B) and animal fibres (beads 7.1 B, 10.2 A) in four instances in total. This polish stage was also observed on the faces of beads 8.2 and 12.1 which were in contact with copper alloy.

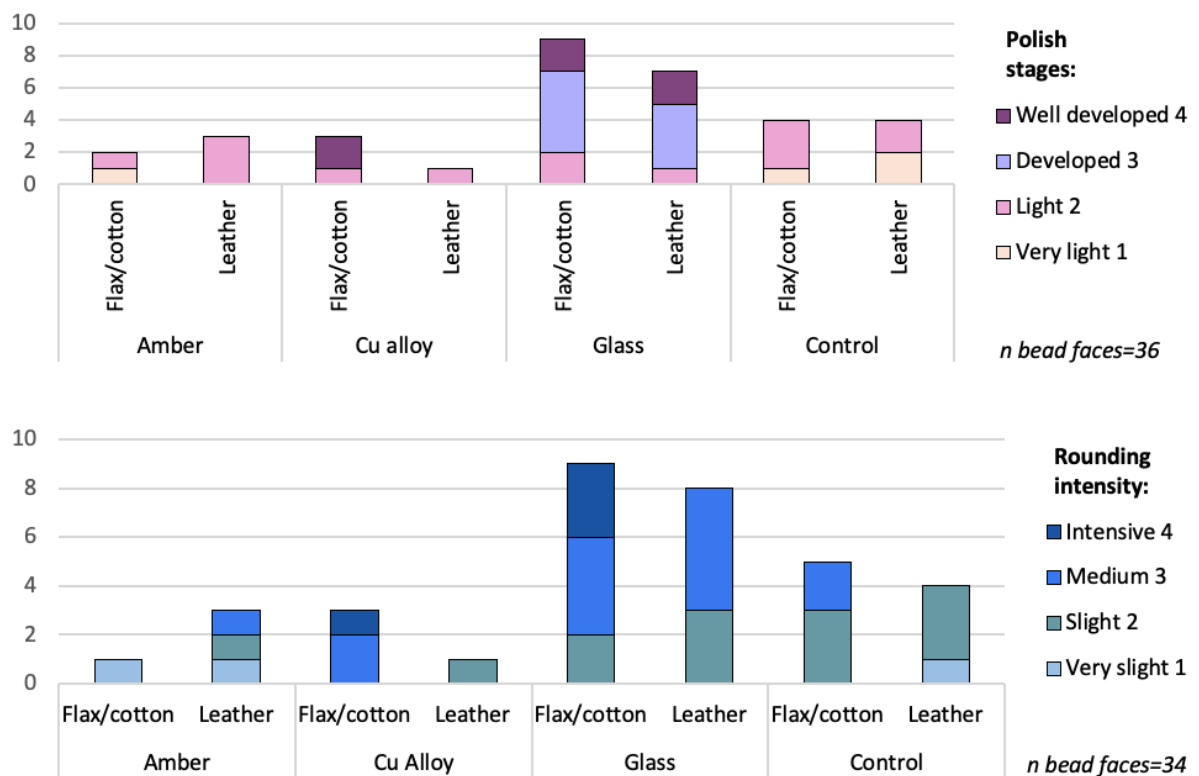


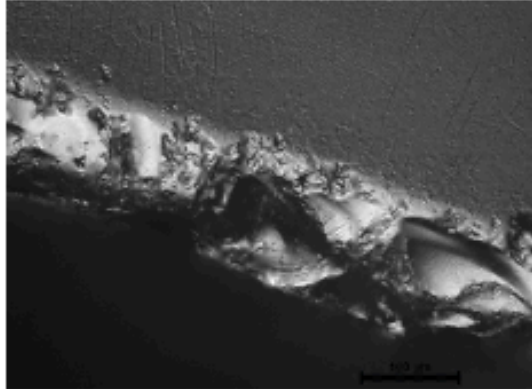
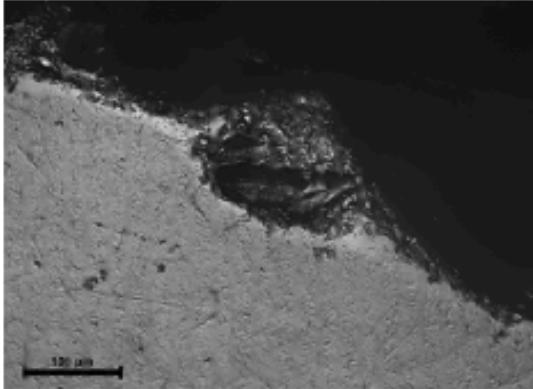
Figure 4.18: Distribution of polish stages (top) and rounding intensity (bottom) along the thread-hole-edge faces by taking into account stringing and contact materials. In the case of multiple ranges for the same bead face, the highest value was selected as most representative.

When developed to well-developed polishes were documented, there did not seem to be much variation in appearance between flax/cotton and leather strings, as both groups showed the fairly bright to dull gamut. In terms of texture, the use of vegetal fibres, due to the highly abrasive nature of the material, seems to translate into the presence of slightly smoother surfaces – interspersed by rough patches – with medium to intensive edge rounding, especially in the case of glass-on-glass interaction. If on the one hand flax/cotton polish appears on average flatter and more invasive, on the other hand, polish caused by leather string is slightly duller and shows fewer abrasion patches. As previously stated, these differences are subtle and may not guarantee a correct identification of the string material, not only because both types can yield similar results and/or differential polish development on the same bead face, but also the cases in which well-developed polish was reported are scarce overall (Figure 4.19).

LEATHER STRING

FLAX/COTTON STRING

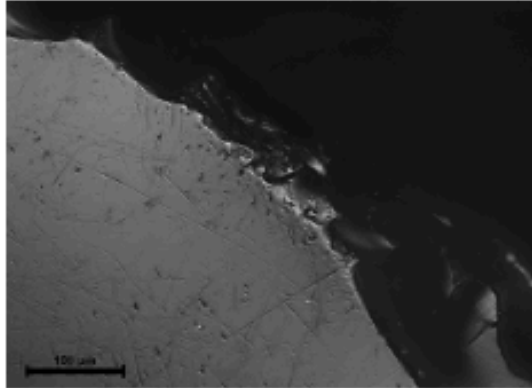
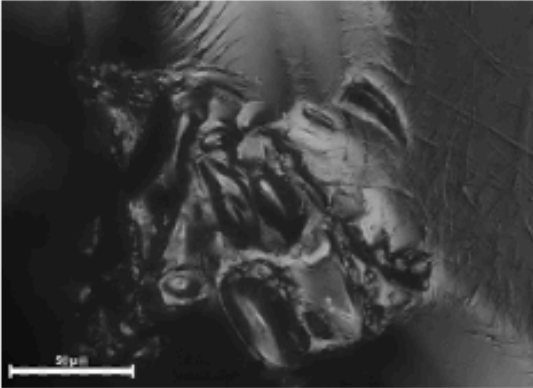
G
L
A
S
S



10.2 A: developed to well-developed, bright to fairly bright and slightly smooth polish with medium rounding.

12.1 B: developed to well-developed bright smooth polish with rough patches. Slight to medium rounding.

A
M
B
E
R

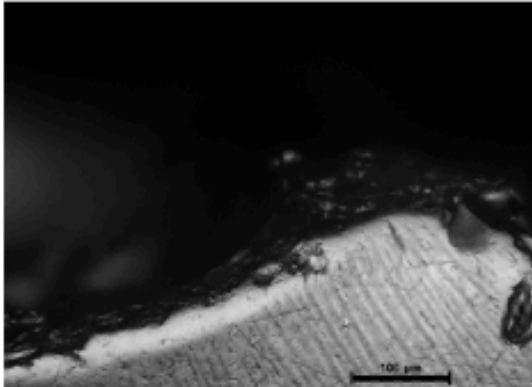
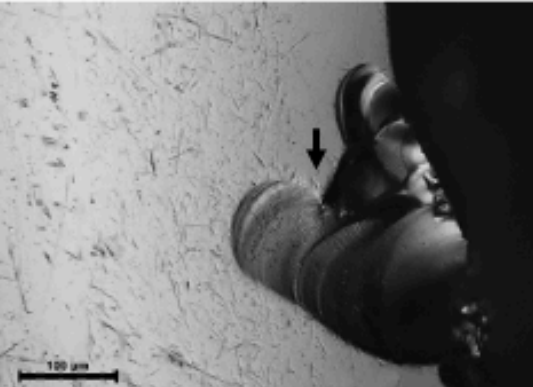


10.1 B: light, bright and slightly smooth to bumpy polish, with slight rounding.

11.1 A: light, bright and slightly smooth polish, with slight rounding.

C
O
P
P
E
R

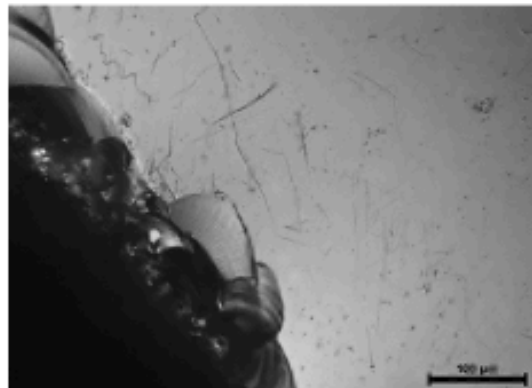
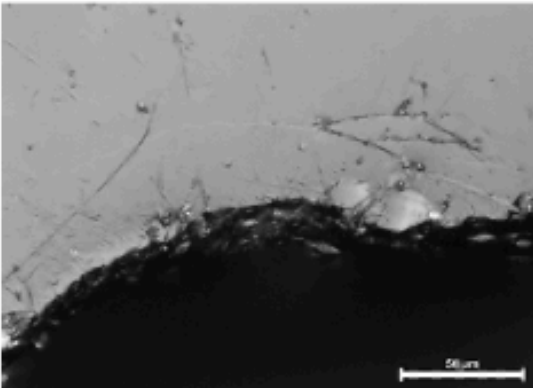
A
L
L
O
Y



4.1 A: very light, fairly bright and slightly smooth polish, with slight rounding.

12.1 A: developed to well-developed, bright, smooth polish with medium to intensive rounding.

C
O
N
T
R
O
L

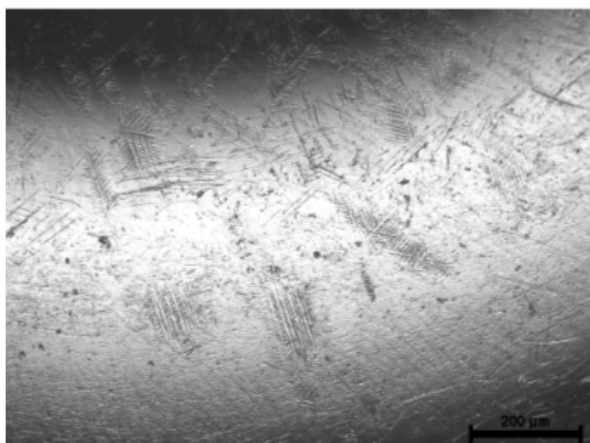


7.2 B: light, fairly bright and slightly smooth polish, with slight rounding.

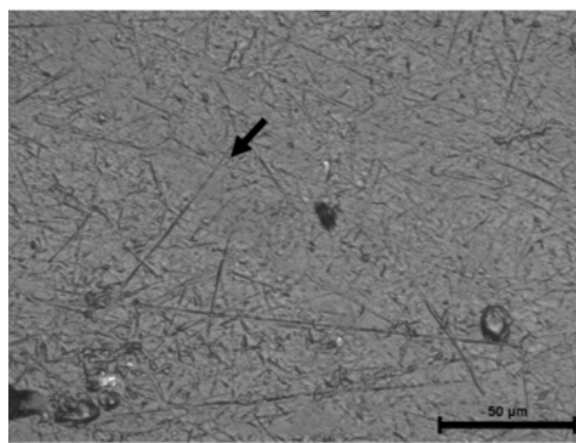
12.2 B: light, bright and slightly smooth polish, with very slight to slight rounding.

Figure 4.19: Appearance and texture of polish and related rounding on thread-hole edges of beads, according to contact face and string material. (Micrographs author's own).

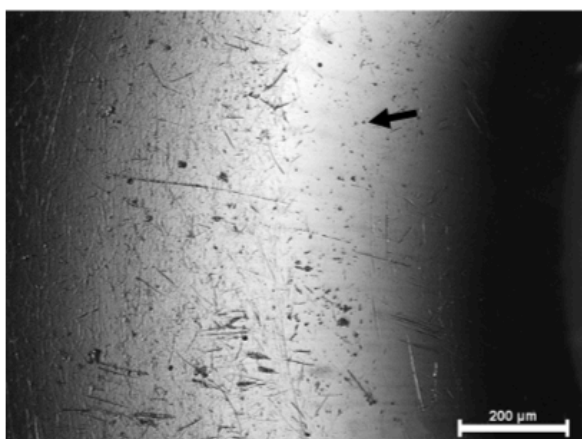
Weak polish was also recorded on the bodies of beads. Due to its high reflectivity, it is very difficult to discriminate whether this is due to use or if it is a surface variation inherent to the glass itself, such as bright spots (Figure 4.20). Nonetheless, whenever very light to light polish is concurrent with rounding, we can infer with a higher degree of certainty that this is the result of a continued wearing of the necklace.



Bead 4.2 A (glass-on-glass, leather): intense, smooth polish and light rounding. Scale 100X.



Bead 5.1 B (glass-on-glass, flax/cotton): bright, smooth polish and light rounding bands indicated by arrow. Scale 500X.



Bead 6.2 A (glass-on-glass, flax/cotton): likely bright spot as the intense, smooth 'polish' indicated by the arrow does not appear to be accompanied by rounding. Scale 100X.

Figure 4.20: Appearance and texture of polish and related rounding on bodies of beads. (Micrographs author's own).

The ambiguous nature of very light polishes is also reflected in the discrepancy between the total number of faces of beads with this type of trace and rounding, as illustrated in the graphs below (Figure 4.21). In any case, generally smooth and bright polish is accompanied by smoothing more frequently on beads in contact with glass, rather than copper alloy and amber. Although the string does not directly contribute to polish formation on the bodies of beads, it can be noted that leather seems to favour the development of both polish and rounding. This may be explained by the fact that once soaked in skin oils and moisture, this stringing material may not only shrink slightly but its surface may also become smoother, which means that when the beads move, they glide from side to side whilst still remaining in

close contact with one another. This hypothesis is supported by the reflections of Volunteer 12, which are reported in paragraph 4.11 within the wider discourse on the (innumerable) variables that can affect wear formation.

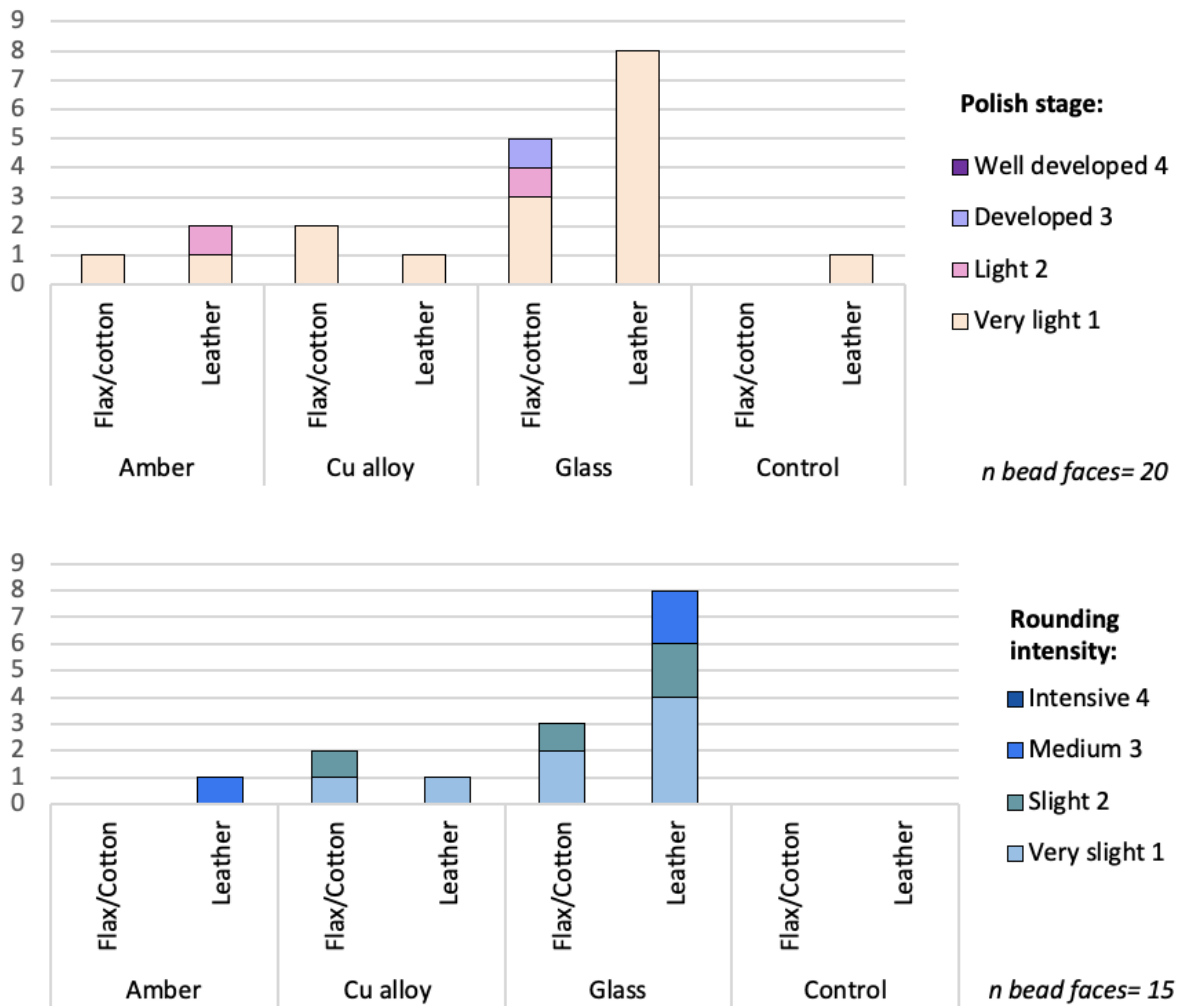


Figure 4.21: Distribution of polish stages (top) and rounding intensity (bottom) on the bodies of beads by taking into account stringing and contact materials. In the case of multiple ranges for the same bead face, the highest value was selected as most representative.

4.9.5 Abrasion and attrition

Unlike rounding, abrasion and attrition are not necessarily correlated with polish. However, areas displaying medium to intensive attrition levels can at times be subject to later abrasive wear, yielding a smoother, brighter surface. Abrasion and attrition were detected on topographic highs either on the micro-chips around the thread-hole area or on the bodies of beads, albeit very rarely and on average in a much lighter form. Abrasion and related pitting were recorded roughly in equal measure between the leather and flax/cotton groups, although it seems more pronounced in the case of necklaces strung with vegetal fibres and

especially for bead faces in contact with glass, confirming the trend observed so far (Figure 4.22).

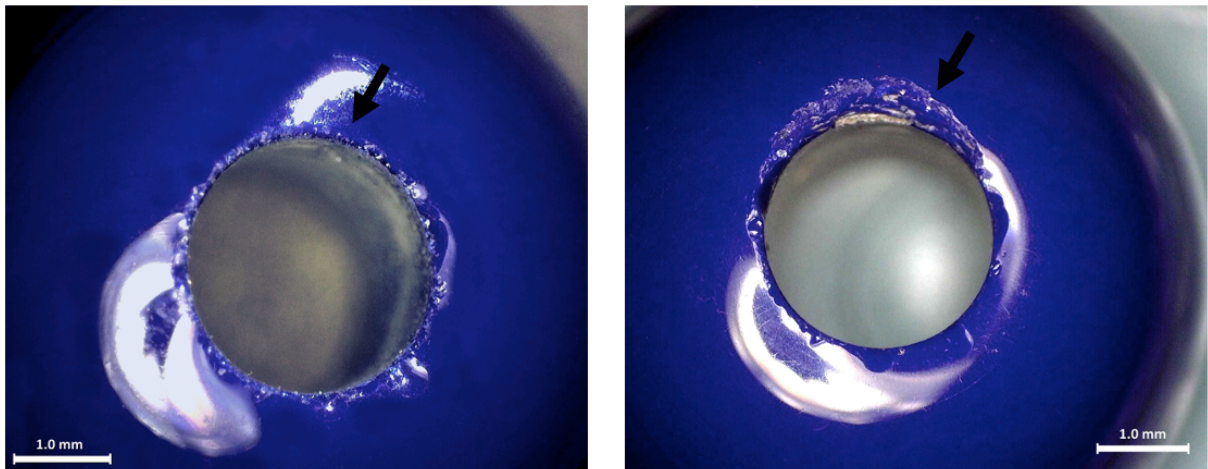


Figure 4.22: 12.2 A glass-on-glass and flax/cotton string, before (left) and after (right) use. The bead face has been photographed in the exact same position in both cases: abrasion and increased chipping of the top portion of the edge, indicated here by arrows, is clearly visible. Scale 60X. (Micrographs author's own).

Light to intensive attrition was visible across all string and contact material combinations for most bead sets including the control faces: the only exception is represented by set 3, where only bead 3.2 A presented attrition patches (Figure 4.23).

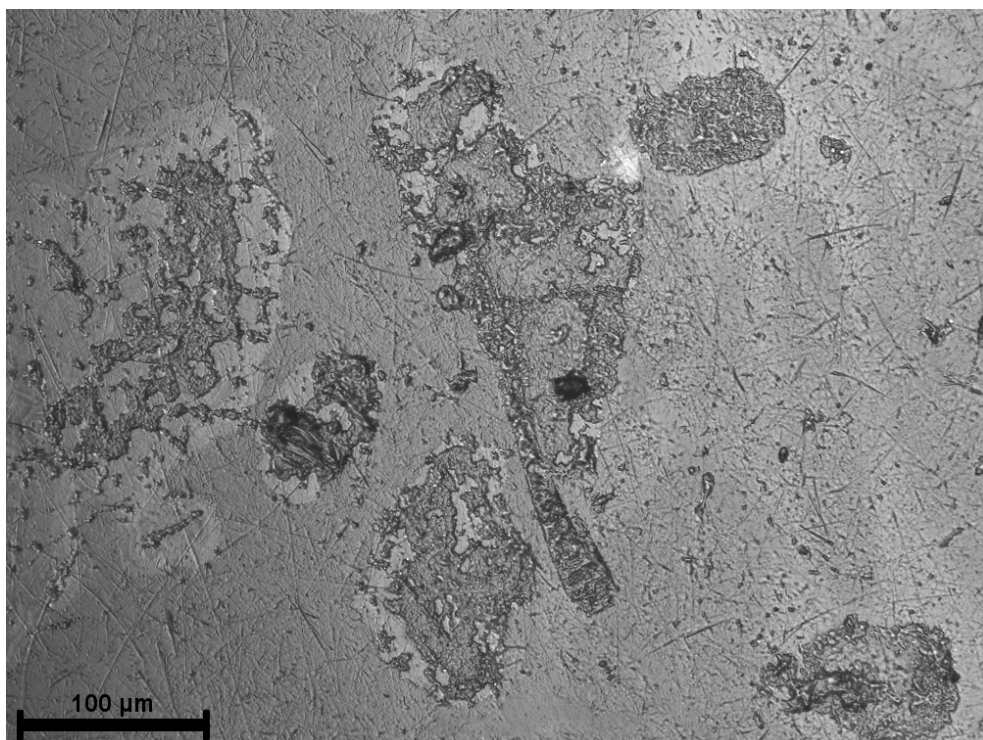


Figure 4.23: Attrition and polish on body of bead 3.2 A (glass-on-glass, vegetal string), likely resulting from the contact with another glass bead. Scale 200X.

If the interaction with an adjacent glass bead appears to be once again a determining factor in medium to intensive attrition, in this case it is difficult to establish the role of the string

material. It is also worth noting that attrition along the edges of beads may not necessarily be a consequence of their use, as it may perhaps be connected with the final steps of the bead-making *chaîne opératoire*, such as the cleaning of the thread-hole by removing the separator with a reaming tool. Alternatively, attrition may be caused by the insertion of the beads through the string during necklace assembly, especially in the instance where the inner diameter of the thread-hole is slightly narrower or just about the same as the thickness of the string, as reported for bead set 4.

4.11 Variables in trace formation

Beside use-duration mentioned at the beginning of Section 4.9, the other variables that contributed to the development of polish, rounding, attrition and abrasion are reported in Table 4.7 below.

<i>Bead set</i>	<i>String</i>	<i>Polish</i>	<i>Rounding</i>	<i>Attrition</i>	<i>Abrasion</i>	<i>Physical activity (hrs/w)</i>	<i>Steam (hrs/w)</i>	<i>Outdoors (hrs/w)</i>	<i>Preference</i>
7	Leather	4	3	4	3	2-4	1-2	2-4	loose, in plain sight
10	Leather	4	3	4	3	2-4	2-4	4-6	tight, in plain sight
12	Flax/cotton	4	4	3	4	2-4	8-10	2-4	loose, in plain sight
8	Flax/cotton	4	4	4	4	> 10	4-6	> 10	loose, in plain sight
4	Leather	3	2	3	2	8-10	4-6	8-10	tight, in plain sight
5	Leather	3	3	3	2	4-6	2-4	2-4	tight, in plain sight
6	Flax/cotton	3	3	3	3	4-6	2-4	4-6	loose, concealed
3	Flax/cotton	3	2	3	2	6-8	2-4	4-6	loose, concealed
11	Flax/cotton	3	3	3	3	8-10	8-10	> 10	tight, concealed

Table 4.7: Variables accounted for in trace formation on experimental beads. The numeric values for polish, rounding, attrition and abrasion, are the highest values recorded within single bead-sets and range from 1 (very light/slight) to 4 (well-developed/intensive) as per information provided in this chapter. Physical activity, steam exposure and time spent outdoors are expressed in hours per week.

Although it is quite difficult to disentangle different but concurring factors on a relatively small dataset, some interesting observations can be made. Despite the fact that flax/cotton

necklaces were worn for variable lengths of time, never reaching the ten-month mark (as opposed to the leather group, which is very homogenous), beads strung with vegetal fibres appear in proportion to yield slightly higher values across the board. Intensive rounding and attrition associated with flax/cotton string, such as the ones displayed in bead sets 8 and 11, could also be due to the fact that both individuals were physically very active, undertaking activities such as manual labour and walking for extended periods of time (between 8-10 and >10 hours a week). Although this pattern does not clearly emerge from the leather string group, we can postulate that to some extent the intensity – and perhaps quality – of physical exercise may have had an impact. Independently from the stringing material, spending time outdoors or being exposed to steam shows no apparent correlation with the development of polish, rounding, abrasion and attrition, as the effect of these two variables may be masked by the factors discussed so far, which perhaps occupy a higher place in the hierarchy. For instance, it is true that the necklace worn by Volunteer 12 has elevated rates across all trace types and high steam exposure (8-10 hours per week). However, this may be rather due to the fact that they were regularly training by doing strenuous activities such as aerobics and weight lifting.

Tentatively, it appears that necklaces that were worn loosely around the neck present on average higher levels of rounding and abrasion, confirming in part what has already been stated by Guzzo Falci et al. (2019), as reported in Section 4.3.2. Furthermore, it has to be said that in terms of wearing preferences, the fact that the necklace may be concealed under garments or in plain sight (i.e., mostly not covered by clothing but as in the previous case still in contact with bare skin) does not seem to matter. In addition, it was noted that on average the second glass bead on each necklace – and specifically always the face that is in contact with glass – shows the highest degree of polish and other associated traces: this was not only due to glass-on-glass interaction, but also to the fact that on this bead the load was more substantial, as this face bears the weight of two beads, which also means that the contact will be constant.

On top of these known factors, we also need to deal with variables that tend to be invisible or uncontrollable: if compared to ‘canonical’ use-wear experiments whereby to ascertain the progression of traces a tool is worked in a specific way, with selected materials and at regular time intervals, this did not happen with the wearing of the necklaces. For instance, the strings used in the experiment were initially dry, but as time went on, they absorbed at

different rates bodily fluids and water; at least in the case of Volunteer 10, who went swimming regularly wearing their necklace, the string had to withstand constant moisture level changes. The words of Volunteer 12 are apt to provide us with an insight on the effect that human agency has on wear formation processes, and on the hidden variables that we may have to be mindful of when analysing beads: *'[...] I've also noticed that because the brass bead is heavier and larger, it pulls the necklace to that side. As a result, the beads sit slightly 'lopsided', with the greatest contact against the brass bead. The central diameter of the bead on the right side is quite small, and the rope is fairly thick, so sometimes this bead spends a while on its own, though I try to correct it as often as I can'*.

4.12 Conclusions

A recording protocol for use-wear analysis on glass beads was devised and applied to experimental replicas which were employed in a ten-month bead-wearing experiment. The different types of wear along with their intensity, distribution and frequency were described by drawing for the large part from the current use-wear literature on obsidian, as the chemical and physical characteristics of the latter are close to artificial glass and hence the traces found on both materials are to some extent morphologically comparable.

With regards to the analysed glass beads, it was noted that variations in the shape, placement, distribution and quantity of traces can help differentiate between wear caused by manufacture and use-related wear. The majority of diagnostic traces were found on the topographic highs of bead faces, which are generally located around the edges of the thread-hole and/or on the most prominent part of the bodies of beads, which are all doughnut-shaped. This is because when the necklaces were worn, both areas were repeatedly subject to bead-on-bead – and string, as is the case for the thread-hole– contact. With the exception of surface defects, which (whenever present) appear more sparsely on bead surfaces, other manufacturing traces, such as microchips and concentric rough or smooth wide striations caused by the mechanical removal of the separator, present a similar placement to that observed for traces of use. As a consequence, wear by use will develop on top of manufacturing traces, leading over time to their partial (or even total) obliteration, especially in the case of striations. Alongside abrasion and/or attrition patches, well-developed to developed polish from use was encountered in particular on glass-on-glass bead interactions: this is somewhat unsurprising as glass is harder than copper alloy and amber beads. In terms of stringing materials, flax/cotton appears to be ever so slightly more abrasive than leather,

thus resulting in a flatter type of polish forming around the thread-hole. Sleeks are the most common type of striation, as they have been recorded for all beads, however these striae are prime markers for use when they are found to be overlapping and are either densely distributed in a chaotic manner, as they often – but not exclusively – occur on the body of the beads, or are tightly arranged with parallel, perpendicular or slightly oblique orientation along and within the thread-hole and related microchips. Rough-bottomed, intermittent, flaked, comet and fern-like striations, which are underpinned by changes in necklace kinematics and/or by the presence of grit, are occasionally to rarely observed. With the exception of intermittent striae, which are more commonly seen on the glass-on-glass/leather string combination, the remaining types were recorded in greater abundance on glass-on-glass/flax-cotton bead sides. Flaked-striations were also frequent in the case of glass on copper alloy beads, indicating that perhaps the rough texture of the latter may have contributed to the formation of such traces.

All in all, it has been possible to establish that the formation and distribution of specific traces of wear by use are related to the shape, material and surface topography of the beads and in minor part, the type of string. Beside the aforementioned differences in hardness, the glass beads were more annular, whereas the amber beads – albeit convex – were discoidal and the copper alloy beads were globular, which means that the points of contact between beads differed according to their shape, thus resulting in slightly different type(s) and frequency of interactions. In addition, as the surface of the copper alloy beads was substantially more ragged when compared to amber and glass beads, we can infer that each type of bead will have trapped dust and oil particles in a slightly different way, producing some variation in trace morphology. Although slight, the evidence around string material appears to show differences in polish appearance between leather and flax.

Beside necklace configurations, several variables such as use-duration, levels of physical activity, steam exposure, time spent outdoors and preferred mode of necklace wearing, were accounted for in the experiment. It emerges that the greater impact in trace formation is caused by moderate to high levels of physical activity and perhaps in minor part by wearing the necklace more loosely. In all likelihood some variables have remained undetected, as the agency of single individuals in their everyday life could not be controlled.

The results of the bead-wearing experiment have helped to clarify which traces can be ascribed to which phase of the life of beads, whether it is manufacture or use. By looking at

necklace kinematics and related tribological processes, this experiment has also provided valuable insight on how traces develop and why they form on given areas of beads. This process of reverse engineering constitutes the baseline from which it was possible to compare and contrast the wear data obtained from the assemblages from Fazzan.

Chapter 5. Use-wear analysis: the case-study of Fazzan, Libya

This chapter discusses the application of use-wear analysis on archaeological glass beads from the Fazzan, which is our selected case-study. The first part of this chapter aims to provide an overview of the Garamantian settlement and cemetery sites in Wadi al-Ajal (Fazzan, south-west Libya) where the glass beads come from. The second and third parts of the chapter will illustrate the rationale behind sample selection, the limitations of the data set and will discuss the results of use-wear analysis performed on 34 beads. The entirety of the glass beads analysed in the present thesis (see Sections 5.4-5.11) come from the excavation and survey work carried out by British archaeologist Charles Daniels between 1958 and 1977. This was integrally published and expanded on by David Mattingly at Leicester University, who directed the Fazzan Project (FP, 1997-2002) and the Desert Migrations Project (DMP) between 2007 and 2011 (Mattingly, 2003, 2007, 2010, 2013a; Mattingly et al., 2007b, 2008). The beads are part of much wider glass assemblages containing vessel glass, bangles, primary and secondary production waste, a drip or hairpin, and mirror fragments: these artefacts were integrally published within Mattingly's monographs (see in particular Cole & Hoffmann, 2007; Hoffmann et al., 2010) and by Duckworth in recent years (2016a,b; 2020b). With the exception of the beads studied here, which are currently kept at Newcastle University, the materials are held at Leicester University as part of the archive of the Trans-SAHARA Project.

a) Archaeological background

5.1 The settlement and cemetery sites of Wadi al-Ajal, Fazzan (SW Libya)

As shown in Figure 5.1, Wadi al-Ajal is part of a main band of oases which run from east to west and include the Wadi ash-Shati to the north, the Murzuq/Hufra basin to the south and the Wadi ash-Sharqiyat further east. Evidence for Garamantian sites is very rich in this part of Fazzan, although attestations are also present for the Wadi Tazzuft/Ghat and Wadi Hikma oases, which are located respectively to the south-west and south-east (Mattingly et al., 2020, p. 54).

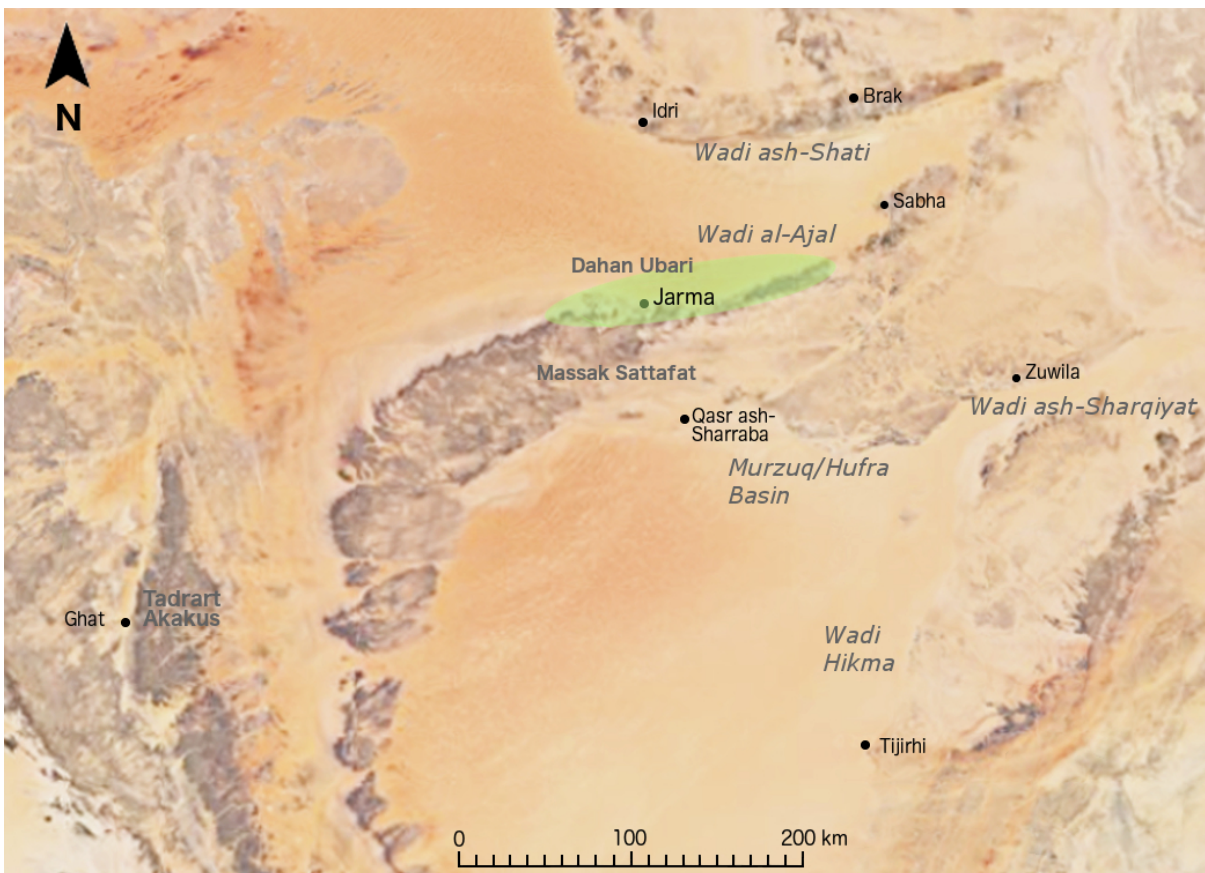


Figure 5.1: Map of Fazzan with main Garamantian oases (in italics) and sites, with Wadi al-Ajal circled in green (Map modified from Mattingly et al., 2020, p. 58. Base map: Google Earth).

Approximately 150km long and 3 to 5km wide, the Wadi al-Ajal depression is delimited to the north by the Dahan Ubari sand sea and to the south by the escarpment of the Massak Sattafat (Mattingly et al., 2020, p. 58).

From 1000 BCE until 700 CE, the Wadi al-Ajal was inhabited by the Garamantes, an agriculturalist, sedentary population for which four stages of settlement development were

identified, as reported in Table 5.1 below (Mattingly et al., 2020, p. 58; Mattingly et al., 2003a, pp. 347-354; Duckworth et al., 2020b, pp. 20-24).

Phase	Type of evidence
Pastoral (undifferentiated) 5500 BCE-1000 BCE	Mesolithic to Neolithic – transition from hunting-gathering to pastoralism and agriculture. Sites along paleolakes in Dahan Ubari, rock art and rock shelters (Wadi Tanzuuf, Massak Sattafat and Akakus), lithic scatters camp sites, burials.
Early Garamantian 1000 BCE-500 BCE	Continuation of Late Pastoral traditions in material culture (e.g. pottery, lithics, ground stone tools and ostrich eggshell and stone bead industries), alongside the birth of hillfort/escarpment sites such as Zinkekra in Wadi al-Ajal and Tinda by Ubari.
Proto-urban Garamantian 500 BCE-1 BCE	Evolution of Zinkekra as proto-urban centre and foundation of the urban site of Jarma. Likely period of introduction of channel irrigation systems (foggaras) for cultivation. Glass beads, Punic bowls, amphorae and cowries are imported from the Mediterranean and Sub-Saharan Africa. Local metal and glassworking alongside bead-making (stone and ostrich eggshell).
Classic Garamantian 1 CE-400 CE	Roman period – Jarma is the Garamantian capital. Public buildings and temples built in stone. Extensive trade with the Roman Empire. Farming activity concentrated in oases at base of depression. Presence of villages and hamlets such as Saniat Gibril, and further towns were established in the main Fazzan oases.
Late Garamantian 400 CE-700 CE	Continuation of previous phase, with emphasis on defensive structures. Jarma provided with a castle-like structure (qasr). Decline in trade with the Roman empire.
Post Garamantian 700 CE-1100 CE Early Islamic 1100 CE-1300 CE Islamic 1300 CE-1500 CE	Further contraction of trade/imports and fortification of additional settlements with qasr. From the 11 th C CE onwards the shift from foggara to well irrigation systems resulted in the abandonment of settlements. Jarma is no longer the regional capital, and the Garamantian kingdom is slowly dismantled. Zuwila becomes an important settlement in the Post Garamantian and Islamic phases, alongside Traghan and Murzuq. Tripoli is directly connected to the kingdom of Bornu/Kanim in Chad: salt is traded in exchange for slaves. In addition, in the Early Islamic period new trans-Saharan trade routes (from Tunisia to Mali and from Morocco to Mauritania) are established. Berber and Arab tribes (Awlad Sulayman and Tuareg) from the north emerge as new enemies.
Early Modern 1700 CE-1951 CE	Demographic decline, general impoverishment. Shortage of human and animal power to work wells and lowering of water table. Outsiders (e.g., Kanimi, Awlad Muhammad, Qaramanli/Ottoman and nomadic groups) try to control the region and its trading activities. Natron from Dahan Ubari is still an important commodity until the early 19 th C. Between 1911 and 1943 Libya was an Italian colony, and following British and French rule, became independent in 1951.

Table 5.1: Phases of human activity in Fazzan. Garamantian phases are highlighted in light blue (Mattingly et al., 2013a, p. 508, pp. 510-511; Mattingly et al., 2003a, pp. 332-368).

Between the 1st millennium BCE and the 1st millennium CE (Early to Late Garamantian periods), the Wadi al-Ajal presents a rich material culture, as attested by local pottery production, traces of metallurgical activities (both ferrous and copper-alloy), semi-precious stone and ostrich eggshell bead industry, notably carnelian and amazonite, and glass working and perhaps making (Mattingly et al., 2003a, pp. 355-361; Duckworth, 2020b). Especially during the Classic Garamantian period, these items, alongside slaves and salt – including natron from Dahan Ubari – were traded with the Roman world in exchange for goods such as amphoras, finewares (in particular African Red Slip) and coarsewares, glass vessels, beads, bangles, mirrors and in all likelihood glass canes and chunks (Mattingly et al., 2003a, pp. 355-361; Leitch et al., 2017; Hoffmann et al., 2010). In addition, from the Garamantian capital of Jarma there is also conspicuous evidence of imports from Sub-Saharan Africa, consisting in ivory, cowrie shells, ebony beads and West African metalwork. In return, the Garamantes would export west and south-west textiles, beads and copper alloys with Mediterranean signatures. As such, the archaeological record shows that Fazzan was a very important player in pre-Islamic trans-Saharan trade as the intermediary, the producer, the innovator and the trader of goods with both the Mediterranean and West Africa (Mattingly et al., 2013a, p. 516; Mattingly et al., 2017).

5.1.1 *Zinkekra*

Situated 4km to the west of modern Jarma, Zinkekra is a flat triangular promontory escarpment which is connected to the rock plateau of the Massak Sattafat by a narrow cliff-like strip of land (Figure 5.2).

Zinkekra is the prime example of an Early/Proto-Urban Garamantian hillfort site, as the top of the hill (ZIN001)⁷ was enclosed by defensive walls ZIN900.000-900.005 and could be accessed from limited points along its northern and southern sides (ZIN002 and ZIN003), which were in turn protected by wall ZIN900.006 and earth embankments ZIN900.007-900.010 (Hawthorne et al., 2010, pp. 19-20, pp. 22-25; Mattingly & Edwards, 2007a, p. 93).

⁷In Mattingly's system each site identifier is formed by three letters for the place name, followed by numerals indicating a specific area, and then the site within this (e.g., ZIN001.034= Zinkekra, area 1, site 34) (Mattingly et al., 2003b, p. 22; Hawthorne et al., 2010, p. 26). As the beads were physically labelled – and thus analysed – using the site codes originally given by Daniels (e.g., ZIN 34 instead of ZIN001.034 or SGB instead of GER002), both nomenclatures will be provided throughout the chapter, with Mattingly's system being generally used for the denomination of sites and Daniels' system for beads.

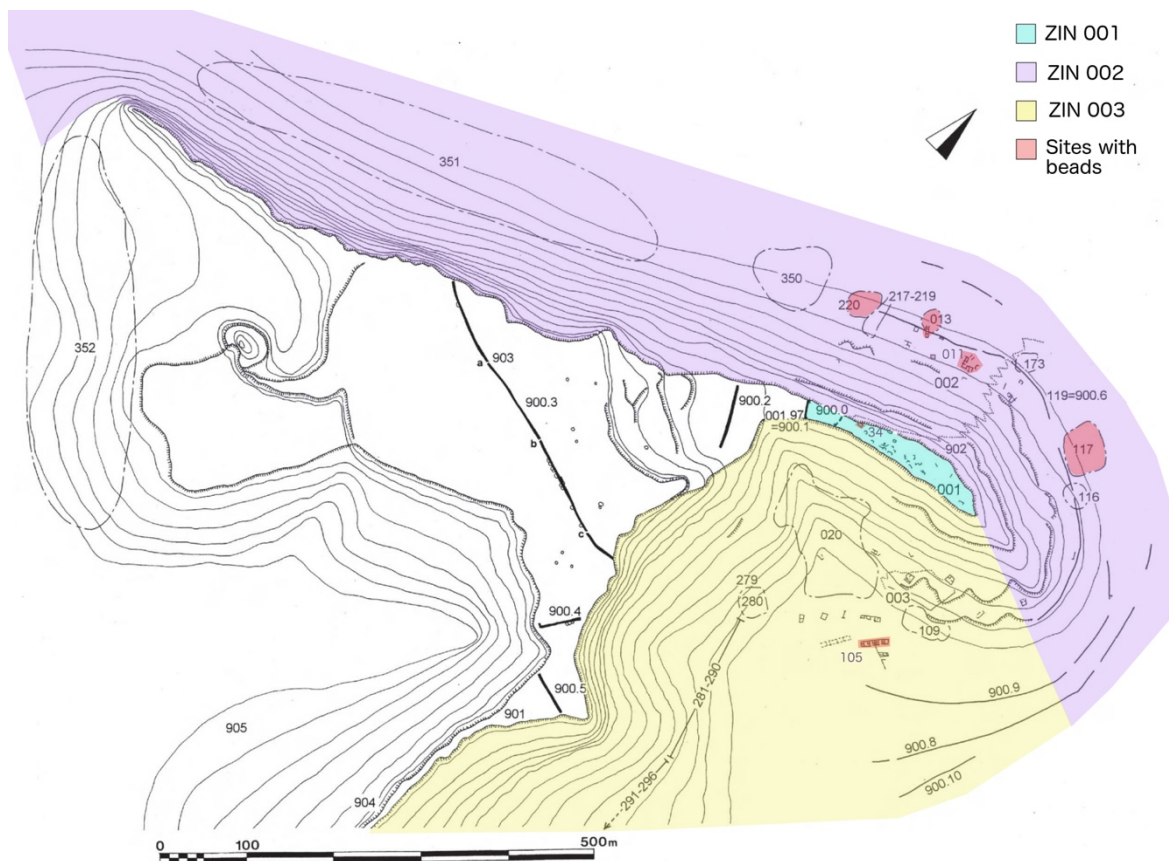


Figure 5.2: Areas investigated by Daniels and by the Fazzan Project in Zinkekra. Top of the hill (ZIN001) is highlighted in light blue, the north side (ZIN002) in purple, and the south side (ZIN003) is in yellow. The sites where the analysed glass beads come from are highlighted in red (Background map: Hawthorne et al. 2010, p. 20).

Although previous archaeological work was undertaken on the south side of the hill (ZIN003) between 1931-1933 by Caputo (member of the Italian mission who between 1936-1944 became the superintendent for the Antiquities of Libya) and in 1962 by Ayoub (controller of Antiquities in Fazzan), it is only with the survey and excavation campaigns overseen by Daniels from 1965 to 1969 and in 1973 that settlement and burial sites were recorded across the top, northern and southern slopes of the escarpment (Hawthorne et al., 2010, p. 19). The evidence accrued alongside the recent application of AMS (Atomic Mass Spectrometry) and radiocarbon dating on organic samples collected by the Fazzan Project, indicate that Zinkekra was inhabited – albeit with discontinuity – between the 8th century BCE to the 2nd century CE (Mattingly et al., 2003b, p. 26; Mattingly et al., 2007a, pp. 294-295; Hawthorne et al., 2010, p. 20).

Daniels detected four phases for the top, the northern and southern slopes of Zinkekra, which correspond to specific archaeological features and structures as reported in Table 5.2 below (Hawthorne et al., 2010, pp. 78-79). The first three phases mark the evolution of Zinkekra from village to proto-urban centre, whereas the fourth phase is represented by the

abandonment of the settlement which led to the development of nucleated cemetery sites right on top of previously inhabited areas on the plateau and along the lower escarpment (Hawthorne et al., 2010, pp. 78-79).

Phase	Type of evidence	Chronology	Periodisation	Sites
1	Hearths.	c. 1000 BCE	Late Pastoral	ZIN002.011; 013
2	Stone oval huts with palm thatched roof.	c. 1000 BCE- 500 BCE	Early Garamantian	ZIN002.011; 013 ZIN003.105
3	Mudbrick buildings, rectilinear in plan. From 1 st century BCE ashlar blocks and mudbrick buildings.	300 BCE- c. 100 CE	Proto-Urban Garamantian to early Classic Garamantian	ZIN001.034 ZIN002.011; 013 ZIN003.105
4	Cemeteries.	1 st C CE-5 th C CE	Classic Garamantian	ZIN002.013; 117; 220

Table 5.2: Phasing of the archaeological evidence from Zinkekra according to C. M. Daniels (table author's own).

The beads analysed here come from habitation as well as cemetery sites scattered across the three areas of Zinkekra. The excavated structures ZIN001.034, ZIN002.011, 013, and ZIN.003.105 yielded glass beads with a general Early Garamantian to Proto-Urban Garamantian chronology, as also exemplified by diagnostic assemblages/types of finds retrieved across all sites, such as local pottery, rubbers, pounders, bead grinders, stone and ostrich eggshell beads (Hawthorne et al., 2010, p. 29, pp. 40-45, p. 71). The abundance of Roman imports such as amphorae, finewares and glass retrieved during the survey of cemeteries ZIN002.117 and 220 indicates a Classic Garamantian chronology (Hawthorne et al., 2010, pp. 78-79). More detailed background information on the sites mentioned thus far is provided in the following paragraphs.

ZIN001.034 (ZIN 34 in Daniels' nomenclature) is a house adjacent to the modern steps that grant access to the top of the promontory (Figure 5.3 top). The building, trapezoidal in plan and measuring approximately 3.80m wide and 6.10m long, was constructed with large unworked stone blocks up to 1.2m in length. The interior was divided into two rooms by a roughly north-south aligned wall. The eastern room, where the remnants of a stone bench were recorded in the southern corner, was further delimited to the north by an east-west running wall (Figure 5.3 bottom).

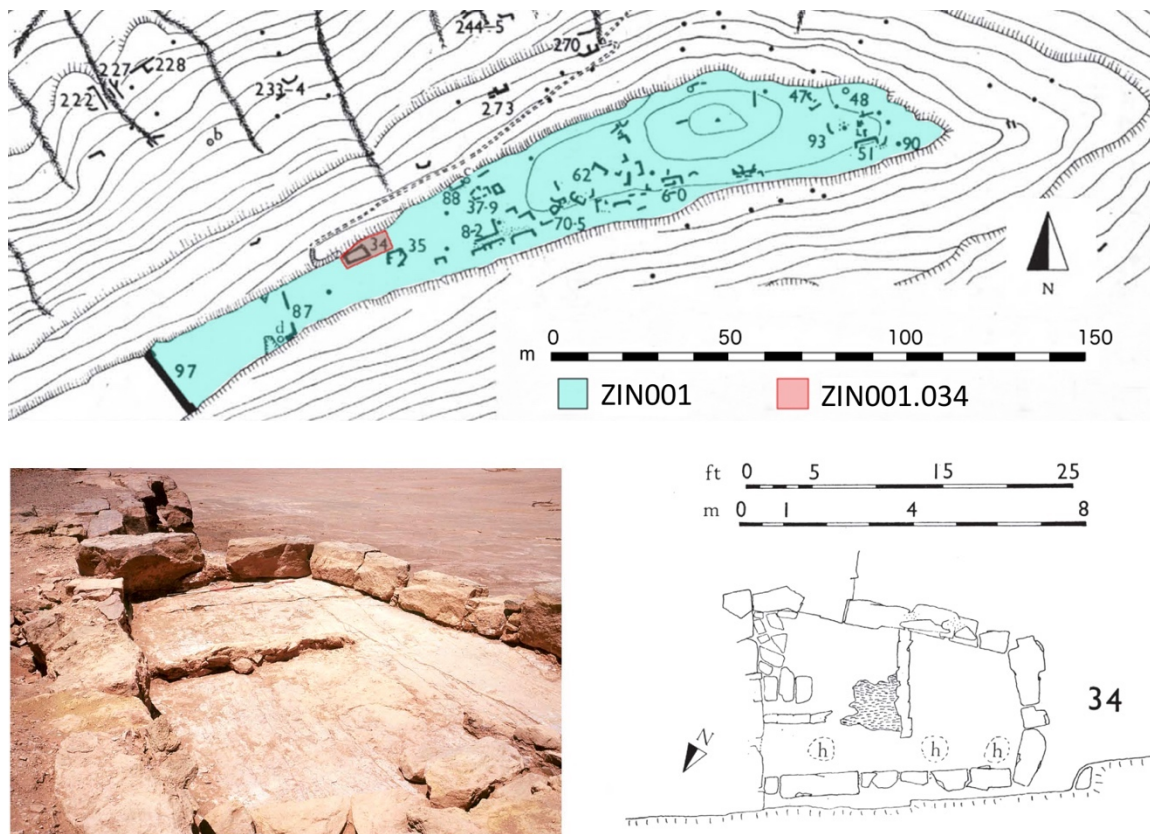


Figure 5.3: The site of ZIN001.034 (picture after Hawthorne et al. 2010, p. 26).

Within the house was an infill, consisting of sand mixed with occupation material. The consistency of this deposit was homogenous throughout, as it lacked stratification. In addition, patches of a trodden mud floor were observed. As shown in the site plan (Figure 5.3 bottom), two hearths lay on the bedrock, whereas others were encountered higher up in the sequence and in the infill. In the southern portion of both rooms thick dung layers were recorded (Daniels, 1968, pp. 162-166; Daniels, 1970, pp. 51-52; Hawthorne et al., 2010, p. 29). The totality of the glass beads recovered from this site (Figure 5.4) can be attributed to Daniels' phase three, which dates between 300 BCE and 100 CE (Hawthorne et al., 2010, p. 79).

ZIN001.034 [ZIN 34]



Figure 5.4: Glass beads from ZIN001.034 (pictures author's own).

A layered eye bead was retrieved from the general lower fill of the building (4), whereas the remainder of the beads come from context (3), which is not described in the excavation reports (Daniels, 1968, pp. 164-166). It is worth noting that the eye bead from context (4) is of the same type as the specimens retrieved from ZIN002.011 and 013 (see paragraphs below). Layered eye beads are attested across the Mediterranean during the Hellenistic period (3rd to 1st centuries BCE); however, they could have been in use for longer in Fazzan (Daniels, 1968, pp. 164-166).

ZIN002.011 (ZIN 11) is a multi-roomed rectangular complex which was in use between 300 BCE-1st century BCE and possibly up until the 1st century CE with stone footings and mudbrick walls. The building complex, which is contemporary to phase 3/4 of ZIN002.013 (see following paragraph), was excavated by Daniels to gather data on the plan of the structures located on the northern slopes of the hill. The shallow stratigraphy meant that it was not possible to warrant a strict distinction between the three phases that were recorded here (Hawthorne et al., 2010, pp. 40-45, p. 81). Nonetheless, the first period was characterised by the presence of pit-hearths encountered within the east-west/north-south aligned trench which cut across the north-south running wall of room G and the northernmost east-west terraces (Figure 5.5).



Figure 5.5: Plan of ZIN002.011 with related phases (picture after Hawthorne et al. 2010, p. 41).

A further feature of the same type was overlain by the partition wall for rooms A and B. The second phase is represented by stone-lined hearths 1-6, located in the central portion of the site. When the hearths went out of use, they were backfilled and then sealed by human and animal occupation debris and dung, which eventually covered the whole of the area. With phase three, the latter layer was finally covered by the mudbrick building to the east⁸ and by the multi-roomed complex and related floors, which survived only in part. The inner stratigraphy of the eastern mudbrick building and of rooms H,A,G and D was compromised of gullies later cut into the floors and by subsequent erosion due to hill-wash (Daniels, 1968, pp. 142-150; Daniels, 1970, pp. 45-48).

Pottery, shells and glass beads – among which are the ones shown in Figure 5.6 – were recovered from surface layer (1), context (10) which dated to phase 2, context (14) with unknown chronology, and context (26), in all likelihood ascribable to phase 3. Deposits (10), (14) and (26) can be attributed to the upper fills of the hearths and to the overlying

⁸ This building is later than the multi-roomed complex and represents the last phase of occupation (Daniels, 1970, pp. 47-48).

occupation layer (Hawthorne et al., 2010, p. 81). The date for the building complex was provided by typology of the eye beads retrieved among the surface finds, even though a nearly complete Hellenistic flask was found (Daniels, 1970, p. 48; Hawthorne et al., 2010, p. 81).

ZIN002.011 [ZIN 11]

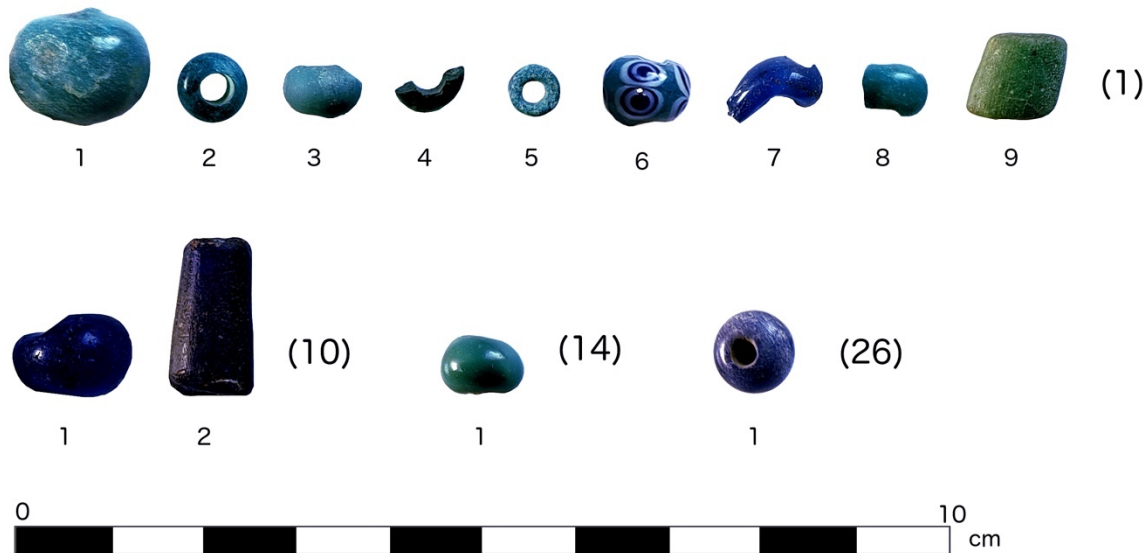


Figure 5.6: Glass beads from ZIN002.011 (pictures author's own).

At the foot of the north slope is **ZIN002.013** (ZIN 13) which is situated to the south-east of ZIN002.011 and to the south of the main east-west terrace wall ZIN900.6 (Figure 5.7). The site was excavated by Daniels to understand its stratigraphic sequence, so that the information collected could complement the data obtained from ZIN002.011. The chronology of phases 1 and 2 for ZIN.002.13 was further refined via AMS and radiocarbon analysis (Hawthorne et al., 2010, pp. 45-51).

Two north-south running trenches, which were positioned along the line of the terrace wall, were excavated to the east (13E) and to the west (13W). As the stratigraphic sequence is virtually identical for both trenches, they will be discussed here jointly. In a similar fashion to ZIN002.011, the first phase, which is dated to 1060-590 cal BCE, is exemplified by hearths 111-113 in 13W and hearth 155 in 13E. The second phase (920-410 cal BCE) is represented by the construction of north-west/south-east aligned buildings, that were eventually sealed by an accumulation of occupation material between 920-390 cal BCE. The area was

subsequently abandoned between 610-310 BCE. Around 300 BCE the east-west terrace wall was built, marking the third phase.

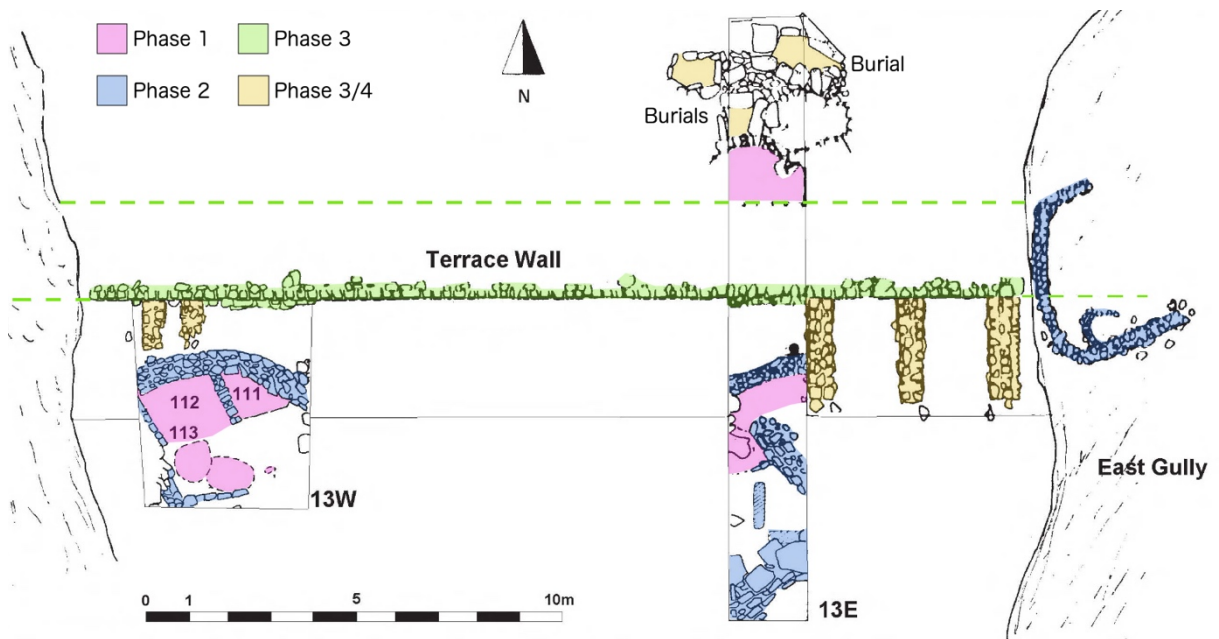


Figure 5.7: Plan of ZIN002.013 with related phases (picture after Hawthorne et al. 2010, p. 45).

From this point onwards until 50 BCE (phase 3/4), parallel north-south running walls, in all likelihood used for the penning of livestock, were erected on top of accumulation deposits along the south face of the terrace wall, which was eventually buried by hill-wash and organic debris (Hawthorne et al., 2010, pp. 45-51, pp. 78-82; Daniels, 1970, pp. 41-45; 1968, pp. 122-142). To the north of the terrace and enclosure walls burials were also recorded. The chronology of phases 3 and 3/4 is provided by eye beads retrieved from the build-up of layers behind the terrace wall in 13W – which include deposit (13) – and from the very topmost layer of sand (1) in E13, which is where the remaining beads shown in Figure 5.8 came from (Hawthorne et al., 2010, pp. 45-51, p. 81).

ZIN002.013 [ZIN 13]

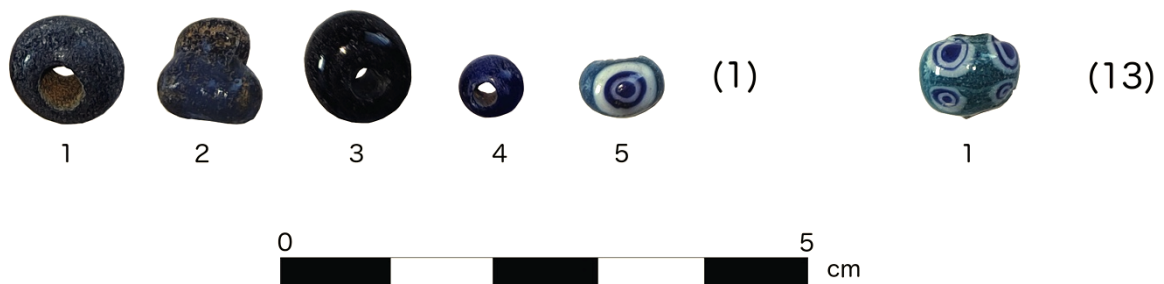


Figure 5.8: Glass beads from ZIN002.013 (picture author's own).

ZIN002.117 and **ZIN002.220** (also known as ZIN 117 and ZIN 220) are broadly contemporary cemetery sites, which were first surveyed by Daniels in the mid to late 1960s, and then at a later date by the Fazzan Project between the late 1990s and the early 2000s. In this latter instance the survey was undertaken to map and typologise the entirety of the cemetery sites of the Wadi al-Ajal (Mattingly et al., 2019 pp. 53-54). Selected burials from ZIN002.220 were excavated by the Desert Migrations Project between 2007 and 2011, as part of a wider programme of survey, excavation and sampling for AMS dating of Proto-Urban Garamantian to Late Garamantian cemetery sites situated along the east-west 20-km stretch running from Jarma escarpment to the Taqallit promontory (Mattingly et al., 2019, p. 54). **ZIN002.117** is located on the lower slopes of the north-eastern end of the Zinkekra promontory (Figure 5.2). As shown in Figure 5.9, ZIN002.117 is a nucleated cemetery site comprising of c. 200-250 burials, which are predominantly stone-lined shafts (type 2b⁹).

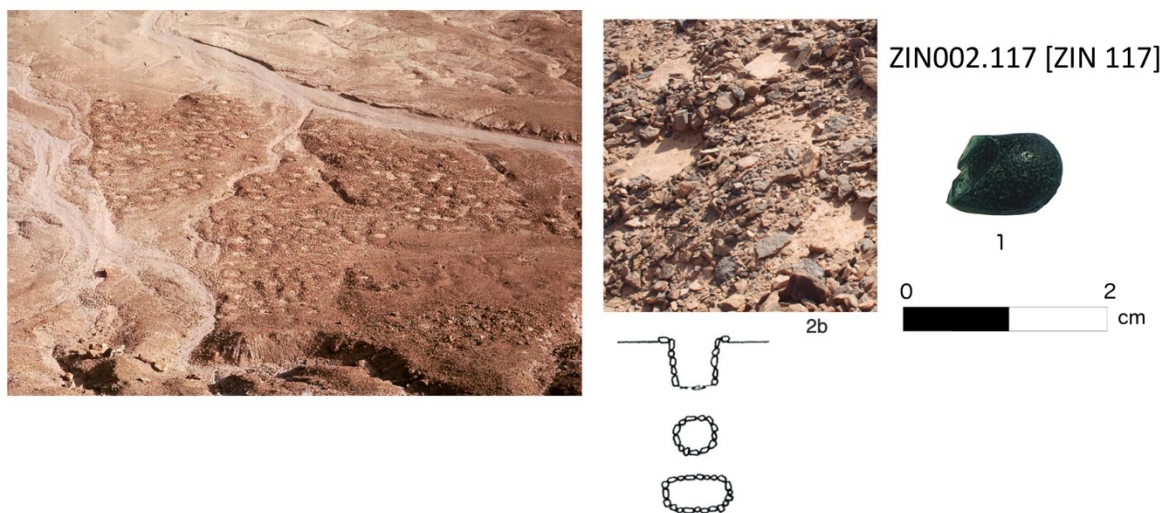


Figure 5.9: View of ZIN002.117, looking north (Hawthorne et al., 2010, p. 56) with shaft burial type 2b characterising the site (Mattingly et al., 2019, p. 58) and photo of bead retrieved from site survey (picture author's own).

Although ZIN002.117 was robbed in antiquity, the retrieval of fineware imports dating between the 1st and the 3rd centuries CE provided a chronological attribution of the site to the Classic Garamantian period (Mattingly & Edwards, 2007a, p. 95; Hawthorne et al., 2010, p. 56; Daniels, 1968, p.153). Although not mentioned by Daniels in the list of finds from Zinkekra, the fragmentary bead pictured in Figure 5.9 (right) was most certainly found during

⁹ Here we will focus only on the types of burial monuments/tombs recorded for the sites subject of this research, however nine types with distinct chronological attributions have been identified in Wadi Al-Ajal, as reported in particular in Mattingly et al. (2019, pp. 57-63) and in Mattingly & Edwards (2003).

the 1965-1967 survey, which among others covered site ZIN002.117 (Daniels, 1968, p. 153; Daniels, 1970, p. 41; Hoffmann et al., 2010, p. 466).

As illustrated in Figure 5.10 (bottom left), Classic Garamantian cemetery site **ZIN002.220** is situated along the north slope gully, and is delimited to the east by earlier traces of walls and of Garamantian occupation ZIN002.217-219 (Mattingly et al., 2019, p. 24; Mattingly & Edwards, 2007a, p. 96; Hawthorne et al., 2010, p. 61).

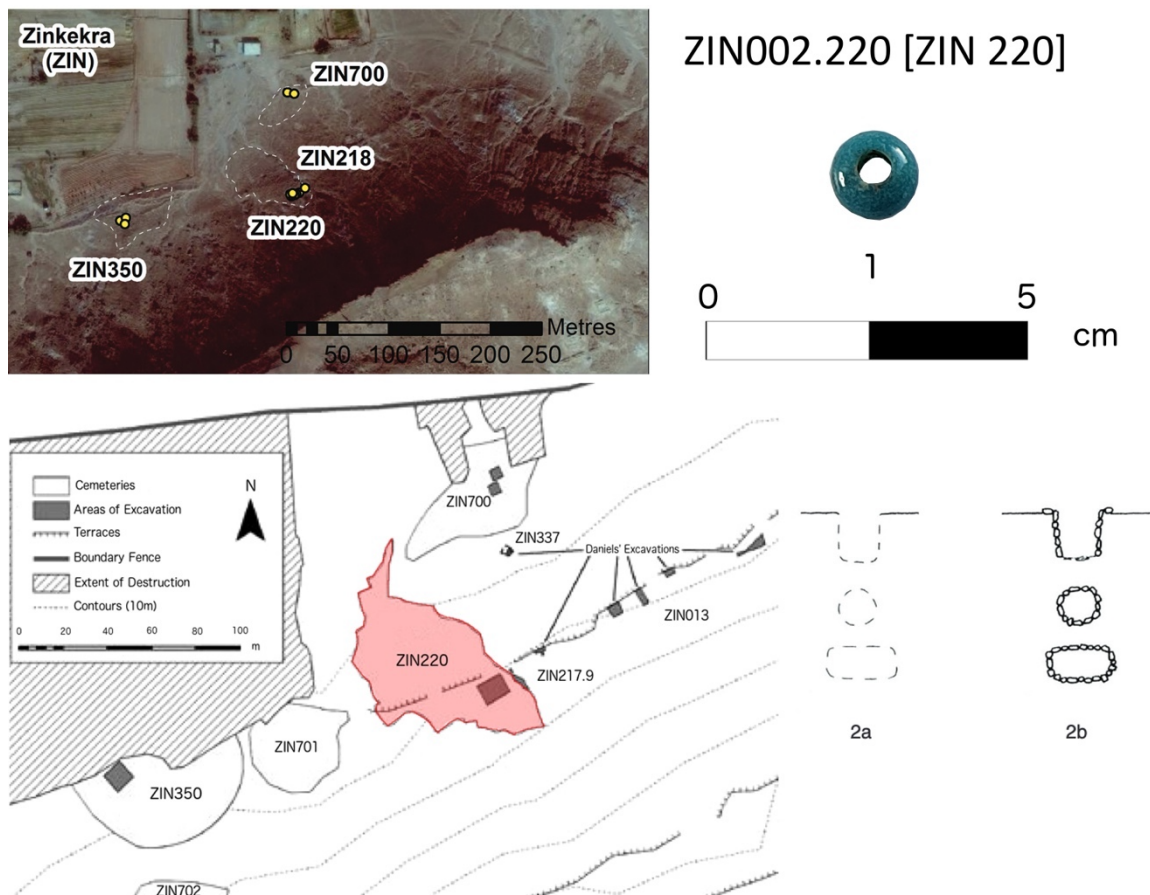


Figure 5.10: Location of cemetery ZIN002.220 with site boundaries highlighted in red; shaft burial types and glass bead (Mattingly et al., 2019, p. 58; bead picture author's own).

Similar to ZIN002.117, the most common grave types encountered in ZIN002.220 are shafts of variable depth, either lined or unlined (types 2a/2b) (Mattingly et al., 2007b, p. 23). A poor level of *in situ* preservation of human remains and grave goods was observed: during the excavations of 8 burials carried out by the DMP, only ZIN220.T3, T18 and T19 contained articulated bone. This is due to the fact that the site was subjected to extensive robbing which very likely occurred in antiquity, as no cuts or other evidence for disturbance were observed from the top of the graves (Mattingly et al., 2007b, p. 23; Mattingly et al., 2019, p. 24).

Although ZIN002.220 can be dated broadly between the 1st and 4th centuries CE on the basis of diagnostic pottery, at least one of the excavated shafts pushed back the occurrence of this tomb type to the Proto-Urban Garamantian period: ZIN220.T19, which was cut by later grave ZIN220.T3, was sampled for AMS dating, yielding an absolute chronology between the 2nd and the 1st centuries cal BCE (Mattingly et al., 2008, p. 54; Mattingly et al., 2019, p. 69, p. 77). As the monochrome bead in Figure 5.10 (top right) was collected during one of the survey campaigns carried out by Daniels between 1960 and 1977, we can only get a very general idea of its context of provenance and date (Cole & Hoffmann, 2007, p. 747; Hoffmann et al., 2010, p. 466).

Located on the southern slope of Zinkekra, to the east of the three houses that make up sites 100-101, is **ZIN003.105** (ZIN 105). This is a 31m long and 5.8m wide building, which was later connected eastwards to building 306 by a wall (Daniels, 1970, p.58). Constructed in the final centuries BCE or first centuries CE, the building consisted of eleven rooms with further internal subdivisions: only rooms 1-3, the northern part of room 7 and rooms 8-10 contained stratification, with an overall scarcity of finds (Figure 5.11 left).

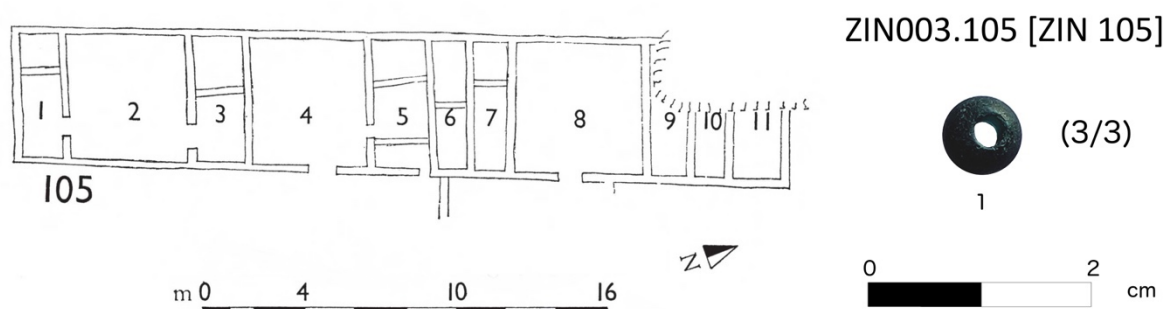


Figure 5.11: Site ZIN003.105 and glass bead from deposit (3/3) (Hawthorne et al., 2010, p. 70; bead picture author's own).

In rooms 1-3 the natural geology was overlain by a dung deposit, which was in turn covered by a trodden mud and dung floor. From the AMS dates obtained for the dung deposit (810-390 cal BCE and 810-200 cal BCE) it has been possible to ascertain that this layer pertained to an earlier structure which was obliterated by the building complex (Mattingly et al., 2007a, pp. 294-295; Hawthorne et al., 2010, p. 71; Daniels, 1968, pp. 189-191). The last phase of use and subsequent abandonment of the building was encountered in rooms 1-3, 7 and 8-10 and is represented by a dung and occupation material deposit which was covered by wall fragments and blown sand (Hawthorne et al., 2010, p. 71). Little pottery was recovered from the surface, the upper layers and the lower dung level encountered in the northern part of

room 3 (Daniels, 1968, pp. 189-191). One glass bead, pictured in Figure 5.11 (right) was retrieved from context (3/3) (Hoffmann et al., 2010, p. 466): in Daniels' stratigraphic report (1968) this bead does not feature in the list of finds, and no description of the deposit that contained it is provided. As such, we can perhaps surmise that the bead could have come from the above-mentioned dung level in room 3.

5.1.2 Old Jarma

The settlement of Old Jarma or *Garama* (GER001 or GER) lies between the northern edge of the oasis zone and at the southern margin of a palaeo-lake, which was in all likelihood still in existence during the Garamantian period (Mattingly, 2013b, p. 30). The ruins of Old Jarma were known since the 1930s, as testified by the accounts provided by the Italian colonial administrators and by the excavation of a sondage carried out by Caputo in 1933 (Mattingly & Edwards, 2007b, pp. 116-118; Mattingly, 2013b, p. 7; pp. 17-19). The earliest substantial archaeological works were initiated by Ayoub in 1962, who undertook a large-scale clearance of the site, revealing stone footed buildings (Figure 5.12).

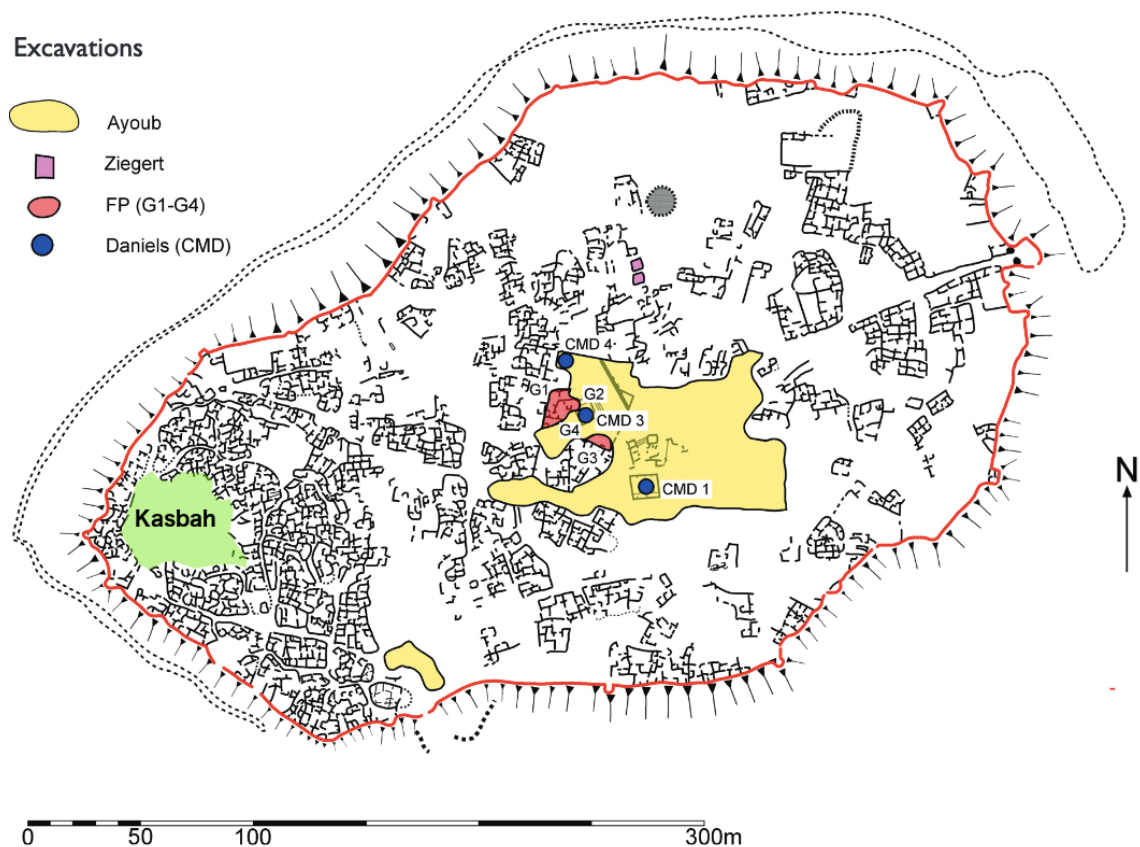


Figure 5.12: Map of Old Jarma with locations of excavations by Ayoub, Ziegert, Daniels and FP. The kasbah (castle-like building) is highlighted in green (Mattingly et al., 2013b, p. 33).

Following in Ayoub's footsteps, Daniels subsequently directed a survey campaign and small-scale excavations in 1963, 1965, and 1969. Also in the 1960s, German archaeologist Helmut

Ziegert excavated two deep trenches – which remain unpublished – to assess the sequence and depth of the archaeological deposits. To consolidate and expand on the previous work, members of the FP excavated selected sites (G1-G4) and carried out a survey of extant buildings between 1997 and 2001 (Mattingly, 2013a, b; Mattingly & Edwards, 2007b, pp. 116-118).

Founded in c. 400 BCE, the city of Old Jarma became the capital of the Garamantes: as early as the 1st century CE, mudbrick constructions coexisted alongside stone buildings with Greco-Roman architectural features (Mattingly et al., 2020, pp. 72-73; Mattingly & Edwards, 2007b, pp. 116-118). In its heyday – mainly during the Classic Garamantian period – Old Jarma was a manufacturing centre, as iron and copper metallurgy, bead-making and carnelian working were important industries (Mattingly & Edwards, 2007b, p. 117). In addition, evidence for potential glassmaking, or at least experimentation with glass at high temperatures, was collected from the excavations by Daniels and by the FP in the form of production waste, which primarily consisted of glassy material fused onto fragments of locally manufactured vessels which could be dated between 180-400 CE (Duckworth, 2020b, pp. 336-337, p. 339).

During the Late Garamantian period, as observed for other coeval sites, Old Jarma was provided with a *qasr*, or a central fortified compound (Mattingly et al., 2020, pp. 72-73). The medieval and early modern evidence is represented by: two mosques, respectively dated to the 11th or 12th century CE and to the 13th-14th century CE, a *kasbah* built in the 15th century CE (GER001.065 or Germa Castello S), and a walled circuit with D shaped towers which was completed by the 16th century CE (Figure 5.13).

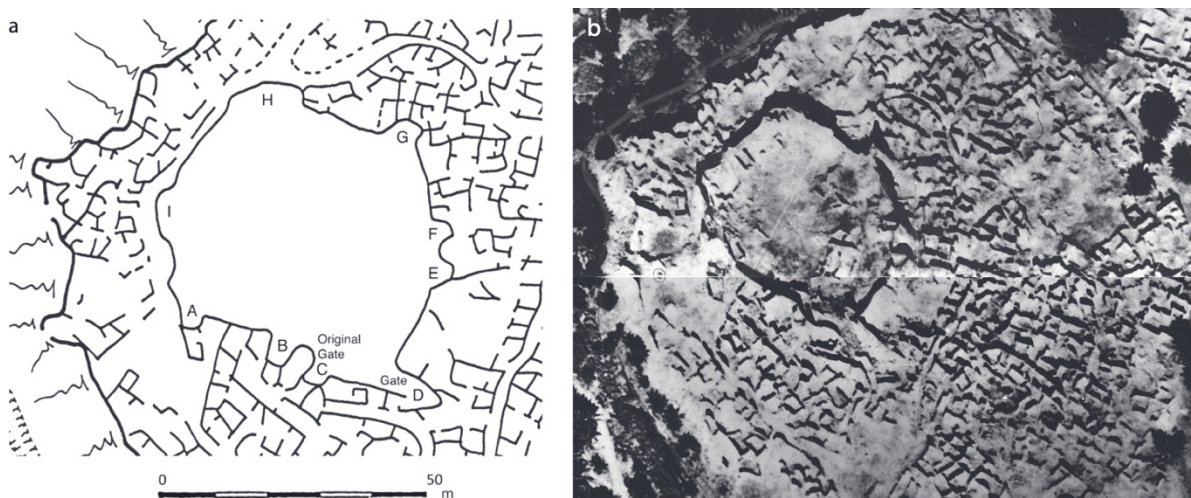


Figure 5.13: a. Plan of the kasbah with its towers (A-I); b. montage of aerial photographs from 1965 showing the northern quarter and kasbah (Mattingly et al., 2013b, p. 43).

Following a period of demographic decline and impoverishment in the 19th century, Jarma was permanently abandoned in the 1930s, as dictated by the Italian authorities (Mattingly et al., 2013b, pp. 43-47; Mattingly & Edwards, 2007b, pp. 116-118).

The four glass beads examined in this thesis and pictured in Figure 5.14 were retrieved during Daniels' survey of the medieval town and of the kasbah (GER001.065), which were respectively carried out in 1969 and in 1965 (Mattingly et al., 2013b, p. 27; Cole & Hoffmann, 2007, pp. 472-473).



Figure 5.14: Glass beads from GER001 and GER001.065 (picture author's own).

5.1.3 Saniat Gibril

Located 300m to the north-east of Old Jarma is the satellite village of Saniat Gibril (GER002), which is also known in Daniels' archive as SGB (Figure 5.15). The site was first investigated by Ayoub in 1962, followed by Daniels, who, in 1965, 1971, and 1973, uncovered multi-phase mudbrick buildings in the eastern portion of the Saniat Gibril. Thanks to ceramic imports, the buildings could be dated between the later 1st century CE and the 4th century CE (Mattingly & Edwards, 2007b, pp. 120-121, p. 124; Mattingly et al., 2010, pp. 131-154). In addition, in 1973 he surveyed 0.40ha on the east side of Old Jarma, establishing that Saniat Gibril extended for roughly 3.5ha, whilst discovering at the same time sites GER005-008 (Mattingly & Edwards, 2007b, p. 116, 120-121). As Daniels only provided a succinct description of his fieldwork results, one strand of the FP sought to combine the integral publication of his excavations with further systematic survey of the areas to the north and west of Saniat Gibril.



Figure 5.15: Map showing Saniat Gibril (GER002) alongside the other sites discovered by Daniels during survey; the stippled grey areas indicate concentrations of ceramic material (Mattingly et al., 2010, p. 123).

The survey, which was undertaken in 1997 and 2000, aimed to collect additional data that would help to understand in more detail the site itself and in relation to the wider context. In addition, in 2009 members of the FP sampled Daniels' spoil heaps to gather further evidence for the activities carried out on site (Mattingly et al., 2003c, pp. 118-121; Mattingly et al., 2010, pp. 126-130).

As shown in Figure 5.16 top, Daniels started his excavations in 1965 with trial trenches 1-5. Trenches 1, 3, and 5 were backfilled after the sequence of walls that they contained was recorded, whereas trenches 2 and 4 were extended in 1971, thus creating a larger excavation area, pictured at the bottom of Figure 5.16. In the same year, areas 6 and 7, which are respectively located to the east and west of area 2, were also opened, revealing the full extent of a building complex, which was made up of individual units with several rooms. Finally, area 8, situated to the west of the main structures, was opened in 1973. This area, which revealed the presence of another building complex, was excavated only in part (Mattingly et al., 2010, pp. 131-154).

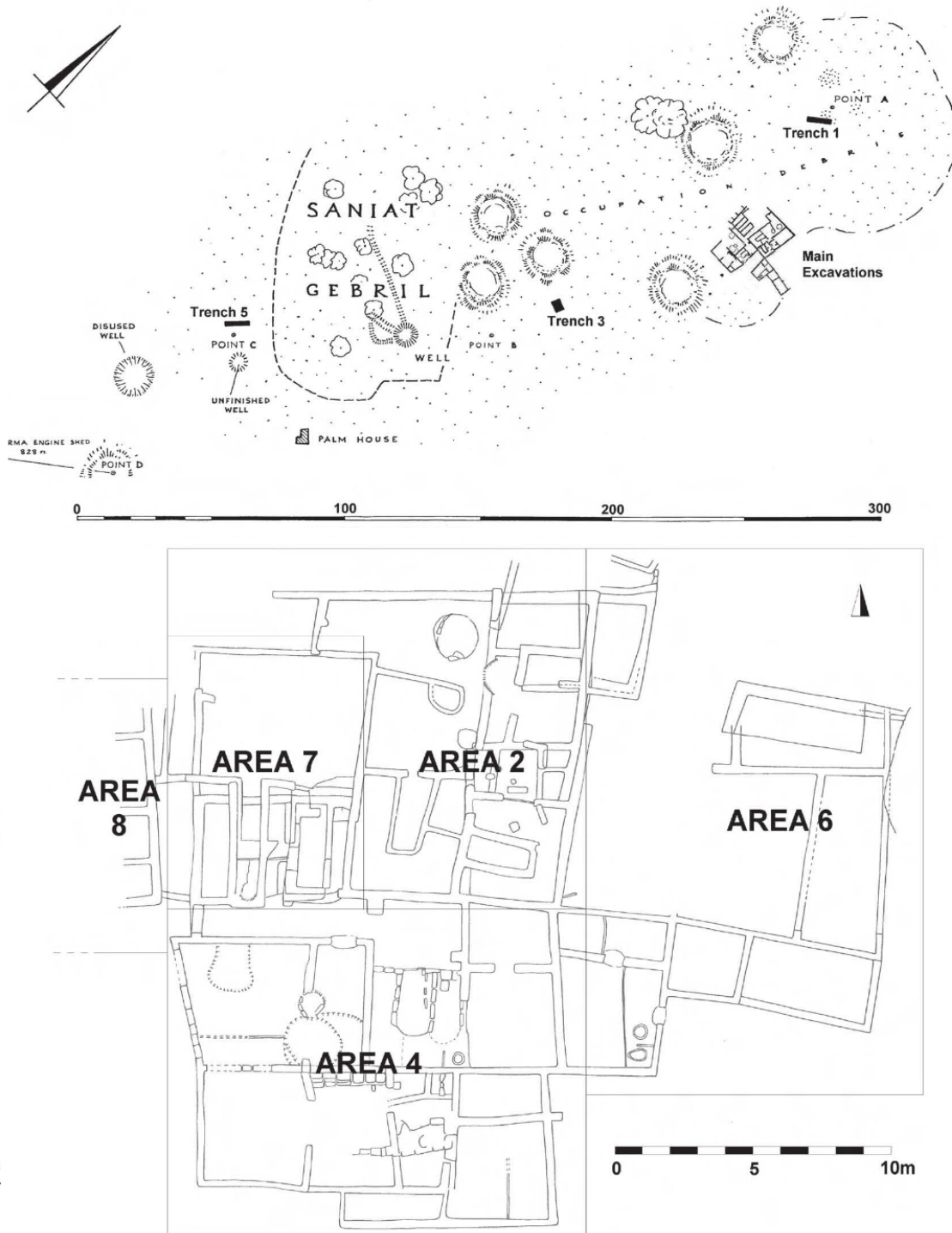


Figure 5.16: (Top) Location of Daniels' trenches and open area excavation in GER002; (bottom) plan of building complex within main excavation, with indication of individual areas (Mattingly et al., 2010, pp. 131-132).

Although the finewares from the FP survey point to an overall chronology for Saniat Gibril between the 2nd/1st century BCE and the 5th century CE, the units within the building complex excavated by Daniels appear to have had three main phases of use between the 1st and the 4th centuries CE, labelled as Period 1 (50-80 CE to mid 2nd century CE), Period 2 (mid

5.1.4 Watwat

The Watwat embayment (UAT), which is named after Qasr WatWat (GER004), is located 2km to the south-west of Old Jarma, along the direct route leading to Zinkekra (Figure 5.18).

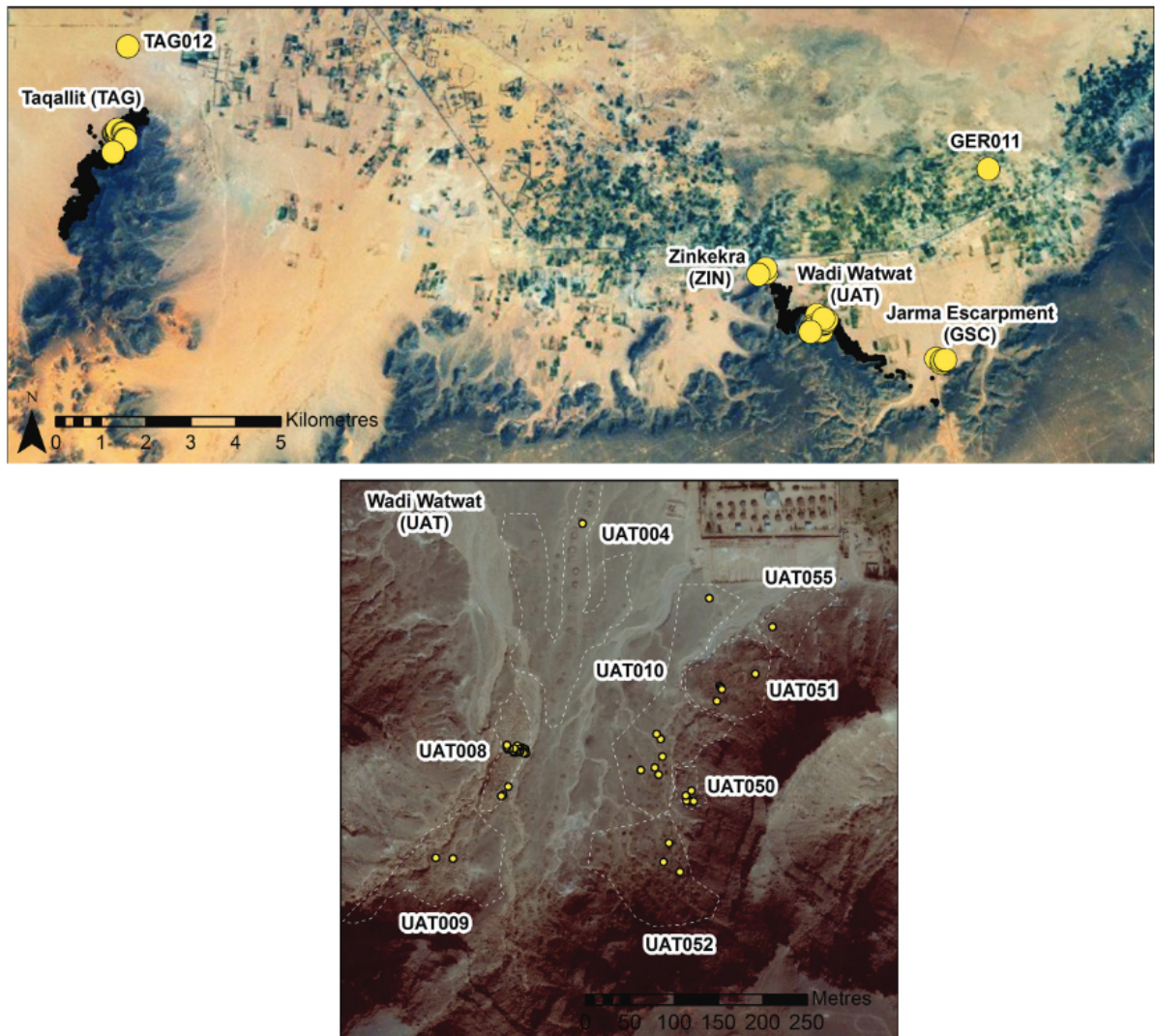


Figure 5.18: Wadi WatWat (UAT) and its sites (Mattingly et al., 2019, p. 55).

It is a small area which includes the Massak escarpment edge and the surroundings below it. Watwat contains several cemetery sites (UAT001-UAT018; UAT023; UAT50-UAT62) that are mostly Proto-Urban to Classic Garamantian in date, each with individual characteristics in terms of combinations, arrangement and variety of grave types (Mattingly & Edwards, 2007c, p. 106; Mattingly et al., 2008, pp. 226-227; Mattingly et al., 2019, p. 86). If sites UAT008 and UAT009 were excavated under the direction of Caputo in the 1930s, it is only with Daniels and his 1965 campaign that Watwat was extensively surveyed (Mattingly & Edwards, 2007c, p. 106). Further archaeological work at Watwat was subsequently undertaken by the DMP in 2007 and 2008, when UAT008 was re-excavated and burial sites along the east and south

sides of the embayment – including UAT004 – were subjected to survey and sample excavations (Mattingly et al., 2007b, pp. 27-30; Mattingly et al., 2008, pp. 225-230).

Roughly north-south aligned, linear cemetery UAT004 (UAT 4) is delimited by mausoleum UAT001 to the north and by the escarpment edge to the south (Figure 5.19). UAT004 consists of 26 stone mound cairns measuring 5m in diameter and approximately 0.30m high which hosted a central burial with potential satellite graves around it, although it appears more likely that the latter are robber cuts: the DMP excavation of cairn UAT004.011, confirmed that the central inhumation had been disturbed, as a fraction of the original grave goods alongside bones were used as backfill materials, and that further exploratory cuts were made into the topsoil by the looters (Mattingly & Edwards, 2007c, p. 109; Mattingly et al., 2007b, p. 27; Mattingly et al., 2008, p. 231). UAT004 is mainly dated to the Classic Garamantian period with traces of an earlier Proto-Urban Garamantian phase. This chronology is supported by pottery sherds collected during survey and excavations, and by the stratigraphic evidence from UAT004.11, which revealed that this mound completely obliterated an earlier structure (Mattingly et al., 2007b, p. 27). As is the case for the ZIN002 cemeteries previously discussed, the bead in Figure 5.19 was retrieved during the survey undertaken by Daniels in the mid-1960s (Cole & Hoffmann, 2007, p. 474).

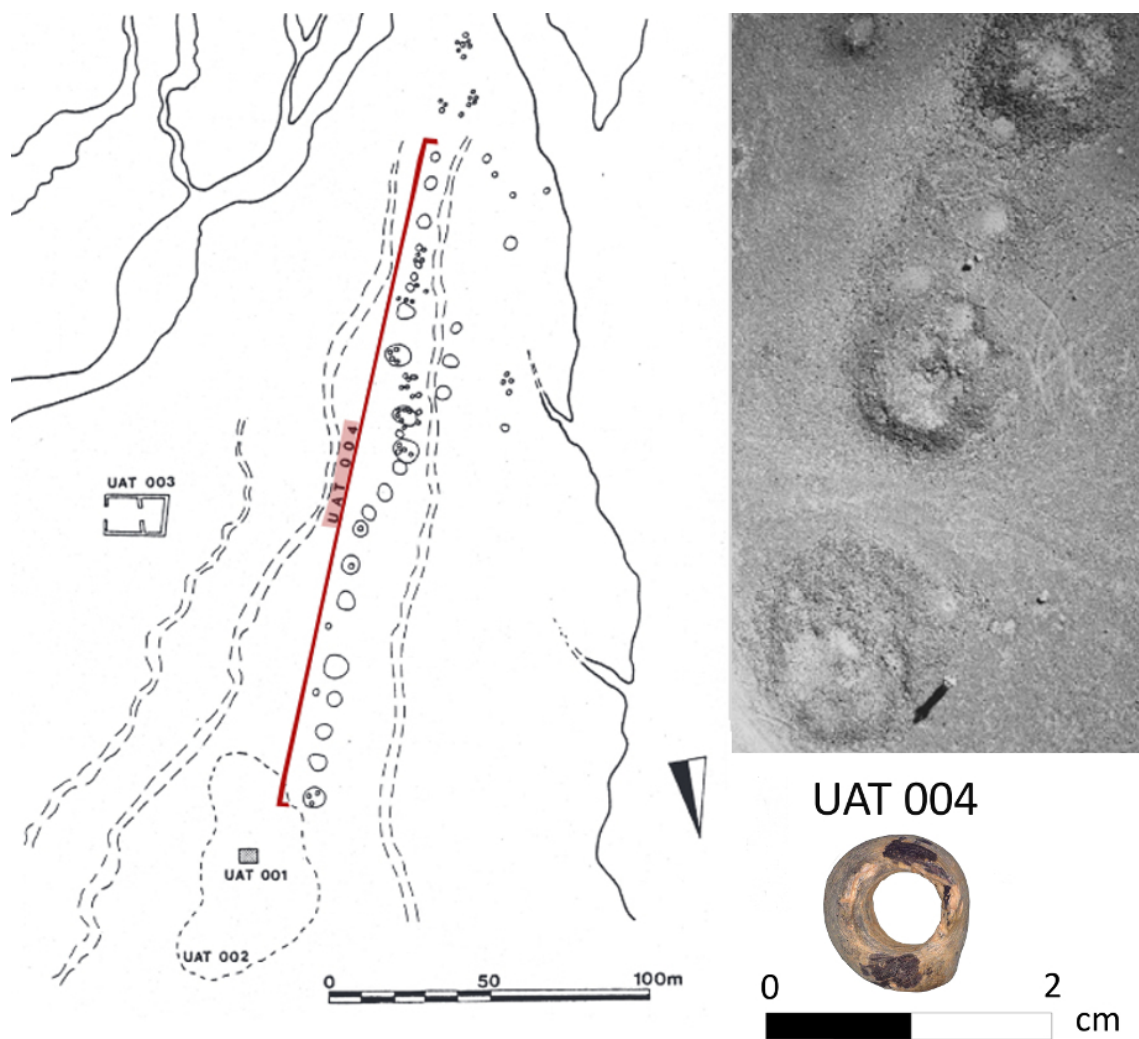


Figure 5.19: UAT004 and the glass bead retrieved from the site (Mattingly & Edwards, 2007c, pp. 108-109; bead photograph author's own).

b) Methods

5.2 Sample selection criteria, research questions and recording methods

The beads from the settlement and cemetery sites of Wadi al-Ajal were deemed to be a suitable sample for use-wear analysis on the basis of: i) size (34 beads in total), which is roughly equivalent to the number of beads employed in the necklace wearing experiment. ii) good overall level of preservation. iii) presence of publications reporting the archaeological context and the chemical fingerprinting for the glass (Duckworth, 2016; 2020b), allowing us not only to relate these materials to the bigger picture, but also to investigate any potential links between wear by use, post-depositional processes and corrosion.

Use-wear analysis was undertaken on selected beads from Fazzan to:

- Compare and contrast archaeological and experimentally generated traces of manufacture and use.
- Ascertain whether it is possible to detect specific bead uses and to estimate relative length of use.
- Assess how trace legibility is affected by post-depositional processes and by the chemistry of individual beads.

The methodology employed for the cleaning and recording of archaeological beads broadly follows the steps applied to the experimental specimens, as outlined in Section 4.7. In this case, however, as the glass beads were stored in their original bags and had received no previous conservation treatment or cleaning, they were first inspected using the Dino-Lite Edge without undergoing any cleaning procedures, to verify if any residues that could inform us on bead use remained on the surfaces. Once it was established that no diagnostic residues that could have been easily removed were present, the beads were then rinsed with distilled water and subsequently dabbed with non-abrasive tissue soaked in absolute ethanol. When compared to HCl solution, which was used on experimental beads, ethanol was deemed in this case a safer option since it did not require any soaking time, as the prolonged contact of beads with an acidic solvent such as HCl could have further damaged any already degraded glass surfaces. The beads, as in the case of the replicas, were always handled with gloves during their observation and cleaning.

The Fazzan beads were allocated identifiers corresponding to the site code and context number as found on the labels contained within finds bags, with each side of the beads recorded as A and B (e.g., ZIN_34_3_Bead 1_A). Whenever several beads had the same nomenclature, these were progressively numbered (e.g., ZIN_34_3_Bead 1; ZIN_34_3_Bead 2 and so forth). The beads were analysed by digital and incident light microscopy with the same equipment and by following the same procedures as for the experimental specimens. In addition, to guarantee consistency in the observation of both replica and archaeological assemblages, the same magnification ranges for each instrument were applied. The stacking, labelling and mapping systems for the micrographs follow the same criteria set out for the experimental assemblage (e.g., M1_ZIN_34_3_B1_A_100x). In the case of the Fazzan assemblage, as the configuration of the beads remains unknown, the traces were documented for each specimen as a whole by always keeping track of the side(s) on which specific traces were recorded. This information is reported in Sections 5.2-5.11, and it is available in full in the Microsoft Excel file in Appendix E.

Since the level of glass surface preservation mirrors the degree of confidence with which we can correctly identify and interpret traces of wear by use, glass degradation was taken into account in the analysis of archaeological beads. The extent of glass deterioration is usually assessed by means of Scanning Electron Microscopy (SEM), as with this technique it is possible to measure the thickness of the corrosion layer and to gather data concerning its chemical make-up. Since SEM analysis was not undertaken in this instance, we were not able to quantify the severity of the corrosion processes affecting the sample subject of this study. As such, the relationship between traces of wear and weathering will be broadly assessed in Section 5.4.

Glass degradation was categorised as illustrated in Table 5.3: the parameters applied here are qualitative, as corrosion is measured against the legibility of traces of wear and/or manufacture at high magnification. This means that the appearance of degraded surfaces at a microscopical level – which may differ from what is observed with a naked eye – was used as the main point of reference to establish the degree of glass corrosion. As a consequence, the classification provided below is functional to the interpretation of the results generated from use-wear analysis and is relative to the dataset examined here.

<i>Degradation stages</i>	<i>Description</i>	<i>Legibility of traces: naked eye</i>	<i>Legibility of traces: high mag</i>	<i>Original surface preservation</i>
<i>Very Good</i>	Pristine glass surface bearing traces of manufacture and wear. In some cases very sparse, slight pitting, mostly visible at high magnification.	Y	Y	100% Perfect trace legibility.
<i>Good</i>	Incipient pitting with accretions/weathering filling in the pits visible by naked eye. Pitting still sparse and rare pockets of iridescence not visible with a naked eye (only high mag).	Y	Y	> 50% Traces are clearly legible for the most part of the surface.
<i>Mediocre</i>	Accretions/ weathering filling in the pits are visible with a naked eye. Iridescence developing over pre-existing damaged surfaces. Traces of wear are still visible with a naked eye.	Y	Y	< 50% Traces are clearly legible for the least part of the surface.
<i>Poor</i>	Traces of wear not visible with a naked eye in some instances. On a microscopic level trace legibility is impaired by extensive weathering, cracking, pitting and/or iridescence, often combined.	Partial	Partial	< 50% Traces are barely legible for the least part of the surface.
<i>Very Poor</i>	Milky weathering and/or iridescence obliterating presence of any traces of wear. Manufacture traces may be still visible with a naked eye.	N	N	Minimal to absent preservation of original surface.

Table 5.3: Stages of glass degradation encountered on Fazzan beads (Table author's own).

5.3 The dataset and its limitations

This section has to be prefaced by stating once more that the Fazzan assemblage is not the original dataset that was intended to be used, as outlined in the Covid Impact Statement at the beginning of this thesis.

As illustrated in Sections 5.1.1-5.1.4 and in Table 5.4, the number of beads from secure contexts is quite limited, and although we do get a general idea of the date and type of site where the beads come from, the results of use-wear analysis performed on this particular dataset will not tell us big stories on bead-use in the Libyan Sahara, but can rather highlight the potential of the application of this technique on archaeological glass beads. The beads studied here, which were collected during Daniels' survey and excavation campaigns, paint a partial picture as they are among selected artefacts that could be transported from Libya to the UK, and as such they represent only a small sample of the total number of beads retrieved in Fazzan, especially if we also take into account the excavations and survey campaigns undertaken by the FP between the 1990s and 2000s. In addition, since the majority of glass beads was retrieved from Zinkekra, the interpretation of our results will be

inevitably slightly skewed towards this dataset. This is further reinforced by the paucity of beads collected from Old Jarma and Watwat, which has allowed us to draw rather broad conclusions with regards to bead use for these sites.

<i>Site</i>	<i>Beads n=</i>	<i>Site Type</i>	<i>Mode of Retrieval</i>	<i>Context</i>	<i>Description</i>	<i>Date</i>
ZIN001.034 (ZIN 34)	1 3 1 Total n=5	Structure – house	Excavation	(1) (3) (4)	Top infill? ? Lower fill of building	300 BCE-100 CE 300 BCE-100 CE 300 BCE-100 CE
ZIN002.011 (ZIN 11)	9 2 1 1 Total n=13	Structure – multiphase building	Excavation	(1) (10) (14) (26)	U/S Dung deposit Upper levels of hearths	- c. 1000-500 BCE ? 300 BCE-100 CE?
ZIN002.013 (ZIN 13)	5 1 Total n=6	Structure – multiphase building	Excavation	(1) (13)	U/S Build-up of sand, dung and mud floors	- 300 BCE-100 CE
ZIN002.117 (ZIN 117)	1	Cemetery	Survey	N/A	U/S	1 CE-400 CE
ZIN002.220 (ZIN 220)	1	Cemetery	Survey	N/A	U/S	1 CE-400 CE
ZIN003.105 (ZIN 105 3/3)	1	Structure – building complex	Excavation	(3/3)	?	c. 1000 BCE-100 CE
GER001 (GER G)	1 1 Total n=2	Settlement area	Survey	(grab) N/A	U/S U/S	c. 400 BCE-1930s
GER001.065 (Germa Castello S)	2	Kasbah	Survey	(grab)	U/S	c. 1400 CE-1930s
GER002 (SGB G)	2	Settlement area	Survey	(grab)	U/S	c. 300 BCE-700 CE
GER002.4 (SGB 4 5/4)	1	Structure – building complex	Excavation	(5/4)	?	c. 200 BCE-400 CE
UAT004 (UAT 4 G)	1	Cemetery	Survey	N/A	U/S	c. 300 BCE-400 CE

Table 5.4: Site types, modes of retrieval, contexts and chronology for glass beads discussed in the thesis. For unstratified beads retrieved from surveys, a general chronological bracket is provided. (Table author’s own).

As summarised in Table 5.4, a total of 26 beads was retrieved during the excavations of individual structures, which were broadly dated between the Proto-Urban Garamantian and the early Classic Garamantian periods and were located at the top of the Zinkekra plateau and along the north and south slopes (ZIN001-003). Two additional beads were collected as surface finds during the surveys of Classic Garamantian cemetery sites ZIN002.117 and 220. With the exception of a single glass bead from the excavation of the Classic Garamantian building complex in Saniat Gibril, the remainder of the beads from this site, alongside the specimens from the Watwat cemetery and the town of Old Jarma and its kasbah, are unstratified, as they were accrued during survey work.

The vagueness of the archaeological contexts is caused by multiple factors, which range from the nature of the site and its mode of investigation through to the importance attributed to glass beads as an artefact category. For example, with regards to the Zinkekra excavations, the glass beads were surface finds or were retrieved from the most recent layers within the stratigraphic sequence (Daniels, 1968, p. 121; 1970, p. 64). On occasion, glass beads (and finds in general) were kept in arbitrary groups according to depth, as for ZIN.001.034 (Hawthorne et al., 2010, p. 29). Moreover, the Zinkekra reports focused on classes of artefacts that could help in the characterisation of the sites, such as pottery (Daniels 1968; 1970). As a result, glass beads were mentioned briefly or not at all, unless they were types considered as specific chronological markers that could be employed to date deposits or features, as is the case for eye beads. If the observations made so far apply to the glass beads from settlement sites, the beads from burials – whether in glass, carnelian, ostrich eggshell, stone or faience – were hardly ever found in primary deposition because of looting, to the point where at excavation stage any specimens left were largely recovered by sieving grave deposits (Mattingly et al. 2019, p. 91).

If in many cases it was impossible to reconstruct with great precision the context of retrieval for the beads, nonetheless we were able to establish a likely chronology: for instance, as the Watwat cemetery was relatively short-lived since it was abandoned after the Classic Garamantian phase, it is likely that the glass bead examined here can be dated to the period that reflects the duration of use of the site; the same can be said for the beads from the kasbah in Old Jarma, which was built in the 15th century CE. This date can be considered as the *terminus post quem* for the collected beads, meaning that the most likely scenario is that they are contemporary with the construction of the kasbah or are later. The post-Roman

origin of these two specimens (Germa Castello S beads 1 and 2) is further corroborated by the compositional and typological data available, as not only the shape and dimensions of both beads appear to be characteristic of the Islamic period, but also the chemical signature of bead 2 indicates that the glass was manufactured to a recipe with the same broad chronology (Cole & Hoffmann, 2007, p. 473; see also Section 5.4 and Appendix C).

Conversely, other unstratified beads fall within a very wide chronological bracket: this is the case for Old Jarma, which was continuously inhabited for approximately 2500 years, and for the Proto-Urban to Late Garamantian settlement of Saniat Gibril, with its occupation spanning nearly a millennium. When distinctive of a certain period, bead typology and manufacturing techniques can sometimes help us to gauge whether there is a potential time window in which given beads were crafted. As for glass chemical analyses, we cannot use this information to directly date beads (or bulk glass compositions), as these artefacts could have been in circulation for a very long time before being discarded or lost.

Concerning the beads from Old Jarma, we are perhaps able to slightly narrow down their chronology. This is due to the fact that the blue ring bead retrieved from this site (GER G bead 1) was deemed to be potentially Islamic on typological grounds (Cole & Hoffmann, 2007, p. 473). As this bead is wound, the manufacturing technique is not indicative of a specific period or geographic area, as the winding method, which was first adopted in conjunction with early glasses from LBA Mesopotamia and Egypt, is still applied to this day across Europe, Asia and Africa to make beads and bangles (see Sections 2.6-2.7). On the contrary, if on the one hand GER G bead 2 has a globular shape that is typologically undiagnostic, on the other hand, the way in which this was crafted can provide us with the earliest possible date of manufacture. Tentatively interpreted as wound, this bead is in actual fact drawn, as shown by the manufacturing striae which run parallel to the thread-hole (Cole & Hoffmann, 2007, p. 473). This means that from a technological standpoint bead 2 dates from the 3rd century BCE onwards, as drawn beads were produced in Mediterranean (and South Asian) workshops from that point in time through to the Islamic period (Pion & Gratuze, 2016, pp. 52-53). The same can be said for the two drawn beads collected in Saniat Gibril (GER002 or SGB G), as they cannot have been made any earlier than 300 BCE.

As shown in Table 5.5, when it comes to bead sizes, shapes, degree of completeness and manufacturing techniques, the dataset is unsurprisingly heterogeneous, however, some of

the assemblages from individual sites share a degree of similarity, allowing us to further characterise the contexts in which the beads were retrieved.

<i>Site and Context no.</i>	<i>Bead no.</i>	<i>Complete %</i>	<i>Description</i>	<i>External Ø (Width)</i>	<i>Thread-hole Ø</i>	<i>Thickness (Height)</i>	<i>Manufacturing Technique</i>
ZIN001.034.1 (ZIN 34/1)	1	100%	Disc bead	0.65 cm	0.2 cm	0.25 cm	Cold working?
ZIN001.034.3 (ZIN 34/3)	1	100%	Globular bead	1 cm	0.35 cm	0.6 cm	Winding
	2	100%	Globular bead	0.8 cm	0.25 cm	0.95 cm	Winding
	3	c.40%	Elongated barrel-shaped bead	0.6 cm	0.4 cm	1.6 cm	Winding
ZIN001.034.4 (ZIN 34/4)	1	100%	Globular bead	1 cm	0.4 cm	0.6 cm	Winding
ZIN002.011.1 (ZIN 11/1)	1	c.50%	Globular bead	1.5 cm	0.3 cm	1.3 cm	Winding
	2	100%	Globular bead	0.75 cm	0.35 cm	0.4 cm	Winding
	3	c.50%	Globular bead	0.8 cm	0.3 cm	0.6 cm	Winding
	4	c.50%	Globular bead	0.8 cm	0.3 cm	0.4 cm	Winding
	5	100%	Disc bead	0.6 cm	0.3 cm	0.2 cm	Cold working?
	6	c.50%	Globular bead	0.8 cm	0.3 cm	0.7 cm	Winding
	7	n/a	Failed globular bead	0.8 cm	0.3 cm	0.5-0.9 cm	Winding
	8	c.30%	Globular bead	0.8 cm	0.4 cm	0.7 cm	Winding
	9	n/a	Cylindrical cane	0.8 cm	n/a	0.7 cm	Drawing
ZIN002.011.10 (ZIN 11/10)	1	c.50%	Globular bead	1.2 cm	0.45 cm	0.9 cm	Winding
	2	100%	Slightly conical cylinder bead	0.6-0.8 cm	0.4 cm	1.7 cm	Winding
ZIN002.011.14 (ZIN 11/14)	1	c.50%	Globular bead	0.9 cm	0.25 cm	0.6 cm	Winding
ZIN002.011.26 (ZIN 11/26)	1	100%	Globular bead	0.9 cm	0.25 cm	0.6 cm	Winding
ZIN002.013.1 (ZIN 13/1)	1	100%	Globular bead	1.1 cm	0.5 cm	0.8 cm	Winding
	2	100%	Segmental bead	0.9-0.7 cm	0.35-0.1 cm	0.9 cm	Winding
	3	100%	Globular bead	1 cm	0.3 cm	0.6 cm	Winding
	4	100%	Globular bead	0.6 cm	0.25 cm	0.4 cm	Winding
	5	c.50%	Globular bead	0.8 cm	0.4 cm	0.6 cm	Winding
ZIN002.013.13 (ZIN 13/13)	1	c.50%	Globular bead	1 cm	0.25 cm	0.8 cm	Winding
ZIN002.117	1	c.40%	Globular bead	1.2 cm	0.4 cm	0.8 cm	Winding

(ZIN 117)							
ZIN002.220 (ZIN 220)	1	100%	Globular bead	0.6 cm	0.2 cm	0.4 cm	Winding
ZIN003.105.3/3 (ZIN 105 3/3)	1	100%	Globular bead	0.75 cm	0.3 cm	0.55 cm	Winding
GER001 (GER G)	1	100%	Ring bead	1.1 cm	0.6 cm	0.5 cm	Winding
	2	100%	Globular bead	0.7 cm	0.2 cm	0.4 cm	Drawing
GER001.065 (Germa Castello S)	1	100%	Cylindrical bead	0.5 cm	0.2 cm	0.6 cm	Drawing
	2	c.50%	Cylindrical bead	0.65 cm	0.3 cm	0.95 cm	Winding
GER002 (SGB G)	1	100%	Cylindrical bead with hexagonal cross-section	0.6 cm	0.3 cm	0.8 cm	Drawing
	2	c.50%	Short cylindrical bead	0.8 cm	0.2 cm	0.8 cm	Drawing
GER002.4 (5/4) (SGB 4 5/4)	1	c.50%	Barrel-shaped bead	0.7 cm	0.25 cm	1.2 cm	Winding
UAT 004 (UAT 4 G)	1	100%	Ring bead	1 cm	0.5 cm	0.5 cm	Winding

Table 5.5: Measurements, descriptions and manufacturing techniques for individual Fazzan beads (Hoffmann et al., 2010, pp. 461-466; Cole & Hoffmann, 2007, pp. 473-474).

In particular, if we consider the buildings and cemetery sites located on top of the Zinkekra spur and on its slopes, the vast majority of beads are made by winding and are globular in shape (n=22). Wound beads were also retrieved from the excavations of the building complex in Saniat Gibril (bead 1 SGB 4 5/4) and from the Old Jarma and Watwat surveys (GER G bead 1; UAT 4 G bead 1). Drawn beads, which tend to be cylindrical, are found in higher proportion within the assemblages from Saniat Gibril (SGB G), Old Jarma and its kasbah (GER G and Germa Castello S).

With regards to the Zinkekra settlement sites, a few beads differ from wound specimens, thus providing us with further insights on bead manufacture and perhaps consumption. Beads 1 and 5 from surface layer (1) in ZIN001.034 and ZIN002.011 are small, thin discs, with similar dimensions. Both beads, which are between 0.25 and 0.25 cm thick, were shaped by working the glass from cold, by using in all likelihood grooved stones similar to the ones retrieved from GER002 and ZIN002.0113, which were usually employed in the making of ostrich eggshell and stone beads, according to a manufacturing tradition that is pre-Garamantian in date (Hoffmann et al., 2010 p. 461). In both cases, and in particular for bead ZIN 34/1 which displays traces of an undetermined residue within the thread-hole, the beads

appear to have been originally made by winding, and as such, they were altered at a later stage.

Furthermore, the ZIN002.011 excavation yielded 'beads' 7 and 9 – both hailing from context (1) – that may be regarded as failed attempts at bead-making and/or manufacture debris, rather than being finished objects. Bead 7 is only partly wound, as it appears likely that during its making the glass was too cold and stiff to be fully wrapped around the mandrel, whereas bead 9 consists of a fragment of cylindrical cane lacking a thread-hole. Another bead that looks as though it may not have been fully functional is the segmental bead from nearby site ZIN002.013. Bead 2, which was found in the top layer, was crafted by stacking two wound beads on top of each other by hot working: the thread-hole diameter for the smaller bead is considerably narrow as measures 0.1 cm, as opposed to 0.35 cm for the larger bead. As such, if this bead were strung or sown on cloth, the thread employed in this operation would have had to be a millimetre in diameter at the most. In addition, the action of intense heat slightly deformed part of the bead (Hoffmann et al., 2010, p. 465).

c) Results

5.4 Surface alterations due to glass degradation

As reported in Table 5.6, very good to good surface preservation of both bead faces was recorded for approximately one third of the sample, in a total of 10 specimens. Beads with little to no corrosion mainly come from the Zinkekra settlement and cemetery sites ZIN001.034, ZIN002.011, .013, .117 and .220, with two beads also retrieved from Old Jarma (GER001 and GER.001.065).

Site and Context no.	Bead no.	Chemical Analysis ID	Composition	Preservation	Type of alteration
ZIN001.034.1 (ZIN 34/1)	1			Poor (A)/Very Poor (B)	Cracking, pitting, iridescence
ZIN001.034.3 (ZIN 34/3)	1			Very good	Pitting, weathering, iridescence
	2			Good	Pitting, weathering, dulling
	3	TSG_167	Mineral soda	Poor	Pitting, weathering
ZIN001.034.4 (ZIN 34/4)	1			Very good	Manufacture surface alterations
ZIN002.011.1 (ZIN 11/1)	1	TSG_169	Mineral soda	Mediocre(A)/Poor(B)	Pitting, weathering, iridescence
	2			Mediocre	Pitting, weathering, dulling
	3	TSG_170	Mineral soda	Poor	Pitting, weathering
	4			Poor	Pitting, weathering
	5			Very poor	Pitting, weathering, iridescence
	6	TSG_168	Mineral soda	Mediocre	Pitting
	7			Mediocre	Pitting, weathering
	8			Mediocre/Poor	Pitting
	9			Very Poor	Pitting, weathering
ZIN002.011.10 (ZIN 11/10)	1	TSG_173	Mineral soda	Good	Pitting
	2			Mediocre(A)/Good(B)	Pitting
ZIN002.011.14 (ZIN 11/14)	1	TSG_174	Mineral soda	Mediocre	Pitting
ZIN002.011.26 (ZIN 11/26)	1			Poor(A)/Mediocre(B)	Pitting, weathering, iridescence
ZIN002.013.1 (ZIN 13/1)	1			Mediocre	Pitting, weathering
	2			Mediocre(A)/Poor(B)	Pitting, weathering
	3			Good	Pitting, weathering, iridescence
	4			Good(A)/Mediocre(B)	Pitting, weathering, iridescence

	5		Good	Pitting, weathering	
ZIN002.013.13 (ZIN 13/13)	1		Mediocre	Pitting, weathering, iridescence	
ZIN002.117 (ZIN 117)	1		Good	Pitting, weathering	
ZIN002.220 (ZIN 220)	1		Very Good	Pitting, weathering	
ZIN003.105 (ZIN 105 3/3)	1		Mediocre	Pitting, weathering	
GER001 (GER G)	1		Very Good	Very light pitting	
	2		Mediocre	Pitting	
GER001.065 (Germa Castello S)	1		Good	Pitting, iridescence	
	2	TSG_176	High K-Pb	Mediocre(A)/Poor(B)	Cracking, dulling
GER002 (SGB G)	1		Poor	Pitting, weathering, iridescence	
	2	TSG_172	Mineral soda	Mediocre	Pitting, weathering, iridescence
GER002.4 (5/4) (SGB 4 5/4)	1	TSG_175	High K-Pb	Poor	Pitting, weathering
UAT 004 (UAT 4 G)	1		Very poor	Pitting, weathering, iridescence	

Table 5.6: Degree and type of corrosion observed on the Fazzan beads (n=34). Broad compositional groups are provided for the chemically analysed beads (n=9). (Table author's own).

When surface preservation ranges from very good to good, glass degradation is either virtually absent, as for ZIN 34/3 bead 1, or is very slight, as it mostly consists of sparse pitting at times arranged in small clusters, as for GER G bead 1 in Figure 5.20. With neat edges and a rough textured base, corrosion pits appear larger and somewhat more regular in shape than manufacture and use-related pits. At this stage, corrosion pits – and potentially other traces such as fractures from accidental damage – are on occasion partly filled by brownish accretions, which may be indicative of weathering processes (GER G bead 1, ZIN 11/10 bead 1, ZIN 13/1 beads 3 and 5, ZIN 34/3 bead 2, ZIN 34/4 bead 1, ZIN 117 bead 1 and ZIN 220 bead 1).

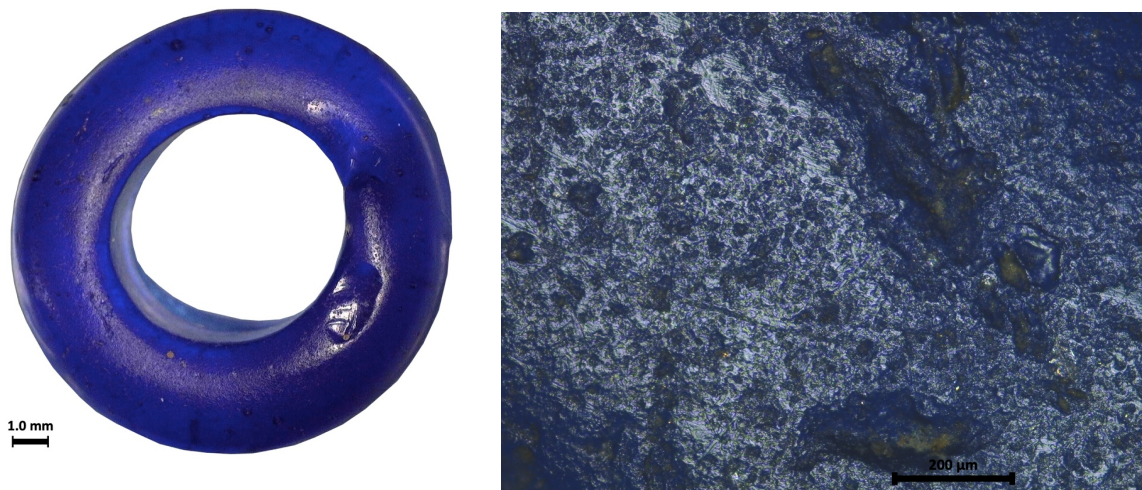


Figure 5.20: Very good level of surface preservation on GER G bead 1. To the left, low magnification, 25x. To the right, 100x micrograph showing abrasion from use overlain by pitting and weathering accretions. (Micrographs author's own).

Levels of preservation that range from mediocre to very poor were observed on 24 beads, some of which display differential corrosion levels between faces (e.g., Germa Castello S bead 2, ZIN 11/1 beads 1 and 8; ZIN 11/26 bead 1, ZIN 13/1 bead 2). Mediocre preservation is characterised by the presence of frequent whitish or brown weathering accretions within striae, fractures or pits; pitting throughout and iridescent spots in localised areas (GER G bead 2, SGB G beads 1 and 2, ZIN 11/1 beads 2, 6 and 7; ZIN 11/14 bead 1, ZIN 13/1 bead 1, ZIN 13/13 bead 1 and ZIN 105 3/3 bead 1). As glass degradation progresses, surface alterations become even more prominent, thus resulting in poorly and very poorly preserved specimens: in addition to weathering, cracking was observed on four beads, Germa Castello S bead 2, ZIN 11/1 beads 5 and 7, and ZIN 34/1 bead 1. In addition, the bead from the kasbah in Old Jarma shows dulling, whereas ZIN 11/1 bead 5, ZIN 11/26 bead 1 (side A especially), and ZIN 34/1 bead 1 present partial flaking of surfaces, which is akin to crizzling (Figure 5.21). This can happen when the surface of a glass is hydrated and has reached an equilibrium with the surrounding environment over a long period of time; as such, when dry conditions occur, the glass will get partially dehydrated and very thin cracks will develop over a short period of time (Gueli et al., 2020, p. 218). For ZIN 11/1 bead 5 and ZIN 34/1 bead 1, which are both discoidal in shape, we can hypothesise that one additional factor that contributed to this specific corrosion phenomenon may be represented by mechanical damage, which derived from polishing during 'manufacture' and from subsequent use.



Figure 5.21: Very poor level of surface preservation on ZIN 11/1 bead 5. To the left, low magnification, 50x. To the right, 100x micrograph showing iridescence and cracking. (Micrographs author's own).

Although they appear similar to spherulites and may at times develop on top of them, the growth rings found on side B of ZIN 11/26 bead 1 and on ZIN 13/13 bead 1, were also observed on Roman glasses retrieved from the seabed (Figure 5.22). Despite their formation mechanisms and growth kinetics (i.e., rates of chemical reaction and related variables) are partly unknown, growth rings occur because the soluble substances in marine water and salt-rich, wet soils react with the soluble substances present in the glass. As a consequence, salt precipitates form on the glass surface, becoming nucleation points for concentric growths (Zanini et al., 2023; Dal Bianco et al., 2004, 2005).

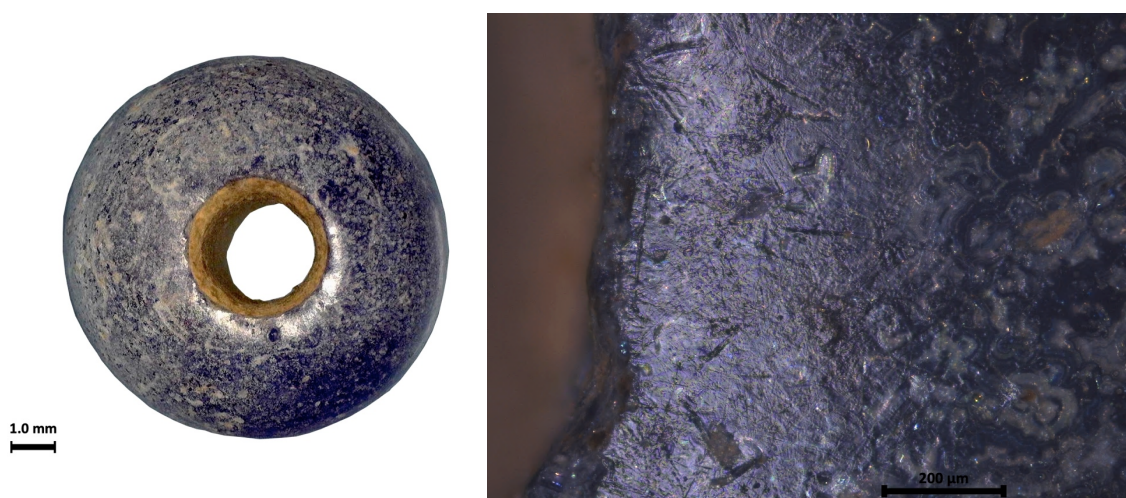


Figure 5.22: Mediocre to poor level of surface preservation on ZIN 11/26 bead 1. To the left, low magnification, 30x. To the right, 100x micrograph showing post-depositional polish, striations and growth rings to the right-hand side. (Micrographs author's own).

In some instances, very little – if any – of the original bead surface survives: for UAT 4 G bead 1, advanced degradation takes the form of severe milky weathering and pitting overlain by iridescence, whereas ZIN 11/1 bead 9 is affected by extensive pitting and cracking (Figure 5.23).

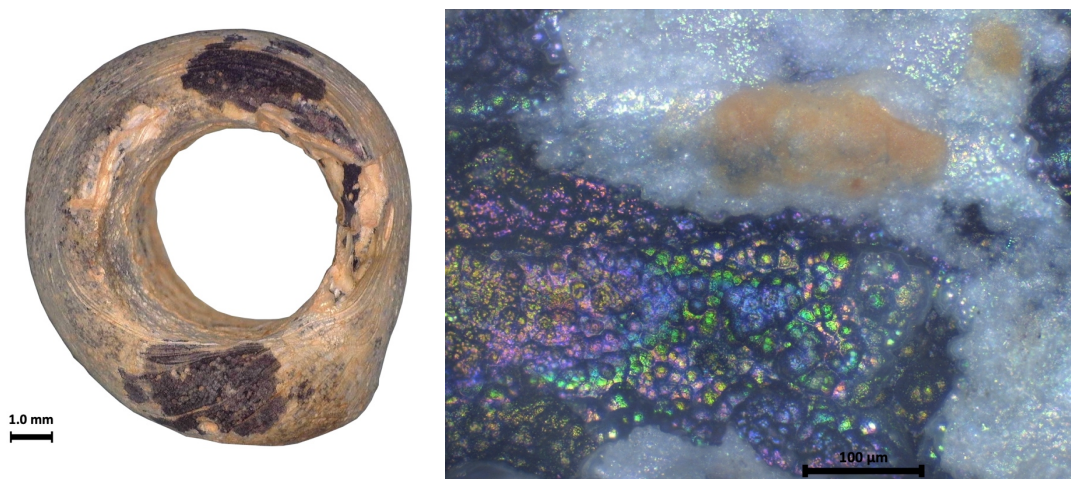


Figure 5.23: Very poor level of surface preservation on UAT G 4 bead 1. To the left, low magnification, 30x. To the right, 200x micrograph showing milky weathering, iridescence and extensive corrosion pitting. (Micrographs author's own).

Differential corrosion was noted among beads from the same context, and, as the intensity of glass degradation can vary for each bead face, it was also recorded on 7 individual beads from ZIN001.034.1, ZIN002.001 deposits (1), (10) and (26); ZIN002.013.1 and GER001.065. In general, glass artefacts with the same composition retrieved from the same site can present different levels of degradation goes to show that corrosion is a very complex phenomenon that depends on a number of variables such as pH and red-ox conditions of burial environments (Dussubieux et al., 2009, p. 158). The differential degradation seen on single bead faces is due to the fact that corrosion processes occur in distinct phases that mirror fluctuations in environmental conditions. As such, iridescent laminar layers which form as a result of alkali loss, will not be uniform in thickness or distribution (Jackson et al., 2012, p. 492).

The descriptions of the corrosion stages provided so far are based on qualitative optical microscopy observations, as already stated in Section 5.2; however, any potential relationship between corrosion appearance and glass composition can be broadly explored by looking at the analytical results for nine beads (Table 5.6). In any case, our considerations will be rather general, as there are at least two limitations with the sample subjected to

chemical analysis: firstly, the small size of the dataset does not allow for pattern recognition; secondly, as per standard procedures, the glass was presumably extracted from beads which were not obviously degraded on a macroscopic scale, so that reliable compositional data could be obtained. As a consequence, the analytical results do not inform us of the chemical make-up and depth of any hypothetical corrosion layers, as they reflect the composition of pristine glass.

Of the nine glass beads analysed to establish the presence of given major, minor and trace elements, seven specimens (ZIN 34/3 bead 3, ZIN 11/1 beads 1, 3, and 6; ZIN 11/10 bead 1, ZIN 11/14 bead 1, SGB G bead 2) are mineral soda glasses broadly consistent with Roman and Late Antique recipes. Germa Castello S bead 2 and SGB 4 5/4 bead 1 (TSG_175-176) are high in potassium and lead, indicating that these beads are compositionally close to medieval soda-lead silica glasses from north Africa and Iberia (for further information on the scientific techniques applied to the beads and results obtained, please consult Appendix C).

As it was possible to attribute each bead to known compositional groups, this confirms that the portion of glass analysed for each specimen was not affected by corrosion. It is also worth noting that Roman glasses are very stable and as such tend to survive quite well, as opposed to plant-ash glass. In any case, no important levels of depletion in alkaline elements (K, Na) or alkaline earth-elements (Ca, Mg) was observed within the sample, and equally no increase in silica, alumina, iron or titanium was recorded (Dussubieux et al., 2009, p. 158; Section 2.4). As the pH of soils is a key variable in the formation of corrosion, it might be worth summarising the findings of Palomar (2017) in relation to accelerated aging burial tests performed on glass. The samples employed for the purpose had different chemical signatures, corresponding to: SLS glass (1st-3rd centuries CE Roman glass and modern window glass), potash-lime glass (Medieval German wood-ash glass), and lead-crystal glass (18th century Spanish glass). The mineral soda glasses from Fazzan, which represent the majority of the chemically analysed sample, are compositionally consistent with the SLS group. For this reason, we will focus on the results obtained for the latter, although it has to be said that the lead-crystal glass yielded similar outcomes. The modern window glass and the Roman glass samples in acidic soils degrade by forming fissures, whereas in the case of neutral and basic soils pitting occurs. In neutral soils, the growth rate of the pits depends on the concentration of alkaline oxides present in the glass; in basic soils, the glass decays without

any period of hydration, meaning that pits cover an area up to four times wider when compared to burial in neutral soils (Palomar, 2017) .

5.5 Alterations resulting from bead manufacture

Bubbles within the glassy matrix – alongside small particles of opacifiers and/or colourants – are the most frequent features observed on the beads from the settlement and cemetery sites from Zinkekra (Figure 5.24). Such alterations can have an impact on the legibility of traces and, albeit indirectly, on the appearance of the bead surface: in particular, when bubbles are sparse, they transmit light, thus creating a bright halo effect.

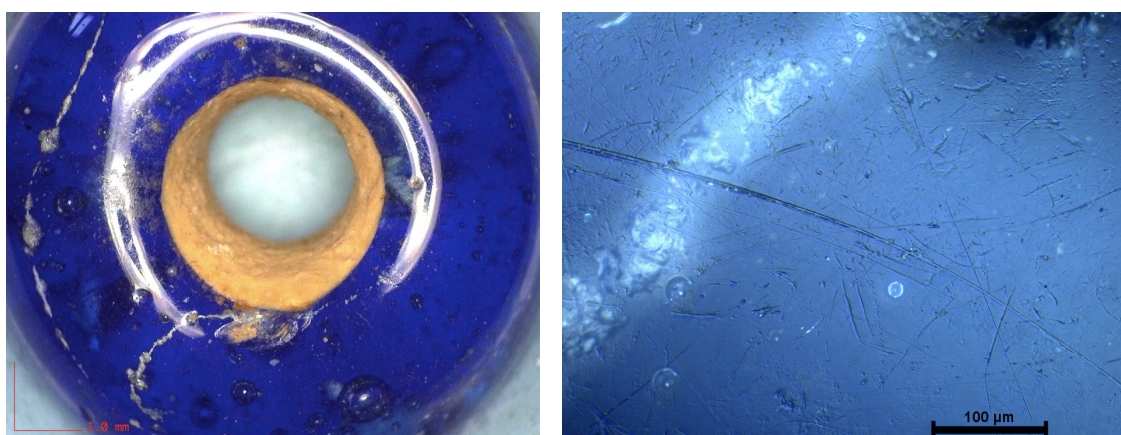


Figure 5.24: ZIN 34/3 bead 1; Large bubbles and sub-surface alterations forming bright spots arranged in a linear fashion. To the left, low magnification, 50x. To the right, 200x. (Micrographs author's own).

As already seen for furnace-made experimental beads, bubbles can be accompanied by surface textural alterations such as pores, ridges, indentations, and spherulites as shown in Figure 5.25 (ZIN: 11/1 beads 3, 6 and 8, 11/26 bead 1, 13/13 bead 1, 34/4 bead 1, 220 bead 1).

With the exception of one drawn bead, where small depressions were recorded along the thread-hole edge (face B, Germa Castello S bead 1), the remaining beads which exhibited irregularities were made by winding. In beads with a very good or good level of preservation, bubbles and inclusions are in most instances the only alterations recorded (ZIN: 11/1 bead 7, 11/10 bead 1, 13/1 beads 2-5, 34/3 beads 1 and 2, 117 bead 1). This is because sub-surface bubbles, which indicate that the mixing (and in this case perhaps also the working) of the glass occurred at low temperatures, have a negligible impact on glass degradation.

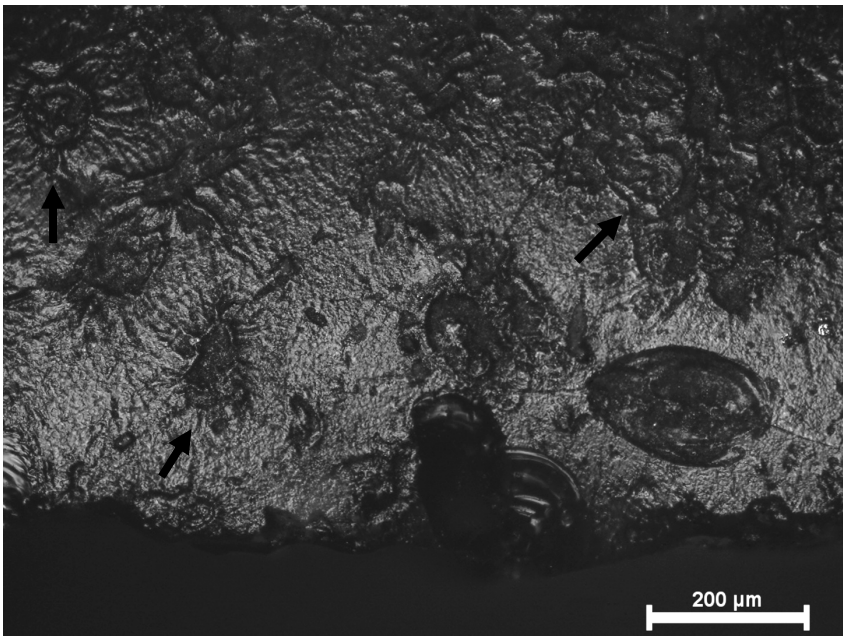


Figure 5.25: ZIN 11/1 bead 8 side B: Spherulites indicated by arrows. Scale 100X. (Micrographs author's own).

Conversely, surface defects, which are due to the partial re-crystallisation of the glass surface in response to environmental stressors which kickstart devitrification processes, will be readily attacked by corrosion as they are already 'weak' areas within the glass (Sections 2.4 and 5.4). In some cases of poor or very poor bead preservation, features that usually seen below the glass surface such as concentric striations caused by winding the hot glass around the mandrel, may become prominent to the touch, as for bead 1 from Watwat (UAT 4 G) and beads 3 and 4 from Zinkekra 11/1.

5.6 Fractures

The variety and nature of fractures encountered on the archaeological beads largely coincides with the types recorded in our reference collection. Sharp impact cones were found in isolation on the bodies of 11 beads. Because of their distribution and frequency, sharp impact cones are not diagnostic of wear as such, but are rather the product of accidental damage caused by the collision between a bead and an object or a surface, as already discussed in Section 2.3. These fractures, which are usually encountered on individual bead faces, could have formed at any point in the life of a bead: when sharp impact cones exhibit smoothing of their edges and are covered by polish, abrasion and striae, they likely developed before or during use (see Germa Castello S bead 1 side B, GER G 1 side B, ZIN 13/1 bead 3, ZIN 13/1 bead 4 side B, ZIN 13/1 bead 5 side B, ZIN 34/4 bead 1 side A, ZIN 117 bead 1 side A, ZIN 220 bead 1 side A). Conversely, if the fractures have neat

edges and are not affected by rounding, traces and polish from use, it means that they formed at a post-depositional stage (ZIN 11/1 bead 4 side B). In some instances it can be quite difficult to provide a 'relative chronology' for these fractures. This occurs when sharp impact cones are weathered or when surface alterations – either due to manufacturing or post-depositional processes – are pervasive, hampering their interpretation and at times even detection (ZIN 13/1 bead 1 side B, ZIN 13/1 bead 2, ZIN 220 bead 1 side B). If corrosion is advanced, as is the case for UAT 4 G bead 1 side B, it is impossible to determine when fractures formed.

Micro-chips, or a number of conchoidal fractures distributed radially along the edge of the thread-hole, were observed on a total of 26 beads, thus indicating that those specimens were somewhat forcefully removed from the metallic wire they had been made on, as also noted in experimental replicas.

Micro-chips were predominantly documented for wound beads, however they were also observed on one drawn bead from Saniat Gibril (Figure 5.26). The fractures along the thread-hole edge of SGB G bead 1 exhibited a flattened contour and were not associated with traces that may indicate mechanical polishing, such as dense, rough polish.



Figure 5.26: SGB G bead 1 side B, micro-chip along thread-hole edge, 50x. (Micrograph author's own).

As a consequence, this bead must have undergone heat treatment to smoothen the sharp edges that resulted from cutting a hollow glass rod into individual beads (for further information on the drawing technique please see Appendix A). As such, the temperature had

to be warm enough to slightly melt and flatten the micro-chips but not to completely re-fuse the glass. Although the drawn bead from the kasbah in Old Jarma (Germa Castello S bead 1) does not display any micro-chips, it certainly has the same smooth finish. Unlike the two specimens discussed so far, which present a seamless body-to-thread-hole transition, the bicolour drawn bead from Saniat Gibril (SGB G bead 2) has a short collar and an umbilical-shaped thread-hole. Such features are typical of the use of crenelated moulds, which, starting from the Roman period, were employed in the segmentation of beads, as seen for example in 5th-6th century CE Egypt (Pion & Gratuze, 2016). In the case of SGB G bead 2, a blunt fracture line along the thread-hole edge was recorded on side B: some degree of polish and rounding are visible on top of small conchoidal fractures, suggesting that wear by use developed on an unfinished surface. If the thread-hole edges were extensively polished by cold-working, we would in all likelihood expect more extensive rounding and much duller polish even before the bead was actually used. As such, in the case of these drawn beads, the evidence presented so far allows us to identify variations in the technological processes employed at specific stages of the *chaîne opératoire*.

Shallow conchoidal fractures, which are not related directly to the crafting of beads by the winding technique, were noted on the external edges of cylindrical bead 2 from ZIN 11/10 (Figure 5.27).

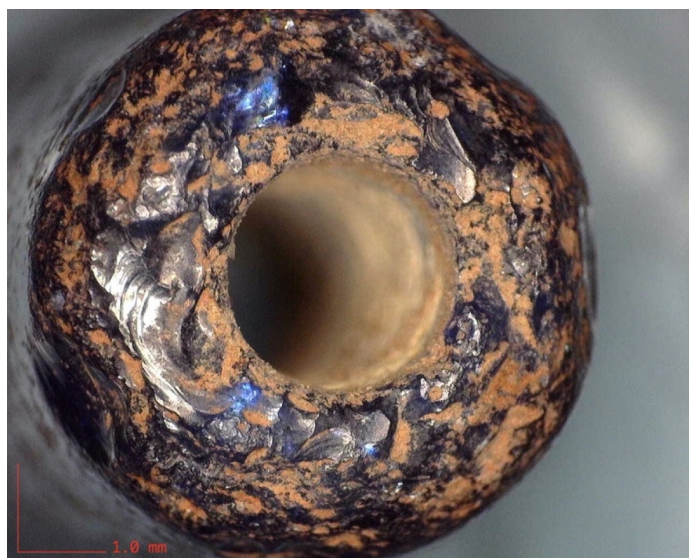


Figure 5.27: ZIN 11/10 bead 2 side A. Micro-chipping due to bead modification, 50x. (Micrograph author's own).

In particular, on side A these chips appear to follow a radial pattern, which may indicate that some deliberate re-working or re-touching of this end of the bead occurred, perhaps to alter

slightly its length and/or shape. In any case, a secure interpretation is not possible as most of the fractures are attacked by weathering which hampers their legibility; furthermore, the chips on the end of side B appear less coherently organised. With this in mind, we cannot exclude a post-depositional origin for all or part of these traces, perhaps in connection with trampling; however, another modified barrel bead from T. 87 in the Garamantian cemetery UAT 008, which was similar in colour and shape to ZIN 11/10 bead 2, was also ground down at both ends (Mattingly et al., 2010, p. 189).

Aside from the corrosion-related fractures generated by the detachment of glass flakes on beads ZIN 11/1 bead 5, ZIN 11/26 bead 1, and ZIN 34/1 bead 1 already discussed in Section 5.4, hairline cracks, which can be considered as the precursors to conchoidal fractures, were only recorded for ZIN 34/3 bead 1 B. As seen on experimental specimens, also in this instance the cracks, which are very faint, are radiating from micro-chips along the thread-hole and for this reason they can be traced back to the manufacturing stage.

As discussed in Section 2.3, c-shaped marks are none other than partial hertzian cone cracks: these fractures are caused by dragging part of the surface of one bead, or any object, onto another (fairly static) bead. As with sharp impact cones, hertzian cone cracks or marks found on the Fazzan beads are the by-product of accidental damage, which may equally have occurred during manufacture, use or discard. C-shaped marks, which broadly correspond to Hurcombe's (1992, p. 37, p. 58) crescent row striations, were not recorded on replica bead sets. They however appear here on the bodies of two wound beads from Zinkekra (ZIN 105 3/3 bead 1, especially on side A and ZIN 117 bead 1 B, where isolated c-shaped marks were surrounded by sharp impact cones (Figure 5.28). In both instances the legibility of any hypothetical relationship between c-shaped marks and other traces is jeopardised by glass degradation, and as such we can only say that they likely formed either during use or when buried in soil.

A line of potential c-shaped marks was also recorded along the thread-hole area of GER G bead 1 A. Considering that blunt impact fractures do not leave many traces on surfaces, such as such as hackle lines or mist (Quinn, 2016, p. 6-34), these marks may well be manufacturing surface alterations, as they are similar in shape to ridges. In any case, we can tell that these traces represent one single action at a specific point in time during

manufacture or use, and that very slight rounding and bright polish affected them at a later stage.

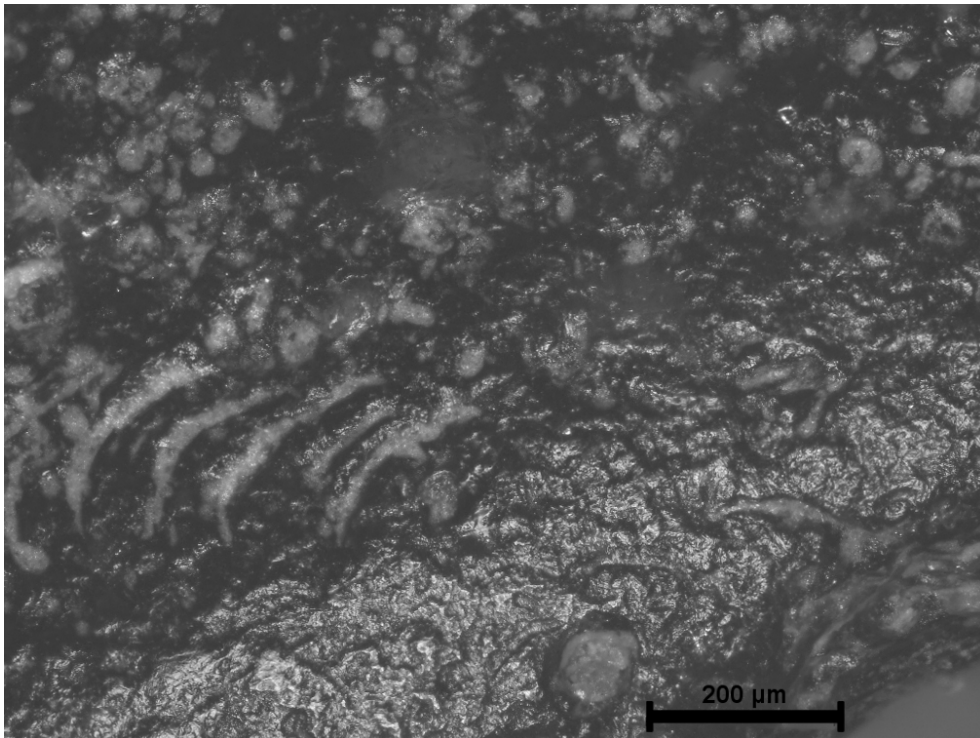


Figure 5.28: ZIN 105 3/3 bead 1 side A. C-shaped marks and polish along thread-hole edge, 100x. (Micrograph author's own).

C-shaped marks¹⁰ were observed at low magnifications on seven of the glass beads from the Lent-Lentseveld Merovingian assemblages (n beads=47) and on two specimens pertaining to the re-enactment dataset (n beads=45) studied by McGloin (2021a, pp. 14-15; p. 100). In particular, partial hertzian cone-cracks had specifically formed on the larger beads from graves 9 and 13, respectively consisting of a necklace and of a string of beads placed by the hip. As a greater number of beads with partial hertzian cone-cracks were observed for grave 13 (n=5), it has been speculated that these fractures were more likely to form if beads could swing and hence repeatedly hit against each other. This requires a relatively wide range of motion. This would be the case for the beads which were worn at the hip as they would oscillate according to the wearer's gait, whereas necklaces tend to remain virtually still on the body (McGloin, 2021a, pp. 108-110). This scenario appears plausible but more data are needed to test this hypothesis and to assess how different loads, impact angles and speed contribute to fracture formation on glass beads. Although McGloin (2021a, p. 101) considers hertzian fractures to be one of the main indicators of wear by use, the scarcity in the

¹⁰ McGloin (2021a;b) uses the terms 'hertzian fracture' and 'c-shaped mark' interchangeably, although the latter is more generic as it is employed to define various types of hertzian fractures, which include – but are not limited to – cone-cracks.

occurrence of this trace across various datasets – including the Fazzan beads presented in this thesis – suggest that c-shaped marks are not necessarily conducive of use as suggested. Of course, there might be some degree of variability within assemblages that reflect different use-duration patterns for individual beads across and within sites. If some beads were worn in the same configuration for long enough, however, we might expect to find clusters of fractures in more or less the same area as one of the clues pointing towards (extended) use. In any case, these fractures, as any trace, should be examined and interpreted accordingly by taking into account all the wear marks present on beads.

5.7 Striations

Glass corrosion can make it difficult to ascertain striation morphology and type(s): as such, the legibility of striae is inversely proportional to the severity of degradation phenomena. This is because when beads are badly preserved the troughs of striations can get infilled by weathering or may acquire a ‘unidimensional’ or flattened appearance presumably caused by the formation of a silica gel layer. In the case of three beads no striations were observed whatsoever, since pitting and corrosion completely altered the appearance of their surfaces (UAT 4 G bead 1, ZIN 11/1 beads 3 and 9). A similar situation is also recorded for ZIN 11/1 bead 5, whereby some sleeks are barely visible because of glass decay.

On archaeological beads, striations can develop not only from manufacture and use (like we have seen for replicas) but can also result from: exposure to given burial conditions, retrieval during excavation and/or survey work, and, although this is not necessarily the case for the Fazzan assemblage, cleaning, conservation and storage. Diagnostic and undiagnostic traces – in this specific instance sleek striations – tend to coexist on bead surfaces, as clearly seen on 16 specimens. As such, to successfully interpret the ‘stratigraphy’ of individual beads, among the other things we also need to pay attention to the type, distribution, frequency and overall dimensions of striae to effectively identify the life-stages underpinning their genesis.

Recorded on the edges and bodies of 31 beads, sleeks are the most frequently encountered type of striation, which is consistent with what has been observed for our reference collection (Section 4.9.3). Also in this instance, when found along the thread-hole edge and/or within micro-chips, clusters of short sleeks – be they perpendicular, parallel, oblique or even chaotic – indicate string action especially when associated with thread-hole edge rounding and polish. When sleeks are clustered on specific areas of the body, they signal

bead-on-bead contact. Sleeks that were almost exclusively from use were documented on 25 beads: when the levels of preservation are generally good, very few obvious post-depositional striae were observed. This is the case for the beads from Saniat Gibril (SGB G beads 1 and 2) Old Jarma and the kasbah (GER G bead 1, Germa Castello S bead 1), and for Zinkekra sites 11 (ZIN 11/1 beads 2 and 6), 13 (ZIN 13/1 beads 4 and 5) and 34 (ZIN 34/3 beads 2 and 3).

More often than not, post-depositional sleeks – and striations in general – can be recognised as such because they are visible on top of corrosion or post-depositional polish, creating further noise as they may contribute to the obliteration of traces of wear by use. As such, these sleeks can be deep and long scratches located mainly on the bodies of beads as for the specimens from Old Jarma (GER G bead 2) and the Zinkekra settlement and cemetery sites (ZIN: 11/1 bead 1, 11/14 bead 1 A, 11/26 bead 1, 13/1 beads 1 and 3 A, 34/3 bead 1, 34/4 bead 1, ZIN 117 bead 1, ZIN 220 bead 1 A); alternatively, they can be short and shallow either standalone or grouped in sparse clusters with the same orientation (ZIN: 11/1 beads 4 and 8, 11/10 bead 2, 11/14 bead 1 B, 11/26 bead 1, 13/1 bead 2 A, 13/13 bead 1, ZIN 34/3 bead 1, ZIN 220 bead 1). Bead ZIN 11/10 1 A presented along the edge of a relatively fresh fracture, a cluster of dense, deep and wide striations (Figure 5.29). The latter were accompanied by patches of a bright residue which could perhaps be interpreted as metal polish, as also seen on obsidian (Hurcombe, 1992, p. 204, plate 96). In all likelihood the striations and residues on ZIN 11/10 bead 1 A are connected to the removal with metal tweezers of a glass sample for chemical analyses.

The narrow, long and shallow sleeks found in isolation on the body of ZIN 11/1 bead 7 B along small attrition patches, are certainly non-use related as this specimen represents a failed attempt at bead-making and as such, it is unlikely that it was ever worn. With the exception of ZIN 11/10 bead 1 A, it is likely that the remainder of the post-depositional sleeks discussed so far formed as a consequence of soil rubbing (or being rubbed) against the bead surface. As sleeks are the consequence of plastic deformation of a surface rather than fracture, we would expect sand particles to be the culprit in this situation, as also noted for the formation of post-depositional traces on obsidian resulting from soil movements due to trampling or from trying to wipe off the dirt from artefacts during excavation (Hurcombe, 1992, pp. 48-49).

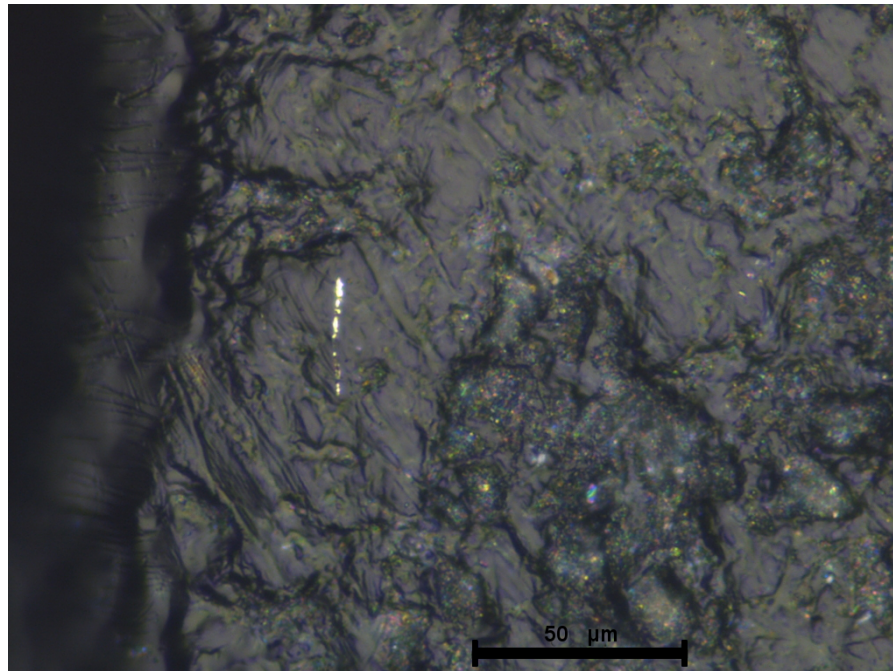


Figure 5.29: ZIN 11/10 bead 1 A. Post-depositional striae and bright metal polish. 500x. (Micrograph author's own).

When the surface preservation is mediocre or poor it is at times impossible to determine the nature of streaks, as their legibility is very fragmentary (Germa Castello bead 2 A, SGB 4 4/5 bead 1, ZIN 34/1 bead 1 and ZIN 105 3/3 bead 1). Although we can presume that some of those striations may have been from use, it is extremely difficult to gauge their real distribution and frequency, as the latter is masked by degradation.

Rough bottomed striations were rarely documented in our reference collection, whereas in the case of the Fazzan assemblage they seem to be more frequent, as they appear on 8 beads, the entirety of which are from Zinkekra. They are generally found on individual bead faces as single striations, mostly short and wide: for this reason, the rough bottom striations observed on seven beads are to be interpreted as the result of accidental damage. When beads are affected by corrosion, so are their striations. When reasonably deep, the microtopography of the base of striations can be chemically altered, hampering secure type attributions (see ZIN 11/26 bead 1 B). In the case of bead ZIN 11/1 bead 6 A we can hypothesise that the long and shallow rough bottom striations on the body may have been caused by sand scraping or being scraped on the glass surfaces, as this occurrence – at least on obsidian – can cause not only streaks, but also intermittent and rough bottom striations (Hurcombe, 1992, p. 49). Conversely, the rough bottomed striations on ZIN 220 bead 1 A are not only found in a cluster, but they are also associated with small patches of abrasion and attrition and are located in proximity to the thread-hole edge (Figure 5.30).

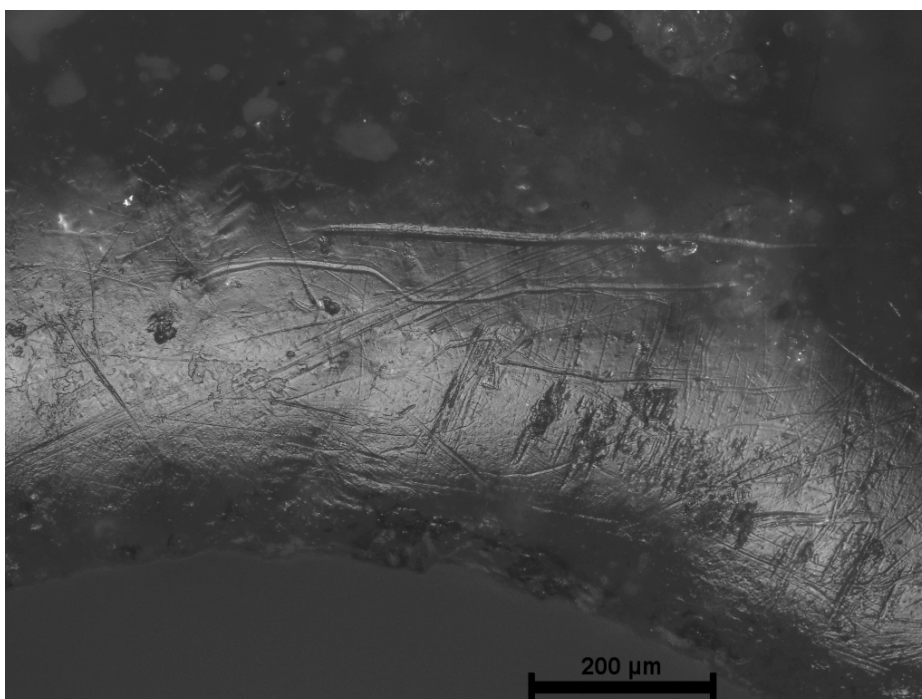


Figure 5.30: ZIN 220 bead 1 A. Rough-bottomed striations, sleeks, abrasion and attrition, 100x. (Micrograph author's own).

Due to the fact that these striae are grouped together and also relatively abundant, and that further abraded areas are sparsely present along the thread-hole edge, we cannot rule out that they may be from use.

Intermittent striae are very rare, as they were noted in isolation only on four specimens from Zinkekra sites 13 (ZIN 13/1 bead 3) and 34 (ZIN 34/3 bead 1, ZIN 34/4 bead 1). These striations, which are narrow and shallow with perpendicular and/or parallel orientation, are found on the edges as well as the bodies of beads. As seen for rough bottomed striations, intermittent striae are also caused by some undetermined abrasive action, which results in occasional damage. No meaningful superimpositions with other traces – in particular sleeks – were observed, and as such it was not possible to establish with certainty whether accidental damage occurred during use or at a later stage.

Ranging from occasional to rare, flaked striae, which are caused by beads coming in contact with other beads, string materials, or objects with great abrasive potential and the ability to capture grit particles, were recorded on the faces of 7 beads from Zinkekra (ZIN: 11/1 beads 2 and 7 A, 13/1 bead 3 B, 34/3 bead 1, 34/4 bead 1, 220 bead 1 B) and Saniat Gibril (SGB G bead 2 A). More often than not, flaked striations tend to be deep and long, and are frequently located on the bodies of beads. Whether isolated or in groups, occasional flaked striae from use were found on beads with good to very good preservation, which present

varying degrees of abrasion and attrition on their surfaces (ZIN: 11/1 bead 2, 13/1 bead 3 B, 34/3 bead 1 and 34/4 bead 1). When these striations are arranged in clusters (ZIN 34/4 bead 1), they tend to agglomerate around – or depart from – abraded patches, which can be in themselves strongly indicative of wear by use, as explained in further detail in Section 5.9. It is worth noting that these striations attributed to use have similar placement, characteristics and interactions with other traces as the experimental beads.

With the exception of ZIN 220 bead 1, which maintained very good surface legibility, rare standalone flaked striations were documented on beads with mediocre surface preservation; when abrasion and attrition are also recorded, this is less localised and not particularly severe. As such, striae with this type of frequency, distribution and indirect association with abraded areas represent occasional damage (ZIN 11/1 bead 7 A and ZIN 220 bead 1 B). Because of glass degradation, it appears that the stria running in parallel to the thread-hole edge of SGB G bead 2 A was ‘chemically etched’, meaning that corrosion altered its overall morphology and as such we can only propose a tentative attribution to the flaked type. This phenomenon has also been reported on obsidian blades and tools (Hurcombe, 1992).

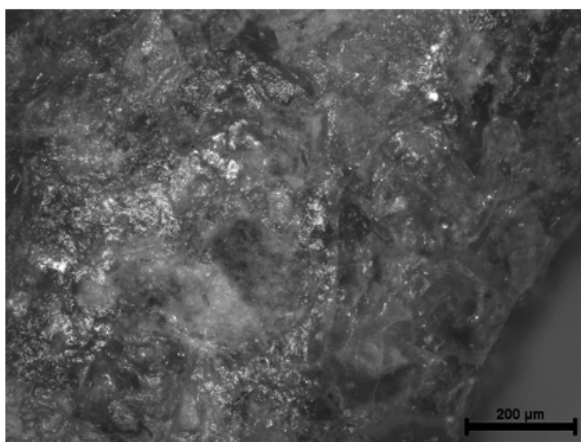
The majority of comet-like striations were recorded on the same beads from Zinkekra and Saniat Gibril as flaked striae were encountered: this is not surprising, as both types of striations are generated by the action of grit or abrasive particles, and, in this specific case, moisture. Similar to what was observed for the experimental replicas, the comet-like striae on the Fazzan beads were more frequently observed on specimens which already showed an abundance of traces. Comet-like striae – and pits – were documented equally on the edges and bodies of 12 beads: when from use, isolated or clustered comet-like striae appear on edges and bodies alongside moderate to intensive localised attrition and/or abrasion and flaked striations (ZIN: 11/1 bead 6, 11/10 bead 2, 11/14 bead 1 A, 13/1 bead 3 B, 34/3 beads 1 and 2 B, 34/4 and 220 bead 1). When standalone comet-like striations or pits were noted on surfaces with scattered, undiagnostic abrasion, attrition and random traces, no obvious interpretation could be made (SGB G bead 2 B, ZIN 11/1 bead 2 A, ZIN 13/1 bead 1 A, ZIN 13/13 A).

5.8 Polish and rounding

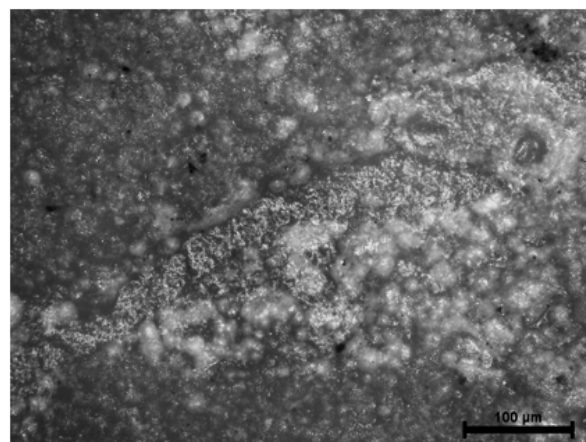
Polish was reported on the majority of the archaeological beads: as observed for all the traces discussed so far, polish from use and polish caused by depositional processes are

frequently concurrent. In the case of beads with moderate to poor preservation rates, the degree of brightness of polishes from use may be masked by corrosion processes (i.e., weathering patinas, pitting, iridescence) and/or by post-depositional polish. In addition, glass decay impacts the texture of surfaces polished from use: depending on the severity of the phenomenon, these surfaces may acquire a ‘flat’ appearance. This is because weathering accretions or more generally a silica-rich gel layer will develop on top of already worn areas and as such have the tendency to fill any pre-existing surface irregularities.

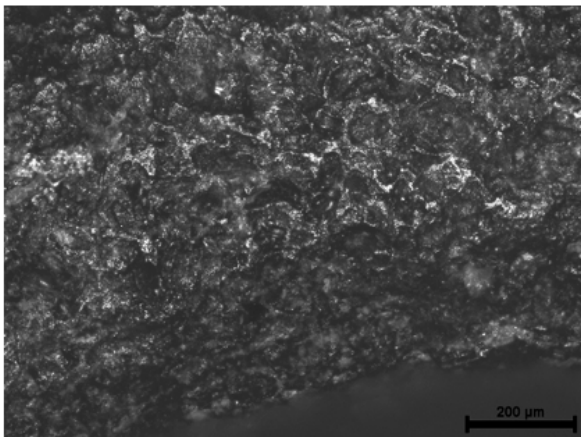
Post-depositional polish alone was found on seven beads, on average with poor to very poor levels of preservation (Figure 5.31).



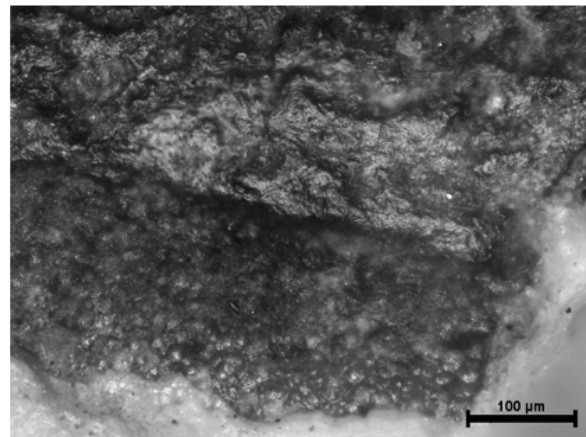
ZIN 11/1 Bead 5. Scale 100X.



ZIN 11/1 Bead 3. Scale 200X.



SGB G 4 4/5. Scale 100X.



SGB G 4 4/5. Scale 200X.

Figure 5.31: Intensely bright post-depositional polish on selected Fazzan beads. In the case of ZIN 11/1 (bead 3) and SGB G 4 4/5 the original bead surface survives in patches, as the remaining glass surfaces is affected by weathering and pitting (micrographs author's own).

This type of polish overlaps previous traces of wear and tends to appear in random patches which are intensely bright and very light, with no rounding or levelling of peaks and striations (ZIN 11/1 beads 3-5, 7 and 9, SGB 4 4/5 bead 1, UAT G 4 bead 1). In the case of ZIN 11/1 bead

5, post-depositional polish most certainly formed on top of polish from use, but due to heavy surface degradation it is impossible to establish some of the original features of the diagnostic polish, as one may be able to appreciate only the presence of rounding as a tell-tale sign of use. This was also noted for ZIN 11/26 bead 1 B, although here some polish from use is still visible. In addition, iridescence from corrosion can also yield shiny surfaces, and as such, this can be found alongside spots of other types of post-depositional polish.

All in all, as this very light and bright polish is very generic, it is very difficult to ascertain what factors caused its appearance in the first place. Nonetheless, it may be helpful to take into account other potential factors in post-depositional polish formation. If glass degradation appears an obvious culprit, bag wear would certainly apply to any Fazzan site that yielded more than one bead, as not only were the glass specimens all bagged together, they were at times also accompanied by beads of ostrich eggshell and stone (in particular – but not limited to – ZIN 11/1 and 13/1). Bag wear tests performed on obsidian caused the flaking of tool surfaces and edge damage (Hurcombe 1992, p. 78); however, as the Fazzan beads were not tightly packed together and are, regardless of their material, considerably smaller, lighter and less angular than tools, it would make sense for them to develop a light polish.

Post-depositional bright spots may have also been caused by soil processes, however, this is a contentious matter, as the appearance of this type of polish varies according to actions and materials: soil abrasion produces dull, rough polish and abrasion on flint, however, when the same material is tumbled and shaken in soil, bright spots will form on tool edges (Keeley 1980, p. 53; Hurcombe, 1992, pp. 74-75). In addition, further non-use tests which were carried out to ascertain the types of traces produced by soil and grit contact on flint tools produced another set of results (Vaughan, 1985, pp. 42-44). In this case, smooth-type and rough-type grit polishes were noted. The first type of polish, which develops on topographic highs and tool edges, is characterised by very bright, smooth and raised polish domes with the occasional occurrence of grooves. Conversely, rough-type grit polish when well-developed is present on the entirety of flint surfaces. Otherwise known as soil sheen, this polish, which is very pitted, flat and rippled in appearance, is generated by the expansion and contraction of moisture-rich soils or waterways caused by seasonal variations. When soil sheen is at the lowest development stage, it is considered generic weak polish, whereas rough, pitted, dull polish with troughs, striations, and microcraters denotes a very advanced development phase (Vaughan, 1985, p. 42). Concerning obsidian, Hurcombe (1992, pp. 74-

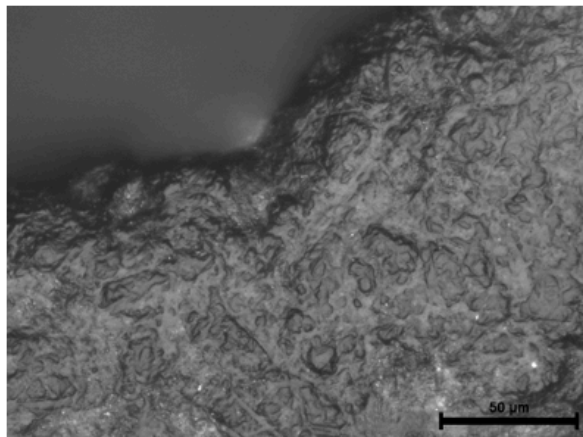
75) did not observe any bright spots due to soil movements for her experimental sets, and, as no prolonged burial tests were performed to record the effects of soil abrasion on artefacts, it was hypothesised that this kind of post-depositional polish would consist of darker abraded areas. As for glass we have no experimental material for direct comparison, we may infer that the polish observed on the Fazzan beads is either too weak to be traced back to soil abrasion, or that the glass surfaces may behave under these circumstances more like flint with faint soil sheen.

Polish from use was detected on the bodied and edges of 28 beads: as seen for experimental beads, also in the case of the archaeological beads, a differential development of diagnostic polish was recorded, as this was not necessarily found on both faces of beads. As indicated in Section 4.9.4, the formation of polish from use largely depends on configuration, string tension and specific bead areas which may be in contact with other beads. With regards to rounding, this appears to form alongside polish, which means that both traces will not only be concurrent but may also have a similar degree of intensity.

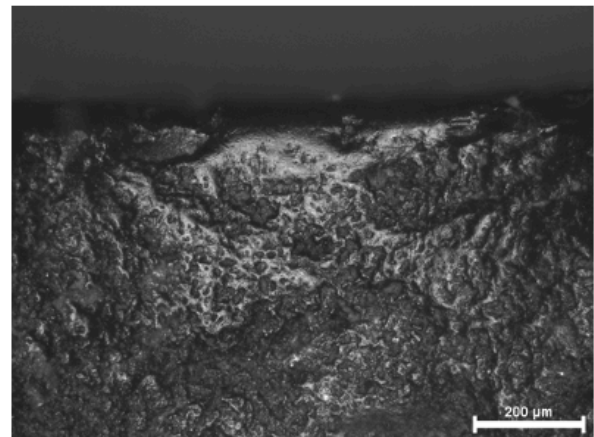
When found along the thread-hole edges, polish from use is mainly given by string action, as observed on experimental specimens. Polish is here associated with rounding and more or less dense clusters of (usually) short sleeks, which can have the same orientation or can be arranged in a chaotic fashion; in addition, sleeks can also be located within microchips. Furthermore, rounding is present in the areas where polish is developed. When found on the bodies of beads (exclusive of Ger G 1 and 1, Germa Castello 1, Zin 11/10 1), polish from wear by use can be seen alongside slight to moderate smoothing of abrasion patches: this testifies that the beads, which are either globular or annular, were kept long enough in the same configuration for these traces to occur in close contact with another bead (see also Section 5.9). At the moment it is not possible to provide an estimate of the use-duration, other than it must have been longer than the 10-month period of the necklace wearing experiment. Disregarding post-depositional polish, the same ranges of polish brightness and textures were observed on archaeological as well as on experimental beads (see Section 4.9.4).

With surface preservation ranging from very good to mediocre, sixteen beads from Old Jarma, the kasbah and Zinkekra, showed developed to well-developed polish. As these beads also presented very light to light polish, the full gamut was observed in the appearance and texture of polish, which ranged on average from bright to fairly dull and from slightly smooth

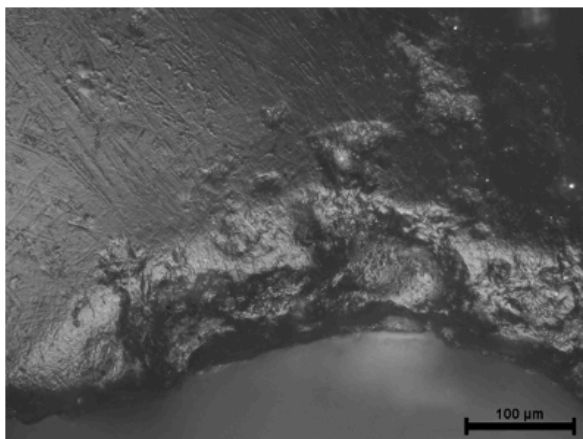
to rough. Representative examples of developed to well-developed edge polish are provided in Figure 5.32.



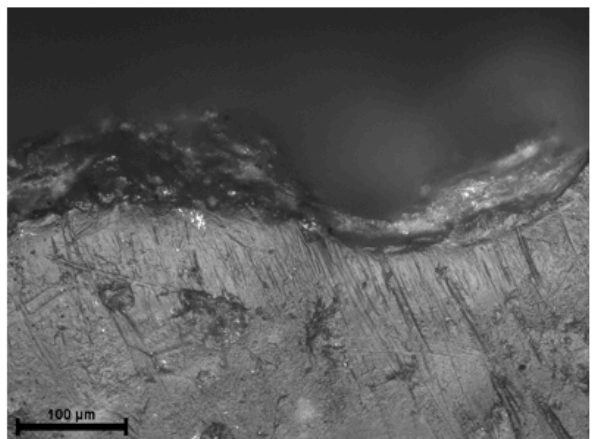
ZIN 13/1 Bead 3: Abrasion and grit-influenced polish with rounding of peaks. Scale 500X.



ZIN 117: Well developed, bright polish. Scale 100X.



ZIN 13/1 Bead 5: Rounding and developed polish. Scale 200X.



ZIN 220 Side B: Smooth polish with rounding and streaks indicating string action. Scale 200X.

Figure 5.32: Polish from use on selected Fazzan beads (micrographs author's own).

As for replica bead sets, polish could not be attributed with certainty to any given string materials, as polish may still be underdeveloped or different use-durations with disparate contact materials can produce similar results (see Section 8.2). As such, polish may form on a bead strung with leather more slowly when compared to a bead strung with vegetal matter, meaning that if they had different use durations we may not be able to differentiate between the two strings used. Nonetheless, some interesting observations can be made on the selected Fazzan beads from Figure 5.32: bead 3 from ZIN 13/1 shows the development of polish and rounding on top of a heavily abraded surface. This type of polish is caused by use, as not only is it circumscribed to the highest portion of the bead, but more importantly, the thread-hole edges appear modified by extensive rounding, which is especially visible in the lower portion of the bead as shown in Figure . As this polish appears similar to what Vaughan

(1981) defines as 'grit-influenced smooth pitted polish' it is likely that the presence of particles of soil or another abrasive material contributed to its formation during use; the slightly lighter and brighter sheen visible in amongst the troughs is likely caused by slight degradation. Of note is also the fact that the polish observed on ZIN 13/1 bead 3 is visually very similar to the polish observed on ZIN 105 3/3 bead 1 B.



Figure 5.33: ZIN 13/1 bead 3; extensive thread-hole rounding visible at low magnification, 30x. (Micrograph author's own).

The developed polish and moderate rounding on the thread-hole edges of ZIN 13/1 bead 5 (Figure 5.32 bottom left), is bright and slightly smooth to bumpy, and as such is very similar to the polish encountered on experimental bead 8.2 A (contact face with copper alloy bead) in Figure 5.34, which was strung with flax/cotton.

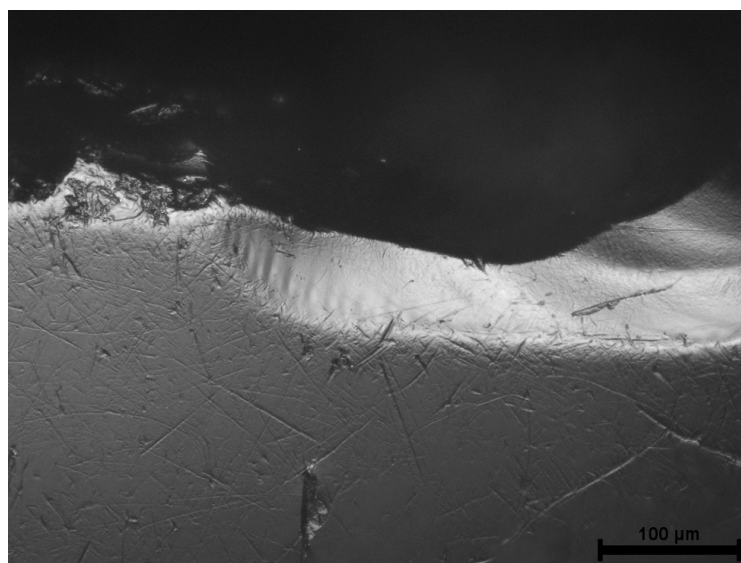


Figure 5.34: ZIN 13/1 bead 5 polish and rounding on micro-chips, 100x. (Micrograph author's own).

In a similar manner, the relatively bright, smooth and flat polish of ZIN 220 bead 1 (Figure 5.32 bottom right) resembles the traces left on obsidian tools after whittling and scraping siliceous and non-siliceous soft wood, palms and bamboo (Kononenko, 2011, p. 58 Plates 3-4, p. 208 Plate 129, p. 209 Plates 133A-133B). Lastly, fragmentary bead 1 from cemetery site ZIN 117 showed on the inner face of the thread-hole edges well-developed smooth, pockmarked polish, which could be compared to the polish deriving from the scraping of damp hide with obsidian for 60 minutes (Hurcombe, 1992, p. 184, Plate 55).

In all of these cases it is possible to surmise that the polish and rounding observed on the beads was caused by organic materials with different degrees of pliability and abilities to capture micro-particles; pronounced abrasion and attrition possibly indicate a raw material that is more responsive to that. All in all, the hypotheses advanced in the previous paragraphs for ZIN 13/1 beads 3 and 5, ZIN 117 bead 1 and ZIN 220 bead 1 do not appear to be that farfetched.

Due to the preservation of organic materials, the FP and DMP excavations in the Taqallit peninsular, Zinkekra and Watwat cemeteries yielded matting made from siliceous herbaceous plants (*Juncus* sp.), wool textiles and leather shrouds, bags and pouches (Mattingly et al. 2019, pp. 85-86). Beads in a variety of materials, found *in situ*, would have been strung on necklaces, sown onto items of clothing or onto bags. As no strings or threads which may have been used for those purposes are recorded, this is likely due to the fact that they did not survive (Mattingly et al. 2008; Mattingly et al. 2019, p. 91).

5.9 Abrasion and attrition

When compared to the experimental dataset, in the case of the Fazzan beads, abrasion is preponderant, as it was recorded on 31 beads from Zinkekra (ZIN: 11/1 beads 1-3 and 6; 11/10 beads 1 and 2; 11/14 bead 1; 13/1 beads 1, 3, and 4; 34/1 bead 1; 34/3 beads 1-3; 34/4 bead 1; 105 3/3 bead 1; 117 bead 1; 220 bead 1), Saniat Gibril, Old Jarma and the kasbah (SGB: G beads 1 and 2; 4 4/5 bead 1; GER G bead 1, Germa Castello S beads 1 and 2). Abrasion from use, which, as seen on 26 beads, ranges from very slight to intensive, appears in dense patches in correspondence with topographic highs on the edges and bodies of beads, respectively indicating string-on-bead and bead-on-bead interaction. On a general note, abrasion tends to be moderate to intensive on the bodies of the beads, whereas on the along the thread-hole edges it is usually lighter, as observed for experimental replicas. This

discrepancy could be due to a multitude of factors, such as the difference in load placed on the two areas of the bead, as in bead-on-bead interaction the load on the body is higher, and the kinematics behaviour of the contact materials alongside their ability to capture abrasive particles. In particular, when abrasion is of the intensive type, this is visible with a naked eye and at low magnifications as very dull, rough patches, either localised or covering a larger area, as respectively seen for example on the bodies of ZIN 34/4 bead 1 and GER G bead 1 (Figure 5.35). In such cases, the distribution of abrasion allows us to observe that a bead must have been worn in the same configuration – and against another bead with a specific shape and contact points – for an extended period of time.

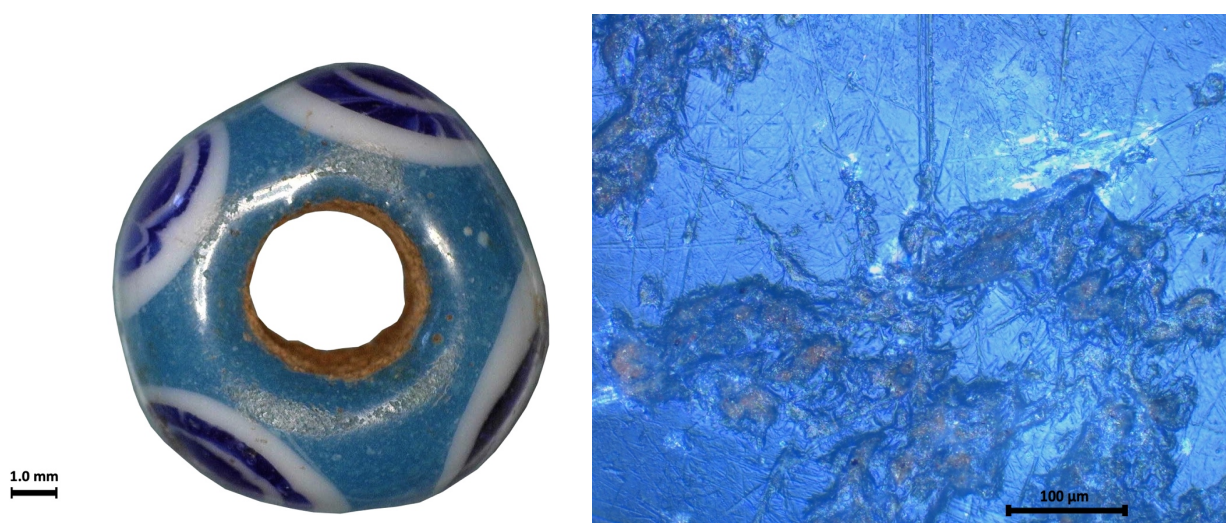


Figure 5.35: ZIN 34/4 bead 1; abrasion on bead-on-bead contact areas. 30x, 200x. (Micrographs author's own).

As observed in the case of polish, when beads show mediocre to poor preservation rates, pitting, weathering and other corrosion phenomena (e.g., flaking of surfaces) obliterate the vast majority of previously abraded areas altering the general glass microtopography. As such, attempts to establish relationship between traces and abrasion patches which are earlier than corrosion, may be unfruitful. Although we may not be able to reconstruct the exact sequence of traces on beads with degradation, if abrasion is present on specific areas of beads, we can surmise that this was caused by use. Abrasion that forms as a consequence of post-depositional factors such as contact with soil will in fact be sparse and randomly placed on bead surfaces, as noted for beads 7 and 8 from ZIN 11/1, beads 2 and 5 from 13/1, and bead 1 from ZIN 13/13 (Figure 5.36). Other abrasive phenomena such as sparse pits likely from use or even manufacture, which, as explained in Section 5.4, have different characteristics when compared to corrosion pits, were visible on 15 specimens.

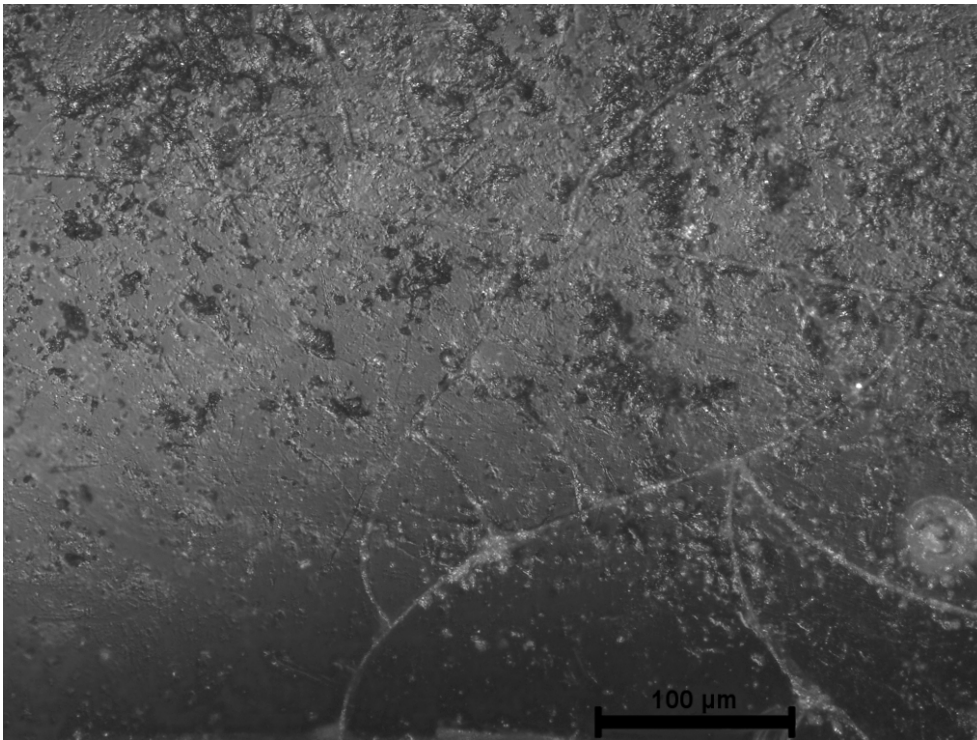


Figure 5.36: ZIN 11/1 bead 7; post-depositional abrasion, 200x. (Micrograph author's own).

When compared to abrasion, attrition is less frequent, as it was observed on 14 beads (ZIN: 11/1 beads 1, 2, 6 and 8; 11/10 bead 2; 11/26 bead 1; 13/1 beads 2-4; 34/4 beads 1 and 3; 220 bead 1; GER G bead 2, and Germa Castello S bead 1). Attrition appears mostly on single bead faces, and is almost always accompanying abrasion. Attrition from use is on average slight to moderate, which translates into the flaking or exfoliation of small areas on topographic highs of the edges and/or bodies of beads, as it is the case for various beads (ZIN: 11/1 beads 2 and 6; 11/10 bead 2; 13/1 beads 3 and 4; 34/4 bead 1; 220 bead 1; Germa Castello S bead 1. See also Figure 4.23). On a general note, the extent of attrition depends on how much the contact material can trap and/or add abrasive particles and on load (Hurcombe, 1992, p. 45).

Similar to what recorded for non-use related abrasion, post-depositional or accidental attrition on glass beads is usually sparse, and when found in clusters, these are arranged in random patterns (GER G bead 2, ZIN 11/1 beads 1 and 8, and ZIN 34/3 bead 3).

5.10 Residues

No residues that could inform us about the use of particular stringing or bead contact materials were observed. Weathering products (perhaps mixed with soil particles) were observed within degradation pits. As seen in the experimental data set, bright, patchy films

and stray fibres, which all result from recent bead handling, were noted in a few instances in circumscribed areas of the Fazzan beads, as skin oils are not always fully dissolved by cleaning.

As such, the majority of the residues recorded here account for accretions within thread-holes, indicating that in most cases the clay slip separator was not removed from the beads. Exceptions are of course present, as for six specimens minimal to no traces of separator were recorded (GER G bead 1, Germa Castello S bead 2, SGB G beads 1 and 2, SGB 4 4/5 bead 1, and ZIN 117). This means that the thread-holes of these beads were in all likelihood thoroughly cleaned and that any leftover clay slip – if present – must have disappeared with use. In some cases, such as for drawn bead SGB G 2 where possible iron particles were observed, we cannot rule out that certain beads may have been manufactured without a separator. For nine beads from Zinkekra 11/1 (beads 2-5), 13/1 (beads 1, 3 and 4), 34/1 (bead 1), 105 3/3 and 220, and one specimen from the kasbah in Old Jarma (Germa Castello S bead 1), it was noted that a thin film of separator still survived on the thread-hole surfaces. As for the previous sub-group of beads we can infer that this is the result of an intentional removal of the separator, however we should not discount the impact of wearing the beads in grinding down the slip. In the case of beads UAT 4 G 1 and ZIN 11/10 1, any remarks were impeded by heavy corrosion and absence of thread-hole area respectively. When separator is present, visual differences across beads were noted, with some clay slips appearing finer (e.g., ZIN 11/1 bead 7, ZIN 11/14 bead 1) and some others coarser (e.g., ZIN 11/26, ZIN 34/3 bead 1). Especially in the case of beads from the same site, this indicates that they were made by different workshops and/or at different points in time.

5.11 Conclusions

A good overlap of trace types between the reference collection and archaeological dataset was observed. In the case of the Fazzan beads no flaked striations were recorded; traces caused by post-depositional processes were preponderant in this sample, as opposed to experimental beads, which perhaps bear overall less traces of wear by use. The degree of preservation of archaeological beads is key in the detection of wear by use. Even though the majority of beads were poorly preserved, it was possible to establish that most of them were used for a period of time, with some being used longer than others. Glass corrosion in particular has a negative impact on the detection of polish from use and its brightness levels, and it can also impair the legibility of striation and general trace morphology. Although their

genesis may not be clear on glass, in most instances post-depositional traces can be easily distinguished from diagnostic wear. This is consistent with what has been observed for obsidian tools, whereby post-depositional abrasion and striations as a consequence of natural or post-depositional factors can be recognised because they are not distributed in a regular fashion and are not aligned with the flake edge (Kononenko 2011, p. 10). If in the case of flint – and to some extent obsidian – it appears clear that post-depositional polish due to the action of soil can completely destroy diagnostic polish, I suggest that for glass this may be due in minor part to physical factors, with the bulk of the damage being caused by chemical interactions between the artefact and the burial environment (Hurcombe, 1992, p. 75).

As for experimental replicas in the case of developed to well-developed polishes there did not seem to be much variation in polish appearance along the thread-hole edges. As such, a consistent problem between the two datasets is the difficulty to ascertain the specific nature of stringing materials, which at least are known to be organic (see also Section 8.2). If we compare the data available for obsidian, it generally appears that dry or hard hide or matter produces more abrasion than wet, damp or soft materials that yield more rounding of edges and relatively matt polish. This, however, is not a hard and fast rule, and although on glass beads the degree of moisture trapped in the string is certainly conducive in the formation of polish and rounding, at present we cannot tell how this correlates with string material. Another factor that could muddle the waters for polish formation processes could be the additional interaction of the (wet or dry) string with silica/clay microparticles still contained within the thread-hole, which could perhaps be responsible for grit-influenced polish from use. In addition, in the case where a bead was restrung multiple times with different materials, different polishes would (partly) overlap, and of course, the more a bead is used, the more pre-existing traces will be obliterated by later wear.

Chapter 6. Towards a Materiality of Colour

This chapter will provide a theoretical grounding for the case-study on the meaning of the colour of glass beads from pre-Roman Abruzzo discussed in Chapter 7. Colour – alongside durability – is one of the most striking characteristics of glass and of beads crafted in this material. Section 6.1 will provide a definition of colour that will be used to ground our discussion on what colour is, how it is experienced through the senses and how it is conceptualised, by highlighting the aspects that are inherently bound to physiological and psychological human experience and elements that are culture-specific. As brilliance is one of the central aspects of colour, particular emphasis will be placed on that and on its importance in relation to raw materials – including glass – and their transformative processes and in the negotiation of power and their power as objects. Finally, the importance of the senses, emotions and memory with regards to wearing, using and curating glass beads will be explored, opening the floor to further considerations on the use of colour in glass beads in death among the pre-Roman peoples from Abruzzo (Italy) in Chapter 7.

6.1 What is colour?

Colour perception has been a central aspect of human experience in modern and ancient societies, shaping our relationship as human beings not only with the material world, but also with symbolic thought. The combination of physiological and cultural responses elicited by interactions with the surrounding environment define the way we think and talk of colour. Put more simply, colour is a product of the entanglement of both nature and nurture.

But what is colour exactly? Coming up with a definition of perceived colour may prove to be a much harder task than expected, as there seems to be a relatively high degree of variability in the terminology used in the scientific literature (Biggam, 2012, p. 2; Elliott et al., 2015, p.3). Nonetheless, if we wanted to describe perceived colour in empirical terms, the definition of colour roughly encountered in the fields of cognitive psychology, linguistics and semantics should suffice (Biggam, 2012, pp. 3-5; Wierzbicka, 2015, p. 297). In this instance colour is defined by:

- hue, which refers to parts of the spectrum of visible light that account for differences in perception, such as blue, green, red.
- saturation or chroma. This refers to the purity of colour, which depends on the amount of grey present in a hue.
- brightness (otherwise known as lightness or value), which varies according to the amount of light reaching the eye and ranges from shiny to matt.

If, on the one hand, each of these parameters poses the correct degree of objectivity and homogeneity when used in experiments in the form of Munsell colour chips, on the other hand, the concept of colour appears to be circular. As Wierzbicka notes (2015, p. 297), in the *'APA Dictionary of Psychology'* (2006, p. 196) hue and saturation are described as qualities of colour, but at the same time colour itself is defined by these very same attributes. In addition, from a physiological and linguistic perspective, these parameters appear to be somewhat reductive, for reasons I will illustrate in the following paragraphs.

Before discussing the relevance of colour and its implications in the archaeological record, we have to turn our attention to how colour is perceived from a physiological, cognitive and linguistic point of view. As this is a very complex matter falling out of my remit, I will only point out the aspects that may be the most salient in questioning approaches to colour theory in archaeology. For further clarity, I will refer to colour and its specific components following the terms indicated in the general definition provided above.

6.2 Colour perception

It is universally acknowledged that colour perception in humans is regulated by first and second stage mechanisms (Figure 6.1). The first stage involves the S, M and L – otherwise known as blue, red and green – cones, which are photoreceptors located in the retina. The S, M, and L cones, which are at the basis of trichromacy, or the ability to mix three spectral lights to match a hue, respectively absorb light at short, medium and long wavelengths. Rods, which are also situated in the retina, are specialised in night vision and are also spectrally tuned, contributing to our perception of colour. The second stage is characterised by colour-encoding processes, as the retinal ganglion cells and the lateral geniculate nucleus in the thalamus calculate how much and in what way the cones were active at the time of viewing. The visual cortex then processes the information in colour-opponent (red-green and blue-yellow) channels, allowing the perception of hues. In addition, further colour-

coding processes occur in other regions of the cortex, completing our perception of colour (Gegenfurtner & Kiper, 2003; Conway, 2009; Conway, 2012; Parry, 2016, p. 216; Siuda-Krzywicka et al., 2019).

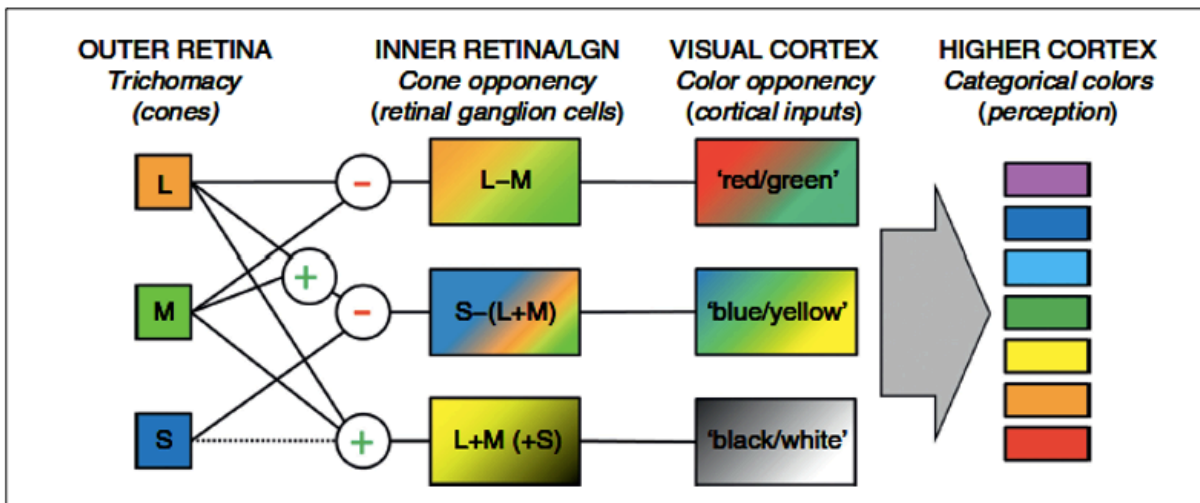


Figure 6.1: Stages of colour processing (Parry, 2016, p. 218).

More importantly, humans – and non-humans – perceive colour in association with objects (object colour), which means that specific colours are seen in relation to specific objects. This is because in nature certain objects would act as reinforcement stimuli to learn associations between colours and rewards, such as food, mates or avoided danger (Siuda-Krzywicka et al., 2019). An example of this could be a red, ripe apple. In this sense colour refers primarily to the surface qualities or attributes of the object, and not to the shape by which this is contained (Davidoff, 1997, p.118). This phenomenon and its cultural implications could be observed in the archaeological record, as it may be likely that certain colours first became associated only with certain objects, being considered by all means as object colours, such as copper in the Balkan Eneolithic. This would have reinforced symbolic aspects of a given colour also in relation to specific artefacts, represented in this case by axes, chisels and daggers. The prominence of copper in this specific context also resulted in the creation of gold, a new object colour with similar qualities (Chapman, 2002 pp. 49-52; Gaydarska & Chapman, 2008, pp.64-65). The presence of given object colours in archaeological contexts could be very important when researching polychromy and the connections between certain colours and types of glass beads. As Conklin (1973) suggests, we should not only be concerned with object colours or coloured materials per se, but we should also consider luminous colour, or the colour of light sources, as they both are an integral part of the experience of viewing.

The reason why we see colours in objects is given by colour constancy, which is the ability to retain a constant perception of colour despite a change in illumination conditions. In this sense, the perception of colour is linked to an evolutionary advantage, as it needs to convey a message: sources of food, such as the previously mentioned red, ripe apple, need to be perceived as such regardless of the viewing conditions. Colour constancy is also responsible for colour memory, providing us with the illusion that the colour of an object is immutable (Conway, 2012). We could then presume that colour constancy and colour appearance mechanisms are the same for every human being. However, the 2015 internet debate around what is now called in literature ‘The Dress’ has highlighted that there are indeed individual differences in the strengths and/or parameters applied to the mechanisms of colour constancy (Olkkonen & Ekroll 2016, pp. 175-176).

‘The Dress’ originally appeared on the social media platform Tumblr and soon became a sensation among the general public, because the answer to the question posed in relation to its colour was not univocal (Figure 6.2). Some individuals would perceive the dress as blue and black/brown, whereas for some others it was white and gold (Gegenfurtner et al., 2015). While there may be variables impacting on the colour perception of ‘The Dress’, such as the white balance settings of the camera with which the picture was taken not reflecting real illumination conditions, or the fact that ‘The Dress’ can be viewed through an LCD screen at different angles and sizes (Gegenfurtner et al., 2015), it appears that the brain may show a bias towards colours of the illuminant associated with daylight, which range from orange to blue in correspondence to the sun rising and setting (Lafer-Sousa & Conway, 2017).

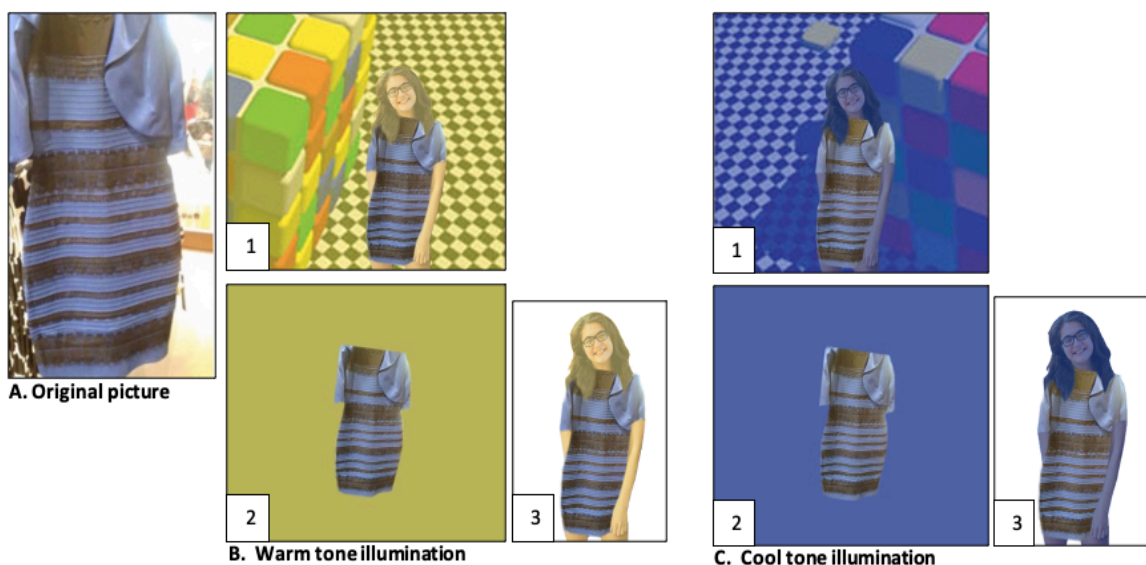


Figure 6.2: A. Original Picture of the dress; 1 B-C. Stimulus used in experiments 1 and 3; 2-3 B-C. Stimuli employed in experiment 3 only (Lafer-Sousa & Conway, 2017: supplements).

This hypothesis has been validated by a set of experiments, which entailed in the first place a verbal test for colour naming of the dress, by filling in the gaps in a sentence. In experiments 1 and 3 the participants were asked to report the dress colour and lighting for both blurry and in focus pictures, whereas in experiment 2 they were tasked with matching visually the colour of the dress with pixels. In addition, for experiments 1 and 3 participants had to rate the illumination of the dress under cool and warm tones. In both experiments a cue-rich background and the image of a white woman, which was superimposed on the dress, were used as stimuli. In experiment 3 further variables were considered to measure the response to warm/cool lighting, and consisted of skin tone only and of a uniform background respectively. In follow-up tests subjects were required to determine the colour of the dress by looking at one enlarged and one blurry picture (Lafer-Sousa et al., 2015; Lafer-Sousa & Conway, 2017).

The evidence resulting from the application of this experimental protocol determined that individual differences in the perception of 'The Dress' are caused by how we respond and adapt best to certain illuminants, or sources of light (Lafer-Sousa & Conway, 2017). The study showed that older people and women saw 'The Dress' more frequently as gold and white, rather than blue and black. This is because both groups are more likely to have a day time chronotype, resulting in a bias towards sky-blue illumination. This bias invests not only the long term, but was also observed on the short term, when subjects had previous experience of viewing 'The Dress'. In addition, some participants underwent a switch in perception, which is likely due to the fact that the picture of the dress is multistable as it presents an ambiguous illumination (Lafer-Sousa et al., 2015; Lafer-Sousa & Conway, 2017).

If colour constancy stabilises our perception of colour by continuously mediating between surface reflectance of an object and illumination conditions, this does not mean that colour appearance cannot change. If the context of viewing is modified spatially, or by a change in background, or even by the introduction of new colours, a change in the perception of colour will follow, revealing a certain degree of ambiguity of colour. The way we experience colour, in both visual and emotional terms, is highly contextual (Whittle, 2003, pp. 117-118; Conway 2012; Olkkonen & Ekroll 2016, p. 159).

6.3 Colour categorisation

Colour perception is therefore a complex physiological process, which depends on a variety of factors such as the physics of light, environmental conditions and the physical properties of the object being viewed. As colour is mostly conceptual, language has the function to simplify and condense our sensorial experience (Biggam, 2012, p. 2). As a consequence, the way we talk about colour does not completely match with the way we see or even sense colour. Only a restricted pool of colours has corresponding names, when in fact humans can differentiate between a higher number of colours (Olkkonen & Ekroll 2016, pp. 171). On a general basis we divide the colour space (i.e., range of colours that we can see) between focal and non-focal colours. Focal colours, or the units upon which colour categorisation is built, are the areas in the colour space that best represent basic colour names (Abbott et al., 2016; Heider, 1971). These colours are deemed to be salient, as they attract our attention the most, especially when compared to non-focal colours (Heider, 1971). The reasons behind focal colour salience are grounded in the physiology of colour perception (Heider, 1971; Siuda-Krzywicka et al., 2019). When it comes to colour categorisation, for as hard as we tried, we would not be able to disentangle nature, or the physiology and psychology of colour perception, from nurture, or the existence of cultural factors such as language.

A review of the evidence drawn from disciplines such as neuroscience, cognitive psychology and biology indicates that albeit with slight variations, colour categories in humans and non-humans may depend on object colour perception. Experiments to determine categorical responses to colour in birds, apes, monkeys and fish have given mixed results as to how animals interpret the colour space.

This inconsistency in outcomes is due, amongst the other things, to the use of stimuli that may not be colours of objects that are fundamental to animals in their natural habitat for survival purposes, otherwise known as ecologically relevant colours, or to the reference metric of choice, as when perceptual parameters were employed, the accuracy of the categorical response decreased (Siuda-Krzywicka et al., 2019). Research carried out on birds, such as a study on blackbirds and American robins which saw the use of eggs in different colours, and an investigation on female zebra finches whereby red and orange were employed to simulate the colours of the beaks of male zebra finches, has demonstrated that colour categorisation occurs successfully when ecologically relevant colours are selected as

stimuli (Hanley et al., 2017; Caves et al., 2018; Siuda-Krzywicka et al., 2019). This is because non-human animals see colours as inseparable from objects, and the constant association of ecologically relevant object colours with rewards causes generalisations to other shades of colour. As a result, object colours that attract the most attention become focal colours, eventually resulting in colour categorisation. Human colour perception is not as strictly bound to objects as it is in non-human animals, as it relies on surface qualities of objects that are then processed into lexical colour categories. Nevertheless, it can be equally hypothesised that the underlying mechanisms of colour categorisation in humans may be similar to what observed in other animals, although variables such as visual system, type of objects deemed as important and range of colours will depend on the species (Siuda-Krzywicka et al., 2019).

Although in humans colour categories rely on automatic language processing, they also seem to develop in children prior to the acquisition of language (Siuda-Krzywicka et al., 2019). As the literature around the topic of colour categories in children is relatively vast, the focus here will be on a recent study which explored colour perception in infants aged 4 to 6 months old. A sample of 295 infants was shown 320 colours in the form of Munsell colour squares, always with maximum chroma (saturation) but with variations in lightness and hue (Skelton, et al. 2017). A novelty preference procedure, which is the standard for this age group, was applied. This relies on the underlying principle whereby if children are shown a colour with which they are familiar with, they will look away, whereas if a given colour is new to them, they will spend more time looking at it (Skelton, et al. 2017; Siuda-Krzywicka et al., 2019).

In the experiment, infants were first familiarised with a hue, and at a second stage the familiar hue was then paired with a new hue, allowing to test for novelty preferences. The results of the evidence collected indicates that infants can distinguish the following categories: red-yellow, green-yellow, blue-green and blue-purple hues, although no intermediary hues within these categories were detected. The colour categories in infants do not fully align with English colour terms and lexicon, but appear to follow mechanisms present across different languages, showing a cross-cultural character. This suggests that the basis of colour categorisation in children is in part regulated by biological factors which underpin human vision (Skelton, et al. 2017). In this case colour categories may then be

culturally reinforced during developmental stages, through interaction with caregivers (Siuda-Krzywicka et al., 2019).

This shows that an ecological origin for colour categories in humans appears to be likely in biological as well as cultural and linguistic terms. The universals in human experience in relation to the environment are connected to the universals of visual semantics, as the biological and cross-cultural associations of colours with objects seem to point in the direction of colour objects such as ‘green plants’ ‘blue sky’ and ‘red blood’ (Wierzbicka, 1990; 2015; Siuda-Krzywicka et al., 2019). This entanglement of biological and cultural factors has implications that can be very important when translated into the study of the past (Janik, 2021). Here, the work of Berlin & Kay (1969) is not only the initial reference point to base the discussion around colour theory in archaeology, but also acts as a springboard, taking us in new directions.

6.4 Berlin & Kay: from ethnolinguistics to colour theory in archaeology

‘Basic Colour Terms: their universality and evolution’ (Berlin & Kay, 1969) is considered a cornerstone in the development of colour theories not only from an ethnolinguistic standpoint but also for archaeologists (Jones & MacGregor, 2002, pp. 3-7).

Drawing from cognitive and experimental psychology, Berlin and Kay came to the conclusion that colour foci were cross-cultural and therefore present in all languages. This implied that the cognitive processes underlying colour perception were universal. The evidence collected automatically undermined the relativistic views of the Sapir-Whorf hypothesis, whereby the perception of colour was seen as arbitrarily shaped by language in any given society (Berlin & Kay, 1969, p. 2).

Berlin and Kay also observed that languages evolved in seven fixed stages, following a diachronic progression. In the first stage only basic terms for black and white would be present, whereas in the last stage up to eleven different terms for basic colours were recorded (Table 6.1). On a synchronous level this meant that different languages were at different developmental stages.

STAGE:	I	II	III	IV	V	VI	VII
Colours	black, white	+ red	+ green/yellow	+ green/yellow	+ blue	+ brown	+ orange, purple, pink,

Table 6.1: Basic colour terms and their stages according to Berlin & Kay (1969). Table author's own.

This evolutionary trajectory of basic colour terms, which would see the emergence of new colour names as societies increasingly become more complex over time, is highly problematic and has been rightfully questioned in several instances (Gillis, 2004, p. 2; Jones & MacGregor, 2002, p. 4). In addition, the use of both Munsell colour chips and bilingual informants to conduct the study, skewed the perspective towards the English language and western standards for colour categorisation (Lucy, 1997; Saunders, 1995; Wierzbicka 1990; Conklin, 1973).

The limitations posed by this model appear even more evident in the case of languages that, unlike English, may have no actual words for colour. If in the English language words for colour are primarily connotated by hue, in other languages, visual descriptors on the scale of brightness and dullness can be used instead, as in the case of the Burarra in Northern Australia. The Warlpiri in central Australia rely on word duplication to refer to salient visual prototypes such as blood, ochre or grass (Wierzbicka, 2015, pp. 299-304). Other societies, like the Hanunóo in the Philippines, may instead categorise colour based not only on lightness and darkness, but also on attributes such as wetness and dryness (Conklin, 1955). In some instances, this phenomenon can be also extended to ancient societies. Written sources from the Aegean Early Bronze Age refer to colour in terms of brightness or dullness (intensity) and saturation (Gillis, 2004, p. 58). In particular, Mycenaean inscriptions attested the presence of four different types of red employed to dye textiles. Here the descriptors used for these terms may refer to the quality or value of the product, and by extension to manufacturing techniques (Nosch, 2004, p. 33). As a consequence, the terms used to describe colour in this context could not be slotted into any of the stages of Berlin and Kay's classification (Gillis, 2004, p. 58).

The debate around the categorisation of basic colour terms is further complicated by the fact that the proposed eleven basic colour terms, with the exception of the green-blue and the yellow-green boundaries, cannot be mapped onto first or second stage mechanisms of human vision (Siuda-Krzywicka et al., 2019, p. 84). Secondly, slight human variability in colour perception and the potential presence of individuals with colour vision deficiencies cannot be fully discounted in the present as well as in the past. Congenital colour vision

deficiencies are the result of genetic anomalies in the photopigments of the cones, which consist in either the lack of one of the classes of cones, or in variations of spectral sensitivities. The M (red) and L (green) cones are the most affected, causing four different types of red-green colour blindness in trichromats and dichromats (Parry, 2016, p. 220).

In individuals with anomalous trichromatic vision the most common congenital colour deficiency is deuteranomaly, or the presence of two L cones with slightly different spectral sensitivities and one S cone: it is estimated that around 5% to 6% of European Caucasian men are affected by this form of colour blindness. Protanomaly, which is a defect of the M cone resulting in a lower sensitivity to red light, is much rarer (Bosten et al., 2005; Parry, 2016, pp. 220-221). Approximately 0.4% of the female population and 4% of African-American, Asian and African men are affected by red-green congenital colour vision deficiencies. These are estimates, as in all of these cases underreporting is likely to be present (Parry, 2016, pp. 222-223).

The impact of congenital colour vision deficiencies on colour perception is variable, depending on the severity of the anomaly (Doron et al., 2019; Parry, 2016). Oliver Sacks (1996) studied the phenomenon of achromatopsia, or complete colour blindness, affecting the totality of the inhabitants of the Micronesian islands of Pingelap and Pohnpei. He observed that the islanders would identify colours on the basis of brightness, shape, texture and non-visual attributes of objects, such as smell. This is of course an extreme case, as especially young adults affected by anomalous trichromacy may be unaware of their condition, whereas dichromats, either affected by protanopia (lack of L cones), or deuteranopia (absence of M cones), may only have a slightly restricted perceptual colour palette (Figure 6.3). Both deuteranopia and protanopia fall within the wider umbrella of red-green colour blindness: in both conditions colour confusion is observed in relation to highly saturated reds and greens and, although in different ways, to blues. In addition, individuals affected by protanopia not only cannot differentiate light brown from green, but also confuse reds with dark browns, and some whites with blue-greens. Deuteranopia more specifically causes colour confusion between reds and light brown and orange (Parry, 2016, p. 220-223).



Figure 6.3: Same scene viewed by trichromatic (A) and dichromatic subjects (B-C). Simulation created with the Web version of the Chromatic Vision Simulator (Parry, 2016, p. 225: Figure 10.6).

Although the colour space of people affected by congenital colour vision deficiencies varies according to the condition, visual functions such as contrast sensitivity, which is the ability to differentiate the foreground from the background determined by changes in luminance, stereo acuity, or the sharpness in the detection of the depth of field, and visual acuity, or sharpness of vision, are retained in most cases (Parry, 2016; Doron et al., 2019). In particular, contrast sensitivity and stereo acuity are in direct correlation with the severity of the colour deficiency. When compared to people with normal vision, anomalous trichromats and multi-gene dichromats have superior visual acuity, contrast sensitivity and stereo acuity. When these parameters were tested in subjects with anomalous trichromacy by using natural grayscale images which contained camouflaged objects, it has been demonstrated that these individuals were able to detect the targets with a high level of accuracy, proving that they can in fact penetrate camouflage more effectively in comparison to subjects with normal vision, as suggested during World War II and later periods (Doron et al., 2019; Bosten et al., 2005). The reason behind this enhanced ability to perform spatial vision tasks is a reflection of several genetic variations in colour vision, or polymorphism, which can be observed in anomalous and normal trichromats (Doron et al., 2019; Parry, 2016, p. 222). If colour blindness may be impossible to observe in the archaeological record due to the incomplete nature of the datum, not only in terms of elements of material culture, but also in relation to specific worldviews and colour symbolism, we should not dismiss the existence of object biographies tied to people affected by colour vision deficiencies.

6.5 Where next?

If Berlin and Kay were correct in postulating the universality of colour perception, why do we, past and present humans, talk about colour so differently? The key to this may not

necessarily lie in how things are perceived, but in where our attention is directed in order to form conceptual categories. This would also explain the different semantic connotations of words for colour in languages that behave like English, and by extension the choices behind the symbolism of certain colours (Wierzbicka, 2015, p. 313; pp. 304-309).

From a neurophysiological point of view, we perceive colours as the surface texture of objects, meaning that hue, saturation and brightness, as well as surface type and appearance – whether rough or smooth, wet or dry – all equally influence our viewing experience (Biggam, 2012, p. 2). If colour perception appears to be primarily grounded in vision, this does not automatically imply that other senses are not employed in the abstraction of colour. This of course translates into language, as terms for colour may incorporate features of visual and sensorial perception that may be indivisible one from another (Biggam, 2012, p. 2). For this reason, when approaching colour in archaeological practice we should not only take into account the material properties and sensorial qualities of artefacts, but also the existence of a synaesthetic ‘sensorial field’ whereby all the senses are intertwined (Scarre, 2002, p. 239; Hamilakis, 2013). The modes of interaction among different senses are culture-specific, providing the foundations for the construction of shared and individual experiences, knowledge and emotions (Nugent, 2020, p.114). Tactility in particular, which allows us to establish the texture of objects, and haptic senses more in general, which help us to gauge other characteristics of objects such as proximity, weight and temperature, to name a few, may have a stronger connection with sight in certain cultural contexts, creating forms of corporeal visibility (Nugent, 2020, p.113; Hamilakis, 2013, pp. 75-80). Tactile or haptic vision is for instance central to religious experience in Byzantium: sacred icons were primarily devised to be touched not only with the hands, but more importantly with the eyes, as it was believed that rays of light would extend out of them allowing one to feel – and to physically connect with – the divine presence (Hamilakis, 2013, p. 76; James, 2003, p. 528). This is not to say that all societies conform to this way of perceiving and sensing colour, but the wider involvement of the sensorium is a possibility.

Colour, as much as the senses, is both universal and culture-specific (Hamilakis, 2013, p.10). No matter where we decide to trace the line between the biological and cultural aspects of colour, they are impossible to pull apart. When studying colour in past and present societies we should step away from the Western dichotomies between material and form, nature and nurture, emotions and rationality, as all these elements act in synergy to form the canvas of

human experience (Conneller, 2011, pp. 125-126; Hamilakis, 2013). However, this does not mean that each component of this entanglement has the same weight in shaping how we interact with our surroundings: culture at times overrides human physiology and psychology not only in the ways we may be experiencing colour through the senses, but also in terms of colour preference, which finds its expression in language and specific worldviews. For the purpose of this research, I suggest we focus on the interactions between cross-cultural and culture-specific aspects of colour and their implications, dismissing any preconceptions rooted in Western culture which consider colour and the senses as dangerous or inferior (Batchelor, 2000; Hamilakis, 2013, pp. 16-56).

6.6 Cross-cultural aspects of colour

Colour can be seen as the sum of various perceptual attributes of an object, which are mostly – but not exclusively – pertinent to the visual field (final paragraph previous section). In this light, it is somehow unsurprising that the main cross-cultural aspects of colour appear to be brilliance and colour patterning, or the way colours are enhanced by the contrast that is produced by juxtaposition with one another (Jones & MacGregor, 2002, p.14; Borić, 2002; Morphy, 1989). As both colour and colour combinations are likely to rely on culture-specific choices made in the selection of meaningful colours by a given human society, this topic will be dealt with in more detail when exploring the use of colour in glass beads from burial sites in Abruzzo (Chapter 7 and in particular Sections 7.7-7.10; Chapter 8, Sections 8.4-8.6).

In the following paragraphs we will instead turn our attention to brilliance and how this could have been paramount in the perception and use of colour in ancient societies, who specifically selected shiny materials and artefacts, amongst which we also find glass beads (Duckworth, 2012; Hoecherl, 2015, p.14). Since colour perception is grounded in human physiology and psychology, with brightness being the component of colour relative to the matt-shiny range, it is very likely that – based on these premises – the experience of brilliance and the predilection for objects displaying lustre surfaces are universal (see Sections 6.3 and 6.7; Turpin & Fabb, 2017). Cross-cultural studies seem to indicate that brilliance can be connected to spiritual power, awe and experiences around death and dying (Turpin & Fabb, 2017; Shushan, 2018): near-death experiences (NDEs) are present across various cultures across North America, Melanesia and Polynesia, and entail among other things seeing bright lights, feelings of transcendence and connection to the divine, existing in quasi-physical form and leaving and then returning to one's body. The physical reactions

produced by NDEs can be likened to what occurs to the body during shamanic practices, which are instead culture specific. The main caveat around this is that not all societies have worldviews that contemplate NDEs, which is to say that if NDEs are not important or do not exist, no emphasis will be placed on bodily reactions that connect brilliance to otherworldly phenomena (Shusan 2018, pp. 3-7; 14-15; 200-204).

As a consequence, we have to consider that in relation to the cultural context examined, the criteria employed to determine which artefacts and materials are the most brilliant and the ways in which they fit within cosmologies will vary accordingly. This is due to the fact that brilliance is integral part of colour, and as much as colour, it possesses an ambiguous nature, given by the interplay between biological and cultural factors. Looking at material and sensorial properties of objects, we will attempt on the one hand to establish what elements of brilliance can be considered cross-cultural in biological terms. On the other hand, we will investigate how these interact with culturally contextual aspects of brilliance – and colour as a whole – such as aesthetics, symbolism, power and value (Morphy 1989; Gillis, 2004).

6.7 From raw materials to artefacts: a tale of brilliance

Perhaps one of the most important features to determine colour perception, brilliance is deeply connected with the material and sensorial properties of objects, whether human-made or found in nature. Brilliance, defined here as the interaction of an object with light, whether refracted, reflected or transmitted, is very rarely an innate characteristic of raw materials, as most of them are dull in their original state. As a result, shine is largely obtained by processing and shaping raw materials into artefacts (Morphy, 1989; Chapman, 2002; 2007, p. 208). Examples of this can be found in the British and Irish Neolithic, when stone axe heads were ground and polished not only for technological and functional reasons, but also to intensify the intrinsic qualities of the raw materials employed (Bradley & Edmonds, 1993, p. 49; Cooney, 2002, p. 95). In a similar fashion, in the Neolithic Balkans and Hungary, native copper, shell pendants, minerals, rocks and pottery vessels were worked to obtain lustrous surfaces (Gaydarska & Chapman 2008; Chapman, 2007, p. 208). This phenomenon is neither restricted to a precise geographical area or period in time, nor to a single class of materials or type of artefacts: the archaeological evidence ranges from Aurignacian beads made of polished ivory and a variety of soft stones, to Iron Age wooden figurines and metallic brooches found in Britain, which were treated to enhance and preserve lustre (Conneller, 2011; Conneller, 2013, pp. 123-126; Hoecherl, 2015, pp. 38-40). In all instances, the physical

transmutation from dull to shiny is a process of creation which acts on symbolic and cultural levels, allowing artefacts to reveal their inner essence (Chapman & Gaydarska, 2006; Chapman, 2007, p. 208; Saunders, 1999).

Brilliance should not be looked at as a standalone quality, as the way this interacts with hue could have reinforced the use of certain object colours. This appears to be clear in the case of raw materials that are naturally shiny, such as gold, quartz, pearl and shell, as they attract attention because of the constant association of brilliance with a certain hue. This would have very likely created a predilection for objects with both characteristics, shaping colour aesthetics in wider terms (Darvill, 2002, p. 75; Gaydarska & Chapman, 2008; Saunders 1999; Hoecherl, 2015, p. 37). The correlation between hue and brilliance has been observed also in contemporary Northern Andean Christian necklaces which are made of coins, shell, bone, stone, metal and glass beads. Although the preferred hue for beads is red, this is not an essential requirement *per se*, as the raw materials need in the first place to display brilliance comparable to that of gold. Regardless of the material or colour used, beads and coins are equivalent, as they both embody light and, by extension life (Ferraro, 2019).

Gold, in particular, has the ability to retain both hue and shine over time, as it never tarnishes, which means that other material properties such as durability may have played a major role in the selection of raw materials (Gaydarska & Chapman, 2008). In addition, sensorial qualities complementing the visual field may have been highly significant in certain contexts, as demonstrated by pre-Hispanic Amerindian metallurgy. The gold-copper-silver alloy known as *tumbaga* in South America or *guanín* in the Caribbean, as well as other copper-based alloys of West Mexico, were all exceptionally valued not only in virtue of their red-purple hue and shine, but also for the smell and sound that they would produce. This combination of visual, auditory and olfactory qualities symbolised fertility and acted as a life-giving force. This is due to the fact that the amalgam of such features conformed to a multi-sensorial world view, which focused on light and brilliance as manifestations of the numinous. Minerals and natural phenomena such as rain, cloud or thunder, are in this sense the predecessors to metals because of their synaesthetic attributes (Saunders, 2003, pp. 17-18; Saunders 2011, pp. 96-99; Oliver, 2000, pp. 196-197, 198-199; Hosler, 1994, 1995; Falchetti, 2003).

In Pan-Amerindian conceptions golden and silvery hues – and by association the divine – could be replicated by smelting ores and by alloying or gilding metals. The transformative action of fire would then generate metallic sound and colour, both embodying the numinous (Lechtman, 1984; Hosler, 1994, pp. 228-230; Hosler 1995; Saunders, 2003, p. 21; Saunders, 2011, p.96; Martínón-Torres et al. 2012). Deemed for this reason more precious than gold and silver alone, human-made alloys were highly charged with supernatural powers, which could only be accessed by shamans, priests, nobles and rulers (Oliver, 2000, pp. 205-209; Hosler, 1995; Saunders, 1998; Saunders, 2003, pp. 17-18; Saunders, 2011, p. 96). If pre-Columbian societies saw metals and metallic ornaments in general as means to attain – and communicate with – the divine, when the Spanish arrived in the Americas, their interest lay primarily in the acquisition of gold for its monetary value which was determined by mineralogical purity, rarity and purchasing power (Oliver, 2000; Saunders, 1998). The European invaders immediately fit within local cosmologies as indigenous populations saw them as supernatural beings not only because of their lustre armours and thunder roaring-like war paraphernalia, but also for their willingness to trade in brilliance, of which they had an ostensibly endless supply in the form of glass beads, metallic artefacts, mirrors and glazed pottery. Although rooted in completely different cultural frameworks, this apparently shared interest in shiny objects shaped the dynamics of conquest (Saunders 1998).

When attempting to interpret the significance of brilliance across societies, there are a few points that need to be addressed around raw materials, production of artefacts and related technologies. Although the supporting evidence here is drawn from metallurgical practices in the Americas and India, the resulting observations may pave the way to novel approaches to material culture studies. In the first instance Western classes of materials, which are part of a system that tends towards homogenisation and uses prime matters as building blocks, cannot be applied as a blanket taxonomy to explain how materials and objects may have been perceived in past and present cultures other than our own (Conneller, 2011, p. 124). This is to say that in Western views, materials are primarily conceived as inert things and as such they are defined by properties that are tangible and observable. Their cultural meaning is seen as a separate addition to their essentially static nature, thus leading to a thing/concept dichotomy whereby materials are somewhat disjointed from their potential symbolism (Conneller, 2011, pp. 14-15). In addition, by focusing on the study of artefacts, archaeology as a discipline has tended to favour form over materials, relegating the latter to

a marginal role (Conneller, 2011, pp. 25-26, p. 32). As Conneller (2011, p. 14, p. 48) points out, materials can not only be animate (also see pp. 59-62), but their relationship with form is not univocal, as artefacts with the same shape can be crafted out of different materials. When this occurs it is because in ontological terms a variety of materials can share the same essence and can thus be worked into the same form (Conneller 2011, p. 14, p. 48).

Among the 16th C Taíno of the Greater Antilles the conceptual and physical category of *guanín* encompassed not only the metal alloy, but also certain species of smelly plants, the feathers of the Cuban *guaní* humming-bird, the *caguamo* turtle and the island of Cayguaní (Oliver, 2000, p. 196). As a general principle, any raw material will have different affordances and constraints, depending on its inherent and symbolic qualities but also on the technological know-how of a given society (Martín-Torres et al., 2012). This combination of factors may to some extent influence the type, shape, finish, and dimensions of artefacts that can be produced in a certain material: both gold and *guanín* were hammered by the Taíno to obtain bodily adornments and sheets which were applied on a variety of objects (Oliver, 2000, pp. 199- 204). Although ornaments in particular were generally small as a result of the manufacturing technique employed, their size could have also reflected a deliberate act, perhaps signalling the presence of a specific set of beliefs with regards to the perceived qualities of the metals (Martín-Torres et al., 2012). In addition, the provenance of *guanín* added a further symbolic dimension to the alloy, which was hence connected to the land of the ancestors (Oliver, 2000, p. 203; Martín-Torres et al., 2012). This illustrates how materials with similar physical and abstract attributes, such as gold and *guanín* in this case, may be used to produce the same categories of objects because they belong to the same cultural domain. With this in mind, the properties of raw materials may have been heightened by artefacts that exhibited similar characteristics, as for West Mexican rattling objects and bells dating between 1200 CE and the Spanish invasion. Made out of silvery-golden copper alloys, these artefacts would shine and emit sounds when moved or touched. In this respect their design reinforced the qualities of the metal itself, whose auditory and visual properties were central to local cosmologies and as a consequence to the display of power in sacred and temporal settings (Hosler, 1995). This is in stark contrast with European conceptions of gold, which when turned into artefacts, would maintain its qualities despite undergoing a change in shape, posing once again the question whether a given raw material

can be considered as a universal entity, when it can exhibit different ontologies in space and time (Conneller, 2011, p.15).

Moreover, the Taíno example shows that technology can be equally regulated by practical knowledge and context specific worldviews, defying the Euro-American preconception of technological advancement, which is measured on a scale of progress ranging from simple to complex. In the case of metallurgy, this would translate in an inevitable shift from base metals to alloys, with related societal implications (Lahiri, 1995; Saunders 2002, p. 218; Conneller, 2011, p. 125). Indian metalworking traditions disprove this postulate, as both ethnographic and archaeological evidence point towards a cultural preference for artefacts in pure copper with no breaks in continuity, resulting in copper and metal alloys being worked concurrently by separate casts up until the 19th century. As its colour was reminiscent of fire, which in turn represented God, copper was thought of as the purest of base metals and was used in rituals in the form of razors and knives as well as to craft vessels acquired by the ruling elites. The cultural relevance of this metal translated into the fact that copper-smiths and craftspeople belonged to a superior cast, whose heritage was tied to royalty and temples (Lahiri, 1995).

In sum, whilst the importance of brilliance appears to be undisputable from a cross-cultural point of view on biological and cognitive grounds (see Sections 6.7 and 6.8), how this is received and understood in relation to physical properties and qualities of given materials is culture-specific. Brilliant artefacts are only the end product of *chaînes opératoires* where the sourcing, selection and transformation of raw materials play an equally important part in the definition of identities. As Western thought privileges a hylomorphic approach, where form prevails over matter, this does not automatically imply that other – ancient or contemporary – societies conform to this model (Conneller, 2011, p. 126). As the archaeological record provides us with a fragmentary picture, we have to be mindful on how to interpret the evidence: as we fill in the gaps, we have to reflect on the nature of our contribution, remaining open to possibilities that defy certain preconceptions.

6.8 Brilliance and the wider culture-specific implications: aesthetics and power

If brilliance is universally experienced by humans, aesthetics is the context-specific mode in which this is embedded and interpreted within a cultural system (Morphy, 1989). For this reason, we have to be careful not to transpose onto the study of past societies a Western

conceptual frame, as this would result in skewing the picture towards the idea whereby art and beauty sit at the core of the debate, thus overlooking aesthetic pluralisms coexisting in time and space (Gell, 2005, pp. 40-43; Morphy, 1992; 1994, pp. 257-258; Taylor, 1994, pp. 250-251; Armstrong 1981, pp.7-8; Robb, 2017).

A case in point for culturally relative understandings of aesthetics is provided by the shift in perception in Northern Australian aboriginal Yolngu paintings when judged in accordance with completely different aesthetic canons. From an emic perspective, the Yolngu see their own artistic production, whose aesthetics is widely grounded in *Bir'yun* or brilliance, as a representation of the Ancestral power. Conversely, the Europeans consider this shininess as an aesthetic attribute which makes Yolngu art pleasing to the eye (Morphy, 1989).

Cultural differences in the understanding of aesthetics are hinged on how particular sensory and material qualities of objects and artefacts, including brilliance, are conceptualised by a given society, thus shaping aesthetic conventions and fashion, which equally affect what could be classed as works of art as well as everyday material culture and practice (Skeates, 2017; Morphy, 1994, p. 258). If aesthetics is culturally relative, the mechanisms that control the existence of aesthetic fields may originate from common human sensorial stimulations caused by the interaction with objects (Gosden, 2001). This engagement produces emotions, which are physical and mental situational reactions that are activated and consolidated by memory. Emotions are experienced by individuals, but as they follow specific cultural codes, they can be understood and shared within members of a community (Harris & Sørensen, 2010; Hamilakis, 2013, pp.197-198). While it may be impossible to tell which sense may prevail in the creation of emotions in a given context (Gosden, 2001), when considering vision, cross-cultural studies have demonstrated that colour is deeply connected with emotional responses and memory (Conway, 2012). Experiments carried out by Gao et al. (2007) and Manav (2007) aimed respectively to establish the influence of cultural backgrounds in the relationship between colour perception and emotions, and to assess how associations between colours and emotions can be applied for specific purposes in the decoration of dwellings. The two studies loosely followed the same methodology, as participants were asked to match adjectives which described emotions to each colour sample shown. Both papers came to the conclusion that regardless of gender, age and nationality, brightness and saturation, rather than hue, have a greater ability to elicit emotional responses (Gao et al., 2007; Manav, 2007). This may suggest once again the

pivotal role of brilliance in colour perception and in related cultural constructs, such as aesthetics. In the same way as emotions, memory is experienced by individuals and is context-specific. When it comes to colour perception, memory is crucial, as the pathways which connect the retina with other regions of the brain allow us to process what is being viewed, through the recollection of our previous experiences (Janik, 2021).

As previously stated, the interdependence of the sensorium and memory produces emotions. The importance of the specific relationship between vision and memory is corroborated further by neuroscientific research which investigated how colour appearance can be affected by memory colour, or the diagnostic colour of an object that can be recalled via visual memory. In this instance, 14 subjects were required to manipulate the colour of images depicting fruits and vegetables until they looked grey. Especially in the case of the banana, it became very clear that when this occupied the grey colour space it still appeared yellowish to the participants. The picture was deemed neutral when it was adjusted towards tones of blue, which is the opponent colour of yellow. This pattern was observed for all items employed in the experiment, demonstrating the impact that memory has on colour appearance (Hansen et al., 2006). As this study saw the use of objects that are exclusively found in nature, the authors expressed their reservations on whether the same experimental protocol would work on human-made items which present an arbitrary colour. From a cultural standpoint, rather than from a strictly scientific perspective, this does not seem implausible especially if we accepted the existence of archetypal object colours, whereby certain shapes may be coupled with specific attributes of colour, such as hue or brilliance. We could hypothesise that this may be the case for Neolithic apatite blue beads which were found in Turkey and Syria. The beads have a typology of their own, consisting in lenticular shapes, barrels, and tubes. This specific repertoire of forms is exclusively associated with the colour blue, making such beads stand out from the assemblages in which they were recovered (Baysal, 2019, pp. 133-136; pp. 149-151). This may suggest that the continuous association between materials, shapes and colours would create aesthetic categories based on a given symbolism.

If sensorial interactions with objects – and the memory thereof – elicit a shared emotional response, then their aesthetics, which, according to context, rests in different measures on tactile, visual and olfactory attributes, is a feature that can be used as a means to convey a particular message or function within a certain society (Morphy, 1989; 1992). For this reason,

aesthetics should be considered here Hamilakis *sensu*, or in its original ancient Greek meaning of sensorial experience (perhaps coming back to affect) rather than as an abstract contemplation of art and beauty rooted in Kantian philosophical thought (2013, p.30). In this respect, material, sensorial and symbolic properties of objects and artefacts can be interconnected, as observed by Keates (2002) in his study on brilliance in Copper Age Northern Italy. Here, the shininess of copper alloy daggers of the Remedello type is a physical and symbolic attribute at the same time. Luminosity is not only the embodiment of the sun, but it is also the concrete manifestation of numinosity, or the experience of otherworldly presences such as the ancestral dead, so much so that daggers are not only found as artefacts in male burials, but they are also engraved on statue-stelae, testifying the extent of the cultural significance of brilliance within funerary and sacred contexts (Keates, 2002, p. 120). Although objects or artefacts may be selected or crafted in virtue of the fact that they are – amongst the other things – pleasing to the senses, aesthetics is not necessarily tied to the idea of beauty as such, but it appears to be more closely related to multi-faceted forms of power, which exert their influence not only on individuals as producers and consumers of material culture, but also on artefacts themselves (Armstrong, 1981, p.6; Morphy, 1989). As observed for the Remedello daggers (Keates, 2002), artefacts may become powerful in their own right in a given cultural context when material, sensorial and symbolic properties are conceptually indivisible, constituting at the same time a single entity in aesthetic terms (Skeates, 2017; Conneller, 2011, p. 15).

Before we start investigating how power is expressed through aesthetics and the variety of ways in which this is received within a community, we have to understand how brilliance fits within the picture. In other words, what makes shiny objects and artefacts stand out so much, to the point that they are deemed powerful? Brilliance is deeply connected to animacy, an ontological state which denotes motion, which is the distinctive feature that sets apart living beings from inert objects. Animacy is contextual on many levels, but primarily because of the variability in what is considered as a living entity across societies (Conneller, 2011, pp. 11-13). Secondly, in order for animacy to manifest itself, an entity has to visually attract the attention through movement, so that there is a clear distinction between the action that is being performed and the background. Transience is a very important aspect of brilliance in connection to vitality, as even static objects of everyday use have the ability to become alive revealing their inner power when either their surface is touched by a source of

light, or through human actions such as ceremonial performances, which are often dictated by a precise sequence of events (Turpin & Fabb, 2017; Fogelin & Schiffer, 2015). Animacy, or more broadly speaking the fact that objects are active, powerful agents with a life of their own, is at the crux of ontologies such as animism, totemism and fetishism (Groleau, 2009; Bird-David, 1999, Skeates, 2016; Fowler, 2021). As pointed out by Fowler in his recent investigation on animism in Neolithic Britain and Ireland (2021), if vitality had to be ascribed to a single ontological category, we would constrain our interpretations within the tight bounds of a construct with no universal value, at the same time losing sight of meaningful relationships which we may have observed. Once again, the way in which animacy is appreciated is context-specific and may be expressed through several concurrent ontologies which may in all likelihood remain indecipherable to us, especially in the case of past societies which left no written accounts. As archaeologists we can shed light on such topics by focusing on how specific artefacts may have been used and on their *chaînes opératoires*, which is also what this thesis sets out to do. Nonetheless, lustrous silk textiles and shiny ornaments like beads, shells, feathers, sequins and mirrors in use across contemporary and ancient societies of Africa, Asia and America testify to the cross-cultural importance of brilliance and animacy in dress and adornment. When worn, these artefacts and materials could be seen as evocative of the sun or the moon shining on bodies of water, representing powerful forces such as life, thereby symbolising fertility and offering protection from ill fate (Rivers, 1999). The association between the animacy of water, brilliance and spiritual powers could also be extended to other types of evidence, such as Neolithic burial sites on coasts of the Irish Sea, where the fluidity and dynamism of water softens the solid stone of the megalithic tombs. Shiny quartz, also employed as one of the construction materials in the monuments, acts as an intermediary in this transformative process, as it represents a form of crystallised water. The effect that quartz and water have on stone is not only physical, as it is a metaphor for the transmutation of the body in its journey from life to death and the afterlife (Fowler & Cummings, 2003).

On a more general level, it is unsurprising that water, which is at the base of human survival, may have a preponderant role in several cosmologies. Ecological psychology experiments carried out on individuals across different age groups show that certain textures in objects are associated with the main visual features of water, favouring its detection. When adults had to score panels with different finishes on a scale of wetness, the glossy panel was ranked

in the highest place (Coss, 1990). Similarly, when presented with metal and plastic plates, children of pre-school age exhibited mouthing behaviour which resembles the action of drinking water, preferring shiny metal plates over plastic ones, or when only plastic plates were handed to them, the ones with a glossy surface were selected instead. This, in addition to the fact that children are drawn to flickering lights which resemble rippling water, proves that the main visual characteristics of water can be identified at a very early stage of infancy for survival purposes (Coss et al., 2003). This evidence refers of course to drinking water, but in the archaeological and ethnographic record some brilliant artefacts or objects, such as Amerindian pearls or West-African dichroic glass *akori* beads embody life nonetheless, although they come – or they are said to come – from the sea, which is probably seen as a provider of food, sustaining life (Saunders, 1999; Gott, 2013). This water-life association is present in different cultural contexts, but it is not universal: at times the earth, as in the case of Ghanaian *Bodom* glass beads, which in the local tradition are believed to emerge from the ground, or the sun, as testified by the symbology of golden metals in the Americas, are seen as life-giving forces instead (Sackey, 1985; Francis, 1993; Saunders, 2002). Although the importance of an element like water may be grounded in evolutionary and biological factors, life, which is the at the core of animacy, can be found in different natural elements and atmospheric phenomena and the way in which these interact with each other in a given physical and symbolic domain (Saunders, 2003, pp. 19-21; Saunders, 2011, p. 81).

If the notion of animacy appears to recur across different cultures, the modes and the objects that express this show variations and for this reason they need to be looked at in context (Fessler & Machery, 2012). It thus appears that whether as a standalone quality or in relation to ontologies other than its own, animacy is what makes shiny objects and artefacts powerful. In the context of 15th and 16th century Nahua material culture, this is exemplified by the converse relationship between *tlazohihhuatl* and *macehualihhuatl* feathers, both employed in the production of garments and implements destined to the elites. *Tlazohihhuatl*, or beloved feathers, are the embodiment of *Tonalli*, which is the force that resides in the body itself, animating every living creature. *Tonalli* represents brilliance and warm, red hues as it is directly connected to the sun and body temperature. When *Tonalli* fades away, sickness and death are inevitable. If *tlazohihhuatl* are the physical manifestation of life which needs to be preserved and as such they cannot be spoiled, *macehualihhuatl*, or commoner feathers, are inanimate objects and can therefore be processed with dyes to alter

their appearance. Although *tlazohihhuitl* and *macehualihhuitl* are two distinct entities, each with their own aesthetics, they are both essential to Nahua feather-work. Due to the constant interaction between *tlazohihhuitl* and *macehualihhuitl*, the artefacts crafted with this technique are on the one hand inanimate objects displaying power through their material attributes, but on the other hand they are also powerful in their own nature because they contain a dynamic living entity that as such can be transferred onto the wearer (Caplan, 2020).

The Nahua feather-work example highlights how certain objects may represent what Armstrong (1981, pp. 6-7) would define as 'works of affecting presence' as they have the ability to elicit feelings through heightened perception: in this regard their aesthetics is an expression of their power, which resides in the fact that they are both object and subject at the same time. Instead of focusing on the latter point, our attention here should be shifted towards the fact that power is not something that a given artefact (extraordinary or of common usage) necessarily *has*, but it is rather an inherent (and at times transient) trait. In addition, different categories and types of power can coexist within the same aesthetic field, as shown by the use of gold and precious beads such as *Conte de Terra*, *Aggrey/Akori* and *Bodom* among the Akan in south-central Ghana. According to local beliefs they possess the same supernatural powers because they are both found below ground and are hence connected to the maternal earth deity Asase Yaa. Gold and precious beads have thus a life of their own but are also life-giving forces: on the one hand their socio-political power has traits of visibility, as it is expressed during performative acts such as the display of golden and bead regalia by Akan rulers on state occasions to reinforce their identity and authority. On the other hand, when such artefacts are worn as *asuman* (personal power objects) their spiritual power, which could be either benign or malevolent, is concealed. As the subterranean common origin of precious beads and gold is what enhances their power, this is re-enacted by hiding them either under items of clothing when worn by women as waist beads, or in funerary brass containers known as *kuduo* at the time of burial. In this instance it has to be noted that the *kuduo*, which is made of a copper-based alloy and therefore is connected to the sacred, the beads, the gold and the earth in which the deceased is placed, act in synergy to strengthen the generative powers of the final resting place of an individual (Gott, 2013).

The concept of (ancestral) power through performance is also observed in other contexts, such as Australian Aboriginal ceremonial practices of song, dance and painting, whereby

brilliance is simultaneously expressed through movement and sound (Turpin & Fabb, 2017). As such, the idea of performance – and its association with power – should not be exclusively relegated to the display of brilliant artefacts in a variety of contexts and modes, but it is also connected to the making or the processing of materials, as it may be the case for glass (Sections 6.9-6.10). The relationship between power, brilliance and animacy is thus expressed in ways that are not universal, as in all likelihood these factors are used to convey given identities (Robertshaw, 2020, p. 411): I suggest here that perhaps the cross-cultural element is represented by the involvement of the senses, which will in turn trigger culture-specific emotions and memories.

Power and the material properties of given artefacts are also intimately bound to value, thus shaping their life trajectories. Value is a culture and context specific construct, as the same material can be highly rated by societies – across time and/or space – for different reasons, hence exhibiting multiple (contemporary and asynchronous) ontologies (Kopytoff, 1986; Conneller, 2011, pp. 14-16). In this sense, the value attributed to pearls (but also metals and glass beads) by Amerindians and European colonisers in the 15th-17th centuries is a good example of how differing world-views can coexist, resulting in an apparently identical valuation of the same object type. In particular, if for the Amerindians pearls were highly prized because of their brilliance which was connected to generative powers, for the Europeans, the value of pearls, which was primarily tied to economic grounds and to the display of wealth, was a function of their exoticism, limited availability and flawlessness (Saunders, 1999). In archaeological contexts discussions around value are often grounded in Euro-American ideas of monetary worth, which, as in the case of the above-mentioned pearls, are built upon concepts such as rarity, scarcity and peculiarity of materials. Brilliant artefacts (among which we find beads) are traditionally regarded as commodities in terms of their exchange value or as luxury goods in virtue of their social significance (Appadurai, 1986; Graeber, 2001; Papadopoulos & Urton, 2012; Robertshaw, 2020, p. 400). As a result, even when the focus is placed on the symbolism of artefacts, this is examined in accordance or in opposition to economic value, which acts as a benchmark. This heavy focus on value is perhaps a result of the origins of archaeology as a discipline in colonialism and anthropology, in which Europeans encountered different valuation systems (Thomas, 1991). Rather than centring our analysis of brilliant objects – and ultimately glass beads – on value, I suggest

that here we should try to explain the role of materiality and sensoriality in shaping our interactions with such artefacts.

6.9 Colour and the senses in glass

Colour in glass studies is traditionally investigated in technological terms, that is to say that the emphasis is placed on chemical compositions and more specifically on the presence of metal oxides which have the function to (de)colourise and/or opacify glasses (see for example Jackson, 2005; Jackson & Cottam, 2015; Paynter & Jackson, 2018). When colour and glass are discussed from theoretical perspectives which take into account social significance, the literature is quite scant. In the case of Late Bronze Age Egyptian and Mesopotamian societies, which had a colour vocabulary and written accounts in relation to the manufacture, trade and use of glass, the debate is centred on whether glass was a cheap alternative or not to (semi-) precious stones such as lapis lazuli, turquoise or carnelian (Thavapalan, 2019; Warburton, 2019, pp. 27-28, 30-31; Hodgkinson, 2019). The lines of enquiry that I intend to expand on in the present work are concerned with the importance of the material qualities and attributes of glass and how such durable and colourful glass objects can be symbolically charged by means of sensorial experiences (Duckworth, 2011, 2012, 2020a).

In this regard, glass is a material like no other, as its artificial nature allows not only to experiment with it in terms of hues and degrees of opacity, but also to create specific shapes and artefacts (Duckworth, 2012; Fenn 2015). Although the main material properties of glass can be divided into colour or hue, lustre intended as reflection, refraction and transmission of light, and hardness and brittleness (Fenn, 2015), hue and lustre should be seen as indivisible attributes of colour (Duckworth, 2012). Such visual properties of glass cannot be separated from hardness and by extension durability, porosity and conduction of heat, as they all have an impact on how the material is perceived, kept and possibly curated (Duckworth, 2020a, p. 233). Glass is perhaps one of the few substances that not only is already brilliant at the raw material stage, but also has the ability to retain brilliance whilst shifting between states: when hot, glass is viscous and glowing, but as it cools down, it becomes solid and lustrous. (Henderson, 2013, p. 1; Duckworth 2020a, p. 232). This liquid to solid transformation is also similar to what occurs to metals – as shown by Amerindian metalworking – but also to water, wood and clay. All these materials can be manipulated

through cultural actions and technological know-how and as such, their attributes are not only empirical but also cultural (Saunders, 2003, p. 24).

The technological (and symbolic) potential of glassy materials was certainly recognised in Egypt and Mesopotamia as early as the 5th millennium BCE, when alkaline glaze is first attested. This was manufactured by using quartz, steatite or a mixture of both alongside some form of copper to confer a blue colour. Faience, which was attested from the mid 2nd millennium BCE, was developed from this early glaze, as it is characterised by the use of crushed quartz as the only carrier. Early glasses are not only contemporary with faience but are also directly related to it, as it is likely that they may have derived from failed attempts at glaze or faience production. The raw materials and methods for making faience and glass were already in place before they were invented: copper working in western Asia dates back to at least the 9th millennium BCE, so crude glazes were known to metal workers long before they were systematically used on pottery. Egyptian glazed vessels were produced from the Middle Kingdom (2040-1782 BCE) onwards. Conversely, the adoption of polychrome faience in the Near East occurs after the use of multi-coloured glass in the manufacture of vessels (Peltenburg, 1971). Once again, this highlights how pottery, metallurgy and glassmaking technologies are to some extent interdependent. As also observed in Section 6.7, technological inventions and innovations follow a non-linear trajectory: when experimentation with a given material occurs it is because certain physical and symbolic qualities or attributes have become important – and hence sought after – in the worldview of a society.

In this light it is then unsurprising that in Late Bronze Age Egypt glass was more likely seen as an artificial stone with magic attributes, which was likened to lapis lazuli and turquoise for the shared material properties (Peltenburg, 1971, p. 7; Tite et al., 2002; Duckworth, 2012). Because of its cultural significance, glass was manufactured in connection with religious contexts, such as temples and was used by the ruling elite to assert their power (Shortland, 2007; Duckworth, 2012). In this sense, the making of glass and also shiny artefacts in various materials and given colours may have been connected to religious and magical beliefs, becoming at times a proxy for political power (Hoecherl, 2015, p.41). As a consequence, glassmaking is not a mimetic craft, apt to imitate other more precious materials, but should instead be considered a creative and transformative act, through the selection and combination of raw materials (Duckworth, 2012).

As suggested by Shortland (2007, p. 271), a parallel can be drawn between second millennium BCE glassmakers and mid-second millennium CE alchemists, who in both cases were literate individuals who operated respectively within temples and churches. In addition, glassmakers and alchemists equally guarded their technological knowledge around the transmutation of base materials into a precious stone, be it glass or the philosopher's stone. If the secrecy of technology appears to be an important aspect in the manufacture of glass, the extent to which restrictions in the transfer of technological know-how can be observed in glass-bead making will be discussed in Section 8.1 of Chapter 8.

In essence, the manufacture of glass (and glass items especially by hot-working) in antiquity can be considered as technology of enchantment becoming enchantment of technology: this is because glass, which is technically difficult to obtain, is crafted with such skill that it appears to be created through magic, thus becoming an enchanted material. In this sense the power of glass lies in the mutability of its state, as it is a material in becoming (Gell, 2005, p. 46).

Beside its inherent shininess, glass also lends itself to polychromy: both qualities can be associated with protective functions, as attested for instance by Iron Age eye beads found in continental Europe and the Mediterranean and by the presence of photoamulets in Late Antique Near Eastern burial contexts (Duckworth, 2020a, p. 236; Giles, 2012, p. 145, p. 149; Lapp, 2021). With regards to first millennium BCE eye beads, their brilliance and contrasting colours attract the attention of the viewer by simultaneously reflecting back the light and by staring back through their 'eyes' (Giles, 2012, p. 145). This type of design is present cross-culturally, perhaps testifying to a shared appreciation and understanding of the inherent qualities of glass. In a similar but yet very different way, some Late Antique photoamulets also capture the brilliant essence of glass not only by virtue of the raw material but also by the shape, symbology and type of items that are crafted with it, such as lamp-shaped pendants and tokens, which metaphorically and physically create or interact with light. Glass tokens in particular were found in Jewish cemeteries in Jericho and Jerusalem, where individual specimens were positioned inside of the mouth of the deceased instead of a metal coin. Both tokens and coins symbolised Charon's obol, or the payment to the ferryman who would transport souls from the world of the living to the one of the dead. In addition, the placement of these objects would stop demons from entering the body, hence favouring eternal life and resurrection: the choice to manufacture tokens out of glass is due to the

inherent ability of the material to reflect and refract light, thus reinforcing its powers. Perhaps the same can be said for glass lamp-shaped pendants from 4th century CE Italy, Tunisia and Egypt, whereby the choice of material and the use of specific hues – such as green to symbolise rebirth in Egyptian contexts – may have enhanced the symbolism and the apotropaic function of these artefacts (Lapp, 2021, pp. 423-425). The spiritual and religious importance of the connection between brilliance and glass is also evident in the case of Byzantine church mosaics made out of glass tesserae, which act as a multitude of mirrors from which the light bounces off (James, 2004, pp. 527-528).

Colour is thus central to glass, and by extension to beads manufactured in this material or in materials with the same characteristics. To better appreciate the impact of colour – but also of beads – on the senses, in the following section we will explore beads as an object category in general, with a focus on symbolic culture-specific and general implications in the use of glass in their crafting.

6.10 Beads as an object category: a focus on glass beads

Across contemporary and ancient societies (glass) beads constitute a multi-faceted symbolic language, whereby visual aspects such as colour, shape and arrangement of the beads play a central role. For their intrinsic material qualities and for the fact that they can be fragmented and reassembled many times, beads have been used in economic transactions as currency in trade, as in the instance of Iroquois strings of beads known as wampum, or as bridewealth in East Africa (Graeber, 2001; Sciama 2001, pp. 16-17; Jargstorf 1995, pp. 115-116). To this day, different types of beads are worn mostly – but not exclusively – by women and children across Africa, South-East Asia and South America to embellish the body, to mark different life stages and to express ritual behaviour according to the cultural context (Sciama & Eicher, 2001; Carey, 2001; Francis, 1999, p.29; Kanungo, 2002). As such, beads can provide us with visual clues about the wearer's identity and ideals of beauty within a society.

Beside the visual importance of brilliance which has been already discussed in Sections 6.7 and 6.8 in relation to a variety of raw materials including glass, an important point to make here is that when shiny beads or garments are worn, they can come to life through the movements of the body, further reinforcing their symbolism or powers (Rivers, 1999, pp. 12-14). This could perhaps be the case for the Iron Age glass eye beads previously mentioned in Section 6.9. The spiritual power of beads or items of adornment in general could also be related to their placement on the body and hence to touch: among the Taíno, *caona* and

guanín are employed to craft ornaments which are, in death, positioned on the eyes, mouth, ears, belly button and joints, thus representing liminal parts of the body, where the material world interacts with the supernatural dimension (Oliver, 2000, pp. 203-204). Prayer and worry beads, which have a protective function, are employed in rosaries in Catholic Medieval Europe and are in use among other religions such as Islam, Hinduism and Buddhism. The importance of these beads, however, resides in their tactility as they can be run through the fingers in moments of stress producing a soothing effect (Sherr-Dubin 2015, pp. 79-92). Touch – and sound – are very important senses in the negotiation of female identities through beads in the Ashanti region in southern Ghana. Mothers adorn their infant daughters with beads strung around their hips, wrists, ankles, calves and forearms, as the beads – by means of physical contact – will help in the development of a beautiful body which is apt for bearing children. Waist beads, or *tomoma*, are an integral part of the female dress and are connected to sexuality and fertility (Gott, 2007, pp. 84-87). One or multiple strands of precious glass beads rest on the hips and pelvis and are traditionally worn under clothing, so that their power can be concealed. A change in fashion occurred in the 1980s, when young women in the Asante capital of Kumasi started to wear looser fitting waist bead strands under dresses, which not only made them more visible, but the beads would also clack together imparting a more sensual gait. In this instance the auditory and visual qualities of the beads are particularly enticing to men (Gott, 2007, p. 84).

The physical qualities and attributes of beads and the specific ways in which societies interact with them appears to be a determinant factor in their transmission as heirlooms. When beads are deemed powerful, they are passed down from one generation to the next, very often following very specific trajectories: in the instance of matrilineal societies such as the Kalabari in Nigeria, the eldest women in the lineage are the keepers and administrators of the beads, whereas among the Kelabit in Sarawak, Borneo, beads are inherited exclusively through women (Eicher 2001; Janowski 2001). Even in the case of heirlooms, the involvement of the senses – in particular vision, with the presence of a specific colour, and touch – appears to be very important: for their wedding necklaces the Samburu in Kenya use *mporo* beads, which are Venetian trade specimens with a white core and a red outer layer replacing earlier carnelian beads. Signalling abundance of cattle and children, thus womanhood and the ability to conceive, *mporo* beads are inherited by women from their mothers and contain the body's *latukuny* (dirt) of many generations who successfully gave birth to children. The ownership of *mporo* and non-*mporo* beads will fluctuate during one's

existence, with old women and babies not possessing any beads, as they embody the fragility of life by having entered or being about to leave this world. In addition, *mporo* beads should not be sold to acquire food, as that would imply eating one's *latukuny* and hence fertility (Straight, 2002).

Materiality becomes then a proxy to understand how ancient societies interacted with glass beads, allowing us to detect potential signs of emotional attachment deriving from memories related to their production and to the embodiment of technological knowledge or from personal relationships through use. This is especially important in the study of societies that do not use any written sources. Signs of wear, breakage or repair – but also the fragmentation or curation of bead sets – are markers of these relationships and the memories thereof, creating bonds that not only last through time but that can also be recognised as such by a community (Foxhall, 2012, p. 186; Tarlow, 2012, p. 180). As for colour perception (Section 6.2), emotions also are grounded in both nature and culture: it is of course easier and more fruitful to direct our efforts towards valuations of emotions that affect societies as collectives, rather than focusing on the micro-scale. In this latter case we can perhaps hypothesise the emotional importance of an object, but we would not be able to pinpoint what type of feelings or memories it would have elicited in an individual (Tarlow, 2000, p. 728).

6.11 Conclusions

As we have seen, the way colour is conceptualised, discussed and perceived results from the interplay between human physiology and culture-specific attitudes. Colour and brilliance, durability and transportability are some of the main prerogatives of glass beads. The uniqueness of glass as a material resides in its artificiality and in the fact that it can be intentionally manipulated to enhance the most prized or valued characteristics such as shine, but also to obtain specific shapes and/or hues that are relevant in a given cultural context. The involvement of the senses must have played a central role in the manufacture of glass and glass objects and their use: glass-makers, glass-workers and bead-makers would have had a very different sensorial experience when compared to the final users of beads. In some contexts such as LBA Egypt we can presume that glass bead consumers understood and appreciated the 'magic' behind this type of technology, whereas we cannot be sure that this may have occurred in pre-roman Abruzzo.

The role of memory and emotions in connection to the senses is also key in the creation of associations between given colours and shapes: as such, certain beads may have become heirlooms as they would evoke specific feelings. The implications of the relationship between bead shape and colour – which could either result in the curation and re-distribution of beads or in their withdrawal from circulation – will be explored in Chapter 7, in the context of Iron Age glass beads from the burial sites of Campovalano, Fossa and Bazzano (Abruzzo, Italy). In this case, we hope that by analysing bead colour combinations, the position of beads on the body alongside the presence or absence of particular items in the grave good make-up, we can shed light as to whether beads were markers of specific identities.

Chapter 7. Use of colour in glass beads: the case-study of Iron Age Abruzzo, Italy

This chapter discusses the use and significance of colour in glass beads from the Iron Age cemetery sites of Campovalano, Fossa and Bazzano located in Abruzzo, central Italy. This chapter is divided in three main sections: first an archaeological background to the sites that are part of the case-study is provided so that the evidence in relation to glass beads can be contextualised in the wider frame of pre-Roman Italy and within the relevant subject-specific scholarship tradition. The second part will illustrate the research questions and the recording methods applied to detect the presence of meaningful glass bead colours and combinations thereof. Lastly, the glass beads from Campovalano, Fossa and Bazzano will be analysed by taking into account burial rite, bead configuration, the presence of beads in other materials and other factors such as age, gender and sex of the deceased.

a) Archaeological background

7.1 The burial sites of Campovalano, Fossa and Bazzano in the wider context

The 1st millennium BCE cemetery sites of Campovalano, Fossa and Bazzano are located in the modern-day central Italian region of Abruzzo (Figure 7.1). Campovalano is located approximately 6 km to the west of the modern municipality of Campoli in the province of Teramo: while this site, which lies on a plateau at the foot of the Mountain of Campoli that forms part of the range of Monti della Laga, is approximately 30 km from the Adriatic coast, Fossa and Bazzano are only 4 km apart and are both situated further inland in the province of L'Aquila, on the floodplain of the river Aterno in the basin known as conca Aquilana.

These cemetery sites are multi-phase: their chronology spans from the Orientalising-Archaic period (end of 8th century BCE-beginning of 5th century BCE) up to the Hellenistic and Roman periods (4th century BCE-1st century CE), with Fossa also presenting an early Iron Age phase (9th century BCE - first half of 8th century BCE). Across the three sites glass beads were found nearly exclusively in female and child burials, the majority of which are dated between the 7th and the 3rd centuries BCE.

In addition, certain aspects of the material culture in Fossa, Bazzano and Campovalano are shared, such as the presence of specific types of weapons (dagger *a stami* or with a hilt which resembles in shape the stamens of a flower, spear-heads etc.), items of adornment

(brooches, chatelaines, pendants, belts) and imported and locally made vessels (for further discussion see Sections 7.1-7.4).



Figure 7.1: Map of modern-day Abruzzo with sites indicated by purple dots (Background map: Ruthven <https://creativecommons.org/licenses/by-sa/4.0/>).

These similarities are due to underlying factors such as regional and supra-regional interactions. The latter can certainly be observed for the Orientalising period, when wealthy local aristocracies across the Mediterranean – including the ones from Campovalano, Fossa and Bazzano – controlled primary resources such as land and raw materials, which were exchanged for (luxury) imports hailing from the East. The existence of such trade networks and non-commercial relationships, is also visible in the grave good make-up of our sites, as lavish goods and objects connected to feasting, banqueting and more widely to eastern royal customs are present in the record (Riva, 2003, p. 71).

With regards to local material culture elements, the discussion becomes more complex as specific groups of artefacts are not only seen as corresponding to given pre-Roman ethnic

groups, but the latter are also discussed on the basis of 1st century CE literary sources such as Pliny and Strabo who modelled their narrative on contemporary Augustan regions, describing already Romanised indigenous people. Although the relevant literature tends to follow Pliny's nomenclature of the various *ethne*, whereby the people from Campovalano are often dubbed as *Praetuttii*, and the sites of Fossa and Bazzano are attributed to the *Vestini Cismontani*, here it has been chosen instead to refer to the respective geographic areas to avoid any misattributions (Naso, 2000, p.45; Scopacasa, 2016; 2015, p.109; Weidig, 2014, p. 14; Menozzi & Acconcia, 2015, pp. 519-521; Bradley & Farney, 2015).

Ethnic and linguistic boundaries did of course exist in Iron Age Italy, although in all likelihood they were fluid and their importance was context-dependent (Naso, 2000, p.45; Scopacasa, 2016; 2015, p.109). In this light, the borders of Picenum, which is the area roughly equivalent to the modern-day Marche region and northern Abruzzo, constantly shifted (Figure 7.2). This mutability is further exacerbated by how the archaeological and literary datum is interpreted: at times the southern boundary of Picenum is set to the river Aterno, hence including Campovalano in its territory, whereas in other instances it has been deemed the Tronto river, which broadly corresponds to the Marche-Abruzzo border (Naso, 2000, 23-26; Weidig, 2014 p.13). As a result, on the basis of its material culture, Orientalising-Archaic Campovalano displays an identity that is yet to be pinned down, as this area was likely inhabited by groups stemming from inner central Italy (Sabina) who in this case shared some traits with the middle Adriatic area, which comprises the coasts of Marche, Abruzzo, Molise and Dalmatia (Riva, 2007, p. 81; Chiaramonte Treré, 2003, p. 484; La Regina, 2011; Weidig, 2014, pp. 13-14).

In any case it has to be noted that, especially in the instance of pre-Roman populations in central Italy, it is not always possible to detect ethnic identities using classes of artefacts: this is the case for weapons as they have a broader regional distribution, hence they are not markers of specific local identities (Benelli, 2015, p. 93).

Similarly, the peoples from Fossa and Bazzano, who were settled in central Abruzzo along the upper Aterno Valley and the western slopes of the Apennines, were tied to the Sabina, although in this case stronger connections with the Tyrrhenian area are present, as testified by the ceramic assemblages and Etruscan imports from both sites dating to the Iron Age (Menozzi & Acconcia, 2015, pp. 519-521; Benelli, 2015, p. 93).

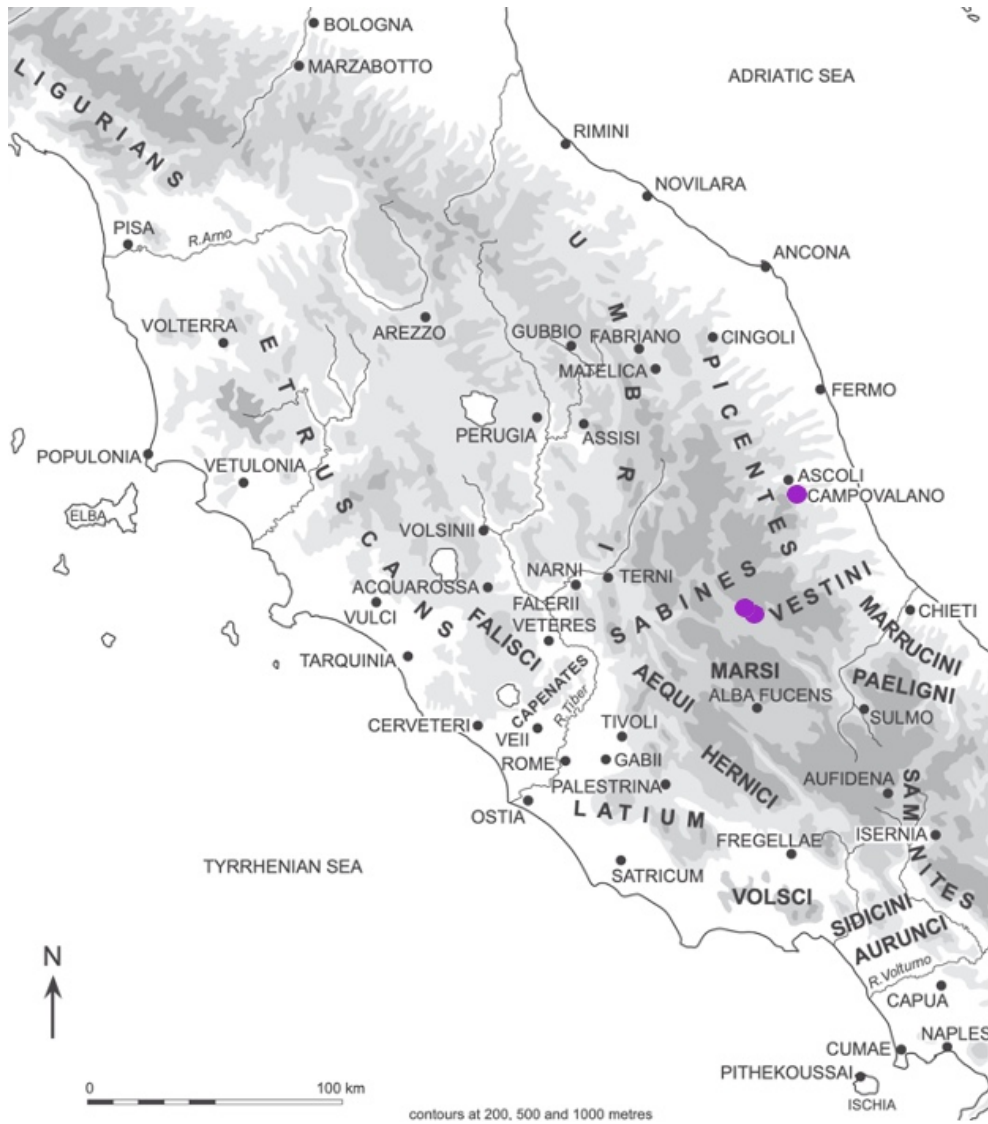


Figure 7.2: Map of pre-Roman central Italy with its peoples. The sites of Campovalano, Fossa and Bazzano are indicated by purple dots (Farney & Bradley, 2015, p. 7. © Cardiff University Archaeology Department, illustrations by Ian Dennis).

As testified by inscriptions which not only bear ethnic names but are written in different local languages, between the 6th and 5th centuries BCE the presence of individual cultural groups in Picenum (including its southern portion and thus northern Abruzzo) becomes more marked. However, changes of a socio-political nature will continue through to the end of the 5th and the beginning of the 4th centuries BCE, when the economic power will be exerted by the middle class, rather than by the aristocracy (Menozzi & Ciarico, 2015, pp. 580-581). This will of course be visible in the grave good make-up of Hellenistic Fossa, Bazzano and Campovalano, as discussed in Sections 7.1-7.4. If the expansion of Rome, which started in the 5th century BCE, was on the one hand one of the key underlying drivers for territorial and ethnic re-organisation, especially for the peoples settled in the mountainous areas of

Abruzzo, on the other hand other contributing factors are the arrival in South Picenum of the Gaul Senones from the Seine basin in France alongside the foundation of Ankon (modern-day Ancona, Marche) by the Greeks from Syracuse (Menozzi & Ciarico, 2015, pp. 580-581; Menozzi & Acconcia, 2015, p. 521).

The Hellenistic period in Abruzzo (mid 4th century BCE to 1st century BCE) appears slightly foggy, as currently there are not many excavation data for this phase. For the site of Fossa – and implicitly for Campovalano as well – Copersino & d’Ercole (2003, p. 335) suggested a sub-division of the Hellenistic period between an Italic and a Roman phase: the Italic-Hellenistic period starts with the Samnite wars and ends with the second Punic war, ranging between the second half of the 4th century BCE and the third quarter of the 3rd century BCE. The Samnite wars are particularly important in the history of pre-Roman Abruzzo, as during the first and second war (343-341 BCE and 326-304 BCE) the peoples from the upper Aterno valley fought against Rome alongside the Samnites, who lived in the inland territories of modern southern Abruzzo, Lazio, Campania and Molise. With the third conflict (298-290 BCE) however, the peoples from the area of Fossa and Bazzano became allies of Rome (Menozzi & Acconcia, 2015, p. 521). The Roman-Hellenistic phase dates between the end of the 3rd century BCE and the beginning of the 1st century CE, or between the second Punic war and the death of Augustus (Copersino & d’Ercole, 2003, p. 335). This distinction in sub-phases will not be used here, as glass beads are not found in contexts that are later than the 3rd century BCE.

The main interpretations of the archaeological evidence collected thus far for each site will be reported in the following sections. However, we have to be aware that they stem from a type of scholarship that is traditionally rooted in a cultural historical approach which is often combined with binary assumptions – such as rich versus poor, man versus woman, etc. – somewhat rooted in present (western) economic, cultural and social models. This is not to say that all observations are completely wrong but they may be more nuanced than expected in reality. This is evident in the fact that it is unclear if certain grave good categories signal affiliation to particular age groups, prestige and/or gender, and to which degree. In addition, we have to be wary of how gender and sex are being discussed in the monographs for the sites: on the one hand, beside grave goods, the dimensions of the grave are also considered an indicator of gender (and age), as usually they reflect the height of the individual at death, with women and children usually smaller than men (Cosentino et al.,

2001, p. 187). It is important to note that grave dimensions may be dictated by sexual dimorphism and hence by the average difference in height between adult males and females, which means that this criterion should not be used to assign gender. In addition, grave size may be dictated by other factors such in which position the individual was interred (e.g., whether the legs were slightly flexed or not). On the other hand, although the results of osteological analyses carried out on the burials of Campovalano, Fossa and Bazzano are reported in dedicated chapters and individual catalogue entries of each publication, sex and gender are usually conflated into one category in the general discussions. Although far from ideal, we have to accept (binary) interpretations of gender, as whenever the osteological sex of individuals could be established, this would match with the expected grave good and/or grave dimension binaries. To avoid any ambiguities between sex and gender, in the following sections we will refer to gender only.

7.2 Campovalano: the site and its glass beads

Although scattered finds were first retrieved at the end of the 19th century, excavations at the site began in 1963 with superintendent Adriano La Regina, after local farmer Luigi Cellini accidentally unearthed artefacts pertaining to a burial when ploughing his field. From 1967 until 1975 several Orientalising-Archaic burials were excavated under the direction of Valerio Cianfarani, who was the superintendent to the *Antichità dell’Abruzzo e del Molise*. Two years later, the fieldwork overseen by Gaetano Messineo led to the discovery of thirty additional burials. Unauthorised construction works carried out between 1981 and 1984 prompted superintendent Vincenzo d’Ercole to conduct rescue excavations, which resulted in the opening of the archaeological museum in Campoli. This kickstarted a project designed to enhance the site by undertaking further excavations, which occurred between 1990 and 1997 with d’Ercole as a director, after the acquisition of 4 ha of the area of archaeological interest by the Italian state (d’Ercole, 2003a). As a result of the prolonged research activity which covered approximately 1.5 ha, c. 621 graves, the majority of which ascribed to the Orientalising-Archaic and Hellenistic phases, have been unearthed so far (Table 7.1): as the site is not fully excavated, the estimate of their final figure is at the least in excess of a thousand (di Donato, 2019, *pers. comm.*¹¹).

¹¹ Leandro di Donato is the director of the museum of Campoli.

Burials n=	Chronology	Periodisation
257	c. 800 BCE- 500 BCE	Orientalising-Archaic phase
269	350 BCE- 100 BCE	Hellenistic phase

Table 7.1: Burials in Campovalano divided per phase. The burials without grave goods are not included in the count.

As shown in Figure 7.3, the majority of burials dating to the Orientalising-Archaic phase are located to the west of the main road running across the cemetery roughly from north-west to south-east.

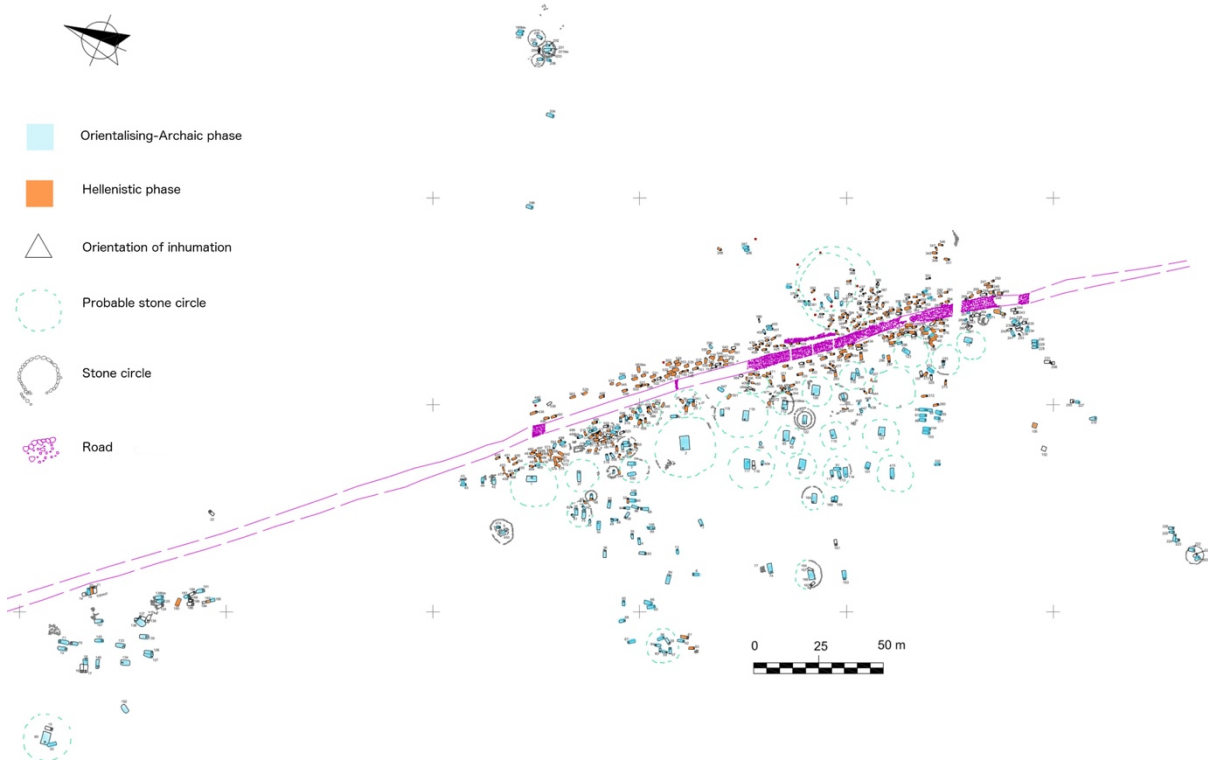


Figure 7.3: Plan of main area and phases of Campovalano. The burials that are outlined in black did not yield any grave goods (after Chiaramonte Treré et al., 2010; d’Ercole et al., 2016, appendices on CDs).

Tombe a fossa, or simple cut graves with variable dimensions and orientation are the most common attestation, although burial mounds with a stone circle or ring ditch (*tumuli con crepidine*) measuring between 4m and 25m in diameter and equally destined to adults and children, are also recorded especially for the Orientalising period (end of 8th-7th century BCE). Perhaps in virtue of the relevance of kinship, some of these tumuli were also re-used during the archaic phase (6th-5th century BCE), when new adult and child burials were either cut into

the top of the mound or cut the stone circle (d'Ercole, 2003b).¹² Conversely, newborns and infants received a slightly different treatment in death, as they were always buried along the outer perimeter of the stone circles (Chiaramonte Treré, 2010a, p. 3). Double circles are also attested from the Archaic phase: in all likelihood the addition of another circle was devised to host further individuals belonging to the same family, thus extending the size of the original grave (d'Ercole, 2003b, p. 7). Evidence from the 5th century BCE is scant, as only a group of four burials (TT. 1,42,45) was recorded to the west of the road. From this period until the end of use of the cemetery, simple cut graves are the only burial type documented. The majority of Hellenistic burials are concentrated in four groups on either side of the road, as observed for the Orientalising-Archaic period (Martellone, 2016c, p. 141). The area of the first cluster, which is situated in the southernmost portion of the site, was initially reserved for female burials, but after the 3rd century BCE also hosted male and child graves. With the exception of newborns interred in the same sector as Orientalising-Archaic period infant graves, the remaining adult and child burials, which have the same alignment as the road do not physically interact with earlier tumuli and are following the road alignment (Martellone, 2016c, pp. 149-150). Conversely, the second group, which is located further north and was exclusively dedicated in the first Hellenistic phase (half of 4th beginning of 3rd century BCE) to male burials, is physically connected with Orientalising tumuli, as north-south oriented graves are either in their close proximity or cut into the circle of the mound. In addition, a group of child burials was documented west of the road (Martellone, 2016c, pp. 150-151). A third and a fourth group, respectively characterised by burials to the east and west of the road and by the presence of T. 604, were also located further north, 40m and 90m from the second sector (Martellone, 2016c, p. 141).

During the Orientalising-Archaic period there appears to be variability in the number and richness of grave goods, which has been interpreted as an indication of social differences (Boccolini, 2003, pp. 153-156). Male identities – both in the case of children and adults – are exemplified by a panoply comprised of a single dagger, one mace and two spearheads (d'Ercole, 2003b, pp.6-7). Female burials are equipped with ceramic and – less frequently – copper alloy vessels, such as basins and cauldrons, which are usually placed by the feet. Elements of dress are usually found in their original position on the body and comprise of

¹² D'Ercole (2003b) refers to 'blood ties' rather than kinship. As there is no textual or other type of evidence (e.g. aDNA studies) that point towards an idea of family revolving around 'shared blood' we will use the term kinship to highlight the fact that this is a culturally specific social practice.

necklaces in amber, glass, metal and bone, iron or copper alloy (and very rarely silver) armbands or *armillae*, brooches, bangles and rings. Other indicators of gender are openwork metallic belts and objects connected to spinning and weaving such as bobbins and spindle whorls (Boccolini, 2003, p. 153-156). Independently from the level of wealth displayed by the grave goods, adornments with likely apotropaic or protective value such as copper alloy hand-shaped pendants, wild boar tusks, animal teeth and conch shells encased in metallic wire were found in female burials as shown in Figure 7.4 (Boccolini, 2003, pp. 156-159; Chiaramonte Treré, 2003, p. 471-473). Pendants in composite materials are also exemplified by a Neolithic polished green axe in filigree with a conch shell on either side and bone or ivory plaques with copper alloy droplets. Some pendant types appear to be markers of age: *bullae*, or hollow spherical pendants in metal containing small seeds or stones that would rattle are recorded in 30% of female burials, especially of young individuals. Amber and bone are also used to manufacture pendants in the shape of *bullae* (Buoite, 2010, pp. 204-205). On a general note it appears that only female burials contain rare or imported objects such as Baltic amber, conch shells from the Red Sea, Egyptian scarabs, shoes from Etruria and glass distaffs, with the latter being found in both T. 119 and 415 (Boccolini, 2003, p. 155).



Figure 7.4: Pendants in metal and other materials from Orientalising-Archaic Campovalano, TT. 115 and 127 (Chiaramonte Treré et al., 2010, appendices on CD rom).

During the Hellenistic-Italic phase (mid-4th century BCE - mid 2nd century BCE) grave goods, which are not always encountered, contract and become standardised: male identities are expressed in particular by the spearhead and the *sauroter* (spear foot) found in the graves of adults and children, whereas female burials are characterised by a wide variety of items of adornment such as glass, amber and gold necklaces and beads, finger rings, brooches and bangles. Other grave goods comprise of one vessel, placed by the feet of the deceased, and a

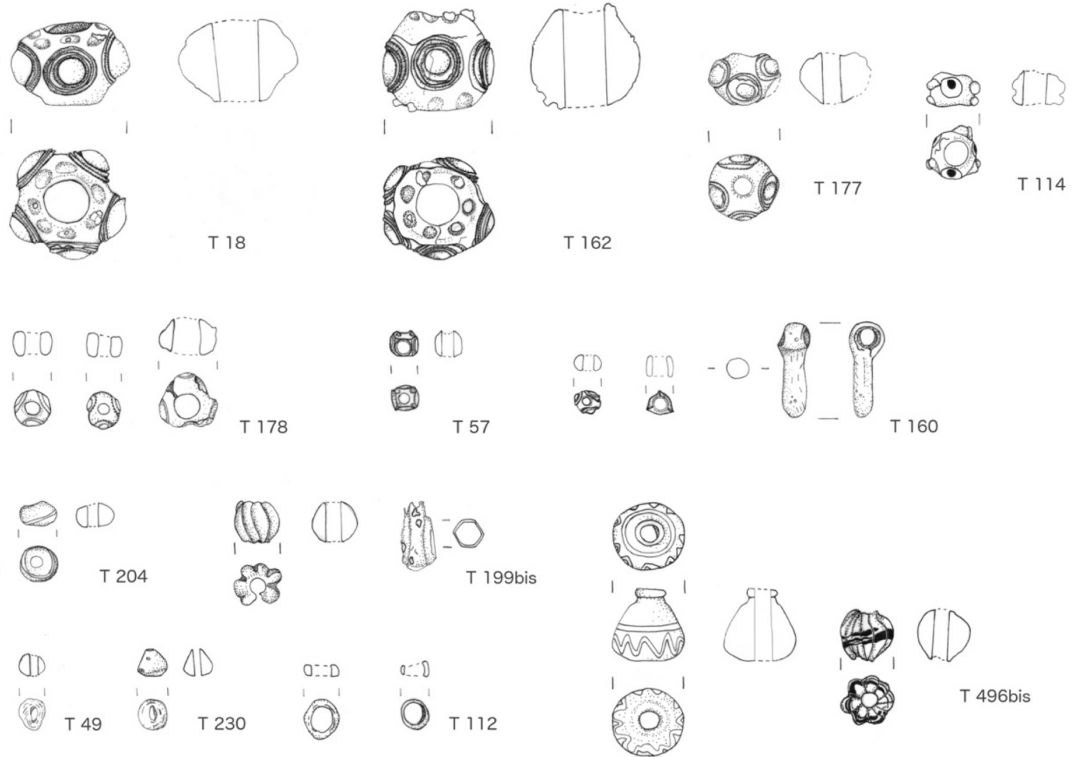
toiletary set. The type of vase and of personal hygiene items, which changes over time, is differentiated according to the gender of the deceased (Martellone, 2016a, pp. 135). This period is also characterised by the introduction of La Tène material cultural elements, which are found in all burials irrespective of social class and are exemplified, amongst the other things, by amphora-shaped glass beads and a glass bangle of type Haevernick 8/a (Martellone, 2016a, p. 136, b, pp. 139-140, c pp. 143-144; Haevernick, 1960). It is unclear if this phenomenon reflects the adoption of a new fashion or customs borrowed from the neighbouring Senones from *Picenum*, or if it is due to Celtic people settling in the territory of Campovalano who mixed with the local population (d'Ercole, 2016, pp. 162-163).

The Orientalising-Archaic and Hellenistic glass beads used here as case-study material come from later excavations and in particular from the campaigns directed by Cianfarani, Messineo and d'Ercole in 1981-1984/1990-2012, with the bulk of Hellenistic burials containing glass beads found between 1990 and 1997. All of the 1st millennium BCE beads from Campovalano examined in the present work were retrieved in simple cut graves, some of which, especially during the Orientalising-Archaic period, are located within stone circles which also enclose other burials (as seen for TT. 51, 57, 60, 75, 114, 162, 212) or are organised in clusters, as is the case for TT. 49, 72, 103, 176 (See Appendix F). A number of Orientalising-Archaic burials were cut by or partly obliterated other graves, with TT. 167, 496, 592 all situated within tumuli and TT. 112, 126, 127 in close proximity to other contemporary burials. For this period glass beads from four male graves (three adults and one infant) are also recorded (Buoite, 2010, p. 210). For Hellenistic period burials, no particular spatial relationships are highlighted, with the exception of TT. 53, 311 and 537, whereby these graves are situated in areas previously occupied either by single individuals or by likely family groups.

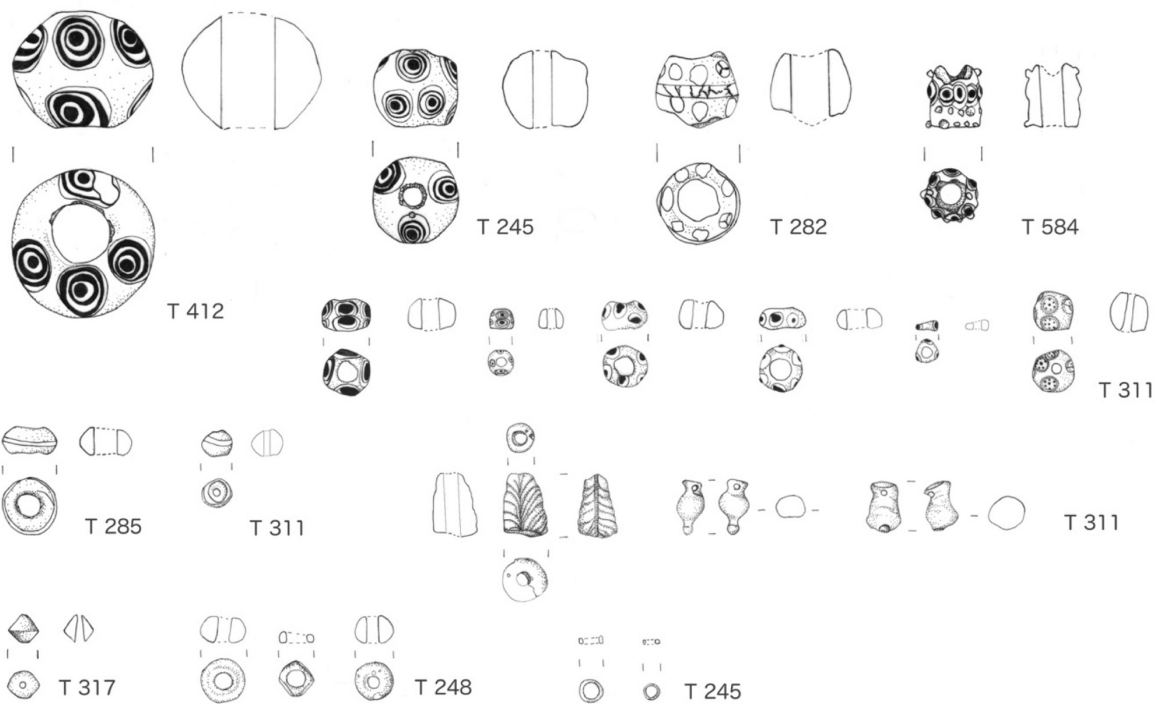
Annular, globular and cylindrical monochrome glass beads are more frequent than polychrome specimens. Glass beads were either worn as necklaces, and were also employed to decorate brooches and to craft garments, as seen for T. 119. According to the grave good catalogue, it is reported that glass beads were also used in bracelets (T. 158) and in pins (Buoite, 2010, p. 210). As illustrated in Figure 7.5, eye beads of various types, which have also been recorded for the Marche area (Bracci, 2007), are present. The most common type among this group is the one with so-called 'equally spaced eyes' (*ad occhi equidistanti*), found in TT. 60, 94, 176, 177. Pear-shaped or truncated cone beads, similar to types from the contemporary site of Capecstrano in the province of L'Aquila, are less frequent and are

encountered in TT. 257, 230,127,212 and 496bis (Buoite, 2010, pp. 210-211; Acconcia, 2018, pp. 136-138). Melon beads are also attested in T. 469bis (here with a horizontal trail) 578 and 199, although in this latter case this specimen – alongside the tubular pendant – may be part of a glass distaff, as further highlighted in Section 7.7.1. Drop pendants from TT. 72 and 160 with cubic and triangular beads, respectively occurring in TT. 60 and 162 and in TT. 167,176 and 60 appear to be typical of Campovalano (Buoite, 2010, p. 210). Hellenistic glass beads, which will disappear with the Romanisation of northern Abruzzo, date between the 4th and the 3rd centuries BCE and include (but are not limited to) a variety of eye beads, human mask pendants of likely Punic provenance, amphora-shaped beads and small biconical beads (Martellone, 2016a, p.136, b, pp. 139-140, c, pp. 143-144).

Orientalising-archaic phase



Hellenistic phase



Scale 1:1 0 5 cm

Figure 7.5: Selection of glass bead types for Orientalising-Archaic and Hellenistic Campovalano (drawings author's own – for complete dataset consult Appendix X)

7.3 Fossa: the site and its glass beads

Discovered in July 1992, 2.5 km from the modern town of Fossa during works commissioned by Edil Abruzzo and Abruzzo Acciai for the construction of industrial buildings, the site was promptly brought to the attention of the Soprintendenza Archeologica dell'Abruzzo. As a result, in 1992 and 1993 Inspector Alessandro Usai excavated trenches A-H alongside a number of sondages, unearthing several burial mounds (Cosentino et al., 2001, pp. 14-16). In 1995 then superintendent V. d'Ercole extended Trench A into an open area for further investigations, as eight tumuli were previously recorded: excavations took place regularly until 2000, the results of which were published in the site monographs (Cosentino et al., 2001, pp. 17-26). After a brief campaign in 2010 (Acconcia & D'Ercole, 2012), fieldwork resumed in 2019 under the direction of d'Ercole thanks to the joint effort of the Soprintendenza Archeologia Belle Arti e Paesaggio per L'Aquila e i Comuni del cratere, Università degli Studi dell'Aquila and the municipality of Fossa (d'Ercole, *pers. comm.*).

The excavations undertaken during the mid and late 1990s, which covered an area of nearly 5000 sq m, allowed archaeologists to observe diachronic changes in terms of burial structures and spatial distribution of the graves (Figure 7.6; Cosentino et al., 2001, p. 21).

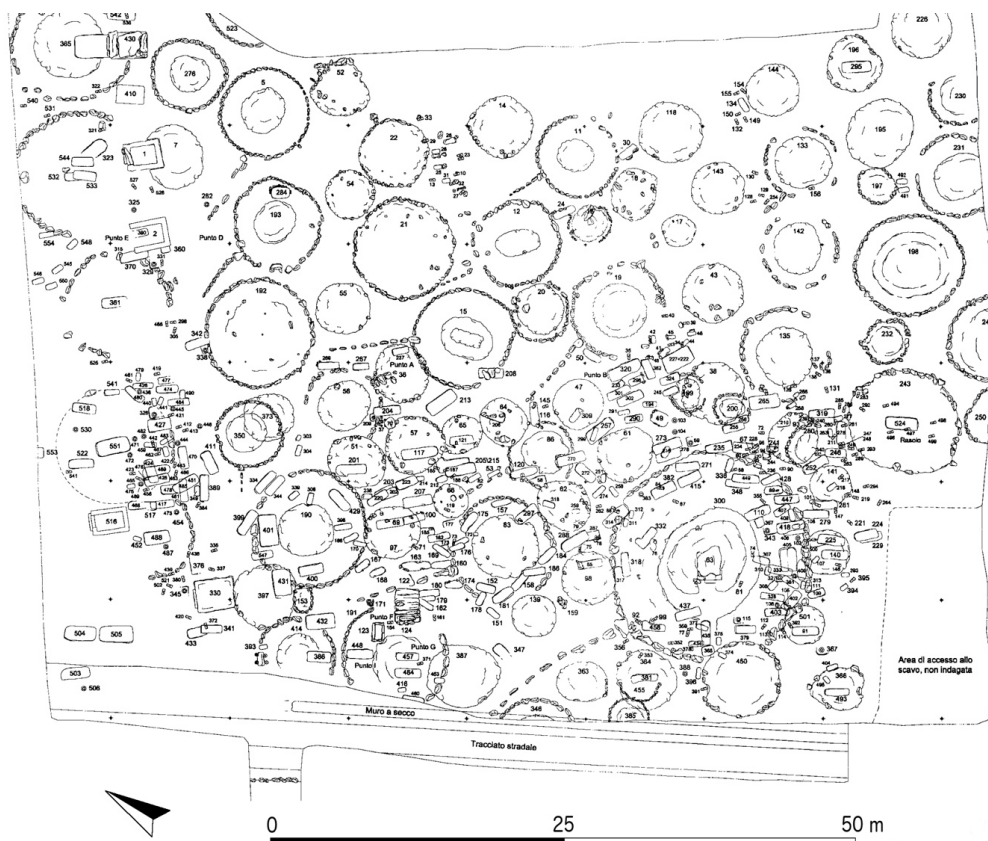


Figure 7.6: General plan of Fossa (Cosentino et al., 2003, p. 9).

In particular, as shown in Table 7.2, three main periods of use of the site were detected, which are represented by the Early Iron Age (9th century-mid 8th century BCE),¹³ the Orientalising-Archaic phase (second half of 8th century BCE-6th century BCE) with a combined total of c. 216 burials, and the Hellenistic phase (mid-4th century BCE-1st century BCE) with c. 150 burials (Fattore & Mancinelli 2003, p. 277; Cosentino et al., 2001, p. 191; Copersino, 2003, p. 307).

Burials n=	Chronology	Periodisation
41	1000-750 BCE	Early Iron Age phase
177	850 BCE-500 BCE	Orientalising-Archaic phase
150	350 BCE-100 BCE	Hellenistic phase

Table 7.2: Burials in Fossa divided per phase. The estimated total reported at the time of the publication of the monograph is of 551 burials across all phases, which presumably takes into account adult and neonatal burials with no grave goods (respectively n=not specified and n=162), both not included in the table (Cosentino & Mieli, 2003, p. 254; pp. 266-272).

The earliest Iron Age burials consist of mounds delimited by a stone circle (*tombe a tumulo con crepidine di pietre*), whereby the stones are either placed vertically or laid flat. These mounds measure 5 to 10m in diameter, although there are exceptions such as T. 300, located in the southern corner of the excavation area, which is 18m wide (Cosentino et al., 2001, pp. 26-28). The spatial distribution of burials and the presence (or absence) of prestige items such as copper alloy basins and pins within the grave goods, led to the hypothesis of the existence of two or three family groups, concentrated to the east and west of T.300. This particular mound was in all likelihood the focal point of the cemetery site during the Early Iron Age, although in the 8th century BCE new groups of tumuli, which are not necessarily linked to T. 300 in a direct manner, start to appear (Cosentino et al., 2001, pp. 204-211).

Albeit of smaller dimensions, burial mounds are also built – often around earlier specimens – during the Orientalising period. Simple cut graves (*tombe a fossa*) appear in this phase and completely replace tumuli during the Archaic period (6th century BCE): in some instances, simple graves are radially distributed around the burial located at the centre of Early Iron Age mounds, at times cutting the stone circle, as is the case for T. 300 (Cosentino et al., 2001, pp. 26-28). More frequently, simple graves are placed between Orientalising tumuli, thus forming alignments and groups, as is the case for some child burials in the central portion of

¹³ The Early Iron Age was also sub-divided into phase 1A and 1B (respectively 9th and 8th centuries BCE), whereas phase 2A (end of 8th century BCE-beginnings of 7th century BCE) roughly corresponds to the start of the Orientalising period (Cosentino et al., 2001, pp. 174-177).

the excavation. Other contemporary graves are parallel to the north-west south-east aligned road to the south, which was still in use during the Roman period. Neonatal burials either within two roof tiles (*coppi*), a wooden container or a stone cist are attested from the mid 6th century BCE, as suggested by their strong spatial association with adult burials dating to the Archaic period (Figure 7.7). This trend, which is also observed in nearby Bazzano, continued into the Roman-Hellenistic phase (Cosentino & Mieli, 2003).

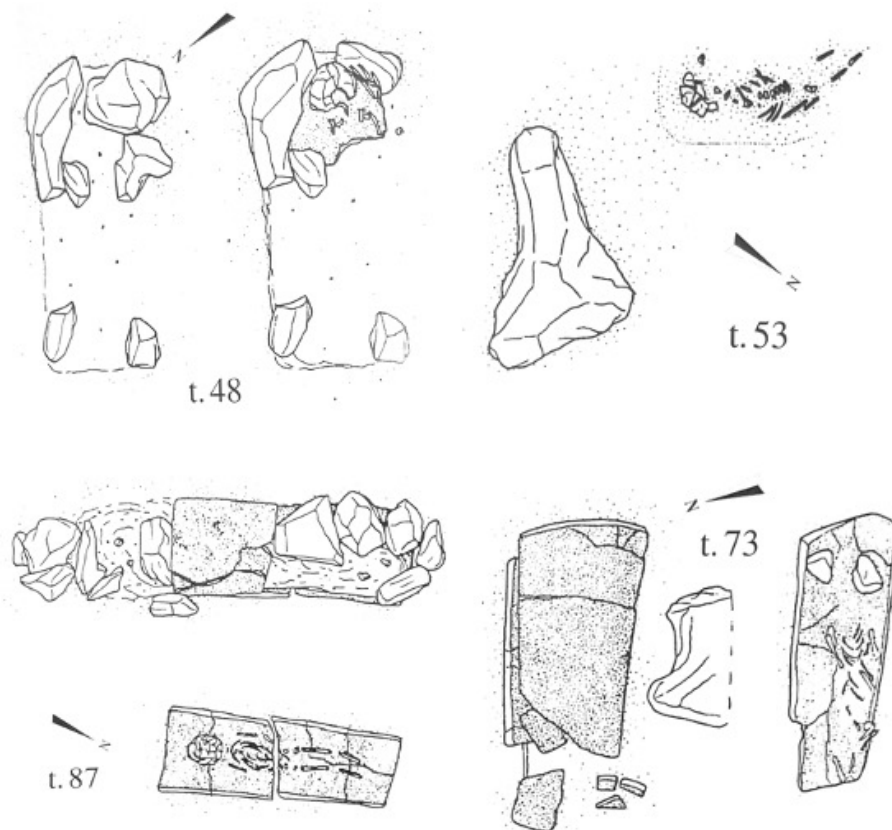


Figure 7.7: Neonatal burials in Fossa. TT. 48 and 53 are simple graves, whereas TT. 87 and 73 are inhumations placed between two roof tiles (Cosentino & Mieli, 2003, p. 257).

In the Hellenistic period, beside simple cut graves, which were still the most common, new grave types are recorded: large rectangular cist burials (*tombe a cassone*) appear at the end of the 3rd century BCE, followed by square chamber tombs (*tombe a camera*) hosting multiple individuals from the same family, which are documented from the beginning of the 2nd century BCE onwards (Copersino, 2003, pp.307-308, p.311). The coexistence of different architectural designs from this point in time onwards suggests that social stratification was present, with simple cut graves, cist burials and chamber tombs respectively belonging to the lower, middle and upper classes (Cosentino et al., 2001, pp. 26-28). In addition, luxury items such as funerary beds made out of carved bone were adopted by the local aristocracies of Fossa, Bazzano and the Aterno valley in general from the 1st century BCE until the start of the

imperial period, when, despite the uniformity of funerary customs across the Italian peninsula, inhumation – rather than cremation – was still the prevalent rite in this area (Copersino, 2003, pp. 316-317; Menozzi & Acconcia, 2017, p. 536). The spatial distribution of Hellenistic burials in Fossa appears to reflect kinship, as testified by the existence of one group of graves situated roughly to the south-east and by two clusters to the south-west of the excavation area. It is also worth noting that most graves appear to delimit areas in use during earlier periods, at times partly obliterating tumuli (Cosentino et al., 2001, pp. 26-28).

Male identities in death are deeply tied to the image of the warrior which is symbolised by the inclusion of swords, spears and javelins in adult male graves. Since weapons have also been found in child burials it may be that such items were kept within the same family, thus reflecting a social asset based on kinship. More generally, gendered grave goods appeared among the subadult population from the beginning of the orientalisising period (Acconcia & D'Ercole, 2012, p. 31; Cosentino et al., 2001, pp. 177-180, p. 187; Scarsella, 2019). Early Iron Age female burials are characterised by the presence of open work metal discs, copper alloy cups (*tazza-attingitoio*) and various brooches, always including a type with a composite amber and bone beaded bow. Regardless of the age of the deceased, amber and/or glass bead necklaces are often found in primary deposition in both adult and child graves. Glass, which initially appears to be more common, was overridden in popularity by amber during the orientalisising period. Albeit rare, other objects found which are attributable to the female gender are belt elements, pins and knives (Cosentino et al., 2001, pp. 180-182). Individuals belonging to the elite are often buried with vessels and utensils used in feasting and banquets, following Greek and Etruscan aristocratic customs (Menozzi & Acconcia, 2017, p. 536).

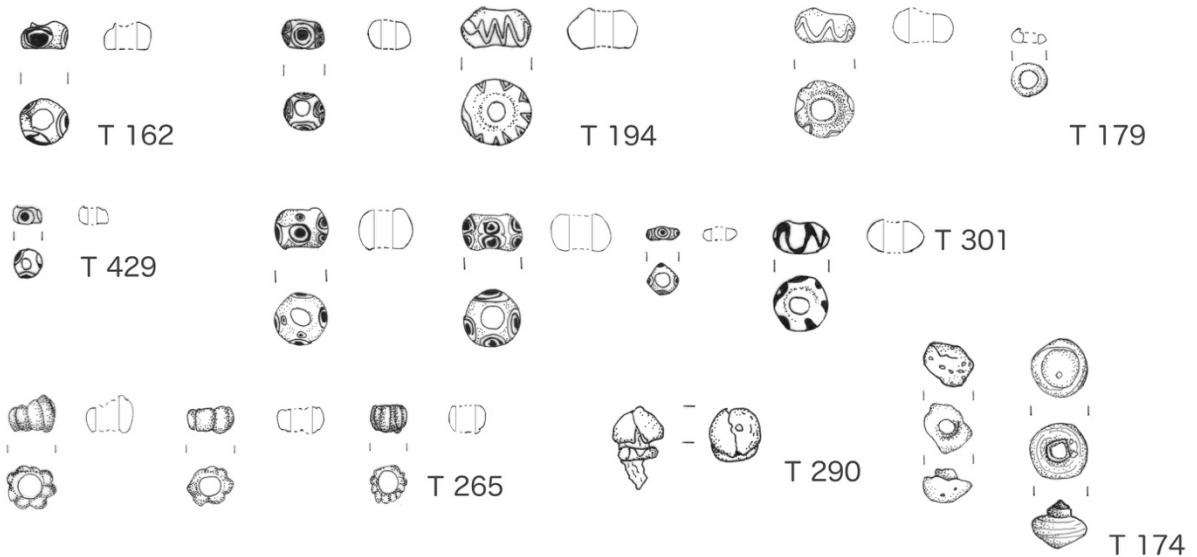
There are no burials that can be securely dated to the 5th century BCE: a relative chronology was established through stratigraphic relationships whenever possible; however, some burials have no grave goods, whereas others contain objects such as brooches and *armillae* that are broadly dated between the 6th and the 4th centuries BCE (Benelli & Rizzitelli, 2003, pp. 322-323). It is only with the beginning of the Hellenistic phase that diagnostic grave goods, such as *Gnathia* style vases, which are a type of black varnished ware typical from Apulia with painted patterns and/or figures, are recorded. Such pottery imports, alongside locally-produced drinking wares provide us with information on the social standing of the deceased. Elements of cultural continuity are represented by brooches, armbands, necklaces

and rings, with the latter crafted in copper alloy for women and in iron for men. Both genders are buried with toiletry items, consisting of tweezers for adult males and a nail cleaner alongside an ear pick for females (Benelli & Rizzitelli, 2003, pp. 323-324). Glass and amber beads are found in female (TT. 252, 265) and child burials (TT. 212 and 228), especially dating to the end of the 4th century and the beginnings of the 3rd century BCE, as after this point in time they became scarcer until their complete disappearance in the 1st century BCE (Benelli & Rizzitelli, 2003, pp. 322-327). Unlike Campovalano (but similarly to Bazzano) male burials no longer contained weapons: in all likelihood this phenomenon is connected to the will of the local population to adopt a non-belligerent stance towards Rome and its expansionist policy. A further explanation may also be found in contemporary political changes that led to the formation of ethnic-territorial states (Benelli & Rizzitelli, 2003, pp. 322-323; Menozzi & Acconcia, 2017, p. 536). Between the end of the 3rd century BCE and the 1st century BCE the grave-goods make up radical changes, as new black varnished ware shapes like *pyxides* or lidded cylindrical boxes, plates, lamps and *unguentaria* are attested alongside utensils for meat consumption during feasts such as *kreagrai* or hooks, spits and knives. If the only items of personal adornment are now rings, other grave goods are toiletry items, gaming counters and strigils (or curved blades to scrape dirt and sweat off the skin after physical activity which are also seen in Campovalano) which represent a late and superficial adoption of the Greek athletic custom alongside local traditions. A new societal asset is reflected in the nearly complete lack of child burials and the subsequent loss of importance of family groups in the cemetery space (Benelli & Rizzitelli, 2003, pp. 324-332; Martellone, 2016d, p. 137).

All the glass beads studied here were unearthed in female adult and child burials during the excavations directed by d'Ercole (please consult Appendix F). The glass beads dating to the Early Iron Age were retrieved within tumuli, whereas the Orientalising-Archaic and Hellenistic specimens were found in simple graves, as previously observed for Campovalano. Beside annular and globular monochrome beads, other Orientalising-Archaic glass beads comprise of monochrome conical brooch pendants (TT. 174 and 190), a single truncated cone bead (T. 269), eye beads with equally spaced - (TT. 227, 429 and 162) or paired eyes (TT. 301, 194), which can be either stratified or not, as in Campovalano (Figure 7.8). Beads decorated with a zig zag trail, which are attested also for the Hellenistic period (T. 179) are also recorded for TT. 301-194. During the 4th and 3rd centuries BCE annular monochrome beads with a diameter < 0.5cm appear to be more popular, similar to what observed for

Campovalano in this phase. Melon beads are now present in the local repertoire, as shown by T. 265. In addition, cylindrical eye beads and eye beads with a central trail of a type also found in Persia and Egypt are now documented, as observed for TT. 212 and 228 (Spaer, 2001, p. 90).

Orientalising-archaic phase



Hellenistic phase



Figure 7.8: Selection of glass bead types for Orientalising-Archaic and Hellenistic Fossa (drawings author's own – for complete dataset consult Appendix F)

7.4 Bazzano: the site and its glass beads

The site, which is located in the industrial area of Bazzano, was discovered in 1992 in a fortuitous manner, as a burial was unearthed during works for the construction of new buildings in the plot belonging to firms Finesa and Fincimec. As a result, excavations were undertaken from 1992 until 1994 by A. Usai from the Soprintendenza per i Beni Archeologici dell'Abruzzo, uncovering 154 burials to the north-east of the excavation area and a ditch

dating to the Roman period. With further construction work scheduled across plots Azzurra, Arcobaleno, Lanificio Margherita, Cesarini, Otefal and Edimo emergency excavations were carried out in 1995 under the direction of R. Tuteri followed by V. d’Ercole between 1997 and 2005 (Figure 7.9).

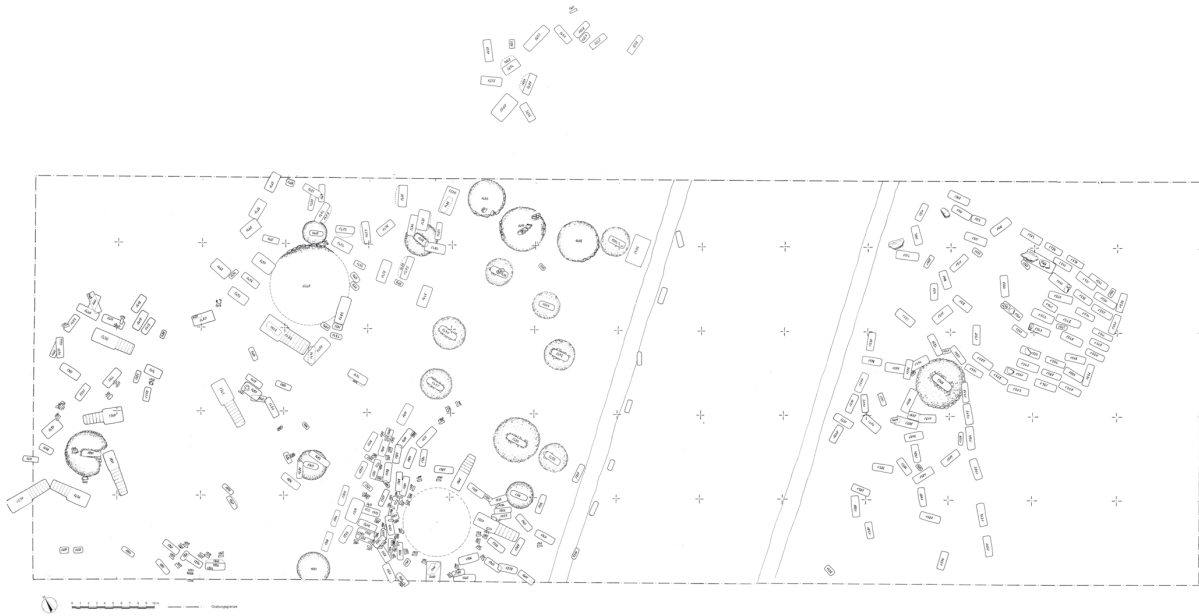


Figure 7.9: Plan of plot Otefal 2004-2005. Scale 1:20 (Weidig, 2014, Beilage 8)

The site of Bazzano yielded 1672 burials in total, approximately 600 of which were Orientalising-Archaic in date (Table 7.3; Weidig, 2014, pp. 19-21, p. 15). Hellenistic period burials, which have been the subject of several dissertations, remain formally unpublished (Weidig, 2014, pp. 25-26).

Burials n=	Chronology	Periodisation
c. 600	850 BCE-500 BCE	Orientalising-Archaic phase
n/a	350 BCE-100 BCE	Hellenistic phase

Table 7.3: Burials in Bazzano divided per phase. The number of burials dating to the Hellenistic period is not reported by Weidig (2014), and as such it cannot be quantified.

For the whole of the Iron Age individuals are either buried within tumuli usually hosting one single inhumation or in simple graves. As a general rule, the length of the grave cut corresponds to the height of the deceased; however, in some cases extra room is provided so that a stone-lined niche for the storage of grave goods can be created (Weidig, 2014, pp. 28-29). Albeit less frequently than observed for Fossa, newborns are buried within roof tiles (please refer back to Figure 7.7). Chamber tombs, which also find parallels with Fossa, are attested for the Hellenistic phase of the cemetery site (Weidig, 2014, pp. 28-29). Female burials appear to be scarcer in number when compared to the ones of children and men: this

may partly be due to the fact that some graves cannot be securely dated to the Orientalising-Archaic period (Weidig, 2014, pp. 617-620). From the last quarter of 7th century BCE until the first half of the 5th century BCE in some instances members of the same family are buried next to each other, thus creating groups which include no more than a generation (Weidig, 2014, pp. 713-720). In addition, warrior burials – at times alongside child burials – are also organised in clusters. When this phenomenon has been observed, female graves are either located at the edges of such groups or are completely absent (Weidig, 2014, pp. 729-730). This suggests that the cemetery space was organised on the basis of family, age and gender groups, with variability in the quality and typology of grave goods pointing towards the presence of social stratification and rank (Weidig, 2014, p. 734).

Spears, daggers and swords have a very strong gendered connotation, as once again the (self?) representation of males as warriors appears to be central in the construction of gender identities in pre-Roman Abruzzo. This phenomenon, which concerns not only adults but also children, appears to be even more pronounced in Bazzano, as the number of weapons retrieved here is much higher when compared to coeval cemetery sites (Weidig, 2014, p. 754). Conversely, grave goods in female and child burials are more varied and seem to be correlated to age groups. This is the case for iron armbands or bracelets which characterise child and teenage graves, as also recorded in Fossa (Weidig, 2014, pp. 679-684; Cosentino et al., 2001, pp. 177-180). It is important to note that there is no correlation between the number of *armillae* and the age of the deceased (Weidig, 2014, pp. 679-684). In a similar manner, brooches positioned on the shoulders are a prerogative of female adults, children and infants: although at least one brooch was recorded in 44% of male burials, this item not only has a different placement, as it located on the chest, but also appears here to be of secondary importance in terms of dress (Weidig, 2014, pp. 669-679). In addition, pendants, rings and small chains were attached to brooches which were also used to secure veils or headgears in female child burials, following the same custom of *Picenum* and Southern Italy. Pendants with apotropaic or magic value of the same types found in Campovalano, were also retrieved in Archaic Bazzano within female graves and more rarely in child and male burials. While copper alloy or iron *bullae* are recorded for both genders and for all age groups, more complex pendants such as wild boar teeth decorated with filigree, bone set in metal or metallic tubular adornments, are documented in female burials and in small numbers also in child graves (Weidig 2014, pp. 284-335, pp. 685-687). Although part of

the female dress, amber beads – of types also documented for *Picenum* and Sabina Tiberina – are not particularly widespread, so much so that during the second half of the 6th century BCE they were retrieved only in TT. 1179, 1191, 985, 109 Azzurra and 101 Finesa (Weidig, 2014, pp. 364-368, p. 692). As for Campovalano, locally manufactured belts in copper alloy, which do not necessarily designate a high-rank individual, are found in female burials (Weidig, 2014, p. 692, pp. 728-729). No material cultural elements that could indicate affiliation to a particular *ethnos* have been detected for the Orientalising-Archaic period: the presence of a local ethnic identity becomes more visible in the general record (in particular through the inscriptions in local languages mentioned in Section 7.1) starting from the 5th century BCE, which is when for Bazzano strong interactions with coastal Abruzzo are recorded, whereas in the previous phase the people from Bazzano had contacts with the Etruscans from Orvieto, Umbrians, Picenes, Sabina Adriatica (Teramo area) as well as Tiberina (Capena and Falerii), southern Abruzzo and Latium (Weidig, 2014, p. 1, pp. 753-754).

The glass beads discussed in Section 7.9 come from simple cut graves located mostly in the areas Otefal and Arcobaleno, followed by further attestations from the plots belonging to Edimo, Cesarini, Azzurra and Finesa (see Appendix F). Some of the burials in question are either located above or below other graves or physically interact with them: in particular TT. 393, 502, 537, 671b and 1127 are partly obliterated by more recent graves, whereas TT. 1179 and 1191 cut earlier graves. In other instances the burials are situated within groups which in all likelihood represent family units, as it is the case for TT. 30, 327, 576, 998 and 1561.

As recorded for the other sites, monochrome globular and annular glass beads are also documented here (Weidig, 2014, pp. 374-375). In addition, melon beads (T. 1583), a double bead in the shape of an eight (T. 588) a large, thin, ring bead (T. 1561) and fragments of small conical pendants (T. 1127) are also present (Figure 7.10)¹⁴. Concerning polychrome beads, layered or simple eyes which are either arranged in double or in single and equally spaced rows, are the most popular decoration (TT. 12, 285, 327, 451, 502, 537, 600, 741, 906, 998, 1127, 1179, 1191, 1203). Eye beads are usually globular or cylindrical; however, triangular specimens were retrieved in TT. 101 and 1191. Beads with a wavy trail or zig-zags are also

¹⁴ Due to the closures caused by Covid-19 I was not able to draw all representative beads; however, photographs of the complete assemblage can be found in Appendix F.

relatively widespread as they were found in TT. 541, 576, 605 and 393: only in the last case this type of bead is in the shape of a truncated cone (Weidig, 2014, pp. 368-374).

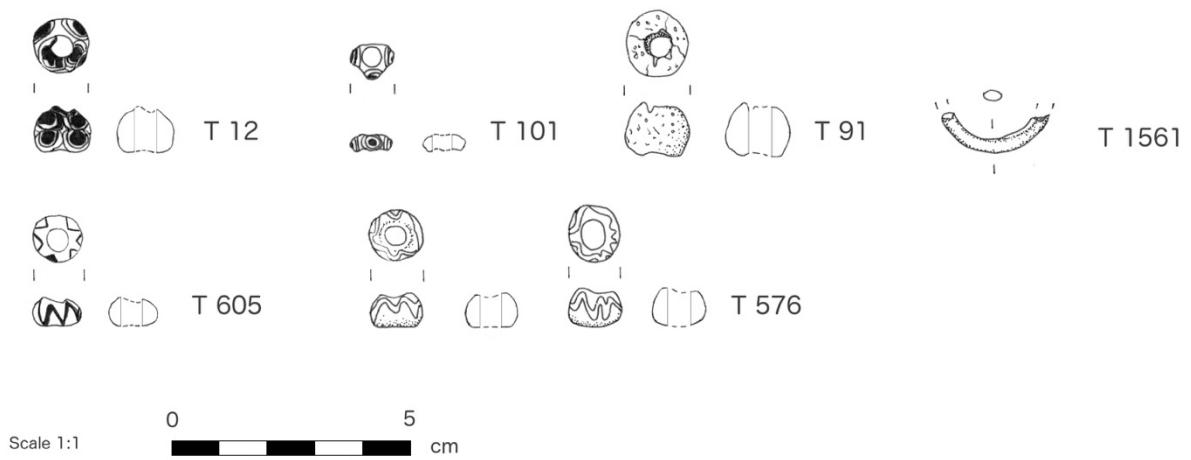


Figure 7.10: Selection of glass bead types for Orientalising-Archaic Bazzano (drawings author's own – for complete dataset consult Appendix F)

b) Methodology

7.5 Research questions and recording methods

The 1st millennium BCE cemetery sites of Campovalano, Fossa and Bazzano (Abruzzo, Italy), were selected for investigations on the meaning of bead colours on the basis of shared characteristics, such as the practice of inhumation as the main burial rite, good osteological evidence for age and gender, their multi-period nature and the presence of shared material culture traits, which are visible not only in the grave good make-up but are also expressed by specific architectural burial types for each phase. The sites and their grave goods are also well known in the literature, as monographs were published for each (Campovalano: Chiaramonte Treré & d'Ercole, 2003; Chiaramonte Treré et al., 2010; d'Ercole et al., 2016; Fossa: Cosentino et al., 2001; d'Ercole & Copersino, 2003; d'Ercole & Benelli, 2004; Bazzano: Weidig, 2014).

The study on the colour of glass beads from 1st millennium BCE Abruzzo was informed by the current thinking on the subjects of materiality and sensoriality of glass, which were used as an interpretative lens to answer the following questions:

- What colours and colour patterning are more preponderant in the record, both synchronically and diachronically?
- Was colour – or certain colours – used to express a certain form of identity or personhood?
- Is there any relationship between given bead shapes or types and their colour?
- Is there any evidence for fragmentation of bead sets and/or continued use?

A total of 3515 beads, located in the National Archaeological Museum of Campi (Teramo) and in the store-rooms belonging to the Soprintendenza Archeologia, Belle Arti e Paesaggio per le Province di L'Aquila e Teramo situated within the New Museum Paludi di Celano (L'Aquila) were photographed *in situ* with a digital SLR camera Canon EOS 50D with macro lens (Canon 50mm F/2.5). The sample is slightly smaller than anticipated as approximately 1500 beads, which were listed on the corresponding site monographs as being kept at those locations, had been moved to other museums or storage facilities at the time of my visits. This large number is partly given by the fact that it was not possible to get hold of 1256 beads which made up a garment retrieved in female burial 119 in Campovalano. Pictures of

the available specimens were thus taken with appropriate scales (2cm, 5cm, 10 cm) and without, using a neutral background consisting of a grey cardboard sheet. Whenever the same accession number was assigned to multiple beads, they were photographed as a group. In the case of beads strung into necklaces, these were left in their current configuration and recorded accordingly. In addition, all the specimens were observed under reflected and transmitted light to ascertain their colour(s) and degree of opacity/translucency. In addition, a selection of the most representative types was also drawn, as shown in Sections 7.2-7.4. The beads, whether whole or fragmentary, were then arbitrarily categorised by colour and degree of translucence by observation under natural light as reported in Table 7.4 below.

Very dark Blue (Opaque)	
Blue (Opaque/Translucent)	
Turquoise (Opaque/Translucent)	
Green (Opaque)	
Yellow (Opaque/Translucent)	
Amber (Opaque/Translucent)	
Dark Amber (Opaque/Translucent)	
Black (Opaque)	
Aquamarine (Translucent)	
Nearly colourless (Translucent)	
White (Opaque)	

Table 7.4: Colours recorded on glass beads, with indication of prevalent degree of translucence (Table author's own).

The beads used for this purpose were examined and photographed by the author, except for the beads from T.30 in Bazzano, for which the colours were derived from the picture contained in the site monograph (Weidig, 2014, p.371).

It was intentionally chosen not to use standardised colour descriptions such as Munsell chips due to the following reasons:

- As reported in Chapter 6, colour categorisation is culture-specific, and as we do not know how the colour space was divided by Iron Age communities in Abruzzo, applying a method that homogenises colours by western, contemporary parameters would not only reinforce any implicit bias, but may also result in very fine-grained subdivisions, which would be detrimental when trying to understand the bigger picture
- Colour in glass is deceiving, as its hue and translucence will vary according to thickness
- Lighting conditions but also hue juxtaposition of similar shades (specifically blues, turquoises and greens), as in the case of in beads already strung in necklaces, will affect colour perception
- Some colours may also not look as they did in antiquity, either due to chemical instability, as is the case for yellow turning into white, or deterioration processes causing surface alterations which range from accretions and discolouration to the presence of metallic particles originally pertaining perhaps to the mandrel or objects in contact with the glass

The colour data for the beads were inputted in separate Microsoft Excel tables for each site (Appendix F). The beads, which were grouped by chronological attribution, were divided between monochrome and polychrome specimens. Irrespective of size or degree of completeness, all beads had equal weighting in my analysis, which means that each specimen (or fragment) was counted individually. By doing so, it has been possible to create tables and charts that show separate colour distribution percentages for monochrome and polychrome beads, allowing for inter- and intra-site comparison. In the case of polychrome beads, the colour of the decorations was recorded separately from the colour of the bodies (or main constituent part) of the beads, by following the system described above. Whenever polychrome beads were manufactured by using the same colour twice (as it is often the case

with blue eye beads with white and blue eyes), the colour in question was logged in only once as pertaining to the body of the bead. The choice of not duplicating the same information for the decorations table was adopted to minimise any over-representation of given colours in the record. Nonetheless, in some instances the – in all likelihood white – trails and/or eyes of some beads had corroded away, which meant that there was no certain indication of the secondary colour(s) employed in crafting such polychrome beads. Although bead fragments constitute a minority within the assemblages examined, it was not always possible to ascertain if they originally pertained to one or multiple beads. As a result, the colour of each fragment was inputted in in the Excel database as an individual entry, which means that we may expect a slight skew in the data in favour of the colours recorded for the fragmentary beads. Needless to say, any object that was not a bead, such as the glass distaff from T. 415 in Campovalano, was not entered in the database. In addition, there may be some contentious evidence, such as the cane eye beads from Campovalano TT. 311, 320, 604, which are all of the same type and present the same characteristics: their bodies have been described on different occasions either as made out of clay (T. 311) or glass (Martellone, 2016d, p. 30, 35, 106); however, when examined *in situ* it was very difficult to establish their actual internal fabric due to degradation and as a consequence, for the avoidance of doubt they were included in the present study (Figure 7.11).



Figure 7.11: Cane-eye beads from T. 311, Campovalano (Photograph author's own).

A similar scenario, which resulted in the application of the approach described above, is represented by the composite material necklace from Bazzano T. 696 shown in Figure 7.12, whereby 1500 beads were catalogued by Weidig (2014, pp. 377-378) as being manufactured from clay on the basis of their appearance. However, he mentions that the investigations carried out by the Istituto Centrale per il Restauro (Central Institute for Restoration or ICR)¹⁵ stated that the beads were likely manufactured using glass instead. This does not appear implausible as glass beads with similar shape, size and colour, which were used as chatelaine pendants or sown on garments, are attested in particular in Abruzzo and Marche during the 6th and 7th centuries BCE (Weidig, 2014, p. 379). My own visual inspection did not provide any clarification, as given the very small dimensions of the beads, which have a diameter between 0.2-0.3 cm, it was difficult to ascertain their material.

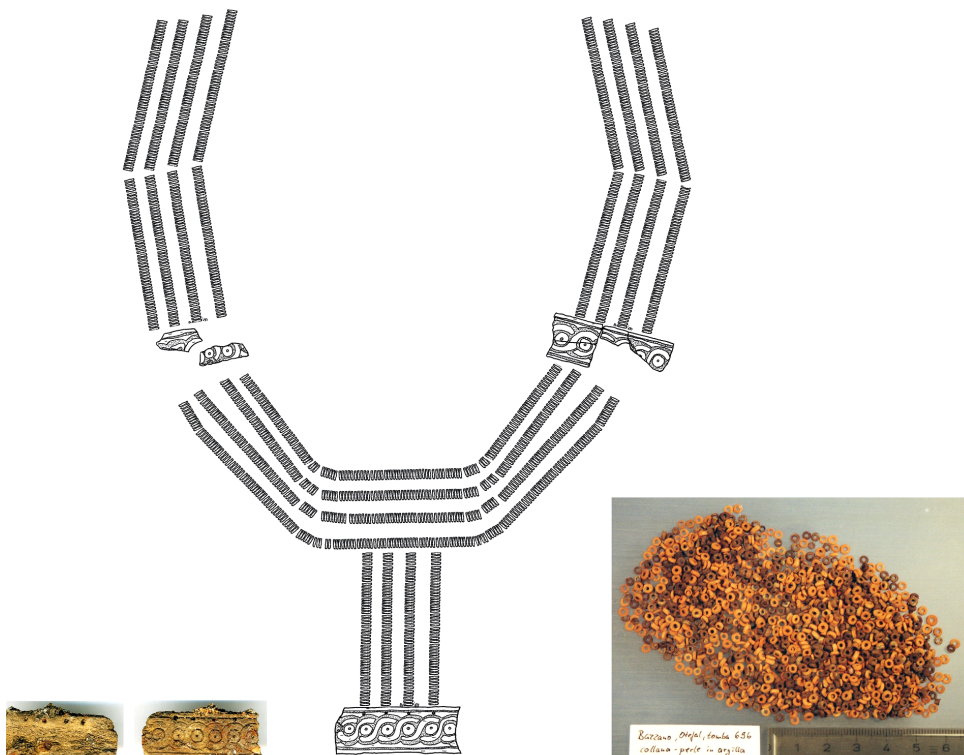


Figure 7.12: Composite material necklace from Bazzano, T. 696 (Weidig, 2014, p. 378).

Each bead (and decoration whenever present) was allocated a unique identification containing the site code, the number of burial and one letter of the alphabet, beginning from 'a' and then moving progressively through the sequence (e.g., CMV_TXX_a). If the beads numbered more than 26, the count was re-started by doubling the letters (e.g., CMV_TXX_aa, ab etc.). In case different beads corresponded to separate artefacts, a number

¹⁵ ICR is a governmental agency for heritage safeguarding and conservation.

was added after the letter (e.g., CMV XX_a1). After this step was completed, pie charts showing the overall percentage of colours of bodies and decorations of beads by site and phase were created. In addition, graphs with colour distribution by burials were also produced. The data were interpreted by focusing on beads as an object category, taking into account colour combinations, potential for fragmentation of sets and potential symbolism.

7.6 Limitations of the dataset

Our interpretation in the use and meaning of colour in Iron Age Abruzzo is inevitably constrained by the fact that we have an incomplete picture for Campovalano, Fossa and Bazzano, which is either due to partial or ongoing excavation, or to the lack of published material for the most recent periods (Section 7.4). Furthermore, I was not able to track down all the glass beads already part of the archives, which means that for all these reasons the results presented in the following paragraphs will only be partly comparable in diachronic inter-site terms.

The information contained in the monographs with regards to the configuration of beads or their location within graves, alongside the results from osteological studies, were used to interpret the significance of colour combinations within single burials for each phase of the sites (Cesana, 2016; Mancinelli et al., 2014; Fattore & Mancinelli, 2003; individual catalogue entries in: Cosentino et al., 2001; d'Ercole & Copersino, 2003; d'Ercole & Benelli, 2004; Weidig, 2014, pp. 879-1296; Boccolini et al., 2003; Chiaramonte Treré & Scotti, 2010; Martellone, 2016d). In the case of Campovalano in particular, the published records for the excavations carried out in the 1960s-70s did not always allow me to ascertain the original position or arrangement of the beads, as this was either not reported to begin with, or was overlooked at the time of collating the documentation (Boccolini et al., 2003; Chiaramonte Treré & Scotti, 2010). Another potential problem is represented by the fact that bead configurations may have included beads or pendants in other materials, such as bone, amber or metals, so we have to be mindful of that when interpreting colour patterning. In addition, a further caveat has to be made, as on a general note the primary deposition of artefacts and human remains can be disturbed by taphonomic processes, soil subsidence, mechanical ploughing and later or earlier stratigraphic evidence (e.g., intercutting burials), just to name a few.

Osteological analyses confirmed the existence of a good correspondence between biological sex of skeletal remains of adult individuals and gendered grave goods, meaning that glass beads can be generally attributed to women when found in adult burials. There are exceptions however, as at times the sexing of the remains could not be undertaken due to poor bone preservation and for this reason burials were gendered on the basis of the grave good make-up. Whenever possible, this criterion was also applied to infant burials, as sex in children cannot be determined on an osteological basis, and the grave goods for very young individuals (from foetus up to 6 years of age) are on average very scarce and rarely provide indication of gender. In order to avoid any confusion, or even worse, to skew any potential interpretation towards pre-conceived ideas, I will preferentially refer to individuals based on their sex or age (e.g., woman, child) when the data are available, whereas in the case of burials whereby only an archaeological determination of gender is reported, this will be clearly signposted. In addition, as osteological analyses can only provide an estimate of age, the cemetery populations of each site are divided in arbitrary age groups which use slightly different year brackets, thus causing inconsistencies in how the data are presented. It is also worth pointing out that biological age does not correspond to social age, as individuals may – or may not be – considered social persons at different ages (Cesana & d’Ercole, 2018, p. 160).

Concerning the assemblages of Campovalano, Fossa and Bazzano, in a good number of cases the location of the beads in the grave and their configuration appears sufficiently clear. If we cannot really say for certain what the original colour composition of necklaces, brooch pendants or bracelets was, we can at least have an idea of colour combinations within the same burial. Caution is required, as at least in one known case (Fossa, T. 56; Figure 7.13) the curator strung only the beads that were complete together in a necklace, leaving fragmentary ones to the side (S. Montanaro, 2019, *pers. comm.*).¹⁶ In this instance, it is impossible to tell whether the central bead, with a large iron rod sticking out of the perforation, was originally part of this configuration or if it was repurposed in antiquity: in any case, this reinterpretation of how an Iron Age necklace should look like could skew the perspective towards erroneous preconceived ideas (Frieman, 2012).

¹⁶ Stefania Montanaro was at the time the conservator for the ‘Soprintendenza Archeologia, Belle Arti e Paesaggio of Abruzzo’, who was responsible for the artefacts stored in the Museum Paludi di Celano (AQ).



Figure 7.13: Reassembled necklace from Fossa, T. 50. The iron rod protruding from the thread-hole of the central bead can be observed (Photograph author's own).

c) Results

7.7 Campovalano: glass beads, colour and identity

7.7.1 *The Orientalising-Archaic phase*

During the Orientalising-Archaic phase monochrome annular to globular beads are preponderant in Campovalano, as already observed by Buoite (2010, p. 209). As shown in Figure 7.14 below, for this category there seems to be a preference for translucent colours such as amber, yellow and turquoise.

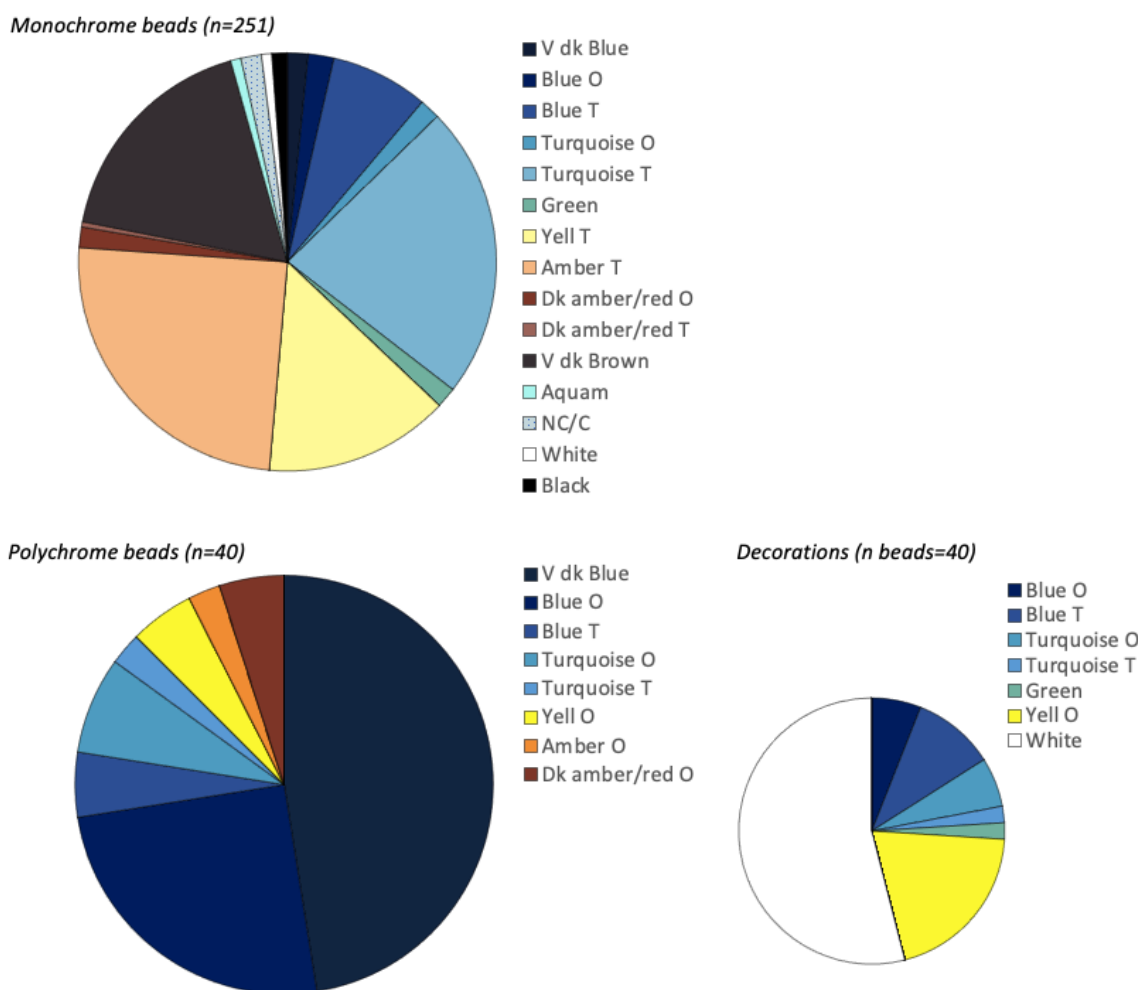


Figure 7.14: Pie charts showing colour percentages for monochrome and polychrome beads with their decorations for the Orientalising-Archaic phase of Campovalano (charts author's own).

Amber glass, at times alongside eye beads of the very dark blue type and/or blue, turquoise and nearly colourless beads, was used in combination with amber itself in five instances (TT. 51, 57, 160 and 239). An apparently considerable amount of very dark brown beads is given by the fact that 44 fragments from T. 415 are included in the total count for this colour when in reality we only have six whole large specimens, which were found in burials where amber

beads were also retrieved (TT. 212, 415, 598). In all cases it is unclear if both amber and glass were together in the same configuration, as the catalogue does not provide this information. The presence of bone, copper and iron pendants was also recorded for these contexts (Chiaramonte Treré & Scotti, 2010, pp. 78-79, 112-115, 132-133).

Only two drop pendants were made from nearly colourless glass (T. 160), which was also used for the manufacture of two thick annular beads (T. 199bis, T. 176). The two aquamarine beads recorded for this phase of the site appear to be slightly problematic: T. 595, which is attributed to the Orientalising-Archaic period, yielded an amphora-shaped bead in this colour, which, based on its typology should be much later, as reported in Section 7.2. In addition, T. 595 is one of the few burials that was deemed to be male, as exemplified by the presence of a spearhead and a mace-head. An aquamarine annular bead was found in T. 199bis, however we cannot rule out that this specimen – together with other translucent turquoise beads from the same burial – may belong to a glass distaff instead, similar to what was observed for T. 592 (Chiaramonte Treré, 2010b, p. 264). Black, white (perhaps once yellow as in the case of T. 595), green, opaque and translucent dark amber/red beads are also rare.

The majority of the bodies of polychrome beads are in opaque hues: very dark blue to blue, followed by dark and light amber, turquoise and yellow, are all seen for various types of eye beads, which account for nearly all of the sample with 36 specimens. The only exceptions are an opaque blue bead with central white trail (T. 204), a fragmentary bead, with a translucent turquoise body onto which yellow trails were applied (T. 439), an opaque blue melon bead with double yellow trails and a pear-shaped bead in the same colour with a white wave trail both from T. 496. It is worth pointing out that especially blue and turquoises (in monochrome and polychrome beads) at times tend to be either semi-opaque or semi-translucent, tentatively indicating low temperature mixing of the glass. If such colours may present some form of ambiguity, the total absence of polychrome black, aquamarine, nearly colourless and – more importantly – amber and translucent yellow beads, allows us to postulate that they were specifically used in simpler shapes. In terms of decorations, white is the main colour applied on polychrome beads as trails or as part of the eyes. Yellow is used for trails and – in one case alongside green (T.162) – prunts, which are protruding (hence not fully fused) round blobs of glass placed on eye beads. Turquoise and blue glass, either opaque or translucent, are exclusively used to craft eyes.

With regards to colour combinations within individual burials during the Orientalising-Archaic period, from the data available we can surmise that the beads were mostly configured in necklaces, the majority of which were multi-coloured. In this case, more often than not all shades and types of blue are associated with turquoises (Figure 7.15). These colours – either individually or in combination – are then followed by yellows, ambers and green; however, no clear pattern in relation to age or gender seems to emerge. While such colour patterns can be attributed to women and children, it is notable that turquoise, yellow and amber (eye)beads were also encountered in T. 507, which was interpreted as a male burial on the basis of the presence of weapons among the grave goods, as the sexing of the remains could not be undertaken (Chiaramonte Treré & Scotti, 2010, p. 125). In the case of monochrome sets, very dark brown glass beads are found in the burials of a young woman (17 to 20? years of age, T. 212), of an adult individual who was gendered as female (T. 415), and in T. 598, which belonged to an infant (0-6 months of age).

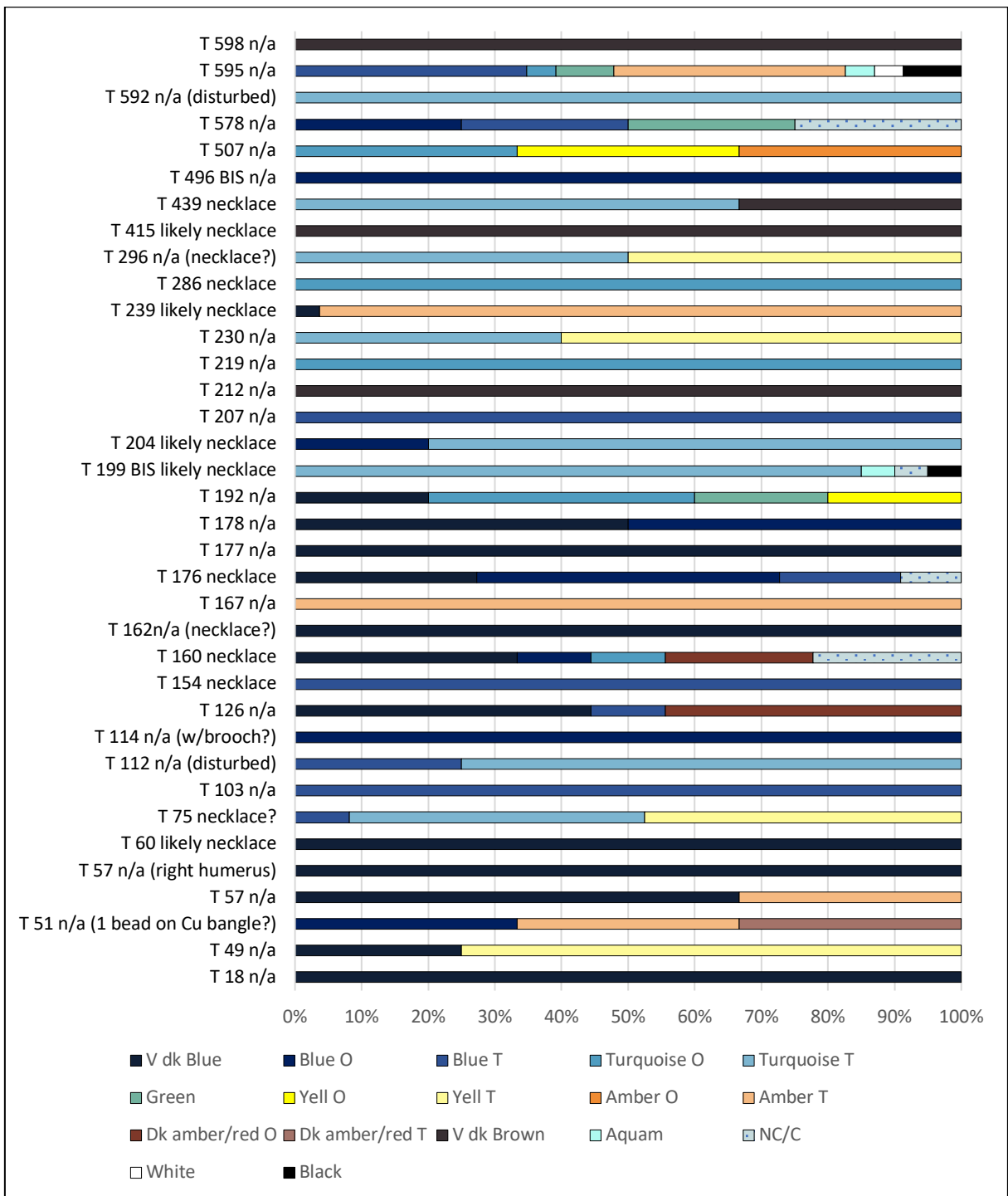


Figure 7.15: Campovalano Orientalising-Archaic phase: percentage of colours of monochrome and polychrome bodies of beads (n=291) per burial (n=35), with respective configurations (chart author's own).

Beside T. 212, which was located within a stone circle also enclosing the burial of a young child (T. 214) where no glass beads were found, all of the above-mentioned graves are not in any sort of physical or spatial relationship with each other. It is also worth mentioning that the only other brown bead, which appears in association with a turquoise bead, was retrieved from the burial of a newborn T. 439, which, once again, is not related to any of the graves which contained dark brown beads.

Very dark blue large eye beads with prunts were encountered respectively in female adult and child burials TT. 18, 57 and 162, with the latter belonging to a very young child/newborn. Of note is the fact that the child in T. 57, was positioned within a circle of burials which also comprised female burial T. 60 (Boccolini et al., 2003, pp. 45-46): both TT. 60 and 57 share the same type of very dark blue cubic eye bead, which, in the case of T. 57 is also accompanied to an amber glass bead. Albeit limited, this type of evidence may point towards the fragmentation of bead sets between closely linked individuals within the same family or group. If we take the example of T. 75, however, this proves that our speculation should not be taken as a rule of thumb: an adult woman who was buried within a stone circle which also contained further graves (TT. 38, 76, 80, 81, 82) was the only individual in the cluster with glass and amber beads (Boccolini et al., 2003, pp. 56-58), meaning that both phenomena do not mutually exclude each other.

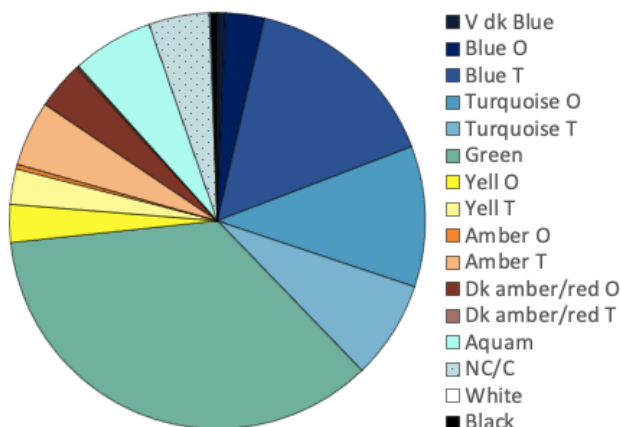
7.7.2 The Hellenistic phase

Although during the 4th and 3rd centuries BCE grave goods contract and become standardised, glass beads, when compared to the earlier period, are present in larger amounts over a similar number of burials (40 for the Italic-Hellenistic phase versus 35 for the Orientalising-Achaic phase). Monochrome annular, globular and small biconical beads are far more abundant than their polychrome counterparts, indicating a continuation of the trend noted for the 7th and 6th centuries BCE. As shown in Figure 7.16, the overall colour distribution of glass beads has undergone some changes, which most certainly reflect a shift in fashion/colour preferences. This is testified by the higher percentage of green, turquoise, translucent blue and aquamarine and nearly colourless beads: green and turquoise beads are often used in combination in necklaces, suggesting that perhaps these two slightly contrasting colours were in strong association or even perceived as different shades of the same hue. Translucent blue beads are more often than not of the small biconical type, which is a shape typical of the Hellenistic period with wide diffusion in the Mediterranean (Spaer, 2001, p. 74).

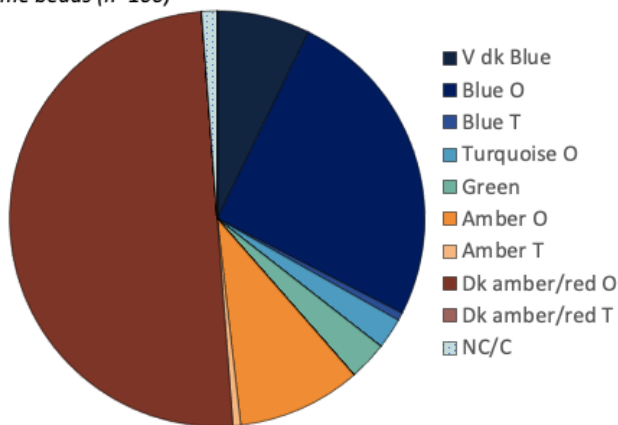
All aquamarine beads and some of the nearly colourless specimens (which are otherwise annular or biconical) are amphora-shaped pendants, which in Abruzzo appear only in Campovalano. They were retrieved from female burials pertaining to children (TT. 334, 458), adolescents (TT. 311, 604) and adults (TT. 151, 243, 245, 320 and 425), with T. 425 and T. 311 in close proximity (Martellone, 2016c, p. 143). Pendants with the same shape and colours are

also attested in the Carpathian Basin, the Balkans and along both sides of the Adriatic Sea, where they were equally worn by women and children in death during the 4th and 3rd centuries BCE (Blecic Kavur & Kavur, 2017; Rustoiu, 2015; d’Ercole, 2016, p. 161; Popovič, 1997, Vellani, 2000). In all of these contexts, amphora-shaped pendants – and specifically in the case of Campovalano any nearly colourless and aquamarine beads – are often found in association with amber beads.

Monochrome beads (n=1125)



Polychrome beads (n=166)



Decorations (n=166)

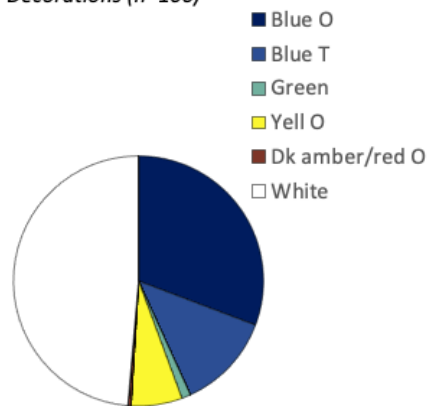


Figure 7.16: Pie charts showing colour percentages for monochrome and polychrome beads with their decorations for the Hellenistic phase of Campovalano (charts author’s own).

The overall amount of translucent yellow and amber glass is stable when compared to the previous phase, with the difference that opaque yellow is now used for monochrome beads. The greater number of opaque dark amber/red beads is due to their exclusive presence in one necklace from T. 604. During the Hellenistic period amber glass beads are encountered on their own (T. 537) or together with similar hues such as yellow (T.245 with eye bead) or even combined with amber itself (T.151, also with amphora-shaped pendants, T.239 with eye beads, T.319 with coral).

Besides the body of two likely Punic mask pendants, with each being the central element of bead necklaces from TT. 458 and 604 (Martellone, 2016a, p.136, Seefried, 1979, p. 20), the number of very dark blue polychrome beads has contracted, with opaque blue eye beads becoming more popular. On a general note, if on the one hand beads with a central trail are rare, and their body can be either blue (TT. 379, 285), green, or translucent amber (T. 604), on the other hand no beads with zig-zags or traileed waves are present in the record. The large amount of opaque dark amber beads is mostly given by their presence in the above-mentioned human mask pendant necklace from T. 604. Although it was not possible to determine with a satisfactory degree of certainty whether the bodies of these cane-cut eye beads¹⁷ were actually made out of glass, it is worth pointing out that this specific type, (largely) in the same colour, was also recorded in TT. 311, 320 and 285 (with amber), with the latter two graves located within the same cluster of burials.

The repertoire of colours used as decorations does not seem to change dramatically when compared to the Orientalising-Achaic phase: the high percentage of white and blues here is due to their use as a secondary colour in the decoration of eye beads, whereas yellow is employed as the main colour for trails and cane segments and prunts on eye beads. Only in the case of a large eye bead from T. 243 was dark amber/red glass seemingly used to fashion eyes.

In individual burials beads are either inserted on brooches or strung together in necklaces (Figure 7.17). When found with brooches, monochrome translucent amber beads are recorded in the instances of adult female burials TT. 151, 537 (woman, 40-44 years old) and T. 245 (woman, 40-44 years old), where an additional opaque yellow bead is present. A variety of large opaque blue eye beads is also reported for this configuration for adult female burials T. 282 (two eye beads with central trail), alongside TT. 412 and 243 which both had a bead with layered eyes respectively used in a brooch or placed on the pelvis. A large bead of the same type, which was associated with green, translucent turquoise and amber annular beads, was retrieved from the grave of a girl in her late teens (T. 546). Except for a blue bead with central white trail with brooch from T. 285, which belonged to a child between 3 and 6 years old, infants are buried either with translucent blue annular beads (T. 486), which were also present with the same configuration on the body of the woman in T. 533, or with eye beads (T. 489, 0-3 months old). Although its exact position could not be ascertained, an eye

¹⁷ Please refer to Appendix A for this specific bead-making technique.

bead was located in T. 487, which belonged to a foetus (Martellone, 2016d, p. 78). Necklaces containing or entirely consisting of glass beads are usually single items which mostly belong to adult women. An exception is represented by the three necklaces from T. 604 pertaining to a young girl (11 to 14 years old). At other times, necklaces are also present alongside individual beads in other configurations, as it is the case for TT. 285 and 243. As already pointed out, the use of translucent beads – especially aquamarine or nearly colourless types – appears to be widespread, in particular in necklaces with more than three glass bead colours (TT. 151,243, 245, 311, 320, 379, 423, 604). Among other hues there are opaque turquoise, blues, green, dark amber, translucent amber and yellow. Interestingly, the above-mentioned opaque hues are more frequently seen in polychrome rather than monochrome beads, and vice-versa for translucent hues.

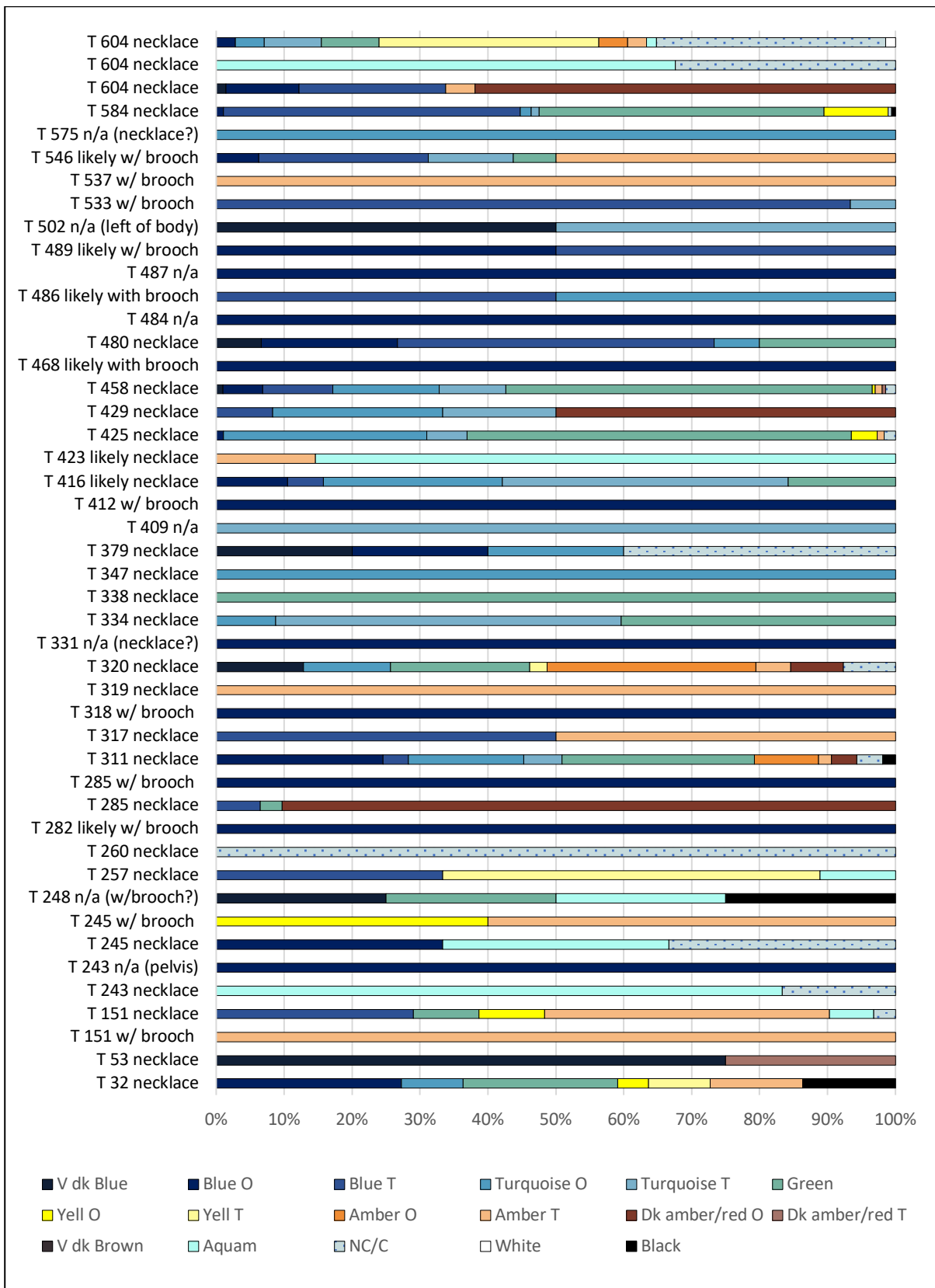


Figure 7.17: Campovalano Hellenistic phase: percentage of colours of monochrome and polychrome bodies of beads (=1287) per burial (n=40), with respective configurations.

7.8 Fossa: glass beads, colour and identity

7.8.1 The Early Iron Age

As it was not possible to locate all the assemblages at the time of the site visit, the Early Iron Age in Fossa is represented here by a reduced (and thus incomplete) sample of beads, which pertain to three burials. For this reason, our observations will be of general character, as they are constrained by the size of the data set. As illustrated in Figure 7.18 monochrome beads are more frequently encountered in the record than polychrome beads. Translucent hues, especially amber and yellow, are favoured, and dark, opaque colours are completely absent; nearly-colourless glass is also used in relatively great quantities in annular/globular beads. Polychrome beads are represented by mostly fragmentary eye beads, which presumably had white decorations that did not survive.

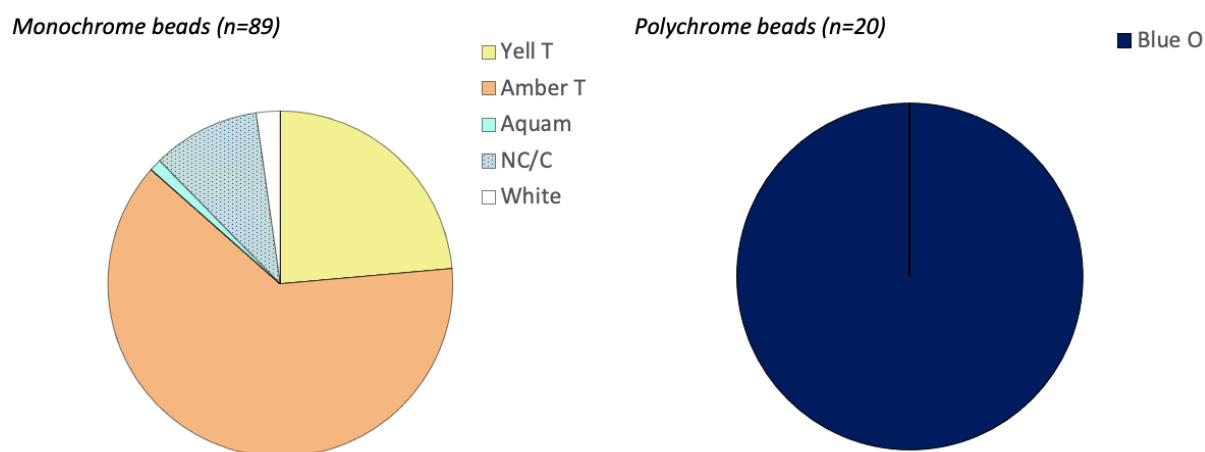


Figure 7.18: Pie charts showing colour percentages for monochrome and polychrome beads with their decorations for the Early Iron Age phase of Fossa (charts author's own).

If we consider colour distribution within single burials (Figure 7.19), the palette is rather limited: amber coloured beads are found in both TT. 56 (adult, 50-60 years old, gendered as female) and 142 (woman, 25-34 years old). In the first instance, the parure is richer, as it contains all the other colours for monochrome beads, and blue eye beads of the same type as T.191, which belonged to an individual of undetermined sex and age (Cosentino et al., 2001, p. 107).

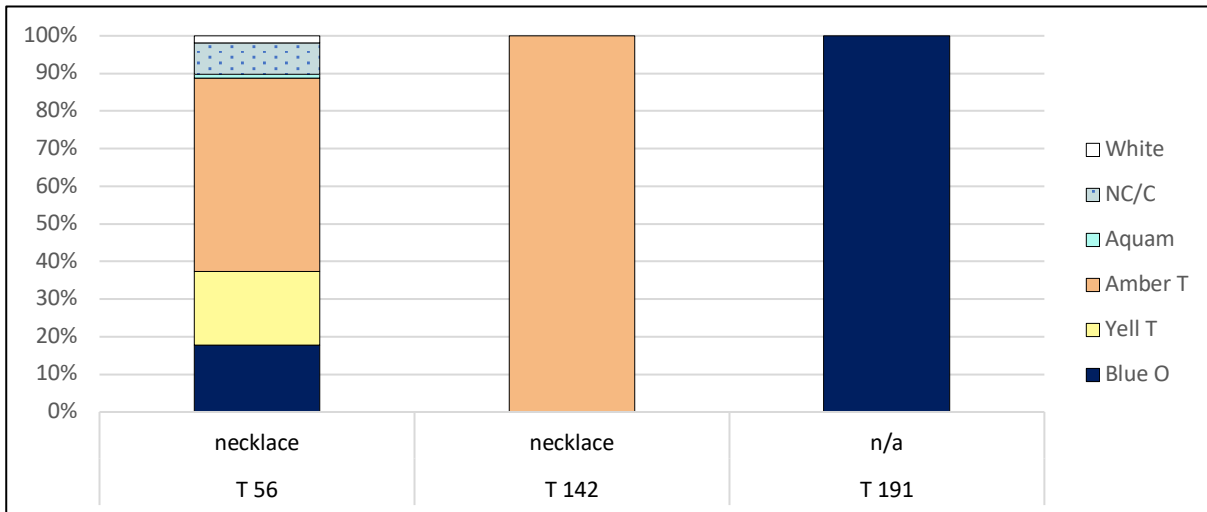


Figure 7.19: Fossa Early Iron Age: percentage of colours of monochrome and polychrome bodies of beads (=109) per burial (n=3), with respective configurations (chart author's own).

7.8.2 The Orientalising-Archaic phase

During the Orientalising-Archaic period, the total sums of monochrome and polychrome beads are roughly equivalent (Figure 7.20). As observed for Campovalano, also in this case there is a high percentage of translucent amber, yellow and turquoise (opaque) monochrome annular and globular beads. Conversely, in Fossa dark and/or other opaque hues (e.g., very dark blue, dark amber, brown, black but also yellow and green) are absent. At the same time, colours which were an integral part of the Early Iron Age repertoire, such as aquamarine and nearly colourless, have now disappeared, and even though translucent yellow is still present, it amounts to a single bead. With regards to polychrome beads, the colours are not as varied as Campovalano: in Fossa there seems to be a predilection for yellows, opaque blue and turquoise, followed by aquamarine. The count of translucent yellow, however, is skewed by many fragments of a truncated cone bead from T. 269, which presumably had a white trail running across its body, now completely corroded. If turquoise is exclusively recorded for beads with layered or stratified eyes, blue and yellow are used for this type and for beads with waves or trails. Although not technically polychrome, the only aquamarine bead with a 'collar' which is formed by a wind of yellow opaque glass, features on the end of a likely brooch pendant, alongside two further pendants, one blue and one yellow decorated with collars in opposing colours (T.290). With the exception of opaque and translucent amber, which was recorded only for monochrome beads, the colour repertoire is shared with polychrome beads. If we leave out the pendants found in T.290 and a blue wave trail on a

bead from T. 301, the use of colours for decorations is very similar to Campovalano and Bazzano.

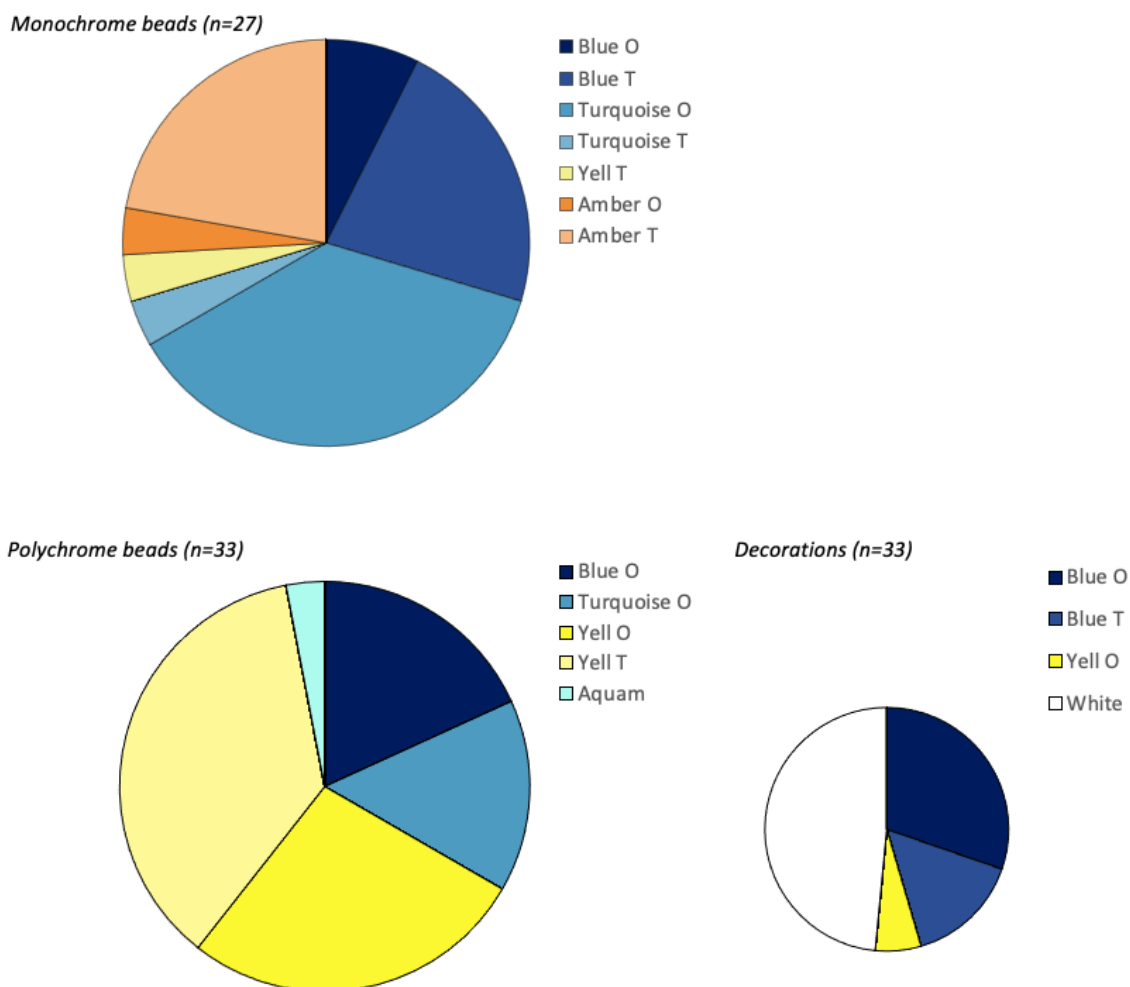


Figure 7.20: Pie charts showing colour percentages for monochrome and polychrome beads with their decorations for the Orientalising-Archaic phase of Fossa (charts author's own).

Blue and turquoise alongside yellow and amber are often combined in composite-material necklaces comprising of bone, amber and metal beads and more rarely in brooches (Figure 7.21). With 14 burials in total, the dataset for the Orientalising-Archaic period is quite small, and as such the evidence presented here should not be taken as being indicative of larger-scale or highly representative patterns; however, there are a few noteworthy observations that can be made. Interestingly, 65% of the graves with glass beads belong to infants and children, ranging between 8-16 months and 6-8 years of age: in this case, monochrome beads – blue, turquoise and yellow in colour – are favoured over polychrome beads. Conversely, opaque turquoise, yellow and blue beads with decorations such as eyes or waves were recorded more frequently among adult individuals aged between 20 and 46 (TT. 227,269, 301 and 429).

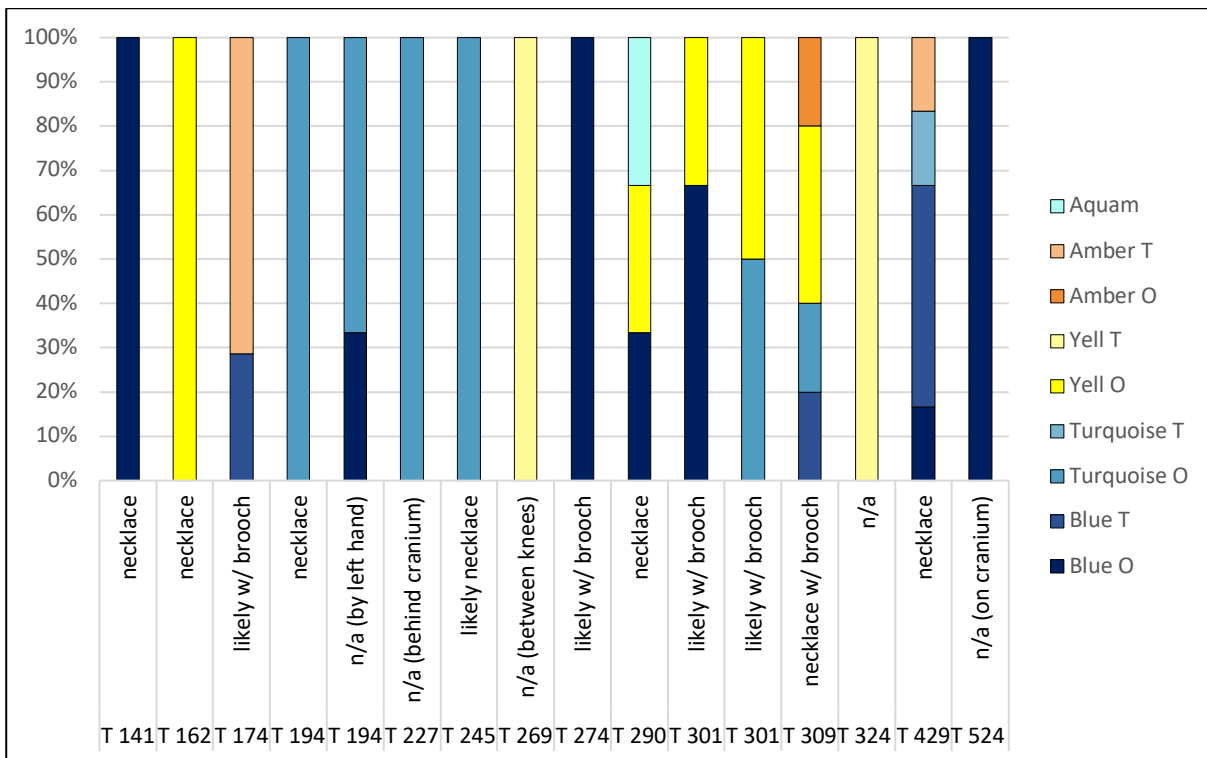


Figure 7.21: Fossa Orientalising-Archaic phase: percentage of colours of monochrome and polychrome bodies of beads (=60) per burial (n=14), with respective configurations (chart author's own).

Moreover, irrespective of colour and size, eye beads tend to be associated with amber and/or amber coloured glass beads, as observed for newborn and infant burials TT. 309 and 194, alongside adult women's graves TT.429 (in all these instances with additional copper alloy and bone beads) and 301. If the infant and child burials mostly yielded necklaces or brooch pendants, the adult group is more heterogenous in terms of glass bead placement on the body and hence configuration. This is exemplified by the graves of two adult women, which respectively contained an eye bead located behind the cranium and perhaps originally either sown onto a garment or formed part of a hairpin (T. 227), and the previously mentioned truncated-cone bead which was placed between the knees (T. 269). Burials tend to be equipped with single items: only TT. 194 and 301 present two different configurations, each consisting of a necklace alongside what could have been perhaps a bracelet and two sets of beads used as brooch ornaments. In terms of a potential connection between shared bead types and colours with the location of graves, TT. 194, 301, 227 and 324, which overall yielded opaque blue zig-zag beads, yellow and turquoise eye beads and a single translucent yellow monochrome bead (T. 324) are situated in the portion of the site which is delimited by contemporary tumuli TT. 47 and 61 to the west and by burial mound T. 38 to the east.

With the exception of the Early Iron Age phase, the Fossa monographs (Volume I: Cosentino et al., 2001; Volume II: d’Ercole & Benelli, 2004; Volume IV: d’Ercole & Copersino, 2003) do not discuss or highlight any specific spatial relationships between individual graves. As a result, we cannot really ascertain whether these individuals were part of the same group or family who used the same type of beads.

7.8.3 The Hellenistic phase

Given the small number of Hellenistic burials, caution is once more required in our interpretation of the colour data: when compared to the Orientalising-Archaic period, monochrome beads are now more commonly found in adult burials, which are only five, whereas infant and child graves amount to three and contain the majority of polychrome specimens. The colour preferences for monochrome beads are geared towards opaque hues, with translucent amber and yellow glass disappearing completely (Figure 7.22).

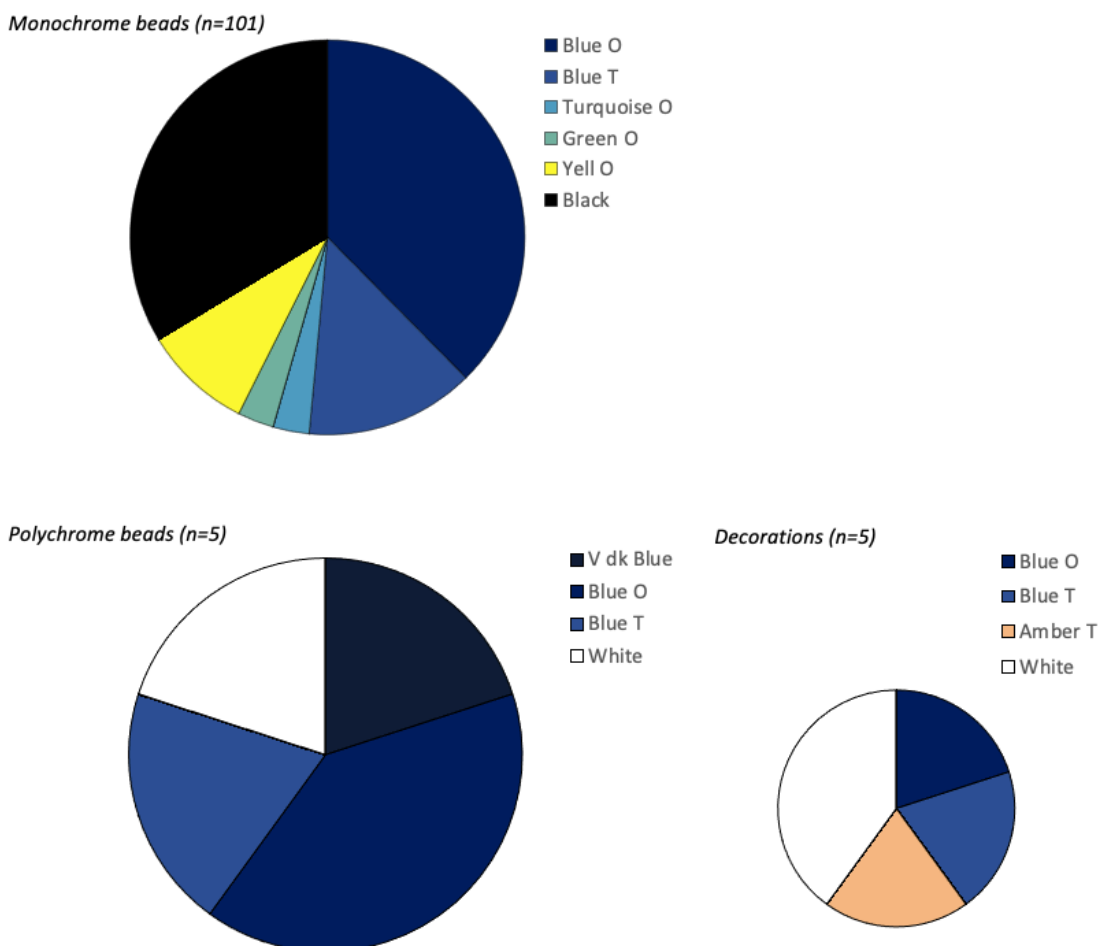


Figure 7.22: Pie charts showing colour percentages for monochrome and polychrome beads with their decorations for the Hellenistic phase of Fossa.

Black beads, which are also sporadically reported for Hellenistic Campovalano, appear to be very frequent in the local repertoire, although blue beads, both opaque and translucent,

amount to approximately 50% of the total. In line with the trend noted for Campovalano, monochrome beads are far more numerous than polychrome beads, represented here by only five specimens. No yellow or turquoise eye beads, which characterised the previous phase in Fossa, are present. Very dark blue is used here for the first time in the bodies of multi-coloured beads, in contrast with Campovalano where this colour was observed in both polychrome and monochrome specimens across all phases. A rare – at least for the area – eye bead with a semi-opaque white body, with translucent amber eyes and white colour trails was also recorded (T. 228). As usual, white is the most common colour employed in decorations, with the remaining opaque and translucent blues used in eye beads. Yellow is completely absent from the record for polychrome beads.

As shown in Figure 7.23, glass beads are more commonly configured in necklaces worn by adult women, as is the case for TT. 220, 223 and 265, with only one attestation from T. 228 that can be attributed to a child, between 3 and 5 years of age. Eye- and monochrome beads are also used as pendants for brooches in the case of child and newborn burials TT. 212 and 268 (5-7 years old and 0-6 months old in that order). Similar to what is observed for Orientalising-Archaic burial T. 227, an eye bead paired with an amber bead was found by the cranium of an adult woman (52-61 years old) in T. 349. Furthermore, two monochrome blue beads were retrieved from the pelvic area of the man in T. 447 (41-74 years old): the placement is identical to the one seen in T. 269, which dates to the previous phase. With regards to colour patterning, it appears that necklaces in particular are crafted by stringing together monochrome blue (opaque and/or translucent), opaque yellow and black beads (TT. 220, 223, 228). In the case of TT. 220 and 228 additional hues, represented by green alongside opaque turquoise beads and by a white eye bead respectively, are also present. In TT. 220, 223, 228 further colours were added through the use of beads in copper alloy, bone or coral. The only necklace with a turquoise and blue colour scheme, one that also employs melon beads is from T. 265. Although this may be the result of the small sample size of the beads from the Hellenistic period, brooches appear to have a restricted palette: a combination of black and blue beads was recorded for T. 268, whereas opaque and translucent blue beads were found in T. 212. Considering that TT. 220, 223, 228 and 268 share the basic combination of black and blue glass beads, it may be tempting to interpret the presence of such colours across several graves as evidence for the fragmentation and subsequent redistribution of an earlier bead-set. As observed for the Orientalising-Archaic

period, also in this instance spatial relationships among different burials cannot be established with any degree of certainty: although these graves are part of a wider group and even though T. 220 appears to be in close proximity to T. 223, the same cannot be said for TT. 268 and 228. This latter burial is situated along the north-eastern edge of the stone circle of Early Iron Age tumulus T. 300: during the Hellenistic phase, the space around this tumulus becomes the burial ground for newborns, who were placed on top of Orientalising-Archaic adult inhumations (Cosentino & Mieli, 2003, p. 256).

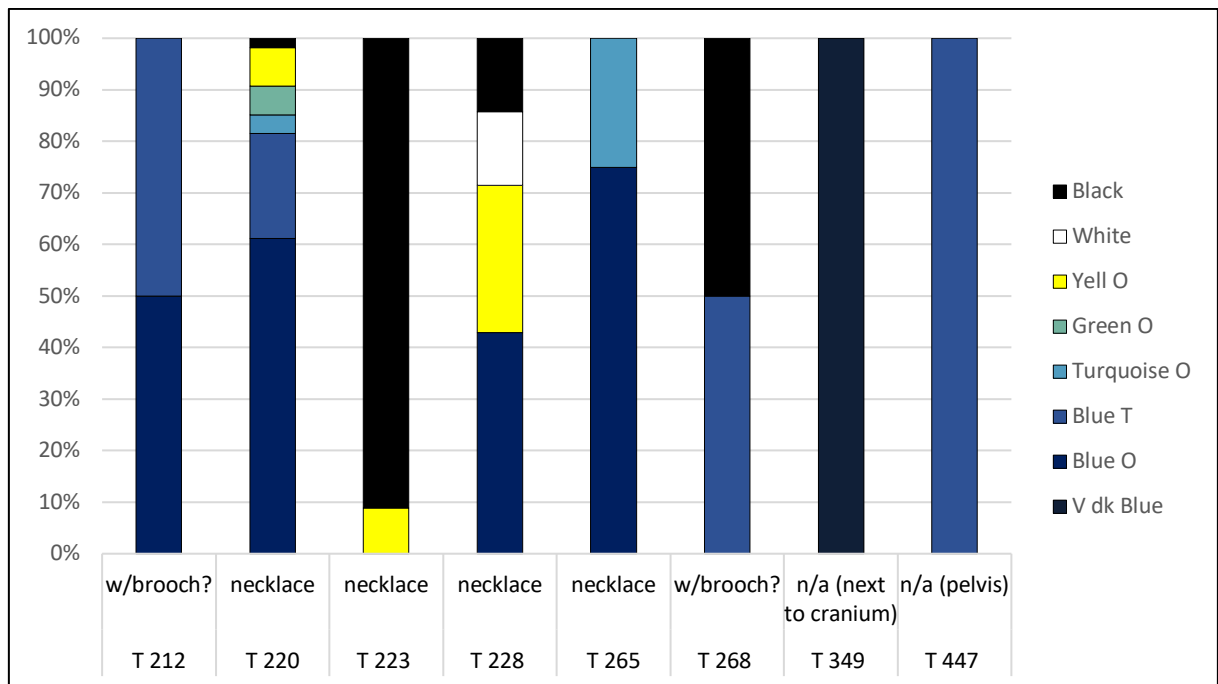


Figure 7.23: Fossa Hellenistic phase: percentage of colours of monochrome and polychrome bodies of beads (=106) per burial (n=8), with respective configurations (chart author's own)..

7.9 Bazzano: glass beads, colour and identity

7.9.1 The Orientalising-Archaic phase

As highlighted in Section 7.4, the dataset for Bazzano is limited to the Orientalising-Archaic period only. The colour wheel for monochrome beads appears to be quite different when compared to the data for same period in Campovalano and Bazzano, although it has to be said that the presence of 850 opaque amber and 652 dark amber/red likely glass beads from T. 696, which have been previously discussed in Section 7.5, muddles the visibility of other colours in the pie chart to the top left of Figure 7.24. For this reason, the entries for these beads were removed from the pie chart to the top right, so that the remaining data can be appreciated more clearly.

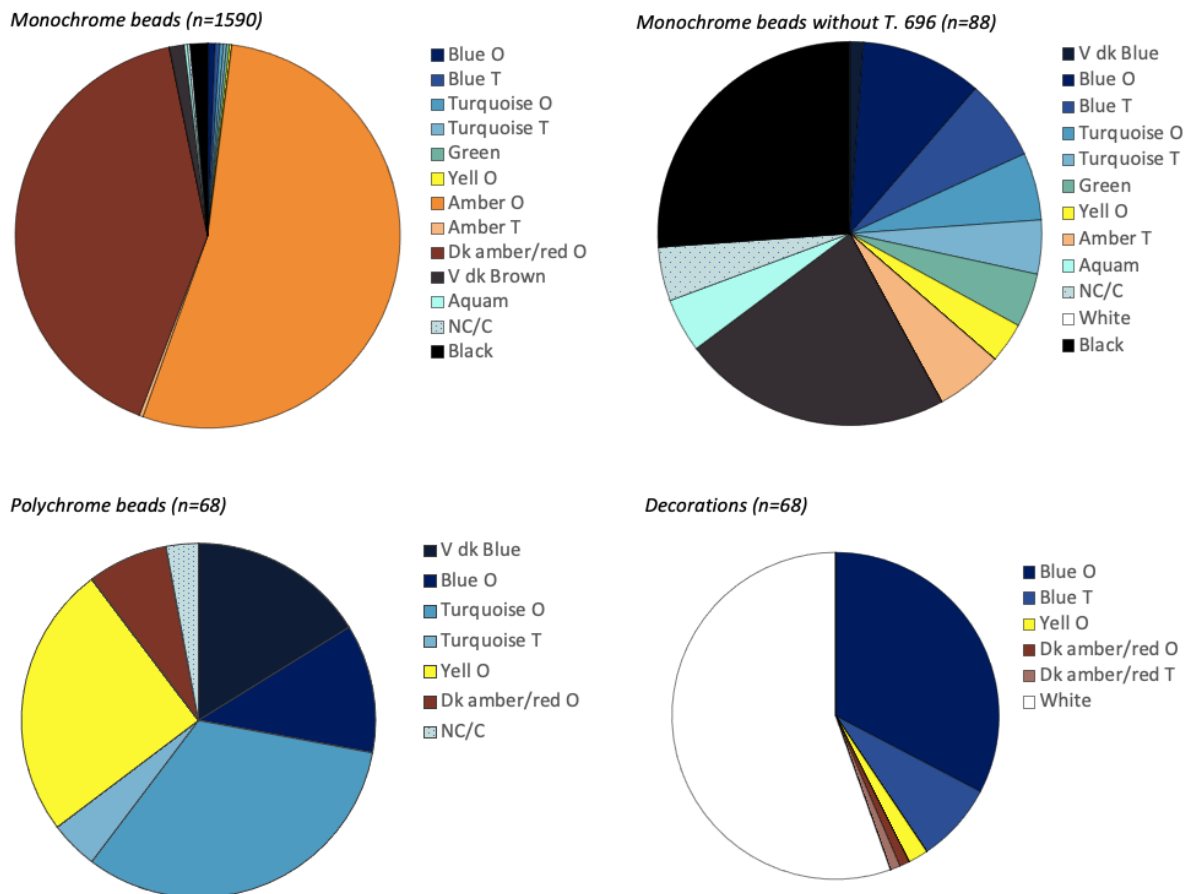


Figure 7.24: Pie charts showing colour percentages for monochrome and polychrome beads with their decorations for the Orientalising-Archaic phase of Bazzano (charts author's own).

Even so, monochrome beads are more abundant than polychrome specimens, which is in line with what has been observed for contemporary Campovalano. After opaque amber and dark amber, black and brown appear to be the most abundant colours, respectively amounting to 20 and 23 beads. Black can be mostly attributed to the beads strung into necklaces which were found in female burials T. 109 and T. 30 which respectively belonged to an adult and an adolescent (here the black beads are combined with the totality of the dark brown beads). Although in different proportions than Orientalising-Archaic Campovalano, blue, turquoise, colourless, aquamarine and green glass beads are also present here. In Bazzano, however, green is never paired with turquoise, but is instead found alongside opaque yellow, which is used for both monochrome and polychrome beads.

Turquoise, which accounts for 32% of the polychrome beads, is only used as the base colour for the bodies of eye beads, whereas blues and yellow are equally observed in beads which are decorated with eyes or with a wave trail/zig-zag. Both types can also occur together, as it is the case for TT. 451 and 576; however, there appears to be a wider variety of base colours for wave beads, as they also can be blue, opaque amber/red and nearly colourless. Of note is the fact that amber beads are found alongside eye beads only, and are either strung together

or come as separate items: this occurrence was observed for female adult burials TT. 1179, 1191 and 101, indicating a very specific combined use of these two different materials. The colours used as decorations are consistent with what is recorded for the other sites during the same phase, with the exception of opaque and translucent dark amber/red – both documented for Hellenistic Campovalano and Fossa – which are attested here in the yellow bead with wave trail from T. 605 and in the small triangular eye bead from T. 101 respectively.

As shown in Figure 7.25, more often than not, beads are strung into necklaces found in both female and child burials, whereas their use as pendants for brooches appears to be the prerogative of infants and, in general, children (TT. 327, 588, 739 – although T. 101 was perhaps an adult burial). Other configurations are also present: in the case of adult male burial T. 12, a turquoise eye bead was retrieved on top of a sword. An additional example whereby glass beads are not in contact with the body is represented by T. 890, which is another male burial, and although this is not part of the analysed data set because the glass beads could not be located in the museum store rooms, it is worth pointing out that in this instance eye beads and beads with a wave trail were placed under a copper alloy cauldron (Weidig, 2014, p. 886, pp. 1184-1185).

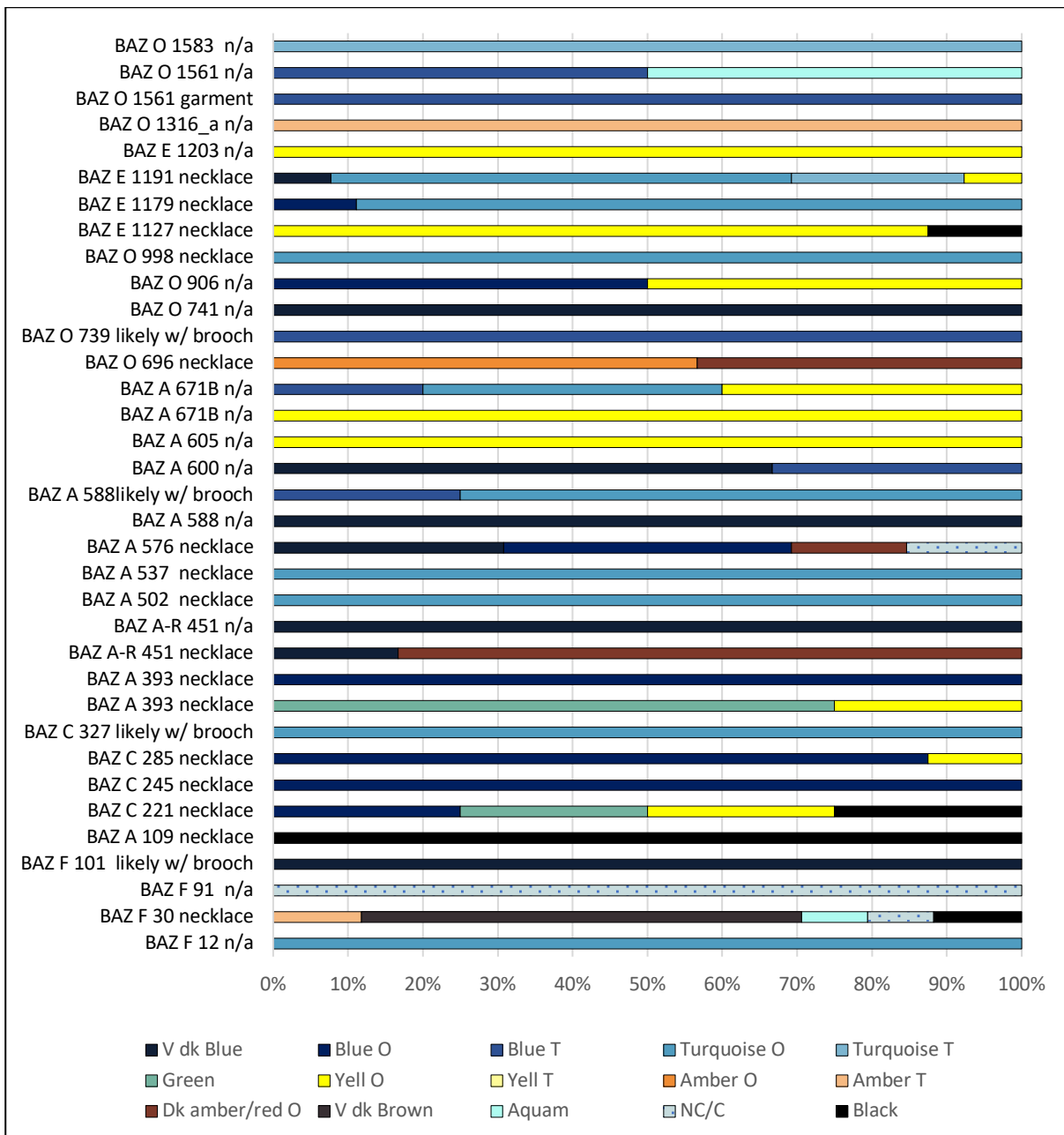


Figure 7.25: Bazzano Orientalising-Archaic phase: percentage of colours of monochrome and polychrome bodies of beads (n=1658) per burial (n=30), with respective configurations (chart author's own).

In addition, in female burial T. 1561, beside the blue glass ring bead retrieved by the left hand and the aquamarine globular bead which was perhaps originally laid on the chest, various brooch pendants encased in a metallic filigree cage – including a translucent blue glass alabastron shown in Figure 7.26 – were found lumped together due to corrosion to the left of the head, but in antiquity they were all likely placed within a folded garment (Weidig, 2014, pp. 1282-1283). It has been suggested that the fragmentary translucent turquoise melon bead retrieved from the centre of the grave of infant or newborn T. 1583 could have

been a similar type of pendant, as here the bead itself was found in association with copper alloy filigree wire and fragments of iron (Weidig, 2014, pp. 1292-1293).



Figure 7.26: Alabastron-shaped glass pendant from Bazzano, T. 1561 (Photograph author's own).

Concerning black beads and related colour combinations, beside the already mentioned necklaces from TT. 30 and 109, single specimens are also attested in female adult burial T. 221 and in child burial 1127, where they are paired with yellow (Figure 7.25). In the instance of T. 221, additional hues such as green and blue are also present. Black beads appear to be strongly correlated with other monochrome (opaque) beads, as they are accompanied by fragmentary yellow eye beads only in the case of T. 1127 and by translucent amber, brown, aquamarine and nearly colourless beads in T. 30. Standalone opaque yellow beads are mostly decorated with eyes, as seen in female adult burial T. 1203, where they were retrieved alongside a faience Egyptian scarab, and in the grave of a woman aged between 19-27 years of age (T. 671B). The other single yellow specimen is the already mentioned bead with wave trail from child burial T. 605 (3.5-6.5 years old). A very similar pattern was noted for individual very dark blue beads, which, with the exception of the specimen from T. 588 (child, 3.5-6.5 years old), are otherwise decorated with eyes, as documented for adult burials TT. 101 and 741 (the latter also contained a child). When combined with another colour, yellow eye beads can be associated with opaque blue beads, which can be of the same type,

as in T. 906, or monochrome, as is the case for T. 285. Translucent blue and turquoise are instead paired with yellow beads in the second necklace from T. 671B. The graves of a woman and of a newborn in particular – T. 451 (20-26 years old) and T. 576 (0-2 months old) – display a similar colour palette and use of polychrome beads whereby very dark blue (and opaque blue) eye beads are found with beads with wave trails, which have opaque amber and nearly colourless bodies respectively. Despite the similarity in the choice of hues, these two individuals are seemingly not related on a stratigraphic or proximity basis: the same consideration can be extended to the whole data-set for Bazzano, as it appears that there is no evident spatial correlation between graves and colour combinations.

7.10 Conclusions

The use of glass beads in Campovalano, Fossa and Bazzano, which were mostly retrieved from child and female burials, does not seem to be necessarily – or exclusively – attributable to gender or a given age group. No specific colour patterns which could be ascribed to one particular form of identity were detected within and across cemeteries: this is partly due to the fact that subsets of colour combinations sometimes are too small (such as two burials) to draw patterns. Specific uses of colours, which on a case-by-case basis can be the prerogative of individual or multiple sites, were instead tentatively observed in relation to configurations and broad bead types. If we take some of the most widespread colours, such as all the shades of blues and turquoises, there appears to be a shared mode of use for the totality of the sites and in all periods: opaque blues and turquoises are in particular favoured for polychrome beads, whereas the translucent counterparts are more likely to be monochrome. Similarly, black is always opaque and it is used in monochrome beads only, as recorded in Orientalising-Archaic Campovalano and Bazzano and in Hellenistic Fossa. Given that we cannot ascertain whether some or all of the beads were locally manufactured, it is impossible to tell the degree of intentionality behind colour selection in these contexts, as the beads may have been made elsewhere in an already restricted colour range from which to choose. A further common trait among all sites for the Orientalising-Archaic and Hellenistic periods is the higher percentage of monochrome beads in comparison to polychrome specimens. In most instances, necklaces are the most recurring configuration for both children and adults, followed by the use of beads as brooch pendants, which in the case of Bazzano appears to be more frequent among newborns, infants and children.

In terms of colour palettes, there are differences among the sites which can be given by the presence or absence of certain colours or by different ratios between specific hues. For example, during the Early Iron Age and the Orientalising-Archaic period, in Fossa and Campovalano there seems to be a predilection for monochrome beads in translucent colours, especially yellow and amber, whereas in Bazzano dark, opaque hues prevail, in particular amber and black. When compared to the previous phase, a contraction in the use of specific colours and/or in polychrome bead types – such as the lack of yellow beads with eyes or trails and a reduction in number of translucent amber beads – was instead observed for Hellenistic Fossa and Campovalano. Conversely, in the 4th century BCE we also witness the introduction of amphora-shaped beads and human mask pendants among the others in

the Campovalano repertoire, and the presence of new types of eye beads at times with unusual colours in Fossa. Such variations are unsurprising, as the sites were in use for a period of 400 to 600 years and had different territorial spheres of influence. As highlighted in Sections 7.2-7.4, Campovalano gravitated more around coastal territories and had stronger ties with the *Picenum* and the Middle Adriatic area, whereas Bazzano and Fossa, being nestled in the mountains, shared cultural aspects with southern Abruzzo, Campania and Latium. Perhaps also due to the geographic location of the sites (and subsequent ease in the acquisition of beads), differences in the total amounts of glass beads were also noted. Campovalano, located between the uplands and the coastal plain, in particular yielded a staggering amount of glass beads if compared to the other two upland sites which are much further inland. In all likelihood this is because Campovalano had easier access to coastal trade networks and ports, which, especially during the Iron Age, were heavily exploited for the circulation of goods; transportation by sea was the fastest and most reliable option, especially when compared to the crossing of mountain passes. Also, of note is the fact that glass bead necklaces in Campovalano became more elaborate during the Hellenistic period, but at the same time the number and variety of all grave goods contracted dramatically.

Across Campovalano, Fossa and Bazzano the percentage of graves containing glass beads is relatively low, and although some rich burials have also yielded glass beads, this does not automatically imply that such ornaments were destined for an elite. In the same way, the rare presence of graves with glass beads within a cluster of burials does not presuppose the existence of close kinship groups among individuals who share the same space. In any case, when family relations are hypothesised, as in Bazzano for T. 30 in particular (but not limited to this single example) more often than not all members of the same group are wearing beads (Weidig, 2014, p. 894). Conversely, similar bead colour combinations may be found in graves that are not in close proximity. Interestingly, the fact that glass beads are not necessarily tied to wealth was also observed for the Early Iron Age site of Osteria dell'Osa in Latium, where glass and amber beads were found in both 'rich and poor' women's and child's graves (Hladíková, 2018, p. 70). This reinforces the idea that we should steer clear of the traditional view of women (and children) in death in Iron Age Abruzzo, which is largely based on rank and gender, rather than on the roles that these individuals may have potentially fulfilled within societies (Faustoferri, 2016, pp. 106-107).

The graphs and pie charts created for each site enabled me to observe a potential relationship between certain shapes and/or colours of beads, be they made out of glass or in other materials. Annular and globular translucent amber glass beads are combined with amber beads with the same shape in 8th to 3rd century BCE Campovalano and in Early Iron Age to Orientalising-Archaic Fossa, perhaps signalling that glass and amber may have been considered as equivalent materials in virtue of their chromatism. Amber glass beads are also attested in earlier funerary contexts, such as in the Villanovan (proto-Etruscan, 9th to 7th centuries BCE) cremation cemetery of Verucchio in Emilia-Romagna and in burials dating to the second half of the 8th century from the same region but also from Latium and Etruria (Koch, 2023, pp. 22-23). In addition, in both Campovalano and Fossa, eye beads are also associated with the above-mentioned translucent amber glass and/or amber beads. Conversely, eye beads in Bazzano were retrieved alongside amber beads only, as otherwise glass is usually combined with bone and copper alloy beads and pendants. The fact that amber and/or amber glass beads are also found in conjunction with eye beads, albeit not necessarily in the same configuration, allows us to presume that such beads carried a multi-layered symbology, which is difficult to decipher and it is likely to be context-dependant. New, perhaps meaningful, bead types are documented In Hellenistic Campovalano, such as opaque amber eye beads and amphora-shaped pendants, which, alongside monochrome nearly colourless and aquamarine beads, also accompany amber beads.

Whether amber and amber coloured glass may have shared the same essence (and perhaps by extension value) because they shared similar properties and how the above-mentioned specific glass bead types interact with each other and what this might signify, will be explored further in Section 8.5 of the discussion chapter.

Chapter 8. Discussion and conclusions

This final chapter summarises the main discussion points in relation to glass bead production, use, and meaning by drawing from the experimental bead-making activities I carried out, use-wear analysis and ethnographic and archaeological data. In particular, in our discussion on bead-making, the emphasis will be placed on the Fazzan assemblages and more specifically on their traces of manufacture and chemical signatures. By considering how the beads were made, we will contextualise our findings within the broader archaeological picture and will consider, among the other things, the existence of communities of practice and of cross-craft interactions. The section on glass bead use will summarise the results from use-wear analysis performed on the beads from Wadi al-Ajal. The last conceptual block is centred on the sensoriality and materiality of glass beads, and how these factors contributed to the creation of identities in death in pre-Roman Abruzzo: particular attention will be dedicated to the relationship between bead shapes, colours and types and to the fragmentation of bead sets. Before moving on to the concluding section, where suggestions for future work are provided, based on the body of evidence in relation to manufacture and consumption, the reader is urged to re-consider how we discuss the lives of glass beads.

8.1 Considerations on glass bead production

As previously discussed in Chapter 2, we know relatively little about the sites where glass(bead)-making and/or glassworking took place. As a result, to make sense of this incomplete picture, we relied on compositional data and on evidence mostly provided by large furnace structures to devise production models which are far from applicable to all artefact categories or even to different geographical areas and periods. A case in point is represented by the glass beads from the Wadi al-Ajal studied in the present work: we cannot ascertain whether they were made locally from raw and/or recycled glass or if they were imported from other areas such as Egypt and the Mediterranean. Based on the broader glassworking and glassmaking evidence for Fazzan, which is exemplified by malformed beads from Zuwila alongside raw glass and glassworking debris from Zinkekra and Jarma, we can hypothesise that both scenarios occurred, especially as we are dealing with a small data set which is compositionally and chronologically heterogeneous (Duckworth et al., 2016a, p. 637; Duckworth, 2020b, p. 346, Appendix C). In particular, some of the 'beads' studied in this thesis, as it is the case for ZIN 11/1 beads 7 and 9, do not represent finished objects, but are rather attempts at bead-making and/or constitute bead-making debris, further supporting

the assumption that glass was in some form worked in domestic contexts (see Chapter 5). As such, these failures are very important as they can provide us with insights on bead-making technology, and more in general on any potential attempts to experiment or innovate (Duckworth et al., 2020b, p. 31).

All of the chemically analysed beads show varying degrees of repeated remelting/recycling. We know that different glasses were mixed together with the addition – either as a deliberate choice or as a result of contamination – of (de)colourants, opacifiers and fluxing agents. The composition of the mineral soda samples, albeit ‘dirtier’, is close to Roman and Late Antique colourless/naturally coloured vessel glass from Fazzan. For example, this is the case for mixed manganese/antimony signature reported for bead TSG_172 and for a glass chunk both from Saniat Gibril. This evidence indicates that at least in some instances broken vessels may have been collected as cullet, which was then re-heated to craft the beads with the addition of colourants or further coloured glass (Duckworth, 2020b, p. 336). An earlier attestation of the mixing of glasses at low temperature is provided by ‘paired’ eye-bead TSG_168, which, although unstratified, belongs to a type commonly found in 1st millennium BCE continental European and Mediterranean contexts, in particular dating to the 5th-4th centuries BCE (Spaer, 2001, pp. 81-84; pp. 90-91; Kunter, 1995, p. 60; pp. 145-168). A similar occurrence was also observed even earlier for Egyptian Late Bronze Age opaque and semi-translucent green glasses from Amarna. These specimens likely resulted from the re-melting of pre-formed objects such as blue and/or turquoise vessels with white and yellow decorations, as indicated by the size of their inclusions and by their lead and antimony contents, which are intermediate to yellow and white glasses (Duckworth, 2011, pp. 150-161). At any rate, it is impossible to ascertain whether TSG_168 was manufactured in Fazzan or elsewhere; however, on the basis of the evidence presented, we can assume that, especially for the manufacture of artefacts such as beads, whereby little quantities of glass would have been needed at one time, recycling may have occurred on a smaller, more haphazard scale when compared for instance to Mediterranean Roman and post-Roman vessel productions. This may also imply that, if bead-making was taking place in Fazzan, this may have been an occasional or seasonal activity.

As compositionally ‘dirty’ glass cannot be easily blown, it probably would have been easier to work the scrap glass by winding or drawing, especially at lower (or inconstant) temperatures. The sample set in this respect shows that although eight of the beads are wound, both

techniques would have been suitable, as TSG_172 is a drawn bead. In addition, besides eye bead TSG_168, the remainder of the beads are either monochrome or present simple decorative techniques, such as trails or the presence of a core in a different colour.

The observations made so far are partly consistent with the results from the bead-making experiments I carried out using small furnaces (Chapter 3), as not only can beads potentially be made using any structure that can retain sufficient heat to melt the glass, but also the 'raw' material itself can come in a variety of forms which do not require batch processing, such as canes and cullet. In addition, the assemblage from Fazzan consists largely of bead types that are rather quick to make and hence do not require careful planning in their design or in their making, which is particularly convenient when working glass using a furnace or structure which exhibits fluctuations in temperatures or that is exposed to the elements. In addition, use-wear analysis performed on selected Fazzan beads informed us further on the techniques employed and of the technological choices of bead-makers during manufacture, which, among other things, are reflected in the ability to control the glass-working temperature, in the use of separators and, in the case of drawn beads, of moulds and heat treatment to polish the surfaces of beads (Chapter 5, Section 5.5).

As highlighted in Sections 2.5-2.7 in Chapter 2, in archaeological terms it is very difficult to establish who exactly made beads; ethnographic data, when combined with the results from the excavations of production centres or trading sites can give us an idea of the manufacturing processes and the degree of specialization involved according to specific social, cultural and economic settings. From both sources of evidence it appears obvious that the bead-making *chaîne opératoire* cannot be separated from other aspects such as raw glass manufacture, types of furnaces, or tools used in the production processes (see also Section 2.1). As a consequence, each stage of glass bead production in given socio-cultural contexts connects different skills sets and individuals. If we investigate glass bead-making technologies, we can by extension understand the social systems in which they exist, and in particular we can establish the nature of relationships and networks for each step of their *chaînes opératoires* (Rebay-Salisbury et al., 2014, p. 2). In addition, since as archaeologists we try to reconstruct ancient technological processes through artefacts, we have to be aware that *chaînes opératoires* may contain intangible steps such as mental or verbal operations, or culture-specific elements, such as magic and the presence of taboos, which make inaction just as important (Conneller, 2011, p. 17).

Given such premises, the best way to investigate bead-making – or any other craft – is perhaps by using the concept of communities of practice, which is based on the tenet whereby learning, and hence the imparting and sharing of knowledge and practices, are social processes. This means that each member within a community of practice will interact, collaborate and share repertoires with other individuals within the same group (Blair, 2016, pp. 97-98; Wenger, 1998, p. 152). This approach presupposes that different communities of practice are part of a network, and when they are interrelated, they form constellations of practice (Blair, 2016, p. 116). This theoretical lens has been successfully applied to the study of over 800 opaque white drawn glass beads from the 17th C Spanish colonial site of Mission Santa Catalina de Guale (St. Catherines Island, Georgia, USA). The XRF (X-Ray Fluorescence) analyses performed on the beads, yielded six different chemical signatures on the basis of the type of opacifiers and other raw ingredients employed. As such, each compositional group represented a single community of practice, or three communities if any genealogical connections were present. These glassmaking communities of practice would have then encroached on at least two bead-making communities of practice which used specific, recognisable techniques, thus forming distinct constellations of practice (Blair, 2016, pp. 103-106). In addition, individuals within the same community of practice may follow the same steps in the *chaîne opératoire* but have different skill levels, as emerged from the analysis of the combed decorations on the Seven Oaks gilded wound beads which also are part of the Mission Santa Catalina de Guale assemblage. In this case, based on the complexity of the decorations and on the marks left on the beads during hot-working, it has been possible to ascertain that two different combs – belonging to as many individuals – were employed for the purpose. In particular, the least amount of skill was observed on beads with simpler decorations corresponding to comb B, whereas from the imprints left on the glass, the teeth of comb A were misaligned, meaning that this tool had been used for a long period of time (Blair, 2016, pp. 106-108).

From the manufacture traces and separator residues recorded on the Fazzan beads studied in the present thesis (Sections 5.5 and 5.10), we can presume that – especially for the Zinkekra habitation sites – different constellations of practice would have coexisted at any given time, however, due to the general character of the archaeological contexts and their wide chronological bracket, we are not able to provide any in-depth interpretations.

Another important point to raise is that the archaeological evidence for glass bead-making is often associated with other types of production, highlighting the importance of potential cross-craft interactions (Chapter 2, Section 2.5). A prime example in the Wadi al-Ajal is represented by the site of Saniat Gibril, where not only a variety of crafts such as glass- and copper working, and jewellery making coexisted in the same space, but they were also carried out alongside domestic activities such as cooking (Robertshaw, 2020, pp. 398-399). This suggests that to some extent pyrotechnological knowledge must have been shared between different individuals and/or activities: glass technology is interconnected to metalworking, and at the same time, these activities rely upon the understanding – and application of – other skills and crafts, such as pottery making (Peake & Freestone, 2012; Fenn, 2015).

This permeability between materials is visible in the Fazzan assemblages which were analysed for the detection of wear by use: Bead 1 from ZIN 34/1, bead 5 from ZIN 11/1 and bead 2 from ZIN 11/10 show modification (and potential reuse). ZIN 34/1 bead 1 and ZIN 11/1 bead 5 in particular, which were likely made by winding to begin with, were polished at a later stage, possibly by using grinders employed in the making of carnelian or ostrich eggshell beads, as suggested by their discoidal shape and by widespread abrasion on their surfaces. This is further corroborated by the retrieval of bead-grinders from these sites, which attest to the fact that this activity was taking place at a household level. Furthermore, this evidence fits nicely with the suggestion that the Garamantes may have worked glass from cold, as hinted by the large glass chunk and by the above-mentioned evidence for the making of beads documented for Saniat Gibril, where semi-precious stones – with Mohs hardness levels similar to glass – such as carnelian were employed (Duckworth, 2020b, p. 340).

Bead alteration, a well-established practice in West Africa, known to Europeans from at least the 17th century CE, and continuing up until the modern period, is reported for various parts of the region. Accounts of travellers dating to the 1600s and later archaeological excavations, testify the presence of sites on the Ghanian coast which were specialised in the reworking and polishing of Venetian glass beads. This occupation remained a source of income for coastal women until the 1990s (Gott, 2014, pp. 16-17). In a similar manner, 20th century itinerant Hausa bead traders from Nigeria were adept at reshaping glass beads by grinding them against stones, so they could fit properly on strands with other beads (Francis, 1999,

pp. 104-105). By doing so, decorations could be removed; otherwise, the length of beads could be modified, or, alternatively, similar to that observed for the above-mentioned beads from habitation sites 11 and 34 in Zinkekra, their surfaces could be ground down until flat. In southern Mauritania, medieval millefiori and mosaic fused-rod beads from Fustat in Egypt, which are known here as *morfia* beads, are heirlooms: as such, single specimens are fragmented into smaller pieces so that further beads can be obtained (Carey, 2003, p. 110). In this light, the modification and repurposing – perhaps also on a symbolic plane – of glass beads carried out in the Wadi al-Ajal, may be considered as a potential precursor of this tradition, which in all likelihood even at that time encompassed a wider network of sites and geographical areas.

Currently we cannot tell how regularly glass bead-making from hot and/or cold occurred in Fazzan. Although there could have been several individuals engaged in this activity with different levels of intensity across sites like Saniat Gibril and sites 11, 13 and 34 in Zinkekra, it is probable that this was not a full-time occupation, but nonetheless required a specific – and transversal – skillset. Moreover, here glassmaking and glassworking are set against a complex, multi-faceted and very often elusive backdrop, where technological transfer is difficult to trace, especially because of the paucity of archaeological data available, as is the case for glass. At any rate, mobility is a very important factor in technological transfer, and as such, the role of nomadic pastoral populations must have been paramount (Duckworth et al., 2020b, pp. 33-36). As we have seen in the previous paragraphs, in the case of bead-making, especially if we look at the metallurgical and jewellery making site of Saniat Gibril, we can think of technological packages, whereby sets of connected technologies seem to appear at the same time. In an area where resources such as fuel can be generally scarce, these very same technologies, albeit complementary, tend to be in competition (Duckworth et al., 2020b, pp. 39-40).

In any case, one of the possible reasons for the birth and diffusion of glassmaking and working is of a socio-cultural nature: in order for glass artefacts to be produced, the knowledge or invention of glass *per se* is not a determining factor, as its adoption will depend on demand, which is regulated by the symbolic, social, political importance given to the material and types of objects that can be produced with it (Fenn, 2015, p. 396). As such, the presence of glass in the Wadi al-Ajal is no exception, as there clearly were – across time and space – communities of consumption in dialogue with communities of practice; bead-makers

could in fact manipulate the colour, shape and size of beads to suit consumers taste or sense of fashion (Robertshaw, 2020, pp. 394-395).

Considering that experimentation with glass, as a raw material or as beads, was to some extent occurring in the Wadi al-Ajal, questions can be raised as to whether glass and glass bead-making technologies were shrouded in secrecy or if they were freely accessible to anyone who was willing to learn. When it comes to glass, if knowledge is restricted, this usually occurs around raw materials and methods: the secrecy around ratios for ingredients employed in glassmaking is perhaps tied to the desire to maintain a certain *status quo* whereby the craftspeople preserve a very specific identity within a given social structure. This could have been the case for the LBA glassmakers in Amarna, or for the contemporary *Masagá* glassmakers (Peltenburg, 1971, p. 11; Shortland, 2007; Robertshaw, 2020, pp. 394-395; Lababidi et al., 2023;). The existence of recipes helps to ensure continuity, but at the same time it favours conservatism, as reported by Peltenburg (1971, p. 10) with regards to Mesopotamian glazes. This is also consistent with what observed for other materials and cultural contexts. For instance, the pre-Hispanic Pueblo society in South-West America (1175-1400 CE), restricted the production rights and by extension the access to tools, materials and knowledge required to make White Mountain Redware pottery, as opposed to Cibola Whiteware, the technology of which was easily accessible (Crown, 2016). As such, also in the case of White Mountain Redware, secrecy is a tool employed to negotiate and maintain identities; however, knowledge is also not shared when active experimentation is taking place (Crown, 2016, p. 69). With this in mind, secrecy is not necessarily related to conservatism as it can be tied to technologies or processes that are well-established, or, in contrast, are not yet stable. When conservatism is present, experimentation and innovation cannot flourish, as especially the latter is the result of the transmission of knowledge across technologies (Peltenburg, 1971, p. 10; Rebay-Salisbury et al., 2014, p.1).

If conservatism appears to be primarily in connection with the making of glass, we cannot rule out similar attitudes in terms of structures and tools employed in bead-making. Given the fact that the archaeological evidence for bead manufacture is generally scant, conservatism can be perhaps spotted more easily in bead use patterns – and hence in the production (or acquisition) of given bead types. Although the assemblage is quite small, for the Zinkekra sites it was possible to note that there was a preference for green, turquoise and blue beads, which were more frequently monochrome; the only polychrome specimens

were eye beads with the same palette. An example of how conservatism can shape bead preferences across communities of consumption and practice and can also denote specific cultural influences is provided by the use of heirloom beads among the Pedi and Venda from South Africa. The beads, which were handed down through generations, were believed to have healing powers and to represent ancestors; once European manufacturers started copying older specimens, the consumers, who were aware of the inauthenticity of the beads, would buy them regardless, thus reinforcing an existing preference. As such, this creates a cycle whereby the beads that are most known and that have specific meanings will then keep on being made, traded and consumed (Wood, 2008, p. 187)

8.2 Considerations on glass bead use

In order to assess what role(s) use wear analysis can play in the interpretation of the life-histories of glass beads, experimental replicas, which acted as a reference collection, and archaeological beads from Fazzan were examined using this technique (Chapters 4 and 5). Although glass is less smooth and presents more defects than obsidian, the latter was taken as the main reference material to classify trace morphology. Due to the inherent discrepancies in the physical characteristics of the two materials, a complete overlap between the two was not possible, leaving us with a partial comparison.

The results obtained from qualitative use-wear analysis on experimental bead sets showed that it is possible to differentiate manufacturing traces from wear by use. In particular, good indicators of use are chaotic striations on the bodies of beads, and short, perpendicular, or oblique striations on the thread-hole edge, which are accompanied by rounding and polish. Moreover, the type, abundance and distribution of traces depends on several variables, such as: the type of string employed and whether this was wet or dry, the shapes of the beads, the hardness of beads in materials other than glass, the stringing technique and load, i.e., the number and dimensions of beads strung together and how they are worn. As glass is a brittle material, it has been noted that the presence of traces that indicate use developed relatively quickly. The 10 necklaces devised for the bead-wearing experiment showed clear signs of micro-wear after each of them was worn by a volunteer for an average of 5 days a week over a 10-month period. In addition, due to the variables listed above, wear by use can develop differentially on bead surfaces. This phenomenon was consistently observed for the control faces of beads, which showed little to no traces, and, whenever polish was noted, it was of the very light, undiagnostic, type.

What emerges from the experimental data set is that different stringing materials (leather versus flax/cotton) seem to produce similar types of wear. This is not only consistent with what observed by Guzzo Falci et al. (2019) for beads in a variety of materials including glass, but it also confirms the results from use-wear analysis on glass tools performed by Conte & Romero (2008), who did not find polish from wood-scraping to differ substantially from dry hide scraping. The major discriminant reported by the two authors was that hide polish appeared less shiny and was characterised by the presence of higher amounts of striations, mostly with oblique and perpendicular orientation. This inability to discern one polishing agent from another is caused by a multitude of factors. In the first place, on the various datasets polish on some artefacts may not have developed enough to show characteristics that are typical of given materials, and as a result this will muddle our interpretation. Secondly, beads *per se* are very mobile and as such they can be curated and re-strung multiple times with different materials and configurations. As such, multiple and coexisting variables are introduced each time, hence affecting the clarity of the relationship between materials, given actions and resulting wear. Thirdly, if we exclude the small reference collection I created, no other experimental specimens have been crafted to date with the purpose of measuring trace formation under given conditions. Lastly, beside the Fazzan beads presented in this thesis, only two archaeological glass bead assemblages have been subjected to use-wear analysis (Cristiani, 2006; McGloin, 2021,a,b). Although this is certainly a start, the results produced by these studies are not fully comparable as slightly different methodologies were used, and, most importantly, we have to remind ourselves that our ideas around issues concerning wear formation or maximum use-duration are currently shaped and constrained by a limited availability of data from experiments and from archaeological contexts.

The glass beads from the settlement and cemetery sites in Wadi al-Ajal, which are broadly attributed to contexts ranging from the 1st millennium BCE to the 1st millennium CE, showed traces of wear that were in the large part consistent for morphology and distribution with what observed for experimental replicas. On the one hand, this demonstrates that the manufacture of replicas and related wear experiments are of vital importance as they provide us with invaluable information for comparison with archaeological and further experimental datasets, whilst allowing us to test hypotheses. On the other hand, experimental reference collections cannot be taken as being fully representative of all the

traces that can be encountered on archaeological beads, as the latter will also present wear traces in connection with post-depositional events. Although we can tell that at least 28 archaeological beads were undoubtedly used, glass degradation processes made interpretation at times difficult by masking or fully obliterating traces of wear by use. This is because chemical corrosion, which depends on several factors such as glass composition and pH of burial environment, tends to develop on surfaces which are already defective or mechanically damaged through use. In addition, in the case of archaeological glass it appears even more evident that chemical degradation can begin as early as the manufacturing stage. As such, the bead-making technology employed in the crafting of particular beads may be of great importance: as discussed in Chapter 2 (Section 2.4), manufacturing processes can create superficial flaws that encourage fracture growth. Experimental work carried out by Jackson et al. (2012), has demonstrated that different shaping techniques such as mould casting, sagging/blowing and grinding affect the rate and degree of glass degradation processes, as these are dependent on surface microstructure, cooling rates and molecular structure of a glass. This suggests that there could be substantial differences between wound and drawn beads, to mention only the most widespread bead-making techniques found in the archaeological record.

When reasonably to well preserved, the beads displayed a more or less marked rounding of the thread-hole edges accompanied by bright to dull polish. When compared to replicas, polish and rounding affected a larger surface percentage of the archaeological beads that were clearly used, as they were probably worn in the same configuration for a period of time that went well beyond the ten-month use-duration of the necklace wearing experiment. As such, polish, rounding and abrasion were concentrated not only on the edges, but also on areas of the body where the bead was adhering the most against another bead.

As the bodies of the glass beads may interact with beads with different textures and in various materials, as also reported in Section 4.9.5, it is impossible at this stage in the research to isolate specific bead materials and to relate them to given ensembles of traces found on archaeological beads. In a similar manner, our reference collection did not provide any clarification as to how string material impacts on attrition and related traces within and around the thread-hole edges of beads. As such, we can perhaps form a broad idea on how different materials which are relevant to our bead datasets by comparing them to the attrition found on obsidian tools. Concerning hard or soft wood, wear from sawing or

whittling developed after 10 minutes; sometimes associated with part-flakes, severe attrition which wore the edge down was noted. In the case of plants and *graminae*, traces of wear by use were present after 10 to 20 minutes respectively. In both instances, mostly light attrition, occasional cracks and partly flaked features were recorded. Lastly, diagnostic traces appeared on obsidian after 5 minutes of working on hide; severe attrition was prevalent in dry hide-scraping experiments, whereas in the case of fresh or fatty hide, attrition was far less developed (Hurcombe, 1992, pp. 40-46).

Considering the fragmentary nature of the contexts from which the beads were discovered and collected, it is impossible to ascertain their configuration(s). We know that at least in the excavated funerary contexts of the Wadi al-Ajal, beads made out of glass and other materials were frequently found in burials of adolescents or children, and in single female graves, where, at least in the latter case, it appears that strings of beads were worn around the neck and the waist, and that beads were also sown on textiles. Albeit in smaller quantities, loose beads were also encountered in male burials (Mattingly et al. 2019, pp. 94-97). In any case, in this instance it was not possible to reconstruct exactly how the beads were worn by the deceased (Mattingly et al. 2019, p. 91). If the beads were sown on items of clothing, we would perhaps expect to see a wider distribution of traces, which would be more prominent on the face in contact with the fabric. We can also surmise that the shape of beads can dictate what they can be used for: as observed for Nguni groups in South Africa such as Zulu, Xhosa and Ndzundza Ndebele, cylindrical and oblate beads are employed in free-standing beadwork, whereas tubular beads are usually strung, and both types are sown on garments (Wood, 2008, p. 187).

8.3 Considerations of glass bead meaning through the lens of colour, materiality and sensoriality

8.3.1 *Glass beads, colour and identities*

From the analysis on glass bead colours carried out in Chapter 7 on assemblages from three main burial sites in 1st millennium BCE Abruzzo, it has emerged that Campovalano, Fossa and Bazzano, present – especially during the orientalisering-archaic period – some common traits, such as the widespread use of blue eye beads and of monochrome turquoise, blue, (translucent) yellow and amber beads. The combination of some beads, whether in one or more colours may denote patterns of use that can be ascribed to individual local cultures, as

is the case with the necklaces from Hellenistic Campovalano and Fossa with their black, blue and yellow monochrome beads. Other types such as layered eye beads however appear to have a broad continental distribution between the 6th and 4th centuries BCE, perhaps indicating a supra-regional aspect of bead consumption (Weidig, 2014, p. 374; Kunter, 1995, p. 227-229). During the Hellenistic phase of Campovalano and Fossa, differences in colour palettes across the two sites become starker, especially in the case of monochrome beads, which, in line with the trend observed for the previous period, continue to out-number polychrome specimens.

With this in mind, it is highly likely that given colours and colour combinations were used to express certain form(s) of identity or personhood among a relatively small number of women, children and infants: considering the long-lived nature of the sites, the complexity and the mutability of socio-political frames roughly over a six-century time span, and the fact that beads are polysemic artefacts, we cannot determine the specific role(s) of glass beads in the negotiation of identities. Besides their partially gendered nature, no clear and consistent patterns of use of certain colours or bead types that would unequivocally satisfy a distribution of such artefacts across age, family, elite or ethnic groups were observed synchronically or diachronically.

Nonetheless, we may be able to question some common assumptions, by initially stating what glass beads do not necessarily do. In pre-Roman Italy beads and pendants in glass or other materials such as amber, bone, coral and animal teeth are commonly found in female and child burials and have been interpreted as amulets with apotropaic or magical value because of their shape, material and sensorial properties (either tactile, visual or auditory) and exoticism (Perego, 2010, Weidig, 2014; Chiaramonte Treré, 2003a). If the societies of Campovalano, Fossa and Bazzano undoubtedly valued such items of adornment because of their intrinsic qualities and perhaps their power, this does not necessarily imply that all (glass) beads were necessarily amulets, or that all amulets were specifically used to protect individuals from premature death or ill health. For this reason, at least in the case of northern Abruzzo, we should not conform to the trope that sees beads as the main markers for fragile and/or marginalised identities.

For all phases examined in the cemetery sites of Campovalano, Fossa and Bazzano, children and infants (including fetuses and newborns) are considered as persons as they are buried

alongside adults, thus receiving the same treatment in death. In particular, during the orientalis-ing-archaic period, the grave goods for children under six years of age consist of items of adornment only, which mirror (for variety and abundance) the ones of adults. Furthermore, as in the case of T. 220 in Campovalano, particularly during the Orientalising-Archaic period, child graves can be physically connected to the ones of male adults, perhaps signalling patrilineal linkages (Cesana & d'Ercole, 2018, pp. 158-159). If children do not occupy a liminal position within these societies, the same observation also applies to women, whose presence is constant in the record. In addition, for the whole duration of use of Campovalano and Fossa as cemetery sites, approximately only 10% and 6% of burials have yielded glass beads, with the figures for the orientalis-ing-archaic phase of Bazzano being even lower, at around a mere 4%. As already postulated, besides the lack of published data for Hellenistic Bazzano, the reason behind this numerical discrepancy may be caused by differences and shifts over time in material culture, territorial assets, spheres of cultural influence and access to communication and trade routes. In any case, what appears clear for all the sites is that glass beads are not encountered in all the graves of infants, children or women, indicating that glass is not conceptually tied to fragility.

In Iron Age Italy glass and amber beads are also traditionally associated with status and wealth (Negroni Catacchio, 2011a; Negroni Catacchio & Gallo, 2021), meaning that beads had a social (and economic) value and could thus be considered as luxury goods (Robertshaw, 2020, p. 400). On the one hand, this may partly explain why in some of the burials of Campovalano during the 4th and 3rd centuries BCE rather simple objects are accompanied by a plethora of complex (and often precious) items of adornment. On the other hand, this phenomenon may also be due to the expression of new (non-)local identities, as Campovalano at this point in time gravitates around the cultural sphere of the Gaul Senones but the same cannot be said for the orientalis-ing-archaic period, where the prestige of glass beads is not linked to their quantity nor to the richness of the grave goods (Buoite, 2010, p. 211; Chiaramonte Treré, 2003a). It appears clear that at least in the latter case the value of beads in all likelihood does not rest on economic grounds. Another important point to make is that glass beads and other grave goods may not reflect the status of an individual in life, and as such, could be markers of identities in death.

As highlighted in Chapter 6, glass is also perceived as valuable on the basis of its exoticism: if the application of such a paradigm works for Western (modern and contemporary) value

systems, ancient societies do not necessarily conform to such a model. Beads have long biographies because of their durability and in virtue of the fact they can be divided and re-strung. This means that when they were shared or redistributed between individuals, as perhaps is the case with some orientalisising-archaic and Hellenistic burials from Campovalano and Fossa (Sections 7.7 and 7.8), their value would have transcended their original provenance, and as such may have rather been tied to memories and emotions elicited by the material and sensorial attributes of the beads.

8.4 Bead shapes, colours and types: glass in imitation of other materials?

The assemblages of Campovalano, Fossa and Bazzano seem to have some aspects of conservatism in the use of colours in relation to given types of beads or shapes: this is notably the case for polychrome beads, which as a rule are fashioned in opaque hues with a prevalence of blue (in particular eye beads). The colour repertoire of monochrome beads appears more variable over time across and within sites, although colours such as blue and amber feature quite heavily. On the basis of these observations, we can advance the hypothesis that perhaps monochrome and polychrome beads – along sub-groups within each macro-category – may have had different meanings and uses.

As previously stated, if not all beads are amulets, certain shapes, materials and decorations can bear magical or amuletic powers. In addition, the placement and configuration of beads on the body, alongside the presence of specific colour combinations or compositions with beads in different materials, could have added layers of meaningful symbolism. This may be the case for at least three categories of beads which are often found in combination with amber and at times also with each other:

- Eye beads
- (Translucent) amber glass
- Amphora-shaped beads

Starting from eye beads, which represent our first category, the combination between beads of this type and amber beads was observed across all sites and periods, whereas the association between amber glass (our second category) and amber beads is particularly seen

in Campovalano, which is also where our third category of beads, i.e., amphora-shaped glass beads, are encountered during the Hellenistic phase.

Because of their sheen and contrasting colours, eye beads may have possessed apotropaic properties (Duckworth 2020, p. 237), with amber also being used for personal protection and medicinal purposes (Negrone Catacchio, 2011a, b). It is possible then that the individual power of these two materials would have been enhanced by their juxtaposition, perhaps resulting at the same time in the construction of new symbols.

With regards to the joint presence of amber glass and amber in necklaces or on brooches, we may postulate that these communities perceived glass and amber to be alike. It may be the case that – although this remains to be seen – amber coloured glass was used to replace broken amber beads, or to create sets of beads with the same chromatism, as observed for jet and jet imitation beads from Neolithic and Bronze Age Scotland (Sheridan & Davis, 2002). In the context of the examined burial sites, amber glass could possibly be considered a skeuomorph for amber, but not in strict imitation of its manufacturing technology or shape (Frieman, 2012a). With the exception of amphora-shaped beads, which will be discussed in the following paragraphs, amber beads in pre-Roman Abruzzo – and more generally in Bronze Age and Iron Age Europe – tend to have specific types, which differ substantially from the ones of glass beads (Negrone Catacchio, 2011b). As much as Upper Palaeolithic beads in shell, ivory, stone, bone, antler and other materials all have lustre as the same common denominator (Conneller, 2013, pp. 125-129), glass is a skeuomorph because of its shared characteristics – primarily brilliance but perhaps here also hue – and purpose with amber. In the same way, in Late Bronze Age Egypt, lapis-lazuli and copper or cobalt coloured glass were both blue, sharing the same essence (Duckworth, 2012). In the case of Anglo-Saxon inlays on metalwork, once again, glass was used to replace missing or broken garnets in virtue of the fact that it was considered as precious as garnet itself, perhaps due to the fact that both materials had similar qualities and attributes (Ahmet, 2016).

In Hellenistic Campovalano, moreover, some of the amber glass beads are biconical or even polychrome, as is the case for translucent beads with a central trail and opaque cane eye beads retrieved in TT. 604, 311 and 285. The affordances, potential and limitations of amber are of course very different from glass, which can be manipulated to create a great variety of shapes and multi-coloured objects. With amber glass being a skeuomorph for amber, it may

be the case that the introduction of such beads in the repertoire could have been a way to expand – in physical and conceptual terms – the shared essence and power of these materials. In this light, skeuomorphism can also be seen as a catalyst for technological innovation, as similar artefacts, which present the same characteristics or properties, share the same cultural category and value as observed in attributes and design of nonceramic vessels transferred onto pottery (Blitz, 2015).

Our third category is represented by amphora-shaped beads, which occur in the whole of their continental distribution area only in nearly colourless or aquamarine glass, signalling a strong relationship between hue and form. In funerary contexts this type is often combined with amber but also coral, and in the case of Campovalano amphora-shaped beads are additionally associated with amber glass beads and eye beads, with the latter either pertaining to the same necklace or featuring as brooch pendants. Rustoiu (2015) reports that these glass beads, which are believed to possess an apotropaic function, were perhaps crafted in the Black Sea region or somewhere in the Mediterranean. At the same time, amphora-shaped beads, which perhaps originated from archaic Greek and Macedonian gold specimens, were also made in the Balkans using amber and bronze.

As seen in the case of *guanín* for the Taíno and of Ghanian precious beads and gold in Chapter 6 (Sections 6.7 and 6.10), what we would class as different materials – or even things – inhabit the same conceptual sphere, which means that they are to some extent equivalent in virtue of their inner power. Perhaps a similar sense of intercommunicability and partial interchangeability between materials is what we see in the case of amphora-shaped beads, amber and eye beads. In particular, we can perhaps advance the hypothesis that the relationship between amphora-shaped beads in glass and amber or metals might be based on their shared brilliance and perhaps on other sensorial qualities. The particularly strong association between hue and shape observed for the glass specimens may have also added further symbolic meaning, which may have conveyed messages of a different nature.

8.5 Evidence for the fragmentation of bead sets and continued use

Considering that glass beads are portable and durable, they could have also been restrung in multiple combinations through time. Our evidence, which consists in relatively isolated cases whereby two or more individuals share the colour and types of beads, does not overtly point to the fragmentation of sets as such; however, we can hypothesise that (some) members of

the same community shared beads at some point. Would that be the case, the fragmentation of bead sets could have occurred during life but also during funerary rituals, as this has been noted with jet and jet-like beads from Neolithic and Bronze Age Scotland (Frieman, 2012b; Sheridan & Davis, 2002). The larger the bead assemblage, the more likely that this would have been in circulation for longer and some beads would either have been lost or new ones added to it. The reasons behind restringing, by adding and/or removing beads, may have to do with fashion but also with the fact that some beads were passed down from one generation to the other, being considered as heirlooms (Frieman, 2012b).

In this sense, bead typologies are of no help, as especially annular or globular beads have a wide spatial and temporal distribution, from the Late Bronze Age to the Hellenistic period and beyond, to the point where they are still manufactured to this day. This also applies to polychrome beads: specimens with a central wave trail are widespread in Europe between the 6th and 5th centuries BCE, but they are known (also in Abruzzo) since the 8th century BCE, with certain types of eye beads, such as the ones with concentric eyes, being equally – if not more – popular for over five centuries, that is to say from the 9th to the 5th century BCE (Weidig 2014, pp. 368-375). Moreover, this is accompanied by the lack of a unitary classification of bead types for the Italian peninsula during the 1st millennium BCE and by the fact that among the various typologies built for eye beads there is no consensus, as their categorisation is based on different and arbitrary criteria. If in this specific instance we are not able to draw any meaningful, in-depth conclusions from our data set, going forward however, use-wear analysis may be able to shed further light on the approximate duration of use of beads, hence helping us to decipher further the concept of fragmentation.

8.6 Re-thinking glass bead biographies

Similar to technology, the concept of life-history traditionally follows a unilinear birth to death trajectory which implies that artefacts, after going through milestones, simply cease to exist; however, if those very same artefacts are still physically present in our world and we can interact with them, it means that they are not ‘dead’, but that they simply are being used and conceptualised in new ways. In this sense, it would perhaps be more apt to talk about object itineraries, as suggested by Joyce & Gillespie (2015). In addition, I suggest here that glass beads should be considered as being situated at the intersection between material properties and materiality, and as such their itineraries as shaped by their very nature. The implications deriving from the affordances of the raw material and related technology are to

some extent practical, but at the same they are also rooted in given world views as highlighted in Chapter 6. In this sense, the properties of glass beads such as lustre, durability, colour(s) and shape, have a deep impact on the senses and emotions, ultimately shaping their life trajectories. Material properties and materiality of glass are not closed-communication systems, but can rather be seen as the two (complementary) faces of the same coin, which are in constant dialogue to the point where they overlap, as shown in Figure 8.1 below.

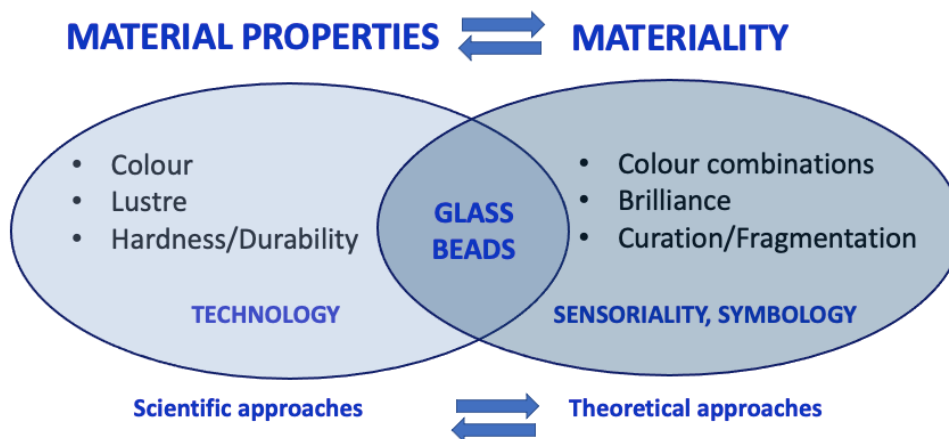


Figure 8.1: Diagram illustrating the role of material properties and materiality of glass in the construction of bead biographies.

The present research has shown that, in order to provide insights on the multifaceted nature of glass beads, it is important to combine scientific and theoretical approaches. When analysing glass beads, we must, of course, take individual routes and methods to answer specific questions; however, when it comes to interpreting the results of our work, we should seek again some convergence. A prime example of this can be found in the words of volunteer 3: *'I noticed how much my seven-year-old son plays with the beads when I am wearing them. He sits and clacks them together, rubs them, examines them. It made me consider the experience of little children, growing up looking at the beads their mothers wore.'* This illustrates my point, as the bead-wearing experiment was not meant to investigate bead perception; however, this showed how the tactility, sound and the overall multisensorial experience of wearing beads is quite pervasive.

8.7 Conclusions, future directions and recommendations

Glass beads are encountered by archaeologists in different cultural contexts across time and space, however they are rarely looked at for what they really are, that is to say an artefact

category that exists in virtue of the interplay between a specific class of material (glass) and a particular object type (beads). On a practical level, properties of glass such as hardness, durability (resistance to corrosion), and colour, dictate the ways beads can be made and – by extension – used, perceived and curated in particular archaeological or historical contexts.

If typologies may help us to devise the geographical and chronological distribution of certain beads, they very often do not take into account how they were made, as the focus is on their appearance. As a result, slight variations in how beads look – but not in their manufacturing processes – may end up being recorded as new types, muddling our understanding of bead consumption and manufacture. Compositional studies to ascertain the chemistry of glass beads can provide us with precious insights into how glass was made from raw ingredients or how it was recycled, however, also in this case the focus is on glassmaking, rather than on the production and use of beads. As a result, if we want to understand glass beads further, we need to explore technological and social aspects by including disciplines such as experimental archaeology, further scientific techniques such as use-wear analysis, and, to consider lived experiences and conceptual categories that do not belong to the western European mindset, ethnography. As such, we need to operate in multiple directions at the same time, by combining information from different sources, so that we can obtain a finer-grained picture.

On one hand, this research has shown the potential of applications of use-wear analysis on glass beads, as it can inform us on the curation, re-use and potential modification of beads. To shed further light on bead itineraries, this technique has to be complemented by a thorough study of the archaeological contexts and also their taphonomy, retrieval and conservation. In particular, the construction of replica-bead furnaces and the bead-wearing experiment have been highly instrumental in reverse-engineering the processes underlying the formation of various traces of wear. On the other hand, the present doctoral thesis has also shown that when approaches based on the materiality and sensoriality of materials (e.g., Duckworth, 2020a; Hamilakis, 2013; Conneller, 2011; Harris & Sørensen, 2010) are applied to glass beads, new layers of meaning can be added to our interpretations, in a sense by bringing beads closer to what could also be our experience of interacting with them.

In particular, the present work generated new questions and lines of enquiry that warrant further investigation:

- Use-wear analysis of glass beads is still in its infancy, and as such, a larger pool of data, alongside the implementation of a shared methodology, which includes a protocol for the cleaning and the recording of the beads, are needed. To ascertain which traces correspond to which actions, to clarify polish formation mechanisms alongside the impact of different polishing agents (vegetal versus animal materials) and to examine the types damage caused by post-depositional processes, further reference collections should be generated by following established protocols for other materials such as obsidian or flint (e.g., Vaughan, 1985; Hurcombe, 1992; Kononenko, 2011). More archaeological assemblages need to be analysed to further consolidate – or refute –the validity of the data produced by this study. In addition, as shown by Guzzo Falci et al. (2019) ethnographic collections containing glass beads can also be employed as comparative material. Lastly, use-wear analysis could be extended to other types of glass artefacts to understand or clarify manufacture, use and discard.
- From the use-wear analysis undertaken on the Fazzan beads, it has become evident that glass degradation can be promoted by mechanical processes, e.g., beads which present extensive wear by use, which makes the glass more susceptible to chemical corrosion. Going forward, SEM and E-SEM analysis of glass bead surfaces should be carried out whenever possible, so that the thickness, composition and distribution of the corrosion layer can be ascertained, and an in-depth analysis of the bead surface microtopography can be carried out. In addition, SEM could be employed in residue analysis on suitable samples, as this may help clarify further modes of bead use.
- Experimental archaeology is still under-used in glass bead studies: more experiments are needed to create reference collections so that manufacturing traces can be observed and the actions behind *chaînes opératoires* reconstructed for other techniques such as drawing or moulding. Making beads in several different types of replica furnaces or structures would help us to investigate labour organisation, raw materials use (including fuel), and any potential cross-craft interactions. More experiential data should be collected with regards to bead-making and glass bead wearing experiences, or general interactions with glass, so that more nuanced interpretations can be produced.
- Concerning the Iron Age glass beads from Abruzzo, the research carried out in the present thesis highlighted some gaps which could be filled to clarify aspects of bead-

use in connection with kin. Although research looking into skeletal estimations of biological kinship is available for Campovalano (Muzzall, 2015) the remaining sites are unexplored. Nonetheless, the potential for bioarchaeological investigations for all the three cemeteries is still not exploited. By combining ancient DNA with isotope studies, we may be able to ascertain whether the beads were passed from mother to daughter in patrilineal descent groups that practiced virilocal burial. Furthermore, the investigation of other dimensions of burial, such as grave goods and their combinations alongside their spatial distribution within tombs, may provide further insight on these communities and their attitudes towards identities in death. Lastly, to establish whether the beads were worn and curated before being deposited in graves, the assemblages from Abruzzo may benefit from use-wear analysis. In addition, if we wanted to discuss colour further and to understand glass trade, communities of practice and use in Iron Age Italy and in the wider Mediterranean context, a subset of beads could be subjected to chemical analyses to determine major, minor and trace elements in raw glass ingredients (e.g.: EPMA and LA-ICP-MS).

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Appendix A: Bead-making techniques

Core-forming

One of the earliest ways to produce glass beads and small objects, such as vessels, was by core forming (Figure 1). This technique, Mesopotamian in its origin, has been known since the 15th century BCE and consisted of the shaping of the glass around a clay and dung core surrounding a rod (Gudenrath, 1999, pp. 238-239). The method devised to apply the glass to the core is still the subject of discussion. Different techniques have been suggested, which entail either the use of glass canes trailed around the core, or the dipping of the core itself into a pot containing molten glass (Nicholson & Henderson, 1999). This second option appears to be less likely, as the glass, which was probably worked at lower temperatures than modern ones, might have been too stiff to allow any dipping (Grose, 1989, p.31; Moorey 1999, p.204). In any case, the core was removed after the creation of the artefact, leaving a hollow in its place. Beads produced with this technique present a very large perforation and are rare in the archaeological record (Spaer 2001, p. 306).

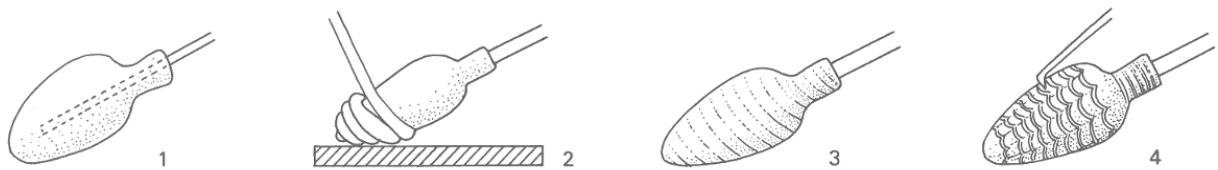


Figure Appendix A 1: Manufacture of a core-formed vessel using glass canes (Moorey, 1999, p. 204, Fig. 13).

Winding

Beads can also be made by winding or twirling the red-hot glass around a thin metal rod, called a mandrel. More often than not, this is coated with a separator to prevent the glass from sticking on the metal. These beads can be recognised by the presence of air bubbles or colour imperfections which are vertical to the perforation. Nowadays, wound beads can either be made in a furnace, or by flame-working, using an open flame in a gas-fired tool known as a lamp (Francis, 1999). Furnace winding, in the broader sense of the term, is considered as ancient as bead-making (Sode, 1995; Kanungo, 2004; Francis, 1999, pp.54-55).

In order to produce wound beads, three different techniques can be applied: furnace-winding, gob-winding and cane-winding. The difference between these methods is based on

the complexity of the process and on the form of the material employed, as all of them can be carried out using a furnace. All wound beads are rod-formed, as the perforation of the beads is given by the use of the mandrel (Spaer, 2001, p.45). Rudimentary furnace-wound beads, still produced in workshops in Cairo, Hebron and Izmir, are obtained by dipping a rod in a crucible containing molten glass, which is known as gather or gob (Figure 2). To fashion a bead, the hot glass is then twirled around the same rod. This manufacturing process appears to be the simplest, as the glass that comes out of the furnace is used directly to make a bead (Spaer, 2001, p. 45; Küçükerman, 1995).

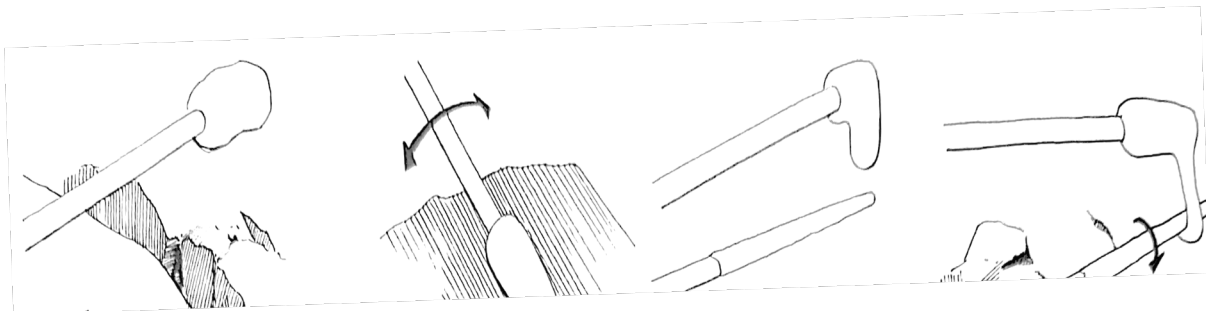


Figure Appendix A 2: The gob-winding process (Gam, 1990, p. 204, drawing by F. Bau).

The most common method used to craft wound beads is a two-step process, called gob- or core-winding. At first a rod is used to collect the glass from the crucible. The glass on the rod is first shaped into a cone, and is then reheated and worked until it is coiled around a mandrel. The molten glass can sometimes be drawn into a solid cane by pulling with the aid of pincers, without removing it from the initial rod (Spaer, 2001, p. 310). Beads are still being crafted following the gob-winding process in Purdalpur, situated in the Indian state of Uttar Pradesh (Sode, 1995; Sode & Kock, 2001b; Kanungo, 2001, 2004).

The making of cane-wound beads, which is currently a process associated with lamp-working, relies on a semi-finished product, rather than a glass gather, and it has previously been assumed to have required a concentrated flame (Francis, 1999, pp. 54-55; Spaer, 2001, p.45). As demonstrated by my own experimental work discussed in Chapter 3 and by the work carried out by Hodgkinson & Bertram (2019), Wiesenberg (2018) and Krzyżanowska & Frankiewicz (2015), beads can be made from glass canes by using small wood-fuelled furnaces, as they can produce sufficient heat to successfully wind the glass.

In order to craft cane-wound beads, a ready-made glass cane is heated until it slumps on the mandrel (Figure 3), which is then twirled so that the hot glass coils around it (Foulds, 2017, p. 17). This technique, which can be easily deployed in small workshops, is commonly regarded

as relatively modern. Lamp-wound beads have been an established and very popular Venetian craft since the 16th century CE. The high demand for these beads gave birth to other European centres of bead-making, such as those located in Bavaria and Moravia, which adopted the same manufacturing method (Sherr Dubin, 2015, pp. 110-111).



Figure Appendix A 3: Bead-making by lamp-work. The glass is coiled for several winds around the mandrel. This is constantly rotated until a round bead is produced. (Pictures author's own).

Nowadays lamp-wound beads are still made in Murano and Venice, and in the northern Indian towns of Purdampur and Varanasi. The use of the lamp-winding technique in India is relatively recent, dating to the late 1930s. This was imported by a Czech couple, the Henricks, who at the time were teaching bead-making at the Benares Hindu University (Sode & Kock, 2001b).

Other minor winding techniques are scoop-winding and drip-winding. The first one is used nowadays in a few bead-making furnaces located in Egypt and the Levant: the molten glass, which is collected from the crucible with a scoop, is then wound on a rod. The bead obtained this way is then worked further in the furnace. The drip winding technique, which is attested in 19th-20th century Japan and Korea, makes use of glass scrap or canes and as such the glass is dripped on a mandrel, that is being turned to form the bead. As the glass is not worked at high temperature, the beads bear small peaks at their ends (Francis, 1999, p. 56, pp. 90-93).

In general, waste products deriving from winding might include broken canes which are too short to be re-worked, beads that are malformed, broken or fused together, bent mandrels, fine trails or small drops of glass (Figure 4). In case the beads were manufactured by melting

the glass in a furnace, remnants of crucibles with traces of glazing could be present alongside fragmented glass objects ready to be recycled, known as cullet (Davidson-Weinberg, 1969, p.149; Hodgkinson, 2015b, pp. 282-284).

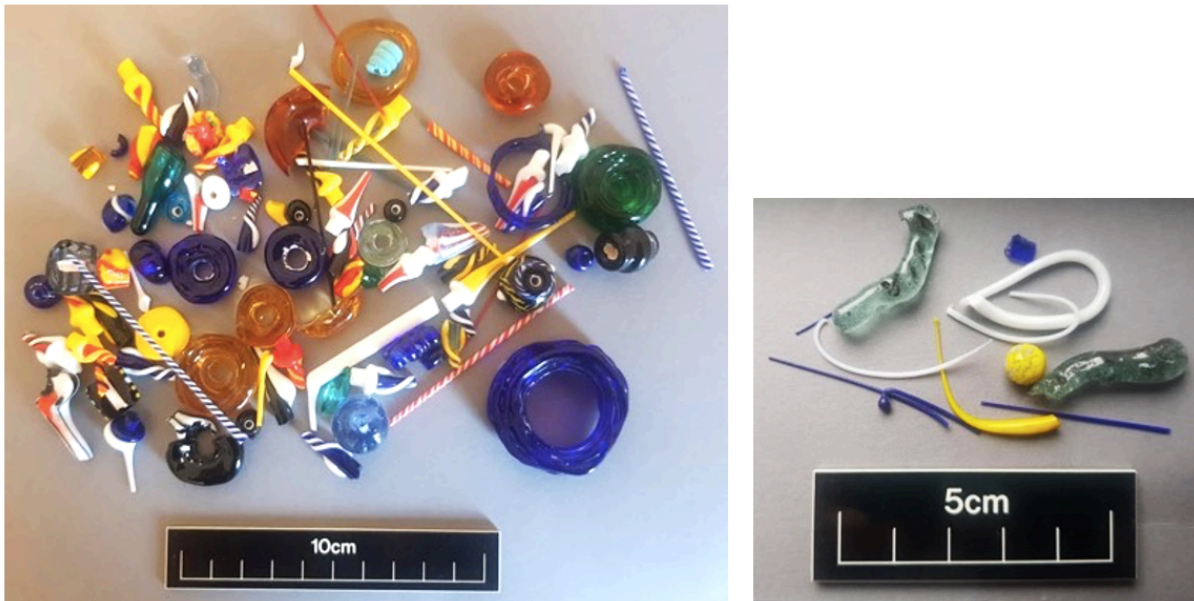


Figure Appendix A 4: On the left, waste produced by a contemporary bead-maker using a lamp. This corresponds to two weeks of waste, working less than 8 hours a day. To the right, waste produced in four working days using a small wood-fuelled furnace constructed by the author. (Pictures author's own).

To this day we cannot fully ascertain whether beads were manufactured from solid glass canes in antiquity (Spaer, 2001, p.305). It is likely that head pendants, a type of ornament which became very popular in the Mediterranean from the 7th up until the 3rd century BCE, were initially core-formed, with finer details added by flame-working (Gudenrath, 1999, p. 240).

Drawing

The production of wound beads using a furnace is a labour-intensive process, which can yield a limited number of specimens at a time. This results in a relatively expensive final product (Van der Sleen, 1973, p. 23). The drawing technique appeared for the first time during the Hellenistic period. This was mostly limited to the production of gold-foil beads, which started in the 3rd century BCE in Rhodes (Spaer, 1993, 2001, p. 130-131). Although winding was still a popular method of production, drawn beads started to be crafted in even greater quantities (Sherr Dubin, 2015, pp. 56-57).

During the Roman Period, glass blowing was invented, and by the Flavian Period this technique was routinely adopted in the crafting of vessels, which were now produced on a much larger scale. As a result, glass became cheaper and as a consequence it spread widely throughout the Roman Empire (Grose, 1989, pp. 241-244). It is not clear how this invention impacted on the production of beads, as the archaeological record does not provide us with information regarding bead-making centres.

Drawn beads have impurities and small air bubbles running parallel to the perforation, as they are made from a long tubular cane, which is then cut into chunks (Figure 5; Francis, 1988, pp. 2-3; Francis, 1999, pp. 56-57). This technique differs from winding, which employs solid canes. This means that the thread-hole of the bead is created not by coiling the glass on a metal wire, but by air itself (Spaer, 2001, p.46). The hollow cane, which does not need to be annealed, can be obtained by a variety of methods, always starting from a glass gather taken from a furnace. This can be blown, manipulated or even pierced with a tool (Francis, 1999, pp. 56-57; Spaer, 2001, p.46). In the Late Iron Age, drawn beads were created by manipulation or piercing techniques only, as glass-blowing had yet to be invented.

The blowing of the glass allows the creation of an air bubble in an efficient and direct way. Alternatively, the air can be trapped by pinching together the ends of a glass strip, previously shaped into a funnel or by puncturing the glass gather (Van der Sleen, 1973, p.25; Spaer, 2001, p.46). Once a hollow is present, with the glass still resting respectively either on the blowpipe or on a rod, a long tube can be created. This is done by placing a rod or pontil at the other extremity of the glass, which is then stretched (Francis, 1991, p. 29; 1999, pp. 56-57). This is a process that requires two or more glass-workers as the cane can be extended for relatively long distances (Van der Sleen, 1973, p.25; Francis, 1991, p. 29). Another way to obtain a drawn cane is by working the farthest end of the glass gather with pincers until edges are crafted. When the gather resembles a funnel or a flower, the edges will be pulled outward, dragging the remaining glass away from the rod. By doing so, tubing can be produced by a single glass-worker. If one end of the tube is then reheated until the extremities are sealed, it is possible to form a bubble by blowing air into it (Corning Museum of Glass, 2016). Inflated tubes, such as the ones produced by the final stage of this technique, are the first attestations of glass-blowing, which took place in 1st century BCE workshops of the Syro-Palestinian area, at a time when no blowpipes were used yet (Tatton-

Brown, 1999; Grose, 1989, p. 241). This might suggest a correlation between the drawing technique and the invention of glass blowing by tube inflation.

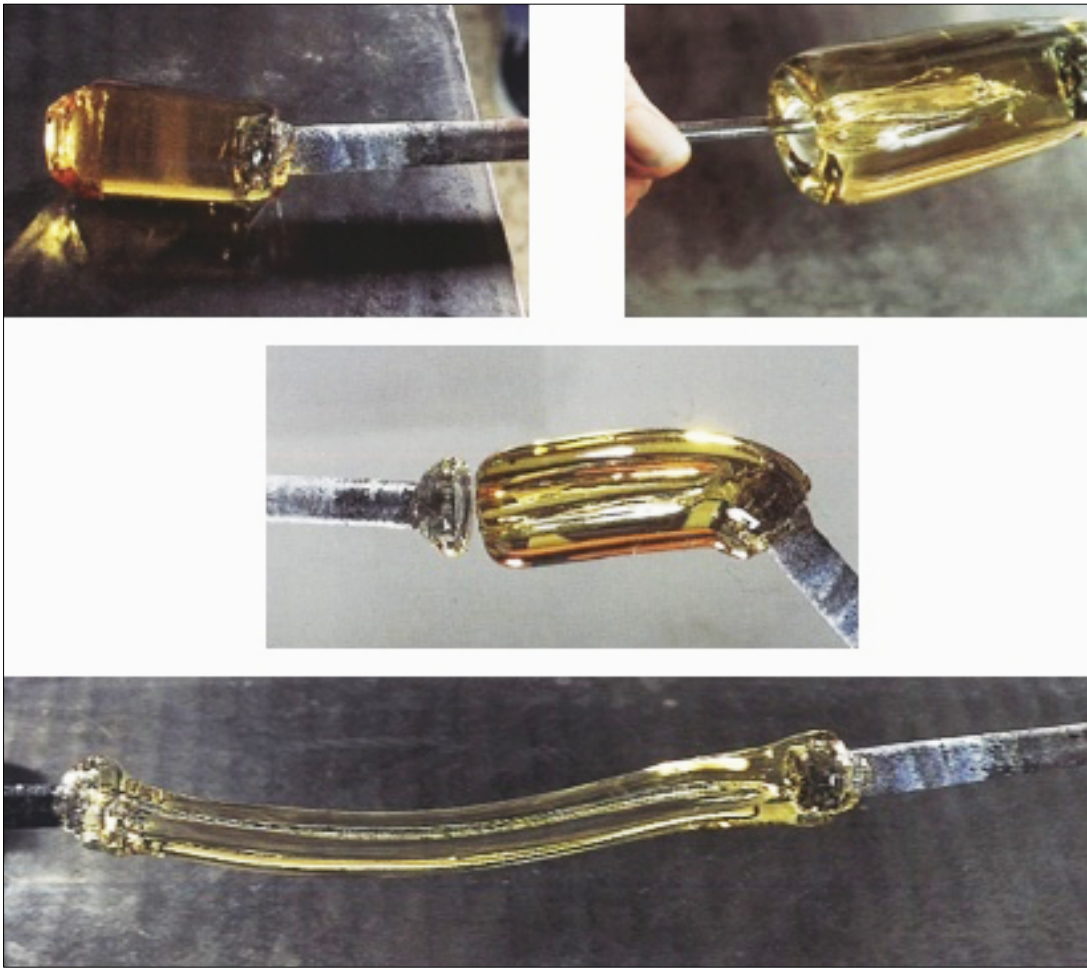


Figure Appendix A 5: Drawing of a hollow cane with the use of an implement (Spaer, 2001, p. 46).

Various decorations can be applied before the glass is pulled. Beads with a casing, that is to say with two or more concentric colours, can be created by adding to the gather layers of glass with different hues. This is the case of chevron beads, whereby each layer is cog-shaped, resulting into a zig-zag pattern visible at the extremities of the bead (Francis 1999, pp.56-57). These were manufactured from the end of the 15th century by the Venetians. A hundred years later, the Dutch followed suit. Since the 16th century, Chevron beads were traded to the Atlantic coast in America and to West Africa (Francis, 1999, pp.64-65).

Gold-glass and silver-glass beads retrieved from archaeological contexts in Great Britain, the Mediterranean, the Near East and the Caucasus are made in a similar fashion, as the metal foil, which is the main decorative feature, is encased between two layers of colourless glass (Boon & Dekóvna, 1977; Spaer, 1993, 2001, pp.130-131). Drawn beads can come in tubes,

discs or spheres. In some instances, as in the case of gold-glass beads, they can be collared and can have either a ribbed or granulated surface (Spaer, 1993). If they have very small dimensions, as in the case of micro- or seed-beads, they could be employed in beadwork, which is currently used for the decoration and production of items by indigenous societies in Africa, Asia and America (Francis, 1999, pp.56-57; Crabtree & Stallebrass, 2009).



Figure Appendix A 6: Types of drawn beads. On the left, gold- and silver-glass beads, possibly from Egypt (Spaer, 1993, p.13). On the right, Venetian chevron beads dating to the 17th century (Crabtree & Stallebrass, 2009, p.21).

As previously discussed, drawn beads were crafted in abundance before the invention of glass blowing in the 1st century BCE. This did not supersede the tooling or the manipulation techniques, and all these different methods, with several variations, coexisted in the Mediterranean and the Near East from then on (Spaer, 2001, p.46).

Drawn glass beads are currently made in Papanaidupet, located in Andhra Pradesh, India. The beads are crafted using a complex and laborious technique, which employs a very long iron rod, called *Lada*. Canes of considerable length can be drawn by up to twelve workers at a time. The final product consists of very small beads, known as ‘Indo-Pacific’ beads due to their historical maritime trade routes. The earliest examples, recovered in Thailand and Southern India, date back to the 3rd century BCE (Francis, 1991). Although this type of

production is slowly being replaced by industrial processes, a few bead-makers are still pursuing this activity. This is because the micro-beads employed in the *Mangal Sutra*, a traditional Tamil wedding necklace, cannot be produced by modern machinery due to their extremely small size (Sode & Kock, 2001b).

Once the cane has been drawn, this is cut into shorter sections in order to form the beads. In the case of Indo-Pacific beads, the tubes are cut from cold directly into bead-sized pieces. This is done by propping up the canes against a blade that has been pushed into the ground. The bead-maker then proceeds to split the tubes into beads with a second blade (Francis 1990, pp. 13-14). When the cane is cut, jagged edges are produced, usually smoothed by tumbling or gently stirring the beads. The temperature at which this occurs is relatively high and can cause a partial re-melting of the glass. In order to prevent this, the beads are placed into a shallow tray containing ashes and dung. This process, which lasts about half an hour and is carried out in a smaller furnace, also helps to get rid of the striations on the surface of the beads. No subsequent annealing is required, and if the ends present a clean cut, beads do not undergo any polishing treatment, as they are deemed fit for sale (Francis, 1990, pp. 14-16, 1991, p. 30; Sode & Kock, 2001b; Pion & Gratuze, 2016).

The evidence for simple and gold-glass beads from Mediterranean, Egyptian and Levantine sites dating from the 3rd century BCE to the 11th century CE, allows us to infer that the sectioning of the canes and the cutting of the beads could have been carried out in a variety of ways. The beads were in fact at times separated individually straight from the tube, with each one being given a smooth finish on the edges by hot-working. This method was typical of the Roman and earlier periods. In other circumstances, a moulding technique for the sectioning and a subsequent cold-working of the single beads by grinding were preferred, especially in the post-Roman period (Spaer, 1993, 2001, p. 47; Guido, 1978, pp. 91-93, 1999, pp. 78-80; Pion & Gratuze, 2016). At other times the ends were left unpolished, resulting in some cases in very sharp edges. The different types of finish always leave a trace around the perforation of the bead. For this reason, we can recognise what techniques were employed during this particular stage of production (Spaer, 2001, p. 131).

Whatever the method used to create the beads in the Mediterranean and the Near East, shorter sections of tube were first obtained by squeezing the heated cane at regular intervals. Prior to the warming of the tube, a metal wire was placed inside the hollow, in

order to keep the original shape of the perforation (Spaer, 2001, p.47; Pion & Gratuze, 2016). If the wire happened to be smaller than the initial perforation, the size of the thread hole would decrease, due to the action of the heat (Boon & Dekóvna, 1977). Segmenting moulds, dating to the 5th and 6th centuries CE, were retrieved during excavations in the Coptic bead-making workshop of Kom-el-Dikka, in Alexandria, Egypt (Rodziewicz, 1984). They have ridges and grooves, so that the heated tubes could be rolled across their surface (Figure 7). This allowed the quick division of the cane into even bead-sized sections, which could be easily cut into single pieces (Spaer, 1993, 2001, p.47). Beads likely manufactured with the use of moulds, but with an Indo-Pacific chemical signature, were found in Merovingian graves in Belgium and France, which are contemporary with the site of Kom-el-Dikka. These findings are very important, as they seem to suggest the presence of long-distance trade networks between southeast Asia and western Europe at that time (Pion & Gratuze, 2016).



Figure Appendix A 7: Left: Drawn beads with different types of finish (Pion & Gratuze, 2016, p. 53). Right: Stone moulds to craft drawn beads found at Kom-el-Dikka, Alexandria (Spaer, 2001, p. 47).

On a general note, beads can be manufactured more effectively and in greater quantities by using the drawing technique. In addition, this type of production possibly aimed to reduce the waste of glass, as suggested by the meagre archaeological evidence for scrap glass in Post-Medieval Dutch bead-making workshops (Sherr Dubin, 2015, p.113). The ethnographic research conducted by Francis in India and Southeast Asia (1990, 1991) highlighted that the type of waste produced on bead manufacturing sites is highly diagnostic, as it varies according to the drawing methods employed. In terms of waste products, tubes drawn with a pontil or a blowpipe produce a moil, which is the leftover glass encasing the end of the blowpipe or of the pontil (Figure 8).

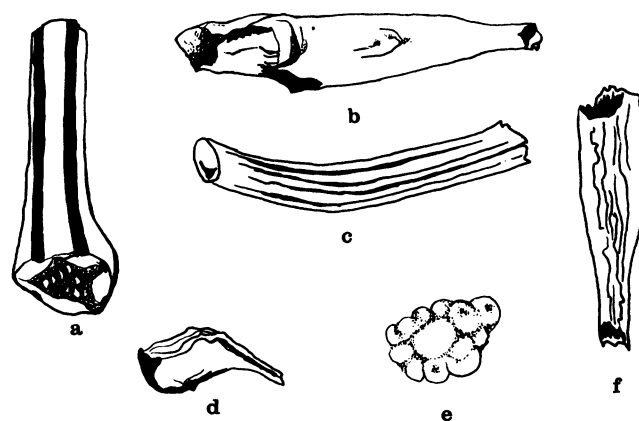


Figure Appendix A 8: Different types of glass waste produced with the drawing technique (Francis, 1991, p. 32).

This particular moi is bulbous and shows a partial perforation. A scar, which indicates where the glass was attached to the tool is also present (Francis, 1991, pp. 30-32). The waste produced by the *Lada* technique mirrors the stages of production in the crafting of the beads. When the glass is initially stirred in the crucible with the aid of a *Gedda Paru*, which is a rod used especially for that purpose, thin curved glass flakes will form on it. Waste material connected to the unsuccessful drawing of the canes is represented by twisted unperforated tubes, which come in different shapes and sizes. A large but thin tube of glass detaches from the rod once the drawing of the cane is completed, falling onto the ground (Francis, 1990, pp. 10- 14; 1991, 30-32). Ends of tubes with knots or still containing refractory material, and small sections of tube can be found in the area where the cutting of the beads took place (Francis, 1990, pp. 13-14). Clusters of beads that have melted together or beads that have stuck to the pan, subsequently discarded and not re-used, testify more in general the use of the drawing technique on a certain site. This type of waste reflects the final stages in the bead making *chaîne opératoire* (Francis, 1991, pp. 30-32; Pion & Gratuze, 2016, pp. 52-53).

Minor bead-making techniques: other rod-formed beads and air-formed beads

Besides winding, other rod-forming techniques can be applied to craft beads, such as folding, moulding and piercing. Folded beads are crafted by wrapping a pre-made strip of glass around the mandrel (Figure 9). The bead is then evened out by marvering, which is the process of rolling the bead onto a smooth stone or metal surface (Spaer, 2001, p. 45).

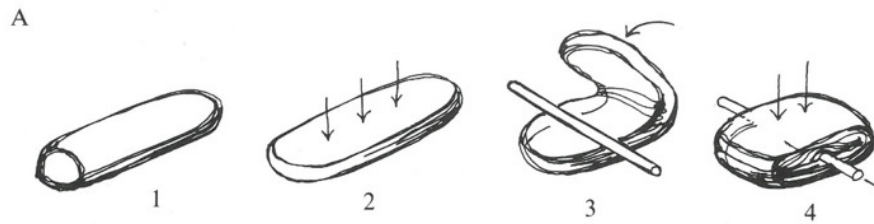


Figure Appendix A 9: The making of a folded bead (Küçükerman, 1988, fig. 10).

When beads are produced with the use of a mould, the perforation is always created by a rod. Stone or clay one-piece moulds, with a pattern placed at the base, were probably preferred in antiquity over other types, as they could be re-used multiple times. The hot glass could have been placed in the mould by pouring it in with the aid of a tip of a rod, or more rarely by letting it sag in. Powdered glass could have been employed as well to fill the mould, which would then be placed in the furnace (Spaer, 2001, p. 313). Finely ground scrap glass from bottles and jars is still used to craft such beads in West Africa. In this case the glass does not reach the molten state, as the type of furnace employed maintains relatively low temperatures. However, the heat is enough to fuse together the individual particles of glass, at least on the surface of the beads (Lamb, 1976).

The perforation of moulded beads is usually obtained by piercing the hot glass with a rod, or by leaving a channel for the rod in the mould itself (Francis, 1999, p. 58; Spaer, 2001, p.45). Moulding was very frequently used in combination with other techniques, such as cold-working, as is the case for Mycenaean relief beads (Nikita, 2003). This manufacturing method became increasingly popular in the 19th century, with the invention of a moulding machine by the Prosser brothers in 1840 (Francis, 1999, p. 58). In general, both folded and moulded beads present seams where the glass was joined together. These can be easily detected by the naked eye. In the case of moulded beads, sometimes these imperfections are smoothed out by hot-working. In the case of beads crafted using machinery, the seams are harder to identify (Francis, 1999, p. 58; Spaer, 2001, p.45). Rod-piercing was mostly used in conjunction with moulding, and only in specific cases, such as for mosaic or multicoloured beads, was it applied as a standalone technique (Spaer, 2001, p.45). The only other method used to create air-formed beads is by blowing. A cane, which has been previously drawn, is either blown freehand or in a mould. Blowing is a technique that was applied to beads in relatively recent times, as it was employed in 17th century France to produce imitation pearls, known as ‘Roman’ (Francis, 1999, p.58; p.71). Blown beads were manufactured as well in the Italian

city of Venice and in the Czech town of Gablonz, respectively during the 19th and 20th century (Jargstorf, 1995, p.59).

Decorations

This section will deal with some of the major types of decorations which are commonly encountered in ancient wound beads. All of the photographs below were taken by the author at historical bead-maker Mike Poole's workshop, and aim to illustrate the processes involved (Figure 10).

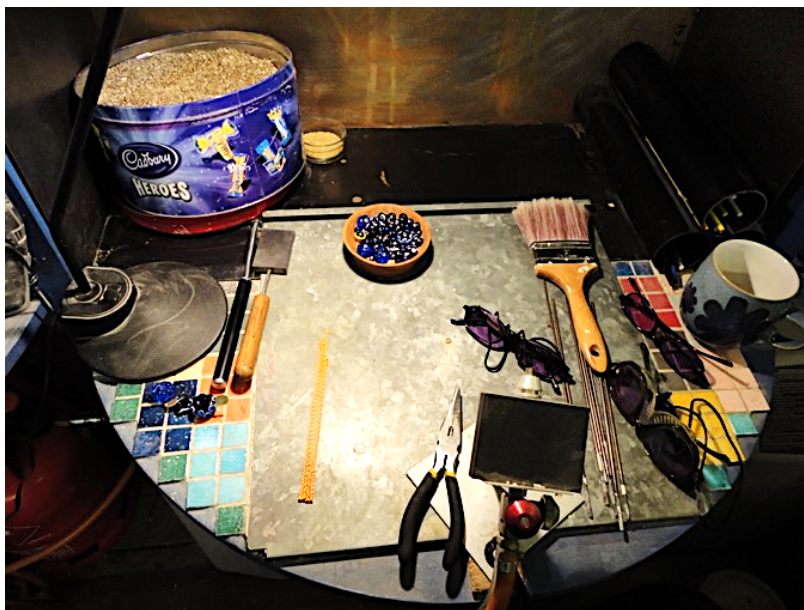


Figure Appendix A 10: The tools used by a contemporary bead-maker. From left to right, a tin of vermiculite, a graphite paddle (marver), stringers, pliers, didymium glasses to reduce the glare of the flame, and mandrels. (Picture author's own).

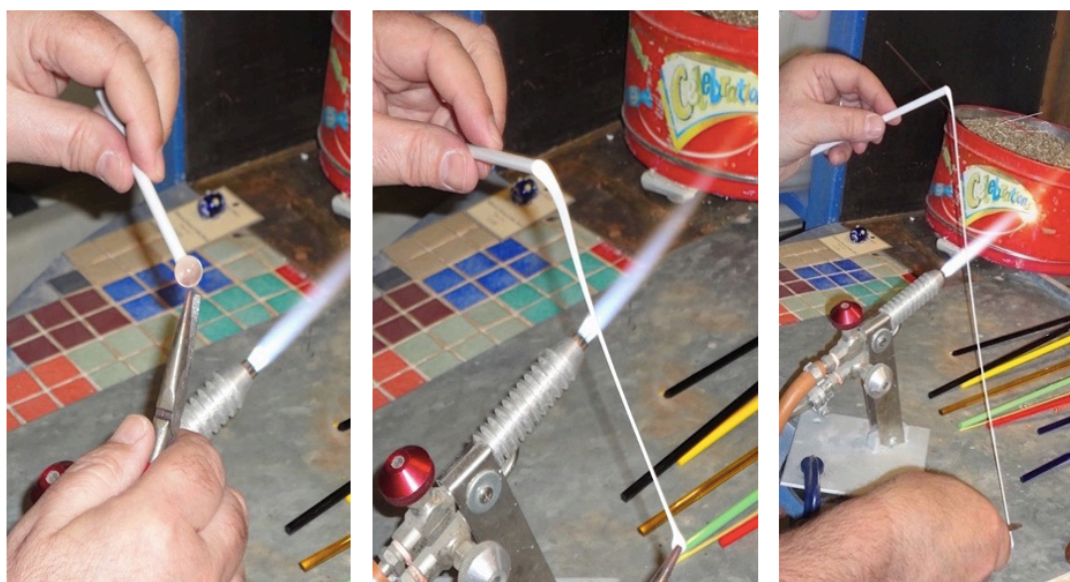
In any case, I have either undertaken or witnessed the process being described, either at Mike Poole's workshop, or at the reconstructed bead furnace at Villa Borg, Germany (June 2019) and during experiments conducted by me at Jarrow Hall (May and September 2019, please see Chapter 3). The techniques shown below can be easily deployed, with a few adjustments, in structures where glass canes are used to make beads, such as small wood-fuelled furnaces. In this case, the entirety of the beads and the applied decorations are crafted by lamp-working. All the techniques shown have been in use since the second millennium BCE in the Mediterranean and the Near East (Spaer, 2001). Bead decoration techniques consist of either: i) the application of additional glass; or ii) the use of hot- or cold-working techniques (Spaer, 2001, p.48). By the latter we mean cutting, carving or etching, which are methods that are restricted to a small minority of beads, and therefore will not be dealt with here. The focus will be instead on beads to which further glass is added

as decoration, and on beads decorated by tooling, which is the use of tools, such as paddles or form irons, during hot-working. Sometimes the two methods are combined, depending on what type of bead is being crafted.

Canes and stringers

Glass canes can be crafted using a furnace or a lamp. Their importance lies in the fact that they are the starting point for different decoration techniques. Canes with a two to three-millimetre diameter are also known as stringers. Monochrome canes or stringers can be trailed around beads to form lines or patterns. Stringers of different colours can be combined to form twisted canes, or if they are bunched-up together in a pattern and then drawn, they can yield mosaic or millefiori glass. The canes obtained with these two methods can then be used to decorate beads (Francis, 1999, p. 59; Sherr Dubin, 2015, p.60).

Monochrome stringers can be crafted following two methods. The first, shown below in Figure 11, uses a pair of pliers to pull and then cut the glass once it has been drawn. Another way to create a small cane is to use two rods of glass. Both ends are melted and then joined together. One of the two ends, previously flattened, serves only as a platform to pull the other cane and no tools are employed in the process. The initial steps to craft a twisted cane, presented in the next section, mirror part of this second method (Figure 12).



A. A cane is heated until a rounded blob of hot glass forms at its end. A small portion of the blob is then pinched with pliers.

B. The remaining glass, which is still at temperature, is then quickly pulled down to reach the right length and thickness.

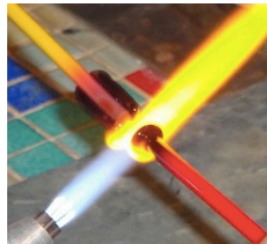
C. The stringer is now ready and will be snapped off the cane with the aid of pliers.

Figure Appendix A 11: Step-by-step process employed in the making of monochrome stringers (pictures author's own).

Twisted canes or stringers require mastery, as they have to be drawn whilst twisting it. This has to be done when the glass is still hot, implying that the time-frame to work the glass is quite narrow. Once the stringer has been removed, a large chunk will be cut off from the cane that had its end initially flattened, in correspondence with the bulbous part where the two canes started being twisted. As it cannot be re-used, this bi-colour end will be scrapped, constituting a potential production waste we may find at a glass bead-making site.



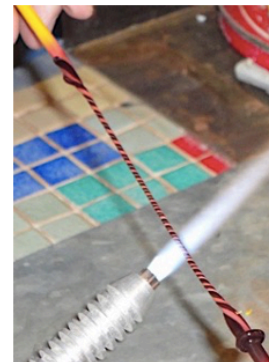
A. Thick trails of red glass are applied at even distance on the yellow cane, which is being kept warm, so that none of the glass melts.



B. The extremity of the red cane, which has been previously heated and then flattened on a marver, is now fused together with the yellow cane.



C- D. The two canes are then heated at the same time: once they are melted together they are quickly twisted to form the stringer.



E. The cane is now ready to be gently snapped at both ends.

Figure Appendix A 12: Step-by-step process employed in the making of twisted stringers/canes (photos by the author).

Beads decorated with trails

As previously stated, monochrome or twisted stringers can be used on wound beads to create decorative lines or stripes, which can be straight or wavy and are otherwise known as trails (Francis, 1999, p. 59; Spaer, 2001, p. 99). A portion of the stringer is usually applied to the warm bead, which is then reheated, so that the decoration can adhere to it (Figure 13).

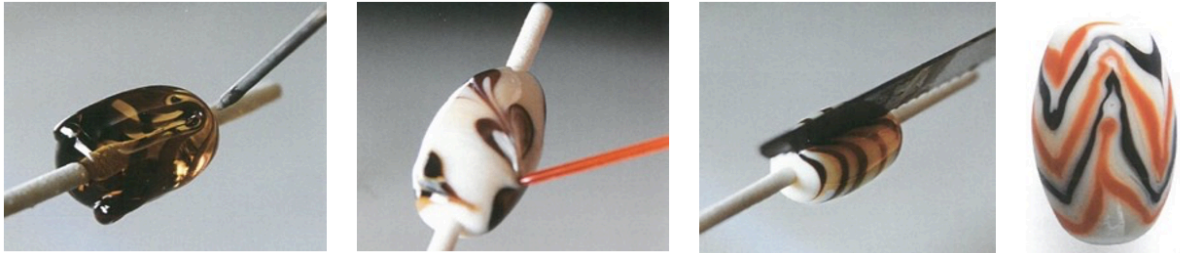
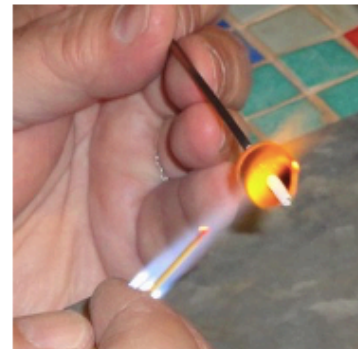


Figure Appendix A 13: From left to right: beads are combed using either a rake, a stringer, or a knife. The final bead will present a feathered decoration (Adams, 2010, p.65, 67).

In some cases, the trails can be left slightly raised, but more often than not they are made to completely melt onto the surface by rotating the bead in the flame or by marvering. In some cases, the tip of a tool or a glass stringer is dragged down the lines to obtain a combed bead (Francis 1999, p. 59; Adams, 2010, pp. 64-66).

Beads with trails and a central wave

These beads can be quite difficult to craft on a lamp, because the bead-maker needs to have a perfect understanding of how the different sections of the flame work in terms of temperature (Figure 14). Unexpectedly, it is much easier to produce beads with trails and a central wave using a small furnace, as the heat is more diffused, which means that the stringer will never melt completely and it will retain its shape, making it easier to apply.



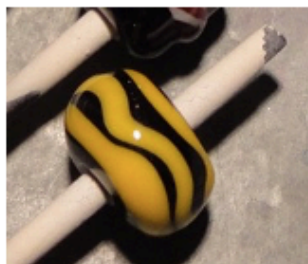
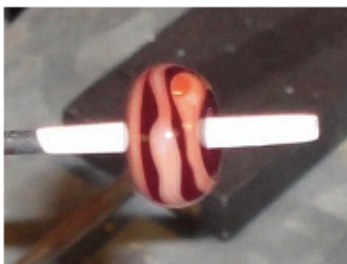
A-B. The stringer is trailed repeatedly on the glass bead, which is being rotated as the bead-maker is going along. The flame is kept at the minimum, in order not to fully melt the stringer.

C. Once a trail has been completed, the stringer is removed by slightly burning it off from the bead, rather than by pulling.



D-E. The trailing process is repeated, this time to form a central wave.

F. Now that the decoration is in place, the whole bead is reheated, so that the trails can sink into the bead, becoming completely flat.

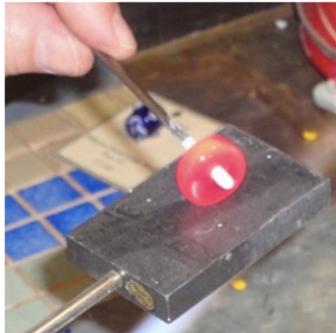


G-H. The yellow trails on the red-hot bead are still glowing, but when the bead is cooled, they return to their original colour.

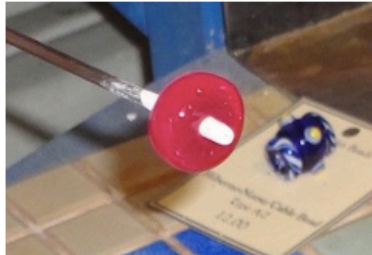
Figure Appendix A 14: Step-by-step process employed in the making of trailed beads (pictures author's own).

Beads decorated with twisted canes

The process is not dissimilar to the one illustrated for the beads decorated with a central wave, although a marver, or a smooth stone or iron paddle, is employed at the start to shape the bead and at the end to flatten the stringer (Figure 15). In this case tooling and the addition of glass are used to shape and decorate the bead.



A. When the bead is still red-hot, it is rolled onto a marver to confer a cylindrical shape.



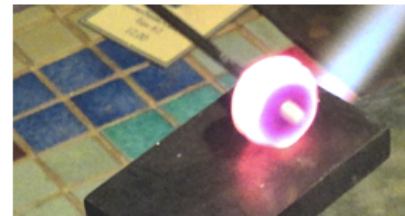
B. Once the desired shape has been obtained, the bead is then left to cool down.



C. The flame is turned down, so that the stringer can be applied. The stringer is gradually heated, to the point where it can stick to the bead without melting. As the stringer starts to slump on the bead, the mandrel is rotated, so that it can cover the whole circumference of the bead.



D-E. The same process is repeated for several times, until the whole surface of the bead is covered by winds of stringer.



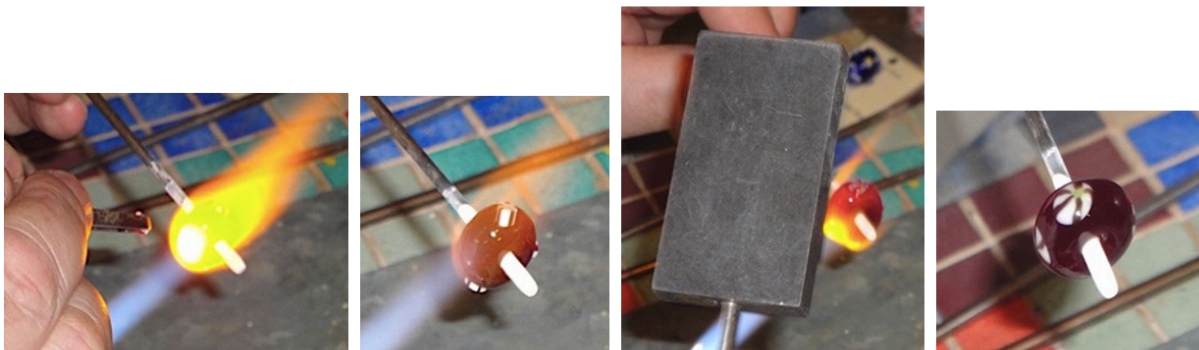
F. The bead is first reheated and then marvered to completely flatten the stringers.

Figure Appendix A 15: Step-by-step process employed in the making of beads decorated with twisted canes (pictures author's own).

Millefiori beads

Mosaic glass originated in Egypt during the second millennium BCE and became very popular from the Hellenistic period onwards, as it was employed to craft or decorate vessels and beads (Spaer, 2001, p.118). The use of mosaic or millefiori beads continued in Europe throughout Late Antiquity and the medieval period, as testified by archaeological finds for the migration period and the Viking era (Guido, 1999, pp. 70- 73; Spaer 2001, p. 122; Callmer, 2003). Millefiori beads, at the height of fashion in Africa in recent times, are still being produced in Murano and Venice (Jargstorf, 1995, p.40). Another contemporary

manufacturing centre which uses traditional methods is Purdalpur in India (Sode & Kock 2001b). These beads can be crafted with a variety of methods. Since the beginning, mosaic canes were usually cut into sections, called murrini, and applied onto wound beads. This is the most common technique and it is shown below in Figure 16. Other ways to make mosaic beads in antiquity entailed the piercing of a cane section with a metal rod, or the application of several cane sections around a mandrel, without a bead (Spaer, 2001, p. 118).



A. Pre-sliced sections of a thin mosaic cane, also known as murrini, are gently pressed on the surface of the hot bead with the aid of tweezers.

B. The murrini are individually heated up by using a very low flame, so that they will slightly sink into the bead.

C. The murrini are heated individually. After that they are gently tapped into the bead with a marver and reheated until flat.

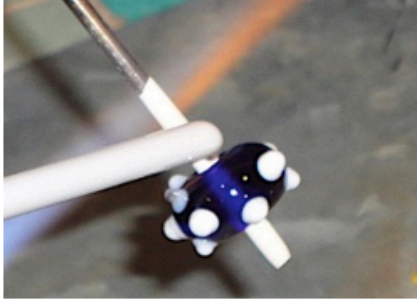
D. The finished bead is ready to be placed in vermiculite. Annealing will follow.

Figure Appendix A 16: Step-by-step process employed in the making of millefiori beads (pictures author's own).

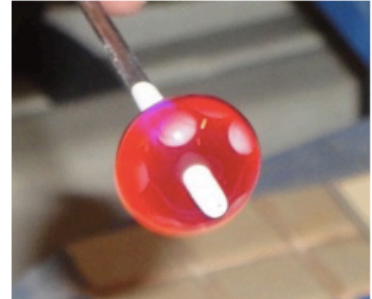
Eye beads

Glass eye beads have been known since the Late Bronze Age in the Near East, although there are earlier precursors recorded in those areas which were crafted in stone. By the first millennium BCE they were very popular also in continental Europe, around the Mediterranean, and in China (Sherr Dubin, 2015, p. 310; Guido, 1978, pp. 45-50; pp. 60-61; Foulds, 2017, pp. 259-250). Eye beads are usually always wound and the positioning and number of the eyes can vary according to the area of manufacture and the period in which they were crafted (Spaer, 2001, pp. 83-87, Kunter, 1995). The eyes could be made by placing a round trail on the surface of the bead. In this case the eye was given by the contrast between by the ringlet formed by the trail and the background colour of the bead itself. In addition, a spot could be placed inside the trail to form the eye (Spaer 2001, p.52). The stratified eyes technique, illustrated below in Figure 17, is common for Iron Age beads retrieved in continental Europe (Kunter, 1995). Different layers decreasing in size and with contrasting colours were superimposed in order to obtain the eye pattern (Spaer, 2001,

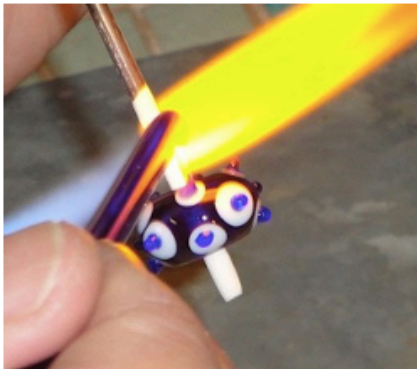
p.52). The most recent manufacturing method contemplated the use of mosaic or cut-cane eyes. This appeared for the first time in the 5th century BCE and became common from the Hellenistic period onwards, replacing the other techniques by Roman times (Sherr Dubin, 2015, p.312).



A. After heating the tip of a white cane, blobs of glass are gently pressed into the warm bead.



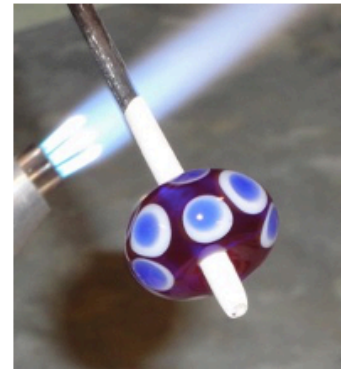
B-C. In order to flatten the small lumps of glass, the bead is subject to reheating. As the white dots melt into the bead, they will expand in size. The more the bead is rotated in the flame, the bigger and flatter the dots. This process is important because it ensures that the extra glass applied to the bead will not detach at any point in the future.



D. Dainty blue blobs are added to form the eye bead. These have to be very small, otherwise when they get reheated and their size increases, they might obliterate the white dots.



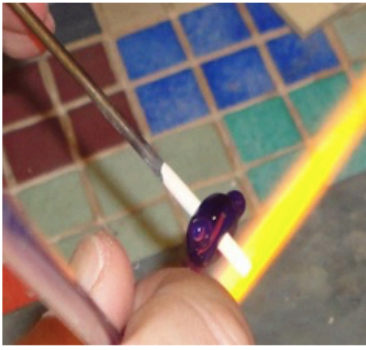
E. The bead is heated up once again to let the blue glass sink in. If the blobs are not slightly molten, their extremities, which are in correspondence to where the glass was pulled off, would remain very sharp.



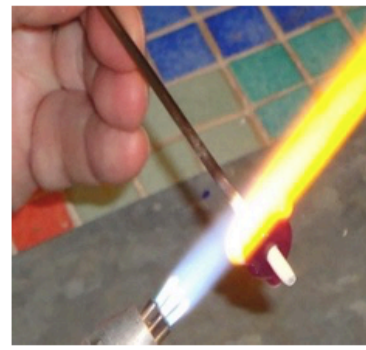
F. The finished eye bead, ready to be put in vermiculite.

Figure Appendix A 17: Step-by-step process employed in the making of eye beads (pictures author's own).

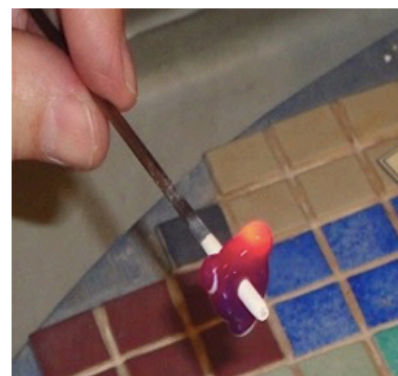
Another variation on eye beads consists in triangular shaped beads with stratified eyes at each end (Figure 18; Spaer, 2001, p.89). In this case the triangular shape is created by applying three dots of hot glass onto a round bead. These are then slightly melted and further decorated.



A. After the crafting of a round bead, three glass blobs are applied at even distance in order to form a triangular shape. The blobs are slightly melted, so that they can adhere to the bead.



B-C. Further blobs, diminishing in size and in contrasting colours, are applied on each end, which is decorated and re-heated individually.



D-E. The bead is kept in shape by pressing the graphite paddle against any areas which are subject to slump, such as the ends. The final outcome is an evenly triangular bead.

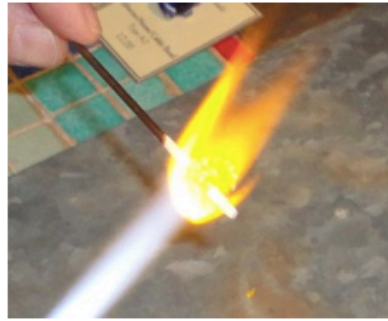
Figure Appendix A 18: Step-by-step process employed in the making of triangular eye beads (photos by the author).

Crumb beads

These beads are obtained by randomly covering the surface of the bead with tiny fragments of crushed glass. This can be done by either rolling the hot bead on top of the crumbs or by scattering the crushed glass over the bead (Figure 19). Although not overly popular, this type of decoration was attested since the second millennium BCE in the Near East, and has since then been used on beads (Ingram, 2014). Crumb beads are known to have been manufactured in Hellenistic Rhodes. They are found in Europe in later periods too, as they were in use by the Migration peoples and the Vikings (Spaer, 2001, p. 127; Guido, 1999, p.27).



A. Whilst the bead is being re-heated, glass crumbs are collected with a spoon. They will be scattered across the entire surface of the hot bead, when this is taken out of the flame.



B. The bead is placed back in the flame and twirled on the mandrel until the crumbs are melted onto the bead.



C. The crumbs are now incorporated into the glass.

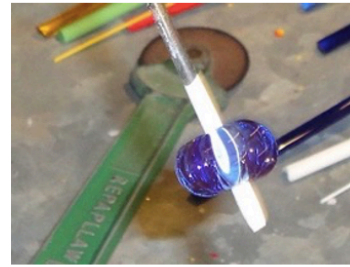


D. The bead is cooling off and will be annealed soon.

Figure Appendix A 19: Step-by-step process employed in the making of crumb beads (pictures author's own).

Melon Beads

The name of these beads is connected to their ribbed surface, which resembles a melon. The earliest specimens were crafted in Egypt using stone, clay or Egyptian faience. Towards the middle of the Bronze Age, melon beads started to be produced in glass as well. These beads became very popular in the Mediterranean and the Near East during the Iron Age, and their production continued throughout the Roman and Medieval periods (Eisen, 1930; Guido, 1978, p. 100; Foulds, 2017, p. 259). The lobes that characterise this type of bead can vary in number and are obtained by running a tool on a heated segment of the bead, as shown in Figure 20 below. Once the bead is decorated, it is not reheated, as that would partly melt the decoration.



A-B. After the bead has been crafted, sections of it are gradually heated one at a time. A tool resembling a pizza cutter, is rolled back and forth across the red-hot portion of the bead. The process is repeated for a number of times, until the whole surface of the bead has been treated.

C. The final result is a melon bead. The number of ridges and grooves varies according to how many sections have been worked with the tool, which is shown in the background.

Figure Appendix A 20: Step-by-step process employed in the making of melon beads (pictures author's own).

Appendix B: Bead-wearing experiment

Questionnaires

Volunteer 1

Profession: Researcher

How many hours per week on average do you do spend doing physical activity/sports? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs v**
- 8-10 hrs
- >10 hrs (Please specify)

What kind of physical activity/sports? - Please tick all that apply

Low impact/leisurely activity

- Walking v**
- Swimming v**
- Cycling
- Gardening v**
- Other (please specify) – Pilates v**

Moderate/High Intensity

- Jogging
- Running
- Weight training/Aerobics v**
- Combat sports (e.g., martial arts, boxing)
- Other (please specify)

How many hours a week on average do you spend outdoors? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs

- 6-8 hrs v**
- 8-10 hrs
- >10 hrs (Please specify)

How many hours per week on average do you spend time cooking (= exposed to steam/high temperatures)?

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs v**
- 8-10 hrs
- >10 hrs (Please specify)

How are you planning to wear the necklace on a regular basis? Please tick the relevant options for each group

- Hanging loose v**
- Tighter around the neck

AND

- In plain sight v**
- Concealed

AND

- On top of items of clothing v**
- On bare skin

Additional information (feel free to add whatever you think might feel relevant which has not been fully covered by the questionnaire):

Volunteer 3

Profession: Lecturer in Archaeology

How many hours per week on average do you do spend doing physical activity/sports? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs v**
- 8-10 hrs
- >10 hrs (Please specify)

What kind of physical activity/sports? - Please tick all that apply

Low impact/leisurely activity

- Walking v (Mainly this)**
- Swimming
- Cycling
- Gardening
- Other (please specify)

Moderate/High Intensity

- Jogging
- Running v**
- Weight training/Aerobics v**
- Combat sports (e.g., martial arts, boxing)
- Other (please specify)

How many hours a week on average do you spend outdoors? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs v**
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

How many hours per week on average do you spend time cooking (= exposed to steam/high temperatures)?

- 1 hr
- 2-4 hrs v**
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

How are you planning to wear the necklace on a regular basis? Please tick the relevant options for each group

- Hanging loose v**
- Tighter around the neck

AND

- In plain sight
- Concealed v**

AND

- On top of items of clothing
- On bare skin v**

Additional information (feel free to add whatever you think might feel relevant which has not been fully covered by the questionnaire):

Volunteer 4

Profession: Retired / Theatre Usher

How many hours per week on average do you do spend doing physical activity/sports? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs v**
- >10 hrs (Please specify)

What kind of physical activity/sports? - Please tick all that apply

Low impact/leisurely activity

- Walking v**
- Swimming v 2x1 hour**
- Cycling
- Gardening v**
- Other (please specify) –Yoga once a week for 1.5 hours v**

Moderate/High Intensity

- Jogging
- Running
- Weight training/Aerobics
- Combat sports (e.g., martial arts, boxing)
- Other (please specify)

How many hours a week on average do you spend outdoors? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs v**
- >10 hrs (Please specify)

How many hours per week on average do you spend time cooking (= exposed to steam/high temperatures)?

- 1 hr
- 2-4 hrs
- 4-6 hrs v**
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

How are you planning to wear the necklace on a regular basis? Please tick the relevant options for each group

- Hanging loose
- Tighter around the neck v**

AND

- In plain sight v**
- Concealed

AND

- On top of items of clothing
- On bare skin v**

Additional information (feel free to add whatever you think might feel relevant which has not been fully covered by the questionnaire):

Volunteer 5

Profession: Researcher

How many hours per week on average do you do spend doing physical activity/sports? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs v**
- 8-10 hrs
- >10 hrs (Please specify)

What kind of physical activity/sports? - Please tick all that apply

Low impact/leisurely activity

- Walking v**
- Swimming
- Cycling
- Gardening
- Other (please specify)

Moderate/High Intensity

- Jogging
- Running
- Weight training/Aerobics v**
- Combat sports (e.g., martial arts, boxing)
- Other (please specify)

How many hours a week on average do you spend outdoors? Please tick the relevant answer

- 1 hr
- 2-4 hrs v**
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

How many hours per week on average do you spend time cooking (= exposed to steam/high temperatures)?

- 1 hr
- 2-4 hrs v**
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

How are you planning to wear the necklace on a regular basis? Please tick the relevant options for each group

- Hanging loose
- Tighter around the neck v**

AND

- In plain sight v**
- Concealed

AND

- On top of items of clothing
- On bare skin v**

Additional information (feel free to add whatever you think might feel relevant which has not been fully covered by the questionnaire):

Volunteer 6

Profession: Laboratory Technician

How many hours per week on average do you do spend doing physical activity/sports? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs v**
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

What kind of physical activity/sports? - Please tick all that apply

Low impact/leisurely activity

- Walking v ~ 3-4 hrs a week**
- Swimming v - occasionally**
- Cycling
- Gardening v - occasionally**
- Other (please specify) – heavy-duty housework! E.g., vacuuming (counts as physical exercise according to my doctor...) ~ 1 hr a week v**

Moderate/High Intensity

- Jogging
- Running
- Weight training/Aerobics
- Combat sports (e.g., martial arts, boxing)
- Other (please specify)

How many hours a week on average do you spend outdoors? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs v**
- 6-8 hrs
- 8-10 hrs

>10 hrs (Please specify)

How many hours per week on average do you spend time cooking (= exposed to steam/high temperatures)?

1 hr

2-4 hrs v

4-6 hrs

6-8 hrs

8-10 hrs

>10 hrs (Please specify)

How are you planning to wear the necklace on a regular basis? Please tick the relevant options for each group

Hanging loose v

Tighter around the neck

AND

In plain sight

Concealed v

AND

On top of items of clothing

On bare skin v

Additional information (feel free to add whatever you think might feel relevant which has not been fully covered by the questionnaire):

Volunteer 7

Profession: Archaeologist

How many hours per week on average do you do spend doing physical activity/sports? Please tick the relevant answer

- 1 hr
- 2-4 hrs v**
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

What kind of physical activity/sports? - Please tick all that apply

Low impact/leisurely activity

- Walking v**
- Swimming
- Cycling
- Gardening
- Other (please specify)

Moderate/High Intensity

- Jogging
- Running
- Weight training/Aerobics v**
- Combat sports (e.g., martial arts, boxing)
- Other (please specify)

How many hours a week on average do you spend outdoors? Please tick the relevant answer

- 1 hr
- 2-4 hrs v**
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

How many hours per week on average do you spend time cooking (= exposed to steam/high temperatures)?

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs v**
- >10 hrs (Please specify)

How are you planning to wear the necklace on a regular basis? Please tick the relevant options for each group

- Hanging loose v**
- Tighter around the neck

AND

- In plain sight v**
- Concealed

AND

- On top of items of clothing
- On bare skin v**

Additional information (feel free to add whatever you think might feel relevant which has not been fully covered by the questionnaire):

I am just very excited about this project, and I can't wait to wear your beautiful beads. (I hope you will make a very nice and glamorous necklace for your little metallurgical friend!)

Volunteer 8

Profession: Field Archaeologist (Project Officer)

How many hours per week on average do you do spend doing physical activity/sports? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify) v – around 30 to 40 hours/week**

What kind of physical activity/sports? - Please tick all that apply

Low impact/leisurely activity

- Walking v**
- Swimming
- Cycling
- Gardening
- Other (please specify)

Moderate/High Intensity

- Jogging
- Running
- Weight training/Aerobics
- Combat sports (e.g., martial arts, boxing)
- Other (please specify) v – Manual labour (use of a trowel, mattock, wheelbarrow etc)**

How many hours a week on average do you spend outdoors? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs

>10 hrs (Please specify) ✓

How many hours per week on average do you spend time cooking (= exposed to steam/high temperatures)?

1 hr

2-4 hrs

4-6 hrs ✓

6-8 hrs

8-10 hrs

>10 hrs (Please specify)

How are you planning to wear the necklace on a regular basis? Please tick the relevant options for each group

Hanging loose ✓

Tighter around the neck

AND

In plain sight ✓

Concealed

AND

On top of items of clothing ✓

On bare skin

Additional information (feel free to add whatever you think might feel relevant which has not been fully covered by the questionnaire):

Volunteer 10

Profession: Senior Lecturer in Archaeology

How many hours per week on average do you do spend doing physical activity/sports? Please tick the relevant answer

- 1 hr
- 2-4 hrs v**
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

What kind of physical activity/sports? - Please tick all that apply

Low impact/leisurely activity

- Walking v**
- Swimming v**
- Cycling v**
- Gardening
- Other (please specify)

Moderate/High Intensity

- Jogging
- Running v**
- Weight training/Aerobics
- Combat sports (e.g., martial arts, boxing)
- Other (please specify)

How many hours a week on average do you spend outdoors? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs v**
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

How many hours per week on average do you spend time cooking (= exposed to steam/high temperatures)?

- 1 hr
- 2-4 hrs v**
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

How are you planning to wear the necklace on a regular basis? Please tick the relevant options for each group

- Hanging loose
- Tighter around the neck v**

AND

- In plain sight v**
- Concealed

AND

- On top of items of clothing
- On bare skin v**

Additional information (feel free to add whatever you think might feel relevant which has not been fully covered by the questionnaire):

Volunteer 11

Profession: Field Archaeologist (Project Officer)

How many hours per week on average do you do spend doing physical activity/sports? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs v**
- >10 hrs (Please specify)

What kind of physical activity/sports? - Please tick all that apply

Low impact/leisurely activity

- Walking v**
- Swimming
- Cycling
- Gardening
- Other (please specify)

Moderate/High Intensity

- Jogging
- Running
- Weight training/Aerobics v**
- Combat sports (e.g., martial arts, boxing)
- Other (please specify)

How many hours a week on average do you spend outdoors? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify) v – Up to 40 hours, I guess.**

How many hours per week on average do you spend time cooking (= exposed to steam/high temperatures)?

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs v**
- >10 hrs (Please specify)

How are you planning to wear the necklace on a regular basis? Please tick the relevant options for each group

- Hanging loose
- Tighter around the neck v**

AND

- In plain sight
- Concealed v**

AND

- On top of items of clothing
- On bare skin v**

Additional information (feel free to add whatever you think might feel relevant which has not been fully covered by the questionnaire):

Volunteer 12

Profession: Lecturer in Prehistoric Archaeology

How many hours per week on average do you do spend doing physical activity/sports? Please tick the relevant answer

- 1 hr
- 2-4 hrs v**
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

What kind of physical activity/sports? - Please tick all that apply

Low impact/leisurely activity

- Walking v**
- Swimming
- Cycling v**
- Gardening
- Other (please specify)

Moderate/High Intensity

- Jogging
- Running v**
- Weight training/Aerobics v**
- Combat sports (e.g., martial arts, boxing)
- Other (please specify)

How many hours a week on average do you spend outdoors? Please tick the relevant answer

- 1 hr
- 2-4 hrs v**
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

How many hours per week on average do you spend time cooking (= exposed to steam/high temperatures)?

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs v**
- >10 hrs (Please specify)

How are you planning to wear the necklace on a regular basis? Please tick the relevant options for each group

- Hanging loose
- Tighter around the neck v**

AND

- In plain sight v**
- Concealed

AND

- On top of items of clothing
- On bare skin v**

Additional information (feel free to add whatever you think might feel relevant which has not been fully covered by the questionnaire):

I originally put my answer to the 'cooking' question at 4-6 hours, but have increased it because of the answer being based on "= exposed to steam/high temperatures", as this would also include bathing and showering (something I try to do every day!!). Hope this is useful!

Volunteer 14

Profession: Student/Archaeologist

How many hours per week on average do you do spend doing physical activity/sports? Please tick the relevant answer

- 1 hr
- 2-4 hrs v**
- 4-6 hrs
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

What kind of physical activity/sports? - Please tick all that apply

Low impact/leisurely activity

- Walking v**
- Swimming
- Cycling
- Gardening
- Other (please specify)

Moderate/High Intensity

- Jogging
- Running
- Weight training/Aerobics
- Combat sports (e.g., martial arts, boxing)
- Other (please specify)

How many hours a week on average do you spend outdoors? Please tick the relevant answer

- 1 hr
- 2-4 hrs
- 4-6 hrs
- 6-8 hrs v**
- 8-10 hrs
- >10 hrs (Please specify)

How many hours per week on average do you spend time cooking (= exposed to steam/high temperatures)?

- 1 hr
- 2-4 hrs
- 4-6 hrs v**
- 6-8 hrs
- 8-10 hrs
- >10 hrs (Please specify)

How are you planning to wear the necklace on a regular basis? Please tick the relevant options for each group

- Hanging loose
- Tighter around the neck v**

AND

- In plain sight v**
- Concealed

AND

- On top of items of clothing
- On bare skin v**

Additional information (feel free to add whatever you think might feel relevant which has not been fully covered by the questionnaire):

Follow-up forms

Volunteer 3

- A) How many times per month you did **not** wear the necklace? Please type in the relevant number of days for each month.

Please count the first month from the day you have received the necklace until the end of the month itself (e.g., if you were given the necklace on 14th February the end of the first month is the end of February. This way the second month will be the whole of March and so on.)

I wore the beads 4 to 5 days a week for the whole experiment.

Additional notes (feel free to add whatever your impressions are or your general reflections on the wearing of the beads):

I noticed how much my seven-year-old son plays with the beads when I am wearing them. He sits and clacks them together, rubs them, examines them. It made me consider the experience of little children, growing up looking at the beads their mothers wore.

Volunteer 4

A) How many times per month you did **not** wear the necklace? Please type in the relevant number of days for each month.

Please count the first month from the day you have received the necklace until the end of the month itself (e.g., if you were given the necklace on 14th February the end of the first month is the end of February. This way the second month will be the whole of March and so on.)

I wore the beads all of every day for the whole experiment

Additional notes (feel free to add whatever your impressions are or your general reflections on the wearing of the beads): -

Volunteer 5

A) How many times per month you did **not** wear the necklace? Please type in the relevant number of days for each month.

Please count the first month from the day you have received the necklace until the end of the month itself (e.g., if you were given the necklace on 14th February the end of the first month is the end of February. This way the second month will be the whole of March and so on.)

I wore the beads every day.

Additional notes (feel free to add whatever your impressions are or your general reflections on the wearing of the beads):

Fiddled with the beads and twisted them around my fingers

Volunteer 6

A) How many times per month you did **not** wear the necklace? Please type in the relevant number of days for each month.

Please count the first month from the day you have received the necklace until the end of the month itself (e.g., if you were given the necklace on 14th February the end of the first month is the end of February. This way the second month will be the whole of March and so on.)

Month 3 (Apr): 2 days

Month 4 (May): 2 days

Month 5 (June): 1 day

Month 6 (July): 2 days

Month 7 (August): 3 days

Month 8 (September): 1 day

Month 9 (October): 0 days

Month 10: (November): 2 days

Additional notes (feel free to add whatever your impressions are or your general reflections on the wearing of the beads):

Initially the cord was quite itchy but that disappeared after a few days of wearing it.

I tend to twiddle around with them a lot...

Volunteer 7

A) How many times per month you did **not** wear the necklace? Please type in the relevant number of days for each month.

Please count the first month from the day you have received the necklace until the end of the month itself (e.g., if you were given the necklace on 14th February the end of the first month is the end of February. This way the second month will be the whole of March and so on.)

I wore the beads all day, every day of the experiment.

Additional notes (feel free to add whatever your impressions are or your general reflections on the wearing of the beads): -

Volunteer 8

A) How many times per month you did **not** wear the necklace? Please type in the relevant number of days for each month.

Please count the first month from the day you have received the necklace until the end of the month itself (e.g., if you were given the necklace on 14th February the end of the first month is the end of February. This way the second month will be the whole of March and so on.)

I wore the beads three or four days a week for the whole experiment.

Additional notes (feel free to add whatever your impressions are or your general reflections on the wearing of the beads):

I fiddled with the beads a lot and sometimes I would put them in my mouth as an involuntary soothing thing.

Volunteer 10

A) How many times per month you did **not** wear the necklace? Please type in the relevant number of days for each month.

Please count the first month from the day you have received the necklace until the end of the month itself (e.g., if you were given the necklace on 14th February the end of the first month is the end of February. This way the second month will be the whole of March and so on.)

I wore the beads at all times apart from when showering or swimming for the first three months of the experiment. For the last six months I did not remove them at all.

Additional notes (feel free to add whatever your impressions are or your general reflections on the wearing of the beads): -

Volunteer 11

A) How many times per month you did **not** wear the necklace? Please type in the relevant number of days for each month.

Please count the first month from the day you have received the necklace until the end of the month itself (e.g., if you were given the necklace on 14th February the end of the first month is the end of February. This way the second month will be the whole of March and so on.)

I wore the beads at least five days a week for the whole experiment.

Additional notes (feel free to add whatever your impressions are or your general reflections on the wearing of the beads):

I fiddled with the beads quite a lot, especially when the weather was warm.

Volunteer 12

A) How many times per month you did **not** wear the necklace? Please type in the relevant number of days for each month.

Please count the first month from the day you have received the necklace until the end of the month itself (e.g., if you were given the necklace on 14th February the end of the first month is the end of February. This way the second month will be the whole of March and so on.)

Month 1: February 2019

A) I only forgot to wear it on two occasions, both overnight after taking a shower (so, probably 24 hours in total).

Month 2: March 2019

I didn't forget to wear it at all!

Month 3: April 2019

A) I forgot to wear it once overnight after taking a shower, so probably 12 hours in total

Month 4: May 2019

A) I didn't wear it the afternoon of the Archaeology Society Ball, or overnight until I got home, so probably 20 hours in total.

Month 5: June 2019

I didn't forget to wear it at all!

Month 6: July 2019

Additional notes (feel free to add whatever your impressions are or your general reflections on the wearing of the beads):

I love wearing the necklace! The rope was a little itchy for the first week, but it has settled down fine. I wear it 'choker' style – quite tight around my neck and wear it every single day for everything (except bathing/showering as per instructions). I also ensure I wear it the same way – with the brass bead to the left. I've also noticed that because the brass bead is heavier and larger, it pulls the necklace to that side. As a result, the beads sit slightly 'lopsided', with the greatest contact against the brass bead. The central diameter of the bead on the right side is quite small, and the rope is fairly thick, so sometimes this bead spends a

while on its own, though I try to correct it as often as I can. The amount of exercise and cooking has varied from month to month, though the general average as predicted on the sheet would still be right.

Appendix C: Chemical composition of the Fazzan beads

The following section will provide an overview of the chemical composition of selected Fazzan glass beads which also underwent use-wear analysis (Figure 1). The beads in question were published by Duckworth in recent years (2016a,b; 2020b), who, in collaboration with Victoria Smith (University of Oxford) and Simon Chenery (British Geological Survey, Keyworth), analysed the assemblage by electron probe microanalysis (EPMA) for major and minor elements, and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) for trace element contents.¹⁸



Figure Appendix C 1: The sample set of beads subjected to chemical analysis (n=18). TSG_166 is not pictured. The red outline encloses the beads discussed in the text (after Duckworth, 2020b, p. 334).

As by no means do we intend to replicate the information already available, the EPMA and LA-ICP-MS results for nine beads out of the published sample set of 18 have been used here to provide a more detailed analysis in terms of bulk glass recipes, (de)colourants, opacifiers and Rare Earth Element (REE) patterns respectively, with the ultimate aim of linking the chemical data to the formation of traces of wear and glass degradation processes. Unless

¹⁸ The types of instruments used, their setup and methodologies employed are reported in Duckworth, 2020b, pp. 341-342. The EPMA and LA-ICP-MS results are reported in Tables C 3 and 4 at the end of this Appendix.

stated otherwise, the compositions of polychrome beads refer to the portion of glass that was employed to manufacture their bodies, however the chemical data for the colours of the decorations are reported in the tables at the end of this appendix.

Bulk glass recipes, (de)colourants and opacifiers

As illustrated in Figure 2, beads TSG_167-170 and TSG_173-174, with a silica (SiO_2) percentage ranging from 65.18% to 71.68%, are soda glasses. As such, they are made using a source of mineral alkali such as natron or trona from evaporitic deposits rich in sodium carbonates. This is indicated by their concentrations of magnesium, MgO (0.33%-0.54%) and potassium, K_2O (0.42%-0.68%) which are consistent with the average of less than 1.5% for both oxides reported for natron glasses (Sayre & Smith, 1961; Shortland et al., 2006; Scott & Degryse, 2014, p.21; Duckworth, 2020b, p. 343; Reade, 2021, p. 13).

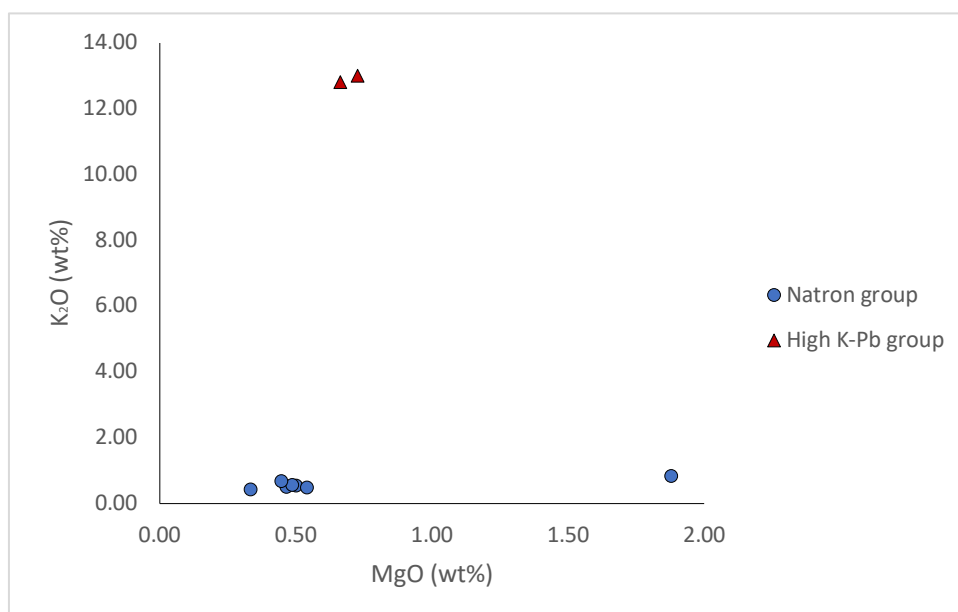


Figure Appendix C 2: Plot of K_2O vs MgO for the analysed beads ($n=9$). In blue mineral soda glasses, in red leaded glasses.

TSG_172 has higher levels of MgO (1.88%) but the potassium percentage in this sample is still consistent with mineral soda glasses, and therefore it can still be ascribed to this group. In line with the overall trend noted for ancient soda glasses, a positive correlation was observed between NaO_2 (sodium) and K_2O for these samples, indicating that some of the potassium was brought in with the soda (Duckworth et al., 2016a, p. 637). On the other hand, TSG_175 and TSG_176 fall within a completely different compositional group as both are lead glasses (15.4%-18.4% PbO) with a high potash content, respectively 12.81% and

13.01%. In this case the silica, which amounts to 50.73% and 48.78%, is much lower than the soda counterparts due to the use of lead as a flux.

The percentage range of lime (calcium oxide, CaO) for the mineral alkali samples sits between 5.24% and 8.37% and is broadly consistent with the concentrations reported for soda-lime glass produced in the Mediterranean since c. 800 BCE up until the 9th century CE, which on average amount to 6.5%-9% (Sayre & Smith, 1961; Henderson, 2000, p. 28; Shortland et al., 2006; Wedepohl et al., 2011). The CaO content of the leaded glasses is considerably lower, between 4.92% and 4.22%. As outlined in Chapter 2, lime confers stability to the glass by diminishing its solubility in water: as mineral soda does not naturally contain lime as an impurity, this has to enter the batch in the form of calcium carbonate (CaCO₃) via other constituents, such as the source of silica. In general, the use of sand with limestone or shell particles is widely attested for this purpose in mineral alkali glasses; although less likely, the hypothesis whereby the calcium may have been intentionally added as a separate ingredient is still subject of debate and therefore it cannot be completely ruled out (Henderson, 1985, p. 277; Freestone, 2006b, p. 207; Reade, 2021, pp. 10-11).

The Rare Earth Element (REE) patterns for the Fazzan beads, which are reported further down below, confirm that the silica component for the whole of the assemblage is derived from sand. The lack of a positive correlation between magnesium and calcium within the whole sample set indicates that these two elements, which are typically found in association, are not coming together in this instance. In addition, for what concerns the soda samples, it appears that here lime was not introduced in the glass through the source of silica as we would expect, as no correlation was reported between the two oxides, whereas the opposite is true for leaded glasses TSG_175 and TSG_176.

Aluminium, iron and titanium (Al, Fe, Ti) oxides are usually contained within the mineral/quartz fraction of the silica source in variable amounts according to the geochemical signature – and therefore provenance – of the raw material. In particular, Al₂O₃ can be found in potassium or calcium rich feldspars and clay minerals present in sand (Wedepohl et al., 2011, p. 90; Henderson, 2013, pp. 59-60). It is also worth noting that in some cases, Al₂O₃, Fe₂O₃, phosphorus (P₂O) and calcium oxides can enter the batch through contamination via the crucible walls or the furnace environment during glassmaking or working processes (Davison, 2003, p. 177; Paynter, 2008; Merkel & Rehren, 2007, p. 223; Rehren & Pusch, 2007,

pp. 231- 233; Jackson et al., 2003, pp. 449-451). The mineral alkali samples from Fazzan contain on average < 1% Fe₂O₃, with a lower iron (0.37%-0.60%) sub-group represented by TSG_168-170 and TSG_174, and a higher iron sub-group (TSG_167,172-173 with 0.79%-0.97%). The Al₂O₃ content, which shows no correlation with iron oxide, is always < 2.5%. Overall, this percentage reflects the average alumina levels present in Hellenistic and Roman glass, meaning that at least some of the glass employed to craft the beads was likely made with mature sands relatively low in impurities (Aerts et al., 2003, p. 569; Brems & Degryse, 2014, p. 119). In addition, as Al₂O₃ values between 1.7% and 3.5% in Roman mineral alkali glasses are caused by the feldspars present in sand, we can hypothesise that this may also be the case for the Fazzan beads (Henderson, 2013, p. 65; Jackson et al., 2003; Foy et al., 2004). The iron and alumina contents reported for the soda samples are in stark contrast with the much lower percentages recorded for leaded glasses TSG_175 and TSG_176, with Fe₂O₃ between 0.32% and 0.23% and Al₂O₃ between 0.53% and 0.28% respectively, indicating on the basis of the REE profiles the presence of two distinct yet geologically similar silica groups within the assemblage.

As we are dealing with a very small sample set which comprises only nine glass beads, it is very difficult – if not impossible – to tease out further significant patterns by discussing the assemblage as a whole. In order to provide a more detailed analysis of compositional subgroupings and of the use of colourants and opacifiers it will be necessary to describe the salient chemical characteristics of each bead individually. These will be provided in the paragraphs below to aid discussion:

Translucent blue bead **TSG_167** presents the highest amounts of chlorine (1.70% Cl) and the lowest percentages of magnesia (0.33% MgO) and potash (0.42% K₂O) within the sample set, indicating that the chlorides were introduced as NaCl (sodium chloride) with the mineral alkali source (Shortland, 2004). On the basis of the contents of the major oxides, the base glass recipe for this bead is broadly consistent with Roman colourless glass technology. This saw the use of antimony (Sb) as a decolouriser during the Hellenistic and early Roman periods, which was then replaced by manganese (Mn) in the 2nd century CE; eventually the two types were re-melted together (Sb/Mn) to obtain fresh glass (Paynter & Jackson, 2019; Jackson & Paynter, 2016; Davison, 2003, p. 78; Sayre, 1963). The average percentage of Sb₂O₅ employed to decolourise glass is 0.6% or Sb 4483 ppm, with minimum recorded values as low as 0.2% (Gliozzo, 2017). In a similar way, the background levels of manganese oxide in

Mediterranean sands range from 0.01% to 0.11% which means that any value above that indicates deliberate addition (Degryse, 2014, p. 79). Based on these premises, it appears difficult to allocate TSG_167 with a reasonable degree of certainty to one of the compositional sub-groups, as the contents recorded for both oxides are very low, with MnO 0.03% and Sb₂O₅ present only in trace (Sb 21.68 ppm). If the amounts of Fe₂O₃ (0.79%), Al₂O₃ (1.71%) and barium (Ba 145 ppm) are consistent with Sb decolourised glass, on the other hand the soda (17.80% Na₂O) and silica percentages (71.68% SiO₂) are closer to Mn decolourised glass, with the CaO to Na₂O ratio fitting within the values recorded for Sb/Mn glass (Gliozzo, 2017; Freestone, 2015; Silvestri et al., 2008; Foster & Jackson, 2010). The negligible amounts of manganese and antimony – which may indicate a depletion in either or both – coupled with ambiguous compositional traits, suggest that bead TSG_167 was made by mixing slightly different glasses together. This hypothesis is further corroborated by the fact that the trace element contents for cobalt and copper are respectively 566.00 ppm and 945.33 ppm, indicating contamination. As a general rule, values between 100 and 1000 ppm of Co, Cu, Sn, Zn, Sb and Pb are considered as evidence of recycling, whereas concentrations > 1000 ppm are representative of an intentional addition of these elements for (de)colouring purposes; contents between 1- 10 ppm are usually found as background levels in raw materials (Bertini et al., 2020; Gliozzo, 2017; Degryse 2014, p.73; Foster & Jackson, 2010; Degryse & Shortland, 2009; Silvestri et al., 2008; Silvestri, 2008; Jackson, 2005; Silvestri et al., 2005; Freestone et al., 2002). In this case, the amounts of cobalt (0.07% CoO)¹⁹ and perhaps in minor part of iron (0.79% Fe₂O₃) oxides contributed to the blue colour of the bead, as especially for CoO minimal quantities (0.02%) are required for this purpose (Henderson, 2013, p. 69).

The iron, alumina, potassium and magnesia contents of **TSG_168**, albeit slightly diluted, are within the ranges recorded for the mineral alkali beads. Low levels of soda (13.56% Na₂O), combined with high amounts of calcium (8.37% CaO), antimony (1.1% Sb₂O₅) and copper (1.12% CuO) indicate that the opaque turquoise colour of this bead was presumably obtained by mixing a glass containing calcium antimonate with a blue glass. The use of calcium antimonate (Ca₂Sb₂O₇ /Ca₂Sb₂O₆) as an opacifier is attested in LBA Egyptian opaque white, turquoise and blue glasses, but also in vessels and mosaic tesserae dating to the Hellenistic and Roman periods (Boschetti et al., 2020; Turner & Rooksby, 1959). As observed

¹⁹ This figure was derived from ppm to oxide conversion.

by Shortland (2002, p. 522) the opaque blue and turquoise glasses from Malkata and Amarna were made by adding antimony or one of its compounds, either as an oxide or as a sulphate, directly to the batch or to the raw materials, yielding a glass lower in calcium when compared to its translucent counterparts. If translucent blue glass were to be mixed with opaque white glass, that would result in an opaque blue glass lower in colourant, as that is likely the case for TSG_168. As calcium antimonate is characterised by low calcium and high antimony, the high levels of CaO in this bead can be explained as a consequence of recycling. In addition, the microscopic examination of TSG_168 showed that the mixing of glasses and/or introduction of colouring agents occurred at low temperatures, as the glassy matrix is characterised by the presence of bubbles throughout, changes in hue and translucence, and streaks of a lighter colour (Figure 3).

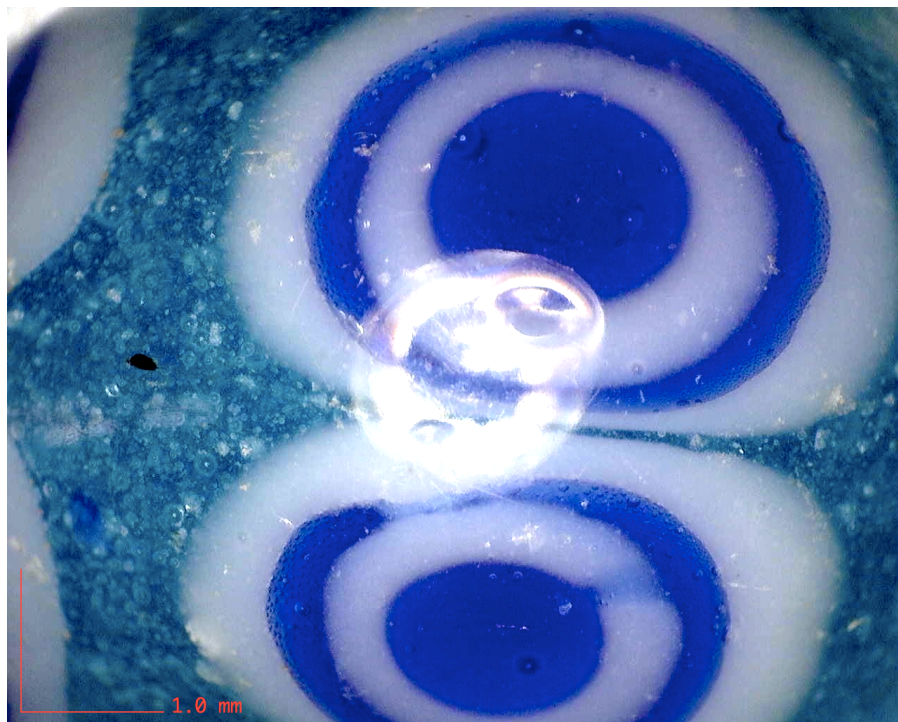


Figure Appendix C 3: Close-up of bead TSG_168: bubbles and streaks of different colour can be seen throughout the glass matrix. (Micrograph author's own).

Further evidence of contamination is given here by the presence of lead, with 0.7% PbO (although this may have been contained in the antimony source and does not necessarily indicate the mixing of glass), slightly higher amounts of Fe₂O₃ (0.46%) and tin with 0.03% SnO₂ (Paynter & Jackson 2019; Huisman et al., 2009; Paynter, 2006). It has to be noted that the trace element amounts for lead, tin and antimony differ from the major element content: this discrepancy can be explained by the fact that these elements can precipitate out in clumps, thus being heterogeneously distributed within the sample. For this reason, the

microprobe data are more reliable to assess the overall composition of a given glass, as they cover a wider area (beam diameter 20-30 microns) when compared to sampling by LA-ICP-MS (Duckworth, 2020b, p. 342)

TSG_169 is an opaque blue-green globular bead fragment, with a base glass composition in accordance with antimony decolourised glass in virtue of its major oxide contents, which include low manganese oxide at 0.01% (Duckworth, 2020b, p. 365; Gliozzo, 2017; Silvestri et al., 2008; Foster & Jackson, 2010; Jackson, 2005). As observed for TSG_167, in this case antimony is present only in trace, with 25.91 ppm, possibly indicating depletion caused by the mixing of glass with the addition of colourants, as indicated by the high amounts of copper oxide (1.47%) and the presence of SnO₂ (0.02%) as a contaminant. Cobalt, zinc and lead are found as trace elements with values below 100 ppm, suggesting that these were contained in the raw glass ingredients and that in all likelihood no recycling or repeated re-melting occurred.

Turquoise opaque bead **TSG_170** presents a mixed base glass, consisting of Levantine 1, which is bluish-greenish in colour, and Roman colourless types (Duckworth, 2020b, p. 365). As indicated by the sand source make-up, Levantine 1 glass originated in the Syro-Palestinian coastal region and was manufactured in the primary centres of Jalame (4th century CE), Dor and Apollonia (6th-7th centuries CE). The soda, lime and iron oxides values for TSG_170 are broadly consistent with this compositional group, which is usually characterised by lower percentages of Na₂O and Fe₂O₃ (approximately 15% and 0.4%), and higher amounts of Al₂O₃ and CaO, at around 3% and 9% respectively (Freestone et al., 2000; Foy et al., 2003; Foster & Jackson, 2009). TSG_170 was opacified with calcium antimonate, as demonstrated by the elevated levels of CaO (7.87%) and Sb₂O₅ (3.37%) with copper oxide (3.30%) being the main colourant, similarly to what already reported for TSG_168. In addition, the concentrations of Pb₂O and SnO₂, with 0.07% and 0.02%, are nearly identical to the values recorded in TSG_168, suggesting also in this case contamination through mixing/recycling.

TSG_172 is a globular drawn bead fragment, with a translucent green core and an outer layer in opaque turquoise glass. As the bead is bichrome, the compositional results reported here refer to the core portion. Containing the highest levels of magnesia, titanium, manganese and iron recorded within the whole sample set, TSG_172 presents ambiguous compositional traits due to the mixing of glasses with different compositions. A prime marker for recycling

is indicated here by the presence of both Sb_2O_5 and MnO , 0.60% and 0.88% respectively (Duckworth, 2020b, p. 346). An elevated percentage of phosphorus pentoxide in TSG_172 (P_2O_5 0.41%) and magnesia (MgO 1.88%) and slightly higher values of potash (K_2O 0.88%)²⁰ may suggest contamination due to fuel ash, occurring during recycling and caused either by vaporisation of potassium in the furnace atmosphere or directly by ash particles. If the glass had been repeatedly recycled, it has been argued that a loss of chlorine (Cl) would occur over time (Paynter, 2008; Al Bashaireh et al., 2016; Barfod et al., 2022, p. 12). In this instance its content is 1.46%, which is still significant: this is because the solubility of chlorine, which is low and does not depend on the initial quantity of sodium chloride available, is influenced by the glass melting temperature and its calcium levels, meaning that if both increase, the amount of chlorine will diminish. Experimental work has demonstrated that the maximum concentrations of chlorine that can be found in a soda-lime-silica glass are between 1.42% and 1.8%, figures which are consistent with the amounts encountered here (Jackson et al., 2018; Tanimoto & Rehren, 2008; Bateson & Turner, 1939). With regards to the use of chromophores in TSG_172, contributing to the green tinge of the glass are the higher levels of Fe_2O_3 (0.97%) and 0.40% of CuO , with their presence due to contamination and/or the introduction of coloured glass in the batch. Recycling markers such as lead and tin are also contained in this bead as trace elements, with values of 464.90 ppm and 354.77 ppm.

The percentages of the major oxides in cobalt blue bead **TSG_173** are indicative of a mixed compositional signature, suggesting that this bead was crafted with Roman colourless or nearly colourless types, including antimony decolourised glass as Sb_2O_5 is found in concentrations of 0.2%. The amounts of calcium oxide and alumina are relatively high, with CaO 7.81% and Al_2O_3 2.26%, and appear to be consistent with glass containing manganese, either as the only decolouriser or in combination with antimony. It is worth pointing out that 4th century CE Levantine 1 glass from Jalame is compositionally similar to late Roman Mn decolourised glass, fact which may explain why the quantities recorded in TSG_173 for calcium and aluminium are close to the values typical of Levantine 1, although if that were the case, we would also expect lower soda, which here amounts to 20.39% (Schibille et al., 2016). TSG_173 is comparable to TSG_168 not only in terms of base glass composition and but also for the colouring agents and contaminants, with Fe_2O_3 0.97%, CuO 0.14% and 557.43

²⁰ The amount of K_2O is abundantly within the values established for natron glass, but on overall it is the highest within the sample set.

ppm cobalt. In addition, tin (SnO 0.2%) and zinc (169.83 ppm) are also present, further indicating the mixing of different glasses.

Based on the percentages of the main glass constituents, the composition of **TSG_174** is consistent with the Levantine 1 glass type (Freestone, 2006b, p. 203; Foster & Jackson, 2009; Duckworth, 2020b, p. 366). Conferring to the glass its opaque turquoise hue, are the very high values of CuO (3.56%), CaO (7.69%) and Sb₂O₅ (3.1%), which indicate the presence of calcium antimonate. These percentages are very close to the ones recorded in TSG_170, although here there is an additional 0.10% of tin, which, combined with elevated copper, allows us to postulate that scrap bronze was likely employed to colour the glass (Sayre & Smith, 1974; Shortland & Tite, 2000; Silvestri et al., 2014).

TSG_175, made out of translucent pinkish-red glass with opaque white and yellow trails, and **TSG_176**, with an opaque white core and red translucent interior, are both wound beads falling within the same compositional group (high potash-lead glass) and for this reason they will be discussed jointly. Concerning TSG_175, the sample for the body of the bead was labelled as pink with colourless: as the EPMA results show a reasonable level of similarity between the so-called 'pink' and 'colourless' portions, the descriptions of which are probably based upon the appearance of the glass sample in resin rather than the original bead. For this reason, it was decided that the pink portion would be used as our compositional reference. In the case of TSG_176 the analytical results provided here refer to the red portion. TSG_175 and TSG_176 present low amounts of soda (6.54% and 7.10% Na₂O), indicating that lead and potash were added to decrease the melting temperature of the glass to improve length, or workability, over a longer period of time (Henderson, 2013, pp. 99-100).

In order to test whether TSG_175 and TSG_176 were made by adding lead to recycled material similar in composition to the low-lead glasses, the EPMA results for all samples were normalised to 100 % following removal of PbO. As can be seen in Table 1, the results demonstrate that the higher-lead glasses were made from different raw materials as they are compositionally distinct from the remainder of the beads analysed, regardless of their lead content. This illustrates that these glasses are likely to be later in date as they seem to pertain – albeit very loosely and only in part – to the Islamic

(soda-)lead glass tradition of Spain, Morocco and Egypt (Schibille et al., 2020; Duckworth et al., 2015; Robertshaw et al., 2010; Carmona et al. 2009; Brill, 1999a,b).

	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	Cl	K ₂ O	CaO	TiO ₂	MnO	Fe ₂ O ₃	CuO	SnO ₂	Sb ₂ O ₅
TSG175	8.30	0.84	0.67	64.38	0.43	1.27	16.25	6.24	0.04	0.01	0.41	0.02	0.00	1.14
TSG176	9.26	0.95	0.36	63.60	0.55	1.30	16.97	5.50	0.02	0.10	0.30	0.01	0.01	1.06
Low-Pb	17.04	0.67	2.01	67.42	0.10	1.32	0.58	7.28	0.07	0.15	0.65	1.45	0.03	1.26

Table Appendix C 1: The two higher lead glasses TSG 175 and TSG 176 normalised to remove their PbO content for comparison with the mean of the low-lead group (n=7).

The high potash and phosphorus pentoxide percentages in TSG_175 and TSG_176, coupled with modest amounts of impurities which are usually associated with the use of plant ash as a flux – notably calcium, magnesia (< 1% MgO), iron and alumina – suggest that a relatively pure potash source was added to the glass to replenish any (mineral) soda lost through repeated re-heating cycles, thus producing a mixed alkali signature.

Although caution is needed due to the presence of marked compositional differences, this phenomenon was also observed for 13th to 19th centuries CE Fazzan bangles, perhaps suggesting the presence of a long-standing manufacturing trend for items of personal adornment which saw the re-melting of glass with the addition of further ingredients to increase its workability (Duckworth et al., 2016b, p. 155),

The normalised results for copper oxide in TSG_175 and TSG_176 indicate that this was not brought in with the lead. In addition, it appears that the chlorine content does not directly correlate with PbO, suggesting that the lead was not directly added to the glass batch in pure metal form (Duckworth et al., 2015, p.36). The trace element amounts of arsenic, respectively 7410 ppm (TSG_175) and 19700 ppm (TSG_176) appear to corroborate this hypothesis, as it is likely that the arsenic in this case was contained within lead slag. Both TSG_175 and TSG_176 were decolourised with antimony (0.9%-0.8% Sb₂O₅). The percentage of manganese appears slightly higher in TSG_176 with 0.08% MnO, even though the trace element values for both samples are > 100 ppm (TSG_175 812.67 ppm and TSG_176 324.33 ppm Mn), indicating contamination. The presence of tin is negligible, with 3386.33 ppm Sb and 0.01% SnO₂ respectively, although in the case of TSG_175 this amount may account for a residual intentional addition to slightly opacify the bead. Tin-based opacifiers were first used in glass the 2nd and 1st centuries BCE, and were subsequently employed during Roman and

Byzantine periods, with tin oxide being also used in later Islamic opaque glazes and enamels (Tite et al., 2008). Both beads present a reddish colour, which may be given in this instance by oxidised iron and perhaps lead, as the amounts of copper (0.02% and 0.01% CuO) do not seem to warrant this. According to the EPMA results, the yellow trail in TSG_175 was made with the same base glass recorded for both beads, but with additional lead and antimony as the colourant-opacifier.

Rare Earth Elements

The Rare Earth Elements (REE) are a metallic group of elements which are naturally present in sediments and sedimentary rocks; they range from Lanthanum (La, with atomic number Z= 57) to Lutetium (Lu, Z= 71). The elements from La to Sm (Samarium) are termed as light REE (LREE), whereas heavy REE (HREE) comprise elements from Gd (Gadolinium) to Lu (Figure 4).

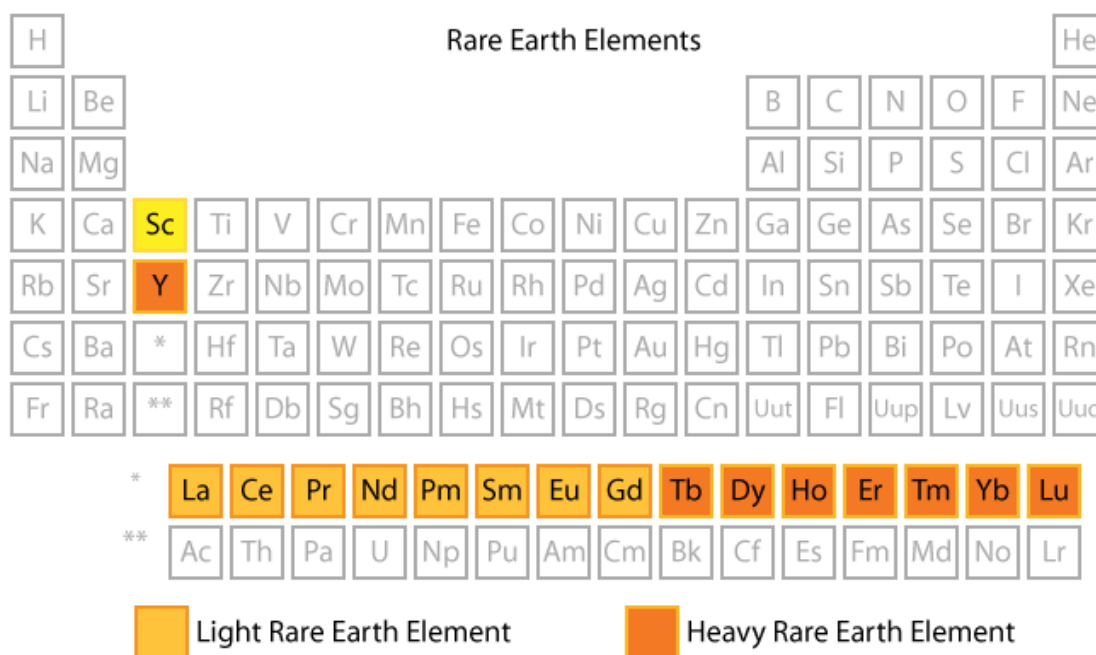


Figure Appendix C 4: Periodic table with Rare Earth Elements highlighted in yellow (LREE) and orange (HREE).

REEs are never found in isolation or partial association as they always occur collectively, with LREE being more abundant in the Earth's crust than HREE. Even though exceptions are present and will be discussed below, on overall REEs can be considered somewhat stable as they are not particularly susceptible to elemental enrichment or depletion which may occur under geological conditions that underpin fractionation. For this reason, REE are very useful markers for the detection of sources of silica employed in glassmaking (Hoshino et al., 2016, pp. 131- 132; Brems & Degryse, 2014, p. 119; Reade, 2021, pp. 33-34).

REEs are characterised by uniform trivalent charge, with the exception of Eu and Ce which can present anomalies due to redox sensitivity and to fractionation relative to neighbouring trivalent rare earth elements. Both Eu and Ce can be found with different oxidation states, depending on the redox conditions of the surrounding environment: Eu, which can be preferentially incorporated in plagioclase, assumes the bi-valence state under reductive conditions, whereas Ce³⁺ becomes Ce⁴⁺ under oxidizing conditions (Costa et al. 2019, p.9; Robertshaw et al., 2006; Seto & Akagi, 2008; Brems & Degryse, 2013, p. 119). The rare earth element distribution in quartz and quartz sands is apparently inherited from older rocks, and may be affected by additional minerals in the glassmaking sands, including kaolinite, feldspar, zircon, monazite, rutile and iron oxides (Wedepohl et al. 2011, pp. 89-90; Henderson, 2013, pp.56-60). Anomalies are thus characteristic of the geological source of the glassmaking sand, due to differences in concentrations based upon fractionation and partial melting of the crustal and mantle source rocks (Wedepohl et al. 2011, p. 90). It is important to note that other glassmaking ingredients may also contribute to the REE profile. Plant ash glass, for example, is made using the ashes of halophytic (salt-tolerant) plants that take up minerals from the soil in which they grow. The analysed beads, however, are consistent with glasses made using a mineral alkali source, so we might surmise that their REE concentrations are primarily related to their sand source.

The REE concentrations for the Fazzan beads were extrapolated from the results from trace element analysis carried out by LA-ICP-MS (Duckworth, 2016a, b, 2020b). The abundance of the REEs was then normalised to the values provided by McDonough & Sun (1995), which reflect the distribution of the REEs in chondrites, as representative of the relative abundance within the solar system and thus their distribution in the Earth's mantle (Wedepohl et al., 2011, p. 90). The REE concentrations, reported below in a logarithmic scale plot (Figure 5), were examined following the work of Brems & Degryse on the REEs present in roman glass (2014, pp. 127-128).

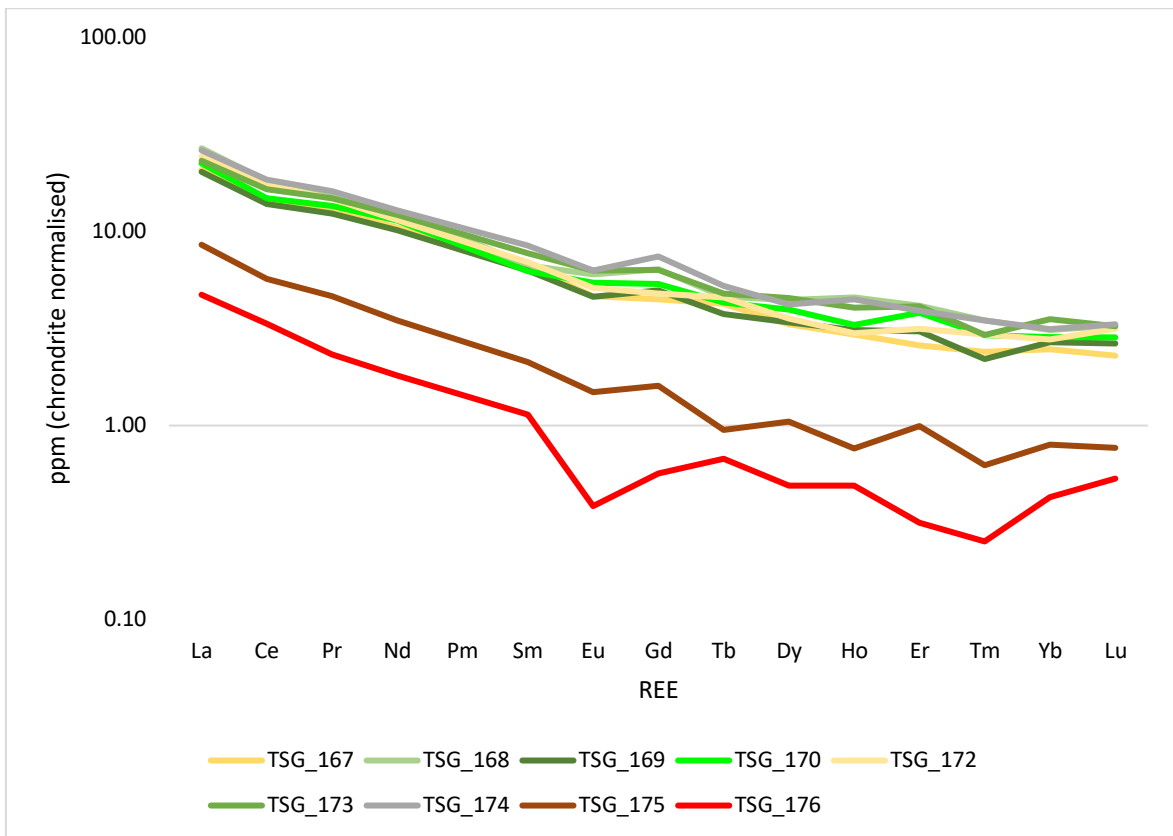


Figure Appendix C 5: Chondrite normalised REE patterns of the glass beads (n=9) analysed by LA-ICP-MS. (Graph author's own).

The REE patterns for each sample do not include Promethium (Pm), which is a radioactive element resulting from the decay of unstable U and Eu isotopes. As a general rule, Pm cannot be measured as it occurs in concentrations way below the detection limits, resulting in a formula which provides a smooth line (Hoshino et al., 2016, p. 131). Two groups of samples can be observed in the plot: when compared to the soda glasses TSG_167-170 and TSG_172-174, the two leaded glasses TSG_175 and TSG_176 present a much shallower curve and, as a result, they can be considered as a separate group. In addition, although all the samples are enriched in LREE, TSG_175 and TSG_176 have in general far lower concentrations of REE, given by the fact that the lead is partly replacing the silica. A negative Eu anomaly, which was observed especially in TSG_176 (extreme) and to a lesser extent in all samples, results from the separation of some crustal melt from a Ca-rich residue, and is indicative of a geological source from melts forming parts of the upper Earth's continental crust. The general patterning of decreasing abundance from the lighter to heavier REEs, and the consistency of the negative Eu anomaly between all beads is in keeping with other mineral alkali glasses, for example as reported by Brems & Degryse (2013, p. 119), Wedepohl et al. (2011, pp. 89-92), and Degryse & Shortland (2009). It implies that all of the beads – including the two high lead beads TSG_175 and TSG_176 – were derived from geologically

similar sands, although there is enough variation within the sample set to imply that we are not dealing with the same batches of glass.

The lower concentrations of REEs in the two high lead glasses can be attributed to their lower silica content; they are otherwise reasonably consistent with the rest of the set. To further assess the validity of our assumption with regards to the use of two distinct raw material sources, the REEs were then normalised against the nominal Si content of 300,000 ppm (approximately 64% Si). As shown in Table 2, the two leaded glasses TSG_175 and TSG_176 are still geologically distinct from the soda glass group, presenting different concentrations of HREE each.

Results (Si corrected)	TSG_167	TSG_168	TSG_169	TSG_170	TSG_172	TSG_173	TSG_174	TSG_175	TSG_176
La	18.61	24.69	18.49	22.38	24.85	22.82	25.81	10.82	6.22
Ce	12.82	16.69	12.60	14.77	17.78	16.29	18.29	7.24	4.39
Pr	11.73	13.96	11.24	13.53	15.02	14.67	15.86	5.89	3.05
Nd	9.41	11.75	9.24	11.32	11.65	11.97	12.63	4.39	2.39
Pm	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sm	5.93	6.16	5.72	6.24	7.08	7.58	8.33	2.68	1.50
Eu	4.15	5.51	4.20	5.43	5.22	6.18	6.20	1.87	0.50
Gd	3.99	5.88	4.53	5.34	4.86	6.23	7.32	2.03	0.74
Tb	3.79	4.23	3.43	4.28	4.65	4.73	5.17	1.20	0.89
Dy	2.98	4.07	3.09	3.96	3.61	4.47	4.15	1.32	0.65
Ho	2.64	4.19	2.82	3.28	3.04	3.97	4.40	0.97	0.64
Er	2.32	3.81	2.79	3.81	3.20	4.06	3.85	1.25	0.41
Tm	2.15	3.20	2.00	2.92	2.99	2.88	3.43	0.79	0.33
Yb	2.21	2.85	2.45	2.85	2.82	3.48	3.09	1.01	0.56
Lu	2.05	3.00	2.40	2.84	3.21	3.20	3.27	0.97	0.70

Table Appendix C 2: REE concentrations with results after Si correction (n beads=9).

Conclusions

As already highlighted, as only nine beads were analysed from the assemblages investigated in this thesis, no meaningful patterns emerged from the analytical results.

Beads TSG_167-170 and TSG_173-174 mineral soda glasses, broadly consistent with Roman colourless or nearly colourless and Levantine 1 types, which are here often combined together. Further evidence for the mixing of different glasses is given by TSG_168, whereby low soda but high calcium, antimony and copper amounts derive from the melting of a glass

containing calcium antimonate together with a blue glass. Samples TSG_175 and TSG_176 pertain to a different glassmaking tradition, as their composition, when compared to the mineral alkali group, shows that they were made from different raw materials and that marked levels of lead and potassium, which are in line with soda-lead medieval Islamic glasses, are present. The REE data confirm that all of the beads were made from different glass batches which used geologically similar sands.

Although we cannot date glass on the basis of its chemistry, known glass recipes for different periods can roughly provide us with a *terminus post quem*: the beads that compositionally appear to match their suggested broad chronology are TSG_167 (3rd century BC-1st century CE) and TSG_173 (1st millennium BCE), whereas beads TSG_174 and TSG_175 are certainly post-Roman.

Table Appendix C 3: Major and minor elements (from Duckworth, 2020b)

Sample	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	Cl	K ₂ O	CaO	MnO	Fe ₂ O ₃	CuO	SnO ₂	Sb ₂ O ₅	PbO
TSG167	17.80	0.33	1.71	71.68	0.03	1.70	0.42	6.32	0.03	0.79	0.12	0.00	0.01	0.01
TSG168	13.56	0.50	2.20	69.87	0.06	1.00	0.53	8.37	0.04	0.46	1.12	0.03	1.09	0.71
TSG168 blue1	12.45	0.51	2.29	69.61	0.05	0.85	0.79	8.90	0.03	2.10	0.50	0.03	1.59	0.06
TSG168 blue2	12.56	0.57	2.25	69.67	0.07	0.82	0.80	8.74	0.00	2.01	0.53	0.01	1.65	0.04
TSG168 white1	12.01	0.55	2.10	66.93	0.04	0.63	0.68	7.93	0.03	0.56	0.02	0.03	8.83	0.04
TSG168 white2	12.13	0.57	2.05	67.02	0.08	0.65	0.70	7.89	0.00	0.58	0.09	0.03	8.83	0.05
TSG169	18.39	0.54	1.77	70.55	0.05	1.05	0.49	5.24	0.01	0.37	1.47	0.01	0.01	0.01
TSG170	15.36	0.46	1.76	64.41	0.03	1.11	0.50	7.87	0.04	0.40	3.30	0.02	3.75	0.70
TSG172	19.47	1.88	1.89	63.09	0.41	1.46	0.84	7.43	0.88	0.97	0.40	0.00	0.59	0.03
TSG172 blue	19.12	0.64	1.91	63.15	0.03	1.53	0.56	4.33	0.07	0.62	4.75	0.25	3.45	0.13
TSG173	20.39	0.49	2.26	65.18	0.06	1.47	0.55	7.81	0.01	0.91	0.14	0.01	0.19	0.03
TSG174	13.79	0.45	2.42	65.21	0.03	1.41	0.68	7.69	0.01	0.60	3.56	0.10	3.11	0.01
TSG175 cless	6.77	0.73	0.59	51.32	0.32	0.95	12.6 7	4.97	0.03	0.32	0.03	0.01	0.97	14.78
TSG175 Pink and streak	6.54	0.66	0.53	50.73	0.34	1.00	12.8 1	4.92	0.01	0.32	0.02	0.00	0.90	15.43
TSG175 yellow	6.69	0.91	0.51	46.70	0.36	0.59	6.01	5.16	0.10	0.38	0.05	0.30	2.70	25.45
TSG176 red	7.10	0.73	0.28	48.78	0.43	0.99	13.0 1	4.22	0.08	0.23	0.01	0.01	0.82	18.40
TSG176 white	5.40	0.35	0.29	44.36	0.29	1.06	9.58	2.92	0.05	0.18	0.05	0.05	0.28	25.16

Table Appendix C 4: Trace elements (from Duckworth, 2020b)

Sample	Li	B	Na	Mg	Al	P	K	Ca	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Rb	Sr
TSG167	3.70	119.53	129866.67	1842.67	8866.67	182.67	3597.00	42300.00	291.13	4.81	6.18	67.97	5566.67	566.00	4.88	945.33	104.40	3.65	6.30	305.83
TSG168	6.67	63.33	89733.33	2872.00	11903.33	275.67	6170.00	62466.67	357.67	6.63	7.97	106.70	7373.33	956.50	9.35	1991.10	120.23	16.30	11.21	456.00
TSG168 stripe	6.84	73.57	89710.00	2957.33	12166.67	283.33	6603.33	64766.67	360.33	7.19	8.41	112.73	13973.33	2239.67	13.00	3902.33	216.40	13.60	11.72	463.33
TSG169	3.32	106.03	131803.33	2528.00	9565.67	225.00	4009.00	35143.33	301.33	7.61	6.22	61.47	2052.33	20.14	4.16	11276.67	16.23	12.19	6.42	272.77
TSG170	5.04	61.43	111223.33	2471.00	9596.00	205.00	4469.33	56746.67	352.30	9.06	8.38	84.60	2817.33	6.44	10.79	26153.33	16.53	47.33	8.77	369.83
TSG172A	4.55	182.47	135023.33	5059.00	10750.67	864.67	7116.67	40930.00	743.00	15.76	14.65	2443.67	7573.00	3.72	10.03	7991.33	50.13	30.60	6.14	439.17
TSG172B	5.73	196.57	129766.67	3109.67	10913.00	330.00	6322.00	31413.33	871.33	12.09	26.83	610.73	4615.67	4.33	15.66	35873.33	138.23	96.90	7.81	338.70
TSG173	3.24	106.57	148430.00	2185.67	12254.00	209.33	4701.67	53040.00	263.33	4.86	6.44	97.37	5655.67	557.43	5.97	967.90	169.83	6.07	8.97	408.20
TSG174	6.26	45.90	97430.00	2403.33	13633.67	214.33	5372.33	54490.00	433.67	7.50	9.08	129.20	3907.00	8.57	13.60	27826.67	25.90	40.93	10.26	403.17
TSG175A	11.65	59.00	48886.67	4343.33	3311.67	1294.67	113100.00	34843.33	204.63	5.73	5.70	94.97	2123.67	1.21	4.66	40.40	31.87	20146.67	20.84	479.33
TSG175B	9.93	66.83	47650.00	5803.33	3528.00	1498.00	59850.00	38563.33	228.73	5.51	5.72	812.67	2988.00	4.31	17.27	331.57	169.20	7410.00	16.13	462.67
TSG175C	11.39	57.47	48546.67	4338.67	3400.33	1266.33	111100.00	34673.33	202.90	5.73	6.11	94.93	2152.67	1.23	4.06	39.67	33.93	18736.67	20.75	477.37
TSG176A	12.24	65.20	52283.33	4394.00	2002.67	1541.33	116360.00	29470.00	109.53	4.05	2.93	324.33	1193.33	2.07	4.86	70.83	32.37	19700.00	31.88	423.23
TSG176B	9.56	50.13	38670.00	3484.67	1859.00	1275.00	84100.00	22846.67	96.90	3.48	7.27	209.87	1067.33	3.43	6.78	118.03	26.40	52830.00	20.82	328.97

Sample	Y	Zr	Nb	Mo	Sn	Sb	Cs	Ba	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Pb	Th	U
TSG167	5.25	29.60	0.95	0.10	2.27	21.68	0.06	145.07	4.93	8.78	1.22	4.80	0.98	0.26	0.89	0.15	0.82	0.16	0.42	0.06	0.40	0.06	0.77	37.43	0.60	1.06
TSG168	6.79	36.10	1.21	0.59	3.69	51136.67	0.14	185.57	6.37	11.14	1.41	5.85	0.99	0.34	1.27	0.17	1.09	0.25	0.66	0.09	0.50	0.08	0.88	421.00	0.74	1.60
TSG168stripe	6.85	33.27	1.26	0.93	4.64	12060.00	0.11	188.20	6.09	11.17	1.44	5.82	1.27	0.34	1.21	0.19	1.16	0.20	0.59	0.09	0.57	0.08	0.82	593.67	0.76	1.09
TSG169	4.82	35.54	1.02	0.24	3.37	25.91	0.09	148.47	4.82	8.49	1.15	4.64	0.93	0.26	0.99	0.14	0.84	0.17	0.49	0.05	0.43	0.07	0.89	11.77	0.69	2.61
TSG170	5.88	43.78	1.12	0.38	153.23	33056.67	0.12	198.70	5.32	9.09	1.26	5.19	0.93	0.31	1.07	0.16	0.98	0.18	0.61	0.07	0.46	0.07	1.12	6599.67	0.70	2.29
TSG172A	5.45	62.62	2.21	1.58	354.77	8023.33	0.09	175.20	5.79	10.71	1.37	5.23	1.03	0.29	0.95	0.17	0.87	0.16	0.50	0.07	0.45	0.08	1.62	464.90	1.13	1.08
TSG172B	5.61	61.37	2.72	0.42	1660.67	30333.33	0.10	143.70	6.57	13.05	1.49	5.66	1.01	0.25	0.95	0.13	0.93	0.17	0.51	0.08	0.55	0.08	1.44	1148.97	1.32	1.16
TSG173	6.50	27.01	1.01	0.24	2.96	869.60	0.05	189.07	5.49	10.14	1.38	5.56	1.14	0.35	1.26	0.17	1.12	0.22	0.66	0.07	0.57	0.08	0.71	424.73	0.63	0.91
TSG174	7.09	33.75	1.35	0.09	496.70	29953.33	0.12	195.77	6.22	11.39	1.50	5.86	1.25	0.35	1.48	0.19	1.04	0.24	0.63	0.09	0.51	0.08	0.88	88.67	0.81	1.11
TSG175A	1.31	14.50	0.86	0.34	50.30	3576.67	0.11	46.63	1.80	3.46	0.41	1.43	0.25	0.05	0.26	0.03	0.25	0.05	0.13	0.02	0.13	0.01	0.36	156533.33	0.48	0.37
TSG175B	1.45	13.90	0.79	0.49	3863.33	31800.00	0.17	54.10	2.03	3.51	0.43	1.59	0.31	0.08	0.32	0.03	0.26	0.04	0.16	0.02	0.13	0.02	0.35	259033.33	0.50	0.47
TSG175C	1.33	14.46	0.78	0.41	48.80	3417.00	0.12	46.43	1.69	3.44	0.38	1.53	0.23	0.06	0.28	0.04	0.21	0.05	0.14	0.02	0.13	0.01	0.36	149333.33	0.49	0.40
TSG176A	0.74	7.19	0.45	0.53	17.20	3206.67	0.06	34.95	1.12	2.05	0.22	0.83	0.17	0.02	0.11	0.02	0.12	0.03	0.05	0.01	0.07	0.01	0.19	185266.67	0.31	0.44
TSG176B	0.67	6.17	0.38	0.36	182.90	208.87	0.07	28.26	0.92	1.82	0.18	0.82	0.15	0.03	0.09	0.02	0.13	0.02	0.04	0.01	0.05	0.01	0.15	262033.33	0.30	0.42

Appendix D: Micrographs and tables of Experimental beads (online)

Appendix E: Micrographs and tables of Fazzan Beads (online)

Appendix F: Photographs and tables of beads from Abruzzo (online)